Bristol Bay red king crab (BBRKC) proposed models May 2025

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Summary

This document details model explorations for BBRKC that include some of those suggested by the crab plan team (CPT) and Scientific and Statistical Committee (SSC), and also version updates to the GMACS modeling framework (model 24.0c, GMACS version 2.20.20, 2025-01-30). All GMACS updates were tested to ensure model fit (likelihood values, output, etc.) matched the last accepted base model from September 2024 (version 2.20.14, 2024-05-20). The models here focus on cleaning up the code and a small dip into selectivity - specifically assumptions for selectivity using the BSFRF data as a prior. The work presented here is the beginning of work to explore these topics and the author acknowledges that further exploration is warranted.

The results of these model explorations are presented in this document in section C. Background on the Bristol Bay red king crab modeling approach, modeling framework (GMACS), and history of the stock and fisheries can be found in the last full SAFE and will not be repeated here. (**BBRKC 2024 SAFE**)

B. Responses to SSC and CPT

CPT and SSC Comments on Assessments in General

Response to SSC Comments (June 2024, Oct 2024):

"The SSC suggests ... guidance for constructing and interpreting jitter analyses..."

Response: The CPT plans to review this guidance and establish some SOPs for jitter analysis interpretation at the May 2025 CPT meeting; the author will follow this guidance for Sept. 2025 models.

"The SSC would like to see additional residual diagnostics other than raw residuals for length composition data from GMACS models. The SSC encourages crab authors to collaborate with ground fish assessment authors regarding the use of One-Step-Ahead and Pearson residuals."

Response: One-Step-Ahead residuals were discussed at the Jan 2025 modeling workshop and are being incorporated into GMACS output figures for use in assessment output.

"The SSC requests that the CPT consider whether distinguishing between full and update assessments, ..., would be useful for crab assessments."

Response: The CPT has not yet taken up this topic.

"The SSC suggests the CPT live link assessments and other documents in their report to facilitate review."

Response: This will be taken into consideration in spring reports and full SAFEs.

"The SSC reiterates the request for the CPT to develop a process to ensure the authors have provided responses to all previous SSC recommendations."

Response: The CPT has developed a google sheet to track requests, further action maybe discussed at the May 2025 meeting.

"The SSC requests the authors and CPT consider coordinating the approach to analyzing the Bering Sea Fisheries Research Foundation (BSFRF) data for two Chionoecetes crab and Bristol Bay red king crab (BBRKC) stocks, and specifically consider developing the results as a prior on selectivity for use in the models."

Response: There was some discussion among authors Jan 2025 modeling workshop, which corresponded to Buck Stockhausen's work on this topic. The CPT has not developed a coordinated approach yet to this topic.

Response to SSC Comments (June 2023, Oct 2023):

"The SSC recommends that a"fallback" Tier 4 alternative be provided, as recommended by the Simpler Modeling workshop. When doing so the SSC asks the authors to provide plots to compare OFLs with the status quo Tier 3 models for previous years, justification for the time series used for status determination and a recommended ABC buffer."

Response: A Tier 4 fallback based on survey data and the REMA model was provided in fall of 2024 and will be provided this Sept.

"For the inclusion of trawl survey data, the SSC suggests crab assessment authors and the CPT be more explicit about best practices for which standard years are included for bottom trawl survey data."

Response: This was addressed by the CPT at our Jan 2024 meeting. See meeting minutes for agreed upon "best practices".

"The SSC recommends the crab stocks begin using the established risk table format from groundfish for assessing uncertainty around buffer considerations"

Response: After viewing draft risk tables in Sept. 2024 the CPT decided to pick up a risk table format for crab stock discussion at the May 2025 meeting. The risk table framework agreed upon at this meeting will be presented with final assessments in Sept. 2025.

"The SSC recommends that uncertainty intervals be included when showing time series of biomass/abundance estimated by models.

Response: These are provided in this document.

CPT and SSC Comments on BBRKC assessment

Responses to SSC Comments (June 2024/Oct 2024):

"The SSC recommends that the author bring forward a model that adds the BSFRF prior on selectivity for the 2025 assessment."

Response: Models 25.1a, 25.1b, and 25.1b2 all use the BSFRF data as a prior on selectivity. The author has concerns over moving to these models without further model exploration for the 2025 assessment and this is discussed in this document.

"The SSC agrees with the additional considerations by the CPT in their minutes prioritizing; 1) considerations of selectivity time periods based on gear types and 2) considerations of time-varying selectivity in the fishery data relative to the survey data."

Response: The selectivity models presented in this document do retain the two time blocks for survey selectivity for the NMFS time series. However, the author has not yet explored time-varying selectivity in the fishery data relative to the survey data and hopes to have some discussion with the CPT on what this exploration could look like.

"The SSC reiterates its request to evaluate whether crab biomass and fishing mortality in the northern district should be included."

Response: Since 2022 the SAFE document has tracked Northern RKC data from the NMFS trawl survey. Overall, the proportions of different size/sex groups of the Northern RKC during a recent dozen years are higher than in the past and do not trend higher except for mature females in 2021. The high survey mature female abundance in the Northern area in 2021 was primarily from three tows and one of them is more than 50% of total mature females. The survey abundance of the Northern RKC will continue to be plotted in the SAFE report in the future. After migration patterns between BBRKC and the Northern RKC are fully understood, we will model them in the stock assessment. An assessment model that includes crab outside the Bristol Bay boundary would have to include updates to data inputs for all catch and survey time series, and also include conversations with managers on the implications of a larger spatial model. Explorations into model based indices for other Bering Sea stocks may provide an option for BBRKC to utilize the Northern district crab to design a model based index that only predicts over the traditional Bristol Bay grid. Work on this is planned for 2025/2026.

"The SSC recommends the author revisit previous CPT discussion and rationale on whether 50% handling mortality is appropriate for both pot and longline (fixed gear) gear and to provide additional information in the next assessment."

Response: This document (May 2025) includes a model run, model 24.0c.1a, that has a reduced handling mortality (20%) for the fixed gear groundfish catch in place of the historical 50% level. No measurable changes to model results were observed, only small changes in management quantities that lie within the range of variability for those estimates (Table 4 and Figure 13). This is likely due to the small magnitude of fixed gear catch in the model compared to directed fishery catch. Ultimately a change in the handling mortality rate for fixed gear would have to be approved by the CPT. A review of the data available to inform handling mortality estimations occurred at the May 2022 CPT meeting (**HM May 2022**). At this time there are no direct research studies conducted on mortality of crab caught as bycatch in the longline or pot groundfish fisheries. Historically ranges of 30 to 50% have been use in various Council analyses and since 2008 a 50% rate has been applied when splitting bycatch between fixed and trawl gear.

Response to CPT Comments (from May 2024):

"Including BSFRF as a 'ghost fleet' as a check on model behavior."

Response: Further exploration of the BSFRF data and its use in the BBRKC model is needed and planned for 2025/2026, it was not examined prior to May 2025.

Split the selectivity into eras to reflect the change in survey gear, but still use the same priors, perhaps with larger CVs in the early era.

Response: Models 25.1a, 25.1b, and 25.1b2 all retain the time blocks for survey selectivity estimation and use the same priors for both periods. Model 25.1b2 has larger CVs for both eras, this resulted in a similar estimation as Model 25.1b for the se.

Selectivity and retention explorations that may include: exploring parameters that allow for the retention curve to asymptote below one, exploring splines for selectivity, and exploring models using time-varying selectivity to better understand model dynamics.

Response: Model sensitivity to selectivity and retention assumptions should be explored but was not prioritized this year. Further direction from the CPT on hypotheses for these model runs would help in determining the appropriate parameterizations to explore moving forward.

Explore including larger size bins in the model to explore dome shaped selectivity.

Response: Including larger size bins than the current model uses (>160mm for males specifically) would require re-visiting the growth matrix for this stock. This matrix has been established for some time and would require some historic data recovery to determine if larger size bin growth could be determined from the same data. To include larger size bins assumptions would need to be made for the growth matrix unless the historic data was recoverable. Additionally, raw data to add size bins to each of the size comp data sets is still in the process but an initial look at the NMFS data to determine if larger size bins should be incorporate was explored here. Figure 1 displays the distribution of size composition for all years of the NMFS data and the associated lower and upper cut offs for the model. Initial exploration does not suggest a large change in size distribution over time, at least for the last 15 years.

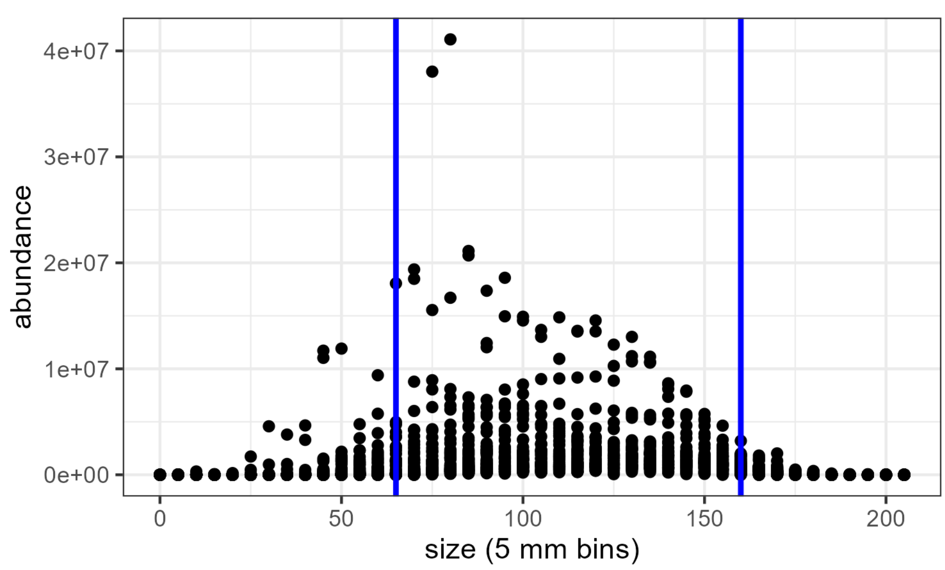

Figure 1: Size composition for all crab in all years in the NMFS trawl survey in 5mm size bins.

Remove shell condition from the model since it's not being used currently

Response: Shell condition was removed from the model, reflected as model 24.0c.2, and has no measurable effect on results since it was not being implemented in the current base model.

Response to SSC Comments specific to this assessment (from October 2023):

Provide basis for the tight prior on M and catchability.

Response: The prior on trawl survey catchability is estimated with a mean of 0.896 and a standard deviation of 0.025 (CV about 0.03) that is based on double-bag experiment results (Weinberg et al. 2004). The prior on M is based on the balance of allowing M to be estimated above the default, historic 0.18 value for males but realizing the limitations of the data to estimate M freely. Future work is planned and will continue to explore the most appropriate estimation of M.

Consider tracking Dungeness crab abundance in the EBS and how this might affect BBRKC dynamics.

Response: Currently there is no abundance estimate of Dungeness crab in the EBS. Conversations have occurred between the author and regional biologist on possible general affects, with the overall consensus that these two species are likely not occupying the same habitat as juveniles/adults. However, the early life spatial occupation for both of these stocks is unknown, so there may be competition for food in these stages. Trends of Dungeness catch over time are being obtained and will be explored in future work.

Explain why equal sample sizes are used for male and female size composition data.

Response: The size composition data for surveys is entered into the model as aggregate data since they are derived from the same survey samples. Therefore the sample size for each is based on the total number of crab measured not those measured by sex.

MCMC output diagnostics, autocorrelation plots and parameter chains

Response: These will be provided in Sept 2025 when a full MCMC is performed on the preferred models. The CPT will have discussions in May 2025 on the suite of diagnostics to report for MCMC output.

Possible effect of high 2011 recruitment as scene in survey size composition figures

Response: Size composition plots in Sept 2023 highlighted a potential recruitment event in 2011 for both males and females from the NMFS survey data (Figures 6 and 7 - Sept 2023 SAFE). This peak occurs as size classes that are not included in the assessment model (< 65mm, figures 43 and 44 - Sept 2023 SAFE), therefore this recruitment likely plays little role in the model estimates and resulting retrospective pattern since it is not seen in subsequent years to be included in the model.

Response to CPT Comments (from May 2023 / Sept 2023):

Reconsider which growth parameters are estimated vs. specified. Consider a model run with growth specified outside the model (CPT Sept 2023)

Response: The author is collaborating with biologists on the availability of more recent growth data, and investigating the feasibility of recovering the original raw data used in the historic growth specifications. Work is underway to determine the best path forward for growth parameterizations for this stock.

Survey selectivity / q / catchability. Reconsider the strong prior and shape of the selectivity curve. Consider using the BSFRF data as a prior on selectivity/catchability as was done in the snow crab assessment (CPT and SSC May/June 2023 and Sept/Oct 2023)

Response: Models presented in May 2024 (24.0 and 24.0b) reflected explorations on using the BSFRF data as a prior on selectivity - similar to snow crab (fall 2023). Further explorations on priors and shape were not explored this round, although the previous assessment author did explore some aspects in models runs between 2020 and 2022.

Revisit blocking on molting probability from tagging data (CPT and SSC May/June 2023)

Response: The blocking of molt probability for males reflects changes in the Bristol Bay ecosystem in the early 80s and has been a historic component of the current model. Models presented in May 2024 reflected removing this blocking to estimate one molting probability for the entire time series. Model 24.0c was adopted in fall of 2024.

Response to SSC/CPT comments prior to 2023: See Fall 2024 document - linked above in intro - for further historical discussion of CPT and SSC comments.

C. Modeling Approaches and Explorations for spring 2025

Assessment Methodology

This assessment model uses the GMACS modeling framework (since 2019) and is detailed in Appendix A of the last full SAFE report (link in the summary section). An updated version of GMACS (version 2.20.20, 2025-01-30) was used in this document compared to that used for the final assessment in fall of 2024 (version 2.20.14, 2024-05-20). The newer version includes updates made during winter 2024/25, including those during the Jan modeling workshop, but did not include any substantive changes to code and therefore were not expected to change model fit. Progress of GMACS development has been documented on the GitHub development site (**GMACS GitHub**).

Model explorations

Models explored in this document:

- **24.0c**: base model (fall 2024), M for males estimated in the model, molt time block removed + updated GMACS
- **24.0c.1**: 24.0c + updated catch time series data for crab fisheries via ADF&G
- **24.0c.1a**: 24.0c.1 + 20% handling mortality for fixed gear
- **24.0c.2**: 24.0c.1 + removing shell condition placeholders from code
- **25.1a**: 24.0c.2 + selectivity informed by BSFRF survey all data
- **25.1b**: 24.0c.2 + selectivity informed by BSFRF survey SBS subset of data
- **25.1b2**: 25.1b + increased SD (2x m25.1b) on selectivity prior for each size bin

Reasoning for model explorations

Six model scenarios are presented in this report. The first set of models are updates to the base model that reflect model structure clean up (model 24.0c.2), data changes (model 24.0c.1), and sensitivities to fixed gear handling mortality (model 24.0c.1a). For these model runs the overall model fit is nearly identical, with similar MLE and likelihood components (Table 4), which is expected due to the minimal changes in the input data.

The rest of the model scenarios explore using a prior on selectivity that is defined from the BSFRF data (models 25.1a, 25.1b, and 25.1b2), building on previous models presented in May of 2024. These models use model 24.0c.2 as the base model, which is the 2024 accepted base model with updated data and GMACS version (this model estimates the base M for males using a log-normal prior with a mean of 0.18 and a CV of 0.04, has no time block for molt probability, has updated catch data, and removal of shell condition considerations).

Recent CPT/SSC comments and the simpler modeling workshop report suggested that the author should explore methods to estimate catchability (Q) for the NMFS trawl survey. In the base models, initial trawl survey catchability is estimated using a normal prior ~(0.896, 0.03) based on double-bag experiment results (Weinberg et al. 2004). The appropriateness of this prior and the relationship between NMFS trawl survey Q and that assumed for the BSFRF survey have been on the list of model suggestions.

Model explorations here use methods similar to those in Szuwalski (2023) to explore using the BSFRF data as a prior on selectivity for the NMFS survey. BSFRF surveys were performed in 5 years (2007, 2008, 2013, 2014, 2015, and 2016) and are currently treated as a separate index in the assessment model, with both the index and size composition data being fit with the Q for BSFRF set to 1. Models 25.1a, 25.1b, and 25.1b2 (based on the base model 24.0c.2) remove the BSFRF data and instead use the information from these data survey data to set a normal prior on selectivity for the NMFS survey. A GAM was fit to inferred selectivity (assuming the full catchability of the BSFRF survey) at size by year, weighted by the sample size (gam(sel~s(size), weights= sample_size)). For these purposes males and females were combined as one sample.

This analysis was performed on two data sets; the first used all of the size composition data for each survey for all years (2007, 2008, and 2013 to 2016), and the second was a subset of this data that included only the side-by-side haul data for the years in which the author had it available (2013 to 2016). The predicted means and standard errors of the resulting estimated GAMs were input as a prior on a selectivity parameter for each size class in GMACS (Figure 2 and 3). Specifically in GMACS parametrization, the selectivity type was set to 0 (parametric) in the .ctl file and catchability was fixed at 1. Model 25.1a uses all of the size composition data and is similar to the May 2024 model presented, but includes both time blocks for survey selectivity - unlike the May 2024 exploration (Figure 2), while models 25.1b and 25.1b2 use the side-by-side subset of data (Figure 3). Model 25.1b2 doubles the standard error associated with each size bin's estimation in an attempt to explore variability.

Results

a. Sensitivity to data and code clarification changes

Models 24.0c, 24.0c.1, 24.0c.1a, and 24.0c.2 reflect updates to the directed catch time series (model 24.0c1), removal of place holder for shell condition (model 24.0c.2), and sensitivities to handling mortality in the fixed gear groundfish fisheries (model 24.0c.1a). The likelihoods for these model comparisons are nearly identical (Table 4). These updates are consist with improved base model practices, therefore model 24.0c.2 was used as the updated base model for further explorations. Changes to the handling mortality rate for fixed gear groundfish bycatch was performed as a model sensitivity as requested by stakeholders and the SSC. Changes to the handling mortality rate would have to be adopted by the CPT before this was put into place in the base model data input.

b. Effective sample sizes and weighting factors

- CVs are assumed to be 0.03 for retained catch biomass, 0.04 for total male biomass, 0.07 for pot bycatch biomass, 0.10 for groundfish bycatch biomass, and 0.23 for recruitment sex ratio. Models also estimate sigmaR for recruitment variation and have a penalty on M variation and many prior-densities.

- Initial trawl survey catchability (Q) is estimated using a normal prior ~(0.896, 0.03) based on double-bag experiment results (Weinberg et al. 2004). These values are used to set a prior for estimating Q in models with both the BSFRF and NMFS data, but not in the 25.0 series of models explored. Refer to the 2024 completed SAFE document for further information on this section.

b. Tables of estimates

- Negative log-likelihood values are summarized in Table 4 for all models, while parameter estimates are summarized in Tables 5 – 7 for a few representative models.
- Natural mortality estimates are shown in Table 3.
- Abundance, MMB, and recruitment time series for a few representative models are found in Tables 8 – 10.

c. Evaluation of the fit to the data and model estimates.

- Selectivities by length (Figures 4 and 5)

Model explorations focus on estimated trawl survey selectivity. The use of the BSFRF data as a prior on survey selectivity in models 25.1a and 25.1b resulted in a difference in selectivity, especially for large size bins. However, the overall shape of the selectivity curve for these models is similar to that estimated in the base model. with the exception of the larger size bins. Survey selectivity affects not only the fitting of the data but also the absolute abundance estimates. These estimated survey selectivities are generally smaller than the capture probabilities in Appendix A - Figure A1 of the SAFE document (refer to last full SAFE draft) because survey selectivities include capture probabilities and crab availability. The reliability of estimated survey selectivities will greatly affect the application of the model to fisheries management since under- or over-estimates of survey selectivities will cause a systematic upward or downward bias of abundance estimates, respectively.

- NMFS trawl survey biomass and BSFRF surveys (Figures 6 – 8).

Among the model scenarios, model estimated NMFS survey biomasses are similar, with some changed in scale due to changes in Q, which is expected.

The fits to BSFRF survey data are similar among the models in the base comparison series as expected due to the small difference in these models.

All models fit the bycatch biomasses very well and similarly so they are not presented in this document.

- Recruitment (Figures 9 and 10)

Recruitment time series are plotted for all model scenarios in groups of like models - base models and selectivity models. Recruitment is estimated at the end of year in GMACS. Estimated recruitment time series are generally similar in trends for all models, with those models that use the BSFRF data to estimate selectivity having a difference in the recruitment scale to match the overall scaling of abundance to match the estimated selectivity.

- Fishing mortality and catch (Figure 12)

The full fishing mortalities for the directed pot fishery at the time of fishing are plotted against mature male biomass on Feb. 15 in the last full SAFE (See BBRKC 2024 SAFE link and Figures 26, 27, and 29). Estimated fishing mortalities in most years before the current harvest strategy was adopted in 1996 were above F35%. Under the current harvest strategy, estimated fishing mortalities were at or above the F35% limits in 1998, 2007-2009, and 2014-2019 for model 24.0c.2, but below the F35% limits in the other post-1995 years.

Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally small and less than 0.07 (not shown in this document but available in last full SAFE). Fits to catch from the directed and non-directed fisheries is displayed in Figure 15 to illustrate the model fit to small updates in the crab catch data from ADF&G.

- Estimated mature male biomass (Figures 13 and 14)

Estimated mature male biomass for all models has a similar trend over time, however the scaling of the biomass is highly dependent, as expected, on estimates of Q in the models. Higher estimated selectivity for a majority of size classes in models 25.1a, 25.1b, and 25.1b2 results in a lower overall scale for mature male biomass compared to the base model. These models are consistently lower in overall scale from about 1990 onward.

- Size composition fits by length and residual plots (Figures 16 – 24).

All models fit the length composition data similarly and well. Modal progressions are tracked well in the trawl survey data, particularly beginning in mid-1990s. Cohorts first seen in the trawl survey data in 1975, 1986, 1990, 1995, 1999, 2002 and 2005 can be tracked over time. Bycatch size composition data provide little information to track modal progression and are not displayed graphically. One-step-ahead (OSA) residuals of proportions of survey males and females appear to be random over length and year for all models, although only the base model representation is presented here. The author looks for guidance from the CPT and other assessment authors on how best to present these results for model comparisons.

d. Retrospective and historical analyses

Retrospective analysis was not performed on these model explorations. Topics explored in these models were not expected to improved retrospective trends and therefore these were not explored at this time. They will be performed on models for the fall full SAFE. Retrospective runs performed for the 2023 SAFE suggested an improvement with estimation of M for males, as reported in the Mohn's *rho* values, from a Mohn's *rho* of 0.373 to 0.226. The improved retrospective pattern in MMB was one of the reasons the model with estimation of a base M value for males was approved in 2023. Model explorations since 2023 have not improved the retrospective patterns.

e. Uncertainty and sensitivity analyses.

- Estimated standard deviations of parameters are summarized in Tables 5 – 7 for a few representative models.
- The last completed SAFE document in 2024 details uncertainty estimates in the current base model parameterization (**BBRKC 2024 SAFE**).

f. Comparison of alternative model scenarios.

In this report (May 2025), six models are presented. Three of these were not expected to have large changes in model fit or likelihood values. For negative likelihood value comparisons (Table 4), the base model comparisons (models 24.0c, 24.0c.1, 24.0c.1a, and 24.0c.2) were nearly identical, which was expected since they reflected data updates, GMACS updates, and had no structural model changes. Small differences in management quantities and MMB scale exist between model 24.0c.1 and 24.0c.1a, which includes reduced handling mortality on the fixed gear groundfish bycatch. Model 24.0c.2 should be considered the most updated reference model and was used to compare other model explorations.

Models 25.1a, 25.1b, and 25.1b2 explore the use of the BSFRF survey data as an informed prior on selectivity for NMFS instead of treating these data as another index/size composition. This approach was similar to that used for snow crab in 2023, and is considered an initial approach to this line of exploration. For these model runs two versions of the BSFRF data sets were used, with the first using overall catch and size composition data from both surveys in all years with data, and the second using a subset of only the side-by-side haul data which is a reduction in sample size and year range. The use of the GAM model estimates for these two data sets as a prior on selectivity in the model was the same, with the same prior information being used for both selectivity time blocks (1975 to 1981, and 1982 to 2023). Model 25.1b2 was run to determine if increasing the error on the prior would change the estimated selectivity curve, this resulted in a more variable selectivity curve but overall the output was similar to model 25.1b. The inferred selectivity patterns estimated using the BSFRF data has an overall shape that is similar to that estimated in the base model, with the exception of the largest size classes which may suggest either a dome-shaped selectivity or support for increased larger size bins in the model (Figure 2 and 3).

Figure 5 visualizes the estimated selectivity relationship using the estimated inferred selectivity from the BSFRF data as a prior. Compared to the base model these models have small increases in selectivity for most size bins and the potential for variable relationships at larger size bins greater than 130 mm carapace length. Model 25.1b2, which has increased variability in the prior for selectivity for both time blocks, allowed for a more variable estimate of selectivity but overall similar shape to model 25.1b. Since these models allow for variability in selectivity estimates they also produce variable estimates of base natural mortality (Table 3), since selectivity and natural mortality are confounding parameters. These models, as current specified, do not reflect improvement in overall model fit. However, variants of this approach should be considered for exploration in the future. Further model explorations are warranted for exploring selectivity and catchability in this model, and the authors would appreciate guidance on potential next steps. Additionally, if the BSFRF data were used as a prior, a more appropriate method to incorporate those data is needed since the method used here ignores correlation among size bins in estimating parameters for selectivity.

Based on the above considerations, the author is hesitant to recommend any of the selectivity alternatives for setting specifications for this fall. The updated base model will be brought forward, model 24.0c.2, and the author can also bring forward alternatives that incorporate changes to fixed gear groundfish handling mortalities if the crab plan team would like to consider those. The author is open to plan team discussion and thoughts on the status of the BSFRF selectivity prior models but is cautious to make changes in selectivity estimates due to concern over how the parameterization is currently performed (lack of correlation between size bins) and the ramifications on population scaling and natural mortality estimation. The author suggests that further work is needed on explorations for selectivity and catchability before variants of models 25.1a and 25.1b should be considered for specification setting.

The CPT/SSC comments above address many other topics that were not able to be addressed in this round of model improvements but are on the author's list for consideration. Some of these topics require more extensive data mining and time prioritization than is currently allotted in the author's workplan. Additionally, the author is currently pursuing analyses to assist the Alaska Department of Fish and Game in updating the State harvest strategy and will update on progress on that front when appropriate in the Council process.

D. Calculation of the OFL and ABC

Tier 3 control rules and methodology behind these calculations are explained in detail in the last full SAFE report published on the NPFMC website (see summary section for link).

Table 1: Changes in management quantities for each scenario explored. Reported quantities are derived from maximum likelihood estimates. MMB, B35, and OFL are reported in 1,000 t. Average male recruitment in millions of animals.

Model	Current MMB	B35	MMB/B_{MSY}	F35	F_{OFL}	OFL	avg male rec	maleM
m24.0c	15.43	18.69	0.83	0.40	0.32	5.02	9.84	0.23
m24.0c.1	15.40	18.65	0.83	0.40	0.32	5.02	9.82	0.23
m24.0c.2	15.40	18.65	0.83	0.40	0.32	5.02	9.82	0.23
m25.1a	14.36	18.76	0.77	0.35	0.26	3.71	7.89	0.21
m25.1b	14.87	19.00	0.78	0.36	0.27	4.02	8.13	0.21
m25.1b2	14.26	18.22	0.78	0.38	0.29	4.05	8.54	0.22

E. Projections and Future Outlook

Projections into the future will be performed in the Sept. 2025 assessment with the models selected from this document.

The projections are subject to many uncertainties. Constant population parameters estimated in the models used for the projections include M, growth, and fishery selectivities. The uncertainty of abundance and biomass estimates in the terminal year also affects the projections. Uncertainties of the projections caused by these constant parameters and abundance estimates in the terminal year would be reduced by the 20% ABC buffer. However, if an extreme event occurs, like a sharp increase of M during the projection period, the ABC buffer would be inadequate, and the projections might underestimate uncertainties. The largest uncertainty is likely from recruitment used for the projections. Higher or lower assumed recruitment would cause too optimistic or too pessimistic projections. Overall, recruitment and M used for projections are main factors for projection uncertainties.

J. Acknowledgements

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K. References

References can be found in the last full SAFE published on the NPFMC website and will not be repeated here. (**BBRKC 2024 SAFE**)

Tables

Catch, sample size, and survey results tables are not repeated here but can be found in the last full completed SAFE (link in summary).

Table 2: Changes in management quantities for each scenario explored. Report quantities are derived from maximum likelihood estimates. Average recruitment is males and females combined in millions of animals.

Model	Current MMB	B35	F35	F_{OFL}	OFL	avg male rec
m24.0c	15.43	18.69	0.40	0.32	5.02	9.84
m24.0c.1	15.40	18.65	0.40	0.32	5.02	9.82
m24.0c.2	15.40	18.65	0.40	0.32	5.02	9.82
m25.1a	14.36	18.76	0.35	0.26	3.71	7.89
m25.1b	14.87	19.00	0.36	0.27	4.02	8.13
m25.1b2	14.26	18.22	0.38	0.29	4.05	8.54

Table 3: Natural mortality estimates for model scenarios during different year blocks.

Model	Sex	baseM	1980-84
m24.0c	female	0.26	1.16
m24.0c	male	0.23	1.01
m24.0c.1	female	0.26	1.16
m24.0c.1	male	0.23	1.01
m24.0c.2	female	0.26	1.16
m24.0c.2	male	0.23	1.01
m25.1a	female	0.25	1.16
m25.1a	male	0.21	0.96
m25.1b	female	0.25	1.14
m25.1b	male	0.21	0.96
m25.1b2	female	0.26	1.16
m25.1b2	male	0.22	0.98

Table 4: Comparisons of negative log-likelihood values and some parameters for all model scenarios.

Component	m24.0c(ref)	m24.0c.1	m24.0c.1a	m24.0c.2	m25.1a	m25.1b	m25.1b2
Pot-ret-catch	-61.35	-61.23	-61.18	-61.23	-62.80	-62.59	-63.30
Pot-totM-catch	30.40	30.74	30.78	30.74	29.41	30.02	28.57
Pot-F-discC	-59.19	-59.19	-59.19	-59.19	-59.19	-59.19	-59.19
Trawl-discC	-66.52	-66.52	-66.52	-66.52	-66.52	-66.52	-66.52
Tanner-M-discC	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54
Tanner-F-discC	-43.51	-43.51	-43.51	-43.51	-43.49	-43.49	-43.49
Fixed-discC	-38.81	-38.81	-38.81	-38.81	-38.81	-38.81	-38.81
Traw-suv-bio	-39.35	-39.44	-39.31	-39.44	-41.46	-40.20	-42.61
BSFRF-sur-bio	-5.00	-5.01	-5.00	-5.01			
Pot-ret-comp	-4084.32	-4084.38	-4084.36	-4084.38	-4083.62	-4085.50	-4086.42
Pot-totM-comp	-2523.39	-2523.04	-2523.02	-2523.04	-2525.67	-2524.43	-2526.21
Pot-discF-comp	-1546.63	-1546.63	-1546.60	-1546.63	-1545.33	-1546.85	-1546.08
Trawl-disc-comp	-6052.23	-6052.36	-6052.32	-6052.36	-6039.81	-6039.70	-6043.00
Tanner-disc-comp	-1276.39	-1276.45	-1276.46	-1276.45	-1275.52	-1274.90	-1276.22
Fixed-disc-comp	-3598.44	-3598.29	-3598.26	-3598.29	-3603.45	-3604.56	-3603.10
Trawl-sur-comp	-7288.60	-7288.44	-7288.33	-7288.44	-7294.50	-7280.86	-7302.88
BSFRF-sur-comp	-844.58	-844.63	-844.61	-844.63			
Recruit-dev	74.44	74.46	74.45	74.46	74.85	73.98	73.97
Recruit-ini	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recruit-sex-R	80.45	80.46	80.45	80.46	80.69	80.72	80.48
Sex-specific-R	0.06	0.06	0.06	0.06	0.07	0.10	0.05
Ini-size-struct	33.22	33.24	33.25	33.24	31.31	31.02	31.35
PriorDensity	224.79	224.80	224.98	224.80	124.52	141.29	160.10
Tot-likelihood	-27128.48	-27127.70	-27127.04	-27127.70	-26382.87	-26354.01	-26366.85
Tot-parms	383.00	383.00	383.00	383.00	415.00	415.00	415.00
MMB35	18690.36	18648.50	18623.80	18648.50	18757.92	19003.22	18216.57
MMB-terminal	15426.70	15403.24	15439.07	15403.24	14356.20	14865.46	14259.93
F35	0.40	0.40	0.40	0.40	0.35	0.36	0.38
$Fofl$	0.32	0.32	0.33	0.32	0.26	0.27	0.29
OFL	5021.81	5018.15	5057.16	5018.15	3710.47	4017.62	4046.81

Table 5: Summary of a selection of estimated model parameter values and standard deviations for model 24.0c for Bristol Bay red king crab.

Index	Name	Value	StdDev
1	Log(Rinitial):	20.0513	0.0559
2	Log(Rbar):	16.5545	0.1409
3	Recruitment-rb-males:	0.8149	0.1439
4	Recruitment-rb-females:	-0.6472	0.2237
5	Gscale-base-male:	1.0386	0.1975
6	Gscale-base-female:	1.3885	0.1220
7	Molt-probability-mu-base-male-period-1:	141.1020	0.5702
8	Molt-probability-CV-base-male-period-1:	0.0671	0.0031
9	M-base-male-mature:	0.2303	0.0064
10	M-male-mature-block-group-1-block-1:	1.4807	0.0311
11	M-base-female-mature:	0.1398	0.0187
12	Sel-Pot-Fishery-male-base-Logistic-mean:	4.7788	0.0080
13	Sel-Pot-Fishery-male-base-Logistic-cv:	2.2645	0.0419
14	Sel-Trawl-Bycatch-male-base-Logistic-mean:	5.1398	0.0471
15	Sel-Trawl-Bycatch-male-base-Logistic-cv:	2.7929	0.0405
16	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-mean:	4.7082	0.2415
17	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-cv:	2.1688	0.3041
18	Sel-Fixed-Gear-male-base-Logistic-mean:	4.7889	0.0189
19	Sel-Fixed-Gear-male-base-Logistic-cv:	2.2898	0.0759
20	Sel-NMFS-Trawl-male-base-Logistic-mean:	4.1302	0.1358
21	Sel-NMFS-Trawl-male-base-Logistic-cv:	2.2388	0.3728
22	Sel-NMFS-Trawl-male-Logistic-mean-block-group-5-block-1:	4.0868	0.2406
23	Sel-NMFS-Trawl-male-Logistic-cv-block-group-5-block-1:	3.5214	0.3763
24	Sel-BSFRF-male-base-Logistic-mean:	4.4639	0.0267
25	Sel-BSFRF-male-base-Logistic-cv:	2.5430	0.0779
26	Sel-Pot-Fishery-female-base-Logistic-mean:	4.5648	0.0186
27	Sel-Pot-Fishery-female-base-Logistic-cv:	2.2265	0.0894
28	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-mean:	4.7361	0.0901
29	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-cv:	0.9029	0.3027
30	Ret-Pot-Fishery-male-base-Logistic-mean:	4.9237	0.0015
31	Ret-Pot-Fishery-male-base-Logistic-cv:	0.6812	0.0522
32	Ret-Pot-Fishery-male-Logistic-mean-block-group-6-block-1:	4.9325	0.0020
33	Ret-Pot-Fishery-male-Logistic-cv-block-group-6-block-1:	0.7309	0.0960
34	Log-fbar-Pot-Fishery:	-1.7448	0.0433
35	Log-fbar-Trawl-Bycatch:	-4.4321	0.0744
36	Log-fbar-Bairdi-Fishery-Bycatch:	-5.7238	0.3230
37	Log-fbar-Fixed-Gear:	-6.5791	0.0670
38	Survey-q-survey-1:	0.9302	0.0258
39	Log-add-cvt-survey-2:	-1.0018	0.2872

Table 6: Summary of a selection of estimated model parameter values and standard deviations for model 24.0c2 for Bristol Bay red king crab.

Index	Name	Value	StdDev
1	Log(Rinitial):	20.0519	0.0559
2	Log(Rbar):	16.5533	0.1409
3	Recruitment-rb-males:	0.8160	0.1444
4	Recruitment-rb-females:	-0.6485	0.2240
5	Gscale-base-male:	1.0401	0.1978
6	Gscale-base-female:	1.3884	0.1220
7	Molt-probability-mu-base-male-period-1:	141.0818	0.5705
8	Molt-probability-CV-base-male-period-1:	0.0672	0.0031
9	M-base-male-mature:	0.2304	0.0064
10	M-male-mature-block-group-1-block-1:	1.4806	0.0311
11	M-base-female-mature:	0.1396	0.0187
12	Sel-Pot-Fishery-male-base-Logistic-mean:	4.7784	0.0080
13	Sel-Pot-Fishery-male-base-Logistic-cv:	2.2628	0.0419
14	Sel-Trawl-Bycatch-male-base-Logistic-mean:	5.1400	0.0471
15	Sel-Trawl-Bycatch-male-base-Logistic-cv:	2.7929	0.0405
16	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-mean:	4.7095	0.2402
17	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-cv:	2.1685	0.3043
18	Sel-Fixed-Gear-male-base-Logistic-mean:	4.7887	0.0189
19	Sel-Fixed-Gear-male-base-Logistic-cv:	2.2889	0.0759
20	Sel-NMFS-Trawl-male-base-Logistic-mean:	4.1294	0.1363
21	Sel-NMFS-Trawl-male-base-Logistic-cv:	2.2383	0.3743
22	Sel-NMFS-Trawl-male-Logistic-mean-block-group-5-block-1:	4.0859	0.2410
23	Sel-NMFS-Trawl-male-Logistic-cv-block-group-5-block-1:	3.5188	0.3754
24	Sel-BSFRF-male-base-Logistic-mean:	4.4641	0.0267
25	Sel-BSFRF-male-base-Logistic-cv:	2.5437	0.0779
26	Sel-Pot-Fishery-female-base-Logistic-mean:	4.5648	0.0186
27	Sel-Pot-Fishery-female-base-Logistic-cv:	2.2264	0.0893
28	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-mean:	4.7360	0.0900
29	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-cv:	0.9029	0.3027
30	Ret-Pot-Fishery-male-base-Logistic-mean:	4.9239	0.0015
31	Ret-Pot-Fishery-male-base-Logistic-cv:	0.6847	0.0522
32	Ret-Pot-Fishery-male-Logistic-mean-block-group-6-block-1:	4.9323	0.0020
33	Ret-Pot-Fishery-male-Logistic-cv-block-group-6-block-1:	0.7261	0.0963
34	Log-fbar-Pot-Fishery:	-1.7453	0.0433
35	Log-fbar-Trawl-Bycatch:	-4.4307	0.0744
36	Log-fbar-Bairdi-Fishery-Bycatch:	-5.7220	0.3230
37	Log-fbar-Fixed-Gear:	-6.5787	0.0670
38	Survey-q-survey-1:	0.9307	0.0258
39	Log-add-cvt-survey-2:	-1.0030	0.2874

Table 7: Summary of a selection of estimated model parameter values and standard deviations for model 25.1b for Bristol Bay red king crab.

Index	Name	Value	StdDev
1	Log(Rinitial):	19.9223	0.0406
2	Log(Rbar):	16.3192	0.1351
3	Recruitment-rb-males:	1.4310	0.2310
4	Recruitment-rb-females:	-0.8977	0.2484
5	Gscale-base-male:	0.7758	0.1836
6	Gscale-base-female:	1.3018	0.1259
7	Molt-probability-mu-base-male-period-1:	141.4015	0.5310
8	Molt-probability-CV-base-male-period-1:	0.0662	0.0030
9	M-base-male-mature:	0.2100	0.0050
10	M-male-mature-block-group-1-block-1:	1.5185	0.0299
11	M-base-female-mature:	0.1698	0.0180
12	Sel-Pot-Fishery-male-base-Logistic-mean:	4.7749	0.0082
13	Sel-Pot-Fishery-male-base-Logistic-cv:	2.2719	0.0441
14	Sel-Trawl-Bycatch-male-base-Logistic-mean:	5.2123	0.0803
15	Sel-Trawl-Bycatch-male-base-Logistic-cv:	2.8679	0.0438
16	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-mean:	4.7285	0.2229
17	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-cv:	2.1647	0.3058
18	Sel-Fixed-Gear-male-base-Logistic-mean:	4.7864	0.0202
19	Sel-Fixed-Gear-male-base-Logistic-cv:	2.3077	0.0810
20	Sel-NMFS-Trawl-male-base-class-1:	-1.3677	0.1509
21	Sel-NMFS-Trawl-male-base-class-2:	-1.1676	0.1272
22	Sel-NMFS-Trawl-male-base-class-3:	-0.9231	0.1010
23	Sel-NMFS-Trawl-male-base-class-4:	-0.8084	0.0831
24	Sel-NMFS-Trawl-male-base-class-5:	-0.6500	0.0708
25	Sel-NMFS-Trawl-male-base-class-6:	-0.4826	0.0619
26	Sel-NMFS-Trawl-male-base-class-7:	-0.3629	0.0566
27	Sel-NMFS-Trawl-male-base-class-8:	-0.2677	0.0533
28	Sel-NMFS-Trawl-male-base-class-9:	-0.2428	0.0528
29	Sel-NMFS-Trawl-male-base-class-10:	-0.1917	0.0510
30	Sel-NMFS-Trawl-male-base-class-11:	-0.1540	0.0498
31	Sel-NMFS-Trawl-male-base-class-12:	-0.1223	0.0492
32	Sel-NMFS-Trawl-male-base-class-13:	-0.1011	0.0482
33	Sel-NMFS-Trawl-male-base-class-14:	-0.0722	0.0476
34	Sel-NMFS-Trawl-male-base-class-15:	-0.0667	0.0472
35	Sel-NMFS-Trawl-male-base-class-16:	-0.0631	0.0473
36	Sel-NMFS-Trawl-male-base-class-17:	-0.0660	0.0482
37	Sel-NMFS-Trawl-male-base-class-18:	-0.0673	0.0491
38	Sel-NMFS-Trawl-male-base-class-19:	-0.0798	0.0509
39	Sel-NMFS-Trawl-male-base-class-20:	-0.0971	0.0537
40	Sel-NMFS-Trawl-male-class-1-block-group-5-block-1:	-1.8775	0.1026
41	Sel-NMFS-Trawl-male-class-2-block-group-5-block-1:	-1.4456	0.1097
42	Sel-NMFS-Trawl-male-class-3-block-group-5-block-1:	-1.1434	0.0834
43	Sel-NMFS-Trawl-male-class-4-block-group-5-block-1:	-0.9973	0.0621
44	Sel-NMFS-Trawl-male-class-5-block-group-5-block-1:	-0.8191	0.0584
45	Sel-NMFS-Trawl-male-class-6-block-group-5-block-1:	-0.6450	0.0466
46	Sel-NMFS-Trawl-male-class-7-block-group-5-block-1:	-0.5491	0.0444
47	Sel-NMFS-Trawl-male-class-8-block-group-5-block-1:	-0.3770	0.0401
48	Sel-NMFS-Trawl-male-class-9-block-group-5-block-1:	-0.2691	0.0370
49	Sel-NMFS-Trawl-male-class-10-block-group-5-block-1:	-0.1784	0.0356
50	Sel-NMFS-Trawl-male-class-11-block-group-5-block-1:	-0.1609	0.0362

51	Sel-NMFS-Trawl-male-class-12-block-group-5-block-1:	-0.0756	0.0351
52	Sel-NMFS-Trawl-male-class-13-block-group-5-block-1:	-0.0708	0.0352
53	Sel-NMFS-Trawl-male-class-14-block-group-5-block-1:	-0.0005	0.0343
54	Sel-NMFS-Trawl-male-class-15-block-group-5-block-1:	-0.0178	0.0355
55	Sel-NMFS-Trawl-male-class-16-block-group-5-block-1:	-0.0877	0.0377
56	Sel-NMFS-Trawl-male-class-17-block-group-5-block-1:	-0.0314	0.0403
57	Sel-NMFS-Trawl-male-class-18-block-group-5-block-1:	-0.0189	0.0410
58	Sel-NMFS-Trawl-male-class-19-block-group-5-block-1:	-0.0481	0.0439
59	Sel-NMFS-Trawl-male-class-20-block-group-5-block-1:	0.0132	0.0402
60	Sel-Pot-Fishery-female-base-Logistic-mean:	4.5401	0.0178
61	Sel-Pot-Fishery-female-base-Logistic-cv:	2.1582	0.1000
62	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-mean:	4.7352	0.0790
63	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-cv:	0.8991	0.3037
64	Ret-Pot-Fishery-male-base-Logistic-mean:	4.9239	0.0015
65	Ret-Pot-Fishery-male-base-Logistic-cv:	0.6904	0.0528
66	Ret-Pot-Fishery-male-Logistic-mean-block-group-6-block-1:	4.9323	0.0020
67	Ret-Pot-Fishery-male-Logistic-cv-block-group-6-block-1:	0.7245	0.0968
68	Log-fbar-Pot-Fishery:	-1.6698	0.0358
69	Log-fbar-Trawl-Bycatch:	-4.3309	0.0708
70	Log-fbar-Bairdi-Fishery-Bycatch:	-5.5868	0.3181
71	Log-fbar-Fixed-Gear:	-6.4971	0.0617

Table 8: Annual abundance estimates (mature males, legal males, and mature females in million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) both estimated by the model and area swept calculated for red king crab in Bristol Bay estimated by length-based model 24.0c during 1975-2024. MMB for year t is on Feb. 15, year t+1.

	Males				Females	Total	Total Survey Biomass	
Year	Mature >119mm	Legal >134mm	MMB >119mm	sd MMB	Mature >89mm	Recruits	Model Est >64mm	Area-Swept >64mm
1975	66.670	33.182	96.838	6.724	66.406		262.090	199.640
1976	76.481	40.888	112.286	6.282	98.442	79.982	301.210	327.610
1977	83.144	46.379	124.291	5.497	130.613	52.871	319.710	371.220
1978	87.389	50.883	128.543	4.708	133.700	82.502	318.060	343.190
1979	75.589	50.806	105.586	3.891	125.667	151.584	302.240	165.450
1980	55.237	40.127	27.302	1.445	126.389	201.305	286.370	247.230
1981	15.788	8.530	5.979	0.833	57.174	88.916	115.310	131.140
1982	7.426	2.341	5.619	0.624	25.684	344.577	65.260	141.900
1983	6.269	2.194	5.799	0.451	17.720	130.461	57.390	48.480
1984	6.435	2.127	4.081	0.335	17.945	88.340	49.620	152.610
1985	7.818	1.821	9.173	0.646	12.429	14.469	33.400	34.140
1986	12.840	4.708	14.823	1.017	17.102	41.708	44.690	47.430
1987	15.580	7.001	20.797	1.282	21.371	13.778	51.380	69.240
1988	15.859	9.068	25.793	1.365	26.888	8.887	55.600	54.600
1989	17.149	10.471	28.898	1.332	25.094	11.167	58.640	55.140
1990	16.462	11.237	25.120	1.261	22.233	28.949	58.670	59.450
1991	12.618	9.353	19.276	1.169	21.583	19.261	53.700	83.890
1992	10.306	6.999	18.015	1.128	23.265	4.679	49.420	37.330
1993	11.889	6.723	17.139	1.230	21.642	12.791	49.300	52.910
1994	11.962	6.827	23.192	1.359	18.283	3.875	45.130	32.100
1995	12.256	8.794	25.973	1.331	16.836	80.693	50.810	38.070
1996	12.272	9.270	24.045	1.240	25.161	13.701	59.390	43.960
1997	11.588	8.299	22.466	1.198	36.703	6.348	65.530	84.030
1998	17.636	8.278	25.992	1.482	31.616	16.840	69.770	84.100
1999	18.934	10.677	30.126	1.660	26.442	46.977	68.860	64.750
2000	16.177	11.684	29.966	1.617	28.327	18.445	70.510	67.380
2001	15.963	10.976	30.144	1.560	32.395	16.215	74.020	52.460
2002	19.226	11.177	34.417	1.607	31.063	72.811	79.030	69.090
2003	20.032	13.021	34.035	1.575	38.551	16.646	84.990	115.760
2004	17.904	12.542	31.249	1.470	48.113	15.279	86.780	130.560
2005	20.239	11.643	32.270	1.475	44.019	53.162	87.870	105.730
2006	19.141	12.467	32.514	1.434	44.137	27.987	87.700	94.480
2007	17.122	12.063	27.329	1.333	48.885	18.253	89.230	103.330
2008	17.755	10.284	26.343	1.391	45.539	10.523	85.990	113.080
2009	17.848	10.421	27.629	1.471	39.251	11.886	80.420	90.550
2010	16.738	10.813	27.177	1.440	34.068	29.069	75.380	80.500
2011	14.171	10.274	26.617	1.330	33.482	18.529	70.570	66.410
2012	12.479	9.525	24.574	1.197	35.489	10.227	68.400	60.700
2013	12.364	8.584	23.333	1.108	33.512	7.509	65.240	62.220
2014	12.057	8.269	21.316	1.035	29.351	4.560	60.100	113.140
2015	10.254	7.566	18.097	0.954	24.785	7.211	52.890	64.170
2016	8.222	6.313	14.770	0.887	20.969	13.995	45.760	60.960
2017	6.400	5.052	11.842	0.828	19.093	6.484	40.360	52.930
2018	5.534	3.994	10.372	0.802	17.539	12.857	37.110	28.800
2019	6.340	3.669	11.184	0.887	15.527	6.750	35.610	28.540
2020	6.950	4.199	12.737	1.002	14.421	7.971		

2021	8.030	4.828	16.125	1.146	13.242	6.424	34.970	28.480
2022	8.616	5.996	18.302	1.239	11.954	14.761	36.150	36.200
2023	8.857	6.502	18.649	1.304	11.855	10.917	37.500	37.970
2024	8.835	6.461	15.427	0.912	12.987	5.807	37.930	46.130

Table 9: Annual abundance estimates (mature males, legal males, and mature females in million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) both estimated by the model and area swept calculated for red king crab in Bristol Bay estimated by length-based model 24.0c.2 during 1975-2024. MMB for year t is on Feb. 15, year t+1.

	Males				Females	Total	Total Survey Biomass	
Year	Mature >119mm	Legal >134mm	MMB >119mm	sd MMB	Mature >89mm	Recruits	Model Est >64mm	Area-Swept >64mm
1975	66.726	33.208	96.896	6.730	66.408		262.340	199.640
1976	76.533	40.906	112.339	6.285	98.447	79.957	301.480	327.610
1977	83.193	46.392	124.338	5.499	130.625	52.898	319.970	371.220
1978	87.439	50.893	128.585	4.708	133.711	82.541	318.300	343.190
1979	75.631	50.816	105.616	3.892	125.675	151.659	302.460	165.450
1980	55.271	40.135	27.310	1.446	126.391	201.103	286.580	247.230
1981	15.801	8.533	5.978	0.834	57.179	88.757	115.380	131.140
1982	7.429	2.340	5.619	0.624	25.684	344.642	65.320	141.900
1983	6.266	2.193	5.796	0.450	17.714	130.347	57.430	48.480
1984	6.435	2.125	4.078	0.334	17.934	88.196	49.650	152.610
1985	7.817	1.820	9.166	0.645	12.415	14.439	33.410	34.140
1986	12.832	4.702	14.798	1.015	17.078	41.593	44.670	47.430
1987	15.555	6.987	20.744	1.278	21.339	13.733	51.320	69.240
1988	15.822	9.043	25.714	1.361	26.846	8.897	55.500	54.600
1989	17.092	10.438	28.781	1.327	25.054	11.155	58.510	55.140
1990	16.396	11.190	24.978	1.257	22.197	28.951	58.530	59.450
1991	12.564	9.302	19.199	1.166	21.546	19.205	53.570	83.890
1992	10.284	6.973	17.960	1.126	23.225	4.660	49.350	37.330
1993	11.877	6.706	17.124	1.228	21.602	12.740	49.240	52.910
1994	11.951	6.822	23.166	1.357	18.247	3.865	45.090	32.100
1995	12.236	8.783	25.931	1.329	16.803	80.461	50.740	38.070
1996	12.242	9.252	23.980	1.237	25.113	13.738	59.290	43.960
1997	11.553	8.274	22.393	1.195	36.636	6.317	65.400	84.030
1998	17.568	8.249	25.865	1.478	31.558	16.800	69.630	84.100
1999	18.864	10.624	30.002	1.656	26.393	46.907	68.690	64.750
2000	16.126	11.637	29.855	1.614	28.277	18.420	70.360	67.380
2001	15.916	10.938	30.039	1.558	32.342	16.179	73.880	52.460
2002	19.174	11.141	34.313	1.606	31.013	72.681	78.890	69.090
2003	19.983	12.982	33.940	1.575	38.496	16.587	84.850	115.760
2004	17.861	12.508	31.164	1.471	48.055	15.269	86.640	130.560
2005	20.180	11.612	32.241	1.476	43.969	53.144	87.730	105.730
2006	19.098	12.447	32.509	1.436	44.101	27.993	87.630	94.480
2007	17.103	12.051	27.359	1.335	48.856	18.253	89.220	103.330
2008	17.755	10.288	26.349	1.393	45.516	10.528	86.040	113.080
2009	17.846	10.417	27.672	1.474	39.234	11.891	80.460	90.550
2010	16.753	10.823	27.243	1.443	34.055	29.073	75.450	80.500
2011	14.195	10.293	26.673	1.333	33.473	18.517	70.660	66.410
2012	12.501	9.541	24.624	1.200	35.482	10.234	68.480	60.700
2013	12.381	8.598	23.374	1.110	33.505	7.497	65.320	62.220
2014	12.068	8.280	21.353	1.037	29.345	4.544	60.160	113.140
2015	10.265	7.575	18.126	0.955	24.780	7.205	52.940	64.170
2016	8.228	6.320	14.789	0.888	20.964	13.989	45.800	60.960
2017	6.399	5.055	11.862	0.828	19.088	6.476	40.390	52.930
2018	5.536	3.997	10.381	0.802	17.534	12.853	37.140	28.800
2019	6.338	3.670	11.185	0.886	15.521	6.738	35.630	28.540
2020	6.947	4.197	12.732	1.001	14.415	7.961		

2021	8.025	4.824	16.115	1.144	13.235	6.417	34.980	28.480
2022	8.608	5.990	18.285	1.237	11.947	14.748	36.150	36.200
2023	8.847	6.494	18.626	1.302	11.847	10.907	37.490	37.970
2024	8.824	6.452	15.403	0.910	12.977	5.802	37.920	46.130

Table 10: Annual abundance estimates (mature males, legal males, and mature females in million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) both estimated by the model and area swept calculated for red king crab in Bristol Bay estimated by length-based model 25.1b during 1975-2024. MMB for year t is on Feb. 15, year t+1.

	Males				Females	Total	Total Survey Biomass	
Year	Mature >119mm	Legal >134mm	MMB >119mm	sd MMB	Mature >89mm	Recruits	Model Est >64mm	Area-Swept >64mm
1975	61.898	30.985	89.783	6.141	58.540		268.750	199.640
1976	72.505	38.479	106.174	5.751	87.061	65.611	305.610	327.610
1977	78.988	44.532	118.567	4.981	113.303	40.716	321.240	371.220
1978	82.950	49.041	122.770	4.259	114.941	61.538	319.000	343.190
1979	71.615	49.093	100.411	3.504	107.492	107.767	302.830	165.450
1980	52.092	38.481	25.812	1.280	106.614	125.872	281.180	247.230
1981	14.805	8.212	5.525	0.746	46.701	46.166	108.300	131.140
1982	6.742	2.194	5.263	0.573	19.808	262.353	69.390	141.900
1983	5.439	2.066	5.324	0.413	14.059	93.121	60.160	48.480
1984	6.264	1.982	4.079	0.324	14.459	74.412	52.910	152.610
1985	7.508	1.821	8.926	0.605	10.437	10.681	35.670	34.140
1986	11.912	4.575	13.775	0.918	14.468	33.105	47.280	47.430
1987	14.244	6.555	18.975	1.140	17.972	12.217	53.330	69.240
1988	14.376	8.380	23.556	1.209	22.341	7.280	56.800	54.600
1989	15.562	9.644	26.408	1.165	21.157	7.606	59.740	55.140
1990	15.005	10.362	22.689	1.090	18.793	23.626	60.080	59.450
1991	11.443	8.543	17.193	1.010	18.253	15.602	54.600	83.890
1992	9.212	6.301	16.030	0.978	19.663	3.736	49.570	37.330
1993	10.597	6.024	14.922	1.066	18.279	10.242	49.480	52.910
1994	10.446	6.035	20.585	1.184	15.569	2.414	44.720	32.100
1995	10.867	7.901	23.491	1.169	14.311	61.854	51.740	38.070
1996	10.975	8.438	21.732	1.093	21.425	14.500	60.410	43.960
1997	10.711	7.540	20.780	1.078	30.544	4.401	65.980	84.030
1998	15.727	7.659	23.081	1.308	26.773	13.128	70.780	84.100
1999	16.820	9.560	26.644	1.453	22.669	36.758	70.080	64.750
2000	14.460	10.510	26.858	1.434	24.366	16.873	71.400	67.380
2001	14.412	9.931	27.339	1.395	27.446	11.188	74.840	52.460
2002	17.362	10.203	31.321	1.427	26.600	59.965	81.500	69.090
2003	18.177	11.968	30.933	1.392	33.370	13.740	87.400	115.760
2004	16.372	11.519	28.569	1.306	41.054	12.358	88.600	130.560
2005	18.432	10.714	29.401	1.291	37.778	43.410	90.700	105.730
2006	17.404	11.490	29.680	1.247	38.776	19.698	90.280	94.480
2007	15.707	11.133	24.917	1.156	42.313	15.572	91.180	103.330
2008	15.914	9.432	23.344	1.181	38.730	9.410	87.380	113.080
2009	15.623	9.303	23.944	1.227	33.904	7.779	81.130	90.550
2010	14.571	9.480	23.316	1.188	29.523	23.841	75.970	80.500
2011	12.367	8.950	23.103	1.101	28.979	15.084	70.910	66.410
2012	10.979	8.386	21.546	0.998	30.821	8.180	68.630	60.700
2013	10.882	7.602	20.467	0.916	29.106	6.348	65.610	62.220
2014	10.652	7.333	18.619	0.843	25.821	3.652	60.480	113.140
2015	8.994	6.701	15.623	0.769	22.101	5.644	53.130	64.170
2016	7.061	5.508	12.451	0.710	18.866	10.904	46.000	60.960
2017	5.455	4.300	9.846	0.670	17.283	4.791	40.420	52.930
2018	4.667	3.361	8.543	0.657	15.666	10.456	37.200	28.800
2019	5.344	3.064	9.235	0.748	13.909	5.109	35.610	28.540
2020	5.884	3.541	10.683	0.863	12.857	6.678		

2021	6.856	4.124	13.928	1.005	11.769	4.855	34.880	28.480
2022	7.504	5.257	16.191	1.107	10.675	10.907	36.290	36.200
2023	7.874	5.814	16.775	1.185	10.503	8.029	37.700	37.970
2024	7.904	5.857	14.701	0.887	11.153	4.064	37.870	46.130

Figures

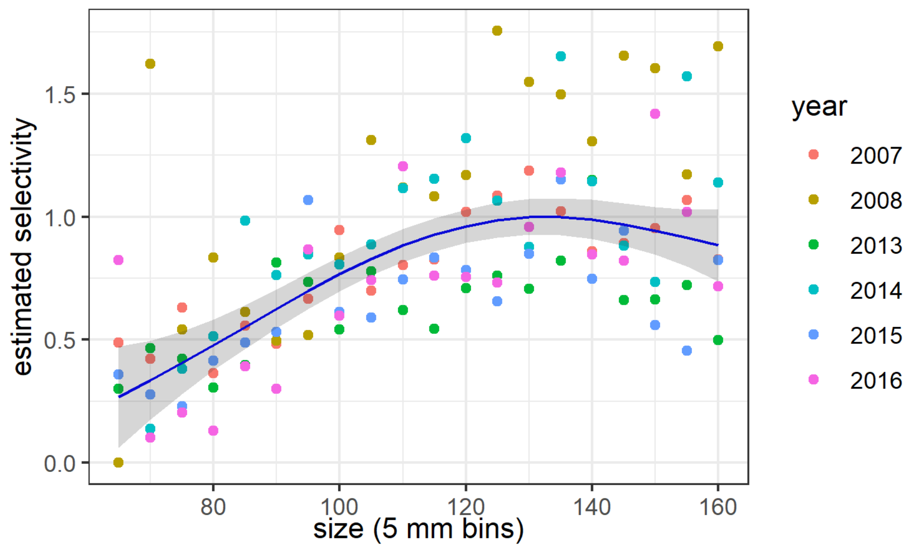

Figure 2: Inferred selectvity estimated using all of the BSFRF data by year, with resulting GAM model fit.

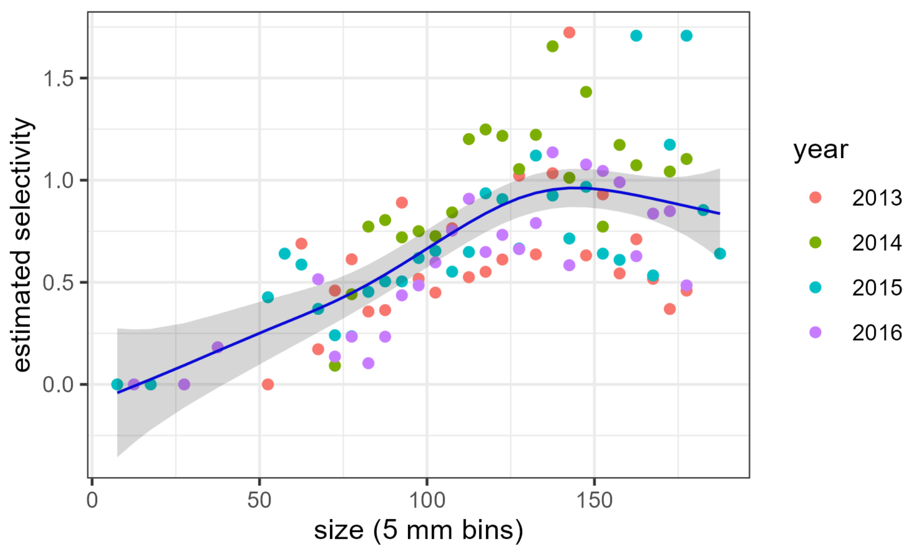

Figure 3: Inferred selectvity estimated from only side-by-side BSFRF data by year, with resulting GAM model fit.

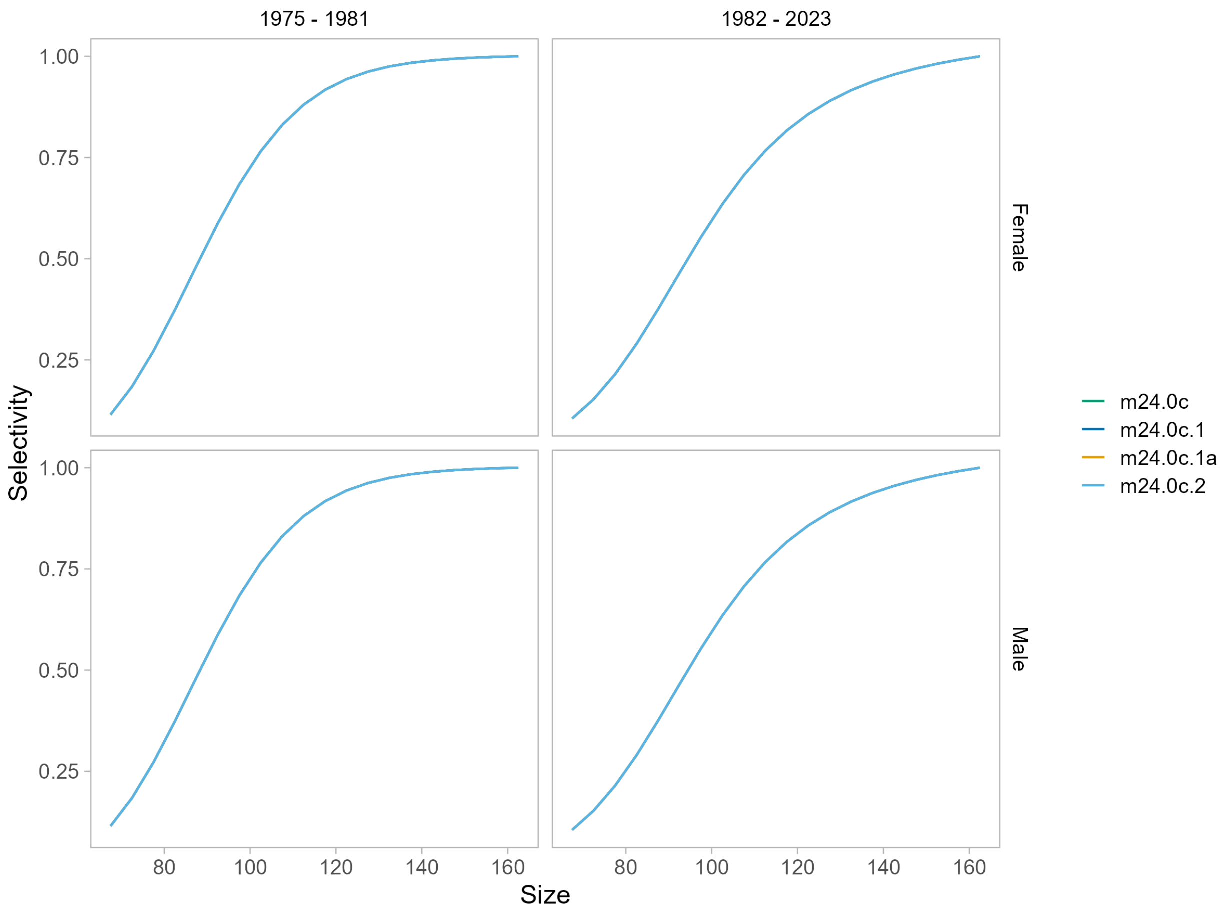

Figure 4: Estimated NMFS trawl survey selectivities under base model updates.

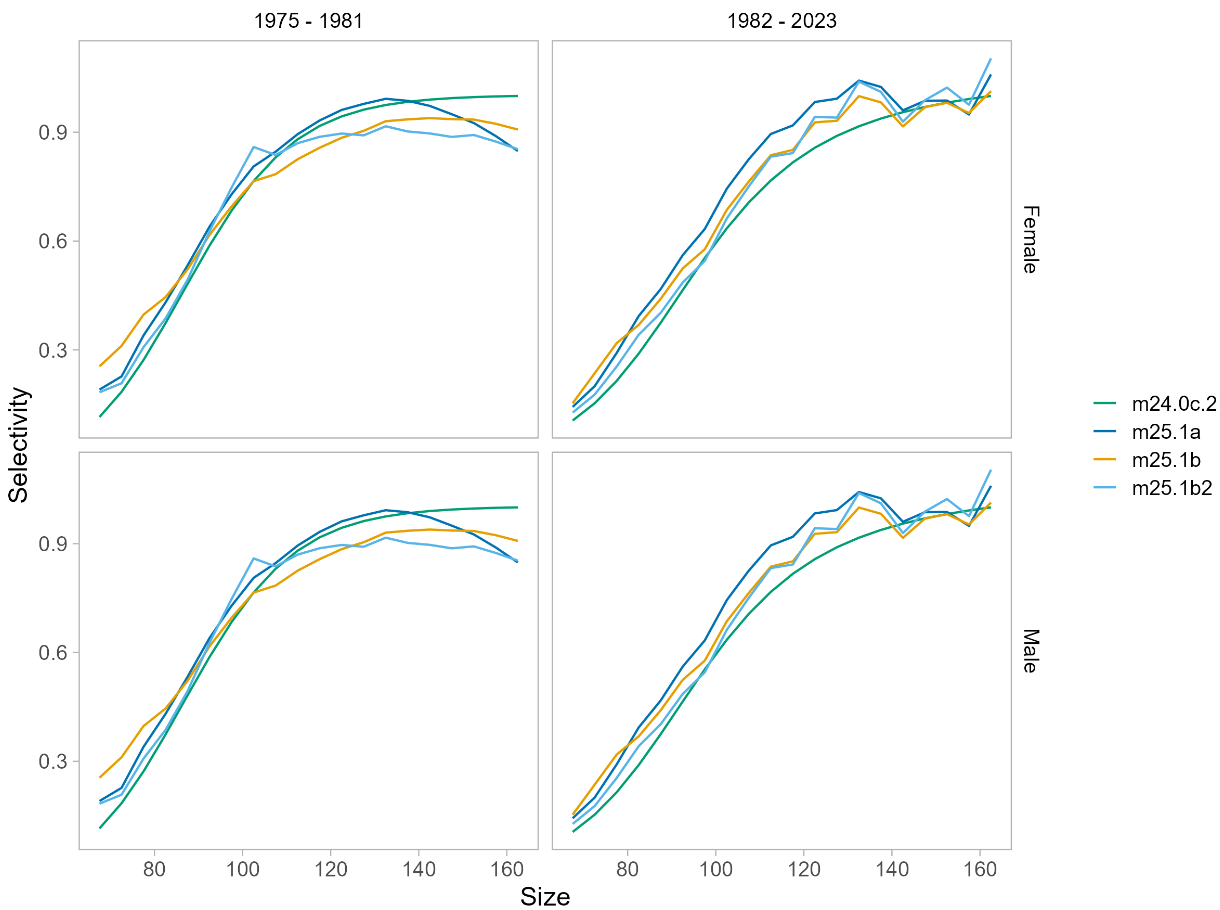

Figure 5: Estimated NMFS trawl survey selectivities under models 24.0c.2, 25.1a, 25.1b, and 25.1b2 under two selectivity periods.

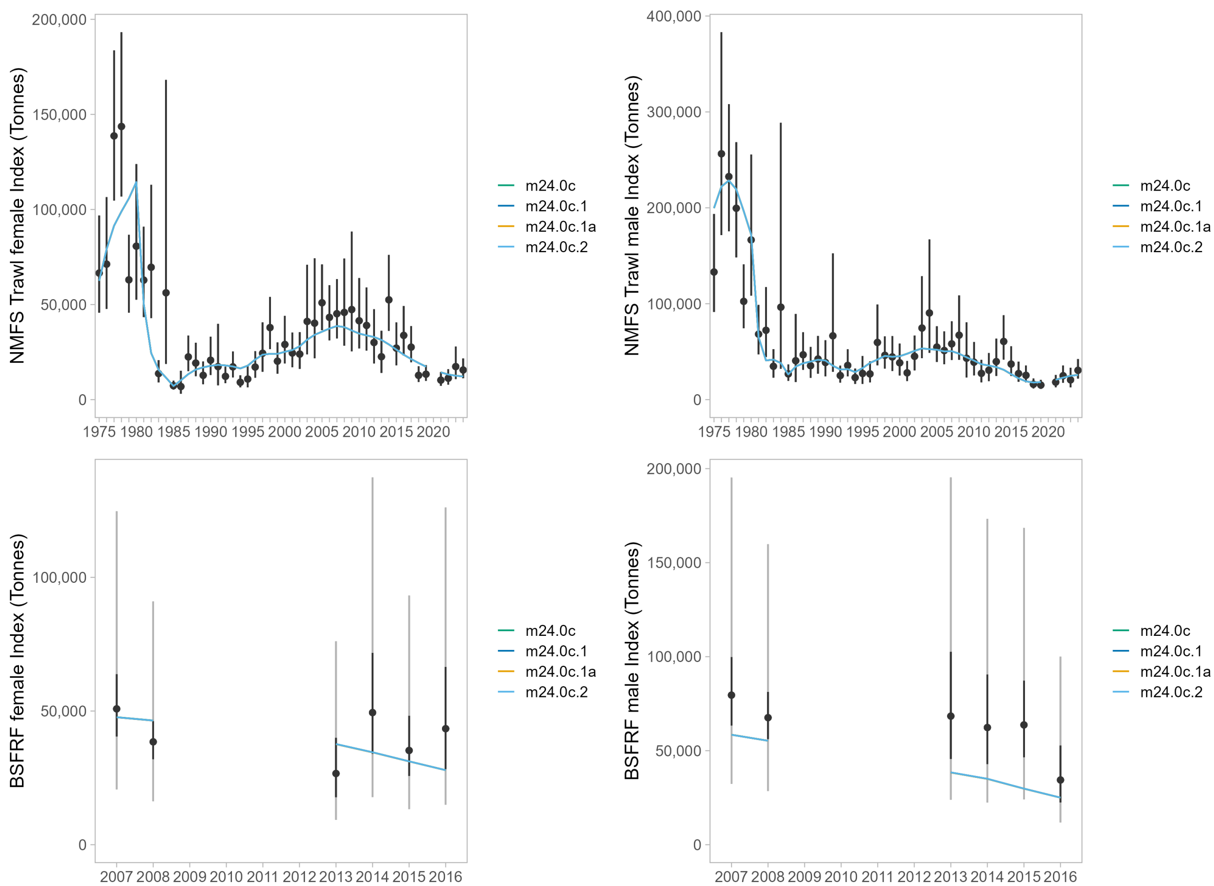

Figure 6: Comparisons of area-swept estimates and model predictions for both the NMFS trawl survey and the BSFRF trawl survey under updated base models 24.0c, 24.0c.1, 24.0c.1a, and 24.0c.2 The error bars are plus and minus 2 standard deviations of the area swept estimates.

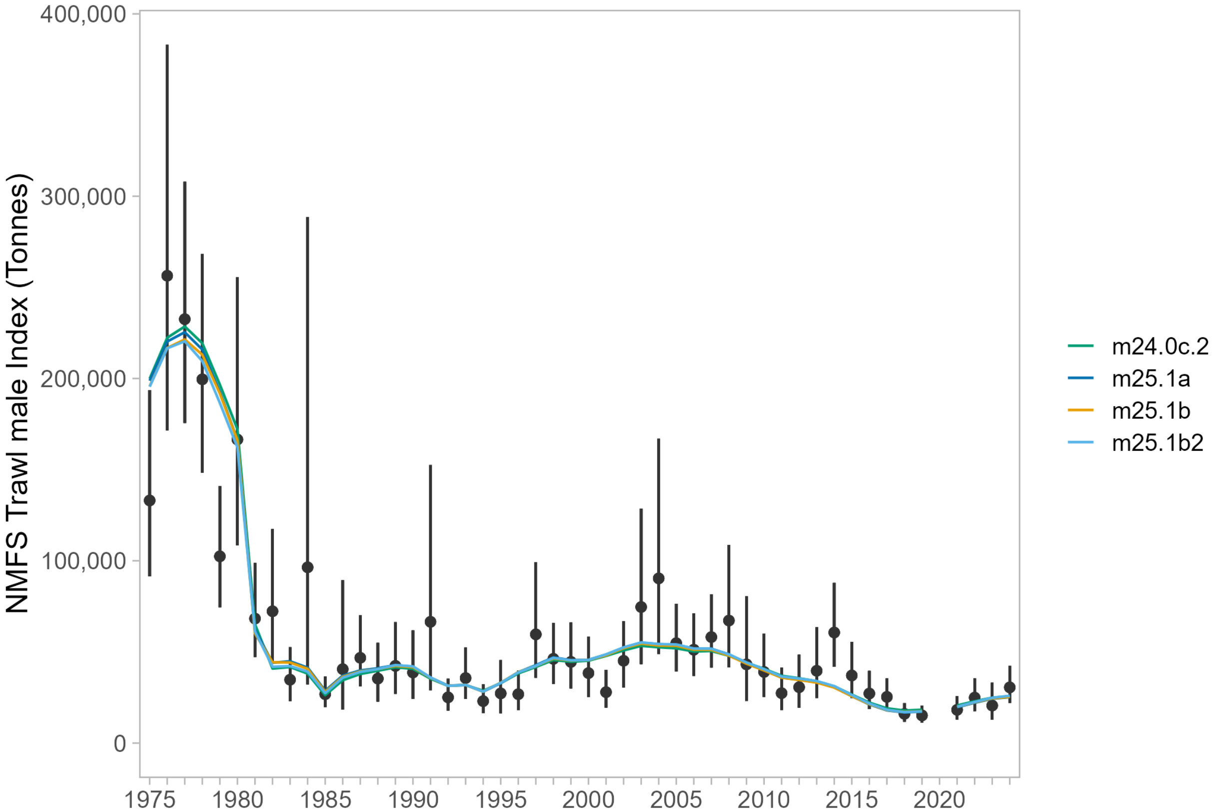

Figure 7: Comparisons of area-swept estimates of total male NMFS survey biomass and model predictions for model estimates in 2024 under models 24.0c.2, m25.1a, m25.1b, and m25.1b2. The error bars are plus and minus 2 standard deviations of the area swept estimates.

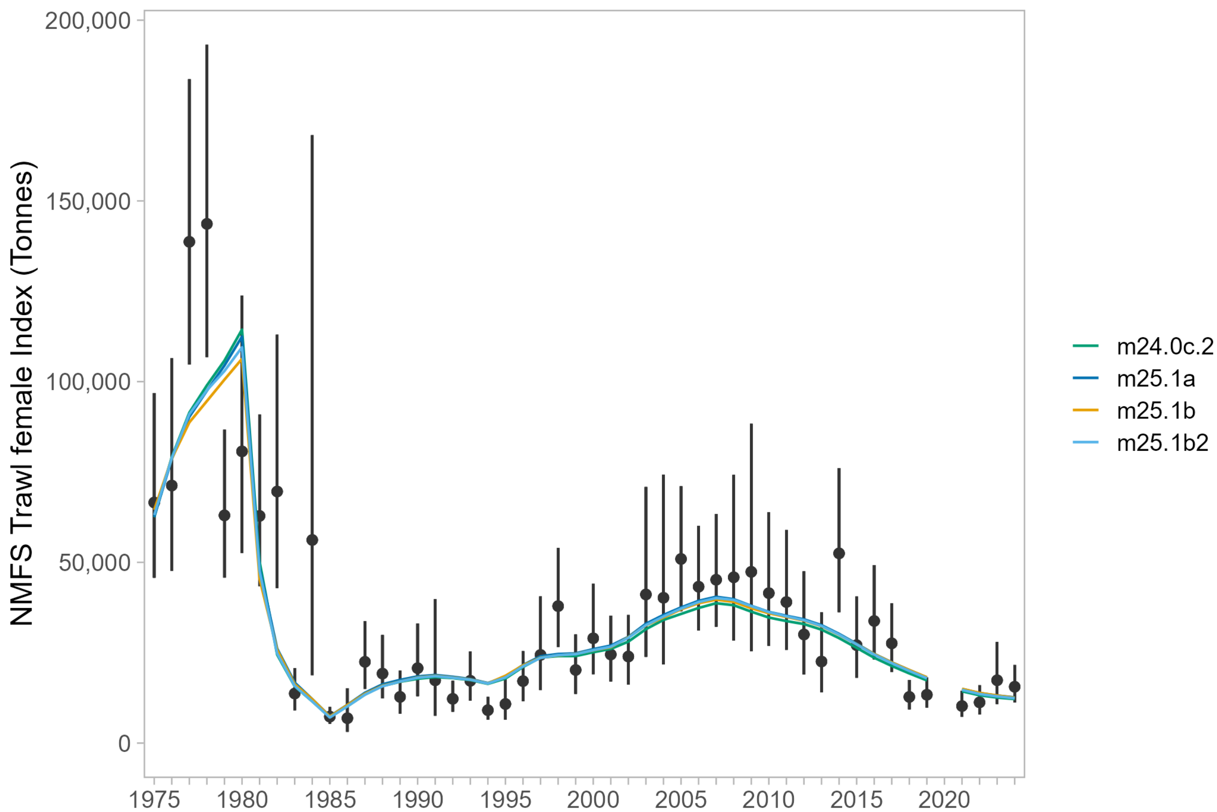

Figure 8: Comparisons of area-swept estimates of total female NMFS survey biomass and model predictions for model estimates in 2024 under models 24.0c.2, m25.1a, m25.1b, and m25.1b2. The error bars are plus and minus 2 standard deviations of the area swept estimates.

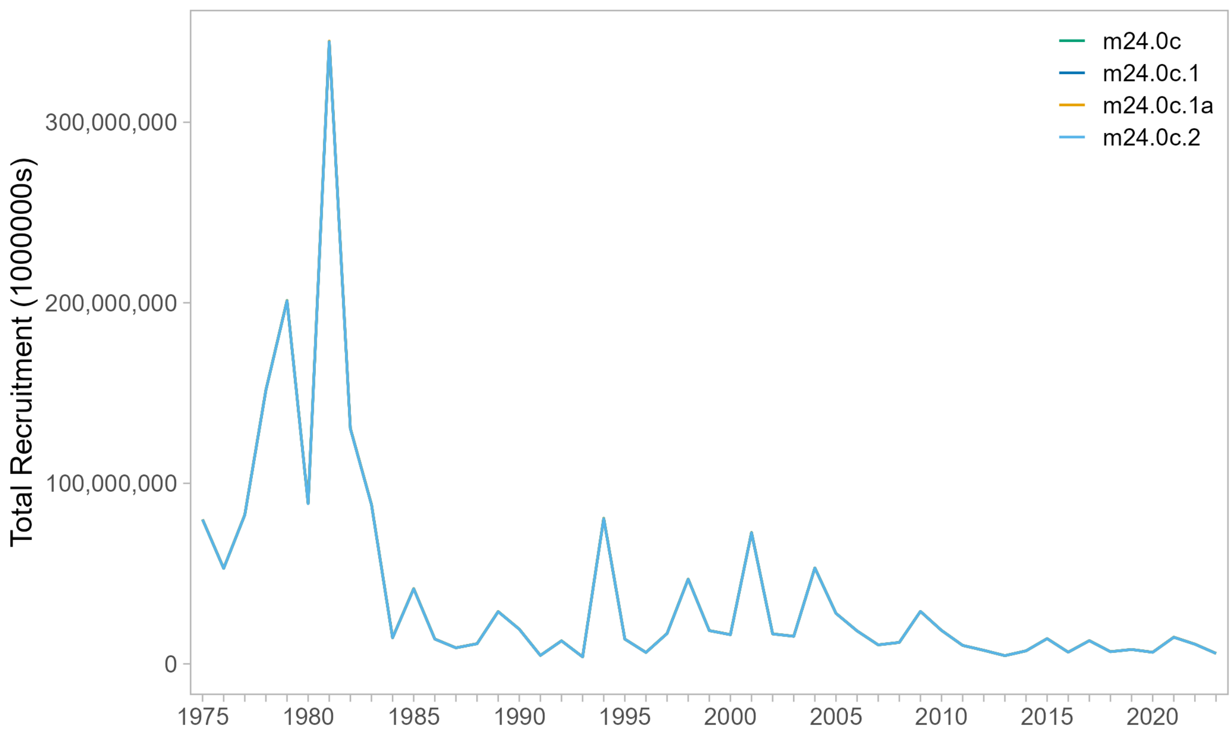

Figure 9: Estimated recruitment (million of individuals) time series during 1976-2023 with models 24.0c, 24.0c.1, 24.0c.1a, and 24.0c.2. Mean male recruits during 1984-2022 was used to estimate B35. Recruitment estimates in the terminal year (2023) are unreliable.

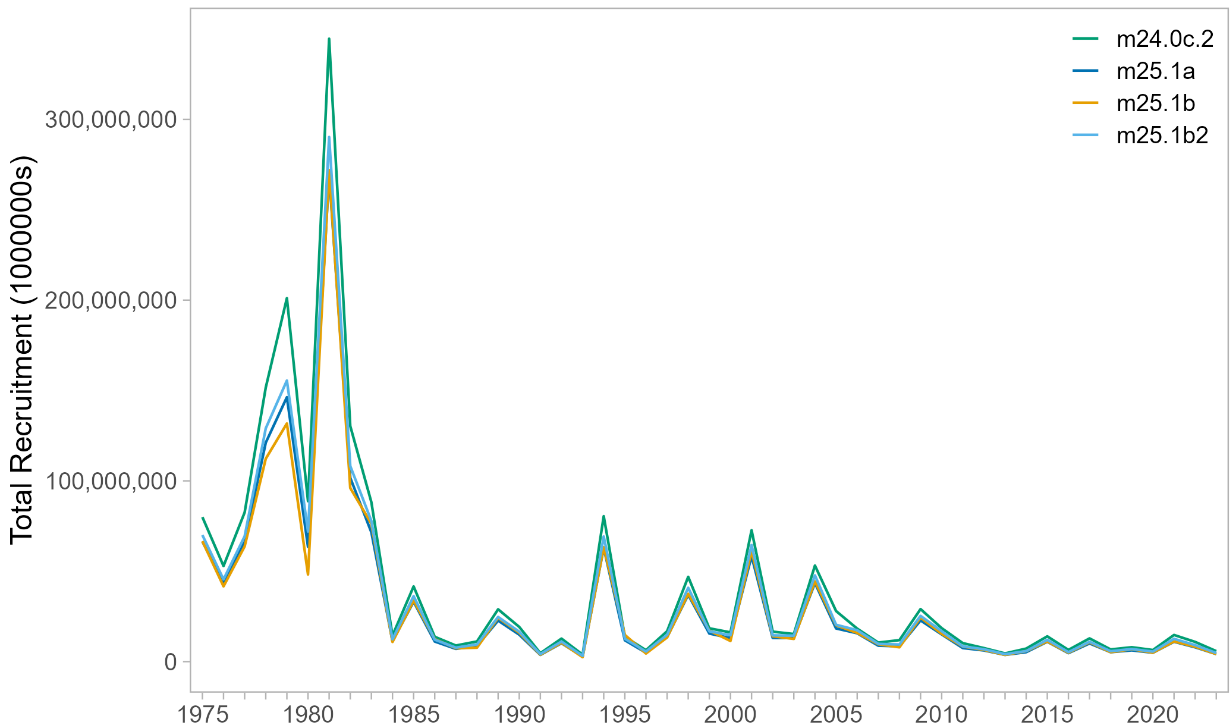

Figure 10: Estimated recruitment (million of individuals) time series during 1976-2023 with models 24.0c.2, m25.1a, m25.1b, and m25.1b2 (those models that remove BSFRF data and use it as a prior for NMFS q). Mean male recruits during 1984-2023 was used to estimate B35. Recruitment estimates in the terminal year (2023) are unreliable.

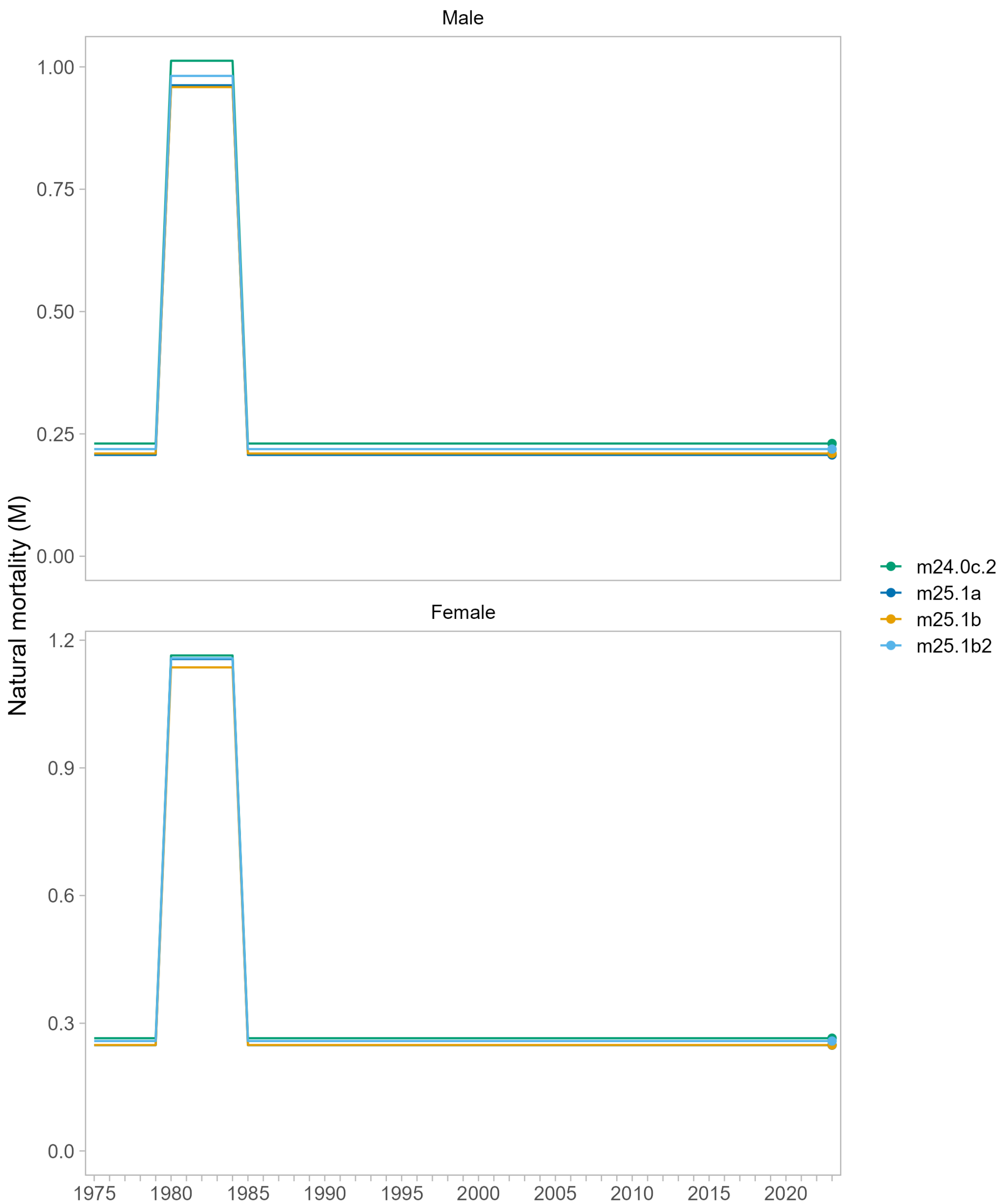

Figure 11: Comparison of natural mortality - either estimated or fixed depending on the model - for models 24.0c.2, m25.1a, m25.1b, and m25.1b2. The table above details the differences in base M for males between these models. Estimates for all 24 series models were the same as 24.0c.2.

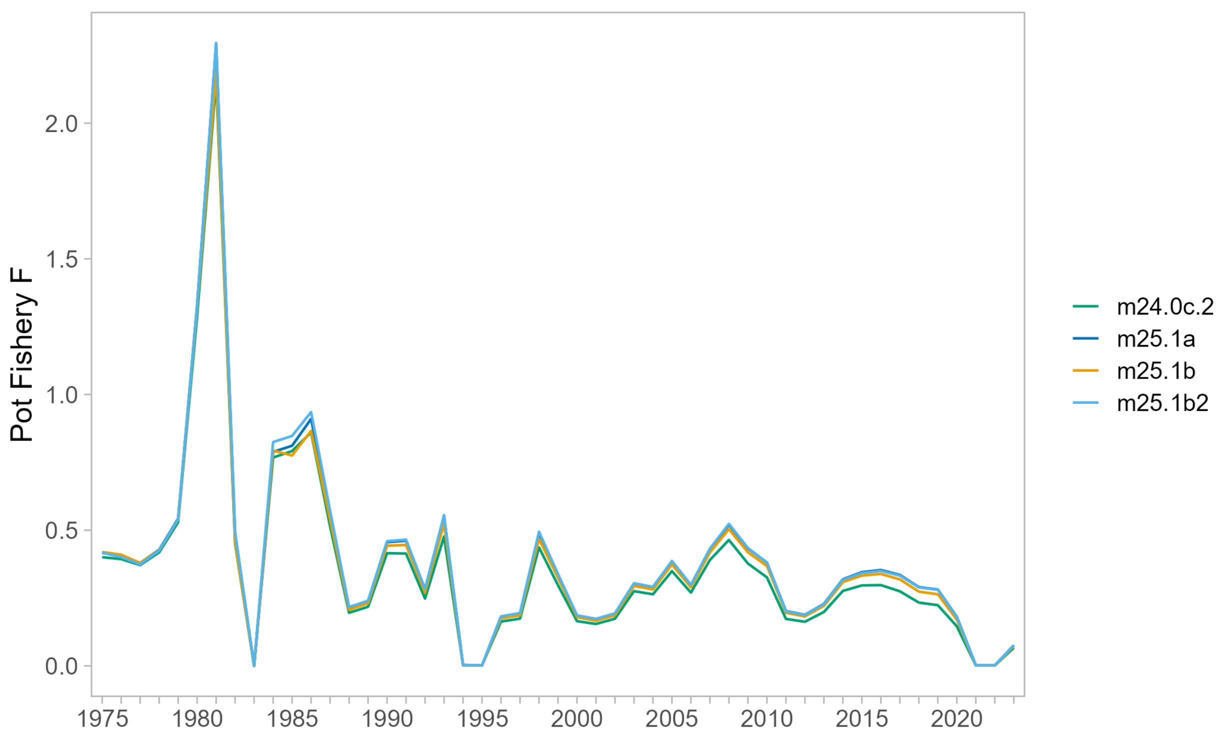

Figure 12: Comparison of estimated fishing mortality for models 24.0c.2, m25.1a, m25.1b, and m25.1b2. All other models are similar to the base models shown here.

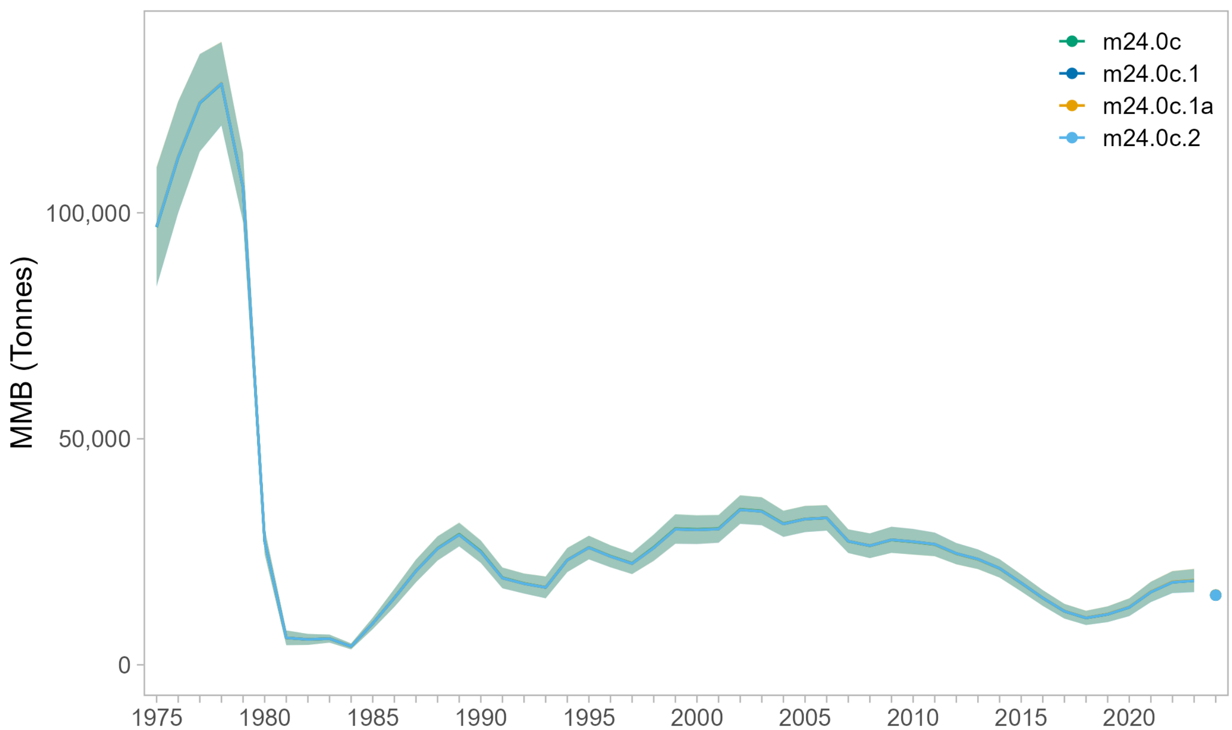

Figure 13: Estimated absolute mature male biomasses during 1975-2023 for models 24.0c, 24.0c.1, 24.0c.1a, 24.0c.2., with projected biomass for 2024. Mature male biomass is estimated on Feb. 15, year+1 (i.e. 2024 value is Feb. 15 2025).

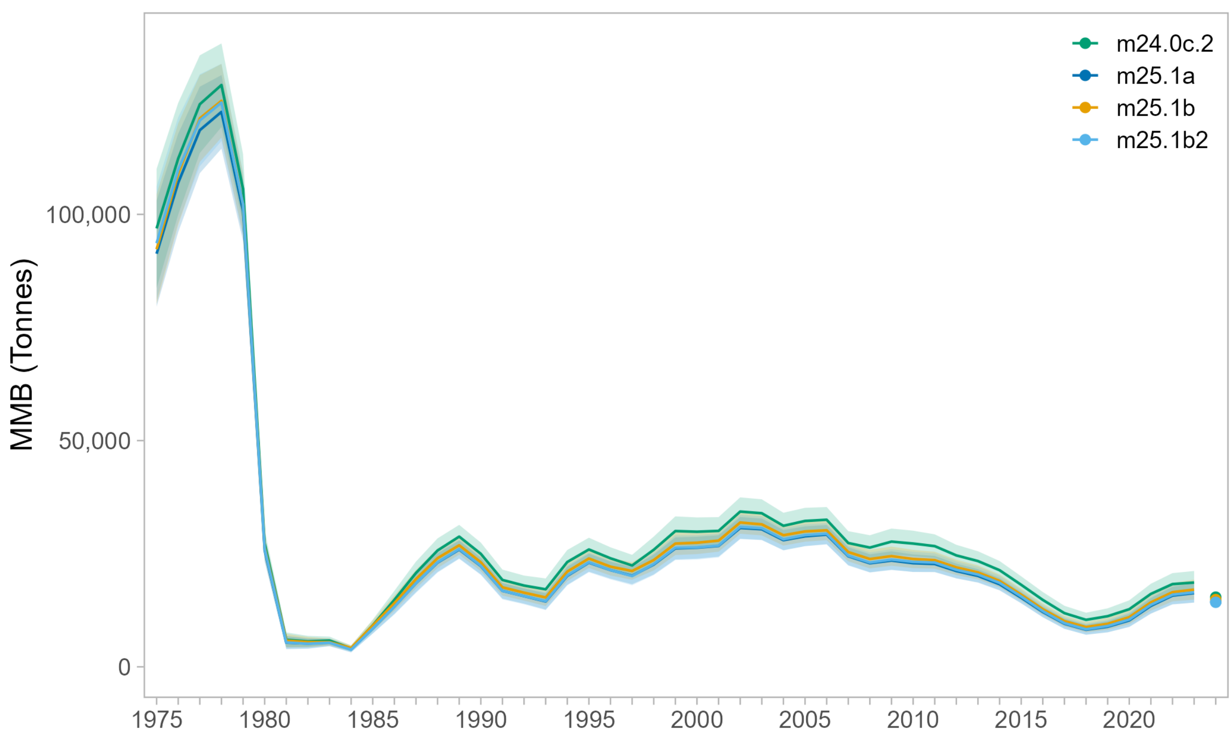

Figure 14: Estimated absolute mature male biomasses during 1975-2023 for models 24.0c.2, m25.1a, m25.1b, and m25.1b2, with projected biomass for 2024. Mature male biomass is estimated on Feb. 15, year+1 (i.e. 2024 value is Feb. 15 2025).

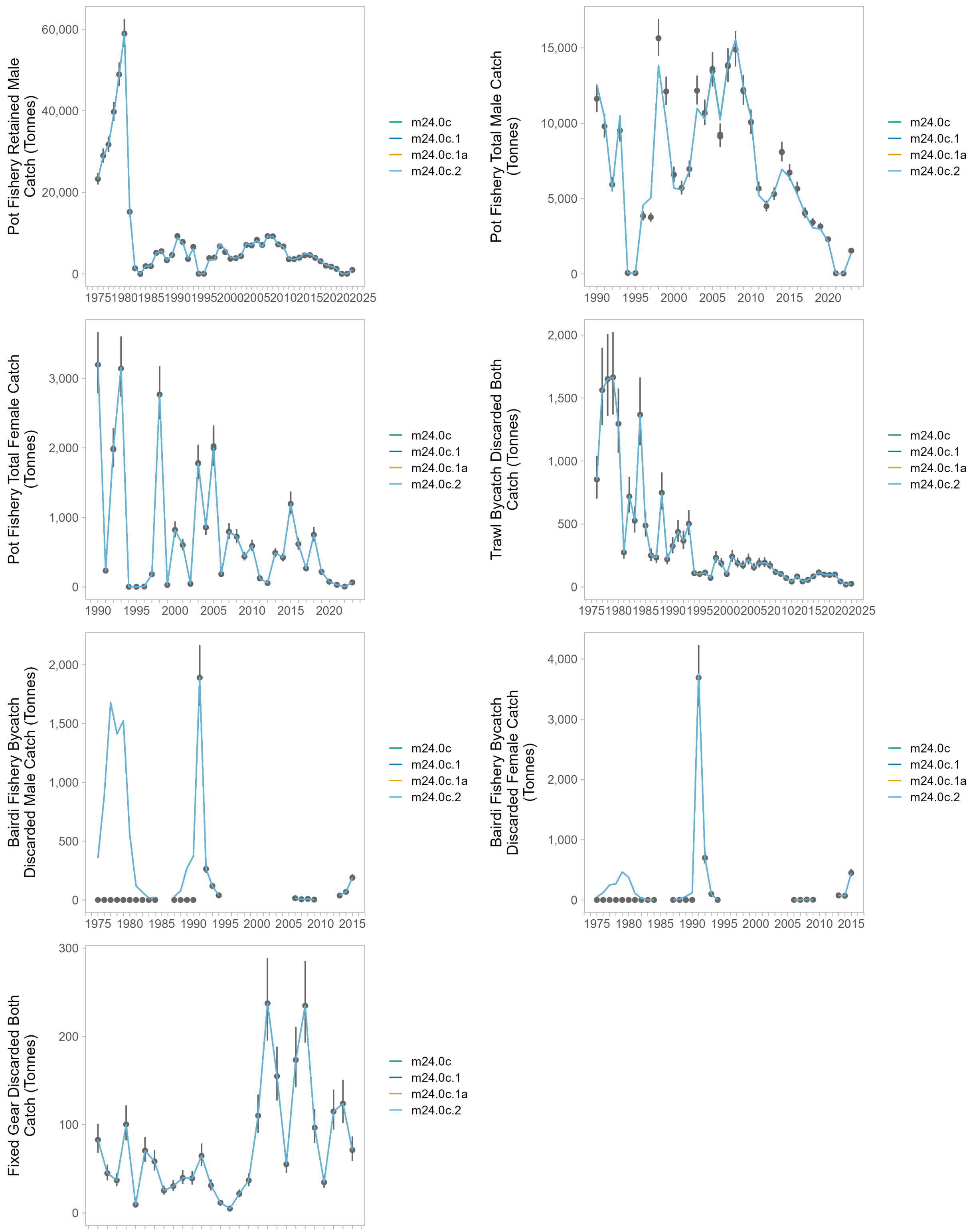

Figure 15: Estimated fit to catch data series **fix** not labeled correctly.

Figure 16: Observed and model estimated length-frequencies of male BBRKC by year retained in the directed pot fishery for models 24.0c.2, 25.1a, 25.1b, and 25.1b2.

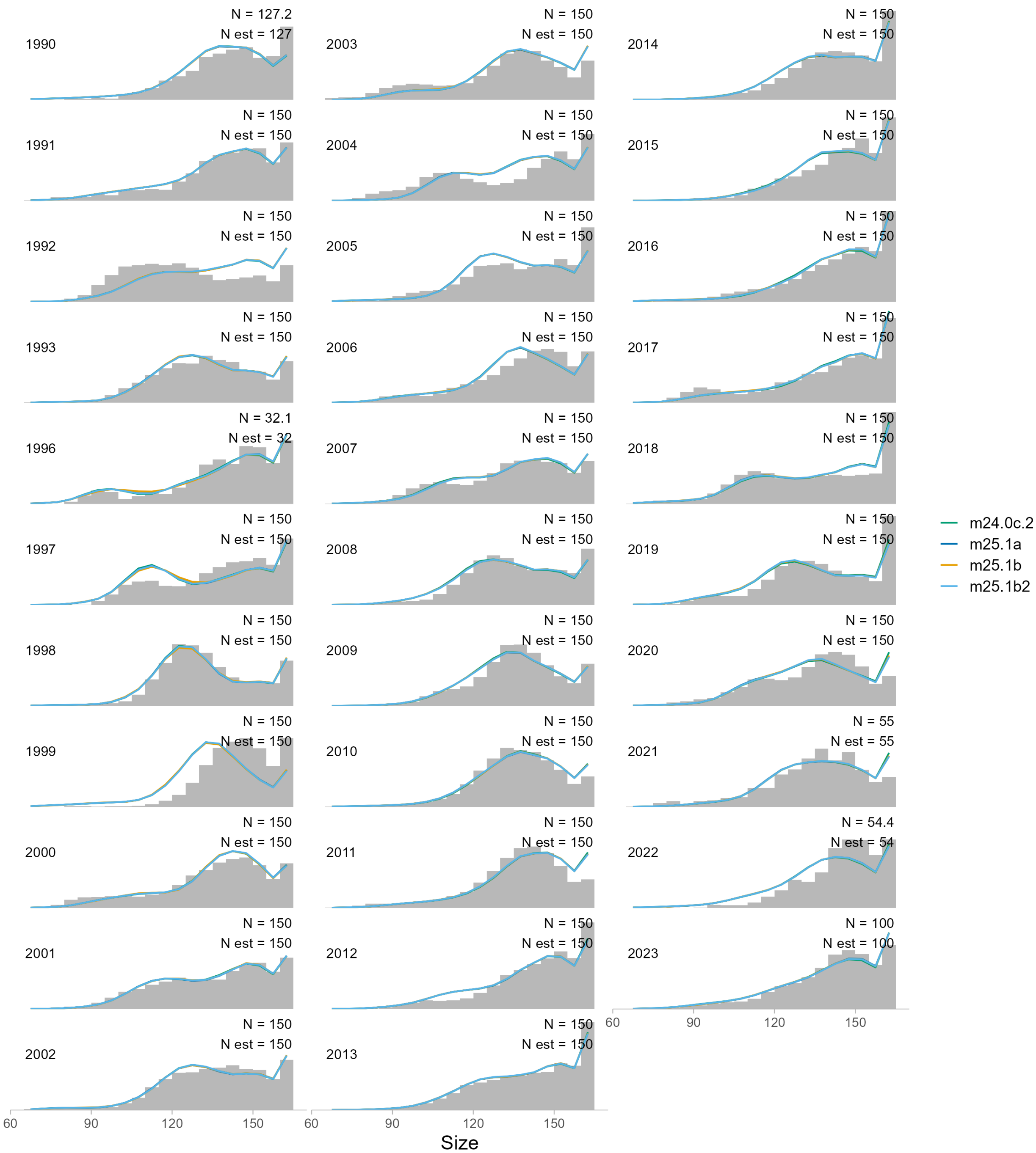

Figure 17: Observed and model estimated length-frequencies of TOTAL male BBRKC by year in the directed pot fishery for models 24.0c.2, 25.1a, 25.1b, and 25.1b2.

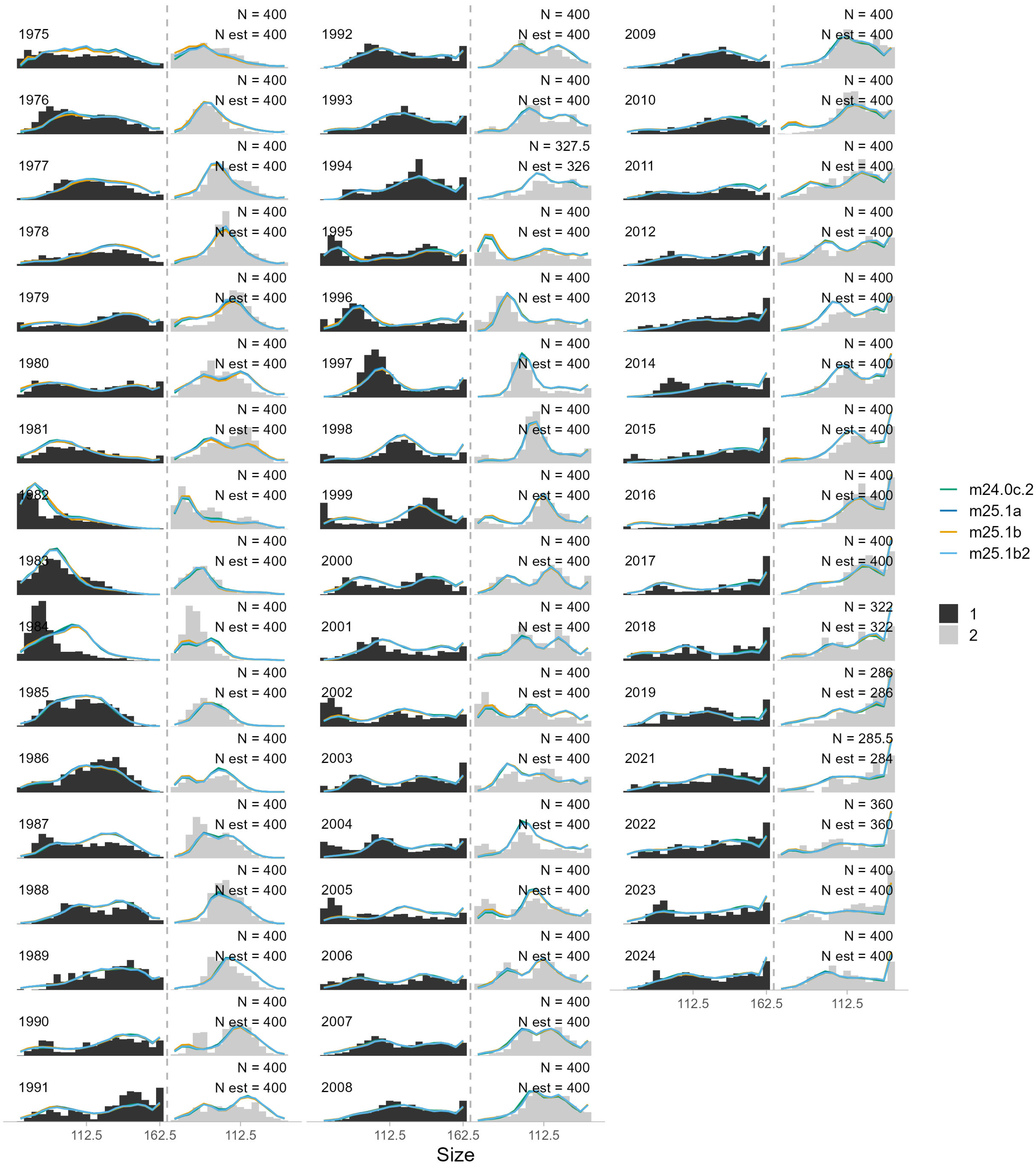

Figure 18: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male (black, 1) and female (gray, 2) red king crab by year for models 24.0c.2, 25.1a, 25.1b, and 25.1b2.

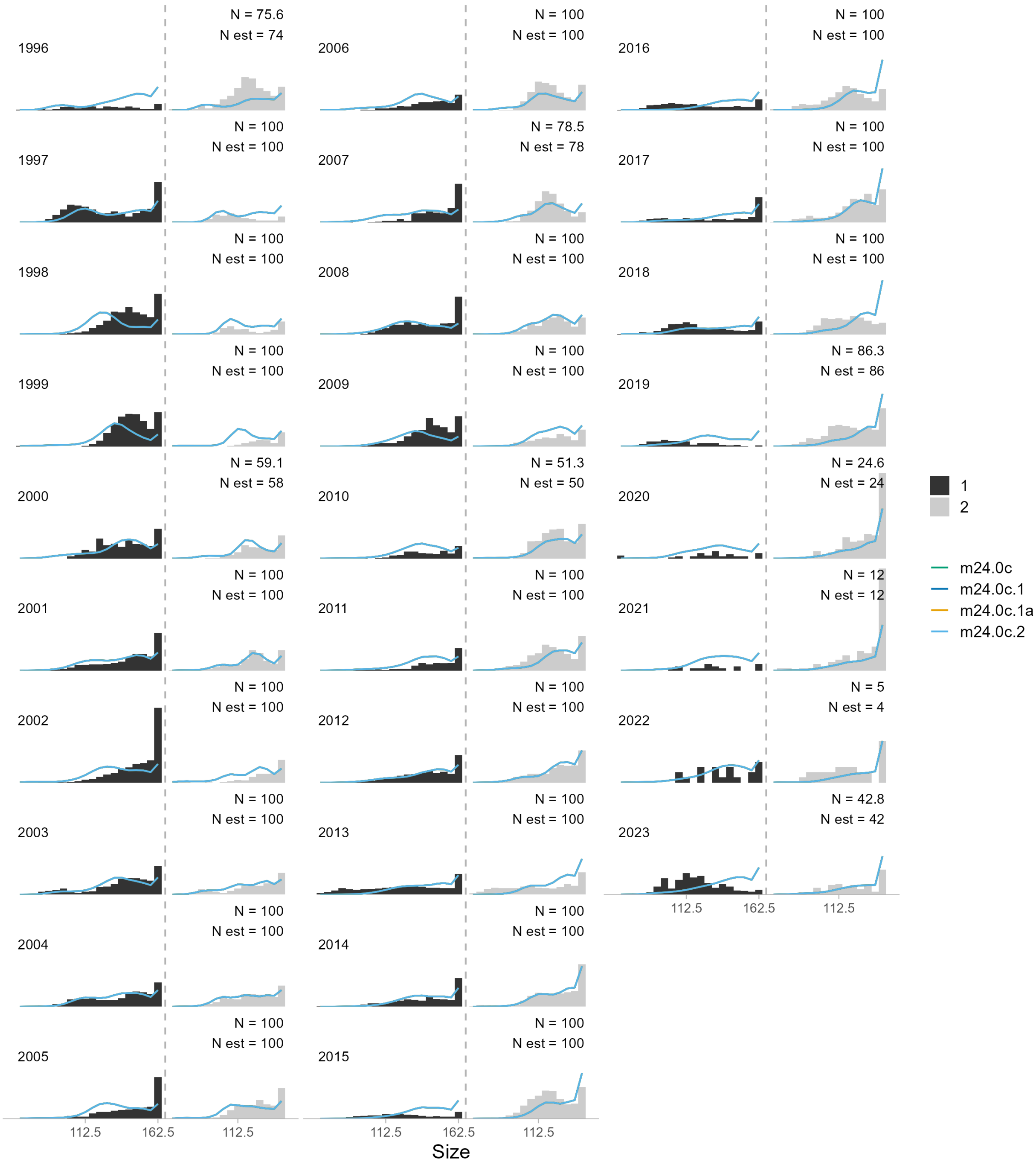

Figure 19: Comparison of length compositions from fixed gear groundfish bycatch of Bristol Bay male (black) and female (gray) red king crab by year for the base model scenarios.

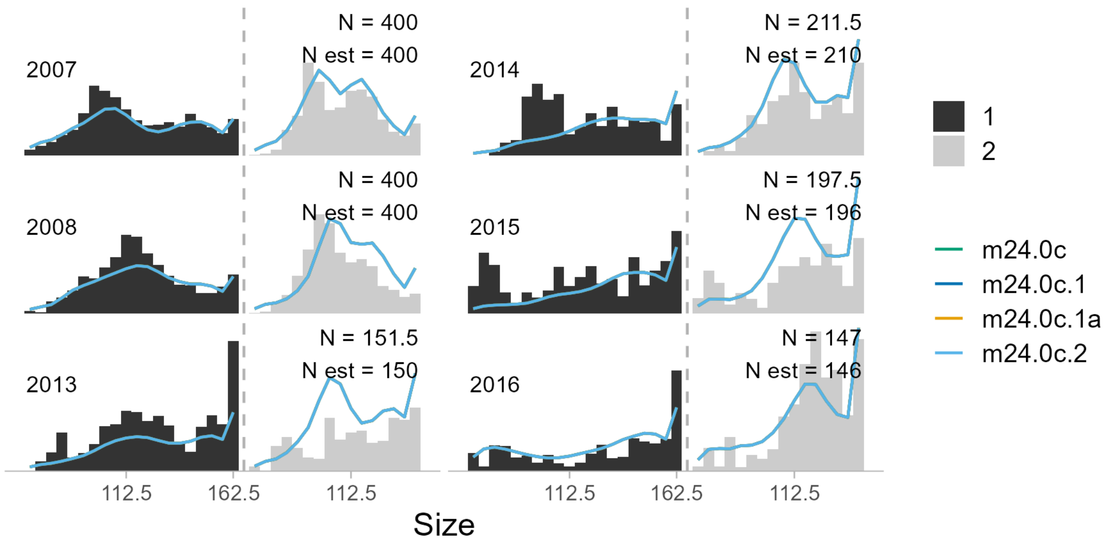

Figure 20: Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 for base model scenarios (male (black) and female (gray) red king crab).

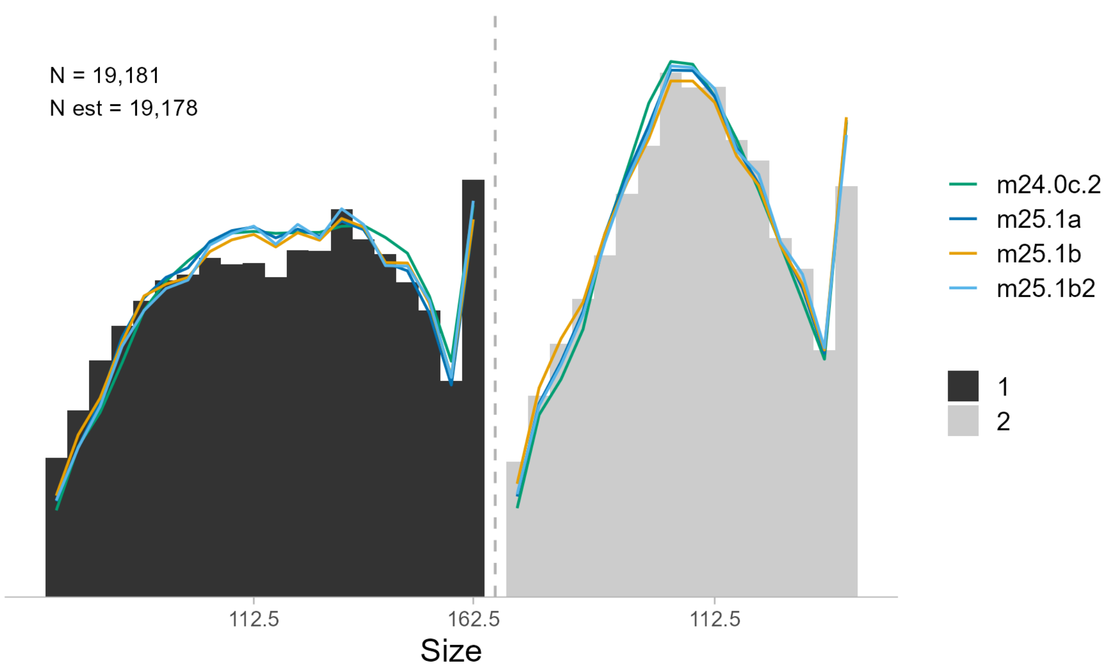

Figure 21: Aggregated size comps over all years for the NMFS survey for males (black) and females (grey) for model runs.

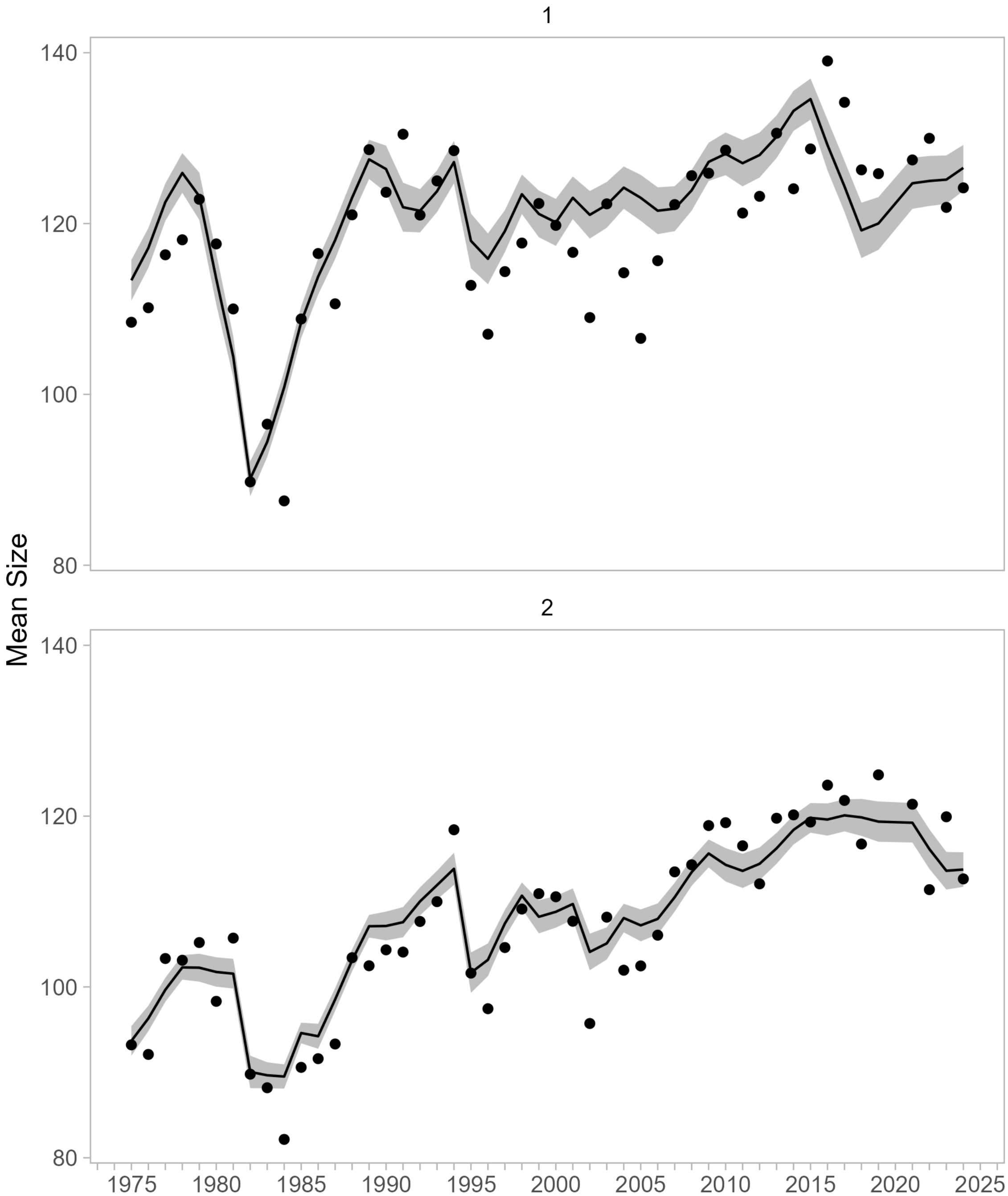

Figure 22: Mean size over all years for the NMFS survey for males (1) and females (2) under model 24.0c.2 (updated base model based on 2024 accepted model).

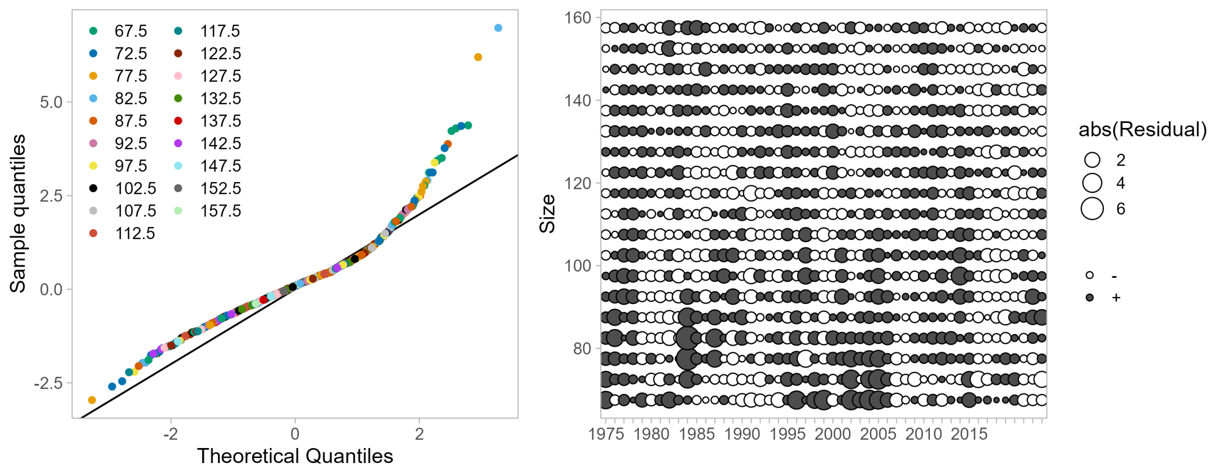

Figure 23: One-step-ahead residuals of size comps for males for the NMFS survey under model 24.0c.2 (updated base model based on 2024 accepted model).

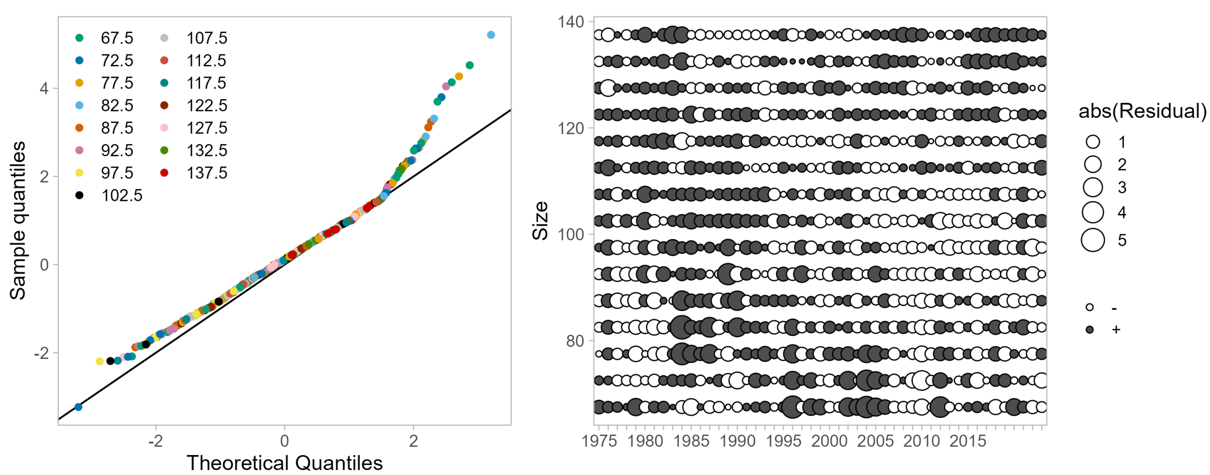

Figure 24: One-step-ahead residuals of size comps for females for the NMFS survey under model 24.0c.2 (updated base model based on 2024 accepted model).