

Assessment of the Yellowfin Sole Stock in the Bering Sea and Aleutian Islands

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Plan Team and SSC Comments

SSC October 2020

The SSC agrees that sex-linked mortality is biologically plausible and concurs with the BSAI-GPT’s and authors’ recommendation to bring forward Model 18.2 (in addition to the 18.1 base model) for consideration in the next assessment.

Authors' response: We have included Model 18.1 and 18.2 in this assessment.

Plan Team September 2020

The Team recommends that, if the authors have time this year or else in the future, they should consider estimating male *M* freely but with female *M* adjusted so that the average across sexes is equal to 0.12

Authors' response: We have included Model 18.1 and 18.2 in this assessment. Further changes to female vs. male natural mortality will be explored in future models.

Plan Team and SSC Comments

SSC December 2019

The SSC suggests the application of the VAST model to estimate the proportion of Yellowfin Sole in the NBS over time, as well as an examination of other available data sources, in particular the ADF&G survey in Norton Sound that has been conducted triennially since 1978 and annually since 2017. The SSC continues to encourage the authors to consider approaches for including the substantial biomass of NBS Yellowfin Sole in the model, with the expectation that NBS surveys will be conducted regularly in the future.

Authors' response: Two models in the current assessment incorporate VAST estimates, one for the EBS (18.3) and one for the EBS+NBS (18.4). Data from the ADF&G survey are presented in this assessment.

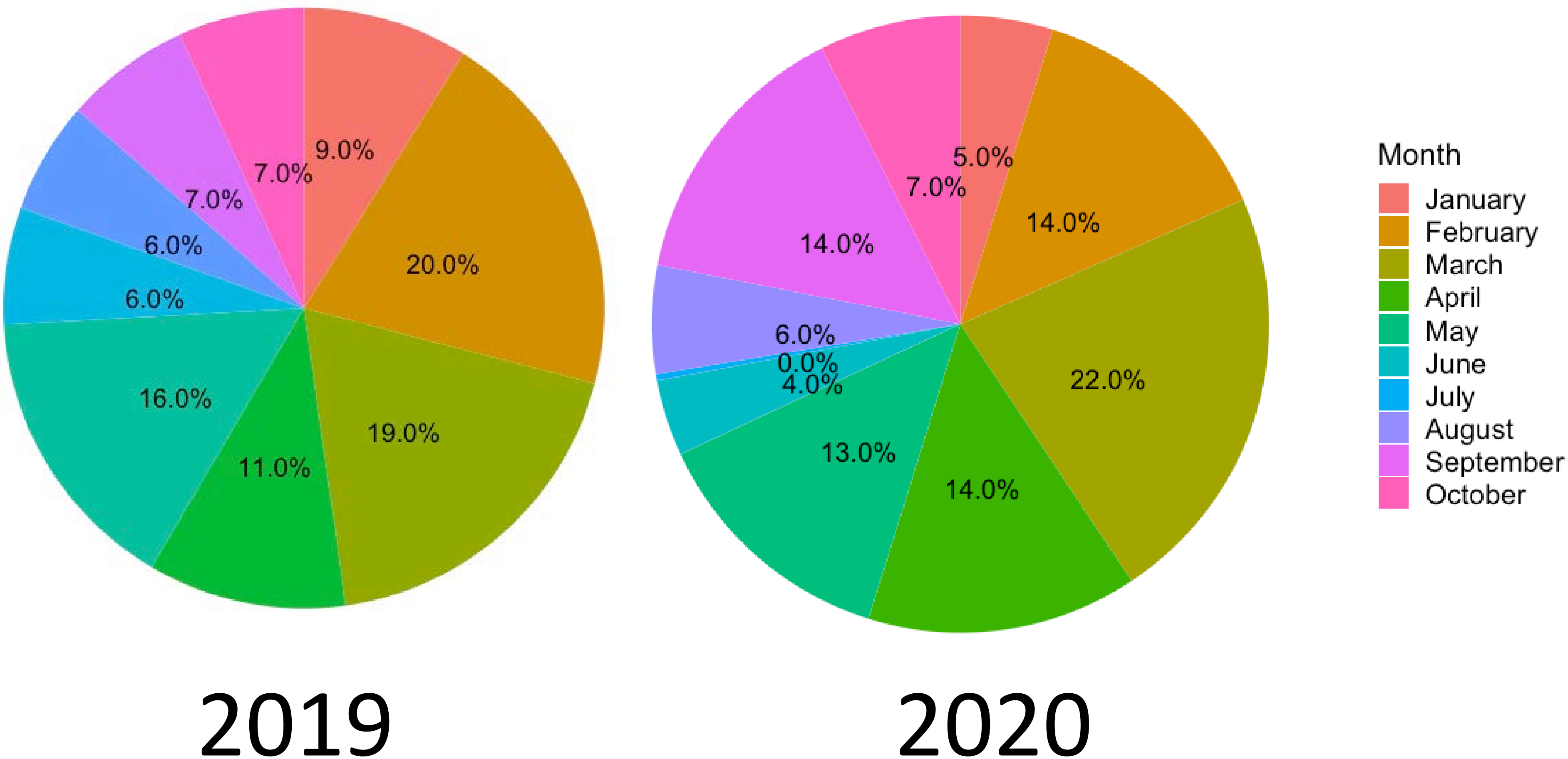
Plan Team and SSC Comments

SSC December 2019

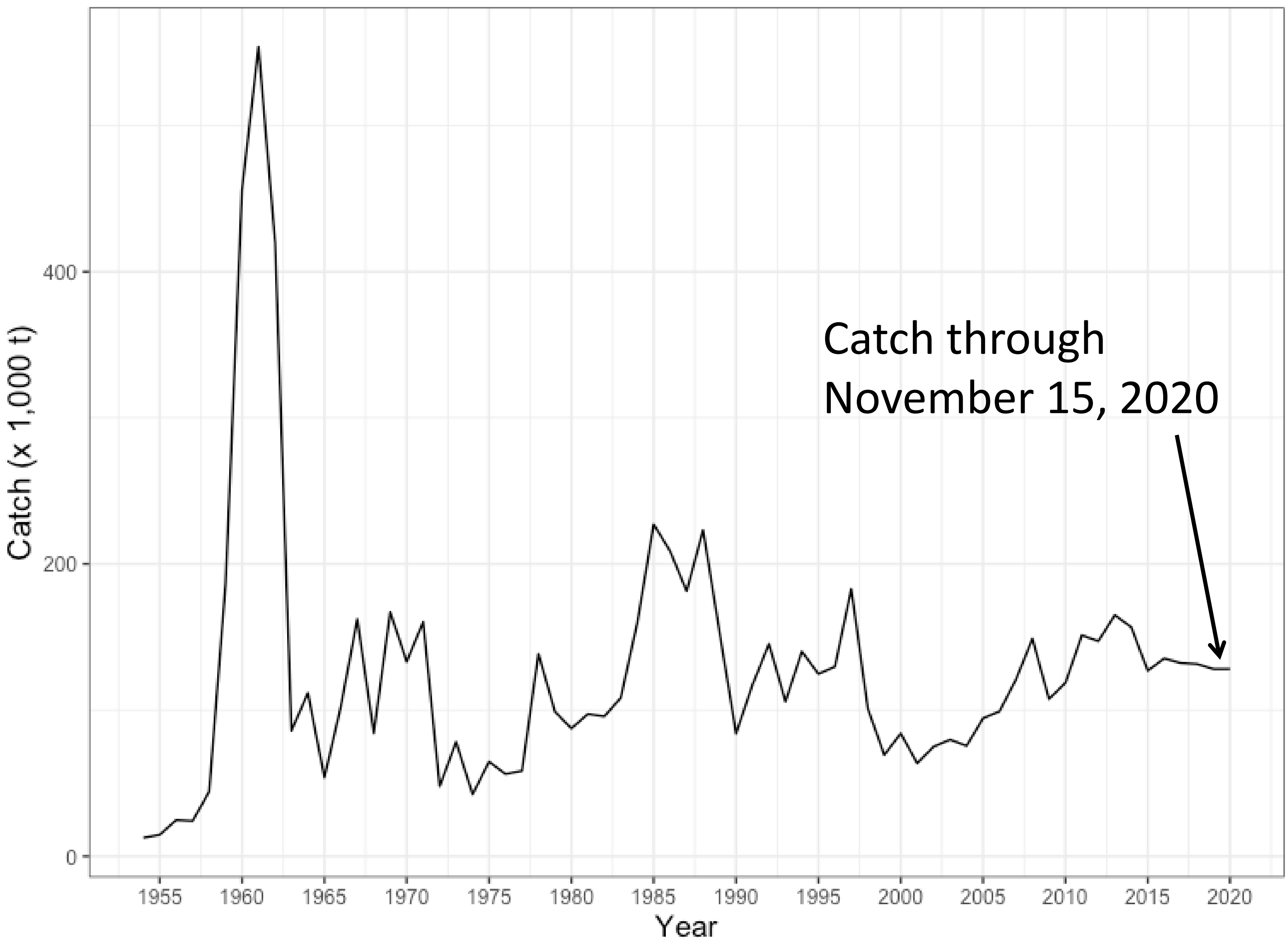
The SSC suggests the authors consider estimating a single selectivity curve for both sexes since the sex-specific selectivities are so similar.

Authors' response: This will be explored in a future year.

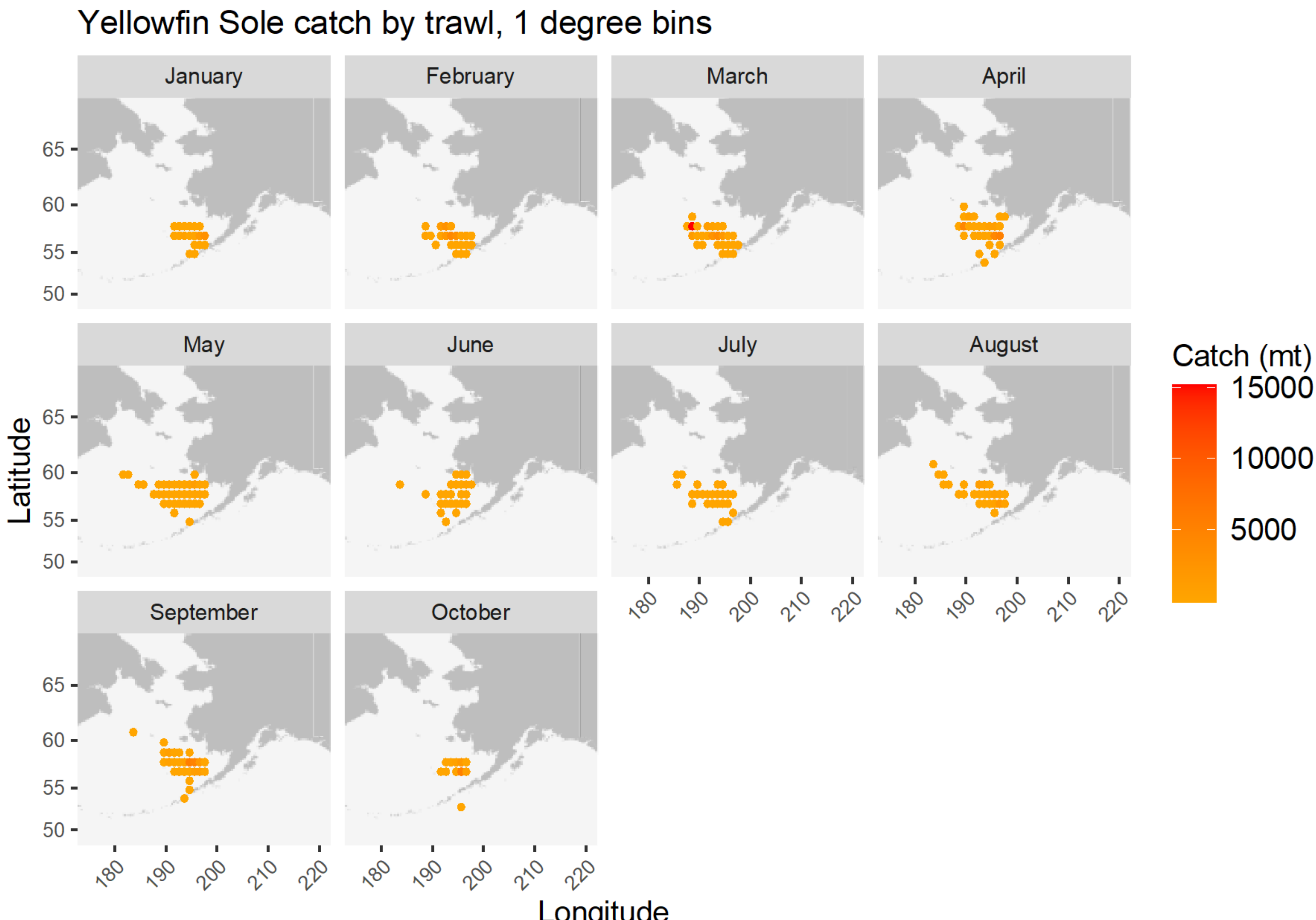
Catch in 2020 was very limited in July



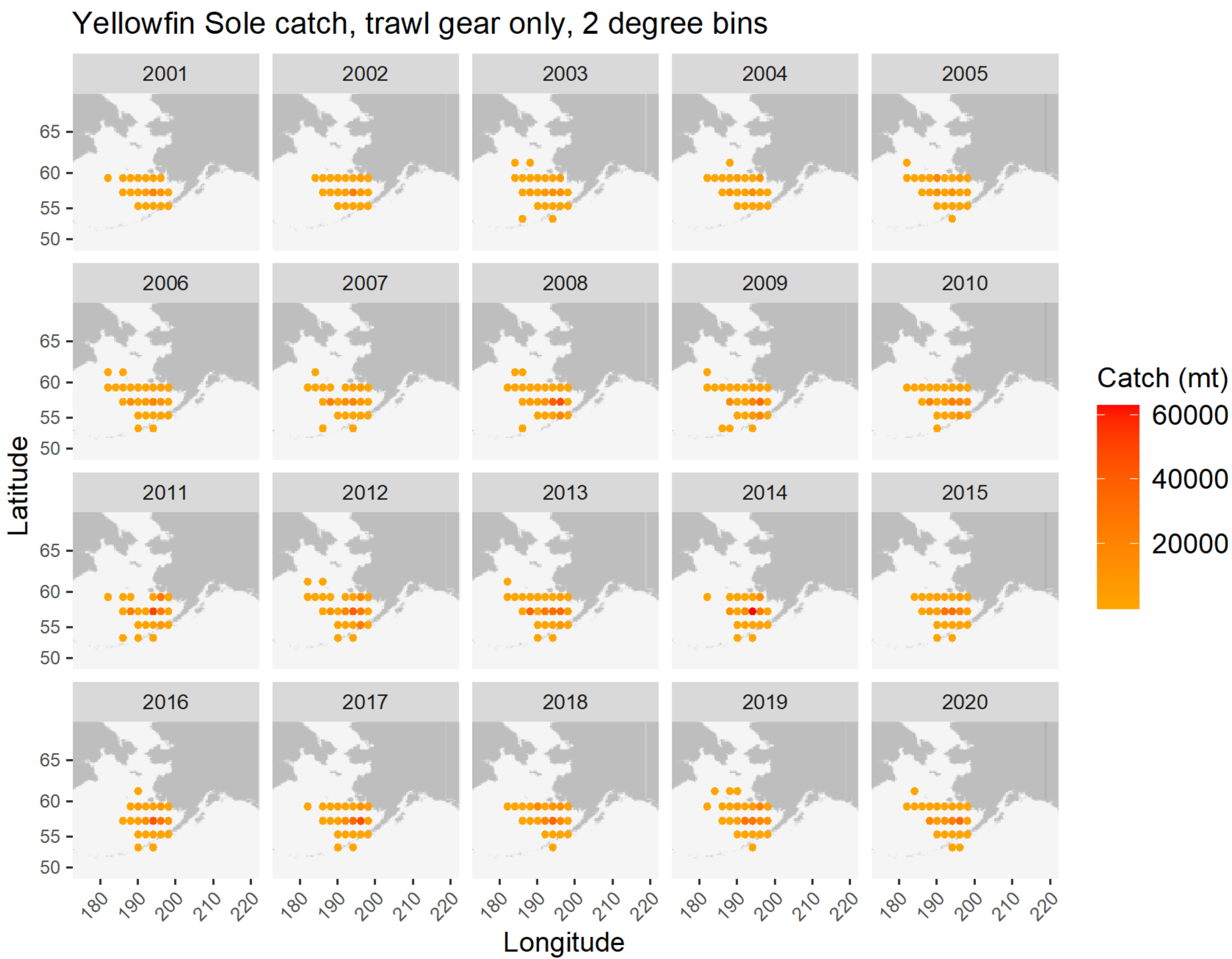
Catch was not low in 2020



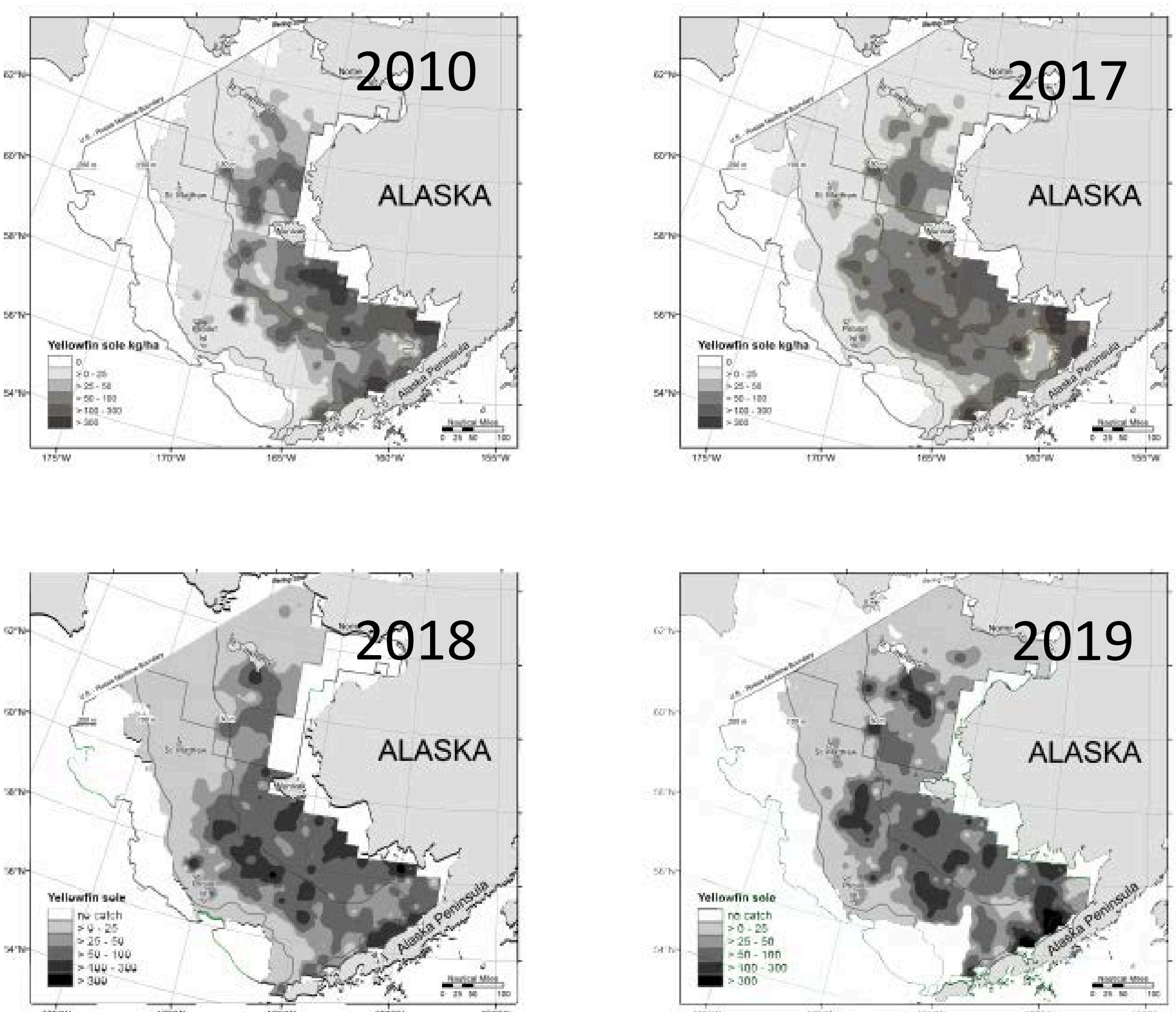
Trawl catch in 2020 by month



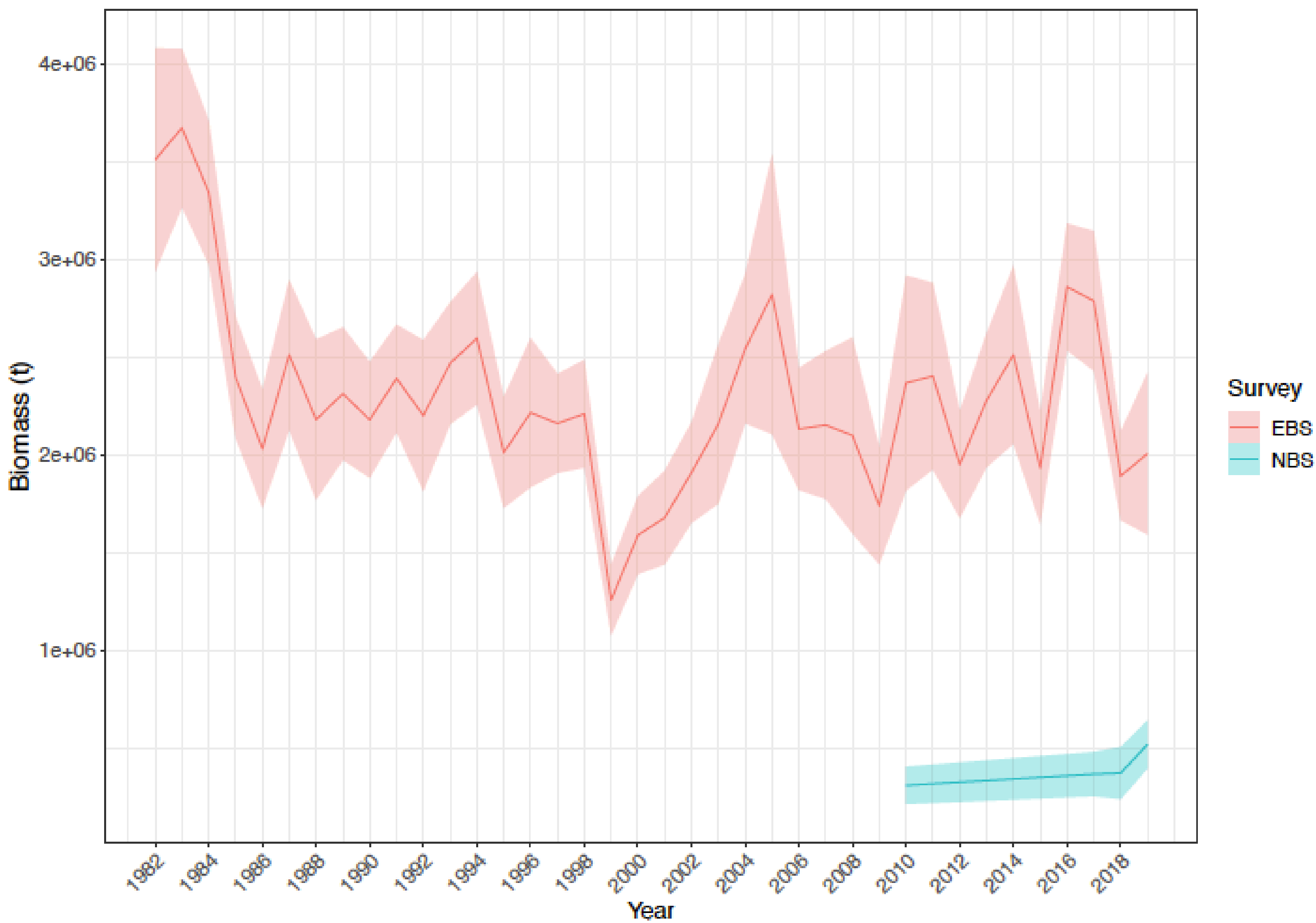
Trawl catch 2001-2020



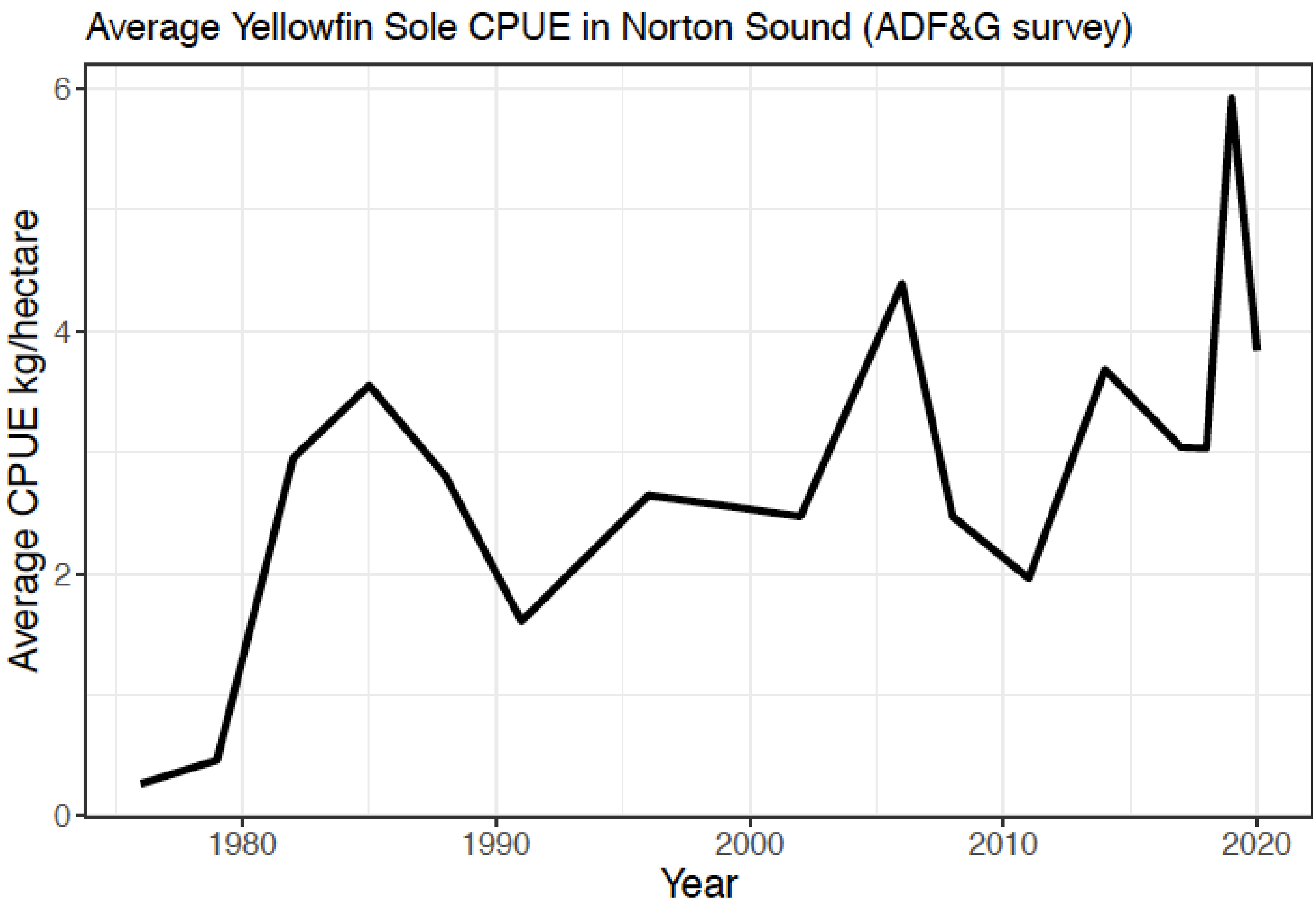
Are Yellowfin Sole moving northward?



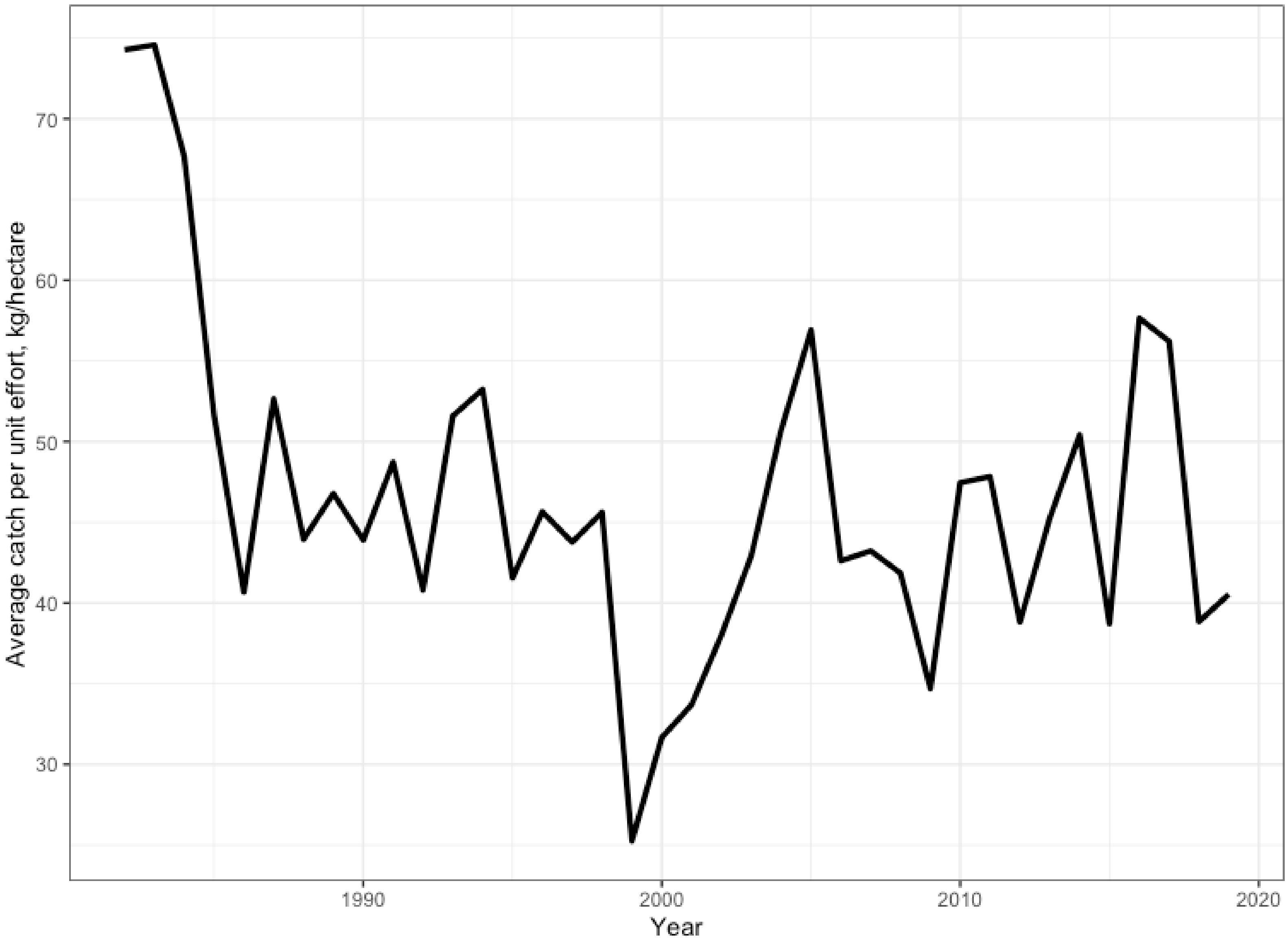
Annual EBS and NBS bottom trawl survey biomass and 95% CI's for Yellowfin Sole, 1982--2019



CPUE appears to be gradually increasing in Norton Sound



Average catch per unit effort on NMFS eastern Bering Sea surveys, 1982-2019.



Models

- Model 18.1

  The accepted 2019 Model 18.1 included the survey mean bottom temperature across stations < 100m as a covariate on survey catchability, as in previous years, but added survey start date as an additional covariate (Nichol et al. 2019).

- Model 18.2

  Female natural mortality (*M*) is fixed at 0.12 while allowing the model to estimate male *M*. This model retains the features of Model 18.1.

Models

- Model 18.3

  Same as Model 18.2 but includes VAST estimates for Eastern Bering Sea biomass and error.

- Model 18.4

  Same as Model 18.2 but includes VAST estimates for Eastern Bering Sea plus Northern Bering Sea biomass and error.

Data included in the model

Data source	Year
Fishery catch	1954 - 2020
Fishery age composition	1964 - 2019
Fishery weight-at-age	Catch-at-age methodology
Survey biomass and standard error	1982 - 2019
Bottom temperature	1982 - 2019
Survey age composition	1979 - 2019
Annual length-at-age and weight-at-age from surveys	1979 - 2019
Age at maturity	Combined 1992 and 2012 samples

Estimates of fishery weight-at-age was based on catch-at-age methodology used in the Walleye Pollock assessment (Ianelli et al. 2019), following Kimura (1989) and modified by Dorn (1992).

Selectivity

- Two parameter formulation of the logistic function.
- Used for fishery and survey.
- Modeled separately for males and females.
- Modeled annually for the fishery.

Catchability

Included survey start date and bottom temperature as follows:

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

where *T*=survey bottom temperature at survey stations less than 100 m (averaged per year for all stations <100 m), *S*=survey start date, and *T:S*=interaction of *T* and *S*.

The result of incorporating bottom temperature and survey start date have resulted in an improved fit to the survey.

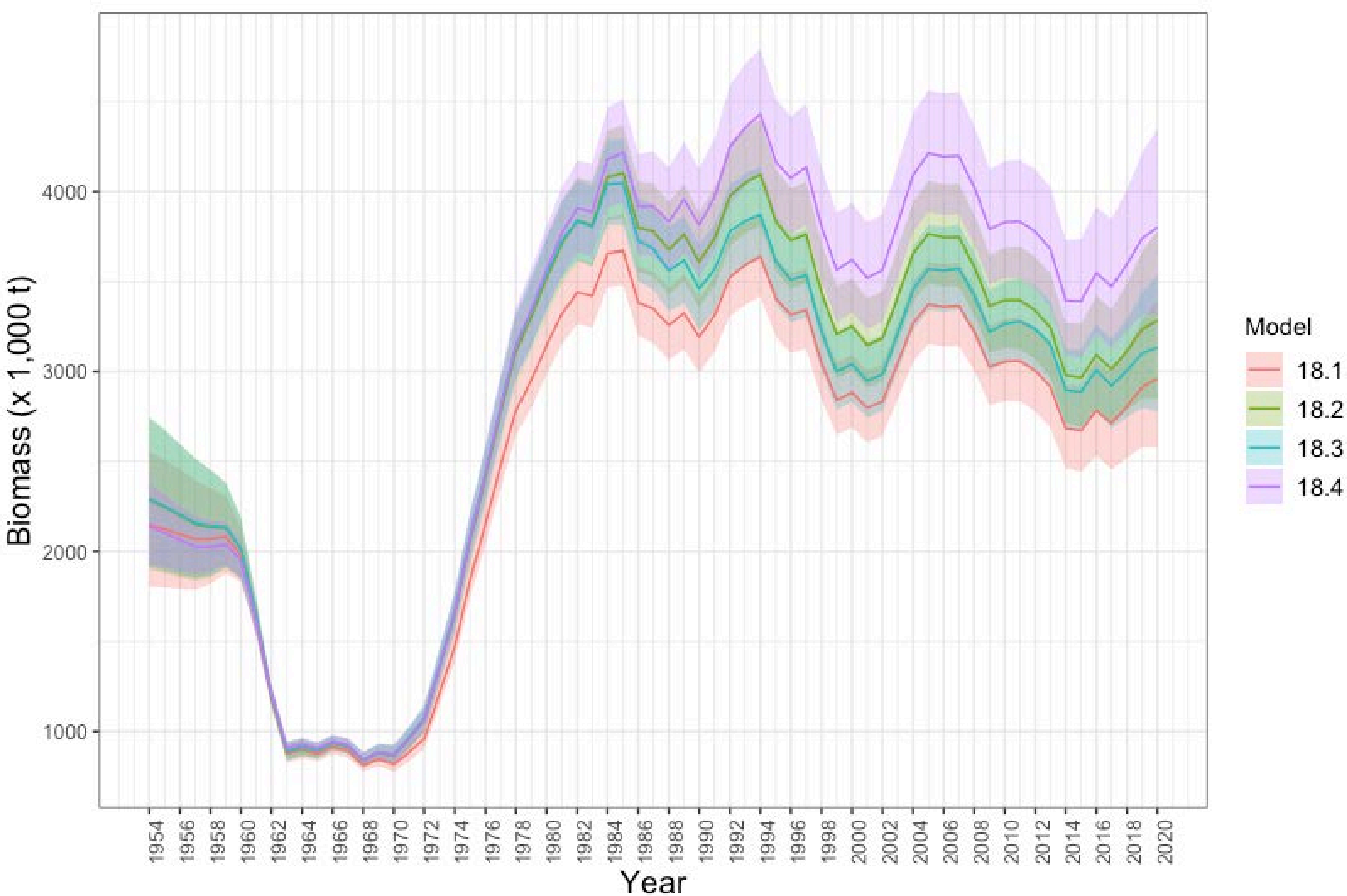
Spawner-Recruit Estimation

Annual recruitment estimates from 1978-2014 were constrained to fit a Ricker (1958) stock recruitment relationship:

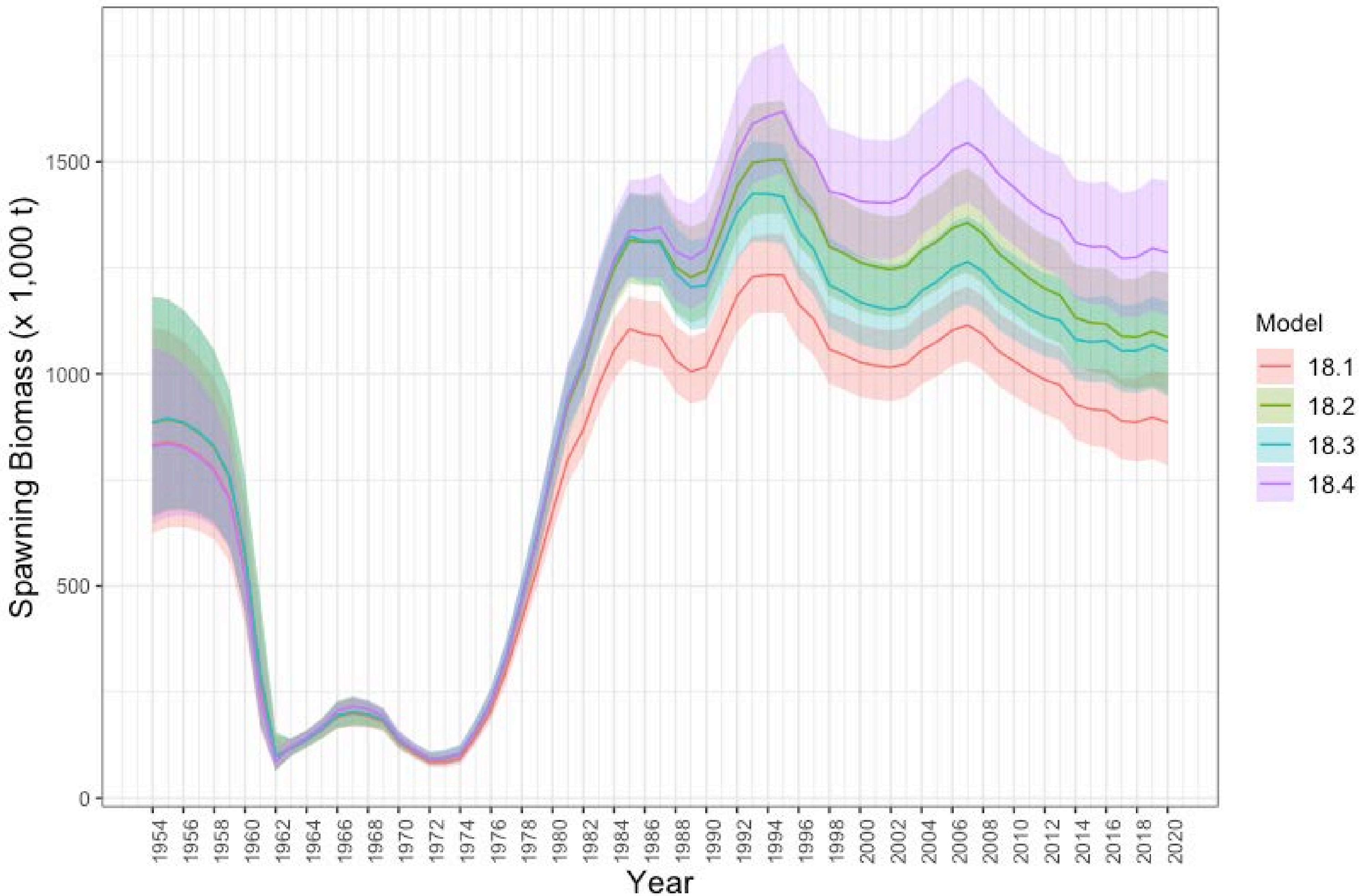
$$R = \alpha S e^{-\beta S}$$

where *R* is age 1 recruitment, *S* is female spawning biomass in metric tons the previous year, and α and β are parameters estimated by the model.

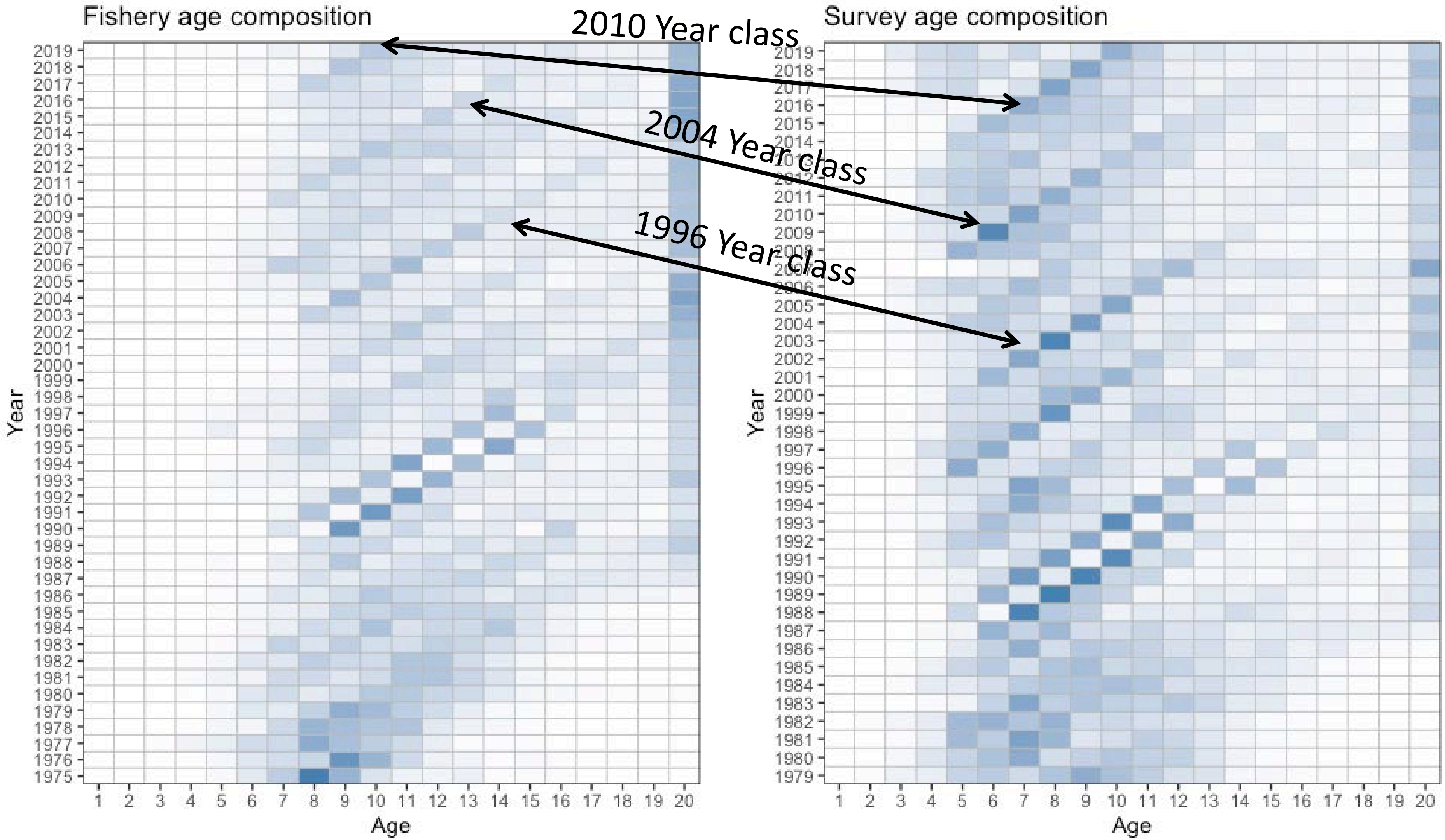
Model estimates of total (age 2+) biomass with 95% confidence intervals



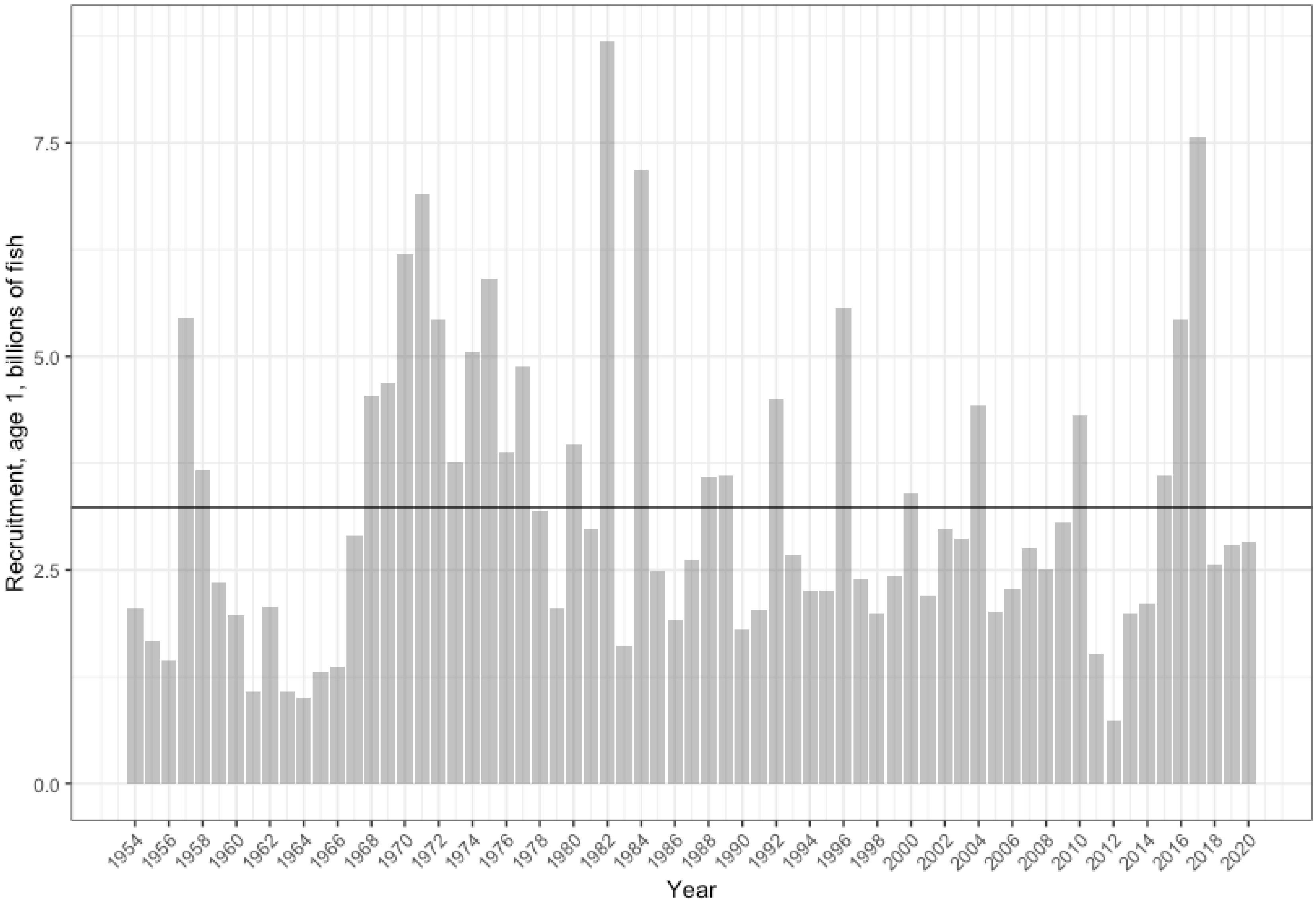
Model estimates of female spawning biomass with 95% confidence intervals



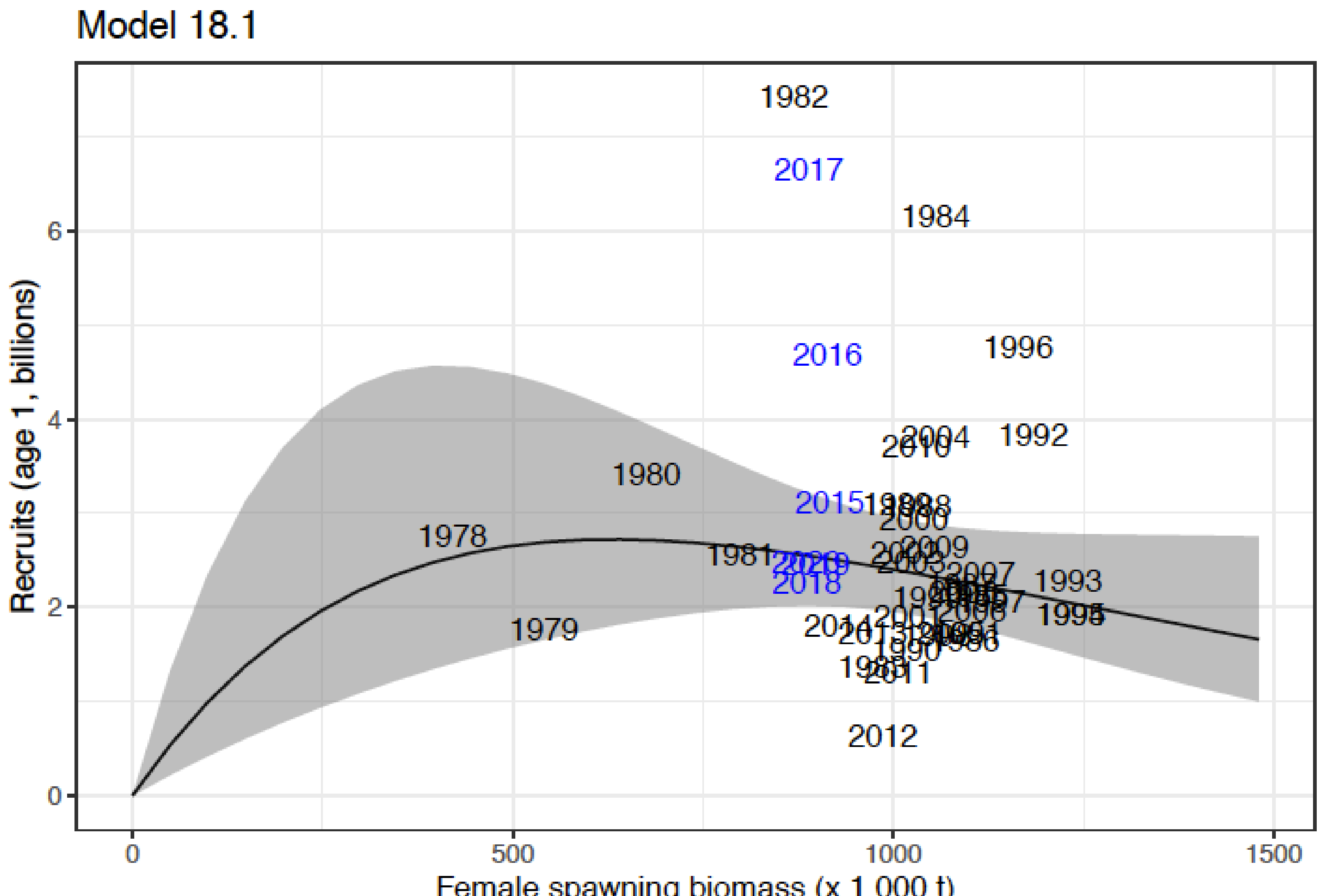
Fishery and survey age classes



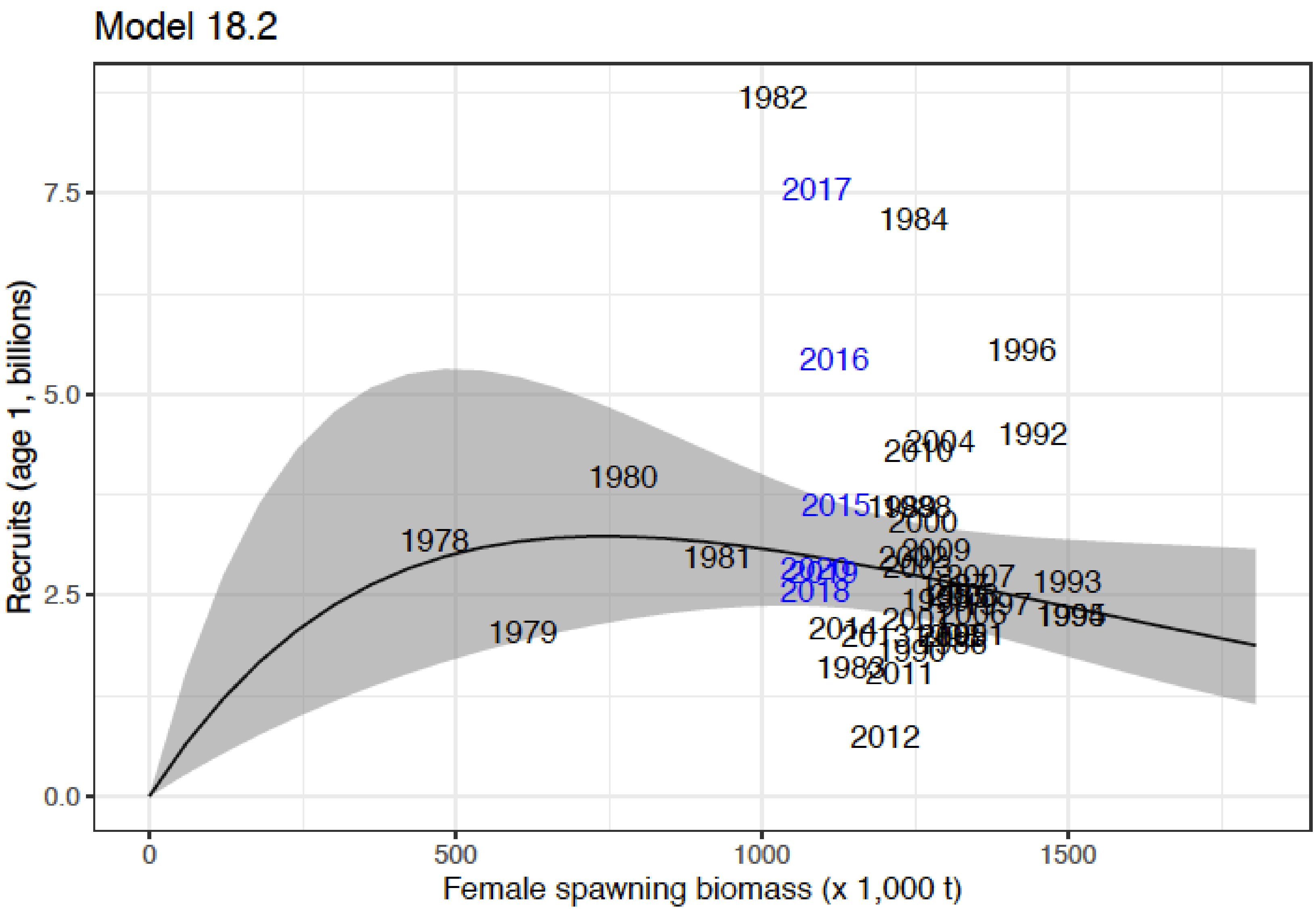
Age 1 recruitment (Model 18.2)



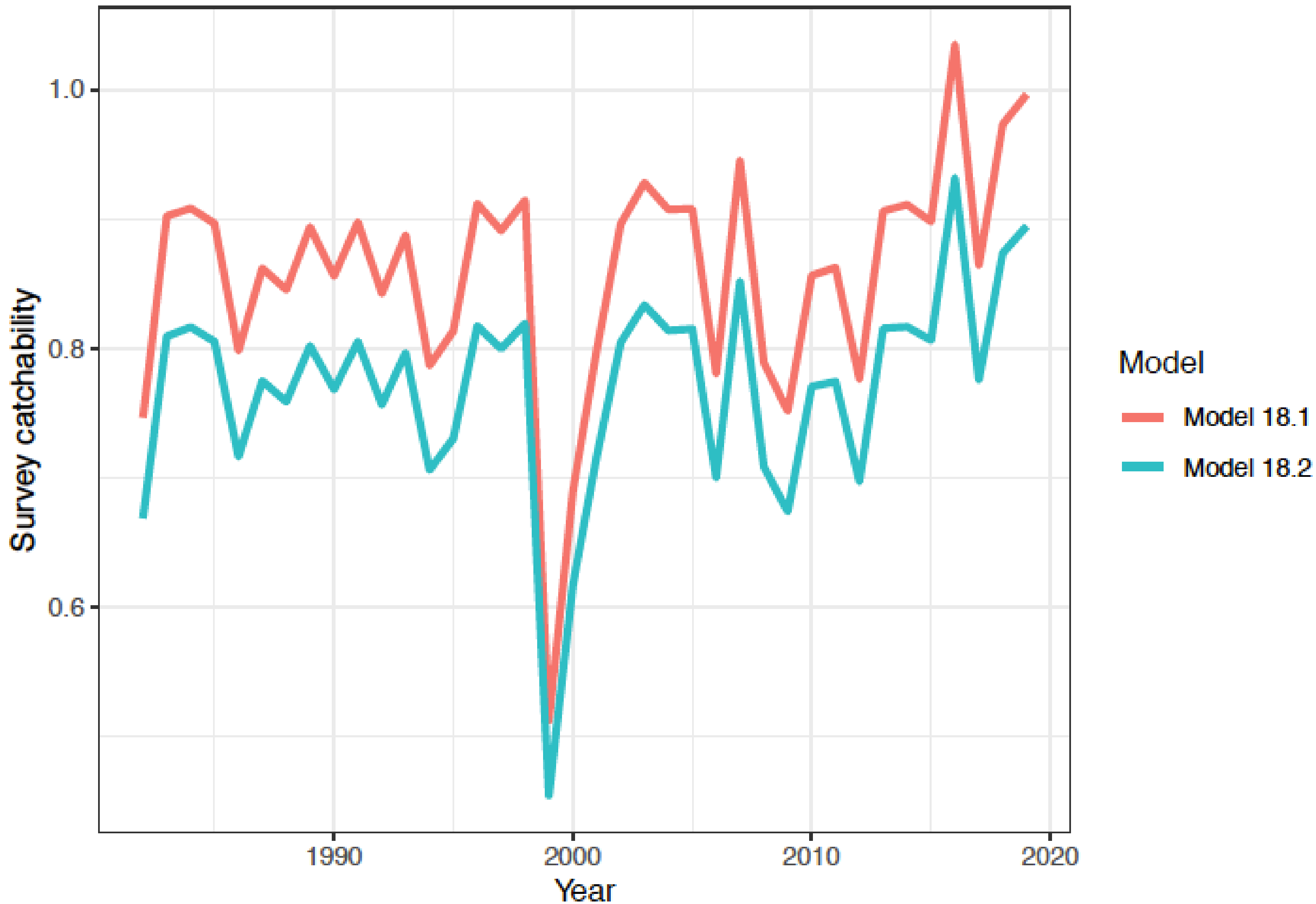
Ricker S-R curve, 95% CIs fit to FSB (years in black) and recruitment 1978-2014, Model 18.1



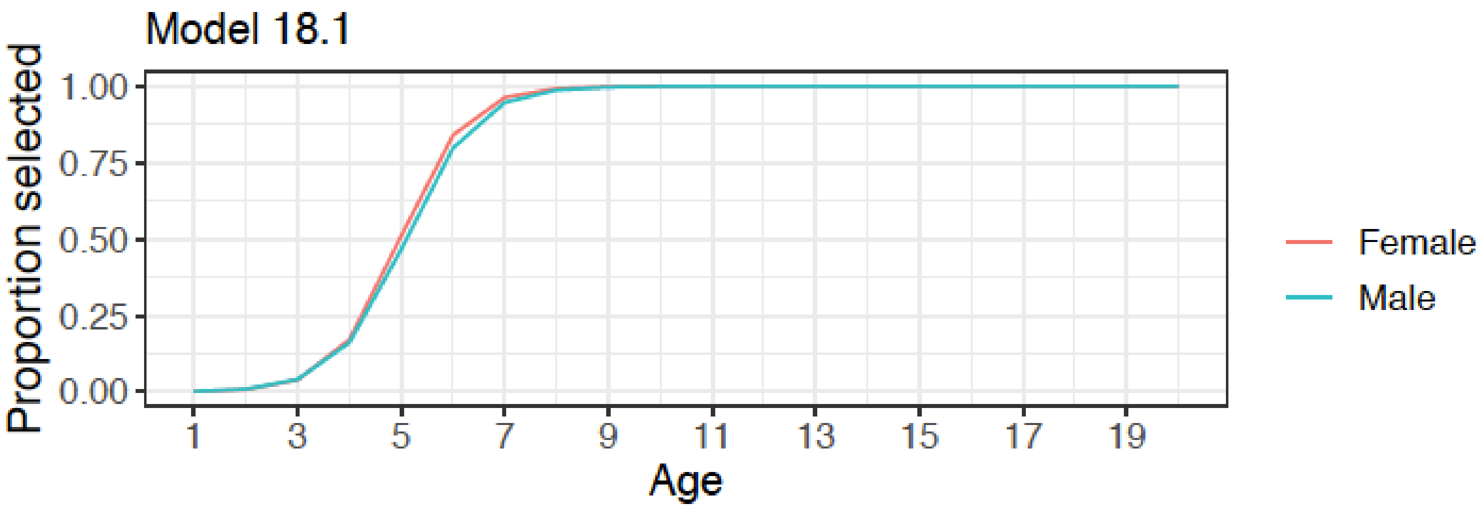
Ricker S-R curve, 95% CIs fit to FSB (years in black) and recruitment 1978-2014, Model 18.2

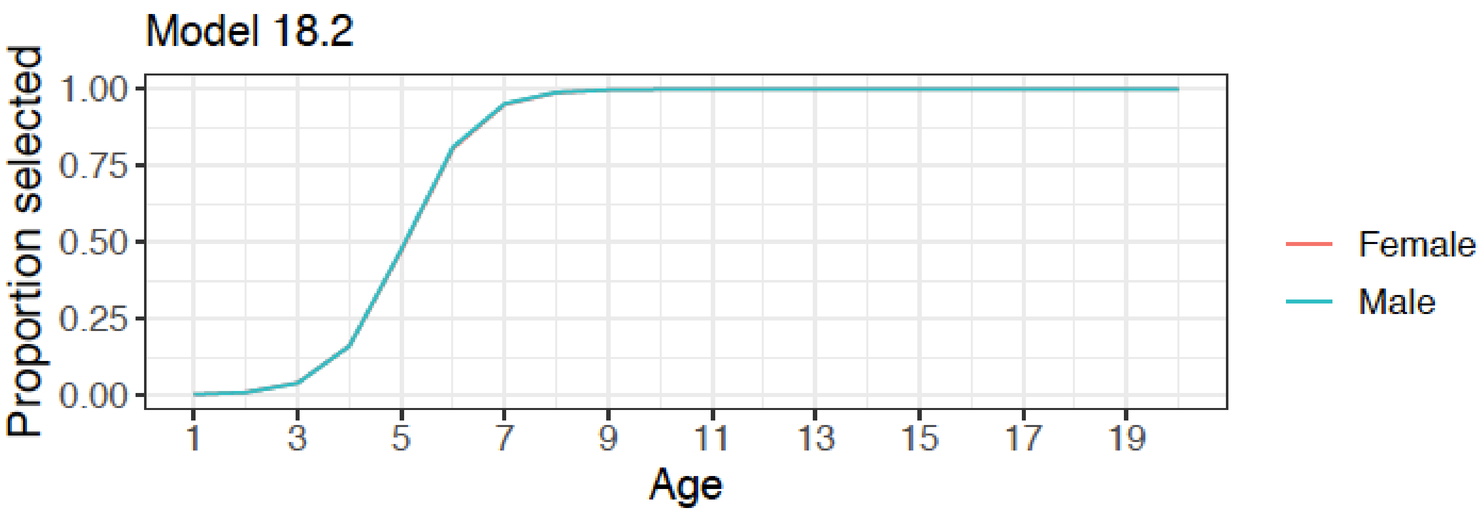


Survey catchability for Models 18.1 and 18.2, 1982-2020.

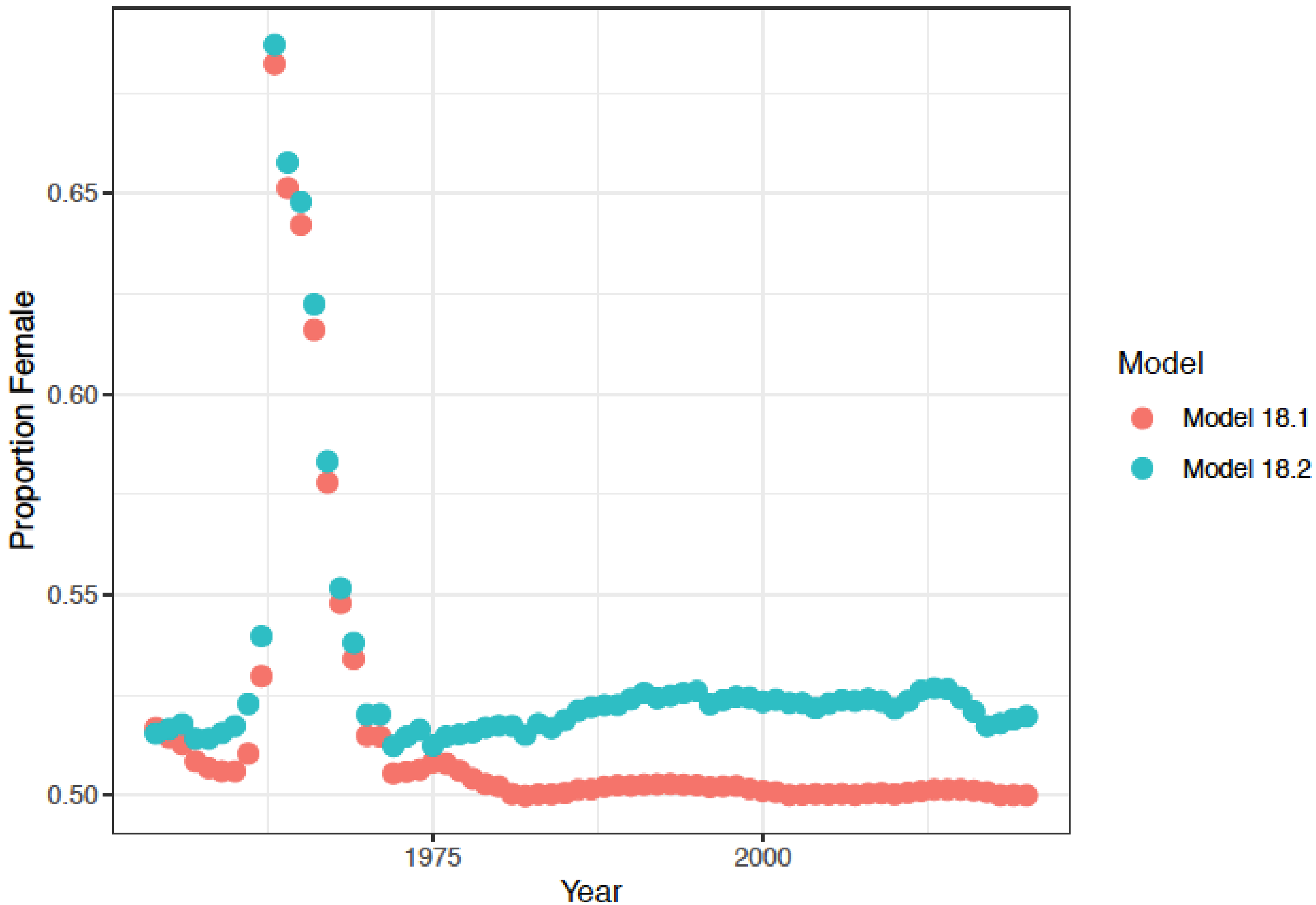


Survey selectivity

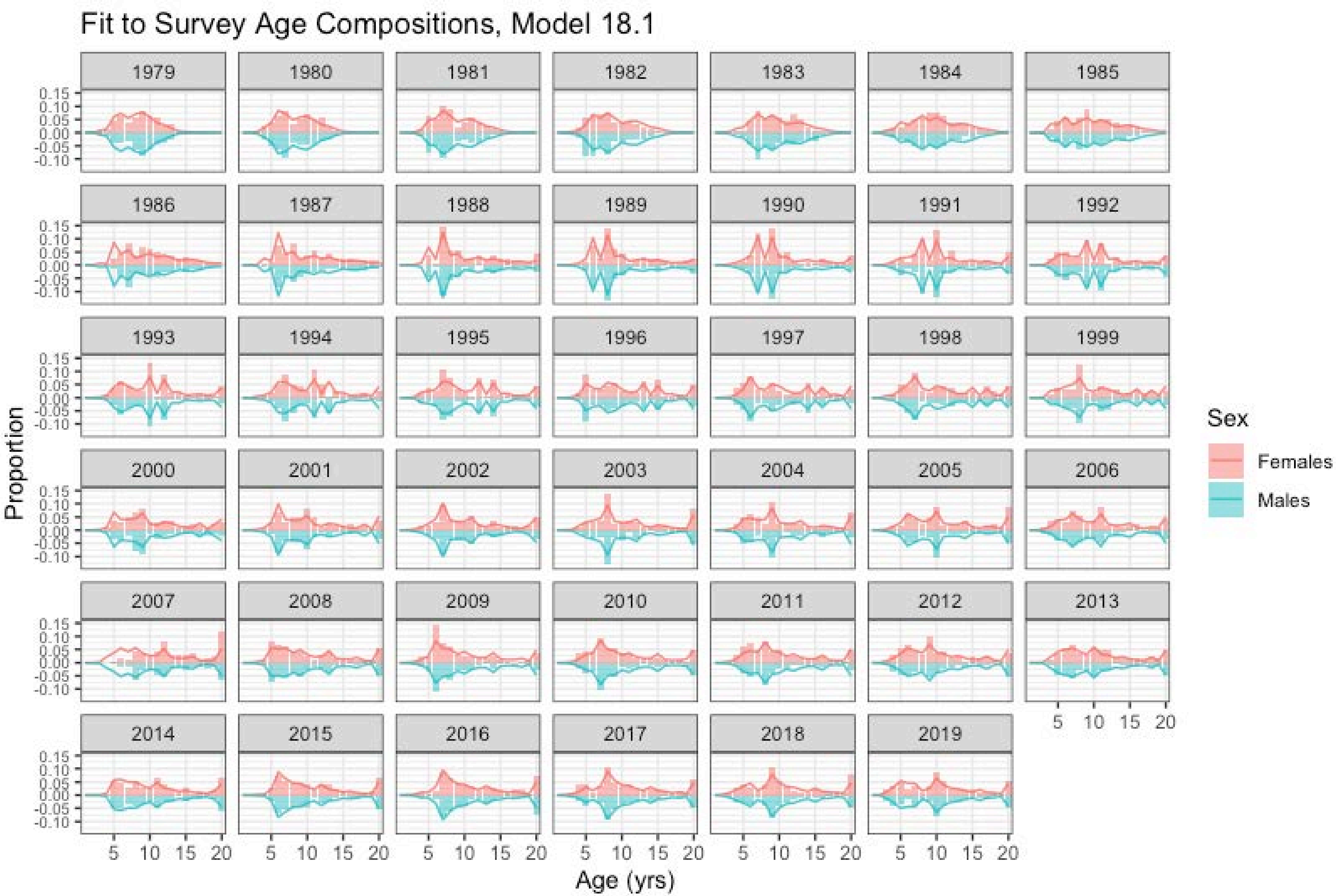




Model estimates of the proportion of female YFS in the population, 1982-2020



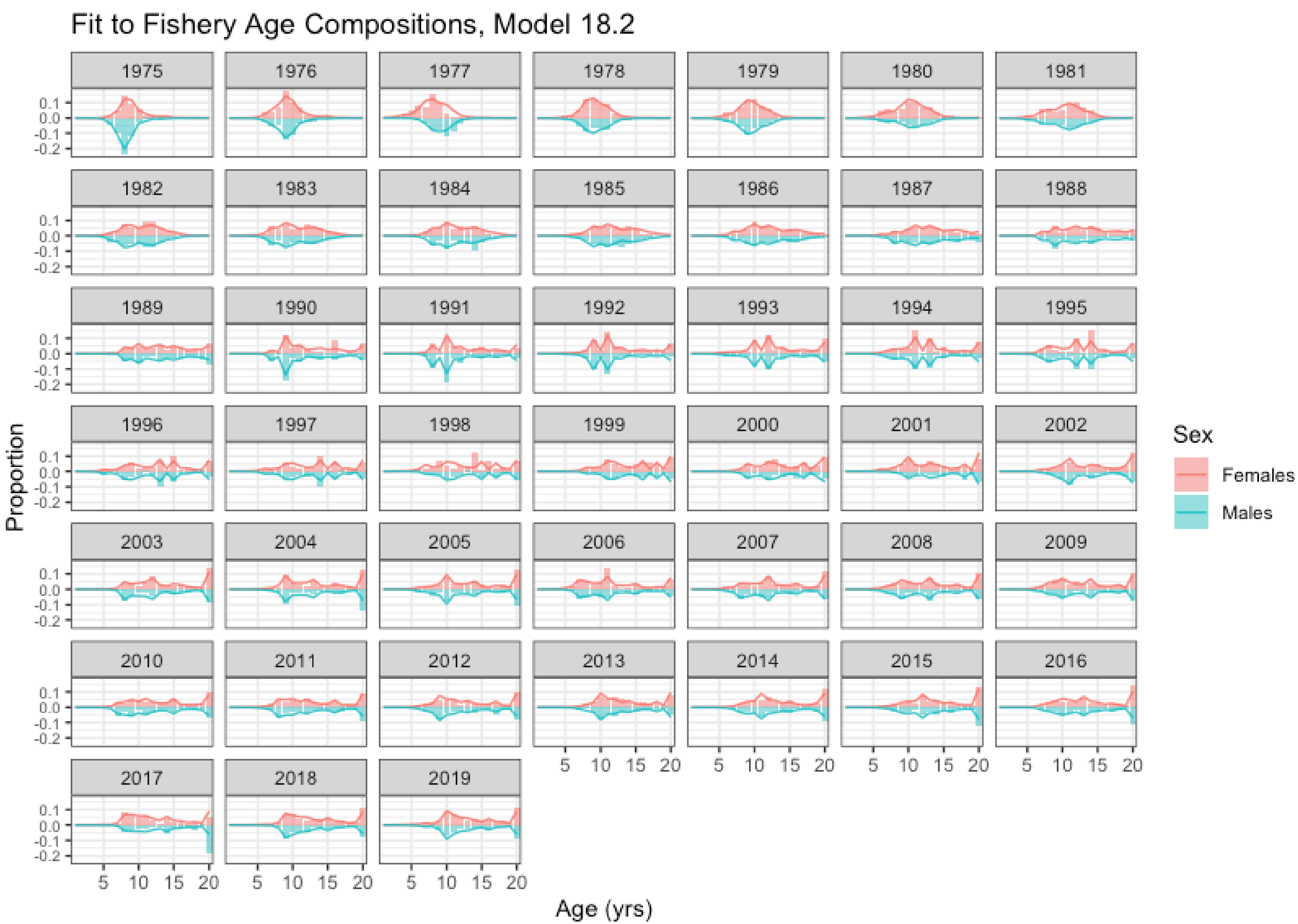
Model 18.1 fit to the time-series of survey age composition, by sex, 1979-2019



Model 18.2 fit to the time-series of survey age composition, by sex, 1979-2019

Model 18.1 fit to the time-series of fishery age composition, by sex

Model 18.2 fit to the time-series of fishery age composition, by sex



Comparison of likelihood values for Models 18.1 and 18.2.

Likelihood component	Model 18.1	Model 18.2
Survey age	604.51	575.56
Fishery age	658.01	620.17
Selectivity	61.41	61.16
Survey biomass	93.23	96.41
Recruitment	28.88	29.67
Catchability	0.0084	0.007
Total	1446.05	1382.98

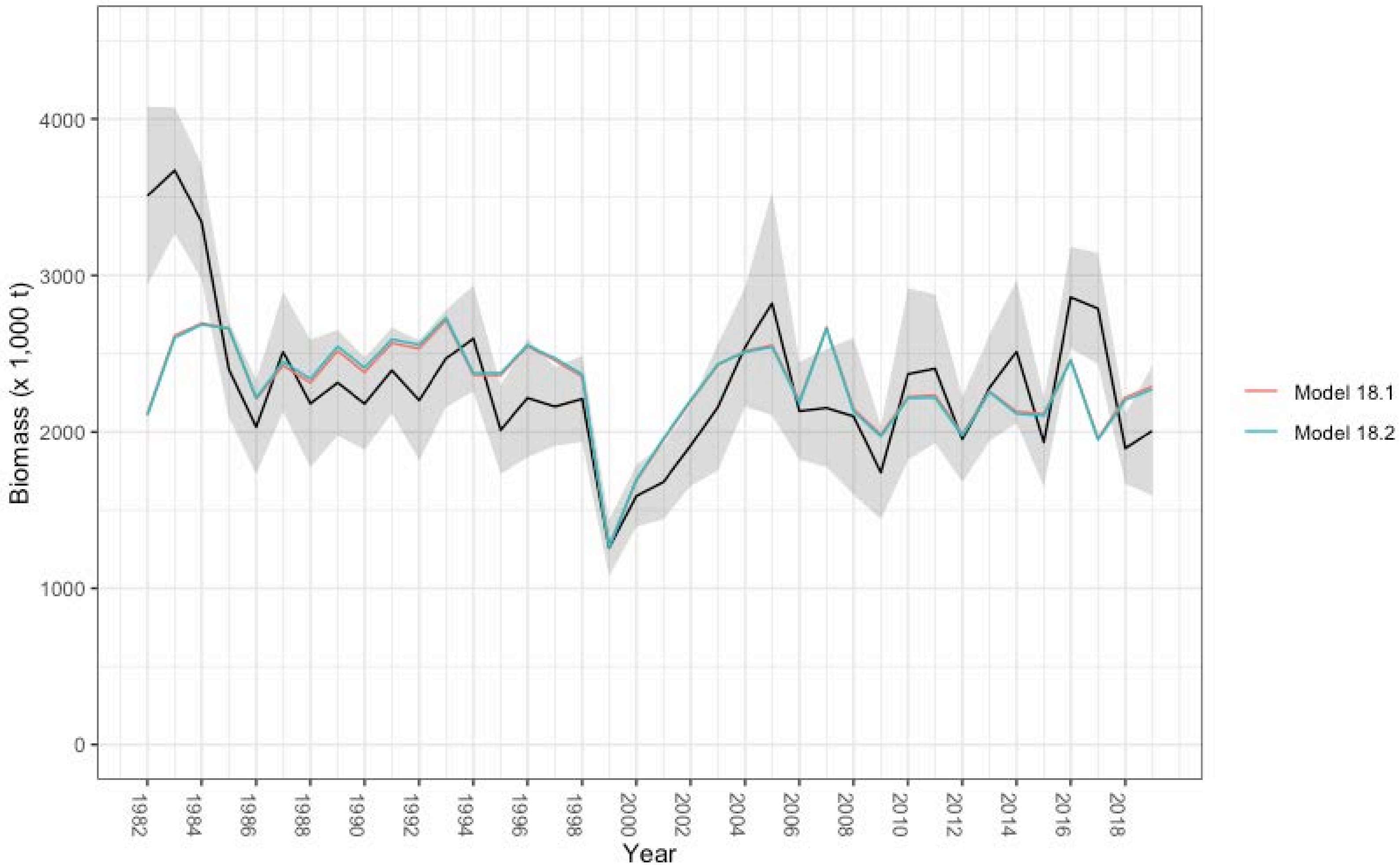
Comparison of reference points for Models 18.1 and 18.2

	Model 18.2 (2020)		Model 18.1 (2020)		Model 18.1 (2019)	
Quantity	2021	2022	2021	2022	2020	2021
M (natural mortality rate)	0.12	0.12	0.12	0.12	0.12, 0.135	0.12, 0.135
Tier	1a	1a	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,755,870	3,025,430	2,486,700	2,733,340	2,466,130	2,472,760
Projected female spawning biomass (t)	1,040,900	996,044	847,101	809,813	859,256	820,588
$B_{100\%}$	1,528,700	1,528,700	1,292,750	1,292,750	1,274,470	1,274,470
$B_{MSY\%}$	559,704	559,704	477,288	477,288	467,194	467,194
F_{OFL}	0.124	0.124	0.123	0.123	0.117	0.117
$maxF_{ABC}$	0.114	0.114	0.112	0.112	0.106	0.106
F_{ABC}	0.114	0.114	0.112	0.112	0.106	0.106
OFL	341,571	374,982	306,410	336,801	289,512	290,290
$maxABC$	313,477	344,140	278,370	305,980	262,632	263,337
ABC	313,477	344,140	278,370	305,980	262,632	263,337
Status	2019	2020	2019	2020	2019	2020
Overfishing	No	n/a	No	n/a	No	n/a
Overfished	n/a	No	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No	n/a	No

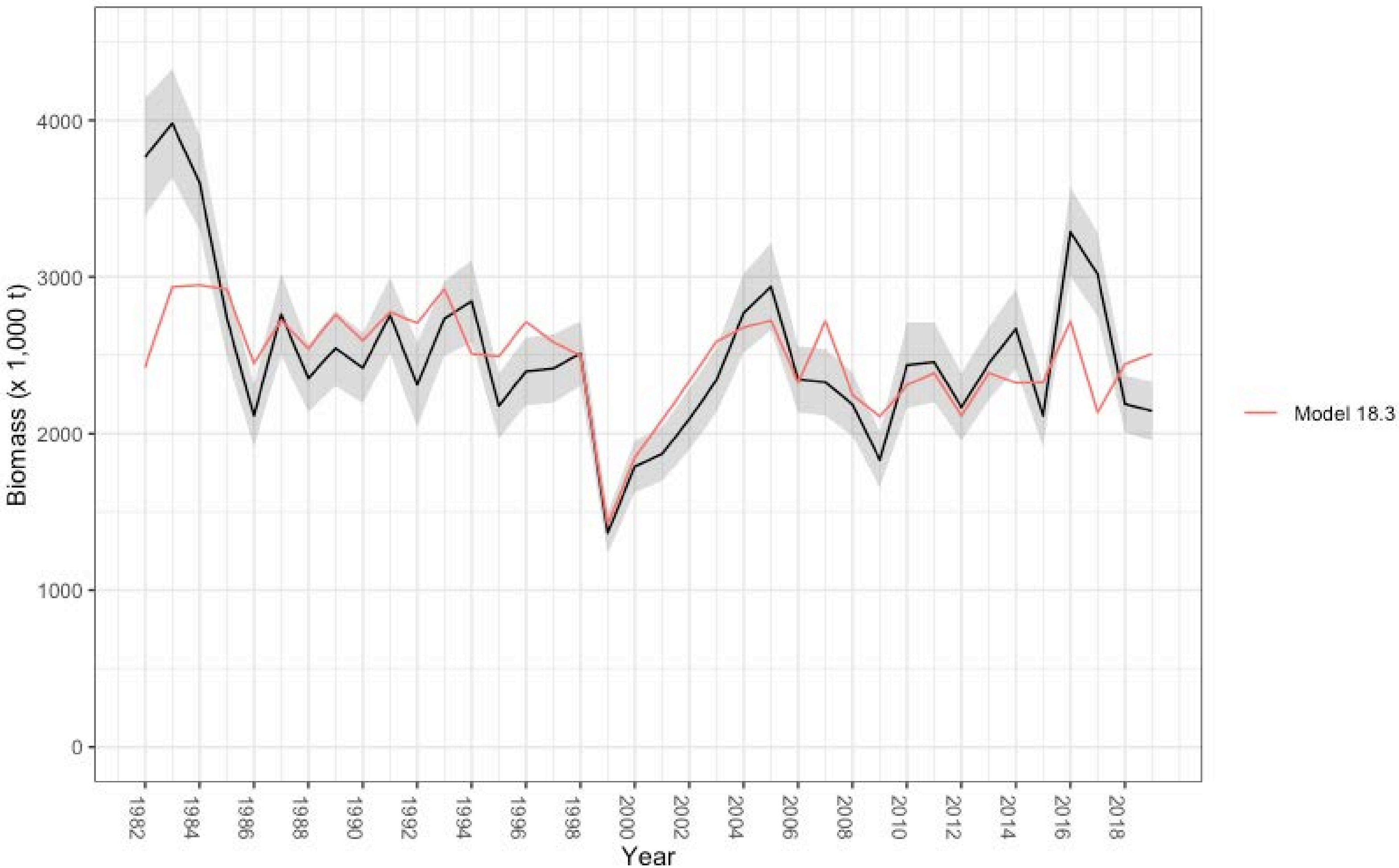
Comparison of reference points for Models 18.3 and 18.4

	Model 18.3		Model 18.4	
Quantity	2021	2022	2021	2022
M (natural mortality rate)	0.12	0.12	0.12	0.12
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,623,500	2,858,590	3,218,080	3,526,600
Projected female spawning biomass (t)	1,005,830	957,179	1,239,380	1,192,870
$B_{100\%}$	1,480,750	1,480,750	1,672,060	1,672,060
$B_{MSY\%}$	551,169	551,169	609,176	609,176
F_{OFL}	0.118	0.118	0.125	0.125
$maxF_{ABC}$	0.107	0.107	0.116	0.116
F_{ABC}	0.107	0.107	0.116	0.116
OFL	310,309	338,115	403,664	442,363
$maxABC$	280,409	305,536	374,641	410,557
ABC	280,409	305,536	374,641	410,557
Status	2019	2020	2019	2020
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

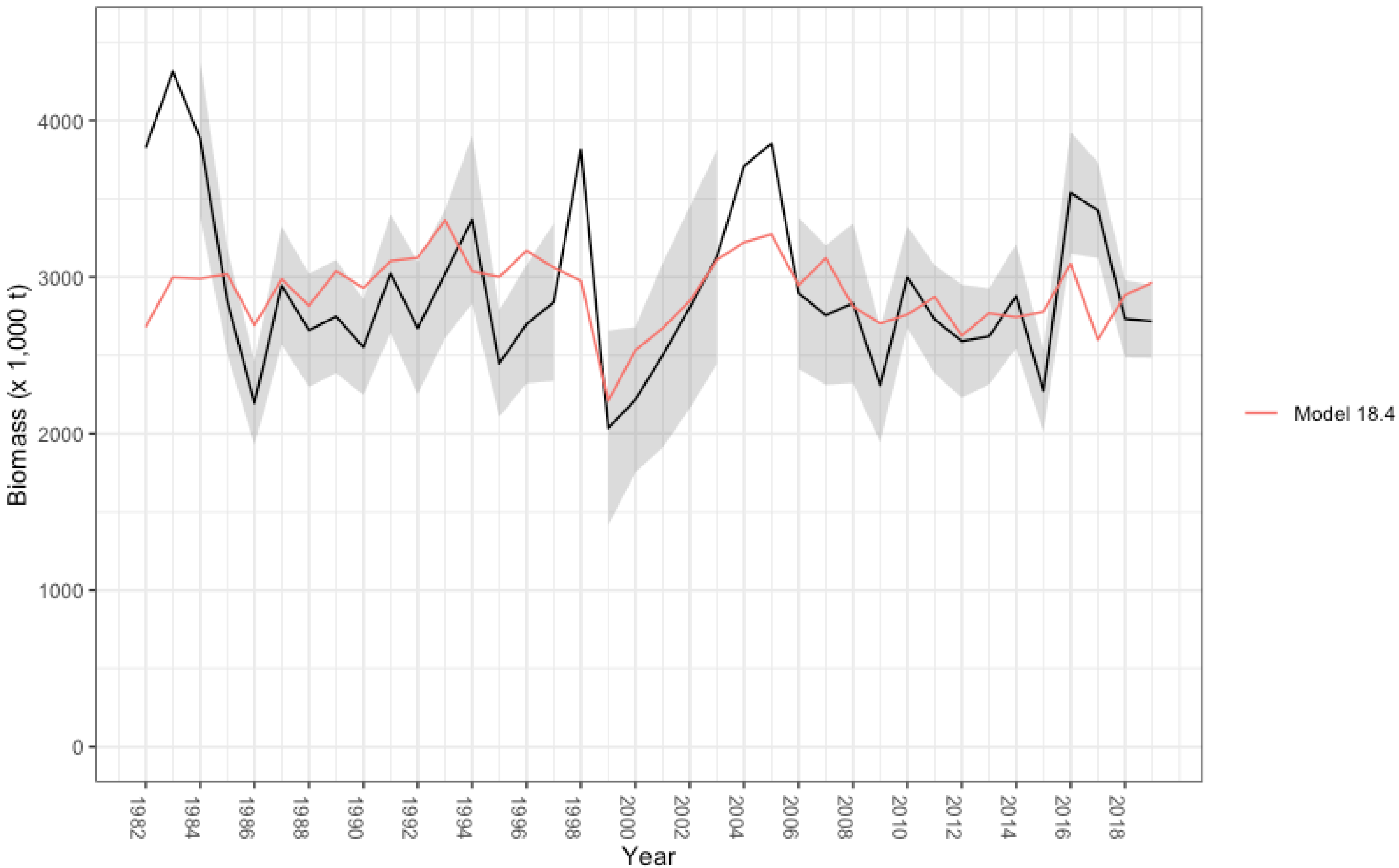
NMFS EBS survey biomass fit to survey data, Models 18.1, 18.2, 1982-2019



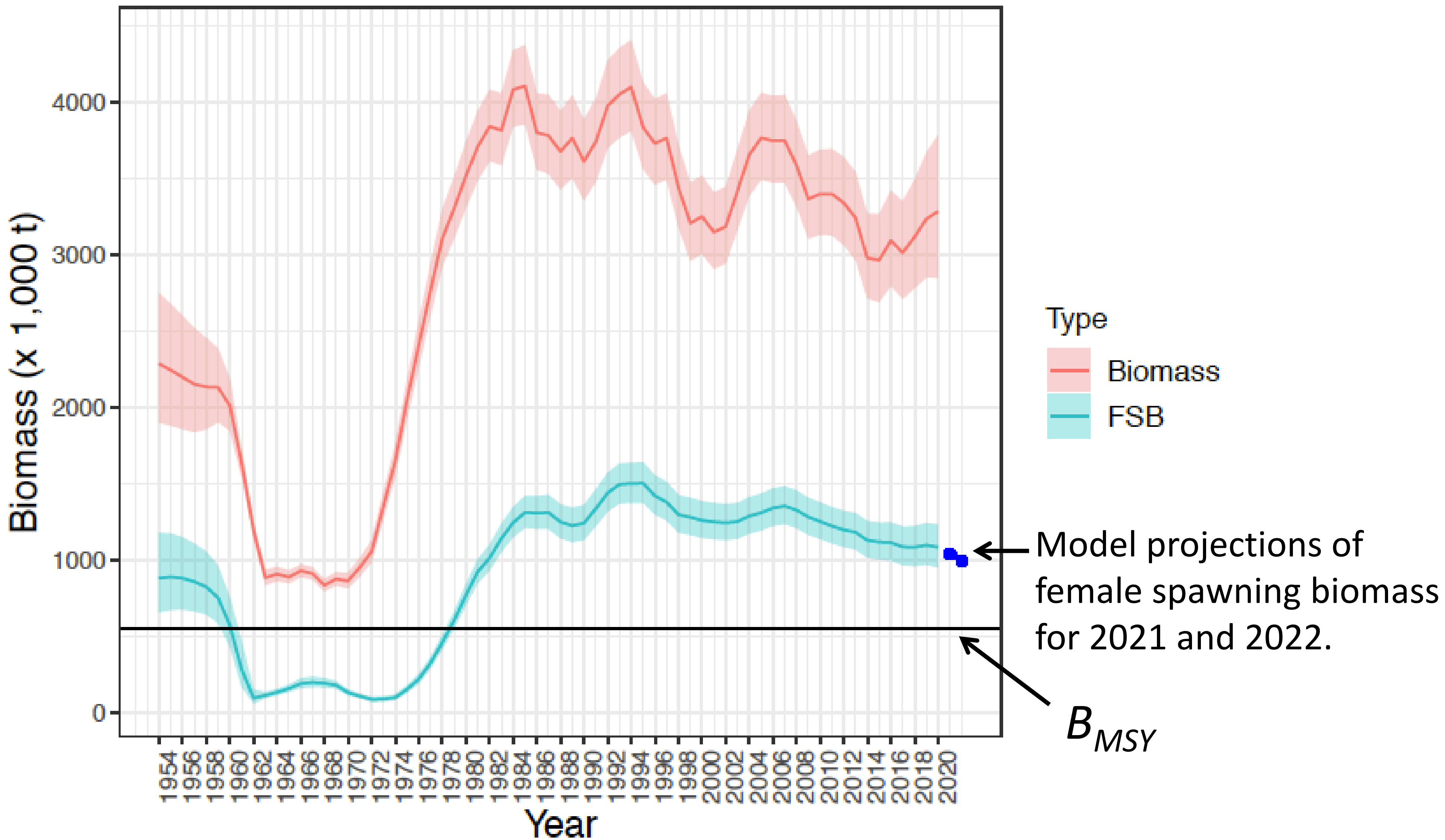
NMFS EBS survey biomass fit to survey data, Model 18.3, 1982-2019



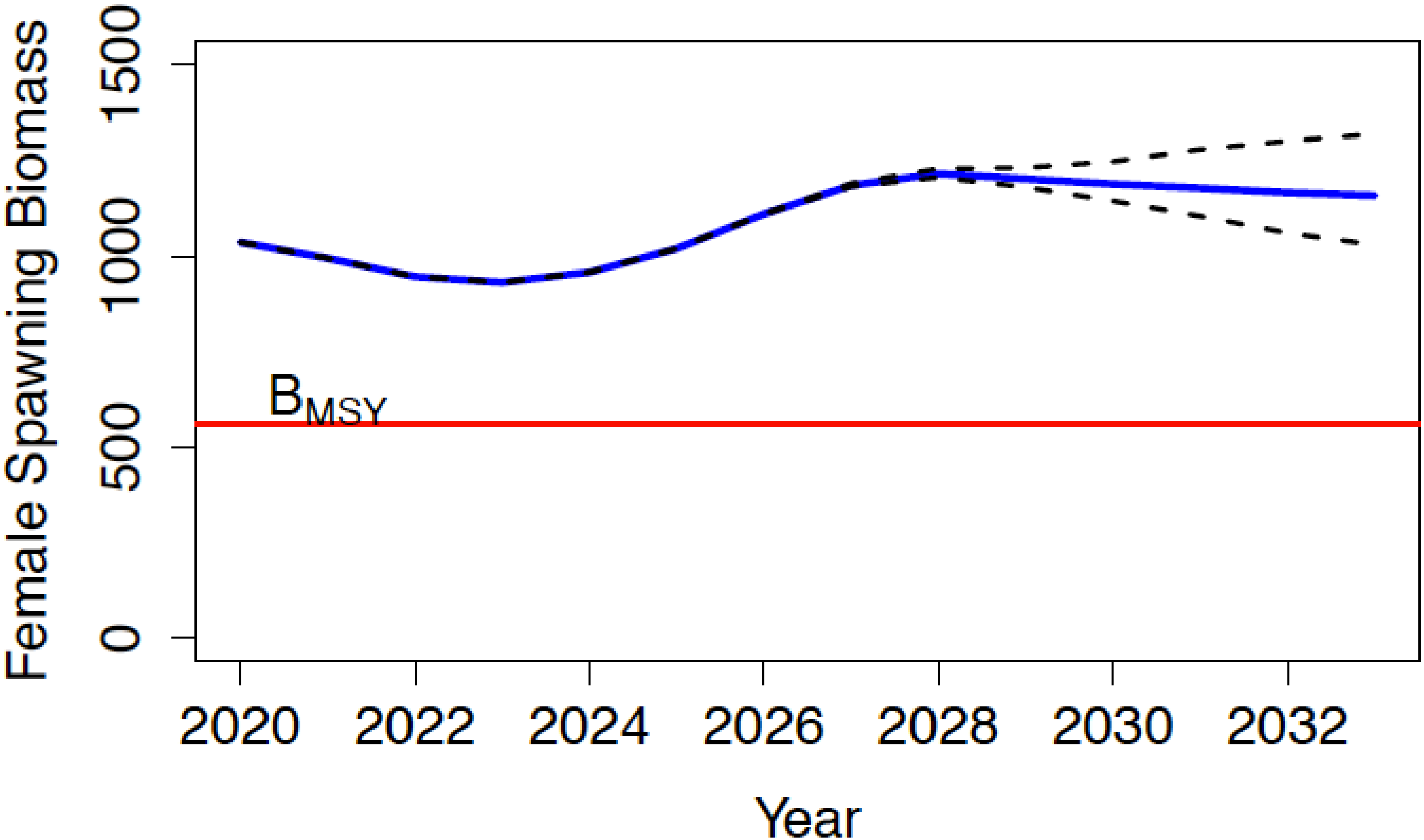
VAST NBS+EBS survey biomass fit to survey data, Model 18.4, 1982-2019



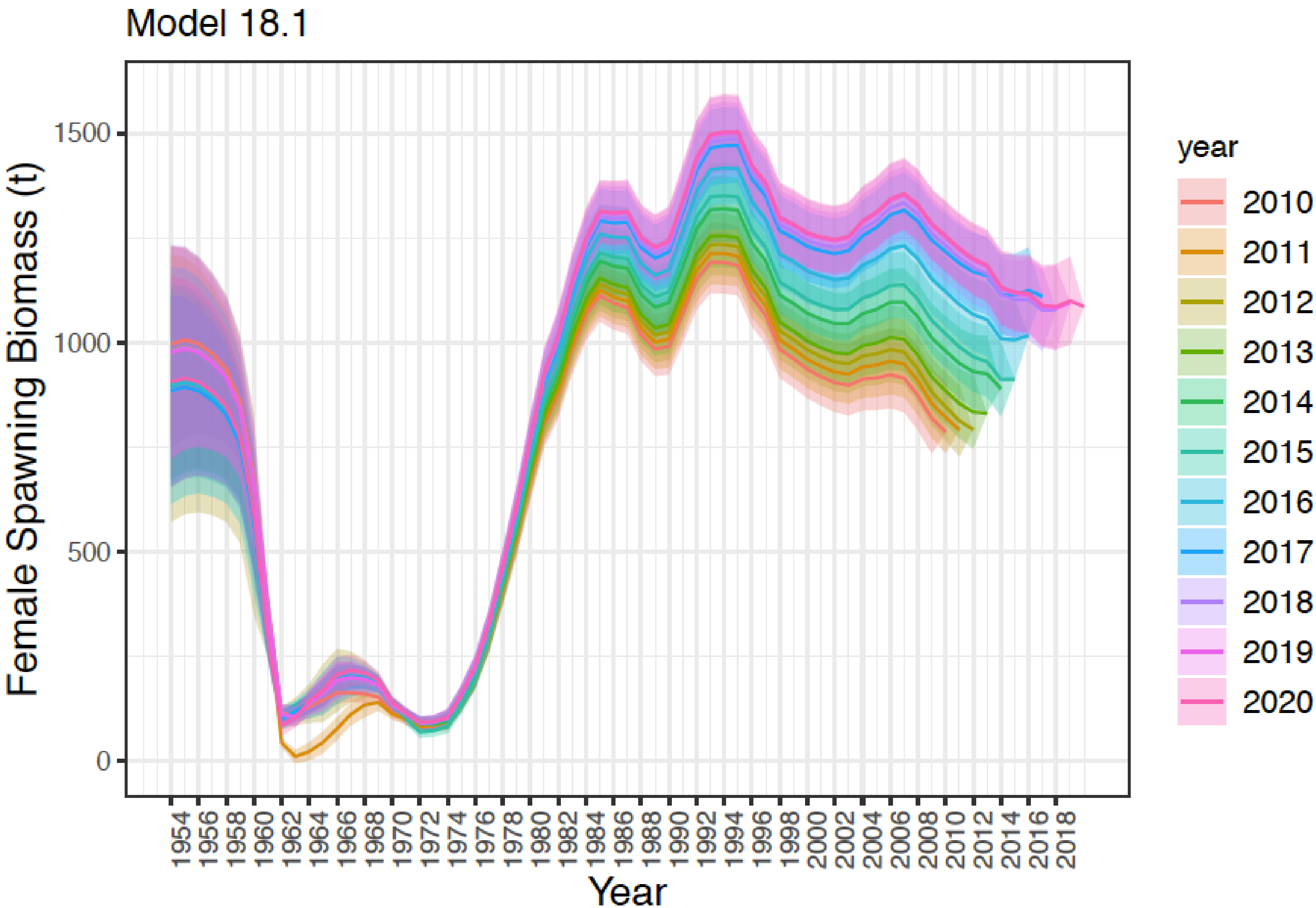
Model 18.2 estimates of total and female spawning biomass with 95% confidence intervals, 1954-2020.



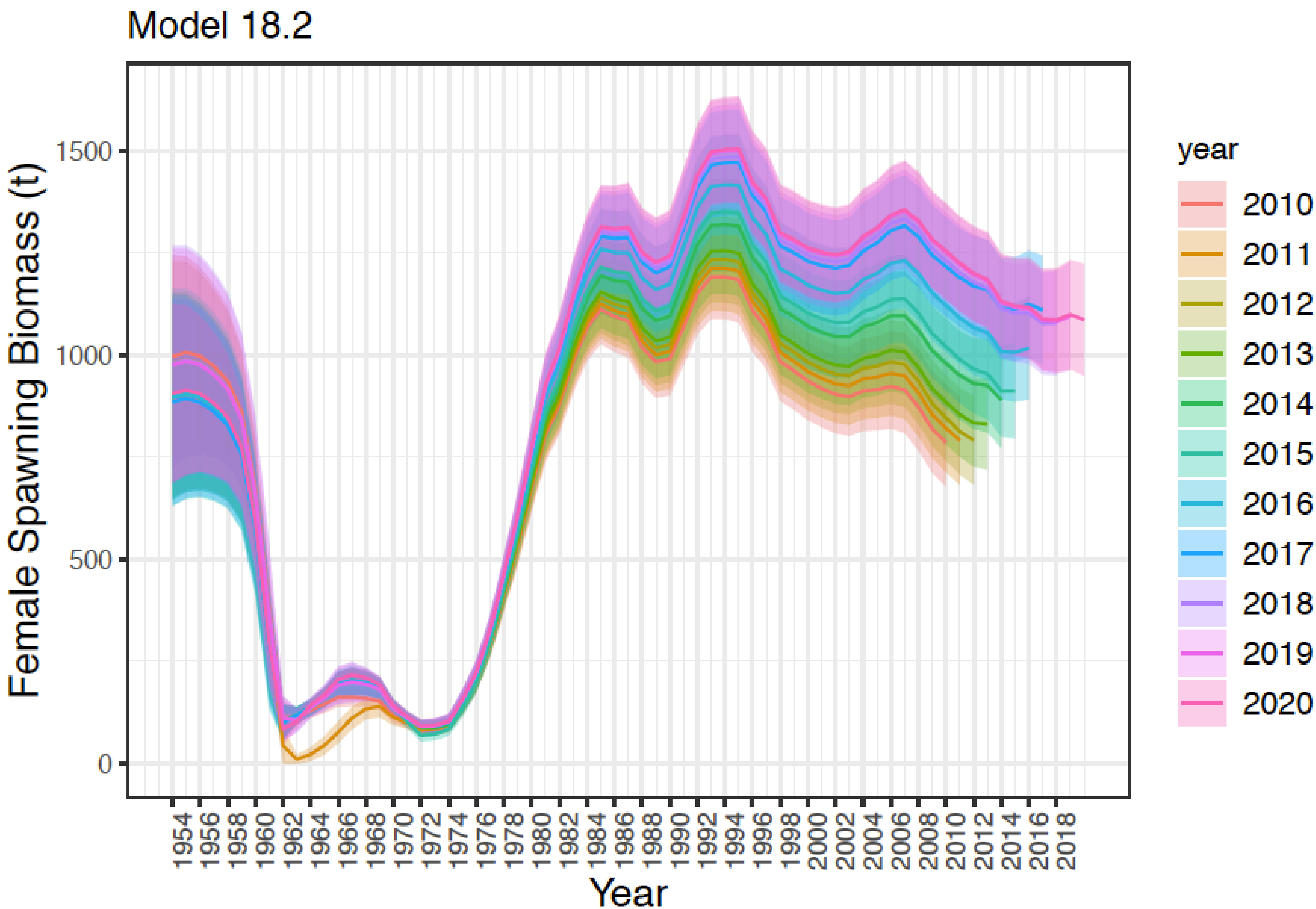
Projected female spawning biomass for 2020-2033 (blue line), and fishing at the 2015-2019 average.



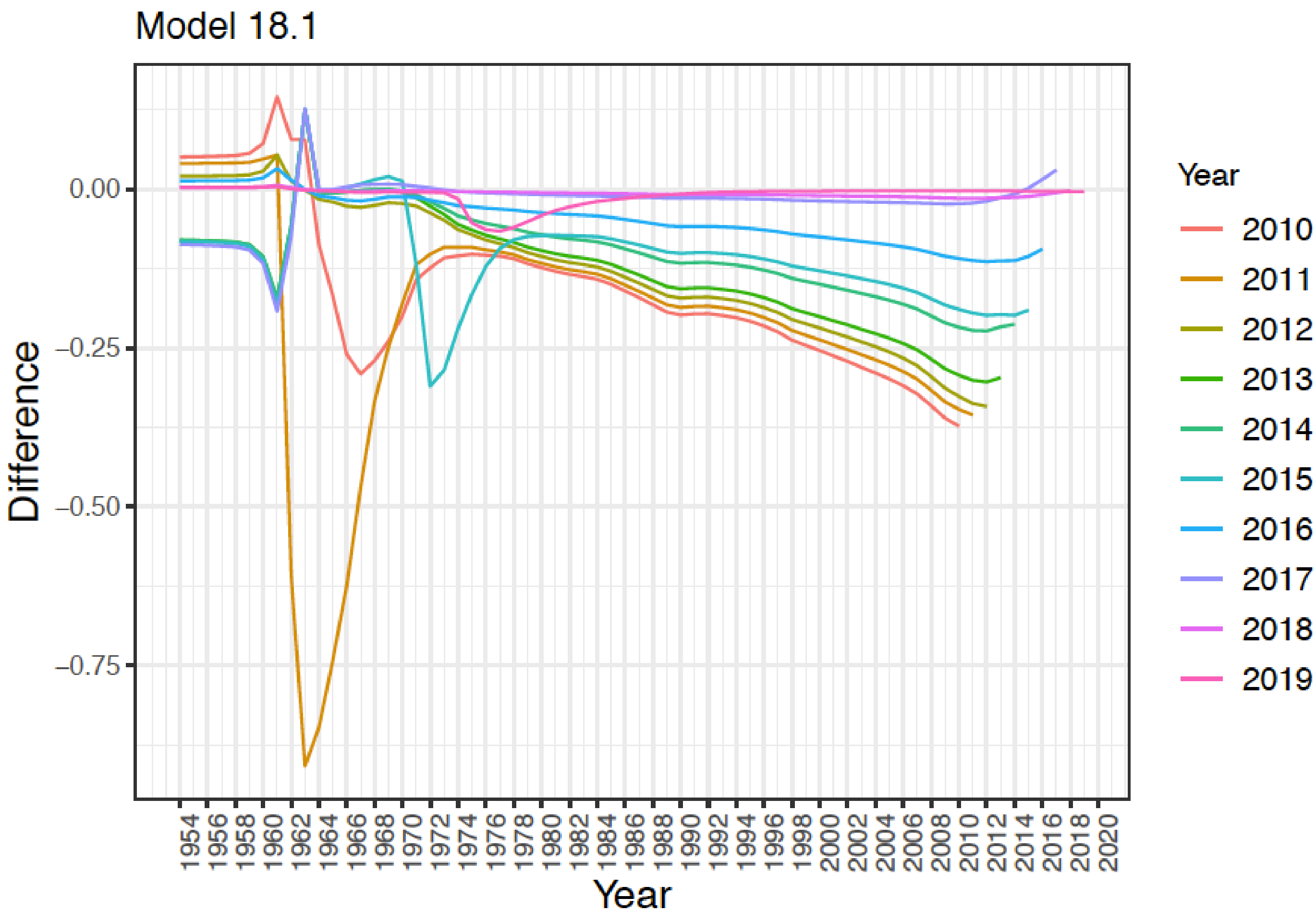
Model 18.1 retrospective plot of FSB, sequentially removed through 2010.



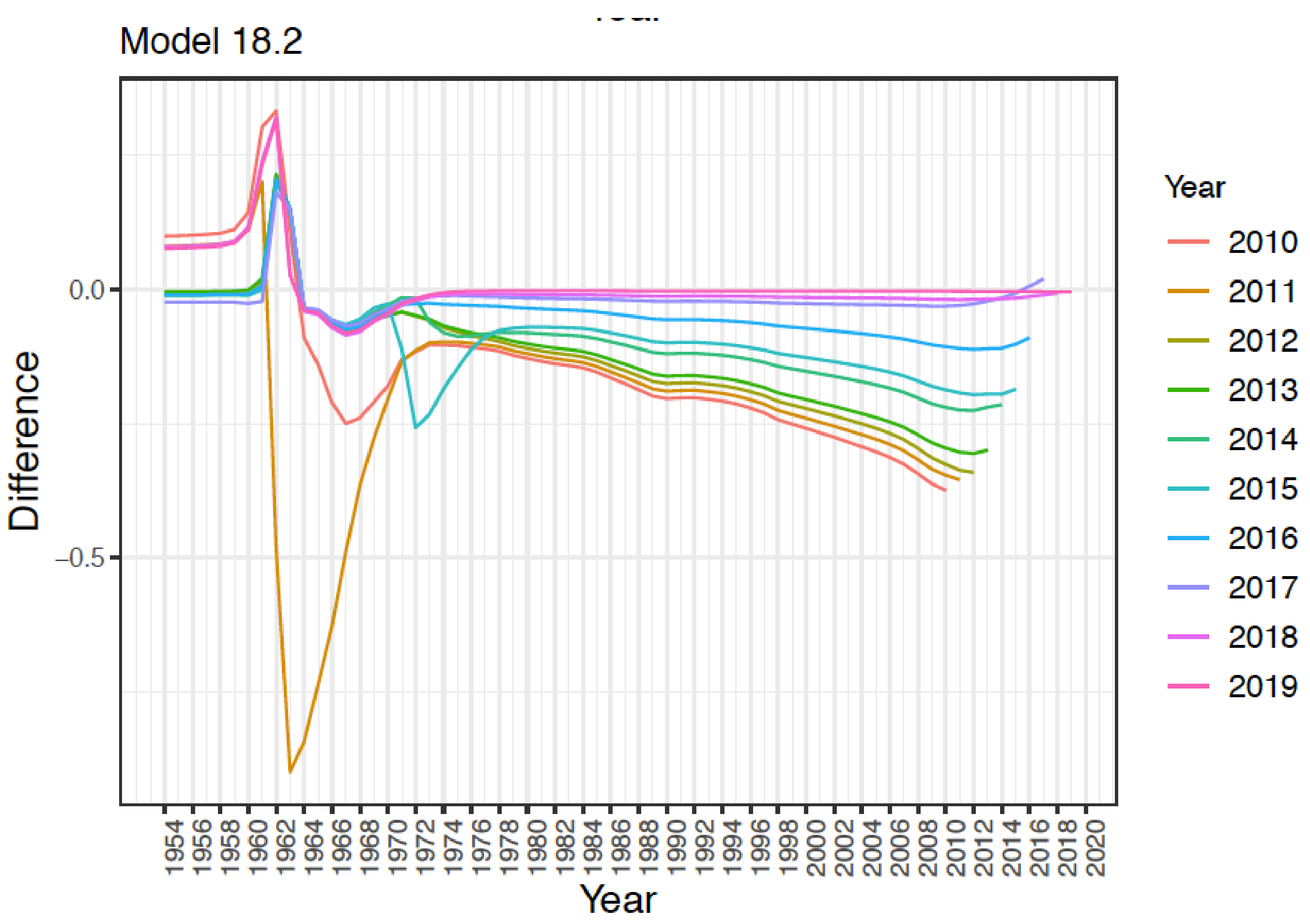
Model 18.2 retrospective plot of FSB, sequentially removed through 2010.



Model 18.1 retrospective plot of female spawning biomass, data sequentially removed through 2010.



Model 18.2 retrospective plot of female spawning biomass, data sequentially removed through 2010.



Uncertainty Assessment (Bryan et al. 2020)

- The BSAI yellowfin sole exhibited a negative bias that became more negative when the most recent survey data were not included in the assessment model (-.209 with survey to -.0.237 without survey).
- Bias in recruitment was greater for EBS Pacific cod, tanner crab and snow crab and less for BSAI yellowfin, northern rock sole, flathead sole, and Greenland turbot when the most recent survey data was missing from the assessment model.
- Based on this analysis, level of uncertainty in the Yellowfin Sole stock is lower than for other species.

Risk Table

Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance	Overall
Level 1: Only minor, low level of concern	Level 1: Stock trends are typical for the stock and expected given stock dynamics; recent recruitment is within the normal range.	Level 1: Stock trends are typical for the stock and expected given stock dynamics; recent recruitment is within the normal range.	Level 1: No apparent environmental/ecosystem concerns	Level 1: Normal.

No changes are recommended to the ABC, based on this risk table assessment.

Risk Table – Assessment Related Considerations

- The BSAI Yellowfin Sole assessment is based on surveys conducted annually on the EBS shelf from 1982-2019
- Fish ages, derived from otoliths collected during the surveys and the fishery to calculate annual estimates of population and fishery age composition, have been validated.
- The assessment model compositional and abundance data well and converges to a single minima in the likelihood surface.
- Recruitment estimates track strong year-classes that are consistent with the data.

- Assessment considerations are not a concern for this assessment.

Risk Table – Population Dynamics Considerations

- The present biomass is estimated at 80% of the peak 1985 level and female spawning biomass is almost double B_{MSY}.
- Projections indicate that the *FSB* will remain well-above the B_{MSY} level through 2033.

- Population dynamics are not a concern for this assessment.

Environmental/Ecosystem Considerations

- Summer bottom temperatures and spatial extent of the cold pool were average, indicating a cooler thermal experience for YFS, which may be adapted to colder temperatures.
- In 2019, YFS condition (weighted length-weight residuals) was positive in the SEBS and NBS and continued upward trends since 2017;
- The mean size of the groundfish community increased in 2019 buoyed by species including YFS, which had above average mean length;
- Sufficient prey availability for YFS over the southern Bering Sea shelf;
- Increase of predators over the eastern Bering Sea shelf indicates increased risk of predation, although size, spatial, and/or temporal mismatches may exist and provide refuge for YFS;

- No apparent ecosystem concerns--level 1.

Fishery Performance Considerations

- Fishery CPUE is not showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, or changes in the percent of TAC taken, changes in the duration of fishery openings.

- No apparent fishery performance considerations – level 1.

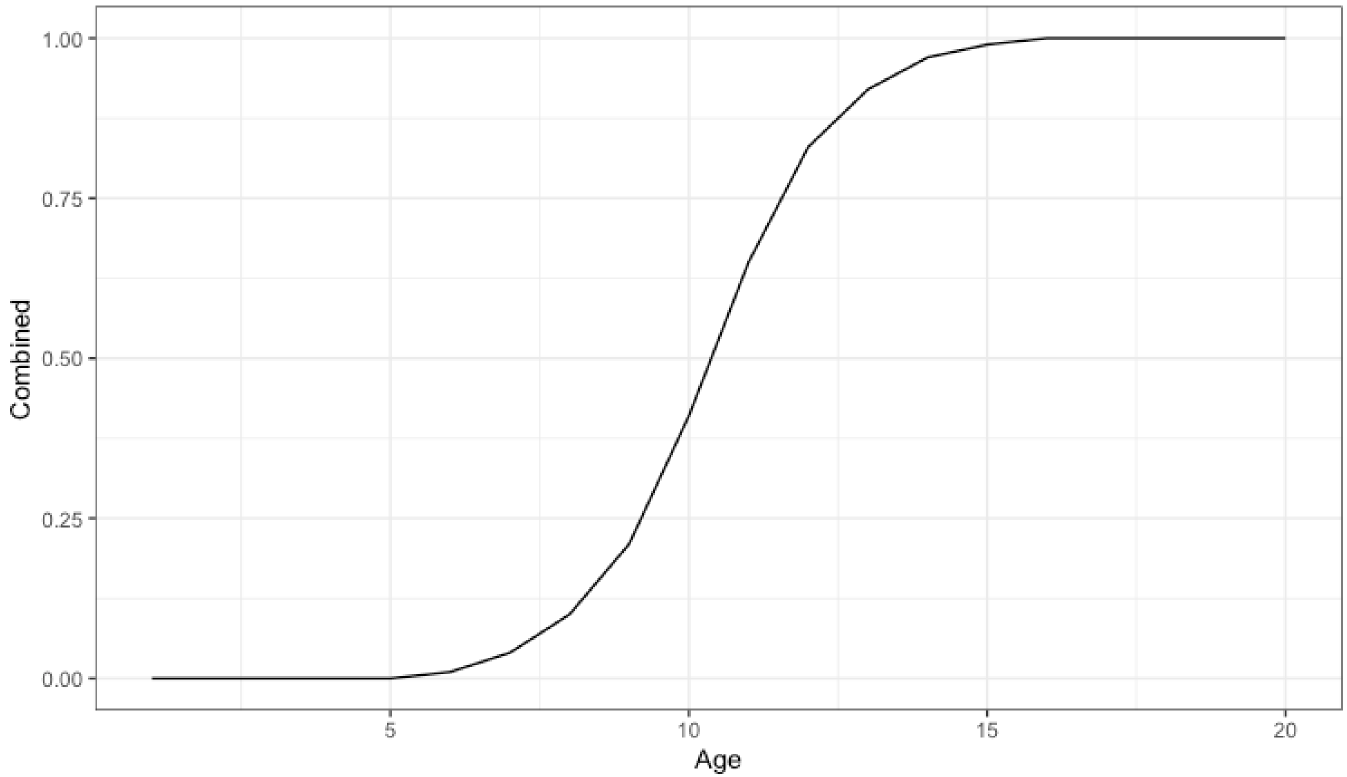
Summary Table

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2020	2021	2021	2022
M (natural mortality rate)	0.12	0.12	0.12, 0.135	0.12, 0.135
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,486,700 t	2,733,340 t	2,755,870 t	3,025,430 t
Projected female spawning biomass (t)	847,101 t	809,813 t	1,040,900 t	996,044 t
$B_{100\%}$	1,275,940 t	1,275,940 t	1,528,700 t	1,528,700 t
$B_{MSY\%}$	477,288 t	477,288 t	559,704 t	559,704 t
F_{OFL}	0.123	0.123	0.124	0.124
$maxF_{ABC}$	0.112	0.112	0.114	0.114
F_{ABC}	0.112	0.112	0.114	0.114
OFL	306,410 t	336,801 t	341,571 t	374,982 t
$maxABC$	278,370 t	305,980 t	313,477 t	344,140 t
ABC	278,370 t	305,980 t	313,477 t	344,140 t
Status	2018	2019	2019	2020
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Projections were based on estimated catches of 127,020 t in 2020 and 139,283 t used in place of maximum ABC for 2021.

Maturity at age

- Yellowfin sole maturity schedules were estimated from two studies.
- Nichol (1995) and Wilderbuer (2015).



Fishery Selectivity

$$S^{f}_{a,t} = [1 + e^{\eta_t (a - \varphi_t)}]^{-1}$$

where a is age, t is year, and φ_t and η_t are time-varying and partitioned (for estimation) into parameters representing the mean and a vector of deviations (log-scale) conditioned to sum to zero. The deviations are constrained by a lognormal prior with a variance that was iteratively estimated. The process of iterating was to first set the variance to a high value to estimate the deviations. The next step was to compare the variability of model estimates. The variance of the model estimates were then rounded up slightly and fixed for subsequent runs. The 2020 values were fixed as the average of the 3 most recent years.

Model estimates of Yellowfin Sole population at age