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 2021 Bering Sea and Aleutian Islands (BSAI) SAFE report. Several models are presented in this document that incorporate new data since the last full assessment in 2021.

Changes in the data

1. The 2021 fishery and survey age compositions were added.
2. The estimate of the total catch made through the end of 2021 was updated as reported by the NMFS Alaska Regional office. The catch through the end of 2022 was estimated based on available data to be 127,712 t. Catch for the 2023 and 2024 projections were assumed to be the mean of the past 5 years, 2018 - 2022, 126,157 t.
3. The 2022 NMFS survey biomass estimate and standard error were included. A model-based (VAST) estimate of the EBS and NBS biomass estimates, standard error, and age composition were used in Model 22.1.

Changes in the assessment methods

Three models are presented in this assessment. Model 18.2 was the accepted model in 2021 and is presented with updated data. Models 22.0 and 22.1 are based on Model 18.2, except that a single sex survey selectivity was used rather than a separate survey selectivity for males and females. Further details are described below.

1. Model 18.2 uses a fixed value for female natural mortality (M=0.12) and allows male natural mortality to be estimated within the model. This model was accepted by the BSAI Plan Team and the SSC in 2021. Survey index data (1982-2022) used design-based eastern Bering Sea estimates.
2. Model 22.0 is the same as Model 18.2 except a single-sex survey selectivity is used rather than a separate survey selectivity for males and females. Survey index data (1982-2022) and age compositions are based on design-based indices for the eastern Bering Sea.
3. Model 22.1 is the same as Model 22.0 except that the survey index data and age compositions (1982-2022) are based on model-based indices (VAST) for the combined Northern Bering Sea and eastern Bering Sea survey region. This is the authors' preferred model.

Summary of Results

The three models presented in this assessment include interpolated survey bottom temperature within the summer bottom trawl area < 100m as a covariate on survey catchability, as well as National Marine Fisheries Service eastern Bering Sea survey start date as an additional covariate within the model, as documented in

Nichol et al. (2019) to be informative for yellowfin sole. These models also specify female natural mortality to be fixed at 0.12 while allowing the model to estimate male natural mortality. Model 22.0 builds upon Model 18.2 by collapsing survey selectivity into a single set of parameters for males and females. Model 22.1 further builds up on Model 22.0 by using model-based survey indices and age compositions from the combined EBS and NBS survey areas. Model 22.1 is the preferred model.

In the eastern Bering Sea (EBS) bottom trawl survey performed in 2022, the EBS yellowfin sole design-based biomass estimate was 25% higher than estimated by the 2021 EBS bottom trawl survey, at 2,039,970 t. Spawning biomass estimated by Model 22.1 was 1.86 * B_{MSY}. Therefore, yellowfin sole continues to qualify for management under Tier 1a. The 1978-2016 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 conducted, which is typical for this assessment.

This assessment updates last year's model with total and spawning biomass estimates that are higher than the 2021 assessment. This year's recommended ABC and OFL are higher than the 2021 assessment, in part due to an increase in biomass estimates as well as the recommended use of the EBS+NBS survey area.

Catch of yellowfin sole as of October 1, 2022 in the Bering Sea and Aleutian Islands was 106,096 t. Over the past 5 years (2017 - 2021), approximately 83.1% of the catch has taken place by this date. Therefore, the full year's estimate of catch in 2022 was extrapolated to be 127,718 t. This is similar to the average catch over the past ten years, 134,698 t. Future catch for the next 10 years, 2023 - 2032, was estimated to be the mean of the catch from the past five years, 2018 - 2021, and the extrapolated full year's catch for 2022, which resulted in an estimate of 126,157 t.

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 following table for the 2021 accepted model (Model 18.2 - 2021) and the 2022 preferred model (Model 22.1). The projected estimate of total biomass for 2023 was higher by 45% from the 2021 assessment of 2,284,820 t, to 3,321,640 t. The model projection of spawning biomass for 2023, assuming catch for 2022 as described above, was 885,444 t, 22% higher than the projected 2022 spawning biomass from the 2021 assessment of 727,101 t. The 2023 and 2024 ABCs using F_{ABC} from this assessment model were higher than last year's 2023 ABC of 326,235 t; 378,499 t and 462,890 t. The 2023 and 2024 OFLs estimated by Model 22.1 were 404,882 t and 495,155 t. Increases in management quantities for the preferred Model 22.1 are largely due to the increased survey area.

The Risk Table indicates an overall risk level of 1 and there were no recommended reductions in ABC.

Quantity	As estimated or *specified last* year for: 2022	2023	As estimated or *recommended this* year for: 2023	2024
M (natural mortality rate)	0.12, 0.135	0.12, 0.135	0.12, 0.125	0.12, 0.125
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	2,479,370 t	2,284,820 t	3,321,640 t	4,062,230 t
Projected female spawning biomass (t)	857,101 t	727,101 t	885,444 t	897,062 t
B_0	1,489,190 t	1,489,190 t	1,407,000 t	1,407,000 t
B_{MSY}	495,904 t	495,904 t	475,199 t	475,199 t
F_{OFL}	0.152	0.152	0.122	0.122
$maxF_{ABC}$	0.143	0.143	0.114	0.114
F_{ABC}	0.143	0.143	0.114	0.114
OFL (t)	377,071 t	347,483 t	404,882 t	495,155 t
$maxABC$	354,014 t	326,235 t	378,499 t	462,890 t
ABC (t)	354,014 t	326,235 t	378,499 t	462,890 t
Status	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Projections were based on estimated catches of 127,712 t in 2022 and 126,157 t used in place of maximum ABC for 2023. This estimate was based on the mean of the past 5 years, 2018 - 2022, which includes the extrapolated catch of 127,712 t for 2022.

Responses to SSC and Plan Team comments on Assessments in General

SSC December 2021

With respect to Risk Tables, the SSC would like to highlight that “risk” is the risk of the ABC exceeding the true (but unknown) OFL, as noted in the October 2021 SSC Risk Table workshop report. Therefore, for all stocks with a risk table, assessment authors should evaluate the risk of the ABC exceeding the true (but unknown) OFL and whether a reduction from maximum ABC is warranted, even if past TACs or exploitation rates are low.

Authors’ response

Noted.

SSC December 2021

During review of the EBS Pacific cod assessment the SSC noted that the VAST model results were sensitive to the number of knots used to structure the analysis. That assessment increased the number of knots from 100 to 750, recognizing that this would likely provide a better approximation to the underlying spatial process. The SSC recommends that all assessment authors consider whether the number of knots used for their species is sufficient to provide a robust analysis, and to compare alternative models including more knots where possible.

Authors’ response

The VAST data generated in this assessment used 750 knots for the abundance index and 50 for the age composition data. These are the same numbers of knots currently used for all Bering Sea stocks, and the number of knots used for all of these abundance indices were increased dramatically last year in response to SSC comments. The knots for the age comps cannot be increased at this time due to computational limitations.

SSC December 2021

The SSC recommends that groundfish, crab and scallop assessment authors do not change recommendations in documents between the Plan Team and the SSC meetings, because it makes it more difficult to understand the context of the Plan Team's rationale and seems counter to the public process without seeing a revision history of the document… *However, this recommendation is not meant to prevent correcting typos, transcription errors, figure labels and other editorial issues for the final posted documents.*

Authors' response

Noted.

Responses to SSC and Plan Team comments specific to this assessmemt

SSC November 2020

The SSC recommends further investigation of previously noted issues as time allows, including possible further adjustments to estimating separate natural mortality for males and females, explorations of the sex ratio relative to the timing of annual spawning migrations as an alternative explanation for a high proportion of females, a potential link between wave height and catchability, and a single selectivity curve for both sexes. We note that the latter is supported by survey selectivity estimates that are virtually indistinguishable in Model 18.2 (2020 Assessment, Fig. 4.17) and by time-varying fishery selectivities that are very similar between males and females since the early 1980s, but diverge widely and inconsistently in some earlier years (2020 Assessment, Fig. 4.18).

Author's response:

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

SSC December 2021

The SSC commends the author for thoroughly addressing the majority of previous SSC comments and noted the much-improved retrospective patterns due to these updates. The SSC looks forward to continued work on previous SSC recommendations, especially bringing forward updated models that include VAST estimates and include NBS data (similar to 2021 models 18.2a and 18.2b) and incorporate NBS bottom temperatures into estimates of survey catchability (if appropriate).

Author's response:

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

Future work will consider bottom temperature throughout the EBS and NBS.

SSC December 2021

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

Author's response:

In this assessment the authors have examined the yellowfin sole modeled parameter space (Model 22.0) using the R package *adnuts*, which offers an expanded toolset for MCMC sampling of ADMB models including use of the random walk Metropolis algorithm (Monnahan and Kristensen 2018). We examined whether previous MCMC runs could have had poor MCMC chain mixing, an insufficiently long chain, or high autocorrelation, or were indicative of challenges within this complex assessment model. A thorough description of the methodology and the results are presented in the document. MCMC diagnostics indicated sufficient mixing and no autocorrelation for all key parameters. However, several male and female selectivity parameters of low inferential importance early in the time series were not well mixed and will be examined prior to the next assessment cycle.

SSC December 2021

The SSC also requests the authors investigate the negative values for recruitment in the lower confidence interval (2021 Assessment, Figure 4.18). *Author's response:*

Negative values for recruitment in the lower confidence interval were due to normally distributed confidence intervals. These have been changed to lognormally distributed confidence intervals. (Table 1).

SSC December 2021

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

Author's response:

Authors have reached out to fishing industry representatives and NMFS economists for information on tariffs, observer coverage and retention, and CPUE. Their responses are summarized here.

Flatfish were among the species to receive relief under the USDA Seafood Tariff Relief Program in 2019-2020. Tariffs impact the price of yellowfin sole. Fishing industry representatives report that after tariffs are applied they wait for the exclusion process to be announced, apply for an exclusion, and the exclusion has thus far been granted each time and it applies retroactively. In 2022, fishing started with the tariffs in place (meaning prices were impacted for the start of the year) and the exclusion request was granted in March of 2022 and applied retroactively back to Oct. 12, 2021 and continues through December 31, 2022. While fish importers from China can apply for a refund of any tariff paid since Oct. 12, 2021, none of those funds reach the fishing industry.

All boats that participate in the yellowfin sole fishery have been fully observed since 2008. A80 vessels have two observers, AFA vessels that fish yellowfin sole have 2 observers, and any trawl Catcher Vessels that participate deliver to either A80 or AFA vessels, so all catch is weighed on certified scales and 99% or more of hauls are sampled by observers. Retention of all species increased under A80; 90% or greater of the groundfish are retained. Historic A80 coop reports with allocations, catch, and retention can be found in (Table 2).

Overall colder water in the Bering Sea in 2022 has resulted in a relatively high catch per unit effort (CPUE).

The tariff battle with China potentially impacted flatfish fishing through lower prices which can affect the incentive to fish. Additionally, supply chain problems stemming from COVID restrictions likely also affected the incentive to fish in 2020 and after. Most flatfish is processed in China. China applied tariffs on products destined for their domestic market, but in an attempt to protect their reprocessing sector, product that came into China and was subsequently exported were excluded from Chinese tariffs. The problematic tariffs would mostly be our (U.S) tariffs on Chinese imports (of fish that we caught).

Introduction

Yellowfin sole (*Limanda aspera*) are one of the most abundant flatfish species in the eastern Bering Sea (EBS) and currently is the target of the largest flatfish fishery in the world. 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 (Figure 1, 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).

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 1). 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 2, 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 3). 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 2, 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 181,389 t (retained and discarded) was the largest since the fishery became completely domestic, but decreased from 1998–2010, averaging 94,004 t (Table 3, Table 2). From 2011-2014 the catch increased, averaging 155,000 t. The 2013 catch totaled approximately 165,000 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 134,698 t. The full year's estimate of catch in 2022 was 127,718 t.

Yellowfin sole accounted for 66% of the retained flatfish catch in 2021 caught in the Eastern Bering Sea by catcher/processors in the Amendment 80 Fleet. The first-wholesale value of yellowfin sole and rock sole showed a small increase from 0.66 USD/pound to 0.67 USD/pound between 2020 and 2021. Export quantities of yellowfin sole and rock sole decreased in 2021 to 48.54 t from 80.75 t in 2020 (Appendix A, Ablelman 2021). In 2021 25% tariffs were imposed on yellowfin sole exports to China, which may have played a role in the decreased catch.

As of late October 2022, the fishing season is ongoing. To estimate the total 2022 catch for the stock assessment model, the average proportion of the 2017-2021 cumulative catch attained by the end of October was applied to the 2022 catch amount at the same time period and resulted in a 2022 catch estimate of 127,718 t, 39.15% of the ABC.

Length distributions of yellowfin sole throughout NMFS areas 509, 513, 514, 516, 521, and 524 ranged from 20-50 cm, and were similar throughout the Bering Sea (Figure 4). Catch proportions of yellowfin sole by month and area were highest in areas 509, 513, 514, and 521 in 2022 (Figure 5). The highest proportion of the catch was taken in February through May. Catches in July are typically low relative to other months, and catch in July 2022 was 1% of the total for 2022. Maps of the locations where yellowfin sole were caught in 2022, by month (through October 1), are shown in Figure 6. The average age of yellowfin sole in the 2021 catch was estimated at 12.44 and 12.89 years for females and males, respectively. Age data for the current year is not yet available, and no survey was conducted in 2020.

The time-series of catch in Table 3 also includes yellowfin sole that were discarded in domestic fisheries from 1987 to the present. Annual discard estimates were calculated from at-sea sampling (Table 2). The rate of discard has ranged from a low of 2% of the total catch in 2019 through 2022 to a high of 29% in 1992. The trend has been toward fuller retention of the catch in recent years, and with the advent of the Amendment 80 harvest practices, discarding is at its lowest level since these estimates have become available. Historically, discarding primarily occurred in the yellowfin sole directed fishery, with lesser amounts in the Pacific cod, Pollock, rock sole, flathead sole, and "other flatfish" fisheries (Table 4).

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 are also available from studies conducted during the bottom trawl surveys. Estimates of fishery weight-at-age was based on catch-at-age methodology used in the walleye pollock assessment (Ianelli et al. 2019), following Kimura (1989) and modified by Dorn (1992).

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

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). The number of otoliths read from the survey has averaged 725 per year and the number from the fishery has averaged 737 (Table 5). Trends for males and female ages from the fishery indicate that 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 7). 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 that has appeared as 5 year olds in the survey (Figure 8).

Catch

This assessment uses fishery catch data from 1954-2022 (Table 3), and fishery catch-at-age (proportions) from 1964-2021 (Table 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 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 - 2022 for vessels >125 feet (Figure 9). Vessels <125 feet appear to have increased CPUE through time. The CPUE shows a negative correlation with bottom temperature, with increased CPUE in the most recent year, which was a cooler/average year in the Bering Sea.

Numbers at age

The proportion of length at age from the fishery was applied to the length frequencies from the aged sample from the fishery, providing fishery proportions at age. 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 6).

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. The stratum-specific age composition estimates were then weighted by the catch within each stratum to arrive at an overall age composition for each year. The three strata were the EBS trimesters of the year (January-April, May-August, and September-December). This method was used to derive the age compositions from 1991–2021 (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 stratum-specific fishery mean weights-at-age are a product of this analysis and these were used as input data to the model (Figure 10).

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 8). Maturity was re-evaluated from a histological analysis of ovaries collected in 2012 (Table 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 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.

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 2022 were lower than in 2021 and close to the mean for the time series (Figure 9).

Length and Weight-at-Age

Sex-specific size at age used in the model is based on the average length-at-age and weight-at-length relationships from the time-series of survey observations over all years since 1971. The survey age data in 2021 indicated that the dominant age class in 2021 were 11 year olds, spawned in 2010, but in 2022 these have been replaced by 5 year olds spawned in 2017 (Figure 8).

Applications of dendrochronology (tree-ring techniques) have been used to develop biochronologies from the otolith growth increments of northern rock sole (*Lepidopsetta polyxystra*), yellowfin sole and Alaska plaice (*Pleuronectes quadrituberculatus*) in the eastern Bering Sea. These techniques ensure that all growth increments are assigned the correct calendar year, allowing for estimation of somatic growth by age and year for chronologies that span approximately 25 years (Matta et al. 2010). The analysis indicated that age 5 yellowfin sole somatic growth exhibits annual variability and has a strong positive correlation with May bottom water temperature in the Bering Sea (Figure 11).

The relationship between temperature and growth was further explored by reanalyzing yellowfin sole growth by age and year. Length-weight data collected when obtaining otolith (age) samples in RACE surveys (n = 7,000 from 1987, 1994 and 1999-2009) also indicate that weight-at-age exhibits annual variability and is highly correlated with summer bottom water temperature observations (shown for age 5 fish in Figure 12). These empirical data indicate good somatic growth correspondence with annual bottom temperature anomalies. These observations were then extended back to 1979 using survey population length-at-age estimates (since weight-at-age is a power function of the length-at-age, Clark et al. 1999, Walters and Wilderbuer 2000).

The use of 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.

Survey Biomass Estimates and Population Age Composition Estimates

Changes were made in 2022 to the eastern Bering Sea survey stratum area table, which resulted in small changes to the biomass and abundance estimates for all survey years for all species. The changes that were made achieved the following objectives:

- The projection was transformed into a standard EPSG format
- 200m contour was made contiguous to the BS slope shapefiles
- EBS and NBS were made contiguous
- The boundary artifact polygon was removed

Shapefiles exclude landmass using the ARDEM dataset (downloaded on 12/29/2017) at 0.0 elevation settings for ARDEM transformation/conversion not recorded. If depth limits are changed to 20m in the future, research into optimal settings is advised. NBS extent excludes station AA-10 which was dropped from sampling beginning in 2017. The southern border of the Chukchi Sea survey extent was altered for contiguity. These changes altered the area of extrapolation for each stratum from 0-1.9%, and increased the overall survey area (EBS + NBS) by 0.01%. Because we want to maintain consistency throughout the data series for trend analysis, these new stratum areas were applied to the entire data series this year.

Indices of relative abundance available from AFSC surveys showed high NMFS surveys biomass estimates in the 1980s (Table 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 30-60 $kg/hectare$ over the eastern Bering Sea time survey from 1982-2021 (Figure 13). In 2021, survey CPUE was the third lowest in the time series, since the year 2000, at 32.93 $kg/hectare$, but it increased to just over 40 $kg/hectare$ in 2022. 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 10 and Figure 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 the magnitude shown between 1980 and 1990, 1998 and 1999, 2008 and 2009, 2011 and 2012, 2014 and 2015, and 2015 and 2016 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 9). While the 2021 EBS trawl survey estimate for yellowfin sole biomass was the third lowest from the entire time series, it was up 24.8 in 2022, at 2039.97 (Table 9). Yellowfin sole biomass estimates from the northern Bering Sea increased from 310,617 t in 2010 to 520,029 t in 2019, and a subsequent decline to 496,038 t in 2021 (Table 11). Northern Bering Sea biomass estimates for 2022 were up 10.5 to 548,027 t in 2022 (Table 11). The center of gravity for yellowfin sole moved west in the late 2010s before moving more east during the past few years, while the northward trend in the center of gravity as continued since about 2014 (Figure 15). The VAST analysis indicates that the effective area occupied by yellowfin sole has decreased since a peak in 2018 (Figure 16).

Variability of yellowfin sole survey biomass estimates (Figure 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. 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 in a past assessment (Wilderbuer and Nichol 2003).

Over the past 18 years, survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol, 1998); 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 12), and the 2016 estimate of biomass was the highest in 32 years and 48% higher than the 2015 estimate. In the current year, 2022, survey biomass estimates were up for the NBS and the EBS, despite lower temperatures (Table 9, Table 11).

We propose several possible 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 12). Increased biomass estimates in 2022 could be a result of favorable conditions for yellowfin sole for the past several years, as well as temperatures that were lower than in 2021 but still slightly above the long-term mean.

Yellowfin sole population numbers-at-age estimated from the annual bottom trawl surveys are shown in Table 12 and their occurrence in trawl survey hauls and associated collections of lengths and age structures since 1982 are shown in Table 5. Their total tonnage caught in the resource assessment surveys since 1982 are listed in Table 7.

Northern Bering Sea survey

Trawl survey sampling was extended to the northern Bering Sea in 2010, 2017, 2018, 2019, 2021, and 2022. The trawl surveys conducted in 2010, 2017, 2019, 2021 and 2022 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, as described above. Since bottom trawl fishing is presently prohibited in the northern Bering Sea, the biomass from this area has typically not been included in the stock assessment model, although Model 22.1 does incorporate EBS+NBS biomass estimates. Large shifts in the abundance of yellowfin sole into the Bering Sea have not been observed, but the distribution of yellowfin sole appears continuous between the eastern and northern Bering Sea, and it is therefore reasonable to include survey data from the region occupied by the entire population.

A time series based on an ADF&G survey in Norton Sound confirmed that the biomass of yellowfin sole has generally increased since 1980. The mean CPUE/km^2 of yellowfin sole in Norton Sound increased from a mean CPUE of 201 over the first five survey years (1976, 1979, 1982, 1985, and 1988) to a mean CPUE of 411 over the last five survey years (2017, 2018, 2019, 2020, and 2021) (Figure 17). There was no Norton Sound survey in 2022.

VAST estimates of biomass

We incorporated vector-autoregressive spatio-temporal (VAST) biomass estimates into Model 22.1, incorporated VAST estimates from the NBS and the EBS from 1982-2022 (Thorson 2019). The software versions of dependent programs used to generate VAST estimates were Microsoft R Open (4.0.2), INLA (21.11.22) (Rue et al. 2009), TMB (1.9.0) (Kristensen et al. 2016), TMBhelper (1.4.0), VAST (3.9.0), FishStatsUtils (2.11.0).

VAST abundance

For model-based indices in the Bering Sea, observations of biomass per unit area were fitted from all grid cells and corner stations in the 83-112 bottom trawl survey of the EBS, 1982-2022, including exploratory northern extension samples in 2001, 2005, and 2006, as well as 83-112 samples available in the NBS in 1982, 1985, 1988, 1991, 2010, and 2017-2021. NBS samples collected prior to 2010 and in 2018 did not follow the 20 nautical mile sampling grid that was used in 2010, 2017, 2019, 2021 and 2022 surveys. Assimilating these data therefore required extrapolating into unsampled areas. This extrapolation was facilitated by including a spatially varying response (Thorson 2019) to mean bottom temperature within the outer and middle domain strata, estimated for both linear predictors of the delta-model. All environmental data used as covariates were computed within the R package coldpool (https://github.com/afsc-gap-products/coldpool; Rohan et al., in review). Detailed comparison of results for EBS pollock has shown that a spatially varying covariate (cold-pool index) has a small but notable effect on these indices and resulting stock assessment outputs (O'Leary et al. 2020).

A Poisson-link delta-model (Thorson 2018) involving two linear predictors, and a gamma distribution to model positive catch rates were used in the VAST model. Population density was extrapolated to the entire EBS and NBS in each year, using extrapolation grids that are available within FishStatsUtils, which were updated since the 2021 assessment cycle based on new shapefiles developed by J. Conner (https://github.com/James-Thorson-NOAA/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. Bilinear interpolation was used 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. Geometric anisotropy was estimated, and included a spatial and spatio-temporal term for both linear predictors. To facilitate interpolation of density between unsampled years, the spatio-temporal fields were structured over time as an AR(1) process (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). However, temporal correlation was not included for intercepts, each linear predictor and year were treated as fixed effects. Finally, we used epsilon bias-correction to correct for retransformation bias (Thorson and Kristensen 2016).

Model fits for evidence of non-convergence were checked by confirming that (1) the derivative of the marginal likelihood with respect to each fixed effect was sufficiently small and (2) that the Hessian matrix was positive definite. A second check for evidence of model fit was performed by computing Dunn-Smyth randomized quantile residuals (Dunn and Smyth 1996) and visualizing these using a quantile-quantile plot within the *DHARMa* R package. The distribution of these residuals was also evaluated over space in each year, and inspected for evidence of residual spatio-temporal patterns.

The motivation for using survey data from the EBS and NBS in Model 22.1 is that accounting for the entire biomass of a stock within its natural boundaries is advantageous to presenting an accurate model, regardless of the footprint of the fishery, especially since YFS likely migrate between the EBS and NBS. In some cases, models can estimate the proportion of a stock outside the survey area via the catchability coefficient if there is mixing between areas ($q<1$), but it is better to include an actual estimate covering the entire area of occurrence. If a population is well-mixed within its distributional area it does not matter if fishing takes place in only a portion of the area. Analogously, yellowfin sole biomass would not be omitted from closed areas.

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.

Data weighting

Model-based and VAST survey age composition data were weighted using the methodology of Francis (2011). Specifically, data weighting was performed on Models 18.2, 22.0, and 22.1 for 2022, as stage 2 weighting that incorporated stage 1 legacy weights using Equation TA1.8 of Francis (2011). Survey age compositions used equal stage 1 weights for each year of the composition dataset (200).

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 conceptual 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 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.

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). The model of yellowfin sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

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.

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 $Z_{t,a} = F_{t,a} + M$.

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 $C_{t,a}$ 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 1956-1975 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 1978-2022 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 1978-2016, and are shown from Model 22.0 (Figure 18) and Model 22.1 (Figure 19).

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,

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

Description of Alternative Models

In this assessment we considered Model 18.2 used in the 2021 assessment updated with 2022 data. This model used a fixed value for female natural mortality (M=0.12) and allowed male natural mortality to be estimated within the model. Model 22.0 was similar to Model 18.2 except it used a single value of survey selectivity for males and females. Model 22.1 built upon Model 22.0 to use model-based VAST estimates of biomass from the eastern Bering Sea plus northern Bering Sea survey area, rather than standard design-based estimates of biomass. Model 22.1 also incorporated model-based estimates of survey age compositions.

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 from first 10 years (1971-1980) was used to fill in years 1954-1970. It was important to select years from the beginning of the time series, as it appears that length and weight at age appears to be increasing in yellowfin sole (Figure 20, but there is no evidence that the length-weight relationship has changed Figure 21). The plot of female weight at length was plotted over time and there does not seem to be any differences in weight at length since at least 1990. Samples from the 1970's do show a somewhat reduced pattern of weight at length, but this may be due in part to differences in sampling protocol.

The mean weight at age from 2021 was used as an estimate for weight at age in 2022, as the 2022 ages have not yet been processed. The most recent data was used for 2022 in consideration of the increase in average size at age (Figure 22, Table 13,Table 14).

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 18.2, 22.0, and 22.1.

Maturity

Yellowfin sole maturity schedules were estimated from in-situ observations from two studies as discussed in the "Data" section (Table 8).

Parameter Estimates

A list of selected parameters estimated inside the model are shown for Model 18.2 in Table 15, for Model 22.0 in Table 16, and for Model 22.1 in Table 17.

Parameters Estimated Inside the Assessment Model

There were 520 parameters estimated by Model 18.2, and 518 estimated by Models 22.0, and 22.1, and last year's model had 514. The number of key parameters are presented below:

Fishing mortality	Selectivity	Survey catchability	Year-class strength	Spawner-recruit	M	Total
70	330 (328)	4	117	2	1	520 (518)

The increase in the number of parameters estimated in this assessment compared to last year (6) can be accounted for by the input of another year of fishery data and the entry of another year-class into the observed population and four more sex-specific fishery selectivity parameters. Models 22.0 and 22.1 have only 518 estimated parameters, due to the removal of two separate male selectivity parameters. The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population over time.

Selectivity

Fishery selectivity in all models and survey selectivity in Model 18.2 were modeled separately for males and females using the two parameter formulation of the logistic function. The model was run with an asymptotic selectivity curve for the older fish in the fishery and survey, but still allowed to estimate the shape of the logistic curve for young fish. The oldest year-classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the 20+ age category. For Models 22.0 and 22.1, a single selectivity curve, for both males and females, was fit for all years of survey data (Figure 23).

Time-varying fishing selectivity curves were estimated because there have been annual changes in management, vessel participation and possibly gear selectivity (Figure 24, Figure 25). 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,

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

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 2022 values were fixed as the average of the 3 most recent years.

The single combined sex survey selectivity for Models 22.0 and 22.1 used only two parameters rather than four.

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:

$$q = e^{-\alpha+\beta T}, \tag{2}$$

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:

$$q = e^{-\alpha+\beta T+\gamma S+\mu T:S}, \tag{3}$$

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 1978-2016 were constrained to fit a Ricker (1958) form of the stock recruitment relationship as follows:

$$R = \alpha S e^{-\beta S}, \tag{4}$$

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 18.2 and two additional exploratory models were examined, Model 22.0 and 22.1. Model 18.2 was the accepted model in the 2021 yellowfin sole stock assessment, and Model 22.1 is the preferred model.

Model 18.2 estimated male natural mortality 0.13843 to be higher than female natural mortality 0.12, which is in common with known life history parameters of other Alaska flatfish. Models 22.0 and 22.1 also estimated higher male than female natural mortality, 0.139 and 0.125 respectively. In Arrowtooth Flounder, higher natural mortality is assumed for males and is 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). Higher natural mortality indicates greater productivity of a stock and therefore higher management quantities. Model 22.1 estimated lower male natural mortality than Models 18.2 or 22.0.

Overall, Models 18.2 and 22.0 provided almost identical results. Models 18.2 and 22.0 vs. 22.1 used different assumptions for the estimates of biomass (design-based vs. VAST); therefore, their likelihoods could not be compared. However, Models 18.2 and 22.0 used the same likelihood assumption. The Akaike Information Criterion was calculated from the hessian and objective function value OFV of the ADMB output .par file to compare models 18.2 and 22.0. The hessian $Hess$ was transformed back into the original parameter space and the marginal likelihood $Likelihood_{MAR}$ was estimated as:

$$Likelihood_{MAR} = -0.5 * Hess_T - OFV, \tag{5}$$

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

$$AIC = 2 * k - 2 * Likelihood_{MAR}, \tag{6}$$

where k is the number of parameters used in the model. The AIC for Model 22.0 was lower (AIC = 6136.6) than for Model 18.2 (AIC = 6154.1), indicating that Model 22.0 is a better-fit model.

In other respects, Models 22.0 and 18.2 appeared to fit the data almost identically. The fit to survey selectivity was similar (Figure 23), survey catchability was similar (Figure 26), sex ratio appeared similar (Figure 27), predicted survey biomass was similar (Figure 28), as were total biomass, numbers at age, and spawning stock biomass (Figure 29,Figure 30, and Figure 31). Therefore, Model 22.0 was considered a better fit to the data, with fewer parameters. Subsequent comparisons did not incorporate Model 18.2, due to the similarity between Model 22.0 and Model 18.2.

Model 22.1 (Figure 26), indicates a shift towards higher survey catchability in 2022, than Models 18.2 and 22.0, corresponding with lower bottom temperatures than in 2021 (Figure 12). The proportion female was estimated to be closer to 50% in Model 22.1 than Model 22.0 and 18.2 (Figure 27). In addition, the anomalous spike in the proportion female in the 1960s is reduced for Model 22.1.

Models 22.0 and 22.1 similarly provided a good fit the survey age compositions (Figure 32, Figure 33) and fishery age compositions (Figure 34, Figure 35).

Models 22.0 and 22.1 fit different survey biomass estimates, but the fit to each appeared to modulate extremes in yearly observations (Figure 28). For example, higher estimated survey biomass was estimated by the model than the survey during the past few years, which is also affected by the temperature covariate on survey catchability. In this relationship, higher than average water temperatures reduce estimates of survey catchability and the opposite is also true. Discrepancies between the survey biomass and the model fit can also be attributed larger confidence intervals on design based estimates of biomass compared with VAST. There was some discontinuity in the fit for 2016 that was consistent among all three models, that corresponded with the second largest temperature anomaly on record, after 2019 Figure 36).

A new approach was taken to MCMC sampling of the yellowfin sole modeled parameter space (using Model 22.0) using the R package *adnuts*. This tool offers improved MCMC sampling of ADMB models including use of the random walk Metropolis algorithm (Monnahan and Kristensen 2018). Markov chain Monte Carlo (MCMC) methods allow for random sampling from a probability distribution, even with a large number of random variables. This allows the algorithm to examine probability distributions underlying parameters that are approximated from the distribution, and to determine whether there are conflicts in probability distributions. By constructing a Markov chain that has the desired distribution as its equilibrium distribution, one can obtain a sample of the desired distribution by recording states from the chain. The more steps that are included, the more closely the distribution of the sample matches the actual desired distribution. We also examined trace plots of selected parameters and the effective sample size and $\hat{R}$,which is the ratio of the spread of all the values combined to the mean spread of each chain; if all the chains are sampling properly from the posterior distribution, this ratio should be 1. In this case, $\hat{R}$ is very close to 1 (Figure 37.

Previous MCMC runs of the yellowfin sole assessment model were performed in ADMB with 1,000,000 iterations and thinning every 200. Explorations in *adnuts* indicated that a larger sample was required to obtain a random probability distribution; 10^7 iterations were required, with thinning every 1000 runs. The outcome indicated good mixing in key parameters distributions estimated by the model (Figure 38). The effective sample size (ESS) for this parameter was 1,146 and $\hat{R}$ was 0.9999575 (Figure 37). Some parameters of low inferential importance were not well mixed, such as several male and female selectivity parameters early in the time series. These parameters will be examined prior to the next assessment cycle.

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 1977-2016 spawner-recruit data in the model. The resulting stock recruitment curve shows average recruitment for the years 2016-2021 except 2017 and 2019 which are above average, based on Model 22.0 (Figure 18, and Model 22.1 Figure 19).

Model 22.1 is the preferred model for estimating the yellowfin sole stock size and management quantities for the 2023 fishing season because it incorporates model-based abundance index and age compositions for the eastern Bering Sea and northern Bering Sea survey areas. In addition, the comparison between Models 18.2 and 22.0 show that a single survey selectivity provides a better model fit, and Model 22.1 incorporates a single survey selectivity curve. Model 22.1 provided consistently higher management quantities than Models 22.0 and 18.2, which is expected given the larger survey area. Reference points resulting from all models, as well as the 2021 accepted model are shown in (Table 18).

Time Series Results

The data was updated in 2022 to include current values of catch, survey biomass estimates, and fishery and survey age compositions from 2021. The latest year of fishery weight-at-age data was included. The eight past years in the Bering Sea have had bottom temperature anomalies above the mean, to varying degree. The temperature-dependent q adjustment for 2022 was 0.79 for Model 18.2, 0.79 for Model 22.0, and 0.96 for Model 22.1.

Fishing Mortality and Selectivity

The full-selection fishing mortality, F, has averaged 0.0795 over the 5 years, 2018 -2022 (Table 19). Model estimated selectivities, Figure 23 and Figure 24 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 22.1 estimated catchability q at an average value of 1 for the period 1982-2022 which resulted in a model estimate of the 2022 age 2+ total biomass at 3.782 million t (Table 10). In comparison, catchability was lower for Models 18.2 and 22.0, which was estimated at 0.82 for both models. 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 10, Figure 30). 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 2024. The present biomass is estimated at 95% of the peak 1985 level. The female spawning biomass has also declined since the peak in 1994, with a 2022 estimate of 923,828 t (Table 20).

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 2035 if the fishing mortality rate continues at the same level as the average of the past 5 years (Figure 39).

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 1967-76 (Table 1 and Figure 40). 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 2016 year-class appeared to be one of the lowest on record (Figure 40, Figure 41). Recruitment for years subsequent to 2016 may be less reliable given the fit to the stock recruitment curve and lack of survey data to confirm recruitment estimates.

Retrospective Analysis

A within-model retrospective analysis was included for the recommended assessment model (Model 22.1), as well as Model 22.0. 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 42 and Figure 43). Mohn's rho for Model 22.1 was 0.007 and for Model 22.0 it was -0.007. Mohn's rho for Model 18.2 (2021) was -0.118. This was an improvement over past assessment models.

A similar retrospective pattern was observed as in recent years, in which earlier retrospective years indicated a lower level of spawning biomass than the current year's data (Figure 42 and Figure 43). The difference in female spawning biomass was negative for most recent years, except for the most recent (Figure 44, Figure 45), and very similar among models. This is an improvement in the retrospective pattern than seen in previous years. 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.

In the 2017 assessment it was demonstrated that low values of Mohn's rho and desirable retrospective patterns of female spawning biomass were obtainable if lower values of M and q were used relative to the base model. The Plan Team and SSC requested a plot of the model-estimated female spawning biomass trajectory that reduced the retrospective pattern using M fixed at 0.09 and q=1.0 on top of the estimated female spawning biomass trajectory with confidence interval from the assessment.

Risk Table

Assessment related considerations

The BSAI yellowfin sole assessment is based on surveys conducted annually on the EBS shelf from 1982-2022, continually 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. The assessment model exhibits good fits to all compositional and abundance data and converges to a single minima in the likelihood surface. MCMC indicated good mixing in key parameters distributions estimated by the model. Recruitment estimates track strong year-classes that are consistent with the data.

The retrospective pattern from the assessment model has typically been less than desirable and has been the subject of some concern for the assessment. However, in the 2021 assessment, reanalysis of survey weights at age resulted in a Mohn's rho value that is still negative, but closer to zero. Peculiar to the yellowfin sole assessment, in comparison to the northern rock sole and Alaska plaice assessments (that have preferable patterns), is the large amount of variability in the annual survey biomass assessments for this stock due to the temperature-influenced availability to the survey. In the 2022 Models 22.0 and 22.1, combining male and female survey selectivities further improved the retrospective pattern.

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

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 1967-76 combined with light exploitation resulted in a biomass increase to a peak of 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, although the 2006-2010 year-classes appear average according to the 2018 stock assessment. The current model for 2022 estimates B_{MSY} at 475,199 t. Projections indicate that the FSB will remain well-above the B_{MSY} level through 2035 (Figure 39).

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

Environmental/ecosystem considerations

Environmental processes: The extended warm phase experienced in the eastern Bering Sea (EBS) that began in approximately 2014 has largely relaxed to normal conditions over the past year (August 2021 - August 2022). The North Pacific Index (NPI) has been positive during 5 out of the last 6 winters, with the exception being the winter of 2018 - 2019. Positive values mean a weak Aleutian Low Pressure System and generally calmer conditions. Sea surface temperature (SST) was within one standard deviation of the long term average and marine heatwaves were relatively weak and short-lived compared to recent years. Estimates of bottom temperature derived from the ROMS model suggest that bottom temperatures in the northern Bering Sea (NBS) over the past year were within normal ranges while the southeastern Bering Sea (SEBS) was significantly cooler than average. The Bering Sea ice extent was generally higher than average throughout much of the 2021-2022 winter. Ice advanced rapidly in November, though there was an abrupt springtime retreat beginning in mid-April. These cool-to-normal winter conditions were favorable to cold pool formation, though not to the areal extent in the years preceding 2014. The 2022 cold pool was near the historical average and resembled other average-to-cool years, most similar to 2017 (Hennon et al. 2022).

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. The center of gravity for the population continued to shift northward, as has been the case for the past several years, and shifted slightly westward in 2022 relative to 2021. The ecosystem 'red flags' that occurred in the NBS in 2021, notably the crab population declines

(Richar 2021) and salmon run failures in the Arctic-Yukon-Kuskokwim region (Liller 2021), continued into 2022 (Richar 2022; Whitehouse 2022). Concerns about the food web dynamics and carrying capacity in the NBS have existed since 2018; monitoring fish condition provides insight into habitat and prey conditions for YFS in the NBS.

Prey: The dominant prey of 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. The biomass of motile epifauna peaked in 2017 and remains above their long-term mean in 2022. Trends in motile epifauna biomass indicate benthic productivity, although individual species and/or taxa may reflect varying time scales of productivity. Brittle stars, sea stars, and other echinoderms are well above their long-term means, while king crabs, tanner crab, and snow crab are all below their long-term means (Whitehouse 2022).

In 2022, fish condition (as measured by length-weight residuals) was above-average in the SEBS and increased from 2021, and was just below average in the NBS and decreased from 2021 (Rohan et al. 2022). These trends in fish condition indicate sufficient prey is available over the southern shelf, supported by similar trends in motile epifauna, resulting in above-average fish condition. No direct or indirect measures of prey availability exist for the northern shelf, where YFS condition has declined since 2019.

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 increased 18% from 2021 to 2022 but remains below the time series mean. There were increases in biomass for the four most dominant species in this guild (yellowfin sole, northern rock sole, flathead sole, and Alaska plaice), though all but flathead sole remain below their long term mean (1982–2022) (Whitehouse 2022). Trends in benthic forager biomass indirectly indicate availability of infauna (i.e., prey of these species), suggesting competition for prey resources remains low in 2022.

Predators: Predators of YFS include Pacific cod and Pacific halibut, which are included in the apex predator guild. The biomass of the apex predator guild increased from 2021 to 2022 to nearly equal to their long term mean. The trend in this guild is largely driven by Pacific cod and arrowtooth flounder, both of which increased from 2021 (Whitehouse 2022). 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.

Summary for Environmental/Ecosystem considerations:

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

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

Fishery performance considerations

At the current time, fishery CPUE shows no contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, or changes in the duration of fishery openings.

Several other fishery performance considerations are as follows:

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

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

We recommend no reduction in ABC, based on this risk table assessment.

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 2022 numbers at age from the stock assessment model are projected to 2022 given the 2021 catch and then a 2022 catch of 134,698 t was applied to the projected 2022 population biomass to obtain the 2023 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 2023 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 2023 biomass estimate.

The geometric mean of the 2023 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 2023 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 2023 harvest (now the 1978-2016 time-series) recommendation (Model 22.1), the $F_{ABC} = F_{Hmean} = 0.114$. The estimate of age 6+ total biomass for 2023 is 3,321,640 t. The calculations outlined above give a Tier 1 ABC harvest recommendation of 378,499 t and an OFL of 404,882 t for 2023. This results in an 7% (26,383 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	2023 Yield
Tier 1 $F_{OFL} = F_{MSY}$	0.122	404,882 t
Tier 1 $F_{ABC} = F_{harmonicmean}$	0.114	378,499 t

A complete record of catch, ABC, and OFL since 1980 is available in Table 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 2022 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2023 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2022. 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 will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2023, 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 2022 recommended in the assessment to the max F_{ABC} for 2023. (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 2017 - 2021 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 2022 or 2) above 1/2 of its MSY level in 2022 and expected to be above its MSY level in 2032 under this scenario, then the stock is not overfished.)
- Scenario 7: In 2023 , 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 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 approaching an overfished condition.)

Simulation results shown in Table 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 39). 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, and that projections of female spawning biomass are also expected to be above B_{MSY} (Figure 46). A phaseplane plot for Model 22.0 shows similar results (Figure 47) The ABC and OFL for 2023 and 2024 assuming average catch rates are shown in the following table.

Year	Catch	FSB	Geom. mean 6+ biomass	ABC	OFL
2023	126,157	885,444	3,321,640	378,499	404,882
2024	126,157	897,062	4,062,230	462,890	495,155

Based on the 2022 assessment Model 22.1, an F=0.201 would have produced a 2021 catch equal to the 2021 OFL, 377,071 t.

Ecosystem Considerations

Ecosystem Effects on the Stock

Prey availability/abundance trends

Yellowfin sole diet by life stage varies as follows: Larvae consume plankton and algae, early juveniles consume zooplankton, late juvenile stage and adults prey includes bivalves, polychaetes, amphipods, mollusks, euphausids, shrimps, brittle stars, sculpins and miscellaneous crustaceans. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not been re-sampled since. The large populations of flatfish which have occupied the middle shelf of the Bering Sea over the past twenty-five years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the yellowfin sole resource.

Predator population trends

As juveniles, it is well-documented from studies in other parts of the world that flatfish are prey for shrimp species in near shore areas. This has not been reported for Bering Sea yellowfn sole due to a lack of juvenile sampling and collections in near shore areas, but is thought to occur. As late juveniles they have been found in stomachs of Pacific cod and Pacific halibut; mostly small yellowfin sole ranging from 7 to 25 cm standard length..

Past, present and projected future population trends of these predator species can be found in their respective SAFE chapters in this volume and also from Annual reports compiled by the International Pacific Halibut Commission. Encounters between yellowfin sole and their predators may be limited since their distributions do not completely overlap in space and time.

Changes in habitat quality

Changes in the physical environment which may affect yellowfin sole distribution patterns, recruitment success and migration timing patterns are catalogued in the Ecosystem Considerations Report of this SAFE report. Habitat quality may be enhanced during years of favorable cross-shelf advection (juvenile survival) and warmer bottom water temperatures with reduced ice cover (higher metabolism with more active feeding).

Fishery Effects on the Ecosystem

1. The yellowfin sole target fishery contribution to the total bycatch of other target species is shown for 1992-2019 in Table 23, and bycatch of the Other Species group (Octopus,Shark, Skate, Squid, and Sculpin) are presented in Table 24. The catch of non-target species from 2003-2019 is shown in Table 25. The yellowfin sole target fishery contribution to the total bycatch of prohibited species is summarized for 2015 as follows:

Prohibited species	yellowfin sole fishery % of total bycatch
Halibut mortality	30
Herring	2
Red King crab	5
C. bairdi	25.5
Other Tanner crab	78.2
Salmon	<1

2. Relative to the predator needs in space and time, the yellowfin sole target fishery has a low selectivity for fish 7-25 cm and therefore has minimal overlap with removals from predation.
3. The target fishery is not perceived to have an effect on the amount of large size target fish in the population due to its history of light to moderate exploitation (6%) over the past 30 years. Population age composition data indicate a large 20+ age group.
4. Yellowfin sole fishery discards are presented in the Catch History section.
5. It is unknown what effect the fishery has had on yellowfin sole maturity-at-age and fecundity, but based on two maturity studies conducted 20 years apart, it is expected to be minimal.
6. Analysis of the benthic disturbance from the yellowfin sole fishery is available in the Preliminary draft of the Essential Fish Habitat Environmental Impact Statement and summarized in Table 26.

Data Gaps and Research Priorities

Genetic studies are needed to confirm the assumption that yellowfin sole consist of a single stock throughout the Bering Sea. Additional studies of maturity at age throughout the range of yellowfin sole (including the northern Bering Sea) are also warranted.

In addition, research is needed to study the spatial variation in juvenile flatfish growth and condition in relation to habitat quality in the Bering Sea. The bottom trawl used in the Bering Sea surveys is not efficient in retaining animals of size $\leq$ 14 cm (Kotwicki et al. 2017). In recent studies where the 83-112 bottom trawl and the 3-m plumb staff beam trawl were fished consecutively at a survey station, the catch per unit effort (CPUE, number/hectare) of juvenile yellowfin sole ($\leq$ 16 cm) estimated from the bottom trawl can be lower than the CPUE from the beam trawl by as high as an order of magnitude, or erroneously indicate absence (Yeung, unpubl. data). As a result of the low catch of small fish in the surveys, there is high uncertainty at the left tail of the age-length curve. The age-at-length from otolith analysis of juveniles collected with the beam trawl (n=84) was consistently older by 1-3 years than the estimated age using the survey-derived age-length key (Matta and Yeung, unpubl. data), suggesting that currently the age of juveniles may have been underestimated. Juvenile yellowfin sole are known historically to be concentrated in shallow, nearshore habitats near Kuskokwim and Togiak Bays in the EBS that are out of bottom-trawl survey range, just as the NBS surveys now showed them in high abundance in habitat of such type in Norton Sound in the NBS. Long-term, systematic survey of the nearshore with appropriate sampling gear will improve the assessment of the density and distribution of juvenile yellowfin sole, and the understanding of the linkages between environmental drivers, habitat quality and usage, and biomass production. Norton Sound and Kuskokwim-Togiak Bays should be focal areas of investigation for their potential importance as nurseries. These coastal areas are of high anthropogenic and environmental sensitivity, and are experiencing anomalously high water temperatures because of climate change that are likely to impact fish growth and condition. To fully assess yellowfin sole stock production, the level of connectivity between the EBS and NBS populations will need to be addressed with tools such as tagging, genomics, biomarkers and otolith microchemistry.

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Tables

Table 1: Model estimates of age 1 recruitment (in billions of fish), 1954-2022, with 95% lower and upper confidence intervals (LCI, HCI) for Model 18.2 (2021), and 2022 Models 18.2, 22.0, and 22.1.

Year	Model 18.2 (2021)	Model 18.2 (2022)	Model 22.0			Model 22.1		
	Recruitment	Recruitment	Recruitment	LCI	HCI	Recruitment	LCI	HCI
1954	2.051	1.631	1.530	1.110	1.951	2.147	1.558	2.735
1955	1.669	1.546	1.284	0.958	1.610	1.736	1.269	2.203
1956	1.44	2.418	1.135	0.742	1.527	1.406	0.817	1.996
1957	5.392	1.765	3.709	2.735	4.682	4.470	1.733	7.208
1958	3.59	1.212	2.575	2.198	2.952	2.807	1.414	4.201
1959	2.326	3.828	1.949	1.675	2.223	1.947	1.392	2.502
1960	1.965	2.672	1.852	1.591	2.112	1.776	1.463	2.090
1961	1.086	1.984	1.102	0.901	1.303	1.033	0.839	1.227
1962	2.065	1.857	2.090	1.817	2.362	1.951	1.693	2.209
1963	1.079	1.072	1.073	0.873	1.273	1.029	0.837	1.221
1964	1	1.961	0.972	0.786	1.157	0.953	0.771	1.134
1965	1.312	1.078	1.324	1.096	1.552	1.245	1.033	1.456
1966	1.364	1.034	1.386	1.143	1.629	1.281	1.055	1.507
1967	2.916	1.343	2.920	2.548	3.292	2.711	2.351	3.071
1968	4.539	1.373	4.398	3.926	4.869	4.162	3.696	4.628
1969	4.663	2.930	4.854	4.352	5.356	4.443	3.951	4.934
1970	6.144	4.386	6.186	5.620	6.751	5.742	5.179	6.305
1971	6.79	4.826	6.773	6.193	7.353	6.335	5.750	6.919
1972	5.309	6.155	5.320	4.831	5.809	4.915	4.422	5.408
1973	3.683	6.742	3.683	3.302	4.065	3.403	3.016	3.789
1974	4.951	5.298	5.024	4.587	5.461	4.588	4.146	5.030
1975	5.751	3.670	5.808	5.346	6.270	5.253	4.789	5.716
1976	3.771	5.008	3.946	3.583	4.309	3.480	3.122	3.838
1977	4.726	5.792	4.893	4.483	5.303	4.337	3.932	4.741
1978	3.084	3.936	3.301	2.977	3.625	2.961	2.639	3.283
1979	1.986	4.880	2.029	1.782	2.275	1.897	1.646	2.148
1980	3.894	3.293	3.987	3.630	4.344	3.715	3.351	4.078
1981	2.927	2.024	3.037	2.732	3.342	2.936	2.618	3.254
1982	8.516	3.979	8.549	7.963	9.136	8.084	7.477	8.690
1983	1.572	3.031	1.350	1.154	1.546	1.362	1.153	1.570
1984	7.031	8.534	6.799	6.302	7.296	6.299	5.792	6.805
1985	2.427	1.347	2.157	1.911	2.402	2.071	1.815	2.326
1986	1.866	6.787	1.787	1.567	2.007	1.587	1.368	1.807
1987	2.551	2.153	2.575	2.309	2.841	2.333	2.065	2.602
1988	3.498	1.784	3.556	3.235	3.876	3.269	2.943	3.595
1989	3.494	2.571	3.571	3.250	3.892	3.465	3.127	3.802
1990	1.741	3.551	1.632	1.430	1.835	1.655	1.436	1.875
1991	1.954	3.566	1.878	1.658	2.098	1.867	1.631	2.103
1992	4.327	1.631	4.375	4.005	4.744	4.197	3.811	4.583
1993	2.557	1.876	2.468	2.210	2.726	2.469	2.191	2.747
1994	2.149	4.369	2.133	1.896	2.371	2.058	1.807	2.308
1995	2.15	2.465	2.010	1.780	2.239	1.970	1.726	2.214
1996	5.255	2.131	5.112	4.703	5.522	4.800	4.382	5.218
1997	2.258	2.007	2.111	1.878	2.345	2.060	1.813	2.308
1998	1.864	5.106	1.749	1.541	1.957	1.774	1.549	1.999
1999	2.271	2.109	2.226	1.989	2.463	2.199	1.947	2.451

2000	3.168	1.748	3.035	2.750	3.321	3.051	2.747	3.355
2001	2.042	2.224	1.982	1.761	2.202	2.015	1.777	2.253
2002	2.735	3.033	2.792	2.519	3.066	2.797	2.508	3.086
2003	2.602	1.980	2.791	2.515	3.066	2.781	2.492	3.070
2004	3.947	2.791	4.256	3.884	4.628	4.273	3.890	4.656
2005	1.798	2.790	1.792	1.578	2.007	1.784	1.558	2.010
2006	1.971	4.256	1.986	1.752	2.220	1.951	1.708	2.194
2007	2.288	1.793	2.251	1.988	2.514	2.204	1.935	2.472
2008	2.092	1.987	2.036	1.783	2.290	2.126	1.857	2.396
2009	2.54	2.253	2.388	2.095	2.681	2.497	2.189	2.805
2010	3.544	2.039	3.296	2.910	3.682	3.382	2.990	3.773
2011	1.292	2.391	1.175	0.979	1.370	1.241	1.027	1.454
2012	0.581	3.301	0.514	0.389	0.640	0.581	0.436	0.726
2013	1.479	1.177	1.248	1.015	1.481	1.284	1.038	1.530
2014	1.669	0.515	1.213	0.952	1.474	1.306	1.026	1.585
2015	2.758	1.251	2.307	1.846	2.768	2.422	1.953	2.891
2016	3.881	1.216	3.224	2.541	3.907	3.161	2.508	3.815
2017	4.371	2.312	9.298	7.548	11.048	6.947	5.618	8.277
2018	2.109	3.250	2.757	1.447	4.067	2.859	1.592	4.126
2019	2.534	9.315	9.583	4.679	14.488	9.086	4.554	13.618
2020	2.622	2.765	2.173	-0.526	4.873	2.439	-0.601	5.478
2021	2.628	9.633	2.535	-0.948	6.019	2.517	-0.947	5.980
2022	-	2.197	2.584	-1.026	6.195	2.548	-1.012	6.108

Table 2: Estimates of retained and discarded (t) yellowfin sole caught in Bering Sea fisheries from 1991 through October 10th, 2022, and the proportion discarded.

Year	Retained (t)	Discarded (t)	Proportion discarded
1991	88,967	28,337	0.24
1992	102,542	42,840	0.29
1993	76,798	29,012	0.27
1994	104,918	35,132	0.25
1995	96,767	27,980	0.22
1996	101,324	28,335	0.22
1997	150,745	32,068	0.18
1998	80,263	20,887	0.21
1999	56,604	12,617	0.18
2000	69,971	14,087	0.17
2001	54,918	8,646	0.14
2002	63,625	11,332	0.15
2003	68,832	10,974	0.14
2004	62,746	12,756	0.17
2005	85,311	9,072	0.1
2006	90,592	8,564	0.09
2007	109,004	11,958	0.1
2008	141,235	7,659	0.05
2009	100,642	6,870	0.06
2010	113,244	5,379	0.05
2011	146,418	4,739	0.03
2012	142,132	5,054	0.03
2013	158,781	6,163	0.04
2014	152,167	4,605	0.03
2015	123,065	3,871	0.03
2016	131,202	4,121	0.03
2017	128,665	3,554	0.03
2018	127,331	4,160	0.03
2019	126,111	2,951	0.02
2020	131,774	2,025	0.02
2021	106,785	2,003	0.02
2022	116,692	2,013	0.02

Table 3: Foreign and domestic catch (t) of yellowfin sole 1954-2022. 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 2022 was downloaded October 13, 2021.

		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	106,096	8.4	106,087	106,096

Table 4: Discarded and retained catch of non-CDQ yellowfin sole, by fishery, in 2021. 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.

Trip target name	Gear type	Discarded (t)	Retained (t)
Halibut	HAL	0	0
Pacific Cod	HAL	358	10
Alaska Plaice	NPT	9	962
Arrowtooth Flounder	NPT	1	2
Atka Mackerel	NPT	0	0
Flathead Sole	NPT	55	1,683
Pacific Cod	NPT	2	32
Pollock - bottom	NPT	4	630
Rock Sole	NPT	98	4,312
Rockfish	NPT	0	4
yellowfin sole	NPT	1,081	99,050
Halibut	POT	0	0
Pacific Cod	POT	370	0
Pollock - bottom	PTR	1	39
Pollock - midwater	PTR	24	55

Table 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 with length	Number of lengths	Hauls with otoliths	N. ages (survey)	N. ages (fishery)
1982	334	246	37023	35	744	2432
1983	353	256	33924	37	709	1178
1984	355	271	33894	56	796	338
1985	357	261	33824	44	802	840
1986	354	249	30470	34	739	1503
1987	357	224	31241	16	798	1071
1988	373	254	27138	14	543	1361
1989	374	236	29672	24	740	1462
1990	371	251	30257	28	792	1220
1991	372	248	27986	26	742	935
1992	356	229	23628	16	606	1203
1993	375	242	26651	20	549	1020
1994	375	269	24448	14	522	573
1995	376	254	22116	20	647	554
1996	375	247	27505	16	721	314
1997	376	262	26034	11	466	397
1998	375	310	34509	15	570	426
1999	373	276	28431	31	770	487
2000	372	255	24880	20	511	583
2001	375	251	26558	25	593	491
2002	375	246	26309	32	723	486
2003	376	241	27135	37	695	590
2004	375	251	26103	26	712	483
2005	373	251	24658	34	635	494
2006	376	246	28470	39	426	490
2007	376	247	24790	66	772	496
2008	375	238	25848	65	830	542
2009	376	235	22018	70	752	515
2010	376	228	20619	77	827	535
2011	376	228	21665	65	753	525
2012	376	242	23519	72	973	504
2013	376	232	23261	70	803	670
2014	376	219	20229	52	790	502
2015	376	223	20830	73	875	622
2016	376	242	26674	69	876	495
2017	376	258	25767	78	886	595
2018	376	255	1830	68	720	608
2019	376	270	25669	67	836	589
2020						660
2021	376	234	18757	201	1030	700

Table 6: Yellowfin sole fishery catch-at-age (proportions), 1975-2021 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	0.1165	0.2873	0.2676	0.1148	0.0606	0.0314	0.0248	0.0289	0.0077	0.0055	0.0025	0.9476
1976	0.0964	0.1650	0.2564	0.2031	0.0885	0.0481	0.0253	0.0201	0.0235	0.0063	0.0044	0.9371
1977	0.1825	0.2004	0.1577	0.1287	0.0690	0.0253	0.0129	0.0067	0.0053	0.0061	0.0016	0.7962
1978	0.0959	0.2090	0.2278	0.1666	0.1276	0.0658	0.0237	0.0120	0.0062	0.0048	0.0057	0.9451
1979	0.0637	0.1471	0.2209	0.1914	0.1274	0.0946	0.0483	0.0173	0.0088	0.0045	0.0035	0.9275
1980	0.0647	0.0721	0.1341	0.1904	0.1692	0.1169	0.0890	0.0462	0.0167	0.0085	0.0044	0.9122
1981	0.0788	0.1048	0.0968	0.1446	0.1709	0.1346	0.0868	0.0638	0.0325	0.0116	0.0059	0.9311
1982	0.0632	0.1417	0.1394	0.0975	0.1215	0.1305	0.0982	0.0621	0.0453	0.0230	0.0082	0.9306
1983	0.1037	0.1068	0.1586	0.1230	0.0777	0.0932	0.0988	0.0740	0.0467	0.0340	0.0173	0.9338
1984	0.0407	0.1058	0.1048	0.1554	0.1209	0.0766	0.0920	0.0975	0.0731	0.0461	0.0336	0.9465
1985	0.0237	0.0680	0.1285	0.1038	0.1416	0.1074	0.0675	0.0809	0.0857	0.0642	0.0405	0.9118
1986	0.0581	0.0585	0.1035	0.1352	0.0922	0.1185	0.0881	0.0551	0.0659	0.0697	0.0523	0.8971
1987	0.0192	0.0555	0.0483	0.0919	0.1301	0.0922	0.1202	0.0898	0.0562	0.0673	0.0713	0.8420
1988	0.0485	0.0501	0.1157	0.0664	0.0922	0.1127	0.0758	0.0970	0.0721	0.0450	0.0539	0.8294
1989	0.0043	0.0810	0.0696	0.1272	0.0638	0.0846	0.1024	0.0686	0.0879	0.0653	0.0408	0.7955
1990	0.0347	0.0209	0.2341	0.1008	0.1136	0.0470	0.0590	0.0703	0.0470	0.0601	0.0446	0.8321
1991	0.0228	0.1028	0.0298	0.2092	0.0782	0.0899	0.0389	0.0505	0.0614	0.0415	0.0534	0.7784
1992	0.0202	0.0478	0.1925	0.0432	0.2328	0.0712	0.0718	0.0287	0.0358	0.0426	0.0284	0.8150
1993	0.0242	0.0265	0.0483	0.1752	0.0393	0.2182	0.0683	0.0699	0.0282	0.0353	0.0420	0.7754
1994	0.0257	0.0481	0.0527	0.0739	0.2045	0.0384	0.1934	0.0577	0.0577	0.0231	0.0287	0.8039
1995	0.0538	0.0982	0.0856	0.0551	0.0630	0.1651	0.0306	0.1536	0.0458	0.0458	0.0183	0.8149
1996	0.0187	0.0975	0.1244	0.0852	0.0504	0.0563	0.1466	0.0271	0.1361	0.0406	0.0406	0.8235
1997	0.0207	0.0354	0.1082	0.1136	0.0769	0.0462	0.0520	0.1361	0.0252	0.1266	0.0378	0.7787
1998	0.0465	0.0440	0.0582	0.1307	0.1120	0.0690	0.0399	0.0444	0.1155	0.0214	0.1072	0.7888
1999	0.0147	0.0595	0.0498	0.0598	0.1281	0.1083	0.0665	0.0385	0.0428	0.1113	0.0206	0.6999
2000	0.0135	0.0429	0.1371	0.0753	0.0634	0.1135	0.0895	0.0537	0.0308	0.0342	0.0888	0.7427
2001	0.0213	0.0447	0.0824	0.1620	0.0689	0.0533	0.0933	0.0731	0.0438	0.0252	0.0279	0.6959
2002	0.0236	0.0263	0.0571	0.0963	0.1693	0.0674	0.0506	0.0876	0.0684	0.0409	0.0235	0.7110
2003	0.0238	0.1183	0.0725	0.0826	0.0918	0.1356	0.0511	0.0377	0.0650	0.0507	0.0303	0.7594
2004	0.0206	0.0491	0.1697	0.0771	0.0757	0.0799	0.1163	0.0436	0.0322	0.0554	0.0432	0.7628
2005	0.0374	0.0496	0.0738	0.1799	0.0690	0.0638	0.0661	0.0957	0.0358	0.0264	0.0455	0.7430
2006	0.0810	0.0869	0.0736	0.0780	0.1589	0.0564	0.0506	0.0518	0.0746	0.0279	0.0205	0.7602
2007	0.0268	0.0733	0.0744	0.0672	0.0755	0.1585	0.0569	0.0513	0.0527	0.0760	0.0284	0.7410
2008	0.0665	0.0757	0.1257	0.0837	0.0593	0.0597	0.1199	0.0424	0.0380	0.0389	0.0561	0.7659
2009	0.0489	0.1023	0.0874	0.1223	0.0765	0.0532	0.0533	0.1069	0.0378	0.0338	0.0346	0.7570
2010	0.0833	0.0929	0.1109	0.0764	0.1022	0.0636	0.0442	0.0443	0.0888	0.0314	0.0281	0.7661
2011	0.0320	0.1404	0.1117	0.1071	0.0675	0.0876	0.0540	0.0375	0.0375	0.0752	0.0266	0.7771
2012	0.0333	0.0544	0.1662	0.1079	0.0964	0.0595	0.0770	0.0474	0.0329	0.0329	0.0660	0.7739
2013	0.0226	0.0493	0.0709	0.1807	0.1053	0.0900	0.0547	0.0704	0.0432	0.0300	0.0300	0.7471
2014	0.0171	0.0494	0.0777	0.0797	0.1726	0.0955	0.0805	0.0488	0.0626	0.0385	0.0267	0.7491
2015	0.0184	0.0371	0.0709	0.0818	0.0747	0.1583	0.0877	0.0740	0.0449	0.0577	0.0354	0.7409
2016	0.0379	0.0681	0.0935	0.1057	0.0830	0.0630	0.1247	0.0675	0.0565	0.0342	0.0439	0.7780
2017	0.0209	0.1017	0.1040	0.0960	0.0922	0.0693	0.0522	0.1033	0.0559	0.0469	0.0284	0.7708
2018	0.0108	0.0443	0.1616	0.1213	0.0921	0.0806	0.0583	0.0433	0.0853	0.0461	0.0386	0.7823
2019	0.0323	0.0245	0.0638	0.1709	0.1120	0.0812	0.0701	0.0505	0.0375	0.0737	0.0398	0.7563
2020	0.0528	0.0771	0.0351	0.0659	0.1527	0.0949	0.0676	0.0580	0.0417	0.0309	0.0608	0.7375
2021	0.0919	0.0717	0.0726	0.0295	0.0540	0.1245	0.0773	0.0551	0.0472	0.0340	0.0252	0.6830

Year	7	8	9	10	11	12	13	14	15	16	17+	Total male proportion over age 7
1975	0.1999	0.3521	0.2197	0.0659	0.0358	0.0118	0.0068	0.0089	0.0028	0.0030	0.0022	0.9089
1976	0.0957	0.1699	0.2830	0.2201	0.0773	0.0448	0.0151	0.0088	0.0115	0.0037	0.0038	0.9337
1977	0.1003	0.2192	0.2457	0.2232	0.1122	0.0320	0.0171	0.0056	0.0033	0.0042	0.0014	0.9642
1978	0.0822	0.1838	0.2246	0.1820	0.1507	0.0749	0.0214	0.0115	0.0038	0.0022	0.0028	0.9399
1979	0.0574	0.1384	0.2235	0.2016	0.1354	0.1024	0.0491	0.0138	0.0074	0.0024	0.0014	0.9328
1980	0.0498	0.0530	0.1038	0.1682	0.1750	0.1398	0.1224	0.0650	0.0196	0.0109	0.0037	0.9112
1981	0.0704	0.0865	0.0818	0.1341	0.1753	0.1469	0.0973	0.0740	0.0356	0.0101	0.0054	0.9174
1982	0.0718	0.1424	0.1332	0.0929	0.1175	0.1275	0.0948	0.0586	0.0428	0.0202	0.0056	0.9073
1983	0.0898	0.0970	0.1543	0.1251	0.0814	0.0999	0.1071	0.0792	0.0489	0.0357	0.0168	0.9352
1984	0.0411	0.1070	0.1048	0.1542	0.1204	0.0771	0.0941	0.1007	0.0745	0.0459	0.0335	0.9533
1985	0.0279	0.0792	0.1369	0.1033	0.1370	0.1034	0.0656	0.0799	0.0854	0.0631	0.0389	0.9206
1986	0.0594	0.0581	0.1018	0.1331	0.0911	0.1175	0.0881	0.0558	0.0679	0.0726	0.0537	0.8991
1987	0.0261	0.0925	0.0676	0.0998	0.1240	0.0839	0.1080	0.0809	0.0512	0.0623	0.0666	0.8629
1988	0.0621	0.0664	0.1315	0.0653	0.0860	0.1044	0.0703	0.0905	0.0678	0.0429	0.0522	0.8394
1989	0.0048	0.0883	0.0726	0.1259	0.0616	0.0818	0.0997	0.0673	0.0866	0.0649	0.0411	0.7946
1990	0.0411	0.0201	0.2092	0.0940	0.1109	0.0472	0.0604	0.0732	0.0493	0.0634	0.0475	0.8163
1991	0.0390	0.1589	0.0393	0.2312	0.0737	0.0749	0.0303	0.0382	0.0461	0.0310	0.0399	0.8025
1992	0.0191	0.0479	0.1973	0.0442	0.2362	0.0708	0.0697	0.0277	0.0347	0.0418	0.0281	0.8175
1993	0.0192	0.0198	0.0365	0.1423	0.0356	0.2181	0.0725	0.0761	0.0314	0.0402	0.0488	0.7405
1994	0.0203	0.0265	0.0293	0.0528	0.1853	0.0403	0.2177	0.0661	0.0656	0.0262	0.0328	0.7629
1995	0.0395	0.0667	0.0684	0.0531	0.0670	0.1812	0.0338	0.1691	0.0495	0.0483	0.0191	0.7957
1996	0.0214	0.0827	0.1082	0.0831	0.0525	0.0595	0.1536	0.0281	0.1395	0.0407	0.0397	0.8090
1997	0.0229	0.0556	0.1468	0.1271	0.0780	0.0450	0.0493	0.1257	0.0229	0.1136	0.0332	0.8201
1998	0.0285	0.0232	0.0330	0.0952	0.1050	0.0758	0.0475	0.0541	0.1403	0.0258	0.1282	0.7566
1999	0.0081	0.0261	0.0207	0.0294	0.0867	0.0995	0.0748	0.0482	0.0558	0.1459	0.0269	0.6221
2000	0.0114	0.0304	0.0979	0.0637	0.0625	0.1227	0.1014	0.0617	0.0354	0.0387	0.0987	0.7245
2001	0.0119	0.0268	0.0590	0.1447	0.0720	0.0594	0.1075	0.0860	0.0517	0.0296	0.0323	0.6809
2002	0.0186	0.0213	0.0501	0.0934	0.1752	0.0715	0.0532	0.0922	0.0726	0.0434	0.0247	0.7162
2003	0.0211	0.1247	0.0790	0.0868	0.0940	0.1380	0.0518	0.0376	0.0647	0.0508	0.0304	0.7789
2004	0.0162	0.0395	0.1499	0.0752	0.0786	0.0856	0.1265	0.0476	0.0347	0.0597	0.0469	0.7604
2005	0.0325	0.0453	0.0715	0.1813	0.0708	0.0662	0.0691	0.1007	0.0378	0.0274	0.0472	0.7498
2006	0.0526	0.0731	0.0741	0.0839	0.1734	0.0615	0.0553	0.0568	0.0823	0.0308	0.0224	0.7662
2007	0.0405	0.1068	0.0912	0.0705	0.0727	0.1465	0.0516	0.0463	0.0476	0.0689	0.0258	0.7684
2008	0.0515	0.0645	0.1211	0.0865	0.0630	0.0639	0.1283	0.0452	0.0405	0.0416	0.0603	0.7664
2009	0.0308	0.0580	0.0630	0.1133	0.0817	0.0605	0.0621	0.1253	0.0442	0.0397	0.0408	0.7194
2010	0.0852	0.0965	0.1156	0.0789	0.1034	0.0634	0.0438	0.0437	0.0872	0.0306	0.0275	0.7758
2011	0.0315	0.1275	0.1055	0.1080	0.0701	0.0910	0.0557	0.0385	0.0384	0.0766	0.0269	0.7697
2012	0.0467	0.0704	0.1839	0.1085	0.0935	0.0567	0.0716	0.0435	0.0299	0.0298	0.0595	0.7940
2013	0.0359	0.0616	0.0739	0.1768	0.1022	0.0879	0.0533	0.0674	0.0409	0.0281	0.0280	0.7560
2014	0.0264	0.0638	0.0836	0.0786	0.1674	0.0930	0.0790	0.0477	0.0602	0.0365	0.0251	0.7613
2015	0.0192	0.0393	0.0744	0.0835	0.0749	0.1588	0.0884	0.0752	0.0454	0.0574	0.0348	0.7513
2016	0.0376	0.0607	0.0842	0.1012	0.0828	0.0644	0.1300	0.0712	0.0603	0.0364	0.0459	0.7747
2017	0.0194	0.1078	0.1140	0.1020	0.0935	0.0682	0.0509	0.1013	0.0553	0.0467	0.0282	0.7873
2018	0.0077	0.0356	0.1502	0.1235	0.0968	0.0845	0.0606	0.0450	0.0895	0.0488	0.0413	0.7835
2019	0.0245	0.0214	0.0629	0.1775	0.1177	0.0851	0.0723	0.0514	0.0381	0.0757	0.0413	0.7679
2020	0.0320	0.0572	0.0329	0.0694	0.1662	0.1037	0.0734	0.0620	0.0440	0.0326	0.0648	0.7382
2021	0.0632	0.0578	0.0709	0.0318	0.0604	0.1396	0.0861	0.0608	0.0513	0.0364	0.0270	0.6853

Table 7: Total tonnage of yellowfin sole caught in resource assessment surveys in the eastern Bering Sea from 1977-2021.

Year	Research catch (t)
2016	98
2017	112
2018	73
2019	85
2020	0
2021	72

Table 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 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	EBS Biomass DB (t)	LCI	UCI	EBS+NBS Biomass MB (t)	LCI	UCI
1982	3,509,130	3,508,559	3,509,700	4,005,490	4,005,011	4,005,968
1983	3,672,420	3,672,015	3,672,824	4,637,480	4,636,866	4,638,093
1984	3,341,320	3,340,953	3,341,686	4,227,010	4,226,475	4,227,544
1985	2,398,080	2,397,771	2,398,388	3,100,980	3,100,660	3,101,299
1986	2,031,600	2,031,298	2,031,901	2,342,630	2,342,378	2,342,881
1987	2,530,210	2,529,824	2,530,595	3,089,570	3,089,238	3,089,901
1988	2,195,920	2,195,507	2,196,332	2,624,770	2,624,534	2,625,005
1989	2,329,420	2,329,078	2,329,761	2,805,170	2,804,872	2,805,467
1990	2,192,590	2,192,292	2,192,887	2,627,180	2,626,915	2,627,444
1991	2,406,530	2,406,253	2,406,806	3,159,460	3,159,177	3,159,742
1992	2,215,410	2,215,022	2,215,797	2,716,520	2,716,140	2,716,899
1993	2,484,910	2,484,596	2,485,223	3,121,570	3,121,206	3,121,933
1994	2,615,720	2,615,379	2,616,060	3,409,740	3,409,290	3,410,189
1995	2,026,890	2,026,605	2,027,174	2,458,590	2,458,303	2,458,876
1996	2,230,820	2,230,435	2,231,204	2,722,210	2,721,892	2,722,527
1997	2,176,540	2,176,285	2,176,794	2,801,760	2,801,391	2,802,128
1998	2,222,670	2,222,392	2,222,947	3,469,400	3,468,695	3,470,104
1999	1,266,420	1,266,239	1,266,600	1,786,590	1,786,254	1,786,925
2000	1,600,280	1,600,079	1,600,480	2,060,409	2,060,130	2,060,689
2001	1,690,560	1,690,319	1,690,800	2,235,030	2,234,727	2,235,332
2002	1,923,070	1,922,811	1,923,328	2,519,680	2,519,306	2,520,053
2003	2,171,730	2,171,319	2,172,140	2,846,480	2,846,071	2,846,888
2004	2,557,800	2,557,417	2,558,182	3,423,500	3,422,996	3,424,003
2005	2,840,250	2,839,528	2,840,971	3,495,370	3,494,916	3,495,823
2006	2,146,500	2,146,186	2,146,813	2,769,500	2,769,177	2,769,822
2007	2,168,040	2,167,660	2,168,419	2,733,990	2,733,650	2,734,329
2008	2,112,690	2,112,187	2,113,192	2,811,620	2,811,209	2,812,030
2009	1,752,060	1,751,759	1,752,360	2,301,320	2,301,008	2,301,631
2010	2,388,160	2,387,605	2,388,714	2,979,480	2,979,182	2,979,777
2011	2,422,500	2,422,019	2,422,980	2,805,090	2,804,758	2,805,421
2012	1,965,410	1,965,135	1,965,684	2,708,880	2,708,527	2,709,232
2013	2,295,210	2,294,866	2,295,553	2,742,200	2,741,897	2,742,502
2014	2,531,400	2,530,941	2,531,858	2,967,810	2,967,488	2,968,131
2015	1,946,300	1,946,012	1,946,587	2,321,780	2,321,532	2,322,027
2016	2,876,800	2,876,474	2,877,125	3,721,760	3,721,384	3,722,135
2017	2,805,160	2,804,683	2,805,636	3,478,470	3,478,188	3,478,751
2018	1,903,040	1,902,812	1,903,267	2,786,270	2,786,042	2,786,497
2019	2,017,620	2,017,203	2,018,036	2,729,680	2,729,473	2,729,886
2021	1,633,970	1,633,755	1,634,184	2,358,660	2,358,473	2,358,846
2022	2,039,970	2,039,705	2,040,234	2,777,020	2,776,793	2,777,246

Table 10: Model estimates of yellowfin sole age 2+ total biomass (t) from the 2021 and 2022 stock assessments, Model 18.2, Model 22.0, and 22.1.

Model	18.2 (2021)	18.2 (2022)	22.0 (2022)			22.1 (2022)		
	Biomass (t)	Biomass (t)	Biomass (t)	LCI	HCI	Biomass (t)	LCI	HCI
1954	2,459,520	2,547,430	2,762,530	2,465,140	3,095,790	2,325,940	1,922,760	2,813,670
1955	2,408,250	2,497,920	2,696,210	2,432,570	2,988,420	2,292,910	1,909,210	2,753,720
1956	2,350,890	2,444,060	2,615,610	2,385,470	2,867,940	2,255,750	1,894,670	2,685,650
1957	2,291,420	2,386,420	2,524,180	2,326,030	2,739,210	2,217,200	1,885,490	2,607,270
1958	2,255,490	2,346,080	2,446,930	2,279,430	2,626,740	2,200,690	1,911,640	2,533,440
1959	2,226,960	2,305,070	2,369,440	2,230,880	2,516,600	2,188,520	1,958,360	2,445,730
1960	2,075,700	2,134,270	2,165,610	2,053,570	2,283,760	2,049,610	1,890,340	2,222,310
1961	1,667,480	1,699,980	1,706,040	1,622,080	1,794,340	1,646,620	1,558,480	1,739,740
1962	1,198,730	1,194,950	1,191,970	1,137,620	1,248,920	1,167,170	1,109,650	1,227,680
1963	883,734	843,446	867,111	834,798	900,674	797,719	744,937	854,241
1964	909,922	881,976	907,101	873,529	941,964	841,190	793,335	891,931
1965	893,725	856,558	875,543	841,797	910,642	823,902	782,879	867,075
1966	936,616	900,292	919,872	884,459	956,703	874,130	835,104	914,981
1967	920,712	891,014	905,739	869,274	943,733	865,892	828,489	904,983
1968	838,598	823,074	824,102	787,864	862,006	803,119	766,511	841,476
1969	884,087	859,462	867,345	827,693	908,897	840,381	800,644	882,090
1970	877,450	861,662	867,975	825,150	913,022	831,048	788,161	876,268
1971	973,328	950,652	954,834	905,566	1,006,780	913,093	863,441	965,600
1972	1,085,260	1,069,310	1,053,280	996,497	1,113,300	1,004,630	946,365	1,066,490
1973	1,389,710	1,359,560	1,343,960	1,275,410	1,416,200	1,282,430	1,211,580	1,357,410
1974	1,692,950	1,635,200	1,625,730	1,544,750	1,710,950	1,557,480	1,473,070	1,646,730
1975	2,106,110	2,028,190	2,012,170	1,915,110	2,114,140	1,931,240	1,829,680	2,038,440
1976	2,473,680	2,374,790	2,360,440	2,248,840	2,477,580	2,266,300	2,149,250	2,389,720
1977	2,839,680	2,722,310	2,709,600	2,584,050	2,841,250	2,602,960	2,471,120	2,741,840
1978	3,184,900	3,049,680	3,038,590	2,900,050	3,183,750	2,920,350	2,774,740	3,073,590
1979	3,383,090	3,234,400	3,224,580	3,075,590	3,380,780	3,097,980	2,941,290	3,263,020
1980	3,596,120	3,437,730	3,428,570	3,270,200	3,594,620	3,294,130	3,127,480	3,469,660
1981	3,784,250	3,621,770	3,613,400	3,447,130	3,787,680	3,472,530	3,297,500	3,656,840
1982	3,910,940	3,756,070	3,748,560	3,577,900	3,927,360	3,596,580	3,417,020	3,785,570
1983	3,879,200	3,727,680	3,719,770	3,548,500	3,899,300	3,570,740	3,390,470	3,760,600
1984	4,139,580	3,983,830	3,976,860	3,794,330	4,168,170	3,822,390	3,629,880	4,025,110
1985	4,156,090	4,001,030	3,994,810	3,807,160	4,191,710	3,842,710	3,644,510	4,051,700
1986	3,840,060	3,689,420	3,683,870	3,503,010	3,874,060	3,544,930	3,353,420	3,747,370
1987	3,818,360	3,666,410	3,661,740	3,476,070	3,857,340	3,526,410	3,329,450	3,735,020
1988	3,699,210	3,548,150	3,543,650	3,359,580	3,737,810	3,429,020	3,232,960	3,636,960
1989	3,769,470	3,607,330	3,603,180	3,411,140	3,806,030	3,497,640	3,292,540	3,715,520
1990	3,608,930	3,449,380	3,445,360	3,257,690	3,643,840	3,357,890	3,156,900	3,571,660
1991	3,722,400	3,559,590	3,555,610	3,363,000	3,759,260	3,479,890	3,273,140	3,699,710
1992	3,943,130	3,773,830	3,770,200	3,567,340	3,984,590	3,693,160	3,475,570	3,924,370
1993	4,000,570	3,827,750	3,824,060	3,616,950	4,043,030	3,760,580	3,538,120	3,997,040
1994	4,031,160	3,859,030	3,855,260	3,646,420	4,076,050	3,810,610	3,585,880	4,049,420
1995	3,762,690	3,597,700	3,593,880	3,393,940	3,805,600	3,562,460	3,347,020	3,791,780
1996	3,647,430	3,485,610	3,481,680	3,285,950	3,689,080	3,470,810	3,259,500	3,695,820
1997	3,671,430	3,507,960	3,504,160	3,306,000	3,714,200	3,502,830	3,289,140	3,730,400
1998	3,344,660	3,190,990	3,187,210	3,000,480	3,385,560	3,201,910	3,000,250	3,417,130
1999	3,114,080	2,969,190	2,965,470	2,787,620	3,154,680	2,990,320	2,798,060	3,195,790
2000	2,923,320	2,783,620	2,779,740	2,612,780	2,957,360	2,823,360	2,642,550	3,016,540
2001	2,907,760	2,765,330	2,761,120	2,592,280	2,940,970	2,815,840	2,632,980	3,011,400

2002	2,951,050	2,804,630	2,800,310	2,631,690	2,979,740	2,868,870	2,686,660	3,063,430
2003	3,243,010	3,078,120	3,073,280	2,890,510	3,267,600	3,167,540	2,970,430	3,377,720
2004	3,363,450	3,186,450	3,181,460	2,993,460	3,381,260	3,292,090	3,090,130	3,507,250
2005	3,430,080	3,242,780	3,237,880	3,047,180	3,440,520	3,352,180	3,148,770	3,568,730
2006	3,440,340	3,251,830	3,246,710	3,053,500	3,452,150	3,376,190	3,170,750	3,594,950
2007	3,348,810	3,162,960	3,157,800	2,968,340	3,359,350	3,294,640	3,094,340	3,507,900
2008	3,178,680	3,001,990	2,996,540	2,813,730	3,191,240	3,152,100	2,959,080	3,357,720
2009	3,183,490	3,001,720	2,996,050	2,807,080	3,197,740	3,167,340	2,968,750	3,379,220
2010	3,310,990	3,123,860	3,117,510	2,916,670	3,332,180	3,308,680	3,098,900	3,532,670
2011	3,233,080	3,059,290	3,052,500	2,852,780	3,266,210	3,259,250	3,052,370	3,480,140
2012	3,057,680	2,893,680	2,887,020	2,690,050	3,098,410	3,089,540	2,887,330	3,305,910
2013	2,918,060	2,763,740	2,756,680	2,560,950	2,967,370	2,971,180	2,771,560	3,185,170
2014	2,869,780	2,717,150	2,709,250	2,506,790	2,928,060	2,947,440	2,742,400	3,167,800
2015	2,844,510	2,690,820	2,682,360	2,471,100	2,911,690	2,936,120	2,723,710	3,165,090
2016	2,876,990	2,724,530	2,715,330	2,492,840	2,957,670	2,983,790	2,762,980	3,222,240
2017	2,901,320	2,740,640	2,730,420	2,495,100	2,987,940	3,018,220	2,786,310	3,269,420
2018	2,695,360	2,551,750	2,541,510	2,313,290	2,792,240	2,809,720	2,588,860	3,049,420
2019	2,894,520	2,757,350	2,745,490	2,487,390	3,030,370	3,010,490	2,767,080	3,275,330
2020	2,972,280	2,846,760	2,833,460	2,553,690	3,143,880	3,065,090	2,809,520	3,343,920
2021	3,371,550	3,291,390	3,274,840	2,925,680	3,665,670	3,443,250	3,139,710	3,776,150
2022		3,704,690	3,685,130	3,251,160	4,177,030	3,782,420	3,411,860	4,193,220

Table 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.

Year	Biomass (t)	LCI	HCI	Haul count	Hauls with catch	Number count	Length count
2010	310,617	215,238	405,997	108	88	88	88
2017	368,156	254,797	481,515	110	98	98	97
2018	373,373	240,861	505,885	49	49	49	49
2019	520,029	398,122	641,936	144	141	141	140
2021	496,038	394,385	394,385	144	138	138	137
2022	548,027	369,505	726,549	144	136	135	135

Table 12: Yellowfin sole population numbers-at-age (millions) estimated from the annual EBS bottom trawl surveys, 1987-2021 (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+
1987	0	0	68	117	786	446	821	252	364	580	344	434	234	261	238	174
1988	0	0	6	344	65	1,363	501	498	164	214	317	187	325	246	198	152
1989	0	0	14	98	720	234	1,341	596	449	74	180	309	235	239	184	82
1990	0	0	70	102	326	1,072	193	1,263	410	484	101	72	107	78	232	127
1991	0	9	127	249	123	407	899	151	1,267	213	527	62	128	87	123	164
1992	0	18	239	464	499	203	274	899	91	794	72	297	124	131	163	104
1993	0	24	100	360	639	437	270	226	1,323	78	872	157	166	69	68	91
1994	0	53	95	223	518	906	556	482	284	1,172	0	516	43	274	142	41
1995	0	19	153	290	182	896	632	276	136	25	638	20	565	104	80	97
1996	0	15	150	793	280	270	421	501	199	141	146	583	112	616	44	29
1997	0	18	326	506	729	257	240	507	229	114	177	184	502	44	315	75
1998	0	9	79	455	401	859	248	194	352	393	351	161	167	252	63	397
1999	0	3	62	189	168	179	704	100	104	238	184	180	70	99	170	102
2000	0	11	54	249	209	307	448	543	191	200	240	221	65	118	146	110
2001	0	1	66	221	478	225	363	371	584	333	74	172	138	114	170	99
2002	0	15	119	163	243	747	325	273	215	433	209	85	290	109	143	137
2003	0	15	114	236	243	278	1,111	218	269	276	242	99	111	163	161	83
2004	10	33	197	442	572	417	218	976	224	213	222	222	107	20	169	187
2005	0	53	168	195	588	414	231	473	877	221	137	184	336	164	50	181
2006	8	67	304	378	277	637	472	177	327	741	133	133	71	157	176	1
2007	0	37	519	349	384	276	505	309	124	228	507	119	138	127	105	77
2008	0	23	115	741	624	545	357	361	196	128	255	355	151	78	85	119
2009	5	37	205	205	1,199	600	495	266	211	219	130	139	197	89	43	1
2010	0	33	330	389	441	902	558	520	331	338	155	167	136	174	99	49
2011	0	14	245	543	712	466	775	413	460	205	227	149	143	145	187	99
2012	10	50	231	397	508	295	244	758	257	336	107	157	37	151	128	150
2013	0	4	89	271	423	535	257	221	411	408	360	120	135	133	133	94
2014	0	0	37	424	386	250	422	232	229	526	343	161	145	230	34	123
2015	0	22	3	168	470	352	309	289	250	150	283	260	135	99	80	68
2016	0	32	71	45	165	748	568	405	365	301	144	246	230	140	163	170
2017	16	79	384	381	122	319	1,007	484	337	379	229	149	203	201	149	118
2018	0	49	182	262	178	91	265	641	326	231	81	76	41	124	99	103
2019	1	124	209	309	156	241	79	211	548	360	130	160	125	123	72	43
2021	0	258	100	1,450	457	317	123	176	94	157	162	108	105	67	54	61

Year	Age (Males)														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17+
1987	0	4	39	104	820	456	655	430	316	267	202	142	102	136	177	211
1988	0	1	9	413	45	1,087	507	406	77	171	25	163	308	173	25	106
1989	0	2	23	181	789	177	1,310	515	358	135	50	104	53	205	35	38
1990	0	10	47	121	318	894	196	1,151	319	265	39	65	67	24	54	73
1991	0	0	103	357	140	277	1,051	68	1,143	330	245	74	64	60	53	91
1992	0	0	141	428	542	251	216	778	109	875	186	206	11	12	59	37
1993	0	20	52	235	651	396	280	248	1,105	70	849	53	53	50	0	48
1994	4	21	71	166	427	954	657	308	191	824	25	623	45	132	11	36
1995	0	0	170	120	272	672	570	95	181	75	481	13	608	49	24	77
1996	0	74	92	822	238	220	413	335	321	137	135	388	58	436	122	92
1997	0	9	216	428	803	182	184	449	246	195	215	109	518	79	266	31
1998	0	46	66	335	546	796	151	215	193	258	328	142	149	178	107	250
1999	0	5	96	136	216	234	555	141	91	299	261	72	51	27	115	34
2000	0	0	35	220	261	144	514	589	79	217	134	77	93	78	66	154
2001	0	0	81	130	604	309	341	324	513	190	80	144	59	67	129	55
2002	0	56	70	152	297	726	303	315	247	419	183	134	207	151	124	20
2003	0	23	93	174	251	244	1,046	231	354	51	277	168	9	69	56	104
2004	4	64	116	477	454	201	400	1,005	267	82	198	226	104	48	253	104
2005	0	48	167	179	453	458	239	297	1,007	123	139	118	131	68	91	126
2006	0	101	174	350	333	508	395	289	300	386	117	156	90	39	11	55
2007	0	58	485	355	408	285	549	210	166	268	336	100	132	70	59	123
2008	0	10	100	667	465	486	346	455	226	145	186	331	63	66	34	104
2009	0	65	145	292	960	467	548	249	251	218	78	31	196	30	29	51
2010	0	78	201	421	373	1,040	466	514	173	190	160	53	117	152	79	53
2011	0	6	151	388	486	360	798	401	226	177	78	81	137	103	157	97
2012	0	69	276	355	348	277	241	429	300	181	98	67	91	34	100	59
2013	0	6	92	369	387	485	212	270	448	201	202	33	89	100	118	18
2014	0	0	8	368	399	288	341	312	253	403	207	194	20	193	94	108
2015	0	29	36	132	430	335	303	314	320	48	181	131	81	0	80	111
2016	0	43	85	20	142	709	548	404	369	126	118	228	181	88	35	92
2017	9	121	233	399	107	262	886	501	312	277	196	108	217	156	37	12
2018	0	39	175	188	229	72	236	523	261	189	95	77	73	75	69	29
2019	0	136	252	234	103	272	109	148	491	271	130	155	84	68	57	94
2021	0	52	189	1,079	517	373	87	106	69	84	158	42	62	37	41	55

Table 13: Mean unsmoothed weight-at-age (grams) for yellowfin sole, based on survey data, females, 1964-2022, except 2020.

Year	Age (Females)																			
	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	195	230	263	294	322	348	372	393	412	429	444	481	590
1965	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1966	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1967	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1968	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1969	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1970	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1971	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1972	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1973	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1974	4	15	34	60	91	125	160	195	230	263	294	322	348	372	393	412	429	444	481	590
1975	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1976	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1977	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1978	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1979	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1980	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1981	8	20	31	55	84	124	165	217	266	301	341	374	407	428	443	480	483	499	590	590
1982	8	20	42	75	98	139	176	214	233	235	331	359	393	410	436	482	470	476	586	590
1983	10	14	26	60	103	162	185	201	243	255	318	350	391	419	455	503	489	503	605	590
1984	14	26	33	57	110	156	177	222	246	294	318	342	375	418	453	498	492	536	617	590
1985	11	16	28	46	77	177	202	251	286	302	314	341	367	417	450	502	520	556	623	590
1986	14	27	23	41	71	103	173	239	284	338	314	336	366	401	439	490	511	547	628	590
1987	10	14	20	47	55	127	179	256	317	324	331	351	375	411	443	475	519	557	619	590
1988	9	12	16	34	66	85	159	237	286	307	351	364	377	393	418	446	490	528	597	590
1989	12	21	33	67	71	112	133	197	279	339	364	384	402	400	422	445	506	490	570	590
1990	11	17	24	38	65	99	126	197	243	321	389	400	411	405	430	436	475	475	559	590
1991	11	16	23	58	56	100	142	156	238	310	394	421	420	429	446	450	486	481	557	590
1992	12	21	29	55	85	121	177	176	283	305	377	417	430	456	454	464	498	485	562	590
1993	15	28	35	64	93	155	165	232	244	301	368	411	438	469	470	477	506	496	563	590
1994	20	46	53	86	87	125	155	235	276	284	355	405	418	470	472	482	486	504	571	590
1995	12	20	28	60	84	123	160	217	284	332	333	403	412	463	470	478	515	495	575	590
1996	11	16	36	51	108	137	167	202	222	311	322	379	403	448	461	487	509	503	567	590
1997	16	34	33	72	85	157	200	236	260	292	336	383	397	439	457	488	492	514	577	590
1998	10	14	36	51	90	104	177	237	278	279	333	383	391	430	439	478	479	513	576	590
1999	9	12	18	37	67	103	131	239	284	296	331	374	398	417	429	474	484	506	593	590
2000	6	8	14	33	36	92	142	192	211	231	294	336	378	361	393	458	491	522	505	609
2001	6	4	8	31	39	62	99	148	195	242	284	383	392	436	424	442	474	528	530	663
2002	6	8	19	27	45	66	105	156	229	246	276	343	328	394	451	480	504	552	560	631
2003	6	8	14	29	56	87	127	171	224	299	328	357	413	454	417	505	374	600	575	652
2004	6	8	14	38	64	101	163	162	231	300	328	359	440	524	551	476	485	500	500	654
2005	6	4	21	40	72	114	156	217	236	284	349	356	377	464	509	505	612	472	620	693
2006	6	6	16	36	76	114	149	206	236	303	308	360	368	592	493	495	532	568	618	740
2007	6	8	16	38	70	113	170	196	239	330	304	351	361	406	456	466	558	568	683	740
2008	6	8	24	31	57	106	140	203	239	281	309	345	395	432	422	501	567	555	594	660
2009	6	6	10	22	51	92	142	182	248	321	334	377	434	429	433	575	874	556	565	697
2010	6	2	16	25	57	84	136	186	218	343	337	403	446	460	517	557	594	620	744	795
2011	6	8	12	30	49	92	145	210	264	318	329	405	419	441	448	621	534	516	623	696
2012	6	6	11	27	53	91	146	167	258	317	367	321	452	529	502	514	562	654	598	730
2013	6	8	12	21	40	102	131	195	275	318	366	399	415	474	473	518	550	555	606	702
2014	6	8	19	16	37	85	145	201	252	306	368	360	428	421	495	592	536	577	570	715
2015	6	8	15	12	40	62	130	215	262	355	418	437	411	484	474	596	647	593	531	731
2016	6	12	25	37	69	86	130	211	329	378	417	415	517	465	509	522	581	580	618	723
2017	6	9	19	51	69	118	143	187	273	366	382	436	536	503	553	647	601	701	585	824
2018	6	8	22	39	88	111	163	236	248	346	421	447	504	478	542	606	586	571	717	677
2019	6	6	21	47	92	160	180	254	277	346	404	583	503	505	570	680	701	673	698	720
2021	6	6	21	47	92	160	180	254	277	346	404	583	503	505	570	680	701	673	698	720
2022	6	6	21	43	103	188	248	321	365	453	438	478	540	564	592	637	602	635	650	667

Table 14: Mean unsmoothed weight-at-age (grams) for yellowfin sole, based on survey data, males, 1964-2022, except 2020, continued on next page.

Year	Age (Females)																			
	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
2021	4	8	20	48	97	126	195	206	237	280	324	384	377	384	431	464	434	454	464	507
2022	4	8	24	59	110	180	232	250	267	332	331	374	420	428	435	455	462	449	431	448

Table 15: Parameter values and their 95% confidence intervals, Model 18.2. Total biomass is presented from 1954 - 2022.

Name	Value	Standard Deviation
male natural mortality	1.3843e-01	1.0888e-03
alpha (q-temp model)	-2.0325e-01	3.3312e-02
beta (q-temp model)	6.3739e-02	1.2623e-02
beta (survey start date)	1.1707e-02	3.0215e-03
beta (start date/temp interaction)	-9.4095e-03	2.8430e-03
mean log recruitment	9.6282e-01	9.0866e-02
log_avg_fmort	-2.4112e+00	7.6356e-02
sel_slope_fsh_f	1.2176e+00	7.9392e-02
sel50_fsh_f	8.4508e+00	2.3235e-01
sel_slope_fsh_m	1.3151e+00	8.8023e-02
sel50_fsh_m	8.5455e+00	2.3116e-01
sel_slope_srv	1.5759e+00	5.7191e-02
sel50_srv	4.9501e+00	4.6519e-02
sel_slope_srv_m	3.9196e-02	4.8862e-02
sel50_srv_m	-5.2061e-03	1.1410e-02
q_srv	7.3827e-01	2.8123e-02
ABC_biom	5.6028e+03	9.1855e+02
ABC_biom	5.8633e+03	9.8860e+02
Bmsy	5.1525e+02	8.2683e+01
Bmsyr	4.4708e+03	4.9100e+02
TotBiom	2.5474e+03	1.9356e+02
TotBiom	2.4979e+03	1.7819e+02
TotBiom	2.4441e+03	1.6075e+02
TotBiom	2.3864e+03	1.4042e+02
TotBiom	2.3461e+03	1.1637e+02
TotBiom	2.3051e+03	8.9702e+01
TotBiom	2.1343e+03	6.3593e+01
TotBiom	1.7000e+03	4.0681e+01
TotBiom	1.1949e+03	2.8426e+01
TotBiom	8.4345e+02	1.8945e+01
TotBiom	8.8198e+02	1.7713e+01
TotBiom	8.5656e+02	1.7036e+01
TotBiom	9.0029e+02	1.7556e+01
TotBiom	8.9101e+02	1.7949e+01
TotBiom	8.2307e+02	1.7893e+01
TotBiom	8.5946e+02	1.9710e+01
TotBiom	8.6166e+02	2.1526e+01
TotBiom	9.5065e+02	2.4926e+01
TotBiom	1.0693e+03	2.9338e+01
TotBiom	1.3596e+03	3.5392e+01
TotBiom	1.6352e+03	4.1936e+01
TotBiom	2.0282e+03	5.0581e+01
TotBiom	2.3748e+03	5.7988e+01
TotBiom	2.7223e+03	6.5091e+01
TotBiom	3.0497e+03	7.1703e+01
TotBiom	3.2344e+03	7.7067e+01
TotBiom	3437.7	81.886
TotBiom	3621.8	85.921
TotBiom	3756.1	88.150
TotBiom	3727.7	88.496
TotBiom	3983.8	94.274
TotBiom	4001.0	96.945
TotBiom	3689.4	93.533
TotBiom	3666.4	96.080
TotBiom	3548.1	95.307
TotBiom	3607.3	99.491
TotBiom	3449.4	97.283
TotBiom	3559.6	99.820
TotBiom	3773.8	105.100
TotBiom	3827.7	107.320
TotBiom	3859.0	108.220
TotBiom	3597.7	103.690
TotBiom	3485.6	101.560
TotBiom	3508.0	102.840
TotBiom	3191.0	97.020
TotBiom	2969.2	92.479
TotBiom	2783.6	86.831
TotBiom	2765.3	87.869
TotBiom	2804.6	87.720
TotBiom	3078.1	95.052
TotBiom	3186.5	97.758
TotBiom	3242.8	99.158
TotBiom	3251.8	100.510
TotBiom	3163.0	98.598
TotBiom	3002.0	95.213
TotBiom	3001.7	98.532
TotBiom	3123.9	104.810
TotBiom	3059.3	104.310
TotBiom	2893.7	103.030
TotBiom	2763.7	102.550
TotBiom	2717.1	106.300
TotBiom	2690.8	111.180
TotBiom	2724.5	117.300
TotBiom	2740.6	124.390
TotBiom	2551.7	120.890
TotBiom	2757.4	137.090
TotBiom	2846.8	149.060

Table 16: Parameter values and their 95% confidence intervals, Model 22.0. Total biomass is presented from 1954 - 2022.

Name	Value	Standard Deviation	Name	Value	Standard Deviation
male natural mortality	1.3894e-01	1.0775e-03	TotBiom	3748.6	87.346
alpha (q-temp model)	-2.0107e-01	3.3096e-02	TotBiom	3719.8	87.681
beta (q-temp model)	6.4116e-02	1.2620e-02	TotBiom	3976.9	93.440
beta (survey start date)	1.1632e-02	3.0199e-03	TotBiom	3994.8	96.114
beta (start date/temp interaction)	-9.4751e-03	2.8424e-03	TotBiom	3683.9	92.737
mean log recruitment	9.4954e-01	9.0016e-02	TotBiom	3661.7	95.291
log_avg_fmort	-2.4061e+00	7.6414e-02	TotBiom	3543.7	94.530
sel_slope_fsh_f	1.2591e+00	8.1167e-02	TotBiom	3603.2	98.690
sel50_fsh_f	8.5857e+00	2.3023e-01	TotBiom	3445.4	96.505
sel_slope_fsh_m	1.2990e+00	8.7360e-02	TotBiom	3555.6	99.032
sel50_fsh_m	8.4216e+00	2.3148e-01	TotBiom	3770.2	104.280
sel_slope_srv	1.6054e+00	4.3061e-02	TotBiom	3824.1	106.490
sel50_srv	4.9389e+00	3.5673e-02	TotBiom	3855.3	107.370
R_logalpha	-4.3413e+00	4.5760e-01	TotBiom	3593.9	102.880
R_logbeta	-6.4650e+00	2.5163e-01	TotBiom	3481.7	100.750
q_srv	8.7797e-01	3.3929e-02	TotBiom	3504.2	102.010
Bmsy	5.0679e+02	7.8127e+01	TotBiom	3187.2	96.234
Bmsyr	4.5108e+03	4.8960e+02	TotBiom	2965.5	91.728
TotBiom	2.7625e+03	1.5745e+02	TotBiom	2779.7	86.111
TotBiom	2.6962e+03	1.3881e+02	TotBiom	2761.1	87.136
TotBiom	2.6156e+03	1.2051e+02	TotBiom	2800.3	86.978
TotBiom	2.5242e+03	1.0322e+02	TotBiom	3073.3	94.236
TotBiom	2.4469e+03	8.6781e+01	TotBiom	3181.5	96.913
TotBiom	2.3694e+03	7.1402e+01	TotBiom	3237.9	98.295
TotBiom	2.1656e+03	5.7530e+01	TotBiom	3246.7	99.622
TotBiom	1.7060e+03	4.3054e+01	TotBiom	3157.8	97.713
TotBiom	1.1920e+03	2.7818e+01	TotBiom	2996.5	94.339
TotBiom	8.6711e+02	1.6466e+01	TotBiom	2996.1	97.621
TotBiom	9.0710e+02	1.7106e+01	TotBiom	3117.5	103.830
TotBiom	8.7554e+02	1.7208e+01	TotBiom	3052.5	103.310
TotBiom	9.1987e+02	1.8058e+01	TotBiom	2887.0	102.040
TotBiom	9.0574e+02	1.8612e+01	TotBiom	2756.7	101.550
TotBiom	8.2410e+02	1.8532e+01	TotBiom	2709.3	105.250
TotBiom	8.6735e+02	2.0297e+01	TotBiom	2682.4	110.070
TotBiom	8.6797e+02	2.1962e+01	TotBiom	2715.3	116.120
TotBiom	9.5483e+02	2.5297e+01	TotBiom	2730.4	123.110
TotBiom	1.0533e+03	2.9193e+01	TotBiom	2541.5	119.630
TotBiom	1.3440e+03	3.5186e+01	TotBiom	2745.5	135.610
TotBiom	1.6257e+03	4.1541e+01	TotBiom	2833.5	147.380
TotBiom	2.0122e+03	4.9744e+01	TotBiom	3274.8	184.750
TotBiom	2.3604e+03	5.7170e+01	TotBiom	3685.1	231.090
TotBiom	2.7096e+03	6.4285e+01			
TotBiom	3.0386e+03	7.0911e+01			
TotBiom	3.2246e+03	7.6278e+01			
TotBiom	3.4286e+03	8.1085e+01			
TotBiom	3.6134e+03	8.5118e+01			

Table 17: Parameter values and their 95% confidence intervals, Model 22.1. Total biomass is presented from 1954 - 2022.

Name	Value	Standard Deviation	Name	Value	Standard Deviation
male natural mortality	1.2509e-01	1.1362e-03	TotBiom	3596.6	92.112
alpha (q-temp model)	-1.6995e-03	3.3892e-02	TotBiom	3570.7	92.507
beta (q-temp model)	5.9665e-02	9.5258e-03	TotBiom	3822.4	98.781
beta (survey start date)	1.1051e-02	2.6077e-03	TotBiom	3842.7	101.770
beta (start date/temp interaction)	-3.2244e-03	2.6783e-03	TotBiom	3544.9	98.455
mean log recruitment	9.3547e-01	9.1088e-02	TotBiom	3526.4	101.360
log_avg_fmort	-2.4500e+00	7.7525e-02	TotBiom	3429.0	100.960
sel_slope_fsh_f	1.3303e+00	8.7700e-02	TotBiom	3497.6	105.710
sel50_fsh_f	8.1261e+00	2.2281e-01	TotBiom	3357.9	103.650
sel_slope_fsh_m	1.2462e+00	8.3892e-02	TotBiom	3479.9	106.600
sel50_fsh_m	8.5714e+00	2.3334e-01	TotBiom	3693.2	112.160
sel_slope_srv	1.6591e+00	5.3376e-02	TotBiom	3760.6	114.690
sel50_srv	4.6244e+00	3.9531e-02	TotBiom	3810.6	115.840
R_logalpha	-4.2486e+00	4.7401e-01	TotBiom	3562.5	111.150
R_logbeta	-6.3758e+00	2.5570e-01	TotBiom	3470.8	109.030
q_srv	1.0878e+00	4.2313e-02	TotBiom	3502.8	110.270
Bmsy	4.7520e+02	7.7606e+01	TotBiom	3201.9	104.170
Bmsyr	4.6790e+03	5.2511e+02	TotBiom	2990.3	99.387
TotBiom	2.3259e+03	2.2189e+02	TotBiom	2823.4	93.457
TotBiom	2.2929e+03	2.1039e+02	TotBiom	2815.8	94.562
TotBiom	2.2558e+03	1.9712e+02	TotBiom	2868.9	94.151
TotBiom	2.2172e+03	1.7995e+02	TotBiom	3167.5	101.780
TotBiom	2.2007e+03	1.5513e+02	TotBiom	3292.1	104.240
TotBiom	2.1885e+03	1.2169e+02	TotBiom	3352.2	104.950
TotBiom	2.0496e+03	8.2936e+01	TotBiom	3376.2	106.010
TotBiom	1.6466e+03	4.5301e+01	TotBiom	3294.6	103.350
TotBiom	1.1672e+03	2.9499e+01	TotBiom	3152.1	99.618
TotBiom	7.9772e+02	2.7313e+01	TotBiom	3167.3	102.570
TotBiom	8.4119e+02	2.4640e+01	TotBiom	3308.7	108.390
TotBiom	8.2390e+02	2.1043e+01	TotBiom	3259.2	106.900
TotBiom	8.7413e+02	1.9965e+01	TotBiom	3089.5	104.600
TotBiom	8.6589e+02	1.9120e+01	TotBiom	2971.2	103.350
TotBiom	8.0312e+02	1.8737e+01	TotBiom	2947.4	106.290
TotBiom	8.4038e+02	2.0357e+01	TotBiom	2936.1	110.280
TotBiom	8.3105e+02	2.2020e+01	TotBiom	2983.8	114.740
TotBiom	9.1309e+02	2.5532e+01	TotBiom	3018.2	120.700
TotBiom	1.0046e+03	3.0019e+01	TotBiom	2809.7	115.060
TotBiom	1.2824e+03	3.6445e+01	TotBiom	3010.5	126.970
TotBiom	1.5575e+03	4.3401e+01	TotBiom	3065.1	133.500
TotBiom	1.9312e+03	5.2174e+01	TotBiom	3443.3	158.970
TotBiom	2.2663e+03	6.0100e+01	TotBiom	3782.4	195.120
TotBiom	2.6030e+03	6.7661e+01			
TotBiom	2.9203e+03	7.4691e+01			
TotBiom	3.0980e+03	8.0412e+01			
TotBiom	3.2941e+03	8.5522e+01			
TotBiom	3.4725e+03	8.9810e+01			

Table 18: Comparison of reference points for Model 18.2 (2022), 18.2 (2021), and Models 22.0 and 22.1 from the current assesssment (lower panel). Values are in metric tons (t). Female, then male natural mortality is listed for each year and model.

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

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

Projections run in 2022 were based on estimated catches of 127,712 t in 2022 and 126,157 t used in place of maximum ABC for 2023. This estimate was based on the mean of the past 5 years, 2018- 2022, which includes an extrapolated catch of 127,712 t for 2022.

Table 19: Model estimates of yellowfin sole full selection fishing mortality (Full sel. F) and exploitation rate (Catch/Total Biomass) for 2022 Models 18.2, 22.0, and 22.1.

Year	Model 18.2		Model 22.0		Model 22.1	
	Full sel. F	Catch/Tot. Biom.	Full sel. F	Catch/Tot. Biom.	Full sel. F	Catch/Tot. Biom.
1954	0.006	0.005	0.006	0.005	0.007	0.005
1955	0.008	0.006	0.007	0.005	0.008	0.006
1956	0.013	0.010	0.012	0.009	0.014	0.011
1957	0.014	0.010	0.013	0.010	0.015	0.011
1958	0.027	0.019	0.025	0.018	0.028	0.020
1959	0.126	0.080	0.115	0.078	0.134	0.085
1960	0.423	0.214	0.378	0.211	0.453	0.223
1961	1.008	0.326	0.848	0.325	1.139	0.336
1962	4.756	0.352	2.757	0.353	4.766	0.360
1963	0.324	0.102	2.573	0.099	0.341	0.108
1964	0.265	0.127	0.258	0.123	0.285	0.133
1965	0.242	0.063	0.254	0.061	0.254	0.065
1966	0.423	0.114	0.447	0.111	0.447	0.117
1967	0.534	0.182	0.553	0.179	0.526	0.187
1968	0.384	0.102	0.366	0.102	0.422	0.105
1969	1.633	0.194	1.801	0.193	0.678	0.199
1970	0.782	0.154	0.742	0.153	0.722	0.160
1971	1.287	0.169	0.830	0.168	0.619	0.176
1972	0.418	0.045	0.292	0.045	0.323	0.048
1973	0.398	0.058	0.407	0.058	0.435	0.061
1974	0.137	0.026	0.136	0.026	0.138	0.027
1975	0.113	0.032	0.117	0.032	0.120	0.033
1976	0.109	0.024	0.116	0.024	0.118	0.025
1977	0.052	0.021	0.053	0.022	0.052	0.022
1978	0.103	0.045	0.105	0.046	0.106	0.047
1979	0.060	0.031	0.061	0.031	0.061	0.032
1980	0.068	0.025	0.069	0.025	0.068	0.027
1981	0.054	0.027	0.054	0.027	0.054	0.028
1982	0.040	0.025	0.040	0.026	0.041	0.027
1983	0.041	0.029	0.041	0.029	0.042	0.030
1984	0.064	0.040	0.064	0.040	0.065	0.042
1985	0.094	0.057	0.094	0.057	0.095	0.059
1986	0.087	0.057	0.087	0.057	0.089	0.059
1987	0.085	0.049	0.085	0.050	0.086	0.051
1988	0.108	0.063	0.108	0.063	0.109	0.065
1989	0.080	0.042	0.081	0.043	0.081	0.044
1990	0.039	0.024	0.039	0.024	0.039	0.025
1991	0.047	0.033	0.048	0.033	0.046	0.034
1992	0.054	0.039	0.054	0.039	0.054	0.039
1993	0.049	0.028	0.050	0.028	0.049	0.028
1994	0.064	0.036	0.064	0.036	0.064	0.037
1995	0.056	0.035	0.056	0.035	0.055	0.035
1996	0.053	0.037	0.053	0.037	0.052	0.037
1997	0.086	0.052	0.086	0.052	0.084	0.052
1998	0.058	0.032	0.058	0.032	0.058	0.032
1999	0.042	0.023	0.042	0.023	0.041	0.023
2000	0.048	0.030	0.048	0.030	0.047	0.030
2001	0.036	0.023	0.036	0.023	0.035	0.023

2002	0.042	0.027	0.042	0.027	0.040	0.026
2003	0.036	0.026	0.036	0.026	0.035	0.025
2004	0.034	0.024	0.034	0.024	0.032	0.023
2005	0.040	0.029	0.040	0.029	0.038	0.028
2006	0.041	0.030	0.042	0.031	0.040	0.029
2007	0.055	0.038	0.055	0.038	0.052	0.037
2008	0.070	0.050	0.071	0.050	0.066	0.047
2009	0.048	0.036	0.048	0.036	0.046	0.034
2010	0.054	0.038	0.054	0.038	0.050	0.036
2011	0.070	0.049	0.070	0.050	0.065	0.046
2012	0.070	0.051	0.070	0.051	0.064	0.048
2013	0.082	0.060	0.082	0.060	0.075	0.056
2014	0.085	0.058	0.085	0.058	0.077	0.053
2015	0.074	0.047	0.074	0.047	0.066	0.043
2016	0.081	0.050	0.081	0.050	0.072	0.045
2017	0.078	0.048	0.078	0.048	0.068	0.044
2018	0.077	0.052	0.078	0.052	0.068	0.047
2019	0.080	0.046	0.080	0.047	0.070	0.043
2020	0.082	0.047	0.083	0.047	0.072	0.044
2021	0.068	0.033	0.068	0.033	0.058	0.032
2022	0.090	0.034	0.091	0.035	0.076	0.034

Table 20: 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 2021 and 2022 stock assessments, including Model 18.2 (2021), 18.2 (2022), 22.0, and 22.1.

Model	18.2 (2021)	18.2 (2022)	22.0			22.1		
Year	FSB (t)	FSB (t)	FSB (t)	LCI	HCI	FSB (t)	LCI	HCI
1954	952,185	986,614	1,072,470	834,022	1,379,090	902,163	670,910	1,213,120
1955	961,277	996,274	1,083,310	856,550	1,370,090	910,428	685,894	1,208,460
1956	952,493	987,468	1,074,320	862,956	1,337,450	901,639	687,244	1,182,920
1957	928,698	963,116	1,048,830	854,874	1,286,800	878,436	676,217	1,141,130
1958	893,148	926,420	1,010,420	834,732	1,223,090	843,822	654,856	1,087,320
1959	818,435	849,554	931,672	778,119	1,115,530	770,719	598,445	992,587
1960	634,298	661,375	742,273	622,086	885,680	590,420	442,694	787,443
1961	339,588	355,831	438,813	357,954	537,937	297,337	177,500	498,081
1962	108,308	47,043	151,547	81,793	280,785	33,713	10,509	108,151
1963	116,980	11,928	104,095	83,554	129,686	5,894	1,464	23,736
1964	135,606	22,919	132,630	116,307	151,243	12,024	3,553	40,689
1965	158,981	38,485	150,050	130,946	171,942	21,594	7,012	66,500
1966	187,964	63,654	169,318	147,905	193,832	36,321	13,639	96,720
1967	191,286	91,786	162,238	141,216	186,389	51,718	23,556	113,548
1968	175,009	104,043	138,893	117,893	163,634	68,311	37,278	125,180
1969	163,243	114,610	139,653	121,815	160,103	69,140	42,318	112,964
1970	123,201	126,257	133,770	117,216	152,661	69,115	50,779	94,071
1971	105,444	103,314	104,770	92,170	119,092	74,327	60,467	91,364
1972	87,711	93,027	75,596	63,468	90,041	67,047	55,243	81,372
1973	91,575	101,994	78,263	65,170	93,985	74,523	62,207	89,278
1974	103,288	111,320	84,138	69,640	101,654	87,493	74,078	103,338
1975	159,562	166,206	130,718	111,767	152,883	137,928	119,356	159,390
1976	229,757	228,987	193,479	171,310	218,515	200,473	177,623	226,263
1977	339,252	328,009	294,914	267,490	325,150	296,953	268,105	328,905
1978	481,917	459,158	429,863	396,053	466,560	421,756	386,123	460,678
1979	634,139	599,868	575,257	534,129	619,552	552,840	509,703	599,629
1980	805,817	759,495	738,318	689,078	791,078	699,582	648,247	754,981
1981	967,949	909,236	891,269	834,147	952,304	835,554	776,315	899,313
1982	1,061,500	995,244	979,979	918,837	1,045,190	912,222	849,060	980,084
1983	1,195,010	1,120,180	1,106,420	1,039,410	1,177,750	1,024,230	955,272	1,098,180
1984	1,301,670	1,220,410	1,209,420	1,137,810	1,285,550	1,112,620	1,039,190	1,191,230
1985	1,370,630	1,285,430	1,276,960	1,200,830	1,357,920	1,166,280	1,088,520	1,249,610
1986	1,365,140	1,281,270	1,274,800	1,196,750	1,357,930	1,155,190	1,075,800	1,240,450
1987	1,367,470	1,285,150	1,280,220	1,199,390	1,366,500	1,153,440	1,071,560	1,241,580
1988	1,302,130	1,224,460	1,220,580	1,140,760	1,305,980	1,096,160	1,015,520	1,183,190
1989	1,275,260	1,199,320	1,196,340	1,115,300	1,283,260	1,074,330	992,562	1,162,830
1990	1,288,130	1,213,870	1,211,600	1,129,260	1,299,930	1,091,800	1,008,580	1,181,900
1991	1,381,330	1,305,450	1,303,880	1,217,340	1,396,580	1,181,860	1,094,070	1,276,690
1992	1,481,730	1,401,930	1,401,050	1,310,010	1,498,430	1,277,710	1,185,030	1,377,640
1993	1,530,450	1,446,650	1,446,270	1,352,170	1,546,920	1,323,910	1,227,900	1,427,430
1994	1,523,110	1,438,020	1,438,000	1,343,790	1,538,820	1,318,420	1,222,170	1,422,260
1995	1,510,140	1,424,400	1,424,650	1,329,710	1,526,370	1,306,810	1,209,800	1,411,590
1996	1,421,340	1,339,560	1,339,900	1,248,790	1,437,650	1,229,900	1,136,870	1,330,550
1997	1,375,170	1,296,350	1,296,760	1,207,190	1,392,970	1,192,110	1,100,710	1,291,090
1998	1,289,700	1,214,790	1,215,160	1,128,980	1,307,920	1,120,550	1,032,630	1,215,950
1999	1,270,610	1,196,400	1,196,790	1,110,980	1,289,230	1,108,230	1,020,580	1,203,400
2000	1,191,140	1,119,790	1,120,140	1,038,590	1,208,090	1,041,530	958,111	1,132,220

2001	1,258,910	1,183,530	1,183,930	1,097,160	1,277,560	1,106,600	1,017,710	1,203,250
2002	1,215,080	1,143,640	1,144,110	1,060,840	1,233,900	1,074,700	989,380	1,167,370
2003	1,273,030	1,199,350	1,199,910	1,113,490	1,293,040	1,134,740	1,046,090	1,230,910
2004	1,313,560	1,237,560	1,238,190	1,150,010	1,333,130	1,177,520	1,087,060	1,275,520
2005	1,350,480	1,270,540	1,271,200	1,180,890	1,368,420	1,210,830	1,118,440	1,310,850
2006	1,395,680	1,311,490	1,312,190	1,218,710	1,412,830	1,253,620	1,158,200	1,356,910
2007	1,338,790	1,253,720	1,254,350	1,164,330	1,351,330	1,201,800	1,110,170	1,300,980
2008	1,253,250	1,170,190	1,170,770	1,086,150	1,261,980	1,129,350	1,043,410	1,222,380
2009	1,302,940	1,212,050	1,212,580	1,123,260	1,309,020	1,178,930	1,088,230	1,277,180
2010	1,366,190	1,266,220	1,266,690	1,171,820	1,369,240	1,236,230	1,140,150	1,340,420
2011	1,259,070	1,165,080	1,165,420	1,077,610	1,260,390	1,144,810	1,056,260	1,240,770
2012	1,247,930	1,154,630	1,154,810	1,065,460	1,251,650	1,143,040	1,053,160	1,240,600
2013	1,184,960	1,097,960	1,097,920	1,010,800	1,192,540	1,094,710	1,007,660	1,189,280
2014	1,143,790	1,060,110	1,059,800	971,888	1,155,660	1,064,040	976,829	1,159,040
2015	1,171,780	1,086,340	1,085,710	991,650	1,188,690	1,096,900	1,004,530	1,197,770
2016	1,145,170	1,063,670	1,062,750	966,826	1,168,190	1,080,390	987,219	1,182,350
2017	1,175,030	1,088,380	1,087,120	983,474	1,201,680	1,114,700	1,014,760	1,224,490
2018	1,062,740	986,764	985,267	887,462	1,093,850	1,018,300	925,191	1,120,780
2019	1,119,540	1,038,460	1,036,520	928,252	1,157,430	1,081,010	978,704	1,194,010
2020	1,075,430	996,104	993,881	884,042	1,117,370	1,045,950	942,796	1,160,390
2021	985,341	913,917	911,523	805,376	1,031,660	967,874	868,869	1,078,160
2022	NA	865,440	862,739	757,047	983,187	923,828	825,889	1,033,380

Table 27: Tier 3 reference points for this year's yellowfin sole assessment model 22.1.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2022	2023	2023	2024
M (natural mortality rate)	0.12, 0.135	0.12, 0.135	0.12, 0.125	0.12, 0.125
Tier	1a	1a	3a	3a
Projected total (age 1+) biomass (t)	2,479,370 t	2,284,820 t	3,301,360 t	3,250,439 t
Projected female spawning biomass (t)	857,101 t	727,101 t	780,284 t	754,839 t
$B_{100\%}$ (B_0 for Tier 1a)	1,489,190 t	1,489,190 t	1,890,560 t	1,890,560 t
$B_{40\%}$	-	-	756,223 t	756,223 t
$B_{35\%}$ (B_{MSY} for Tier 1a)	495,904 t	495,904 t	661,695 t	661,695 t
F_{OFL}	0.152	0.152	0.14	0.14
$maxF_{ABC}$	0.143	0.143	0.117	0.117
F_{ABC}	0.143	0.143	0.117	0.117
OFL (t)	377,071 t	347,483 t	226,860 t	240,517 t
$maxABC$	354,014 t	326,235 t	190,898 t	195,438 t
ABC (t)	269,649 t	258,567 t	190,898 t	195,438 t
Status	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Projections were based on estimated catches of 127,712 t in 2022 t in 2022 and 126,157 t used in place of maximum ABC for 2023.

Table 21: Yellowfin sole total allowable catch (TAC), overfishing limit (OFL), and acceptable biological catch (ABC) levels, 1980-2021. Catch for the Bering Sea and Aleutian Islands was recorded through October 1, 2021. Data is in metric tons. Estimates for 2023 were calculated using Model 22.1, and the 2023 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	106,096
2023		378,499	404,882	

Table 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 22.1.

Scenarios 1 and 2 Maximum ABC harvest permissible			
Year	FSB	Catch	F
2022	805,605	126,157	0.077
2023	764,832	189,433	0.113
2024	739,149	201,306	0.113
2025	755,647	224,793	0.113
2026	817,069	246,893	0.113
2027	887,769	265,725	0.113
2028	965,724	270,666	0.113
2029	998,469	259,417	0.113
2030	999,121	248,410	0.113
2031	969,210	236,782	0.113
2032	928,365	227,859	0.113
2033	898,234	219,448	0.113
2034	857,174	213,525	0.113
2035	835,356	208,284	0.113

Scenario 3 Harvest at average F over past 5 years			
Year	FSB	Catch	F
2022	805,605	126,157	0.077
2023	775,163	120,050	0.071
2024	777,481	131,450	0.071
2025	819,975	150,175	0.071
2026	909,648	168,270	0.071
2027	1,011,315	184,489	0.071
2028	1,123,010	192,062	0.071
2029	1,187,907	188,446	0.071
2030	1,216,645	184,256	0.071
2031	1,206,980	178,703	0.071
2032	1,178,202	174,392	0.071
2033	1,158,923	169,815	0.071
2034	1,120,270	166,747	0.071
2035	1,103,340	163,961	0.071

Scenario 4, Maximum Tier 3 ABC harvest permissible set at F60			
Year	FSB	Catch	F
2022	786,896	95,621	0.055
2023	799,004	105,660	0.055
2024	850,980	121,521	0.055
2025	951,458	137,007	0.055
2026	1,065,402	151,120	0.055
2027	1,190,845	158,502	0.055
2028	1,269,335	156,816	0.055
2029	1,310,548	154,500	0.055
2030	1,310,660	150,835	0.055
2031	1,288,490	148,015	0.055
2032	1,275,499	144,800	0.055
2033	1,239,523	142,755	0.055
2034	1,226,309	140,828	0.055
2035			

Scenario 5 No fishing			
Year	FSB	Catch	F
2022	800,710	0	0
2023	853,453	0	0
2024	947,593	0	0
2025	1,097,523	0	0
2026	1,269,239	0	0
2027	1,460,915	0	0
2028	1,607,733	0	0
2029	1,715,270	0	0
2030	1,772,584	0	0
2031	1,795,020	0	0
2032	1,826,501	0	0
2033	1,818,703	0	0
2034	1,838,483	0	0
2035			

Alternative 6, Determination of whether yellowfin sole are currently overfished

Year	FSB	Catch	F
2022	805,605	126,157	0.077
2023	759,491	224,729	0.136
2024	719,933	235,146	0.136
2025	724,308	259,560	0.136
2026	773,088	282,252	0.136
2027	830,391	301,021	0.136
2028	894,116	303,295	0.136
2029	913,901	287,330	0.136
2030	903,961	272,391	0.136
2031	867,388	257,594	0.136
2032	823,560	246,407	0.136
2033	791,029	236,229	0.135
2034	751,388	226,684	0.134
2035	730,801	218,141	0.131

Scenario 7, Determination of whether stock is approaching an overfished condition

Year	FSB	Catch	F
2022	805,605	126,157	0.077
2023	764,832	189,433	0.113
2024	739,149	201,306	0.113
2025	750,555	266,790	0.136
2026	796,596	288,470	0.136
2027	850,994	306,206	0.136
2028	911,659	307,537	0.136
2029	928,396	290,712	0.136
2030	915,691	275,071	0.136
2031	876,774	259,704	0.136
2032	830,971	248,071	0.136
2033	796,923	237,575	0.136
2034	755,982	228,048	0.134
2035	734,266	219,278	0.132

Table 23: Incidental catch of FMP Groundfish in the yellowfin sole fishery. Source: NMFS AKRO Blend/Catch Accounting System; 1991 - October 12, 2022. The following abbreviations are used: Fl. = flounder, Flathead = Flathead Sole, AK = Alaska, Atka = Atka Mackerel, RF = rockfish, POP = Pacific Ocean Perch, SR = Shortraker, RE = Rougheye, N. = Northern, G. Turbot = Greenland Turbot, O. = Other.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Alaska Plaice	0	0	0	0	0	0	0	0	0	0	10,395	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arrowtooth Fl.	366	1,017	1,595	345	819	386	2,382	1,631	1,998	1,845	997	1,132	263	645	350	213	1,969	1,851	1,619	2,331	987	2,042	2,216	1,685	3,249	1,262	3,075	3,219	2,015	1,540	728
Atka Mackerel	1	0	0	0	0	0	0	32	0	0	0	16	0	110	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0
AK Plaice	0	0	0	0	0	0	0	0	0	0	0	8,395	5,835	8,711	13,972	16,357	13,511	10,631	12,044	18,305	13,594	15,978	14,372	11,681	8,163	12,782	15,340	12,953	16,596	11,798	7,762
Kamchatka Fl.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	122	148	498	427	284	164	218	230	128	93	45
O. Flatfish	0	0	0	0	0	0	0	0	0	0	0	213	433	653	877	2,850	1,235	241	977	1,585	1,206	388	2,886	1,041	1,135	1,734	3,282	1,476	2,175	1,025	548
Shortraker RF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,107	2,234	2,683	1,970	1,072	1,294	1,931	2,561	3,508	2,480	3,473	2,398
Squid	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flathead	0	0	0	3,929	3,165	3,896	5,323	2,309	2,644	3,231	2,190	2,856	1,076	1,247	2,025	1,735	5,579	3,497	2,695	3,229	2,095	4,179	3,998	3,337	4,103	3,106	3,966	4,133	3,498	3,005	5,302

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Flounder	16,826	9,620	12,422	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G. Turbot	0	4	4	67	8	4	103	69	23	32	2	3	0	6	8	0	0	3	1	5	5	35	56	42	7	8	26	6	12	5	2
Non.TAC.Species	0	0	0	0	0	0	0	21	188	173	165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern RF	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1
Other	7,990	3,847	3,983	2,904	2,565	4,754	3,570	2,765	3,641	3,969	4,946	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. Flatfish	0	0	0	12,239	10,962	17,222	9,182	11,449	10,286	6,844	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Rockfish	0	0	0	3	22	12	1	3	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Other Species	0	0	0	0	0	0	0	0	0	0	0	3,002	1,602	2,136	2,297	3,996	4,191	4,346	3,561	0	0	0	0	0	0	0	0	0	0	0	0
Pacific Cod	8,700	8,723	16,415	13,181	8,684	12,825	10,233	4,383	5,192	6,531	6,259	4,634	3,574	3,769	2,545	2,519	5,767	10,716	11,117	16,204	19,380	24,339	15,218	12,168	11,985	14,648	12,582	11,769	12,063	8,934	8,312

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
POP	0	4	0	0	0	0	1	12	1	0	1	10	0	15	0	0	0	0	0	0	0	16	0	0	2	0	0	0	63	1	0
Pollock	13,100	15,253	33,200	27,041	22,254	24,100	15,339	8,701	13,425	16,502	14,489	11,578	10,383	10,312	5,966	4,020	9,827	7,036	5,179	8,673	11,197	20,171	24,712	21,281	22,306	23,414	28,235	23,153	31,653	24,844	21,052
Rex Sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock Sole	14,646	7,300	8,096	7,486	12,903	16,693	9,826	10,774	7,345	5,810	10,664	8,314	9,972	10,090	7,971	8,241	10,468	8,978	9,624	9,694	9,179	7,688	7,030	9,772	7,948	12,196	9,362	9,204	11,243	8,120	8,113
Sablefish	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3	0	0
Sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,804	1,940	1,920	1,259	1,082	948	1,308	1,246	1,534	1,451	0	0
Shark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3	1	4	2	2	1	7
Sharpchin/N. RF	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SR/RE/Sharpchin/N. RF	0	0	0	0	0	0	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0	4	0	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 24: Bycatch of Other Species in the yellowfin sole directed fishery, which includes Octopus, Shark, Skate, Squid, and Sculpin. These species are included in the FMP but not available by species in the FMP Groundfish Incidental catch table. Bycatch reported in metric tons. Source: NMFS AKRO Catch Accounting System, Nontarget Estimates; available for 2003 and later. Data through October 12, 2022.

Year	BSAI.Skate	BSAI.Skate.and.GOA.Skate..Other	BSAI.Squid	Octopus	Other	Other.Species
1992	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	26	0
2000	0	0	0	0	3	0
2001	0	0	0	0	21	0
2002	0	0	0	0	1,042	0
2003	0	0	1	0	0	1,529
2004	0	0	0	0	0	598
2005	0	0	0	0	0	944
2006	0	0	0	0	0	1,133
2007	0	0	0	0	0	1,410
2008	0	0	0	0	0	1,303
2009	0	0	0	0	0	1,785
2010	0	0	0	0	0	1,913
2011	2,107	0	0	1	0	0
2012	2,234	0	0	1	0	0
2013	2,683	0	0	0	0	0
2014	1,970	0	0	0	0	0
2015	1,072	0	0	0	0	0
2016	1,294	0	0	0	0	0
2017	0	1,931	0	0	0	0
2018	0	2,561	0	0	0	0
2019	0	3,508	0	0	0	0
2020	0	2,480	0	0	0	0
2021	0	3,473	0	0	0	0
2022	0	2,398	0	1	0	0

Table 25: Catch (t) of BSAI non-target and ecosystem species of birds in the yellowfin sole fishery, 1992-2022. Source: NMFS AKRO CAS.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Birds...Gull	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Birds...Murre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Birds...Northern.Fulmar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Birds...Other	0	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0	0	0
Birds...Shearwaters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Birds...Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 28: Catch (t) of BSAI non-target and ecosystem species (excluding birds) in the yellowfin sole fishery, 1992-2022. Source: NMFS AKRO CAS.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Benthic.urochordata	1,671	1,701	674	520	114	347	204	155	133	147	197	116	260	225	319	207	188	108	175	119
Bivalves	1	1	1	0	0	1	1	1	1	0	1	0	1	0	0	0	1	1	1	0
Brittle.star.unidentified	34	32	28	19	7	18	5	4	14	13	5	11	11	6	2	2	4	3	5	1
Capelin	0	4	0	0	0	0	0	0	3	2	0	1	1	0	0	0	0	0	0	0
Corals.Bryozoans...Corals.Bryozoans.Unidentified	0	0	1	9	0	8	0	0	0	0	3	0	0	0	0	1	0	0	0	1
Eelpouts	19	12	7	4	2	5	5	5	29	14	51	69	30	56	8	26	21	16	27	2
Eulachon	0	0	0	0	5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Giant.Grenadier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0
Greenlings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Grenadier...Rattail.Grenadier.Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gunnels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hermit.crab.unidentified	87	51	83	26	35	36	15	17	15	10	6	8	4	2	2	0	2	2	2	2
Invertebrate.unidentified	556	625	421	177	40	70	30	25	65	121	25	44	6	7	11	3	1	1	1	1
Large.Sculpins	238	823	1,057	1,058	2,269	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Bigmouth.Sculpin	0	0	0	0	0	47	26	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Great.Sculpin	0	0	0	0	0	1,203	1,346	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Hemilepidotus.Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Myoxocephalus.Unidentified	0	0	0	0	0	129	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Plain.Sculpin	0	0	0	0	0	1,273	914	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Red.Irish.Lord	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Warty.Sculpin	0	0	0	0	0	68	49	0	0	0	0	0	0	0	0	0	0	0	0	0
Large.Sculpins...Yellow.Irish.Lord	0	0	0	0	0	133	145	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc.crabs	14	21	11	10	28	14	11	12	20	19	39	20	22	13	15	5	5	8	5	3
Misc.crustaceans	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc.fish	95	91	66	42	71	66	48	29	39	54	46	26	36	30	42	25	30	30	60	25
Misc.inverts..worms.etc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other.osmerids	4	4	0	0	35	9	0	2	2	4	1	9	4	5	2	0	12	4	1	2
Other.Sculpins	1,157	131	105	68	195	38	74	0	0	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	0	0	0	0	0	0	0	0	0
Pacific.Sandfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pandalid.shrimp	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
Polychaete.unidentified	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0
Saffron.Cod	0	0	0	0	0	0	0	0	0	31	1	42	3	0	0	0	2	0	0	0
Sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,774	1,237
Scypho.jellies	111	298	115	46	42	145	223	152	307	179	463	804	381	67	93	161	677	334	623	137
Sea.anemone.unidentified	6	6	2	4	8	24	25	20	14	6	23	5	4	1	2	2	4	6	4	7
Sea.pens.whips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea.star	1,941	1,867	1,611	1,308	1,462	1,828	683	795	1,674	1,735	1,372	2,106	2,248	2,050	1,616	1,468	1,816	1,799	1,768	769
Smelt..Family.Osmeridae.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Snails	118	191	69	141	95	139	57	57	74	34	46	33	36	24	24	13	22	29	38	25
Sponge.unidentified	11	6	12	3	0	6	69	16	15	14	16	1	2	1	2	5	2	1	2	3
Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
State.managed.Rockfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stichaeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surf.smelt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
urchins.dollars.cucumbers	2	0	2	0	3	4	7	1	0	0	0	0	0	0	2	0	3	4	3	3

Table 26: Ecosystem indicators for yellowfin sole, interpretation and evaluation.

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
Predator population trends			
Fish (Pacific cod, halibut, skates)	Stable	Possible increases to YFS mortality	
Changes in habitat quality			
Temperature regime	Cold years yellowfin sole catchability and herding may decrease, timing of migration may be prolonged	Likely to affect surveyed stock	No concern (dealt with in model)
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability
Yellowfin sole effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Low bycatch levels of (spp)	Bycatch levels small relative to HAPC biota	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
Fishery concentration in space and time	Low exploitation rate	Little detrimental effect	No concern
Fishery effects on amount of large size target fish	Low exploitation rate	Natural fluctuation	No concern
Fishery contribution to discards and offal production	Stable trend	Improving, but data limited	Possible concern
Fishery effects on age-at-maturity and fecundity	Unknown		Possible concern

Figures

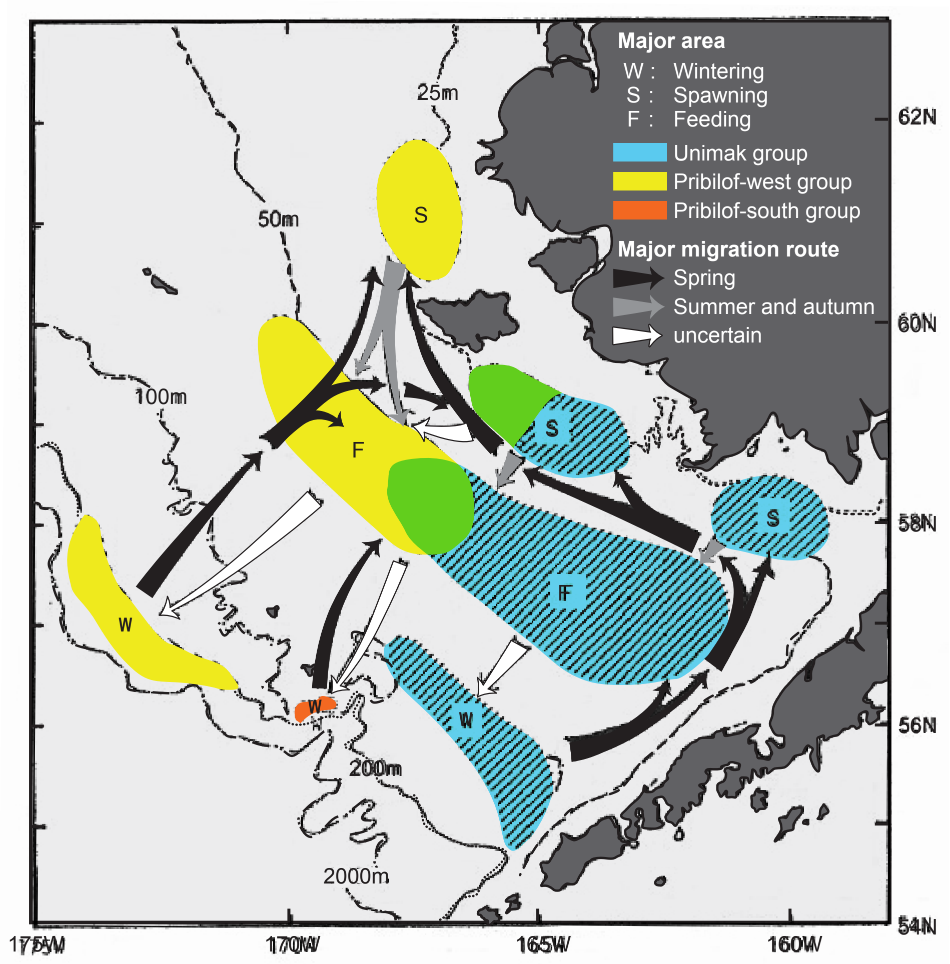


Figure 1: Distribution of wintering, spawning, and feeding areas for yellowfin sole in the Bering Sea, and observed regional grouping. Migration routes from wintering to feeding take place in spring, and the dates that yellowfin sole return to their wintering areas are unknown, adapted from Wakabayashi (1989).

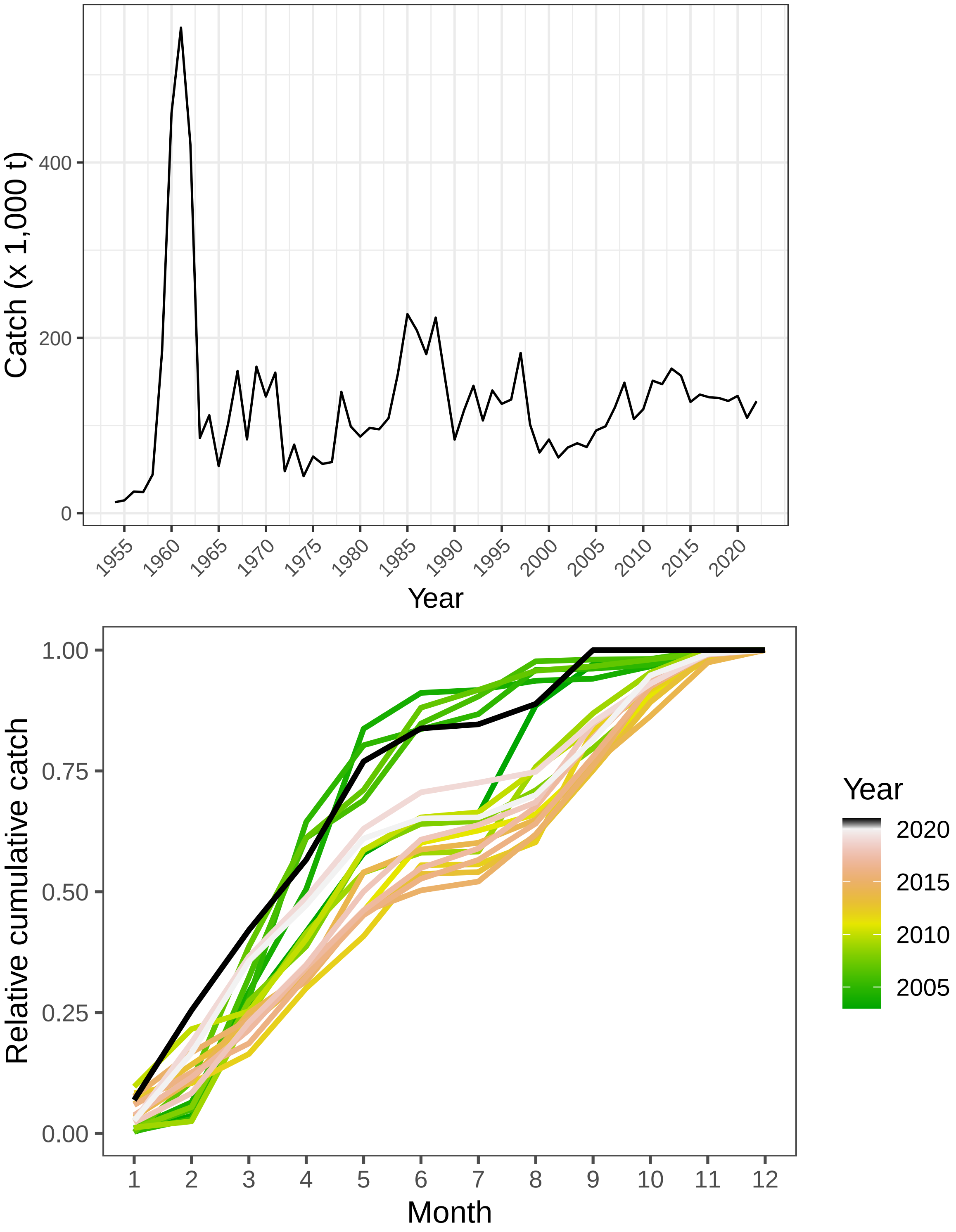


Figure 2: Yellowfin sole annual total catch (1,000s t) in the eastern Bering Sea from 2003-2022 (upper panel). Yellowfin sole annual cumulative catch by month and year (non CDQ) 2003-October 1, 2022 (lower panel).

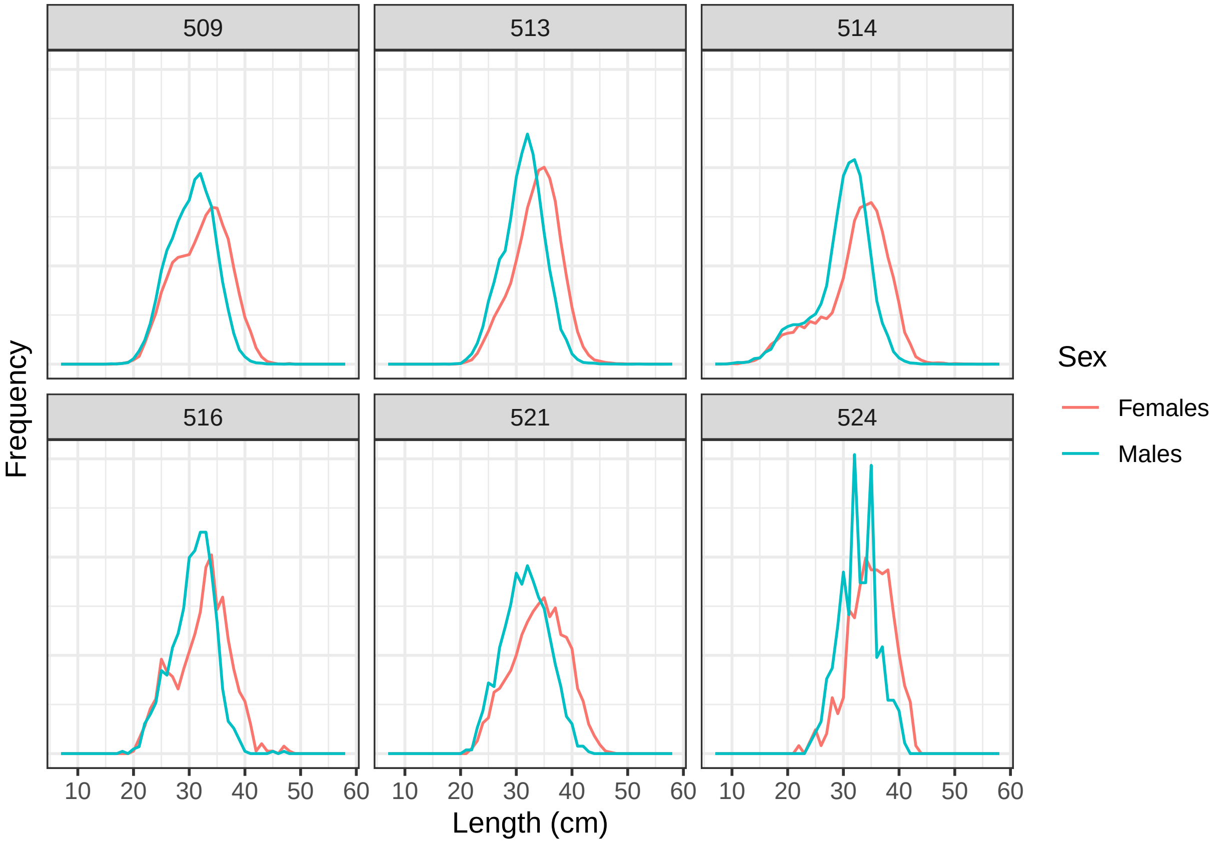


Figure 4: Size composition of the yellowfin sole catch in 2022 (through October 12) caught by trawl gear, by subarea, for the primary areas where yellowfin sole are caught, 509, 513, 514, 516, 521, and 524.

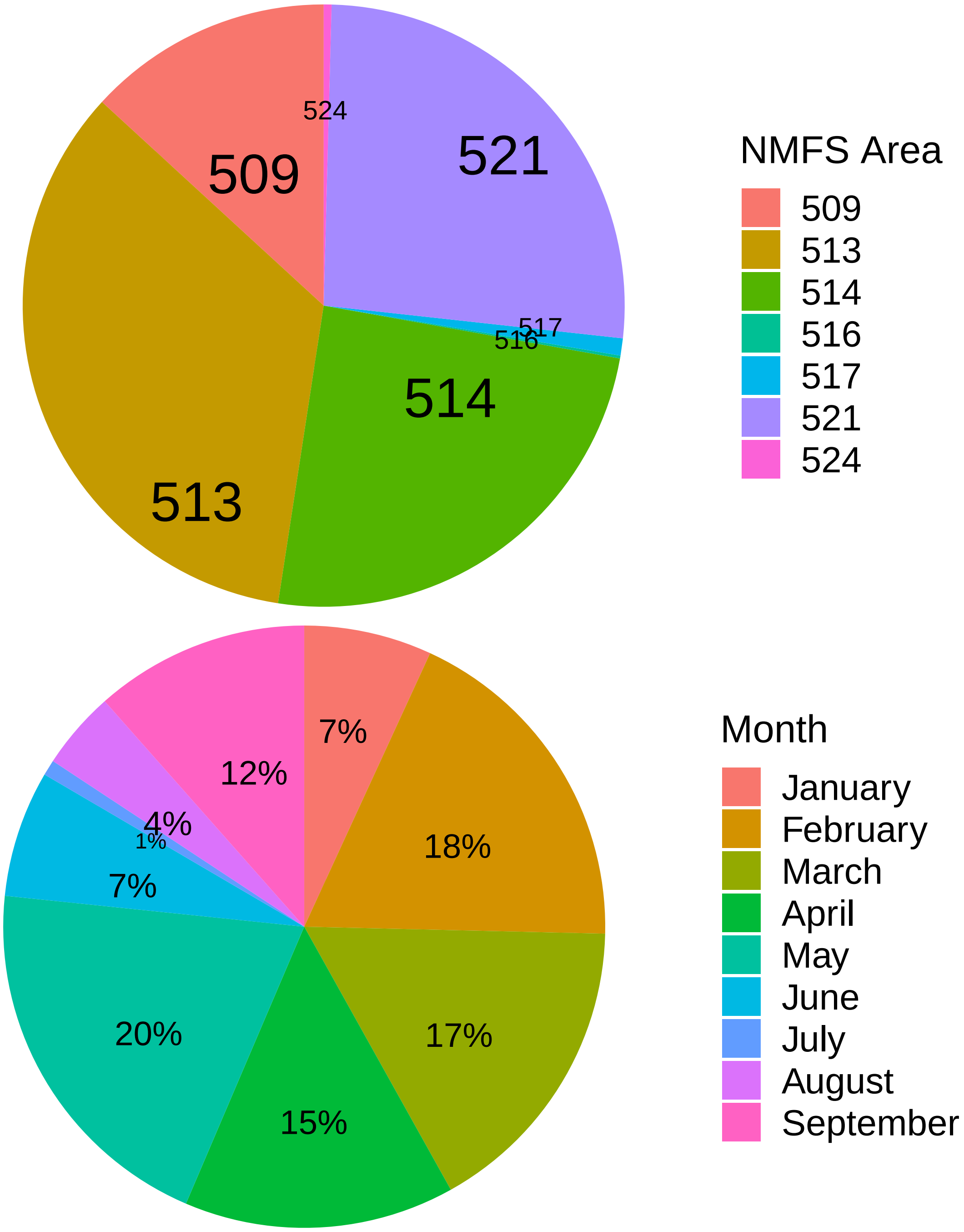


Figure 5: Yellowfin sole catch proportion by area in which catch through October 12, 2022 was greater than 100 t (upper panel) and by month (lower panel) in the eastern Bering Sea in 2022, through October 1.

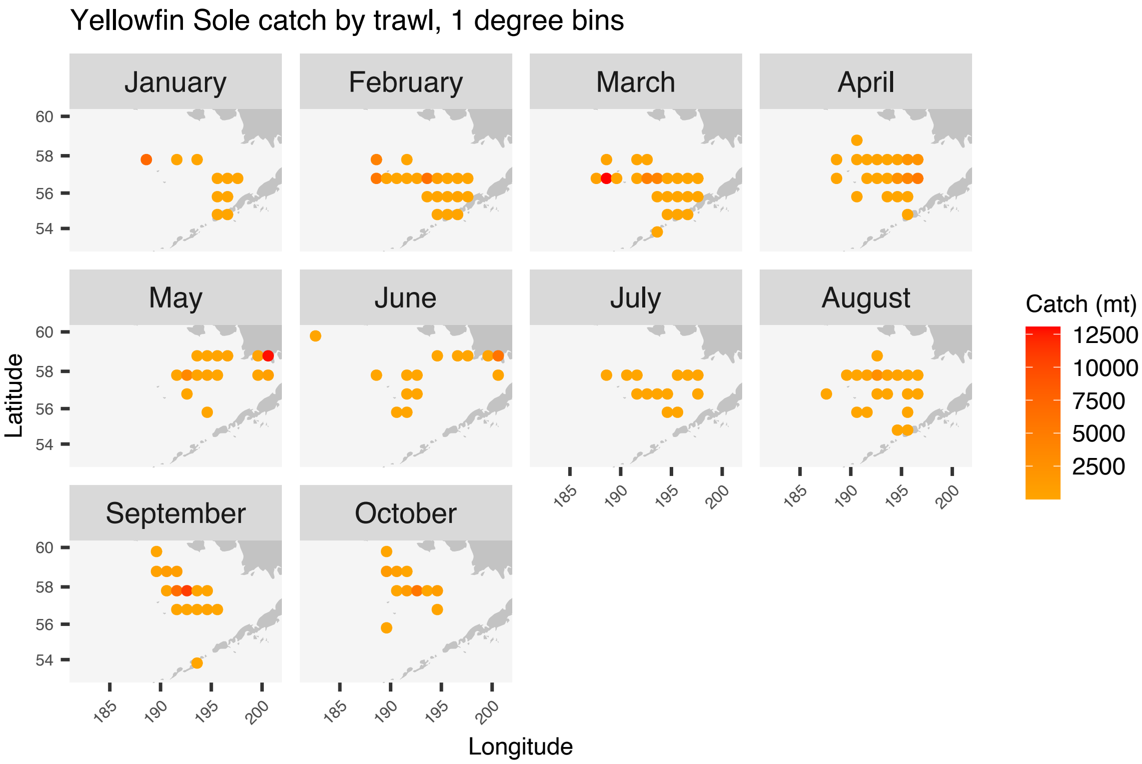


Figure 6: Catch of yellowfin sole in the BSAI in 2022 by month (through October 12), reported by observers. Circles represent presence of yellowfin sole the catch by the following gear types: non-pelagic trawl, pair trawl, or pelagic trawl.

Figure 7: Age frequency of females and males from the yellowfin sole fishery, 1975 - 2021.

Figure 8: Age frequency of yellowfin sole females and males from the AFSC/NMFS research surveys, 1977-2021.

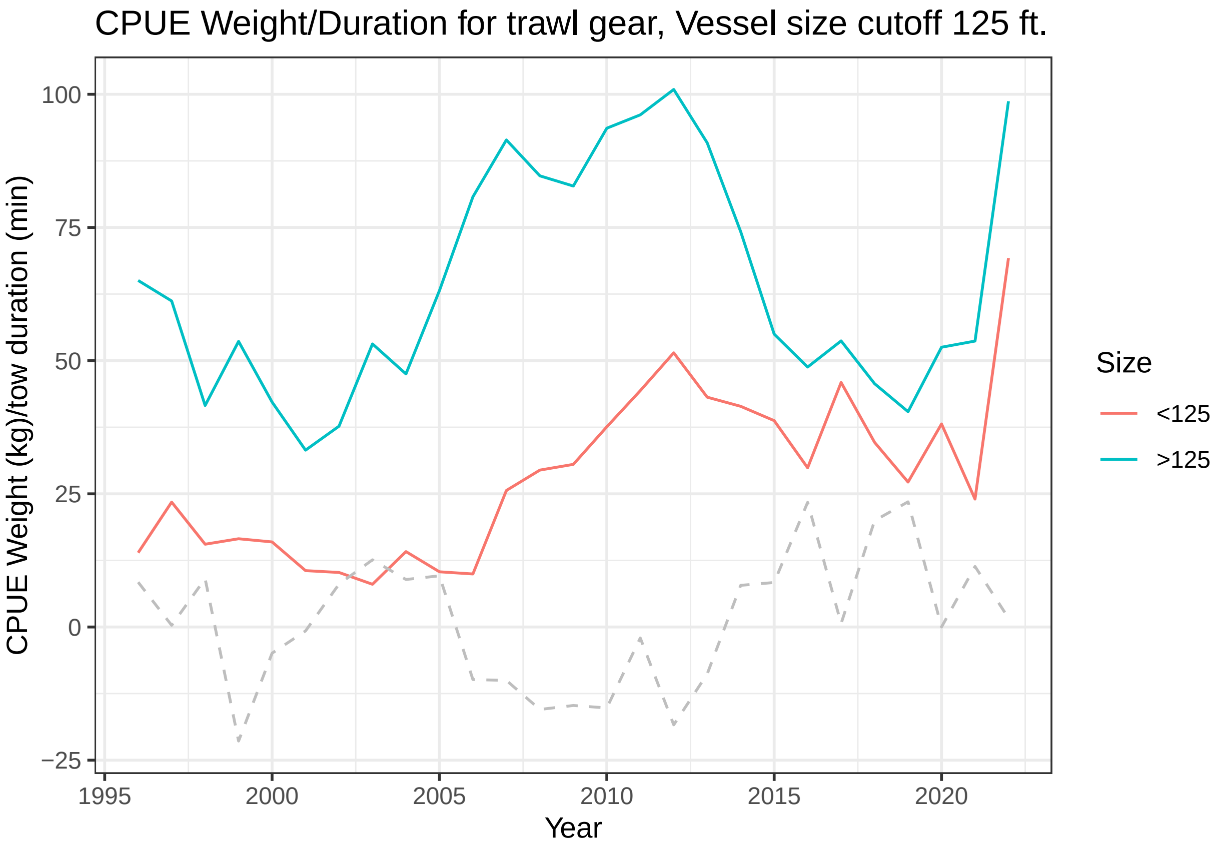
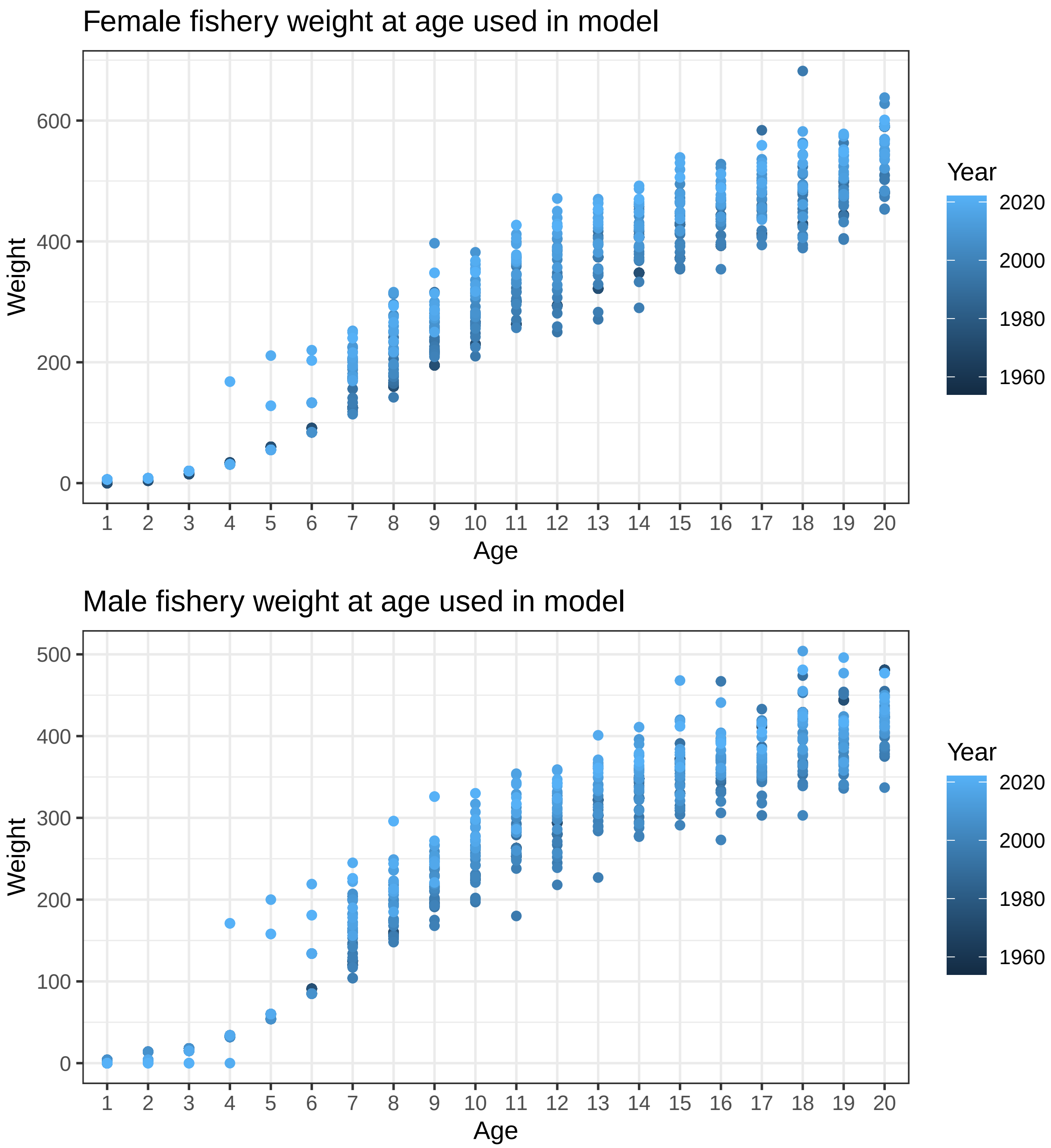


Figure 9: Catch per unit effort based on yellowfin sole fishery data, 1996-2022. CPUE weight (kg)/trawl duration (min) is shown for vessels greater and less than 125 ft, and only including self-made tows. Estimates of relative CPUE are complete through October 26, 2022. Results are limited to Catcher/Processor 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 1996-2022 (x10 for visualization) are shown as a dotted line.



Female fishery weight at age used in model

Male fishery weight at age used in model

Figure 10: Estimates of weight (g) at age for yellowfin sole females and males, based on fishery data 1954-2022, and used in this year's models.

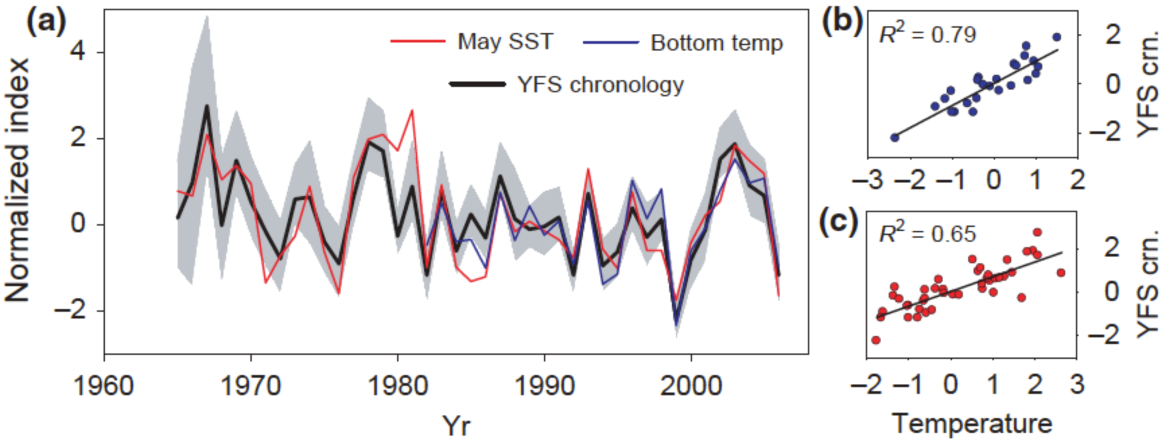


Figure 11: Master chronology for yellowfin sole and time series of mean summer bottom temperature and May sea surface temperature for the eastern Bering Sea (Panel a). All data were normalized to a mean of 0 and standard deviation of 1. Correlations of chronologies with bottom temperature and sea surface temperature are shown in panels b and c, respectively (Matta et al. 2010).

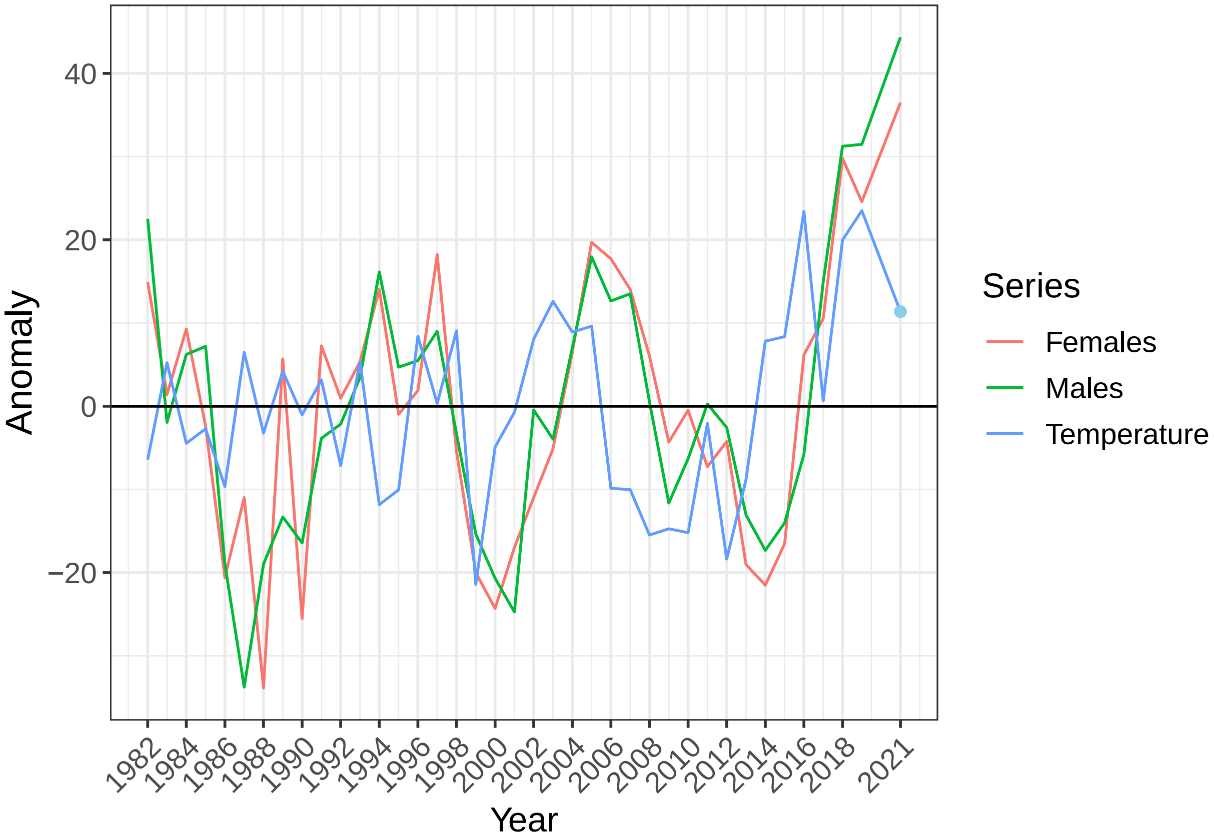


Figure 12: Yellowfin sole length-at-age anomalies, for 5-year old males and females, and bottom temperature anomalies from the eastern Bering Sea survey area <100 m. Correspondence in these residuals is apparent with a 2-3 year lag effect from the mid-1990s to 2022 (excluding 2020). Late 1980s and early 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 2022.

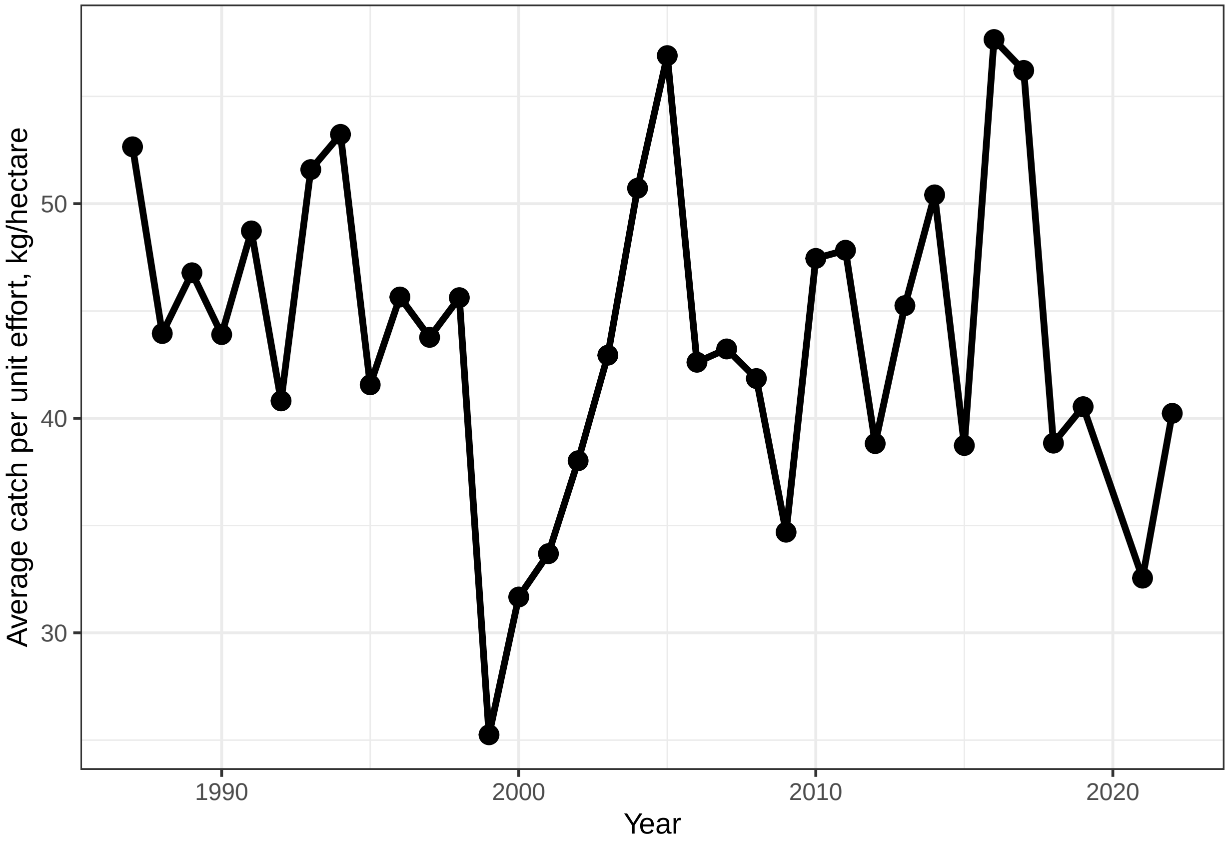


Figure 13: Average catch per unit effort on NMFS eastern Bering Sea surveys, 1987-2022, in kg/hectare.

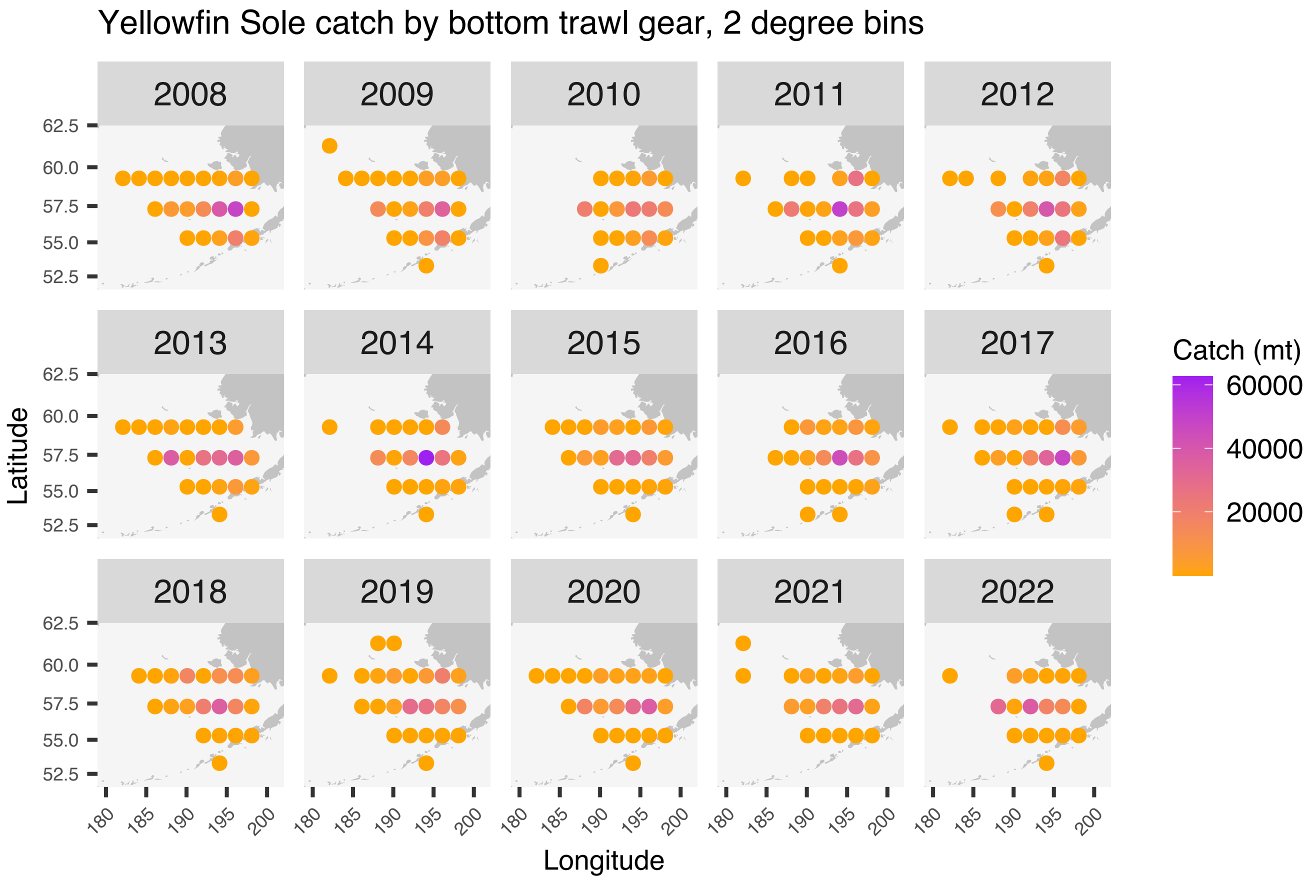


Figure 3: Catch of yellowfin sole by non-pelagic trawl gear in the eastern Bering Sea, 2008-2022, by year, reported by observers. Colored circles represent catch of yellowfin sole, with darker shades representing higher catch.

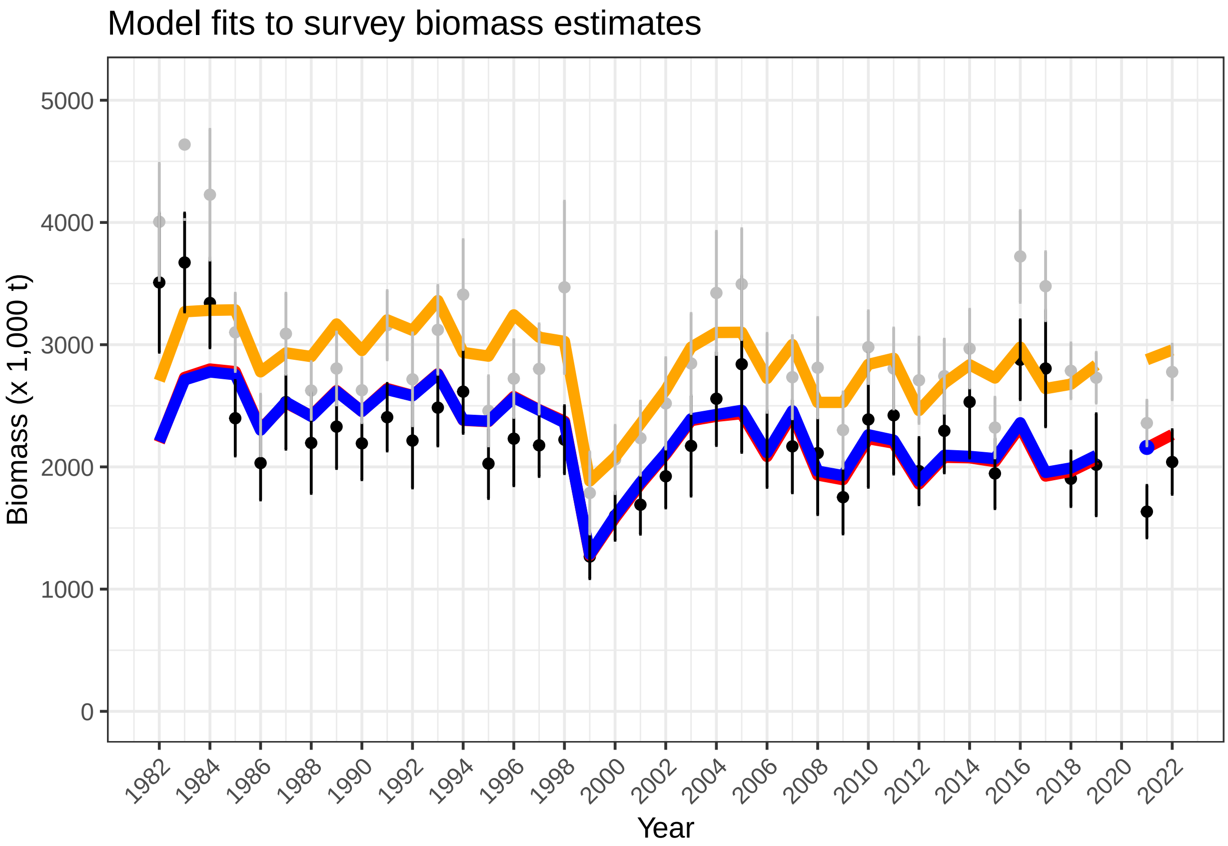


Figure 14: Annual eastern Bering Sea bottom trawl survey biomass point estimates and 95% confidence intervals for yellowfin sole, 1982-2022, with Model 18.2 (red line) Model 18.2 (2021, blue line) fit to EBS design-based survey estimates (black dots and confidence intervals) and Model 22.1 (orange line) fit to NBS+EBS VAST estimates of survey biomass (grey dots with confidence intervals).

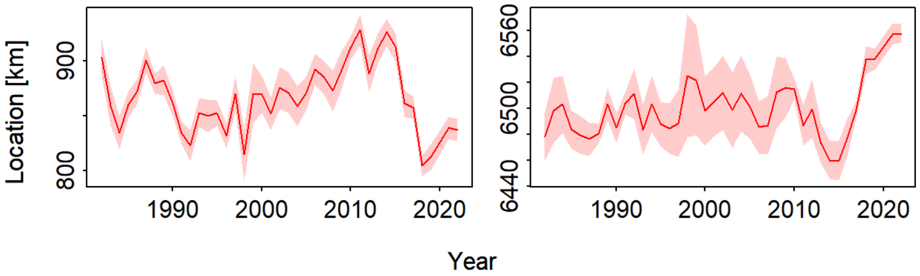


Figure 15: Center of gravity plot with eastings (Longitude) in the left panel and northings (Latitude) in the right panel. The units are in kilometers.

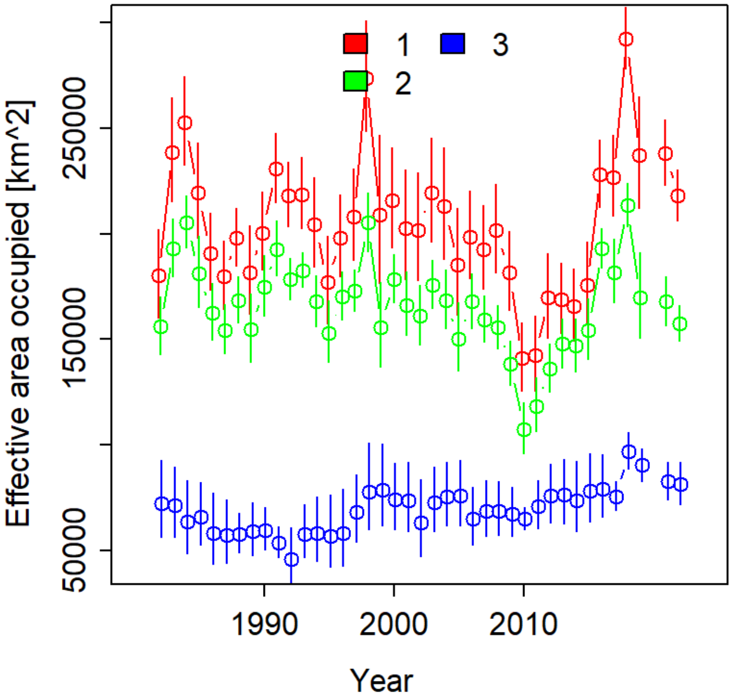


Figure 16: The effective area occupied by yellowfin sole, estimated in the VAST analysis, in the eastern Bering Sea (green), northern Bering Sea (blue) and the combined region (red).

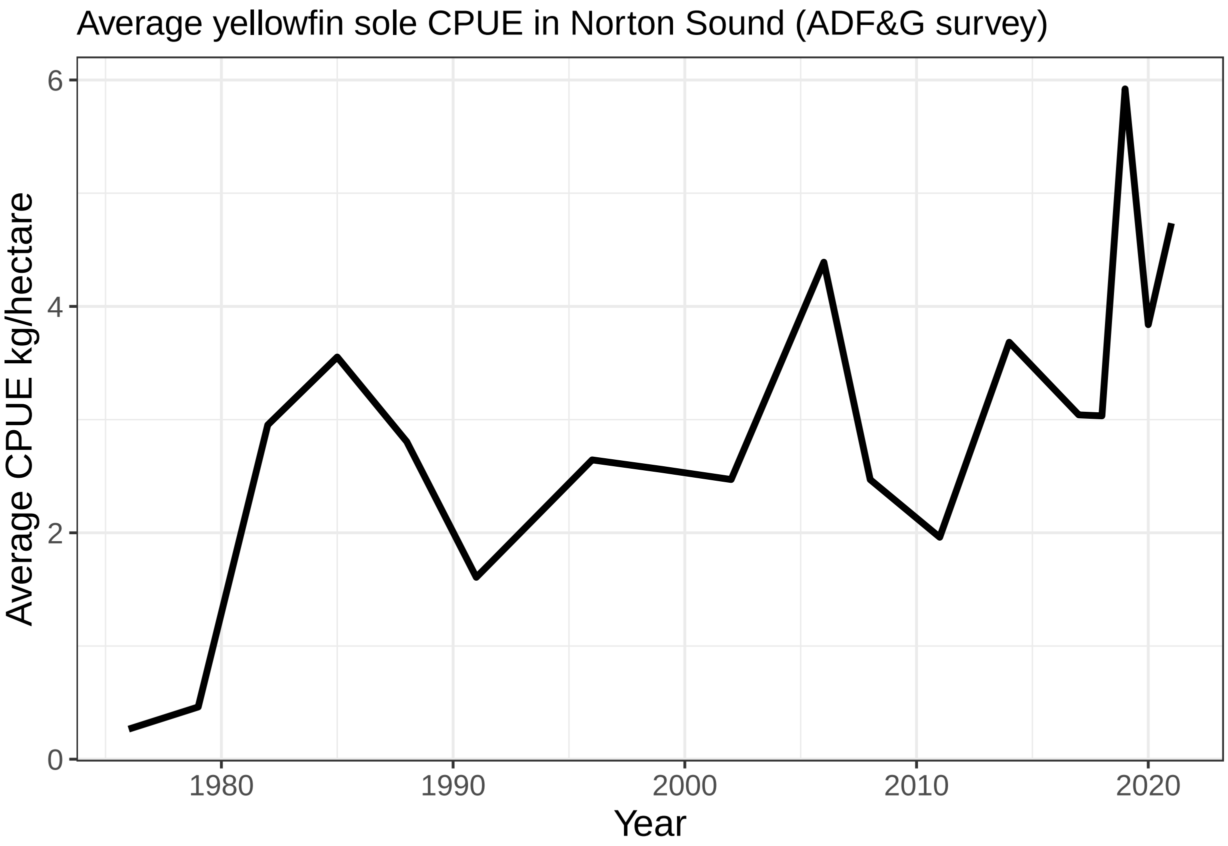


Figure 17: Average catch per unit effort (CPUE) of yellowfin sole in Norton Sound, based on ADF&G survey time series, 1976 - 2021.

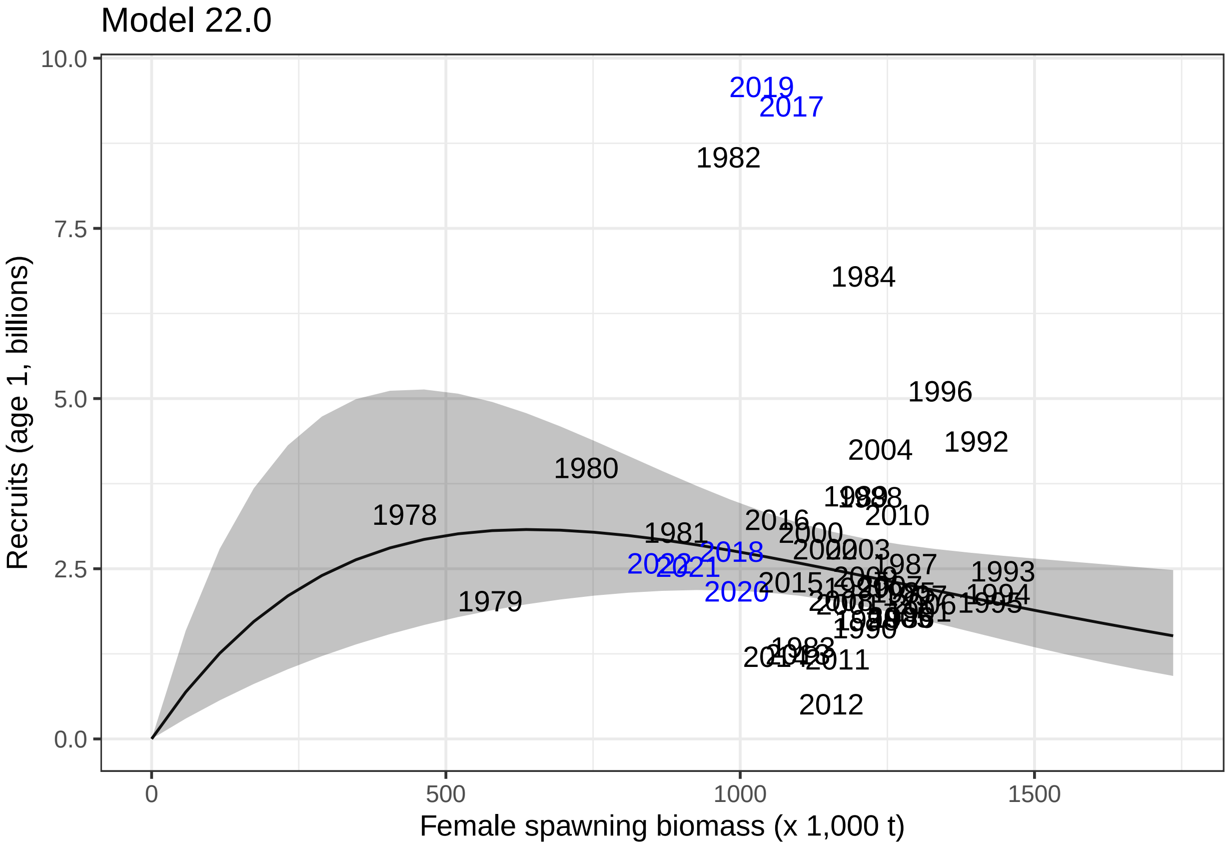


Figure 18: Ricker stock recruitment curve for yellowfin sole Model 22.0 with 95% confidence intervals (shaded region) fit to female spawning biomass and recruitment data from 1978-2016. Years in black indicate data used to fit the model, years in blue were not used to fit the model.

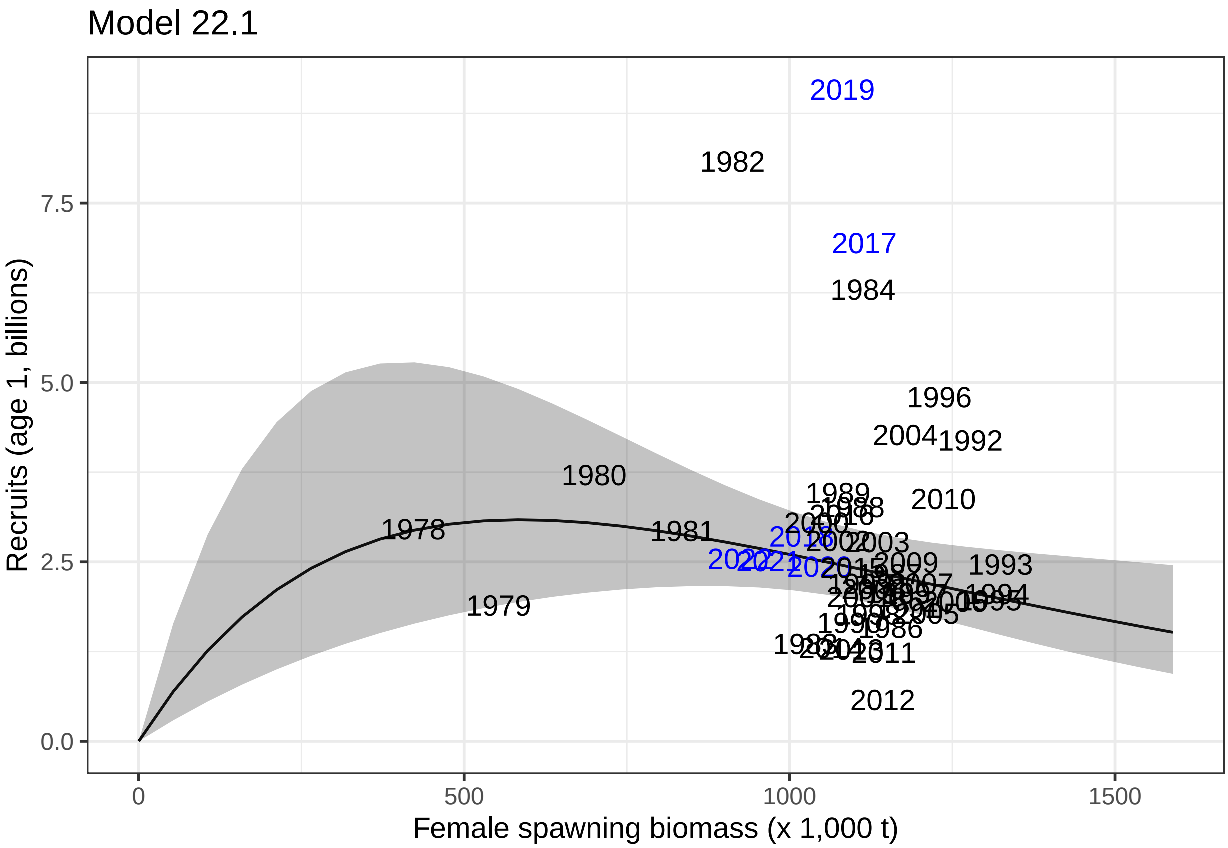


Figure 19: Ricker stock recruitment curve for yellowfin sole Model 22.1 with 95% confidence intervals (shaded region) fit to female spawning biomass and recruitment data from 1978-2016. Years in black indicate data used to fit the model, years in blue were not used to fit the model.

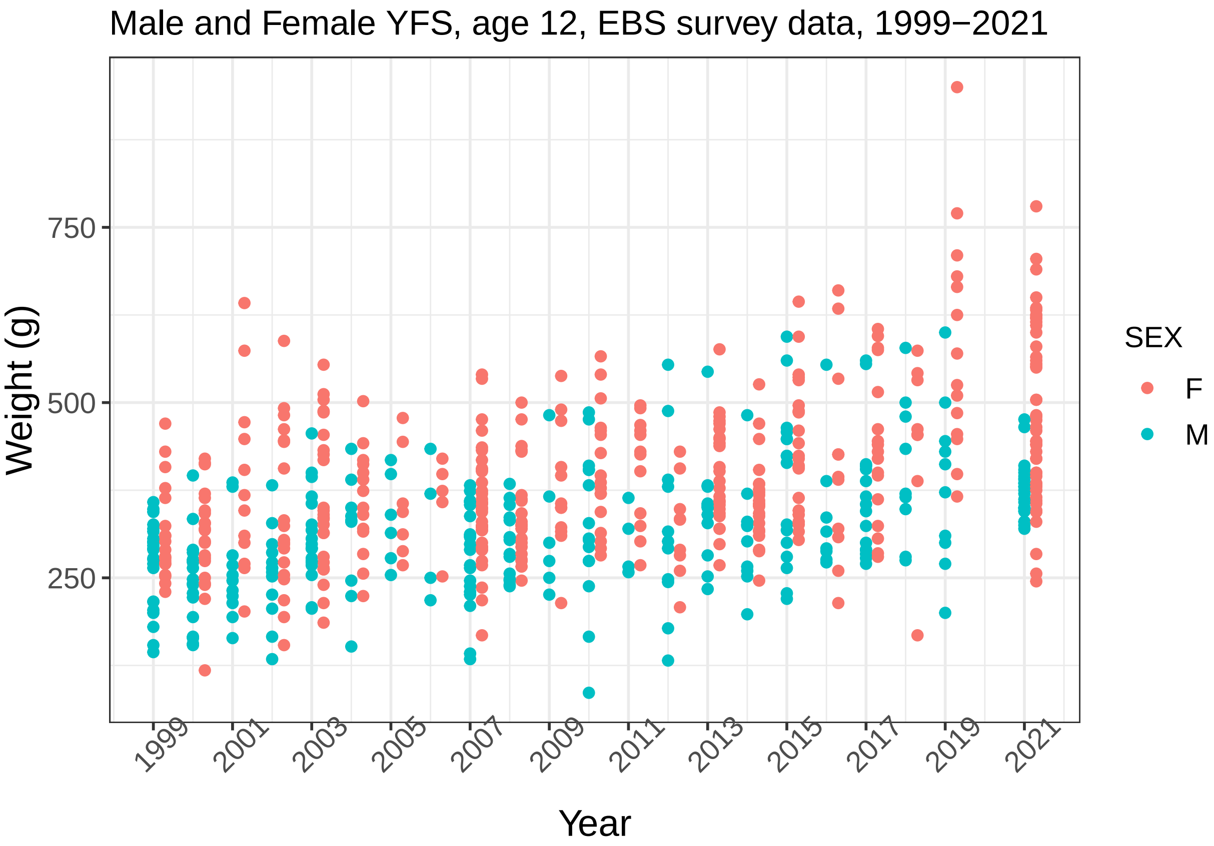


Figure 20: Mean weight at age (g) for yellowfin sole Age 12 females and males from the eastern Bering Sea survey and fishery, 1999-2021. Data includes 680 survey ages from the Bering Sea.

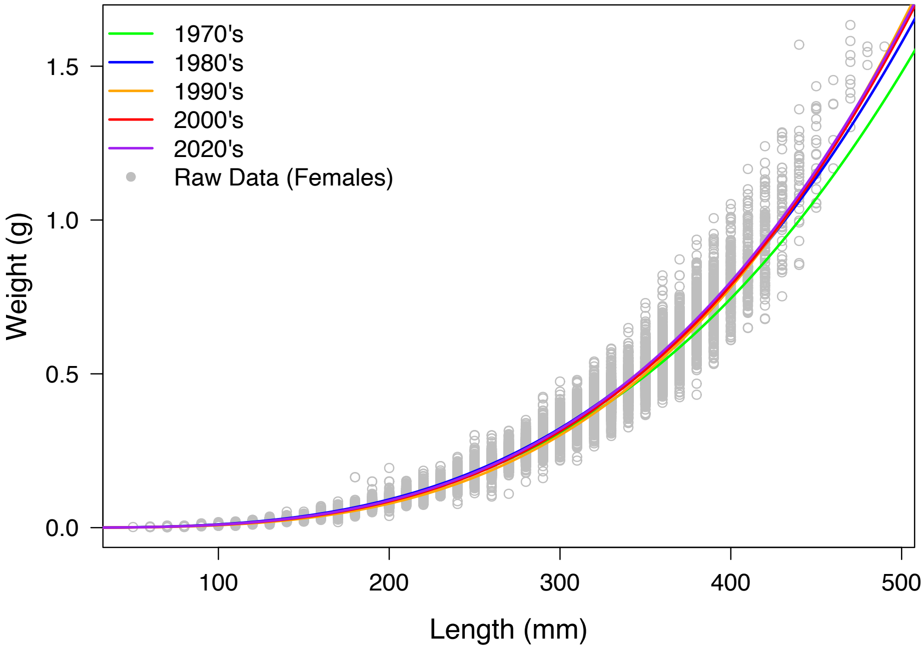
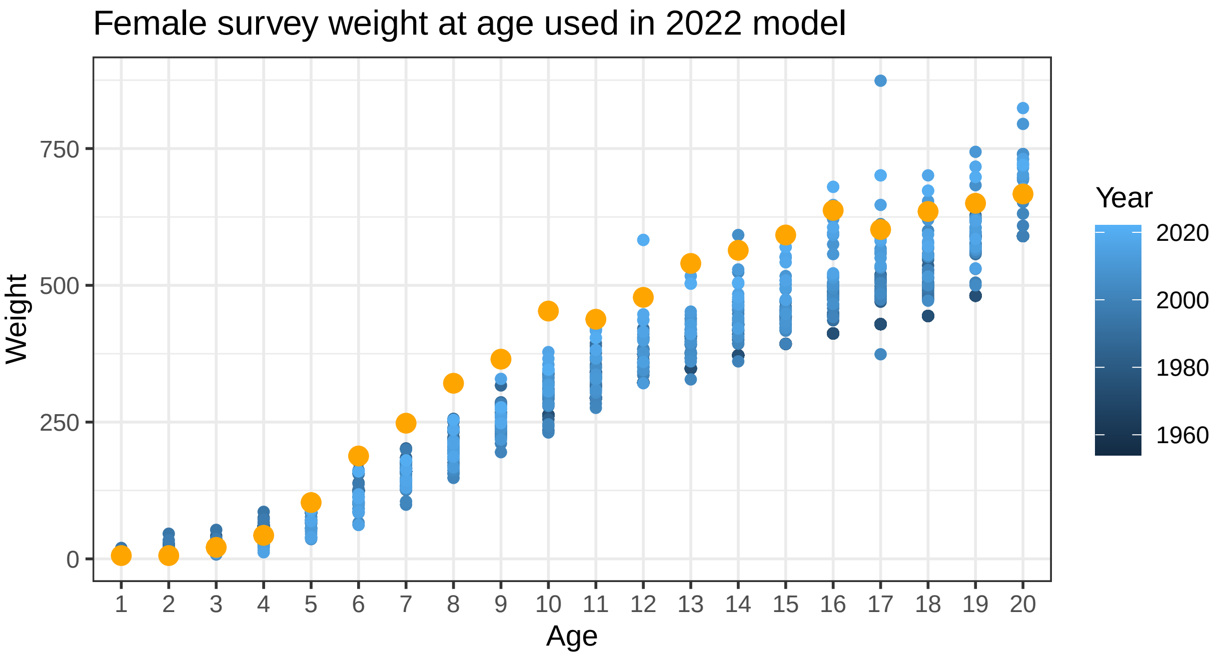


Figure 21: Yellowfin sole weight at length by decade, females, fitted to the von Bertalanffy growth model.


Female survey weight at age used in 2022 model

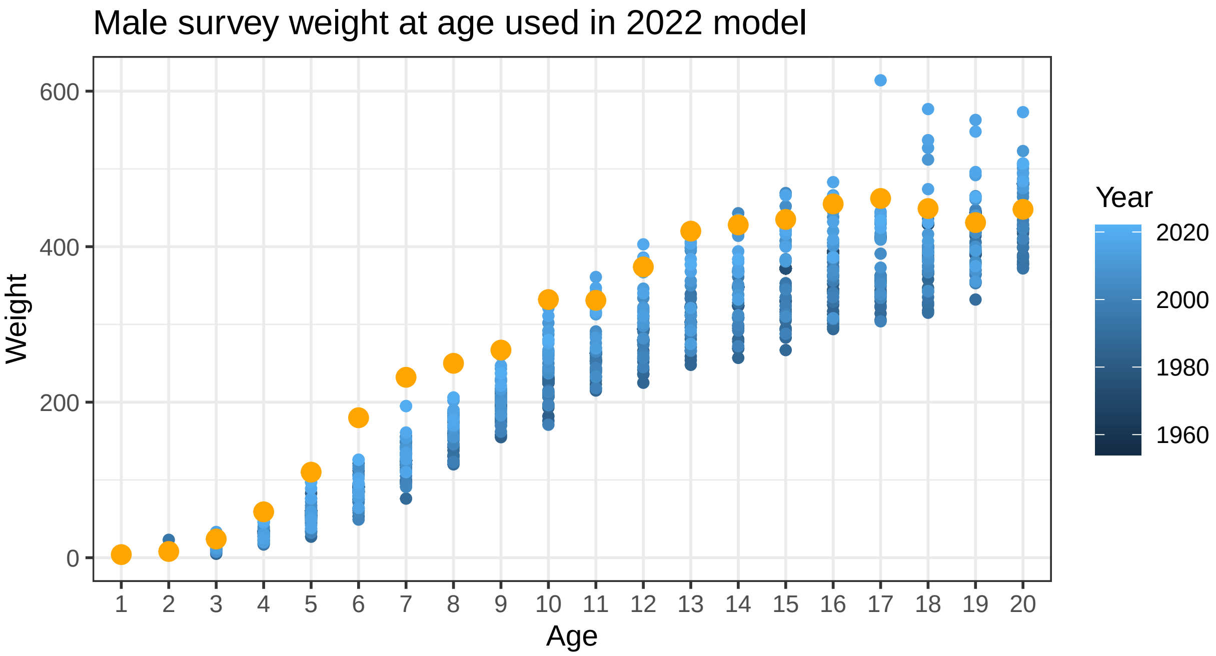

Male survey weight at age used in 2022 model

Figure 22: Mean weight at age (g) for yellowfin sole females and males from the eastern Bering Sea survey, 1954-2022 used in Model 18.2. Estimates for 2022 are highlighted in yellow.

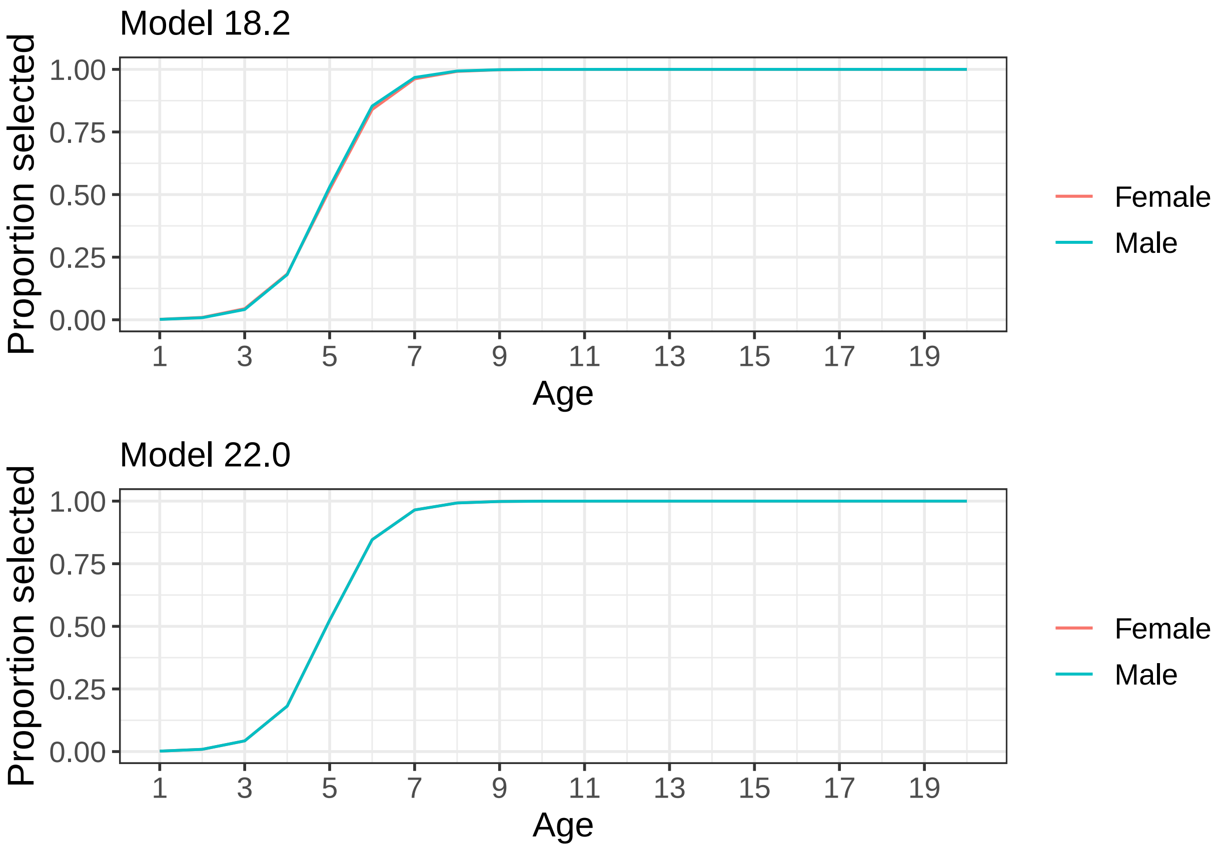


Figure 23: Estimate of yellowfin sole survey selectivity for males and females, Model 18.2 upper panel, and combined sex survey selectivity Model 22.0 lower panel.

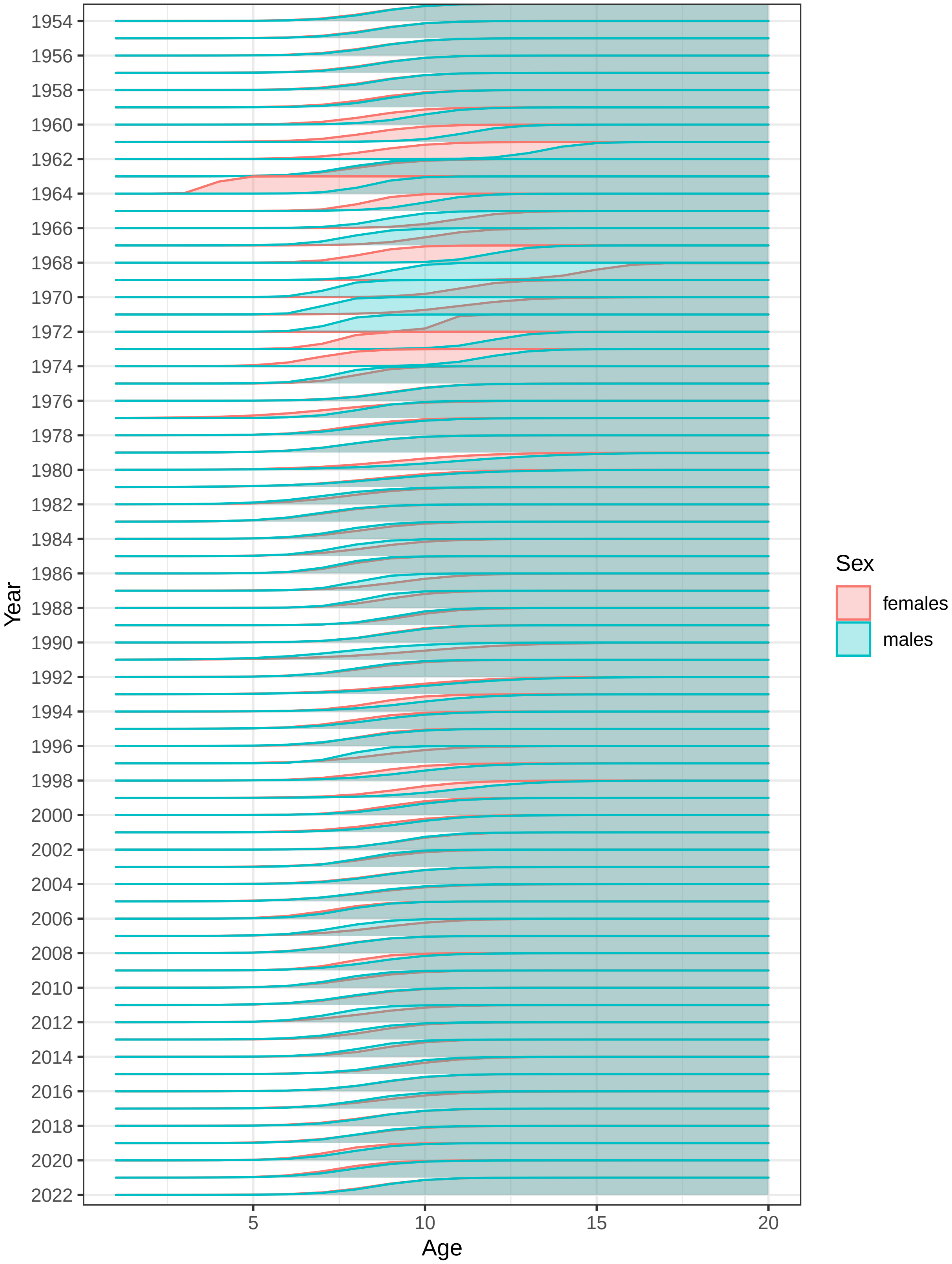


Figure 24: Estimate of yellowfin sole fishery selectivity for males and females, 1954-2022, Model 18.2.

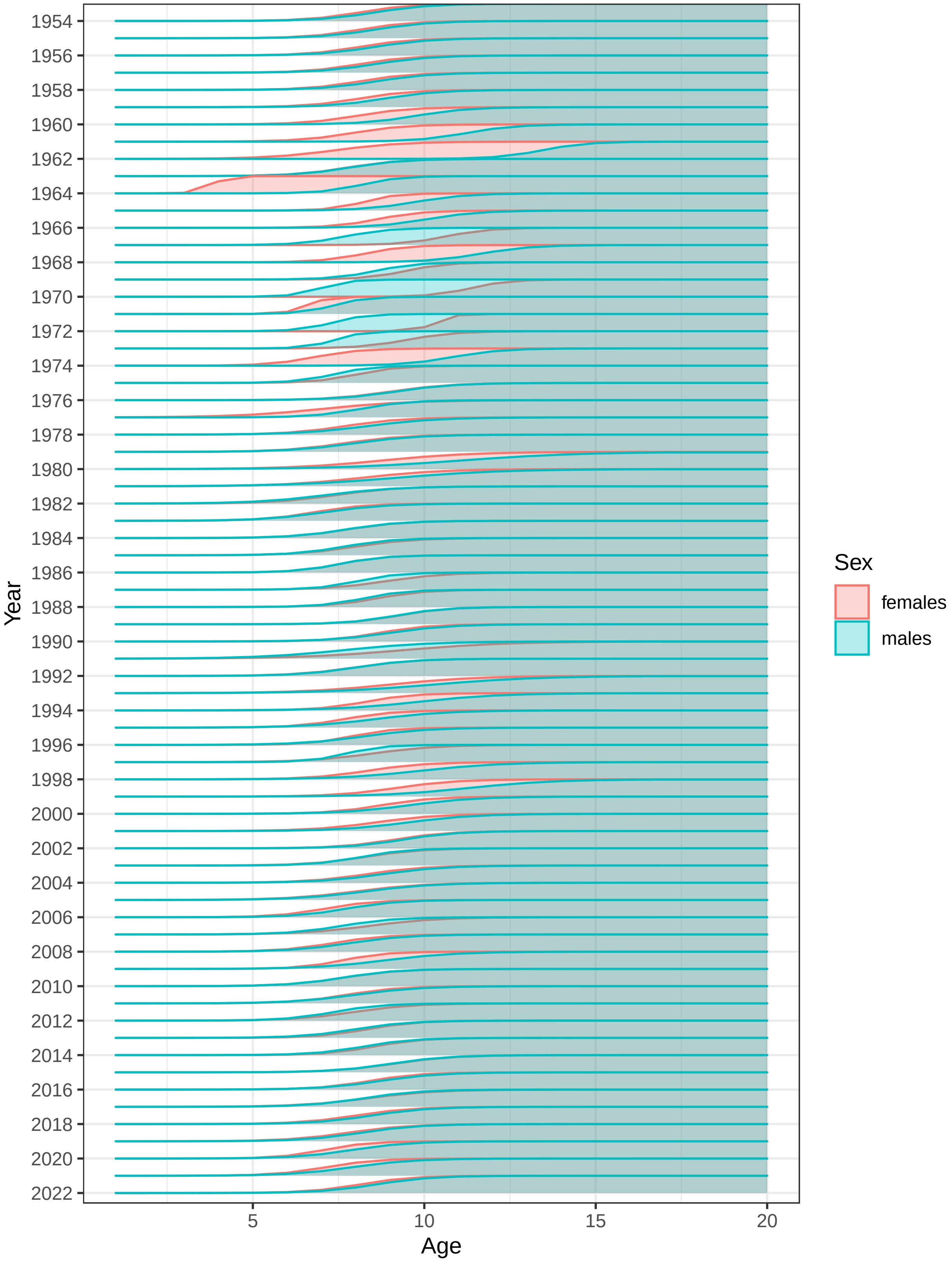


Figure 25: Estimate of yellowfin sole fishery selectivity for males and females, 1954-2022, Model 22.1.

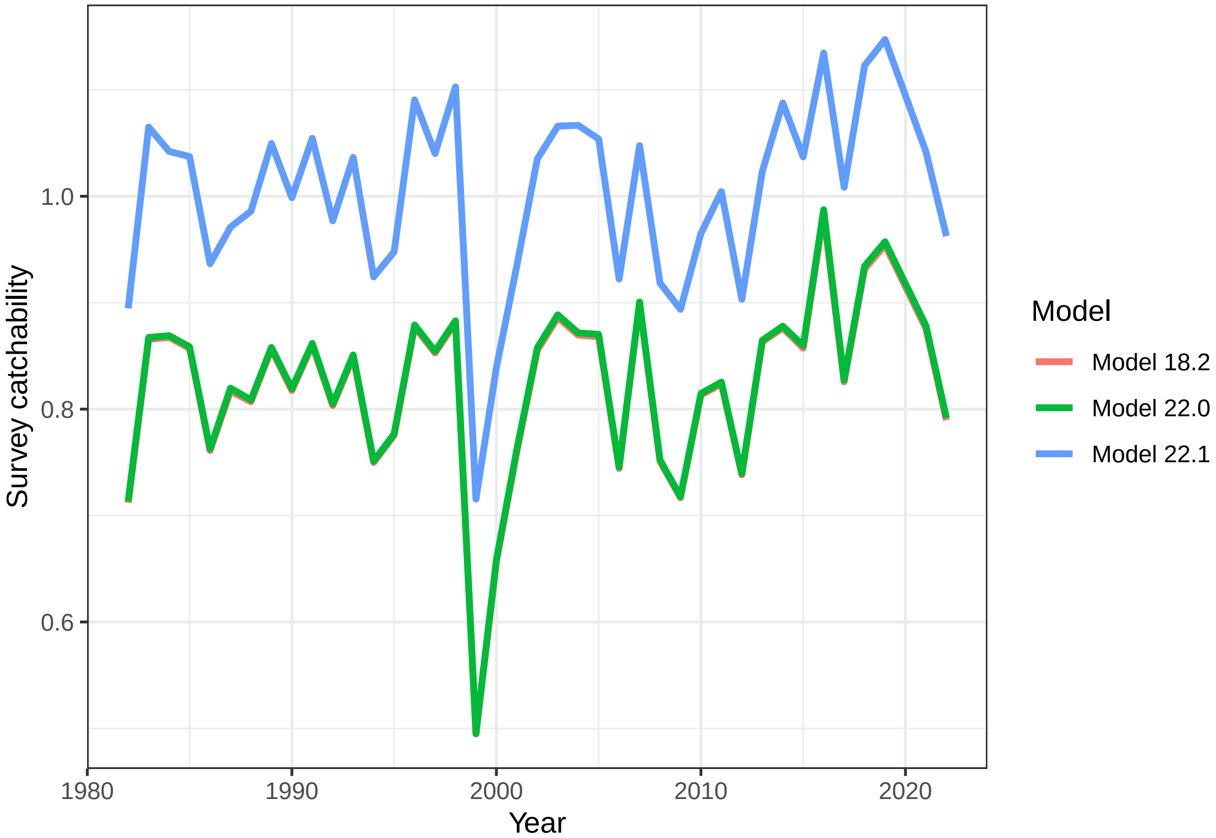


Figure 26: Survey catchability for yellowfin sole Model 18.2 and 22.0, 1982-2022. Survey catchability for Models 18.2 and 22.0 appears as a single line because it is nearly identical for these two models.

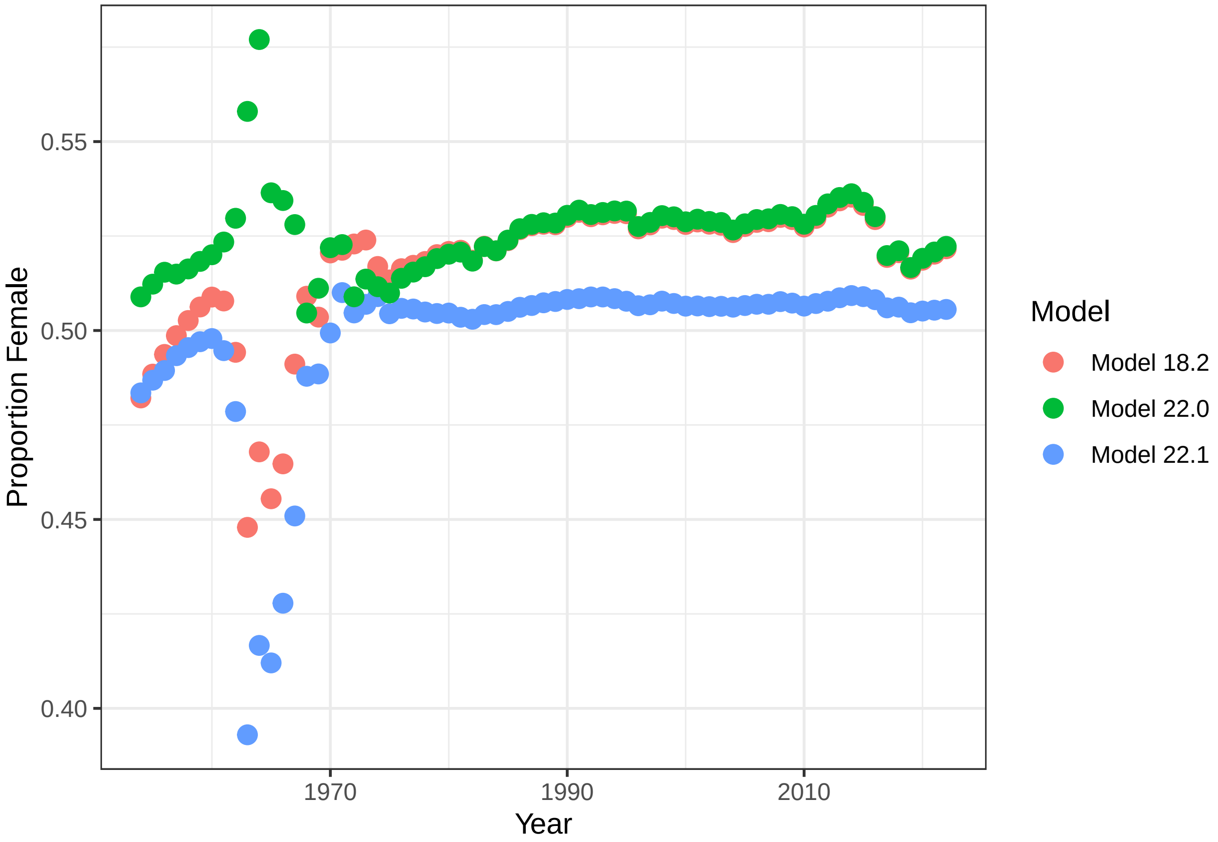


Figure 27: Model estimates of the proportion of female yellowfin sole in the population, 1982-2022 for Models 18.2, 22.0, and 22.1. Note that the proportion female from Models 18.2 and 22.0 are superimposed.

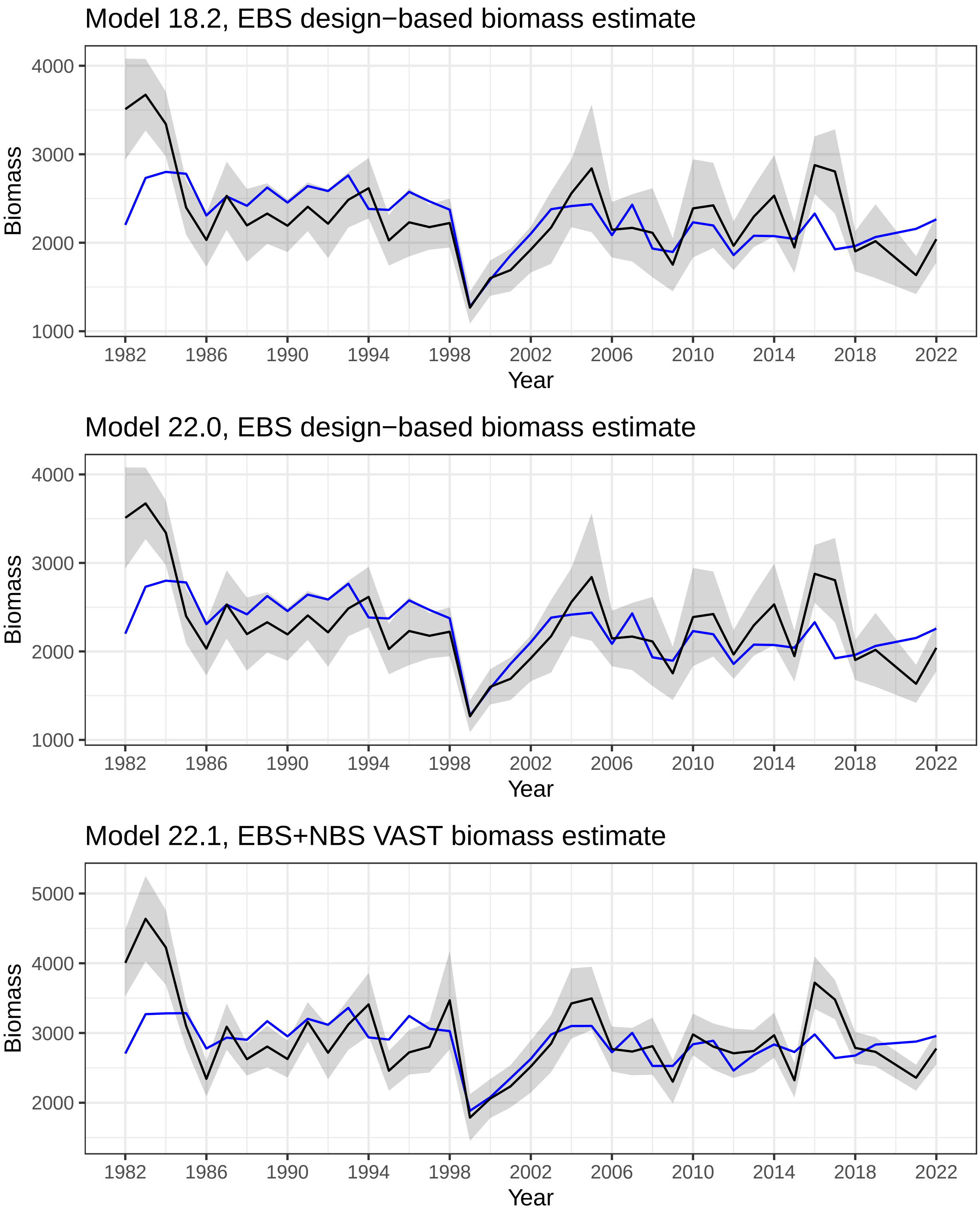


Figure 28: Model 18.2 (upper panel), Model 22.0 (middle panel), and Model 22.1 (lower panel) fit to NMFS Bering Sea survey biomass estimates for yellowfin sole, from 1982-2022. Models 18.2 and 22.0 incorporate design-based estimates from the EBS only, while Model 22.1 used NBS+EBS model-based (VAST) estimates. Blue lines are model estimates, grey represent survey estimates.

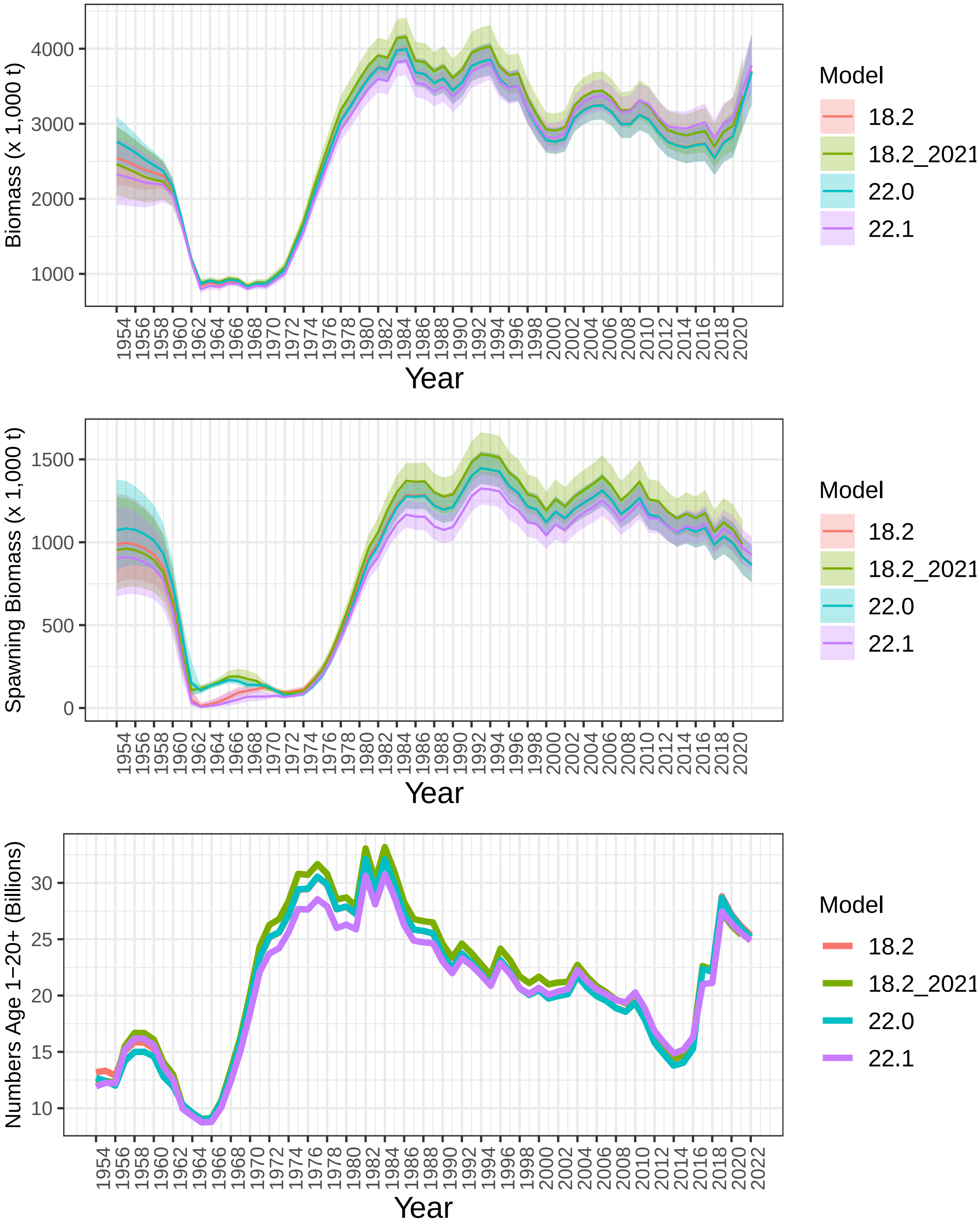


Figure 29: Total (age 2+) and spawning stock biomass for yellowfin sole, and total numbers, based on Models 18.2 (2021), 18.2, 22.0, and 22.1, from 1954-2022. Note that Models 18.2 and 22.0 are so similar that they appear superimposed.

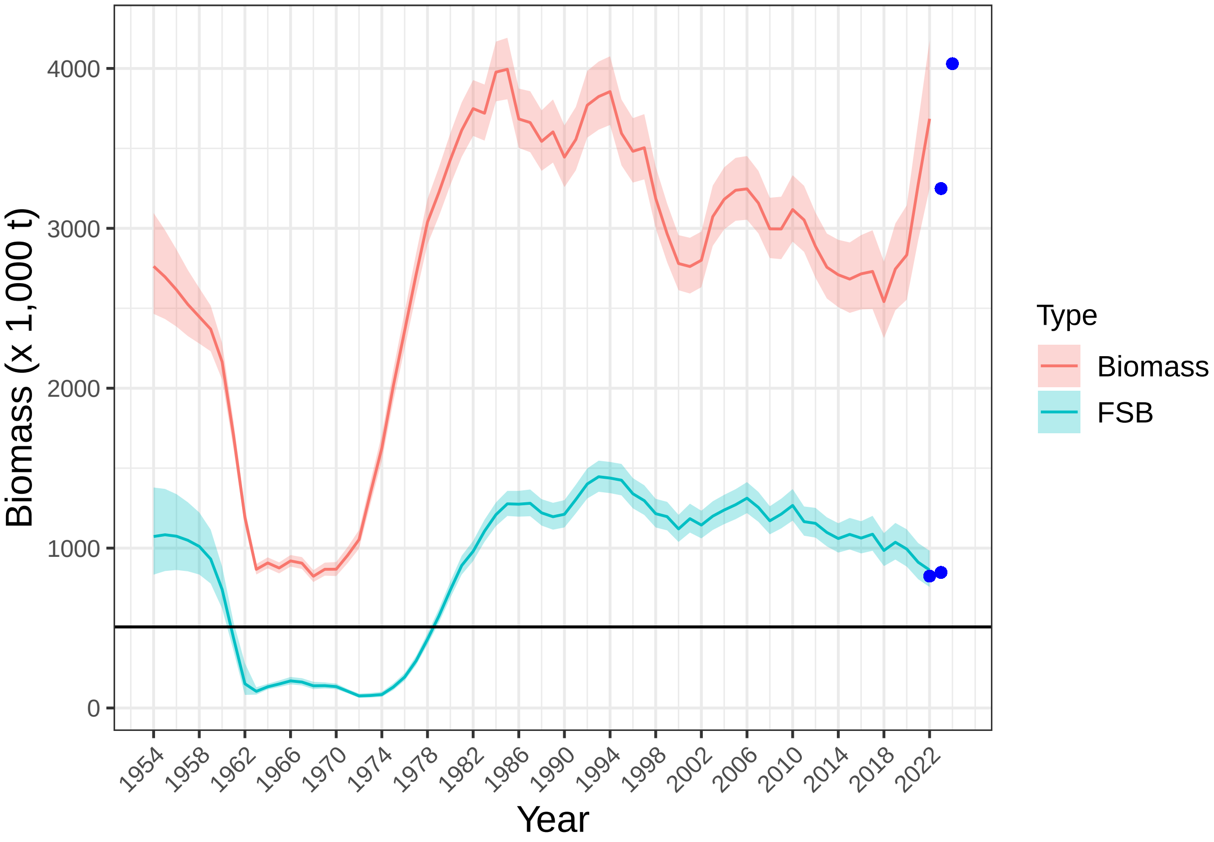


Figure 30: Model estimates of yellowfin sole total (age 2+) and female spawning biomass with 95% confidence intervals, 1954-2022, Model 22.0. Dots indicate projections for 2023 and 2024.

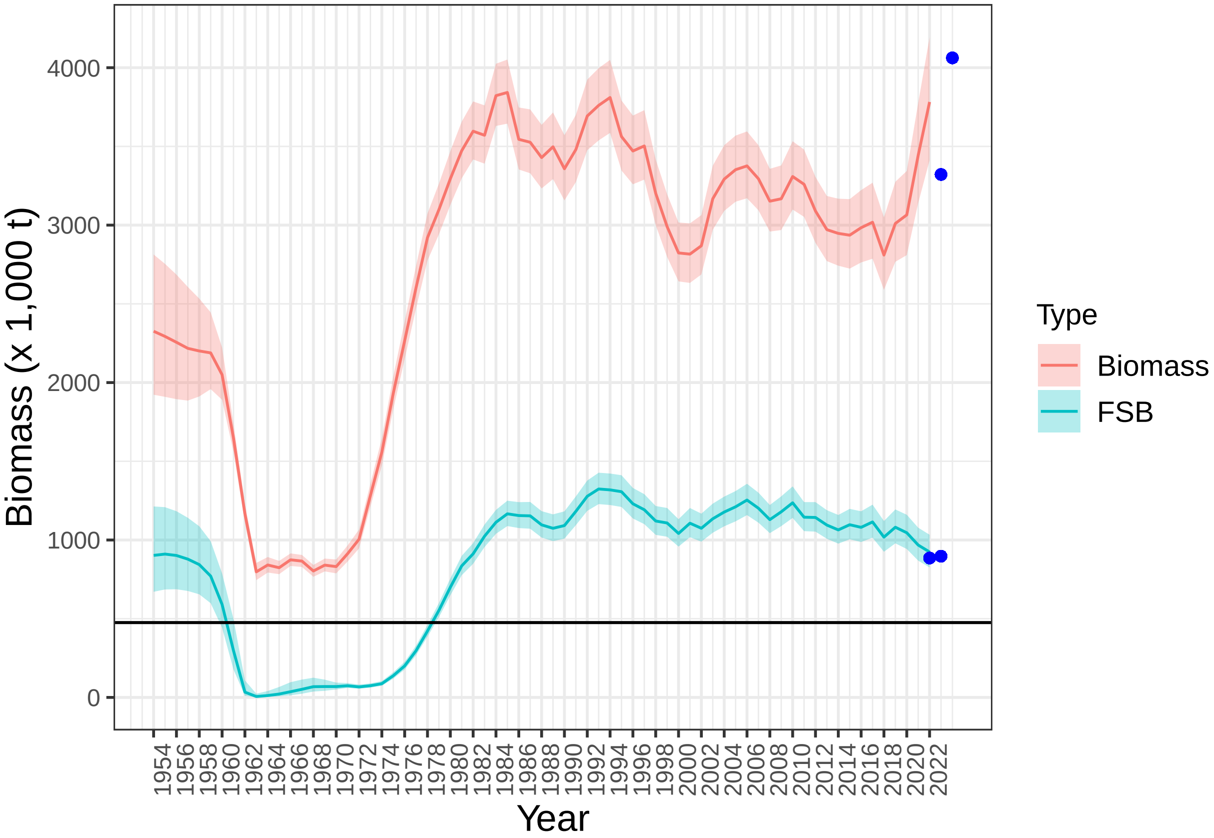


Figure 31: Model estimates of yellowfin sole total (age 2+) and female spawning biomass with 95% confidence intervals, 1954-2022, Model 22.1. Dots indicate projections for 2023 and 2024.

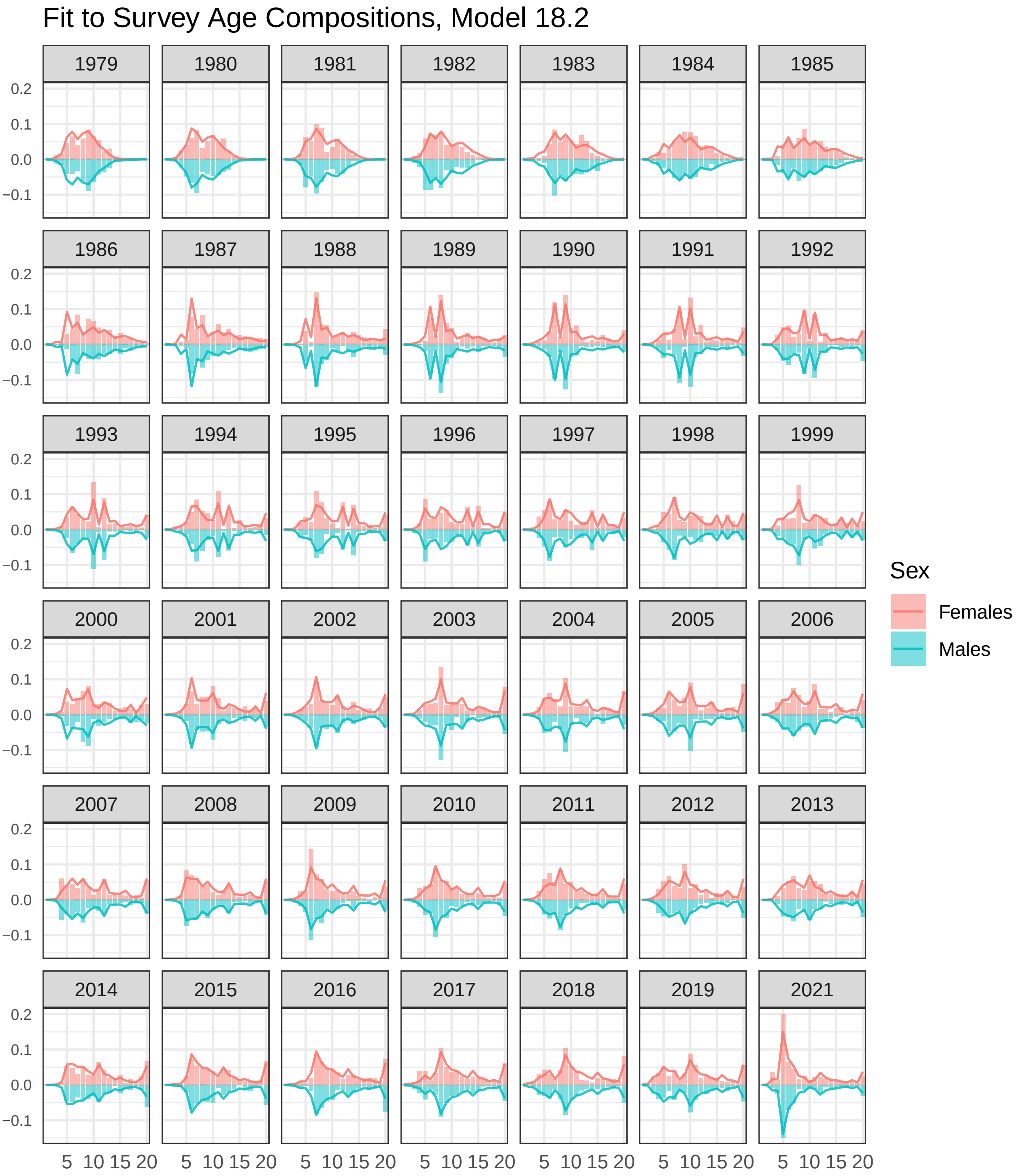


Figure 32: Model 22.0 fit to the time-series of yellowfin sole survey age composition, by sex, 1979-2021. The x-axis represents age.

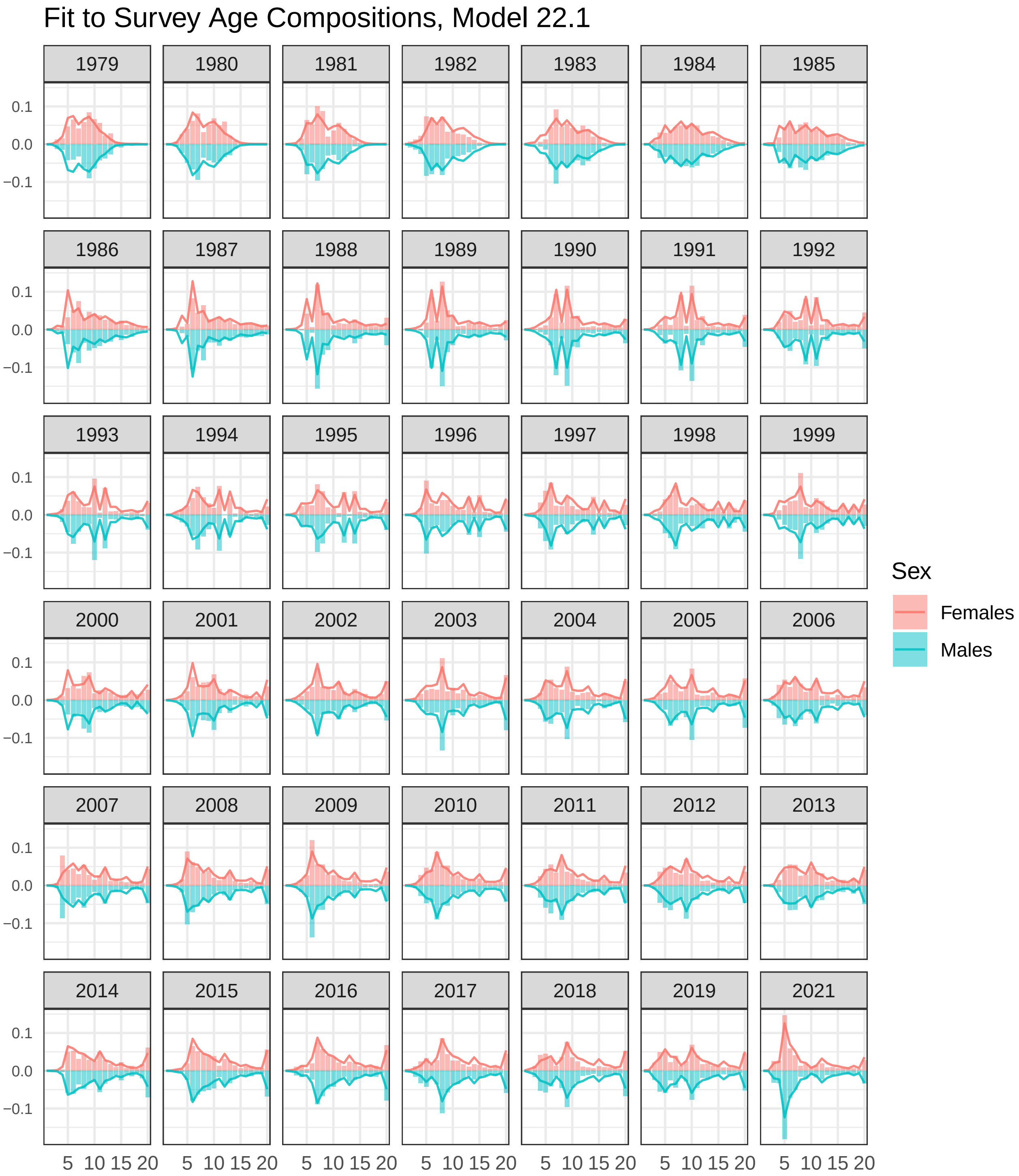


Figure 33: Model 22.1 fit to the time-series of yellowfin sole survey age composition, by sex, 1979-2021. The x-axis represents age.

Figure 34: Model 22.0 fit to the time-series of yellowfin sole fishery age composition, by sex, 1975-2021. The x-axis represents age.

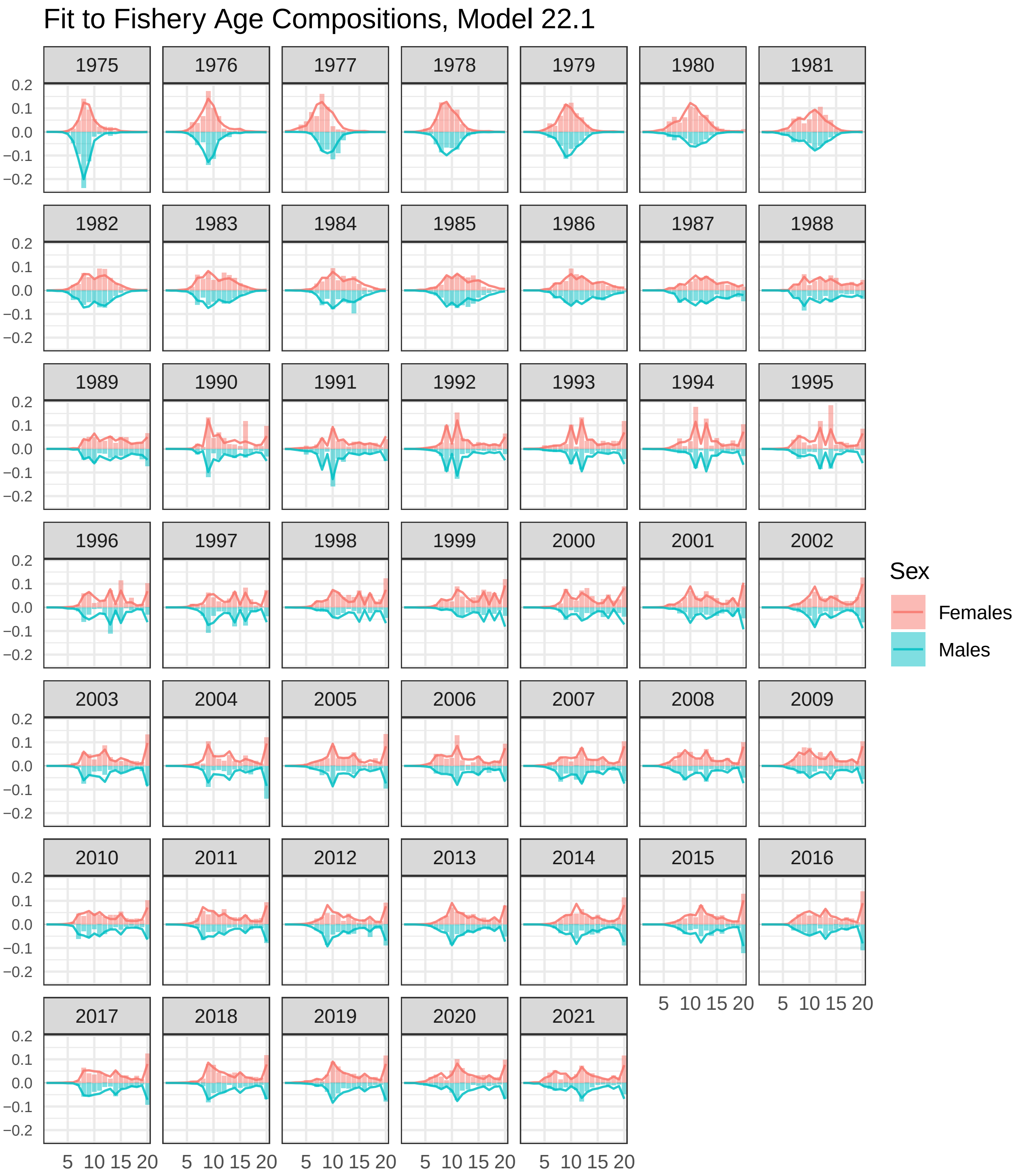


Figure 35: Model 22.1 fit to the time-series of yellowfin sole fishery age composition, by sex, 1975-2021. The x-axis represents age.

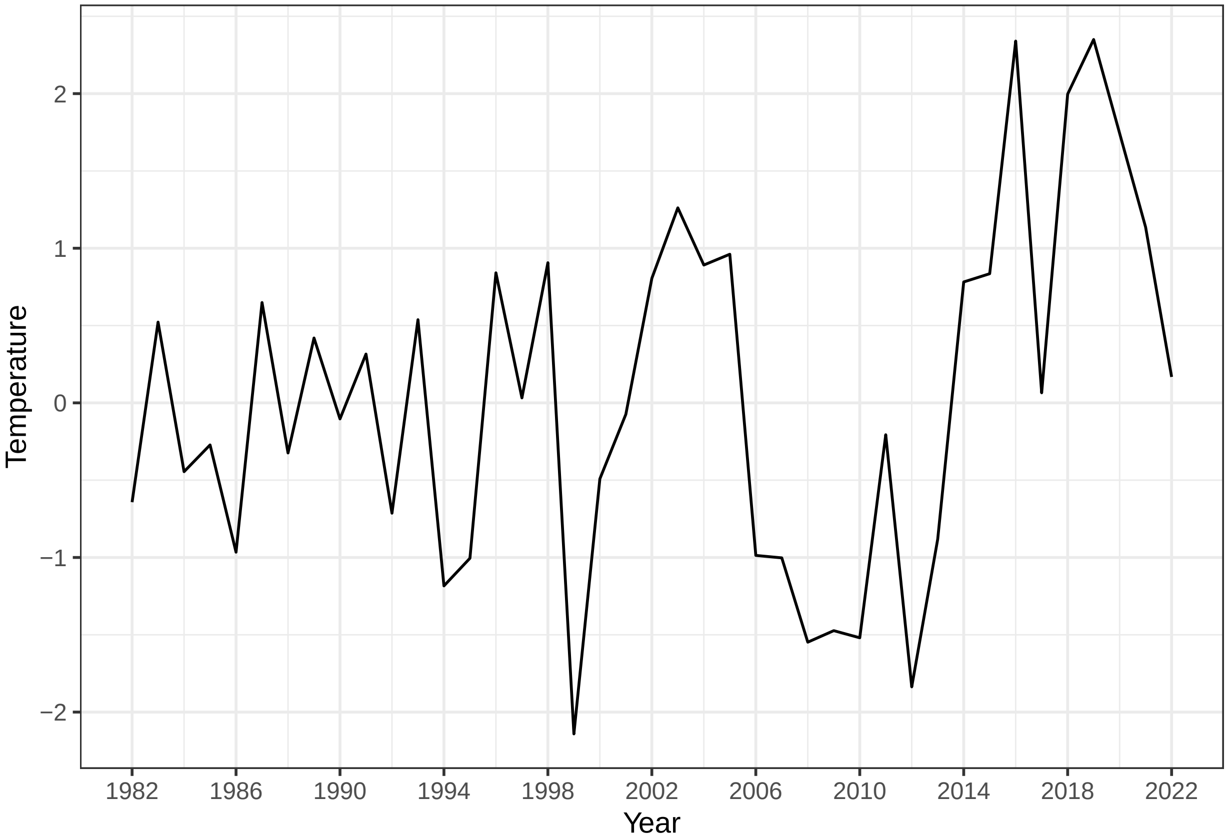


Figure 36: Bottom temperature anomalies from the NMFS survey <100 m, 1982-2022.

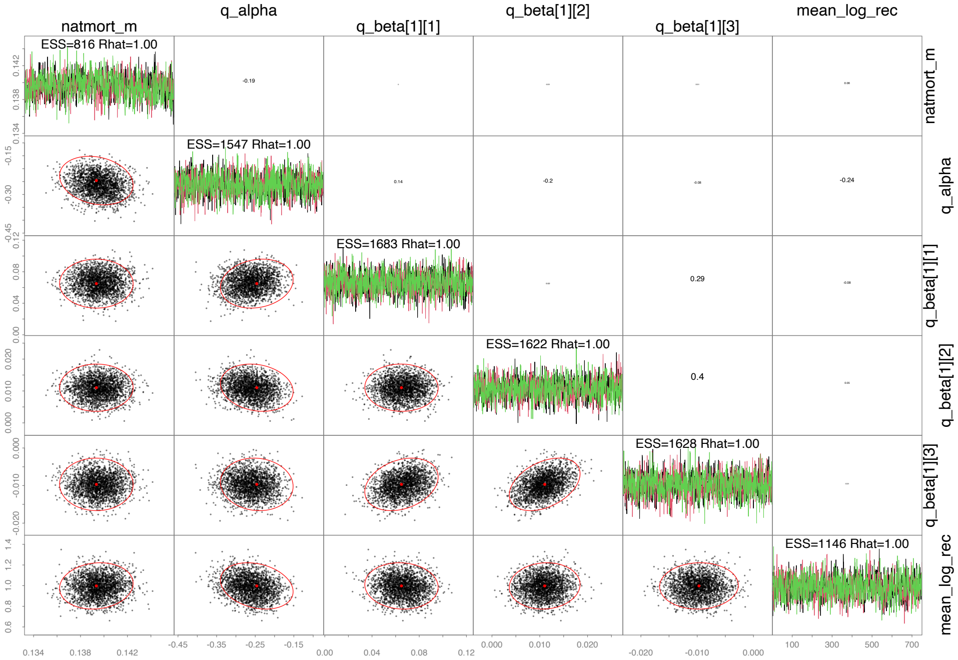


Figure 37: Pairwise parameter posteriors, trace plots, and confidence ellipses for several estimated parameters in the yellowfin sole Model 22.0: male natural mortality (‘natmort_m’), and survey catchability parameters (‘q_alpha’ and ‘q_beta’), as well as the mean of log(Recruitment). The effective sample size (ESS) and Rhat are also shown for each parameter. Rhat is the ratio of the spread of all the values combined to the mean spread of each chain; if all the chains are sampling properly from the posterior distribution, this ratio should be 1.

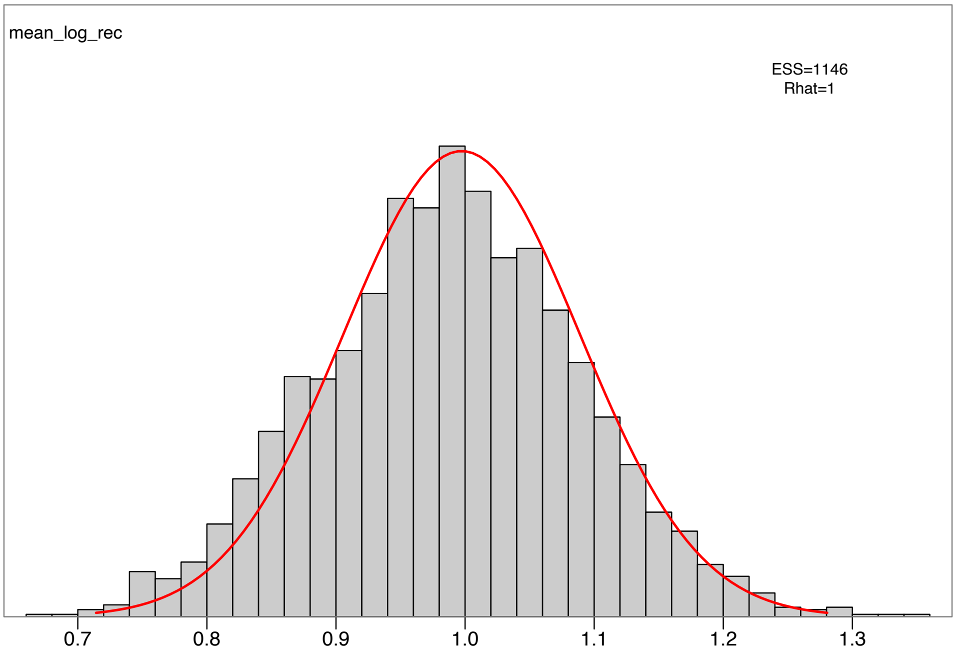


Figure 38: Markov Chain Monte Carlo distribution for the mean log(Recruitment) parameter estimated by Model 22.0 for yellowfin sole. Output was generated in the R package *adnuts* using 10,000,000 iterations and thinning every 1,000.

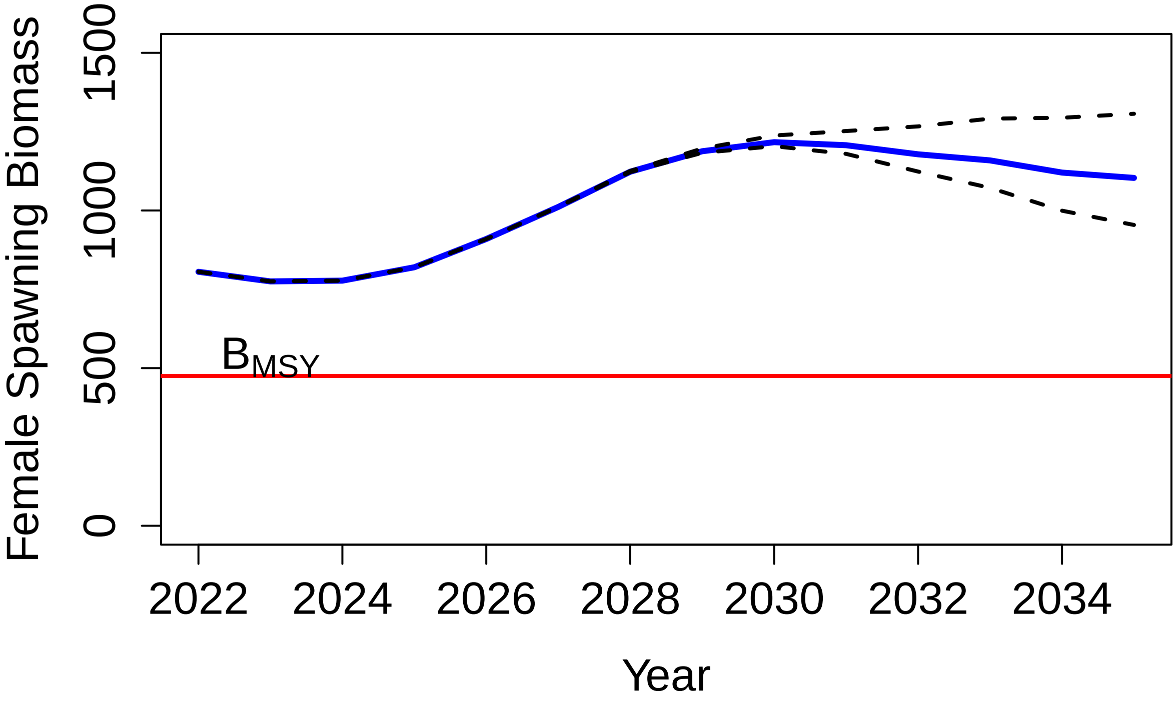


Figure 39: Projected yellowfin sole female spawning biomass for 2022 to 2035 (blue line), with 5% and 95% confidence intervals, and fishing at the 5-year (2017-2021) average fishing mortality rate, F= 0.0675 , Model 22.1.

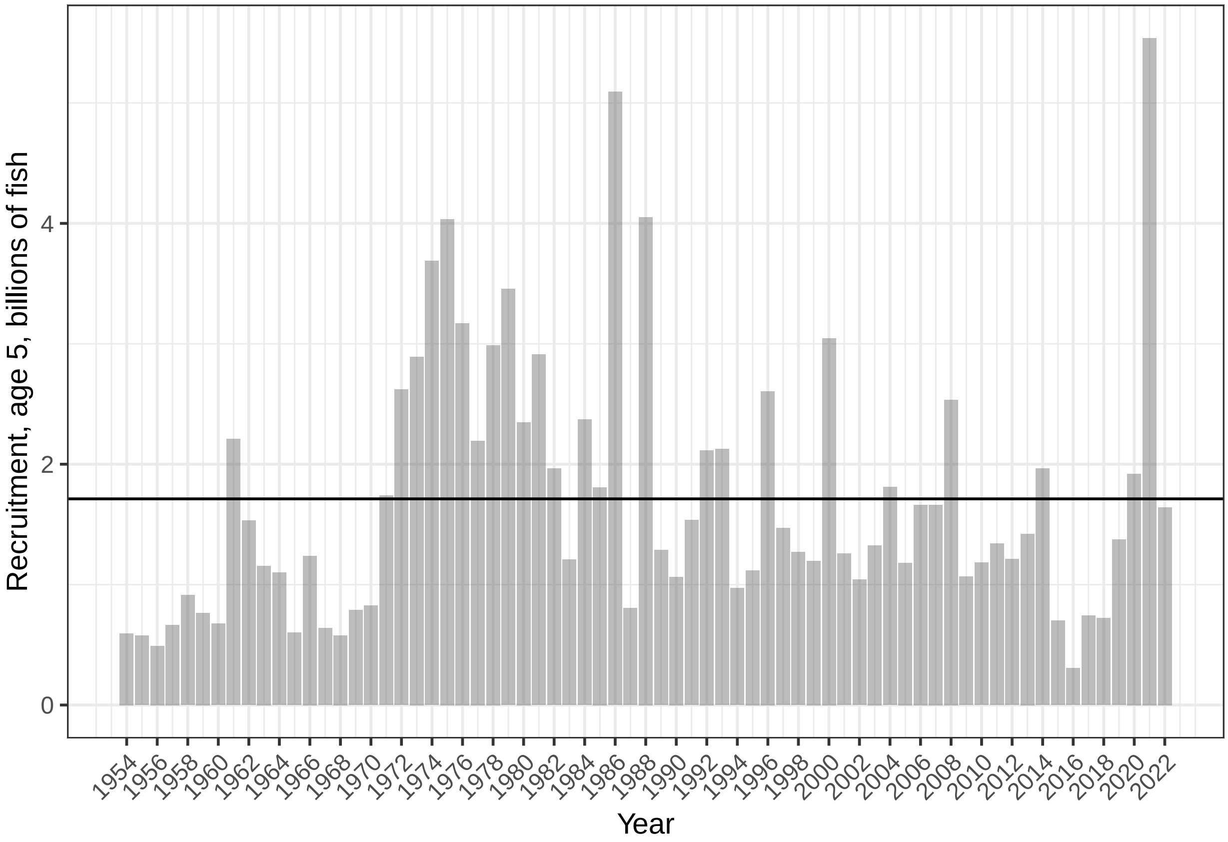


Figure 40: Year-class strength of age 5 yellowfin sole estimated by the stock assessment model. The horizontal line represents the average of the estimates from recruitment, 1954-2022, 1.71 billion, Model 22.0.

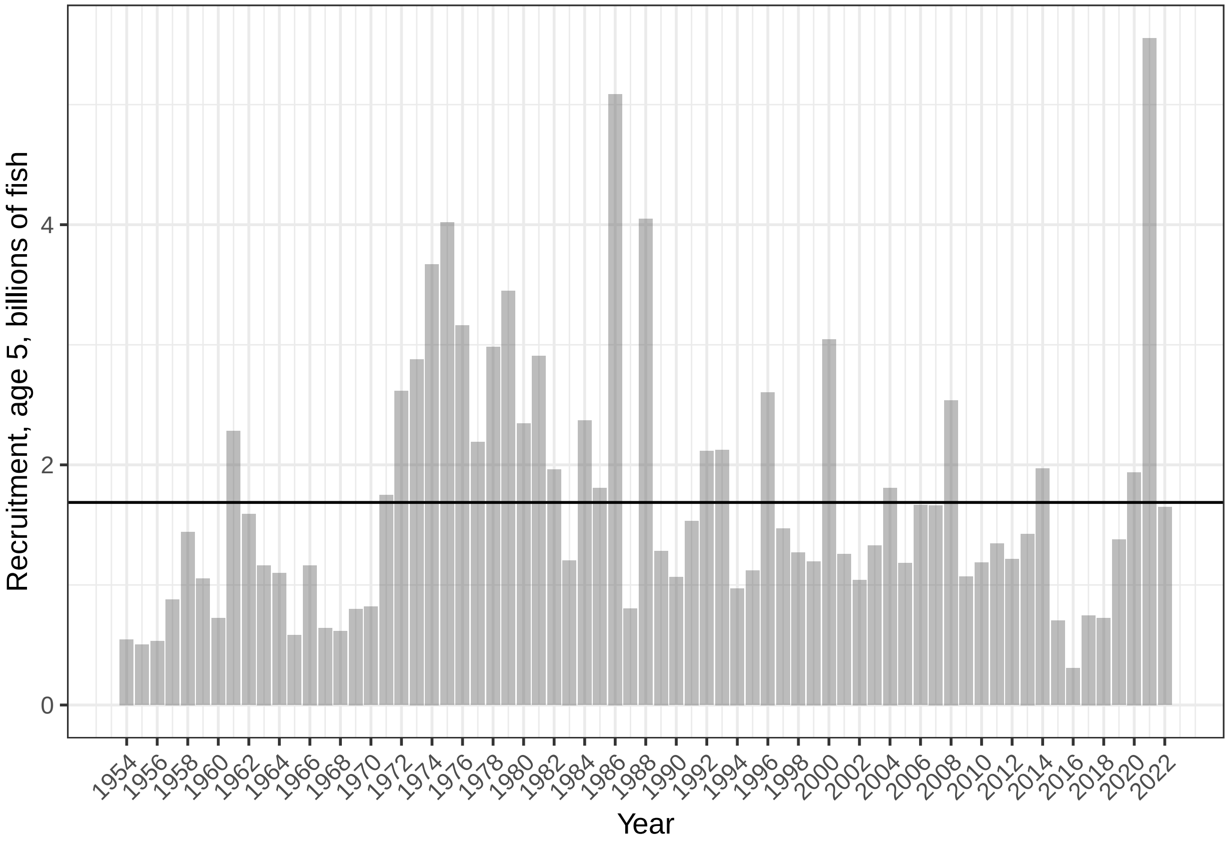


Figure 41: Year-class strength of age 5 yellowfin sole estimated by the stock assessment model. The horizontal line represents the average of the estimates from recruitment, 1954-2019, 1.69 billion, Model 22.1.

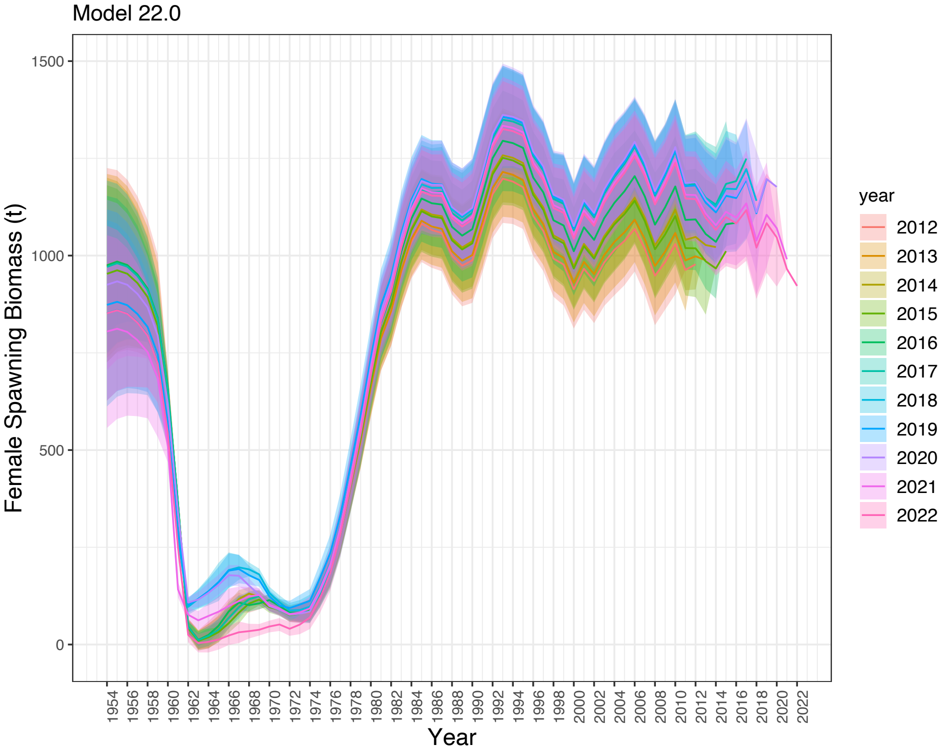


Figure 42: Retrospective plot of female spawning biomass for yellowfin sole Model 22.0. Mohn's Rho for this model was -0.007.

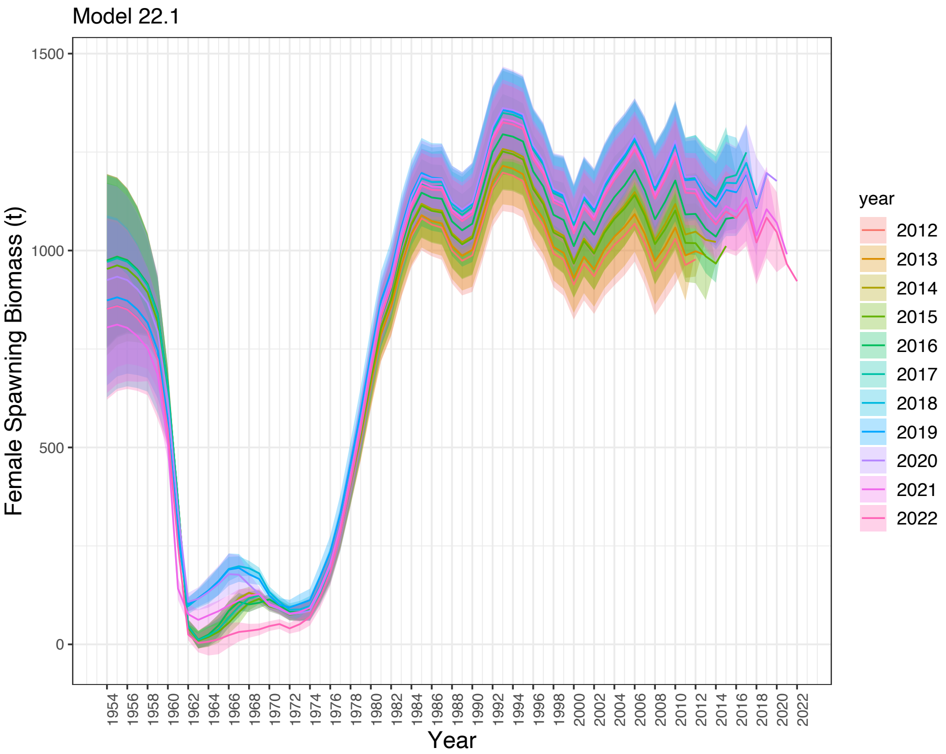


Figure 43: Retrospective plot of female spawning biomass for yellowfin sole Model 22.1. Mohn's rho for this model was 0.007.

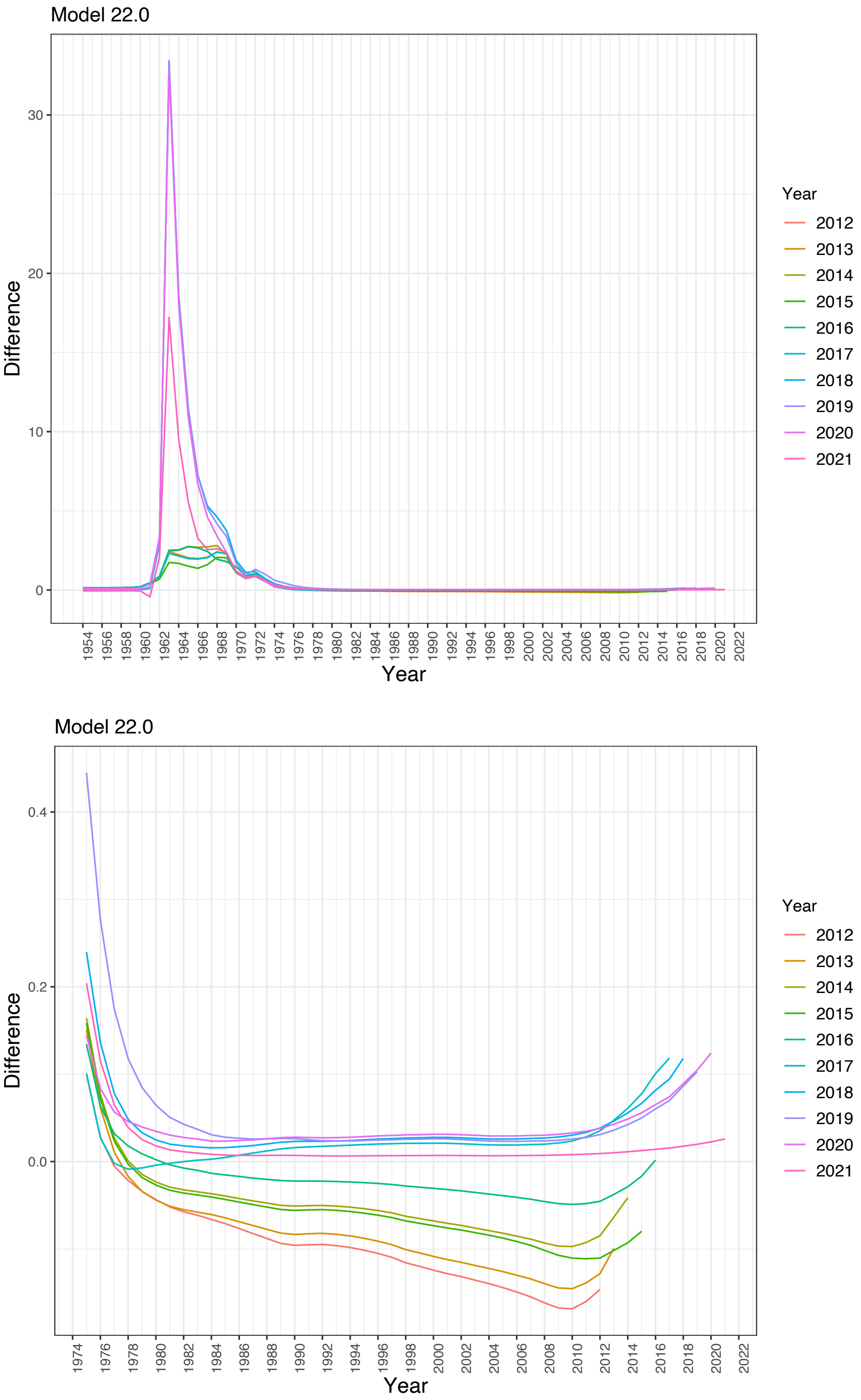
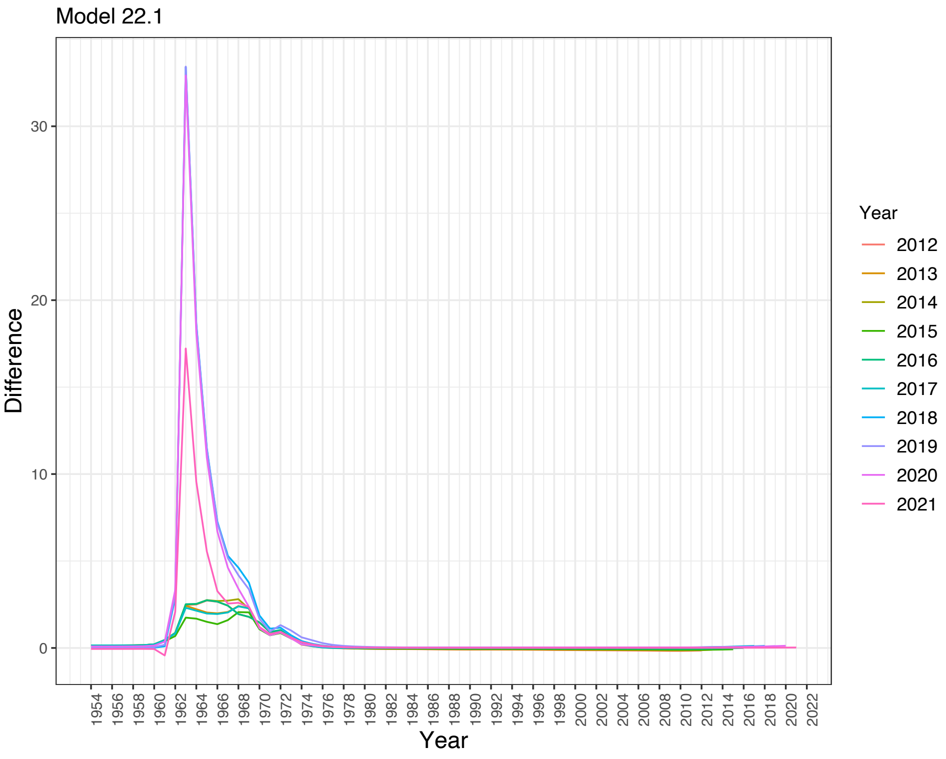


Figure 44: Relative differences in spawning biomass between the 2022 model and the retrospective model run for years 2021 through 2012, yellowfin sole Model 22.0. The upper panel includes all years while the lower panel is shown for 1974 - 2022.



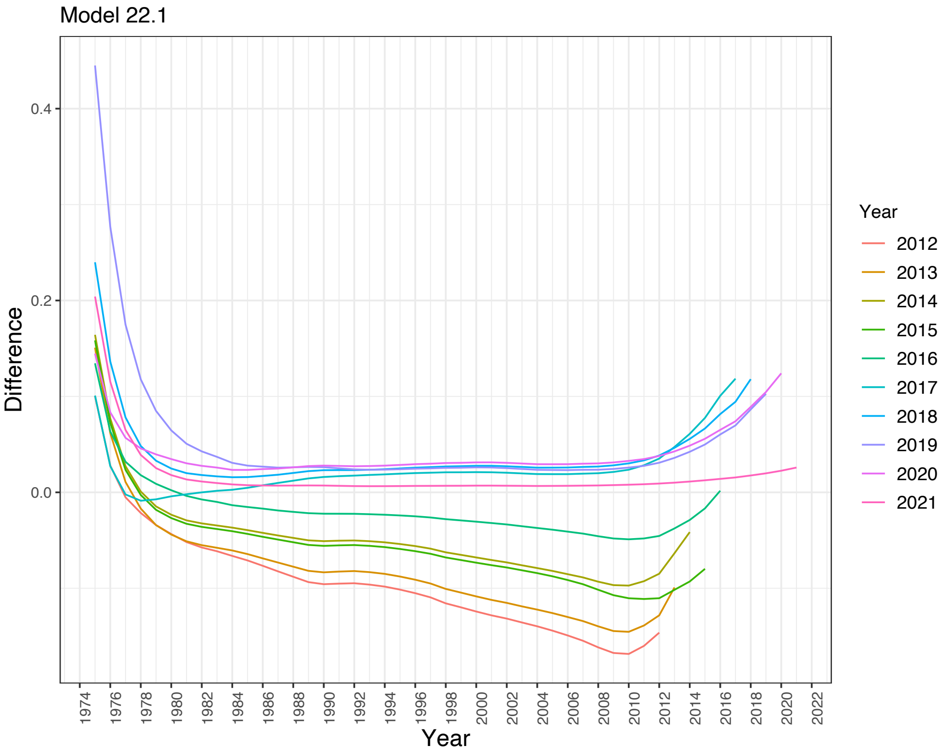


Figure 45: Relative differences in spawning biomass between the 2022 model and the retrospective model run for years 2021 through 2012, yellowfin sole Model 22.1. The upper panel includes all years while the lower panel is shown for 1974 - 2022.

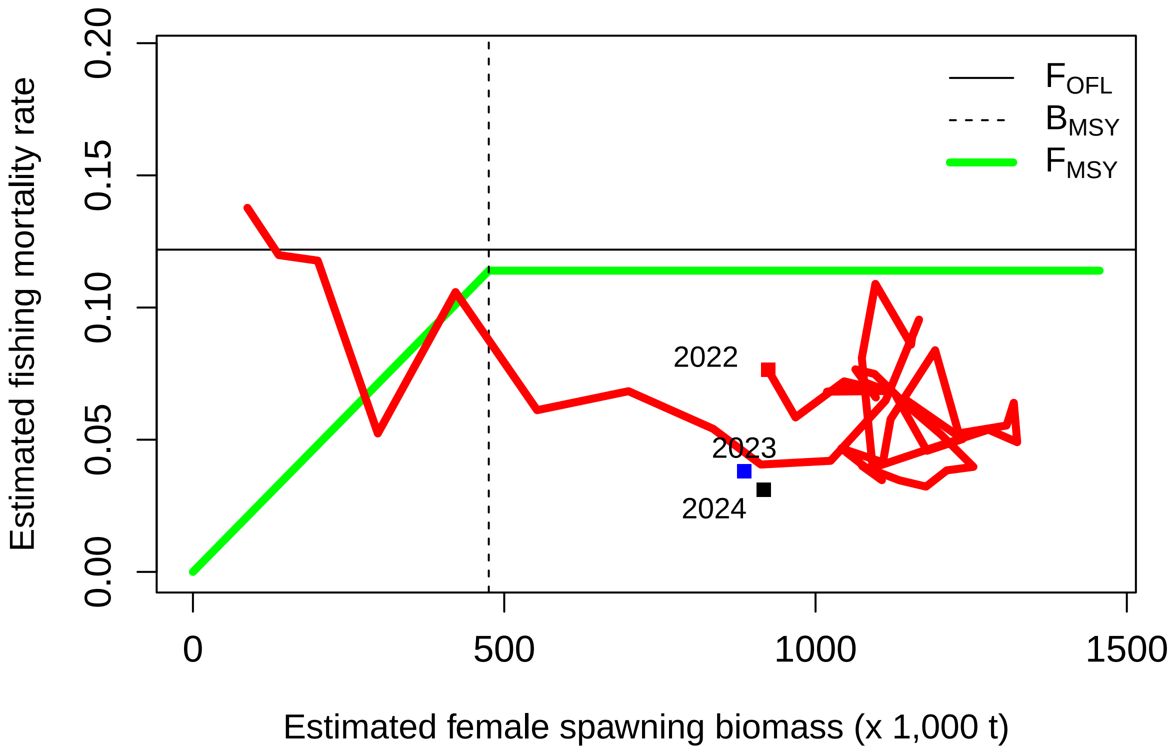


Figure 46: Yellowfin sole fishing mortality rate and female spawning biomass from 1975 to 2022 compared to the F35% and F40% control rules, based on Model 22.1. Vertical line is B35%. Squares indicate estimates for 2022, 2023, and 2024.

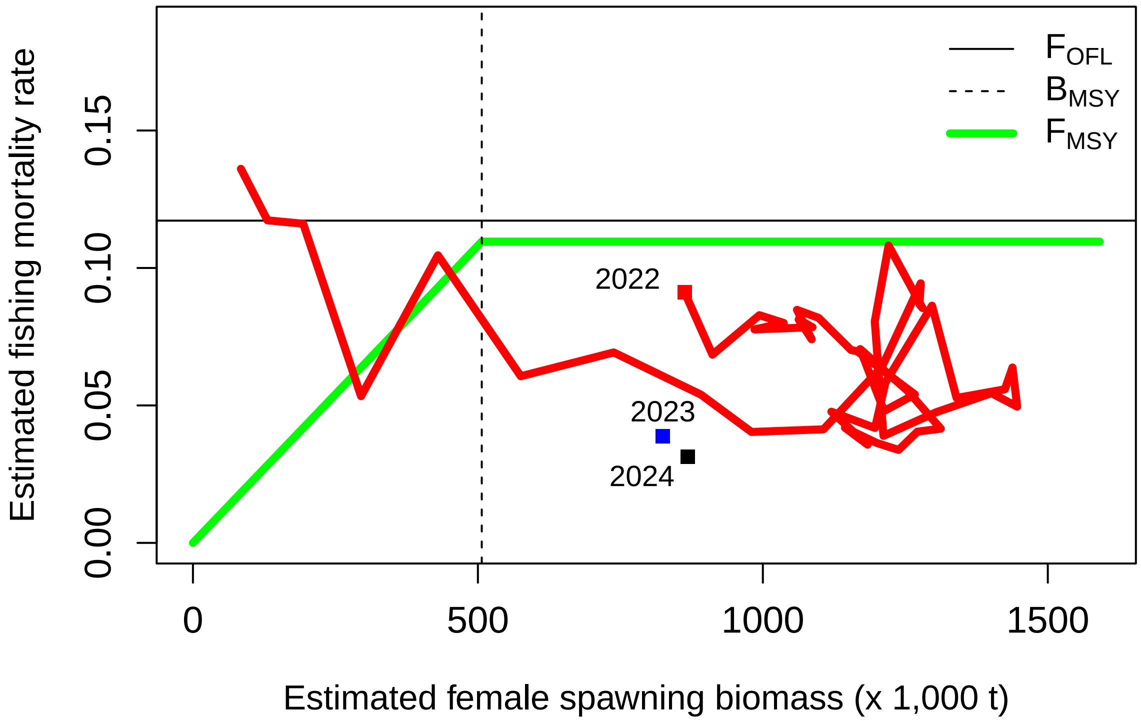


Figure 47: Yellowfin sole fishing mortality rate and female spawning biomass from 1975 to 2022 compared to the F35% and F40% control rules, based on Model 22.0. Vertical line is B35%. Squares indicate estimates for 2022, 2023, and 2024.

Appendix A

Flatfish (BSAI) Economic Performance Report for 2021 (Author: Ben Fissel) with updated tables for 2022 (Author: Anna Abelman).

BSAI FMP flatfish are predominantly caught in the Eastern Bering Sea by catcher/processors in the Amendment 80 Fleet. In 2020, total catch of FMP flatfish in the BSAI was 214 thousand t. Retained catch was 203.5 thousand t, which was a 3% increase over 2019 and was below the average catches between 2011-2015. The two most significant flatfish species in terms of market value and volume are yellowfin and rock sole. These two species accounted for 65% and 12%, respectively, of the retained flatfish catch. Flathead sole, arrowtooth flounder, and Kamchatka flounder are also caught in significant quantities accounting for approximately 5-10% of the retained flatfish. The remainder of the catch volume is comprised of other flatfish which includes Alaska plaice and Greenland turbot. First-wholesale value decreased 17% to $175 million with a 20% decrease in prices.

COVID-19 had an unprecedented impact on fisheries in Alaska. Undoubtedly, one of the significant economic impacts experienced by the industry were the mitigation costs experienced by the fishing and processing industries to continue to supply national and global markets for seafood. Existing data collections do not adequately capture these costs, and as such, this report focuses on catch, revenues, and effort and changes occurring during the most recent year. BSAI flatfish catch levels relative to TAC were within a typical range suggesting that COVID-19 did not have a significant impact on catch levels. In contrast to changes in landings, however, there was a notable decrease in prices for many of the products with significant exports to China for reprocessing. This includes BSAI flatfish, which has significant end markets in North America and Europe in both foodservice and retail. The downward pressure on these prices is likely the result of COVID-19 related logistical difficulties in international shipping and inspections, as well as foodservice closures, and compounded the downward pressure on prices from tariffs. This downward pressure on fish product prices in the first-wholesale market coupled with cost pressure from COVID-19 mitigation efforts likely resulted in negative impacts on net revenues (Table B1).

In 2008, Amendment 80 to the BSAI FMP rationalized the non-pollock groundfish fisheries by instituting a catch-share system that annually allocates quota. The group of catcher processors managed under this system is referred to as the Amendment 80 Fleet. The species targeted by the Amendment 80 fleet include flatfish. Amendment 80 also mandated improved retention and utilization of fishery resources, which lowered discard and bycatch rates. Since 2008 total FMP flatfish catch has increased to an average of 265 thousand t over 2008-2012 from 184 thousand t in 2003-2007, and retention has increased from approximately 70% to more than 90%. In late 2014 flatfish harvest specification flexibility was implemented through Amendment 105 that allows Amendment 80 and CDQ entities to exchange harvest allocation between yellowfin sole, rock sole, and flathead sole. The Alaska flatfish undergo relatively low fishing pressure and harvests are routinely below their TAC and TACs are below the Allowable Biological Catches (ABC) because of the 2 million metric ton cap on Bering Sea groundfish catch. While the TAC is not typically a binding constraint on the fishery, industry may react to TAC changes. Since 2012 approximately 75-80% of the aggregate flatfish TACs have been caught and TACs are approximately 43-55% of the aggregate ABCs, though these proportions vary across individual species.

First-wholesale value in the BSAI flatfish fisheries decreased 17% to $175million with a 23% decrease in yellowfin sole price, a 14% decrease in the rock sole price, a 25% decrease in the flathead sole price, and a 14% decrease in the arrowtooth flounder price. Prices for most flatfish were at a decadal high in 2018 and the decreases in 2020 brought the average 2020 price across species to a level that was approximately equal to the 2011-2015 average price. Flatfish are primarily processed into the headed-and-gutted (H&G) and whole fish product forms and changes in production largely reflect changes in catch. The export volume of yellowfin sole and rock sole is approximately 75-90% of the annual volume of processed products. Exports are primarily destined for China and South Korea, with China typically accounting approximately 80-85% of total exports. In 2019 China's share of exports dropped to 71% and South Korea's share of value increased from approximately 15% to 20% in 2019. A significant share of this product is re-processed into fillets and re-exported to North American and European markets. Flatfish can serve as a substitute for other higher priced whitefish products, and price changes for these other species can influence flatfish demand. Some rock sole is processed as H&G with roe, which is a higher priced product that is primarily destined for Japanese markets. The Alaska flatfish fishery became MSC certified in 2010 and received the Responsible Fishery Management (RFM) certification in 2014. Certification provides access to some markets, particularly in Europe, and may enhance value. Some media reports have attributed the price increase in 2011 to the MSC certification and Asian markets where demand is expected to increase with growth in the middle class population. Reduced fishing opportunities in 2013-2014 for higher valued Atka mackerel may have diverted additional fishing effort towards flatfish increasing catch in these years. Increased supply and inventories from the additional catch put downward pressure on prices. As Atka mackerel fishing resumed more normal levels in 2015 and later, flatfish supply and inventories were reduced, prices began to rise. Atka mackerel catches were high in 2017 and 2018 which may have contributed to the reduced catch of flatfish despite high prices. Because of China's significance as a re-processor of flatfish products, the tariffs between the U.S. and China, which begun in 2018, have put downward pressure on flatfish prices which has inhibited value growth in rockfish markets. Flatfish were among the species to receive relief under the USDA Seafood Tariff Relief Program in 2019-2020. Industry lacks immediate alternative reprocessing options to China on a large scale. Export quantities of flatfish increased in 2020 from 2019 and the share of exports to China was consistent with the average over the last decade (Table B2). The COVID-19 pandemic created supply chain logistical difficulties, particularly in China, which put downward pressure on prices. In addition, foodservice closures in major markets also likely impacted prices negatively for flatfish finished goods.

Table B1. BSAI flatfish catch and first-wholesale market data. Total and retained catch (thousand metric tons), number of vessels, first-wholesale production (thousand metric tons), value (million US$), price (US$ per pound), and head and gut share of production; 2011-2015 average and 2016-2020.

	2011-2016 Average	2017	2018	2019	2020	2021
Total catch K mt	262.22	211.4	212.2	208.6	214.1	169.2
Retained catch K mt	238.152	198.71	197.47	198.22	203.52	160.99
Yellowfin sole share of retained	57.35%	64.73%	64.48%	63.62%	64.68%	66.28%
Rock sole share of retained	22.14%	17.08%	13.75%	12.30%	12.12%	8.31%
Flathead sole share of retained	4.96%	4.07%	5.15%	7.52%	4.07%	5.89%
Arrowtooth and Kamchatka flounder share of retained	8.62%	4.95%	4.48%	6.70%	8.36%	8.96%
Vessels #	37.2	35	35	35	33	28
Total flatfish first-wholesale production K mt	142.45	116.9	115.11	116.18	121.32	91.69
Total flatfish first-wholesale value M US$	$192.83	$192.37	$211.65	$209.83	$174.56	$118.38
Total flatfish first-wholesale price/lb US$	$0.61	$0.75	$0.83	$0.82	$0.65	$0.59
Yellowfin sole share of value	53.04%	57.57%	64.55%	61.41%	61.73%	63.76%
Yellowfin sole price/lb US$	$0.54	$0.65	$0.81	$0.78	$0.60	$0.55
Rock sole share of value	22.65%	15.75%	13.76%	11.63%	12.01%	6.84%
Rock sole price/lb US$	$0.66	$0.72	$0.89	$0.83	$0.72	$0.55
Flathead sole share of value	5.33%	4.17%	5.63%	7.28%	3.36%	5.05%
Flathead sole price/lb US$	$0.78	$0.86	$0.96	$0.85	$0.63	$0.58
Arrowtooth and Kamchatka flounder share of value	9.90%	8.64%	4.54%	6.74%	9.45%	12.04%
Arrowtooth and Kamchatka flounder price/lb US$	$0.77	$1.36	$1	$0.91	$0.79	$0.82
H&G share of value	86.32%	89.68%	93.04%	93.95%	92.83%	96.44%

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table B2. Flatfish U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, BSAI share of U.S. production. U.S. yellowfin sole and rock sole export volume (thousand metric tons), U.S. export value (million US dollars), U.S. export price (US dollars per pound), the share of U.S. export value from China, and the Euro/U.S. Dollar exchange rate; 2012-2016 average and 2017-2021.

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

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau, http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx. 1 - The BSAI FMP share of U.S. production is calculated as the BSAI retained catch divided by the FAO's U.S. production of flounder, halibut and sole.