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

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Executive Summary

Summary of Changes in Assessment Inputs

The following substantive changes have been made to the BSAI yellowfin sole assessment relative to the 2023 Bering Sea and Aleutian Islands (BSAI) SAFE report.

Changes in the data

1. The model-based survey age compositions were updated with data through 2023, and mean survey weight at age was added for 2023.
2. The estimate of the total catch made through the end of 2023 was updated, and the 2024 catch was extrapolated based on the catch through October 1, and the mean proportion caught for the remainder of the year over the past 5 years.
3. The 2024 model-based estimate of the combined EBS and NBS NMFS survey biomass and standard error (1982-2024) were used.

Changes in the assessment methods

There has been no change in the assessment methodology since 2023.

Summary of Results

The model presented in this assessment includes interpolated survey bottom temperature within the summer bottom trawl area < 100 m as a covariate on survey catchability, as well as National Marine Fisheries Service eastern Bering Sea survey start date and the interaction of start date and temperature (Nichol et al. 2019). Female natural mortality was fixed at 0.12 while allowing the model to estimate male natural mortality. The model uses model-based vector autoregressive spatio-temporal (VAST) survey indices and age compositions from the combined EBS and NBS survey areas.

In the eastern Bering Sea (EBS) bottom trawl survey conducted in 2024, the EBS yellowfin sole model-based biomass estimate was 7% higher than estimated for 2023, at 2,022,780 t. Spawning biomass estimated by Model 23.0 for 2025 was 1.56 * B_{MSY}. The 2025 B_{MSY} was 479,711 t and female spawning biomass was 748,076 t. Therefore, yellowfin sole continues to qualify for management under Tier 1a. The 1978-2018 age-1 recruitments and the corresponding spawning biomass estimates were used to fit the stock recruitment curve and determine the Tier 1 harvest recommendations. Tier 3 estimates were also calculated, which is typical for this assessment. This assessment updates last year's model with total and spawning biomass estimates for

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

Note: Projections were based on estimated catches of 74,288 t in 2024 and 116,803 t used in place of maximum ABC for 2025. This estimate was based on the mean catch over the past 5 years, 2020 - 2024, which includes the extrapolated catch of 74,288 t for 2024.

2025 that are lower than the 2023 estimates for 2025. This year's recommended ABC and OFL are lower than the 2023 assessment, coincident with decreased estimates of total and spawning biomass.

Catch of yellowfin sole as of October 1, 2024 in the Bering Sea and Aleutian Islands was 59,044 t. Over the past 5 years (2019 - 2023), approximately 79.5% of the catch has taken place by this date. Therefore, the full year's estimate of catch in 2024 was extrapolated to be 74,288 t. This is lower than the average catch over the past ten years, 123,905 t. For projections, future catch for the next 10 years, 2025 - 2034, was estimated to be the mean of the catch from the past five years, 2020 - 2023, and the extrapolated full year's catch for 2024, which resulted in an estimate of 116,803 t, used in place of maximum ABC for 2025.

Yellowfin sole female spawning biomass continues to be above B_{MSY} and the annual harvest remains below the ABC level. Management quantities are given in the results summary table for the 2023 accepted model (Model 23.0) with data through 2024. The projected estimate of total biomass for 2025 was lower by 12% from the 2023 assessment of 2,616,800 t, to 2,308,550 t. The model projection of spawning biomass for 2025, assuming catch for 2024 as described above, was 748,076 t, 13% lower than the projected 2025 spawning biomass from the 2023 assessment of 857,354 t. The 2025 and 2026 ABCs using F_{ABC} from this assessment model were lower than last year's 2025 ABC of 276,917 t; 262,557 t and 267,639 t. The 2025 and 2026 OFLs estimated by Model 23.0 were 299,247 t and 305,039 t.

All Risk Table elements were rated as level 1, "No concern". There were no recommended reductions in ABC.

Responses to SSC and Plan Team comments on Assessments in General

SSC October 2023

When there are time-varying biological and fishery parameters in the model, the SSC requests that a table be included in the SAFE that documents how reference points are calculated.

Response

This table has been included (Table 4.1), and calculation of reference points with time-varying parameters is included in the Analytical Approach section.

SSC October 2023

The SSC is encouraged by the development of One-Step-Ahead (OSA) residuals as an improvement to Pearson residuals for assessing fits to compositional data. The SSC welcomes a presentation on their use and interpretation, as well as a discussion of how to select one age to remove from the calculation. The SSC recognizes that the first and last age in many assessments prove challenging to fit, and therefore are the target of specific evaluation of residuals, making it problematic to remove them. The SSC encourages exploration of alternative approaches that may include calculating the OSA residuals with multiple ages removed one at a time and/or adding a compositional bin (e.g., age-1 if the first age with appreciable data is age-2). Another approach to consider would be a two-step process, producing the OSA residuals with the youngest age removed, then using those residuals to identify the best fitting age, then removing that age in the next step.

Response

For consistency, all authors at the AFSC remove the last age/length bin, which provides consistency with other NOAA stock assessment groups. Misfit in the dropped bin is still present in the residuals, but active research is ongoing for best practices for OSAs with composition data at the AFSC. We plan to continue with this approach until research indicates otherwise. OSA residuals are included in this assessment.

SSC December 2023

The SSC reiterates that only fishery performance indicators that provide some inference regarding biological status of the stock should be used. SSC recommendation #5 from page 34 of the June 2021 SSC report states: "The SSC recommends that the fishery/community performance column should focus on information that would inform the biological status of the resource (e.g., an unexplained drop in CPUE that could indicate un-modelled stock decline, or a spatial shift indicating changes in species' range), and not the effects of proposed ABCs on the fishery or communities or bycatch related considerations. The SSC recognizes that the community impact information is critical for informed decision making for TAC setting and recommends this information be included in other Council documents…". Examples of useful indicators include CPUE, fishery spatial and temporal patterns, and catches of thin or unhealthy fish (i.e., poor condition).

Response

Noted.

SSC December 2023

When risk scores are reported, the SSC requests that a brief justification of the score be provided, even when that score indicates no elevated risk.

Response

Noted.

Responses to SSC and Plan Team comments specific to this assessmemt

SSC December 2023

The SSC requests that the authors update the Analytical Approach section of the SAFE document to clearly describe both (1) how sex-structured population dynamics are represented within this model including assumptions about the sex ratio at recruitment, and (2) describe the likelihood functions that are used to fit this model to data and specifically whether the survey and fishery age composition proportions are assumed to sum to 1.0 across ages within sexes or across ages and sexes. The SSC suggests that greater transparency in methods will help identify how much information on sex ratio at age is being provided to the model.

Response

This has been provided in the Analytical Approach section.

SSC December 2023

The SSC supports the November 2023 BSAI GPT recommendations for the author to conduct a model sensitivity analysis to evaluate the current approach used for natural mortality. The SSC suggests an evaluation of whether it is possible to estimate sex-specific natural mortality, and an evaluation of whether this approach is a significant improvement overestimating a single natural mortality for both sexes.

Response

This will be conducted in a future assessment.

SSC December 2023

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

Yellowfin sole length-weight residuals have been declining in the northern Bering Sea since 2019 but are above average (overall) in the EBS, based on 2024 data. In the EBS, even though overall the residuals are positive, they are 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).

SSC December 2023

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 (Figure 4.2). The fishery is unlikely to select this year class until approximately 2024 (not yet aged) or 2025.

SSC December 2023

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.

SSC December 2023

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.

SSC December 2023

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.

SSC December 2023

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 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).

Introduction

Yellowfin sole (*Limanda aspera*) are one of the most abundant flatfish species in the eastern Bering Sea (EBS) and the largest flatfish fishery off Alaska. Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approx. lat. 49°N) to the Chukchi Sea (approx. lat. 70°N) and south along the Asian coast off the South Korean coast in the Sea of Japan (approximately lat. 35°N). Their abundance in the Aleutian Islands region is considered low to negligible.

Adults exhibit a benthic lifestyle and occupy separate spawning areas in winter and feeding distributions in summer on the eastern Bering Sea shelf, Wakabayashi 1989). Adults begin a migration from over-wintering grounds near the shelf margins (>100 m) onto the inner shelf (15-75 m) in April or early May each year for spawning and feeding. Adults migrate back offshore in fall and winter as a response to ice cover/cold water of the inner and central shelf water in winter (Bakkala 1979). Young yellowfin sole remain in the shallow nearshore nursery areas throughout their first few years of life. They begin to disperse offshore age 3-5, and by 5-8 years they follow adult migratory patterns (Bakkala 1979). The maximum age observed in yellowfin sole is 43 for females and 38 for males.

Year-class strength of flatfishes is thought to be determined during the first few years of life between the pelagic egg and benthic settlement (van der Veer et al., 2015). Temperature in the early life stages can affect egg size, larval duration, size at settlement, as well as the size of suitable nursery habitat (Yeung and Cooper 2019). It has been hypothesized that colder bottom temperatures delay migration and spawning in yellowfin sole. As a result, mature individuals may reside in nearshore nursery grounds during months in which the NMFS survey occurs, which likely decreases survey biomass estimates during cold years (Nichol et al., 2019; Yeung and Cooper 2019).

Yellowfin sole may be less sensitive to temperature due to their settlement timing, relative to northern rock sole, which seems to be sensitive to temperature. Yellowfin sole settle later in summer, when the influence of the cold pool is weaker and nearshore bottom temperature is relatively stable and high (Yeung and Yang, 2018). In contrast, yellowfin sole migrate across the shelf to spawn near their nursery habitat, rather than relying on currents for larval transport to nursery habitat (Nichol and Acuna, 2001); therefore, their larvae may be less susceptible to variable currents (Yeung and Cooper 2019).

There appear to be several distinct stocks, although the genetic basis remains to be determined. The stocks are referred to as the Unimak group, the Pribilof-west group, and the Pribilof-east group (Figure 4.3). Yellowfin sole are managed as a single stock in the BSAI management area as there is presently no direct evidence of stock structure.

Fishery

Yellowfin sole has been targeted with bottom trawls on the Bering Sea shelf since the fishery began in 1954. It was overexploited by foreign fisheries in 1959 - 1962 when catches averaged 404,000 t annually (Figure 4.4, top panel). Catch is typically taken throughout the Bering Sea shelf, as far north as 65°N and low to negligible amounts are taken in the Aleutian Islands (Figure 4.5). Catches declined to an annual average of

117,800 t from 1963 - 1971 and further declined to an annual average of 50,700 t from 1972 - 1977. The lower yield in this latter period was partially due to the discontinuation of the Union of Soviet Socialist Republics (U.S.S.R.) fishery. In the early 1980s, after the stock condition had improved, catches again increased reaching a peak of over 227,000 t in 1985.

During the 1980s, there was also a major transition in the characteristics of the fishery. Yellowfin sole were traditionally taken exclusively by foreign fisheries and these fisheries continued to dominate through 1984. However, U.S. fisheries developed rapidly during the 1980s in the form of joint ventures, and during the last half of the decade began to dominate and then take all of the catch as the foreign fisheries were phased out of the Eastern Bering Sea. Since 1990, only domestic harvesting and processing has occurred.

The management of the yellowfin sole fishery changed significantly in 2008 with the implementation of Amendment 80 to the BSAI Fisheries Management Plan. The Amendment directly allocated fishery resources among BSAI trawl harvesters in consideration of their historic harvest patterns and future harvest needs to improve retention and utilization of fishery resources by the non-AFA (American Fisheries Act) trawl catcher/processor fleet. This was accomplished by extending the groundfish retention standards to all H&G (headed and gutted, fish are processed with heads and viscera removed) vessels and also by providing the ability to form cooperatives within the newly formed Amendment 80 sector. In addition, Amendment 80 also mandated additional monitoring requirements which included observer coverage on all hauls, motion-compensating scales for weighing samples, flow scales to obtain accurate catch weight estimates for the entire catch, no mixing of hauls and no on-deck sorting. The partitioning of TAC (total allowable catch) and PSC (prohibited species catch) among cooperatives has significantly changed the way the annual catch has accumulated (Figure 4.4, lower panel) and the rate of target catch per bycatch ton. There is now a more even and slow attainment of the annual catch relative to the pre-Amendment 80 fishing behavior.

In 2010, following a comprehensive assessment process, the yellowfin sole fishery was certified under the Marine Stewardship Council environmental standard for sustainable and well-managed fisheries. The certification also applies to all the major flatfish fisheries in the BSAI and GOA.

In 2011, federally permitted vessels using non-pelagic trawl gear whose harvest resulted in flatfish retained catch that was greater than any other retained fishery category were required to use modified trawl gear. The modifications required the use of elevating devices to raise the section of the trawl warps between the doors and the trawl wing tips by 2.5 inches off the seafloor. The purpose of the management action was to reduce damage of non-target animals, particularly those that form habitat structure or support other fisheries while not substantially reducing flatfish catch rates or causing gear handling problems (Rose et al. 2010).

Yellowfin sole are typically headed and gutted, frozen at sea, and then shipped primarily to China and South Korea. Reprocessed yellowfin sole from China may also be sold to Japan, US, and Europe as fillets, among other countries (AFSC 2016). The 1997 catch of 182,814 t (retained and discarded) was the largest since the fishery became completely domestic, but decreased from 1998–2010, averaging 94,004 t (Table 4.2, Table 4.3). From 2011-2014 the catch increased, averaging 155,000 t. The 2013 catch totaled approximately 182,814 t (73% of the ABC), and was the highest annual catch since 1988. Catches have declined since 2013 and the average catch over the past ten years was 123,905 t. The full year's estimate of catch in 2024 was 74,287 t. This estimate was based on catch data downloaded October 1, 2024, and projected forward through the remainder of the year. This estimate represents 26.83% of the 2023 ABC.

Length distributions of yellowfin sole throughout NMFS areas 509, 513, 514, 516, 521, and 524 ranged from 20-50 cm, and were largest in the northern areas 514, 521, and 524 (Figure 4.6).

The CPUE shows a negative correlation with bottom temperature, with increased CPUE in 2022, which was a cooler/average year in the Bering Sea. This relationship does not appear to be strong in all years, including 2023 and 2024, in which temperature was lower but CPUE was down.

Bycatch of yellowfin sole takes place primarily in the directed rock sole fishery, followed by the flathead sole fishery, and smaller amounts in the pollock fisheries (Table 4.4). Catch by month and gear indicates that trawl catches were typically more inshore, while longline gear targeted yellowfin sole along the Bering Sea shelf (Figure 4.7, Figure 4.8). With both geartypes, some of the highest catches took place during spawning season (summer months).

Data

The data used in this assessment include estimates of total catch, bottom trawl survey biomass estimates and their 95% confidence intervals, catch-at-age from the fishery, eastern Bering Sea survey bottom temperatures <100 m, and population age composition estimates from the bottom trawl survey. Weight-at-age and proportion mature-at-age from studies conducted during the bottom trawl surveys were also used. Estimates of fishery weight-at-age were based on catch-at-age methodology used in the walleye pollock assessment (Ianelli et al. 2019), following Kimura (1989) and modified by Dorn (1992). This year there were 635 ages available for the VAST age compostion estimates, but the 316 ages from the NBS survey were not read early enough to be incorporated. The 2023 fishery ages were not read prior to this assessment.

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

Fishery

Age Determination

Yellowfin sole ages have been determined at the AFSC by using the break and burn method on otoliths collected in surveys and from fisheries since 1979. In 2016 the age determination methods for yellowfin sole were validated using the bomb-produced uptake measurement of 14C method (Kastelle et al. 2016). There have been an average of 721 fish aged on EBS trawl surveys since 1982 and 735 fish aged from fishery collections during that time period (Table 4.5). The number of hauls which from which otoliths have been taken from the survey has averaged 46 per year (Table 4.5).

Trends for males and female ages from the fishery indicate that the 2010 year class has been the dominant cohort and the 2015 age class may be entering the fishery as a new dominant cohort at age 7 (Figure 4.9). Survey age data shows a different trend, likely due to higher survey selectivity at younger ages. Survey age data indicates an extremely strong 2017 year class has appeared (Figure 4.2) and persists through age data for 2023, and is expected to appear in fishery age data for 2024 or 2025.

Catch

This assessment uses fishery catch data from 1954-2024 (Table 4.2), and estimates fishery catch-at-age (proportions) from 1975 -2023 (Table 4.6). Removals from sources other than those that are included in the Alaska Region's official estimate of catch including removals due to scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs are tabulated and presented in Table 4.7. Catch per unit effort calculated from fishery trawl data, based on the catch in kg and duration of the tow, does not indicate a strong upward or downward trend through the time series, 1996 - 2024 for vessels >125 feet (Figure 4.10), although 2022 showed an increase, and 2023 through 2024 appeared back to a relative mean value. Vessels <125 feet appear to have increased CPUE through time.

Numbers at age

The proportion of length at age is taken from aged fishery otoliths. The fishery age composition has always been primarily composed of fish older than 9 years with a large amount of 20+ fish, although the proportion has declined from 90% over age 7 to 70% over age 7 since the 1970's (Table 4.6). The years 2021 and 2022 show the lowest proportions over age 7 (69%) while the most recent year of data (2023) shows an increase to 73%.

Weight-at-age

The fishery weight-at-age composition was based on the catch-at-age methodology of Kimura (1989) and modified by Dorn (1992), as implemented in the 2019 walleye pollock stock assessment (Ianelli et al. 2019). Length-stratified age data were used to construct age-length keys for each stratum and sex. These keys are then applied to randomly sampled catch length frequency data. This method was used to derive the age compositions from 1991–2022 (the period for which all the necessary information was readily available). The catch-at-age estimation method uses a two-stage bootstrap resampling of the data with 1,000 bootstraps. Observed tows were first selected with replacement, followed by resampling actual lengths and age specimens given that set of tows. This method allows an objective way to specify the effective sample size for fitting fishery age composition data within the assessment model. Estimates of fishery mean weights-at-age are a product of this analysis and these were used as input data to the model (Figure 4.11).

Maturity-at-age

Nichol (1995) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys (Table 4.8). Maturity was re-evaluated from a histological analysis of ovaries collected in 2012 (Table 4.8). Results were very similar to the earlier study with only a 2% difference in estimates of yellowfin sole female spawning biomass (TenBrink and Wilderbuer 2015). The current maturity schedule uses estimates derived from both the 1992 and the 2012 collections (Table 4.8). For yellowfin sole sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole females are 82% selected to the fishery by age 10 whereas they have been found to be only 40% mature at this age.

A new study was published in 2022 which provided a new analysis of the maturity-at-age schedule of 209 yellowfin sole samples taken from the northern Bering Sea (TenBrink 2022). The maturity curve resulting from this study was very similar to that of previous studies ($A_{50\%}$ 95% confidence interval: 9.47–10.76 years). This maturity curve was not incorporated into the 2024 assessment because samples were taken from the northern Bering Sea only, but this information may be incorporated into a future assessment model.

Survey

Eastern Bering Sea bottom temperature

The eastern Bering Sea bottom temperatures <100 m were computed within the R package coldpool (https://github.com/afsc-gap-products/coldpool; Rohan et al., in review). Temperatures in 2024 were lower than in 2023 and slightly below the mean for the time series (Figure 4.10).

Length and Weight-at-Age

Sex-specific size at age used in the model is based on the length-weight relationships from the time-series of survey observations over all years since 1971. The use of empirical annual observed population mean weight-at-age (time-varying) from the trawl survey allows for time-varying (year effect on growth) in the age-structured stock assessment model. We have found that weight-at-age has increased over the time series, and the most recent estimates are among the highest observed (Figure 4.12). In the future, this relationship may be used to forecast growth patterns; however, the use of empirical weight at age provides the changes over time directly into the model.

Survey Biomass Estimates and Population Age Composition Estimates

Indices of relative abundance available from AFSC surveys showed high NMFS surveys biomass estimates in the 1980s (Table 4.9. High levels of biomass in the late 1970s have been documented through Japanese commercial pair trawl data and catch-at-age modeling in past assessments (Bakkala and Wilderbuer 1990). Average survey CPUE for yellowfin sole has fluctuated from approximately 2,500-7,500 kg/km^2 over the eastern Bering Sea time survey from 1982-2024 (Figure 4.13). The CPUE for 2024 was the third lowest in the time series, at 3,153 kg/km^2. The lowest occurred in 1999, 2,524 kg/km^2, which corresponded to the lowest survey biomass estimate for yellowfin sole in the eastern Bering Sea, and this year's estimate represents an increase from 2023.

Biomass estimates for yellowfin sole from the annual bottom trawl survey on the eastern Bering Sea shelf showed a doubling of survey biomass between 1975 and 1979 with a further increase to over 3.3 million t in 1981 (Table 4.10 and Figure 4.14). Total survey abundance estimates fluctuated from 1983 to 1990 with biomass ranging from as high as 3.5 million t in 1983 to as low as 1.9 million t in 1986. Biomass estimates since 1990 indicate an even trend at high levels of abundance for yellowfin sole, with the exception of the results from the 1999 and 2000 summer surveys, which were at lower levels. Surveys from 2001-2005 estimated an increase each year but the estimates since 2006 indicate a stable level with some annual variability. However, the 2012 estimate is a 19% decrease from 2011 and the 2013 and 2014 surveys have estimated a 17% increase over 2012. Similarly, there was a 24% decrease from 2014 to 2015 followed by a 48% increase from 2015 to 2016, the highest biomass estimate since 1984. Fluctuations of these magnitudes are unreasonable considering the elements of slow growth and long life span of yellowfin sole combined with low to moderate exploitation rate, characteristics which should produce more gradual changes in abundance (Table 4.9).

The 2024 EBS trawl survey estimate for yellowfin sole biomass was and increase from the 2023 estimate, which represented the second lowest from the time series. Overall, a declining pattern has been observed since 2016 (Table 4.9, Figure 4.14), in addition to a longer term declining pattern since 2005. Similarly, in the northern Bering Sea, yellowfin sole biomass estimates were the lowest in the time series in 2023 at 2,023 t (Table 4.11).

The center of gravity for yellowfin sole moved west in the late 2010s before moving eastward during the past several years, while a northward trend in the center of gravity occurred between 2014 and 2023 and has moved southward in 2024 (Figure 4.15). The VAST analysis indicates that the total effective area occupied by yellowfin sole has decreased since a peak in 2018. The effective area occupied in the eastern Bering Sea has been declining since 2018 and the area occupied in the northern Bering Sea has been on a slowly increasing trend over most of the time series since 2000 (Figure 4.16).

Variability of yellowfin sole survey biomass estimates (Figure 4.14) is in part due to the availability of yellowfin sole to the survey area (Nichol 1998, Nichol et al. 2019). Yellowfin sole are known to undergo annual migrations from wintering areas off the shelf-slope break to near shore waters where they spawn throughout the spring and summer months (Nichol 1995; Wakabayashi 1989; Wilderbuer et al. 1992). Exploratory survey sampling in coastal waters of the eastern Bering Sea during early summer indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey than in the survey proper. Commercial bottom trawlers have commonly found high concentrations of yellowfin sole in areas such as near Togiak Bay (Low and Narita 1990) and in more recent years from Kuskokwim Bay to just south of Nunivak Island. The coastal areas are sufficiently large enough to offer a substantial refuge for yellowfin sole from the current survey.

Experiments examining the bridle efficiency of the Bering Sea survey trawl indicate that yellowfin sole are herded into the trawl path from an area between the wing tips of the net and the point where the bridles contact the seafloor (Somerton and Munro 2001). The herding experiments suggest that the survey trawl vulnerability (a component of catchability) is greater than 1.0. In a previous assessment, the likelihood profile of q from the model indicated a small variance with a narrow range of likely values with a low probability of q being equal to the value of 1.0 (Wilderbuer and Nichol 2003).

Survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 2019); estimates have generally been lower during cold years. The 1999 survey, which was conducted in exceptionally cold waters, indicated a decline in biomass that was unrealistic. The bottom temperatures during the 2000 survey were much warmer than in 1999, and the biomass increased, but still did not approach estimates from earlier years. Average bottom temperature and biomass both increased again during the period 2001 − 2003, with the 2003 value the highest temperature and biomass observed over the 22 year time series up to that time. Given that both the 1999 and 2000 surveys were conducted two weeks earlier than previous surveys, it is possible that the time difference may also have also affected the availability of yellowfin sole to the survey. If, for example, the timing of peak yellowfin sole spawning in nearshore waters corresponded to the time of the survey, a greater proportion of the population would be unavailable to the standard survey area. This pattern was observed again in 2009 and 2012 when the temperatures and the bottom trawl survey point estimates were lower. Summer shelf bottom temperatures in 2012 were the 2nd coldest recorded by the survey and the time-series and resulted in a 19% decline from 2011. Temperatures in the Bering Sea have been higher than the mean since 2013 (Figure 4.17), and the 2016 estimate of biomass was the highest in 32 years and 48% higher than the 2015 estimate. In the current year, 2024, survey biomass estimates were up for the EBS (Table 4.9, and there was no 2024 NBS survey Table 4.11). The combined EBS+NBS VAST estimate for 2024 resulted in a shift downward for the entire time series (Figure 4.18), which resulted in lower estimates of biomass and reference points.

We propose several reasons why survey biomass estimates are often lower during years when bottom temperatures are low. First, catchability may be lower because yellowfin sole may be less active when cold. Less active fish may be less susceptible to herding and more likely to escape under the foot rope of survey gear. Secondly, bottom temperatures may influence the timing of the inshore spawning migrations of yellowfin sole and therefore affect their availability to the survey area (Nichol et al. 2019). Because yellowfin sole spawning grounds include nearshore areas outside the survey area, availability of fish within the survey area can vary with the timing of this migration and the timing of the survey. In the case of 2016, a very warm year in the Bering Sea, it appears that a higher portion of the adult biomass was distributed on the shelf (outside of the spawning areas) relative to the average of all previous survey years, indicating earlier spawning migration. Third, yellowfin sole growth appears to be correlated with temperature, as can be seen with greater length anomalies of 5 year old males in females in warm years and smaller lengths in cold years (Figure 4.17). Temperatures have been lower since 2022 after a decade of anomalously high temperatures, and biomass estimates have also declined from the long-term mean (Figure 4.18, Figure 4.19).

Yellowfin sole population numbers-at-age are estimated based on otolith collections from annual EBS bottom trawl surveys Table 4.12. The occurrence of yellowfin sole in trawl survey hauls and associated collections of lengths and age structures since 1982 have not changed significantly (Table 4.5). The number of hauls from which age structures have been collected increased in 2021 when otolith collections changed from stratified to random. The total tonnage caught in the resource assessment surveys since 1982 is listed in Table 4.7.

The survey age data from 2021 through 2023 indicate that the dominant age class was spawned in 2017 (Figure 4.2). This appears to be a significant age class that may have contributed to the increase in biomass in 2024.

Northern Bering Sea survey

Trawl survey sampling was extended to the northern Bering Sea in 2010, 2017, 2018, 2019, 2021, 2022, and 2023. The trawl surveys conducted in 2010, 2017, 2019, 2021, 2022, and 2023 occupied the same areas with similar sampling densities. The 2018 survey was a reduced effort and only sampled a subset of the northern Bering Sea. Stations in 2018 were 30 nautical miles apart (instead of 20 nm) and excluded Norton Sound and inshore areas north of Nunivak Island. For comparison among years, 2018 biomass estimates were derived by truncating the areal coverage of the 2010 and 2017 surveys to include only the area covered in 2018 that was common to all three surveys, and this was treated as a single stratum. This truncated area was 158,286 square kilometers (compared to 200,207 square kilometers in 2010 and 2017). There has been an increase in the biomass estimate of yellowfin sole in the northern Bering Sea since 2010, but it decreased from 2022 to 2023. Large shifts in the abundance of yellowfin sole into the Bering Sea have not been observed. The center distribution of yellowfin sole may be related to temperature, as northward shifts were concurrent with anomalously warm temperatures 2014-2021, followed shifts southward during recent years of cooler temperatures (Figure 4.15. The spatial distribution of the yellowfin sole stock in the eastern and northern Bering Sea appears continuous, and the survey data from the region occupied by the entire population has been included since 2022.

Norton Sound survey

A time series based on an ADF&G survey in Norton Sound confirmed that the biomass of yellowfin sole has increased over time. The mean CPUE of yellowfin sole in Norton Sound increased from a mean CPUE of 278 kg/hectare over the first five survey years (1996 through 2018) to a mean CPUE of 605 kg/hectare over the last four survey years (2019, 2020, 2021, and 2023) (Figure 4.20). There was no Norton Sound survey in 2022.

VAST abundance

The software versions of dependent programs used to generate model-based estimates were equivalent or later than these minimum standards: R (4.0.2), MKL libraries via Microsoft R Open (4.0.2), INLA (21.11.22), Matrix (1.4-0), TMB (1.7.22), VAST (3.9.0), cpp VAST_v13_1_0, FishStatsUtils (2.10.0), DHARMa (0.4.5).

For model-based indices in the Bering Sea, we fitted observations of biomass per unit area from all grid cells and corner stations in the 83-112 bottom trawl survey of the EBS, 1982-2023, including exploratory northern extension samples in 2001, 2005, 2006, as well as 83-112 samples available in the NBS in 1982, 1985, 1991, 2010, 2017-2019, and 2021-2024 surveys. Assimilating these data therefore required extrapolating into unsampled areas. This extrapolation was facilitated by including a spatially varying response (Thorson 2019a) to the mean bottom temperature for EBS shelf strata with bottom depth <100 m (excluding northwest strata 82 and 90) from an interpolated temperature product computed using the *coldpool* R package. This spatially varying response was estimated for both linear predictors of the delta-model, and detailed comparison of results for EBS pollock has shown that it has a small but notable effect on these indices and resulting stock assessment outputs (O'Leary et al. 2020). All models were fitted in the *VAST* R package (Thorson and Barnett 2017; Thorson 2019b).

We used a Poisson-link delta-model (Thorson 2018) involving two linear predictors, and a gamma distribution to model positive catch rates. We extrapolated population density to the entire EBS and NBS in each year, using AFSC GAP-vetted extrapolation grids within FishStatsUtils. These extrapolation grids are defined using 3705 m (2 nmi) × 3705 m (2 nmi) cells; this results in 36,690 extrapolation-grid cells for the eastern Bering Sea and 15,079 in the northern Bering Sea. We used bilinear interpolation to interpolate densities from 750 "knots" to these extrapolation grid cells; knots were approximately evenly distributed over space, in proportion to the dimensions of the extrapolation grid. We estimated geometric anisotropy (how spatial autocorrelation declines with differing rates over distance in some cardinal directions than others) and included a spatial and spatio-temporal term for both linear predictors. To facilitate interpolation of density between unsampled years, we specified that the spatio-temporal fields were structured over time as initially as an AR(1) process (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). However, during initial model runs, the AR(1) correlation parameter rho was estimated to be close to 1 for the first linear predictor. As a result, the model was collapsed into a simpler structure by specifying rho = 1, i.e., modeling spatiotemporal variation as a random walk, for both linear predictors. We do not include any temporal correlation for intercepts, which we treated as fixed effects for each linear predictor and year. Finally, we used epsilon bias-correction to correct for retransformation bias (Thorson and Kristensen 2016).

We checked model fits for convergence by confirming that (1) the derivative of the marginal likelihood with respect to each fixed effect was sufficiently small (less than ~ 0.001) and (2) that the Hessian matrix was positive definite. We then checked for evidence of model fit by computing Dunn-Smyth randomized quantile residuals (Dunn and Smyth 1996) and visualizing these using a quantile-quantile plot within the *DHARMa* R package (Hartig 2021). We also evaluated the distribution of these residuals over space in each year, and inspected them for evidence of residual spatio-temporal patterns.

Model-based estimates for the entire time series will change slightly from year to year of new data, because of the AR1 correlation between spatiotemporal fields. In 2024 we did not conduct the NBS survey, so all NBS estimates are based on EBS survey estimates and the past spatial and temporal correlation between regions (Figure 4.21). Both the design and model-based estimate slightly increase for the EBS in 2024 and either slightly decline in the NBS or remain the same (Figure 4.18).

VAST estimates of age compositions

For model-based estimation of age compositions in the Bering Sea, observations of numerical abundance-at-age were fitted at each sampling location. This was made possible by applying a year-specific, region-specific (EBS and NBS) age-length key to records of numerical abundance and length-composition. These estimates were computed in VAST, assuming a Poisson-link delta-model (Thorson 2018) involving two linear predictors, and a gamma distribution to model positive catch rates. Density covariates were not computed in estimation of age composition for consistency with models used in the previous assessment and due to computational limitations. The same extrapolation grid was used as implemented for abundance indices, but here spatial and spatiotemporal fields were modeled with a mesh with coarser spatial resolution than the index model, using 50 knots. This reduction in the spatial resolution of the model, relative to that used abundance indices, was necessary due to the increased computational load of fitting multiple age categories and using epsilon bias-correction. The same diagnostics were implemented to check convergence and model fit as those used for abundance indices. The age composition estimates for the separate EBS and NBS regions are shown, but the combined were used in the assessment (Figure 4.22, Figure 4.23).

Data weighting

Model-based and VAST survey age composition data were weighted using the methodology of Francis (2011). Specifically, survey age composition data in Model 23.0 was initially weighted based on the number of hauls from which otoliths were collected. Stage 2 weighting was performed using Equation TA1.8 of Francis (2011) for three iterations. The mean survey age composition weights were used to weight fishery age composition data, as a constant annual value. The effective sample size weights for the fishery and survey are provided in Table 4.13.

Analytic Approach

General Model Structure

The abundance, mortality, recruitment and selectivity of yellowfin sole were assessed with a stock assessment model using the AD Model Builder language (Fournier et al. 2012; Ianelli and Fournier 1998). The model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information (Fournier and Archibald 1982). The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This was accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics was optimized by maximizing a log(likelihood) function given some distributional assumptions about the observed data.

The model includes starts in 1954 includes ages one through 20+. In the 20+ group, fish older than twenty are allowed to accumulate into an age category that includes fish of age twenty and older (20+). Since the sex-specific weight-at-age for yellowfin sole diverges after age of maturity (about age 10 for 40% of the stock), with females growing larger than males, the current assessment model is coded to accommodate the sex-specific aspects of the population dynamics of yellowfin sole. The model allows for the input of sex-specific estimates of fishery and survey age composition and weight-at-age and provides sex-specific estimates of population numbers, fishing mortality, fishery and survey age composition and allows for the estimation of sex-specific natural mortality and catchability. The model retains the utility to fit combined sex data inputs, and fishery and survey selectivity are not split by sex.

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

The AD Model Builder software fits the data components using automatic differentiation (Griewank 2000) software developed as a set of libraries (AUTODIFF C++ library).

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 1981 and 1982 indicate that the 83-112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-81. Allowing the model to tune to these early survey estimates would underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Although this underestimate would have little effect on the estimate of current yellowfin sole biomass, it would affect the spawner and recruitment estimates for the time-series. Hence, the pre-1982 survey biomass estimates were omitted from the analysis.

There are sex-specific parameters for length-weight relationships, weight-at-age (for fishery and survey), and proportions-at-age (for fishery and survey). The total proportion of males and female proportions at age sum to 1, and the total proportion of females and males sums to the proportion of each estimated in the population. The NBS+EBS survey proportion at age has been estimated using VAST since 2022. The catch-at-age methodology of Kimura (1989) was used to estimate mean fishery weights-at-age in the model, separately for males and females. As of 2023, selectivity is combined for males and sexes; they share the same selectivity parameters, as it was found to improve the fit to the data. Fishery selectivity is estimated annually while survey selectivity is constant over time. The initial male and female proportions at age are based on the mean initial proportions (a single estimated value), that is modified for each age by a vector of sex-specific initial devs. For the 20 years prior to the start year in the model, sex-specific natural mortality is applied to calculate numbers at age. In subsequent years, recruitment of males and females does not differ. Total biomass is the sum of male and female numbers at age, as are other derived quantities for the population.

Several aspects of the likelihood include male-and female- specific parameterization. The recruitment likelihood includes the initial male and female deviations as well as the combined recruitment deviations throughout the modeled time period. Finally, the age likelihood includes the fit to the fishery and survey age compositions, which are split by sex.

Total mortality Z in the model was modeled as the sum of fishing mortality F and natural mortality M, such that total mortality in year t at age a is $Z_{t,a} = F_{t,a} + M_x$. The subscript x refers to sex.

Fishing mortality at each year and age, $F_{t,a}$, was the product of age-specific fishing gear selectivity s_a and the median year-effect of fishing mortality μ^F, with normally distributed error,

$$F_{t,a} = s_a \mu^F e^{\epsilon_t^F}, \epsilon_t^F \backsim N(0, \sigma_F^2),$$

where ϵ_t^F is the residual year-effect of fishing mortality and σ_F is the standard deviation of fishing mortality. Age-specific fishing selectivity s_a was calculated using the logistic equation

$$s_a = \frac{1}{1 + e^{(-\alpha + age\beta)}}.$$

Catch in year t for age a fish $C_{t,a}$ (both sexes combined) was calculated:

$$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}(1 - e^{Z_{t,a}})N_{t,a},$$

where $N_{t,a}$ is the number of fish at time t, age a. Total catch in each year C_t was the sum of catch over all ages, $C_t = \sum_a C_{t,a}$, and the proportion at age in catch was $P_{t,a} = \frac{C_{t,a}}{C_t}$.

Recruitment from 1956-1977 was modeled as $N_{t,1} = R_t = R_0 e^{\tau_t}, \tau_t \backsim N(0, \sigma_R^2)$, where R_0 is the geometric mean of the modeled age 1 recruitment from 1956-1975, and σ_R is the standard deviation of recruitment.

Recruitment from 1978-2024 was determined using the Ricker stock recruitment curve,

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

where S is the spawning stock biomass (Ricker 1958). Parameters α and β were estimated by fitting spawning biomass and recruitment during the period 1978-2018, and are shown from Model 23.0 (Figure 4.24).

The number of fish in year $t + 1$ at age a was the number of fish in the previous year subjected to natural and fishing mortality,

$$N_{t+1,a+1} = N_{t,a} e^{-Z_{t,a}}.$$

The "plus group" included all fish age 20 and older included fish surviving from age 19 as well as those age 20 and higher,

$$N_{t+1,A} = N_{t,a}e^{-Z_{t,A-1}} + N_{t,A}e^{-Z_{t,A}}.$$

Spawning biomass was calculated as the product of weight-at-age and the number of mature females at each age,

$$S_t = \sum N_{t,a} W_{t,a} \phi_a,$$

where ϕ_a is the proportion of mature females at age a and $W_{a,t}$ is the mean body weight in kg of fish age a in year t. Survey biomass was assumed to be the product of catchability q, survey selectivity s_a, and the biomass,

$$Biomass_{survey,t} = q \sum N_{t,a} W_{t,a} s_a.$$

In the model, fishery selectivity is annually varying. The fishery selectivity estimate two years prior to the current year is used for MSY and reference-point calculations (2022 if the current year is 2024). Fishery selectivity is required to calculate yield per recruit and biomass per recruit, which are in-turn used to calculate maximum sustainable yield. Survey catchability is also annually varying, based on survey start date and bottom temperature. However, this parameter is not incorporated directly into reference point calculations (Table 4.1).

Description of Alternative Models

In this assessment we considered Model 23.0 used in the 2023 assessment updated with 2024 data. No alternative models are presented for management, but three models were included for comparative purposes to demonstrate the effect of 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.

Parameters Estimated Outside the Assessment Model

Weight at age

Parameters of the von Bertalanffy growth curve were estimated for yellowfin sole, by sex, from the trawl survey database::

Sex	L_{inf}	K	t_0	n
Males	34.03	0.161	0.515	656
Females	38.03	0.137	0.297	709

A sex-specific length-weight relationship was also calculated from the survey database using the power function, $Weight(g) = a * Length(cm)^b$, where a and b are parameters estimated to provide the best fit to the data.

Weight at age from the survey time series were evaluated as follows. Survey weights at age were available from 1984 through 2019 (19,074 records). Weight-at-age was calculated for all ages 1-19 as well as the age 20 plus group (all ages 20 and over). There were some gaps due to years in which no fish of a particular age had been collected. Where possible, these gaps were filled with survey length at age data converted to weight at age. Between 1971 through 2019, there were lengths associated with aged yellowfin sole for more years than weights. Lengths at age were converted to weights at age and used to fill gaps using a sex-specific length-weight relationship based on all available current data. The relationship between weight and length was calculated using the power function, $Weight(g) = a * Length(cm)^b$, where a and b are parameters estimated to provide the best fit to the data. The parameter estimates and the number of individual data points are shown below.

Sex	a	b	n
Males	0.0091	3.068	10,663
Females	0.0059	3.205	13,702

Finally, annual age categories for which no length-at-age or weight-at-age were available were filled by calculating weight at age (using the power relationship described above) from a mean overall length at age for males and females from 1971-2019 data.

The mean weight at age from 2023 was used as an estimate for weight at age in 2024, as the 2024 ages have not yet been processed.

Natural mortality

Natural mortality (M) was initially estimated by a least squares analysis where catch at age data were fitted to Japanese pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimized) occurred at a value of M=0.12 (Bakkala and Wespestad 1984). This was also the value which provided the best fit to the observable population characteristics when M was profiled over a range of values in the stock assessment model using data up to 1992. Since then, natural mortality has been estimated as a free parameter in some of the stock assessment model runs which have been evaluated the past five years. A fixed female natural mortality at M=0.12 and male natural mortality estimated by the model is used in Model 23.0.

Maturity

Yellowfin sole maturity schedules were estimated from in-situ observations from two studies as discussed in the "Data" section (Table 4.8).

AIC

The Akaike Information Criterion was calculated from the hessian and objective function value OFV of the ADMB output .par file to compare models 23.0 and 23.0_noEC. The hessian $Hess$ was transformed back into the original parameter space and the marginal likelihood $Likelihood_{MAR}$ was estimated as:

$$Likelihood_{MAR} = -0.5 * Hess_T - OFV, \tag{1}$$

The marginal likelihood was then used to calculate AIC, as follows:

$$AIC = 2 * k - 2 * Likelihood_{MAR}, \tag{2}$$

where k is the number of parameters used in the model.

Parameter Estimates

A list of selected parameters estimated inside the model are shown for Model 23.0 with 2023 data in Table 4.14 and for Model 23.0 with 2023 dadta in Table 4.15.

Parameters Estimated Inside the Assessment Model

There were 382 estimated by Model 23.0 in 2023 and 386 estimated by Model 23.0 in 2024. The increase was due to an additional estimate of fishing mortality, 2 fishery selectivity parameters, and a recruitment deviation estimate for 2024. Key parameters are presented below:

Fishing mortality	Selectivity	Survey catchability	Recruitment deviation	Spawner-recruit	M	Total
72	184	4	72	2	1	386

The selectivity parameters include 2 parameters for survey selectivity, 2x71 for fishery selectivity, and 2x20 selectivity parameters used for MSY estimates. There are also 2x19 initial deviations for the initial population size and one mean initial size estimate.

Selectivity

Survey selectivity was constant and a single curve was estimated for males and females (Figure 4.25). Time-varying fishing selectivity curves were estimated because there have been annual changes in management, vessel participation and likely gear selectivity (Figure 4.26). The selectivity pattern is increasing logistic for the fishery and survey. The oldest year-classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the 20+ age category. A logistic equation was used to model fishery selectivity and is a function of time-varying parameters specifying the age and slope at 50% selection, φ_t and η_t, respectively. The fishing selectivity (S^f) for age a and year t is modeled as,

$$S^f_{a,t} = [1 + e^{\eta_t(a-\varphi_t)}]^{-1}, \tag{3}$$

where φ_t and η_t are time-varying and partitioned (for estimation) into parameters representing the mean and a vector of deviations (log-scale) conditioned to sum to zero. The deviations are constrained by a lognormal prior with a variance that was iteratively estimated. The process of iterating was to first set the variance to a high value to estimate the deviations. The next step was to compare the variability of model estimates. The variance of the model estimates was then rounded up slightly and fixed for subsequent runs. The 2024 values were fixed as the average of the 3 most recent years.

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis (300) was placed on the catch likelihood component to force the model to closely match the observed catch.

Survey Catchability

Past assessments have examined the relationship between estimates of survey biomass and bottom water temperature. To better understand how water temperature may affect the catchability of yellowfin sole to the survey trawl, catchability was estimated for each year in the stock assessment model as:

$$q = e^{-\alpha+\beta T}, \tag{4}$$

where q is catchability, T is the average annual bottom water temperature anomaly at survey stations less than 100 m, and α and β are parameters estimated by the model. The catchability equation has two parts. The $e^{-\alpha}$ term is a constant or time-independent estimate of q. The second term, $e^{\beta T}$ is a time-varying (annual) q which responds to metabolic aspects of herding or distribution (availability) which can vary annually with bottom water temperature. The result of incorporating bottom temperature to estimate annual q has resulted in an improved fit to the survey (described in the 2018 BSAI yellowfin sole assessment).

The survey catchability model includes survey start date (expressed as deviation in days (- and +) from the average survey start date of June 4th). This feature has been used since 2018, and its interaction with annual bottom water temperature is added to the catchability equation as:

$$q = e^{-\alpha+\beta T+\gamma S+\mu T:S}, \tag{5}$$

where T=survey bottom temperature (averaged per year for all stations <100 m), S=survey start date, and $T:S$=interaction of T and S. Earlier survey start dates usually encounter colder water and since the timing of the survey start date is positively correlated with bottom water temperature, improvement in fitting the survey biomass estimates can be gained by estimating two new parameters (μ and γ). Akaike information criterion (AIC) were used to determine if the additional variables (S and $T:S$) improved the regression fit. The improvement in fit was more than offset by the additional two parameters (Nichol et al. 2019).

Spawner-Recruit Estimation

Annual recruitment estimates from 1978-2018 were constrained to fit a Ricker (1958) form of the stock recruitment relationship as follows:

$$R = \alpha S e^{-\beta S}, \tag{6}$$

where R is age 1 recruitment, S is female spawning biomass in metric tons the previous year, and α and β are parameters estimated by the model. This stock recruitment curve expresses a peak level of recruitment at an intermediate stock abundance and density dependence at higher stock sizes. The spawner-recruit fitting is estimated in a later phase after initial estimates of survival, numbers-at-age and selectivity are obtained.

Results

Model Evaluation

For this assessment, Model 23.0 is presented with updated data for 2024. Model 23.0 was the accepted model in the 2023 yellowfin sole stock assessment.

Model 23.0 estimated male natural mortality 0.128 to be higher than female natural mortality 0.12, which is in common with known life history parameters of other Alaska flatfish. For example, arrowtooth flounder males are assumed to have higher natural mortality, consistent with their skewed sex ratio (Wilderbuer and Turnock 2009). Higher natural mortality for male flatfish has been assumed for flatfish from other regions as well (Maunder and Wong 2011).

Model 23.0 fit the data well overall. Survey selectivity estimated as a single curve indicated that 50% selectivity occurred between 4 and 5 years, and fully selected by age 7 (Figure 4.25). The predicted fit to survey biomass was similar (Figure 4.27), as were total biomass, numbers at age, and spawning stock biomass (Figure 4.28, and Figure 4.29.

Model 23.0 (Figure 4.30) indicates a shift towards higher survey catchability, than Model 23.0 from 2023, corresponding with lower bottom temperatures than in 2023 (Figure 4.17). The proportion female was estimated to be lower and closer to 50% in Model 23.0 (2024) than Model 23.0 from 2023 (Figure 4.31).

Model 23.0 similarly provided a good fit the survey age compositions (Figure 4.32), as well as the fishery age compositions (Figure 4.33) and survey biomass (Figure 4.14).

Given the uncertainty of the productivity of yellowfin sole at low spawning stock sizes, and because the AFSC policy for reference point time-series selection is to use the post 1977 regime shift values unless there is a compelling reason to do otherwise, the productivity of yellowfin sole in this assessment was estimated by fitting the 1977-2018 spawner-recruit data in the model. The resulting stock recruitment curve shows average recruitment for the years 2019-2024 except 2020 which was above average (Figure 4.24).

A series of alternative models were included to demonstrate the addition of data sources. VAST data requires that indices for survey biomass and age composition be recalculated each year (Figure 4.34). The addition of the 2024 fishery catch (and final 2023 catch) in Model 23.0 2024a 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.

Time Series Results

The data was updated in 2024 to include current values of catch, survey biomass estimates, and survey age compositions from 2023. The latest year of fishery weight-at-age data was included (2022), as no new fishery ages were available for 2023 (Table 4.16 and Table 4.17). The eight past years in the Bering Sea have had bottom temperature anomalies above the mean, to varying degrees, but 2023 and 2024 have been near and below average. The temperature-dependent q adjustment for 2024 was 1.16.

Residual Patterns

One step ahead (OSA) residuals have replaced Pearson residuals for the current assessment because they are independent and identically distributed (iid), and normally distributed. They were calculated by removing the last age bin. For the fishery, the male and female patterns are similar for age compositional data (Figure 4.35), but generally the scale was below 2 standard deviations. For the survey, males and females show similar patterns, and the patterns are typically small-scale anfd generally do not exceed one standard deviation (Figure 4.36). Both the fishery and survey show a reverse S-shaped curve in the Q-Q plot, indicating a heavy-tailed but symmetric distribution. The standardized deviation of normalized residuals (SDNR) was ~0.75 for the survey and fishery. In general SDNR much greater than 1 is not consistent with a good fit to the data. A value less than 1 indicates that the data was fitted better than expected, and is not a cause for concern (Francis 2011).

Fishing Mortality and Selectivity

The full-selection fishing mortality, F, has averaged 0.078 over the 5 years, 2020 -2024 (Table 4.18). Model estimated selectivities, Figure 4.25 and Figure 4.26 indicate that yellowfin sole are 50% selected by the fishery at about age 9 and nearly fully selected by age 13, with annual variability. Based on results from the stock assessment model, annual average exploitation rates of yellowfin sole since 1977 ranged from 3% to 7% of the total biomass, and have averaged approximately 4%.

Abundance Trends

Model 23.0 estimated catchability q at an average value of 1.2 for the period 1982-2024 which resulted in a model estimate of the 2024 age 2+ total biomass at 2.412 million t (Table 4.10). Model results indicate that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (700,000-1,000,000 t) after a period of high exploitation (Table 4.10, Figure 4.29). Sustained above average recruitment from 1967-1976 combined with light exploitation resulted in a biomass increase to a peak of approximately 3.6 million t by 1985. The population biomass has since been in a slow decline as the strong 1981 and 1983 year-classes have passed through the population, with only the 1991, 1995 and 2003 year-classes at levels observed during the 1970s. The current model indicates that the population is increasing and predicts that it will continue to increase through 2026. The present biomass is estimated at 70% of the peak 1984 level. The female spawning biomass has also declined since the peak in 1985, with a 2024 estimate of 751,023 t and 748,076 t for 2025 (Table 4.19).

Allowing q to be correlated with annual bottom temperature and survey start date provides a better fit to the bottom trawl survey estimates than using a q fixed at the average value (Fig. 4.18, Wilderbuer et al. 2018). Both the trawl survey and the stock assessment model indicate that the yellowfin sole resource (total biomass) increased during the 1970s and early 1980s to a peak level during the mid-1980s. The yellowfin sole population biomass slowly decreased over the 23 years since the mid-1990s as the majority of year-classes during those years were below average strength. Average to above average recruitment from 2006 to 2009 is expected to maintain the abundance of yellowfin sole at a level above B_{MSY} in the near future. The stock assessment projection model indicates a generally stable trend in female spawning biomass through 2037 if the fishing mortality rate continues at the same level as the average of the past 5 years (Figure 4.37).

The VAST model for the Northern + Eastern Bering Sea has been used in the yellowfin sole assessment since 2022. We included a model without the environmental covariates on survey catchability (Model 23.0_noEC) to check whether it provides a better fit to the data with the VAST indices, because VAST accounts for an unsurveyed portion of the population. 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 (Table 4.20), justifying the continued use of the environmental covariates on survey catchability.

Recruitment Trends

The primary reason for the sustained increase in abundance of yellowfin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year-classes spawned in 1967-1976 (Figure 4.38). The 1981 year-class was the strongest observed (and estimated) during the time series, followed by the 1983 year-class. Survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year-classes were average and the 1986 and 1988 year-classes were above average. Recruitment since 1990 has been below the long-term average in most years, and the 2015 - 2020 year-classes appear to be one of the lowest on record (Figure 4.38). Recruitment for years subsequent to 2020 may be less reliable given the lack of survey data to confirm recruitment estimates. Given the large proportion of new recruits from the 2017 year class that are apparent in survey age composition data, it is probable that future assessments will indicate higher recruitment in 2017.

Retrospective Analysis

A within-model retrospective analysis was included for Model 23.0. In this analysis, retrospective female spawning biomass was calculated by sequentially dropping data one year at a time and then comparing the peeled estimate to the reference stock assessment model used in the assessment (Figure 4.39). The same series of VAST survey estimates was used for each retrospective peel (rather than replacing the series with previous years estimates). Retrospective differences in female spawning biomass between sequential years for yellowfin sole indicate that the 2024 model with the final year of data removed provided higher estimates of SSB than the full 2024 model (Figure 4.40). Mohn's rho for Model 23.0 in 2024 was 0.042, smaller than the 2023 Mohn's rho of 0.06. The directionality of the retrospective peels can provide insight into the retrospective pattern. For Model 23.0 the first four retrospective peels were positively different from the terminal year, but the remaining peels resulted in an upward shift of the entire time series (Figure 4.40), indicating that information in the 3-4 terminal years result in a downward shift of the time series. However, the Mohn's rho values presented here are within the range of acceptable values and do not indicate any significant retrospective issues in Model 23.0. The Mohn's rho does not exceed the rule of thumb guideline for long-lived stocks proposed by Hurtado-Ferro at al. (2015), which includes flatfish, that values of Mohn's rho higher than 0.20 or lower than -0.15 may be an indication of a retrospective pattern.

Other diagnostics

Several alternative models were used for comparative purposes. Model 23.0_noEC removed the environmental covariates (bottom temperature and survey start date) on survey catchability.

We also present several models that show the effect of the different data sources. All alternative models used data through 2024. Model 23.0 2024a included fishery catch through 2024 but did not have the current estimates of survey age composition or the 2024 VAST survey index. Model 23.0 2024b added the 2024 VAST survey index to Model 23.0 2024a but did not include the updated survey age composition.

Harvest Recommendations

Scenario Projections and Two-Year Ahead Overfishing Level

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. The 2024 numbers at age from the stock assessment model are projected to 2025 given the 2024 estimated full year's catch, and then a 2025 catch of 123,905 t was applied to the projected 2025 population biomass to obtain the 2025 OFL.

The SSC determined in December 2006 that yellowfin sole would be managed under the Tier 1 harvest guidelines, and therefore future harvest recommendations would be based on maximum sustainable yield MSY and the associated fishing effort F_{MSY} values calculated from a spawner-recruit relationship. MSY is an equilibrium concept and its value is dependent on both the spawner-recruit estimates which are assumed to represent the equilibrium stock size-recruitment relationship and the model used to fit the estimates. In the yellowfin sole stock assessment model, a Ricker form of the stock-recruit relationship was fit to various combinations of these data and estimates of F_{MSY} and B_{MSY} were calculated, assuming that the fit to the stock-recruitment data represents the long-term productivity of the stock (details provided in Wilderbuer et al. 2018). The 2025 ABC is calculated using Tier 1 methodology. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2025 biomass estimate.

The geometric mean of the 2025 biomass estimate, B_{gm}, is estimated using the equation $B_{gm} = e^{ln(B)-(cv^2/2)}$, where B is the point estimate of the 2025 biomass from the stock assessment model and cv^2 is the coefficient of variation of the point estimate (a proxy for sigma). The harmonic mean of F_{MSY}, F_{har} is estimated as $F_{har} = e^{ln(F_{MSY}-(ln(sd^2)/2)}$, where F_{MSY} is the peak mode of the F_{MSY} distribution and sd^2 is the square of the standard deviation of the F_{MSY} distribution.

In 2006 the SSC selected the 1978-2001 data set for the Tier 1 harvest recommendation. Using this approach for the 2025 harvest (now the 1978-2018 time-series) recommendation (Model 23.0), the $F_{ABC} = F_{Hmean} = 0.114$. The estimate of age 6+ total biomass for 2025 is 2,308,550 t. The calculations outlined above give a Tier 1 ABC harvest recommendation of 262,557 t and an OFL of 299,247 t for 2025. This results in an 12% (36,690 t) buffer between ABC and OFL.

The stock assessment analysis must also consider harvest limits, usually described as overfishing fishing mortality levels with corresponding yield amounts. Amendment 56 to the BSAI FMP sets the Tier 1 harvest limit at the F_{MSY} fishing mortality value. The overfishing limit mortality values, ABC fishing mortality values and their corresponding yields are given as follows:

Harvest level	F value	2025 Yield
Tier 1 $F_{OFL} = F_{MSY}$	0.13	299,247 t
Tier 1 $F_{ABC} = F_{harmonicmean}$	0.114	262,557 t

A complete record of catch, ABC, and OFL since 1980 is available in Table 4.21.

Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was implemented in 1977.

For each scenario, the projections begin with the vector of 2024 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2025 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2024. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2025, are as follows (max F_{ABC} refers to the maximum permissible value of F_{ABC} under Amendment 56):

- Scenario 1: In all future years, F is set equal to max F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- Scenario 2: In all future years, F is set equal to a constant fraction of max F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2024 recommended in the assessment to the max F_{ABC} for 2025. (Rationale: When F_{ABC} is set at a value below max F_{ABC}, it is often set at the value recommended in the stock assessment.)
- Scenario 3: In all future years, F is set equal to the 2019 - 2023 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
- Scenario 4: In all future years, F is set equal to F_{60}%. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- Scenario 5: In all future years, F 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 follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

- Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is 1) above its MSY level in 2024 or 2) above 1/2 of its MSY level in 2024 and expected to be above its MSY level in 2034 under this scenario, then the stock is not overfished.)
- Scenario 7: In 2025 , F is set equal to max F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (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.)

Simulation results shown in Table 4.22 indicate that yellowfin sole are not currently overfished and are not approaching an overfished condition. If fishing continues at the same fishing mortality as in the past 5 years, the stock is projected to remain well above B_{MSY} (Figure 4.37). A phase plane figure of the estimated time-series of yellowfin sole female spawning biomass (FSB) relative to the harvest control rule indicates that the stock is above B_{MSY}, has been consistently fished below F_{MSY} for decades (Figure 4.41)

The ABC and OFL based on the recommended model 23.0 for 2025 and 2026 assuming average catch rates are shown in the following table.

Year	Catch	FSB	Geom. mean 6+ biomass	ABC	OFL
2025	116,803	748,076	2,308,550	262,557	299,247
2026	116,803	758,695	2,353,240	267,639	305,039

Risk Table and ABC Recommendation

Assessment related considerations

The BSAI yellowfin sole assessment is based on surveys conducted annually on the EBS shelf from 1982-2024, anually except for 2020 due to the COVID-19 pandemic. Fish ages, derived from otoliths collected during the surveys and the fishery to calculate annual estimates of population and fishery age composition, have been validated. Survey age composition data is used in the assessment from 1982-2023. The assessment model exhibits good fits to all compositional and abundance data, and converges to a single minima in the likelihood surface. Recruitment estimates track strong year-classes that are consistent with the data. The retrospective pattern and Mohn's rho value, 0.042, indicate that there are no significant time varying trends that are not accounted for by the model (Figure 4.39.

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

Population dynamics considerations

Stock assessment model results indicate that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (700,000-1,000,000 t) after a period of high exploitation. Sustained above-average recruitment from 1967-1976 combined with light exploitation resulted in a biomass increase to a peak in 1985. The population biomass has since been in a slow decline over the time series since a peak in the mid-1980s. Only the 1991, 1995 and 2003 year-classes have achieved levels observed during the 1970s. The 2023 survey estimate is the second lowest in the time series since 1982, while the 2024 survey estimate is an increase from 2023. The current model for 2024 estimates B_{MSY} at 479,711 t. Projections indicate that the FSB will remain above the B_{MSY} level through 2038. The large 2017 year class will be age 8 in 2025 and will become selected by the fishery as it grows. This is predicted to result in higher population size estimates for the yellowfin sole stock.

Given the increase observed in 2024 as well as the incoming 2017 year class, we propose a level 1 designation for the population dynamics category in the risk table.

Environmental/ecosystem considerations

Environmental processes: The eastern Bering Sea (EBS) experienced a prolonged period of above-average thermal conditions from 2014 through 2021. Since 2021, and continuing from August 2023–August 2024, thermal conditions in the EBS have been close to historical baselines of many metrics. There have been no sustained marine heatwaves over the southeastern or northern Bering Sea shelves since January 2021 (Callahan and Lemagie, 2024), and observed (Rohan and Barnett, 2024) modeled (Kearney, 2024) EBS bottom temperatures were mostly near-normal over the past year. Sea surface temperatures (SSTs) and bottom temperatures were near the long-term means in all regions by summer 2024. Notable deviations include (i) warm SSTs in the outer domain from fall 2023 through spring 2024 and (ii) unusually warm bottom temperatures in the northern outer domain since spring 2024 that may indicate an intrusion of shelf water (Callahan et al., 2024).

Atmospheric conditions are one of the primary drivers that impact the oceanographic setting in the EBS. Both the North Pacific Index (NPI) and Aleutian Low Index (ALI) provide complementary views of the atmospheric pressure system in the North Pacific. During winter 2023-2024, the NPI was average (Siddon, 2024) and the strength and location of the Aleutian Low Pressure System were both near climatological averages (Overland and Wang, 2024). Thus, despite delayed formation of sea ice in fall 2023 (Thoman, 2024), cold winds from the Arctic helped advance sea ice to near-normal extent by mid-winter. Near-normal sea ice extent and thickness (Thoman, 2024b, 2024c) may have contributed to a cold pool (<2°C water) of average spatial extent (Siddon, 2024), though the footprint of the coldest waters (<0°C) in 2024 was 75% smaller than in 2023 (Rohan and Barnett, 2024b).

December 2023 had significant along-shelf winds (to the southeast) that could have driven offshore Ekman transport. Weaker, but more sustained winds that also favored offshore transport occurred from March to May 2024 (Hennon, 2024). Beginning in May and continuing through summer 2024, persistent storms resulted in a deeper mixed layer, which entrained deeper, cooler water, such that SSTs remained cooler through at least August 2024 (Stabeno, 2024).

For projections into 2025, the National Multi-Model Ensemble (NMME) predicts that SSTs over the EBS are expected to be near normal (anomalies within <0.5°C of the 1982–2010 baseline) (Lemagie, 2024). With the expected transition to La Niña, cooler conditions in the EBS may follow. Relatively cool SSTs may contribute to earlier formation of sea ice than has been observed over the last several years (Thoman, 2024b). Yellowfin sole (YFS) demonstrate earlier migration to spawning grounds and earlier spawning events under warmer conditions. In addition, somatic growth of YFS increases in warmer temperatures. A proposed thermal window (Yeung et al., 2021) suggests continued warming over the EBS shelf may result in temperatures above the thermal physiological maximum of YFS. Adult YFS are distributed off-shelf in winter, therefore may have experienced average (northern shelf) to cooler (southern shelf) bottom temperature conditions this past winter (Callahan et al., 2024). Yellowfin sole move inshore during summer for spawning and young-of-the-year (YOY) rear in inshore habitats. Therefore, offshore Ekman transport may have hindered on-shelf migration (Hennon, 2024) and YOY may have experienced average hatching and rearing temperatures in 2024 (Callahan et al., 2024).

Prey: Early life stages of YFS may consume pelagic zooplankton, such as small copepods. The Rapid Zooplankton Assessment in the southeastern Bering Sea (SEBS) in spring noted moderate abundance of small copepods, but low abundance of large copepods along the middle shelf (higher in the outer shelf) and near-zero abundance of euphausiids in the RZA, which is typical for the spring. In summer, small copepods remained abundant throughout the region. Large copepods remained in low abundance while euphausiids increased, especially towards the northern portion of the SEBS. In fall, both small and large copepods as well as euphausiids were in low abundance, but increased towards the north. In the northern Bering Sea (NBS) in fall, small copepods had moderate and consistent abundances throughout the sampling grid, large copepods were patchy with the highest values north and south of St. Lawrence Island, and euphausiids were very low (Kimmel et al., 2024).

The dominant prey of adult YFS are polychaete worms, miscellaneous worms, clams, and benthic amphipods. Direct measurements of infaunal abundance trends are not available, however, abundance trends of motile epifauna that also consume infauna (i.e., indirect measurements) are quantified from the bottom trawl survey. Trends in motile epifauna biomass indicate benthic productivity, although individual species and/or taxa may reflect varying time scales of productivity. The biomass of motile epifauna increased from 2023 to 2024 and remains above the long term mean (Siddon, 2024). No direct or indirect measures of prey availability exist for the northern Bering Sea shelf.

In 2024, adult fish condition (as measured by length-weight residuals) over the SEBS was above average; no survey occurred in the NBS in 2024 (Prohaska et al., 2024). Over the southern shelf, trends in motile epifauna, as an indirect measure of prey availability, mirror trends in adult fish condition, increasing from 2023 to 2024.

Competitors: Competitors for YFS prey resources include other benthic foragers, like northern rock sole and flathead sole. The trend in biomass of the benthic foragers guild from the standard bottom trawl survey grid increased from 2023 to 2024, but remained below the time series mean. Trends in benthic forager biomass indirectly indicate availability of infauna (i.e., prey of these species), suggesting competition for prey resources remains low in 2024 (Siddon, 2024).

Predators: Predators of YFS include Pacific cod and Pacific halibut, which are included in the apex predator guild. The biomass of apex predators measured during the standard bottom trawl survey in 2024 was nearly equal to their value in 2023 and below their long term mean. However, the trend in the apex predator guild is largely driven by Pacific cod, which decreased 5.5% from 2023 (Siddon, 2024). While an increase in Pacific cod abundance may represent increased predation pressure for YFS, the spatial distribution of Pacific cod may provide a potential refuge from predation in the inner domain. The biomass of Pacific halibut decreased from 2023 to 2024, therefore represents no increase in predation pressure.

Summary for Environmental/Ecosystem considerations:

- Environment: The EBS shelf experienced oceanographic conditions that were largely average based on historical time series of multiple metrics over the past year (August 2023 - August 2024). Adult YFS may have experienced average to cooler bottom temperatures in the off-shelf region during winter 2023/2024 (based on ROMS) and YOY may have experienced average bottom temperatures in inshore spawning and rearing habitats during summer 2024 (based on BTS). Cooler temperatures may result in delayed migration to spawning grounds, delayed spawning, and decreased somatic growth.
- Prey: Sufficient prey may have been available for early life stages of YFS (small copepods) and for adult YFS (via trends in motile epifauna) over the SEBS shelf based on trends in fish condition.

- Competition: The trend in biomass of benthic foragers increased from 2023 to 2024 but remained below the time series mean, indicating competition for prey resources remains low in 2024.
- Predation: Trends in biomass of Pacific cod and Pacific halibut both declined from 2023 to 2024, along with potential spatial refuge from predation in the inner domain, suggest no increase in predation pressure.

Together, the most recent data available suggest an ecosystem risk Level 1 – Normal: "No apparent ecosystem concerns related to biological status (e.g., environment, prey, competition, predation), or minor concerns with uncertain impacts on the stock."

Fishery performance considerations

The 2024 fishery CPUE has declined since 2023, but overall, CPUE is within the range observed over the past several decades. Fishing reports in 2024 indicate that the yellowfin sole CPUE was good, but that halibut bycatch was high. Due to low prices for yellowfin sole and a surplus of frozen product on the market, fishing has been lower in 2024. There are no specific concerns regarding stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, or changes in the duration of fishery openings.

We propose a level 1 designation for the fishery performance category in the risk table.

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

The Risk Table does not warrant a reduction from the maximum permissible ABC under the Tier 3 harvest control rule. We recommend no reduction in ABC based on this risk table assessment.

Status Determination

The yellowfin sole stock in the Bering Sea and Aleutian Island is not being subjected to overfishing, is not currently overfished, and is not approaching an overfished condition.

F_{limit}

Report the F (based on this year's Model 23.0) that would have produced a catch for last year equal to the 2023 OFL (404,882 t) is 0.318. This value is reported in the SARA files as the F_LIMIT and included in the species information system (SIS) output.

Ecosystem Considerations

See Environmental/Ecosystem Considerations above.

Fishery Effects on the Ecosystem

Incidental catches of FMP groundfish taken in yellowfin sole fisheries are reported for 2009 - 2024 (Table 4.23). Pollock, followed by Pacific cod comprise the highest bycatch, followed by flatfish. Skates are also encountered, averaging over 2,000 t annually since 2011 (Table 4.24). Nontarget bycatch includes primarily benthic invertebrates such as scypho jellies, sea stars, and tunicates (Table 4.25) as well as birds, which are rarely encountered. Prohibited species include halibut, which resulted in fishery closures in 2024, as well as crab, salmon, and herring (Table 4.26). Salmon are rarely encountered, but crab are commonly encountered, over a million annually for some species in some years.

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Tables

Table 4.1: How time-varying parameters were incorporated into reference point calculations.

Time-varying parameter	Usage
Fishery selectivity	The 2022 estimates were used to calculate MSY and reference points.

Table 4.2: Foreign and domestic catch (t) of yellowfin sole 1954-2024. Foreign catches are designated as joint venture processing (JVP), and non-foreign catches as domestic annual processing (DAP). Domestic catch since 1991 is subdivided into catch from the Aleutian Islands and the Bering Sea. Catch for 2024 was downloaded October 1, 2024. The extrapolated catch for the full year was 74,288 t.

		Domestic				
Year	Foreign	JVP	DAP	Aleutian Islands	Bering Sea	Total
1954	12,562					12,562
1955	14,690					14,690
1956	24,697					24,697
1957	24,145					24,145
1958	44,153					44,153
1959	185,321					185,321
1960	456,103					456,103
1961	553,742					553,742
1962	420,703					420,703
1963	85,810					85,810
1964	111,777					111,777
1965	53,810					53,810
1966	102,353					102,353
1967	162,228					162,228
1968	84,189					84,189
1969	167,134					167,134
1970	133,079					133,079
1971	160,399					160,399
1972	47,856					47,856
1973	78,240					78,240
1974	42,235					42,235
1975	64,690					64,690
1976	56,221					56,221
1977	58,373					58,373
1978	138,433					138,433
1979	99,019					99,019
1980	77,768	9,623				87,391
1981	81,255	16,046				97,301
1982	78,331	17,381				95,712
1983	85,874	22,511				108,385
1984	126,762	32,764				159,526
1985	100,706	126,401				227,107
1986	57,197	151,400				208,597
1987	1,811	179,613	4			181,428
1988		213,323	9,833			223,156
1989		151,501	1,664			153,165
1990		69,677	14,293			83,970
1991			117,303		117,303	117,303
1992			145,386	3.6	145,382	145,386
1993			105,810		105,810	105,810
1994			140,050	0.2	140,050	140,050
1995			124,752	5.6	124,746	124,752
1996			129,659	0.4	129,659	129,659
1997			182,814	1.2	182,813	182,814
1998			101,155	4.7	101,150	101,155
1999			69,234	12.8	69,221	69,234

2000	84,071	12.5	84,058	84,071
2001	63,579	14.5	63,564	63,579
2002	74,986	28.5	74,957	74,986
2003	79,806	0.4	79,806	79,806
2004	75,511	8.8	75,502	75,511
2005	94,385	1.8	94,383	94,385
2006	99,160	3.8	99,156	99,160
2007	120,964	2.4	120,962	120,964
2008	148,894	0.5	148,893	148,894
2009	107,513	1.1	107,512	107,513
2010	118,624	0.2	118,624	118,624
2011	151,158	1.1	151,157	151,158
2012	147,187	1.1	147,186	147,187
2013	164,944	0.3	164,944	164,944
2014	156,772	0.3	156,772	156,772
2015	126,937	0	126,937	126,937
2016	135,324	0.2	135,324	135,324
2017	132,220	0.6	132,219	132,220
2018	131,496	4.5	131,491	131,496
2019	128,051	4.6	129,061	128,051
2020	133,799	11.1	133,788	133,799
2021	108,788	53.9	108,734	108,788
2022	154,253	8.7	154,245	154,253
2023	112,889	1.3	112,888	112,889
2024	59,044	0	59,044	59,044

Table 4.3: Estimates of retained and discarded (t) yellowfin sole caught in Bering Sea fisheries from 1991 through October 1, 2024, and the proportion discarded.

Year	Retained (t)	Discarded (t)	Proportion discarded
1991	88,967	28,337	0.24
1992	102,542	42,843	0.29
1993	76,798	29,012	0.27
1994	104,918	35,132	0.25
1995	96,770	27,982	0.22
1996	101,324	28,335	0.22
1997	150,745	32,069	0.18
1998	80,267	20,888	0.21
1999	56,604	12,629	0.18
2000	69,971	14,100	0.17
2001	54,918	8,661	0.14
2002	63,625	11,361	0.15
2003	68,832	10,974	0.14
2004	62,746	12,765	0.17
2005	85,311	9,074	0.1
2006	90,592	8,568	0.09
2007	109,004	11,960	0.1
2008	141,235	7,659	0.05
2009	100,642	6,871	0.06
2010	113,244	5,380	0.05
2011	146,418	4,738	0.03
2012	142,132	5,055	0.03
2013	158,781	6,162	0.04
2014	152,167	4,605	0.03
2015	123,065	3,872	0.03
2016	131,203	4,121	0.03
2017	128,665	3,554	0.03
2018	127,331	4,164	0.03
2019	126,111	2,955	0.02
2020	131,774	2,025	0.02
2021	106,785	2,003	0.02
2022	151,493	2,760	0.02
2023	111,154	1,735	0.02
2024	59,692	1,156	0.02

Table 4.4: Discarded and retained catch of non-CDQ yellowfin sole, by fishery, in 2023. Gear types include longline (HAL), bottom trawl (NPT), pot (POT), and pelagic trawl (PTR). Catch was non-zero for all target-gear combinations shown, but may appear as zero as results were rounded to the nearest metric ton (t). Source: NMFS AKRO BLEND/Catch Accounting System.

	Gear type	Discarded (t)	Retained (t)
Halibut	HAL	1	0
Other species	HAL	0	0
Pacific cod	HAL	283	0
Alaska Plaice	NPT	2	115
Atka mackerel	NPT	0	4
Flathead sole	NPT	17	2,350
Kamchatka Fl.	NPT	0	0
Other flatfish	NPT	0	0
Other species	NPT	0	0
Pacific cod	NPT	12	28
Pollock - bottom	NPT	6	722
Rock sole	NPT	192	12,731
Rockfish	NPT	0	0
Yellowfin sole	NPT	1,108	95,182
Pacific cod	POT	110	0
Pollock - bottom	PTR	0	0
Pollock - midwater	PTR	3	17

Table 4.5: Occurrence of yellowfin sole in the eastern Bering Sea trawl survey and collections of length and age structures and the number of otoliths aged from the survey. The final column represents the number of otoliths read in each year from the fishery.

Year	Total hauls	Hauls w length	N. lengths	Hauls w otoliths	Hauls w nages	N. otoliths	N. ages (survey)	N. ages (fishery)	V10
1982	329	246	37,023	35	35	744	744	2432	
1983	353	256	33,924	37	37	709	709	1178	
1984	355	271	33,894	56	56	821	796	338	
1985	353	261	33,824	44	43	810	802	840	
1986	354	249	30,470	34	34	739	739	1503	
1987	357	224	31,241	16	16	798	798	1071	
1988	373	254	27,138	14	14	543	543	1361	
1989	374	236	29,672	24	24	740	740	1462	
1990	371	251	30,257	28	28	792	792	1220	
1991	372	248	27,986	26	26	742	742	935	
1992	356	229	23,628	16	16	606	606	1203	
1993	375	242	26,651	20	20	549	549	1020	
1994	375	269	24,448	14	14	526	522	573	
1995	376	254	22,116	20	20	654	647	554	
1996	375	247	27,505	16	16	729	721	314	
1997	376	262	26,034	11	11	470	466	397	
1998	375	310	34,509	15	15	575	570	426	
1999	373	276	28,431	31	31	777	770	487	
2000	372	255	24,880	20	20	517	511	583	
2001	375	251	26,558	25	25	604	593	491	
2002	375	246	26,309	32	32	738	723	486	
2003	376	241	27,135	37	37	699	695	590	
2004	375	251	26,103	26	26	725	712	483	
2005	373	251	24,658	35	35	663	653	494	
2006	376	246	28,470	39	39	428	426	490	
2007	376	247	24,790	66	66	779	772	496	
2008	375	238	25,848	65	65	858	830	542	
2009	376	235	22,018	70	70	783	751	515	
2010	376	228	20,619	77	77	841	827	535	
2011	376	228	21,665	65	64	784	753	525	
2012	376	242	23,519	72	72	992	973	504	
2013	376	232	23,261	70	70	821	803	670	
2014	376	219	20,229	52	52	799	790	502	
2015	376	223	20,830	73	73	878	875	622	
2016	376	242	92,368	69	69	884	876	495	
2017	376	258	25,767	78	78	896	886	595	
2018	376	262	27,285	68	68	724	720	608	
2019	376	270	25,669	67	67	836	832	589	
2020	-	-	-	-	-	-	-	660	
2021	376	234	18,757	201	200	1030	983	700	
2022	376	238	16,765	195	195	619	581	635	-
2023	376	233	15,501	172	172	514	508	-	
2024	350	212	15,673	160	-	479	-	-	

Table 4.6: Yellowfin sole fishery catch-at-age (proportions) estimated by the model, 1975-2023 female first then male, ages 7-17+.

Year	7	8	9	10	11	12	13	14	15	16	17+	Total female proportion over age 7
1975	0.1467	0.2972	0.2256	0.0952	0.0561	0.0253	0.0181	0.0224	0.0082	0.0073	0.0043	0.9064
1976	0.0973	0.1665	0.2709	0.1947	0.0831	0.0496	0.0225	0.0161	0.0200	0.0073	0.0065	0.9345
1977	0.1622	0.2064	0.1738	0.1629	0.0879	0.0337	0.0195	0.0087	0.0062	0.0077	0.0028	0.8718
1978	0.0891	0.1947	0.2193	0.1631	0.1416	0.0736	0.0278	0.0159	0.0071	0.0051	0.0063	0.9436
1979	0.0591	0.1422	0.2159	0.1894	0.1256	0.1046	0.0536	0.0201	0.0115	0.0052	0.0037	0.9309
1980	0.0679	0.0818	0.1499	0.1951	0.1614	0.1053	0.0874	0.0448	0.0168	0.0096	0.0043	0.9243
1981	0.0821	0.1070	0.0991	0.1462	0.1673	0.1302	0.0828	0.0680	0.0347	0.0130	0.0075	0.9379
1982	0.0623	0.1399	0.1306	0.0943	0.1213	0.1304	0.0989	0.0622	0.0509	0.0260	0.0097	0.9265
1983	0.0802	0.0916	0.1546	0.1218	0.0815	0.1018	0.1082	0.0818	0.0514	0.0420	0.0214	0.9363
1984	0.0366	0.0964	0.0976	0.1528	0.1166	0.0770	0.0959	0.1018	0.0769	0.0483	0.0395	0.9394
1985	0.0244	0.0625	0.1192	0.0981	0.1408	0.1043	0.0683	0.0847	0.0899	0.0679	0.0426	0.9027
1986	0.0438	0.0478	0.0833	0.1224	0.0902	0.1246	0.0912	0.0595	0.0737	0.0782	0.0590	0.8737
1987	0.0225	0.0595	0.0537	0.0833	0.1174	0.0855	0.1178	0.0862	0.0562	0.0696	0.0739	0.8256
1988	0.0566	0.0491	0.0928	0.0599	0.0782	0.1037	0.0741	0.1016	0.0742	0.0484	0.0600	0.7986
1989	0.0073	0.0840	0.0633	0.1002	0.0583	0.0733	0.0963	0.0686	0.0940	0.0686	0.0447	0.7586
1990	0.0400	0.0284	0.2037	0.0856	0.0915	0.0455	0.0546	0.0708	0.0503	0.0689	0.0503	0.7896
1991	0.0366	0.1427	0.0510	0.2127	0.0683	0.0668	0.0325	0.0388	0.0503	0.0358	0.0490	0.7845
1992	0.0212	0.0539	0.1884	0.0567	0.2073	0.0620	0.0587	0.0281	0.0334	0.0432	0.0307	0.7836
1993	0.0232	0.0318	0.0624	0.1861	0.0531	0.1929	0.0579	0.0550	0.0264	0.0314	0.0406	0.7608
1994	0.0243	0.0421	0.0536	0.0843	0.2019	0.0502	0.1707	0.0498	0.0467	0.0224	0.0265	0.7725
1995	0.0452	0.0791	0.0850	0.0675	0.0793	0.1683	0.0402	0.1348	0.0392	0.0367	0.0176	0.7929
1996	0.0222	0.0863	0.1142	0.0933	0.0632	0.0696	0.1444	0.0342	0.1144	0.0332	0.0311	0.8061
1997	0.0259	0.0496	0.1356	0.1274	0.0861	0.0541	0.0582	0.1196	0.0283	0.0945	0.0274	0.8067
1998	0.0354	0.0419	0.0623	0.1402	0.1207	0.0795	0.0497	0.0533	0.1096	0.0259	0.0866	0.8051
1999	0.0114	0.0435	0.0480	0.0660	0.1403	0.1178	0.0770	0.0480	0.0515	0.1059	0.0250	0.7344
2000	0.0139	0.0394	0.1213	0.0878	0.0784	0.1273	0.0948	0.0592	0.0363	0.0388	0.0796	0.7768
2001	0.0185	0.0395	0.0791	0.1612	0.0867	0.0677	0.1049	0.0770	0.0479	0.0294	0.0313	0.7432
2002	0.0231	0.0283	0.0577	0.0985	0.1695	0.0827	0.0620	0.0946	0.0691	0.0429	0.0263	0.7547
2003	0.0243	0.1142	0.0833	0.0909	0.0975	0.1346	0.0608	0.0445	0.0675	0.0492	0.0305	0.7973
2004	0.0205	0.0491	0.1685	0.0912	0.0841	0.0844	0.1142	0.0513	0.0374	0.0567	0.0413	0.7987
2005	0.0333	0.0528	0.0831	0.1936	0.0834	0.0697	0.0677	0.0906	0.0405	0.0296	0.0448	0.7891
2006	0.0587	0.0744	0.0816	0.0919	0.1767	0.0698	0.0565	0.0542	0.0722	0.0322	0.0235	0.7917
2007	0.0338	0.0901	0.0882	0.0812	0.0848	0.1589	0.0623	0.0503	0.0482	0.0642	0.0287	0.7907
2008	0.0551	0.0723	0.1273	0.0906	0.0712	0.0699	0.1283	0.0500	0.0402	0.0385	0.0513	0.7947
2009	0.0400	0.0832	0.0878	0.1293	0.0844	0.0642	0.0624	0.1141	0.0444	0.0357	0.0342	0.7797
2010	0.0755	0.0897	0.1151	0.0862	0.1093	0.0679	0.0508	0.0492	0.0898	0.0349	0.0281	0.7965
2011	0.0332	0.1277	0.1102	0.1130	0.0766	0.0936	0.0575	0.0429	0.0415	0.0757	0.0294	0.8013
2012	0.0393	0.0639	0.1675	0.1102	0.0999	0.0647	0.0779	0.0476	0.0355	0.0343	0.0626	0.8034
2013	0.0312	0.0574	0.0758	0.1704	0.1046	0.0926	0.0595	0.0716	0.0437	0.0326	0.0315	0.7709
2014	0.0245	0.0587	0.0810	0.0823	0.1619	0.0948	0.0826	0.0529	0.0635	0.0387	0.0289	0.7698
2015	0.0209	0.0440	0.0817	0.0887	0.0795	0.1496	0.0865	0.0751	0.0480	0.0577	0.0352	0.7669
2016	0.0418	0.0712	0.0932	0.1052	0.0839	0.0661	0.1191	0.0679	0.0587	0.0375	0.0450	0.7896
2017	0.0244	0.1048	0.1110	0.0999	0.0939	0.0701	0.0541	0.0969	0.0551	0.0477	0.0305	0.7884
2018	0.0146	0.0434	0.1396	0.1174	0.0944	0.0851	0.0627	0.0482	0.0862	0.0490	0.0424	0.7830
2019	0.0261	0.0335	0.0647	0.1518	0.1104	0.0844	0.0749	0.0550	0.0422	0.0754	0.0429	0.7613
2020	0.0329	0.0582	0.0492	0.0702	0.1418	0.0973	0.0728	0.0642	0.0470	0.0360	0.0644	0.7340
2021	0.0609	0.0570	0.0689	0.0468	0.0611	0.1199	0.0815	0.0608	0.0536	0.0392	0.0301	0.6798
2022	0.0765	0.0866	0.0617	0.0639	0.0408	0.0521	0.1014	0.0687	0.0513	0.0451	0.0330	0.6811
2023	0.1171	0.0971	0.0872	0.0554	0.0553	0.0349	0.0445	0.0865	0.0586	0.0437	0.0385	0.7188

Year	7	8	9	10	11	12	13	14	15	16	17+	Total male proportion over age 7
1975	0.1488	0.2990	0.2252	0.0943	0.0552	0.0247	0.0175	0.0215	0.0078	0.0069	0.0041	0.9050
1976	0.0992	0.1683	0.2718	0.1939	0.0821	0.0487	0.0219	0.0156	0.0191	0.0069	0.0061	0.9336
1977	0.1643	0.2076	0.1735	0.1614	0.0864	0.0329	0.0188	0.0084	0.0060	0.0073	0.0027	0.8693
1978	0.0908	0.1970	0.2202	0.1625	0.1400	0.0722	0.0270	0.0154	0.0068	0.0048	0.0059	0.9426
1979	0.0604	0.1442	0.2173	0.1892	0.1245	0.1029	0.0523	0.0195	0.0111	0.0049	0.0035	0.9298
1980	0.0696	0.0832	0.1514	0.1955	0.1605	0.1039	0.0856	0.0436	0.0162	0.0092	0.0041	0.9228
1981	0.0844	0.1091	0.1003	0.1468	0.1668	0.1288	0.0812	0.0662	0.0336	0.0125	0.0071	0.9368
1982	0.0640	0.1427	0.1323	0.0947	0.1210	0.1291	0.0972	0.0607	0.0492	0.0249	0.0093	0.9251
1983	0.0827	0.0938	0.1570	0.1227	0.0814	0.1010	0.1066	0.0799	0.0498	0.0404	0.0204	0.9357
1984	0.0380	0.0992	0.0997	0.1549	0.1172	0.0769	0.0949	0.1001	0.0750	0.0467	0.0379	0.9405
1985	0.0254	0.0645	0.1222	0.0998	0.1421	0.1045	0.0679	0.0835	0.0880	0.0659	0.0411	0.9049
1986	0.0457	0.0495	0.0856	0.1248	0.0912	0.1251	0.0909	0.0588	0.0723	0.0761	0.0570	0.8770
1987	0.0236	0.0620	0.0555	0.0853	0.1194	0.0863	0.1180	0.0856	0.0554	0.0682	0.0718	0.8311
1988	0.0594	0.0512	0.0959	0.0615	0.0796	0.1048	0.0744	0.1011	0.0733	0.0474	0.0583	0.8069
1989	0.0077	0.0879	0.0658	0.1033	0.0597	0.0744	0.0970	0.0686	0.0932	0.0675	0.0437	0.7688
1990	0.0419	0.0296	0.2105	0.0878	0.0931	0.0460	0.0548	0.0704	0.0497	0.0674	0.0489	0.8001
1991	0.0382	0.1477	0.0524	0.2168	0.0691	0.0671	0.0324	0.0384	0.0494	0.0348	0.0473	0.7936
1992	0.0222	0.0559	0.1941	0.0580	0.2104	0.0624	0.0586	0.0279	0.0329	0.0422	0.0297	0.7943
1993	0.0244	0.0332	0.0645	0.1912	0.0541	0.1951	0.0581	0.0548	0.0261	0.0308	0.0395	0.7718
1994	0.0255	0.0440	0.0556	0.0867	0.2061	0.0509	0.1716	0.0497	0.0463	0.0220	0.0259	0.7843
1995	0.0475	0.0825	0.0879	0.0692	0.0808	0.1701	0.0403	0.1341	0.0387	0.0360	0.0171	0.8042
1996	0.0234	0.0901	0.1182	0.0958	0.0644	0.0704	0.1449	0.0341	0.1131	0.0326	0.0303	0.8173
1997	0.0272	0.0517	0.1403	0.1308	0.0877	0.0547	0.0583	0.1191	0.0279	0.0926	0.0267	0.8170
1998	0.0373	0.0438	0.0647	0.1444	0.1234	0.0806	0.0500	0.0533	0.1087	0.0255	0.0846	0.8163
1999	0.0121	0.0458	0.0501	0.0684	0.1443	0.1203	0.0780	0.0483	0.0514	0.1048	0.0246	0.7481
2000	0.0147	0.0413	0.1262	0.0906	0.0803	0.1294	0.0956	0.0592	0.0361	0.0382	0.0778	0.7894
2001	0.0195	0.0414	0.0822	0.1661	0.0887	0.0687	0.1057	0.0770	0.0475	0.0289	0.0306	0.7563
2002	0.0245	0.0297	0.0601	0.1019	0.1740	0.0842	0.0626	0.0949	0.0688	0.0424	0.0258	0.7689
2003	0.0256	0.1191	0.0862	0.0933	0.0993	0.1361	0.0610	0.0443	0.0667	0.0482	0.0297	0.8095
2004	0.0215	0.0513	0.1745	0.0937	0.0857	0.0854	0.1147	0.0511	0.0370	0.0557	0.0403	0.8109
2005	0.0349	0.0550	0.0858	0.1985	0.0848	0.0704	0.0678	0.0900	0.0400	0.0289	0.0435	0.7996
2006	0.0615	0.0774	0.0842	0.0941	0.1794	0.0704	0.0565	0.0538	0.0711	0.0315	0.0228	0.8027
2007	0.0355	0.0938	0.0912	0.0833	0.0864	0.1605	0.0625	0.0501	0.0476	0.0629	0.0279	0.8017
2008	0.0577	0.0752	0.1313	0.0928	0.0723	0.0705	0.1283	0.0496	0.0396	0.0377	0.0498	0.8048
2009	0.0420	0.0867	0.0908	0.1327	0.0860	0.0649	0.0626	0.1135	0.0438	0.0350	0.0333	0.7913
2010	0.0791	0.0932	0.1187	0.0882	0.1110	0.0684	0.0508	0.0488	0.0885	0.0341	0.0273	0.8081
2011	0.0348	0.1327	0.1136	0.1157	0.0778	0.0944	0.0575	0.0426	0.0409	0.0740	0.0285	0.8125
2012	0.0411	0.0665	0.1728	0.1128	0.1014	0.0652	0.0780	0.0473	0.0350	0.0335	0.0607	0.8143
2013	0.0328	0.0599	0.0786	0.1751	0.1067	0.0937	0.0598	0.0713	0.0432	0.0320	0.0306	0.7837
2014	0.0258	0.0614	0.0841	0.0848	0.1656	0.0962	0.0832	0.0528	0.0629	0.0381	0.0282	0.7831
2015	0.0221	0.0462	0.0851	0.0916	0.0815	0.1522	0.0873	0.0753	0.0478	0.0569	0.0345	0.7805
2016	0.0441	0.0745	0.0967	0.1083	0.0858	0.0671	0.1199	0.0678	0.0582	0.0369	0.0439	0.8032
2017	0.0257	0.1094	0.1150	0.1027	0.0958	0.0710	0.0544	0.0966	0.0546	0.0468	0.0297	0.8017
2018	0.0154	0.0455	0.1450	0.1210	0.0965	0.0864	0.0632	0.0482	0.0855	0.0482	0.0414	0.7963
2019	0.0276	0.0351	0.0673	0.1567	0.1131	0.0858	0.0756	0.0550	0.0419	0.0743	0.0419	0.7743
2020	0.0347	0.0610	0.0511	0.0723	0.1451	0.0988	0.0734	0.0642	0.0466	0.0355	0.0629	0.7456
2021	0.0641	0.0595	0.0714	0.0481	0.0624	0.1215	0.0819	0.0607	0.0530	0.0385	0.0293	0.6904
2022	0.0804	0.0903	0.0638	0.0656	0.0415	0.0527	0.1017	0.0684	0.0506	0.0442	0.0321	0.6913
2023	0.1229	0.1012	0.0902	0.0568	0.0562	0.0352	0.0446	0.0860	0.0579	0.0428	0.0374	0.7312

Table 4.7: Total tonnage of yellowfin sole caught in resource assessment surveys in the eastern Bering Sea from 1977-2023, by the Alaska Department of Fish & Game (ADFG), International Pacific Fisheries Commission (IPHC), and the National Marine Fisheries Service (NMFS).

Year	ADFG	IPHC	NMFS	Total
2006	0.0	0.0	0.0	0.0
2007	0.0	0.0	0.0	0.0
2010	0.0	0.0	118.6	118.6
2011	0.1	0.0	100.9	101.0
2012	0.0	0.0	83.4	83.4
2013	0.0	0.0	75.0	75.1
2014	0.0	0.0	82.6	82.6
2015	0.0	0.1	64.8	64.9
2016	0.1	0.0	97.8	97.9
2017	0.0	0.0	112.1	112.2
2018	0.1	0.0	72.5	72.5
2019	0.1	0.0	84.5	84.7
2020	0.0	0.0	0.0	0.0
2021	0.0	0.0	71.6	71.6
2022	0.1	0.0	87.4	87.4
2023	0.0	0.0	47.9	47.9

Table 4.8: Female yellowfin sole proportion mature at age from Nichol (1995) and TenBrink and Wilderbuer (2015).

	Nichol (1995)	TenBrink and Wilderbuer (2015)	Total
Age	1992, 1993 samples	2012 samples	Combined
1	0.000	0.00	0.00
2	0.000	0.00	0.00
3	0.001	0.00	0.00
4	0.004	0.00	0.00
5	0.008	0.00	0.00
6	0.020	0.01	0.01
7	0.046	0.03	0.04
8	0.104	0.09	0.10
9	0.217	0.21	0.21
10	0.397	0.43	0.41
11	0.612	0.68	0.65
12	0.790	0.86	0.83
13	0.899	0.94	0.92
14	0.955	0.98	0.97
15	0.981	0.99	0.99
16	0.992	1.00	1.00
17	0.997	1.00	1.00
18	1.000	1.00	1.00
19	1.000	1.00	1.00
20	1.000	1.00	1.00

Table 4.9: Yellowfin sole design-based (DB) biomass estimates (t) from the annual eastern Bering Sea shelf bottom trawl survey, and model-based (MB) biomass estimates for the combined northern and eastern Bering Sea survey areas (EBS+NBS), with upper (UCI) and lower (LCI) 95% confidence intervals. Note that surveys were not conducted in 2020.

Year	Model-based estimate (2023)			Model-based estimate (2024)			Design-based estimate		
	EBS+NBS	LCI	UCI	EBS+NBS	LCI	UCI	EBS	LCI	UCI
1982	4,027,030	4,026,482	4,027,577	4,012,970	4,012,486	4,013,453	3,406,341	2,818,736	3,993,947
1983	4,568,050	4,567,398	4,568,701	4,645,390	4,644,776	4,646,003	3,474,787	3,063,656	3,885,918
1984	4,185,330	4,184,745	4,185,914	4,246,000	4,245,458	4,246,541	3,159,622	2,787,378	3,531,866
1985	3,024,480	3,024,146	3,024,813	3,105,250	3,104,928	3,105,571	2,414,441	2,096,973	2,731,909
1986	2,336,500	2,336,219	2,336,780	2,352,470	2,352,216	2,352,723	1,923,496	1,612,859	2,234,134
1987	3,022,300	3,021,953	3,022,646	3,087,340	3,087,009	3,087,670	2,530,209	2,140,961	2,919,458
1988	2,635,670	2,635,416	2,635,923	2,631,620	2,631,383	2,631,856	2,195,923	1,774,749	2,617,096
1989	2,775,430	2,775,116	2,775,743	2,804,980	2,804,683	2,805,276	2,329,416	1,980,460	2,678,372
1990	2,622,700	2,622,419	2,622,980	2,633,570	2,633,304	2,633,835	2,192,586	1,892,488	2,492,683
1991	3,153,540	3,153,238	3,153,841	3,166,840	3,166,556	3,167,123	2,406,530	2,127,620	2,685,440
1992	2,884,600	2,884,144	2,885,055	2,724,190	2,723,808	2,724,571	2,215,413	1,820,065	2,610,761
1993	3,137,850	3,137,434	3,138,265	3,130,010	3,129,645	3,130,374	2,484,908	2,168,595	2,801,220
1994	3,556,680	3,556,107	3,557,252	3,431,940	3,431,482	3,432,397	2,615,721	2,271,486	2,959,957
1995	2,529,190	2,528,843	2,529,536	2,475,100	2,474,807	2,475,392	2,026,892	1,736,109	2,317,674
1996	2,723,150	2,722,794	2,723,505	2,735,080	2,734,758	2,735,401	2,230,818	1,838,398	2,623,237
1997	2,871,530	2,871,075	2,871,984	2,821,510	2,821,134	2,821,885	2,176,543	1,919,107	2,433,978
1998	3,551,080	3,550,259	3,551,900	3,496,900	3,496,186	3,497,613	2,222,673	1,942,539	2,502,808
1999	2,020,680	2,020,155	2,021,204	1,817,780	1,817,424	1,818,135	1,266,417	1,082,100	1,450,734
2000	2,125,330	2,124,987	2,125,672	2,073,620	2,073,335	2,073,904	1,600,280	1,398,145	1,802,414
2001	2,338,410	2,338,025	2,338,794	2,249,590	2,249,282	2,249,897	1,690,555	1,444,657	1,936,453
2002	2,603,860	2,603,406	2,604,313	2,521,940	2,521,567	2,522,312	1,923,067	1,661,477	2,184,657
2003	2,915,860	2,915,402	2,916,317	2,846,410	2,846,003	2,846,816	2,171,729	1,752,807	2,590,650
2004	3,494,700	3,494,133	3,495,266	3,433,310	3,432,805	3,433,814	2,557,795	2,171,491	2,944,100
2005	3,568,890	3,568,381	3,569,398	3,504,700	3,504,242	3,505,157	2,840,246	2,104,313	3,576,179
2006	2,898,850	2,898,459	2,899,240	2,794,580	2,794,248	2,794,911	2,146,498	1,829,351	2,463,646
2007	2,825,340	2,824,942	2,825,737	2,758,160	2,757,813	2,758,506	2,168,037	1,780,455	2,555,619
2008	3,012,310	3,011,801	3,012,818	2,842,390	2,841,970	2,842,809	2,112,687	1,594,407	2,630,968
2009	2,407,410	2,407,058	2,407,761	2,316,830	2,316,516	2,317,143	1,752,059	1,445,392	2,058,726
2010	3,118,130	3,117,799	3,118,460	2,985,410	2,985,112	2,985,707	2,388,160	1,822,160	2,954,161
2011	2,876,520	2,876,164	2,876,875	2,812,180	2,811,847	2,812,512	2,422,504	1,931,852	2,913,156
2012	2,875,650	2,875,253	2,876,046	2,746,000	2,745,636	2,746,363	1,965,412	1,688,055	2,242,768
2013	2,817,990	2,817,656	2,818,323	2,763,400	2,763,092	2,763,707	2,295,205	1,948,003	2,642,406
2014	3,047,780	3,047,426	3,048,133	2,981,080	2,980,755	2,981,404	2,531,399	2,063,497	2,999,301
2015	2,396,930	2,396,655	2,397,204	2,335,960	2,335,710	2,336,209	1,946,300	1,655,744	2,236,857
2016	3,796,820	3,796,422	3,797,217	3,727,530	3,727,150	3,727,909	2,876,796	2,547,622	3,205,971
2017	3,711,310	3,710,979	3,711,640	3,502,670	3,502,384	3,502,955	2,805,164	2,324,139	3,286,190
2018	2,961,540	2,961,279	2,961,800	2,794,610	2,794,381	2,794,838	1,903,041	1,673,587	2,132,495
2019	2,875,140	2,874,905	2,875,374	2,743,450	2,743,241	2,743,658	2,017,620	1,592,272	2,442,967
2021	2,476,000	2,475,787	2,476,212	2,372,550	2,372,361	2,372,738	1,633,967	1,417,385	1,850,550
2022	2,936,470	2,936,215	2,936,724	2,785,320	2,785,094	2,785,545	2,039,968	1,773,113	2,306,822
2023	2,007,140	2,006,955	2,007,324	1,889,620	1,889,460	1,889,779	1,393,378	1,133,407	1,653,350
2024	-	-	-	2,022,780	2,022,500	2,023,059	1,503,618	1,250,990	1,756,245

Table 4.10: Model estimates of yellowfin sole age 2+ total biomass (t) from the 2023 and 2024 stock assessments, Model 23.0 (2023) and Model 23.0 (2024). Input survey biomass data is based on model-based (VAST) estimates for the NBS+EBS.

Model	23.0 (2023)	23.0 (2024)		
	Biomass (t)	Biomass (t)	LCI	HCI
1954	2,423,160	2,739,280	2,337,920	3,209,560
1955	2,376,930	2,684,280	2,318,380	3,107,930
1956	2,331,800	2,614,330	2,292,770	2,980,970
1957	2,289,230	2,531,310	2,260,340	2,834,770
1958	2,268,840	2,458,410	2,240,200	2,697,870
1959	2,250,120	2,380,980	2,212,200	2,562,630
1960	2,101,830	2,173,990	2,044,610	2,311,560
1961	1,692,110	1,709,170	1,606,410	1,818,500
1962	1,227,300	1,180,860	1,094,900	1,273,570
1963	883,637	857,976	781,057	942,471
1964	924,513	897,054	815,383	986,906
1965	919,805	887,860	800,698	984,511
1966	980,248	941,940	847,080	1,047,420
1967	984,241	937,952	834,246	1,054,550
1968	929,434	873,459	759,591	1,004,400
1969	989,666	922,071	793,447	1,071,550
1970	996,636	917,063	771,331	1,090,330
1971	1,089,240	996,884	829,408	1,198,180
1972	1,201,470	1,095,950	903,679	1,329,130
1973	1,489,500	1,370,340	1,148,610	1,634,870
1974	1,768,630	1,636,490	1,385,680	1,932,690
1975	2,159,530	2,004,510	1,717,140	2,339,980
1976	2,489,620	2,321,300	2,005,360	2,687,000
1977	2,810,960	2,632,580	2,292,140	3,023,590
1978	3,106,430	2,919,400	2,558,820	3,330,800
1979	3,255,780	3,062,700	2,688,490	3,488,990
1980	3,411,190	3,214,690	2,830,800	3,650,630
1981	3,532,460	3,337,630	2,948,380	3,778,270
1982	3,559,160	3,372,930	2,991,480	3,803,030
1983	3,493,000	3,313,210	2,937,590	3,736,850
1984	3,632,020	3,453,080	3,069,670	3,884,380
1985	3,575,340	3,403,860	3,019,540	3,837,090
1986	3,257,450	3,094,820	2,729,140	3,509,490
1987	3,148,250	2,991,850	2,629,610	3,403,990
1988	3,001,610	2,854,090	2,503,810	3,253,370
1989	3,027,420	2,867,700	2,512,470	3,273,140
1990	2,868,040	2,716,290	2,375,210	3,106,350
1991	2,965,970	2,805,910	2,462,260	3,197,530
1992	3,156,260	2,975,720	2,621,100	3,378,330
1993	3,242,770	3,044,370	2,683,760	3,453,430
1994	3,318,830	3,106,810	2,742,720	3,519,230
1995	3,092,680	2,889,820	2,542,150	3,285,020
1996	3,039,190	2,832,800	2,489,610	3,223,300
1997	3,109,230	2,885,880	2,535,810	3,284,280
1998	2,840,060	2,625,980	2,293,730	3,006,350
1999	2,641,850	2,440,170	2,123,510	2,804,060
2000	2,519,430	2,326,040	2,026,510	2,669,840

2001	2,505,700	2,312,340	2,010,820	2,659,070
2002	2,608,310	2,402,400	2,098,600	2,750,190
2003	2,936,550	2,703,220	2,370,780	3,082,270
2004	3,115,450	2,861,520	2,517,180	3,252,960
2005	3,223,170	2,952,920	2,604,140	3,348,410
2006	3,260,800	2,986,120	2,635,260	3,383,690
2007	3,211,900	2,937,950	2,596,780	3,323,940
2008	3,081,100	2,820,350	2,493,290	3,190,310
2009	3,110,560	2,840,310	2,504,430	3,221,220
2010	3,248,490	2,964,830	2,615,280	3,361,090
2011	3,205,520	2,926,870	2,589,510	3,308,170
2012	3,049,110	2,770,530	2,446,320	3,137,710
2013	2,928,580	2,655,850	2,343,700	3,009,570
2014	2,887,920	2,611,540	2,300,950	2,964,050
2015	2,866,870	2,581,910	2,267,540	2,939,870
2016	2,881,680	2,586,400	2,273,230	2,942,700
2017	2,873,180	2,536,470	2,217,410	2,901,440
2018	2,615,040	2,330,620	2,039,110	2,663,810
2019	2,673,750	2,374,260	2,071,880	2,720,770
2020	2,574,660	2,288,160	1,992,010	2,628,340
2021	2,623,810	2,337,800	2,038,150	2,681,510
2022	2,719,490	2,424,630	2,105,490	2,792,140
2023	2,716,370	2,373,960	2,044,780	2,756,140
2024		2,412,520	2,065,680	2,817,590

Table 4.11: Yellowfin sole design-based biomass estimates (t) from the northern Bering Sea survey, with upper and lower 95% confidence intervals, as well as number of hauls, hauls with yellowfin sole, and hauls in which length data was obtained. There was no NBS survey in 2024. Age data from 2023 was not used in the assessment model.

Year	Biomass (t)	LCI	HCI	Haul count	Hauls with catch	Hauls with length	Otoliths read	Hauls with otoliths
2010	427,374	331,321	523,426	141	121	121	351	46
2017	434,087	336,225	531,949	143	131	130	536	50
2019	520,031	395,637	644,425	144	141	140	0	33
2021	496,045	392,315	599,775	144	138	137	0	122
2022	548,026	365,861	730,191	144	136	135	362	123
2023	393,304	314,123	472,485	116	108	108	316	107

Table 4.12: Yellowfin sole population numbers-at-age (millions) estimated from the annual EBS bottom trawl surveys, 1987-2023 (Current year data is not yet available and there was no survey in 2020). Data in years 1987 or later come from the 'plusnw' extended survey area. Females are presented first, followed by males. Continued on next page.

Year	Age (Females)															
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1982	75	368	700	2,430	2,977	2,852	3,242	1,689	1,659	1,665	1,409	819	493	319	102	68
1983	0	9	114	299	1,460	2,755	1,646	2,078	1,827	1,471	2,256	1,693	576	313	118	54
1984	0	106	555	528	855	1,490	1,682	2,223	2,159	1,882	1,083	1,167	961	478	348	152
1985	0	7	210	876	1,156	793	1,233	1,786	861	1,012	1,065	750	581	627	400	154
1986	0	15	48	437	698	1,333	558	1,147	1,039	754	567	635	392	501	272	307
1987	0	0	69	118	787	447	822	252	365	581	344	434	234	261	239	174
1988	0	0	6	345	65	1,364	501	498	165	215	317	188	326	247	198	152
1989	0	0	15	98	721	235	1,341	596	449	75	180	310	236	240	185	83
1990	0	0	70	102	327	1,073	193	1,263	410	484	102	72	108	79	232	127
1991	0	10	128	250	124	407	900	151	1,268	214	527	63	129	87	124	164
1992	0	19	240	465	499	203	275	900	91	794	73	297	125	132	163	104
1993	0	24	101	361	640	437	271	226	1,323	79	872	158	166	69	68	92
1994	0	54	95	223	519	907	556	482	285	1,172	0	517	44	274	143	42
1995	0	19	154	291	183	896	633	277	136	25	639	21	565	105	81	98
1996	0	16	151	793	281	271	421	501	200	141	147	583	113	617	45	29
1997	0	18	326	506	730	257	240	508	229	114	177	185	502	44	316	76
1998	0	10	80	455	402	860	248	194	353	393	352	162	168	252	64	398
1999	0	3	62	190	168	179	705	101	104	238	184	181	70	99	170	102
2000	0	11	55	250	210	307	449	544	192	200	240	222	66	118	147	111
2001	0	1	66	221	478	226	363	371	585	334	74	172	139	115	170	100
2002	0	16	119	164	243	748	326	274	216	434	209	86	291	110	144	137
2003	0	15	114	236	244	279	1,111	218	270	277	243	99	111	164	162	83
2004	10	34	198	442	572	418	219	976	224	213	222	223	108	20	170	187
2005	0	53	168	196	588	415	232	474	878	221	137	185	337	164	51	181
2006	8	68	304	378	278	637	472	177	327	742	134	134	71	157	177	2
2007	0	38	520	349	384	276	505	310	125	228	507	120	138	127	105	77
2008	0	24	115	742	624	546	357	361	196	128	255	355	152	79	86	119
2009	5	38	206	206	1,200	601	495	267	212	220	130	139	198	89	43	2
2010	0	33	331	390	442	902	559	521	332	338	156	168	136	174	100	50
2011	0	14	245	544	713	467	775	414	460	206	228	150	143	146	188	99
2012	10	50	231	398	509	296	245	758	258	337	107	157	37	151	129	150
2013	0	4	89	271	423	535	258	222	412	408	361	120	136	134	134	95
2014	0	0	37	424	387	250	422	233	230	527	343	161	145	230	35	123
2015	0	23	3	169	470	352	310	289	251	150	284	260	136	100	81	68
2016	1	33	72	46	165	748	569	406	365	302	144	246	231	141	163	171
2017	17	80	384	382	123	320	1,007	484	338	380	229	149	204	201	149	119
2018	0	50	183	263	178	92	265	642	327	232	81	76	42	125	100	104
2019	2	124	210	309	157	242	80	211	549	360	130	161	126	124	72	44
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	259	100	1,450	457	318	123	177	95	157	162	109	106	67	55	62
2022	0	97	361	282	1,406	425	405	88	160	81	127	174	87	73	77	66
2023	0	17	132	339	279	752	482	181	32	47	20	125	80	82	54	32

Year	Age (Females)															
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1982	178	388	859	3,567	3,566	2,120	3,348	1,288	1,549	927	943	965	605	16	47	14
1983	0	1	126	354	1,403	3,371	1,576	2,044	1,320	1,368	1,412	1,107	832	1,076	151	89
1984	0	135	493	646	994	1,469	1,660	1,225	1,575	1,437	716	758	402	631	244	111
1985	0	83	343	833	1,107	519	1,289	1,044	795	893	714	444	516	311	222	33
1986	0	25	95	217	747	1,303	524	653	568	670	422	410	230	421	163	272
1987	0	5	40	104	820	457	655	431	317	267	203	142	102	137	178	212
1988	0	2	10	414	46	1,088	508	407	78	172	25	163	308	174	25	107
1989	0	2	24	182	790	177	1,311	515	359	135	50	104	54	205	36	39
1990	0	11	48	122	319	895	196	1,152	320	265	40	65	67	24	55	73
1991	0	0	104	357	140	277	1,051	68	1,144	331	246	75	65	61	53	92
1992	0	0	141	428	543	252	216	779	110	875	186	206	12	12	60	38
1993	0	20	53	236	652	396	281	249	1,105	70	849	53	53	51	0	49
1994	4	22	71	166	428	955	658	308	191	824	26	624	46	132	11	37
1995	0	0	170	121	272	673	570	95	181	76	482	14	608	50	25	78
1996	0	74	93	822	238	221	414	335	321	138	135	389	59	437	122	93
1997	0	10	216	429	804	182	185	449	247	196	216	109	519	79	266	31
1998	0	46	67	335	546	797	152	215	194	258	329	143	150	179	108	250
1999	0	5	96	136	216	234	556	142	91	300	261	72	52	27	116	34
2000	0	0	36	221	261	145	515	590	79	217	135	77	93	79	67	154
2001	0	0	82	131	604	310	342	324	514	191	80	144	60	67	129	55
2002	0	56	71	153	298	727	304	316	248	419	184	135	207	151	124	20
2003	0	24	93	174	251	244	1,046	231	354	52	277	169	10	70	56	105
2004	4	64	117	478	455	202	400	1,005	267	83	199	226	104	48	253	105
2005	0	49	168	180	454	458	240	298	1,007	124	140	119	132	68	92	127
2006	0	102	174	351	334	508	396	290	300	387	117	156	90	39	12	55
2007	0	58	486	355	409	286	550	211	167	269	337	100	132	70	60	123
2008	0	10	100	667	466	487	347	456	227	145	186	332	63	66	35	104
2009	0	65	146	293	961	468	549	250	252	219	79	31	197	30	29	51
2010	0	78	201	422	374	1,041	466	514	173	191	161	53	118	153	79	54
2011	1	7	151	388	486	361	799	402	227	178	78	82	138	104	158	97
2012	0	70	277	356	348	277	241	430	300	181	99	68	91	34	101	60
2013	0	7	93	369	387	485	213	270	448	201	202	34	90	101	119	19
2014	0	0	9	369	400	288	341	313	253	404	208	194	20	193	95	108
2015	1	29	36	132	430	335	304	315	321	48	181	132	81	1	81	112
2016	0	44	86	20	143	710	548	405	369	126	118	228	182	89	35	92
2017	10	121	233	399	107	262	886	502	313	277	196	108	217	156	37	12
2018	0	40	175	189	230	72	236	524	261	189	96	77	73	75	69	30
2019	0	137	253	234	103	272	110	149	492	272	131	156	85	68	57	95
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	53	190	1,079	518	373	88	107	69	85	159	43	62	37	42	56
2022	0	74	121	444	1,041	488	308	80	95	62	107	144	67	25	137	67
2023	0	0	102	228	238	685	391	182	41	39	18	34	68	81	22	34

Table 4.13: Effective sample sizes used for survey and fishery age compositions, by year: the number of survey hauls from which yellowfin sole otoliths were taken (Survey hauls), survey effective sample size (ESS), and fishery effective sample size.

Year	Survey hauls	ESS survey	ESS fishery
1979	30	14	21.5
1980	30	14	21.5
1981	30	14	21.5
1982	32	15	21.5
1983	34	16	21.5
1984	49	23	21.5
1985	41	20	21.5
1986	33	15	21.5
1987	16	8	21.5
1988	17	8	21.5
1989	23	11	21.5
1990	27	13	21.5
1991	25	12	21.5
1992	15	7	21.5
1993	20	10	21.5
1994	13	7	21.5
1995	20	10	21.5
1996	16	8	21.5
1997	11	5	21.5
1998	15	7	21.5
1999	29	13	21.5
2000	32	15	21.5
2001	32	15	21.5
2002	32	15	21.5
2003	36	16	21.5
2004	26	12	21.5
2005	33	15	21.5
2006	37	17	21.5
2007	58	28	21.5
2008	57	28	21.5
2009	64	32	21.5
2010	85	41	21.5
2011	54	26	21.5
2012	65	32	21.5
2013	57	28	21.5
2014	47	22	21.5
2015	66	32	21.5
2016	60	29	21.5
2017	88	42	21.5
2018	63	30	21.5
2019	62	30	21.5
2021	120	58	21.5
2022	132	63	21.5
2023	146	70	21.5

Table 4.14: Parameter values and their 95% confidence intervals, Model 23.0 used in 2023. Spawning biomass is presented from 1954 - 2023.

Name	Value	Standard Deviation	Name	Value	Standard Deviation
male natural mortality	1.3657e-01	4.9348e-03	SSB	1237.30000	132.300000
alpha (q-temp model)	1.0349e-01	8.4087e-02	SSB	1202.50000	132.480000
beta (q-temp model)	6.8618e-02	1.0890e-02	SSB	1106.00000	126.920000
beta (survey start date)	5.8988e-03	3.0066e-03	SSB	1039.10000	124.210000
beta (start date/temp interaction)	-2.6649e-03	3.1919e-03	SSB	1010.80000	120.910000
mean log recruitment	9.3771e-01	1.0623e-01	SSB	1050.60000	120.930000
log_avg_fmort	-6.8001e-01	1.6941e-01	SSB	1100.30000	121.380000
log_avg_fmort	-2.5071e+00	1.1524e-01	SSB	1122.90000	121.530000
sel_slope_fsh_f	1.2022e+00	1.4434e-01	SSB	1119.50000	119.490000
sel50_fsh_f	8.1960e+00	3.0661e-01	SSB	1110.80000	118.790000
sel_slope_srv	1.5805e+00	2.3845e-01	SSB	1051.50000	113.940000
sel50_srv	4.3214e+00	2.0110e-01	SSB	1025.00000	112.160000
R_logalpha	-4.5682e+00	6.3025e-01	SSB	967.91000	108.950000
R_logbeta	-6.5551e+00	4.2407e-01	SSB	966.26000	108.850000
SSB	9.4219e+02	1.6237e+02	SSB	914.91000	104.140000
SSB	9.5082e+02	1.5860e+02	SSB	977.69000	111.060000
SSB	9.4165e+02	1.5262e+02	SSB	965.46000	107.570000
SSB	9.1744e+02	1.4530e+02	SSB	1036.00000	113.240000
SSB	8.8127e+02	1.3727e+02	SSB	1098.60000	117.690000
SSB	8.0547e+02	1.2776e+02	SSB	1148.70000	121.380000
SSB	6.1885e+02	1.1624e+02	SSB	1206.20000	126.900000
SSB	2.9886e+02	1.2454e+02	SSB	1176.80000	123.550000
SSB	1.1692e+02	6.1322e+01	SSB	1127.60000	118.280000
SSB	7.5739e+01	2.8012e+01	SSB	1194.30000	126.350000
SSB	8.4801e+01	2.2081e+01	SSB	1264.80000	134.320000
SSB	1.0096e+02	2.0496e+01	SSB	1186.30000	124.730000
SSB	1.2307e+02	2.1285e+01	SSB	1190.80000	126.220000
SSB	1.3183e+02	2.2207e+01	SSB	1144.30000	121.110000
SSB	1.3282e+02	2.3702e+01	SSB	1112.40000	119.770000
SSB	1.3126e+02	2.5796e+01	SSB	1149.20000	124.480000
SSB	1.1364e+02	2.7128e+01	SSB	1133.60000	122.220000
SSB	1.0292e+02	2.9468e+01	SSB	1171.40000	128.800000
SSB	9.6388e+01	3.2572e+01	SSB	1062.20000	114.900000
SSB	1.0926e+02	3.7710e+01	SSB	1113.50000	121.530000
SSB	1.3006e+02	4.2728e+01	SSB	1061.60000	118.170000
SSB	2.0030e+02	5.6259e+01	SSB	971.29000	109.600000
SSB	2.7573e+02	6.5252e+01	SSB	980.12000	114.090000
SSB	3.8676e+02	7.6949e+01	SSB	916.71000	109.200000
SSB	5.2307e+02	8.9032e+01	msy	479.93000	201.030000
SSB	6.6282e+02	1.0056e+02	Fmsy	0.17357	0.089271
SSB	8.2029e+02	1.1176e+02	logFmsy	-1.75120	0.514320
SSB	9.6963e+02	1.2081e+02	Fmsyr	0.11339	0.042140
SSB	1.0474e+03	1.2299e+02	logFmsyr	-2.17690	0.371640
SSB	1.1600e+03	1.2857e+02			
SSB	1.2389e+03	1.3067e+02			
SSB	1.2764e+03	1.3356e+02			

Table 4.15: Parameter values and their 95% confidence intervals, Model 23.0 with data through 2024. Spawning biomass is presented from 1954 - 2024.

Name	Value	Standard Deviation	Name	Value	Standard Deviation
male natural mortality	1.2770e-01	3.7386e-03	SSB	1116.60000	96.616000
alpha (q-temp model)	1.5933e-01	6.7189e-02	SSB	1083.90000	96.886000
beta (q-temp model)	7.4190e-02	1.0286e-02	SSB	995.94000	92.874000
beta (survey start date)	7.9193e-03	2.6824e-03	SSB	935.93000	90.995000
beta (start date/temp interaction)	-3.7024e-03	2.7790e-03	SSB	913.79000	88.827000
mean log recruitment	8.0449e-01	9.9499e-02	SSB	955.08000	89.210000
log_avg_fmort	-5.5987e-01	1.3098e-01	SSB	1003.80000	89.890000
log_avg_fmort	-2.4506e+00	9.9578e-02	SSB	1023.50000	90.119000
sel_slope_fsh_f	1.1922e+00	1.1554e-01	SSB	1015.90000	88.396000
sel50_fsh_f	8.2175e+00	2.7611e-01	SSB	1002.60000	87.571000
sel_slope_srv	1.6495e+00	1.9312e-01	SSB	942.86000	83.557000
sel50_srv	4.2940e+00	1.4611e-01	SSB	913.54000	81.734000
R_logalpha	-4.5416e+00	6.1149e-01	SSB	857.33000	78.900000
R_logbeta	-6.4160e+00	4.0102e-01	SSB	853.78000	78.645000
SSB	1.0680e+03	1.4924e+02	SSB	806.52000	75.115000
SSB	1.0787e+03	1.4263e+02	SSB	861.00000	80.083000
SSB	1.0695e+03	1.3401e+02	SSB	848.51000	77.386000
SSB	1.0437e+03	1.2437e+02	SSB	910.36000	81.397000
SSB	1.0047e+03	1.1434e+02	SSB	964.10000	84.460000
SSB	9.2569e+02	1.0254e+02	SSB	1005.00000	86.784000
SSB	7.3896e+02	8.6008e+01	SSB	1052.50000	90.445000
SSB	4.4929e+02	4.6924e+01	SSB	1022.40000	87.561000
SSB	1.1583e+02	4.5154e+01	SSB	976.86000	83.536000
SSB	6.3264e+01	1.4612e+01	SSB	1030.90000	88.905000
SSB	7.7592e+01	1.3658e+01	SSB	1088.40000	94.133000
SSB	9.5767e+01	1.4106e+01	SSB	1020.50000	87.121000
SSB	1.1781e+02	1.5256e+01	SSB	1022.60000	87.860000
SSB	1.2581e+02	1.5986e+01	SSB	981.73000	84.030000
SSB	1.2553e+02	1.6898e+01	SSB	950.81000	82.865000
SSB	1.2200e+02	1.7953e+01	SSB	978.70000	85.968000
SSB	1.0285e+02	1.8336e+01	SSB	961.43000	84.277000
SSB	8.9917e+01	1.9383e+01	SSB	985.31000	88.489000
SSB	8.0517e+01	2.0950e+01	SSB	892.72000	79.107000
SSB	8.8485e+01	2.4152e+01	SSB	932.14000	83.786000
SSB	1.0376e+02	2.7271e+01	SSB	884.07000	81.611000
SSB	1.6234e+02	3.6060e+01	SSB	802.35000	75.683000
SSB	2.2944e+02	4.2353e+01	SSB	802.29000	78.621000
SSB	3.3130e+02	5.0945e+01	SSB	786.69000	81.091000
SSB	4.5914e+02	6.0191e+01	SSB	751.02000	77.879000
SSB	5.9089e+02	6.9323e+01	msy	453.73000	179.900000
SSB	7.3839e+02	7.8331e+01	Fmsy	0.18361	0.090066
SSB	8.7700e+02	8.5815e+01	logFmsy	-1.69500	0.490540
SSB	9.4859e+02	8.8066e+01	Fmsyr	0.12142	0.043913
SSB	1.0509e+03	9.2690e+01	logFmsyr	-2.10850	0.361660
SSB	1.1220e+03	9.4800e+01			
SSB	1.1543e+03	9.7318e+01			

Table 4.16: Mean unsmoothed survey weight-at-age (grams) for yellowfin sole females, 1964-2023.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1965	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1966	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1967	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1968	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1969	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1970	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1971	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1972	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1973	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1974	4	15	34	60	91	125	160.0	195	230	263	294	322	348	372	393	412	429	444	481	590
1975	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1976	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1977	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1978	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1979	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1980	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1981	8	20	31	55	84	124	165.0	217	266	301	341	374	407	428	443	480	483	499	590	590
1982	8	20	42	75	98	139	176.0	214	233	235	331	359	393	410	436	482	470	476	586	590
1983	10	14	26	60	103	162	185.0	201	243	255	318	350	391	419	455	503	489	503	605	590
1984	14	26	33	57	110	156	177.0	222	246	294	318	342	375	418	453	498	492	536	617	590
1985	11	16	28	46	77	177	202.0	251	286	302	314	341	367	417	450	502	520	556	623	590
1986	14	27	23	41	71	103	173.0	239	284	338	314	336	366	401	439	490	511	547	628	590
1987	10	14	20	47	55	127	179.0	256	317	324	331	351	375	411	443	475	519	557	619	590
1988	9	12	16	34	66	85	159.0	237	286	307	351	364	377	393	418	446	490	528	597	590
1989	12	21	33	67	71	112	133.0	197	279	339	364	384	402	400	422	445	506	490	570	590
1990	11	17	24	38	65	99	126.0	197	243	321	389	400	411	405	430	436	475	475	559	590
1991	11	16	23	58	56	100	142.0	156	238	310	394	421	420	429	446	450	486	481	557	590
1992	12	21	29	55	85	121	177.0	176	283	305	377	417	430	456	454	464	498	485	562	590
1993	15	28	35	64	93	155	165.0	232	244	301	368	411	438	469	470	477	506	496	563	590
1994	20	46	53	86	87	125	155.0	235	276	284	355	405	418	470	472	482	486	504	571	590
1995	12	20	28	60	84	123	160.0	217	284	332	333	403	412	463	470	478	515	495	575	590
1996	11	16	36	51	108	137	167.0	202	222	311	322	379	403	448	461	487	509	503	567	590
1997	16	34	33	72	85	157	200.0	236	260	292	336	383	397	439	457	488	492	514	577	590
1998	10	14	36	51	90	104	177.0	237	278	279	333	383	391	430	439	478	479	513	576	590
1999	9	12	18	37	67	103	131.0	239	284	296	331	374	398	417	429	474	484	506	593	590
2000	6	8	14	33	36	92	142.0	192	211	231	294	336	378	361	393	458	491	522	505	609
2001	6	4	8	31	39	62	99.0	148	195	242	284	383	392	436	424	442	474	528	530	663
2002	6	8	19	27	45	66	105.0	156	229	246	276	343	328	394	451	480	504	552	560	631
2003	6	8	14	29	56	87	127.0	171	224	299	328	357	413	454	417	505	374	600	575	652
2004	6	8	14	38	64	101	163.0	162	231	300	328	359	440	524	551	476	485	500	500	654
2005	6	4	21	40	72	114	156.0	217	236	284	349	356	377	464	509	505	612	472	620	693
2006	6	6	16	36	76	114	149.0	206	236	303	308	360	368	592	493	495	532	568	618	740
2007	6	8	16	38	70	113	170.0	196	239	330	304	351	361	406	456	466	558	568	683	740
2008	6	8	24	31	57	106	140.0	203	239	281	309	345	395	432	422	501	567	555	594	660
2009	6	6	10	22	51	92	142.0	182	248	321	334	377	434	429	433	575	874	556	565	697
2010	6	2	16	25	57	84	136.0	186	218	343	337	403	446	460	517	557	594	620	744	795
2011	6	8	12	30	49	92	145.0	210	264	318	329	405	419	441	448	621	534	516	623	696
2012	6	6	11	27	53	91	146.0	167	258	317	367	321	452	529	502	514	562	654	598	730
2013	6	8	12	21	40	102	131.0	195	275	318	366	399	415	474	473	518	550	555	606	702
2014	6	8	19	16	37	85	145.0	201	252	306	368	360	428	421	495	592	536	577	570	715
2015	6	8	15	12	40	62	130.0	215	262	355	418	437	411	484	474	596	647	593	531	731
2016	6	12	25	37	69	86	130.0	211	329	378	417	415	517	465	509	522	581	580	618	723
2017	6	9	19	51	69	118	21.5	187	273	366	382	436	536	503	553	647	601	701	585	824
2018	6	8	22	39	88	111	163.0	236	248	346	421	447	504	478	542	606	586	571	717	677
2019	6	6	21	47	92	160	180.0	254	277	346	404	583	503	505	570	680	701	673	698	720
2020	6	6	21	47	92	160	180.0	254	277	346	404	583	503	505	570	680	701	673	698	720
2021	6	6	21	43	103	188	248.0	321	365	453	438	478	540	564	592	637	602	635	650	667
2022	6	6	17	49	85	151	244.0	338	391	437	524	516	518	626	635	646	644	739	784	734
2023	6	6	19	40	85	132	211.0	312	365	439	534	525	576	597	611	651	723	720	821	868

Table 4.17: Mean unsmoothed survey weight-at-age (grams) for yellowfin sole males, 1964-2023.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1964	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1965	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1966	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1967	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1968	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1969	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1970	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1971	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1972	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1973	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1974	0	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481
1975	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1976	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1977	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1978	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1979	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1980	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1981	4	14	18	32	54	85	120	156	193	225	253	280	303	324	330	344	355	366	390	423
1982	4	11	25	50	83	112	133	142	158	182	242	266	286	309	345	352	361	384	418	420
1983	4	5	5	23	57	95	156	156	155	176	233	256	271	295	331	341	344	385	414	417
1984	4	10	20	31	57	121	150	181	202	193	223	242	259	281	316	325	330	394	394	406
1985	4	11	23	32	51	84	148	186	214	227	218	236	254	269	307	317	340	399	423	399
1986	4	9	18	27	34	61	98	176	217	233	215	225	248	257	293	313	322	389	405	389
1987	4	8	14	17	27	53	97	157	211	226	228	236	266	269	267	294	306	358	364	386
1988	4	7	10	18	45	75	76	138	207	242	238	252	281	278	283	297	314	347	355	381
1989	4	7	10	27	47	72	142	130	179	244	252	279	300	298	295	305	336	325	370	377
1990	4	9	16	22	44	64	98	120	175	197	261	295	312	309	305	301	324	318	332	377
1991	4	9	17	29	51	75	100	132	180	212	266	302	323	328	319	308	341	315	378	379
1992	4	9	17	28	53	86	97	125	174	208	262	302	322	368	345	329	349	328	394	373
1993	4	9	18	45	56	93	135	145	206	209	257	294	339	369	347	341	362	335	397	372
1994	4	23	32	53	76	92	116	182	198	207	255	291	334	367	353	362	355	369	394	387
1995	4	10	19	32	59	88	110	154	177	207	250	278	333	361	349	380	359	375	406	399
1996	4	10	19	32	54	107	134	163	184	215	241	277	324	349	347	374	355	398	365	410
1997	4	8	14	37	64	75	149	174	185	239	240	274	315	308	335	362	363	400	353	427
1998	4	10	20	27	49	79	113	156	208	207	244	274	296	308	324	356	354	401	354	429
1999	4	6	7	18	37	63	95	123	170	171	241	263	287	292	324	340	362	375	355	434
2000	4	8	33	30	34	71	105	157	162	244	218	245	266	272	288	335	304	342	364	428
2001	4	8	20	22	32	49	95	151	170	196	244	259	296	299	313	307	362	436	447	410
2002	4	8	17	22	53	58	91	146	204	213	232	257	274	309	345	362	334	383	440	423
2003	4	8	27	39	53	83	112	170	189	250	265	308	267	443	407	370	360	367	381	469
2004	4	8	14	36	59	95	150	158	207	260	321	311	311	368	469	384	414	392	465	464
2005	4	4	19	40	72	115	134	162	206	265	291	334	395	312	310	364	391	374	418	446
2006	4	8	18	32	67	118	144	183	207	237	233	318	350	417	452	438	352	343	380	449
2007	4	8	17	33	67	105	139	177	208	244	287	282	302	351	408	369	339	381	400	449
2008	4	8	8	27	50	95	121	181	192	244	270	298	312	346	384	405	373	399	436	481
2009	4	8	10	20	42	85	128	155	200	287	276	316	399	338	430	308	439	384	369	481
2010	4	8	13	24	48	80	141	167	183	302	315	322	356	414	402	401	417	512	461	501
2011	4	4	11	31	59	88	133	188	227	262	341	302	398	338	381	445	409	416	440	523
2012	4	8	12	27	53	88	126	183	216	256	283	320	292	422	420	387	431	393	355	475
2013	4	8	12	20	41	77	131	189	228	267	269	346	275	371	383	420	456	407	395	487
2014	4	8	20	30	59	86	154	188	243	292	313	311	321	332	424	466	429	527	492	495
2015	4	6	19	25	38	64	135	202	230	321	361	386	368	367	400	432	445	537	563	494
2016	4	8	33	46	50	83	127	190	260	332	327	340	406	394	416	409	443	474	375	505
2017	4	8	21	46	76	102	110	170	247	311	347	367	404	380	466	483	614	577	496	573
2018	4	8	23	45	89	95	161	178	221	276	316	403	384	435	421	386	424	431	548	484
2019	4	8	20	48	97	126	195	206	237	280	324	384	377	384	431	464	434	454	464	507
2020	4	8	20	48	97	126	195	206	237	280	324	384	377	384	431	464	434	454	464	507
2021	4	8	24	59	110	180	232	250	267	332	331	374	420	428	435	455	462	449	431	448
2022	4	4	21	42	82	162	228	266	325	362	383	414	412	435	447	472	499	547	524	570
2023	4	7	12	30	83	137	197	222	330	317	394	452	476	441	445	578	469	495	638	563

Table 4.18: Model estimates of yellowfin sole full selection fishing mortality (Full sel. F) and exploitation rate (Catch/Total Biomass) for Model 23.0 (2023), and 23.0 (2024).

Year	Model 23.0 (2023)		Model 23.0 (2024)	
	Full sel. F	Catch/Tot. Biom.	Full sel. F	Catch/Tot. Biom.
1954	0.007	0.005	0.006	0.005
1955	0.008	0.006	0.007	0.005
1956	0.014	0.011	0.012	0.009
1957	0.014	0.011	0.012	0.01
1958	0.028	0.019	0.024	0.018
1959	0.132	0.082	0.112	0.078
1960	0.456	0.217	0.363	0.21
1961	1.417	0.327	0.719	0.324
1962	1.062	0.343	3.528	0.356
1963	0.326	0.097	0.327	0.1
1964	0.277	0.121	0.272	0.125
1965	0.212	0.059	0.21	0.061
1966	0.361	0.104	0.364	0.109
1967	0.464	0.165	0.472	0.173
1968	0.265	0.091	0.271	0.096
1969	0.597	0.169	0.619	0.181
1970	0.407	0.134	0.425	0.145
1971	0.491	0.147	0.533	0.161
1972	0.177	0.04	0.203	0.044
1973	0.242	0.053	0.287	0.057
1974	0.074	0.024	0.085	0.026
1975	0.091	0.03	0.103	0.032
1976	0.074	0.023	0.087	0.024
1977	0.044	0.021	0.048	0.022
1978	0.092	0.045	0.098	0.047
1979	0.056	0.03	0.059	0.032
1980	0.045	0.026	0.049	0.027
1981	0.045	0.028	0.048	0.029
1982	0.039	0.027	0.041	0.028
1983	0.042	0.031	0.044	0.033
1984	0.064	0.044	0.067	0.046
1985	0.095	0.064	0.101	0.067
1986	0.092	0.064	0.097	0.067
1987	0.088	0.058	0.093	0.061
1988	0.117	0.074	0.123	0.078
1989	0.089	0.051	0.094	0.053
1990	0.046	0.029	0.048	0.031
1991	0.052	0.04	0.055	0.042
1992	0.068	0.046	0.071	0.049
1993	0.055	0.033	0.059	0.035
1994	0.077	0.042	0.082	0.045
1995	0.07	0.04	0.074	0.043
1996	0.066	0.043	0.07	0.046
1997	0.105	0.059	0.111	0.063
1998	0.069	0.036	0.075	0.039
1999	0.048	0.026	0.052	0.028
2000	0.055	0.033	0.06	0.036

2001	0.04	0.025	0.044	0.027
2002	0.047	0.029	0.051	0.031
2003	0.04	0.027	0.044	0.03
2004	0.036	0.024	0.04	0.026
2005	0.042	0.029	0.046	0.032
2006	0.044	0.03	0.047	0.033
2007	0.055	0.038	0.06	0.041
2008	0.071	0.048	0.077	0.053
2009	0.047	0.035	0.052	0.038
2010	0.053	0.037	0.058	0.04
2011	0.068	0.047	0.073	0.052
2012	0.066	0.048	0.072	0.053
2013	0.077	0.056	0.085	0.062
2014	0.078	0.054	0.086	0.06
2015	0.065	0.044	0.073	0.049
2016	0.07	0.047	0.079	0.052
2017	0.068	0.046	0.076	0.052
2018	0.07	0.05	0.079	0.056
2019	0.074	0.048	0.083	0.054
2020	0.078	0.052	0.088	0.058
2021	0.064	0.041	0.073	0.047
2022	0.085	0.057	0.099	0.064
2023	0.047	0.028	0.076	0.048
2024	-	-	0.052	0.031

Table 4.19: Model estimates of yellowfin sole female spawning biomass (FSB) in the eastern Bering Sea in metric tons (t) and upper (HCI) and lower (LCI) 95% confidence intervals from the 2023 and 2024 stock assessments, including Model 23.0 (2023), and 23.0 (2024).

Model	23.0 (2023)			23.0 (2024)		
Year	FSB (t)	LCI	HCI	FSB (t)	LCI	HCI
1954	942,185	669,184	1,326,560	1,068,030	808,719	1,410,480
1955	950,817	682,656	1,324,320	1,078,680	828,962	1,403,620
1956	941,647	682,378	1,299,420	1,069,510	833,254	1,372,750
1957	917,440	669,672	1,256,880	1,043,720	823,097	1,323,480
1958	881,269	646,586	1,201,130	1,004,710	800,770	1,260,590
1959	805,469	587,675	1,103,980	925,689	742,245	1,154,470
1960	618,848	426,433	898,084	738,958	585,955	931,913
1961	298,863	134,248	665,332	449,285	364,797	553,341
1962	116,917	43,620	313,377	115,826	54,587	245,764
1963	75,738	37,009	154,997	63,263	40,099	99,810
1964	84,800	50,807	141,537	77,591	54,712	110,039
1965	100,964	67,548	150,909	95,767	71,443	128,371
1966	123,067	87,301	173,485	117,806	91,023	152,469
1967	131,833	94,348	184,210	125,811	97,676	162,049
1968	132,825	93,216	189,263	125,529	96,016	164,113
1969	131,256	88,926	193,735	122,001	91,038	163,493
1970	113,644	70,969	181,980	102,854	72,208	146,505
1971	102,921	58,707	180,434	89,917	58,712	137,708
1972	96,388	49,935	186,056	80,517	48,258	134,339
1973	109,262	55,857	213,726	88,485	51,764	151,255
1974	130,058	68,558	246,725	103,761	61,879	173,987
1975	200,295	115,430	347,554	162,345	104,671	251,797
1976	275,727	172,869	439,786	229,439	159,100	330,875
1977	386,760	260,797	573,561	331,305	244,030	449,792
1978	523,068	373,051	733,411	459,136	353,637	596,107
1979	662,815	490,181	896,249	590,894	467,687	746,558
1980	820,285	625,415	1,075,870	738,390	597,586	912,371
1981	969,633	756,487	1,242,830	877,001	721,457	1,066,080
1982	1,047,420	828,856	1,323,610	948,595	788,162	1,141,680
1983	1,160,050	930,045	1,446,930	1,050,900	881,248	1,253,200
1984	1,238,910	1,003,890	1,528,960	1,122,000	947,837	1,328,160
1985	1,276,440	1,036,010	1,572,670	1,154,300	975,480	1,365,900
1986	1,237,270	999,653	1,531,370	1,116,600	939,463	1,327,130
1987	1,202,480	965,322	1,497,910	1,083,860	906,741	1,295,570
1988	1,105,970	879,813	1,390,260	995,939	826,819	1,199,650
1989	1,039,080	818,816	1,318,580	935,929	770,892	1,136,300
1990	1,010,820	796,426	1,282,940	913,793	752,686	1,109,380
1991	1,050,570	835,173	1,321,530	955,079	792,655	1,150,790
1992	1,100,260	883,004	1,370,970	1,003,760	839,459	1,200,220
1993	1,122,900	904,920	1,393,400	1,023,470	858,505	1,220,140
1994	1,119,520	904,879	1,385,090	1,015,920	853,937	1,208,630
1995	1,110,750	897,410	1,374,810	1,002,560	842,146	1,193,540
1996	1,051,540	847,189	1,305,170	942,863	789,995	1,125,310
1997	1,025,010	824,082	1,274,930	913,543	764,138	1,092,160
1998	967,906	773,338	1,211,430	857,325	713,472	1,030,180
1999	966,259	771,889	1,209,570	853,779	710,404	1,026,090
2000	914,905	729,169	1,147,950	806,522	669,724	971,264

2001	977,689	779,568	1,226,160	860,999	715,134	1,036,620
2002	965,461	773,138	1,205,630	848,507	707,296	1,017,910
2003	1,036,050	833,149	1,288,350	910,357	761,559	1,088,230
2004	1,098,610	887,288	1,360,270	964,100	809,421	1,148,340
2005	1,148,700	930,420	1,418,180	1,004,960	845,821	1,194,030
2006	1,206,230	977,920	1,487,840	1,052,460	886,542	1,249,430
2007	1,176,780	954,450	1,450,900	1,022,400	861,729	1,213,040
2008	1,127,590	914,724	1,389,980	976,864	823,555	1,158,710
2009	1,194,250	967,065	1,474,810	1,030,900	867,853	1,224,570
2010	1,264,790	1,023,370	1,563,180	1,088,450	915,860	1,293,560
2011	1,186,290	961,872	1,463,060	1,020,500	860,584	1,210,120
2012	1,190,830	963,920	1,471,150	1,022,570	861,395	1,213,910
2013	1,144,280	926,529	1,413,210	981,729	827,526	1,164,670
2014	1,112,410	897,460	1,378,840	950,814	798,987	1,131,490
2015	1,149,250	925,999	1,426,320	978,700	821,298	1,166,270
2016	1,133,570	914,256	1,405,500	961,429	807,093	1,145,280
2017	1,171,400	940,773	1,458,550	985,314	823,618	1,178,760
2018	1,062,240	856,132	1,317,970	892,719	747,991	1,065,450
2019	1,113,460	895,683	1,384,190	932,143	779,051	1,115,320
2020	1,061,580	850,278	1,325,400	884,068	735,315	1,062,910
2021	971,291	775,613	1,216,340	802,349	664,682	968,529
2022	980,120	777,156	1,236,090	802,287	659,804	975,541
2023	916,707	722,973	1,162,360	786,690	640,483	966,273
2024	NA	NA	NA	751,023	610,694	923,597

Table 4.20: Likelihood components and AIC for Model 23.0 and the same model without the environmental covariates on survey catchability (Model 23.0_noEC). Survey_q represents the mean over years.

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_likelihood	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

Table 4.21: Yellowfin sole total allowable catch (TAC), overfishing limit (OFL), and acceptable biological catch (ABC) levels, 1980-2024. Catch for the Bering Sea and Aleutian Islands was recorded through October 1, 2024. Data is in metric tons. Estimates for 2024 were calculated using Model 23.0, and the 2024 TAC has not yet been set.

Year	TAC	ABC	OFL	Catch
1980	117,000	169,000	n/a	87,391
1981	117,000	214,500	n/a	97,301
1982	117,000	214,500	n/a	95,712
1983	117,000	214,500	n/a	108,385
1984	230,000	310,000	n/a	159,526
1985	229,900	310,000	n/a	227,107
1986	209,500	230,000	n/a	208,597
1987	187,000	187,000	n/a	181,428
1988	254,000	254,000	n/a	223,156
1989	182,675	241,000	n/a	153,165
1990	207,650	278,900	n/a	83,970
1991	135,000	250,600	n/a	117,303
1992	235,000	372,000	452,000	145,386
1993	220,000	238,000	275,000	105,810
1994	150,325	230,000	269,000	140,050
1995	190,000	277,000	319,000	124,752
1996	200,000	278,000	342,000	129,659
1997	230,000	233,000	339,000	182,814
1998	220,000	220,000	314,000	101,155
1999	207,980	212,000	308,000	69,234
2000	123,262	191,000	226,000	84,071
2001	113,000	176,000	209,000	63,579
2002	86,000	115,000	136,000	74,986
2003	83,750	114,000	136,000	79,806
2004	86,075	114,000	135,000	75,511
2005	90,686	124,000	148,000	94,385
2006	95,701	121,000	144,000	99,160
2007	136,000	225,000	240,000	120,964
2008	225,000	248,000	265,000	148,894
2009	210,000	210,000	224,000	107,513
2010	219,000	219,000	234,000	118,624
2011	196,000	239,000	262,000	151,158
2012	202,000	203,000	222,000	147,187
2013	198,000	206,000	220,000	164,944
2014	184,000	239,800	259,700	156,772
2015	149,000	248,800	266,400	126,937
2016	144,000	211,700	228,100	135,324
2017	154,000	260,800	287,000	132,220
2018	154,000	277,500	306,700	131,496
2019	154,000	263,200	290,000	128,051
2020	150,700	260,918	287,307	133,800
2021	200,000	313,477	341,571	108,788
2022	250,000	354,014	377,014	154,253
2023	230,000	378,499	404,882	112,889
2024		262,557	299,247	59,044

Table 4.22: Projections of yellowfin sole female spawning biomass (FSB), future catch, and full selection fishing mortality rates (F) for seven future harvest scenarios. Estimates of FSB and catch are in metric tons (t). All estimates are based on Model 23.0.

Scenarios 1 and 2 Maximum ABC harvest permissible			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	465,472	116,788	0.085
2026	481,237	135,017	0.094
2027	498,240	145,068	0.097
2028	517,389	157,081	0.101
2029	534,697	164,952	0.105
2030	547,861	170,036	0.108
2031	555,246	172,282	0.109
2032	554,697	170,593	0.108
2033	558,119	171,185	0.108
2034	559,472	169,645	0.107
2035	560,434	168,722	0.106
2036	562,107	168,722	0.105
2037	564,529	168,088	0.105

Scenario 3 Harvest at average F over past 5 years			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	465,472	116,788	0.085
2026	480,596	140,855	0.098
2027	496,244	145,614	0.098
2028	515,793	151,745	0.098
2029	535,462	154,617	0.098
2030	552,690	156,398	0.098
2031	565,131	157,932	0.098
2032	569,472	157,993	0.098
2033	577,206	159,739	0.098
2034	581,995	160,223	0.098
2035	585,334	161,157	0.098
2036	588,522	162,449	0.098
2037	591,860	162,517	0.098

Scenario 4, Maximum Tier 3 ABC harvest permissible set at F60			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	465,472	116,788	0.085
2026	487,368	78,475	0.054
2027	523,709	83,933	0.054
2028	564,727	90,122	0.054
2029	605,968	94,296	0.054
2030	644,408	97,666	0.054
2031	676,635	100,658	0.054
2032	697,585	102,406	0.054
2033	721,406	105,101	0.054
2034	739,794	106,670	0.054
2035	754,755	108,431	0.054
2036	767,995	110,343	0.054
2037	780,359	111,207	0.054

Scenario 5 No fishing			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	465,472	116,788	0.085
2026	495,671	0	0.000
2027	558,984	0	0.000
2028	630,439	0	0.000
2029	704,720	0	0.000
2030	778,091	0	0.000
2031	845,416	0	0.000
2032	898,517	0	0.000
2033	955,326	0	0.000
2034	1,003,958	0	0.000
2035	1,046,859	0	0.000
2036	1,085,884	0	0.000
2037	1,122,714	0	0.000

Alternative 6, Determination of whether yellowfin sole are currently overfished			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	462,250	145,596	0.107
2026	469,597	153,431	0.109
2027	480,468	161,391	0.112
2028	494,199	171,853	0.115
2029	506,921	178,074	0.118
2030	516,254	181,577	0.121
2031	520,646	182,990	0.122
2032	518,147	180,567	0.121
2033	519,610	181,811	0.121
2034	519,237	180,734	0.121
2035	518,578	179,888	0.120
2036	518,729	179,972	0.119
2037	519,655	179,319	0.119

Scenario 7, Determination of whether stock is approaching an overfished condition			
Year	FSB	Catch	F
2024	461,280	74,288	0.058
2025	464,722	123,525	0.090
2026	479,109	133,882	0.093
2027	493,585	169,697	0.115
2028	504,898	178,576	0.118
2029	515,163	183,123	0.120
2030	522,267	185,164	0.122
2031	524,806	185,415	0.123
2032	520,852	182,102	0.122
2033	521,335	182,757	0.122
2034	520,305	181,261	0.121
2035	519,238	180,189	0.120
2036	519,105	180,136	0.119
2037	519,852	179,401	0.119

Table 4.23: Incidental catch of FMP Groundfish in the yellowfin sole fisheries (in metric tons), 2009 - 2024. Source: NMFS AKRO Blend/Catch Accounting System.

	2009	2010	2011	2012	2013	2014	2015	2016
Arrowtooth Flounder	1,852	1,620	2,332	987	2,042	2,216	1,686	3,250
Atka Mackerel	0	0	0	0	0	0	0	0
BSAI Alaska Plaice	10,632	12,044	18,306	13,594	15,979	14,373	11,681	8,164
BSAI Kamchatka Flounder	0	0	91	122	149	498	427	284
BSAI Other Flatfish	242	978	1,586	1,207	388	2,887	1,041	1,136
BSAI Shortraker Rockfish	0	0	0	0	0	0	0	0
BSAI Skate and GOA Skate, Other	0	0	2,107	2,235	2,683	1,970	1,073	1,295
BSAI Squid	0	0	0	0	0	0	0	0
Flathead Sole	3,497	2,695	3,230	2,095	4,180	3,999	3,337	4,104
Greenland Turbot	4	1	5	6	35	57	43	8
Northern Rockfish	0	0	0	0	0	0	0	0
Octopus	0	0	2	1	1	0	0	1
Other Rockfish	0	0	0	0	0	0	1	0
Other Species	4,347	3,561	0	0	0	0	0	0
Pacific Cod	10,717	11,118	16,204	19,380	24,340	15,218	12,168	11,985
Pacific Ocean Perch	0	0	0	0	17	1	0	3
Pollock	7,037	5,179	8,674	11,198	20,172	24,713	21,282	22,306
Rock Sole	8,978	9,625	9,695	9,180	7,688	7,031	9,773	7,949
Rougheye Rockfish	0	0	0	0	0	0	0	0
Sablefish	0	0	0	0	0	0	1	0
Sculpin	0	0	1,804	1,941	1,921	1,260	1,083	949
Shark	0	0	1	0	1	1	1	4
Squid	0	0	0	0	0	0	0	0
Yellowfin Sole	97,904	102,756	136,797	134,286	147,466	139,485	107,941	107,496

	2017	2018	2019	2020	2021	2022	2023	2024
Arrowtooth Flounder	1,263	3,076	3,219	2,016	1,541	1,335	1,014	1,164
Atka Mackerel	0	0	0	0	19	0	0	0
BSAI Alaska Plaice	12,782	15,340	12,954	16,595	11,798	9,732	11,871	5,568
BSAI Kamchatka Flounder	165	218	230	129	93	77	83	69
BSAI Other Flatfish	1,734	3,283	1,476	2,176	1,026	552	540	523
BSAI Shortraker Rockfish	0	0	0	2	0	0	0	0
BSAI Skate and GOA Skate, Other	1,932	2,562	3,508	2,481	3,474	3,362	2,234	1,271
BSAI Squid	0	0	0	0	0	0	0	0
Flathead Sole	3,106	3,967	4,133	3,499	3,005	6,003	2,629	2,070
Greenland Turbot	8	26	6	13	5	4	11	4
Northern Rockfish	0	0	0	0	0	0	0	0
Octopus	0	0	0	0	0	1	1	0
Other Rockfish	0	1	1	0	0	1	1	1
Other Species	0	0	0	0	0	0	0	0
Pacific Cod	14,648	12,582	11,770	12,062	8,934	10,034	7,481	5,102
Pacific Ocean Perch	0	1	1	63	2	1	1	0
Pollock	23,414	28,235	23,153	31,651	24,845	26,515	22,348	15,238
Rock Sole	12,196	9,362	9,204	11,240	8,121	8,957	10,126	6,717
Rougheye Rockfish	0	0	0	0	0	0	0	0
Sablefish	1	7	0	4	0	0	0	0
Sculpin	1,308	1,247	1,535	1,452	0	0	0	0
Shark	2	4	3	3	1	7	1	1
Squid	0	0	0	0	0	0	0	0
Yellowfin Sole	110,445	109,832	111,504	120,541	100,131	144,486	96,290	62,273

Table 4.24: Incidental catch of other species in the yellowfin sole fisheries, in metric tons, 1992 - 2024. Source: NMFS AKRO Blend/Catch Accounting System.

	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
BSAI Skate and GOA Skate, Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BSAI Squid	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Octopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	26	4	21	1,042	0	0	0	0	0	0
Other Species	0	0	0	0	0	0	0	0	0	0	1,530	598	945	1,133	1,410	1,304
Shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	5	0	11	0	2	1	0	0	0	0	0	0	0	0	0

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
BSAI Skate and GOA Skate, Other	0	0	2,107	2,235	2,683	1,970	1,073	1,295	1,932	2,562	3,508	2,481	3,474	3,362	2,234	1,271
BSAI Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus	0	0	2	1	1	0	0	1	0	0	0	0	0	1	1	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Species	1,786	1,913	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shark	0	0	1	0	1	1	1	4	2	4	3	3	1	7	1	1
Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.25: Incidental catch of nontarget species in yellowfin sole fisheries, 2003 - 2024, in metric tons (number for seabirds). Source: NMFS AKRO Catch Accounting System (continued on the next page).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Benthic urochordata	1672	1701	675	520	114	348	205	156	133	148	197
Birds - Gull	0	0	0	0	0	0	0		0	0	0
Birds - Murre	0	0		0	0	0	0		0	0	0
Birds - Northern Fulmar	0	0	0	0	0	0				0	
Birds - Other	0	0	0	0	0	0		0	0	0	0
Birds - Other Alcid	0	0	0	0	0	0		0	0	0	0
Birds - Shearwaters	0	0	0	0	0	0	0		0	0	0
Birds - Unidentified	0	0		0	0	0	0		0	0	0
Bivalves	2	1	1	0	0	1	1	2	2	1	1
Brittle star unidentified	34	32	29	20	8	19	5	4	14	13	6
Capelin	0	4	0	0	0	0	0	1	4	2	0
Corals Bryozoans	0	0	0	0	0	0	0	0	0	0	0
Eelpouts	19	12	8	5	2	6	5	5	29	14	52
Eulachon	0	0	0	0	5	0	0	0	0	0	0
Giant Grenadier	0	0	0	0	0	0	0	0	0	0	0
Greenlings	1	1	0	1	0	0	0	0	0	0	0
Rattail Grenadier Unid.	0	0	0	0	0	0	0	0	0	0	0
Gunnels	0	0	0	0	0	0	0	0	0	0	0
Hermit crab unidentified	88	52	84	27	36	37	15	17	16	10	6
Invertebrate unidentified	556	626	421	177	40	70	31	26	65	121	25
Large Sculpins	239	823	1058	1059	2270	0	0	0	0	0	0
Misc crabs	14	22	12	11	28	14	11	12	21	20	40
Misc crustaceans	0	0	0	2	1	1	1	1	1	1	1
Misc fish	96	91	66	42	71	66	49	29	39	55	47
Misc inverts (worms etc)	0	0	0	0	0	0	0	0	0	0	0
Other osmerids	4	4	0	1	36	10	1	3	2	5	1
Other Sculpins	1158	131	105	68	195	39	75	0	0	0	0
Pacific Sand lance	0	0	0	0	0	0	0	0	0	0	0
Pacific Sandfish	0	0	0	0	0	0	0	0	0	0	0
Pandalid shrimp	0	1	0	1	0	0	0	1	2	1	2
Polychaete unid.	0	0	0	0	0	0	0	0	0	0	0
Saffron Cod	0	0	0	0	0	0	0	0	1	31	1
Sculpin	0	0	0	0	0	0	0	0	0	0	0
Scypho jellies	112	299	116	47	42	146	223	152	308	179	463
Sea anemone unid.	0	0	0	0	0	0	0	0	0	0	0
Sea pens whips	0	0	0	0	0	0	0	1	0	0	0
Sea star	1941	1868	1612	1309	1462	1829	684	796	1674	1736	1372
Smelt (Family Osmeridae)	0	0	0	0	0	0	0	0	0	0	0
Snails	118	191	70	142	95	140	58	58	75	34	46
Sponge unidentified	11	7	12	3	0	7	69	17	15	14	17
Squid	0	0	0	0	0	0	0	0	0	0	0
State-managed Rockfish	0	0	0	0	0	0	0	0	0	0	0
Stichaeidae	0	0	0	0	1	0	0	0	0	0	0
Surf smelt	0	0	0	0	0	0	0	0	0	0	0
urchins dollars cucumbers	2	0	3	1	3	5	8	1	1	1	1

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Benthic urochordata	116	261	226	320	208	189	109	175	250	166	37
Birds - Gull	0	0	0	0	0	0	0	0	0	0	0
Birds - Murre		0		0	0	0	0	0	0	0	0
Birds - Northern Fulmar		0			0	0			0	0	0
Birds - Other	0	0	0	0	0	0	0	0	0	0	0
Birds - Other Alcid	0	0	0	0	0	0	0	0	0	0	0
Birds - Shearwaters				0	0	0	0	0	0		0
Birds - Unidentified		0	0	0	0	0	0	0		0	0
Bivalves	1	2	1	1	1	2	1	1	1	1	1
Brittle star unidentified	12	11	6	2	3	4	4	6	3	5	0
Capelin	1	2	0	0	0	0	0	0	0	0	0
Corals Bryozoans	0	0	0	0	0	0	0	0	0	0	0
Eelpouts	70	30	57	8	27	21	17	27	8	14	7
Eulachon	1	0	3	0	0	0	0	0	0	0	0
Giant Grenadier	0	0	0	0	11	0	0	0	0	0	0
Greenlings	0	0	1	0	0	1	2	2	2	2	0
Rattail Grenadier Unid.	0	0	0	0	0	0	0	0	0	0	0
Gunnels	0	0	0	0	0	0	0	0	0	0	0
Hermit crab unidentified	9	5	3	3	1	3	3	3	4	2	1
Invertebrate unidentified	44	6	8	11	4	1	1	2	2	2	0
Large Sculpins	0	0	0	0	0	0	0	0	0	0	0
Misc crabs	21	22	14	15	6	5	8	6	5	3	3
Misc crustaceans	0	1	0	0	0	0	0	1	1	1	0
Misc fish	27	36	30	43	25	30	31	53	37	38	15
Misc inverts (worms etc)	0	0	0	0	0	0	0	0	0	1	0
Other osmerids	9	5	5	3	0	13	5	1	2	2	3
Other Sculpins	0	0	0	0	0	0	0	0	0	0	0
Pacific Sand lance	0	0	0	0	0	0	0	0	0	0	0
Pacific Sandfish	0	0	0	0	0	0	1	0	0	0	2
Pandalid shrimp	1	0	1	0	0	0	1	1	0	1	1
Polychaete unid.	0	0	0	0	0	0	0	0	0	0	0
Saffron Cod	42	3	0	0	0	3	1	0	0	0	0
Sculpin	0	0	0	0	0	0	0	1775	1552	1155	706
Scypho jellies	805	382	68	94	162	677	335	624	203	238	166
Sea anemone unid.	0	0	0	0	0	0	0	0	0	0	0
Sea pens whips	0	0	0	0	0	0	0	0	0	0	0
Sea star	2107	2248	2051	1617	1469	1817	1799	1769	1373	883	276
Smelt (Family Osmeridae)	0	0	0	0	0	0	0	0	0	0	0
Snails	34	36	24	25	14	23	29	38	43	18	5
Sponge unidentified	2	2	1	2	5	3	1	3	5	3	1
Squid	0	0	0	0	0	0	1	0	0	0	0
State-managed Rockfish	0	0	0	0	0	0	0	0	0	0	0
Stichaeidae	0	0	0	0	0	0	0	0	0	0	0
Surf smelt	0	0	0	0	0	0	0	0	0	0	0
urchins dollars cucumbers	0	1	0	2	1	3	5	3	9	7	5

Table 4.26: Incidental catch of prohibited species in the yellowfin sole fisheries, 1992 - 2024. Source: NMFS AKRO Blend/Catch Accounting System, PSC Estimates. Reported in metric tons for halibut and herring, counts of fish (x 1,000) for crab and salmon.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Bairdi Tanner Crab	1,491	995	1,125	1,349	742	1,001	851	445	479	322	275	234	258	742	333	324	379
Blue King Crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
Chinook Salmon	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Golden (Brown) King Crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	795	850	794	730	973	1159	1286	1109	1093	1291	1256	865	NA	NA	NA	NA	NA
Herring	395	215	82	43	246	135	15	88	24	26	17	33	82	48	15	55	84
Non-Chinook Salmon	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Opilio Tanner (Snow) Crab	10,609	9,469	8,462	3,196	1,971	3,365	2,478	631	2,376	1,049	697	339	1,396	2,508	707	1,220	603
Other King Crab	55	6	13	2	1	1	2	3	3	0	2	0	0	0	0	0	0
Red King Crab	61	18	17	9	6	10	9	14	17	32	23	29	39	59	36	13	38

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Bairdi Tanner Crab	329	290	766	311	562	390	270	141	249	124	213	468	474	355	394	155
Blue King Crab	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chinook Salmon	0	0	0	0	1	0	1	3	1	1	2	1	1	0	0	0
Golden (Brown) King Crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halibut	NA	1060	1111	1181	1438	1614	909	1155	1258	1767	2314	1306	1171	1625	1045	719
Herring	23	3	19	16	27	25	31	33	34	48	59	50	115	22	86	20
Non-Chinook Salmon	0	0	0	0	0	2	1	1	1	7	2	0	1	0	0	0
Opilio Tanner (Snow) Crab	283	1,579	679	570	565	334	422	118	69	1,272	649	482	162	176	734	405
Other King Crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red King Crab	23	19	9	8	11	6	9	17	49	20	59	49	34	8	10	7

Figures

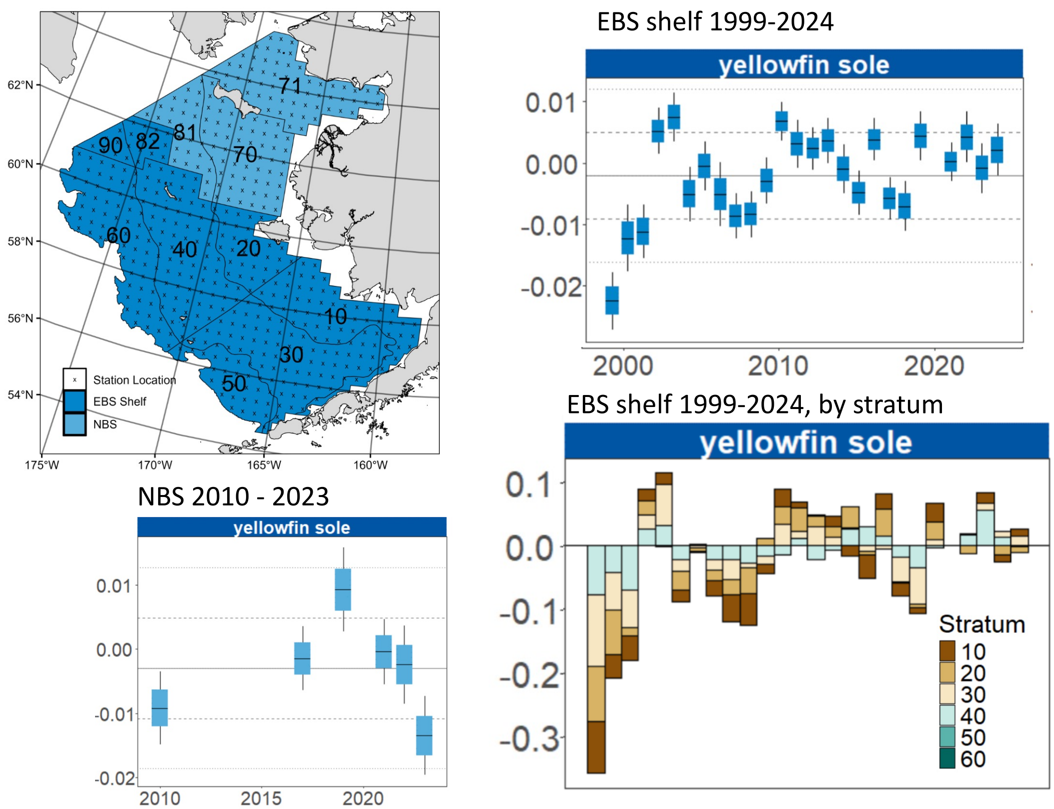
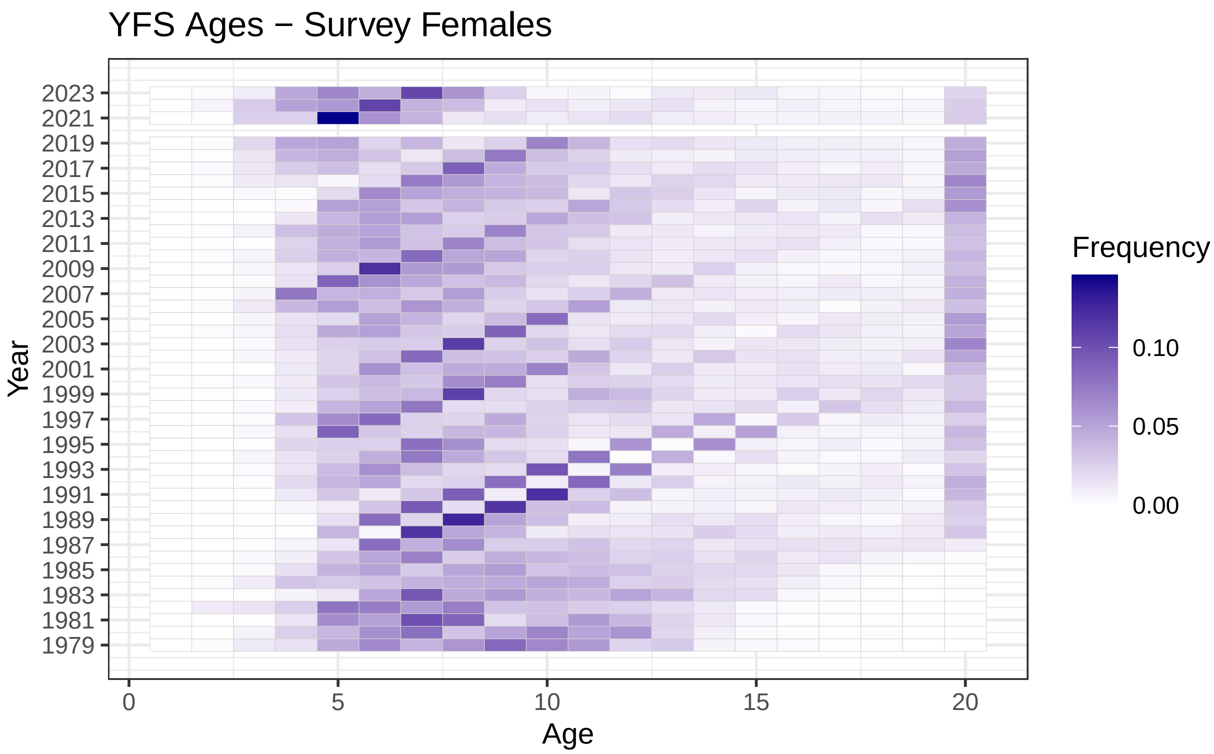


Figure 4.1: Strata map for the eastern and northern Bering Sea (upper left), length-weight residuals of yellowfin sole in the eastern Bering Sea (EBS) combined (upper right), EBS by strata (lower right), and northern Bering Sea (lower left).



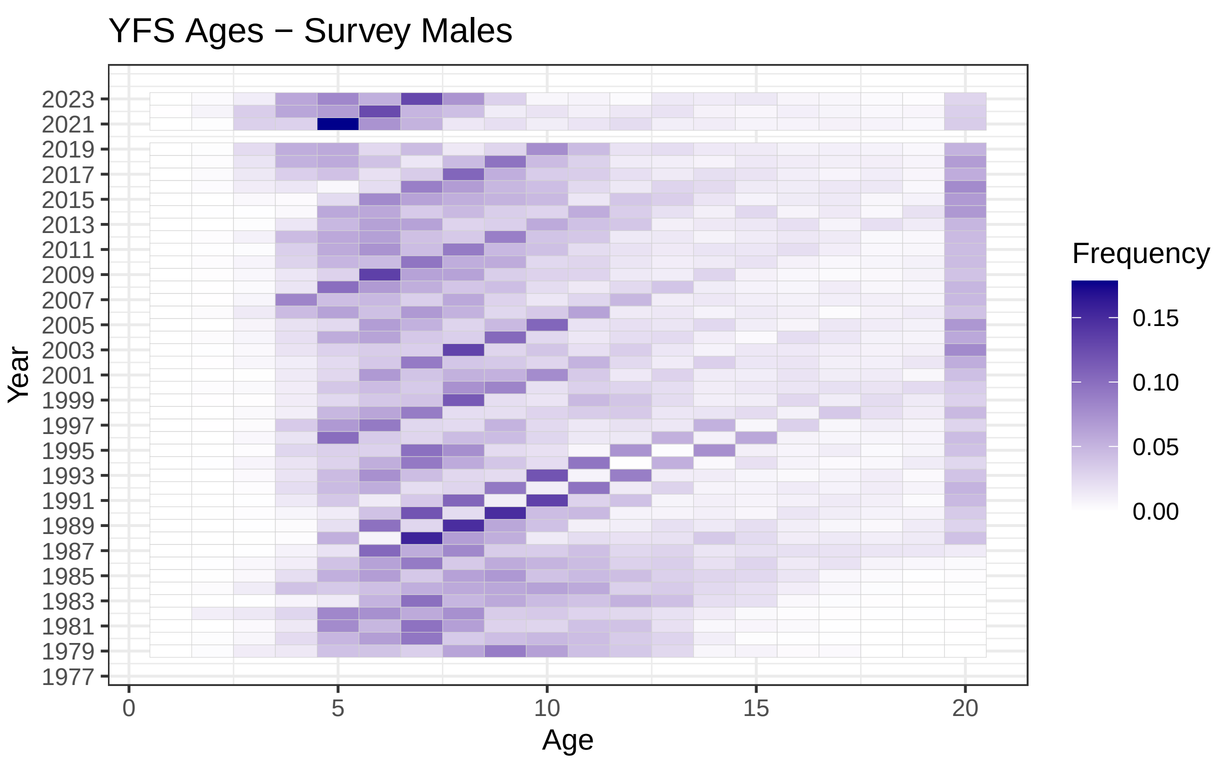


Figure 4.2: Age frequency of yellowfin sole females and males from the AFSC/NMFS research surveys, 1977-2023.

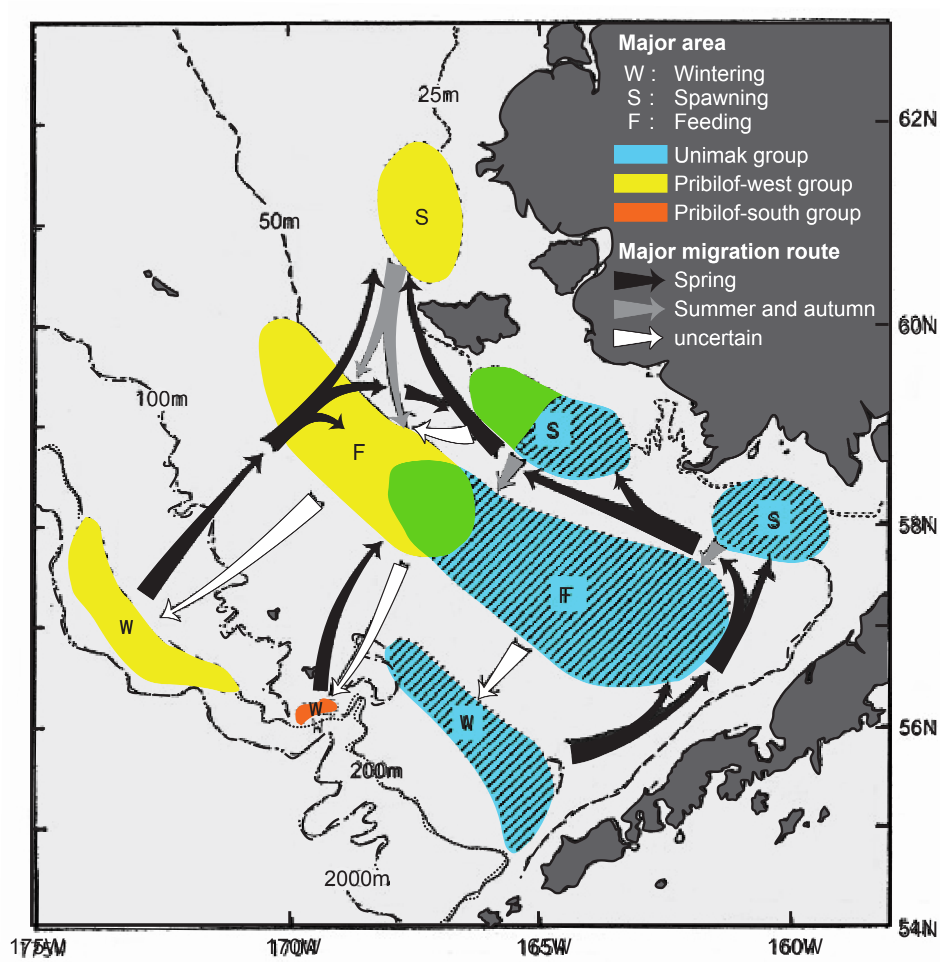


Figure 4.3: Distribution of wintering, spawning, and feeding areas for yellowfin sole in the Bering Sea, and observed regional grouping. Migration routes from wintering to feeding take place in spring, and the dates that yellowfin sole return to their wintering areas are unknown, adapted from Wakabayashi (1989).

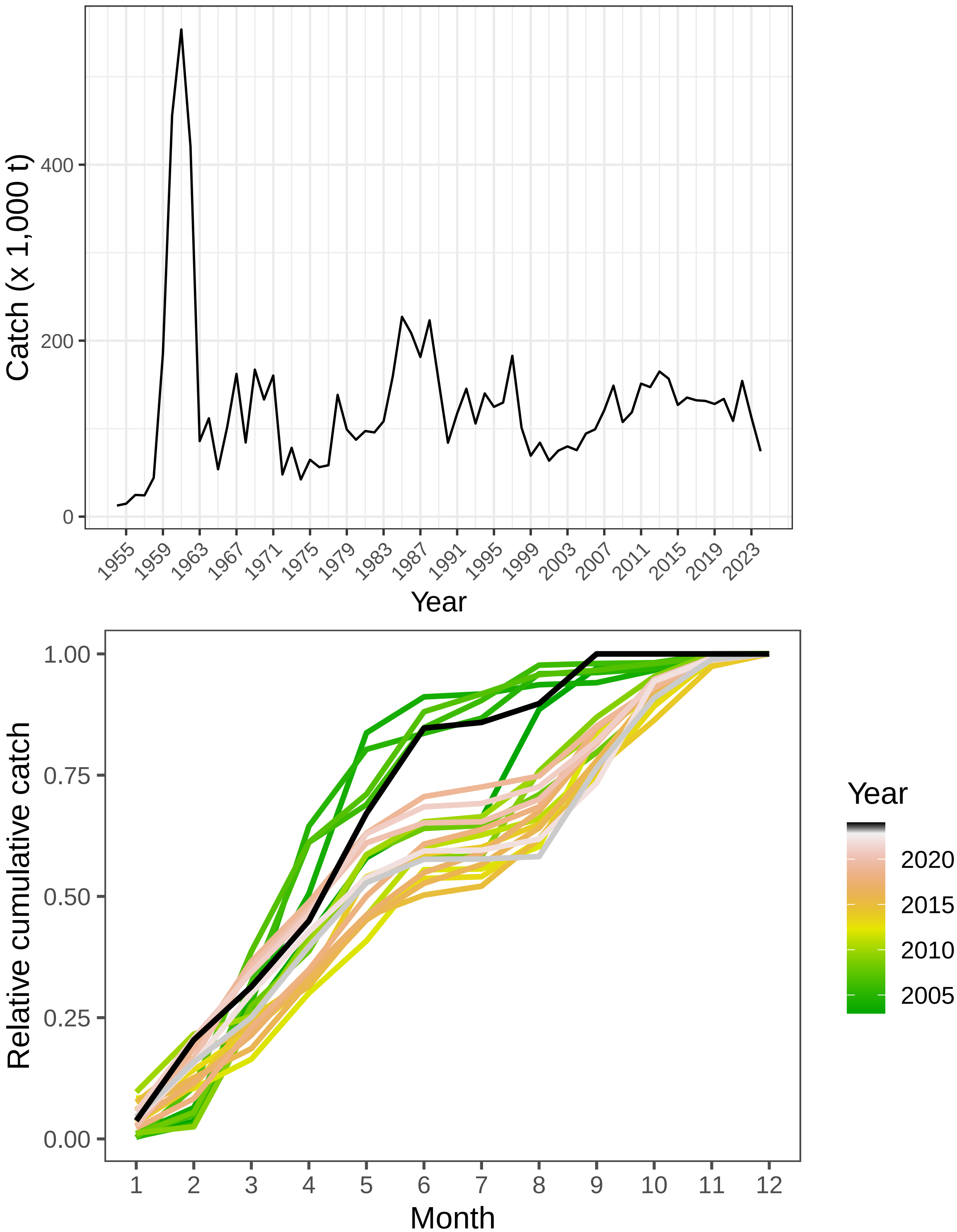


Figure 4.4: Yellowfin sole annual total catch (1,000 t) in the eastern Bering Sea from 2003-2024 (upper panel). Yellowfin sole annual cumulative catch by month and year (non CDQ) 2003-October 1, 2024 (lower panel).

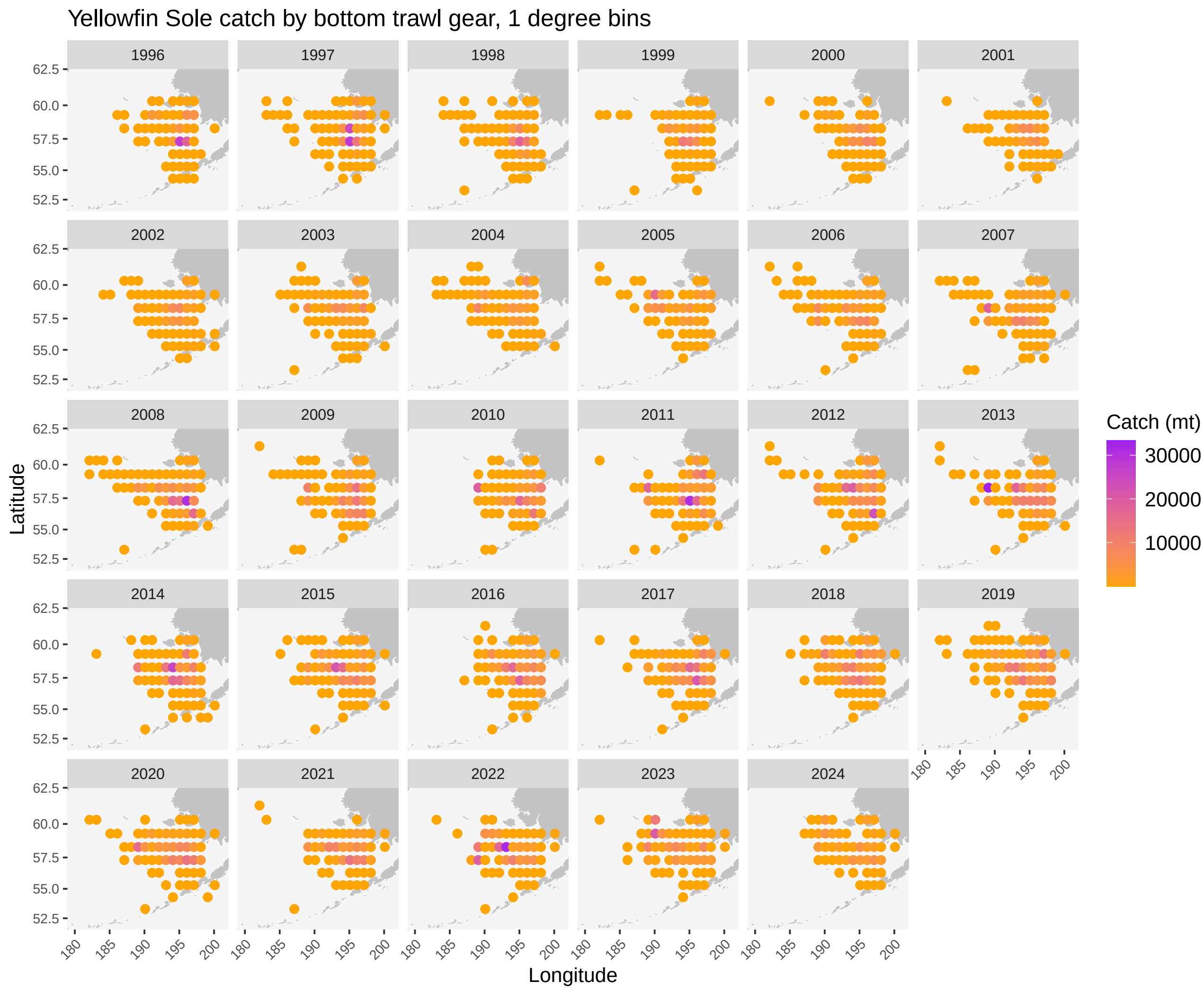


Figure 4.5: Catch of yellowfin sole by non-pelagic trawl gear in the eastern Bering Sea, 2008-2024, by year, reported by observers. Colored circles represent catch of yellowfin sole, with darker shades representing higher catch.

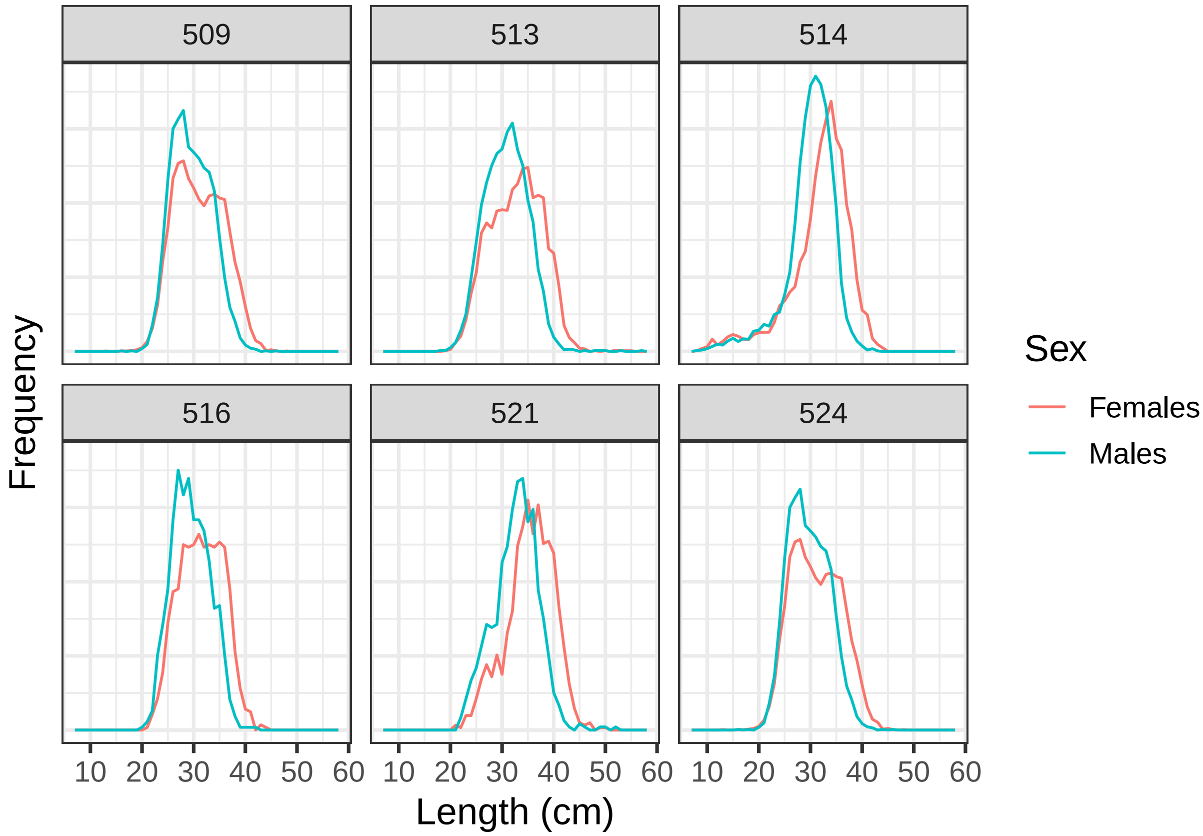


Figure 4.6: Size composition of the yellowfin sole catch in 2024 (through October 17) caught by trawl gear, by subarea, for the primary areas where yellowfin sole are caught, 509, 513, 514, 516, 521, and 524.

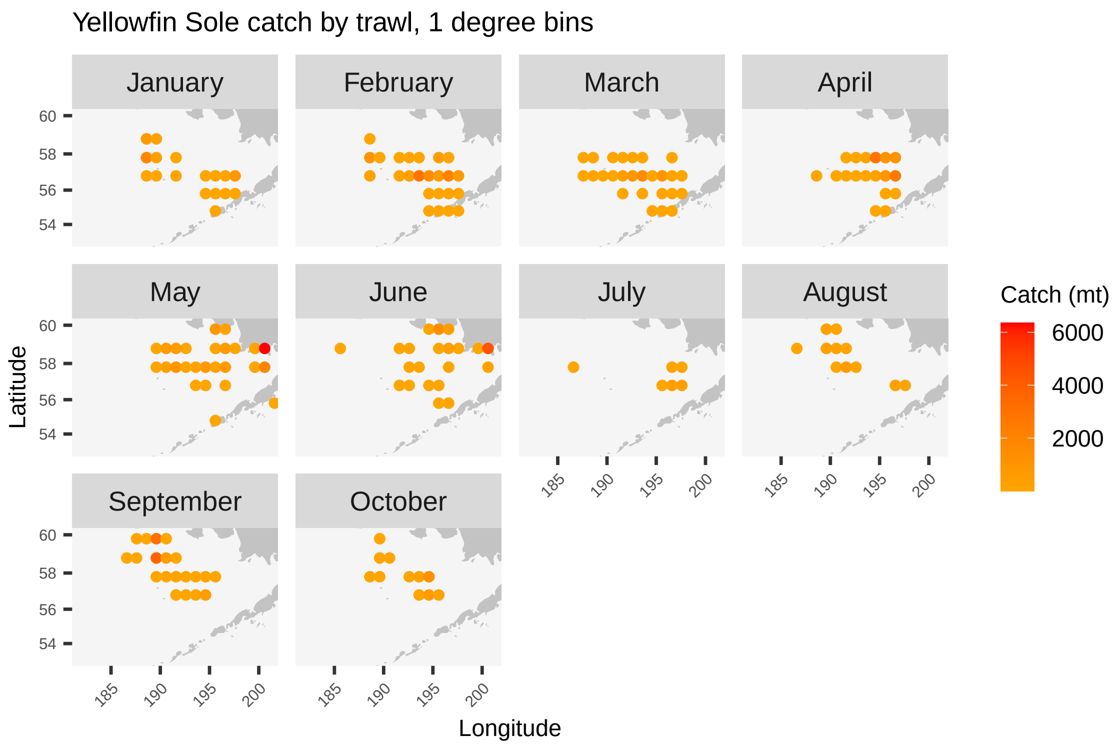


Figure 4.7: Catch of yellowfin sole in the BSAI in 2024 by month (through October 1), reported by observers. Circles represent yellowfin sole catch by the following gear types: non-pelagic trawl, pair trawl, or pelagic trawl.

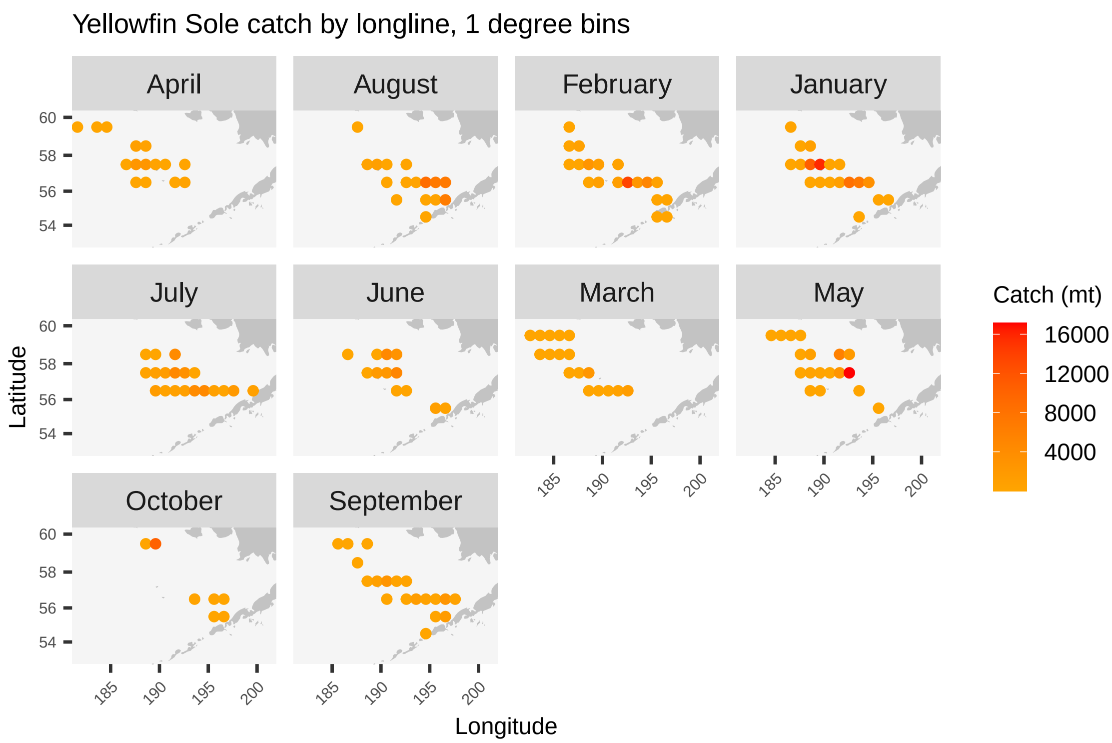


Figure 4.8: Catch of yellowfin sole in the BSAI in 2024 using longline gear by month (through October 1), reported by observers.

Figure 4.9: Age frequency of females and males from the yellowfin sole fishery, 1975 - 2023.

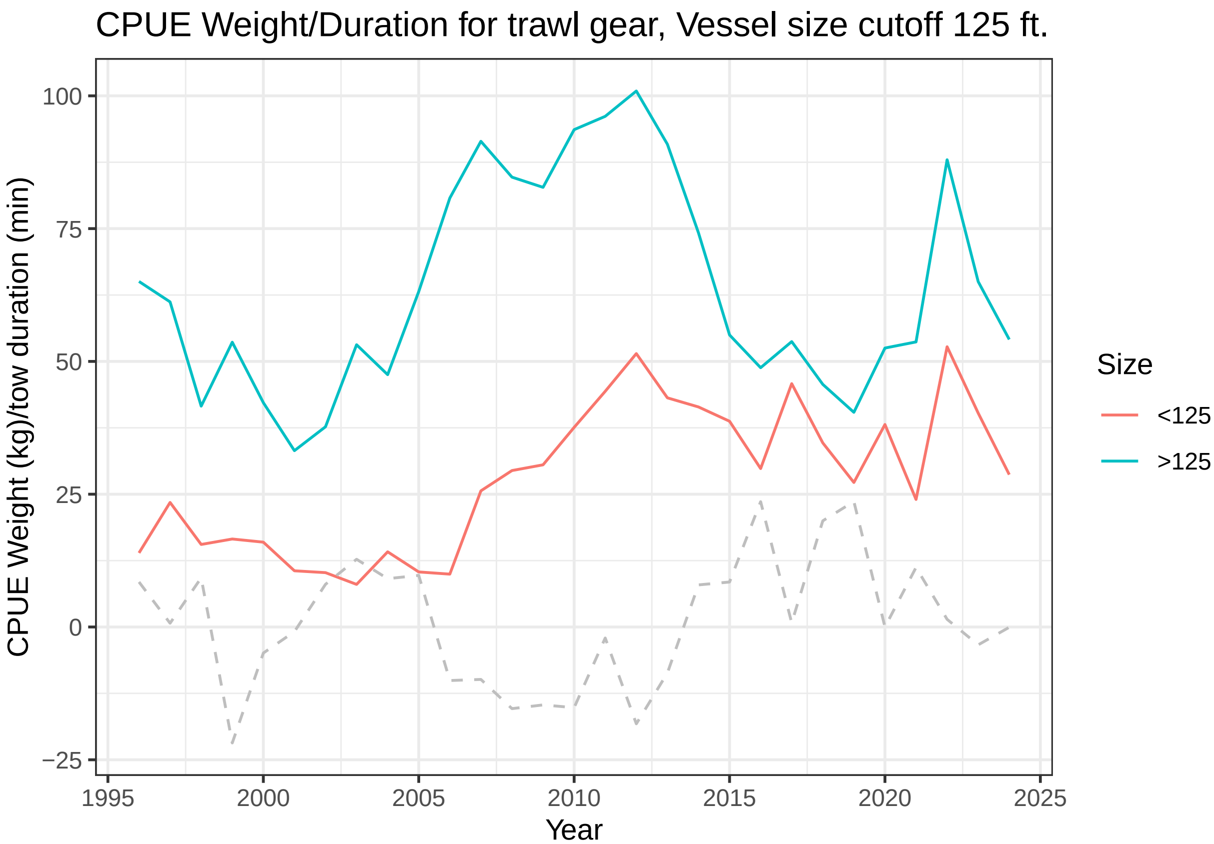


Figure 4.10: Catch per unit effort based on yellowfin sole fishery data, 1996-2024. CPUE weight (kg)/trawl duration (min) is shown for vessels greater and less than 125 ft, and only including self-made tows. Estimates of relative CPUE are complete through October 1, 2024. Results are limited to Catcher/Processor and Catcher vessels and tow duration >0 and <the 90% percentile of all the data (974 minutes). Source: NMFS/AKRO Catch Accounting System. The EBS bottom temperature anomalies from 1996-2024 (x10 for visualization) are shown as a dotted line.

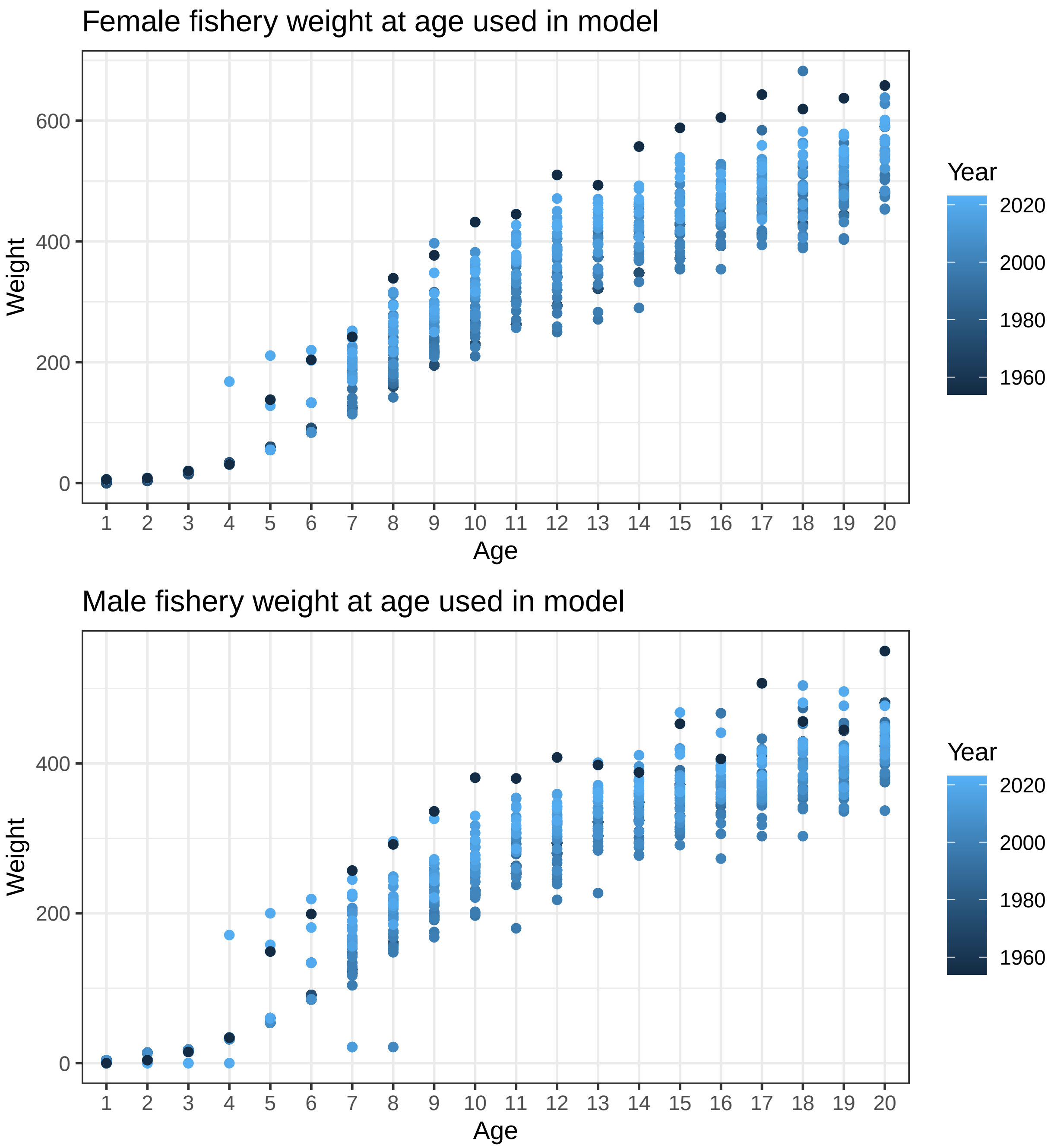


Figure 4.11: Estimates of weight (g) at age for yellowfin sole females and males, based on fishery data 1954-2023, and used in this year's models.

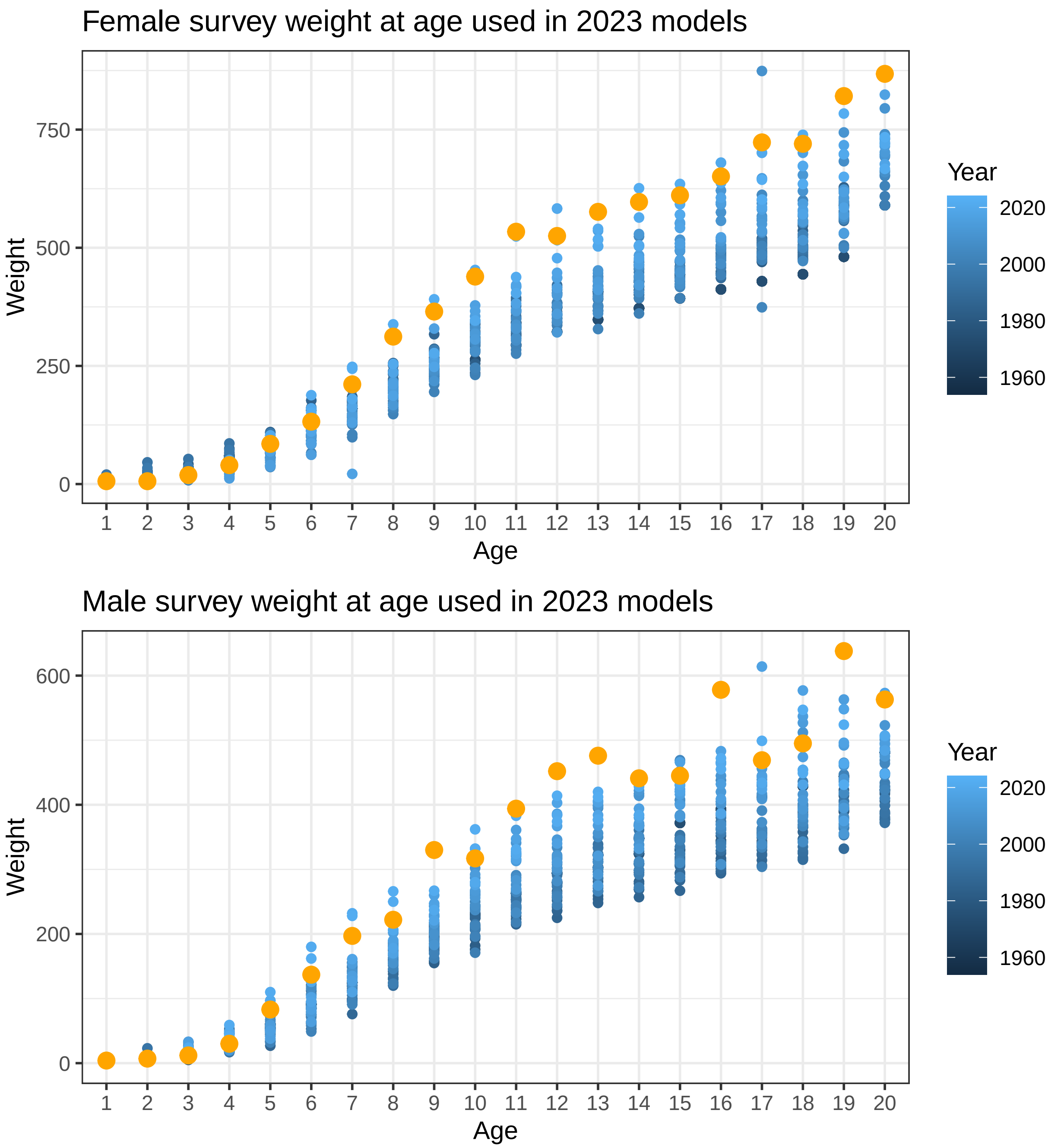


Figure 4.12: Mean weight at age (g) for yellowfin sole females and males from the eastern Bering Sea survey, 1954-2024 used in Model 23.0. Estimates for 2024 are highlighted in yellow.

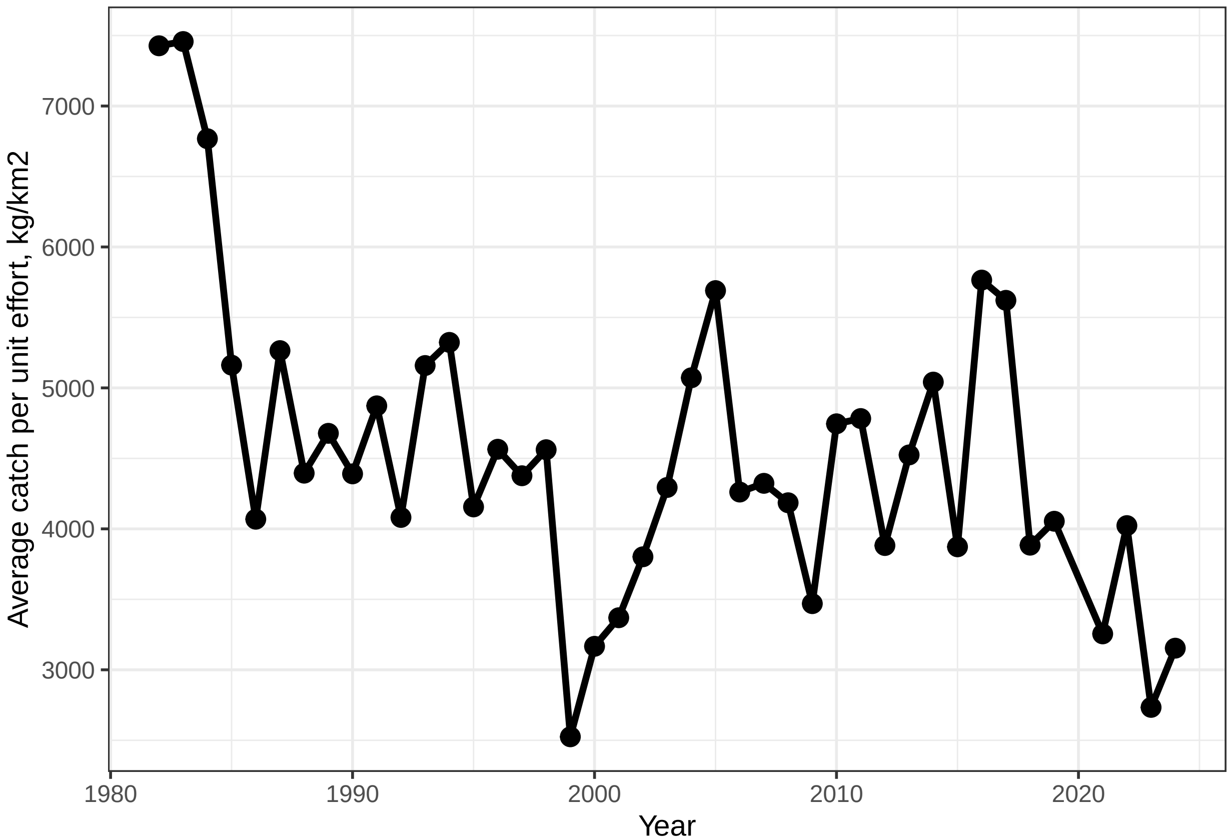


Figure 4.13: Average catch per unit effort on NMFS eastern Bering Sea surveys, 1987-2024, in kg/km2.

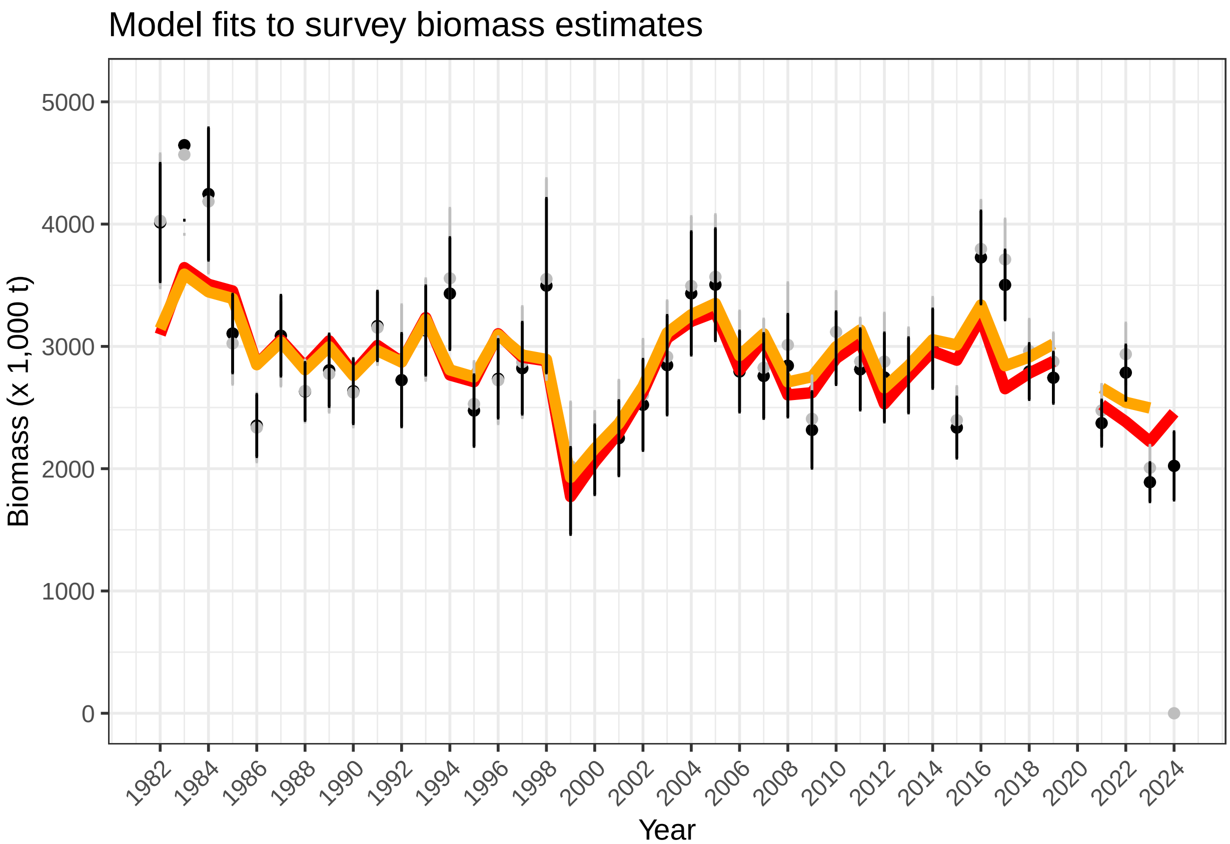


Figure 4.14: Annual eastern Bering Sea bottom trawl survey biomass point estimates and 95% confidence intervals for yellowfin sole, 1982-2024, with 2024 Model 23.0 (red line), 2023 Model 23.0 (orange line). VAST survey estimates with 95% confidence intervals are in grey (2023 estimate) and black (2024 estimate).

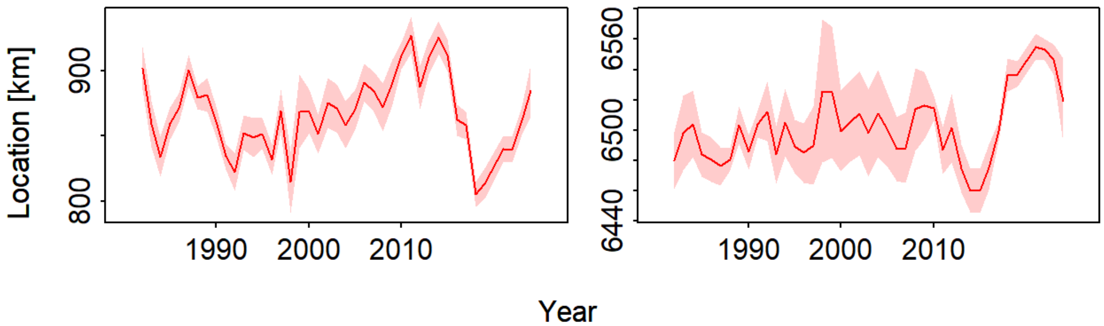


Figure 4.15: Center of gravity plot with eastings (Longitude) in the left panel and northings (Latitude) in the right panel. The units are in kilometers.

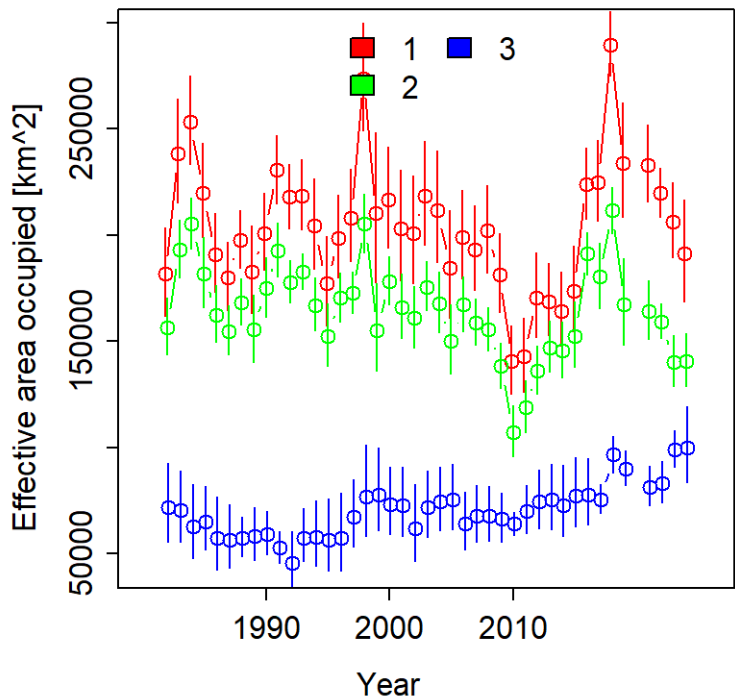


Figure 4.16: The effective area occupied by yellowfin sole, estimated in the VAST analysis, in the eastern Bering Sea (green), northern Bering Sea (blue) and the combined region (red).

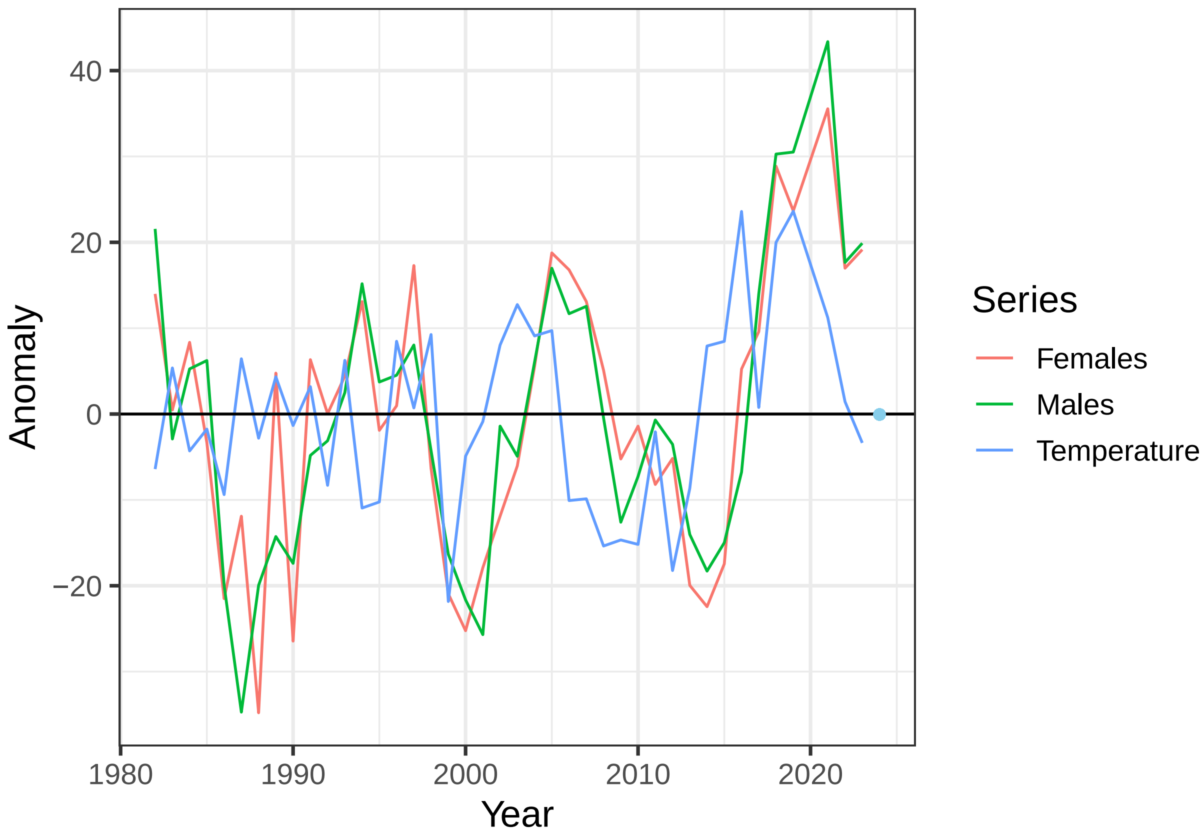


Figure 4.17: Yellowfin sole length-at-age anomalies, for 5-year old males and females, and bottom temperature anomalies from the eastern Bering Sea survey area <100 m. Correspondence in these residuals is apparent with a 2-3 year lag effect from the mid-1990s to 2022 (excluding 2020). Late 1980s and early 1990s pattern may be a density-dependent response in growth from the large 1981 and 1983 year-classes. Note: Bottom temperature anomalies were scaled up by a factor of 10 to demonstrate the pattern and match length anomalies. Age data is not yet available for 2023, but the 2023 temperature anomaly is represented by a blue point.

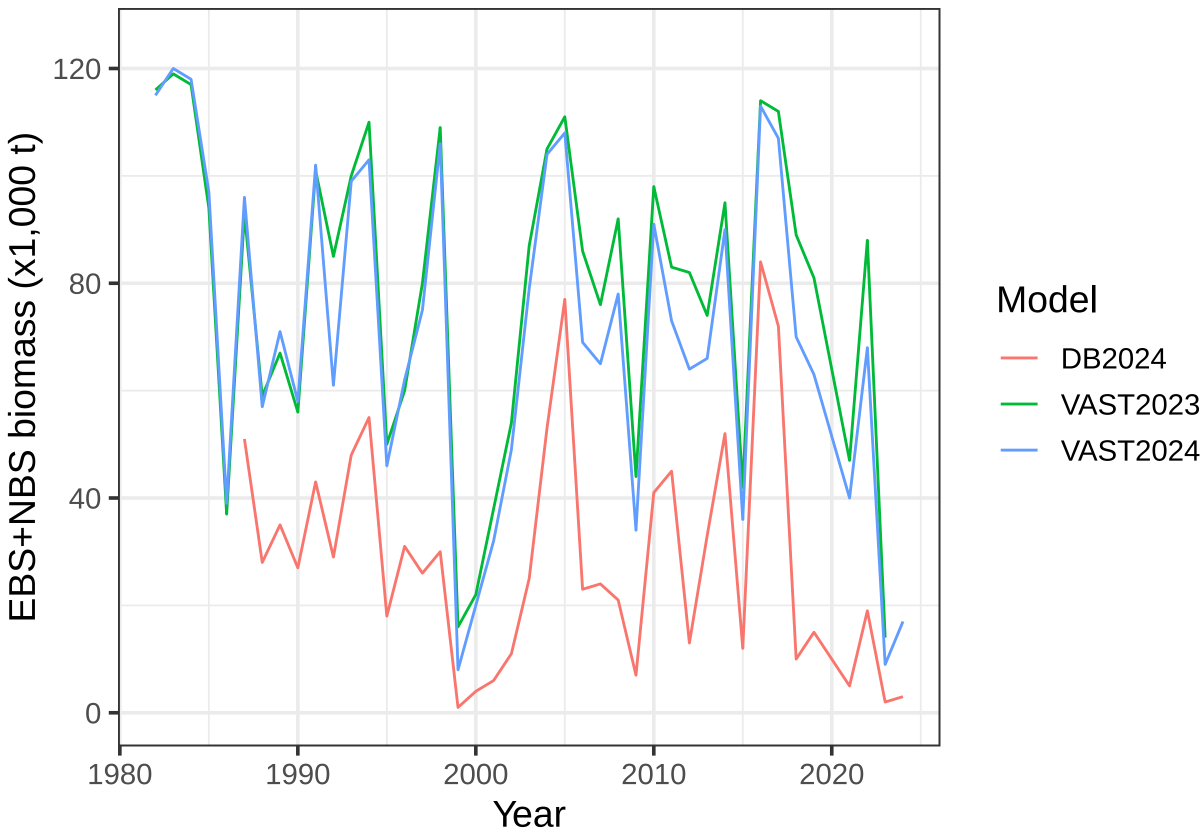


Figure 4.18: VAST biomass estimates for the EBS+NBS, generated in 2023 and 2024. The design-based (DB) timeseries is the design-based estimate of biomass.

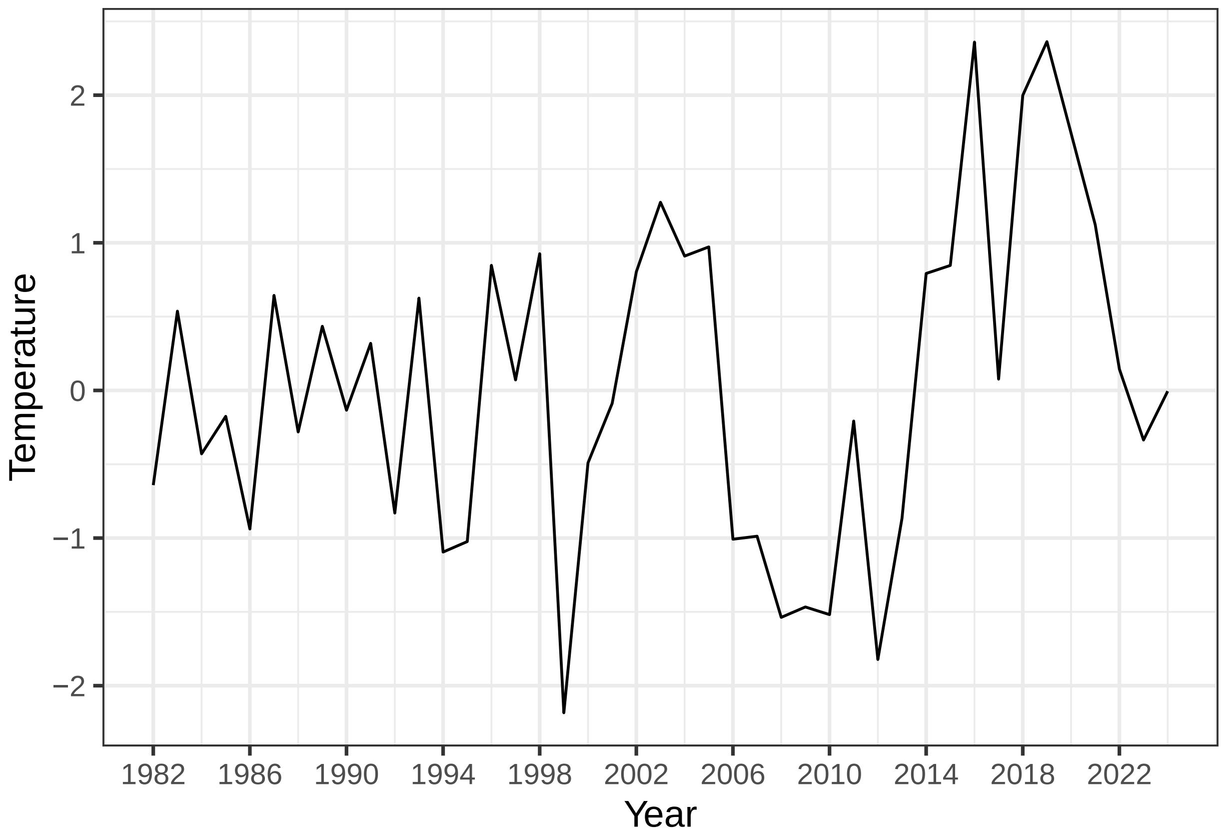


Figure 4.19: Bottom temperature anomalies from the NMFS survey <100 m, 1982-2023.

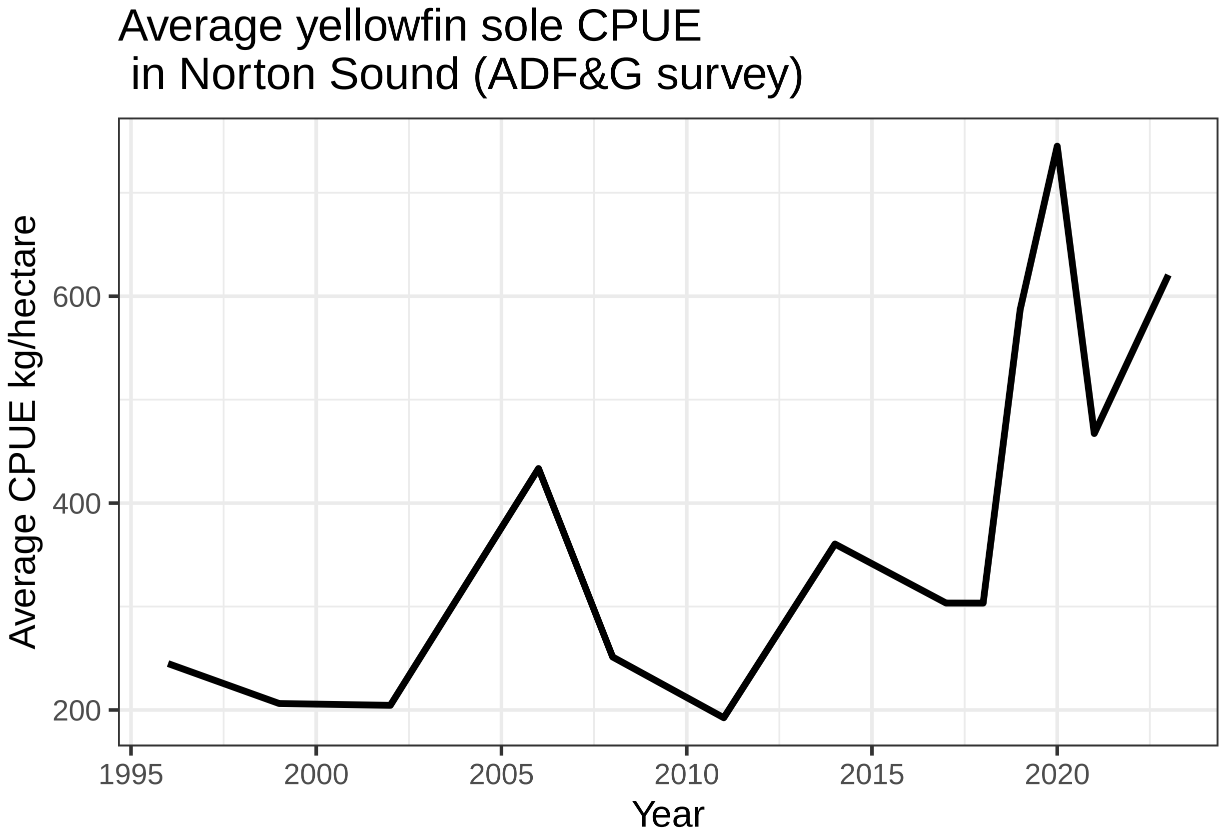


Figure 4.20: Average catch per unit effort (CPUE) of yellowfin sole in Norton Sound, based on ADF&G survey time series, 1996 - 2023.

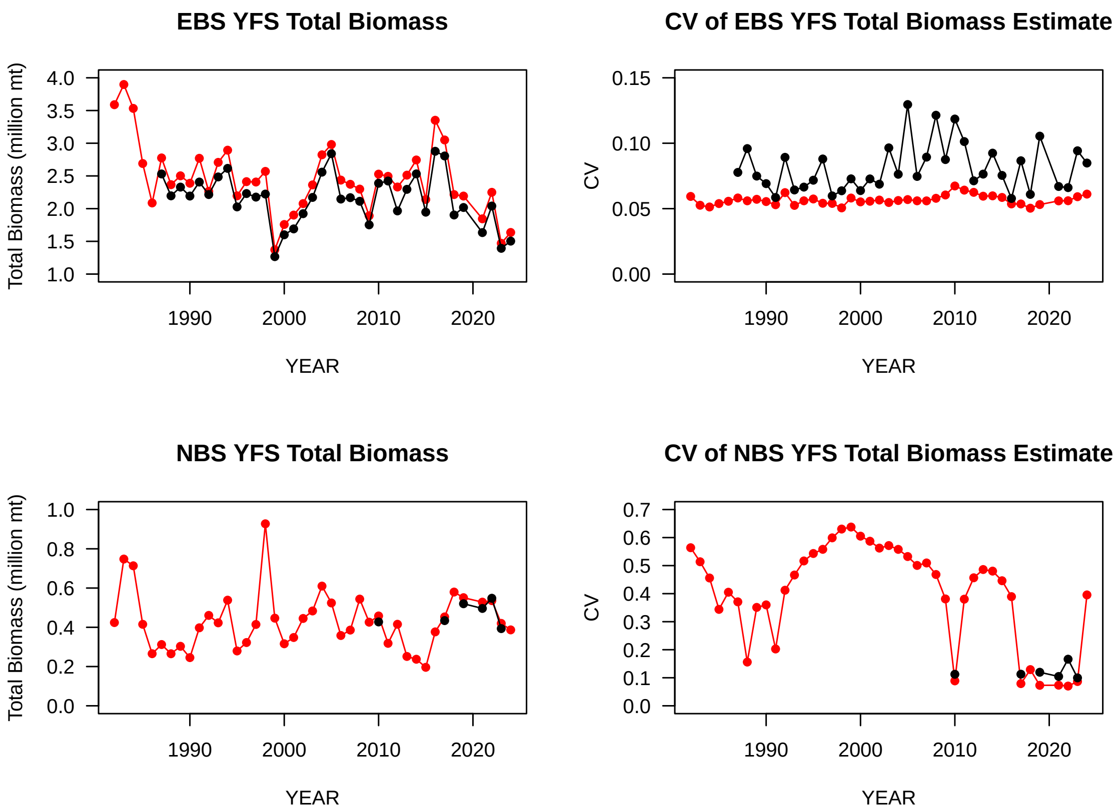


Figure 4.21: Design-based (black) and VAST (red) estimates of biomass and CV for the EBS and NBS in 2024.

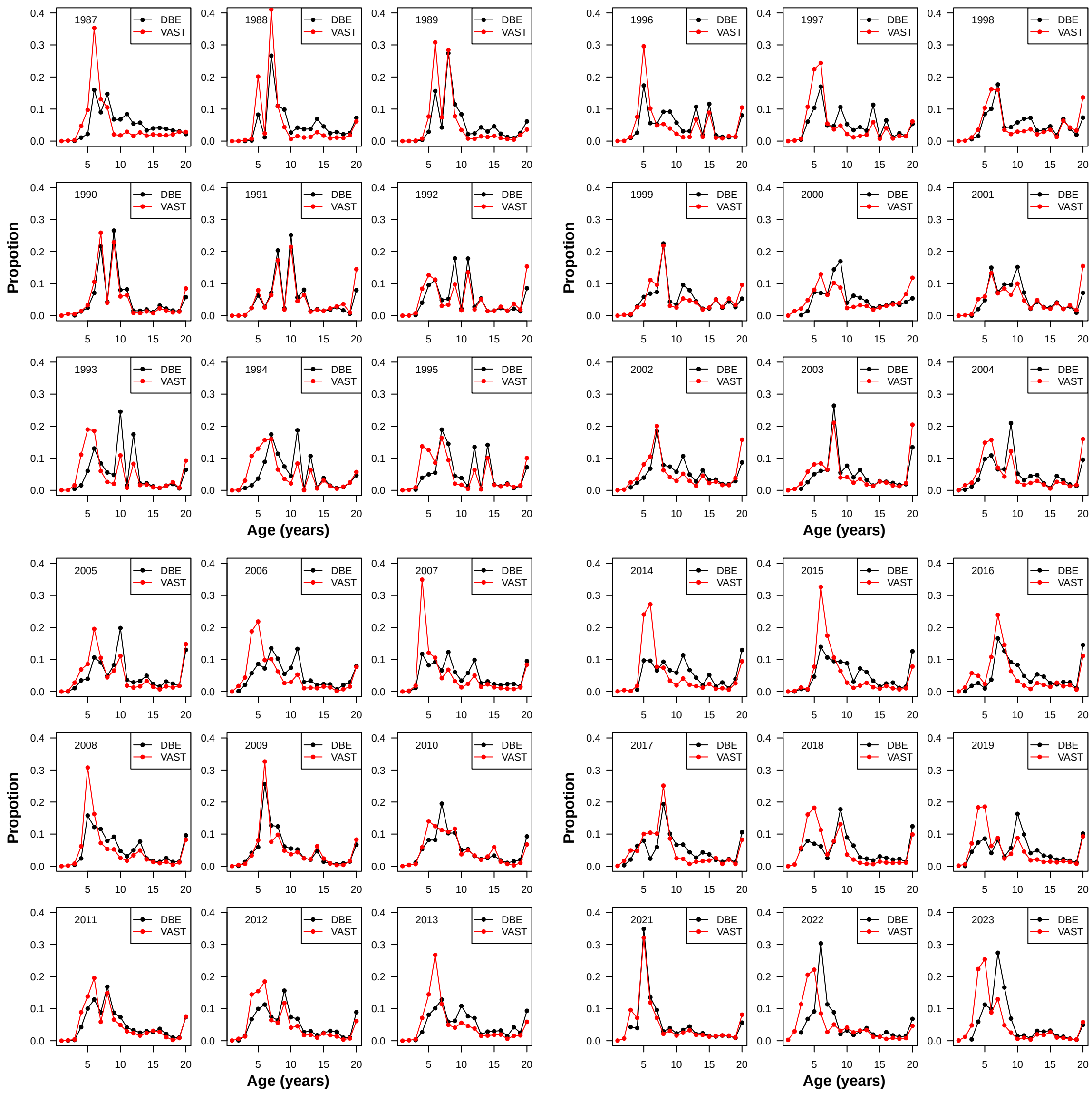


Figure 4.22: Age compositions (design-based and VAST) for all EBS age data, 1987 - 2023.

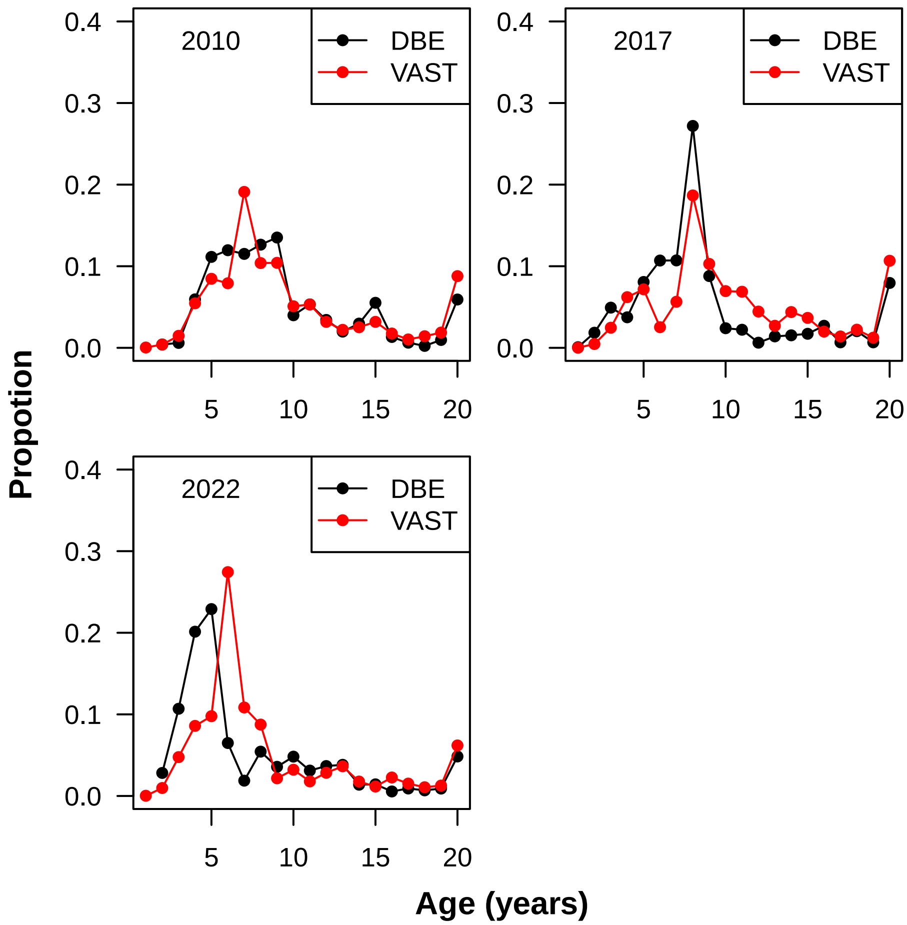


Figure 4.23: Age compositions (design-based and VAST) for all NBS age data.

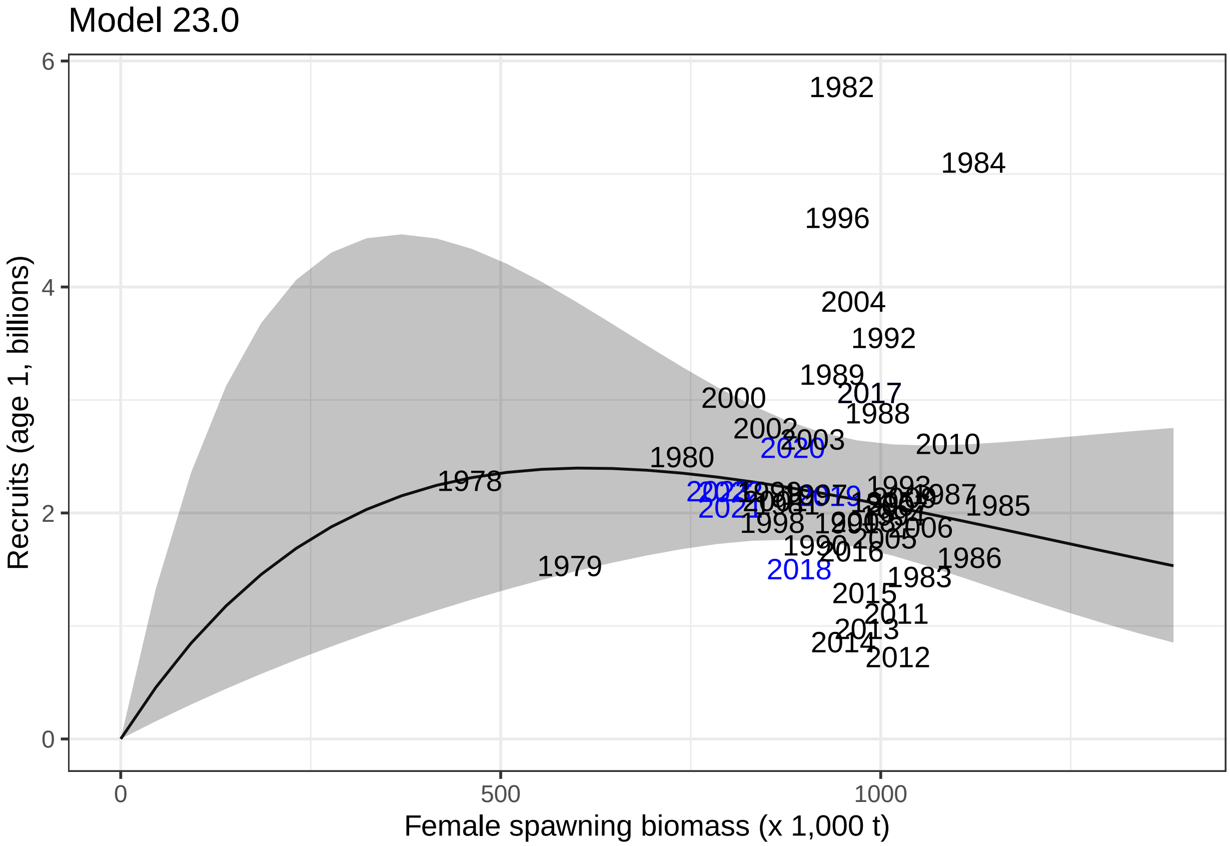


Figure 4.24: Ricker stock recruitment curve for yellowfin sole Model 23.0 with 95% confidence intervals (shaded region) fit to female spawning biomass and recruitment data from 1978-2018. Years in black indicate data used to fit the model, years in blue were not used to fit the model.

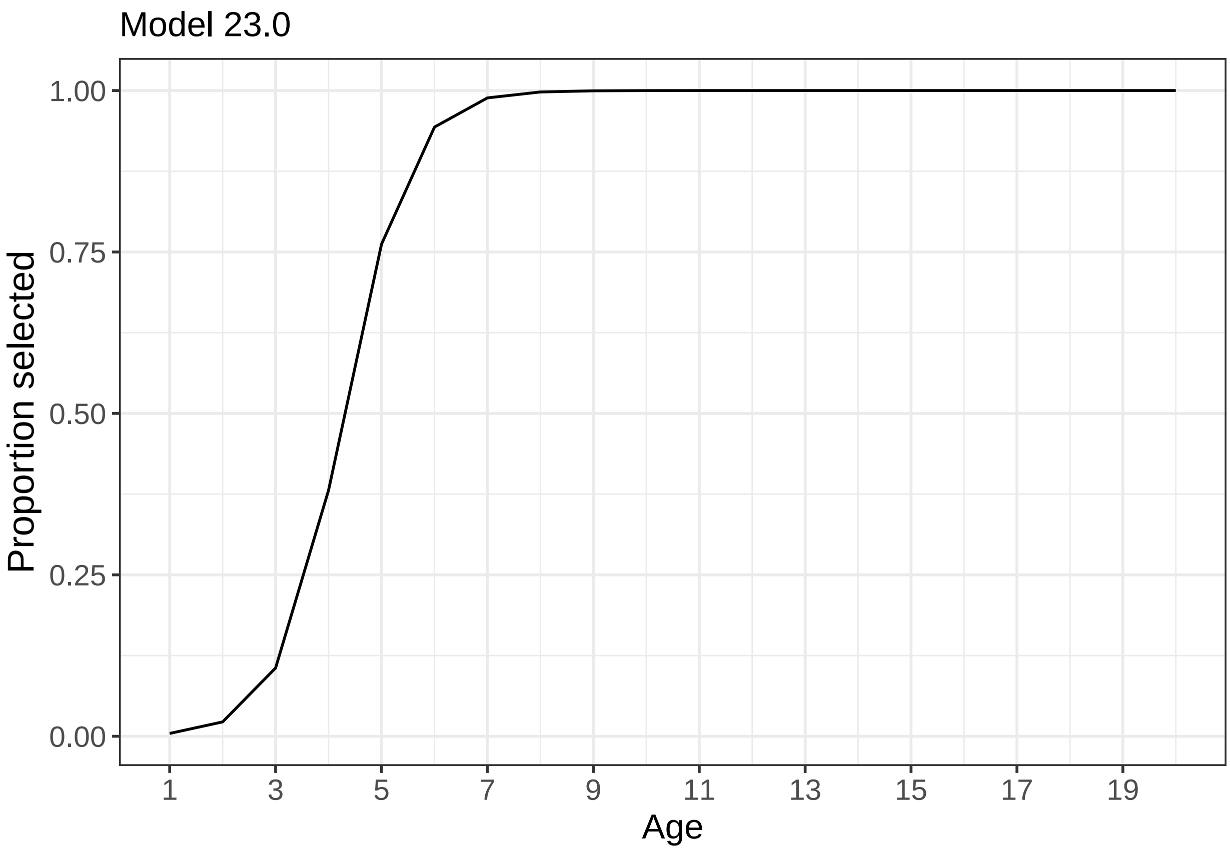


Figure 4.25: Estimate of yellowfin sole survey selectivity, Model 23.0.

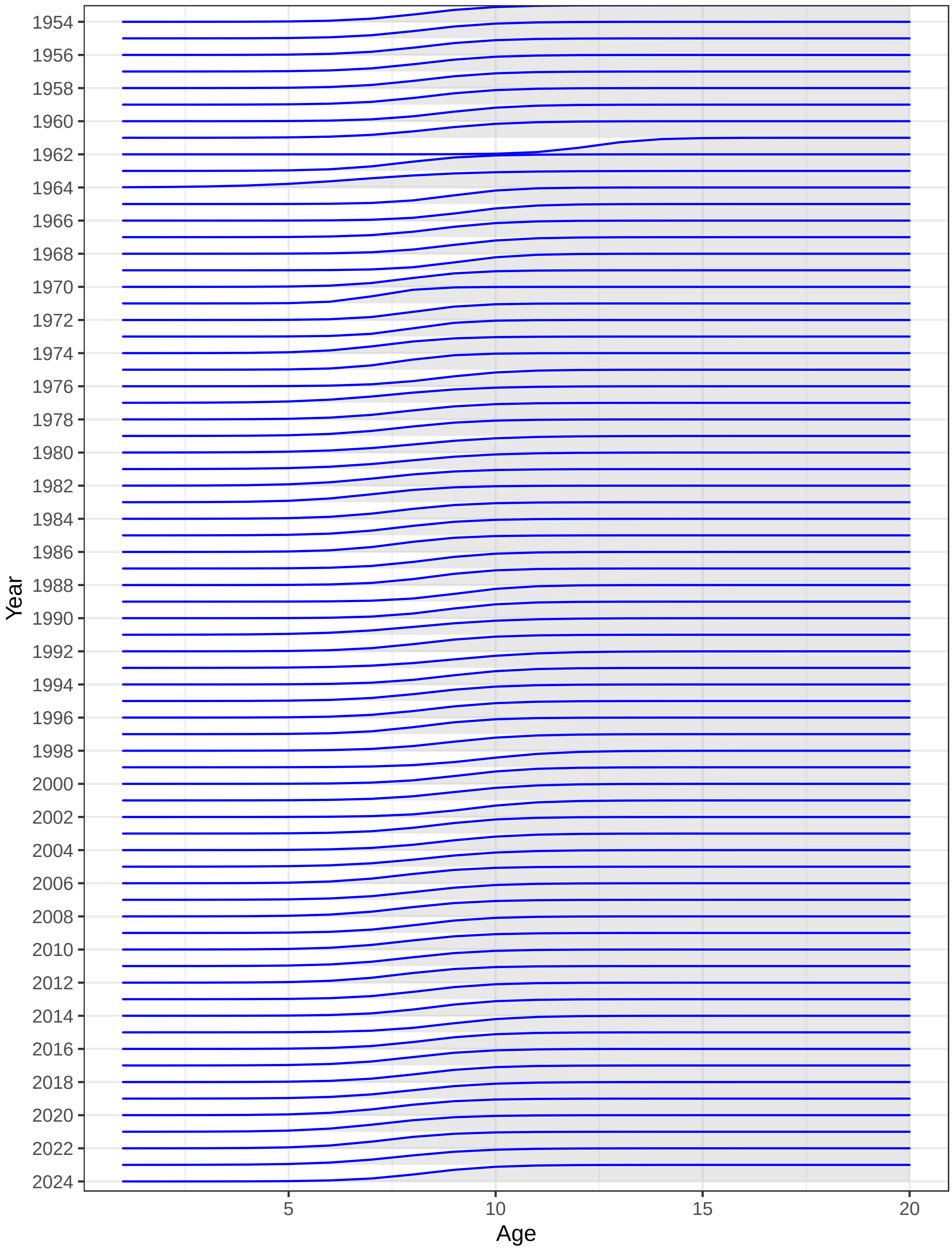


Figure 4.26: Estimate of yellowfin sole fishery selectivity by year, 1954-2024, Model 23.0.

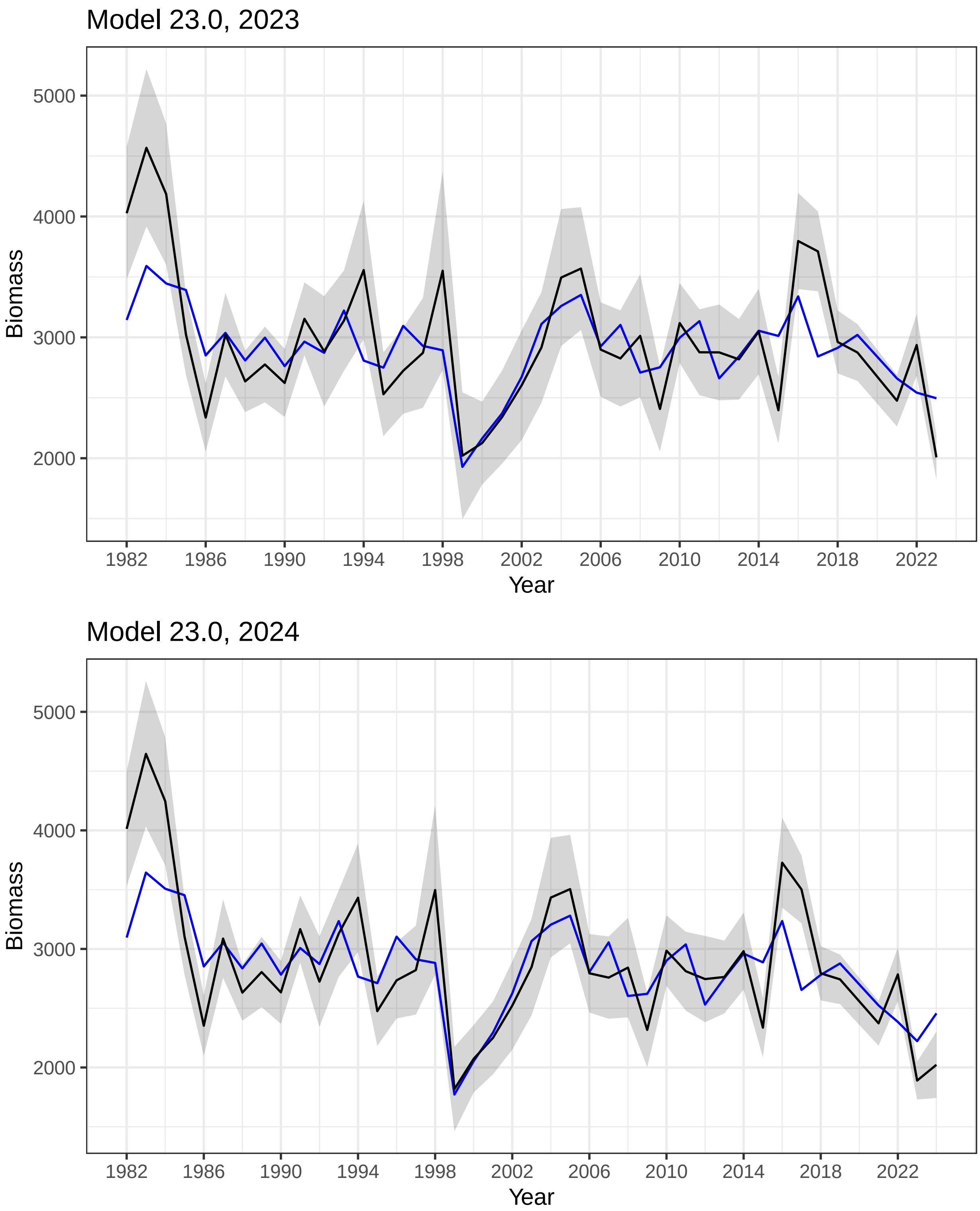


Figure 4.27: Model 23.0 from 2023 (upper panel), Model 23.0 from 2024 (lower panel) fit to NMFS NBS+EBS model-based (VAST) estimates for yellowfin sole, from 1982-2024. The 2024 VAST index differs from the 2023 index due to the addition of an additional year (which affects the entire time series). Blue lines are model estimates, grey represent survey estimates.

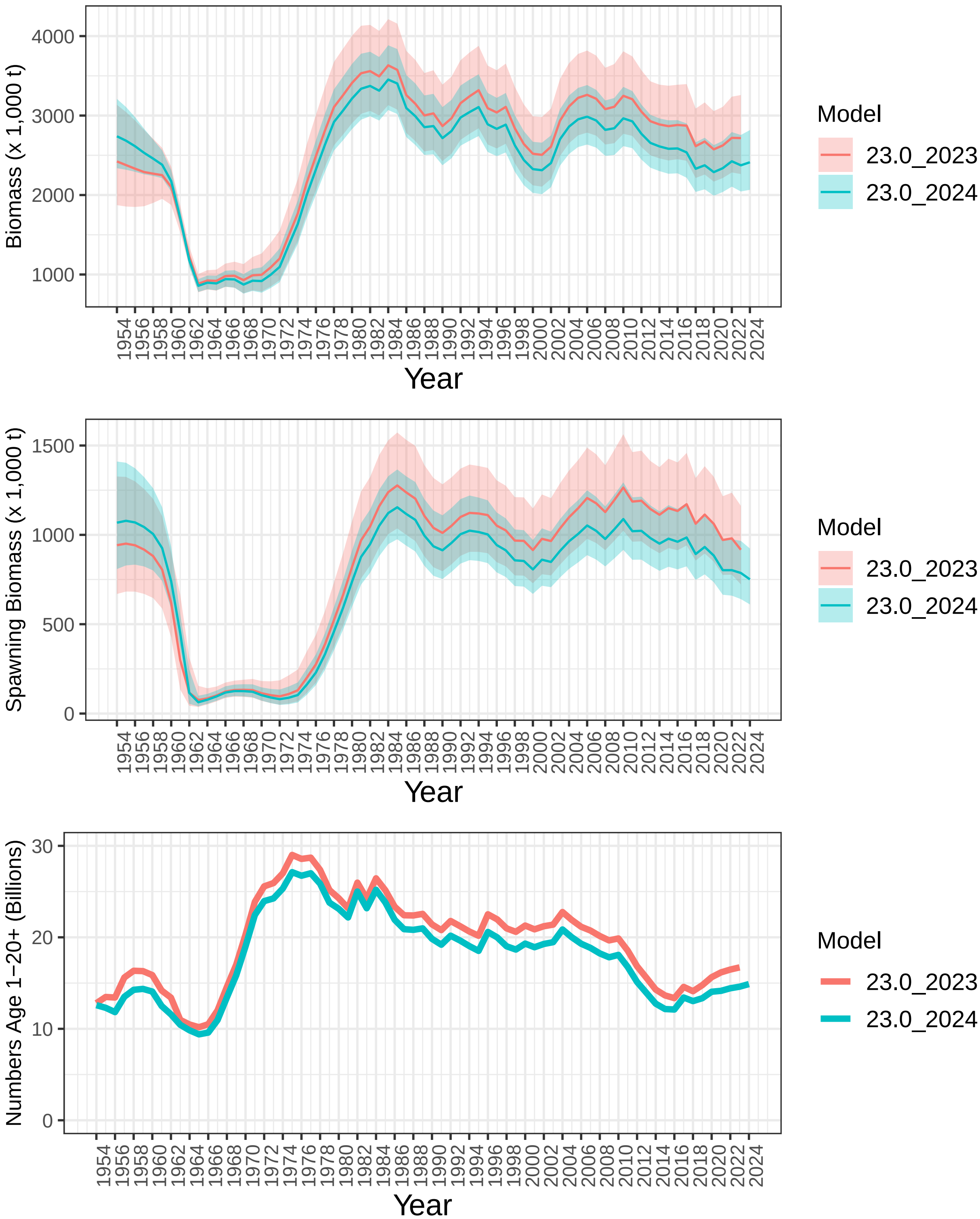


Figure 4.28: Total (age 2+) and spawning stock biomass for yellowfin sole, and total numbers, based on Models 23.0 (2023), 23.0 (2024).

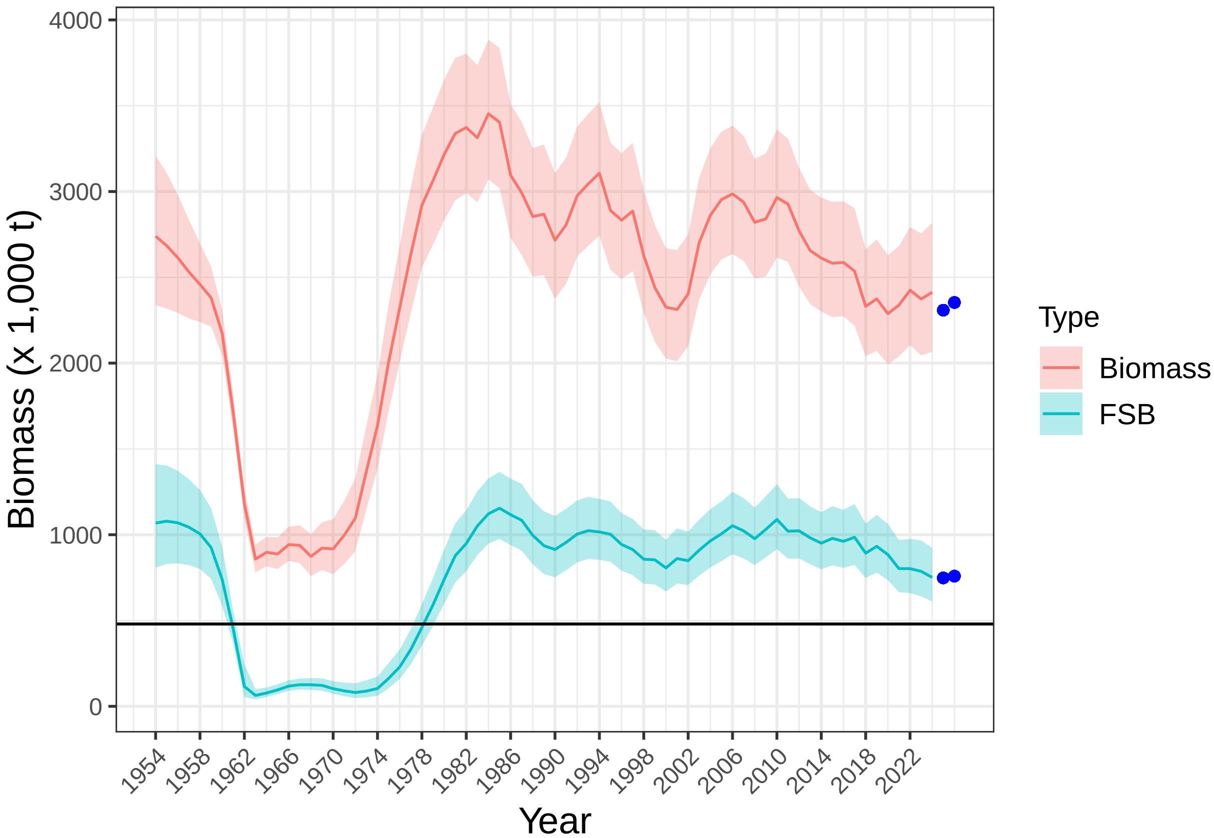


Figure 4.29: Model estimates of yellowfin sole total (age 2+) and female spawning biomass with 95% confidence intervals, 1954-2024, Model 23.0. Dots indicate projections for 2025 and 2026.

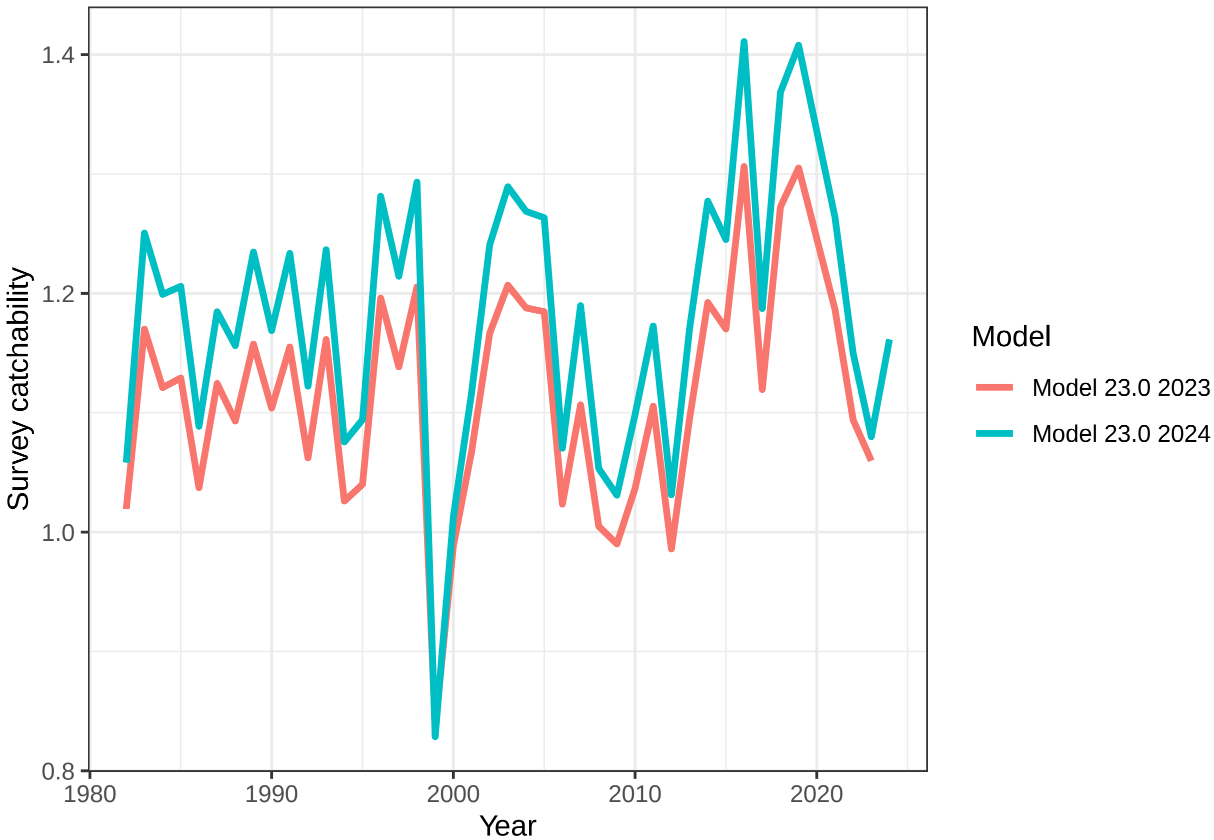


Figure 4.30: Survey catchability for yellowfin sole Model 23.0 (2023 and 2024 versions), 1982-2024.

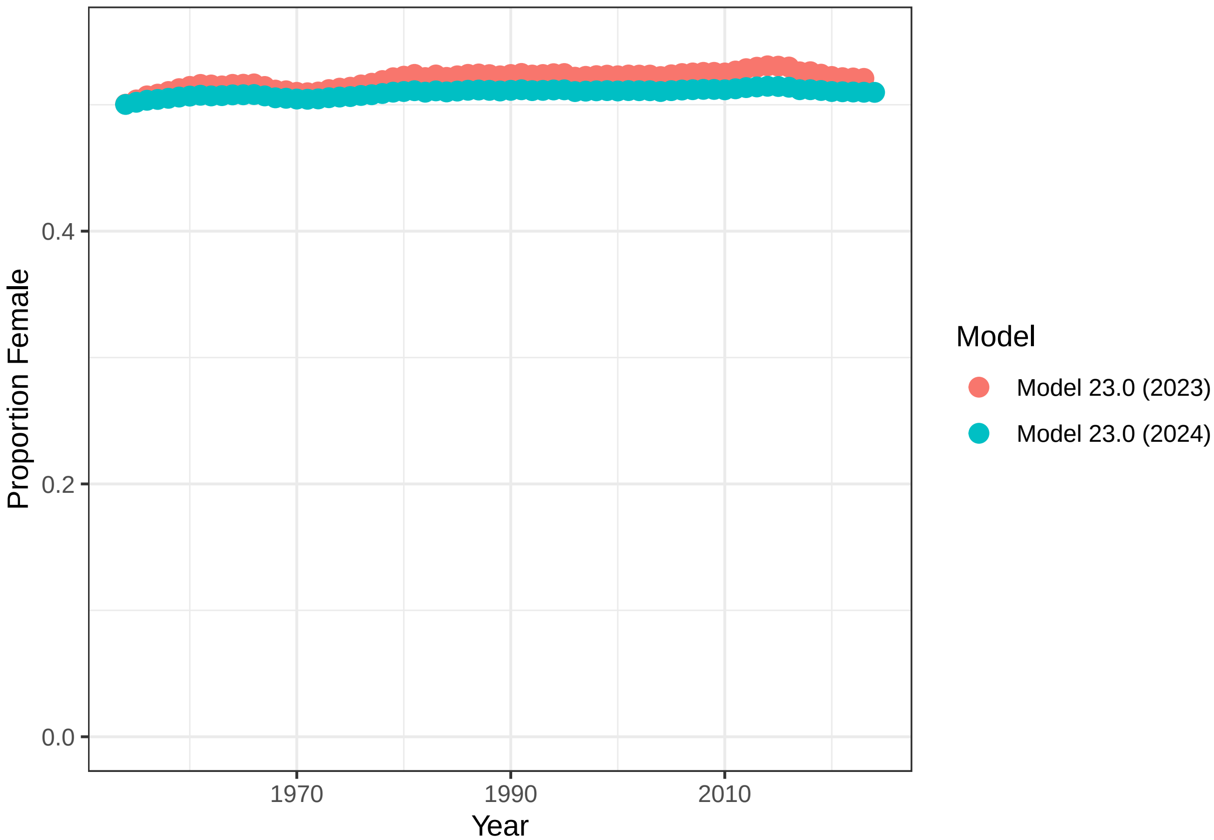


Figure 4.31: Model estimates of the proportion of female yellowfin sole in the population, 1982-2024 for Model 23.0 (from 2023 and 2024)

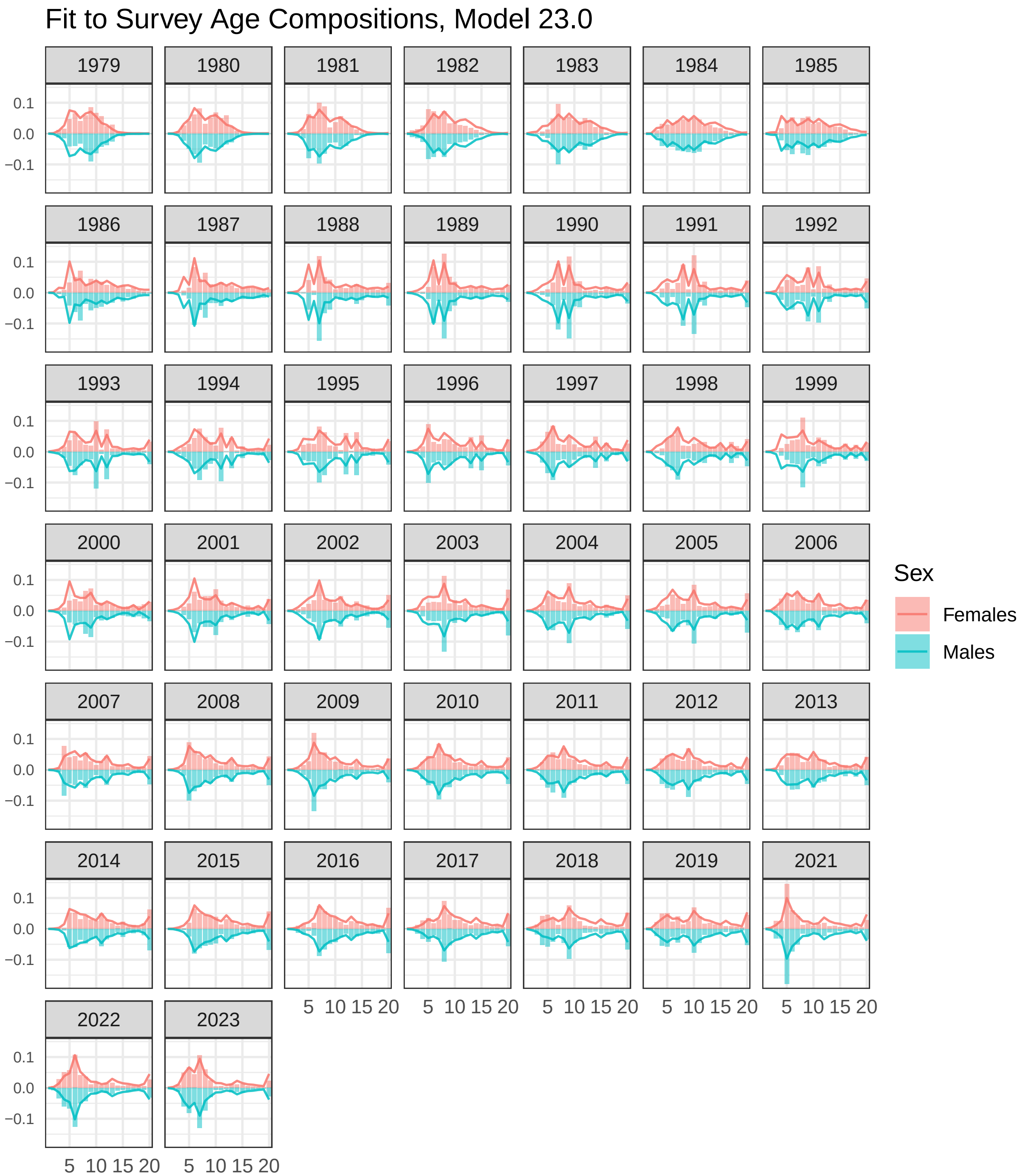


Figure 4.32: Model 23.0 fit to the time-series of yellowfin sole survey age composition, by sex, 1979-2023. The x-axis represents age.

Figure 4.33: Model 23.0 fit to the time-series of yellowfin sole fishery age composition, by sex, 1975-2023. The x-axis represents age.

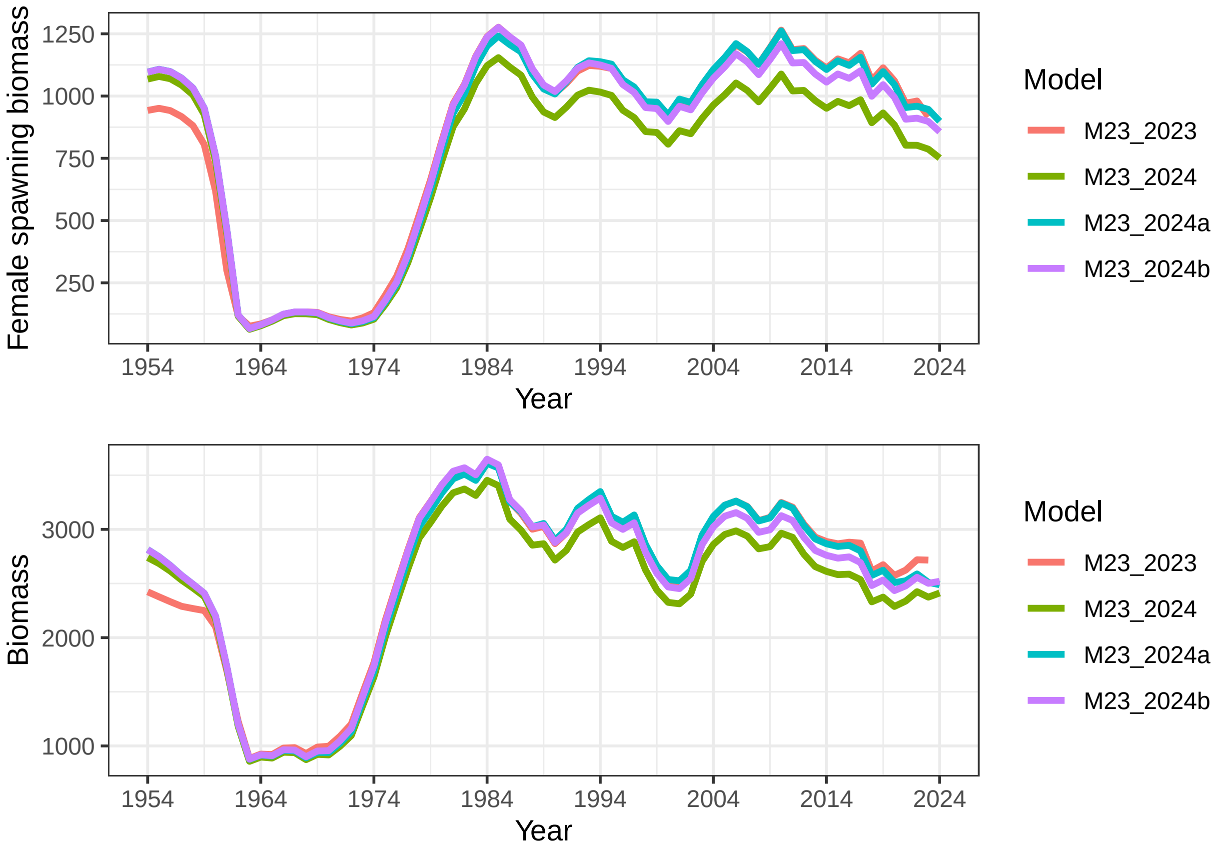


Figure 4.34: Upper panel: Biomass estimates, Lower panel: female spawning biomass. Model 23.0 2024a includes fishery catch through 2024 but not 2023 survey age compositions or 2024 su frvey index. Model 23.0 2024b added the 2024 survey index to Model 23.0a but not the updated survey age composition.

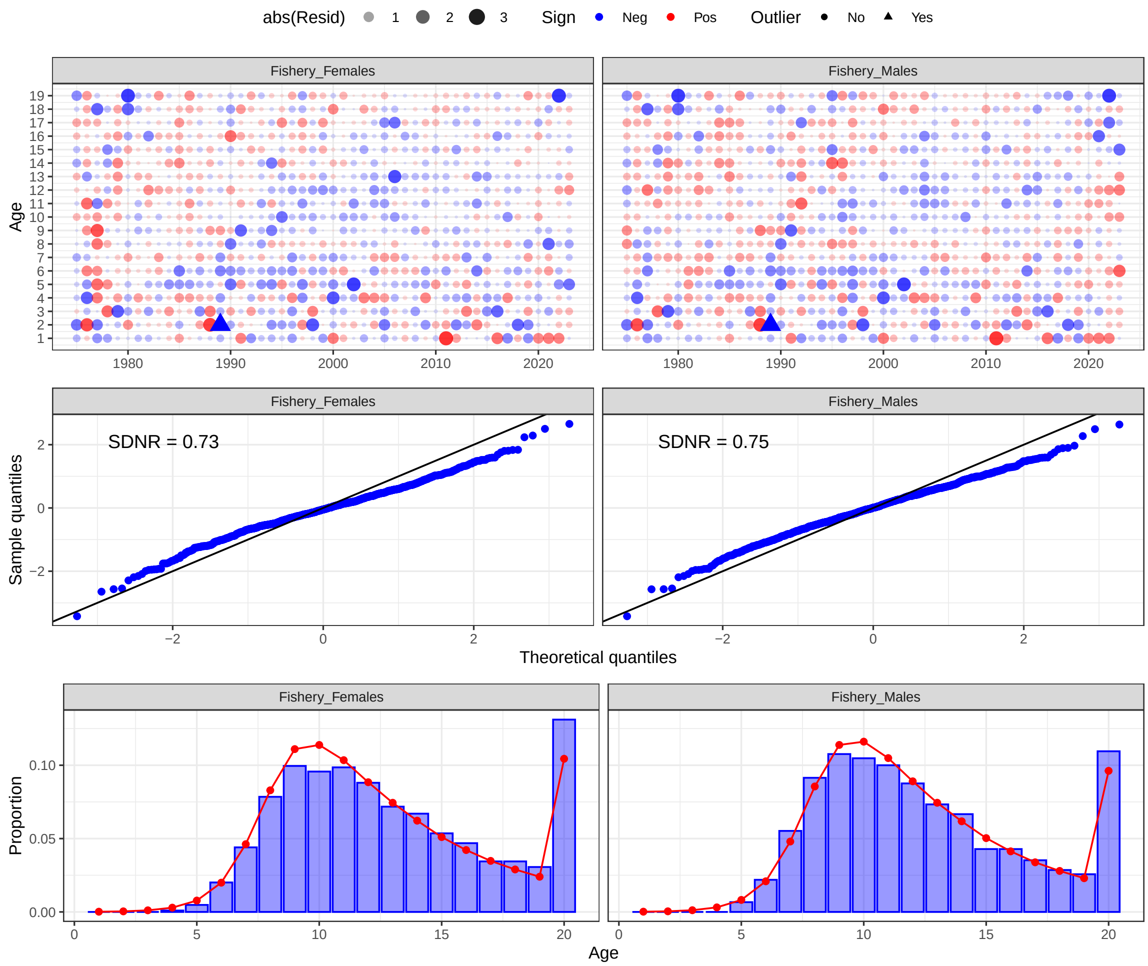


Figure 4.35: One-step ahead residuals for yellowfin sole fishery ages, females and males.

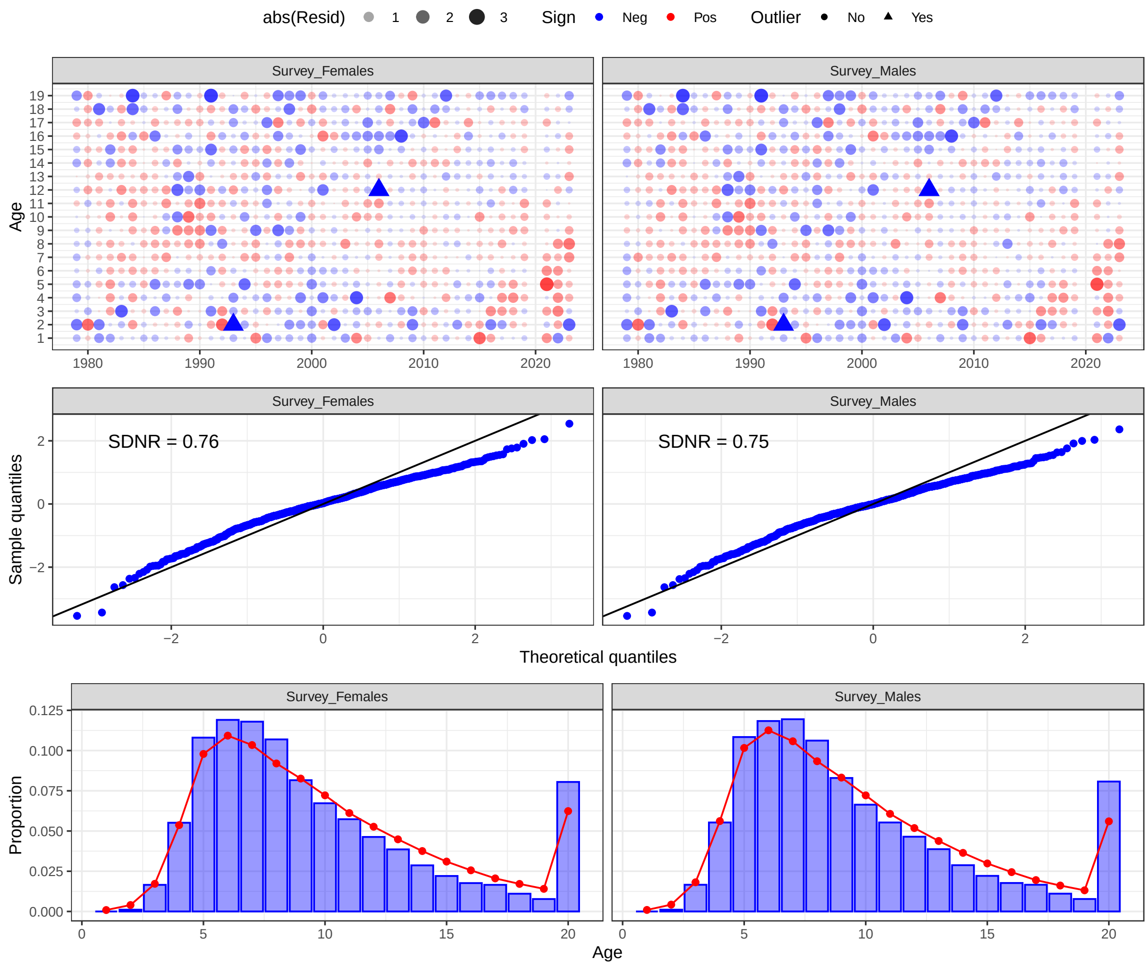


Figure 4.36: One step ahead residuals for yellowfin sole survey ages, females and males.

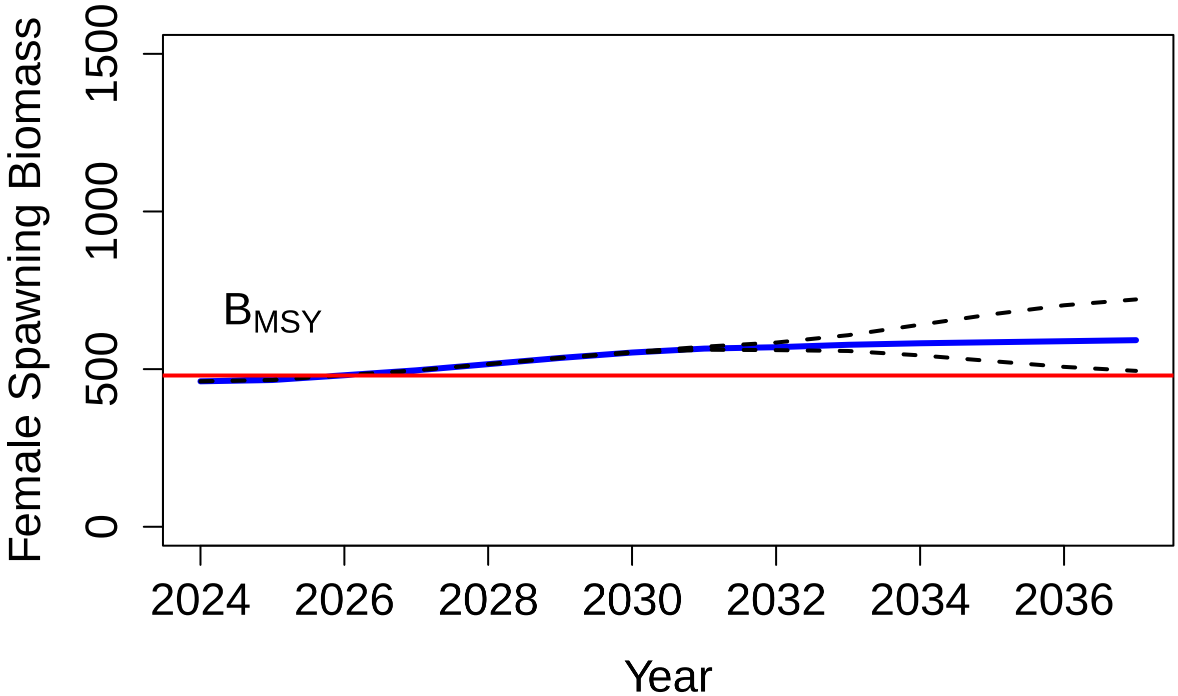


Figure 4.37: Projected yellowfin sole female spawning biomass for 2024 to 2037 (blue line), with 5% and 95% confidence intervals, and fishing at the 5-year (2018-2022) average fishing mortality rate, F= 0.0846 , Model 23.0.

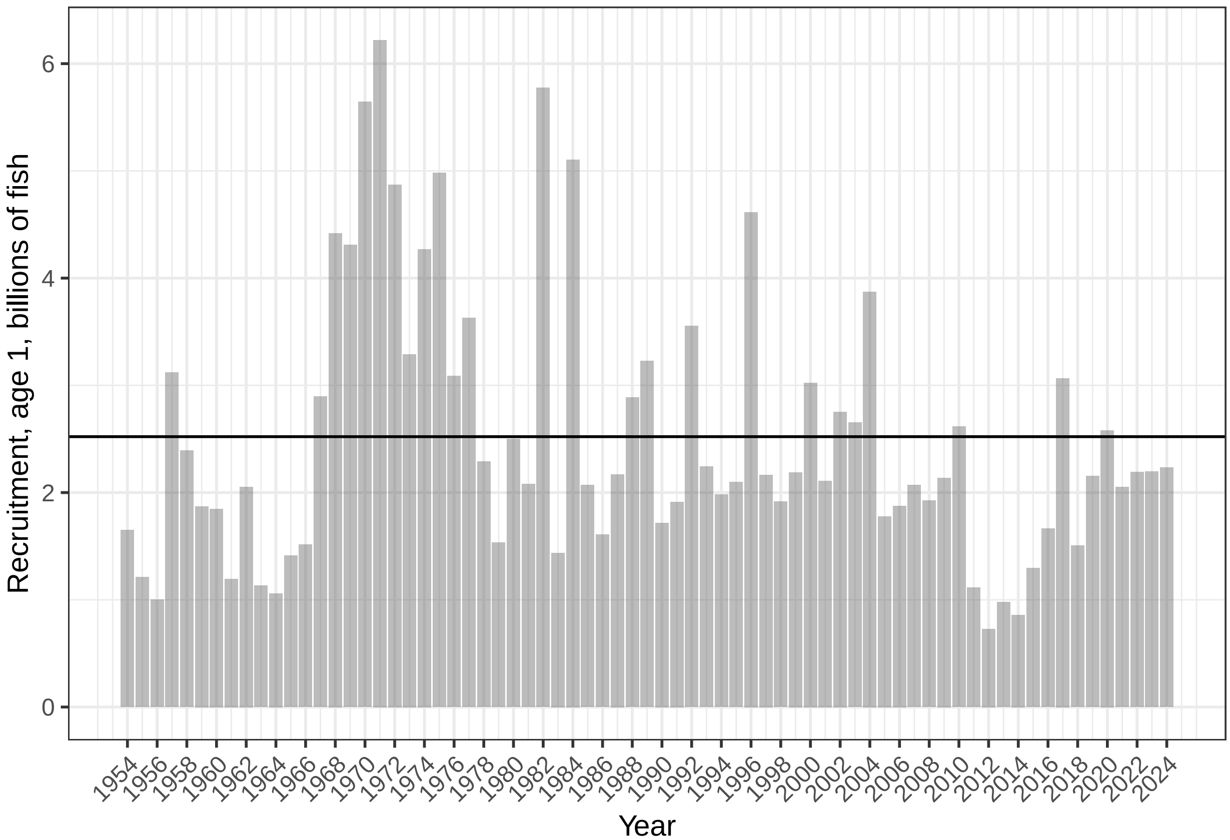


Figure 4.38: Year-class strength of age 1 yellowfin sole estimated by the stock assessment model. The horizontal line represents the average of the estimates from recruitment, 1954-2019, 2.5 billion, Model 23.0.

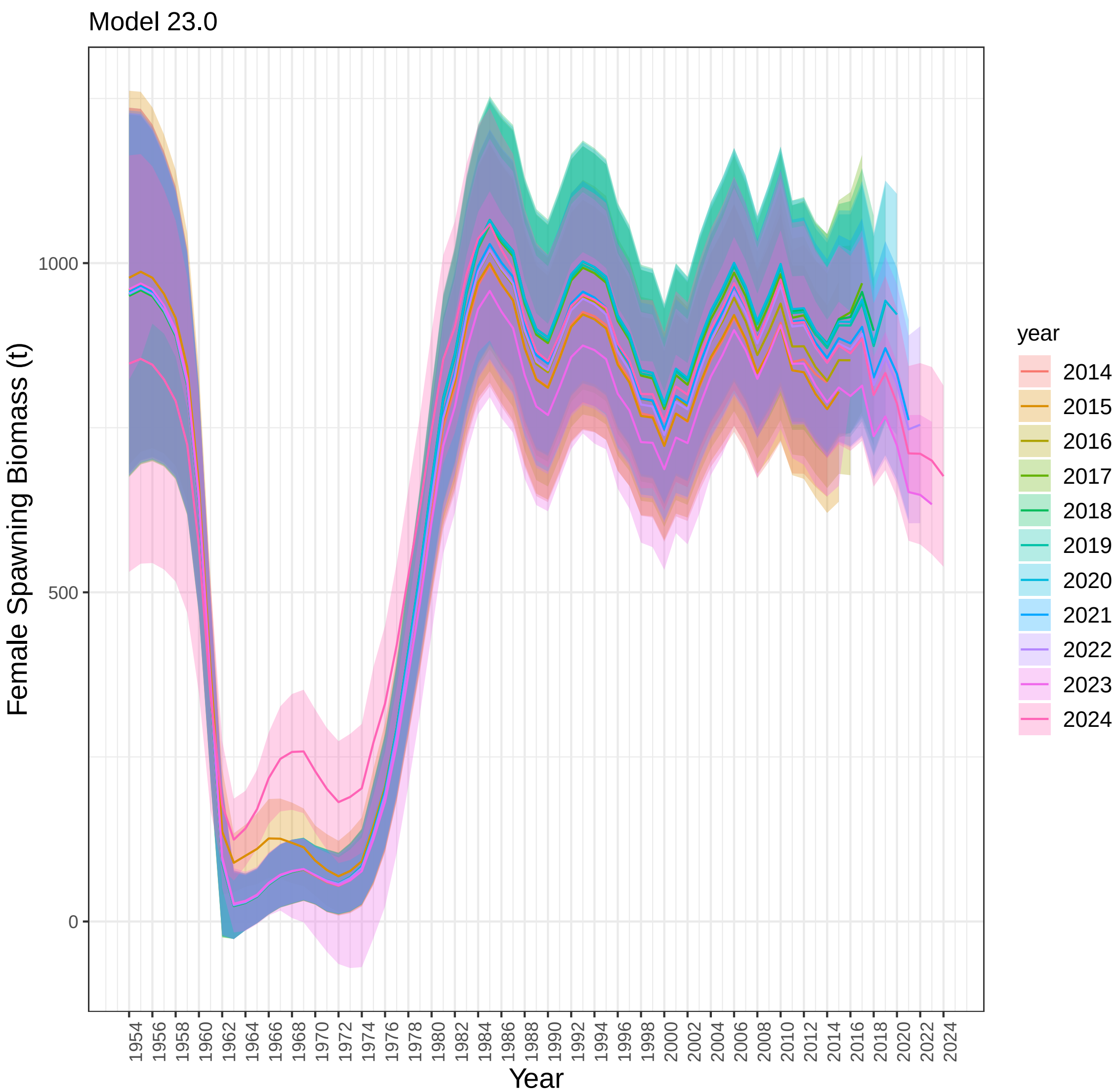


Figure 4.39: Retrospective plot of female spawning biomass for yellowfin sole Model 23.0. Mohn's Rho for this model was 0.06.

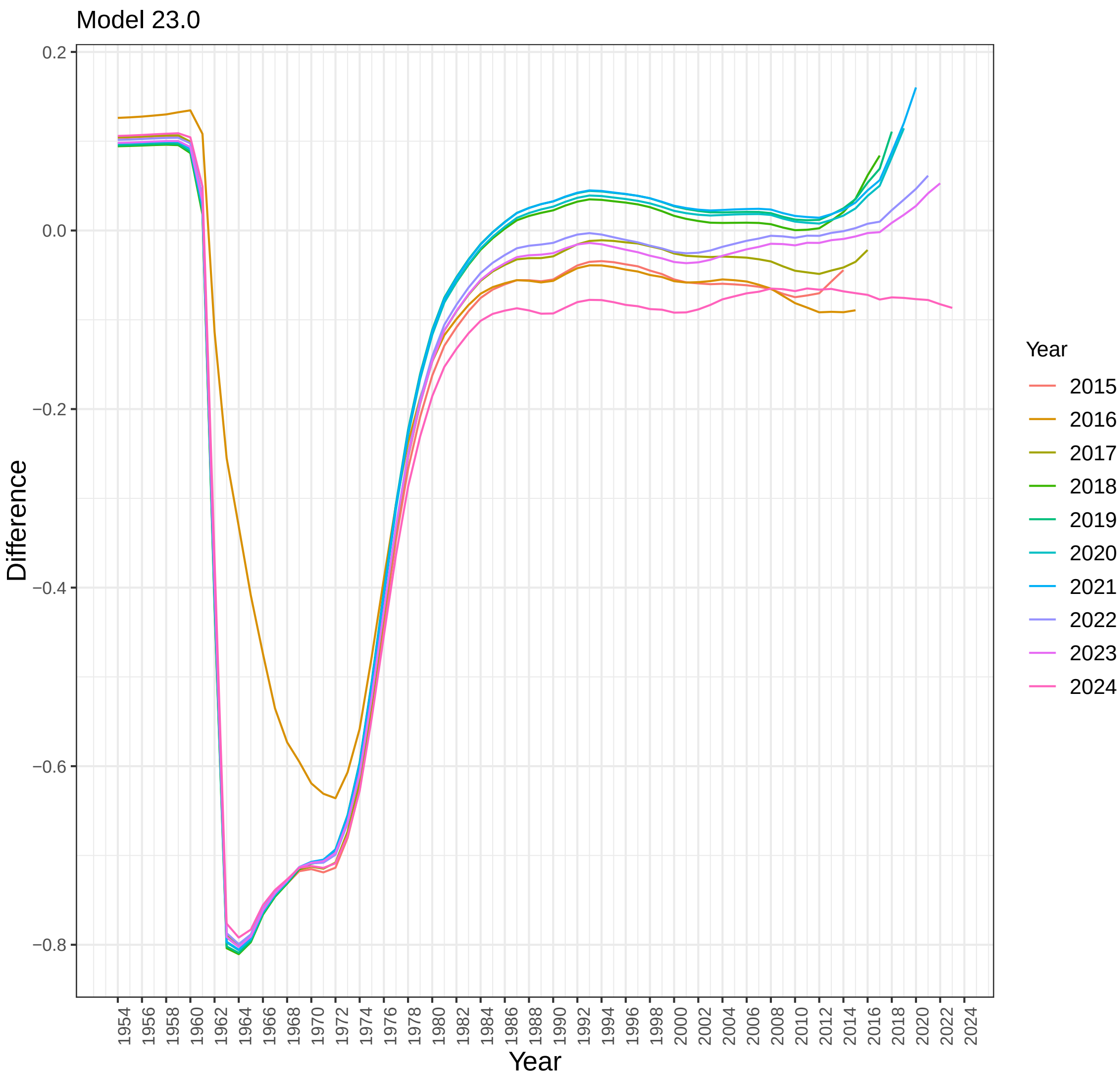


Figure 4.40: Retrospective differences in female spawning biomass between sequential years for yellowfin sole Model 23.0, shown as past years relative to the current year. The 2024 model with the final year of data removed provided higher estimates of SSB than the full 2024 model.

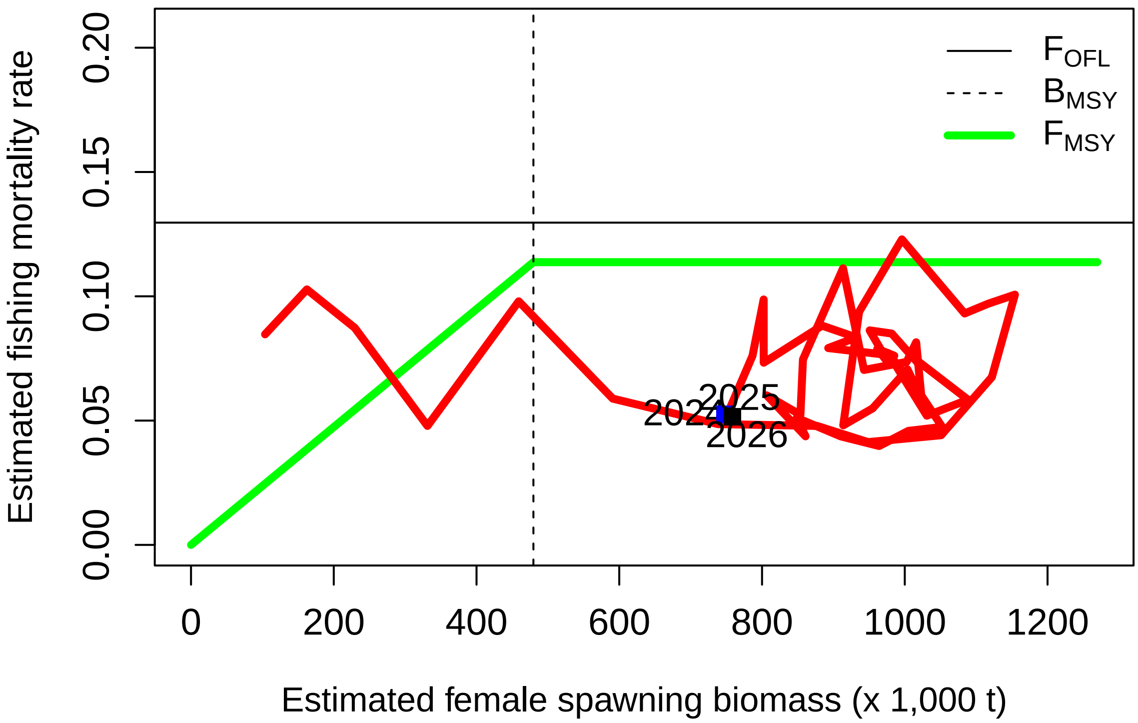


Figure 4.41: Yellowfin sole fishing mortality rate and female spawning biomass from 1975 to 2024 compared to the F35% and F40% control rules, based on Model 23.0. Vertical line is B35%. Squares indicate estimates for 2024, 2025, and 2026.