8. Assessment of the Flathead Sole Stock in the Gulf of Alaska

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Executive Summary

Summary of Changes in Assessment Inputs

1. Added catch data: finalized catch for 2017-2021, estimated catch biomass for 2022 using observed catches through October 13, 2022 added to average catches thereafter;
2. Added design-based Gulf of Alaska Trawl Survey biomass data for 2019 and 2021;
3. Added Gulf of Alaska Trawl Survey length composition data for 2019 and 2021;
4. Added Fishery length composition data from 2018-2022, current through October 13, 2022.
5. Updated all historical data to reflect what is currently available in AFSC and AKFIN databases.
6. Updated aging error matrix using Punt et al. (2008) method for GOA Flathead Sole double reads; previous values were from BSAI FHS.

Summary of Results

No new models were considered this year. The previously accepted model, referred to herein as Model 17.0 (2017) was updated with new data, as described above, and the modeling software was bridged from Stock Synthesis v3.24u to v3.30.17. The present model is referred to as Model 17.1a (2022).

The key results of the assessment, based on the author's preferred model (Model 17.1a (2022)), are compared to the accepted 2021 partial update assessment (Kapur 2021) in the table below.

Quantity	As estimated or *specified last* year for: 2022	2023	As estimated or *recommended this* year for: 2023	2024
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	279,975	276,796	294,188	293,277
Projected Female spawning biomass (t)	97,614	97,876	94,059	95,932
$B_{100\%}$	91,551	91,551	92,582	92,582
$B_{40\%}$	36,620	36,620	37,033	37,033
$B_{35\%}$	32,043	32,043	32,404	32,404
F_{OFL}	0.36	0.36	0.36	0.36
$maxF_{ABC}$	0.28	0.28	0.29	0.29
F_{ABC}	0.28	0.28	0.29	0.29
OFL (t)	48,928	48,757	48,161	49,073
maxABC (t)	40,175	40,046	39,480	40,222
ABC (t)	40,175	40,046	39,480	40,222
Status	As determined *last year* for: 2020	2021	As determined *this year* for: 2021	2022
Overfishing	no	NA	no	NA
Overfished	NA	no	NA	no
Approaching Overfished	NA	no	NA	no

Projections are based on catches of 687 t used in place of maximum permissible ABC for 2022 and 1908 t used in place of maximum permissible ABC for 2023 and 2024. The 2022 catch was estimated using the true observed catches from AKFIN (through October 13, 2022), plus the average weekly catches from Oct 14-Dec 31 from the last five years. The 2023 and 2024 catch was estimated as the average of the total catch in each of the last 5 years (2017-2021).

Area Allocation of Harvest

Area apportionment for ABC of Flathead sole is currently based on the proportion of survey biomass projected for each area using the new survey averaging random effects model "REMA" developed by the survey averaging working group (see https://github.com/afsc-assessments/rema for more information). A bridging exercise confirmed that this package, written in Template Model Builder, produces the same results as the ADMB-RE package used for this stock in previous years when fitting the three geographic strata simultaneously. Please refer to the 2017 full stock assessment report (Turnock *et al.* 2017) for information regarding the apportionment rationale for GOA Flathead sole.

The following table shows the recommended ABC apportionment for 2023 and 2024. The author notes that in previous projections of the Flathead sole model (including those done in 2021), the time series of recruitment and spawning biomass used for projections began in 1984 (the start of the main period for recruitment deviations), not 1977 as requested by a 1999 memo by R. Marasco. For consistency between previous assessments and the current assessment (Model 17.1a (2022)), inputs to the projection model continue to use the time series of recruitment and SSB beginning in 1984, which corresponds to the onset of most survey data. Projections assume recruitment at age 3.

Quantity	Year	Western	Central	West Yakutat	Southeast	Total (t)
Area Apportionment %		32.40	54.43	5.88	7.29	
ABC (t)	2023	12,793	21,487	2,320	2,880	39,480
ABC (t)	2024	13,033	21,892	2,363	2,934	40,222

Responses to SSC and Plan Team Comments on Assessments in General

"The Team recommends all GOA authors evaluate any bottom trawl survey information used in their assessment prior to 1990 including the 1984 and 1987 surveys and conduct sensitivity analyses to evaluate their usefulness to the assessment. This may apply for Aleutian Islands surveys but this was only raised during GOA assessment considerations."

This was also raised in the FHS-specific CIE review (discussed below). Sensitivity analyses were conducted leaving out these data, and derived quantities remained nearly identical for the recent period.

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

A risk table has been included in this assessment; 2021 was a partial assessment. No important concerns or issues were identified, so no reduction from maxABC is recommended.

"Any new model that diverges substantially from the currently accepted model will be marked with the two-digit year …" (SSC December 2016)

The model presented this year follows this convention and is labeled as Model 17.1a (2022), to reflect that the structure has not changed from the previously accepted full model from 2017. The latter is referred to as Model 17.0 (2017).

Responses to SSC and Plan Team Comments Specific to this Assessment

"The SSC concurs with the PT and author that a priority for future assessments is to analyze ageing error data for GOA flathead sole using methods described in Punt et al. (2008) and to incorporate a resulting ageing error matrix into the assessment. In addition, the SSC supports the PT and author's recommendations that future analyses should explore the relationship between natural mortality and catchability in the model, alternative parameter values, and the effects of these parameters on estimation of selectivity and other parameters. Finally, the SSC encourages the author to explore ways to better account for scientific uncertainty, especially uncertainty associated with parameters that are currently fixed in the model. (SSC Dec 2017)"

This assessment re-conducted the likelihood profiling exercises on catchability (q), natural mortality (M), and combinations thereof done in the previous full assessment (Turnock *et al.* 2017). The data weights remained unchanged during profiling. For this cycle, we extended the upper limit of q values included in the profile to $log(10)$ (about 2.3), and also conducted a profile on unfished recruitment R_0. Results from these investigations are shown in Figures 8.38 to 10.42. When each parameter is profiled independently (Figures 8.38 and 10.40), the minimum total negative log-likelihood for Model 17.1a (2022) occurred at q = 1.56 and M = 0.26 (in Model 17.0 (2017), these values were 1.4 and 0.28, respectively; though values over 1.4 for q were not explored in 2017). The profile on q is shallow for all data besides the age data below 1.6, and both the index and length composition data profiles on q were minimized closer to 1. It appears that given the current model structure, there is conflict between the age and length data regarding the value of M, whereby the age data suggests the highest overall value for M (0.28) and the length composition data suggests M to be half of that (0.14). This conflict was also observed during the last assessment (Turnock *et al.* 2017). When q and M for both sexes are profiled concurrently, the total likelihood was minimized at roughly the same values as those found in the independent exercise (1.64 for q and 0.27 for M, Figure 8.41), qualitatively similar to that of the previous assessment). However, there are a range of combinations of these values which were statistically indistinguishable. Profiles wherein natural mortality was fixed at various combinations for each sex indicated that the total likelihood was minimized when M for both sexes was 0.255 (Figure 8.39. We did not have time to examine the individual components of these 2-dimensional likelihood profiles; revisiting selectivity is likely needed to aid interpretation of these results, which was out of scope for the current assessment. A profile on R_0 (Figure 8.42) indicated that unfished recruitment is well-estimated in the present model configuration, where the length data suggests a slightly higher value for R_0 than other datasets. This finding is consistent with observations during the data weighting process, whereby the length data consistently suggest a higher model scale (higher $R0$ and lower M), and the dynamics change greatly if those data are not up-weighted. For future iterations, assessors should consider the interaction between data weights (which up-weight all lengths and down-weight all CAAL data), the corresponding fits to the survey (which are poor in the last two years) and length compositions (which improve when M is below 0.18). Overall, it was out of the scope of the present assessment to propose any of these explorations as alternative models, but there is a strong basis for revisiting any or all of these parameterizations to satisfy the SSC/PT requests moving forward. See also Data Gaps and Research Priorities.

A comparison of the biomass time series for the new base model using both this updated ageing error matrix (Model 17.1a (2022)) and using the matrix from the previously accepted assessment is shown in Figure 8.43. The ageing error matrix has been updated using the latest age-read data specific for GOA Flathead sole. A detailed overview of how the matrix values were chosen is available at https://mkapur-noaa.github.io/goa-fhs-2022/AgeingError_Writeup_Static.html.

Responses to CIE (2019) Comments agreed upon by all three reviewers

The comments below are from Appendix 4 of the CIE review conducted in July 2019 by panelists Cordue, Tingley, and Trzcinski. Note that this review included rex and Dover soles in addition to flathead, and the Appendix indicates that some comments might be applicable to flathead only in a general sense.

"The Gulf of Alaska Bottom Trawl Surveys (BTS) conducted in 1984 and 1987 used different vessels, a different approach and with different timing. These surveys should not be considered as part of the same timeseries as the subsequent BTS timeseries. Specifically, the biomass estimates and the composition data from these two surveys should be dropped from each of these assessments, and probably from all other assessments also…The surveys in 1990 and 1993 had a different timing (later) and somewhat different survey structure. While clearly not as 'different' as the 1984 and 1987 surveys, there is sufficient difference that model sensitivities should be run on a species-by-species (stock-by-stock) basis that include and exclude the biomass and composition data from these two surveys."

We did not have time to conduct more than one sensitivity analysis for this topic (e.g., removing 1980s survey data, separating early 1990s survey data, and combinations thereof). Instead, we conducted one sensitivity analysis where all survey biomass, length composition, and conditional age-at-length data before 1990 were truncated (removed) due to the differences in survey design. Because the intent with this assessment was to keep the data and model structure as similar as possible to the 2017 assessment, the survey biomass and length data from the 1980s are still included in the base model. Like the 2017 assessment, the 2022 model does not include disabled Conditional Age-at-Length (CAAL) data from the survey before 1990.

A stable web site with abbreviated results from sensitivity runs explored during this assessment is available online at https://mkapur-noaa.github.io/goa-fhs-2022/sensitivities_goa_fhs_2022.html. Because we are not proposing any of these model runs as alternative models they have been excluded from this document, but qualitative descriptions of the results are included in the applicable sections.

"A more consistent, analytical and defensible approach to the scaling and stratification of fisheries data should be followed. This should meet accepted 'best practice' approaches, including, for example, studying the spatial and temporal patterns of length and age followed by appropriate stratification and scaling."

The authors agree. Revisiting the methods by which, for example, composition data are expanded from survey hauls is an active area of research. We did not revisit it for this assessment cycle.

"Models should not assume that the survey q is equal to 1. Informed priors should be developed on a stock-by-stock basis."

Model 17.1a (2022) has q fixed at 1, as in the previous assessment (Model 17.0 (2017)). We explored a sensitivity run where q was either estimated with bounds from -15 to 15, or calculated analytically from the biomass available to the survey. In both cases, q was either estimated or calculated to be ~1.6, consistent with the location of the MLE shown in the likelihood profile (Figure 8.40). However, these changes resulted in worse fits to the survey and drastically different biomass time series, so further research is needed before incorporating either approach (with the potential inclusion of a prior) as suggested by the CIE. The author recommends discussions with the Survey group about the encounter rate of Flathead sole, and the potential for design-based indices to alleviate some of these issues.

"Recruitment deviates should not be estimated where there is no information to inform the estimation, i.e. there has to be age data from a survey or fishery to inform the estimation process."

We conducted a sensitivity for Model 17.1a (2022) wherein the "early" period for recruitment deviations begins at the onset of survey biomass & length composition data in 1983 (though see note above about differences in survey design). In that sensitivity model, terminal SSB values are lower than Model 17.1a (2022), there is a notably low recruitment deviation estimated in 2018, and survey fits in the recent years are lower (and more accurate) than Model 17.1a (2022). This sensitivity also fit the first and third year of survey biomass data more accurately, and effectively captured the declining trend in survey abundance (whereas the fits to the same data for Model 17.1a (2022) suggest an overall upward trend).

Introduction

Flathead sole (*Hippoglossoides elassodon*) are distributed from northern California, off Point Reyes, northward along the west coast of North America and throughout the Gulf of Alaska (GOA) and the Eastern Bering Sea (EBS), the Kuril Islands, and possibly the Okhotsk Sea (Hart 1973). They occur primarily on mixed mud and sand bottoms Mcconnaughey and Smith (2011) in depths < 300 m (Stark 1995). The flathead sole distribution overlaps with the similar-appearing Bering flounder (*Hippoglossoides robustus*) in the northern half of the Bering Sea and the Sea of Okhotsk (Hart 1973), but not in the Gulf of Alaska.

Adults exhibit a benthic lifestyle and occupy separate winter spawning and summertime feeding distributions on the EBS shelf and in the GOA. From over-winter grounds near the shelf margins, adults begin a migration onto the middle and outer continental shelf in April or May each year for feeding. The spawning period may range from as early as January but is known to occur in March and April, primarily in deeper waters near the margins of the continental shelf. Eggs are large (2.75 to 3.75 mm) and females have egg counts ranging from about 72,000 (20 cm fish) to almost 600,000 (38 cm fish). Eggs hatch in 9 to 20 days depending on incubation temperatures within the range of 2.4 to 9.8°C and have been found in ichthyoplankton sampling on the southern portion of the BS shelf in April and May (Waldron 1981). Larvae absorb the yolk sac in 6 to 17 days, but the extent of their distribution is unknown. Nearshore sampling indicates that newly settled larvae are in the 40 to 50 mm size range (Norcross 1996). Fifty percent of flathead sole females in the GOA are mature at 8.7 years, or at about 33 cm (Stark 2004). Juveniles less than age 2 have not been found with the adult population and probably remain in shallow nearshore nursery areas.

Fishery

Description of the Directed Fishery

Flathead sole in the Gulf of Alaska are caught in a directed fishery using bottom trawl gear. Typically 25 or fewer shore-based catcher vessels from 58-125' participate in this fishery, as do 5 catcher-processor vessels (90-130'). Fishing seasons are driven by seasonal halibut prohibited species catch (PSC) apportionments, with approximately 7 months of fishing occurring between January and November. Catches of flathead sole occur almost entirely in the Western and Central management areas in the gulf (statistical areas 610 and 620 + 630, respectively, Table 8.1). Recruitment to the fishery begins at about age 3.

Catch Patterns

Historically, catches of flathead sole have exhibited decadal-scale trends that are likely due to management actions to reduce halibut bycatch (Figure 8.1). From a high of ~2000 t in 1980, annual catches declined steadily to a low of ~150 t in 1986 but then increased steadily, reaching a high of ~3100 t in 1996. Catches subsequently declined over the next three years, reaching a low of ~900 t in 1999, followed by an increasing trend through 2010, when the catch reached its highest level ever (3,854 t). Catch then declined to 2,000 t in 2015 and was 2,421 t in 2016, and has fallen below 1000 t in recent years. Catches are largely driven by bycatch caps for the flathead sole fishery. Based on observer data, the majority of the flathead sole catch in the Gulf of Alaska is taken in the Shelikof Strait and on the Albatross Bank near Kodiak Island, as well as near Unimak Island (Stockhausen 2011). Previously, most of the catch is taken in the first and second quarters of the year (Stockhausen 2011).

Management Measures

Annual catches of Flathead sole have been well below TACs in recent years (Figure 8.2), although the population appears to be capable of supporting higher exploitation rates. Limits on Flathead sole catches are driven by restrictions on halibut PSC, not by attainment of the TAC (Stockhausen 2011). The stock within the GOA is managed as a unit stock but with area-specific ABC and TAC apportionments to avoid the potential for localized depletion. Little is known on the stock structure of this species. See Stockhausen (2011) for a description of the management history of Flathead sole. Non-commercial catch of GOA Flathead sole are in shown in Appendix 10a. Supplemental catch data.

Data

The following table summarizes the data used in the stock assessment model for Flathead sole:

Source	Data	Years
U.S. trawl fishery	Catch biomass	1977-2022
	Catch length composition	1982, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022
GOA bottom trawl survey	Survey biomass	1984-1999 (triennial), 2001-2021 (biennial)
	Survey length composition	1984-1999 (triennial), 2001-2021 (biennial)
	Survey age composition, conditioned on length	1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021

Fishery

Catch

The assessment included catch data from 1977 to 2022 (Figure 8.1). 2022 catches were estimated by adding the observed catch as of October 13, 2022 to the average catch from Oct 14-Dec 31 from the previous 5 years, for a total estimate of 687 t. Historically, catches have been well below the management specifications, on the order of 10% of Total Allowable Catch over the last 10 years (Figure 8.2). Catches of flathead sole occur almost entirely in the Western and Central management areas in the GOA (statistical areas 610 and 620 + 630, respectively (Table 8.1)).

Age and Size Composition

Fishery length composition data were included in 2cm bins from 6-70 cm. Compositional data were omitted in years where there were less than 15 hauls that included measured flathead sole: 1983, 1985, 1986, 1988, 1989, 1990 and 1999. The effective sample size for fishery length composition data were the annual number of hauls (Pennington and Volstad 1994). These data were current on AKFIN as of October 13, 2022. Fishery length composition observations used in the assessment can be seen in the Stock Synthesis data file (`data.ss`) hosted here: https://github.com/mkapur-noaa/goa-fhs-2022/ModelFiles_PlanTeam.

Survey

Biomass Estimates from Trawl Surveys

Survey biomass estimates originate from a cooperative bottom trawl survey conducted by the U.S. and Japan in 1984 and 1987 and a U.S. bottom trawl survey conducted by the Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (RACE) Division thereafter. Calculations for final survey biomass and variance estimates are fully described in Wakabayashi et al. (1985). Depths 0-500 meters were fully covered in each survey and occurrence of Flathead sole at depths greater than 500 meters is rare (Table 8.4). The survey excluded the eastern region of the Gulf of Alaska (the Yakutat and Southeastern areas) in 2001. As discussed above, GOA trawl surveys in 1984 and 1987 were done in cooperation with Japanese fleets and had gear-area combinations distinct from later years, in addition to 30-minute tows. In 1993, the GOA trawl survey design changed from 30-minute to 15-minute tows. These changes are not reflected in the current model structure, but were examined via a sensitivity run and are discussed further in the Data Gaps and Research Recommendations section.

The total survey biomass estimates and CVs that were used in the assessment are listed in Table 8.5. Survey biomass decreased slightly from 185,840 t in 2019 to 180,000 t in 2021. Figure 8.3 shows maps of survey CPUE in the GOA for the most recent two survey years; survey CPUE in both years was highest in the Central and Western GOA.

Age and Size Composition

This assessment includes sex-specific length compositions from the trawl survey, as well as age frequencies of fish by length (conditional age-at-length, CAAL). For both compositional data types, the effective sample size was the number of hauls (Pennington and Volstad 1994); see section on data weighting for further discussion. CAAL data before 1990 was not included for consistency with previous models. Marginal survey age composition data is also included in the data input file, but is "ghosted" and therefore does not contribute to the joint negative log likelihood.

We use conditional age-at-length data for the following reasons: 1) The approach preserves information on the relationship between length and age and provides information on variability in length-at-age such that growth parameters and variability in growth can be estimated within the model. 2) The approach resolves the issue of double-counting individual fish when using both length- and age-composition data (as length-composition data are used to calculate the marginal age compositions). See Stewart (2005) for further discussion of the use of conditional age-at-length data in fishery stock assessments.

Input survey length composition and CAAL data, and the corresponding sample sizes used in the assessment can be seen in the Stock Synthesis data file (`data.dat`) hosted here: https://github.com/mkapur-noaa/goa-fhs-2022/ModelFiles_PlanTeam.

Analytical approach

General Model Structure

Assessment models for Flathead sole have been conducted using the Stock Synthesis (SS, Methot and Wetzel (2013)) framework since 2018, with visualization via the r4ss package (Taylor *et al.* (2016)). A benchmark assessment was last completed in 2017 (Turnock *et al.* (2017)) using a previous version of SS (version 3.24). The current assessment model was bridged to the most recent version of SS as of early 2022 (version 3.30.17). The bridging approach was selected to produce results most similar to the 2017 benchmark. Specifically, there are discrepancies in the way survey timing is handled in SSv3.30+ and versions prior to 3.30, which meant that we needed to specify the observed survey index as occurring in at the beginning of the year, while aligning the observed survey length and age compositions with the mid-year biomass (month seven). An examination of likelihoods by component indicated that the converted model (before new data are added) was statistically identical to Model 17.0 (2017).

The proposed assessment model (Model 17.1a (2022)), with updated data and SS software, covers years 1978 to 2022 (there was a typographical error in the previous assessment document; Model 17.0 (2017) also began in 1978). Age classes included in the model run from 1-29 years. Age at recruitment was set at

0 years. The oldest age class in the model, age 29, serves as a plus group. Survey catchability was fixed at 1.0.

Fishery and Survey Selectivity

Fishery and survey selectivity parameters are estimated within the assessment model using an age-based time-invariant double normal functional form, which facilitates exploration of previous or alternative selectivity forms. The double-normal curve for both the survey and fishery is constrained by fixing the descending limb parameter(s) to mimic a logistic shape, as previous assessments found no evidence for dome-shaped selectivity in either. Male selectivity curves for the fishery and survey are estimated as an offset from the respective female curves. The treatment of estimated and fixed double-normal selectivity parameters by fleet and sex are presented in Table 8.6.

Conditional Age-at-Length (CAAL)

A conditional age-at-length approach was used: expected age composition within each length bin was fit to age data conditioned on length (conditional age-at-length) in the objective function, rather than fitting the expected marginal age-composition to age data (which are typically calculated as a function of the conditional age-at-length data and the length-composition data). This approach provides the information necessary to estimate growth curves and variability about mean growth within the assessment model. In addition, the approach allows for all of the length and age-composition information to be used in the assessment without double-counting each sample. The von-Bertalanffy growth curve and variability in the length-at-age relationship were evaluated within the model using the conditional age-at-length approach.

Data Weighting

In the 2013 assessment, the assumptions about data-weighting were re-evaluated using a more formal approach for assessing variability in mean proportions-at-age and proportions-at-length (Francis 2011). To account for process error (e.g. variance in selectivities among years), the relative weights for length or age composition data (lambdas) were adjusted according to the method described in Francis (2011), which accounts for correlations in length- and age-composition data (data-weighting method number T3.4 was used). The 2013 assessment used weights calculated using the Francis (2011) method, but the weights for the fishery length-composition data were increased slightly to improve model stability.

In Model 17.0 (2017), and the 2015 assessment that preceded it, the method described in Francis (2011) was not used because of concerns raised about its use when using conditional age-at-length data. The effective sample size for length composition data was changed to the number of hauls (Volstad and Pennington 1994). In those assessments, scientists implemented the McAllister-Ianelli (McAllister and Ianelli 1997) method for weighting among data sources. In Model 17.1a (2022), the McAllister-Ianelli weights were tuned one time, following the update to the new SS software and addition of all data sources.

Ageing Error Matrix

Stock Synthesis accommodates the specification of ageing error bias and imprecision. The 2015 and 2017 stock assessments incorporated ageing error by using an existing ageing error matrix for BSAI Flathead sole, for which error increased linearly from age 0 to a maximum at age 16. External to this assessment, we revisited the ageing error data for GOA Flathead sole using methods described in Punt et al. (2008) as requested by the recent CIE review. Read-replicate data was made available by the Age & Growth program. We created several candidate models that varied in their treatment of the reader identities, and found that the best model (lowest AIC) was obtained by a pooled-data model which assumed constant bias and sigma across readers (bias is the different-integer age read, and sigma is the variation in true age). A comparison of the previous and updated ageing error matrices is shown in Figure 8.4. BSAI and

GOA Flathead sole are aged by the same individuals using the same techniques and ageing error is expected to be very similar.

A comparison of the biomass time series for the new base model using both this updated ageing error matrix (Model 17.1a (2022)) and using the matrix from the previously accepted assessment is shown in Figure 8.43. The ageing error matrix has been updated using the latest age-read data specific for GOA Flathead sole. A detailed overview of how the matrix values were chosen is available at https://mkapur-noaa.github.io/goa-fhs-2022/AgeingError_Writeup_Static.html.

An examination of Model 17.1a (2022) using the previous ageing error matrix did not have a significant effect on derived quantities.

Recruitment Deviations

Recruitment deviations for the period 1978-1983 were estimated as "early-period" recruits separately from "main-period" recruits 1984-2020 such that the vector of recruits for each period had a sum-to-zero constraint, rather than forcing a sum-to-zero constraint across all recruitment deviations. The "main" recruitment period ends in 2020 as the age at recruitment used for projections beginning in 2023 is assumed to be three years. Recruitment deviations are set to zero for 2021 and 2022.

Recruitment deviations prior to the start of composition data and in the most recent years in the time-series are less informed than in the middle of the time-series, which creates a bias in the estimation of recruitment deviations and mean recruitment that is corrected by estimating a bias adjustment factor following Methot and Taylor (2011). The breakpoints for the bias adjustment ramp are shown in Figure 8.6, and are characterized by a linear increase from zero to a plateau of from 0.9342 from 1950-1993, after corresponding to the onset of regular compositional data; constant bias adjustment from 1993-2016, and a decline from the plateau to zero between years 2016-2022.

These breakpoints were identified using the method presented in Methot and Taylor (2011) as implemented in the `SS_fitbiasramp` function from `r4ss`. Briefly, this method tunes the breakpoints of the bias adjustment ramp to ensure that the estimated recruitment deviates are lognormally mean-unbiased. This approach therefore groups the data and time series into periods of lesser and greater information based on data availability, such that the start of the ramp aligns with the availability of composition data, the ramp down begins the last year those data are informative about recruitment, and the adjustment level is informed by life history.

Description of Alternative Models

No alternative models are presented for consideration this year.

The model presented herein follows the same model structure and data input types as the most recent accepted assessment (Model 17.0 (2017)) for GOA flathead sole. This model has been updated to Stock Synthesis version 3.30.17, and the ageing error matrix has been updated along with all other data sources to reflect the current information provided by AKFIN.

A stable web site with abbreviated results from sensitivity runs explored during this assessment is available online at https://mkapur-noaa.github.io/goa-fhs-2022/sensitivities_goa_fhs_2022.html. Because we are not proposing any of these model runs as alternative models they have been excluded from this document, but qualitative descriptions of the results are included in the applicable sections.

We also present the previously accepted model in its original form (in Synthesis version 3.24) for comparison in Figures 8.7 to 10.11. No new model structures are recommended this year.

Parameters Estimated Outside the Assessment Model

The survey catchability q, time- and age-invariant natural mortality for females and males, variability of recruitment (σ_R), the maturity ogive, the ageing error matrix, sex-specific length-at-age transition matrices, and the weight-length relationship were either estimated outside the assessment model and/or fixed within it, following the same structure as Model 17.0 (2017).

Natural Mortality

The natural mortality rates were fixed at 0.2 for both sexes, as was done for previous assessments. We explore likelihood profiles over M, as well as combinations of M and q, in Likelihood Profile Analyses.

Weight at Length

The weight-length relationship used in Model 17.0 (2017) (Turnock *et al.* 2017) is used in the current assessment: $w_l = \alpha L^{\beta}$ where α = 0.00000428 and β = 3.2298, with length (L) in centimeters and weight (w) in kilograms.

Maturity at Age Ogive

The female maturity ogive was specified using an age-based logistic curve, with slope parameter -0.773 (corresponding to a 95% age-at-maturity of 12.54 years) and age at 50% maturity 8.74. These were obtained by histological analysis of 180 samples of GOA Flathead sole ovaries collected in the central Gulf of Alaska from January 1999 (Stark 2004) and are the same as was used in Model 17.0 (2017).

Standard Deviation of log Recruitment (σ_R)

Variability of the recruitment deviations that were estimated in previous Flathead sole assessments was approximately $\sigma_R = 0.6$, which is fixed within the current assessment.

Survey Catchability

The survey catchability parameter q was fixed at 1.0, as for previous Flathead sole assessments. We explored a sensitivity run where survey catchability was allowed to be calculated analytically or estimated, as well as a likelihood profile on $ln(q)$ (Figure 8.40).

Parameters Estimated Inside the Assessment Model

A total of 86 parameters were estimated inside the assessment model. These included: 1) the log of unfished recruitment (R_0) 2) 43 log-scale recruitment deviations; 3) Sex-specific parameters corresponding to von-Bertalanffy growth, maturity, and natural morality (10) and 4) 8 selectivity parameters in total for the fishery fleet and survey (see Table 8.5).

The model also estimates a fishing mortality rate for each model year using the hybrid method. Details on the estimation method for the aforementioned parameters are below.

Recruitment

The log of unfished recruitment (R_0), log-scale recruitment deviations for an early period (1978-1983) and a main period (1984-2020) were estimated (see Recruitment Deviations). A 1:1 sex ratio is assumed.

Growth

Sex-specific growth parameters (asymptotic size in cm $L_{\infty,sex}$, length at minimum reference age in cm $L_{age=2,sex}$, growth rate k_{sex} in cm^{-yr}, CV of length-at-age at ages 2 and 29) were estimated inside the assessment model.

Selectivity and fishing mortality

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

Objective Function

Parameter estimates were obtained by minimizing the overall sum of a weighted set of negative log-likelihood components derived from fits to the model data described above and a set of penalty functions used to improve model convergence and impose various constraints (Methot and Wetzel (2013)). Fits to observed annual fishery size and age compositions, as well as survey biomass estimates and size and conditional age-at-length compositions were included among the set of likelihood components. A likelihood component based on recruitment deviations from the mean was also included. Penalties were imposed to achieve good fits to annual fishery catches (biomass) and the assumed historical fishery catch. The functions used are described in more detail in Methot and Wetzel (2013) and in Appendix B of McGilliard et al. (2018).

Results

Model Evaluation

Comparison of model update(s) from 2017

Model 17.0 (2017) and Model 17.1a (2022) have very similar time series of spawning biomass (Figure 8.7), survey biomass (Figure 8.8), recruitment (Figure 8.9), fishing mortality (Figure 8.10), and stock status. The parameters of the estimated growth curves were also very similar (Table 8.7). The resultant derived quantities are similar in their mean estimate and ranges, corroborating the stable nature of the model to data and configurations found previously (Turnock *et al.* 2017). While likelihoods are not directly comparable between Model 17.0 (2017) and Model 17.1a (2022), a model run using the same (updated) software as Model 17.0 (2017) and the 2017 data had statistically indistinguishable likelihoods by component (Table 8.6).

Results for the recommended model: Model 17.1a (2022)

Individual parameter estimates for Model 17.0 (2017) and Model 17.1a (2022) are shown in Tables 8.8 through 10.10. The estimated fishery and survey selectivity curves for Model 17.1a (2022) are shown in Figure 8.11. Although selectivity curves for males and females are similar, it is puzzling that males would be selected at slightly younger ages than females in both fleets, given that they grow more slowly than females (Figure 8.12). Future work will explore potential causes for this result, particularly in light of recent changes in mean length (see below).

Fits to fishery and survey length composition data, aggregated over years are shown in Figure 8.13. Aggregated fits to fishery length composition data show that the model predicted slightly more females of length 40-45cm in the fishery than were observed. Similarly, the model predicted slightly more females in the survey of size 40-45cm as well as size 25-30cm, with fewer females between bins 30-40 than observed. Overall, model fits to the length composition data, aggregated over years were reasonable. Figures 8.15 to 10.17 show annual (disaggregated) fits to fishery and survey length composition data. Fits to fishery length composition data were particularly poor in 1990; fishery selectivity appears to have been quite different in that year. Fits to survey length composition data were also poor in years 1984, 1987, and 1990. Survey methods in 1984 and 1987 differed from the current protocol and we would expect differences in fits in these years (Turnock *et al.* (2017)). Future versions of this model may discard data from these years (see Responses to SSC and Plan Team Comments on Assessments in General).

Figures 8.18 and 10.19 show model fits to the mean length from each data source. Mean length in the fishery is mostly stable, with a slight increase from around 32 cm to 35 cm in recent years; the model fits these data as a flat line. In contrast, the mean length in the survey data has declined since 2011, from around 33 cm to between 29 cm and 30 cm in the last two years; the model does not fully capture this decline in 2019, but confidence intervals are wider than for the fishery data. Figure 8.14 illustrates the residuals associated with the model fits to the length composition data from both sources, which are similar to the last accepted assessment in that residuals are quite large for the fishery (though without any clear patterning) and acceptably small for the survey. It is recommended that future cycles replace the Pearson residual with a more statistically appropriate method and revisit selectivity for both sources.

Figures 8.20 to 10.23 show that the model fits reasonably well to the mean age at each length from each data source. Observed standard deviations are expected to differ from estimated standard deviations about the age-at-length for older ages and larger size bins due to low sample size. Figures 8.24 and 10.25 show Pearson residuals in age-at-length model fits. One very large residual occurs in 1999, but otherwise, the Pearson residuals are relatively small.

Data weights in Model 17.0 (2017) were specified using the McAllister-Ianelli method, as the Francis (2011) method was at the time unsuitable for models with conditional age-at-length data. Those original weights were allowed to exceed 1, and acted as a multiplier on the the input variance for the survey length and age data, and fishery length data. The previous model weights suggested "up-weighting" both length composition data sources, with a multiplier of 1.19 for the fishery lengths and 1.017 for the survey lengths. The survey conditional age-at-length data was down weighted by nearly two thirds, with a multiplier of 0.345. After adding in all the new data for Model 17.1a (2022), we ran the tuning algorithm from the r4ss R package one time starting from an unweighted model to obtain new McAllister-Ianelli weights. As in Model 17.0 (2017), the recommended values continued to up-weight the length compositions for the fishery (1.25) and survey (1.10) and down-weight the CAAL data by roughly the same amount as before (0.33). These new values are used in the final base model.

A sensitivity analysis using the Francis method, which has since been updated to work with CAAL data, suggested down-weighting all data sources (fishery lengths to 0.22, survey lengths to 0. 47, and survey CAAL to 0.22); this resulted in a much flatter SSB trend for the last five years, and slightly improved the survey biomass fits. A stable web site with abbreviated results from sensitivity runs explored during this assessment is available online at https://mkapur-noaa.github.io/goa-fhs-2022/sensitivities_goa_fhs_2022.html. Because we are not proposing any of these model runs as alternative models they have been excluded from this document, but qualitative descriptions of the results are included in the applicable sections.

In summary, the data weights suggest that the model scale is particularly sensitive to the treatment of the CAAL data, which both methods down-weighted (this finding is consistent with the results of the Likelihood Profile Analyses), and therefore that the input sample sizes used for these data are highly influential for derived quantities.

Time Series Results

Time series of stock spawning biomass, age-0 recruitment, fishing mortality, and standard deviations thereof for the current and previous assessments are shown in Table 8.10 and Figures 8.27 and 10.28. Time series of numbers-at-age and numbers-at-length, including mean age and length through time, are shown in Figures 8.29 to 10.32. Figure 8.27 shows spawning stock biomass estimates and corresponding asymptotic 95% confidence intervals. Figure 8.33 shows that biomass has been above $B_{35\%}$ and F has been low relative to $F_{35\%}$ for each year in the time series.

Retrospective Analysis

Retrospective analyses were conducted by iteratively running Model 17.1a (2022), each time removing one additional year of data, starting with the most recent year of data. Previous assessments had moderate retrospective patterns (Turnock *et al.* 2017).

The retrospective model estimates for Model 17.1a (2022), including spawning biomass, recruitment, apical fishing mortality and fits to the survey are shown in Figures 8.34 to 10.37. Estimates of spawning biomass and fishing mortality for the retrospective runs were very similar to one another, while recruitment in recent years differed among models, but a consistent retrospective pattern was not clear. A lack of information about young and small Flathead sole in the assessment may have contributed to variation in estimates of recruitment in the most recent years of the model. In addition, the model is configured to fix recruitment for the most recent three years to mean recruitment, complicating the interpretation of the retrospective pattern for recruitment. The Mohn's ρ values by component for Model 17.1a (2022) were: 0.1107 (SSB), -0.2704 (Recruitment), and -0.0493 (Fishing Mortality).

Hurtado-Ferro et al. (2014) developed some rules of thumb for ranges of Mohn's ρ values that may arise without the influence of model mis-specification. They found that values between -0.15 and 0.20 for longer-lived species and values between -0.22 and 0.30 for shorter-lived species could arise without the influence of model mis-specification based on a simulation-estimation study. The values for Mohn's ρ for Model 17.1a (2022) are within these bounds for spawning biomass and fishing mortality, but outside them for recruitment. However, the Mohn's ρ value for recruitment was not very meaningful, as it reflects comparisons between estimated recruitments from the current assessment to retrospective years in which recruitment was fixed to the mean value.

Likelihood Profile Analyses

This assessment re-conducted the likelihood profiling exercises on catchability (q), natural mortality (M), and combinations thereof done in the previous full assessment (Turnock *et al.* 2017). The data weights remained unchanged during profiling. For this cycle, we extended the upper limit of q values included in the profile to $log(10)$ (about 2.3), and also conducted a profile on unfished recruitment R_0. Results from these investigations are shown in Figures 8.38 to 10.42. When each parameter is profiled independently (Figures 8.38 and 10.40), the minimum total negative log-likelihood for Model 17.1a (2022) occurred at q = 1.56 and M = 0.26 (in Model 17.0 (2017), these values were 1.4 and 0.28, respectively; though values over 1.4 for q were not explored in 2017). The profile on q is shallow for all data besides the age data below 1.6, and both the index and length composition data profiles on q were minimized closer to 1. It appears that given the current model structure, there is conflict between the age and length data regarding the value of M, whereby the age data suggests the highest overall value for M (0.28) and the length composition data suggests M to be half of that (0.14). This conflict was also observed during the last assessment (Turnock *et al.* 2017). When q and M for both sexes are profiled concurrently, the total likelihood was minimized at roughly the same values as those found in the independent exercise (1.64 for q and 0.27 for M, Figure 8.41), qualitatively similar to that of the previous assessment). However, there are a range of combinations of these values which were statistically indistinguishable. Profiles wherein natural mortality was fixed at various combinations for each sex indicated that the total likelihood was minimized when M for both sexes was 0.255 (Figure 8.39). We did not have time to examine the individual components of these 2-dimensional likelihood profiles; revisiting selectivity is likely needed to aid interpretation of these results, which was out of scope for the current assessment. A profile on R_0 (Figure 8.42) indicated that unfished recruitment is well-estimated in the present model configuration, where the length data suggests a slightly higher value for R_0 than other datasets. This finding is consistent with observations during the data weighting process, whereby the length data consistently suggest a higher model scale (higher $R0$ and lower M), and the dynamics change greatly if those data are not up-weighted. For future iterations, assessors should consider the interaction between data weights (which up-weight all lengths and down-weight all CAAL data), the corresponding fits to the survey (which are poor in the last two years) and length compositions (which improve when M is below 0.18). Overall, it was out of the scope of the present assessment to propose any of these explorations as alternative models, but there is a strong basis for revisiting any or all of these parameterizations to satisfy the SSC/PT requests moving forward. See also Data Gaps and Research Priorities.

Harvest recommendations

The reference fishing mortality rate for Flathead sole is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per recruit analysis. Assuming that the average recruitment from the 1984-2020 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ times the equilibrium number of recruits. Since reliable estimates of the 2022 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and B>$B_{40\%}$, the Flathead sole reference fishing mortality is defined in Tier 3a. For this tier, F_{ABC} is constrained to be ≤ $F_{40\%}$, and F_{OFL} is defined to be $F_{35\%}$.

Because the Flathead sole stock has not been overfished in recent years and the stock biomass is relatively high, it is not recommended to adjust F_{ABC} downward from its upper bound.

Amendment 56 Reference Points

Specification of OFL and Maximum Permissible ABC

Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age-3 recruitments between 1984 and 2022. Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2023 estimates of these reference points are shown below. Values are from the projection model for Model 17.1a (2022) and should not be compared directly to outputs from Stock Synthesis.

Quantity	Value
Stock Spawning Biomass (2023)	94,059
$B_{40\%,2023}$	37,033
$F_{40\%,2023}$	0.29
$maxF_{ABC,2023}$	0.29
$B_{35\%,2023}$	32,404
$F_{35\%,2023}$	0.36
$F_{OFL,2023}$	0.36
ABC_{2023}	39,480
OFL_{2023}	48,161

Female spawning biomass for 2023 is estimated at 94,059 t. This is above the $B_{40\%}$ value of 37,033 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates yields an ABC in 2023 of 39,480 t and an OFL of 48,161 t.

Area Allocation of Harvests

TAC for Flathead sole in the Gulf of Alaska are divided among four smaller management areas (Western, Central, West Yakutat and Southeast Outside). The area-specific ABC for Flathead sole in the GOA are divided up over the four management areas by applying the fraction of the survey biomass estimated for each area (relative to the total over all areas) in 2023 and 2024 from the survey averaging random effects model to the 2023 and 2024 ABCs, defined above. The area-specific allocations for 2023 and 2024 are:

Quantity	Year	Western	Central	West Yakutat	Southeast	Total (t)
Area Apportionment %		32.40	54.43	5.88	7.29	
ABC (t)	2023	12,793	21,487	2,320	2,880	39,480
ABC (t)	2024	13,033	21,892	2,363	2,934	40,222

Harvest Projections

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).

For each scenario, the projections begin with the vector of 2022 numbers at age as 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 after 2022 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 2019, are as follow ("$maxF_{ABC}$" refers to the maximum permissible value of F_{ABC} under Amendment 56):

- Scenario 1: In all future years, *F* is set equal to $maxF_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- Scenario 2: In 2022 and 2023, *F* is set equal to a constant fraction of $maxF_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2019-2021 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)
- Scenario 3: In all future years, *F* is set equal to 50% of $maxF_{ABC}$. (Rationale: This scenario provides a likely lower bound on FABC that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- Scenario 4: In all future years, *F* is set equal to the 2018-2022 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 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 follows (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 expected to be 1) above its MSY level in 2018 or 2) above ½ of its MSY level in 2018 and above its MSY level in 2028 under this scenario, then the stock is not overfished.)
- Scenario 7: In 2022 and 2023, *F* is set equal to max F_{ABC}, and in all subsequent years F is set equal to FOFL. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2020 or 2) above 1/2 of its MSY level in 2020 and expected to be above its MSY level in 2030 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for each of the seven standard projection scenarios (Tables 8.12 through 10.14). The difference for this assessment for projections is in Scenario 2 (Author's *F*); we use pre-specified catches to increase accuracy of short-term projections in fisheries where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two-year ahead specifications.

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. While Scenario 6 gives the best estimate of OFL for 2022, it does not provide the best estimate of OFL for 2023, because the mean 2022 catch under Scenario 6 is predicated on the 2022 catch being equal to the 2022 OFL, whereas the actual 2022 catch will likely be less than the 2022 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Risk Table and ABC recommendation

The SSC in its December 2018 minutes recommended that all assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. The following template is used to complete the risk table:

	Assessment-related considerations	***Population dynamics considerations***	***Environmental/ecosystem considerations***	***Fishery Performance***
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. “Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.”
2. “Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.”
3. “Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.”
4. “Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.”

Assessment considerations

Overall, the model fits all the data sets very well. Both the survey index, and survey and fishery composition data show no concerning patterns. All parameters were well estimated, without any convergence issues. Adding the new data had a minimal impact on estimated parameters and management quantities, corroborating the general stability of the model found in previous assessments. We therefore conclude there are no increased concerns and set this consideration at level 1.

Population dynamics considerations

The spawning stock biomass has been above target for the entire time period for which there are data (Figure 8.33). The estimated age 3+ biomass has increased steadily since 2010, coincident with more positive than negative recruitment deviations in the last 10 years (Figure 8.28). Since we have no increased concerns we set the concern level to 1.

Ecosystem considerations

Overall, we scored this category as a level 1 (no increased concern) based on moderate thermal conditions at depth, some indications of increased prey availability (although prey data are limited), and no indications of increased predation or competition. This category is also attributed a level 1 due to unknown trends in abundance of most prey and a lack of a mechanistic understanding for the direct and indirect effects of environmental change on the survival and productivity of flathead sole. This is the first risk table produced for GOA flathead sole and, therefore, their potential responses to the period of marine heatwave years in the Gulf of Alaska (2014-2016 and 2019) have not been documented in previous SAFE reports. While direct (e.g., larval survival, growth and consumption rates) and indirect (e.g., forage conditions, predation pressure) mechanistic relationships of prolonged warm thermal conditions at surface and at depth are not well understood for flathead sole, it is reasonable to expect a signal in their population trends reflective of this time period.

Fishery performance

This fishery has consistently caught only a small fraction of the ABC for the last 10 years (Figure 8.2). We did not examine CPUE trends nor spatial patterns of fishing. There are no changes in the duration of fishing openings. Altogether, we see no cause for concern and give this consideration a level 1 as well.

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: No increased concerns	Level 1: No increased concerns	Level 1: No increased concerns	Level 1: No increased concerns

Ecosystem Considerations

Ecosystem Effects on the Stock

Deeper ocean temperatures are predicted to be average, and surface temperatures average to cooler through 2022-2023. It is reasonable to expect that these trends would contribute to good thermal conditions for flathead sole during a time when they are spawning, growth, and over-winter survival. Flathead sole benthic habitat ranges from winter/spring spawning grounds along the shelf margins (<300m) to spring feeding on the shelf to shallow nearshore nursery habitat, primarily in the western GOA. Summer bottom thermal conditions along the shelf edge (250m) were slightly above average in the western GOA (5.17°C) (Longline survey: Siwicke 2022). Temperatures at depth along the shelf were below average in the spring (Seward Line Survey: 5.4°C, Danielson 2022), above average in the summer (Seward Line Survey: 5.52°C, ADF&G trawl survey off Kodiak: 6.09°C) (Seward Line: Danielson 2022, ADF&G trawl: Worton 2022). Surface temperatures that may represent thermal conditions of nearshore nursery areas were cooler than average in the winter, warming to above average in the summer and fall, with fall marine heatwave conditions in the eastern GOA (Satellite: Lemagie 2022, Seward Line: Danielson 2022, ADF&G trawl survey: Worton 2022). Spring primary productivity varied spatially from below to above average chlorophyll-*a* concentrations, with slightly later than average spring bloom timing in the western GOA (Satellite, Gann 2022). Elevated spring productivity was observed along the Seward Line (CGOA), in terms of a high phytoplankton size index, suggesting increased bottom up productivity in the western GOA that could influence the 2022 zooplankton prey base for juvenile flathead sole (Strom 2022). Eddy kinetic energy along the shelf edge was approximately average in the WGOA and below average in the EGOA, with a resulting neutral (WGOA) to weaker (EGOA) influence on transport of ichthyoplankton from slope to shelf feeding areas required for growth and survival of larval flathead sole (Cheng 2022).

Prey Availability/Abundance trends

Limited indicators of prey availability suggest good but highly uncertain forage conditions. Primary prey for adult Flathead sole include pandalid shrimp and brittle stars, while juveniles rely on euphausiids and mysids. Other prey for both age groups include polychaetes, mollusks, bivalves and hermit crabs, and to a lesser extent (but important commercially) age-0 Tanner crab and age-0 walleye pollock. Starfish have increased in 2022 around Kodiak and intertidal regions in northern GOA, since their dramatic decline in 2017 (ADF&G trawl survey, Worton 2022, Intertidal monitoring: Coletti 2022). Shrimp CPUEs have been increasing in the Chirikof, Yakutat, and Southeastern regions over the last few surveys (as of 2021 AFSC trawl survey, Palsson 2021), while they have declined in relative abundance in the other areas with respect to historic peaks. In contrast to trends in crab biomass in the Bering sea, Tanner crab biomass has significantly increased in inshore and offshore stations around Kodiak since 2019 (ADF&G trawl survey, Worton 2022). Age-0 pollock was relatively high but uncertain in WGOA (Beach Seine, Laurel 2022). Euphausiids trends are spatially varying, based on above average trends in southeast Alaska (NOAA SECM survey, Fergusson 2022) and below average planktivorous seabird reproductive success (Drummond 2022). We have no data availability of polychaetes, mollusks, bivalves and hermit crabs biomass or abundance.

Predator population trends

There are no indications that predation and competition pressure will have changed in 2022. Important predators on adult Flathead sole include Pacific cod and Pacific halibut, while arrowtooth flounder, sculpins, walleye pollock and Pacific cod are the major predators on juveniles. In general, apex fish predators in the GOA are at relatively low abundances (including cod and arrowtooth flounder, although sablefish are abundant) (Whitehouse 2021), although sablefish are abundant and arrowtooth flounder had slightly increased biomass east of Kodiak in 2022 (ADF&G trawl survey, Worton 2022).

Fishery Effects on the Ecosystem

Non-target catch in the directed GOA flathead sole fishery are shown in Table 8.14. Prohibited species catch in the directed GOA flathead sole fishery are shown in Table 8.15. Historically, the flathead sole fishery has caught a high proportion of the brittlestar, eelpouts, gunnels, polychaetes, and Stichaeidae in some years. In 2014 and 2015, proportion of non-target species caught in the flathead sole fishery ranged from 0 to 32% (32% of Pandalid shrimp were caught in the flathead sole fishery in 2015). Prohibited species catch in the flathead sole fishery were 0-2% of the prohibited species catch of each of these species in 2014 and 2015.

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Data Gaps and Research Priorities

Future assessments of this stock should consider the following:

1) Investigating, and possibly improving, fits to the survey biomass index and mean-length data from the survey for recent years, which both appear to be declining. This might be achieved by revisiting the selectivity curve for both sexes and fleets, which presently suggests that males are selected at a younger age than females, and results in large Pearson residuals for the fishery length compositions (but see point 2). In 2017, authors stated that simultaneous survey likelihood profiles over M and q indicated instability in the fishery selectivity parameters, which needs to be investigated for the interpretation of the likelihood profiles to be meaningful. We also encourage a consistent application of the survey month, which was selected for this cycle to maintain consistency with the previous benchmark assessment but should probably be made uniform. When re-examining selectivity, consider the truncation and/or separation of early survey data due to changes in survey design, and the start year for recruitment deviates, as discussed in the CIE review.

2) Replacing the Pearson residual for compositional data with a more statistically sound method, such as one-step-ahead regression (Trijoulet *et al.* (2023)). This might indicate that fishery compositional fits are not as poor as they currently seem.

3) Reviewing the interaction of the data weighting paradigm, the fixing of catchability at 1, and the input sample sizes for the compositional data. Using the McAllister-Ianelli weights (as was done here) or switching back to the Francis weights did not have a major effect on derived quantities, however, a sensitivity run (not shown) with no data weighting produced a much lower biomass time series and was unable to fit the survey (with fixed catchability). This suggests that there is conflict between the dynamics indicated by the conditional age-at-length data, which was consistently down-weighted, and the length composition data (consistent with the results of our likelihood profile analysis). The specification of the input sample sizes for AFSC groundfish assessments is an active area of research.

4) Continue exploring the relationship between overall uncertainty, natural mortality and catchability in the model, potentially including the development of a prior; consider using some of the new methods presented in the FishLife package by J. Thorson (AFSC). As above, explore the effects of these parameters on estimation of selectivity and other parameters.

5) Examining the genetic stock structure of Flathead sole throughout its range and within the Gulf of Alaska and the Bering Sea is important for understanding whether spatial management units are properly allocated.

6) Investigating the degree of bycatch (of Flathead sole, or flatfish in general) within the halibut fisheries, as reducing bycatch would better enable these fisheries to obtain ABCs.

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Tables

Table 8.1. Total and regional observed annual catch (t) of GOA Flathead sole through Oct 13, 2022. Data are from NMFS Observer Program and Alaska Regional Office. Note that in the base model, a total catch of 687 t was used as the 2022 full year estimate.

Year	Total Catch (t)	Western Gulf	Central Gulf	Eastern Gulf
1977	1,034			
1978	452			
1979	165			
1980	2,068			
1981	1,070			
1982	1,368			
1983	1,080			
1984	549			
1985	320			
1986	147			
1987	151			
1988	520			
1989	747			
1990	1,447			
1991	1,237	199	1,036	2.00
1992	2,315	355	1,947	13.00
1993	2,824	581	2,242	0.24
1994	2,525	499	2,013	13.00
1995	2,180	589	1,563	28.00
1996	3,074	807	2,166	101.00
1997	2,441	449	1,934	59.00
1998	1,731	556	1,168	7.00
1999	897	186	687	25.00
2000	1,548	259	1,274	15.00
2001	1,912	600	1,311	0.48
2002	2,146	420	1,725	0.17
2003	2,459	525	1,934	0.06
2004	2,398	828	1,571	0.01
2005	2,552	611	1,941	0.00
2006	3,142	462	2,679	0.88
2007	3,130	666	2,462	2.00
2008	3,446	297	3,149	0.07
2009	3,663	303	3,359	1.00
2010	3,903	462	3,441	0.50
2011	2,732	393	2,338	0.34
2012	2,167	277	1,890	0.20
2013	2,819	588	2,230	0.19
2014	2,557	219	2,337	0.90
2015	2,001	199	1,802	0.61
2016	2,422	228	2,191	2.00
2017	2,050	73	1,978	0.14
2018	2,202	150	2,051	0.37
2019	2,668	210	2,457	0.45
2020	1,911	100	1,811	0.12
2021	708	111	596	0.53
2022	535	41	493	0.17

Table 8.2. Historical OFLs, ABCs, TACs, total observed catch and percent retention through 13 Oct, 2022.

Year	OFL	ABC	TAC	Total Catch	% Retained
1995	31,557	28,790	9,740	2,180	71
1996	31,557	52,270	9,740	3,074	77
1997	34,010	26,110	9,040	2,441	83
1998	34,010	26,110	9,040	1,731	83
1999	34,010	26,110	9,040	897	62
2000	34,210	26,270	9,060	1,548	84
2001	34,210	26,270	9,060	1,912	87
2002	29,530	22,690	9,280	2,146	87
2003	51,560	41,390	11,150	2,459	87
2004	64,750	51,720	10,880	2,398	80
2005	56,500	45,100	10,390	2,552	86
2006	47,003	37,820	9,077	3,142	89
2007	48,658	39,110	9,148	3,130	91
2008	55,787	44,735	11,054	3,446	89
2009	57,911	46,464	11,181	3,663	97
2010	59,295	47,422	10,441	3,903	95
2011	61,412	49,133	10,587	2,732	97
2012	59,380	47,407	30,319	2,167	94
2013	61,036	48,738	30,496	2,819	88
2014	50,664	41,231	27,746	2,557	94
2015	50,792	41,349	27,756	2,001	93
2016	42,840	35,020	27,832	2,422	96
2017	43,128	35,243	27,856	2,050	93
2018	43,011	35,266	26,388	2,202	98
2019	44,865	36,782	26,489	2,668	95
2020	46,572	38,196	28,262	1,911	98
2021	47,982	39,377	28,392	708	79
2022	48,928	40,175	27,437	535	88

Table 8.3. Survey biomass by area and depth.

	1 - 100 m	101 - 200 m	201 - 300 m	301 - 500 m	501 - 700 m	701 - 1000 m
			CENTRAL GOA			
1984	64,191	85,916	8,431	0	0	0
1987	64,607	38,880	9,962	36	0	0
1990	100,061	52,600	8,591	5		
1993	64,289	40,912	8,775	0		
1996	56,342	59,964	6,422	3		
1999	95,624	40,352	3,366	14	0	0
2001	44,046	37,467	3,906	11		
2003	84,916	76,161	9,775	0	0	
2005	61,294	75,699	5,050	0	0	0
2007	72,109	95,906	9,627	0	0	0
2009	60,575	62,431	5,904	0	0	0
2011	66,969	50,067	11,391	0	0	
2013	72,923	42,847	5,293	0	0	
2015	52,914	67,331	5,955	0	0	0
2017	70,815	44,934	7,338	0	0	
2019	42,643	45,968	5,670	0	0	
2021	48,069	52,496	3,315	0	0	
			EASTERN GOA			
1984	21,029	24,596	74	4	0	0
1987	6,060	23,835	564	0	0	
1990	11,040	11,010	991	17		
1993	4,839	10,377	1,434	193		
1996	10,772	4,607	674	6		
1999	5,145	13,271	182	0	0	0
2003	7,790	11,542	56	0	0	
2005	2,060	9,365	135	151	0	0
2007	9,050	16,196	154	0	0	0
2009	10,111	6,150	90	0	0	0
2011	19,801	10,785	577	0	0	
2013	11,007	6,886	146	0	0	
2015	13,257	10,924	503	0	0	0
2017	3,196	11,030	266	0	0	
2019	12,377	12,299	174	0	0	
2021	15,558	13,170	1,158	0	0	
			WESTERN GOA			
1984	33,754	11,278	66	1	0	0
1987	20,815	12,761	27	0	0	0
1990	45,913	12,696	131	0		
1993	43,834	13,854	68	5		
1996	52,543	13,974	174	41		
1999	44,578	5,018	33	0	8	0
2001	49,387	18,667	100	11		
2003	53,313	13,718	24	0	0	
2005	51,541	7,805	112	0	0	0
2007	59,759	18,560	42	0	0	0
2009	68,139	11,814	163	0	0	0
2011	63,066	12,866	117	0	0	
2013	52,263	9,841	28	0	0	
2015	51,636	15,991	37	0	0	0
2017	86,797	12,169	42	0	0	
2019	55,653	10,996	62	0	0	
2021	36,057	10,078	92	7	0	

Table 8.4. Survey biomass estimates and CVs used in the assessment as an absolute index of abundance.

Year	Observed Biomass (t)	CV
1984	249,341	0.12
1987	177,546	0.11
1990	243,055	0.12
1993	188,579	0.13
1996	205,521	0.09
1999	207,590	0.12
2001	153,594	0.12
2003	257,294	0.08
2005	213,213	0.08
2007	281,402	0.08
2009	225,377	0.11
2011	235,639	0.09
2013	201,233	0.09
2015	218,548	0.08
2017	236,588	0.11
2019	185,840	0.09
2021	180,000	0.11

Table 8.5. Treatment of selectivity parameters for survey and fishery fleet. Bracketed values indicate parameter bounds, if applicable.

Parameter.Name	Fishery	Survey
Peak (age at plateau start)	Estimated [1,16]	Estimated [1,20]
Width of plateau	Fixed (30)	Fixed (30)
Ascending width (log)	Estimated [-4,12]	Estimated [-4,12]
Descending width (log)	Fixed (8)	Fixed (8)
Initial selectivity at age 0	Fixed (-10)	Fixed (-10)
Final selectivity at age 29	Fixed (15)	Fixed (15)
Male peak offset	Estimated [-15,15]	Estimated [-15,15]
Male Ascending width (log) offset	Estimated [-15,15]	Estimated [-15,15]
Male Descending width (log) offset	Fixed (0)	Fixed (0)
Male final offset (transformation required)	Fixed (1)	Fixed (0)
Male apical selectivity	Fixed (1)	Fixed (1)

Table 8.6. Likelihood components for the base case 2022 model, the base case model with new data removed (data are as for the 2015 model), and the 2017 model. Values for likelihood components for the 2022 base case model cannot be compared directly with the other two models. The likelihoods for the 2017 model and the 2022 model with 2017 data vary slightly due to changes in the underlying software.

component	Model 17.0 (2017)	Model 17.1a (2022) with 2017 data	Model 17.1a (2022)
TOTAL	1,534.88000	1,536.27000	1,780.16000
Survey	-19.01160	-18.74870	-11.60820
Length_comp	539.11800	538.99700	687.64100
Age_comp	1,019.12000	1,020.45000	1,113.70000
Recruitment	-4.34713	-4.42665	-9.57505

Table 8.7. Final parameter estimates of growth parameters and unfished recruitment in log space for Model 17.1a (2022) and Model 17.0 (2017).

Parameter	Model 17.1a (2022)	Model 17.0 (2017)
Natural Mortality (both sexes)	0.200	0.200
Length at age 2 (females, cm)	10.129	9.473
Linf (females, cm)	43.648	44.398
von Bertalanffy k (females, cm/yr)	0.192	0.188
CV in length-at-age 2 (females)	0.141	0.107
CV in length-at-age 59 (females)	0.099	0.095
Length at age 2 (males, cm)	0.200	9.543
Linf (males, cm)	36.501	36.860
von Bertalanffy k (males, cm/yr)	0.260	0.256
CV in length-at-age 2 (males)	0.156	0.128
CV in length-at-age 59 (males)	0.085	0.081
Unfished Recruitment (millions)	383.528	370.248

Table 8.8. Final parameter estimates of fishery selectivity parameters for Model 17.1a (2022) and Model 17.0 (2017).

Parameter	Model 17.1a (2022)	Model 17.0 (2017)
Age_DblN_peak_Fishery(1)	12.258	12.416
Age_DblN_top_logit_Fishery(1)	30.000	30.000
Age_DblN_ascend_se_Fishery(1)	2.712	2.772
Age_DblN_descend_se_Fishery(1)	8.000	8.000
Age_DblN_start_logit_Fishery(1)	-10.000	-10.000
Age_DblN_end_logit_Fishery(1)	15.000	999.000
AgeSel_1Male_Peak_Fishery	-1.026	-0.984
AgeSel_1Male_Ascend_Fishery	-0.139	-0.116
AgeSel_1Male_Descend_Fishery	0.000	0.000
AgeSel_1Male_Final_Fishery	1.000	1.000
AgeSel_1Male_Scale_Fishery	1.000	1.000
AgeSel_1Male_Peak_Fishery	-1.026	-0.984
AgeSel_1Male_Ascend_Fishery	-0.139	-0.116
AgeSel_1Male_Descend_Fishery	0.000	0.000
AgeSel_1Male_Final_Fishery	1.000	1.000
AgeSel_1Male_Scale_Fishery	1.000	1.000

Table 8.9. Final parameter estimates of survey selectivity parameters for Model 17.1a (2022) and Model 17.0 (2017).

Parameter	Model 17.1a (2022)	Model 17.0 (2017)
Age_DblN_peak_Survey(2)	7.158	7.246
Age_DblN_top_logit_Survey(2)	30.000	30.000
Age_DblN_ascend_se_Survey(2)	2.115	2.136
Age_DblN_descend_se_Survey(2)	8.000	8.000
Age_DblN_start_logit_Survey(2)	-10.000	-10.000
Age_DblN_end_logit_Survey(2)	15.000	999.000
AgeSel_2Male_Peak_Survey	-0.688	-0.672
AgeSel_2Male_Ascend_Survey	-0.307	-0.304
AgeSel_2Male_Descend_Survey	0.000	0.000
AgeSel_2Male_Final_Survey	0.000	0.000
AgeSel_2Male_Scale_Survey	1.000	1.000
AgeSel_2Male_Peak_Survey	-0.688	-0.672
AgeSel_2Male_Ascend_Survey	-0.307	-0.304
AgeSel_2Male_Descend_Survey	0.000	0.000
AgeSel_2Male_Final_Survey	0.000	0.000
AgeSel_2Male_Scale_Survey	1.000	1.000

Table 8.10. Spawning Biomass, Recruitment, and Apical fishing mortality with associated standard deviations (in parentheses) from Model 17.0 (2017) and Model 17.1a (2022).

Year	Spawning Biomass		Recruitment		Apical F	
	Model 17.0 (2017)	Model.17.1a (2022)	Model 17.0 (2017)	Model.17.1a (2022)	Model 17.0 (2017)	Model.17.1a (2022)
1979	55,329 (5,639)	56,139 (5,696)	254,217 (108,203)	274,219 (119,661)	0.0019 (2e-04)	0.0019 (2e-04)
1980	53,164 (5,189)	54,689 (5,304)	295,871 (104,607)	330,563 (120,302)	0.0251 (0.0026)	0.024 (0.0024)
1981	50,591 (4,764)	52,949 (4,931)	298,640 (105,063)	331,390 (115,828)	0.0135 (0.0013)	0.0128 (0.0012)
1982	49,601 (4,384)	52,871 (4,598)	301,837 (109,935)	347,196 (110,083)	0.0176 (0.0016)	0.0163 (0.0015)
1983	50,043 (4,062)	54,263 (4,318)	310,388 (113,553)	331,921 (101,075)	0.0136 (0.0012)	0.0124 (0.0011)
1984	52,752 (3,826)	57,829 (4,116)	312,914 (109,924)	314,314 (85,635)	0.0065 (5e-04)	0.0058 (5e-04)
1985	57,864 (3,712)	63,602 (4,018)	254,293 (95,021)	312,777 (73,037)	0.0034 (3e-04)	0.003 (2e-04)
1986	64,246 (3,730)	70,420 (4,032)	257,547 (84,653)	226,759 (62,774)	0.0014 (1e-04)	0.0013 (1e-04)
1987	70,210 (3,799)	76,619 (4,084)	284,249 (83,858)	339,469 (67,854)	0.0013 (1e-04)	0.0012 (1e-04)
1988	74,582 (3,814)	81,094 (4,076)	263,313 (84,409)	255,374 (63,511)	0.0042 (3e-04)	0.0038 (2e-04)
1989	77,204 (3,752)	83,755 (3,996)	396,687 (80,399)	398,770 (64,180)	0.0059 (4e-04)	0.0054 (3e-04)
1990	78,661 (3,648)	85,217 (3,875)	227,652 (61,534)	259,725 (51,981)	0.0114 (7e-04)	0.0104 (6e-04)
1991	79,153 (3,534)	85,644 (3,745)	272,732 (66,731)	366,936 (54,905)	0.0097 (6e-04)	0.0089 (5e-04)
1992	79,341 (3,427)	85,654 (3,621)	439,867 (73,399)	325,309 (51,880)	0.0182 (0.001)	0.0168 (9e-04)
1993	78,632 (3,325)	84,662 (3,500)	269,811 (58,947)	333,007 (47,417)	0.0225 (0.0013)	0.0208 (0.0011)
1994	77,422 (3,223)	83,106 (3,378)	291,525 (57,569)	323,773 (42,981)	0.0205 (0.0011)	0.0189 (0.001)
1995	76,343 (3,119)	81,640 (3,255)	239,369 (51,515)	227,532 (35,161)	0.0179 (0.001)	0.0167 (9e-04)
1996	75,654 (3,018)	80,570 (3,135)	190,681 (46,582)	209,619 (33,726)	0.0256 (0.0014)	0.0239 (0.0013)
1997	74,888 (2,928)	79,460 (3,027)	380,569 (56,823)	359,380 (42,086)	0.0205 (0.0011)	0.0192 (0.001)
1998	74,787 (2,850)	79,087 (2,934)	303,875 (56,718)	347,730 (43,471)	0.0145 (8e-04)	0.0136 (7e-04)
1999	75,239 (2,782)	79,321 (2,854)	459,538 (67,704)	412,366 (47,724)	0.0074 (4e-04)	0.007 (4e-04)
2000	76,223 (2,724)	80,033 (2,783)	247,556 (59,278)	256,085 (40,926)	0.0127 (7e-04)	0.012 (6e-04)
2001	76,843 (2,675)	80,283 (2,717)	311,548 (53,037)	297,748 (39,007)	0.0156 (8e-04)	0.0148 (7e-04)
2002	76,961 (2,629)	80,031 (2,650)	300,180 (52,046)	330,589 (39,779)	0.0175 (9e-04)	0.0167 (8e-04)
2003	76,495 (2,575)	79,250 (2,578)	424,688 (61,899)	369,597 (43,143)	0.0202 (0.001)	0.0193 (9e-04)
2004	75,654 (2,514)	78,090 (2,499)	313,186 (60,690)	327,431 (42,785)	0.0199 (0.001)	0.0192 (9e-04)
2005	75,132 (2,460)	77,198 (2,426)	408,867 (63,402)	360,545 (43,625)	0.0214 (0.0011)	0.0207 (0.001)
2006	75,223 (2,436)	76,856 (2,377)	270,004 (55,695)	272,926 (38,971)	0.0263 (0.0013)	0.0256 (0.0012)
2007	75,678 (2,449)	76,812 (2,363)	309,512 (57,506)	268,912 (38,976)	0.026 (0.0014)	0.0255 (0.0013)
2008	76,430 (2,490)	77,004 (2,373)	249,208 (53,433)	290,336 (40,814)	0.0283 (0.0015)	0.0279 (0.0014)
2009	76,955 (2,546)	76,961 (2,392)	364,575 (68,319)	343,202 (48,282)	0.0298 (0.0016)	0.0296 (0.0015)
2010	77,306 (2,614)	76,769 (2,418)	559,803 (94,755)	606,335 (69,216)	0.0311 (0.0016)	0.0317 (0.0016)
2011	77,712 (2,702)	76,595 (2,457)	519,302 (105,101)	431,887 (71,338)	0.022 (0.0012)	0.0222 (0.0011)
2012	78,839 (2,815)	77,115 (2,510)	427,776 (101,288)	354,057 (73,156)	0.0172 (9e-04)	0.0174 (9e-04)
2013	80,171 (2,942)	77,818 (2,571)	370,248 (12,278)	318,449 (72,138)	0.022 (0.0012)	0.0225 (0.0011)
2014	80,854 (3,072)	77,930 (2,632)	370,248 (12,278)	332,472 (78,803)	0.0198 (0.0011)	0.0204 (0.001)
2015	81,321 (3,208)	77,983 (2,694)	370,248 (12,278)	445,106 (99,745)	0.0146 (8e-04)	0.0159 (8e-04)
2016	82,110 (3,369)	78,511 (2,774)	370,248 (12,278)	589,093 (125,784)	0.0179 (0.001)	0.0192 (9e-04)
2017	83,296 (3,600)	79,580 (2,902)	370,248 (12,278)	416,785 (120,649)	0.0106 (6e-04)	0.016 (8e-04)

2018	81,880 (3,106)	224,191 (95,229)	0.0167 (9e-04)
2019	84,798 (3,382)	440,116 (176,385)	0.0194 (0.0011)
2020	87,357 (3,690)	238,097 (131,516)	0.0134 (8e-04)
2021	89,578 (3,998)	383,528 (14,230)	0.0048 (3e-04)
2022	91,832 (4,326)	383,528 (14,230)	0.0046 (3e-04)

Table 8.11. Projected mean stock spawning biomass (in t) for the seven harvest scenarios listed in the Harvest Recommendations section.

Year	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2022	91,834	91,834	91,834	91,834	91,834	91,834	91,834
2023	94,059	94,059	94,059	94,059	94,059	94,059	94,059
2024	95,932	95,932	95,932	95,932	95,932	74,398	78,387
2025	97,718	97,718	97,718	97,718	97,718	61,637	67,553
2026	80,442	80,442	98,772	95,104	99,656	52,660	56,592
2027	67,237	67,237	98,836	91,930	100,545	45,975	48,521
2028	57,515	57,515	98,218	88,574	100,665	41,236	42,838
2029	50,707	50,707	97,242	85,393	100,322	38,094	39,080
2030	46,027	46,027	96,073	82,509	99,678	36,056	36,617
2031	42,810	42,810	94,821	79,952	98,857	34,884	35,150
2032	40,639	40,639	93,595	77,756	97,977	34,285	34,394
2033	39,238	39,238	92,469	75,933	97,125	34,034	34,070
2034	38,389	38,389	91,487	74,464	96,356	33,966	33,972
2035	37,917	37,917	90,662	73,309	95,695	33,983	33,980

Table 8.12. Projected mean fishing mortality for the seven harvest scenarios listed in the Harvest Recommendations section.

Year	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2022	0.005	0.005	0.005	0.005	0.005	0.005	0.005
2023	0.013	0.013	0.013	0.013	0.013	0.362	0.288
2024	0.012	0.012	0.012	0.012	0.012	0.362	0.288
2025	0.288	0.288	0.012	0.062	0.000	0.362	0.362
2026	0.288	0.288	0.012	0.062	0.000	0.362	0.362
2027	0.288	0.288	0.012	0.062	0.000	0.362	0.362
2028	0.288	0.288	0.012	0.062	0.000	0.362	0.362
2029	0.288	0.288	0.012	0.062	0.000	0.359	0.361
2030	0.288	0.288	0.012	0.062	0.000	0.347	0.351
2031	0.288	0.288	0.012	0.062	0.000	0.338	0.340
2032	0.288	0.288	0.012	0.062	0.000	0.332	0.333
2033	0.286	0.286	0.012	0.062	0.000	0.330	0.330
2034	0.284	0.284	0.012	0.062	0.000	0.330	0.330
2035	0.283	0.283	0.012	0.062	0.000	0.330	0.330

Table 8.13. Projected mean catch (t) for the seven harvest scenarios listed in the Harvest Recommendations section.

Year	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2022	687	687	687	687	687	687	687
2023	1,908	1,908	1,908	1,908	1,908	48,161	39,480
2024	1,908	1,908	1,908	1,908	1,908	38,112	32,879
2025	40,947	40,947	1,867	9,629	0	31,569	34,592
2026	33,624	33,624	1,889	9,372	0	26,945	28,941
2027	28,026	28,026	1,888	9,042	0	23,524	24,800
2028	23,924	23,924	1,867	8,672	0	21,125	21,916
2029	21,112	21,112	1,840	8,330	0	19,463	20,023
2030	19,234	19,234	1,816	8,044	0	17,965	18,388
2031	17,956	17,956	1,791	7,796	0	17,014	17,223
2032	17,072	17,072	1,767	7,583	0	16,529	16,613
2033	16,454	16,454	1,745	7,411	0	16,348	16,372
2034	16,052	16,052	1,727	7,276	0	16,321	16,322
2035	15,829	15,829	1,713	7,171	0	16,356	16,351

Table 8.14. Non-target catch in the directed GOA flathead sole fishery as a proportion of total weight of bycatch of each species. Conditional highlighting from white (lowest numbers) to green (highest numbers) is applied. No seabird bycatch was recorded in the GOA flathead sole fishery. 2015 and 2016 appear to just contain the nontarget catch for flathead trips, and are therefore > 1. These data have not been updated since 2016.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Benthic urochordata		0.02						0	0.1	0.07	0.06						
Bivalves		0.34	0.15	0.09	0	0.11	0	0.01	0.07		0.03			0			
Brittle star unidentified								0.84	0.01			0.06		0			
Capelin										0							
Corals Bryozoans - Corals Bryozoans Unidentified						0.03		0.03									
Dark Rockfish							0.01										
Eelpouts		0.07	0.04	0.18	0.12	0.02		0.94	0.24	0.06	0		0.07				
Eulachon		0	0.02	0		0	0	0.01	0		0.01		0.24	0.03			
Giant Grenadier							0	0.01			0						
Greenlings		0						0.01	0.02								
Grenadier - Rattail Grenadier Unidentified		0.01	0	0.01				0	0	0.04							
Gunnels				1		0.25											
Hermit crab unidentified		0	0			0.06		0	0.05		0		0.02				
Invertebrate unidentified		0.02		0		0	0		0.02								
Large Sculpins		0.02	0	0	0												
Large Sculpins - Bigmouth Sculpin						0.01	0.01										
Large Sculpins - Great Sculpin						0	0.01										
Large Sculpins - Plain Sculpin							0										
Large Sculpins - Warty Sculpin						0.42											
Large Sculpins - Yellow Irish Lord						0.01	0										
Misc crabs		0.17					0	0.02	0		0			0			
Misc fish		0	0	0	0	0.01	0.01	0.05	0	0.01	0		0	0			
Other osmerids				0.08		0			0					0			
Other Sculpins		0	0.01	0.02	0	0	0										
Pandalid shrimp		0.01	0.08	0.1	0	0.02	0.02	0.2	0.02	0.07	0.02		0.31	0.07			
Polychaete unidentified			0						1				0.14				
Scypho jellies		0		0			0	0			0			0			
Sea anemone unidentified		0.02		0		0.02	0	0.05	0.02		0			0			
Sea pens whips		0						0.01	0.01		0.01			0.01			
Sea star		0.01	0.03	0	0	0	0	0.01	0.01	0	0		0	0			
Snails		0.03	0.07	0.02	0	0.05	0.01	0.03	0.08	0.03	0.03		0.01	0			
Sponge unidentified		0.21						0.01	0	0							
Squid																	
Stichaeidae		0	0.75	0.55		0.07	0.01	0.32	0.02		0.07		0.22	0.16			
urchins dollars cucumbers		0.01	0.04					0.03	0.03		0.01		0	0			

Table 8.15. Prohibited species catch in tons caught in the GOA flathead sole fishery in 2018, 2019 and 2021

Species	Halibut 2018	Halibut 2019	Halibut 2021	PSCNQ 2018	PSCNQ 2019	PSCNQ 2021
Bairdi Tanner Crab				17.554	740.839	30.692
Blue King Crab						
Chinook Salmon				0.466	175.709	2.149
Golden (Brown) King Crab				0.014	0.22	0.486
Halibut	0.124	8.439	0.572	0.185	12.596	0.681
Herring				0.001	0.024	0.004
Non-Chinook Salmon				0.406	1.814	4.472
Opilio Tanner (Snow) Crab						
Red King Crab						

Figures

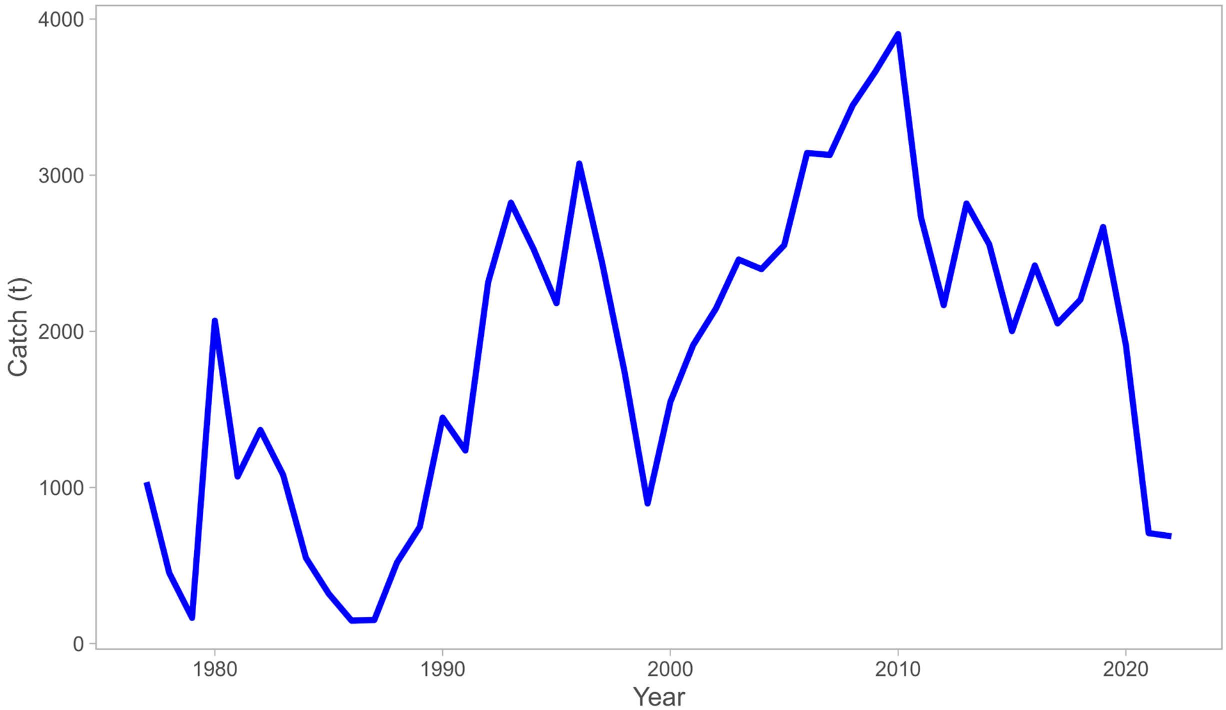

Figure 8.1. Catch biomass 1978-2022 (2022 catch is estimated).

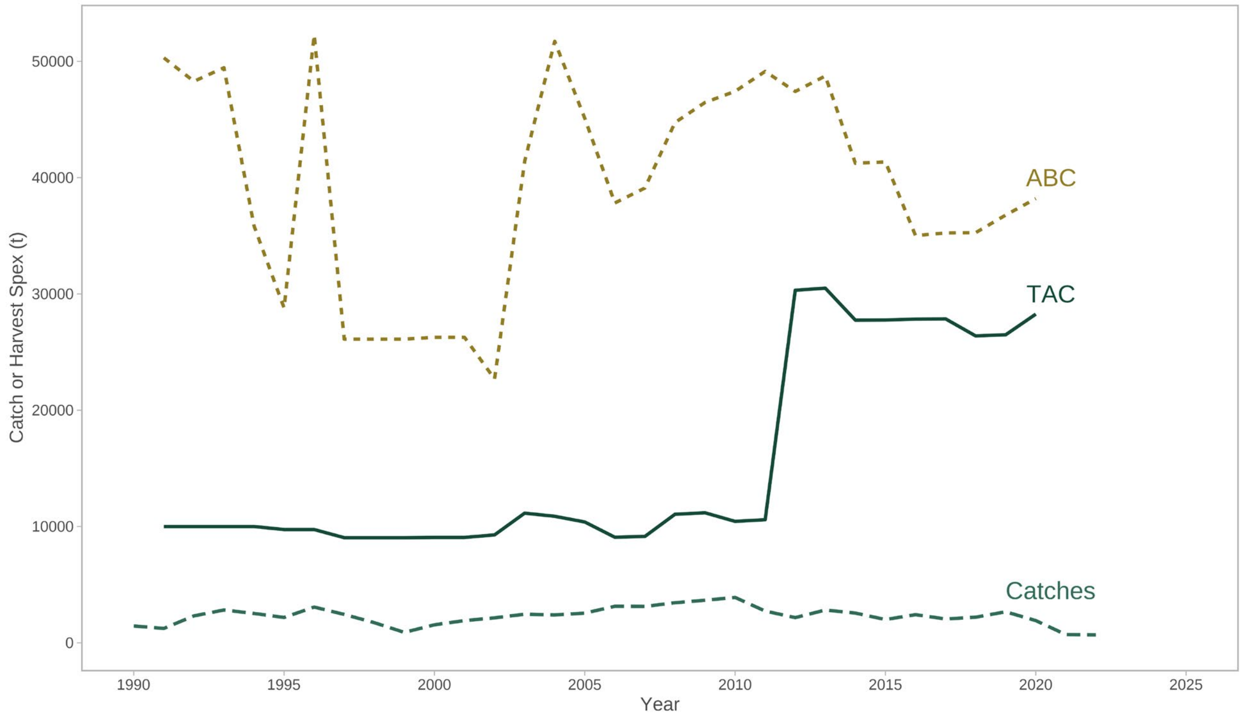

Figure 8.2. Catch biomass and harvest specifications in tons from the Federal Register for GOA Flathead Sole.

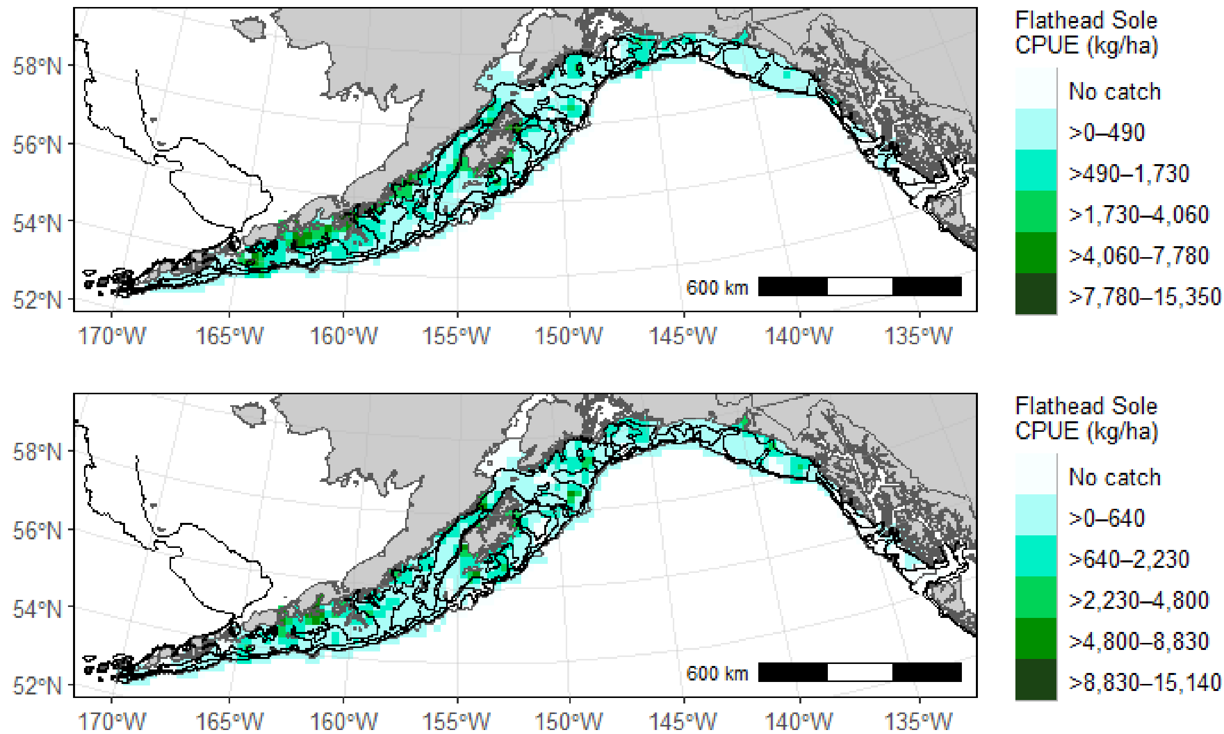

Figure 8.3. GOA trawl survey catch per unit effort in kg/km2 in 2019 (top panel) and 2021 (bottom panel)

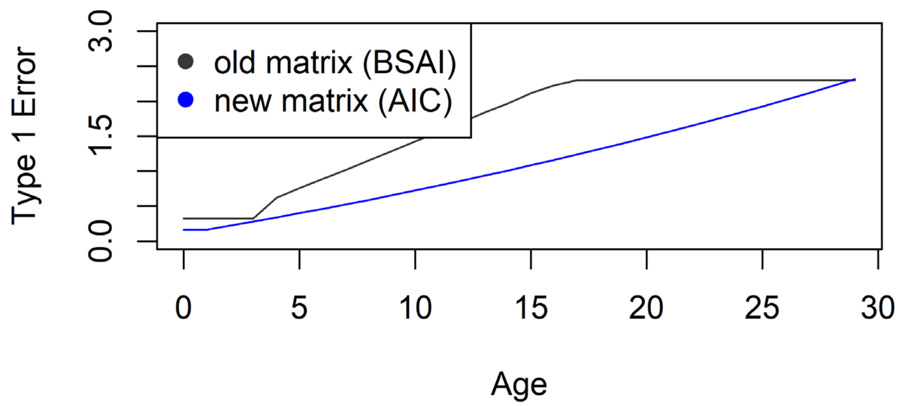

Figure 8.4. Values for ageing error matrix in previous model (black lines) and Model 17.1a (blue lines). The previous model's values were based on BSAI age reads of Flathead sole.

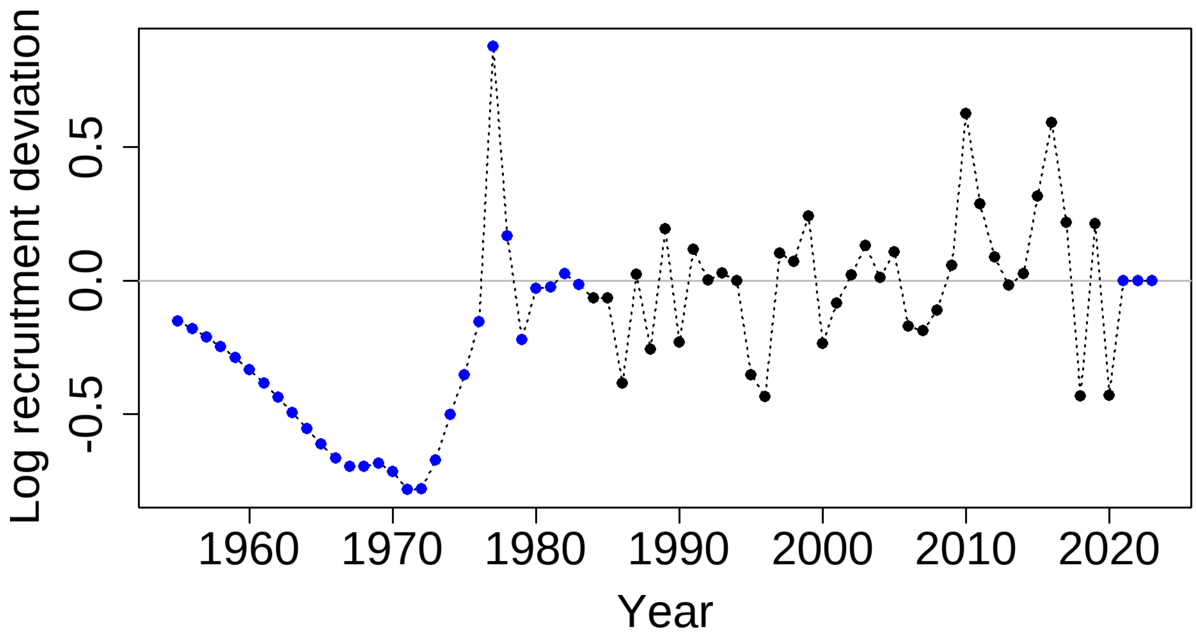

Figure 8.5. Estimated recruitment deviations.

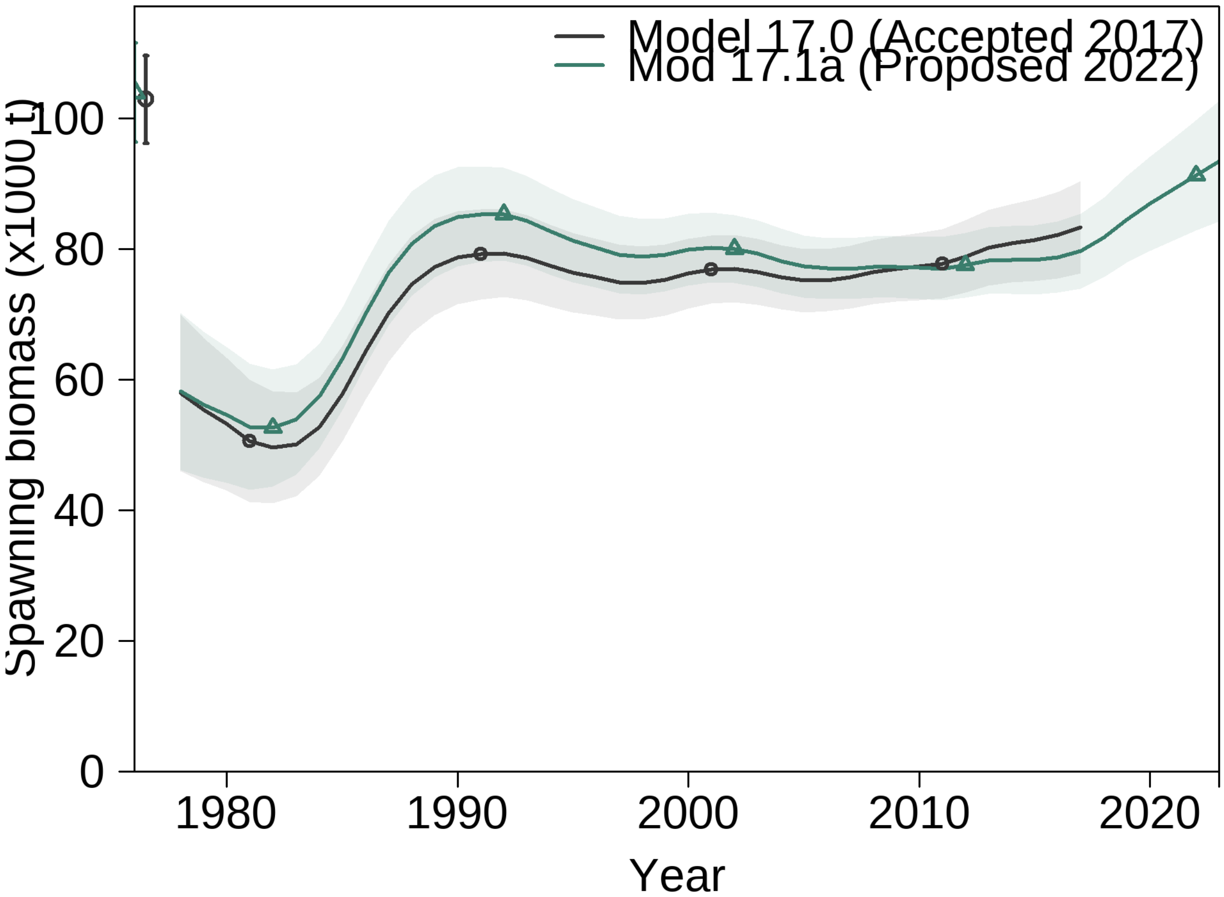

Figure 8.6. Time series of spawning biomass with asymptotic 95% confidence intervals (ribbons) for Model 17.1a (2022) (green lines and/or points) and Model 17.0 (2017) (grey lines and/or points).

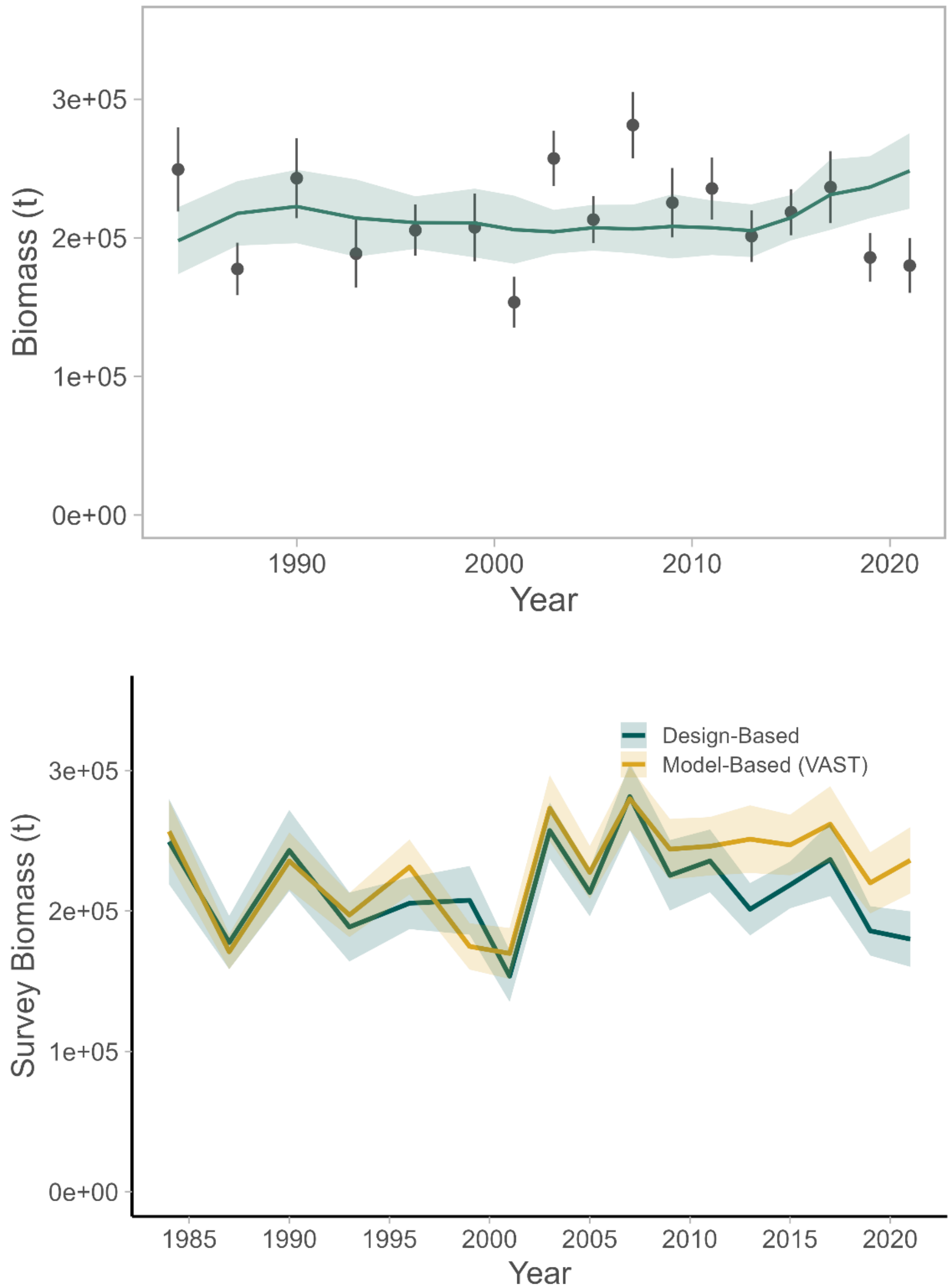

Figure 8.7. (Top) Observed survey biomass index (points), estimated survey biomass (lines), and asymptotic 95% confidence intervals (vertical lines and transparent ribbons), for Model 17.1a (2022) (green lines and/or points). (Bottom) Comparison of design-based and model-based survey indices. The model-based survey index (gold line) is estimated using a spatio-temporal model (VAST, Thorson et. al. 2019) and indicates a more stable trend for the last 10 years. It is not used in the assessment model and is shown here for comparative purposes only.

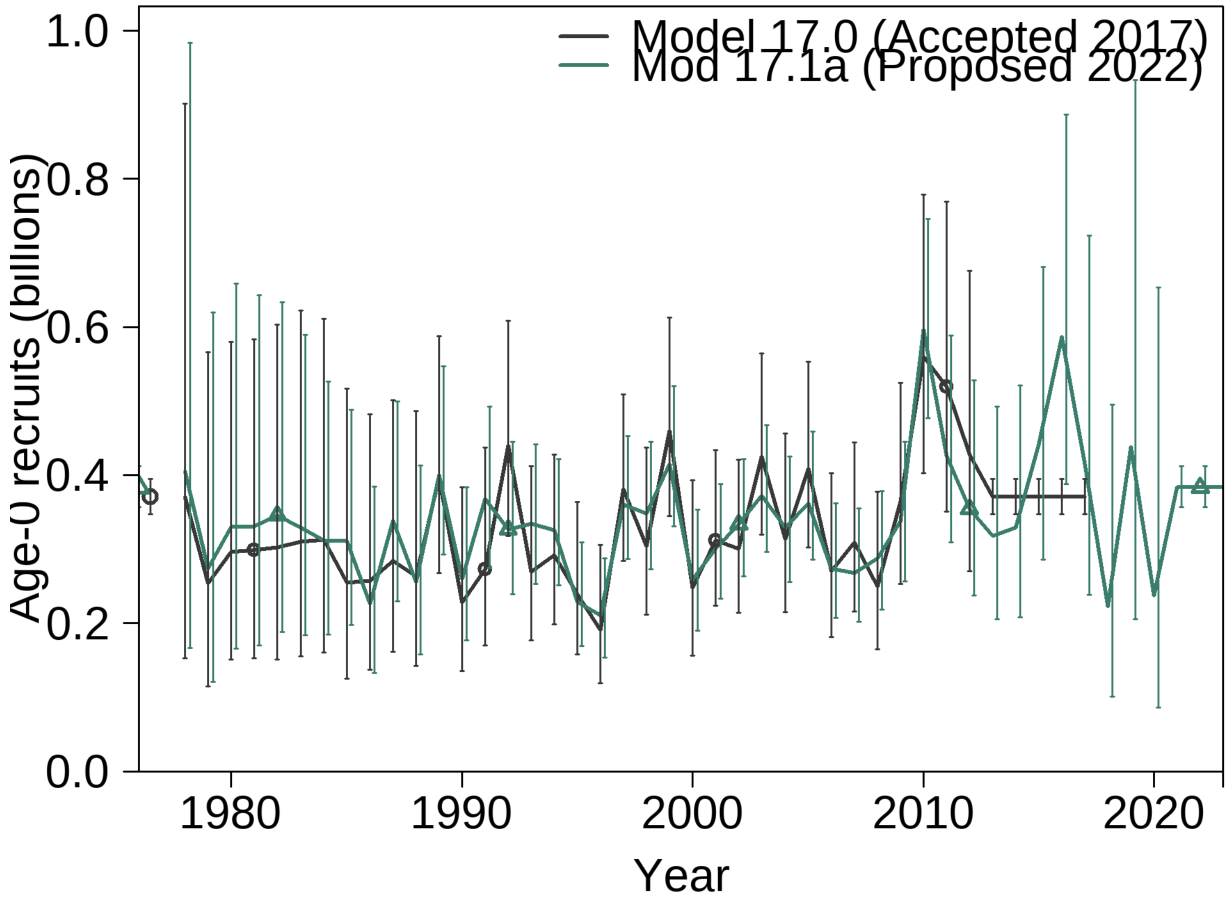

Figure 8.8. Time series of age-0 recruits for Model 17.1a (2022) (green lines and/or points) and Model 17.0 (2017) (grey lines and/or points).

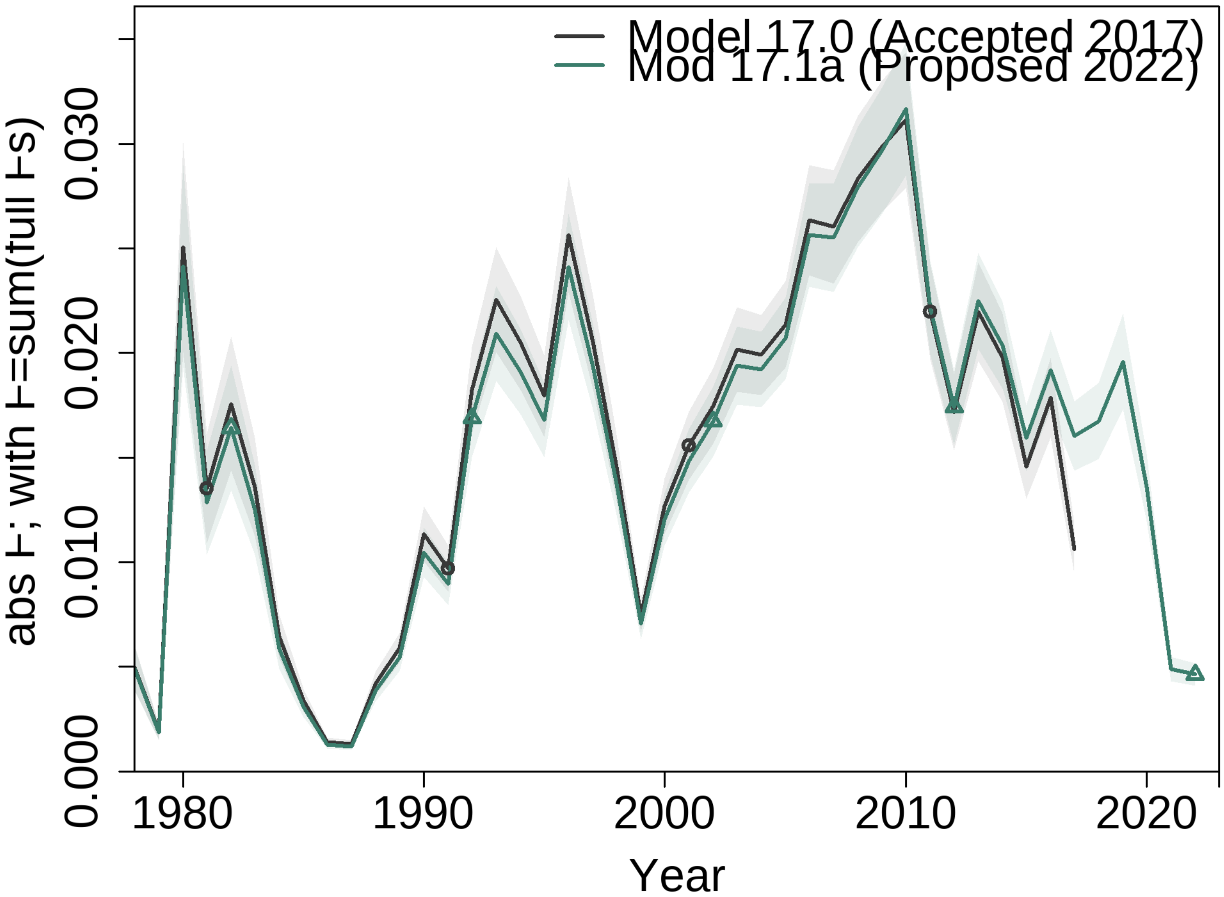

Figure 8.9. Apical fishing mortality for Model 17.1a (2022) (green lines and/or points) and Model 17.0 (2017) (grey lines and/or points).

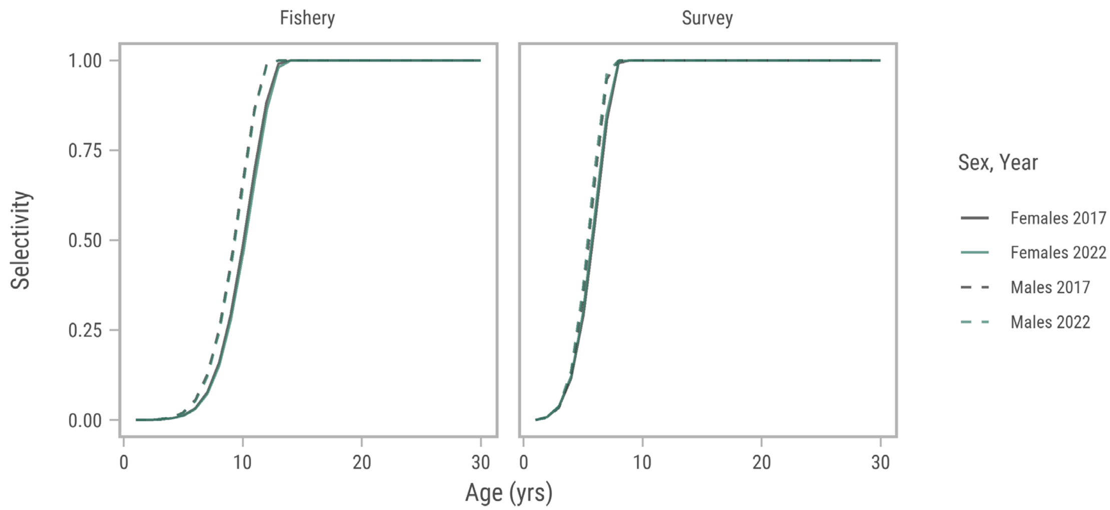

Figure 8.10. Sex-specific age selectivity curves by fleet (panels) for Model 17.1a (2022) (green lines and/or points) and Model 17.0 (2017) (grey lines and/or points). Male selectivity curves are dashed; female curves are solid.

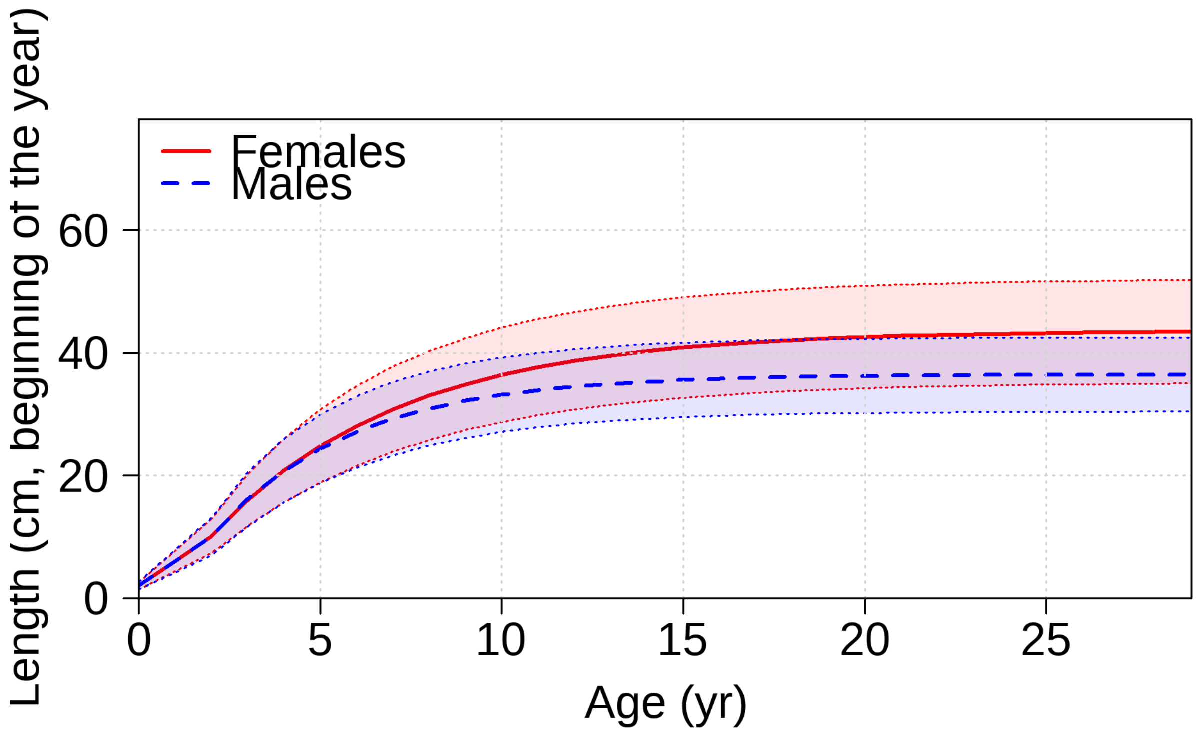

Figure 8.11. Estimated length-at-age relationship with 95% asymptotic confidence intervals for males (blue) and females (red). The blue dashed line and red solid line show the mean relationship and dotted lines show confidence intervals.

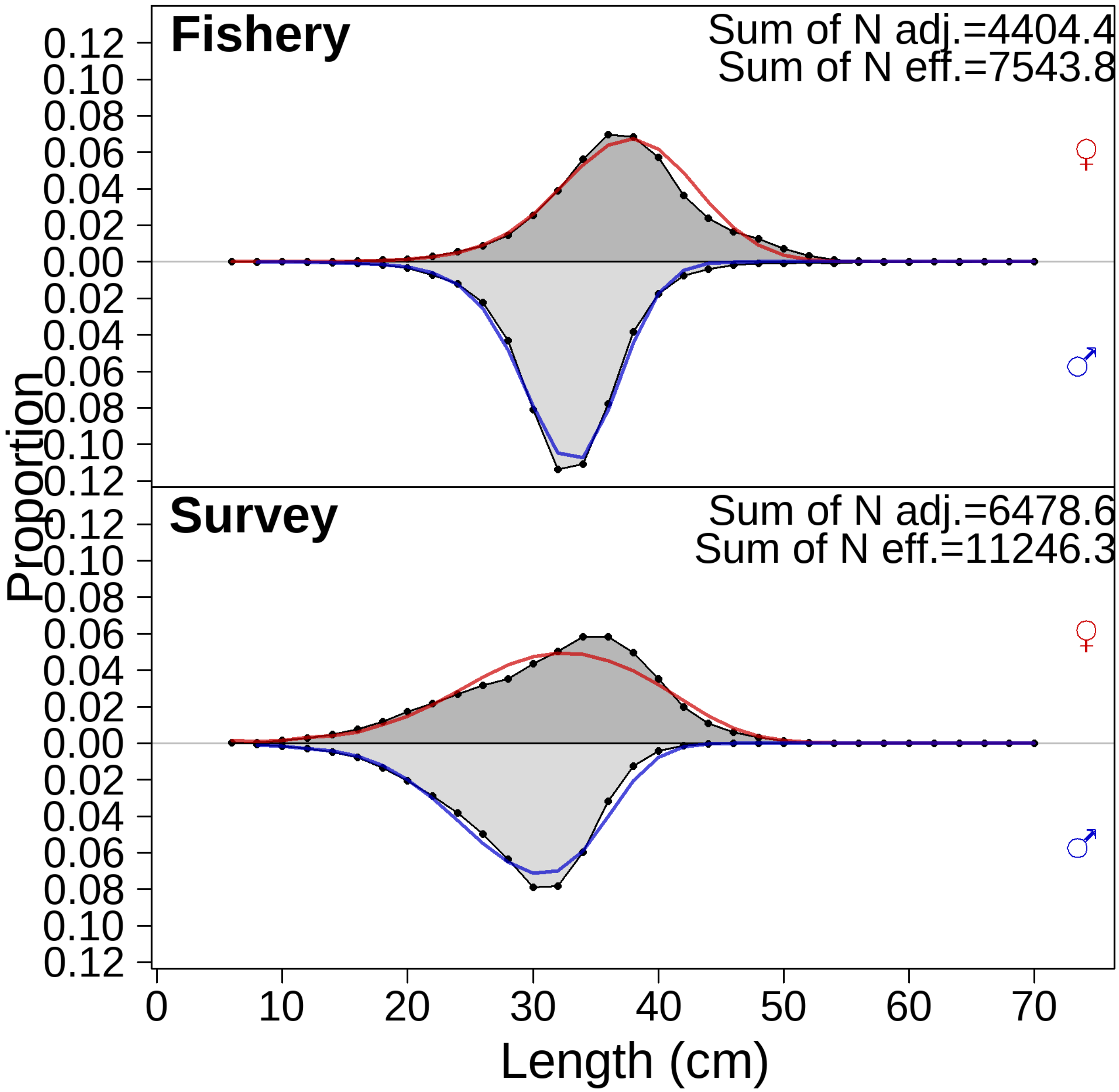

Figure 8.12. Observed (grey shaded area, black points and lines) and expected (colored lines) proportions-at-length by sex for Model 17.1a (2022). Females are shown in the upper half of each plot (red lines), males in the lower half (blue lines). Compositions for the fishery (upper panel) and survey (lower panel) are aggregated over all years of available data.

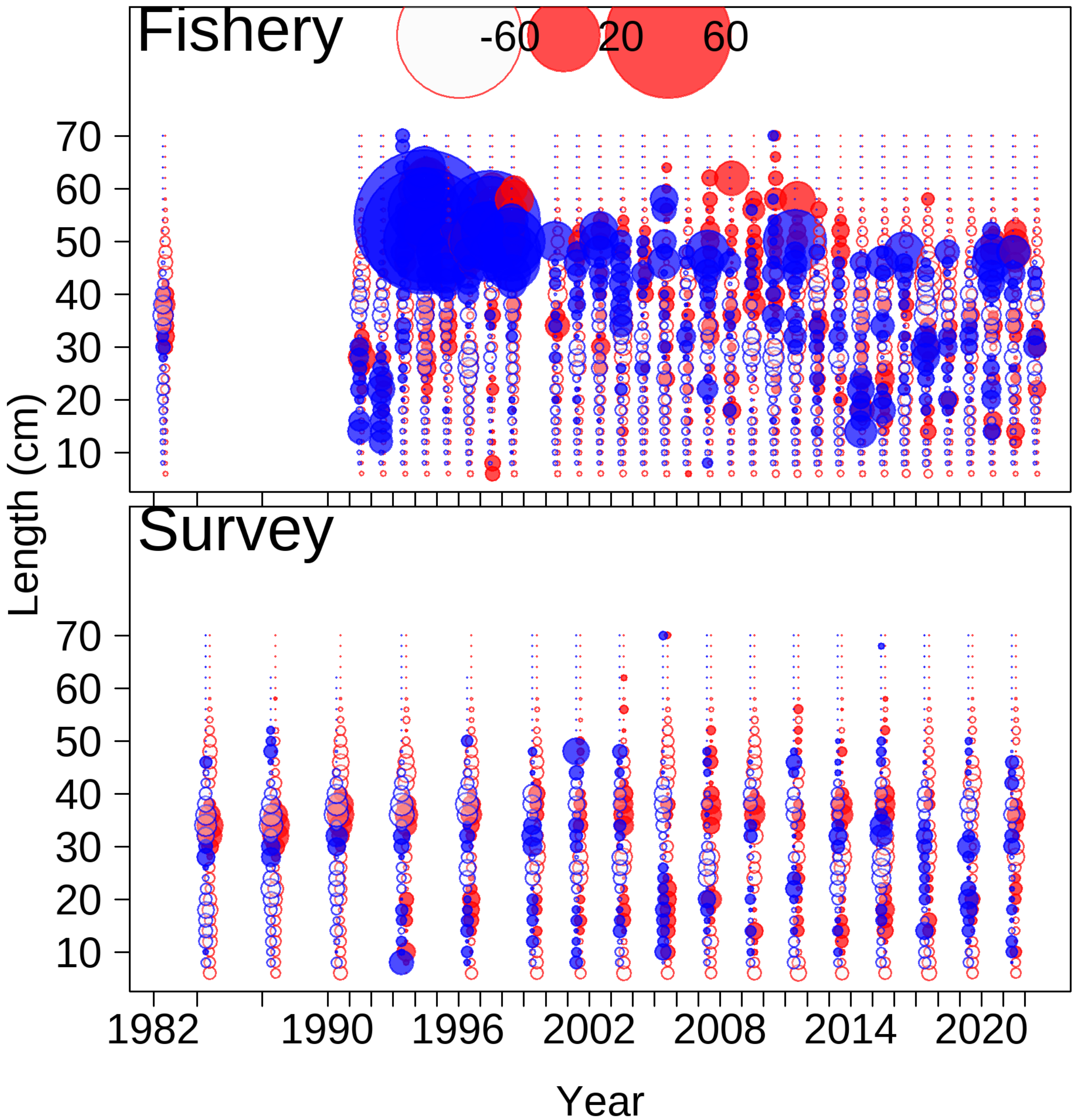

Figure 8.13. Pearson residuals for length-composition data for the fishery (top) and survey (bottom). Females are red, males are blue. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

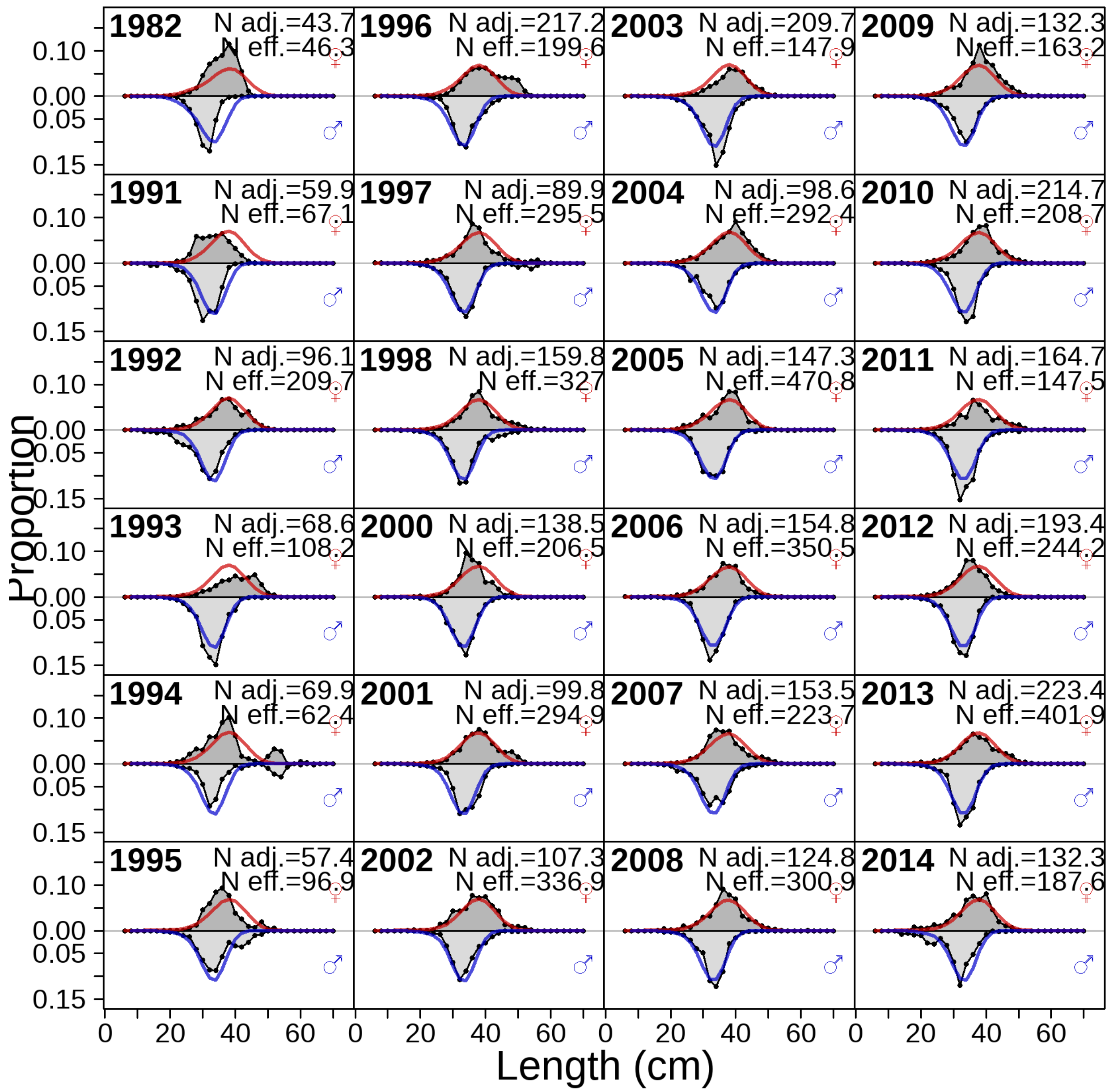

Figure 8.14. Observed (grey shaded area, black points and lines) and expected (colored lines) proportions-at-length by sex for Model 17.1a (2022). Females are shown in the upper half of each plot (red lines), males in the lower half (blue lines). Data shown for the Fishery (1 of 2).

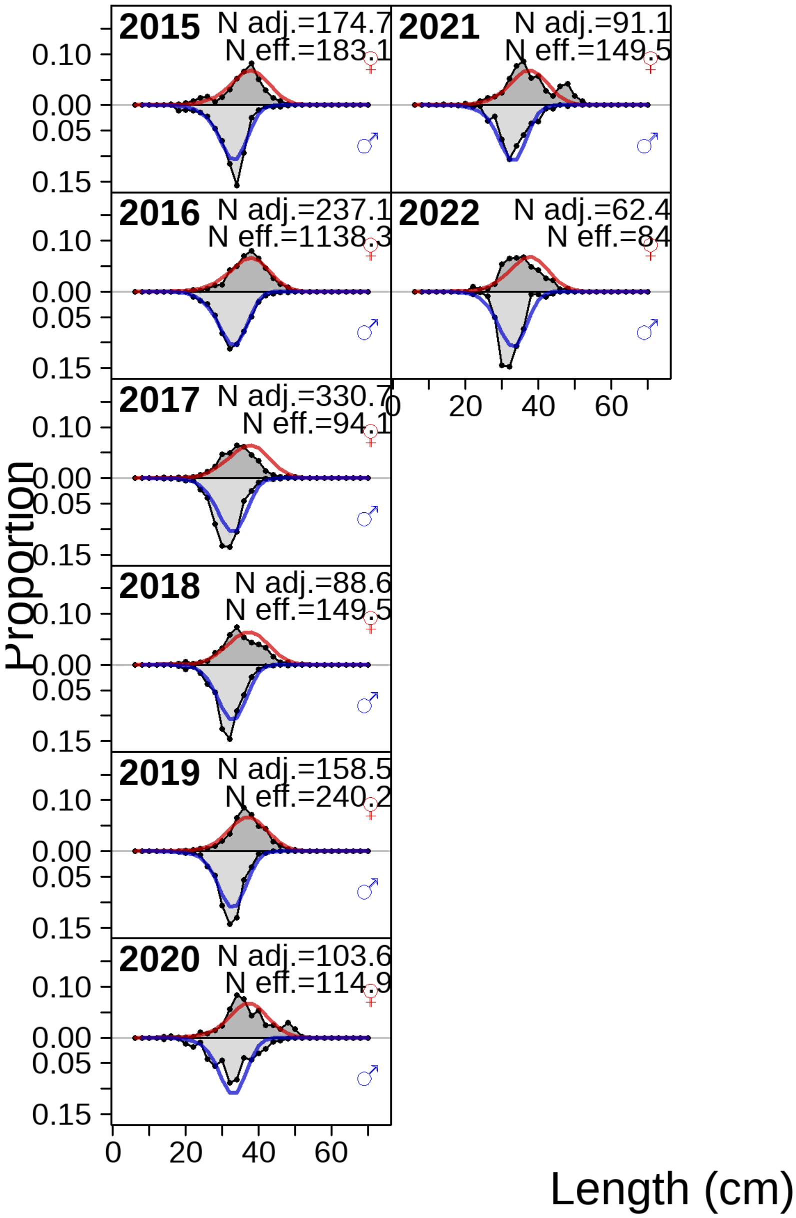

Figure 8.15. Observed (grey shaded area, black points and lines) and expected (colored lines) proportions-at-length by sex for Model 17.1a (2022). Females are shown in the upper half of each plot (red lines), males in the lower half (blue lines). Data shown for the Fishery (2 of 2).

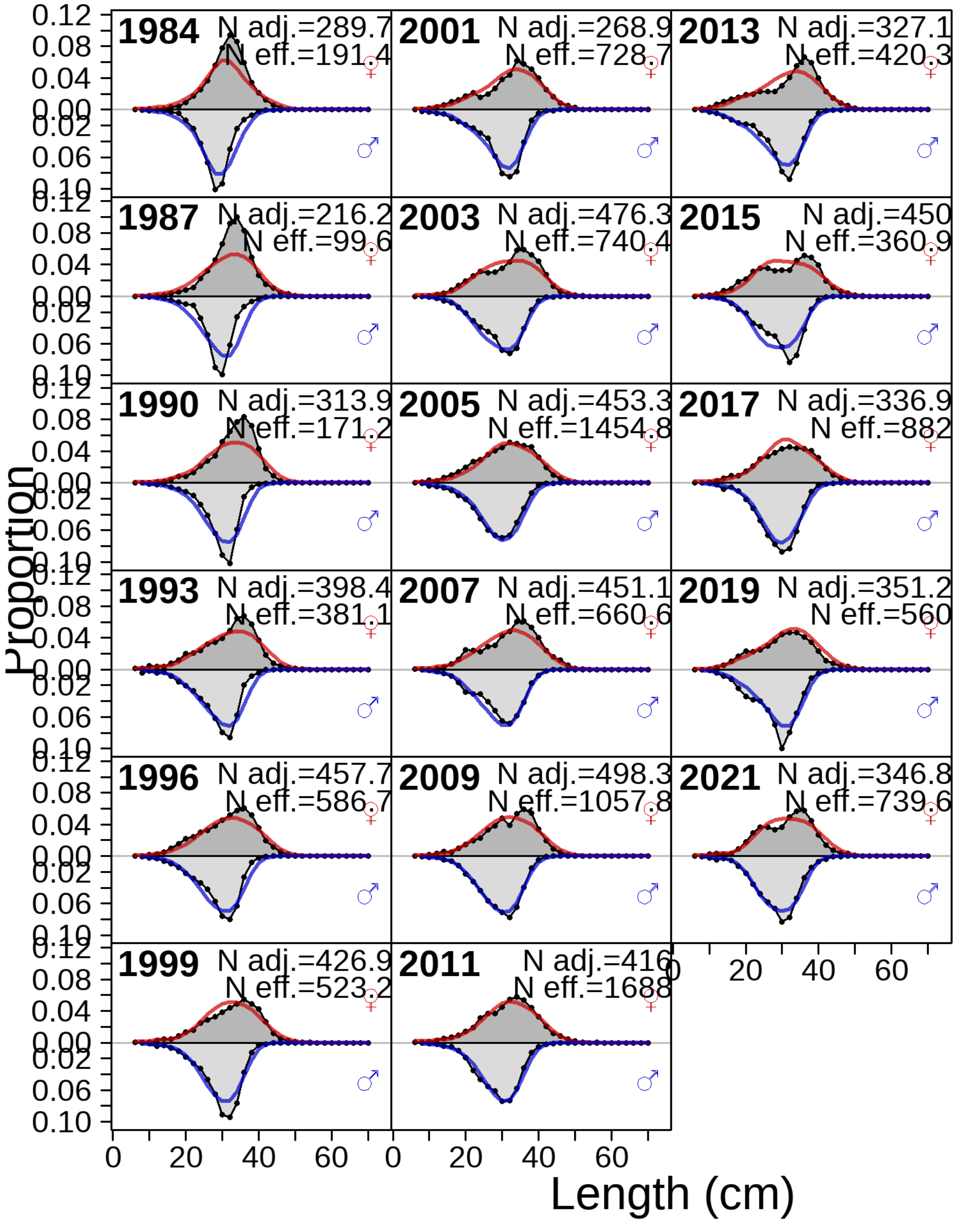

Figure 8.16. Observed (grey shaded area, black points and lines) and expected (colored lines) proportions-at-length by sex for Model 17.1a (2022). Females are shown in the upper half of each plot (red lines), males in the lower half (blue lines). Data shown for the Survey.

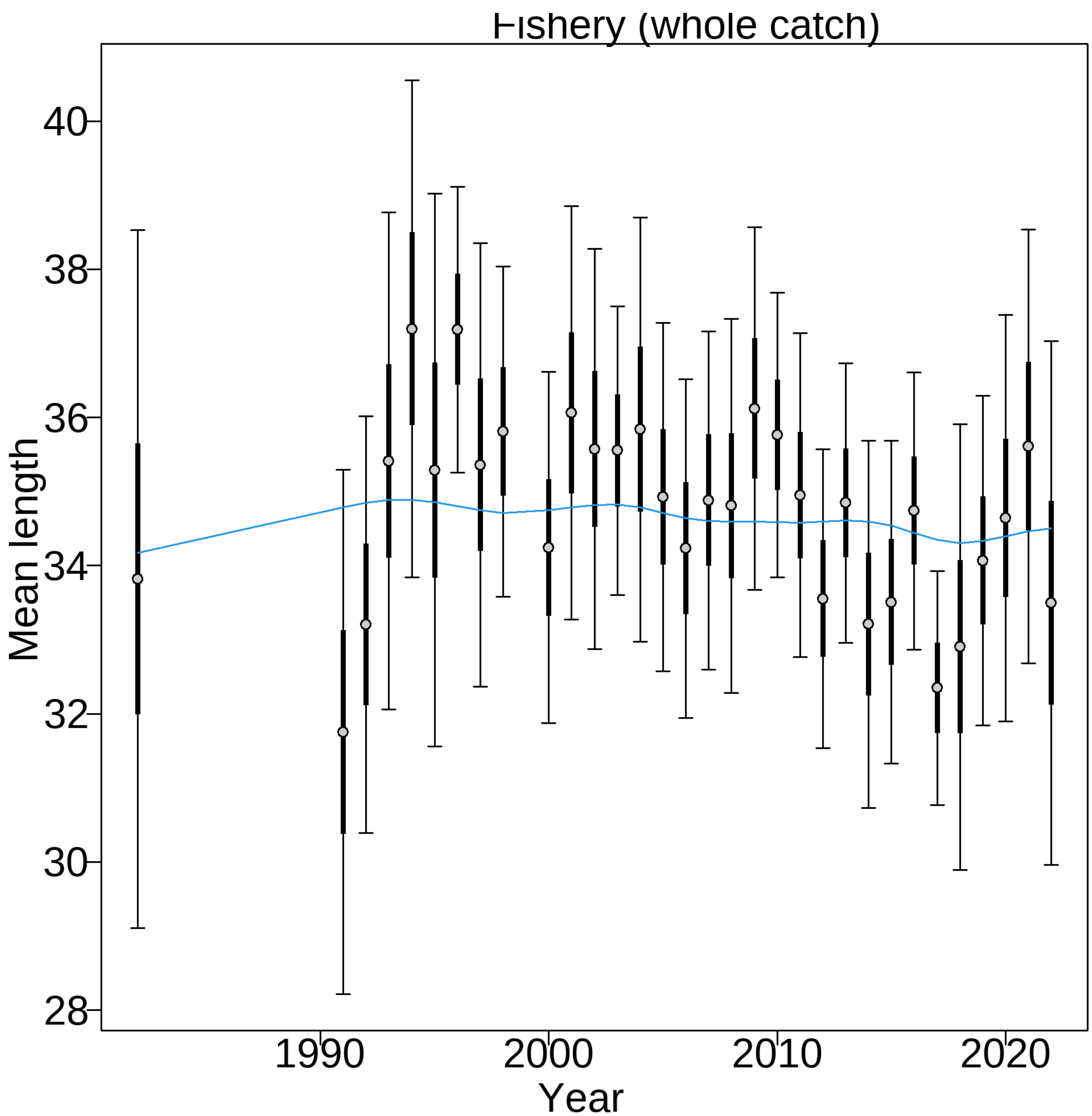

Figure 8.17. Mean length for Survey with 95% confidence intervals based on input sample sizes. Thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval); see section on data weighting for further details. Data shown for the Fishery.

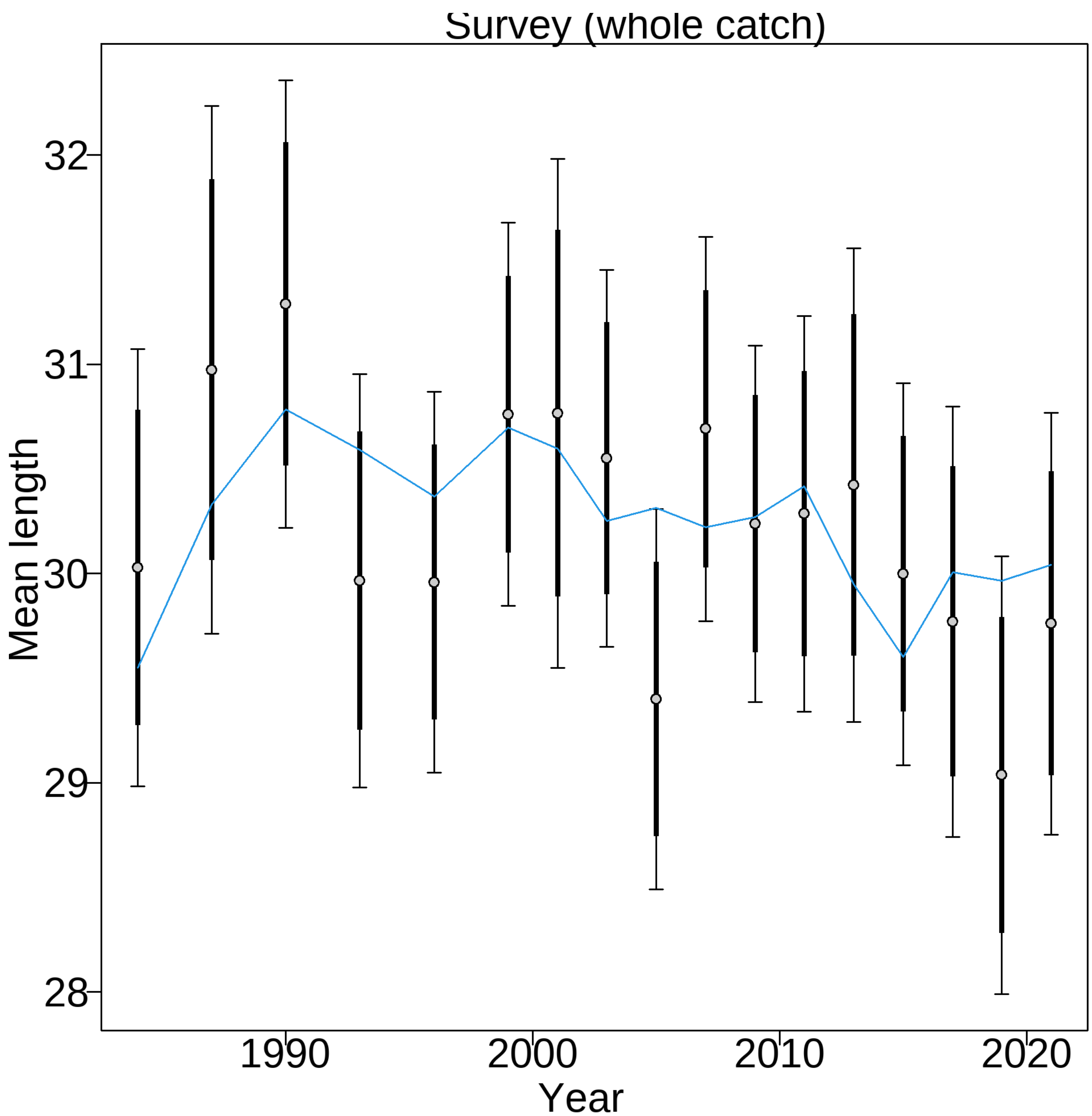

Figure 8.18. Mean length for Survey with 95% confidence intervals based on input sample sizes. Thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval); see section on data weighting for further details. Data shown for the Survey.

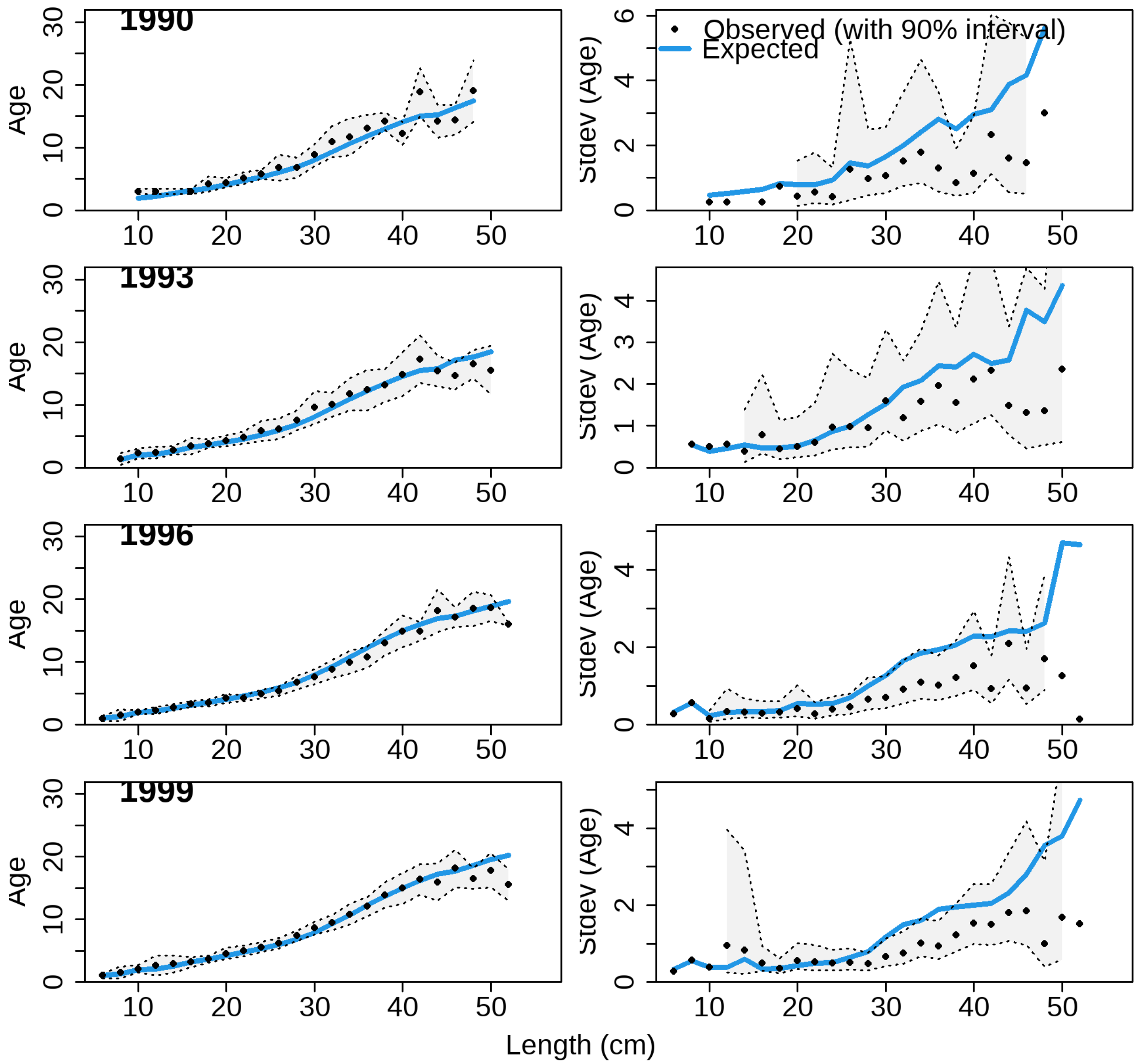

Figure 8.19. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for the Model 17.1a for years 1990-1999 (1 of 4).

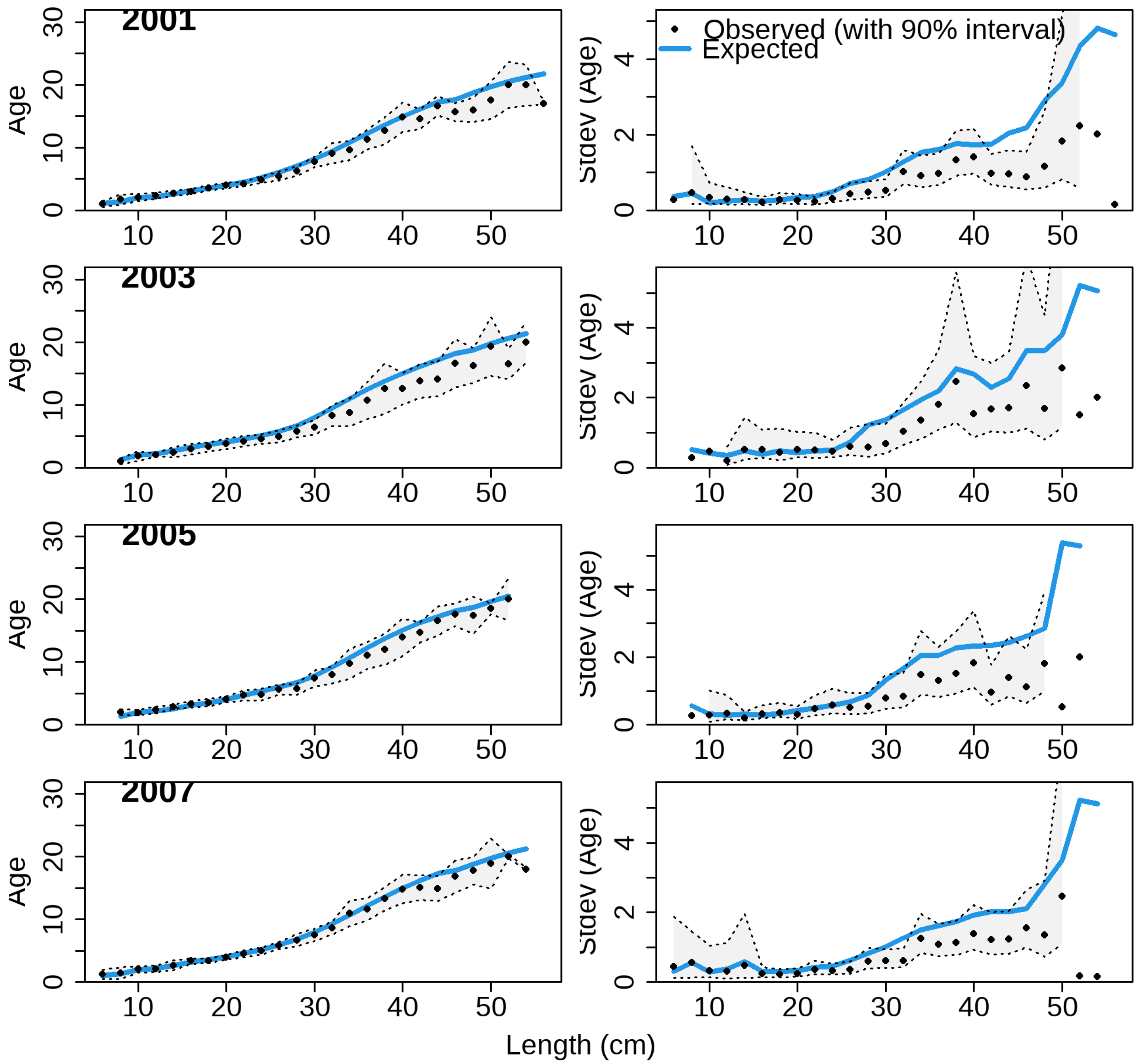

Figure 8.20. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for the Model 17.1a for years 2001-2007 (2 of 4).

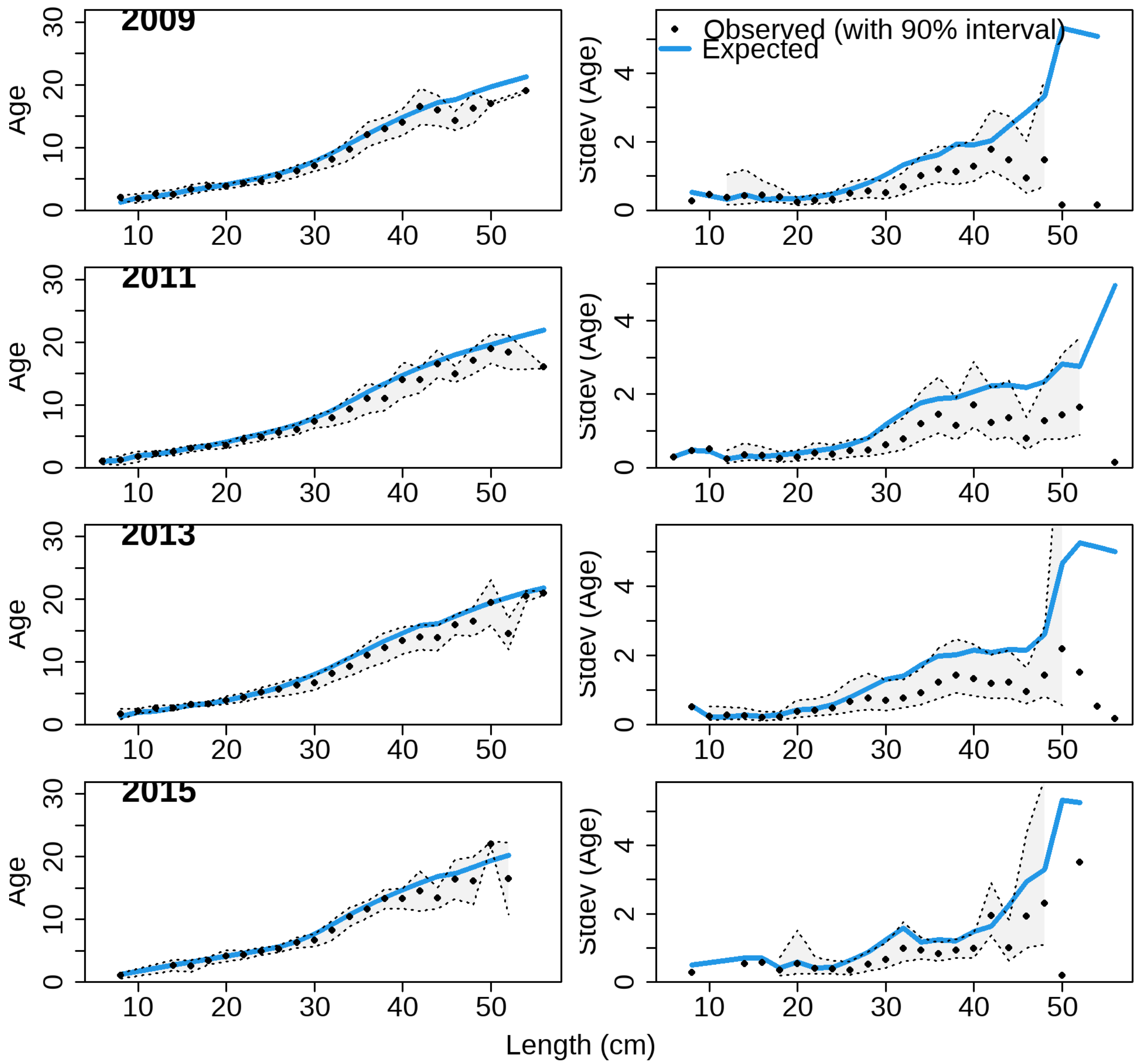

Figure 8.21. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for the Model 17.1a for years 2009-2015 (3 of 4).

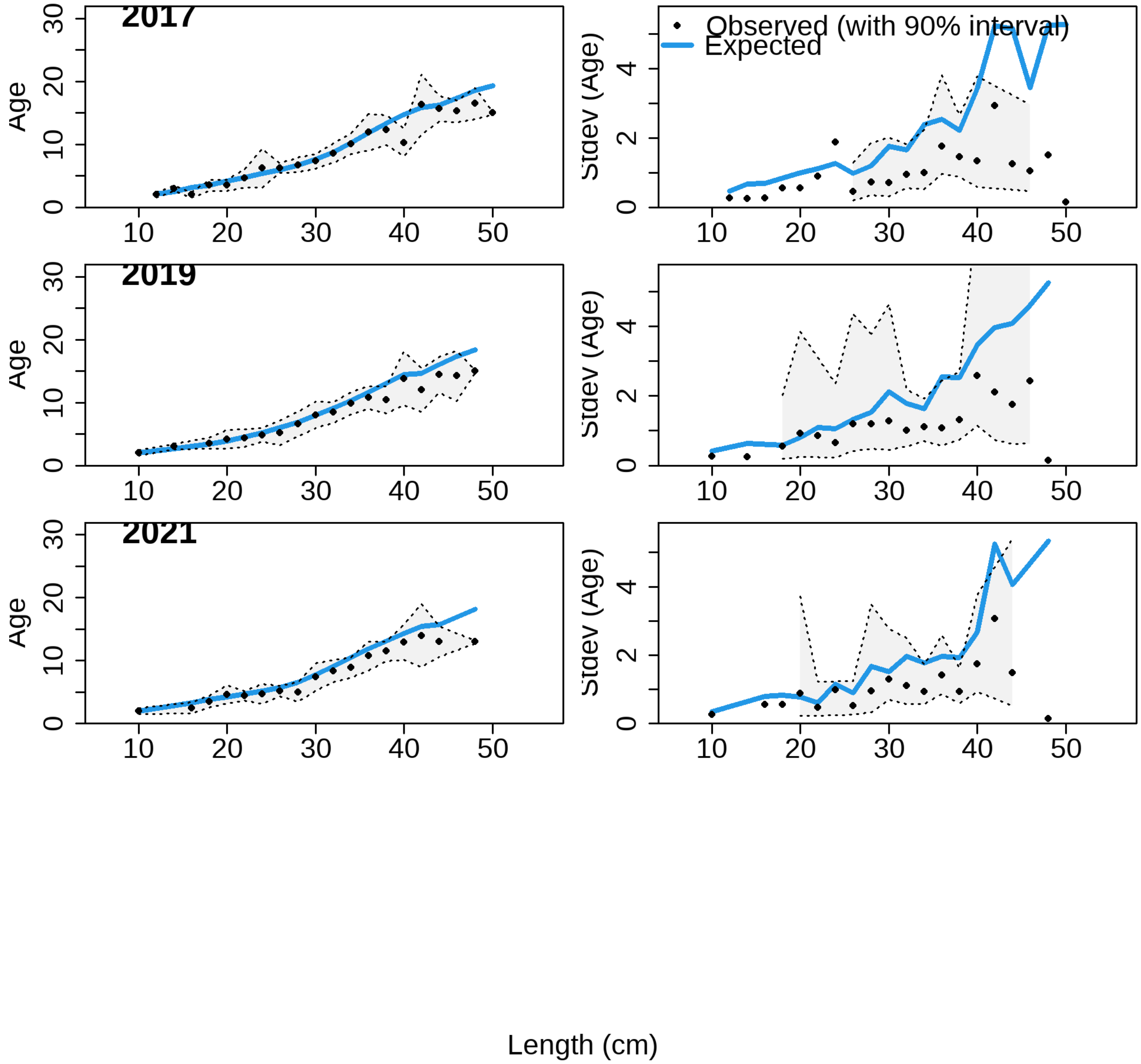

Figure 8.22. Observed and expected mean age-at-length for both females and males with 90% intervals about observed age-at-length (left panels) and observed and expected standard deviation in age-at-length (right panels) for the Model 17.1a for years 2017-2021 (4 of 4).

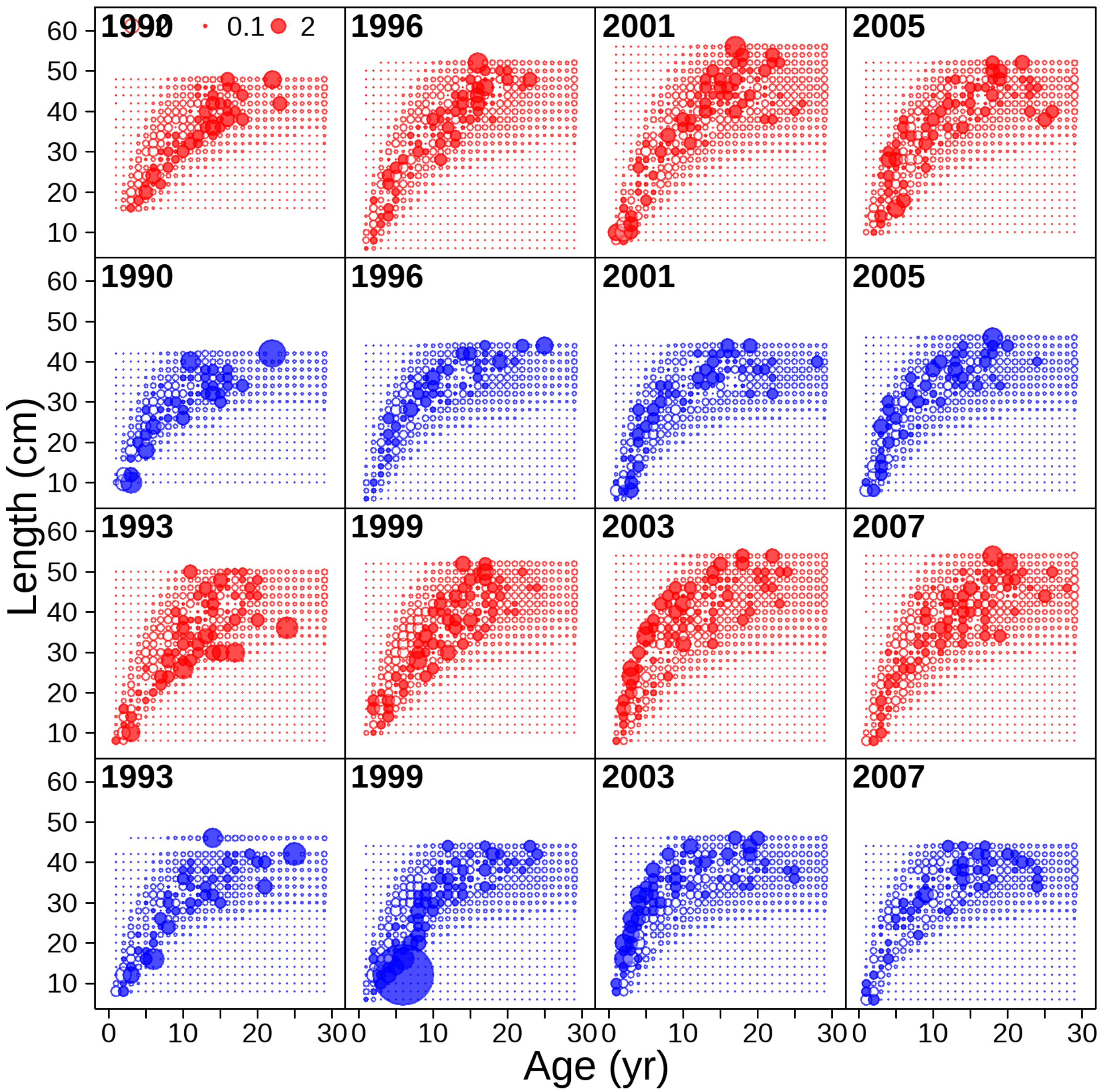

Figure 8.23. Pearson residuals associated with fits to the conditional age-at-length composition data within the model for females (red) and males (blue) for the survey, years 1990-2007 (1 of 2).

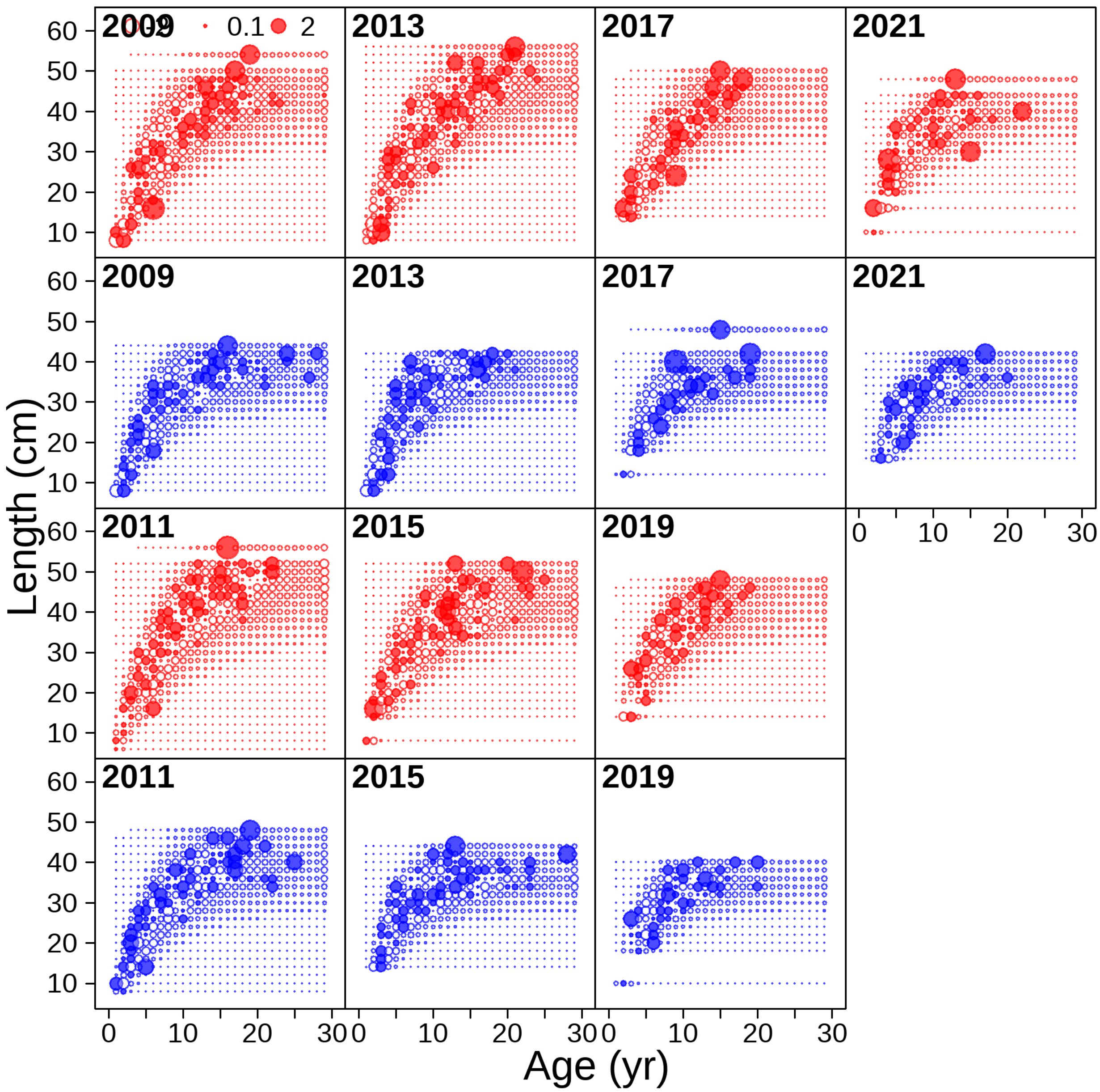

Figure 8.24. Pearson residuals associated with fits to the conditional age-at-length composition data within the model for females (red) and males (blue) for the survey, years 2009-2021 (2 of 2).

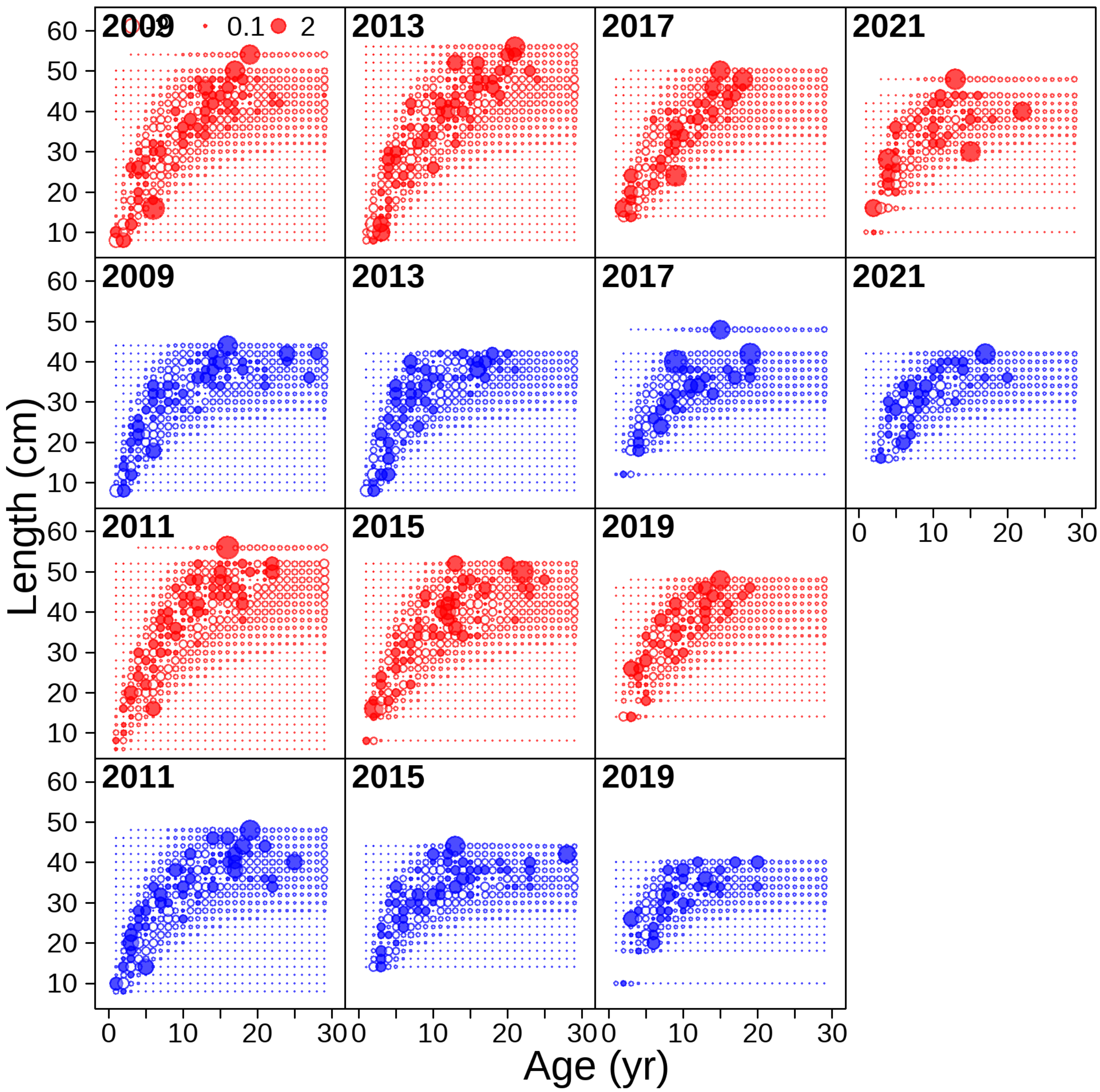

Figure 8.25. Pearson residuals associated with fits to the conditional age-at-length composition data within the model for females (red) and males (blue) for the survey, years 2009-2021 (2 of 2).

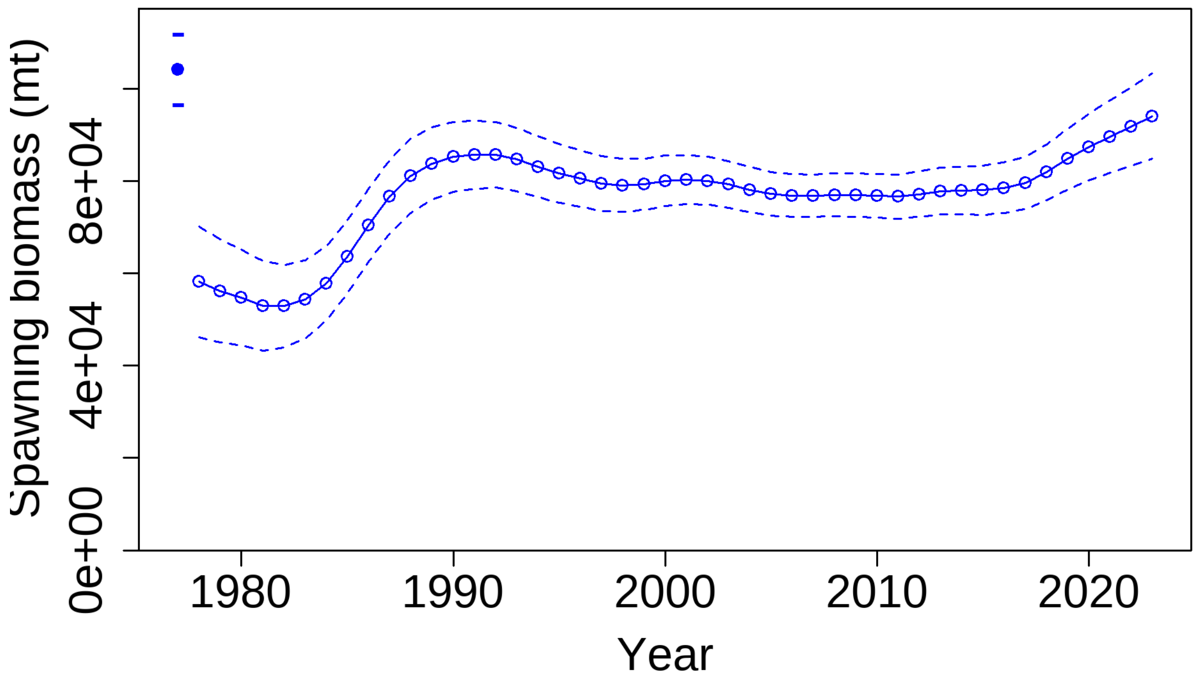

Figure 8.26. Spawning stock biomass time series of estimated over time (solid blue line and circles) and asymptotic 95% confidence intervals (blue dashed lines and/or bars) for Model 17.1a (2022). Point at 1977 is virgin biomass.

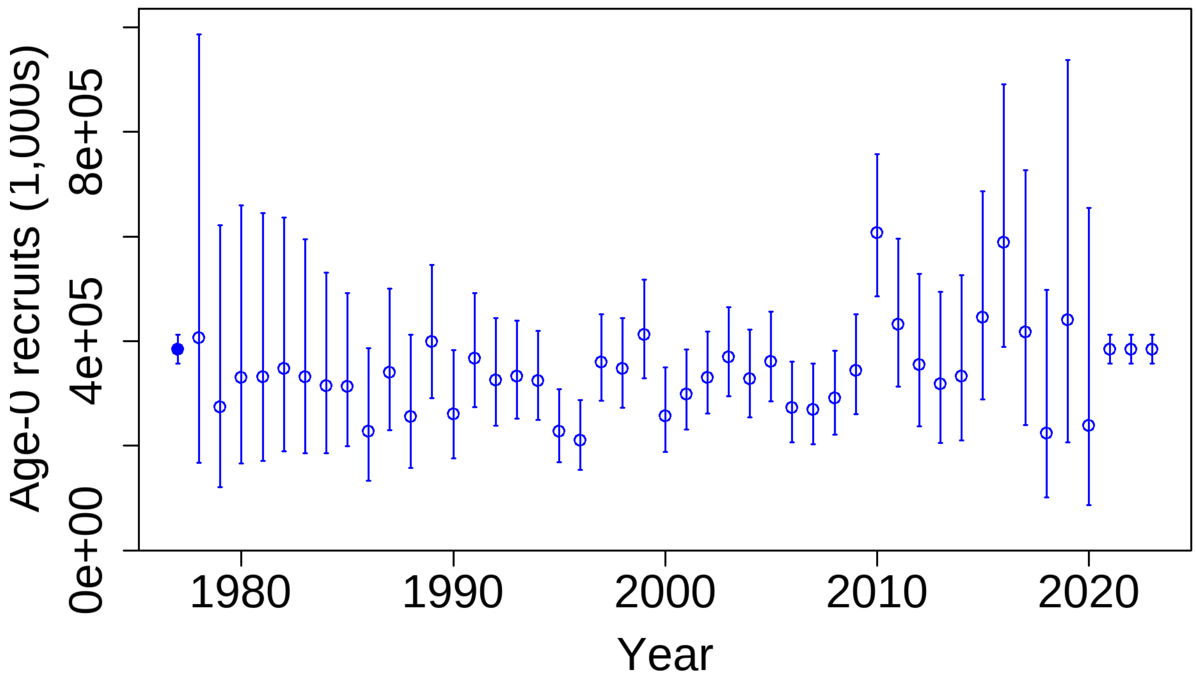

Figure 8.27. Age-zero recruitment time series of estimated over time (solid blue line and circles) and asymptotic 95% confidence intervals (blue dashed lines and/or bars) for Model 17.1a (2022). Point at 1977 is virgin recruitment.

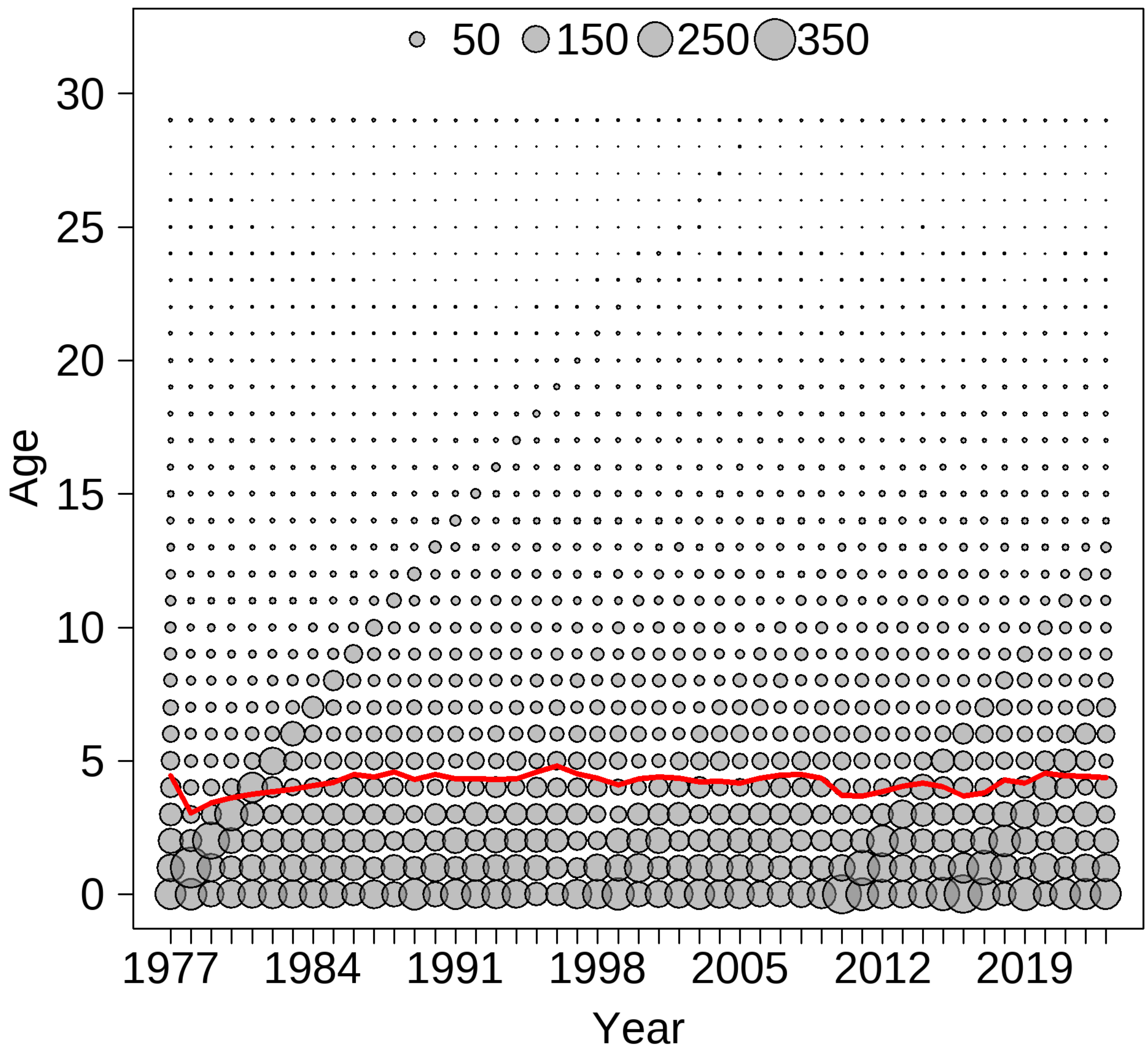

Figure 8.28. Numbers at age (grey bubbles) by year for females. Red line indicates mean age through time (1 of 2).

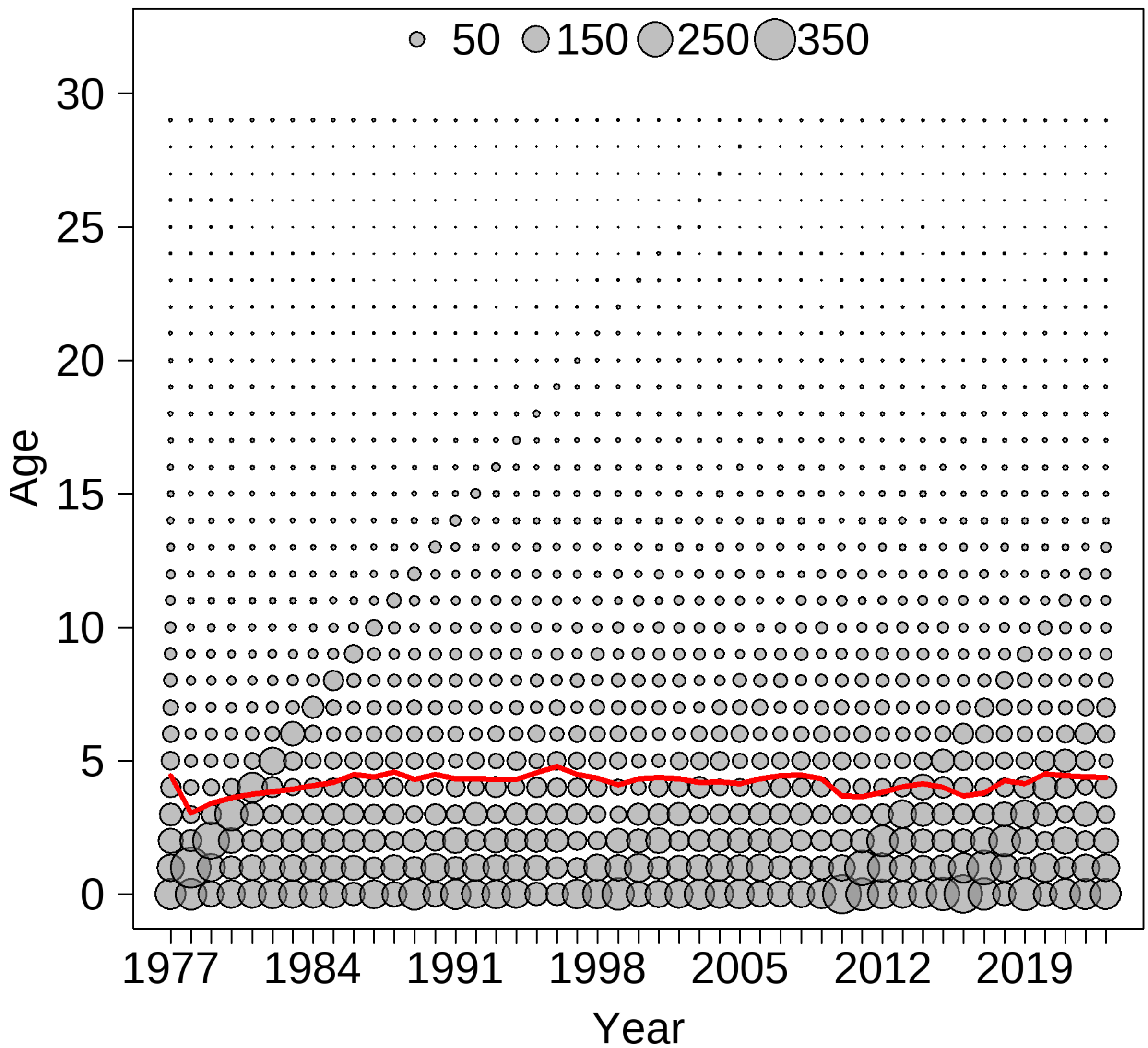

Figure 8.39. Numbers at age (grey bubbles) by year for males. Red line indicates mean age through time (2 of 2).

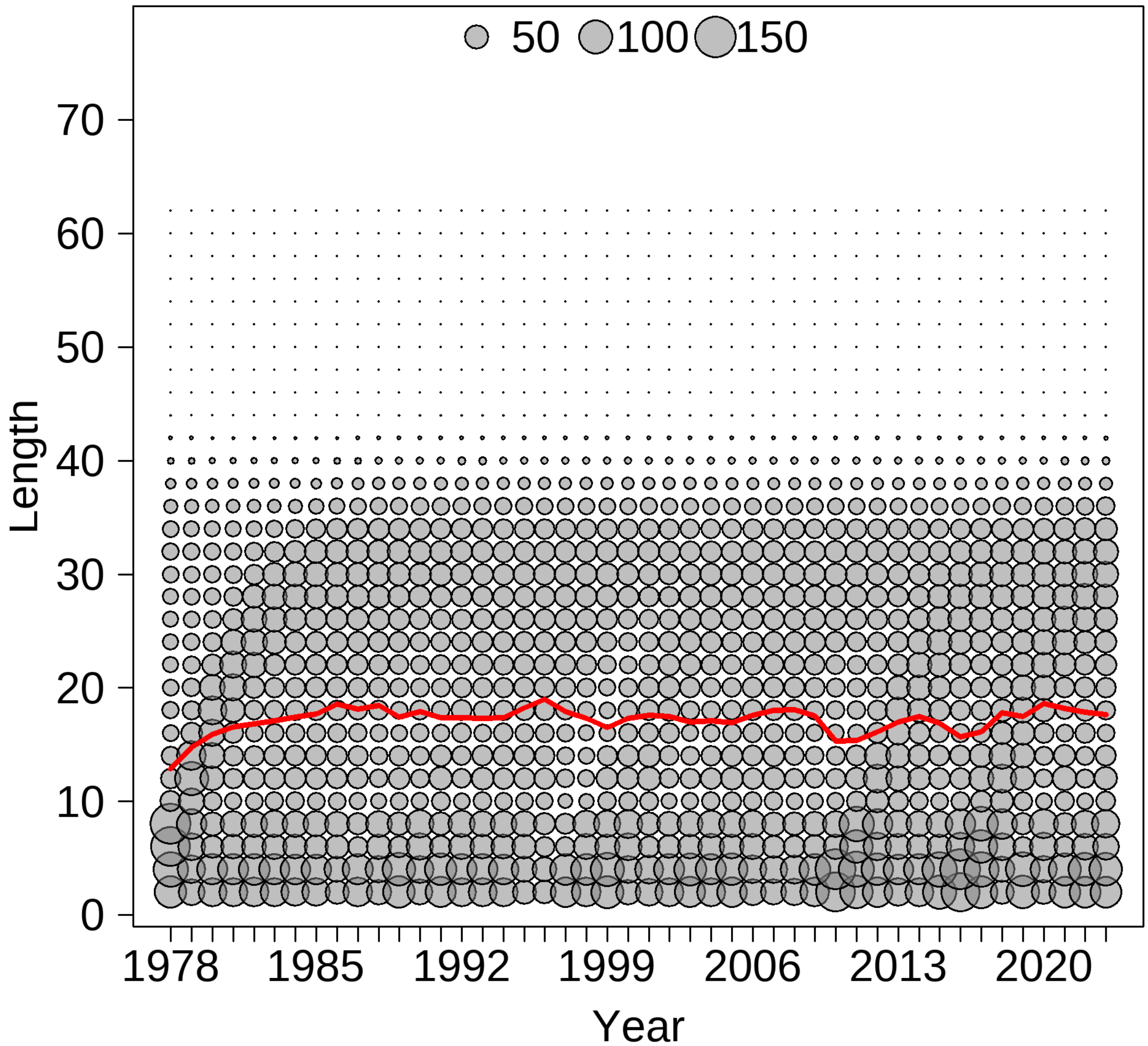

Figure 8.30. Numbers at length (grey bubbles) by year for females (left) and males (right). Red line indicates mean length through time (1 of 2).

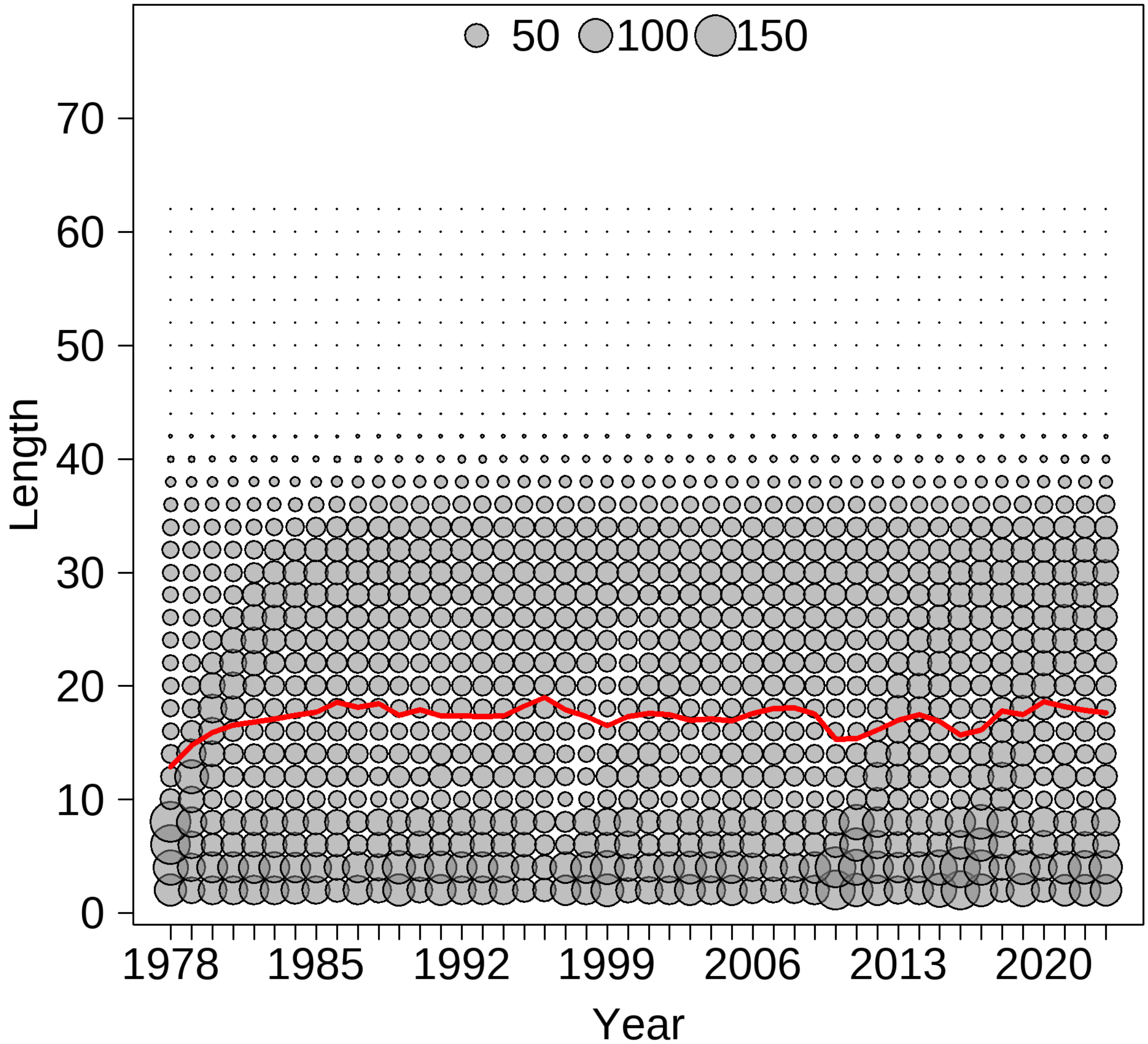

Figure 8.31. Numbers at length (grey bubbles) by year for females (left) and males (right). Red line indicates mean length through time (2 of 2).

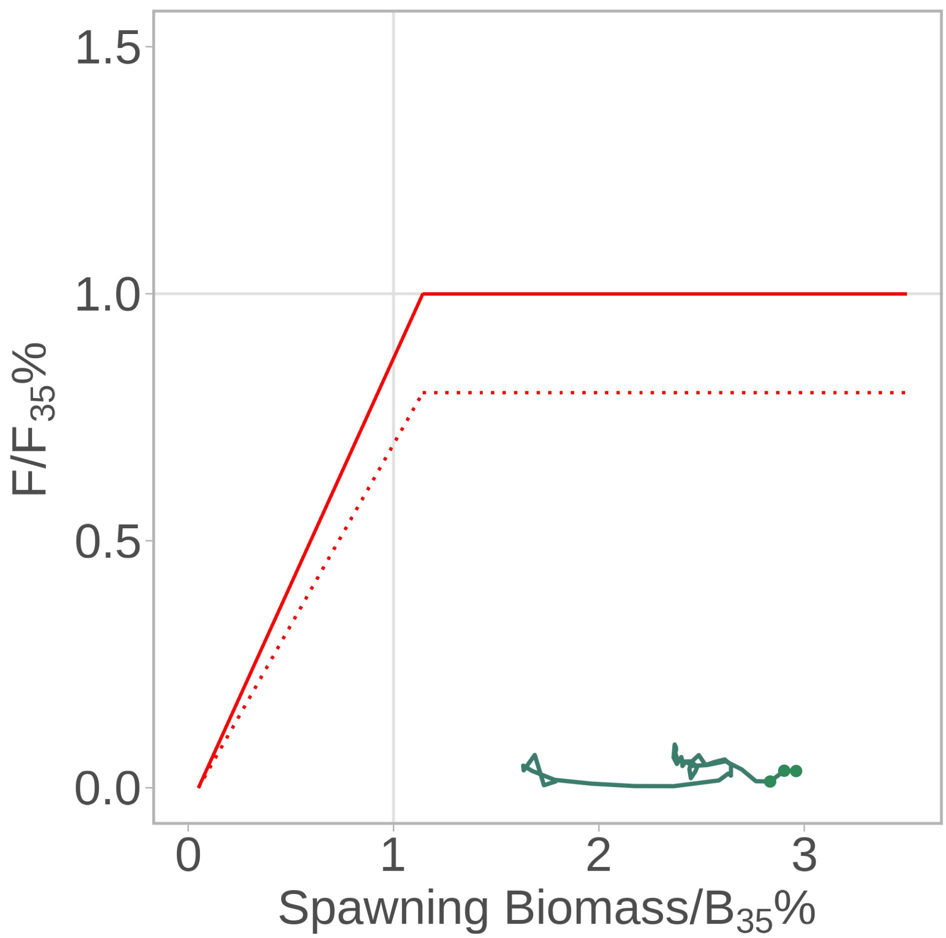

Figure 8.32. Spawning stock biomass relative to $B_{35\%}$ and fishing mortality (F) relative to $F_{35\%}$ from 1978-2021 (solid green line), the OFL control rule (solid red line), the max_{ABC} control rule (dotted red line), $B_{35\%}$ (vertical grey line), and $F_{35\%}$ (horizontal grey line). The 2022-2024 spawning biomass and fishing mortality rates (green points) are as predicted by Alternatives 1 and 2 from the harvest projections.

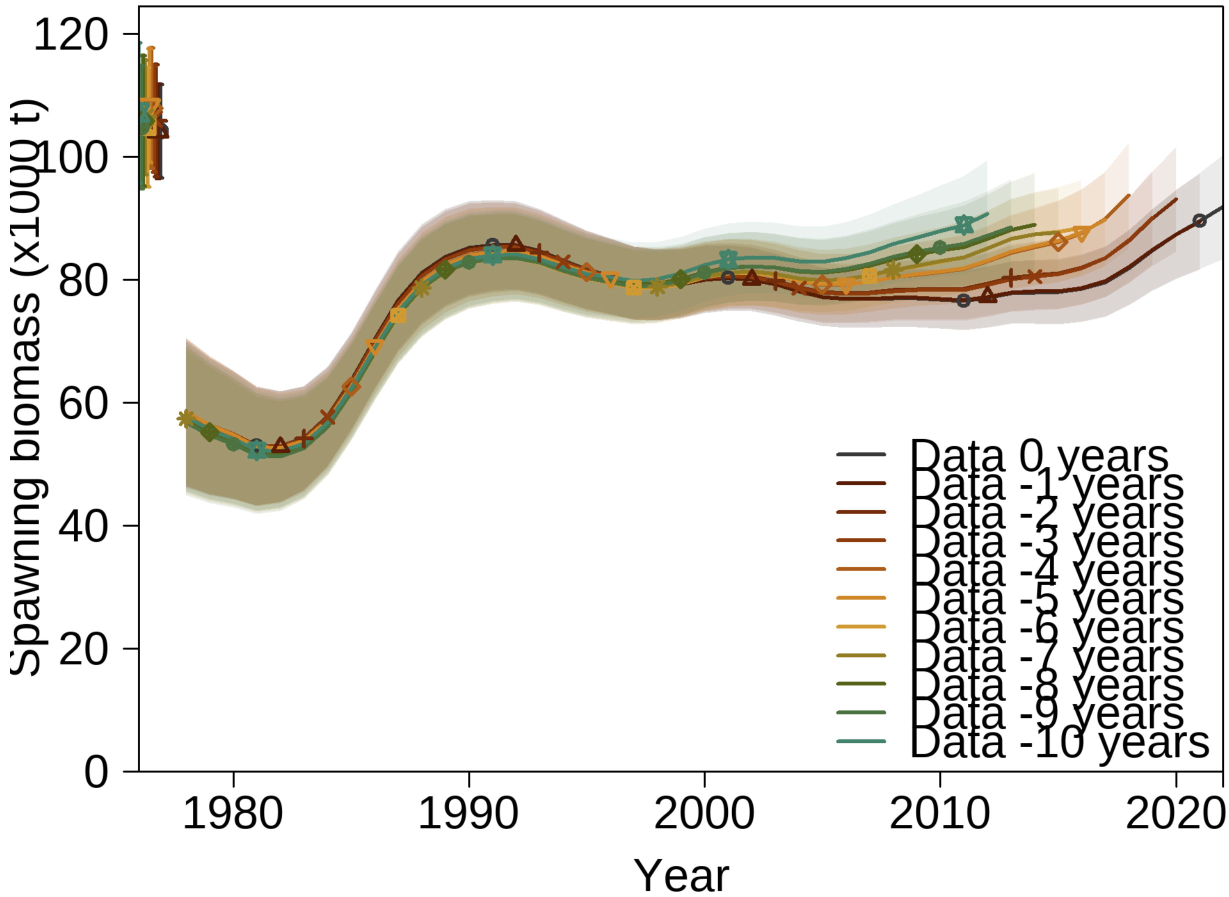

Figure 8.33. Spawning stock biomass for base case model runs with 0 to 10 years of the most recent data removed Points in upper left are virgin biomass.

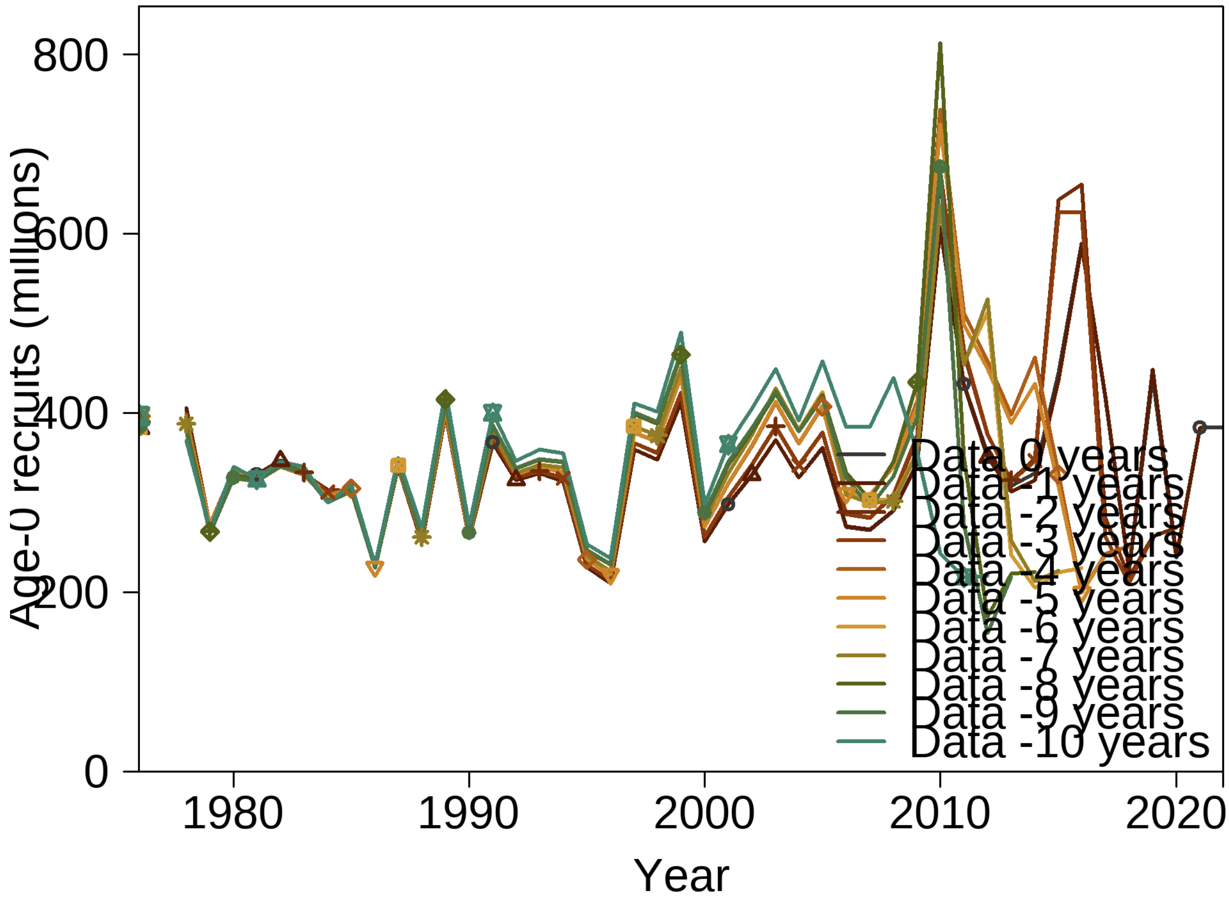

Figure 8.34. Age-0 recruitment for base case model runs with 0 to 10 years of the most recent data removed. The last three years of recruitments for each run were fixed at the mean.

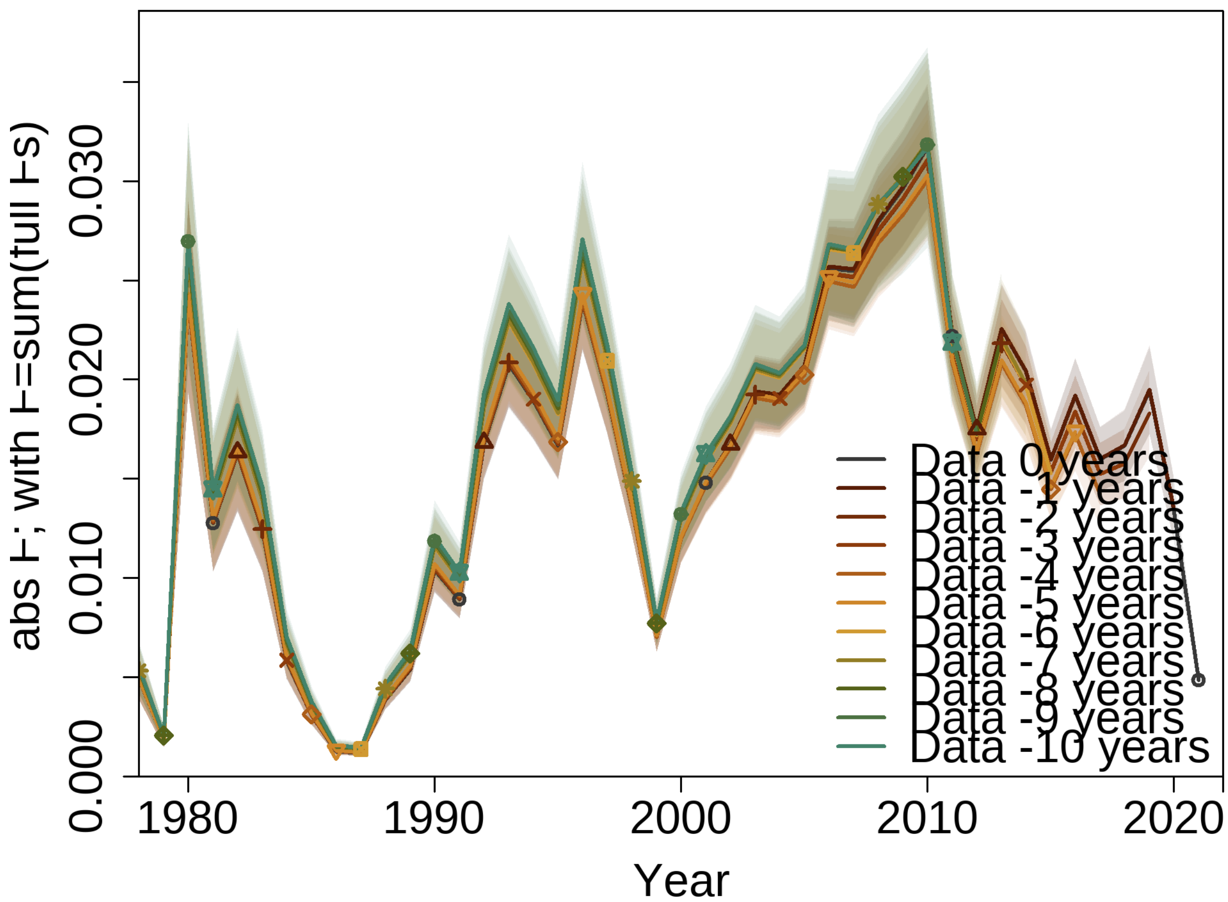

Figure 8.36. Apical fishing mortality for base case model runs with 0 to 10 years of the most recent data removed

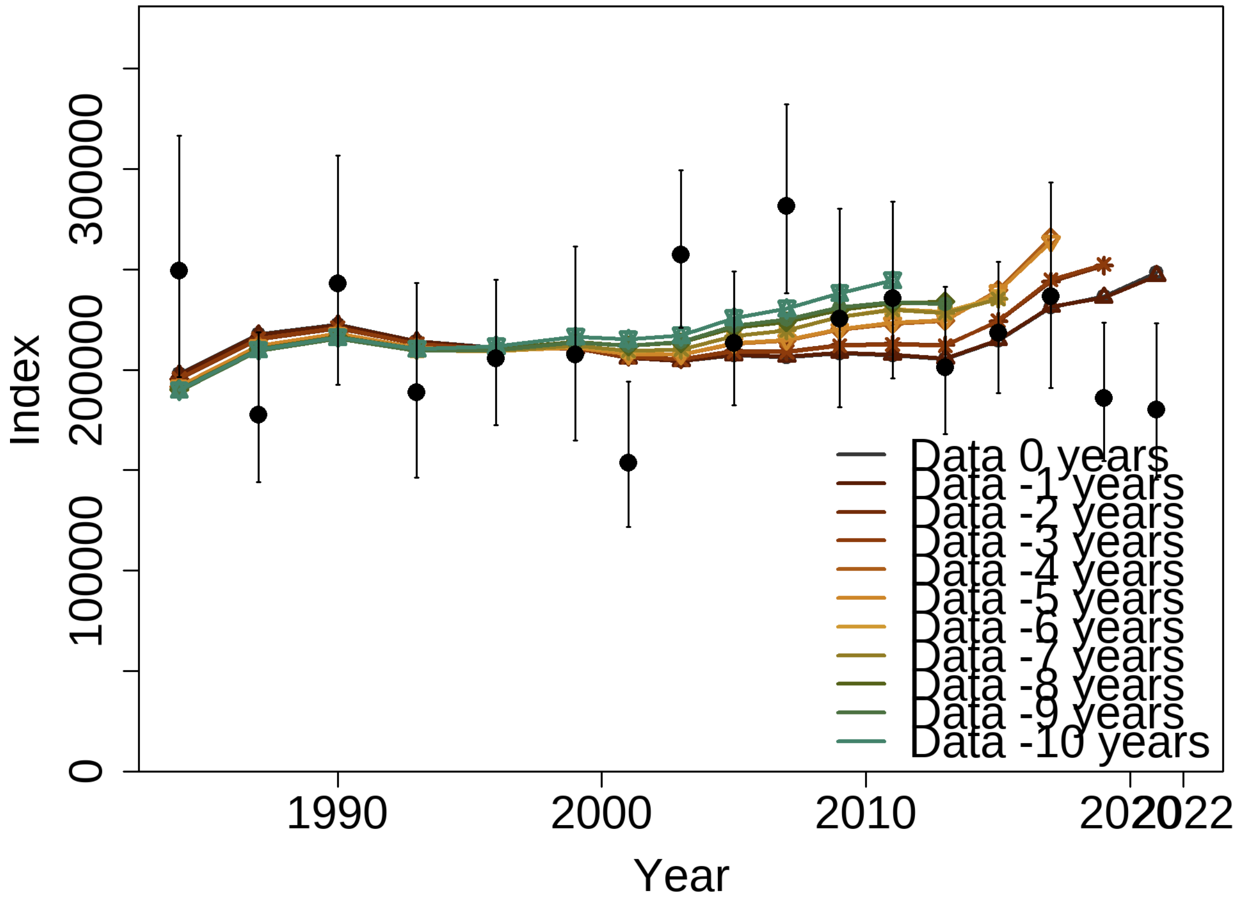

Figure 8.37. Model fit to survey biomass for the base case model with 0 to 10 years of the most recent data removed. Biomass in years where no survey occurred are not plotted.

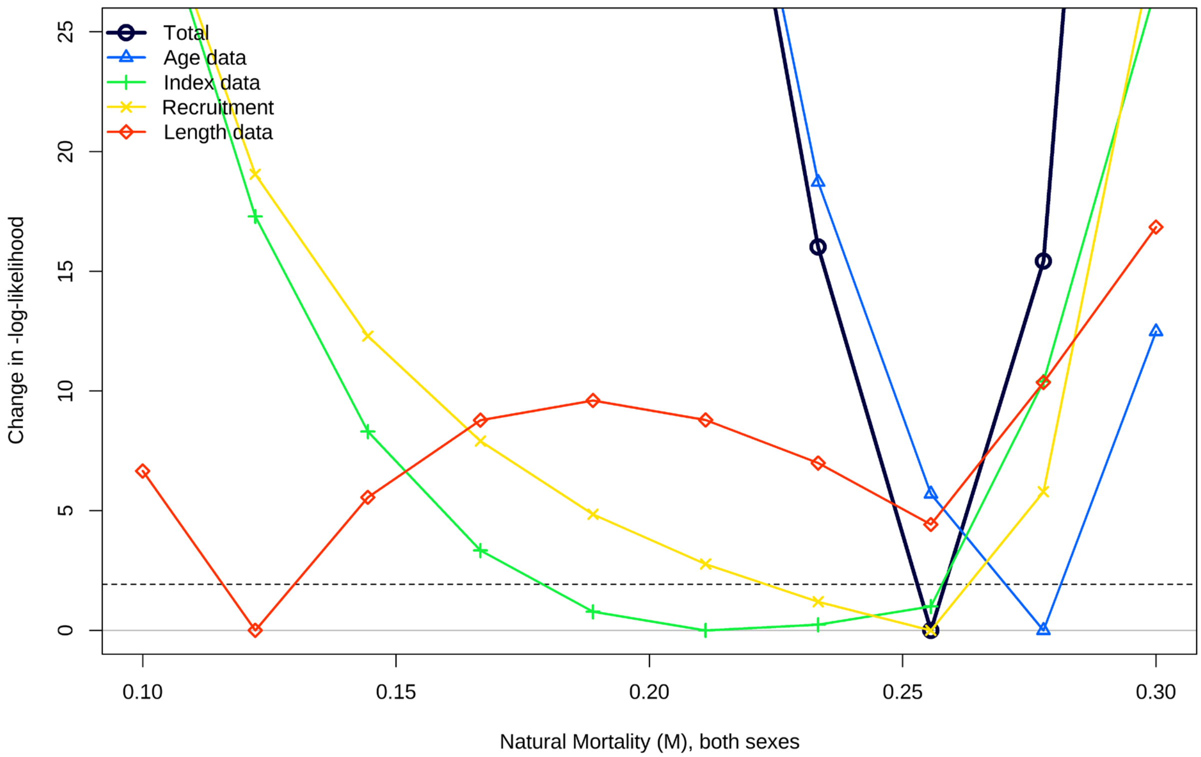

Figure 8.38. Likelihood profiles by data component for Natural Mortality, wherein both sexes were fixed to the same value simultaneously. Horizontal dashed line indicates a log-likelihood difference of 1.92 from Model 17.1a; runs below this line are statistically indistinguishable.

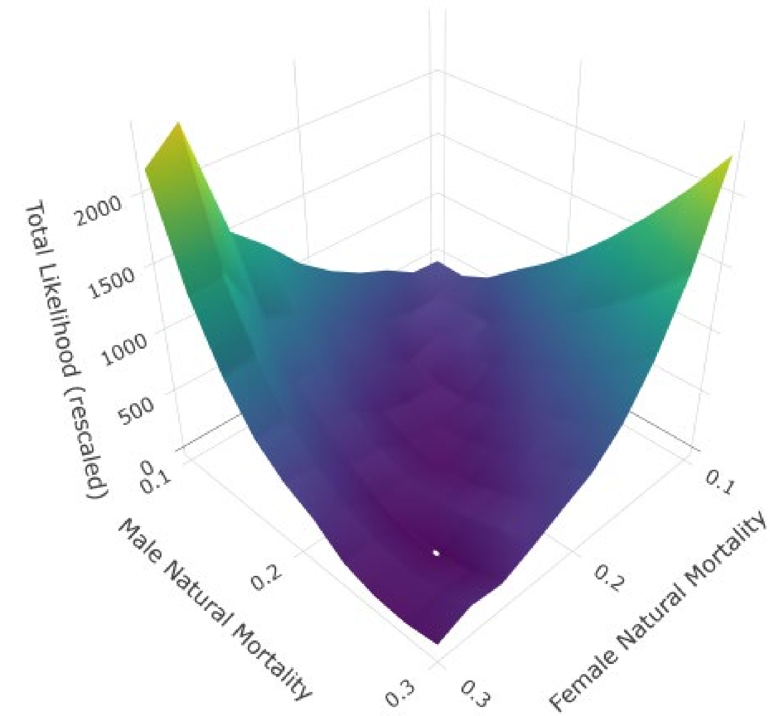

Figure 8.39. 3-d visualization of simultaneous profile over natural mortality for each sex separately. The white contour indicates a log-likelihood difference of 1.92 from Model 17.1a; models within these bounds are statistically indistinguishable. The minimum likelihood occured when both sexes' M = 0.256. It is fixed to 0.2 in the base model.

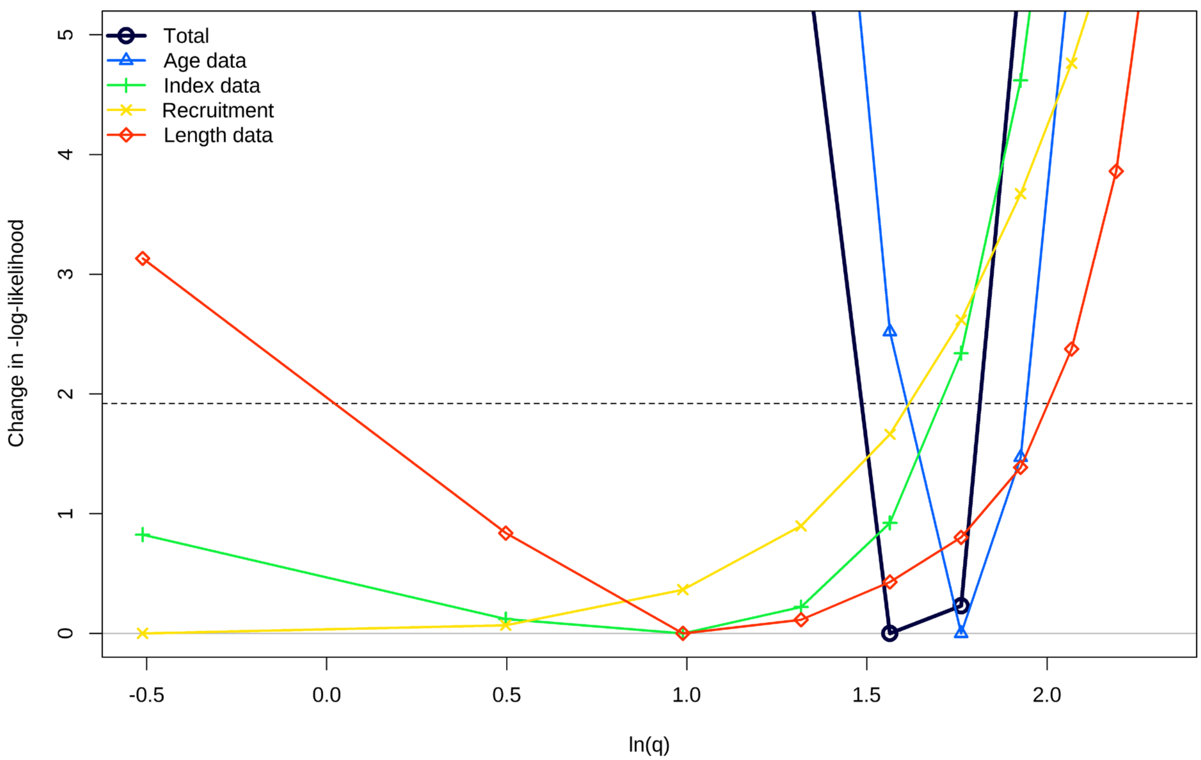

Figure 8.40. Likelihood profiles by data component for the log of catchability (ln(q)). Horizontal dashed line indicates a log-likelihood difference of 1.92 from Model 17.1a; runs below this line are statistically indistinguishable.

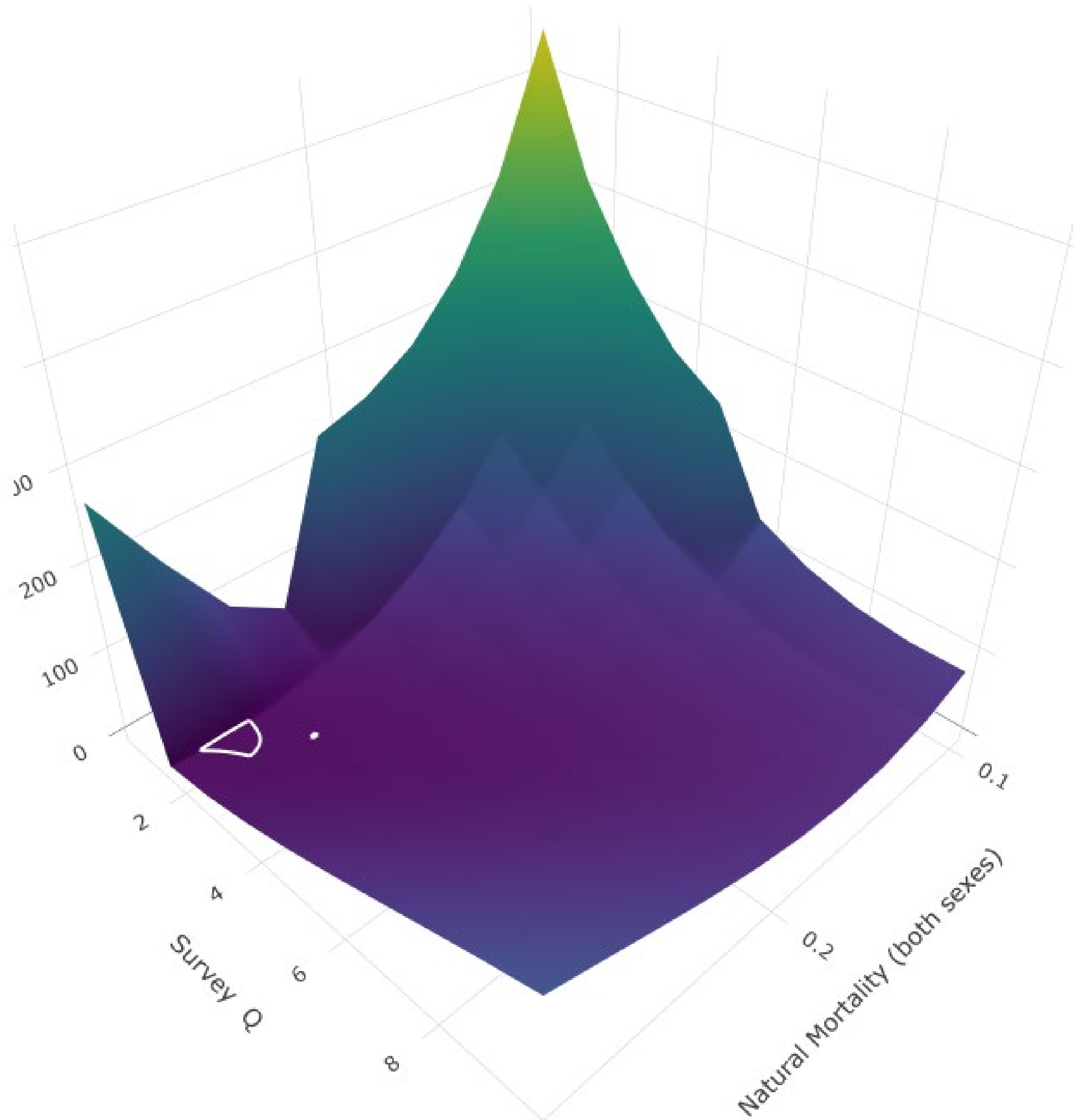

Figure 8.41. 3-d visualization of simultaneous profile over natural mortality and survey catchability. Natural mortality was identical for both sexes in these runs. The white contours indicate a log-likelihood difference of 1.92 from Model 17.1a; models within these bounds are statistically indistinguishable. The minimum likelihood occurred at q = 1.64 and M = 0.27. Q is fixed to 1 and M is fixed to 0.2 in the base model.

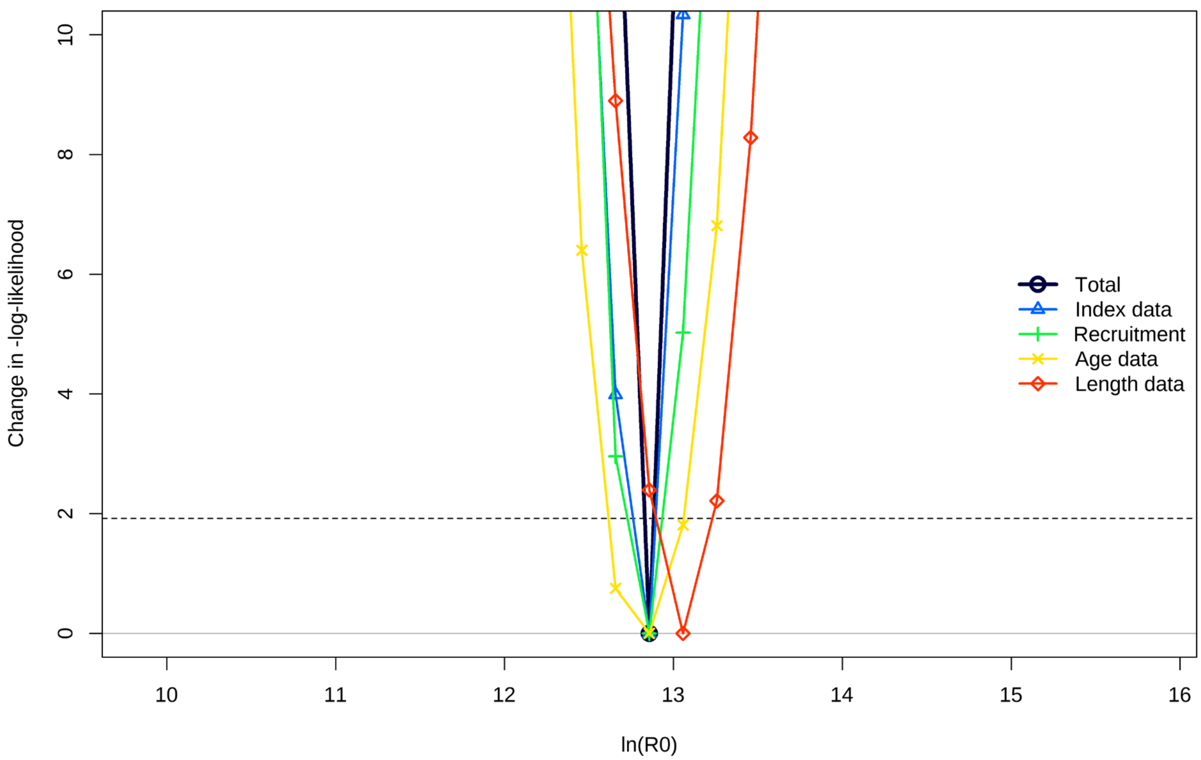

Figure 8.42. Likelihood profiles by data component for the log of unfished recruitment (ln[R0]). Horizontal dashed line indicates a log-likelihood difference of 1.92 from Model 17.1a; runs below this line are statistically indistinguishable.

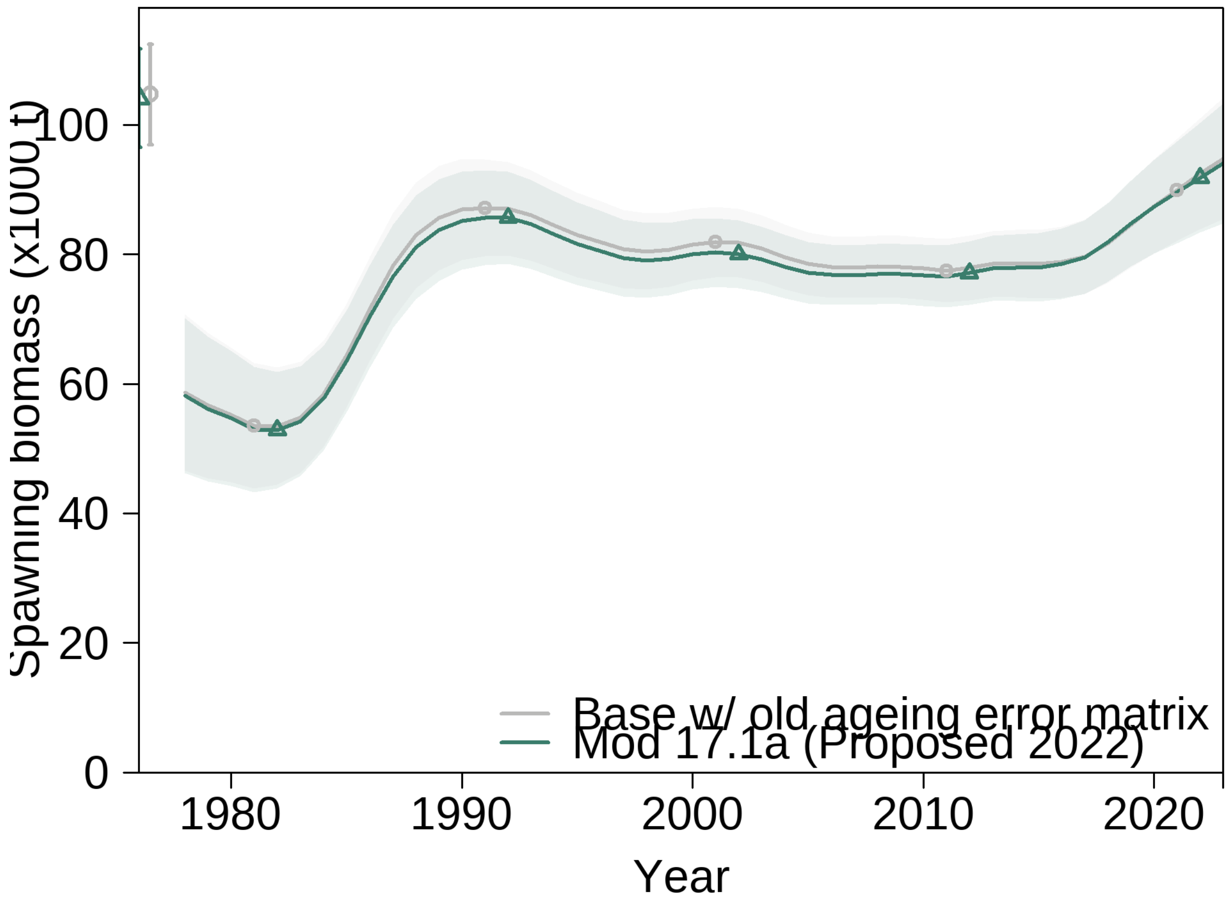

Figure 8.43. SSB survey time series for the proposed 2022 base model (17.1a) with the new aging error matrix (green lines and points) and the previous matrix (grey lines and points).

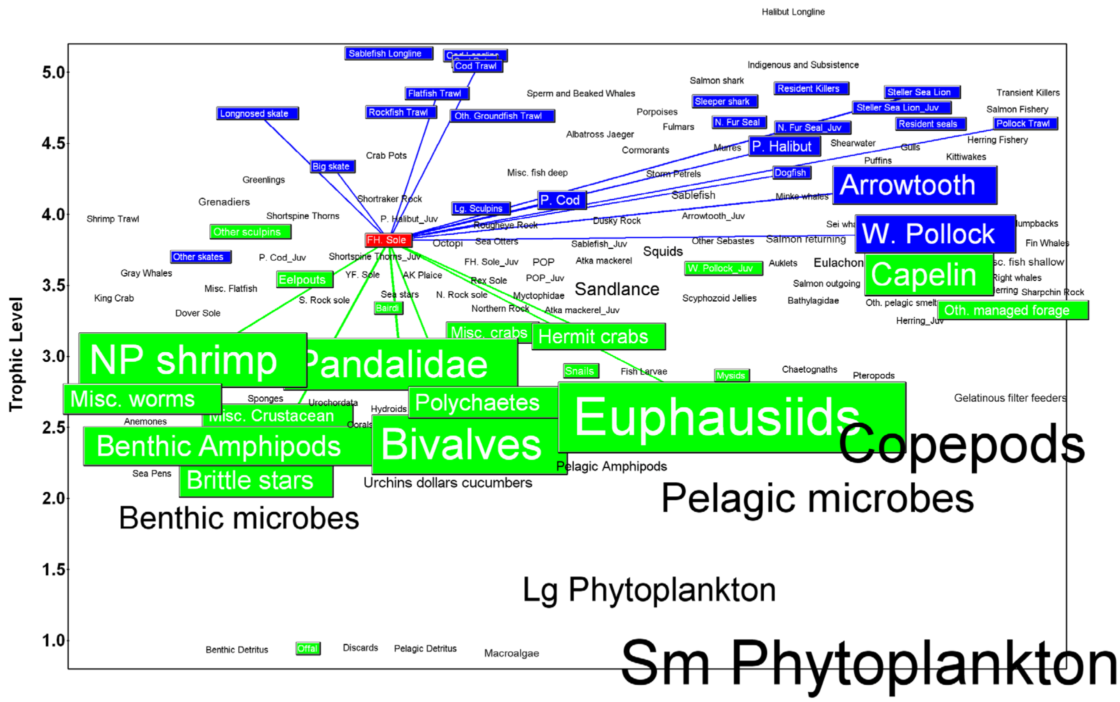

Figure 8.44. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., 2007) highlighting adult flathead sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

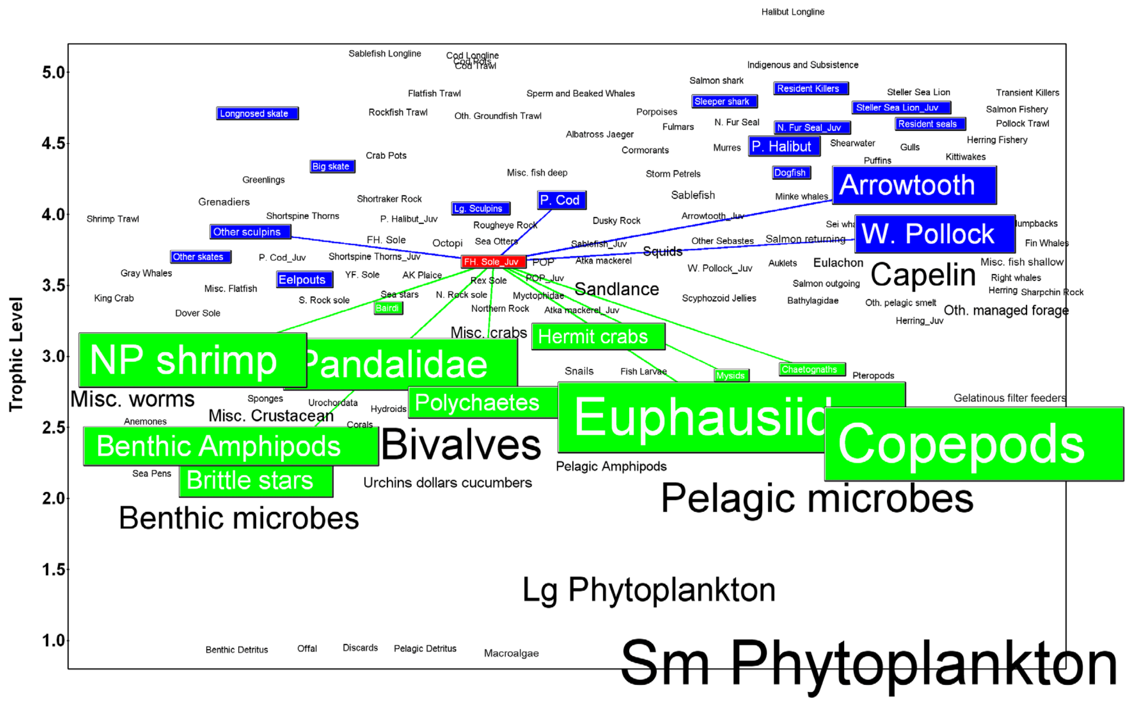

Figure 8.45. Gulf of Alaska food web from the GOA ecosystem model (Aydin et al., 2007) highlighting juvenile flathead sole links to predators (blue boxes and lines) and prey (green boxes and lines). Box size reflects relative standing stock biomass.

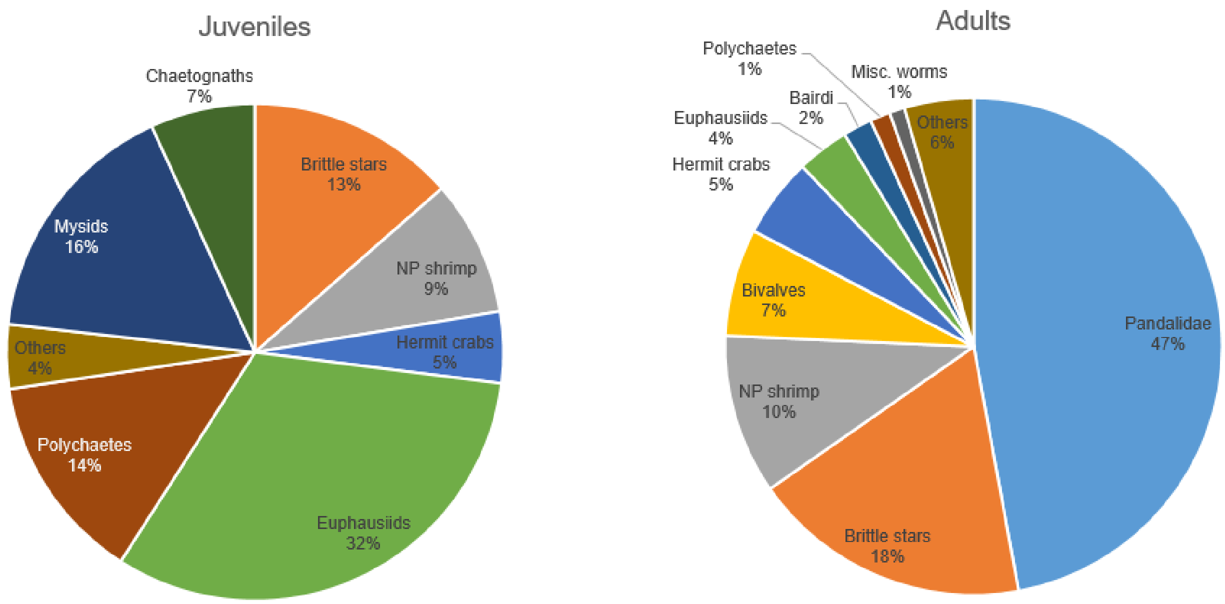

Figure 8.46. Diet composition for Gulf of Alaska juveniles (left) and adults (right) flathead sole from the GOA ecosystem model (data from Aydin et al., 2007).

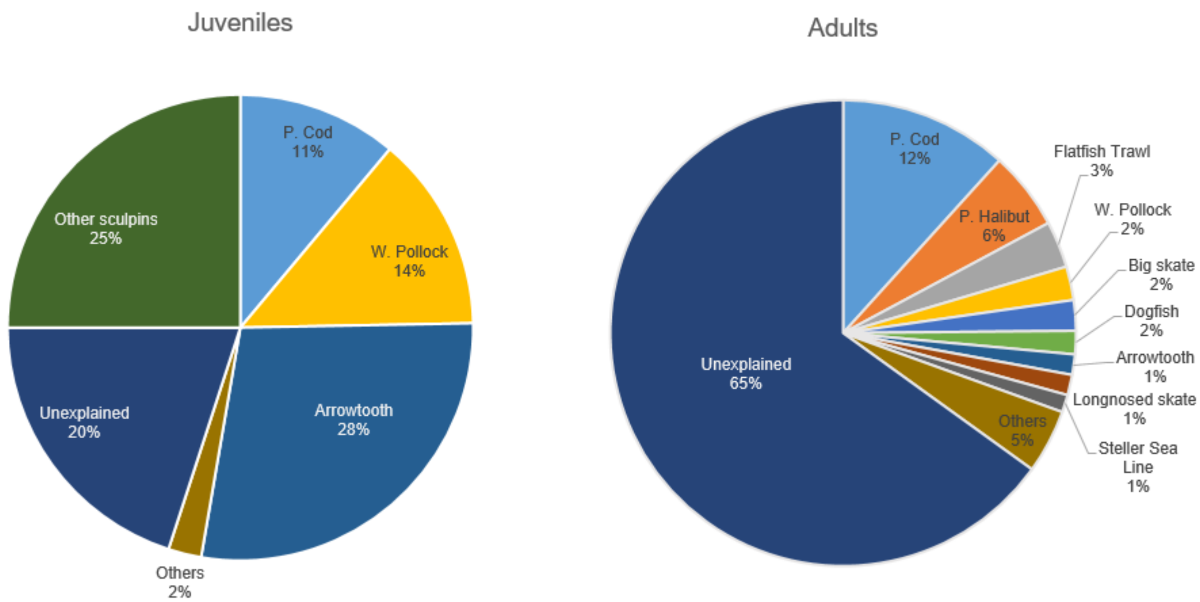

Figure 8.47. Decomposition of natural mortality for Gulf of Alaska juveniles (left) and adults (right) flathead sole from the GOA ecosystem model (data from Aydin et al., 2007).

Appendix 10a. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, a dataset has been generated to help estimate total catch and removals from NMFS stocks in Alaska. This dataset estimates total removals that occur during non-directed groundfish fishing activities. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates.

Table 8.17. Non-Commercial Catches of GOA Flathead Sole from ADF&G; values in t. “Other Sources” include ADF&G Sablefish Longline Survey, Kachemak Bay Large Mesh Trawl Survey, Kodiak Scallop Dredge, Prince William Sound Large Mesh Trawl Survey Scallop Dredge Survey, Small-Mesh Trawl Survey. St. Matthews Crab Survey, and the Yakutat Scallop Dredge.

Year	ADF&G Large Mesh Trawl Survey	Other ADF&G Sources
1988		
1989		
1990		
1991		
1992		
1993		
1994		
1995		
1996		
1997		
1998	2	0
1999	5	0.01
2000	3	2
2001	6	0
2002	2	0
2003	5	3
2004	4	3
2005	6	3
2006	3	3
2007	4	0.39
2008	2	0
2009	5	0.01
2010	84	12
2011	84	9
2012	93	8
2013	79	5
2014	73	6
2015	88	6
2016	81	2
2017	83	13
2018	77	2
2019	82	3
2020	67	6
2021	61	0.46

Year	IPHC annual LL survey
1988	
1989	
1990	
1991	
1992	
1993	
1994	
1995	
1996	
1997	
1998	
1999	
2000	
2001	
2002	
2003	
2004	
2005	
2006	
2007	
2008	
2009	
2010	4
2011	1
2012	29
2013	
2014	20

Year	IPHC annual LL survey
2015	2
2016	5
2017	2
2018	19
2019	2
2020	14
2021	9

Table 8.18. Non-Commercial Catches of GOA Flathead Sole from the IPHC; values in kg.

Year	Annual LL survey	GOA Acoustic Twl Survey	GOA Bottom Twl Survey	Kenai PWS Acoustic Twl Survey	Salmon EFP	Shelikof acoustic survey	Shelikof and Elikof EWT	nmfs_shelikof_straight_walleye_pollock_acoustic_trawl_survey	nmfs_shumagin_and_sanak_eit	nmfs_shumagin_islands_walleye_pollock_acoustic_trawl_survey	nmfs_shumigans_acoustic_survey	nmfs_structure_of_gulf_of_alaska_forage_fish_communities	nmfs_western_gulf_of_alaska_pollock_acoustic_cooperative_survey	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shelikof_strait_and_vicinity	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shumagin_islands_and_vicinity
1988	26														
1989	54														
1990	81														
1991	54														
1992	67														
1993	56														
1994	40														
1995	82														
1996	49														
1997	46														
1998	35														
1999	34														
2000	12														
2001	17														
2002	24														

Year	Annual LL survey	GOA Acoustic Twl Survey	GOA Bottom Twl Survey	Kenai PWS Acoustic Twl Survey	Salmon EFP	Shelikof acoustic survey	Shelikof and Elikof EWT	nmfs_shelikof_straight_walleye_pollock_acoustic_trawl_survey	nmfs_shumagin_and_sanak_eit	nmfs_shumagin_islands_walleye_pollock_acoustic_trawl_survey	nmfs_shumigans_acoustic_survey	nmfs_structure_of_gulf_of_alaska_forage_fish_communities	nmfs_western_gulf_of_alaska_pollock_acoustic_cooperative_survey	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shelikof_strait_and_vicinity	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shumagin_islands_and_vicinity
2003	16														
2004	20														
2005	7														
2006	40														
2007	29														
2008	38														
2009	54														
2010	82					4					201	8	16		
2011	39		13,653												
2012	19						7		3						
2013	56		9,699		380										
2014	63				180										
2015	52		13,689												
2016	18														
2017	35	7	10,413	0.43				0.21		0.75					

Year	Annual LL survey	GOA Acoustic Twl Survey	GOA Bottom Twl Survey	Kenai PWS Acoustic Twl Survey	Salmon EFP	Shelikof acoustic survey	Shelikof and Elikof EWT	nmfs_shelikof_straight_walleye_pollock_acoustic_trawl_survey	nmfs_shumagin_and_sanak_eit	nmfs_shumagin_islands_walleye_pollock_acoustic_trawl_survey	nmfs_shumigans_acoustic_survey	nmfs_structure_of_gulf_of_alaska_forage_fish_communities	nmfs_western_gulf_of_alaska_pollock_acoustic_cooperative_survey	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shelikof_strait_and_vicinity	nmfs_winter_acoustic_trawl_survey_of_walleye_pollock_in_shumagin_islands_and_vicinity
2018	25							1.00		4.00					
2019	25		7,894											85	
2020	6													2	1
2021	10		7,980												

Table 8.19. Non-Commercial Catches of GOA Flathead Sole from NMFS; values in kg.