3. Assessment of the Sablefish Stock in Alaska

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November 2023

This report may be cited as:

Goethel, D.R., Cheng, M.L.H., Echave, K.B., Marsh, C., Rodgveller, C.J., Shotwell, K., and Siwicke, K. 2023. Assessment of the sablefish stock in Alaska. North Pacific Fishery Management Council, Anchorage, AK. Available here.

The last operational full assessment for sablefish was in 2021 and a full description of the final model *21.12* can be found in the 2021 SAFE document:
https://www.fisheries.noaa.gov/resource/data/2021-assessment-sablefish-stock-alaska

The following documents are associated with this report and can be found at the associated links:
Appendix 3C. Ecosystem and Socioeconomic Profile (ESP): Available here
Appendix 3D. Sablefish Bycatch in the Eastern Bering Sea: Available here
Appendix 3E. Catch Rates and Observations from the Fixed Gear Fleet: Available here
Appendix 3F. Observer Coverage and Sampling of the Sablefish Stock: Available here

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Executive Summary

Summary of Changes to the Assessment

Minor updates to data inputs and model structure were integrated into the sablefish (*Anoplopoma fimbria*) assessment for 2023 to align with AFSC assessment good practices, to address comments from the North Pacific Fisheries Management Council's (NPFMC) Science and Statistical Committee (SSC), and to optimize model performance. The final author recommended model for the 2023 SAFE is model *23.5*. A full description of model *21.12* can be found in the 2021 SAFE, and model *23.5* maintains the same primary structure.

Changes to the Input Data

New data included in the author recommended assessment model *23.5* were:

1. Relative abundance and length data from the 2023 NOAA domestic longline survey.
2. Relative biomass and length data from the 2023 NOAA Gulf of Alaska trawl survey, and removal of the 1984 and 1987 trawl survey index and length data (per AFSC best practice guidance).
3. Length data from the fixed gear fishery for 2022.
4. Length data from the trawl fisheries for 2022.
5. Age data from the longline survey and fixed gear fishery for 2022.
6. Updated catch for 2022.
7. Observed catch for 2023 and projected catch for the portion of the fishing year not yet completed.
8. Non-commercial catch of sablefish in federal waters was included (per SSC request) and added to the fixed gear fishery total catch for 1977 to 2023.
9. For 2023, estimates of killer and sperm whale depredation in the fishery were held constant at 2022 values.
10. Fixed gear fishery catch-per-unit effort (CPUE) data from logbooks and observers were updated through 2022 and a new CPUE standardization approach (Cheng et al., 2023) that combined data from both hook-and-line and pot gear was implemented, which replaced the previously used nominal CPUE index that included only hook-and-line gear.

Changes to the Assessment Methodology

A total of five new model runs were developed for the 2023 SAFE, which culminated in the final author recommended model *23.5* that incorporated all individual changes. The models explored for 2023 were:

- *Model 21.12*: the continuity model matching the 2022 SAFE model but with updated data for 2023.
- *Model 23.1*: removed the 1984 and 1987 trawl survey biomass index and length composition data.
- *Model 23.2*: incorporated all sources of non-commercial catch in federal waters in the total catch.
- *Model 23.3*: revised the stock-recruit bias correction, updated selectivity parameter sharing, and remove unnecessarily estimated fishing mortality parameters.
- *Model 23.4*: implemented a standardized CPUE index that combined data from both the hook-and-line and pot gear types (Cheng et al., 2023).
- *Model 23.5*: integrated all updates from models *23.1—23.4*; this is the final author recommended model for sablefish management advice in 2023.

Summary of Results

The longline survey abundance index (relative population numbers, RPNs) demonstrated no change from 2022, which followed a 17% increase in 2022 and a 9% increase in 2021 (Figure 3.4). The trawl survey biomass index decreased by 50% from 2021 to 2023, but had previously increased by nearly five-fold from 2013 through 2021 (Figure 3.4). The standardized fishery CPUE index increased by 37% from 2021 to 2022 (Figure 3.4). Model *23.5* demonstrated good fit to the primary abundance indices, although the extreme decline observed in the 2023 trawl survey could not be replicated by the model (Figure 3.12). Mean fits to the compositional data were adequate, but year and age- or length-specific residual patterns were present (Figures 3.13—3.33). For instance, recent year classes tend to be initially overestimated and subsequently underestimated in the longline survey and fixed gear fishery age compositions. Yet, no strong diagnostic or retrospective issues were noted (Figures 3.45—3.46), and the model demonstrated consistent estimation with the 2022 model *21.12* (Figure 3.47).

The model estimates that all year classes since 2014 have been at or well above the time series average (Figure 3.38). Age-2+ biomass has nearly tripled from a time series low of 233,000 t in 2015 to 695,000 t in 2023, which represents sablefish population levels on par with those at the time the fishery developed in the 1960s (Figure 3.34). Similarly, spawning stock biomass (SSB) has nearly doubled from the time series low of 82,000 t in 2017 to 157,000 t in 2023 (Figure 3.34). Thus, the SSB in 2023 is at 52% of the unfished SSB (i.e., $B_{100\%}$). However, the lack of sablefish greater than 10 years of age (i.e., the age when sablefish are more than 90% mature), especially compared to historic levels of older and larger fish, remains concerning for a long-lived species, and should continue to be monitored (Figures 3.35 – 3.36). Survival of recent cohorts to fully mature age classes will be essential to ensure the long-term productivity of the resource and fishery, given that the 2014 through 2020 cohorts currently comprise more than 75% of the SSB (Figure 3.52). However, catch has been well below acceptable biological catch (ABC) with the proportion of the quota utilized averaging ~70% over the last three years. The declining ABC utilization, corresponding reductions in market value, and recent rapid fishery changes (i.e., transition from predominantly hook-and-line gear to pot gear), represent the only source of elevated risk table concern. The 'fishery performance' category was rated 'level 2 – major concern', while all other risk table scores were 'level 1 – no concern'.

Sablefish are managed under Tier 3 of the NPFMC harvest control rule, which aims to maintain the population at $B_{40\%}$. Since projected female spawning biomass (combined areas) for 2024 is equivalent to $B_{62\%}$, sablefish is in sub-tier "a" of Tier 3. Spawning biomass is projected to increase rapidly in the near-term, and the maximum permissible value of F_{ABC} under Tier 3a is 0.086, which translates into **a Tier 3a maximum permissible 2024 ABC (combined areas) of 47,367 t**. **After adjusting for whale depredation, the final author recommended ABC is 47,146 t.** The OFL fishing mortality rate is 0.101, which translates into a 2024 OFL (combined areas) of 55,385 t. Thus, current model projections indicate that the Alaskan sablefish stock is not subject to overfishing, not overfished, and not approaching an overfished condition.

Summary Table

Quantity/Status	As estimated or specified *last* year for (model *21.12*): 2023*	2024*	As estimated or recommended *this* year for (model *23.5*): 2024**	2025**
M (natural mortality rate, estimated)	0.105	0.105	0.113	0.113
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	678,562	675,058	700,353	691,260
Projected female spawning biomass (t)	159,788	186,126	185,079	209,500
$B_{100\%}$	305,595	305,595	299,901	299,901
$B_{40\%}$	122,238	122,238	119,960	119,960
$B_{35\%}$	106,958	106,958	104,965	104,965
F_{OFL}	0.096	0.096	0.101	0.101
$maxF_{ABC}$	0.081	0.081	0.086	0.086
F_{ABC}	0.081	0.081	0.086	0.086
OFL (t)	47,857	49,040	55,385	55,620
OFL_w (t)^	**47,390**	**48,561**	**55,084**	**55,317**
max ABC (t)	40,861	41,876	47,367	47,572
ABC (t)	40,861	41,876	47,367	47,572
ABC_w (t)^*	**40,502**	**41,539**	**47,146**	**47,350**
Status	As determined *last* year for: 2021	2022	As determined *this* year for: 2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*2022 SAFE projections for biomass and SSB were based on specified catches of 33,600 t in 2023 and 34,000 t in 2024 (based on the ratio of estimated catch to max ABC in 2022, which was 0.82 based on a 2022 estimated catch of 28,6300 t and an ABC of 34,863 t) used in place of maximum permissible ABC for 2023 and 2024.
**The 2023 SAFE projections were based on specified catches of 31,500 t in 2024 and 30,800 t in 2025 (a yield ratio of 0.66 was assumed based on a 2023 specified catch of 27,200 t and an ABC of 40,500 t). Similarly, the 2025 ABC is based on removals equivalent to the 2024 specified catch. This was done in response to management requests for a more accurate two-year projection. SSB and biomass are slightly less than presented when the full ABC is removed.
^ABC_w and OFL_w are the final author recommended ABCs and OFLs after accounting for whale depredation.

Spatial Catch Apportionment

Based on biological rationale, the SSC adopted a five-year average survey apportionment method in 2020. A five-year moving average of the longline survey proportions of biomass in each region are used to apportion catch to management area. The apportionment values are updated yearly as new survey data is collected.

Accounting for Whale Depredation

For the final recommended ABC (ABC_w) or OFL (OFL_w), sperm and killer whale depredation in the fixed gear fishery is accounted for by reducing the maximum ABC by the last estimate of the three-year average of depredation estimates by area. By accounting for whale depredation in the assessment and associated catch projections, the approach does not create additional regulations or burden for in-season management.

Whale Depredation ABC Table with Final Author Recommended 2024 ABC.

Area	AI	BS	WG	CG	WY*	EY*	Total
2023 ABC	8,892	8,450	4,533	9,972	2,970	6,044	40,861
2024 ABC	13,108	11,474	4,718	9,670	2,683	5,714	47,367
2020 - 2022 Mean Depredation	5	18	19	20	40	121	222
Ratio 2024:2023 ABC	1.47	1.36	1.04	0.97	0.90	0.95	1.16
Deduct 3-Year Adjusted Mean	-7	-24	-20	-19	-36	-114	-221
****2024 ABC_w**	13,100	11,450	4,699	9,651	2,647	5,599	47,146

*Before 95:5 hook and line : trawl split between WY and EY/SE shown below.
**ABC_w is the author recommended ABC that accounts for whale depredation.

Whale Depredation ABC Table with Final Author Recommended 2025 ABC.

Area	AI	BS	WG	CG	WY*	EY*	Total
2023 ABC	8,892	8,450	4,533	9,972	2,970	6,044	40,861
2025 ABC	13,165	11,524	4,739	9,712	2,695	5,739	47,572
2020 - 2022 Mean Depredation	5	18	19	20	40	121	222
Ratio 2025:2023 ABC	1.5	1.4	1.0	1.0	0.9	0.9	1.2
Deduct 3-Year Adjusted Mean	-8	-24	-20	-19	-36	-115	-222
****2025 ABC_w**	13,156	11,499	4,719	9,693	2,659	5,624	47,350

*Before 95:5 hook and line : trawl split between WY and EY/SE shown below.
**ABC_w is the author recommended ABC that accounts for whale depredation.

West Yakutat and East Yakutat/Southeast ABC Gear Adjustment Table.

Year	West Yakutat	E. Yakutat/ Southeast
2024	2,926	5,320
2025	2,940	5,343

*ABCs represent total regional ABC_w across gears (after whale depredation adjustments), but with the 5% trawl allocation in EY/SE reallocated to WY.

Whale Depredation OFL Table with Final Author Recommended 2024 and 2025 OFLs.

Year	2024	2025
OFL	55,385	55,620
3-Year Mean Depredation	222	222
Inflation Factor (Projected % Increase)	1.36	1.36
Deduct 3-Year Mean	-302	-303
***OFL_w**	**55,084**	**55,317**

*OFL_w is the author recommended OFL that accounts for whale depredation.

Groundfish Plan Team Summary Table by Region

Area	Year	Biomass (4+)*	OFL**	ABC#	TAC	Catch^
GOA	2022	240,600	--	22,794	22,794	15,291
	2023	317,000	--	23,201	23,201	13,581
	2024	337,300	--	22,596	--	--
	2025	330,200		22,695	--	--
BS	2022	168,000	--	5,264	5,264	4,548
	2023	151,000	--	8,417	7,996	4,851
	2024	194,100	--	11,450	--	--
	2025	190,000	--	11,499	--	--
AI	2022	121,200	--	6,463	6,463	2,067
	2023	153,000	--	8,884	8,440	1,924
	2024	169,900	--	13,100	--	--
	2025	166,300	--	13,156	--	--

*Biomass represents the value projected by the model used to determine the ABC in that year, while regional biomass is based on the longline survey proportions by area in the terminal year of the associated model.
**The OFL is set for the entire Alaska management region, so no area specific OFLs are provided.
#The ABC is based on model *21.12* and a 50% then 75% stair step from fixed apportionment to the 5-year average survey apportionment for 2022 and 2023 ABCs. For 2024 and 2025, model *23.5* was used and no stair step was applied for ABCs. Also, these values are after the whale depredation adjustments described above.
^As of October 10, 2023 Alaska Fisheries Information Network, (www.akfin.org).

Whale Adjusted Catch Tables by Region

Year	**2023**				**2024**		**2025**	
Region	OFL_w	ABC_w	TAC	Catch*	OFL_w	ABC_w**	OFL_w	ABC_w**
BS	--	8,417	7,996	4,851	--	11,450	--	11,499
AI	--	8,884	8,440	1,924	--	13,100	--	13,156
GOA	--	23,201	23,201	13,581	--	22,596	--	22,695
WGOA	--	4,473	4,473	2,357	--	4,699	--	4,719
CGOA	--	9,921	9,921	5,547	--	9,651	--	9,693
***WYAK	--	3,205	3,205	2,068	--	2,926	--	2,940
***EY/SEO	--	5,602	5,602	3,610	--	5,320	--	5,343
Total	47,390	40,502	39,637	20,357	55,084	47,146	55,317	47,350

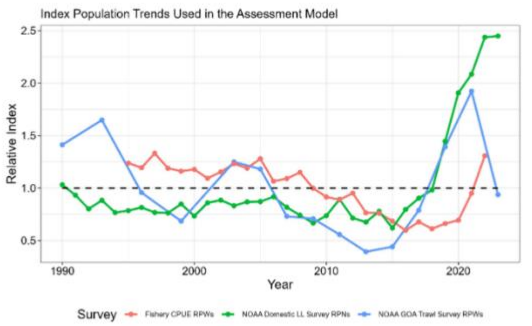
*As of October 10, 2023 Alaska Fisheries Information Network, (www.akfin.org).
**After 95:5 trawl split shown above and after whale depredation methods described above.

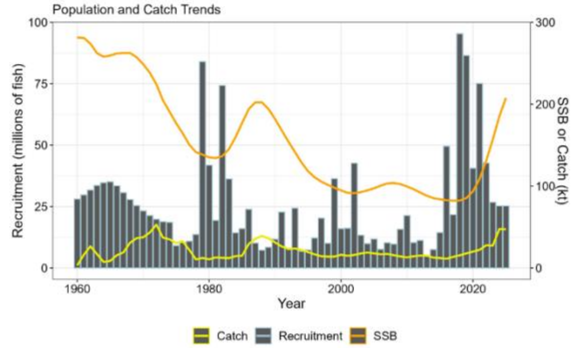
Graphical Summary

2023 Alaskan Sablefish SAFE (*Anoplopoma fimbria*)

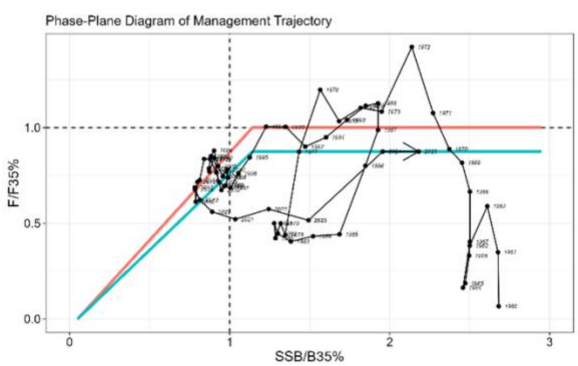
Data and Stock Assessment Model

- Following steady increases in abundance and biomass indices since 2015, the 2023 NOAA longline survey abundance was stable matching the 2022 value, the NOAA Gulf of Alaska trawl survey declined precipitously, and the fixed gear fishery CPUE continued to increase.
- The author proposed model (*23.5*) integrated minor data refinements and parametrization updates, but the main structure was consistent with the previously accepted model (*21.12*).
- The biomass and SSB continue to increase, while recruitment has been at or above the mean since 2014.





Stock Status and ABC Recommendations



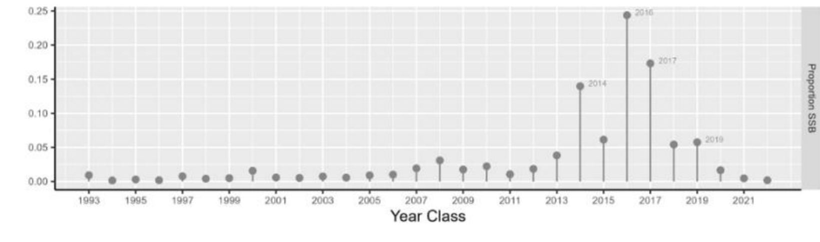
Quantity	2022 SAFE (Projections for 2023)	2023 SAFE (Projections for 2024)
$B_{100\%}$	305,595	299,901
$B_{40\%}$	122,238	119,960
$SSB_{(Terminal\_Yr+1)}$	159,788	185,079
$SSB_{(Terminal\_Yr+1)}/B_{100\%}$	52%	62%
$F_{ABC(Terminal\_Yr+1)}$	0.081	0.086
$ABC_{w(Terminal\_Yr+1)}$	40,502	47,146
$OFL_{w(Terminal\_Yr+1)}$	47,390	55,084

*SSB projections are based on specified catch for the terminal year. ABC_w and OFL_w are the recommended values after whale depredation has been taken into account.

- The resource is *not overfished* and *overfishing is not occurring.*
- Recent ABCs have not been fully utilized with catch averaging ~70% of the ABC over the last 3 years.
- The ABC increased by 16% due to continued maturation and growth (in weight) of the population.

Other Considerations

- The population age-structure remains contracted relative to historic levels.
- 2014 – 2020 year classes comprise > 75% of projected 2024 SSB.



Responses to SSC and Plan Team Comments

SSC Concerns on Assessments in General

This section lists new or outstanding SSC comments pertaining generally to AFSC assessments. SSC comments are provided in italics with responses to each comment directly following.

The SSC suggests a revision to the [risk table] category levels: from the existing four to three categories (normal, increased, extreme).

For 2023, category Level 2 (Substantially Increased Concern) is no longer being considered, with only Levels 1, 3, and 4 (Normal, Major Concern, and Extreme Concern) being used. Level 1 is revised from "Normal" to "No Concern" to align with the other categories. The current text for these categories are retained.

There was some SSC discussion with the presenter about Dr. Monnahan's recommendations regarding the use of one-step-ahead as opposed to Pearson residuals for evaluating compositional data fits within stock assessments. It was clarified that while this is an area of ongoing research, the JGPT did not have a formal recommendation for use or a process for updating SAFE guidelines at this time.

A comparison of Pearson and one-step-ahead residuals was undertaken for sablefish in 2023. Initial results are provided in the next section in response to a comment on residuals specific to the sablefish assessment.

SSC Concerns Specific to the Sablefish Assessment

This section lists new or outstanding SSC comments specific to the 2022 Alaskan sablefish assessment and 2023 model updates presented during the fall meetings. SSC comments are provided in italics with responses to each comment directly following.

Annual updates to the [whale depredation] model may be unnecessary due to the limited amount of mortality. However, if data were lacking to inform the model and pot gear catch continues to increase, it may be worthwhile to provide stability and simplicity in how the estimates were applied. Additionally, the ESP could be an appropriate place to document changes in depredation.

The SSC agrees that in the future, particularly if pot gear catch continues to increase, it may be worth exploring ways to provide stability and simplicity in how the depredation estimates are applied and possibly update these estimates less frequently.

Given the relatively small magnitude of estimated whale depredation, the SSC supports only periodic updates of this information, but continued inclusion of the mortality in the assessment and projected ABC calculations.

For 2023, the whale depredation estimates were maintained at the values estimated in 2022 (when the entire fishery whale depredation model was revised). The primary rationale for utilizing a static depredation estimate was that a primary data source for the whale depredation analysis (i.e., the catch-in-areas database) was not updated in time for the 2023 assessment. It is unclear if this database will be updated in future years. As such, given SSC and PT recommendations, it was determined that holding depredation estimates at a constant rate based on the 2022 value would be adequate for 2023. Moreover, given the increasing proportion of catch coming from the pot fishery (84% in 2023), which has no assumed depredation, it is believed that using 2022 values for the coming years will be adequate (if not a slight overestimate of depredation).

The Teams commended Matt for his work and look forward to reviewing a possible sablefish assessment configuration that includes this combined gear [standardized CPUE] index.

As proposed during the 2022 assessment cycle, the standardized CPUE index that combines hook-and-line and pot gear types replaced the nominal hook-and-line CPUE index for the 2023 model (i.e., the impact of switching just the CPUE index is demonstrated with model *23.4* and integrated in the final author proposed model *23.5*). The impact of switching the CPUE indices on assessment time series trends and parameter estimates was minimal (Figure 3.9).

The SSC recommends including other sources of mortality (e.g., recreational and research catches) noting that they are of a comparable magnitude to whale depredation. Further, the SSC recommends consideration of whether there is biological justification for continuing to assess sablefish in federal waters and some State waters separately.

The SSC also reiterates its recommendation from December 2022 to incorporate additional sources of mortality within the assessment (e.g., recreational and survey/ research removals).

As requested, all major sources of sablefish removals in federal waters are now accounted for in the assessment model by adding all non-commercial catch into the fixed gear fishery total catch. Non-commercial catch included the NOAA longline survey (the predominant source of non-commercial catch), the IPHC longline survey, the NOAA bottom trawl surveys, and the state of Alaska sport fishery catch not associated with ADFG managed and assessed sablefish stocks (i.e., occurring in areas not associated with the Northern Southeast Inside, NSEI, or Southern Southeast Inside, SSEI, fisheries). Because the magnitude of non-commercial catch was low in comparison to commercial catch (i.e., on the order of 1 - 3%), the impact of including this catch data in the assessment was negligible (Figure 3.9). Also, former appendix 3B, which detailed sources of non-commercial catch, is no longer being provided, because all of this data is now explicitly integrated into the assessment and the non-commercial catch is provided in Table 3.1.

The SSC appreciates the analyses to date investigating the rapid transition from longline to pot gear in the sablefish fishery and the possible ways in which this shift can be best modeled in the stock assessment. There was considerable discussion on the relative merits of including a calibrated fishery CPUE series, separating the two gears into different fleets, allowing for changes in selectivity to reflect the change in gear types, or some combination of these approaches. The SSC recommends side-by-side comparisons of size and age distributions from the two gear types to better understand potential differences in selectivity. As recommended last year, the SSC would also like to see a model that allows for separate fleets, even if compositional data are sparse, to evaluate how important differences in selectivity might be to assessment results. The SSC recommends that this investigation be a high priority for the next assessment.

Analysis of recent trends in the fixed gear fishery is provided in Appendix 3E. Age and length compositions differed between gear types in earlier in the time series (Figure A), likely due to sample size limitations for pot gear and pot gear data only coming from the Bering Sea and Aleutian Islands (i.e., using conical pots). For recent years (i.e., post-2017, corresponding to when slinky pots were legalized in the GOA) when adequate sample sizes exist for both gear types, distributions demonstrate stronger overlap. In general, pot gear appears to select for slightly younger, smaller individuals (Figure A). However, understanding the selectivity of pot gear is complicated by its increasing use occurring concomitantly with rapid changes in the population (i.e., skewed towards smaller and younger fish due to the large recent recruitment events). Data collected as the population age structure expands may help to elucidate whether pot gear is less selective of larger, older fish or if this apparent trend is due to current population demographics.

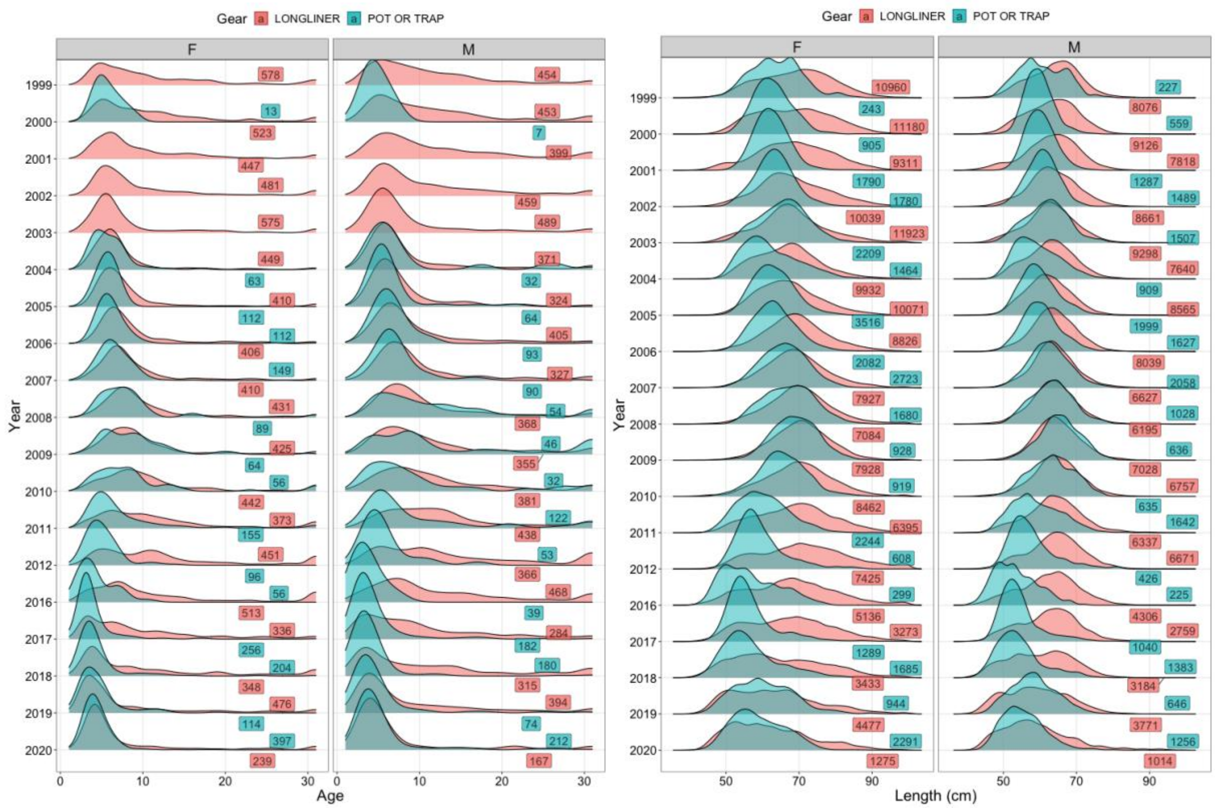


Figure A. Comparison of age (left panel) and length (right panel) compositions across years (y-axis), gears (colors), and sexes (panels). Numbers on the panels denote sample sizes for respective gear types.

Size distributions from hook-and-line gear and slinky pot gear from AFSC longline survey experimental legs are also available for the past three years (Figure B; Sullivan et al., 2022). In general, size distributions between hook-and-line and slinky pot gear were comparable, suggesting that contact selectivity between the two gears may be similar.

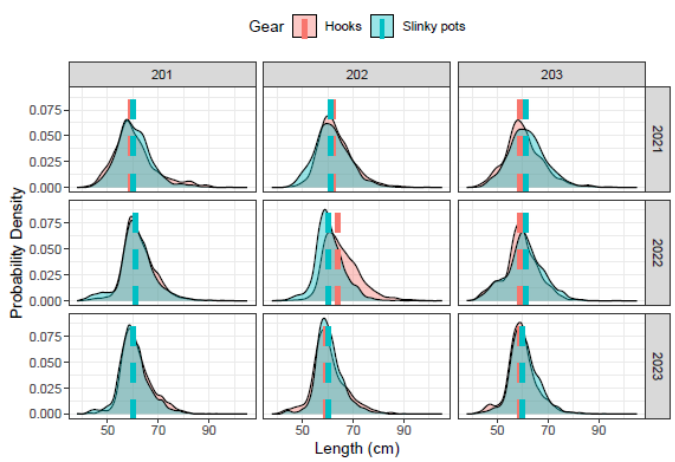


Figure B. Comparison of size distributions between hook-and-line gear and slinky pots from experiments conducted on the AFSC longline survey. Dotted lines represent the median size of individuals, column panels denote the stations where experiments took place, and row panels are the different years the experiments were conducted.

A model that reparametrizes the sablefish assessment to explicitly include a pot gear fleet was developed by M. Cheng (University of Alaska-Fairbanks) and is currently in review with *Fisheries Research* (a draft of the manuscript can be obtained from the authors upon request). Using the 2022 SAFE model (*21.12*), the fixed gear fleet was disaggregated with selectivity parameters and fishing mortality estimated for each gear. As expected, a combination of sparse compositional data across the model time series along with the extreme demographic state of the population (i.e., high abundance of small, young fish) when pot gear became a major source of removals impeded the ability to adequately estimate selectivity for the pot fleet. Thus, the reparametrized pot fleet model was only able to achieve adequate model performance for logistic selectivity when the selectivity slope parameters were shared with the hook-and-line fleet or when a highly constrained domed-shape gamma selectivity function was assumed (see Figure C). Although biomass estimates and trends were consistent between model *21.12* and pot fleet parametrizations, recommended harvest levels (i.e., ABCs) were much higher for the pot fleet model assuming gamma selectivity (Figure C). Increased ABCs for the model assuming domed-shape selectivity for the pot fleet is likely attributable to the reduction of mortality on large, old, and mature individuals, which are no longer vulnerable to fishing.

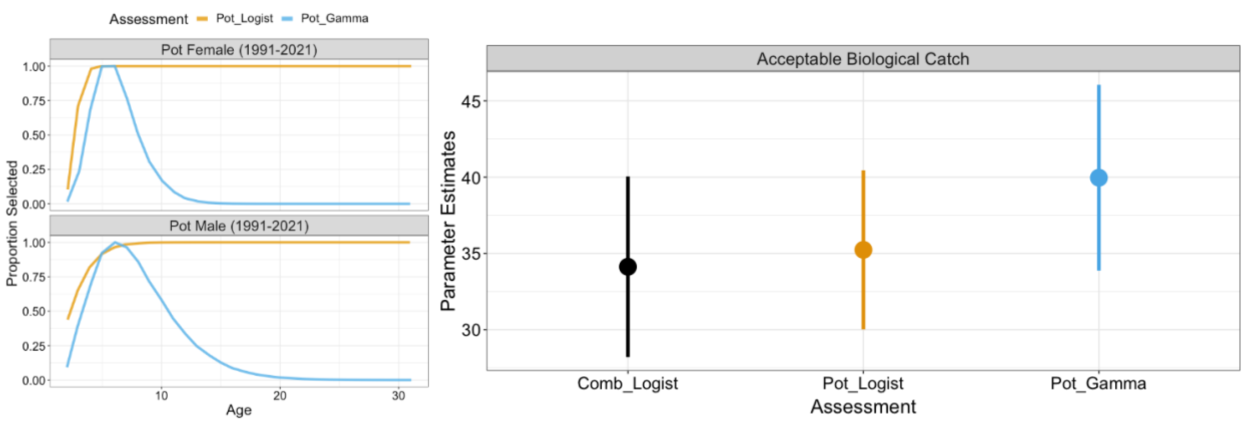


Figure C. Results from the Cheng et al. (In Review) pot gear fleet model explorations. Estimated selectivity (left panel) for the pot fleet model assuming logistic selectivity (orange line: Pot_Logist) and the pot fleet model assuming gamma selectivity (blue line: Pot_Gamma). Comparison of Acceptable Biological Catch (right panel) for model *21.12* (black: Comb_Logist), the pot fleet model assuming logistic selectivity (orange: Pot_Logist), and the pot fleet model assuming gamma selectivity (blue: Pot_Gamma).

Further work using simulation modeling (M. Cheng, UAF) is underway to identify optimal methods for addressing rapid changes in fishery fleet structure. Model evaluations will explore the impact of 1) disaggregating fleet structure, 2) using time-blocked selectivity, and 3) implementing continuous time-varying selectivity to account for transitions in fleet structure. Results will be presented during the 2024 assessment cycle. Based on the limited time series and associated sample sizes of data from pot gear along with unstable performance of the disaggregated pot gear model, it is not recommended that the sablefish assessment integrate a pot fleet at this time. As always, the structure of the sablefish model will be reevaluated in the future pending results from ongoing research, availability of new data, and observed changes in the biological resource, fishery dynamics, or assessment performance.

Provide bubble plots of Pearson residuals for all age and length data including the sign and scale of residuals; this is standard practice to effectively evaluate tuning and lack of fit.

Evaluating compositional model fits using Pearson residuals has the potential to result in spurious conclusions regarding lack of fit and/or independence, because correlated observations are retained. One-step-ahead (OSA) residuals, which decorrelate observations arising from multinomial distributions, are increasingly being recommended as best practice for interpreting stock assessment model fits (Trijoulet et al., 2023). The overall interpretation of OSA and Pearson residuals is similar: large magnitude (e.g., greater than three) or systematic trends in residuals could indicate model misspecification. Bubble plots of residuals were developed by M. Cheng (UAF) for both Pearson and OSA residuals, which are presented for the two primary compositional data sources (i.e., the longline survey and fixed gear fishery).

For fits to the age compositions from the NOAA longline survey, both OSA and Pearson residuals (Figure E) indicate a lack of fit (i.e., underestimating for OSA) to the recent large cohorts entering the population (e.g., since 2016). However, Pearson residuals incorrectly indicate a systematic pattern of negative residuals for intermediate to older age-classes. Comparing residual patterns of NOAA longline survey length compositions (females and males), Pearson residuals indicate systematic patterns in residuals throughout time, revealing runs of positive and negative residuals across a wide range of sizes. Although some systematic patterns are also detected in OSA residuals, which manifest as runs of positive residuals at intermediate sizes, the lack of fit is less severe than suggested by Pearson residuals.

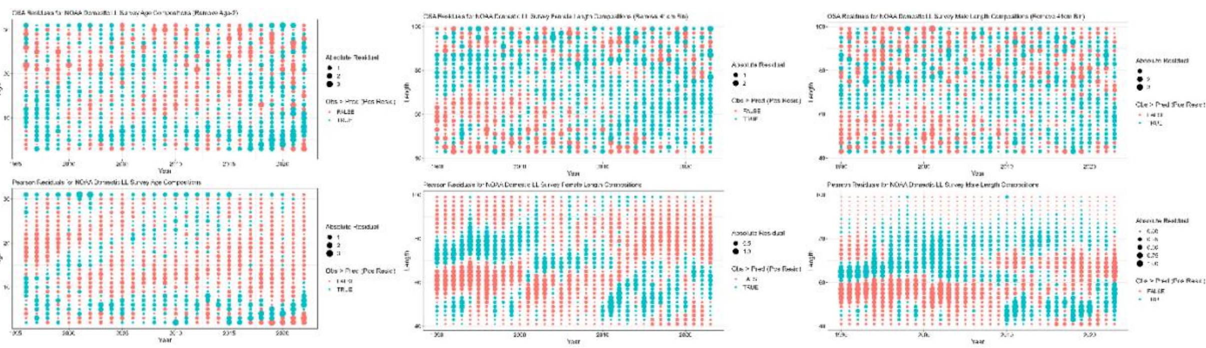


Figure E. One step ahead (OSA) residuals (top row) and Pearson residuals (bottom row) for compositional data (age in the first column, female lengths in the middle column, and male lengths in the last column) from the NOAA domestic longline survey. Color denotes negative (red) or positive (blue) residuals.

For the fixed gear fishery age compositions (Figure F), similar lack of fit to recent year classes is present, particularly in the OSA residuals. Furthermore, Pearson residuals indicate large patterns of negative residuals for a wide range of age classes. For OSA, positive runs of residuals are detected for younger age classes throughout time. For length compositions from the fixed gear fishery, Pearson residuals indicate systematic patterns through time, manifesting as multiple runs of positive and negative residuals for various size classes. Again, similar to fits to the NOAA longline survey length composition data, these patterns are largely absent from OSA residuals. However, a run of negative residuals for intermediate size classes of females is present.

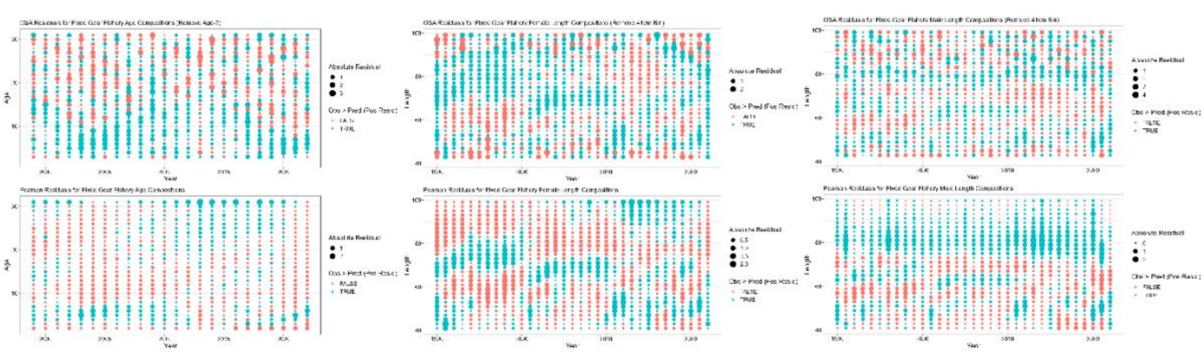


Figure F. One step ahead (OSA) residuals (top row) and Pearson residuals (bottom row) for compositional data (age in the first column, female lengths in the middle column, and male lengths in the last column) from the NOAA domestic longline survey. Color denotes negative (red) or positive (blue) residuals.

Although the observed residual patterns are not ideal, the bubble plots may tend to exaggerate lack of model fit to compositional data, given that the aggregate fit to these data appear adequate (Figures 3.15, 3.17, 3.22, and 3.28). The underestimation of recent year classes at peak abundance in the compositional data (e.g., ages three through six) has been documented in recent SAFEs. However, the lack of fit has not been a major source of retrospective patterns or resulted in other concerning model diagnostics. Moreover, there are a number of model assumptions and parametrizations that may be causing poor fit to the data, which will be explored in the coming years. In particular, fitting length composition data when age composition data is available can lead to tension in the model, given that measurement error can lead to disparate signals. Because age composition data provides a more direct measurement of cohort magnitude (and since the sablefish assessment is age structured), it is likely more appropriate to fit only the age data for fleets and years for which it is available. Moreover, the model currently fits sex-aggregated age data, which may limit information on sex-specific selectivity. Future assessment models will explore disaggregation of the age composition data.

Plan Team Concerns Specific to the Sablefish Assessment

This section lists new or outstanding PT comments specific to the 2022 Alaskan sablefish assessment and 2023 model updates presented during the fall meetings. PT comments are provided in italics with responses to each comment directly following.

The Teams recommended an evaluation of trends in abundance of the plus age group from the longline survey and fixed gear fishery along with a figure showing the plus group absolute abundance (as opposed to the proportions) in the future.

A new figure showing the abundance by age across years has been added to the SAFE for both females and males (Figures 3.35 and 3.36).

As is done in many tuna assessments, it may be more appropriate to implement an 'index' fishery that utilizes a time-invariant selectivity and density-weighted compositions (i.e., where the composition data by region is weighted by the CPUE and not the catch) along with the associated CPUE index.

The Teams supported all proposed modeling changes for the 2023 operational update assessment, including replacing the nominal CPUE index with a standardized index, and using the last assessments whale depredation values.

The final author recommended model (*23.5*) utilizes the standardized CPUE index and whale depredation is fixed at the 2022 value. The alternate approach suggested for fitting the CPUE index (i.e., using an 'index' fishery with time-invariant selectivity) was not explored in 2023. Given uncertainty in the availability of the data used for the CPUE index in coming years, it may be necessary to remove the index from future assessments. Moreover, the limited impact of the CPUE index on assessment estimates make detailed analysis of how CPUE is fit in the model a relatively low priority.

Introduction

For a full description of the sablefish resource and fishery dynamics, see Goethel et al. (2021; available at https://www.fisheries.noaa.gov/resource/data/2021-assessment-sablefish-stock-alaska).

Sablefish are found from northern Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), northward in the Bering Sea (BS), and into the northwestern Pacific Ocean off the Siberian coast of Russia and the Kuril Islands in Japan (Wolotira et al. 1993). Genetic work by Jasonowicz et al. (2017) found no population sub-structure throughout their range along the US West Coast to Alaska, and suggested that observed differences in growth and maturation rates may be due to phenotypic plasticity or are environmentally driven. Sablefish are assessed as a single, homogeneous population in Federal waters off Alaska, because of their high movement rates and panmictic stock structure. However, management is by discrete regions to distribute exploitation throughout their wide geographical range, including the Bering Sea, Aleutian Islands, Western Gulf of Alaska (GOA), Central GOA, West Yakutat, and East Yakutat/Southeast Outside.

Adult sablefish live at depths greater than 200 m and are highly mobile, though, exact movement patterns and drivers are not well understood. Spawning occurs in winter at depths of 300 - 500 m near the edges of the continental slope (Mason et al. 1983). Juvenile sablefish spend their first two to three years on the continental shelf of the GOA and the southeast BS. After their second summer, they begin moving offshore to deeper water, typically reaching their adult habitat, the upper continental slope, at 4 to 5 years of age. This corresponds to the age range when sablefish start becoming reproductively viable (Mason et al. 1983, Rodgveller et al. 2016).

Population Trends in Nearby Regions Not Incorporated in the Assessment Model

Alaska Northern Southeast and Southern Southeast Inside Waters

Sablefish in the Northern Southeast Inside (NSEI) Subdistrict waters and Southern Southeast Inside (SSEI) Subdistrict waters of Alaska are treated as separate stocks from the federal population, but some migration into and out of Alaska federal and state waters has been confirmed with tagging studies (Hanselman et al. 2015). NSEI sablefish continue to demonstrate similar population trends as the federal stock with strong recent recruitment observed, particularly the 2016-year class (Figure 3.1a). Although the biomass is increasing, CPUE and abundance remain well below levels seen in the 1980s and 1990s. In SSEI waters, the longline survey CPUE showed a 19% decline in 2022 after an overall upward trajectory between 2015 and 2021 (Figure 3.1a). Alaska state fisheries are seeing a similar rapid transition from hook-and-line gear to pot gear as the federal fishery, with a complete transition between the two gear types from 2019 to 2022.

Canada

The estimated biomass trend for the British Columbia stock of sablefish is similar to that in Alaska federal waters, with strong increases in the mid-2010s due to above average recruitment in 2016 – 2017. Spawning stock biomass has shown consistent increases in recent years (Figure 3.1b). The survey index value in 2022 was 10% greater than the 2021 value, representing the second highest in the time series since it was initiated in 2003. Annual TACs for the BC Sablefish stock are set using a surplus production model implemented as part of a management procedure approach chosen through management strategy evaluation (Kendra Holt, pers. comm.).

United States West Coast (Washington, Oregon, and California)

For the United States west coast stock of sablefish (assessed by NOAA’s Northwest Fisheries Science

Center), the estimated trajectory of relative spawning biomass across the times series is highly variable. The population increased rapidly in the 1970s to near unfished levels, declined for the next two decades to near $B_{40\%}$ target biomass levels around 2000, and has increased again in recent years (Figure 3.1c). The above-average cohorts from 2008, 2013, 2015, 2016, 2020, and 2021 are driving the recent increase in spawning biomass. In particular, the recruitment events from 2020 and 2021 are two of the three largest in the time series.

Pacific Sablefish Transboundary Assessment Team (PSTAT)

Concurrent sablefish trends seen in Alaska, Canada, and the West Coast highlights the need to better understand the contribution to Alaska sablefish productivity from other areas. A Pacific Sablefish Transboundary Assessment Team (PSTAT) consisting of scientists from the U.S. (west coast and Alaska regions, including both federal and state scientists) and Canada has been working to better understand the dynamics, population trends, and biology of sablefish across the eastern Pacific Ocean (Fenske et al. 2019; https://www.pacificsablefishscience.org/). In 2023, the group completed the first phase of a stakeholder-informed management strategy evaluation (MSE) research project. Results indicated that the US West Coast appeared the most vulnerable to localized depletion, given differences in recruitment between the northern and southern regions. The group is also developing spatially explicit tagging analyses and operating models to explore the impacts of regional management measures on the coast wide population through MSE. Additionally, age reading groups across agencies have addressed sablefish ageing discrepancies by developing standardized ageing criteria through the Committee of Age Reading Experts (CARE) group.

Fishery

Sablefish have been exploited since the end of the 19th century with rapid fishery expansion in the 1960s when Japanese longliners began operations in the eastern BS (Table 3.1, Figures 3.2 and 3.3). Heavy fishing by foreign vessels expanded into the GOA during the 1970s and total catch peaked at 53,000 t in 1972, which led to a substantial population decline and implementation of fishery regulations in Alaska. By 1988 the U.S. harvested all sablefish taken in Alaska, primarily by hook-and-line gear in the eastern and central GOA. In 1995, individual fishery quotas (IFQs) were implemented for hook-and-line vessels. Since 2021, the majority of removals by the fixed gear fleet was taken by pot gear (Table 3.1, Figure 3.2), primarily driven by the increasing popularity of collapsible ‘slinky’ pots. Further details on the Alaskan sablefish fisheries can be found in Appendices 3D – 3F (links provided on title page). Appendix 3D describes the catch of small sablefish in eastern Bering Sea in the various trawl fisheries. Appendix 3E provides a detailed analysis of the fixed gear fishery catch rates as well as comparisons of age- and length-based removals among gear types within the fixed gear sector. Appendix 3F summarizes sampling and observer coverage rates in fisheries landing sablefish, including analysis of coverage rates by electronic monitoring (EM).

Management Measures and Bycatch

A summary of historical catch and management measures pertinent to sablefish in Alaska are provided in Table 3.2. Under current regulations, release of any sablefish by the sablefish IFQ fishery is prohibited, as long as there is remaining IFQ for persons onboard the fishing vessel. Sablefish discards in groundfish target fisheries are dominated by trawl fisheries in recent years, primarily in the BSAI due to an influx of recent large year classes in the BS, but discards declined substantially in 2023 (Table 3B.1; Appendix 3B). Bycatch of federally managed groundfish species in the sablefish target fishery has primarily been composed of shortspine thornyhead, arrowtooth flounder, halibut, skates, and shortraker and rougheye rockfish (Table 3B.2; Appendix 3B). In terms of non-target bycatch, grenadiers are consistently the primary species encountered in the target sablefish fishery (Table 3B.3; Appendix 3B). The predominant prohibited species catch (PSC) in both the BSAI and GOA sablefish target fisheries is golden king crab and tanner crab (Table 3B.4; Appendix 3B).

Data

A variety of data sources are included in the assessment and were updated for 2023 (Table 3.3), including fishery catch (Table 3.1), fishery and survey compositional data (Table 3.4), and various indices of abundance and biomass (Figure 3.4; Table 3.5). Japan and the U.S. conducted a cooperative longline survey for sablefish in the GOA annually from 1978 to 1994, adding the AI region in 1980 and the eastern BS in 1982 (Sasaki 1985). Since 1987, the NOAA domestic longline for sablefish has been conducted in the GOA with the aim of continuing the cooperative longline survey time series, with biennial sampling of the AI beginning in 1996 and biennial sampling of the eastern BS in 1997. Sablefish length data were randomly collected for all survey years. Since 1996, a random sample of otoliths has been collected and aged (~1,200 per year; Table 3.4). Relative population abundance in numbers (RPNs) are computed annually using survey catch rates scaled to management area size. The lowest RPN values in the domestic survey time series occurred in 2015, but have increased steadily with 2019 through 2023 survey RPNs representing some of the highest in the time series (Figure 3.4). Although RPNs had been trending upwards in most regions in recent years, RPNs were down slightly in the western GOA and BS in 2023 (Figures 3.5 – 3.6). The NOAA longline survey RPN indices are adjusted to account for whale depredation, but the impact on the final index is minimal (Figure 3.7; Hanselman et al., 2018). Interactions between the fishery and survey are described in Appendix 3A.

Since 1984, NOAA has conducted triennial or biennial trawl surveys in the GOA on the upper continental slope to 500 m depth. Since the full range of adult sablefish habitat is not always sampled and adult sablefish may also outswim the net, trawl survey indices are developed primarily as an index of juvenile sablefish biomass. The GOA trawl survey index was at its lowest level of the time series in 2013, more than quadrupled until 2021, then declined precipitously by ~50% in 2023 (Figure 3.4; Table 3.5). Lengths are sampled during each survey year (Table 3.4).

Records of catch weight and effort for vessels that target sablefish are collected by observers and by vessel captains in voluntary and required logbooks (see Appendix 3E for a complete description of these data). Based on Japanese longline fishery catch rate data, a nominal index of historical CPUE is included from 1964 – 1981 (Table 3.5). For the domestic fishery, a nominal CPUE index from hook-and-line gear was previously included in model *21.12*. A combined gear (i.e., including data from both hook-and-line and pot gear) standardized CPUE index has now been developed (Cheng et al., 2023), which better accounts for factors impacting catch rates, and is integrated in the author recommended model *23.5*. Since 2020, CPUE has been increasing rapidly, similar to rates of increase in the NOAA longline survey RPNs over the same period (Figure 3.4).

The catch used in this assessment (Table 3.1) represents total catch (landings plus bycatch or discards assuming 100% mortality), and includes catch from minor state-managed fisheries (i.e., these are reported by federal statistical areas and directly incorporated into the NOAA catch accounting system) in the northern GOA and in the AI region (constituting about 1% of the average total catch). Additionally, the author preferred model (*23.5*) incorporates all non-commercial sablefish removals, including research catches and Alaska state sport fishery removals not associated with the NSEI or SSEI fisheries. Whale depredation on hook-and-line gear has been pervasive in the fishery, and methods for estimating fixed gear fishery whale depredation are also integrated into the assessment and associated catch projections (Peterson and Hanselman, 2017). Estimated depredation is generally below 1,000 t per annum, often composing less than 1% of the total catch. Despite relatively low overall impact relative to total catch, the impact of depredation varies by area and species with orca depredation higher in western regions (primarily the WG) and sperm whale depredation more significant in the CG and EG (Figure 3.8). For 2023, fishery whale depredation was held constant at 2022 levels due to primary data sets used in the whale depredation analysis not being updated in time for the assessment.

Length compositions from the U.S. fixed gear (longline and pot) and U.S. trawl fisheries are both measured by sex (Table 3.4), and gear- and sex-specific proportions-at-length are fit in the assessment. Only years that have sample sizes of at least 300 per sex are included. The length compositions are weighted by catch (in numbers) in each Fisheries Management Plan (FMP) area to obtain a representative estimate of catch-at-length.

Age compositions from the U.S. fixed gear fishery are available since 1999 with adequate coverage and sample sizes (~1,200 otoliths aged yearly) to be fit in the assessment as sex-aggregated proportion-at-age (Table 3.4). The age compositions are weighted by the catch (in numbers) in each FMP area to obtain a representative estimate of catch-at-age.

Data Input Changes for 2023

Aside from updating the time series of each data set, there were four important changes to the inputs for the assessment in 2023, as integrated in the author recommended model *23.5* (i.e., the impact of each change is explicitly demonstrated by a new model run, see next section). Data changes included: assuming constant fishery whale depredation (i.e., fixing 2023 depredation estimates at 2022 values); removing the 1984 and 1987 trawl survey and associated length compositions (see model *23.1*); incorporating non-commercial catch in federal waters (see model *23.2*); and replacing the nominal hook-and-line fishery CPUE index with a standardized combined gear (i.e., hook-and-line and pot gear) index (see model *23.4*).

Analytic approach

Model Structure

The final author recommended model *23.5* utilizes the same general structure as the previously accepted sablefish model *21.12* with minor updates to recruitment bias correction and selectivity (see 'Model Alternatives' section). The complete model structure is described in the 2021 SAFE (full documentation is available at: https://www.fisheries.noaa.gov/resource/data/2021-assessment-sablefish-stock-alaska). The model was coded in the AD Model Builder software, a C++ based software for development and fitting of general nonlinear statistical models (Fournier et al. 2012).

An age structured statistical catch-at-age (SCAA) framework is utilized, which tracks population numbers-at-age by sex. The model assumed a single Alaska-wide stock. Recruitment occurs at age-2, and age-based dynamics are then tracked from age-2 to age-31+, where the terminal age is a plus group. Recruitment at age-2 is calculated as a yearly deviation from an average recruitment parameter. Primary demographic parameters are estimated outside the model and treated as fixed inputs, including maturity- (single time block), length- (two time blocks, pre- and post-1996), and weight-at-age (single time block; see Table 3.9 in Goethel et al., 2022 for age-based values for all inputs). The model assumes two primary fishing fleets (i.e., the directed fixed gear fishery and the combined trawl gear fishery) with independent dynamics. To allow fitting length data directly, predicted age compositions are converted to size compositions using input size-at-age transition matrices. Because sablefish can be difficult to age, an ageing error matrix is directly integrated into the assessment based on known-age otoliths (Hanselman et al. 2012).

Each of the data sources described in the previous section (see Table 3.3) are fit directly in the model, and a statistical maximum likelihood estimation (MLE) framework enables estimation of key parameters (i.e., a total of 249 parameters are estimated; Table 3.6). Projections of future catch limits (e.g., ABC and OFL) are handled externally and described in the 'Harvest Recommendations' section.

Definitions

Recruitment is the estimated number of age-2 sablefish (in millions of fish). Total biomass (in kilotons) is the abundance of all sablefish age-2 and older multiplied by sex-specific input weight-at-age. Spawning stock biomass (SSB) is the mass of mature (based on input age-based maturity) females (in kilotons). Summary fishing mortality is fully selected *F*, which is the instantaneous mortality at the age of maximum fishery selectivity, summed across fleets.

Model Alternatives and Justification

A total of five new model runs were developed for the 2023 SAFE, culminating in the final proposed *23.5* model, which includes all individual changes. The models explored for 2023 included:

- *Model 21.12*: a continuity model matching the previously accepted model for management of sablefish, which was the same as the 2022 SAFE model but with updated data for 2023 (note that 2023 whale depredation estimates were assumed equal to the 2022 estimates).
- *Model 23.1*: removed the 1984 and 1987 trawl survey biomass index and length composition data, per AFSC best practice recommendations (no other changes were made from model *21.12*).
- *Model 23.2*: incorporated all sources of non-commercial catch in federal waters into the total catch used in the assessment model, per SSC requests (no other changes were made from model *21.12*).
- *Model 23.3*: included minor updates to:
    - The stock-recruit bias correction in the model [i.e., rectified a legacy coding error; implemented the Methot and Taylor (2011) time-varying bias correction; allowed the model to estimate the recruitment variance term (σ_R); and added an early fixed recruitment variance term to help constrain estimation in years with very limited data].
    - Selectivity parametrization to aid model stability [i.e., shared all selectivity parameters between the domestic fixed gear fishery during the early time block (pre-1995) with the Japanese longline fishery; and shared all selectivity parameters between the NOAA domestic longline survey during the early time-block (pre-2016) with the Japanese cooperative longline survey].
    - Fishing mortality parametrization to remove unnecessarily estimated parameters (i.e., removed fishing mortality deviations for early years of the trawl fishery when no catch was reported; and no longer treated fishing mortality reference point parameters as estimated quantities).
- *Model 23.4*: replaced the nominal hook-and-line CPUE index with a standardized index that combined data from both the hook-and-line and pot gear types (Cheng et al., 2023), as recommended by the SSC and PT in 2022 (no other changes were made from model *21.12*).
- *Model 23.5*: integrated all updates from models *23.1—23.4*; this is the final author recommended model for sablefish management advice in 2023.

Most proposed model changes are updates to data that were recommended based on AFSC assessment good practices (i.e., dropping early trawl survey data, model *23.1*), requested by the SSC (i.e., integrating non-commercial catch, model *23.2*), or were approved during previous assessment cycles (i.e., utilizing the combined gear standardized CPUE index, model *23.4*). The minor model structural changes implemented in model *23.4* were primarily meant to improve model performance by rectifying any coding issues, integrate good practices in assessment modeling, and aid model stability. All of the proposed model changes integrated in the author recommended model *23.5* are relatively minor, and each was examined in-depth to ensure that no major changes to model performance or population dynamics resulted.

Model Bridging and Final Model Development

Each of the updates to model *21.12* were implemented in isolation as defined in the previous section. The single change models were then examined for any major differences in performance or population trajectories from the previously accepted model *21.12*. All of the changes were then implemented simultaneously for the author recommended model *23.5*. Once the final author recommended model was selected, Francis data reweighting (i.e., accounting for correlations among ages or length bins in the compositional data; Francis, 2017) was applied to adjust data weights to account for the addition of the 2023 data. Finally, a jitter analysis was implemented to identify if altering the starting parameters led to an improved fit to the observed data. For the jitter analysis, the model was rerun 50 times with parameter values altered from the initial conditions by adding a small random deviation selected from a uniform distribution. If a given jitter run resulted in a lower total negative log-likelihood value, then that model was chosen as the final author recommended model. Thus, the final model *23.5* included all proposed data and model changes, integrated updated data weights, and was based on the best fit to the data after performing a jitter analysis.

Uncertainty

Two forms of uncertainty are evaluated for key parameters, including the Hessian approximations from the MLEs and the posterior distributions from Markov Chain Monte Carlo (MCMC) simulations. The posterior distributions from MCMC were computed based on one million parameter draws with the chain thinned to 5,000 to remove serial correlation between successive draws, and a 10% burn-in was used to remove draws from the beginning of the chain.

Model Diagnostic Analyses

Retrospective Analysis

Retrospective analysis is the examination of the consistency among successive estimates of the same parameters obtained as new data are sequentially removed from a model. A seven-year retrospective (i.e., terminal years 2017 through 2023) analysis was undertaken to examine whether any significant time trends in spawning biomass or recruitment were present. ‘Mohn’s rho’ (ρ), a measure of overall retrospective bias, was calculated as the mean of the relative ‘bias’ across all retrospective peels.

Historical Assessment Retrospective Analysis

An historical assessment retrospective analysis addresses consistency across successive stock assessment applications with the actual data available in the terminal model year. Two versions of an historical retrospective analysis were conducted: the ‘all model’ historical retrospective compared the actual assessment outputs from the model used as the basis of management advice for a given SAFE year (i.e., going back to the 2016 SAFE; this included successive applications of models *16.5*, *21.12*, and *23.5*); the ‘current model’ historical retrospective utilized the current assessment model *23.5* applied to the actual data available at the time of the given SAFE (i.e., terminal years 2018 through 2023 were included). Mohn’s rho was calculated based on the difference between the projected SSB from a two-year projection to the corresponding realized SSB in the 2023 model.

Profile Likelihoods

Likelihood profiles allow exploration of how the likelihood response surface varies for different values of a given parameter. A likelihood profile was developed for the primary scaling parameter, mean recruitment.

Incremental Influence of New Data

A data building analysis was developed to demonstrate how new data affected parameter estimates (e.g., the magnitude of the most recent year class). For this exercise, the 2023 catch data was added along with one additional new data source and the model was run. In the case of fishery independent surveys, the associated index was always added in combination with associated compositional data.

Index Sensitivity Analysis

An index sensitivity analysis was implemented to demonstrate the influence of each index by removing a given index and comparing model outputs. When a given fishery-independent index was removed, all associated age and length composition data were also removed from the model.

Results

Model Bridging and Final Model

None of the changes to the data (i.e., models *23.1*, *23.2*, and *23.4*) had an appreciable impact on population trajectories or data fits compared to model *21.12* (Figure 3.9). Removing the historical trawl survey data (model *23.1*) led to slight increases in recruitment and scaling in the early part of the time series, while adding the non-commercial catch (model *23.2*) and standardized CPUE (model *23.4*) had similar minor impacts on scaling in the latter half of the time series (Figure 3.9). Changes to model structure (model *23.3*) led to increased recruitment in the 1960s followed by slightly reduced recruitment in the 1970s compared to model *21.12* (Figure 3.9). However, model *23.3* led to much more reasonable estimates of initial age structure (i.e., model *21.12* estimates extreme year class sizes for certain ages in the initial age distribution) and more stable recruitment estimates in periods of reduced data (i.e., pre-1977 cohorts). Because model *21.12* estimates such extreme cohort sizes in the initial age structure, it results in a rapid increase in SSB in the mid-1960s before rapidly declining with the onset of large-scale fishing (Figure 3.9). The spawning stock biomass (SSB) trend in model *23.3* is much more reasonable and does not demonstrate the same initial rapid increases, which were model artefacts of the instability in initial age structure estimation (Figure 3.9). With the change in the initial biomass trends, model *23.3* has a slightly lower population scaling compared to model *21.12*, but differences in scaling are offset by changes in the reference points leading to ABCs that differ by less than 3%. Simultaneously implementing all proposed model changes (model *23.5*) led to slightly reduced recruitment estimates compared to model *23.3*, but overall differences were negligible. ABCs from model *21.12* and model *23.5* were within 1% of each other, despite limited differences in recruitment and population scaling (Figure 3.9). Given that model *23.5* implements minor changes that align with assessment good practices, improves model stability and estimation performance, and does not greatly alter population trends or fits to observed data compared to model *21.12*, it is being recommended as the author preferred model for the 2023 SAFE.

Data Reweighting

Francis reweighting was applied after incorporating all of the new data for 2023. The updated 'lambdas' (overall weight) for each data source only varied slightly from the 2022 model (Table 3.7). The Francis approach continues to emphasize fishery length compositions over associated age compositions. In the future, it is recommended that the length data should be removed from the model when associated age data is available, given that these data sources are likely leading to internal tension in the model fitting process. Moreover, the age data should be disaggregated by sex (as is done for length data) to provide more information on sex-specific dynamics. The data reweighting had no appreciable impact on model dynamics (Figure 3.9).

Jitter Analysis

The jitter analysis identified a handful of model runs with slightly lower total negative log-likelihoods, which provided minimally improved fits to the observed data compared to the initial run of model *23.5*. Thus, the final author recommended model *23.5* utilized the jitter run with the minimum negative log-likelihood (Figure 3.10, dashed line). The resulting final model *23.5* had slightly reduced population scaling, though recruitment estimates remained unchanged compared to the initial version of model *23.5* (Figure 3.9). Compared to model *21.12*, there was a moderate downward scaling of population SSB and mean recruitment in the final version of model *23.5*, but resultant ABCs were identical (i.e., 0% difference).

Model Evaluation

The objective function values by data source indicated that the compositional data, particularly the NOAA longline survey ages and the fixed gear fishery lengths, had the largest contributions (Figure 3.10). Although trends in one-step-ahead (OSA) residuals were noted for the compositional data (see 'Response to SSC and Plan Team Comments' Section), the aggregate fits to compositional data appeared adequate. Moreover, there were essentially no changes to data fits compared to the 2022 SAFE (model *21.12*; Goethel et al., 2022).

Goodness of fit

Model *23.5* demonstrated good fit to the indices with predicted values generally within the confidence intervals of the observations, except for a few years of the trawl survey biomass index (i.e., early values and the large decline in 2023) and the Japanese CPUE index (Figure 3.12). The lack of fit to the 2023 trawl survey decline is not surprising, given that this trend is not reflected in any of the other data sources. Mean fits to the compositional data were adequate, but some strong year and age- or length-specific residual patterns were present (Figures 3.13—3.33). For instance, recent year classes tend to be initially overestimated and subsequently underestimated (i.e., at ages when these year classes reach their peak abundance) in the longline survey and fixed gear fishery age compositions (Figures 3.11 – 3.18). Thus, primary estimation uncertainty pertains to the magnitude of recent year classes. The aggregated fits to the length composition data demonstrated a general tendency to overestimate fish in the 55cm to 65cm range, then underestimate the proportion of fish in the 65cm to 75cm range (Figures 3.19 – 3.33). However, in recent years, the trend is reversed with an underestimation of small fish and overestimation of the proportion of larger fish (e.g., in the NOAA longline survey, Figures 3.23 – 3.24, and the fixed gear fishery, Figures 3.29 – 3.30). The recent patterns may be indicative of changing dynamics in the population that is not well accounted for in the model (e.g., reduced growth within recent extreme year classes or reduced availability of large fish to the gears) or may represent discrepancies in the age and length data (e.g., due to measurement error) that the model is not able to rectify. For instance, given the extreme magnitude of the 2016 cohort in the age composition data in 2022, the model is likely expecting there to be a preponderance of fish in the 62 – 70cm size bins in the 2022 and 2023 NOAA longline survey and fixed gear fishery length data. However, the survey data shows few fish greater than 60 – 64 cm (Figures 3.23 –3.24) with a similar, though less pronounced, pattern in the fishery data (Figures 3.29 – 3.30). Length compositions from the trawl gear tend to be more variable and are not particularly well fit (Figures 3.25 – 3.27 for the survey and 3.31 – 3.33 for the fishery).

Time Series Results

Sablefish abundance and biomass dropped throughout much of the 1960s and 1970s (Table 3.8, Figure 3.34), as the population began to be heavily exploited, with catches peaking at 53,000 t in 1972 (Table 3.1, Figure 3.2). The population recovered in the mid-1980s due to a series of strong year classes in the late 1970s (Figures 3.35 – 3.36). The population subsequently declined as these strong year classes were removed, with a slight rebound in the early 2000s due to a handful of above average year classes in the late 1990s, then declined to a time series low in 2015 (Figure 3.34). Associated with a series of above average recruitment events since 2014, age-2+ biomass has nearly tripled since 2015 to 695,000 t in 2023, which represents sablefish population levels on par with those at the time the fishery developed in the 1960s (Figure 3.34). Although increased abundance at younger ages has driven increases in population biomass, the population age structure remains truncated compared to historical levels (Figures 3.35 – 3.37). SSB typically lags behind biomass with less pronounced extremes and, aside from a ten-year upswing in the 1980s, has been on a downward trajectory for the entire time series (Table 3.8; Figure 3.34). SSB has nearly doubled from the time series low of 82,000 t in 2017 to 157,000 t in 2023 (Figure 3.34). However, SSB remains well below time series high levels observed in the 1960s.

Sablefish are characterized by highly spasmodic recruitment events with periodic year classes that are well above average, then prolonged periods of depressed recruitment (Figure 3.38). Moreover, no apparent relationship between SSB and subsequent recruitment exists, with many of the larger cohorts being spawned from relatively low SSB (Figure 3.39). However, the large recruitment events in the late 1970s and early 1980s were associated with a more balanced age structure (Figures 3.35 – 3.36), which may indicate a potential age diversity and spawning portfolio effect on recruitment success (e.g., Griffiths et al., 2023). The largest historical recruitment event was the 1977 year class followed by the 1980 year class, but below average recruitment events then occurred throughout much of the 1980s and early 1990s (Table 3.8, Figure 3.38). Starting in 2014, recruitment has been at or above the time series mean (Figure 3.38). The 2016 and 2017 year classes are the two largest cohorts in the time series (Table 3.8). However, the size of recent strong recruitment events (e.g., the 2018 through 2020 year classes) is uncertain, given that they are informed by limited age and length composition data. Thus, it is common for variability to exist in estimates of recent year class strength in subsequent SAFE models. For instance, the 2022 SAFE estimated a large 2019 cohort, which was being driven by the 2021 trawl survey, but that estimate decreased in the 2023 model *23.5* with the addition of age and length data from other sources (Figure 3.40). It is expected that a similar, but opposite, pattern will be observed with the 2020 year class, which is being estimated at a relatively low value (i.e., compared to recent cohorts), primarily due to the strong decline in the 2023 trawl survey index. Thus, the size of this cohort will likely increase in subsequent assessments.

Generally, selectivity has shifted towards younger fish for the longline survey and fixed gear fishery over time (Figure 3.41). Males tend to be selected at an older age than females in all fleets, likely because they are smaller at a given age. Compared to the fixed gear, younger fish are more vulnerable and older fish are less vulnerable to trawl gear, because trawling often occurs on the continental shelf in shallower waters (< 300 m) where young sablefish reside (i.e., this is reflected in the dome-shaped trawl gear selectivity patterns).

Fishing mortality was estimated to be high in the 1970s, relatively low in the early 1980s, then increased in the 1990s before undergoing a gradual decline throughout the 2000s (Figure 3.42). Over the last five years, fishing mortality has steadily declined and is on par with the low levels of the early 1980s. Recent management has generally constrained fishing mortality to below limit reference point values, while biomass is above limit reference point values indicating that the resource is not overfished and overfishing is not occurring (Figure 3.43).

Uncertainty

MLE and MCMC estimates of parameters were similar with the MLE values closer to the MCMC medians, while the magnitude of recent recruitment events tended to show slight divergence with MCMC estimates generally higher than MLE (Table 3.12). Similarly, estimates of uncertainty in key parameters were comparable with MCMC estimates demonstrating larger variability. The MLE estimates of projected spawning biomass for 2024 (185,079 t) and 2025 (209,5004 t; based on the maximum permissible ABC and specified catch projections) fall near the center of the posterior distribution of spawning biomass from MCMC, while the MCMC distributions indicate an extremely high probability of being above $B_{40\%}$ in both years (Figures 3.44).

Comparison to Last Year's Model

Despite a slight downward scaling of model *23.5* compared to *21.12* in terms mean recruitment, SSB, and reference points (see Summary Table), model trends are generally consistent (Table 3.10). The only major differences occur at the beginning of the time series, primarily in terms of early recruitment trends, which are due to the reparameterization of the recruitment bias adjustment in model *23.5*. However, recent estimates of SSB and biomass are consistent among models, with the 2022 SAFE projected biomass for 2023 being within 3,000 t of the realized 2023 SSB as estimated by model *23.5*; both models indicate the stock was at $B_{52\%}$ in 2023. One main difference among model estimates, which was predicted in the 2022 SAFE, was that the magnitude of the 2019 year class (i.e., the 2021 recruitment event) has been moderately downgraded (Figure 3.40). Because the 2019 year class was being primarily informed by the 2021 trawl survey data in the 2022 model, it was expected that this estimate would change once updated age and length observations from other data sources were available.

Model Diagnostic Analyses

Retrospective Analysis

The retrospective analysis indicated that the model is quite consistent, demonstrating a slight tendency to underestimate population scale and terminal SSB (Mohn's ρ = -0.03; Figure 3.45). Although variability exists in the estimates of recent year class strength, there is no consistent directional trend (Figure 3.46). However, there is a tendency to initially overestimate year class strength, which may reflect the over influence of trawl survey data as it provides the first observations of new cohorts. Given that the trawl survey often conflicts with subsequent data from fishery and longline survey age and length compositions, the initial year class estimates tend to undergo a downward scaling in subsequent years.

Historical Assessment Retrospective Analysis

Aside from former model *16.5* (i.e., used as the basis of management advice prior to 2021), which tended to severely overestimate population SSB growth, recent models have been highly consistent from one year to the next (i.e., based on the 'all model' historical retrospective; Figure 3.47). As noted, the 2023 projected SSB from the 2022 implementation of model *21.12* was only 3,000 t higher than the realized SSB from model *23.5* in 2023, and there was no difference in stock status (i.e., the population was at $B_{52\%}$ in both model implementations).

Furthermore, applying model *23.5* to the data available at the time of previous assessments (i.e., the 'current model' retrospective) demonstrated that the two-year projections were again consistent (Figure 3.48). There was a slight pattern of increased population scaling as new data is added with concomitant underestimation of SSB in previous years, as was seen in the normal retrospective analysis. The observed patterns are primarily driven by the uncertainty in recent recruitment events and the assumption of average recruitment in the model terminal year. Mainly, as the most recent recruitment value goes from being fixed at the time series mean to being an estimated parameter in the following year, it is estimated to be larger (i.e., as has been the case most years since 2014), which leads to an increase in mean recruitment and population scale.

Profile Likelihoods

A profile likelihood analysis for the log of the mean recruitment parameter demonstrated slight model tension among data sources with the indices and length composition data supporting much higher values than the age composition data (Figure 3.49).

Incremental Influence of New Data

As new data were added to the model, there were no strong changes in model dynamics or population trajectories (Figure 3.50). As was expected based on similar analyses in previous years, the biggest differences across model runs as new data points were added was the magnitude of recent recruitment events. Despite strong declines in the trawl survey biomass index in 2023, it is still supporting higher estimates of the 2019 year class compared to other data sources (e.g., the longline survey age compositions). Conversely, the trawl survey data is now indicating smaller estimates of the 2016 year class and lower values for the 2020 year class than other data sources. Given that the strong decline in the 2023 trawl survey index was not supported by other indices, it is expected that the 2020 year class will likely increase in coming years as the longline survey and fishery age compositions begin to observe the 2020 cohort.

Index Sensitivity Analysis

As was observed with the incremental data analysis, the primary differences when various indices were removed is in the interpretation of recent recruitment (Figure 3.51). Removal of the trawl survey index led to a large decrease in the 2019 year class estimate and a similar increase in the 2020 year class. Thus, apparent tension among the trawl survey index and length compositions compared to the NOAA longline survey index and compositional data is likely a primary driver of fluctuations in year class estimates from one model year to the next as well as recruitment retrospective patterns (Figure 3.46). Future explorations into the removal of the trawl survey data from the sablefish assessment may be warranted, given that the trawl survey does not consistently sample the entire sablefish population distribution, only encounters juvenile sablefish, and appears to provide conflicting signals as to the magnitude of sablefish recruitment events. Conversely, removal of the CPUE index had little impact on model results. As expected, removing the longline index greatly reduced both recruitment and SSB estimates, given that this is the primary data source informing model scale and productivity.

Harvest Recommendations

Population Projections

A standard set of projections is required by Amendment 56 for each stock managed under Tiers 1, 2, or 3. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the MSFCMA ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56), including:

- *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}.
- *Scenario 2*: In 2024 and 2025, F is set equal to the F associated with the specified catch, which is the whale corrected ABC multiplied by the fraction of the 2023 ABC that was harvested (i.e., a harvest ratio of 66% was assumed in 2023). For the remainder of the future years, maximum permissible ABC is used.
- *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}.
- *Scenario 4*: In all future years, F is set equal to the 2018 – 2022 average F.

- *Scenario 5*: In all future years, *F* is set equal to zero.
- *Scenario 6*: In all future years, *F* is set equal to F_{OFL}. This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its B_{MSY} level in 2023, or 2) above ½ of its B_{MSY} level in 2023 and above its B_{MSY} level in 2032 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}. This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its B_{MSY} level in 2025, or 2) above 1/2 of its B_{MSY} level in 2025 and expected to be above its B_{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 (Table 3.11). In Scenario 2 (Specified Catch), the specified catches are used to increase the accuracy of the short-term projections. For current year catch, an expansion factor is applied to the observed catch (at the time the data is downloaded for the assessment in early October), which is calculated as a 3-year average of catch removals between October 1 and December 31 in the last three complete catch years (i.e., 2020 – 2022 for the 2023 catch). For catch projections in the two years following the assessment terminal year, the ratio of the terminal year catch to terminal year ABC is used to determine the fraction of the ABC to be removed in each projection year. This method results in slightly higher future ABCs due to the lower initial removals in the initial projection years.

Status Determination

For the purpose of ABC and OFL reporting, the specified catch projections (Scenario 2) are used and reported in the executive summary. 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?

The official catch estimate for the most recent complete year (2022) is 26,900 t, which is less than the 2022 OFL of 34,500 t. Therefore, the stock is not being subjected to overfishing. Because 2023 SSB is at $B_{52\%}$ (i.e., above $B_{35\%}$), sablefish are not overfished. Similarly, given that the 2025 SSB is projected to be at $B_{70\%}$ (i.e., above $B_{35\%}$), sablefish are not approaching an overfished condition (Table 3.11).

Thus, **overfishing is not occurring** on Alaskan sablefish and the stock **is not overfished nor is it approaching an overfished condition.**

Acceptable Biological Catches (ABCs) and Overfishing Limits (OFLs)

Sablefish are managed under Tier 3 of the NPFMC harvest control rule, which aims to maintain the population at $B_{40\%}$. The updated point estimate of $B_{40}\%$ is 119,960 t. Since projected female spawning biomass (combined areas) for 2024 is 185,079 t (equivalent to $B_{62\%}$), sablefish is in sub-tier "a" of Tier 3. The updated point estimates of $F_{40\%}$, and $F_{35\%}$ from this assessment are 0.086 and 0.101, respectively. Thus, the maximum permissible value of F_{ABC} under Tier 3a is 0.086, which translates into a 2024 ABC (combined areas, before whale adjustments) of 47,367 t. The OFL fishing mortality rate is 0.101, which translates into a 2024 OFL (combined areas) of 55,385 t. **After adjusting for whale depredation, the final author recommended ABC_w is 47,146 t in 2024 and 47,350 t in 2025. The whale adjusted OFL_w is 55,084 t in 2024 and 55,317 t in 2025.**

Fishing Mortality to Achieve Previous Year's OFL

Species Information System (SIS) requirements require reporting the fishing mortality rate from the current model that would have produced a catch for the previous year equivalent to the previous year's OFL. The OFL for last year (2022) was 40,400 t. The fishing mortality rate required to harvest the OFL would have been 0.082 based on the 2023 model.

Risk Table ABC Considerations

The risk table approach is used to highlight externalities to the assessment across four categories (i.e., assessment, population dynamics, environmental and ecosystem, and fishery performance) that may indicate potential issues that should be considered when managers are determining future ABC recommendations. In particular, high risk table scores can be used to justify setting an ABC below the maximum permissible ABC.

Assessment Related Considerations

The sablefish assessment is data-rich and the quality of the data that goes into the model is generally considered to be high. All sablefish indices indicate rapid population growth in recent years, aside from the terminal year decline in the trawl survey. Similarly, the age and length composition data continue to indicate strong recent recruitment. Despite some minimal data conflicts, the suite of diagnostic analyses implemented demonstrate that the author recommended sablefish assessment is robust and consistent. No strong retrospective patterns exist, though SSB tends to be slightly underestimated as new data are added to the model. The primary assessment uncertainty is the magnitude of recent recruitment events, but catch projections are generally robust to this uncertainty. Moreover, the rapid transition to pot gear, which is implicitly handled through a selectivity time block in the fixed gear fishery fleet and the integration of a combined gear CPUE index, remains another potential source of uncertainty. However, the lack of explicit modeling of the pot gear fleet does not appear to be detrimentally impacting assessment performance at this time (see 'Response to SSC and PT Comments' Section for results from a gear disaggregated assessment model). **Therefore, the assessment related concern is 'level 1 – no concern'.**

Population Dynamics Considerations

Overall, sablefish productivity remains high and the population continues to grow rapidly. However, the lack of sablefish greater than 10 years of age (i.e., the age when sablefish are greater than 90% mature), especially compared to historic levels of older and larger fish, remains concerning for such an extremely long-lived species, and needs to be carefully monitored (Figures 3.35—3.36). The resulting evenness of the age distribution of sablefish has dropped rapidly as has the diversity in the ages contributing to the overall SSB (Figure 3.52). The model projects that the 2014 – 2020 year classes will comprise over 75% of total SSB in 2024, despite none of these cohorts being fully mature. Unfortunately, the NPFMC harvest control rule does not recognize the potential importance of a well-distributed age composition in the population (i.e., all fish considered mature are treated equally in the model). Similarly, if the recent increase in productivity is associated with transient environmental or ecosystem conditions, then it is likely that the sablefish resource and fishery will be reliant on these handful of year classes for a decade or more. For instance, the sudden appearance of numerous large year classes starting in 2014 occurred at historically low SSB levels (Figure 3.39), which suggests that these recruitment events may be environmentally driven. Because the exact drivers are not known, a transition to more depressed recruitment levels (as has typically happened following periods of high recruitment) may occur at any time (Figure 3.53). However, large year classes (e.g., 2016 and 2017) are helping to expand the age structure and will likely reach fully mature ages at relatively high abundance. Thus, population trends are generally positive and indicate continued growth of the population. **Hence, the population dynamics related concern is a 'level 1 – no concern'.**

Environmental and Ecosystem Considerations

Environmental conditions indicate that temperatures were within, or slightly cooler than, known optimal ranges for young-of-the-year and juvenile sablefish. However, spring chlorophyll-a concentrations were the lowest in the time series in the GOA and second lowest in the Bering Sea with peak spring bloom timing occurring late in the GOA, which may have negative implications for the prey base of larval sablefish. Conversely, the foraging opportunities for juvenile and pre-recruit sablefish were likely sufficient, given an adequate zooplankton and forage fish prey base, though levels were reduced from 2022. Similarly, above average condition factors for large female sablefish indicate that food supply was adequate in recent years. Predation by other groundfish likely remains low, whereas competition for zooplankton prey may have increased in 2023 (i.e., due to high returns of pink salmon in the GOA and a continued increase in other groundfish populations across the GOA and BSAI). Based on the ecosystem information related to Alaskan sablefish provided in the 2023 EBS and GOA Ecosystem Status Reports (ESRs) along with the sablefish Ecosystem and Socioeconomic Profile (ESP; Appendix 3C), the **environmental and ecosystem related concern is a 'level 1 – no concern'**.

Fishery Performance Considerations

In recent years, there has been an increasing shift to pot gear in the Gulf of Alaska (i.e., in less than five years it has gone from a negligible portion of the total catch to over 80% of the fixed gear removals), which is not explicitly accounted for in the assessment model. However, the newly integrated combined gear standardized CPUE index better reflects catch rates in the fixed gear fishery compared with the nominal index used in previous assessments that included data from only hook-and-line gear. Perhaps more importantly, the rapid decline in overall market conditions, particularly due to the influx of small sablefish, may be contributing to differences in targeting and selectivity in all fisheries. For example, if there is active avoidance of small fish and shifting effort onto larger, mature fish, then it may place additional pressure on the spawning stock and be hard to detect quickly. However, as ABCs have increased recently (Figure 3.53), the proportion of the quota utilized has declined (i.e., averaging around 70% over the last three years). Catch levels well below the maximum permissible ABC may provide additional biological protection. However, the socioeconomic factors driving low fishery value (see ESP, Appendix 3C) and below maximum utilization of the resource merit consideration, and require further analysis from an economic and social science perspective. **Given the extent of recent rapid change in the fishery and limited analysis of socio-economic drivers of resource utilization, the fishery performance concern is a 'level 2 – major concern'.**

Risk Table Summary

For the 2023 sablefish risk table, three scores were a 'level 1 – no concern' with the fishery performance category rated 'level 2 – major concern'. Given the lack of major concerns for sablefish, no additional reductions in ABC are being recommended (though deductions for whale depredation are still incorporated). Although the projected maximum permissible ABC would represent the second largest catch on record, the ABC has not been fully harvested in recent years. Moderate concerns do still exist due to the contracted population age structure, especially considering that over 75% of SSB will be from the 2014 to 2020 year classes. In the future, alternative harvest control rules (e.g., capped quota increases) might be warranted for sablefish to increase the long-term harvest value, while helping to stabilize long-term sablefish dynamics (i.e., to prevent cyclical declines as the resource transitions between high and low recruitment levels; e.g., Licandeo et al., 2020).

Area Apportionment of Harvests

An apportionment method that tracks regional biomass, or a proxy thereof, is likely the best defense against localized depletion or other conservation concerns (e.g., disproportionately targeting spawners in only a handful of regions or population strongholds). Based on a biological perspective, the five-year average survey apportionment method was recommended by the SSC in 2020, because it tracks biomass across management regions to the best of our current ability (i.e., by using estimates of regional biomass from the yearly longline survey that targets sablefish in primary adult habitat). Because a moving five-year average is used, the apportionment values change each year as new survey data is added into the calculation.

Data Gaps and Research Priorities

A better understanding of juvenile distribution, spawning locations, and habitat utilization (e.g., through integration of electronic and satellite tagging studies with existing conventional mark-recapture work) is needed. In terms of the assessment model, the following research is being considered:

1) Explore the impact of the removal of various data sources that may no longer be updated or may not be reflective of population trends across the entire population.
2) Pending NPFMC action on small sablefish release amendments, explore methods for handling discards in the assessment model.
3) Transition the assessment model from AD Model Builder (ADMB) to Template Model Builder (TMB; work has been completed, model testing is ongoing).
4) Explore selectivity and fleet assumptions using simulation (ongoing work led by M. Cheng, UAF).
5) Explore best practices for sex-specific models (e.g., allow for fitting sex-specific age compositions and estimation of sex ratio) through simulation (ongoing work led by M. Cheng, UAF).
6) Develop quantitative methods to inform recent recruitment based on analysis of environmental data and alternate data sets available in the ESP (ongoing work led by K. Oke, NOAA post-doc).
7) Implement a spatially explicit, tag-integrated assessment model for sablefish that can be used as a companion to the single region operational assessment (work is wrapping up, led by C. Marsh, NOAA post-doc)
    a. Expand the spatial model into a full life cycle model that incorporates larval individual-based modeling outputs to inform connectivity during early life history stages and ecosystem drivers of settlement success (work ongoing).
8) Develop a closed loop simulation model to explore alternate SSB-metrics and capped management procedures (work is ongoing and a post-doctoral researcher is being sought).
9) Develop a coast wide sablefish operating model through the Pacific Sablefish Transboundary Assessment Team (PSTAT; work ongoing, led by M. Kapur, AFSC).
10) Consider new strategies for incorporating variation in growth (e.g., through internal estimation of growth parameters) and maturity, including accounting for cohort effects and skipped spawning.
11) Develop stock assessment parametrizations that address time- and age-varying natural mortality.

Acknowledgments

The authors wish to acknowledge the many additional contributors that help make this sablefish assessment possible each year. The feedback we receive from industry participants is vital in aiding our understanding of patterns in the fishery and the stock. The careful data collection by fishery observers and survey biologists is greatly appreciated and form the backbone of all of our assessments. Finally, we thank our excellent AFSC Age and Growth program.

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Tables

Table 3.1. Alaska sablefish total catch (t). Eastern GOA includes West Yakutat and East Yakutat / Southeast. 2023 catches are as of October 10, 2023 (from www.akfin.org). The 2023 catch value is incomplete and does not include specified catch. The values in this table are not adjusted for whale depredation. Abbreviations are: Bering Sea (BS), Aleutian Islands (AI), Western Gulf of Alaska (WGOA), Central Gulf of Alaska (CGOA), Eastern Gulf of Alaska (EGOA), West Yakutat (WY), East Yakutat/Southeast Outside (EY/SEO), non-commercial (Non-Comm.), Hook and Line (HAL).

		By Area								By Gear			
Year	**Total**	**AI**	**BS**	**WGOA**	**CGOA**	**EGOA**	**WY**	**EY/SEO**	**Non-Comm.**	**HAL**	**Trawl**	**Pot**	**Percent Trawl**
1960	3,100	-	1,861	-	-	1,193	-	-	-	3,100	-	-	-
1961	16,100	-	15,627	-	-	451	-	-	-	16,100	-	-	-
1962	26,400	-	25,989	-	-	390	-	-	-	26,400	-	-	-
1963	16,900	664	13,706	266	1,324	941	-	-	-	10,600	6,300	-	37
1964	7,300	1,541	3,545	92	955	1,140	-	-	-	3,300	4,000	-	55
1965	8,700	1,249	4,838	764	1,449	433	-	-	-	900	7,800	-	90
1966	15,600	1,341	9,505	1,093	2,632	1,012	-	-	-	3,800	11,800	-	76
1967	19,200	1,652	11,698	523	1,955	3,368	-	-	-	3,900	15,300	-	80
1968	31,000	1,673	14,374	297	1,658	12,938	-	-	-	11,200	19,800	-	64
1969	36,800	1,673	16,009	836	4,214	14,099	-	-	-	15,400	21,400	-	58
1970	37,800	1,248	11,737	1,566	6,703	16,604	-	-	-	22,700	15,100	-	40
1971	43,500	2,936	15,106	2,047	6,996	16,382	-	-	-	22,900	20,600	-	47
1972	53,000	3,531	12,758	3,857	11,599	21,320	-	-	-	28,500	24,500	-	46
1973	36,900	2,902	5,957	3,962	9,629	14,439	-	-	-	23,200	13,700	-	37
1974	34,600	2,477	4,258	4,207	7,590	16,006	-	-	-	25,500	9,100	-	26
1975	29,900	1,747	2,766	4,240	6,566	14,659	-	-	-	23,300	6,600	-	22
1976	31,700	1,659	2,923	4,837	6,479	15,782	-	-	-	25,400	6,300	-	20
1977	21,403	1,897	2,718	2,968	4,270	9,543	-	-	3	18,900	2,500	-	12
1978	10,414	821	1,193	1,419	3,090	3,870	-	-	14	9,200	1,200	-	12
1979	12,031	782	1,376	999	3,189	5,391	-	-	131	10,400	1,500	-	12
1980	10,584	275	2,205	1,450	3,027	3,461	-	-	184	8,400	2,000	-	19
1981	12,838	533	2,605	1,595	3,425	4,425	-	-	238	11,000	1,600	-	12
1982	12,348	964	3,238	1,489	2,885	3,457	-	-	348	10,200	1,800	-	15
1983	12,082	684	2,712	1,496	2,970	3,818	-	-	282	10,200	1,600	-	13
1984	14,511	1,061	3,336	1,326	3,463	4,618	-	-	411	10,300	3,800	-	26
1985	15,076	1,551	2,454	2,152	4,209	4,098	-	-	576	13,000	1,500	-	10
1986	29,419	3,285	4,184	4,067	9,105	8,175	-	-	519	21,600	7,300	-	25
1987	35,666	4,112	4,904	4,141	11,505	10,500	-	-	466	27,600	7,600	-	21
1988	39,107	3,616	4,006	3,789	14,505	12,473	-	-	707	29,300	9,100	-	23
1989	35,564	3,704	1,516	4,533	13,224	11,852	-	-	764	27,500	7,300	-	21
1990	30,880	2,120	2,330	1,993	12,066	11,707	-	-	664	25,532	4,684	-	15
1991	27,092	2,190	1,209	1,931	11,178	9,938	4,069	5,869	645	23,349	3,097	-	11
1992	24,574	1,553	613	2,221	10,355	9,158	4,408	4,750	674	20,977	2,910	13	12
1993	26,099	2,078	669	740	11,955	9,976	4,620	5,356	682	22,912	2,506	-	10
1994	24,174	1,727	694	539	9,377	11,243	4,493	6,750	594	20,614	2,938	29	12
1995	21,080	1,119	930	1,747	7,673	9,223	3,872	5,352	388	18,062	2,613	18	12
1996	17,834	764	648	1,649	6,773	7,558	2,899	4,659	441	15,147	2,187	59	12
1997	14,951	781	552	1,374	6,234	5,666	1,930	3,735	344	12,975	1,632	1	11
1998	14,242	535	563	1,432	5,922	5,422	1,956	3,467	368	12,386	1,487	1	10
1999	13,977	683	675	1,488	5,874	4,867	1,709	3,159	390	11,566	1,985	37	14
2000	15,894	1,049	742	1,587	6,173	6,020	2,066	3,953	324	13,402	2,019	149	13
2001	14,435	1,074	864	1,588	5,518	5,021	1,737	3,284	370	12,057	1,783	225	12
2002	15,205	1,118	1,144	1,865	6,180	4,441	1,550	2,891	457	11,993	2,243	512	15
2003	16,797	1,118	1,012	2,118	6,994	5,170	1,822	3,347	386	13,671	2,060	680	12
2004	17,896	955	1,041	2,173	7,310	6,041	2,241	3,801	376	15,042	1,656	822	9
2005	16,951	1,481	1,070	1,930	6,706	5,399	1,824	3,575	366	13,741	1,556	1,288	9
2006	15,904	1,151	1,078	2,151	5,921	5,251	1,889	3,362	353	13,218	1,246	1,087	8
2007	16,284	1,169	1,182	2,101	6,004	5,502	2,074	3,429	326	13,087	1,235	1,636	8
2008	14,857	899	1,141	1,679	5,495	5,337	2,016	3,321	305	12,490	1,122	940	8
2009	13,364	1,100	916	1,423	4,967	4,656	1,831	2,825	302	11,370	1,057	635	8
2010	12,275	1,048	752	1,354	4,512	4,270	1,579	2,692	339	10,422	1,005	510	8
2011	13,328	1,027	707	1,395	4,922	4,936	1,902	3,034	341	11,251	1,180	556	9
2012	14,144	1,205	744	1,352	5,328	5,243	2,033	3,210	272	12,259	1,102	511	8
2013	13,851	1,082	635	1,358	5,187	5,349	2,102	3,246	240	12,134	1,037	439	7
2014	11,806	813	314	1,194	4,736	4,489	1,671	2,817	259	10,195	1,025	326	9
2015	11,179	422	210	998	4,626	4,677	1,866	2,811	246	9,721	1,090	122	10
2016	10,472	340	531	1,052	4,195	4,106	1,651	2,455	248	8,701	1,336	187	13
2017	12,552	588	1,150	1,181	4,838	4,510	1,694	2,816	285	8,464	2,272	1,531	18
2018	14,494	664	1,536	1,389	5,778	4,881	1,861	3,019	246	8,690	3,780	1,778	26
2019	16,912	663	3,162	1,533	6,280	4,915	1,802	3,113	360	8,268	5,154	3,130	30
2020	19,416	1,232	5,329	1,462	6,041	4,971	1,835	3,137	381	5,813	7,493	5,730	39
2021	21,748	1,578	4,169	1,994	7,325	6,201	2,329	3,872	481	4,644	4,853	11,771	22
2022	27,420	2,230	5,514	3,028	8,165	7,971	2,750	5,221	512	4,056	5,366	17,485	20
2023	20,762	1,924	4,851	2,357	5,547	5,677	2,068	3,610	405	2,384	5,316	12,657	26

Table 3.2. Summary of management measures with time series of catch, ABC, OFL, and TAC. All values are in tons. 2023 catches are as of October 10, 2023 (from www.akfin.org). The 2023 catch value is incomplete and does not include specified catch as incorporated in the assessment model. Catch does not include non-commercial catch (i.e., as opposed to Table 3.1).

Year	Catch	OFL	ABC	TAC	Management measure
1980	10,400			18,000	Amendment 8 to the Gulf of Alaska Fishery Management Plan established the West and East Yakutat management areas for sablefish.
1981	12,600			19,300	
1982	12,000			17,300	
1983	11,800			14,500	
1984	14,100			14,800	
1985	14,500			13,500	Amendment 14 of the GOA FMP allocated sablefish quota by gear type: 80% to fixed gear and 20% to trawl gear in WGOA and CGOA and 95% fixed to 5% trawl in the EGOA.
1986	28,900			21,400	Pot fishing banned in Eastern GOA.
1987	35,200			27,700	Pot fishing banned in Central GOA.
1988	38,400		44,200	36,400	
1989	34,800		37,100	32,200	Pot fishing banned in Western GOA.
1990	30,200		33,400	33,200	Amendment 15 of the BSAI FMP allocated sablefish quota by gear type: 50% to fixed gear in and 50% to trawl in the EBS, and 75% fixed to 25% trawl in the Aleutian Islands.
1991	26,400		28,800	28,800	
1992	23,900	34,100	25,200	25,200	Pot fishing banned in Bering Sea (57 FR 37906).
1993	25,400	33,200	25,000	25,000	
1994	23,600	35,900	28,800	28,800	
1995	20,700	25,700	25,300	25,300	Amendment 20 to the Gulf of Alaska Fishery Management Plan and 15 to the Bering Sea/Aleutian Islands Fishery Management Plan established IFQ management for sablefish beginning in 1995. These amendments also allocated 20% of the fixed gear allocation of sablefish to a CDQ reserve for the Bering Sea and Aleutian Islands.
1996	17,400	22,800	19,600	19,400	Pot fishing ban repealed in Bering Sea except from June 1-30.
1997	14,600	45,600	17,200	16,800	Maximum retainable allowances for sablefish were revised in the Gulf of Alaska. The percentage depends on the basis species.
1998	13,900	27,800	16,800	16,800	
1999	13,600	24,700	15,900	15,400	
2000	15,600	21,500	17,200	17,200	
2001	14,100	20,700	16,900	16,900	
2002	14,700	26,100	17,300	17,300	
2003	16,400	28,900	20,900	20,900	
2004	17,500	30,800	23,000	22,600	
2005	16,600	25,400	21,000	21,000	
2006	15,600	25,300	21,000	20,700	
2007	16,000	23,700	20,100	20,100	
2008	14,600	21,300	18,000	18,000	Pot fishing ban repealed in Bering Sea for June 1-30 (74 FR 28733).
2009	13,100	19,000	16,100	16,100	
2010	11,900	18,000	15,200	15,200	
2011	13,000	19,000	16,000	16,000	
2012	13,900	20,400	17,200	17,200	
2013	13,600	19,200	16,200	16,200	
2014	11,500	16,200	13,700	13,700	
2015	10,900	16,100	13,700	13,700	NPFMC passes Amendment 101 to allow pot fishing in the GOA.
2016	10,200	13,400	11,800	11,800	Whale depredation accounted for in survey and fishery.
2017	12,300	15,400	13,100	13,100	Pot fishing begins in the GOA.
2018	14,200	29,500	15,000	15,000	
2019	16,600	32,800	15,100	15,100	
2020	19,000	50,500	22,000	18,300	TAC set below ABC based on AP recommendation.
2021	21,300	60,400	29,600	26,100	
2022	26,900	40,400	34,500	34,500	OFL changed to Alaska-wide.
2023	20,400	47,400	40,500	39,600	

Table 3.3. Data used in the 2023 assessment model (model *23.5*). Years in **bold** are data new to this assessment.

Source	Data	Years
Fixed Gear Fisheries	Catch	1960 – **2023**
Trawl Fisheries	Catch	1960 – **2023**
Non-Commercial Catch	Catch	1977 – **2023**
Japanese Longline Fishery	Catch-per-Unit-Effort (CPUE)	1964 – 1981
U.S. Fixed Gear Fisheries	CPUE, Length	1990 – **2022**
	Age	1999 – **2022**
U.S. Trawl Fisheries	Length	1990,1991,1999, 2005 – **2022**
Japan-U.S. Cooperative Longline Survey	RPNs, Length	1979 - 1994
	Age	1981, 1983, 1985, 1987, 1989, 1991, 1993
NOAA Domestic Longline Survey	RPNs, Length	1990 – **2023**
	Age	1996 – **2022**
NOAA GOA Trawl Survey	Biomass index	1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021, **2023**
	Lengths	1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021, **2023**

Table 3.4. Sample sizes for age and length data. Japanese fishery data are from Sasaki (1985), U.S. fishery data are from the observer databases, and longline survey data are from longline survey databases. Trawl survey data are from AKFIN. All fish were sexed before measurement, except for the Japanese fishery data.

	Age Samples			Length Samples				
Year	**Japanese Coop LL Survey**	**NOAA LL Survey**	**US Fixed Gear Fishery**	**Japanese Coop LL Survey**	**NOAA LL Survey**	**NOAA GOA Trawl Survey**	**US Fixed Gear Fishery**	**US Trawl Gear Fishery**
1979				19,349				
1980				40,949				
1981	1,146			34,699				
1982				65,092				
1983	889			66,517				
1984				100,029				
1985	1,294			125,129				
1986				128,718				
1987	1,057			102,639				
1988				114,239				
1989	655			115,067				
1990				78,794	101,530	5,115	32,936	1,204
1991	902			69,653	95,364		28,182	655
1992				79,210	104,786		20,929	
1993	1,178			80,596	94,699	7,552	21,943	
1994				74,153	70,431		11,914	
1995					93,413		17,735	
1996		1,176			84,038	4,296	14,416	
1997		1,214			86,690		20,330	
1998		1,191			57,773		8,932	
1999		1,186	1,141		79,451	4,020	28,070	447
2000		1,236	1,148		62,513		32,208	471
2001		1,214	1,003		83,726	3,501	30,315	422
2002		1,136	1,059		75,937		33,719	527
2003		1,128	1,185		77,668	4,949	36,077	463
2004		1,185	1,145		82,767		31,199	717
2005		1,187	1,114		74,433	4,607	36,213	2,541
2006		1,178	1,154		77,758		32,497	898
2007		1,174	1,115		73,480	3,665	29,854	2,142
2008		1,184	1,164		71,661		23,414	2,268
2009		1,197	1,126		67,978	3,455	24,674	1,897
2010		1,176	1,159		75,010		24,530	1,634
2011		1,199	1,190		87,498	2,061	22,659	1,877
2012		1,186	1,165		63,116		22,203	2,533
2013		1,190	1,157		51,586	1,178	16,093	2,674
2014		1,183	1,126		52,290		19,524	2,210
2015		1,190	1,176		52,110	2,027	20,056	2,320
2016		1,197	1,169		66,232		12,857	1,630
2017		1,190	1,190		71,202	2,830	12,345	2,625
2018		1,188	1,174		71,912		13,269	3,306
2019		1,193	1,140		102,725	7,541	13,537	2,620
2020		1,186	1,188		104,723		9,122	9,421
2021		1,189	1,183		91,599	8,166	15,762	7,681
2022		1,193	1,174		76,836		16,152	6,485
2023					67,824	2,790		

Table 3.5. Sablefish abundance or biomass index values used in the assessment model. Relative population number equals CPUE in numbers weighted by respective strata areas (in 1000s of fish). Relative population weight equals CPUE in weight multiplied by strata areas (in kilotons). NMFS trawl survey biomass estimates (kilotons) are from the Gulf of Alaska at depths < 500 m.

	Relative Population Numbers (RPNS)		Relative Population Weights (RPWs) or Biomass				
Year	NOAA Domestic LL Survey*	Japanese COOP LL Survey*	NOAA Domestic LL Survey*	Japanese COOP LL Survey*	NOAA GOA Trawl Survey	Japanese Fishery CPUE	Fixed Gear Fishery CPUE
1964						1,452	
1965						1,806	
1966						2,462	
1967						2,855	
1968						2,336	
1969						2,443	
1970						2,912	
1971						2,401	
1972						2,247	
1973						2,318	
1974						2,295	
1975						1,953	
1976						1,780	
1977						1,511	
1978						942	
1979		413		1,075		809	
1980		387		968		1,040	
1981		458		1,146		1,343	
1982		613		1,572			
1983		621		1,632			
1984		685		1,804			
1985		903		2,569			
1986		838		2,456			
1987		667		2,068			
1988		707		2,088			
1989		661		2,177			
1990	642	449	2,103	1,454	214		
1991	580	386	2,031	1,321			
1992	499	402	1,718	1,390			
1993	550	395	1,842	1,318	250		
1994	477	366	1,846	1,288			
1995	489		1,759				0.35
1996	507		1,941		145		0.34
1997	478		1,850				0.37
1998	475		1,678				0.33
1999	527		1,788		104		0.33
2000	456		1,576				0.33
2001	535		1,780				0.31
2002	551		1,895				0.32
2003	517		1,710		189		0.35
2004	540		1,663				0.33
2005	542		1,654		179		0.36
2006	571		1,844				0.30
2007	509		1,627		111		0.31
2008	461		1,530				0.32
2009	415		1,399		107		0.28
2010	459		1,528				0.26
2011	556		1,680		84		0.25
2012	445		1,294				0.27
2013	421		1,292		60		0.22
2014	484		1,467				0.21
2015	386		1,201		67		0.19
2016	495		1,373				0.17
2017	562		1,399		119		0.19
2018	611		1,260				0.17
2019	900		1,798		211		0.19
2020	1,187		2,614				0.20
2021	1,298		2,888		291		0.27
2022	1,517		3,580				0.37
2023	1,524		3,346		142		

*Indices were extrapolated for survey areas not sampled every year, including Aleutian Islands (1979, 1995, and subsequent odd numbered years) or Bering Sea (1979-1981, 1995, 1996, and subsequent even numbered years).

Table 3.6. Summary of the parameters estimated within the assessment model.

Parameter Name	Symbol	Number of Parameters
Catchability	q	7
Mean recruitment	μ_r	1
Recruitment Variance	σ_R	1
Natural mortality	M	1
Recruitment deviations	τ_y	91
Average fishing mortality	μ_f	2
Fishing mortality deviations	φ_y	125
Fishery selectivity	fs_a	14
Survey selectivity	ss_a	8
Total		249

Table 3.7. Input or adjusted data weights (i.e., 'lambdas') for each data source after Francis data reweighting was applied. Note that the Francis reweighting method assumes fixed weights for the indices.

Data Source	2022 (Model *21.12*)	2023 (Model *23.5*)
Fixed Gear Catch	50.000	50.000
Trawl Catch	50.000	50.000
Longline Survey RPN	0.448	0.448
Coop Survey RPN	0.448	0.448
Fixed Gear Fishery CPUE	0.448	0.448
Japan Longline Fishery CPUE	0.448	0.448
Trawl Survey RPW	0.448	0.448
Fixed Gear Age Composition	0.799	0.798
Longline Survey Age Composition	3.961	3.724
Coop Longline Survey Age Composition	1.142	1.272
Fixed Gear Fishery Length Composition Males	5.592	5.216
Fixed Gear Fishery Length Composition Females	5.099	4.945
Trawl Fishery Size Composition Males	0.272	0.255
Trawl Fishery Size Composition Females	0.372	0.350
Longline Survey Size Composition Males	1.389	1.115
Longline Survey Size Composition Females	1.658	1.500
Coop Survey Size Composition Males	1.086	0.902
Coop Survey Size Composition Females	1.622	1.268
Trawl Survey Size Composition Males	0.599	0.450
Trawl Survey Size Composition Females	0.773	0.673

Table 3.8. Estimates (MLE mean) of sablefish recruitment (millions of age-2 fish), total biomass (kt), and spawning biomass (kt) with lower and upper lower 95% credible intervals (2.5%, 97.5%) from MCMC.

Year	Recruits	2.5% CI	97.5% CI	SSB	2.5% CI	97.5% CI	Biomass	2.5% CI	97.5% CI
1960	28	14	68	282	243	411	694	588	1,096
1961	30	14	73	281	243	411	699	593	1,114
1962	32	15	77	274	237	404	695	587	1,117
1963	34	16	83	262	226	393	685	573	1,114
1964	35	16	86	258	222	389	687	575	1,116
1965	35	16	84	260	223	392	702	588	1,139
1966	33	16	79	262	225	398	713	599	1,153
1967	31	15	70	263	224	402	715	601	1,149
1968	28	14	61	263	224	404	708	600	1,133
1969	25	13	55	257	219	400	686	581	1,103
1970	23	13	49	249	211	392	655	554	1,057
1971	21	12	45	238	201	381	621	524	1,004
1972	20	11	41	225	189	364	580	488	948
1973	19	11	41	205	170	341	528	442	877
1974	19	11	39	191	157	322	494	411	829
1975	9	2	24	177	145	301	453	375	764
1976	10	2	28	164	135	284	417	344	710
1977	11	2	28	151	122	264	380	310	653
1978	14	2	43	141	114	249	358	291	616
1979	84	42	177	138	113	241	426	350	728
1980	42	3	118	135	111	233	464	374	779
1981	19	2	95	134	110	229	482	393	817
1982	74	6	172	137	113	229	553	450	916
1983	36	2	120	145	121	240	592	490	983
1984	14	2	47	160	134	260	604	501	991
1985	16	2	54	177	149	284	605	505	982
1986	24	4	58	194	164	309	607	510	972
1987	10	2	29	202	171	322	576	485	919
1988	7	2	20	202	170	326	531	447	852
1989	8	2	22	194	162	317	481	403	776
1990	12	3	27	182	151	301	436	364	709
1991	23	12	47	168	139	282	411	340	674
1992	8	1	21	155	127	261	378	313	619
1993	24	16	49	142	117	239	367	303	603
1994	7	2	17	129	106	218	340	280	564
1995	7	1	18	118	96	200	315	259	518
1996	12	5	27	111	90	188	297	245	492
1997	20	11	41	106	86	178	293	241	486
1998	10	2	24	102	83	170	282	232	465
1999	36	25	72	98	80	164	301	248	500
2000	16	3	37	95	78	158	304	249	504
2001	16	3	39	92	75	153	305	250	504
2002	43	26	83	91	75	153	335	274	557
2003	13	3	33	93	76	155	338	277	562
2004	10	2	24	95	77	159	332	272	551
2005	12	5	27	97	79	164	323	264	539
2006	8	2	18	101	81	169	309	252	512
2007	10	4	23	103	84	174	296	242	495
2008	10	3	21	104	84	176	282	229	470
2009	16	7	33	102	83	173	275	224	460
2010	21	11	43	100	80	168	278	225	464
2011	10	3	25	96	78	162	272	221	457
2012	11	5	25	92	74	156	265	216	444
2013	5	1	12	88	71	150	250	204	419
2014	8	2	17	85	69	146	237	191	397
2015	14	7	30	84	67	144	233	189	390
2016	50	35	89	83	66	141	269	217	453
2017	22	10	47	82	66	140	286	231	479
2018	95	68	170	82	66	140	382	306	645
2019	87	59	161	85	68	144	483	390	813
2020	41	9	88	94	75	157	540	434	906
2021	75	46	154	109	87	182	627	506	1,053
2022	43	8	97	131	105	218	677	543	1,119
2023				157	126	260	695	557	1,148

Table 3.9. Key parameter estimates along with their uncertainty, including 95% credible intervals from MCMC analysis. Recruitment year classes are in millions of fish and SSB is in kilotons (kt).

Parameter or Quantity	μ (MLE)	σ *(MLE)*	μ (MCMC)	Median (MCMC)	σ *(MLE)*	97.5% CI	2.5% CI
q (LL Survey)	6.41	0.93	5.96	6.00	0.99	7.75	3.91
q (Coop LL Survey)	4.60	0.64	4.27	4.31	0.69	5.53	2.84
q (Trawl Survey)	0.86	0.18	0.76	0.75	0.17	1.12	0.46
Natural Mortality	0.11	0.01	0.12	0.12	0.01	0.14	0.10
ln Mean Recruit	3.29	0.19	3.38	3.36	0.23	3.89	2.99
Recruit Variance	1.04	0.10	1.23	1.22	0.11	1.45	1.02
Projected Catch (Terminal+1)	47.50	7.41	51.99	50.31	10.17	77.60	36.90
Terminal SSB	156.65	24.35	174.27	167.67	34.15	259.65	125.89
2014 Year Class	49.54	9.96	55.32	52.81	13.83	88.60	34.84
2016 Year Class	95.37	19.45	106.50	101.66	26.22	170.34	68.41
2017 Year Class	86.48	20.31	99.76	95.69	26.75	161.21	59.12
2018 Year Class	40.60	18.04	41.32	38.90	20.94	88.17	8.60
2019 Year Class	75.09	21.00	87.94	83.78	27.71	154.12	45.87
Last Estimated Year Class	42.69	19.86	43.22	40.57	23.01	96.98	8.04

Table 3.10. Comparison of the 2022 SAFE model (*21.12*) estimates and the 2023 SAFE model (*23.5*) estimates.

	Recruits (millions)			SSB (kt)			Biomass (kt)		
Year	2022 SAFE	2023 SAFE	Difference (%)	2022 SAFE	2023 SAFE	Difference (%)	2022 SAFE	2023 SAFE	Difference (%)
1960	23.5	28.0	16	208.9	281.5	26	794.8	693.7	-15
1961	22.7	29.7	24	240.7	281.0	14	819.2	699.3	-17
1962	20.3	31.7	36	274.9	274.0	0	817.4	695.1	-18
1963	17.9	33.6	47	301.8	262.4	-15	794.5	684.7	-16
1964	16.2	34.7	53	323.3	258.0	-25	773.6	687.3	-13
1965	15.5	35.1	56	337.2	259.5	-30	757.1	701.7	-8
1966	15.7	33.4	53	340.8	262.0	-30	735.9	713.2	-3
1967	16.5	30.7	46	334.4	262.6	-27	706.9	714.6	1
1968	17.6	27.8	37	322.1	262.6	-23	675.2	708.3	5
1969	19.0	25.4	25	301.2	257.4	-17	634.6	686.3	8
1970	21.2	23.2	9	276.4	249.0	-11	593.2	655.4	9
1971	22.3	21.3	-5	250.9	238.4	-5	555.9	621.3	11
1972	19.5	19.8	1	224.3	224.5	0	513.8	579.7	11
1973	16.0	18.8	15	195.1	204.7	5	461.4	528.1	13
1974	14.7	18.6	21	175.6	190.8	8	426.1	493.9	14
1975	15.3	9.1	-68	158.7	176.8	10	395.2	452.8	13
1976	13.2	10.3	-29	145.4	164.4	12	368.3	416.9	12
1977	10.8	10.9	1	131.8	150.5	12	337.8	379.8	11
1978	12.0	13.7	12	123.7	141.4	13	319.6	357.5	11
1979	70.8	84.0	16	122.3	138.4	12	378.0	425.6	11
1980	48.7	41.8	-17	121.1	135.1	10	425.8	464.2	8
1981	17.5	19.3	10	122.7	134.2	9	446.1	482.2	7
1982	51.5	74.3	31	126.7	136.6	7	496.3	553.4	10
1983	40.0	36.2	-11	136.2	145.1	6	538.3	592.4	9
1984	31.3	14.3	-119	151.1	159.7	5	569.9	603.7	6
1985	6.6	16.0	59	168.4	177.0	5	568.2	604.8	6
1986	20.9	23.9	13	185.4	194.0	4	572.0	606.9	6
1987	13.8	10.1	-37	193.7	202.3	4	549.3	576.2	5
1988	4.2	7.2	41	194.4	202.3	4	505.9	531.1	5
1989	5.5	8.4	34	188.0	194.2	3	456.3	480.7	5
1990	11.0	11.7	6	177.4	181.8	2	414.3	436.4	5
1991	22.4	22.8	2	165.1	168.1	2	391.0	410.7	5
1992	5.4	7.9	32	152.4	154.6	1	358.4	378.1	5
1993	23.7	24.3	2	140.1	141.8	1	348.5	366.8	5
1994	5.5	6.8	19	127.4	128.9	1	322.3	340.1	5
1995	6.8	7.3	6	116.6	118.1	1	298.4	314.8	5
1996	10.7	12.2	12	109.1	110.7	1	281.0	297.3	5
1997	19.8	20.3	2	104.0	105.5	1	277.6	292.8	5
1998	8.1	10.1	20	100.1	101.5	1	266.7	282.4	6
1999	34.5	36.4	5	96.6	98.0	1	285.0	301.4	5
2000	14.8	16.0	8	93.6	94.8	1	287.9	304.3	5
2001	14.8	16.2	9	90.5	91.7	1	288.1	304.7	5
2002	40.9	42.6	4	90.1	91.4	1	317.7	334.9	5
2003	12.0	13.3	10	91.4	92.6	1	320.7	337.8	5
2004	9.2	9.9	7	93.5	94.8	1	315.6	331.8	5
2005	11.2	11.8	5	96.1	97.4	1	308.1	323.2	5
2006	6.9	7.6	9	99.4	100.5	1	294.9	308.9	5
2007	9.6	10.2	6	102.4	103.2	1	283.4	296.1	4
2008	9.2	9.7	5	103.2	103.7	0	270.1	281.6	4
2009	14.5	15.7	8	102.2	102.4	0	263.8	274.9	4
2010	21.4	21.3	-1	99.8	99.6	0	268.0	277.6	3
2011	8.6	10.3	17	96.8	96.2	-1	262.2	271.9	4
2012	11.9	11.2	-7	93.0	92.1	-1	257.7	265.3	3
2013	3.8	4.7	19	89.4	88.2	-1	243.3	250.2	3
2014	7.2	7.5	3	86.7	85.3	-2	230.9	236.7	2
2015	14.6	14.4	-1	85.6	83.9	-2	228.4	232.7	2
2016	48.4	49.5	2	84.8	82.8	-2	265.3	269.4	2
2017	22.3	21.7	-3	84.4	82.1	-3	284.3	286.4	1
2018	91.6	95.4	4	84.8	82.3	-3	377.3	381.8	1
2019	77.7	86.5	10	88.0	85.4	-3	470.1	482.9	3
2020	44.2	40.6	-9	96.2	93.5	-3	531.5	540.4	2
2021	90.5	75.1	-21	111.8	108.7	-3	636.8	626.7	-2
2022	16.3	42.7	62	133.8	130.6	-2	664.8	676.7	2

Table 3.11. Sablefish spawning biomass (tons), fishing mortality, and yield (tons) for the seven projection harvest scenarios (columns) outlined in the 'Population Projections' section. The 'Specified Catch' scenario uses the proportion of the ABC utilized in 2023 (based on projected catch through the end of the year) to set the realized yield for 2024 and 2025.

Year	Maximum Permissible F	Author's F (Specified Catches)	Half maximum F	5-year Average F	No Fishing	Overfished	Approaching Overfished
				Spawning biomass (t)			
2023	156,651	156,651	156,651	156,651	156,651	156,651	156,651
2024	185,079	185,079	185,079	185,079	185,079	185,079	185,079
2025	203,611	209,500	212,231	209,806	221,218	200,643	203,611
2026	215,170	228,076	233,714	228,420	253,874	208,963	215,170
2027	219,220	232,195	247,936	239,618	280,471	209,876	216,024
2028	216,630	229,131	254,761	243,557	299,745	204,562	210,397
2029	209,391	220,989	255,525	241,784	312,126	195,179	200,513
2030	199,787	210,221	252,312	236,465	319,224	184,019	188,748
2031	189,583	198,750	247,000	229,467	322,802	172,764	176,858
2032	179,790	187,708	240,832	221,980	324,179	162,314	165,801
2033	170,874	177,638	234,523	214,660	324,211	153,037	155,973
2034	163,029	168,764	228,487	207,863	323,472	145,043	147,498
2035	156,280	161,120	222,941	201,754	322,336	138,318	140,347
2036	150,553	154,620	217,962	196,367	321,029	132,794	134,448
				Fishing mortality			
2023	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2024	0.09	0.06	0.04	0.05	-	0.10	0.10
2025	0.09	0.06	0.04	0.05	-	0.10	0.10
2026	0.09	0.09	0.04	0.05	-	0.10	0.10
2027	0.09	0.09	0.04	0.05	-	0.10	0.10
2028	0.09	0.09	0.04	0.05	-	0.10	0.10
2029	0.09	0.09	0.04	0.05	-	0.10	0.10
2030	0.09	0.09	0.04	0.05	-	0.10	0.10
2031	0.09	0.09	0.04	0.05	-	0.10	0.10
2032	0.09	0.09	0.04	0.05	-	0.10	0.10
2033	0.09	0.09	0.04	0.05	-	0.10	0.10
2034	0.09	0.09	0.04	0.05	-	0.10	0.10
2035	0.09	0.09	0.04	0.05	-	0.10	0.10
2036	0.09	0.09	0.04	0.05	-	0.10	0.10
				Yield (t)			
2023	27,160	27,160	27,160	27,160	27,160	27,160	27,160
2024	47,367	31,485	24,138	30,664	-	55,385	47,367
2025	46,361	30,816	24,535	30,843	-	53,489	46,361
2026	44,536	46,905	24,436	30,412	-	50,735	52,069
2027	42,336	44,441	24,026	29,621	-	47,666	48,833
2028	40,051	41,881	23,438	28,648	-	44,618	45,618
2029	37,845	39,413	22,764	27,608	-	41,772	42,616
2030	35,812	37,140	22,066	26,576	-	39,216	39,921
2031	34,043	35,158	21,407	25,630	-	37,040	37,623
2032	32,556	33,488	20,817	24,799	-	35,246	35,726
2033	31,293	32,067	20,283	24,063	-	33,746	34,141
2034	30,203	30,845	19,796	23,402	-	32,409	32,763
2035	29,254	29,795	19,355	22,814	-	31,111	31,443
2036	28,429	28,899	18,969	22,308	-	29,955	30,251

Figures

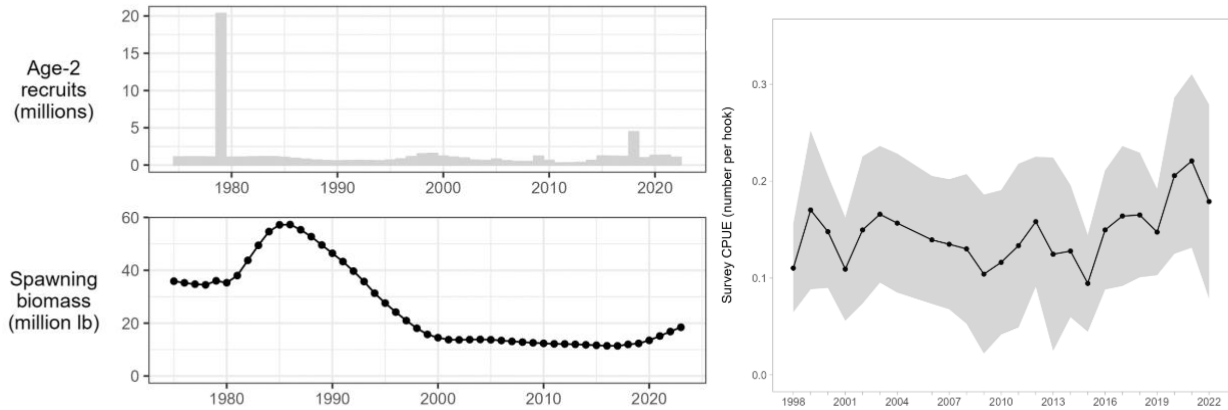


Figure 3.1a. Model predictions for the ADFG Northern Southeast Inside (NSEI) sablefish stock assessment (left panels; reproduced here with permission from Phil Joy, pers. comm., https://github.com/commfish/seak_sablefish) of age-2 recruitment (millions; top) and female spawning stock biomass (million pounds; bottom). Southern Southeast Inside (SSEI) sablefish longline survey catch-per-unit-effort (CPUE) in individuals per hook (right panel) from 1998 to 2022 (except 2005; reproduced here with permission from Ehresmann and Olson, 2022).

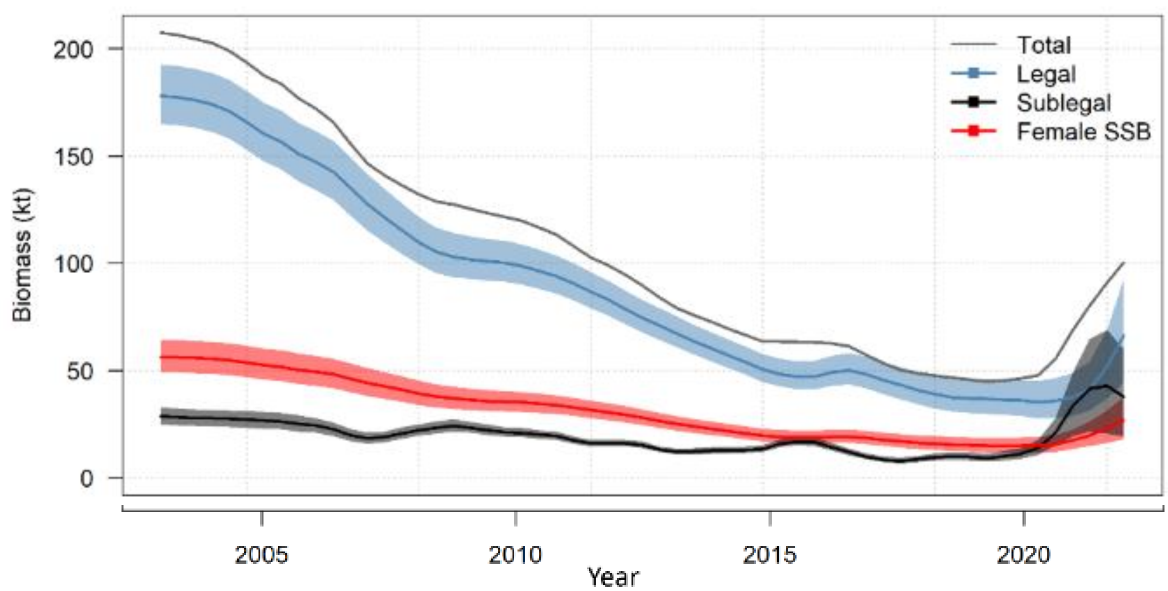


Figure 3.1b. Time series of total biomass, legal-sized biomass, sub-legal-sized biomass, and female spawning biomass (SSB) estimates for the British Columbia stock of sablefish based on weighted averages over the five OM scenarios used in 2022. Note that total, legal, and sub-legal biomass estimates include both female and male fish, while SSB is shown for only female Sablefish (reproduced here with permission from Kendra Holt, DFO Canada, pers. comm.).

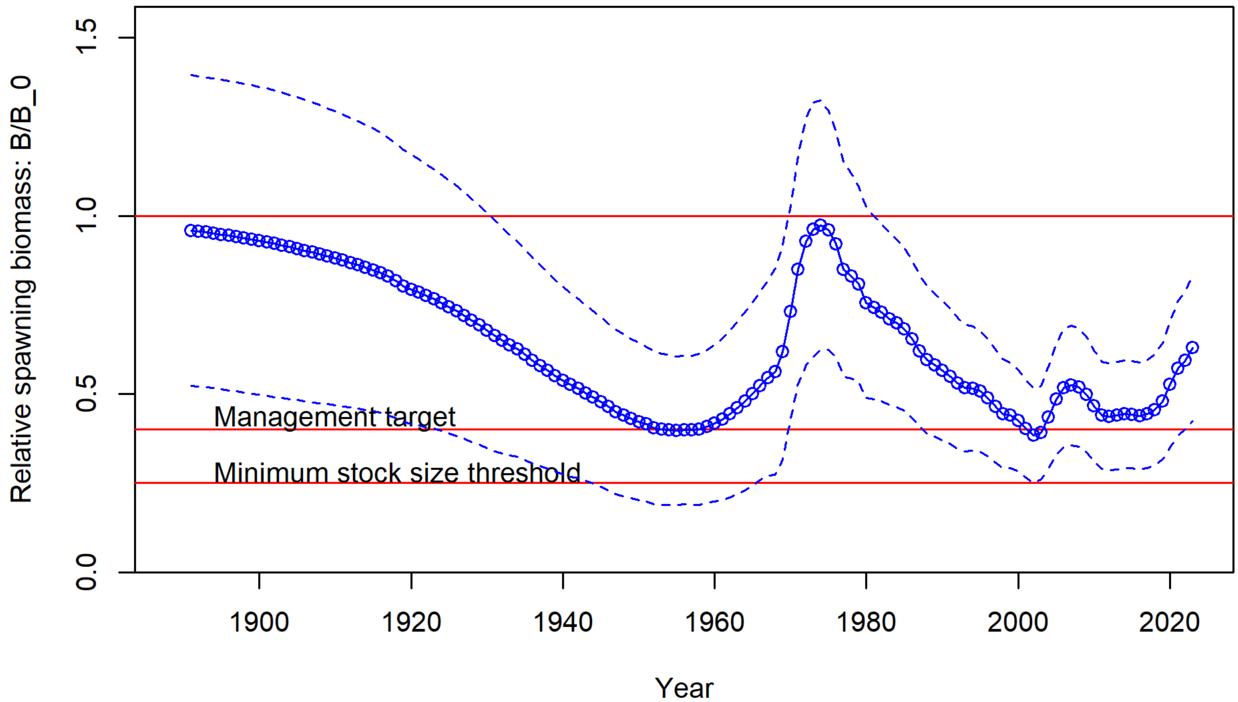


Figure 3.1c. Time series of total biomass relative to the unfished biomass for west coast USA sablefish (reproduced here with permission from Johnson et al. 2023).

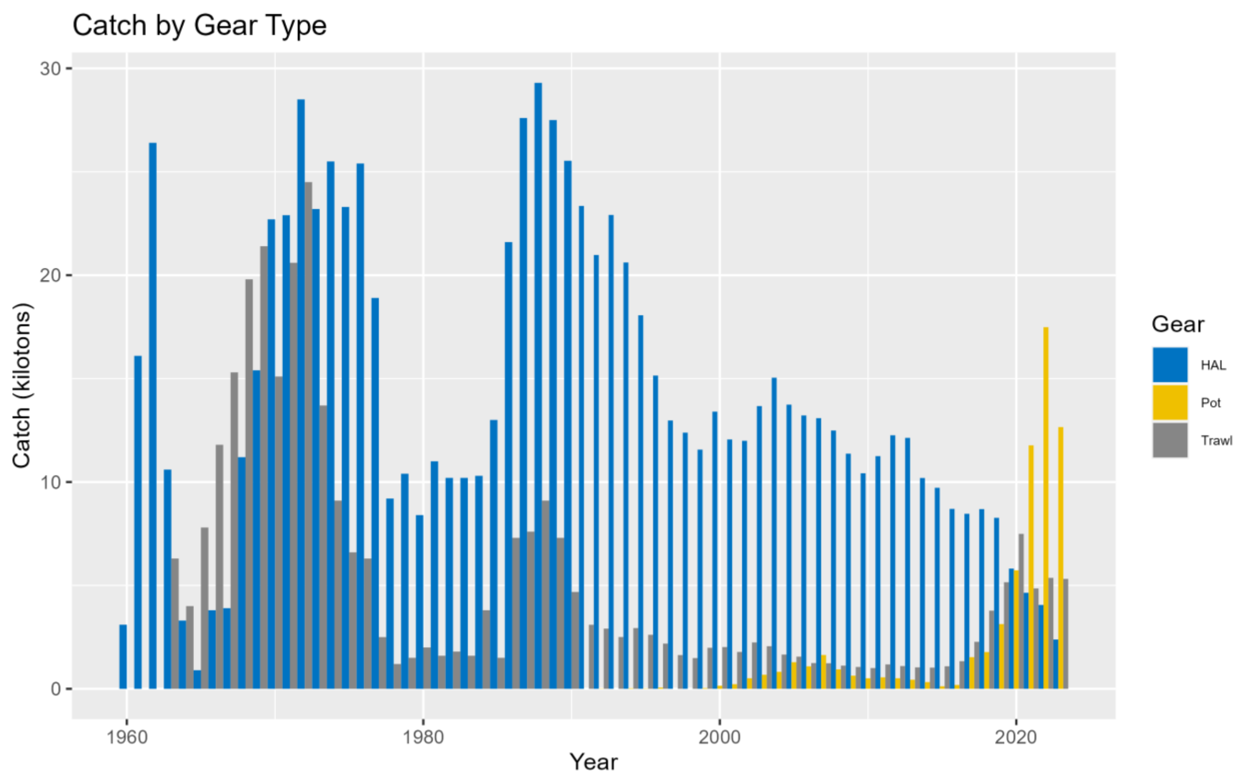


Figure 3.2. Sablefish catch (kt) by gear type. Note that hook and line (HAL) and pot gear catch are combined into a single 'fixed gear' fleet in the model.

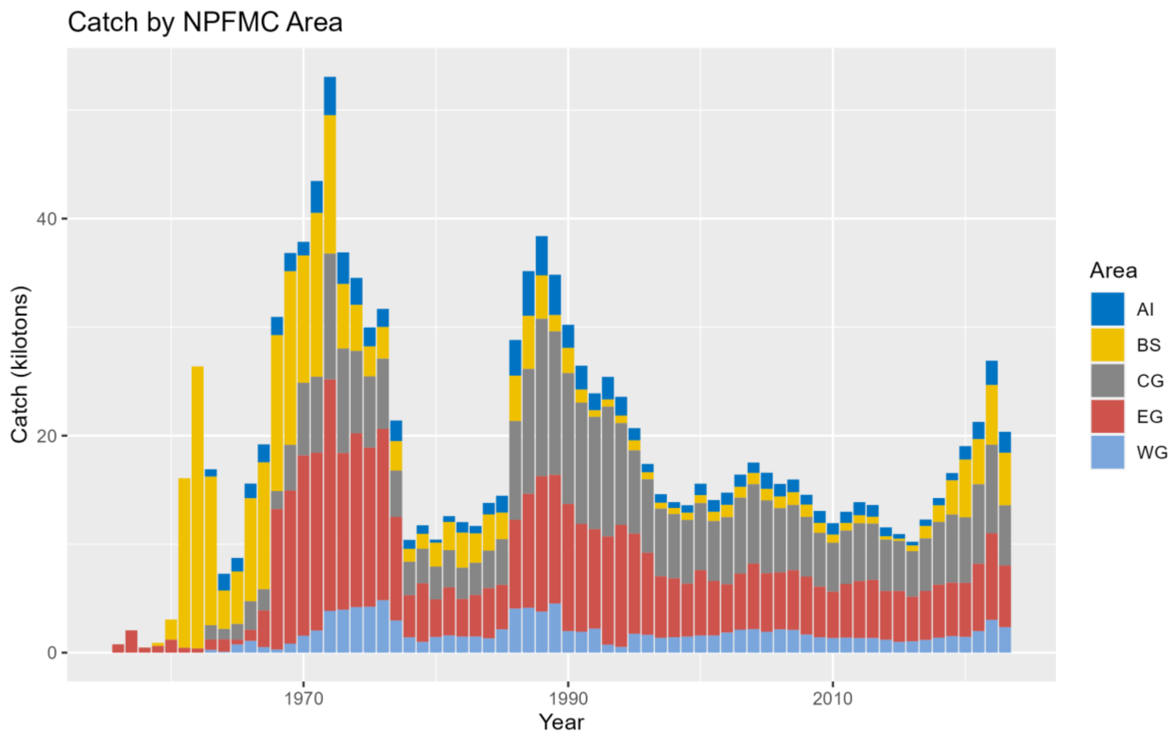


Figure 3.3. Sablefish total catch (kt) summed across all fleets by North Pacific Fishery Management Council area.

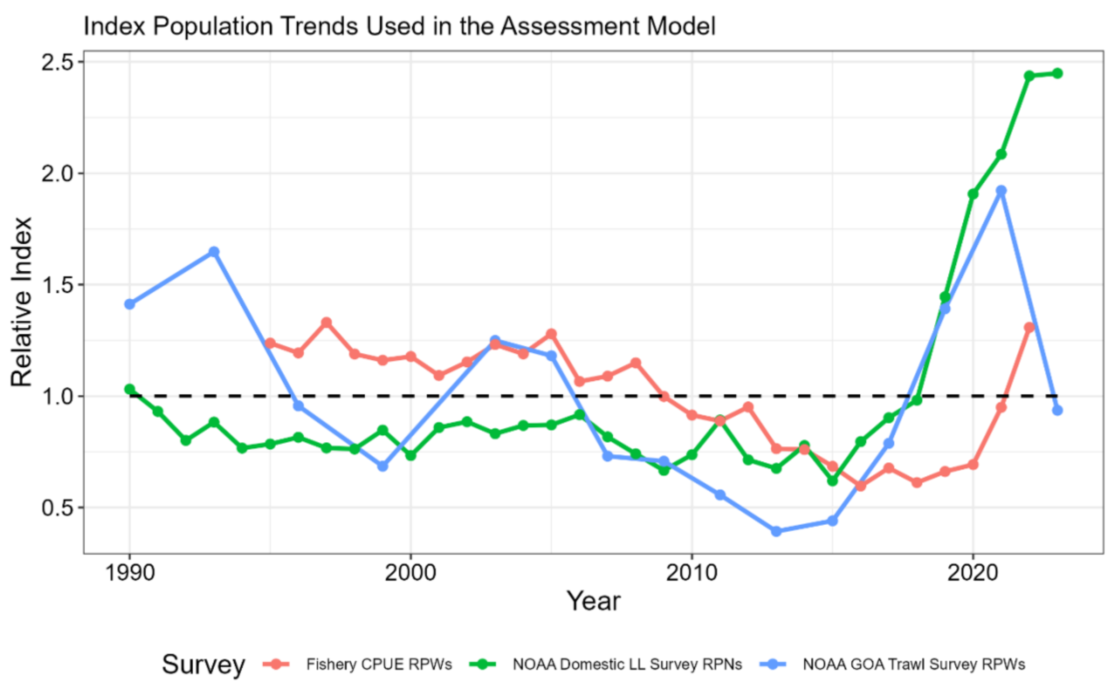


Figure 3.4. Comparison of the three indices used in the stock assessment model, including the NOAA domestic longline survey relative population numbers (RPNs), the fixed gear fishery standardized CPUE (in weight), and the NOAA Gulf of Alaska (stations < 500m depth) trawl survey relative population weights (RPWs). Each index is relativized to the associated mean value for the time series.

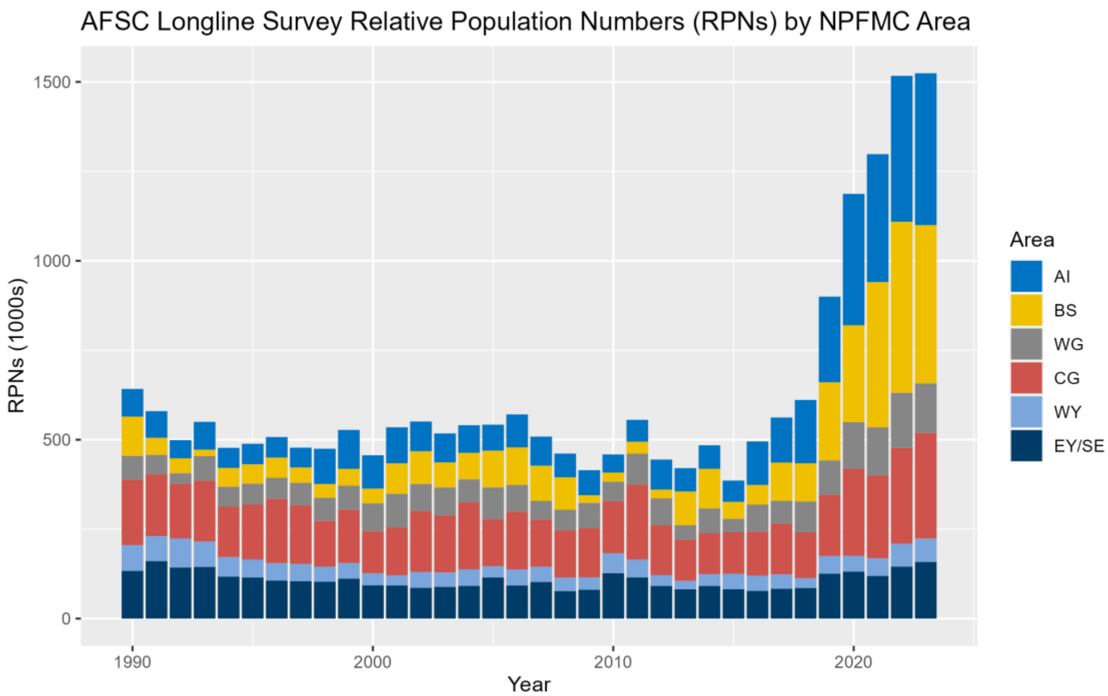


Figure 3.5. Relative abundance (relative population number in thousands) by region from the NOAA domestic longline survey. Note that the Bering Sea is surveyed in odd years and the Aleutian Islands are surveyed in even years (i.e., sampling occurs every other year in these regions), and that regional trends for these regions are extrapolated based on the overall trend from the Gulf of Alaska in off years.

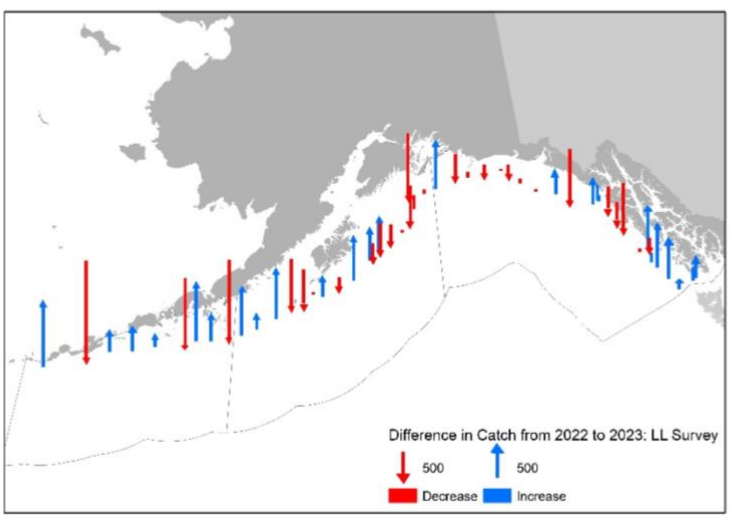


Figure 3.6. Comparison of the 2022 and 2023 longline survey in the Gulf of Alaska in terms of the difference in numbers of fish caught per station from 2022 in the 2023 survey. Numbers are not corrected for sperm whale depredation.

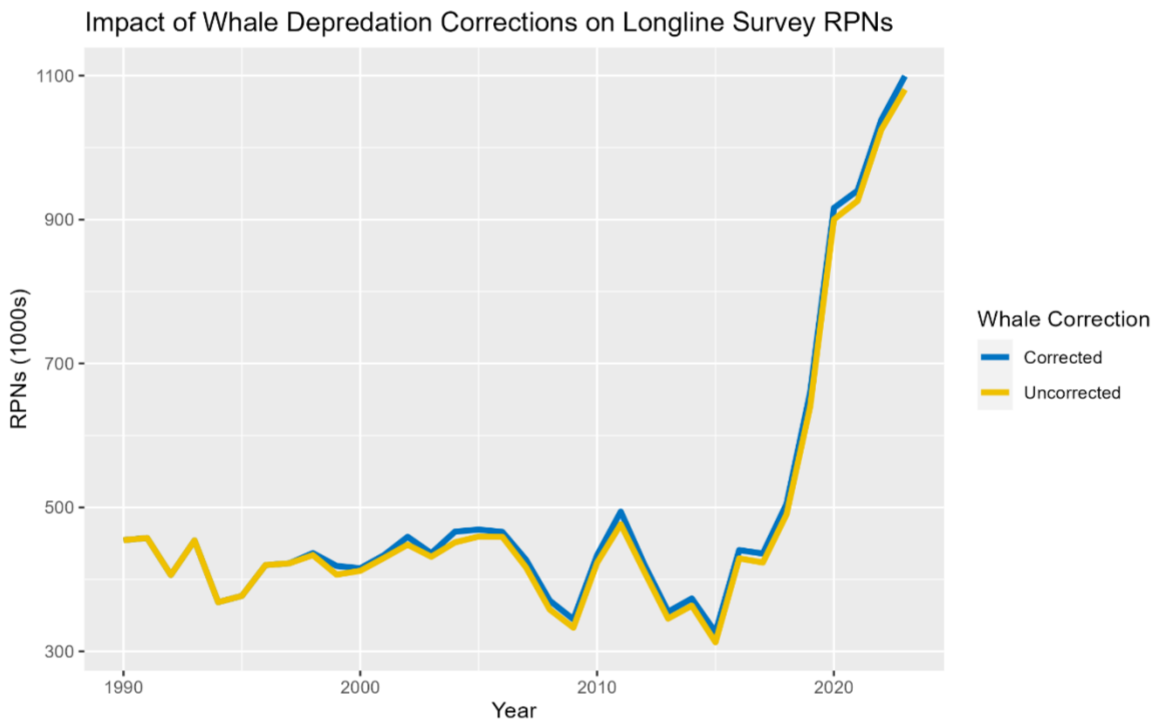


Figure 3.7. Longline survey relative population numbers (1000s of fish) with (blue line) and without (yellow line) corrections for sperm whale depredation.

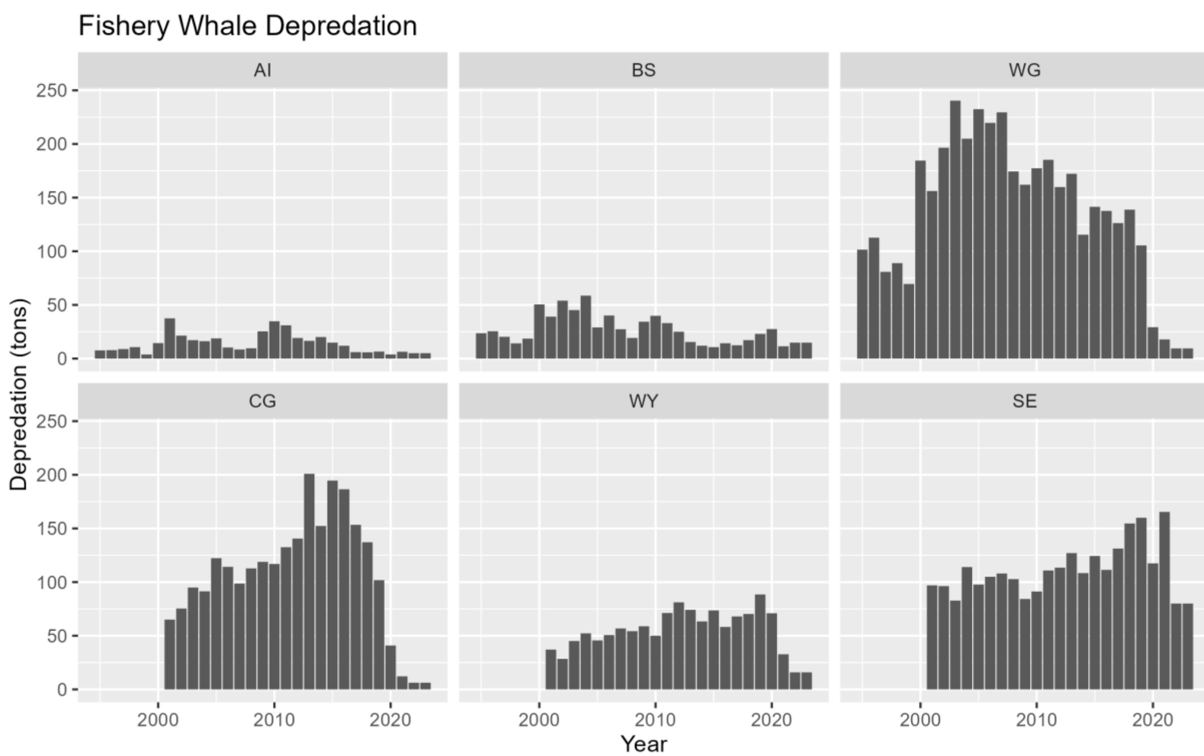


Figure 3.8. Estimated whale depredation in the sablefish fixed gear fishery. Depredation estimates reflect catch removals (tons) by region (panel) due to orcas (top row) and sperm whales (bottom row). Starting in 2023, estimates are held constant at 2022 values.

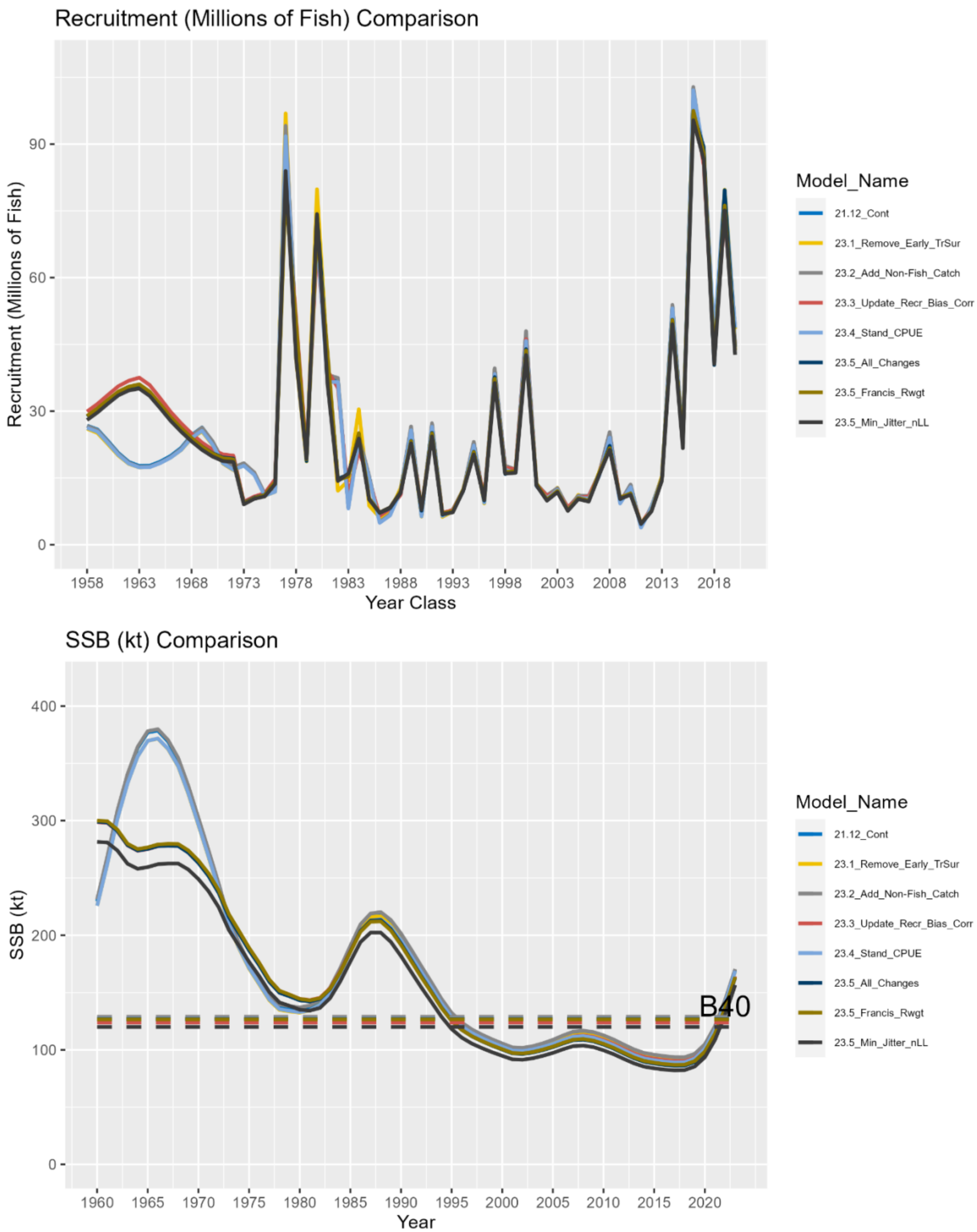
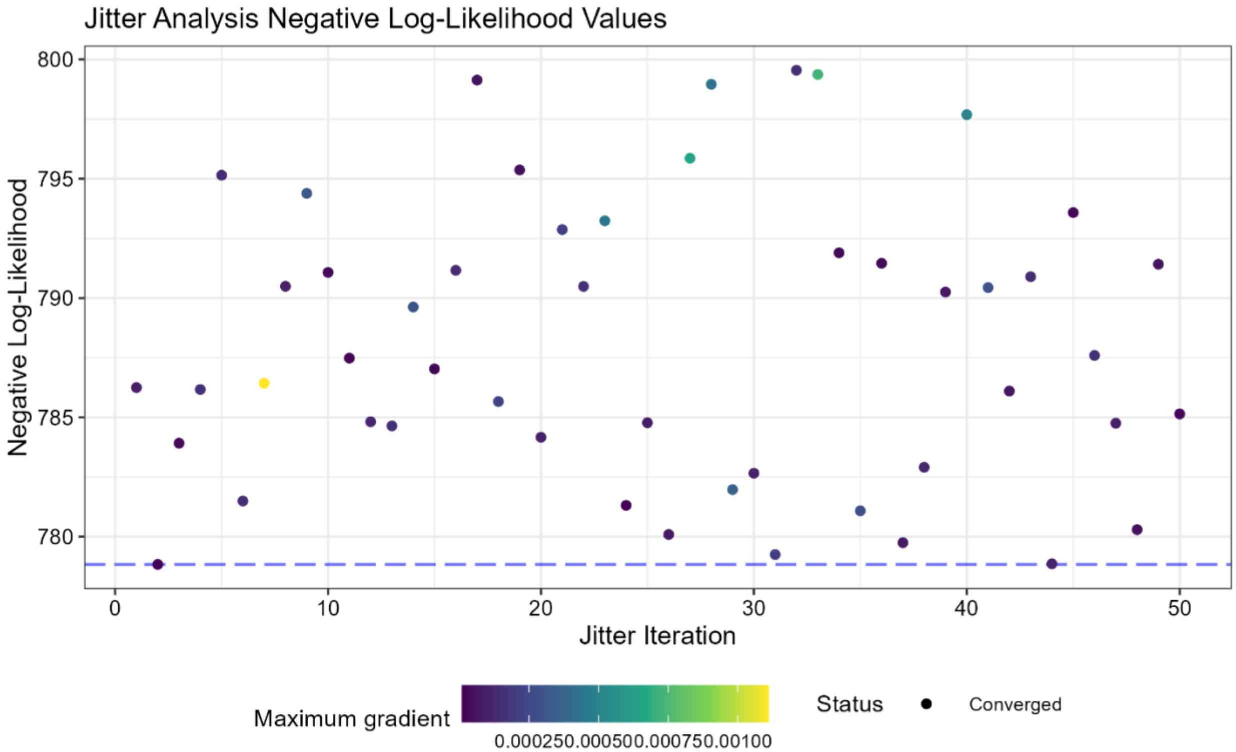


Figure 3.9. Results of the model bridging exercise in terms of recruitment (top panel; millions of fish) and spawning stock biomass (bottom panel; kt). See the main text for a description of each model run.



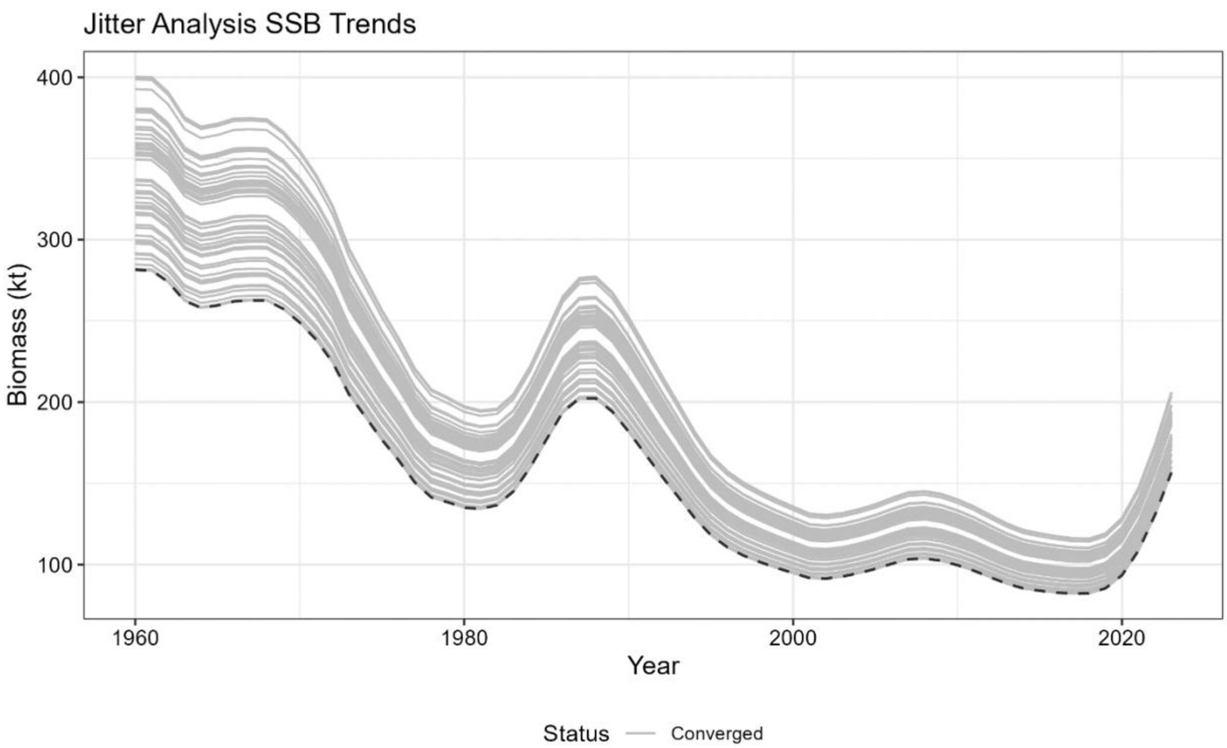
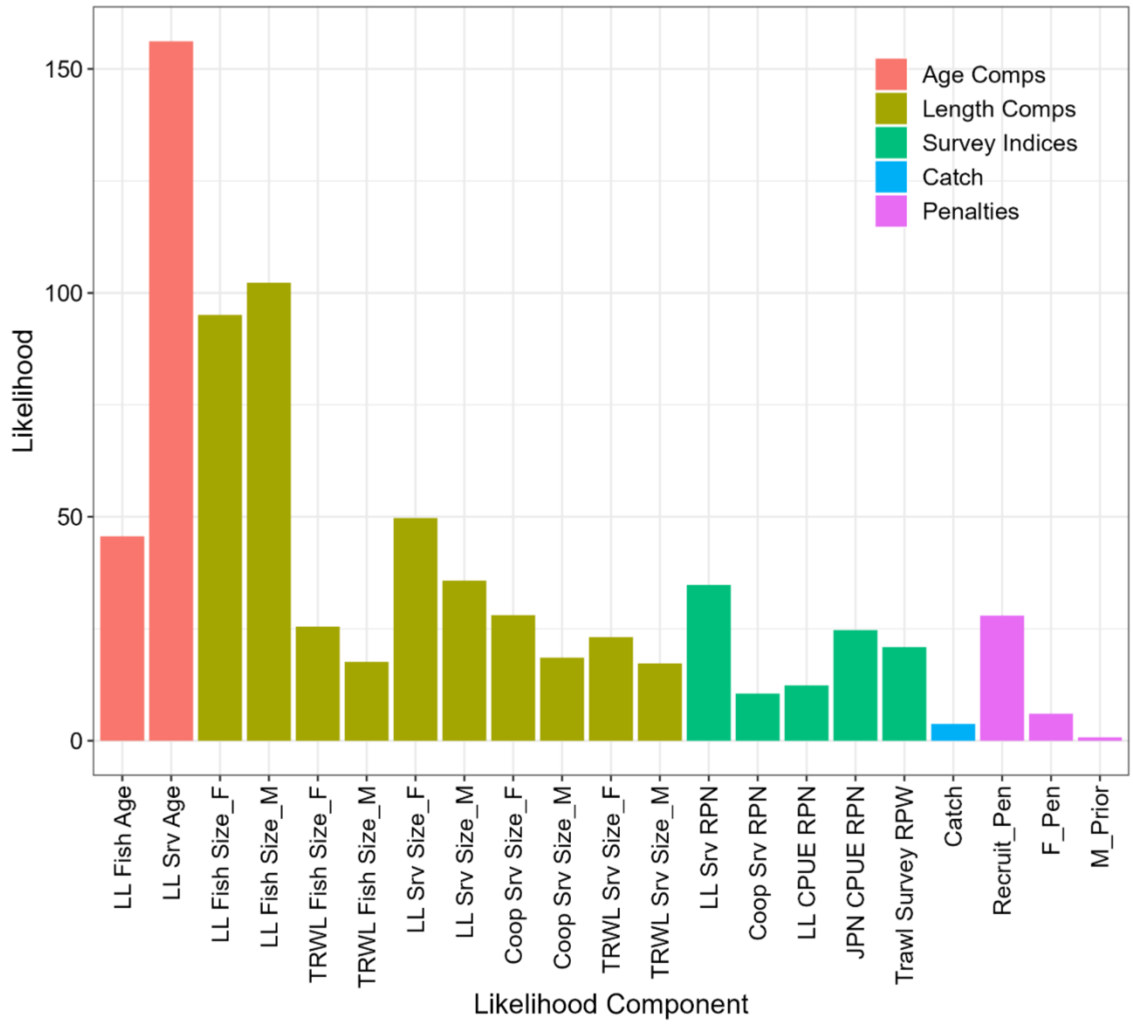


Figure 3.10. Results of the jitter analysis in terms of total negative log-likelihood values (top panel) and SSB estimates (kt; bottom panel). All 50 model runs are shown, and the model run demonstrating the lowest negative log-likelihood is emphasized with the dashed line in both panels.



Converged?	Maximum Gradient	Negative Log-Likehood	# Parameters
TRUE	3.89e-05	778.84	249

Figure 3.11. Contributions to the total negative log-likelihood by data component.

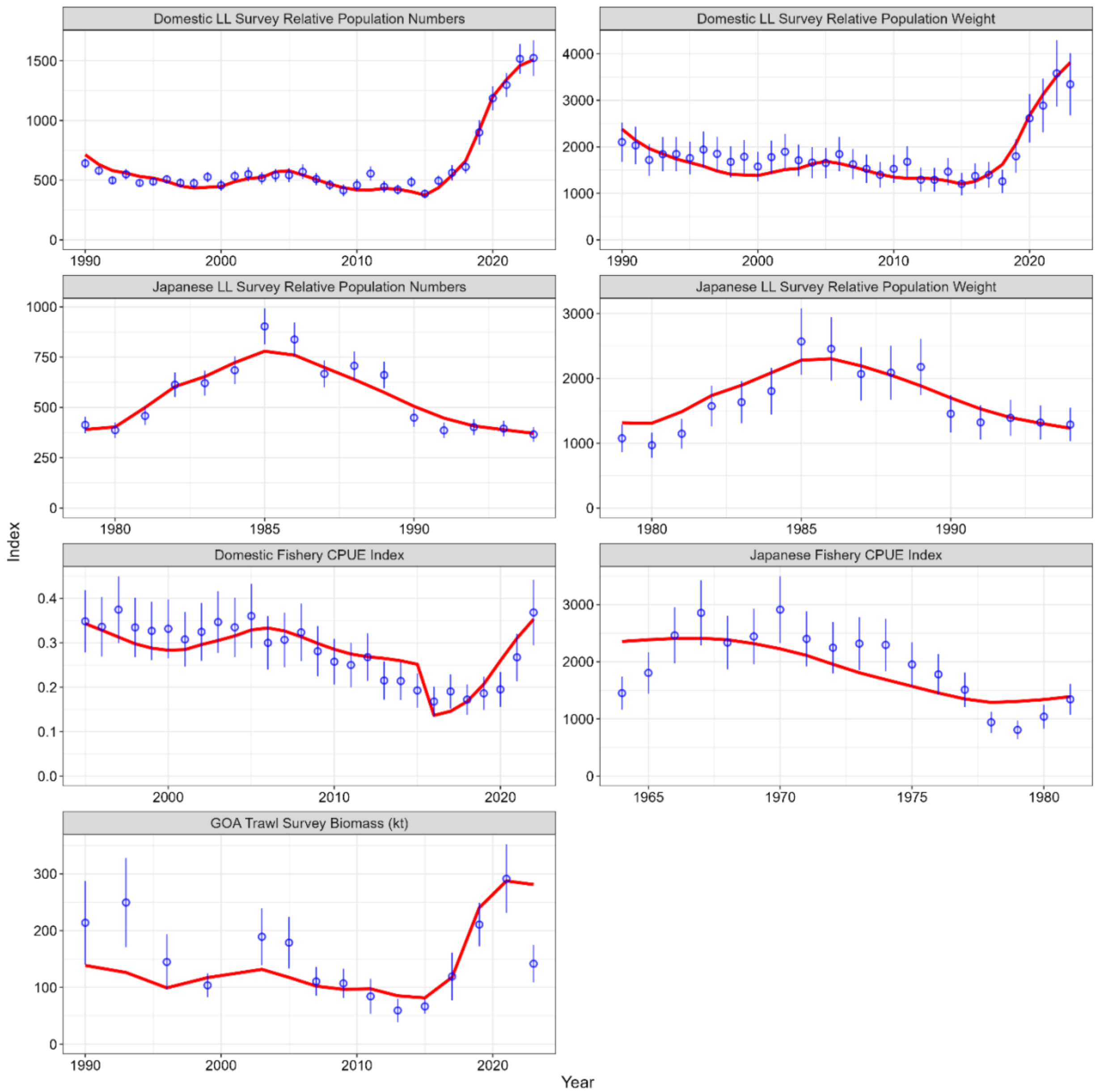


Figure 3.12. Observed (blue dots with approximate 95% confidence intervals) and predicted (red lines) sablefish indices of abundance and biomass. By row, these indices are: the NOAA domestic longline survey (top panels) relative population numbers (1,000s of fish; left) and weight (kt; right); the Japanese cooperative survey (second row) relative population numbers (1,000s of fish; left) and weight (kt; right); fishery CPUE indices (in weight; third row) for the domestic fishery (standardized; left) and historic Japanese fishery (kt; right); and the NOAA Gulf of Alaska (stations < 500m depth) trawl survey (kt; bottom panel) relative population weight. For the NOAA and Japanese longline surveys, only the relative population numbers are fit in the model, but the associated weights are presented for comparison.

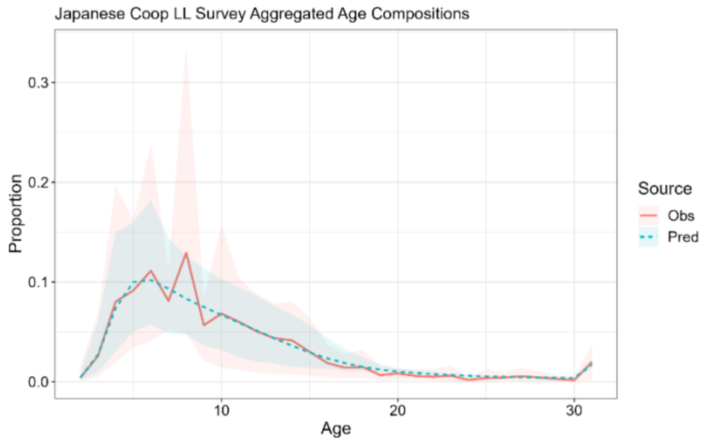


Figure 3.13. Mean observed (red line) Japanese cooperative longline survey age compositions aggregated across years and sexes along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals.

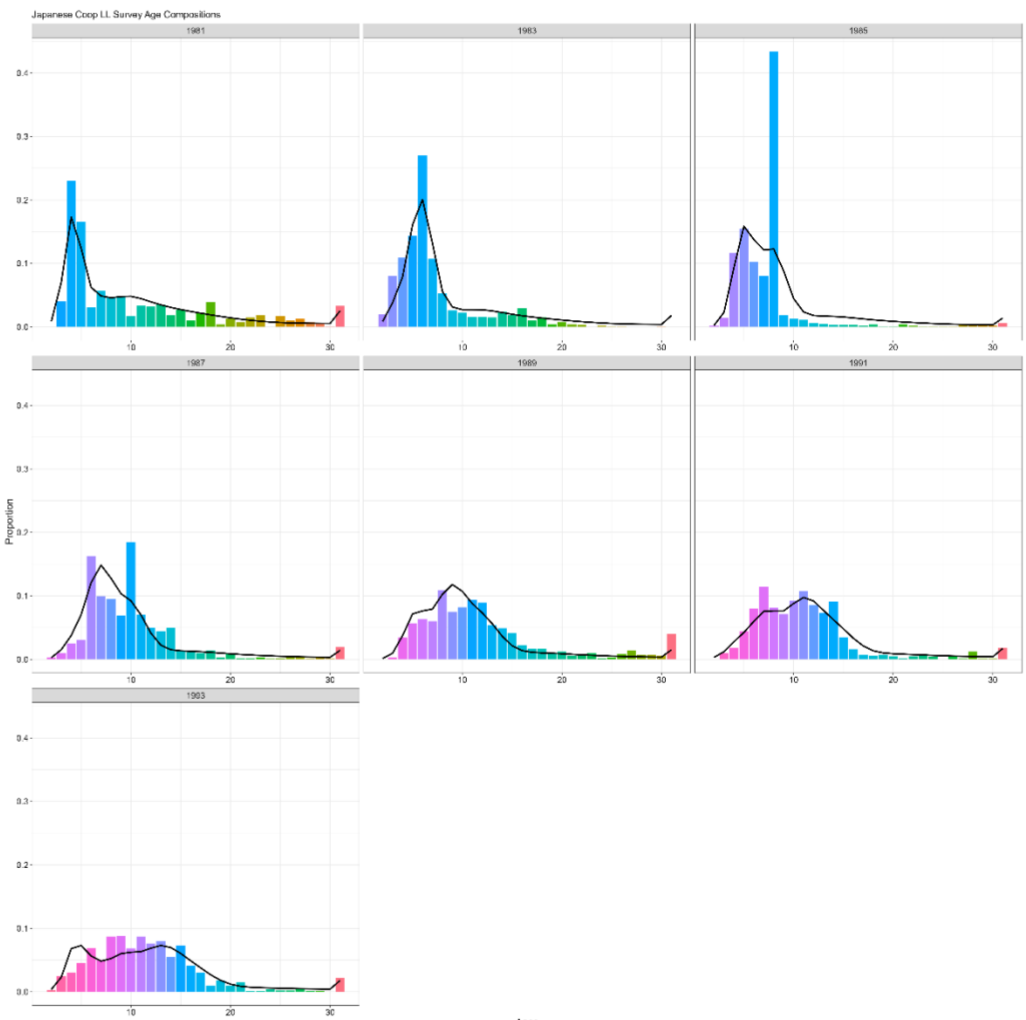


Figure 3.14. Japanese cooperative longline survey age compositions. Bars are observed frequencies and the line is predicted frequencies.

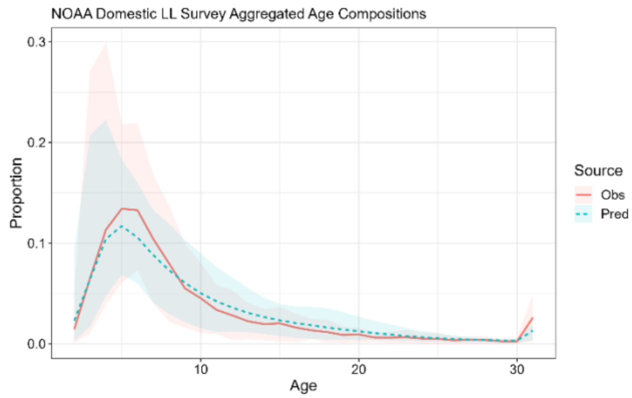


Figure 3.15. Mean observed (red line) NOAA domestic longline survey age compositions aggregated across years and sexes along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals.

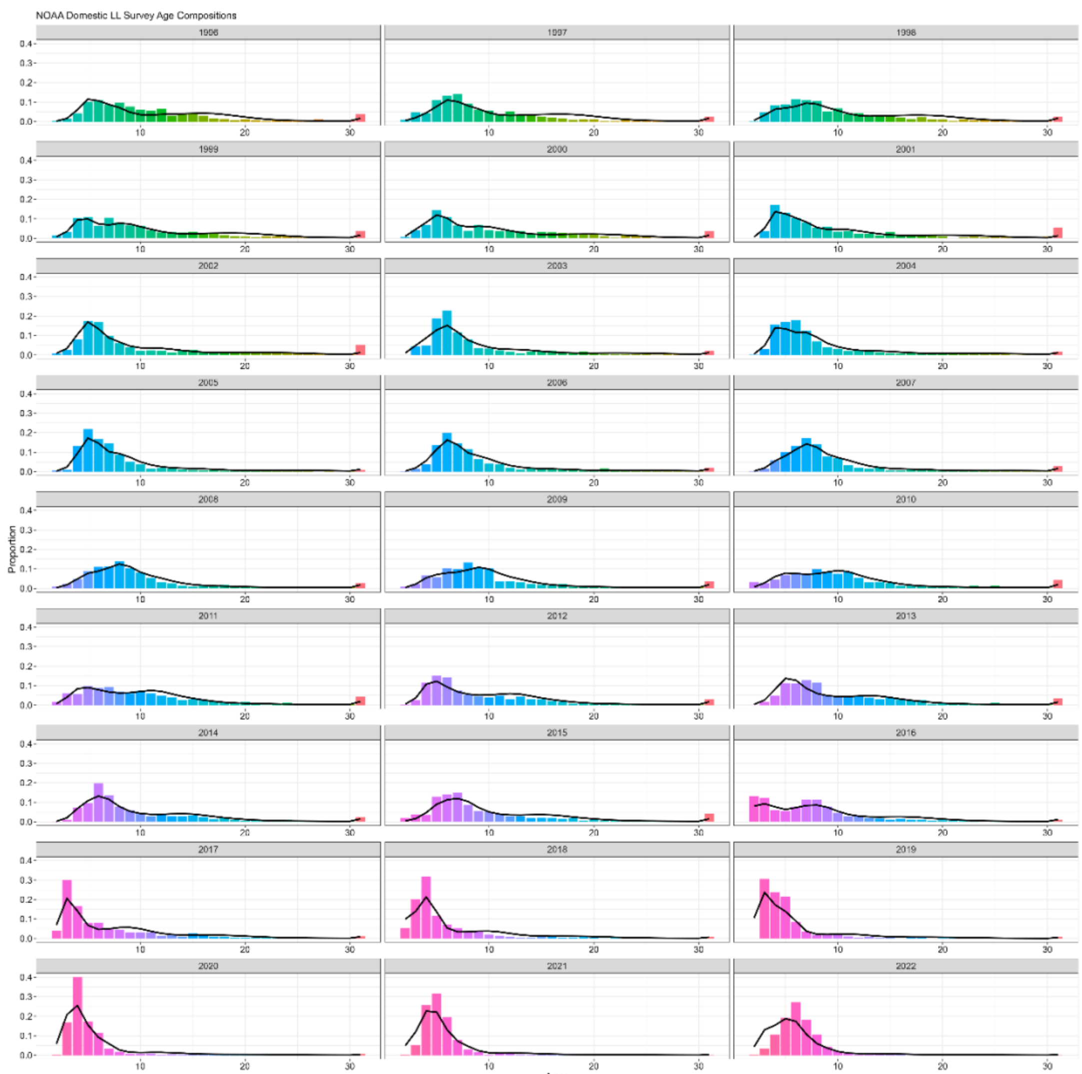


Figure 3.16. NOAA domestic longline survey age compositions. Bars are observed frequencies and lines are predicted frequencies.

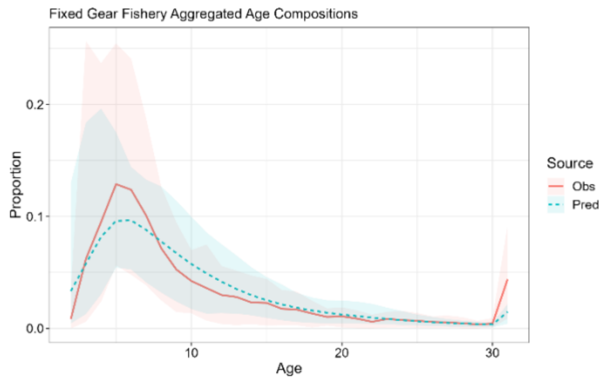


Figure 3.17. Mean observed (red line) fixed gear fishery age compositions aggregated across years and sexes along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals.

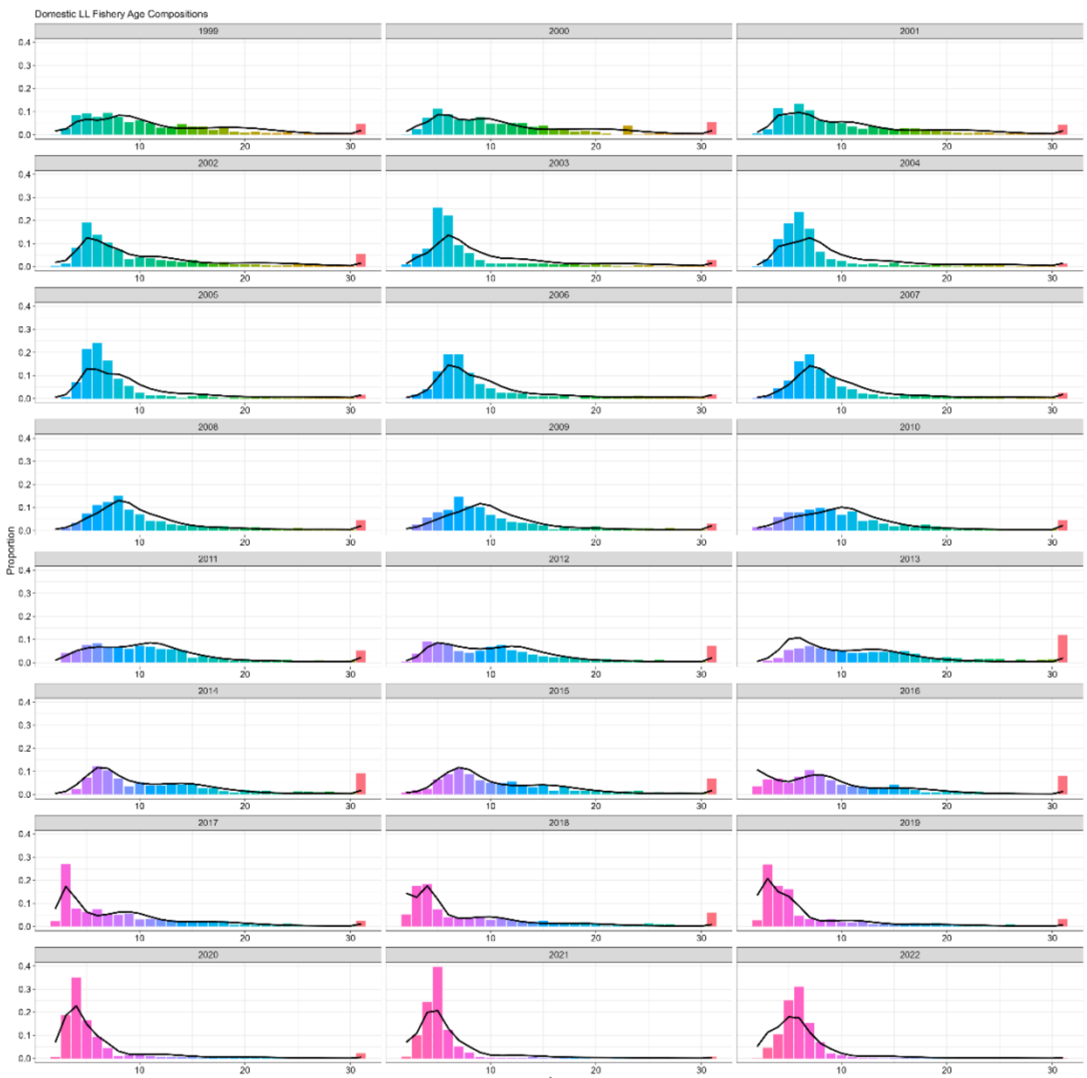


Figure 3.18. Domestic fixed gear fishery age compositions. Bars are observed frequencies and lines are predicted frequencies.

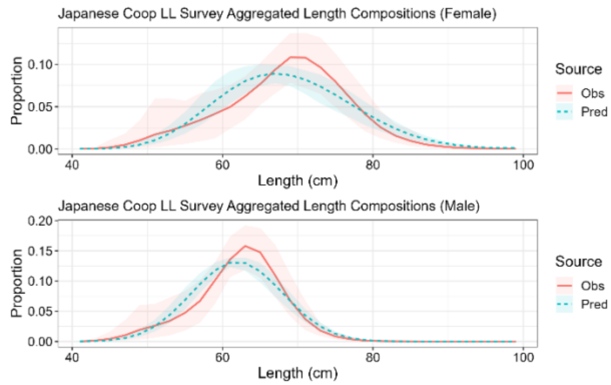


Figure 3.19. Mean observed (red line) Japanese cooperative longline survey length compositions aggregated across years along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals. Fit to female length compositions are in the top panel and fit to male length compositions are in the bottom panel.

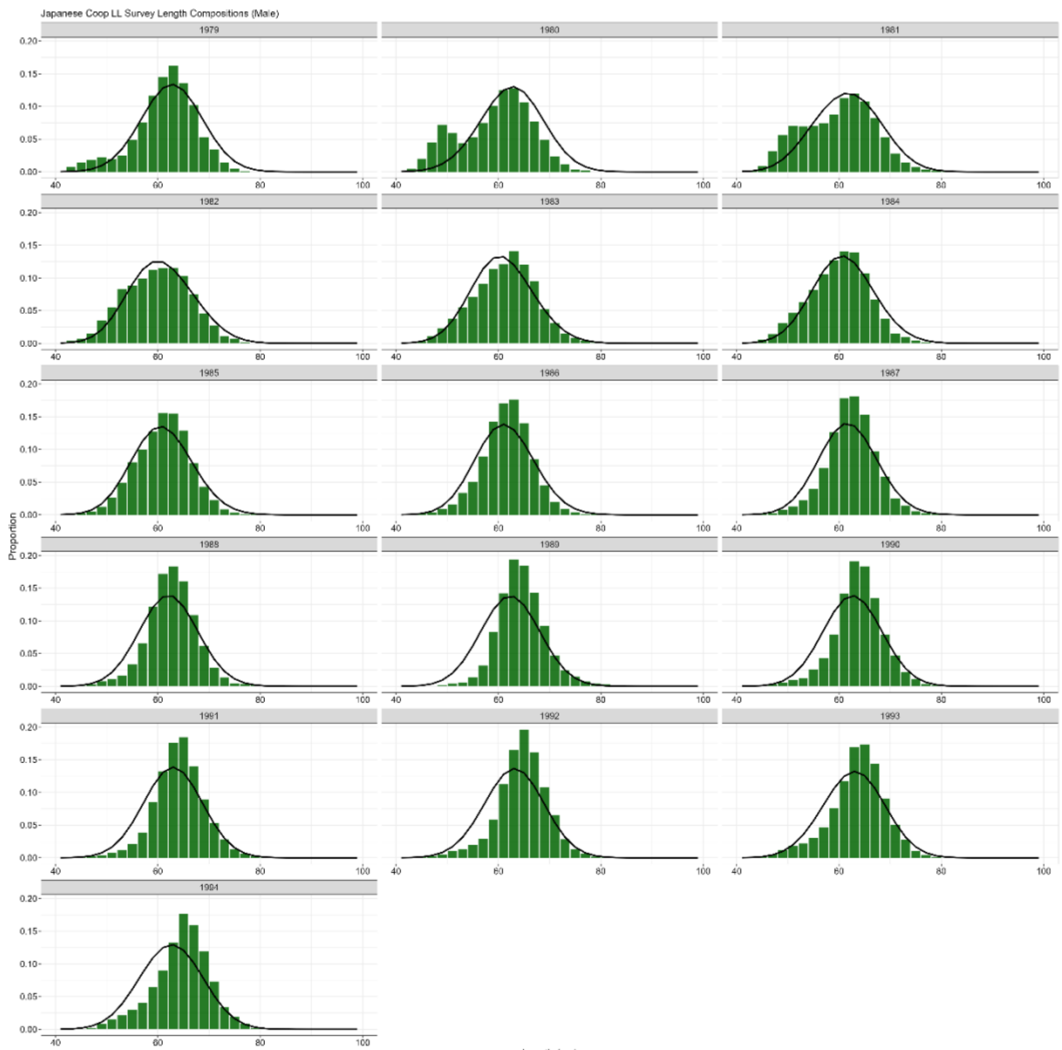


Figure 3.20. Japanese cooperative longline survey male length compositions. Bars are observed frequencies and lines are predicted frequencies.

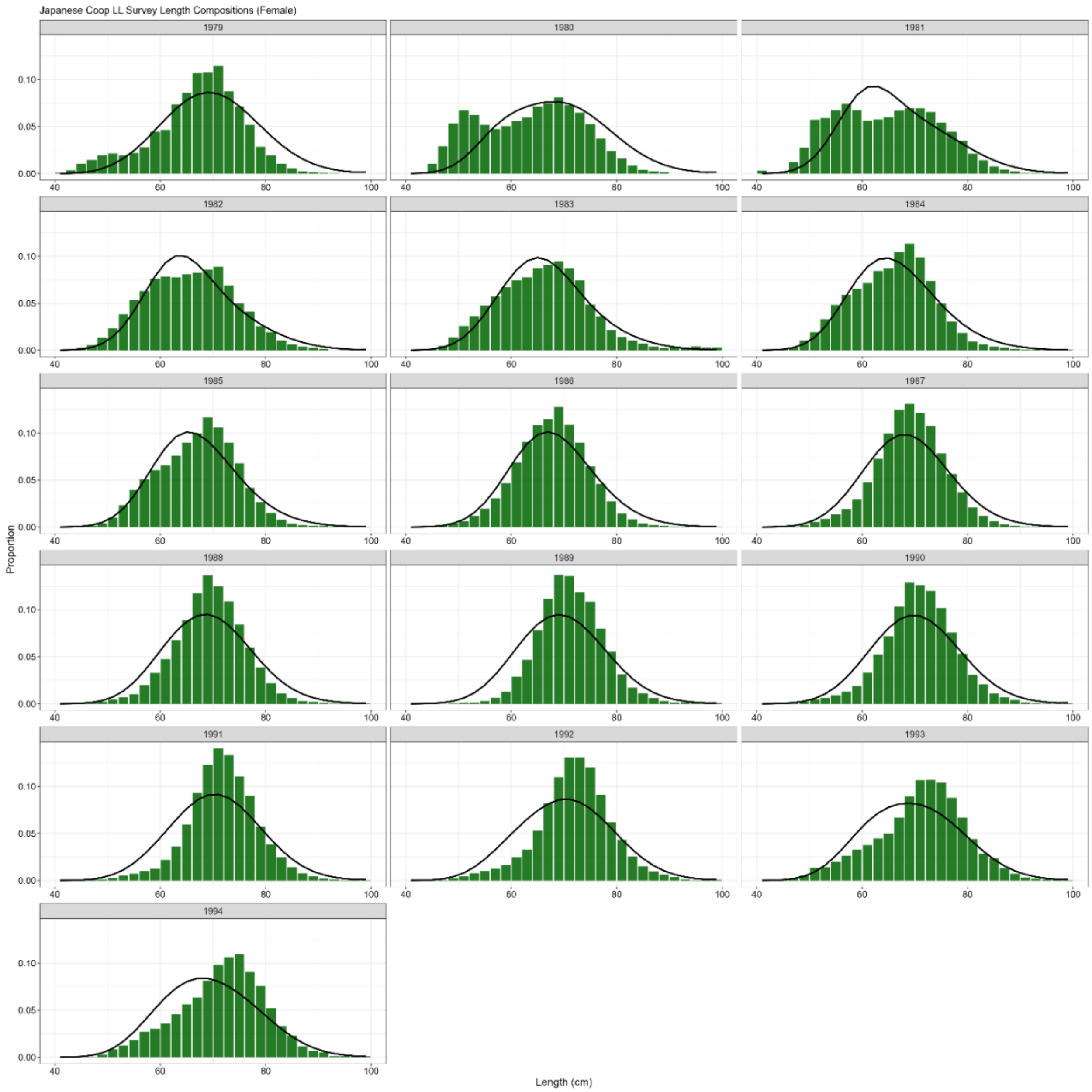


Figure 3.21. Japanese cooperative longline survey female length compositions. Bars are observed frequencies and lines are predicted frequencies.

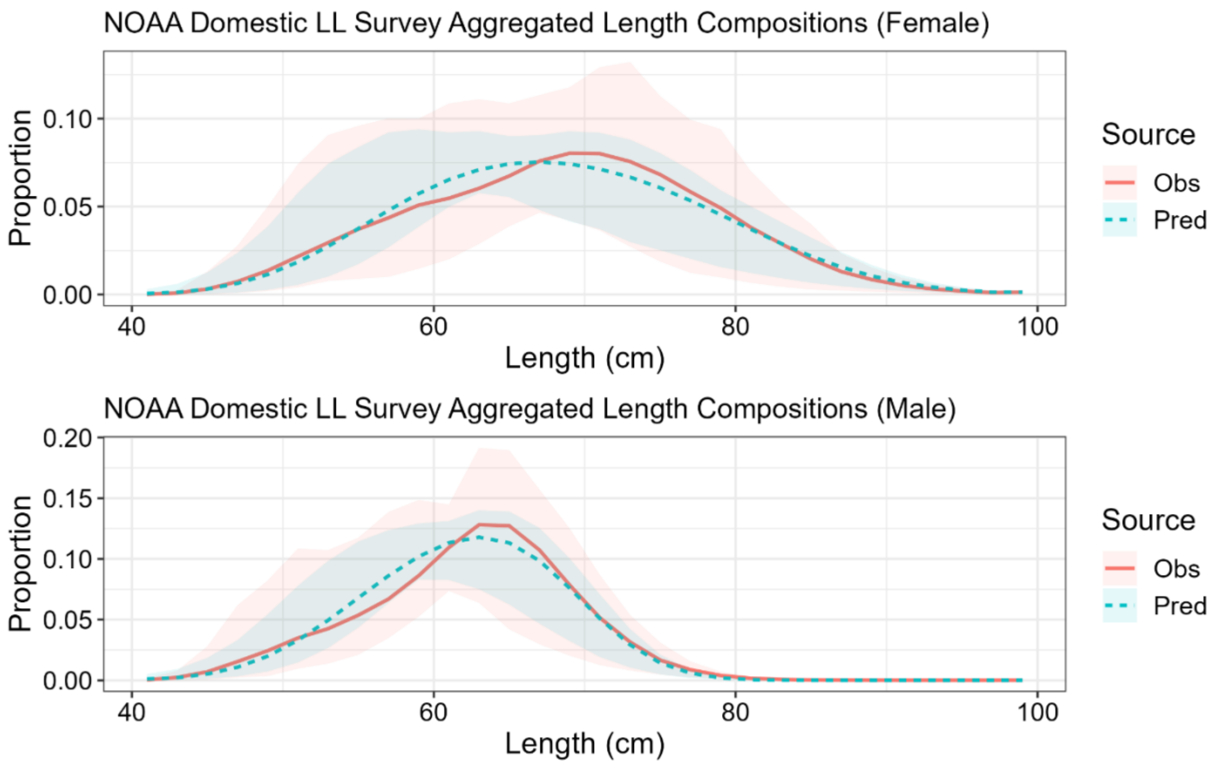


Figure 3.22. Mean observed (red line) NOAA domestic longline survey length compositions aggregated across years along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals. Fit to female length compositions are in the top panel and fit to male length compositions are in the bottom panel.

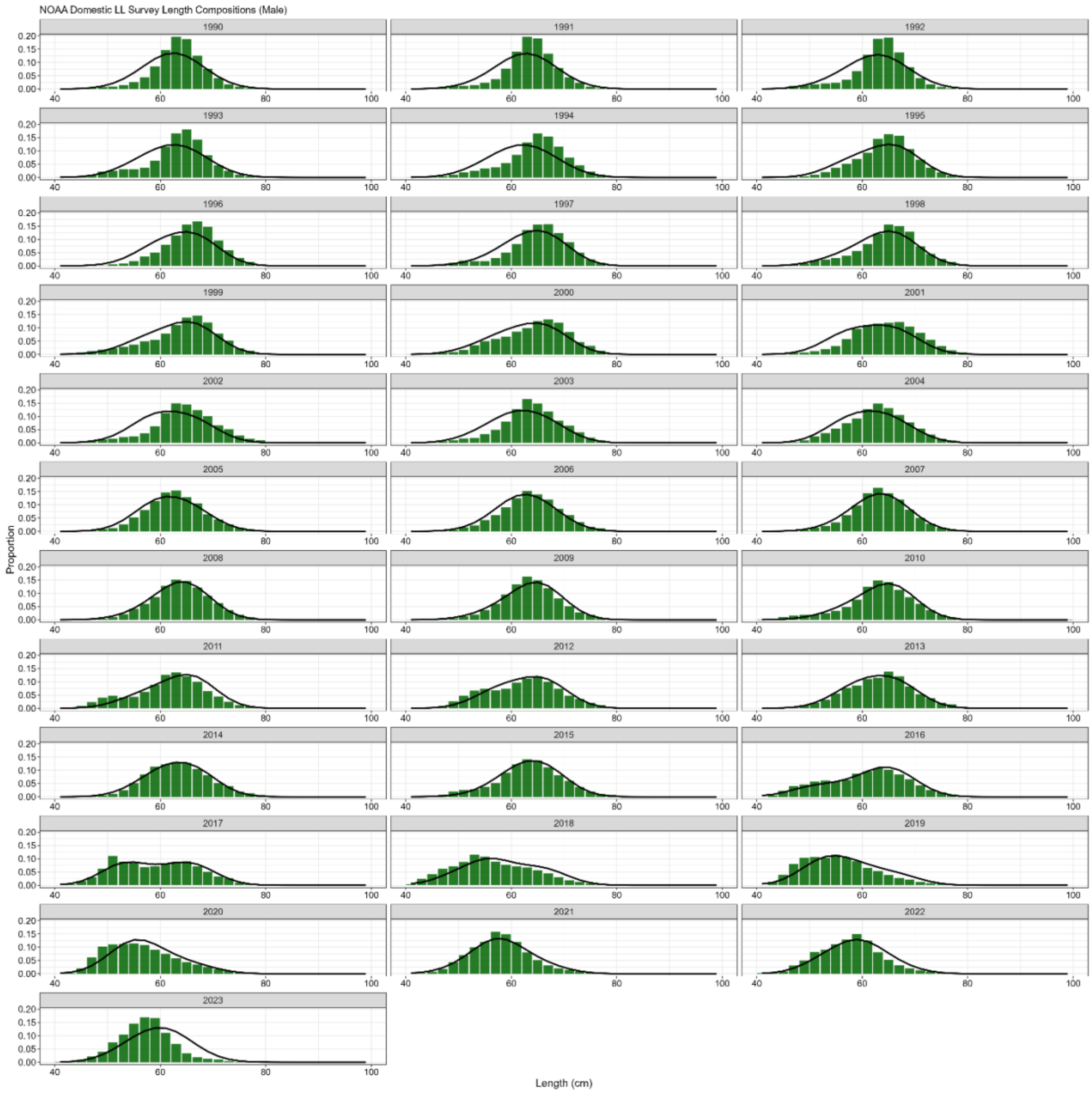


Figure 3.23. NOAA domestic longline survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

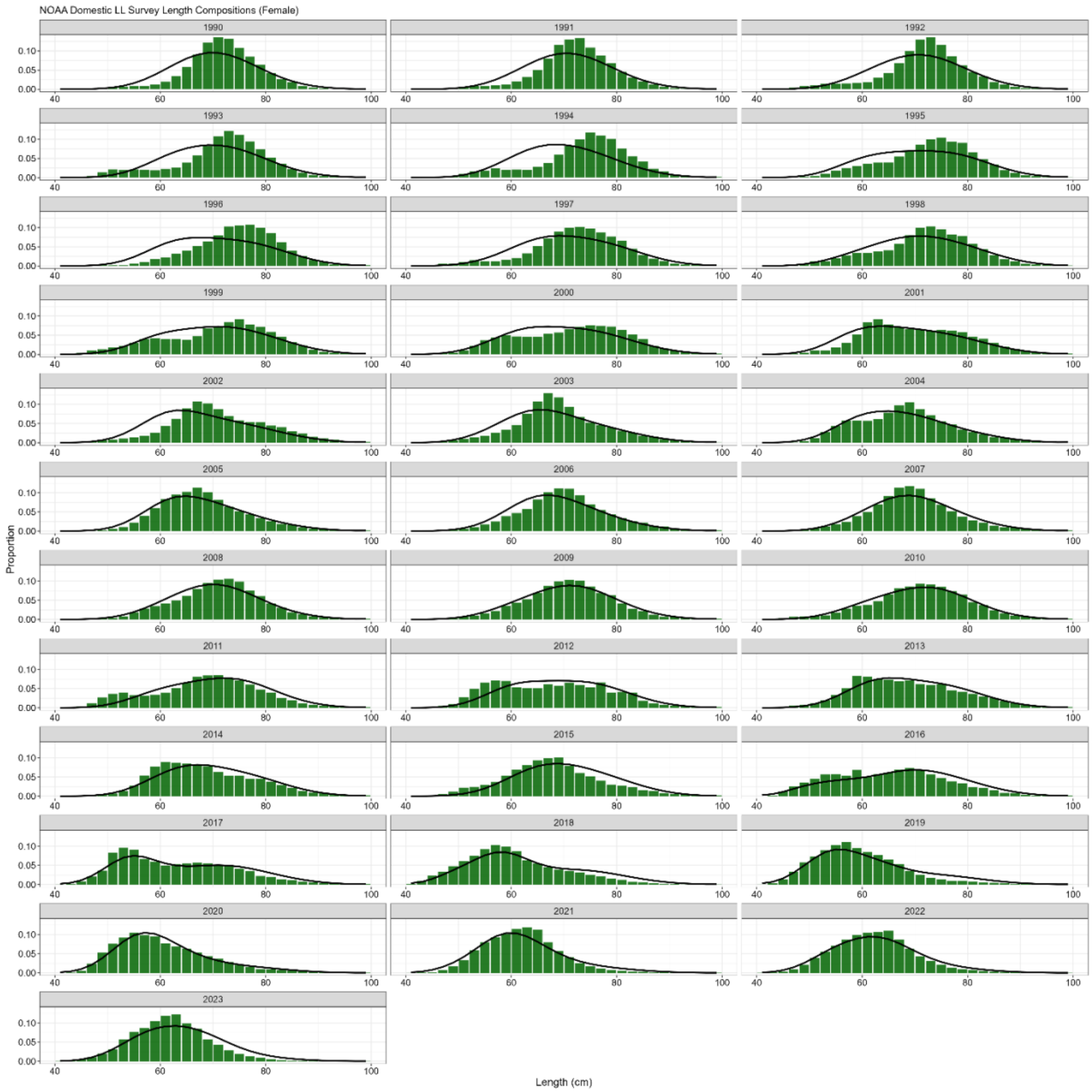


Figure 3.24. NOAA domestic longline survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

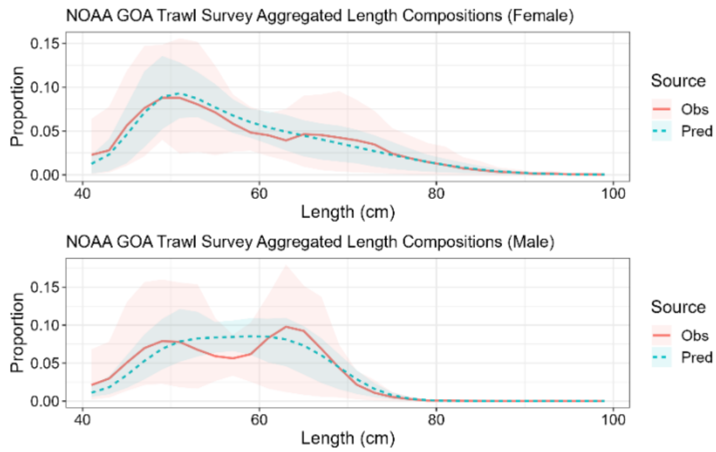


Figure 3.25. Mean observed (red line) NOAA Gulf of Alaska trawl survey (stations < 500m depth) length compositions aggregated across years along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals. Fit to female length compositions are in the top panel and fit to male length are in the bottom panel.

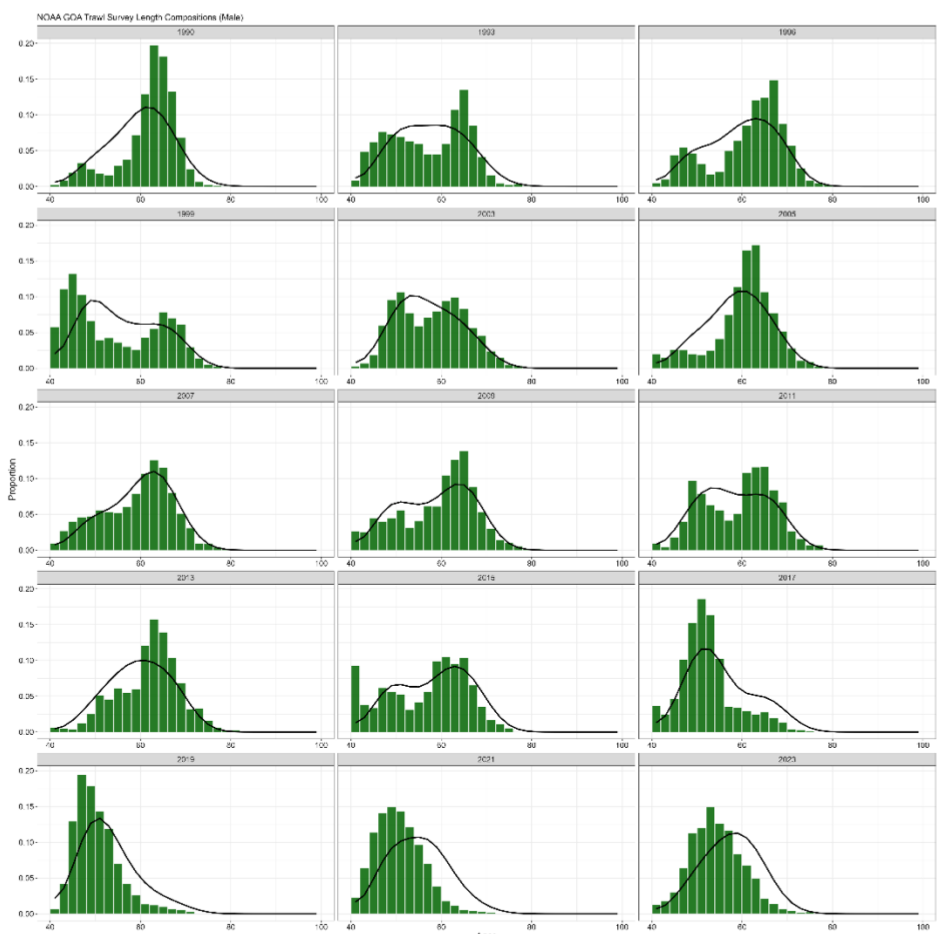


Figure 3.26. NOAA Gulf of Alaska (stations < 500m depth) trawl survey length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

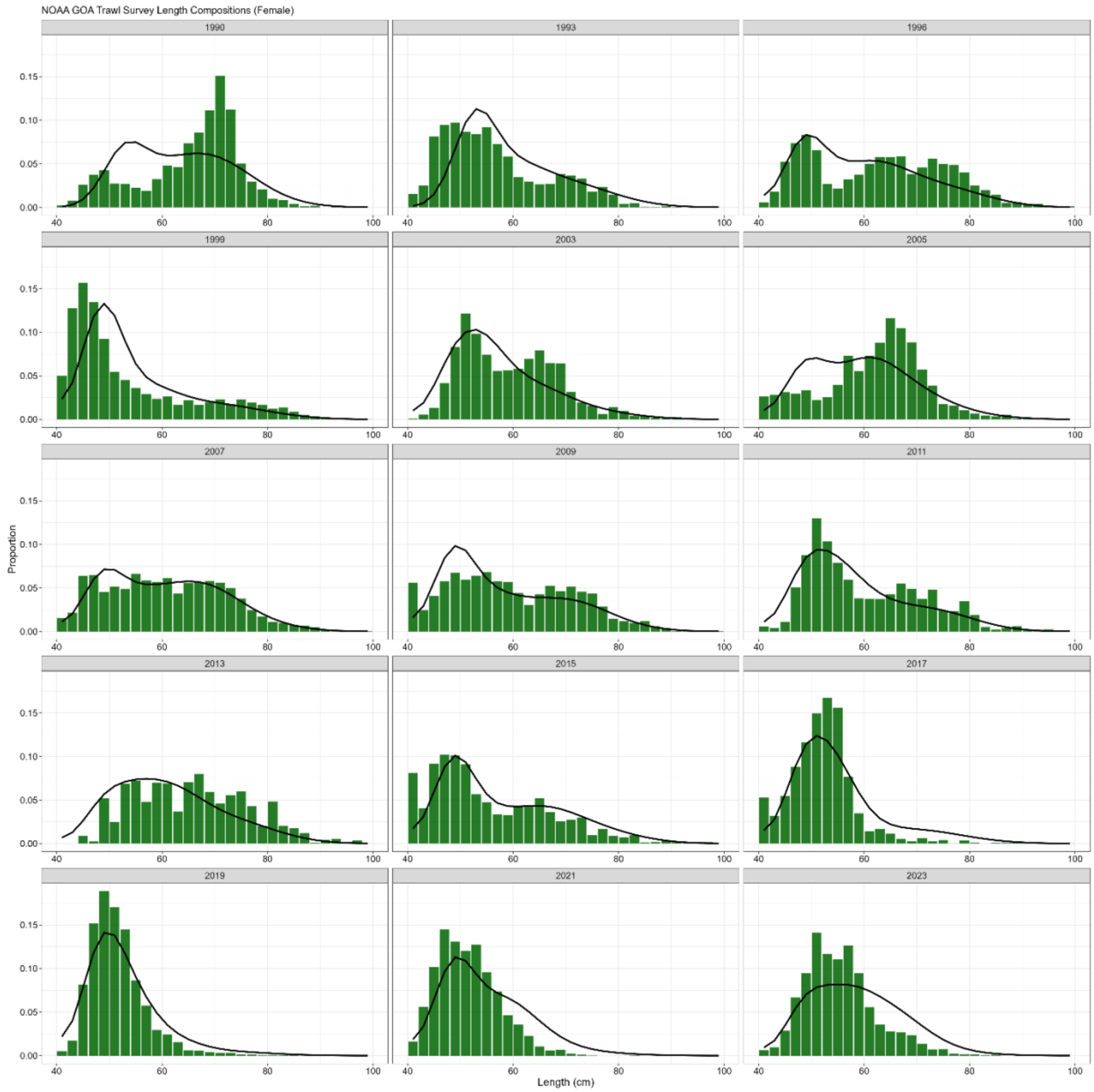


Figure 3.27. NOAA Gulf of Alaska (stations < 500m depth) trawl survey length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

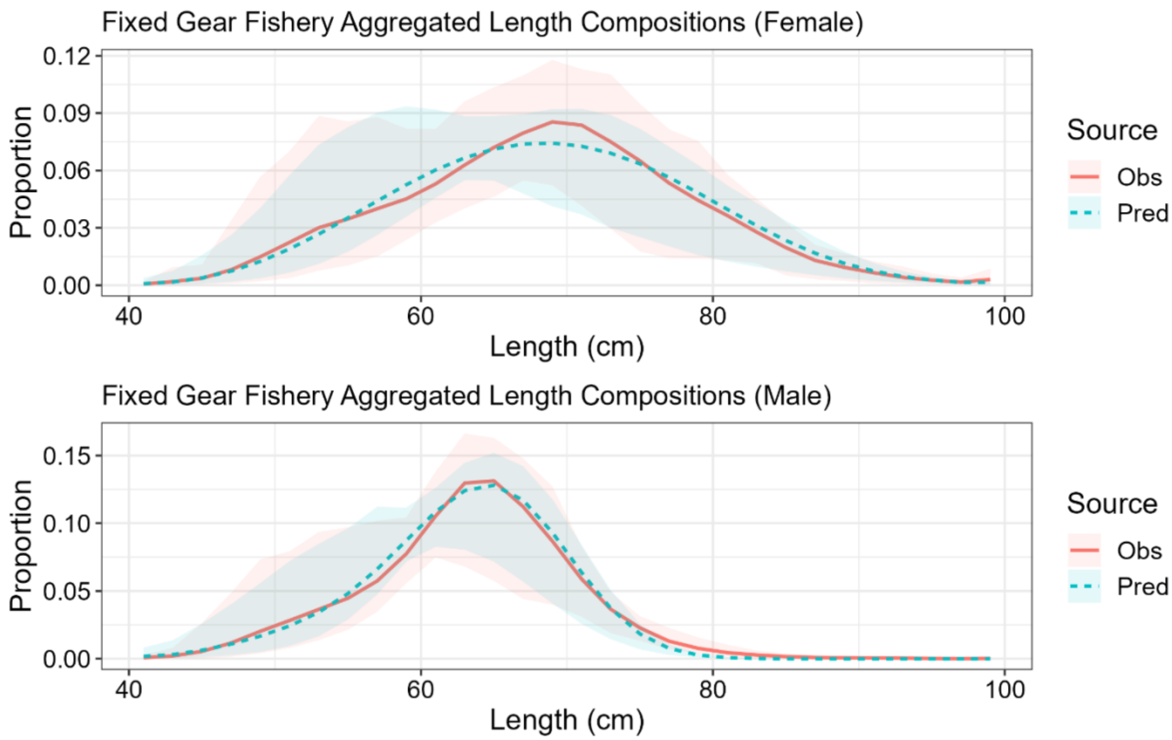


Figure 3.28. Mean observed (red line) domestic fixed gear fishery length compositions aggregated across years along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals. Fit to female length compositions are in the top panel and fit to male length compositions are in the bottom panel.

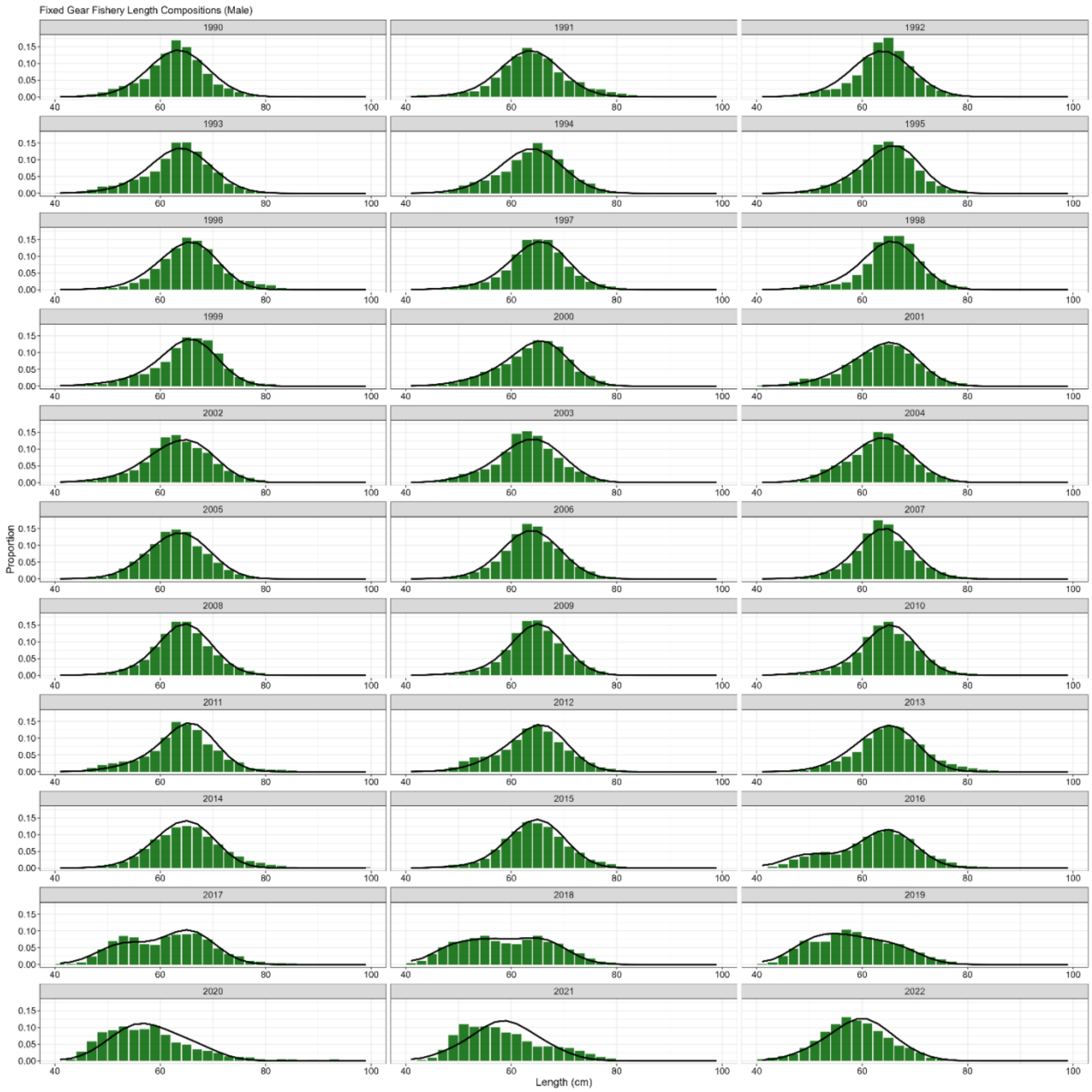


Figure 3.29. Domestic fixed gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

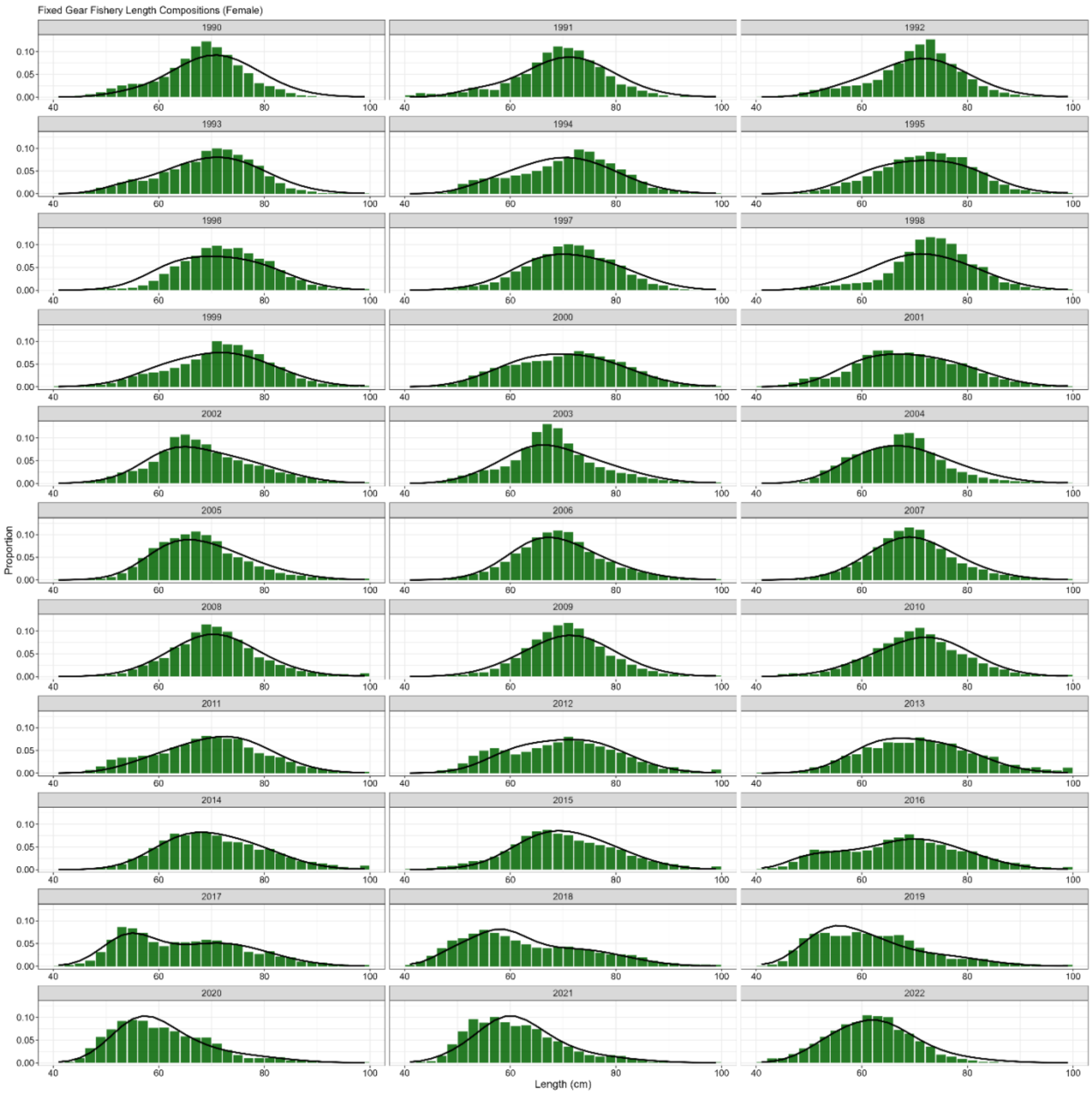


Figure 3.30. Domestic fixed gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

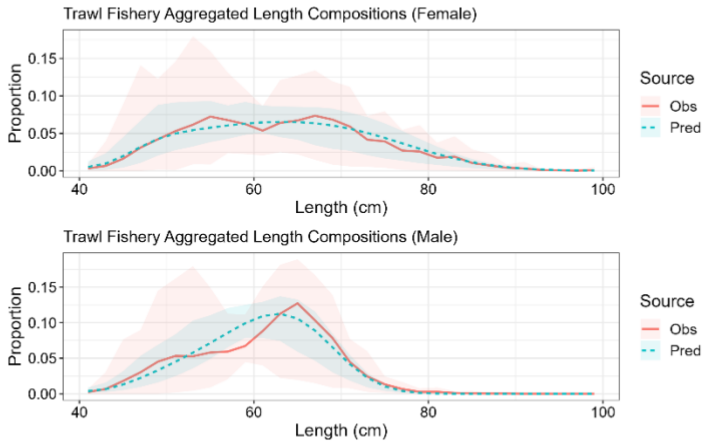


Figure 3.31. Mean observed (red line) domestic trawl gear fishery length compositions aggregated across years along with the average fit of the model (blue line). The red fill is the 90% empirical confidence intervals, while the blue fill is the model estimated 90% confidence intervals. Fit to female length compositions are in the top panel and fit to male length compositions are in the bottom panel.

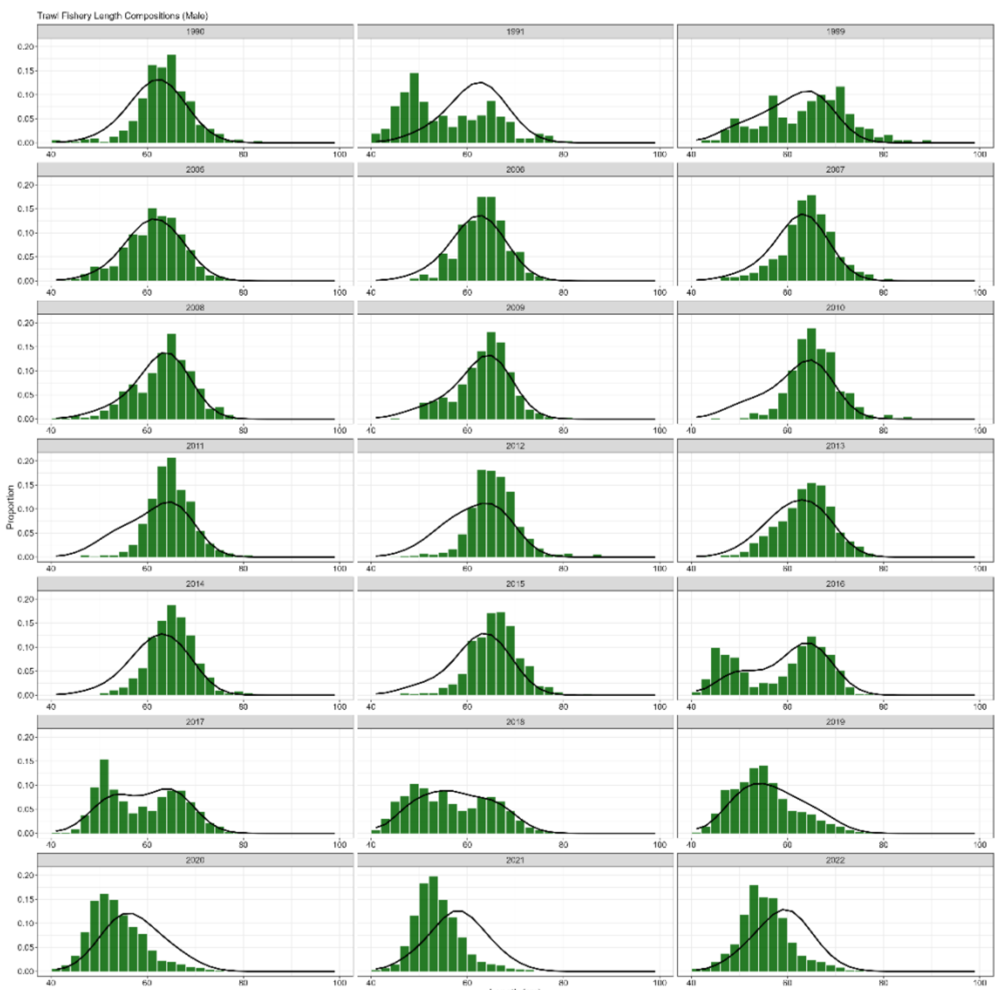


Figure 3.32. Domestic trawl gear fishery length (cm) compositions for males. Bars are observed frequencies and lines are predicted frequencies.

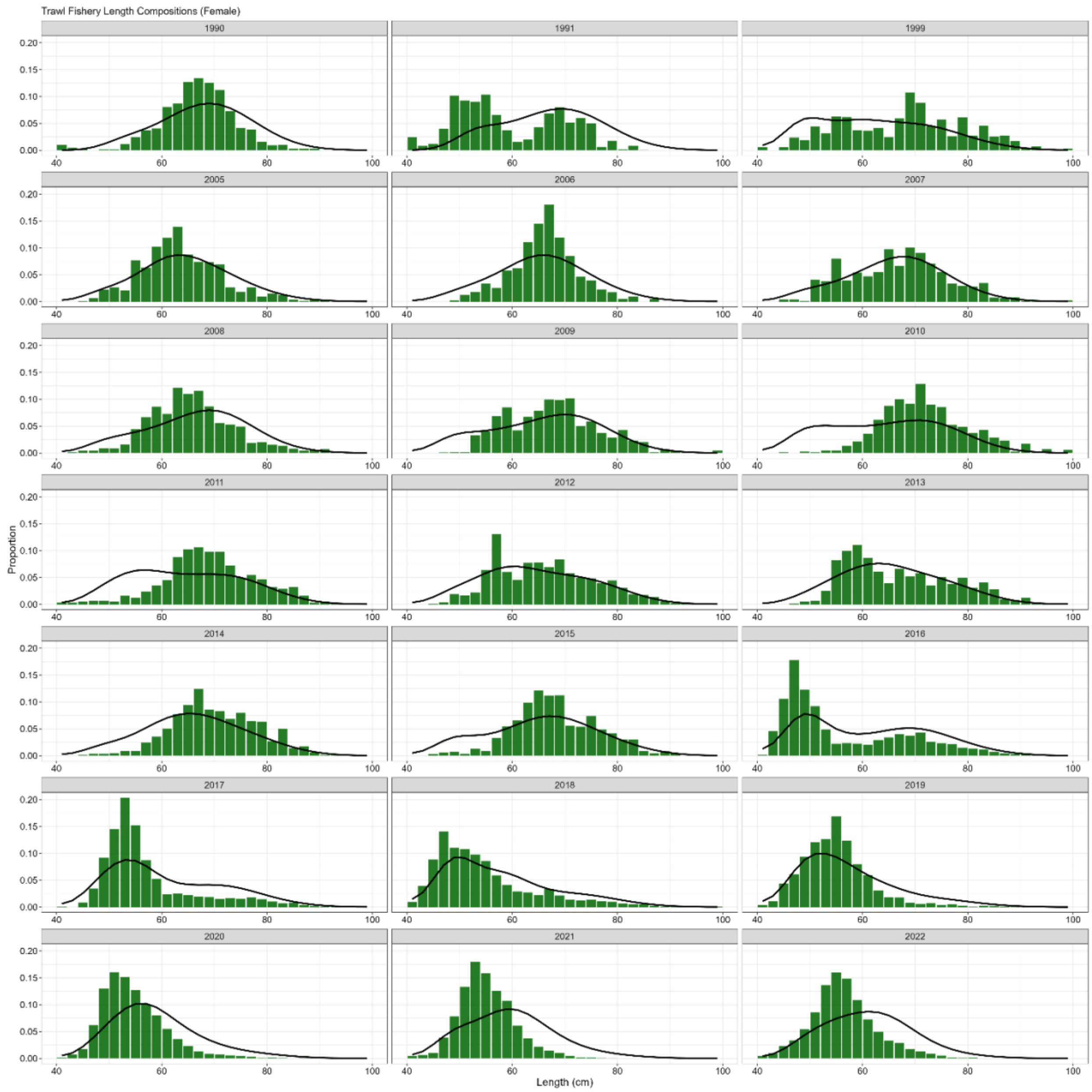


Figure 3.33. Domestic trawl gear fishery length (cm) compositions for females. Bars are observed frequencies and lines are predicted frequencies.

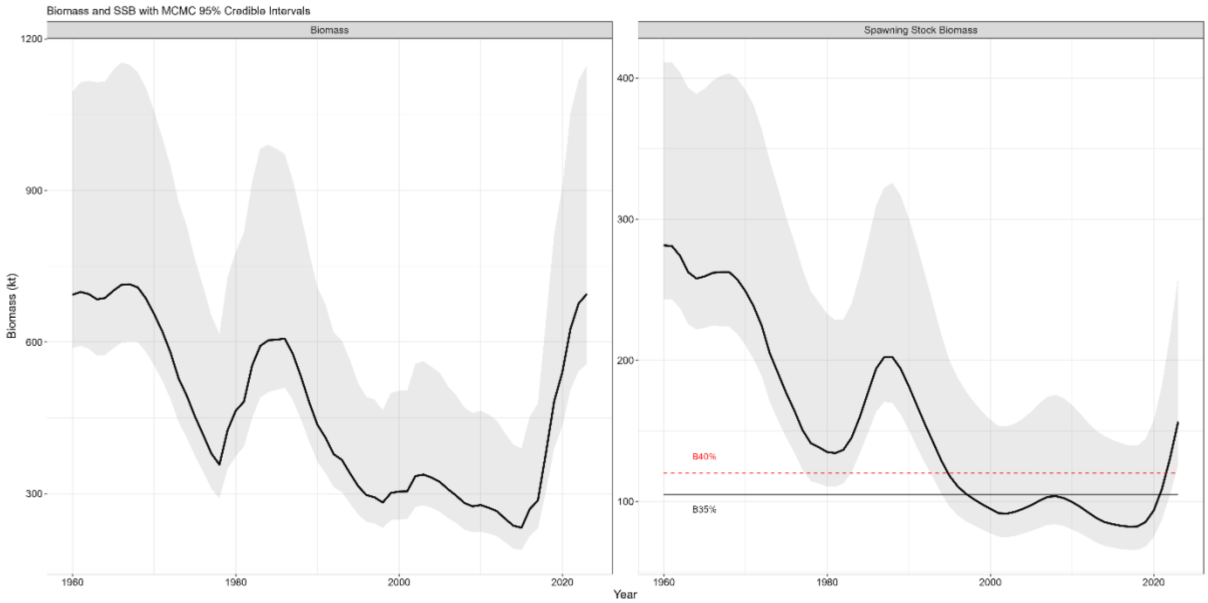


Figure 3.34. Estimated sablefish total biomass (top panel) and spawning biomass (bottom panel) with 95% MCMC credible intervals (grey fill). Values are in kilotons. The $B_{35\%}$ (black solid line) and $B_{40\%}$ (red dashed line) reference points are shown on the SSB panel.

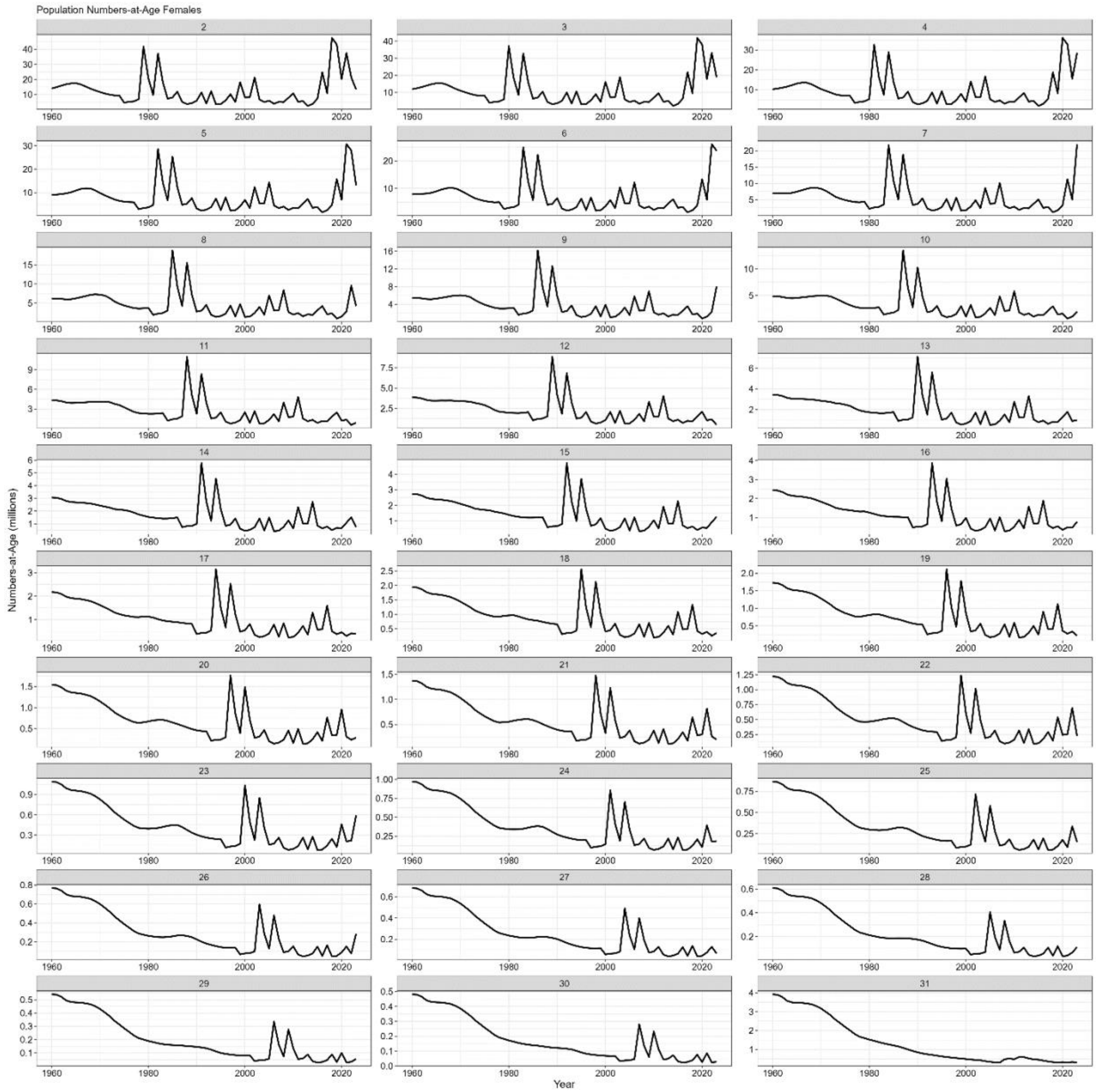


Figure 3.35. Model estimated female population numbers by age and year. Abundance is in millions of fish.

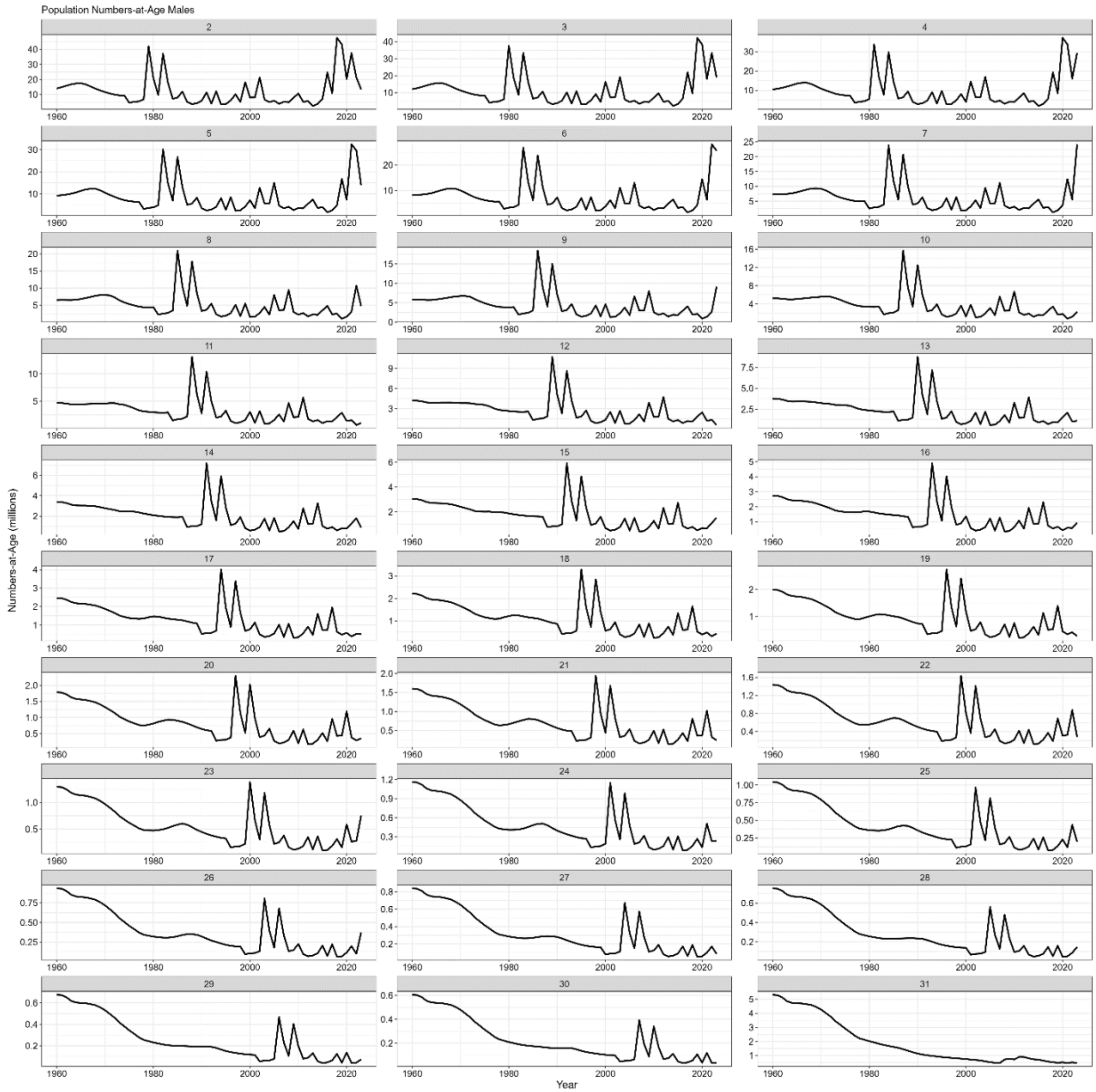


Figure 3.36. Model estimated male population numbers by age and year. Abundance is in millions of fish.

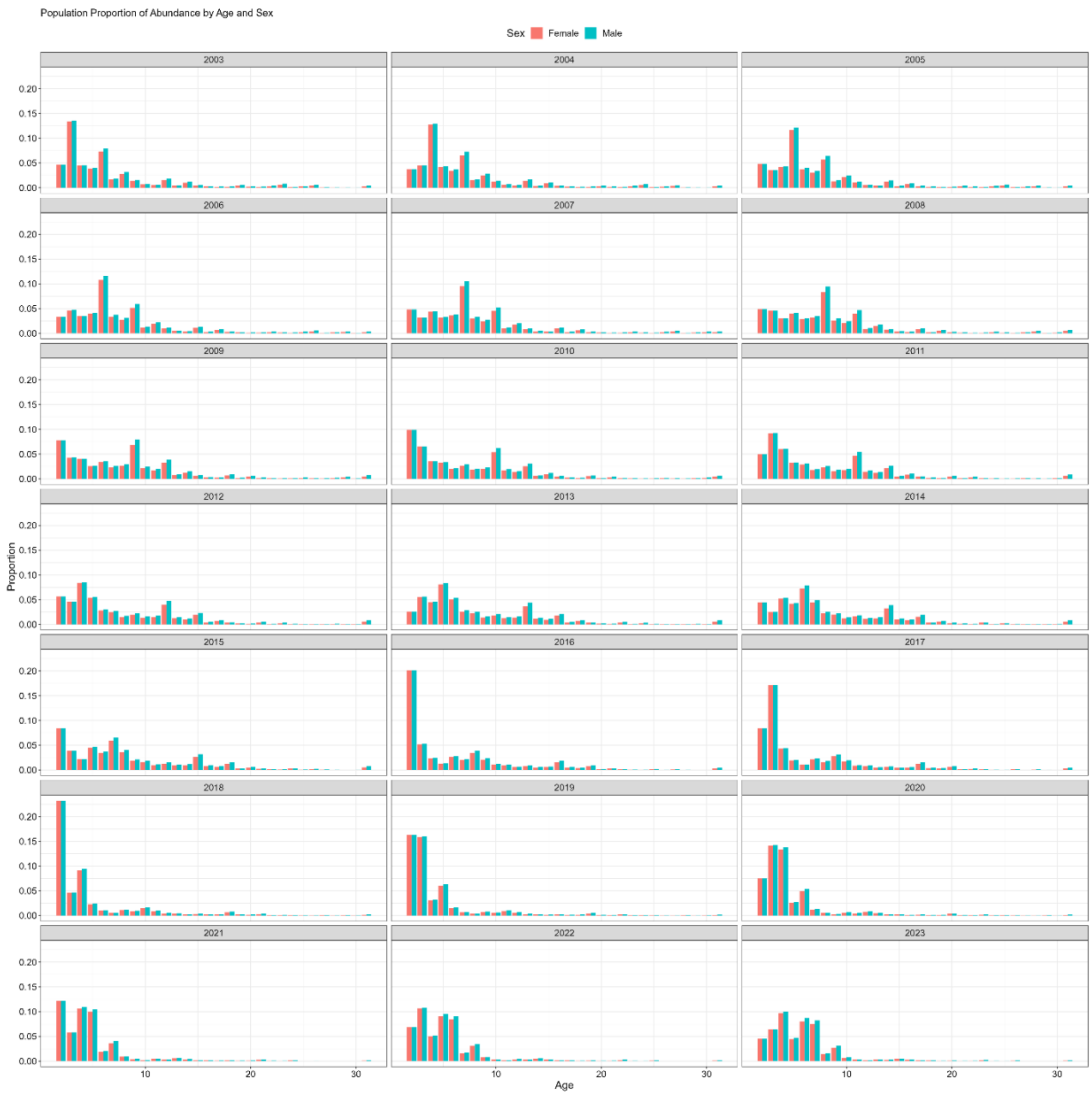


Figure 3.37. Model estimated proportions-at-age and sex by year. Female proportions are red bars and male proportions are blue bars.

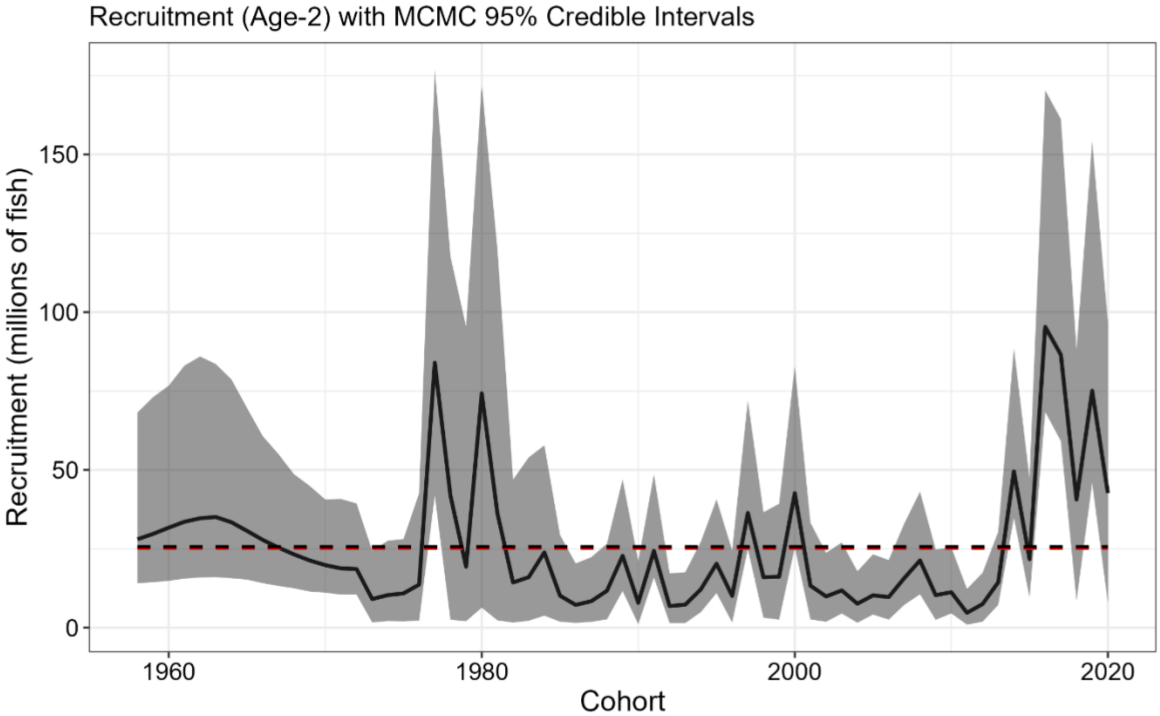


Figure 3.38. Estimated recruitment of age-2 sablefish (millions of fish; black line) with 95% credible intervals (grey fill) from MCMC by cohort (recruitment year minus two). Red line is time series mean, while black line is mean from year classes between 1977 and 2020. The estimate for the 2021 year class (terminal year 2023 recruitment event) is omitted, because it is fixed to the estimated mean recruitment value (μ_r) with no deviation parameter estimated.

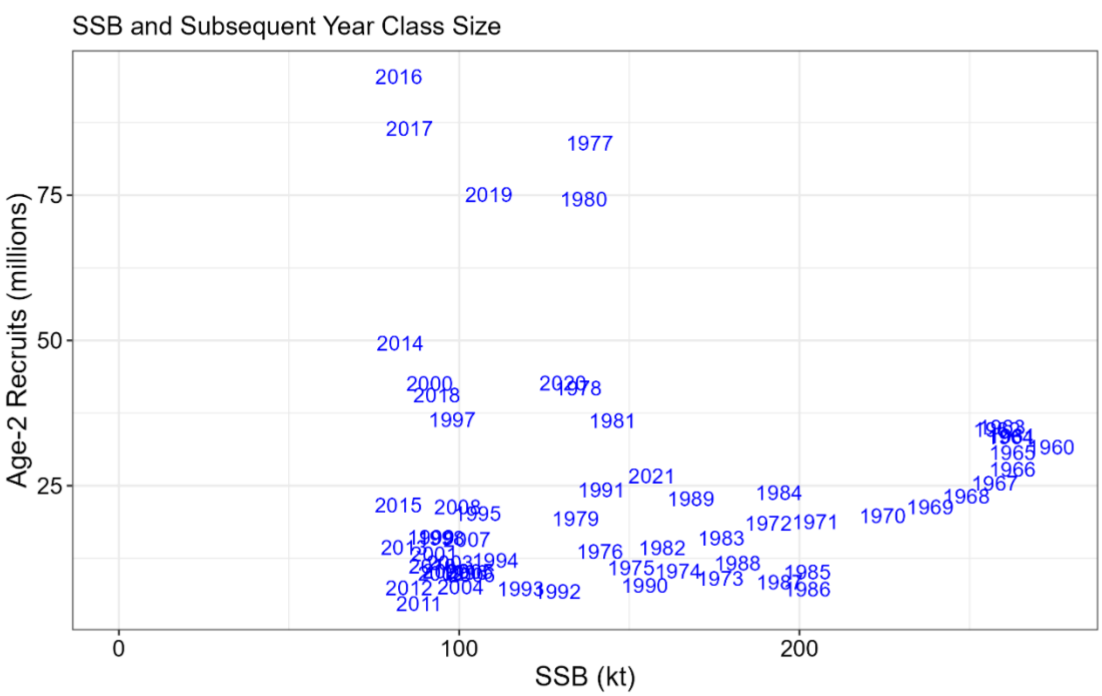


Figure 3.39. Age-2 recruits (millions of fish) and corresponding spawning stock biomass (kilotons) for each year class (identified by plotted year text).

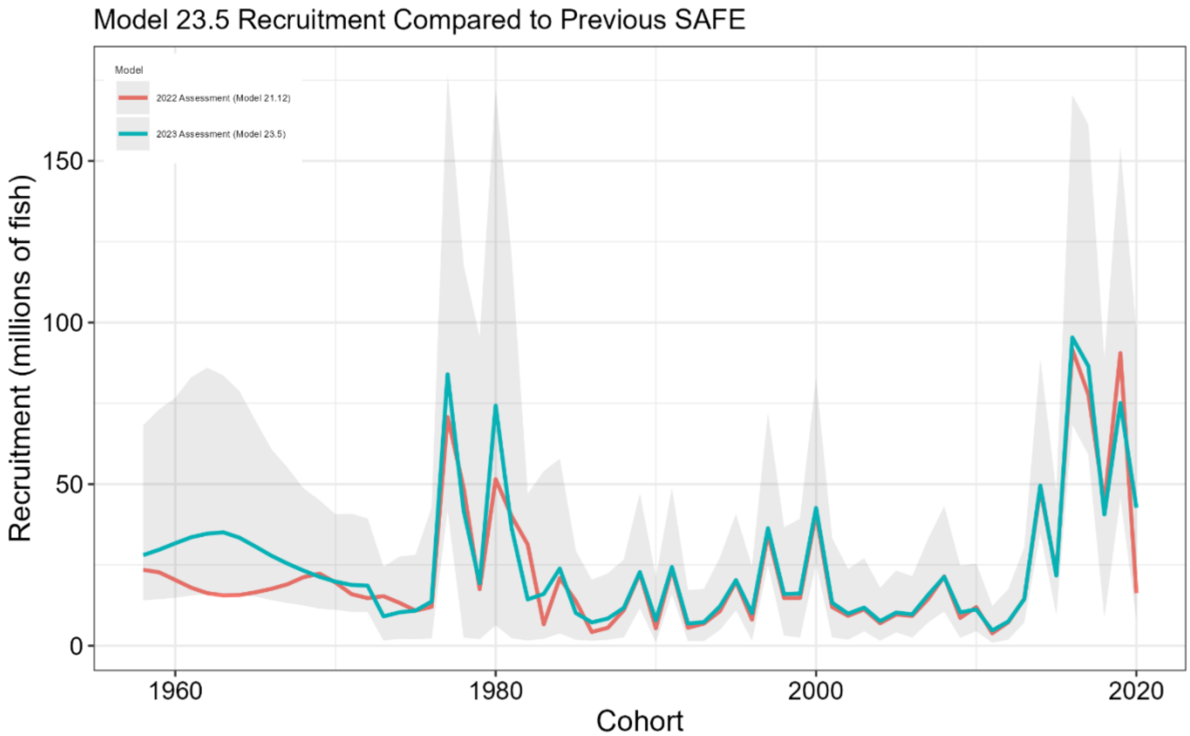


Figure 3.40. Estimated recruitment by cohort (recruitment year minus two) in number of age-2 fish (millions of fish) for the 2022 (red line) and 2023 (blue line) final SAFE models with 95% credible intervals (grey fill) from MCMC for the 2023 model. Note that the 2020 yearclass for the 2022 model is equivalent to the estimated mean recruitment value (μ_r).

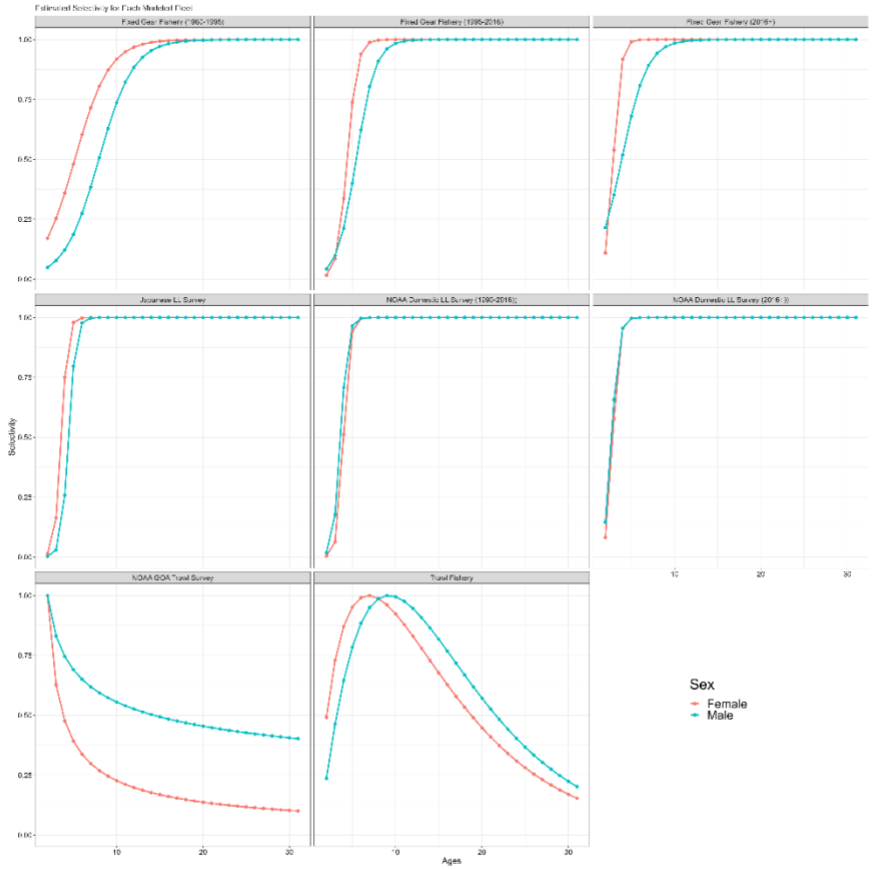


Figure 3.41. Estimated fishery and survey selectivity. Fixed gear fishery selectivity is in the top row for the three time blocks (i.e., pre-IFQ, IFQ, and recent), the longline survey selectivities are in the middle row (Japanese cooperative, left, NOAA domestic, center and right), and trawl survey (left) and fishery (right) in the bottom row. Female selectivity is given by the red line and male selectivity by the blue line.

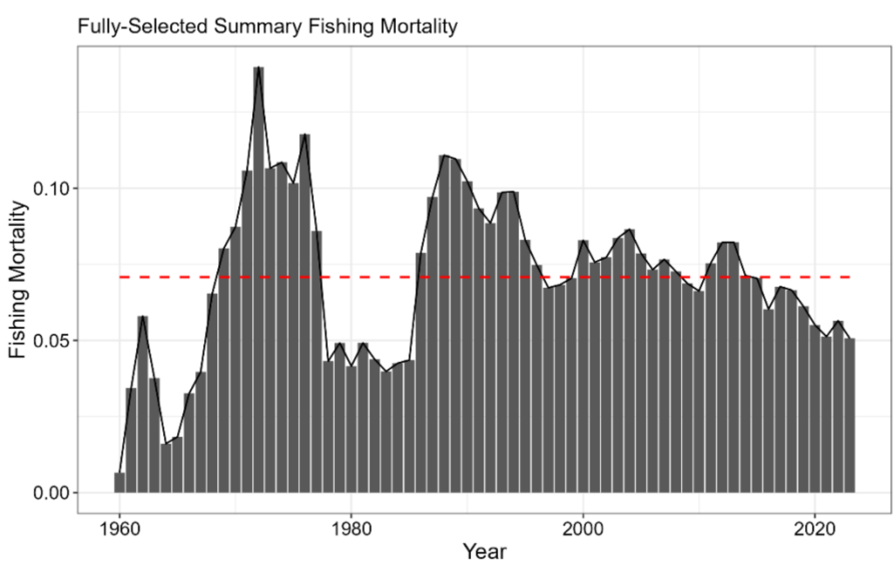


Figure 3.42. Time series of fully selected fishing mortality aggregated across the fixed gear and trawl fisheries. Red line is the mean fishing mortality for the entire time series.

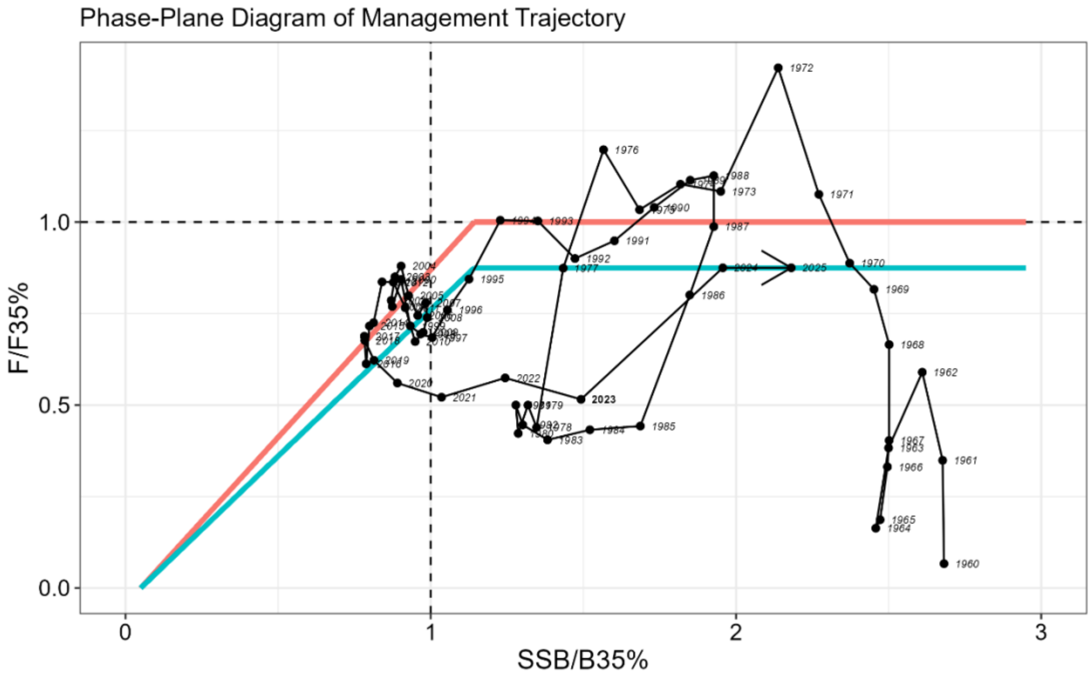


Figure 3.43. Phase-plane diagram illustrating the time series of sablefish estimated spawning biomass relative to the level at $B_{35\%}$ and fishing mortality relative to $F_{35\%}$ (equal to F_{OFL}). F_{ABC} for the max ABC is equivalent to $F_{40\%}$, which is demonstrated by the blue lines. The red line represents fishing at F_{OFL}, but with a target of $B_{40\%}$ (i.e., the inflection point occurs at a biomass ratio greater than one).

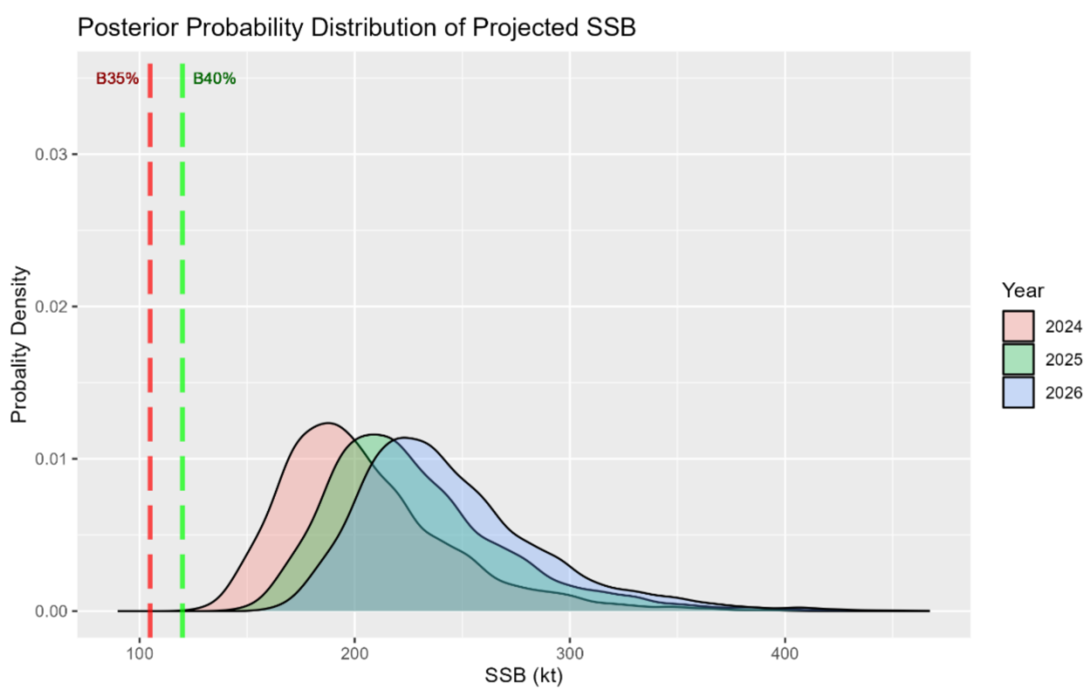


Figure 3.44. Posterior probability distribution from MCMC for projected spawning biomass (kilotons) in years 2024 – 2026. The dashed lines are $B_{35\%}$ and $B_{40\%}$.

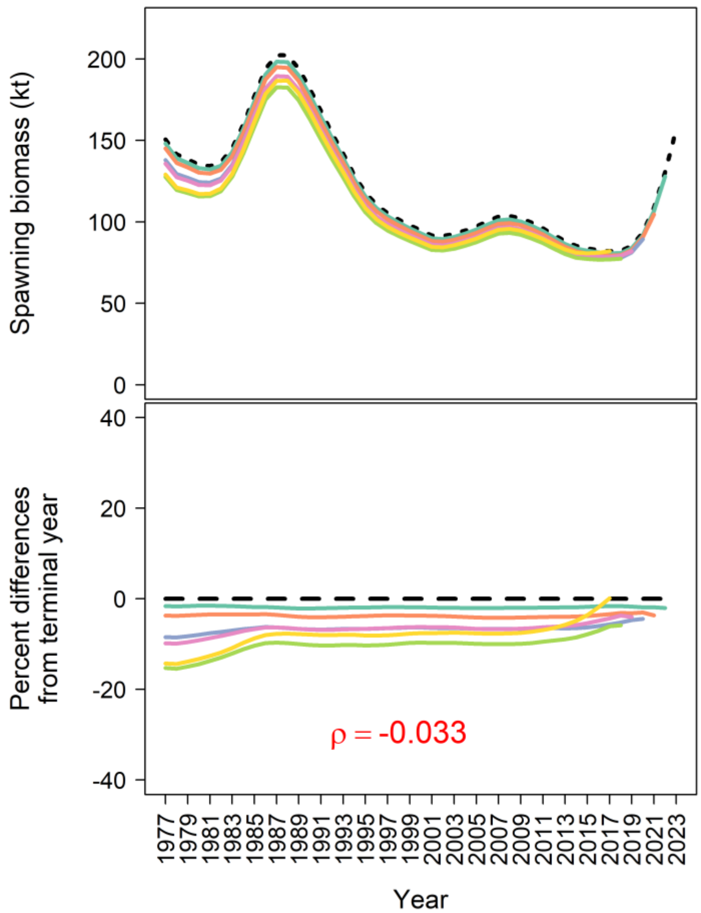


Figure 3.45. Retrospective trends for spawning biomass (top) and percent difference from terminal year (bottom). Mohn's rho (ρ) is provided in red (bottom panel).

Figure 3.46. Squid plot of subsequent estimates of age-2 recruitment for 2014 to 2020 year classes from retrospective analysis.

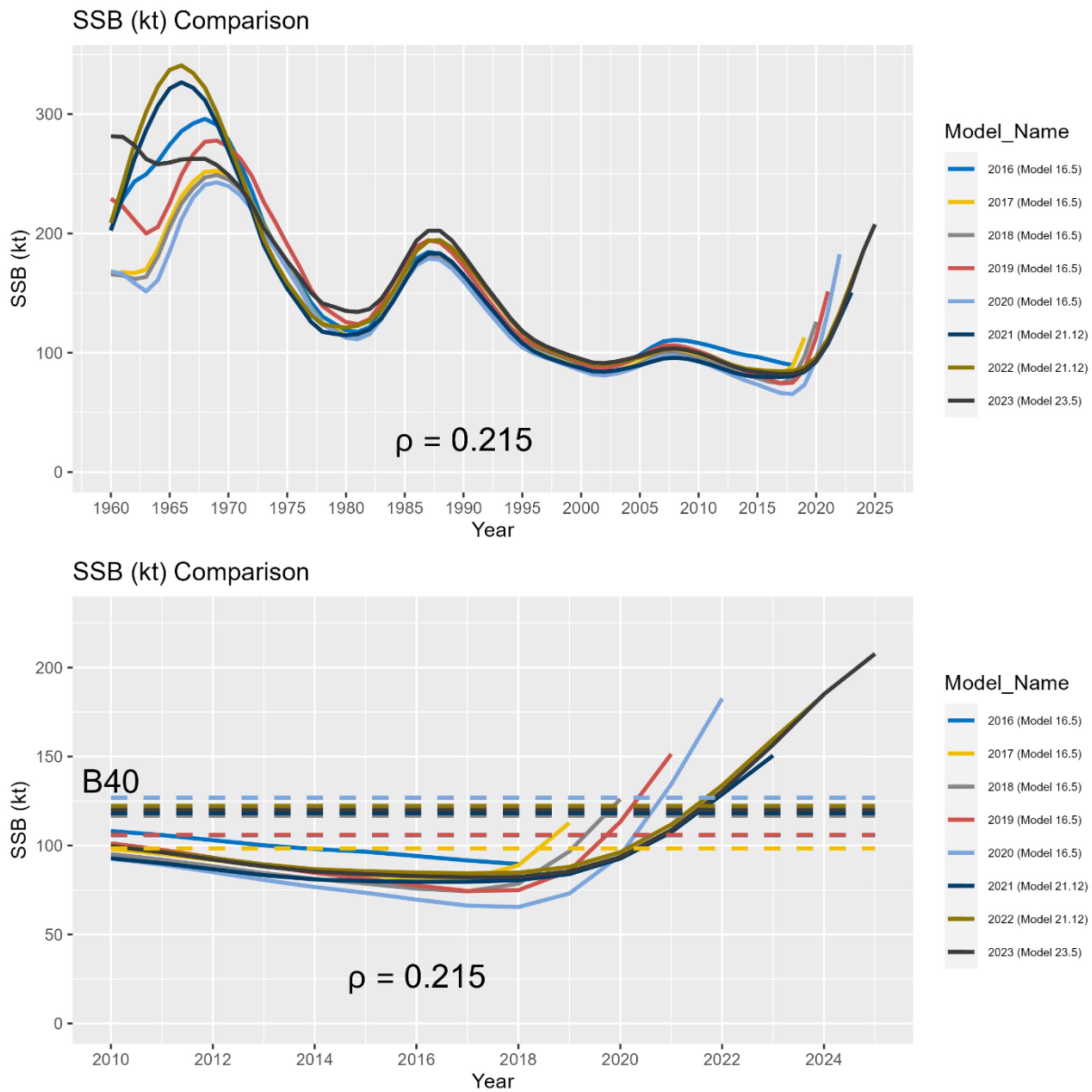


Figure 3.47. Results of the 'all model' historical retrospective illustrating estimated and projected (terminal year + 2 years) spawning stock biomass (in kilotons). Results are based on the accepted model in each terminal model year, including application of the *23.5* model for 2023, the *21.12* model for the 2021 and 2022 model years, and the *16.5* model for earlier model years. The top panel shows the entire time series of SSB from each assessment model, while the bottom panel shows the same results since 2010 overlaid with corresponding estimates of $B_{40\%}$. Mohn's rho for two year SSB projections is provided below the lines in each plot.

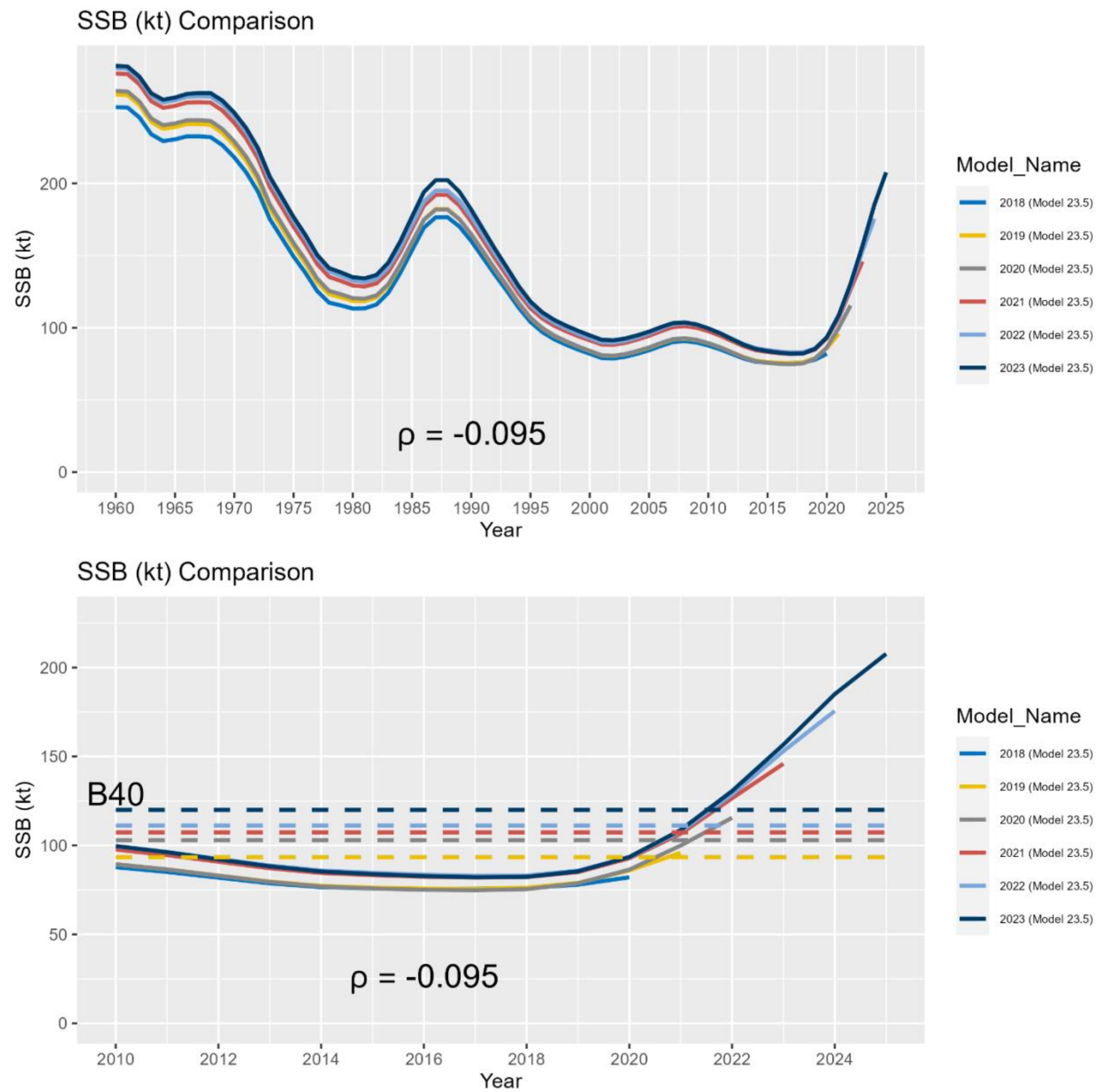


Figure 3.48. Results of the 'current model' historical retrospective illustrating estimated and projected (terminal year + 2 years) spawning stock biomass (in kilotons). Results are based on application of the *23.5* model to the available data at the time of the last five sablefish assessments (i.e., terminal model years from 2018 to 2023). The top panel shows the entire time series of SSB from each assessment model, while the bottom panel shows the same results since 2010 overlaid with corresponding estimates of $B_{40\%}$. Mohn's rho for two year SSB projections is provided below the lines in each plot.

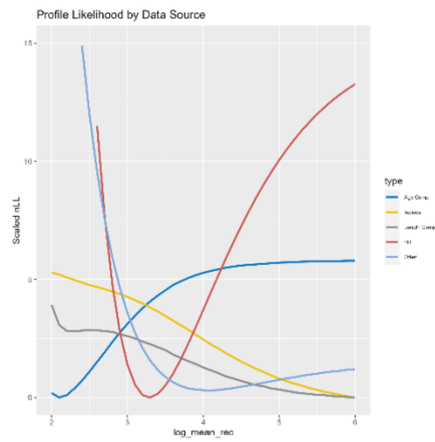


Figure 3.49. Likelihood profiles by data type (line color) for the mean recruitment parameter in logarithmic space.

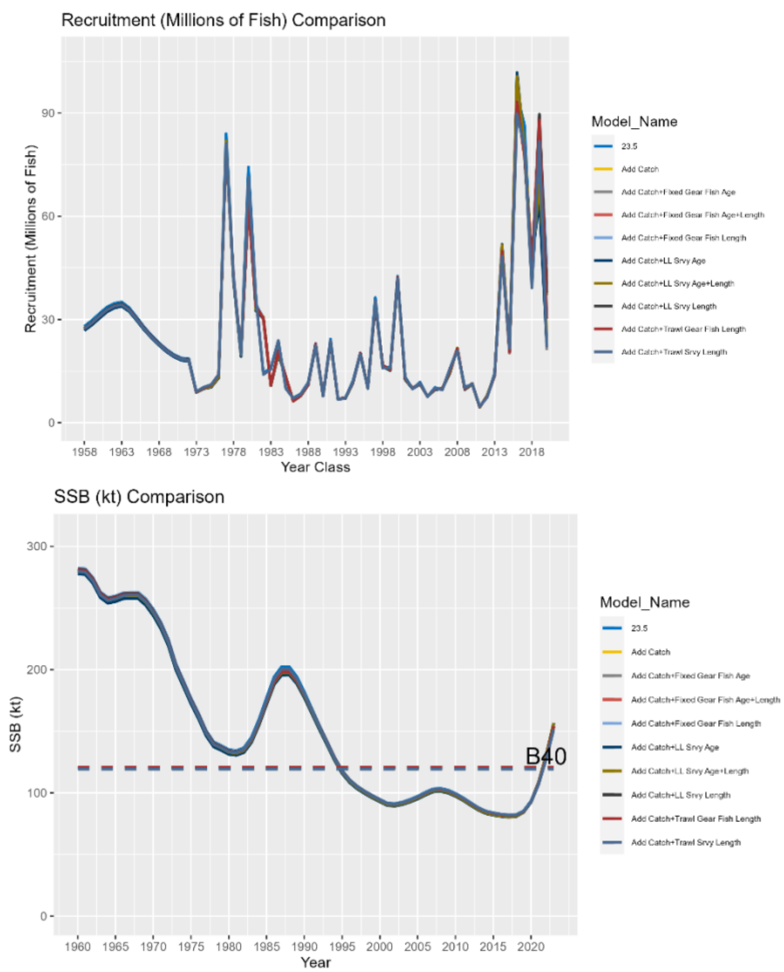


Figure 3.50. Results of an incremental data addition exercise where each new year of data for the 2023 model is added in a step-wise fashion. All model runs include the 2023 fishery catch data. For compositional data associated with fishery independent indices, each run also includes the associated survey index. The top panel illustrates the model estimated recruitment (millions of fish). The bottom panel depicts the time series of SSB (kt).

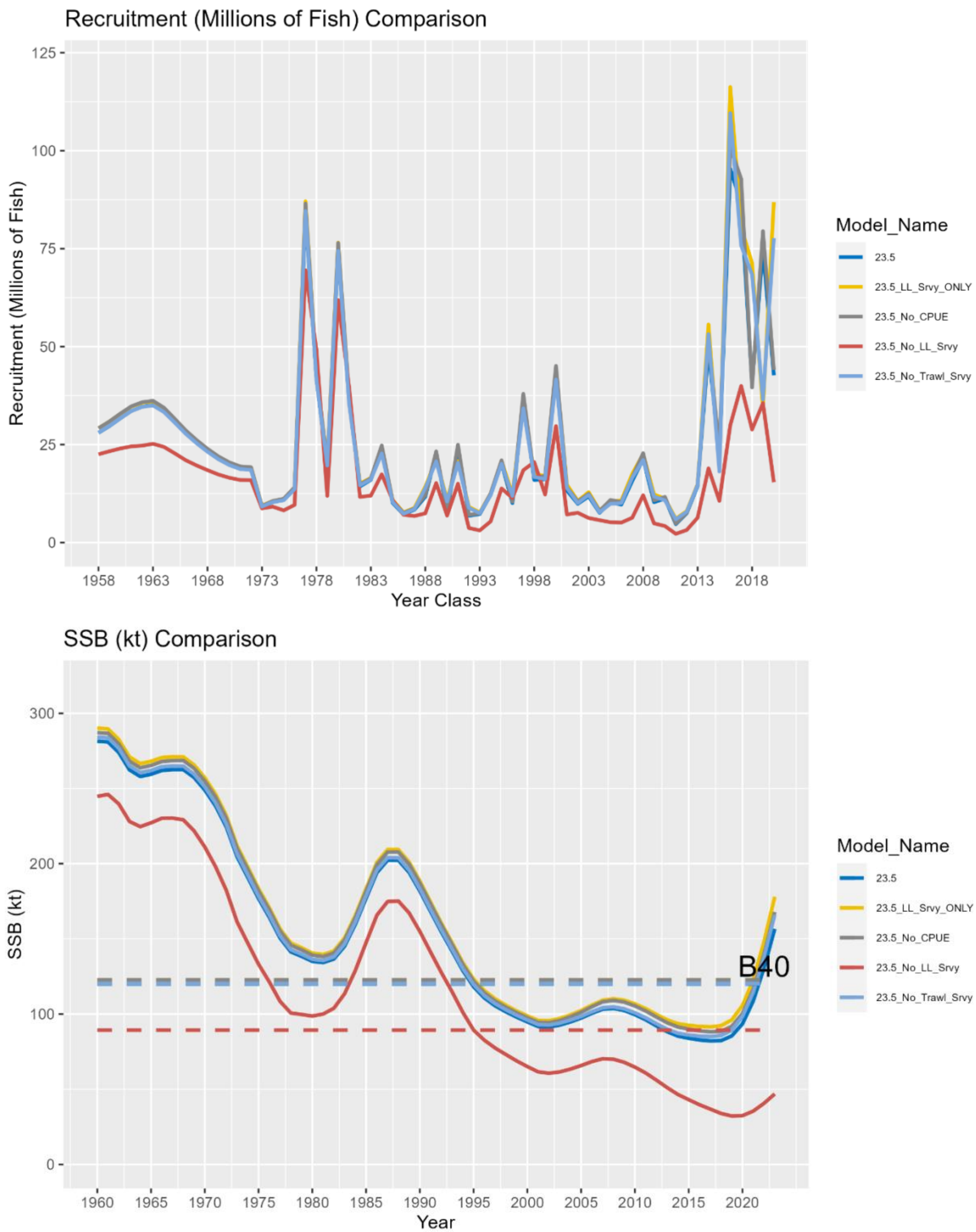


Figure 3.51. Results of an index sensitivity analysis where the model is rerun after removing each index (and any associated compositional data in the case of fishery independent surveys) one at a time. The top panel illustrates the model estimated recruitment (millions of fish). The bottom panel depicts the time series of SSB (kt).

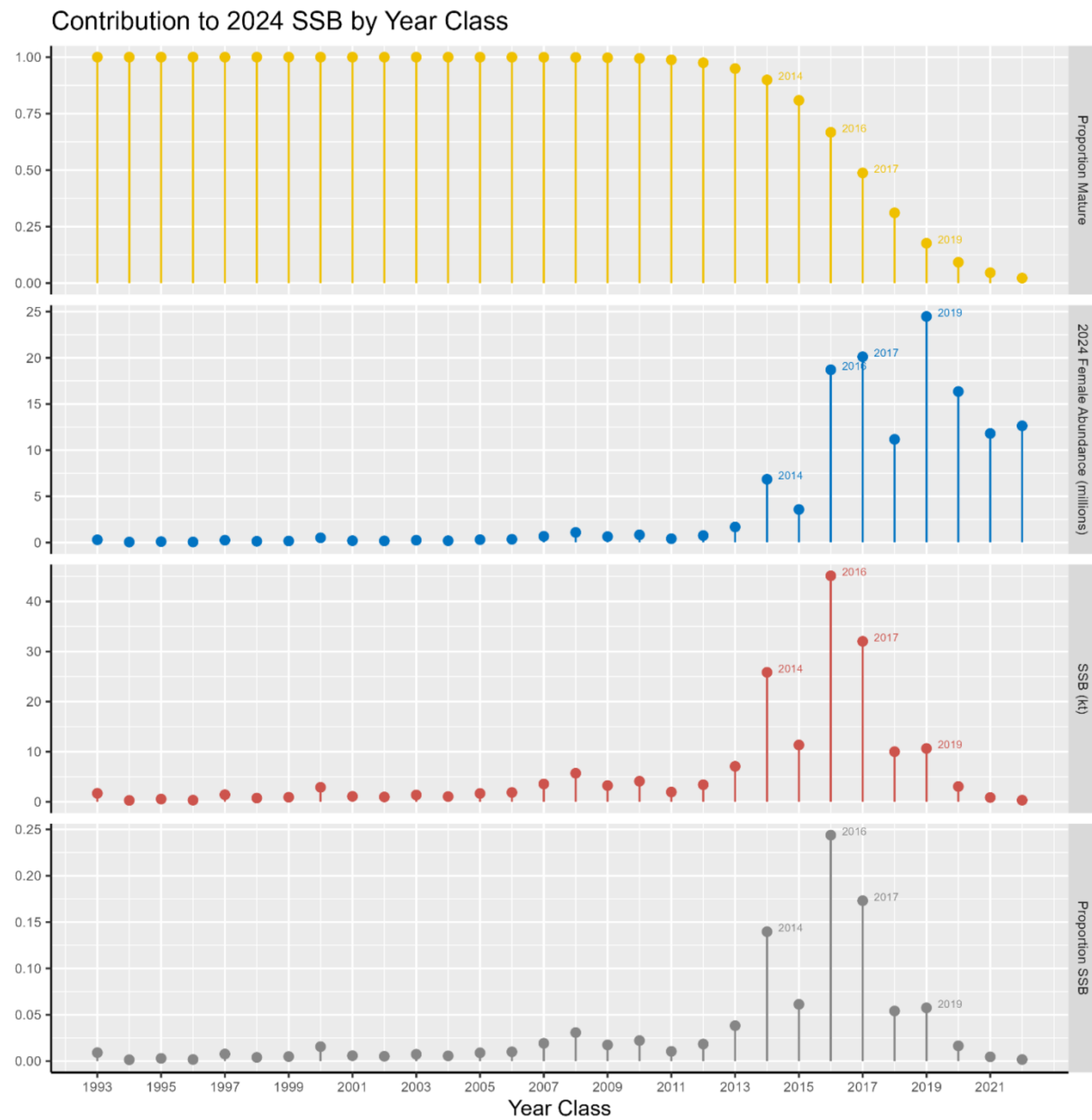


Figure 3.52. Proportion mature (top panel), projected 2024 female (assuming a 50:50 sex ratio) abundance (millions of fish; second panel from top), projected 2024 spawning stock biomass (kilotons; third panel from top), and proportional contribution to 2024 SSB (bottom panel) for each of the last 30 year classes. Note that the 1993 year class represents all contributions from all earlier year classes (i.e., fish in the plus group age). Abundance of the 2021 and 2022 year classes are based on mean recruitment, because these year classes have not yet been estimated in the 2023 assessment model.

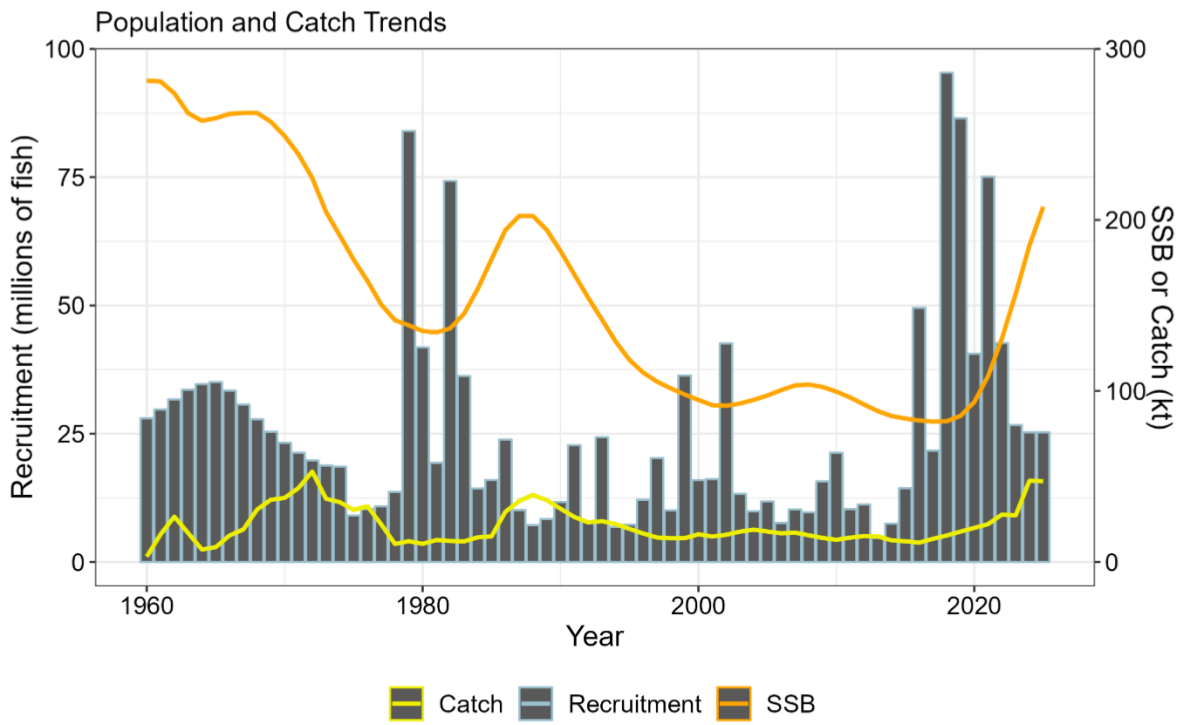


Figure 3.53. Time series of sablefish SSB (orange line), catch (yellow line), and recruitment (grey bars). Projected dynamics for 2024 and 2025 are included based on the maximum permissible ABC and average recruitment. Note the cyclical dynamics associated with spasmodic recruitment. Transitory increases in SSB subsequent to periods of strong recruitment are often followed by a persistent downward time series trend. Catches often rapidly increase following high recruitment periods, while recruitment reverts back towards average levels.

Appendix 3A. Sablefish Longline Survey: Fishery and Whale Interactions

NMFS has requested the assistance of the fishing fleet to avoid the annual longline survey stations since the inception of sablefish IFQ management in 1995. We request that fishermen stay at least five nm away from each survey station for 7 days before and 3 days after the planned sampling date (3 days allows for survey delays). Since 2021, survey calendars have been made available online (https://www.fisheries.noaa.gov/resource/document/alaska-sablefish-longline-survey-station-schedule). While the survey is being conducted, the skipper of the vessel makes announcements on the radio detailing the planned set locations for the upcoming days. Vessels encountered near survey stations are contacted by the survey vessel captain and interviewed to determine potential effects on survey catches. Typically, vessels have been aware of the survey and have not been fishing close to survey locations. Even with communication, there are some instances where survey gear was fished nearby commercial fishing gear or where commercial fishing had recently occurred. There are generally few interactions during the 90-day survey (Table 3A.1). In 2023 there were eight instances of vessel interactions that may have impacted survey catch or required the survey vessel to move the day's sets from their originally intended locations. In the GOA, there were 5 interactions with pot boats (3 in East Yakutat/Southeast, 1 in West Yakutat, and 1 in the Central GOA) and 3 interactions with longline vessels (1 in the western GOA and 2 in the central GOA). There were no vessel interactions in the Bering Sea. As discussed in the main text, the number of sets impacted by whales is also tallied (Table 3A.2) and those sets are dropped (for orca interaction) or catch rates inflated using the survey whale inflation factor (for sperm whales; see 'Whale Depredation Estimation' section).

Tables

Table 3A.1. Count of longline survey and fishery vessel interactions by area, fishery gear type, and year.

	Longline		Trawl		Pot		Total	
Year	Stations	Vessels	Stations	Vessels	Stations	Vessels	Stations	Vessels
1995	8	7	9	15	0	0	17	22
1996	11	18	15	17	0	0	26	35
1997	8	8	8	7	0	0	16	15
1998	10	9	0	0	0	0	10	9
1999	4	4	2	6	0	0	6	10
2000	10	10	0	0	0	0	10	10
2001	1	1	1	1	0	0	2	2
2002	3	3	0	0	0	0	3	3
2003	4	4	2	2	0	0	6	6
2004	5	5	0	0	1	1	6	6
2005	1	1	1	1	0	0	2	2
2006	6	6	1	2	0	0	7	8
2007	8	6	2	2	0	0	10	8
2008	2	2	2	2	0	0	4	4
2009	3	3	0	0	0	0	3	3
2010	2	2	1	1	0	0	3	3
2011	3	3	0	0	0	0	3	3
2012	5	5	0	0	0	0	5	5
2013	5	5	0	0	0	0	5	5
2014	2	2	0	0	0	0	2	2
2015	3	3	1	1	0	0	6	6
2016	5	5	1	1	0	0	6	6
2017	8	10	3	3	3	3	13	16
2018	9	9	3	3	0	0	12	12
2019	4	4	1	1	4	4	9	9
2020	1	1	1	1	3	3	5	5
2021	0	0	0	0	4	4	4	4
2022	1	1	0	0	7	7	8	8
2023	2	3	0	0	4	5	6	8

Table 3.A2. Count of stations where sperm (S) or killer whale (K) depredation occurred and the number of stations sampled (in parentheses) by management area. Only stations used for RPN calculations are included. Areas not surveyed in a given year are left blank. If there were no whale depredation data taken, it is denoted with an "n/a". Killer whale depredation did not always occur on all skates of gear, and only those skates with depredation were removed from calculations of RPNs and RPWs.

	BS (16)		AI (14)		WG (10)		CG (16)		WY (8)		EY/SE (17)	
Year	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**	**S**	**K**
1996			n/a	1	n/a	0	n/a	0	n/a	0	n/a	0
1997	n/a	2			n/a	0	n/a	0	n/a	0	n/a	0
1998			0	1	0	0	0	0	4	0	0	0
1999	0	7			0	0	3	0	6	0	4	0
2000			0	1	0	1	0	0	4	0	2	0
2001	0	5			0	0	3	0	0	0	2	0
2002			0	1	0	4	3	0	4	0	2	0
2003	0	7			0	3	2	0	1	0	2	0
2004			0	0	0	4	3	0	4	0	6	0
2005	0	2			0	4	0	0	2	0	8	0
2006			0	1	0	3	2	1	4	0	2	0
2007	0	7			0	5	1	1	5	0	6	0
2008			0	3	0	2	2	0	8	0	9	0
2009	0	10			0	2	5	1	3	0	2	0
2010			0	3	0	1	2	1	2	0	6	0
2011	0	7			0	5	1	1	4	0	9	0
2012			1	5	1	5	2	0	4	0	3	0
2013	0	11			0	2	2	2	3	0	7	0
2014			1	3	0	4	4	0	6	0	4	0
2015	0	9			0	5	4	0	6	0	7	0
2016			1	0	0	3	3	2	5	0	6	0
2017	0	11			1	2	4	0	3	0	9	0
2018			0	2	0	3	3	0	7	0	9	0
2019	0	10			1	4	6	3	6	0	4	0
2020			0	7	1	5	3	1	4	0	6	0
2021	0	10			0	1	5	0	1	0	2	0
2022			0	1	0	4	2	0	1	0	5	0
2023	0	12			0	3	2	1	2	0	8	0

Appendix 3B. Supplemental Catch Data

In order to address NS1 total accounting requirements, discards (Table 3B.1), FMP bycatch (Table 3B.2), nontarget bycatch (Table 3B.3), and prohibited species catch (PSC; Table 3B.4) are reported in this appendix. Note that all non-commercial catch is now accounted for in the assessment model catch, so no additional table is provided for these sources of removal.

Tables

Table 3.B1. Retained and discarded catch of sablefish (t) by year, fleet, and management (FMP) region. Abbreviations are: HAL = hook-and-line; POT = pot; and TRW = trawl. Source: NMFS Alaskan Regional Office Catch Accounting System via AKFIN (www.akfin.org), accessed on October 24, 2023. Discards are included in the assessment model catch assuming 100% mortality.

		Gulf of Alaska		**Bering Sea/ Aleutian Islands**	
Year	**Gear Type**	**Retained**	**Discarded**	**Retained**	**Discarded**
2019	HAL	7,187	626	274	181
	POT	1,876	632	595	28
	TRW	1,139	1,268	1,319	1,428
2020	HAL	4,954	440	188	231
	POT	4,614	136	948	32
	TRW	1,088	1,243	2,239	2,924
2021	HAL	3,723	354	252	315
	POT	9,647	193	1,881	50
	TRW	1,142	460	1,374	1,876
2022	HAL	3,234	400	200	222
	POT	13,493	155	3,781	56
	TRW	1,354	527	2,209	1,276
2023	HAL	2,288	267	164	116
	POT	10,995	53	3,322	7
	TRW	1,106	302	3,537	482

Table 3.B2. Bycatch (t) of FMP groundfish species by year in the targeted sablefish fishery. Source: NMFS Alaskan Regional Office Catch Accounting System via AKFIN (www.akfin.org), accessed on October 24, 2023.

	2019		2020		2021		2022		2023	
Species	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**	**R**	**D**
Arrowtooth Flounder	239.4	18.3	410.6	24.1	504.1	34.4	437.3	38.5	227.9	170.5
BSAI Kamchatka Flounder	1.3	15.0	7.4	9.0	3.9	9.7	18.9	60.3	20.9	235.6
BSAI Other Flatfish	0.2	5.7	0.2	0.7	0.7	5.0	14.6	22.4	6.3	133.8
BSAI Shortraker Rockfish	0.4	8.0	0.3	1.1	0.1	1.6	2.3	6.4	2.1	16.9
BSAI and GOA Skate	203.0	0.3	174.3	0.5	68.3	3.9	71.2	0.6	66.8	4.4
Flathead Sole	4.2	7.0	5.3	6.5	1.4	3.0	5.3	31.4	3.2	79.8
GOA Deep Water Flatfish	21.3	1.3	14.3	0.2	13.6	0.6	19.9	2.0	11.6	0.1
GOA Demersal Shelf Rockfish	2.7	11.5	1.0	9.8	2.1	17.5	2.1	20.7	0.4	18.1
GOA Dusky Rockfish	0.5	0.3	0.3	0.6	0.0	0.2	0.0	1.1	0.0	5.6
GOA Rex Sole	15.6	1.2	6.8	1.5	2.2	0.3	3.3	0.7	1.0	2.1
GOA Skate, Big	28.4	0.4	28.0	0.7	31.0	2.4	28.5	1.5	27.0	1.6
GOA Skate, Longnose	160.1	2.5	54.1	7.9	122.3	4.8	214.4	4.7	87.3	4.6
GOA Thornyhead Rockfish	70.0	358.9	18.6	227.1	12.2	108.9	11.5	76.3	7.2	53.3
Greenland Turbot	2.3	11.6	1.0	10.4	1.7	1.9	7.2	91.3	9.7	117.9
Halibut	519.0	837.3	217.1	589.1	222.7	604.3	294.6	663.5	111.4	500.1
Octopus	10.1	0.0	2.6	0.0	1.3	0.0	2.1	0.2	7.8	0.2
Other Rockfish	40.6	33.2	12.8	17.6	27.8	22.6	26.5	119.6	47.9	105.7
Pacific Cod	38.5	24.9	19.9	39.7	16.4	64.6	13.1	23.6	5.0	43.9
Pacific Ocean Perch	2.1	28.5	1.7	58.5	0.4	23.7	12.4	40.7	17.9	104.6
Pollock	3.9	8.4	13.8	6.7	55.8	5.2	13.0	26.3	14.9	139.0
Rougheye Rockfish	197.5	91.2	49.2	125.2	62.5	96.6	35.1	98.7	15.4	92.6
Shortraker Rockfish	326.5	94.2	135.6	100.4	116.4	71.1	35.6	56.9	23.4	46.4

Table 3.B3. Bycatch of nontarget species and HAPC biota in the targeted sablefish fishery. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN, October 24, 2023.

Species Group	2019	2020	2021	2022	2023
Benthic urochordata	0.15	0.01	0.07	0.04	0.17
Brittle star	0.41	0.29	0.33	2.58	0.69
Corals Bryozoans	3.33	1.08	1.48	2.95	0.29
Eelpouts	0.21	0.14	0.55	9.52	19.74
Giant Grenadier	2,954.14	1,408.95	795.91	594.09	850.31
Grenadier	1,020.82	482.61	167.89	141.67	91.51
Hermit crab	0.01	0.01	0.01	0.07	0.08
Invertebrate	0.38	0.06	0.13	0.25	0.04
Misc crabs	3.21	4.25	3.86	5.34	8.52
Misc fish	91.78	39.16	29.05	71.70	8.82
Pandalid shrimp	0.00	0.04	-	0.04	0.28
Sculpin	-	-	4.26	7.93	13.38
Scypho jellies	0.69	0.34	0.26	0.58	0.87
Sea anemone	1.75	1.01	2.58	3.92	8.67
Sea pens whips	0.58	0.54	0.22	0.04	0.03
Sea star	5.94	7.47	3.83	16.70	7.90
Snails	7.54	2.91	3.71	7.06	20.09
Sponge	0.31	0.33	0.30	0.68	0.95
Squid	1.23	0.73	0.47	10.26	24.04
Urchins, dollars, cucumbers	1.27	0.54	0.34	1.39	5.51

Table 3.B4. Prohibited Species Catch (PSC) estimates (in tons for halibut and numbers of animals for crab and salmon) by year and management (FMP) region for the sablefish target fishery. HAL is hook and line gear; POT is pot gear; and TRW is trawl gear. Source: NMFS Alaska Regional Office Catch Accounting System PSCNQ via AKFIN (www.akfin.org), accessed on October 24, 2023.

Gulf of Alaska

Species	Gear Type	2019	2020	2021	2022	2023
Bairdi Tanner Crab	HAL	68	-	10	16	31
	POT	199	96	359	474	104
	TRW	-	1,668	1,535	1,554	246
Blue King Crab	HAL	-	-	-	-	-
	POT	-	-	-	-	-
	TRW	-	-	-	-	-
Chinook Salmon	HAL	-	-	-	-	-
	POT	-	-	-	-	-
	TRW	-	-	711	-	-
Golden (Brown) King Crab	HAL	79	47	17	31	5
	POT	95	39	64	189	1,116
	TRW	-	-	-	-	16
Halibut	HAL	563	147	117	116	27
	POT	5	37	73	78	25
	TRW	10	21	35	18	3
Herring	HAL	-	-	-	-	-
	POT	-	-	-	-	-
	TRW	-	-	-	-	-
Non-Chinook Salmon	HAL	258	114	149	11	-
	POT	-	-	-	-	-
	TRW	-	-	-	-	-
Opilio Tanner (Snow) Crab	HAL	-	-	-	-	-
	POT	-	2	-	-	-
	TRW	-	-	-	-	-
Red King Crab	HAL	-	-	0	-	-
	POT	-	-	-	-	-
	TRW	-	-	-	-	-

Bering Sea/Aleutian Islands

Species	Gear Type	2019	2020	2021	2022	2023
Bairdi Tanner Crab	HAL	5	2	4	14	18
	TRW	-	-	-	69	1,223
Blue King Crab	HAL	1	1	0	9	2
	POT	-	-	-	-	-
Chinook Salmon	HAL	0	0	0	0	0
	POT	-	-	-	-	-
	TRW	-	-	-	-	-
Golden (Brown) King Crab	POT	4,255	5,789	28,750	10,340	21,282
	TRW	38	-	135	618	2,510
Halibut	HAL	1	4	11	0	0
	TRW	6	1	3	7	29
Herring	HAL	-	-	-	-	-
	POT	-	-	-	-	-
	TRW	-	-	0	-	0
Non-Chinook Salmon	HAL	0	0	0	0	0
	POT	-	-	-	-	-
Opilio Tanner (Snow) Crab	HAL	19	14	29	44	75
	POT	108	374	846	1,675	1,160
	TRW	-	-	-	171	212
Red King Crab	POT	6	18	-	-	23
	TRW	-	-	-	-	-