9. Assessment of the Flathead Sole-Bering Flounder Stock Complex Stock in the Bering Sea and Aleutian Islands

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# Executive Summary

## Summary of Changes in Assessment Inputs

*Changes in the input data*: This assessment includes updated catch for 2023, assumed catches of 14,334 t for 2024, 10,731 t for 2025 and 10,731 t for 2026 (Figure 1) and see [How Future Catch is Specified](#authorsF) for details). New input data otherwise include bottom trawl survey biomass for years 2021-2023; conditional age-at-length data from the bottom trawl survey for years 2021 and 2023; marginal fishery age compositions from 2020 and 2021; and marginal fishery length compositions from 2020-2023. The Age and Growth program was not able to provide marginal fishery age compositions for more recent years due to staffing shortages.

*Changes in the assessment methodology*: The assessment methodology is the same as the most recent full assessment conducted in 2020 (Monnahan and Haehn 2020).

## Summary of Results

For the 2025 fishery, we recommend the maximum allowable ABC of 79,581 t. This ABC is a 16.7% increase from the ABC recommended by last year’s model for 2024 of 68,203 t. The increase is attributed to the fact that the model has observed two years of elevated survey biomass in 2021 and 2022, and that the projection model routine has been updated to use recruitment values from 1977-present to be consistent with programmatic approaches; these recruits are on average higher than what was previously used (1964-present).

|  | As estimated or *specified last* year for: | | As estimated or *recommended this* year for: | |
| --- | --- | --- | --- | --- |
| **Quantity/Status** | 2024 | 2025 | 2025\* | 2026\* |
| M (natural mortality) | 0.2 | 0.2 | 0.2 | 0.2 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 2+) biomass (t) | 609,488 | 608,230 | 792,890 | 823,385 |
| Projected female spawning biomass (t) | 165,629 | 169,452 | 204,328 | 219,898 |
| B100% | 203,658 | 203,658 | 245,942 | 245,942 |
| B40% | 81,463 | 81,463 | 98,376 | 98,376 |
| B35% | 71,280 | 71,280 | 86,080 | 86,080 |
| FOFL | 0.46 | 0.46 | 0.43 | 0.43 |
| *max*FABC | 0.37 | 0.37 | 0.35 | 0.35 |
| FABC | 0.37 | 0.37 | 0.35 | 0.35 |
| OFL (t) | 81,605 | 82,699 | **96,198** | 100,528 |
| *max*ABC (t) | 67,289 | 68,203 | 79,581 | 83,205 |
| ABC (t) | 67,289 | 68,203 | **79,581** | 83,205 |
|  | As determined *last* year for: | | As determined *this* year for: | |
| **Status** | 2023 | 2024 | 2024 | 2025 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |
| \*Projections are based on an estimated catch of 14,334 t for 2024 and estimates of 10,731 t and 10,731 t used in place of maximum permissible ABC for 2025 and 2026. | | | | |

## Responses to SSC and Plan Team Comments on Assessments in General

“The SSC requests that all authors fill out the risk table in 2019…” (SSC December 2018)

We provide a risk table in the Harvest Recommendations section. After completing this exercise, we do not recommend ABC be reduced below maximum permissible ABC.

## Responses to SSC and Plan Team Comments Specific to this Assessment

*1. Continue exploration of environmental drivers of FHS stock distribution and behavior, as average summer bottom temperature appears inadequate (SSC, December 2018)*

This is out of scope for the present assessment, but might be addressed for the next Full assessment (2028).

*2. Investigate data from the NBS for Bering Flounder (SSC, December 2018)*

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*3. Consider separately modeling the pelagic trawl fishery with its own selectivity curve (Plan Team, November 2020)*

This request does not seem sensible for this stock, as there is not a pelagic trawl fishery for BSAI Flathead sole. This comment will be removed from future SAFE reports.

# Introduction

Operational Update: The reader is referred to the full operational stock assessment (Monnahan and Haehn 2020) for the description of Flathead sole-Bering flounder biology and life history.

# Fishery

Operational Update: The reader is referred to the last full operational stock assessment assessment (Monnahan and Haehn 2020) for the full description of Flathead sole-Bering flounder fishery history, fishery effort and CPUE, and information regarding discarding.

Table ?? shows a time series of total catch, total ABC, total OFL and TAC. Relevant management measures are shown in Table ??.

# Data

Operational Update: The data description for Flathead sole-Bering flounder has been truncated to highlight relevant updates or changes made for this cycle. The reader is referred to the last full assessment (Monnahan and Haehn 2020) for the entirety of this section.

The following table summarizes the data used for this assessment.

| **Source** | **Data** | **Species** | **Years** |
| --- | --- | --- | --- |
| NMFS Aleutian Islands Groundfish Trawl Survey | Survey biomass (linear regression used to combine BS shelf survey estimates with AI survey estimates for a single survey biomass index) | Flathead only; no Bering flounder were caught in the Aleutian Islands | 1983, 1986, 1991-2000 (triennial), 2002-2006 (biennial), 2010-2022 (biennial) |
| NMFS Bering Sea Shelf Groundfish Survey (standard survey area only; excludes survey strata 70, 81, 82, 90, 140, 150, and 160) | Survey biomass (linear regression used to combine BS shelf survey estimates with AI survey estimates for a single survey biomass index) | Flathead sole and Bering flounder combined | 1982-2019, 2021-2023 (except 2020) |
| Conditional age-at-length composition | Flathead sole only | 1982, 1985, 1992-1995, 1999-2019, 2021 |
| Marginal length composition | Flathead sole only | 1982-2019, 2021-2023 (except 2020) |
| U.S. trawl fisheries | Catch (pelagic and non-pelagic trawl in the Bering Sea and Aleutian Islands; a very small amount of catch is taken with hook and line and is included in the total catch biomass) | Flathead sole and Bering flounder combined | 1963-2024 |
| Marginal age composition (Bering Sea only; non-pelagic trawl only) | Flathead sole only | 2000, 2001, 2004-2007,2009-2021 |
| Marginal length composition (Bering Sea only; non-pelagic trawl only) | Flathead sole only | 1977-1999, 2002-2003, 2008, 2020-2023 |
| Foreign trawl fisheries in the BSAI | Catch (Bering Sea and Aleutian Islands; trawl) | Flathead sole and Bering flounder combined | 1964-1987 |

## Fishery

Catches as used in the model are shown in Table ??; discards are not used in the model. Fishery-dependent compositional data (catch-at-length and catch-at-age, and associated input sample sizes) are shown in Tables ?? and ??, respectively.

## Survey

Survey biomass estimates and associated sampling variability (annual CVs) are shown in Table ??. Survey compositional data (survey conditional ages-at-length, and associated input sample sizes) are shown in Table ??.

# Analytical approach

Operational Update: The data description for Flathead sole-Bering flounder has been truncated to highlight relevant details and changes made for this cycle. The reader is referred to the last full assessment (Monnahan and Haehn 2020) for the entirety of this section.

## General Model Structure

The model structure used for this Operational Update is unchanged from 2020. The BSAI flathead sole assessment is a two-sex, age-structured statistical catch-at-age model in Stock Synthesis (SS3, Methot and Wetzel (2013)). The assessment model was transitioned from version 3.30.16 to the latest version of SS3 available as of January 2024 (3.30.22). No detectable changes in derived quantities nor likelihoods occurred as a result of this software change (see externally-linked document [here](https://afsc-assessments.github.io/bsai-fhs/2024_bridging_analysis.html#stock-synthesis-software-update-3.30.22) for more details).

## Description of Base Model

This model is an Operational Update. The configuration matches the accepted model from 2020, with updated data. A full revision to the modeling framework is anticipated in the next cycle (2028). There are no alternative models presented here.

## Parameters Estimated Outside the Assessment Model

The survey catchability, time- and age-invariant natural mortality for females and males, variability of recruitment (), the parameters of the maturity ogive, the ageing error matrix, and the weight-length relationship were estimated outside the assessment model. The survey catchability parameter was set to 1.0. The natural mortality rates were set to 0.2 for both sexes, and was equal to 0.5, consistent with previous assessments. The maturity ogive for flathead sole followed an age-based logistic curve where age at 50% maturity was 9.7 and age at 95% maturity was 12.8. The ageing error matrix was taken directly from the Stock Synthesis model used in assessments prior to 2004 (Spencer et al., 2004). A length–weight relationship of the form was fit to survey data from 1982-2016 for males and females combined, with parameter estimates a = 0.00298 and b = 3.327 (weight in g, length in cm).

A comparison of these values is as follows:

| Symbol, Description | 2020 Value | Updated Value |
| --- | --- | --- |
| , asymptotic weight | 901 g | 899 g |
| , weight-at-age growth rate | 0.2 | unchanged |
| , age at weight zero | -0.37 | -0.38 |
| , , slope and intercept of linear relationship between sd(length at age) and age, post 1980s | -0.02, 2.18 | -0.02, 2.17 |

## Parameters Estimated Inside the Assessment Model

The parameters estimated conditionally inside the assessment model are listed in the table below.

Parameters estimated within the assessment model.

| Parameter | Symbol | Number |
| --- | --- | --- |
| log(mean recruitment) |  | 1 |
| Recruitment variability |  | 1 |
| Spawner-per-recruit reference points | , , | 3 |
| Recruitment deviations |  | 89 |
| Average fishing mortality |  | 1 |
| Fishing mortality deviations |  | 63 |
| Fishery selectivity coefficients |  | 6 |
| Survey selectivity coefficients |  | 2 |
| Maturity-at-age coefficients |  | 2 |
| Total |  | 170 |

### Recruitment

The log of unfished recruitment (), log-scale recruitment deviations for an early period 1964-1972 and a main period (1973-2020) were estimated. A 1:1 sex ratio is assumed. The age-0 recruitment was fixed to equal mean recruitment for the most recent four years because too few flathead sole are observed at ages 0-3 to estimate recruitment reliably.

### Growth

Sex-specific growth parameters (, , , CV of length-at-age 3, CV of length-at-age 21+) were estimated inside the assessment model.

### Selectivity and fishing mortality

Survey selectivity parameters were estimated using age-based, sex-specific, asymptotic curves that were time-invariant and are listed in the table below. The double-normal curve was used to easily allow previous and future explorations of alternative survey selectivity forms. Here the double-normal curve is constrained to mimic a logistic shape because there was no evidence for dome-shaped survey selectivity.

Fishery selectivity parameters for logistic, length-based, sex-specific curves were estimated (the parameters for each curve were the length at 50% selectivity to the fishery and slope of the selectivity curve). Separate fishery selectivity curves were estimated for 2 distinct time periods (1964-1987 and 1988-present).

Finally, annual fishing mortality rates were estimated (1964-2024).

Treatment of age-based selectivity parameters for the survey. The fishery uses age-based logistic selectivity.

| Double-normal selectivity parameters | Treatment for Survey |
| --- | --- |
| Peak: beginning age for the |  |
| plateau | *estimated* |
| Width: width of plateau | set to 12 |
| Ascending width (log space) | *estimated* |
| Descending width (log |  |
| space) | set to 3 |
| Initial: selectivity at |  |
| smallest age bin | set to 0 |
| Final: selectivity at |  |
| largest age bin | Follows shape of descending |
| limb | *estimated* |
| Male Peak Offset | *estimated* |
| Male ascending width offset |  |
| (log space) | *estimated* |
| Male descending width |  |
| offset (log space) | set to 1 |
| Male “Final” |  |
| offset (transformation required) | set to 1 |
| Male apical selectivity | set to 1 |

# Selected Model Results

Operational Update: This section has been condensed to follow the newest guidelines for “Operational Update Assessments” to the best of the Authors’ ability. A minimal set of figures and tables are provided here; links to electronic files for supplementary data (e.g., numbers-at-age from the base model) are included in-text.

The model used in this assessment is the same as the model accepted in 2020 (Model 18.2c (2020)) with updated data and parameter priors. Model 18.2c (2020) with data updated through year (presented as Model 18.2c (2024)) generally results in reasonable fits to the data (see Figure), estimates biologically plausible parameters (see Tables), and produces consistent patterns in abundance compared to previous assessments (Figure 9).

## Model Evaluation

### Residual Analysis and Convergence Criteria

The model achieved convergence as defined by an invertible Hessian matrix and a low maximum gradient component (less than1e-4), was achieved using the hess\_step function in ADMB. Time-series plots of observed and predicted values, and the time-series of recruitment deviations did not suggest unusual residual patterns, or different behavior than in previous assessments. The uncertainty around parameter estimates and related derived quantities were in line with previous models.

### Parameter Estimates and Parameter Uncertainty

Table ?? lists all estimated parameters in Model 18.2c (2024). It includes the associated asymptotic standard error estimates or other statistical measures of uncertainty. Time series of deviation parameters (fishing mortality rates and recruitment deviations from (1964-2024)) are shown in Figures 9 and 10, respectively.

Table ?? shows the maximum likelihood estimate (MLE) of key parameters with corresponding 95% credible intervals given by the asymptotic uncertainty.

### Time Series Results

*Definitions:* **Spawning biomass** is the estimated weight of mature females. **Total biomass** is the estimated weight of all FHS ages 3 and greater. **Recruitment** is measured as the number of age-zero individuals. **Fishing mortality** is the mortality at the age the fishery has fully selected the fish. Key results have been summarized in Table ??. Model predictions generally fit the data well (Figures .2 through 10.3). A comma-separated electronic file containing the estimated numbers-at-age is available at <https://github.com/afsc-assessments/bsai-fhs/blob/main/2024/mgmt/18.2c_2024/natage.csv>.

#### Biomass

Spawning biomass was at a low in 1983 of 83,017 t, reached a peak in 1998 of 227,466 t, slowly decreased through 2020 and recently increased to a current spawning biomass of 187,261 t in 2024 (Figure 9). These trends correspond to a period of high recruitment from 1980-1990, a period low recruitment occurred from 2004-2010 (Figure 10) and increasing survey observations since 2015 (Figure 3). The survey data are fit well throughout the time series.

#### Fishing Mortality

Historical apical fishing mortality was between 0.009 and 0.056 for the historical period of foreign fleets and the joint venture fishery. The estimates of uncertainty in fishing mortality during this period are artificially small due to the absence of a stock-recruitment relationship. Fishing mortality reached a peak in 1990 at 0.114, and remained between 0.059 and 0.094in the 1990s and early 2000s. Fishing mortality reached another peak of approximately 0.119 in 2008 and has declined since then (Figure 12).

#### Selectivity

Figure 11 shows the estimated length-based fishery selectivity curves and estimated age-based survey selectivity curves for Model 18.2c (2024). Both fleets indicate that males are caught at smaller lengths than females.

The time-blocked fishery survey selectivity curves Model 18.2c (2024) indicate selection of smaller fish of both sexes in the early period (1964-1987) versus the later period (1988-present). The early period is characterized by a paucity of compositional data (Figure 1). The survey data (beginning in 1982) do not suggest that length-at-age was distinct across these time periods. We also do not suspect that the growth curves of fish captured by the fishery, as the aggregate fits to fishery length data (Figure 5) are satisfactory (despite the fact that data from many of those years were not included in the joint likelihood; only the survey data was used to inform growth parameters and variability in growth in the model).

#### Recruitment

Recruitment (as measured by age-0 fish) is moderately variable (Figure 9). A period of high recruitments occurred from 1980-1990, and a period low recruitments occurred from 2004-2010 (Figure 10). The age-0 recruitment was fixed to equal mean recruitment for the most recent four years because too few flathead sole are observed at ages 0-3 to estimate recruitment reliably.

Flathead sole do not seem to exhibit a stock-recruitment relationship because large recruitment has occurred during periods of high and low biomass (Figure 9 and Table ??).Model 18.2c (2024) does not specify an explicit stock-recruitment relationship. The average annual recruitment (in numbers) spawned after 1976 is estimated to be 1.025 million.

### Comparison to Previous Model

A comparison of key derived quantities from the base model and the most recent full assessment is shown in Figure 9. Parameter estimates and likelihood functions have remained similar to Model 18.2c (2020), and the 95% credible intervals of the current parameter estimates encompass the Model 18.2c (2020) medians (Figure 9 and Tables ?? and ??).

## Harvest recommendations

Operational Update: This section been truncated to provide minimal background and highlight relevant updates or changes made for this cycle. The reader is referred to the last full assessment (Monnahan and Haehn 2020) for the entirety of this section, including details on the projection approach.

### Amendment 56 Reference Points

This stock complex is managed under Tier 3a of Amendment 56. The following table shows the reference points calculated for the 2024 assessment.

| Reference Point | Description | Value |
| --- | --- | --- |
|  | The equilibrium spawning biomass that would be obtained in the absence of fishing | 245,942 t |
|  | 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing | 98,376.5 t |
|  | 35% of the equilibrium spawning biomass that would be obtained in the absence of fishing | 86,079.5 t |
|  | The fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing | 0.35 |
| ABC | Yield at in 2025 | 79,581 t |
|  | The fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing | 0.43 |
| OFL | Yield at in 2025 | 96,198 t |

### Specification of OFL and Maximum Permissible ABC

#### Standard Harvest Scenarios (Harvest Projections)

**UPDATE THIS SECTION GIVEN PROJ TEAM GUIDANCE**

A standard set of projections is required for each stock managed under Tier 3 of Amendment 56. Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. They are as follows (“max” refers to the maximum permissible value of under Amendment 56):

* *Scenario 1*: In all future years, is set equal to max (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
* *Scenario 2*: In 2025 and 2026, is set equal to a constant fraction of max , where this fraction is equal to the ratio of the realized catches in 2021-2023 to the ABC (which is generally the same as the TAC) recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: Using recent catch to ABC ratios will yield more realistic projections for the POP fishery, which rarely realizes its full TAC or ABC). The exact calculation of these values is shown [below](#authorsF).
* *Scenario 3*: In all future years, is set equal to 50% of max . (Rationale: This scenario provides a lower bound on that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
* *Scenario 4*: In all future years, is set equal to the 2018-2022 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average may provide a better indicator of FTAC than .)
* *Scenario 5*: In all future years, is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA’s requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as ):

* *Scenario 6*: In all future years, is set equal to . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2024 or 2) above ½ of its MSY level in 2024 and above its MSY level in 2034 under this scenario, then the stock is not overfished.) While Scenario 6 gives the best estimate of OFL for 2024, it does not provide the best estimate of OFL for 2025, because the mean 2024 catch under Scenario 6 is predicated on the 2024 catch being equal to the 2024 OFL, whereas the actual 2024 catch will likely be less than the 2024 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.
* *Scenario 7*: In 2025 and 2026, is set equal to max, and in all subsequent years is set equal to . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2026 or 2) above 1/2 of its *MSY* level in 2026 and expected to be above its MSY level in 2036 under this scenario, then the stock is not approaching an overfished condition.)

#### How Future Catches are Specified for Scenario 2 (Author’s F)

The method for specifying catches in years 2024 to 2026 has not changed from the 2020 assessment.

For Scenario 2 (*Author’s F*); we use pre-specified catches to increase accuracy of short-term projections in fisheries where the catch is usually less than the ABC. We specify 2024 catches as the most current observed catches plus the typical landings through the present date through the end of the calendar year, and the catches for years 2025 and 2026 as the average catch from 2019 to 2023, which is 10,731 t.

Projected catches, spawning biomass, and fishing mortality rates corresponding to the alternative harvest scenarios over a 13-year period are shown in Tables ?? through ??.

## Risk Table and ABC recommendation

The risk table scoring for POP has not changed since 2021, with the exception that the 2021 SSC requested that the number of Risk Table categories (i.e., levels of concern) be reduced from four to three. Per leadership instruction in 2023, we have consolidated what were previously categories 2 and 3 (“substantially increased” and “major concern” into a single category, “increased/major concern”). This impacts the first two considerations, which were rated a level 2 in the 2021 Assessment.

| *Assessment-related considerations* | *Population dynamics considerations* | *Environmental/ecosystem considerations* | *Fishery Performance* |
| --- | --- | --- | --- |
| Level 2: Major concern | Level 2: Major concern | Level 1: No concern | Level 1: No concern |

An abridged summary of the considerations that led to this determination for each category follows.

### Assessment considerations

The GOA POP assessment model exhibits a strong negative retrospective pattern (spawning biomass continues to increase with new data), though this effect was less pronounced in the 2023, likely due to high uncertainty in the observed survey biomass. This is driven by ongoing increases in the trawl survey biomass, which have been consistently under-estimated since 2013, and may be suggestive of model misspecification.

*This results in a Level 2 assessment considerations rating, a major concern.*

### Population dynamics considerations

The model estimates above-average recruitment events in the last three decades to account for the increasing survey biomass observations (Figures 10.3, 10.9 and 10.10). The estimated recruitment events are still insufficient to satisfactorily fit the recent survey data; these increases are not observed in the early time series nor are they typical for an ecosystem that is warming (with the exception of sablefish).

The unusual trend of rapid increases in stock size and recruitment estimates *results in a Level 2 population dynamics rating, a major concern.*

### Environmental/Ecosystem considerations

This year, the GOA ecosystem was characterized by moderate thermal conditions, mixed trends for zooplankton abundance, moderate predation, and increased competition for zooplankton prey resources. The warmer surface waters predicted for 2024 may be favorable for POP larval survival. Ecosystem: While optimal temperatures for POP life stages are not known, it is reasonable to expect that the 2023 average ocean temperatures at depth on the shelf edge (for adults) and surface temperatures (for larvae) were adequate for POP. POP are semi-demersal/pelagic, outer shelf and continental slope (150-420 m depths) dwellers as adults, with a pelagic then inshore benthic juvenile stage (age 1 to 3) in the Gulf of Alaska (GOA) (Carlson and Haight 1976, Love et al. 2002, Rooper and Bolt 2005, Rooper et al. 2007, NPFMC 2010). There is evidence that POP are being observed higher in the water column, potentially a result of an expanding population. As warm spring temperatures are favorable for larval survival (Doyle 2009), cooler spring to above average summer temperatures varying from 5.8°C (WGOA Bottom Trawl Survey, O’Leary 2023) to 10.5°C (Icy Strait, SEAK, Fergusson 2023) were cooler than optimal, but not considered detrimental. While optimal temperatures are not known for adults, there is no indication of concern given bottom temperatures along the shelf edge in the GOA cooled to average in 2023 (AFSC longline survey: Siwicke 2023). Surface temperatures are predicted to warm in late winter/early spring of 2024, in alignment with El Niño conditions (Bond 2023). These warmer surface temperatures in April/May (larval release) may be favorable for larval survival. As it takes time for warm surface waters to extend to depth, shelf bottom temperatures are not expected to warm in the spring.

Prey: Planktivorous foraging conditions were average to below average across the GOA in 2023. The primary prey of the adult POP include calanoid copepods, euphausiids, myctophids, and miscellaneous prey in the GOA (Byerly 2001, Yang 2000, Yang 2003). POP body condition increased to average in 2023 after below average condition (i.e. lower weights at length) since 2015 (Bottom Trawl Survey, O’Leary, 2023b). The timing of this declining trend matches the time frame of increasing POP population since the 2014-2016 marine heatwave and could be explained by prey availability and competition within an expanding population. Zooplankton biomass in the WGOA progressed from below average in the spring (lower calanoid copepod biomass and higher euphausiid biomass) to improved conditions in the summer (above average biomass of large calanoid copepods and euphausiids, but continued lower small copepod biomass; Shelikof St., Kimmel 2023, and Seward Line, Hopcroft 2023). Summer planktivorous foraging conditions were somewhat improved with above average large calanoid copepod and euphausiid biomass, but continued lower small copepod biomass (Shelikof, Kimmel 2023). Eastern GOA inside waters had below average total zooplankton biomass, although euphuasiids were above average here as in the western GOA. Planktivorous seabird reproductive success, an indicator of zooplankton availability and nutritional quality, was approximately average south of Kodiak (Chowiet Isl.), and in the central GOA (Middleton Island on shelf edge off Seward) (Drummond 2023, Whelan 2023), and above average in the EGOA (St. Lazaria Isl.).

Predators & Competitors: Predation pressure is considered moderate and competition may have increased in 2023. Predators of juvenile POP include Pacific halibut, arrowtooth flounder, seabirds, rockfish, salmon, and lingcod (Moss 2016). Predators of adults include Pacific halibut, sablefish, and sperm whales (Moss 2016). Halibut and arrowtooth flounder populations remain low relative to previous levels, and, in general, there is no cause to suspect increased predation pressure on larval or adult demersal shelf rockfish. Potential competitors include large returns of pink salmon (Whitehouse, 2023, Vulstek, 2023), a relatively large and increasing population of walleye pollock, other POP as the population continues to increase, and continued large year classes of juvenile sablefish. POP are being found shallower in the water column, increasing their habitat overlap and potential competition for zooplankton prey with walleye pollock.

The most recent data available *result in a Level 1 ecosystem rating, no apparent concerns.*

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### Fishery performance

There have been no recent changes to spatial distribution of catch, percent of TAC taken, or fishing duration. There are no indications of adverse signals or concerns about the fishery in terms of resource-use, performance, or behavior.

*Fishery Performance for POP is scored as Level 1 (normal concern)*.

### Risk Table Summary and ABC recommendation

*We do not recommend a reduction in ABC because the retrospective pattern in this assessment indicates an increasing population abundance, and the population is well above .* We acknowledge that the current assessment model does not appropriately explain these dynamics at present.

### Status Determination

The status definitions under the MSFCMA have been truncated from this report.

#### Overfishing

The official catch estimate for the most recent complete year (2023) is 8,988 t. This is less than the 2023 OFL of 82,699 t. *The stock is not subject to overfishing.*

#### Overfished (Harvest Scenario 6)

The minimum stock size threshold (MSST) for POP is given by the which is 86,079.5 in 2024. The estimated stock spawning biomass in 2024 is nearly double the MSST at 204,328. *The stock is not overfished*.

#### Approaching Overfished (Harvest Scenario 7)

The mean estimated stock spawning biomass in 2026 is above the MSST. *The stock is not approaching an overfished state*.

# Ecosystem Considerations

Operational Update: The Ecosystem Considerations for POP are unchanged. The reader is referred to the last full assessment (Hulson et al., 2021) for the entirety of this section, which has been summarized below. The Fishery Impacts on the Ecosystem and GOA Rockfish Economic Performance Report for 2020 have been removed from this document.

In general, a determination of ecosystem considerations for POP is hampered by the lack of biological and habitat information.

## Ecosystem Effects on the Stock

**Prey availability/abundance trends**: Similar to many other rockfish species, stock condition of POP appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval POP may be an important determining factor of year class strength.

**Predator population trends**: POP are preyed upon by a variety of other fish at all life stages, and to some extent marine mammals during late juvenile and adult stages. Whether the impact of any particular predator is significant or dominant is unknown.

**Changes in physical environment**: Stronger year classes corresponding to the period around 1977 have been reported for many species of groundfish in the GOA, including POP, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. POP appeared to have strong 1986-88 year classes, and there may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown.

# Data Gaps and Research Priorities

Operational Update: The reader is referred to the last full stock assessment (Hulson et al., 2021) for the entirety of the POP Data Gaps and Research Priorities section.

# Acknowledgements

The authors would like to acknowledge fruitful discussions with P. Spencer and the input of the 2023 September Groundfish Plan Team, as well as a review by C. Lunsford.

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# Auxiliary Files

A script to reproduce the analyses presented in this assessment is available at <https://github.com/afsc-assessments/bsai-fhs/blob/main/2024/R/2024_analysis.R>.

# Tables

# Figures

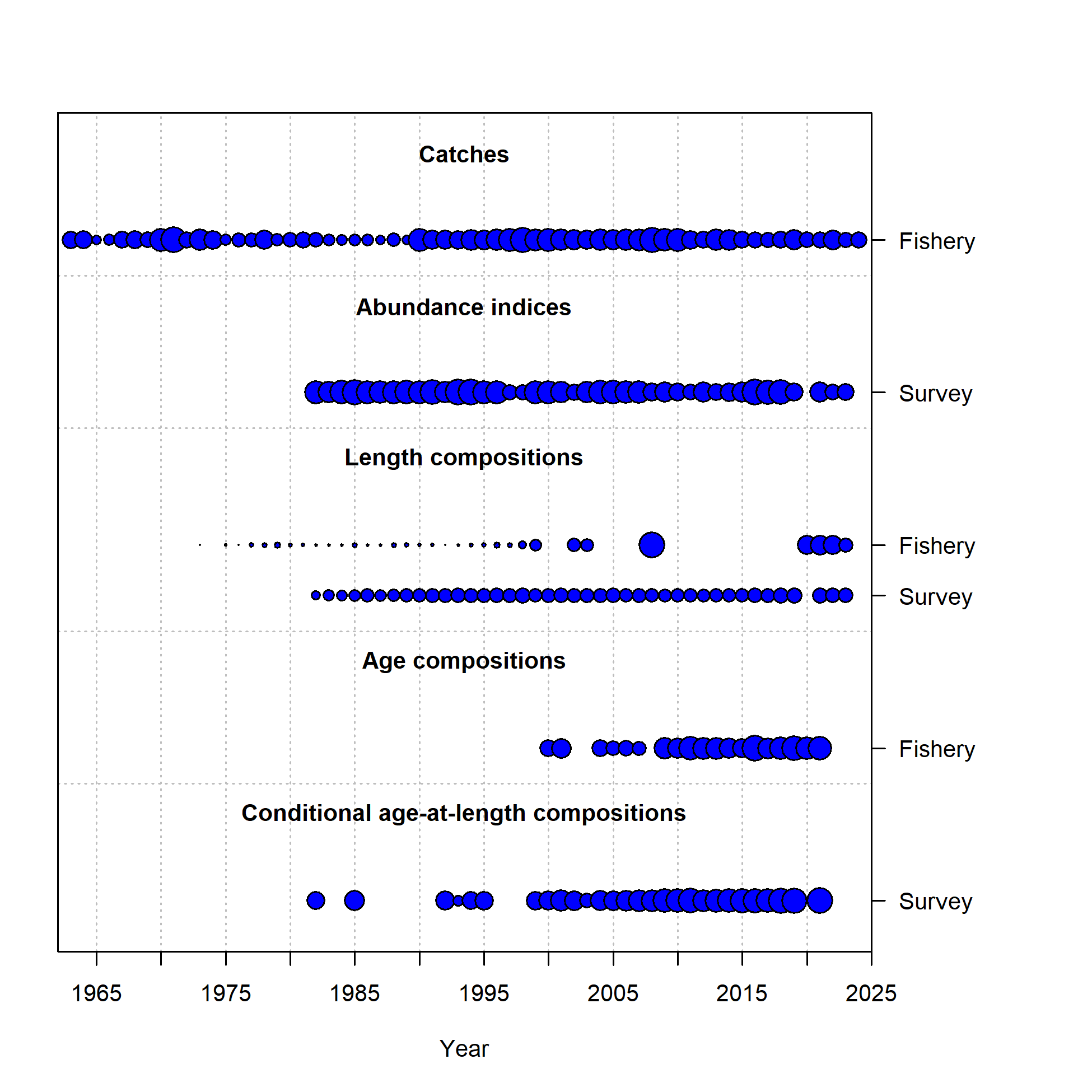


Figure 9.1. Data included in the update assessment, Model 18.2c (2024).

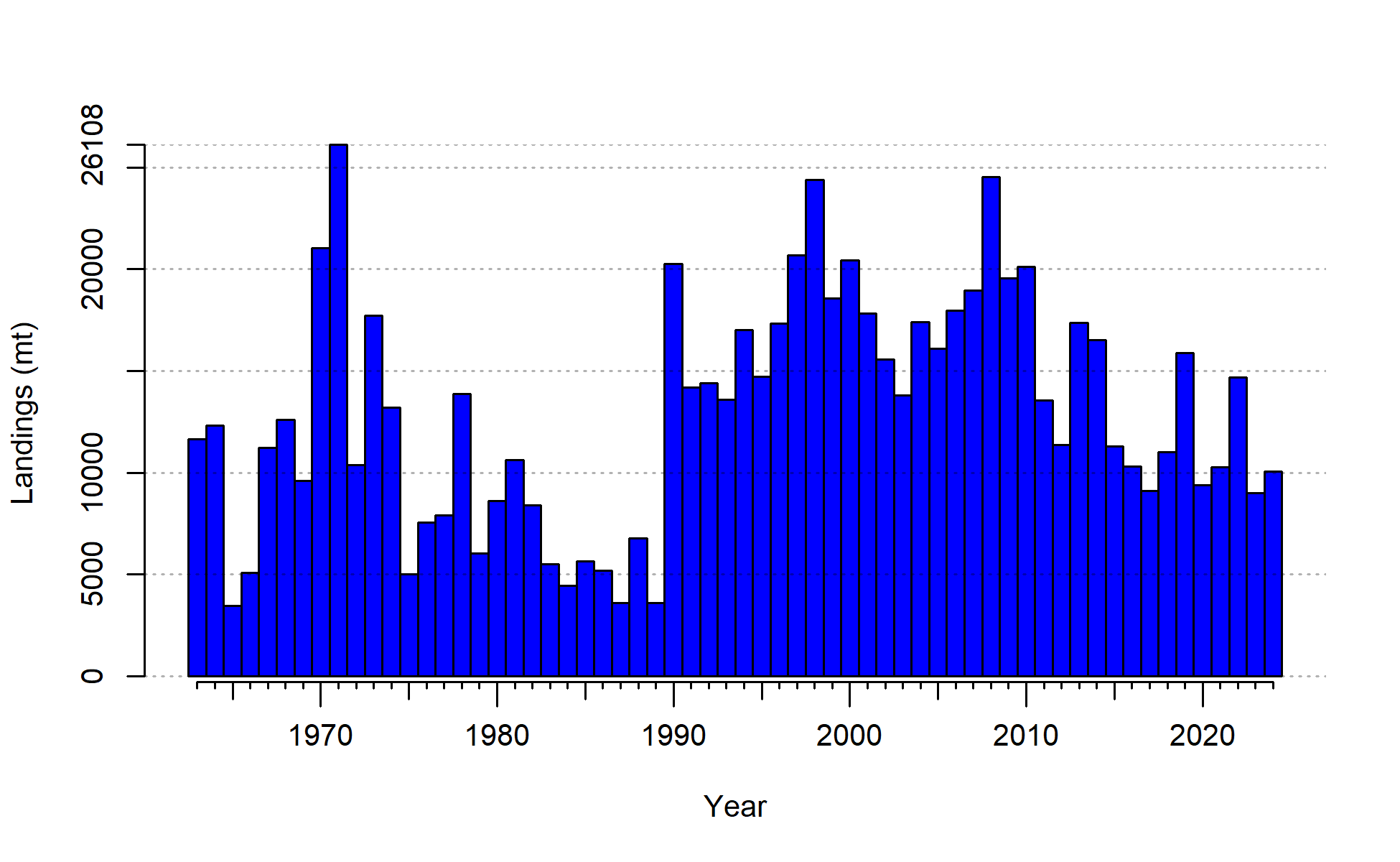


Figure 9.2. Observed catches for BSAI FHS.

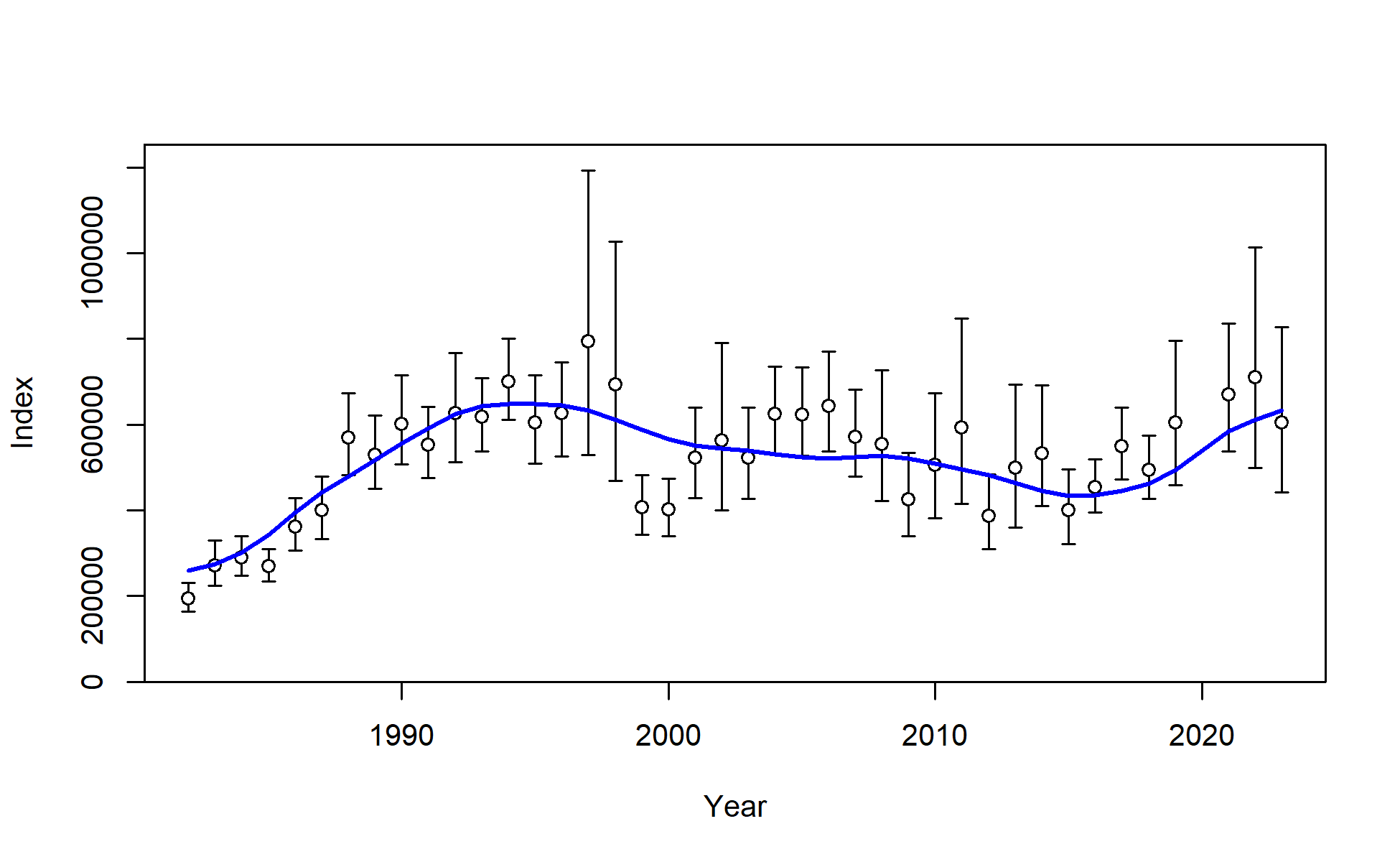


Figure 9.3. BS/AI Combined Trawl Survey observed biomass estimates with 95% sampling error confidence intervals for BSAI FHS (black points and vertical bars). Model expectations are shown in blue.

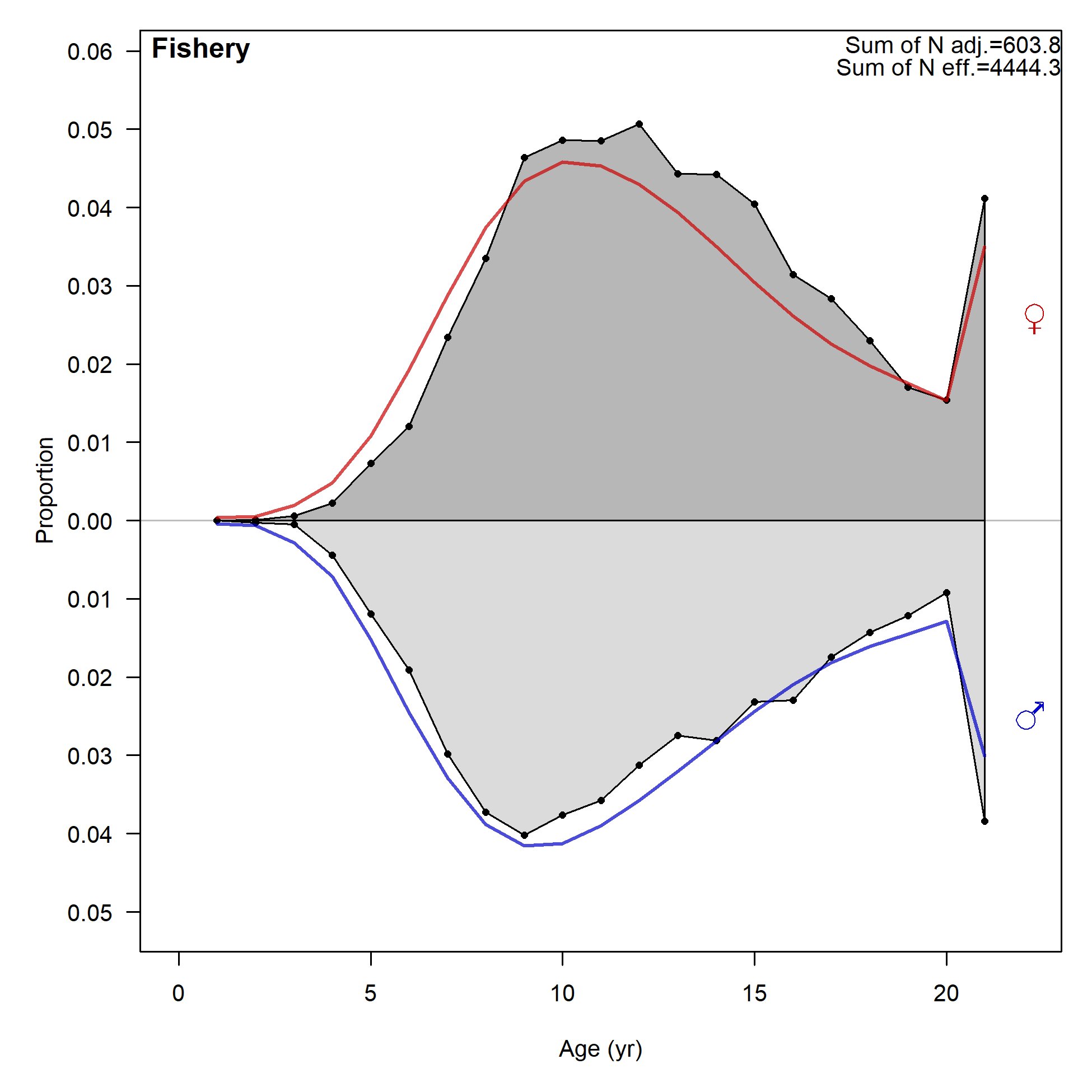


Figure 9.4. Observed (grey polygons) and predicted (colored lines) fishery age compositions for BSAI FHS.

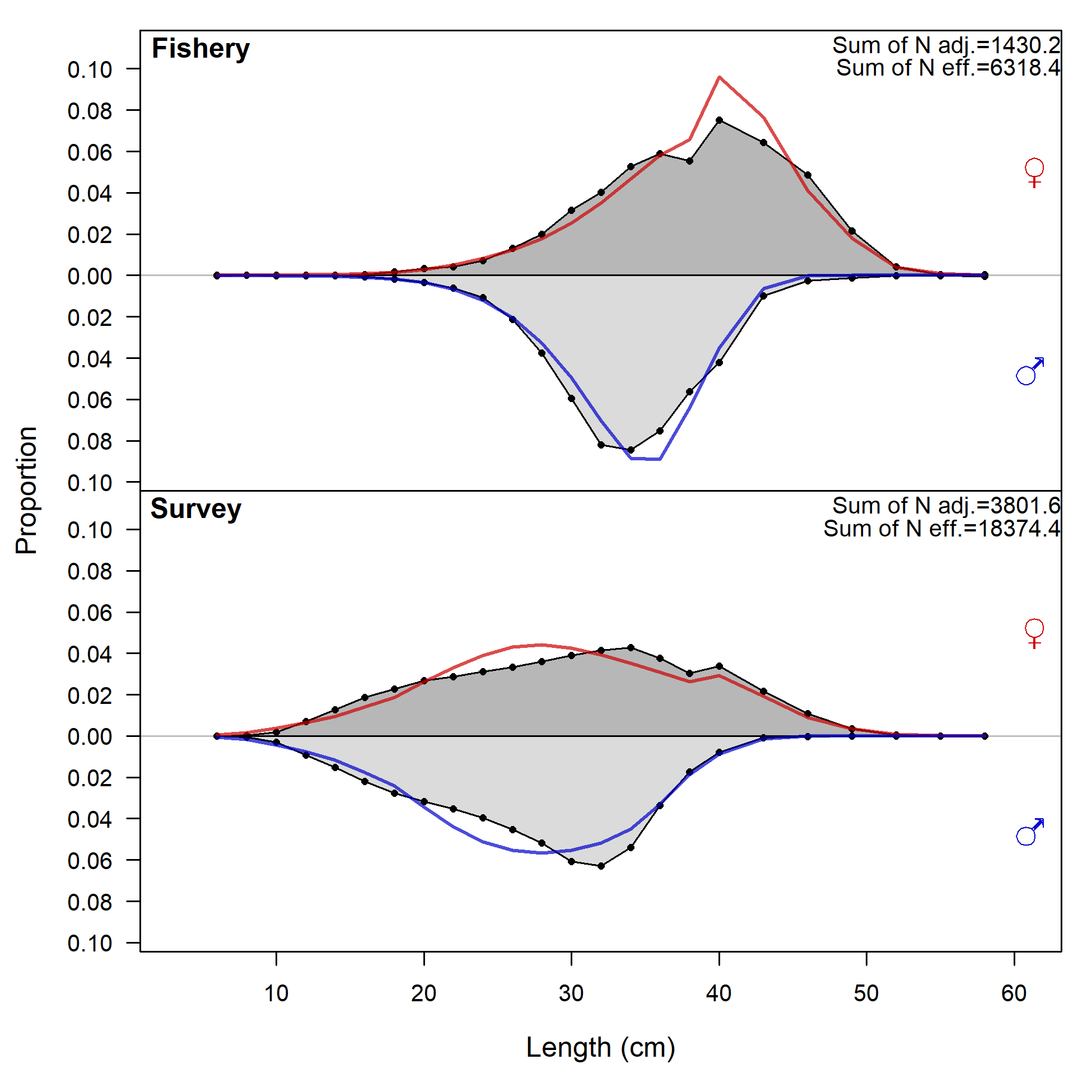


Figure 9.5. Observed (grey polygons) and predicted (colored lines) fishery and survey length (cm) compositions for BSAI FHS. Note that many years of the Fishery length composition data are not included in the joint likelihood (in lieu of age compositions).

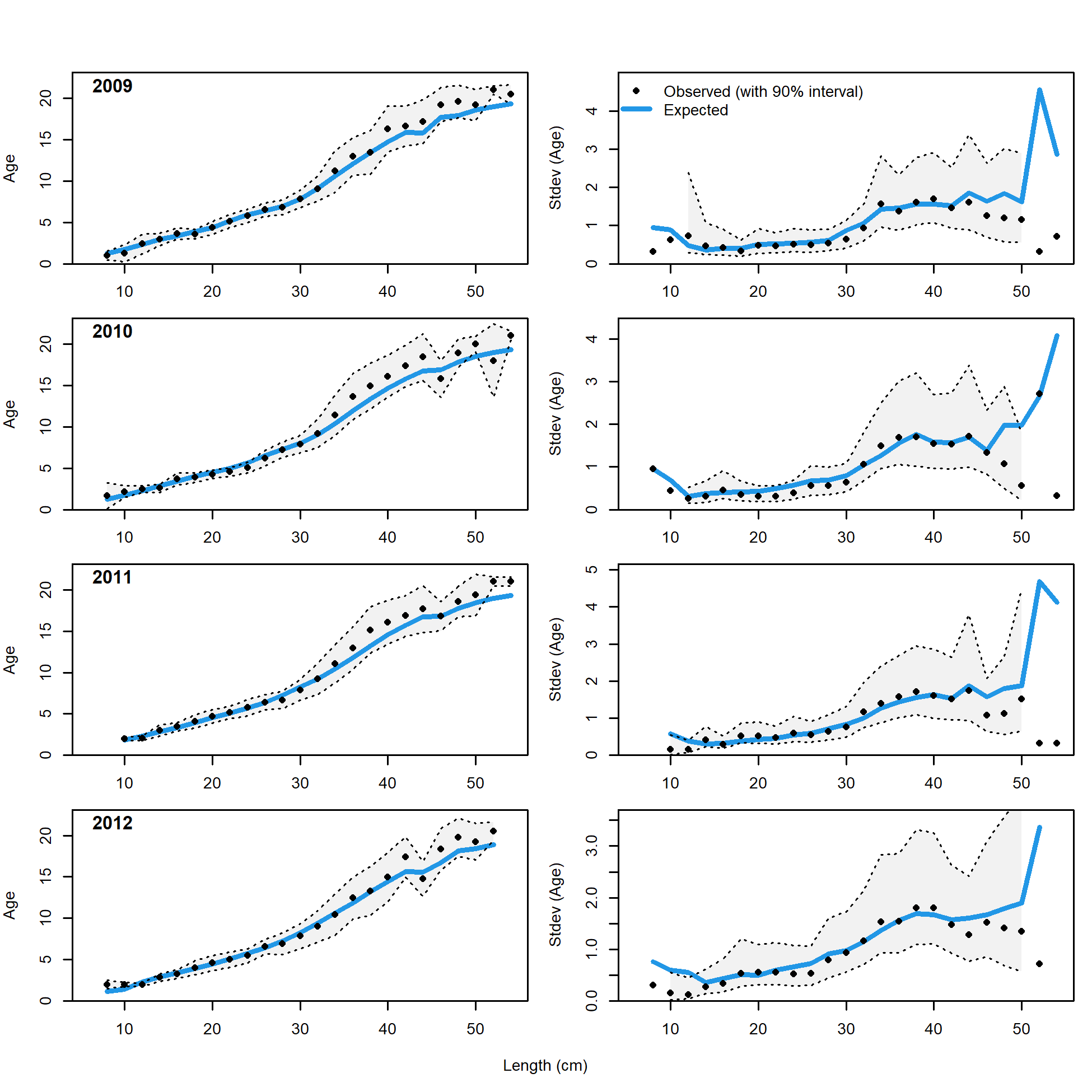


Figure 9.6. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for Model 18.2c (2024) for years 2009-2012 (1 of 3).

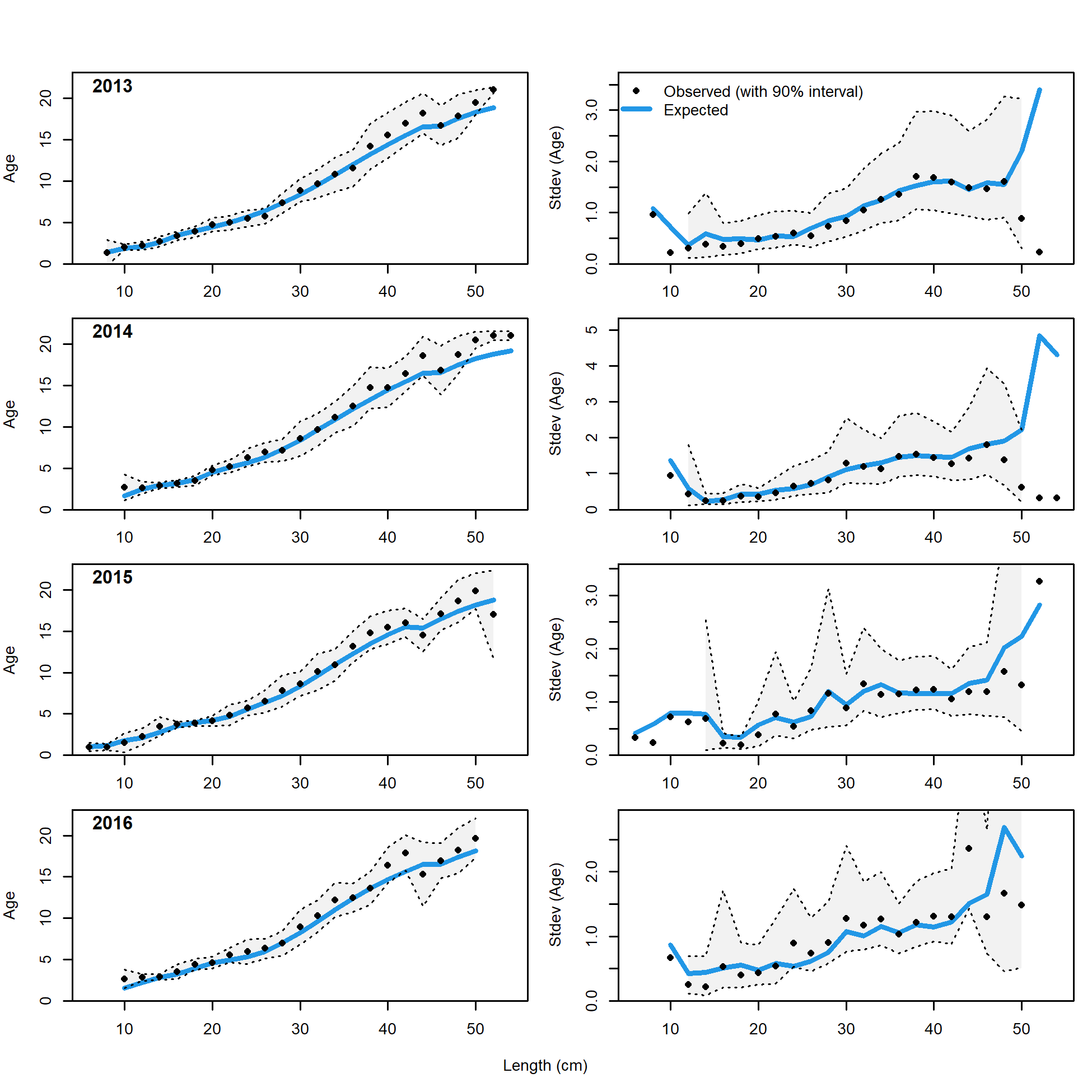


Figure 9.7. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for Model 18.2c (2024) for years 2013-2016 (2 of 3).

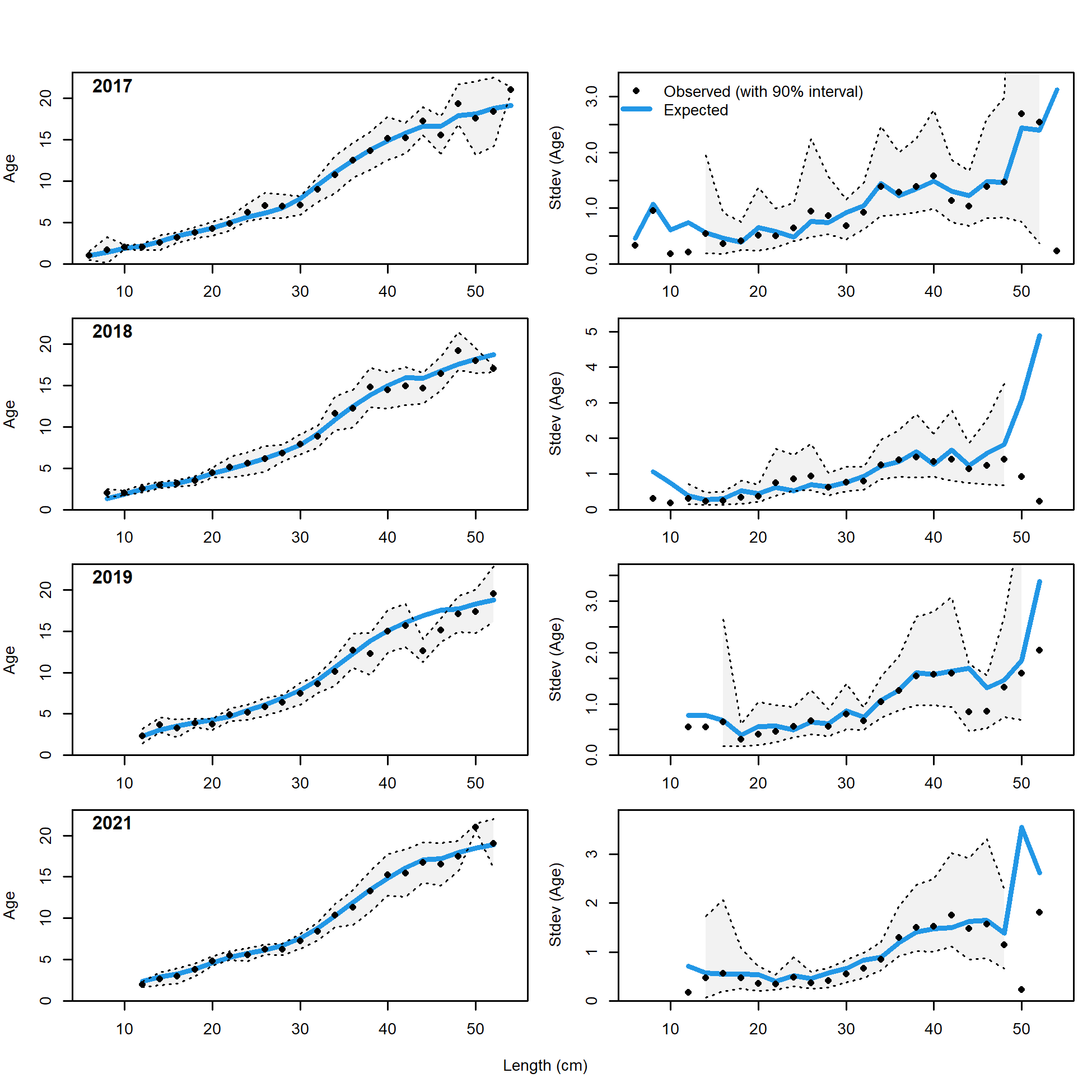


Figure 9.8. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for Model 18.2c (2024) for years 2017-2021 (3 of 3).

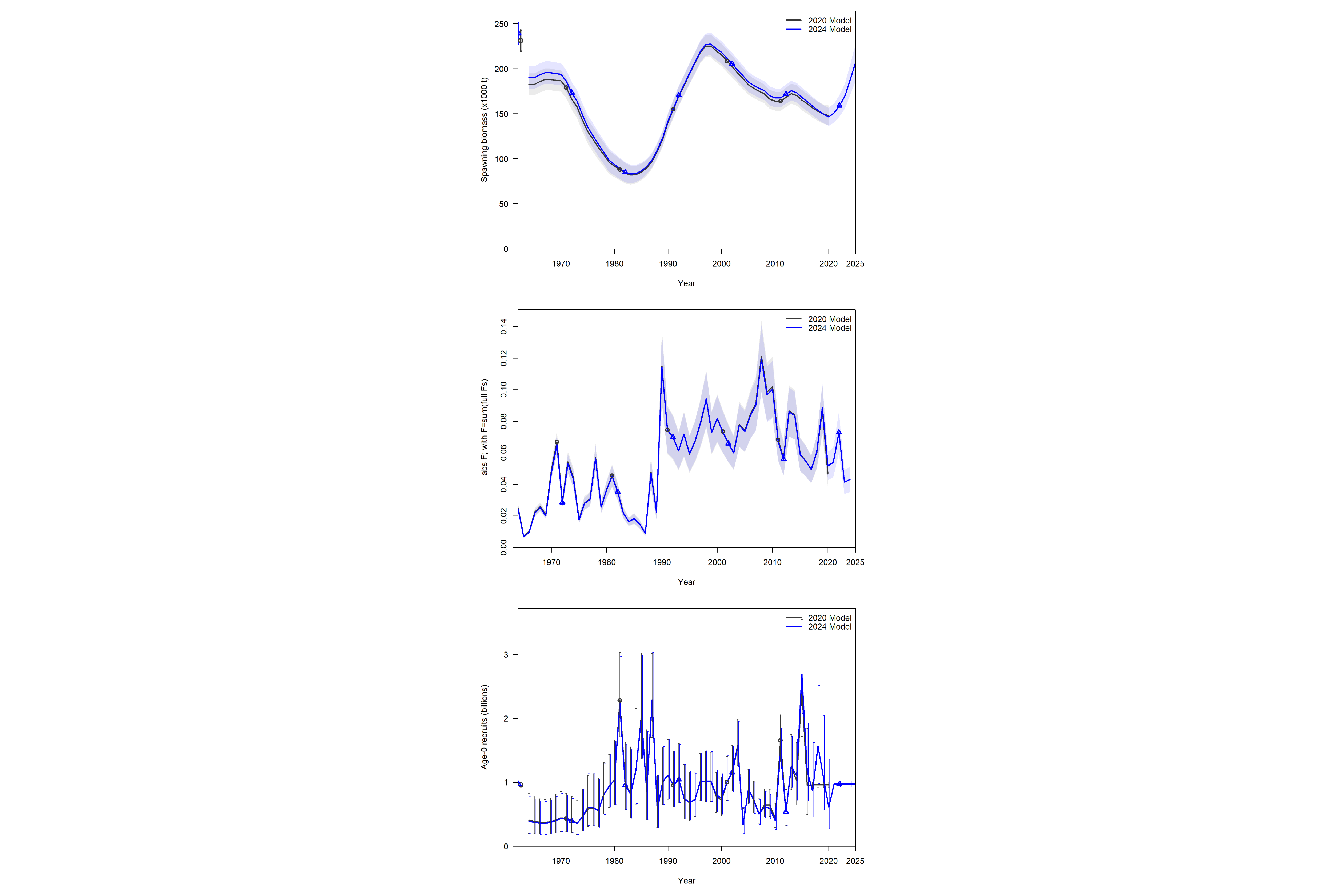


Figure 9.9. Comparison of spawning biomass, fishing mortality rates, and recruitment for the 2024 Update model (blue) and 2020 Full model (grey). The shaded ribbon represents the 95% quantile.

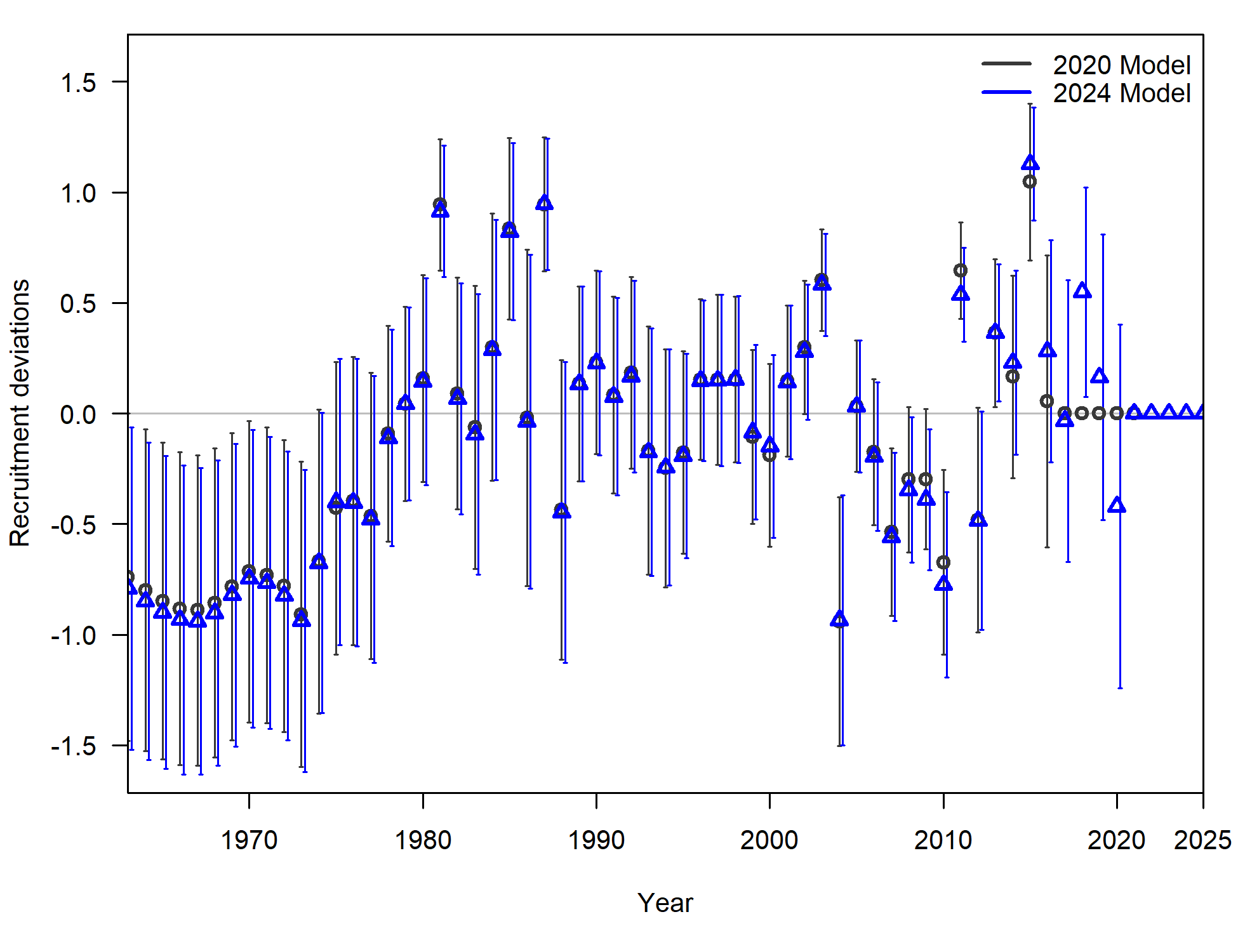


Figure 9.10. Time series of recruitment deviations, from the 2024 base model (blue) and 2021 base model (grey), with 95% intervals.

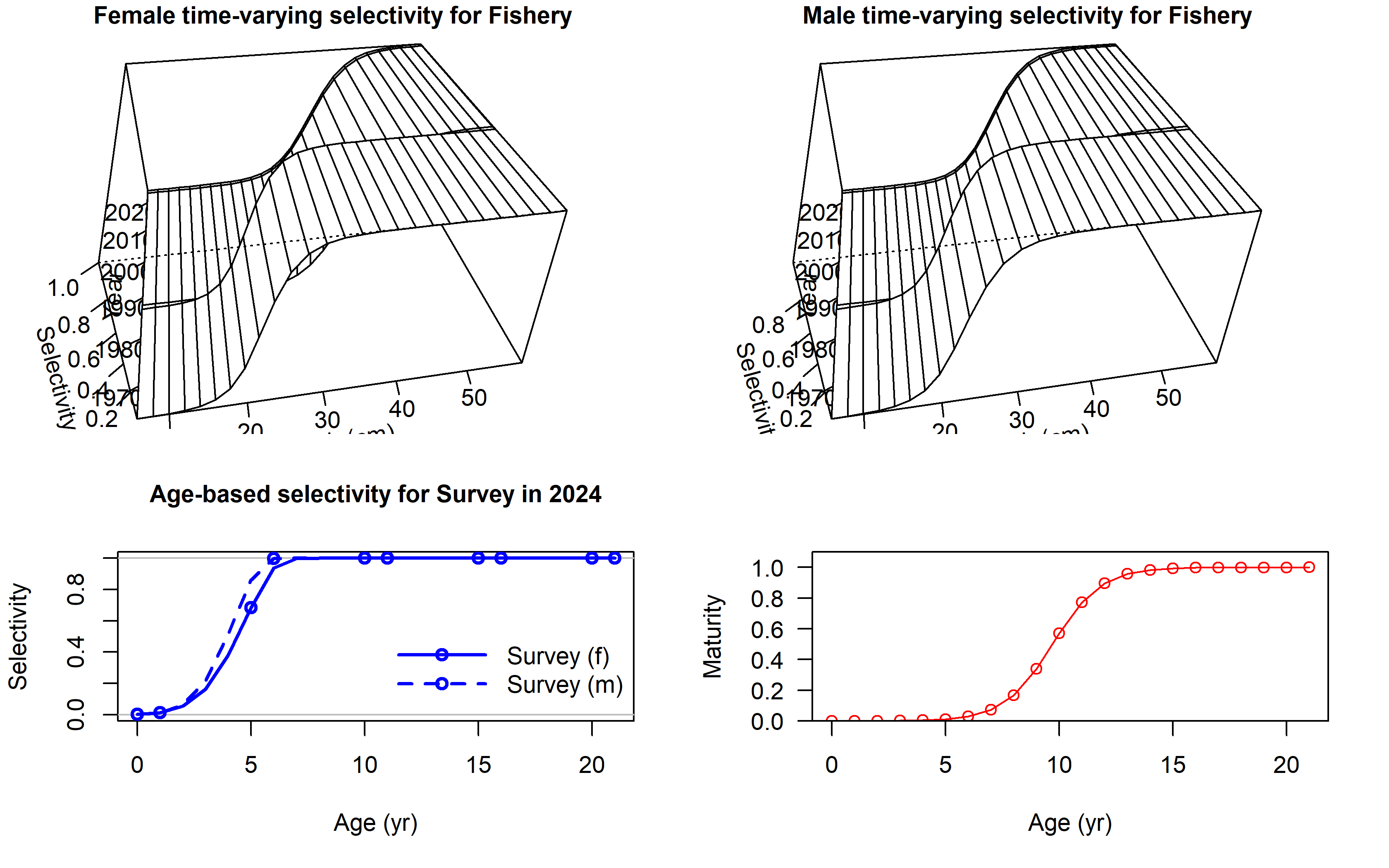


Figure 9.11. Estimated length- or age-based selectivity curves, and female maturity-at-age for BSAI FHS.

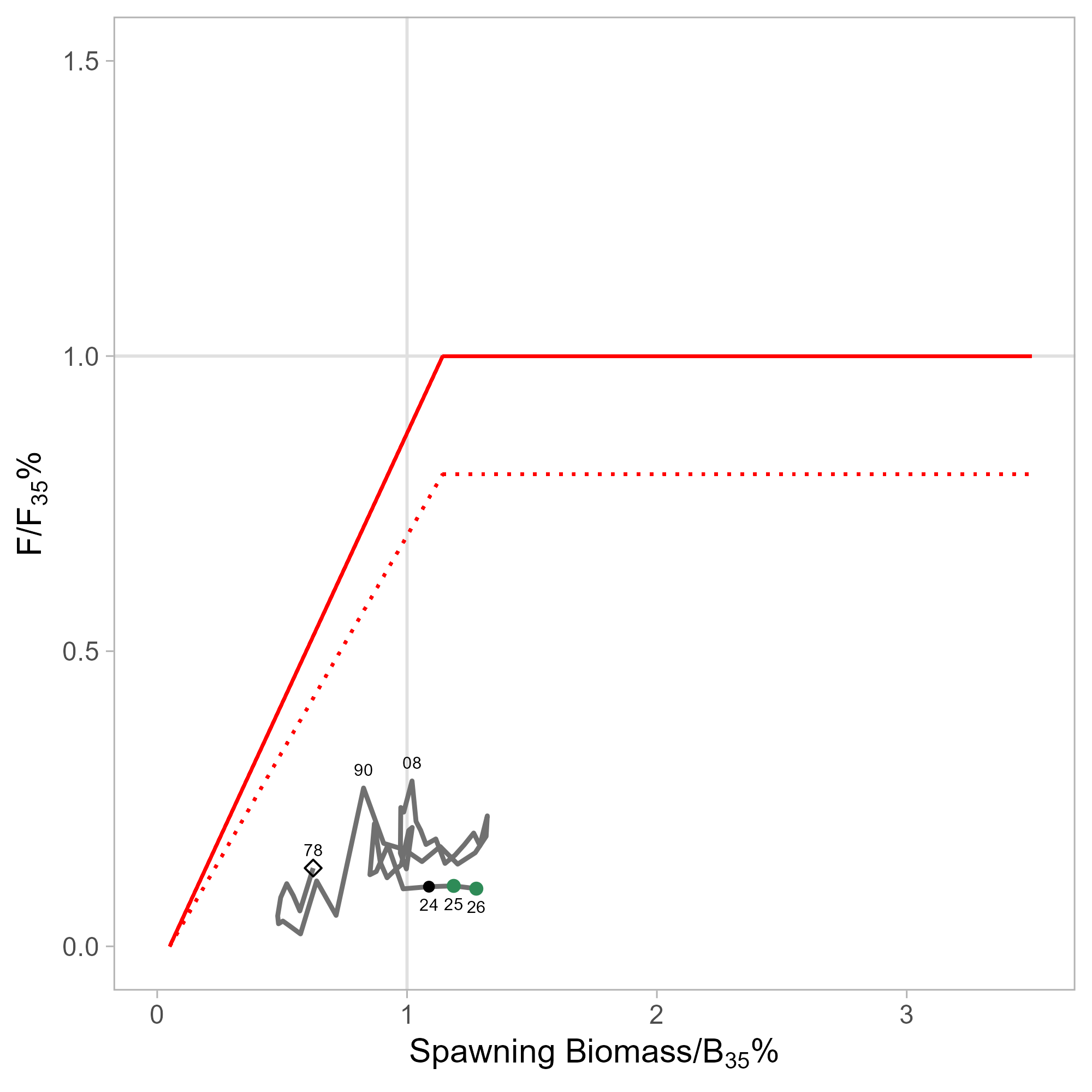


Figure 9.12. Time series of estimated fishing mortality versus estimated spawning stock biomass (phase-plane plot) for 1978-2026, including applicable OFL and maximum FABC definitions for the stock, including 2 years of projected values. Target levels correspond to B35% and F35% for author recommended model.