Bristol Bay Red King Crab Stock Assessment 2024

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Executive Summary

1. **Stock**: Red king crab (RKC), *Paralithodes camtschaticus*, in Bristol Bay, Alaska.

2. **Catches**: The domestic RKC fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lb (58,943 t). The catch declined dramatically in the early 1980s and remained at low levels during the last three decades. After rationalization, catches were relatively high before the 2010/11 season but have been on a declining trend since 2014. The retained catch in 2023/24 was approximately 2.12 million lb (960 t), similar to the last open fishery in 2020/21 when retained catch was approximately 2.65 million lb (1,257 t). These season harvests follow a steady decline in total allowable catch (TAC) from 2016 on. The directed pot fishery was closed in 2021/22 and 2022/23 due to low mature female abundance in accordance with the State of Alaska harvest strategy. The magnitude of bycatch from groundfish trawl and fixed gear fisheries has been stable and small relative to stock abundance during the last 10 years. The decline of the directed pot fishery crab/pot lift (CPUE) has been much less than the retained catch decline, with the 2020/21 CPUE having about 12.5% reduction from the average CPUE during the recent 20 years. The 2023/24 CPUE of 20.54 crab/potlift was approximately a 13.7% decline from the average since 2000.

3. **Data sources**: Data extent is provided visually in Figure 2.

4. **Stock biomass**: Estimated mature biomass increased dramatically in the mid-1970s, then decreased precipitously in the early 1980s. Estimated mature crab abundance increased during 1985-2007 with mature females being about four times more abundant in 2007 than in 1985 and mature males being about two times more abundant in 2007 than in 1985. Estimated mature abundance was steadily declining since 2017, but appears to be increasing slowly in the last few years.The projected mature male survey biomass in 2024 is approximately 51.4% of the estimated mean survey biomass for the entire time series, which includes many periods of low biomass throughout history. The estimated mature female survey biomass was low from 2018 to 2022, but the 2024 estimated value increased to approximately 46.9% of the mean.

5. **Recruitment**: Estimated recruitment was high during the 1970s and early 1980s and has generally been low since 1985 (1979 year class). During 1984-2023, estimated recruitment was above the historical average (1976-2023 reference years) only in 1984, 1986, 1990, 1995, 1999, 2002, 2005, 2006, and 2010. Estimated recruitment was extremely low during the last 14 years, and even lower during the recent nine years. With the low recruitment in recent years, the projected mature biomass is expected to decline during the next few years with a below-average fishing mortality of 0.167 to 0.25 yr^{-1}.

6. **Management performance**: The stock was above Minimum Stock Size Threshold (MSST) in 2023/24 (99% of B_{MSY}) and hence was not overfished. Since total catch was below the OFL (overfishing limit), overfishing did not occur. The projection using the lowest recruitment periods during 2013-2023 would not likely result in “approaching an overfished condition” based on the current harvest

strategy. The current version of GMACS uses an average of sex ratios of recruitment during the reference period to estimate $B_{35\%}$, which results in a stable sex ratio (about 50%) for the reference point calculation. A 20% buffer was suggested by the CPT and SSC for 2021 - 2023, and is recommended by the author in 2024 for similar reasons to previous years. Tables below represent the status and catch specifications for model 24.0c in 1,000 t and million lb (Tables 1 and 2).

Table 1: Status and catch specifications (1000 t) for the CPT recommended model (24.0c).

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	12.12	13.96	1.20	1.26	1.57	2.14	1.61
2021/22	12.01	16.64	0	0.02	0.10	2.23	1.78
2022/23	9.68	18.34	0	0.02	0.11	3.04	2.43
2023/24	9.35	18.65	0.975	0.96	1.34	4.42	3.54
2024/25		15.43				5.02	4.02

Table 2: Status and catch specifications (million lb) for the CPT recommended model (24.0c).

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	26.7	30.8	2.77	2.65	3.47	4.72	3.54
2021/22	26.5	36.7	0	0.04	0.22	4.91	3.92
2022/23	21.34	40.44	0	0.05	0.24	6.70	5.35
2023/24	20.6	41.11	2.15	2.12	2.96	9.75	7.8
2024/25		34.01				11.07	8.86

7. **Basis for the OFL**:

Table 3: Basis for the OFL (1000 t) from the CPT recommended model (24.0c).

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18
2021/22	3b	24.2	14.9	0.62	0.17	1984-2020	0.18
2022/23	3b	24.03	17.0	0.71	0.20	1984-2021	0.18
2023/24	3b	19.36	14.98	0.77	0.30	1984-2022	0.23
2024/25	3b	18.69	15.43	0.83	0.33	1984-2023	0.23

Table 4: Basis for the OFL (million lb) from the CPT recommended model (24.0c).

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2020/21	3b	56.1	32.9	0.59	0.16	1984-2019	0.18
2021/22	3b	53.4	33.0	0.62	0.17	1984-2020	0.18
2022/23	3b	53.0	37.4	0.71	0.20	1984-2021	0.18
2023/24	3b	42.7	33.0	0.77	0.30	1984-2022	0.23
2024/25	3b	41.2	34.01	0.83	0.33	1984-2023	0.23

8. **Probability density function of the OFL**: The estimated probability distributions of MMB and OFL in 2024 are illustrated in Figures 52, 53, and 57 for models 23.0a and 24.0c.

9. **Basis for ABC recommendation**: The ABC (acceptable biological catch) buffer was increased from 10% to 20% in 2018, and an additional buffer of 5% was added in 2020 due to the lack of a 2020 survey. A 20% buffer was recommended by the Crab Plan Team (CPT) and Scientific and Statistical Committee (SSC) for ABC estimation since 2021/22. Reoccurring concerns for this stock are still present (cold pool distributional shifts, declining trends in mature biomass, lack of large recruitment pulses, retrospective patterns), as well as low mature female biomass the last few years, all contribute to a recommended 20% buffer for 2024/25. A draft risk table is provided in Appendix D. This document details some of the same concerns for the stock that has been considered in the ABC buffer discussion but does not raise any new concerns. The process for using risk tables to assist in ABC buffer determination is under development for BSAI crab stocks.

A. Summary of Major Changes

1. Changes in Management of the Fishery

There are no new changes in management of the fishery.

2. Changes to the Input Data

a. Updated groundfish fisheries bycatch data during 1986-2023.
b. Updated crab fisheries data: directed, cost-recovery, and bycatch.
c. Updated NMFS survey data for 2024, biomass and length compositions.
d. Updated length composition data for directed and non-directed fisheries.

3. Changes in Assessment Methodology

a. Updated version of GMACS (version 2.20.14, 2024-05-20) is used.
b. The analyses of terminal years of recruitment are updated.
c. Two models are compared in this report (See Section E.3.a for details). These models represent the 2023 accepted model and a model with constant molt probability for males:

23.0a: model 21.1b (2022) + estimating a constant base M for males.

24.0c: model 23.0a + no time blocks for molt probability for males and females.

4. Changes in Assessment Results

Two model scenarios are compared in this report. In the May 2024 draft report the accepted model in 2023 (23.0a) was presented using an updated GMACS version and with MMB estimated in the correct season of the model (refer to May 2024 document for more details, this reflects a timing of MMB estimation within the year as a correction to model output). Model versions have minimal impact on model results and are vetted as they are updated to ensure this. Model 23.0a is considered the base model and was used to compare to the other model scenarios (labeled model 23.0.p7 in the May 2024 report to reflect the comparison of the season estimation change for MMB). The additional model considered in this document is model 24.0c, which is model 23.0a with constant molt probability for males and females for the entire time series.

Model explorations look to balance realism with parsimony or simplicity and model 24.0c reflects this. This model produces very similar results to the base model, 23.0a, including a nearly identical MMB projection for 2024/25 and resulting OFL. Difference between these two models primarily occur in the very early part of the time series and do not affect the most recent projections, status, or specifications for this stock. Retrospective patterns for both models are similar and improved from the previous base model of 21.1b.

For specification in 2024/25, model 24.0c is recommended due to parsimony and reduction in the number of parameters. The base model - 23.0a - would also be appropriate for consideration if the molt probability time block was considered to be of historical importance. Results for the author-recommended model, 24.0c, are presented in the specification tables in the executive summary but values for management-related quantities for all models are summarized in Tables 1, 14, and 16.

B. Responses to SSC and CPT

CPT and SSC Comments on Assessments in General

Response to SSC Comments (June 2024):

"The SSC requests the authors and CPT consider coordinating the approach to analyzing the Bering Sea Fisheries Research Foundation (BSFRF) data for the 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: The CPT plans on taking up this topic during the Jan 2025 modeling workshop.

Responses 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 Sept. 2023 and will be provided this Sept. The author provide as much additional information as possible along with these model results.

"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: The CPT discussed picking up risk tables for the three main stocks at our Jan 2024 meeting. It was decided that authors would provide draft risk tables for the Sept. 2024 assessments. A draft risk table is provided here in Appendix D.

"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):

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

Response: This is planned for May 2025.

"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: These will be considered, as time allows, for May 2025.

Response to CPT Comments (from May 2024):

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

Response: Will be considered, as time allows, for May 2025.

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

Response: Will be considered, as time allows, for May 2025.

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: Will be considered, as time allows, for May 2025.

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

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. Due to the time intense nature of data recovery this task may not be achievable in May 2025 but will remain on the list for future explorations.

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

Response: This is planned for May 2025 model explorations.

Response to SSC Comments (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 effects, 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 are 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: Due to changes in GMACS and modeling output the diagnostic plots were delayed for this document, but the author plans to create them for next Sept.

Possible effect of high 2011 recruitment as seen 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 for 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) reflect explorations on using the BSFRF data as a prior on selectivity - similar to snow crab in 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 24.0c and 24.0d reflect removing this blocking to estimate one molting probability for the entire time series.

Response to SSC comments specific to this assessment (from October 2022):

"The SSC recommends that a high priority be placed on trying to isolate factors that reduce the retrospective bias in mature male biomass."

Response: The author agrees that this should be a high priority, however current explorations have not shed light on these factors yet. This is still a high priority for the author.

"The SSC recommends investigation of the highly biased fits to the BSFRF index and suggests that the current approach of inflating the variance to account for lack of fit is inappropriate when obvious bias is present."

Response: We agree with this recommendation, and are investigating this avenue along with exploring catchability for both surveys. One method to account for this is to use the BSFRF survey to inform a prior on NMFS q and not have it fit directly in the model (Models. 24.0a and 24.0b in this document).

"The accumulation of large males and particularly large females in the plus group indicates length bin groups may need to be re-evaluated."

Response: We acknowledge this observation, recognizing this has only been an issue for about the last 10 years of size compositions since recruitment has been poor. Explorations on extending the size bins is on the list of further work for this model, but was not prioritized on this cycle.

"The SSC noted that the NMFS and the State determined that the survey re-tows would not be conducted in 2022, despite meeting the threshold to do so. The SSC requests an examination from the assessment author of the potential value of these re-tows, and whether re-tows provide a more or less accurate index of abundance."

Response: Model 23.2 was explored in May of 2023 as a bookend for the model output without any retow data. If the CPT and SSC wish to see more variations of this model we can provide them, i.e. removing some years and not all as one possibility. While female re-tow data does not highly affect male model outcomes it does affect fishery closures since the State of Alaska harvest strategy uses a mature female threshold for opening.

Response to SSC Comments specific to this assessment (from June 2022):

The SSC noted that during preliminary model runs in May, a full document need not be produced, but one that focuses a summary of model features and runs would be sufficient.

Response: Starting in May 2023 the proposed model run document reflects these changes, focusing on model runs and explorations. Model structure and historical information is linked to via the NPFMC website in the summary section and not repeated in the May documents. The author welcomes further suggestions on the "proposed model" run documents since the CPT does not formally have a format for these.

"The SSC recommends exploring how to estimate both catchabilities (NMFS trawl survey and BSFRF survey), but with a linked prior to influence them to scale together (i.e., assume some approximate value of how much higher q is for that survey)."

Response: This is on the author's list of future work to be addressed with explorations of catchability for both surveys, but has not been explored in this document.

Response to CPT Comments (from May 2022):

"The CPT recommended examining how the initial conditions of abundance are treated as a future analysis"

Response: This has not yet been addressed, but is on the list for future work.

Response to SSC Comments specific to this assessment (from October 2021):

"The SSC requests that in addition to temperature effects on the timing of the molt-mate cycle, the authors explore other potential drivers (e.g., prey quality or quantity) that could underlie the incomplete molt-mate cycle observed in 2021. Based on NMFS trawl survey female biomass estimates, the State of Alaska closed the BBRKC fishery. Next year's assessment should estimate the probability that the stock is currently in the overfished condition."

Response: NMFS staff did an evaluation of re-tow survey protocol in Spring 2022; no changes were adopted at that time. Probabilities in the overfished condition for some models were estimated in September 2021, May 2022, and for the base model in September 2022. Model 23.2 was presented in May 2023, as an exploration of the base model (21.1b) without the retow data for females. This model has minimal effects on the federal harvest control rules, but does estimate a lower biomass for females which would directly affect the State harvest strategy.

"The SSC recommends that authors should carefully consider assessment implications of the stock boundaries given the evidence of crabs outside of the managed area. The SSC suggests that the authors should still be

able to use data from outside stock boundaries, even if not used in the input survey abundance estimates. For example, the abundance seen outside stock boundaries could be treated as covariate informing catchability within the model. This analysis seems particularly important for females that are increasingly outside of the current stock boundaries and are at low abundance, triggering the State closure. The SSC recommends that the authors formulate separate survey abundance time series inside and outside of the defined area that could prove useful in the assessment model (e.g., informing catchability). If this is not an option in the stock assessment, then it highlights the need for ESRs or ESPs to track movement of these crabs both through survey results and developing indices from local knowledge."

Response: The current version of GMACS seems not to be able to use the Northern RKC survey index to inform BBRKC survey catchability. We tried to add a model to include both BBRKC and Northern RKC data, but the groundfish fisheries bycatch is not currently available in the Northern area. In the last two full SAFEs - September 2022 and 2023 - we plotted more proportional data of the Northern RKC. Overall, the proportions of different size 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.

"The SSC supports the BSFRF collaborative work with ADF&G and NMFS to tag BBRKC."

Response: We fully support tagging efforts, especially those to understand seasonal movement and the flow of individuals in or out of the Bristol Bay management area.

"It would be useful to investigate if there is a mechanism for higher natural mortality or fishing mortality for females only during that early time period while following the CPT recommendation of looking at model 21.0 with constant but separate Ms by sex. Since Model 21.0 estimates a very high level of fishing mortality, but does seem to account for the decline in large females, there may be a fishery selectivity issue in that period. If the modelers choose not to continue to use historic data prior to 1985, this suggestion may not be useful."

Response: Figuring out the exact causes of high mortality in the early 1980s is always difficult and we summarize the potential causes in Appendix A of the last full SAFE, section C-vi, "Potential Reasons for High Mortality during the Early 1980s". The directed fishery does not catch many large females and small crab, so it is difficult to remove these crab from the population without a large mortality event. If this period of high natural mortality was a concern, it would be preferred to start the model in 1985, which has two advantages: avoiding the early 1980s period so that a constant M over time can be used, and the same NMFS survey gear throughout the whole model time period.

"The SSC supports continued exploration of the use of VAST estimates for this assessment, particularly if their use will inform mechanisms underlying shifting distributions outside of the current management area."

Response: We also support improvement of VAST estimates and are willing to provide feedback to Jon for further improvement. In general the CPT has not prioritized using VAST output in crab models but we hope to revisit this soon, potentially at the Jan 2025 modeling workshop.

Response to CPT Comments (from September 2021):

"When projecting the stock to determine whether it is approaching an overfished condition, identify the uncertainties included and ignored in the projection. It is particularly important to distinguish those that are captured in the projection (i.e. those associated with the model) and the additional uncertainties that form the basis for the ABC buffer."

Response: Uncertainties are discussed in the projection section included in the final SAFE in Sept. 2023.

"When projecting MMB, label figures with the date to which it is projected (e.g., Feb. 15, 2022), not just the year (which can lead to confusion)."

Response: Working on following this recommendation as we improve plotting standardization from GMACS output.

"Consider a model in which the data starts in 1985 (as suggested by the CIE reviewers)."

Response: Model 22.0 starts in 1985, and was presented in May 2022, May 2023, and Sept 2023. After discussions during the 2023/24 CPT meetings the author is uncertain whether removing the early part of the time series is appropriate. Therefore the model will not be presented again unless specifically requested.

Response to SSC Comments specific to this assessment (from June 2021):

"The SSC supports exploring more modern methods for estimating natural mortality, but notes that this method still relies strongly on the maximum age for BBRKC. The SSC recommends continued research to validate the ages for this stock."

Response: We agree with this suggestion. The maximum age was determined by old tagging data, and due to funding and personnel constraints, age validation for BBRKC is more likely a long-term goal than a short-term project.

"The likelihood profile suggests that the values of M for male and female might be similar and that the current difference may be because of the constraint of base M to a low value. When M is misspecified, it can be the cause of a strong positive retrospective pattern, which BBRKC has. The SSC would have liked to have seen compositional fits and a retrospective analysis for model 19.6 or some model with a higher M value, particularly to see if it fits the plus group better. Despite the increase in F35%, there was not a commensurate increase in OFL. An exploration of the underlying reasons for this outcome is needed."

Response: Based on our past modelling experience, when M values for males and females are estimated separately, estimated M values tended to be always higher for females than for males. The likelihood profile was created through fixing M values for males and estimating M values for females, and when the fixed M values for males were very high, estimated M values for females tended to be similar to M values for males. The increase in F35% but not a commensurate increase in OFL is due to reduction of mature male biomass caused by the high M.

The last likelihood profile on M was computed in May 2020 and can be found in the 2023 SAFE document comments. Model 19.6 uses male base M of 0.257 estimated by Then et al. (2015), and the likelihood profile of base M from 0.1 to 0.4 was presented in previous SAFE versions. It appears that the maximum likelihood value is achieved with a base M of 0.31 for males and 0.321 for females.

In May 2023, models 23.0, 23.0a, 23.0b, and 23.3 all involve variations of higher base M values for males. Higher base M values do not appear to improve the plus group fittings. In Sept 2023, the accepted model was 23.0a which estimates M for males with a tight prior. This was an increase in M (~0.23) from previous fixed values of 0.18 and is thought to be more appropriate for king crab stocks.

"In addition to the CPT recommended models (19.3d, 19.3e, and 19.3g), the SSC recommends a simplified version of model 19.3d that estimates one natural mortality parameter across sex and time, and one shared catchability and selectivity curve for the NMFS trawl survey to help make several selectivity parameters better defined."

Response: We named this as model 21.0 and included it in the September 2021 assessment.

"The SSC requests that the current crab management zones be included in the maps of VAST model-derived spatial distributions of BBRKC."

Response: We will ask Dr. Jon Richar to add the current crab management zones to the VAST spatial plots.

"The SSC also looks forward to the summary report from the March 2021 CIE Review for this stock."

Response: The summary report of the 2021 CIE review is included in Appendix D of the 2022 full SAFE (referenced on the NPFMC website).

Response to CPT Comments (from May 2021):

"The CPT was concerned that the 'information' content of the data with respect to natural mortality could be related to strong assumptions elsewhere in the model, and recommended further exploration of natural mortality after September and suggested attending the June 2021 CAPAM workshop on natural mortality, which may provide some insights into best practices. A large increase in estimated natural mortality would likely increase fishing mortality reference points, with management implications."

Response: Model runs in May 2022/2023 addressed some variations on M. Estimated M values in the length-based crab models tend to have higher values than the other approaches, and confounding among estimated M, survey selectivity/catchability, and recruitment in a length-based model makes it difficult to accurately estimate M in the model. The base model accepted in fall 2023 (model 23.0a) includes an estimated M for males using a tight prior. Further exploration of the appropriateness of this prior are planned.

C. Introduction

1. Scientific Name

Red king crab (RKC), *Paralithodes camtschaticus*, in Bristol Bay, Alaska.

2. Distribution

Red king crab inhabit intertidal waters to depths >200 m of the North Pacific Ocean from British Columbia, Canada, to the Bering Sea, and south to Hokkaido, Japan, and are found in several areas of the Aleutian Islands, eastern Bering Sea, and the Gulf of Alaska.

3. Stock Structure

The State of Alaska divides the Aleutian Islands and eastern Bering Sea into three management registration areas to manage RKC fisheries: Aleutian Islands, Bristol Bay, and Bering Sea (ADF&G 2012). The Bristol Bay area includes all waters north of the latitude of Cape Sarichef (54°36’ N lat.), east of 168°00’ W long., and south of the latitude of Cape Newenham (58°39’ N lat.) and the fishery for RKC in this area is managed separately from fisheries for RKC outside of this area; i.e., the red king crab in the Bristol Bay area are assumed to be a separate stock from red king crab outside of this area. This report summarizes the stock assessment results for the Bristol Bay RKC stock. In 2023 a stock structure template was developed for red king crab in the Bering Sea and can be found on the NPFMC website (**RKC Bering Sea stock structure**).

4. Life History

Red king crab have a complex life history. Fecundity is a function of female size, ranging from tens of thousands to hundreds of thousands of eggs produced (Haynes 1968; Swiney et al. 2012). The eggs are extruded by females, fertilized in the spring, and held by females for about 11 months (Powell and Nickerson 1965). Fertilized eggs are hatched in the spring, most during April-June (Weber 1967). Primiparous females are bred a few weeks earlier in the season than multiparous females. Larval duration and juvenile crab growth depend on temperature (Stevens 1990; Stevens and Swiney 2007). Male and female RKC mature at 5–12 years old, depending on stock and temperature (Stevens 1990; Loher et al. 2001) and may live >20 years (Matsuura and Takeshita 1990). Males and females attain a maximum size of 227 mm and 195 mm carapace length (CL), respectively (Powell and Nickerson 1965). Female maturity is evaluated by the size at which females are observed to carry egg clutches. Male maturity can be defined by multiple criteria including spermataphore production and size, chelae vs. carapace allometry, and participation in mating in situ (reviewed by Webb 2014). For management purposes, females >89 mm CL and males >119 mm CL are assumed to be mature for Bristol Bay RKC. Juvenile RKC molt multiple times per year until age 3 or 4; thereafter, molting continues annually in females for life and in males until maturity. Male molting frequency declines after attaining functional maturity.

5. Fishery

The RKC stock in Bristol Bay, Alaska, supports one of the most valuable fisheries in the United States. A review of the history of the Bristol Bay RKC fishery is provided in Fitch et al. (2012) and Otto (1989). The Japanese fleet started the fishery in the early 1930s, stopped fishing from 1940 to 1952, and resumed the fishery from 1953 until 1974. The Russian fleet fished for RKC from 1959 to 1971. The Japanese fleet employed primarily tanglenets with a very small proportion of catch from trawls and pots. The Russian fleet used only tanglenets. United States trawlers started fishing Bristol Bay RKC in 1947, but the effort and catch declined in the 1950s. The domestic RKC pot fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lb (58,943 t), worth an estimated $115.3 million ex-vessel value. The catch declined dramatically in the early 1980s and has remained at low levels during the last two decades (Tables 9 and 10). After the early 1980s stock collapse, the Bristol Bay RKC fishery took place during a short period in the fall (usually lasting about a week) with the catch quota based on the stock assessment conducted the previous summer (Zheng and Kruse 2002). Beginning with the 2005/2006 season, new regulations associated with fishery rationalization resulted in an increase in the duration of the fishing season (October 15 to January 15). With the implementation of crab rationalization, the annual guideline harvest level (GHL) was changed to a total allowable catch (TAC). Before rationalization, the implementation errors were quite high for some years and sum of actual catches from 1980 to 2007 was about 6% less than the sum of GHL/TAC over that period.

6. Management History

King and Tanner crab stocks in the Bering Sea and Aleutian Islands are managed by the State of Alaska through a federal king and Tanner crab fishery management plan (FMP). Under the FMP, management measures are divided into three categories: (1) fixed in the FMP, (2) frame-worked in the FMP, and (3) discretion of the State of Alaska. The State of Alaska is responsible for determining and establishing the GHL/TAC under the framework in the FMP. Harvest strategies for the Bristol Bay RKC fishery have changed over time.

Two major management objectives for the fishery are to maintain a healthy stock that ensures reproductive viability and to provide for sustained levels of harvest over the long term (ADF&G 2012). In attempting to meet these objectives, the GHL/TAC is coupled with size-sex-season restrictions. Only males $\geq$ 6.5 in carapace width (equivalent to 135mm CL) may be harvested and no fishing is allowed during molting and mating periods (ADF&G 2012). Specification of TAC is based on a harvest rate strategy. Before 1990, harvest rates on legal males were based on population size, abundance of prerecruits to the fishery, postrecruit abundance, and rates varied from less than 20% to 60% (Schmidt and Pengilly 1990). In 1990, the harvest strategy was modified, and a 20% mature male harvest rate was applied to the abundance of mature-sized ($\geq$ 120 mm CL) males with a maximum 60% harvest rate cap of legal ($\geq$ 135 mm CL) males (Pengilly and Schmidt 1995). In addition, a minimum threshold of 8.4 million mature-sized females ($\geq$ 90 mm CL) was added to existing management measures to avoid recruitment overfishing (Pengilly and Schmidt 1995). Based on a new assessment model and research findings (Zheng et al. 1995a, 1995b, 1997a, 1997b), the Alaska Board of Fisheries adopted a new harvest strategy in 1996. That strategy had two mature male harvest rates: 10% when effective spawning biomass (ESB) is between 14.5 and 55.0 million lb and 15% when ESB is at or above 55.0 million lb (Zheng et al. 1996). The maximum harvest rate cap of legal males was changed from 60% to 50%. A threshold of 14.5 million lb of ESB was also added. In 1997, a minimum threshold of 4.0 million lb was established as the minimum GHL for opening the fishery and maintaining fishery viability and manageability when the stock abundance is low. The Board modified the current harvest strategy in 2003 by adding a mature harvest rate of 12.5% when the ESB is between 34.75 and 55.0 million lb and in 2012 eliminated the minimum GHL threshold. The current harvest strategy is illustrated in (Figure 1).

D. Data

1. Summary of New Information

a. Updated groundfish fisheries bycatch data during 1986-2023.
b. Updated crab fishery data: directed, cost-recovery, and bycatch data for 2023/2024
c. Updated survey data for 2024
d. Updated length-frequencies distributions for all data sets for 2023/2024

Data types and availability periods are illustrated in Figure 2.

2. Catch Data

Data on landings of Bristol Bay RKC by length and year and catch per unit effort from 1960 to 1973 were obtained from annual reports of the International North Pacific Fisheries Commission (Hoopes et al. 1972; Jackson 1974; Phinney 1975) and from the Alaska Department of Fish and Game from 1974 to 2020 (Tables 9 and 10). Bycatch data are available starting from 1990 and were obtained from the ADF&G observer database and reports (Gaeuman 2013) (Table 11). Sample sizes for catch by length and sex are summarized in Table 12. Relatively large samples were taken from the retained catch each year. Sample sizes for trawl bycatch were the annual sums of length frequency samples in the National Marine Fisheries Service (NMFS) database.

a. Catch Biomass

Retained catch and estimated bycatch biomasses are summarized in Tables 9 and 10 and illustrated in Figure 3. Retained catch and estimated bycatch from the directed fishery include the general, open-access fishery (prior to rationalization), or the individual fishery quota (IFQ) fishery (after rationalization), as well as the Community Development Quota (CDQ) fishery and the ADF&G cost-recovery harvest. Starting in 1973, the fishery generally occurred during the late summer and fall. Before 1973, a small portion of retained catch in some years was caught from April to June. The years in Tables 9 and 10 are defined as crab year from July 1 to June 30. Bycatch data for the cost-recovery fishery before 2006 were not available. In this report, pot fisheries include both the directed fishery and RKC bycatch in the Tanner crab pot fishery, and trawl fisheries and fixed gear fisheries are groundfish fisheries. Observers did not separate retained and discarded catch of legal-sized crab after 2017 in the directed pot fishery, so the male discarded biomass from the directed fishery has been estimated by the subtraction method (subtracting the retained catch from the estimated total catch) since 2018 (B. Daly, ADF&G, pers. com.).

b. Catch Size Composition

Retained catches by length and shell condition and bycatches by length, shell condition, and sex were obtained for stock assessments. From 1960 to 1966, only retained catch length compositions from the Japanese fishery were available. Retained catches from the Russian and U.S. fisheries were assumed to have the same length compositions as the Japanese fishery during this period. From 1967 to 1969, the length compositions from the Russian fishery were assumed to be the same as those from the Japanese and U.S. fisheries. After 1969, foreign catch declined sharply and only length compositions from the U.S. fishery were used to distribute catch by length.

c. Catch per Unit Effort

Catch per unit effort (CPUE) is defined as the number of retained crab per tan (a unit fishing effort for tanglenets) for the Japanese and Russian tanglenet fisheries and the number of retained crab per potlift for the U.S. fishery (Table 10). Soak time, while an important factor influencing CPUE, is difficult to standardize. Furthermore, complete historical soak time data from the U.S. fishery are not available. Based on the approach of Balsiger (1974), all fishing effort from Japan, Russia, and U.S. were standardized to the Japanese tanglenet from 1960 to 1971, and the CPUE was standardized as crab per tan. Except for the peak-to-crash years of the late 1970s and early 1980s, the correspondence between U.S. fishery CPUE and area-swept survey abundance is poor (Figure 4). Due to the difficulty in estimating commercial fishing catchability and crab availability to the NMFS annual trawl survey data, commercial CPUE data were not used in the model.

3. National Marine Fisheries Service (NMFS) Survey Data

The NMFS has conducted annual trawl surveys of the eastern Bering Sea since 1968. Two vessels, each towing an eastern otter trawl with an 83 ft headrope and a 112 ft footrope, conducted this multispecies, crab-groundfish survey during the summer. Stations were sampled in the center of a systematic 20 X 20 nm grid overlaid in an area of approximately 140,000 nm^2. Since 1972, the trawl survey has covered the full stock distribution except in nearshore waters. The survey in Bristol Bay occurs primarily during late May and June. Tow-by-tow trawl survey data for Bristol Bay RKC during 1975-2023 were provided by NMFS. Due to survey data quality issues, only survey data after 1974 are used in the assessment models.

Abundance estimates by sex, carapace length, and shell condition were derived from survey data using an area-swept approach (Figures 5 and 6). Until the late 1980s, NMFS used a post-stratification approach, but subsequently treated Bristol Bay as a single stratum; the estimates shown for Bristol Bay in Figures 4 – 6 were made without post-stratification. If multiple tows were made at a single station in a given year, the average of the abundances from all tows within that station was used as the estimate of abundance for that station. The new time series since 2015 discards all "hot spot" tows. The VAST estimated biomasses were not considered in this year's assessment but may be considered in the future.

In addition to the standard surveys conducted in early June (late May to early June in 1999 and 2000), a portion of the distribution of Bristol Bay RKC was resurveyed in 1999, 2000, 2006-2012, and 2021 to better assess mature female abundance. Resurveys performed in late July, about six weeks after the standard survey, included 31 stations (1999), 23 stations (2000), 31 stations (2006, 1 bad tow and 30 valid tows), 32 stations (2007-2009), 23 stations (2010), and 20 stations (2011, 2012, and 2021) with high female densities. The resurveys were necessary because a high proportion of mature females had not yet molted or mated when sampled during the standard survey time. Differences in area-swept estimates of abundance between the standard surveys and resurveys of these same stations are attributed to survey measurement errors or to seasonal changes in distribution between survey and resurvey periods. More large females were observed in the resurveys than during the standard surveys in 1999 and 2000, presumably because most mature females had not molted prior to the standard surveys. As in 2006, area-swept estimates of males >89 mm CL, mature males, and legal males within the 32 resurvey stations in 2007 were not significantly different (p = 0.74, 0.74 and 0.95; paired t-test of sample means) between the standard survey and resurvey tows. However, similar to 2006, area-swept estimates of mature females within the 32 resurvey stations in 2007 were significantly different (p = 0.03; paired t-test) between the standard survey and resurvey tows. Resurvey stations were close to shore during 2010-2012, and mature and legal male abundance estimates were lower for the re-tow than the standard survey. Following the CPT recommendation, we used the standard survey data for male abundance estimates and only the resurvey data, plus the standard survey data outside the resurveyed stations, to assess female abundances during resurvey years.

4. Bering Sea Fisheries Research Foundation Survey Data (BSFRF)

The BSFRF conducted trawl surveys for Bristol Bay RKC in 2007 and 2008 with a small-mesh trawl net and 5-minute tows (S. Goodman, BSFRF, pers. com.). The surveys occurred at similar times as the NMFS standard surveys and covered about 97% of the Bristol Bay survey area. Few Bristol Bay RKC were found outside the BSFRF survey area. Because of the small mesh size, the BSFRF surveys were expected to catch more RKC within the swept area. Crab abundances of different size groups were estimated by the kriging method. Mature male abundances were estimated to be 22.331 million crab (CV = 0.0634) in 2007 and 19.747 million crab (CV = 0.0765) in 2008. BSFRF also conducted a side-by-side survey concurrent with the NMFS trawl survey during 2013-2016 in Bristol Bay. In May 2017, survey biomass and size composition estimates from 2016 BSFRF side-by-side trawl survey data were updated. Ratios of NMFS survey abundances/total NMFS and BSFRF side-by-side trawl survey abundances are illustrated in Figures 7 and 8, and ratios of NMFS survey abundances/BSFRF side-by-side trawl survey abundances are shown in Figures 9 – 11.

As a comparison to the estimated NMFS survey catchability (0.896) at 162.5 mm CL by the double-bag experiment (Weinberg et al. 2004), we computed an overall ratio (q=0.891) of NMFS survey abundances/BSFRF side-by-side trawl survey abundances for legal crab ($\geq$ 135mm carapace length) as follows:

$$q = \frac{\sum_{y=2013,l=135mm}^{y=2016,l=\infty} r_{y,l} n_{y,l}}{\sum_{y=2013,l=135mm}^{y=2016,l=\infty} n_{y,l}}$$

where $r_{y,l}$ is the ratio of NMFS survey abundance/BSFRF side-by-side trawl survey abundance in year y and length group l, and $n_{y,l}$ is the combined survey abundance of side-by-side surveys in year y and length group l. Due to small catch, all haul data were combined to compute the ratios for each length group and year.

E. Analytic Approach

1. History of Modeling Approaches for this Stock

To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, ADF&G developed a length-based analysis (LBA) in 1994 that incorporates multiple years of data and multiple data sources in the estimation procedure (Zheng et al. 1995a). Annual abundance estimates of the Bristol Bay RKC stock from the LBA have been used to manage the directed crab fishery and to set crab bycatch limits in the groundfish fisheries since 1995 (Figure 1). An alternative length-based model (research model) was developed in 2004 to include small size crab to determine federal overfishing limits. Given that the crab abundance declined sharply during the early 1980s, the LBA estimated natural mortality for different periods of years, whereas the research model estimated additional mortality beyond a base constant natural mortality during 1980-1984. In this report, we present only the research model that was fit to the data from 1975 to 2024.

2. Model Description

The original LBA model was described in detail by Zheng et al. (1995a, 1995b) and Zheng and Kruse (2002). The model combines multiple sources of survey, catch, and bycatch data using a maximum likelihood approach to estimate abundance, recruitment, selectivity, fishing mortality, catch, and bycatch of commercial pot fisheries and groundfish trawl fisheries. Since 2019, GMACS (General Model for Alaska Crab Stocks) has been used for this stock assessment. A full model description is provided in Appendix A.

a-f. See Appendix A

g. Critical assumptions of the model:

i. The base natural mortality is estimated with a tight prior, a log-normal prior with a mean of 0.18 yr_1 for males and a CV of 0.04. The mean value was estimated assuming a maximum age of 25 and applying the 1% rule (Zheng 2005). A fixed base M of 0.18 yr_1 for males has been used in accepted model until Sept. 2023, when the current estimated base M was adopted.
ii. Survey and fisheries selectivities are a function of length and were constant over shell condition. Selectivities may or may not be a function of sex except for groundfish fisheries bycatch selectivities, which are the same for both sexes. Two different NMFS survey selectivities were estimated: (1) 1975-1981 and (2) 1982-2023, based on modifications to the trawl gear used in the assessment survey.
iii. Growth is a function of length. For females, growth-per-molt increments as a function of length are estimated for three periods (1975-1982, 1983-1993, and 1994-2023) based on sizes at maturity. Once mature, female red king crab have a much smaller growth increment per molt.
iv. Annual molting probabilities are an inverse logistic function of length for males. Females are assumed to molt annually.
v. Annual fishing seasons for the directed fishery are short.

vi. The prior mean for NMFS survey catchability (Q) is estimated to be 0.896 with a standard deviation of 0.025 for some models, based on a trawl experiment by Weinberg et al. (2004); Q is assumed to be constant over time and is estimated in the model. The BSFRF survey catchability is assumed to be 1.0. The prior mean of 0.896 for NMFS survey Q (at 162.5 mm carapace length) is also close to the abundance-weighted average ratio of 0.891 for crab $\geq$ 135 mm CL across four years of side-by-side NMFS and BSFRF survey data (Figure 11).
vii. Males mature at sizes $\geq$ 120 mm CL. For convenience, female abundance is summarized at sizes $\geq$ 90 mm CL as an index of mature females.
viii. Measurement errors are assumed to be normally distributed for length compositions and are log-normally distributed for biomasses.

h. Changes to the above since previous assessment: see Section A.3 for changes to the assessment methodology.

i. Assessment results by GMACS have been compared to the previous assessment models, and the code is online and available from the author and on GitHub (**GMACS GitHub repo**). As per the May 2024 plan team document, the time of year in which SSB is estimated from the model output changed to accommodate a correct for timing within each year. The May 2024 proposed model runs document details this change, and shows that it has minimal affect on the model output.

3. Model Selection and Evaluation

a. Alternative model configurations (models):

23.0a: the base model for September 2023 based on model 21.1b that has the accepted updates from Sept 2023 (1 below), May 2022 (2 - 12 below) and 2024 (13 below). Basic features of this model include:

(1) An estimated constant M for males during 1980-1984, and an estimated constant (base) M for males during the other years using a log-normal prior with a mean of 0.18 and a CV of 0.04. There is an estimated constant multiplier being used to multiply male M for female M such that M for females is relative to M for males each year.

(2) Including BSFRF survey data during 2007-2008 and 2013-2016.

(3) Estimating a constant NMFS survey catchability over time in the model and assuming BSFRF survey catchability to be 1.0.

(4) Assuming the BSFRF survey selectivities as the availability to the NMFS trawl survey because the BSFRF survey gear has very small mesh sizes and has tighter contact to the sea floor. This implies that crab occurring in nearshore areas are not available to trawl survey gears.

(5) Two levels of molting probabilities for males: one before 1980 and one after 1979, based on survey shell condition data. Each level has two parameters.

(6) Estimating effective sample size from observed sample sizes. Stage-1 effective sample sizes are estimated as min $(0.25 * n$, N) for trawl surveys and min $(0.05 * n$, N) for catch and bycatch, where n is the sum of observed sample sizes for two sexes, and N is the maximum sample size (200 for trawl surveys, 150 for retained catch and total males from the directed pot fishery and 50 for females from the pot fishery and for both males and females from the Tanner crab and groundfish fisheries). There is justification for enforcing a maximum limit to effective sample sizes because the number of length measurements is large (Fournier et al. 1998).

(7) Standard survey data for males and NMFS survey re-tow data (if available during cold years) for females.

(8) Estimating initial year length compositions.

(9) Using total observer male biomass and total observer male length composition data in the directed pot fishery to replace discarded male biomass and discarded male length composition data.

(10) Using total male selectivity and retained proportions in the directed pot fishery to replace retained selectivity and discarded male selectivity; and due to high grading problems in some years since rationalization, estimating two logistic curves for retained proportions: one before rationalization (before 2005) and another after 2004.

(11) Equal annual effective sample sizes of male and female length compositions for all size composition data sets.

(12) Updated groundfish fisheries bycatch data.

(13) Uses the recently updated version of GMACS (version 2.20.14).

24.0c: model 23.0a + no molt probability time blocks
(1) removes the time block for molt probability for males and females (item 5 above) which reduces the parameter count by 2.

b. Progression of results:

See the new results at the beginning of the report.

c. Evidence of search for balance between realistic and simpler models:

Model 24.0c reflects work towards this balance to determine if simplification of the model could be warrented.

d. Convergence status/criteria: ADMB default convergence criteria.
e. Sample sizes for length composition data: observed sample sizes are summarized in Table 12.
f. Credible parameter estimates: All estimated parameters seem to be credible and within bounds.
g. Model selection criteria: The likelihood values are used to select among alternatives that could be legitimately compared by that criterion.
h. Residual analysis: Residual plots are illustrated in various figures.
i. Model evaluation is provided under Results, below.
j. Jittering: The Stock Synthesis Approach is used to perform jittering to find the optimum:
The Jitter factor of 0.1 is multiplied by a random normal deviation $rdev = N(0, 1)$, to a transformed parameter value based upon the predefined parameter:

$$temp = 0.5 * rdev * Jitter * ln(\frac{P_{max} - P_{min} + 0.0000002}{P_{val} - P_{min} + 0.0000001} - 1)$$

with the final jittered starting parameter value back-transformed as:

$$P_{new} = P_{min} + (\frac{P_{max} - P_{min}}{1.0 + exp(-2.0 * temp)})$$

where P_{max} and P_{min} are upper and lower bounds of parameters and P_{val} is the estimated parameter value before the jittering.

Jittering was performed using GMACS for both models presented in this report and are summarized under section 4.f. uncertainty and sensitivity analyses.

Assessment Methodology

This assessment model again uses the modeling framework GMACS and is detailed in Appendix A. An updated version of GMACS (version 2.20.14, 2024-5-20) was used.

4. Results

a. Effective sample sizes and weighting factors

i. CVs are assumed to be 0.03 for retained catch biomass, 0.04 for total male biomass, 0.07 for pot bycatch biomasses, 0.10 for groundfish bycatch biomasses, 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.

ii. Initial trawl survey catchability (Q) is estimated to be 0.896 with a standard deviation of 0.025 (CV about 0.03) based on the double-bag experiment results (Weinberg et al. 2004). These values are used to set a prior for estimating Q in all models.

b. Parameter estimates and tables

i. Negative log-likelihood values and parameter estimates are summarized in Tables 16 – 18 for all models.

ii. Natural mortality estimates are shown in Table 13 for all models.

iii. Area-swept estimates of mature female abundance and model estimates of effective spawning biomass (Zheng et al. 1995b) during 2011-2024 for groundfish fisheries bycatch calculation are provided in Table 15.

iv. Abundance and biomass time series are provided in Tables 19 – 20 for models 23.0a and 24.0c.

v. Recruitment time series for models 23.0a and 24.0c are provided in Tables 19 – 20.

vi. Time series of catch biomass is provided in Tables 9 and 10.

Length-specific fishing mortality is equal to selectivity-at-length times the full selection fishing mortality. Estimated full pot fishing mortalities for females and full fishing mortalities for groundfish fisheries bycatch are low due to low bycatch and handling mortality rates less than 1.0. Estimated recruits varied greatly among years (Tables 19 – 20). Estimated selectivities for female pot bycatch are close to 1.0 for all mature females, and the estimated full fishing mortalities for female pot bycatch are lower than those for male retained catch and bycatch (Tables 17 – 18 for models 23.0a and 24.0c).

c. Graphs of estimates

i. Estimated selectivities by length are provided in Figures 12 and 19, and estimated molting probabilities by length are illustrated in Figures 13 and 14.

One of the most important results is estimated trawl survey selectivity (Figures 12). 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 Figure A1 because survey selectivities include capture probabilities and crab availability. The NMFS survey catchability is estimated to be 0.896 from the trawl experiment. The reliability of estimated survey selectivities will greatly affect the application of the model to fisheries management. Under- or over-estimates of survey selectivities will cause a systematic upward or downward bias of abundance estimates, respectively. Information about crab availability in the survey area at survey times will help estimate the survey selectivities. Higher estimated natural mortalities generally result in lower NMFS survey selectivities, while the estimated survey selectivities after 1981 are similar among the models.

For all models, estimated molting probabilities during 1975-2023 (Figures 13 and 14) are generally lower than those estimated from the 1954-1961 tagging data, but are similar to the 1966-1969 tagging data (Balsiger 1974). Lower molting probabilities mean more oldshell crab, possibly due to changes in molting probabilities over time or shell aging errors. Overestimates or underestimates of oldshell crab will result in lower or higher estimates of male molting probabilities. Molt probabilities between models 23.0a and 24.0c are similar for the majority of the time series (Figure 14).

ii. Estimated male and female survey biomasses are shown for NMFS surveys (Figures 15 and 16) and BSFRF surveys (Figures 17 and 18). Absolute mature male biomasses are illustrated in Figures 21 and 22. Mature female abundance (a trigger in the State harvest strategy) is illustrated in Figure 23.

The survey male biomass estimates in 2024 increased from those in 2023, reaching higher levels than have been observed since 2015. Survey female biomass estimates decreased some from 2023, but is higher than most values since 2018. Estimated population biomass increased dramatically in the mid-1970s then decreased precipitously in the early 1980s. Estimated biomass generally increased during 1985-2003 for males and during 1985-2007 for females, then declined, and have steadily declined since the late 2000s (Figures 15, 16, 21, and 22). Absolute mature male biomasses for all models have a similar trend over time (Figures 21 and 22). All models fit the catch and bycatch biomasses very well.

The fit to BSFRF survey data and estimated survey selectivities are illustrated in Figures 17 and 18, but are all similar in their results.

iii. Estimated total recruitment time series are plotted in Figure 24 for models 23.0a and 24.0c. Recruitment is estimated at the end of year in GMACS and is moved up one year for the beginning of next year. Estimated recruitment time series for all models is similar. Compared to the base models used in 2022 and prior years, estimated recruitments among models with higher M values are generally higher.

Like the results of previous models, the terminal year recruitment analysis with models 23.0a and 24.0c suggests the estimated recruitment in the last year should not be used for estimating $B_{35\%}$ (Figures 48 to 51).

iv. Estimated fishing mortality rates are plotted against mature male biomass in Figures 26, and 27 for models 23.0a and 24.0c, and estimated M and directed pot fishing mortality values over time are illustrated in Figure 28 and 29 for models 23.0a and 24.0c.

The average of estimated male recruits from 1984 to 2023 (Figure 25) and mature male biomass per recruit are used to estimate $B_{35\%}$. The full fishing mortalities for the directed pot fishery at the time of fishing are plotted against mature male biomass on Feb. 15 (Figures 26 and 27). Estimated fishing mortalities in most years before the current harvest strategy was adopted in 1996 were above $F_{35\%}$ (Figures 26 and 27). Under the current harvest strategy, estimated fishing mortalities were at or above the $F_{35\%}$ limits in 1998-1999, 2008, and 2016-2019 for model 23.0a, but below the $F_{35\%}$ limits in the other post-1995 years.

For model 23.0a and model 24.0c, estimated full pot fishing mortalities ranged from 0.00 to 2.17 during 1975-2023, with estimated values over 0.40 during 1975-1982, 1984-1987, 1990-1991, 1993, 1998 and 2008 (Table 19, Figures 26 and 27). Estimated fishing mortalities for pot female are generally small in recent years, less than 0.06 since 2000. Groundfish fisheries bycatches, both trawl and fixed gear, since 2000 are generally small and less than 0.02.

For model 23.0a and 24.0c, estimated M values are 1.01 during 1980-1984 and 0.23 for the other years for males, and 1.16 during 1980-1984 and 0.27 for the other years for females, with estimated female M values equaling to 1.14 times male M values (Figure 28). Biologically, females mature earlier than males and likely have higher M values. M values for all models are listed in Table 13.

v. Estimated mature male biomass and recruitment are plotted to illustrate their relationships with model 23.0a (Figure 30). Annual stock productivities are illustrated in Figure 31. Stock productivity (recruitment/mature male biomass) is generally lower during the last 20 years (Figure 31). However, there are high variations for the relation of stock productivity against mature male biomass.

Egg clutch data collected during summer surveys may provide information about mature female reproductive conditions (Figures 32 and 33). Although egg clutch data are subject to rating errors as well as sampling errors, data trends over time may be useful. Proportions of empty clutches for newshell mature females >89 mm CL are high in some years before 1990 but have been low since 1990 (Figure 32). The highest proportion of empty clutches was in 1980 and 1986, and primarily involved soft shell females (shell condition 1). Clutch fullness fluctuated annually around average levels during two periods: before 1991 and after 1990 (Figure 32). The average clutch fullness is similar for these two periods (Figure 32). Egg clutch fullness in the last ten years appears to oscillate up and down from the later period average but still remains higher than 75%.

d. Evaluation of the fit to the data.

i. Observed vs. estimated catches are plotted in Figure 34, with bycatch mortalities from different sources shown in Figure 34 for all models.

ii. Model fits to NMFS survey biomass are shown in Figures 15 and 16.

iii. Model fits to catch and survey proportions by length are illustrated in Figures 35 − 40 and residual bubble plots are shown in Figures 41 − 42.

All models fit the fishery biomass data well and the survey biomass reasonably well (Figures 15, 16, 34). Because the model estimates annual fishing mortality for directed pot male catch, pot female bycatch, and trawl and fixed gear bycatch, the deviations of observed and predicted (estimated) fishery biomass are mainly due to size composition differences. All models fit the NMFS area-swept biomass data almost identically (Figures 15 and 16). All models also fit the length composition data well (Figures 35 – 40). Model progressions are tracked well in the trawl survey data, particularly beginning in mid-1990s (Figures 38 and 5. Cohorts first seen in the trawl survey data in 1975, 1986, 1990, 1995, 1999, 2002 and 2005 can be tracked over time. Some cohorts can be tracked over time in the pot bycatch as well (Figure 35), but the bycatch data did not track the cohorts as well as the survey data. Groundfish bycatch data provide little information to track modal progression.

Residuals of survey biomasses and proportions of length are plotted to examine their patterns. Residuals were calculated as observed minus predicted and standardized by the estimated standard deviation. Residuals of survey biomasses did not show any consistent patterns for all models (Figures 41 − 42). Generally, residuals of proportions of survey males and females appear to be random over length and year for all models (Figures 41 − 43). Models with higher base M values (both models in this document) improve the plus group (males > 160 mm CL and females > 140mm CL) fittings slightly.

e. Retrospective and historical analyses

Retrospective analyses were conducted for this report using the 2024 models. The 2024 model hindcast results are based on sequentially excluding one-year of data to evaluate the current model performance with fewer data.

i. Retrospective analysis (retrospective bias in base model or models).
The performance of the 2024 model includes sequentially excluding one-year of data. Model 23.0a produces some upward biases during 2013-2020 with higher terminal year estimates of mature male biomass in 2014-2020 (Figure 45). Higher than expected BSFRF survey biomass during 2007-2008 and 2013-2016 and NMFS survey biomass in 2014 likely caused these biases. Also, much lower than

expected NMFS survey biomass during 2018-2019 results in lower biomass estimates in 2020 and 2021. Model 24.0c had similar results. Mohn's rho calculations for these retrospective runs were the same for both models and generally considered high (Mohn's rho = 0.23).

Ratios of estimated retrospective recruitments to terminal estimates in 2024 as a function of number of years estimated in the model converge to 1.0 as the number of years increases (Figures 48 and 50). Standard deviations of the ratios drop sharply from one year estimated in the model to two years (Figures 49 and 51), showing great uncertainty of recruitment estimates for terminal years. Based on these results, we suggest not using recruitment estimates in a terminal year for overfishing/overfished determination.

f. Uncertainty and sensitivity analyses.

i. Estimated standard deviations of parameters are summarized in Tables 17 – 18 for models 23.0a and 24.0c. Estimated standard deviations of mature male biomass are listed in Tables 19 – 20.

ii. Probabilities for mature male biomass and OFL in 2023 were illustrated in Figures 52 and 53 for model 24.0c using the MCMC approach.

iii. Probabilities for mature male biomass below the minimum threshold (0.5* $B_{35\%}$) in 2024 were plotted in Figure 54 for model 24.0c using the MCMC approach.

iv. Sensitivity analysis for handling mortality rate was included in the SAFE report in May 2010. The baseline handling mortality rate for the directed pot fishery was set at 0.2. A 50% reduction and 100% increase respectively resulted in 0.1 and 0.4 as alternatives. Overall, a higher handling mortality rate resulted in slightly higher estimates of mature abundance, and a lower rate resulted in a minor reduction of estimated mature abundance. Differences of estimated legal male abundance and mature male biomass were small for these handling mortality rate changes.

v. Sensitivity of weights. Sensitivity of weights was examined in the SAFE report in May 2010. Weights to biomasses (trawl survey biomass, retained catch biomass, and bycatch biomasses) were reduced to 50% or increased to 200% to examine their sensitivity to abundance estimates. Weights to the penalty terms (recruitment variation and sex ratio) were respectively reduced or increased. Overall, estimated biomasses were similar under different weights except during the mid-1970s. The variation of estimated biomasses in the mid-1970s was mainly caused by the changes in estimates of additional mortalities in the early 1980s.

vi. Jittering. Models 23.0a and 24.0c underwent jittering (using 100 iterations of sd =0.1) with both models converging on the MLE >90% of the time. Those jitter runs that did not converge to the MLE were not an improvement to the MLE.

g. Comparison of alternative model scenarios.

Sensitivity to data weighting comparisons, based on the data through 2010, were reported in the SAFE report in May 2011. Estimating length proportions in the initial year (scenario 1a) resulted in a better fit of survey length compositions at an expense of 36 more parameters than model 1. Abundance and biomass estimates with model 1a were similar between models. Using only standard survey data (scenario 1b) resulted in a poorer fit of survey length compositions and biomass than scenarios using both standard and re-tow data (scenarios 1, 1a, and 1c) and had the lowest likelihood value. Although the likelihood value was higher for using both standard survey and re-tow data for males (scenario 1) than using only standard survey for males (scenario 1c), estimated abundances and biomasses were almost identical. The higher likelihood value for scenario 1 over scenario 1c was due to trawl bycatch length compositions.

In the SAFE report in September 2020, seven models were compared. The population biomass estimates in 2020 were slightly higher than those in 2019. Absolute mature male biomasses for all models had a similar trend over time. Among the seven models, model estimated relative NMFS survey biomasses and mature biomasses were similar, especially for models 19.0a and 19.0b and for models 19.3 and 19.3a. Biomass estimates for models 19.0a and 19.0b were higher during recent years than the other five model scenarios. As expected, model 19.3b estimated a higher trawl survey catchability (>1.0), thus resulting in overall lower absolute biomass estimates. Differences of biomass estimates between models 19.0a and 19.0b and models 19.3, 19.3a, 19.3l, and 19.3h could largely be explained by different structures of natural mortality. All seven models fitted the catch and bycatch biomasses very well.

The SAFE report in 2021 and 2022 were also focused on the themes of different structures of natural mortality and potential data time series reductions. Additionally, model exploration in May 2023 began explorations on survey catchability estimation, but those are not explored in the models here since they were not deemed appropriate for model selection at this time. In May 2024 model explorations focused on survey selectivity/availability estimation using the BSFRF survey for prior information instead of an additional survey and removing the time block for molt probability in the base model. Selectivity work is still under development but removal of the molt probability time block is brought forward as an alternative model in this report.

In this report (September 2024), two models are compared. For negative likelihood value comparisons (Table 16), models 23.0a and 24.0c differ in two parameters (the time block for male/female molt probability). The total negative likelihood values between these models are similar, with the reduction of two parameters in model 24.0c providing a slightly better overall fit.

Model 23.0a - which was the accepted model in 2023 - is considered the “base” model for this assessment with an updated GMACS version and updated data for time series that occur in the 2023/2024 crab year (Figure @ref(fig:m23.0a_data_range)). Model 23.0a estimates a base M for males, using a tight prior around an M value of 0.18. In the 2023 assessment it was determined that estimating a base M for males was an improvement in overall model fit for BBRKC. Model 23.0a is used as the base model to compare to model 24.0c, which is the other potential candidate model for specification setting.

Model 24.0c is based on model 23.0a with the removal of the time block for molt probability, where the model has a constant molt probability over the entire time series for both males and females. The time block removed in this model was in the earliest part of the time series and does not appear to have a significant affect on model output, with the resulting terminal year MMB and $B_{35\%}$ being very similar between these two models and the resulting OFL is nearly identical (Table 14).

Based on the model results, it appears that the choice of preferred models leans towards parsimony and simplification, recommending model 24.0c for specification setting in September 2024. However, model 23.0a would also be an acceptable alternative if the goal was to keep the historic molt probability change in place within the model structure. Values for specifications are presented for model 24.0c (Tables 1 and 3), but values for the other models are presented in Table 14.

F. Calculation of the OFL and ABC

1. Bristol Bay RKC is currently placed in Tier 3b (NPFMC 2007).
2. For Tier 3 stocks, estimated biological reference points include $B_{35\%}$ and $F_{35\%}$. Estimated model parameters are used to conduct mature male biomass-per-recruit analysis.
3. Specification of the OFL:

The Tier 3 OFL is calculated using the F_{OFL} control rule:

$$F_{OFL} = \begin{cases} 0_{directedpot} & \frac{B}{B^*} \leq \beta \\ F^* \frac{(\frac{B}{B^*} - \alpha)}{1-\alpha} & \beta < \frac{B}{B^*} \leq 1 \\ F^* & \frac{B}{B^*} > 1 \end{cases} \tag{1}$$

Where

B = a measure of the productive capacity of the stock such as spawning biomass or fertilized egg production. A proxy of B is mature male biomass (MMB) estimated at the time of primiparous female mating (February 15).

$F^* = F_{35\%}$, a proxy for F_{MSY}, which is a full selection instantaneous F that will produce MSY at the MSY producing biomass.

$B^* = B_{35\%}$, a proxy for B_{MSY}, which is the value of biomass at the MSY producing level.

β = a parameter with restriction that $0 \le \beta < 1$. A default value of 0.25 is used.

α = a parameter with restriction that $0 \le \alpha \le \beta$. A default value of 0.1 is used.

Because trawl bycatch fishing mortality is not related to pot fishing mortality, average trawl bycatch fishing mortality during 2019 to 2023 is used for the per recruit analysis as well as for projections in the next section. Some discards of legal males occurred after the Individual Fishery Quota (IFQ) fishery started in 2005, but the discard rates were much lower during 2007-2013 than in 2005 after the fishing industry minimized discards of legal males. However, due to high proportions of large oldshell males, the discard rate increased greatly in 2014. The current models estimate two levels of retained proportions before 2005 and after 2004. The retained proportions after 2004 and total male selectivities are used to represent current trends for per recruit analysis and projections. Average molting probabilities during 2016-2023 are used for per recruit analysis and projections. For the models in 2024, the averages are the same since they are constant over time during at least the last 15 years.

Average recruitments during 1984-2023 are used to estimate $B_{35\%}$ (Figure 25). Estimated $B_{35\%}$ is compared with historical mature male biomass in Figure 30. The period of 1984-2023 corresponds to the 1976/77 regime shift, and the recruitment period 1984-present has been used since 2011 to set the overfishing limits. Several factors support our recommendation. First, estimated recruitment was lower after 1983 than before 1984, which corresponded to brood years 1978 and later, after the 1976/77 regime shift. Second, high recruitments during the late 1960s and 1970s generally occurred when the spawning stock was primarily located in the southern Bristol Bay, whereas the recent spawning stock has been concentrated in the middle of Bristol Bay. Oceanic current flows favor larvae hatched in the southern Bristol Bay (see the section on Ecosystem Considerations for SAFE reports in 2008 and 2009). Finally, stock productivity (recruitment/mature male biomass) was higher before the 1976/1977 regime shift.

The control rule is used for stock status determination. If total catch exceeds OFL estimated at B, then "overfishing" occurs. If B equals or declines below $_{50\%}$ B_{MSY} (i.e., MSST), the stock is "overfished." If B/B_{MSY} or $B/B_{MSYproxy}$ equals or declines below β, then the stock productivity is severely depleted, and the directed fishery is closed.

The estimated probability distributions of MMB and OFL in 2024 are illustrated in Figures 52, 53 and 57 for models 23.0a and 24.0c. Based on SSC suggestions in 2011, $ABC = 0.9 * OFL$ and in October 2018, $ABC = 0.8 * OFL$. The CPT then recommended $ABC = 0.8 * OFL$ in May 2018 (accepted by the SSC), which is used to estimate ABC in this report. Due to the stock being at low levels and the lack of a 2020 survey, the CPT recommended an additional 5% buffer in September 2020, resulting in $ABC = 0.75 * OFL$ for 2020. A 20% buffer was suggested by the CPT for 2021 - 2023, and is recommended by the author in 2024 for similar reasons to previous years. A draft risk table is provided in appendix D, which details concerns for this stock which are similar to those listed above.

MCMC runs with 500,000 replicates and 500 draws with model 23.0a and 24.0c are used for estimating the probability of estimated mature male biomass being below the minimum threshold ($0.5 * B_{35}$) (Figure 54). The probability (converted to a percentage) is estimated to be about 0% for model 24.0c (Figure 55).

Status and catch specifications (1,000 t) (model 24.0c):

Table 5: Status and catch specifications (1000 t) for model 24.0c.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	12.12	13.96	1.20	1.26	1.57	2.14	1.61
2021/22	12.01	16.64	0	0.02	0.10	2.23	1.78
2022/23	9.68	18.34	0	0.02	0.07	3.04	2.43
2023/24	9.35	18.65	0.975	0.96	1.34	4.42	3.54
2024/25		15.43				5.02	4.02

Status and catch specifications (million lb, model 24.0c):

Table 6: Status and catch specifications (million lb) for model 24.0c.

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	26.7	30.8	2.77	2.65	3.47	4.72	3.54
2021/22	26.5	36.7	0	0.04	0.22	4.91	3.92
2022/23	21.34	40.44	0	0.05	0.24	6.70	5.35
2023/24	20.6	41.11	2.15	2.12	2.96	9.75	7.8
2024/25		34.01				11.07	8.86

Table 7: Basis for the OFL (1000 t) from model 24.0c.

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18
2021/22	3b	24.2	14.9	0.62	0.17	1984-2020	0.18
2022/23	3b	24.03	17.0	0.71	0.20	1984-2021	0.18
2023/24	3b	19.36	14.98	0.77	0.30	1984-2022	0.23
2024/25	3b	18.69	15.43	0.83	0.33	1984-2023	0.23

The biological reference points and OFL are illustrated in Tables 14 and 16 for all models, these are based on the $B_{35\%}$ estimated from the average male recruitment during 1984-2023.

Table 8: Basis for the OFL (million lb) from model 24.0c.

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2020/21	3b	56.1	32.9	0.59	0.16	1984-2019	0.18
2021/22	3b	53.4	33.0	0.62	0.17	1984-2020	0.18
2022/23	3b	53.0	37.4	0.71	0.20	1984-2021	0.18
2023/24	3b	42.7	33.0	0.77	0.30	1984-2022	0.23
2024/25	3b	41.2	34.01	0.83	0.33	1984-2023	0.23

G. Rebuilding Analysis

NA, not applicable for this stock

H. Data Gaps and Research Priorities

1. The following data gaps exist for this stock:

a. Information about changes in natural mortality in the early 1980s,
b. Unobserved trawl bycatch in the early 1980s,
c. Natural mortality,
d. Crab availability to the trawl surveys,
e. Juvenile crab abundance,
f. Female growth per molt as a function of size and maturity,
g. Changes in male molting probability over time,
h. A better understanding of larval distribution and subsequent recruit distribution.

2. Research priorities:

a. Estimating natural mortality,
b. Estimating crab availability to the trawl surveys,
c. Surveying juvenile crab abundance in nearshore,
d. Studying environmental factors that affect the survival rates from larvae to recruitment.

I. Projections and outlook

1. Projections

Future population projections primarily depend on future recruitment, but crab recruitment is difficult to predict. Therefore, annual recruitment for the projections is a random selection from estimated recruitments during 2013-2023, a low recruitment period. Four levels of fishing mortality for the directed pot fishery are used in the projections: 0, 0.083, 0.167 and 0.25. A fishing mortality of 0.167 is similar to the estimated F_{ofl} of 0.146 in 2020/2021, and 0.083 is similar to the F_ofl of 0.067 in 2023/24 which are the last two open fishery seasons. MCMC runs with 500,000 replicates and 500 draws are used for the projection.

As expected, projected mature male biomasses are much higher without the directed fishing mortality than under other positive mortality values. At the end of 10 years, projected mature male biomass is below $B_{35\%}$ for all models with a fishing mortality of 0.083 or higher due to low recruitments for both models (Figures

55 and 58). Due to the poor recruitment in recent years, the projected biomass is expected to decline during the next few years with a fishing mortality of greater than F = 0.167.

Even though the stock was not overfished in 2023/24, there is still a question whether the stock is “approaching an overfished condition”, which is defined as “when it is projected that there is more than a 50 percent chance that the biomass of the stock or stock complex will decline below the MSST within two years” by the National Standards 1 (NS1). If the stock is not fished more than a fishing mortality of 0.25 for the directed pot fishery in the 2024/2025 and 2025/26 seasons, the projection using the lowest recruitment periods during 2013-2023 would not likely result in “approaching an overfished condition” for either model (Figure 56). With additional low recruitment estimate used to compute $B_{35\%}$, the estimated MSST would decline further in 2025.

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 recruitments used for the projections. Higher or lower assumed recruitments would cause too optimistic or too pessimistic projections. Overall, recruitments and M used for projections are main factors for projection uncertainties.

2. Near Future Outlook

The near future outlook for the Bristol Bay RKC stock ranges from a steady state to a declining trend. The three recent above-average year classes (hatching years 1990, 1994, and 1997) had entered the legal population by 2006 (Figures 5 and 6). The above-average year class (hatching year 2000) with lengths centered around 87.5 mm CL for both males and females in 2006 and with lengths centered around 112.5-117.5 mm CL for males and around 107.5 mm CL for females in 2008 has largely entered the mature male population in 2009 and the legal population by 2014 (Figures 5 and 6). However, no additional strong cohorts were observed in the survey data after this cohort through the 2010s or 2020s (Figure 5, 6, 59 and 60). A huge tow of juvenile crab of size 45-55 mm in 2011 was not tracked during 2012-2024 surveys and is unlikely to be a strong cohort. The high survey abundances of large males and mature females in 2014 cannot be explained by the survey data during the previous years and were also inconsistent with the 2016-2024 survey results (Figures 59 and 60). Due to lack of improved recruitment, mature and legal crab may continue to decline next year in the presence of fishing pressure.

The closure of the directed fishery for seasons 2021/22 and 2022/23 appears to have allowed abundance of male and female crab to hold steady, with survey data observing only small increases in the overall population. Effects of fishery closures on recruitment are unknown due to the 6 to 7 year lag between spawning and crab recruitment into the assessment model. Current crab abundance is still low relative to the late 1970s, and without favorable environmental conditions, recovery to the high levels of the late 1970s is unlikely in the near future.

Understanding the mechanisms behind the recruitment failure is essential to the future health of the BBRKC stock. The 5 to 7 years between spawning and recruitment to the survey size crab are an unknown for this stock. Identifying critical life history conditions would assist in predicting the future outlook of the stock. These include, but are not limited to, identifying juvenile nursery grounds and understanding juvenile survival within Bristol Bay.

Although mature crab abundance in Bristol Bay has declined in recent years, mature crab abundance and biomass north of Bristol Bay has been generally stable during last 16 years (Figures 63 and 62). Overall, the proportions of different size 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 mature female abundance in the Northern area survey 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 provided in figures in the SAFE report in the future. After migration patterns between BBRKC and the Northern RKC are more fully understood, we will examine their relationships and model them in the stock assessment.

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Tables

Table 9: Bristol Bay red king crab annual catch and bycatch mortality biomass (t) from July 1 to June 30. A handling mortality rate of 0.20 for the directed pot, 0.25 for the Tanner fishery, 0.80 for trawl, and 0.50 for fixed gear was assumed to estimate bycatch mortality biomass. The male bycatch biomass in the directed pot fishery is not estimated outside of a model and not included in this Table. Pot bycatch and Tanner crab fishery bycatch are estimated through expanding the mean observer bycatch per pot to total fishery pot. The pot male bycatch after 2017 is estimated through the subtraction method (B. Daly, ADFG, pers. com.). The trawl and fixed gear fishery bycatches are obtained from the NMFS database. The directed pot bycatch before 1990 and Tanner crab fishery bycatch before 1991 are not available from the observer data and thus not included in this table. These include recently updated estimates from the pot fisheries observer data in 2022.

	Retained				Bycatch			
Year	US	Cost Recovery	Foreign	Total	Females	Trawl	Fixed	Tanner
1953	1331.30		4705.60	6036.90				
1954	1149.90		3720.40	4870.20				
1955	1029.20		3712.70	4741.90				
1956	973.40		3572.90	4546.40				
1957	339.70		3718.10	4057.80				
1958	3.20		3541.60	3544.80				
1959	0.00		6062.30	6062.30				
1960	272.20		12200.70	12472.90				
1961	193.70		20226.60	20420.30				
1962	30.80		24618.70	24649.60				
1963	296.20		24930.80	25227.00				
1964	373.30		26385.50	26758.80				
1965	648.20		18730.60	19378.80				
1966	452.20		19212.40	19664.60				
1967	1407.00		15257.00	16664.10				
1968	3939.90		12459.70	16399.60				
1969	4718.70		6524.00	11242.70				
1970	3882.30		5889.40	9771.70				
1971	5872.20		2782.30	8654.50				
1972	9863.40		2141.00	12004.30				
1973	12207.80		103.40	12311.20				
1974	19171.70		215.90	19387.60				
1975	23281.20		0.00	23281.20				
1976	28993.60		0.00	28993.60		682.80		
1977	31736.90		0.00	31736.90		1249.90		
1978	39743.00		0.00	39743.00		1320.60		
1979	48910.00		0.00	48910.00		1331.90		
1980	58943.60		0.00	58943.60		1036.50		
1981	15236.80		0.00	15236.80		219.40		
1982	1361.30		0.00	1361.30		574.90		
1983	0.00		0.00	0.00		420.40		
1984	1897.10		0.00	1897.10		1094.00		
1985	1893.80		0.00	1893.80		390.10		
1986	5168.20		0.00	5168.20		200.60		
1987	5574.20		0.00	5574.20		186.40		
1988	3351.10		0.00	3351.10		598.40		
1989	4656.00		0.00	4656.00		175.20		
1990	9236.20	36.60	0.00	9272.80	639.20	259.90		

1991	7791.80	93.40	0.00	7885.10	46.80	349.40		1401.80
1992	3648.20	33.60	0.00	3681.80	395.30	293.50		244.40
1993	6635.40	24.10	0.00	6659.60	628.30	401.40		54.60
1994	0.00	42.30	0.00	42.30	0.40	87.30		10.80
1995	0.00	36.40	0.00	36.40	0.30	82.10		0.00
1996	3812.70	49.00	0.00	3861.70	1.00	90.80	41.40	0.00
1997	3971.90	70.20	0.00	4042.10	36.50	57.50	22.50	0.00
1998	6693.80	85.40	0.00	6779.20	553.90	186.10	18.50	0.00
1999	5293.50	84.30	0.00	5377.90	5.60	150.50	50.10	0.00
2000	3698.80	39.10	0.00	3737.90	164.40	81.70	4.70	0.00
2001	3811.50	54.60	0.00	3866.20	120.80	192.80	35.30	0.00
2002	4340.90	43.60	0.00	4384.50	9.10	151.20	29.20	0.00
2003	7120.00	15.30	0.00	7135.30	356.90	136.90	12.70	0.00
2004	6915.20	91.40	0.00	7006.70	171.80	173.50	15.20	0.00
2005	8305.00	94.70	0.00	8399.70	405.40	124.70	19.90	0.00
2006	7005.30	137.90	0.00	7143.20	37.50	151.70	19.60	3.80
2007	9237.90	66.10	0.00	9303.90	159.90	154.10	32.30	1.80
2008	9216.10	0.00	0.00	9216.10	144.80	136.60	15.60	4.00
2009	7226.90	45.50	0.00	7272.50	88.30	87.20	5.80	1.60
2010	6728.50	33.00	0.00	6761.50	118.50	78.70	2.40	0.00
2011	3553.30	53.80	0.00	3607.10	25.00	53.80	10.90	0.00
2012	3560.60	61.10	0.00	3621.70	11.20	32.40	14.90	0.00
2013	3901.10	89.90	0.00	3991.00	98.10	61.90	39.50	28.50
2014	4530.00	8.60	0.00	4538.60	84.90	32.00	82.70	42.00
2015	4522.30	91.40	0.00	4613.70	239.10	41.70	67.90	84.20
2016	3840.40	83.40	0.00	3923.90	123.40	59.80	27.60	0.00
2017	2994.10	99.60	0.00	3093.70	53.40	91.40	86.70	0.00
2018	1954.10	72.40	0.00	2026.50	150.10	72.60	117.30	0.00
2019	1719.80	55.50	0.00	1775.30	43.30	75.70	48.30	0.00
2020	1200.60	56.40	0.00	1257.00	15.20	78.70	17.40	0.00
2021	0.00	17.40	0.00	17.40	5.90	34.50	57.40	0.00
2022	0.00	23.10	0.00	23.10	0.90	15.20	61.90	0.00
2023	972.60	0.00	0.00	972.60	13.10	20.50	35.60	0.00

Table 10: Annual retained catch (millions of crab) and catch per unit effort (CPUE) of the Bristol Bay red king crab fishery.

	Japanese Tanglenet		Russian Tanglenet		US Pot		Standardized
Year	Catch	CPUE	Catch	CPUE	Catch	CPUE	CPUE
1960	1.95	15.20	2.00	10.40	0.088		15.80
1961	3.03	11.80	3.44	8.90	0.062		12.90
1962	4.95	11.30	3.02	7.20	0.01		11.30
1963	5.48	8.50	3.02	5.60	0.101		8.60
1964	5.89	9.20	2.80	4.60	0.123		8.50
1965	4.22	9.30	2.23	3.60	0.223		7.70
1966	4.21	9.40	2.56	4.10	0.14	52	8.10
1967	3.76	8.30	1.59	2.40	0.397	37	6.30
1968	3.85	7.50	0.55	2.30	1.278	27	7.80
1969	2.07	7.20	0.37	1.50	1.749	18	5.60
1970	2.08	7.30	0.32	1.40	1.683	17	5.60
1971	0.89	6.70	0.26	1.30	2.405	20	5.80
1972	0.87	6.70			3.994	19	
1973	0.23				4.826	25	
1974	0.48				7.71	36	
1975					8.745	43	
1976					10.603	33	
1977					11.733	26	
1978					14.746	36	
1979					16.809	53	
1980					20.845	37	
1981					5.308	10	
1982					0.541	4	
1983					No directed	fishery	
1984					0.794	7	
1985					0.796	9	
1986					2.1	12	
1987					2.122	10	
1988					1.236	8	
1989					1.685	8	
1990					3.13	12	
1991					2.661	12	
1992					1.208	6	
1993					2.27	9	
1994					No directed	fishery	
1995					No directed	fishery	
1996					1.264	16	
1997					1.338	15	
1998					2.238	15	
1999					1.923	12	
2000					1.272	12	
2001					1.287	19	
2002					1.484	20	
2003					2.51	18	
2004					2.272	23	
2005					2.763	30	
2006					2.477	31	
2007					3.154	28	
2008					3.064	22	

2009	2.553	21
2010	2.41	18
2011	1.298	28
2012	1.176	30
2013	1.272	27
2014	1.501	26
2015	1.527	31
2016	1.281	38
2017	0.997	20
2018	0.63	20
2019	0.549	16
2020	0.455	21
2021	No directed	fishery
2022	No directed	fishery
2023	0.322	21

Table 11: Total observer catch and bycatch (metric ton) of Bristol Bay red king crab. No handling mortality rates are applied. These include recently updated estimates from the pot fishery observer data in 2022. Directed pot fishery data are the result of the cost-recovery fishery when the directed fishery was closed for the 2021/22 and 2022/23 seasons

	Directed Pot Total		Bycatch Fisheries		
Year	Males	Females	Trawl	Fixed	Tanner
1975			0		
1976			853.494		
1977			1,562.31		
1978			1,650.78		
1979			1,664.93		
1980			1,295.63		
1981			274.229		
1982			718.61		
1983			525.554		
1984			1,367.55		
1985			487.576		
1986			250.758		
1987			233.045		
1988			747.996		
1989			219.023		
1990	11621.80	3196.20	324.883		
1991	9792.90	233.90	436.783		5,580.84
1992	5916.20	1976.30	366.816		962.846
1993	9516.80	3141.50	501.77		218.112
1994	62.30	1.88	109.129		39.395
1995	52.80	1.61	102.623		0
1996	3845.20	5.10	113.495	82.86	0
1997	3758.80	182.70	71.862	44.98	0
1998	15644.80	2769.30	232.58	36.92	0
1999	12112.30	28.00	188.101	100.24	0
2000	6579.70	821.90	102.161	9.45	0
2001	5711.50	604.00	241.011	70.55	0
2002	6961.40	45.60	189.018	58.38	0
2003	12166.50	1784.40	171.114	25.35	0
2004	10692.00	859.20	216.889	30.42	0
2005	13615.90	2027.10	155.924	39.80	0
2006	9254.00	187.40	189.66	39.13	15.217
2007	13871.90	799.40	192.571	64.66	7.142
2008	14894.90	724.20	170.754	31.16	16.07
2009	12218.80	441.30	109.0	10.00	6.499
2010	10095.40	592.60	98.4	4.60	0
2011	5665.30	124.80	67.2	18.80	0
2012	4495.50	55.90	40.5	29.70	0
2013	5305.90	490.70	77.3	78.90	113.063
2014	8113.80	424.30	40.0	165.40	137.786
2015	6726.80	1195.60	52.1	135.90	639.573
2016	5651.80	617.20	74.8	55.20	0
2017	4077.20	266.90	114.3	173.30	0
2018	3423.20	750.40	90.8	234.60	0
2019	3144.60	218.00	94.6	96.60	0
2020	2299.70	76.10	98.4	34.80	0
2021	33.80	29.40	43.1	114.80	0

2022	28.30	4.60	19.0	123.90	0
2023	1543.50	65.40	25.7	71.30	0

Table 12: Annual sample sizes (>64 mm CL) in numbers of crab for trawl surveys, retained catch, directed pot, Tanner crab, trawl, and fixed gear fishery bycatches of Bristol Bay red king crab.

	Trawl Survey		Retained	Pot Total		Bycatch Combined		
Year	Males	Females	Catch	Males	Females	Trawl	Fixed	Tanner
1975	2,815	2,042	29,570					
1976	2,699	1,466	26,450			3,003		
1977	2,734	2,424	32,596			14,703		
1978	2,735	2,793	27,529			10,439		
1979	1,158	1,456	27,900			10,049		
1980	1,917	1,301	34,747			87,152		
1981	591	664	18,029			91,806		
1982	1,911	1,948	11,466			131,469		
1983	1,343	733	0			309,374		
1984	1,209	778	4,404			505,115		
1985	790	414	4,582			200,460		
1986	959	341	5,773			2,126		
1987	1,123	1,011	4,230			998		
1988	708	478	9,833			630		
1989	764	403	32,858			4,641		
1990	729	535	7,218	2,544	696	908		
1991	1,180	490	36,928	4,696	375	275		3,131
1992	509	357	25,550	4,775	2,379	333		965
1993	725	576	32,942	10,200	5,944	5		497
1994	416	239	0	0	0	571		17
1995	685	407	0	0	0	120		
1996	755	753	8,896	642	11	1,209	756	
1997	1,280	702	16,143	10,016	906	339	1,269	
1998	1,067	1,123	17,116	24,537	9,655	1,430	1,036	
1999	765	618	18,685	6,892	40	629	1,602	
2000	734	730	14,143	32,709	8,470	729	591	
2001	599	736	13,735	25,135	5,436	795	5,029	
2002	972	826	16,837	32,317	706	1,139	3,503	
2003	1,360	1,250	18,178	44,600	12,474	516	1,872	
2004	1,852	1,271	22,465	38,772	6,666	636	2,184	
2005	1,198	1,563	27,971	94,622	26,782	1,040	2,146	
2006	1,178	1,432	18,451	73,315	3,991	1,168	1,868	140
2007	1,228	1,305	22,809	115,507	12,691	1,225	785	53
2008	1,228	1,183	24,997	89,771	8,564	1,596	1,164	145
2009	837	941	19,336	97,868	6,055	1,170	1,089	193
2010	708	1,004	20,347	69,276	6,872	901	513	
2011	531	912	10,904	42,931	1,920	439	1,190	
2012	585	707	9,084	21,404	563	281	2,977	
2013	647	569	10,396	32,332	6,051	481	8,523	814
2014	1,107	1,257	9,718	31,216	2,663	261	4,285	631
2015	615	681	11,971	24,533	7,457	409	4,472	2,872
2016	378	812	11,003	30,030	5,832	617	4,329	
2017	385	508	10,067	30,002	4,043	718	1,415	
2018	285	359	7,825	25,635	9,840	893	5,382	
2019	273	299	8,134	25,999	2,894	823	863	
2020			3,850	16,650	961	764	246	
2021	324	247	101	1,100	1433	503	120	
2022	401	319	100	1088	299	90	50	
2023	407	435	3,651	11,767	909	124	428	

2024	559	436

Table 13: Natural mortality estimates for model scenarios during different year blocks.

Model	Sex	baseM	1980-84
m23.0a	female	0.27	1.16
m23.0a	male	0.23	1.01
m24.0c	female	0.26	1.16
m24.0c	male	0.23	1.01

Table 14: 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	MMB/B_{MSY}	F35	F_{OFL}	OFL	Avg Male Rec	Male M
m23.0a	15.42	18.73	0.82	0.40	0.32	5.02	9.88	0.23
m24.0c	15.43	18.69	0.83	0.40	0.32	5.02	9.84	0.23

Table 15: Area-swept estimates of mature female abundance (million crab >89mm) and model estimates of effective spawning biomass (ESB, LBA model from Zheng et al. 1995b; 1000 t) during 2011-2023 for groundfish fisheries bycatch (prohibited species catch, PSC) calculation. (*mature female abundance in 2020 is the model projected value). Note that PSC limits apply to previous-year ESB.

Year	Mature Female Abundance	Effective Spawning Biomass (1000t)
2011	28.52	19.54
2012	21.121	20.03
2013	15.694	22.38
2014	38.58	23.27
2015	18.666	21.10
2016	22.633	19.15
2017	18.497	18.04
2018	9.106	15.09
2019	8.587	12.71
2020	9.668*	11.39
2021	6.432	9.46
2022	8.004	8.89
2023	11.054	9.32
2024	11.7	10.19

Table 16: Comparisons of negative log-likelihood values and some parameters for all model scenarios. Reference models are versions with MMB estimated in season 7.

Component	m23.0a(ref)	m24.0c
Pot-ret-catch	-61.52	-61.35
Pot-totM-catch	30.37	30.40
Pot-F-discC	-59.19	-59.19
Trawl-discC	-66.52	-66.52
Tanner-M-discC	-43.54	-43.54
Tanner-F-discC	-43.51	-43.51
Fixed-discC	-38.81	-38.81
Traw-suv-bio	-39.76	-39.35
BSFRF-sur-bio	-5.11	-5.00
Pot-ret-comp	-4086.55	-4084.32
Pot-totM-comp	-2523.23	-2523.39
Pot-discF-comp	-1546.61	-1546.63
Trawl-disc-comp	-6049.77	-6052.16
Tanner-disc-comp	-1276.34	-1276.39
Fixed-disc-comp	-3598.19	-3598.44
Trawl-sur-comp	-7290.66	-7288.60
BSFRF-sur-comp	-844.56	-844.58
Recruit-dev	74.51	74.44
Recruit-ini	0.00	0.00
Recruit-sex-R	80.42	80.45
Sex-specific-R	0.06	0.06
Ini-size-struct	33.76	33.22
PriorDensity	231.69	224.79
Tot-likelihood	-27123.07	-27128.41
Tot-parms	385.00	383.00
MMB35	18726.92	18690.28
MMB-terminal	15424.70	15426.58
F35	0.40	0.40
$Fofl$	0.32	0.32
OFL	5017.68	5021.76

Table 17: Summary of estimated model parameter values and standard deviations for model 23.0a for Bristol Bay red king crab.

Index	Name	Value	StdDev
1	Log(Rinitial)	20.0244	0.0584
2	Log(Rbar)	16.5605	0.1410
3	Recruitment-rb-males	0.8085	0.1421
4	Recruitment-rb-females	-0.6425	0.2234
5	Scaled-logN-for-male-mature-mature-newshell-class-2	1.0517	0.4415
6	Scaled-logN-for-male-mature-mature-newshell-class-3	0.7430	0.4837
7	Scaled-logN-for-male-mature-mature-newshell-class-4	0.9545	0.3342
8	Scaled-logN-for-male-mature-mature-newshell-class-5	0.7881	0.3047
9	Scaled-logN-for-male-mature-mature-newshell-class-6	0.6030	0.2939
10	Scaled-logN-for-male-mature-mature-newshell-class-7	0.5474	0.2744
11	Scaled-logN-for-male-mature-mature-newshell-class-8	0.3655	0.2756
12	Scaled-logN-for-male-mature-mature-newshell-class-9	0.3811	0.2629
13	Scaled-logN-for-male-mature-mature-newshell-class-10	0.3990	0.2566
14	Scaled-logN-for-male-mature-mature-newshell-class-11	0.1567	0.2789
15	Scaled-logN-for-male-mature-mature-newshell-class-12	0.1213	0.2751
16	Scaled-logN-for-male-mature-mature-newshell-class-13	-0.0024	0.2866
17	Scaled-logN-for-male-mature-mature-newshell-class-14	0.0928	0.2657
18	Scaled-logN-for-male-mature-mature-newshell-class-15	-0.0754	0.2042
19	Scaled-logN-for-male-mature-mature-newshell-class-16	-0.3220	0.1970
20	Scaled-logN-for-male-mature-mature-newshell-class-17	-0.4789	0.1989
21	Scaled-logN-for-male-mature-mature-newshell-class-18	-0.8312	0.2124
22	Scaled-logN-for-male-mature-mature-newshell-class-19	-1.2943	0.2332
23	Scaled-logN-for-male-mature-mature-newshell-class-20	-1.3369	0.2355
24	Scaled-logN-for-female-mature-mature-newshell-class-1	1.5133	0.6280
25	Scaled-logN-for-female-mature-mature-newshell-class-2	1.5091	0.4885
26	Scaled-logN-for-female-mature-mature-newshell-class-3	1.4212	0.3833
27	Scaled-logN-for-female-mature-mature-newshell-class-4	1.1841	0.3511
28	Scaled-logN-for-female-mature-mature-newshell-class-5	1.1081	0.3026
29	Scaled-logN-for-female-mature-mature-newshell-class-6	0.6339	0.3223
30	Scaled-logN-for-female-mature-mature-newshell-class-7	0.2293	0.3560
31	Scaled-logN-for-female-mature-mature-newshell-class-8	-0.0086	0.3593
32	Scaled-logN-for-female-mature-mature-newshell-class-9	-0.2047	0.3498
33	Scaled-logN-for-female-mature-mature-newshell-class-10	-0.5478	0.3688
34	Scaled-logN-for-female-mature-mature-newshell-class-11	-0.9413	0.3803
35	Scaled-logN-for-female-mature-mature-newshell-class-12	-1.2020	0.3851
36	Scaled-logN-for-female-mature-mature-newshell-class-13	-1.4341	0.3839
37	Scaled-logN-for-female-mature-mature-newshell-class-14	-1.8194	0.3730
38	Scaled-logN-for-female-mature-mature-newshell-class-15	-1.9273	0.3694
39	Scaled-logN-for-female-mature-mature-newshell-class-16	-1.8705	0.3494
40	Gscale-base-male	1.0240	0.1971
41	Gscale-base-female	1.3881	0.1220
42	Molt-probability-mu-base-male-period-1	142.8725	1.7269
43	Molt-probability-CV-base-male-period-1	0.0555	0.0096
44	Molt-probability-mu-male-block-group-3-block-1	140.8796	0.5948
45	Molt-probability-CV-male-block-group-3-block-1	0.0686	0.0033
46	M-base-male-mature	0.2302	0.0064
47	M-male-mature-block-group-1-block-1	1.4764	0.0314
48	M-base-female-mature	0.1411	0.0187
49	Sel-Pot-Fishery-male-base-Logistic-mean	4.7798	0.0082
50	Sel-Pot-Fishery-male-base-Logistic-cv	2.2700	0.0420

51	Sel-Trawl-Bycatch-male-base-Logistic-mean	5.1384	0.0471
52	Sel-Trawl-Bycatch-male-base-Logistic-cv	2.7902	0.0410
53	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-mean	4.7115	0.2395
54	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-cv	2.1683	0.3043
55	Sel-Fixed-Gear-male-base-Logistic-mean	4.7893	0.0190
56	Sel-Fixed-Gear-male-base-Logistic-cv	2.2924	0.0760
57	Sel-NMFS-Trawl-male-base-Logistic-mean	4.1405	0.1300
58	Sel-NMFS-Trawl-male-base-Logistic-cv	2.2689	0.3558
59	Sel-NMFS-Trawl-male-Logistic-mean-block-group-5-block-1	4.0785	0.2566
60	Sel-NMFS-Trawl-male-Logistic-cv-block-group-5-block-1	3.5926	0.4178
61	Sel-BSFRF-male-base-Logistic-mean	4.4647	0.0267
62	Sel-BSFRF-male-base-Logistic-cv	2.5392	0.0769
63	Sel-Pot-Fishery-female-base-Logistic-mean	4.5648	0.0186
64	Sel-Pot-Fishery-female-base-Logistic-cv	2.2264	0.0893
65	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-mean	4.7367	0.0902
66	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-cv	0.9029	0.3028
67	Ret-Pot-Fishery-male-base-Logistic-mean	4.9235	0.0015
68	Ret-Pot-Fishery-male-base-Logistic-cv	0.6771	0.0523
69	Ret-Pot-Fishery-male-Logistic-mean-block-group-6-block-1	4.9325	0.0020
70	Ret-Pot-Fishery-male-Logistic-cv-block-group-6-block-1	0.7322	0.0955
71	Log-fbar-Pot-Fishery	-1.7437	0.0432
72	Log-fbar-Trawl-Bycatch	-4.4336	0.0746
73	Log-fbar-Bairdi-Fishery-Bycatch	-5.7280	0.3250
74	Log-fbar-Fixed-Gear	-6.5849	0.0674
75	Log-fdev-Pot-Fishery-year-1975-season-3	0.9239	0.1215
76	Log-fdev-Pot-Fishery-year-1976-season-3	0.8872	0.0914
77	Log-fdev-Pot-Fishery-year-1977-season-3	0.8079	0.0752
78	Log-fdev-Pot-Fishery-year-1978-season-3	0.9009	0.0614
79	Log-fdev-Pot-Fishery-year-1979-season-3	1.1135	0.0556
80	Log-fdev-Pot-Fishery-year-1980-season-3	1.9791	0.0589
81	Log-fdev-Pot-Fishery-year-1981-season-3	2.5195	0.1127
82	Log-fdev-Pot-Fishery-year-1982-season-3	0.9622	0.1484
83	Log-fdev-Pot-Fishery-year-1983-season-3	-8.6840	0.0989
84	Log-fdev-Pot-Fishery-year-1984-season-3	1.4686	0.0988
85	Log-fdev-Pot-Fishery-year-1985-season-3	1.4903	0.0912
86	Log-fdev-Pot-Fishery-year-1986-season-3	1.5759	0.0780
87	Log-fdev-Pot-Fishery-year-1987-season-3	1.0643	0.0669
88	Log-fdev-Pot-Fishery-year-1988-season-3	0.0991	0.0547
89	Log-fdev-Pot-Fishery-year-1989-season-3	0.2087	0.0486
90	Log-fdev-Pot-Fishery-year-1990-season-3	0.8534	0.0398
91	Log-fdev-Pot-Fishery-year-1991-season-3	0.8574	0.0428
92	Log-fdev-Pot-Fishery-year-1992-season-3	0.3402	0.0473
93	Log-fdev-Pot-Fishery-year-1993-season-3	0.9962	0.0514
94	Log-fdev-Pot-Fishery-year-1994-season-3	-4.1708	0.0488
95	Log-fdev-Pot-Fishery-year-1995-season-3	-4.5660	0.0423
96	Log-fdev-Pot-Fishery-year-1996-season-3	-0.0770	0.0408
97	Log-fdev-Pot-Fishery-year-1997-season-3	-0.0122	0.0412
98	Log-fdev-Pot-Fishery-year-1998-season-3	0.9035	0.0439
99	Log-fdev-Pot-Fishery-year-1999-season-3	0.5227	0.0433
100	Log-fdev-Pot-Fishery-year-2000-season-3	-0.0668	0.0417
101	Log-fdev-Pot-Fishery-year-2001-season-3	-0.1319	0.0412
102	Log-fdev-Pot-Fishery-year-2002-season-3	-0.0128	0.0399
103	Log-fdev-Pot-Fishery-year-2003-season-3	0.4480	0.0387

104	Log-fdev-Pot-Fishery-year-2004-season-3	0.4052	0.0387
105	Log-fdev-Pot-Fishery-year-2005-season-3	0.6972	0.0392
106	Log-fdev-Pot-Fishery-year-2006-season-3	0.4417	0.0385
107	Log-fdev-Pot-Fishery-year-2007-season-3	0.8066	0.0386
108	Log-fdev-Pot-Fishery-year-2008-season-3	0.9718	0.0407
109	Log-fdev-Pot-Fishery-year-2009-season-3	0.7715	0.0418
110	Log-fdev-Pot-Fishery-year-2010-season-3	0.6264	0.0413
111	Log-fdev-Pot-Fishery-year-2011-season-3	-0.0114	0.0398
112	Log-fdev-Pot-Fishery-year-2012-season-3	-0.0749	0.0384
113	Log-fdev-Pot-Fishery-year-2013-season-3	0.1251	0.0380
114	Log-fdev-Pot-Fishery-year-2014-season-3	0.4572	0.0381
115	Log-fdev-Pot-Fishery-year-2015-season-3	0.5269	0.0395
116	Log-fdev-Pot-Fishery-year-2016-season-3	0.5308	0.0432
117	Log-fdev-Pot-Fishery-year-2017-season-3	0.4552	0.0494
118	Log-fdev-Pot-Fishery-year-2018-season-3	0.2858	0.0566
119	Log-fdev-Pot-Fishery-year-2019-season-3	0.2435	0.0625
120	Log-fdev-Pot-Fishery-year-2020-season-3	-0.1839	0.0639
121	Log-fdev-Pot-Fishery-year-2021-season-3	-4.6282	0.0625
122	Log-fdev-Pot-Fishery-year-2022-season-3	-4.6837	0.0616
123	Log-fdev-Pot-Fishery-year-2023-season-3	-0.9637	0.0646
124	Log-fdev-Trawl-Bycatch-year-1976-season-5	0.2870	0.1256
125	Log-fdev-Trawl-Bycatch-year-1977-season-5	0.7319	0.1172
126	Log-fdev-Trawl-Bycatch-year-1978-season-5	0.7142	0.1114
127	Log-fdev-Trawl-Bycatch-year-1979-season-5	0.7897	0.1101
128	Log-fdev-Trawl-Bycatch-year-1980-season-5	1.5091	0.1132
129	Log-fdev-Trawl-Bycatch-year-1981-season-5	1.2873	0.1253
130	Log-fdev-Trawl-Bycatch-year-1982-season-5	2.5825	0.1216
131	Log-fdev-Trawl-Bycatch-year-1983-season-5	2.3381	0.1124
132	Log-fdev-Trawl-Bycatch-year-1984-season-5	3.5952	0.1123
133	Log-fdev-Trawl-Bycatch-year-1985-season-5	2.3772	0.1123
134	Log-fdev-Trawl-Bycatch-year-1986-season-5	1.2717	0.1127
135	Log-fdev-Trawl-Bycatch-year-1987-season-5	0.7829	0.1100
136	Log-fdev-Trawl-Bycatch-year-1988-season-5	1.5418	0.1054
137	Log-fdev-Trawl-Bycatch-year-1989-season-5	0.1031	0.1041
138	Log-fdev-Trawl-Bycatch-year-1990-season-5	0.5449	0.1042
139	Log-fdev-Trawl-Bycatch-year-1991-season-5	0.9572	0.1056
140	Log-fdev-Trawl-Bycatch-year-1992-season-5	0.7957	0.1057
141	Log-fdev-Trawl-Bycatch-year-1993-season-5	1.2563	0.1083
142	Log-fdev-Trawl-Bycatch-year-1994-season-5	-0.5022	0.1052
143	Log-fdev-Trawl-Bycatch-year-1995-season-5	-0.7783	0.1036
144	Log-fdev-Trawl-Bycatch-year-1996-season-5	-0.7013	0.1037
145	Log-fdev-Trawl-Bycatch-year-1997-season-5	-1.1530	0.1035
146	Log-fdev-Trawl-Bycatch-year-1998-season-5	0.1428	0.1041
147	Log-fdev-Trawl-Bycatch-year-1999-season-5	-0.1485	0.1040
148	Log-fdev-Trawl-Bycatch-year-2000-season-5	-0.9118	0.1033
149	Log-fdev-Trawl-Bycatch-year-2001-season-5	-0.1344	0.1031
150	Log-fdev-Trawl-Bycatch-year-2002-season-5	-0.4250	0.1028
151	Log-fdev-Trawl-Bycatch-year-2003-season-5	-0.5207	0.1026
152	Log-fdev-Trawl-Bycatch-year-2004-season-5	-0.2893	0.1025
153	Log-fdev-Trawl-Bycatch-year-2005-season-5	-0.5668	0.1025
154	Log-fdev-Trawl-Bycatch-year-2006-season-5	-0.3995	0.1022
155	Log-fdev-Trawl-Bycatch-year-2007-season-5	-0.3272	0.1023
156	Log-fdev-Trawl-Bycatch-year-2008-season-5	-0.3595	0.1027

157	Log-fdev-Trawl-Bycatch-year-2009-season-5	-0.7243	0.1028
158	Log-fdev-Trawl-Bycatch-year-2010-season-5	-0.8817	0.1027
159	Log-fdev-Trawl-Bycatch-year-2011-season-5	-1.3417	0.1023
160	Log-fdev-Trawl-Bycatch-year-2012-season-5	-1.8524	0.1023
161	Log-fdev-Trawl-Bycatch-year-2013-season-5	-1.1262	0.1023
162	Log-fdev-Trawl-Bycatch-year-2014-season-5	-1.6839	0.1024
163	Log-fdev-Trawl-Bycatch-year-2015-season-5	-1.2976	0.1030
164	Log-fdev-Trawl-Bycatch-year-2016-season-5	-0.7654	0.1040
165	Log-fdev-Trawl-Bycatch-year-2017-season-5	-0.3193	0.1056
166	Log-fdev-Trawl-Bycatch-year-2018-season-5	-0.3675	0.1072
167	Log-fdev-Trawl-Bycatch-year-2019-season-5	-0.3229	0.1091
168	Log-fdev-Trawl-Bycatch-year-2020-season-5	-0.3037	0.1103
169	Log-fdev-Trawl-Bycatch-year-2021-season-5	-1.2585	0.1103
170	Log-fdev-Trawl-Bycatch-year-2022-season-5	-2.1993	0.1113
171	Log-fdev-Trawl-Bycatch-year-2023-season-5	-1.9466	0.1140
172	Log-fdev-Bairdi-Fishery-Bycatch-year-1975-season-5	-0.1163	0.0682
173	Log-fdev-Bairdi-Fishery-Bycatch-year-1976-season-5	0.6699	0.0682
174	Log-fdev-Bairdi-Fishery-Bycatch-year-1977-season-5	1.2283	0.0682
175	Log-fdev-Bairdi-Fishery-Bycatch-year-1978-season-5	1.0927	0.0682
176	Log-fdev-Bairdi-Fishery-Bycatch-year-1979-season-5	1.3824	0.0682
177	Log-fdev-Bairdi-Fishery-Bycatch-year-1980-season-5	1.4242	0.0682
178	Log-fdev-Bairdi-Fishery-Bycatch-year-1981-season-5	0.9927	0.0682
179	Log-fdev-Bairdi-Fishery-Bycatch-year-1982-season-5	0.4764	0.0682
180	Log-fdev-Bairdi-Fishery-Bycatch-year-1983-season-5	-0.9874	0.0682
181	Log-fdev-Bairdi-Fishery-Bycatch-year-1984-season-5	-0.5787	0.0682
182	Log-fdev-Bairdi-Fishery-Bycatch-year-1987-season-5	-1.0994	0.0682
183	Log-fdev-Bairdi-Fishery-Bycatch-year-1988-season-5	-0.2563	0.0682
184	Log-fdev-Bairdi-Fishery-Bycatch-year-1989-season-5	0.9401	0.0682
185	Log-fdev-Bairdi-Fishery-Bycatch-year-1990-season-5	1.4182	0.0682
186	Log-fdev-Bairdi-Fishery-Bycatch-year-1991-season-5	3.2464	0.0750
187	Log-fdev-Bairdi-Fishery-Bycatch-year-1992-season-5	1.2808	0.1091
188	Log-fdev-Bairdi-Fishery-Bycatch-year-1993-season-5	0.5477	0.1240
189	Log-fdev-Bairdi-Fishery-Bycatch-year-1994-season-5	-0.7663	0.0861
190	Log-fdev-Bairdi-Fishery-Bycatch-year-2006-season-5	-2.1186	0.0737
191	Log-fdev-Bairdi-Fishery-Bycatch-year-2007-season-5	-2.9827	0.1009
192	Log-fdev-Bairdi-Fishery-Bycatch-year-2008-season-5	-2.4202	0.1167
193	Log-fdev-Bairdi-Fishery-Bycatch-year-2009-season-5	-3.5102	0.0746
194	Log-fdev-Bairdi-Fishery-Bycatch-year-2013-season-5	-0.8362	0.0965
195	Log-fdev-Bairdi-Fishery-Bycatch-year-2014-season-5	-0.1081	0.1217
196	Log-fdev-Bairdi-Fishery-Bycatch-year-2015-season-5	1.0809	0.1486
197	Log-fdev-Fixed-Gear-year-1996-season-5	0.5317	0.1031
198	Log-fdev-Fixed-Gear-year-1997-season-5	-0.1259	0.1024
199	Log-fdev-Fixed-Gear-year-1998-season-5	-0.3578	0.1030
200	Log-fdev-Fixed-Gear-year-1999-season-5	0.5571	0.1023
201	Log-fdev-Fixed-Gear-year-2000-season-5	-1.8631	0.1017
202	Log-fdev-Fixed-Gear-year-2001-season-5	0.0988	0.1013
203	Log-fdev-Fixed-Gear-year-2002-season-5	-0.1561	0.1009
204	Log-fdev-Fixed-Gear-year-2003-season-5	-0.9904	0.1008
205	Log-fdev-Fixed-Gear-year-2004-season-5	-0.8167	0.1006
206	Log-fdev-Fixed-Gear-year-2005-season-5	-0.5497	0.1005
207	Log-fdev-Fixed-Gear-year-2006-season-5	-0.5952	0.1003
208	Log-fdev-Fixed-Gear-year-2007-season-5	-0.0516	0.1003
209	Log-fdev-Fixed-Gear-year-2008-season-5	-0.7596	0.1006

210	Log-fdev-Fixed-Gear-year-2009-season-5	-1.7617	0.1004
211	Log-fdev-Fixed-Gear-year-2010-season-5	-2.5979	0.1000
212	Log-fdev-Fixed-Gear-year-2011-season-5	-1.1073	0.0997
213	Log-fdev-Fixed-Gear-year-2012-season-5	-0.5398	0.0995
214	Log-fdev-Fixed-Gear-year-2013-season-5	0.6078	0.0994
215	Log-fdev-Fixed-Gear-year-2014-season-5	1.4622	0.0995
216	Log-fdev-Fixed-Gear-year-2015-season-5	1.1514	0.0997
217	Log-fdev-Fixed-Gear-year-2016-season-5	0.2574	0.1003
218	Log-fdev-Fixed-Gear-year-2017-season-5	1.5378	0.1012
219	Log-fdev-Fixed-Gear-year-2018-season-5	1.9361	0.1020
220	Log-fdev-Fixed-Gear-year-2019-season-5	1.0867	0.1030
221	Log-fdev-Fixed-Gear-year-2020-season-5	0.0475	0.1041
222	Log-fdev-Fixed-Gear-year-2021-season-5	1.1654	0.1049
223	Log-fdev-Fixed-Gear-year-2022-season-5	1.1896	0.1065
224	Log-fdev-Fixed-Gear-year-2023-season-5	0.6433	0.1087
225	Log-foff-Pot-Fishery	-2.7530	0.0433
226	Log-foff-Bairdi-Fishery-Bycatch	-0.1269	0.4816
227	Log-fdov-Pot-Fishery-year-1990-season-3	1.9130	0.0842
228	Log-fdov-Pot-Fishery-year-1991-season-3	-0.7464	0.0834
229	Log-fdov-Pot-Fishery-year-1992-season-3	1.9252	0.0846
230	Log-fdov-Pot-Fishery-year-1993-season-3	1.7631	0.0859
231	Log-fdov-Pot-Fishery-year-1994-season-3	-0.4564	0.0844
232	Log-fdov-Pot-Fishery-year-1995-season-3	-0.2423	0.0823
233	Log-fdov-Pot-Fishery-year-1996-season-3	-3.7333	0.0813
234	Log-fdov-Pot-Fishery-year-1997-season-3	-0.3768	0.0822
235	Log-fdov-Pot-Fishery-year-1998-season-3	1.3880	0.0830
236	Log-fdov-Pot-Fishery-year-1999-season-3	-2.8315	0.0821
237	Log-fdov-Pot-Fishery-year-2000-season-3	1.1073	0.0811
238	Log-fdov-Pot-Fishery-year-2001-season-3	0.8240	0.0811
239	Log-fdov-Pot-Fishery-year-2002-season-3	-1.9298	0.0805
240	Log-fdov-Pot-Fishery-year-2003-season-3	1.1688	0.0804
241	Log-fdov-Pot-Fishery-year-2004-season-3	0.3761	0.0807
242	Log-fdov-Pot-Fishery-year-2005-season-3	0.8945	0.0803
243	Log-fdov-Pot-Fishery-year-2006-season-3	-1.2776	0.0796
244	Log-fdov-Pot-Fishery-year-2007-season-3	-0.2350	0.0796
245	Log-fdov-Pot-Fishery-year-2008-season-3	-0.4968	0.0800
246	Log-fdov-Pot-Fishery-year-2009-season-3	-0.7488	0.0802
247	Log-fdov-Pot-Fishery-year-2010-season-3	-0.2515	0.0799
248	Log-fdov-Pot-Fishery-year-2011-season-3	-1.1328	0.0790
249	Log-fdov-Pot-Fishery-year-2012-season-3	-1.8491	0.0785
250	Log-fdov-Pot-Fishery-year-2013-season-3	0.1642	0.0783
251	Log-fdov-Pot-Fishery-year-2014-season-3	-0.2426	0.0784
252	Log-fdov-Pot-Fishery-year-2015-season-3	0.8204	0.0787
253	Log-fdov-Pot-Fishery-year-2016-season-3	0.2711	0.0799
254	Log-fdov-Pot-Fishery-year-2017-season-3	-0.3876	0.0819
255	Log-fdov-Pot-Fishery-year-2018-season-3	0.9205	0.0848
256	Log-fdov-Pot-Fishery-year-2019-season-3	-0.1674	0.0869
257	Log-fdov-Pot-Fishery-year-2020-season-3	-0.6967	0.0870
258	Log-fdov-Pot-Fishery-year-2021-season-3	2.8904	0.0865
259	Log-fdov-Pot-Fishery-year-2022-season-3	1.2002	0.0868
260	Log-fdov-Pot-Fishery-year-2023-season-3	0.1715	0.0886
261	Log-fdov-Bairdi-Fishery-Bycatch-year-1975-season-5	-0.0000	0.0962
262	Log-fdov-Bairdi-Fishery-Bycatch-year-1976-season-5	0.0001	0.0962

263	Log-fdov-Bairdi-Fishery-Bycatch-year-1977-season-5	0.0003	0.0962
264	Log-fdov-Bairdi-Fishery-Bycatch-year-1978-season-5	0.0002	0.0963
265	Log-fdov-Bairdi-Fishery-Bycatch-year-1979-season-5	0.0004	0.0963
266	Log-fdov-Bairdi-Fishery-Bycatch-year-1980-season-5	0.0001	0.0963
267	Log-fdov-Bairdi-Fishery-Bycatch-year-1981-season-5	-0.0001	0.0963
268	Log-fdov-Bairdi-Fishery-Bycatch-year-1982-season-5	-0.0001	0.0962
269	Log-fdov-Bairdi-Fishery-Bycatch-year-1983-season-5	-0.0001	0.0962
270	Log-fdov-Bairdi-Fishery-Bycatch-year-1984-season-5	-0.0001	0.0962
271	Log-fdov-Bairdi-Fishery-Bycatch-year-1987-season-5	-0.0001	0.0962
272	Log-fdov-Bairdi-Fishery-Bycatch-year-1988-season-5	0.0001	0.0962
273	Log-fdov-Bairdi-Fishery-Bycatch-year-1989-season-5	0.0003	0.0962
274	Log-fdov-Bairdi-Fishery-Bycatch-year-1990-season-5	0.0007	0.0963
275	Log-fdov-Bairdi-Fishery-Bycatch-year-1991-season-5	1.4975	0.1603
276	Log-fdov-Bairdi-Fishery-Bycatch-year-1992-season-5	1.7847	0.1303
277	Log-fdov-Bairdi-Fishery-Bycatch-year-1993-season-5	0.5924	0.1455
278	Log-fdov-Bairdi-Fishery-Bycatch-year-1994-season-5	-3.4423	0.1113
279	Log-fdov-Bairdi-Fishery-Bycatch-year-2006-season-5	-2.1771	0.1701
280	Log-fdov-Bairdi-Fishery-Bycatch-year-2007-season-5	-0.8013	0.1322
281	Log-fdov-Bairdi-Fishery-Bycatch-year-2008-season-5	0.0420	0.1359
282	Log-fdov-Bairdi-Fishery-Bycatch-year-2009-season-5	0.4005	0.1019
283	Log-fdov-Bairdi-Fishery-Bycatch-year-2013-season-5	0.9814	0.1742
284	Log-fdov-Bairdi-Fishery-Bycatch-year-2014-season-5	0.1984	0.1590
285	Log-fdov-Bairdi-Fishery-Bycatch-year-2015-season-5	0.9222	0.1833
286	Rec-dev-est-1975	0.9881	0.2709
287	Rec-dev-est-1976	0.5516	0.2999
288	Rec-dev-est-1977	0.9701	0.2423
289	Rec-dev-est-1978	1.5811	0.2056
290	Rec-dev-est-1979	1.8730	0.2134
291	Rec-dev-est-1980	1.0732	0.2579
292	Rec-dev-est-1981	2.4005	0.1609
293	Rec-dev-est-1982	1.4313	0.1766
294	Rec-dev-est-1983	1.0450	0.1622
295	Rec-dev-est-1984	-0.7606	0.2432
296	Rec-dev-est-1985	0.2987	0.1595
297	Rec-dev-est-1986	-0.8116	0.2359
298	Rec-dev-est-1987	-1.2481	0.2687
299	Rec-dev-est-1988	-1.0178	0.2225
300	Rec-dev-est-1989	-0.0634	0.1602
301	Rec-dev-est-1990	-0.4720	0.1786
302	Rec-dev-est-1991	-1.8920	0.3405
303	Rec-dev-est-1992	-0.8827	0.1924
304	Rec-dev-est-1993	-2.0702	0.3956
305	Rec-dev-est-1994	0.9629	0.1423
306	Rec-dev-est-1995	-0.8221	0.2469
307	Rec-dev-est-1996	-1.5857	0.3356
308	Rec-dev-est-1997	-0.6050	0.1992
309	Rec-dev-est-1998	0.4195	0.1516
310	Rec-dev-est-1999	-0.5216	0.2175
311	Rec-dev-est-2000	-0.6408	0.2553
312	Rec-dev-est-2001	0.8570	0.1500
313	Rec-dev-est-2002	-0.6236	0.2612
314	Rec-dev-est-2003	-0.7041	0.2629
315	Rec-dev-est-2004	0.5432	0.1533

316	Rec-dev-est-2005	-0.1010	0.1752
317	Rec-dev-est-2006	-0.5295	0.1849
318	Rec-dev-est-2007	-1.0824	0.2284
319	Rec-dev-est-2008	-0.9569	0.2296
320	Rec-dev-est-2009	-0.0613	0.1766
321	Rec-dev-est-2010	-0.5164	0.2150
322	Rec-dev-est-2011	-1.1089	0.2263
323	Rec-dev-est-2012	-1.4193	0.2174
324	Rec-dev-est-2013	-1.9149	0.2610
325	Rec-dev-est-2014	-1.4544	0.2190
326	Rec-dev-est-2015	-0.7931	0.1676
327	Rec-dev-est-2016	-1.5640	0.2369
328	Rec-dev-est-2017	-0.8829	0.1831
329	Rec-dev-est-2018	-1.5284	0.2572
330	Rec-dev-est-2019	-1.3620	0.2287
331	Rec-dev-est-2020	-1.5728	0.2551
332	Rec-dev-est-2021	-0.7429	0.1928
333	Rec-dev-est-2022	-1.0461	0.2422
334	Rec-dev-est-2023	-1.6793	0.3828
335	Logit-rec-prop-est-1975	0.0942	0.4678
336	Logit-rec-prop-est-1976	-0.7546	0.5218
337	Logit-rec-prop-est-1977	-0.1453	0.3674
338	Logit-rec-prop-est-1978	-0.3230	0.2597
339	Logit-rec-prop-est-1979	0.2596	0.2592
340	Logit-rec-prop-est-1980	0.4249	0.3502
341	Logit-rec-prop-est-1981	0.5038	0.1418
342	Logit-rec-prop-est-1982	0.6225	0.2468
343	Logit-rec-prop-est-1983	0.0816	0.1789
344	Logit-rec-prop-est-1984	0.4151	0.4546
345	Logit-rec-prop-est-1985	-0.4552	0.1707
346	Logit-rec-prop-est-1986	0.2276	0.4221
347	Logit-rec-prop-est-1987	-0.1965	0.4798
348	Logit-rec-prop-est-1988	0.3721	0.3981
349	Logit-rec-prop-est-1989	-0.0699	0.1710
350	Logit-rec-prop-est-1990	0.1872	0.2459
351	Logit-rec-prop-est-1991	0.5991	0.7638
352	Logit-rec-prop-est-1992	0.3263	0.3040
353	Logit-rec-prop-est-1993	-1.3868	1.0218
354	Logit-rec-prop-est-1994	-0.3152	0.0899
355	Logit-rec-prop-est-1995	1.3924	0.7026
356	Logit-rec-prop-est-1996	0.1799	0.6885
357	Logit-rec-prop-est-1997	0.5150	0.3474
358	Logit-rec-prop-est-1998	-0.0812	0.1424
359	Logit-rec-prop-est-1999	0.2987	0.3706
360	Logit-rec-prop-est-2000	-0.7306	0.4639
361	Logit-rec-prop-est-2001	-0.4810	0.1277
362	Logit-rec-prop-est-2002	-0.4532	0.4527
363	Logit-rec-prop-est-2003	-0.0868	0.4592
364	Logit-rec-prop-est-2004	-0.3924	0.1459
365	Logit-rec-prop-est-2005	-0.1084	0.2286
366	Logit-rec-prop-est-2006	0.4379	0.2862
367	Logit-rec-prop-est-2007	-0.1269	0.3772
368	Logit-rec-prop-est-2008	-0.5382	0.3769

369	Logit-rec-prop-est-2009	-0.6952	0.2084
370	Logit-rec-prop-est-2010	-0.4300	0.3104
371	Logit-rec-prop-est-2011	-0.5898	0.3697
372	Logit-rec-prop-est-2012	-0.1577	0.3540
373	Logit-rec-prop-est-2013	-0.4827	0.4816
374	Logit-rec-prop-est-2014	-0.4139	0.3461
375	Logit-rec-prop-est-2015	0.2486	0.2110
376	Logit-rec-prop-est-2016	0.4159	0.4371
377	Logit-rec-prop-est-2017	0.6302	0.2840
378	Logit-rec-prop-est-2018	-0.2132	0.4644
379	Logit-rec-prop-est-2019	0.5021	0.4205
380	Logit-rec-prop-est-2020	0.4179	0.4750
381	Logit-rec-prop-est-2021	0.0683	0.2600
382	Logit-rec-prop-est-2022	0.0174	0.3915
383	Logit-rec-prop-est-2023	0.3897	0.7791
384	Survey-q-survey-1	0.9322	0.0257
385	Log-add-cvt-survey-2	-1.0137	0.2881

Table 18: Summary 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	Scaled-logN-for-male-mature-mature-newshell-class-2	1.0224	0.4504
6	Scaled-logN-for-male-mature-mature-newshell-class-3	0.7244	0.4837
7	Scaled-logN-for-male-mature-mature-newshell-class-4	0.9312	0.3388
8	Scaled-logN-for-male-mature-mature-newshell-class-5	0.7536	0.3118
9	Scaled-logN-for-male-mature-mature-newshell-class-6	0.5618	0.3014
10	Scaled-logN-for-male-mature-mature-newshell-class-7	0.5170	0.2799
11	Scaled-logN-for-male-mature-mature-newshell-class-8	0.3509	0.2794
12	Scaled-logN-for-male-mature-mature-newshell-class-9	0.3824	0.2654
13	Scaled-logN-for-male-mature-mature-newshell-class-10	0.4091	0.2577
14	Scaled-logN-for-male-mature-mature-newshell-class-11	0.1875	0.2760
15	Scaled-logN-for-male-mature-mature-newshell-class-12	0.1715	0.2699
16	Scaled-logN-for-male-mature-mature-newshell-class-13	0.0594	0.2788
17	Scaled-logN-for-male-mature-mature-newshell-class-14	0.1659	0.2532
18	Scaled-logN-for-male-mature-mature-newshell-class-15	-0.0158	0.1982
19	Scaled-logN-for-male-mature-mature-newshell-class-16	-0.2760	0.1913
20	Scaled-logN-for-male-mature-mature-newshell-class-17	-0.4397	0.1937
21	Scaled-logN-for-male-mature-mature-newshell-class-18	-0.7884	0.2074
22	Scaled-logN-for-male-mature-mature-newshell-class-19	-1.2523	0.2287
23	Scaled-logN-for-male-mature-mature-newshell-class-20	-1.3109	0.2287
24	Scaled-logN-for-female-mature-mature-newshell-class-1	1.5250	0.5927
25	Scaled-logN-for-female-mature-mature-newshell-class-2	1.4831	0.4823
26	Scaled-logN-for-female-mature-mature-newshell-class-3	1.3880	0.3824
27	Scaled-logN-for-female-mature-mature-newshell-class-4	1.1528	0.3515
28	Scaled-logN-for-female-mature-mature-newshell-class-5	1.0841	0.3031
29	Scaled-logN-for-female-mature-mature-newshell-class-6	0.6214	0.3241
30	Scaled-logN-for-female-mature-mature-newshell-class-7	0.2105	0.3600
31	Scaled-logN-for-female-mature-mature-newshell-class-8	-0.0300	0.3631
32	Scaled-logN-for-female-mature-mature-newshell-class-9	-0.2238	0.3534
33	Scaled-logN-for-female-mature-mature-newshell-class-10	-0.5703	0.3720
34	Scaled-logN-for-female-mature-mature-newshell-class-11	-0.9617	0.3825
35	Scaled-logN-for-female-mature-mature-newshell-class-12	-1.2222	0.3867
36	Scaled-logN-for-female-mature-mature-newshell-class-13	-1.4529	0.3851
37	Scaled-logN-for-female-mature-mature-newshell-class-14	-1.8285	0.3738
38	Scaled-logN-for-female-mature-mature-newshell-class-15	-1.9352	0.3699
39	Scaled-logN-for-female-mature-mature-newshell-class-16	-1.8823	0.3500
40	Gscale-base-male	1.0386	0.1975
41	Gscale-base-female	1.3885	0.1220
42	Molt-probability-mu-base-male-period-1	141.1022	0.5702
43	Molt-probability-CV-base-male-period-1	0.0671	0.0031
44	M-base-male-mature	0.2303	0.0064
45	M-male-mature-block-group-1-block-1	1.4807	0.0311
46	M-base-female-mature	0.1398	0.0187
47	Sel-Pot-Fishery-male-base-Logistic-mean	4.7788	0.0080
48	Sel-Pot-Fishery-male-base-Logistic-cv	2.2645	0.0419
49	Sel-Trawl-Bycatch-male-base-Logistic-mean	5.1398	0.0471
50	Sel-Trawl-Bycatch-male-base-Logistic-cv	2.7929	0.0405

51	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-mean	4.7082	0.2414
52	Sel-Bairdi-Fishery-Bycatch-male-base-Logistic-cv	2.1688	0.3041
53	Sel-Fixed-Gear-male-base-Logistic-mean	4.7889	0.0189
54	Sel-Fixed-Gear-male-base-Logistic-cv	2.2898	0.0759
55	Sel-NMFS-Trawl-male-base-Logistic-mean	4.1302	0.1358
56	Sel-NMFS-Trawl-male-base-Logistic-cv	2.2388	0.3728
57	Sel-NMFS-Trawl-male-Logistic-mean-block-group-5-block-1	4.0868	0.2406
58	Sel-NMFS-Trawl-male-Logistic-cv-block-group-5-block-1	3.5213	0.3763
59	Sel-BSFRF-male-base-Logistic-mean	4.4639	0.0267
60	Sel-BSFRF-male-base-Logistic-cv	2.5430	0.0779
61	Sel-Pot-Fishery-female-base-Logistic-mean	4.5648	0.0186
62	Sel-Pot-Fishery-female-base-Logistic-cv	2.2265	0.0894
63	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-mean	4.7361	0.0901
64	Sel-Bairdi-Fishery-Bycatch-female-base-Logistic-cv	0.9029	0.3027
65	Ret-Pot-Fishery-male-base-Logistic-mean	4.9237	0.0015
66	Ret-Pot-Fishery-male-base-Logistic-cv	0.6812	0.0522
67	Ret-Pot-Fishery-male-Logistic-mean-block-group-6-block-1	4.9325	0.0020
68	Ret-Pot-Fishery-male-Logistic-cv-block-group-6-block-1	0.7309	0.0960
69	Log-fbar-Pot-Fishery	-1.7448	0.0433
70	Log-fbar-Trawl-Bycatch	-4.4320	0.0744
71	Log-fbar-Bairdi-Fishery-Bycatch	-5.7238	0.3230
72	Log-fbar-Fixed-Gear	-6.5791	0.0670
73	Log-fdev-Pot-Fishery-year-1975-season-3	0.8291	0.0911
74	Log-fdev-Pot-Fishery-year-1976-season-3	0.8112	0.0721
75	Log-fdev-Pot-Fishery-year-1977-season-3	0.7534	0.0633
76	Log-fdev-Pot-Fishery-year-1978-season-3	0.8722	0.0560
77	Log-fdev-Pot-Fishery-year-1979-season-3	1.1080	0.0545
78	Log-fdev-Pot-Fishery-year-1980-season-3	1.9972	0.0587
79	Log-fdev-Pot-Fishery-year-1981-season-3	2.5127	0.1136
80	Log-fdev-Pot-Fishery-year-1982-season-3	0.9452	0.1489
81	Log-fdev-Pot-Fishery-year-1983-season-3	-8.6911	0.0996
82	Log-fdev-Pot-Fishery-year-1984-season-3	1.4776	0.0995
83	Log-fdev-Pot-Fishery-year-1985-season-3	1.5078	0.0908
84	Log-fdev-Pot-Fishery-year-1986-season-3	1.5905	0.0778
85	Log-fdev-Pot-Fishery-year-1987-season-3	1.0766	0.0667
86	Log-fdev-Pot-Fishery-year-1988-season-3	0.1086	0.0545
87	Log-fdev-Pot-Fishery-year-1989-season-3	0.2166	0.0484
88	Log-fdev-Pot-Fishery-year-1990-season-3	0.8605	0.0395
89	Log-fdev-Pot-Fishery-year-1991-season-3	0.8650	0.0425
90	Log-fdev-Pot-Fishery-year-1992-season-3	0.3489	0.0469
91	Log-fdev-Pot-Fishery-year-1993-season-3	1.0056	0.0510
92	Log-fdev-Pot-Fishery-year-1994-season-3	-4.1626	0.0485
93	Log-fdev-Pot-Fishery-year-1995-season-3	-4.5593	0.0420
94	Log-fdev-Pot-Fishery-year-1996-season-3	-0.0701	0.0405
95	Log-fdev-Pot-Fishery-year-1997-season-3	-0.0047	0.0408
96	Log-fdev-Pot-Fishery-year-1998-season-3	0.9118	0.0435
97	Log-fdev-Pot-Fishery-year-1999-season-3	0.5310	0.0430
98	Log-fdev-Pot-Fishery-year-2000-season-3	-0.0593	0.0414
99	Log-fdev-Pot-Fishery-year-2001-season-3	-0.1241	0.0408
100	Log-fdev-Pot-Fishery-year-2002-season-3	-0.0053	0.0396
101	Log-fdev-Pot-Fishery-year-2003-season-3	0.4548	0.0384
102	Log-fdev-Pot-Fishery-year-2004-season-3	0.4117	0.0385
103	Log-fdev-Pot-Fishery-year-2005-season-3	0.7032	0.0390

104	Log-fdev-Pot-Fishery-year-2006-season-3	0.4471	0.0384
105	Log-fdev-Pot-Fishery-year-2007-season-3	0.8121	0.0384
106	Log-fdev-Pot-Fishery-year-2008-season-3	0.9785	0.0405
107	Log-fdev-Pot-Fishery-year-2009-season-3	0.7781	0.0416
108	Log-fdev-Pot-Fishery-year-2010-season-3	0.6325	0.0412
109	Log-fdev-Pot-Fishery-year-2011-season-3	-0.0056	0.0396
110	Log-fdev-Pot-Fishery-year-2012-season-3	-0.0692	0.0382
111	Log-fdev-Pot-Fishery-year-2013-season-3	0.1308	0.0378
112	Log-fdev-Pot-Fishery-year-2014-season-3	0.4625	0.0379
113	Log-fdev-Pot-Fishery-year-2015-season-3	0.5315	0.0394
114	Log-fdev-Pot-Fishery-year-2016-season-3	0.5352	0.0431
115	Log-fdev-Pot-Fishery-year-2017-season-3	0.4599	0.0493
116	Log-fdev-Pot-Fishery-year-2018-season-3	0.2911	0.0566
117	Log-fdev-Pot-Fishery-year-2019-season-3	0.2485	0.0625
118	Log-fdev-Pot-Fishery-year-2020-season-3	-0.1804	0.0639
119	Log-fdev-Pot-Fishery-year-2021-season-3	-4.6266	0.0625
120	Log-fdev-Pot-Fishery-year-2022-season-3	-4.6838	0.0616
121	Log-fdev-Pot-Fishery-year-2023-season-3	-0.9648	0.0647
122	Log-fdev-Trawl-Bycatch-year-1976-season-5	0.2066	0.1130
123	Log-fdev-Trawl-Bycatch-year-1977-season-5	0.6718	0.1101
124	Log-fdev-Trawl-Bycatch-year-1978-season-5	0.6767	0.1084
125	Log-fdev-Trawl-Bycatch-year-1979-season-5	0.7745	0.1095
126	Log-fdev-Trawl-Bycatch-year-1980-season-5	1.5158	0.1131
127	Log-fdev-Trawl-Bycatch-year-1981-season-5	1.2770	0.1254
128	Log-fdev-Trawl-Bycatch-year-1982-season-5	2.5754	0.1217
129	Log-fdev-Trawl-Bycatch-year-1983-season-5	2.3370	0.1124
130	Log-fdev-Trawl-Bycatch-year-1984-season-5	3.6029	0.1121
131	Log-fdev-Trawl-Bycatch-year-1985-season-5	2.3886	0.1120
132	Log-fdev-Trawl-Bycatch-year-1986-season-5	1.2832	0.1125
133	Log-fdev-Trawl-Bycatch-year-1987-season-5	0.7928	0.1099
134	Log-fdev-Trawl-Bycatch-year-1988-season-5	1.5490	0.1053
135	Log-fdev-Trawl-Bycatch-year-1989-season-5	0.1087	0.1041
136	Log-fdev-Trawl-Bycatch-year-1990-season-5	0.5507	0.1042
137	Log-fdev-Trawl-Bycatch-year-1991-season-5	0.9636	0.1055
138	Log-fdev-Trawl-Bycatch-year-1992-season-5	0.8024	0.1057
139	Log-fdev-Trawl-Bycatch-year-1993-season-5	1.2647	0.1082
140	Log-fdev-Trawl-Bycatch-year-1994-season-5	-0.4959	0.1051
141	Log-fdev-Trawl-Bycatch-year-1995-season-5	-0.7738	0.1036
142	Log-fdev-Trawl-Bycatch-year-1996-season-5	-0.6968	0.1037
143	Log-fdev-Trawl-Bycatch-year-1997-season-5	-1.1479	0.1035
144	Log-fdev-Trawl-Bycatch-year-1998-season-5	0.1497	0.1041
145	Log-fdev-Trawl-Bycatch-year-1999-season-5	-0.1419	0.1039
146	Log-fdev-Trawl-Bycatch-year-2000-season-5	-0.9064	0.1033
147	Log-fdev-Trawl-Bycatch-year-2001-season-5	-0.1292	0.1031
148	Log-fdev-Trawl-Bycatch-year-2002-season-5	-0.4196	0.1028
149	Log-fdev-Trawl-Bycatch-year-2003-season-5	-0.5157	0.1026
150	Log-fdev-Trawl-Bycatch-year-2004-season-5	-0.2847	0.1025
151	Log-fdev-Trawl-Bycatch-year-2005-season-5	-0.5618	0.1024
152	Log-fdev-Trawl-Bycatch-year-2006-season-5	-0.3950	0.1021
153	Log-fdev-Trawl-Bycatch-year-2007-season-5	-0.3227	0.1023
154	Log-fdev-Trawl-Bycatch-year-2008-season-5	-0.3540	0.1026
155	Log-fdev-Trawl-Bycatch-year-2009-season-5	-0.7187	0.1028
156	Log-fdev-Trawl-Bycatch-year-2010-season-5	-0.8766	0.1027

157	Log-fdev-Trawl-Bycatch-year-2011-season-5	-1.3374	0.1023
158	Log-fdev-Trawl-Bycatch-year-2012-season-5	-1.8484	0.1023
159	Log-fdev-Trawl-Bycatch-year-2013-season-5	-1.1222	0.1023
160	Log-fdev-Trawl-Bycatch-year-2014-season-5	-1.6799	0.1024
161	Log-fdev-Trawl-Bycatch-year-2015-season-5	-1.2941	0.1029
162	Log-fdev-Trawl-Bycatch-year-2016-season-5	-0.7621	0.1040
163	Log-fdev-Trawl-Bycatch-year-2017-season-5	-0.3159	0.1056
164	Log-fdev-Trawl-Bycatch-year-2018-season-5	-0.3640	0.1072
165	Log-fdev-Trawl-Bycatch-year-2019-season-5	-0.3194	0.1091
166	Log-fdev-Trawl-Bycatch-year-2020-season-5	-0.3012	0.1103
167	Log-fdev-Trawl-Bycatch-year-2021-season-5	-1.2575	0.1103
168	Log-fdev-Trawl-Bycatch-year-2022-season-5	-2.2000	0.1113
169	Log-fdev-Trawl-Bycatch-year-2023-season-5	-1.9486	0.1141
170	Log-fdev-Bairdi-Fishery-Bycatch-year-1975-season-5	-0.1164	0.0682
171	Log-fdev-Bairdi-Fishery-Bycatch-year-1976-season-5	0.6698	0.0682
172	Log-fdev-Bairdi-Fishery-Bycatch-year-1977-season-5	1.2282	0.0682
173	Log-fdev-Bairdi-Fishery-Bycatch-year-1978-season-5	1.0926	0.0682
174	Log-fdev-Bairdi-Fishery-Bycatch-year-1979-season-5	1.3823	0.0682
175	Log-fdev-Bairdi-Fishery-Bycatch-year-1980-season-5	1.4242	0.0682
176	Log-fdev-Bairdi-Fishery-Bycatch-year-1981-season-5	0.9927	0.0682
177	Log-fdev-Bairdi-Fishery-Bycatch-year-1982-season-5	0.4764	0.0682
178	Log-fdev-Bairdi-Fishery-Bycatch-year-1983-season-5	-0.9874	0.0682
179	Log-fdev-Bairdi-Fishery-Bycatch-year-1984-season-5	-0.5787	0.0682
180	Log-fdev-Bairdi-Fishery-Bycatch-year-1987-season-5	-1.0994	0.0682
181	Log-fdev-Bairdi-Fishery-Bycatch-year-1988-season-5	-0.2563	0.0682
182	Log-fdev-Bairdi-Fishery-Bycatch-year-1989-season-5	0.9401	0.0682
183	Log-fdev-Bairdi-Fishery-Bycatch-year-1990-season-5	1.4182	0.0682
184	Log-fdev-Bairdi-Fishery-Bycatch-year-1991-season-5	3.2475	0.0748
185	Log-fdev-Bairdi-Fishery-Bycatch-year-1992-season-5	1.2810	0.1098
186	Log-fdev-Bairdi-Fishery-Bycatch-year-1993-season-5	0.5491	0.1228
187	Log-fdev-Bairdi-Fishery-Bycatch-year-1994-season-5	-0.7649	0.0868
188	Log-fdev-Bairdi-Fishery-Bycatch-year-2006-season-5	-2.1192	0.0736
189	Log-fdev-Bairdi-Fishery-Bycatch-year-2007-season-5	-2.9838	0.1014
190	Log-fdev-Bairdi-Fishery-Bycatch-year-2008-season-5	-2.4206	0.1160
191	Log-fdev-Bairdi-Fishery-Bycatch-year-2009-season-5	-3.5099	0.0743
192	Log-fdev-Bairdi-Fishery-Bycatch-year-2013-season-5	-0.8370	0.0962
193	Log-fdev-Bairdi-Fishery-Bycatch-year-2014-season-5	-0.1089	0.1217
194	Log-fdev-Bairdi-Fishery-Bycatch-year-2015-season-5	1.0801	0.1485
195	Log-fdev-Fixed-Gear-year-1996-season-5	0.5331	0.1031
196	Log-fdev-Fixed-Gear-year-1997-season-5	-0.1241	0.1024
197	Log-fdev-Fixed-Gear-year-1998-season-5	-0.3551	0.1030
198	Log-fdev-Fixed-Gear-year-1999-season-5	0.5595	0.1023
199	Log-fdev-Fixed-Gear-year-2000-season-5	-1.8612	0.1018
200	Log-fdev-Fixed-Gear-year-2001-season-5	0.1005	0.1013
201	Log-fdev-Fixed-Gear-year-2002-season-5	-0.1549	0.1009
202	Log-fdev-Fixed-Gear-year-2003-season-5	-0.9893	0.1008
203	Log-fdev-Fixed-Gear-year-2004-season-5	-0.8158	0.1006
204	Log-fdev-Fixed-Gear-year-2005-season-5	-0.5488	0.1005
205	Log-fdev-Fixed-Gear-year-2006-season-5	-0.5946	0.1003
206	Log-fdev-Fixed-Gear-year-2007-season-5	-0.0507	0.1003
207	Log-fdev-Fixed-Gear-year-2008-season-5	-0.7584	0.1006
208	Log-fdev-Fixed-Gear-year-2009-season-5	-1.7607	0.1004
209	Log-fdev-Fixed-Gear-year-2010-season-5	-2.5973	0.1000

210	Log-fdev-Fixed-Gear-year-2011-season-5	-1.1072	0.0997
211	Log-fdev-Fixed-Gear-year-2012-season-5	-0.5399	0.0995
212	Log-fdev-Fixed-Gear-year-2013-season-5	0.6075	0.0994
213	Log-fdev-Fixed-Gear-year-2014-season-5	1.4616	0.0995
214	Log-fdev-Fixed-Gear-year-2015-season-5	1.1504	0.0997
215	Log-fdev-Fixed-Gear-year-2016-season-5	0.2563	0.1003
216	Log-fdev-Fixed-Gear-year-2017-season-5	1.5368	0.1012
217	Log-fdev-Fixed-Gear-year-2018-season-5	1.9353	0.1020
218	Log-fdev-Fixed-Gear-year-2019-season-5	1.0857	0.1030
219	Log-fdev-Fixed-Gear-year-2020-season-5	0.0458	0.1041
220	Log-fdev-Fixed-Gear-year-2021-season-5	1.1623	0.1049
221	Log-fdev-Fixed-Gear-year-2022-season-5	1.1852	0.1064
222	Log-fdev-Fixed-Gear-year-2023-season-5	0.6381	0.1087
223	Log-foff-Pot-Fishery	-2.7511	0.0432
224	Log-foff-Bairdi-Fishery-Bycatch	-0.1263	0.4792
225	Log-fdov-Pot-Fishery-year-1990-season-3	1.9132	0.0842
226	Log-fdov-Pot-Fishery-year-1991-season-3	-0.7468	0.0834
227	Log-fdov-Pot-Fishery-year-1992-season-3	1.9242	0.0846
228	Log-fdov-Pot-Fishery-year-1993-season-3	1.7614	0.0859
229	Log-fdov-Pot-Fishery-year-1994-season-3	-0.4570	0.0845
230	Log-fdov-Pot-Fishery-year-1995-season-3	-0.2416	0.0823
231	Log-fdov-Pot-Fishery-year-1996-season-3	-3.7329	0.0813
232	Log-fdov-Pot-Fishery-year-1997-season-3	-0.3771	0.0822
233	Log-fdov-Pot-Fishery-year-1998-season-3	1.3868	0.0830
234	Log-fdov-Pot-Fishery-year-1999-season-3	-2.8327	0.0821
235	Log-fdov-Pot-Fishery-year-2000-season-3	1.1067	0.0812
236	Log-fdov-Pot-Fishery-year-2001-season-3	0.8230	0.0811
237	Log-fdov-Pot-Fishery-year-2002-season-3	-1.9308	0.0805
238	Log-fdov-Pot-Fishery-year-2003-season-3	1.1685	0.0804
239	Log-fdov-Pot-Fishery-year-2004-season-3	0.3760	0.0807
240	Log-fdov-Pot-Fishery-year-2005-season-3	0.8948	0.0803
241	Log-fdov-Pot-Fishery-year-2006-season-3	-1.2768	0.0796
242	Log-fdov-Pot-Fishery-year-2007-season-3	-0.2345	0.0796
243	Log-fdov-Pot-Fishery-year-2008-season-3	-0.4976	0.0801
244	Log-fdov-Pot-Fishery-year-2009-season-3	-0.7495	0.0802
245	Log-fdov-Pot-Fishery-year-2010-season-3	-0.2520	0.0799
246	Log-fdov-Pot-Fishery-year-2011-season-3	-1.1331	0.0790
247	Log-fdov-Pot-Fishery-year-2012-season-3	-1.8495	0.0785
248	Log-fdov-Pot-Fishery-year-2013-season-3	0.1635	0.0784
249	Log-fdov-Pot-Fishery-year-2014-season-3	-0.2430	0.0784
250	Log-fdov-Pot-Fishery-year-2015-season-3	0.8206	0.0787
251	Log-fdov-Pot-Fishery-year-2016-season-3	0.2715	0.0799
252	Log-fdov-Pot-Fishery-year-2017-season-3	-0.3878	0.0820
253	Log-fdov-Pot-Fishery-year-2018-season-3	0.9198	0.0848
254	Log-fdov-Pot-Fishery-year-2019-season-3	-0.1681	0.0870
255	Log-fdov-Pot-Fishery-year-2020-season-3	-0.6960	0.0871
256	Log-fdov-Pot-Fishery-year-2021-season-3	2.8927	0.0865
257	Log-fdov-Pot-Fishery-year-2022-season-3	1.2040	0.0868
258	Log-fdov-Pot-Fishery-year-2023-season-3	0.1760	0.0886
259	Log-fdov-Bairdi-Fishery-Bycatch-year-1975-season-5	-0.0000	0.0962
260	Log-fdov-Bairdi-Fishery-Bycatch-year-1976-season-5	0.0001	0.0962
261	Log-fdov-Bairdi-Fishery-Bycatch-year-1977-season-5	0.0004	0.0962
262	Log-fdov-Bairdi-Fishery-Bycatch-year-1978-season-5	0.0003	0.0963

263	Log-fdov-Bairdi-Fishery-Bycatch-year-1979-season-5	0.0004	0.0963
264	Log-fdov-Bairdi-Fishery-Bycatch-year-1980-season-5	0.0001	0.0963
265	Log-fdov-Bairdi-Fishery-Bycatch-year-1981-season-5	-0.0001	0.0963
266	Log-fdov-Bairdi-Fishery-Bycatch-year-1982-season-5	-0.0001	0.0962
267	Log-fdov-Bairdi-Fishery-Bycatch-year-1983-season-5	-0.0001	0.0962
268	Log-fdov-Bairdi-Fishery-Bycatch-year-1984-season-5	-0.0001	0.0962
269	Log-fdov-Bairdi-Fishery-Bycatch-year-1987-season-5	-0.0001	0.0962
270	Log-fdov-Bairdi-Fishery-Bycatch-year-1988-season-5	0.0000	0.0962
271	Log-fdov-Bairdi-Fishery-Bycatch-year-1989-season-5	0.0002	0.0962
272	Log-fdov-Bairdi-Fishery-Bycatch-year-1990-season-5	0.0006	0.0963
273	Log-fdov-Bairdi-Fishery-Bycatch-year-1991-season-5	1.4968	0.1590
274	Log-fdov-Bairdi-Fishery-Bycatch-year-1992-season-5	1.7860	0.1309
275	Log-fdov-Bairdi-Fishery-Bycatch-year-1993-season-5	0.5927	0.1444
276	Log-fdov-Bairdi-Fishery-Bycatch-year-1994-season-5	-3.4424	0.1118
277	Log-fdov-Bairdi-Fishery-Bycatch-year-2006-season-5	-2.1776	0.1696
278	Log-fdov-Bairdi-Fishery-Bycatch-year-2007-season-5	-0.8008	0.1323
279	Log-fdov-Bairdi-Fishery-Bycatch-year-2008-season-5	0.0419	0.1353
280	Log-fdov-Bairdi-Fishery-Bycatch-year-2009-season-5	0.3996	0.1017
281	Log-fdov-Bairdi-Fishery-Bycatch-year-2013-season-5	0.9818	0.1731
282	Log-fdov-Bairdi-Fishery-Bycatch-year-2014-season-5	0.1983	0.1586
283	Log-fdov-Bairdi-Fishery-Bycatch-year-2015-season-5	0.9221	0.1832
284	Rec-dev-est-1975	0.9497	0.2813
285	Rec-dev-est-1976	0.5358	0.3070
286	Rec-dev-est-1977	0.9807	0.2418
287	Rec-dev-est-1978	1.5890	0.2051
288	Rec-dev-est-1979	1.8727	0.2136
289	Rec-dev-est-1980	1.0556	0.2596
290	Rec-dev-est-1981	2.4102	0.1607
291	Rec-dev-est-1982	1.4390	0.1765
292	Rec-dev-est-1983	1.0491	0.1621
293	Rec-dev-est-1984	-0.7601	0.2429
294	Rec-dev-est-1985	0.2986	0.1594
295	Rec-dev-est-1986	-0.8090	0.2353
296	Rec-dev-est-1987	-1.2476	0.2685
297	Rec-dev-est-1988	-1.0192	0.2226
298	Rec-dev-est-1989	-0.0666	0.1602
299	Rec-dev-est-1990	-0.4740	0.1786
300	Rec-dev-est-1991	-1.8891	0.3396
301	Rec-dev-est-1992	-0.8834	0.1922
302	Rec-dev-est-1993	-2.0776	0.3957
303	Rec-dev-est-1994	0.9585	0.1423
304	Rec-dev-est-1995	-0.8147	0.2459
305	Rec-dev-est-1996	-1.5839	0.3354
306	Rec-dev-est-1997	-0.6083	0.1994
307	Rec-dev-est-1998	0.4175	0.1516
308	Rec-dev-est-1999	-0.5173	0.2170
309	Rec-dev-est-2000	-0.6462	0.2562
310	Rec-dev-est-2001	0.8558	0.1500
311	Rec-dev-est-2002	-0.6199	0.2605
312	Rec-dev-est-2003	-0.7056	0.2631
313	Rec-dev-est-2004	0.5412	0.1533
314	Rec-dev-est-2005	-0.1004	0.1752
315	Rec-dev-est-2006	-0.5278	0.1846

316	Rec-dev-est-2007	-1.0785	0.2277
317	Rec-dev-est-2008	-0.9567	0.2296
318	Rec-dev-est-2009	-0.0624	0.1767
319	Rec-dev-est-2010	-0.5127	0.2149
320	Rec-dev-est-2011	-1.1071	0.2262
321	Rec-dev-est-2012	-1.4160	0.2170
322	Rec-dev-est-2013	-1.9148	0.2610
323	Rec-dev-est-2014	-1.4566	0.2194
324	Rec-dev-est-2015	-0.7934	0.1675
325	Rec-dev-est-2016	-1.5628	0.2370
326	Rec-dev-est-2017	-0.8782	0.1830
327	Rec-dev-est-2018	-1.5226	0.2568
328	Rec-dev-est-2019	-1.3563	0.2284
329	Rec-dev-est-2020	-1.5720	0.2557
330	Rec-dev-est-2021	-0.7401	0.1929
331	Rec-dev-est-2022	-1.0418	0.2424
332	Rec-dev-est-2023	-1.6731	0.3831
333	Logit-rec-prop-est-1975	0.0219	0.4782
334	Logit-rec-prop-est-1976	-0.8408	0.5544
335	Logit-rec-prop-est-1977	-0.1410	0.3670
336	Logit-rec-prop-est-1978	-0.3072	0.2596
337	Logit-rec-prop-est-1979	0.2635	0.2592
338	Logit-rec-prop-est-1980	0.4249	0.3519
339	Logit-rec-prop-est-1981	0.5009	0.1412
340	Logit-rec-prop-est-1982	0.6220	0.2461
341	Logit-rec-prop-est-1983	0.0873	0.1787
342	Logit-rec-prop-est-1984	0.4199	0.4544
343	Logit-rec-prop-est-1985	-0.4480	0.1702
344	Logit-rec-prop-est-1986	0.2359	0.4215
345	Logit-rec-prop-est-1987	-0.1867	0.4795
346	Logit-rec-prop-est-1988	0.3718	0.3981
347	Logit-rec-prop-est-1989	-0.0699	0.1711
348	Logit-rec-prop-est-1990	0.1901	0.2460
349	Logit-rec-prop-est-1991	0.6100	0.7630
350	Logit-rec-prop-est-1992	0.3320	0.3035
351	Logit-rec-prop-est-1993	-1.4208	1.0287
352	Logit-rec-prop-est-1994	-0.3183	0.0901
353	Logit-rec-prop-est-1995	1.4035	0.7010
354	Logit-rec-prop-est-1996	0.1871	0.6880
355	Logit-rec-prop-est-1997	0.5174	0.3482
356	Logit-rec-prop-est-1998	-0.0810	0.1424
357	Logit-rec-prop-est-1999	0.3086	0.3700
358	Logit-rec-prop-est-2000	-0.7370	0.4679
359	Logit-rec-prop-est-2001	-0.4782	0.1276
360	Logit-rec-prop-est-2002	-0.4437	0.4507
361	Logit-rec-prop-est-2003	-0.0821	0.4600
362	Logit-rec-prop-est-2004	-0.3935	0.1461
363	Logit-rec-prop-est-2005	-0.1050	0.2284
364	Logit-rec-prop-est-2006	0.4459	0.2860
365	Logit-rec-prop-est-2007	-0.1131	0.3754
366	Logit-rec-prop-est-2008	-0.5394	0.3772
367	Logit-rec-prop-est-2009	-0.6928	0.2087
368	Logit-rec-prop-est-2010	-0.4225	0.3102

369	Logit-rec-prop-est-2011	-0.5800	0.3689
370	Logit-rec-prop-est-2012	-0.1476	0.3530
371	Logit-rec-prop-est-2013	-0.4805	0.4820
372	Logit-rec-prop-est-2014	-0.4164	0.3472
373	Logit-rec-prop-est-2015	0.2485	0.2109
374	Logit-rec-prop-est-2016	0.4155	0.4370
375	Logit-rec-prop-est-2017	0.6367	0.2840
376	Logit-rec-prop-est-2018	-0.2032	0.4629
377	Logit-rec-prop-est-2019	0.5099	0.4202
378	Logit-rec-prop-est-2020	0.4181	0.4763
379	Logit-rec-prop-est-2021	0.0709	0.2602
380	Logit-rec-prop-est-2022	0.0182	0.3918
381	Logit-rec-prop-est-2023	0.3879	0.7792
382	Survey-q-survey-1	0.9302	0.0258
383	Log-add-cvt-survey-2	-1.0018	0.2872

Table 19: 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 23.0a during 1975-2022. 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	60.929	30.558	86.720	8.720	65.170		247.790	199.640
1976	71.222	38.252	102.709	8.333	97.010	83.620	288.460	327.610
1977	79.045	44.229	116.635	7.237	128.669	54.040	309.730	371.220
1978	84.281	49.611	123.117	5.806	131.745	82.124	311.350	343.190
1979	73.792	50.339	102.942	4.159	124.035	151.300	298.270	165.450
1980	54.498	40.179	27.221	1.426	125.099	202.591	284.010	247.230
1981	15.636	8.432	5.913	0.816	57.107	91.045	114.880	131.140
1982	7.391	2.305	5.592	0.615	25.886	343.312	65.190	141.900
1983	6.320	2.179	5.849	0.453	17.870	130.251	57.440	48.480
1984	6.507	2.142	4.155	0.344	18.054	88.515	49.780	152.610
1985	7.914	1.841	9.325	0.664	12.538	14.549	33.620	34.140
1986	12.983	4.748	15.058	1.043	17.253	41.966	44.950	47.430
1987	15.749	7.061	21.081	1.310	21.552	13.826	51.680	69.240
1988	16.020	9.141	26.074	1.392	27.116	8.935	55.910	54.600
1989	17.292	10.544	29.155	1.356	25.302	11.250	58.930	55.140
1990	16.585	11.301	25.343	1.282	22.414	29.218	58.960	59.450
1991	12.722	9.411	19.471	1.188	21.758	19.418	54.000	83.890
1992	10.399	7.054	18.196	1.147	23.462	4.694	49.720	37.330
1993	11.997	6.771	17.337	1.249	21.830	12.878	49.610	52.910
1994	12.086	6.877	23.413	1.379	18.444	3.927	45.440	32.100
1995	12.371	8.852	26.182	1.350	16.981	81.540	51.130	38.070
1996	12.378	9.330	24.242	1.258	25.366	13.683	59.750	43.960
1997	11.681	8.357	22.649	1.214	37.013	6.376	65.910	84.030
1998	17.802	8.327	26.271	1.507	31.876	16.999	70.170	84.100
1999	19.117	10.744	30.441	1.687	26.659	47.353	69.270	64.750
2000	16.338	11.764	30.255	1.641	28.554	18.478	70.920	67.380
2001	16.110	11.062	30.418	1.583	32.649	16.402	74.440	52.460
2002	19.387	11.254	34.711	1.631	31.302	73.347	79.450	69.090
2003	20.185	13.091	34.315	1.597	38.845	16.687	85.410	115.760
2004	18.044	12.611	31.505	1.491	48.483	15.396	87.180	130.560
2005	20.393	11.709	32.542	1.496	44.346	53.589	88.270	105.730
2006	19.284	12.530	32.772	1.454	44.458	28.139	88.090	94.480
2007	17.251	12.126	27.562	1.352	49.233	18.332	89.620	103.330
2008	17.901	10.346	26.599	1.411	45.856	10.547	86.370	113.080
2009	17.999	10.485	27.896	1.491	39.524	11.956	80.780	90.550
2010	16.876	10.878	27.425	1.459	34.297	29.278	75.720	80.500
2011	14.285	10.338	26.829	1.347	33.700	18.573	70.880	66.410
2012	12.575	9.584	24.758	1.211	35.718	10.271	68.680	60.700
2013	12.452	8.636	23.503	1.121	33.718	7.530	65.500	62.220
2014	12.129	8.311	21.459	1.046	29.530	4.587	60.310	113.140
2015	10.311	7.598	18.210	0.962	24.933	7.270	53.070	64.170
2016	8.268	6.339	14.860	0.893	21.092	14.084	45.920	60.960
2017	6.439	5.074	11.919	0.833	19.204	6.515	40.510	52.930
2018	5.571	4.015	10.443	0.807	17.637	12.875	37.240	28.800
2019	6.383	3.687	11.261	0.892	15.610	6.751	35.720	28.540
2020	6.991	4.214	12.809	1.007	14.494	7.974		

2021	8.062	4.839	16.179	1.149	13.305	6.458	35.030	28.480
2022	8.636	5.999	18.329	1.240	12.009	14.810	36.180	36.200
2023	8.868	6.499	18.654	1.304	11.906	10.936	37.510	37.970
2024	8.844	6.454	15.425	0.912	13.038	5.806	37.930	46.130

Table 20: 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 1975-2022. 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	60.929	30.558	96.837	6.724	65.170		262.090	199.640
1976	71.222	38.252	112.285	6.282	97.010	79.984	301.210	327.610
1977	79.045	44.229	124.290	5.497	128.669	52.872	319.710	371.220
1978	84.281	49.611	128.542	4.708	131.745	82.503	318.060	343.190
1979	73.792	50.339	105.586	3.891	124.035	151.587	302.240	165.450
1980	54.498	40.179	27.302	1.445	125.099	201.308	286.370	247.230
1981	15.636	8.432	5.978	0.833	57.107	88.918	115.310	131.140
1982	7.391	2.305	5.619	0.624	25.886	344.580	65.260	141.900
1983	6.320	2.179	5.799	0.451	17.870	130.462	57.390	48.480
1984	6.507	2.142	4.081	0.335	18.054	88.341	49.620	152.610
1985	7.914	1.841	9.173	0.646	12.538	14.469	33.400	34.140
1986	12.983	4.748	14.823	1.017	17.253	41.708	44.680	47.430
1987	15.749	7.061	20.797	1.282	21.552	13.778	51.380	69.240
1988	16.020	9.141	25.793	1.365	27.116	8.887	55.600	54.600
1989	17.292	10.544	28.897	1.332	25.302	11.167	58.640	55.140
1990	16.585	11.301	25.119	1.261	22.414	28.949	58.670	59.450
1991	12.722	9.411	19.276	1.169	21.758	19.261	53.700	83.890
1992	10.399	7.054	18.015	1.128	23.462	4.679	49.420	37.330
1993	11.997	6.771	17.139	1.230	21.830	12.791	49.300	52.910
1994	12.086	6.877	23.192	1.359	18.444	3.875	45.130	32.100
1995	12.371	8.852	25.973	1.331	16.981	80.693	50.810	38.070
1996	12.378	9.330	24.045	1.240	25.366	13.701	59.390	43.960
1997	11.681	8.357	22.466	1.198	37.013	6.348	65.530	84.030
1998	17.802	8.327	25.991	1.482	31.876	16.840	69.770	84.100
1999	19.117	10.744	30.126	1.660	26.659	46.977	68.860	64.750
2000	16.338	11.764	29.965	1.617	28.554	18.445	70.510	67.380
2001	16.110	11.062	30.144	1.560	32.649	16.215	74.020	52.460
2002	19.387	11.254	34.417	1.607	31.302	72.811	79.030	69.090
2003	20.185	13.091	34.035	1.575	38.845	16.646	84.990	115.760
2004	18.044	12.611	31.248	1.470	48.483	15.279	86.780	130.560
2005	20.393	11.709	32.269	1.475	44.346	53.162	87.870	105.730
2006	19.284	12.530	32.514	1.434	44.458	27.987	87.700	94.480
2007	17.251	12.126	27.329	1.333	49.233	18.253	89.230	103.330
2008	17.901	10.346	26.342	1.391	45.856	10.524	85.990	113.080
2009	17.999	10.485	27.629	1.471	39.524	11.886	80.420	90.550
2010	16.876	10.878	27.177	1.440	34.297	29.071	75.380	80.500
2011	14.285	10.338	26.616	1.330	33.700	18.530	70.570	66.410
2012	12.575	9.584	24.574	1.197	35.718	10.227	68.400	60.700
2013	12.452	8.636	23.333	1.108	33.718	7.509	65.240	62.220
2014	12.129	8.311	21.316	1.035	29.530	4.560	60.100	113.140
2015	10.311	7.598	18.097	0.954	24.933	7.210	52.890	64.170
2016	8.268	6.339	14.770	0.887	21.092	13.995	45.760	60.960
2017	6.439	5.074	11.842	0.828	19.204	6.484	40.360	52.930
2018	5.571	4.015	10.371	0.802	17.637	12.857	37.110	28.800
2019	6.383	3.687	11.183	0.887	15.610	6.750	35.610	28.540
2020	6.991	4.214	12.737	1.002	14.494	7.971		

2021	8.062	4.839	16.125	1.146	13.305	6.424	34.970	28.480
2022	8.636	5.999	18.302	1.239	12.009	14.761	36.150	36.200
2023	8.868	6.499	18.649	1.304	11.906	10.917	37.500	37.970
2024	8.844	6.454	15.427	0.912	13.038	5.807	37.930	46.130

Figures

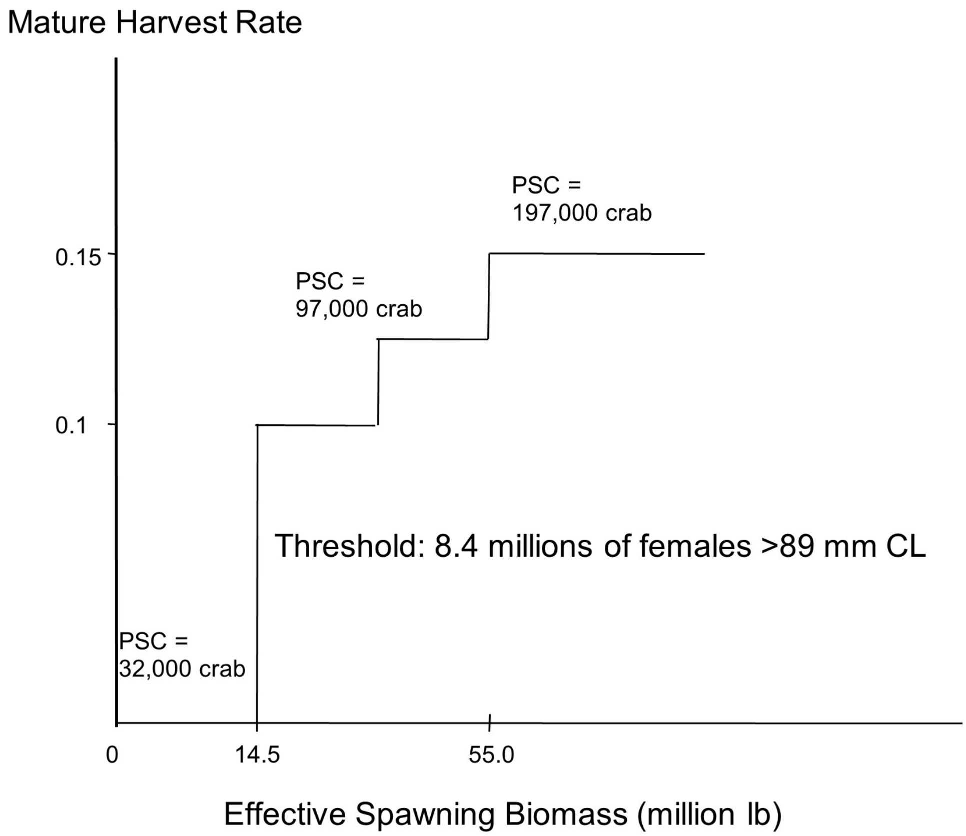

Figure 1: Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and the associated annual prohibited species catch (PSC) limits (numbers of crab) of Bristol Bay red king crab in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of effective spawning biomass (ESB, Zheng et al. 1995b), whereas PSC limits apply to previous-year ESB (Effective Spawning Biomass).

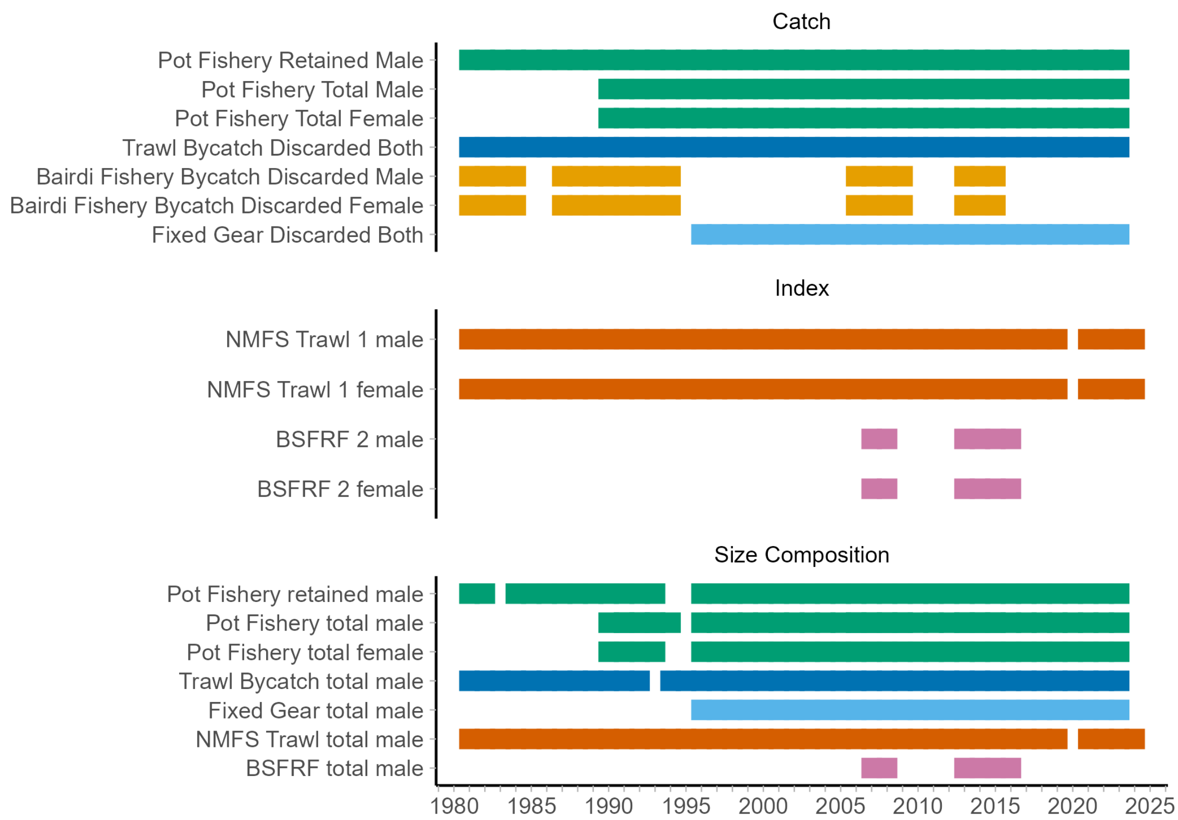

Figure 2: Data types and ranges used for the BBRKC stock assessment.

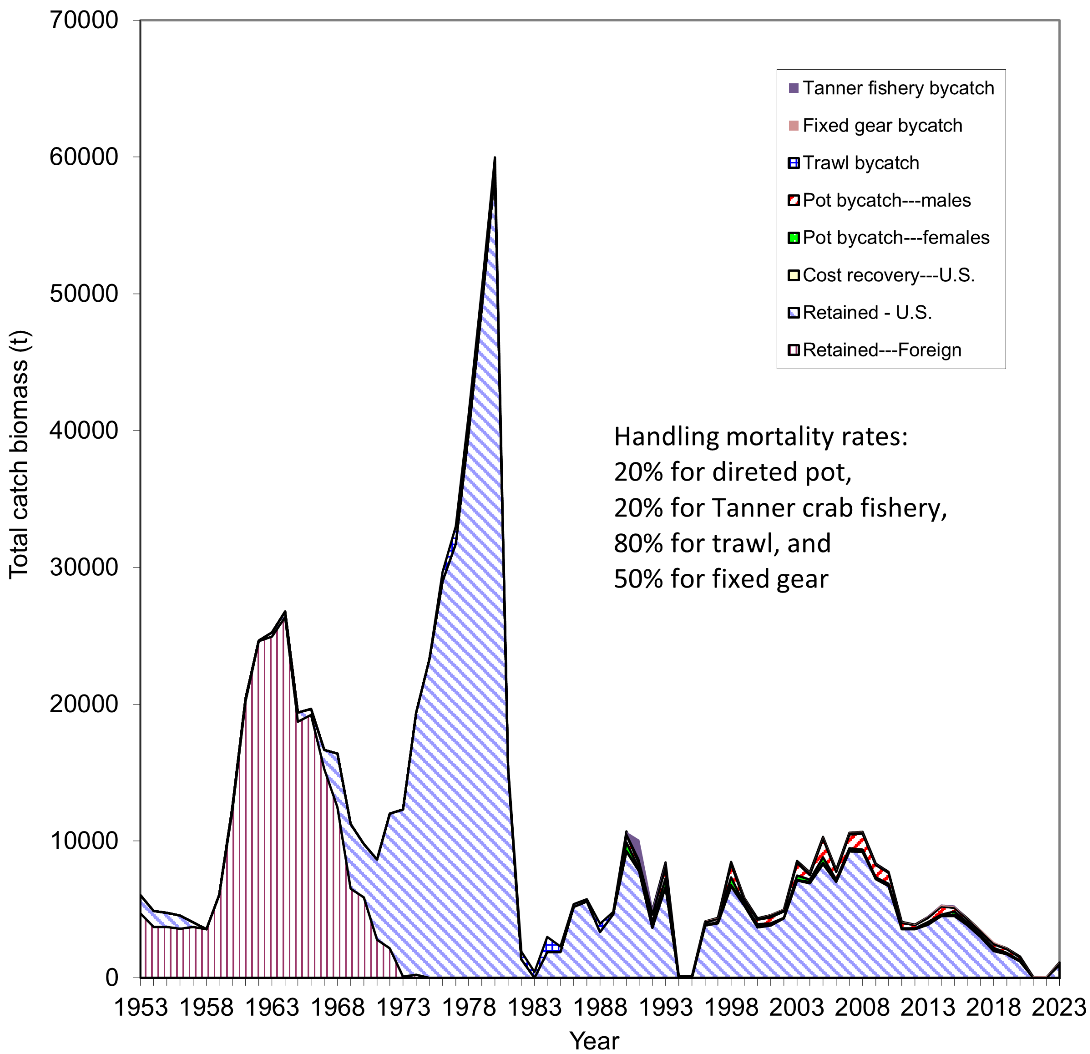

Figure 3: Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1953 to 2022. Directed pot bycatch data were not available from the observer program before 1990 and are not included in this figure.

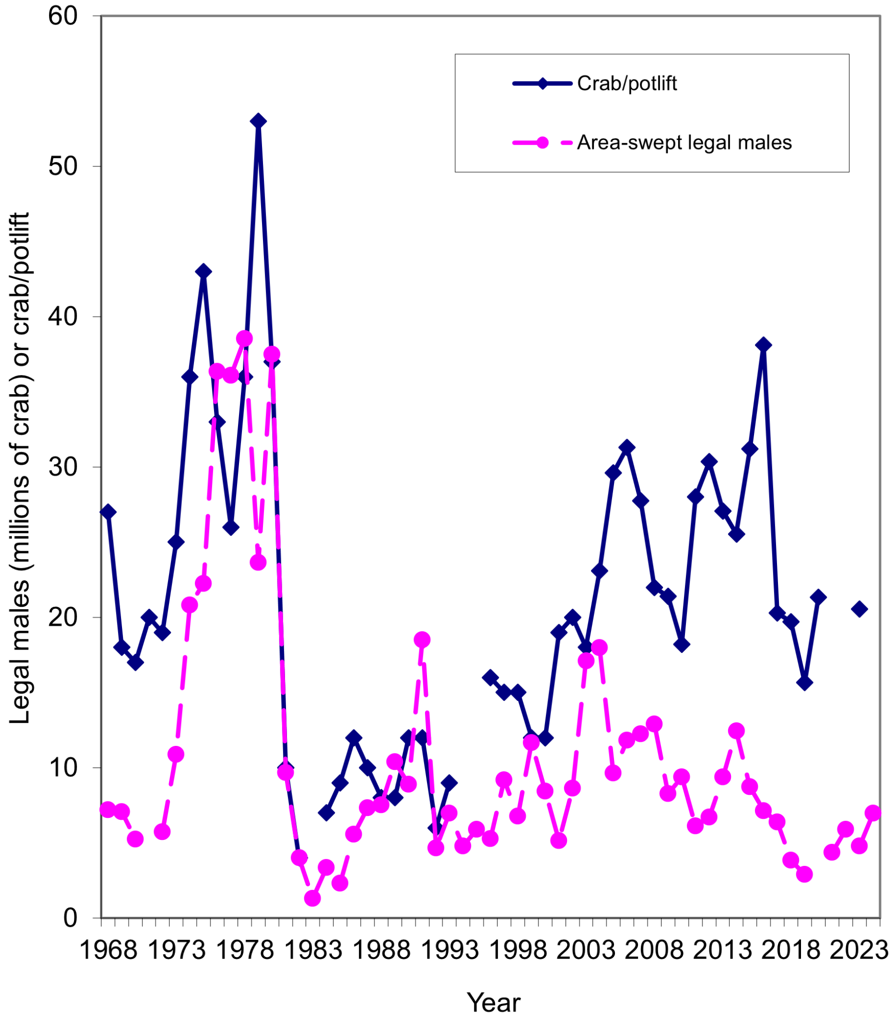

Figure 4: Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2024.

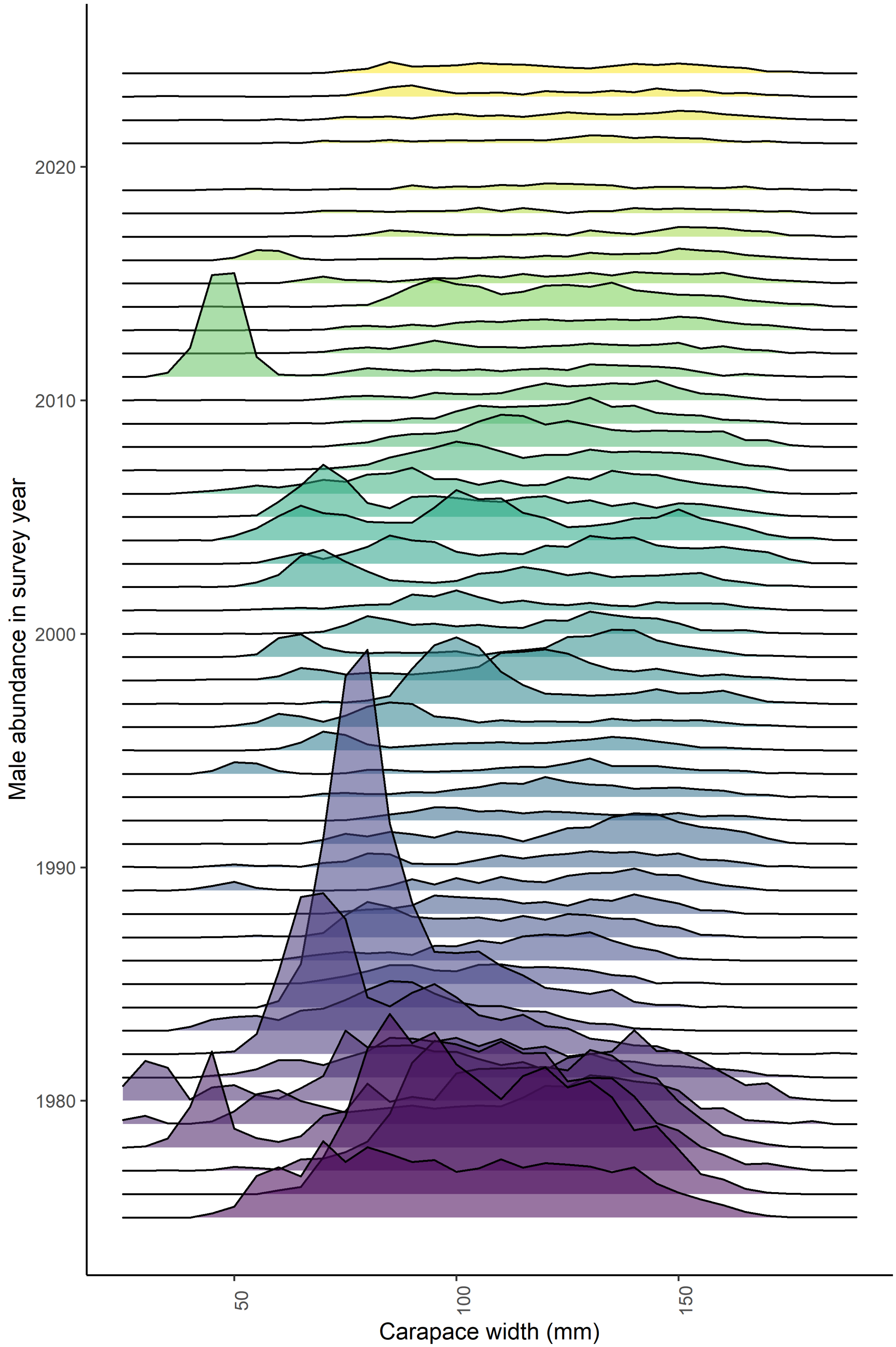

Figure 5: Survey abundances by 5-mm carapace length bin for male Bristol Bay red king crab from 1975 to 2024.

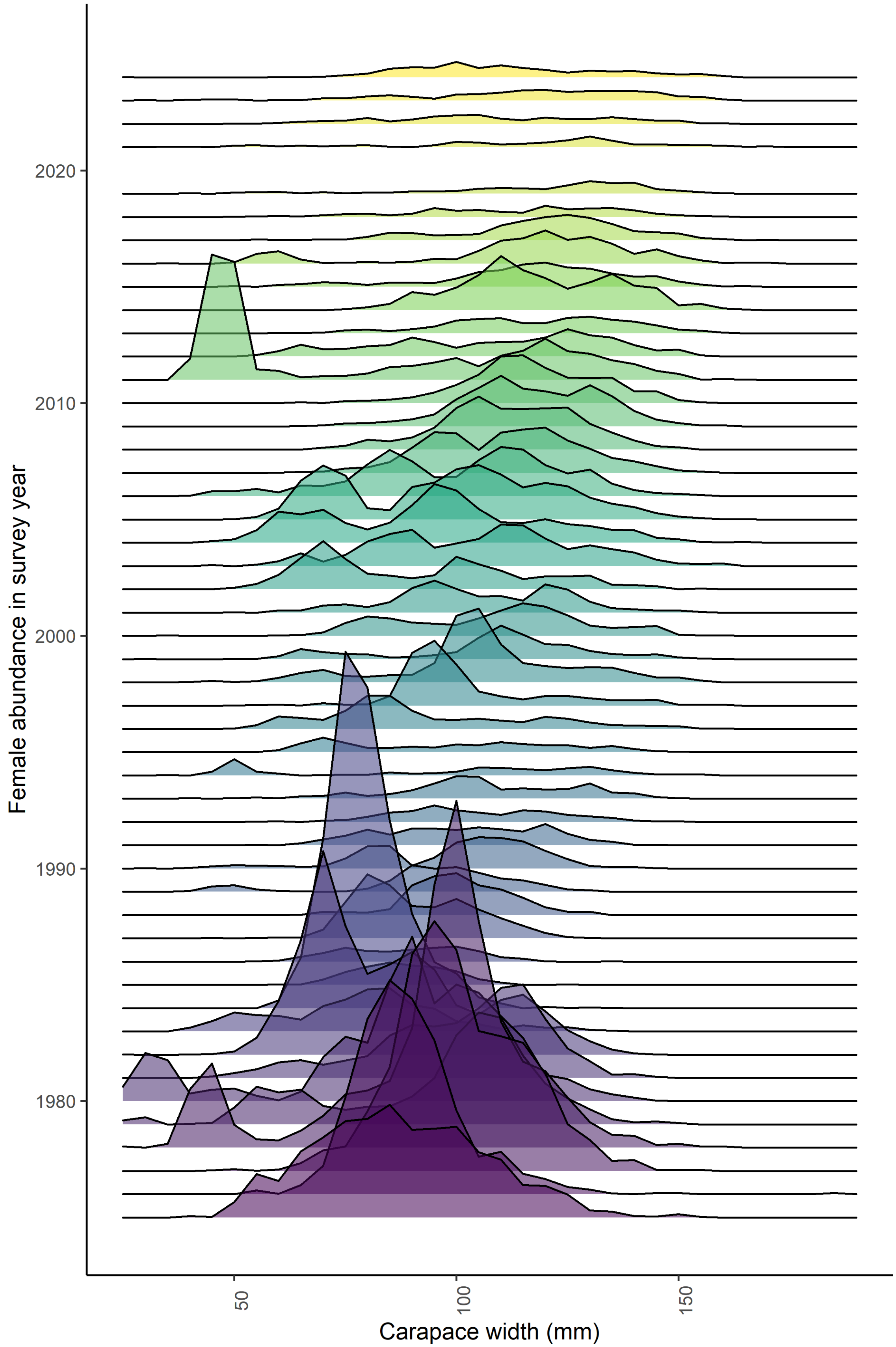

Figure 6: Survey abundances by 5-mm carapace length bin for female Bristol Bay red king crab from 1975 to 2024.

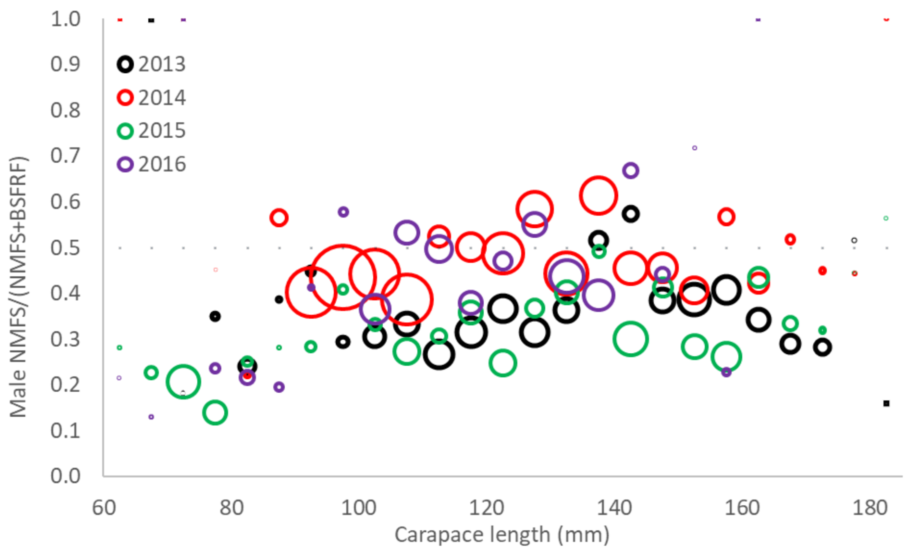

Figure 7: Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for male Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

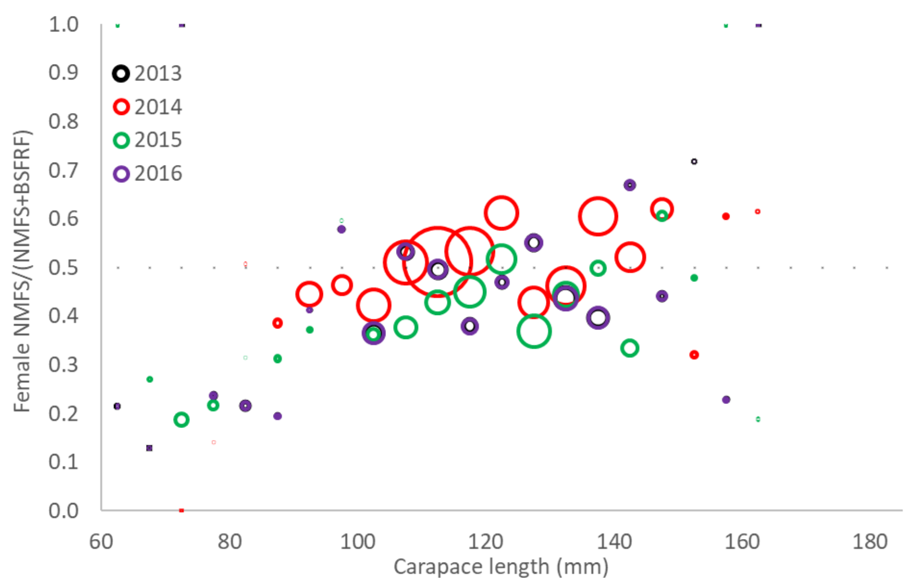

Figure 8: Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for female Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

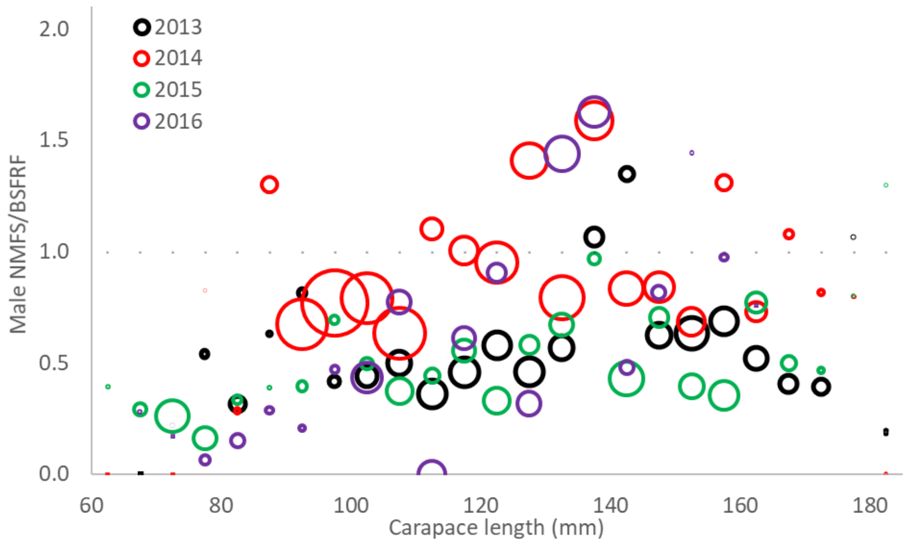

Figure 9: Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for male Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

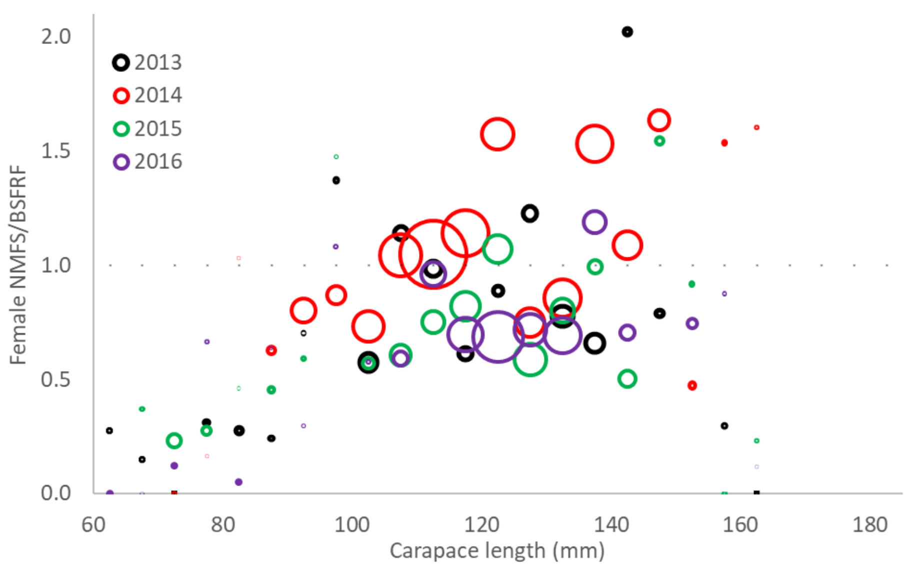

Figure 10: Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for female Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

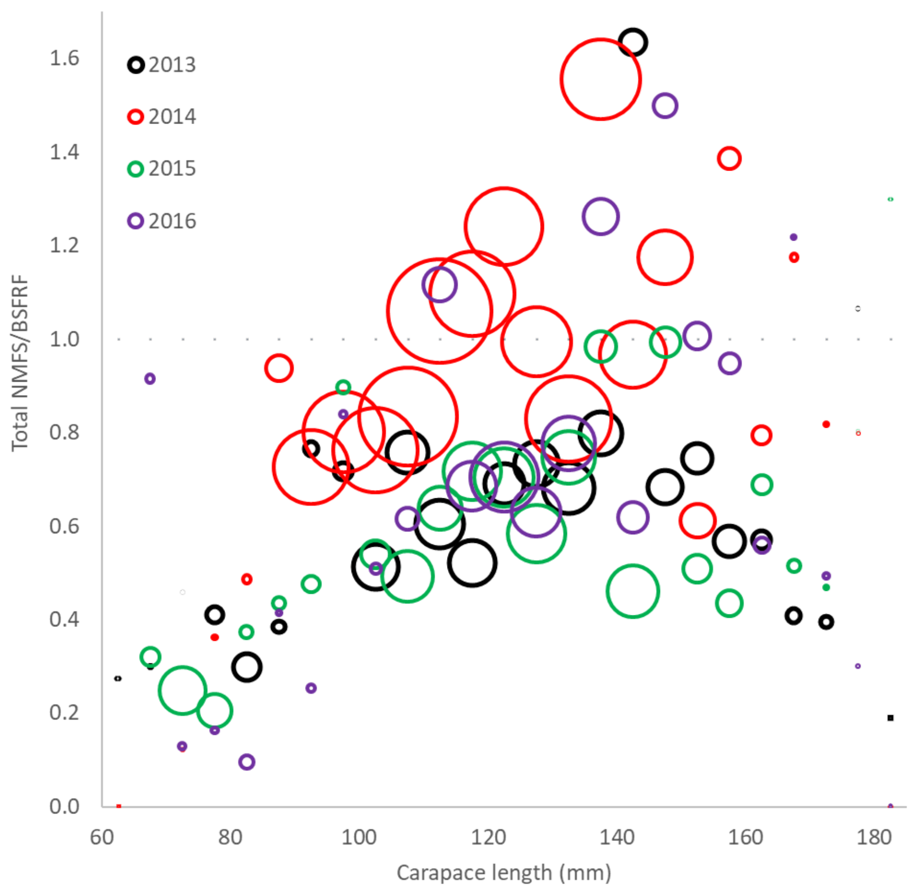

Figure 11: Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for male Bristol Bay red king crab. Sizes of circles are proportional to total abundances. The abundance-weighted average ratio is 0.891 for crab =135 mm carapace length from all four years of data. The approach to compute this overall ratio is documented in section D. Data, 4. Bering Sea Fisheries Research Foundation Survey Data.

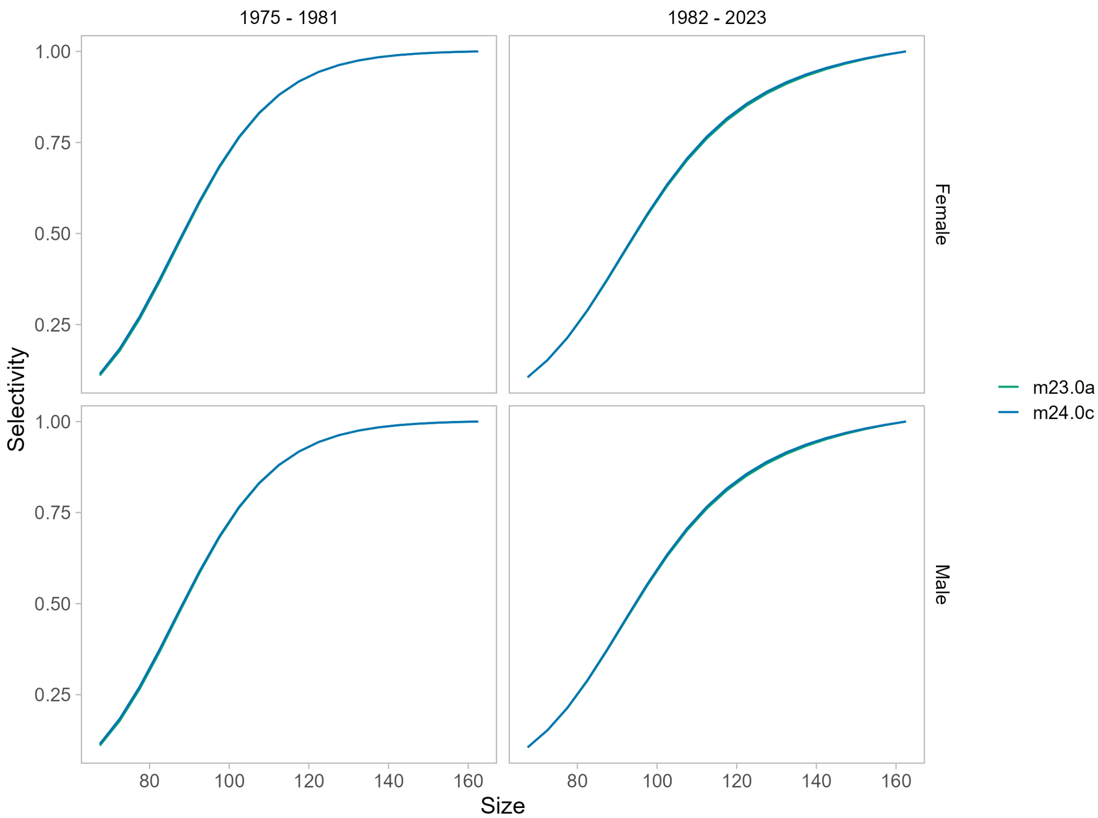

Figure 12: Estimated NMFS trawl survey selectivities under models 23.0a and 24.0c.

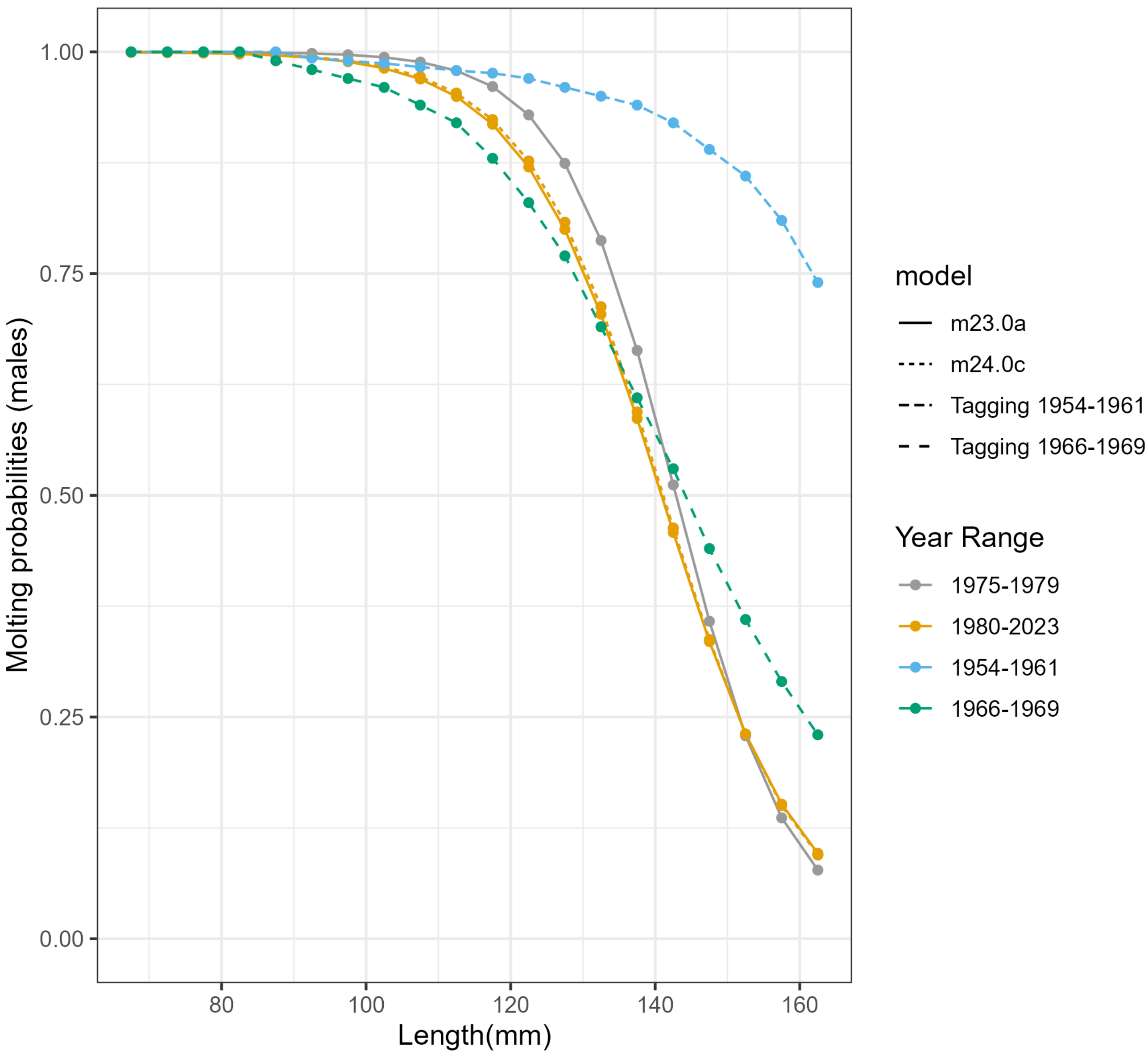

Figure 13: Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with models 23.0a and 24.0c, the 1980 to 2023 molt probability for model 24.0c reflects the entire time series from 1975 to 2023. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2024 were estimated with a length-based model.

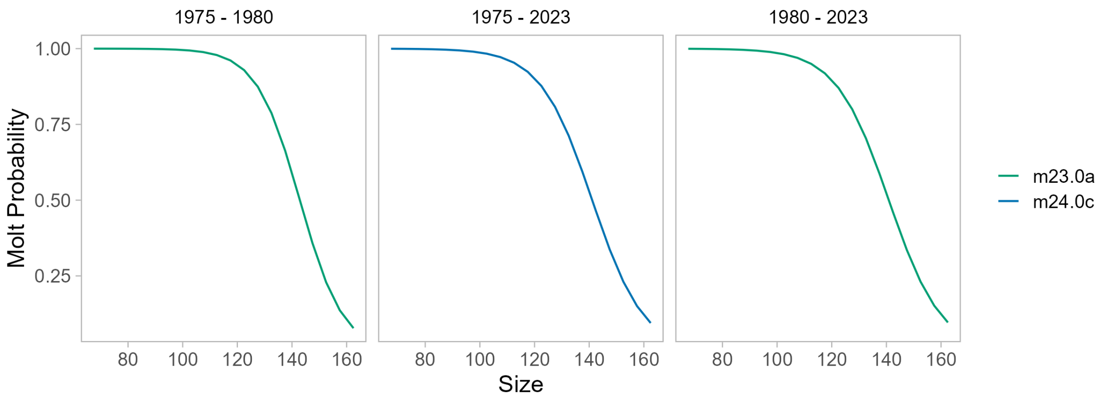

Figure 14: Comparison of estimated probabilities of molting of male red king crab in Bristol Bay with models 23.0a and 24.0c. Molting probability for 1975-1979, 1980-2023 reflect the historic time block for molt proability. The first panel should read 1975 - 1979.

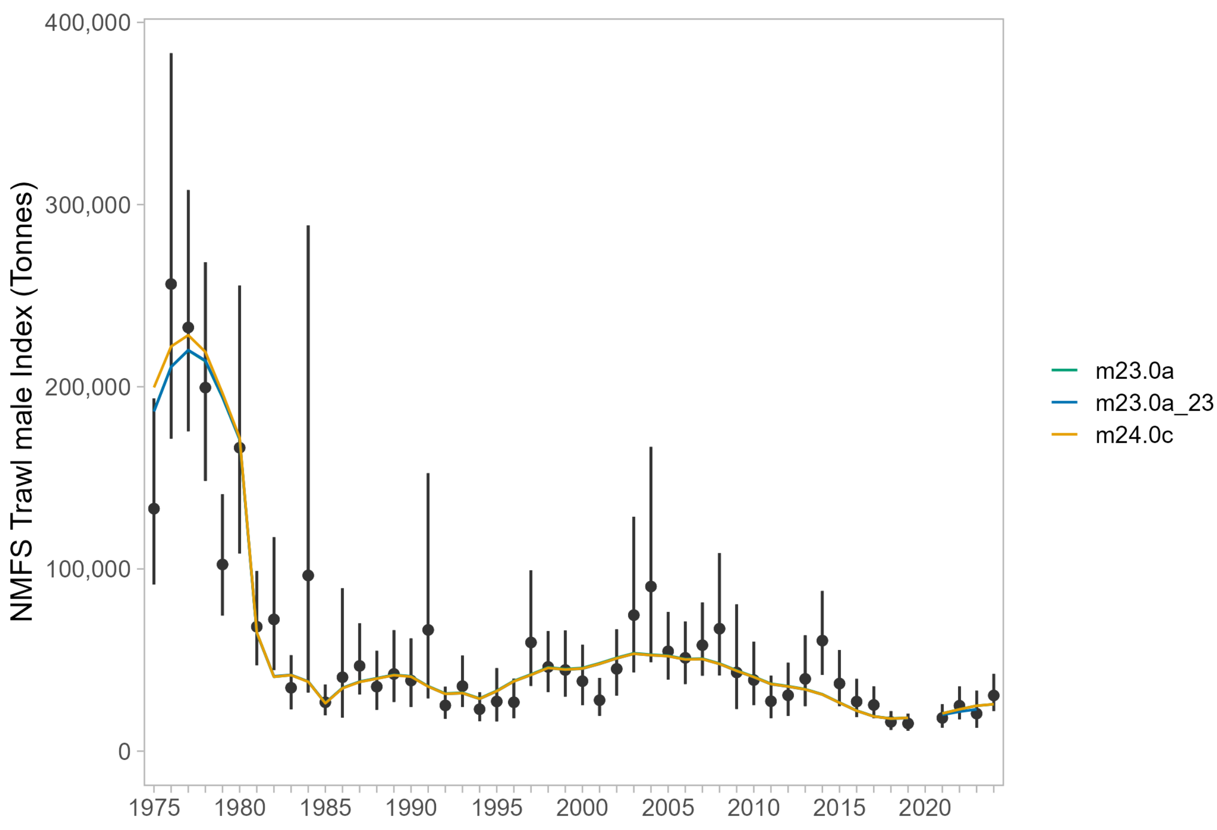

Figure 15: Comparisons of area-swept estimates of total male NMFS survey biomass and model prediction for model estimates in 2024 under models 23.0a and 24.0c; also included is model 23.0a from 2023 for reference. The error bars are plus and minus 2 standard deviations.

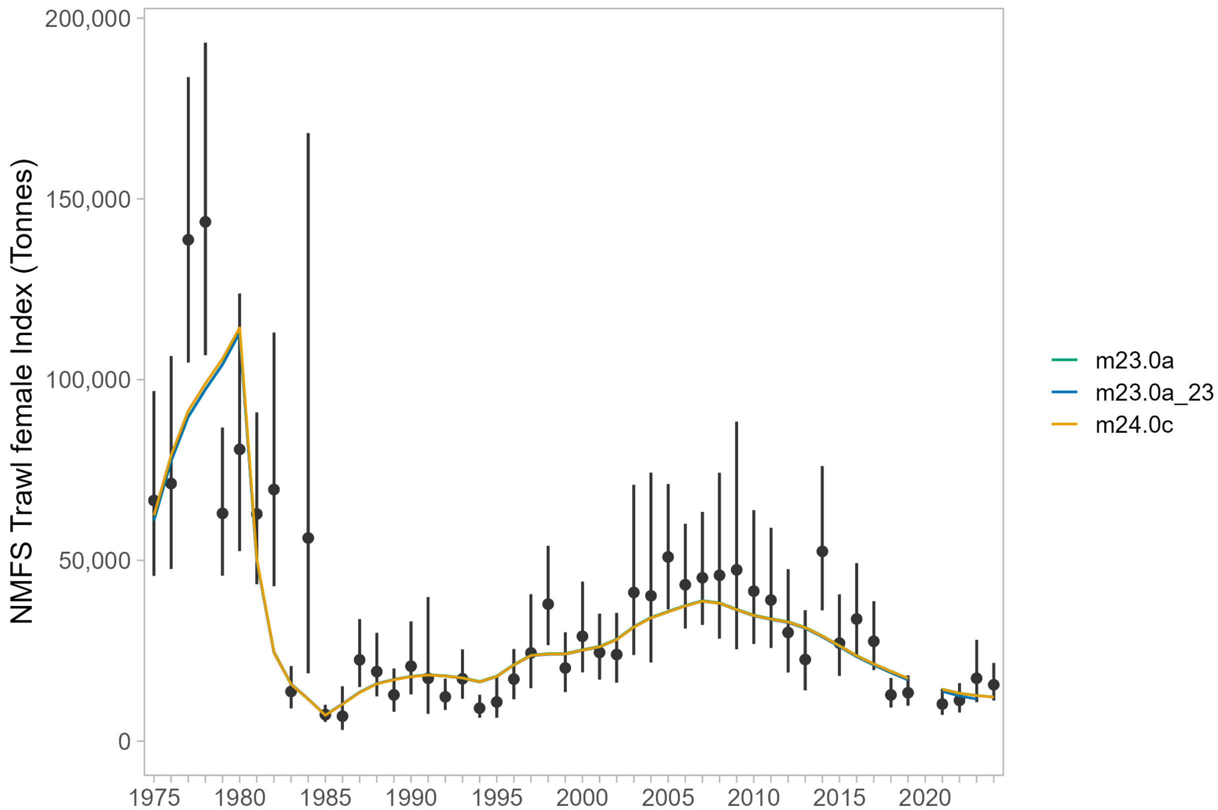

Figure 16: Comparisons of area-swept estimates of total female NMFS survey biomass and model prediction for model estimates in 2024 under models 23.0a and 24.0c; also included is model 23.0a from 2023 for reference. The error bars are plus and minus 2 standard deviations.

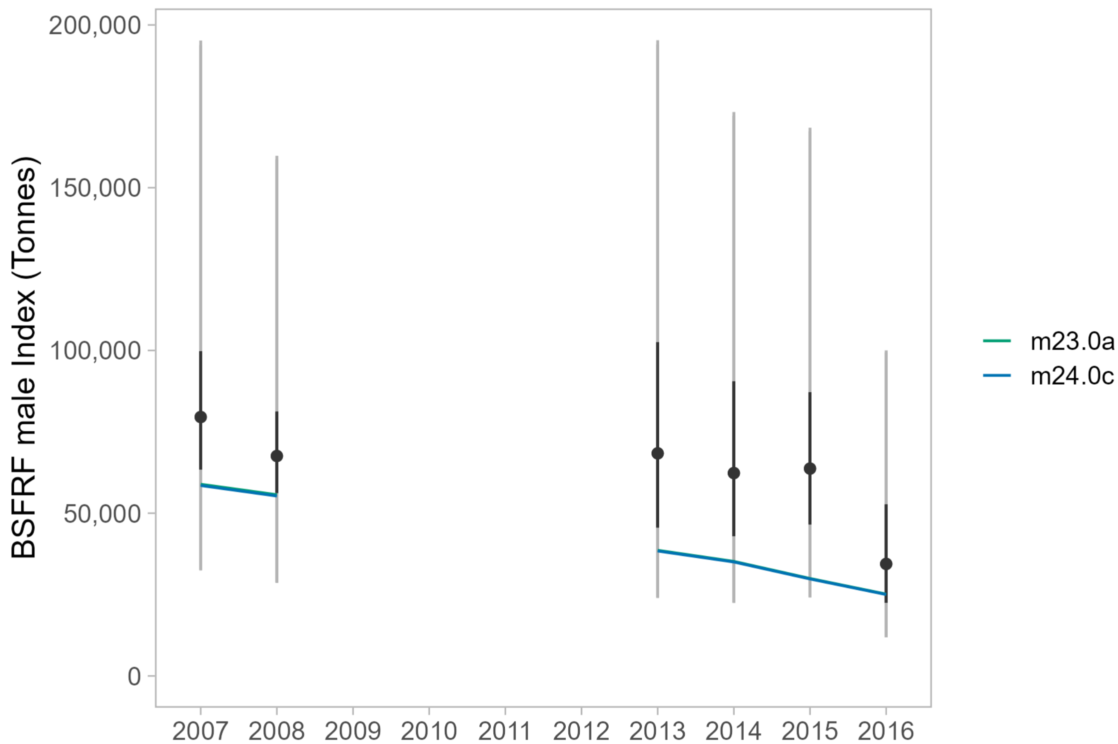

Figure 17: Comparisons of survey biomass estimates for males from the BSFRF survey and model prediction for model estimates in 2024 (models 23.0a and 24.0c). The error bars are plus and minus 2 standard deviations of model 23.0a. The BSFRF survey catchability is assumed to be 1.0 for all models.

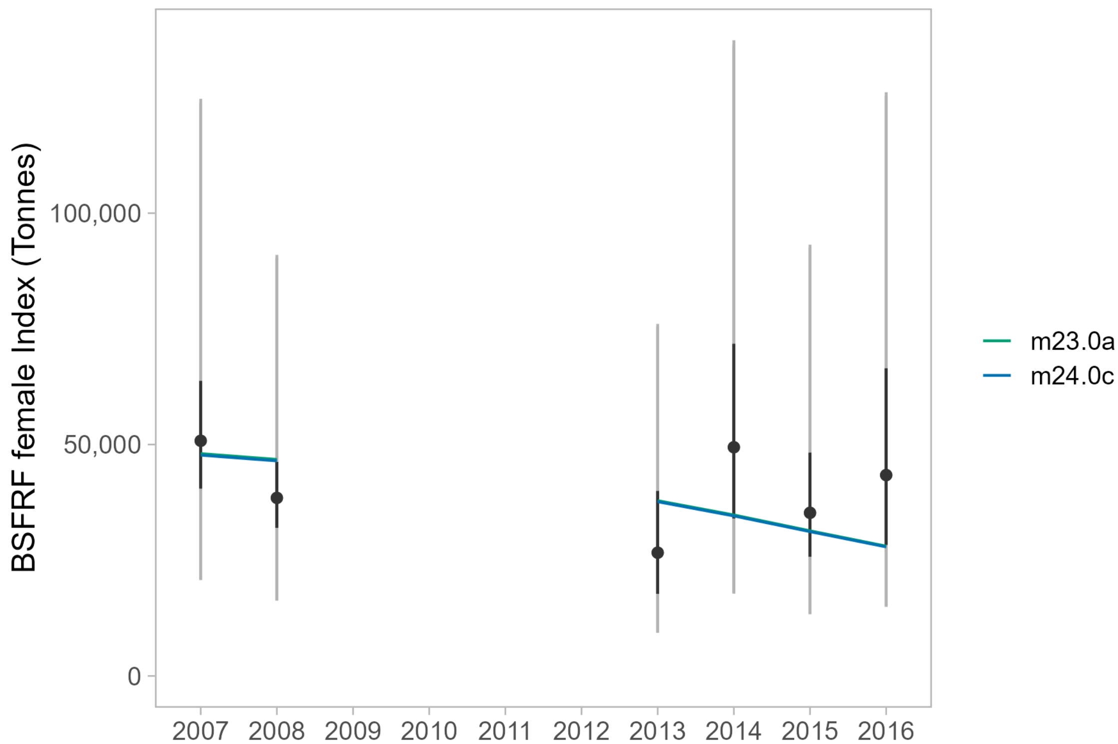

Figure 18: Comparisons of survey biomass estimates for females from the BSFRF survey and model prediction for model estimates in 2024 (models 23.0a and 24.0c). The error bars are plus and minus 2 standard deviations of model 23.0a. The BSFRF survey catchability is assumed to be 1.0 for all models.

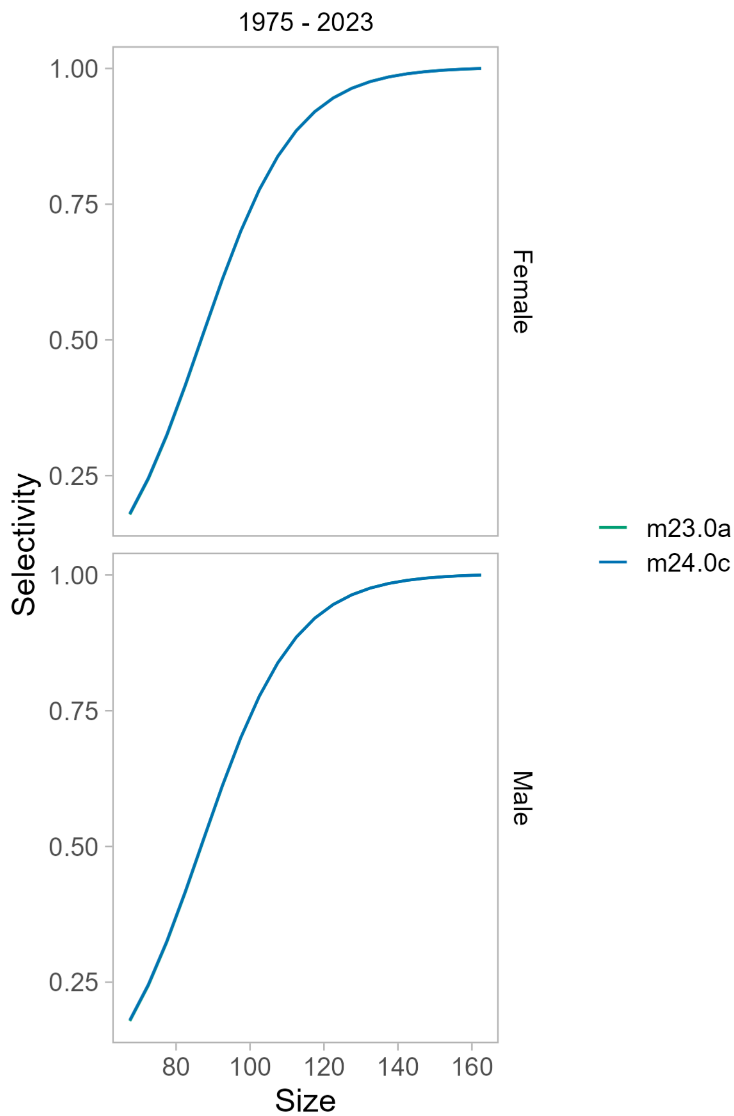

Figure 19: Estimated BSFRF trawl survey selectivities under models 23.0a and 24.0c.

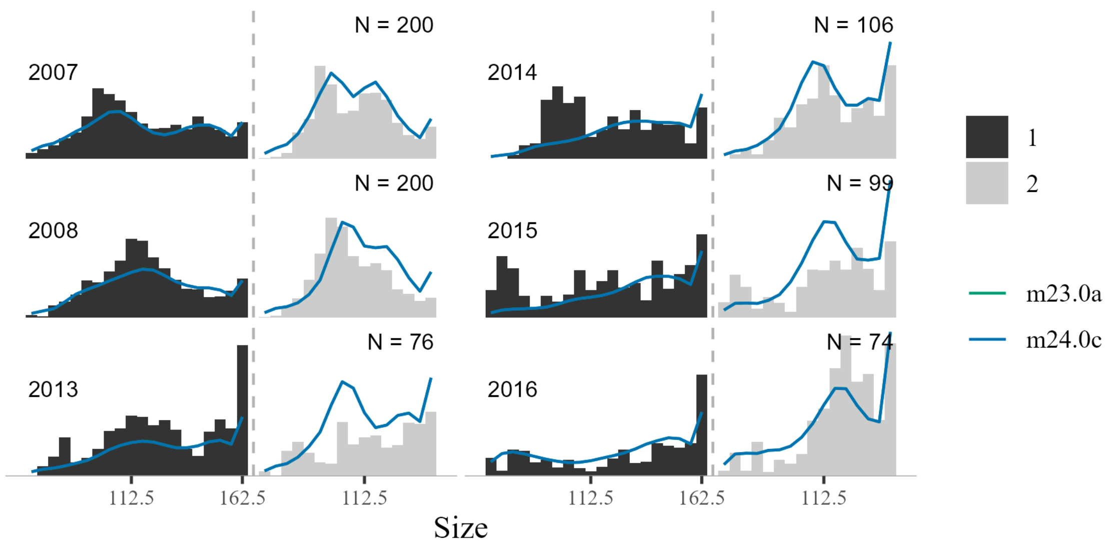

Figure 20: Comparisons of length compositions for males (1) and females (2) for the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 for both model scenarios.

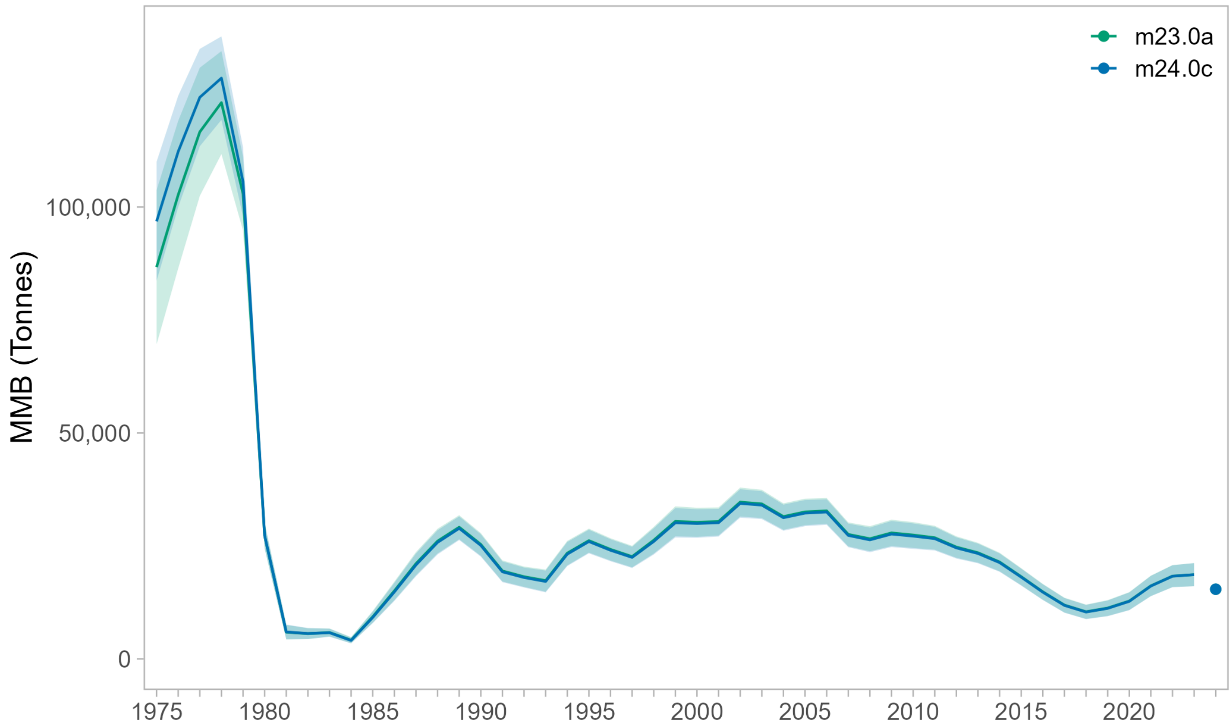

Figure 21: Estimated absolute mature male biomasses during 1975-2024 for models 23.0a and 24.0c. Mature male biomass is estimated on Feb. 15, year+1.

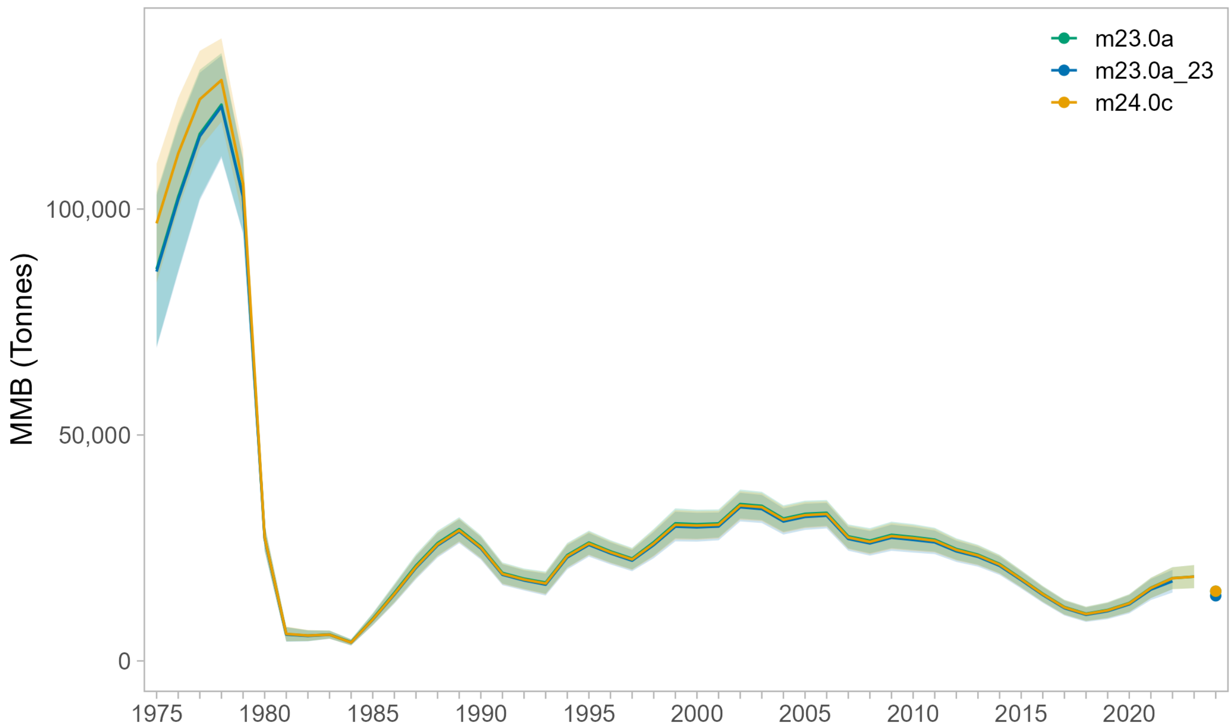

Figure 22: Estimated absolute mature male biomasses during 1975-2024 for models 23.0a in 2023 and 2024. Mature male biomass is estimated on Feb. 15, year+1.

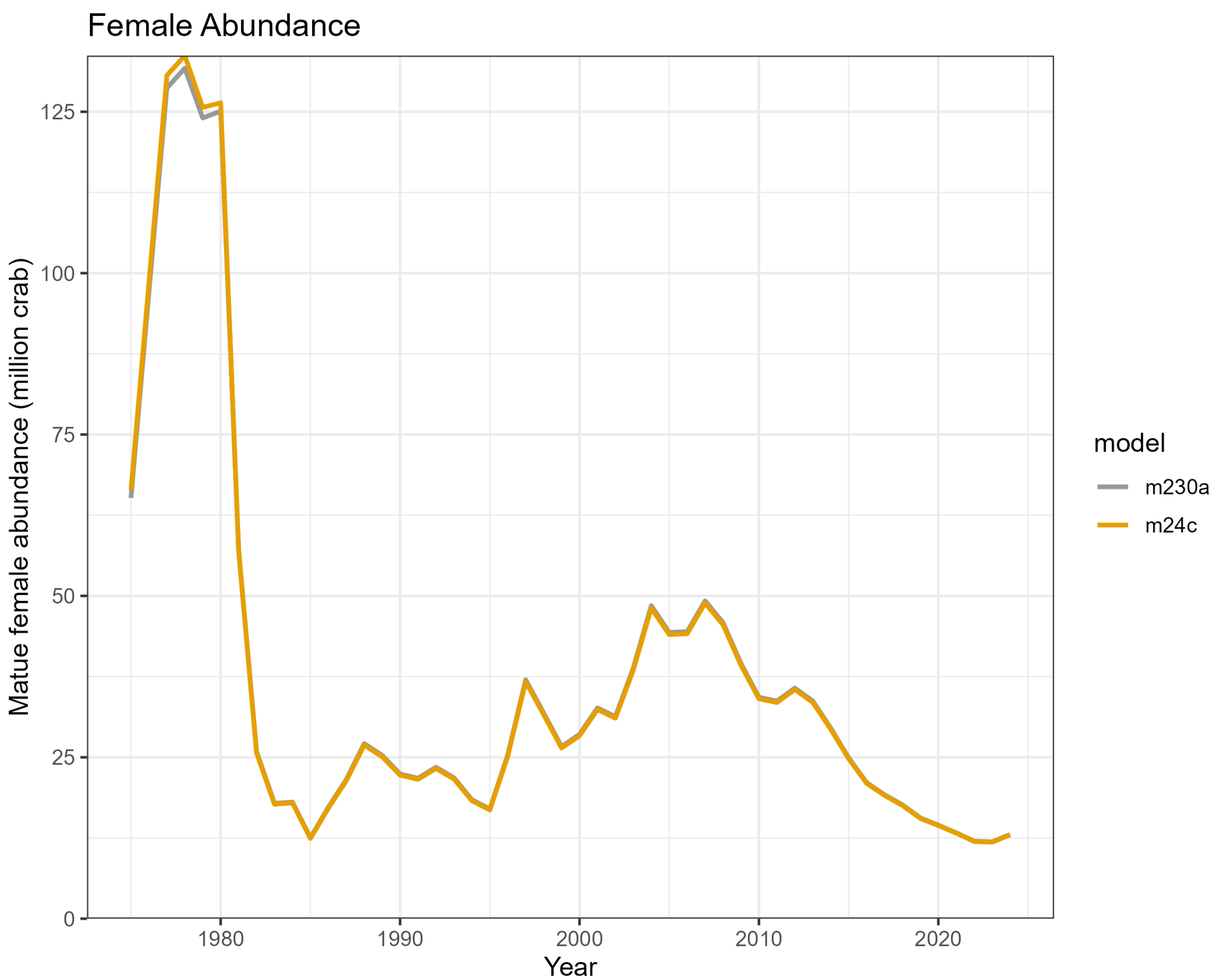

Figure 23: Estimated absolute mature female abundance during 1985-2024 for models 23.0a (2023 and 2024) and 24.0c.

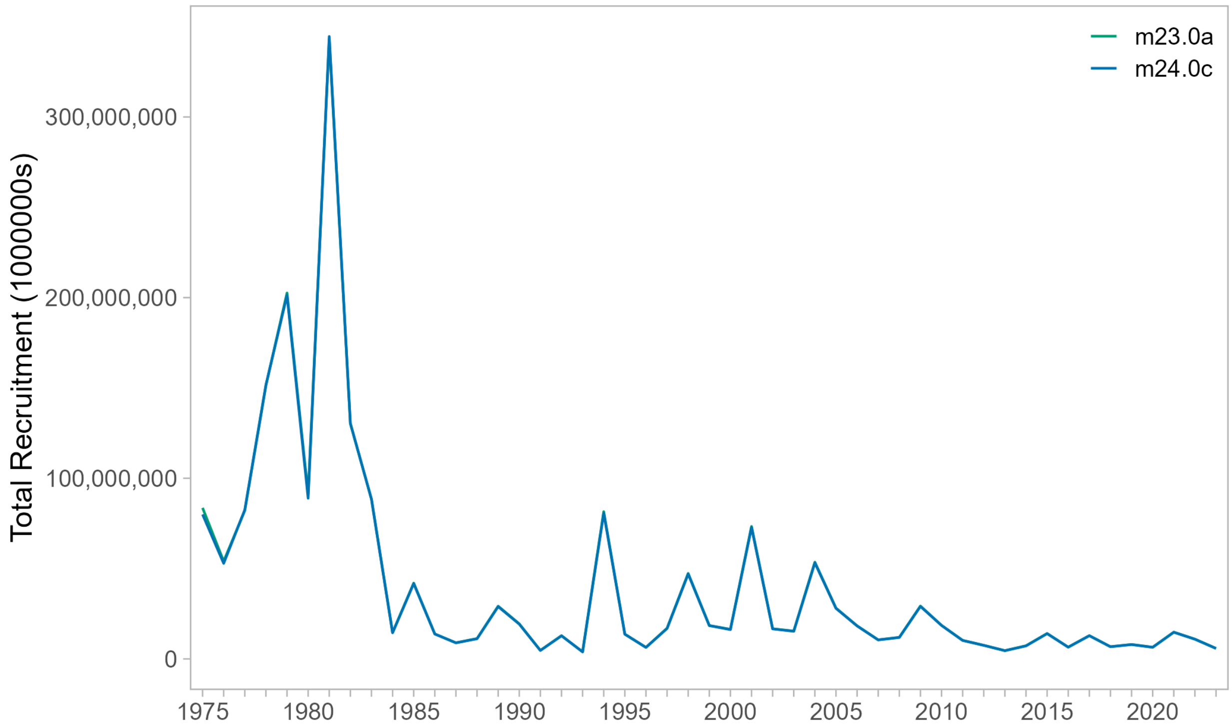

Figure 24: Estimated total (male and female) recruitment time series during 1976-2023 with models 23.0a and 24.0c. Mean male recruits during 1984-2023 was used to estimate B35. Recruitment estimates in the terminal year (2024) are unreliable.

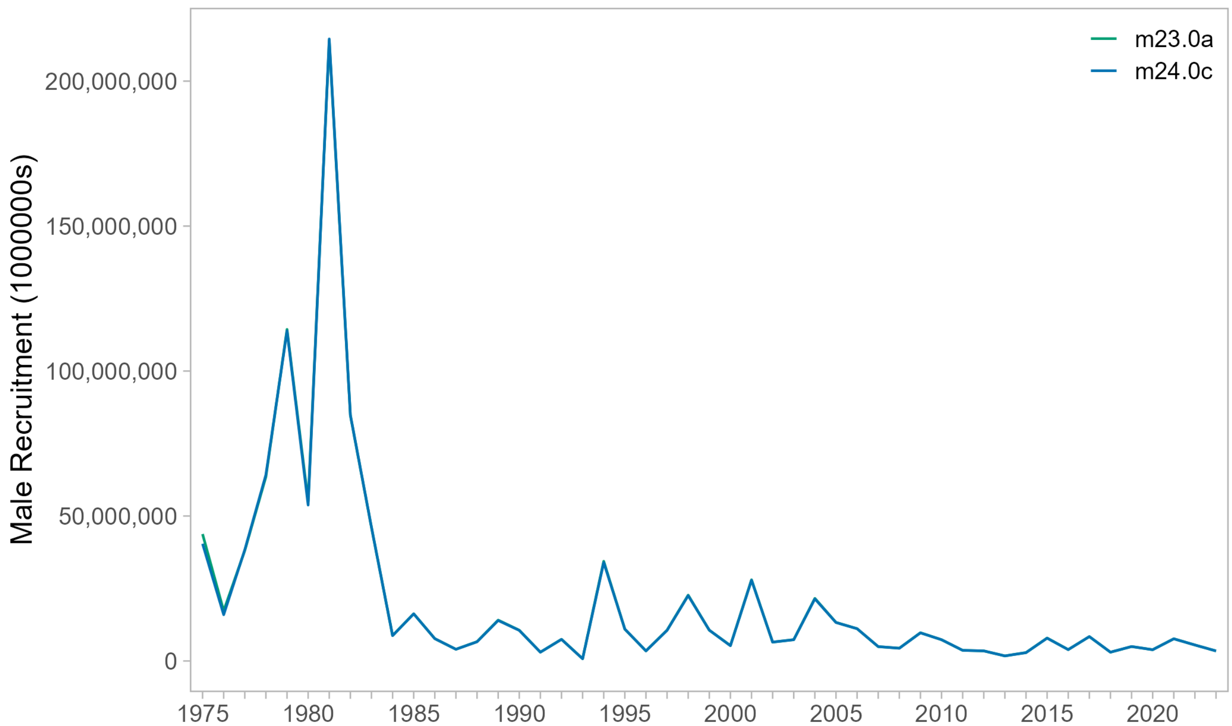

Figure 25: Estimated male recruitment time series during 1976-2023 with models 23.0a and 24.0c. Mean male recruits during 1984-2023 was used to estimate B35. Recruitment estimates in the terminal year (2024) are unreliable.

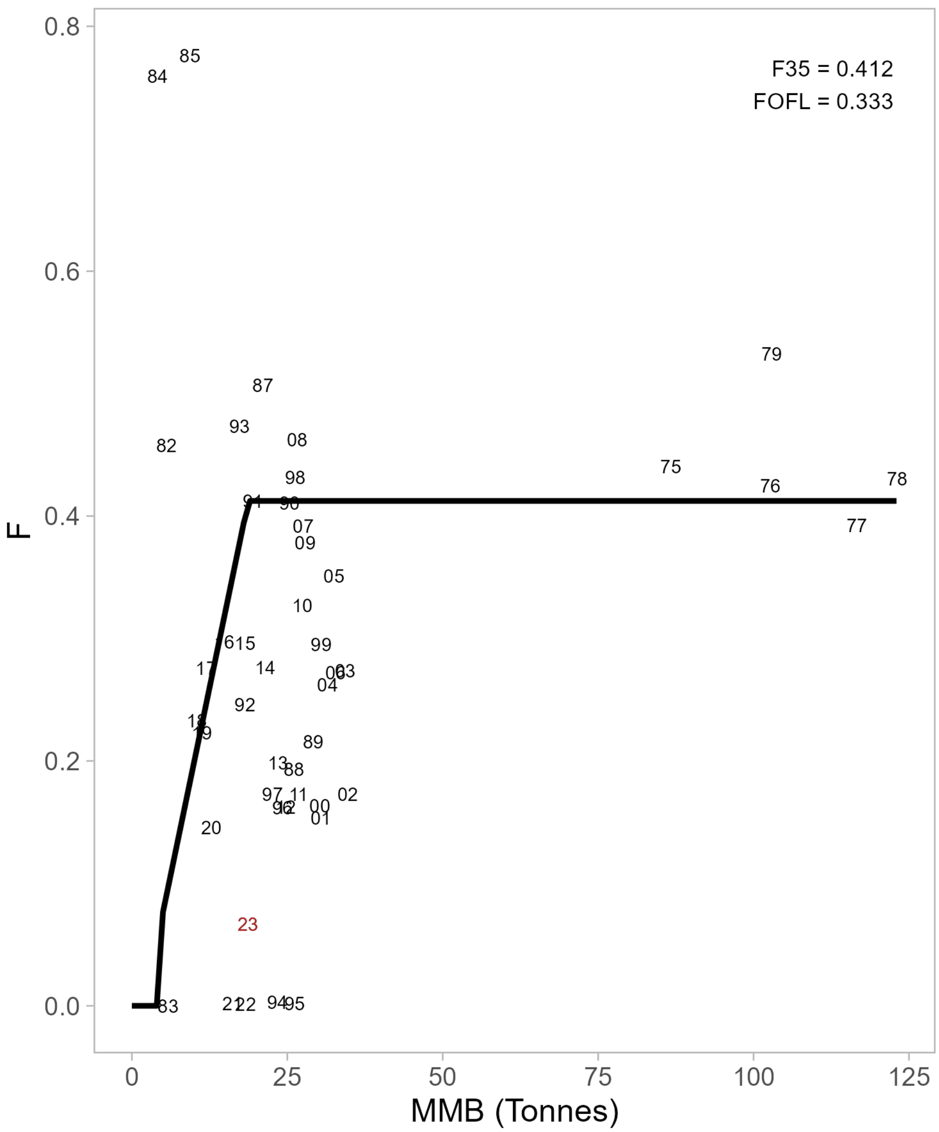

Figure 26: Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2023 under model 23.0a. Average of recruitment from 1984 to 2023 was used to estimate B35.

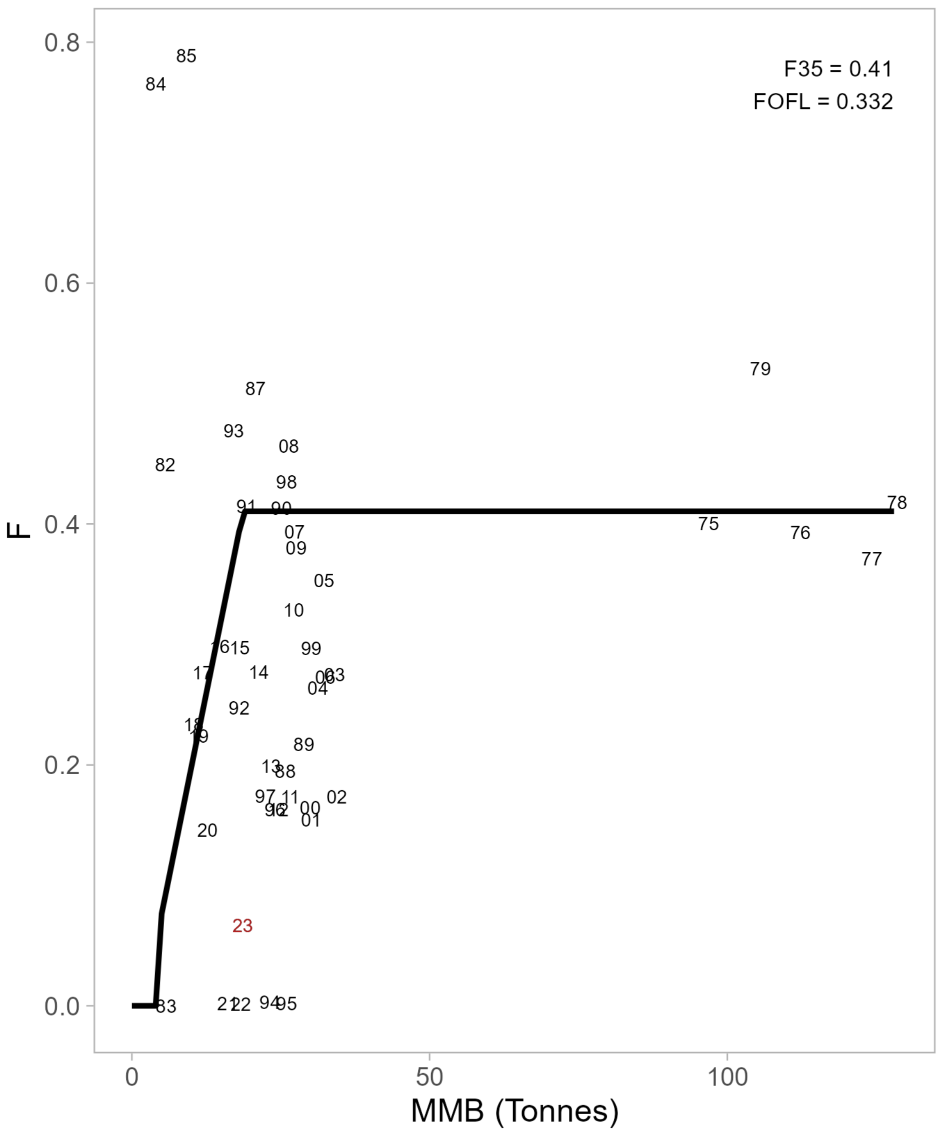

Figure 27: Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2023 under model 24.0c. Average of recruitment from 1984 to 2023 was used to estimate B35.

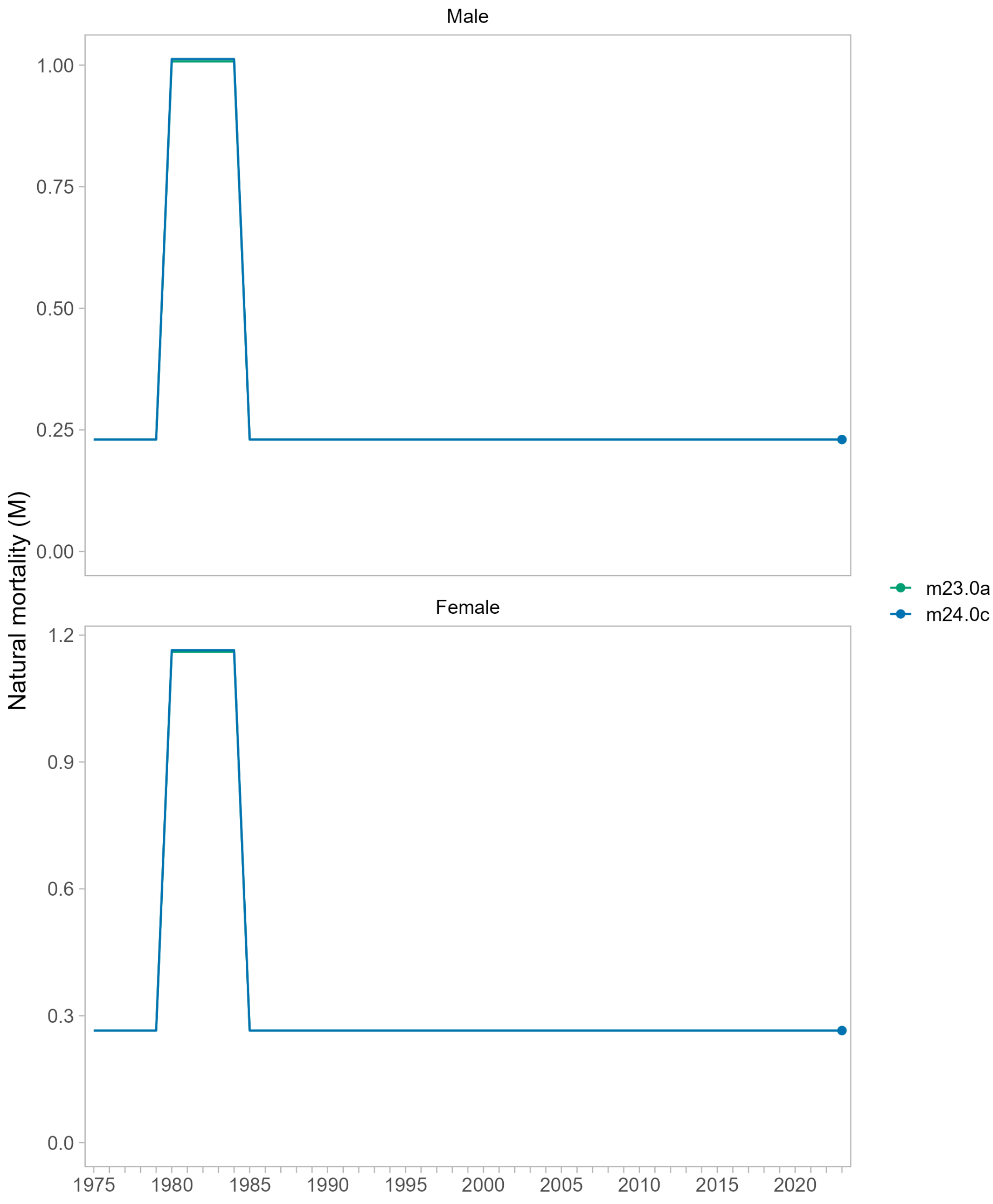

Figure 28: Comparison of estimated natural mortality for models 23.0a and 24.0c.

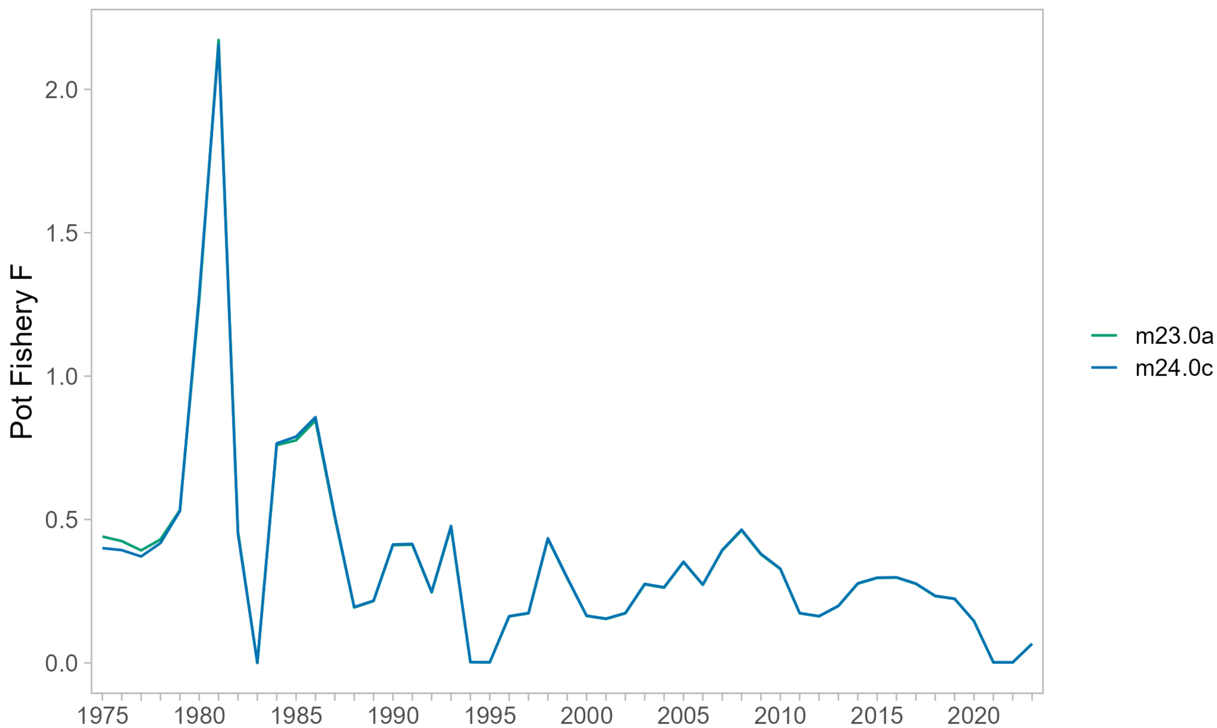

Figure 29: Comparison of estimated fishing mortality for the directed pot fishery for models 23.0a and 24.0c.

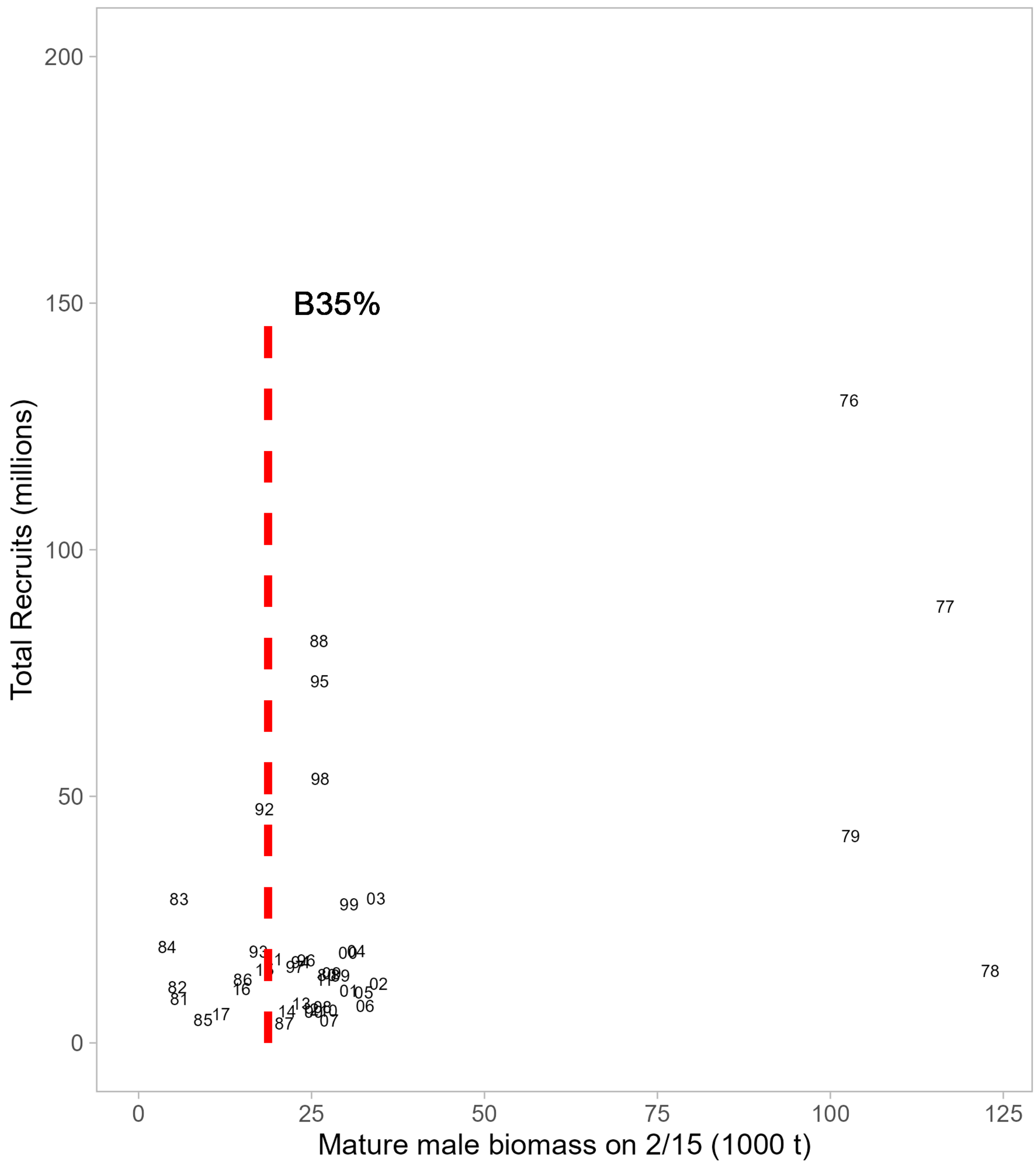

Figure 30: Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6 year time lag) for Bristol Bay red king crab under model 23.0a. Numerical labels are years of mating, and the vertical dotted line is the estimated B35 based on the mean recruitment level during 1984 to 2023.

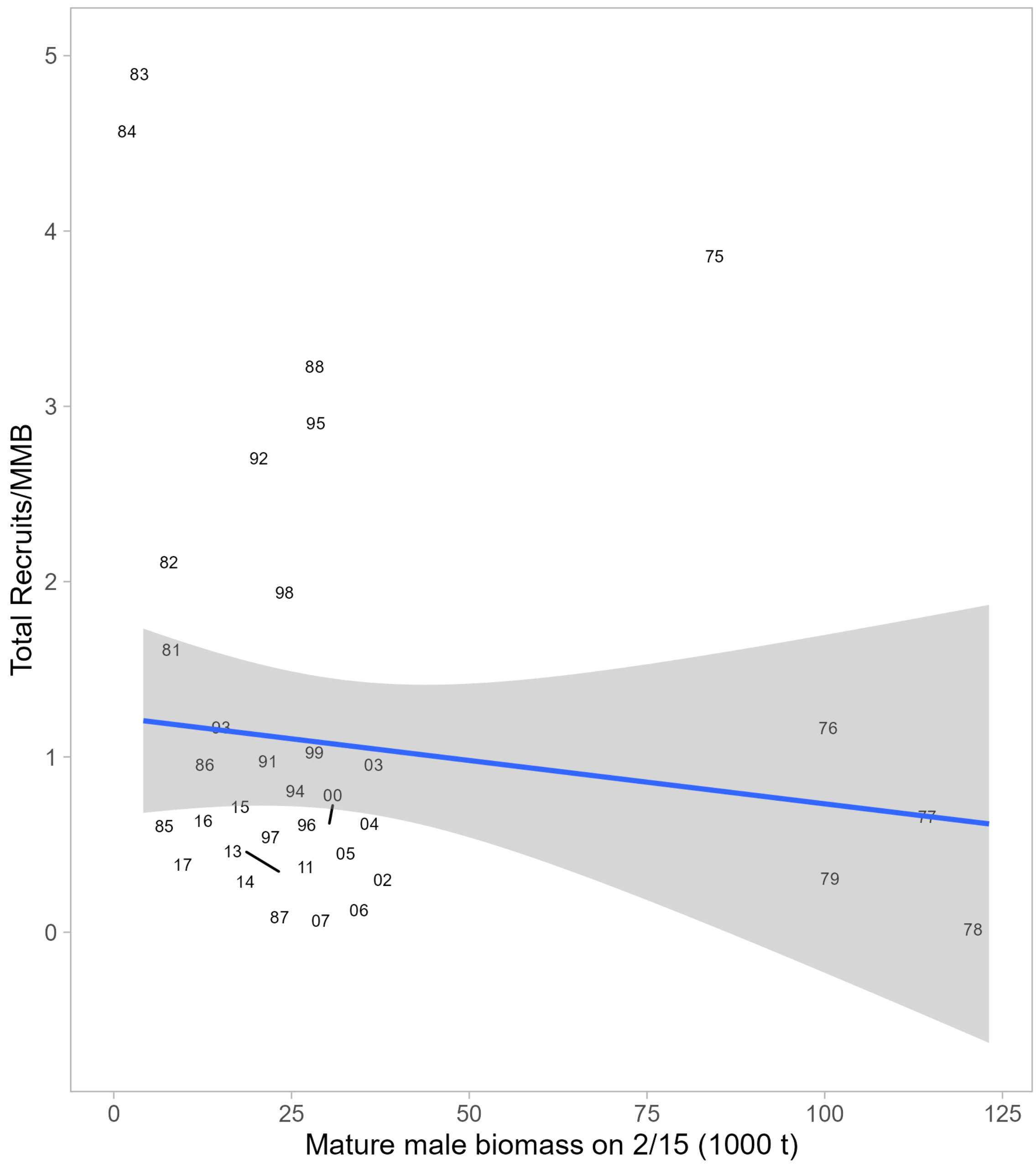

Figure 31: Relationships between recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab under model 23.0a. Numerical labels are years of mating, and the line is the regression line for data of 1978-2017.

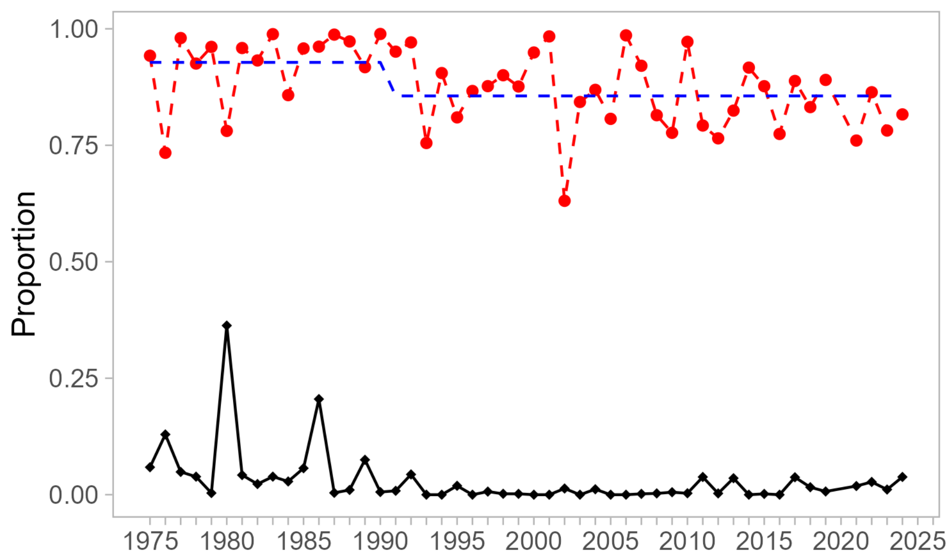

Figure 32: Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2023 from survey data. Oldshell females were excluded. The blue dashed line is the mean clutch fullness during two periods before 1992 and after 1991.

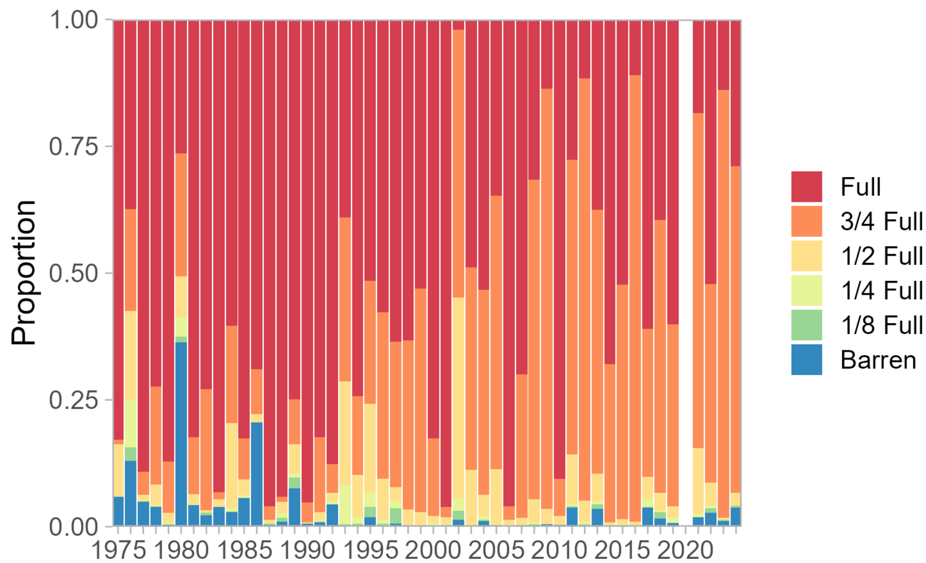

Figure 33: Clutch fullness distribution of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2023 from survey data. Oldshell females were excluded.

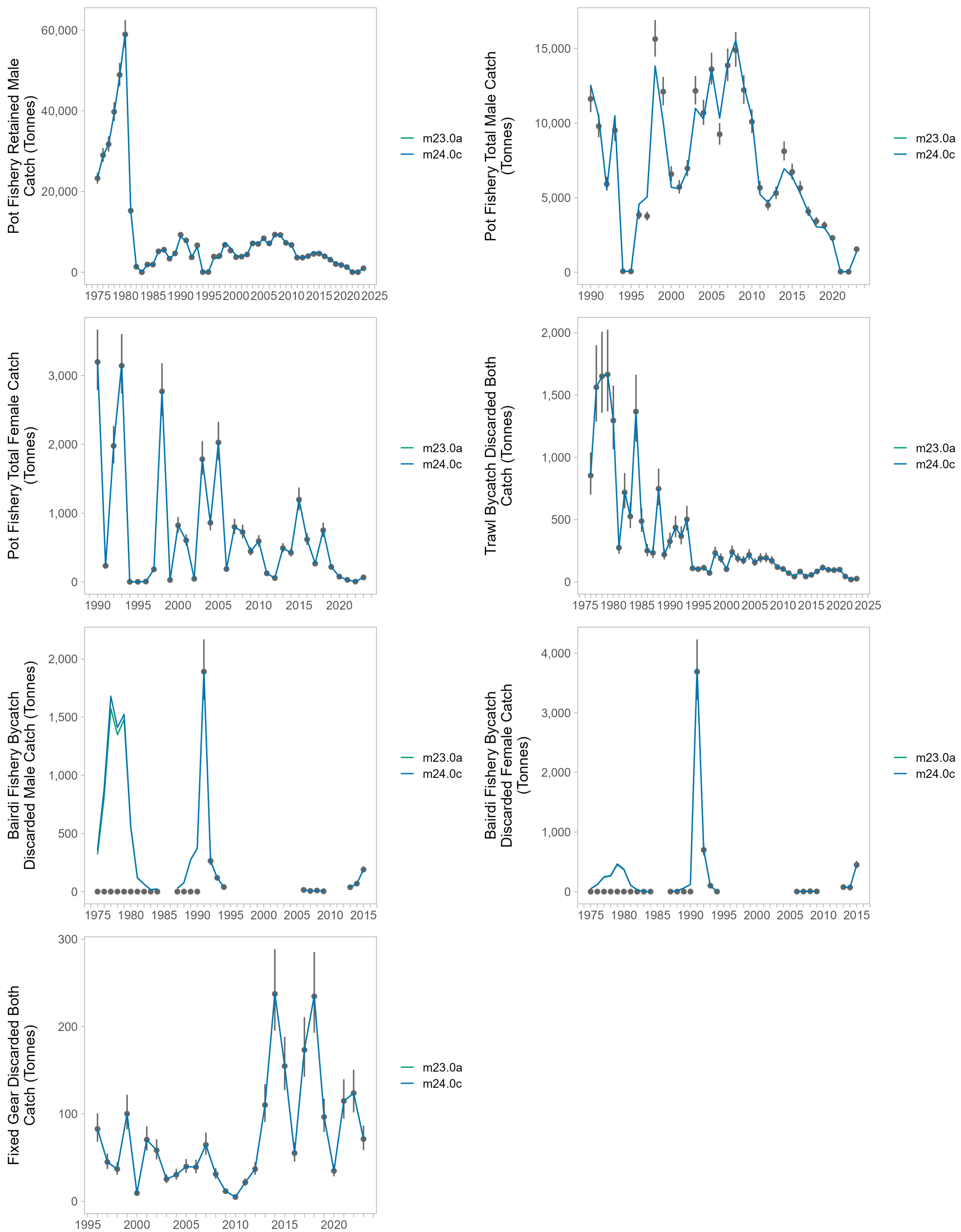

Figure 34: Observed (dots) and predicted (lines) RKC catch and bycatch biomass under models 23.0a and 24.0c. Note that model fit for Tanner crab fishery bycatch reflects utilizing effort data for extrapolation to bycatch in the early part of the time series.

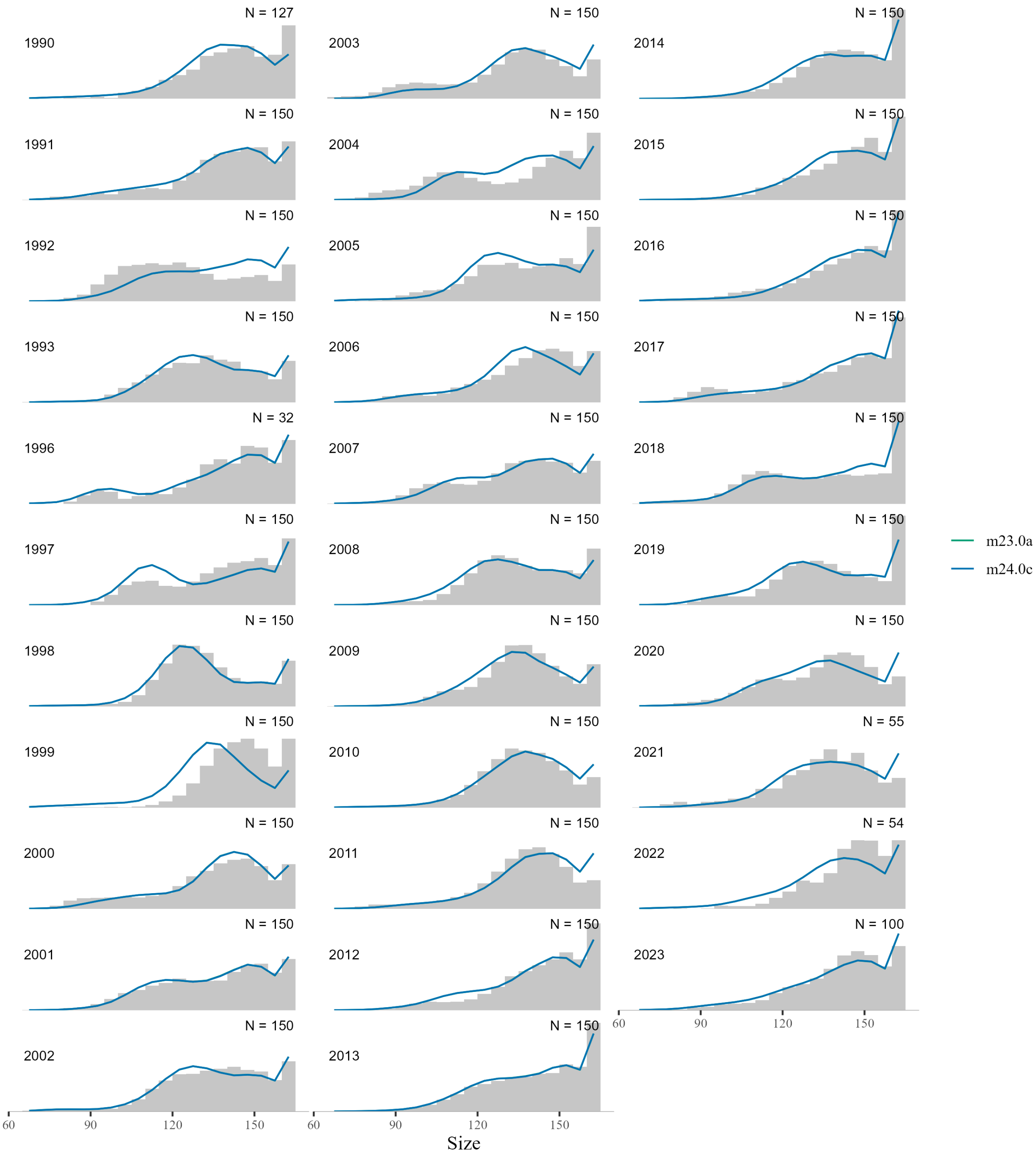

Figure 35: Observed and model estimated total observer length-frequencies of male BBRKC by year in the directed pot fishery for all model scenarios.

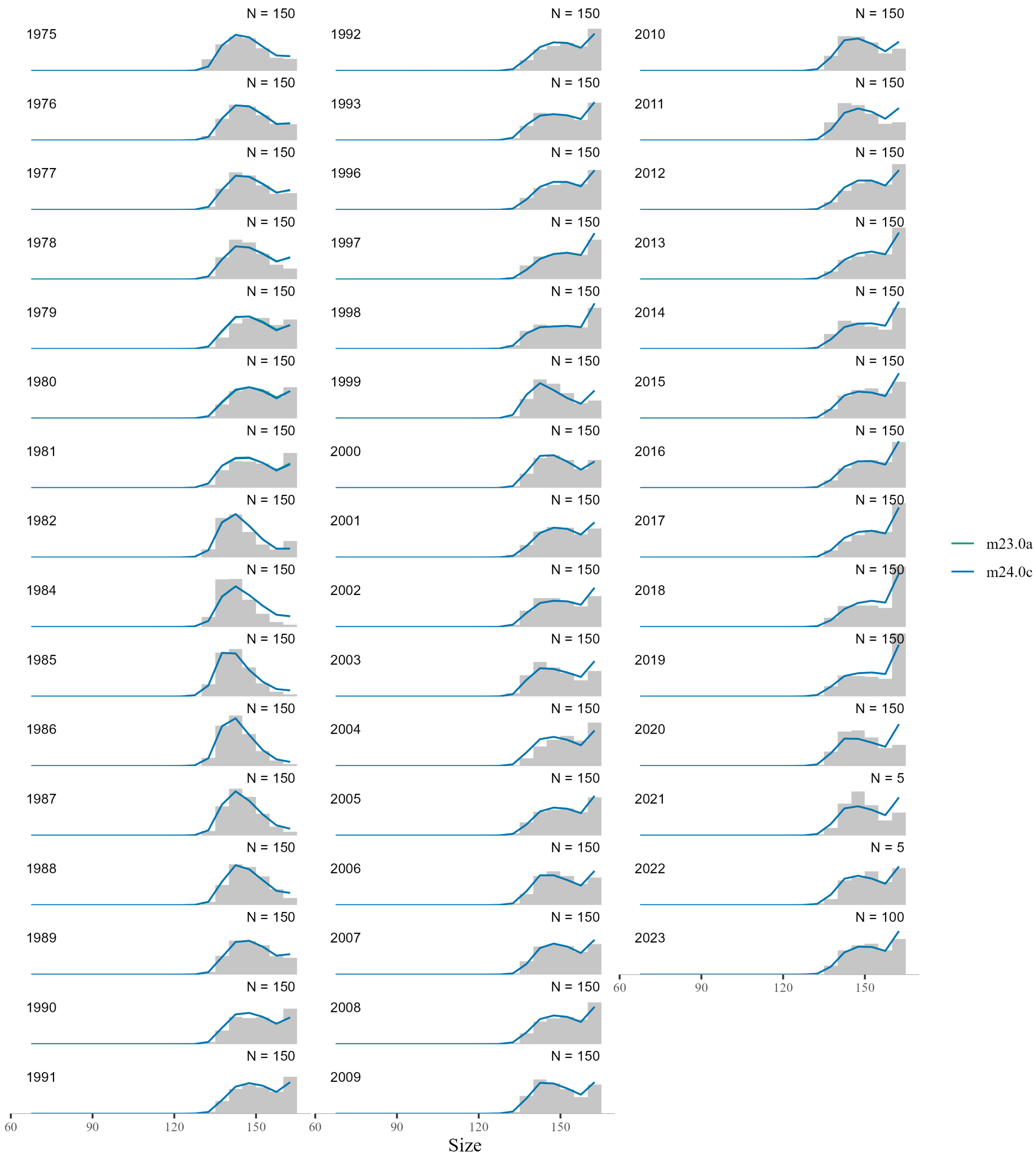

Figure 36: Observed and model estimated length-frequencies of male BBRKC by year retained in the directed pot fishery for the base model and model scenarios 23.0a and 24.0c.

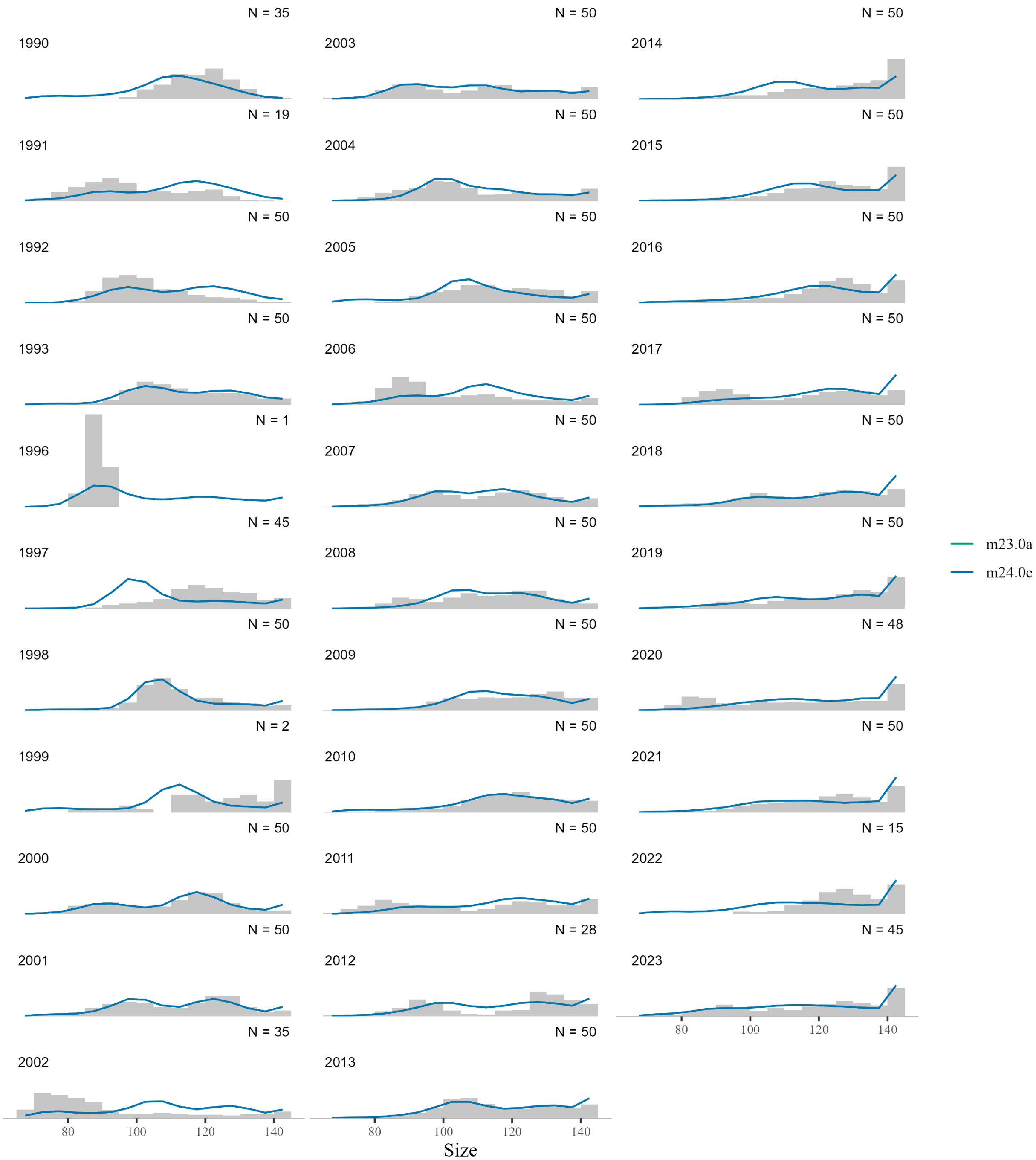

Figure 37: Observed and model estimated total observer length-frequencies of discarded female BBRKC by year in the directed pot fishery for all model scenarios.

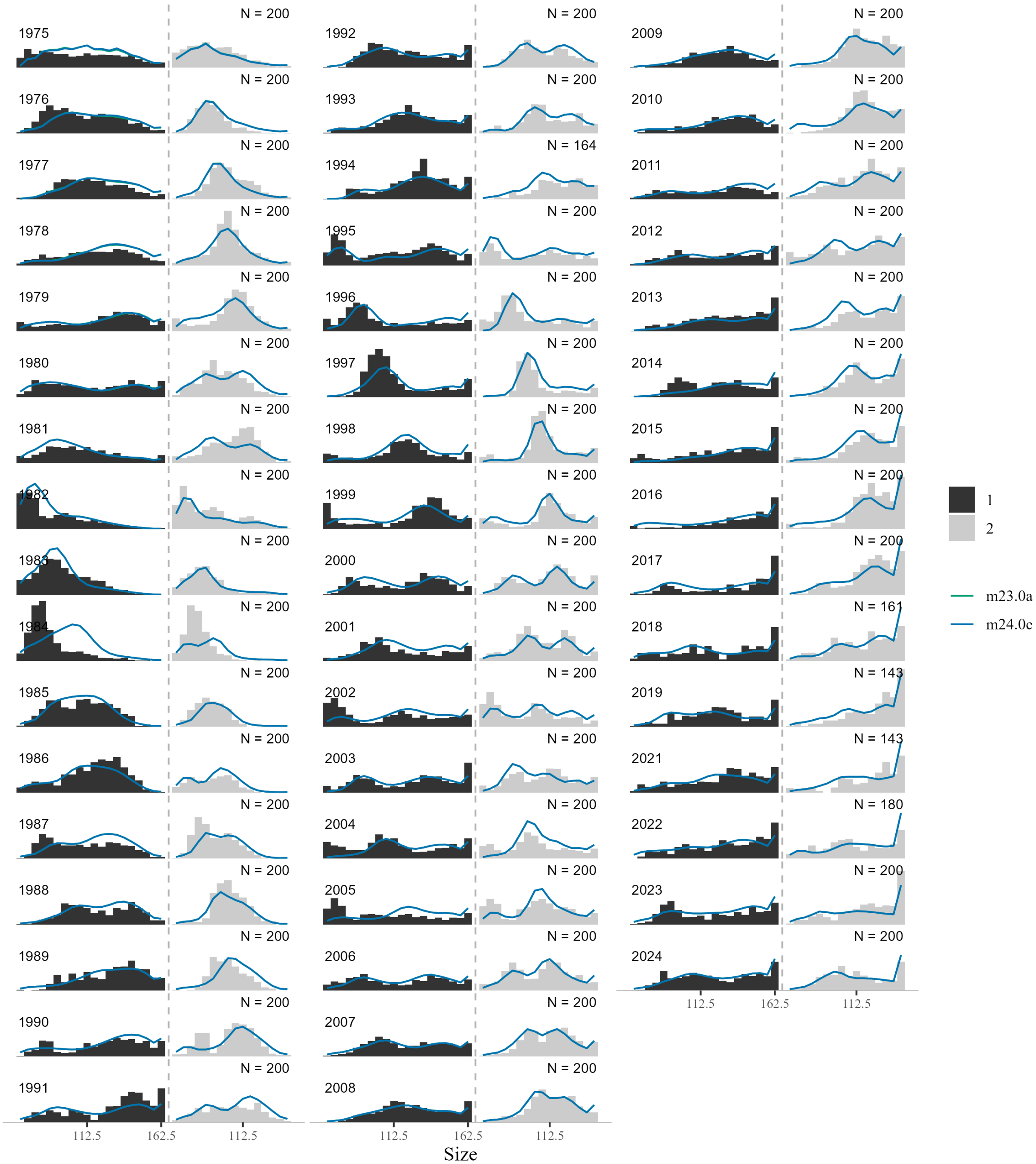

Figure 38: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male (black) and female (gray) red king crab by year for the base models and model scenarios 23.0a and 24.0c.

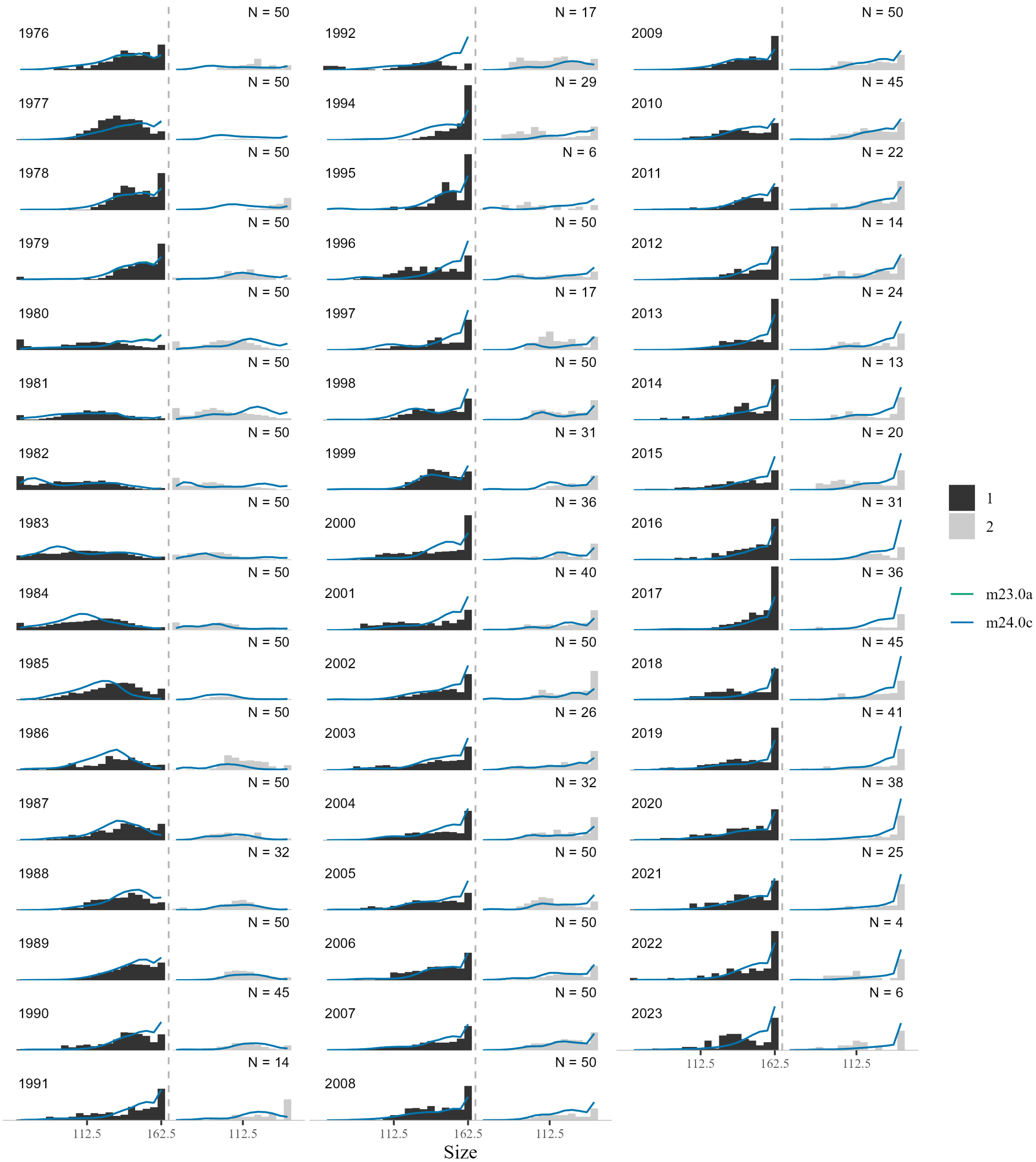

Figure 39: Comparison of observer and model estimated discarded length frequencies of Bristol Bay male (black) and female (gray) red king crab by year in the groundfish trawl fisheries bycatch for all model scenarios.

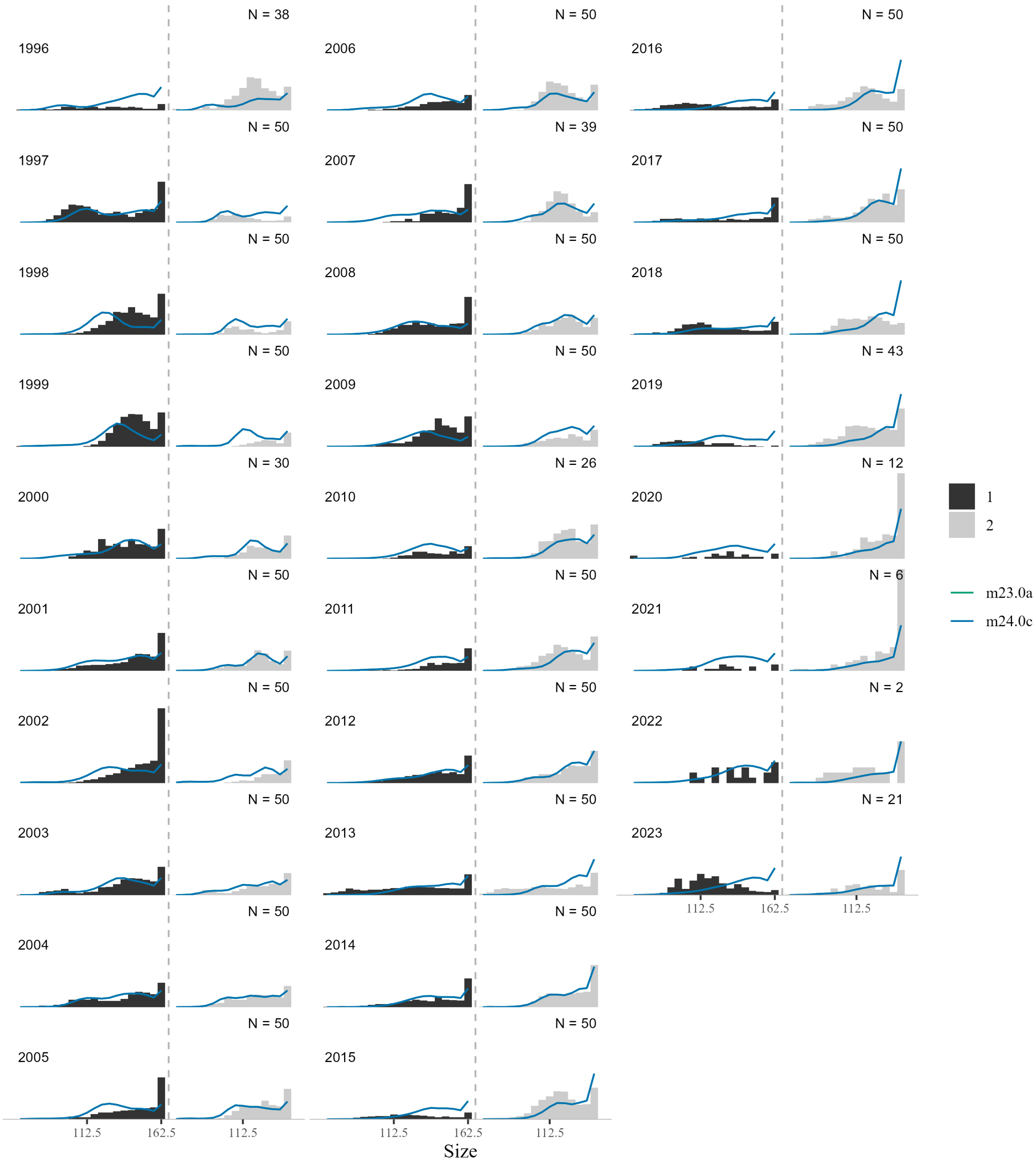

Figure 40: Comparison of observer and model estimated discarded length frequencies of Bristol Bay male (black) and female (gray) red king crab by year in the groundfish fixed gear fisheries bycatch for all model scenarios.

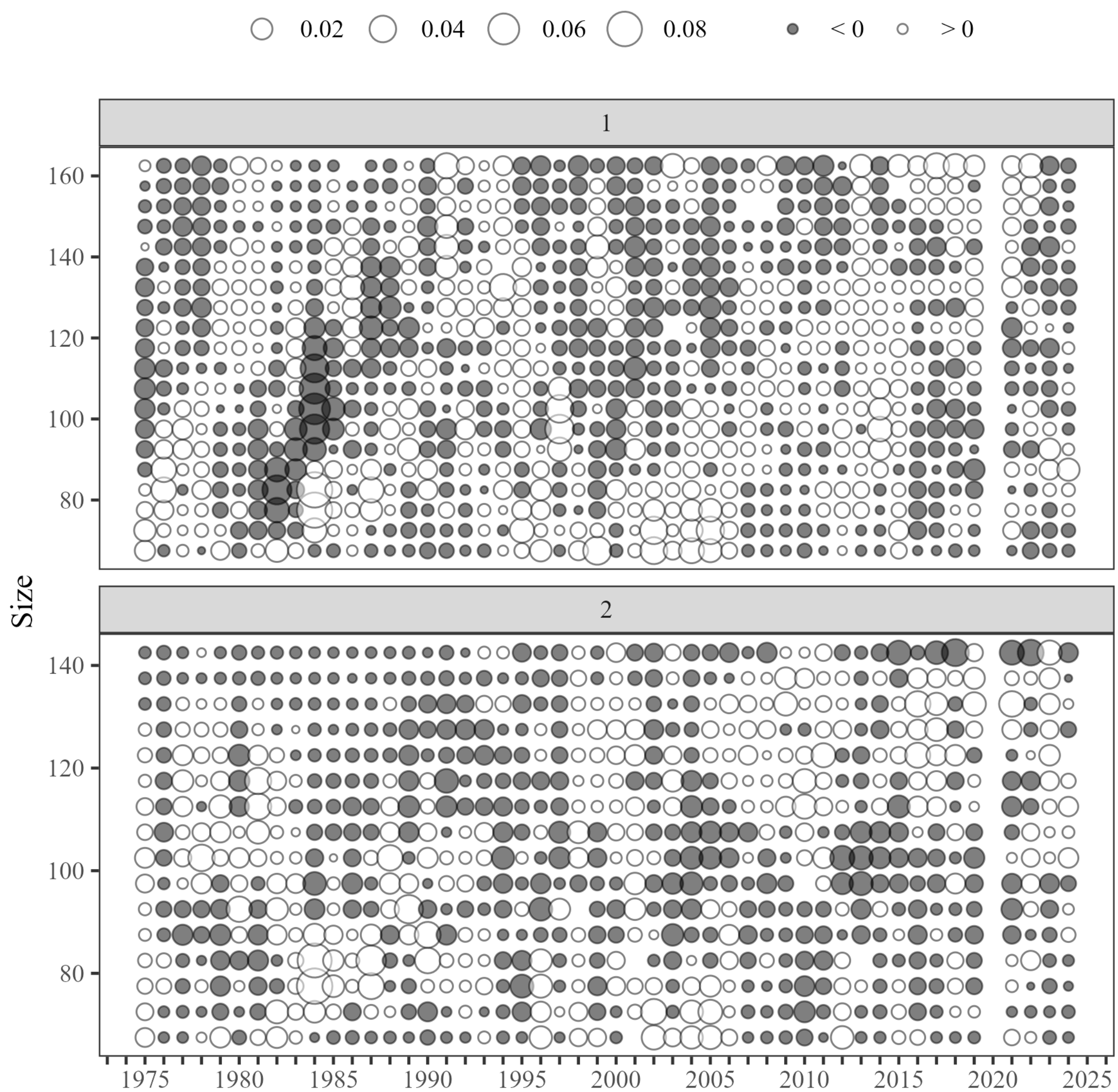

Figure 41: Bubble plots for residuals of proportions of NMFS survey males (1) and females (2) red king crab by year and carapace length (mm) under model 23.0a.

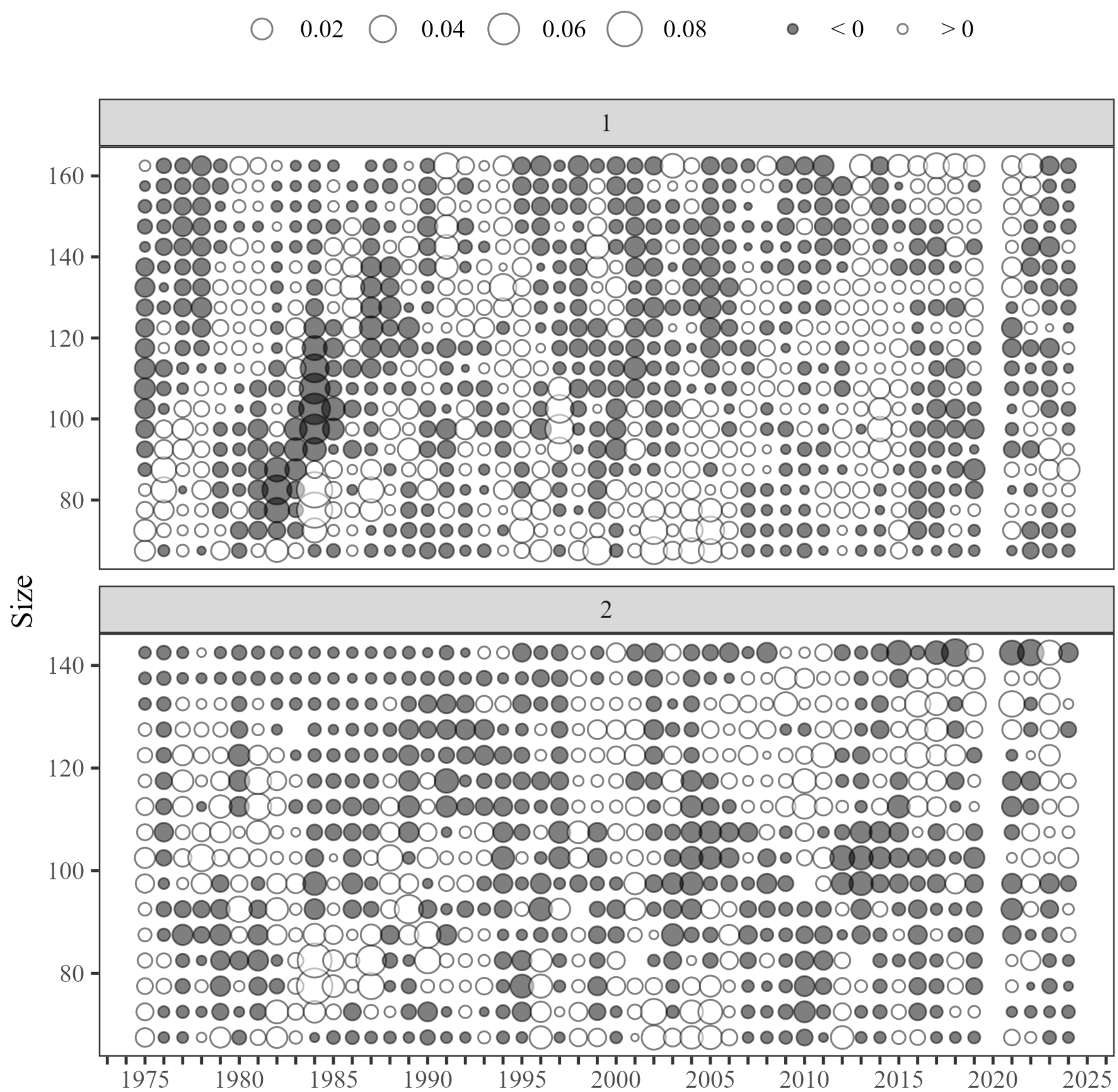

Figure 42: Bubble plots for residuals of proportions of NMFS survey males (1) and females (2) red king crab by year and carapace length (mm) under model 24.0c.

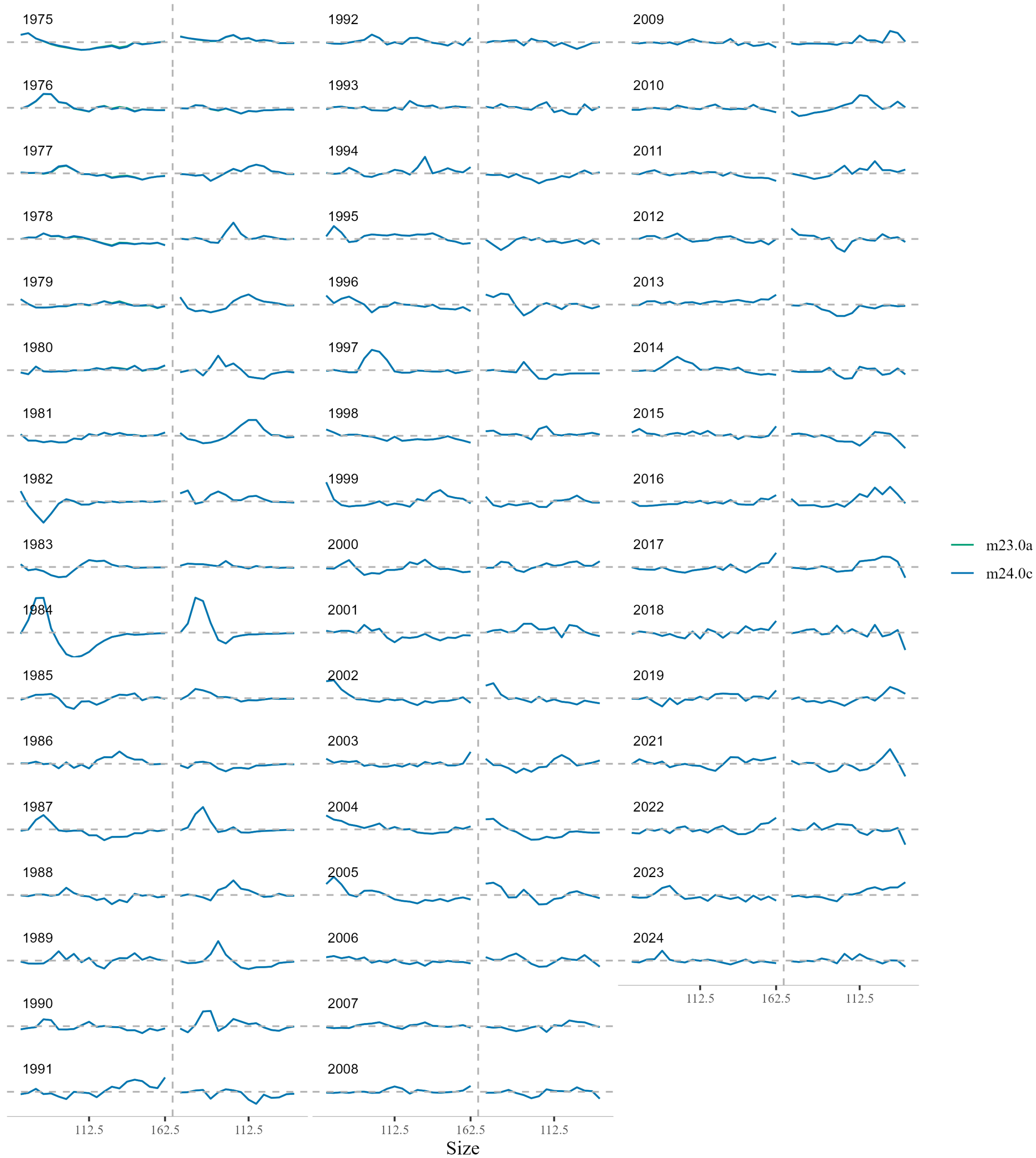

Figure 43: Residual line plot for male (left panel each year) and female (right panel each) size and year for the NMFS trawl survey size composition data sets for models 23.0a and 24.0c.

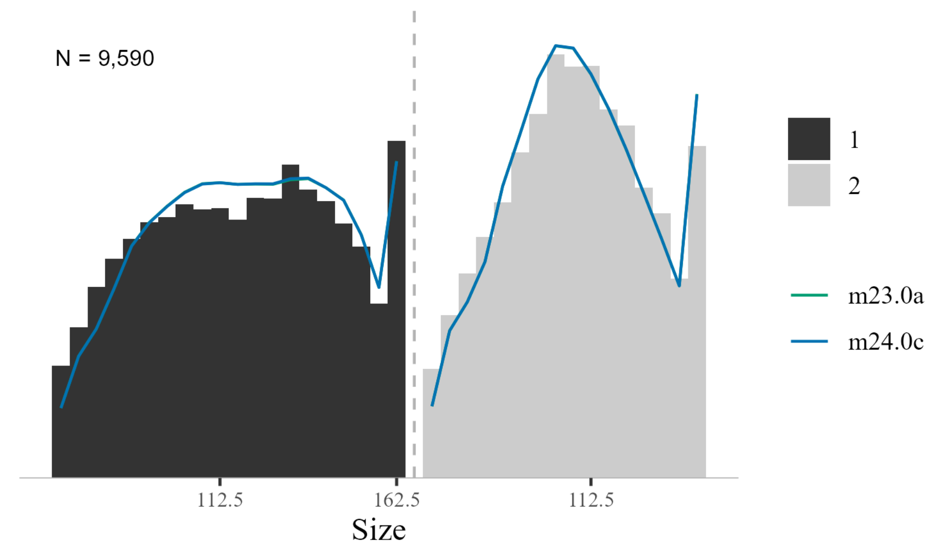

Figure 44: Aggregated size comps over all years for the NMFS survey for males (black) and females (grey) for both models.

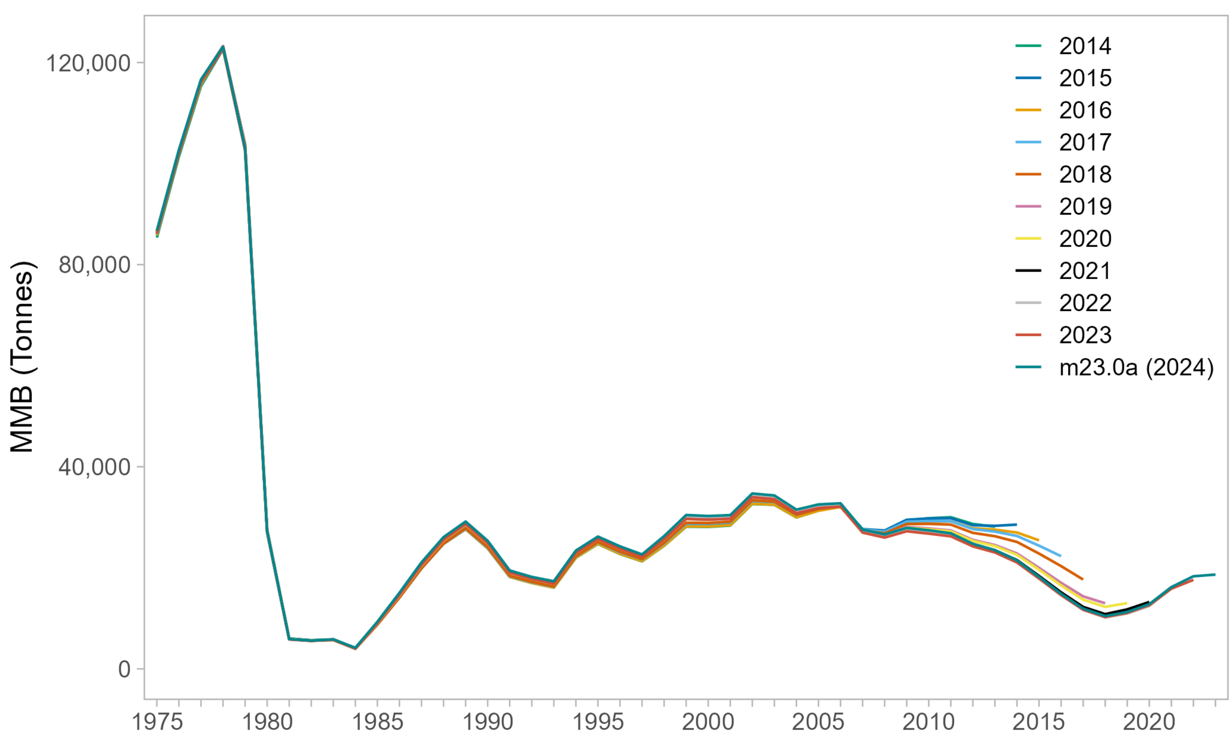

Figure 45: Comparison of retrospective estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2014-2024 using model 23.0a. These are results using the 2024 model (Mohn's rho = 0.2289). Legend shows the terminal year.

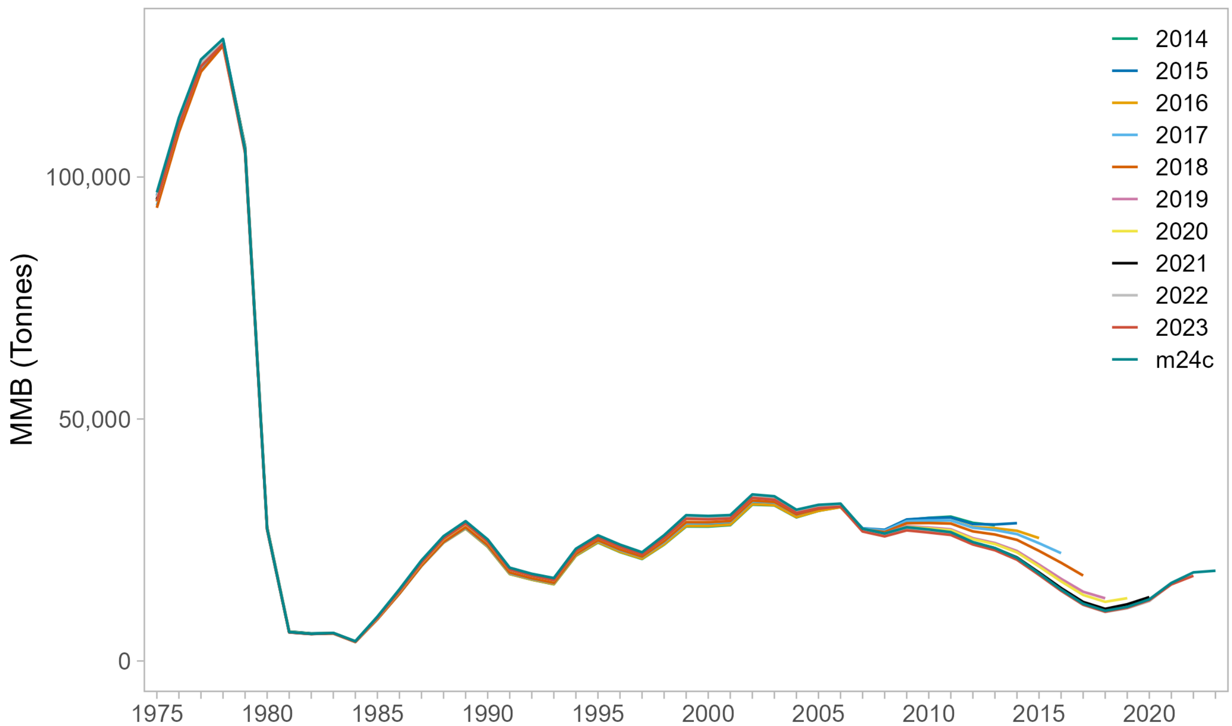

Figure 46: Comparison of retrospective estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2014-2024 using model 24.0c. These are results using the 2024 model (Mohn's rho = 0.2334). Legend shows the terminal year.

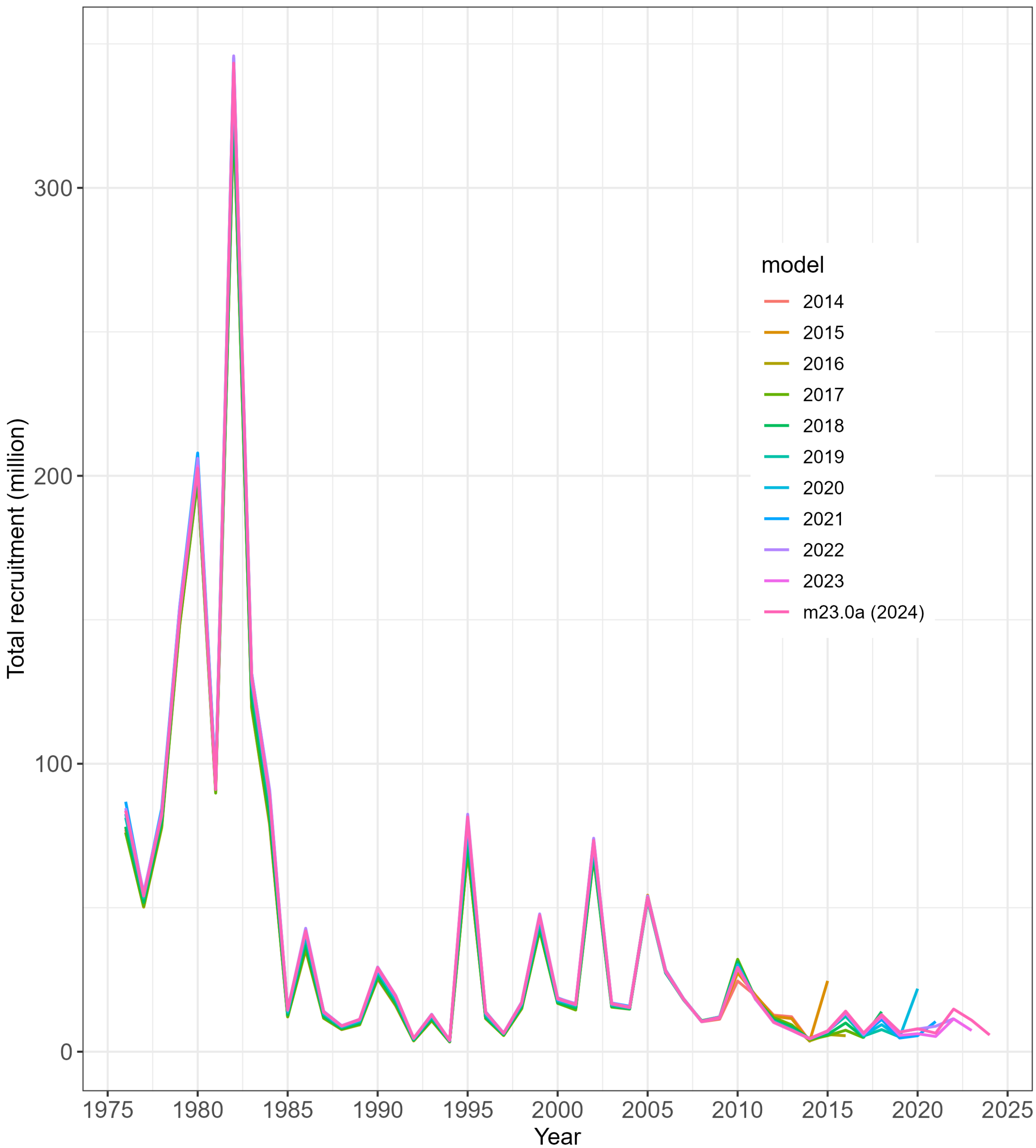

Figure 47: Comparison of retrospective estimates of total recruitment for model 23.0a of Bristol Bay red king crab from 1976 to 2024 made with terminal years 2014-2024. Legend shows the terminal year.

Figure 48: Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 23.0a.

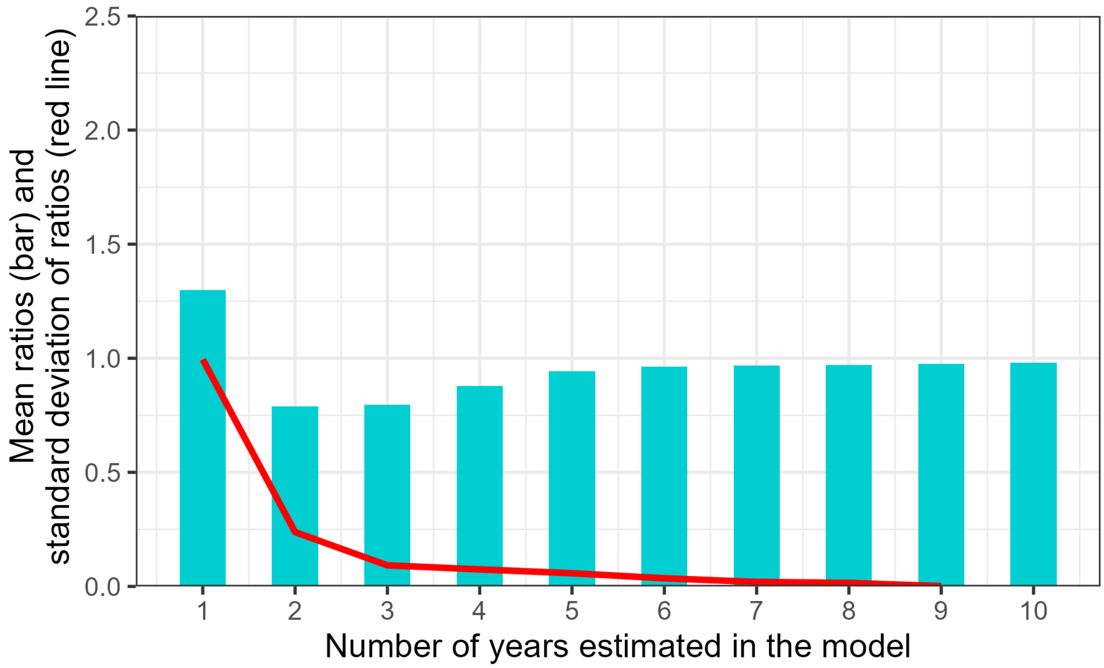

Figure 49: Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2023) and standard deviations (red line) of the ratios as a function of the number of years in the model for model 23.0a.

Figure 50: Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 24.0c.

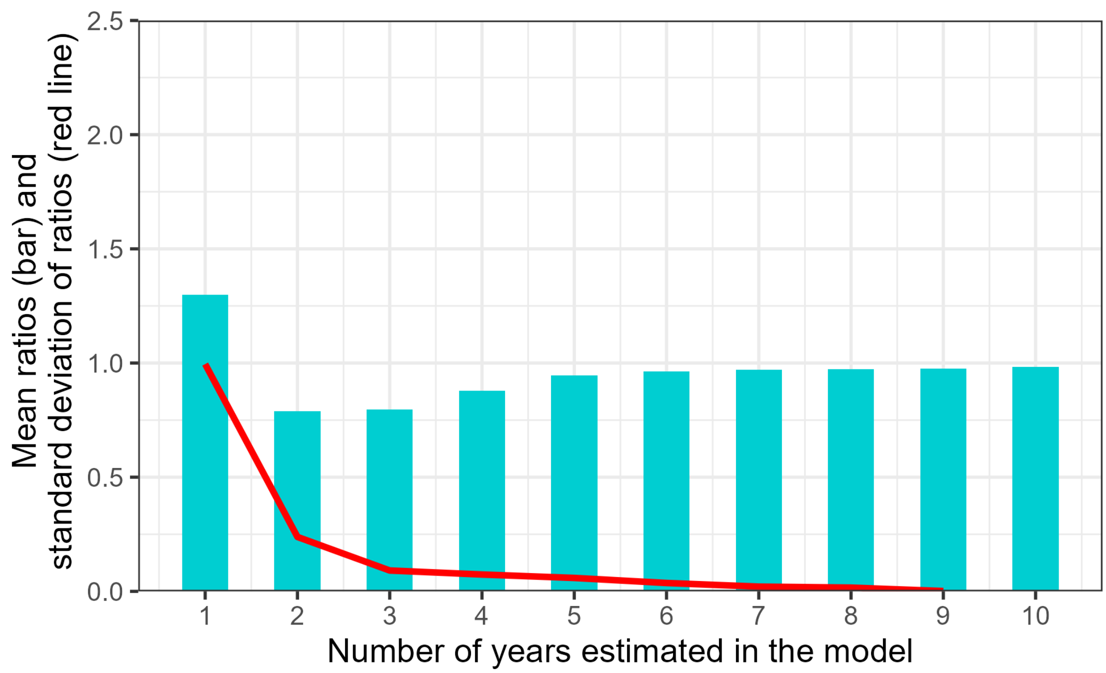

Figure 51: Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2023) and standard deviations (red line) of the ratios as a function of the number of years in the model for model 24.0c.

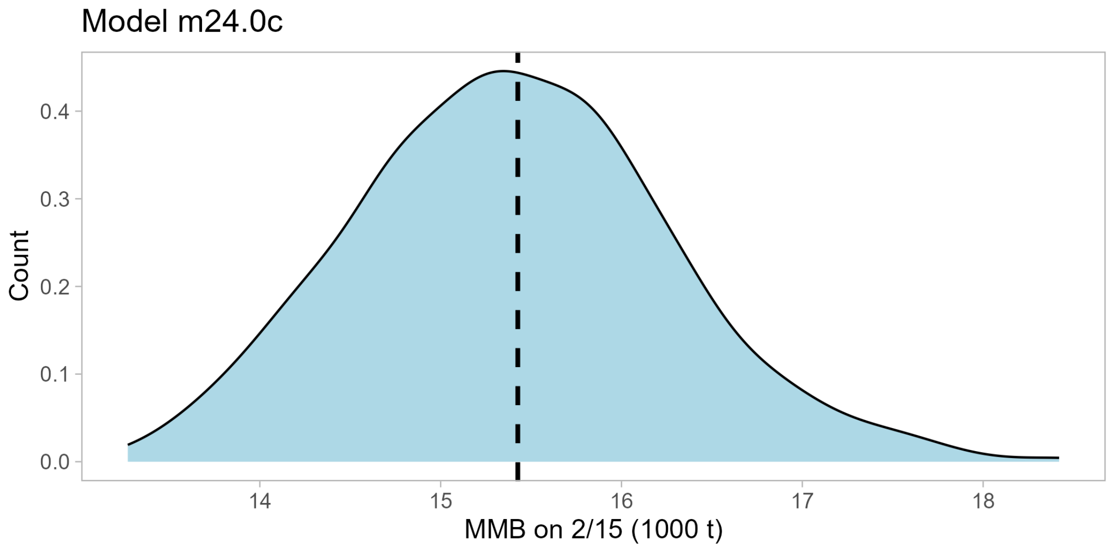

Figure 52: Histogram of estimated mature male biomass on Feb. 15, 2025, under model 24.0c with the MCMC approach.

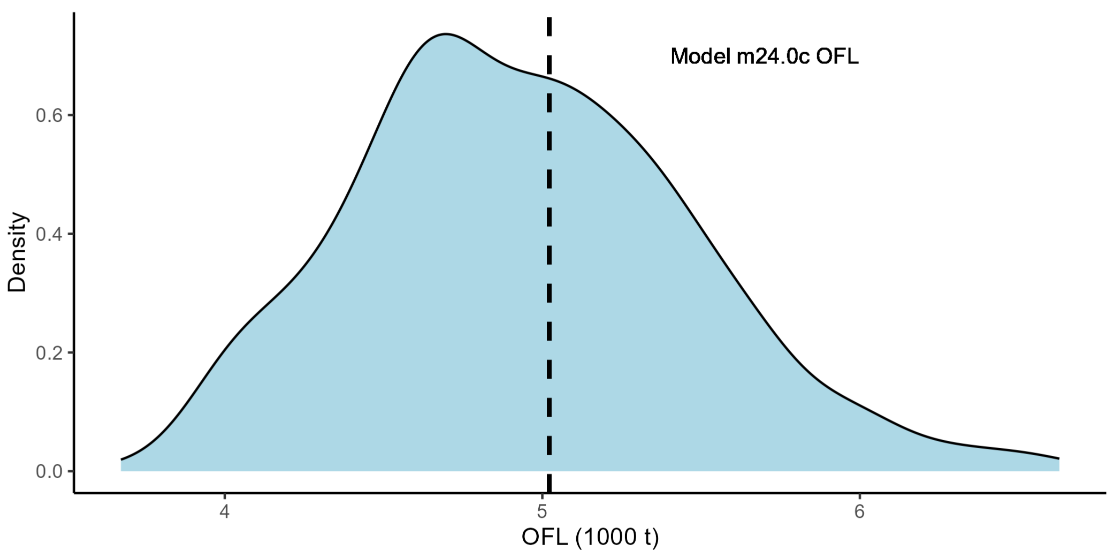

Figure 53: Histogram of the 2024/25 estimated OFL under model 24.0c with the MCMC approach.

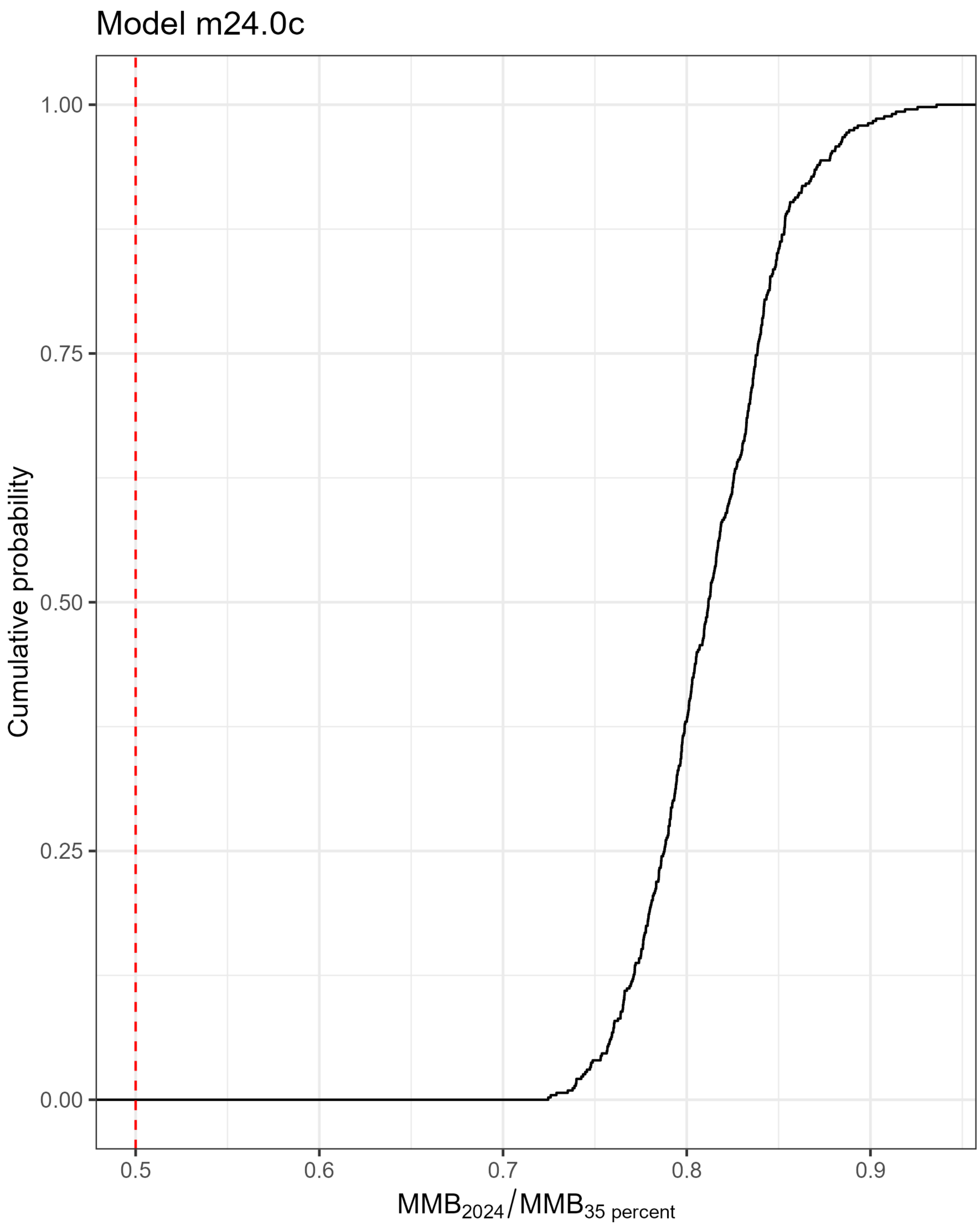

Figure 54: Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2025, to corresponding estimated B35 values under model 24.0c with the MCMC approach. Zero probability is below the estimated minimum thresholds.

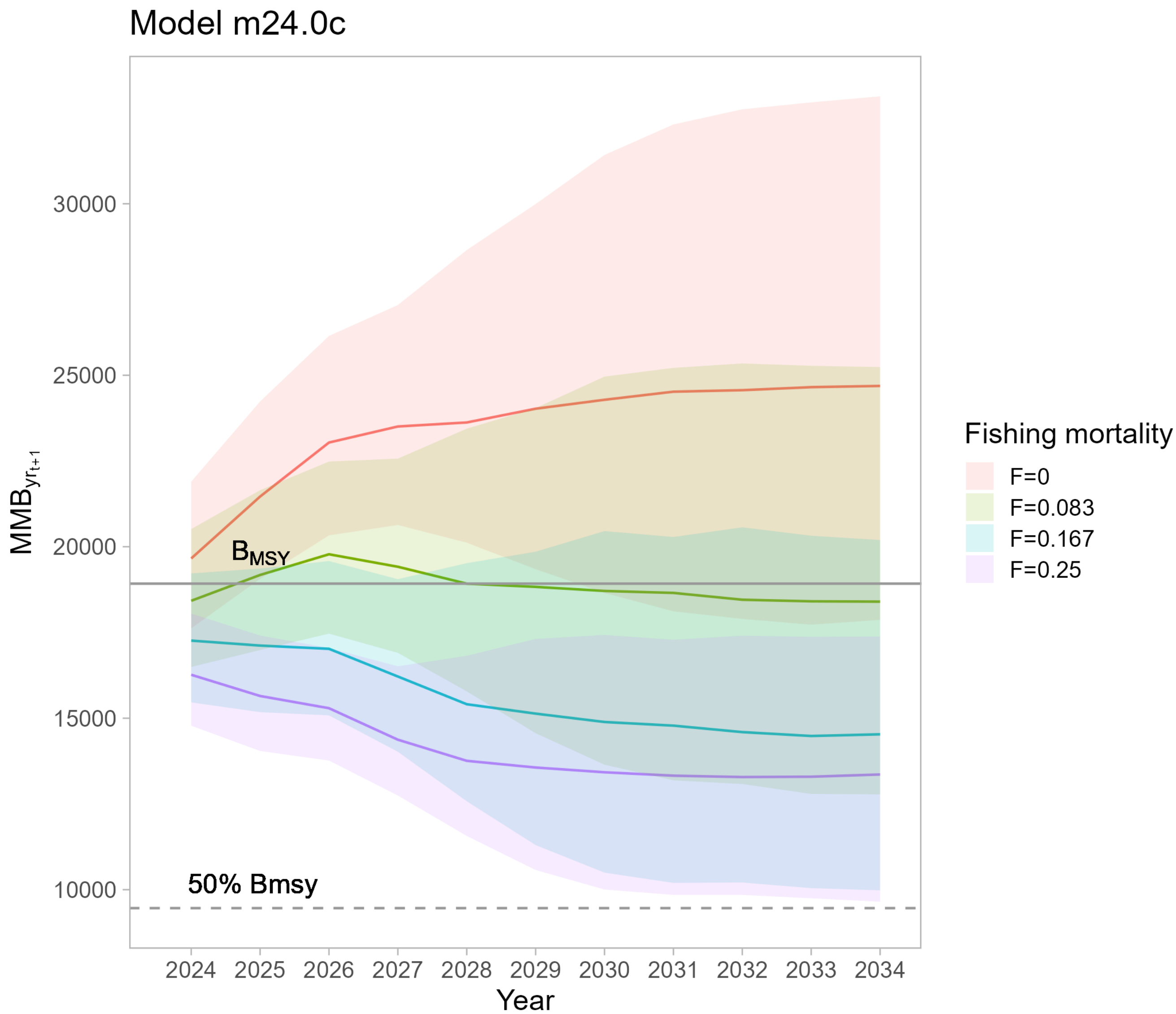

Figure 55: Projected mature male biomass (MMB) on Feb. 15 with four fishing mortalities in the directed fishery: F = 0, F = 0.083, F = 0.167, and F = 0.25, during 2024-2034. Input parameter estimates are based on model 24.0c. Crab year "2024" represents Feb. 15, 2025. Shaded areas represent a 0.05 to 0.95 limits.

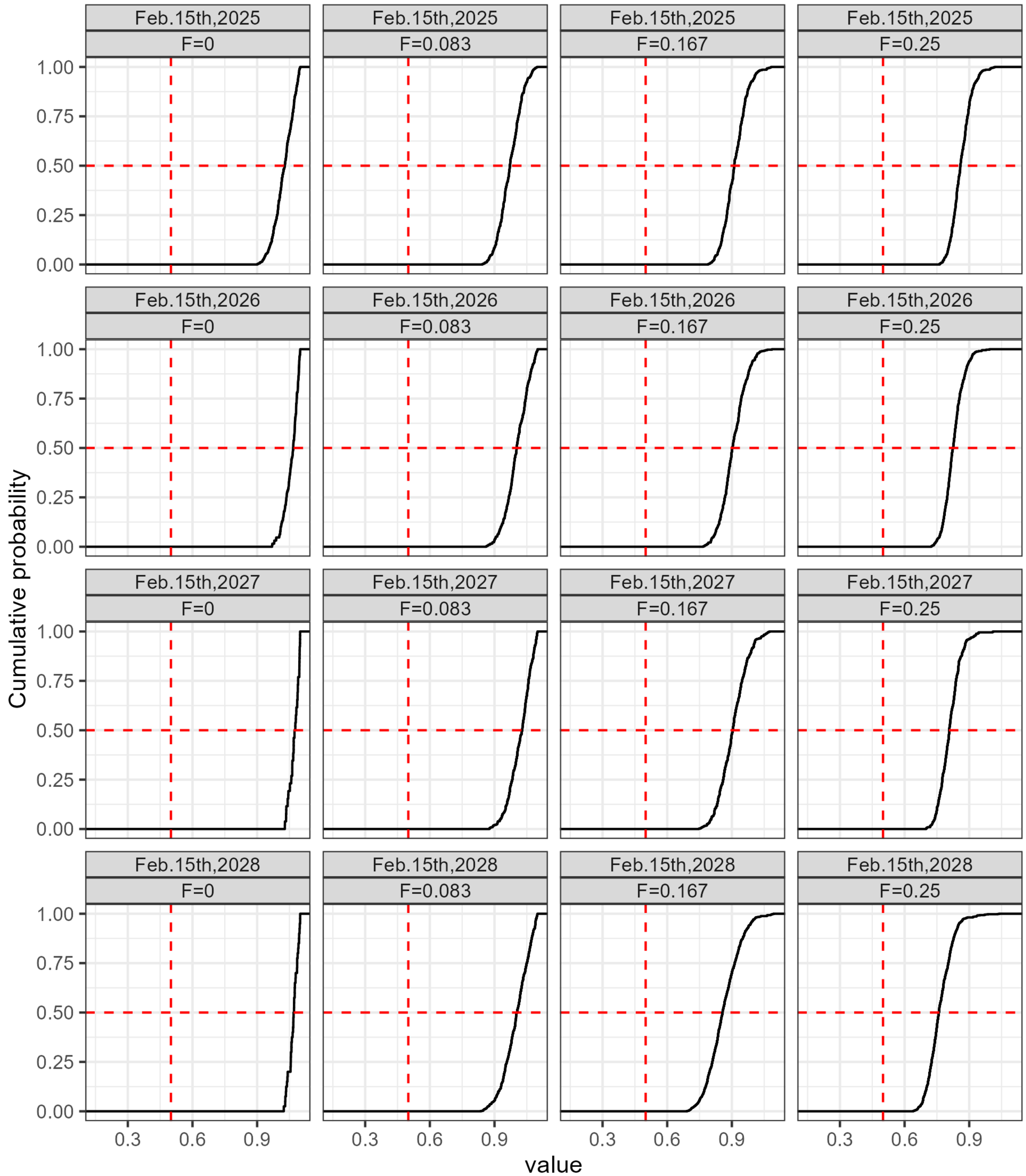

Figure 56: Cumulative probabilities of estimated ratios of MMB during 2024-2027 as represented by projected biomass on Feb.15th in year t+1, to corresponding estimated B35 values under model 24.0c with the MCMC approach and four fishing mortality values. Feb. 15, 2025 represents crab year "2024".

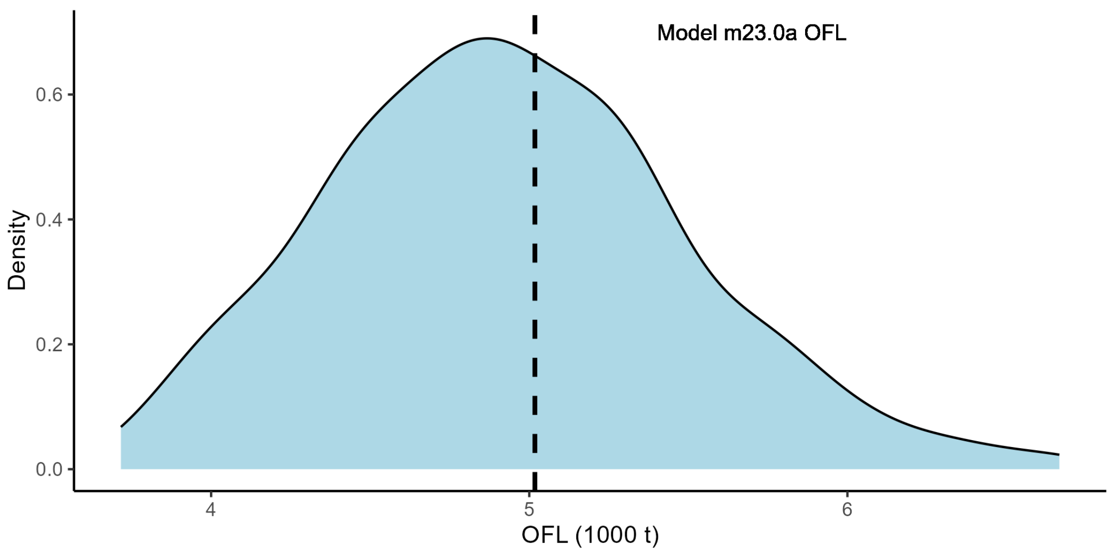

Figure 57: Histogram of the 2024/25 estimated OFL under model 23.0a with the MCMC approach.

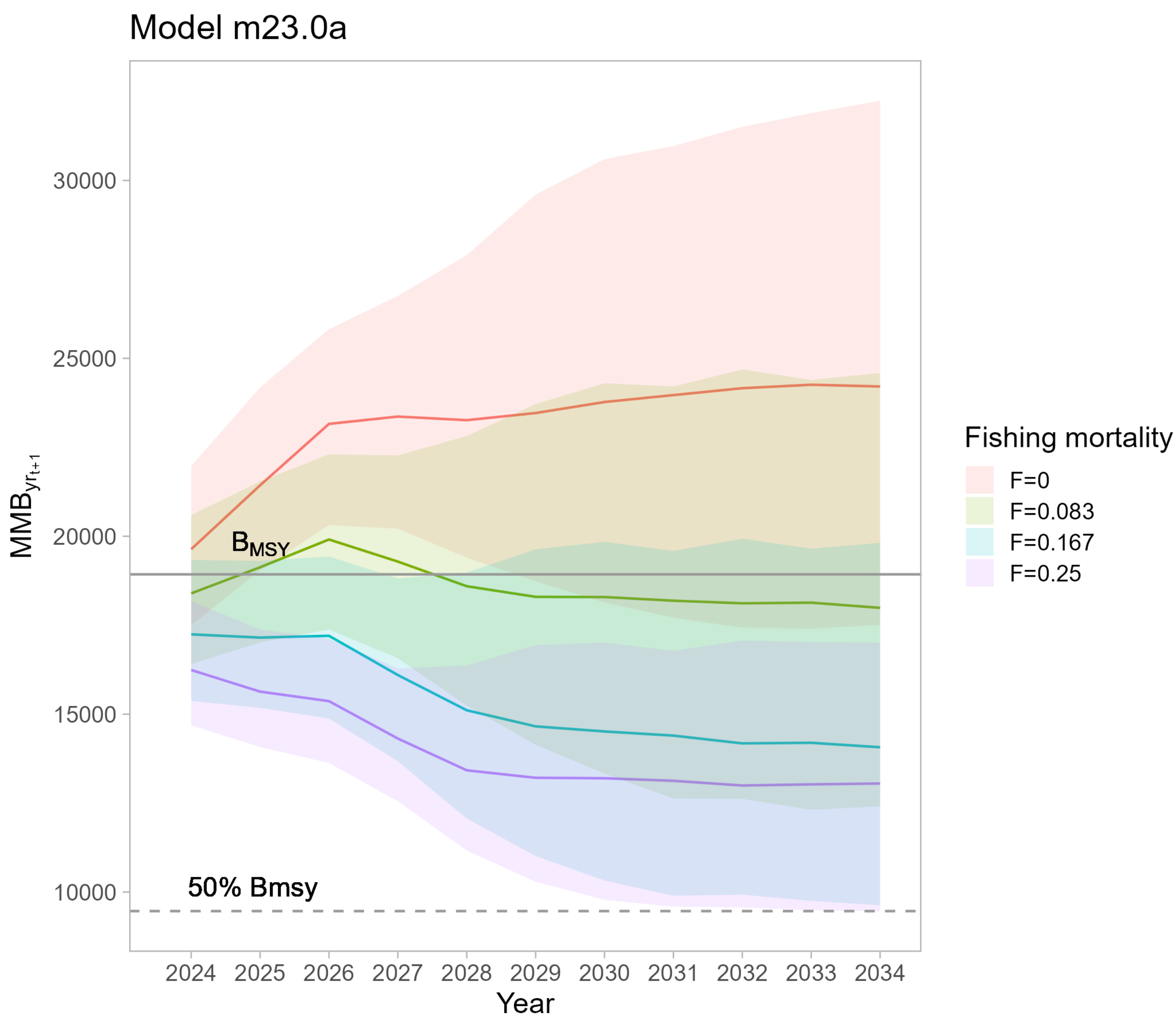

Figure 58: Projected mature male biomass on Feb. 15 with four fishing mortalities in the directed fishery: F = 0, F = 0.083, F = 0.167, and F = 0.25, during 2024-2034. Input parameter estimates are based on model 23.0a. Crab year "2024" represents Feb. 15, 2025. Shaded areas represent 0.05 to 0.95 limits.

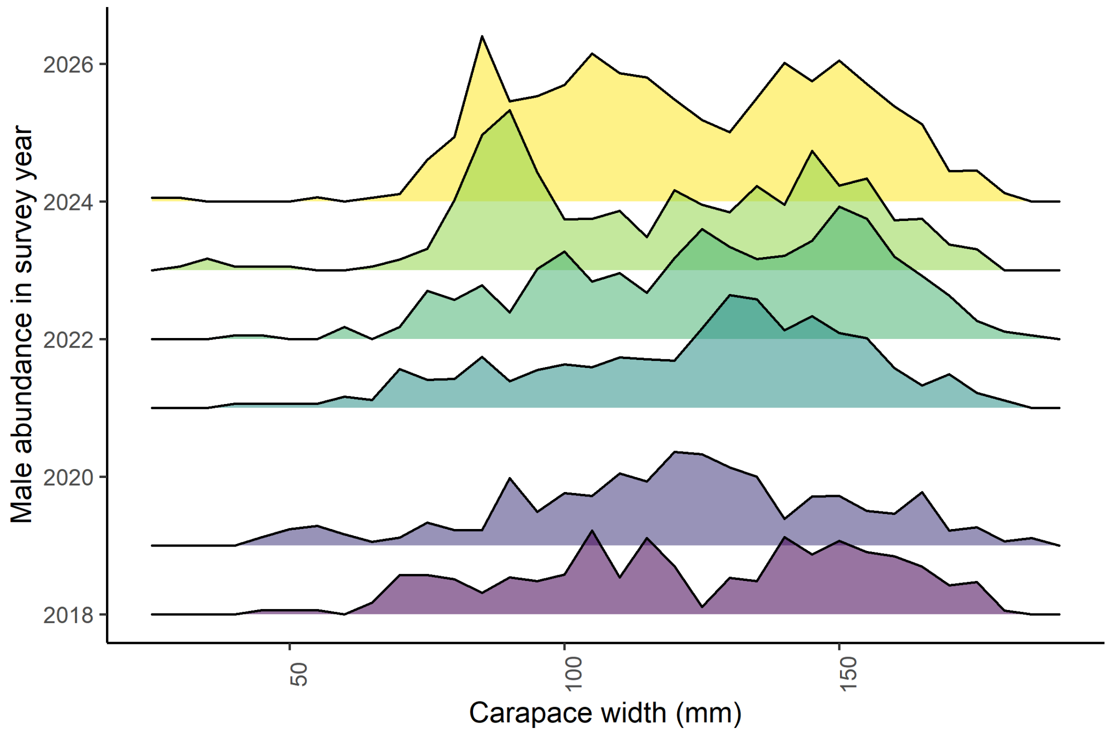

Figure 59: Length frequency distributions of male red king crab in Bristol Bay from NMFS trawl surveys during 2017-2024. For purposes of these graphs, abundance estimates are based on area-swept methods.

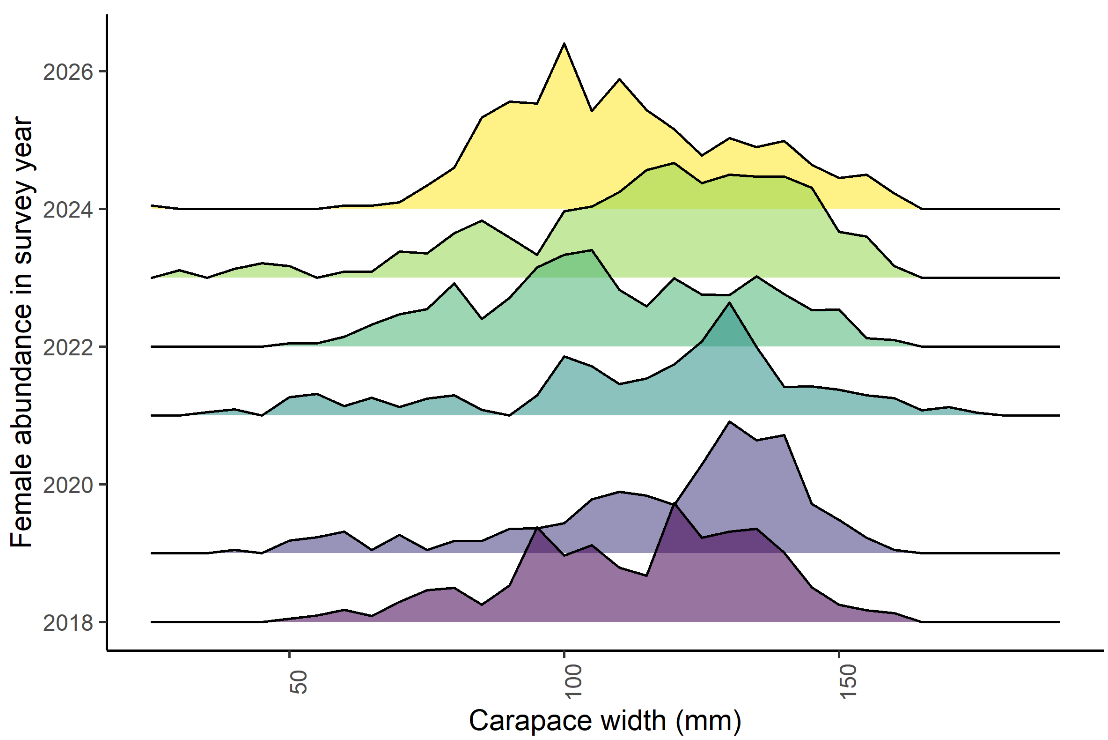

Figure 60: Length frequency distributions of female red king crab in Bristol Bay from NMFS trawl surveys during 2017-2024. For purposes of these graphs, abundance estimates are based on area-swept methods.

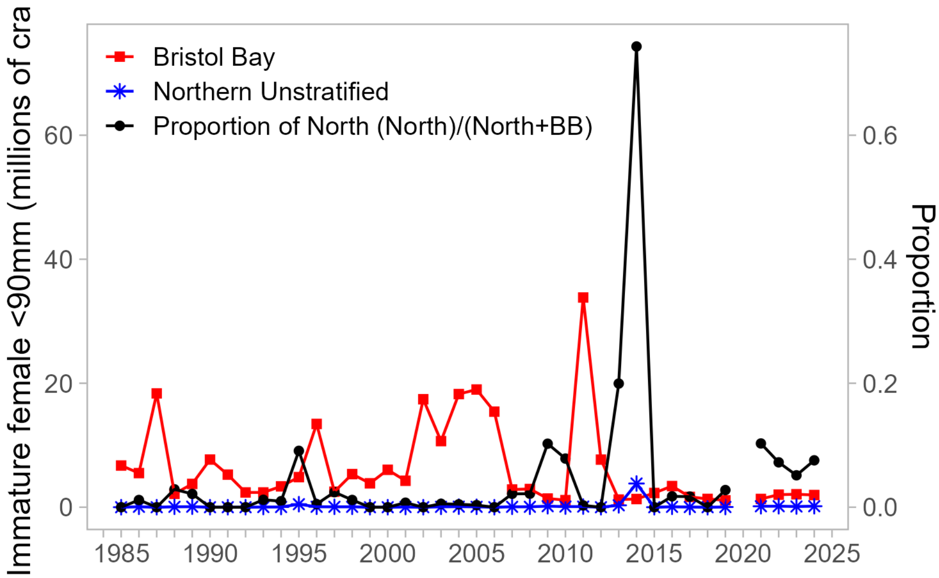

Figure 61: Comparisons of NMFS survey area-swept estimates of total female crab <90 mm CL abundance in Bristol Bay area (BB) and north of Bristol Bay area (North) during 1985-2023.

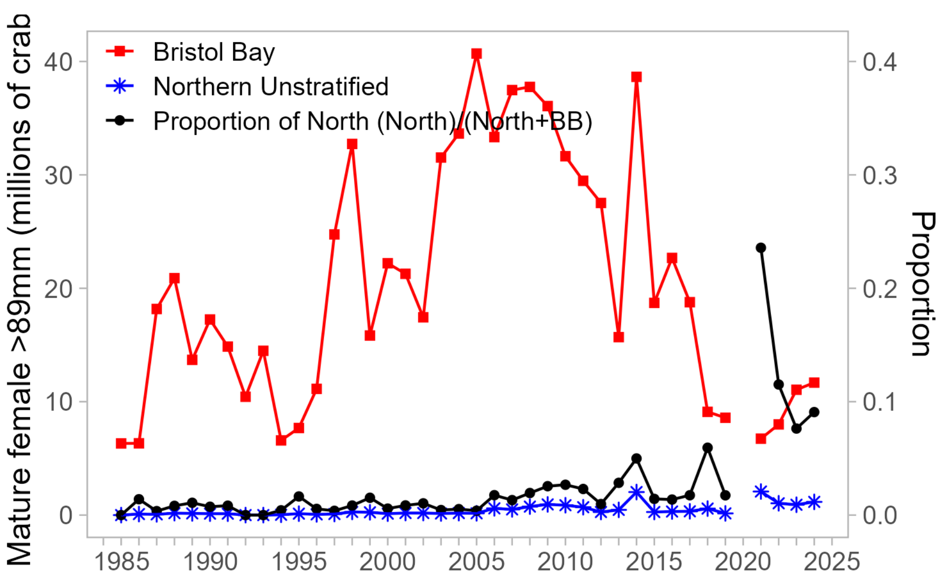

Figure 62: Comparisons of NMFS survey area-swept estimates of mature female crab abundance in Bristol Bay area (BB) and north of Bristol Bay area (North) during 1985-2023.

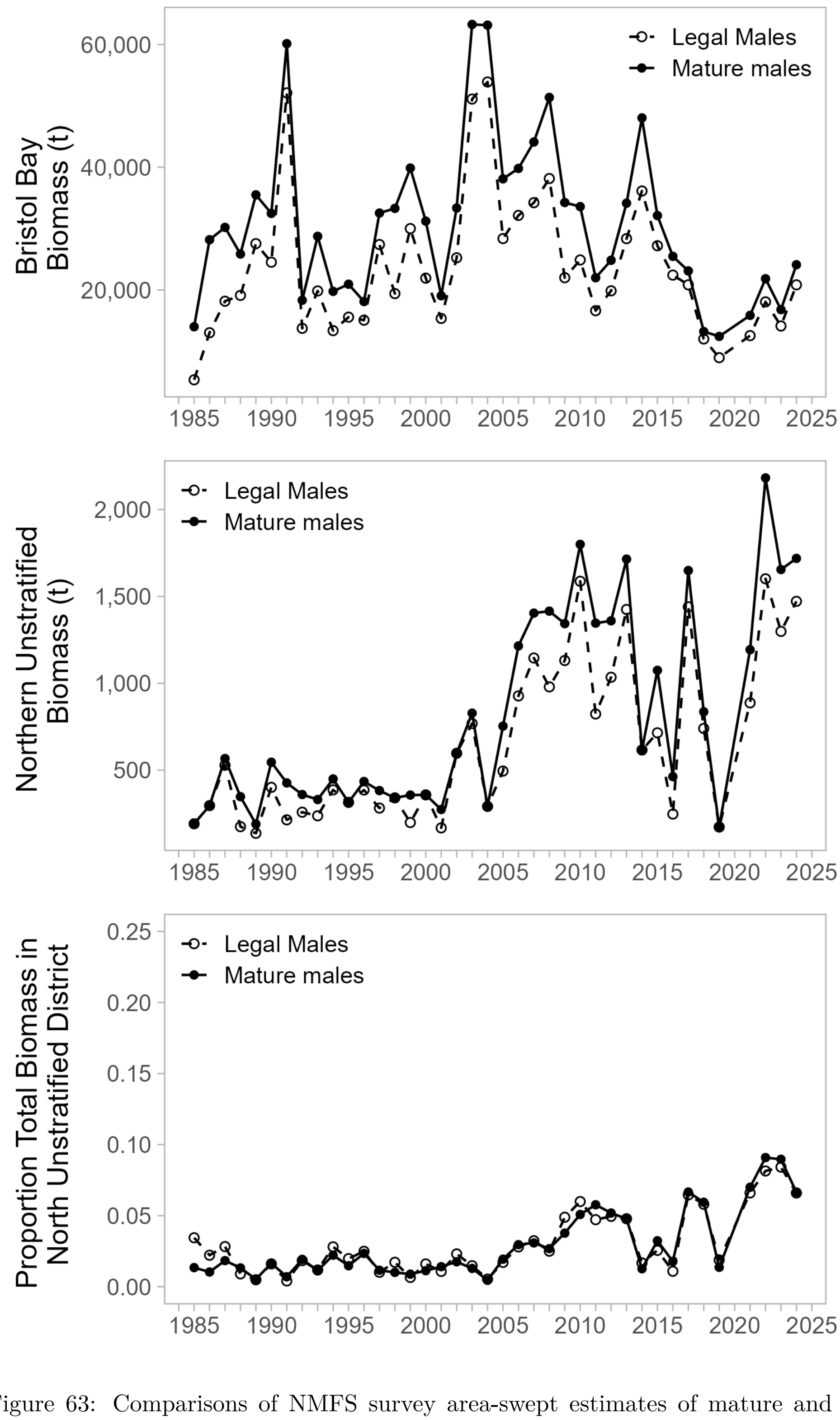

Figure 63: Comparisons of NMFS survey area-swept estimates of mature and legal male abundances in Bristol Bay area (BB) and north of Bristol Bay area (North) during 1985-2024. NOTE the large scale differences between panels 1 and 2.

Appendices

Appendix A, B, and D can be found on the agenda as separate attachments.

Appendix A: Description of GMACS with Bristol Bay Red King Crab Options

Appendix B: Data files for model 23.0a (more readable versions can be requested from teh author - katie.palof@alaska.gov)

Appendix D: Draft Risk Table for BBRKC 2024

Appendix C. Tier 4 fallback REMA exploration

At the March 2023 simpler model working group meeting a "fallback" option for model output was discussed to be used as an alternative option if the current assessment model is not usable. This option is detailed in the working group report under "Proposed"Fallback" model options".

This is a Tier 4 approach where:

- B or current year's biomass is equal to survey-estimated (ideally using the REMA R package) vulnerable male biomass. Vulnerable male biomass is male crabs likely to be susceptible to both the directed and incidental catch fisheries
- OFL = M (adjusted by the stock status as defined in the Crab FMP) * B
- ABC = buffer * OFL

REMA model for BBRKC

For BBRKC the male biomass that is determined to be vulnerable to the directed and incidental catch fisheries is the mature male biomass, crab > 119mm CL. Crab at this size are approximately one or more molt increments away from legal size and therefore are likely to be found with legal size male crab and be vulnerable to discard mortality. This modeling exercise applies two ABC buffers - one similar to the 2023 Tanner crab REMA model, where the ABC buffer is estimated to be the CV of the final year of the REMA output rounded to the nearest 5% (which for 2024 is 15%), and the Tier 3 20% buffer. The Tier 3 resulting ABC (using a buffer of 20%) is labeled ABC in the table below, and the alternative buffer calculation (using a buffer of 15%) is labeled ABC_2.

As defined by the Crab FMP stock status is determined by the current years biomass (B) compared to the average biomass over a period of time. For consistencies with the current modeling approaches for BBRKC the time period used is 1984 to 2023, as this is the same time period that is used in the Tier 3 model for calculation status determination.

Calculation of Reference Points

The Tier 4 OFL is calculated using the F_{OFL} control rule:

$$F_{OFL} = \begin{cases} 0 & \frac{MMB}{B_{MSY}} \leq 0.25 \\ \frac{M(\frac{MMB}{B_{MSY}} - \alpha)}{1-\alpha} & 0.25 < \frac{MMB}{B_{MSY}} < 1 \\ M & MMB > B_{MSY} \end{cases} \tag{2}$$

where MMB is quantified at the mean time of mating date (15 February), B_{MSY} is defined as the average MMB for a specified period, $M = 0.23$ yr^{-1}, and $\alpha = 0.1$. The Tier 4 OFL (Table 21) was calculated by applying a fishing mortality determined by the harvest control rule (above) to the mature male biomass at the time of mating (B_{proj} or Current B).

Table 21: Specificatoins using the REMA output on mature male NFMS trawl survey area-swept biomass.

avgB	Current B	MMB/B_{MSY}	M	F_{OFL}	OFL	ABC	ABC 2
27.94	22.98	0.82	0.23	0.18	4.24	3.39	3.60

Figures

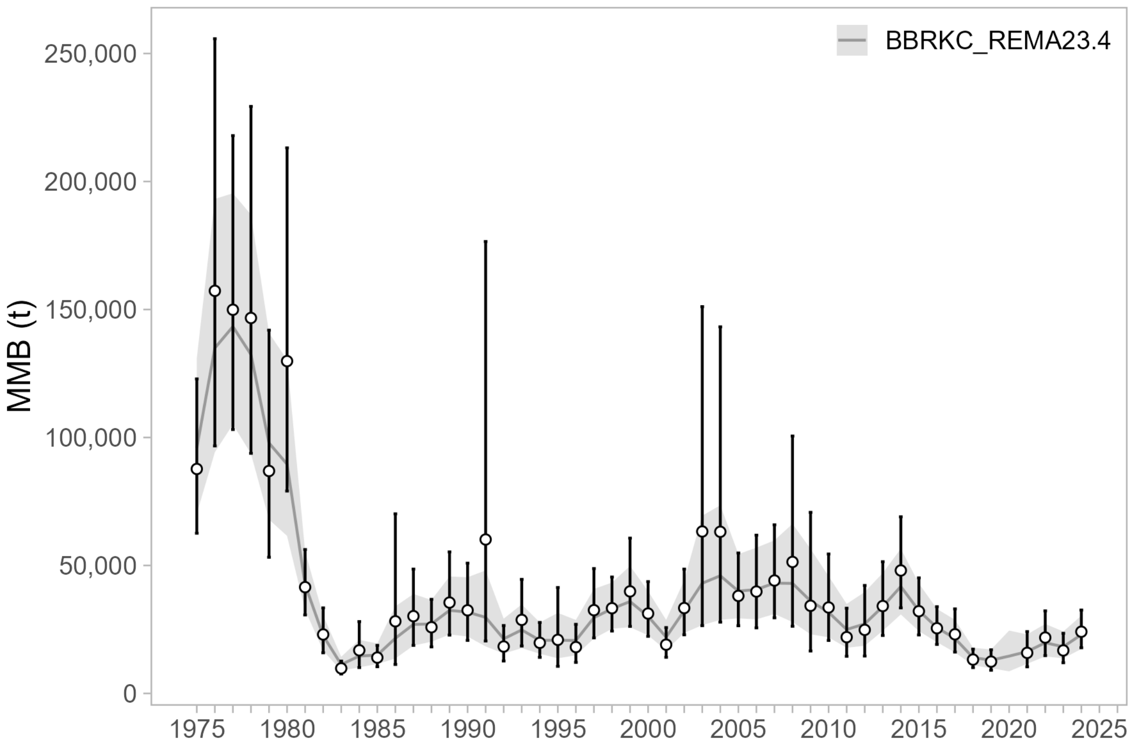

Figure 64: Comparisons of area-swept estimates of mature MALE NMFS survey biomass (males > 119 mm) and REMA model predicted fit.