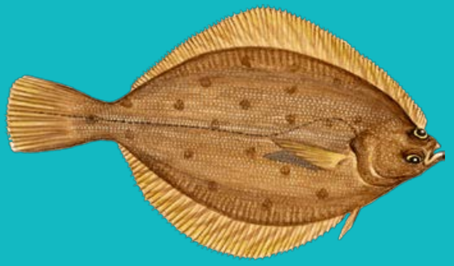
NOAA FISHERIES

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

Ingrid Spies, Lewis Barnett, Rebecca Haehn, James Ianelli, Emily Markowitz, Zack Oyafuso, Elizabeth Siddon, Cynthia Yeung


Selected SSC comments, November 2020

The SSC recommends …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.

Authors' response:

A single survey selectivity curve was implemented in Models 22.0 and 22.1 in response to this comment. Future work will explore single fishery selectivities for males and females as well as the other comments noted.

Selected SSC comments, December 2021

The SSC looks forward to … updated models that include VAST estimates and include NBS data (similar to 2021 models 18.2a and 18.2b) and incorporate NBS bottom temperatures into estimates of survey catchability (if appropriate).

Author's response:

We have included a model (Model 22.1) that includes a model-based survey index for the combined EBS and NBS regions. Model-based age compositions for the EBS and NBS combined region were also used. Given the computational effort required to generate model-based age compositions, we support the use of cloud computing for future model-based data synthesis.

Selected SSC comments, December 2021

An important issue discussed by the SSC was the posterior probability distributions for key model parameters (2021 Assessment, Figure 4.31) still indicate the absence of the smooth probability distributions that are often associated with model convergence and efficient MCMC sampling...could result from poor MCMC chain mixing, an insufficiently long chain, or high autocorrelation, and may be indicative of important estimation challenges within this complex assessment model. The SSC requests the authors present standard MCMC convergence diagnostics including trace plots, autocorrelation, and potential scale reduction factors for model parameters and derived quantities.

Author's response:

This will be discussed in this presentation.

NOAA FISHERIES

Selected SSC comments, December 2021

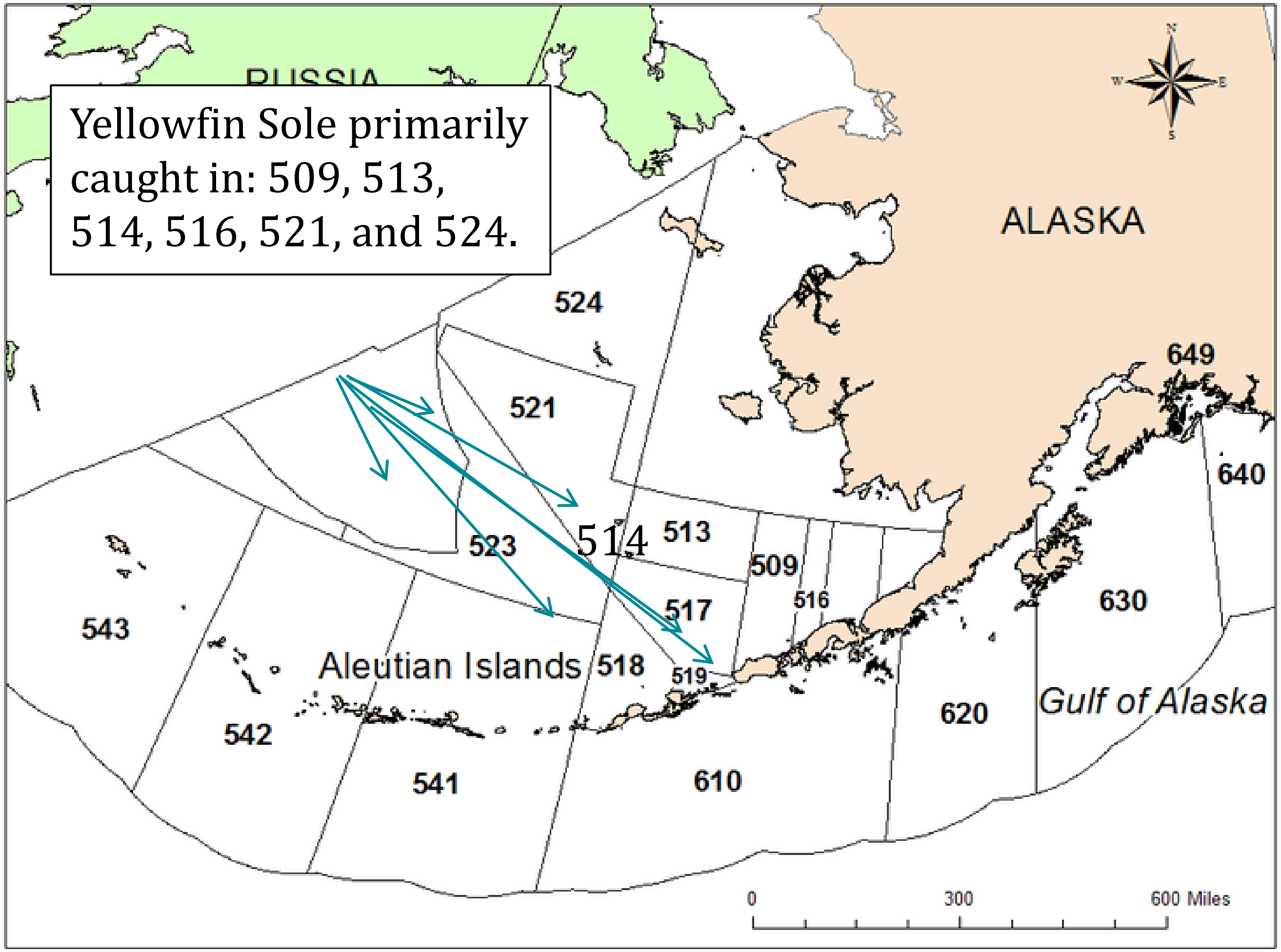
Finally, the author and the BSAI GPT highlighted potential impacts associated with the implementation of Amendment 80, including an incentive to reduce discards of smaller fish and changes in observer coverage. The SSC encourages the author to seek input from the industry to explore these potential effects along with other factors (e.g. markets, tariffs) that may be impacting fishery catch compositions.

Tariffs and COVID have impacted the fishing industry.

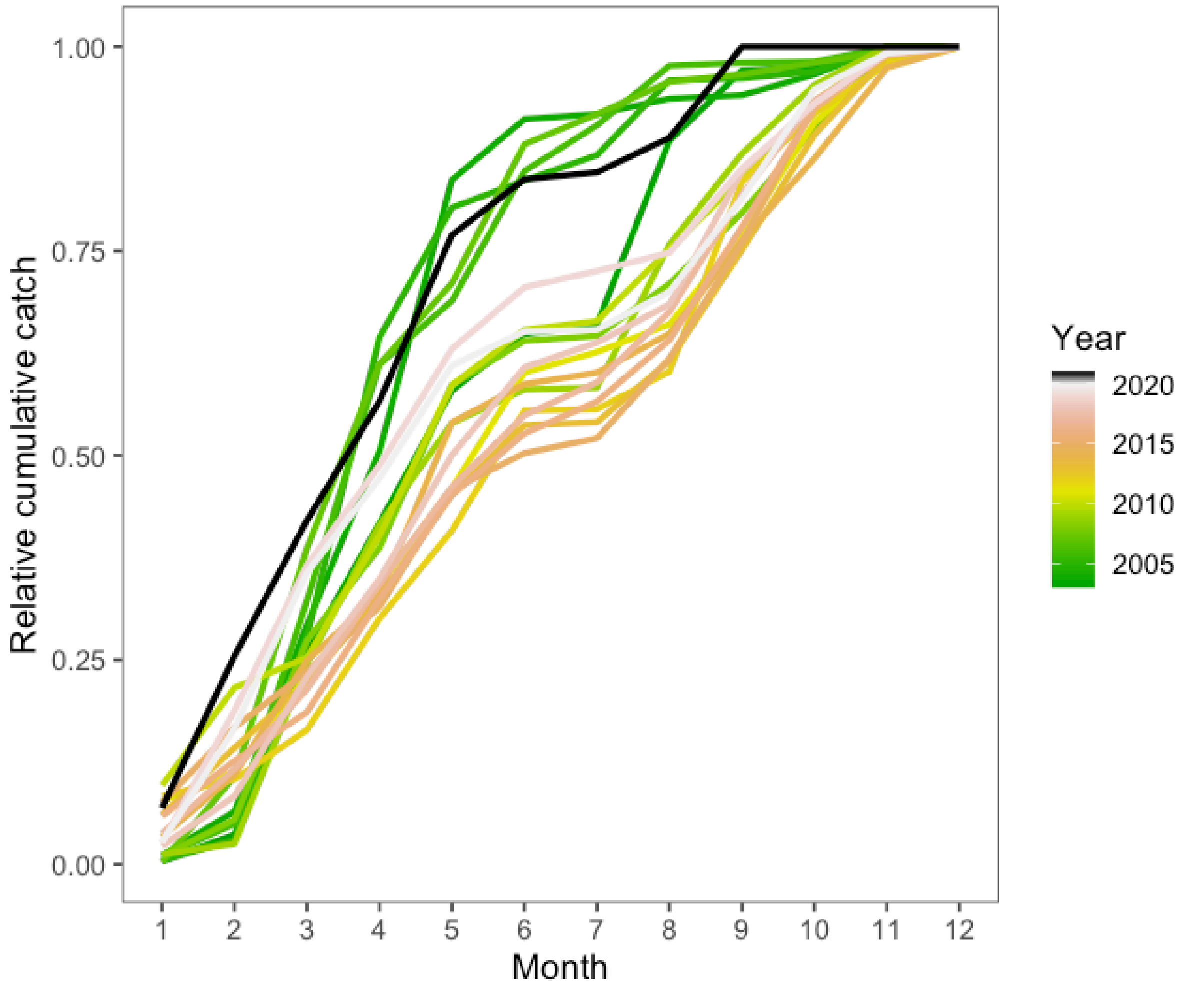
	2011-2016 Average	2017	2018	2019	2020	2021
Global production of flounder, halibut, and sole K mt	1011.47	977.32	994.28	954.56	934.23	-
US share global production	30%	27%	25%	27%	27%	-
BSAI FMP flatfish share of U.S.1	85.16%	80.79%	85.52%	81.79%	83.62%	-
Export quantity of yellowfin sole and rock sole K mt	84.61	81.36	72	76.7	80.75	48.54
Export value of yellowfin sole and rock sole M US$	$119.93	$115.26	$107.06	$118.43	$118.12	$71.69
Export price/lb of yellowfin sole and rock sole US$	$0.64	$0.64	$0.67	$0.70	$0.66	$0.67
China's share of yellowfin sole and rock sole export value	82.69%	81.67%	78.63%	70.60%	79.60%	73.59%
Exchange rate, Euro/Dollar	0.82	0.89	0.85	0.89	0.88	0.845

Fishery and catch

Yellowfin sole catch in the eastern Bering Sea

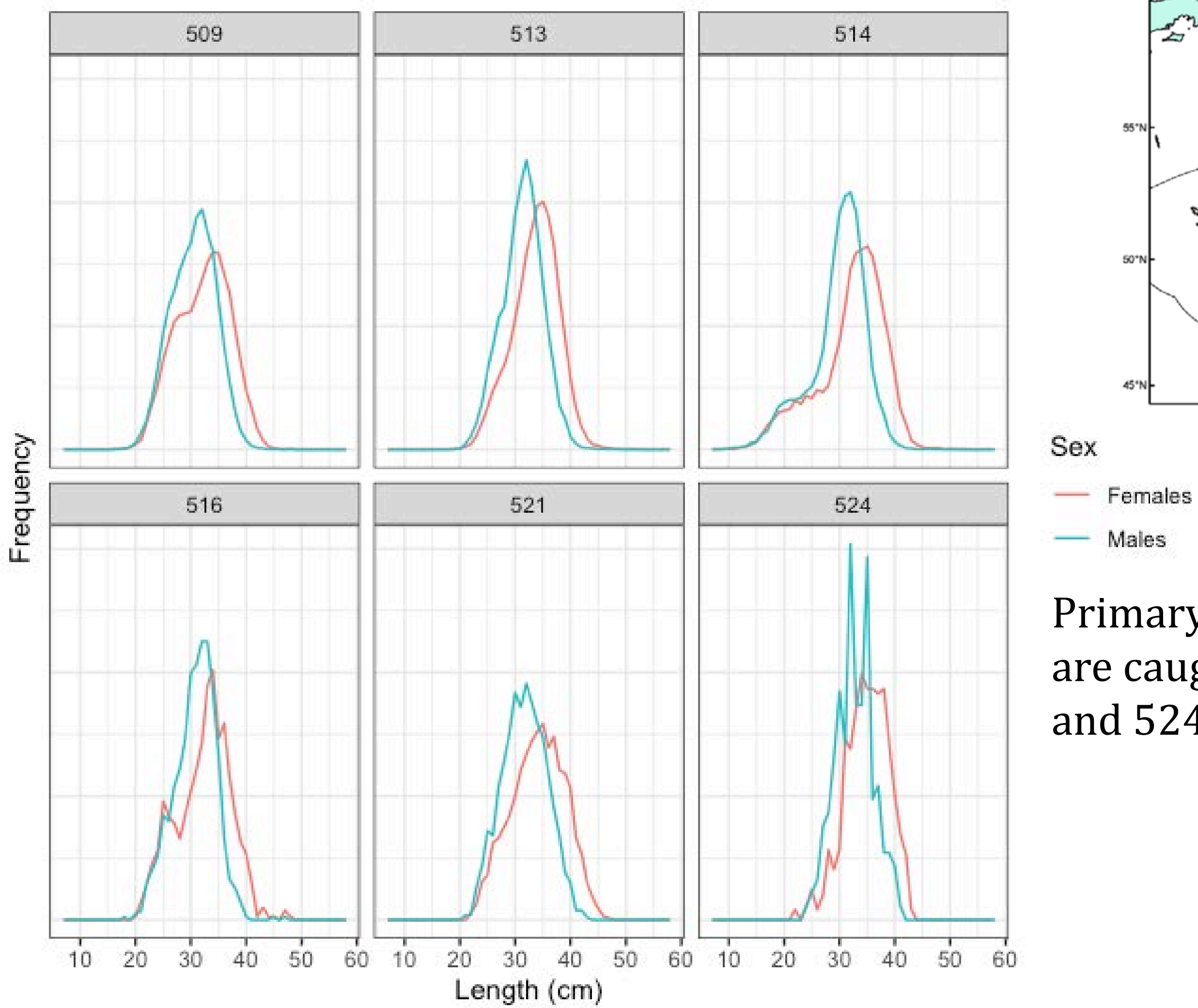


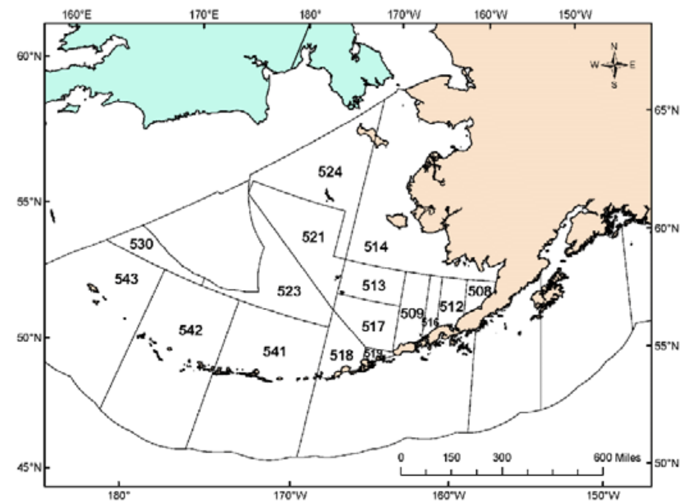
Yellowfin sole annual cumulative catch by month and year (non CDQ) 2003-October 1, 2022



NOAA FISHERIES

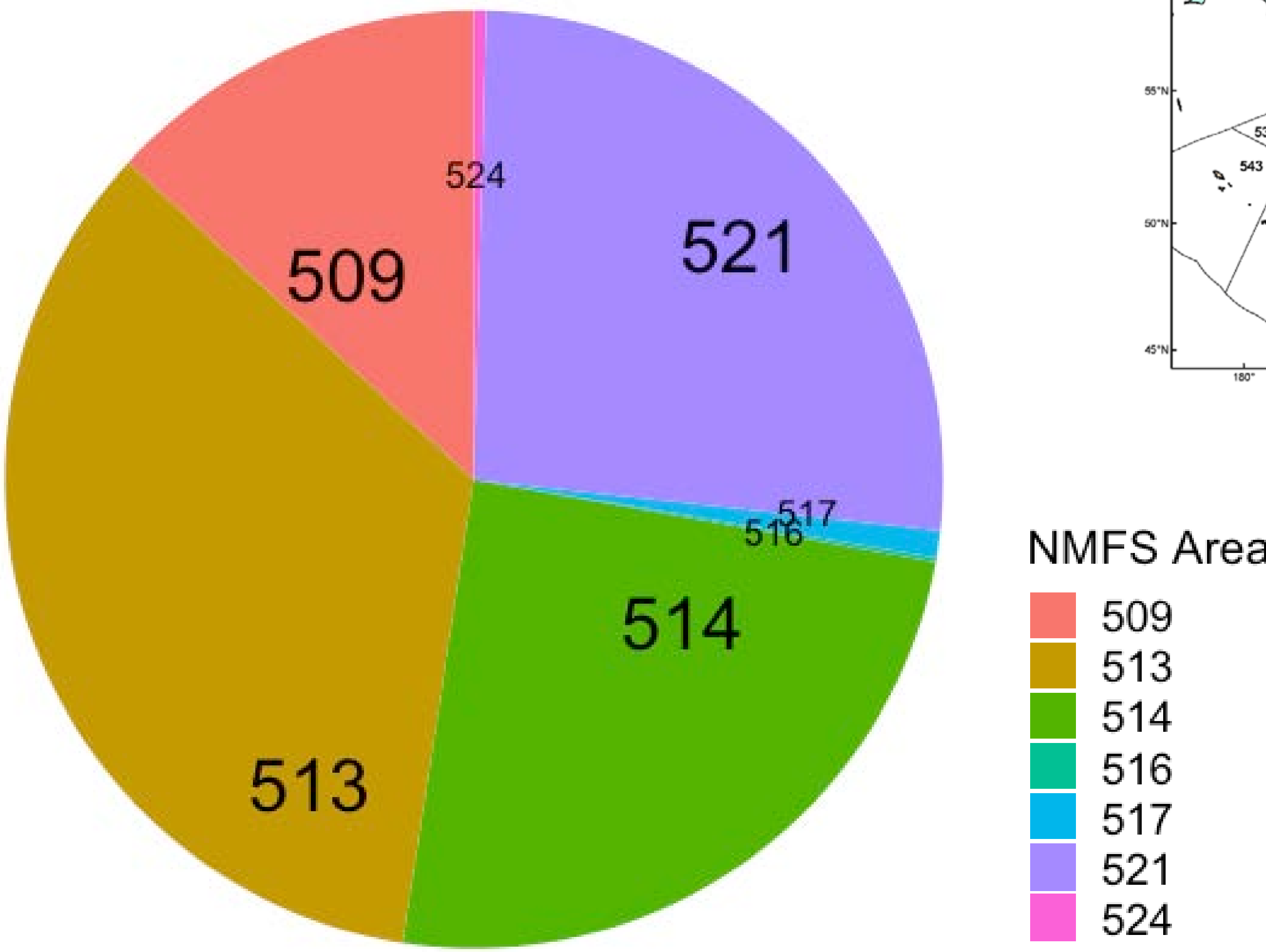
Size composition of the yellowfin sole catch in 2022 caught by trawl gear, by subarea

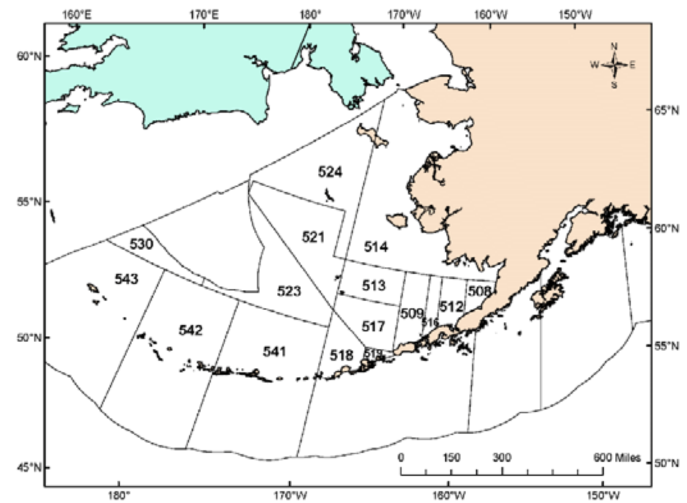




Primary areas where yellowfin sole are caught: 509, 513, 514, 516, 521, and 524. Catch is through October 12.

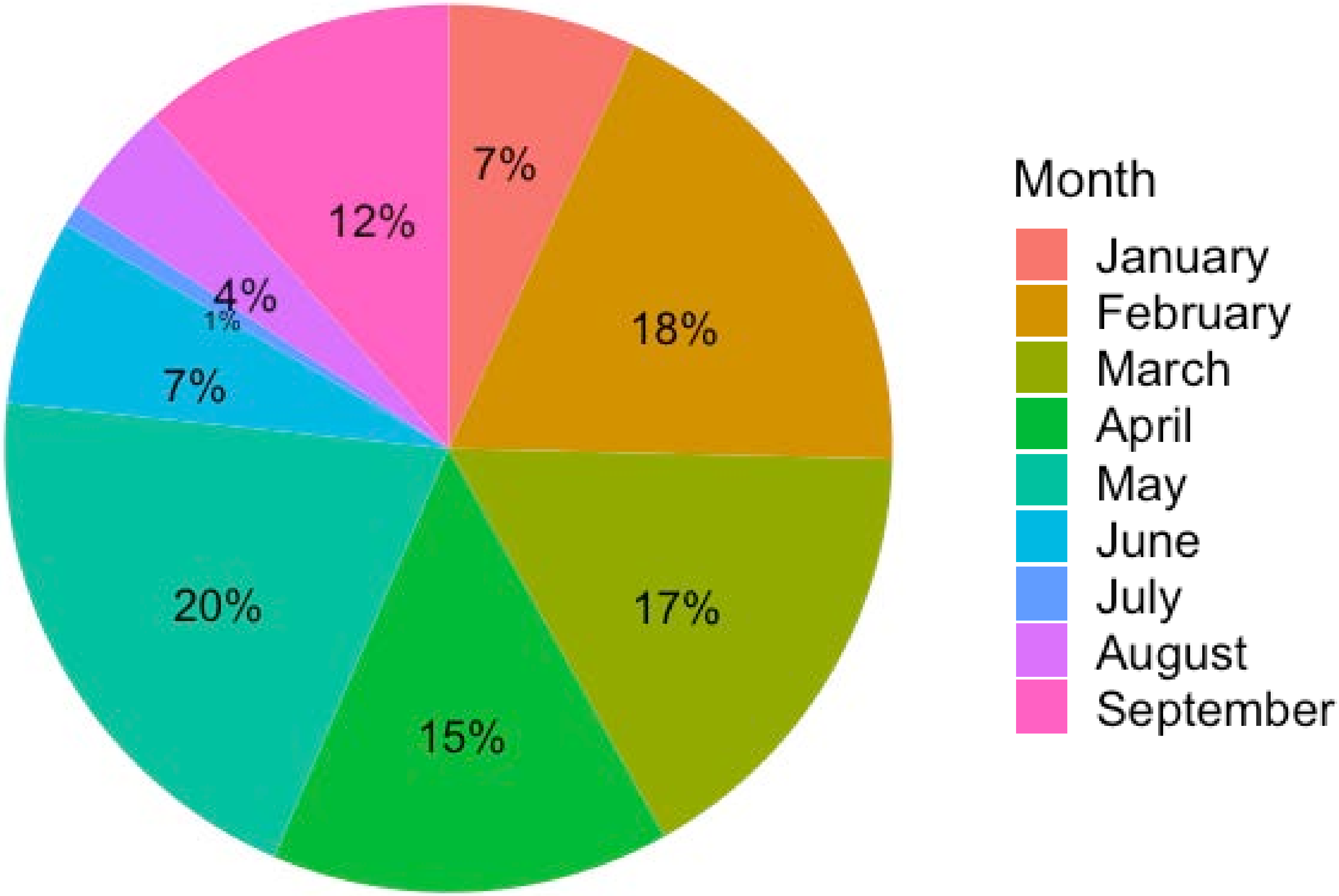
Yellowfin sole catch proportion by area January 1, 2022 through October 12, 2022



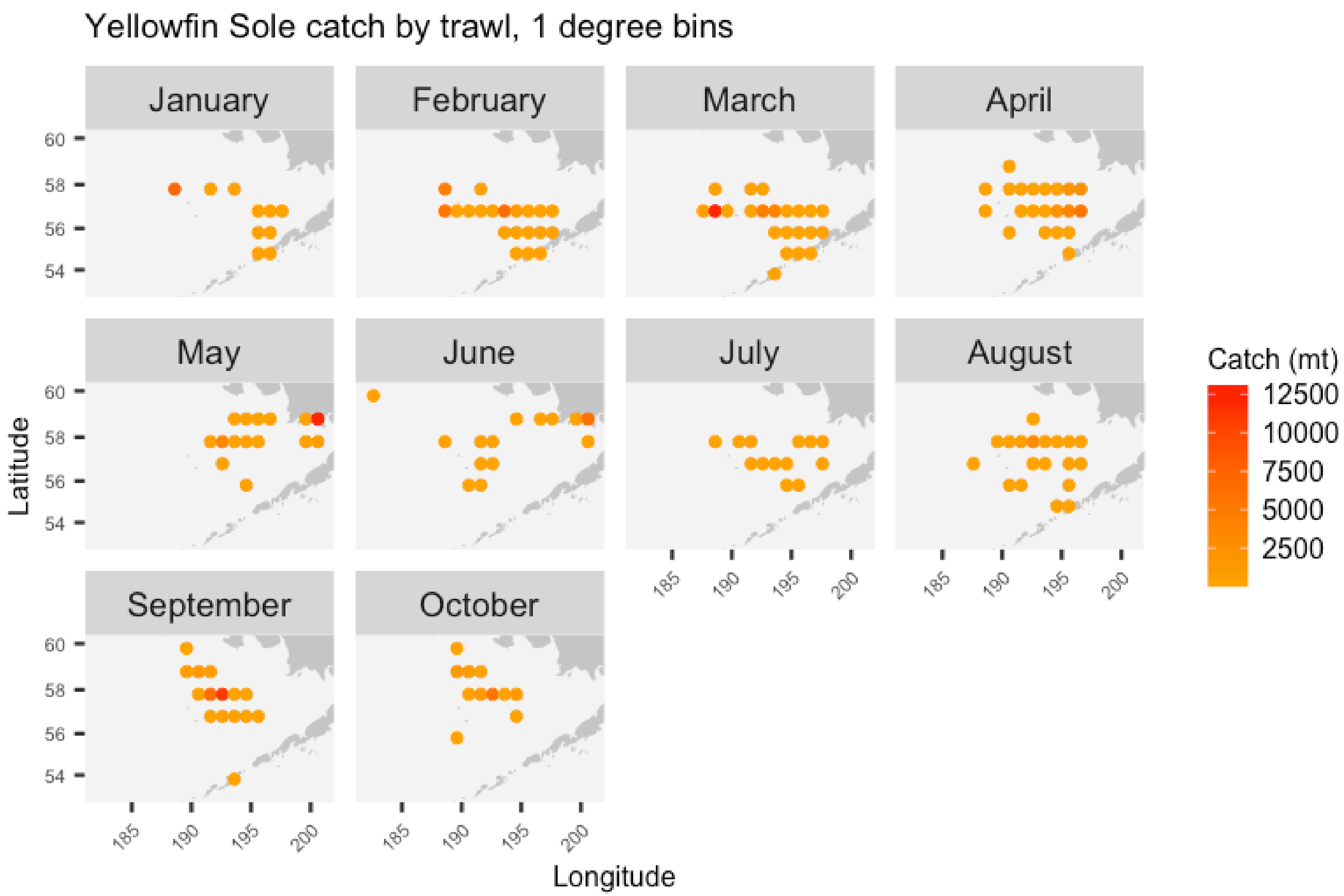


NOAA FISHERIES

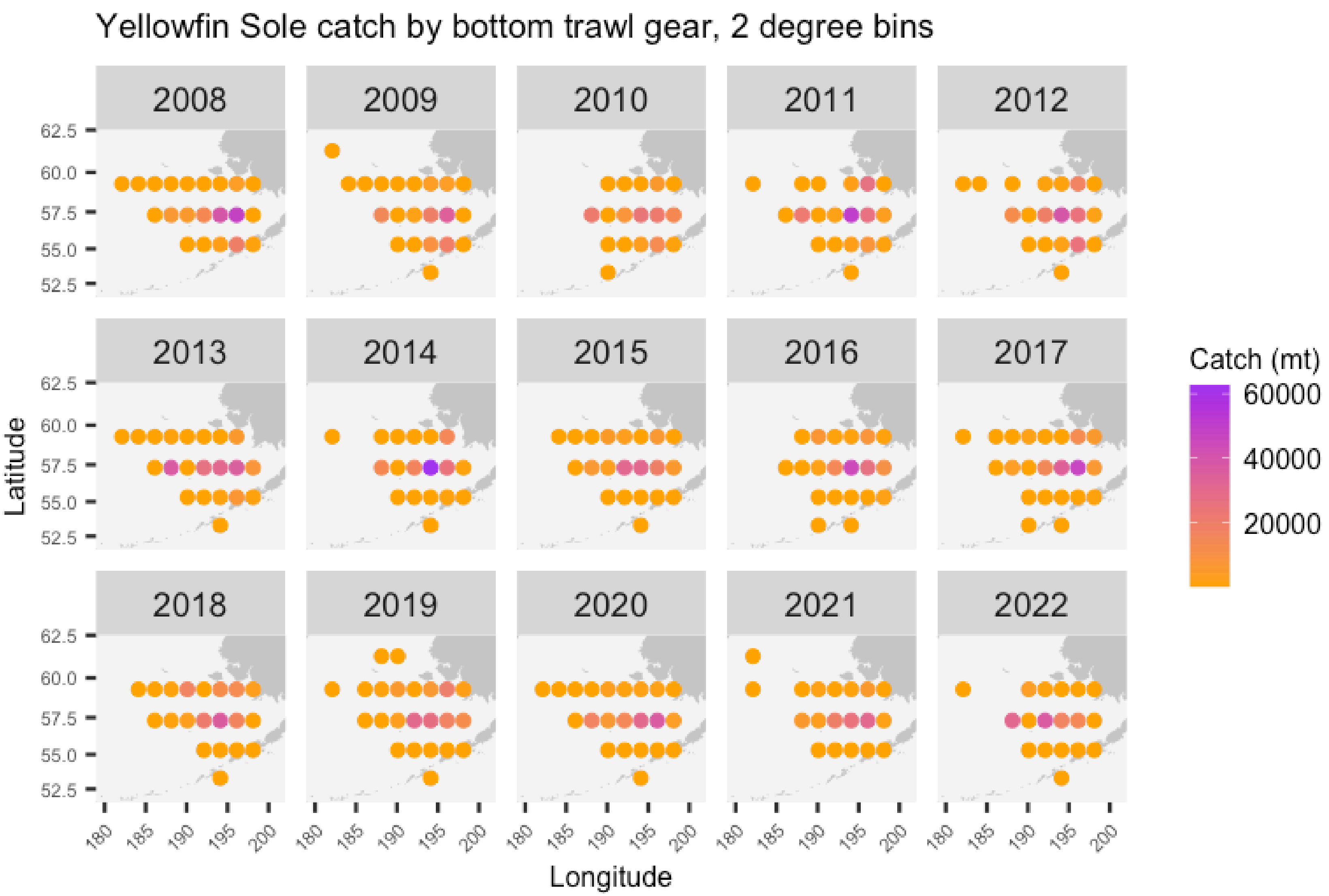
Yellowfin sole catch proportion by month January 1 through October 12, 2022

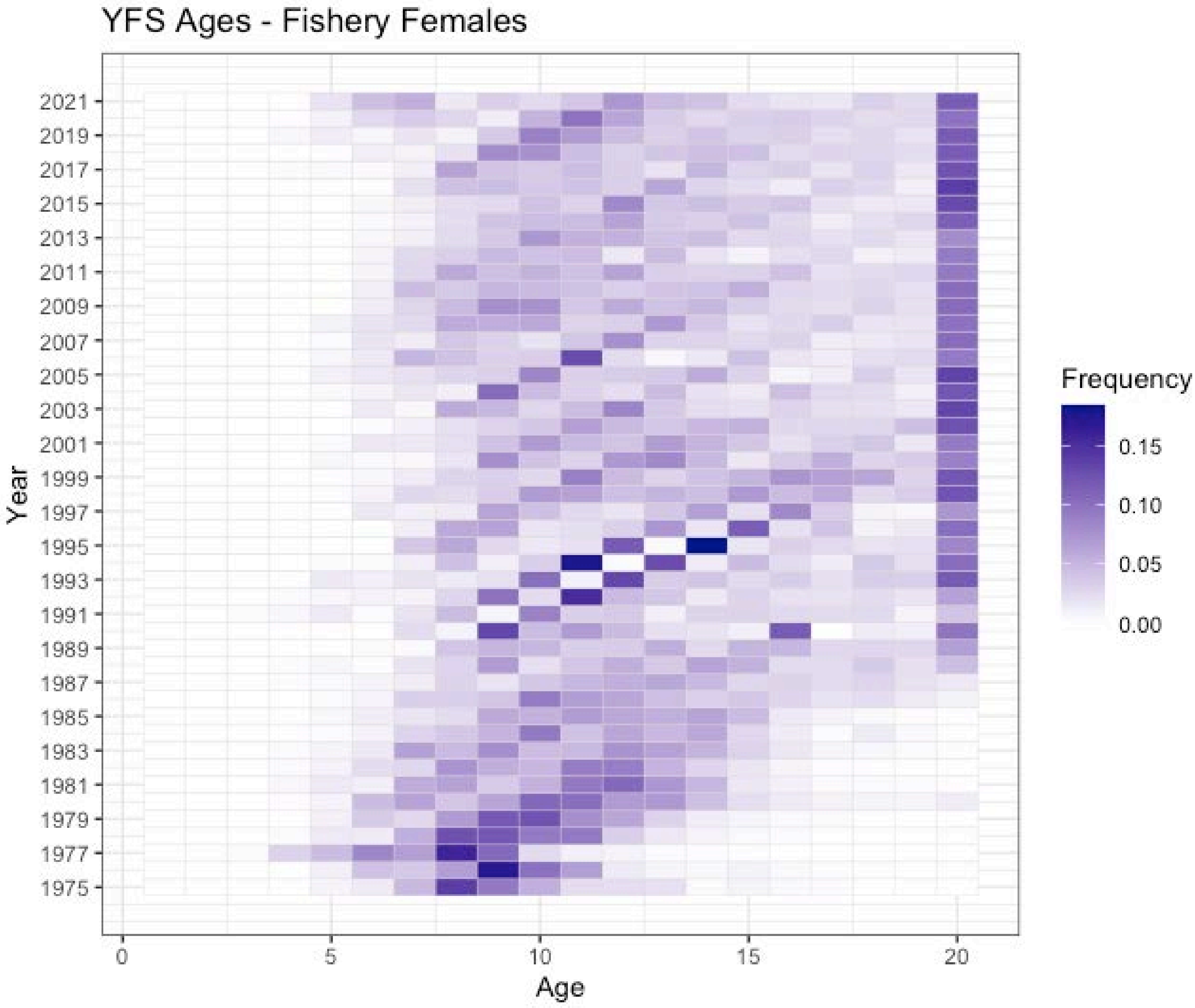


Catch of yellowfin sole in the BSAI in 2022 by month reported by observers.

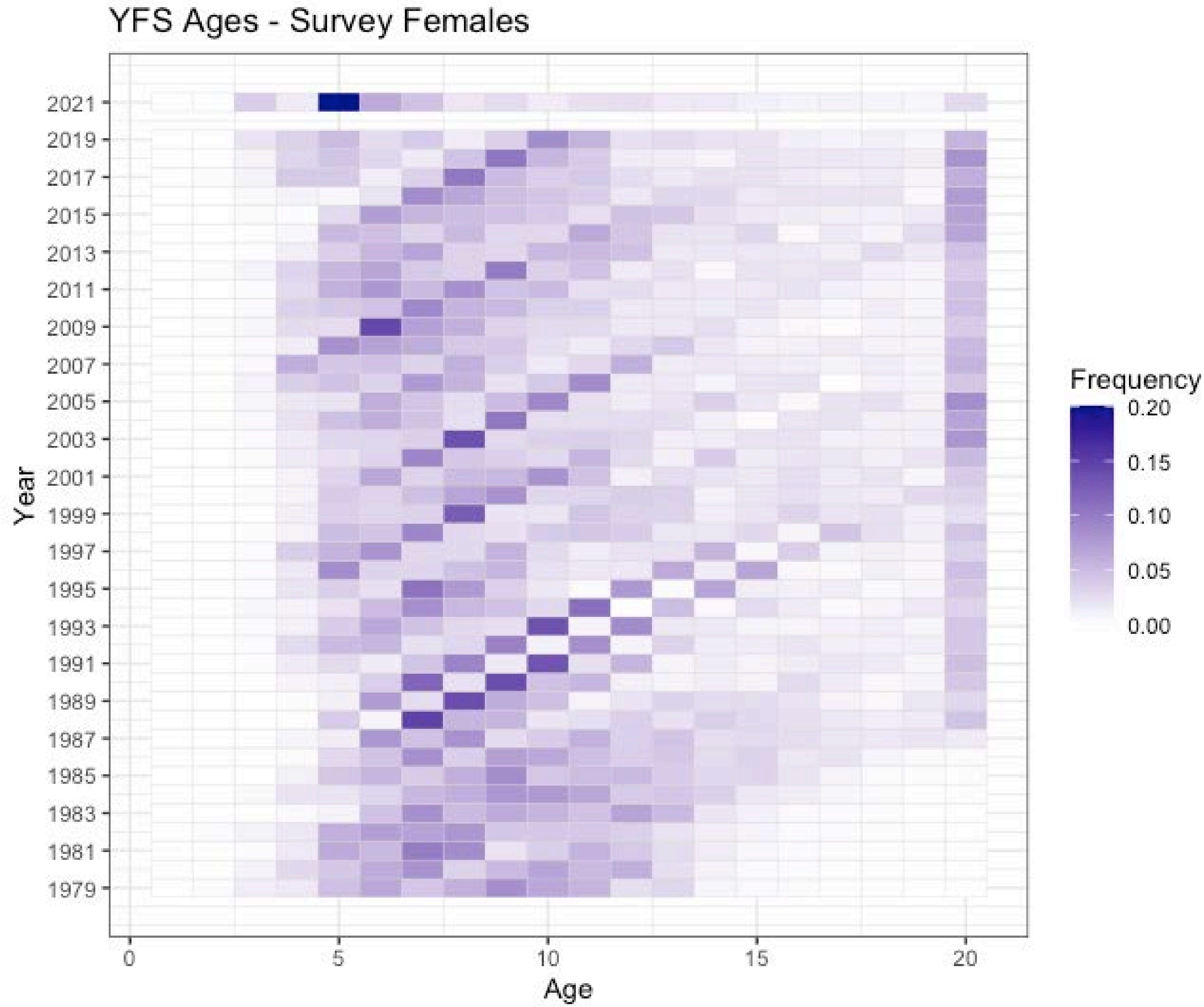


Catch of yellowfin sole by non-pelagic trawl gear in the eastern Bering Sea, 2008-2022, by year, reported by observers.

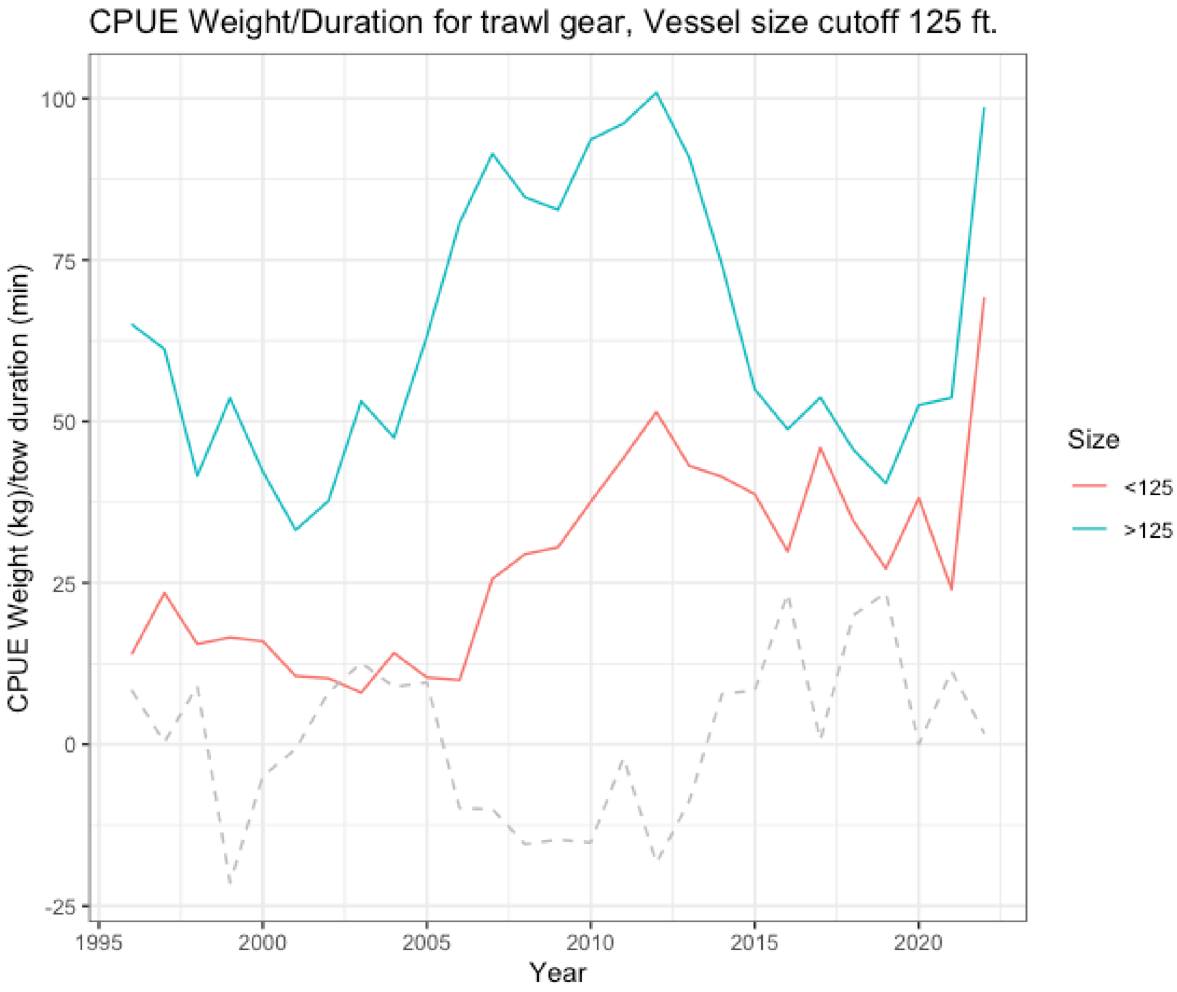




YFS Ages - Fishery Females
Year
2021
2019
2017
2015
2013
2011
2009
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1983
1981
1979
1977
1975
Age
0
5
10
15
20
Frequency
0.15
0.10
0.05
0.00

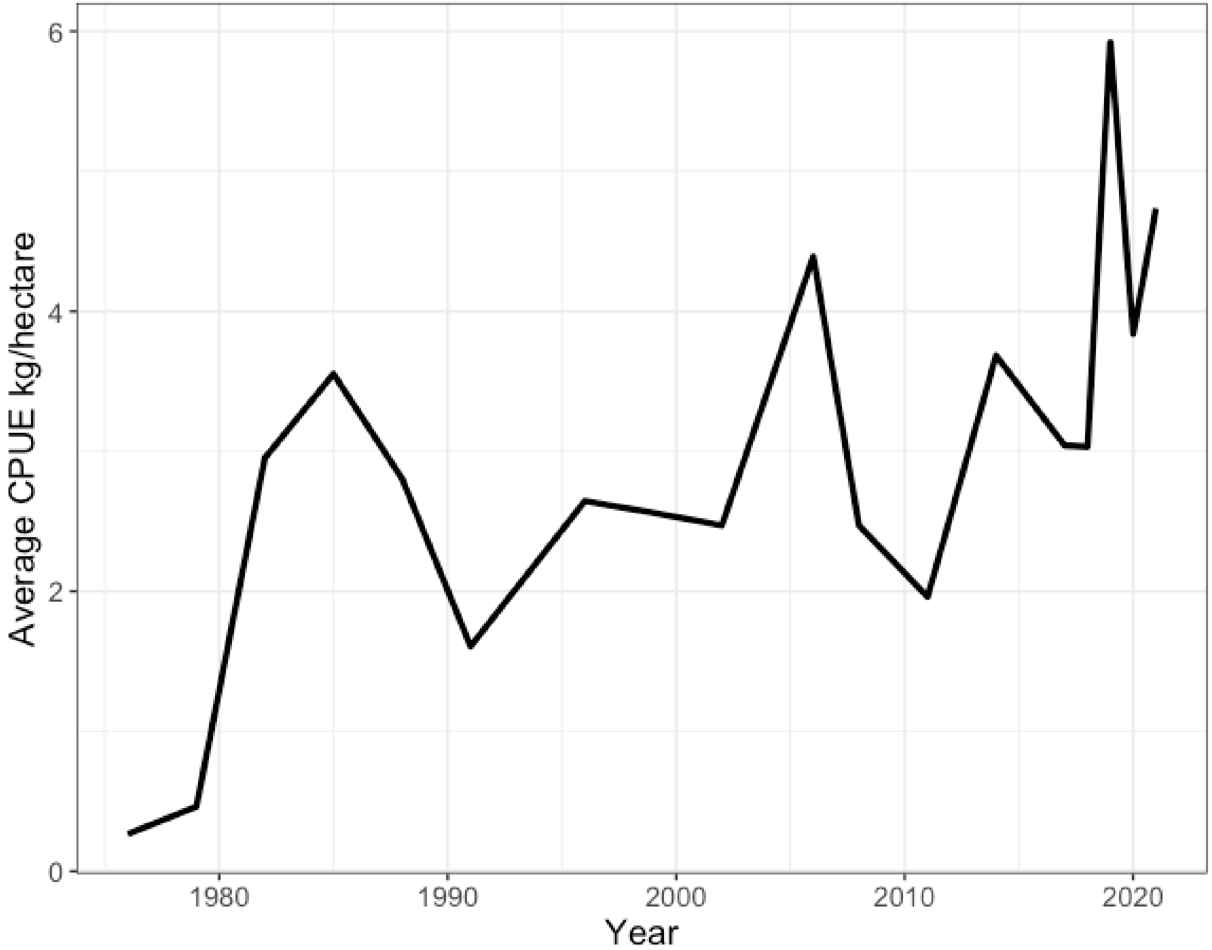

YFS Ages - Survey Females
Year
2021
2019
2017
2015
2013
2011
2009
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1983
1981
1979
0
5
10
15
20
Age
Frequency
0.20
0.15
0.10
0.05
0.00

Catch per unit effort based on yellowfin sole fishery data, 1996-2022.

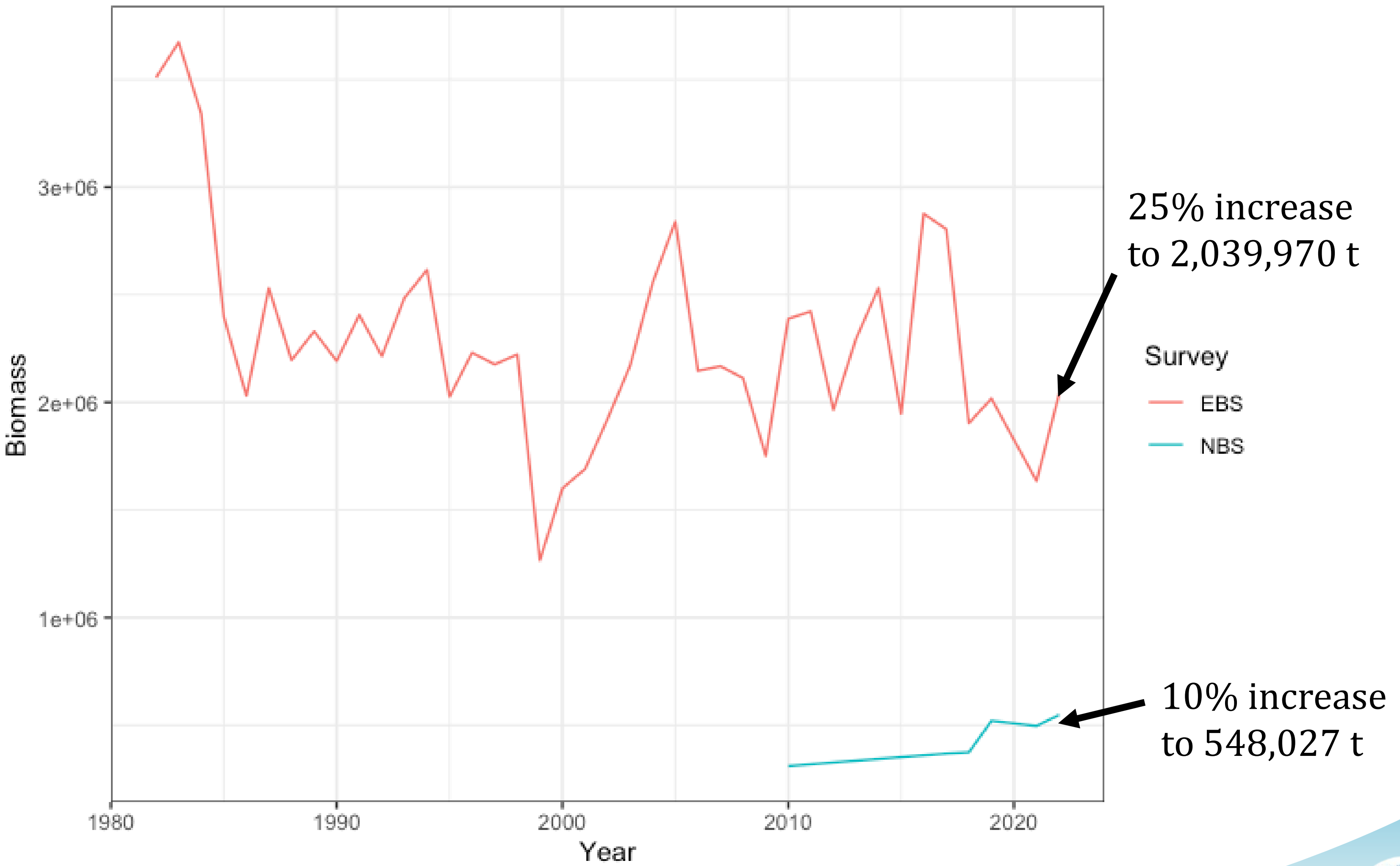


Survey results 2022

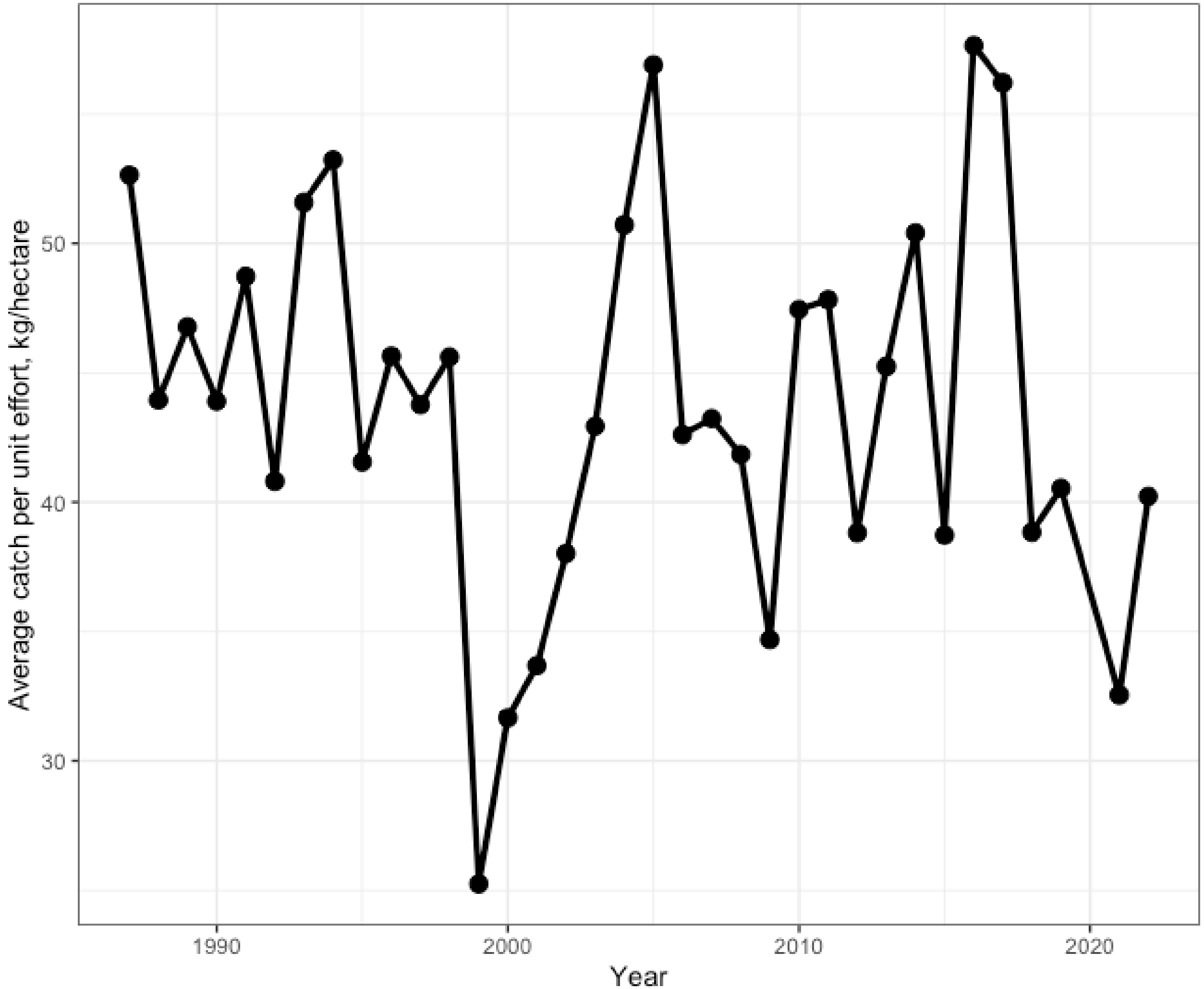
Average catch per unit effort (CPUE) of yellowfin sole in Norton Sound, based on ADF&G survey time series, 1976 – 2021 (no survey 2022)



EBS and NBS trawl survey, Yellowfin Sole biomass estimates (t) 1982 - 2022

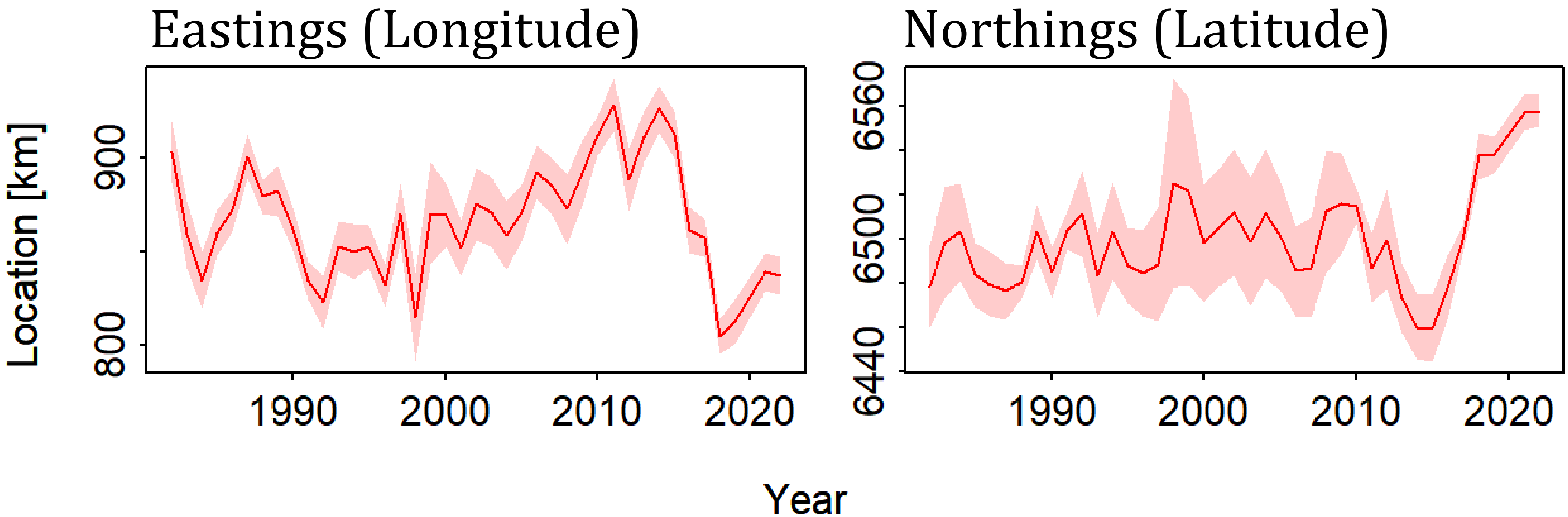


Average catch per unit effort on NMFS eastern Bering Sea surveys, 1987-2022, in kg/hectare.

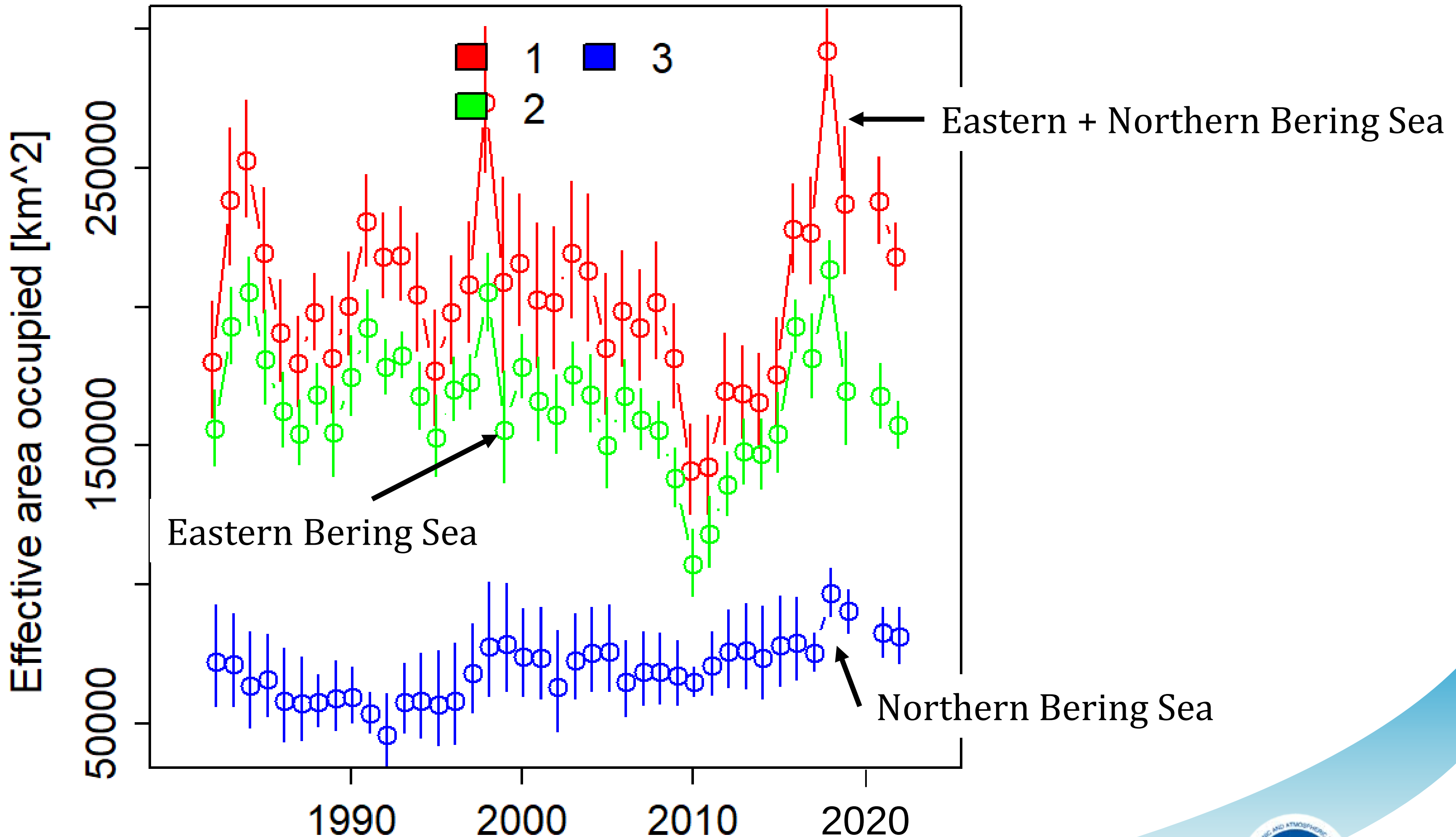


NOAA FISHERIES

Center of gravity plot with for yellowfin sole center of abundance through time



The effective area occupied by yellowfin sole, estimated in the VAST analysis



Models

Yellowfin sole models presented in this assessment

Model 18.2:

- Fixed female natural mortality (M=0.12),
- Male natural mortality estimated.
- Accepted by the BSAI Plan Team and the SSC in 2021.
- Survey index data (1982-2022) used design-based eastern Bering Sea estimates.

Model 22.0: same as Model 18.2 except

- Single-sex survey selectivity is used rather separate
- Survey index data (1982-2022) and age compositions are based on design-based indices for the eastern Bering Sea.

Model 22.1: same as Model 22.0 except

- VAST survey index data and age comps (1982-2022) for NBS+EBS.

Data used in the assessment models

Data source	Year
Fishery catch	1954 - 2022
Fishery age composition	1964 - 2021
Fishery weight-at-age	Catch-at-age methodology
Survey biomass and standard error	1982 - 2022 (not 2020)
Bottom temperature	1982 - 2022
Survey age composition	1979 - 2021 (not 2020)
Annual length-at-age and weight-at-age from surveys	1979 - 2021 (not 2020)
Age at maturity	Combined 1992 and 2012 samples

Model-based (VAST) index and age compositions used in Model 22.1.

Survey weight at age is incorporated in the model based on empirical weight at age data.

Fishery weight at age is implemented using catch-at-age methodology.

How does the model currently incorporate temperature (and timing)?

- Survey catchability is proportional to temperature through the equation

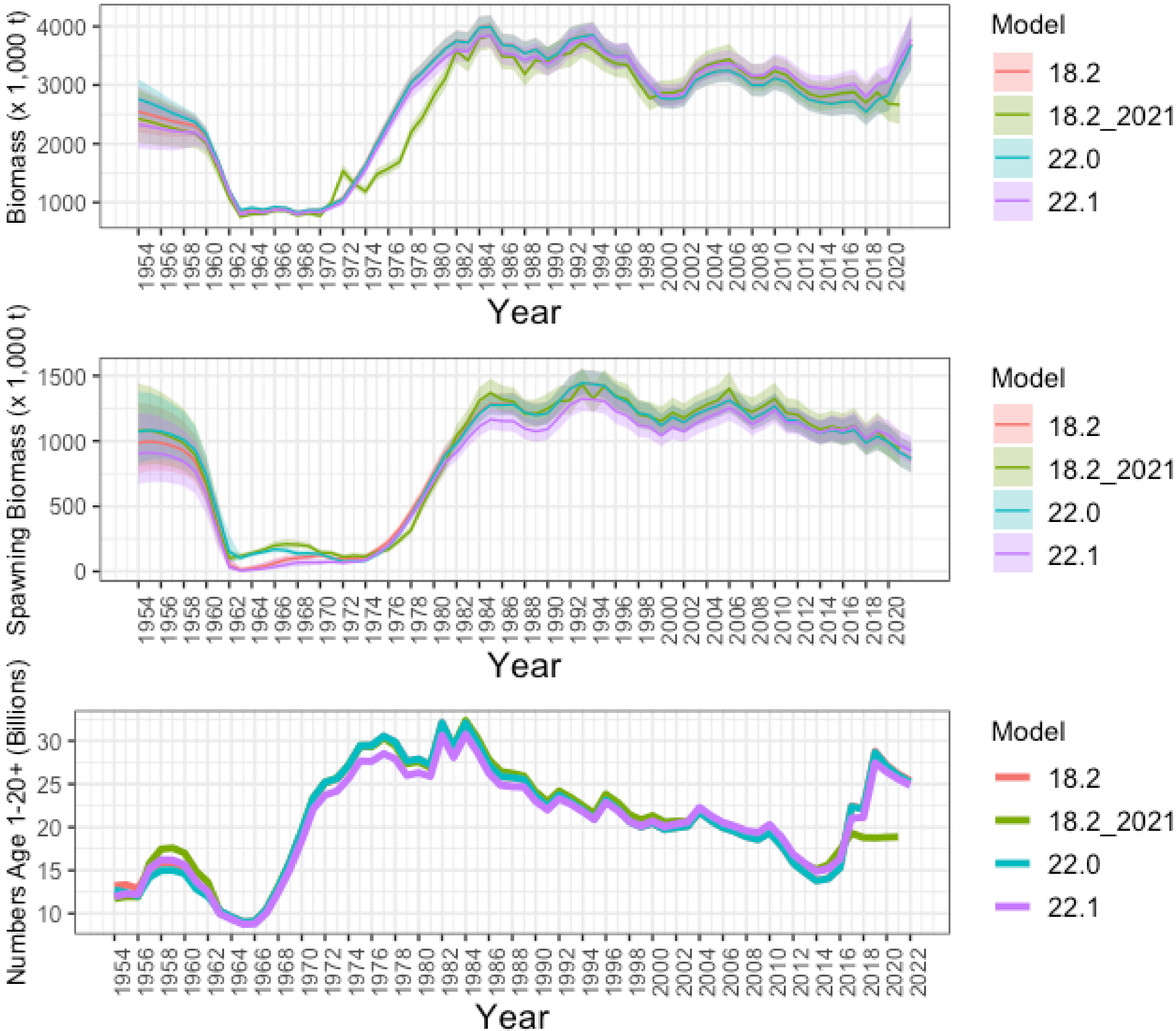
$$q = e^{-\alpha + \beta T + \gamma S + \mu T:S}$$

EBS survey start date

EBS survey catchability

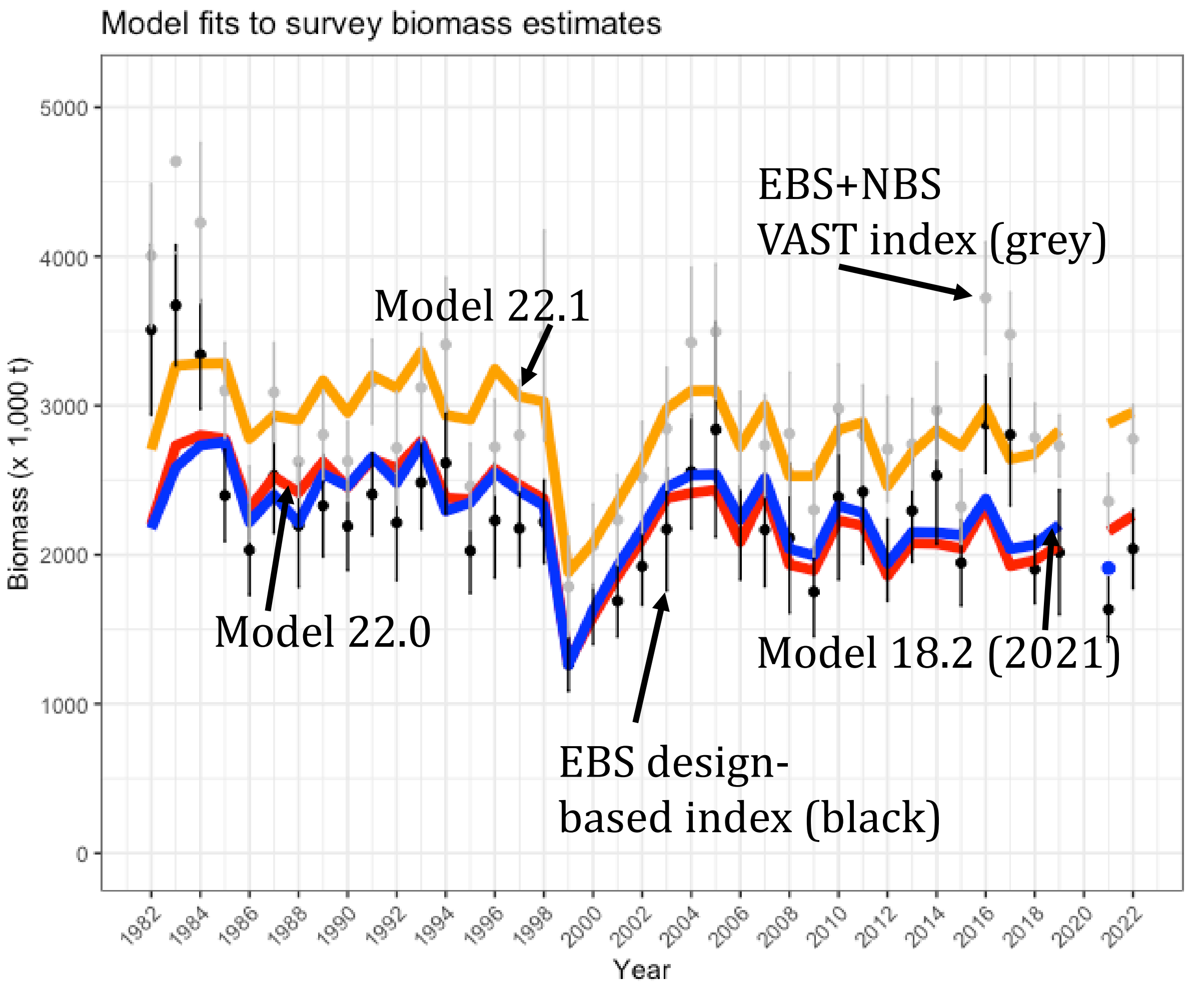
Parameters estimated within the model

EBS bottom temperature anomaly

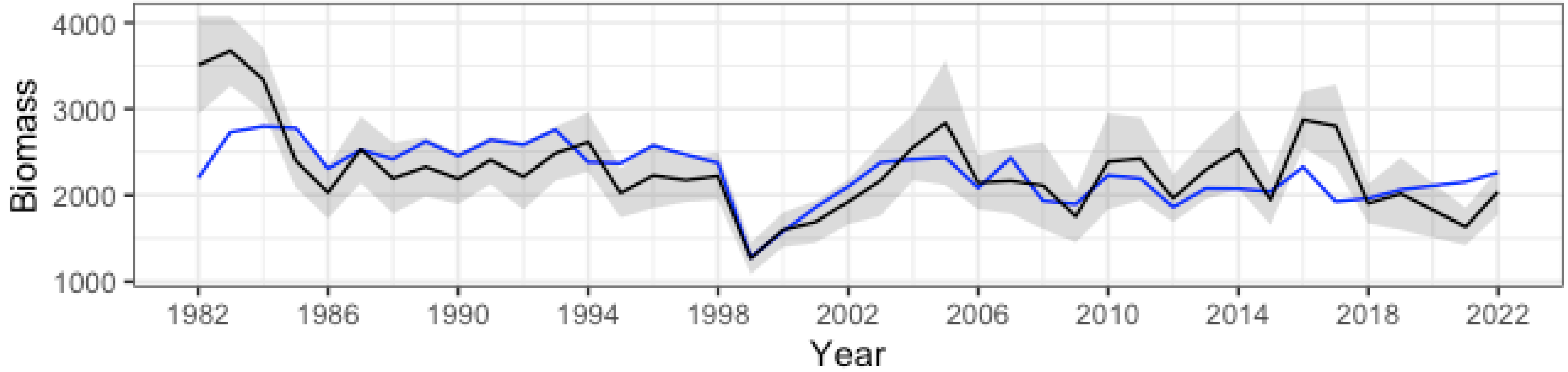


NOAA FISHERIES

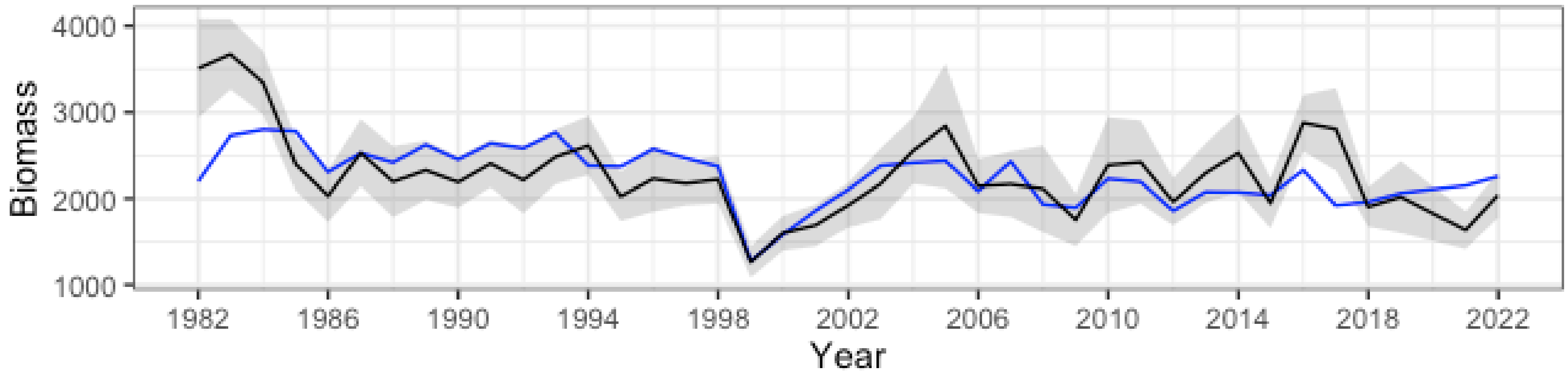
Annual eastern Bering Sea bottom trawl survey biomass point estimates and 95% confidence intervals for yellowfin sole, 1982-2022.



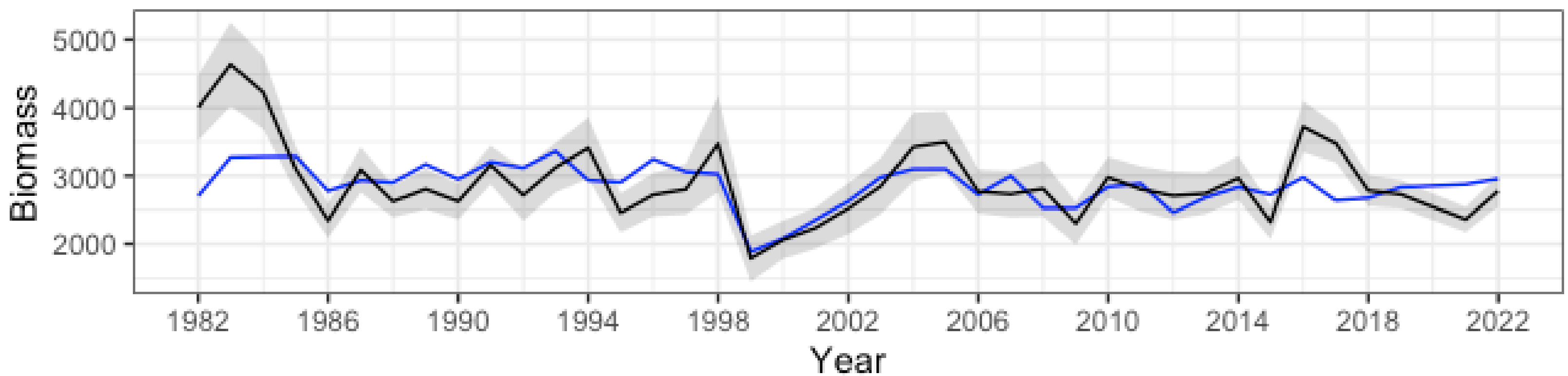
Model 18.2, EBS design-based biomass estimate



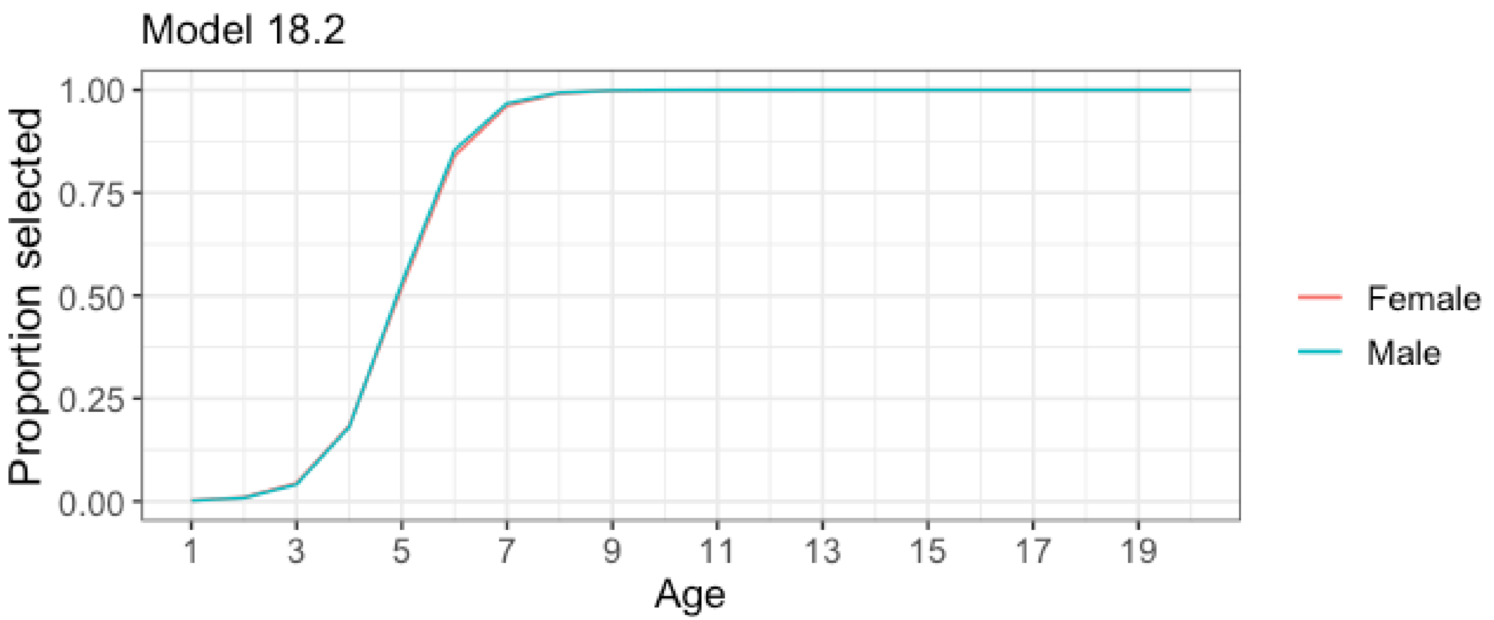
Model 22.0, EBS design-based biomass estimate

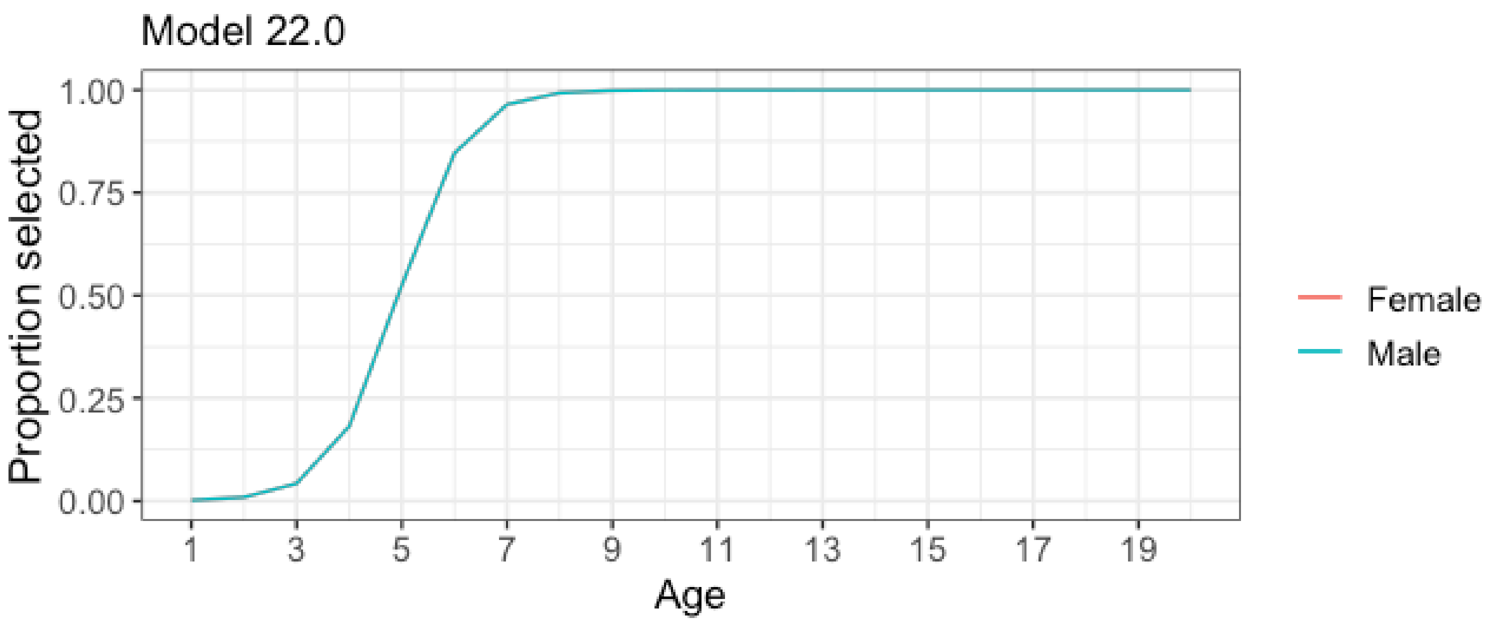


Model 22.1, EBS+NBS VAST biomass estimate

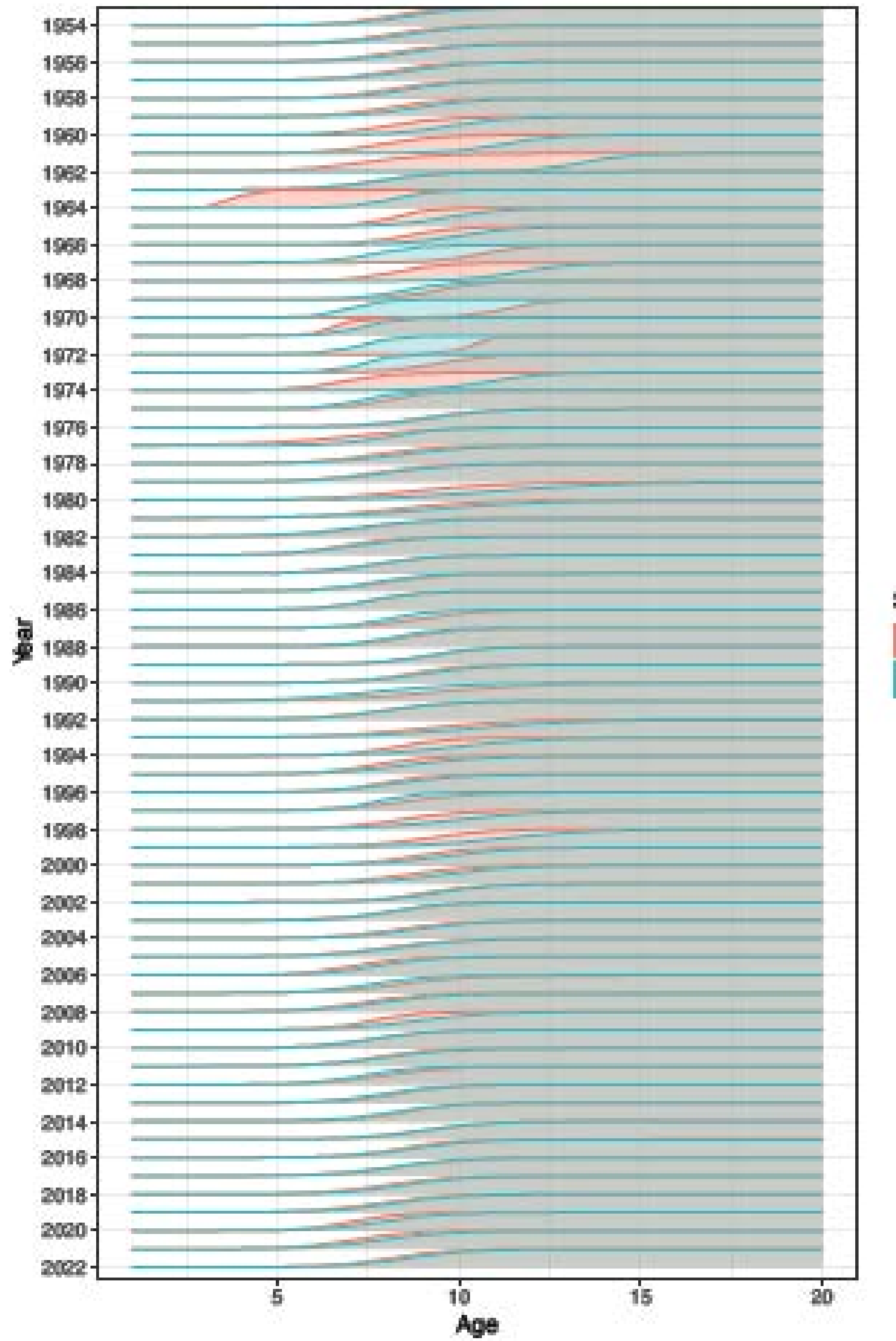


Selectivity

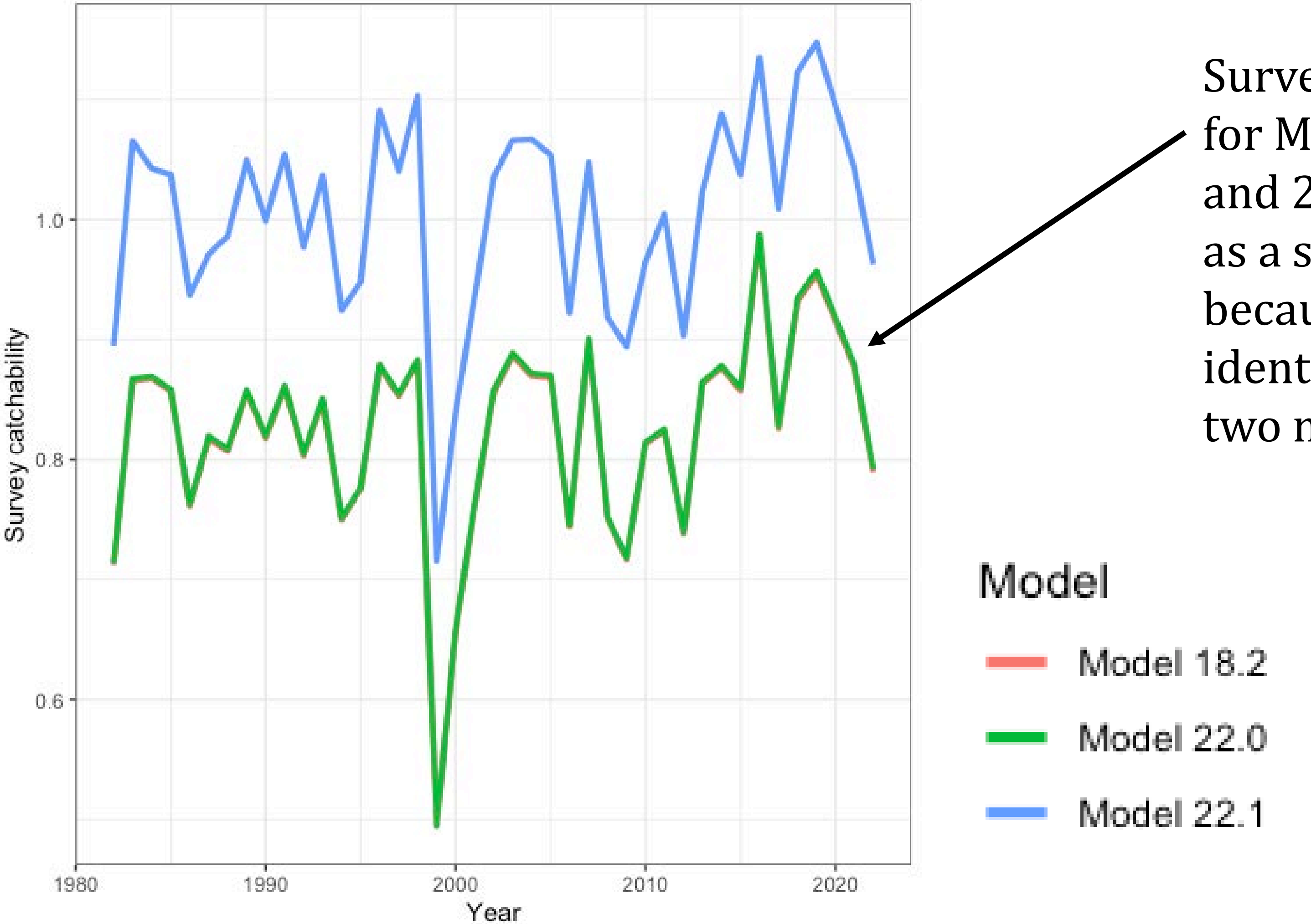




Fishery selectivity

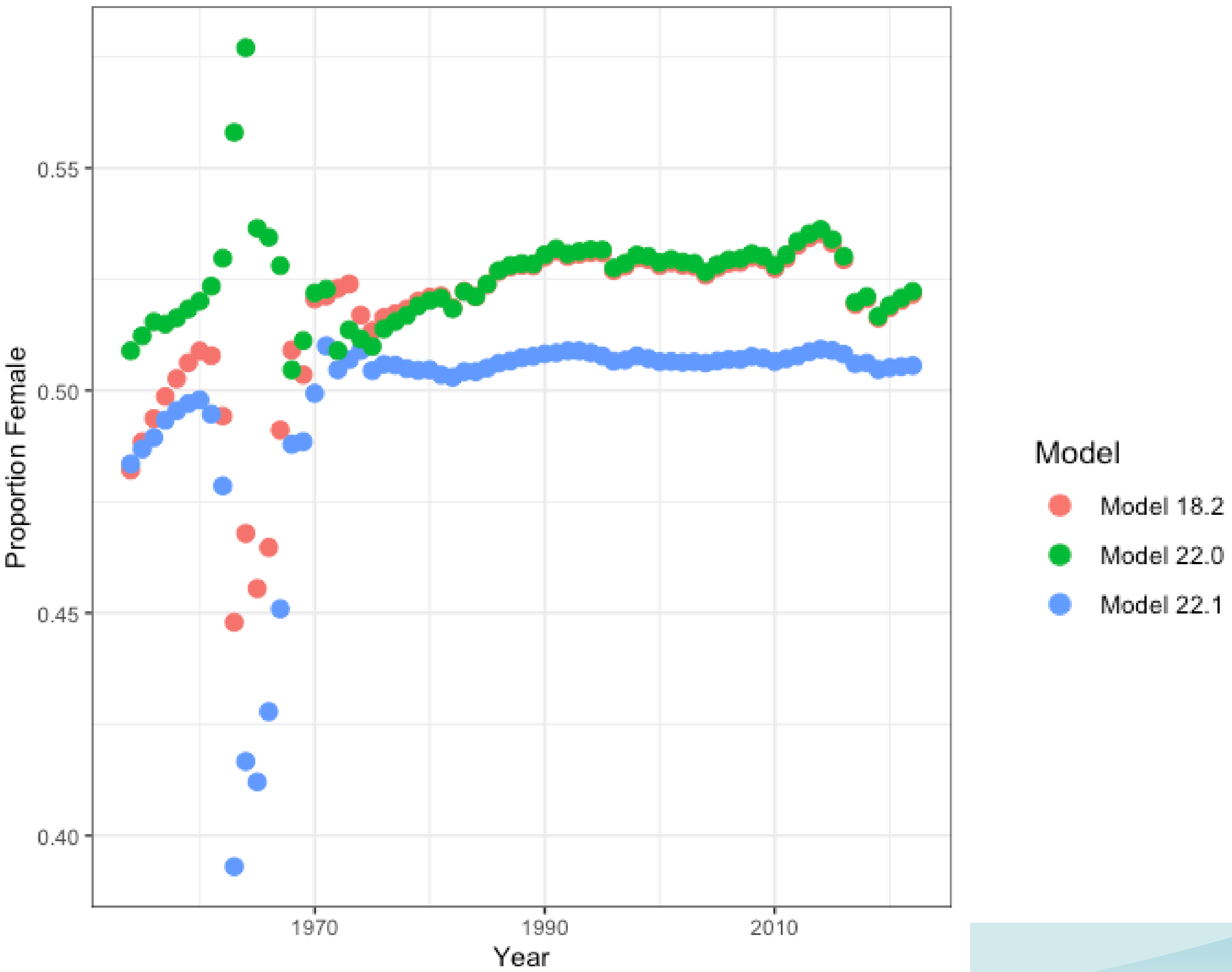


Survey catchability for yellowfin sole Model 18.2 and 22.0, 1982-2022

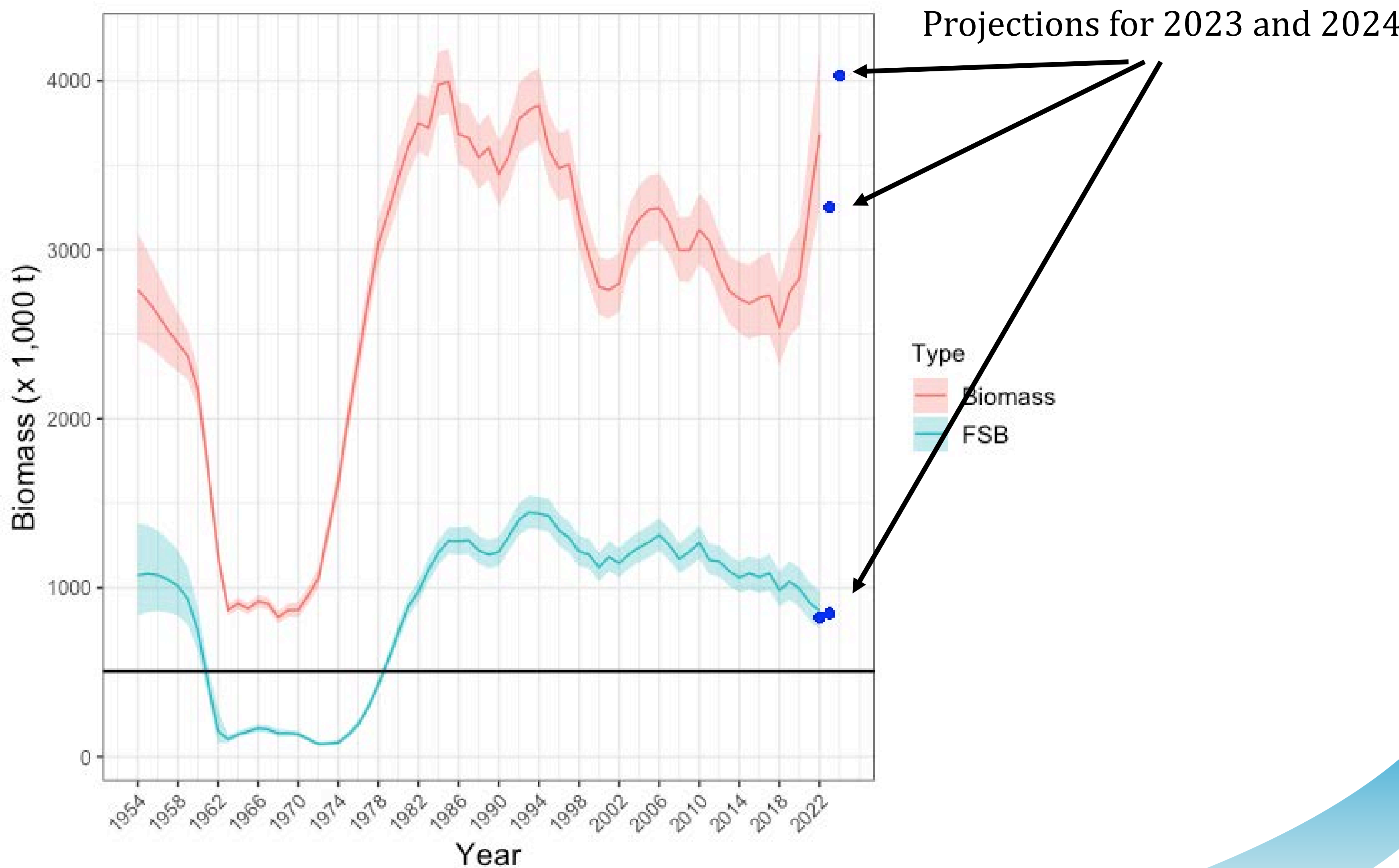


Survey catchability for Models 18.2 and 22.0 appears as a single line because it is nearly identical for these two models

Model estimates of the proportion of female yellowfin sole in the population, 1982-2022

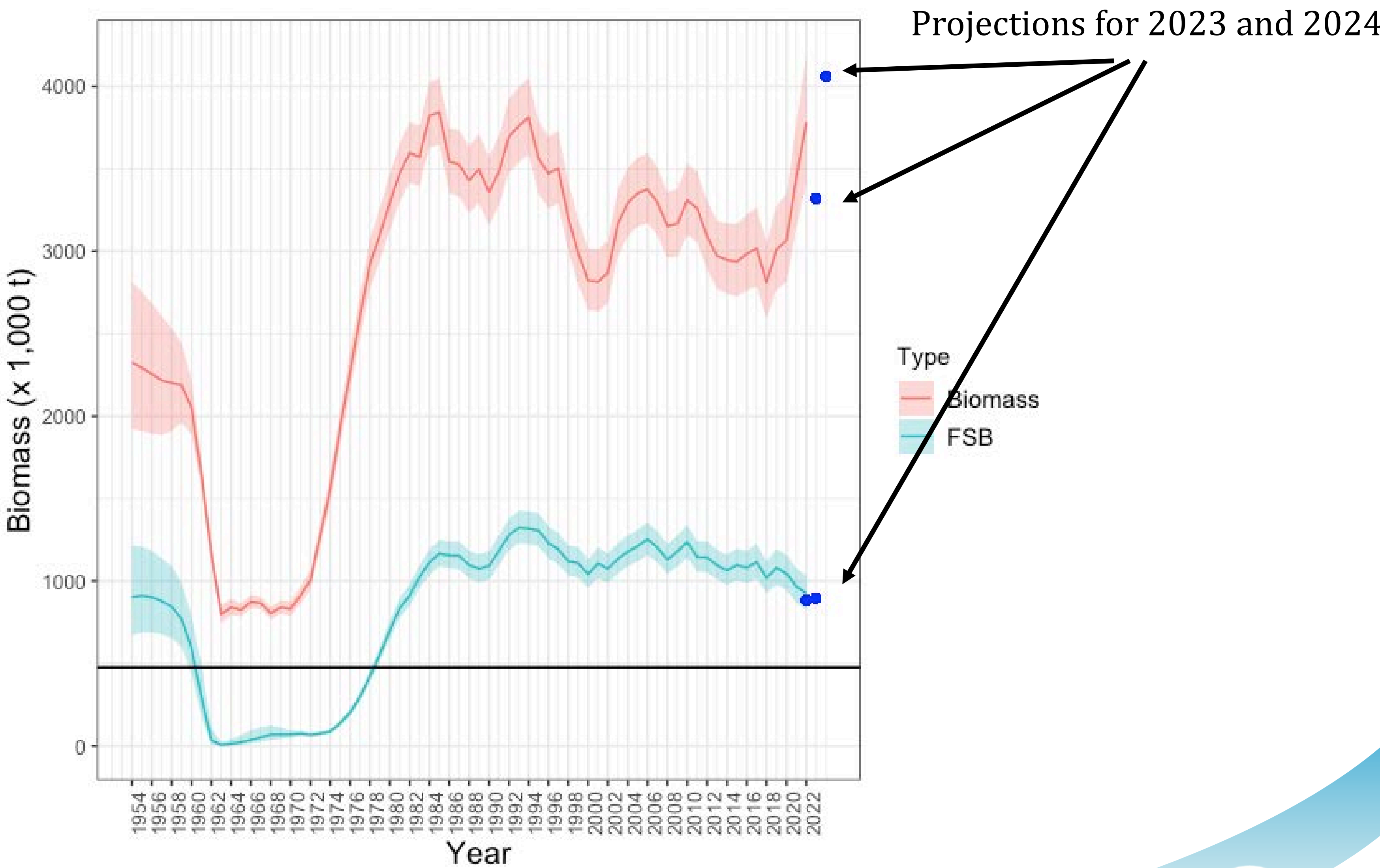


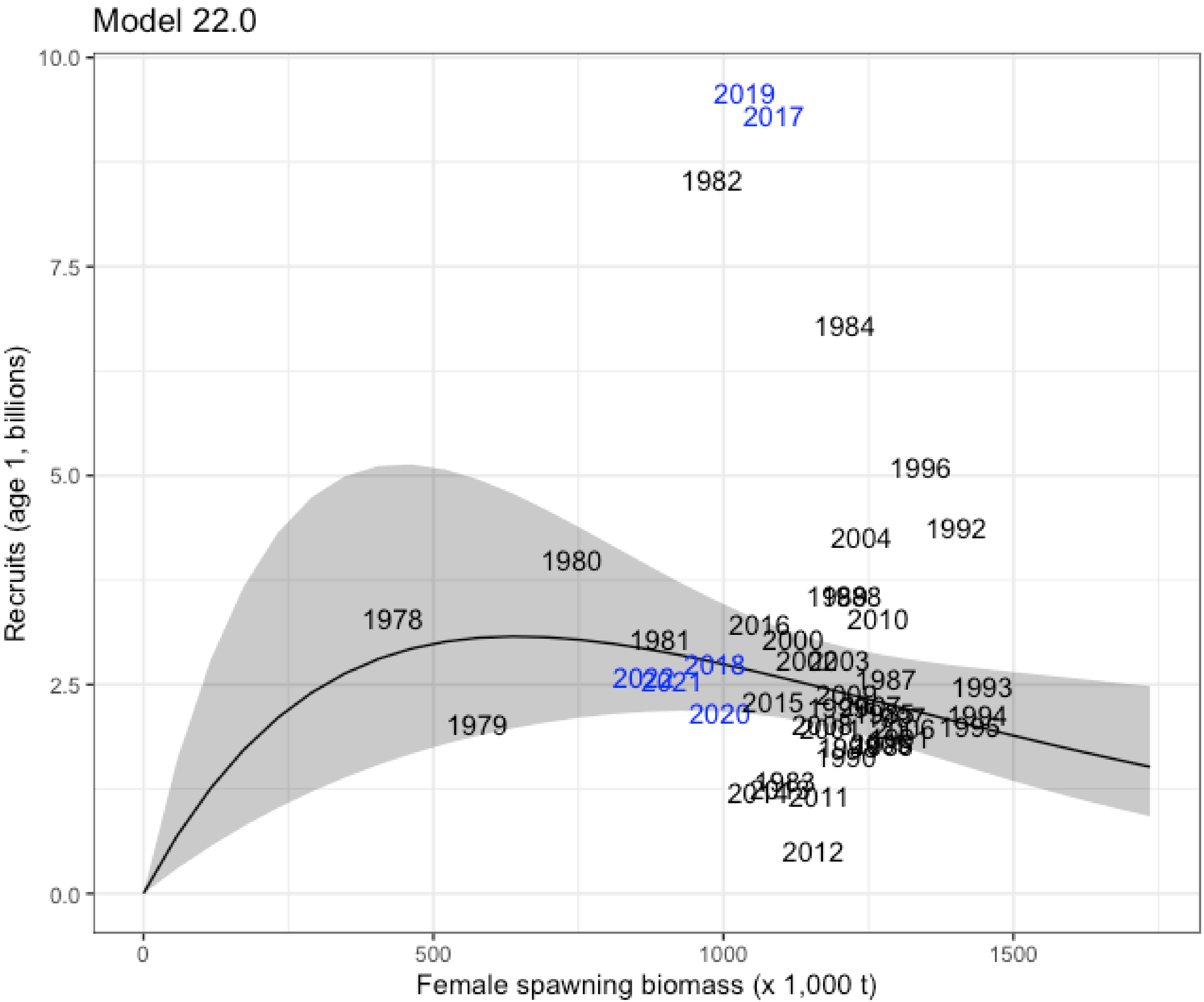
Model estimates of yellowfin sole total (age 2+) and female spawning biomass, Model 22.0

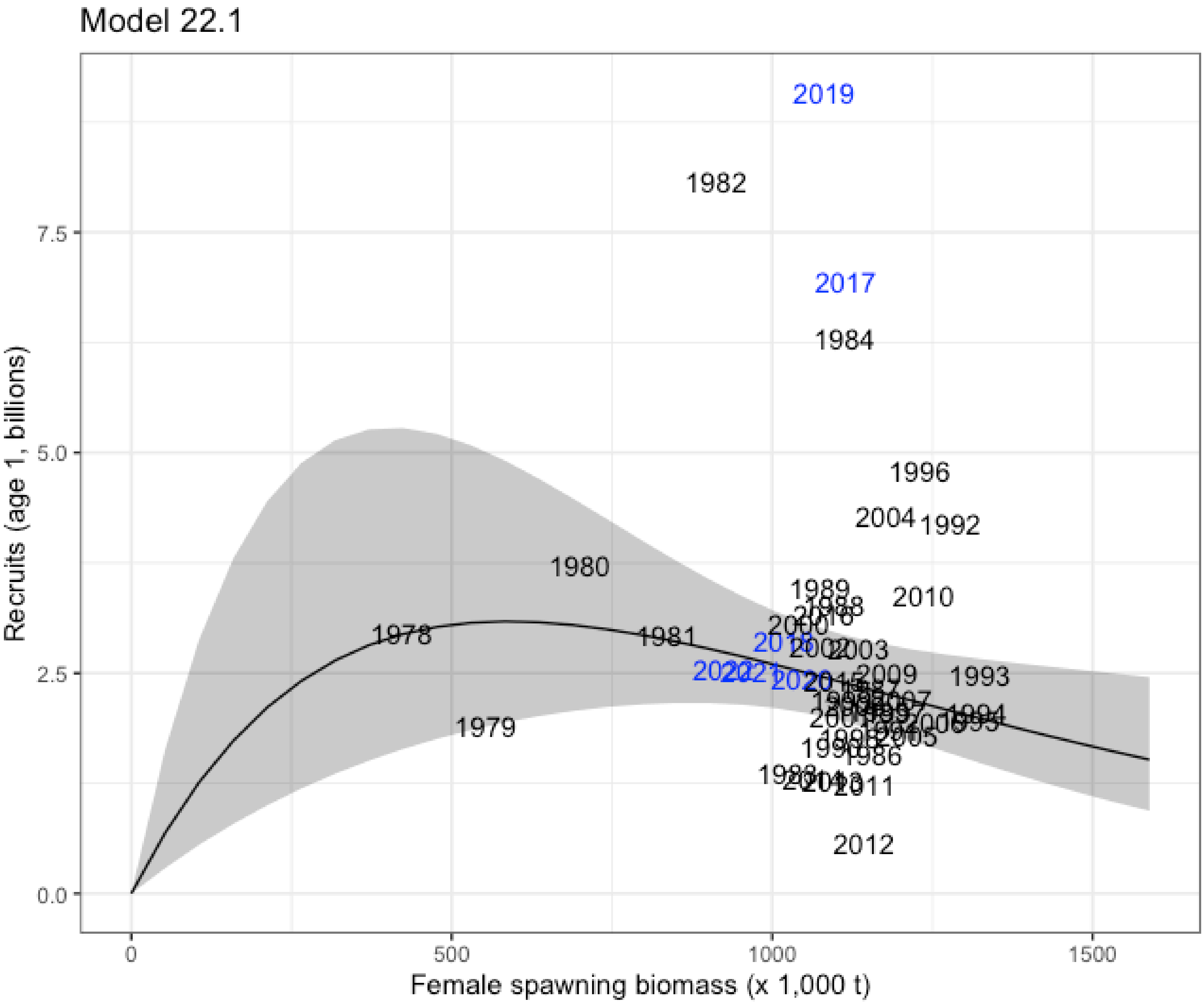


NOAA FISHERIES

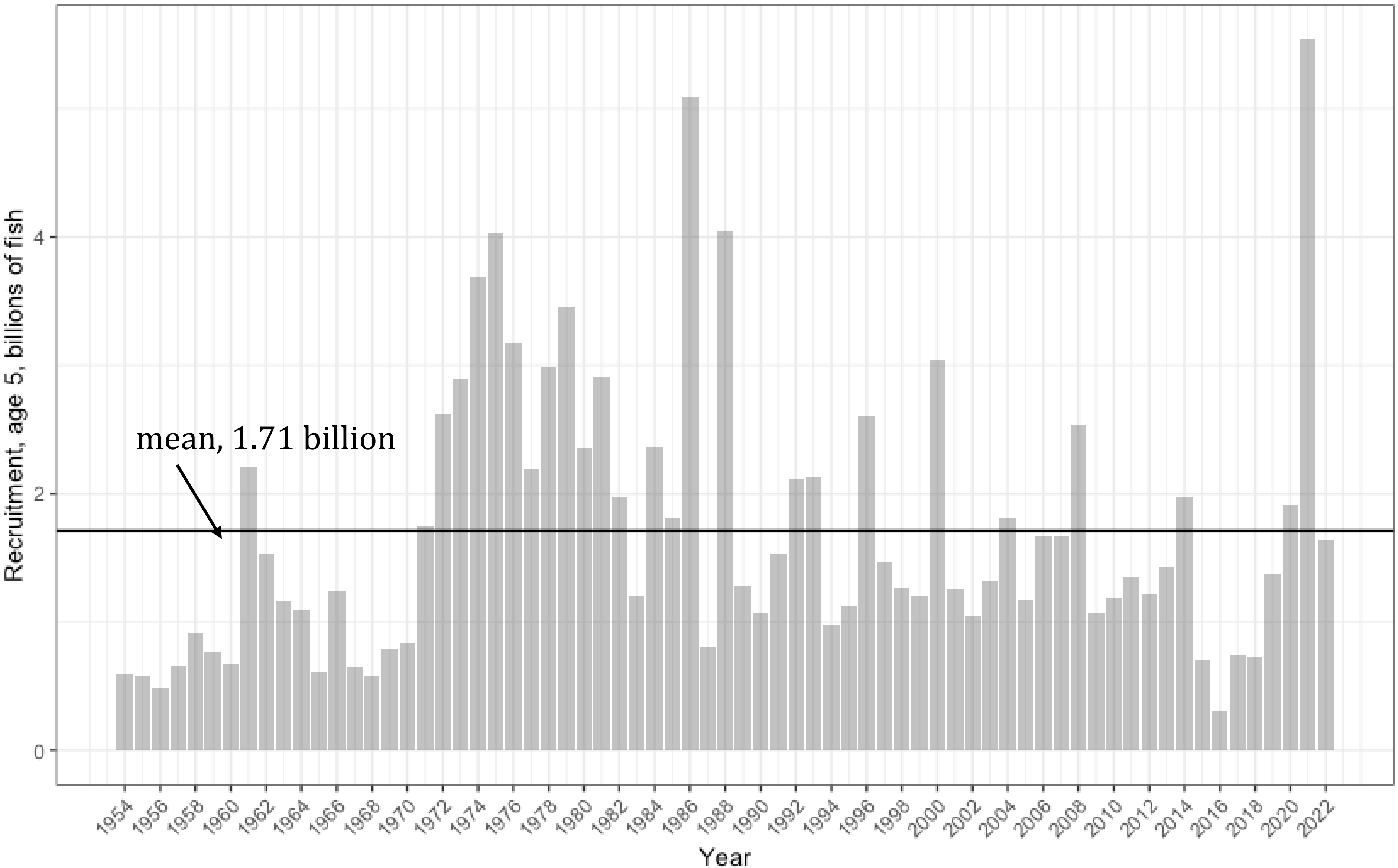
Model estimates of yellowfin sole total (age 2+) and female spawning biomass, Model 22.1



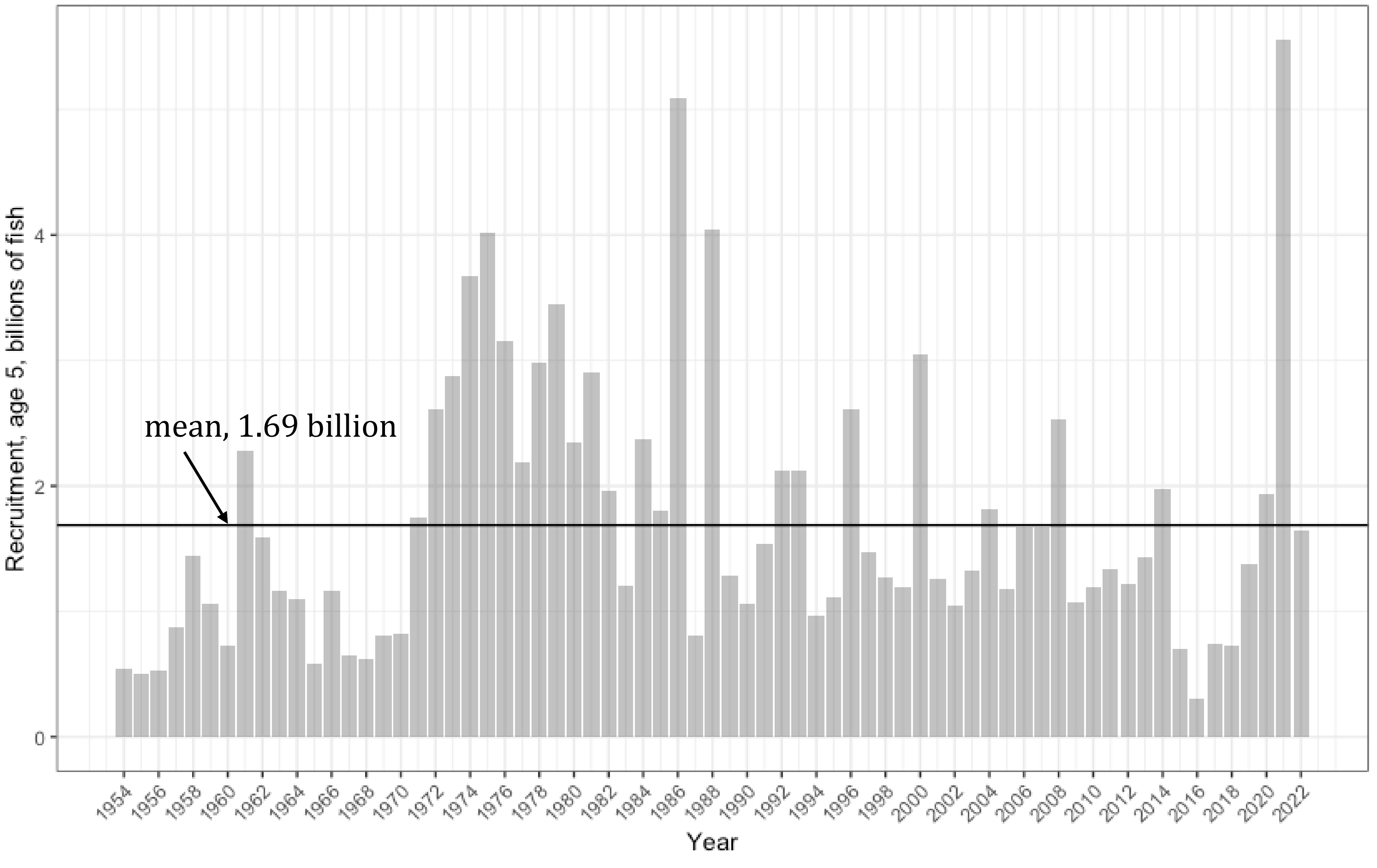

Model 22.0
Recruits (age 1, billions)
Female spawning biomass (x 1,000 t)
0.0
2.5
5.0
7.5
10.0
0
500
1000
1500
2019
2017
1982
1984
1996
2004
1992
1980
2010
1978
2016
1981
2000
2003
2018
1987
2021
1993
2015
2020
1979
1994
1995
1990
2011
2012


Model 22.1
Recruits (age 1, billions)
Female spawning biomass (x 1,000 t)
0.0
2.5
5.0
7.5
0
500
1000
1500
2019
1982
2017
1984
1996
2004
1992
1980
1989
2010
1978
1981
2003
2009
1993
1979
2012
2011

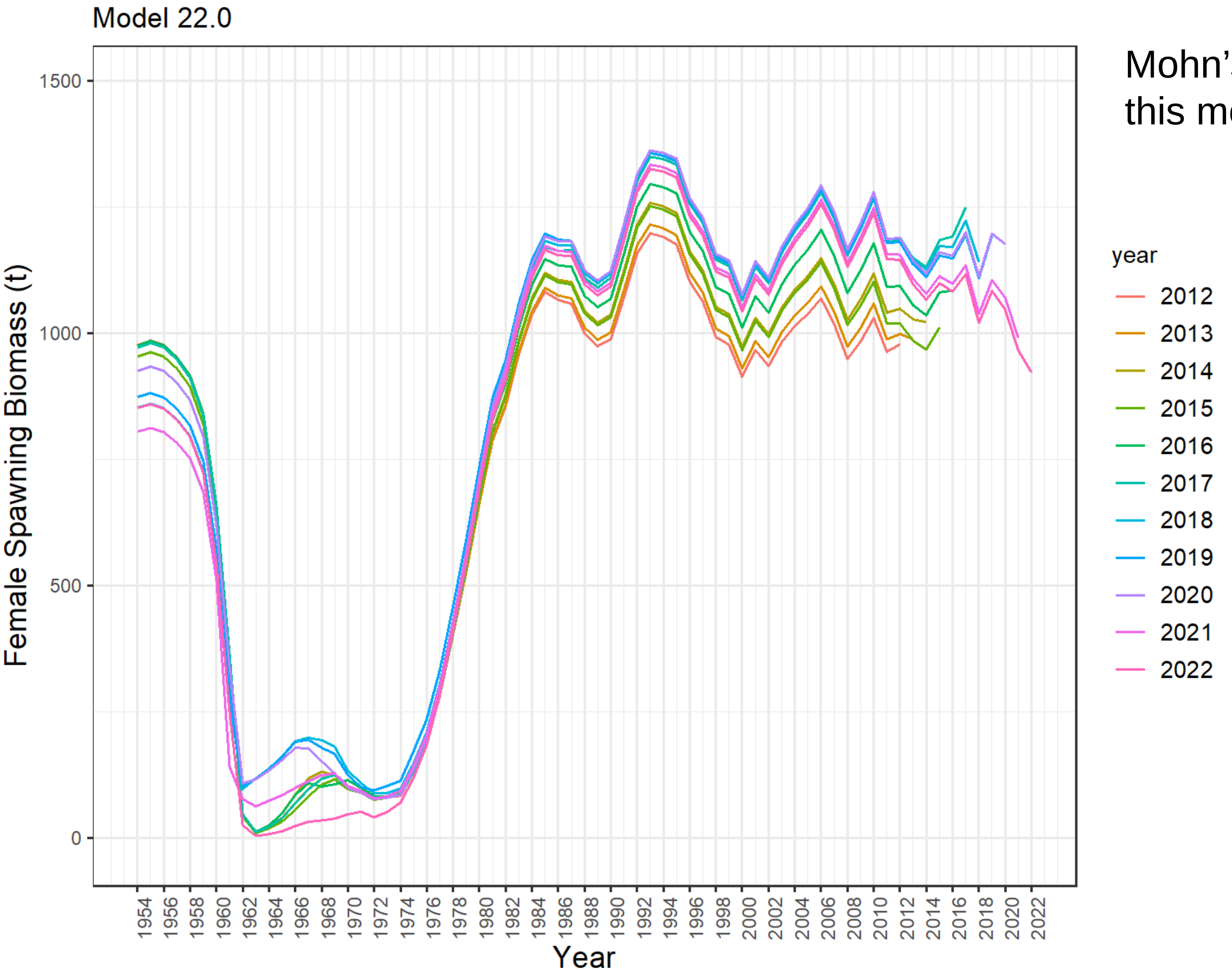
Year-class strength of age 5 yellowfin sole, Model 22.0.



Year-class strength of age 5 yellowfin sole, Model 22.1

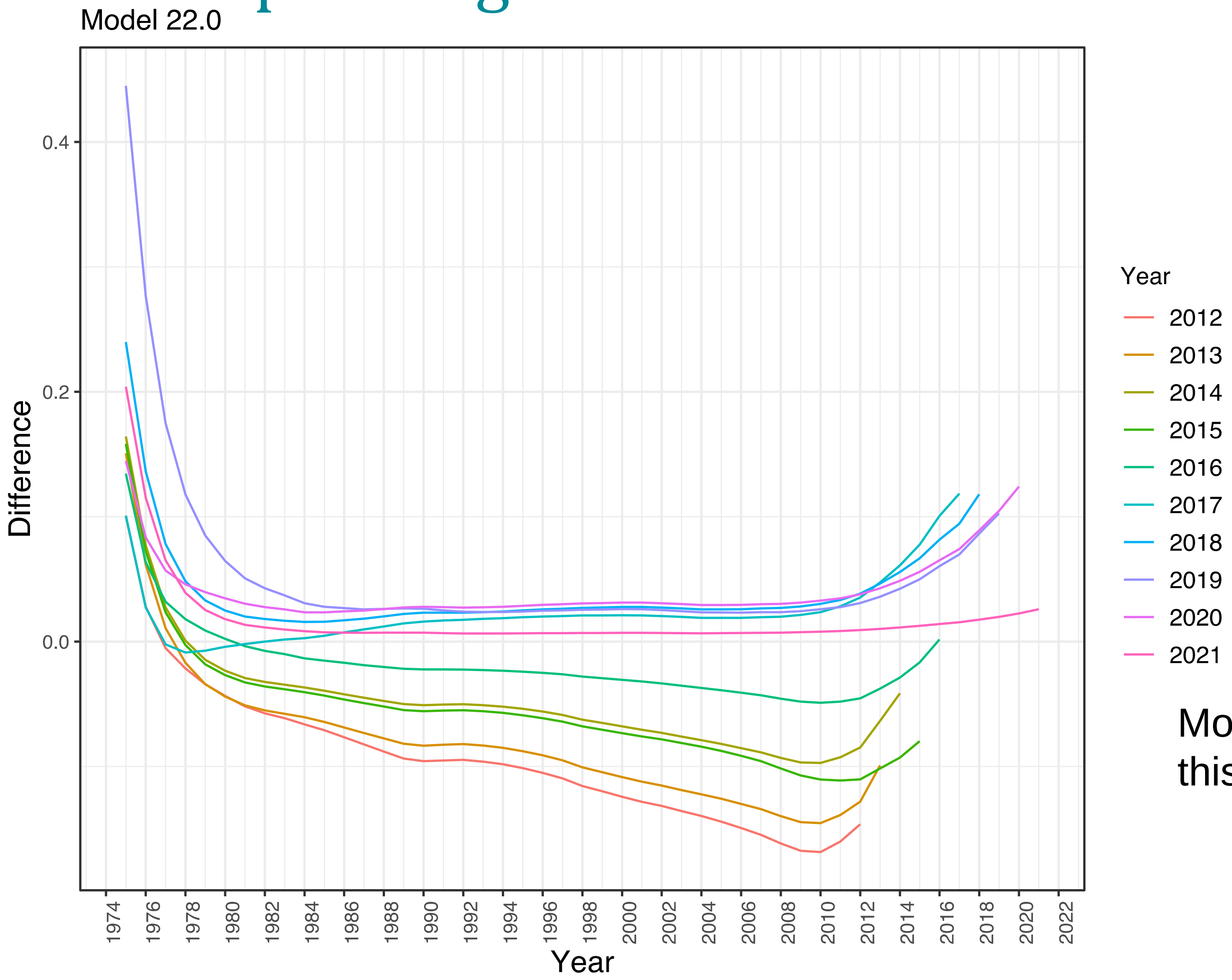


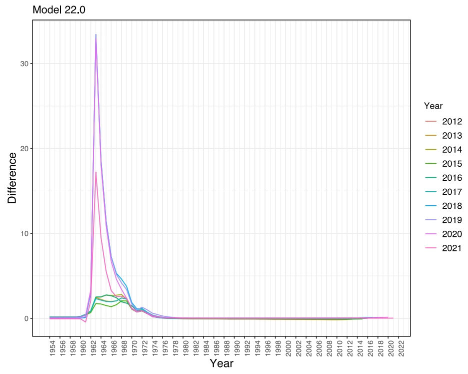
Retrospective plot: female spawning biomass Model 22.0



Mohn's Rho for this model was -0.007.

Retrospective relative difference from terminal year female spawning biomass Model 22.0

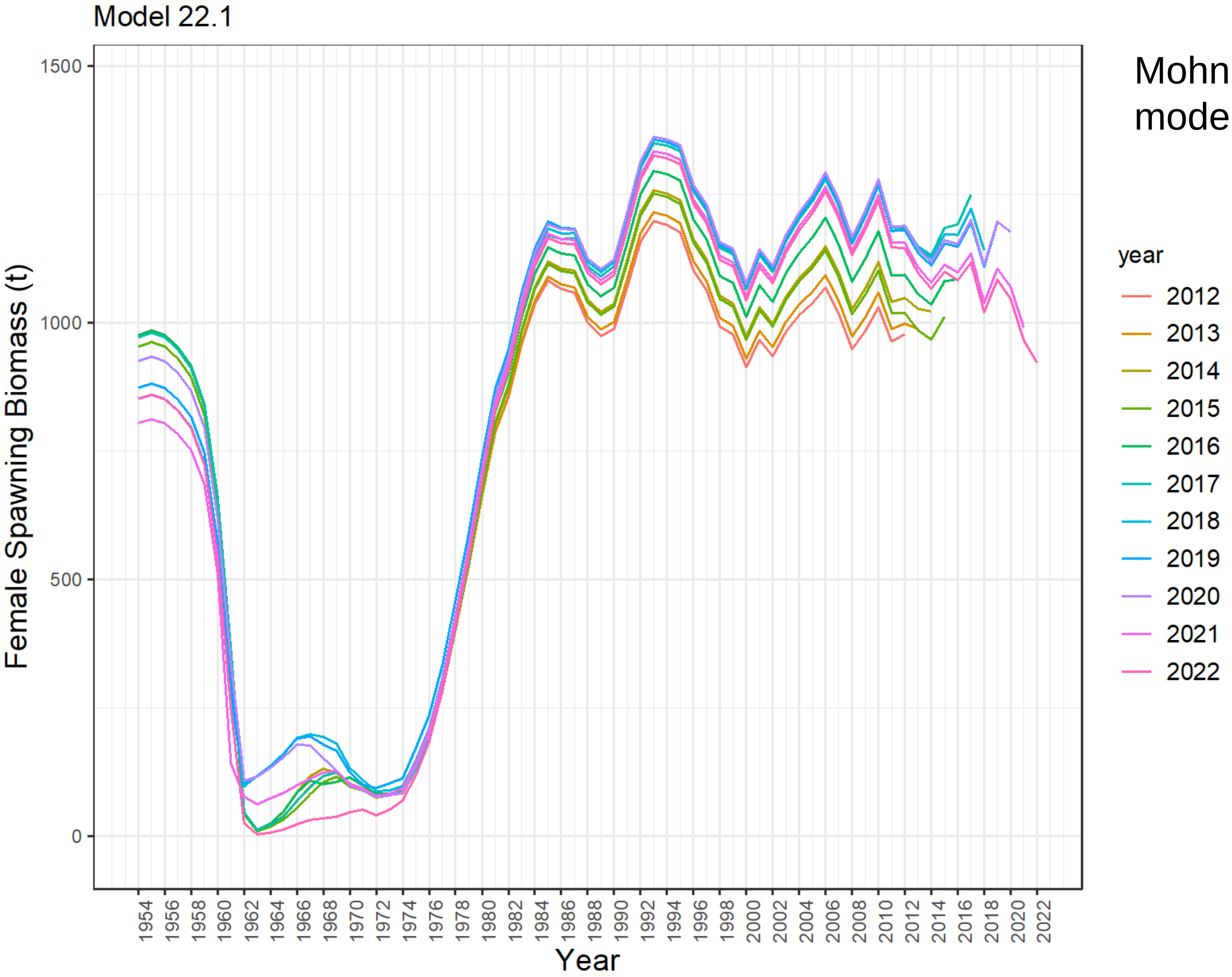




Mohn's Rho for this model was -0.007.

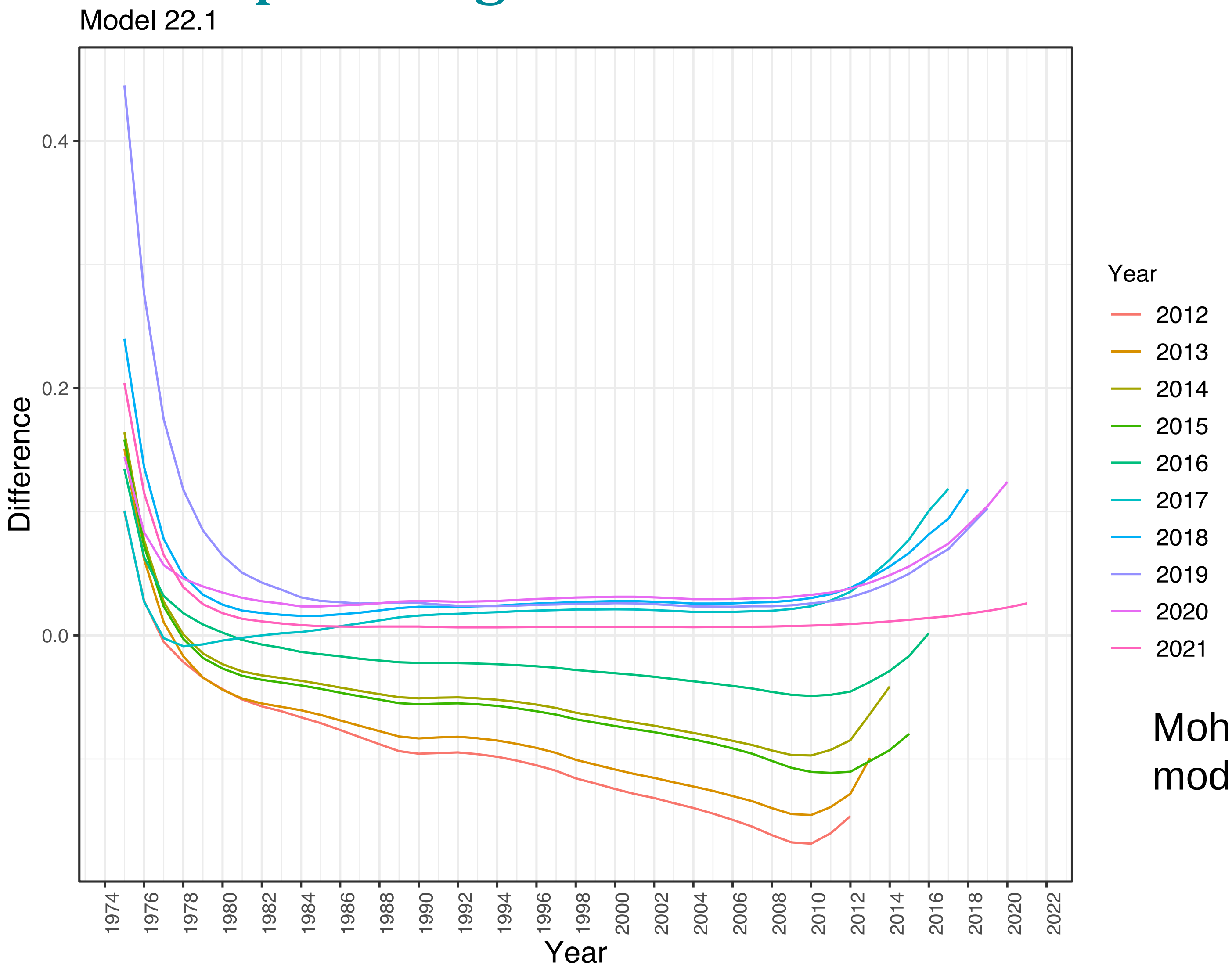
U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

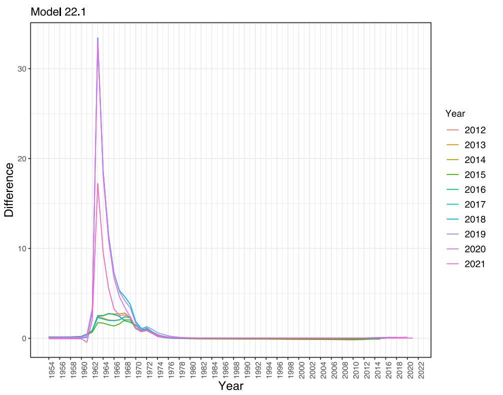
Retrospective plot: female spawning biomass Model 22.1



Mohn's rho for this model was 0.007.

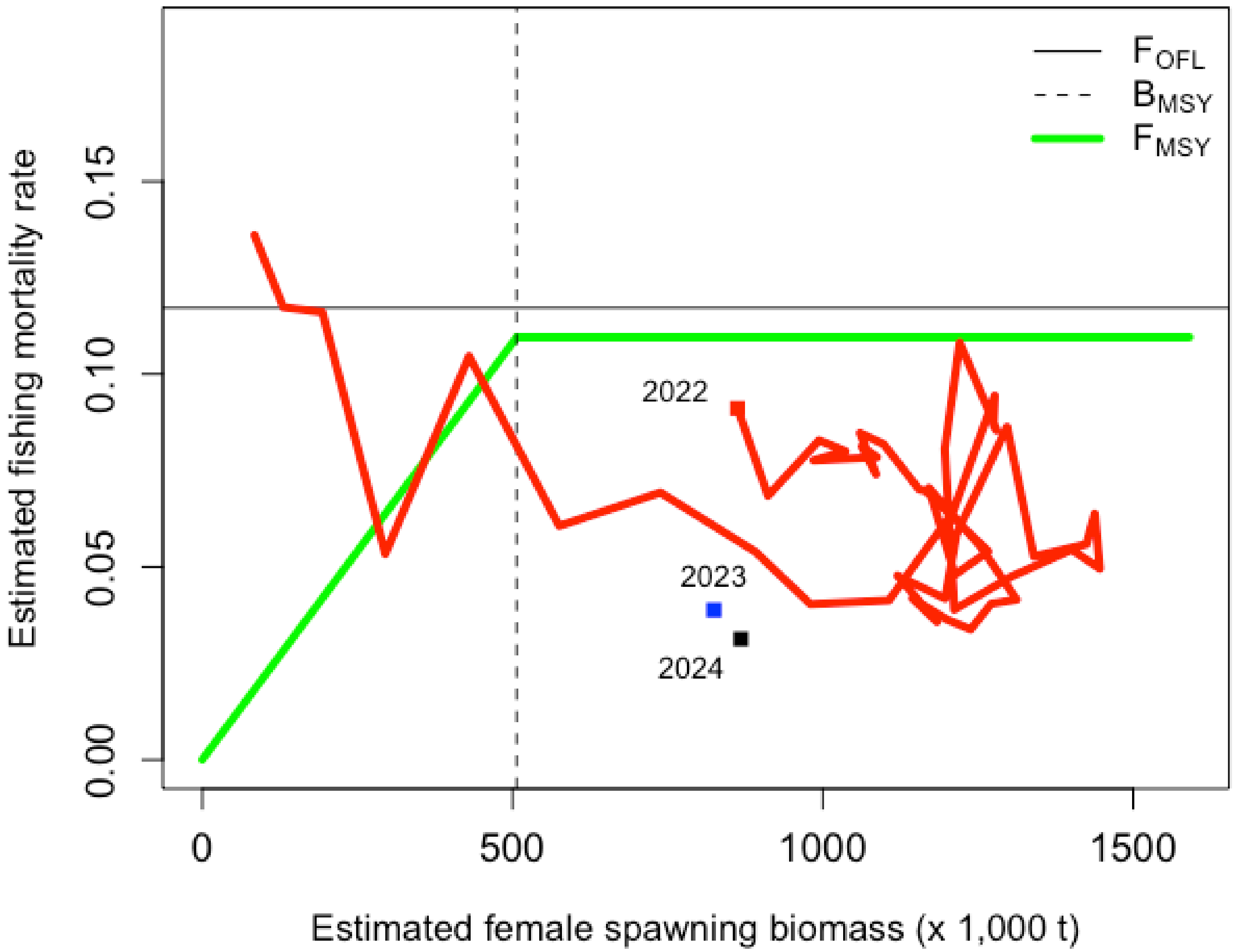
Retrospective relative difference from terminal year female spawning biomass Model 22.1





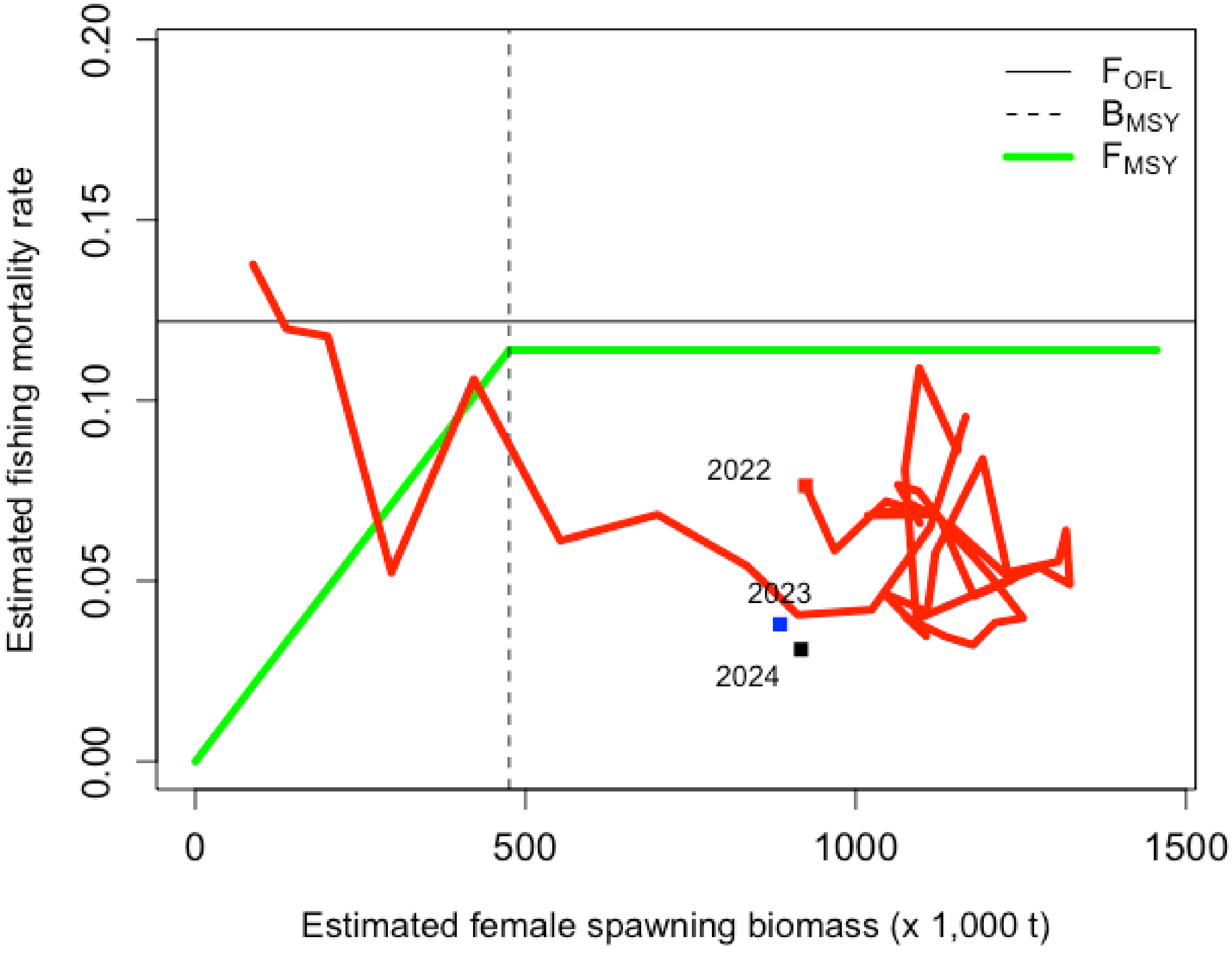
Mohn's rho for this model was 0.007.

Yellowfin sole fishing mortality rate vs. female spawning biomass, 1975 – 2022, Model 22.0



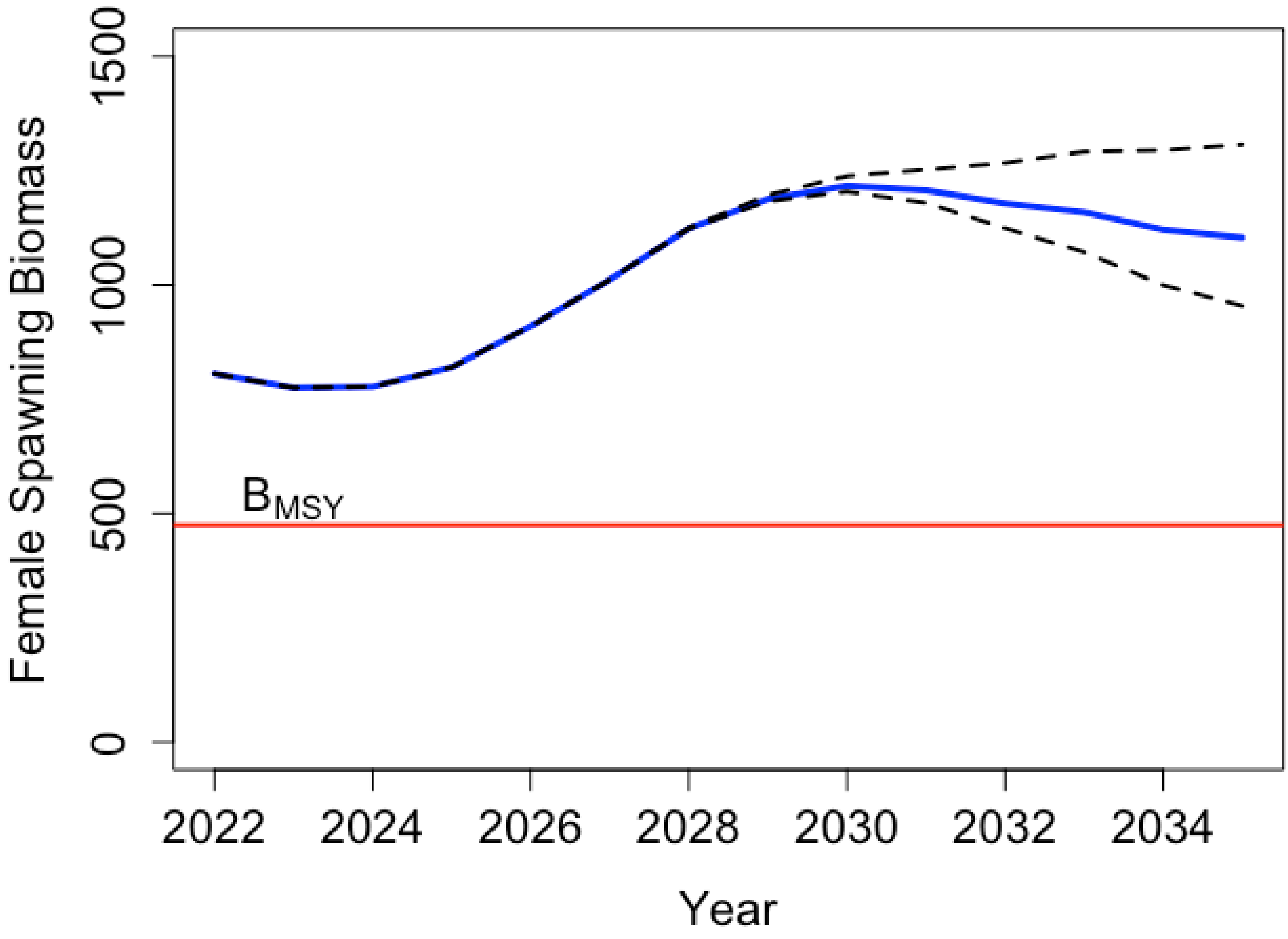
Vertical line is B35%. Squares indicate estimates for 2022, 2023, and 2024

Yellowfin sole fishing mortality rate vs. female spawning biomass, 1975 – 2022, Model 22.1



Vertical line is B35%. Squares indicate estimates for 2022, 2023, and 2024

Projected yellowfin sole female spawning biomass for 2022-2035, with 95% CI's, Model 22.1



Fishing at the 5-year (2017-2021) average F=0.067.

MCMC analysis

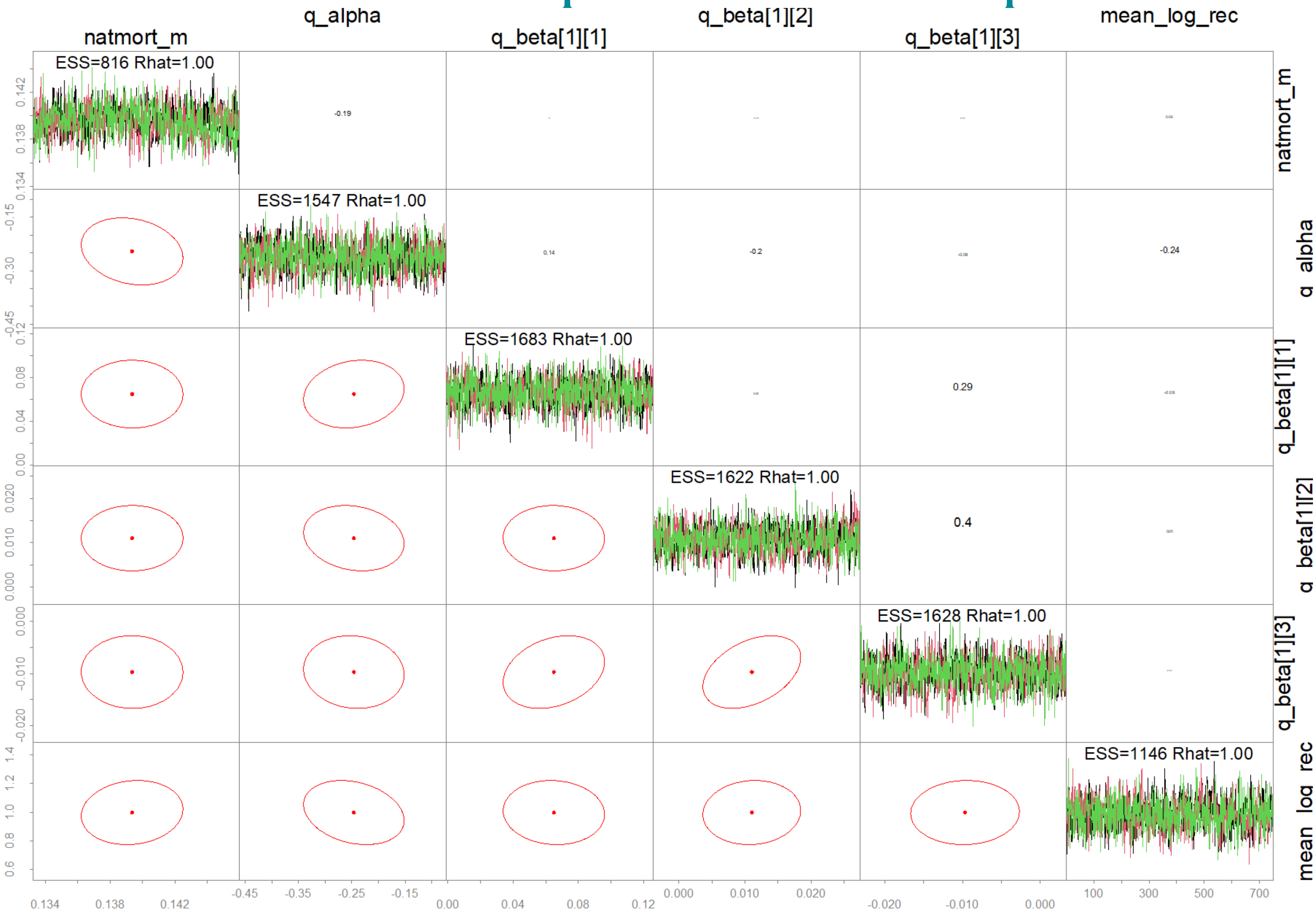
To address the absence of smooth probability distributions that are often associated with model convergence and efficient MCMC sampling

- Model 22.0 was analyzed using the R package *adnuts*.
- We increased the number of iterations and number of iterations between thinning from previous assessments.
- We examined trace plots of selected parameters and the effective sample size and $\hat{r}$.

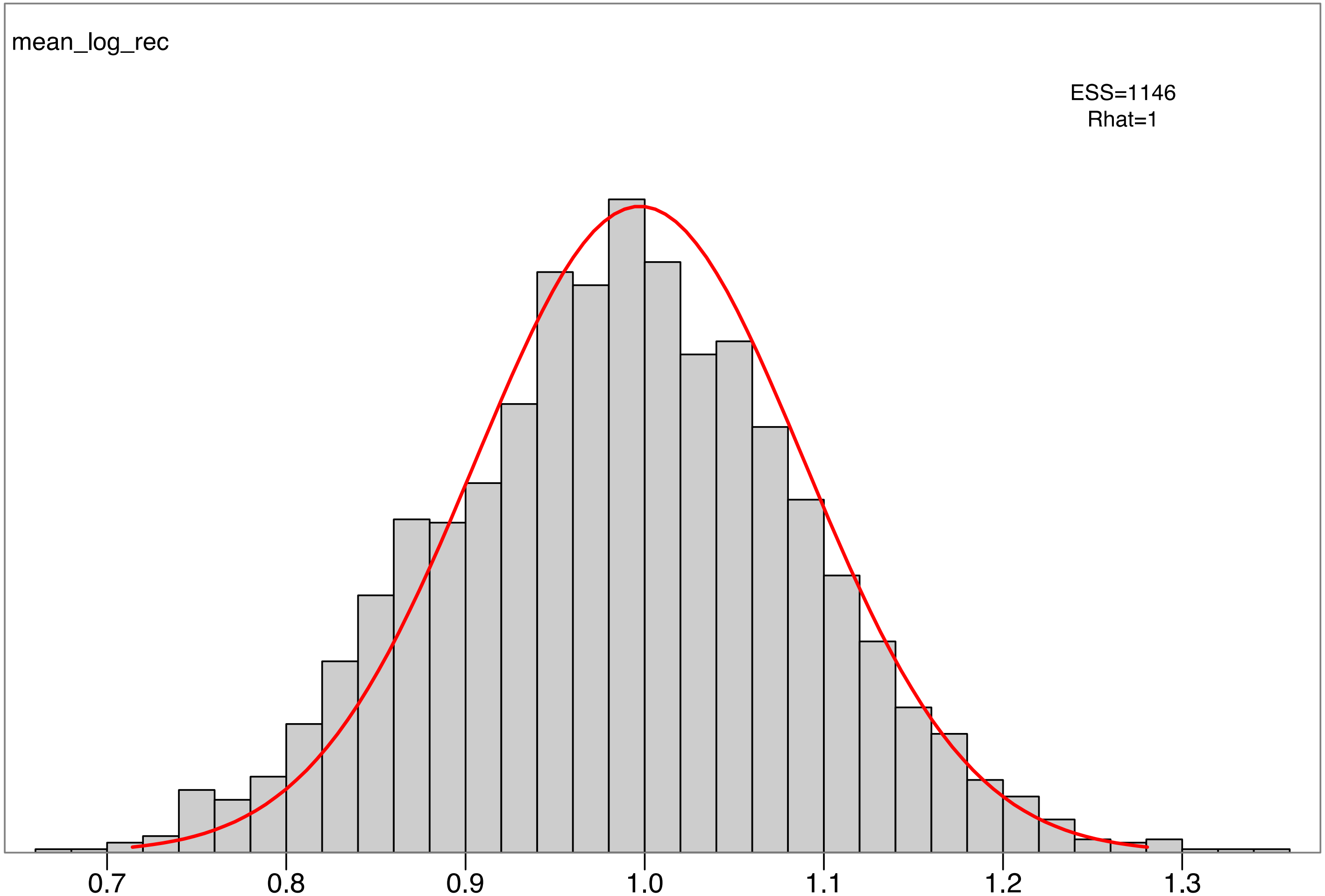
MCMC analysis

- Previous MCMC runs of the yellowfin sole assessment model were performed in ADMB with 1,000,000 iterations and thinning every 200.
- Explorations in *adnuts* indicated that 10^7 iterations were required, with thinning every 1000 runs.
- The outcome indicated good mixing in key parameters distributions estimated by the model.
- Some parameters of low inferential importance were not well mixed, such as several male and female selectivity parameters early in the time series. These parameters will be examined prior to the next assessment cycle.

Pairwise parameter posteriors, trace plots, and confidence ellipses for several parameters



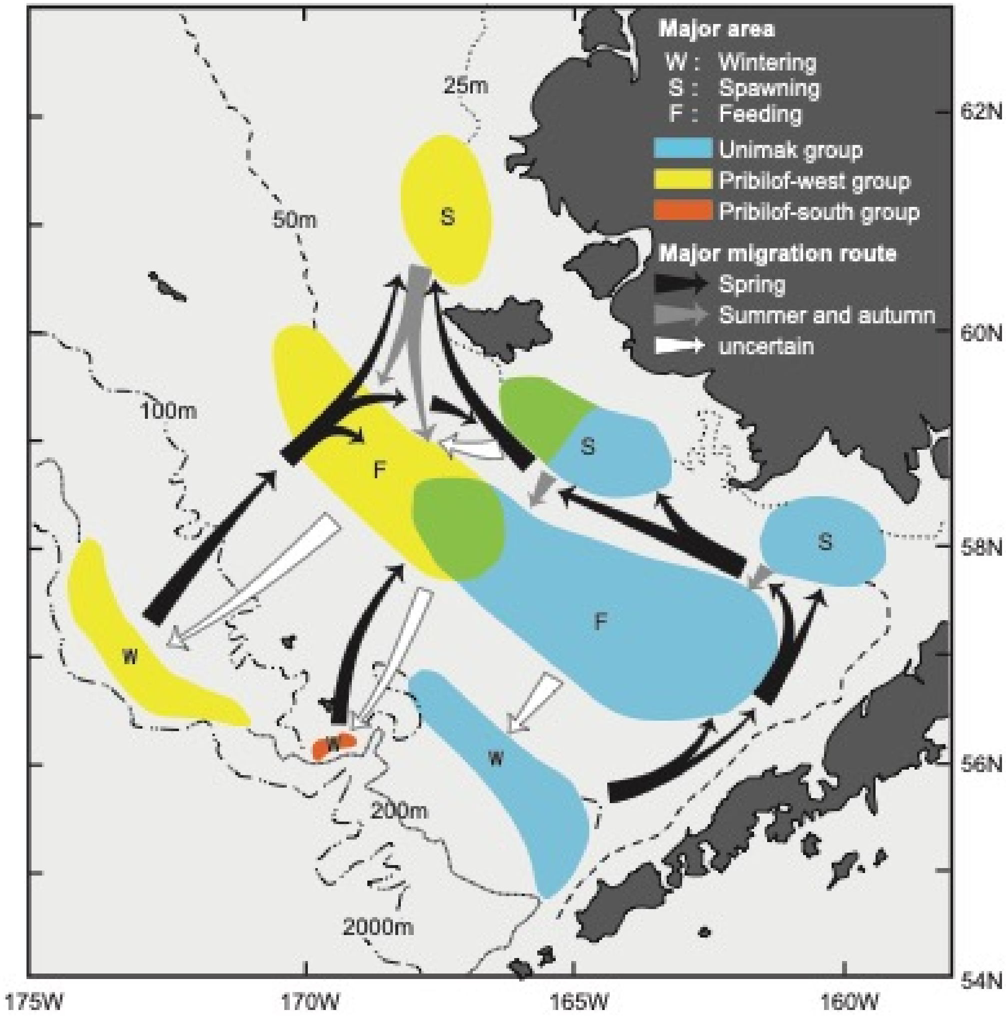
Markov Chain Monte Carlo distribution for the mean log(Recruitment) parameter yellowfin sole Model 22.0



NOAA FISHERIES

Stock structure

Distribution of wintering, spawning, and feeding areas for yellowfin sole in the Bering Sea



Migration wintering to feeding take place in spring. The dates that yellowfin sole return to their wintering areas are unknown. Colors indicate observed regional grouping (Wakabayashi 1989).

Risk Table - Assessment related considerations

- The assessment model exhibits good fits to all compositional and abundance data and converges to a single minima in the likelihood surface.
- MCMC indicated good mixing in key parameters distributions estimated by the model.
- Recruitment estimates track strong year-classes that are consistent with the data.
- In the 2022 Models 22.0 and 22.1, combining male and female survey selectivities improved the retrospective pattern.

We propose a level 1 designation for the assessment category in the risk table, given the improvement to the retrospective pattern and favorable outcome of MCMC evaluation.

Risk Table - Population dynamics considerations

The current model for 2022 (Model 22.1) estimates B_{MSY} at 475,199 t. Projections indicate that the FSB will remain well-above the B_{MSY} level through 2035.

We propose a level 1 designation for the population dynamics category in the risk table.

Risk table - Environmental/ecosystem considerations

- Environment: The extended warm phase experienced by the eastern Bering Sea (EBS) that began in approximately 2014 has largely relaxed to normal conditions over the past year (August 2021 - August 2022).
- Prey: Sufficient prey may have been available for YFS over the southern shelf based on trends in motile epifauna.
- Fish condition was above-average in the SEBS and increased from 202; condition was just below average in the NBS and decreased from 2021.
- Competition: Trends in benthic forager biomass suggest competition for prey resources remains low in 2022.
- Predation pressure may be mixed; an increase in Pacific cod biomass may be countered by potential refuge from predation in the inner domain.

- Together, the most recent data available suggest an ecosystem risk level 1 – Normal: No apparent environmental/ecosystem concerns.

Risk Table - Fishery performance considerations

- Landings of benthic foragers (including YFS) remained relatively stable through 2018.
- Landings of benthic forager flatfish may be larger than salmon, but salmon ex-vessel value is higher because it commands a higher price.
- Export quantity and value have declines from 2020-2021, likely due to tariffs and possibly COVID.

- Fishery performance risk level 1 – Normal.

Risk Table

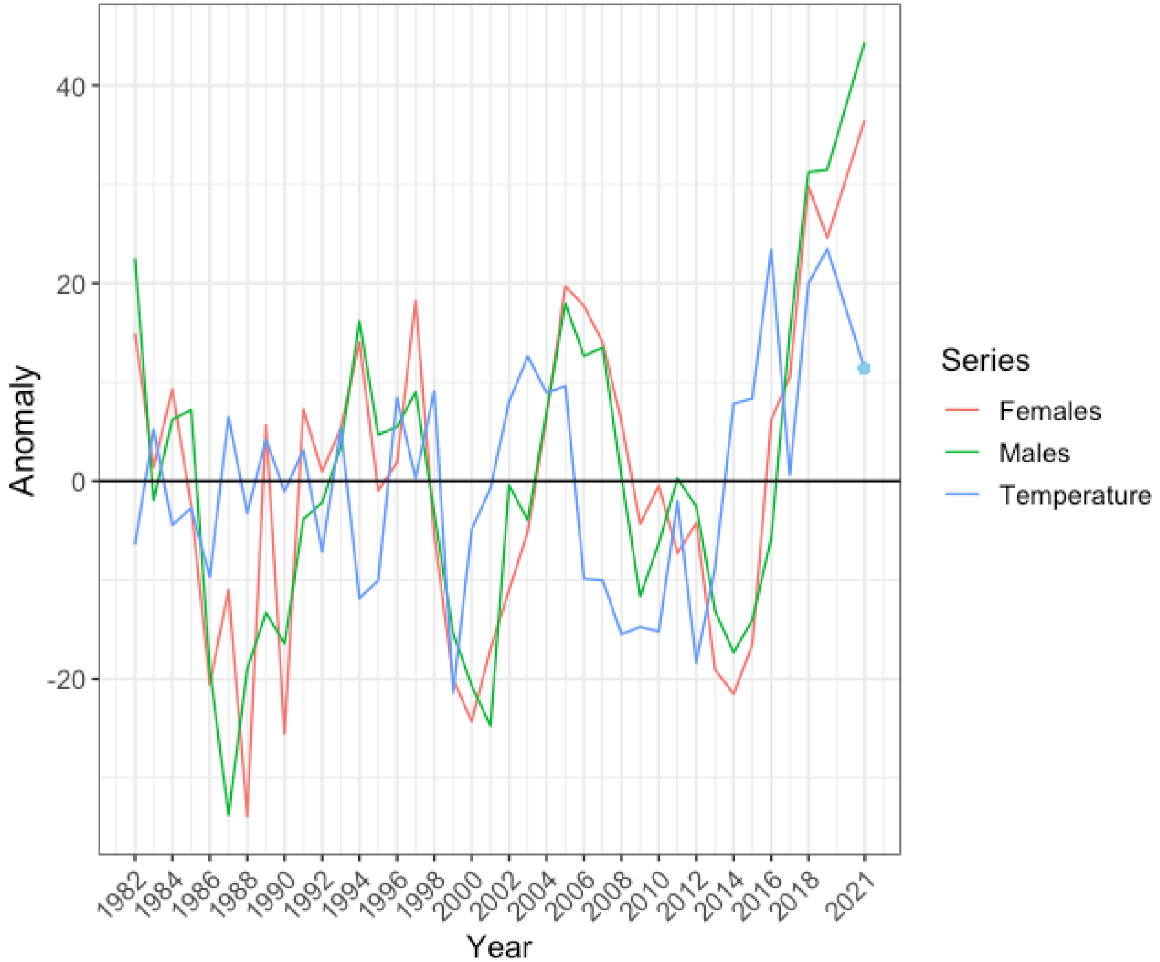
Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance
Level 1: There has been an improvement to the retrospective pattern.	Level 1: The EBS survey estimate in 2022 was an increase over 2021.	Level 1: 2022 was a cool/average thermal year in the EBS and NBS	Level 1: Normal.

Future work:

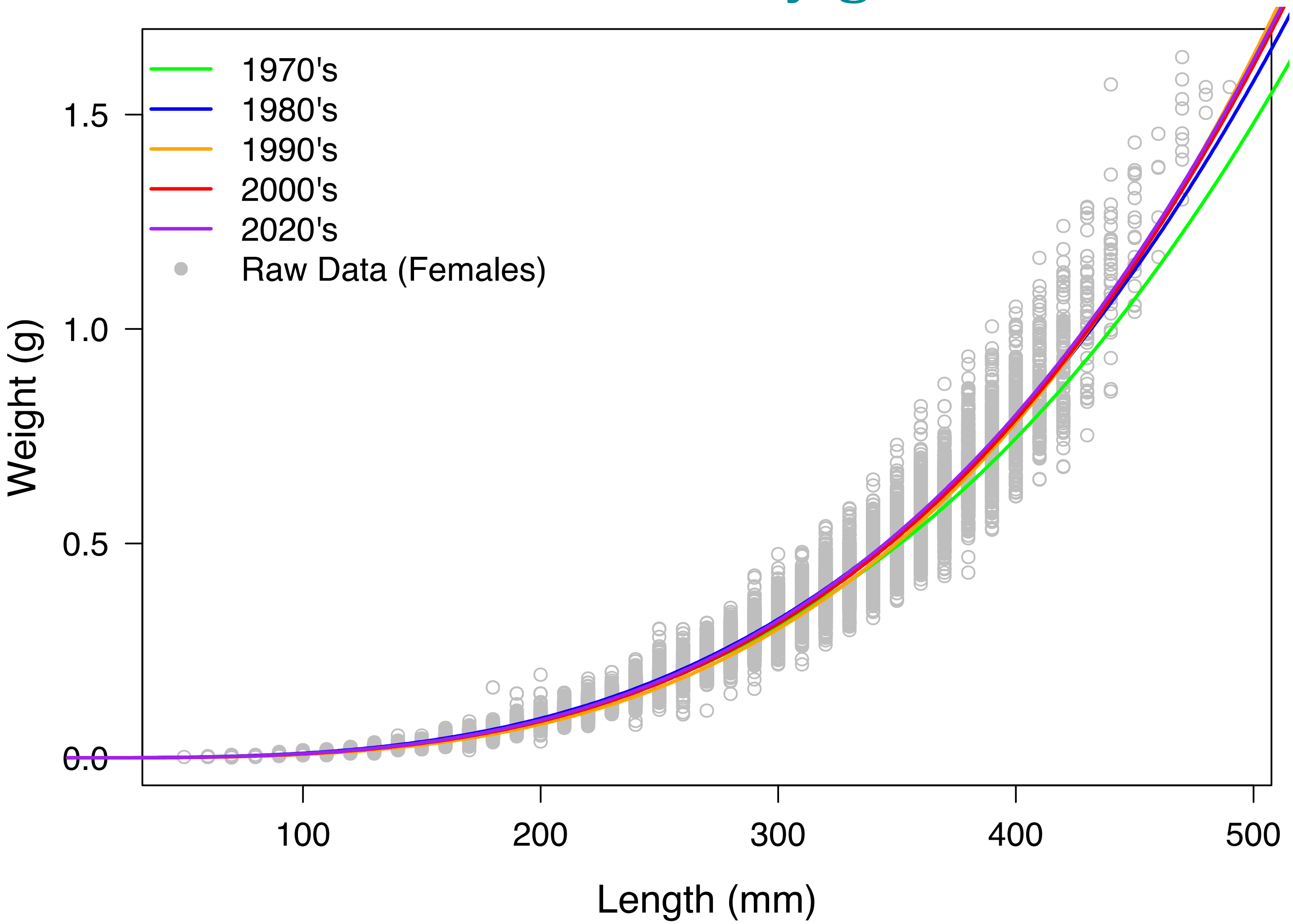
1. Combine male and female fishery selectivity.

2. Temperature-mediated growth model.

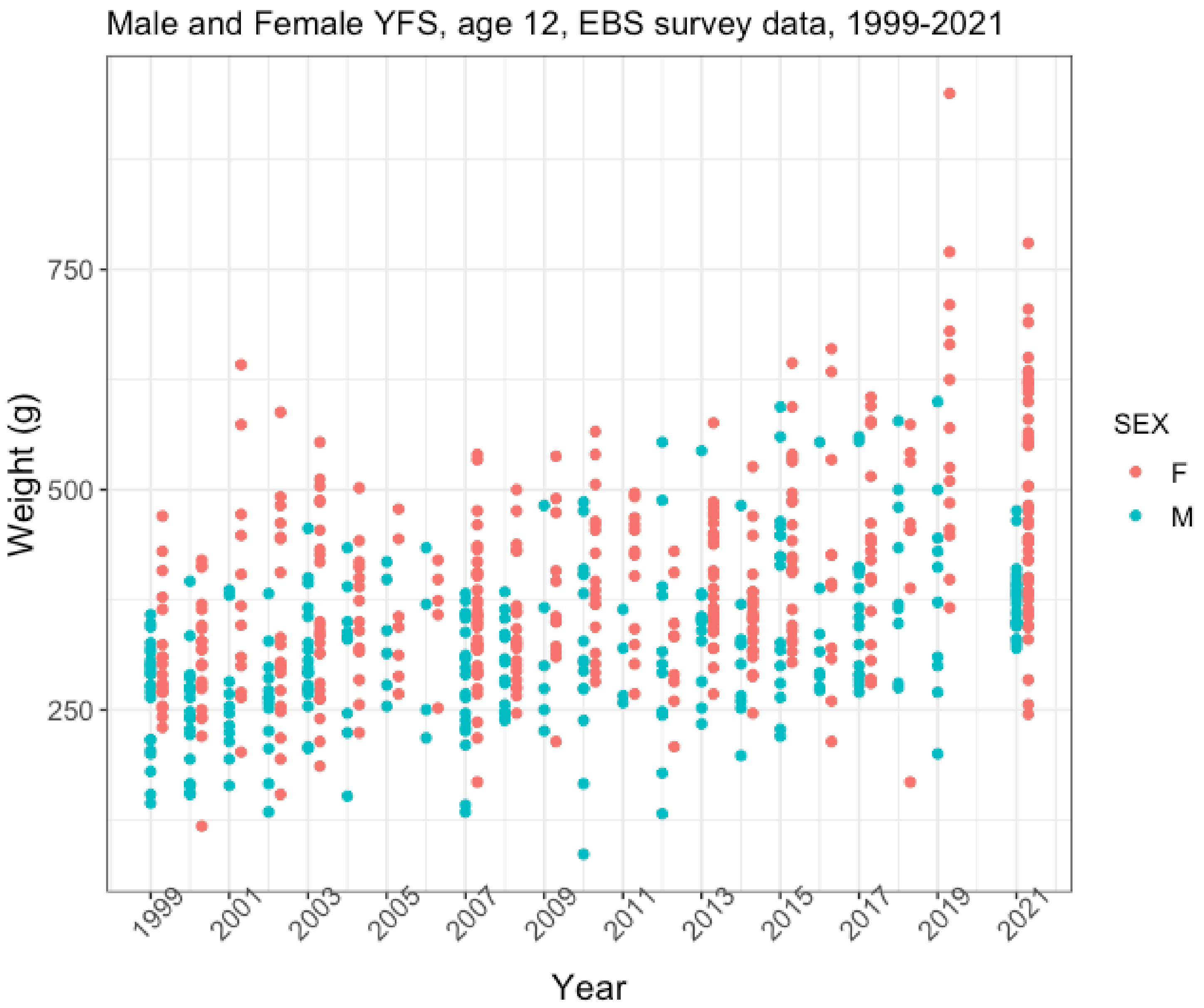
Yellowfin sole length-at-age anomalies, for 5-year old males and females, and bottom temperature anomalies from the eastern Bering Sea survey area <100 m.



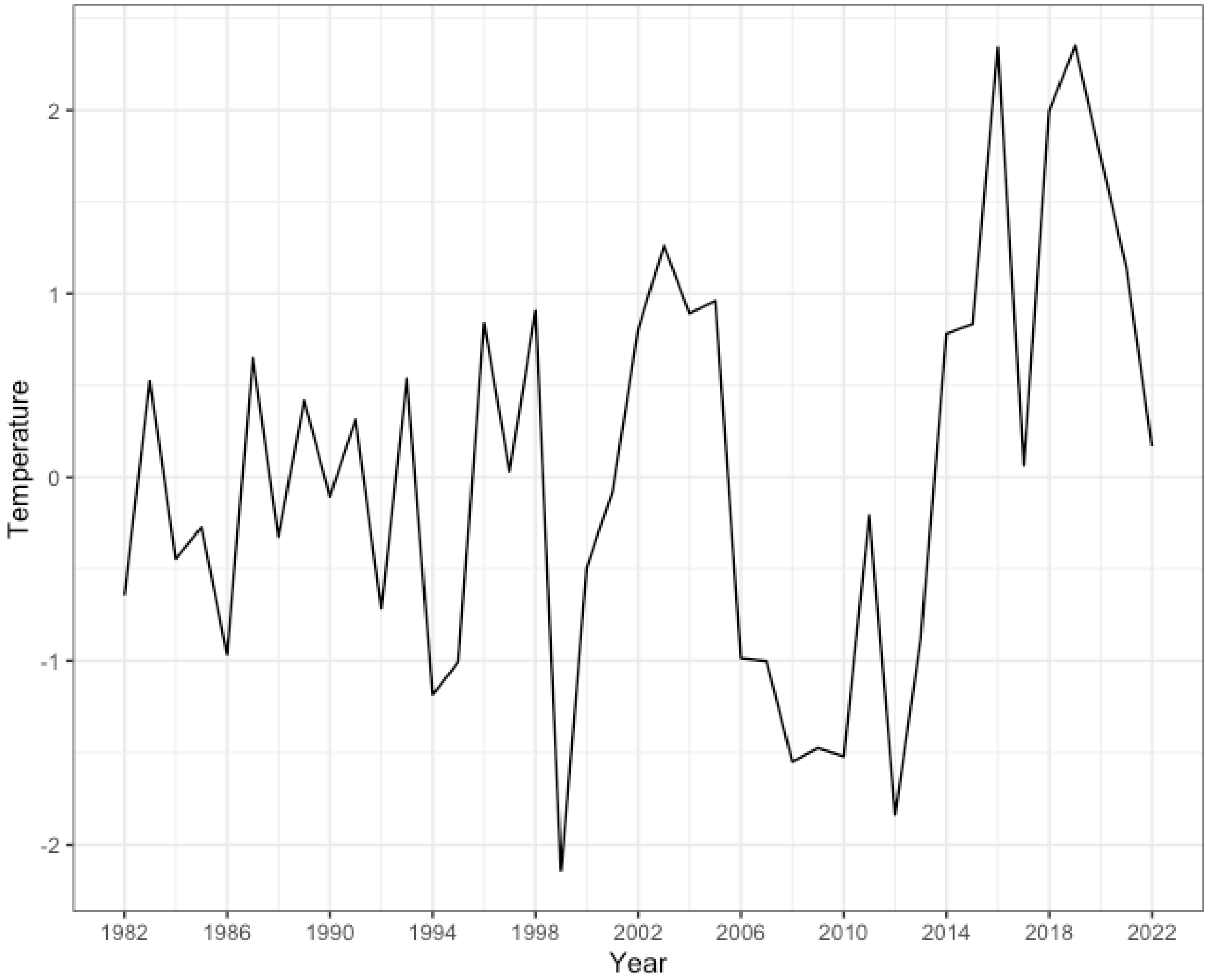
Yellowfin sole weight at length by decade, females, fitted to the von Bertalanffy growth model.



Temperature– mediated growth model



Bottom temperature anomalies from the NMFS survey <100 m, 1982-2022



Reference Table for Model 22.1

Quantity	As estimated or *specified* *last* year for: 2022	2023	As estimated or *recommended* *this* year for: 2023	2024
M (natural mortality rate)	0.12, 0.135	0.12, 0.135	0.12, 0.125	0.12, 0.125
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,479,370 t	2,284,820 t	3,321,640 t	4,062,230 t
Projected female spawning biomass (t)	857,101 t	727,101 t	885,444 t	897,062 t
B_0	1,489,190 t	1,489,190 t	1,407,000 t	1,407,000 t
B_{MSY}	495,904 t	495,904 t	475,199 t	475,199 t
F_{OFL}	0.152	0.152	0.122	0.122
$maxF_{ABC}$	0.143	0.143	0.114	0.114
F_{ABC}	0.143	0.143	0.109	0.110
OFL (t)	377,071 t	347,483 t	404,882 t	495,155 t
$maxABC$	354,014 t	326,235 t	378,499 t	462,890 t
ABC (t)	354,014 t	326,235 t	378,499 t	462,890 t
Status	2020	2021	2021	2022
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 127,712 t in 2022 and 126,157 t used in place of maximum ABC for 2023. This estimate was based on the mean of the past 5 years, 2018 - 2022, which includes the extrapolated catch of 127,712 t for 2022.

Questions?

Tier 3 reference table for Model 22.1

Quantity	As estimated or *specified* *last* year for: 2022	2023	As estimated or *recommended* *this* year for: 2023	2024
M (natural mortality rate)	0.12, 0.135	0.12, 0.135	0.12, 0.125	0.12, 0.125
Tier	1a	1a	3a	3a
Projected total (age 1+) biomass (t)	2,479,370 t	2,284,820 t	3,301,360 t	3,250,439 t
Projected female spawning biomass (t)	857,101 t	727,101 t	780,284 t	754,839 t
$B_{100\%}$ (B_0 for Tier 1a)	1,489,190 t	1,489,190 t	1,890,560 t	1,890,560 t
$B_{40\%}$	-	-	756,223 t	756,223 t
$B_{35\%}$ (B_{MSY} for Tier 1a)	495,904 t	495,904 t	661,695 t	661,695 t
F_{OFL}	0.152	0.152	0.14	0.14
$maxF_{ABC}$	0.143	0.143	0.117	0.117
F_{ABC}	0.143	0.143	0.117	0.117
OFL (t)	377,071 t	347,483 t	226,860 t	240,517 t
$maxABC$	354,014 t	326,235 t	190,898 t	195,438 t
ABC (t)	269,649 t	258,567 t	190,898 t	195,438 t
Status	2020	2021	2021	2022
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 127,712 t in 2022 t in 2022 and 126,157 t used in place of maximum ABC for 2023.

Comparison of Model 18.2 (2022) and Model 18.2 (2021)

	Model 18.2 (2022)		Model 18.2 (2021)	
Quantity	2023	2024	2023	2024
M (natural mortality rate)	0.12, 0.138	0.12, 0.138	0.12, 0.14	0.12, 0.14
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	3,265,700	4,051,680	2,479,370	2,284,820
Projected female spawning biomass (t)	827,515	850,621	857,101	727,101
B_0	1,484,500	1,484,500	1,489,190	1,489,190
B_{MSY}	515,251	515,251	495,904	495,904
F_{OFL}	0.113	0.113	0.152	0.152
$maxF_{ABC}$	0.105	0.105	0.143	0.143
F_{ABC}	0.105	0.105	0.143	0.143
OFL	369,038	457,857	377,071	347,483
$maxABC$	342,438	424,854	354,014	326,235
ABC	342,438	424,854	354,014	326,235
Status	2021	2022	2021	2022
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

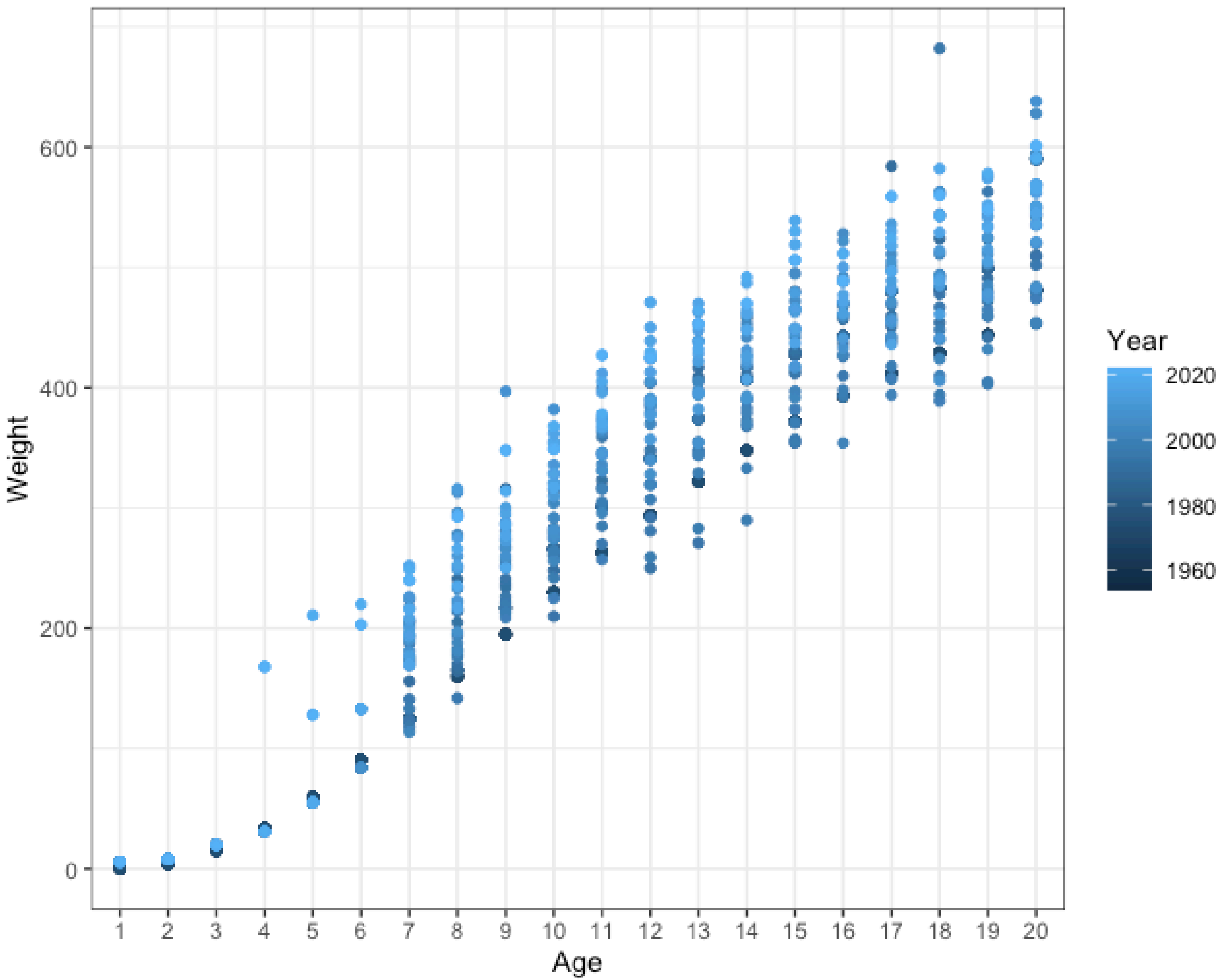
Comparison of Model 22.0 and Model 22.1

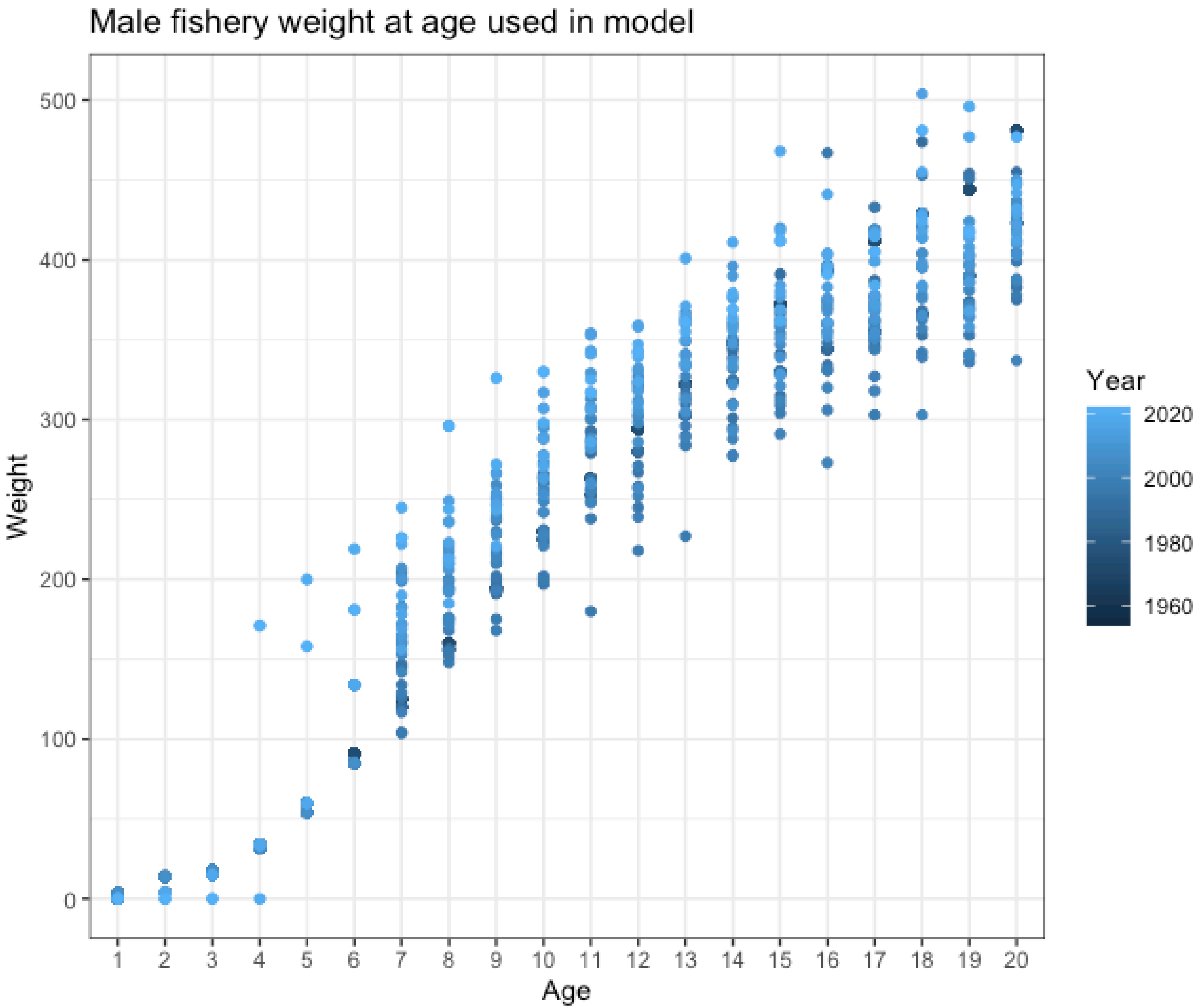
Quantity	Model 22.0 2023	Model 22.0 2024	Model 22.1 2023	Model 22.1 2024
M (natural mortality rate)	0.12, 0.139	0.12, 0.139	0.12, 0.125	0.12, 0.125
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	3,248,690	4,029,770	3,321,640	4,062,230
Projected female spawning biomass (t)	824,586	847,814	885,444	897,062
B_0	1,478,700	1,478,700	1,407,000	1,407,000
B_{MSY}	506,792	506,792	475,199	475,199
F_{OFL}	0.117	0.117	0.122	0.122
$maxF_{ABC}$	0.11	0.11	0.114	0.114
F_{ABC}	0.11	0.11	0.114	0.114
OFL	380,786	472,338	404,882	495,155
$maxABC$	356,013	441,608	378,499	462,890
ABC	356,013	441,608	378,499	462,890
Status	**2021**	**2022**	**2021**	**2022**
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

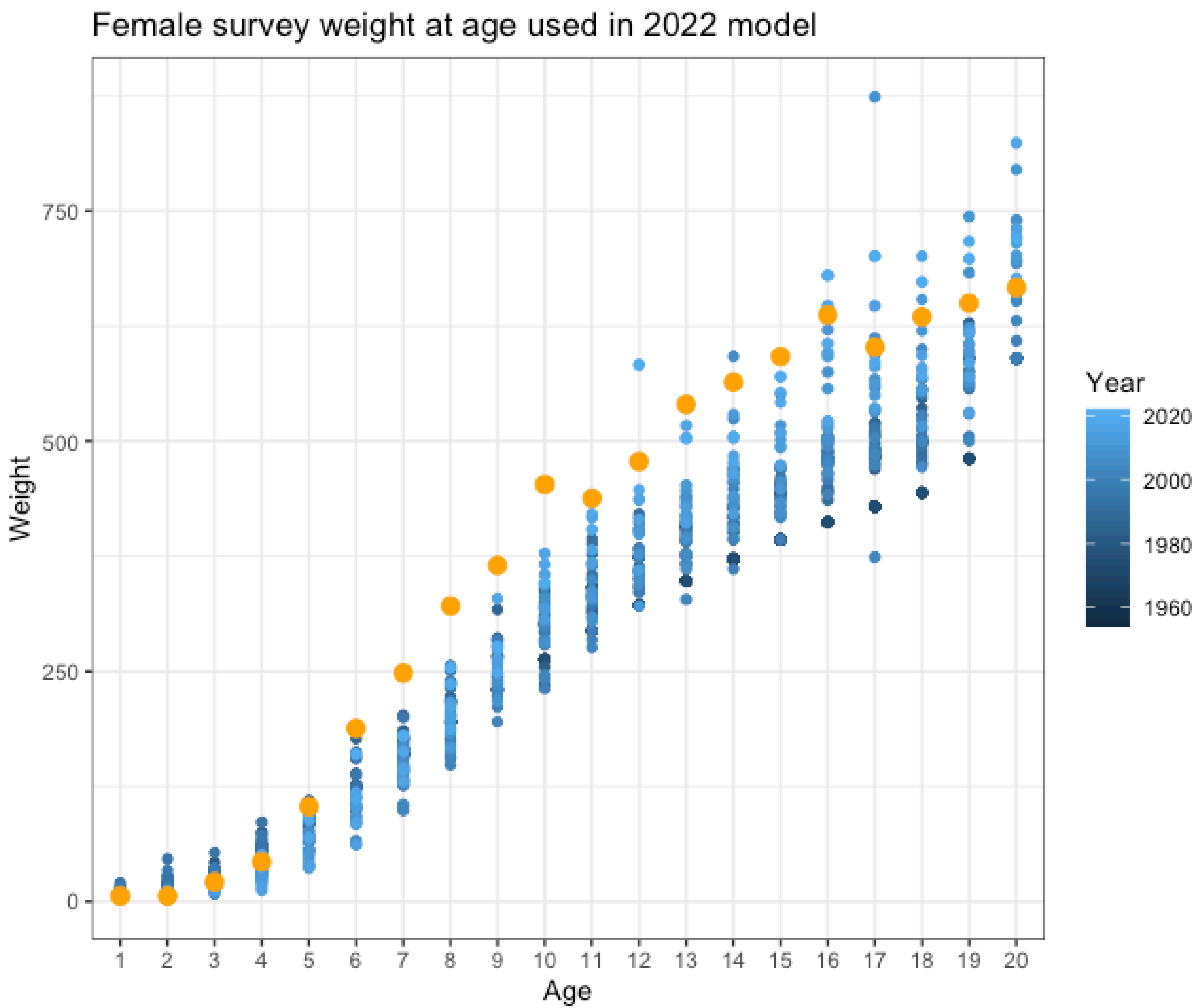
Fishery weight-at-age

- The fishery weight-at-age composition is estimated as described in Kimura (1989) and modified by Dorn (1992).
- Length-stratified age data were used to construct age-length keys for each stratum and sex.
- The strata are January - April, May - August, and September - December.
- These keys were then applied to randomly sampled catch length frequency data.
- The stratum-specific age composition estimates were then weighted by the catch biomass within each stratum to arrive at an overall age composition for each year.
- The catch-at-age estimation method uses a two-stage bootstrap re-sampling of the data (1,000 bootstrap resamples).
- Observed tows were first selected with replacement, followed by re-sampling actual lengths and age specimens given that set of tows.
- Lengths were converted to weights and used in the model.

Female fishery weight at age used in model

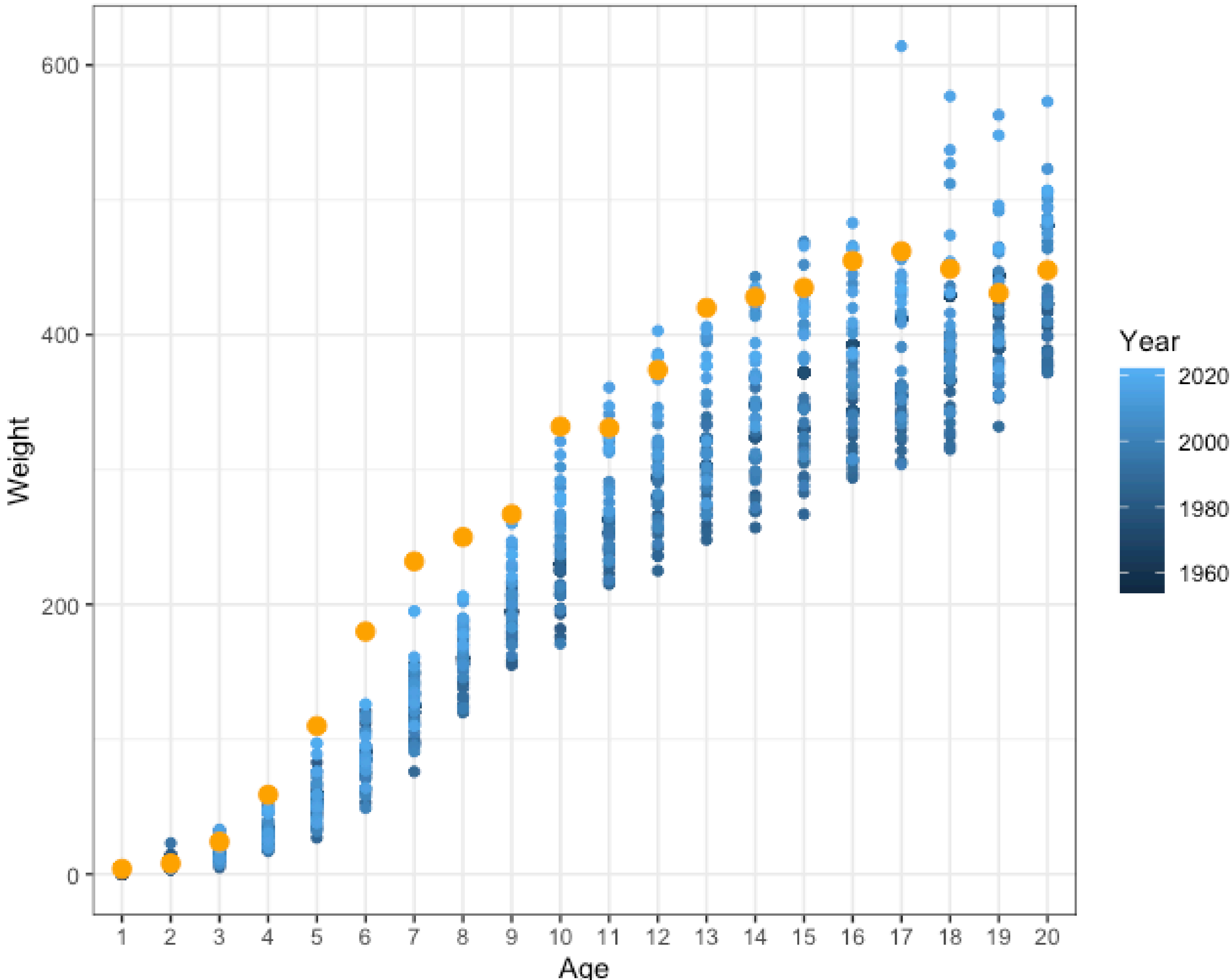


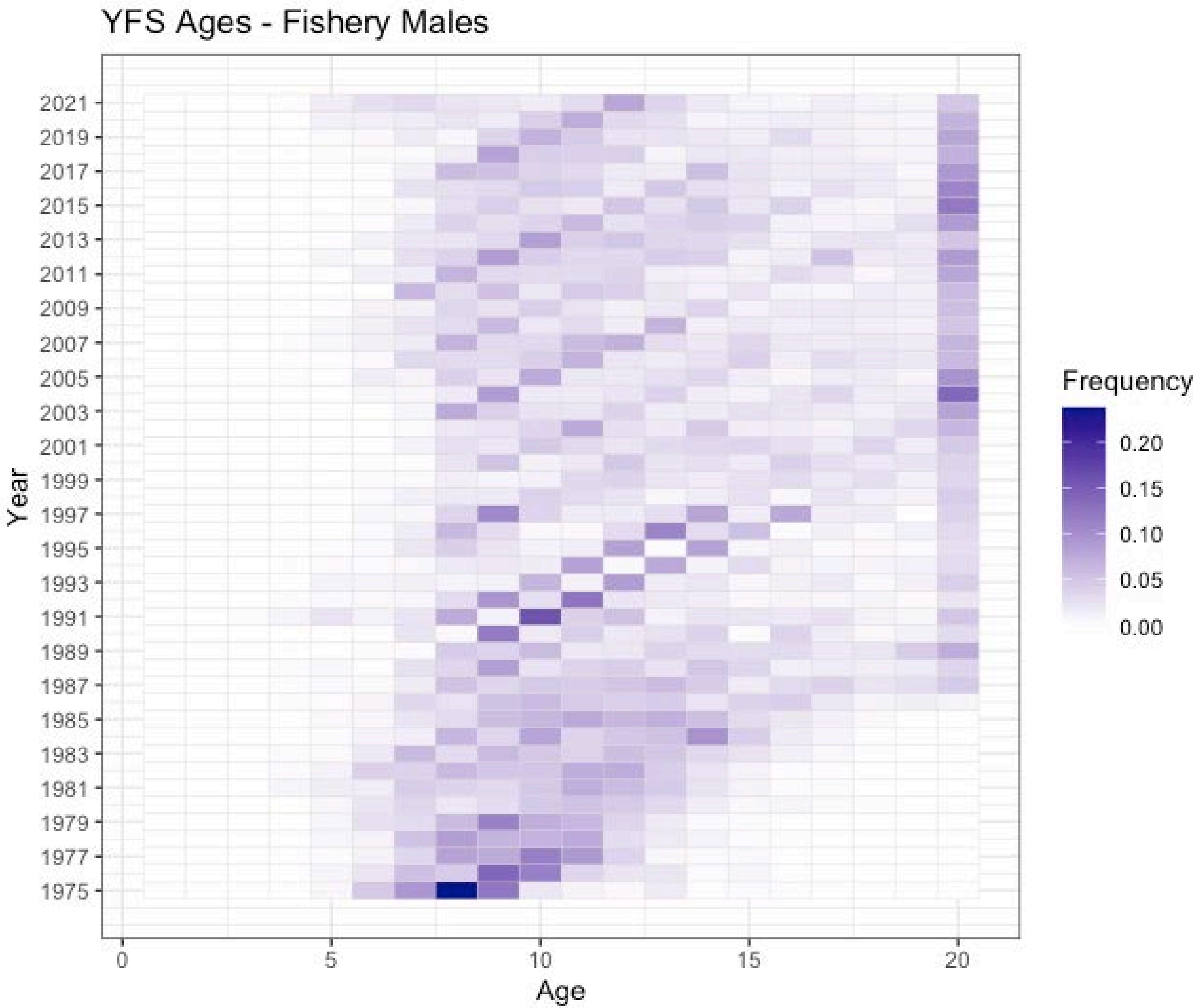

Male fishery weight at age used in model
Weight
0
100
200
300
400
500
Age
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Year
2020
2000
1980
1960



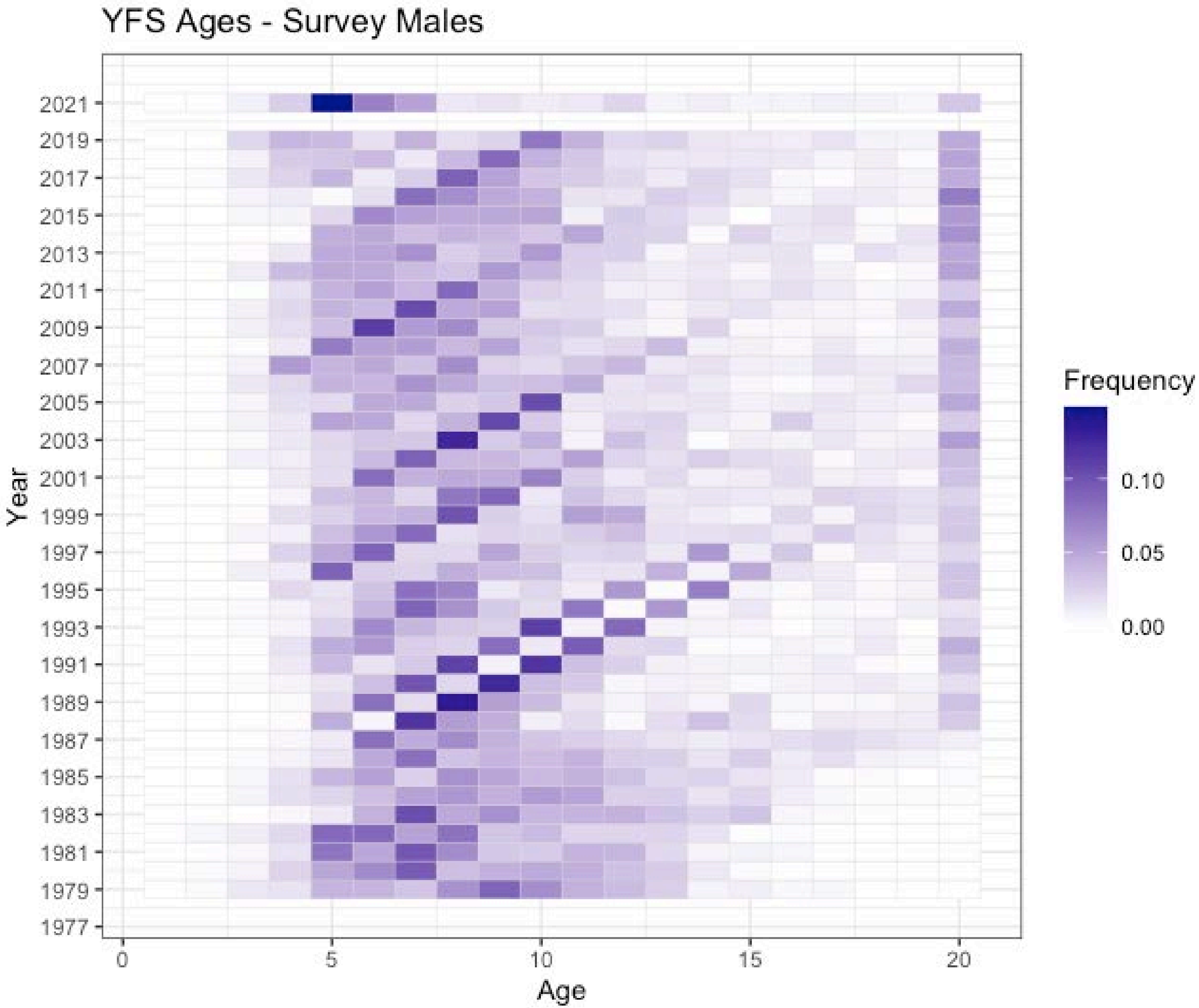
Female survey weight at age used in 2022 model
Weight
Age
750
500
250
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Year
2020
2000
1980
1960

Male survey weight at age used in 2022 model





Age frequenc
yellowfin sol



YFS Ages - Survey Males
Year
2021
2019
2017
2015
2013
2011
2009
2007
2005
2003
2001
1999
1997
1995
1993
1991
1989
1987
1985
1983
1981
1979
1977
0
5
10
15
20
Age
Frequency
0.10
0.05
0.00

Distributional assumptions

The suite of parameters estimated by the model are classified by three likelihood components:

Data component	Distributional assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log-normal

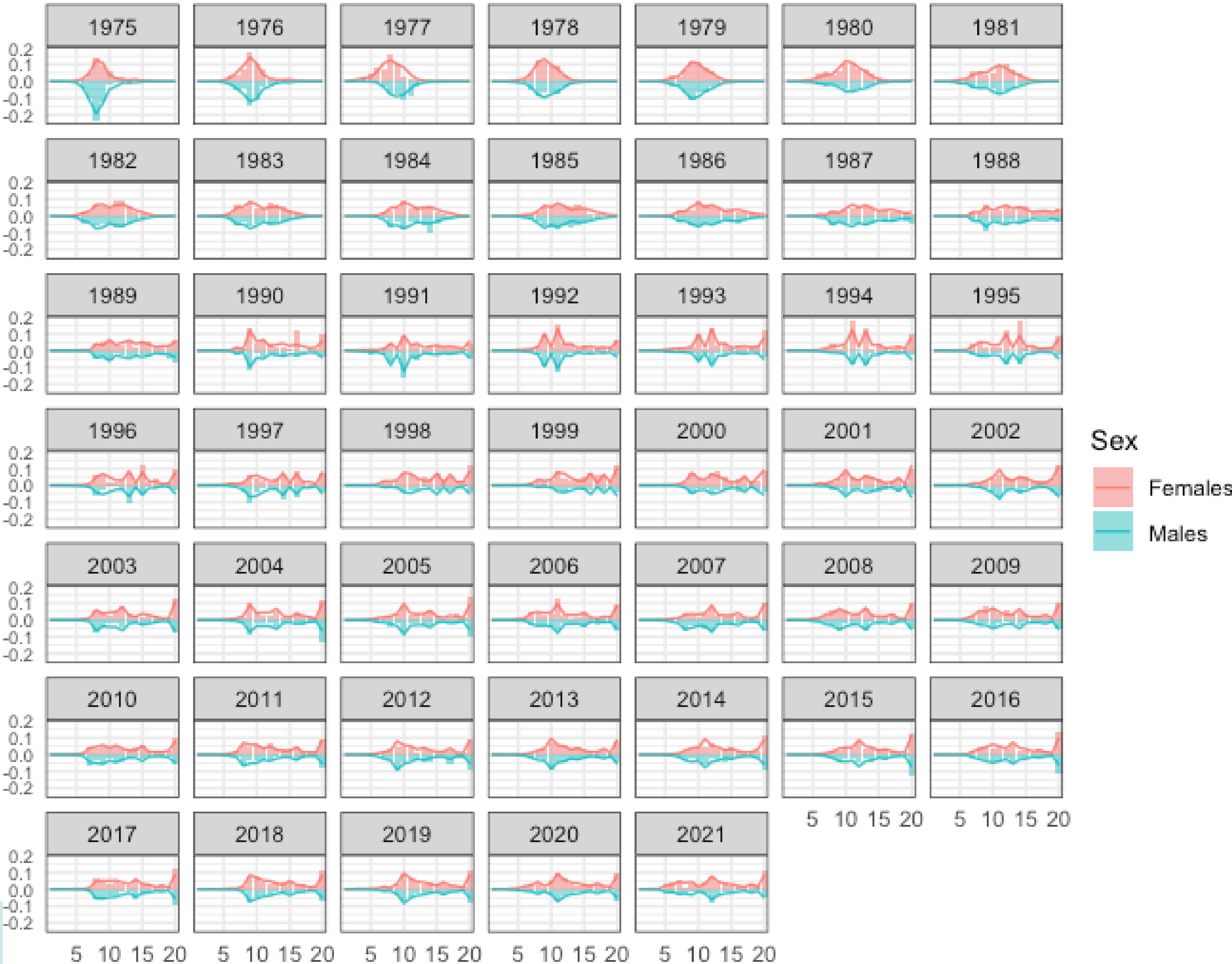
Fit to Survey Age Compositions, Model 18.2

NOAA FISHERIES

Fit to Survey Age Compositions, Model 22.1

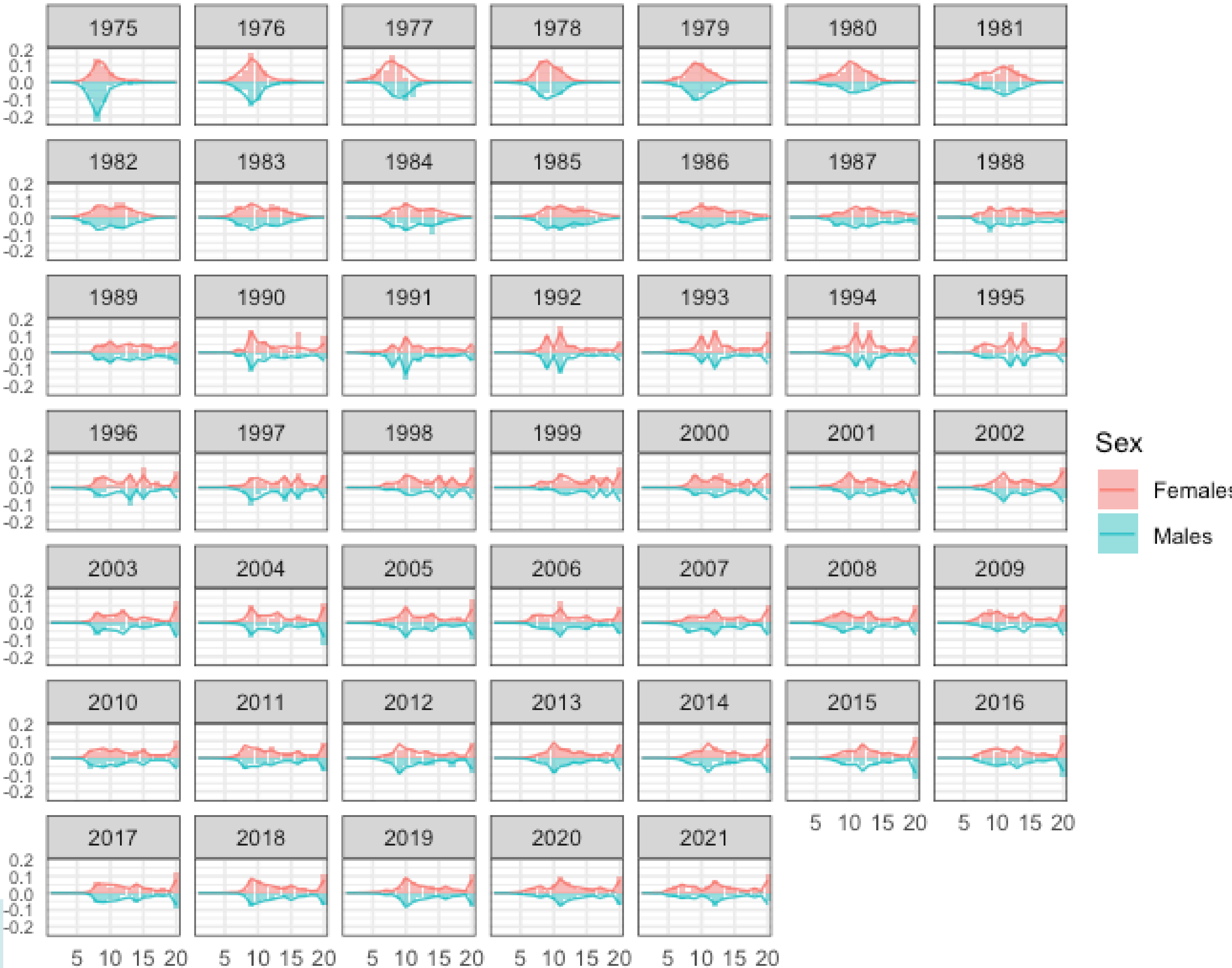
NOAA FISHERIES

Fit to Fishery Age Compositions, Model 22.0

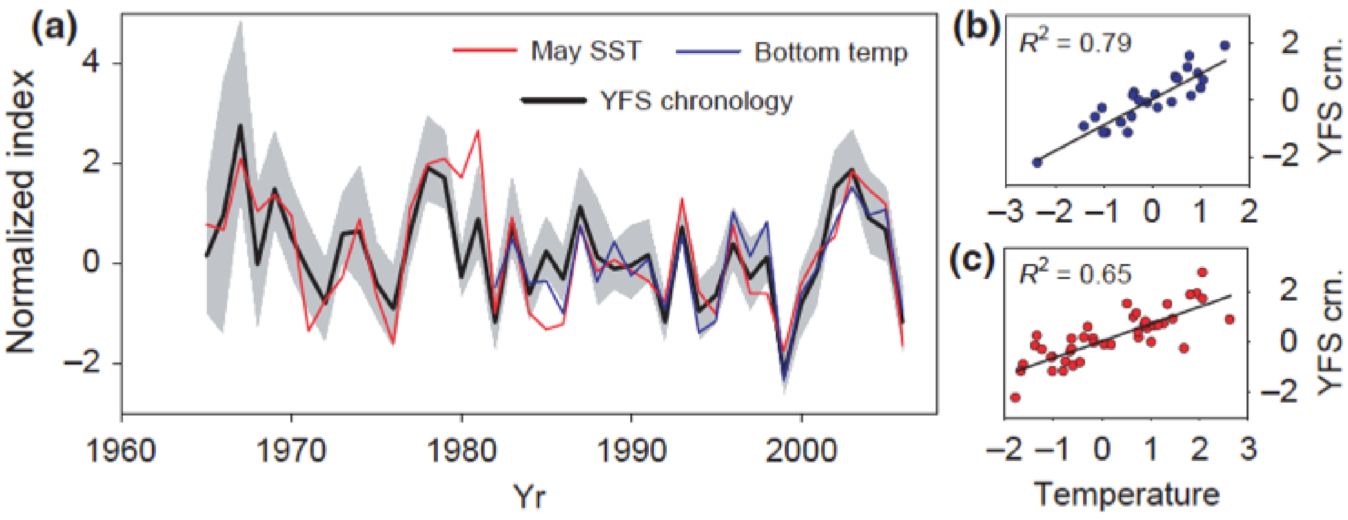


NOAA FISHERIES

Fit to Fishery Age Compositions, Model 22.1



Master chronology for yellowfin sole and time series of mean summer bottom temperature and May sea surface temperature for the eastern Bering Sea.



Correlations of chronologies with bottom temperature

and sea surface temperature

(Matta et al. 2010).

NOAA FISHERIES