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

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November 14, 2024 Presentation to the Bering Sea and Aleutian Islands Plan Team

NOAA FISHERIES

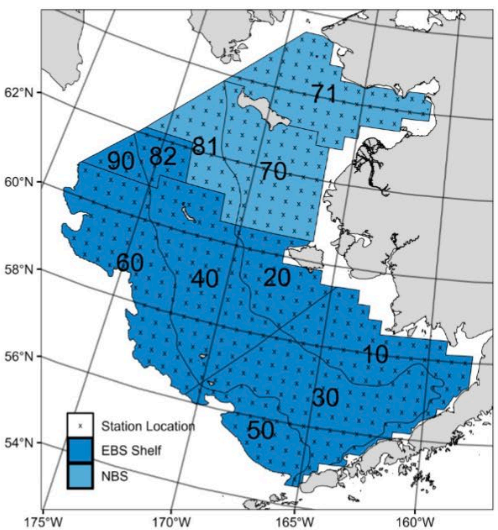
Selected SSC comments (SSC December 2023)

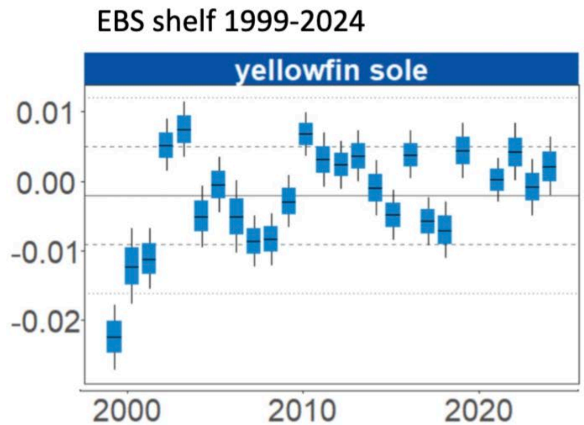
SSC: The SSC recommends that the author examine and reconcile (if necessary) the seeming contradiction in body conditions between the weight at age matrix in the assessment and the body condition metric presented for the risk table.

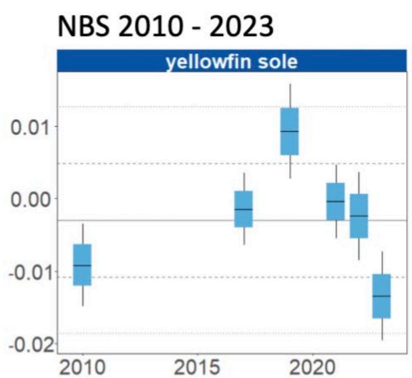
Response:

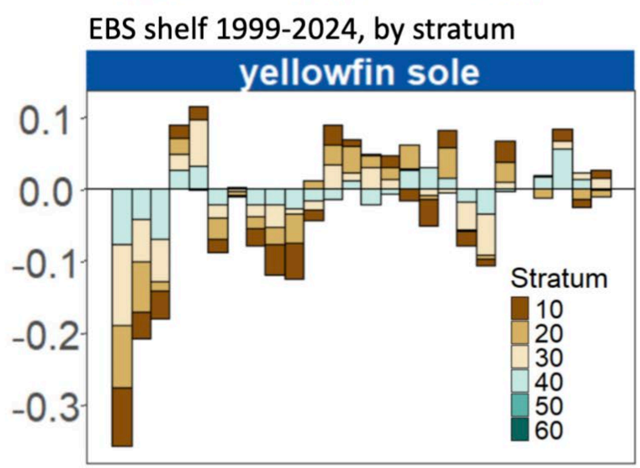
YFS length-weight residuals have been declining in the NBS since 2019 but are above average (overall) in the EBS, based on 2024 data. In the EBS, overall the residuals are positive, but negative in strata 20 which is the northern part of the southern inner domain, which aligns with YFS condition being negative in the northern shelf. Weight at age of yellowfin sole taken by the EBS survey has been increasing over time, which translates to faster growth. Therefore, faster growth and positive length-weight residuals are present in the EBS, but negative length-weight residual appear in the NBS. The NBS survey is a shorter time series, so anomalies may not be as reliable as for the EBS survey (Figure 4.1).

Strata map for the eastern and northern Bering Sea (upper left), length-weight residuals of yellowfin sole in the eastern Bering Sea (EBS) combined (upper right), EBS by strata (lower right), and northern Bering Sea (lower left)









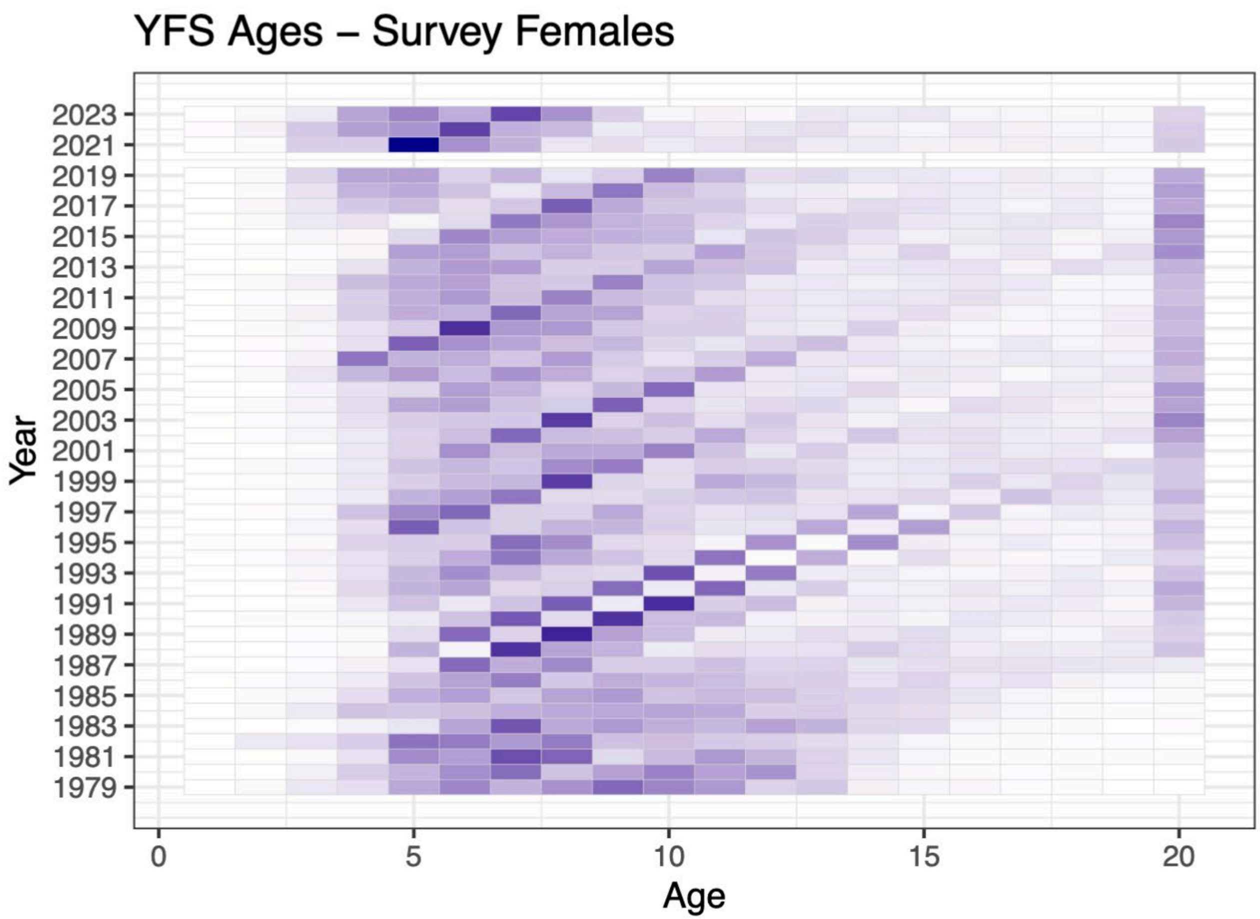
1. YFS length-weight residuals have been declining in the NBS since 2019 but are above average (overall) in the EBS, based on 2024 data.
2. In the EBS, residuals are positive, but negative in strata 20 in the northern part of the southern inner domain, which aligns with negative YFS condition in the northern shelf.
3. Weight at age of YFS taken by EBS survey has increased over time, -->faster growth.
4. Therefore, faster growth and positive length-weight residuals are present in the EBS, but negative length-weight residual appear in the NBS. The NBS survey based on fewer years, so anomalies may not be as reliable as for the EBS survey.

Selected SSC comments (SSC December 2023)

SSC: The SSC recommends the author investigate (or provide discussion of) the sharp decline in the size of the 2017-year class.

Response:
The 2017 year class is still apparent in 2023 survey ages and does not appear to have experienced a sharp decline. The fishery is unlikely to select this year class until approximately 2024 (not yet aged) or 2025.

Age frequency of yellowfin sole females and males from the AFSC/NMFS research surveys, 1977-2023



Selected SSC comments (SSC December 2023)

SSC: The SSC notes time-varying fisheries selectivity is modeled beginning in 1954. Time-varying selectivity should only be modeled for periods with informative data in the assessment.

Response:

The authors acknowledge this as a target for consideration of a future model change. Catch estimates are available starting in 1954 but not weight or age data.

Selected SSC comments (SSC December 2023)

SSC: The SSC supports the transition to the stock synthesis platform for yellowfin sole but notes that the data available for the yellowfin sole stock assessment is perhaps the best in the world, making yellowfin sole a good test bed for advanced modeling techniques.

Response:

Noted. An SS3 model is planned for 2025.

Selected SSC comments (SSC December 2023)

SSC: The VAST model for the Northern + Eastern Bering Sea was included in the yellowfin sole assessment in 2022. Since VAST accounts for an unsurveyed portion of the population, the SSC requests that the temperature-dependent catchability relationship be rechecked to confirm that the relationship is still significant and in the same direction as before.

Response:

We included a model without the environmental covariates on survey catchability (Model 23.0_noEC) for comparison to check whether it still provides a better fit to the data. The model with the environmental covariates on cachability still provided a better fit to the data (AIC=2957.58 and 386 parameters with environmental covariates, AIC=3003.735 and 382 parameters without).

The model incorporates bottom temperature and survey timing into the equation for catchablity.

Survey catchability is proportional to temperature through this equation:

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

EBS survey catchability

Parameters estimated within the model

EBS bottom temperature anomaly

EBS survey start date

Selected SSC comments (SSC December 2023)

Likelihood components and AIC for Model 23.0 and Model 23.0_noEC.

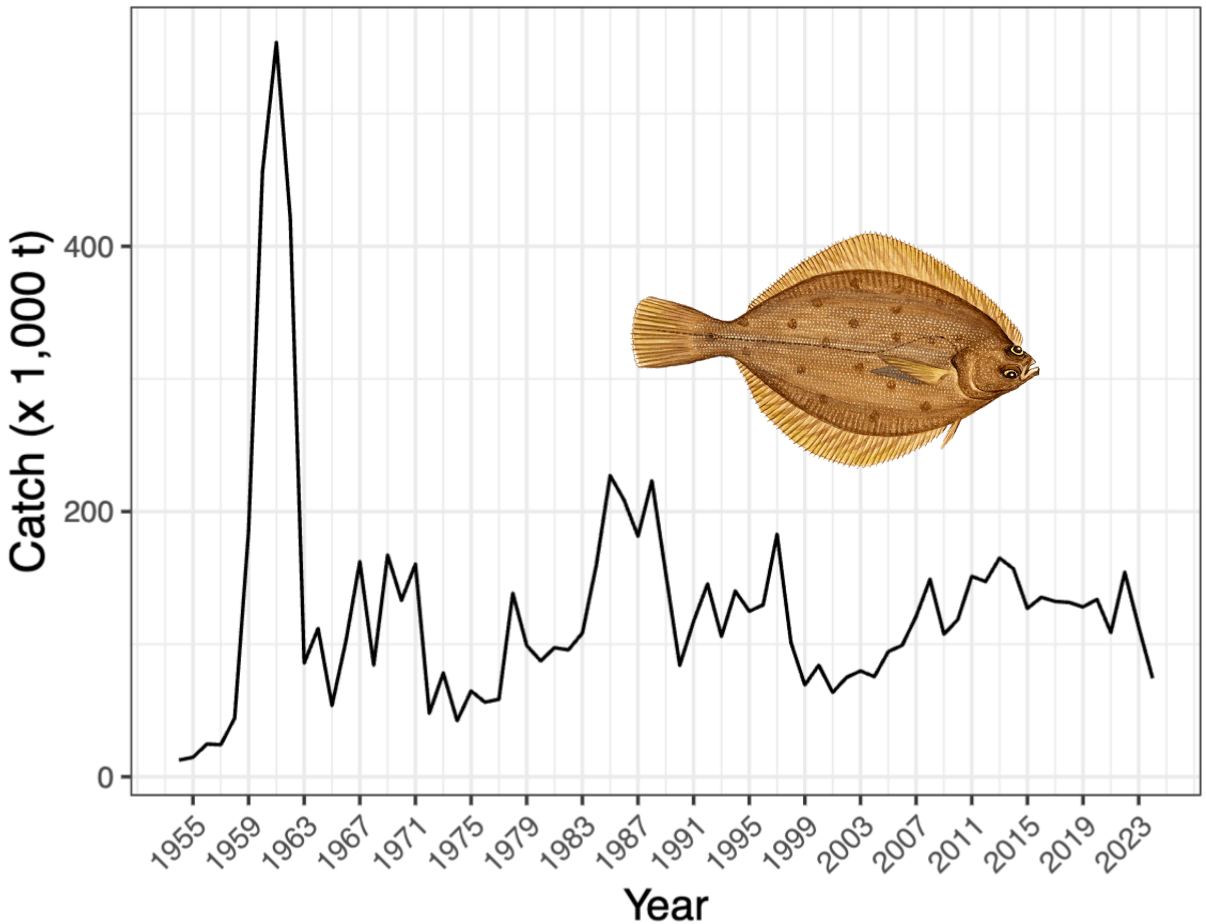
Likelihood component	Model 23.0	Model 23.0_noEC
survey_likelihood	139.586	102.683
catch_likelihood	0.002	0.002
age_likelihood_for_fishery	99.836	103.202
age_likeihood_for_survey	79.278	66.096
recruitment_likelilhood	27.992	26.591
selectivity_likelihood	10.373	10.022
Total likelihood	357.067	308.596
F_penalty	0.13	0.129
survey_q	0.931	1.178
Natural mortality (F/M)	0.12/0.131	0.12/0.128
Number of parameters	386	382
AIC	2957.58	3003.735

AIC estimated by transforming the hession back into the original parameter space to calculate the marginal likelihood.
The AIC for Model 23.0 is a 46 point improvement over the model without the linked q. ΔAIC>10 indicates support for Model 23.0.

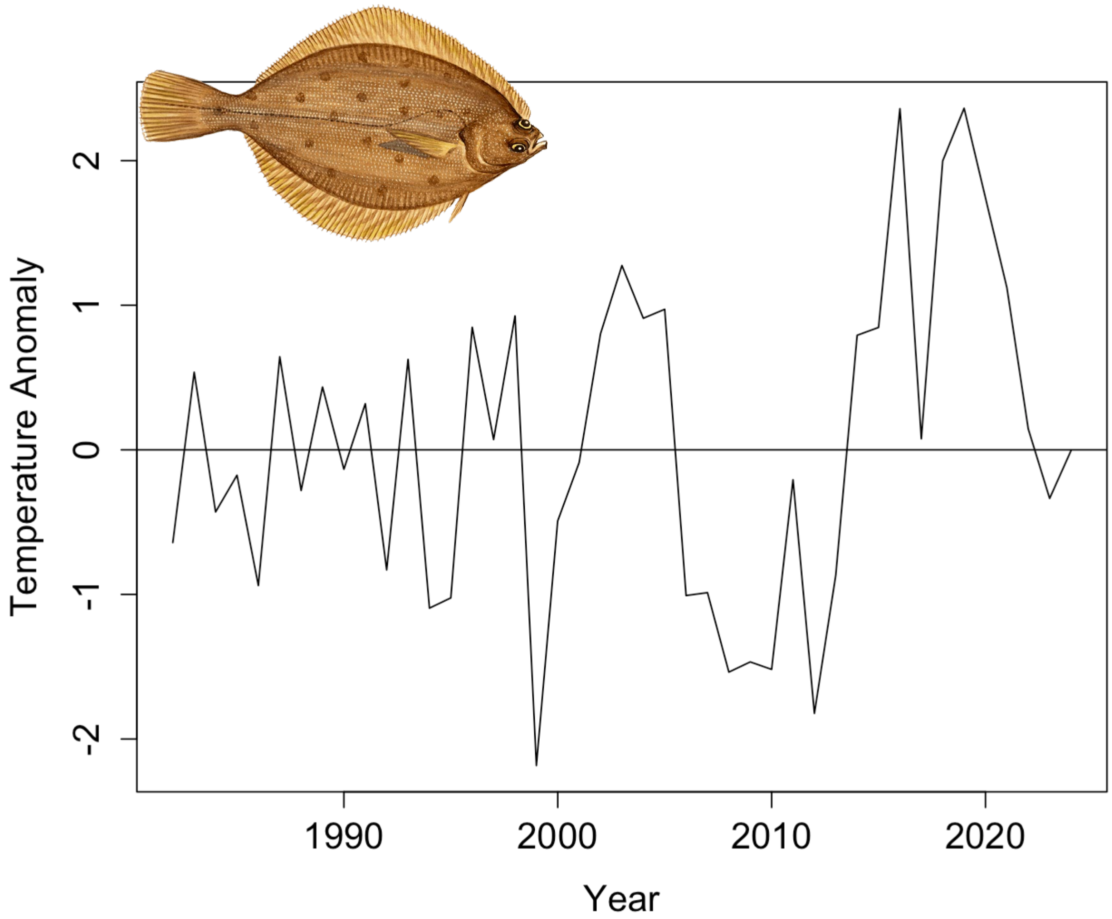
Survey_q represents the mean over years.

Fishery and catch

Yellowfin sole annual total catch (1,000s t) in the eastern Bering Sea from 2003-2024



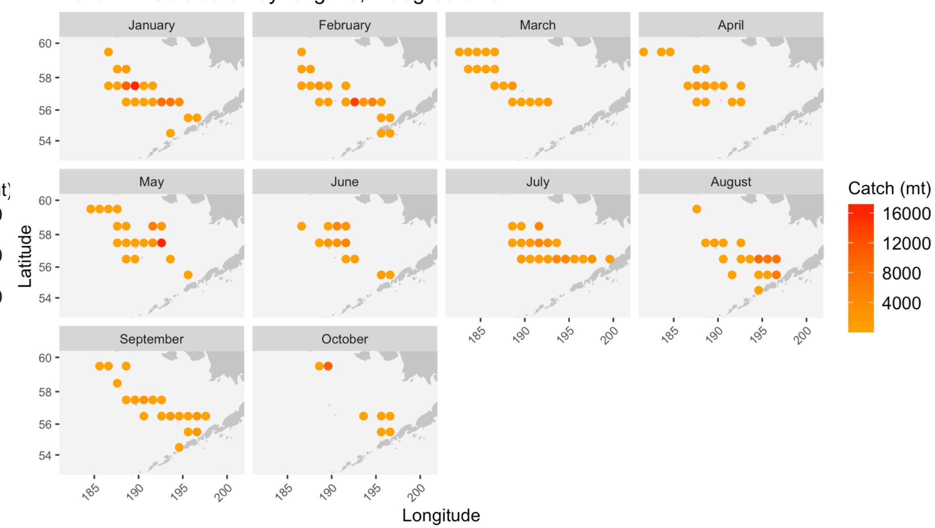
Bottom temperature anomalies from the NMFS survey <100 m, 1982-2024

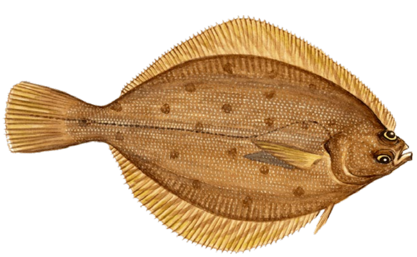


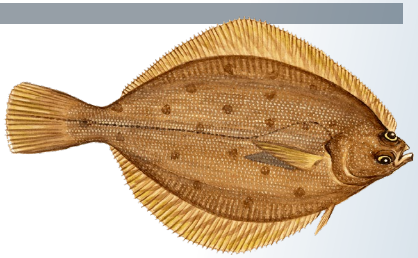
Catch and CPUE in 2024

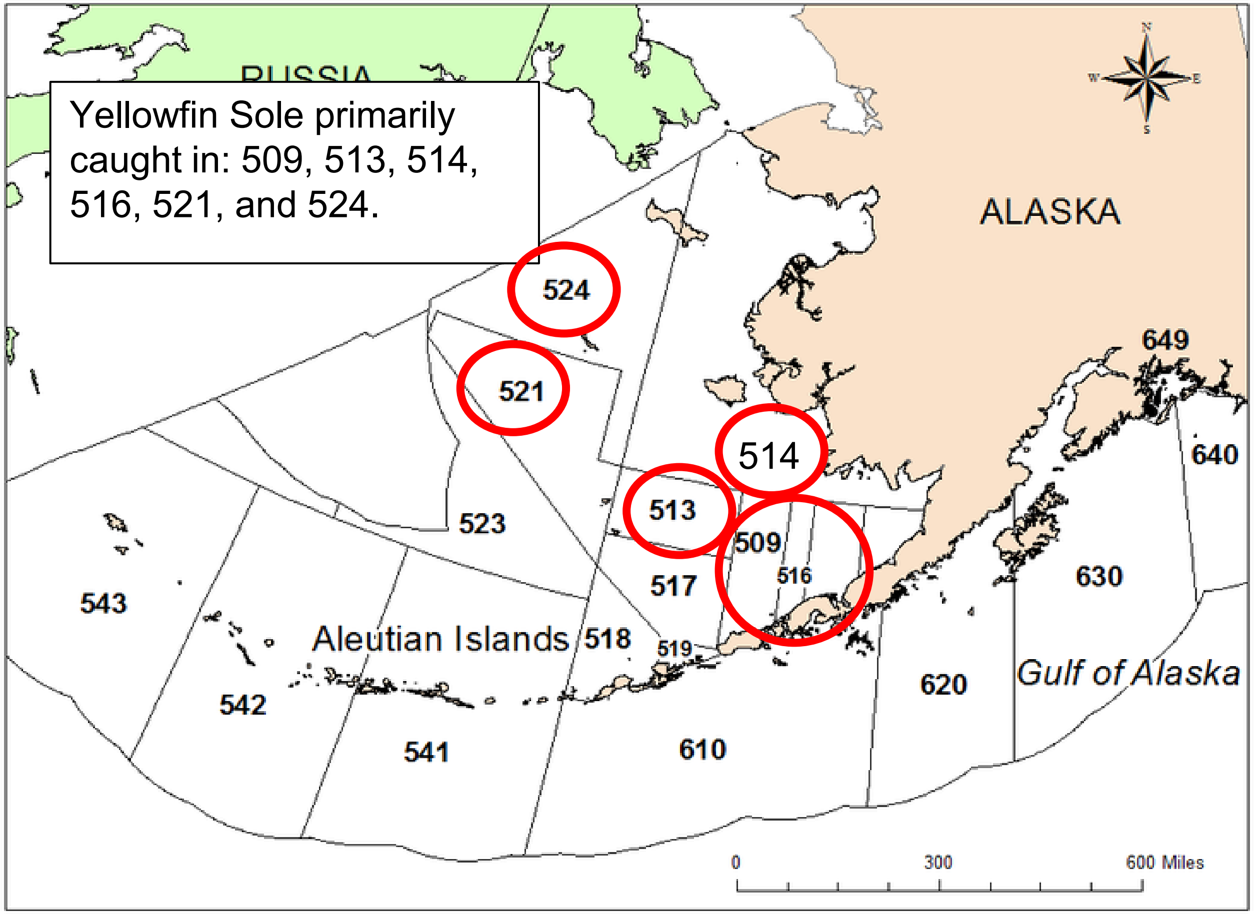
Yellowfin Sole catch by trawl, 1 degree bins

Yellowfin Sole catch by longline, 1 degree bins

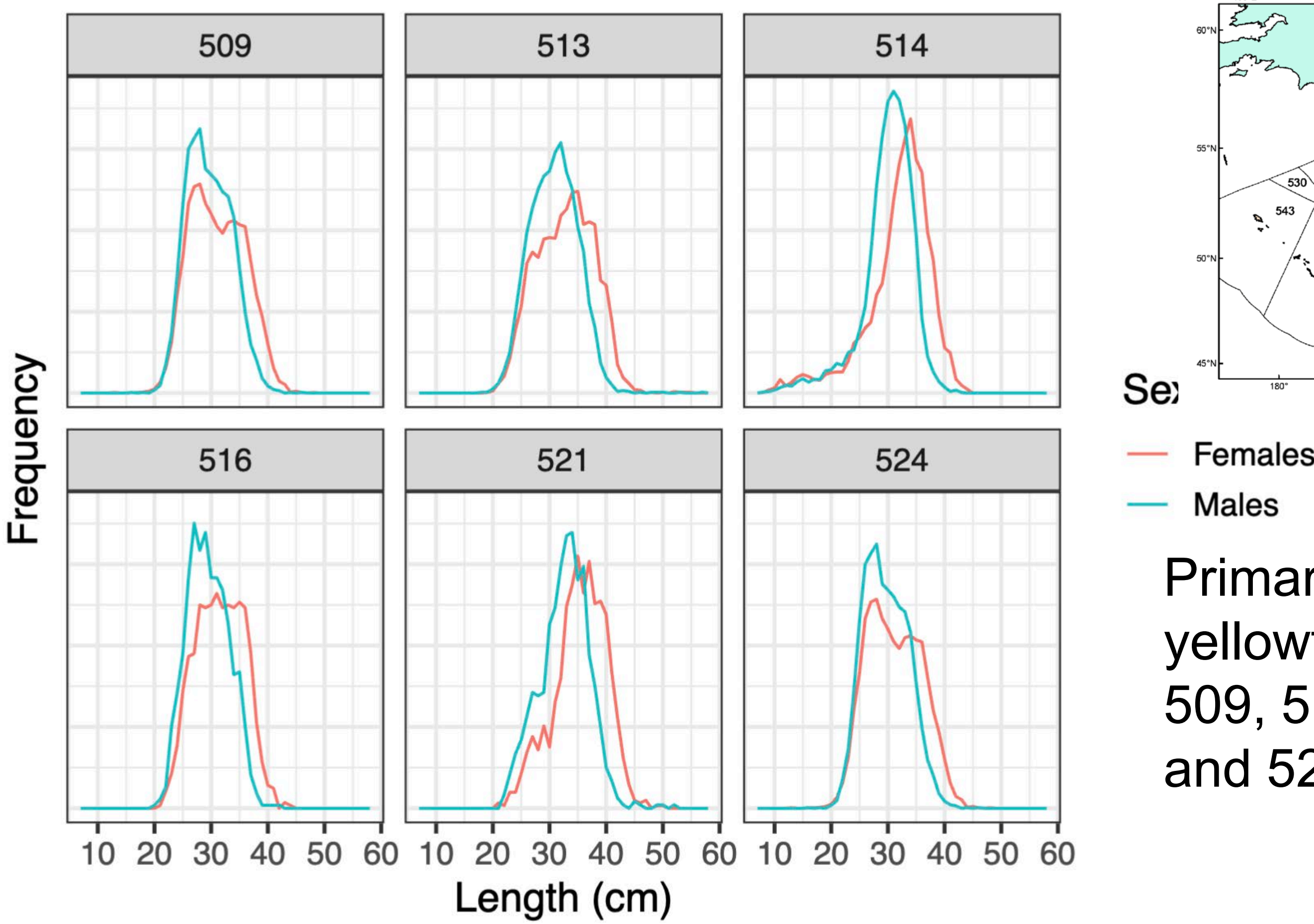


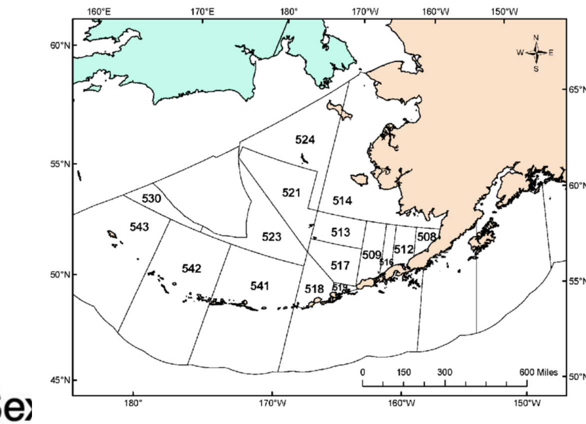





Yellowfin Sole primarily caught in: 509, 513, 514, 516, 521, and 524.
RUSSIA
ALASKA
524
521
514
513
509
516
517
523
543
542
541
518
519
Aleutian Islands
610
620
630
640
649
Gulf of Alaska
N
S
E
W
0
300
600 Miles

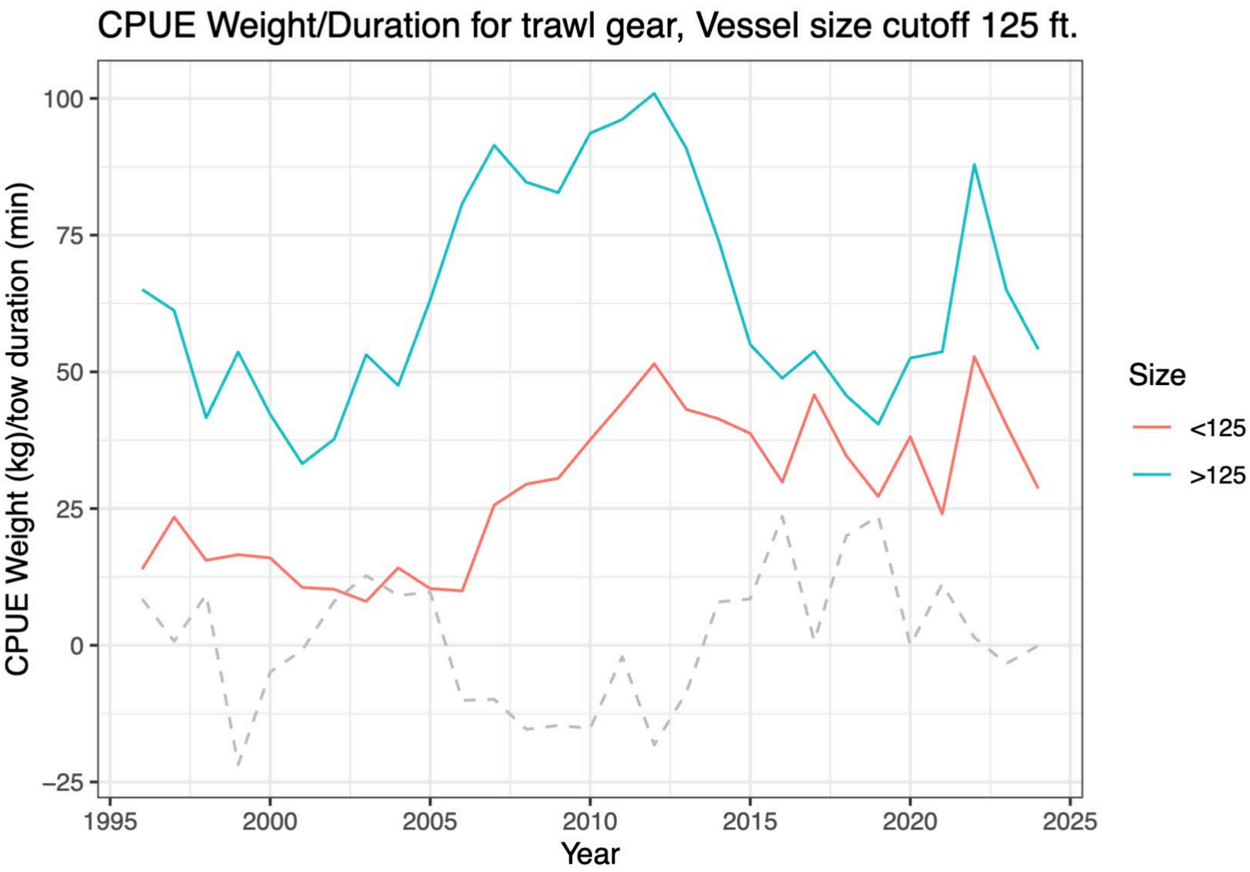
Size composition of the yellowfin sole catch in 2024 caught by trawl gear, by subarea





Primary areas where yellowfin sole are caught: 509, 513, 514, 516, 521, and 524.

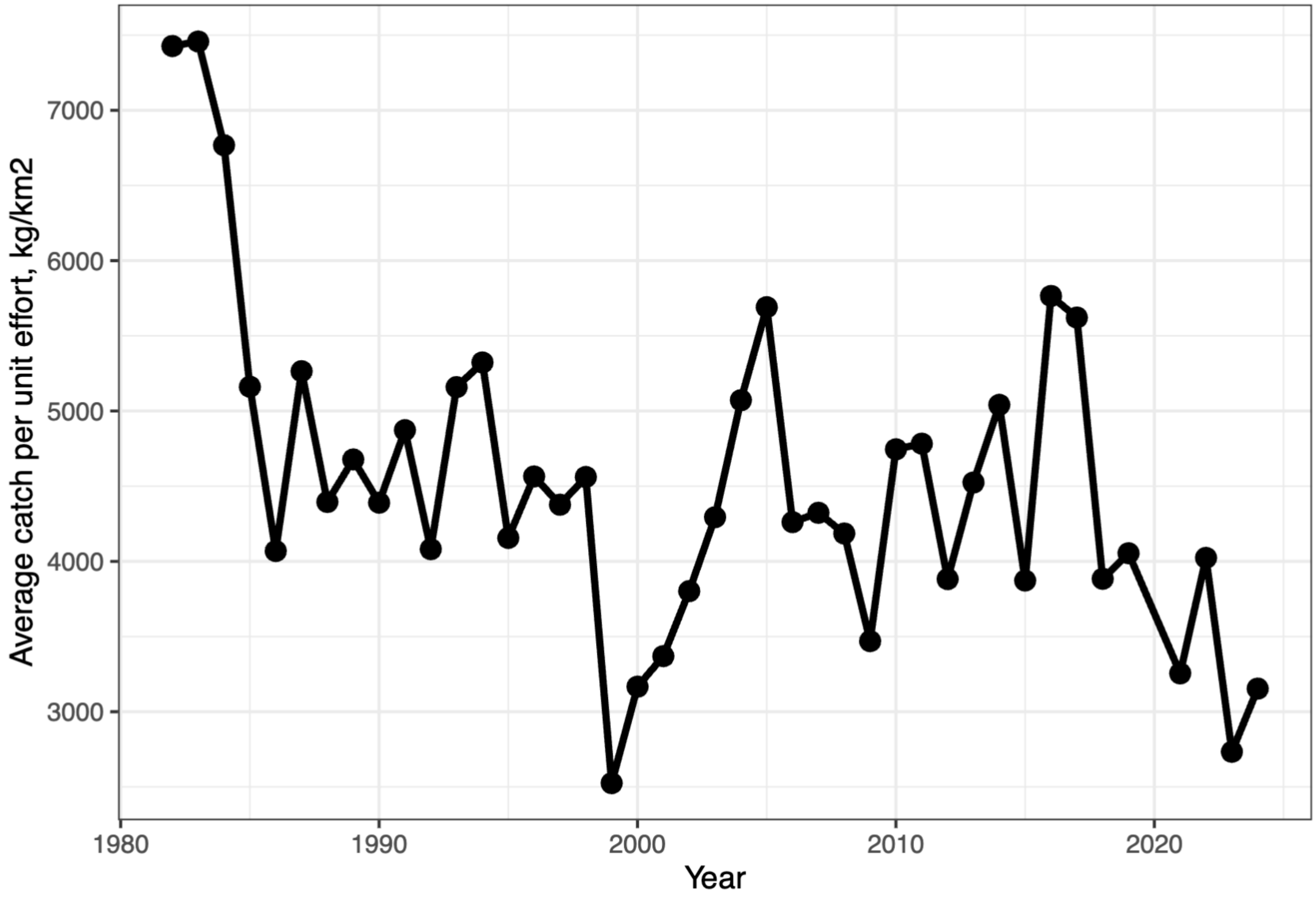
Catch per unit effort based on yellowfin sole fishery data, 1996-2024



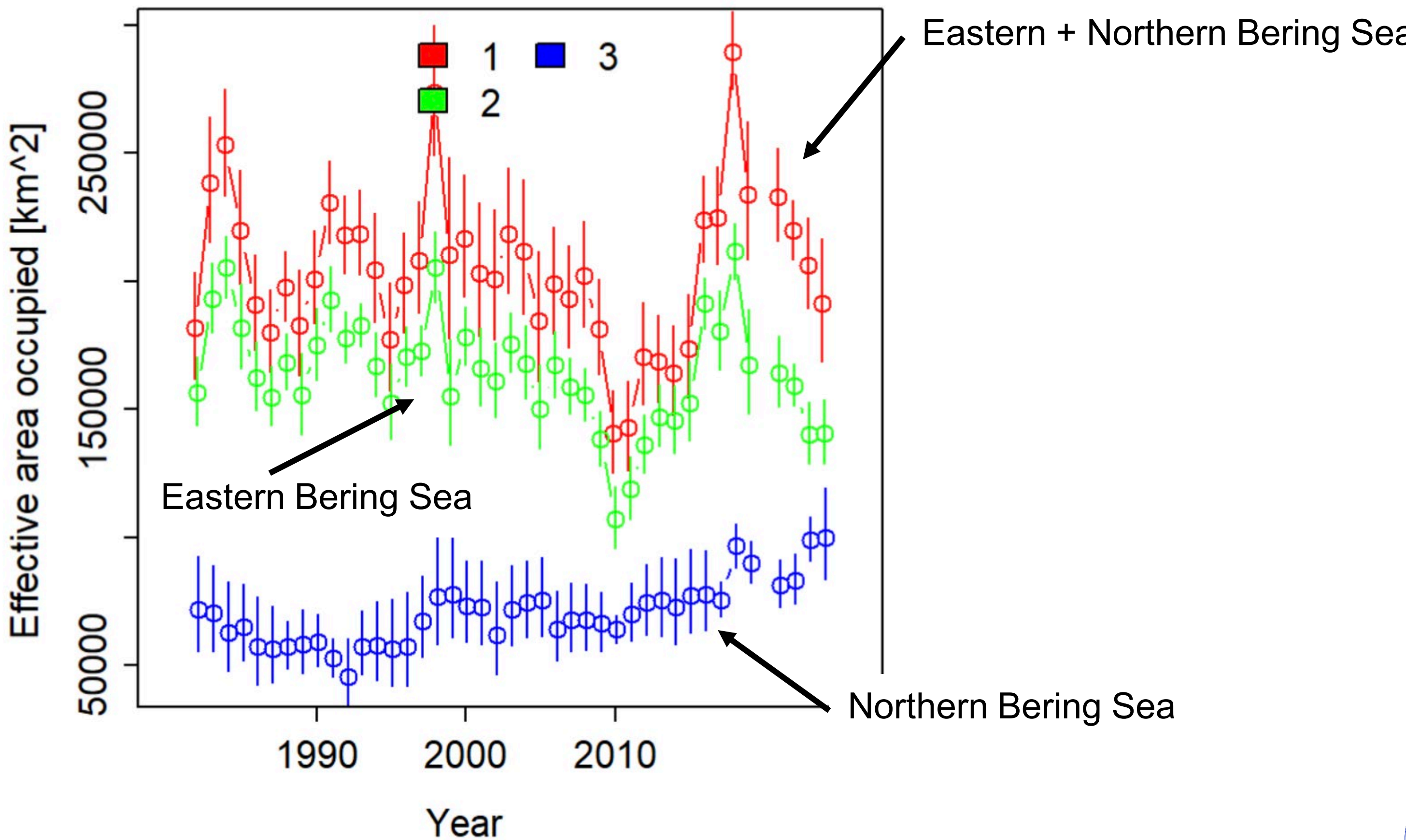
The EBS bottom temperature anomalies from 1996-2024 (x10 for visualization) are shown as a dotted line.

Survey

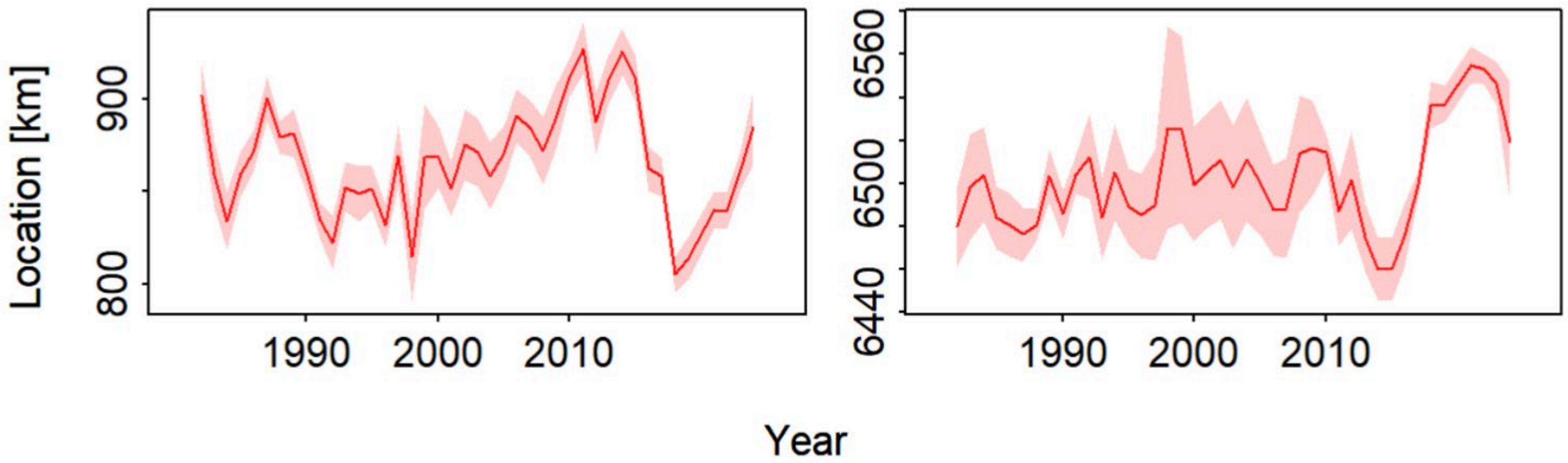
Average catch per unit effort on NMFS eastern Bering Sea surveys, 1987-2022, in kg/hectare



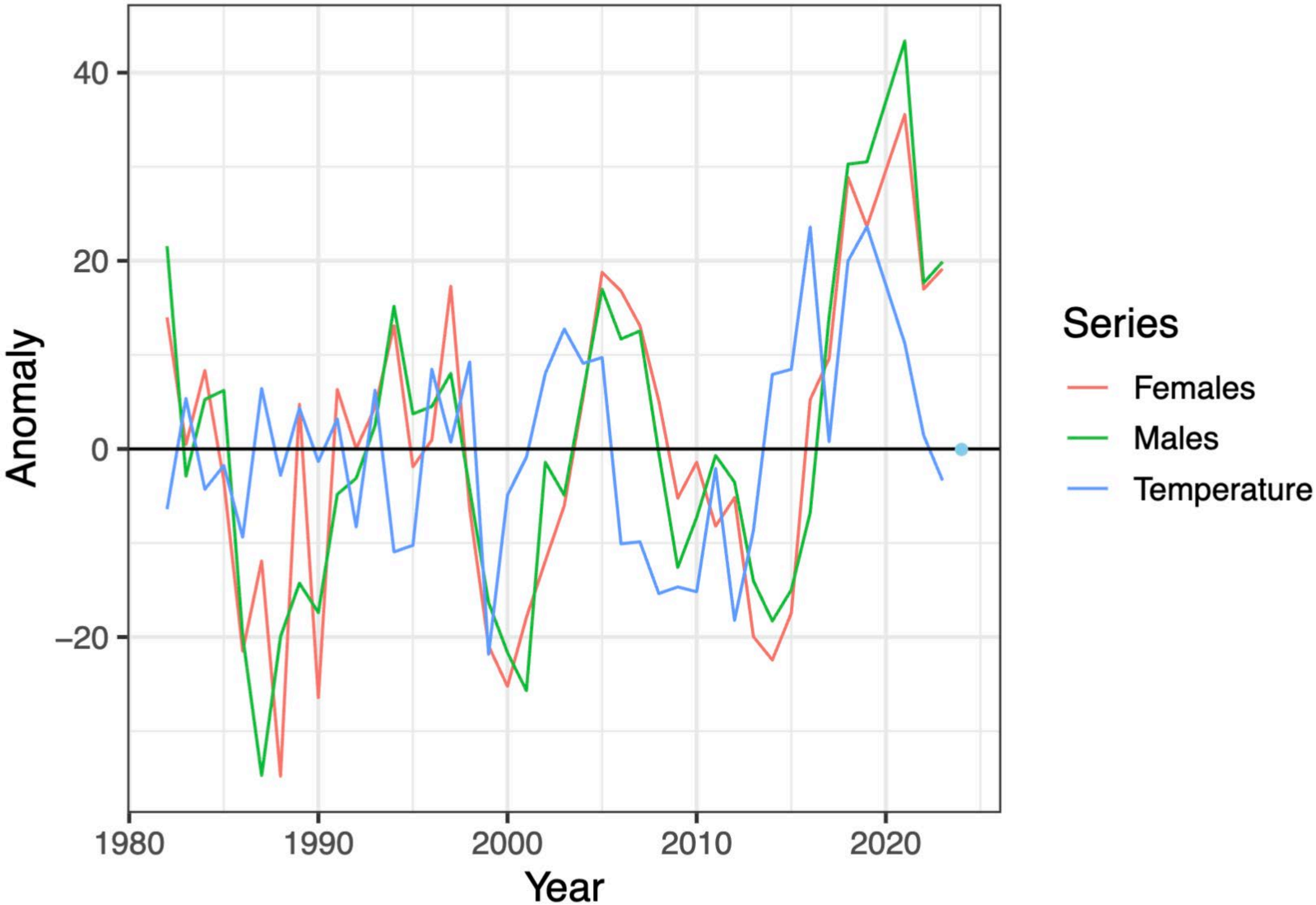
The effective area occupied by yellowfin sole (VAST) has declined in the EBS, increased in the NBS



Center of gravity plot with eastings (Longitude) in the left panel and northings (Latitude) in the right panel for VAST index estimate (EBS+NBS)

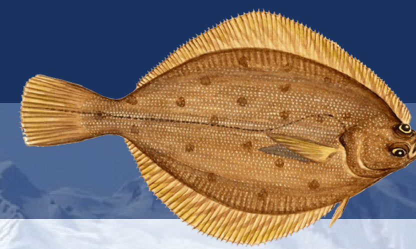


Yellowfin sole length-at-age anomalies, for 5-year old males and females, and bottom temperature anomalies from the eastern Bering Sea survey area <100 m.



Models

2024 Model – BSAI yellowfin sole



- Model 23.0
  - Accepted by the BSAI Plan Team and the SSC in 2023.

Models for comparative purposes:
Model 23.0_2024_noEC
Model 23.0_2024a
Model 23.0_2024b

Data

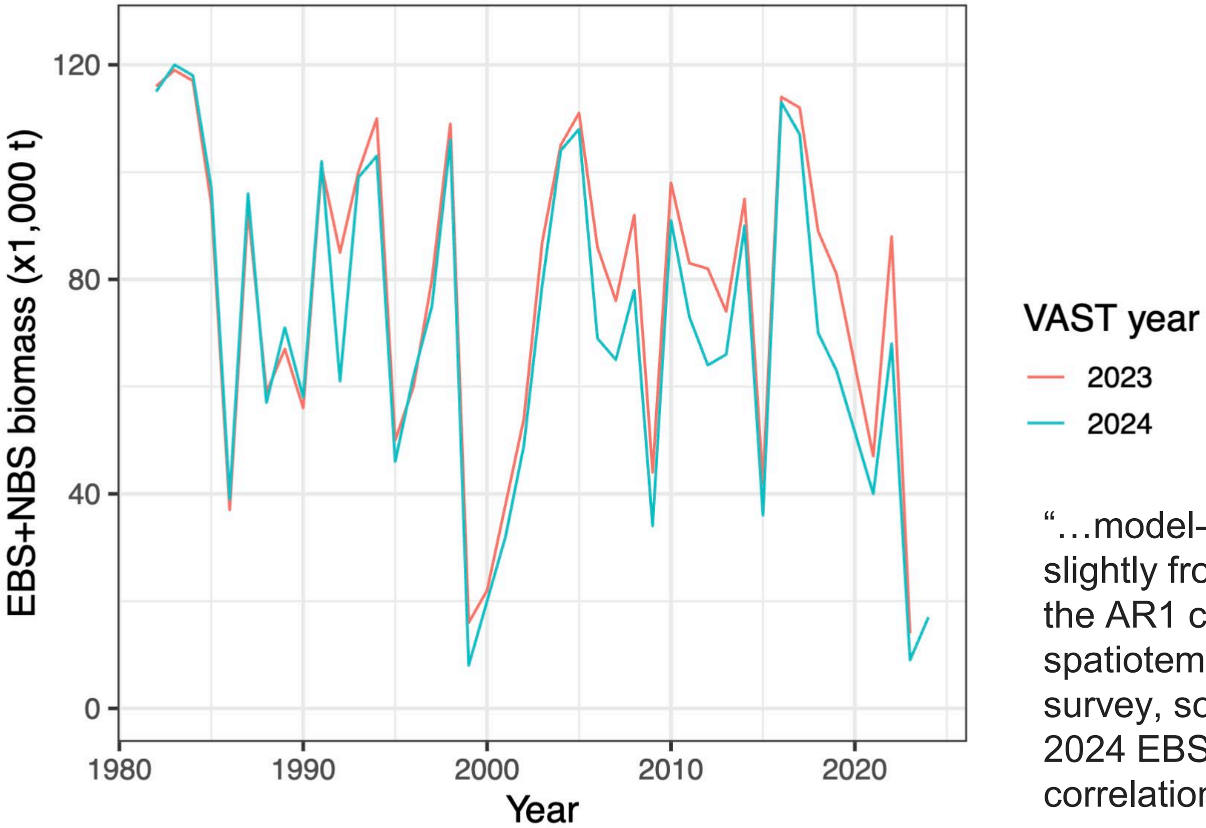
Data used in Model 23.0

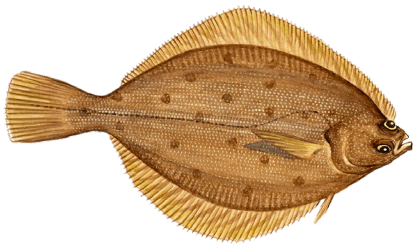
Data source	Year
Fishery catch	1954 - 2024
Fishery age composition	1975 - 2022
Fishery weight-at-age	Catch-at-age methodology
Survey biomass and standard error	1982 - 2024 (not 2020)
Bottom temperature	1982 - 2024
Survey age composition	1979 - 2023 (not 2020)
Annual length-at-age and weight-at-age from surveys	1979 - 2023 (not 2020)
Age at maturity	Combined 1992 and 2012 samples

Survey age composition, survey biomass, and standard error estimated using VAST for EBS+NBS combined.

Sensitivity testing

VAST biomass estimates for the EBS+NBS, generated in 2023 and 2024



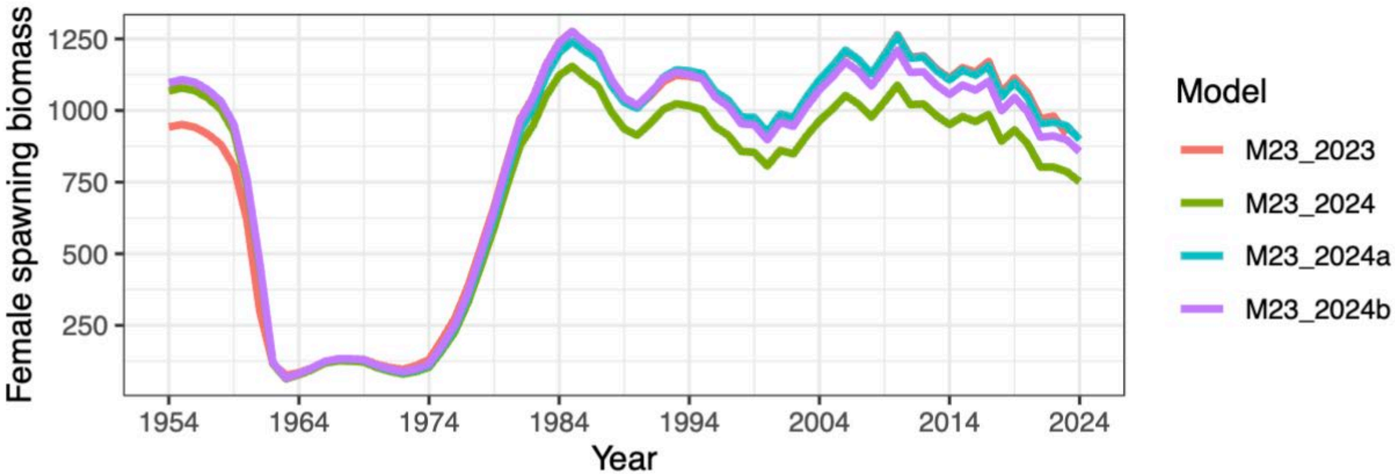


"…model-based estimates will change slightly from year to year because of the AR1 correlation between spatiotemporal fields. In 2024, no NBS survey, so NBS estimates based on 2024 EBS data + past spatial, temporal correlation between regions."

Models for comparative purposes to demonstrate the addition of data sources

- Model 23.0 2024a includes fishery catch through 2024 but not 2024 survey age compositions or 2024 survey index.
- Model 23.0 2024b added the 2024 survey index to Model 23.0a but not the updated survey age composition.

	Model 23.0_2024a	Model 23.0_2024b	Model 23.0
Fishery catch	Through 2024	Through 2024	Through 2024
VAST survey index	2023 VAST	2024 VAST	2024 VAST
VAST survey age composition	2023 survey age composition	2023 survey age composition	2024 survey age composition

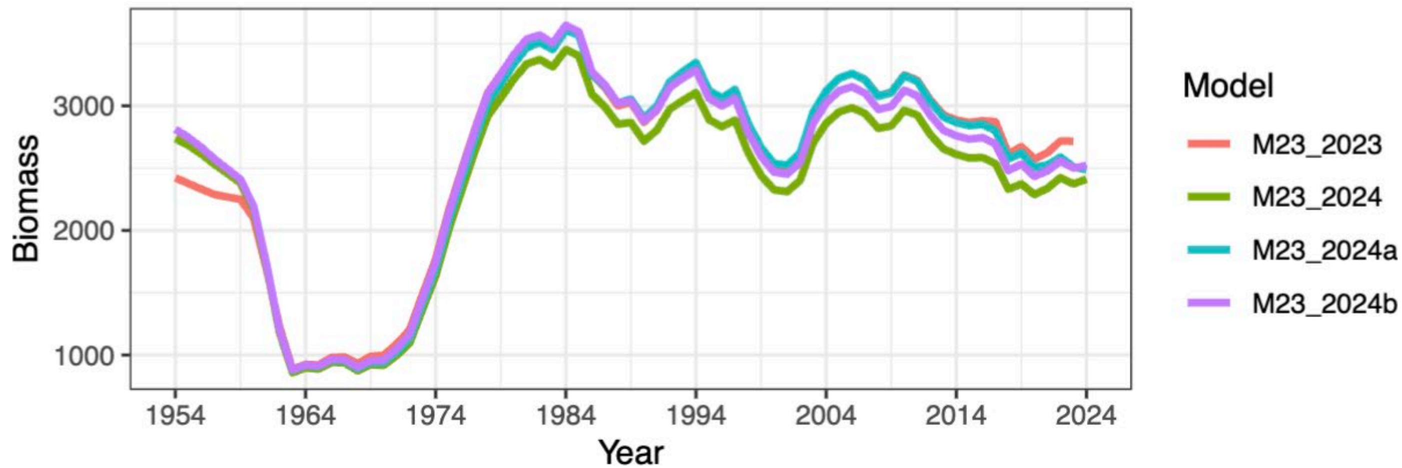


- Model 23.0_2024a: The addition of the 2024 fishery catch (and final 2023 catch) in reduced biomass and spawning biomass in the final 5 years.

- The addition of the survey biomass and standard deviation in Model 23.0 2024b shifted spawning biomass and biomass downward over the final 20 years.

- The addition of the VAST survey age composition in Model 23.0 2024 shifted biomass further downward over the final 50 years of the model.

	Model 23.0_2024a	Model 23.0_2024b	Model 23.0
Fishery catch	Through 2024	Through 2024	Through 2024
VAST survey index	2023 VAST	2024 VAST	2024 VAST
VAST survey age composition	2023 survey age composition	2023 survey age composition	2024 survey age composition



- Model 23.0_2024a: The addition of the 2024 fishery catch (and final 2023 catch) in reduced biomass and spawning biomass in the final 5 years.
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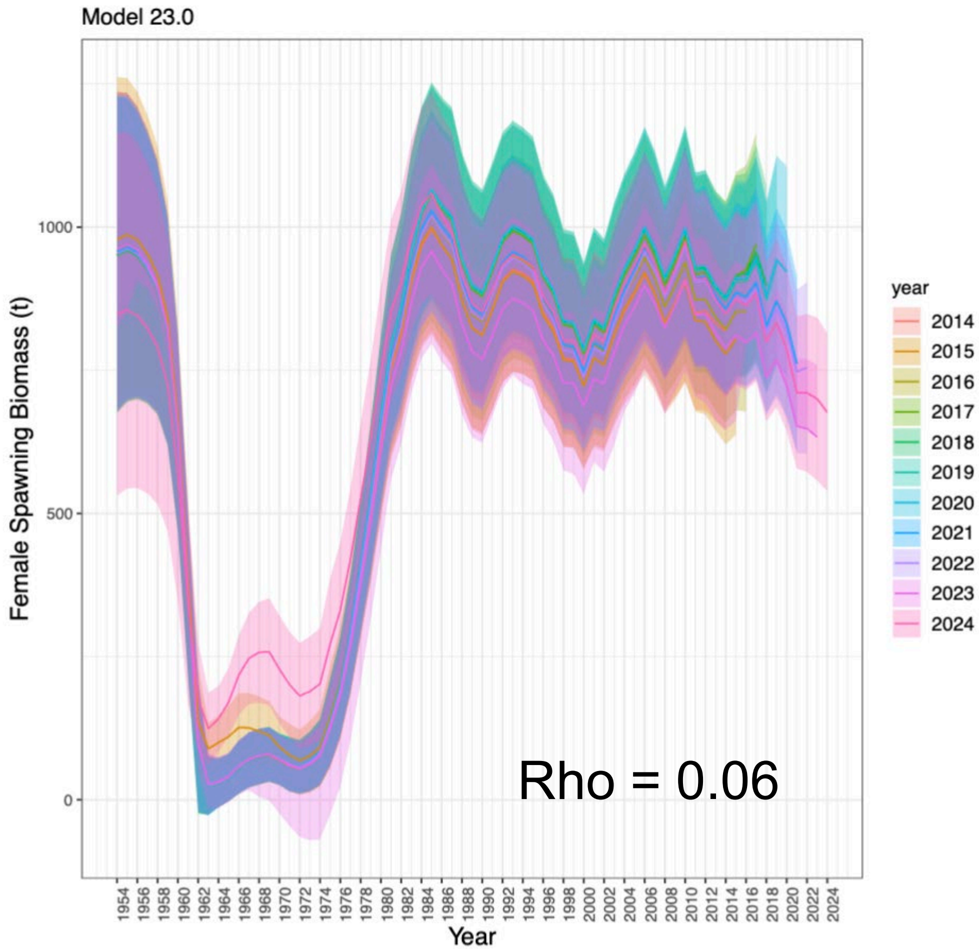
- The addition of the VAST survey age composition in Model 23.0 2024 shifted biomass further downward over the final 50 years of the model.

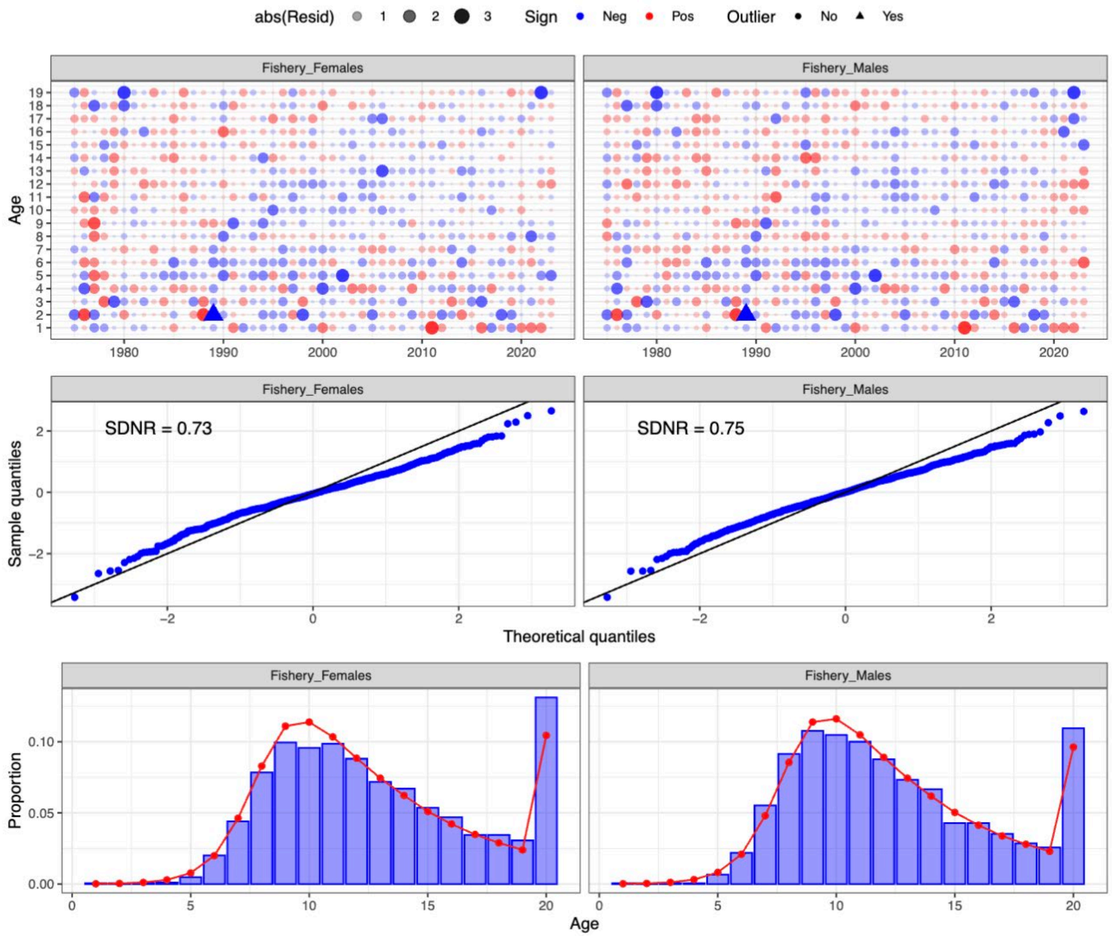
	Model 23.0_2024a	Model 23.0_2024b	Model 23.0
Fishery catch	Through 2024	Through 2024	Through 2024
VAST survey index	2023 VAST	2024 VAST	2024 VAST
VAST survey age composition	2023 survey age composition	2023 survey age composition	2024 survey age composition

Model Diagnostics

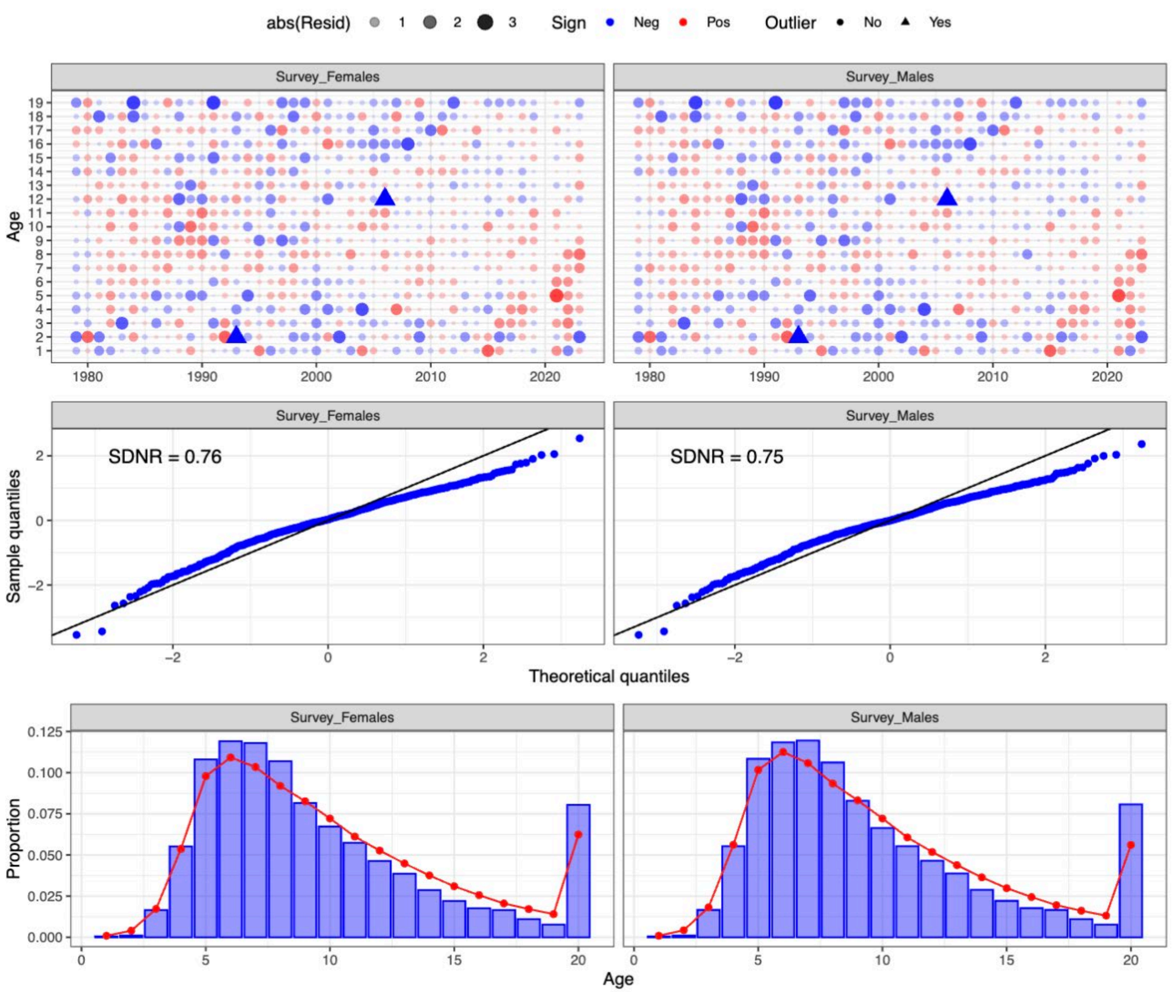
Retrospective plot of female spawning biomass for yellowfin sole, Model 23.0



One-step-ahead residuals for the yellowfin sole fishery ages

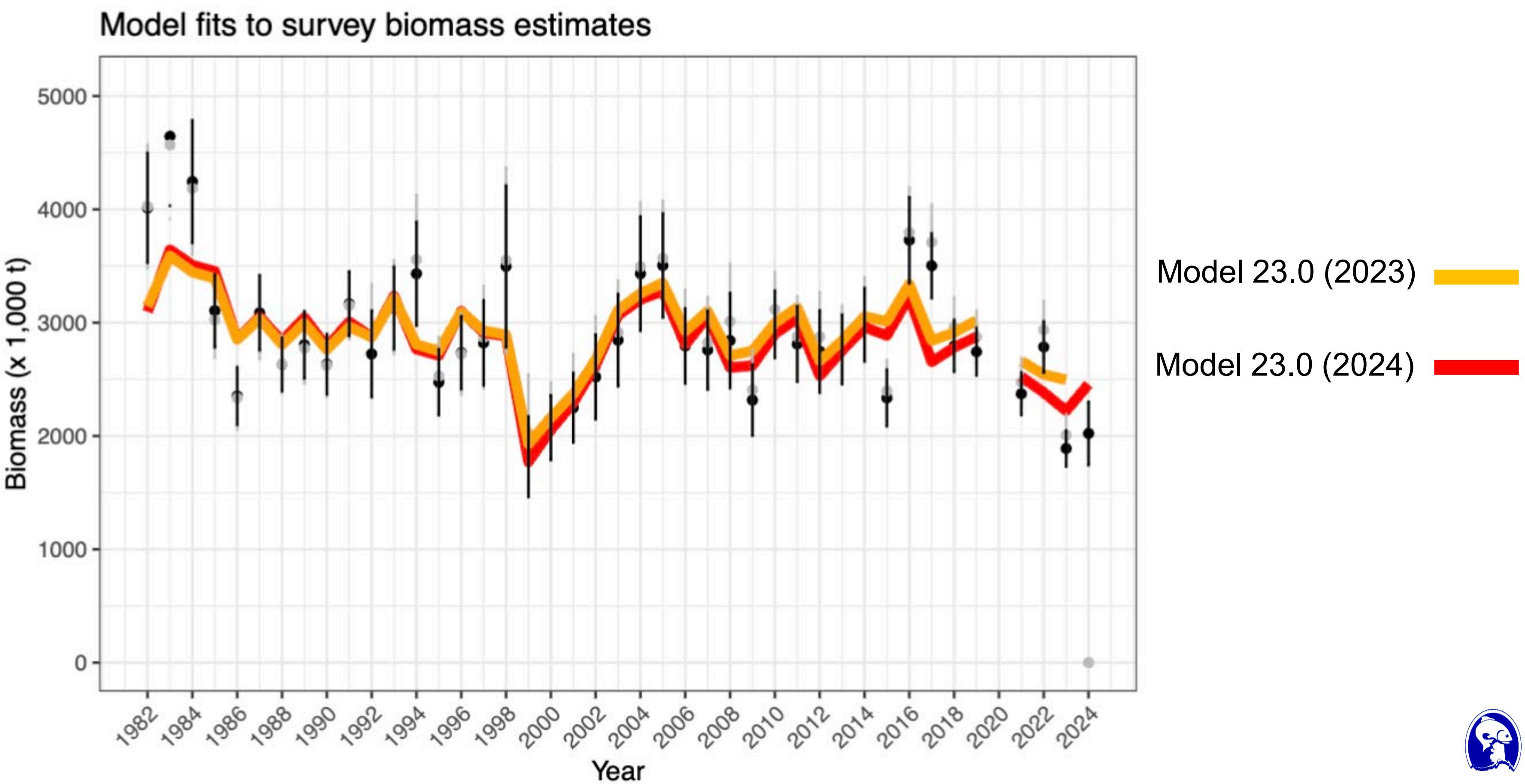


One-step-ahead residuals for the yellowfin sole survey ages

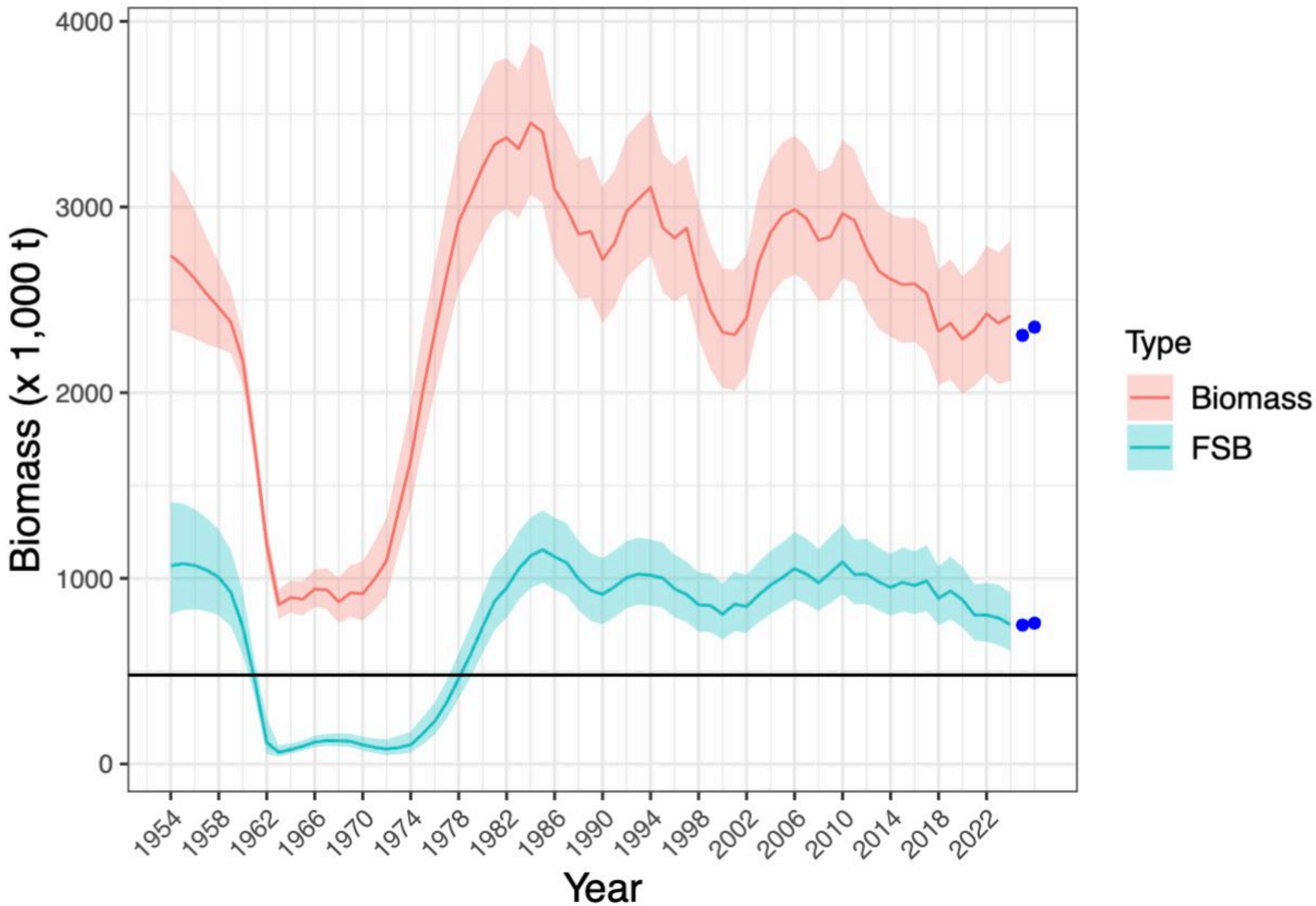


Results

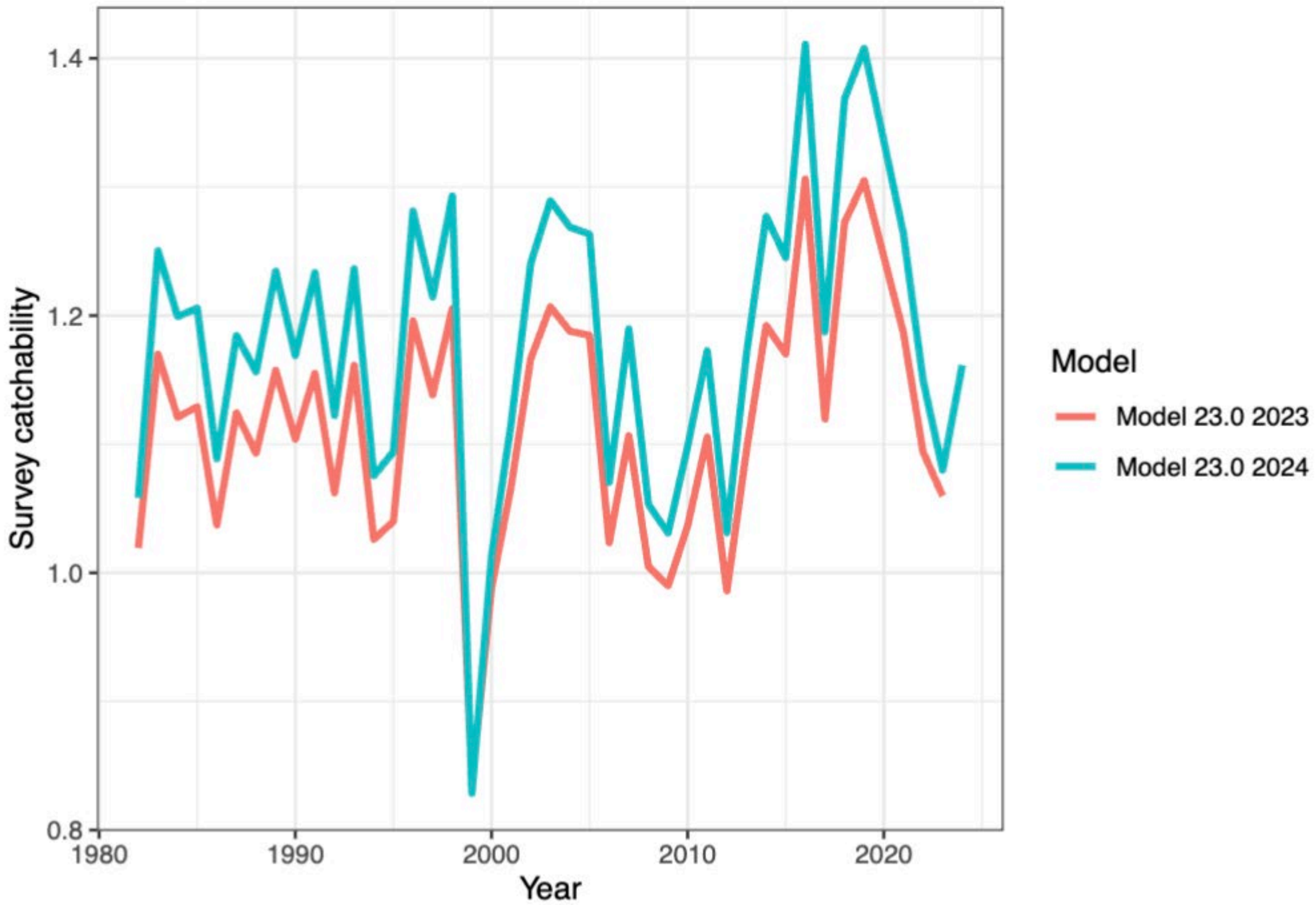
Annual EBS bottom trawl survey biomass and 95% CI for yellowfin sole, 1982-2024, Model 23.0 (2023, orange line), and Model 23.0 (2024, red)



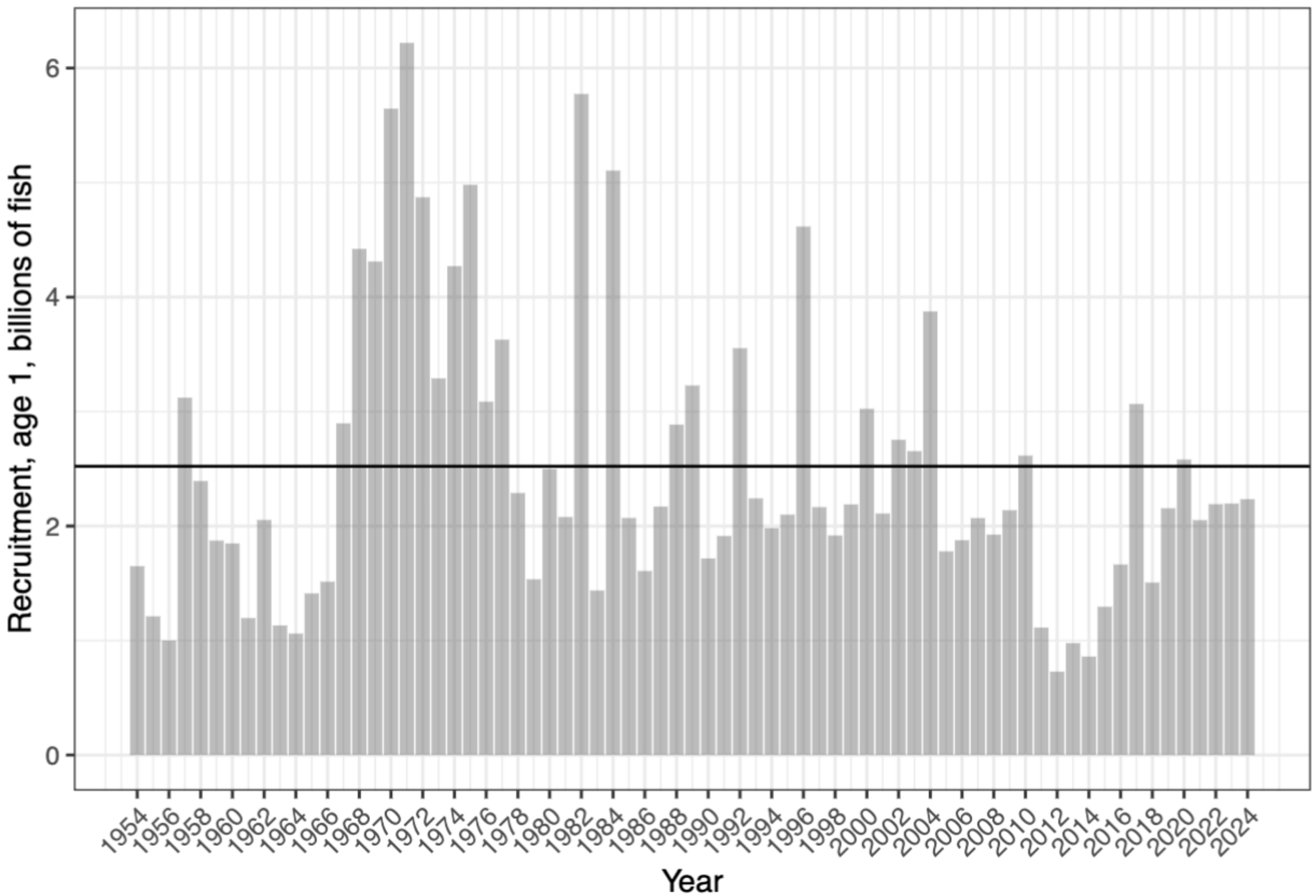
Model estimates of yellowfin sole total (age 2+) and female spawning biomass with 95% confidence intervals, 1954-2024, Model 23.0. Dots indicate projections for 2025 and 2026.



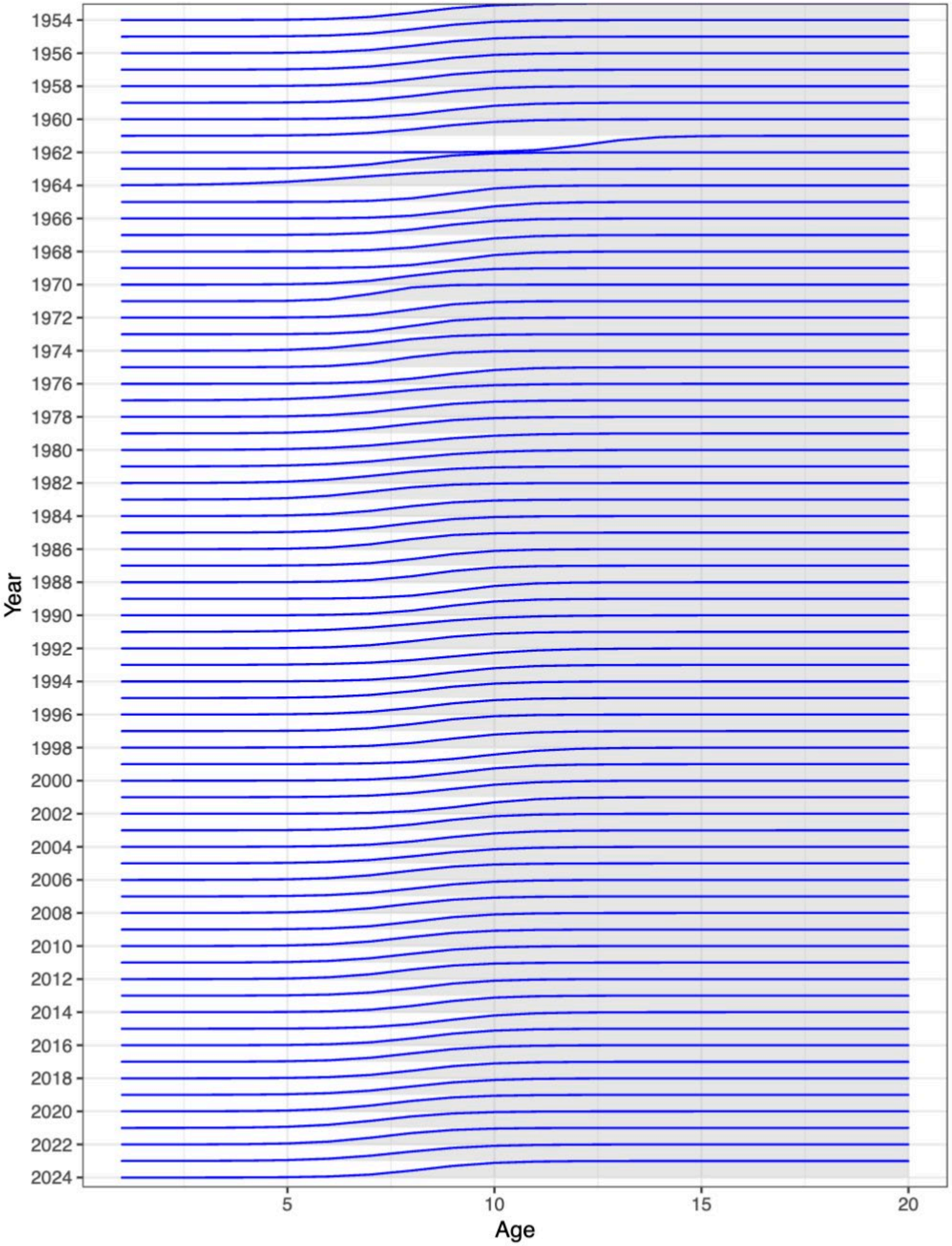
Survey catchability for yellowfin sole Model 23.0 (2023 and 2024)



Year-class strength of age 1 yellowfin sole estimated by the stock assessment model. The horizontal line represents the average of the estimates from recruitment, 1954-2019, 2.5 billion, Model 23.0

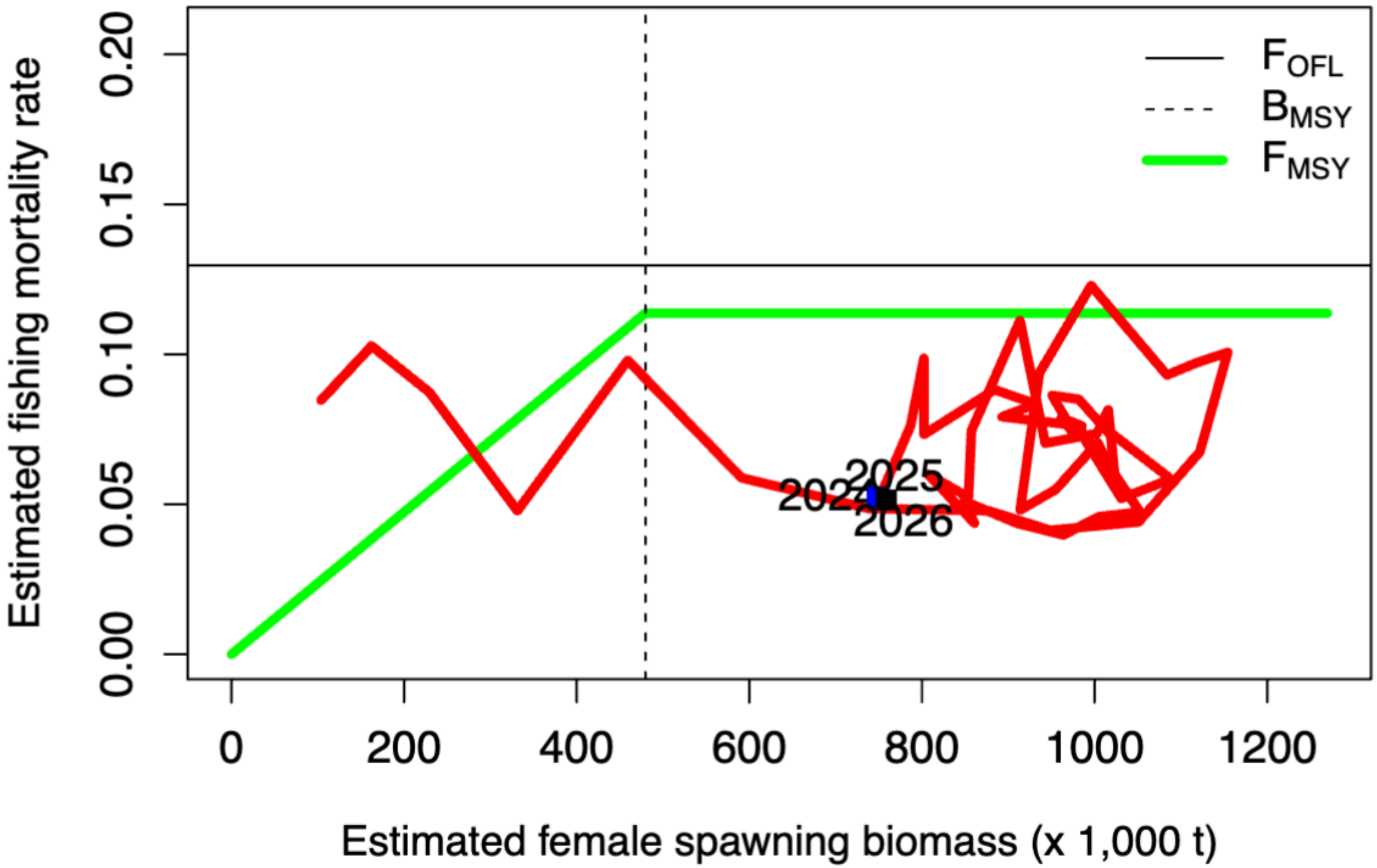


(50% survey selectivity at ~4 years)



Estimate of yellowfin sole fishery selectivity for males and females, 1954-2024, Model 23.0

Yellowfin sole fishing mortality rate and female spawning biomass from 1975 to 2024 compared to the $F_{35\%}$ and $F_{40\%}$ control rules, based on Model 23.0. Vertical line is $B_{35\%}$. Squares indicate estimates for 2024, 2025, and 2026.



Model 23.0 Summary Table

Quantity	As estimated or *specified* *last* year for: 2024	2025	As estimated or *recommended* *this* year for: 2025	2026
M (natural mortality rate)	0.12, 0.125	0.12, 0.125	0.12, 0.128	0.12, 0.128
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,512,810 t	2,616,800 t	2,308,550 t	2,353,240 t
Projected female spawning biomass (t)	881,640 t	857,354 t	748,076 t	758,695 t
B_0	1,516,980 t	1,516,980 t	1,383,020 t	1,383,020 t
B_{MSY}	539,657 t	539,657 t	479,711 t	479,711 t
F_{OFL}	0.121	0.121	0.13	0.13
$maxF_{ABC}$	0.106	0.106	0.114	0.114
F_{ABC}	0.106	0.106	0.114	0.114
OFL (t)	305,298 t	317,932 t	299,247 t	305,039 t
$maxABC$	265,913 t	276,917 t	262,557 t	267,639 t
ABC (t)	265,913 t	276,917 t	262,557 t	267,639 t
Status	2022	2023	2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Risk Table

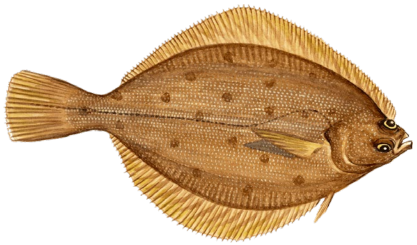
Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal

Model 23.0 Summary Table

	As estimated or *specified* *last* year for:		As estimated or *recommended* *this* year for:	
Quantity	2024	2025	2025	2026
M (natural mortality rate)	0.12, 0.125	0.12, 0.125	0.12, 0.128	0.12, 0.128
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,512,810 t	2,616,800 t	2,308,550 t	2,353,240 t
Projected female spawning biomass (t)	881,640 t	857,354 t	748,076 t	758,695 t
B_0	1,516,980 t	1,516,980 t	1,383,020 t	1,383,020 t
B_{MSY}	539,657 t	539,657 t	479,711 t	479,711 t
F_{OFL}	0.121	0.121	0.13	0.13
$maxF_{ABC}$	0.106	0.106	0.114	0.114
F_{ABC}	0.106	0.106	0.114	0.114
OFL (t)	305,298 t	317,932 t	299,247 t	305,039 t
$maxABC$	265,913 t	276,917 t	262,557 t	267,639 t
ABC (t)	265,913 t	276,917 t	262,557 t	267,639 t
Status	2022	2023	2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

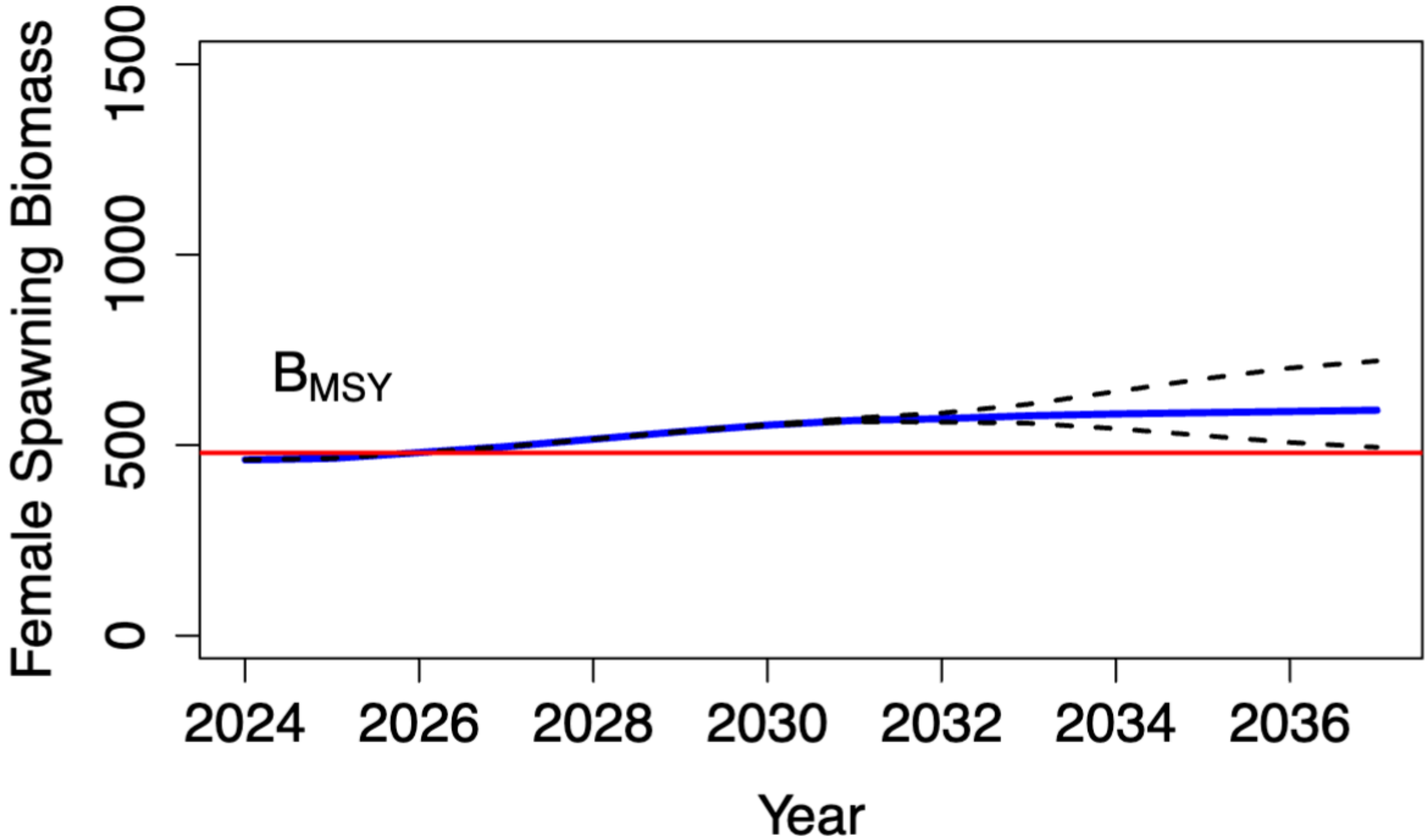
Acknowledgments

We thank the age and growth lab for all their work, RACE GAP and volunteers on the EBS trawl survey, and the FMA program and observers for providing fishery dependent data.

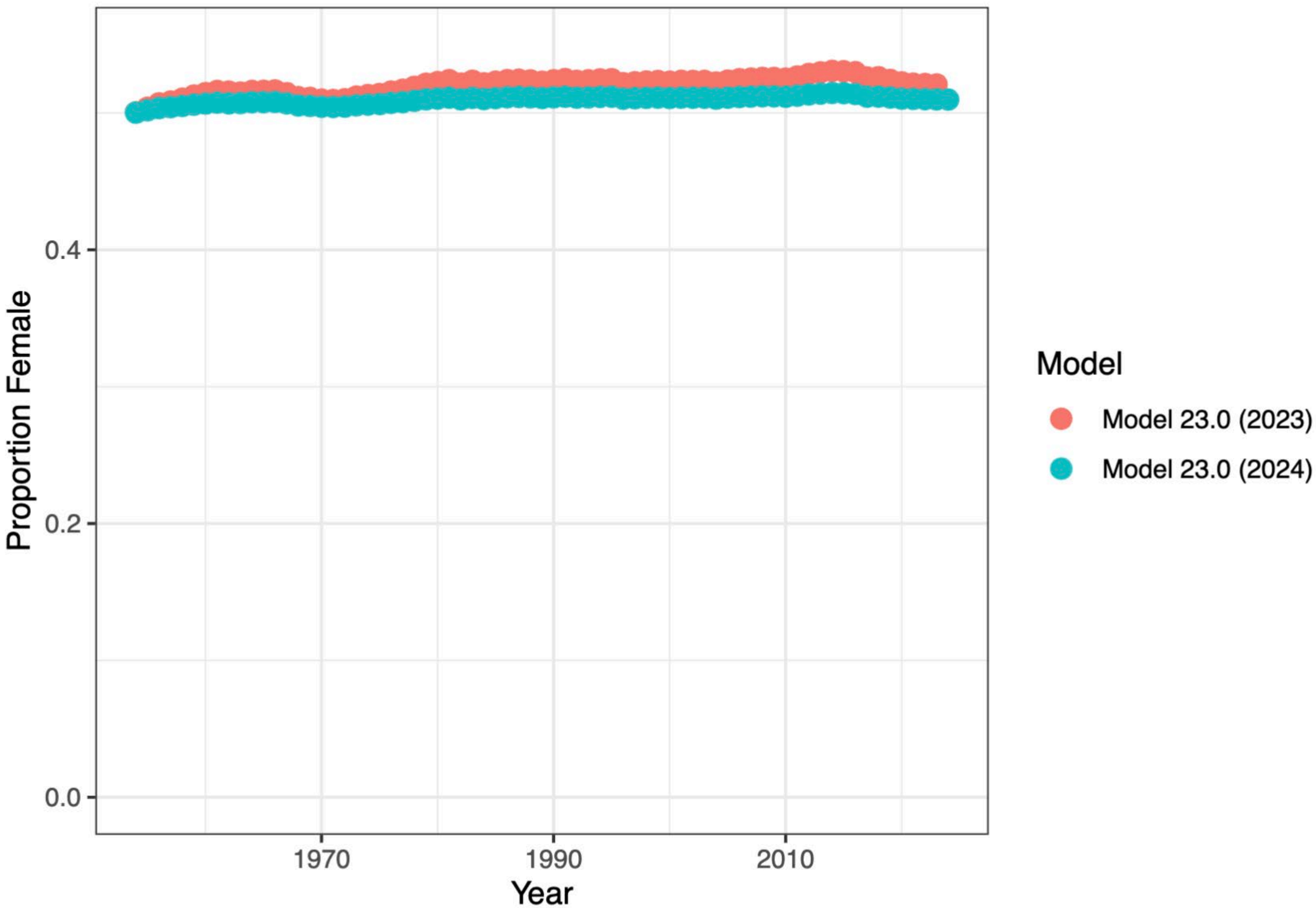


Extra Slides

Projected yellowfin sole female spawning biomass for 2024 to 2037 (blue line), fishing at the 5-year (2019-2023) average fishing mortality rate, F=0.0846, Model 23.0.



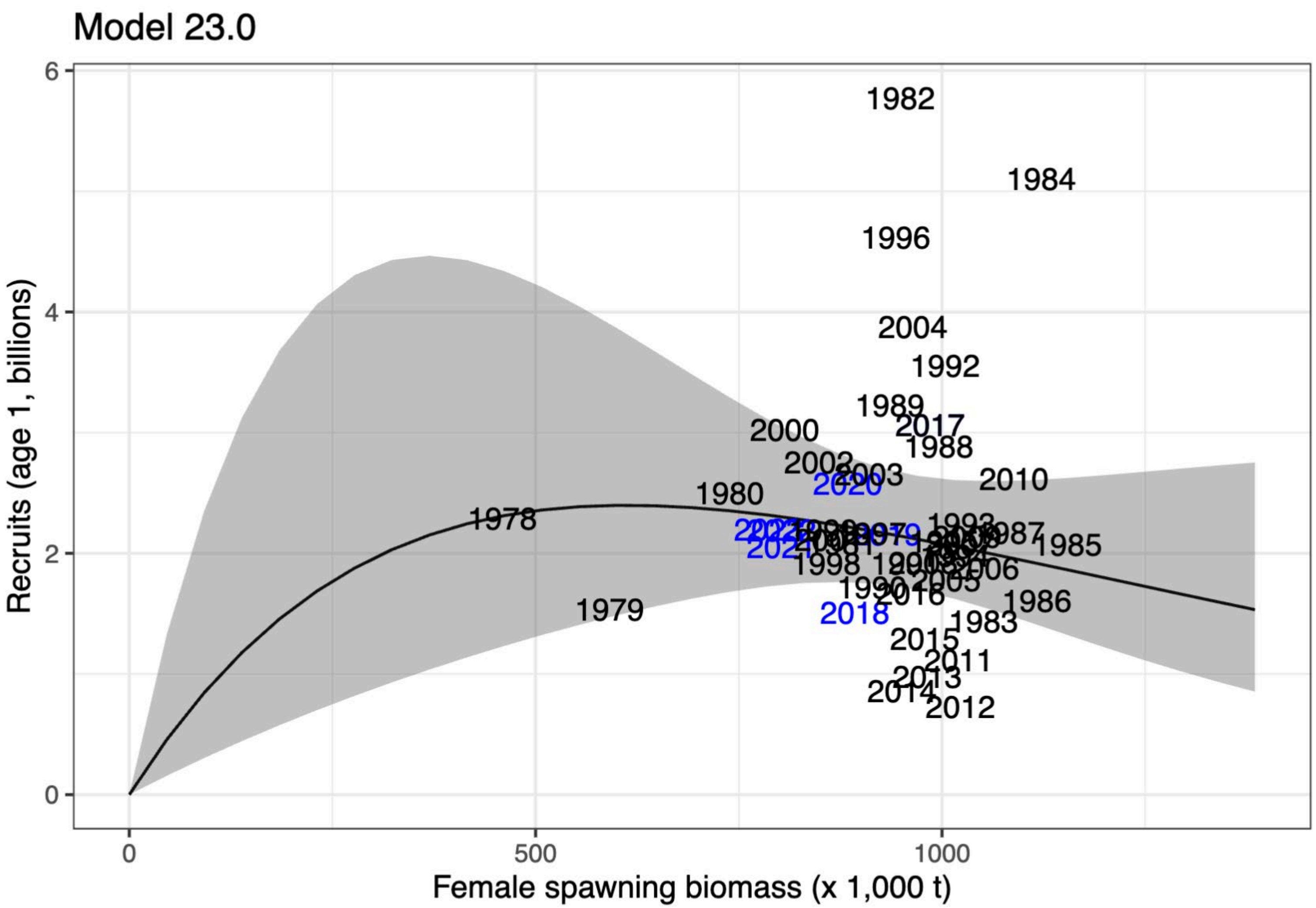
Model estimates of the proportion of female yellowfin sole in the population, 1982-2024 for Model 23.0 (2023 and 2024)



Data weighting, Model 23.0

- Survey age comps was initially weighted based on the number of hauls from which otoliths were collected.
- VAST survey age composition data were weighted using Francis (2011).
- The mean survey age composition weights were used to weight fishery age composition data.

Ricker stock recruitment curve for yellowfin sole Model 23.0 with 95% confidence intervals (shaded region) fit to female spawning biomass and recruitment data from 1978-2017

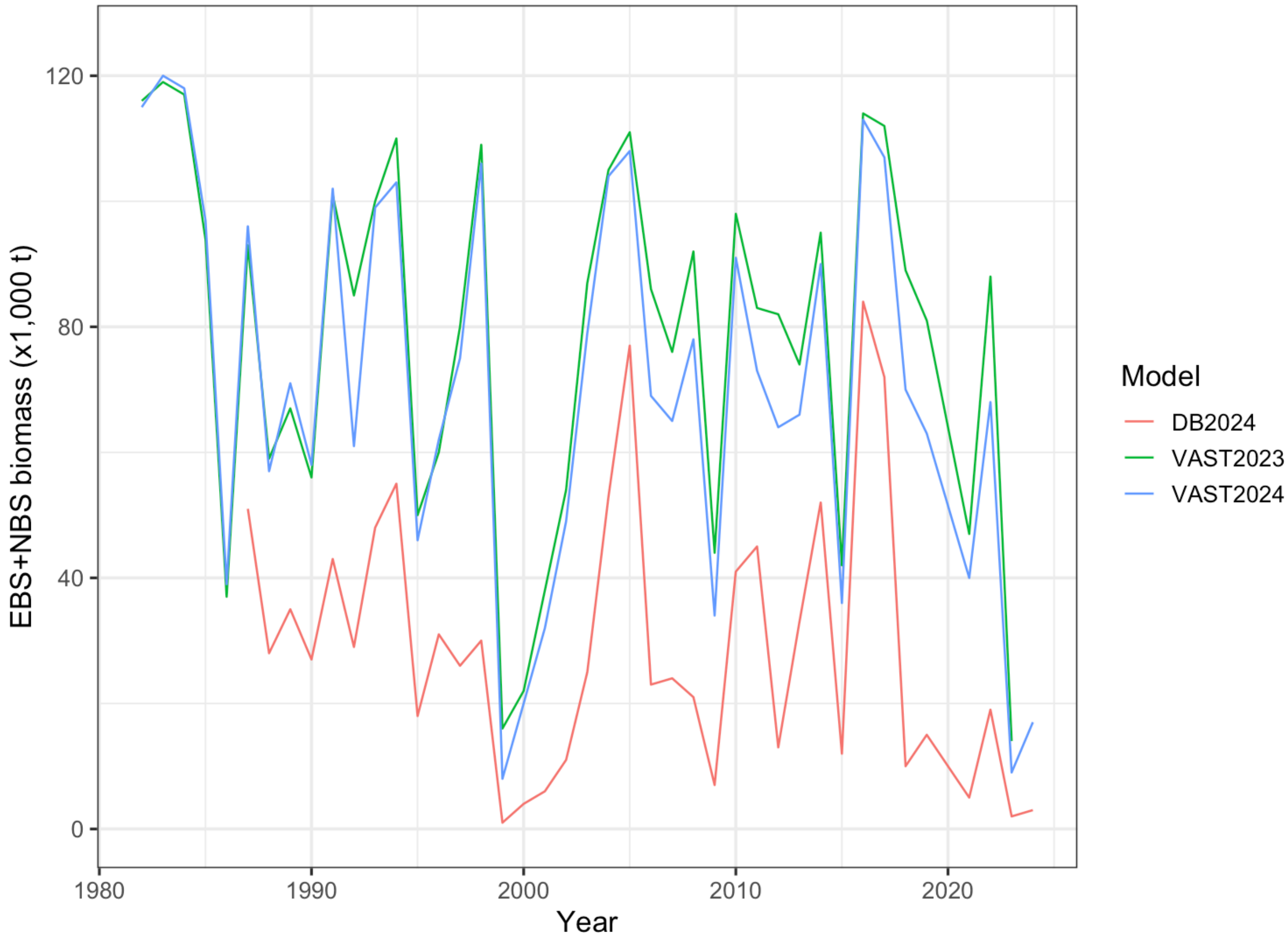


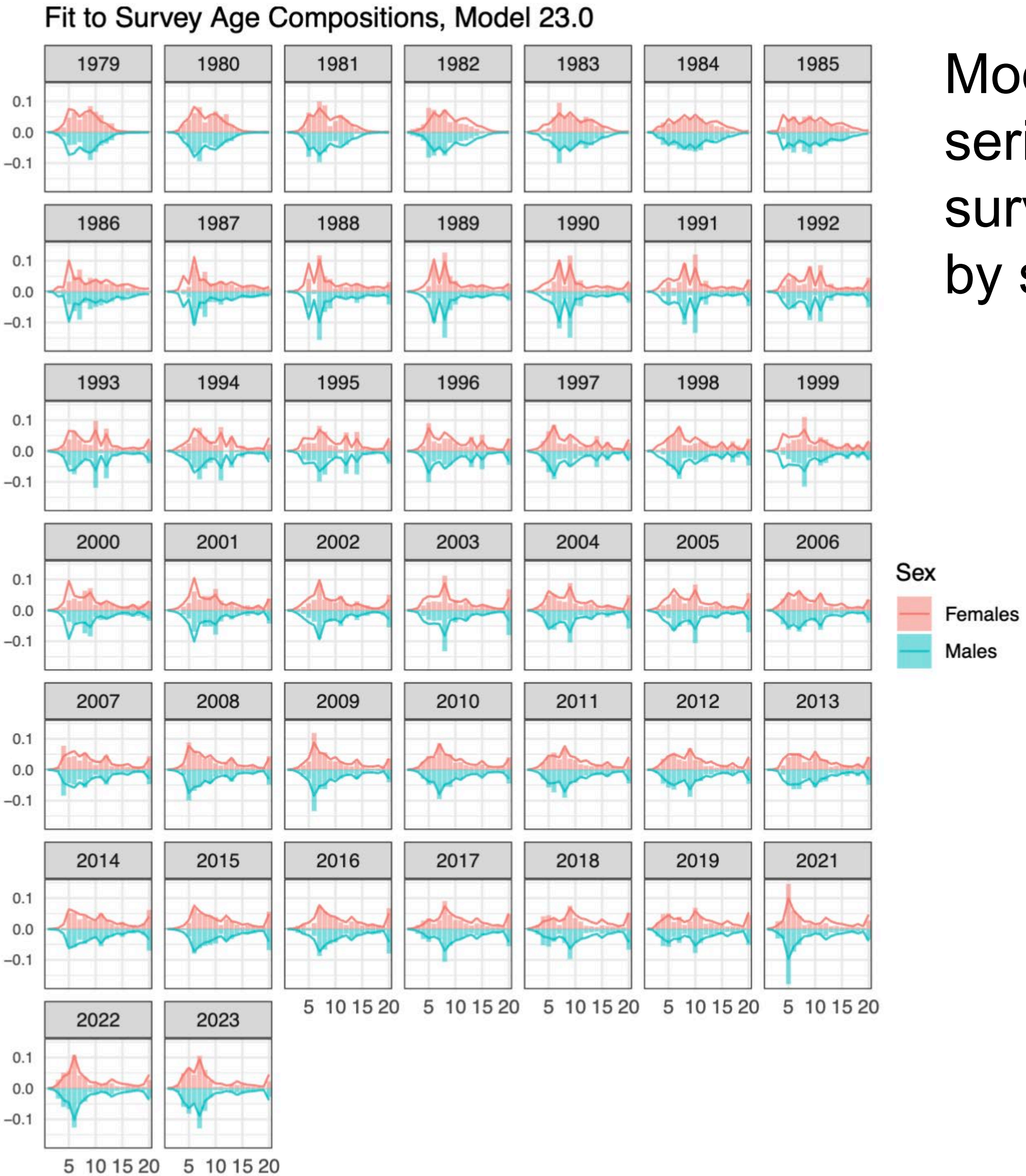
Distributional Assumptions

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

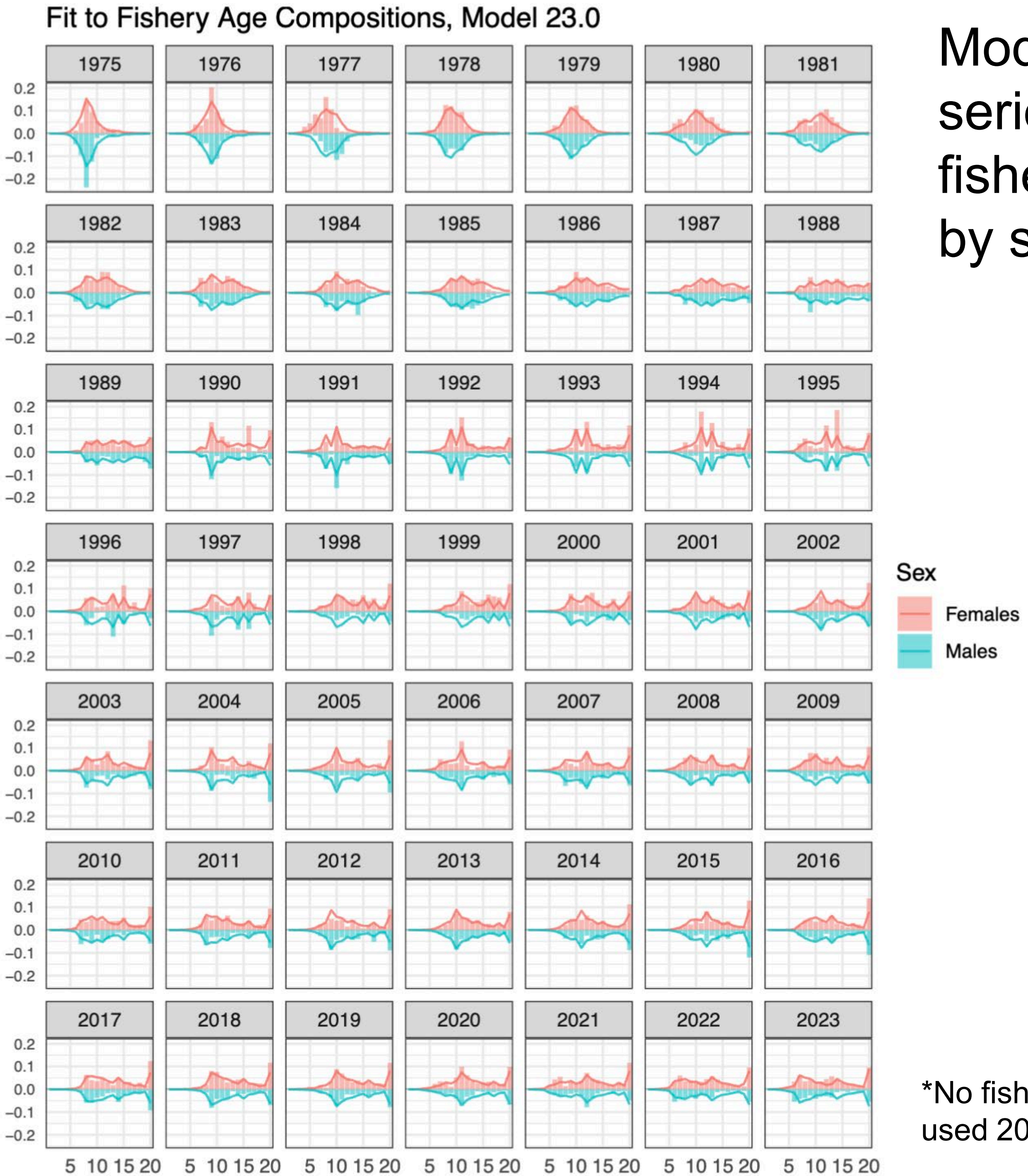
VAST and design-based survey indices





Model 23.0 fit to the time-series of yellowfin sole survey age composition, by sex, 1979-2023

*NBS ages were provided for 2023



Model 23.0 fit to the time-series of yellowfin sole fishery age composition, by sex, 1975-2023

*No fishery ages for 2023, used 2022 estimates.

Selected SSC comments (SSC December 2023)

SSC: The SSC requests documentation of the early catch-at-age data used in the assessment. The data availability table in the document indicates that the fishery catch-at-age data begin in 1964, but the data tables only show catch-at-age data starting in 1975. Older catch-at-age data should be removed if it cannot be documented.

Response:

Table 4.2 provides catches starting in 1954. The data availability table has been corrected to begin fishery catch-at-age data at 1975.