Bristol Bay red king crab (BBRKC) proposed models May 2023

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Summary

The model explorations presented here include those suggested by CPT and SSC, and model sensitivity to GMACS updates. The model explorations can be divided into four areas of exploration: 1) starting the base model in 1985, which has been considered in prior years, 2) models to explore the base level of natural mortality for males, and 3) models to begin an exploration of Q estimation for the NMFS trawl survey, and 4) exploration of model output without including the survey retow data for females in years where retows were performed (1999, 2000, 2006 to 2012, 2017, and 2021).The models presented here are the beginning of work to explore these topics and the author acknowledges that further exploration is warranted. Additionally, an updated version of GMACS was used for these model explorations and model fit was similar with slight differences in reference point calculations with these updates.

The results of these model explorations are presented in this document in section C. Background on the Bristol Bay red king crab modeling approach, modeling framework (GMACS), and history of the stock and fisheries can be found in the last full SAFE published on the NPFMC website and will not be repeated here. (link here: BBRKC 2022 SAFE)

B. Responses to SSC and CPT

CPT and SSC Comments on Assessments in General

Response to SSC Comments (June 2022, Oct 2022):

"The SSC recommends that the RKC authors work together to complete a stock structure template for June 2023."

Response: A draft stock structure template for RKC in the Bering Sea will be presented at the May 2023 CPT meeting.

"The SSC suggests that the CPT develop guidelines for when to change model start dates"

Response: This topic was taken up at the Jan 2023 CPT meeting, with some basic guidelines presented in those minutes that included keeping data unless there was a strong reason (environmental, poor data quality, model instability) to exclude the data and data exclusion did not lead to drastic model output changes. Model 22.0, where data starts in 1985 vs 1975, is presented in this document.

Response to SSC Comments (from February 2022):

"The SSC supports the CPT general recommendations that all stock assessments include results from the currently accepted model with new data (base model) so that changes in model performance can be assessed. Values for management-related quantities for all models that may be recommended by the CPT or SSC should also be available."

Response: We have followed these recommendations.

CPT and SSC Comments on BBRKC assessment

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 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. Among the models presented here four address variations in M for males, including higher fixed M values and estimated M for males.

"The CPT was interested in more exploration of the retrospective patterns, which seem to have increased since the last assessment despite no new data being added. Reported Mohn's rhos were starting to reach concerning magnitudes in the proposed models?"

Response: The catch and bycatch updates in May 2022 made the retrospective patterns slightly worse than before. 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 and 2021-2022 results in lower biomass estimates in recent years. The biases for total abundance are much smaller than mature male biomass. Explorations further, since May 2022, on retrospective patterns are underway but not presented here.

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 here and will be 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: We followed this recommendation.

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

Response: Model 22.0 start in 1985, and was presented in May 2022, Sept 2023, and in this document. After discussions during the Jan/Feb council cycle the author is uncertain whether removing the early part of the time series is appropriate. However, this model is presented here as an option.

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 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 constraint, 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.

As a reference, we copied the likelihood profile computed in May 2020 below. 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 is as follow:

It appears that the maximum likelihood value is achieved with a base M of 0.31 for males and 0.321 for females.

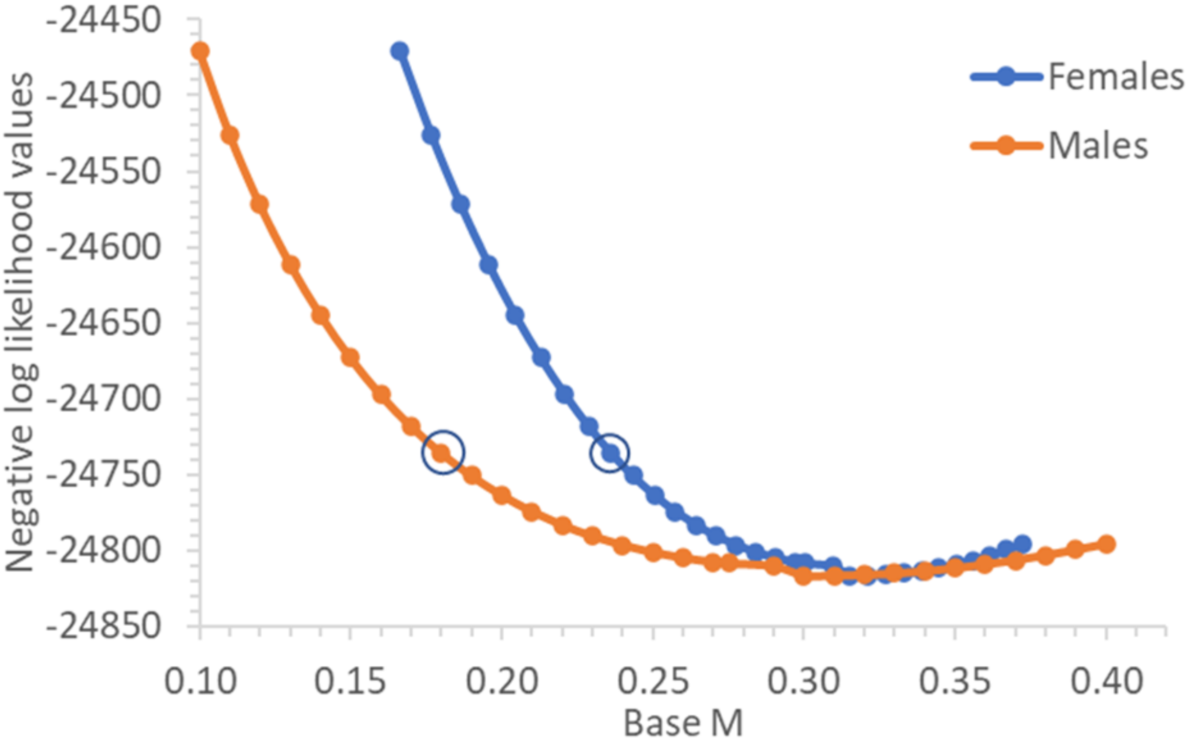

Figure 1: Likelihood profile on M from May 2020 and 2021, current values of M are circled on the profile.

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 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 last full SAFE (see link in summary above).

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 is presented here, in May 2023, was an exploration of the base model (21.1b) without the retow data for females. This model does not drastically affect 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 full SAFE - September 2022 - we plotted more proportional data of the Northern RKC in Figures 35a and 35b. 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 fishery. 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, we hope to revisit this soon.

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: The May 2023 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 this document. 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 authors list of future work to be addressed with explorations of catchability for both surveys, but has not yet been explored in this document.

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 are still ongoing.

C. Modeling Approaches and Explorations for spring 2023

Assessment Methodology

This assessment model uses the GMACS modeling framework (since 2019) and is detailed in Appendix A of the last full SAFE report (link in the summary section). An updated version of GMACS (version 2.01.M.01, 2023-03-13) was used. The fall 2022 assessment used version 2.01.F (2022-04-16). Progress of GMACS development has been documented on the GitHub development site (link GMACS GitHub).

Model explorations

Model explored in this document:

- **21.1b**: base model, accepted for specifications in Fall 2022
- **21.1b (update)**: base model + updated GMACS version
- **22.0:** 21.1b model with data after 1985 instead of 1975
- **23.0**: 21.1b + "base" M value for males fixed at M=0.257 (based on Then et al. 2015)
- **23.0a**: 21.1b + "base" M value for males estimated in the model
- **23.0b**: 21.1b + "base" M value for males fixed at M=0.31 (best estimate based on 2020 likelihood profile work)
- **23.1a**: 21.1b + double CV on NMFS Q prior
- **23.2**: 21.1b without the retow data for females from the NMFS trawl survey (biomass and size comps)
- **23.3**: 23.0a (base M for males estimated) + 23.1a (double CV on NMFS q prior)

Reasoning for model explorations

Nine model scenarios are presented in this report. The first two models have very close results and were compared to determine the sensitivity of the base model to GMACS updates (version 2.01E vs version 2.01.M.01). Small differences in the reference points are present with this update, but overall model fit is nearly identical, including the MLE and likelihood components (Table 4 and 5).

The rest of the model scenarios can be divided into four areas of exploration: 1) starting the base model in 1985, which has been considered in prior years (model 22.0), 2) models to explore the base level of natural mortality for males (models 23.0, 23.0a, 23.0b, and 23.3), and 3) models to begin an exploration of q estimation for the NMFS trawl survey (23.1a and 23.3), and 4) exploration of a model (model 23.2) without including the survey retow data for females in years where a retows were performed (1999, 2000, 2006 to 2012, 2017, and 2021).

The model start date has been discussed in prior modeling scenarios, most specifically in spring of 2022, and was a suggestion from the latest CIE review. Beginning the model in 1985 has advantages which include: a fixed base M value for males, avoiding the dramatic abundance declines of the early 1980s, and recruitment associated with the extremely large M is not including in the $B_{35\%}$ estimate. However, the retrospective pattern on mature male biomass increased with this truncated model, which is troubling and a reason to be cautious in adopting it before determining the cause of the retrospective bias.

Exploring natural mortality has been a repeated theme in this model, with explorations being performed the last few years during spring model scenarios. The models runs here build on those explorations. They include two models with higher fixed base M for males - one at 0.257, which is the estimate of natural mortality based on Then et al. (2015) and is documented in May 2021 proposed runs with a max age of 25, and one at 0.31, which is the estimate of natural mortality for males based on a likelihood profile performed in 2020 (graphical output is included in the SSC/CPT comment responses). Additionally, a model was run that included estimating the base M for males using a log-normal prior with a mean of 0.18 and a CV of 0.04.

Both the recent years CPT/SSC comments and the simpler modeling workshop report suggested that further work be done to determine the most appropriate method to estimate catchability (Q) for the NMFS trawl survey. Currently, initial trawl survey catchability is estimated to be 0.896 with a standard deviation of 0.025 (CV about 0.03) that is based on double-bag experiment results (Weinberg et al. 2004). However, the appropriateness of this prior and the relationship between NMFS trawl survey Q and that assumed for the BSFRF survey should be explored further. The models presented here are just a beginning of this exploration since they assume the same prior distribution mean but increase the variability to a CV of 0.06.

The final model scenario (model 23.2) explored in this document is one to determine the sensitivity of model output to the female retow data being included in the modeling process. Female BBRKC have been observed to delay the molt and mate cycle in cold temperature years. When this occurs catch of females on leg 1 of the NMFS trawl survey can be low and include many females that have egg conditions that are barren, eyed, or hatching. The historic protocol has been to resample females llater in the summer when the percentage of females that have not completed the molt-mate cycle is greater than 10%. Historically this has occurred in eleven years since 1999. When resampling is performed the “retow” data for females at those stations resampled replaces the original data in the biomass and size composition data sets. The male information from the retows is not used. Model 23.2 is the base model (21.1b) with a new data file which includes the original leg 1 female data. More information on the retow procedure and data can be found in the Jan and May 2022 CPT meeting agendas on the NPFMC website.

Results

a. Sensitivity to new GMACS versions

Models 21.1b and 21.1b (update) reflect sensitivities of the model to updates in GMACS. The likelihoods for these two models are identical (Table 4). However, there are slight differences in terminal year MMB, $B_{35\%}$, and resulting F_{ofl} and specifications (Table 2). The estimated $F_{35\%}$ is the same for both models.

b. Effective sample sizes and weighting factors

- CVs are assumed to be 0.03 for retained catch biomass, 0.04 for total male biomass, 0.07 for pot bycatch 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.

- 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, except models 23.1a and 23.3 which the same distribution with a CV of 0.06.

b. Tables of estimates

- Negative log-likelihood values are summarized in Tables 4 – 6 for all models, while parameter estimates are summarized in Tables 7 – 10 for a few respesentative models.
- Natural mortality estimates are shown in Table 3.
- Abundance, MMB, and recruitment time series for a few representative models are found in Tables 11 – 15.

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

- Selectivities by length (Figures 15, 16, and 17)

One of the most important results is estimated trawl survey selectivity. 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 (refer to last full SAFE draft) because survey selectivities include capture probabilities and crab availability. The NMFS survey catchability (Q) 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. Those models with a higher CV on the prior distribution of Q for the NMFS survey both estimated a value above 1.

- Molting probability by length (Figures 18, 19, and 20)

For all models, estimated molting probabilities during 1975-2022 are generally lower than those estimated from the 1954-1961 and 1966-1969 tagging data (Balsiger 1974, Figure 9a and 9b in the last full SAFE). 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.

- NMFS trawl survey biomass and BSFRF surveys (Figures 2 – 9).

The survey male biomass estimates in 2022 are slightly higher than those in 2018, 2019, and 2021, but the survey female biomass estimates are lower than 2018 and 2019, and up slightly from 2021. Estimated population biomass increased dramatically in the mid-1970s then decreased precipitously in the early 1980s. Estimated biomass had increased during 1985-2003 for males and during 1985-2007 for females, then declined, and have steadily declined since the late 2000s.

Among the model scenarios, model estimated relative NMFS survey biomasses are similar, with some changed in scale due to changes in M and Q which is expected. All models fit the catch and bycatch biomasses very well and similarly so they are not presented in this document. Residuals of survey biomasses did not show any consistent patterns for all models (Figures 10 and 11).

The fit to BSFRF survey data are similar among the models, with some variability in scale due to changes in M and trawl survey Q, however these are expected due to the large additional CV placed on these data.

- Recruitment (Figures 12, 13, and 14)

Recruitment time series are plotted for all model scenarios (Figure 12), and also in groups of like models. 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 are generally similar in trends for all models, with those models with higher M values having generally higher recruitment. Like the results of previous models, the terminal year recruitment analysis with model 21.1b suggests the estimated recruitment in the last year should not be used for estimating $B_{35\%}$ (2022 BBRKC SAFE).

- Fishing mortality (Figure 24)

The average of estimated male recruits from 1984 to 2021 for models starting in 1975 and from 1986 to 2021 for models starting in 1985 (Figure 12a) and mature male biomass per recruit are used to estimate B35%. The full fishing mortalities for the directed pot fishery at the time of fishing are plotted against mature male biomass on Feb. 15 in the last full SAFE (See BBRKC 2022 SAFE link and Figures 13a, 13.b and 13c). Estimated fishing mortalities in most years before the current harvest strategy was adopted in 1996 were above F35%. Under the current harvest strategy, estimated fishing mortalities were at or above the F35% limits in 1998-1999, 2005, 2007-2010, and 2014-2019 for models 21.1b, but below the F35% limits in the other post-1995 years. For model 21.1b, estimated full pot fishing mortalities ranged from 0.00 to 2.27 during 1975-2020, with estimated values over 0.40 during 1975-1982, 1984-1987, 1990-1991, 1993, 1998 and 2007-2009 (Figure 24). Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally small and less than 0.07.

- Estimated mature male biomsss (Figures 25, 26, and 27)

Estimated mature male biomass for all models have a similar trend over time, however the scaling of the biomass is highly dependent, as expected, on estimates of natural mortality (M) and Q in the model. Overall, higher estimates of M for males produce larger estimates of mature male biomass for most of the time series. Recent mature male biomass, in the last five years or so, was relatively similar for all models except model 23.1 with the increase in estimated NMFS Q. Model 23.3, which estimates M for males and has a larger CV on the Q prior, produced similar results to the base model, with the except of the last five years (Figure 26). All models were compared to model 22.0 in Figure 27, which allows for a closer look at the more recent time frame since this plot starts in 1985.

- Size composition fits by length and residual bubble plots (Figures 28 – 37).

All models fit the length composition data similarly and well. Modal progressions are tracked well in the trawl survey data, particularly beginning in mid-1990s. Cohorts first seen in the trawl survey data in 1975, 1986, 1990, 1995, 1999, 2002 and 2005 can be tracked over time. Bycatch size composition data provide little information to track modal progression and is not displayed graphically. Residuals of proportions of length are plotted to examine their patterns. Residuals were calculated as observed minus predicted and standardized by the estimated standard deviation. Generally, residuals of proportions of survey males and females appear to be random over length and year for all models, however models with higher base M - models 23.0 and 23.0b - improve the plus group fittings slightly.

d. Retrospective and historical analyses

Retrospective analysis was performed for a selection of models - 21.1b, 22.0, 23.0a, and 23.3 - to represent the base model and determine if the retrospective pattern is reduced by estimating M (model 23.0a), or estimating M and relaxing the prior on Q (model 23.3) (Figures 44 – 47). Retrospective analysis were performed using the GMACS retrospective feature which runs the current years model (2022) and sequentially excludes one year of data to evaluate current model performance in hindcast.

The retrospective pattern for MMB did improve with estimation of M for males, as reported in the Mohn's rho values on Figures 46 and 47, from a Mohn's rho of 0.373 to 0.226. While overall model fit was not improved with estimate of M for males (see likelihood tables) the improved retrospective pattern in MMB maybe a reason to consider this model for specifications in the fall. The base model (21.1b) has a fairly larger retrospective pattern (Mohn's rho = 0.373), and this pattern is increased in model 22.0. The source of the increased retrospective pattern in model 22.0 is one of the hesitations of adopting this reduced data version of model 21.1b for specifications. Further work is needed to understand this increased pattern.

e. Uncertainty and sensitivity analyses.

- Estimated standard deviation of parameters are summarized in Tables 7 – 10 for a few respesentative models.
- The last completed SAFE document in 2022 details uncertainty estimates in the current base model parameterization in further detail (link here: BBRKC 2022 SAFE).

f. Sensitity to NMFS female data in retow years

Model fit and overall performance were similar for the base model run with (21.1b) and without (23.2) the retow data, as reflected in the likelihood table (Table 6). However, the reference points and specifications in this table reflect the overall differences in mature male biomass and subsequent reductions in OFL without the female retow data. Figures 38 – 42 are provided to illustrate the differences in the data sets and estimated mature male biomass (MMB).

Figures 38 and 39 reflect differences in area-swept biomass estimates and model fit to these data. As expected there are no noticeable differences for males since this data is not resampled, however female fit is reduced overall due to the removal of retow stations (Figure 38). Figure 38 reflects the difference in area-swept and model fit in years with retow data, which are shown with two data points in those years. In the retow years the lower data point reflects the "no retow" data set, since leg 1 female biomass in those years is lower than the retow biomass. The lower biomass in the leg 1 survey data for females reflects the females still undergoing their molt-mate cycle and likely being unavailable to the survey sampling area or gear. Years with retow data (99, 00, 06 – 12, 17, 21) have differences in survey size compositions and size composition fits (Figure 40). These differences reflect the larger sample sizes of females in the retows in those years with retow data and the general rightward shift of size distributions in retow data due to those females having completed the molt-mate cycle. Estimated mature male biomass in the model without retow data (23.2) is lower than the base model, reflecting the effects of having less female biomass in the population dynamics model in retow years (Figure 41).

While the overall dynamics and estimation of males in the model are minimally effected by the lack of female retow data, female abundance, specifically, mature female abundance is reduced in most years (Table 15, Figure 43). Mature female abundance (and biomass) is a vital part of the State of Alaska harvest strategy which can trigger closures of this fishery when it drops below a threshold, as has occurred in both the 2021/2022 and the 2022/2023 fisheries. The author supports continuation of the retow/resampling protocol in those years where there are sufficient females that haven't completed the molt-mate cycle. Sampling females at the same time in their annual cycle is vital to accurately modeling the population (both abundance and size compositions) and when this is delayed due to spring temperatures or other factors, changes in the sampling timing (retows) are vital to tracking the population. This analysis did not address the appropriateness of the 10% threshold currently in place, but this has been discussed during the Jan and May 2022 CPT meetings.

g. Comparison of alternative model scenarios.

In this report (May 2023), nine models are compared. For negative likelihood value comparisons (Tables 4 and 5), none of the model runs improved the total likelihood over the base model (21.1b). The base model was run using the most recent updates to GMACS (version 2.01.M.01) and compared to output from the runs in September 2022. The likelihood components of these runs were identical out to three digits, however reference point differences, although small, do exist (Table 4). The difference were determined to be minimal and this updated version of GMACS was used for the rest of the models runs in this report. The rest of the model scenarios are compared to this updated version of the base model 21.1b (update).

Model 22.0 represents the base model with a start date for the data of 1985 instead of 1975. This model was explored in both May 2022 and September 2022, and is presented here as an option to bring forward in September of 2023 if the reduction in data is appropriate. Concerns over the increased retrospective pattern in this model still exist (Figure 45)

Four models (23.0, 23.0a, 23.0b, 23.3) either had higher base natural mortality (M) estimates for males or estimated M. Of these models the two that estimated male natural mortality had slightly better fits than those with higher fixed values, however none of these models improved fit over the base model (21.1b). All of these models increased natural mortality on both the male and female portions of the population, since female mortality is estimated as on offset of males (Table 3). Increases in natural mortality produce models results that increase the scale of recruitment and mature male biomass, but had similar fits to survey data. Larger size classes did appear to fit better with higher natural mortality but this was not reflected in the overall fit to size compositions. Increasing natural mortality on males also leads to higher $\mathrm{F}_{35\%}$ values and therefore larger $\mathrm{F}_{\mathrm{OFL}}$ values. Based on the likelihood profile performed in 2020 (see CPT/SSC comments section Figure 1) it does appear that male natural mortality should be higher than the assumed 0.18 in the base model, however model explorations here did not reflect this improvement in total likelihood. While the author does acknowledge that natural mortality should be updated, determining the correct value or prior to estimate M is important due to the large ramifications on the references points. Future work on natural mortality could include repeating the likelihood profile from 2020, exploring the sensitivity to estimating M with different prior configurations and exploring the relationship between estimating M and Q simultaneously with less informative priors.

Two models (23.1a and 23.3) evaluated increased variability (double the CV) on the very informative prior on Q for the NMFS trawl survey. Increasing the variability in the prior distribution resulted in a Q estimate >1 for both of these models (Table 5). Since the models assume the BSFRF survey catchability (Q) is 1.0, it is not realistic for the Q value for the NMFS survey to be greater than 1. The BSFRF survey uses small mesh sizes, the net footrope goes into mud, and the camera records the net footrope touching and leaving the sea bottom. Therefore, theoretically, it is reasonable to assume its catchability to be 1.0. Earlier model explorations in May 2022 suggested that, when it is allowed to be estimated, the BSFRF catchability is estimated to be greater than 1. Overall, more work is needed to fully address the need to explore Q estimation in this model and how it relates to the assumed catchability of 1.0 for the BSFRF survey. As discussed at the simpler modeling workshop in March 2023, further work is needed to explore the interplay between these two catchability estimates and to determine a prior on NMFS Q that would be less strict and more appropriate.

Based on the above considerations, we recommend model continuing to use the base model (21.1b) for overfishing definition determination in September 2023 due to a simple approach: a fixed base M of 0.18 for males, less confounding between estimating M and survey catchability, and acceptable data fittings. Model 22.0 is also an option, however this reduced data version of the base model has a larger retrospective pattern for mature male biomass, suggesting some caution in transitioning to this version of the base model. We are open to bringing forward variations of models that increase natural mortality but do not have a preferred model at this time for that improvement.

D. Calculation of the OFL and ABC

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

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

Model	Current MMB	B35	MMB/B_{MSY}	F35	F_{OFL}	OFL	avg rec	maleM
21.1b (2022-update)	16.76	22.25	0.75	0.30	0.22	3.21	15.26	0.18
21.1b (2022)	16.95	24.03	0.71	0.30	0.20	3.04		0.18
22.0 1985	16.97	20.48	0.83	0.30	0.24	3.64	13.99	0.18
23.0 M=0.257	14.97	19.14	0.78	0.46	0.35	4.52	25.77	0.26
23.0a Mest	15.43	19.79	0.78	0.40	0.31	4.13	21.97	0.23
23.0b M=0.31	14.09	18.21	0.77	0.58	0.44	5.28	36.23	0.31
23.1a inc CV q	15.49	21.66	0.72	0.30	0.20	2.78	14.68	0.18
23.3 Mest incCV	14.97	19.92	0.75	0.37	0.27	3.49	18.93	0.22

E. Projections and Future Outlook

Projections into the future will be performed in the Sept. 2023 assessment with the models selected from this document.

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

J. Acknowledgements

Drs. Andre Punt, James Ianelli, and D'Arcy Webber first applied BBRKC data to GMACS for stock assessments and our GMACS model mainly comes from their work. Thanks to Tyler Jackson (ADF&G) for assistance with survey data summaries, REMA modeling code and review of this document.

K. References

References can be found in the last full SAFE published on the NPFMC website and will not be repeated here. (link here: BBRKC 2022 SAFE)

Tables

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

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

Model	Current MMB	B35	F35	F_{OFL}	OFL	avg rec
21.1b (2022-update)	16.76	22.25	0.30	0.22	3.21	15.26
21.1b (2022)	16.95	24.03	0.30	0.20	3.04	
22.0 1985	16.97	20.48	0.30	0.24	3.64	13.99
23.0 M=0.257	14.97	19.14	0.46	0.35	4.52	25.77
23.0a Mest	15.43	19.79	0.40	0.31	4.13	21.97
23.0b M=0.31	14.09	18.21	0.58	0.44	5.28	36.23
23.1a inc CV q	15.49	21.66	0.30	0.20	2.78	14.68
23.3 Mest incCV	14.97	19.92	0.37	0.27	3.49	18.93

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

Model	Sex	baseM	1980-84	1985-22
21.1b (2022-update)	Female	0.24	1.17	
21.1b (2022-update)	Male	0.18	0.89	
22.0 1985	Female			0.23
22.0 1985	Male			0.18
23.0 M=0.257	Female	0.29	1.15	
23.0 M=0.257	Male	0.26	1.04	
23.0a Mest	Female	0.27	1.16	
23.0a Mest	Male	0.23	0.99	
23.0b M=0.31	Female	0.32	1.16	
23.0b M=0.31	Male	0.31	1.13	
23.1a inc CV q	Female	0.24	1.18	
23.1a inc CV q	Male	0.18	0.88	
23.3 Mest incCV	Female	0.26	1.17	
23.3 Mest incCV	Male	0.22	0.96	

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

Component	Ref22	Ref23s	m23.0	m23.0a	m23.0b	m23.1a	m23.3
Pot-ret-catch	-60.88	-60.88	-62.32	-61.86	-63.32	-61.59	-61.97
Pot-totM-catch	26.55	26.55	25.44	25.87	24.37	25.25	25.29
Pot-F-discC	-55.70	-55.70	-55.72	-55.71	-55.72	-55.69	-55.71
Trawl-discC	-63.75	-63.75	-63.75	-63.75	-63.75	-63.74	-63.75
Tanner-M-discC	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54
Tanner-F-discC	-43.48	-43.48	-43.52	-43.51	-43.52	-43.48	-43.50
Fixed-discC	-36.04	-36.04	-36.04	-36.04	-36.04	-36.04	-36.04
Traw-suv-bio	-35.47	-35.47	-37.38	-37.66	-35.69	-36.47	-37.70
BSFRF-sur-bio	-2.94	-2.94	-5.51	-4.83	-6.47	-1.74	-3.28
Pot-ret-comp	-3932.20	-3932.20	-3941.02	-3938.84	-3945.00	-3933.46	-3937.79
Pot-totM-comp	-2369.46	-2369.46	-2370.57	-2370.25	-2371.05	-2370.45	-2370.66
Pot-discF-comp	-1449.36	-1449.36	-1449.76	-1449.83	-1449.45	-1449.48	-1449.91
Trawl-disc-comp	-5836.10	-5836.10	-5846.22	-5843.90	-5849.24	-5833.97	-5840.29
Tanner-disc-comp	-1274.28	-1274.28	-1277.41	-1276.99	-1277.43	-1274.82	-1276.69
Fixed-disc-comp	-3393.50	-3393.50	-3389.38	-3390.67	-3386.48	-3393.24	-3391.35
Trawl-sur-comp	-6984.67	-6984.67	-6994.36	-6993.08	-6993.27	-6989.36	-6994.41
BSFRF-sur-comp	-843.53	-843.53	-845.00	-845.16	-843.83	-844.36	-845.40
Recruit-dev	70.56	70.56	71.88	71.47	72.93	70.39	71.06
Recruit-ini	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recruit-sex-R	76.98	76.98	76.98	76.98	77.02	76.95	76.96
$Log_f dev_0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	43.83	43.83	39.05	40.27	36.96	43.73	41.22
Sex-specific-R	0.01	0.01	0.02	0.01	0.04	0.01	0.00
Ini-size-struct		30.88	35.30	33.72	39.36	31.28	33.07
PriorDensity	267.30	267.30	227.65	252.04	220.97	271.19	259.03
Tot-likelihood	-25908.79	-25908.79	-25985.17	-25955.27	-25992.17	-25912.63	-25945.36
Tot-likeli-no-PD	-25641.49	-25641.49	-25757.52	-25703.23	-25771.20	-25641.45	-25686.33
Tot-parameter	372.00	372.00	372.00	373.00	372.00	372.00	373.00
MMB35	24026.11	22250.75	19136.75	19786.44	18209.52	21655.02	19919.11
MMB-terminal	16952.82	16761.49	14970.68	15431.45	14092.35	15489.83	14971.20
F35	0.30	0.30	0.46	0.40	0.58	0.30	0.37
$F_o fl$	0.20	0.22	0.35	0.31	0.44	0.20	0.27
OFL	3035.63	3213.98	4517.20	4132.66	5284.13	2783.29	3492.78
ABC	2428.50	2571.19	3613.76	3306.13	4227.30	2226.63	2794.22
NMFS Q	0.97	0.97	0.93	0.94	0.91	1.05	1.01

Table 5: Comparisons of negative log-likelihood values and some parameters for year and Q model scenarios.

Component	Ref22	Ref23s	m22.0	m23.1a	m23.3
Pot-ret-catch	-60.88	-60.88	-34.89	-61.59	-61.97
Pot-totM-catch	26.55	26.55	26.55	25.25	25.29
Pot-F-discC	-55.70	-55.70	-55.70	-55.69	-55.71
Trawl-discC	-63.75	-63.75	-51.28	-63.74	-63.75
Tanner-M-discC	-43.54	-43.54	-26.12	-43.54	-43.54
Tanner-F-discC	-43.48	-43.48	-26.08	-43.48	-43.50
Fixed-discC	-36.04	-36.04	-36.04	-36.04	-36.04
Traw-suv-bio	-35.47	-35.47	-44.09	-36.47	-37.70
BSFRF-sur-bio	-2.94	-2.94	-3.33	-1.74	-3.28
Pot-ret-comp	-3932.20	-3932.20	-3131.80	-3933.46	-3937.79
Pot-totM-comp	-2369.46	-2369.46	-2370.52	-2370.45	-2370.66
Pot-discF-comp	-1449.36	-1449.36	-1449.09	-1449.48	-1449.91
Trawl-disc-comp	-5836.10	-5836.10	-4681.05	-5833.97	-5840.29
Tanner-disc-comp	-1274.28	-1274.28	-1273.40	-1274.82	-1276.69
Fixed-disc-comp	-3393.50	-3393.50	-3394.74	-3393.24	-3391.35
Trawl-sur-comp	-6984.67	-6984.67	-5503.89	-6989.36	-6994.41
BSFRF-sur-comp	-843.53	-843.53	-842.35	-844.36	-845.40
Recruit-dev	70.56	70.56	41.27	70.39	71.06
Recruit-ini	0.00	0.00	0.00	0.00	0.00
Recruit-sex-R	76.98	76.98	60.67	76.95	76.96
$Log_f dev_0$	0.00	0.00	0.00	0.00	0.00
M-deviation	43.83	43.83	0.00	43.73	41.22
Sex-specific-R	0.01	0.01	0.15	0.01	0.00
Ini-size-struct		30.88	50.88	31.28	33.07
PriorDensity	267.30	267.30	233.93	271.19	259.03
Tot-likelihood	-25908.79	-25908.79	-22510.90	-25912.63	-25945.36
Tot-likeli-no-PD	-25641.49	-25641.49	-22276.97	-25641.45	-25686.33
Tot-parameter	372.00	372.00	308.00	372.00	373.00
MMB35	24026.11	22250.75	20482.89	21655.02	19919.11
MMB-terminal	16952.82	16761.49	16974.17	15489.83	14971.20
F35	0.30	0.30	0.30	0.30	0.37
$F_o fl$	0.20	0.22	0.24	0.20	0.27
OFL	3035.63	3213.98	3644.53	2783.29	3492.78
ABC	2428.50	2571.19	2915.62	2226.63	2794.22
NMFS Q	0.97	0.97	0.94	1.05	1.01

Table 6: Comparisons of negative log-likelihood values and some parameters for base with WITHOUT retow data. The differnce between values in the base model (21.1b) and the no retow model calculated here.

Component	Ref23s	m23.2	Ref23s - m23.2
Pot-ret-catch	-60.88	-61.13	0.25
Pot-totM-catch	26.55	26.33	0.22
Pot-F-discC	-55.70	-55.69	-0.01
Trawl-discC	-63.75	-63.75	0.00
Tanner-M-discC	-43.54	-43.54	0.00
Tanner-F-discC	-43.48	-43.48	0.00
Fixed-discC	-36.04	-36.04	0.00
Traw-suv-bio	-35.47	-28.41	-7.06
BSFRF-sur-bio	-2.94	-2.32	-0.62
Pot-ret-comp	-3932.20	-3930.20	-2.00
Pot-totM-comp	-2369.46	-2369.30	-0.16
Pot-discF-comp	-1449.36	-1446.12	-3.24
Trawl-disc-comp	-5836.10	-5839.11	3.01
Tanner-disc-comp	-1274.28	-1276.42	2.14
Fixed-disc-comp	-3393.50	-3389.12	-4.38
Trawl-sur-comp	-6984.67	-6988.66	3.99
BSFRF-sur-comp	-843.53	-851.34	7.80
Recruit-dev	70.56	70.46	0.10
Recruit-ini	0.00	0.00	0.00
Recruit-sex-R	76.98	76.80	0.18
$Log_f dev_0$	0.00	0.00	0.00
M-deviation	43.83	43.34	0.49
Sex-specific-R	0.01	0.00	0.00
Ini-size-struct	30.88	30.13	0.75
PriorDensity	267.30	270.47	-3.17
Tot-likelihood	-25908.79	-25907.09	-1.71
Tot-likeli-no-PD	-25641.49	-25636.62	-4.87
Tot-parameter	372.00	372.00	0.00
MMB35	22250.75	21948.38	302.37
MMB-terminal	16761.49	16096.94	664.55
F35$Fofl$	0.22	0.21	0.01
OFL	3213.98	2986.65	227.34
ABC	2571.19	2389.32	181.87
NMFS Q	0.97	0.96	0.01

Table 7: Summary of estimated model parameter values and standard deviations for model 21.1b for Bristol Bay red king crab.

Index	Name	Value	StdDev	index	name	value	stddev
1	theta[2]	0.2806	0.0137	47	log-slx-pars[1]	4.7589	0.0081
2	theta[4]	19.8230	0.0492	48	log-slx-pars[2]	2.2637	0.0457
3	theta[5]	16.2130	0.1382	49	$log-slx-pars[3]$	4.5067	0.0164
4	theta[7]	0.6801	0.1269	50	$log-slx-pars[4]$	2.0196	0.1128
5	theta[9]	-0.4722	0.2300	51	$log-slx-pars[5]$	5.1532	0.0562
6	theta[13]	0.9585	0.4197	52	$log-slx-pars[6]$	2.8524	0.0451
7	theta[14]	0.6513	0.4686	53	$log-slx-pars[7]$	4.7198	0.2203
8	theta[15]	0.8577	0.3327	54	$log-slx-pars[8]$	2.1642	0.3057
9	theta[16]	0.7070	0.3050	55	$log-slx-pars[9]$	4.7461	0.0776
10	theta[17]	0.5437	0.2950	56	$log-slx-pars[10]$	0.9000	0.3036
11	theta[18]	0.4993	0.2773	57	$log-slx-pars[11]$	4.7902	0.0225
12	theta[19]	0.3417	0.2776	58	$log-slx-pars[12]$	2.3401	0.0861
13	theta[20]	0.3758	0.2641	59	$log-slx-pars[13]$	4.1063	0.1760
14	theta[21]	0.4077	0.2585	60	$log-slx-pars[14]$	2.2340	0.3785
15	theta[22]	0.1806	0.2815	61	$log-slx-pars[15]$	3.7730	0.6042
16	theta[23]	0.1583	0.2773	62	$log-slx-pars[16]$	3.2901	0.4094
17	theta[24]	0.0527	0.2871	63	$log-slx-pars[17]$	4.4273	0.0293
18	theta[25]	0.1687	0.2626	64	$log-slx-pars[18]$	2.4346	0.0717
19	theta[26]	-0.0101	0.2037	65	$log-slx-pars[19]$	4.9232	0.0015
20	theta[27]	-0.2385	0.1957	66	$log-slx-pars[20]$	0.6733	0.0533
21	theta[28]	-0.3903	0.1978	67	$log-slx-pars[21]$	4.9323	0.0020
22	theta[29]	-0.7380	0.2114	68	$log-slx-pars[22]$	0.7269	0.0987
23	theta[30]	-1.1978	0.2326	69	$log-fbar[1]$	-1.5741	0.0424
24	theta[31]	-1.2427	0.2349	70	$log-fbar[2]$	-4.3057	0.0753
25	theta[52]	1.2937	0.6788	71	$log-fbar[3]$	-5.5994	0.2891
26	theta[53]	1.4536	0.4621	72	$log-fbar[4]$	-6.5135	0.0720
27	theta[54]	1.3953	0.3671	73	$log-fdev[1]$	0.8181	0.1187
28	theta[55]	1.1698	0.3356	74	$log-fdev[1]$	0.7763	0.0905
29	theta[56]	1.0828	0.2950	75	$log-fdev[1]$	0.6876	0.0742
30	theta[57]	0.6001	0.3185	76	$log-fdev[1]$	0.7811	0.0603
31	theta[58]	0.2144	0.3527	77	$log-fdev[1]$	0.9930	0.0541
32	theta[59]	-0.0245	0.3616	78	$log-fdev[1]$	1.8613	0.0563
33	theta[60]	-0.2143	0.3548	79	$log-fdev[1]$	2.3941	0.1192
34	theta[61]	-0.5455	0.3741	80	$log-fdev[1]$	0.8159	0.1766
35	theta[62]	-0.9321	0.3856	81	$log-fdev[1]$	-8.8971	0.1258
36	theta[63]	-1.1898	0.3902	82	$log-fdev[1]$	1.1431	0.1123
37	theta[64]	-1.4206	0.3887	83	$log-fdev[1]$	1.2166	0.0892
38	theta[65]	-1.7907	0.3767	84	$log-fdev[1]$	1.3864	0.0731
39	theta[66]	-1.8971	0.3727	85	$log-fdev[1]$	0.9205	0.0641
40	theta[67]	-1.8384	0.3524	86	$log-fdev[1]$	-0.0176	0.0529
41	Grwth[21]	0.9724	0.1853	87	$log-fdev[1]$	0.0970	0.0474
42	Grwth[42]	1.4543	0.1221	88	$log-fdev[1]$	0.7447	0.0387
43	Grwth[85]	142.5000	1.7272	89	$log-fdev[1]$	0.7579	0.0413
44	Grwth[86]	0.0577	0.0101	90	$log-fdev[1]$	0.2422	0.0460
45	Grwth[87]	139.8900	0.5962	91	$log-fdev[1]$	0.9096	0.0506
46	Grwth[88]	0.0709	0.0033	92	$log-fdev[1]$	-4.2422	0.0485
93	$log-fdev[1]$	-4.6513	0.0420	143	$log-fdev[2]$	-0.2215	0.1035
94	$log-fdev[1]$	-0.1805	0.0407	144	$log-fdev[2]$	-0.9811	0.1029
95	$log-fdev[1]$	-0.1322	0.0411	145	$log-fdev[2]$	-0.2115	0.1028
96	$log-fdev[1]$	0.7830	0.0435	146	$log-fdev[2]$	-0.5106	0.1026

97	$log - fdev[1]$	0.4264	0.0425	147	$log - fdev[2]$	-0.6040	0.1023
98	$log - fdev[1]$	-0.1598	0.0410	148	$log - fdev[2]$	-0.3709	0.1023
99	$log - fdev[1]$	-0.2393	0.0406	149	$log - fdev[2]$	-0.6464	0.1022
100	$log - fdev[1]$	-0.1277	0.0395	150	$log - fdev[2]$	-0.4768	0.1020
101	$log - fdev[1]$	0.3365	0.0383	151	$log - fdev[2]$	-0.3992	0.1020
102	$log - fdev[1]$	0.2944	0.0383	152	$log - fdev[2]$	-0.4264	0.1022
103	$log - fdev[1]$	0.5850	0.0388	153	$log - fdev[2]$	-0.7837	0.1023
104	$log - fdev[1]$	0.3386	0.0382	154	$log - fdev[2]$	-0.9316	0.1023
105	$log - fdev[1]$	0.7039	0.0382	155	$log - fdev[2]$	-1.3938	0.1020
106	$log - fdev[1]$	0.8744	0.0398	156	$log - fdev[2]$	-1.9139	0.1022
107	$log - fdev[1]$	0.6904	0.0405	157	$log - fdev[2]$	-1.1986	0.1024
108	$log - fdev[1]$	0.5603	0.0399	158	$log - fdev[2]$	-1.7623	0.1027
109	$log - fdev[1]$	-0.0753	0.0388	159	$log - fdev[2]$	-1.3781	0.1034
110	$log - fdev[1]$	-0.1510	0.0380	160	$log - fdev[2]$	-0.8520	0.1050
111	$log - fdev[1]$	0.0361	0.0379	161	$log - fdev[2]$	-0.4181	0.1072
112	$log - fdev[1]$	0.3656	0.0384	162	$log - fdev[2]$	-0.4827	0.1097
113	$log - fdev[1]$	0.4381	0.0407	163	$log - fdev[2]$	-0.3890	0.1126
114	$log - fdev[1]$	0.4372	0.0460	164	$log - fdev[2]$	-0.4206	0.1148
115	$log - fdev[1]$	0.3470	0.0544	165	$log - fdev[2]$	-1.4143	0.1154
116	$log - fdev[1]$	0.1558	0.0641	166	$log - fdev[3]$	-0.1164	0.0682
117	$log - fdev[1]$	0.0952	0.0724	167	$log - fdev[3]$	0.6699	0.0682
118	$log - fdev[1]$	-0.3416	0.0762	168	$log - fdev[3]$	1.2283	0.0682
119	$log - fdev[1]$	-4.7973	0.0754	169	$log - fdev[3]$	1.0927	0.0682
120	$log - fdev[2]$	0.1955	0.1246	170	$log - fdev[3]$	1.3825	0.0682
121	$log - fdev[2]$	0.6344	0.1164	171	$log - fdev[3]$	1.4243	0.0682
122	$log - fdev[2]$	0.6136	0.1106	172	$log - fdev[3]$	0.9927	0.0682
123	$log - fdev[2]$	0.6898	0.1090	173	$log - fdev[3]$	0.4764	0.0682
124	$log - fdev[2]$	1.4063	0.1117	174	$log - fdev[3]$	-0.9874	0.0682
125	$log - fdev[2]$	1.1759	0.1308	175	$log - fdev[3]$	-0.5787	0.0682
126	$log - fdev[2]$	2.4577	0.1315	176	$log - fdev[3]$	-1.0994	0.0682
127	$log - fdev[2]$	2.1780	0.1190	177	$log - fdev[3]$	-0.2563	0.0682
128	$log - fdev[2]$	3.3979	0.1162	178	$log - fdev[3]$	0.9401	0.0682
129	$log - fdev[2]$	2.1920	0.1113	179	$log - fdev[3]$	1.4182	0.0682
130	$log - fdev[2]$	1.1294	0.1111	180	$log - fdev[3]$	3.2392	0.0753
131	$log - fdev[2]$	0.6759	0.1087	181	$log - fdev[3]$	1.2842	0.0952
132	$log - fdev[2]$	1.4523	0.1044	182	$log - fdev[3]$	0.5810	0.1195
133	$log - fdev[2]$	0.0217	0.1035	183	$log - fdev[3]$	-0.7569	0.0817
134	$log - fdev[2]$	0.4752	0.1035	184	$log - fdev[3]$	-2.1370	0.0733
135	$log - fdev[2]$	0.8987	0.1047	185	$log - fdev[3]$	-2.9906	0.0931
136	$log - fdev[2]$	0.7353	0.1050	186	$log - fdev[3]$	-2.4124	0.1116
137	$log - fdev[2]$	1.2117	0.1077	187	$log - fdev[3]$	-3.4942	0.0753
138	$log - fdev[2]$	-0.5556	0.1048	188	$log - fdev[3]$	-0.8446	0.0935
139	$log - fdev[2]$	-0.8423	0.1033	189	$log - fdev[3]$	-0.1192	0.1111
140	$log - fdev[2]$	-0.7744	0.1035	190	$log - fdev[3]$	1.0639	0.1328
141	$log - fdev[2]$	-1.2399	0.1034	191	$log - fdev[4]$	0.5616	0.1029
142	$log - fdev[2]$	0.0581	0.1038	192	$log - fdev[4]$	-0.0995	0.1020
193	$log - fdev[4]$	-0.3142	0.1025	243	$log - fdov[1]$	-0.2264	0.0781
194	$log - fdev[4]$	0.6062	0.1017	244	$log - fdov[1]$	0.8337	0.0786
195	$log - fdev[4]$	-1.8220	0.1012	245	$log - fdov[1]$	0.2865	0.0802
196	$log - fdev[4]$	0.1333	0.1008	246	$log - fdov[1]$	-0.3643	0.0830
197	$log - fdev[4]$	-0.1242	0.1005	247	$log - fdov[1]$	0.9639	0.0873
198	$log - fdev[4]$	-0.9575	0.1004	248	$log - fdov[1]$	-0.1064	0.0910
199	$log - fdev[4]$	-0.7831	0.1002	249	$log - fdov[1]$	-0.6262	0.0930
200	$log - fdev[4]$	-0.5087	0.1001	250	$log - fdov[1]$	2.9719	0.0935

201	$log - fdev[4]$	-0.5550	0.0998	251	$log - fdov[3]$	-0.0000	0.0962
202	$log - fdev[4]$	-0.0075	0.0998	252	$log - fdov[3]$	0.0001	0.0962
203	$log - fdev[4]$	-0.7066	0.1001	253	$log - fdov[3]$	0.0003	0.0963
204	$log - fdev[4]$	-1.7032	0.0999	254	$log - fdov[3]$	0.0002	0.0963
205	$log - fdev[4]$	-2.5377	0.0995	255	$log - fdov[3]$	0.0004	0.0963
206	$log - fdev[4]$	-1.0571	0.0992	256	$log - fdov[3]$	0.0001	0.0963
207	$log - fdev[4]$	-0.5014	0.0993	257	$log - fdov[3]$	-0.0001	0.0963
208	$log - fdev[4]$	0.6391	0.0992	258	$log - fdov[3]$	-0.0002	0.0962
209	$log - fdev[4]$	1.4910	0.0994	259	$log - fdov[3]$	-0.0002	0.0962
210	$log - fdev[4]$	1.1751	0.0998	260	$log - fdov[3]$	-0.0001	0.0962
211	$log - fdev[4]$	0.3451	0.1006	261	$log - fdov[3]$	-0.0001	0.0962
212	$log - fdev[4]$	1.9485	0.1021	262	$log - fdov[3]$	0.0001	0.0962
213	$log - fdev[4]$	2.2071	0.1034	263	$log - fdov[3]$	0.0003	0.0962
214	$log - fdev[4]$	1.0046	0.1051	264	$log - fdov[3]$	0.0008	0.0963
215	$log - fdev[4]$	0.7948	0.1071	265	$log - fdov[3]$	1.5461	0.1689
216	$log - fdev[4]$	0.7711	0.1086	266	$log - fdov[3]$	1.8041	0.1204
217	$log - foff[1]$	-2.7810	0.0392	267	$log - fdov[3]$	0.5732	0.1410
218	$log - foff[3]$	-0.0947	0.4139	268	$log - fdov[3]$	-3.4397	0.1083
219	$log - fdov[1]$	1.9692	0.0834	269	$log - fdov[3]$	-2.1342	0.1452
220	$log - fdov[1]$	-0.7007	0.0826	270	$log - fdov[3]$	-0.7753	0.1260
221	$log - fdov[1]$	1.9731	0.0839	271	$log - fdov[3]$	0.0427	0.1316
222	$log - fdov[1]$	1.8095	0.0855	272	$log - fdov[3]$	0.3874	0.1024
223	$log - fdov[1]$	-0.4211	0.0843	273	$log - fdov[3]$	0.9426	0.1675
224	$log - fdov[1]$	-0.1909	0.0823	274	$log - fdov[3]$	0.1621	0.1524
225	$log - fdov[1]$	-3.6958	0.0813	275	$log - fdov[3]$	0.8893	0.1668
226	$log - fdov[1]$	-0.3284	0.0819	276	rec-dev-est	1.0659	0.2693
227	$log - fdov[1]$	1.4567	0.0821	277	rec-dev-est	0.6272	0.2946
228	$log - fdov[1]$	-2.7733	0.0813	278	rec-dev-est	1.0732	0.2404
229	$log - fdov[1]$	1.1551	0.0805	279	rec-dev-est	1.6579	0.2066
230	$log - fdov[1]$	0.8810	0.0805	280	rec-dev-est	1.9213	0.2160
231	$log - fdov[1]$	-1.8656	0.0799	281	rec-dev-est	1.1274	0.2568
232	$log - fdov[1]$	1.2178	0.0800	282	rec-dev-est	2.3960	0.1651
233	$log - fdov[1]$	0.4249	0.0800	283	rec-dev-est	1.4422	0.1793
234	$log - fdov[1]$	0.9582	0.0795	284	rec-dev-est	1.0719	0.1664
235	$log - fdov[1]$	-1.2260	0.0790	285	rec-dev-est	-0.7683	0.2501
236	$log - fdov[1]$	-0.1865	0.0790	286	rec-dev-est	0.3220	0.1627
237	$log - fdov[1]$	-0.4497	0.0793	287	rec-dev-est	-0.8427	0.2446
238	$log - fdov[1]$	-0.7143	0.0795	288	rec-dev-est	-1.2692	0.2766
239	$log - fdov[1]$	-0.2328	0.0793	289	rec-dev-est	-1.0076	0.2228
240	$log - fdov[1]$	-1.1290	0.0784	290	rec-dev-est	-0.0539	0.1637
241	$log - fdov[1]$	-1.8454	0.0780	291	rec-dev-est	-0.5177	0.1838
242	$log - fdov[1]$	0.1777	0.0780	292	rec-dev-est	-1.9847	0.3571
293	rec-dev-est	-0.8862	0.1972	339	logit-rec-prop-est	0.7513	0.7366
294	rec-dev-est	-2.0231	0.4237	340	logit-rec-prop-est	0.2314	0.2837
295	rec-dev-est	0.9938	0.1467	341	logit-rec-prop-est	-0.2221	0.6917
296	rec-dev-est	-0.9359	0.2604	342	logit-rec-prop-est	-0.2982	0.0868
297	rec-dev-est	-1.5991	0.3392	343	logit-rec-prop-est	1.3170	0.6596
298	rec-dev-est	-0.5730	0.1984	344	logit-rec-prop-est	0.4308	0.6458
299	rec-dev-est	0.4228	0.1553	345	logit-rec-prop-est	0.4978	0.3237
300	rec-dev-est	-0.5679	0.2245	346	logit-rec-prop-est	-0.0487	0.1405
301	rec-dev-est	-0.5344	0.2394	347	logit-rec-prop-est	0.1927	0.3629
302	rec-dev-est	0.8500	0.1540	348	logit-rec-prop-est	-0.5306	0.3733
303	rec-dev-est	-0.6268	0.2651	349	logit-rec-prop-est	-0.4892	0.1243
304	rec-dev-est	-0.6977	0.2646	350	logit-rec-prop-est	-0.4194	0.4259

305	rec-dev-est	0.5861	0.1563
306	rec-dev-est	-0.1504	0.1822
307	rec-dev-est	-0.5422	0.1890
308	rec-dev-est	-1.1242	0.2364
309	rec-dev-est	-0.9923	0.2360
310	rec-dev-est	-0.0097	0.1777
311	rec-dev-est	-0.5566	0.2266
312	rec-dev-est	-1.1029	0.2326
313	rec-dev-est	-1.4205	0.2224
314	rec-dev-est	-1.8899	0.2675
315	rec-dev-est	-1.4276	0.2247
316	rec-dev-est	-0.7559	0.1743
317	rec-dev-est	-1.6191	0.2571
318	rec-dev-est	-0.8157	0.1965
319	rec-dev-est	-1.4246	0.2768
320	rec-dev-est	-1.3345	0.2789
321	rec-dev-est	-1.2031	0.2729
322	rec-dev-est	-0.8933	0.3155
323	logit-rec-prop-est	-0.0931	0.4330
324	logit-rec-prop-est	-0.8439	0.5129
325	logit-rec-prop-est	-0.2348	0.3572
326	logit-rec-prop-est	-0.4392	0.2662
327	logit-rec-prop-est	0.0778	0.2548
328	logit-rec-prop-est	0.2729	0.3358
329	logit-rec-prop-est	0.3426	0.1403
330	logit-rec-prop-est	0.3951	0.2307
331	logit-rec-prop-est	-0.0948	0.1752
332	logit-rec-prop-est	0.4617	0.4628
333	logit-rec-prop-est	-0.4967	0.1653
334	logit-rec-prop-est	0.2060	0.4188
335	logit-rec-prop-est	-0.1060	0.4577
336	logit-rec-prop-est	0.4334	0.3885
337	logit-rec-prop-est	-0.0908	0.1666
338	logit-rec-prop-est	0.1670	0.2418
351	logit-rec-prop-est	0.0090	0.4443
352	logit-rec-prop-est	-0.3928	0.1385
353	logit-rec-prop-est	-0.0906	0.2371
354	logit-rec-prop-est	0.3604	0.2802
355	logit-rec-prop-est	-0.1851	0.3702
356	logit-rec-prop-est	-0.4287	0.3590
357	logit-rec-prop-est	-0.7863	0.1942
358	logit-rec-prop-est	-0.4598	0.3166
359	logit-rec-prop-est	-0.5222	0.3463
360	logit-rec-prop-est	-0.2282	0.3318
361	logit-rec-prop-est	-0.2873	0.4284
362	logit-rec-prop-est	-0.3142	0.3272
363	logit-rec-prop-est	0.3314	0.2184
364	logit-rec-prop-est	0.5365	0.4742
365	logit-rec-prop-est	0.8001	0.3077
366	logit-rec-prop-est	0.1872	0.4672
367	logit-rec-prop-est	0.6617	0.5233
368	logit-rec-prop-est	0.1945	0.4444
369	logit-rec-prop-est	-0.7554	0.5133
370	m-dev-est[1]	1.5942	0.0295
371	survey-q[1]	0.9671	0.0251
372	$log - add - cv$[2]	-0.7751	0.2733

Table 8: Summary of estimated model parameter values and standard deviations for model 23.0a for Bristol Bay red king crab.

Index	Name	Value	StdDev	index	name	value	stddev
1	theta[1]	0.2331	0.0065	47	Grwth[88]	0.0691	0.0035
2	theta[2]	0.1544	0.0185	48	log-slx-pars[1]	4.7802	0.0083
3	theta[4]	20.0280	0.0596	49	log-slx-pars[2]	2.2732	0.0423
4	theta[5]	16.5630	0.1451	50	log-slx-pars[3]	4.5591	0.0191
5	theta[7]	0.7479	0.1240	51	log-slx-pars[4]	2.2112	0.0946
6	theta[9]	-0.5331	0.2146	52	log-slx-pars[5]	5.1257	0.0434
7	theta[13]	1.0859	0.4288	53	log-slx-pars[6]	2.7762	0.0405
8	theta[14]	0.7391	0.4898	54	log-slx-pars[7]	4.7167	0.2357
9	theta[15]	0.9577	0.3347	55	log-slx-pars[8]	2.1674	0.3045
10	theta[16]	0.7955	0.3038	56	log-slx-pars[9]	4.7354	0.0913
11	theta[17]	0.6109	0.2927	57	log-slx-pars[10]	0.9032	0.3027
12	theta[18]	0.5505	0.2737	58	log-slx-pars[11]	4.8117	0.0220
13	theta[19]	0.3709	0.2744	59	log-slx-pars[12]	2.3382	0.0765
14	theta[20]	0.3822	0.2619	60	log-slx-pars[13]	4.1733	0.1085
15	theta[21]	0.3964	0.2556	61	log-slx-pars[14]	2.2435	0.3168
16	theta[22]	0.1539	0.2775	62	log-slx-pars[15]	4.1083	0.2409
17	theta[23]	0.1163	0.2733	63	log-slx-pars[16]	3.6372	0.4140
18	theta[24]	-0.0083	0.2842	64	log-slx-pars[17]	4.4685	0.0277
19	theta[25]	0.0844	0.2641	65	log-slx-pars[18]	2.5731	0.0769
20	theta[26]	-0.0845	0.2038	66	log-slx-pars[19]	4.9234	0.0015
21	theta[27]	-0.3290	0.1967	67	log-slx-pars[20]	0.6752	0.0524
22	theta[28]	-0.4861	0.1988	68	log-slx-pars[21]	4.9326	0.0020
23	theta[29]	-0.8382	0.2124	69	log-slx-pars[22]	0.7324	0.0972
24	theta[30]	-1.3001	0.2331	70	log-fbar[1]	-1.6187	0.0441
25	theta[31]	-1.3442	0.2354	71	log-fbar[2]	-4.3429	0.0757
26	theta[52]	1.3448	0.8001	72	log-fbar[3]	-5.7198	0.3290
27	theta[53]	1.5540	0.4965	73	log-fbar[4]	-6.5428	0.0768
28	theta[54]	1.4512	0.3825	74	log-fdev[1]	0.8007	0.1206
29	theta[55]	1.2009	0.3505	75	log-fdev[1]	0.7665	0.0912
30	theta[56]	1.1192	0.3025	76	log-fdev[1]	0.6884	0.0753
31	theta[57]	0.6424	0.3224	77	log-fdev[1]	0.7813	0.0616
32	theta[58]	0.2368	0.3562	78	log-fdev[1]	0.9948	0.0559
33	theta[59]	-0.0025	0.3595	79	log-fdev[1]	1.8659	0.0589
34	theta[60]	-0.2019	0.3501	80	log-fdev[1]	2.4172	0.1136
35	theta[61]	-0.5439	0.3686	81	log-fdev[1]	0.8647	0.1534
36	theta[62]	-0.9395	0.3800	82	log-fdev[1]	-8.8006	0.1030
37	theta[63]	-1.1990	0.3847	83	log-fdev[1]	1.3204	0.1000
38	theta[64]	-1.4322	0.3834	84	log-fdev[1]	1.3569	0.0918
39	theta[65]	-1.8200	0.3725	85	log-fdev[1]	1.4454	0.0776
40	theta[66]	-1.9288	0.3689	86	log-fdev[1]	0.9361	0.0669
41	theta[67]	-1.8713	0.3489	87	log-fdev[1]	-0.0302	0.0545
42	Grwth[21]	0.9767	0.1886	88	log-fdev[1]	0.0792	0.0486
43	Grwth[42]	1.4075	0.1236	89	log-fdev[1]	0.7237	0.0398
44	Grwth[85]	143.0300	1.7313	90	log-fdev[1]	0.7267	0.0430
45	Grwth[86]	0.0556	0.0096	91	log-fdev[1]	0.2086	0.0475
46	Grwth[87]	141.1000	0.6200	92	log-fdev[1]	0.8649	0.0517
93	log-fdev[1]	-4.3008	0.0490	143	log-fdev[2]	0.0445	0.1040
94	log-fdev[1]	-4.6952	0.0424	144	log-fdev[2]	-0.2468	0.1039
95	log-fdev[1]	-0.2051	0.0409	145	log-fdev[2]	-1.0096	0.1032
96	log-fdev[1]	-0.1388	0.0412	146	log-fdev[2]	-0.2314	0.1031

97	log-fdev[1]	0.7782	0.0438	147	log-fdev[2]	-0.5212	0.1027
98	log-fdev[1]	0.3973	0.0433	148	log-fdev[2]	-0.6170	0.1025
99	log-fdev[1]	-0.1915	0.0417	149	log-fdev[2]	-0.3855	0.1025
100	log-fdev[1]	-0.2561	0.0411	150	log-fdev[2]	-0.6625	0.1024
101	log-fdev[1]	-0.1359	0.0399	151	log-fdev[2]	-0.4949	0.1021
102	log-fdev[1]	0.3243	0.0386	152	log-fdev[2]	-0.4223	0.1022
103	log-fdev[1]	0.2820	0.0387	153	log-fdev[2]	-0.4535	0.1026
104	log-fdev[1]	0.5749	0.0392	154	log-fdev[2]	-0.8170	0.1027
105	log-fdev[1]	0.3201	0.0386	155	log-fdev[2]	-0.9725	0.1027
106	log-fdev[1]	0.6846	0.0387	156	log-fdev[2]	-1.4306	0.1024
107	log-fdev[1]	0.8515	0.0408	157	log-fdev[2]	-1.9392	0.1024
108	log-fdev[1]	0.6524	0.0418	158	log-fdev[2]	-1.2108	0.1026
109	log-fdev[1]	0.5088	0.0415	159	log-fdev[2]	-1.7657	0.1028
110	log-fdev[1]	-0.1278	0.0400	160	log-fdev[2]	-1.3759	0.1036
111	log-fdev[1]	-0.1909	0.0388	161	log-fdev[2]	-0.8398	0.1050
112	log-fdev[1]	0.0097	0.0385	162	log-fdev[2]	-0.3882	0.1070
113	log-fdev[1]	0.3428	0.0389	163	log-fdev[2]	-0.4297	0.1094
114	log-fdev[1]	0.4146	0.0409	164	log-fdev[2]	-0.3145	0.1123
115	log-fdev[1]	0.4198	0.0453	165	log-fdev[2]	-0.3331	0.1144
116	log-fdev[1]	0.3469	0.0525	166	log-fdev[2]	-1.3200	0.1149
117	log-fdev[1]	0.1823	0.0613	167	log-fdev[3]	-0.1163	0.0682
118	log-fdev[1]	0.1457	0.0693	168	log-fdev[3]	0.6699	0.0682
119	log-fdev[1]	-0.2790	0.0731	169	log-fdev[3]	1.2283	0.0682
120	log-fdev[1]	-4.7253	0.0729	170	log-fdev[3]	1.0926	0.0682
121	log-fdev[2]	0.1908	0.1256	171	log-fdev[3]	1.3824	0.0682
122	log-fdev[2]	0.6376	0.1173	172	log-fdev[3]	1.4242	0.0682
123	log-fdev[2]	0.6215	0.1115	173	log-fdev[3]	0.9927	0.0682
124	log-fdev[2]	0.7011	0.1103	174	log-fdev[3]	0.4764	0.0682
125	log-fdev[2]	1.4266	0.1132	175	log-fdev[3]	-0.9874	0.0682
126	log-fdev[2]	1.2059	0.1254	176	log-fdev[3]	-0.5787	0.0682
127	log-fdev[2]	2.4987	0.1224	177	log-fdev[3]	-1.0994	0.0682
128	log-fdev[2]	2.2450	0.1129	178	log-fdev[3]	-0.2563	0.0682
129	log-fdev[2]	3.4905	0.1126	179	log-fdev[3]	0.9401	0.0682
130	log-fdev[2]	2.2673	0.1121	180	log-fdev[3]	1.4182	0.0682
131	log-fdev[2]	1.1623	0.1124	181	log-fdev[3]	3.2374	0.0757
132	log-fdev[2]	0.6743	0.1098	182	log-fdev[3]	1.2740	0.1066
133	log-fdev[2]	1.4344	0.1052	183	log-fdev[3]	0.5416	0.1255
134	log-fdev[2]	-0.0040	0.1040	184	log-fdev[3]	-0.7739	0.0858
135	log-fdev[2]	0.4376	0.1041	185	log-fdev[3]	-2.1191	0.0739
136	log-fdev[2]	0.8497	0.1056	186	log-fdev[3]	-2.9807	0.0999
137	log-fdev[2]	0.6888	0.1057	187	log-fdev[3]	-2.4166	0.1179
138	log-fdev[2]	1.1494	0.1083	188	log-fdev[3]	-3.5061	0.0753
139	log-fdev[2]	-0.6066	0.1051	189	log-fdev[3]	-0.8306	0.0965
140	log-fdev[2]	-0.8805	0.1036	190	log-fdev[3]	-0.1014	0.1205
141	log-fdev[2]	-0.8017	0.1037	191	log-fdev[3]	1.0888	0.1480
142	log-fdev[2]	-1.2516	0.1035	192	log-fdev[4]	0.5354	0.1033
193	log-fdev[4]	-0.1110	0.1023	243	log-fdov[1]	0.2110	0.0784
194	log-fdev[4]	-0.3297	0.1028	244	log-fdov[1]	-0.1903	0.0785
195	log-fdev[4]	0.5787	0.1021	245	log-fdov[1]	0.8783	0.0791
196	log-fdev[4]	-1.8490	0.1015	246	log-fdov[1]	0.3366	0.0805
197	log-fdev[4]	0.1143	0.1011	247	log-fdov[1]	-0.3153	0.0829
198	log-fdev[4]	-0.1395	0.1007	248	log-fdov[1]	1.0008	0.0864
199	log-fdev[4]	-0.9756	0.1006	249	log-fdov[1]	-0.0793	0.0897
200	log-fdev[4]	-0.7992	0.1004	250	log-fdov[1]	-0.5981	0.0916

201	log-fdev[4]	-0.5267	0.1002	251	log-fdov[1]	3.0015	0.0926
202	log-fdev[4]	-0.5748	0.1000	252	log-fdov[3]	-0.0000	0.0962
203	log-fdev[4]	-0.0272	0.1000	253	log-fdov[3]	0.0001	0.0962
204	log-fdev[4]	-0.7285	0.1004	254	log-fdov[3]	0.0003	0.0962
205	log-fdev[4]	-1.7312	0.1002	255	log-fdov[3]	0.0003	0.0963
206	log-fdev[4]	-2.5709	0.0998	256	log-fdov[3]	0.0004	0.0963
207	log-fdev[4]	-1.0855	0.0995	257	log-fdov[3]	0.0001	0.0963
208	log-fdev[4]	-0.5186	0.0994	258	log-fdov[3]	-0.0001	0.0963
209	log-fdev[4]	0.6324	0.0994	259	log-fdov[3]	-0.0001	0.0962
210	log-fdev[4]	1.4905	0.0995	260	log-fdov[3]	-0.0001	0.0962
211	log-fdev[4]	1.1825	0.1000	261	log-fdov[3]	-0.0001	0.0962
212	log-fdev[4]	0.3654	0.1008	262	log-fdov[3]	-0.0001	0.0962
213	log-fdev[4]	1.9858	0.1021	263	log-fdov[3]	0.0000	0.0962
214	log-fdev[4]	2.2644	0.1035	264	log-fdov[3]	0.0002	0.0962
215	log-fdev[4]	1.0785	0.1052	265	log-fdov[3]	0.0006	0.0963
216	log-fdev[4]	0.8782	0.1072	266	log-fdov[3]	1.4844	0.1578
217	log-fdev[4]	0.8613	0.1087	267	log-fdov[3]	1.7767	0.1284
218	log-foff[1]	-2.8025	0.0447	268	log-fdov[3]	0.5891	0.1472
219	log-foff[3]	-0.1343	0.4895	269	log-fdov[3]	-3.4400	0.1110
220	log-fdov[1]	1.9330	0.0840	270	log-fdov[3]	-2.1828	0.1752
221	log-fdov[1]	-0.7196	0.0832	271	log-fdov[3]	-0.8074	0.1321
222	log-fdov[1]	1.9554	0.0844	272	log-fdov[3]	0.0363	0.1371
223	log-fdov[1]	1.7974	0.0858	273	log-fdov[3]	0.3962	0.1026
224	log-fdov[1]	-0.4165	0.0844	274	log-fdov[3]	0.9938	0.1743
225	log-fdov[1]	-0.2003	0.0823	275	log-fdov[3]	0.2125	0.1576
226	log-fdov[1]	-3.7003	0.0813	276	log-fdov[3]	0.9396	0.1838
227	log-fdov[1]	-0.3505	0.0822	277	rec-dev-est	1.0614	0.2674
228	log-fdov[1]	1.4152	0.0828	278	rec-dev-est	0.5557	0.2985
229	log-fdov[1]	-2.8001	0.0819	279	rec-dev-est	0.9867	0.2438
230	log-fdov[1]	1.1373	0.0810	280	rec-dev-est	1.5740	0.2089
231	log-fdov[1]	0.8529	0.0809	281	rec-dev-est	1.8722	0.2161
232	log-fdov[1]	-1.9027	0.0804	282	rec-dev-est	1.0998	0.2580
233	log-fdov[1]	1.1920	0.0803	283	rec-dev-est	2.3745	0.1642
234	log-fdov[1]	0.3976	0.0806	284	rec-dev-est	1.4260	0.1783
235	log-fdov[1]	0.9174	0.0801	285	rec-dev-est	1.0710	0.1651
236	log-fdov[1]	-1.2534	0.0795	286	rec-dev-est	-0.7370	0.2447
237	log-fdov[1]	-0.2085	0.0795	287	rec-dev-est	0.3412	0.1625
238	log-fdov[1]	-0.4679	0.0799	288	rec-dev-est	-0.7774	0.2393
239	log-fdov[1]	-0.7150	0.0801	289	rec-dev-est	-1.2152	0.2742
240	log-fdov[1]	-0.2136	0.0798	290	rec-dev-est	-0.9874	0.2247
241	log-fdov[1]	-1.0924	0.0790	291	rec-dev-est	-0.0392	0.1642
242	log-fdov[1]	-1.8063	0.0785	292	rec-dev-est	-0.4352	0.1813
293	rec-dev-est	-1.9047	0.3515	339	logit-rec-prop-est	0.1336	0.2310
294	rec-dev-est	-0.8516	0.1969	340	logit-rec-prop-est	0.8058	0.7406
295	rec-dev-est	-2.0686	0.4486	341	logit-rec-prop-est	0.1945	0.2810
296	rec-dev-est	0.9987	0.1469	342	logit-rec-prop-est	-0.2878	0.7204
297	rec-dev-est	-0.7936	0.2499	343	logit-rec-prop-est	-0.3770	0.0892
298	rec-dev-est	-1.5654	0.3460	344	logit-rec-prop-est	1.1971	0.6083
299	rec-dev-est	-0.5638	0.2006	345	logit-rec-prop-est	0.4087	0.6577
300	rec-dev-est	0.4518	0.1553	346	logit-rec-prop-est	0.4572	0.3258
301	rec-dev-est	-0.5054	0.2204	347	logit-rec-prop-est	-0.1067	0.1394
302	rec-dev-est	-0.5739	0.2495	348	logit-rec-prop-est	0.1859	0.3512
303	rec-dev-est	0.8862	0.1539	349	logit-rec-prop-est	-0.5711	0.3957
304	rec-dev-est	-0.5713	0.2604	350	logit-rec-prop-est	-0.5526	0.1240

305	rec-dev-est	-0.6714	0.2656
306	rec-dev-est	0.5733	0.1570
307	rec-dev-est	-0.0765	0.1781
308	rec-dev-est	-0.5149	0.1870
309	rec-dev-est	-1.0726	0.2306
310	rec-dev-est	-0.9349	0.2320
311	rec-dev-est	-0.0369	0.1818
312	rec-dev-est	-0.5162	0.2217
313	rec-dev-est	-1.0957	0.2300
314	rec-dev-est	-1.4387	0.2230
315	rec-dev-est	-1.9312	0.2679
316	rec-dev-est	-1.4830	0.2181
317	rec-dev-est	-0.8374	0.1729
318	rec-dev-est	-1.6574	0.2516
319	rec-dev-est	-0.8941	0.1920
320	rec-dev-est	-1.5066	0.2762
321	rec-dev-est	-1.3827	0.2781
322	rec-dev-est	-1.2685	0.2720
323	rec-dev-est	-0.9573	0.3110
324	logit-rec-prop-est	-0.0921	0.4266
325	logit-rec-prop-est	-0.7795	0.5087
326	logit-rec-prop-est	-0.2170	0.3626
327	logit-rec-prop-est	-0.3918	0.2656
328	logit-rec-prop-est	0.1977	0.2573
329	logit-rec-prop-est	0.3589	0.3375
330	logit-rec-prop-est	0.4654	0.1425
331	logit-rec-prop-est	0.5576	0.2376
332	logit-rec-prop-est	0.0126	0.1736
333	logit-rec-prop-est	0.4452	0.4454
334	logit-rec-prop-est	-0.5017	0.1645
335	logit-rec-prop-est	0.1551	0.3997
336	logit-rec-prop-est	-0.1417	0.4496
337	logit-rec-prop-est	0.3817	0.3865
338	logit-rec-prop-est	-0.1024	0.1688
351	logit-rec-prop-est	-0.4288	0.4141
352	logit-rec-prop-est	-0.0896	0.4375
353	logit-rec-prop-est	-0.4243	0.1421
354	logit-rec-prop-est	-0.1585	0.2223
355	logit-rec-prop-est	0.4157	0.2783
356	logit-rec-prop-est	-0.1206	0.3577
357	logit-rec-prop-est	-0.4791	0.3498
358	logit-rec-prop-est	-0.7229	0.2042
359	logit-rec-prop-est	-0.4535	0.3061
360	logit-rec-prop-est	-0.5153	0.3406
361	logit-rec-prop-est	-0.1922	0.3341
362	logit-rec-prop-est	-0.3151	0.4280
363	logit-rec-prop-est	-0.3393	0.3151
364	logit-rec-prop-est	0.3087	0.2128
365	logit-rec-prop-est	0.5791	0.4722
366	logit-rec-prop-est	0.7686	0.3005
367	logit-rec-prop-est	0.2050	0.4676
368	logit-rec-prop-est	0.6016	0.5165
369	logit-rec-prop-est	0.2677	0.4487
370	logit-rec-prop-est	-0.7427	0.5048
371	m-dev-est[1]	1.4479	0.0317
372	survey-q[1]	0.9371	0.0258
373	log-add-cv[2]	-0.9828	0.2867

Table 9: Summary of estimated model parameter values and standard deviations for model 23.3 for Bristol Bay red king crab.

Index	Name	Value	StdDev	index	name	value	stddev
1	theta[1]	0.2158	0.0052	47	Grwth[88]	0.0683	0.0035
2	theta[2]	0.1978	0.0179	48	log-slx-pars[1]	4.7777	0.0084
3	theta[4]	19.9350	0.0567	49	log-slx-pars[2]	2.2784	0.0430
4	theta[5]	16.4160	0.1436	50	log-slx-pars[3]	4.5459	0.0185
5	theta[7]	0.7281	0.1233	51	log-slx-pars[4]	2.1714	0.0988
6	theta[9]	-0.5093	0.2173	52	log-slx-pars[5]	5.1384	0.0477
7	theta[13]	1.0895	0.4146	53	log-slx-pars[6]	2.7955	0.0411
8	theta[14]	0.7285	0.4794	54	log-slx-pars[7]	4.7175	0.2329
9	theta[15]	0.9436	0.3311	55	log-slx-pars[8]	2.1670	0.3048
10	theta[16]	0.7852	0.3015	56	log-slx-pars[9]	4.7389	0.0842
11	theta[17]	0.6064	0.2911	57	log-slx-pars[10]	0.9017	0.3031
12	theta[18]	0.5513	0.2728	58	log-slx-pars[11]	4.8108	0.0231
13	theta[19]	0.3728	0.2744	59	log-slx-pars[12]	2.3508	0.0793
14	theta[20]	0.3896	0.2619	60	log-slx-pars[13]	4.1588	0.1200
15	theta[21]	0.4087	0.2556	61	log-slx-pars[14]	2.2521	0.3353
16	theta[22]	0.1666	0.2782	62	log-slx-pars[15]	4.0531	0.2797
17	theta[23]	0.1303	0.2743	63	log-slx-pars[16]	3.5758	0.4157
18	theta[24]	0.0086	0.2852	64	log-slx-pars[17]	4.4543	0.0280
19	theta[25]	0.1056	0.2643	65	log-slx-pars[18]	2.5437	0.0781
20	theta[26]	-0.0667	0.2037	66	log-slx-pars[19]	4.9233	0.0015
21	theta[27]	-0.3054	0.1961	67	log-slx-pars[20]	0.6743	0.0526
22	theta[28]	-0.4604	0.1982	68	log-slx-pars[21]	4.9325	0.0020
23	theta[29]	-0.8121	0.2120	69	log-slx-pars[22]	0.7286	0.0975
24	theta[30]	-1.2741	0.2331	70	log-fbar[1]	-1.5448	0.0514
25	theta[31]	-1.3177	0.2353	71	log-fbar[2]	-4.2568	0.0832
26	theta[52]	1.3359	0.7447	72	log-fbar[3]	-5.6214	0.3250
27	theta[53]	1.5100	0.4862	73	log-fbar[4]	-6.4608	0.0846
28	theta[54]	1.4162	0.3799	74	log-fdev[1]	0.7918	0.1197
29	theta[55]	1.1734	0.3492	75	log-fdev[1]	0.7498	0.0908
30	theta[56]	1.0948	0.3030	76	log-fdev[1]	0.6634	0.0757
31	theta[57]	0.6230	0.3232	77	log-fdev[1]	0.7499	0.0627
32	theta[58]	0.2213	0.3577	78	log-fdev[1]	0.9564	0.0576
33	theta[59]	-0.0156	0.3617	79	log-fdev[1]	1.8248	0.0605
34	theta[60]	-0.2130	0.3533	80	log-fdev[1]	2.4082	0.1161
35	theta[61]	-0.5528	0.3718	81	log-fdev[1]	0.8696	0.1603
36	theta[62]	-0.9449	0.3828	82	log-fdev[1]	-8.8318	0.1082
37	theta[63]	-1.2037	0.3872	83	log-fdev[1]	1.2655	0.1019
38	theta[64]	-1.4357	0.3856	84	log-fdev[1]	1.3177	0.0906
39	theta[65]	-1.8165	0.3740	85	log-fdev[1]	1.4303	0.0763
40	theta[66]	-1.9249	0.3702	86	log-fdev[1]	0.9359	0.0663
41	theta[67]	-1.8685	0.3504	87	log-fdev[1]	-0.0290	0.0542
42	Grwth[21]	1.0032	0.1892	88	log-fdev[1]	0.0761	0.0483
43	Grwth[42]	1.4191	0.1234	89	log-fdev[1]	0.7221	0.0393
44	Grwth[85]	143.4000	1.7721	90	log-fdev[1]	0.7363	0.0421
45	Grwth[86]	0.0544	0.0095	91	log-fdev[1]	0.2281	0.0471
46	Grwth[87]	141.3300	0.6755	92	log-fdev[1]	0.8979	0.0526
93	log-fdev[1]	-4.2676	0.0498	143	log-fdev[2]	0.0567	0.1042
94	log-fdev[1]	-4.6804	0.0422	144	log-fdev[2]	-0.2314	0.1040
95	log-fdev[1]	-0.1994	0.0406	145	log-fdev[2]	-1.0012	0.1032
96	log-fdev[1]	-0.1361	0.0410	146	log-fdev[2]	-0.2301	0.1031

97	log-fdev[1]	0.7873	0.0440	147	log-fdev[2]	-0.5250	0.1027
98	log-fdev[1]	0.4131	0.0435	148	log-fdev[2]	-0.6204	0.1025
99	log-fdev[1]	-0.1793	0.0416	149	log-fdev[2]	-0.3901	0.1025
100	log-fdev[1]	-0.2505	0.0411	150	log-fdev[2]	-0.6639	0.1024
101	log-fdev[1]	-0.1361	0.0399	151	log-fdev[2]	-0.4978	0.1021
102	log-fdev[1]	0.3207	0.0386	152	log-fdev[2]	-0.4211	0.1022
103	log-fdev[1]	0.2773	0.0387	153	log-fdev[2]	-0.4436	0.1025
104	log-fdev[1]	0.5712	0.0392	154	log-fdev[2]	-0.8028	0.1027
105	log-fdev[1]	0.3166	0.0386	155	log-fdev[2]	-0.9566	0.1026
106	log-fdev[1]	0.6822	0.0386	156	log-fdev[2]	-1.4214	0.1023
107	log-fdev[1]	0.8589	0.0405	157	log-fdev[2]	-1.9370	0.1024
108	log-fdev[1]	0.6686	0.0416	158	log-fdev[2]	-1.2125	0.1025
109	log-fdev[1]	0.5291	0.0412	159	log-fdev[2]	-1.7671	0.1027
110	log-fdev[1]	-0.1104	0.0396	160	log-fdev[2]	-1.3757	0.1034
111	log-fdev[1]	-0.1803	0.0384	161	log-fdev[2]	-0.8379	0.1048
112	log-fdev[1]	0.0159	0.0382	162	log-fdev[2]	-0.3854	0.1070
113	log-fdev[1]	0.3482	0.0384	163	log-fdev[2]	-0.4277	0.1097
114	log-fdev[1]	0.4224	0.0402	164	log-fdev[2]	-0.3139	0.1129
115	log-fdev[1]	0.4317	0.0448	165	log-fdev[2]	-0.3384	0.1152
116	log-fdev[1]	0.3634	0.0529	166	log-fdev[2]	-1.3383	0.1155
117	log-fdev[1]	0.2017	0.0633	167	log-fdev[3]	-0.1163	0.0682
118	log-fdev[1]	0.1646	0.0725	168	log-fdev[3]	0.6698	0.0682
119	log-fdev[1]	-0.2676	0.0763	169	log-fdev[3]	1.2282	0.0682
120	log-fdev[1]	-4.7284	0.0750	170	log-fdev[3]	1.0926	0.0682
121	log-fdev[2]	0.1741	0.1254	171	log-fdev[3]	1.3823	0.0682
122	log-fdev[2]	0.6128	0.1176	172	log-fdev[3]	1.4242	0.0682
123	log-fdev[2]	0.5898	0.1120	173	log-fdev[3]	0.9927	0.0682
124	log-fdev[2]	0.6647	0.1110	174	log-fdev[3]	0.4765	0.0682
125	log-fdev[2]	1.4002	0.1130	175	log-fdev[3]	-0.9874	0.0682
126	log-fdev[2]	1.2140	0.1261	176	log-fdev[3]	-0.5787	0.0682
127	log-fdev[2]	2.5023	0.1242	177	log-fdev[3]	-1.0994	0.0682
128	log-fdev[2]	2.2269	0.1139	178	log-fdev[3]	-0.2563	0.0682
129	log-fdev[2]	3.4702	0.1128	179	log-fdev[3]	0.9401	0.0682
130	log-fdev[2]	2.2508	0.1116	180	log-fdev[3]	1.4182	0.0682
131	log-fdev[2]	1.1627	0.1122	181	log-fdev[3]	3.2412	0.0755
132	log-fdev[2]	0.6827	0.1098	182	log-fdev[3]	1.2834	0.1035
133	log-fdev[2]	1.4360	0.1051	183	log-fdev[3]	0.5710	0.1279
134	log-fdev[2]	-0.0071	0.1040	184	log-fdev[3]	-0.7633	0.0852
135	log-fdev[2]	0.4431	0.1040	185	log-fdev[3]	-2.1371	0.0744
136	log-fdev[2]	0.8679	0.1053	186	log-fdev[3]	-2.9919	0.0978
137	log-fdev[2]	0.7095	0.1056	187	log-fdev[3]	-2.4176	0.1178
138	log-fdev[2]	1.1912	0.1091	188	log-fdev[3]	-3.5029	0.0759
139	log-fdev[2]	-0.5823	0.1052	189	log-fdev[3]	-0.8409	0.0960
140	log-fdev[2]	-0.8739	0.1035	190	log-fdev[3]	-0.1107	0.1189
141	log-fdev[2]	-0.8000	0.1037	191	log-fdev[3]	1.0824	0.1459
142	log-fdev[2]	-1.2529	0.1035	192	log-fdev[4]	0.5393	0.1032
193	log-fdev[4]	-0.1095	0.1021	243	log-fdov[1]	0.2081	0.0785
194	log-fdev[4]	-0.3188	0.1028	244	log-fdov[1]	-0.1939	0.0786
195	log-fdev[4]	0.5911	0.1021	245	log-fdov[1]	0.8709	0.0791
196	log-fdev[4]	-1.8417	0.1014	246	log-fdov[1]	0.3231	0.0804
197	log-fdev[4]	0.1164	0.1010	247	log-fdov[1]	-0.3371	0.0830
198	log-fdev[4]	-0.1416	0.1006	248	log-fdov[1]	0.9731	0.0873
199	log-fdev[4]	-0.9782	0.1006	249	log-fdov[1]	-0.1096	0.0915
200	log-fdev[4]	-0.8027	0.1004	250	log-fdov[1]	-0.6240	0.0933

201	log-fdev[4]	-0.5280	0.1003	251	log-fdov[1]	2.9872	0.0936
202	log-fdev[4]	-0.5777	0.1000	252	log-fdov[3]	-0.0000	0.0962
203	log-fdev[4]	-0.0268	0.1000	253	log-fdov[3]	0.0001	0.0962
204	log-fdev[4]	-0.7221	0.1004	254	log-fdov[3]	0.0004	0.0962
205	log-fdev[4]	-1.7223	0.1002	255	log-fdov[3]	0.0003	0.0963
206	log-fdev[4]	-2.5609	0.0997	256	log-fdov[3]	0.0005	0.0963
207	log-fdev[4]	-1.0805	0.0994	257	log-fdov[3]	0.0002	0.0963
208	log-fdev[4]	-0.5189	0.0995	258	log-fdov[3]	-0.0001	0.0963
209	log-fdev[4]	0.6290	0.0994	259	log-fdov[3]	-0.0002	0.0962
210	log-fdev[4]	1.4870	0.0995	260	log-fdov[3]	-0.0002	0.0962
211	log-fdev[4]	1.1794	0.0999	261	log-fdov[3]	-0.0001	0.0962
212	log-fdev[4]	0.3626	0.1007	262	log-fdov[3]	-0.0001	0.0962
213	log-fdev[4]	1.9830	0.1021	263	log-fdov[3]	0.0000	0.0962
214	log-fdev[4]	2.2602	0.1036	264	log-fdov[3]	0.0003	0.0962
215	log-fdev[4]	1.0723	0.1055	265	log-fdov[3]	0.0007	0.0963
216	log-fdev[4]	0.8678	0.1076	266	log-fdov[3]	1.4990	0.1592
217	log-fdev[4]	0.8415	0.1089	267	log-fdov[3]	1.7806	0.1256
218	log-foff[1]	-2.8089	0.0439	268	log-fdov[3]	0.5715	0.1486
219	log-foff[3]	-0.1303	0.4638	269	log-fdov[3]	-3.4405	0.1106
220	log-fdov[1]	1.9531	0.0842	270	log-fdov[3]	-2.1585	0.1638
221	log-fdov[1]	-0.7118	0.0831	271	log-fdov[3]	-0.7936	0.1300
222	log-fdov[1]	1.9573	0.0844	272	log-fdov[3]	0.0365	0.1370
223	log-fdov[1]	1.7886	0.0862	273	log-fdov[3]	0.3905	0.1029
224	log-fdov[1]	-0.4258	0.0848	274	log-fdov[3]	0.9842	0.1711
225	log-fdov[1]	-0.1926	0.0825	275	log-fdov[3]	0.2025	0.1567
226	log-fdov[1]	-3.6903	0.0815	276	log-fdov[3]	0.9260	0.1798
227	log-fdov[1]	-0.3394	0.0823	277	rec-dev-est	1.0962	0.2630
228	log-fdov[1]	1.4229	0.0828	278	rec-dev-est	0.5919	0.2963
229	log-fdov[1]	-2.7967	0.0820	279	rec-dev-est	1.0083	0.2442
230	log-fdov[1]	1.1424	0.0810	280	rec-dev-est	1.5894	0.2089
231	log-fdov[1]	0.8628	0.0809	281	rec-dev-est	1.8708	0.2166
232	log-fdov[1]	-1.8877	0.0804	282	rec-dev-est	1.0959	0.2574
233	log-fdov[1]	1.2083	0.0804	283	rec-dev-est	2.3756	0.1643
234	log-fdov[1]	0.4149	0.0807	284	rec-dev-est	1.4260	0.1785
235	log-fdov[1]	0.9362	0.0801	285	rec-dev-est	1.0766	0.1652
236	log-fdov[1]	-1.2356	0.0796	286	rec-dev-est	-0.7352	0.2449
237	log-fdov[1]	-0.1928	0.0795	287	rec-dev-est	0.3420	0.1624
238	log-fdov[1]	-0.4619	0.0798	288	rec-dev-est	-0.7874	0.2399
239	log-fdov[1]	-0.7183	0.0801	289	rec-dev-est	-1.2292	0.2751
240	log-fdov[1]	-0.2221	0.0799	290	rec-dev-est	-0.9875	0.2234
241	log-fdov[1]	-1.1015	0.0790	291	rec-dev-est	-0.0533	0.1641
242	log-fdov[1]	-1.8118	0.0785	292	rec-dev-est	-0.4636	0.1819
293	rec-dev-est	-1.9192	0.3499	339	logit-rec-prop-est	0.1348	0.2336
294	rec-dev-est	-0.8604	0.1962	340	logit-rec-prop-est	0.7863	0.7307
295	rec-dev-est	-2.0612	0.4402	341	logit-rec-prop-est	0.2132	0.2806
296	rec-dev-est	0.9950	0.1468	342	logit-rec-prop-est	-0.2904	0.7084
297	rec-dev-est	-0.8269	0.2518	343	logit-rec-prop-est	-0.3627	0.0885
298	rec-dev-est	-1.5590	0.3408	344	logit-rec-prop-est	1.2090	0.6143
299	rec-dev-est	-0.5630	0.1997	345	logit-rec-prop-est	0.4301	0.6495
300	rec-dev-est	0.4490	0.1552	346	logit-rec-prop-est	0.4701	0.3248
301	rec-dev-est	-0.5108	0.2205	347	logit-rec-prop-est	-0.0863	0.1395
302	rec-dev-est	-0.5590	0.2469	348	logit-rec-prop-est	0.1947	0.3524
303	rec-dev-est	0.8833	0.1539	349	logit-rec-prop-est	-0.5475	0.3896
304	rec-dev-est	-0.5790	0.2614	350	logit-rec-prop-est	-0.5299	0.1241

305	rec-dev-est	-0.6694	0.2645
306	rec-dev-est	0.5752	0.1569
307	rec-dev-est	-0.0932	0.1790
308	rec-dev-est	-0.5174	0.1870
309	rec-dev-est	-1.0817	0.2313
310	rec-dev-est	-0.9454	0.2326
311	rec-dev-est	-0.0322	0.1812
312	rec-dev-est	-0.5230	0.2220
313	rec-dev-est	-1.0959	0.2300
314	rec-dev-est	-1.4400	0.2230
315	rec-dev-est	-1.9303	0.2684
316	rec-dev-est	-1.4764	0.2189
317	rec-dev-est	-0.8319	0.1732
318	rec-dev-est	-1.6569	0.2526
319	rec-dev-est	-0.8824	0.1925
320	rec-dev-est	-1.4927	0.2757
321	rec-dev-est	-1.3729	0.2774
322	rec-dev-est	-1.2555	0.2718
323	rec-dev-est	-0.9442	0.3113
324	logit-rec-prop-est	-0.0524	0.4217
325	logit-rec-prop-est	-0.7810	0.5062
326	logit-rec-prop-est	-0.2439	0.3639
327	logit-rec-prop-est	-0.4270	0.2688
328	logit-rec-prop-est	0.1499	0.2584
329	logit-rec-prop-est	0.3302	0.3365
330	logit-rec-prop-est	0.4156	0.1410
331	logit-rec-prop-est	0.4924	0.2343
332	logit-rec-prop-est	-0.0242	0.1734
333	logit-rec-prop-est	0.4598	0.4486
334	logit-rec-prop-est	-0.4857	0.1642
335	logit-rec-prop-est	0.1786	0.4042
336	logit-rec-prop-est	-0.1247	0.4530
337	logit-rec-prop-est	0.3943	0.3851
338	logit-rec-prop-est	-0.1126	0.1688
351	logit-rec-prop-est	-0.4122	0.4170
352	logit-rec-prop-est	-0.0530	0.4383
353	logit-rec-prop-est	-0.4141	0.1416
354	logit-rec-prop-est	-0.1423	0.2256
355	logit-rec-prop-est	0.4216	0.2793
356	logit-rec-prop-est	-0.1194	0.3596
357	logit-rec-prop-est	-0.4592	0.3512
358	logit-rec-prop-est	-0.7208	0.2027
359	logit-rec-prop-est	-0.4468	0.3074
360	logit-rec-prop-est	-0.5083	0.3407
361	logit-rec-prop-est	-0.2009	0.3338
362	logit-rec-prop-est	-0.3227	0.4288
363	logit-rec-prop-est	-0.3393	0.3161
364	logit-rec-prop-est	0.3012	0.2133
365	logit-rec-prop-est	0.5557	0.4698
366	logit-rec-prop-est	0.7719	0.3009
367	logit-rec-prop-est	0.1962	0.4656
368	logit-rec-prop-est	0.6085	0.5138
369	logit-rec-prop-est	0.2475	0.4469
370	logit-rec-prop-est	-0.7546	0.5068
371	m-dev-est[1]	1.4884	0.0311
372	survey-q[1]	1.0075	0.0396
373	log-add-cv[2]	-0.8133	0.2808

Table 10: Summary of estimated model parameter values and standard deviations for model 22.0 for Bristol Bay red king crab.

Index	Name	Value	StdDev	index	name	value	stddev
1	theta[2]	0.2533	0.0157	47	log-slx-pars[3]	4.5009	0.0163
2	theta[4]	17.8510	0.0407	48	log-slx-pars[4]	1.9927	0.1158
3	theta[5]	15.8170	0.1562	49	log-slx-pars[5]	5.2082	0.0927
4	theta[7]	0.6484	0.1226	50	log-slx-pars[6]	2.9321	0.0539
5	theta[9]	-0.4560	0.2505	51	log-slx-pars[7]	4.7312	0.2230
6	theta[13]	0.7587	0.4965	52	log-slx-pars[8]	2.1651	0.3058
7	theta[14]	0.7777	0.4753	53	log-slx-pars[9]	4.7178	0.0907
8	theta[15]	1.1311	0.3504	54	log-slx-pars[10]	0.9033	0.3023
9	theta[16]	1.3200	0.2848	55	log-slx-pars[11]	4.7870	0.0226
10	theta[17]	1.2547	0.2650	56	log-slx-pars[12]	2.3391	0.0876
11	theta[18]	0.9886	0.2722	57	log-slx-pars[13]	3.9460	0.3795
12	theta[19]	0.9454	0.2593	58	log-slx-pars[14]	2.9559	0.3842
13	theta[20]	1.2024	0.2217	59	log-slx-pars[15]	4.4345	0.0330
14	theta[21]	1.1938	0.2159	60	log-slx-pars[16]	2.4245	0.0904
15	theta[22]	1.0114	0.2226	61	log-slx-pars[17]	4.9239	0.0017
16	theta[23]	0.9577	0.2150	62	log-slx-pars[18]	0.6719	0.0705
17	theta[24]	0.8155	0.2182	63	log-slx-pars[19]	4.9324	0.0021
18	theta[25]	0.4861	0.2233	64	log-slx-pars[20]	0.7341	0.0987
19	theta[26]	0.0439	0.1945	65	log-fbar[1]	-1.6448	0.0476
20	theta[27]	-0.4270	0.1967	66	log-fbar[2]	-4.6935	0.0818
21	theta[28]	-1.0824	0.2201	67	log-fbar[3]	-5.9731	0.3070
22	theta[29]	-1.6618	0.2526	68	log-fbar[4]	-6.5478	0.0728
23	theta[30]	-2.3396	0.2764	69	log-fdev[1]	1.0302	0.1191
24	theta[31]	-2.0036	0.3613	70	log-fdev[1]	1.2495	0.0789
25	theta[52]	-0.0991	0.5990	71	log-fdev[1]	0.8568	0.0628
26	theta[53]	0.3955	0.6556	72	log-fdev[1]	0.0051	0.0522
27	theta[54]	0.8694	0.5457	73	log-fdev[1]	0.1532	0.0465
28	theta[55]	1.0765	0.4280	74	log-fdev[1]	0.8094	0.0371
29	theta[56]	1.2241	0.3361	75	log-fdev[1]	0.8206	0.0388
30	theta[57]	1.0492	0.3136	76	log-fdev[1]	0.3046	0.0427
31	theta[58]	0.8305	0.3107	77	log-fdev[1]	0.9692	0.0467
32	theta[59]	0.3681	0.3475	78	log-fdev[1]	-4.1815	0.0448
33	theta[60]	-0.3715	0.3929	79	log-fdev[1]	-4.5906	0.0392
34	theta[61]	-0.8220	0.3861	80	log-fdev[1]	-0.1205	0.0381
35	theta[62]	-1.5225	0.3759	81	log-fdev[1]	-0.0739	0.0382
36	theta[63]	-1.6162	0.3730	82	log-fdev[1]	0.8418	0.0402
37	theta[64]	-1.5463	0.3728	83	log-fdev[1]	0.4818	0.0395
38	theta[65]	-1.7687	0.3635	84	log-fdev[1]	-0.1064	0.0382
39	theta[66]	-1.9073	0.3530	85	log-fdev[1]	-0.1845	0.0379
40	theta[67]	-1.8742	0.3436	86	log-fdev[1]	-0.0706	0.0372
41	Grwth[21]	0.8966	0.1924	87	log-fdev[1]	0.3938	0.0364
42	Grwth[42]	1.4881	0.1342	88	log-fdev[1]	0.3508	0.0366
43	Grwth[64]	139.7000	0.6121	89	log-fdev[1]	0.6405	0.0367
44	Grwth[65]	0.0707	0.0033	90	log-fdev[1]	0.3949	0.0364
45	log-slx-pars[1]	4.7588	0.0083	91	log-fdev[1]	0.7591	0.0362
46	log-slx-pars[2]	2.2663	0.0461	92	log-fdev[1]	0.9284	0.0369
93	log-fdev[1]	0.7429	0.0372	143	log-fdev[3]	-0.7271	0.0661
94	log-fdev[1]	0.6118	0.0365	144	log-fdev[3]	0.1160	0.0661
95	log-fdev[1]	-0.0242	0.0357	145	log-fdev[3]	1.3122	0.0661
96	log-fdev[1]	-0.1000	0.0351	146	log-fdev[3]	1.7903	0.0661

97	log-fdev[1]	0.0875	0.0350	147	log-fdev[3]	3.6163	0.0764
98	log-fdev[1]	0.4157	0.0355	148	log-fdev[3]	1.6652	0.0948
99	log-fdev[1]	0.4857	0.0379	149	log-fdev[3]	0.9601	0.1268
100	log-fdev[1]	0.4816	0.0431	150	log-fdev[3]	-0.3831	0.0805
101	log-fdev[1]	0.3872	0.0514	151	log-fdev[3]	-1.7635	0.0740
102	log-fdev[1]	0.1919	0.0610	152	log-fdev[3]	-2.6141	0.0915
103	log-fdev[1]	0.1290	0.0692	153	log-fdev[3]	-2.0363	0.1162
104	log-fdev[1]	-0.3088	0.0732	154	log-fdev[3]	-3.1225	0.0771
105	log-fdev[1]	-4.7616	0.0732	155	log-fdev[3]	-0.4789	0.0960
106	log-fdev[2]	2.3657	0.1140	156	log-fdev[3]	0.2433	0.1138
107	log-fdev[2]	1.3385	0.1123	157	log-fdev[3]	1.4222	0.1372
108	log-fdev[2]	0.9435	0.1088	158	log-fdev[4]	0.5783	0.1029
109	log-fdev[2]	1.7781	0.1042	159	log-fdev[4]	-0.0855	0.1020
110	log-fdev[2]	0.3807	0.1031	160	log-fdev[4]	-0.3054	0.1025
111	log-fdev[2]	0.8468	0.1028	161	log-fdev[4]	0.6135	0.1017
112	log-fdev[2]	1.2712	0.1036	162	log-fdev[4]	-1.8136	0.1012
113	log-fdev[2]	1.1077	0.1038	163	log-fdev[4]	0.1422	0.1009
114	log-fdev[2]	1.5786	0.1063	164	log-fdev[4]	-0.1149	0.1005
115	log-fdev[2]	-0.1828	0.1036	165	log-fdev[4]	-0.9488	0.1004
116	log-fdev[2]	-0.4677	0.1023	166	log-fdev[4]	-0.7746	0.1002
117	log-fdev[2]	-0.4034	0.1025	167	log-fdev[4]	-0.5009	0.1001
118	log-fdev[2]	-0.8739	0.1024	168	log-fdev[4]	-0.5466	0.0998
119	log-fdev[2]	0.4168	0.1027	169	log-fdev[4]	-0.0007	0.0998
120	log-fdev[2]	0.1376	0.1025	170	log-fdev[4]	-0.7021	0.1001
121	log-fdev[2]	-0.6195	0.1019	171	log-fdev[4]	-1.6997	0.0998
122	log-fdev[2]	0.1503	0.1019	172	log-fdev[4]	-2.5355	0.0995
123	log-fdev[2]	-0.1488	0.1017	173	log-fdev[4]	-1.0549	0.0992
124	log-fdev[2]	-0.2428	0.1015	174	log-fdev[4]	-0.4999	0.0992
125	log-fdev[2]	-0.0107	0.1016	175	log-fdev[4]	0.6387	0.0992
126	log-fdev[2]	-0.2888	0.1014	176	log-fdev[4]	1.4877	0.0994
127	log-fdev[2]	-0.1178	0.1012	177	log-fdev[4]	1.1680	0.0999
128	log-fdev[2]	-0.0432	0.1012	178	log-fdev[4]	0.3336	0.1007
129	log-fdev[2]	-0.0743	0.1014	179	log-fdev[4]	1.9323	0.1021
130	log-fdev[2]	-0.4308	0.1015	180	log-fdev[4]	2.1866	0.1035
131	log-fdev[2]	-0.5773	0.1014	181	log-fdev[4]	0.9808	0.1051
132	log-fdev[2]	-1.0370	0.1011	182	log-fdev[4]	0.7707	0.1071
133	log-fdev[2]	-1.5569	0.1013	183	log-fdev[4]	0.7506	0.1086
134	log-fdev[2]	-0.8432	0.1015	184	log-foff[1]	-2.7874	0.0390
135	log-fdev[2]	-1.4097	0.1017	185	log-foff[3]	-0.2079	0.4247
136	log-fdev[2]	-1.0287	0.1024	186	log-fdov[1]	2.0001	0.0837
137	log-fdev[2]	-0.5069	0.1039	187	log-fdov[1]	-0.6740	0.0828
138	log-fdev[2]	-0.0783	0.1060	188	log-fdov[1]	1.9946	0.0840
139	log-fdev[2]	-0.1483	0.1084	189	log-fdov[1]	1.8298	0.0856
140	log-fdev[2]	-0.0586	0.1111	190	log-fdov[1]	-0.4078	0.0843
141	log-fdev[2]	-0.0894	0.1134	191	log-fdov[1]	-0.1829	0.0822
142	log-fdev[2]	-1.0767	0.1141	192	log-fdov[1]	-3.6921	0.0812
193	log-fdov[1]	-0.3231	0.0818	243	rec-dev-est	-0.5559	0.2646
194	log-fdov[1]	1.4619	0.0821	244	rec-dev-est	-1.1831	0.3341
195	log-fdov[1]	-2.7674	0.0813	245	rec-dev-est	-0.1718	0.2083
196	log-fdov[1]	1.1608	0.0805	246	rec-dev-est	0.8065	0.1711
197	log-fdov[1]	0.8835	0.0804	247	rec-dev-est	-0.1788	0.2345
198	log-fdov[1]	-1.8660	0.0799	248	rec-dev-est	-0.1237	0.2464
199	log-fdov[1]	1.2188	0.0799	249	rec-dev-est	1.2175	0.1708
200	log-fdov[1]	0.4278	0.0800	250	rec-dev-est	-0.2248	0.2705

201	log-fdov[1]	0.9630	0.0795	251	rec-dev-est	-0.2996	0.2678
202	log-fdov[1]	-1.2233	0.0790	252	rec-dev-est	0.9674	0.1722
203	log-fdov[1]	-0.1832	0.0790	253	rec-dev-est	0.2312	0.1954
204	log-fdov[1]	-0.4467	0.0793	254	rec-dev-est	-0.1312	0.2012
205	log-fdov[1]	-0.7126	0.0795	255	rec-dev-est	-0.7393	0.2492
206	log-fdov[1]	-0.2333	0.0793	256	rec-dev-est	-0.5739	0.2437
207	log-fdov[1]	-1.1323	0.0784	257	rec-dev-est	0.3635	0.1938
208	log-fdov[1]	-1.8517	0.0780	258	rec-dev-est	-0.1306	0.2364
209	log-fdov[1]	0.1681	0.0780	259	rec-dev-est	-0.7305	0.2478
210	log-fdov[1]	-0.2377	0.0781	260	rec-dev-est	-1.0071	0.2329
211	log-fdov[1]	0.8214	0.0787	261	rec-dev-est	-1.4580	0.2722
212	log-fdov[1]	0.2723	0.0804	262	rec-dev-est	-1.0201	0.2313
213	log-fdov[1]	-0.3795	0.0833	263	rec-dev-est	-0.3282	0.1867
214	log-fdov[1]	0.9477	0.0876	264	rec-dev-est	-1.1821	0.2615
215	log-fdov[1]	-0.1258	0.0913	265	rec-dev-est	-0.3977	0.2091
216	log-fdov[1]	-0.6502	0.0929	266	rec-dev-est	-0.9859	0.2823
217	log-fdov[1]	2.9387	0.0933	267	rec-dev-est	-0.9166	0.2853
218	log-fdov[3]	-0.0001	0.0933	268	rec-dev-est	-0.7783	0.2863
219	log-fdov[3]	0.0001	0.0933	269	rec-dev-est	-0.4415	0.3303
220	log-fdov[3]	0.0004	0.0933	270	logit-rec-prop-est	-0.4515	0.1502
221	log-fdov[3]	0.0009	0.0933	271	logit-rec-prop-est	0.2476	0.4204
222	log-fdov[3]	1.5463	0.1424	272	logit-rec-prop-est	-0.0702	0.4590
223	log-fdov[3]	1.8286	0.1185	273	logit-rec-prop-est	0.4630	0.3714
224	log-fdov[3]	0.5980	0.1447	274	logit-rec-prop-est	-0.0615	0.1634
225	log-fdov[3]	-3.4250	0.1078	275	logit-rec-prop-est	0.2344	0.2435
226	log-fdov[3]	-2.1810	0.1438	276	logit-rec-prop-est	0.5805	0.6653
227	log-fdov[3]	-0.8009	0.1174	277	logit-rec-prop-est	0.3133	0.2866
228	log-fdov[3]	0.0262	0.1356	278	logit-rec-prop-est	-0.4631	0.6527
229	log-fdov[3]	0.3760	0.1036	279	logit-rec-prop-est	-0.2388	0.0882
230	log-fdov[3]	0.9614	0.1506	280	logit-rec-prop-est	1.3038	0.6044
231	log-fdov[3]	0.1684	0.1454	281	logit-rec-prop-est	0.4161	0.6018
232	log-fdov[3]	0.9005	0.1738	282	logit-rec-prop-est	0.5416	0.3197
233	rec-dev-est	0.7420	0.1749	283	logit-rec-prop-est	-0.0177	0.1417
234	rec-dev-est	-0.4784	0.2527	284	logit-rec-prop-est	0.2188	0.3638
235	rec-dev-est	-0.9007	0.2848	285	logit-rec-prop-est	-0.5031	0.3687
236	rec-dev-est	-0.5834	0.2268	286	logit-rec-prop-est	-0.4440	0.1276
237	rec-dev-est	0.3273	0.1776	287	logit-rec-prop-est	-0.4166	0.4219
238	rec-dev-est	-0.1320	0.1965	288	logit-rec-prop-est	0.0461	0.4339
239	rec-dev-est	-1.5812	0.3630	289	logit-rec-prop-est	-0.3504	0.1387
240	rec-dev-est	-0.4811	0.2093	290	logit-rec-prop-est	-0.0688	0.2387
241	rec-dev-est	-1.5434	0.4100	291	logit-rec-prop-est	0.3814	0.2788
242	rec-dev-est	1.3768	0.1636	292	logit-rec-prop-est	-0.1839	0.3775
293	logit-rec-prop-est	-0.4512	0.3556	301	logit-rec-prop-est	0.5162	0.4559
294	logit-rec-prop-est	-0.7235	0.2005	302	logit-rec-prop-est	0.8106	0.3073
295	logit-rec-prop-est	-0.5107	0.3129	303	logit-rec-prop-est	0.1217	0.4535
296	logit-rec-prop-est	-0.4608	0.3582	304	logit-rec-prop-est	0.5871	0.4879
297	logit-rec-prop-est	-0.2370	0.3315	305	logit-rec-prop-est	0.0964	0.4478
298	logit-rec-prop-est	-0.3057	0.4215	306	logit-rec-prop-est	-0.9692	0.5669
299	logit-rec-prop-est	-0.2780	0.3207	307	survey-q[1]	0.9407	0.0273
300	logit-rec-prop-est	0.3273	0.2116	308	log-add-cv[2]	-0.8165	0.2758

Table 11: Annual abundance estimates (mature >119mm, legal >134mm, 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 21.1b during 1975-2022. MMB for year t is on Feb. 15, year t+1.

Year	Mature males	Legal males	MMB	SD MMB	Mature Female	Total Recruits	Total-Model Est-Survey	Total Area-swept
1975	55.54	28.23	83.210	8.27	54.79		235.86	199.64
1976	65.22	35.52	99.070	7.98	83.13	63.88	275.71	327.61
1977	72.44	41.30	113.030	6.92	110.37	41.20	297.01	371.22
1978	77.71	46.49	119.800	5.50	114.47	64.35	300.17	343.19
1979	68.28	47.42	99.940	3.87	109.51	115.47	288.72	165.45
1980	50.10	37.75	30.330	1.60	111.47	150.26	273.37	247.23
1981	14.47	8.03	6.550	1.05	48.86	67.94	109.14	131.14
1982	6.78	2.16	6.560	0.93	21.39	241.56	65.17	141.90
1983	6.18	2.17	7.410	0.68	14.20	93.07	57.65	48.48
1984	6.15	2.29	5.230	0.43	13.98	64.27	50.62	152.61
1985	7.56	1.88	9.680	0.65	9.73	10.20	34.84	34.14
1986	12.17	4.65	15.060	0.99	13.64	30.36	45.54	47.43
1987	14.36	6.69	20.400	1.19	17.03	9.47	51.33	69.24
1988	14.45	8.46	25.120	1.25	21.45	6.18	54.70	54.60
1989	15.55	9.75	27.980	1.19	20.23	8.03	57.35	55.14
1990	15.01	10.44	24.140	1.12	18.06	20.85	57.42	59.45
1991	11.55	8.65	18.450	1.06	17.43	13.11	52.33	83.89
1992	9.28	6.46	17.240	1.03	18.58	3.02	47.66	37.33
1993	10.50	6.16	15.850	1.11	17.27	9.07	47.20	52.91
1994	10.35	6.02	21.700	1.22	14.68	2.91	42.63	32.10
1995	10.86	7.89	24.840	1.22	13.57	59.44	48.70	38.07
1996	11.15	8.55	23.320	1.16	19.69	8.63	58.05	43.96
1997	10.59	7.79	22.060	1.14	28.74	4.45	64.18	84.03
1998	15.90	7.75	24.940	1.35	25.23	12.41	68.06	84.10
1999	16.97	9.73	28.680	1.49	21.32	33.58	66.66	64.75
2000	14.65	10.65	28.900	1.49	22.73	12.47	68.28	67.38
2001	14.47	10.22	29.280	1.45	25.76	12.89	71.90	52.46
2002	17.32	10.41	33.340	1.46	25.01	51.48	76.96	69.09
2003	18.14	12.05	32.900	1.43	30.66	11.76	83.11	115.76
2004	16.36	11.63	30.410	1.35	37.82	10.95	84.59	130.56
2005	18.23	10.84	30.940	1.31	35.03	39.54	85.55	105.73
2006	17.34	11.42	31.320	1.27	35.33	18.93	85.40	94.48
2007	15.64	11.18	26.310	1.20	39.20	12.79	86.95	103.33
2008	16.02	9.51	24.990	1.22	36.75	7.15	83.34	113.08
2009	15.87	9.46	25.860	1.26	32.18	8.16	77.33	90.55
2010	14.75	9.69	25.140	1.22	28.17	21.79	72.26	80.50
2011	12.49	9.15	24.850	1.14	27.73	12.61	67.80	66.41
2012	11.13	8.61	23.280	1.06	29.49	7.30	66.17	60.70
2013	11.04	7.87	22.210	0.99	27.88	5.32	63.45	62.22
2014	10.76	7.57	20.210	0.93	24.65	3.32	58.71	113.14
2015	9.24	6.89	17.220	0.89	21.09	5.28	51.91	64.17
2016	7.48	5.80	14.190	0.87	17.96	10.33	45.24	60.96
2017	5.94	4.70	11.590	0.85	16.33	4.36	40.30	52.93
2018	5.17	3.80	10.340	0.86	14.91	9.73	37.30	28.80
2019	5.92	3.52	11.240	0.98	13.12	5.29	36.02	28.54
2020	6.49	4.03	12.860	1.14	12.07	5.79		
2021	7.67	4.65	16.640	1.36	10.98	6.61	36.14	28.48
2022	8.66	5.96	16.760	1.16	10.20	9.01	38.02	36.20

Table 12: Annual abundance estimates (mature >119mm, legal >134mm, 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.

Year	Mature males	Legal males	MMB	SD MMB	Mature Female	Total Recruits	Total-Model Est-Survey	Total Area-swept
1975	60.886	30.519	90.444	9.074	65.941		247.771	199.643
1976	71.147	38.129	107.000	8.695	97.946	90.202	288.150	327.615
1977	78.998	44.067	121.502	7.556	128.875	54.404	309.117	371.223
1978	84.202	49.442	128.203	6.084	132.243	83.711	310.136	343.189
1979	73.285	50.125	106.519	4.299	124.635	150.612	295.815	165.449
1980	53.586	39.705	32.436	1.756	125.807	202.942	279.396	247.226
1981	15.330	8.316	6.959	0.995	57.981	93.740	113.420	131.145
1982	7.219	2.249	6.656	0.772	26.608	335.347	63.724	141.898
1983	6.332	2.155	7.163	0.563	18.432	129.886	56.039	48.476
1984	6.439	2.173	5.067	0.419	18.488	91.073	49.082	152.607
1985	7.968	1.845	9.823	0.704	13.101	14.935	33.652	34.138
1986	13.031	4.775	15.808	1.113	17.981	43.901	45.105	47.434
1987	15.831	7.081	22.140	1.406	22.424	14.343	51.952	69.245
1988	16.107	9.186	27.388	1.499	28.166	9.258	56.253	54.597
1989	17.395	10.583	30.643	1.465	26.164	11.626	59.319	55.136
1990	16.666	11.351	26.640	1.384	22.973	30.009	59.349	59.451
1991	12.802	9.452	20.504	1.282	22.227	20.196	54.306	83.892
1992	10.473	7.096	19.169	1.235	23.966	4.646	49.907	37.334
1993	12.058	6.804	18.242	1.344	22.215	13.317	49.722	52.906
1994	12.163	6.908	24.605	1.483	18.692	3.944	45.498	32.104
1995	12.425	8.892	27.477	1.448	17.038	84.726	51.243	38.068
1996	12.399	9.345	25.391	1.343	25.772	14.113	59.786	43.959
1997	11.720	8.362	23.739	1.292	38.029	6.523	65.855	84.030
1998	17.874	8.321	27.543	1.613	32.657	17.759	70.096	84.101
1999	19.132	10.768	31.820	1.804	27.108	49.035	69.244	64.754
2000	16.351	11.759	31.618	1.752	29.176	18.827	70.873	67.381
2001	16.107	11.046	31.764	1.687	33.386	17.580	74.373	52.455
2002	19.440	11.220	36.307	1.741	31.948	75.710	79.462	69.086
2003	20.184	13.092	35.825	1.701	39.844	17.626	85.408	115.760
2004	18.063	12.589	32.911	1.587	49.779	15.947	87.138	130.556
2005	20.384	11.680	33.948	1.591	45.327	55.368	88.239	105.727
2006	19.292	12.499	34.199	1.545	45.402	28.911	87.996	94.477
2007	17.235	12.105	28.735	1.432	50.201	18.650	89.387	103.327
2008	17.895	10.302	27.725	1.495	46.593	10.677	85.983	113.082
2009	17.948	10.450	29.011	1.579	39.908	12.253	80.267	90.547
2010	16.795	10.814	28.455	1.540	34.372	30.079	75.131	80.501
2011	14.201	10.257	27.816	1.418	33.708	18.624	70.190	66.408
2012	12.512	9.500	25.676	1.274	35.691	10.434	67.860	60.697
2013	12.391	8.560	24.368	1.177	33.479	7.404	64.543	62.217
2014	12.037	8.237	22.184	1.096	29.097	4.525	59.269	113.135
2015	10.237	7.512	18.807	1.009	24.361	7.083	51.961	64.175
2016	8.183	6.264	15.299	0.939	20.372	13.508	44.726	60.958
2017	6.368	4.997	12.227	0.881	18.316	5.949	39.165	52.935
2018	5.482	3.942	10.661	0.860	16.530	12.763	35.692	28.805
2019	6.242	3.597	11.442	0.969	14.369	6.918	34.044	28.539
2020	6.791	4.096	12.940	1.114	13.121	7.831		
2021	7.961	4.681	16.574	1.317	11.859	8.777	33.650	28.476
2022	8.765	5.919	15.431	1.013	11.003	11.982	35.123	36.198

Table 13: Annual abundance estimates (mature >119mm, legal >134mm, 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 23.3 during 1975-2022. MMB for year t is on Feb. 15, year t+1.

Year	Mature males	Legal males	MMB	SD MMB	Mature Female	Total Recruits	Total-Model Est-Survey	Total Area-swept
1975	57.198	28.754	84.369	8.511	59.954		251.703	199.643
1976	67.155	36.122	100.403	8.288	89.179	80.651	293.772	327.615
1977	74.887	41.960	114.793	7.305	117.607	48.708	316.207	371.223
1978	80.384	47.355	122.009	5.922	121.251	73.866	318.430	343.189
1979	70.506	48.357	101.973	4.172	114.861	132.072	304.232	165.449
1980	51.590	38.479	30.796	1.666	116.200	175.004	285.914	247.226
1981	14.580	8.049	6.312	0.948	52.558	80.627	114.139	131.145
1982	6.681	2.096	6.163	0.773	23.656	289.907	64.012	141.898
1983	5.939	2.044	6.838	0.569	16.214	112.169	56.489	48.476
1984	6.078	2.114	4.806	0.413	16.238	79.089	49.829	152.607
1985	7.507	1.779	9.238	0.683	11.470	12.920	34.309	34.138
1986	12.189	4.541	14.610	1.090	15.865	37.938	45.740	47.434
1987	14.632	6.621	20.265	1.388	19.788	12.262	52.298	69.245
1988	14.842	8.511	25.217	1.484	24.852	7.884	56.388	54.597
1989	16.090	9.851	28.328	1.447	23.170	10.039	59.534	55.136
1990	15.481	10.601	24.438	1.361	20.428	25.552	59.619	59.451
1991	11.815	8.763	18.539	1.263	19.723	16.952	54.180	83.892
1992	9.533	6.488	17.286	1.222	21.148	3.954	49.304	37.334
1993	10.895	6.204	16.071	1.334	19.596	11.400	48.975	52.906
1994	10.839	6.173	22.104	1.482	16.513	3.431	44.425	32.104
1995	11.234	8.079	25.102	1.458	15.115	72.892	50.546	38.068
1996	11.373	8.614	23.295	1.365	22.681	11.788	59.561	43.959
1997	10.771	7.737	21.840	1.317	33.413	5.669	65.698	84.030
1998	16.395	7.716	24.993	1.635	28.883	15.347	69.974	84.101
1999	17.483	9.893	28.856	1.837	24.078	42.225	68.848	64.754
2000	14.946	10.789	28.859	1.793	25.871	16.170	70.515	67.381
2001	14.783	10.188	29.169	1.731	29.546	15.409	74.248	52.455
2002	17.919	10.404	33.516	1.776	28.394	65.188	79.590	69.086
2003	18.723	12.209	33.104	1.731	35.280	15.105	85.851	115.760
2004	16.782	11.753	30.458	1.615	43.940	13.799	87.563	130.556
2005	18.913	10.917	31.307	1.607	40.186	47.902	88.672	105.727
2006	17.926	11.658	31.653	1.555	40.294	24.551	88.354	94.477
2007	16.040	11.328	26.445	1.440	44.558	16.064	89.782	103.327
2008	16.523	9.585	25.228	1.501	41.450	9.137	86.106	113.082
2009	16.454	9.631	26.265	1.585	35.687	10.471	80.097	90.547
2010	15.345	9.917	25.675	1.548	30.858	26.096	74.870	80.501
2011	12.953	9.374	25.278	1.431	30.262	15.973	69.937	66.408
2012	11.463	8.732	23.481	1.293	32.038	9.007	67.854	60.697
2013	11.398	7.909	22.358	1.194	30.119	6.385	64.745	62.217
2014	11.104	7.636	20.324	1.108	26.291	3.911	59.588	113.135
2015	9.444	6.956	17.177	1.021	22.131	6.157	52.271	64.175
2016	7.528	5.783	13.911	0.954	18.582	11.729	44.984	60.958
2017	5.836	4.592	11.066	0.901	16.742	5.140	39.404	52.935
2018	5.003	3.607	9.638	0.884	15.146	11.151	35.921	28.805
2019	5.694	3.291	10.373	0.997	13.202	6.057	34.305	28.539
2020	6.213	3.762	11.837	1.141	12.073	6.828		
2021	7.336	4.333	15.424	1.342	10.934	7.679	34.105	28.476
2022	8.191	5.564	14.971	1.064	10.154	10.483	35.853	36.198

Table 14: Annual abundance estimates (mature >119mm, legal >134mm, 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 22.0 during 1975-2022. MMB for year t is on Feb. 15, year t+1.

Year	Mature males	Legal males	MMB	SD MMB	Mature Female	Total Recruits	Total-Model Est-Survey	Total Area-swept
1985	8.557	2.35	11.651	0.965	8.44		34.983	34.138
1986	12.986	5.351	17.143	1.183	11.908	31.07	44.854	47.434
1987	14.402	7.309	21.340	1.315	15.698	9.169	50.338	69.245
1988	14.418	8.689	25.552	1.322	20.545	6.011	53.589	54.597
1989	15.533	9.777	28.169	1.255	19.574	8.255	56.086	55.136
1990	15.089	10.459	24.356	1.176	17.604	20.523	56.08	59.451
1991	11.608	8.711	18.620	1.108	17.115	12.964	51.198	83.892
1992	9.366	6.515	17.426	1.079	18.263	3.043	46.836	37.334
1993	10.616	6.219	16.093	1.156	17.056	9.144	46.525	52.906
1994	10.513	6.101	22.010	1.27	14.609	3.161	42.186	32.104
1995	10.986	8.007	25.120	1.268	13.638	58.618	47.973	38.068
1996	11.305	8.643	23.651	1.213	19.628	8.485	57.278	43.959
1997	10.662	7.906	22.290	1.187	28.458	4.532	63.631	84.03
1998	16.156	7.799	25.401	1.414	25.175	12.459	67.618	84.101
1999	17.27	9.916	29.280	1.57	21.402	33.141	66.212	64.754
2000	14.88	10.863	29.431	1.555	22.783	12.372	67.855	67.381
2001	14.67	10.391	29.770	1.511	25.786	13.073	71.515	52.455
2002	17.558	10.556	33.871	1.526	25.156	49.985	76.328	69.086
2003	18.387	12.227	33.442	1.488	30.609	11.816	82.352	115.76
2004	16.544	11.81	30.880	1.406	37.556	10.964	83.936	130.556
2005	18.45	10.978	31.431	1.375	35.019	38.925	84.824	105.727
2006	17.553	11.59	31.797	1.336	35.322	18.643	84.702	94.477
2007	15.802	11.33	26.723	1.256	39.147	12.975	86.364	103.327
2008	16.242	9.63	25.461	1.288	36.866	7.063	83.001	113.082
2009	16.095	9.624	26.353	1.335	32.483	8.334	77.219	90.547
2010	14.996	9.858	25.679	1.294	28.616	21.279	72.204	80.501
2011	12.713	9.34	25.376	1.211	28.161	12.983	67.831	66.408
2012	11.31	8.78	23.735	1.119	29.908	7.126	66.312	60.697
2013	11.238	8.006	22.677	1.05	28.489	5.404	63.718	62.217
2014	10.954	7.718	20.672	0.997	25.26	3.443	59.092	113.135
2015	9.414	7.039	17.660	0.956	21.759	5.334	52.412	64.175
2016	7.648	5.935	14.603	0.933	18.643	10.655	45.84	60.958
2017	6.089	4.83	11.990	0.915	17.006	4.536	41.04	52.935
2018	5.319	3.918	10.721	0.919	15.634	9.94	38.162	28.805
2019	6.122	3.635	11.695	1.046	13.838	5.52	36.977	28.539
2020	6.713	4.187	13.370	1.208	12.782	5.916		
2021	7.939	4.82	17.230	1.434	11.737	6.793	37.146	28.476
2022	8.922	6.167	16.974	1.182	10.992	9.513	38.94	36.198

Table 15: Annual abundance estimates (mature >119mm, legal >134mm, 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 23.2 (no retow) during 1975-2022. MMB for year t is on Feb. 15, year t+1.

Year	Mature males	Legal males	MMB	SD MMB	Mature Female	Total Recruits	Total-Model Est-Survey	Total Area-swept
1975	56.746	28.77	85.508	8.471	54.857		240.228	199.643
1976	66.303	36.269	101.443	8.052	81.733	61.826	278.948	327.615
1977	72.925	41.948	114.567	6.932	107.72	39.427	298.086	371.223
1978	77.799	46.725	120.393	5.462	111.224	61.52	298.694	343.189
1979	67.991	47.317	99.526	3.831	105.811	109.644	285.198	165.449
1980	49.476	37.361	29.852	1.567	106.983	139.107	267.853	247.226
1981	14.308	7.991	6.501	1.006	46.95	62.535	107.141	131.145
1982	6.737	2.178	6.596	0.865	20.578	227.188	63.656	141.898
1983	6.103	2.203	7.423	0.624	13.812	90.504	56.898	48.476
1984	6.033	2.312	5.211	0.426	13.697	63.284	50.315	152.607
1985	7.455	1.894	9.577	0.653	9.702	9.852	34.887	34.138
1986	12.062	4.623	14.911	0.989	13.494	30.01	45.36	47.434
1987	14.251	6.657	20.241	1.189	16.792	9.4	50.975	69.245
1988	14.319	8.421	24.921	1.242	21.024	6.138	54.111	54.597
1989	15.39	9.69	27.734	1.187	19.764	7.896	56.488	55.136
1990	14.868	10.359	23.877	1.113	17.601	20.282	56.412	59.451
1991	11.413	8.568	18.183	1.049	16.943	12.747	51.331	83.892
1992	9.137	6.377	16.949	1.021	17.9	2.896	46.567	37.334
1993	10.325	6.067	15.508	1.091	16.52	8.548	45.859	52.906
1994	10.156	5.908	21.300	1.197	13.914	2.531	41.126	32.104
1995	10.653	7.765	24.408	1.196	12.645	53.456	46.783	38.068
1996	10.944	8.406	22.887	1.143	17.568	9.341	55.68	43.959
1997	10.381	7.645	21.610	1.121	24.911	5.183	61.227	84.03
1998	15.617	7.612	24.383	1.327	22.311	12.756	64.805	84.101
1999	16.695	9.564	28.106	1.476	19.357	33.311	63.62	58.692
2000	14.415	10.478	28.364	1.47	21.315	11.139	65.549	52.072
2001	14.266	10.056	28.805	1.432	24.182	11.899	69.067	52.455
2002	17.111	10.275	32.880	1.447	23.057	47.096	73.731	69.086
2003	17.908	11.922	32.402	1.411	27.818	11.27	79.449	115.76
2004	16.064	11.476	29.825	1.33	33.684	10.485	80.372	130.556
2005	17.877	10.654	30.249	1.294	31.136	32.847	80.62	105.727
2006	17.033	11.204	30.640	1.255	30.445	22.537	80.101	81.835
2007	15.381	10.97	25.723	1.176	33.668	12.745	81.681	88.573
2008	15.776	9.339	24.440	1.202	33.316	6.894	78.4	97.713
2009	15.635	9.309	25.331	1.246	29.48	8.825	72.735	74.094
2010	14.513	9.542	24.618	1.205	26.043	20.974	68.12	59.259
2011	12.27	8.993	24.352	1.125	26.099	12.42	64.151	47.647
2012	10.941	8.456	22.821	1.036	27.836	6.603	62.791	58.222
2013	10.851	7.728	21.761	0.965	26.243	5.305	60.198	62.217
2014	10.549	7.432	19.732	0.904	23.021	3.146	55.592	113.135
2015	9.035	6.744	16.752	0.856	19.683	5.002	49.001	64.175
2016	7.303	5.652	13.748	0.829	16.729	9.347	42.534	60.958
2017	5.763	4.565	11.163	0.81	15.05	4.112	37.738	46.474
2018	4.968	3.662	9.861	0.813	13.543	9.352	34.785	28.805
2019	5.667	3.365	10.673	0.937	11.916	5.349	33.557	28.539
2020	6.163	3.844	12.154	1.088	11.027	6.243		
2021	7.316	4.415	15.841	1.3	10.395	5.828	33.834	27.368
2022	8.271	5.702	16.097	1.116	9.893	8.383	35.685	36.198

Figures

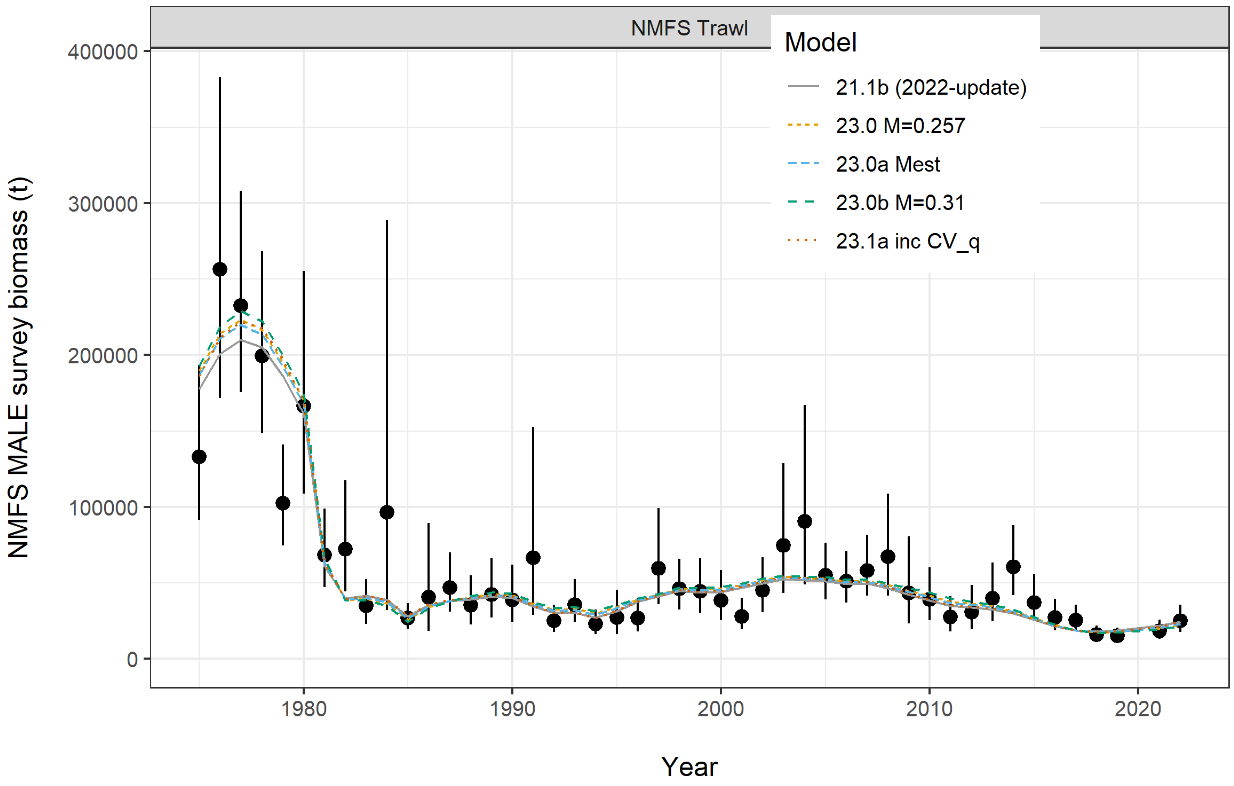

Figure 2: Comparisons of area-swept estimates of total MALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b, 23.0, 23.0a, 23.0b, and 23.1a. The error bars are plus and minus 2 standard deviations of model 21.1b.

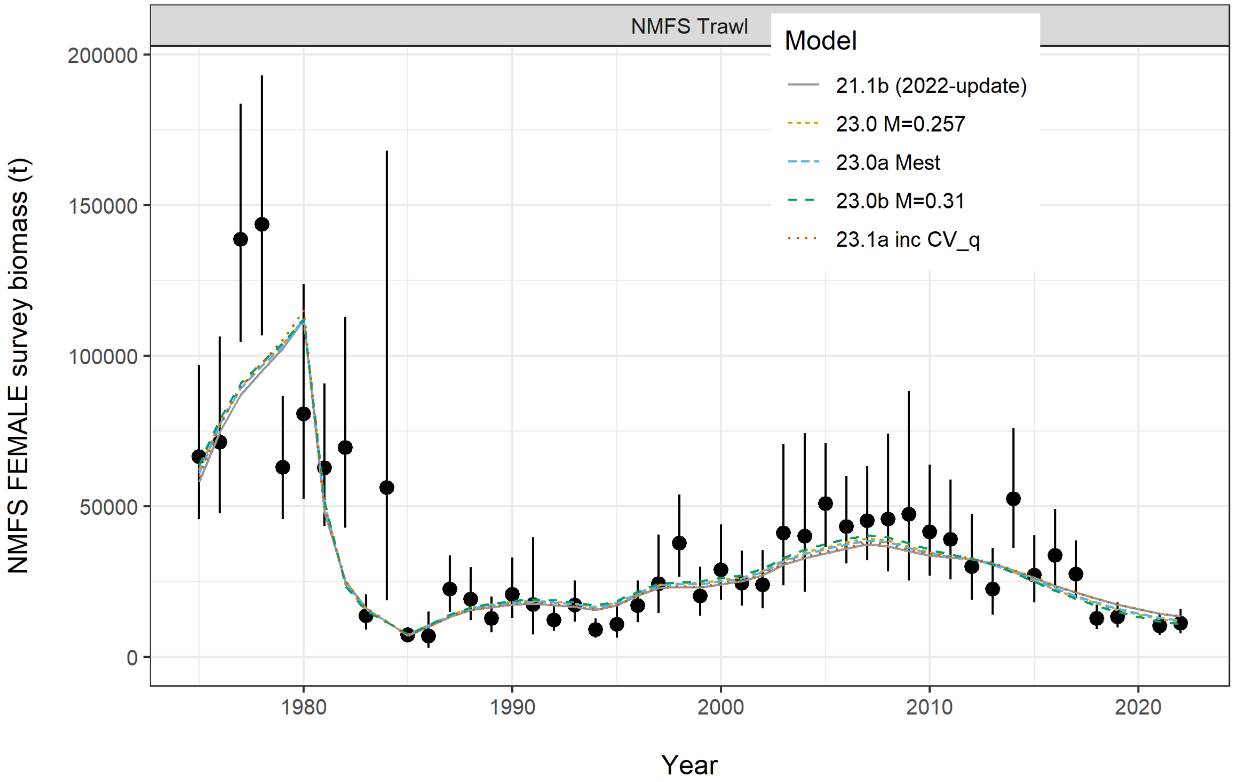

Figure 3: Comparisons of area-swept estimates of total FEMALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b, 23.0, 23.0a, 23.0b, and 23.1a. The error bars are plus and minus 2 standard deviations of model 21.1b.

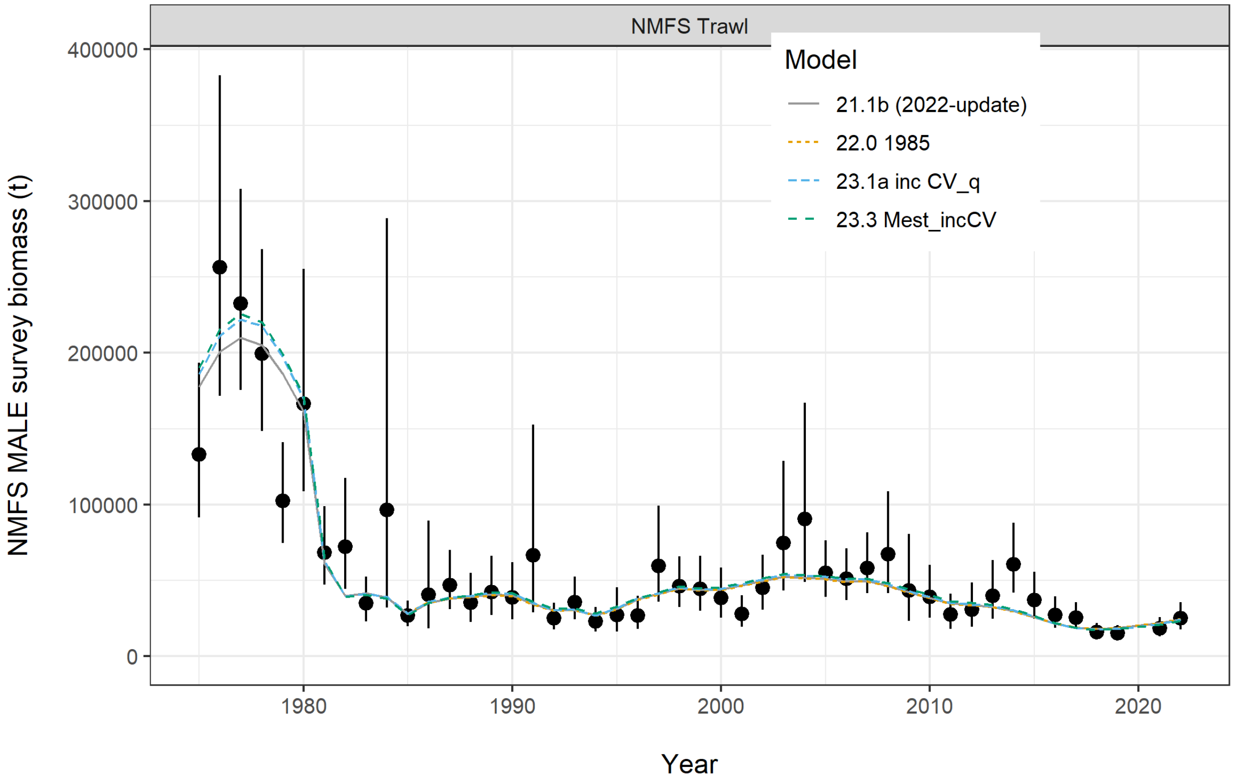

Figure 4: Comparisons of area-swept estimates of total MALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b, 22.0, 23.1a, and 23.3. The error bars are plus and minus 2 standard deviations of model 21.1b.

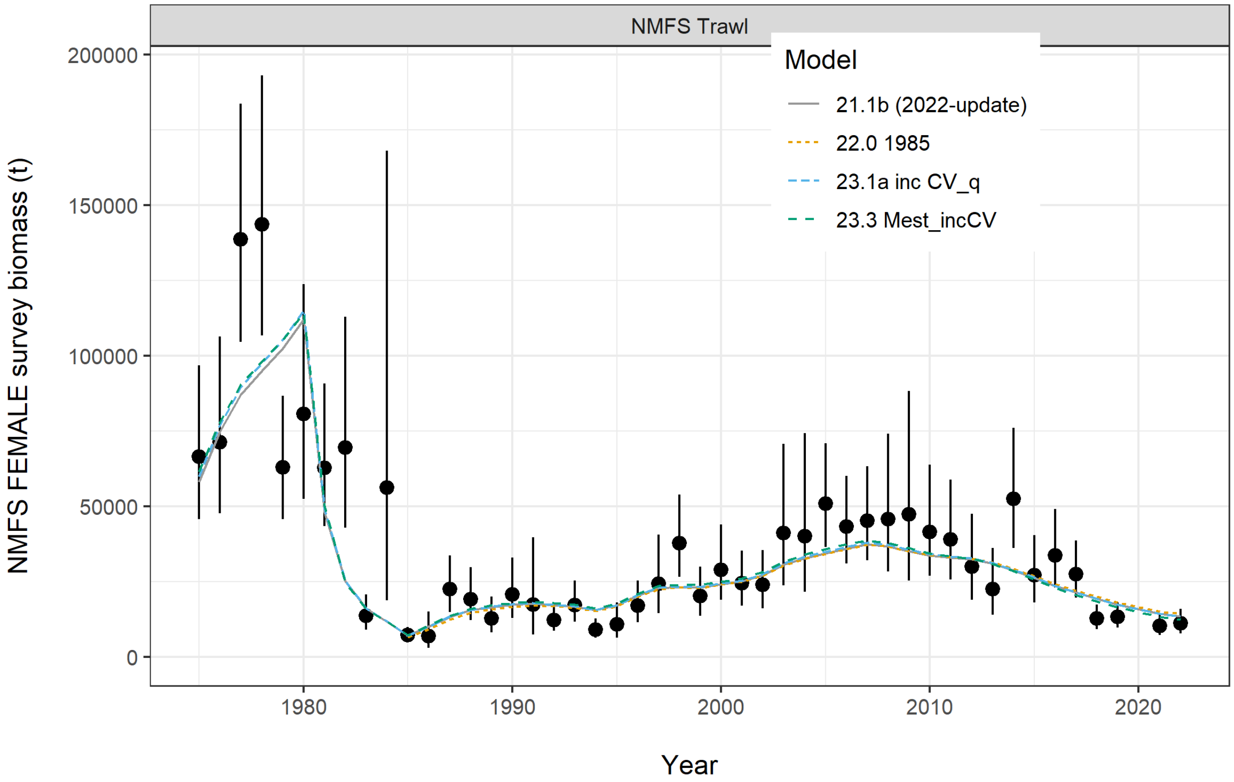

Figure 5: Comparisons of area-swept estimates of total FEMALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b, 22.0, 23.1a, and 23.3. The error bars are plus and minus 2 standard deviations of model 21.1b.

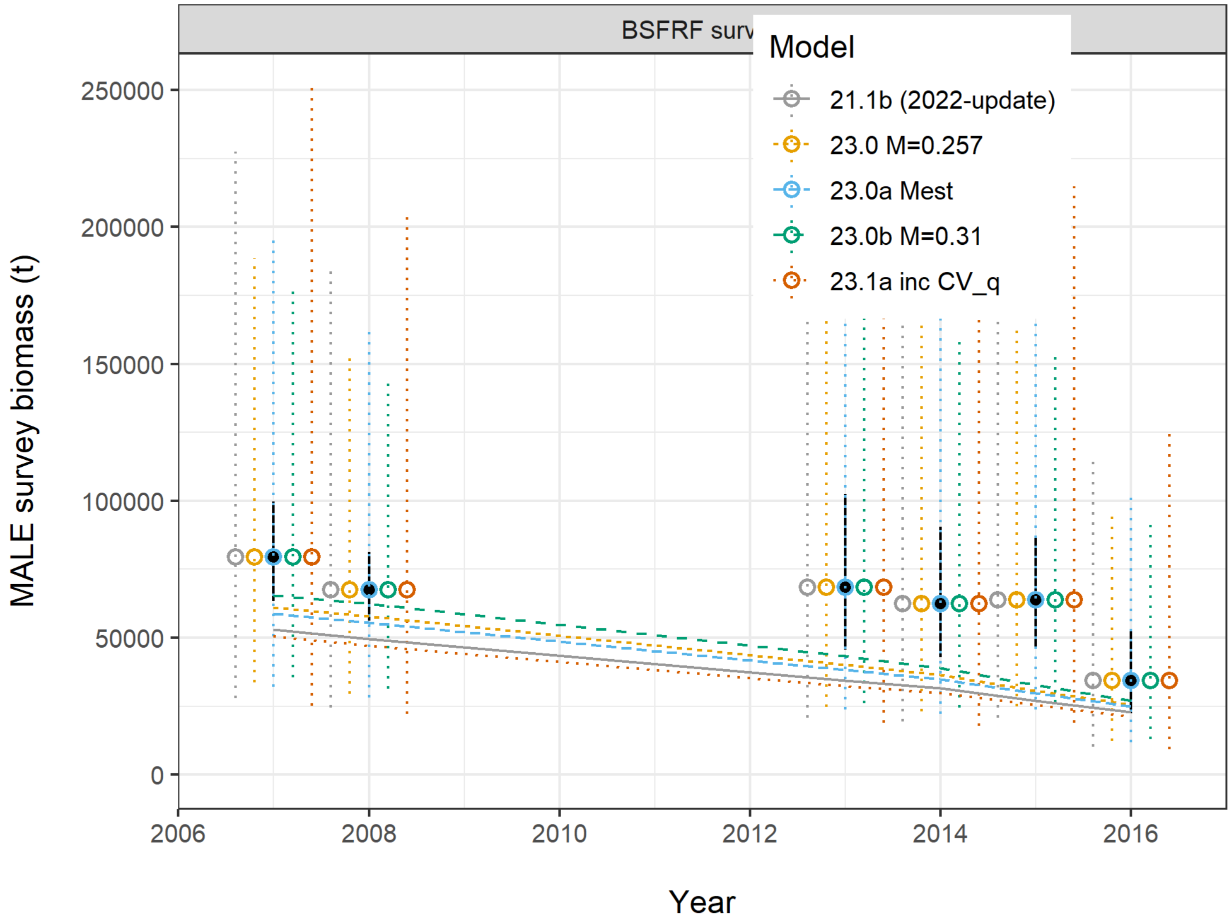

Figure 6: Comparisons of survey biomass estimates for MALES from the BSFRF survey and model prediction for model estimates in 2022 (models 21.1b, 23.0, 23.0a, 23.0b, and 23.1a). The error bars are plus and minus 2 standard deviations of model 21.1b. The BSFRF survey catchability is assumed to be 1.0 for all models.

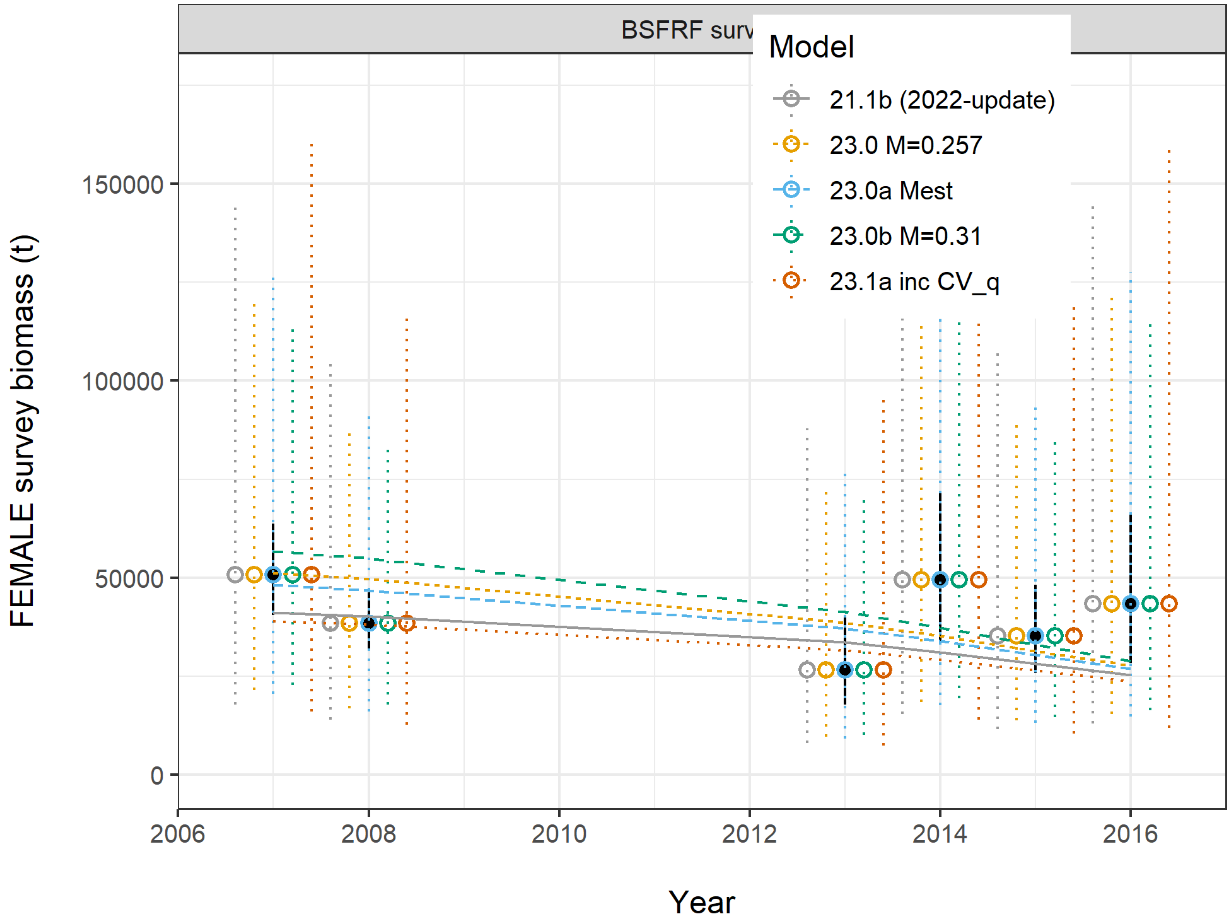

Figure 7: Comparisons of survey biomass estimates for FEMALES from the BSFRF survey and model prediction for model estimates in 2022 (models 21.1b, 23.0, 23.0a, 23.0b, and 23.1a). The error bars are plus and minus 2 standard deviations of model 21.1b. The BSFRF survey catchability is assumed to be 1.0 for all models.

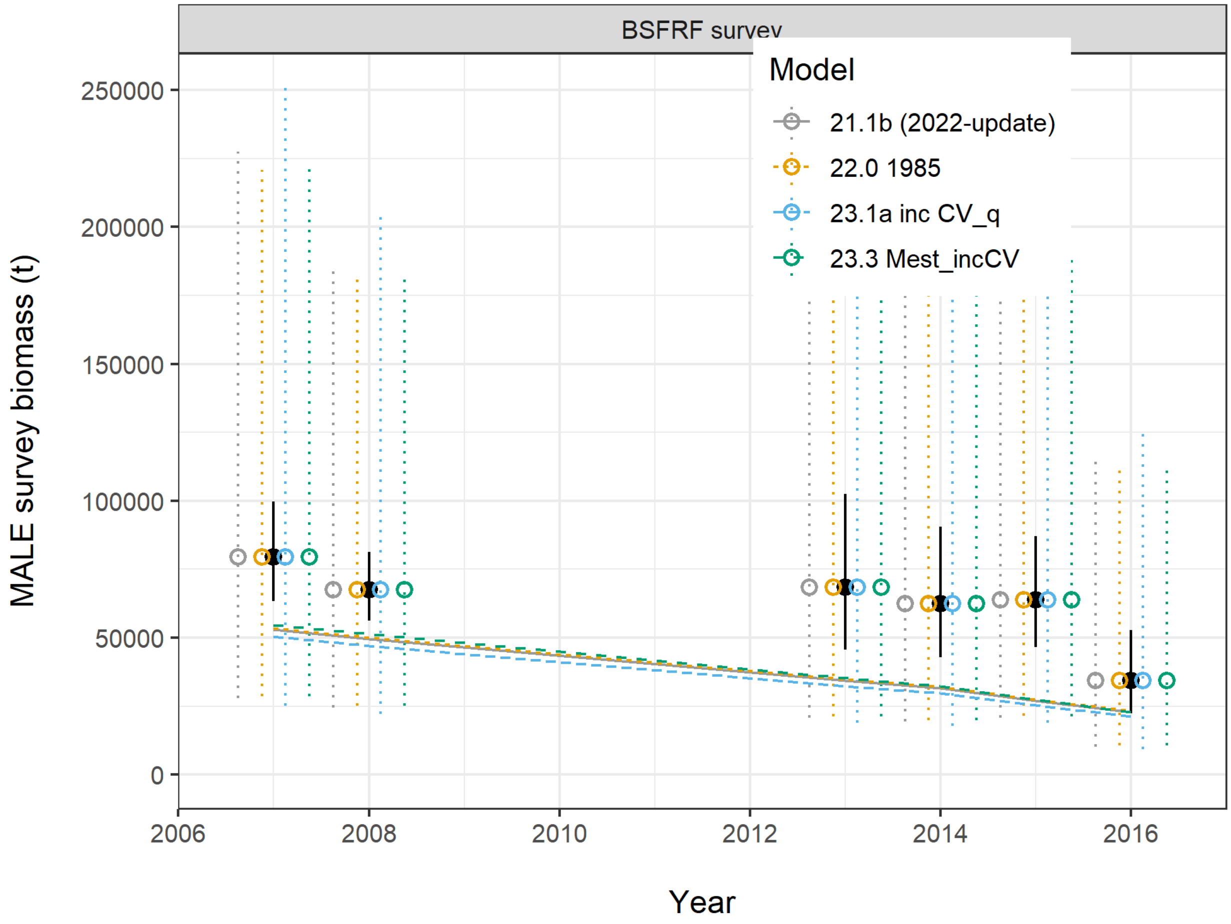

Figure 8: Comparisons of survey biomass estimates for MALES from the BSFRF survey and model prediction for model estimates in 2022 (models 21.1b, 22.0, 23.1a, and 23.3). The error bars are plus and minus 2 standard deviations of model 21.1b. The BSFRF survey catchability is assumed to be 1.0 for all models.

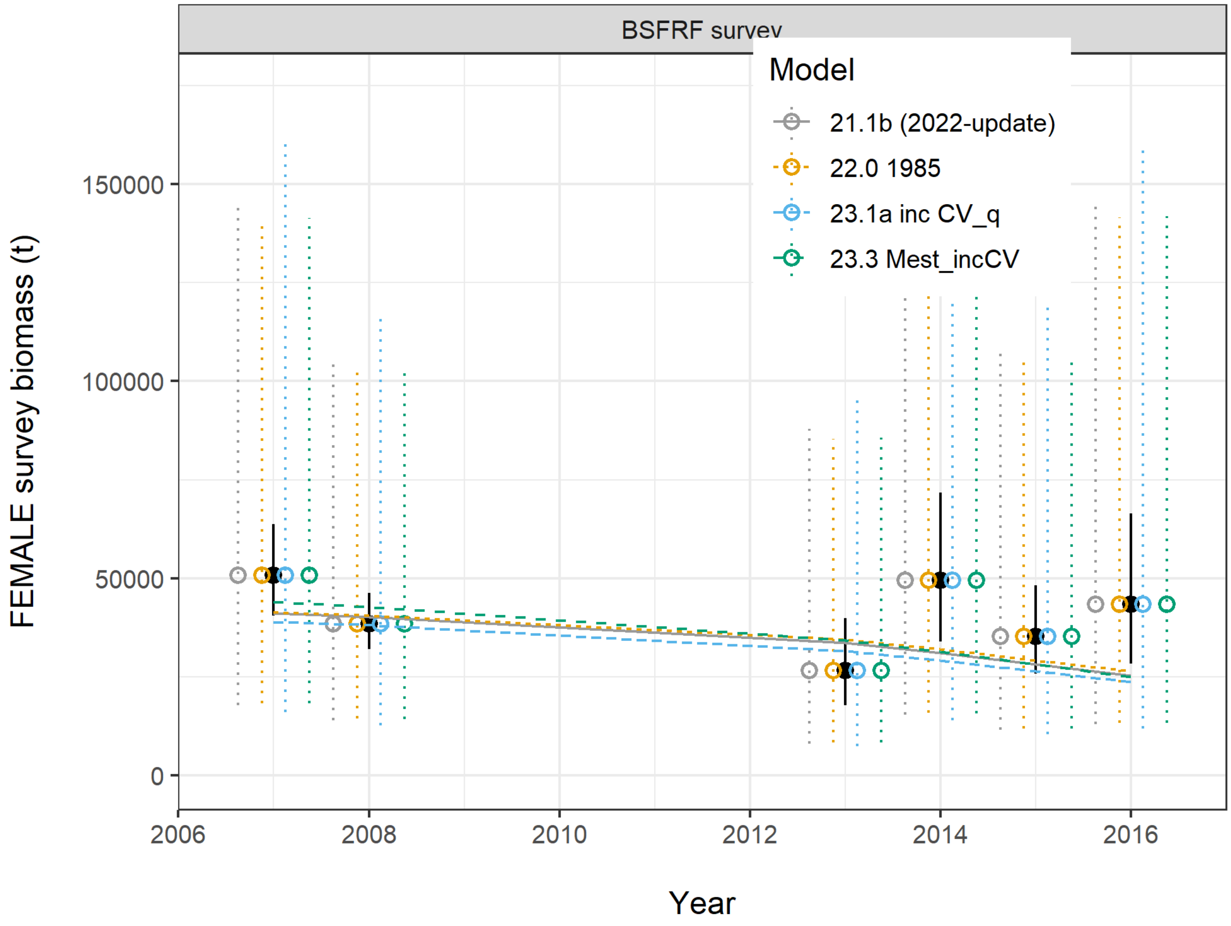

Figure 9: Comparisons of survey biomass estimates for FEMALES from the BSFRF survey and model prediction for model estimates in 2022 (models 21.1b, 22.0, 23.1a, and 23.3). The error bars are plus and minus 2 standard deviations of model 21.1b. The BSFRF survey catchability is assumed to be 1.0 for all models.

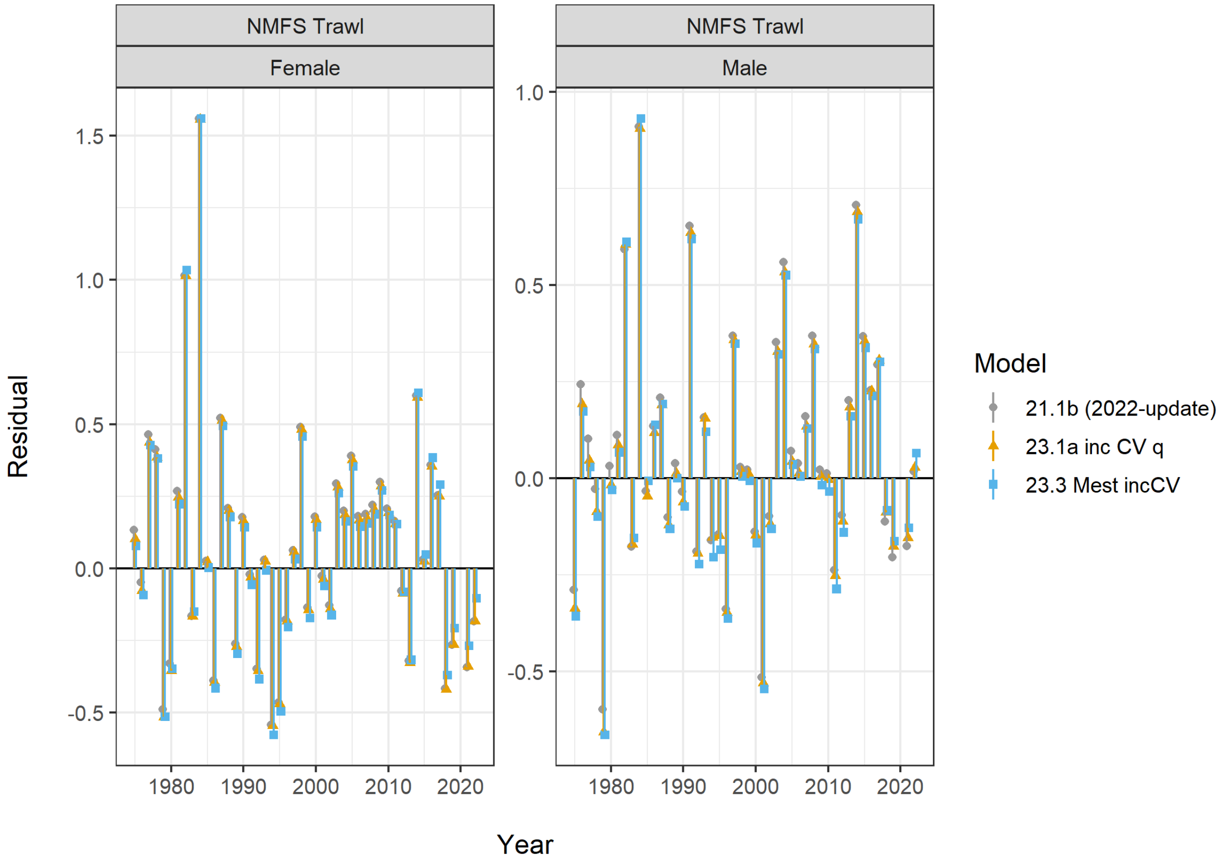

Figure 10: Standardized residuals of NMFS survey biomass under models 21.1b, 23.0, and 23.0b, those models that increase CV on survey Q.

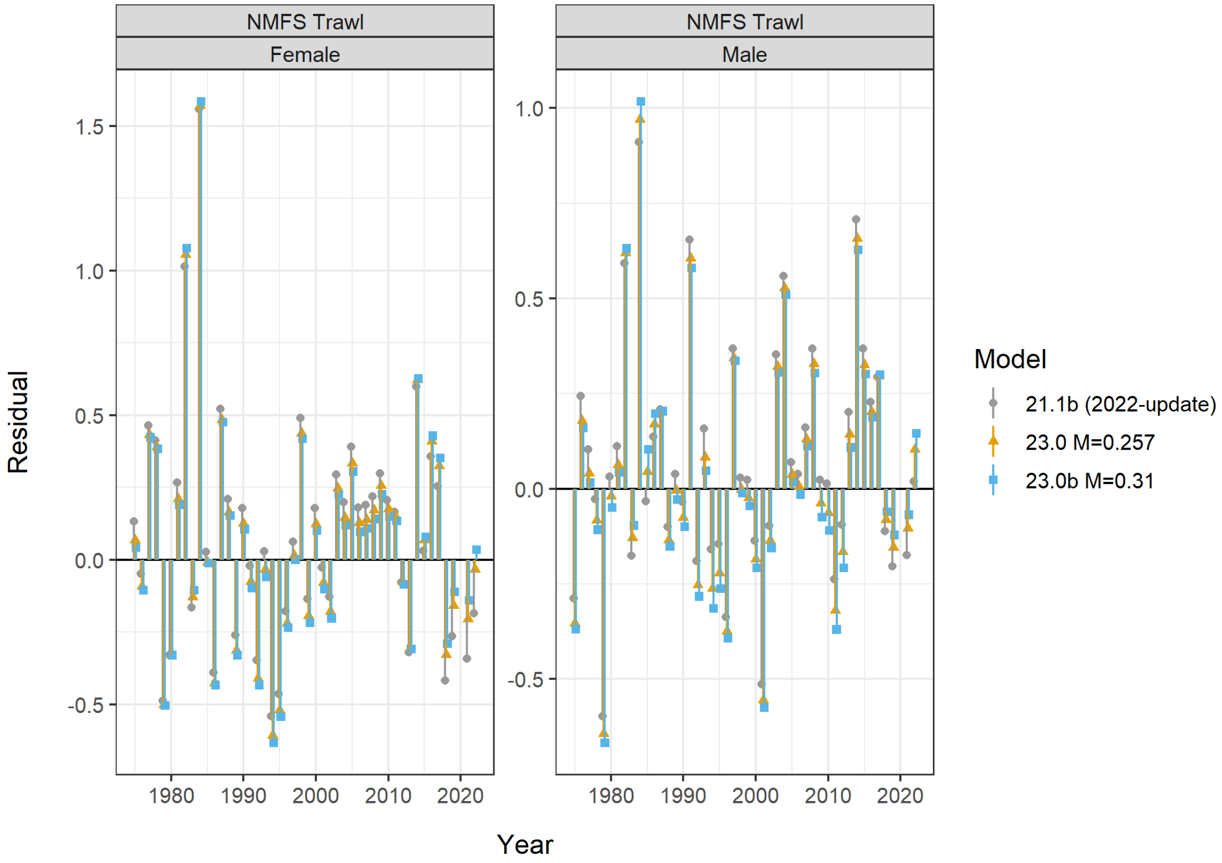

Figure 11: Standardized residuals of NMFS survey biomass under models 21.1b, 23.0, and 23.0b, those models that have a higher base value for M for males.

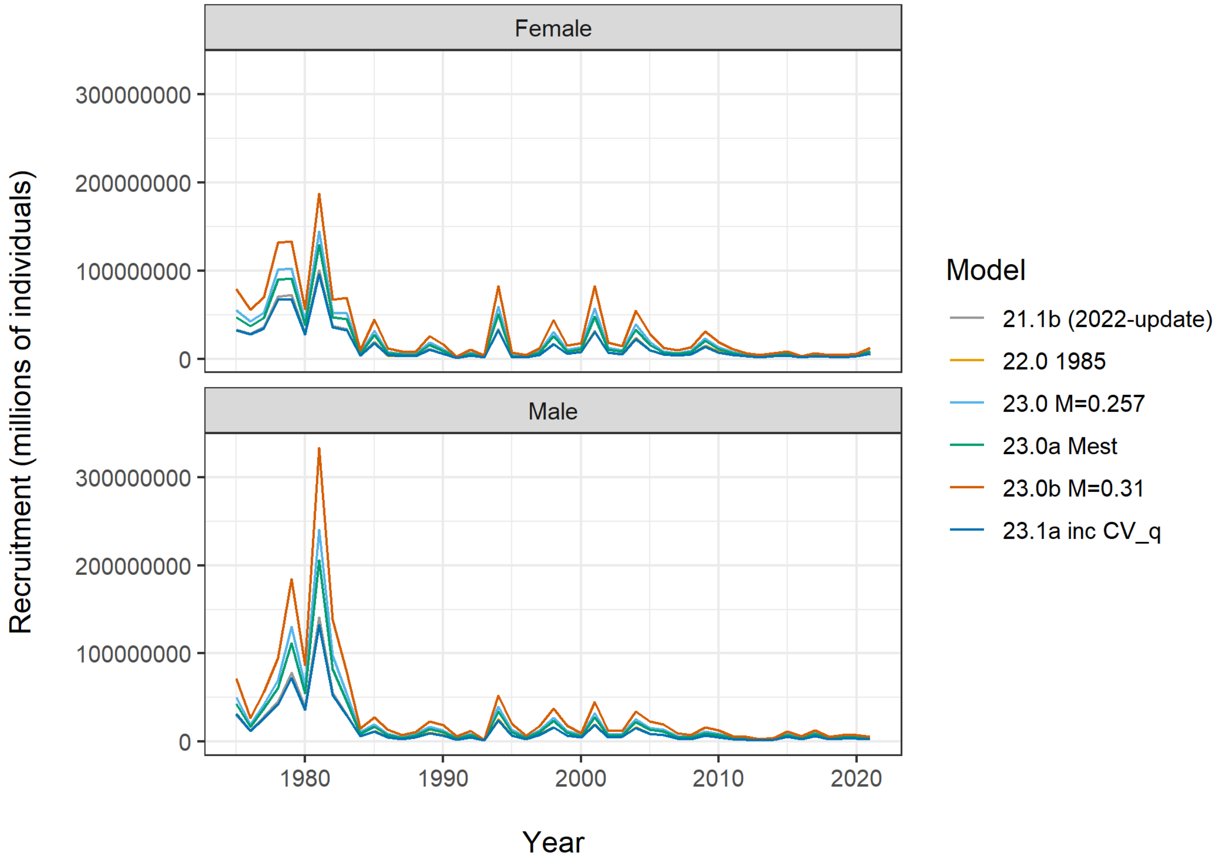

Figure 12: Estimated recruitment time series during 1976-2021 with models 21.1b, 22.0, 23.0, 23.0a, 23.0b, and 23.1a. Mean male recruits during 1984-2021 was used to estimate B35. Recruitment estimates in the terminal year (2022) are unreliable.

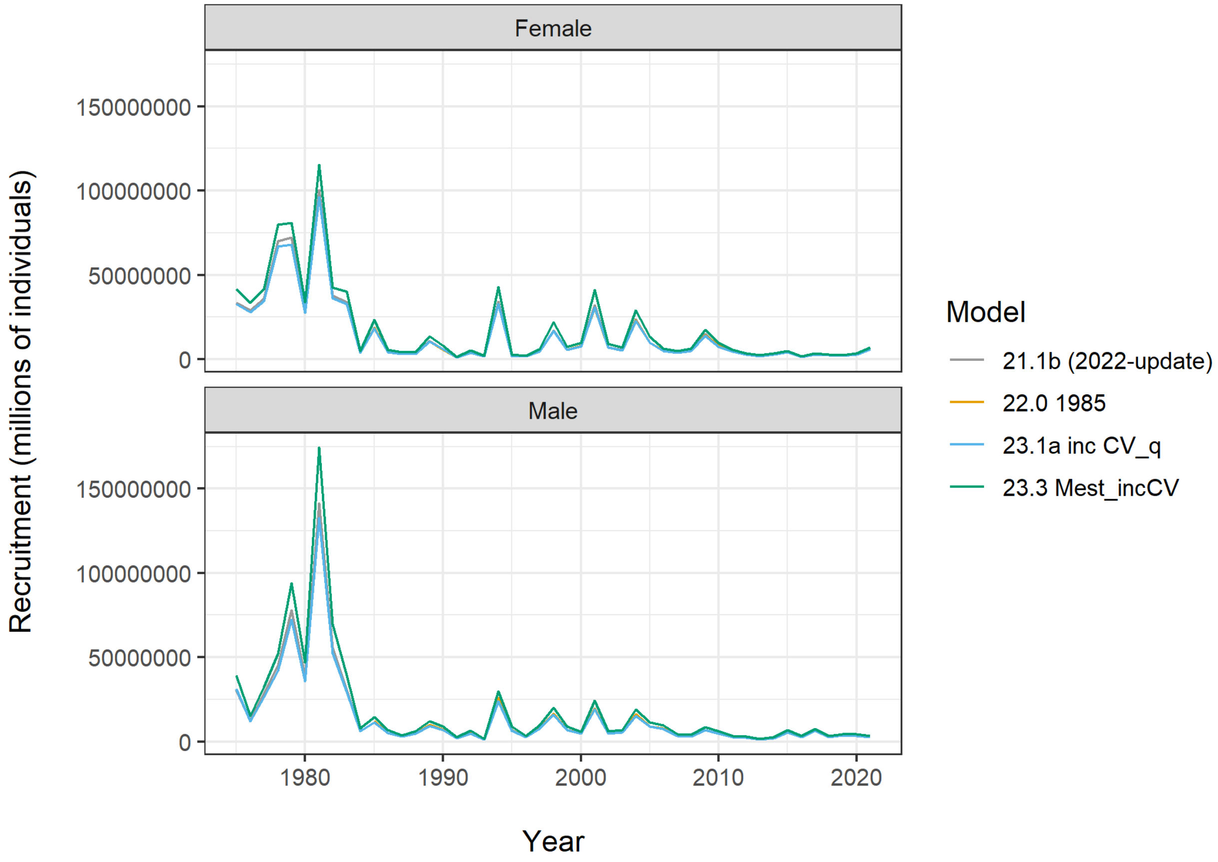

Figure 13: Estimated recruitment time series during 1976-2021 with models 21.1b, 22.0, 23.1a, and 23.3 (those models that capture changes in the CV for q for the NMFS survey). Mean male recruits during 1984-2021 was used to estimate B35. Recruitment estimates in the terminal year (2022) are unreliable.

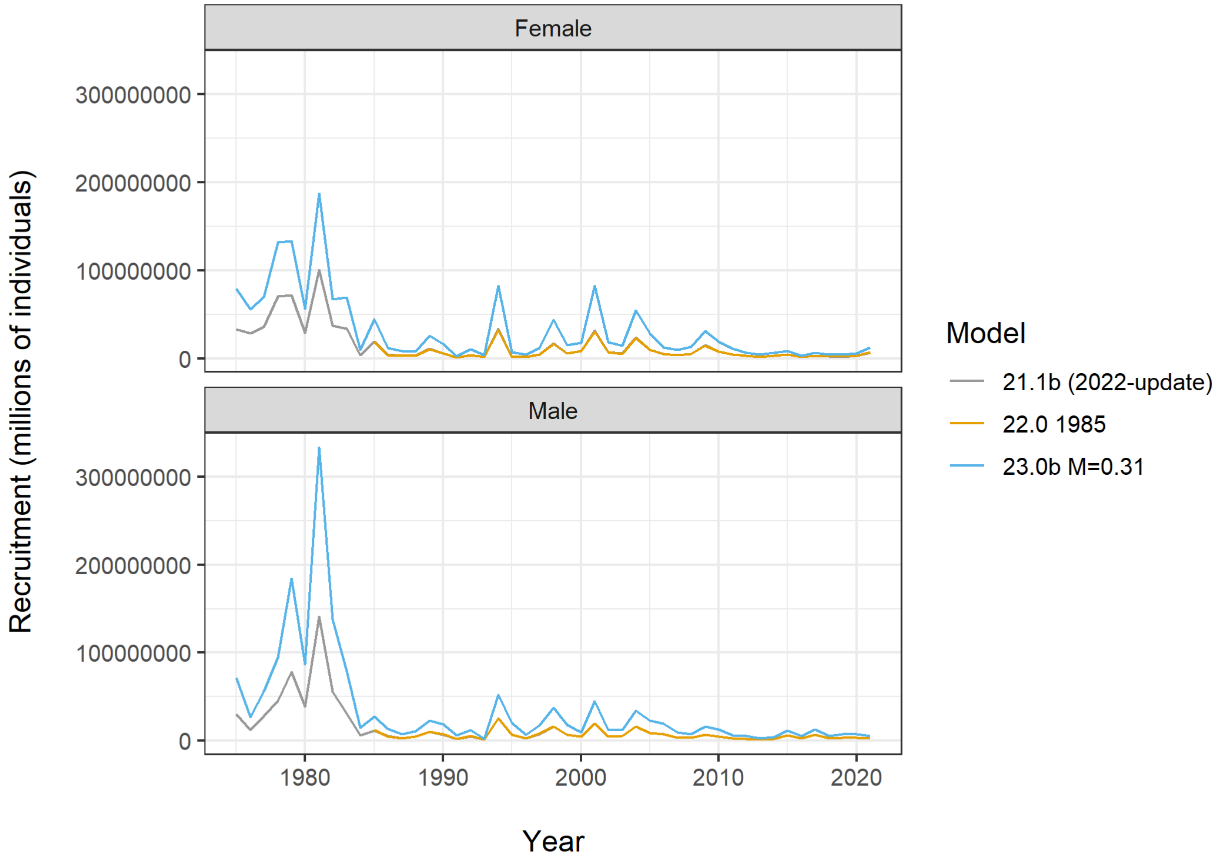

Figure 14: Estimated recruitment time series during 1976-2021 with models 21.1b, 22.0, and 23.0b (base compared to high base M for males). Mean male recruits during 1984-2021 was used to estimate B35. Recruitment estimates in the terminal year (2022) are unreliable.

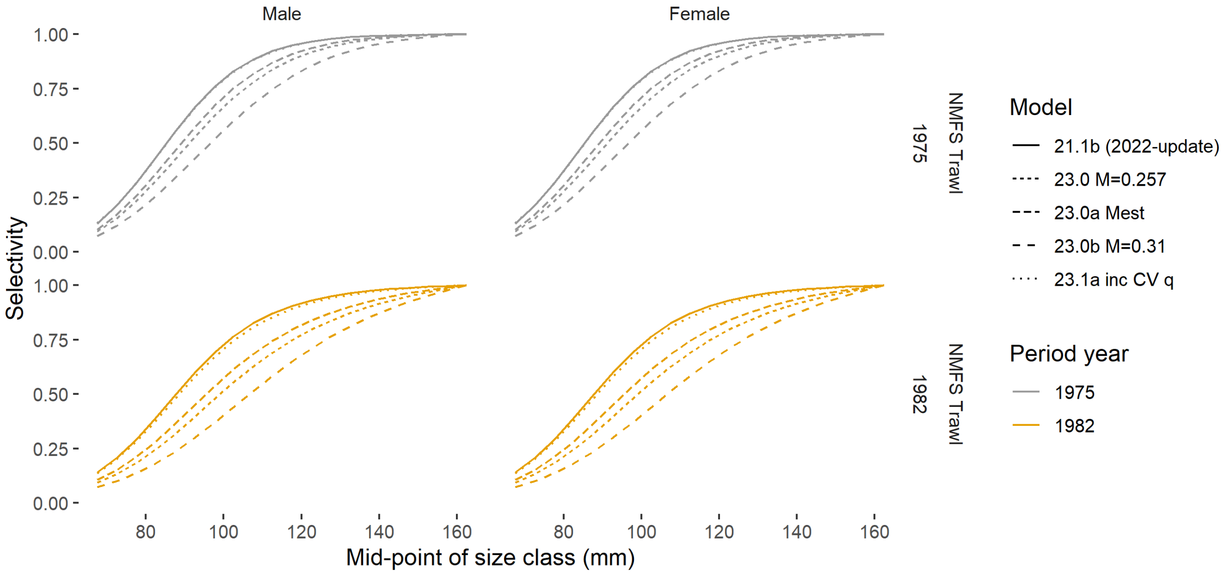

Figure 15: Estimated NMFS trawl survey selectivities under models 21.1b, 23.0, 23.0a, 23.0b, and 23.1a.

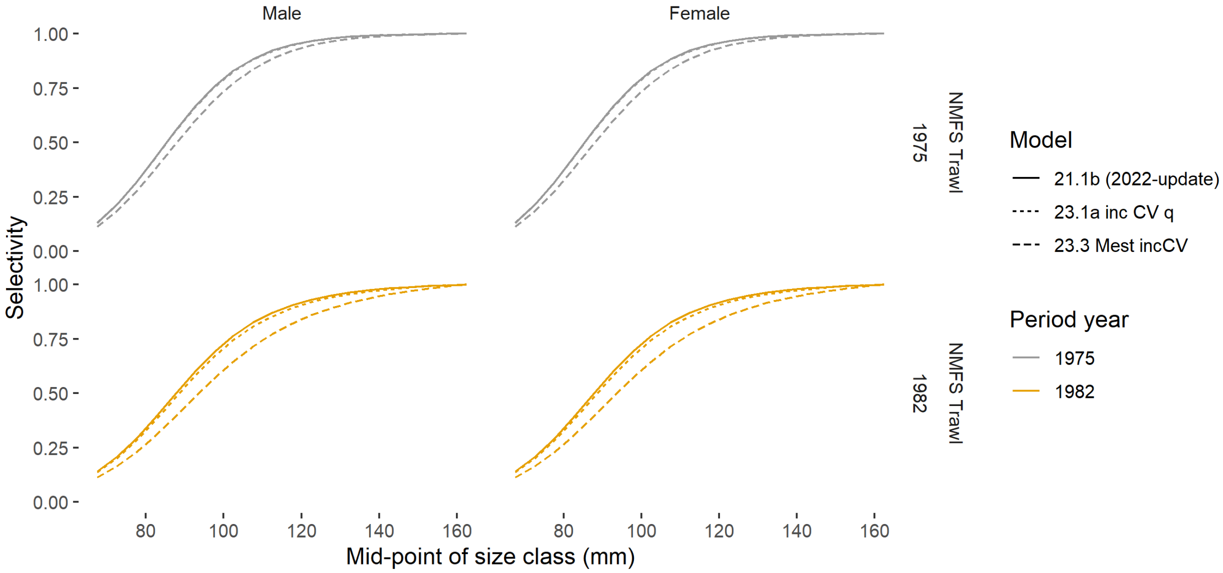

Figure 16: Estimated NMFS trawl survey selectivities under models 21.1b, 23.1a, and 23.3.

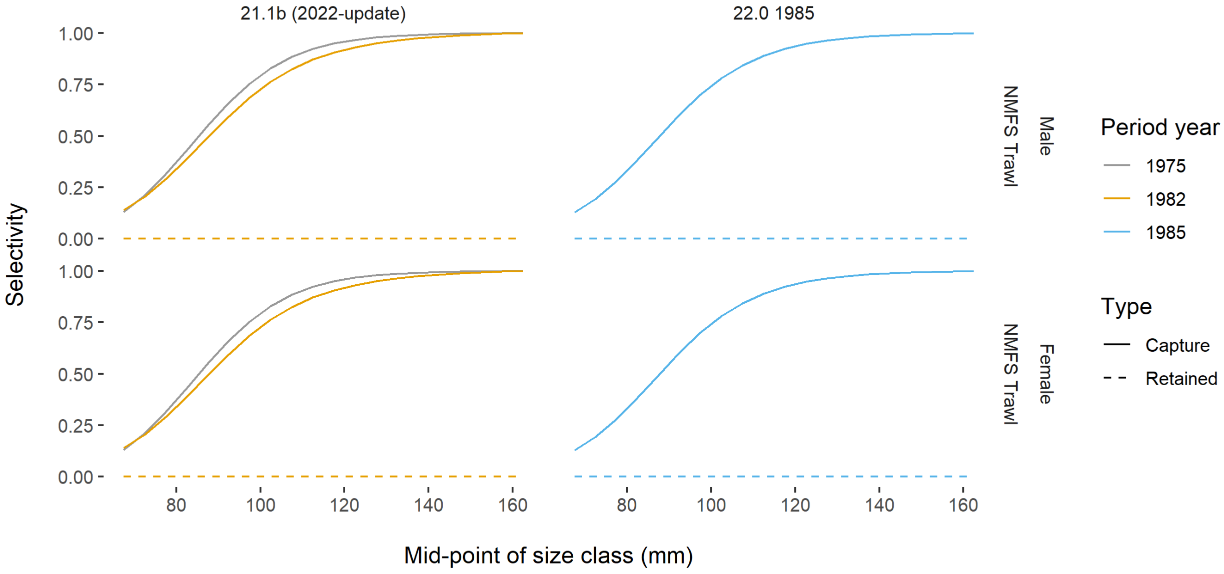

Figure 17: Estimated NMFS trawl survey selectivities under models 21.1b and 22.0.

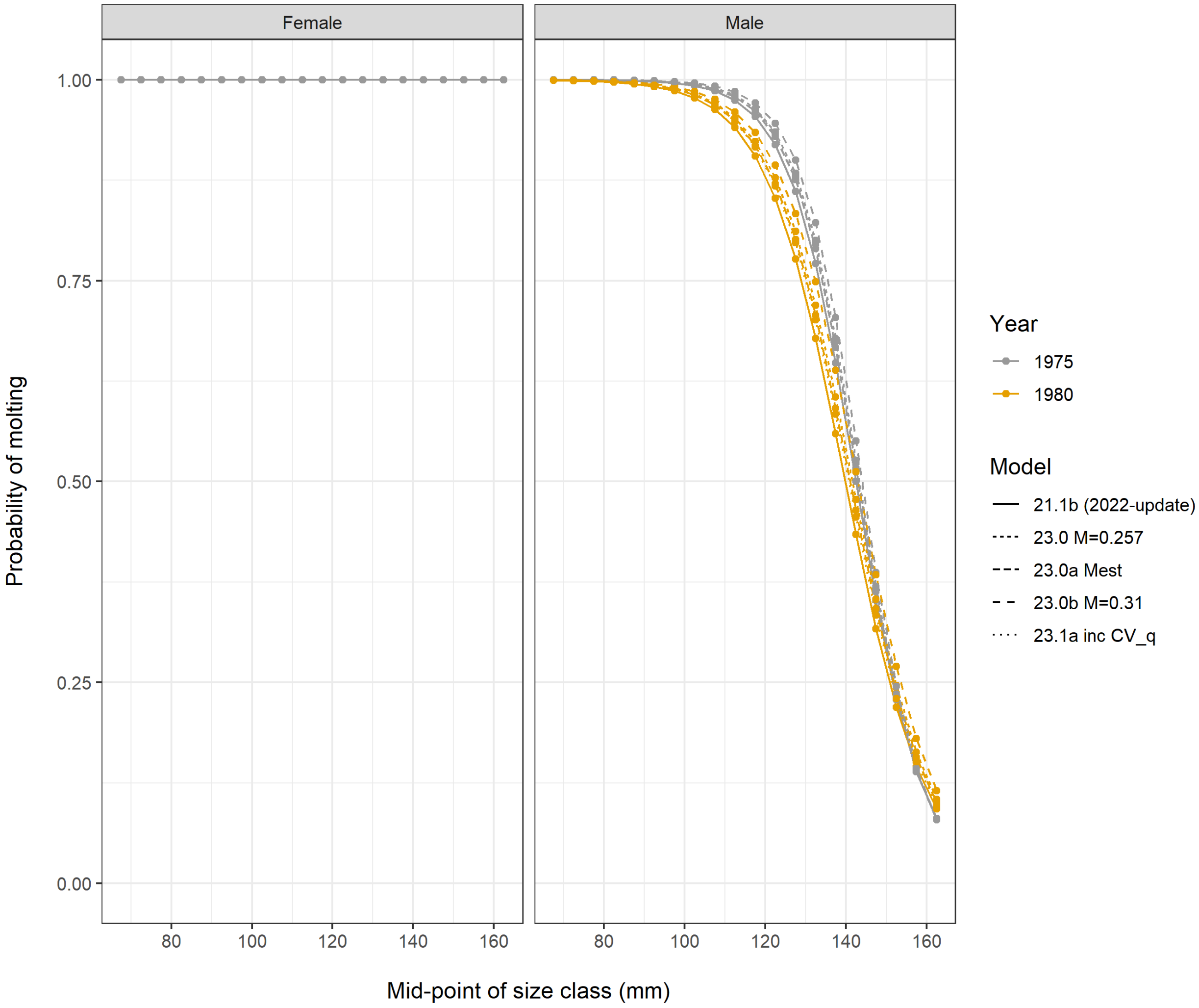

Figure 18: Comparison of estimated probabilities of molting of female and male red king crab in Bristol Bay for two periods - 1975-1979 and 1980-2022 - for models 21.1b, 23.0, 23.0a, 23.0b, and 23.1.

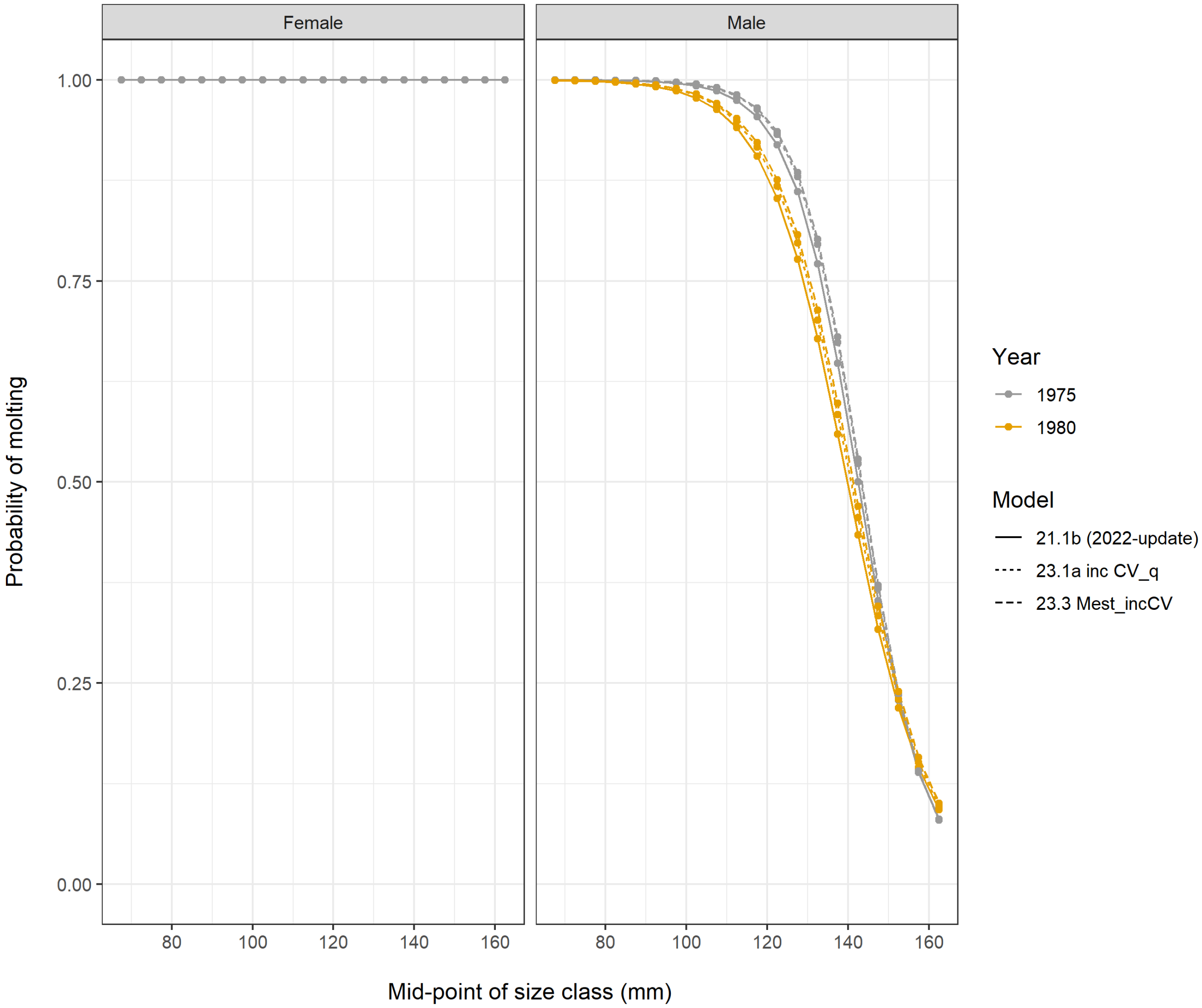

Figure 19: Comparison of estimated probabilities of molting of female and male red king crab in Bristol Bay for two periods - 1975-1979 and 1980-2022 - for models 21.1b, 23.1a, and 23.3 which compare the base model with those that have a larger CV for q estimation for the NMFS trawl survey.

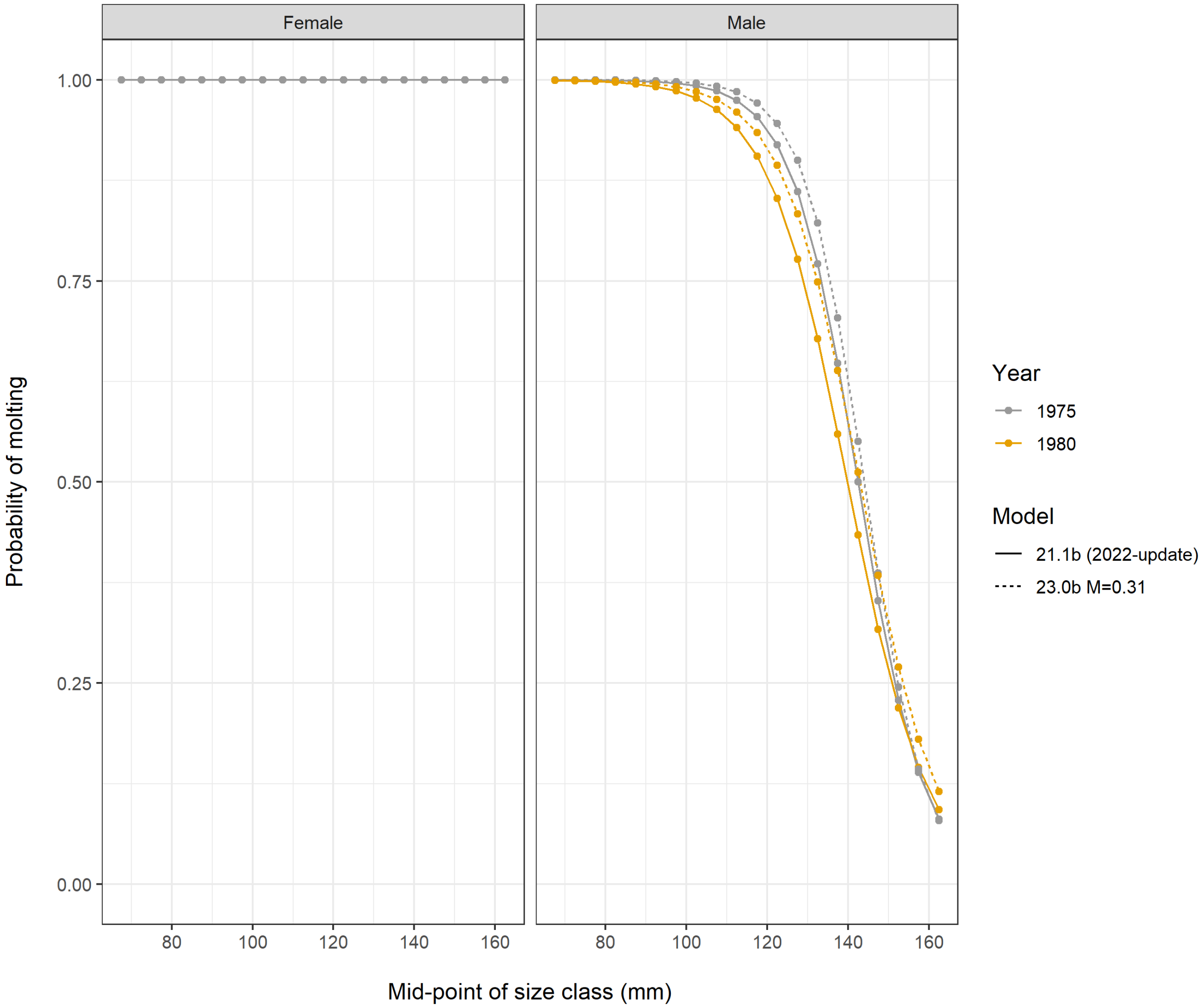

Figure 20: Comparison of estimated probabilities of molting of female and male red king crab in Bristol Bay for two periods - 1975-1979 and 1980-2022 - for models 21.1b and 23.0b which reflect changes due to a larger M value for males.

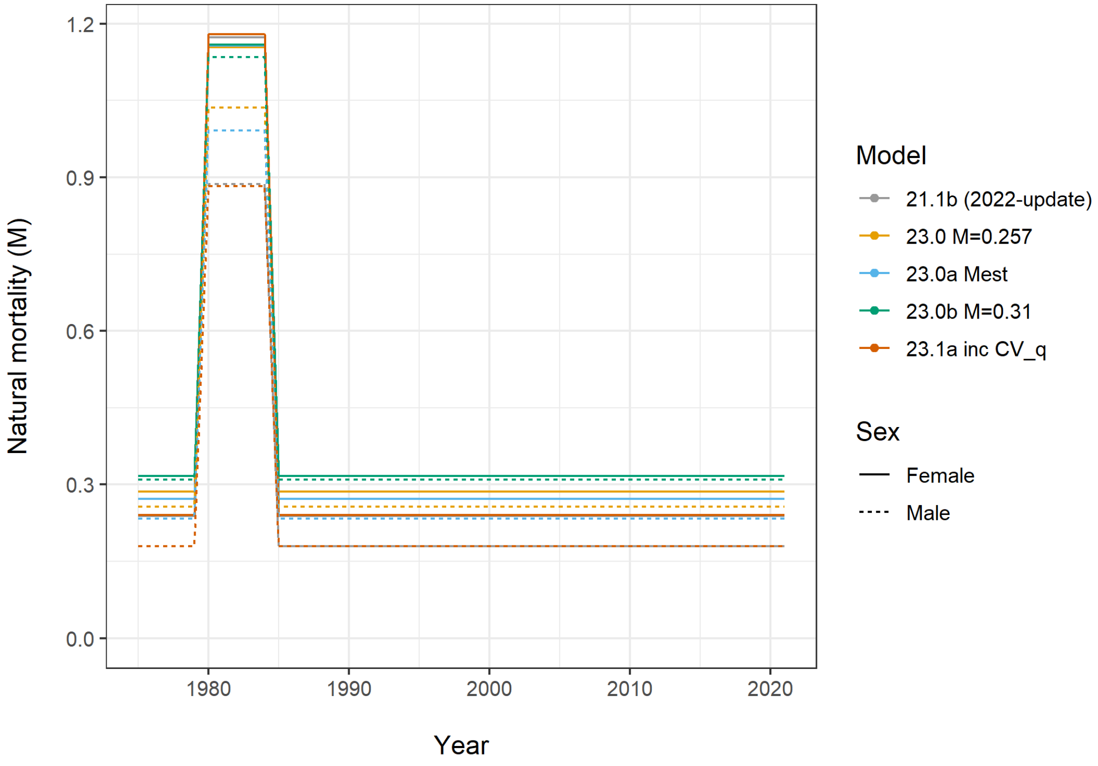

Figure 21: Comparison of natural mortality - either estimated or fixed depending on the model - for models 21.1b, 23.0, 23.0a, 23.0b, and 23.1.

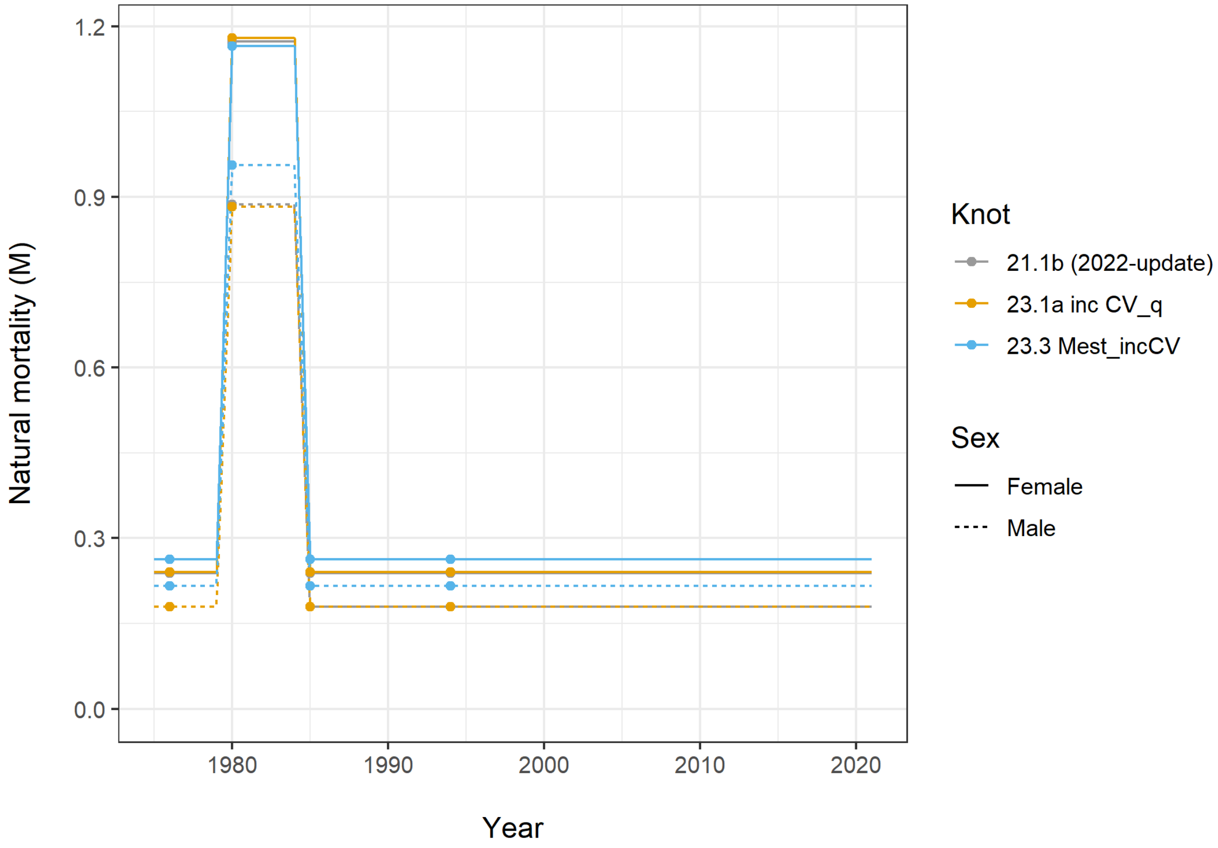

Figure 22: Comparison of natural mortality - either estimated or fixed depending on the model - for models 21.1b, 23.1. and 23.3.

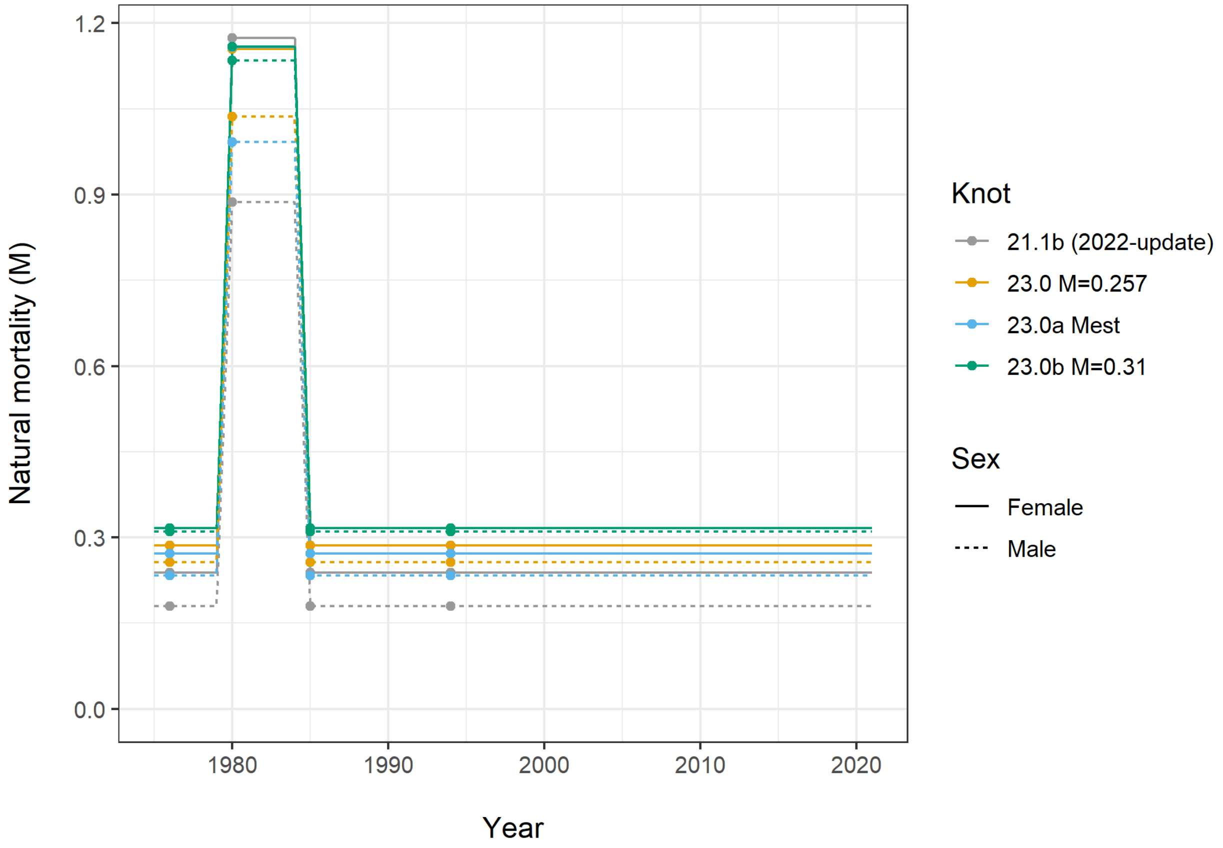

Figure 23: Comparison of natural mortality - either estimated or fixed depending on the model - for models 21.1b, 23.0, 23.0a, and 23.0b.

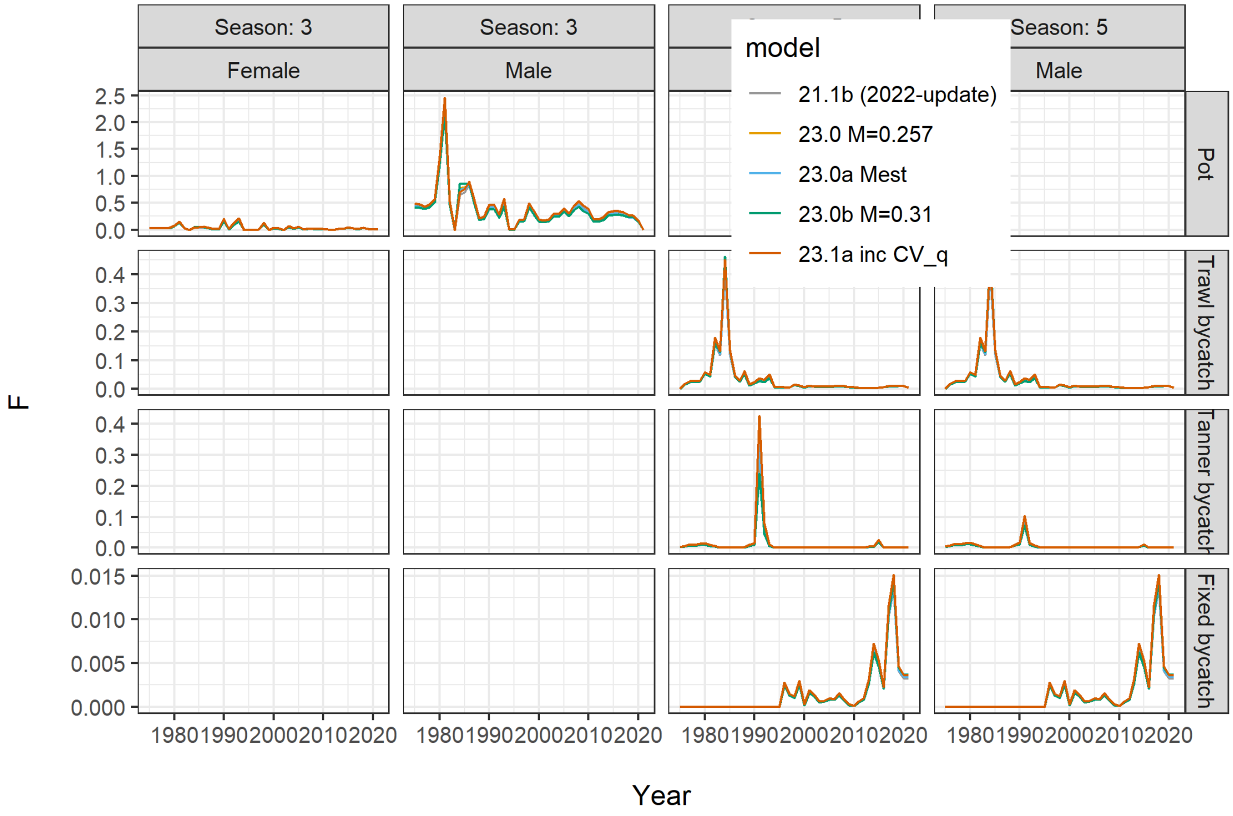

Figure 24: Comparison of estimated fishing mortality for models 21.1b, 23.0, 23.0a, 23.0b, and 23.1.

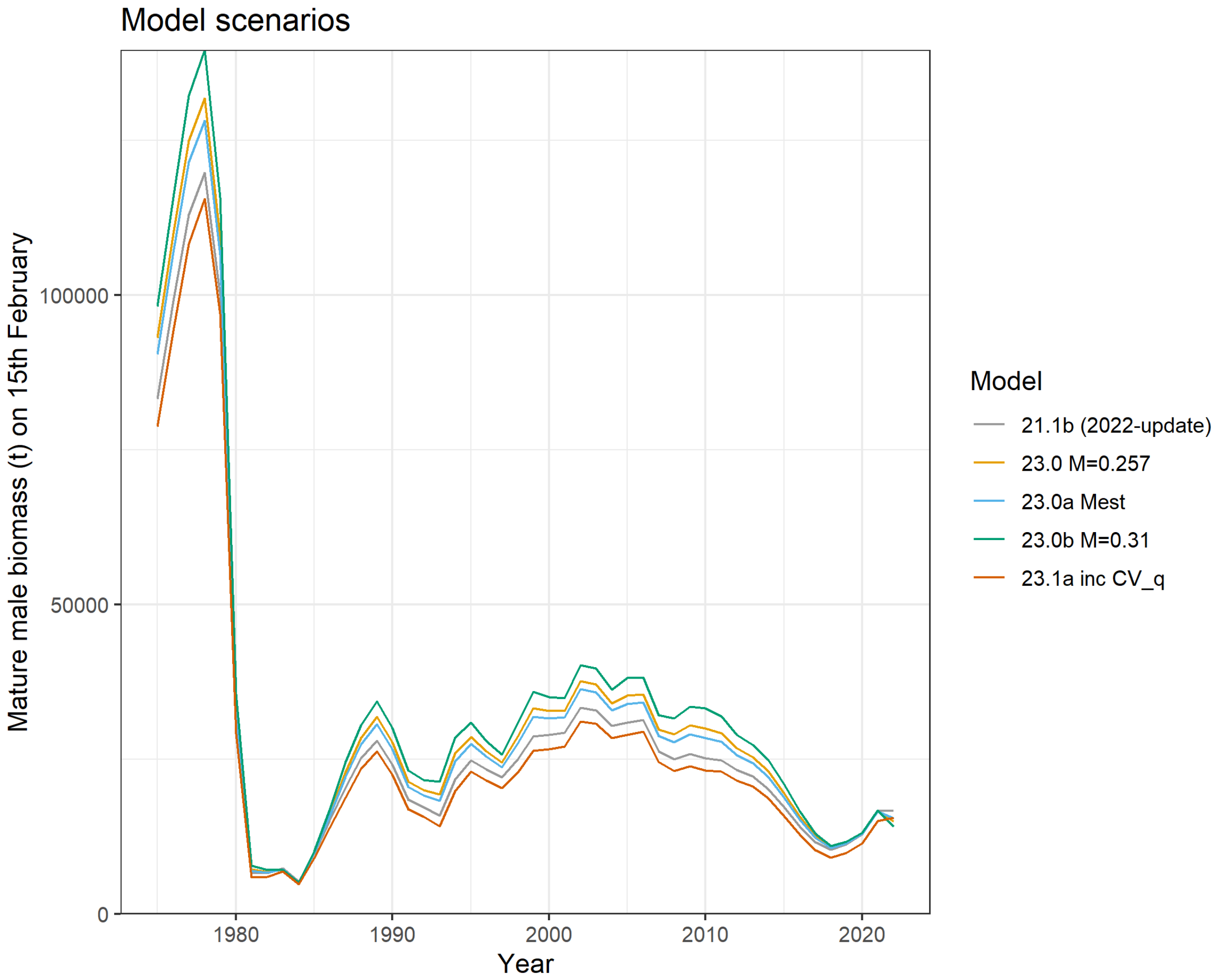

Figure 25: Estimated absolute mature male biomasses during 1975-2022 for models 21.1b, 23.0, 23.0a, 23.0b, and 23.1. Mature male biomass is estimated on Feb. 15, year+1.

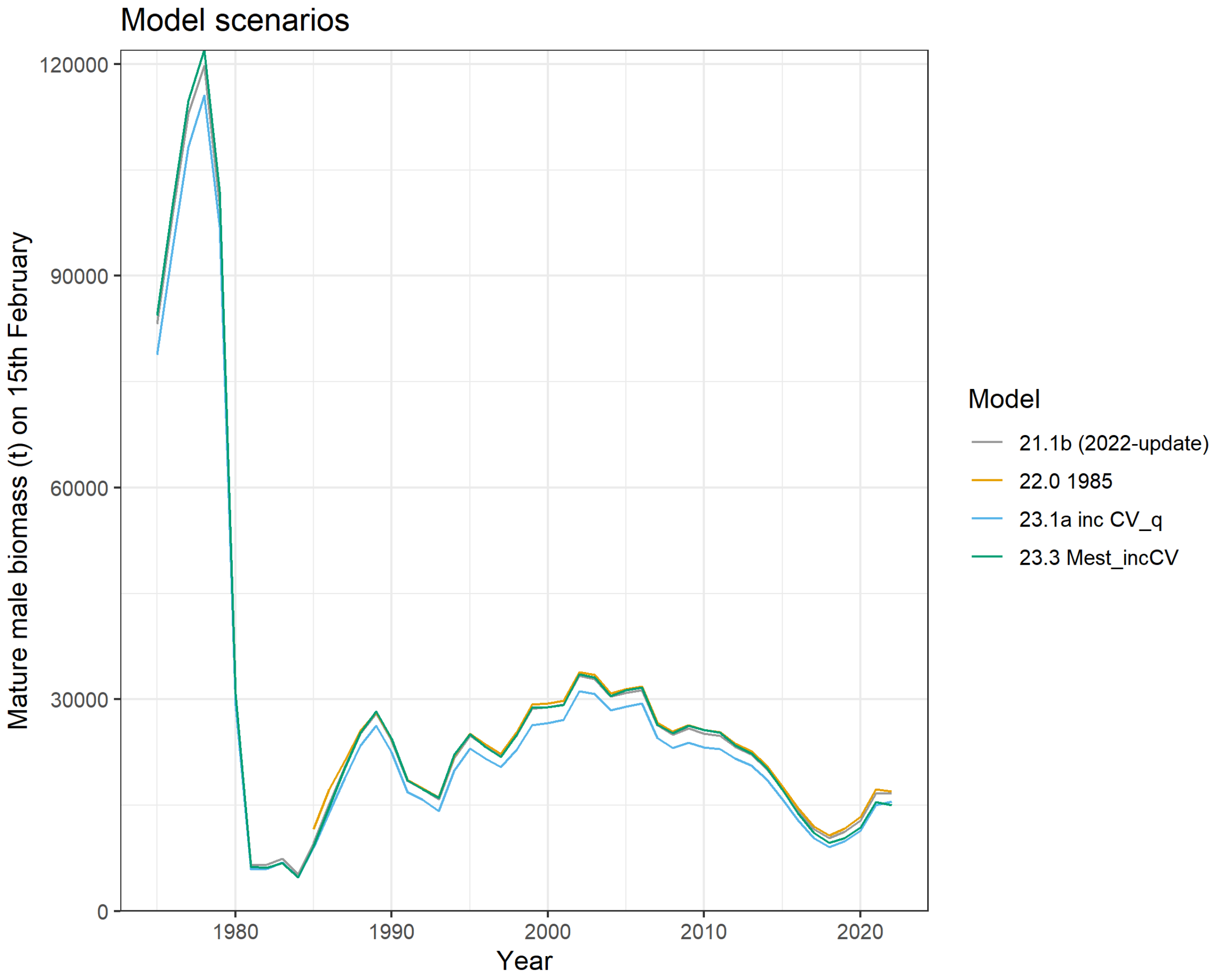

Figure 26: Estimated absolute mature male biomasses during 1975-2022 for models 21.1b, 22.0, 23.1, and 23.3. Mature male biomass is estimated on Feb. 15, year+1.

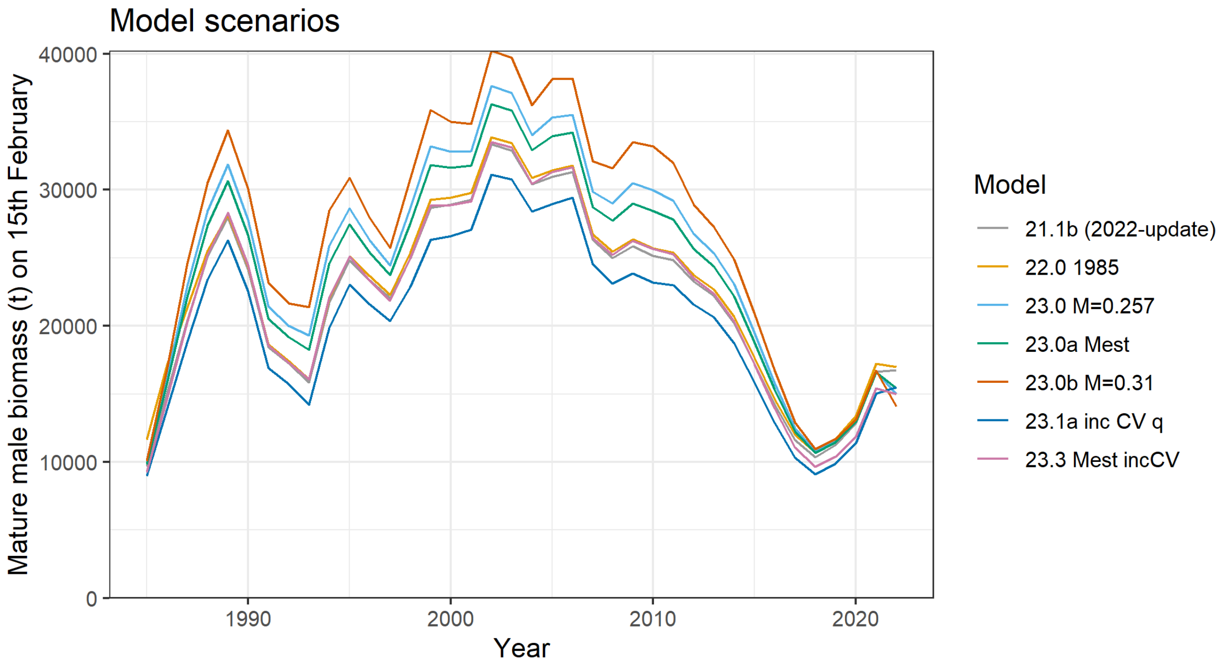

Figure 27: Estimated absolute mature male biomasses during 1985-2022 for models 21.1b, 22.0, 23.0, 23.0a, 23.0b, and 23.1. Mature male biomass is estimated on Feb. 15, year+1.

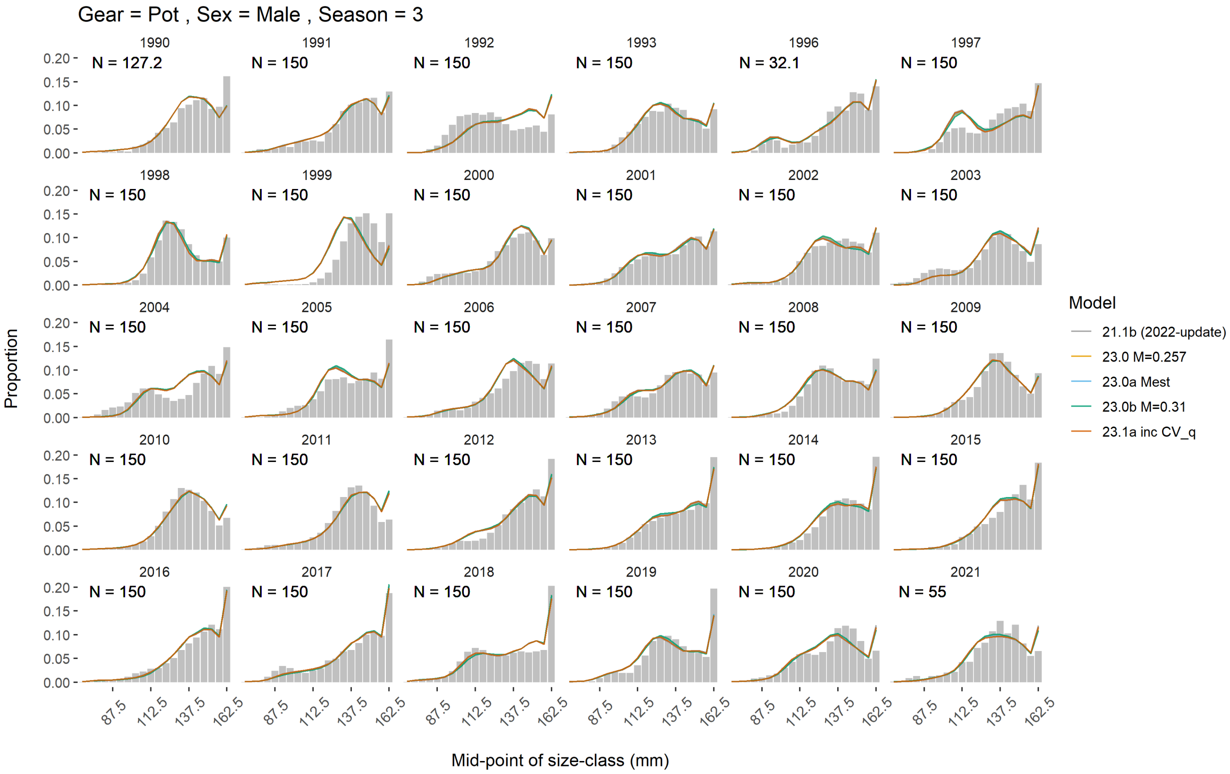

Figure 28: Observed and model estimated retained legnth-frequencies of male BBRKC by year retained in the directed pot fishery for the model scenarios.

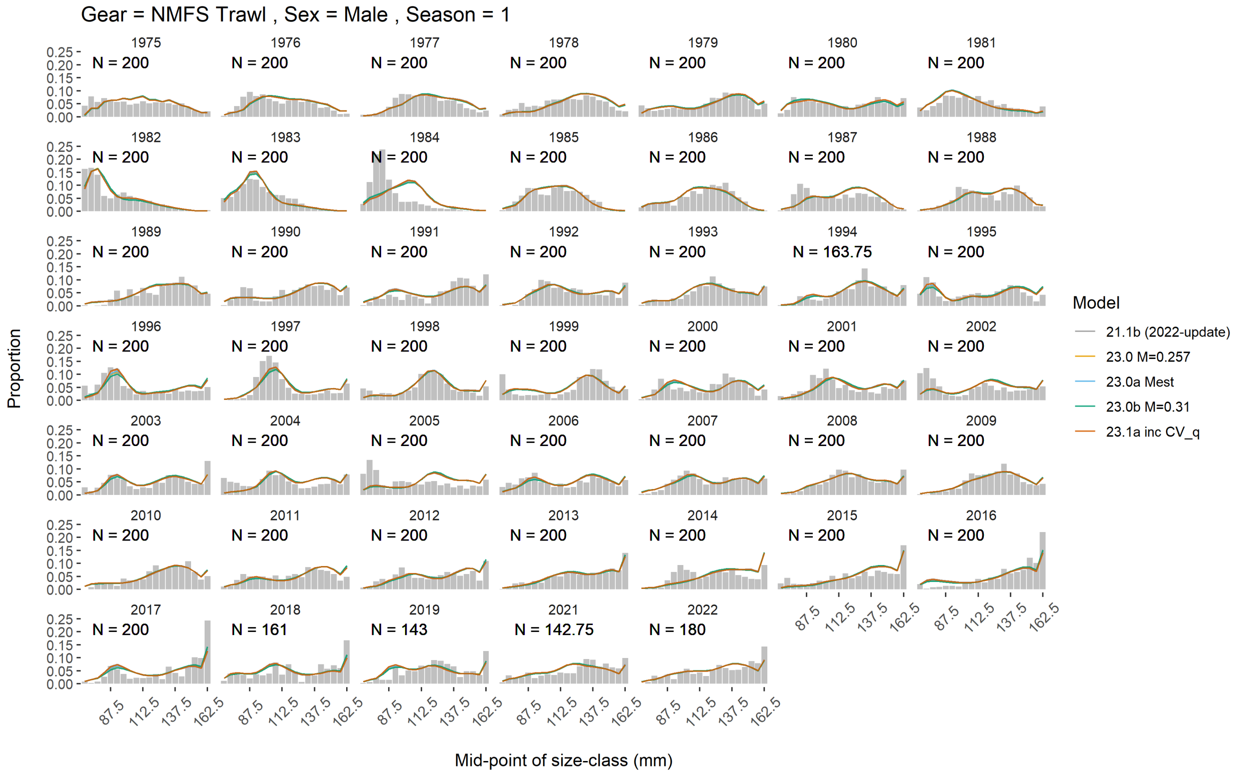

Figure 29: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year for most model scenarios.

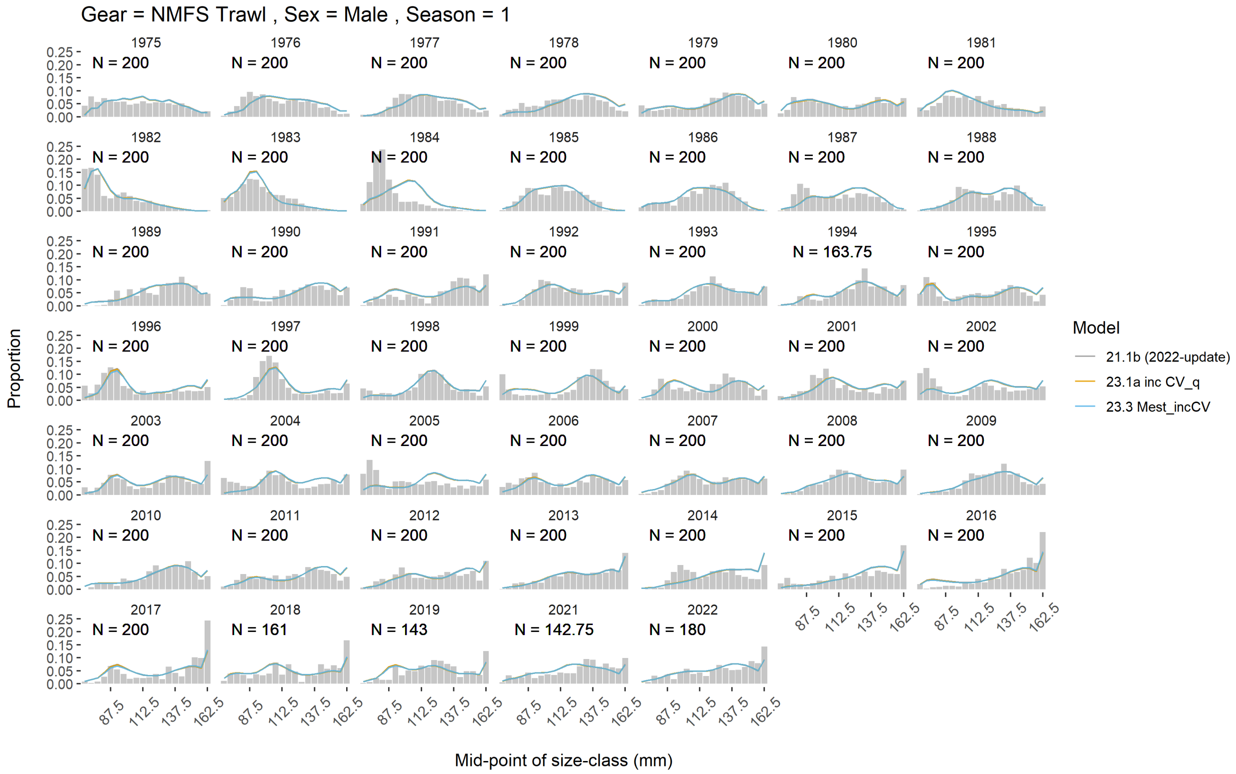

Figure 30: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year for model scenarios that include changes in the prior on Q.

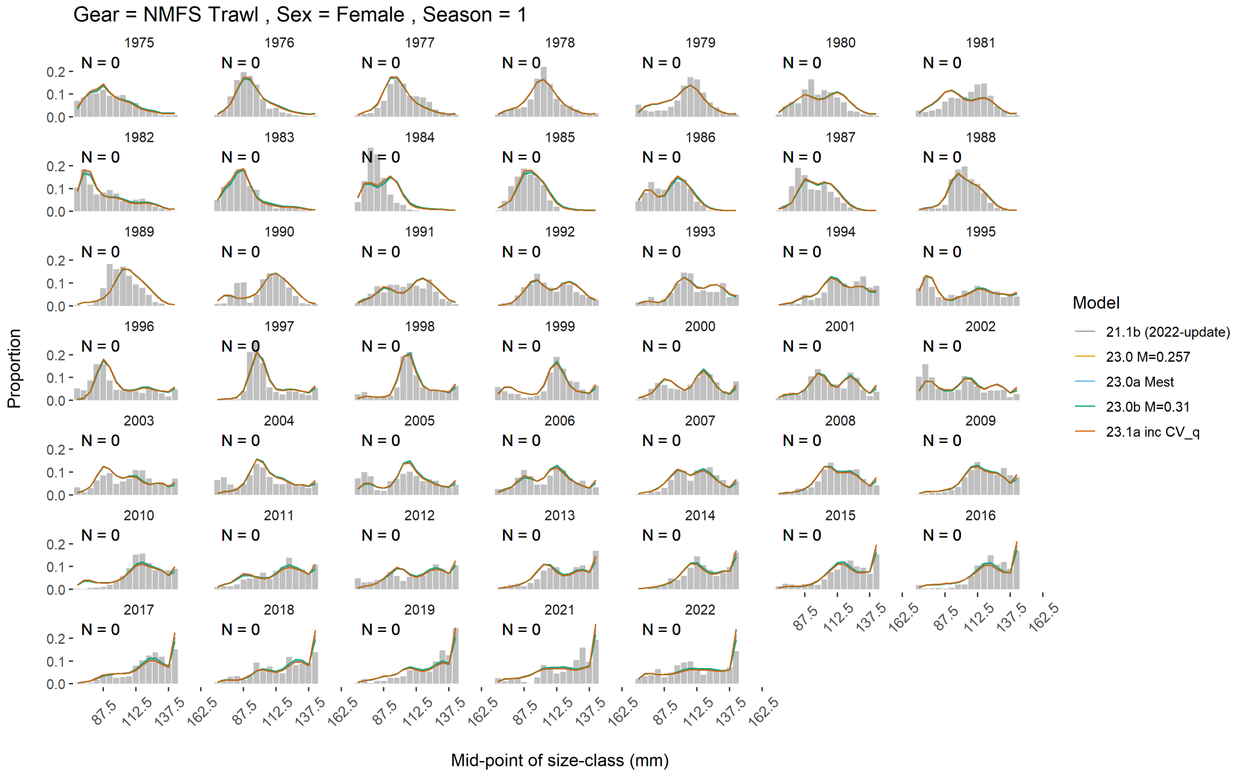

Figure 31: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay FEMALE red king crab by year for most model scenarios.

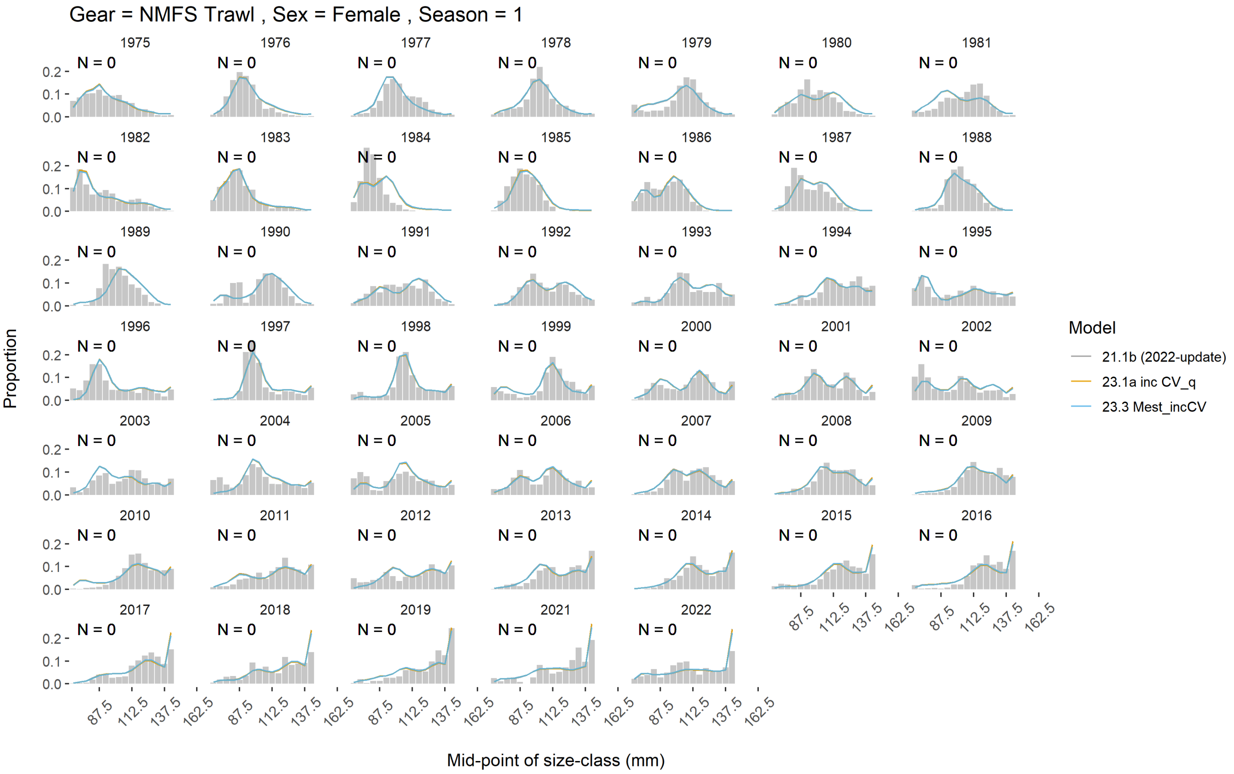

Figure 32: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year for model scenarios that include changes in the prior on Q.

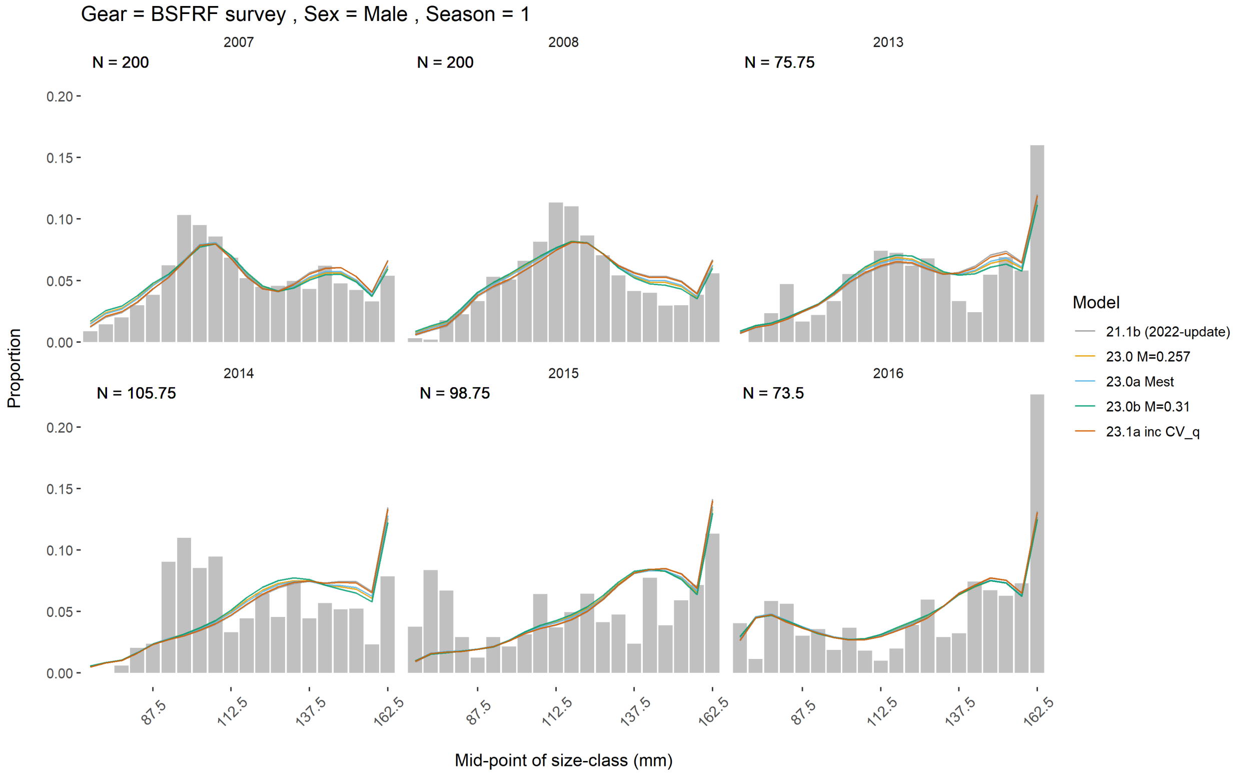

Figure 33: Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 for most model scenarios.

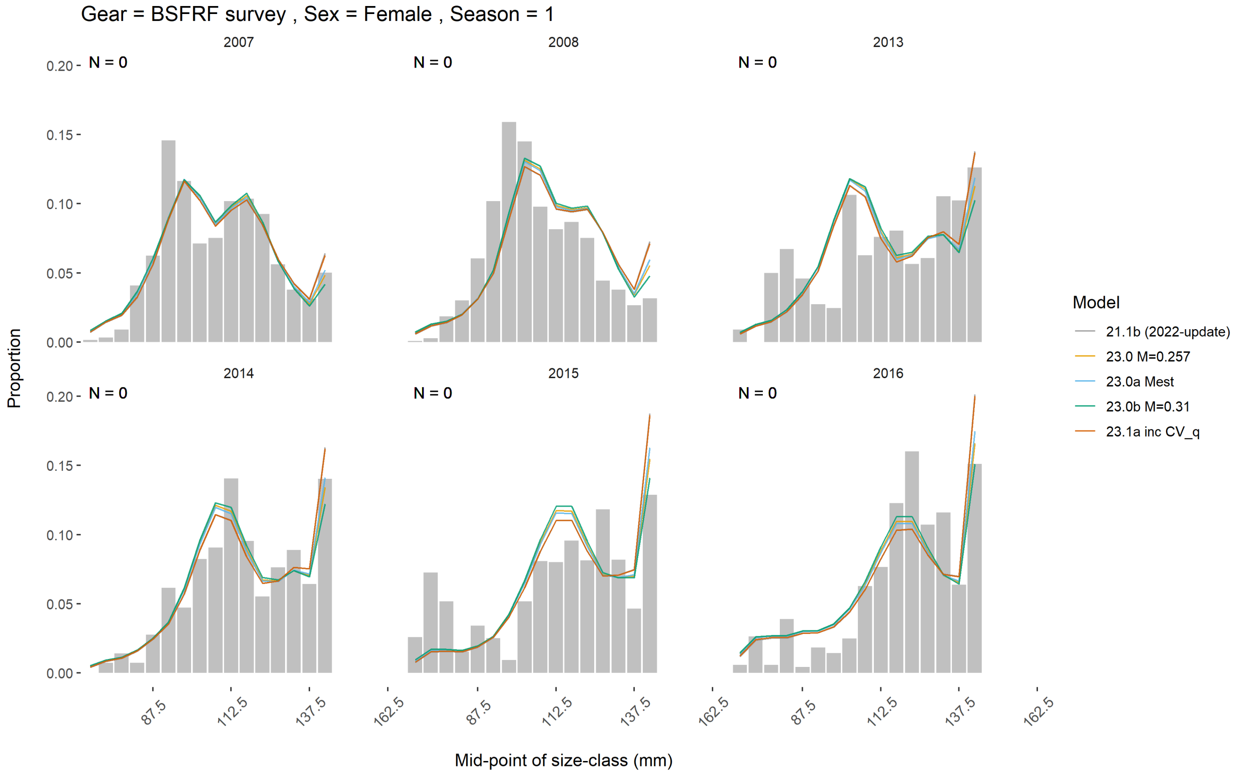

Figure 34: Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 for most model scenarios.

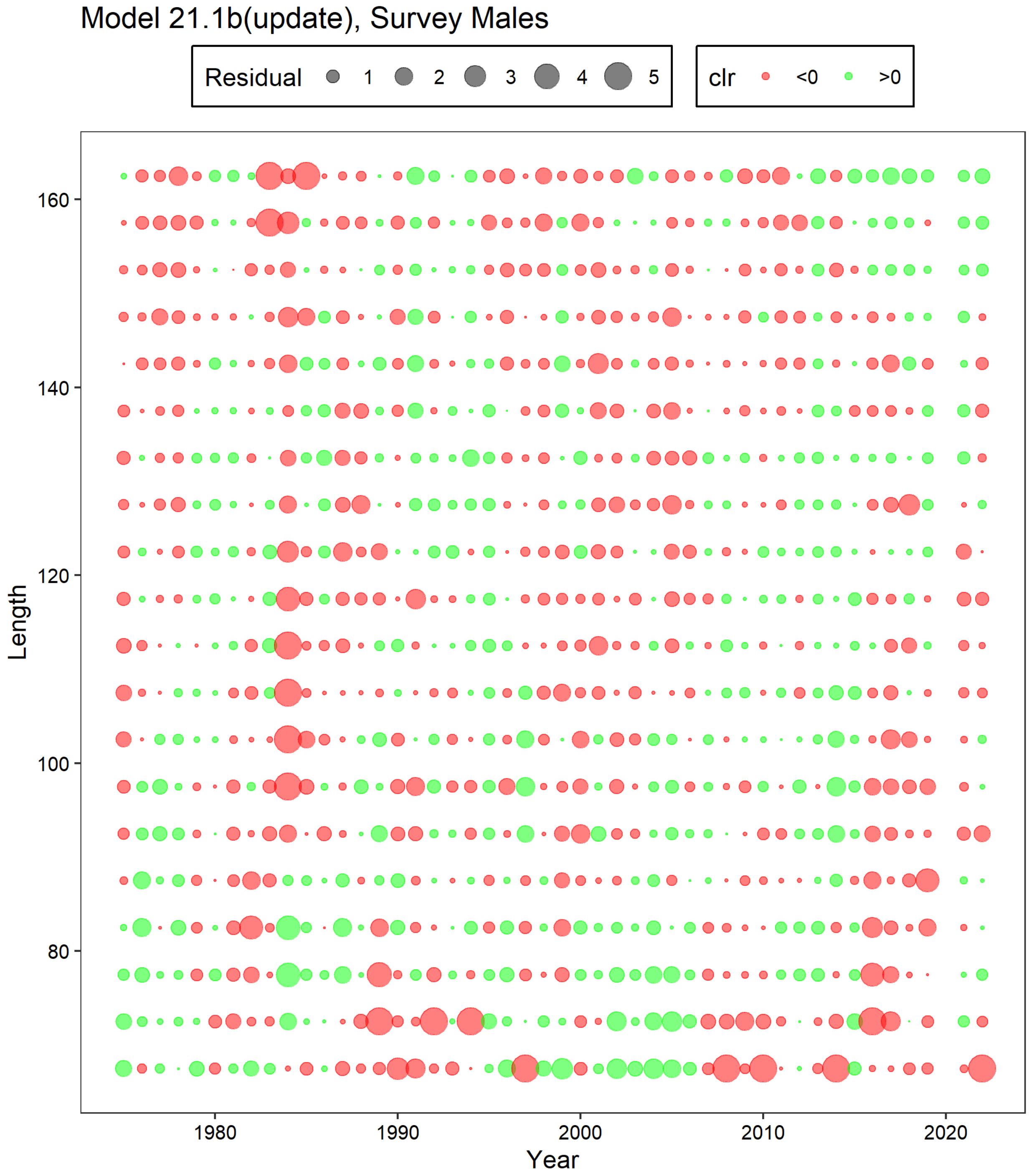

Figure 35: Bubble plots of residuals for MALES by size and year for the NMFS trawl survey size composition data sets for BBRKC in the 'base' model (21.1b) 2022 update.

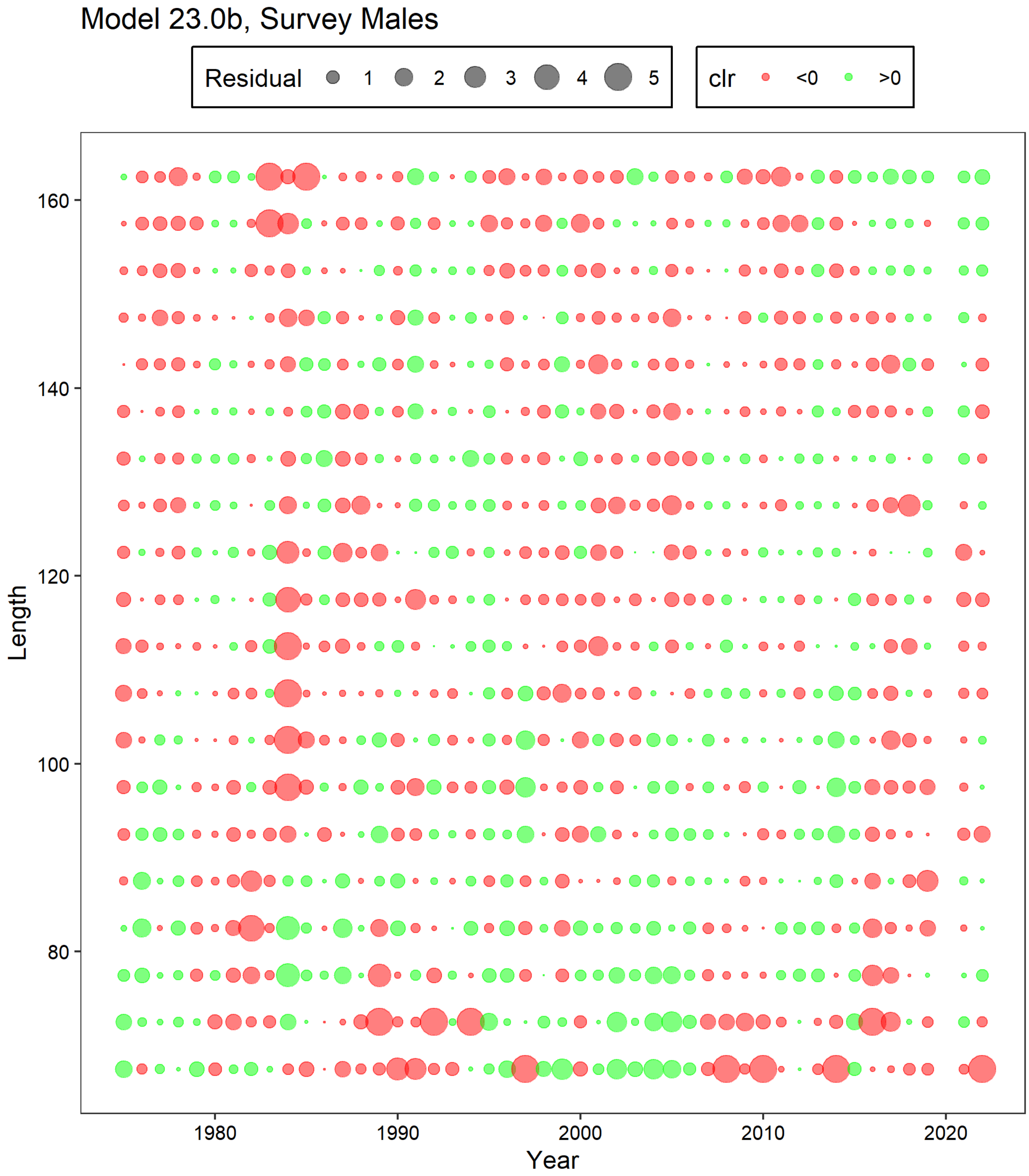

Figure 36: Bubble plots of residuals for MALES by size and year for the NMFS trawl survey size composition data sets for BBRKC in the 'high M' model 23.0b.

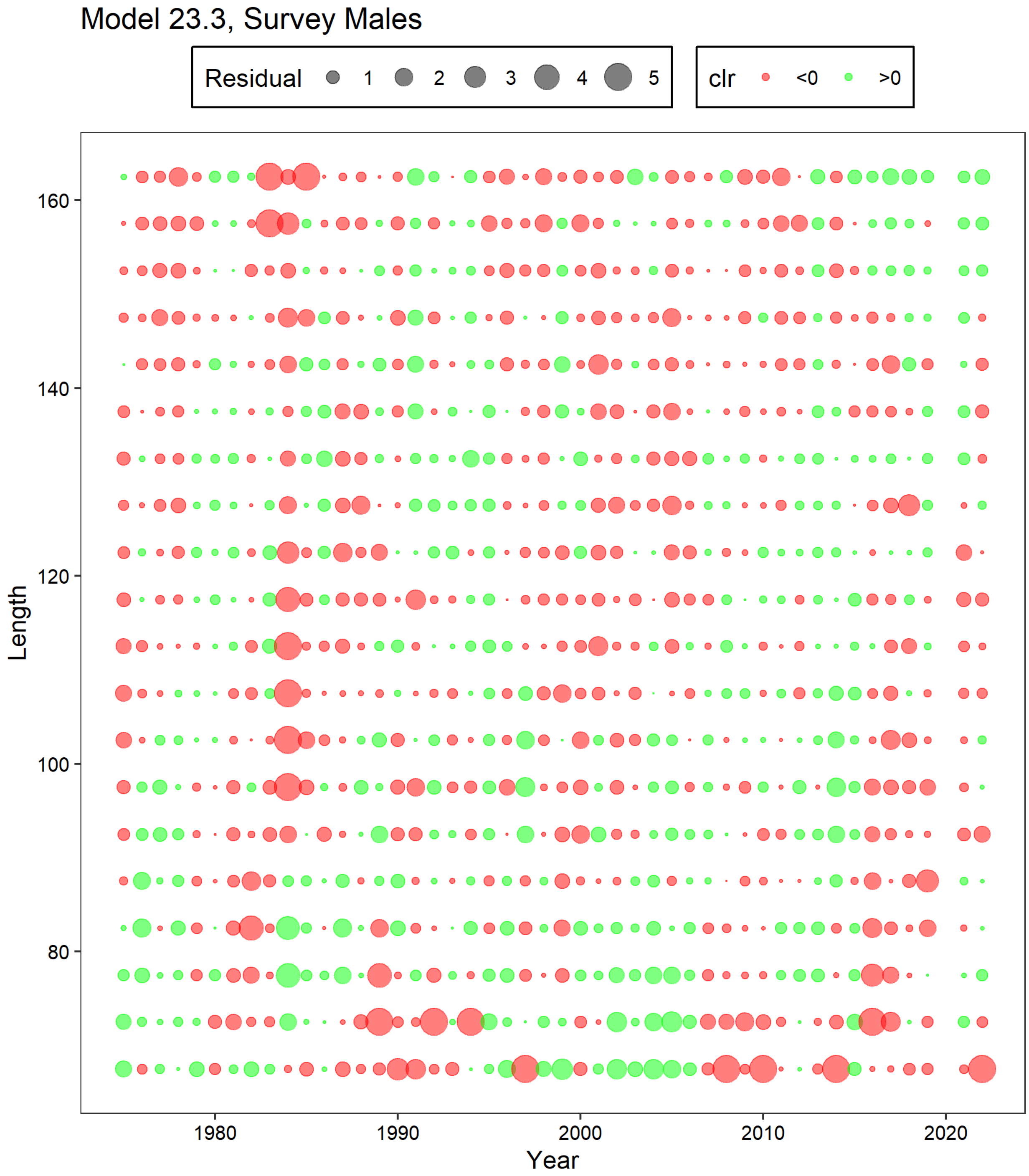

Figure 37: Bubble plots of residuals for MALES by size and year for the NMFS trawl survey size composition data sets for BBRKC in the 'estimate M and inc CV on q' model 23.3.

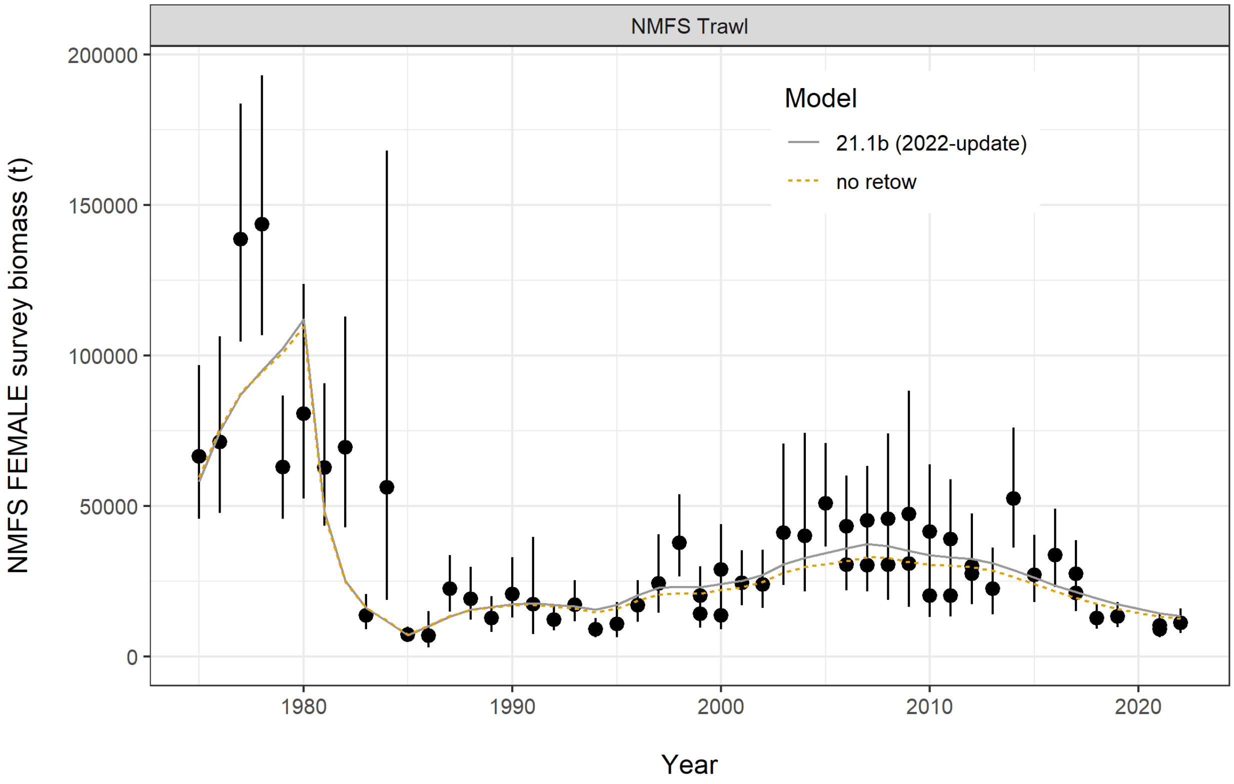

Figure 38: Comparisons of area-swept estimates of total FEMALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b and 23.2 (no retow data). In years with retow data (99,00,06 to 12,17,21) there are two data point for the area-swept estimates. The lower of these data points reflects the leg 1 survey data or the data WITHOUT retows. The error bars are plus and minus 2 standard deviations of model 21.1b.

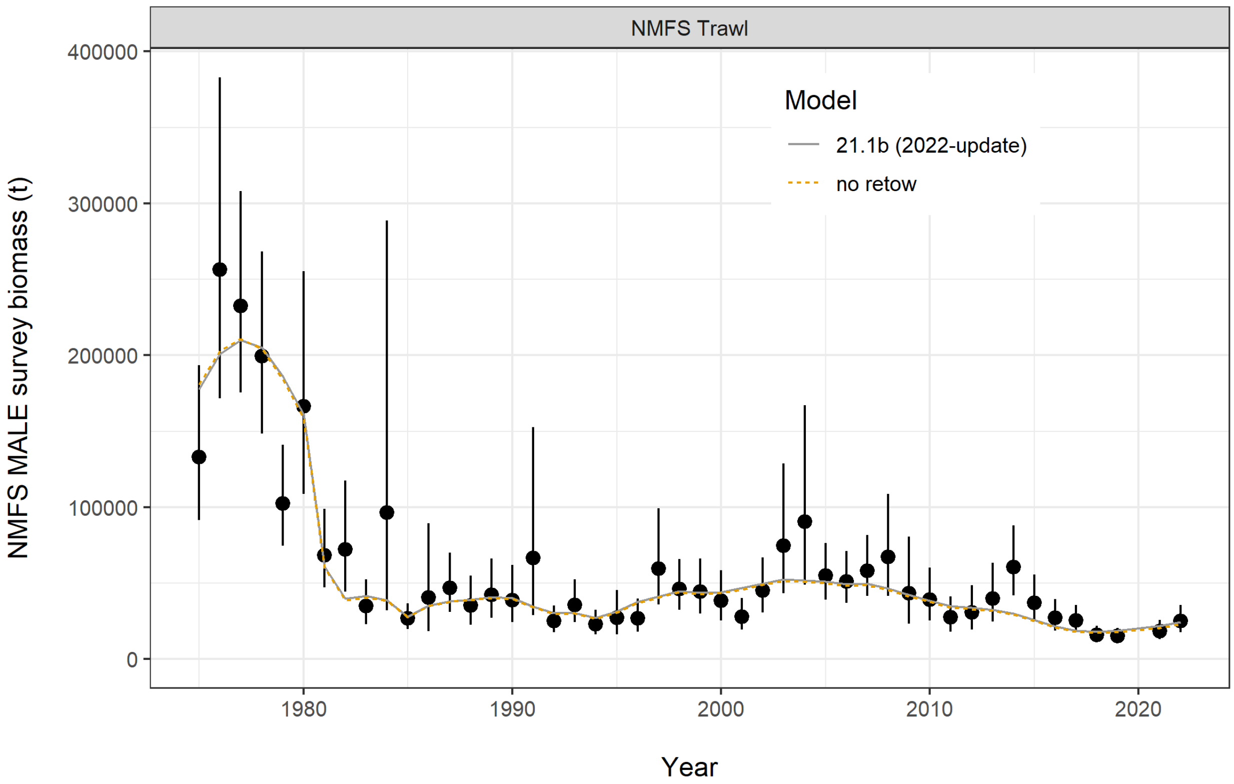

Figure 39: Comparisons of area-swept estimates of total MALE NMFS survey biomass and model prediction for model estimates in 2022 under models 21.1b and 23.2 (no retow data). The error bars are plus and minus 2 standard deviations of model 21.1b.

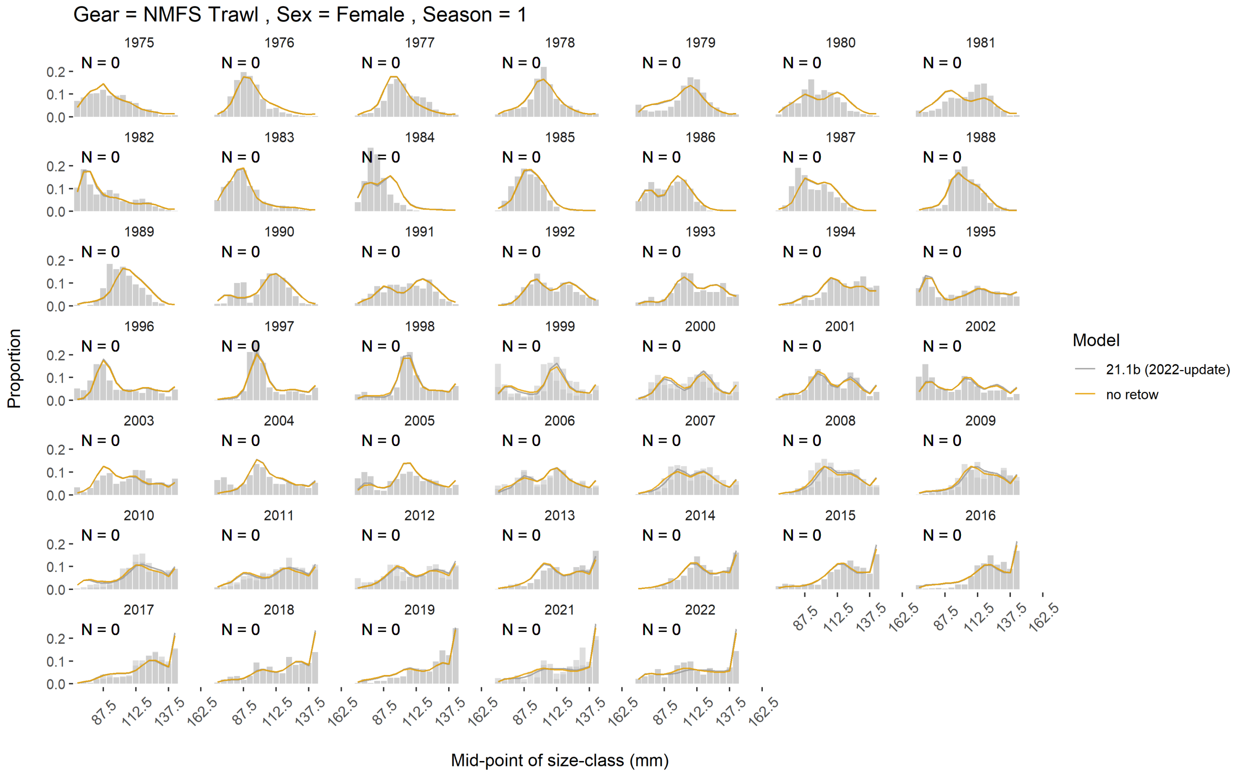

Figure 40: Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year for the base model(21.1b) vs base model with NO retow data (23.2). Difference exist is years with retow data (99,00,06 to 12,17,21).

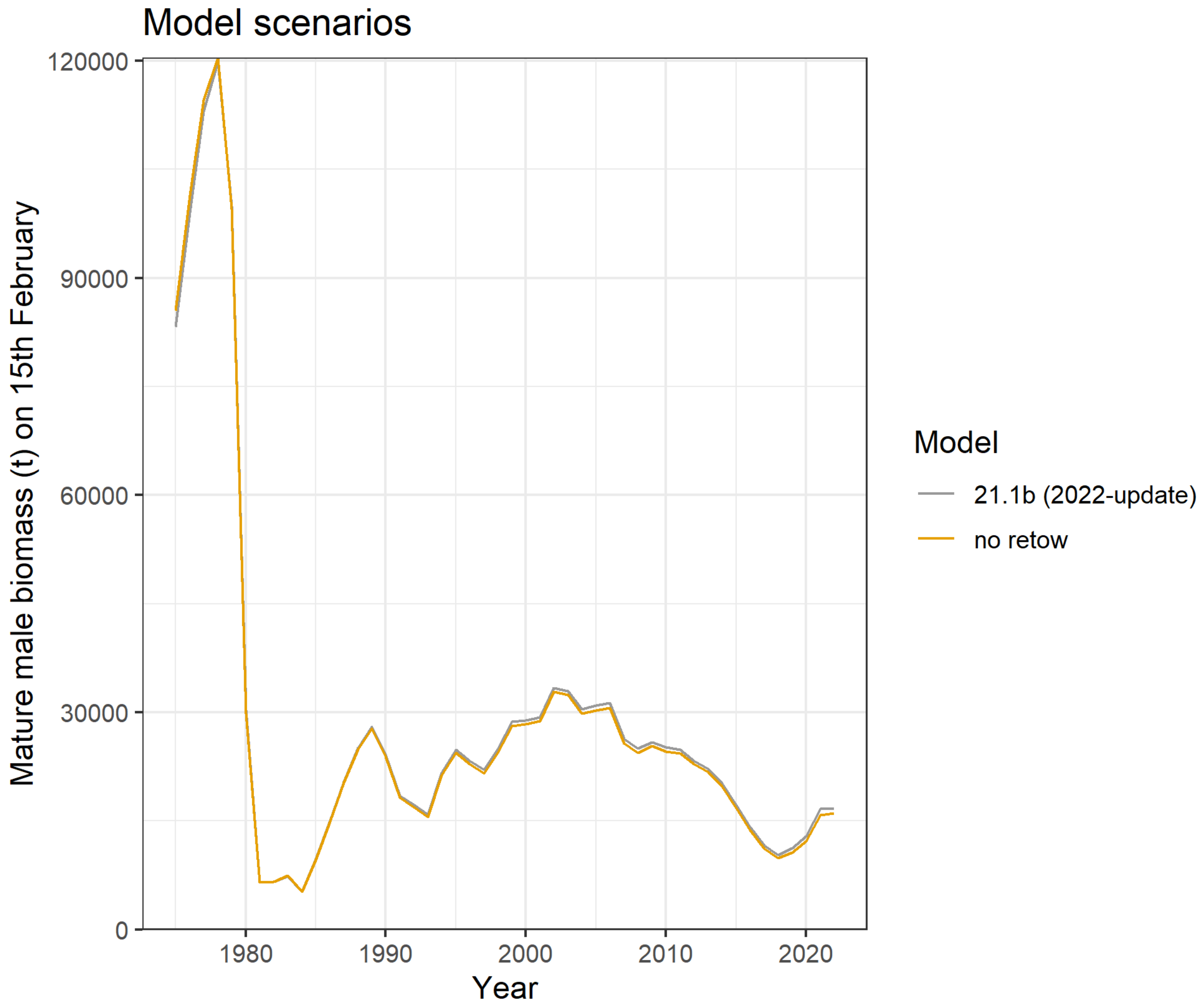

Figure 41: Estimated absolute mature male biomasses during 1975-2022 for models 21.1b and 23.2, difference reflect the influence of retow data for females on the population dynamics model. Mature male biomass is estimated on Feb. 15, year+1.

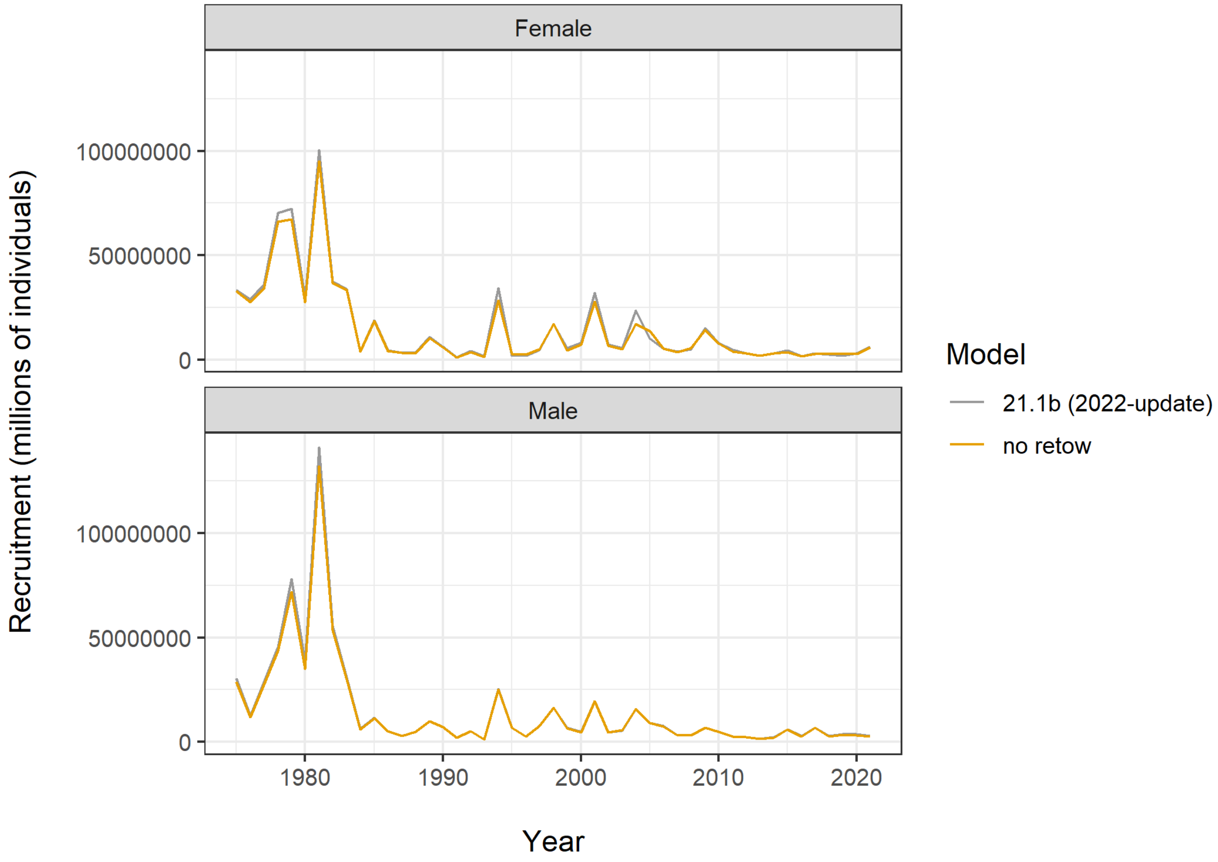

Figure 42: Estimated recruitment time series during 1976-2021 with models 21.1b and 23.2 (no retow data). Mean male recruits during 1984-2021 was used to estimate B35. Recruitment estimates in the terminal year (2022) are unreliable.

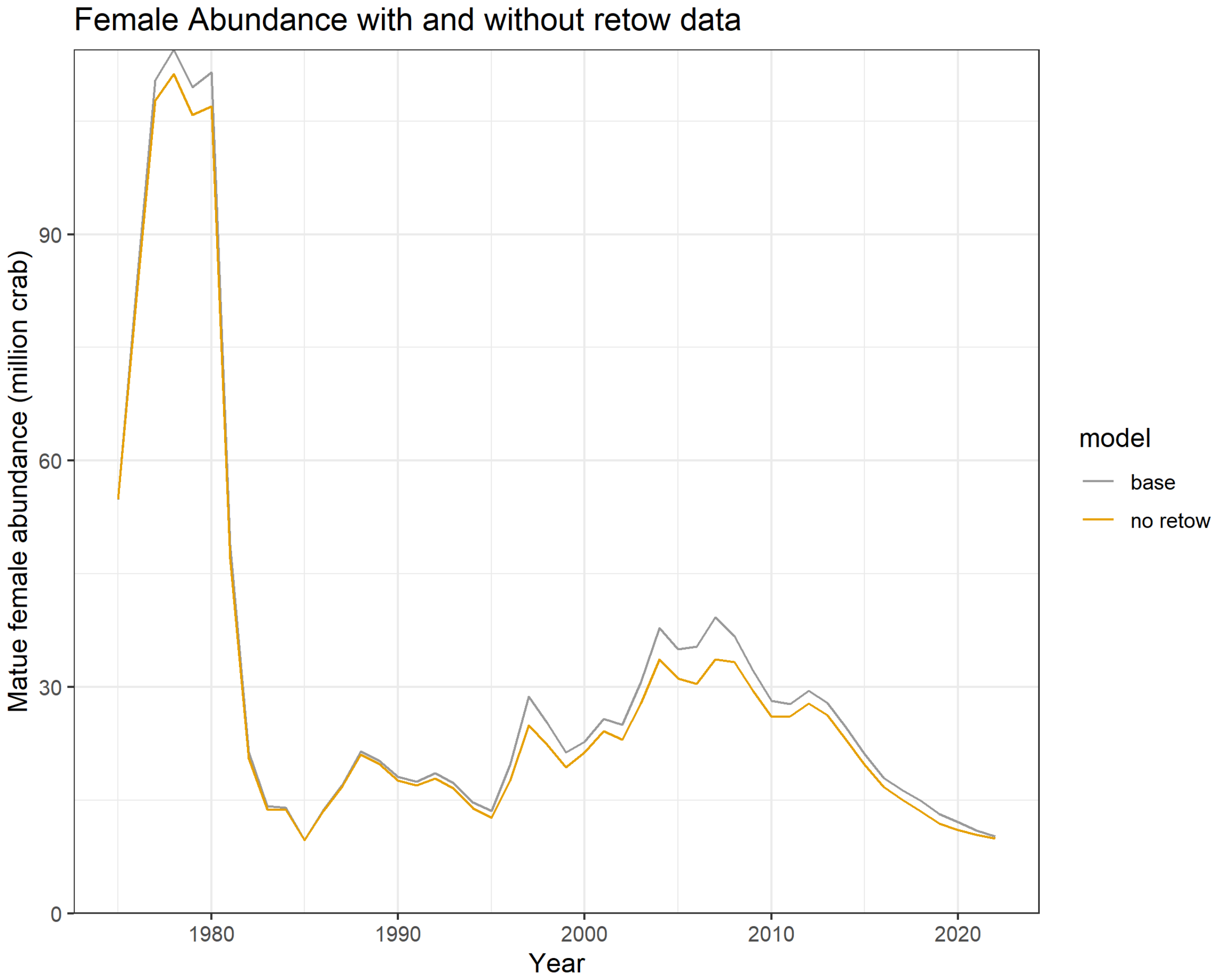

Figure 43: Estimated mature female abundance (million crab) time series during 1975-2022 with models 21.1b and 23.2 (no retow data).

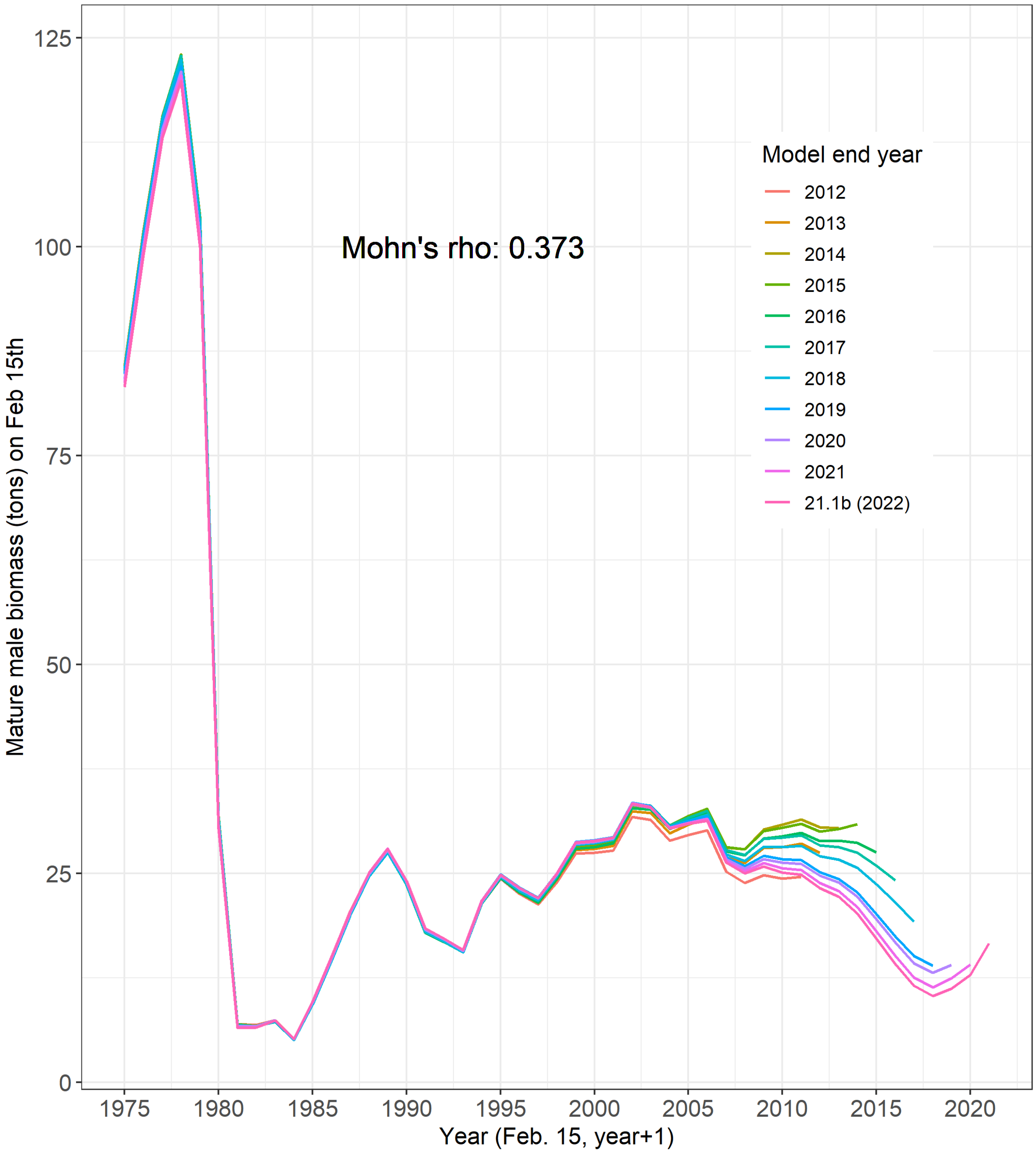

Figure 44: Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2012-2022 using model 21.1b. These are results of the 2022 model. Legend shows the terminal year

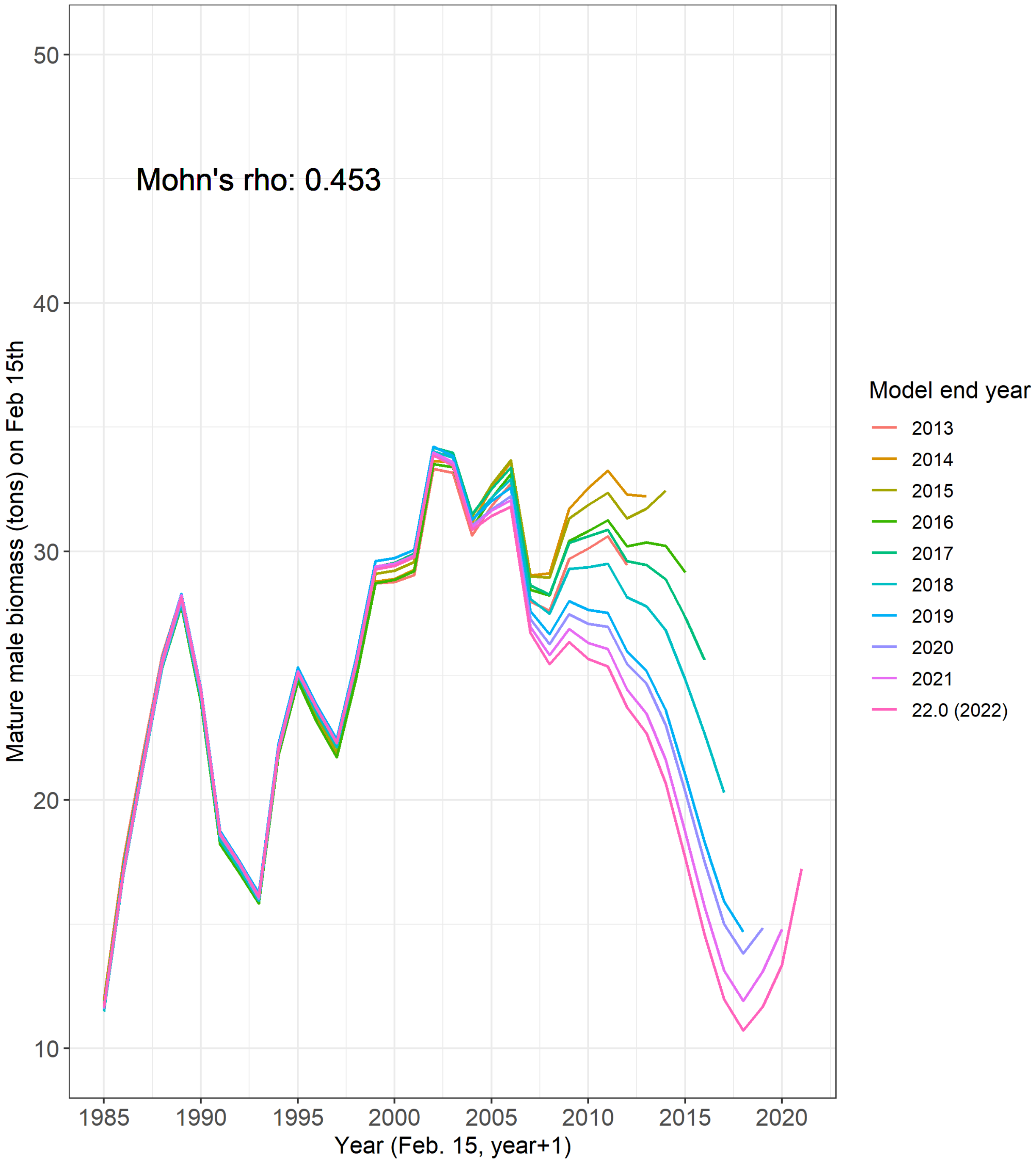

Figure 45: Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2012-2022 using model 22.0. These are results of the 2022 model. Legend shows the terminal year

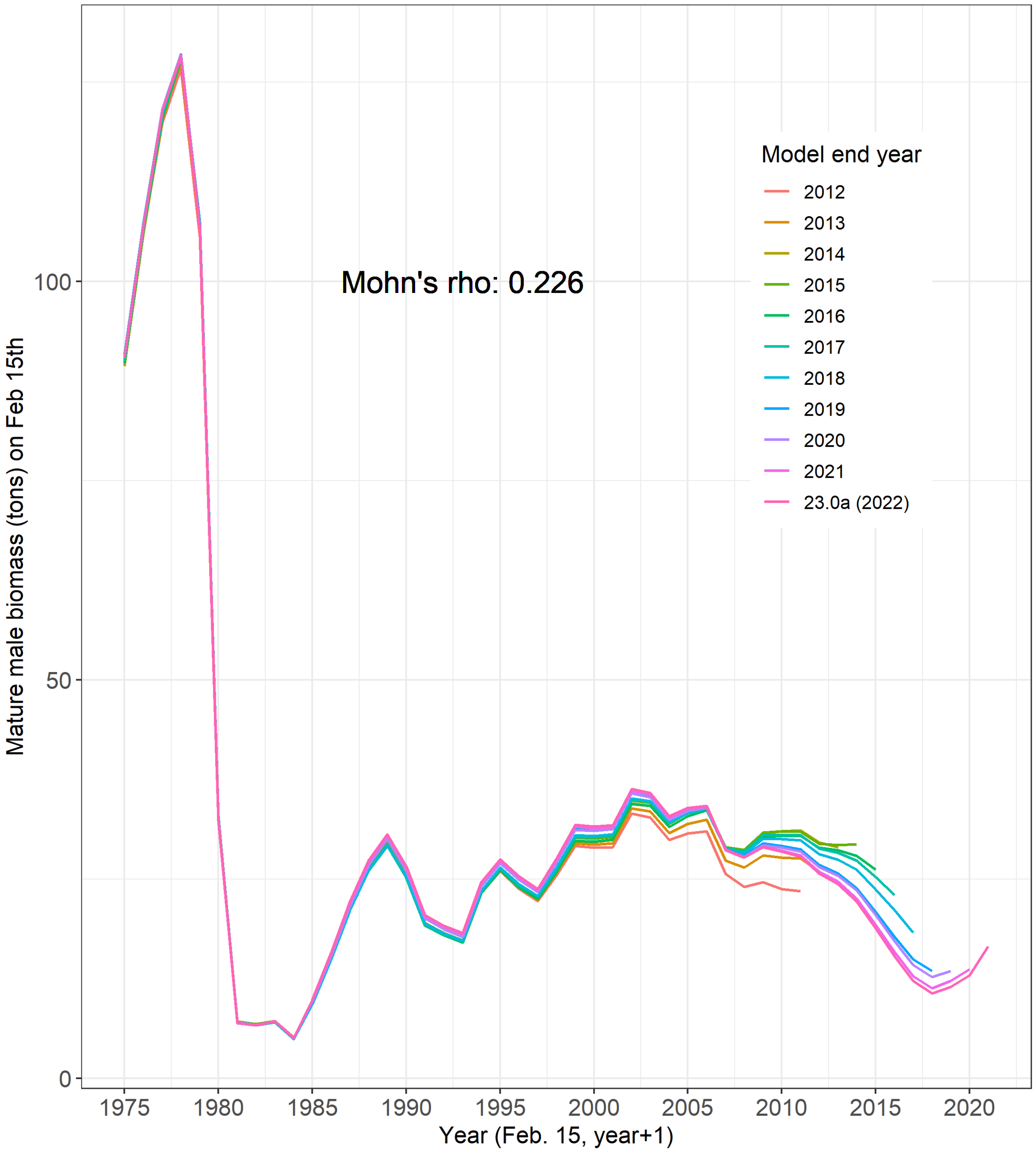

Figure 46: Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2012-2022 using model 23.0a. These are results of the 2022 model. Legend shows the terminal year

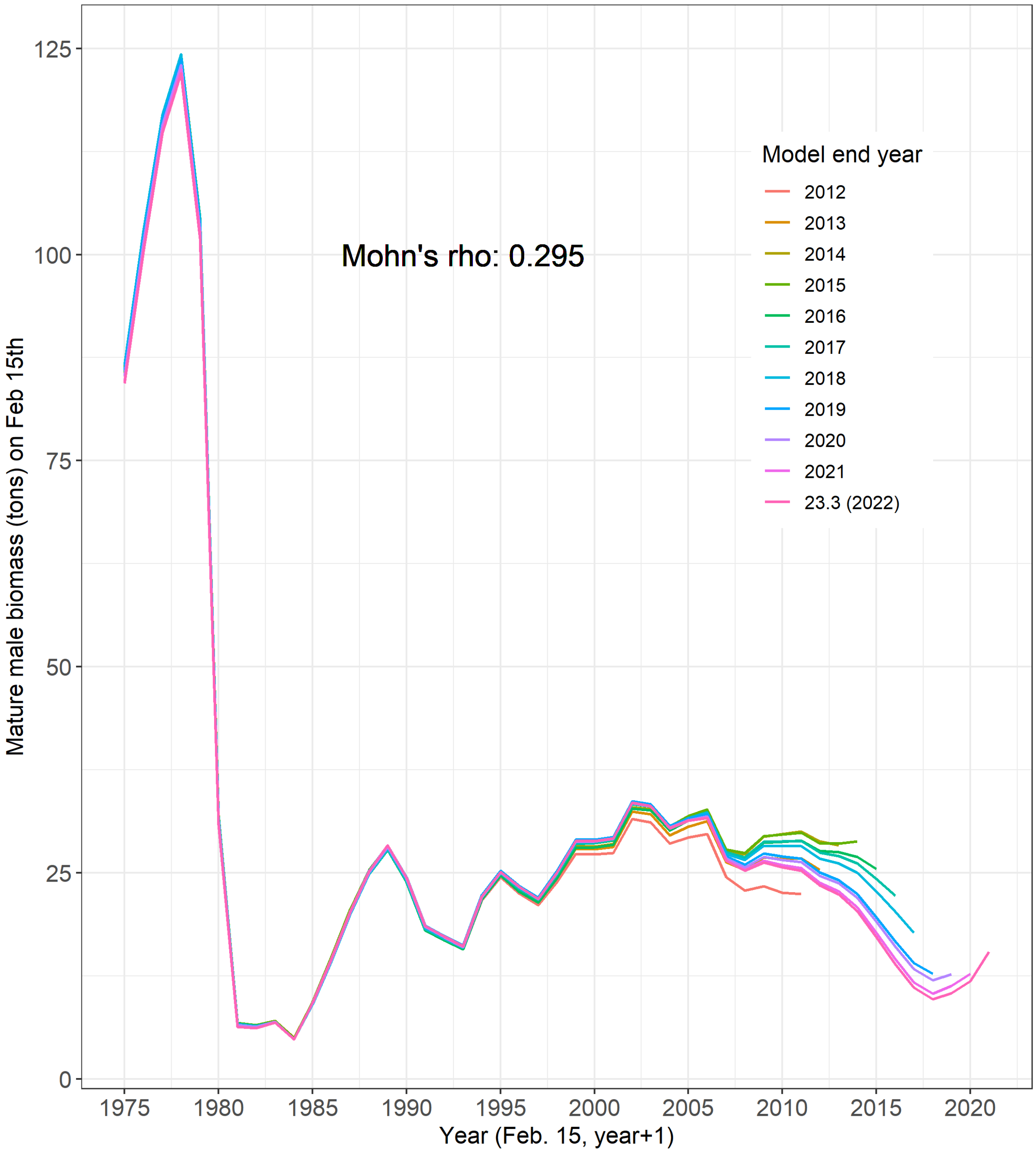

Figure 47: Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab with terminal years 2012-2022 using model 23.3. These are results of the 2022 model. Legend shows the terminal year

Appendix A. Simpler model working group 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. Crab at this size are approximately one molt increment 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 a similar buffer as the Tier 3 model (20%), although the actual buffer used if this model approach was adopted would likely be different.

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 2021.

Calculation of Reference Points

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

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

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, $M = 0.18$ yr^{-1}, and $\alpha = 0.1$. The Tier 4 OFL (Table 16) 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 16: 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
28443.11	20328.15	0.71	0.18	0.12	2499.12	1999.30

Figures

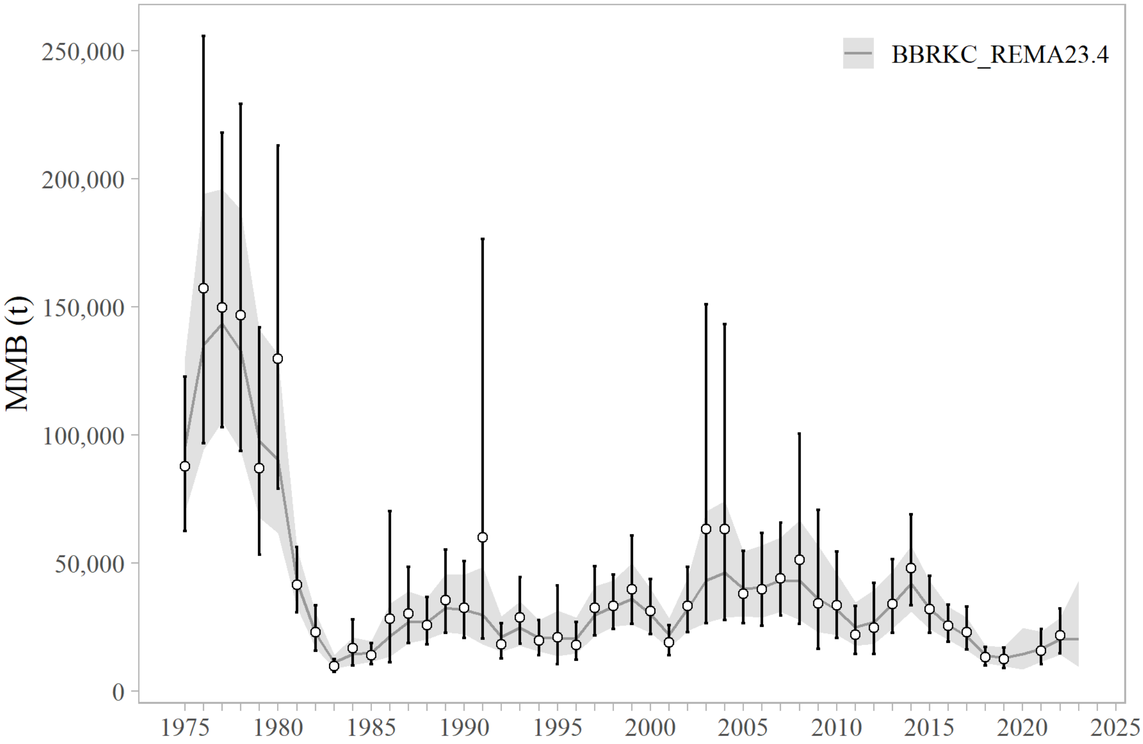

Figure 48: Comparisons of area-swept estimates of mature MALE NMFS survey biomass (males > 119 mm) and REMA model predicted fit.