13. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska

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Executive Summary

The rougheye and blackspotted (RE/BS) rockfish complex is assessed on a biennial schedule to coincide with the availability of new bottom trawl survey data (Hollowed et al. 2016). For this on-cycle year, we present a full operational stock assessment document with updated assessment and projection model results to recommend harvest levels for the next two years. In off-cycle years, we present a harvest projection consisting of an executive summary with recent survey trends and recommended harvest levels for the next two years based on the projection model with updated fishery catch.

We use a statistical age-structured model as the primary assessment tool for the GOA RE/BS rockfish complex, which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels, and a random effects model for apportionment (REMA), which partitions the Acceptable Biological Catch (ABC) between the western, central, and eastern GOA management areas. The data sets used in the assessment include total catch biomass, fishery age and size compositions, bottom trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions.

We recommend a change from Model 15.4 to Model 23.1b, which includes the following changes: (1) removal of the 1984 and 1987 bottom trawl survey data from the assessment and apportionment models; (2) a new natural mortality (*M*) prior, maturity curve, and ageing error matrix; (3) updated data used to estimate the weight-at-age vector and age-length transition matrix, which had not been updated since 2015; (4) constrained catchability (*q*) parameters for both surveys and fixed recruitment variability σ_R; (5) updated apportionment methods using the *rema* R library. The recommended new apportionment method averages proportions of both the REMA-predicted biomass from the bottom trawl survey and the REMA-predicted relative population weights from the longline survey, thus balancing data conflict between the two surveys.

Summary of Changes in Assessment Inputs

Changes in the input data:

1) Updated catch estimate for 2022, and new catch estimates used in projections for 2023-2025 (see *Specified Catch Estimation* subsection in **Harvest Recommendations** section)
2) New fishery lengths for 2021
3) New fishery ages for 2022
4) New bottom trawl survey biomass estimates for 2023 and removal of the 1984 and 1987 estimates in the assessment and apportionment models.
5) New bottom trawl survey ages for 2019 and 2021 and removal of the 1984 and 1987 data.
6) New longline survey relative population numbers (RPN) and weights (RPW) for 2022 and 2023
7) New longline survey RPN-weighted length frequencies for 2022 and 2023.

8) Updated weight-at-age vector and age-length transition matrix using status quo methodology that utilizes bottom trawl survey age data from 1990-2021 and length and weight data through 2023.

Changes in the assessment methodology (for the recommended model):

1) *M* was fixed at 0.042 based on the Cope and Hamel (2022) longevity estimator and maximum ages from the GOA fishery and bottom trawl surveys.
2) New maturity-at-age using data from Conrath (2017) and Conrath and Hulson (2022).
3) New ageing error using the *nwfscAgeingError* R library (Punt et al. 2008; Thorson et al. 2012).
4) Priors on bottom trawl and longline survey catchabilities were constrained with a coefficient of variation (CV) of 0.05 and mean of 1.0 in order to improve model stability and retrospective behavior.
5) Recruitment variability σ_R was fixed in order to improve model stability and retrospective behavior.

Assessment model numbering and definitions:

1) **Model 15.4**: the base assessment model used in 2021 with updated catches, abundance indices, and composition data. This model was first approved in 2015.
2) **Model 15.4a**: same as Model 15.4 but with the 1984 and 1987 bottom trawl survey data removed.
3) **Model 23.1**: same as Model 15.4a but with the updated weight-at-age vector and age-length transition matrix, new *M* prior, new maturity curve, and new ageing error matrix.
4) **Model 23.1a**: same as Model 23.1 but with constrained priors on the bottom trawl survey biomass and the longline survey RPNs (Mean = 1.0, CV = 0.05) and no longer estimating σ_R.
5) **Model 23.1b (author recommended)**: same as Model 23.1a but with *M* fixed to the prior mean of 0.042.

Changes in the apportionment methodology:

1) Transition to the *rema* R library.
2) Estimation of the scaling parameters that convert area-specific longline survey RPWs to units of biomass. These are currently fixed at 1.
3) Use the average of the proportion predicted biomass and proportion predicted RPWs by area to inform apportionment ratios.

Apportionment model numbering and definitions:

1) **Apportionment 19***: the base apportionment model used in 2021 with longline survey scaling parameters fixed at 1. The "*" denotes transition to the *rema* R library. This model was first approved in 2019.
2) **Apportionment 19a***: same as Apportionment 19* but with the 1984 and 1987 bottom trawl survey data removed.
3) **Apportionment 23**: same model inputs but with the area-specific longline survey scaling parameters estimated. This apportionment method uses the average of the proportion predicted biomass and proportion predicted RPWs by area to inform apportionment ratios.

Summary of Results

Using Model 23.1b, the maximum permissible ABC for 2024 is 1,302 t. This ABC is 69% higher than the 2024 ABC of 772 t from the 2022 harvest projection. **Due to major concerns in the assessment and population dynamics categories of the risk table, we recommend a reduction from the maximum permissible ABC of 1,302 t to 1,037 t for 2024.** We used a "stair step" approach, where we split the difference between the 2024 ABC specified last year and the 2024 maximum ABC estimated this year. We applied the same logic to obtain the reduction for 2025, splitting the difference between the 2024 ABC specified last year and the 2025 maximum ABC estimated this year. The author-recommended

ABCs for 2024 and 2025 reflect an increase from last year; however, they are roughly 20% less than the 2010-2021 average ABC of 1,282 t. Furthermore, as described in detail in this assessment, last year's ABCs were based on an assessment model with high retrospective bias (Mohn's rho=0.61) and were the lowest ABCs ever recommended for the RE/BS complex (see Table 13-2 for a full time series of ABCs).

Reference values for the RE/BS rockfish stock complex are summarized in the following table, with the recommended ABC and OFL values in bold.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2023	2024	2024	2025
M (natural mortality rate)	0.034	0.034	0.042	0.042
Tier	3a	3a	3a	3a
Projected total (ages 3+) biomass (t)	25,837	25,755	46,029	46,109
Projected female spawning biomass (t)	8,554	8,514	12,986	13,005
$B_{100\%}$	14,776	14,776	21,878	21,878
$B_{40\%}$	5,911	5,911	8,751	8,751
$B_{35\%}$	5,172	5,172	7,657	7,657
F_{OFL}	0.046	0.046	0.045	0.045
$maxF_{ABC}$	0.038	0.038	0.038	0.038
F_{ABC}	0.038	0.038	0.030	0.030
OFL (t)	930	927	**1,555**	**1,566**
maxABC (t)	775	772	1,302	1,310
ABC (t)	775	772	**1,037**	**1,041**
Status	As determined *last* year for:		As determined *this* year for:	
	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on an estimated catch of 487 t for 2023, and estimates of 547 t and 539 t used in place of maximum permissible ABC for 2024 and 2025 in response to a Plan Team request to obtain more accurate two-year projections. Please see section on Specified Catch Estimation subsection in the Harvest Recommendations section for more details.
**The recommended F_{ABC} for 2024 and 2025 is based on the estimated *Fs* from the projection model using the 2024 and 2025 recommended ABCs as catch for those years.

The stock is not being subjected to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The test for determining whether overfishing is occurring is based on the 2022 catch compared to the 2022 OFL. The official total catch for 2022 is 469 t, which is less than the 2022 OFL of 947 t; therefore, the stock is not being subjected to overfishing. The tests for evaluating whether a stock is overfished or approaching a condition of being overfished require examining model projections of female spawning biomass relative to $B_{35\%}$ for 2024 and 2025. The estimates of spawning biomass for 2024 and 2025 from the current year projection model are 12,986 t and 13,005 7 t, respectively. Both estimates are above the $B_{35\%}$ estimate of 7,657 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

Abundance Trends, Model Selection, and Application of the Risk Table

Abundance indices from the bottom trawl survey and longline survey suggest a relatively stable population over the full time series, though there is evidence of recent declines coupled with a high degree of interannual variability. The 2023 longline survey RPN decreased 21% from 2022. The 2023 longline survey RPN was the lowest on record, and 34% lower than the mean of the time series (1993-2023). The longline survey RPNs have been below average since 2020. The 2023 bottom trawl biomass increased 27% from 2021; however, the 2021 biomass was the lowest on record and the 2023 biomass is still 28% below the mean of the time series (1990-2023). The last five out of six bottom trawl surveys are below the mean. **The downward trends in both survey indices warranted an increase to "Level 2 – Major Concern" in the population dynamics section of the Risk Table.**

The recent and continued decline in both abundance indices has destabilized the base model (Model 15.4), resulting in a one-way positive retrospective pattern that went from bad in 2021 (Mohn's rho=0.61) to worse in 2023 (Mohn's rho=1.05). The cause of this large retrospective bias is clear. Model 15.4 estimates all scaling parameters, including mean recruitment, both survey catchabilities (with no prior), natural mortality (with a prior CV=0.1), and recruitment variability (with a prior CV=0.06). Evidence from likelihood profiles and posterior pairwise comparisons show high correlations among all scaling parameters estimated in the model. In order for Model 15.4 to fit the declines in the abundance index data, both survey catchabilities have increased dramatically and to biologically unreasonable values. For example, the bottom trawl survey q estimates ranged between 1.1 and 1.2 in 2013-2017 and is now 2.4. Similarly, longline survey q estimates ranged between 0.62 and 0.68 in 2013-2017 and is now estimated to be greater than 1.5. Because of the high parameter correlation among the scaling parameters in the model and lack of constraint on the estimable parameter space, estimates of mean recruitment decreased by 50% over the same time period.

The instability of Model 15.4 necessitated action beyond the planned updates to biological assumptions (M prior, maturity, ageing error, and growth) that were proposed in September 2023. Model 23.1, which included only the planned updates to biological assumptions, also showed a large positive retrospective bias due to unstable parameter estimation. In Model 23.1a, we constrained the priors on both catchability parameters to a mean of 1.0 and CV of 0.05 and turned off the estimation of σ_R. While constraining these parameters limited the potential for strong retrospective bias, we continued to see a one-way retrospective pattern in M and mean recruitment, again in response to recent declines in the abundance indices. Therefore, in Model 23.1b (the author-recommended model), we fixed M to the new prior mean of 0.042, such that only one scaling parameter (mean recruitment) is estimated. Model 23.1b resulted in a positive but reduced retrospective bias relative to the base model (Mohn's rho=0.14), estimates of population scale that are consistent with historical assessments of the stock, and slightly improved fits to some of the composition data. However, Model 23.1b does not capture the recent declines in both indices of abundance and instead estimates an increasing trend in abundance due to increased recruitment strength in recent years. Additionally, while it is justifiable to constrain or fix parameters for which we cannot get reliable estimates, we acknowledge that the new catchability priors and fixed parameters in Model 23.1b likely result in underestimates of uncertainty. **In summary, due to retrospective patterns in the assessment, poor fits to the data overall, and high uncertainty in the scale and trend of the stock, we rated the assessment section of the Risk Table a "Level 2 – Major Concern."**

Area Allocation of Harvests

We continue to recommend the two-survey REMA model, which was bridged to Template Model Builder using the *rema* R library (Apportionment 19*). This model estimates a single, shared process error in the GOA and equally weights the longline and bottom trawl survey abundance indices. In 2023, we recommend the following changes to apportionment methodology (Apportionment 23): (1) removal of the 1984 and 1987 bottom trawl survey data; (2) estimation of areas-specific scaling parameters, which are currently fixed at 1.0; and (3) calculating apportionment ratios by averaging the area-specific proportions of both REMA-predicted biomass from the bottom trawl survey and REMA-predicted RPWs (currently only the area-specific proportion of REMA-predicted biomass is used). Collectively, these changes dramatically improve model fits to the data and more effectively balance data conflicts between the bottom trawl and longline surveys.

The following table shows the recommended apportionment for 2024 and 2025 using Apportionment 23 and the author-recommended ABCs:

Area Allocation		Western GOA	Central GOA	Eastern GOA	Total
		19.0%	**30.4%**	**50.6%**	**100.0%**
2024	Area ABC (t)	197	315	525	1,037
	OFL (t)				1,555
2025	Area ABC (t)	198	317	526	1,041
	OFL (t)				1,566

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
RE/BS complex	2022	26,060	947	788	788	469
	2023	25,837	930	781	775	385
	2024	46,029	1,555	1,037		
	2025	46,109	1,566	1,041		

Stock/ Assemblage	Area	2023 OFL	2023 ABC	2023 TAC	2023 Catch[2]	2024 OFL	2024 ABC	2025 OFL	2025 ABC
RE/BS complex	W		180	180	101		197		198
	C		232	232	135		315		317
	E		363	363	149		525		526
	Total	930	775	775	385	1,555	1,037	1,566	1,041

[1]Total biomass (ages 3+) from the projection model run in the previous year (i.e., 2022 biomass is from the 2021 assessment, 2023 biomass is from the 2022 assessment, and 2024 and 2025 biomass are from this assessment).

[2]Current as of October 16, 2023. Source: NMFS Alaska Regional Office Catch Accounting System via the AKFIN database (http://www.akfin.org).

Responses to SSC and Plan Team Comments on Assessments in General

The SSC recommends that for future Tier 1-3 assessments some consideration be given as to how best to represent biomass estimates in the Executive Summary table for each stock (currently, model total biomass and spawning stock biomass are provided) so that the relationship of the biomass to the OFL and ABC in the stock status table is clear. (SSC, December 2022)
We define total biomass as age-3+ and include this in the executive summary; however, we note that RE/BS are not fully recruited into the fishery until at least 15 years old.

The SSC highlights that in several cases adjustments to estimated recruitment were proposed for forward projection as a way to deal with large and highly uncertain recruitment events. The SSC highlights that ad hoc adjustments are less than ideal in this context and that model-based approaches to constraining extreme and uncertain recruitments are preferred. In cases where a revised or fixed recruitment estimate for a year class is assumed, the SSC requests:

- *Authors include a footnote in the projection summary table (Executive Summary table in SAFE chapters) indicating the exact nature of the adjustment to recruitment for transparency.*

● *Authors include a figure showing how previous recruitment estimates have changed, or been revised downward, in past years with the addition of new data (similar to Fig 3.33, pg. 88 in the 2022 Sablefish SAFE chapter), in addition to the standard retrospective figure for recruitment.* (SSC, December 2022)
We will try to remember this guidance moving forward.

The SSC reminds authors and PTs to please bring forward and respond to SSC comments from previous assessments, particularly where updates with minimal change to the assessment have been conducted in the intervening year(s). (SSC, December 2022)
We value your feedback and will do our best to maintain a record of outstanding SSC and PT recommendations.

The SSC supports the JGPT recommendation to make reporting of fish condition routine and standardized across assessments. (SSC, December 2022)
We could not find this JGPT's recommendation but did find the following comment in the JGPT October 2022 minutes: "Team discussion noted that index of fish condition comes up in many assessments and a standardized approach for defining condition and providing for as many stocks as possible would be useful." In 2023, the Groundfish Assessment Program and Ecosystem Status Report team provided separate rougheye and blackspotted condition indicators from the bottom trawl survey. However, we decided not to use them this year, because they were standardized to a long-term mean that included the 1984 and 1987 surveys. We made a request to the data provider that these data be removed in order to be consistent with other data in our assessments. Additionally, we request additional feedback from the Joint GPT and SSC on if they think condition indicators would be useful for species that experience barotrauma, and if so, how to present the data (i.e., combined RE/BS or separate).

The SSC reiterates its previous recommendation that the number of levels should be collapsed from four to three to make the choices easier for the authors. Further, the SSC recommends that the PTs review previous risk scores, as well as GPT and SSC recommended reductions from maxABC across stocks, from previous years prior to beginning the process each year. (SSC, December 2022)
We have updated the risk table accordingly in 2023.

The SSC recommends that groundfish, crab and scallop assessment authors do not change recommendations in documents between the Plan Team and the SSC meetings, because it makes it more difficult to understand the context of the Plan Team's rationale and seems counter to the public process without seeing a revision history of the document. (SSC, December 2021).
We appreciate the SSC's guidance on this topic and will craft recommendations accordingly.

<u>REMA</u>
The Teams recommended that stock assessment authors transition from the ADMB random-effects survey smoother to this package which implements the same model with several improvements. (Joint GPT, September 2022)
The SSC supports the JGPT's recommendation that stock assessment authors transition from the ADMB RE variants to the rema framework, which implements the same model variants in a single framework with several improvements. (SSC, October 2022)
The SSC suggests that assessment authors coordinate, to the degree possible, on how and when the features of this new software will be used, such that similar applications will be brought forward using consistent approaches. (SSC, October 2022)
The SSC appreciates the innovative work being done by the assessment authors through random effects (RE) modeling, by treating area-specific process variation as a random effect to properly weight and, where appropriate, consistently weight, the variation across areas. If not currently included in assessments, the SSC requests full documentation of the justification for the weighting schemes applied. Specific to GOA assessments, the SSC also supports a previous GOA GPT recommendation to use a

common process error across the GOA and to compare that approach with the current approach that allows process error to vary by sub-region. If process errors are treated separately by sub-region, then justification for that decision should be provided. (SSC, December 2022)
We recommend transitioning to the *rema* R library for apportionment in 2023. As part, we recommend estimating, instead of fixing, the area-specific scaling parameters. This dramatically improved the model fits to the available survey data. Otherwise we assume equal weighting between the surveys and process error is shared across areas.

Responses to SSC and Plan Team Comments Specific to this Assessment

<u>1984 and 1987 Bottom trawl survey data</u>
The SSC supports removing the 1984 and 1987 bottom trawl survey estimates from the survey index. (SSC, September 2023)
The author-preferred assessment and apportionment models have removed abundance and composition data from these years. Additionally, we have removed these data from analyses estimating parameters outside the model using bottom trawl survey data.

<u>Natural mortality</u>
The Team supported the author's investigation into M but recommended the author explore the application of the prior variance used for M. (GOA GPT, September 2023)
The SSC concurs with the GOA-GPT recommendation for the author to continue investigating M and to explore the application of the prior variance used for M. (SSC, October 2023)
In response to these recommendations, we developed a prior mean and variance based on the five oldest RE/BS specimens in the GOA and the recommended new ageing error matrix. Please see the "Parameters Estimated Outside the Assessment Model" section for more information about the recommended new *M* for 2023.

<u>Maturity</u>
The Team recommended using the authors approach. Additionally, the Team recommended alternative methods be explored that take skip spawning into account. (GOA GPT, September 2023)
The SSC supports incorporating maturity data not previously used that comes from both rougheye and blackspotted rockfish determined through visual species identification and supports exploring alternative methods that account for skip spawning. (SSC, October 2023)
We appreciate the Team's guidance on this topic and plan to consult experts during the off-season about how to appropriately model rockfish maturity while accounting for skip spawning. Additionally, because we combined data for both species, it would also be appropriate to weight samples by their estimated population abundance if possible. Please see the "Parameters Estimated Outside the Assessment Model" section for more information on the recommended new maturity curve for 2023.

<u>Ageing error and growth</u>
The Team supports the author's recommendation to update these data components with new data.
The SSC supports the author and GOA-GPT recommendation to incorporate new data for the aging error matrix, the size-at-age matrix, and weight-at-age vector. (SSC, October 2023)
In the absence of a strong recommendation to use either weight-at-age from a weight-based von Bertalanffy growth curve (status quo) or weight-at-age from a length-based von Bertalanffy growth curve converted to weight using the weight-length relationship, we decided to remain with the status quo method in order to maintain consistency with the other Tier 3 GOA rockfish stocks. Please see the "Parameters Estimated Outside the Assessment Model" section for more information on the recommended new ageing error, weight-at-age, and age-length transition matrix for 2023.

Apportionment
The Team supports the author recommended approach for apportionment.
The SSC supports the author and GOA-GPT recommended new apportionment methods (the same approach proposed for shortraker rockfish) that incorporate rema model estimates of area-specific catchability (q), has a single, shared process error, and starts in 1990. This method averages proportions of both the rema predicted biomass from the bottom trawl survey and the rema-predicted relative population weights from the longline survey and helps balance the data conflict between the two surveys. (SSC, October 2023)
We recommend this apportionment method be used for 2023.

Abundance indices
These declines had significant impacts on the parameters that govern the scale of the population. In particular, estimates of trawl survey catchability increased from 1.7 to 2.2, longline survey catchability increased from 1.2 to nearly 1.7, and mean recruitment decreased from approximately 1.6 to 1.2 million fish. The GOA GPT noted that the large changes in survey catchability estimates resulted in a downward shift in the long-term biomass trajectory for this stock. However, because the surveys exhibit inconsistent trends and partition biomass differently among areas, it is unclear if these signals reflect a genuine conservation concern or are the byproduct of survey data conflicts. The SSC concurs with the author and the GOA GPT that it would be prudent to estimate survey indices using the same depth strata definitions and to examine weighting CPUE by a variable other than total geographic area that may be more relevant to this complex (e.g., Essential Fish Habitat within a stratum). (SSC, December 2021)
We explored this topic in depth and determined it would require a prohibitive amount of effort to develop assessment-specific indices for this stock complex. After more consideration we think it's prudent to abandon the idea of using EFH to weight CPUE in both surveys because EFH maps were developed using bottom trawl survey data only.

Retrospective bias
Relative to past assessments, the 2021 assessment model exhibited a strong positive retrospective pattern (Mohn's rho = 0.611). It is also notable that there has been an increase in Mohn's rho in each of the last three assessments (2017 = 0.009, 2019 = 0.167, 2021 = 0.611). This "one-way" retrospective pattern is a cause for concern and is likely due to the recent sudden declines in both population indices that are used in the assessment. The relatively noninformative priors used for catchabilities within this model result in some shifts in scale being accentuated with sudden changes in these indices. The authors recognized this and stated their intent to investigate catchability in future assessments and explore how that relates to this progressive retrospective pattern. (SSC, December 2021)
Finally, the SSC notes that if the current trend in retrospective bias continues after model and data issues (catchability in particular) are addressed, the author will need to revisit risk table ranks and reassess whether a reduction from maxABC is necessary. (SSC, December 2021)
When we added new data to the base model for 2023, the positive retrospective pattern further degraded to a troubling Mohn's rho of 1.16. The base model freely estimates catchabilities and estimates σ_R and M with moderately informative priors. In order to alleviate these severe retrospective patterns, we recommend Model 23.1b, which constrains both catchabilities using a lognormal prior (mean=1.0, CV=0.05), fixed σ_R at the prior mean of 1.1, and fixed M at the updated prior mean of 0.042. Model 23.1b has a more acceptable Mohn's rho of 0.14. Recommended model changes, results, and model selection criteria are described in detail in the Model Structure and Model Evaluation sections.

Selectivity

The dome-shaped trawl survey selectivity for this complex is expected given that adult habitat is typically in rocky areas along the shelf break where the trawl survey gear's sampling is limited. However,

estimates in this assessment suggest that selectivity is changing considerably for older fish in the survey, which is unexpected given occupied habitat should not change above a certain age. For example, the GOA GPT noted it was unclear why 40-year-old fish would be so much less selected than a 30-year-old fish. Future research could consider alternative parameterizations that would allow for more constrained estimates of selectivity at older ages. (SSC 2021)
The Team recommended that the author investigate how selectivity is modeled. In particular, there were some abrupt changes between ages in the average fishery selectivity." (Plan Team, November 2019)
We agree with the SSC and Plan Team's recommendation to investigate selectivity; however, we were unable to adequately address this recommendation in 2023. We plan to explore selectivity in future assessments and welcome further comments or recommendations on this topic.

Introduction

Life History and Distribution

Rougheye (*Sebastes aleutianus*) and blackspotted (*S. melanostictus*) rockfish inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California and includes the Bering Sea (Kramer and O'Connell 1988). The two species occur in sympatric distribution, with rougheye extending farther south along the Pacific Rim and blackspotted extending into the western Aleutian Islands (Orr and Hawkins 2008). The overlap of the two species is quite extensive, ranging primarily from southeast Alaska through the Alaska Peninsula (Gharrett et al. 2005, Orr and Hawkins 2008). The center of abundance for both species appears to be Alaskan waters, particularly the eastern Gulf of Alaska (GOA). Adults in the GOA inhabit a narrow band along the upper continental slope at depths of 300-500 m; outside of this depth interval, abundance decreases considerably (Ito, 1999). These species often co-occur with shortraker rockfish (*S. borealis*).

Though relatively little is known about their biology and life history, rougheye and blackspotted (RE/BS) rockfish appear to be K-selected with late maturation, slow growth, extreme longevity, and low natural mortality. As with other *Sebastes* species, RE/BS rockfish are ovoviviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of RE/BS in Alaska. One study on their reproductive biology indicated that rougheye had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott 1994). There is no information as to when males inseminate females or if migrations for spawning/breeding occur. The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is labor-intensive. The post-larvae and early young-of-the-year stages also appear to be pelagic (Matarese et al. 1989, Gharrett et al. 2002). Genetic techniques have been used recently to identify post-larval RE/BS rockfish from opportunistically collected samples in epipelagic waters far offshore in the Gulf of Alaska, which is the only documentation of habitat preference for this life stage.

There is no information on when juvenile RE/BS rockfish become demersal. Juvenile RE/BS rockfish (15- to 30-cm fork length) are frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been observed in a variety of locations, ranging from inshore fjords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile RE/BS rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adult RE/BS rockfish are demersal and are known to inhabit particularly steep, rocky areas of the continental slope at depths of 300 to 500 m, and potentially deeper (Zenger and Sigler 1992, Krieger and Ito 1999), with post-larval rockfish documented in epipelagic waters in offshore waters of the Gulf of Alaska (GOA) (Kondzela et al. 2007). Observations from a manned submersible in this habitat indicate that these species prefer steep slopes and are often associated with boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, rougheye rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*) (Clausen and Fujioka, 2007). A study developing habitat-based indices of abundance for several species of rockfish found that a variety of environmental factors such as local slope, bottom depth, and coral/sponge abundance were significant in the best-fitting RE/BS rockfish habitat model (Rooper and Martin, 2012). The 2022 5-year Essential Fish Habitat (EFH) analysis (e.g. Pirtle et al. 2022) provided species distribution models from the bottom trawl survey for RE/BS late juveniles and adults, separated by species. However, the at-sea identification was used to develop these models (which can have high misidentification rates, please see the **Evidence for Stock Structure** section below) and our recommendation was to combine the two species for the next EFH update and use the models for general distribution of juveniles and adults but not abundance trends.

Food habit studies in Alaska indicate that the diet of adult RE/BS rockfish is primarily shrimp (especially pandalids) and that fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). However, juvenile RE/BS rockfish (less than 30-cm fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (*Chionoecetes bairdi*). Other prey include octopi and copepods (Yang et al. 2006). Predators of RE/BS rockfish likely include halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Research on black rockfish (*Sebastes melanops*) has shown that larval survival may dramatically increase with the age of the mother (Berkeley et al. 2004, Bobko and Berkeley 2004). McGilliard et al. (2017) showed that this type of offspring size effect or different spawning times by age may lead to increased recruitment variability with increased fishing mortality. Pacific ocean perch and RE/BS rockfish were examined by de Bruin et al. (2004) for senescence in reproductive activity of older fish, and they found that oogenesis continues at advanced ages. Leaman (1991) showed that older *Sebastes* individuals have slightly higher egg dry weight than their middle-aged counterparts. A study of Pacific ocean perch near Kodiak Island found a significant effect of maternal age on offspring provisioning, which may imply greater fitness for older females (Arnold et al. 2018). Despite empirical evidence supporting age-dependent fecundity and reproductive success of *Sebastes* and other marine teleosts (Hixon et al. 2014), stock assessments for Alaska rockfish assume that the reproductive success of mature fish is proportional to weight and therefore independent of age.

Evidence of Stock Structure

Since 2007, we have responded to issues regarding the difficulty identifying RE/BS rockfish and the development of a rationale for assessment decisions regarding this species complex. Reports have included summaries of studies on the genetic and phenotypic differences between RE/BS rockfish, discussion of the research regarding at-sea misidentification rates, and projects developed to understand species-specific life history characteristics (Shotwell et al. 2008, 2009). We completed a full stock structure evaluation of RE/BS rockfish following the template provided by the Stock Structure Working Group (SSWG, Spencer et al. 2010) and provided this evaluation in **Appendix A** of the 2010 GOA RE/BS rockfish executive summary SAFE report (Shotwell et. al 2010). Brief summaries of RE/BS rockfish speciation and the stock structure template are provided below.

Rougheye and Blackspotted Speciation

Several studies on the genetic differences between the observed types of rougheye rockfish indicate two distinct species (Gharrett et al. 2005, Hawkins et al. 2005, Orr and Hawkins 2006, summarized in Shotwell et al. 2009). The proposed speciation was initiated by Tsuyuki and Westrheim (1970) after electrophoretic studies of hemoglobin resolved distinct banding patterns in rougheye rockfish. Subsequent allozyme-based studies demonstrated clear isolation between samples (Seeb 1986) and five distinguishable loci for the two types of rougheye (Hawkins et al. 1997). A later allozyme study found the two types occurred in sympatry (overlapping distribution without interbreeding), but samples with depth information demonstrated a significantly deeper depth for what was later described as blackspotted rockfish (Hawkins et al. 2005). Another study analyzed the variation in mitochondrial DNA and microsatellite loci and distinguished the two species with relatively little hybridization (Gharrett et al. 2005).

In 2008, the presence of the two species was formally verified (Orr and Hawkins 2008). Rougheye rockfish are typically pale with spots absent from the spinous dorsal fin and possibly has mottling on the body. Blackspotted rockfish are darker with spotting almost always present on the dorsal fin and body. However, the distributions of these phenotypic parameters tend to overlap with only slight differences in gill rakers, body depth, and coloration (Gharrett et al. 2006). Spatially, rougheye rockfish has been defined as the southern species extending farther south along the Pacific Rim, while blackspotted rockfish was considered the northern species extending farther into the western Aleutian Islands and Bering Sea (Orr and Hawkins 2008).

A recent study used otolith shape analysis (i.e. morphometrics), weight, and age to accurately identify RE/BS rockfish 86% and 97% of the time, respectively (Harris et al. 2019). In comparison, field-based identification rates range from 62-66% for rougheye rockfish and 92-94% for blackspotted rockfish. These findings, which were based on 1,847 specimens collected during research surveys and confirmed using genetics, demonstrated that otolith morphometrics can be used to improve species identification rates, especially for rougheye rockfish. This method could be used to reliably identify archived otoliths from the past 20-30 years.

Stock Structure Template Summary

We summarize the available information on stock structure for the GOA RE/BS rockfish complex in Table 13-1. Since the formal verification of the two species has only recently occurred, most data on RE/BS rockfish is for both species combined. We follow the example framework recommended by the SSWG for identifying spatial structure (Spencer et al. 2010) and elaborate on each category within this template to evaluate stock structure for RE/BS rockfish. Please refer to Shotwell et al. (2010) for the complete stock structure evaluation.

Non-genetic information suggests population structure by large management areas of eastern, central, and western GOA. This is evident in opposite trajectories for population trends by area, significantly different age, length, and growth parameters by area, and significant differences in parasite prevalence and intensity by area.

Genetic studies have generally been focused on the speciation of the RE/BS complex; however, there is some limited data about genetic structure within blackspotted rockfish as well as genetic data for shortraker rockfish, which has a similar life history as RE/BS rockfish. In general, these studies did not detect genetic stock structure within RE/BS and shortraker rockfish across their range in Alaska. Specifically, a microsatellite study which analyzed over a thousand individuals from the Aleutian Islands and Bering Sea with ~10 genetic markers found no genetic stock structure in this region (see Spencer et al. 2014 BSAI blackspotted/rougheye assessment for more details). More recently, genetic structure of blackspotted rockfish was reevaluated with low coverage whole genome resequencing using data from millions of markers (W. Larson, personal communication). Samples from Oregon and British Columbia were compared with samples from the Gulf of Alaska, Aleutian Islands and Bering Sea and no genetic structure was detected, indicating high gene flow in this species across nearly their full species range. Similar results were found in shortraker rockfish analyzed with whole genome resequencing (W. Larson, personal communication). It is hypothesized that the high gene flow observed in RE/BS and shortraker rockfish is due to long distance larval dispersal. For rockfish with no genetic structure, it is likely that areas that are locally depleted will be replenished by larval transport over longer (i.e., evolutionary) timescales. Additionally, the amount of genetic flow that would result in a finding of no genetic structure is typically very low, and genetic methods often have little power to detect migration rates that would result in demographically independent populations (Waples et al. 2008), which is the relevant scale for fisheries management. Thus, a finding of no genetic structure does not imply that populations are demographically coupled and local depletion could cause reduced abundance because adult movement is likely low.

Currently, GOA RE/BS rockfish is managed as a Tier 3a species with area-specific Acceptable Biological Catch (ABC) and gulf-wide Overfishing Level (OFL). Given the multiple layers of precaution instituted with relatively low Maximum Retained Allowance (MRA) percentages, a bycatch only fishery status, subarea ABCs and TACs, and the generally low area-specific harvest rates, we continue to recommend the current management specifications for RE/BS rockfish.

Fishery

History

RE/BS rockfish have been managed as a “bycatch” only species complex since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Since 1977, gulf-wide catches of the RE/BS rockfish have been between 130-2,418 t (Table 13-2). Catches peaked in the late 1980s and early 1990s, declined rapidly in the mid-1990s and have been relatively stable since 2010. RE/BS rockfish are generally caught in either bottom trawls or with hook-and-line (i.e. “longline”) gear, with approximately 55-75% taken in the trawl fisheries and 30-45% taken in the hook-and-line fisheries in recent years, though the percentage taken by hook-and-line gear has decreased since 2017 when pot gear was legalized in the GOA sablefish fishery.

In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery and reported in the Catch Accounting System (CAS). These types of removals may include sport fishery harvest, research catches, or subsistence catch. Research catches of RE/BS rockfish have been reported in previous stock assessments and estimates of all removals not associated with a directed fishery including research catches are presented in Appendix 13A.

Management Measures

In 1991, the North Pacific Fishery Management Council (NPFMC) divided the slope rockfish assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. Although each management subgroup was assigned its own value of ABC (acceptable biological catch) and TAC (total allowable catch), shortraker/rougheye rockfish and other slope rockfish were discussed in the same SAFE chapter because all species in these groups were classified into tiers 4 or lower in the overfishing definitions. This resulted in an assessment approach based primarily on survey biomass estimates rather than age-structured modeling. In 1993, a fourth management subgroup, northern rockfish (*S. polyspinis*), was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC and TAC, whereas prior to 1991, one ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on the distribution of survey biomass.

In 2007 the Central Gulf of Alaska Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central Gulf of Alaska rockfish fishery. This rationalization program established cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish species. This implementation impacts primary rockfish management groups but will affects secondary rockfish groups with a maximum retained allowance (MRA). The primary rockfish management groups are Pacific ocean perch, northern rockfish, and pelagic shelf rockfish (changed to dusky rockfish only in 2012), while the secondary species include rougheye, blackspotted, and shortraker rockfish. Effects of this program to RE/BS rockfish include: 1) an extended fishing season lasting from May 1 – November 15, 2) changes in spatial distribution of fishing effort within the Central GOA, 3) improved at-sea and plant observer coverage for vessels participating in the rockfish fishery, and 4) a higher potential to harvest 100% of the TAC in the Central GOA region. Recent comparison of catches show that the Rockfish Program has resulted in much higher observer coverage of catch in the Central GOA; however, there does not seem to be a major shift in the spatial distribution of RE/BS catch (Shotwell et al. 2014b, Figure 13-1). We will continue to monitor available fishery data to help understand potential effects the Rockfish Program may have on the RE/BS rockfish stock in the Central GOA.

A summary of key management measures since the creation of the slope rockfish assemblage in 1988 and a time series of catch, OFL, ABC, and TAC are shown in Table 13-3.

Bycatch

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order. The primary fisheries that catch RE/BS rockfish as bycatch are the targeted rockfish and sablefish fisheries with occasional surges from the flatfish fishery (Table 13-4). For the combined GOA rockfish trawl fisheries during 2018-2022 (Table 13-5), the largest non-rockfish bycatch groups are on average arrowtooth flounder (1,546 t/year), walleye pollock (1,079 t/year), Atka mackerel (822 t/year), sablefish (809 t/year), and Pacific cod (445 t/year). Non-FMP species catch in the rockfish target fisheries is generally dominated on average by giant grenadier and miscellaneous fish (Table 13-6). Prohibited species catch in the GOA rockfish fishery has been generally low for most species (Table 13-7), and this has been particularly true since the implementation of the Central GOA Rockfish Program (Shotwell et al. 2014b). Halibut catch during rockfish targeted hauls between 2018 and 2022 was 127 t.

Discards

The table below indicates that discards of RE/BS rockfish have ranged from approximately 12% to 45% with an average of 23.6% between 2013 and 2023. The increase in 2018 is attributed to discards in the sablefish hook-and-line fishery in the Eastern GOA but is not completely understood. Regardless of the cause, the discard rate for RE/BS rockfish has decreased to below average since 2020.

Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
% Discarded	23.5	20.0	26.4	32.3	25.1	45.0	29.2	13.8	18.8	13.7	11.6

Data

The following table summarizes the data used in the recommended assessment model with 1984 and 1987 bottom trawl survey data removed (bold denotes new or updated data for this assessment):

Source	**Data**	**Years**
Fisheries	Catch	1977-2019, 2020, 2021, 2022, 2023
	Age	1990, 2004, 2006, 2008, 2009, 2010, 2012, 2014, 2016, 2018, 2020, **2022**
	Length	1991-1992, 2002-2003, 2005, 2007, 2011, 2013, 2015, 2017, 2019, **2021**
AFSC bottom trawl survey	Biomass index	~~1984, 1987,~~ 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021, **2023**
	Age	~~1984, 1987,~~ 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, **2019, 2021**
AFSC longline survey	Relative Population Number (RPN)	1993-2019, 2020, 2021, **2022, 2023**
	Length	1993-2019, 2020, 2021, **2022, 2023**

Fishery

Catch

Catches of RE/BS rockfish have ranged between 130 t to 2,418 t since 1977. The catches from 1977-1992 were from Soh (1998), which reconstructs the catch history using an information weighting factor (λ) to combine catch histories from both survey and fishery information. Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally, we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system ("blend estimates"). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye/blackspotted in the catch based on data from the FMA Observer Program (Clausen et al. 2004, Appendix A). Observed catches from the FMA database by area, gear, and species for hauls sampled by observers were used to calculate proportions of RE/BS catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for RE/BS rockfish (Figure 13-1, Table 13-2).

One caveat of the observer catch data prior to 2014 is that these data are based only on trips that had observers on board. Consequently, they may be biased toward larger vessels, which had more complete observer coverage. This bias may be a particular problem for RE/BS rockfish that were caught by longliners. Much of the longline catch is taken by small vessels that have no observer coverage. Hence, the observer catch data probably reflects more what the trawl fishery catches. However, these data may provide a more accurate estimate of the true proportion of RE/BS catch than the proportion based on the blend estimates. The blend estimates are derived from a combination of data turned in by fishermen, processors, and observers. In the case of fishermen and processors, prior to 2004 there was no requirement to report catches of shortraker/rougheye rockfish by species, and fishermen and processors were free to report their catch as either shortraker, rougheye, or shortraker/rougheye combined. Shortraker and rougheye rockfish are often difficult for an untrained person to separate taxonomically, and fishermen and processors had no particular incentive to accurately identify the fish to species. In contrast, all observers in the FMA Observer Program are trained in identification of Alaska groundfish, and they are instructed as to the importance of accurate identifications. Consequently, the catch data based on information from the FMA Observer Program may be more reliable than those based on the blend estimate. We use the observer estimates of catch from 1993-2004. Catches are reported separately for RE/BS and shortraker since 2005.

Although all gears are combined in the stock assessment, there have been some noteworthy changes in gear dynamics related to bycatch of RE/BS. In particular, catches from hook-and-line and trawl gear were relatively stable until pot gear was legalized in the GOA for sablefish IFQ fisheries. Since that time, the proportion of total catch from pot gear has increased from 0 to 8%. This has had some downstream effects on the fishery and length data and future trends should be monitored.

Age composition

RE/BS rockfish appear to be among the longest-lived of all *Sebastes* species (Chilton and Beamish 1982, Munk 2001). Interpretation of annuli on otoliths is extremely difficult; however, NMFS age readers determined that aging of RE/BS rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). We use ages from both the bottom trawl and longline fishery but only the at-sea processed samples. RE/BS rockfish otolith samples from onshore processing facilities have been aged; however, the sample sizes from onshore processing facilities are generally low and the distribution of ages is quite different from the at-sea samples. Fishery age compositions are treated as a random and representative sample for that year and the overall GOA fishery. Therefore, we do not use these samples in calculating the fishery age compositions. The FMA Domestic Observer Program began in 1990 and although this first year was considered preliminary, the 1990 ages are the only age compositions we have from the fishery prior to 2004. We, therefore, utilize this data in the model since it is considered important for estimating catch-at-age in the early 1990s. Fishery age compositions are available from 1990, 2004, 2006, 2008, 2009, 2010, 2012, 2014, 2016, 2018, 2020, and 2022 (Table 13-8, Figure 13-2).

We generally request fishery ages only for years that do not overlap with an AFSC bottom trawl survey since analyzing otoliths for long-lived rockfish such as RE/BS rockfish is time-consuming. However, we do have two overlapping years with the bottom trawl survey samples in 1990 and 2009 for comparison. Sample sizes from the fishery are typically between 300 and 400 otoliths (Table 13-8).

Prior to legalization of pot gear for sablefish in the GOA in 2017, the average percentage of age samples from longline and trawl gear was 66% and 34%, respectively. Since 2017, the percentage for longline gear has decreased to 38%, trawl has increased to 45% and pot gear now makes up 16%. RE/BS are selected into fishing gear at old ages compared to many other rockfish species. Between 1990 and 2018, fishery ages averaged 30-40 years old; however, mean age was 27 and 24 years in 2020 and 2022, respectively. This decline may be attributed to declines in the number of samples coming from hook-and-line gear relative to trawl and pot. Similar trends have been observed for the fishery length data.

Size composition
Fishery size compositions from 1991-1992, 2002-2003, 2005, 2007, 2011, 2013, 2015, 2017, 2019, and 2021 are included in this full assessment (Table 13-9, Figure 13-3). Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of RE/BS rockfish. Table 13-9 summarizes the available size compositions from 1991-2021. Sample sizes from 1993-2001 were limited for RE/BS rockfish and in other years range from 300 to 2500. In general, we do not use size compositions in the model when age compositions are available because we consider age data to be a more reliable measure of population structure for these long-lived species. Additionally, RE/BS rockfish are selected late to the fishery and size compositions tend to be relatively uninformative as year classes will blend together. Since we anticipate fishery ages for non-trawl survey years, we do not include the size compositions for off-cycle years in the model.

Survey

AFSC Bottom Trawl Biomass Estimates
Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999. These surveys became biennial starting in 2001. The surveys provide much information on RE/BS rockfish, including an abundance index, age composition, and growth characteristics. The surveys theoretically provide an estimate of absolute biomass, but we treat survey biomass estimates as a relative index in the stock assessment model. The 1984 and 1987 trawl survey data were removed in 2023. A different survey design was used in the eastern GOA in 1984; furthermore, much of the survey effort in the western and central GOA in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 700 m or 1,000 m), but the 2001 biennial survey did not sample the eastern Gulf of Alaska. Because the 2001 survey did not cover the entire Gulf of Alaska, we omitted this survey from our assessment model for RE/BS rockfish.

Summaries of biomass estimates from the 1984-2023 surveys are provided in Table 13-10 and Figure 13-1. The 2023 bottom trawl biomass increased 27% from 2021; however, the 2021 biomass was the lowest on record and the 2023 biomass is still 28% below the mean of the time series (1990-2023). Biomass estimates from the last five out of six bottom trawl surveys are below the mean. The trends by area were not consistent, as there were decreases in the central and western GOA and an increase in the eastern GOA.

Compared with other species of *Sebastes*, the trawl survey biomass estimates for RE/BS rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The exception to this was the 2019 survey where the CV was approximately 69% in the central GOA, which is the largest on record for this stock. This was due to one particularly large tow near Kodiak. The otherwise low CVs are an indication of the rather uniform distribution for this species compared with other slope rockfish (discussed previously in *Life History and Distribution* section). Despite this precision, however, trawl surveys are believed to do a relatively poor job of assessing abundance of adult RE/BS rockfish on the upper continental slope. Nearly all the RE/BS catch from this survey is found at depths of 300-500 m. Much of this area is not trawlable by the survey's gear because of its steep and rocky bottom, except at gully entrances where the bottom is not as steep. If RE/BS rockfish are located disproportionately on rough, untrawlable bottom, then the trawl survey may underestimate their abundance. Conversely, if the bulk of their biomass is on smoother, trawlable bottom, then we could be overestimating their abundance with the trawl survey estimates. Consequently, trawl survey biomass estimates for RE/BS rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, utilization of both the trawl survey and longline survey (which can sample where trawl surveys cannot) abundance indices should alleviate some of this concern.

In 2007, the trawl survey began separating rougheye rockfish from blackspotted rockfish using a species identification key (Orr and Hawkins, 2008). Biomass estimates of the two species by region somewhat support distributional differences; blackspotted estimates were higher in the western GOA and rougheye estimates were higher in the eastern GOA (discussed previously in *Evidence of Stock Structure* section). However, both species were identified in all regions, implying some overlap throughout the GOA. Over all areas, more blackspotted rockfish were identified than rougheye in 2007 (56% versus 44%), while in subsequent surveys the reverse occurred, with 63% to 73% rougheye and 37% to 27% blackspotted. The initial shift may have been due to decreases in misidentification rates at-sea between the two species as new identification keys and more training have been incorporated. Despite this apparent improvement, misidentification rates are still shifting from year to year and given the lack of species-specific catch we continue to combine all survey data for both species until a complete evaluation of the genetically corrected species' specific life history characteristics are made available.

AFSC Bottom Trawl Age Compositions
Sixteen years of bottom trawl survey age compositions are used in the assessment model with ages 42 and greater pooled into a plus (+) group (Table 13-11 and Figure 13-4). Survey age sample sizes are generally higher than fishery age sample sizes, ranging from 194 to 1,038. Although RE/BS rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected over these survey years was 135 (AFSC 2010). Ages averaged between 15 and 20 years between 1990 and 2017, but mean age was 13 y in 2019 and 2021. Since 2007, when the survey began identifying RE/BS rockfish as separate species, rougheye compositions tend to be spread evenly across ages, while blackspotted tend to be much older, although this has changed since the 2013 survey as the fish in general are younger overall. Given misidentification rates, we combine these two age compositions for all years in the stock assessment model.

AFSC Bottom Trawl Size Compositions
Gulf-wide population size compositions for RE/BS rockfish are in Table 13-12 and Figure 13-5 and sample sizes range from 1,700 to 5,600. Trawl survey size data are used in estimating growth and constructing the age-length transition matrix but are not fit in the stock assessment model since survey ages for most years were available. Investigations into including the most recent survey's length composition as a proxy for unavailable age composition were presented in Appendix 9B of the GOA POP November 2014 assessment. The results of that analysis suggest that the utility of using only the most recent survey's length composition is case specific and may be a subject for future research.

AFSC Longline Abundance Index
Catch, effort, and length data were collected for RE/BS rockfish during longline surveys and RPNs are available for GOA RE/BS annually since 1993. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000) and may also provide a reasonable index for RE/BS rockfish in addition to the AFSC bottom trawl survey (Rodgveller et al. 2011). Relative population abundance indices are computed annually using survey catch per unit of effort (CPUE) rates that are multiplied by the area size of the stratum within each geographic area.

RPN estimates for RE/BS rockfish have been variable throughout the time series (Table 13-10, Figure 13-1) but have been below average since 2020. The 2023 longline survey RPN decreased 21% from 2022. The 2023 longline survey RPN was the lowest on record, and 34% lower than the mean of the time series (1993-2023). The declines in 2023 were observed in the eastern, central, and western GOA, though declines in the eastern GOA were the most dramatic (Table 13-10). These declines coincide with all-time high catches of sablefish in this survey; however, there is limited evidence of hook competition due to adequate numbers of baited hooks being available (Rodgveller et al. 2008; Shotwell et al. 2014a). It is also possible that behavioral interactions between sablefish and RE/BS rockfish may inhibit RE/BS rockfish from feeding, but this is purely speculative.

As mentioned in the previous section, the trawl survey does not typically sample the high relief habitat of RE/BS rockfish. This is not the case with the longline survey which can sample a large variety of habitats. One drawback, however, is that juvenile fish are not susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment because most fish are similar in size once they have reached full selection of the longline gear and there is no RE/BS age data for the longline survey. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. Another potential concern is the unknown effect due to competition between larger predators for hooks (Rodgveller et al. 2008). However, Shotwell et al. (2014a) investigated the potential for hook competition on the longline survey and found that it was very unlikely to be large, and if it occurs it happens only in occasional specific year and station combinations.

AFSC Longline Size Compositions
Although no rockfish otoliths are collected on the longline survey, large samples of RE/BS lengths have been collected gulfwide since 1993. Lengths are now collected for nearly all RE/BS rockfish caught ranging from 3,500 to 7,000 (Table 13-13, Figure 13-6). The influence of such large sample sizes in the stock assessment model are somewhat remedied by taking the square root of sample size relative to the max of the series and scaling to 100 to determine the weight for each year. The implications of these assumptions toward weighting of samples sizes should be addressed and is an area for future research.

Since the longline survey does not sample in proportion to area, we weight longline survey size compositions by area abundance (RPNs) instead of raw sample size. Updated longline survey size compositions are available from 1993-2023 using all strata information and are calculated using the same length bins as the fishery and AFSC bottom trawl data. The long-term mean length in the longline survey is 45 cm. The longline survey size compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 13-13, Figure 13-6).

Analytic Approach

Model Structure

We present model results for the RE/BS rockfish complex based on an age-structured model using AD Model Builder software (Fournier et al. 2012). The assessment model is based on a generic rockfish model developed in a workshop held in February 2001 (Courtney et al. 2007; Box 1) and resembles the other age-structured models for rockfish in the GOA. The assessment model is single sex, with one combined fishing fleet and two fishery-independent indices (bottom trawl survey biomass and longline survey RPNs). Age and length composition data are fit in the model, and the range of age and length bins for data are 3-42+ years and 20-60+ cm, respectively. Recruitment is modeled as mean recruitment with annual deviations.

Several changes to the assessment inputs were made in 2023 that included updating the natural mortality prior, maturity, ageing error, weight-at-age, and the age-length transition matrix. Additionally, assessment methodology was changed by fixing M at the new prior mean, constraining catchability parameters using a lognormal prior with mean of 1.0 and CV of 0.05 following the BSAI BS/RE assessment, and turning off the estimation of recruitment variability. We recommend Model 23.1b, which includes all of these updates.

BOX 1. AD Model Builder Rougheye/Blackpotted Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of weight-at-age
m_a	Vector of maturity-at-age
a_0	Age it first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale
μ_f	Average fishing mortality
F_y	Annual fishing mortality deviation
σ_y	Annual recruitment deviation
σ_R	Recruitment variability
fs_a	Vector of selectivity-at-age for fishery
ss_a	Vector of selectivity-at-age for survey
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year *y* and age class *a*
$Z_{y,a}$	Total mortality for year *y* and age class *a*
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length conversion matrix
q_1	Trawl survey catchability
q_2	Longline survey catchability
SB_y	Spawning biomass in year *y*, (=$m_a\ w_a\ N_{y,a}$)
M_{prior}	Prior mean for natural mortality
$q_{1,prior}$	Prior mean for trawl survey catchability
$q_{2,prior}$	Prior mean for longline survey catchability
$\sigma_{R,prior}$	Prior mean for recruitment variability
σ_M^2	Prior CV for natural mortality
σ_{q1}^2	Prior CV for trawl survey catchability
σ_{q2}^2	Prior CV for longline survey catchability
$\sigma_{\sigma_R}^2$	Prior CV for recruitment variability

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1-e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Trawl survey biomass index (t)

$$\hat{I}_{2y} = q_2 \sum_a N_{y,a} * \frac{s_a}{\max(s_a)}$$

Longline survey abundance index (RPN)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr-a_0-a-1}\right)} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{(\mu_r)} e^{-(a-a_0)M}}{\left(1-e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment
Number at ages between recruitment and pooled age class
Number in pooled age class

Formulae for likelihood components	**BOX 1 (Continued)**
$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$	Catch likelihood
$L_2 = \lambda_2 \sum_y \left(\ln I_{1y} - \ln \hat{I}_{1y} \right)^2 / \left(2\sigma^2_{I_1} \right)$	Trawl survey biomass index likelihood
$L_3 = \lambda_3 \sum_y \left(\ln I_{2y} - \ln \hat{I}_{2y} \right)^2 / \left(2\sigma^2_{I_2} \right)$	Longline survey abundance index (RPN) likelihood
$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Fishery length composition likelihood (same used for fishery ages)
$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*_y \sum_a^{a+} \left(P_{y,a} + 0.001 \right) * \ln \left(\hat{P}_{y,a} + 0.001 \right)$	Trawl survey age composition likelihood
$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Trawl survey size composition likelihood (not fit)
$L_7 = \lambda_7 \sum_{styr}^{endyr} -n^*_y \sum_l^{l+} \left(P_{y,l} + 0.001 \right) * \ln \left(\hat{P}_{y,l} + 0.001 \right)$	Longline survey size composition likelihood
$L_8 = \frac{1}{2\sigma^2_M} \left(\ln M / M_{prior} \right)^2$	Penalty on deviation from prior distribution of natural mortality
$L_9 = \frac{1}{2\sigma^2_{q_1}} \left(\ln q_1 / q_{1prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for trawl survey
$L_{10} = \frac{1}{2\sigma^2_{q_2}} \left(\ln q_2 / q_{2prior} \right)^2$	Penalty on deviation from prior distribution of catchability coefficient for longline survey
$L_{11} = \frac{1}{2\sigma^2_{\sigma_r}} \left(\ln \sigma_r / \sigma_{r(prior)} \right)^2$	Penalty on deviation from prior distribution of recruitment deviations
$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln(\sigma_r) \right]$	Penalty on recruitment deviations
$L_{13} = \lambda_{13} \sum_y \varepsilon_y^2$	Fishing mortality regularity penalty
$L_{14} = \lambda_{14} \bar{s}^2$	Average selectivity penalty (attempts to keep average selectivity near 1)
$L_{15} = \lambda_{15} \sum_{a_0}^{a_+} \left(s_i - s_{i+1} \right)^2$	Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)
$L_{16} = \lambda_{16} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1}) \right)^2$	Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)
$L_{total} = \sum_{i=1}^{16} L_i$	Total objective function value

Parameters Estimated Outside the Assessment Model

Natural mortality

Natural mortality (*M*) in Models 15.4 and 15.4a is modeled using a lognormal prior mean of 0.03 and CV=0.1. The mean of 0.03 is based on a study by McDermott (1994), which used gonadosomatic index (GSI) data and the GSI-based *M* estimator M_{GSI} from Gunderson and Dygert (1988). The McDermott GSI study was conducted prior to the formalization of RE/BS as separate species and used combined data from the Bering Sea, Aleutian Islands, Gulf of Alaska, British Columbia, and the U.S. West Coast. They found *M* to range between 0.030 and 0.039 depending on if Stage V (late vitellogenesis) and Stage VI (containing at least some oocytes in the migratory nucleus stage) ovaries were used to determine GSI versus strictly Stage VI ovaries. McDermott (1994) recommended GSI estimates determined using Stage VI samples but cautioned this approach could result in an overestimation of GSI and thus *M* if oocytes hydrate in the migratory nucleus stage before the coalescence of yolk. Sullivan et al. (2022) revisited the GSI data from McDermott (1994) using updated M_{GSI} methods (Gunderson 1997, Hamel 2015) and found M_{GSI} to range between 0.023 and 0.032. These values are substantially lower than the M_{GSI} estimates reported in McDermott (1994) despite using the same GSI inputs, which was an expected outcome based on updates to M_{GSI} methodology over time (Gunderson and Dygert 1988, Gunderson 1997, Hamel 2015).

We updated the *M* prior based on longevity ($M_{t_{max}}$), where t_{max} is the maximum age for a species (Hamel and Cope 2022). This is based on recommendations from Then et al. (2015), which found that $M_{t_{max}}$ estimators exhibit superior predictive performance relative to growth-based estimators or combined approaches that averaged multiple *M* estimates. Hamel and Cope (2022) recently reevaluated Then et al. (2015) and Hoenig's (1982, 1983) $M_{t_{max}}$ methods by assuming a logarithmic transformation of M and t_{max} to account for heteroscedasticity in the original Then data set. The updated $M_{t_{max}}$ in Hamel and Cope (2022) assumes a lognormal distribution, where the median (mean in log-space) is given

$$M_{t_{max}} = \frac{5.4}{t_{max}},$$

In order to account for uncertainty in t_{max} and ageing error, a new prior was developed as follows. First, we queried the survey and fishery databases to obtain the five oldest specimens of RE/BS in the GOA, which ranged from age 126 to 135 y. Second, we constructed a distribution of potential ages for each of these five specimens using the age-specific standard deviation from the new ageing error matrix. We calculated *M* using the $M_{t_{max}}$estimator for each sample in the combined distribution from step 2. The mean and CV of the combined distribution of *M* was 0.042 and 0.058, respectively, which was used as the updated *M* prior in the Models 23.1 and 23.1a. In the recommended Model 23.1b, *M* is fixed to the mean of 0.042.

Maturity

Maturity is fixed in Models 15.4 and 15.4a using a vector of age-specific proportion of females mature based on maturity-at-length estimated in McDermott (1994), which was converted to maturity-at-age using the size-age transition matrix estimated in 2015 (Table 13-16). As described in the natural mortality section, McDermott (1994) was conducted prior to the formalization of RE/BS as separate species and used combined data from the Bering Sea, Aleutian Islands, Gulf of Alaska, British Columbia, and the U.S. West Coast.

We updated the maturity schedule using data collected in 2009 and 2010 during special cruises, standard bottom trawl surveys, and by fishery observers in the GOA (personal communication, Christina Conrath, AFSC, Groundfish Assessment Program; methods detailed in Sullivan 2023). These data were identified to species using macroscopic field identification methods and resultant maturity curves show that blackspotted rockfish mature later (age at 50% maturity; a_{50}=27.4 y) and at a slower rate compared to rougheye rockfish (a_{50}=19.5 y; Conrath 2017). These data have not been used in earlier stock assessments because species identification in the study was not verified using genetics (Shotwell and Hanselman 2019). However, these data are preferred over McDermott (1994) because they are specific to the assessment region (GOA), were analyzed using modern histological methods, and have age estimates associated with each specimen. Because no other inputs to the assessment (e.g., growth, natural mortality, etc.) are currently species-specific, we recommend a combined species approach.

We estimated maturity using a generalized linear model approach for logistic regression, where the probability of being mature (p) is a function of age (a):

$$\log\left(\frac{p_a}{1-p_a}\right) = \beta_0 + \beta_1 a,$$

We then derived a_{50} and the instantaneous rate of maturation (δ) using $a_{50} = -\beta_0/\beta_1$ and $\delta = (\beta_0 + \beta_1)/(1 - a_{50})$. Using these derived parameter estimates, maturity-at-age can be attained using

$$p_a = \left(\frac{1}{1+\exp\left(\delta(a-a_{50})\right)}\right).$$

Models were fit using custom software coded in Template Model Builder. Following methods in Conrath and Hulson (2021), a penalty term of 1e3 was added to negative log-likelihood to constrain maturity predictions at age-0 to equal approximately zero.

The updated RE/BS maturity model resulted in an a_{50} of 23.17 y and a δ of -0.164. The resultant maturity curve suggests that RE/BS mature more slowly and at older ages compared to the current assessment, which has an a_{50} of 18 y (Table 13-16). We evaluated the sensitivity of model results to the penalty term and species-specific inputs in Sullivan 2023. The model with no penalty had a slower maturation rate and smaller a_{50}, whereas the model with the higher penalty had a faster maturation rate and higher a_{50}. Similar to Conrath (2017), the species-specific models suggest that RE rockfish mature earlier and at a faster rate compared to BS rockfish.

Ageing error

Ageing error, or the uncertainty in an age reader's interpretation of annuli on a fish's otolith relative to the true age of the animal, is represented in the assessment as a matrix that specifies the probability of the fish of a true age a being aged at age a'. The Model 15.4 and Model 15.4a ageing error matrix was first adopted in 2015 and was developed using 1,589 age reader and tester pairs from 1984, 1987, 1990, 1993, 1996, 1999, 2003-2007, and 2009 bottom trawl surveys. It assumes that break-and-burn ages were unbiased and that uncertainty around the true age was normally distributed. It is used to fit both bottom trawl survey and fishery age composition data.

For the Model 23 series, we updated the ageing error matrix using bottom trawl survey and fishery data through 2021 using a total of 2,974 reader and tester pairs (Sullivan 2023). Fishery data are appropriate to use in this case because RE/BS older than 25 y are better represented in the fishery data, whereas younger RE/BS are better represented in the survey data (right-hand panels in **Error! Reference source not found.** of Sullivan 2023).

We re-evaluated the assumption that the current ageing process is unbiased by examining unique reader-tester pairs and the frequency for which the final age equals the reader age. We found that the full data set included 22 unique reader and tester pairs based on seven unique readers (Sullivan 2023). On average, the final age was equal to the reader age only 55% of the time and this ranged between 36% and 100% of the time depending on the unique reader and tester pair. These results make assessing individual bias very challenging, because neither reader nor tester could be considered unbiased. Additionally, the final read cannot be used to assess precision because the reader and tester often consult with one another to obtain the final age, and therefore the final age is not independent. For these reasons, we recommend maintaining the current assumption that RE/BS age data are unbiased and only using the read and test ages in the ageing error analysis. Ideally, age reader bias would be revisited for this assessment using an unbiased reference data set as described in Punt et al. (2008).

We updated the ageing error matrix using the *nwfscAgeingError* R library based in ADMB that is commonly used at the Northwest Fisheries Science Center and has been applied to several Alaskan stocks including GOA flathead sole and GOA pollock (Punt et al. 2008; Thorson et al. 2012). We compared the following models which differed in the parametric relationship between ageing error and true age: 1) M.1.0_LinearSD_NoBias: a 1-parameter linear relationship of the standard deviation (SD) with true age; 2) M.2.0_CurvilinearSD_NoBias: a 3-parameter Hollings-form relationship of SD with true age; 3) M.3.0_CurvilinearCV_NoBias: a 3-parameter Hollings-form relationship of coefficient of variation (CV) with true age. We then compared models using Akaike Information Criterion (AIC), where the model with the lowest AIC is considered superior in terms of fit and parsimony (Sullivan 2023).

The best model by AIC assumed a curvilinear relationship between SD and true age (M.2.0_CurvilinearSD_NoBias), and we recommend using this ageing error matrix in 2023 (Figure 4 of Sullivan 2023). The resulting SDs from all alternative models were generally higher than the currently assumed SD, though the curvilinear models generally scaled SD similarly to the current model at older ages. The curvilinear functional form is a defensible choice for long-lived species, where we may expect the rate of increasing imprecision to asymptote at older ages.

Growth

The weight-at-age vector and age-length transition matrix are treated as fixed, static inputs to the stock assessment model. These inputs were last updated in 2015 for Models 15.4 and 15.4a (Shotwell et al. 2015). Length-at-age is obtained using the von Bertalanffy growth model fit in ADMB:

$$L_a = L_\infty(1 - \exp(-k(age - t_0))),$$

Inputs to the model are the observed length-at-age mean and standard deviation (SD) from bottom trawl survey data, correcting for length-stratified sampling as specified in Bettoli and Miranda (2001). There is assumed to be a linear relationship between the observed SD of length-at-age and log-transformed age. Using the predicted SD of length-at-age from this linear model, the age-length transition matrix is constructed for the probability of different size classes for each age.

Weight-at-age is obtained by first fitting the allometric length-weight relationship:

$$W = \alpha L^\beta.$$

The β parameter was then fixed in the weight-based formulation of the von Bertalanffy model fit in ADMB:

$$W_a = W_\infty(1 - \exp(-k(age - t_0)))^\beta,$$

Inputs to this model are the observed weight-at-age mean and SD from bottom trawl survey data, correcting for length-stratified sampling as specified in Bettoli and Miranda (2001).

For the Model 23 series, we updated weight-at-age and the age-length transition matrix using bottom trawl survey data between 1990 and 2021. A comparison of the old (2015) and new (2021) length-at-age and weight parameters are below:

Old (2015) length-at-age parameters: L_∞= 49.6 cm, k =0.09, t_0=-0.69, n=6,738
New (2021) length-at-age parameters: L_∞= 54.2 cm, k =0.07, t_0=-1.5, n=7,638

Old (2015) weight-at-age parameters: W_∞= 1,639 g, k =0.12, t_0=-0.38, β = 3.086, n=5,806
New (2021) weight-at-age parameters: W_∞= 1,843 g, k =0.10, t_0=-0.88, β = 3.097, n=7,063

The 2015 and updated weight-at-age vectors are presented in Table 13-16. The 2015 and updated age-length transition matrices are presented in Figure 6 of Sullivan 2023.

Parameters Estimated Inside the Assessment Model

The parameters estimated in the recommended Model 23.1b are as follows: selectivity (up to full selectivity) for surveys and fishery, mean recruitment, annual recruitment deviations, mean fishing mortality, annual fishing mortality deviations, and reference fishing mortality rates. Other derived quantities are described in Box 1.

Assumptions for the global scaling parameters in all candidate models are outlined in the table below:

<table>
<tr><th>Model</th><th>Natural Mortality</th><th>Bottom Trawl (BTS) and Longline Survey (LLS) Catchability (q)</th><th>Recruitment Variability (σ_R)</th></tr>
<tr><td>Model 15.4</td><td rowspan="2">Estimated with lognormal prior mean=0.03 and CV=0.1</td><td rowspan="3">Estimated with lognormal priors; BTS mean=1.0 and CV=5.0; LLS mean=1.0 and CV=1.0</td><td rowspan="3">Estimated with lognormal prior mean=1.1 and CV=0.06</td></tr>
<tr><td>Model 15.4a</td></tr>
<tr><td>Model 23.1</td><td rowspan="2">Estimated with lognormal prior mean=0.042 and CV=0.058 based on updated prior</td></tr>
<tr><td>Model 23.1a</td><td rowspan="2">Estimated with lognormal priors; BTS mean=1.0 and CV=0.05; LLS mean=1.0 and CV=0.05</td><td rowspan="2">Fixed at the original prior mean of 1.1</td></tr>
<tr><td>Model 23.1b (recommended)</td><td>Fixed at the updated prior mean=0.042</td></tr>
</table>

Catchability parameters are highly uncertain for rockfish. In Models 15.4, 15.4a, and 23.1, a lognormal prior mean of 1.0 with very broad CVs of 5.0 and 1.0 were assigned for the trawl and longline survey, respectively. For the trawl survey, a value of 1.0 assumes all fish in the area swept are captured, there is no herding of fish from outside the area swept, and there is no effect of untrawlable grounds for the sizes of fish selected. This area-swept concept does not necessarily apply to the longline survey; however, since the RPNs for RE/BS rockfish are of the same magnitude as the trawl survey estimates, we deemed this a reasonable assumption. These prior distributions allow the catchability parameters more freedom than has been allowed to *M* in past assessment. The broad CVs on catchability has led to model instability and retrospective bias in recent assessments; therefore, in Models 23.1a and 23.1b, we recommend a more informed CV of 0.05 following the BSAI BS/RE assessment (Spencer et al. 2022).

In Models 15.4 and Model 15.4a, *M* is estimated using a moderately informed lognormal prior with mean of 0.03 and CV of 0.1 (see Parameters estimated outside of the model for more details). This was updated in 2023 to a mean of 0.042 and CV of 0.058 based on a longevity estimator and uncertainty in maximum age and ageing error. Natural mortality is estimated using this new prior in Models 23.1 and 23.1a, but we recommend *M* is fixed in Model 23.1b due to persistent parameter correlation between *M* and mean recruitment and a strong retrospective bias in the parameter estimates in recent years.

Recruitment variability (σ_R) is the process error assigned to the annual recruitment deviations. In Models 15.4, 15.4a, and 23.1, σ_R is estimated using a lognormal prior with a mean of 1.1 and CV of 0.06. Fits to the composition data are generally very poor in the RE/BS assessment, making it highly unlikely that we could obtain a reliable estimate of σ_R along with mean recruitment and recruitment deviations. Additionally, σ_R is best estimated in a state-space framework, because the penalized likelihood estimate can be biased (de Valpine and Hilborn 2005, Miller et al. 2016). Therefore, we recommend fixing σ_R at the current prior mean of 1.1 in Models 23.1a and 23.1b, which supports the hypothesis that recruitment is quite variable in RE/BS rockfish.

Selectivity-at-age for the trawl survey is estimated with a reparametrized gamma function, which was chosen to be the most reasonable in parsimonious fit in Shotwell et al. (2015):

$$s_{a,s}^{g} = \left(\frac{a}{a_{\max}}\right)^{a_{\max,g,s}/p} e^{(a_{\max,g,s}-a)/p}$$

$$p = 0.5\left[\sqrt{a_{\max,\,g,s}{}^{2} + 4\delta_{g,s}{}^{2}} - a_{\max,\,g,s}\right]$$

Selectivity-at-age for the longline survey and the combined (trawl and longline) fisheries continue to be fit with the non-parametric first-differences methods that were used in the original rockfish template (Courtney et al. 2007).

Uncertainty

Evaluation of model uncertainty is obtained through a Markov Chain Monte Carlo (MCMC) algorithm (Gelman et al. 1995). The chain length of the MCMC was 10,000,000 and was thinned to one iteration out of every 2,000. We omit the first 1,000,000 iterations to allow for a burn-in period. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters (computed as the 5th and 95th percentiles of the MCMC samples).

Results

Model Evaluation

The base model, Model 15.4, and the closely related Model 15.4a, were deemed unacceptable for management due to extremely high positive retrospective bias. Planned updates to the *M* prior, maturity schedule, ageing error matrix, and growth assumptions were not sufficient in remedying retrospective patterns and resulted in further decreases in population scale (Model 23.1). While substantial (albeit predictable) improvements in retrospective behavior and parameter stability were achieved in Models 23.1a and 23.1b by updating priors or fixing several scaling parameters, these changes came at the cost of degraded fits to abundance index data in recent years. Model 23.1b was selected as the author-recommended model for 2023; however, we had major concerns with all candidate models and therefore recommend a reduction from maximum ABC (see Risk table section for more details).

The 2023 assessment model evaluation is summarized in the table below with the author-recommended model in bold.

Model	Description	Mohn's rho	Summary of Key Results	2024 Age-3+ Biomass*	2024 Spawning Biomass*	2024 ABC*
Model 15.4 (Base)	- No updated biological assumptions - Estimates both q's (no prior), M (prior), σ_R (prior)	1.05	- Extremely high positive retrospective bias in spawning biomass - Strong retrospective patterns and high parameter correlation among all global scaling parameters (both q's, M, mean recruitment) - Unreasonably high estimates of trawl survey q (>2) - High reliance on length composition data	29,081	9,642	794
Model 15.4a	Same as Model 15.4 but removes 1984/1987 trawl survey data	1.16	Same as Model 15.4 but with even worse retrospective bias	27,574	9,245	751
Model 23.1	Same as Model 15.4a but with updated biological assumptions	0.42	- Bad retrospective bias in spawning biomass and strong retrospective trends in global scaling parameters - Unreasonably high estimates of both q's (>2) - Biomass scales that significantly lower than any model result to date - Slight improvements in the fits to the index data	16,154	3,890	432
Model 23.1a	Same as Model 23.1 but with priors on both q's and fixed σ_R	0.13	- Greatly improved retrospective behavior, except for continued retrospective trends in M - Biomass scales that are consistent with Model 15.4 results *before* it started exhibiting retrospective patterns - Degraded fits to index data in recent years - Recent biomass trajectories are inconsistent with index trends	45,252	11,876	1,460
Model 23.1b	**Same as Model 23.1a but fixes *M***	**0.14**	**- Same as Model 23.1a but with no retrospective pattern in *M***	**46,129**	**13,022**	**1,305**

*Age-3+ biomass, spawning biomass, and ABC values shown above are output from the assessment model (not the projection model). They are intended to be illustrative only and may differ slightly from projection model results used for management.

We used a combination of the following criteria to evaluate models:

1) Visual examination of fits to the bottom trawl and longline survey data (Figure 13-1) and composition data (Figures 13-2 through 13-6) show relatively poor fits to the data in all candidate models.

2) Parameter estimates and relative change and contribution of data to the likelihood (Table 13-14 and 13-15).
3) Model estimates of key quantities of interest, including age-3+ recruitment, fishing mortality, age-3+ biomass, spawning biomass, and selectivity (Tables 13-16 through 13-18, Figures 13-7 and 13-8). These results show large differences in biomass trajectories in models when q's are freely estimated or constrained.
4) Analysis of retrospective patterns in spawning biomass and parameter estimates (Figure 13-9) shows high positive retrospective bias and patterns in scaling parameters in recent year peels.
5) Evaluation of MCMC posterior densities and pairwise comparisons (Figure 13-10) shows high parameter correlation in models when all scaling parameters are estimated.
6) Review of model fits to the data using a comparison of root mean square error (RMSE) as described in Spencer et al. (2022; Table 13-19). RMSE values reveal tradeoffs between the candidate models in terms of fit to various data sources.
7) Pearson and one-step ahead (OSA) residuals (Trijoulet et al. 2023) were evaluated for age and length composition data (Figures 13-11 through 13-14). Residual analyses show that fits to the composition data are very poor and violate most assumptions.
8) Likelihood profiling over M, q, and σ_R (Figure 13-15) shows high parameter correlation between the scaling parameters, conflict between data sources in the model, and the lack of informative data for estimating q.

Time Series Results

Table 13-14 provides parameter estimates for recent full assessment models and the current updated and recommended models for comparison purposes. Tables 13-15 through 13-18 summarize other results for the 2023 author-recommended and base models.

Definitions
Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all RE/BS rockfish age three and older. Recruitment is measured as number of age-3 RE/BS rockfish. Fishing mortality is fully-selected F, meaning the mortality at the age fish are fully selected to the fishery.

Biomass and Exploitation Trends
Total and spawning biomass trajectories for the base (Model 15.4) and author-recommended (Model 23.1b) models show very different trends in total and spawning biomass throughout the time series (Figure 13-7). In particular, Model 15.4 and other candidate models that freely estimate both survey catchabilities show a consistent, downward trajectory in the population over time. These decreasing trends should be interpreted with caution given that these models show extremely high positive retrospective bias in spawning biomass and strong retrospective patterns in the estimates of global scaling parameters (Figure 13-9), which is discussed in more detail in the *Retrospective Analysis* section of the document. In particular, estimates of survey catchabilities for Models 15.4, 15.4a, and 23.1 are unrealistically high given that a catchability greater than 1.0 is generally associated with species that exhibit herding from outside the trawl area swept, which we do not expect for RE/BS rockfish. Additionally, while high catchabilities could also be associated with the effects of untrawlable habitat, this seems unlikely for the ages of RE/BS selected into the trawl gear (Figure 13-8). Finally, neither of these hypotheses are relevant to the longline survey, which also show strong retrospective patterns in catchability (Figure 13-9). Instead, there is substantial evidence to support the conclusion that unreasonably high estimates of catchability and retrospective bias in Models 15.4, 15.4a, and 23.1 are the result of high parameter correlation between catchability, M, and recruitment (as demonstrated by pairwise plots of marginal posterior distributions from MCMC simulations in Figure 13-10 and likelihood profiles in Figure 13-15), unconstrained estimation of several global scaling parameters, and recent declines in abundance indices.

In contrast, Models 23.1a and 23.1b that constrain estimation of both survey catchabilities show relatively flat biomass trajectories, and Model 23.1b estimates biomass to be increasing in recent years due to increases in recruitment in recent years. As previously described, these constraints improve overall model stability by reducing the potential for strong retrospective patterns; however, they come at a cost to the fits to the longline survey RPNs (Figure 13-1). Because *M* is assumed to be low and catchabilities are constrained, the model is unable to respond well to large interannual changes in abundance.

All candidate models exhibit similar trends and magnitudes of fully-selected fishing mortality, except Model 23.1, which estimates fishing mortality to be higher than the other models in response to the large decrease in population scale in that model (Figure 13-7). Fully-selected fishing mortality increased in the late 1980s and early 1990s due to the high levels of estimated catch and returned to relatively low levels from 1993 to present (Figures 13-1 and 13-7). The spike may be due to the management of RE/BS rockfish in the slope rockfish complex prior to 1991 and the disproportionate harvest on shortraker due to their high value. RE/BS would also be caught as they often co-occur with shortraker. In general, fishing mortality is relatively low because historically most of the available TAC has not been caught. There was an increasing trend in fishing mortality from 2010-2019, but this trend reversed in 2020-2023 due to decreased catch of RE/BS.

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. We present a similar graph termed a phase plane which plots the ratio of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to $B_{35\%}$. Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The phase for RE/BS rockfish has been above the F_{OFL} adjusted limit for only three years in 1988, 1989, and 1990 (Figure 13-16). Overfishing did not occur during those years based on the F_{OFL} estimate at the time. Since 1990, spawning biomass of RE/BS rockfish has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

Recruitment

In general, recruitment is highly variable, particularly in the most recent years when very little information exists on this part of the population (Figure 13-7). As has been shown for many years in this assessment, there continues to be no clear spawner-recruit relationship for RE/BS rockfish, and there is little contrast in spawning stock biomass. Although trends in recruitment are similar among all candidate models, Models 23.1a and 23.1b estimate the overall scale in recruitment to be much higher than Models 15.4, 15.4a, and 23.1 (Figure 13-7). This is not surprising given the strong retrospective bias in log mean recruitment in Models 15.4, 15.4a, and 23.1. Annual recruitment patterns were relatively consistent among all candidate models, with 2006, 2010, and 2016 year classes estimated to be the largest cohorts in recent years in most models.

Uncertainty

From the MCMC chains described previously, we summarize the marginal posterior densities of key parameters (Figure 13-10) and credible intervals (Table 13-14) for the candidate models. We also use these posterior distributions to show uncertainty around time series estimates such as total biomass, spawning biomass, and recruitment (Figure 13-7, Table 13-18).

Table 13-14 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the mean and median estimates along with 95% credible intervals from MCMC simulations. The MLE and MCMC standard deviations are similar for both survey catchabilities within models, and it is clear that estimates of these parameters are highly uncertain in Models 15.4, 15.4a, and 23.1.

There is an unresolved issue with the estimation of σ_r in the model. In Models 15.4, 15.4a, and 23.1, which estimate σ_r, the MLEs are all around 0.8, whereas the MCMC medians are between 1.0 and 1.1. The MCMC estimates are much closer to the assumed prior mean of 1.1 for σ_r in those models; however, we were unable to reconcile these differences in the current assessment. Assumptions related to σ_r and recruitment should be re-evaluated in the next full assessment.

Retrospective Analysis

Retrospective analysis is the examination of the consistency among successive estimates of the same parameters obtained as new data are added to a model (Hurtado-Ferro et al. 2015). Retrospective analysis has been applied most commonly to age-structured assessments, and poor retrospective behavior can arise for many reasons, ranging from bias in the data (e.g., catch misreporting, non-random sampling) to different types of model misspecification (e.g., incorrect values of natural mortality, temporal trends in values set to be invariant).

One common measure of the retrospective bias is Mohn's ρ ("rho") which indicates the size and direction of the bias (Hanselman et al. 2013). For this assessment, a within-model retrospective analysis of all candidate models was conducted for the last 10 years of the time-series by dropping data one year at a time from the current preferred model. The retrospective female spawning biomass and the relative difference in female spawning biomass from the 2023 model are shown in Figure 13-9 for all candidate models, along with retrospective patterns for global scaling parameters.

Compared to previous assessments, the base model exhibits a very high positive retrospective bias, meaning that estimates of spawning biomass decrease as data are added to the model. A comparison of the revised Mohn's ρ statistic presented in the 2019 through 2021 assessments, along with all candidate models for 2023 are presented in the table below (author-preferred model in bold).

Statistic	2019 (M15.4)	2021 (M15.4)	2023 (M15.4)	2023 (M15.4a)	2023 (M23.1)	2023 (M23.1a)	**2023 (M23.1b)**
Mohn's ρ	0.17	0.61	1.05	1.16	0.42	0.13	**0.14**

The strong retrospective pattern was revealed in recent years when new data was added to the model. It appears that the free estimation of catchabilities within this model results in some shifts in scale that become accentuated with sudden changes in abundance indices. Not surprisingly, when we constrained the catchability parameters using priors, the retrospective pattern improved, though Models 23.1a and 23.1b still exhibit positive retrospective bias. We attempted less constrained priors on the catchability parameters (e.g., the GOA northern rockfish assessment constrains the trawl survey catchability with mean of 1.0 and a CV of 0.45; Williams et al. 2022); however, the less informed priors resulted in unrealistically high estimates of catchability in the RE/BS model and persistent retrospective patterns. This may be because there is limited data informing these parameters in the model, or because of high parameter correlation between the two catchabilities (Figures 13-10 and 13-15). Future analyses could focus on the contribution of composition data to retrospective bias (e.g., as exhibited in likelihood profiles, Figure 13-15), or alternative strategies to link the two survey catchabilities (e.g., through the use of a scaling parameter as is done in the REMA model).

Harvest Recommendations

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level"

(OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, RE/BS rockfish in the GOA are managed under Tier 3 of Amendment 56. 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 recruits from 1980-2022 (i.e. the 1977-2019 year classes). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
21,878 (t)	8,751 (t)	7,657 (t)	0.038	0.045

Specification of OFL and Maximum Permissible ABC

Estimated female spawning biomass for 2024 is 12,986t. This is above the $B_{40\%}$ value of 8,751 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 for 2024 yields the following maximum ABC and OFL:

$F_{40\%}$	0.038
ABC (t)	1,302
$F_{35\%}$	0.045
OFL (t)	1,555

Population 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 2023 numbers-at-age as estimated in the assessment. This vector is then projected forward to the beginning of 2024 using the schedules of natural mortality and selectivity from Model 23.1b and the best available estimate of total (year-end) catch for 2023. 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 2023 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 2024, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In 2024 and 2025, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2020-2022 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 of F will yield more realistic projections.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 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 follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2023 or 2) above ½ of its MSY level in 2023 and above its MSY level in 2033 under this scenario, then the stock is not overfished.)

Scenario 7: In 2024 and 2025, F is set equal to max F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2025 or 2) above ½ of its MSY level in 2025 and expected to be above its MSY level in 2035 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios based on maximum likelihood estimates from the main assessment (Table 13-20). 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 such as RE/BS 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. The methodology for determining these pre-specified catches is described below in *Specified Catch Estimation*.

Status Determination

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.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2022) is 469 t. This is less than the 2022 OFL of 947 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2023:

a) If spawning biomass for 2023 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2023 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c) If spawning biomass for 2023 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 13-20).

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a) If the mean spawning biomass for 2025 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2025 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2025 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2035. If the mean spawning biomass for 2033 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 13-20, the stock is not currently overfished and is not approaching an overfished condition. The F that would have produced a catch for 2022 equal to the 2022 OFL was 0.027.

Specified Catch Estimation

In response to Gulf of Alaska Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in GOA rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by mid-October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, to obtain the current years catch we expand the catch after mid-October to the 3-year average ratio of catch through mid-October to the total annual catch.

New data added to the projection model included updated catch data from 2022 (469 t) and new estimated catches for 2023-2025. The 2023 catch was estimated by increasing the official catch as of 2023-10-16 by an expansion factor of 1.27, which accounts for the average fraction of catch taken after October 16 in the last three complete years (2020-2022). This expansion factor resulted in an estimated catch for 2023 of 487 t. To estimate future catches, we updated the yield ratio to 0.42, which was the average ratio of catch to ABC for the last three complete catch years (2020-2022). This yield ratio was multiplied by the projected ABCs from the updated projection model to generate catches of 547 t in 2024 and 539 t in 2025.

Area Allocation of Harvests

The current method for apportioning the GOA-wide ABCs to eastern, central, western GOA management areas was first adopted in 2019 (Apportionment 19; Shotwell et al. 2019) and relies on the two-survey (i.e., bottom trawl and longline surveys) version of the random effects model (REMA; Hulson et al. 2021; Table 13-10). Here we recommend several important updates to the underlying REMA model used for apportionment and apportionment methodology:

1) We recommend that the base REMA model be implemented using the *rema* R library, which was endorsed by the GOA Groundfish Plan Team (GPT) and Scientific and Statistical Committee (SSC) in 2022. The *rema* R library uses Model Builder (TMB; Kristensen et al. 2016) instead of AD Model Builder (ADMB; Fournier et al. 2012). Sullivan (2023) demonstrated that implementing the base REMA model using *rema* (Apportionment 19*) results in nearly identical model results.
2) We recommend removing the 1984 and 1987 bottom trawl survey biomass estimates (Apportionment 19a*) based on recommendations from the GOA GPT and SSC in 2022 (Table 13-10). Sullivan (2023) demonstrated this resulted in a minimal change in predicted biomass trajectories.
3) In Apportionment 23, we recommend estimating (instead of fixing) the REMA model's area-specific scaling parameters (ϙ). These parameters, which are currently fixed to 1, scale the area-specific longline survey relative population weights (RPW) to biomass. The assumption that ϙ=1 means that 1 RPW is equal to 1 mt of biomass, which is invalid because the RPW is an area-weighted catch-per-unit effort index and the units are not meaningful. Moreover, fixing the ϙ parameters in the REMA model results in poor fits to both survey indices (Figure 13-17A).
4) In Apportionment 23, we recommend using the average of the REMA-predicted biomass and REMA-predicted RPWs to inform apportionment ratios, instead of only REMA-predicted biomass. In the case of GOA RE/BS, there is data conflict between the trawl and longline survey indices. Specifically, the longline survey RPWs suggest higher proportions of biomass in the eastern and western GOA compared to the bottom trawl survey biomass (Figure 13-17A). The proposed alternative approach has the benefit of utilizing information from the RPWs to inform relative scale of biomass among regions, thus striking a balance between the conflicting survey indices (Figure 13-17B).

For the 2023 assessment, the author-recommended REMA model (Apportionment 23) estimates area-specific ϙ, has a single, shared process error, starts in 1990, and uses the new apportionment method that averages proportions of predicted RPW and biomass by area. Results for the alternative apportionment methods are found in Table 13-21.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in Tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.046), the overfishing level is set equal to 1,555 t in 2024 and 1,556 t in 2025 for RE/BS rockfish. The recommended 2024 OFL is 625 t greater than the 2023 OFL of 1,456 t, which reflects a 67% increase in OFL.

Should the ABC be reduced below the maximum permissible ABC?
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. In 2023, the risk table was modified to use three levels of concern instead of four.

Proposed Risk Table Levels of Concern for 2023

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: No Concern	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: 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 3: 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

Assessment considerations
We rated the assessment risk as Level 2 **– Major Concern:** “Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.”

In the Model Evaluation section, we describe strong positive retrospective bias, high parameter correlation, and dubious parameter estimates for catchability in the base and several candidate models presented in this document (Figure 13-9). While constraining estimation of the survey catchabilities with a prior and fixing σ_R and M limited the potential for strong retrospective bias in the model, it came at the expense of degraded fits to abundance indices (Figure 13-1) and estimated biomass trajectories that are inconsistent with trends in the abundance indices (i.e., the model suggests biomass is increasing due to recent recruitment, but the abundance indices suggest the stock is declining; Figures 13-1 and 13-7). Additionally, by constraining so many influential parameters in the model, we are likely understating the uncertainty in the results. Visual examination of model fits (Figures 13-1 through 13-6) and residual analyses (Figures 13-11 through 13-14) show persistently poor fits across model configurations and a high reliance on compositional data (Table 13-14 and Figure 13-15). We made good progress this year updating several important biological assumptions, but unfortunately this was overshadowed by model instability and uncertainty in stock scale and trend. We recommend a full (not update) operational assessment in 2025.

Population dynamics considerations
The most recent survey data support a population dynamics risk **Level 2 – Major Concern**: “Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.”

In recent years there have been unprecedented drops in both the trawl and longline survey indices of abundance. The 2023 longline survey RPN decreased 21% from 2022. The 2023 longline survey RPN was the lowest on record, and 34% lower than the mean of the time series (1993-2023; Table 13-10). The longline survey RPNs have been below average since 2020. The 2023 bottom trawl biomass increased 27% from 2021; however, the 2021 biomass was the lowest on record and the 2023 biomass is still 28% below the mean of the time series (1990-2023; Table 13-10). The last five out of six bottom trawl surveys have been below the mean. These declines are not well-captured in the recommended stock assessment model, because they are neither consistent with the known biology for the complex (low *M*, slow growth, etc.), nor is consistent with fishery removals, which have been well below ABC for the last two decades (Table 13-2).

Environmental/Ecosystem considerations
The most recent data available suggest an ecosystem risk **Level 1 – No Concern**: “No apparent environmental/ecosystem concerns.” This score is informed by approximately average physical environmental conditions, mixed trends/unknown status of foraging conditions, potential for increased competition for larvae, and moderate predation pressure (supporting data throughout Ferriss 2023). In general, there is a lack of a mechanistic understanding for the direct and indirect effects of ecosystem changes on the survival and productivity of RE/BS rockfish.

Environment: While optimal temperatures for RE/BS rockfish life stages are not known, it is reasonable to expect that the 2023 average ocean temperatures at depth on the shelf edge were adequate for adult rockfish (longline survey; Siwicke 2023 in Ferriss 2023). Cooler (winter) to warmer (summer) surface temperatures, provided good pelagic conditions for age-0 rockfish during a time when they are growing to a size that promotes over winter survival (bottom trawl survey; O’Leary and Rohan 2023 in Ferriss 2023). RE/BS rockfish are found around structural epifauna, and multiple datasets from non-target surveys show a continuous decline in sponges since 2015. These trends are observed in the western and central GOA in the longline survey, Shumagin and Kodiak areas (bottom trawl survey; Laman and Dowlin 2023 in Ferriss 2023) and in general across the GOA as part of the structural epifauna broader group (groundfish observer program; Whitehouse 2023a in Ferriss 2023). While a reduction in this habitat cannot be quantifiably connected to population-level effects on RE/BS rockfish, the potential loss of important habitat is a note of concern.

Prey**:** Trends in adult RE/BS rockfish prey (shrimp, especially pandalids, Tanner crab, and deep-water fish including myctophids, but also euphausiids) were unknown with some signs of decrease (Fergusson and Strasburger 2023 in Ferriss 2023). Larval RE/BS rockfish prey (zooplankton) was below average to average on the GOA shelf, in the spring and summer (Kimmel et al. 2023 and Hopcroft 2023 in Ferriss 2023).

Predators & Competitors**:** There is no cause to suspect increased predation pressure on larval or adult RE/BS rockfish. Little is known about the impacts of predators, such as fish and marine mammals, on adult RE/BS rockfish. Juvenile rockfish could be predated upon by Pacific cod, arrowtooth flounder, P. halibut, sablefish, and seabirds. Similarly, little is known about direct competitors of RE/BS rockfish, though they overlap in distribution with sablefish, shortraker rockfish, grenadier, and many other species.

Fishery performance:
We rated the fishery performance considerations as **Level 1 – No Concern**: "No apparent fishery/resource-use performance and/or behavior concerns". There is no directed fishing of RE/BS rockfish, and they can only be retained as "incidentally-caught." Catch of RE/BS rockfish fluctuates moderately by gear type and year, but trends are relatively stable by area and catch has always remained well below the TAC.

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

Using Model 23.1b, the maximum permissible ABC for 2024 is 1,302 t. This ABC is 69% higher than the 2024 ABC of 772 t from the 2022 harvest projection. **Due to major concerns in the assessment and population dynamics categories of the risk table, we recommend a reduction from maximum allowable to 1,037 t for 2024.** We used a "stair step" approach, where we split the difference between the 2024 ABC specified last year and the 2024 maximum ABC estimated this year. We applied the same logic to obtain the reduction for 2025, splitting the difference between the 2024 ABC specified last year and the 2025 maximum ABC estimated this year. The author-recommended ABCs for 2024 and 2025 reflect an increase from last year; however, they are roughly 20% less than the 2010-2021 average ABC of 1,282 t (Table 13-2).

Ecosystem Considerations

Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of rougheye/blackspotted rockfish appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval RE/BS rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval RE/BS rockfish (Gharrett et. al 2001). Food habit studies in Alaska indicate that the diet of RE/BS rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). Juvenile RE/BS rockfish in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Recent food studies show the most common prey of RE/BS as pandalid shrimp, euphausiids, and tanner crab (*Chionoecetes bairdi*). Other prey include octopi and copepods (Yang et al. 2006).

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent marine mammals during late juvenile and adult stages. Likely predators of RE/BS rockfish likely include halibut, Pacific cod, and sablefish. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile rockfish, but information on these life stages and their predators is unknown.

Changes in physical environment: Strong year classes corresponding to the period around 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including RE/BS rockfish. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effect on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents.

Anthropogenic causes of changes in physical environment: Bottom habitat changes from effect of various fisheries could alter survival rates by altering available shelter, prey, or other functions. The 2023 Ecosystem/Environemtnal considerations section of the Risk Table describe multiple datasets from non-target surveys show a continuous decline in sponges since 2015. These trends are observed in the western and central GOA in the longline survey, Shumagin and Kodiak areas (bottom trawl survey; Laman and Dowlin 2023 in Ferriss 2023) and in general across the GOA as part of the structural epifauna broader group (groundfish observer program; Whitehouse 2023a in Ferriss 2023). While a reduction in this habitat cannot be quantifiably connected to population-level effects on RE/BS rockfish, the potential loss of important habitat is a note of concern.

There is little information on when juvenile fish become demersal. Juvenile RE/BS rockfish 6 to 16 inches (15 to 40 cm) fork length have been frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates (Clausen et al. 2003). They are generally found at shallower, more inshore areas than adults and have been taken in a variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye or blackspotted rockfish, it is reasonable to suspect that juvenile RE/BS rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for RE/BS rockfish account for very little bycatch of HAPC biota. This low bycatch may be explained by the fact that these fish are taken as bycatch or topping off in fisheries classified as targeting other species, thus any bycatch is attributed to other target species.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: Unknown

Fishery-specific effects on amount of large size target fish: Unknown

Fishery contribution to discards and offal production: Fishery discard rates during 2013-2023 have been 12-45% for the RE/BS rockfish stock complex.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.

Fishery-specific effects on EFH living and non-living substrate: unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move around rocks and boulders on the bottom. Table 13-6 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries.

Data Gaps and Research Priorities

Future assessment priorities include updates to or analysis of (1) catchability assumptions, (2) survey and fishery selectivity assumptions, (3) data weighting approaches and the model's reliance on length composition data, (4) refinements to survey index data and the use of one versus two survey indices, (5) treatment of fishery catch and composition data, which currently combines longline and trawl fishery data, and (6) investigation into recruitment assumptions.

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Tables

Table 13-1. Summary of available data on stock structure for GOA RE/BS rockfish.

Factor and criterion	Available information
Harvest and trends	
Fishing mortality (5-year average percent of F_{ABC})	Recent catch in the Western GOA are near F_{ABC}, and far below F_{ABC} in the Central and Eastern GOA
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Catches are distributed similarly to survey abundance, except for a potential nursery area in Amatuli Gully region
Population trends (Different areas show different trend directions)	Population trend is stable for overall Gulf of Alaska, declining toward the Western GOA, and increasing toward the Eastern GOA
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	The generation time is > 19 years
Physical limitations (Clear physical inhibitors to movement)	No known physical barriers; predominant current patterns move from east to west, potential restriction in gullies and canyons
Growth differences (Significantly different LAA, WAA, or LW parameters)	Significantly different growth curves and length-at-age relationships between the Western GOA, Central GOA, and Eastern GOA.
Age/size-structure (Significantly different size/age compositions)	Mean length is significantly higher in WGOA, mean age is significantly higher in WGOA
Spawning time differences (Significantly different mean time of spawning)	Unknown
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Age at 50% maturity younger for rougheye rockfish (19.6 years) than blackspotted rockfish (27.4 years), no genetic ID confirmation on samples (Conrath 2017)
Time-varying maturity, fecundity, and skip-spawning rates	No changes in maturity or fecundity rates were observed for rougheye rockfish between 2008 and 2015, though estimated skip spawning rates were significantly less in 2016 (22%) than 2010 (37%) (Conrath and Hulson 2021)
Morphometrics (Field identifiable characters)	Unknown within species, hypothesized pigmentation differences between species (Gharrett et al. 2006, Orr and Hawkins 2008)
Meristics (Minimally overlapping differences in counts)	Unknown within species, significantly different means of dorsal spines and gill rakers (Gharrett et al. 2006)
Otolith morpohometrics	New study uses otolith morphometrics, weight, and age to accurately identify RE/BS rockfish 86.2% and 97.3% of the time, respectively (Harris et al. 2019)
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available, but potential to reduce barotrauma with new pressure tanks
Natural tags (Acquired tags may show movement smaller than management areas)	Parasite analysis shows structure by INPFC management area and between species (Moles et al. 1998, Hawkins et al. 2005)
Genetics	
Isolation by distance (Significant regression)	No significant isolation by distance for Type I or Type II rougheye (likely blackspotted and rougheye, respectively) (Gharrett et al. 2007)
Dispersal distance (<<Management areas)	Low, but significant F_{st} for both types indicates some limits to dispersal (Gharrett et al. 2007)
Pairwise genetic differences (Significant differences between geographically distinct collections)	Adjacency analysis suggests genetic structure on scale of INPFC management areas for Type I (blackspotted) and potentially finer scale structure for Type II (rougheye) (Gharrett et al. 2007)

Table 13-2. Estimated commercial catch (t) for GOA RE/BS rockfish, with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas (t), 1991-2023. Catch is provided through the most recent full year estimate (2022).

Year	Catch (t)				OFL	ABC	TAC
	Total	Western GOA	Central GOA	Eastern GOA			
1977	1443						
1978	568						
1979	645					ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004 (gray shade). Separate catch accounting were established for GOA RE/BS rockfish since 2005.	
1980	1353						
1981	719						
1982	569						
1983	628						
1984	760						
1985	130						
1986	438						
1987	525						
1988	1621						
1989	2185	Catch defined as follows: 1977-1992 from Soh (1998), 1993-2004 from observer program, 2005-present from NMFS AKRO Catch Accounting System via Alaska Fisheries Information Network (AKFIN, www.akfin.org).					
1990	2418						
1991	350					2,000	2,000
1992	1127					1,960	1,960
1993	583					1,960	1,764
1994	579					1,960	1,960
1995	704					1,910	1,910
1996	558					1,910	1,910
1997	545					1,590	1,590
1998	665					1,590	1,590
1999	320					1,590	1,590
2000	530					1,730	1,730
2001	591					1,730	1,730
2002	273					1,620	1,620
2003	394					1,620	1,620
2004	301					1,318	1,318
2005	294	53	126	115	1,531	1,007	1,007
2006	372	58	141	172	1,180	983	983
2007	440	71	195	174	1,148	988	988
2008	382	75	190	117	1,548	1,286	1,286
2009	275	76	98	100	1,545	1,284	1,284
2010	426	89	211	126	1,568	1,302	1,302
2011	557	27	370	159	1,579	1,312	1,312
2012	599	32	376	191	1,472	1,223	1,223
2013	580	10	390	179	1,482	1,232	1,232
2014	760	25	552	183	1,497	1,244	1,244
2015	564	52	357	155	1,345	1,122	1,122
2016	697	65	501	131	1,596	1,328	1,328
2017	553	41	338	174	1,594	1,327	1,327
2018	795	80	439	276	1,735	1,444	1,444
2019	790	93	448	249	1,715	1,428	1,428
2020	398	5	186	208	1,452	1,209	1,209
2021	407	22	182	203	1,456	1,212	1,212
2022	469	97	185	187	947	788	788
2023	-	-	-	-	930	775	775

Table 13-3. History of management measures with associated time series of catch, ABC, and TAC for GOA RE/BS rockfish. Catch since 2005 is provided through the most recent full year estimate (2022). Source: NMFS Alaska Region (AKRO) Catch Accounting System via Alaska Fisheries Information Network (AKFIN) database (http://www.akfin.org/).

Year	Catch (t)	ABC	TAC	Management Measures
1988	1,621	16,800	16,800	The slope rockfish assemblage, including rougheye, is one of three management groups for Sebastes implemented by the North Pacific Management Council. Previously, Sebastes in Alaska were managed as "Pacific ocean perch complex" (rougheye included) or "other rockfish"
1989	2,185	20,000	20,000	
1990	2,418	17,700	17,700	
1991	350	2,000	2,000	Slope assemblage split into three management subgroups with separate ABCs and TACs: Pacific ocean perch, shortraker/rougheye rockfish, and all other slope species
1992	1,127	1,960	1,960	
1993	583	1,960	1,764	
1994	579	1,960	1,960	
1995	704	1,910	1,910	
1996	558	1,910	1,910	
1997	545	1,590	1,590	
1998	665	1,590	1,590	
1999	320	1,590	1,590	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	530	1,730	1,730	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	591	1,730	1,730	
2002	273	1,620	1,620	
2003	394	1,620	1,620	
2004	301	1,318	1,318	Shortraker and rougheye rockfish divided into separate subgroups and assigned individual ABCs and TACs
2005	294	1,007	1,007	Rougheye managed separately from shortraker as age structured model accepted to determine ABC and moved to Tier 3 status
2006	372	983	983	
2007	440	988	988	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	382	1,286	1,286	RE/BS formally verified as separate species so assessment called the rougheye/blackspotted rockfish complex
2009	275	1,284	1,284	
2010	426	1,302	1,302	
2011	557	1,312	1,312	Rockfish Program continues from pilot initiative
2012	599	1,223	1,223	
2013	580	1,232	1,232	
2014	760	1,244	1,244	
2015	564	1,122	1,122	
2016	697	1,328	1,328	
2017	553	1,327	1,327	
2018	795	1,444	1,444	
2019	790	1,428	1,428	
2020	398	1,209	1,209	
2021	407	1,212	1,212	
2022	469	788	788	
2023	-	775	775	

Table 13-4. Catch (t) of RE/BS rockfish as bycatch in other fisheries from 2005 to 2022. Other fisheries category not included due to confidentiality (# vessels or # processors is fewer than or equal to 2). Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 10/12/2023.

Year	Rockfish	Sablefish	Flatfish	Halibut	Walleye Pollock	Pacific Cod
2005	106.2	119.1	15.4	36.0	16.1	0.6
2006	82.5	178.6	39.6	46.2	22.6	2.0
2007	113.5	143.6	90.2	63.7	27.7	1.3
2008	104.5	115.1	57.4	54.5	41.3	8.9
2009	97.3	86.2	33.9	39.9	10.6	6.5
2010	183.4	101.3	64.5	42.6	30.2	3.9
2011	286.7	132.1	63.9	36.5	34.9	2.5
2012	218.7	208.1	122.1	26.3	20.5	3.7
2013	274.0	213.2	48.6	35.9	6.4	1.9
2014	359.4	177.4	153.6	43.5	22.2	3.9
2015	224.6	170.8	76.7	76.4	12.7	2.5
2016	351.5	166.2	90.8	35.3	48.7	4.1
2017	269.4	148.3	81.3	33.7	3.0	17.2
2018	317.1	299.1	131.7	35.1	9.4	2.5
2019	320.2	282.3	107.0	38.1	40.7	2.0
2020	88.5	171.6	87.0	20.3	30.7	0.3
2021	162.3	156.8	21.9	23.2	39.8	3.2
2022	220.7	130.7	3.1	24.1	90.0	0.7
Average	210.0	166.7	71.6	39.5	28.2	3.8

Table 13-5. Incidental catch (t) of FMP groundfish species caught in rockfish targeted fisheries in the Gulf of Alaska during the last five years, 2018-2022. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 10/12/2023.

Species Group Name	2018	2019	2020	2021	2022	Average
Pacific Ocean Perch	22,172	22,258	22,881	27,399	26,358	24,213.7
Dusky Rockfish	2,691	2,151	2,061	2,669	2,483	2,410.9
Northern Rockfish	2,152	2,313	2,317	2,303	1,813	2,179.5
Arrowtooth Flounder	761	733	890	2,523	2,823	1,546.0
Walleye Pollock	917	686	647	1,559	1,588	1,079.4
Atka Mackerel	1,140	824	602	674	867	821.5
Sablefish	708	801	647	893	995	808.6
Other Rockfish	992	669	522	975	869	805.4
Pacific Cod	401	322	170	660	670	444.6
Shortraker Rockfish	269	269	225	240	181	237.0
Rougheye Rockfish	317	320	89	162	221	221.8
Thornyhead Rockfish	362	177	138	113	215	200.8
Rex Sole	136	117	189	99	132	134.4
Flathead Sole	48	40	95	135	74	78.6
Sharks	48	62	33	32	17	38.4
Deep Water Flatfish	66	39	19	19	35	35.8
Shallow Water Flatfish	57	34	22	33	30	35.1
Longnose Skates	46	28	24	31	31	32.0
Sculpin	65	53	30	0	0	29.7
Demersal Shelf Rockfish	57	56	11	5	5	26.9
Other Skates	28	26	10	19	14	19.4
Squid	29	0	0	0	0	5.7
Big Skates	6	5	6	4	6	5.5
Octopus	3	9	1	1	1	2.9
Halibut	Conf.	<1	2	Conf.	Conf.	Conf.

Table 13-6. Non-FMP species bycatch (t) for Gulf of Alaska rockfish targeted fisheries during the last five years, 2018-2022. Conf. = Confidential data since # vessels or # processors is fewer than or equal to 2. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 10/12/2023.

Species Group Name	2018	2019	2020	2021	2022	Average
Giant Grenadier	1,691	754	302	252	197	639.2
Misc fish	137	359	87	164	87	166.9
State-managed Rockfish	53	46	53	12	33	39.6
Squid	0	11	32	28	43	23
Sculpin	0	0	0	24	40	13
Sponge unid.	14	6	1	1	6	5
Greenlings	5	10	3	3	4	5
Scypho jellies	1	8	4	3	1	3
Grenadier unid.	5	4	2	Conf.	2	Conf.
Sea star	4	1	1	1	1	2
Snails	6	2	<1	1	<1	2
Sea anemone unidentified	<1	2	1	2	1	1
Corals Bryozoans unid.	1	1	<1	2	<1	1
Benthic urochordata	<1	<1	<1	<1	4	1
urchins dollars cucumbers	<1	<1	1	<1	<1	<1
Other osmerids	0	Conf.	1	<1	<1	Conf.
Misc crabs	<1	<1	<1	<1	<1	<1
Stichaeidae	1	0	Conf.	0	Conf.	Conf.
Pandalid shrimp	<1	<1	<1	<1	<1	<1
Eulachon	<1	<1	<1	0	0	<1
Smelt (family Osmeridae)	0	0	0	<1	<1	<1
Misc crustaceans	Conf.	<1	<1	<1	<1	Conf.
Eelpouts	<1	<1	<1	Conf.	Conf.	Conf.
Invertebrate unid.	<1	<1	Conf.	<1	<1	Conf.
Lanternfishes (myctophidae)	Conf.	<1	<1	<1	0	Conf.
Pacific Hake	<1	Conf.	<1	0	0	Conf.
Brittle star unid.	<1	<1	<1	<1	<1	<1
Sea pens whips	<1	<1	Conf.	Conf.	<1	Conf.
Capelin	0	Conf.	<1	0	0	Conf.
Hermit crab unid.	<1	Conf.	<1	<1	<1	Conf.
Bivalves	Conf.	Conf.	<1	Conf.	Conf.	Conf.
Birds - Northern Fulmar	Conf.	Conf.	0	Conf.	0	Conf.
Birds - Shearwaters	0	Conf.	0	0	0	Conf.
Misc deep fish	0	Conf.	0	0	Conf.	Conf.
Polychaete unid.	0	Conf.	0	0	Conf.	Conf.
Bristlemouths	0	0	Conf.	0	0	Conf.
Misc inverts (worms etc)	0	0	Conf.	Conf.	Conf.	Conf.
Gunnels	0	0	0	Conf.	0	Conf.
Pacific sand lance	0	0	0	Conf.	0	Conf.

Table 13-7. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and counts in thousands of animals for crab and salmon for the GOA rockfish fishery during the last five years, 2018-2022. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN with catch through 10/12/2023.

Species Group Name	2018	2019	2020	2021	2022	Average
Non-Chinook Salmon	325	380	723	1,628	4,002	1,411.7
Bairdi Tanner Crab	321	64	1,146	2,279	191	800.3
Chinook Salmon	336	410	655	1,042	1,137	716.1
Golden (Brown) King Crab	324	223	60	114	136	171.4
Halibut	100	115	111	179	129	127.0
Herring	<1	2	<1	<1	1	0.6
Red King Crab	<1	<1	0	0	0	<1
Opilio Tanner (Snow) Crab	<1	0	0	0	0	<1
Blue King Crab	0	0	0	0	0	0.0

Table 13-8. Fishery age compositions for GOA RE/BS rockfish and sample sizes by year. Pooled age 42+ includes all fish 42 and older.

Age	1990	2004	2006	2008	2009	2010	2012	2014	2016	2018	2020	2022
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0081	0.0000	0.0000	0.0074
7	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025
8	0.0033	0.0000	0.0000	0.0034	0.0000	0.0041	0.0000	0.0000	0.0027	0.0028	0.0157	0.0123
9	0.0266	0.0000	0.0028	0.0103	0.0000	0.0083	0.0000	0.0045	0.0000	0.0085	0.0105	0.0123
10	0.0498	0.0049	0.0000	0.0103	0.0097	0.0041	0.0000	0.0023	0.0054	0.0056	0.0105	0.0295
11	0.0332	0.0000	0.0000	0.0069	0.0032	0.0165	0.0000	0.0068	0.0081	0.0056	0.0209	0.0565
12	0.0266	0.0000	0.0083	0.0069	0.0000	0.0207	0.0061	0.0045	0.0161	0.0141	0.0209	0.0393
13	0.0166	0.0049	0.0055	0.0172	0.0162	0.0165	0.0030	0.0091	0.0054	0.0225	0.0471	0.0295
14	0.0365	0.0049	0.0083	0.0172	0.0032	0.0289	0.0182	0.0045	0.0134	0.0225	0.0262	0.0369
15	0.0100	0.0171	0.0193	0.0137	0.0097	0.0165	0.0030	0.0091	0.0081	0.0254	0.0366	0.0688
16	0.0066	0.0098	0.0193	0.0241	0.0325	0.0083	0.0121	0.0363	0.0081	0.0225	0.0366	0.0344
17	0.0166	0.0122	0.0138	0.0412	0.0195	0.0124	0.0121	0.0204	0.0242	0.0507	0.0209	0.0369
18	0.0033	0.0073	0.0055	0.0344	0.0162	0.0248	0.0182	0.0204	0.0215	0.0423	0.0471	0.0614
19	0.0166	0.0196	0.0110	0.0515	0.0325	0.0372	0.0030	0.0249	0.0242	0.0366	0.0157	0.0393
20	0.0133	0.0416	0.0110	0.0928	0.0552	0.0207	0.0152	0.0363	0.0323	0.0620	0.0576	0.0369
21	0.0133	0.0391	0.0138	0.0275	0.0260	0.0413	0.0212	0.0295	0.0242	0.0451	0.0314	0.0246
22	0.0133	0.0440	0.0303	0.0412	0.0325	0.0248	0.0091	0.0227	0.0430	0.0310	0.0262	0.0491
23	0.0100	0.0465	0.0331	0.0206	0.0260	0.0165	0.0364	0.0522	0.0134	0.0197	0.0157	0.0295
24	0.0199	0.0367	0.0441	0.0206	0.0162	0.0165	0.0242	0.0204	0.0376	0.0225	0.0471	0.0295
25	0.0199	0.0318	0.0468	0.0447	0.0519	0.0620	0.0152	0.0340	0.0403	0.0225	0.0366	0.0319
26	0.0266	0.0171	0.0358	0.0447	0.0519	0.0165	0.0152	0.0272	0.0323	0.0197	0.0314	0.0221
27	0.0365	0.0244	0.0331	0.0172	0.0519	0.0289	0.0212	0.0317	0.0349	0.0225	0.0314	0.0221
28	0.0133	0.0196	0.0331	0.0412	0.0422	0.0413	0.0273	0.0317	0.0349	0.0169	0.0157	0.0123
29	0.0498	0.0269	0.0413	0.0206	0.0357	0.0455	0.0212	0.0476	0.0296	0.0254	0.0366	0.0098
30	0.0365	0.0196	0.0165	0.0103	0.0519	0.0207	0.0545	0.0476	0.0376	0.0141	0.0209	0.0098
31	0.0399	0.0367	0.0275	0.0241	0.0195	0.0413	0.0545	0.0227	0.0134	0.0169	0.0052	0.0221

Age	1990	2004	2006	2008	2009	2010	2012	2014	2016	2018	2020	2022
32	0.0266	0.0318	0.0275	0.0275	0.0357	0.0413	0.0273	0.0431	0.0242	0.0366	0.0419	0.0000
33	0.0399	0.0244	0.0165	0.0447	0.0195	0.0124	0.0182	0.0385	0.0349	0.0141	0.0314	0.0074
34	0.0498	0.0244	0.0165	0.0137	0.0097	0.0124	0.0273	0.0340	0.0376	0.0225	0.0419	0.0197
35	0.0365	0.0244	0.0138	0.0000	0.0325	0.0207	0.0152	0.0385	0.0296	0.0225	0.0314	0.0098
36	0.0432	0.0293	0.0358	0.0103	0.0162	0.0165	0.0333	0.0227	0.0296	0.0366	0.0262	0.0197
37	0.0299	0.0098	0.0193	0.0206	0.0130	0.0248	0.0182	0.0204	0.0081	0.0169	0.0157	0.0123
38	0.0100	0.0342	0.0193	0.0069	0.0292	0.0165	0.0182	0.0136	0.0134	0.0113	0.0105	0.0172
39	0.0233	0.0269	0.0083	0.0241	0.0130	0.0207	0.0212	0.0091	0.0108	0.0113	0.0052	0.0098
40	0.0266	0.0318	0.0275	0.0137	0.0162	0.0124	0.0212	0.0136	0.0215	0.0085	0.0052	0.0074
41	0.0166	0.0147	0.0386	0.0034	0.0195	0.0041	0.0182	0.0181	0.0134	0.0085	0.0105	0.0098
42+	0.1561	0.2836	0.3168	0.1924	0.1916	0.2397	0.3909	0.2018	0.2581	0.2338	0.1152	0.1155
Sample size	301	409	363	291	308	242	330	441	372	355	191	407
Number of hauls	29	242	234	182	202	129	179	246	176	249	125	258

Table 13-9. Fishery size compositions for GOA RE/BS rockfish and sample size by year and pooled pairs of adjacent lengths.

Length (cm)	1991	1992	2002	2003	2005	2007	2011	2013	2015	2017	2019	2021
20	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0019	0.0028
22	0.0000	0.0022	0.0057	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0012	0.0005	0.0035
24	0.0000	0.0029	0.0029	0.0004	0.0007	0.0006	0.0010	0.0020	0.0017	0.0023	0.0038	0.0014
26	0.0000	0.0052	0.0029	0.0000	0.0007	0.0013	0.0000	0.0040	0.0006	0.0041	0.0053	0.0021
28	0.0015	0.0044	0.0000	0.0024	0.0026	0.0031	0.0030	0.0020	0.0033	0.0058	0.0043	0.0049
30	0.0023	0.0103	0.0000	0.0004	0.0026	0.0069	0.0050	0.0020	0.0039	0.0093	0.0081	0.0091
32	0.0038	0.0096	0.0029	0.0024	0.0040	0.0044	0.0121	0.0050	0.0045	0.0093	0.0115	0.0070
34	0.0068	0.0206	0.0057	0.0047	0.0026	0.0144	0.0111	0.0040	0.0112	0.0146	0.0125	0.0140
36	0.0060	0.0243	0.0086	0.0063	0.0139	0.0151	0.0131	0.0089	0.0100	0.0175	0.0158	0.0126
38	0.0165	0.0449	0.0286	0.0137	0.0119	0.0264	0.0151	0.0208	0.0195	0.0315	0.0187	0.0176
40	0.0218	0.0619	0.0200	0.0251	0.0185	0.0314	0.0272	0.0455	0.0262	0.0321	0.0235	0.0225
42	0.0436	0.0744	0.0457	0.0440	0.0310	0.0427	0.0524	0.0554	0.0402	0.0520	0.0436	0.0520
44	0.1158	0.0898	0.0629	0.0668	0.0568	0.0634	0.0574	0.0733	0.0547	0.0701	0.0594	0.0527
46	0.1188	0.0560	0.1000	0.1013	0.0832	0.0653	0.0524	0.0733	0.0675	0.0643	0.0704	0.0555
48	0.0910	0.0457	0.0914	0.0907	0.0727	0.0641	0.0806	0.0554	0.0736	0.0432	0.0637	0.0758
50	0.0301	0.0250	0.0771	0.0668	0.0654	0.0603	0.0645	0.0347	0.0669	0.0537	0.0494	0.0555
52	0.0105	0.0096	0.0229	0.0408	0.0502	0.0484	0.0393	0.0228	0.0424	0.0409	0.0359	0.0358
54	0.0068	0.0140	0.0086	0.0181	0.0317	0.0157	0.0312	0.0158	0.0251	0.0257	0.0168	0.0253
56	0.0030	0.0074	0.0029	0.0137	0.0165	0.0101	0.0131	0.0228	0.0084	0.0181	0.0149	0.0169
58	0.0030	0.0066	0.0057	0.0043	0.0119	0.0075	0.0070	0.0099	0.0100	0.0053	0.0120	0.0119
60+	0.0331	0.0169	0.0057	0.0145	0.0383	0.0132	0.0141	0.0743	0.0312	0.0222	0.0316	0.0316
Sample size	1,330	1,358	350	2,546	1,514	1,592	993	1,010	1,793	1,712	2,087	1,424
Number of hauls	30	43	30	355	354	329	220	179	372	324	429	279

Table 13-10. Design-based estimates with coefficient of variation (CV) of GOA RE/BS rockfish bottom trawl survey biomass and longline survey relative population numbers (RPN) and weights (RPW). The GOA-wide estimates of biomass and RPNs are used as relative indices of abundance in the assessment model, whereas the area-specific estimates of biomass and RPWs are used as inputs to the apportionment model. No sampling was performed in the Eastern GOA for the 2001 survey and we exclude this year from our assessment model. Bottom trawl survey data from 1984 and 1987 have been removed from the author-preferred assessment and apportionment models.

	Assessment Model Inputs		Apportionment Model Inputs					
	Biomass (CV)	RPN (CV)	Biomass (CV)			RPW (CV)		
Year	GOA-wide	GOA-wide	WGOA	CGOA	EGOA	WGOA	CGOA	EGOA
1984	45,091 (0.162)	-	8,779 (0.317)	32,416 (0.207)	3,896 (0.202)	-	-	-
1985	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-
1987	43,681 (0.112)	-	2,737 (0.343)	21,881 (0.159)	19,063 (0.174)	-	-	-
1988	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-
1990	44,837 (0.207)	-	1,329 (0.476)	35,467 (0.258)	8,041 (0.193)	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	61,864 (0.233)	23,567 (0.184)	10,891 (0.785)	41,616 (0.275)	9,358 (0.207)	7,771 (0.440)	7,134 (0.304)	20,556 (0.272)
1994	-	-	-	-	-	5,601 (0.374)	3,547 (0.303)	29,844 (0.229)
1995	-	-	-	-	-	15,462 (0.385)	11,576 (0.267)	16,192 (0.226)
1996	45,913 (0.162)	25,774 (0.160)	3,449 (0.346)	28,396 (0.233)	14,067 (0.226)	7,168 (0.453)	7,948 (0.322)	24,484 (0.185)
1997	-	-	-	-	-	10,775 (0.466)	10,020 (0.365)	40,529 (0.279)
1998	-	-	-	-	-	8,998 (0.306)	8,443 (0.371)	21,323 (0.124)
1999	39,560 (0.146)	27,480 (0.154)	6,156 (0.513)	20,781 (0.174)	12,622 (0.257)	8,117 (0.287)	8,623 (0.346)	24,469 (0.217)
2000	-	-	-	-	-	13,812 (0.367)	11,863 (0.285)	34,658 (0.196)
2001	-	-	6,945 (0.548)	24,740 (0.238)	-	11,883 (0.380)	13,658 (0.310)	20,450 (0.230)
2002	-	-	-	-	-	14,647 (0.340)	10,387 (0.349)	17,999 (0.161)
2003	43,202 (0.156)	24,530 (0.157)	8,921 (0.341)	24,610 (0.197)	9,670 (0.363)	9,573 (0.353)	7,398 (0.378)	23,794 (0.194)
2004	-	-	-	-	-	13,088 (0.425)	5,581 (0.350)	21,238 (0.174)
2005	47,875 (0.180)	18,987 (0.193)	3,621 (0.258)	32,898 (0.254)	11,356 (0.164)	4,660 (0.569)	8,417 (0.332)	16,414 (0.269)
2006	-	-	-	-	-	6,930 (0.328)	10,780 (0.346)	15,586 (0.180)
2007	59,889 (0.173)	34,057 (0.164)	3,773 (0.268)	39,419 (0.243)	16,697 (0.232)	14,374 (0.391)	11,853 (0.274)	23,325 (0.173)
2008	-	-	-	-	-	8,607 (0.382)	10,309 (0.249)	27,974 (0.176)
2009	50,774 (0.163)	30,017 (0.180)	2,765 (0.265)	33,154 (0.211)	14,855 (0.297)	8,738 (0.361)	16,821 (0.415)	18,012 (0.134)
2010	-	-	-	-	-	15,383 (0.354)	9,279 (0.325)	25,531 (0.143)
2011	43,714 (0.162)	40,520 (0.201)	3,305 (0.428)	32,181 (0.211)	8,228 (0.168)	17,197 (0.453)	9,865 (0.329)	30,819 (0.271)

	Assessment Model Inputs		Apportionment Model Inputs					
	Biomass (CV)	RPN (CV)	Biomass (CV)			RPW (CV)		
Year	GOA-wide	GOA-wide	WGOA	CGOA	EGOA	WGOA	CGOA	EGOA
2012	-	-	-	-	-	10,853 (0.369)	7,171 (0.435)	22,500 (0.232)
2013	27,580 (0.184)	24,102 (0.206)	3,922 (0.242)	11,207 (0.293)	12,452 (0.302)	11,173 (0.439)	7,070 (0.328)	14,917 (0.225)
2014	-	-	-	-	-	10,757 (0.405)	9,304 (0.371)	29,602 (0.176)
2015	34,559 (0.144)	31,721 (0.200)	1,345 (0.219)	18,135 (0.200)	15,079 (0.224)	15,689 (0.446)	8,960 (0.443)	25,338 (0.204)
2016	-	-	-	-	-	12,610 (0.405)	7,965 (0.285)	17,695 (0.245)
2017	39,919 (0.180)	36,840 (0.183)	6,722 (0.451)	11,297 (0.212)	21,900 (0.277)	16,867 (0.349)	12,223 (0.438)	24,183 (0.196)
2018	-	-	-	-	-	10,999 (0.303)	7,897 (0.272)	17,118 (0.154)
2019	55,494 (0.485)	32,920 (0.202)	1,381 (0.337)	38,696 (0.686)	15,417 (0.277)	16,927 (0.402)	11,742 (0.321)	17,705 (0.161)
2020	-	-	-	-	-	8,237 (0.448)	4,820 (0.147)	18,753 (0.253)
2021	24,612 (0.119)	21,170 (0.159)	5,242 (0.280)	12,661 (0.171)	6,709 (0.195)	10,160 (0.371)	4,431 (0.246)	20,308 (0.157)
2022	-	-	-	-	-	8,251 (0.402)	7,574 (0.265)	20,352 (0.195)
2023	31,356 (0.095)	18,467 (0.172)	1,753 (0.564)	11,473 (0.161)	18,130 (0.118)	8,057 (0.383)	5,323 (0.282)	12,845 (0.137)

Table 13-11. AFSC bottom trawl survey relative age compositions for GOA RE/BS rockfish since 1984. Pooled age 42+ includes all fish 42 and older. The 1984 and 1987 data have been removed from the author-preferred assessment model.

Age	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021
3	0.0000	0.0000	0.0011	0.0342	0.0023	0.0000	0.0285	0.0375	0.0065	0.0113	0.0125	0.0490	0.0055	0.0213	0.0321	0.0137
4	0.0005	0.0006	0.0025	0.0122	0.0003	0.0247	0.0184	0.0468	0.0093	0.0099	0.0096	0.0367	0.0125	0.0241	0.0165	0.0646
5	0.0000	0.0061	0.0058	0.0108	0.0204	0.0518	0.0669	0.0844	0.0331	0.0191	0.0578	0.0357	0.0831	0.0068	0.0349	0.1010
6	0.0000	0.0652	0.0105	0.0237	0.1446	0.0251	0.0466	0.0385	0.0794	0.0498	0.0324	0.0360	0.0434	0.0295	0.0519	0.1133
7	0.0035	0.0460	0.0395	0.0155	0.0173	0.0327	0.0275	0.0652	0.0430	0.0349	0.0493	0.0700	0.0400	0.1343	0.0503	0.1201
8	0.0892	0.0249	0.0503	0.0211	0.0201	0.0587	0.0554	0.0510	0.0130	0.0608	0.0429	0.0555	0.0416	0.1051	0.0811	0.0778
9	0.0338	0.0401	0.1100	0.0492	0.0321	0.1376	0.0509	0.0532	0.0465	0.0438	0.0982	0.0387	0.0676	0.0790	0.0867	0.0580
10	0.0215	0.0533	0.1684	0.0727	0.0232	0.0505	0.0233	0.0791	0.0331	0.0389	0.0438	0.0480	0.0680	0.0333	0.0507	0.0627
11	0.0075	0.1381	0.0918	0.0665	0.0246	0.0434	0.0203	0.0339	0.0220	0.0561	0.0765	0.0674	0.0583	0.0786	0.0393	0.0663
12	0.0255	0.0959	0.0231	0.0898	0.0458	0.0186	0.0376	0.0504	0.0318	0.0377	0.0766	0.0669	0.0601	0.0534	0.0486	0.0293
13	0.0100	0.0474	0.0548	0.0755	0.0410	0.0433	0.0387	0.0178	0.0481	0.0378	0.0560	0.0561	0.0553	0.0451	0.0527	0.0295
14	0.0310	0.0445	0.0876	0.0571	0.0710	0.0442	0.0427	0.0403	0.0150	0.0369	0.0408	0.0387	0.0725	0.0387	0.0447	0.0395
15	0.0747	0.0445	0.0285	0.0486	0.0698	0.0451	0.0136	0.0513	0.0273	0.0506	0.0544	0.0302	0.0481	0.0535	0.0202	0.0428
16	0.0938	0.0156	0.0132	0.0633	0.0682	0.0546	0.0309	0.0327	0.0362	0.0441	0.0273	0.0296	0.0475	0.0324	0.0859	0.0298
17	0.0400	0.0171	0.0075	0.0457	0.0517	0.0463	0.0254	0.0339	0.0411	0.0374	0.0257	0.0250	0.0395	0.0341	0.0413	0.0303
18	0.0280	0.0149	0.0036	0.0229	0.0277	0.0565	0.0169	0.0226	0.0349	0.0309	0.0151	0.0178	0.0502	0.0177	0.0191	0.0127
19	0.0120	0.0078	0.0206	0.0244	0.0353	0.0298	0.0195	0.0205	0.0315	0.0250	0.0260	0.0117	0.0094	0.0309	0.0504	0.0105
20	0.0036	0.0038	0.0073	0.0242	0.0387	0.0362	0.0466	0.0315	0.0282	0.0414	0.0089	0.0202	0.0169	0.0089	0.0175	0.0086
21	0.0094	0.0257	0.0088	0.0235	0.0212	0.0188	0.0312	0.0108	0.0308	0.0199	0.0176	0.0127	0.0212	0.0261	0.0129	0.0067
22	0.0083	0.0070	0.0074	0.0114	0.0200	0.0192	0.0396	0.0179	0.0572	0.0240	0.0230	0.0244	0.0115	0.0068	0.0153	0.0102
23	0.0113	0.0246	0.0098	0.0221	0.0187	0.0175	0.0396	0.0117	0.0344	0.0182	0.0095	0.0142	0.0173	0.0077	0.0024	0.0139
24	0.0160	0.0117	0.0211	0.0098	0.0116	0.0130	0.0246	0.0116	0.0108	0.0202	0.0250	0.0104	0.0122	0.0036	0.0078	0.0031
25	0.0272	0.0068	0.0044	0.0153	0.0094	0.0097	0.0297	0.0121	0.0197	0.0258	0.0179	0.0141	0.0155	0.0065	0.0090	0.0030
26	0.0259	0.0070	0.0101	0.0054	0.0114	0.0055	0.0297	0.0147	0.0279	0.0229	0.0123	0.0111	0.0067	0.0027	0.0600	0.0067
27	0.0403	0.0045	0.0000	0.0045	0.0073	0.0071	0.0173	0.0166	0.0297	0.0083	0.0253	0.0157	0.0051	0.0066	0.0015	0.0015
28	0.0462	0.0064	0.0104	0.0113	0.0100	0.0122	0.0112	0.0068	0.0243	0.0145	0.0126	0.0081	0.0103	0.0013	0.0353	0.0070
29	0.0369	0.0311	0.0196	0.0037	0.0058	0.0074	0.0113	0.0082	0.0103	0.0139	0.0085	0.0093	0.0050	0.0058	0.0002	0.0060
30	0.0540	0.0253	0.0051	0.0138	0.0106	0.0070	0.0198	0.0055	0.0037	0.0217	0.0069	0.0111	0.0060	0.0056	0.0096	0.0010
31	0.0637	0.0229	0.0174	0.0107	0.0095	0.0092	0.0122	0.0031	0.0243	0.0128	0.0184	0.0092	0.0159	0.0046	0.0008	0.0018

Age	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021
32	0.0295	0.0287	0.0110	0.0105	0.0100	0.0048	0.0098	0.0083	0.0129	0.0127	0.0060	0.0070	0.0061	0.0232	0.0025	0.0016
33	0.0198	0.0262	0.0162	0.0101	0.0141	0.0051	0.0113	0.0096	0.0025	0.0194	0.0013	0.0077	0.0042	0.0059	0.0116	0.0052
34	0.0128	0.0103	0.0181	0.0108	0.0154	0.0080	0.0048	0.0035	0.0022	0.0072	0.0077	0.0040	0.0024	0.0057	0.0000	0.0037
35	0.0125	0.0076	0.0204	0.0076	0.0171	0.0033	0.0076	0.0105	0.0226	0.0063	0.0070	0.0129	0.0036	0.0040	0.0003	0.0000
36	0.0093	0.0151	0.0280	0.0174	0.0133	0.0134	0.0080	0.0089	0.0139	0.0086	0.0054	0.0042	0.0019	0.0000	0.0003	0.0023
37	0.0067	0.0124	0.0106	0.0043	0.0052	0.0066	0.0054	0.0000	0.0155	0.0029	0.0035	0.0025	0.0044	0.0063	0.0021	0.0000
38	0.0085	0.0070	0.0075	0.0072	0.0082	0.0034	0.0030	0.0038	0.0148	0.0044	0.0029	0.0076	0.0011	0.0011	0.0000	0.0000
39	0.0086	0.0073	0.0067	0.0028	0.0058	0.0033	0.0008	0.0029	0.0010	0.0040	0.0032	0.0053	0.0036	0.0000	0.0000	0.0000
40	0.0213	0.0000	0.0094	0.0128	0.0062	0.0053	0.0059	0.0000	0.0025	0.0048	0.0054	0.0053	0.0051	0.0003	0.0002	0.0000
41	0.0148	0.0057	0.0077	0.0038	0.0059	0.0059	0.0057	0.0059	0.0112	0.0029	0.0011	0.0035	0.0050	0.0094	0.0000	0.0000
42+	0.0424	0.0408	0.0241	0.0237	0.0293	0.0153	0.0620	0.0369	0.0479	0.0585	0.0256	0.0667	0.0162	0.0400	0.0040	0.0157
Sample size	369	348	194	775	701	574	488	424	435	928	402	1,038	501	488	425	523
Number of hauls	16	14	27	67	44	64	101	96	67	72	79	140	87	118	103	128

Table 13-12. AFSC bottom trawl survey length compositions for GOA RE/BS rockfish. Data are not fit in the model.

Length (cm)	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017	2019	2021	2023
20	0.0079	0.0112	0.0106	0.0142	0.0427	0.0690	0.0494	0.0454	0.0329	0.0377	0.0285	0.0771	0.0500	0.0427	0.0267	0.0519	0.0558
22	0.0101	0.0309	0.0156	0.0153	0.0507	0.0673	0.0583	0.0465	0.0352	0.0459	0.0568	0.0495	0.0572	0.0291	0.0349	0.0640	0.0625
24	0.0216	0.0297	0.0226	0.0184	0.0594	0.0503	0.0475	0.0509	0.0493	0.0523	0.0517	0.0463	0.0647	0.0498	0.0402	0.0689	0.0681
26	0.0272	0.0268	0.0232	0.0296	0.0530	0.0475	0.0296	0.0558	0.0471	0.0707	0.0428	0.0567	0.0623	0.0793	0.0537	0.0654	0.0774
28	0.0154	0.0220	0.0335	0.0275	0.0366	0.0484	0.0436	0.0672	0.0413	0.0609	0.0478	0.0647	0.0565	0.0917	0.0559	0.1066	0.0732
30	0.0304	0.0403	0.0554	0.0433	0.0580	0.0776	0.0638	0.0624	0.0446	0.0603	0.0676	0.0378	0.0546	0.0645	0.0435	0.0869	0.0912
32	0.0359	0.0453	0.0811	0.0486	0.0439	0.0608	0.0600	0.0532	0.0520	0.0475	0.0525	0.0560	0.0639	0.0669	0.0519	0.0764	0.0548
34	0.0404	0.0459	0.0945	0.0666	0.0426	0.0619	0.0481	0.0687	0.0453	0.0416	0.0624	0.0520	0.0813	0.0745	0.0573	0.0795	0.0848
36	0.0616	0.0557	0.1110	0.0741	0.0605	0.0603	0.0436	0.0645	0.0544	0.0478	0.0571	0.0659	0.0732	0.0601	0.0495	0.0530	0.0673
38	0.0625	0.0731	0.0992	0.0971	0.0491	0.0713	0.0560	0.0591	0.0699	0.0509	0.0745	0.0833	0.0716	0.0637	0.0461	0.0637	0.0488
40	0.0865	0.0826	0.0859	0.1249	0.0676	0.0793	0.0596	0.0754	0.0853	0.0671	0.0873	0.0826	0.0912	0.0623	0.1006	0.0683	0.0377
42	0.1144	0.0859	0.0586	0.1312	0.1084	0.0747	0.0904	0.0921	0.0909	0.0742	0.0936	0.0730	0.0748	0.0667	0.1755	0.0708	0.0357
44	0.1718	0.1134	0.0889	0.1380	0.1126	0.0791	0.1191	0.0849	0.1309	0.0879	0.0890	0.0537	0.0604	0.0533	0.1229	0.0384	0.0444
46	0.1280	0.1273	0.0900	0.0885	0.0905	0.0668	0.0995	0.0567	0.0781	0.0848	0.0650	0.0605	0.0464	0.0564	0.0750	0.0348	0.0584
48	0.0881	0.0949	0.0523	0.0412	0.0582	0.0397	0.0708	0.0361	0.0591	0.0719	0.0573	0.0460	0.0308	0.0462	0.0240	0.0250	0.0576
50	0.0395	0.0453	0.0250	0.0137	0.0260	0.0276	0.0292	0.0244	0.0411	0.0464	0.0289	0.0495	0.0179	0.0319	0.0181	0.0120	0.0423
52	0.0192	0.0320	0.0087	0.0059	0.0209	0.0065	0.0117	0.0146	0.0172	0.0282	0.0131	0.0248	0.0126	0.0211	0.0059	0.0135	0.0153
54	0.0094	0.0127	0.0110	0.0037	0.0039	0.0034	0.0084	0.0090	0.0115	0.0092	0.0105	0.0074	0.0106	0.0066	0.0051	0.0074	0.0139
56	0.0066	0.0057	0.0072	0.0006	0.0081	0.0014	0.0029	0.0043	0.0045	0.0059	0.0036	0.0067	0.0019	0.0041	0.0021	0.0022	0.0049
58	0.0059	0.0046	0.0071	0.0037	0.0024	0.0021	0.0005	0.0061	0.0033	0.0038	0.0007	0.0013	0.0071	0.0042	0.0026	0.0025	0.0025
60+	0.0176	0.0146	0.0188	0.0139	0.0048	0.0052	0.0081	0.0228	0.0061	0.0047	0.0094	0.0051	0.0111	0.0249	0.0082	0.0088	0.0033
Sample size	4,627	3,411	3,522	5,639	3,943	3,677	2,924	3,697	4,253	4,155	2,475	1,671	2,517	2,173	2,078	1,772	1,457
Number of hauls	108	44	99	201	238	230	206	242	216	223	164	142	185	150	137	151	137

Table 13-13. AFSC longline survey size compositions for GOA RE/BS rockfish. Lengths are area-weighted by all available strata and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.0016	0.0003	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0003	0.0000	0.0000	0.0000	0.0004	0.0006	0.0006	0.0014
26	0.0028	0.0000	0.0013	0.0000	0.0011	0.0000	0.0014	0.0015	0.0039	0.0015	0.0000	0.0019	0.0034	0.0020	0.0037	0.0014
28	0.0046	0.0022	0.0042	0.0012	0.0017	0.0018	0.0054	0.0009	0.0060	0.0016	0.0019	0.0067	0.0146	0.0137	0.0007	0.0056
30	0.0105	0.0047	0.0075	0.0041	0.0149	0.0079	0.0103	0.0055	0.0172	0.0115	0.0071	0.0207	0.0260	0.0236	0.0152	0.0154
32	0.0314	0.0181	0.0209	0.0113	0.0056	0.0103	0.0155	0.0125	0.0183	0.0155	0.0140	0.0262	0.0417	0.0182	0.0400	0.0269
34	0.0294	0.0149	0.0157	0.0374	0.0182	0.0202	0.0288	0.0200	0.0329	0.0235	0.0206	0.0373	0.0442	0.0210	0.0407	0.0480
36	0.0457	0.0318	0.0248	0.0394	0.0389	0.0306	0.0447	0.0469	0.0525	0.0524	0.0208	0.0474	0.0544	0.0263	0.0624	0.0705
38	0.0583	0.0467	0.0727	0.0594	0.0673	0.0459	0.0667	0.0697	0.0663	0.0617	0.0533	0.0669	0.0612	0.0427	0.0633	0.0689
40	0.0955	0.0625	0.0711	0.0891	0.0540	0.0816	0.0842	0.0782	0.0899	0.0849	0.0668	0.0811	0.0679	0.0641	0.0776	0.0725
42	0.1017	0.0953	0.1060	0.1048	0.0976	0.0928	0.1030	0.0977	0.0871	0.1166	0.0936	0.0987	0.0915	0.0994	0.1044	0.0941
44	0.1152	0.1221	0.1609	0.1388	0.1314	0.1368	0.1430	0.1247	0.1106	0.1273	0.1338	0.1314	0.1301	0.1336	0.1566	0.1188
46	0.1486	0.1326	0.1511	0.1391	0.1524	0.1510	0.1573	0.1342	0.1388	0.1270	0.1634	0.1518	0.1272	0.1543	0.1324	0.1260
48	0.0993	0.1559	0.1281	0.1446	0.1478	0.1470	0.1362	0.1397	0.1293	0.1268	0.1540	0.1257	0.1334	0.1614	0.1122	0.1128
50	0.1176	0.0997	0.0941	0.1021	0.0931	0.1103	0.0969	0.1010	0.1012	0.0894	0.0910	0.0946	0.0796	0.0897	0.0717	0.0921
52	0.0538	0.0701	0.0507	0.0489	0.0513	0.0667	0.0548	0.0660	0.0482	0.0621	0.0554	0.0466	0.0364	0.0538	0.0438	0.0615
54	0.0181	0.0474	0.0380	0.0313	0.0266	0.0335	0.0189	0.0359	0.0278	0.0304	0.0230	0.0200	0.0243	0.0297	0.0192	0.0291
56	0.0246	0.0240	0.0151	0.0116	0.0153	0.0179	0.0045	0.0184	0.0139	0.0147	0.0129	0.0157	0.0049	0.0133	0.0213	0.0177
58	0.0092	0.0102	0.0137	0.0090	0.0112	0.0110	0.0040	0.0090	0.0053	0.0190	0.0163	0.0062	0.0083	0.0093	0.0030	0.0127
60	0.0320	0.0615	0.0242	0.0278	0.0716	0.0346	0.0241	0.0385	0.0498	0.0342	0.0722	0.0205	0.0507	0.0433	0.0311	0.0247
Sample size	4,178	4,647	6,360	5,848	6,153	4,678	6,082	7,386	4,925	5,033	4,816	5,058	4,233	4,479	6,720	5,871
Number of hauls	65	70	71	75	68	59	63	62	60	64	61	60	58	63	64	64

Table 13-13 (continued). AFSC longline survey size compositions for GOA RE/BS rockfish. Lengths are area-weighted by all available strata and are binned in adjacent pairs and pooled at 60 and greater cm.

Length (cm)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
22	0.0006	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.0011	0.0009	0.0014	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0060	0.0016	0.0000	0.0000	0.0000	0.0000
26	0.0009	0.0055	0.0029	0.0015	0.0017	0.0016	0.0007	0.0018	0.0022	0.0034	0.0007	0.0007	0.0009	0.0006	0.0009
28	0.0061	0.0095	0.0065	0.0063	0.0039	0.0038	0.0051	0.0057	0.0035	0.0022	0.0051	0.0029	0.0037	0.0034	0.0063
30	0.0165	0.0213	0.0256	0.0124	0.0203	0.0160	0.0073	0.0157	0.0141	0.0131	0.0134	0.0128	0.0033	0.0054	0.0150
32	0.0186	0.0334	0.0330	0.0148	0.0340	0.0212	0.0200	0.0202	0.0329	0.0283	0.0288	0.0179	0.0120	0.0158	0.0332
34	0.0278	0.0442	0.0507	0.0300	0.0544	0.0353	0.0185	0.0360	0.0437	0.0406	0.0547	0.0200	0.0250	0.0309	0.0381
36	0.0404	0.0732	0.0698	0.0532	0.0748	0.0602	0.0428	0.0564	0.0585	0.0578	0.0611	0.0446	0.0520	0.0539	0.0618
38	0.0828	0.0730	0.0928	0.0778	0.0559	0.0789	0.0528	0.0669	0.0493	0.0822	0.0975	0.0628	0.0491	0.0821	0.0773
40	0.0870	0.0813	0.0902	0.0959	0.0780	0.1072	0.0765	0.0886	0.0917	0.0988	0.1073	0.0798	0.0662	0.0880	0.1183
42	0.1131	0.1078	0.1139	0.1063	0.0986	0.1043	0.1212	0.0877	0.1030	0.1058	0.1056	0.0934	0.0771	0.1139	0.1100
44	0.1256	0.1322	0.1128	0.1266	0.1430	0.1135	0.1455	0.1058	0.1422	0.1446	0.1190	0.1046	0.1307	0.1116	0.1071
46	0.1040	0.1193	0.1057	0.1270	0.1324	0.1096	0.1316	0.1186	0.1304	0.1338	0.1151	0.1233	0.1258	0.1272	0.1110
48	0.1018	0.0884	0.0919	0.1057	0.1307	0.1147	0.1272	0.1232	0.1298	0.1184	0.0894	0.1302	0.1497	0.1189	0.1246
50	0.1092	0.0660	0.0712	0.0975	0.0686	0.0944	0.0964	0.1048	0.0803	0.0739	0.0698	0.1146	0.1174	0.0861	0.0784
52	0.0675	0.0332	0.0356	0.0581	0.0399	0.0495	0.0674	0.0717	0.0500	0.0438	0.0441	0.0596	0.0687	0.0576	0.0459
54	0.0354	0.0196	0.0229	0.0327	0.0202	0.0226	0.0344	0.0394	0.0277	0.0151	0.0290	0.0522	0.0342	0.0377	0.0288
56	0.0258	0.0159	0.0096	0.0070	0.0119	0.0173	0.0140	0.0195	0.0114	0.0155	0.0142	0.0131	0.0234	0.0215	0.0237
58	0.0071	0.0090	0.0045	0.0055	0.0138	0.0095	0.0169	0.0094	0.0141	0.0028	0.0077	0.0089	0.0098	0.0120	0.0048
60	0.0287	0.0661	0.0591	0.0417	0.0179	0.0403	0.0208	0.0286	0.0152	0.0137	0.0360	0.0586	0.0509	0.0333	0.0149
Sample size	4,796	6,144	5,991	5,272	3,882	6,922	5,583	4,657	6,130	5,919	6,163	4,556	4,898	5,713	4,047
Number of hauls	64	63	68	60	59	63	61	62	66	66	63	66	63	68	65

Table 13-14. Likelihoods and MLE estimates of key parameters from the last two full assessment models, the current base model (Model 15.4), and the current author-preferred model (Model 23.1b) for GOA RE/BS. Note that the amounts of data differ between these models so likelihood component values are not comparable.

		2019 (Model 15.4)	***2021 (Model 15.4)***	***2023 (Model 15.4)***	***2023 (Model 23.1b)***
Likelihoods	**Weight**				
Catch (1977-2005/2005-present)	5/50	0.023	0.088	0.121	0.192
Trawl Biomass	1	9.753	13.499	14.436	20.442
Longline Biomass	1	15.904	19.387	21.539	20.659
Fishery Ages	1	26.097	30.603	40.335	43.504
Trawl Survey Ages	1	38.972	41.837	49.753	43.228
Fishery Sizes	1	64.373	70.673	107.929	99.931
Trawl Survey Sizes	0	0.000	0	0.000	0.000
Longline Survey Sizes	1	109.850	97.993	156.042	189.491
Data-Likelihood		264.972	274.079	390.155	417.446
Penalties/Priors					
Recruit Deviations	1	-13.181	-14.228	-15.893	19.498
Selectivity Penalties					
Fishery	1	2.319	2.149	1.742	3.710
Fishery Domeshape	1	0.002	0.003	0.003	0.021
Trawl Survey	1	0	0	0.000	0.000
Trawl Domeshape	1	0	0	0.000	0.000
Longline	1	0.315	0.462	0.671	0.592
Longline Domeshape	1	0.007	0.026	0.047	0.000
F Regularity	0.1	1.143	1.135	1.163	1.476
σ_r prior		12.154	12.738	13.555	0.000
q-trawl		0.006	0.012	0.015	0.701
q-longline		0.013	0.129	0.095	0.035
M		1.639	0.941	0.082	0.000
Total penalties/priors		4.419	3.369	1.480	26.033
Objective Fun. Total		269.391	280.817	391.635	443.479
Parameter Estimates					
Number Parameters		174	178	182	180
q-trawl		1.714	2.195	2.389	1.061
q-longline		1.178	1.663	1.545	1.013
M		0.036	0.034	0.031	0.042
σ_r		0.805	0.799	0.791	1.100
Mean Recruitment (mil)		1.591	1.183	1.208	1.612
$F_{40\%}$		0.040	0.038	0.035	0.038
$B_{100\%}$ (t)		20,658	14,776	16,914	21,850
$B_{40\%}$ (t)		8,263	5,911	6,611	8,751
$ABC_{F40\%}$ (t)		1,209	788	794	1,305

Table 13-15. Maximum likelihood mean parameter estimates (MLE), Hessian-derived 95% confidence intervals, with mean, median, and 95% credible intervals (MCMC Mean, MCMC Median, BCI-Lower, and BCI-Upper, respectively) from MCMC simulations for key parameters in candidate models. Log Rbar=log mean recruitment, M=natural mortality, Longline q=longline survey catchability, Trawl q=trawl survey catchability, and sigmaR=recruitment variability. CIs are not reported when parameters are fixed.

Model	Quantity	MLE Mean	CI-Lower	CI-Upper	MCMC Mean	MCMC Median	BCI-Lower	BCI-Upper
M15.4a_2023	Log Rbar	0.156	-0.394	0.712	-0.073	-0.114	-0.619	0.709
M23.1_2023	Log Rbar	0.142	-0.177	0.464	-0.285	-0.283	-0.676	0.106
M23.1a_2023	Log Rbar	0.934	0.611	1.261	0.581	0.579	0.268	0.898
M23.1b_2023	Log Rbar	0.478	0.249	0.708	0.161	0.162	-0.099	0.419
M15.4a_2023	M	0.031	0.026	0.036	0.032	0.032	0.027	0.038
M23.1_2023	M	0.044	0.039	0.049	0.044	0.044	0.039	0.049
M23.1a_2023	M	0.052	0.047	0.056	0.052	0.052	0.048	0.057
M23.1b_2023	M	0.042	-	-	0.042	0.042	-	-
M15.4a_2023	Longline q	1.54	0.41	2.67	1.64	1.59	0.73	2.84
M23.1_2023	Longline q	2.53	1.84	3.24	2.64	2.64	1.94	3.37
M23.1a_2023	Longline q	1.00	0.90	1.10	1.01	1.01	0.92	1.11
M23.1b_2023	Longline q	1.01	0.92	1.11	1.02	1.02	0.93	1.11
M15.4a_2023	Trawl q	2.63	1.25	4.03	2.54	2.53	1.15	3.96
M23.1_2023	Trawl q	2.72	1.95	3.50	2.70	2.69	1.96	3.52
M23.1a_2023	Trawl q	1.04	0.93	1.14	1.03	1.03	0.94	1.12
M23.1b_2023	Trawl q	1.06	0.97	1.16	1.06	1.05	0.96	1.15
M15.4a_2023	sigmaR	0.78	0.69	0.88	1.04	1.04	0.92	1.17
M23.1_2023	sigmaR	0.81	0.71	0.91	1.08	1.08	0.96	1.22
M23.1a_2023	sigmaR	1.10	-	-	1.10	1.10	-	-
M23.1b_2023	sigmaR	1.10	-	-	1.10	1.10	-	-

Table 13-16. Estimated GOA RE/BS rockfish population numbers-at-age (thousands) in 2023, percent mature-at-age, weight-at-age, fishery percent selected-at-age, bottom trawl survey (BTS) percent selected-at-age, and longline survey (LLS) percent selected-at-age for the author-recommended model M23.1b_2023 with the base model M15.4_2023 in parentheses.

Age	Numbers in 2023 (1000s)	Maturity (%)	Weight (g)	Fishery Selectivity (%)	BTS Selectivity (%)	LLS Selectivity (%)
3	1,601 (1,202)	4 (0)	50 (53)	0 (0)	31 (24)	0 (0)
4	1,520 (1,151)	4 (0)	89 (99)	0 (0)	50 (44)	0 (0)
5	1,423 (1,072)	5 (0)	139 (158)	0 (1)	63 (61)	0 (0)
6	2,213 (1,324)	6 (0)	199 (228)	1 (1)	74 (73)	0 (0)
7	3,348 (1,603)	7 (0)	266 (306)	1 (3)	82 (83)	0 (0)
8	2,301 (1,205)	8 (0)	338 (388)	3 (5)	88 (90)	0 (0)
9	2,352 (1,186)	9 (0)	414 (473)	5 (9)	92 (95)	0 (0)
10	1,980 (927)	10 (1)	493 (558)	7 (13)	96 (98)	0 (0)
11	1,111 (687)	12 (2)	572 (642)	6 (15)	98 (100)	0 (1)
12	1,108 (707)	14 (4)	652 (723)	6 (15)	99 (100)	2 (5)
13	3,662 (1,473)	16 (8)	730 (801)	5 (14)	100 (99)	6 (16)
14	1,507 (770)	18 (14)	805 (875)	8 (18)	100 (98)	22 (47)
15	1,048 (619)	21 (22)	878 (945)	20 (34)	99 (95)	59 (90)
16	827 (491)	24 (31)	948 (1,010)	100 (100)	98 (93)	100 (100)
17	1,915 (748)	27 (40)	1,015 (1,070)	100 (100)	97 (89)	100 (80)
18	639 (462)	30 (50)	1,078 (1,125)	100 (100)	95 (86)	100 (80)
19	752 (488)	34 (59)	1,138 (1,176)	100 (100)	93 (82)	100 (80)
20	863 (504)	37 (66)	1,194 (1,222)	100 (100)	91 (79)	100 (80)
21	1,211 (577)	41 (72)	1,246 (1,265)	100 (100)	89 (75)	100 (80)
22	1,464 (563)	45 (77)	1,294 (1,303)	100 (100)	86 (71)	100 (80)
23	991 (513)	49 (81)	1,340 (1,338)	100 (100)	84 (67)	100 (80)
24	429 (326)	53 (84)	1,382 (1,369)	100 (100)	81 (63)	100 (80)
25	1,129 (527)	57 (92)	1,420 (1,398)	100 (100)	79 (60)	100 (80)
26	601 (374)	61 (92)	1,456 (1,423)	100 (100)	76 (56)	100 (80)
27	426 (320)	65 (92)	1,489 (1,446)	100 (100)	73 (53)	100 (80)
28	713 (436)	69 (92)	1,519 (1,467)	100 (100)	71 (49)	100 (80)
29	1,330 (453)	72 (92)	1,547 (1,485)	100 (100)	68 (46)	100 (80)
30	346 (287)	75 (92)	1,572 (1,502)	100 (100)	65 (43)	100 (80)
31	365 (251)	78 (92)	1,595 (1,517)	100 (100)	63 (40)	100 (80)
32	469 (249)	81 (92)	1,617 (1,530)	100 (100)	60 (37)	100 (80)
33	1,601 (681)	83 (92)	1,636 (1,542)	100 (100)	58 (35)	100 (80)
34	237 (205)	86 (92)	1,654 (1,553)	100 (100)	55 (32)	100 (80)
35	256 (183)	87 (92)	1,670 (1,562)	100 (100)	53 (30)	100 (80)
36	169 (171)	89 (92)	1,685 (1,571)	100 (100)	51 (28)	100 (80)
37	189 (181)	91 (92)	1,699 (1,578)	100 (100)	49 (26)	100 (80)
38	248 (201)	92 (92)	1,711 (1,585)	100 (100)	46 (24)	100 (80)
39	347 (230)	93 (92)	1,722 (1,591)	100 (100)	44 (22)	100 (80)

Age	Numbers in 2023 (1000s)	Maturity (%)	Weight (g)	Fishery Selectivity (%)	BTS Selectivity (%)	LLS Selectivity (%)
40	501 (239)	94 (92)	1,732 (1,596)	100 (100)	42 (20)	100 (80)
41	295 (214)	95 (92)	1,742 (1,601)	100 (100)	40 (19)	100 (80)
42	426 (346)	96 (92)	1,750 (1,605)	100 (100)	38 (17)	100 (80)
43	625 (290)	96 (92)	1,758 (1,609)	100 (100)	37 (16)	100 (80)
44	177 (154)	97 (92)	1,765 (1,612)	100 (100)	35 (15)	100 (80)
45	138 (127)	97 (92)	1,771 (1,615)	100 (100)	33 (14)	100 (80)
46	162 (142)	98 (92)	1,777 (1,618)	100 (100)	32 (13)	100 (80)
47	738 (406)	98 (92)	1,782 (1,620)	100 (100)	30 (12)	100 (80)
48	110 (147)	98 (92)	1,787 (1,622)	100 (100)	29 (11)	100 (80)
49	115 (118)	99 (92)	1,791 (1,624)	100 (100)	27 (10)	100 (80)
50	118 (112)	99 (92)	1,795 (1,626)	100 (100)	26 (9)	100 (80)
51	131 (113)	99 (92)	1,799 (1,627)	100 (100)	25 (8)	100 (80)
52+	2,845 (3,874)	99 (92)	1,818 (1,634)	100 (100)	23 (8)	100 (80)

Table 13-17. Estimated time series of female spawning biomass (t), age-3 recruitment (1000's), age-3+ biomass (t), catch divided by 3+ biomass, and number of age-3 recruits for GOA RE/BS rockfish. Estimates are shown for Model 15.4 (base) and Model 23.1b (author-recommended).

	Spawning biomass (t)		Recruitment (1000's)		Age-3+ Biomass		Catch/Age-3+ Biomass	
Year	2023 (M15.4)	2023 (M23.1b)	2023 (M15.4)	2023 (M23.1b)	2023 (M15.4)	2023 (M23.1b)	2023 (M15.4)	2023 (M23.1b)
1977	18,840	12,160	1,005	1,425	50,841.7	42,958	0.028	0.034
1978	18,411	11,736	1,146	1,211	49,485.9	42,316	0.011	0.013
1979	18,310	11,686	3,007	7,610	49,057.1	42,890	0.013	0.015
1980	18,155	11,632	989	1,547	48,509.0	43,235	0.028	0.031
1981	17,689	11,337	844	1,246	47,274.8	42,792	0.015	0.017
1982	17,459	11,303	969	1,500	46,650.6	42,998	0.012	0.013
1983	17,278	11,347	1,731	4,971	46,200.8	43,477	0.014	0.014
1984	17,066	11,392	1,955	3,185	45,722.9	43,864	0.017	0.017
1985	16,793	11,411	1,148	2,080	45,106.2	44,071	0.003	0.003
1986	16,780	11,667	1,217	3,318	45,121.6	44,959	0.010	0.010
1987	16,632	11,838	1,117	2,174	44,822.5	45,475	0.012	0.012
1988	16,444	11,990	932	1,466	44,427.3	45,837	0.036	0.035
1989	15,823	11,783	796	1,055	42,992.1	44,996	0.051	0.049
1990	14,996	11,373	720	897	41,049.1	43,492	0.059	0.056
1991	14,109	10,862	735	1,288	38,924.8	41,678	0.009	0.008
1992	14,038	11,059	789	1,128	38,682.1	41,953	0.029	0.027
1993	13,677	11,011	2,513	7,254	37,767.9	41,651	0.015	0.014
1994	13,538	11,132	879	2,015	37,342.5	41,780	0.016	0.014
1995	13,396	11,253	845	1,487	36,906.3	41,888	0.019	0.017
1996	13,208	11,324	924	1,335	36,346.3	41,833	0.015	0.013
1997	13,087	11,446	1,398	4,885	35,953.3	42,061	0.015	0.013
1998	12,971	11,567	1,286	2,485	35,581.8	42,259	0.019	0.016
1999	12,801	11,639	899	1,405	35,086.4	42,293	0.009	0.008
2000	12,766	11,822	998	1,870	34,938.8	42,670	0.015	0.012
2001	12,657	11,928	1,336	3,313	34,597.5	42,879	0.017	0.014
2002	12,469	12,002	780	1,184	34,181.0	42,943	0.008	0.006
2003	12,409	12,178	1,165	2,581	34,095.0	43,354	0.012	0.009
2004	12,299	12,304	1,209	3,588	33,893.2	43,682	0.009	0.007
2005	12,246	12,458	1,175	2,802	33,789.9	44,097	0.009	0.007
2006	12,203	12,609	967	1,876	33,689.5	44,482	0.011	0.008
2007	12,119	12,732	879	1,534	33,504.9	44,750	0.013	0.010
2008	12,015	12,825	790	1,233	33,240.2	44,892	0.011	0.009
2009	11,936	12,934	1,217	3,504	33,044.0	45,151	0.008	0.006
2010	11,902	13,076	759	1,432	32,934.1	45,432	0.013	0.009
2011	11,806	13,164	921	1,737	32,666.8	45,527	0.017	0.012
2012	11,657	13,200	1,105	2,393	32,271.0	45,481	0.019	0.013
2013	11,492	13,219	2,040	5,570	31,885.0	45,537	0.018	0.013
2014	11,338	13,239	946	1,615	31,510.6	45,522	0.024	0.017
2015	11,135	13,192	888	1,552	30,962.7	45,309	0.018	0.012
2016	10,981	13,211	1,158	2,652	30,635.2	45,336	0.023	0.015
2017	10,773	13,181	1,433	3,019	30,202.2	45,255	0.018	0.012
2018	10,630	13,202	1,410	2,832	29,940.8	45,340	0.027	0.018
2019	10,390	13,136	1,818	3,954	29,481.5	45,251	0.027	0.017
2020	10,146	13,068	1,454	2,507	29,057.1	45,162	0.014	0.009
2021	10,063	13,144	1,141	1,547	29,054.0	45,459	0.014	0.009
2022	9,982	13,211	1,187	1,584	29,062.9	45,716	0.016	0.010
2023	9,887	13,256	1,202	1,601	29,023.8	45,877	0.013	0.008

Table 13-18. Estimated time series of recruitment, total biomass (3+), and female spawning biomass from Model 23.1b, the author-preferred model, for RE/BS rockfish in the Gulf of Alaska. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC posterior distribution.

	Recruits (Age-3, 1000s)			**Total age-3+ biomass (t)**			**Spawning biomass (t)**		
Year	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**	**Mean**	**2.5%**	**97.5%**
1977	1,425	122	6,746	42,958	38,393	48,396	12,160	9,825	13,682
1978	1,211	124	6,402	42,316	37,952	47,683	11,736	9,521	13,258
1979	7,610	350	12,408	42,890	38,552	48,279	11,686	9,576	13,227
1980	1,547	145	8,155	43,235	38,977	48,600	11,632	9,635	13,172
1981	1,246	114	5,911	42,792	38,657	48,136	11,337	9,437	12,833
1982	1,500	135	7,329	42,998	38,911	48,349	11,303	9,521	12,802
1983	4,971	239	10,254	43,477	39,349	48,805	11,347	9,624	12,852
1984	3,185	231	10,556	43,864	39,740	49,142	11,392	9,748	12,923
1985	2,080	170	8,300	44,071	39,993	49,320	11,411	9,847	12,948
1986	3,318	200	7,835	44,959	40,854	50,199	11,667	10,143	13,238
1987	2,174	182	6,427	45,475	41,359	50,688	11,838	10,343	13,409
1988	1,466	144	4,402	45,837	41,693	51,052	11,990	10,524	13,580
1989	1,055	117	3,217	44,996	40,820	49,986	11,783	10,358	13,295
1990	897	101	2,627	43,492	39,408	48,238	11,373	10,023	12,796
1991	1,288	130	3,596	41,678	37,668	45,789	10,862	9,588	12,117
1992	1,128	120	3,949	41,953	37,969	46,063	11,059	9,789	12,317
1993	7,254	1,947	11,147	41,651	37,603	45,691	11,011	9,758	12,235
1994	2,015	160	7,379	41,780	37,707	45,715	11,132	9,876	12,354
1995	1,487	144	4,701	41,888	37,788	45,895	11,253	9,987	12,482
1996	1,335	134	5,159	41,833	37,683	45,904	11,324	10,056	12,564
1997	4,885	348	9,108	42,061	37,854	46,125	11,446	10,171	12,702
1998	2,485	206	7,413	42,259	38,042	46,386	11,567	10,274	12,829
1999	1,405	130	4,891	42,293	38,027	46,480	11,639	10,343	12,918
2000	1,870	158	5,858	42,670	38,368	46,930	11,822	10,512	13,116
2001	3,313	323	6,495	42,879	38,496	47,166	11,928	10,605	13,222
2002	1,184	134	4,289	42,943	38,532	47,296	12,002	10,668	13,292
2003	2,581	282	6,208	43,354	38,894	47,771	12,178	10,819	13,484
2004	3,588	342	7,946	43,682	39,184	48,160	12,304	10,935	13,629
2005	2,802	257	6,763	44,097	39,566	48,584	12,458	11,080	13,798
2006	1,876	164	4,949	44,482	39,924	49,022	12,609	11,214	13,965
2007	1,534	164	4,119	44,750	40,132	49,324	12,732	11,316	14,101
2008	1,233	143	4,184	44,892	40,250	49,467	12,825	11,399	14,214
2009	3,504	475	6,367	45,151	40,476	49,729	12,934	11,488	14,343
2010	1,432	161	4,718	45,432	40,737	50,028	13,076	11,610	14,501
2011	1,737	175	4,737	45,527	40,784	50,158	13,164	11,686	14,606
2012	2,393	229	7,088	45,481	40,720	50,126	13,200	11,715	14,671
2013	5,570	976	10,090	45,537	40,748	50,145	13,219	11,728	14,686
2014	1,615	149	5,566	45,522	40,711	50,113	13,239	11,731	14,714
2015	1,552	144	4,910	45,309	40,416	49,849	13,192	11,681	14,672
2016	2,652	234	7,392	45,336	40,399	49,919	13,211	11,684	14,705
2017	3,019	251	8,404	45,255	40,225	49,892	13,181	11,636	14,678
2018	2,832	202	9,877	45,340	40,227	50,036	13,202	11,646	14,704
2019	3,954	278	11,393	45,251	39,993	49,986	13,136	11,574	14,650
2020	2,507	192	9,103	45,162	39,791	50,017	13,068	11,496	14,587
2021	1,547	136	6,012	45,459	39,936	50,445	13,144	11,560	14,663
2022	1,584	130	9,507	45,716	40,083	50,919	13,211	11,606	14,733
2023	1,601	123	10,570	45,877	40,107	51,401	13,256	11,643	14,784

Table 13-19. Root mean square error (RMSE) and relative RMSE for all candidate models and data sources fit in the model. Results are sorted such that the best fitting models (lowest RMSE and relative RMSE) are listed first within each data source.

Model	Data	RMSE	Relative RMSE
M23.1a_2023	Historical catch (wt = 5)	11.454	0.005
M23.1b_2023	Historical catch (wt = 5)	26.314	0.012
M15.4a_2023	Historical catch (wt = 5)	43.227	0.019
M23.1_2023	Historical catch (wt = 5)	47.444	0.021
M15.4_2023	Historical catch (wt = 5)	47.915	0.021
M15.4a_2023	Modern catch (wt = 50)	3.614	0.007
M15.4_2023	Modern catch (wt = 50)	3.685	0.007
M23.1a_2023	Modern catch (wt = 50)	4.971	0.010
M23.1_2023	Modern catch (wt = 50)	5.034	0.010
M23.1b_2023	Modern catch (wt = 50)	7.290	0.014
M23.1b_2023	Fishery age compositions	0.021	0.053
M23.1a_2023	Fishery age compositions	0.021	0.054
M23.1_2023	Fishery age compositions	0.022	0.057
M15.4a_2023	Fishery age compositions	0.026	0.067
M15.4_2023	Fishery age compositions	0.026	0.067
M15.4a_2023	Fishery length compositions	0.025	0.108
M15.4_2023	Fishery length compositions	0.025	0.108
M23.1b_2023	Fishery length compositions	0.026	0.113
M23.1a_2023	Fishery length compositions	0.026	0.114
M23.1_2023	Fishery length compositions	0.027	0.118
M23.1a_2023	Longline survey RPNs	5,940.008	0.269
M23.1_2023	Longline survey RPNs	6,103.659	0.277
M23.1b_2023	Longline survey RPNs	6,158.420	0.279
M15.4_2023	Longline survey RPNs	6,475.738	0.294
M15.4a_2023	Longline survey RPNs	6,506.356	0.295
M15.4_2023	Longline survey length compositions	0.015	0.092
M15.4a_2023	Longline survey length compositions	0.015	0.092
M23.1_2023	Longline survey length compositions	0.017	0.107
M23.1a_2023	Longline survey length compositions	0.018	0.110
M23.1b_2023	Longline survey length compositions	0.019	0.114
M15.4a_2023	Trawl survey age compositions	0.014	0.083
M23.1a_2023	Trawl survey age compositions	0.015	0.087
M23.1_2023	Trawl survey age compositions	0.015	0.088
M23.1b_2023	Trawl survey age compositions	0.015	0.089
M15.4_2023	Trawl survey age compositions	0.015	0.089
M23.1_2023	Trawl survey biomass	11,348.646	0.305
M15.4_2023	Trawl survey biomass	11,742.486	0.315
M15.4a_2023	Trawl survey biomass	11,860.487	0.318
M23.1a_2023	Trawl survey biomass	13,301.863	0.357
M23.1b_2023	Trawl survey biomass	15,025.098	0.403

Table 13-20. Standard projection model results of spawning biomass, fishing mortality, and yield for seven harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see *Harvest Recommendations* section. $B_{40\%}$ = 8,751 t, $B_{35\%}$ = 7,657 t, $F_{40\%}$ = 0.038 and $F_{35\%}$ = 0.045.

Year	Maximum permissible F	Author's F (Estimated catches)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
Spawning biomass (t)							
2023	12,957	12,957	12,957	12,957	12,957	12,957	12,957
2024	12,873	12,986	12,970	12,995	13,068	12,835	12,873
2025	12,627	13,005	12,948	13,033	13,280	12,501	12,627
2026	12,387	12,910	12,927	13,071	13,493	12,179	12,350
2027	12,155	12,659	12,905	13,108	13,708	11,869	12,033
2028	11,938	12,423	12,890	13,150	13,928	11,579	11,736
2029	11,727	12,193	12,871	13,189	14,144	11,301	11,451
2030	11,526	11,973	12,855	13,228	14,360	11,038	11,180
2031	11,335	11,761	12,840	13,269	14,577	10,789	10,923
2032	11,153	11,560	12,828	13,310	14,796	10,553	10,680
2033	10,978	11,365	12,814	13,350	15,011	10,327	10,447
2034	10,810	11,178	12,799	13,388	15,224	10,113	10,226
2035	10,654	11,002	12,789	13,427	15,436	9,914	10,020
2036	10,506	10,835	12,776	13,465	15,643	9,728	9,828
Fishing Mortality							
2023	0.014	0.014	0.014	0.014	0.014	0.014	0.014
2024	0.038	0.016	0.019	0.014	0.000	0.045	0.038
2025	0.038	0.015	0.019	0.014	0.000	0.045	0.038
2026	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2027	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2028	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2029	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2030	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2031	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2032	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2033	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2034	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2035	0.038	0.038	0.019	0.014	0.000	0.045	0.045
2036	0.038	0.038	0.019	0.014	0.000	0.045	0.045
Yield (t)							
2023	487	487	487	487	487	487	487
2024	1,302	547	657	489	-	1,555	1,302
2025	1,283	539	659	493	-	1,522	1,283
2026	1,307	1,360	682	513	-	1,540	1,561
2027	1,268	1,319	674	508	-	1,485	1,504
2028	1,233	1,281	666	505	-	1,434	1,452
2029	1,217	1,262	667	508	-	1,407	1,424
2030	1,209	1,251	672	513	-	1,390	1,406
2031	1,201	1,240	676	518	-	1,374	1,389
2032	1,208	1,245	688	529	-	1,376	1,390
2033	1,190	1,225	687	530	-	1,349	1,362
2034	1,158	1,190	677	524	-	1,306	1,317
2035	1,128	1,158	668	519	-	1,265	1,276
2036	1,102	1,130	661	515	-	1,230	1,240

* Projections are based on an estimated catch of 487 t for 2023, and estimates of 547 t and 539 t used in place of maximum permissible ABC for 2024 and 2025 in response to a Plan Team request to obtain more accurate two-year projections. Please see section on Specified Catch Estimation subsection in the Harvest Recommendations section for more details.

Table 13-21. Alternative two-survey random effects (REMA) models and apportionment methods for 2024 and 2025. Recommended apportionment in bold.

Apportionment Model	Apportionment Method	Western GOA	Central GOA	Eastern GOA
Apportionment 19*	REMA-predicted biomass	17.9%	30.5%	51.6%
Apportionment 23	REMA-predicted biomass	10.4%	46.3%	43.2%
Apportionment 23	**Average of REMA-predicted biomass and REMA-predicted RPW**	**19.0%**	**30.4%**	**50.6%**

Figures

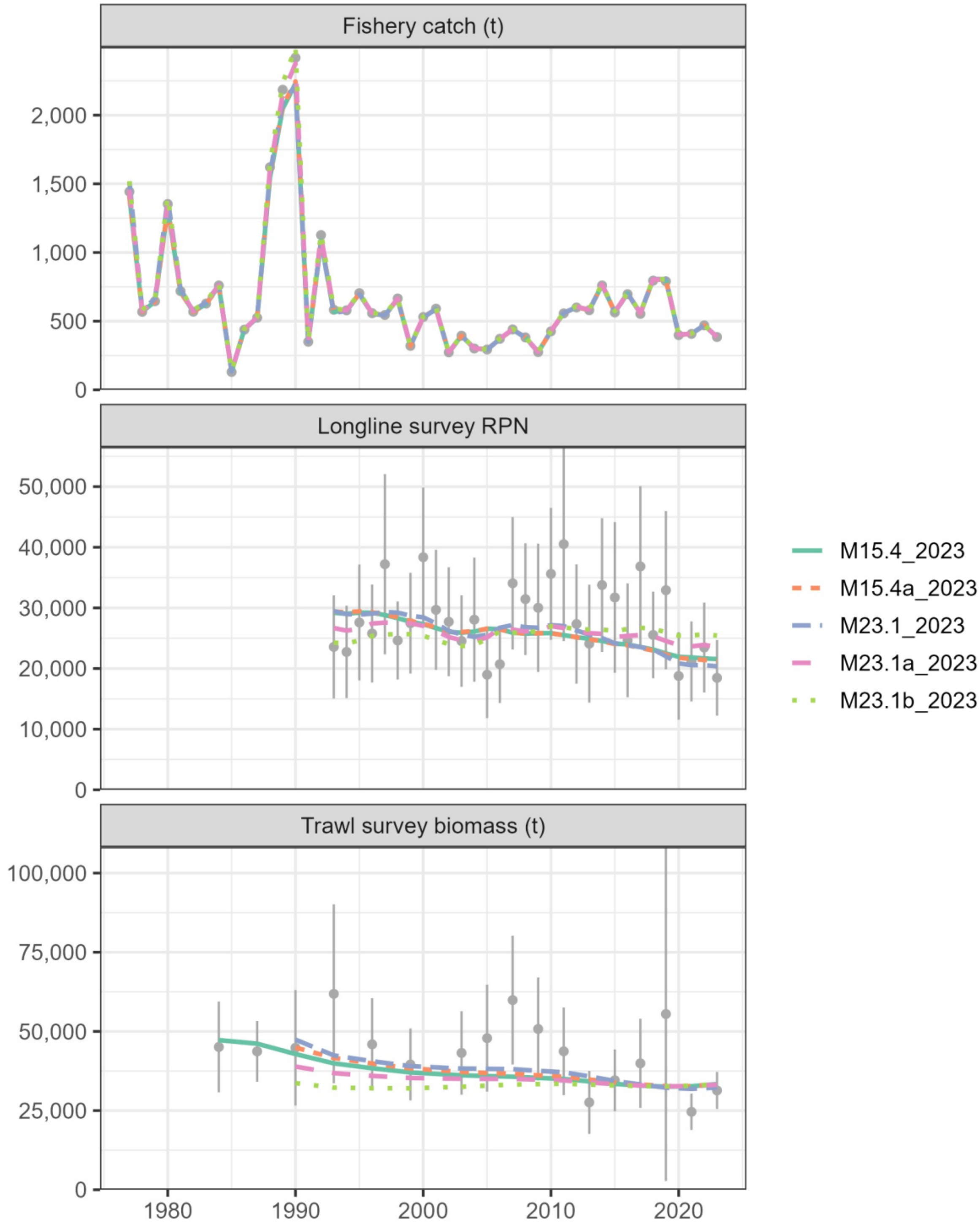

Figure 13-1. Candidate assessment model fits to commercial catch in tons (top), longline survey relative population numbers (RPN; middle), and trawl survey biomass in tons (bottom). Observed = grey points with 95% confidence intervals, predicted from candidate assessment models = colored lines. M23.1b (green dotted lines) is the author-preferred model.

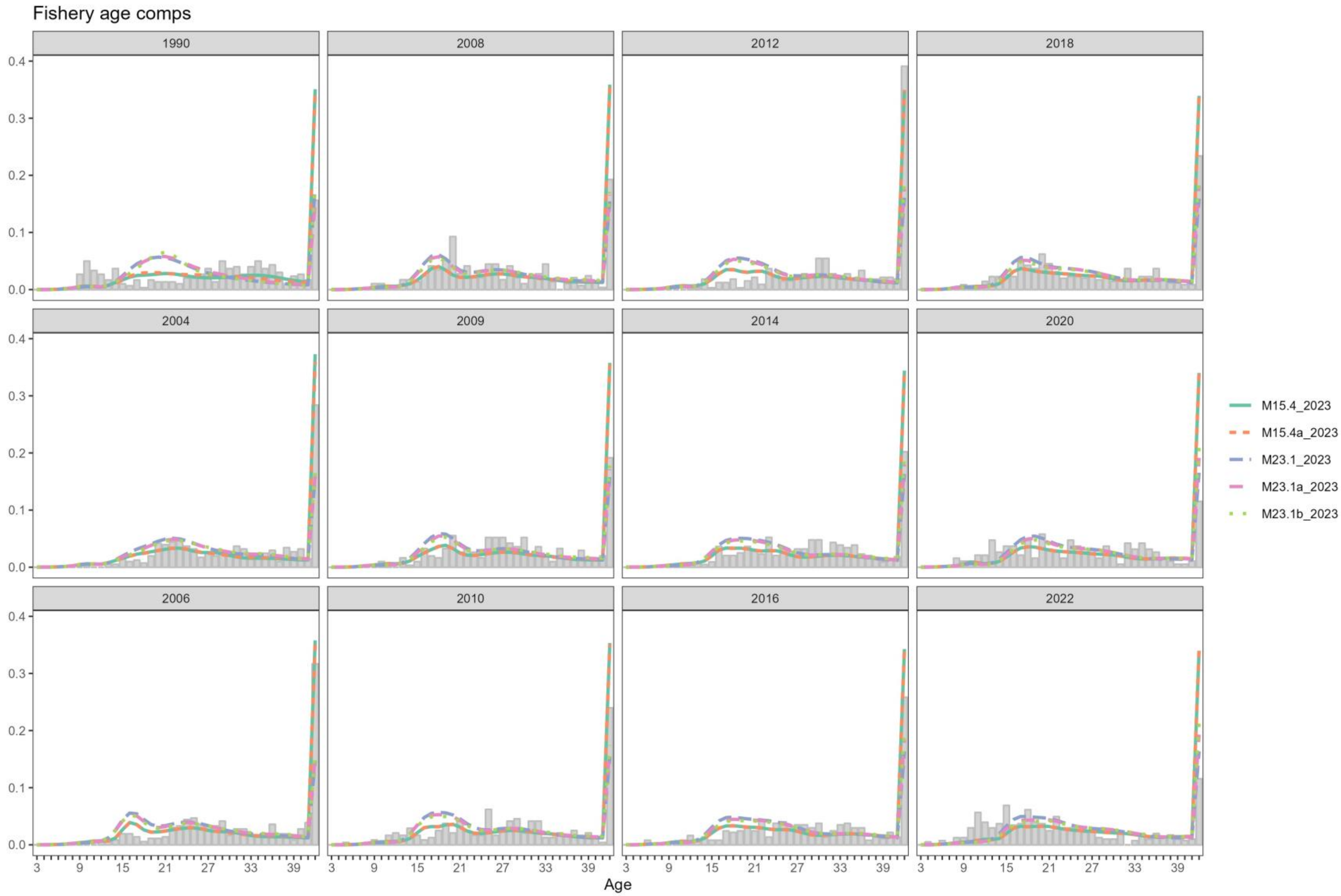

Figure 13-2. Fishery age composition data. Observed = grey bars, predicted from candidate assessment models = colored lines. M23.1b (green dotted lines) is the author-preferred model.

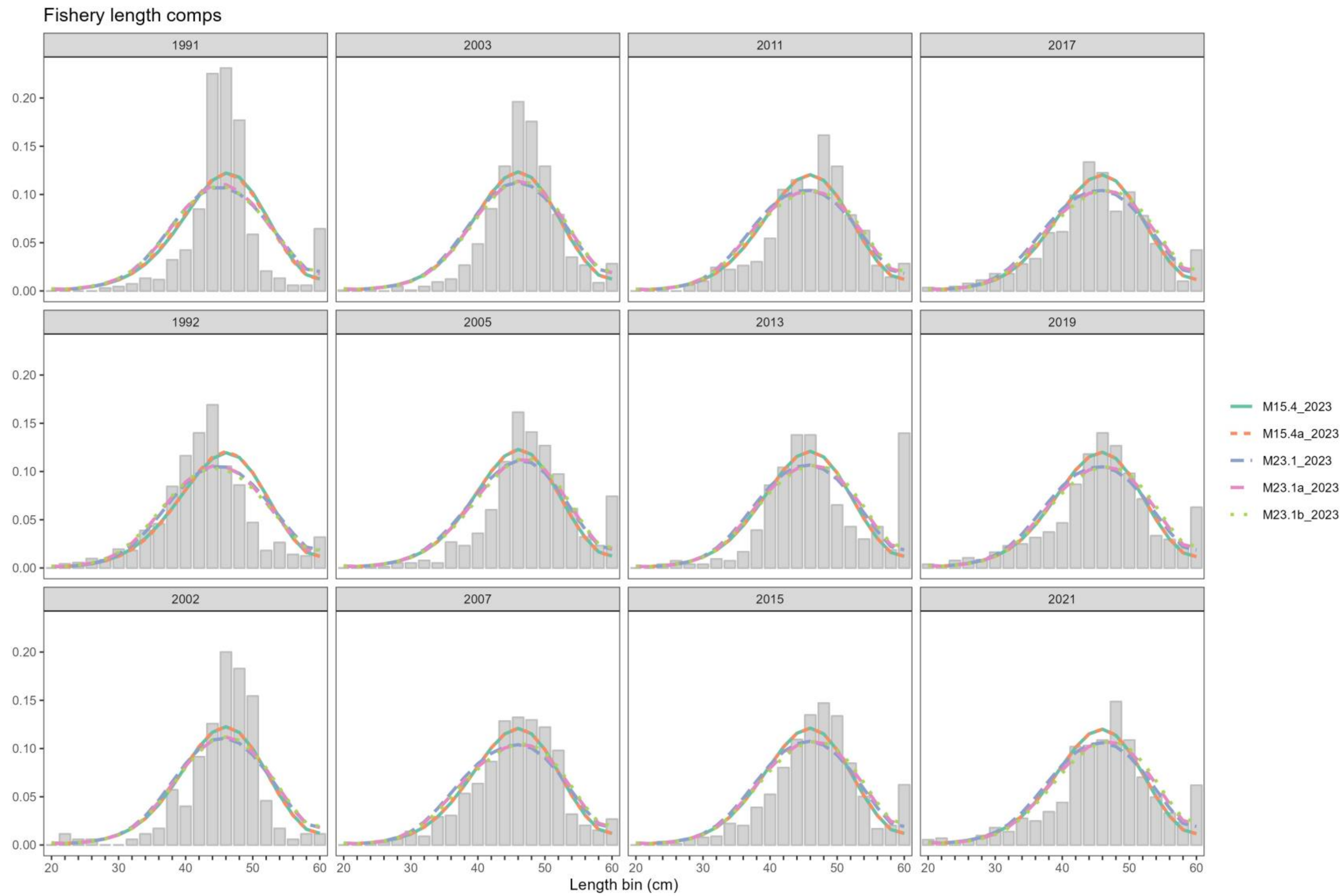

Figure 13-3. Fishery length composition data. Observed = grey bars, predicted from candidate assessment models = colored lines. M23.1b (green dotted lines) is the author-preferred model.

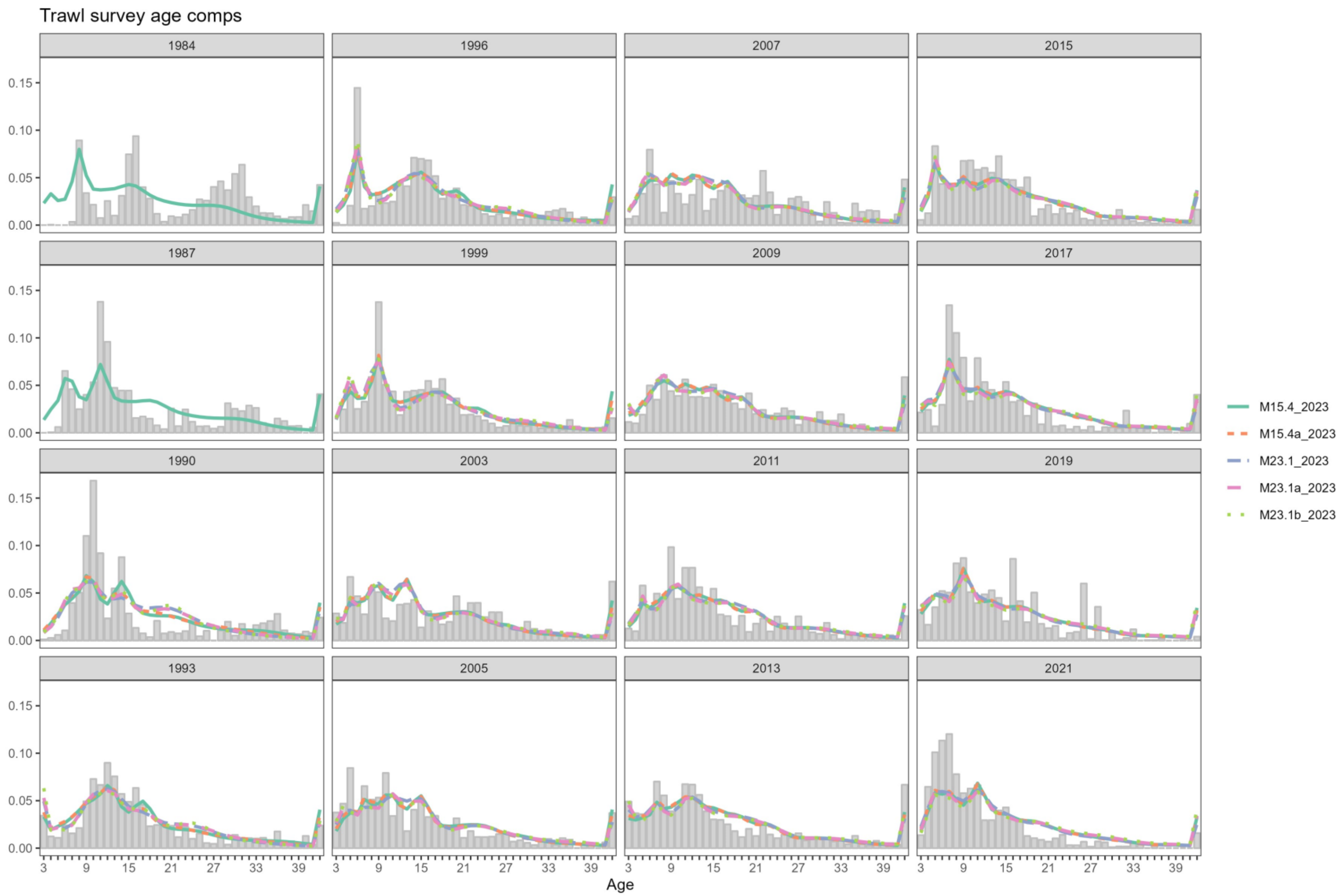

Figure 13-4. Bottom trawl survey age composition data. Observed = grey bars, predicted from candidate assessment models = colored lines. M23.1b (green dotted lines) is the author-preferred model.

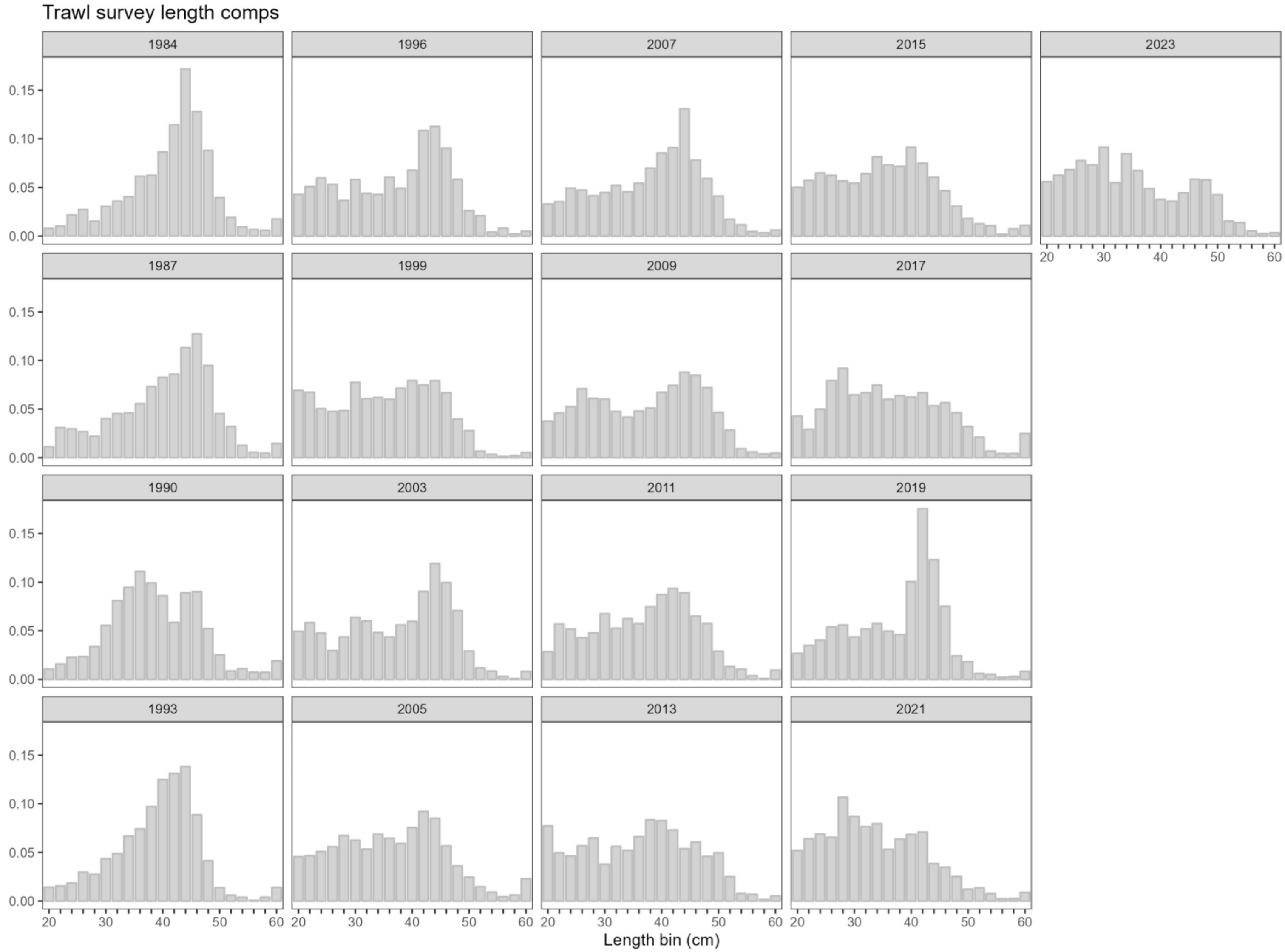

Figure 13-5. Bottom trawl survey length composition data. These data are not currently fit in the assessment model.

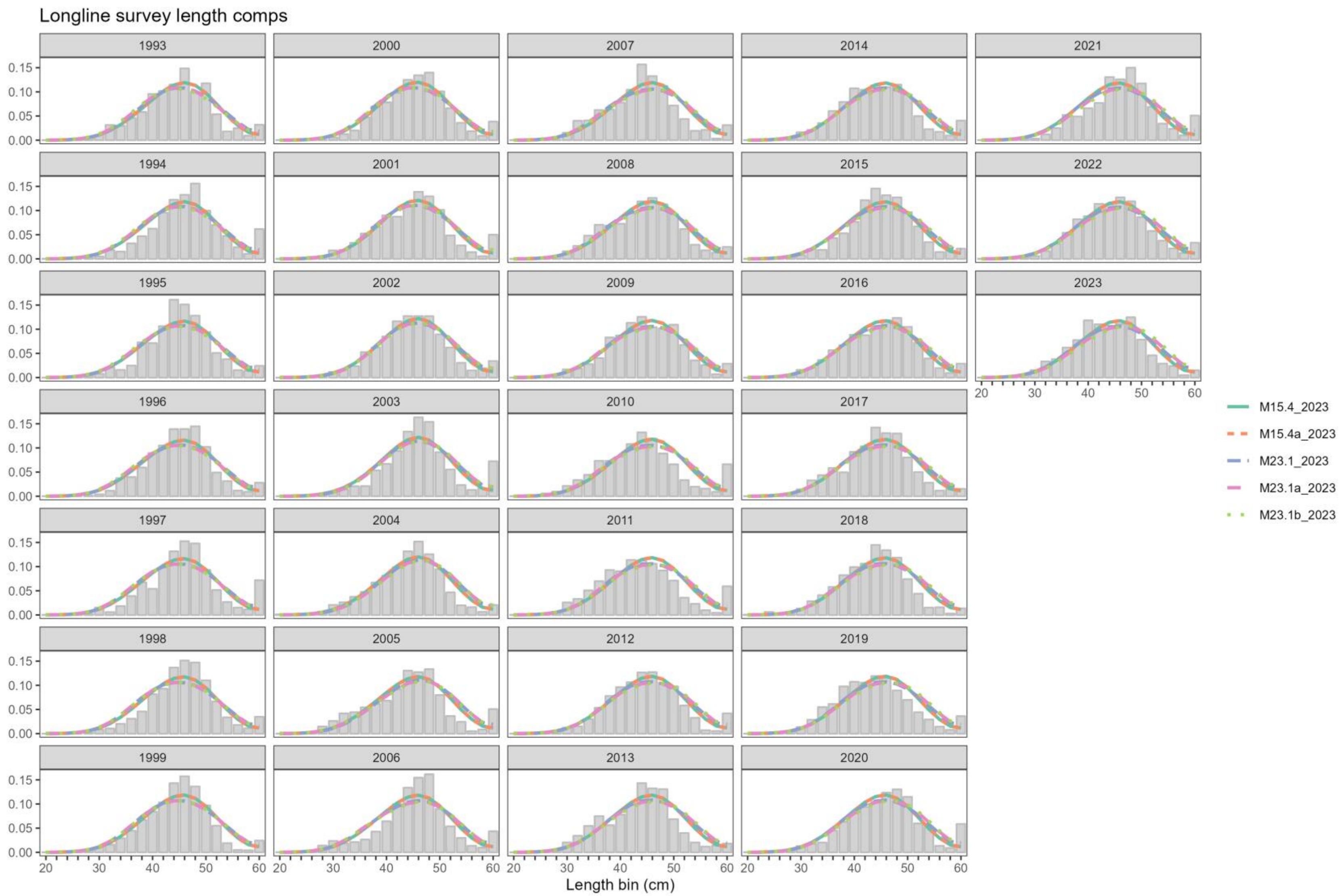

Figure 13-6. Longline survey length composition data. Observed = grey bars, predicted from candidate assessment models = colored lines.M23.1b (green dotted lines) is the author-preferred model.

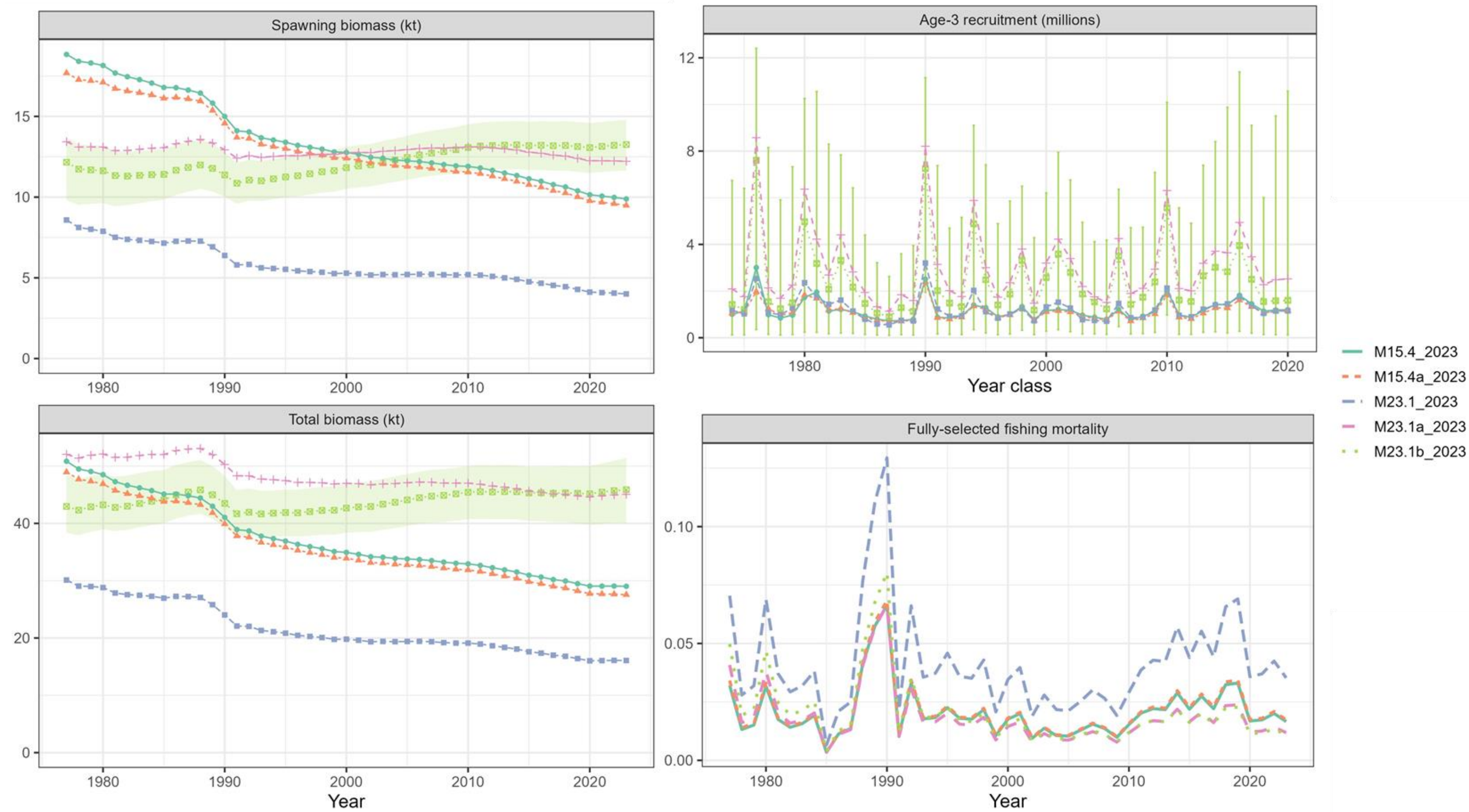

Figure 13-7. Estimates of spawning biomass (kt), total age-3+ biomass (kt), age-3 recruitment in millions, and fully-selected fishing mortality, for all candidate models. For M23.1b (the author-preferred model), we show 95% credible intervals for biomass and recruitment estimates.

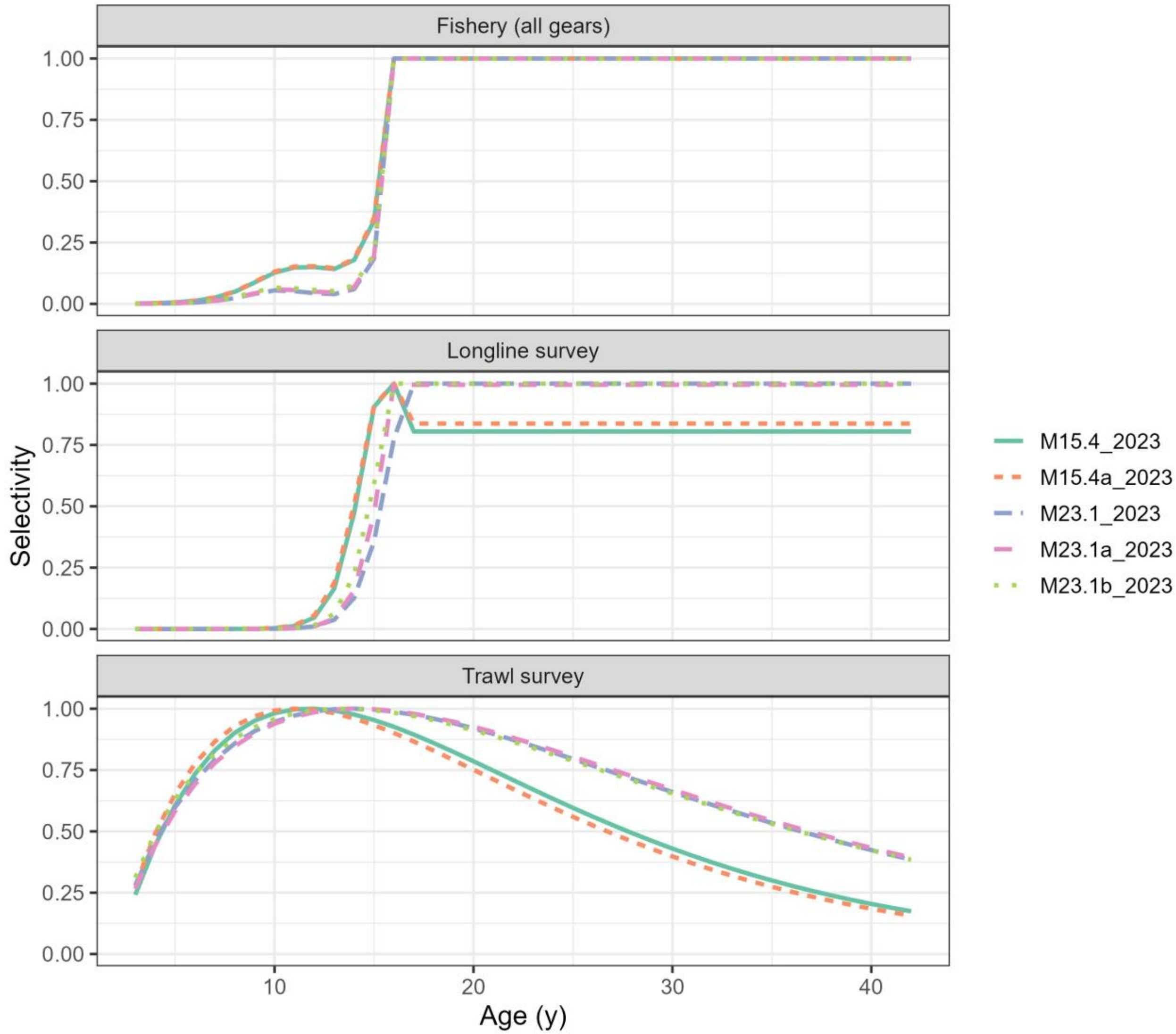

Figure 13-8. Age-based selectivity estimates for the fishery, bottom trawl survey, and longline fishery. Results shown for all candidate models. M23.1b (green dotted lines) is the author-preferred model.

(A) Model 15.4

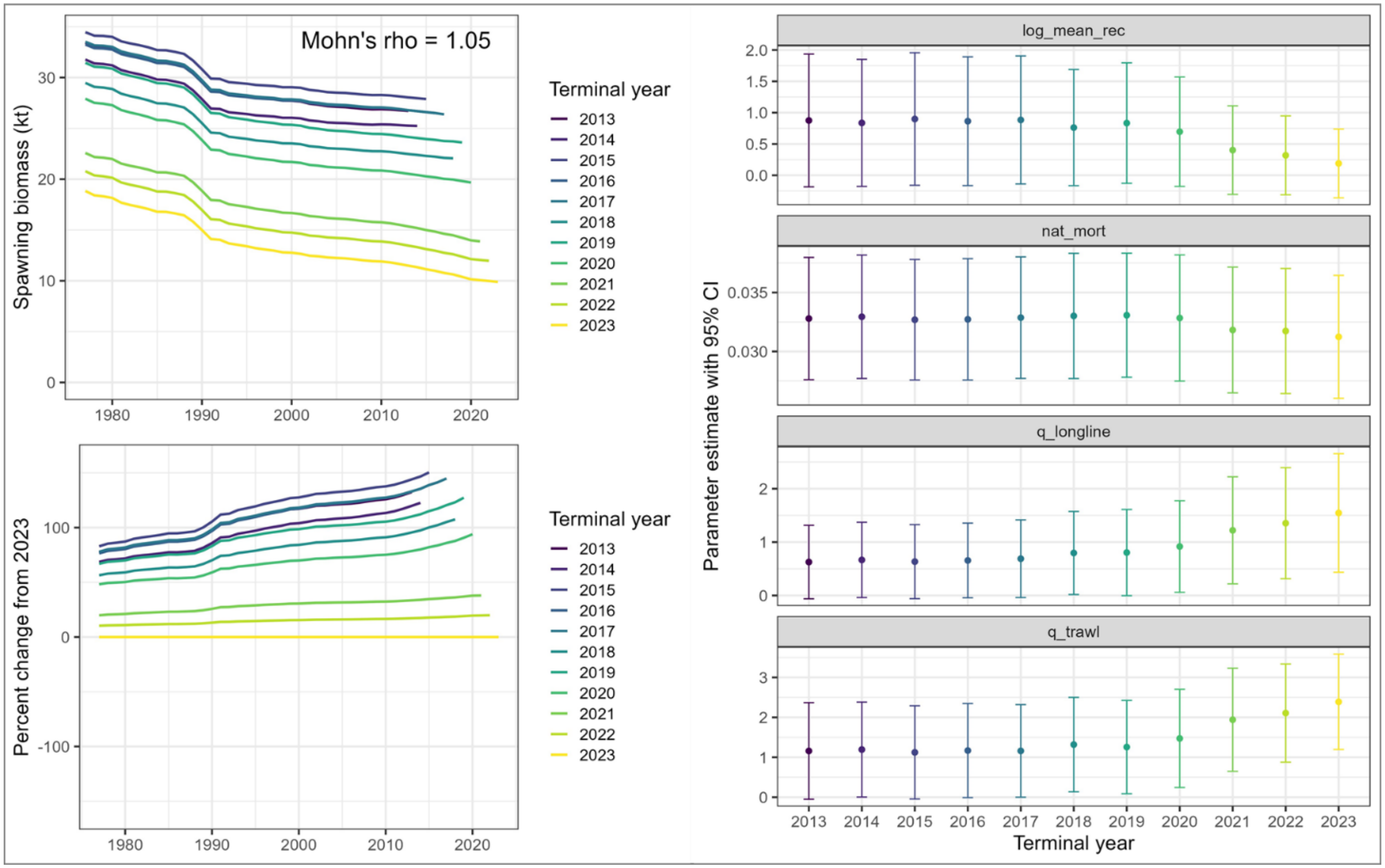

Figure 13-9. Retrospective analysis results for all candidate models, where Model 23.1b is the author-preferred model. For each model, we show the following: (1) retrospective peels of estimated female spawning biomass (top left); (2) percent change from the 2023 model (bottom left) are shown; and (3) parameter estimates with 95% confidence intervals (right) from ten retrospective peels for mean recruitment in log space (log_mean_rec), natural mortality (nat_mort), longline survey catchability (q_longline), and bottom trawl survey catchability (q_trawl).

(B) Model 15.4a

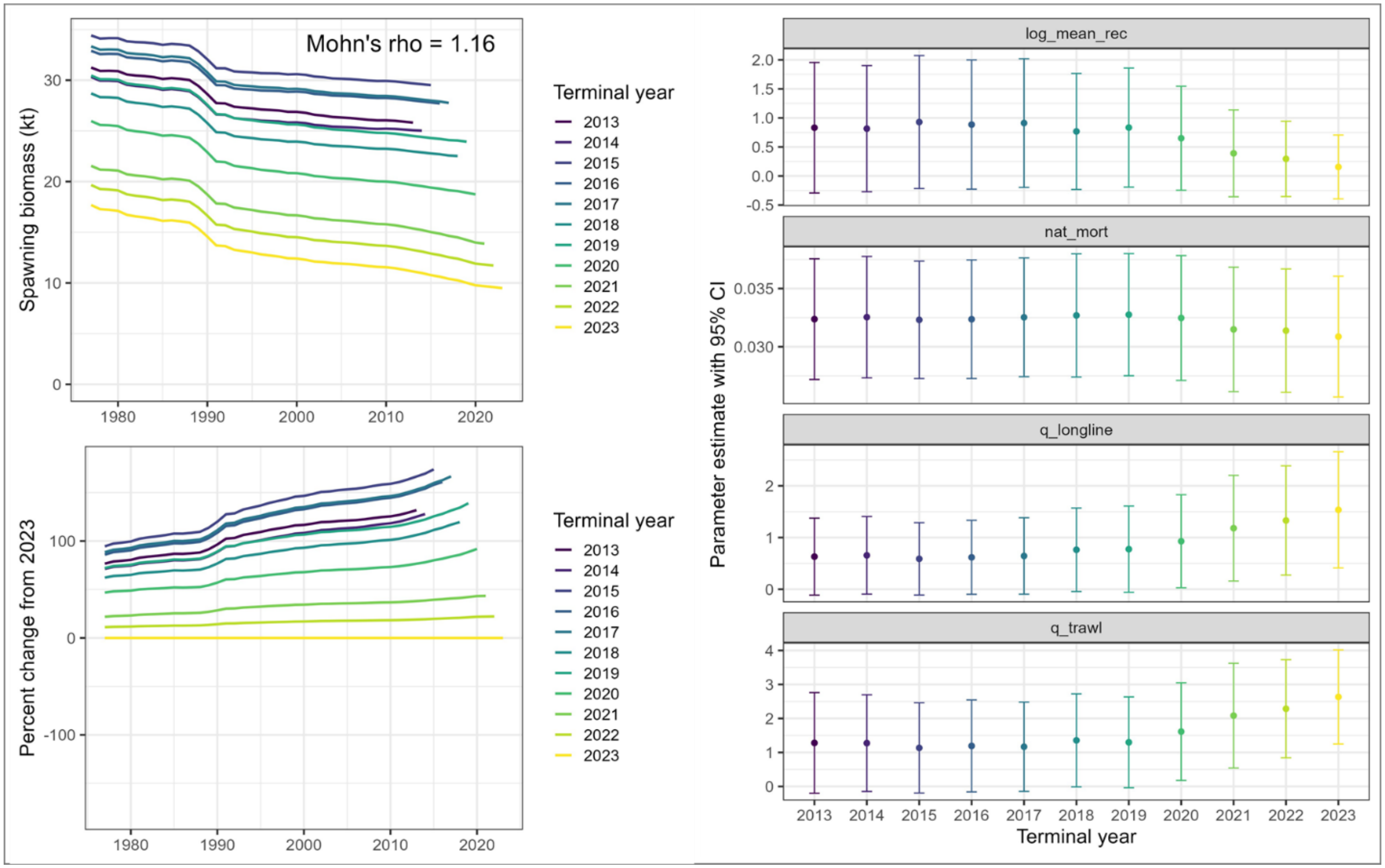

Figure 13-9 (continued)

(C) Model 23.1

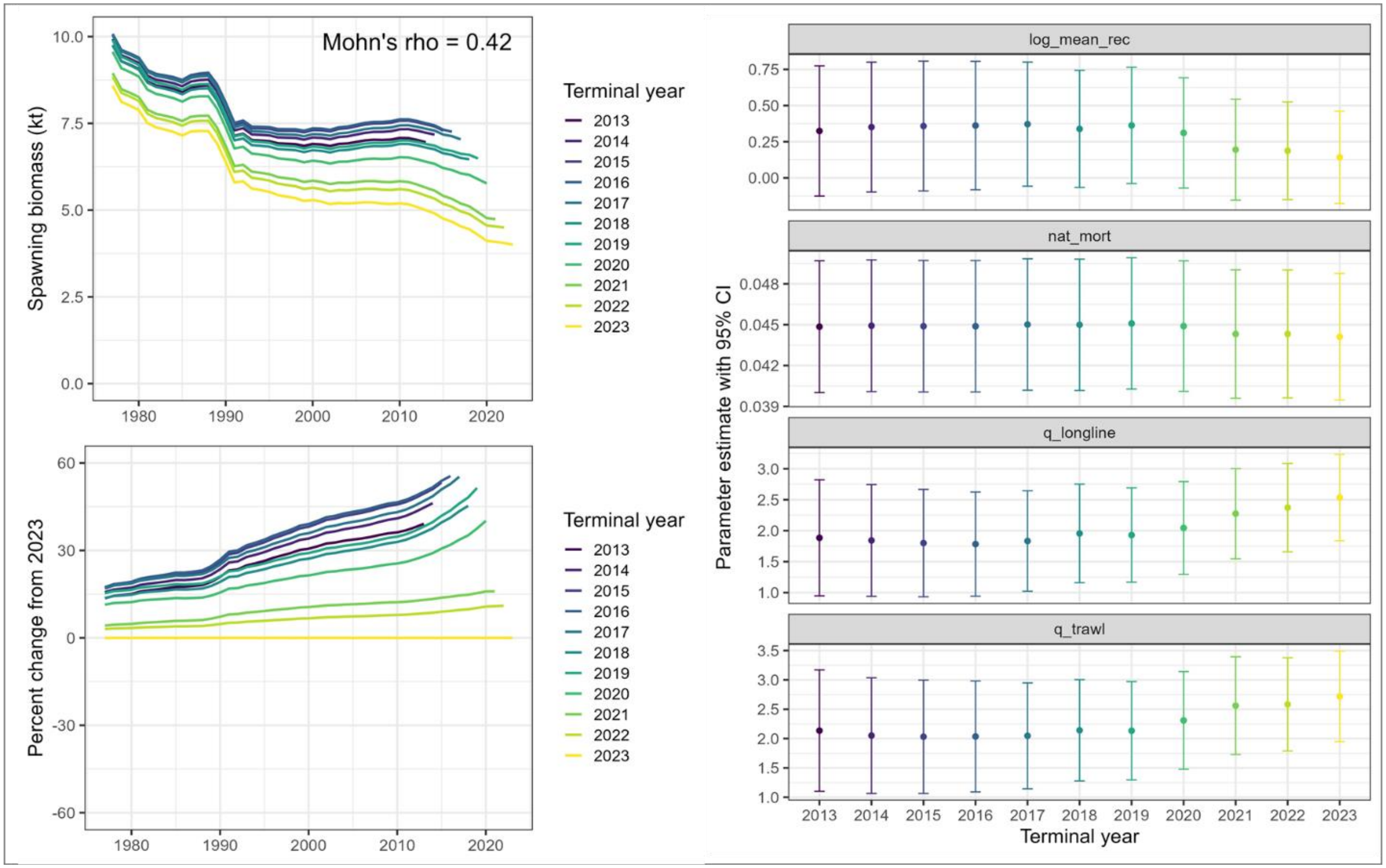

Figure 13-9 (continued)

(D) Model 23.1a

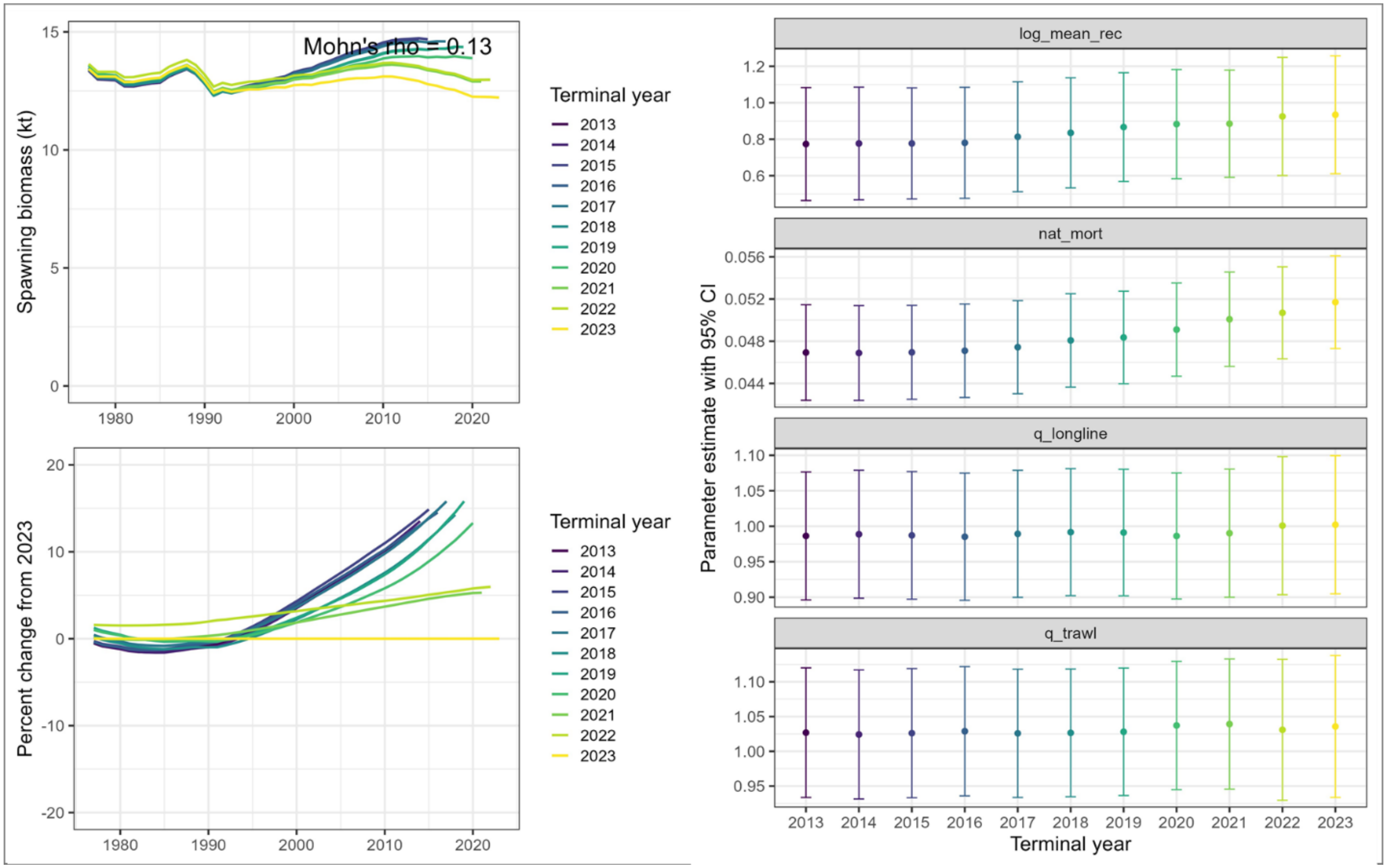

Figure 13-9 (continued)

(E) Model 23.1b (author-recommended)

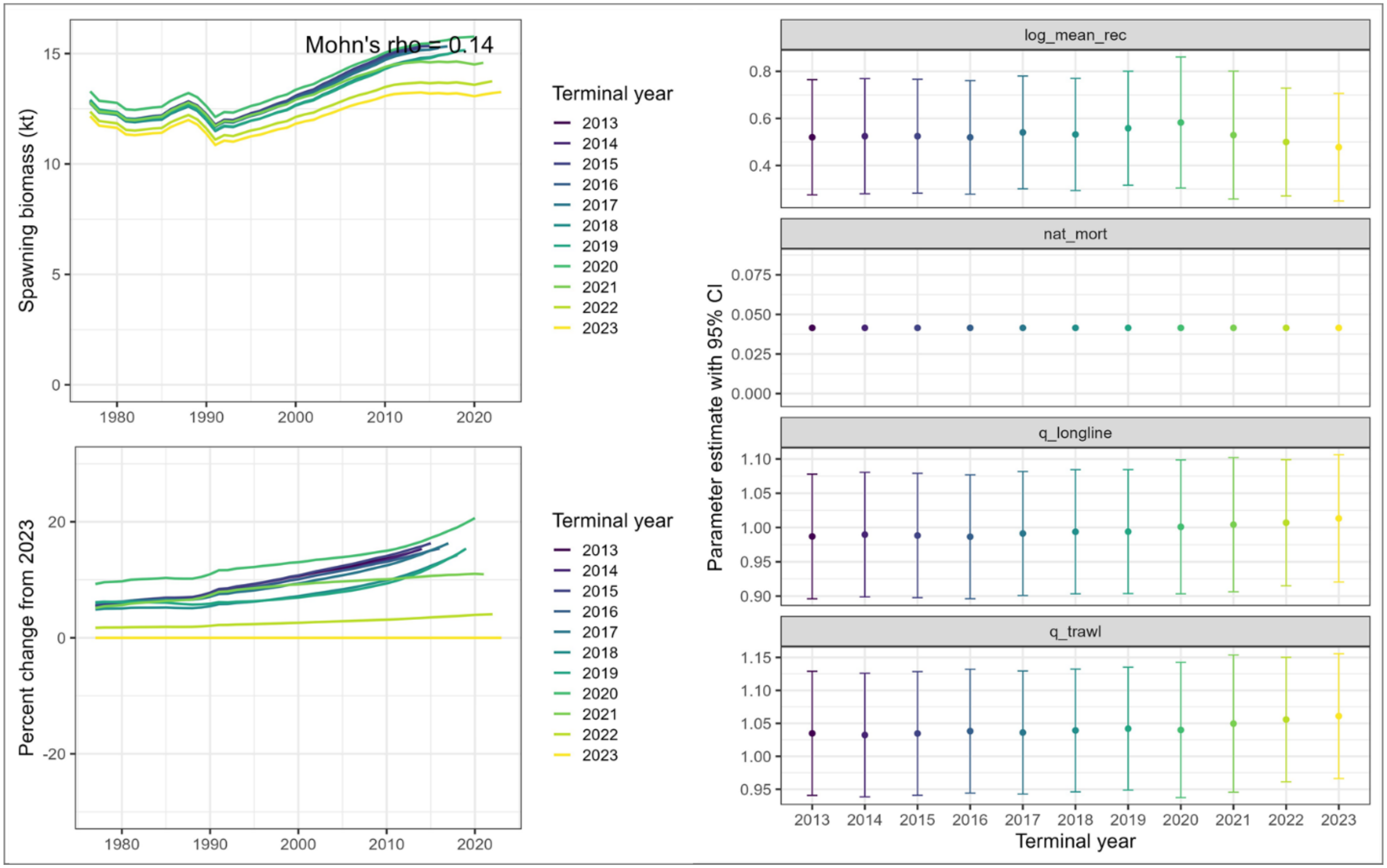

Figure 13-9 (continued)

(A) Model 15.4a

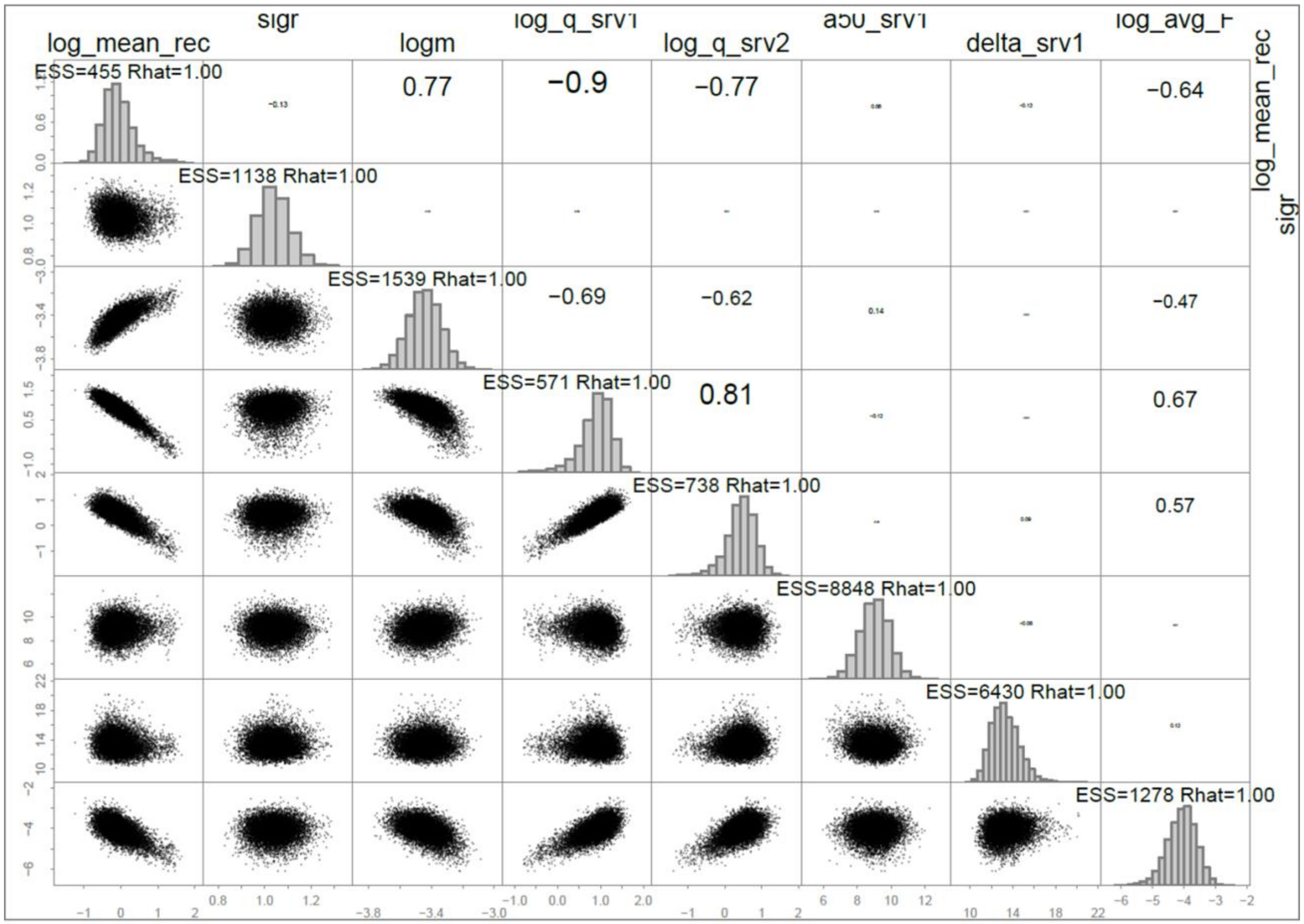

Figure 13-10. Convergence diagnostics and pairwise plots of the MCMC marginal posterior distributions for several key parameters. For brevity, only results for Model 15.4a, Model 23.1, Model 23.1a, and Model 23.1b are shown.

(B) Model 23.1

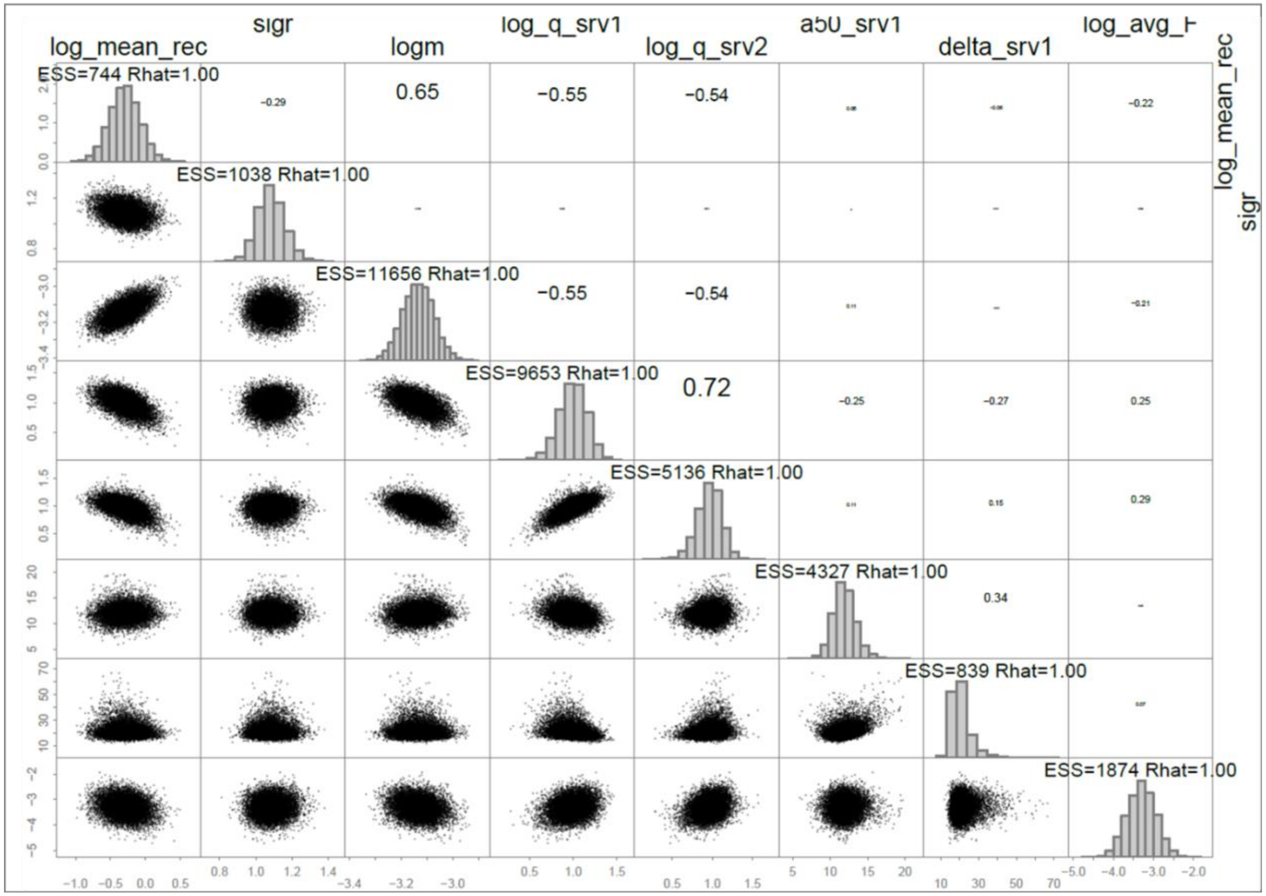

Figure 13-10 (continued)

(C) Model 23.1a

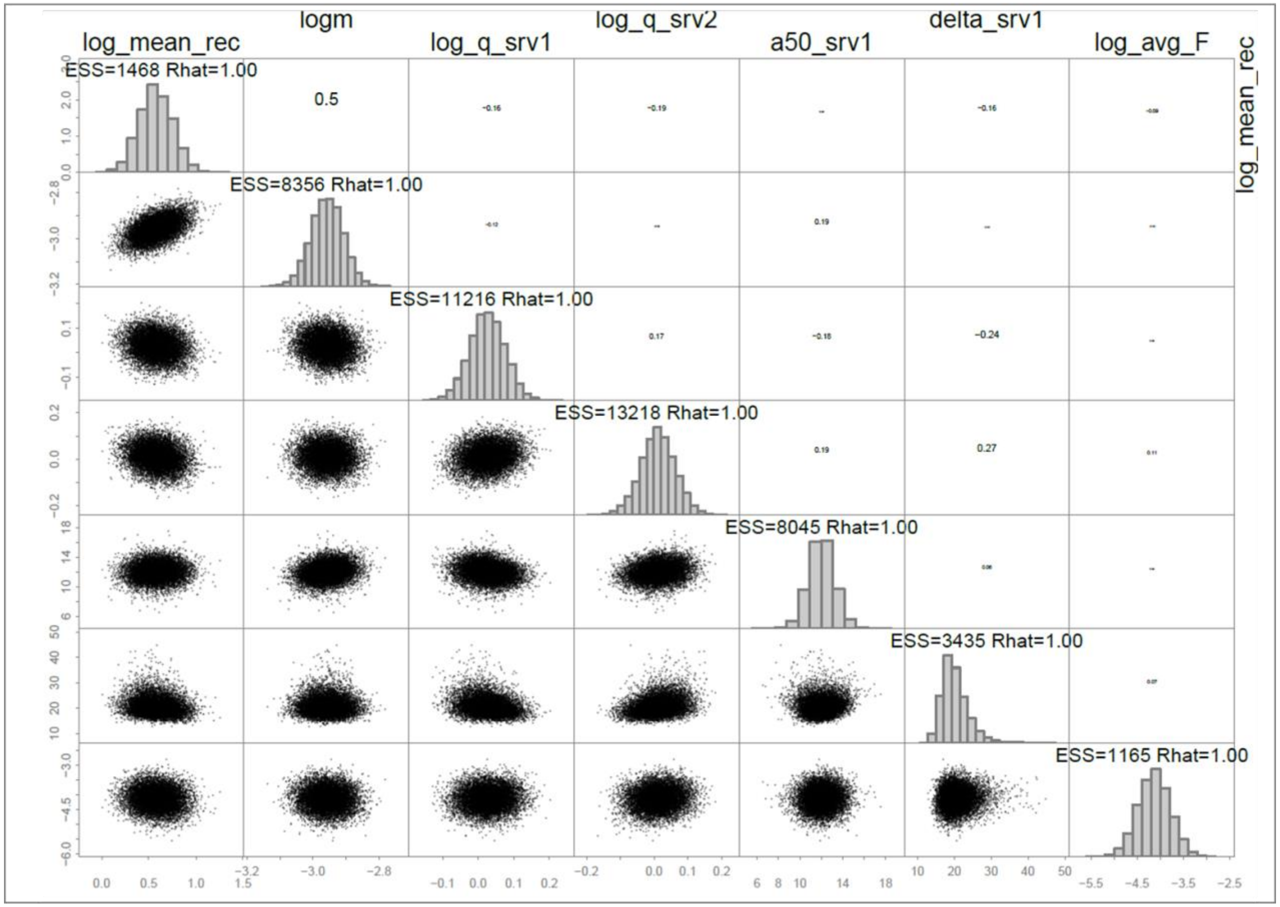

Figure 13-10 (continued)

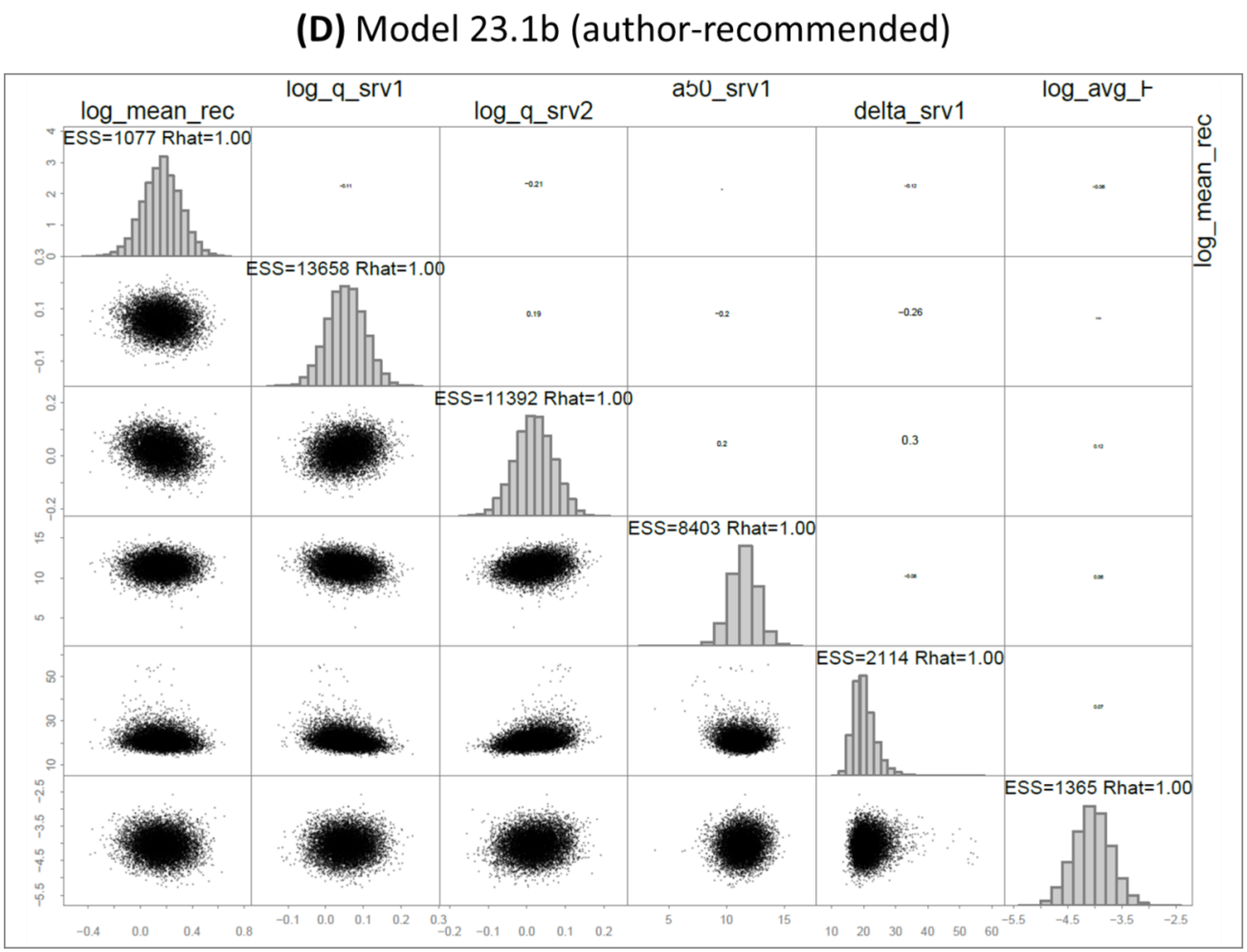

Figure 13-10 (continued)

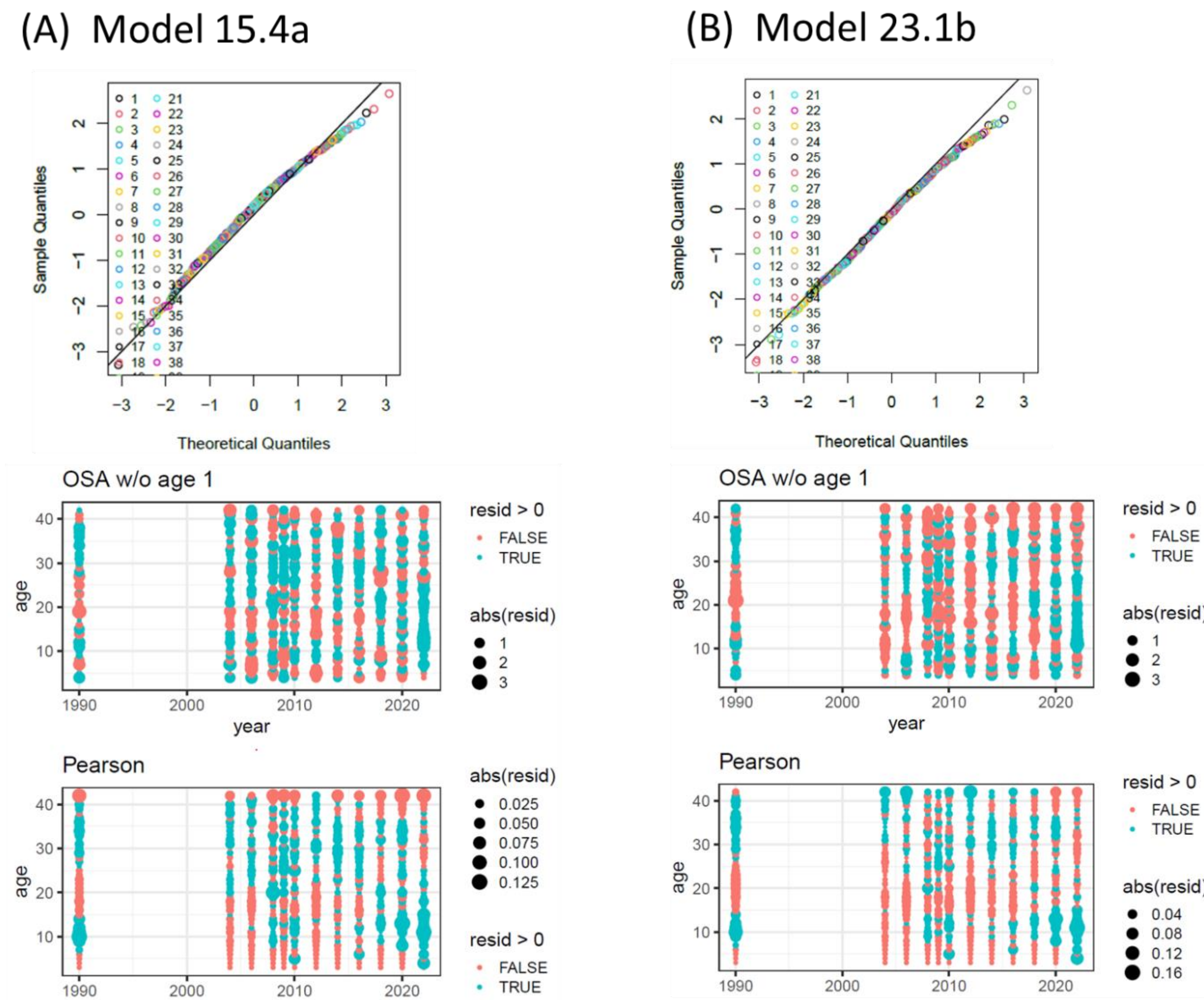

Figure 13-11. A comparison of one-step ahead (OSA) and Pearson residuals for fishery age composition data. The first age bin (age-3) was dropped for the OSA analysis. For brevity, only results for Model 15.4a and Model 23.1b are shown.

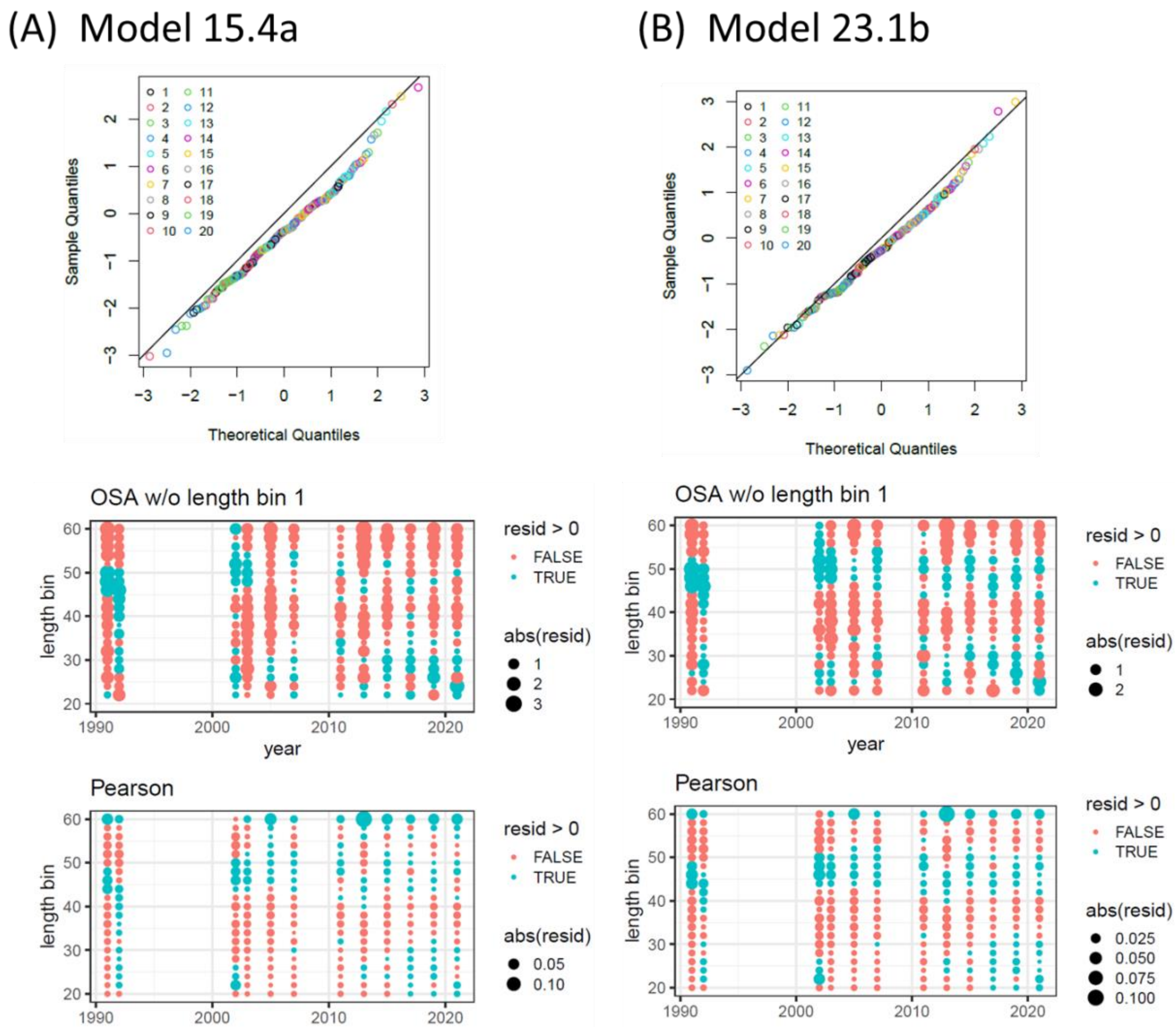

Figure 13-12. A comparison of one-step ahead (OSA) and Pearson residuals for fishery length composition data in Model 15.4a and Model 23.1b. The first length bin (20 cm) was dropped for the OSA analysis.

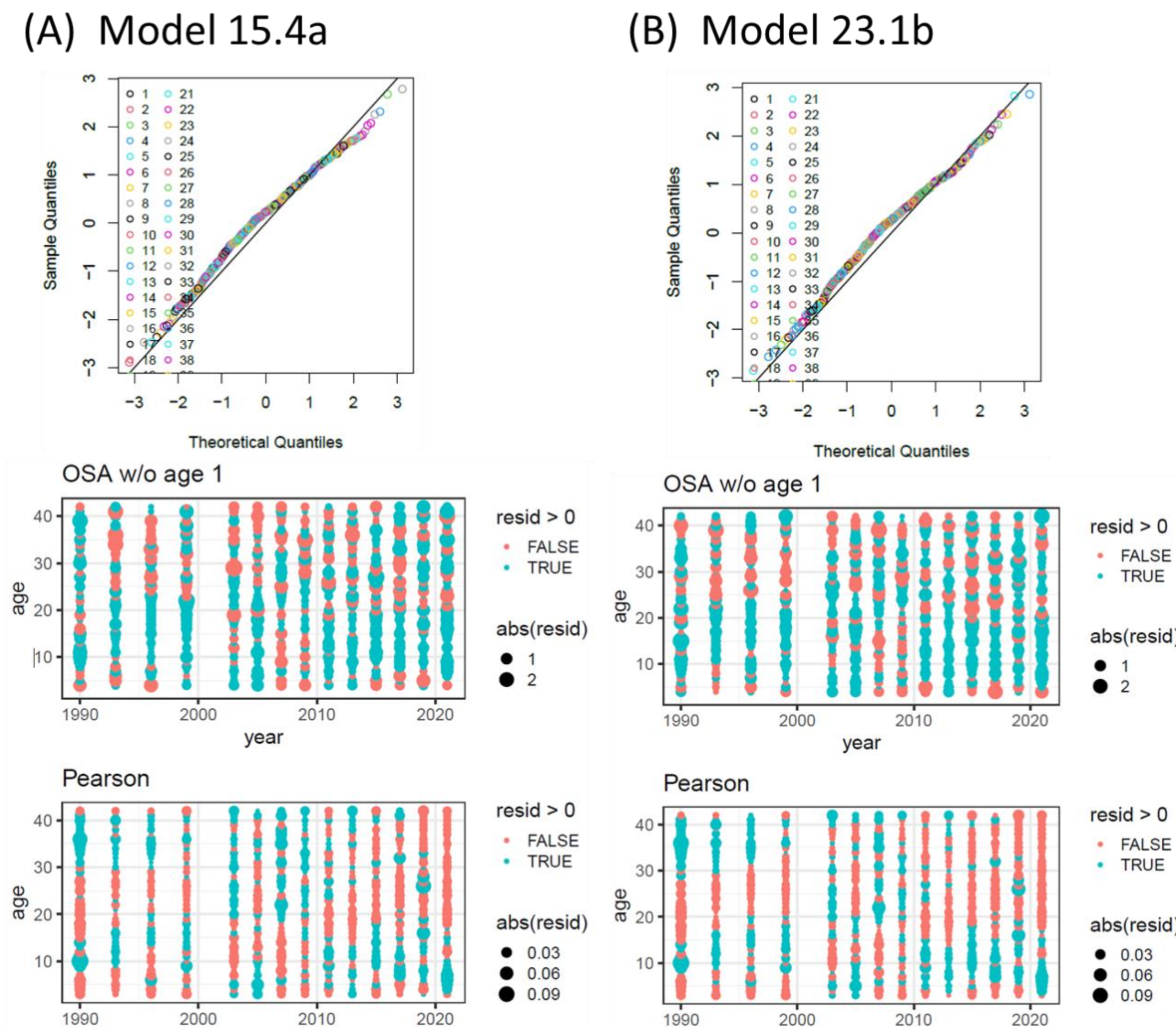

Figure 13-13. A comparison of one-step ahead (OSA) and Pearson residuals for bottom trawl survey age composition data in Model 15.4a and Model 23.1b. The first age bin (age-3) was dropped for the OSA analysis.

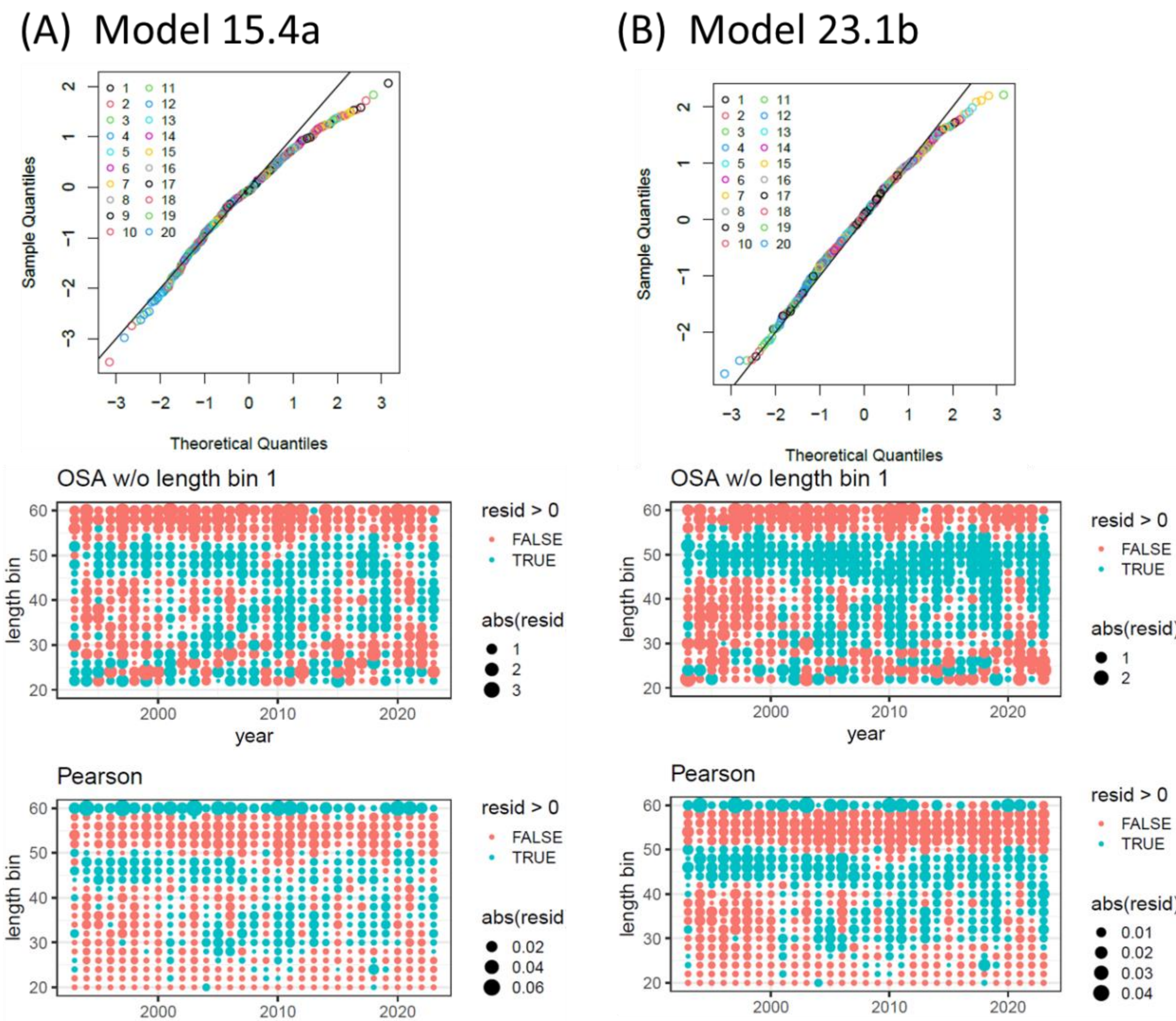

Figure 13-14. A comparison of one-step ahead (OSA) and Pearson residuals for longline survey length composition data in Model 15.4a and Model 23.1b. The first length bin (20 cm) was dropped for the OSA analysis.

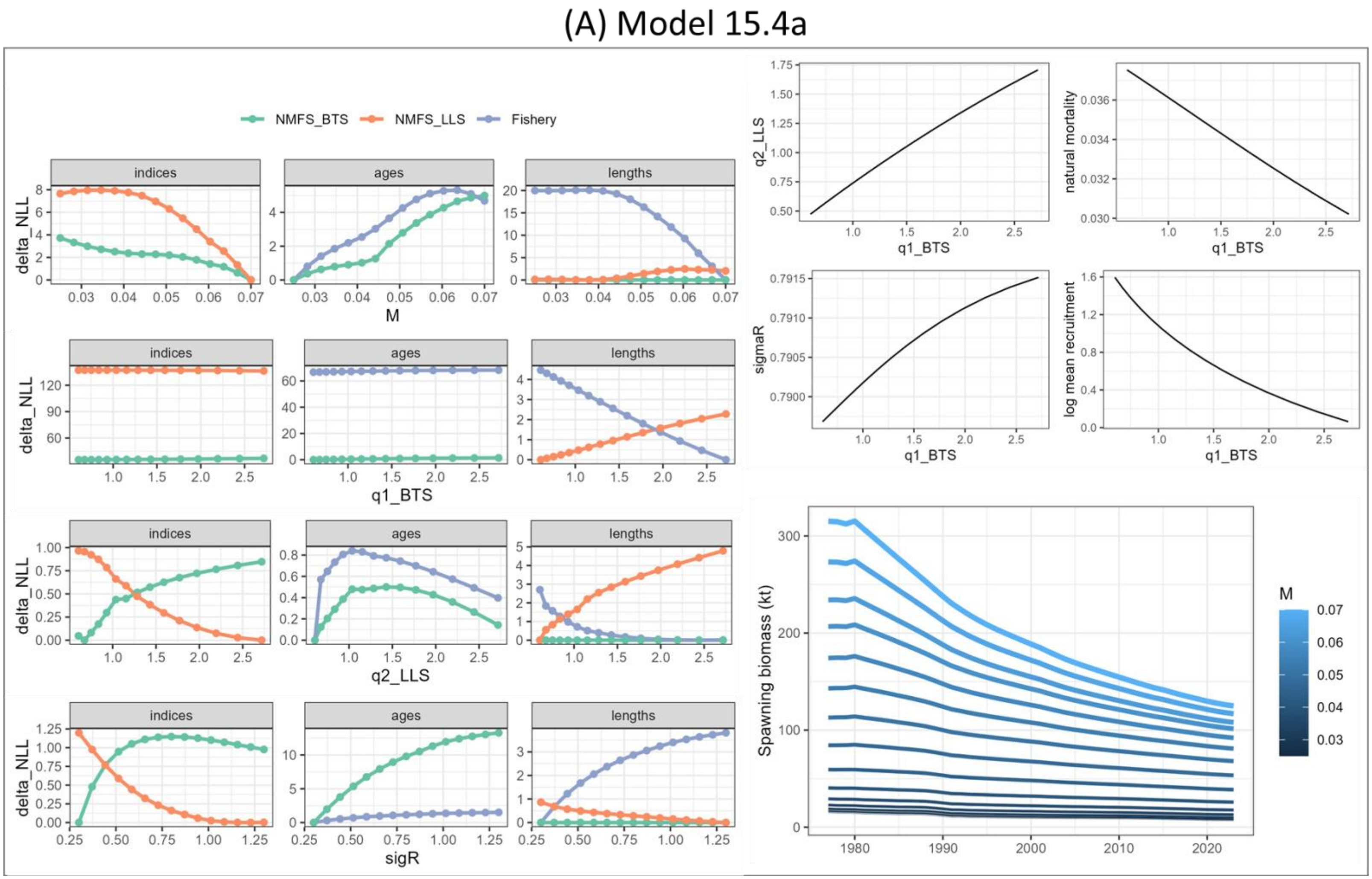

Figure 13-15. Left: Likelihood profiles over natural mortality (*M*), bottom trawl survey catchability (q1_BTS), longline survey catchability (q2_LLS), and recruitment variability (sigR), where the negative log likelihood is separated by data source (BTS=bottom trawl survey, LLS=longline survey, or fishery) and data type (indices, ages, and length). Top right: Parameter estimates of q2_LLS, natural mortality, sigmaR, and log mean recruitment when profiling over q1_BTS. Bottom right: Spawning biomass estimates for the scaling parameter that exhibited the strongest influence on biomass trajectory (*M* for Model 15.4a, q1_BTS for Model 23.1b).

(B) Model 23.1b

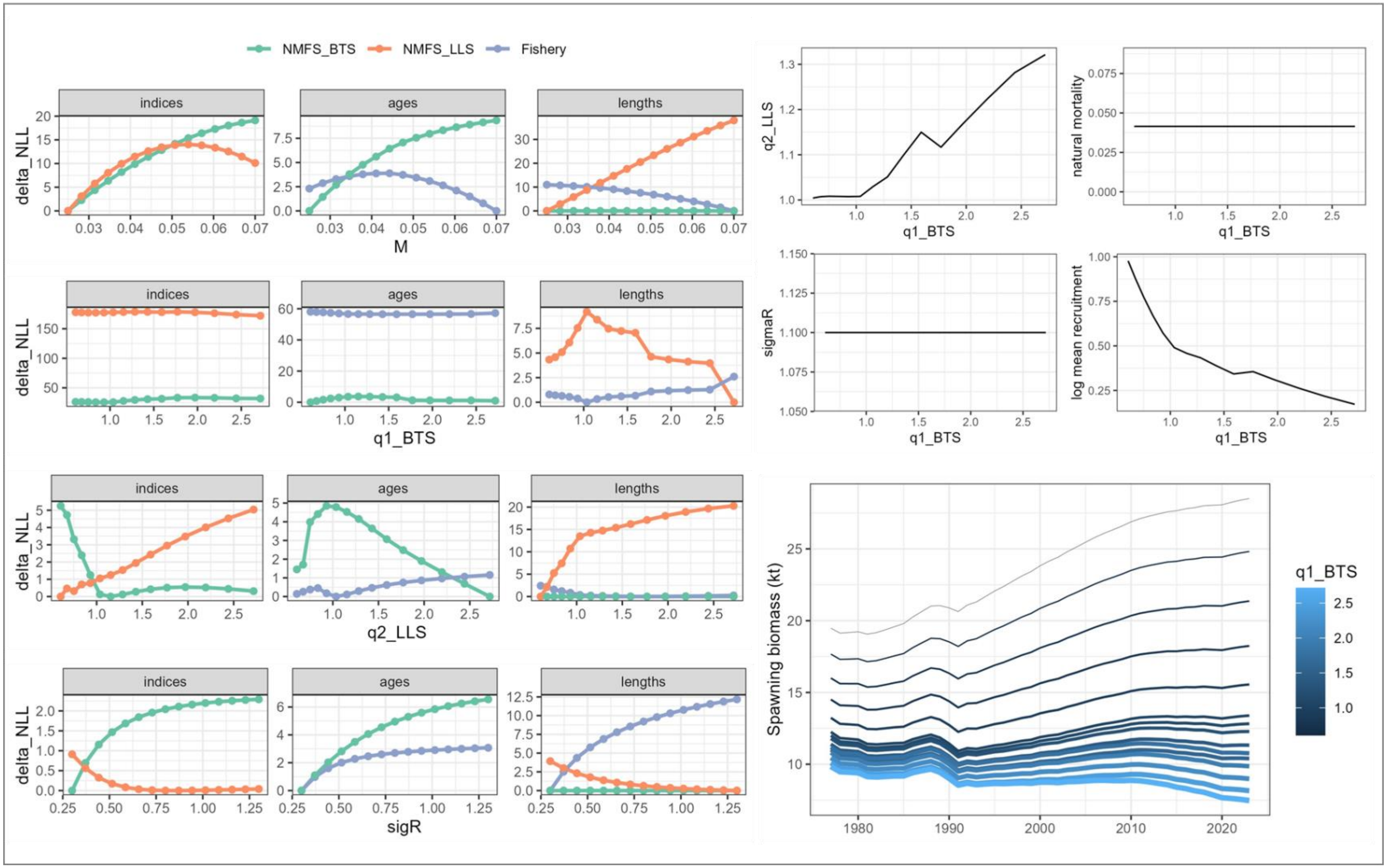

Figure 13-15 (continued)

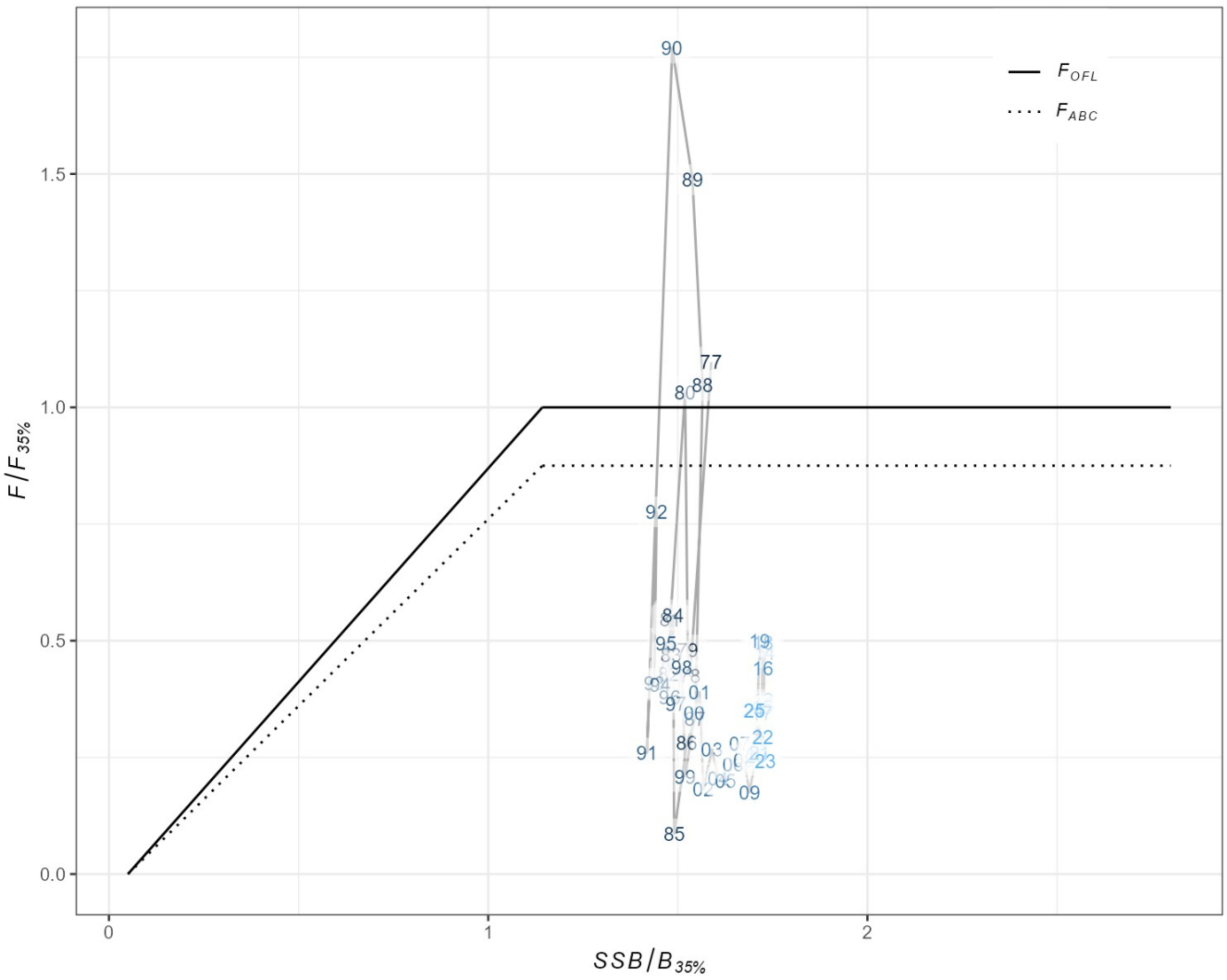

Figure 13-16. Time series of GOA RE/BS rockfish estimated spawning biomass relative to the target $B_{35\%}$ level and fishing mortality relative to F_{OFL} for author-recommended model.

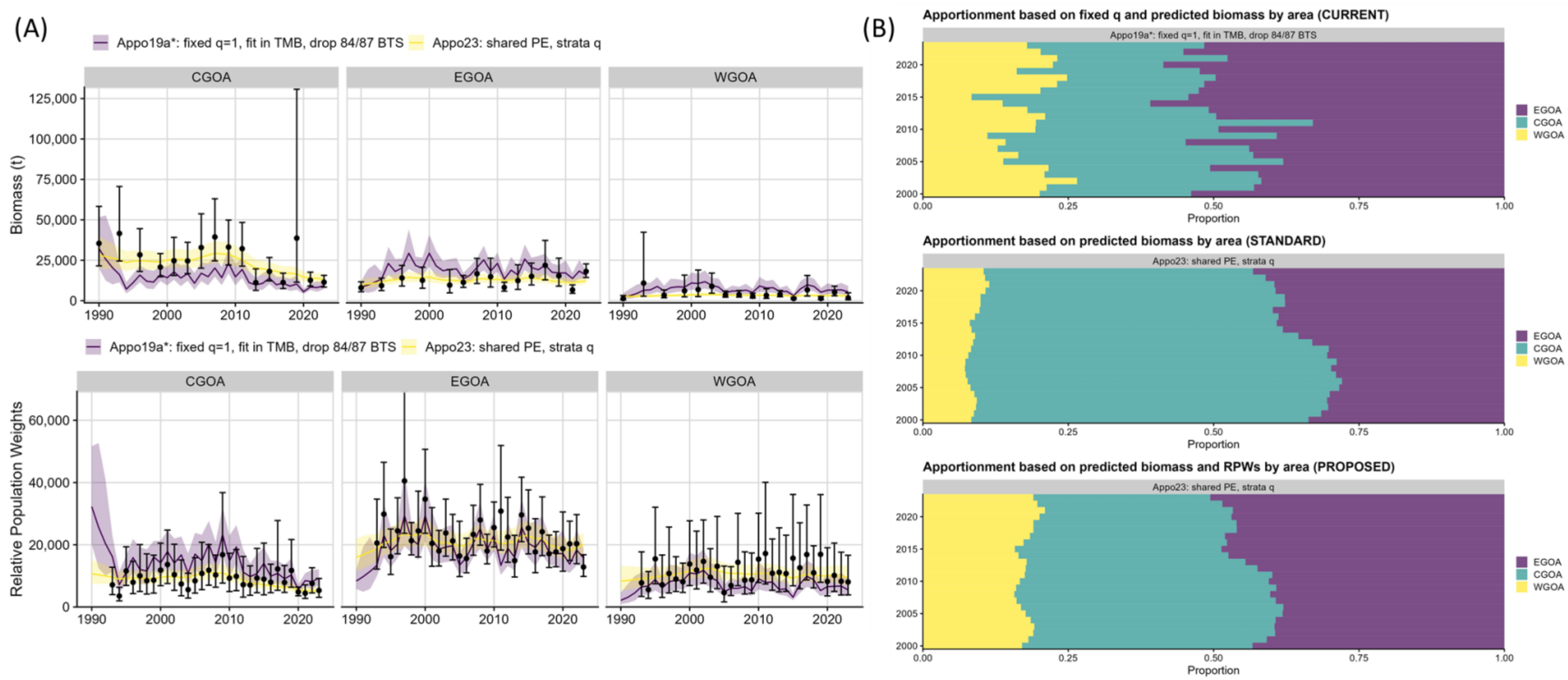

Figure 13-17. (A) Two-survey random effects (REMA) model fits to the GOA bottom trawl survey (BTS) biomass (top panels) and longline survey (LLS) relative population weights (RPWs; bottom panels) by central, eastern, and western Gulf of Alaska (CGOA, EGOA, WGOA) management area, where the points and error bars are the design-based survey estimates and the lines with shaded regions are the model predictions and 95% confidence intervals from the REMA model. (B) Apportionment results (i.e. the proportion of Acceptable Biological Catch that would be apportioned to each management area) for 2000-2023 based on the alternative method of apportionment using Apportionment 19* for the "current" and Apportionment 23 for the "standard" and "proposed" methods.

Appendix 13A. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals in the Gulf of Alaska (GOA) are presented. Non-commercial removals are catches that do not occur during directed groundfish fishing activities (Appendix Table 13A-1). 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. Although data are not available for a complete accounting of all research catches, the values in Appendix Table 13A-1 indicate that generally RE/BS stock research removals have been modest relative to the fishery catch and compared to the research removals for many other species. These catches represent <1% of the recommended ABC in these years and represents a low risk to the RE/BS stock.

Appendix Table 13A-1. Removals of Gulf of Alaska rougheye/blackspotted rockfish (t) from activities not related to directed fishing, since 2010.

Year	NMFS Longline Survey	NMFS GOA Bottom Trawl Survey	IPHC Longline Survey	ADF&G Large-mesh Trawl Survey	Sport Fishery	Other
2010	4.7	-	1.2	0.0	0.1	<0.05
2011	1.9	1.5	0.5	0.8	<0.05	0.0
2012	2.8	-	0.7	0.2	0.1	<0.05
2013	1.5	0.9	0.6	1.0	<0.05	<0.05
2014	4.6	-	0.7	0.5	<0.05	<0.05
2015	3.1	1.7	0.5	0.6	<0.05	<0.05
2016	2.7	-	1.2	-	<0.05	0.0
2017	3.6	1.6	0.4	-	0.4	0.6
2018	3.8	-	1.6	0.7	0.1	0.1
2019	4.2	0.9	1.8	0.6	0.1	<0.05
2020	2.0	-	1.4	0.4	<0.05	0.0
2021	0.8	0.8	1.1	0.3	<0.05	<0.05
2022	3.5	-	1.2	0.4	0.3	0.0