BRISTOL BAY RED KING CRAB STOCK ASSESSMENT IN SPRING 2022

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Executive Summary

1. Stock: Red king crab (RKC), *Paralithodes camtschaticus,* in Bristol Bay, Alaska.
2. Catches: The domestic RKC fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lb (58,943 t). The catch declined dramatically in the early 1980s and remained at low levels during the last three decades. After rationalization, catches were relatively high before the 2010/11 season but have been on a declining trend since 2014. The retained catch in 2020/21 was approximately 2.65 million lb (1,257 t), compared to 4.5 million lb (2,027 t) in 2018/19, following a reduction in total allowable catch (TAC). The magnitude of bycatch from groundfish trawl and fixed gear fisheries has been stable and small relative to stock abundance during the last 10 years. The decline of the directed pot fishery crab/pot lift (CPUE) has been much less than the retained catch decline, with the 2020/21 CPUE having about 12.5% reduction from the average CPUE during the recent 20 years.
3. Stock biomass: Estimated mature biomass increased dramatically in the mid-1970s, then decreased precipitously in the early 1980s. Estimated mature crab abundances increased during 1985-2007 with mature females being about four times more abundant in 2007 than in 1985 and mature males being about two times more abundant in 2007 than in 1985. Estimated mature abundance has steadily declined since 2007. The projected mature male biomass in 2021 is less than 50% of the peak value (around 2002) during the last 40 years. The estimated mature female biomass has also been very low during the last four years. The estimated mature female abundance was below the state of Alaska harvest strategy threshold of 8.4 million of crab for a fishery opening in 2021.
4. Recruitment: Estimated recruitment was high during the 1970s and early 1980s and has generally been low since 1985 (1979-year class). During 1984-2020, estimated recruitment was above the historical average (1976-2019 reference years) only in 1984, 1986, 1995, 1999, 2002, and 2005. Estimated recruitment was extremely low during the last 12 years, and even lower during the recent eight years. With the low recruitment in recent years, the projected mature biomass is expected to decline during the next few years with a below-average fishing mortality of 0.25 yr^{-1}.

5. Management performance:

Status and catch specifications (1,000 t) (model 21.1):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	12.74^A	24.86^A	2.99	3.09	3.60	5.60	5.04
2018/19	10.62^B	16.92^B	1.95	2.03	2.65	5.34	4.27
2019/20	12.72^C	14.24^C	1.72	1.78	2.22	3.40	2.72
2020/21	12.12^D	13.96^D	1.20	1.26	1.57	2.14	1.61
2021/22		14.95^D				2.23	1.78

The stock was above MSST in 2020/21 and hence was not overfished. Since total catch was below OFL, overfishing did not occur. The projection using the lowest recruitment periods during 2013-2020 would not likely result in "approaching an overfished condition" based on the current harvest strategy. The relatively low MSST in 2018/19 and $B_{35\%}$ in 2019/20 below was caused by a problem of the previous GMACS version using the only sex ratio of recruitment in the terminal year for $B_{35\%}$ computation in 2019. The lower estimated male recruitment ratio in the terminal year in 2019 resulted in a lower mean male recruitment for $B_{35\%}$ computation. The current version of GMACS uses an average of sex ratios of recruitment during the reference period to estimate $B_{35\%}$, which results in a stable sex ratio (about 50%) for the reference point calculation.

The ABC buffer was increased from 10% to 20% in 2018, and an additional buffer of 5% was added in 2020 due to the lack of a 2020 survey. A 20% buffer was recommended by the CPT and SSC for ABC estimation for 2021/22.

Status and catch specifications (million lb):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	28.1^A	54.8^A	6.60	6.82	7.93	12.35	11.11
2018/19	23.4^B	37.3^B	4.31	4.31	5.85	11.76	9.41
2019/20	28.0^C	31.4^C	3.80	3.91	4.89	7.50	6.00
2020/21	26.7^D	30.8^D	2.77	2.65	3.47	4.72	3.54
2021/22		33.0^D				4.91	3.92

Notes:
A – Calculated from the assessment reviewed by the Crab Plan Team in September 2018
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2019
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2020
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2021

6. Basis for the OFL: Values are in 1,000 t (model 21.1):

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2017/18	3b	25.1	21.3	0.85	0.24	1984-2017	0.18
2018/19	3b	25.5	20.8	0.82	0.25	1984-2017	0.18
2019/20	3b	21.2	16.0	0.75	0.22	1984-2018	0.18
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18
2021/22	3b	24.2	14.9	0.62	0.17	1984-2020	0.18

Basis for the OFL: Values are in million lb:

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2017/18	3b	55.2	47.0	0.85	0.24	1984-2017	0.18
2018/19	3b	56.2	45.9	0.82	0.25	1984-2017	0.18
2019/20	3b	46.8	35.2	0.75	0.22	1984-2018	0.18
2020/21	3b	56.1	32.9	0.59	0.16	1984-2019	0.18
2021/22	3b	53.4	33.0	0.62	0.17	1984-2020	0.18

A. Summary of Major Changes

1. Changes to management of the fishery: None.

2. Changes to the input data:

a. Updated groundfish fisheries bycatch data during 1986-2020.

3. Changes to the assessment methodology:

a. Updated version of GMACS (version 2.01.E, Feb. 6, 2022) is used.

b. The analyses of terminal years of recruitment are updated.

c. Eleven models are compared in this report (See Section E.3.a for details):

21.1: the base model for September 2021.

21.1a: model 21.1 + using the recently updated version of GMACS (version 2.01.E).

21.1b: model 21.1a + updated groundfish fisheries bycatch data.

22.0: model 21.1b + starting in 1985.

22.0a: model 22.0 + estimating a constant *M* for males.

22.0b: model 22.0a + estimating a catchability Q for the BSFRF survey.

22.0c: model 22.0a + no BSFRF survey data.

22.0d: model 22.0c + fixing *M* = 0.18 for males.

22.0e: model 22.0d + estimating a constant *M* for males during 2015-2018.

22.1: model 21.1b + no BSFRF survey data.

22.1a: model 22.1 + estimating a constant *M* for males during 2015-2018.

These models are designed for evaluating BSFRF data, the impacts of *M* and BSFRF data on retrospective patterns and starting the model in 1985.

4. Changes to assessment results:

Eleven model scenarios are compared in this draft report. The first three models, 21.1, 21.1a, and 21.1b, have very close results. Model 21.1, the base model in 2021, was run with the updated GMACS version 2.01.E (finalized on Feb. 6, 2022), resulting in model 21.1a. The groundfish bycatch was updated when the AKFIN database was updated recently, resulting in model 21.1b. The GMACS update and the groundfish fisheries bycatch update have hardly affected the results. Model 21.1b was used to compare the other eight new model scenarios.

Among the new eight models, six models start in 1985 and were used to evaluate model starting year, BSFRF survey data, and one extra level of *M* during 2015-2018. Model 22.0 is the reduced timer series data version of model 21.1b, and the overall results are similar. The notable differences are smaller $B_{35\%}$ (22,141 t vs 24,325 t) and NMFS survey catchability (0.93 vs 0.96), and higher MMB in the terminal year (2021) (1,5507 t vs 1,5118 t) and higher OFL (2,718 t vs 2,298 t) for model 22.0. These differences are probably caused by a high recruitment in 1984 (associated with the very high *M*) being used for $B_{35\%}$ computation for model 21.1b and more influence of BSFRF survey data for model 22.0. Estimating *M* for males in model 22.0a significantly increases likelihood values, slightly increases annual mature male biomass, and results in an estimated $B_{35\%}$ about 10% lower than model 22.0. A high *M* also results in higher $F_{35\%}$ and OFL for model 22.0a. Contrasting with assuming catchability being 1.0 for the BSFRF survey, model 22.0b estimates it in the model. As expected, the results of model 22.0b are similar to model 22.0a because the extra variance in the model has greatly reduced the influence of BSFF survey catchability, even though the estimated catchability is 1.36. Model 22.0c drops the BSFRF survey data and results in better fits to the other data. The retrospective bias is greatly reduced with model 22.0c over model 22.0 (Mohn's rho values from 0.376 to 0.235). The results of models 22.0b and 22.0c may indicate the problem of assuming catchability to be 1.0 for the BSFRF survey. With *M*=0.18 for males and without the BSFRF survey data, model 22.0d has very similar results with model 22.0, but with a smaller Mohn's rho value (0.329 vs 0.376). Model 22.0e uses a similar approach to Model 21.2 in 2021 to address the survey abundance decline during recent years through adding a time block of *M* (2015-2018) and to reduce the retrospective bias. Mohn's rho declines from 0.376 for model 22.0 to 0.135 for model 22.0e, and model 22.0e also fits the NMFS survey biomass much better during recent years. Model 22.0e results in overall higher mature male biomass estimates over time, higher $B_{35\%}$ estimate, and lower mature male biomass estimate in the terminal year (2021).

Relative to model 21.1b, model 22.1 drops the BSFRF data and model 22.1a adds a time block of *M* (2015-2018), similar to model 22.0e. Like the results of models starting in 1985, dropping the BSFRF data improves fits to the other data and reduces the retrospective bias. Combining no

BSFRF data and a time block of *M* during 2015-2018 greatly reduces retrospective bias from Mohn's rho of 0.347 for model 21.1b to 0.135 for model 22.1a.

Based on the model results, it appears that the choice of preferred models depends on two factors: assumption of BSFRF survey catchability and estimation of *M*. 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. However, its small net opening and going into sea bottom could potentially cause herding effects, especially for long leg animals like red king crab where legs could get caught and pull the animal into the net. Parts of the lower bridles of survey nets could touch, or come close enough to sea bottom, to herd or push crab into the net path. We discussed with industry representative, Scott Goodman (BSFRF), about the herding effects of the BSFRF trawl survey a few years ago and it appears that the effects have not been evaluated. Model 22.0c estimated the catchability as 1.36, much higher than 1.0 assumed in the other models. Dropping the BSFRF data from the models hardly impacts the model results and reduces the model retrospective bias. Furthermore, if the BSFRF survey catchability is larger than 1.0 we assumed for the models, it could cause conservation concern. If possible, we suggest an evaluation of the herding effects of the BSFRF trawl survey in the near future, and eliminate the models that use the BSFRF survey data for time being.

Considerations for *M* estimation are whether to estimate a base *M* for males for the whole time series or to add a time block during 2015-2018. Either of these two approaches reduces the retrospective bias considerably. The concern with estimating a base *M* for males for the whole time series is potential confounding with estimating trawl survey catchability. It is also hard to find good biological reasons for adding a time block during 2015-2018 other than speculating that the population consisted of very old crab due to low recruitment for over a decade. Very old crab tend to have a higher *M*.

Based on the above considerations, we recommend model 22.0d as the base model for overfishing definition determination in September 2022 due to its simple approach: a fixed base *M* of 0.18 for males, less confounding between estimating *M* and survey catchability, avoiding dramatic abundance decline during the early 1980s, no recruitment associated with an extremely high *M* being used for estimating $B_{35\%}$, and acceptable data fittings. Model 22.1 is a strong run-up and is a viable alternative. If estimating a base *M* value for males in the model is acceptable, then model 22.0c is also a good alternative, which fits the data well and greatly reduces retrospective bias from model 22.0. Values for management-related quantities for all models are summarized in likelihood Tables 5b, 5c, 5d, and 5e.

B. Responses to SSC and CPT Comments

1. Responses to the most recent two sets of SSC and CPT comments on assessments in general:

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.

2. Responses to the most recent two sets of SSC and CPT comments specific to this 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: We continue to examine M in May 2022. 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 eleven models in May 2022, seven are somewhat related to M change from the previous base model 21.1.

"The CPT recommended presenting Models 19.3d, 19.3e, and 19.3g in September with updated data."

Response: We ran these three models as well as another model suggested by the SSC for September 2021.

"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 make 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 results in lower biomass estimates in 2020 and 2021. The biases for total abundance are much smaller than mature male biomass. High natural mortality during 2018-19 reduces these upward biases for model 21.2.

In May 2022, we continue to examine the retrospective patterns further. It appears that adding a time block of *M* during 2015-2018 and dropping BSFRF survey data greatly reduces retrospective bias from Mohn's rho of 0.347 for model 21.1b to 0.135 for model 22.1a.

"Model 19.3c probably should have been labeled model 21.0, given the large change in inputs?"

Response: To avoid confusion, we do not change the model label this time. The year in the model label will be changed when the major model changes, such as the model suggested by the SSC in June 2021, which is named as model 21.0 in the draft SAFE report in September 2021.

"When calculating the probability of being overfished via MCMC, it is necessary to calculate $B_{35\%}$ *for each draw to compare the MMB from that draw. If this is not done, the comparison is not consistent."*

Response: We have followed this recommendation.

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: we list uncertainties in the projection section in the draft SAFE report in May 2022.

"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 follow this recommendation.

"Consider a model with constant M, but estimated separately for males and females (i.e., similar to Model 21.0, but with sex-specific M's) for May 2022."

Response: Models 22.0, 22.0a, 22.0b, 22.0c and 22.0d with starting year of 1985 in May 2022 are constant *M* and estimated separately for males and females.

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

Response: Models 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e in May 2022 start in 1985. These models are used to examine *M*, BSFRF survey data, and retrospective bias.

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

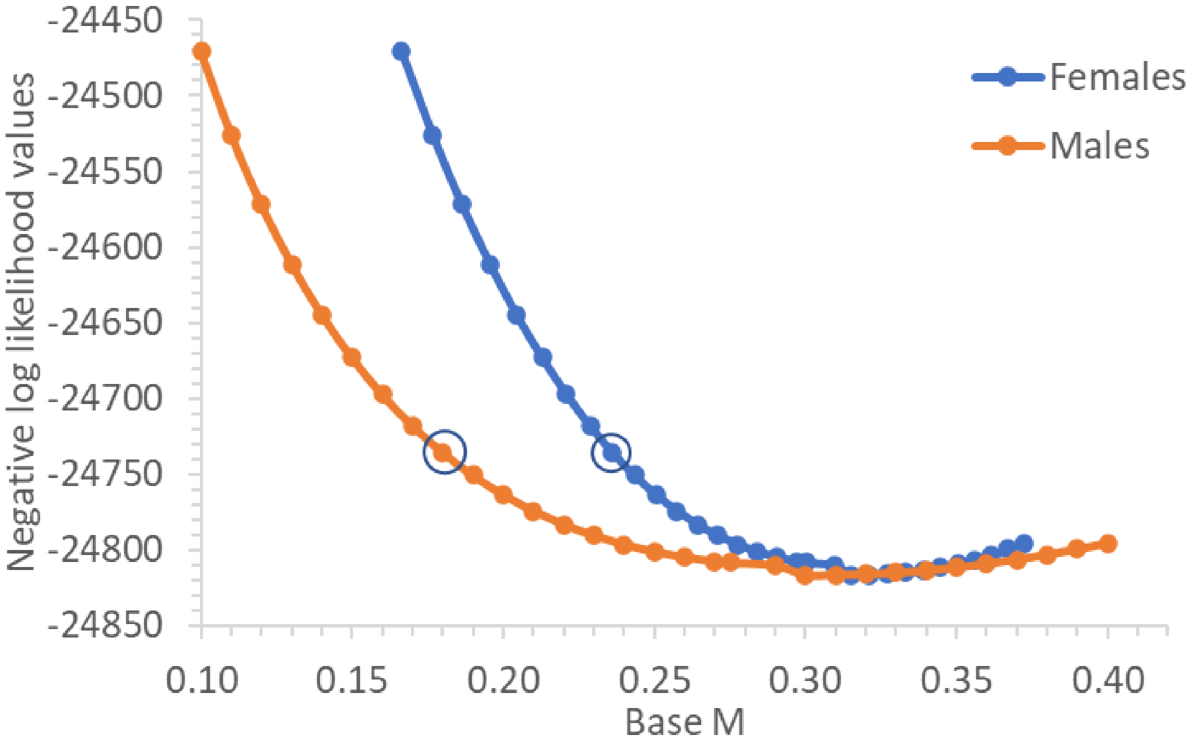
“The SSC supports exploring more modern methods for estimating natural mortality, but notes that this method still relies strongly on the maximum age for BBRKC. The SSC recommends continued research to validate the ages for this stock.”

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 like 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.

In May 2022, instead of continuing to examine model 19.6, we examine new models starting in 1985 with constant *M* over time: models 22.0, 22.0a, 22.0b, 22.0c, and 22.0d. Model 22.0a with model estimated *M* of 0.226 for males and 0.261 for females is close to model 19.6. Bubble plots are illustrated for models 22.0, 22.0a, and 22.0d in Figures 25c, 25d, 25e, 26c, 26d, and 26e. Higher base *M* values do improve the plus group fittings somewhat for model 22.0a.

"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.

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 is doing evaluation of re-tow survey protocol. Probabilities in the overfished condition for some models were estimated in September 2021 and are estimated in the draft SAFE report for five models in May 2022.

"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. We plot 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 agree and have urged tagging studies for a few years.

"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, 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. We prefer 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. Hopefully, we will be able to use the VAST results in the models soon.

C. Introduction

1. Species

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

2. General distribution

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

3. Stock Structure

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

4. Life History

Red king crab have a complex life history. Fecundity is a function of female size, ranging from tens of thousands to hundreds of thousands (Haynes 1968; Swiney et al. 2012). The eggs are extruded by females, fertilized in the spring, and held by females for about 11 months (Powell and Nickerson 1965). Fertilized eggs are hatched in the spring, most during April-June (Weber 1967). Primiparous females are bred a few weeks earlier in the season than multiparous females.

Larval duration and juvenile crab growth depend on temperature (Stevens 1990; Stevens and Swiney 2007). Male and female RKC mature at 5–12 years old, depending on stock and temperature (Stevens 1990; Loher et al. 2001) and may live >20 years (Matsuura and Takeshita 1990). Males and females attain a maximum size of 227 mm and 195 mm carapace length (CL), respectively (Powell and Nickerson 1965). Female maturity is evaluated by the size at which females are observed to carry egg clutches. Male maturity can be defined by multiple criteria including spermataphore production and size, chelae vs. carapace allometry, and participation in mating *in situ* (reviewed by Webb 2014). For management purposes, females >89 mm CL and males >119 mm CL are assumed to be mature for Bristol Bay RKC. Juvenile RKC molt multiple times per year until age 3 or 4; thereafter, molting continues annually in females for life and in males until maturity. Male molting frequency declines after attaining functional maturity.

5. Fishery

The RKC stock in Bristol Bay, Alaska, supports one of the most valuable fisheries in the United States. A review of the history of the Bristol Bay RKC fishery is provided in Fitch et al. (2012) and Otto (1989). The Japanese fleet started the fishery in the early 1930s, stopped fishing from 1940 to 1952, and resumed the fishery from 1953 until 1974. The Russian fleet fished for RKC from 1959 to 1971. The Japanese fleet employed primarily tanglenets with a very small proportion of catch from trawls and pots. The Russian fleet used only tanglenets. United States trawlers started fishing Bristol Bay RKC in 1947, but the effort and catch declined in the 1950s. The domestic RKC pot fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lb (58,943 t), worth an estimated $115.3 million ex-vessel value. The catch declined dramatically in the early 1980s and has remained at low levels during the last two decades (Tables 1a and 1b). After the early 1980s stock collapse, the Bristol Bay RKC fishery took place during a short period in the fall (usually lasting about a week) with the catch quota based on the stock assessment conducted the previous summer (Zheng and Kruse 2002). Beginning with the 2005/2006 season, new regulations associated with fishery rationalization resulted in an increase in the duration of the fishing season (October 15 to January 15). With the implementation of crab rationalization, the annual guideline harvest level (GHL) was changed to a total allowable catch (TAC). Before rationalization, the implementation errors were quite high for some years and sum of actual catches from 1980 to 2007 was about 6% less than the sum of GHL/TAC over that period.

6. Fisheries Management

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

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

D. Data

1. Summary of New Information

a. Updated groundfish fisheries bycatch data during 1986-2020.

Data types and availability periods are illustrated in Figure 2.

2. Catch Data

Data on landings of Bristol Bay RKC by length and year and catch per unit effort from 1960 to 1973 were obtained from annual reports of the International North Pacific Fisheries Commission (Hoopes et al. 1972; Jackson 1974; Phinney 1975) and from the Alaska Department of Fish and Game from 1974 to 2020 (Tables 1a and 1b). Bycatch data are available starting from 1990 and were obtained from the ADF&G observer database and reports (Gaeuman 2013) (Table 2). Sample sizes for catch by length and shell condition are summarized in Table 3a. Relatively large samples were taken from the retained catch each year. Sample sizes for trawl bycatch were the annual sums of length frequency samples in the National Marine Fisheries Service (NMFS) database.

(i). Catch Biomass

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

(ii). Catch Size Composition

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

(iii). Catch per Unit Effort

Catch per unit effort (CPUE) is defined as the number of retained crab per tan (a unit fishing effort for tanglenets) for the Japanese and Russian tanglenet fisheries and the number of retained crab per potlift for the U.S. fishery (Table 1b). Soak time, while an important factor influencing CPUE, is difficult to standardize. Furthermore, complete historical soak time data from the U.S. fishery are not available. Based on the approach of Balsiger (1974), all fishing effort from Japan, Russia, and U.S. were standardized to the Japanese tanglenet from 1960 to 1971, and the CPUE was standardized as crab per tan. Except for the peak-to-crash years of the late 1970s and early 1980s, the correspondence between U.S. fishery CPUE and area-swept survey abundance is poor (Figure 4). Due to the difficulty in estimating commercial fishing catchability and crab availability to the NMFS annual trawl survey data, commercial CPUE data were not used in the model.

3. NMFS Survey Data

The NMFS has conducted annual trawl surveys of the eastern Bering Sea since 1968. Two vessels, each towing an eastern otter trawl with an 83 ft headrope and a 112 ft footrope, conducted this multispecies, crab-groundfish survey during the summer. Stations were sampled in the center of a systematic 20 X 20 nm grid overlaid in an area of ≈140,000 nm^2. Since 1972, the trawl survey has covered the full stock distribution except in nearshore waters. The survey in Bristol Bay occurs primarily during late May and June. Tow-by-tow trawl survey data for Bristol Bay RKC during 1975-2021 were provided by NMFS. Due to survey data quality issue, only survey data after 1974 are used in the assessment models.

Abundance estimates by sex, carapace length, and shell condition were derived from survey data using an area-swept approach (Figures 5a and 5b). Until the late 1980s, NMFS used a post-stratification approach, but subsequently treated Bristol Bay as a single stratum; the estimates shown for Bristol Bay in Figures 4, 5a, and 5b were made without post-stratification. If multiple tows were made at a single station in a given year, the average of the abundances from all tows within that station was used as the estimate of abundance for that station. The new time series since 2015 discards all “hot spot” tows. We used the new area-swept estimates provided by NMFS in 2021. The VAST estimated biomasses are compared to area-swept biomasses in Figure 6.

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

4. Bering Sea Fisheries Research Foundation Survey Data

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

As a comparison to the estimated NMFS survey catchability (0.896) at 162.5 mm CL by the double-bag experiment, we computed an overall ratio (*q*=0.891) of NMFS survey abundances/BSFRF side-by-side trawl survey abundances for legal crab (≥135 mm carapace length) as follow:

$$q = \sum_{y=2013,l=135mm}^{y=2016,l=\infty} r_{y,l}\ n_{y,l} / \sum_{y=2013,l=135mm}^{y=2016,l=\infty} n_{y,l} \qquad (1)$$

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

E. Analytic Approach

1. History of Modeling Approaches

To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, ADF&G developed a length-based analysis (LBA) in 1994 that incorporates multiple years of data and multiple data sources in the estimation procedure (Zheng et al. 1995a). Annual abundance estimates of the Bristol Bay RKC stock from the LBA have been used to manage the directed crab fishery and to set crab bycatch limits in the groundfish fisheries since 1995 (Figure 1). An alternative length-based model (research model) was developed in 2004 to include small size crab to determine federal overfishing limits. Given that the crab abundance declined sharply during the early 1980s, the LBA estimated natural mortality for different periods of years, whereas the research model estimated additional mortality beyond a base constant natural mortality during 1980-1984. In this report, we present only the research model that was fit to the data from 1975 to 2021.

2. Model Description

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

a-f. See Appendix A.

g. Critical assumptions of the model:

  i. The base natural mortality is kept constant at 0.18yr^{-1} for males, shell condition, and length and was estimated assuming a maximum age of 25 and applying the 1% rule (Zheng 2005).

  ii. Survey and fisheries selectivities are a function of length and were constant over shell condition. Selectivities may or may not be a function of sex except for groundfish fisheries bycatch selectivities, which are the same for both sexes. Two different NMFS survey selectivities were estimated: (1) 1975-1981 and (2) 1982-2021, based on modifications to the trawl gear used in the assessment survey.

iii. Growth is a function of length. For females, growth-per-molt increments as a function of length are estimated for three periods (1975-1982, 1983-1993, and 1994-2021) based on sizes at maturity. Once mature, female red king crab have a much smaller growth increment per molt.

iv. Molting probabilities are an inverse logistic function of length for males. Females molt annually.

v. Annual fishing seasons for the directed fishery are short.

vi. The prior mean for NMFS survey catchability (*Q*) is estimated to be 0.896 with a standard deviation of 0.025 for some models, based on a trawl experiment by Weinberg et al. (2004); *Q* is assumed to be constant over time and is estimated in the model. The BSFRF survey catchability is assumed to be 1.0. The prior mean of 0.896 for NMFS survey *Q* (at 162.5 mm carapace length) is also close to the abundance-weighted average ratio of 0.891 for crab ≥135 mm CL across four years of side-by-side NMFS and BSFRF survey data (Figure 7c).

vii. Males mature at sizes ≥120 mm CL. For convenience, female abundance is summarized at sizes ≥90 mm CL as an index of mature females.

viii. Measurement errors are assumed to be normally distributed for length compositions and are log-normally distributed for biomasses.

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

i. Outline of methods used to validate the code used to implement the model and whether the code is available: Assessment results by GMACS have been compared to the previous assessment models, and the code is online and available from the first author.

3. Model Selection and Evaluation

a. Alternative model configurations (models):

21.1: the base model for September 2021. Basic features of this model include:

(1) An estimated constant *M* for males during 1980-1984, a constant (base) *M* of 0.18 for males during the other years, and an estimated constant multiplier being used to multiply male *M* for female *M*. That is, *M* for females is relative to *M* for males each year.

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

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

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

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

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

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

(8) Estimating initial year length compositions.

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

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

(11) Equal annual effective sample sizes of male and female length compositions.

21.1a: model 21.1 + using the recently updated version of GMACS (version 2.01.E).

21.1b: model 21.1a + updated groundfish fisheries bycatch data.

22.0: model 21.1b + starting in 1985.

22.0a: model 22.0 + estimating a constant M for males.

22.0b: model 22.0a + estimating a catchability Q for the BSFRF survey.

22.0c: model 22.0a + no BSFRF survey data.

22.0d: model 22.0c + fixing M = 0.18 for males.

22.0e: model 22.0d + estimating a constant M for males during 2015-2018.

22.1: model 21.1b + no BSFRF survey data.

22.1a: model 22.1 + estimating a constant M for males during 2015-2018.

b. Progression of results: See the new results at the beginning of the report.

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

d. Convergence status/criteria: ADMB default convergence criteria.

e. Sample sizes for length composition data: observed sample sizes are summarized in Table 3a.

f. Credible parameter estimates: All estimated parameters seem to be credible and within bounds.

g. Model selection criteria: The likelihood values are used to select among alternatives that could be legitimately compared by that criterion.

h. Residual analysis: Residual plots are illustrated in various figures.

i. Model evaluation is provided under Results, below.

j. Jittering: The Stock Synthesis Approach is used to perform jittering to find the optimum:

The *Jitter* factor of 0.1 is multiplied by a random normal deviation $rdev = N(0,1)$, to a transformed parameter value based upon the predefined parameter:

$$temp = 0.5\ rdev\ Jitter\ \ln\left(\frac{P_{\max} - P_{\min} + 0.0000002}{P_{val} - P_{\min} + 0.0000001} - 1\right), \tag{6}$$

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

$$P_{new} = P_{\min} + \frac{P_{\max} - P_{\min}}{1.0 + \exp(-2.0\ temp)}, \tag{7}$$

where P_{max} and P_{min} are upper and lower bounds of parameters and P_{val} is the estimated parameter value before the jittering. Jittering results are not updated and presented in this report.

4. Results

a. Effective sample sizes and weighting factors.

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

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

iii. Harmonic means of implied sample sizes and maximum caps of effective sample sizes for models 21.1b, 22.0, 22.0c, 22.0d, 22.0e, 22.1, and 22.1a are summarized in Table 4.

b. Tables of estimates.

   i. Negative log-likelihood values and parameter estimates are summarized in Tables 5a, 5b, 5c, 5d, 5e, 6a, 6b, 6c, and 6d for all eleven models.

   ii. Natural mortality estimates are shown in Table 7 for nine models.

iii. Area-swept estimates of mature female abundance and model estimates of effective spawning biomass (Zheng et al. 1995b) during 2011-2021 for groundfish fisheries bycatch calculation are provided in Table 8.

iv. Abundance and biomass time series are provided in Tables 9a, 9b, 9c, 9d, and 9e for models 21.1b, 22.0, 22.0d, 22.0e, and 22.1.

v. Recruitment time series for models 21.1b, 22.0, 22.0d, 22.0e, and 22.1 are provided in Tables 9a, 9b, 9c, 9d, and 9e.

vi. Time series of catch biomass is provided in Tables 1a and 1b.

Length-specific fishing mortality is equal to selectivity-at-length times the full selection fishing mortality. Estimated full pot fishing mortalities for females and full fishing mortalities for groundfish fisheries bycatch are low due to low bycatch and handling mortality rates less than 1.0. Estimated recruits varied greatly among years (Tables 9a, 9b, 9c, 9d, and 9e). Estimated selectivities for female pot bycatch are close to 1.0 for all mature females, and the estimated full fishing mortalities for female pot bycatch are lower than those for male retained catch and bycatch (Tables 6a, 6b, and 6c for models 21.1b, 22.0, 22.0d, and 22.1).

c. Graphs of estimates.

i. Estimated selectivities by length are provided in Figures 8a, 8b, 8c, 8d, 8e, and 8f for six models and estimated molting probabilities by length are illustrated in Figures 9a, 9b, and 9c for models 21.1b, 22.1, 22.0, and 22.0d.

One of the most important results is estimated trawl survey selectivity (Figures 8a and 8b). Survey selectivity affects not only the fitting of the data but also the absolute abundance estimates. These estimated survey selectivities are generally smaller than the capture probabilities in Figure A1 because survey selectivities include capture probabilities and crab availability. The NMFS survey catchability is estimated to be 0.896 from the trawl experiment. The reliability of estimated survey selectivities will greatly affect the application of the model to fisheries management. Under- or over-estimates of survey selectivities will cause a systematic upward or downward bias of abundance estimates, respectively. Information about crab availability in the survey area at survey times will help estimate the survey selectivities. Higher estimated natural mortalities generally result in lower NMFS survey selectivities, while the estimated survey selectivities after 1981 are similar among the models.

For all models, estimated molting probabilities during 1975-2021 (Figures 9a, 9b, and 9c) are generally lower than those estimated from the 1954-1961 and 1966-1969 tagging data (Balsiger 1974). Lower molting probabilities mean more oldshell crab, possibly due to changes in molting probabilities over time or shell aging errors. Overestimates or underestimates of oldshell crab will result in lower or higher estimates of male molting probabilities.

ii. Estimated male and female survey biomasses are shown for NMFS surveys (Figures 10a and 10b) and BSFRF surveys (Figure 10c). Absolute mature male biomasses are illustrated in Figures 11a and 11b.

The survey male biomass estimates in 2021 are slightly higher than those in 2018 and 2019, but the survey female biomass estimates are lower. 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 (Figures 10a-10c, 11a, and 11b). Absolute mature male biomasses for all models except for models 22.0e and 22.1a have a similar trend over time (Figures 11a and 11b). Among the eleven models, model estimated relative NMFS survey biomasses are similar for five models 21.1, 21.1a, 21.1b, 22.0, and 22.1. Models 22.0a, 22.0b, and 22.0c estimate a constant *M* for males, resulting in slightly higher NMFS survey biomass estimates from the early 2000s and lower in recent years than the above five models. Models 22.0e and 22.1a, having a time block of high *M* during 2015-2018, amplify the above differences and fit the NMFS trawl survey biomass better than the other nine models. Absolute mature male biomass estimates are higher for models 22.0e and 22.1a during the early 2000s-mid-2010s and lower during 2017-2020 than the other nine models. All eleven models fit the catch and bycatch biomasses very well.

The fit to BSFRF survey data and estimated survey selectivities are illustrated in Figures 10c-10e. Model 22.0b, estimating a catchability >1.0 for the BSFRF survey, fits the BSFRF survey biomass much better than the other models.

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 $B_{35\%}$.

iii. Estimated recruitment time series are plotted in Figure 12a and recruitment length distributions in Figure 12b for models 21.1b, 22.1, and 22.0. Recruitment is estimated at the end of year in GMACS and is moved up one year for the beginning of next year. Estimated recruitment time series for models 21.1, 21.1a, 21.1b, 22.0, 22.0d, and 22.1 are similar. Estimated recruitments among models with higher *M* values are generally higher.

iv. Estimated fishing mortality rates are plotted against mature male biomass in Figures 13a, 13.b, and 13c for models 21.1b, 22.1, and 22.0d, and estimated *M* and directed pot fishing mortality values over time are illustrated in Figure 13d for models 21.1b, 22.0, 22.0e, and 22.1a.

The average of estimated male recruits from 1984 to 2020 for models starting in 1975 and from 1986 to 2020 for models starting in 1985 (Figure 12a) and mature male biomass per recruit are used to estimate $B_{35\%}$. The full fishing mortalities for the directed pot fishery at the time of fishing are plotted against mature male biomass on Feb. 15 (Figures 13a, 13.b and 13c). Estimated fishing mortalities in most years before the current harvest strategy was adopted in 1996 were above $F_{35\%}$ (Figures 13a and 13b). Under the current harvest strategy, estimated fishing mortalities were at or above the $F_{35\%}$ limits in 1998-1999, 2005, 2007-2010, and 2014-2019 for models 21.1b and 22.1, but below the $F_{35\%}$ 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 (Table 6a, Figure 13a). For model 22.1, estimated full pot fishing mortalities ranged from 0.00 to 2.37 during 1975-2020, with estimated values over 0.40 in the same years as model 21.1b. Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally small and less than 0.07.

For model 21.1b, estimated *M* values are 0.89 during 1980-1984 and 0.18 for the other years for males, and 1.18 during 1980-1984 and 0.24 for the other years for females, with estimated female *M* values equaling to 1.325 times male *M* values (Figure 13c). For model 22.1, estimated *M* values are 0.88 during 1980-1984 and 0.18 for the other years for males, and 1.17 during 1980-1984 and 0.24 for the other years for females, with estimated female *M* values equaling to 1.327 times male *M* values. Biologically, females mature earlier than males and likely have higher *M* values. *M* values for nine models are listed in Table 7.

v. Estimated mature male biomass and recruitment are plotted to illustrate their relationships with model 21.1b (Figure 14a). Annual stock productivities are illustrated in Figure 14b.

Stock productivity (recruitment/mature male biomass) is generally lower during the last 20 years (Figure 14b). However, there are high variations for the relation of stock productivity against mature male biomass.

Egg clutch data collected during summer surveys may provide information about mature female reproductive conditions. Although egg clutch data are subject to rating errors as well as sampling errors, data trends over time may be useful. Proportions of empty clutches for newshell mature females >89 mm CL are high in some years before 1990 but have been low since 1990 (Figure 15). The highest proportion of empty clutches (0.2) was in 1986, and primarily involved soft shell females (shell condition 1). Clutch fullness fluctuated annually around average levels during two periods: before 1991 and after 1990 (Figure 15). The average clutch fullness is similar for these two periods (Figure 15). Egg clutch fullness during 2016-2018 was relatively low, then increased in 2019, and declined again in 2021.

d. Graphic evaluation of the fit to the data.

i. Observed vs. estimated catches are plotted in Figure 16a, with bycatch mortalities from different sources shown in Figure 16b for six models.

ii. Model fits to NMFS survey biomass are shown in Figure 10 with a standardized residual plot in Figures 17a-17f for models 21.1b, 22.0, 22.0d, 22.0e, 22.1, and 22.1a.

iii. Model fits to catch and survey proportions by length are illustrated in Figures 18-24 and residual bubble plots are shown in Figures 25-26.

All models fit the fishery biomass data well and the survey biomass reasonably well (Figures 10 and 16). Because the model estimates annual fishing mortality for directed pot male catch, pot female bycatch, and trawl and fixed gear bycatch, the deviations of observed and predicted (estimated) fishery biomass are mainly due to size composition differences. Models 21.1, 21.1a, and 21.1b fit the NMFS area-swept biomass data almost identically (Figure 10a), and models 22.0e and 22.1a with a time block of high *M* during 2015-2018 fit the NMFS area-swept biomass data better than the other models.

All models also fit the length composition data well (Figures 18-24). Modal progressions are tracked well in the trawl survey data, particularly beginning in mid-1990s (Figures 18 and 19). Cohorts first seen in the trawl survey data in 1975, 1986, 1990, 1995, 1999, 2002 and 2005 can be tracked over time. Some cohorts can be tracked over time in the pot bycatch as well (Figure 21), but the bycatch data did not track the cohorts as well as the survey data. Groundfish bycatch data provide little information to track modal progression (Figures 23 and 24).

Residuals of survey biomasses and proportions of length are plotted to examine their patterns. Residuals were calculated as observed minus predicted and standardized by the estimated standard deviation. Residuals of survey biomasses did not show any consistent patterns for all models (Figures 17a-17f), although models 22.0e and 22.1a with a time block of high *M* during 2015-2018 have small absolute residuals during recent years. Generally, residuals of proportions of survey males and females appear to be random over length and year for all models (Figures 25a-25e and 26a-26e). Models with higher base *M* values like models 22.0a and 22.0c improve the plus group fittings slightly.

e. Retrospective and historic analyses.

Two kinds of retrospective analyses were conducted for this report: (1) the 2021 models (models 19.3d, 21.1, and 21.2) hindcast results and (2) historical results. The 2021 model hindcast results are based on sequentially excluding one-year of data to evaluate the current model performance with fewer data. The historical results are the trajectories of biomass and abundance from previous assessments that capture both new data and changes in methodology over time. Treating the 2021 estimates as the baseline values, we can evaluate how well the model had done in the past.

i. Retrospective analysis (retrospective bias in base model or models).

The performance of the 2021 model includes sequentially excluding one-year of data. Model 21.1b produces some upward biases during 2009-2020 with higher terminal year estimates of mature male biomass in 2009-2010 and 2014-2020 (Figure 27a). Higher than expected BSFRF survey biomass during 2007-2008 and 2013-2016 and NMFS survey biomass in 2014 likely caused these biases. Also, much lower than expected NMFS survey biomass during 2018-2019 results in lower biomass estimates in 2020 and 2021. Model 22.1 without the BSFRF survey data reduces the retrospective bias somewhat (Figure 27b). Model 22.1a without the BSFRF survey data and with a time block of high M during 2015-2018 reduces the retrospective bias substantially (Figure 27c). The biases for total abundance are much smaller than for mature male biomass. Models 22.0, 22.0d, and 22.0e with starting year of 1985, corresponding to models 21.1b, 22.1, and 22.1a with starting year of 1975, have similar results (Figures 27d-27g). Model 22.0c with higher base *M* values has a

Mohn's rho value of 0.235 (Figure 27e), between 0.376 for model 22.0 and 0.135 for model 22.0e (Table 5d).

ii. Historic analysis (plot of actual estimates from current and previous assessments).

The model first fit the data from 1985 to 2004 in the terminal year of 2004. Thus, sequentially incrementing the terminal year provided 17 historical assessments for comparison with the 2021 assessment model results (Figures 29a and 29b). The main differences of the 2004 model were weighting factors and effective sample sizes for the likelihood functions. In 2004, the weighting factors were 1,000 for survey biomass, 2,000 for retained catch biomass and 200 for bycatch biomasses. The effective sample sizes were set to be 200 for all proportion data but weighting factors of 5, 2, and 1 were also respectively applied to retained catch proportions, survey proportions and bycatch proportions. Estimates of time series of abundance in 2004 were generally higher than those estimated after 2004 (Figures 29a and 29b).

In 2005, to improve the fit for retained catch data, the weight for retained catch biomass was increased to 3,000 and the weight for retained catch proportions was increased to 6. All other weights were not changed. In 2006, all weights were re-configured. No weights were used for proportion data, and instead, effective sample sizes were set to 500 for retained catch, 200 for survey data, and 100 for bycatch data. Weights for biomasses were changed to 800 for retained catch, 300 for survey, and 50 for bycatch. The weights in 2007 were the same as 2006. Generally, estimates of time series of abundance in 2005 were slightly lower than in 2006 and 2007, and there were few differences between estimates in 2006 and 2007 (Figures 29a and 29b).

In 2008, estimated coefficients of variation for survey biomass were used to compute likelihood values as suggested by the CPT in 2007. Thus, weights were re-configured to: 500 for retained catch biomass, 50 for survey biomass, and 20 for bycatch biomasses. Effective sample size was lowered to 400 for the retained catch data. These changes were necessary for the estimation to converge and for a relatively good balanced fit to both biomasses and proportion data. Also, sizes at 50% selectivities for all fisheries data were allowed to change annually, subject to a random walk pattern, for all assessments before 2008. The 2008 model did not allow annual changes in any fishery selectivities. Except for higher estimates of abundance during the late 1980s and early 1990s, estimates of time series of abundance in 2008 were generally close to those in 2006 and 2007 (Figures 29a and 29b).

During 2009-2013, the model was extended to the data through 1968. No weighting factors were used for the NMFS survey biomass during 2009-2013 assessments. Since 2013, the model has fitted the data only back to 1975 for consistency with trawl survey data. Two levels of molting probabilities over time were used, shell conditions for males were combined, and length composition data of the BSFRF survey were used. In 2014 and 2015, the trawl survey time series were re-estimated and a trawl survey catchability was estimated for some models.

Model 19.3 with GMACS was used for 2020. Among many differences from previous models, one main difference is the natural mortality structure. Natural mortalities for females are proportional to natural mortalities for males for model 19.3, and one less natural mortality parameter is estimated for females than the previous models. Model 19.3 results in relatively low abundance estimates in recent years.

Overall, both historical results (historic analysis) and the 2021 model results (retrospective analysis) produced some upward biases due to low survey biomass in during 2018-2021. Models 22.0e and 22.1a substantially reduced these biases. The results are better than those by assessments for Pacific halibut (*Hippoglossus stenolepis*) (Parma 1993) and some eastern Bering Sea groundfish stocks (Zheng and Kruse 2002; Ianelli et al. 2003). Since the most recent model was not used to set TAC or overfishing limits until 2009, historical implications for management from the stock assessment errors cannot be evaluated at the current time. However, management implications of the ADF&G stock assessment model were evaluated by Zheng and Kruse (2002).

Ratios of estimated retrospective recruitments to terminal estimates in 2021 as a function of number of years estimated in the model show converging to 1.0 as the number of years increases (Figure 28b). Standard deviations of the ratios drop sharply from one year estimated in the model to two years (Figure 28c), showing great uncertainty of recruitment estimates for terminal years. Based on these results, we suggest not using recruitment estimates in a terminal year for overfishing/overfished determination.

f. Uncertainty and sensitivity analyses

   i. Estimated standard deviations of parameters are summarized in Tables 6a-6d for models 21.1b, 22.0, 22.0d, and 22.1. Estimated standard deviations of mature male biomass are listed in Table 9.

   ii. Probabilities for mature male biomass and OFL in 2021 were illustrated in Figures 30a-30f for models 21.1b, 22.0, 22.0d, 22.0e, and 22.1 using the MCMC approach. The confidence intervals are quite narrow.

   iii. Probabilities for mature male biomass below the minimum threshold (0.5* $B_{35\%}$) in 2021 were plotted in Figures 31a-31e for models 21.1b, 22.0, 22.0d, 22.0e, and 22.1 using the MCMC approach.

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

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

g. Comparison of alternative models

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

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

In this report (May 2022), eleven models are compared. For negative likelihood value comparisons (Tables 5b and 5c), models 22.0c with high base M values and 22.1a with a time block of high M during 2015-2018 have the highest total likelihood values for models starting in 1985 and 1975, respectively, without the BSFRF survey data. High base M values estimated inside the models or additional time block of high M during 2015-2018 generally result in significantly higher total likelihood values.

The first three models, 21.1, 21.1a, and 21.1b, have very close results. Model 21.1, the base model in 2021, was run with the updated GMACS version 2.01.E (finalized on Feb. 6, 2022), resulting in model 21.1a. The groundfish bycatch was updated when the AKFIN database was updated recently, resulting in model 21.1b. The GMACS update and the groundfish fisheries bycatch update have hardly affected the results. Model 21.1b was used to compare the other eight new model scenarios.

Among the new eight models, six models start in 1985 and were used to evaluate model starting year, BSFRF survey data, and one extra level of M during 2015-2018. Model 22.0 is the short data version of model 21.1b and the overall results are similar. The notable differences are smaller $B_{35\%}$ (22,14 1 t vs 24,325 t) and NMFS survey catchability (0.93 vs

0.96), and higher MMB in the terminal year (2021) (15,507 t vs 15,118 t) and higher OFL (2,718 t vs 2,298 t) for model 22.0. These differences are probably caused by a high recruitment in 1984 (associated with the very *M*) being used for $B_{35\%}$ computation for model 21.1b and more influence of BSFRF survey data for model 22.0. Estimating a base *M* for males for model 22.0a significantly increases likelihood values, slightly increases annual mature male biomass, and results in an estimated $B_{35\%}$ about 10% lower than model 22.0. A high *M* also results in higher $F_{35\%}$ and OFL for model 22.0a. Contrasting with assuming catchability being 1.0 for the BSFRF survey, model 22.0b estimates it in the model. As expected, the results of model 22.0b are similar to model 22.0a because the extra variance in the model has greatly reduced the influence of BSFF survey catchability, even though the estimated catchability is 1.36. Model 22.0c drops the BSFRF survey data and results in better fits to the other data. The retrospective bias is greatly reduced with model 22.0c over model 22.0 (Mohn's rho values from 0.376 to 0.235). The results of models 22.0b and 22.0c may indicate the problem of assuming catchability to be 1.0 for the BSFRF survey. With *M*=0.18 for males and without the BSFRF survey data, model 22.0d has very similar results with model 22.0, but with a smaller Mohn's rho value (0.329 vs 0.376). Model 22.0e uses a similar approach to Model 21.2 in 2021 to address the survey abundance decline during recent years through adding a time block of *M* (2015-2018) and to reduce the retrospective bias. Mohn's rho declines from 0.376 for model 22.0 to 0.135 for model 22.0e, and model 22.0e also fits the NMFS survey biomass much better during recent years. Model 22.0e results in overall higher mature male biomass estimates over time, higher $B_{35\%}$ estimate, and lower mature male biomass estimate in the terminal year (2021).

Relative to model 21.1b, model 22.1 drops the BSFRF data and model 22.1a adds a time block of *M* (2015-2018), similar to model 22.0e. Like the results of models starting in 1985, dropping the BSFRF data improve fits to the other data and reduces the retrospective bias. Combining no BSFRF data and a time block of *M* during 2015-2018 greatly reduces retrospective bias from Mohn's rho of 0.347 for model 21.1b to 0.135 for model 22.1a.

Based on the model results, it appears that the choice of preferred models depends on two factors: assumption of BSFRF survey catchability and estimation of *M*. 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. However, its small net opening and going into sea bottom could potentially cause herding effects, especially for long leg animals like red king crab. Parts of the lower bridles of survey nets could touch or close to sea bottom and herd or push crab into the net path. We talked to Scott Goodman about the herding effects of the BSFRF trawl survey a few years ago and it appears that the effects have not been evaluated. Model 22.0c estimated the catchability as 1.36, much higher than 1.0 assumed to the other models. Dropping the BSFRF data from the models does hardly impact the model results and reduces the model retrospective bias. Furthermore, if the BSFRF survey catchability is larger than 1.0 we assumed for the models, it could cause conservation concern. We suggest BSFRF evaluate the herding effects of the BSFRF trawl survey in the future if possible and eliminate the models that use the BSFRF survey data for time being.

Considerations of *M* estimation are whether to estimate a base *M* for males for the whole time series or to add a time block during 2015-2018. Either of these two approaches reduces the retrospective bias considerably. Concern of estimating a base *M* for males for the whole time series is potential confounding with estimating trawl survey catchability. It is also hard to find good reasons to add a time block during 2015-2018 other than very old crab due to low recruitment for over a decade. Very old crab tend to have a higher *M*.

Based on the above considerations, we recommend model 22.0d as the base model for overfishing definition determination in September 2022 due to a simple approach: a fixed base *M* of 0.18 for males, less confounding between estimating *M* and survey catchability, avoiding dramatic abundance decline during the early 1980s, no recruitment associated with an extremely high *M* being used for estimating $B_{35\%}$, and acceptable data fittings. Model 22.1 is a strong run-up and is a viable alternative. If estimating a base *M* value for males in the model is acceptable, then model 22.0c is also a good alternative, which fits the data well and greatly reduces retrospective bias from model 22.0. Values for management-related quantities for all models are summarized in likelihood Tables 5b, 5c, 5d, and 5e.

F. Calculation of the OFL and ABC

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

The Tier 3 control rule formula is as follows:

a) $\frac{B}{B^*} > 1$ $\qquad F_{OFL} = F^*$

b) $\beta < \frac{B}{B^*} \le 1$ $\qquad F_{OFL} = F^*\left(\frac{B/B^* - \alpha}{1-\alpha}\right)$ (2)

c) $\frac{B}{B^*} \le \beta$ $\qquad$ directed pot fishery $F = 0$ and $F_{OFL} \le F^*$

Where

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

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

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

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

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

Because trawl bycatch fishing mortality is not related to pot fishing mortality, average trawl bycatch fishing mortality during 2016 to 2020 is used for the per recruit analysis as well as for projections in the next section. Some discards of legal males occurred after the Individual Fishery Quota (IFQ) fishery started in 2005, but the discard rates were much lower during 2007-2013 than in 2005 after the fishing industry minimized discards of legal males. However, due to high proportions of large oldshell males, the discard rate increased greatly in 2014. The current models estimate two levels of retained proportions before 2005 and after 2004. The retained proportions after 2004 and total male selectivities are used to represent current trends for per recruit analysis and projections. Average molting probabilities during 2015-2020 are used for per recruit analysis and projections. For the models in 2021, the averages are the same since they are constant over time during at least the last 15 years.

Average recruitments during 1984-2020 for models starting in 1975 and during 1986-2020 for models starting in 1985 are used to estimate $B_{35\%}$ (Figure 12a). Estimated $B_{35\%}$ is compared with historical mature male biomass in Figure 14a. The period of 1984-2020 corresponds to the 1976/77 regime shift, and the recruitment period 1984-present has been used since 2011 to set the overfishing limits. Several factors support our recommendation. First, estimated recruitment was lower after 1983 than before 1984, which corresponded to brood years 1978 and later, after the 1976/77 regime shift. Second, high recruitments during the late 1960s and 1970s generally occurred when the spawning stock was primarily located in the southern Bristol Bay, whereas the recent spawning stock has been concentrated in the middle of Bristol Bay. Oceanic current flows favor larvae hatched in the southern Bristol Bay (see the section on Ecosystem Considerations for SAFE reports in 2008 and 2009). Finally, stock productivity (recruitment/mature male biomass) was higher before the 1976/1977 regime shift.

The control rule is used for stock status determination. If total catch exceeds OFL estimated at B, then “overfishing” occurs. If B equals or declines below 0.5 B_{MSY} (i.e., MSST), the stock is “overfished.” If B/B_{MSY} or B/B_{MSY}-proxy equals or declines below β, then the stock productivity is severely depleted, and the directed fishery is closed.

The estimated probability distributions of MMB in 2021 are illustrated in Figure 30 for different models. Based on SSC suggestions in 2011, ABC = 0.9*OFL and in October 2018, ABC = 0.8*OFL. The CPT then recommended ABC = 0.8*OFL in May 2018 (accepted by the SSC), which is used to estimate ABC in this report. Due to the stock being close to an overfished condition and the lack of a 2020 survey, the CPT recommended an additional 5% buffer in September 2020, resulting in ABC = 0.75*OFL for 2020. A 20% buffer was suggested by the CPT for 2021.

MCMC runs with 500,000 replicates and 500 draws with models 21.1b, 22.0, 22.0d, 22.0e, and 22.1 are used for estimating the probabilities of estimated mature male biomass being below the minimum threshold (0.5*$B_{35\%}$) (Figure 31). The probabilities (converted to a percentage) are estimated to be about 0%, 0%, 0%, 60.0%, and 1.5%, respectively, for these five models.

Status and catch specifications (1,000 t) (model 21.1):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	12.74^{A}	24.86^{A}	2.99	3.09	3.60	5.60	5.04
2018/19	10.62^{B}	16.92^{B}	1.95	2.03	2.65	5.34	4.27
2019/20	12.72^{C}	14.24^{C}	1.72	1.78	2.22	3.40	2.72
2020/21	12.12^{D}	13.96^{D}	1.20	1.26	1.57	2.14	1.61
2021/22		14.95^{D}				2.23	1.78

The stock was above MSST in 2020/21 and hence was not overfished. Since total catch was below OFL, overfishing did not occur. The relatively low MSST in 2018/19 and B_{MSY} in 2019/20 below was caused by a problem of the previous GMACS version using the only sex ratio of recruitment in the terminal year for $B_{35\%}$ computation in 2019. The lower estimated male recruitment ratio in the terminal year in 2019 resulted in a lower mean male recruitment for $B_{35\%}$ computation. The current version of GMACS uses an average of sex ratios of recruitment during the reference period to estimate $B_{35\%}$, which results in a much more stable sex ratio (about 50%) for the reference point calculation.

Status and catch specifications (million lb) (model 21.1):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	28.1^{A}	54.8^{A}	6.60	6.82	7.93	12.35	11.11
2018/19	23.4^{B}	37.3^{B}	4.31	4.31	5.85	11.76	9.41
2019/20	28.0^{C}	31.4^{C}	3.80	3.91	4.89	7.50	6.00
2020/21	26.7^{D}	30.8^{D}	2.77	2.65	3.47	4.72	3.54
2021/22		33.0^{D}				4.91	3.92

Notes:

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2018
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2019
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2020
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2021

Basis for the OFL: Values are in 1,000 t (model 21.1):

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2017/18	3b	25.1	21.3	0.85	0.24	1984-2017	0.18
2018/19	3b	25.5	20.8	0.82	0.25	1984-2017	0.18
2019/20	3b	21.2	16.0	0.75	0.22	1984-2018	0.18
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18
2021/22	3b	24.2	14.9	0.62	0.17	1984-2020	0.18

Basis for the OFL: Values are in million lb (model 21.1):

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2017/18	3b	55.2	47.0	0.85	0.24	1984-2017	0.18
2018/19	3b	56.2	45.9	0.82	0.25	1984-2017	0.18
2019/20	3b	46.8	35.2	0.75	0.22	1984-2018	0.18
2020/21	3b	56.1	32.9	0.59	0.16	1984-2019	0.18
2021/22	3b	53.4	33.0	0.62	0.17	1984-2020	0.18

Based on the $B_{35\%}$ estimated from the average male recruitment during 1984-2020, the biological reference points and OFL are illustrated in Table 4.

Based on the CPT/SSC recommendation of 20% buffer rule in May 2018 and an additional buffer of 5% by the CPT for 2020 due to the lack of a 2020 survey, ABC = 0.75*OFL (Table 4). A 20% buffer was recommended by the CPT for ABC estimation for 2021/22.

G. Rebuilding Analyses

NA

H. Data Gaps and Research Priorities

1. The following data gaps exist for this stock:
    a. Information about changes in natural mortality in the early 1980s,
    b. Un-observed trawl bycatch in the early 1980s,
    c. Natural mortality,
    d. Crab availability to the trawl surveys,
    e. Juvenile crab abundance,
    f. Female growth per molt as a function of size and maturity,
    g. Changes in male molting probability over time,
    h. A better understanding of larval distribution and subsequent recruit distribution.
2. Research priorities:
    a. Estimating natural mortality,
    b. Estimating crab availability to the trawl surveys,
    c. Surveying juvenile crab abundance in nearshore,
    d. Studying environmental factors that affect the survival rates from larvae to recruitment.

I. Projections and Future Outlook

1. Projections

Future population projections primarily depend on future recruitment, but crab recruitment is difficult to predict. Therefore, annual recruitment for the projections is a random selection from estimated recruitments during 2013-2020, a low recruitment period. Four levels of fishing mortality for the directed pot fishery are used in the projections: 0, 0.083, 0.167 and 0.25. A fishing mortality of 0.167 is similar to the estimated F_{ofl} of 0.173 in 2021 with model 21.1b. MCMC runs with 500,000 replicates and 500 draws are used for the projection.

As expected, projected mature male biomasses are much higher without the directed fishing mortality than under other positive mortality values. At the end of 10 years, projected mature male biomass is below $B_{35\%}$ for all models with a fishing mortality of 0.083 or higher due to low recruitments (Table 10; Figure 32). Due to the poor recruitment in recent years, the projected biomass is expected to decline during the next few years with a fishing mortality of 0.25.

Even though the stock is not overfished in 2021, there is still a question whether the stock is "approaching an overfished condition", which is defined as "when it is projected that there is more than a 50 percent chance that the biomass of the stock or stock complex will decline below the MSST within two years" by the National Standards 1 (NS1). If the stock is not fished more than a fishing mortality of 0.167 for the directed pot fishery in the 2021/2022 and 2022/2023 seasons, the projection using the lowest recruitment periods during 2013-2020 would not likely result in "approaching an overfished condition" for models 21.1b, 22.0, 22.0d, and 22.1 (Figure 33). A constant fishing mortality of 0.083 may increase the risk of "approaching an overfished condition" for model 22.0e. With additional low recruitment estimate used to compute $B_{35\%,}$ the estimated MSST would decline further in 2022.

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

2. Near Future Outlook

The near future outlook for the Bristol Bay RKC stock is a declining trend. The three recent above-average year classes (hatching years 1990, 1994, and 1997) had entered the legal population by 2006 (Figure 34). Most individuals from the 1997-year class will continue to gain weight to offset loss of the legal biomass to fishing and natural mortalities. The above-average year class (hatching year 2000) with lengths centered around 87.5 mm CL for both males and females in 2006 and with lengths centered around 112.5-117.5 mm CL for males and around 107.5 mm CL for females in 2008 has largely entered the mature male population in 2009 and the legal population by 2014 (Figure 34). However, no additional strong cohorts were observed in the survey data after this cohort through 2010 (Figure 34). A huge tow of juvenile crab of size 45-55 mm in 2011 was not tracked during 2012-2021 surveys and is unlikely to be a strong cohort. The high survey abundances of large males and mature females in 2014 cannot be explained by the survey data during the previous years and were also inconsistent with the 2016-2021 survey results (Figure 34). Due to lack of recruitment, mature and legal crab should continue to decline next year. Current crab abundance is still low relative to the late 1970s, and without favorable environmental conditions, recovery to the high levels of the late 1970s is unlikely.

Although mature crab abundance in Bristol Bay has declined in recent years, mature crab abundance and biomass north of Bristol Bay have been variable greatly stable during last 16 years (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 plot in the SAFE report in the future. After migration patterns between BBRKC and the Northern RKC are fully understood, we will examine their relationships and model them in the stock assessment.

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K. Literature Cited

Alaska Department of Fish and Game (ADF&G). 2012. Commercial king and Tanner crab fishing regulations, 2012-2013. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau. 170 pp.

Balsiger, J.W. 1974. A computer simulation model for the eastern Bering Sea king crab. Ph.D. dissertation, Univ. Washington, Seattle, WA. 198 pp.

Fitch, H., M. Deiman, J. Shaishnikoff, and K. Herring. 2012. Annual management report for the commercial shellfish fisheries of the Bering Sea, 2010/11. *In* Fitch, H. M. Schwenzfeier, B. Baechler, T. Hartill, M. Salmon, M. Deiman, E. Evans, E. Henry, L. Wald, J. Shaishnikoff, K. Herring, and J. Wilson. 2012. Annual management report for the commercial and subsistence fisheries of the Aleutian Islands, Bering Sea and the Westward Region's shellfish observer program, 2010/11. Alaska Department of Fish and Game, Fishery Management report No. 12-22, Anchorage.

Fournier, D.A., J. Hampton, and J.R. Sibert. 1998. MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with application to South Pacific albacore, *Thunnus alalunga*. Can.J.Fish.Aquat. Sci., 55: 2105-2116.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27: 233-249.

Gaeuman, W.G. 2013. Summary of the 2012/13 mandatory crab observer program database for the Bering Sea/Aleutian Islands commercial crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 13-54, Anchorage.

Gray, G.W. 1963. Growth of mature female king crab *Paralithodes camtschaticus* (Tilesius). Alaska Dept. Fish and Game, Inf. Leafl. 26.

Griffin, K. L., M. F. Eaton, and R. S. Otto. 1983. An observer program to gather in-season and post-season on-the-grounds red king crab catch data in the southeastern Bering Sea. Contract 82-2, North Pacific Fishery Management Council, Anchorage.

Haynes, E.B. 1968. Relation of fecundity and egg length to carapace length in the king crab, *Paralithodes camtschaticus*. Proc. Nat. Shellfish Assoc. 58: 60-62.

Hoopes, D.T., J.F. Karinen, and M. J. Pelto. 1972. King and Tanner crab research. Int. North Pac. Fish. Comm. Annu. Rep. 1970: 110-120.

Ianelli, J.N., S. Barbeaux, G. Walters, and N. Williamson. 2003. Eastern Bering Sea walleye pollock stock assessment. Pages 39-126 *in* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pacific Fishery Management Council, Anchorage.

Jackson, P.B. 1974. King and Tanner crab fishery of the United States in the Eastern Bering Sea, 1972. Int. North Pac. Fish. Comm. Annu. Rep. 1972: 90-102.

Loher, T., D.A. Armstrong, and B.G. Stevens. 2001. Growth of juvenile red king crab (*Paralithodes camtschaticus*) in Bristol Bay (Alaska) elucidated from field sampling and analysis of trawl-survey data. Fish. Bull. 99: 572-587.

Matsuura, S., and K. Takeshita. 1990. Longevity of red king crab, *Paralithodes camtschaticus*, revealed by long-term rearing study. Pages 247-266 *in* Proceedings of the International Symposium on King and Tanner Crabs. University Alaska Fairbanks, Alaska Sea Grant College Program Report 90-04, Fairbanks.

McCaughran, D.A., and G.C. Powell. 1977. Growth model for Alaskan king crab (*Paralithodes camtschaticus*). J. Fish. Res. Board Can. 34: 989-995.

North Pacific Fishery Management Council (NPFMC). 2007. Environmental assessment for proposed amendment 24 to the fishery management plan for Bering Sea and Aleutian Islands king and Tanner crabs to revise overfishing definitions.

Otto, R.S. 1989. An overview of eastern Bering Sea king and Tanner crab fisheries. Pages 9–26 *in* Proceedings of the International Symposium on King and Tanner Crabs, Alaska Sea Grant College Program Report No. 90-04.

Parma, A.M. 1993. Retrospective catch-at-age analysis of Pacific halibut: implications on assessment of harvesting policies. Pages 247-266 *in* G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II (eds.). Proceedings of the international symposium on management strategies for exploited fish populations. University of Alaska Fairbanks, Alaska Sea Grant Rep. 90-04.

Paul, J.M., and A.J. Paul. 1990. Breeding success of sublegal size male red king crab *Paralithodes camtschaticus* (Tilesius, 1815) (Decapopa, Lithodidae). J. Shellfish Res. 9: 29-32.

Paul, J.M., A.J. Paul, R.S. Otto, and R.A. MacIntosh. 1991. Spermatophore presence in relation to carapace length for eastern Bering Sea blue king crab (*Paralithodes platypus,* Brandt, 1850) and red king crab (P. camtschaticus, Tilesius, 1815). J. Shellfish Res. 10: 157-163.

Pengilly, D., S.F. Blau, and J.E. Blackburn. 2002. Size at maturity of Kodiak area female red king crab. Pages 213-224 *in* A.J. Paul, E.G. Dawe, R. Elner, G.S. Jamieson, G.H. Kruse, R.S. Otto, B. Sainte-Marie, T.C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.

Pengilly, D., and D. Schmidt. 1995. Harvest strategy for Kodiak and Bristol Bay red king crab and St. Matthew Island and Pribilof Islands blue king crab. Alaska Dep. Fish and Game, Comm. Fish. Manage. and Dev. Div., Special Publication 7. Juneau, AK.

Phinney, D.E. 1975. United States fishery for king and Tanner crabs in the eastern Bering Sea, 1973. Int. North Pac. Fish. Comm. Annu. Rep. 1973: 98-109.

Powell, G.C. 1967. Growth of king crabs in the vicinity of Kodiak, Alaska. Alaska Dept. Fish and Game, Inf. Leafl. 92. 106 pp.

Powell, G. C., and R.B. Nickerson. 1965. Aggregations among juvenile king crab (*Paralithodes camtschaticus,* Tilesius) Kodiak, Alaska. Animal Behavior 13: 374–380.

Schmidt, D., and D. Pengilly. 1990. Alternative red king crab fishery management practices: modeling the effects of varying size-sex restrictions and harvest rates, Pages 551-566 *in* Proc. Int. Symp. King and Tanner Crabs, Alaska Sea Grant Rep. 90-04.

Sparks, A.K., and J.F. Morado. 1985. A preliminary report on diseases of Alaska king crabs, Pages 333-340 *in* Proc. Int. Symp. King and Tanner Crabs, Alaska Sea Grant Rep. 85-12.

Stevens, B.G. 1990. Temperature-dependent growth of juvenile red king crab (*Paralithodes camtschaticus*), and its effects on size-at-age and subsequent recruitment in the eastern Bering Sea. Can. J. Fish. Aquat. Sci. 47: 1307-1317.

Stevens, B.G., and K. Swiney. 2007. Hatch timing, incubation period, and reproductive cycle for primiparous and multiparous red king crab, *Paralithodes camtschaticus*. J. Crust. Bio. 27(1): 37-48.

Swiney, K. M., W.C. Long, G.L. Eckert, and G.H. Kruse. 2012. Red king crab, *Paralithodes camtschaticus*, size-fecundity relationship, and interannual and seasonal variability in fecundity. Journal of Shellfish Research, 31:4, 925-933.

Then, A. Y., J. M. Hoenig, N. G. Hall, and D. A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. – ICES J. Mar. Sci. 72: 82–92.

Webb. J. 2014. Reproductive ecology of commercially important Lithodid crabs. Pages 285-314 *in* B.G. Stevens (ed.): King Crabs of the World: Biology and Fisheries Management. CRC Press, Taylor & Francis Group, New York.

Weber, D.D. 1967. Growth of the immature king crab *Paralithodes camtschaticus* (Tilesius). Int. North Pac. Fish. Comm. Bull. 21:21-53.

Weber, D.D., and T. Miyahara. 1962. Growth of the adult male king crab, *Paralithodes camtschaticus* (Tilesius). Fish. Bull. U.S. 62:53-75.

Weinberg, K.L., R.S. Otto, and D.A. Somerton. 2004. Capture probability of a survey trawl for red king crab (*Paralithodes camtschaticus*). Fish. Bull. 102:740-749.

Zheng, J. 2005. A review of natural mortality estimation for crab stocks: data-limited for every stock? Pages 595-612 *in* G.H. Kruse, V.F. Gallucci, D.E. Hay, R.I. Perry, R.M. Peterman, T.C. Shirley, P.D. Spencer, B. Wilson, and D. Woodby (eds.). Fisheries Assessment and Management in Data-limited Situation. Alaska Sea Grant College Program, AK-SG-05-02, Fairbanks.

Zheng, J., and G.H. Kruse. 2002. Retrospective length-based analysis of Bristol Bay red king crabs: model evaluation and management implications. Pages 475-494 *in* A.J. Paul, E.G. Dawe, R. Elner, G.S. Jamieson, G.H. Kruse, R.S. Otto, B. Sainte-Marie, T.C. Shirley, and D. Woodby (eds.). Crabs in Cold Water Regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.

Zheng, J., M.C. Murphy, and G.H. Kruse. 1995a. A length-based population model and stock-recruitment relationships for red king crab, *Paralithodes camtschaticus*, in Bristol Bay, Alaska. Can. J. Fish. Aquat. Sci. 52:1229-1246.

Zheng, J., M.C. Murphy, and G.H. Kruse. 1995b. Updated length-based population model and stock-recruitment relationships for red king crab, *Paralithodes camtschaticus,* in Bristol Bay, Alaska. Alaska Fish. Res. Bull. 2:114-124.

Zheng, J., M.C. Murphy, and G.H. Kruse. 1996. Overview of population estimation methods and recommended harvest strategy for red king crabs in Bristol Bay. Alaska Department of Fish and Game, Reg. Inf. Rep. 5J96-04, Juneau, Alaska. 37 pp.

Zheng, J., M.C. Murphy, and G.H. Kruse. 1997a. Analysis of the harvest strategies for red king crab, *Paralithodes camtschaticus*, in Bristol Bay, Alaska. Can. J. Fish. Aquat. Sci. 54:1121-1134.

Zheng, J., M.C. Murphy, and G.H. Kruse. 1997b. Alternative rebuilding strategies for the red king crab *Paralithodes camtschaticus* fishery in Bristol Bay, Alaska. J. Shellfish Res. 16:205-217.

Table 1a. Bristol Bay red king crab annual catch and bycatch mortality biomass (t) from July 1 to June 30. A handling mortality rate of 20% for the directed pot, 25% for the Tanner fishery, 80% for trawl, and 50% or fixed gear was assumed to estimate bycatch mortality biomass. The male bycatch biomass in the directed pot fishery is not estimated outside of a model and not included in this Table. Pot bycatch and Tanner crab fishery bycatch are estimated through expanding the mean observer bycatch per pot to total fishery pot. The pot male bycatch after 2017 is estimated through the subtraction method (B. Daly, ADF&G, personal communication). The trawl and fixed gear fishery bycatches are obtained from the NMFS database. The directed pot bycatch before 1990 and Tanner crab fishery bycatch before 1991 are not available from the observer data and thus not included in this table. These include recently updated estimates from the pot fisheries observer data in 2021.

Year	Retained Catch				Pot Bycatch	Trawl Bycatch	Fixed Bycatch	Tanner Fishery Bycatch
	U.S.	Cost-Recovery	Foreign	Total	Females			
1953	1331.3		4705.6	6036.9				
1954	1149.9		3720.4	4870.2				
1955	1029.2		3712.7	4741.9				
1956	973.4		3572.9	4546.4				
1957	339.7		3718.1	4057.8				
1958	3.2		3541.6	3544.8				
1959	0.0		6062.3	6062.3				
1960	272.2		12200.7	12472.9				
1961	193.7		20226.6	20420.3				
1962	30.8		24618.7	24649.6				
1963	296.2		24930.8	25227.0				
1964	373.3		26385.5	26758.8				
1965	648.2		18730.6	19378.8				
1966	452.2		19212.4	19664.6				
1967	1407.0		15257.0	16664.1				
1968	3939.9		12459.7	16399.6				
1969	4718.7		6524.0	11242.7				
1970	3882.3		5889.4	9771.7				
1971	5872.2		2782.3	8654.5				
1972	9863.4		2141.0	12004.3				
1973	12207.8		103.4	12311.2				
1974	19171.7		215.9	19387.6				
1975	23281.2		0	23281.2				
1976	28993.6		0	28993.6		682.8		
1977	31736.9		0	31736.9		1249.9		
1978	39743.0		0	39743.0		1320.6		
1979	48910.0		0	48910.0		1331.9		
1980	58943.6		0	58943.6		1036.5		
1981	15236.8		0	15236.8		219.4		
1982	1361.3		0	1361.3		574.9		
1983	0.0		0	0.0		420.4		
1984	1897.1		0	1897.1		1094.0		
1985	1893.8		0	1893.8		390.1		
1986	5168.2		0	5168.2		200.6		
1987	5574.2		0	5574.2		186.4		
1988	3351.1		0	3351.1		598.4		
1989	4656.0		0	4656.0		175.2		
1990	9236.2	36.6	0	9272.8	639.2	259.9		
1991	7791.8	93.4	0	7885.1	46.8	349.4		1401.8
1992	3648.2	33.6	0	3681.8	395.3	293.5		244.4
1993	6635.4	24.1	0	6659.6	628.3	401.4		54.6
1994	0.0	42.3	0	42.3	0.4	87.3		10.8
1995	0.0	36.4	0	36.4	0.3	82.1		0.0

1996	3812.7	49.0	0	3861.7	1.0	90.8	41.4	0.0
1997	3971.9	70.2	0	4042.1	36.5	57.5	22.5	0.0
1998	6693.8	85.4	0	6779.2	553.9	186.1	18.5	0.0
1999	5293.5	84.3	0	5377.9	5.6	150.5	50.1	0.0
2000	3698.8	39.1	0	3737.9	164.4	81.7	4.7	0.0
2001	3811.5	54.6	0	3866.2	120.8	192.8	35.3	0.0
2002	4340.9	43.6	0	4384.5	9.1	151.2	29.2	0.0
2003	7120.0	15.3	0	7135.3	356.9	136.9	12.7	0.0
2004	6915.2	91.4	0	7006.7	171.8	173.5	15.2	0.0
2005	8305.0	94.7	0	8399.7	405.4	124.7	19.9	0.0
2006	7005.3	137.9	0	7143.2	37.5	151.7	19.6	3.8
2007	9237.9	66.1	0	9303.9	159.9	154.1	32.3	1.8
2008	9216.1	0.0	0	9216.1	144.8	136.6	15.6	4.0
2009	7226.9	45.5	0	7272.5	88.3	94.9	5.8	1.6
2010	6728.5	33.0	0	6761.5	118.5	83.2	2.4	0.0
2011	3553.3	53.8	0	3607.1	25.0	56.2	10.9	0.0
2012	3560.6	61.1	0	3621.7	11.2	34.1	18.4	0.0
2013	3901.1	89.9	0	3991.0	98.1	66.9	55.1	28.5
2014	4530.0	8.6	0	4538.6	84.9	34.5	118.7	42.0
2015	4522.3	91.4	0	4613.7	239.1	45.1	77.4	84.2
2016	3840.4	83.4	0	3923.9	123.4	67.3	29.7	0.0
2017	2994.1	99.6	0	3093.7	53.4	91.7	130.0	0.0
2018	1954.1	72.4	0	2026.5	150.1	78.0	154.7	0.0
2019	1719.8	55.5	0	1775.3	43.3	80.7	45.1	0.0
2020	1200.6	56.4	0	1257.0	15.2	80.7	37.6	0.0

Table 1b. Annual retained catch (millions of crab) and catch per unit effort of the Bristol Bay red king crab fishery.

Year	Japanese Tanglenet		Russian Tanglenet		U.S. Pot		Standardized Crab/tan
	Catch	Crab/tan	Catch	Crab/tan	Catch	Crab/Potlift	
1960	1.949	15.2	1.995	10.4	0.088		15.8
1961	3.031	11.8	3.441	8.9	0.062		12.9
1962	4.951	11.3	3.019	7.2	0.010		11.3
1963	5.476	8.5	3.019	5.6	0.101		8.6
1964	5.895	9.2	2.800	4.6	0.123		8.5
1965	4.216	9.3	2.226	3.6	0.223		7.7
1966	4.206	9.4	2.560	4.1	0.140	52	8.1
1967	3.764	8.3	1.592	2.4	0.397	37	6.3
1968	3.853	7.5	0.549	2.3	1.278	27	7.8
1969	2.073	7.2	0.369	1.5	1.749	18	5.6
1970	2.080	7.3	0.320	1.4	1.683	17	5.6
1971	0.886	6.7	0.265	1.3	2.405	20	5.8
1972	0.874	6.7			3.994	19	
1973	0.228				4.826	25	
1974	0.476				7.710	36	
1975					8.745	43	
1976					10.603	33	
1977					11.733	26	
1978					14.746	36	
1979					16.809	53	
1980					20.845	37	
1981					5.308	10	
1982					0.541	4	
1983					0.000		
1984					0.794	7	
1985					0.796	9	
1986					2.100	12	
1987					2.122	10	
1988					1.236	8	
1989					1.685	8	
1990					3.130	12	
1991					2.661	12	
1992					1.208	6	
1993					2.270	9	
1994							
1995							
1996					1.264	16	
1997					1.338	15	
1998					2.238	15	
1999					1.923	12	
2000					1.272	12	
2001					1.287	19	
2002					1.484	20	
2003					2.510	18	
2004					2.272	23	
2005					2.763	30	
2006					2.477	31	
2007					3.154	28	
2008					3.064	22	
2009					2.553	21	
2010					2.410	18	
2011					1.298	28	
2012					1.176	30	
2013					1.272	27	
2014					1.501	26	
2015					1.527	31	
2016					1.281	38	
2017					0.997	20	
2018					0.630	20	
2019					0.549	16	
2020					0.455	21	

Table 2. Total observer catch and bycatch (metric ton) of Bristol Bay red king crab. No handling mortality rates are applied. These include recently updated estimates from the pot fishery observer data in 2021.

	Directed Pot Total		Trawl	Fixed	Tanner
Year	Males	Females	Bycatch	Bycatch	Bycatch
1975			0.000		
1976			853.494		
1977			1,562.313		
1978			1,650.775		
1979			1,664.925		
1980			1,295.625		
1981			274.229		
1982			718.610		
1983			525.554		
1984			1,367.550		
1985			487.576		
1986			250.758		
1987			233.045		
1988			747.996		
1989			219.023		
1990	11621.800	3196.200	324.883		
1991	9792.900	233.900	436.783		5,580.843
1992	5916.200	1976.300	366.816		962.846
1993	9516.800	3141.500	501.770		218.112
1994	62.300	1.877	109.129		39.395
1995	52.800	1.612	102.623		0.000
1996	3845.200	5.100	113.495	82.859	0.000
1997	3758.800	182.700	71.862	44.979	0.000
1998	15644.800	2769.300	232.580	36.916	0.000
1999	12112.300	28.000	188.101	100.242	0.000
2000	6579.700	821.900	102.161	9.446	0.000
2001	5711.500	604.000	241.011	70.553	0.000
2002	6961.400	45.600	189.018	58.382	0.000
2003	12166.500	1784.400	171.114	25.351	0.000
2004	10692.000	859.200	216.889	30.422	0.000
2005	13615.900	2027.100	155.924	39.802	0.000
2006	9254.000	187.400	189.660	39.134	15.217
2007	13871.900	799.400	192.571	64.655	7.142
2008	14894.900	724.200	170.754	31.158	16.070
2009	12218.800	441.300	118.672	11.614	6.499
2010	10095.400	592.600	104.005	4.944	0.000
2011	5665.300	124.800	70.286	21.726	0.000
2012	4495.500	55.900	42.641	36.897	0.000
2013	5305.900	490.700	83.613	110.208	113.063
2014	8113.800	424.300	43.129	237.374	137.786
2015	6726.800	1195.600	56.410	154.775	639.573
2016	5651.800	617.200	84.127	59.418	0.000
2017	4077.200	266.900	114.624	260.011	0.000
2018	3423.200	750.400	97.561	309.415	0.000
2019	3144.600	218.000	100.915	90.291	0.000
2020	2299.700	76.100	100.842	75.130	0.000

Table 3a. Annual sample sizes (>64 mm CL) in numbers of crab for trawl surveys, retained catch, directed pot, Tanner crab, trawl, and fixed gear fishery bycatches of Bristol Bay red king crab. These include recently updated estimates from the pot fisheries observer data and are used for models 19.3c-19.6 in 2021.

Year	Trawl Survey		Retained Catch	Pot Total	Pot Bycatch	Trawl Bycatch	Fixed G. Bycatch	Tanner Fishery Bycatch
	Males	Females		Males	Females	Combined	Combined	Combined
1975	2.815	2.042	29.570					
1976	2,699	1,466	26,450			3,003		
1977	2,734	2,424	32,596			14,703		
1978	2,735	2,793	27,529			10,439		
1979	1,158	1,456	27,900			10,049		
1980	1,917	1,301	34,747			87,152		
1981	591	664	18,029			91,806		
1982	1,911	1,948	11,466			131,469		
1983	1,343	733	0			309,374		
1984	1,209	778	4,404			505,115		
1985	790	414	4,582			200,460		
1986	959	341	5,773			2,126		
1987	1,123	1,011	4,230			998		
1988	708	478	9,833			630		
1989	764	403	32,858			4,641		
1990	729	535	7,218	2,544	696	908		
1991	1,180	490	36,928	4,696	375	275		3,131
1992	509	357	25,550	4,775	2,379	333		965
1993	725	576	32,942	10,200	5,944	5		497
1994	416	239	0	0	0	571		17
1995	685	407	0	0	0	120		
1996	755	753	8,896	642	11	1,209	756	
1997	1,280	702	16,143	10,016	906	339	1,269	
1998	1,067	1,123	17,116	24,537	9,655	1,430	1,036	
1999	765	618	18,685	6,892	40	629	1,602	
2000	734	730	14,143	32,709	8,470	729	591	
2001	599	736	13,735	25,135	5,436	795	5,029	
2002	972	826	16,837	32,317	706	1,139	3,503	
2003	1,360	1,250	18,178	44,600	12,474	516	1,872	
2004	1,852	1,271	22,465	38,772	6,666	636	2,184	
2005	1,198	1,563	27,971	94,622	26,782	1,040	2,146	
2006	1,178	1,432	18,451	73,315	3,991	1,168	1,868	140
2007	1,228	1,305	22,809	115,507	12,691	1,225	785	53
2008	1,228	1,183	24,997	89,771	8,564	1,596	1,164	145
2009	837	941	19,336	97,868	6,055	1,170	1,089	193
2010	708	1,004	20,347	69,276	6,872	901	513	
2011	531	912	10,904	42,931	1,920	439	1,190	
2012	585	707	9,084	21,404	563	281	2,977	
2013	647	569	10,396	32,332	6,051	481	8,523	814
2014	1,107	1,257	9,718	31,216	2,663	261	4,285	631
2015	615	681	11,971	24,533	7,457	409	4,472	2,872
2016	378	812	11,003	30,030	5,832	617	4,329	
2017	385	508	10,067	30,002	4,043	718	1,415	
2018	285	359	7,825	25,635	9,840	893	5,382	
2019	273	299	8,134	25,999	2,894	823	863	
2020			3,850	16,650	961	764	246	
2021	324	247						

Table 3b. Comparison of area-swept and VAST-based male Bristol Bay red king crab biomass estimates from the NMFS trawl survey. Difference = (area-swept – VAST)/[(area-swept + VAST)/2]. Reduction = (area-swept – VAST)/area-swept.

	Area-swept		VAST		Biomass	CV
Year	Biomass	CV	Biomass	CV	Differ.%	Reduction%
1975	133.084	0.171	148.119	0.099	-10.69	42.37
1976	256.362	0.222	243.853	0.089	5.00	59.74
1977	232.539	0.176	239.346	0.080	-2.89	54.39
1978	199.542	0.200	196.698	0.090	1.44	54.94
1979	102.448	0.239	96.579	0.101	5.90	57.79
1980	166.524	0.240	141.622	0.096	16.16	59.90
1981	68.294	0.144	73.903	0.081	-7.89	44.07
1982	72.296	0.263	60.766	0.096	17.33	63.40
1983	34.762	0.210	34.590	0.088	0.50	58.16
1984	96.418	0.549	47.590	0.108	67.81	80.41
1985	26.819	0.154	29.607	0.090	-9.88	41.62
1986	40.549	0.481	27.200	0.098	39.41	79.62
1987	46.769	0.225	42.384	0.095	9.84	57.78
1988	35.374	0.168	37.874	0.092	-6.83	45.42
1989	42.358	0.222	40.527	0.094	4.42	57.83
1990	38.728	0.227	37.492	0.099	3.24	56.50
1991	66.528	0.543	36.916	0.149	57.25	72.63
1992	25.096	0.178	26.546	0.099	-5.62	44.19
1993	35.671	0.210	36.554	0.109	-2.45	48.32
1994	23.003	0.173	25.230	0.105	-9.23	39.35
1995	27.252	0.327	23.646	0.103	14.17	68.56
1996	26.816	0.187	28.476	0.104	-6.01	44.62
1997	59.638	0.244	55.682	0.101	6.86	58.76
1998	46.209	0.162	50.277	0.092	-8.43	43.25
1999	44.529	0.210	46.095	0.109	-3.46	48.10
2000	38.391	0.164	46.505	0.101	-19.12	38.40
2001	27.943	0.146	31.181	0.088	-10.95	39.84
2002	45.140	0.195	48.796	0.101	-7.78	48.09
2003	74.641	0.406	60.035	0.101	21.69	75.04
2004	90.354	0.395	64.126	0.104	33.96	73.78
2005	54.790	0.181	55.097	0.098	-0.56	46.06
2006	51.215	0.197	54.277	0.088	-5.80	55.27
2007	58.144	0.184	62.256	0.091	-6.83	50.34
2008	67.214	0.302	61.024	0.103	9.65	65.93
2009	43.170	0.365	39.091	0.113	9.92	69.05
2010	39.021	0.237	40.329	0.101	-3.30	57.57
2011	27.385	0.207	29.640	0.106	-7.91	48.65
2012	30.655	0.255	34.232	0.117	-11.02	54.08
2013	39.650	0.207	42.819	0.105	-7.68	49.11
2014	60.649	0.192	64.111	0.097	-5.55	49.56
2015	37.085	0.174	42.030	0.093	-12.50	46.41
2016	27.185	0.148	30.230	0.091	-10.61	38.84
2017	25.335	0.174	26.252	0.086	-3.56	50.61
2018	16.034	0.138	18.270	0.091	-13.03	33.75
2019	15.170	0.163	16.262	0.093	-6.95	42.65
2021	18.235	0.202	17.185	0.133	5.93	34.14
Mean	61.631	0.234	58.942	0.099	2.69	53.24
Min					-19.12	33.75
Max					67.81	80.41

Table 3c. Comparison of area-swept and VAST-based female Bristol Bay red king crab biomass estimates from the NMFS trawl survey. Difference = (area-swept – VAST)/[(area-swept + VAST)/2]. Reduction = (area-swept – VAST)/area-swept.

	Area-swept		VAST		Biomass	CV
Year	Biomass	CV	Biomass	CV	Differ.%	Reduction%
1975	66.559	0.301	58.081	0.127	13.60	57.79
1976	71.252	0.235	68.255	0.106	4.30	55.08
1977	138.684	0.188	134.450	0.097	3.10	48.60
1978	143.647	0.196	125.444	0.099	13.53	49.30
1979	63.001	0.179	53.741	0.091	15.86	49.34
1980	80.701	0.327	67.448	0.118	17.89	63.92
1981	62.850	0.257	55.937	0.107	11.64	58.30
1982	69.601	0.251	61.728	0.103	11.99	58.91
1983	13.714	0.247	11.953	0.106	13.72	56.95
1984	56.189	0.710	19.191	0.154	98.16	78.28
1985	7.319	0.251	6.680	0.116	9.12	53.59
1986	6.885	0.331	5.835	0.122	16.51	63.20
1987	22.476	0.320	17.208	0.125	26.55	61.01
1988	19.224	0.411	13.843	0.153	32.55	62.72
1989	12.778	0.347	9.644	0.121	27.95	65.03
1990	20.723	0.401	14.301	0.138	36.67	65.47
1991	17.364	0.415	11.900	0.124	37.34	70.14
1992	12.238	0.247	10.797	0.116	12.51	53.03
1993	17.235	0.248	15.702	0.127	9.31	48.83
1994	9.102	0.219	8.425	0.126	7.72	42.42
1995	10.816	0.247	9.454	0.117	13.44	52.54
1996	17.143	0.270	14.672	0.126	15.54	53.41
1997	24.392	0.352	19.315	0.131	23.23	62.79
1998	37.893	0.250	31.954	0.113	17.01	54.82
1999	20.225	0.339	19.950	0.138	1.37	59.28
2000	28.991	0.330	31.734	0.143	-9.04	56.73
2001	24.513	0.294	21.338	0.123	13.85	58.20
2002	23.947	0.289	20.469	0.122	15.66	57.63
2003	41.119	0.221	37.258	0.114	9.85	48.58
2004	40.202	0.255	32.518	0.109	21.13	57.43
2005	50.937	0.205	44.651	0.109	13.15	46.93
2006	43.262	0.200	54.154	0.113	-22.36	43.48
2007	45.183	0.223	53.047	0.105	-16.01	53.10
2008	45.867	0.322	47.268	0.124	-3.01	61.57
2009	47.377	0.327	45.385	0.120	4.29	63.32
2010	41.480	0.271	42.706	0.119	-2.91	56.21
2011	39.023	0.256	41.777	0.121	-6.82	52.62
2012	30.042	0.334	30.582	0.150	-1.78	55.21
2013	22.567	0.359	22.856	0.145	-1.27	59.51
2014	52.486	0.227	65.939	0.129	-22.72	43.09
2015	27.090	0.295	30.854	0.133	-12.99	54.81
2016	33.773	0.259	36.498	0.114	-7.75	55.92
2017	27.599	0.250	29.231	0.106	-5.74	57.70
2018	12.771	0.224	14.247	0.117	-10.93	47.79
2019	13.369	0.185	15.989	0.100	-17.85	46.11
2021	10.241	0.244	10.576	0.109	-3.23	55.17
Mean	37.475	0.285	34.674	0.120	9.22	56.00
Min					-22.72	42.42
Max					98.16	78.28

Table 4. Comparison of harmonic means of implied sample sizes and maximum caps (N) of effective sample sizes for models 21.1b, 22.0, 22.0c, 22.0d, 22.0e, 22.1, and 22.1a.

		Models						
		21.1b	22.0	22.0c	22.0d	22.0e	22.1	22.1a
	N	Harm.S	Harm.S	Harm.S	Harm.S	Harm.S	Harm.S	Harm.S
Retained catch	150	171.4	185.7	196.6	186.7	190.0	176.0	179.3
Pot total males	150	221.6	222.4	228.2	225.6	225.5	224.2	225.0
Pot total females	50	28.7	28.7	28.6	28.7	28.9	28.8	28.9
Trawl bycatch	50	59.5	58.3	59.2	55.3	61.5	57.7	62.3
Tanner fishery bycatch	50	25.4	25.3	25.7	25.2	25.5	25.5	25.7
Fixed gear bycatch	50	45.4	45.0	46.1	44.4	46.9	45.1	47.1
NMFS survey	200	176.8	205.2	210.3	201.6	203.4	175.9	174.5
BSFRF survey	200	119.8	116.2					

Table 5a. Number of parameters for the model (Models 21.1, 21.1a, 21.1b, 22.0, 22.0a, 22.0b, 22.0c, 22.0d, 22.0e, 221, and 22.1a). Red values indicate different values among models.

Parameter counts	**21.1** **21.1a** **21.1b**	**22.0**	**22.0a**	**22.0b**	**22.0c**	**22.0d**	**22.0e**	**22.1**	**22.1a**
Fixed growth parameters	0	0	0	0	0	0	0	0	0
Fixed recruitment parameters	2	2	2	2	2	2	2	2	2
Fixed length-weight relationship parameters	6	6	6	6	6	6	6	6	6
Fixed mortality parameters	5	5	4	4	4	5	5	5	5
Fixed survey catchability parameter	1	1	1	0	0	0	0	0	0
Fixed high grading parameters	0	0	0	0	0	0	0	0	0
Total number of fixed parameters	14	14	13	12	12	13	13	13	13
Free survey catchability parameter	1	1	1	2	1	1	1	1	1
Free growth parameters	6	4	4	4	4	4	4	6	6
Initial abundance (1975 or 1985)	1	1	1	1	1	1	1	1	1
Recruitment-distribution parameters	2	2	2	2	2	2	2	2	2
Mean recruitment parameters	1	1	1	1	1	1	1	1	1
Male recruitment deviations	46	36	36	36	36	36	36	46	46
Female recruitment deviations	46	36	36	36	36	36	36	46	46
Natural mortality parameters	2	1	2	2	2	1	2	2	3
Mean & offset fishing mortality parameters	6	6	6	6	6	6	6	6	6
Pot male fishing mortality deviations	46	36	36	36	36	36	36	46	46
Bycatch mortality from Tanner crab fishery	50	30	30	30	30	30	30	50	50
Pot female bycatch fishing mortality devia.	31	31	31	31	31	31	31	31	31
Trawl bycatch fishing mortality deviations	45	36	36	36	36	36	36	45	45
Fixed gear bycatch fishing mortality devia.	25	25	25	25	25	25	25	25	25
Initial (1975 or 1985) length compositions	35	35	35	35	35	35	35	35	35
Survey extra CV	1	1	1	1	0	0	0	0	0
Free selectivity parameters	22	20	20	20	18	18	18	20	20
Total number of free parameters	366	302	303	304	300	299	300	363	364
Total number of fixed and free parameters	380	316	316	316	312	312	313	376	377

Table 5b. Negative log likelihood components and their differences for Models 21.1, 21.1a, and 21.1b, and some management quantities. Highlighted cells in yellow color show prior density values and total negative likelihood values without prior density. Biomass is in metric ton, and abundance is in millions of crab.

	Models			Differences		
	21.1	21.1a	21.1b	21.1a-21.1	21.1b-21.1a	21.1b-21.1
Pot-ret-catch	-59.74	-59.66	-59.84	0.09	-0.19	-0.10
Pot-totM-catch	27.61	26.81	26.63	-0.80	-0.18	-0.98
Pot-F-discC	-53.95	-53.96	-53.95	0.00	0.00	0.00
Trawl-discC	-62.36	-62.36	-62.36	0.00	0.00	0.00
Tanner-M-discC	-43.54	-43.54	-43.54	0.00	0.00	0.00
Tanner-F-discC	-43.48	-43.48	-43.48	0.00	0.00	0.00
Fixed-discC	-34.65	-34.65	-34.65	0.00	0.00	0.00
Trawl-suv-bio	-34.10	-34.38	-34.32	-0.27	0.06	-0.21
BSFRF-sur-bio	-3.40	-3.53	-3.54	-0.13	-0.01	-0.14
Pot-ret-comp	-3872.23	-3873.72	-3873.93	-1.49	-0.21	-1.70
Pot-totM-comp	-2302.59	-2298.49	-2298.66	4.10	-0.17	3.93
Pot-discF-comp	-1394.84	-1394.61	-1394.66	0.23	-0.05	0.18
Trawl-disc-comp	-5714.29	-5712.94	-5706.80	1.35	6.14	7.49
TC-disc-comp	-1275.74	-1274.18	-1274.23	1.56	-0.05	1.51
Fixed-disc-comp	-3290.39	-3290.66	-3287.71	-0.27	2.95	2.68
Trawl-sur-comp	-6847.63	-6844.89	-6844.76	2.74	0.13	2.87
BSFRF-sur-comp	-844.38	-843.76	-843.68	0.63	0.07	0.70
Recruit-dev	69.20	69.86	69.84	0.66	-0.02	0.64
Recruit-sex-R	75.35	75.39	75.40	0.04	0.00	0.05
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	43.88	43.91	43.93	0.03	0.02	0.05
Sex-specific-R	0.01	0.01	0.01	0.00	0.00	0.00
Ini-size-struct.	30.60	30.80	30.82	0.20	0.02	0.22
PriorDensity	267.59	266.66	266.97	-0.92	0.31	-0.62
Tot-likelihood	-25363.1	-25355.4	-25346.5	7.75	8.85	16.60
Tot-likeli-no-PD	-25630.7	-25622.0	-25613.5	8.67	8.54	17.21
Tot-parameter	366	366	366	0.00	0.00	0.00
$MMB_{35\%}$	24236.51	24297.66	24324.64	61.14	26.99	88.13
MMB-terminal	14946.66	15018.38	15117.77	71.72	99.38	171.11
$F_{35\%}$	0.293	0.299	0.298	0.01	0.00	0.01
F_{ofl}	0.168	0.172	0.173	0.00	0.00	0.00
OFL	2225.06	2266.20	2297.52	41.14	31.32	72.46
ABC	1780.05	1812.96	1838.02	32.91	25.05	57.97
NMFS Q	0.965	0.961	0.961	0.00	0.00	0.00
Mature females	10.261	10.288	10.294	0.03	0.01	0.03

Table 5c. Negative log likelihood components and their differences for Models 21.1b, 22.1, and 22.1a, and some management quantities. Highlighted cells in yellow color show prior density values and total negative likelihood values without prior density. Biomass is in metric ton, and abundance is in millions of crab.

	Models			Differences		
	21.1b	22.1	22.1a	22.1-21.1b	22.1a-22.1	22.1a-21.1b
Pot-ret-catch	-59.84	-61.90	-62.09	-2.05	-0.20	-2.25
Pot-totM-catch	26.63	24.17	24.07	-2.46	-0.10	-2.56
Pot-F-discC	-53.95	-53.95	-53.93	0.00	0.02	0.02
Trawl-discC	-62.36	-62.36	-62.36	0.00	0.00	0.00
Tanner-M-discC	-43.54	-43.54	-43.54	0.00	0.00	0.00
Tanner-F-discC	-43.48	-43.48	-43.45	0.00	0.03	0.03
Fixed-discC	-34.65	-34.65	-34.65	0.00	0.00	0.00
Trawl-suv-bio	-34.32	-33.64	-48.21	0.68	-14.58	-13.90
BSFRF-sur-bio	-3.54					
Pot-ret-comp	-3873.93	-3875.36	-3877.21	-1.43	-1.85	-3.28
Pot-totM-comp	-2298.66	-2300.81	-2300.99	-2.15	-0.18	-2.33
Pot-discF-comp	-1394.66	-1394.31	-1393.92	0.35	0.39	0.74
Trawl-disc-comp	-5706.80	-5705.89	-5713.14	0.91	-7.25	-6.34
TC-disc-comp	-1274.23	-1274.42	-1274.93	-0.20	-0.51	-0.71
Fixed-disc-comp	-3287.71	-3292.38	-3291.66	-4.67	0.72	-3.95
Trawl-sur-comp	-6844.76	-6843.20	-6829.87	1.55	13.34	14.89
BSFRF-sur-comp	-843.68					
Recruit-dev	69.84	68.91	68.84	-0.93	-0.08	-1.01
Recruit-sex-R	75.40	75.47	75.54	0.07	0.07	0.14
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	43.93	43.74	46.08	-0.18	2.34	2.16
Sex-specific-R	0.01	0.02	0.00	0.01	-0.02	-0.01
Ini-size-struct.	30.82	29.67	29.74	-1.15	0.07	-1.08
PriorDensity	266.97	256.27	246.28	-10.70	-9.99	-20.69
Tot-likelihood	-25346.5	-24521.6	-24539.4	824.88	-17.78	807.10
Tot-likeli-no-PD	-25613.5	-24777.9	-24785.7	835.58	-7.79	827.79
Tot-parameter	366	363	364	-3.00	1.00	-2.00
MMB$_{35\%}$	24324.64	22377.43	23565.61	-1947.22	1188.18	-759.03
MMB-terminal	15117.77	14690.78	11756.88	-426.99	-2933.90	-3360.88
F$_{35\%}$	0.298	0.298	0.297	0.00	0.00	0.00
F$_{ofl}$	0.173	0.184	0.132	0.01	-0.05	-0.04
OFL	2297.52	2356.41	1362.84	58.89	-993.57	-934.68
ABC	1838.02	1885.13	1090.27	47.11	-794.85	-747.74
NMFS Q	0.961	0.964	0.960	0.00	0.00	0.00
Mature females	10.294	10.470	7.998	0.18	-2.47	-2.30
Mohn's rho, 12yr	0.347	0.285	0.135	-0.06	-0.15	-0.21
Mohn's rho, 10yr	0.308	0.246	0.090	-0.06	-0.16	-0.22

Table 5d. Negative log likelihood components for Models 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e, and some management quantities. Highlighted cells in yellow color show prior density values and total negative likelihood values without prior density. Biomass is in metric ton, and abundance is in millions of crab.

	Models					
	22.0	22.0a	22.0b	22.0c	22.0d	22.0e
Pot-ret-catch	-33.77	-35.02	-35.31	-36.83	-35.84	-36.51
Pot-totM-catch	26.95	25.21	24.79	23.17	24.32	23.76
Pot-F-discC	-53.96	-53.97	-53.97	-53.97	-53.96	-53.93
Trawl-discC	-49.89	-49.89	-49.89	-49.89	-49.89	-49.89
Tanner-M-discC	-26.12	-26.12	-26.12	-26.12	-26.12	-26.12
Tanner-F-discC	-26.08	-26.10	-26.09	-26.09	-26.07	-26.04
Fixed-discC	-34.65	-34.65	-34.65	-34.65	-34.65	-34.65
Trawl-suv-bio	-42.78	-45.92	-45.78	-45.60	-42.47	-58.52
BSFRF-sur-bio	-4.08	-5.06	-8.90			
Pot-ret-comp	-3077.50	-3076.20	-3076.53	-3076.72	-3074.10	-3074.42
Pot-totM-comp	-2299.43	-2300.56	-2301.01	-2302.70	-2301.75	-2301.75
Pot-discF-comp	-1394.68	-1395.23	-1395.21	-1394.83	-1394.31	-1394.13
Trawl-disc-comp	-4551.54	-4555.20	-4554.71	-4550.92	-4546.89	-4555.69
TC-disc-comp	-1273.30	-1276.01	-1276.21	-1276.15	-1273.33	-1273.81
Fixed-disc-comp	-3288.92	-3287.56	-3287.55	-3292.33	-3293.60	-3293.17
Trawl-sur-comp	-5364.11	-5373.73	-5373.89	-5371.44	-5361.80	-5350.07
BSFRF-sur-comp	-842.44	-844.72	-844.81			
Recruit-dev	40.97	41.44	41.52	40.88	40.61	40.32
Recruit-sex-R	58.98	58.98	58.97	59.03	59.03	59.08
M-deviation	0.00	0.00	0.00	0.00	0.00	2.43
Sex-specific-R	0.16	0.19	0.18	0.25	0.20	0.24
Ini-size-struct.	53.90	55.68	55.73	55.70	51.14	51.28
PriorDensity	233.10	221.11	223.61	209.61	221.55	209.45
Tot-likelihood	-21949.2	-21983.3	-21985.8	-21149.6	-21117.9	-21142.2
Tot-likeli-no-PD	-22182.3	-22204.4	-22209.5	-21359.2	-21339.5	-21351.6
Tot-parameter	302	303	304	300	299	300
$MMB_{35\%}$	22140.56	19757.11	19477.53	19801.19	22071.25	23629.49
MMB-terminal	15507.25	14231.05	13760.88	13910.34	14904.71	11491.02
$F_{35\%}$	0.299	0.390	0.386	0.384	0.299	0.298
F_{ofl}	0.200	0.269	0.260	0.257	0.191	0.128
OFL	2718.29	3278.66	3068.35	3038.05	2475.48	1293.32
ABC	2174.63	2622.93	2454.68	2430.44	1980.38	1034.65
NMFS Q	0.931	0.918	0.931	0.925	0.939	0.934
BSFRF Q	1.000	1.000	1.359			
Mature females	11.210	11.560	11.160	11.543	11.256	8.328
Mohn's rho, 12yr	0.376			0.235	0.329	0.135
Mohn's rho, 10yr	0.343			0.199	0.287	0.086

Table 5e. Differences of negative log likelihood components and some management quantities among models 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e.

	Model Differences				
	22.0a-22.0	22.0b-22.0a	22.0c-22.0a	22.0d-22.0c	22.0e-22.0d
Pot-ret-catch	-1.25	-0.29	-1.81	0.99	-0.67
Pot-totM-catch	-1.74	-0.42	-2.03	1.15	-0.56
Pot-F-discC	-0.01	0.00	0.00	0.01	0.02
Trawl-discC	0.00	0.00	0.00	0.00	0.00
Tanner-M-discC	0.00	0.00	0.00	0.00	0.00
Tanner-F-discC	-0.02	0.00	0.00	0.02	0.03
Fixed-discC	0.00	0.00	0.00	0.00	0.00
Trawl-suv-bio	-3.14	0.14	0.33	3.13	-16.05
BSFRF-sur-bio	-0.99	-3.83			
Pot-ret-comp	1.30	-0.33	-0.52	2.62	-0.32
Pot-totM-comp	-1.13	-0.45	-2.14	0.95	0.01
Pot-discF-comp	-0.55	0.01	0.39	0.52	0.18
Trawl-disc-comp	-3.65	0.48	4.28	4.03	-8.80
Tanner-disc-comp	-2.71	-0.20	-0.14	2.82	-0.48
Fixed-disc-comp	1.36	0.01	-4.77	-1.27	0.43
Trawl-sur-comp	-9.61	-0.16	2.28	9.64	11.74
BSFRF-sur-comp	-2.28	-0.09			
Recruit-dev	0.47	0.08	-0.56	-0.27	-0.29
Recruit-sex-R	0.00	-0.01	0.05	0.00	0.04
M-deviation	0.00	0.00	0.00	0.00	2.43
Sex-specific-R	0.03	-0.01	0.06	-0.05	0.04
Ini-size-structure	1.79	0.05	0.02	-4.56	0.14
PriorDensity	-11.99	2.50	-11.49	11.94	-12.10
Tot-likelihood	-34.12	-2.52	833.71	31.67	-24.22
Tot-like-no-PD	-22.13	-5.02	845.21	19.73	-12.12
Tot-parameter	1.00	1.00	-3.00	-1.00	1.00
$MMB_{35\%}$	-2383.45	-279.58	44.08	2270.06	1558.24
MMB-terminal	-1276.20	-470.17	-320.71	994.38	-3413.70
$F_{35\%}$	0.09	0.00	-0.01	-0.08	0.00
F_{ofl}	0.07	-0.01	-0.01	-0.07	-0.06
OFL	560.37	-210.31	-240.61	-562.57	-1182.16
ABC	448.30	-168.25	-192.49	-450.05	-945.73
NMFS Q	-0.01	0.01	0.01	0.01	-0.01
Mature females	0.35	-0.40	-0.02	-0.29	-2.93
Mohn's rho, 12yr				0.09	-0.19
Mohn's rho, 10yr				0.09	-0.20

Table 6a. Summary of estimated model parameter values and standard deviations for model 21.1b for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2811	0.0140	47	log_slx_pars[1]	4.7607	0.0084
2	theta[4]	19.8270	0.0495	48	log_slx_pars[2]	2.2786	0.0464
3	theta[5]	16.2290	0.1402	49	log_slx_pars[3]	4.5075	0.0170
4	theta[7]	0.6789	0.1336	50	log_slx_pars[4]	2.0359	0.1151
5	theta[9]	-0.4896	0.2380	51	log_slx_pars[5]	5.1509	0.0557
6	theta[13]	0.9639	0.4271	52	log_slx_pars[6]	2.8497	0.0452
7	theta[14]	0.6561	0.4741	53	log_slx_pars[7]	4.7253	0.2162
8	theta[15]	0.8604	0.3355	54	log_slx_pars[8]	2.1631	0.3060
9	theta[16]	0.7065	0.3073	55	log_slx_pars[9]	4.7430	0.0782
10	theta[17]	0.5407	0.2968	56	log_slx_pars[10]	0.9000	0.3035
11	theta[18]	0.4977	0.2783	57	log_slx_pars[11]	4.7955	0.0240
12	theta[19]	0.3382	0.2784	58	log_slx_pars[12]	2.3508	0.0883
13	theta[20]	0.3731	0.2647	59	log_slx_pars[13]	4.1260	0.1574
14	theta[21]	0.4056	0.2589	60	log_slx_pars[14]	2.2314	0.3554
15	theta[22]	0.1792	0.2816	61	log_slx_pars[15]	3.7290	0.6695
16	theta[23]	0.1587	0.2774	62	log_slx_pars[16]	3.3257	0.4253
17	theta[24]	0.0539	0.2872	63	log_slx_pars[17]	4.4289	0.0294
18	theta[25]	0.1694	0.2626	64	log_slx_pars[18]	2.4467	0.0711
19	theta[26]	-0.0085	0.2037	65	log_slx_pars[19]	4.9232	0.0015
20	theta[27]	-0.2384	0.1958	66	log_slx_pars[20]	0.6743	0.0534
21	theta[28]	-0.3914	0.1978	67	log_slx_pars[21]	4.9313	0.0020
22	theta[29]	-0.7395	0.2114	68	log_slx_pars[22]	0.6991	0.1016
23	theta[30]	-1.1998	0.2325	69	log_fbar[1]	-1.4830	0.0430
24	theta[31]	-1.2458	0.2349	70	log_fbar[2]	-4.2899	0.0762
25	theta[52]	1.2133	0.7471	71	log_fbar[3]	-5.6073	0.2919
26	theta[53]	1.4707	0.4684	72	log_fbar[4]	-6.5544	0.0765
27	theta[54]	1.4105	0.3686	73	log_fdev[1]	0.7253	0.1189
28	theta[55]	1.1791	0.3362	74	log_fdev[1]	0.6839	0.0907
29	theta[56]	1.0908	0.2942	75	log_fdev[1]	0.5958	0.0743
30	theta[57]	0.6070	0.3173	76	log_fdev[1]	0.6892	0.0604
31	theta[58]	0.2212	0.3507	77	log_fdev[1]	0.8999	0.0543
32	theta[59]	-0.0171	0.3590	78	log_fdev[1]	1.7665	0.0566
33	theta[60]	-0.2063	0.3518	79	log_fdev[1]	2.3010	0.1190
34	theta[61]	-0.5414	0.3717	80	log_fdev[1]	0.7253	0.1774
35	theta[62]	-0.9286	0.3838	81	log_fdev[1]	-8.9868	0.1271
36	theta[63]	-1.1886	0.3889	82	log_fdev[1]	1.0550	0.1138
37	theta[64]	-1.4184	0.3876	83	log_fdev[1]	1.1263	0.0893
38	theta[65]	-1.7915	0.3761	84	log_fdev[1]	1.2986	0.0735
39	theta[66]	-1.8965	0.3723	85	log_fdev[1]	0.8328	0.0645
40	theta[67]	-1.8374	0.3519	86	log_fdev[1]	-0.1065	0.0532
41	Grwth[21]	0.9957	0.1910	87	log_fdev[1]	0.0081	0.0476
42	Grwth[42]	1.4085	0.1211	88	log_fdev[1]	0.6559	0.0391
43	Grwth[85]	142.380	1.7327	89	log_fdev[1]	0.6687	0.0417
44	Grwth[86]	0.0584	0.0103	90	log_fdev[1]	0.1531	0.0464
45	Grwth[87]	139.840	0.6021	91	log_fdev[1]	0.8207	0.0510
46	Grwth[88]	0.0713	0.0034	92	log_fdev[1]	-4.3317	0.0489

93	log_fdev[1]	-4.7416	0.0423
94	log_fdev[1]	-0.2706	0.0410
95	log_fdev[1]	-0.2218	0.0414
96	log_fdev[1]	0.6939	0.0438
97	log_fdev[1]	0.3368	0.0428
98	log_fdev[1]	-0.2497	0.0413
99	log_fdev[1]	-0.3290	0.0409
100	log_fdev[1]	-0.2175	0.0398
101	log_fdev[1]	0.2462	0.0385
102	log_fdev[1]	0.2035	0.0386
103	log_fdev[1]	0.4912	0.0390
104	log_fdev[1]	0.2423	0.0384
105	log_fdev[1]	0.6064	0.0383
106	log_fdev[1]	0.7745	0.0401
107	log_fdev[1]	0.5855	0.0409
108	log_fdev[1]	0.4509	0.0404
109	log_fdev[1]	-0.1880	0.0394
110	log_fdev[1]	-0.2661	0.0387
111	log_fdev[1]	-0.0826	0.0390
112	log_fdev[1]	0.2400	0.0404
113	log_fdev[1]	0.3019	0.0442
114	log_fdev[1]	0.2870	0.0513
115	log_fdev[1]	0.1801	0.0613
116	log_fdev[1]	-0.0266	0.0717
117	log_fdev[1]	-0.0978	0.0797
118	log_fdev[1]	-0.5300	0.0828
119	log_fdev[2]	0.1743	0.1248
120	log_fdev[2]	0.6134	0.1165
121	log_fdev[2]	0.5923	0.1107
122	log_fdev[2]	0.6674	0.1091
123	log_fdev[2]	1.3817	0.1117
124	log_fdev[2]	1.1506	0.1308
125	log_fdev[2]	2.4354	0.1317
126	log_fdev[2]	2.1586	0.1191
127	log_fdev[2]	3.3809	0.1163
128	log_fdev[2]	2.1748	0.1113
129	log_fdev[2]	1.1121	0.1112
130	log_fdev[2]	0.6586	0.1088
131	log_fdev[2]	1.4349	0.1045
132	log_fdev[2]	0.0045	0.1036
133	log_fdev[2]	0.4580	0.1036
134	log_fdev[2]	0.8814	0.1048
135	log_fdev[2]	0.7176	0.1050
136	log_fdev[2]	1.1932	0.1078
137	log_fdev[2]	-0.5748	0.1048
138	log_fdev[2]	-0.8614	0.1034
139	log_fdev[2]	-0.7931	0.1036
140	log_fdev[2]	-1.2583	0.1035
141	log_fdev[2]	0.0392	0.1038
142	log_fdev[2]	-0.2412	0.1035
143	log_fdev[2]	-1.0006	0.1030
144	log_fdev[2]	-0.2306	0.1029
145	log_fdev[2]	-0.5300	0.1026
146	log_fdev[2]	-0.6242	0.1024
147	log_fdev[2]	-0.3919	0.1023
148	log_fdev[2]	-0.6689	0.1022
149	log_fdev[2]	-0.5010	0.1019
150	log_fdev[2]	-0.4257	0.1020
151	log_fdev[2]	-0.4563	0.1022
152	log_fdev[2]	-0.8173	0.1024
153	log_fdev[2]	-0.9690	0.1024
154	log_fdev[2]	-1.4335	0.1022
155	log_fdev[2]	-1.9560	0.1024
156	log_fdev[2]	-1.2445	0.1028
157	log_fdev[2]	-1.8144	0.1033
158	log_fdev[2]	-1.4386	0.1046
159	log_fdev[2]	-0.9227	0.1067
160	log_fdev[2]	-0.4996	0.1097
161	log_fdev[2]	-0.5735	0.1128
162	log_fdev[2]	-0.4866	0.1161
163	log_fdev[2]	-0.5152	0.1184
164	log_fdev[3]	-0.1164	0.0682
165	log_fdev[3]	0.6699	0.0682
166	log_fdev[3]	1.2283	0.0682
167	log_fdev[3]	1.0927	0.0682
168	log_fdev[3]	1.3825	0.0682
169	log_fdev[3]	1.4243	0.0682
170	log_fdev[3]	0.9927	0.0682
171	log_fdev[3]	0.4765	0.0682
172	log_fdev[3]	-0.9874	0.0682
173	log_fdev[3]	-0.5788	0.0682
174	log_fdev[3]	-1.0994	0.0682
175	log_fdev[3]	-0.2563	0.0682
176	log_fdev[3]	0.9401	0.0682
177	log_fdev[3]	1.4182	0.0682
178	log_fdev[3]	3.2534	0.0764
179	log_fdev[3]	1.3000	0.0942
180	log_fdev[3]	0.5966	0.1212
181	log_fdev[3]	-0.7444	0.0817
182	log_fdev[3]	-2.1280	0.0737
183	log_fdev[3]	-2.9820	0.0922
184	log_fdev[3]	-2.4072	0.1130
185	log_fdev[3]	-3.4945	0.0761
186	log_fdev[3]	-0.8613	0.0938
187	log_fdev[3]	-0.1450	0.1111
188	log_fdev[3]	1.0257	0.1335
189	log_fdev[4]	0.6095	0.1031
190	log_fdev[4]	-0.0493	0.1020
191	log_fdev[4]	-0.2620	0.1025
192	log_fdev[4]	0.6569	0.1017

193	log_fdev[4]	-1.7728	0.1012	243	log_fdov[1]	-0.2255	0.0855
194	log_fdev[4]	0.1824	0.1008	244	log_fdov[1]	1.1200	0.0905
195	log_fdev[4]	-0.0755	0.1005	245	log_fdov[1]	0.0632	0.0944
196	log_fdev[4]	-0.9098	0.1004	246	log_fdov[1]	-0.4482	0.0962
197	log_fdev[4]	-0.7356	0.1001	247	log_fdov[3]	0.0000	0.0962
198	log_fdev[4]	-0.4619	0.1000	248	log_fdov[3]	0.0001	0.0962
199	log_fdev[4]	-0.5101	0.0997	249	log_fdov[3]	0.0003	0.0963
200	log_fdev[4]	0.0359	0.0997	250	log_fdov[3]	0.0002	0.0963
201	log_fdev[4]	-0.6651	0.1000	251	log_fdov[3]	0.0004	0.0963
202	log_fdev[4]	-1.6654	0.0998	252	log_fdov[3]	0.0000	0.0963
203	log_fdev[4]	-2.5043	0.0994	253	log_fdov[3]	-0.0001	0.0963
204	log_fdev[4]	-1.0274	0.0991	254	log_fdov[3]	-0.0002	0.0962
205	log_fdev[4]	-0.4747	0.0992	255	log_fdov[3]	-0.0002	0.0962
206	log_fdev[4]	0.6624	0.0992	256	log_fdov[3]	-0.0001	0.0962
207	log_fdev[4]	1.5089	0.0996	257	log_fdov[3]	-0.0001	0.0962
208	log_fdev[4]	1.1861	0.1003	258	log_fdov[3]	0.0001	0.0962
209	log_fdev[4]	0.3484	0.1015	259	log_fdov[3]	0.0003	0.0962
210	log_fdev[4]	1.9437	0.1034	260	log_fdov[3]	0.0008	0.0963
211	log_fdev[4]	2.1962	0.1051	261	log_fdov[3]	1.5382	0.1640
212	log_fdev[4]	0.9917	0.1071	262	log_fdov[3]	1.7969	0.1187
213	log_fdev[4]	0.7917	0.1095	263	log_fdov[3]	0.5670	0.1425
214	log_foff[1]	-2.8743	0.0401	264	log_fdov[3]	-3.4432	0.1081
215	log_foff[3]	-0.1159	0.4150	265	log_fdov[3]	-2.1448	0.1468
216	log_fdov[1]	2.0545	0.0834	266	log_fdov[3]	-0.7853	0.1247
217	log_fdov[1]	-0.6156	0.0825	267	log_fdov[3]	0.0360	0.1328
218	log_fdov[1]	2.0585	0.0838	268	log_fdov[3]	0.3850	0.1030
219	log_fdov[1]	1.8935	0.0855	269	log_fdov[3]	0.9542	0.1644
220	log_fdov[1]	-0.3387	0.0843	270	log_fdov[3]	0.1789	0.1496
221	log_fdov[1]	-0.1103	0.0821	271	log_fdov[3]	0.9156	0.1664
222	log_fdov[1]	-3.6109	0.0811	272	rec_dev_est	1.0884	0.2634
223	log_fdov[1]	-0.2418	0.0818	273	rec_dev_est	0.6112	0.2952
224	log_fdov[1]	1.5411	0.0820	274	rec_dev_est	1.0884	0.2394
225	log_fdov[1]	-2.6914	0.0812	275	rec_dev_est	1.6601	0.2078
226	log_fdov[1]	1.2368	0.0804	276	rec_dev_est	1.9374	0.2168
227	log_fdov[1]	0.9617	0.0803	277	rec_dev_est	1.1477	0.2581
228	log_fdov[1]	-1.7868	0.0798	278	rec_dev_est	2.3924	0.1667
229	log_fdov[1]	1.2975	0.0799	279	rec_dev_est	1.4416	0.1797
230	log_fdov[1]	0.5047	0.0800	280	rec_dev_est	1.0601	0.1675
231	log_fdov[1]	1.0382	0.0794	281	rec_dev_est	-0.7611	0.2449
232	log_fdov[1]	-1.1449	0.0790	282	rec_dev_est	0.2996	0.1642
233	log_fdov[1]	-0.1052	0.0789	283	rec_dev_est	-0.8367	0.2384
234	log_fdov[1]	-0.3677	0.0793	284	rec_dev_est	-1.2746	0.2699
235	log_fdov[1]	-0.6294	0.0795	285	rec_dev_est	-1.0082	0.2199
236	log_fdov[1]	-0.1459	0.0793	286	rec_dev_est	-0.0684	0.1651
237	log_fdov[1]	-1.0409	0.0784	287	rec_dev_est	-0.5291	0.1843
238	log_fdov[1]	-1.7564	0.0780	288	rec_dev_est	-1.9615	0.3478
239	log_fdov[1]	0.2690	0.0780	289	rec_dev_est	-0.8967	0.1970
240	log_fdov[1]	-0.1294	0.0783	290	rec_dev_est	-1.9691	0.3904
241	log_fdov[1]	0.9402	0.0793	291	rec_dev_est	0.9771	0.1483
242	log_fdov[1]	0.4068	0.0816	292	rec_dev_est	-0.9236	0.2576

293	rec_dev_est	-1.5929	0.3288	339	logit_rec_prop_es	0.2969	0.5888
294	rec_dev_est	-0.5724	0.1970	340	logit_rec_prop_es	0.4651	0.3086
295	rec_dev_est	0.4131	0.1566	341	logit_rec_prop_es	-0.0439	0.1396
296	rec_dev_est	-0.5640	0.2217	342	logit_rec_prop_es	0.1486	0.3471
297	rec_dev_est	-0.5352	0.2366	343	logit_rec_prop_es	-0.6079	0.3767
298	rec_dev_est	0.8456	0.1553	344	logit_rec_prop_es	-0.4755	0.1241
299	rec_dev_est	-0.6212	0.2595	345	logit_rec_prop_es	-0.4976	0.4213
300	rec_dev_est	-0.6713	0.2555	346	logit_rec_prop_es	-0.0756	0.4158
301	rec_dev_est	0.5849	0.1574	347	logit_rec_prop_es	-0.3867	0.1378
302	rec_dev_est	-0.1383	0.1816	348	logit_rec_prop_es	-0.1191	0.2313
303	rec_dev_est	-0.5287	0.1884	349	logit_rec_prop_es	0.3375	0.2702
304	rec_dev_est	-1.1058	0.2335	350	logit_rec_prop_es	-0.2306	0.3632
305	rec_dev_est	-0.9620	0.2312	351	logit_rec_prop_es	-0.4782	0.3512
306	rec_dev_est	0.0100	0.1764	352	logit_rec_prop_es	-0.7918	0.1898
307	rec_dev_est	-0.5357	0.2216	353	logit_rec_prop_es	-0.4487	0.3063
308	rec_dev_est	-1.0732	0.2279	354	logit_rec_prop_es	-0.5284	0.3395
309	rec_dev_est	-1.3903	0.2199	355	logit_rec_prop_es	-0.1759	0.3260
310	rec_dev_est	-1.8549	0.2607	356	logit_rec_prop_es	-0.2849	0.4171
311	rec_dev_est	-1.4171	0.2206	357	logit_rec_prop_es	-0.2633	0.3210
312	rec_dev_est	-0.7272	0.1772	358	logit_rec_prop_es	0.4493	0.2240
313	rec_dev_est	-1.6197	0.2554	359	logit_rec_prop_es	0.5061	0.4553
314	rec_dev_est	-0.9717	0.2078	360	logit_rec_prop_es	0.5148	0.3026
315	rec_dev_est	-1.8293	0.3539	361	logit_rec_prop_es	0.6671	0.6287
316	rec_dev_est	-1.7537	0.3899	362	logit_rec_prop_es	1.3049	0.7094
317	rec_dev_est	-1.0465	0.3458	363	logit_rec_prop_es	0.1879	0.5656
318	logit_rec_prop_es	-0.1694	0.4111	364	m_dev_est[1]	1.5981	0.0297
319	logit_rec_prop_es	-0.9341	0.5493	365	survey_q[1]	0.9609	0.0253
320	logit_rec_prop_es	-0.2605	0.3528	366	log_add_cv[2]	-0.8388	0.2772
321	logit_rec_prop_es	-0.4550	0.2689				
322	logit_rec_prop_es	0.0575	0.2518				
323	logit_rec_prop_es	0.2094	0.3278				
324	logit_rec_prop_es	0.3425	0.1406				
325	logit_rec_prop_es	0.3695	0.2245				
326	logit_rec_prop_es	-0.0802	0.1746				
327	logit_rec_prop_es	0.3465	0.4248				
328	logit_rec_prop_es	-0.4702	0.1659				
329	logit_rec_prop_es	0.1462	0.3922				
330	logit_rec_prop_es	-0.1448	0.4415				
331	logit_rec_prop_es	0.3852	0.3663				
332	logit_rec_prop_es	-0.0789	0.1665				
333	logit_rec_prop_es	0.1738	0.2394				
334	logit_rec_prop_es	0.4915	0.6418				
335	logit_rec_prop_es	0.2454	0.2807				
336	logit_rec_prop_es	-0.5075	0.6372				
337	logit_rec_prop_es	-0.2777	0.0875				
338	logit_rec_prop_es	1.1408	0.5639				

Table 6b. Summary of estimated model parameter values and standard deviations for model 22.0 for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2521	0.0162	47	log_slx_pars[3]	4.5019	0.0169

2	theta[4]	17.855	0.0409	48	log_slx_pars[4]	2.0121	0.1181
3	theta[5]	15.819	0.1591	49	log_slx_pars[5]	5.2062	0.0921
4	theta[7]	0.6568	0.1302	50	log_slx_pars[6]	2.9313	0.0541
5	theta[9]	-0.4747	0.2592	51	log_slx_pars[7]	4.7369	0.2189
6	theta[13]	0.7428	0.5012	52	log_slx_pars[8]	2.1640	0.3060
7	theta[14]	0.7803	0.4746	53	log_slx_pars[9]	4.7130	0.0914
8	theta[15]	1.1291	0.3522	54	log_slx_pars[10]	0.9032	0.3023
9	theta[16]	1.3235	0.2855	55	log_slx_pars[11]	4.7918	0.0240
10	theta[17]	1.2554	0.2663	56	log_slx_pars[12]	2.3488	0.0899
11	theta[18]	0.9873	0.2738	57	log_slx_pars[13]	3.8934	0.4506
12	theta[19]	0.9447	0.2605	58	log_slx_pars[14]	2.9907	0.4151
13	theta[20]	1.2034	0.2223	59	log_slx_pars[15]	4.4383	0.0330
14	theta[21]	1.1941	0.2164	60	log_slx_pars[16]	2.4402	0.0891
15	theta[22]	1.0117	0.2231	61	log_slx_pars[17]	4.9239	0.0017
16	theta[23]	0.9573	0.2156	62	log_slx_pars[18]	0.6728	0.0706
17	theta[24]	0.8154	0.2190	63	log_slx_pars[19]	4.9314	0.0020
18	theta[25]	0.4846	0.2239	64	log_slx_pars[20]	0.7059	0.1017
19	theta[26]	0.0414	0.1948	65	log_fbar[1]	-1.5326	0.0483
20	theta[27]	-0.4311	0.1971	66	log_fbar[2]	-4.6860	0.0829
21	theta[28]	-1.0867	0.2203	67	log_fbar[3]	-5.9838	0.3103
22	theta[29]	-1.6673	0.2528	68	log_fbar[4]	-6.5940	0.0772
23	theta[30]	-2.3456	0.2765	69	log_fdev[1]	0.9229	0.1203
24	theta[31]	-2.0078	0.3622	70	log_fdev[1]	1.1407	0.0794
25	theta[52]	-0.1060	0.5950	71	log_fdev[1]	0.7472	0.0630
26	theta[53]	0.4041	0.6508	72	log_fdev[1]	-0.1057	0.0523
27	theta[54]	0.8799	0.5385	73	log_fdev[1]	0.0413	0.0467
28	theta[55]	1.0792	0.4258	74	log_fdev[1]	0.6973	0.0375
29	theta[56]	1.2268	0.3353	75	log_fdev[1]	0.7082	0.0391
30	theta[57]	1.0533	0.3130	76	log_fdev[1]	0.1923	0.0430
31	theta[58]	0.8346	0.3099	77	log_fdev[1]	0.8569	0.0470
32	theta[59]	0.3725	0.3464	78	log_fdev[1]	-4.2943	0.0450
33	theta[60]	-0.3650	0.3915	79	log_fdev[1]	-4.7037	0.0394
34	theta[61]	-0.8141	0.3847	80	log_fdev[1]	-0.2332	0.0384
35	theta[62]	-1.5193	0.3755	81	log_fdev[1]	-0.1862	0.0385
36	theta[63]	-1.6140	0.3725	82	log_fdev[1]	0.7297	0.0404
37	theta[64]	-1.5455	0.3723	83	log_fdev[1]	0.3692	0.0396
38	theta[65]	-1.7684	0.3632	84	log_fdev[1]	-0.2193	0.0383
39	theta[66]	-1.9074	0.3528	85	log_fdev[1]	-0.2972	0.0380
40	theta[67]	-1.8739	0.3434	86	log_fdev[1]	-0.1834	0.0372
41	Grwth[21]	0.9241	0.2010	87	log_fdev[1]	0.2806	0.0365
42	Grwth[42]	1.4334	0.1327	88	log_fdev[1]	0.2369	0.0367
43	Grwth[64]	139.64	0.6198	89	log_fdev[1]	0.5235	0.0367
44	Grwth[65]	0.0712	0.0034	90	log_fdev[1]	0.2749	0.0363
45	log_slx_pars[1]	4.7605	0.0086	91	log_fdev[1]	0.6377	0.0361
46	log_slx_pars[2]	2.2812	0.0469	92	log_fdev[1]	0.8041	0.0368
93	log_fdev[1]	0.6128	0.0372	143	log_fdev[3]	1.3122	0.0661
94	log_fdev[1]	0.4768	0.0367	144	log_fdev[3]	1.7903	0.0661
95	log_fdev[1]	-0.1629	0.0359	145	log_fdev[3]	3.6320	0.0778
96	log_fdev[1]	-0.2411	0.0355	146	log_fdev[3]	1.6828	0.0936
97	log_fdev[1]	-0.0576	0.0359	147	log_fdev[3]	0.9773	0.1287

98	log_fdev[1]	0.2629	0.0373	148	log_fdev[3]	-0.3690	0.0805
99	log_fdev[1]	0.3213	0.0413	149	log_fdev[3]	-1.7534	0.0744
100	log_fdev[1]	0.3022	0.0485	150	log_fdev[3]	-2.6047	0.0905
101	log_fdev[1]	0.1900	0.0584	151	log_fdev[3]	-2.0306	0.1178
102	log_fdev[1]	-0.0216	0.0685	152	log_fdev[3]	-3.1231	0.0781
103	log_fdev[1]	-0.0953	0.0764	153	log_fdev[3]	-0.4976	0.0963
104	log_fdev[1]	-0.5275	0.0799	154	log_fdev[3]	0.2147	0.1137
105	log_fdev[2]	2.3550	0.1142	155	log_fdev[3]	1.3801	0.1379
106	log_fdev[2]	1.3273	0.1124	156	log_fdev[4]	0.6286	0.1031
107	log_fdev[2]	0.9325	0.1088	157	log_fdev[4]	-0.0334	0.1021
108	log_fdev[2]	1.7673	0.1042	158	log_fdev[4]	-0.2518	0.1025
109	log_fdev[2]	0.3697	0.1032	159	log_fdev[4]	0.6656	0.1017
110	log_fdev[2]	0.8354	0.1029	160	log_fdev[4]	-1.7627	0.1012
111	log_fdev[2]	1.2594	0.1037	161	log_fdev[4]	0.1930	0.1009
112	log_fdev[2]	1.0956	0.1038	162	log_fdev[4]	-0.0646	0.1005
113	log_fdev[2]	1.5653	0.1063	163	log_fdev[4]	-0.8996	0.1004
114	log_fdev[2]	-0.1963	0.1036	164	log_fdev[4]	-0.7258	0.1002
115	log_fdev[2]	-0.4807	0.1024	165	log_fdev[4]	-0.4532	0.1000
116	log_fdev[2]	-0.4160	0.1026	166	log_fdev[4]	-0.5010	0.0997
117	log_fdev[2]	-0.8864	0.1025	167	log_fdev[4]	0.0430	0.0997
118	log_fdev[2]	0.4032	0.1027	168	log_fdev[4]	-0.6611	0.1000
119	log_fdev[2]	0.1233	0.1025	169	log_fdev[4]	-1.6627	0.0998
120	log_fdev[2]	-0.6334	0.1019	170	log_fdev[4]	-2.5033	0.0993
121	log_fdev[2]	0.1368	0.1019	171	log_fdev[4]	-1.0265	0.0991
122	log_fdev[2]	-0.1626	0.1017	172	log_fdev[4]	-0.4747	0.0992
123	log_fdev[2]	-0.2576	0.1015	173	log_fdev[4]	0.6601	0.0992
124	log_fdev[2]	-0.0264	0.1015	174	log_fdev[4]	1.5030	0.0996
125	log_fdev[2]	-0.3065	0.1014	175	log_fdev[4]	1.1757	0.1003
126	log_fdev[2]	-0.1374	0.1012	176	log_fdev[4]	0.3328	0.1016
127	log_fdev[2]	-0.0655	0.1012	177	log_fdev[4]	1.9228	0.1034
128	log_fdev[2]	-0.1007	0.1013	178	log_fdev[4]	2.1705	0.1052
129	log_fdev[2]	-0.4614	0.1014	179	log_fdev[4]	0.9627	0.1071
130	log_fdev[2]	-0.6120	0.1014	180	log_fdev[4]	0.7627	0.1094
131	log_fdev[2]	-1.0741	0.1012	181	log_foff[1]	-2.8799	0.0397
132	log_fdev[2]	-1.5967	0.1014	182	log_foff[3]	-0.2342	0.4241
133	log_fdev[2]	-0.8871	0.1018	183	log_fdov[1]	2.0866	0.0836
134	log_fdev[2]	-1.4605	0.1023	184	log_fdov[1]	-0.5881	0.0826
135	log_fdev[2]	-1.0888	0.1035	185	log_fdov[1]	2.0805	0.0839
136	log_fdev[2]	-0.5779	0.1055	186	log_fdov[1]	1.9140	0.0855
137	log_fdev[2]	-0.1608	0.1084	187	log_fdov[1]	-0.3261	0.0841
138	log_fdev[2]	-0.2404	0.1113	188	log_fdov[1]	-0.1039	0.0820
139	log_fdev[2]	-0.1574	0.1144	189	log_fdov[1]	-3.6084	0.0811
140	log_fdev[2]	-0.1843	0.1168	190	log_fdov[1]	-0.2373	0.0817
141	log_fdev[3]	-0.7271	0.0661	191	log_fdov[1]	1.5457	0.0820
142	log_fdev[3]	0.1160	0.0661	192	log_fdov[1]	-2.6867	0.0812
193	log_fdov[1]	1.2413	0.0803	243	rec_dev_est	-0.1562	0.2326
194	log_fdov[1]	0.9629	0.0803	244	rec_dev_est	-0.1206	0.2465
195	log_fdov[1]	-1.7888	0.0797	245	rec_dev_est	1.2292	0.1730
196	log_fdov[1]	1.2971	0.0799	246	rec_dev_est	-0.2085	0.2679
197	log_fdov[1]	0.5063	0.0799	247	rec_dev_est	-0.2603	0.2619

198	log_fdov[1]	1.0414	0.0794
199	log_fdov[1]	-1.1437	0.0789
200	log_fdov[1]	-0.1032	0.0789
201	log_fdov[1]	-0.3659	0.0793
202	log_fdov[1]	-0.6289	0.0795
203	log_fdov[1]	-0.1477	0.0792
204	log_fdov[1]	-1.0456	0.0783
205	log_fdov[1]	-1.7642	0.0779
206	log_fdov[1]	0.2578	0.0780
207	log_fdov[1]	-0.1423	0.0783
208	log_fdov[1]	0.9266	0.0794
209	log_fdov[1]	0.3915	0.0818
210	log_fdov[1]	-0.2413	0.0857
211	log_fdov[1]	1.1030	0.0906
212	log_fdov[1]	0.0420	0.0943
213	log_fdov[1]	-0.4759	0.0959
214	log_fdov[3]	-0.0001	0.0933
215	log_fdov[3]	0.0001	0.0933
216	log_fdov[3]	0.0004	0.0933
217	log_fdov[3]	0.0009	0.0933
218	log_fdov[3]	1.5409	0.1361
219	log_fdov[3]	1.8237	0.1176
220	log_fdov[3]	0.5923	0.1461
221	log_fdov[3]	-3.4291	0.1078
222	log_fdov[3]	-2.1942	0.1422
223	log_fdov[3]	-0.8116	0.1161
224	log_fdov[3]	0.0185	0.1372
225	log_fdov[3]	0.3730	0.1044
226	log_fdov[3]	0.9721	0.1455
227	log_fdov[3]	0.1846	0.1431
228	log_fdov[3]	0.9285	0.1741
229	rec_dev_est	0.7348	0.1773
230	rec_dev_est	-0.4572	0.2477
231	rec_dev_est	-0.8934	0.2802
232	rec_dev_est	-0.5736	0.2257
233	rec_dev_est	0.3257	0.1799
234	rec_dev_est	-0.1243	0.1976
235	rec_dev_est	-1.5712	0.3638
236	rec_dev_est	-0.4692	0.2091
237	rec_dev_est	-1.5168	0.3887
238	rec_dev_est	1.3741	0.1661
239	rec_dev_est	-0.5254	0.2650
240	rec_dev_est	-1.1749	0.3334
241	rec_dev_est	-0.1568	0.2084
242	rec_dev_est	0.8098	0.1733
293	logit_rec_prop_es	-0.3102	0.4167
294	logit_rec_prop_es	-0.2386	0.3186
295	logit_rec_prop_es	0.4404	0.2187
296	logit_rec_prop_es	0.4600	0.4394
297	logit_rec_prop_es	0.5103	0.3027
248	rec_dev_est	0.9811	0.1742
249	rec_dev_est	0.2608	0.1957
250	rec_dev_est	-0.0998	0.2015
251	rec_dev_est	-0.7019	0.2475
252	rec_dev_est	-0.5309	0.2411
253	rec_dev_est	0.4018	0.1944
254	rec_dev_est	-0.0926	0.2332
255	rec_dev_est	-0.6777	0.2435
256	rec_dev_est	-0.9533	0.2315
257	rec_dev_est	-1.4054	0.2686
258	rec_dev_est	-0.9835	0.2303
259	rec_dev_est	-0.2802	0.1907
260	rec_dev_est	-1.1661	0.2625
261	rec_dev_est	-0.5267	0.2211
262	rec_dev_est	-1.4024	0.3825
263	rec_dev_est	-1.3559	0.4364
264	rec_dev_est	-0.6228	0.3850
265	logit_rec_prop_es	-0.4368	0.1509
266	logit_rec_prop_es	0.1892	0.3938
267	logit_rec_prop_es	-0.1183	0.4454
268	logit_rec_prop_es	0.4130	0.3511
269	logit_rec_prop_es	-0.0445	0.1633
270	logit_rec_prop_es	0.2408	0.2397
271	logit_rec_prop_es	0.3239	0.6189
272	logit_rec_prop_es	0.3273	0.2808
273	logit_rec_prop_es	-0.7833	0.6518
274	logit_rec_prop_es	-0.2140	0.0892
275	logit_rec_prop_es	1.1290	0.5304
276	logit_rec_prop_es	0.2660	0.5687
277	logit_rec_prop_es	0.5060	0.3051
278	logit_rec_prop_es	-0.0096	0.1411
279	logit_rec_prop_es	0.1739	0.3475
280	logit_rec_prop_es	-0.5948	0.3802
281	logit_rec_prop_es	-0.4237	0.1277
282	logit_rec_prop_es	-0.5090	0.4263
283	logit_rec_prop_es	-0.0428	0.4098
284	logit_rec_prop_es	-0.3410	0.1385
285	logit_rec_prop_es	-0.1004	0.2330
286	logit_rec_prop_es	0.3568	0.2689
287	logit_rec_prop_es	-0.2387	0.3731
288	logit_rec_prop_es	-0.5022	0.3529
289	logit_rec_prop_es	-0.7302	0.1983
290	logit_rec_prop_es	-0.4934	0.3058
291	logit_rec_prop_es	-0.4811	0.3513
292	logit_rec_prop_es	-0.1851	0.3265

298	logit_rec_prop_es	0.4962	0.6309
299	logit_rec_prop_es	1.0554	0.7018
300	logit_rec_prop_es	-0.0907	0.6439
301	survey_q[1]	0.9327	0.0276
302	log_add_cv[2]	-0.8913	0.2810

Table 6c. Summary of estimated model parameter values and standard deviations for model 22.0d for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2500	0.0166	47	log_slx_pars[3]	4.5016	0.0173
2	theta[4]	17.844	0.0406	48	log_slx_pars[4]	2.0093	0.1207
3	theta[5]	15.814	0.1589	49	log_slx_pars[5]	5.2293	0.1066
4	theta[7]	0.6661	0.1398	50	log_slx_pars[6]	2.9354	0.0542
5	theta[9]	-0.4758	0.2712	51	log_slx_pars[7]	4.7386	0.2176
6	theta[13]	0.7596	0.4914	52	log_slx_pars[8]	2.1638	0.3062
7	theta[14]	0.7939	0.4709	53	log_slx_pars[9]	4.7104	0.0899
8	theta[15]	1.1366	0.3527	54	log_slx_pars[10]	0.9024	0.3024
9	theta[16]	1.3236	0.2879	55	log_slx_pars[11]	4.7970	0.0253
10	theta[17]	1.2612	0.2665	56	log_slx_pars[12]	2.3624	0.0910
11	theta[18]	0.9956	0.2725	57	log_slx_pars[13]	4.4839	0.0111
12	theta[19]	0.9483	0.2589	58	log_slx_pars[14]	2.4535	0.0597
13	theta[20]	1.1994	0.2213	59	log_slx_pars[15]	4.9240	0.0017
14	theta[21]	1.1871	0.2154	60	log_slx_pars[16]	0.6746	0.0707
15	theta[22]	1.0026	0.2222	61	log_slx_pars[17]	4.9316	0.0020
16	theta[23]	0.9492	0.2144	62	log_slx_pars[18]	0.7083	0.1015
17	theta[24]	0.8048	0.2178	63	log_fbar[1]	-1.5024	0.0475
18	theta[25]	0.4752	0.2231	64	log_fbar[2]	-4.6451	0.0827
19	theta[26]	0.0374	0.1941	65	log_fbar[3]	-5.9533	0.3100
20	theta[27]	-0.4340	0.1962	66	log_fbar[4]	-6.5673	0.0787
21	theta[28]	-1.0911	0.2197	67	log_fdev[1]	0.9133	0.1185
22	theta[29]	-1.6699	0.2521	68	log_fdev[1]	1.1354	0.0789
23	theta[30]	-2.3472	0.2760	69	log_fdev[1]	0.7412	0.0631
24	theta[31]	-2.0013	0.3580	70	log_fdev[1]	-0.1159	0.0523
25	theta[52]	-0.1218	0.5860	71	log_fdev[1]	0.0280	0.0464
26	theta[53]	0.4187	0.6458	72	log_fdev[1]	0.6837	0.0371
27	theta[54]	0.8917	0.5369	73	log_fdev[1]	0.6962	0.0388
28	theta[55]	1.0851	0.4293	74	log_fdev[1]	0.1828	0.0429
29	theta[56]	1.2338	0.3382	75	log_fdev[1]	0.8503	0.0471
30	theta[57]	1.0591	0.3149	76	log_fdev[1]	-4.3030	0.0450
31	theta[58]	0.8348	0.3111	77	log_fdev[1]	-4.7171	0.0392
32	theta[59]	0.3714	0.3460	78	log_fdev[1]	-0.2477	0.0381
33	theta[60]	-0.3646	0.3899	79	log_fdev[1]	-0.1998	0.0382
34	theta[61]	-0.8143	0.3828	80	log_fdev[1]	0.7192	0.0404
35	theta[62]	-1.5245	0.3744	81	log_fdev[1]	0.3574	0.0397
36	theta[63]	-1.6190	0.3714	82	log_fdev[1]	-0.2336	0.0383
37	theta[64]	-1.5486	0.3710	83	log_fdev[1]	-0.3120	0.0380
38	theta[65]	-1.7722	0.3623	84	log_fdev[1]	-0.1993	0.0372
39	theta[66]	-1.9112	0.3520	85	log_fdev[1]	0.2621	0.0364
40	theta[67]	-1.8772	0.3425	86	log_fdev[1]	0.2175	0.0366
41	Grwth[21]	0.8925	0.2057	87	log_fdev[1]	0.5050	0.0368
42	Grwth[42]	1.4103	0.1344	88	log_fdev[1]	0.2552	0.0365
43	Grwth[64]	139.90	0.6131	89	log_fdev[1]	0.6183	0.0364
44	Grwth[65]	0.0700	0.0033	90	log_fdev[1]	0.7890	0.0373
45	log_slx_pars[1]	4.7622	0.0087	91	log_fdev[1]	0.6083	0.0377
46	log_slx_pars[2]	2.2847	0.0469	92	log_fdev[1]	0.4853	0.0372

93	log_fdev[1]	-0.1494	0.0362	143	log_fdev[3]	3.6231	0.0770
94	log_fdev[1]	-0.2291	0.0357	144	log_fdev[3]	1.6749	0.0945
95	log_fdev[1]	-0.0464	0.0359	145	log_fdev[3]	0.9734	0.1318
96	log_fdev[1]	0.2773	0.0370	146	log_fdev[3]	-0.3783	0.0794
97	log_fdev[1]	0.3400	0.0404	147	log_fdev[3]	-1.7726	0.0745
98	log_fdev[1]	0.3326	0.0471	148	log_fdev[3]	-2.6193	0.0870
99	log_fdev[1]	0.2378	0.0571	149	log_fdev[3]	-2.0333	0.1124
100	log_fdev[1]	0.0363	0.0682	150	log_fdev[3]	-3.1147	0.0782
101	log_fdev[1]	-0.0356	0.0775	151	log_fdev[3]	-0.4848	0.0941
102	log_fdev[1]	-0.4831	0.0829	152	log_fdev[3]	0.2323	0.1126
103	log_fdev[2]	2.3652	0.1141	153	log_fdev[3]	1.4080	0.1391
104	log_fdev[2]	1.3387	0.1124	154	log_fdev[4]	0.6251	0.1030
105	log_fdev[2]	0.9401	0.1090	155	log_fdev[4]	-0.0351	0.1020
106	log_fdev[2]	1.7675	0.1042	156	log_fdev[4]	-0.2496	0.1026
107	log_fdev[2]	0.3648	0.1031	157	log_fdev[4]	0.6652	0.1018
108	log_fdev[2]	0.8306	0.1028	158	log_fdev[4]	-1.7669	0.1012
109	log_fdev[2]	1.2562	0.1037	159	log_fdev[4]	0.1872	0.1008
110	log_fdev[2]	1.0925	0.1038	160	log_fdev[4]	-0.0723	0.1004
111	log_fdev[2]	1.5681	0.1065	161	log_fdev[4]	-0.9097	0.1003
112	log_fdev[2]	-0.1986	0.1036	162	log_fdev[4]	-0.7374	0.1001
113	log_fdev[2]	-0.4893	0.1023	163	log_fdev[4]	-0.4653	0.1000
114	log_fdev[2]	-0.4268	0.1025	164	log_fdev[4]	-0.5157	0.0997
115	log_fdev[2]	-0.8968	0.1024	165	log_fdev[4]	0.0290	0.0997
116	log_fdev[2]	0.3988	0.1027	166	log_fdev[4]	-0.6690	0.1001
117	log_fdev[2]	0.1194	0.1026	167	log_fdev[4]	-1.6644	0.0999
118	log_fdev[2]	-0.6421	0.1019	168	log_fdev[4]	-2.5017	0.0994
119	log_fdev[2]	0.1250	0.1019	169	log_fdev[4]	-1.0256	0.0992
120	log_fdev[2]	-0.1760	0.1017	170	log_fdev[4]	-0.4742	0.0993
121	log_fdev[2]	-0.2723	0.1015	171	log_fdev[4]	0.6618	0.0993
122	log_fdev[2]	-0.0433	0.1015	172	log_fdev[4]	1.5069	0.0996
123	log_fdev[2]	-0.3236	0.1014	173	log_fdev[4]	1.1832	0.1002
124	log_fdev[2]	-0.1556	0.1012	174	log_fdev[4]	0.3452	0.1014
125	log_fdev[2]	-0.0837	0.1013	175	log_fdev[4]	1.9386	0.1032
126	log_fdev[2]	-0.1139	0.1014	176	log_fdev[4]	2.1885	0.1050
127	log_fdev[2]	-0.4670	0.1015	177	log_fdev[4]	0.9801	0.1072
128	log_fdev[2]	-0.6103	0.1015	178	log_fdev[4]	0.7761	0.1100
129	log_fdev[2]	-1.0705	0.1012	179	log_foff[1]	-2.9176	0.0407
130	log_fdev[2]	-1.5936	0.1014	180	log_foff[3]	-0.2788	0.4177
131	log_fdev[2]	-0.8839	0.1017	181	log_fdov[1]	2.1189	0.0838
132	log_fdev[2]	-1.4541	0.1021	182	log_fdov[1]	-0.5581	0.0829
133	log_fdev[2]	-1.0782	0.1032	183	log_fdov[1]	2.1082	0.0841
134	log_fdev[2]	-0.5610	0.1051	184	log_fdov[1]	1.9387	0.0858
135	log_fdev[2]	-0.1357	0.1078	185	log_fdov[1]	-0.3002	0.0845
136	log_fdev[2]	-0.2096	0.1108	186	log_fdov[1]	-0.0749	0.0823
137	log_fdev[2]	-0.1246	0.1143	187	log_fdov[1]	-3.5817	0.0813
138	log_fdev[2]	-0.1564	0.1173	188	log_fdov[1]	-0.2143	0.0819
139	log_fdev[3]	-0.7271	0.0661	189	log_fdov[1]	1.5640	0.0821
140	log_fdev[3]	0.1160	0.0661	190	log_fdov[1]	-2.6685	0.0814
141	log_fdev[3]	1.3122	0.0661	191	log_fdov[1]	1.2589	0.0805
142	log_fdev[3]	1.7903	0.0661	192	log_fdov[1]	0.9783	0.0804

193	log_fdov[1]	-1.7752	0.0799
194	log_fdov[1]	1.3084	0.0800
195	log_fdov[1]	0.5158	0.0800
196	log_fdov[1]	1.0460	0.0796
197	log_fdov[1]	-1.1406	0.0792
198	log_fdov[1]	-0.0967	0.0792
199	log_fdov[1]	-0.3578	0.0796
200	log_fdov[1]	-0.6299	0.0799
201	log_fdov[1]	-0.1599	0.0797
202	log_fdov[1]	-1.0594	0.0788
203	log_fdov[1]	-1.7764	0.0783
204	log_fdov[1]	0.2455	0.0784
205	log_fdov[1]	-0.1587	0.0787
206	log_fdov[1]	0.9053	0.0796
207	log_fdov[1]	0.3574	0.0818
208	log_fdov[1]	-0.2928	0.0858
209	log_fdov[1]	1.0418	0.0910
210	log_fdov[1]	-0.0204	0.0955
211	log_fdov[1]	-0.5225	0.0982
212	log_fdov[3]	-0.0001	0.0933
213	log_fdov[3]	0.0001	0.0933
214	log_fdov[3]	0.0004	0.0933
215	log_fdov[3]	0.0010	0.0933
216	log_fdov[3]	1.5645	0.1308
217	log_fdov[3]	1.8493	0.1188
218	log_fdov[3]	0.6142	0.1490
219	log_fdov[3]	-3.4032	0.1075
220	log_fdov[3]	-2.1901	0.1420
221	log_fdov[3]	-0.8133	0.1138
222	log_fdov[3]	0.0020	0.1330
223	log_fdov[3]	0.3474	0.1046
224	log_fdov[3]	0.9593	0.1434
225	log_fdov[3]	0.1674	0.1415
226	log_fdov[3]	0.9011	0.1738
227	rec_dev_est	0.7235	0.1774
228	rec_dev_est	-0.4510	0.2461
229	rec_dev_est	-0.8961	0.2797
230	rec_dev_est	-0.5774	0.2254
231	rec_dev_est	0.3145	0.1801
232	rec_dev_est	-0.1288	0.1974
233	rec_dev_est	-1.5616	0.3589
234	rec_dev_est	-0.4677	0.2090
235	rec_dev_est	-1.5267	0.3936
236	rec_dev_est	1.3721	0.1661
237	rec_dev_est	-0.5155	0.2645
238	rec_dev_est	-1.1627	0.3309
239	rec_dev_est	-0.1462	0.2084
240	rec_dev_est	0.8186	0.1732
241	rec_dev_est	-0.1512	0.2327
242	rec_dev_est	-0.0911	0.2440
243	rec_dev_est	1.2449	0.1731
244	rec_dev_est	-0.2038	0.2710
245	rec_dev_est	-0.1978	0.2607
246	rec_dev_est	1.0001	0.1767
247	rec_dev_est	0.0915	0.2188
248	rec_dev_est	-0.0427	0.2101
249	rec_dev_est	-0.6572	0.2592
250	rec_dev_est	-0.5620	0.2472
251	rec_dev_est	0.3645	0.1964
252	rec_dev_est	-0.0077	0.2227
253	rec_dev_est	-0.7953	0.2661
254	rec_dev_est	-0.9102	0.2387
255	rec_dev_est	-1.3700	0.2796
256	rec_dev_est	-1.0524	0.2457
257	rec_dev_est	-0.2595	0.1927
258	rec_dev_est	-1.2136	0.2690
259	rec_dev_est	-0.5105	0.2191
260	rec_dev_est	-1.3883	0.3743
261	rec_dev_est	-1.3134	0.4250
262	rec_dev_est	-0.6147	0.3794
263	logit_rec_prop_es	-0.4244	0.1509
264	logit_rec_prop_es	0.1950	0.3915
265	logit_rec_prop_es	-0.1006	0.4441
266	logit_rec_prop_es	0.4338	0.3542
267	logit_rec_prop_es	-0.0550	0.1640
268	logit_rec_prop_es	0.2315	0.2393
269	logit_rec_prop_es	0.4104	0.6230
270	logit_rec_prop_es	0.2970	0.2788
271	logit_rec_prop_es	-0.6685	0.6475
272	logit_rec_prop_es	-0.2379	0.0898
273	logit_rec_prop_es	1.1323	0.5415
274	logit_rec_prop_es	0.3081	0.5721
275	logit_rec_prop_es	0.4765	0.3037
276	logit_rec_prop_es	-0.0305	0.1406
277	logit_rec_prop_es	0.1547	0.3472
278	logit_rec_prop_es	-0.5868	0.3699
279	logit_rec_prop_es	-0.4655	0.1284
280	logit_rec_prop_es	-0.4834	0.4283
281	logit_rec_prop_es	-0.1067	0.4032
282	logit_rec_prop_es	-0.4433	0.1473
283	logit_rec_prop_es	0.0818	0.3115
284	logit_rec_prop_es	0.2633	0.2928
285	logit_rec_prop_es	-0.2526	0.3962
286	logit_rec_prop_es	-0.4522	0.3638
287	logit_rec_prop_es	-0.7290	0.2047
288	logit_rec_prop_es	-0.6223	0.2778
289	logit_rec_prop_es	-0.4294	0.4001
290	logit_rec_prop_es	-0.4960	0.3433
291	logit_rec_prop_es	-0.1320	0.4414
292	logit_rec_prop_es	-0.3529	0.3547

293	logit_rec_prop_es	0.4342	0.2265
294	logit_rec_prop_es	0.4586	0.4602
295	logit_rec_prop_es	0.5145	0.2989
296	logit_rec_prop_es	0.5436	0.6258
297	logit_rec_prop_es	1.1455	0.7018
298	logit_rec_prop_es	-0.0122	0.6212
299	survey_q[1]	0.9393	0.0270

Table 6d. Summary of estimated model parameter values and standard deviations for model 22.1 for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2826	0.0144	47	log_slx_pars[1]	4.7623	0.0084
2	theta[4]	19.790	0.0488	48	log_slx_pars[2]	2.2811	0.0462
3	theta[5]	16.226	0.1400	49	log_slx_pars[3]	4.5092	0.0175
4	theta[7]	0.6663	0.1408	50	log_slx_pars[4]	2.0384	0.1169
5	theta[9]	-0.4702	0.2516	51	log_slx_pars[5]	5.1596	0.0581
6	theta[13]	0.9649	0.4342	52	log_slx_pars[6]	2.8496	0.0441
7	theta[14]	0.6754	0.4796	53	log_slx_pars[7]	4.7266	0.2158
8	theta[15]	0.8748	0.3275	54	log_slx_pars[8]	2.1630	0.3061
9	theta[16]	0.6967	0.2983	55	log_slx_pars[9]	4.7396	0.0776
10	theta[17]	0.5181	0.2884	56	log_slx_pars[10]	0.8993	0.3036
11	theta[18]	0.4817	0.2716	57	log_slx_pars[11]	4.8013	0.0253
12	theta[19]	0.3300	0.2749	58	log_slx_pars[12]	2.3643	0.0890
13	theta[20]	0.3821	0.2631	59	log_slx_pars[13]	4.4312	0.0195
14	theta[21]	0.4313	0.2562	60	log_slx_pars[14]	2.0954	0.1126
15	theta[22]	0.2111	0.2790	61	log_slx_pars[15]	4.4906	0.0112
16	theta[23]	0.1959	0.2755	62	log_slx_pars[16]	2.5399	0.0551
17	theta[24]	0.0948	0.2854	63	log_slx_pars[17]	4.9231	0.0015
18	theta[25]	0.2101	0.2615	64	log_slx_pars[18]	0.6742	0.0533
19	theta[26]	0.0278	0.2038	65	log_slx_pars[19]	4.9315	0.0020
20	theta[27]	-0.2030	0.1961	66	log_slx_pars[20]	0.7008	0.1014
21	theta[28]	-0.3559	0.1982	67	log_fbar[1]	-1.4594	0.0423
22	theta[29]	-0.7050	0.2117	68	log_fbar[2]	-4.2569	0.0760
23	theta[30]	-1.1690	0.2332	69	log_fbar[3]	-5.5816	0.2922
24	theta[31]	-1.2125	0.2354	70	log_fbar[4]	-6.5307	0.0781
25	theta[52]	1.0391	0.9371	71	log_fdev[1]	0.6835	0.1179
26	theta[53]	1.4788	0.5098	72	log_fdev[1]	0.6379	0.0886
27	theta[54]	1.3730	0.3856	73	log_fdev[1]	0.5546	0.0726
28	theta[55]	1.1052	0.3448	74	log_fdev[1]	0.6625	0.0597
29	theta[56]	1.0224	0.2929	75	log_fdev[1]	0.8834	0.0536
30	theta[57]	0.5750	0.3079	76	log_fdev[1]	1.7596	0.0563
31	theta[58]	0.2047	0.3408	77	log_fdev[1]	2.3211	0.1173
32	theta[59]	-0.0204	0.3512	78	log_fdev[1]	0.7806	0.1733
33	theta[60]	-0.2081	0.3485	79	log_fdev[1]	-8.9452	0.1205
34	theta[61]	-0.5399	0.3715	80	log_fdev[1]	1.0801	0.1081
35	theta[62]	-0.9278	0.3858	81	log_fdev[1]	1.1250	0.0883
36	theta[63]	-1.1863	0.3917	82	log_fdev[1]	1.2905	0.0729
37	theta[64]	-1.4141	0.3910	83	log_fdev[1]	0.8272	0.0643
38	theta[65]	-1.7808	0.3789	84	log_fdev[1]	-0.1141	0.0529
39	theta[66]	-1.8844	0.3751	85	log_fdev[1]	-0.0013	0.0473
40	theta[67]	-1.8272	0.3555	86	log_fdev[1]	0.6468	0.0387
41	Grwth[21]	0.9698	0.1933	87	log_fdev[1]	0.6615	0.0413
42	Grwth[42]	1.3945	0.1232	88	log_fdev[1]	0.1482	0.0461
43	Grwth[85]	142.27	1.7257	89	log_fdev[1]	0.8182	0.0509
44	Grwth[86]	0.0590	0.0100	90	log_fdev[1]	-4.3362	0.0487
45	Grwth[87]	140.08	0.5902	91	log_fdev[1]	-4.7503	0.0420
46	Grwth[88]	0.0702	0.0033	92	log_fdev[1]	-0.2801	0.0406

93	log_fdev[1]	-0.2306	0.0410	143	log_fdev[2]	-0.5424	0.1025
94	log_fdev[1]	0.6885	0.0436	144	log_fdev[2]	-0.6384	0.1023
95	log_fdev[1]	0.3298	0.0426	145	log_fdev[2]	-0.4082	0.1023
96	log_fdev[1]	-0.2591	0.0411	146	log_fdev[2]	-0.6858	0.1022
97	log_fdev[1]	-0.3390	0.0407	147	log_fdev[2]	-0.5190	0.1019
98	log_fdev[1]	-0.2289	0.0395	148	log_fdev[2]	-0.4443	0.1020
99	log_fdev[1]	0.2321	0.0382	149	log_fdev[2]	-0.4708	0.1023
100	log_fdev[1]	0.1886	0.0384	150	log_fdev[2]	-0.8249	0.1023
101	log_fdev[1]	0.4773	0.0390	151	log_fdev[2]	-0.9696	0.1023
102	log_fdev[1]	0.2272	0.0384	152	log_fdev[2]	-1.4322	0.1021
103	log_fdev[1]	0.5915	0.0384	153	log_fdev[2]	-1.9555	0.1023
104	log_fdev[1]	0.7631	0.0401	154	log_fdev[2]	-1.2446	0.1026
105	log_fdev[1]	0.5839	0.0410	155	log_fdev[2]	-1.8127	0.1030
106	log_fdev[1]	0.4615	0.0405	156	log_fdev[2]	-1.4343	0.1041
107	log_fdev[1]	-0.1731	0.0394	157	log_fdev[2]	-0.9137	0.1060
108	log_fdev[1]	-0.2534	0.0386	158	log_fdev[2]	-0.4842	0.1088
109	log_fdev[1]	-0.0718	0.0387	159	log_fdev[2]	-0.5542	0.1118
110	log_fdev[1]	0.2525	0.0396	160	log_fdev[2]	-0.4677	0.1153
111	log_fdev[1]	0.3169	0.0428	161	log_fdev[2]	-0.5036	0.1184
112	log_fdev[1]	0.3109	0.0493	162	log_fdev[3]	-0.1164	0.0682
113	log_fdev[1]	0.2181	0.0591	163	log_fdev[3]	0.6698	0.0682
114	log_fdev[1]	0.0185	0.0699	164	log_fdev[3]	1.2283	0.0682
115	log_fdev[1]	-0.0539	0.0790	165	log_fdev[3]	1.0927	0.0682
116	log_fdev[1]	-0.5039	0.0840	166	log_fdev[3]	1.3824	0.0682
117	log_fdev[2]	0.1434	0.1241	167	log_fdev[3]	1.4243	0.0682
118	log_fdev[2]	0.5873	0.1158	168	log_fdev[3]	0.9927	0.0682
119	log_fdev[2]	0.5764	0.1103	169	log_fdev[3]	0.4765	0.0682
120	log_fdev[2]	0.6629	0.1088	170	log_fdev[3]	-0.9874	0.0682
121	log_fdev[2]	1.3998	0.1114	171	log_fdev[3]	-0.5787	0.0682
122	log_fdev[2]	1.1985	0.1280	172	log_fdev[3]	-1.0994	0.0682
123	log_fdev[2]	2.4807	0.1283	173	log_fdev[3]	-0.2563	0.0682
124	log_fdev[2]	2.1879	0.1166	174	log_fdev[3]	0.9401	0.0682
125	log_fdev[2]	3.4017	0.1144	175	log_fdev[3]	1.4182	0.0682
126	log_fdev[2]	2.1841	0.1111	176	log_fdev[3]	3.2469	0.0758
127	log_fdev[2]	1.1194	0.1112	177	log_fdev[3]	1.2942	0.0951
128	log_fdev[2]	0.6634	0.1089	178	log_fdev[3]	0.5944	0.1240
129	log_fdev[2]	1.4340	0.1045	179	log_fdev[3]	-0.7513	0.0807
130	log_fdev[2]	-0.0007	0.1035	180	log_fdev[3]	-2.1447	0.0738
131	log_fdev[2]	0.4533	0.1035	181	log_fdev[3]	-2.9944	0.0888
132	log_fdev[2]	0.8784	0.1048	182	log_fdev[3]	-2.4085	0.1084
133	log_fdev[2]	0.7150	0.1050	183	log_fdev[3]	-3.4858	0.0764
134	log_fdev[2]	1.1956	0.1079	184	log_fdev[3]	-0.8519	0.0918
135	log_fdev[2]	-0.5771	0.1048	185	log_fdev[3]	-0.1322	0.1103
136	log_fdev[2]	-0.8690	0.1033	186	log_fdev[3]	1.0466	0.1346
137	log_fdev[2]	-0.8024	0.1035	187	log_fdev[4]	0.6091	0.1030
138	log_fdev[2]	-1.2672	0.1034	188	log_fdev[4]	-0.0476	0.1020
139	log_fdev[2]	0.0355	0.1038	189	log_fdev[4]	-0.2561	0.1026
140	log_fdev[2]	-0.2450	0.1036	190	log_fdev[4]	0.6599	0.1017
141	log_fdev[2]	-1.0086	0.1029	191	log_fdev[4]	-1.7738	0.1011
142	log_fdev[2]	-0.2413	0.1028	192	log_fdev[4]	0.1797	0.1008

193	log_fdev[4]	-0.0801	0.1004
194	log_fdev[4]	-0.9169	0.1003
195	log_fdev[4]	-0.7440	0.1001
196	log_fdev[4]	-0.4707	0.1000
197	log_fdev[4]	-0.5215	0.0997
198	log_fdev[4]	0.0248	0.0997
199	log_fdev[4]	-0.6706	0.1001
200	log_fdev[4]	-1.6652	0.0999
201	log_fdev[4]	-2.5016	0.0995
202	log_fdev[4]	-1.0260	0.0992
203	log_fdev[4]	-0.4743	0.0993
204	log_fdev[4]	0.6632	0.0993
205	log_fdev[4]	1.5110	0.0996
206	log_fdev[4]	1.1904	0.1002
207	log_fdev[4]	0.3563	0.1013
208	log_fdev[4]	1.9538	0.1031
209	log_fdev[4]	2.2069	0.1048
210	log_fdev[4]	0.9996	0.1071
211	log_fdev[4]	0.7937	0.1099
212	log_foff[1]	-2.9086	0.0410
213	log_foff[3]	-0.1621	0.4110
214	log_fdov[1]	2.0859	0.0836
215	log_fdov[1]	-0.5868	0.0827
216	log_fdov[1]	2.0848	0.0840
217	log_fdov[1]	1.9167	0.0858
218	log_fdov[1]	-0.3147	0.0845
219	log_fdov[1]	-0.0831	0.0823
220	log_fdov[1]	-3.5852	0.0813
221	log_fdov[1]	-0.2202	0.0820
222	log_fdov[1]	1.5569	0.0822
223	log_fdov[1]	-2.6757	0.0813
224	log_fdov[1]	1.2523	0.0805
225	log_fdov[1]	0.9755	0.0805
226	log_fdov[1]	-1.7742	0.0799
227	log_fdov[1]	1.3083	0.0800
228	log_fdov[1]	0.5130	0.0801
229	log_fdov[1]	1.0409	0.0796
230	log_fdov[1]	-1.1446	0.0792
231	log_fdov[1]	-0.1023	0.0792
232	log_fdov[1]	-0.3630	0.0796
233	log_fdov[1]	-0.6336	0.0799
234	log_fdov[1]	-0.1604	0.0798
235	log_fdov[1]	-1.0567	0.0789
236	log_fdov[1]	-1.7702	0.0784
237	log_fdov[1]	0.2556	0.0784
238	log_fdov[1]	-0.1462	0.0787
239	log_fdov[1]	0.9199	0.0795
240	log_fdov[1]	0.3759	0.0816
241	log_fdov[1]	-0.2709	0.0853
242	log_fdov[1]	1.0677	0.0904
243	log_fdov[1]	0.0122	0.0948
244	log_fdov[1]	-0.4810	0.0977
245	log_fdov[3]	0.0000	0.0962
246	log_fdov[3]	0.0001	0.0962
247	log_fdov[3]	0.0003	0.0963
248	log_fdov[3]	0.0003	0.0963
249	log_fdov[3]	0.0004	0.0963
250	log_fdov[3]	0.0000	0.0963
251	log_fdov[3]	-0.0001	0.0963
252	log_fdov[3]	-0.0002	0.0962
253	log_fdov[3]	-0.0002	0.0962
254	log_fdov[3]	-0.0001	0.0962
255	log_fdov[3]	-0.0001	0.0962
256	log_fdov[3]	0.0001	0.0962
257	log_fdov[3]	0.0003	0.0962
258	log_fdov[3]	0.0008	0.0963
259	log_fdov[3]	1.5576	0.1561
260	log_fdov[3]	1.8207	0.1191
261	log_fdov[3]	0.5897	0.1449
262	log_fdov[3]	-3.4174	0.1074
263	log_fdov[3]	-2.1431	0.1492
264	log_fdov[3]	-0.7889	0.1220
265	log_fdov[3]	0.0193	0.1292
266	log_fdov[3]	0.3570	0.1034
267	log_fdov[3]	0.9444	0.1622
268	log_fdov[3]	0.1655	0.1477
269	log_fdov[3]	0.8936	0.1664
270	rec_dev_est	1.0708	0.2700
271	rec_dev_est	0.5517	0.3068
272	rec_dev_est	1.0056	0.2502
273	rec_dev_est	1.6103	0.2114
274	rec_dev_est	1.8855	0.2220
275	rec_dev_est	1.2230	0.2548
276	rec_dev_est	2.3661	0.1664
277	rec_dev_est	1.4065	0.1797
278	rec_dev_est	1.0557	0.1664
279	rec_dev_est	-0.7616	0.2424
280	rec_dev_est	0.2936	0.1639
281	rec_dev_est	-0.8310	0.2372
282	rec_dev_est	-1.2732	0.2696
283	rec_dev_est	-1.0098	0.2209
284	rec_dev_est	-0.0731	0.1663
285	rec_dev_est	-0.5300	0.1846
286	rec_dev_est	-1.9574	0.3467
287	rec_dev_est	-0.8874	0.1966
288	rec_dev_est	-1.9817	0.3978
289	rec_dev_est	0.9809	0.1482
290	rec_dev_est	-0.9204	0.2603
291	rec_dev_est	-1.5849	0.3300
292	rec_dev_est	-0.5488	0.1964

293	rec_dev_est	0.4252	0.1565
294	rec_dev_est	-0.5665	0.2228
295	rec_dev_est	-0.4940	0.2326
296	rec_dev_est	0.8674	0.1553
297	rec_dev_est	-0.6273	0.2658
298	rec_dev_est	-0.5912	0.2525
299	rec_dev_est	0.6147	0.1601
300	rec_dev_est	-0.3036	0.2080
301	rec_dev_est	-0.4620	0.1988
302	rec_dev_est	-1.0489	0.2471
303	rec_dev_est	-0.9963	0.2409
304	rec_dev_est	-0.0043	0.1826
305	rec_dev_est	-0.4486	0.2125
306	rec_dev_est	-1.1615	0.2510
307	rec_dev_est	-1.3254	0.2272
308	rec_dev_est	-1.8159	0.2770
309	rec_dev_est	-1.4582	0.2366
310	rec_dev_est	-0.6836	0.1788
311	rec_dev_est	-1.6612	0.2638
312	rec_dev_est	-0.9365	0.2054
313	rec_dev_est	-1.8080	0.3508
314	rec_dev_est	-1.6814	0.3816
315	rec_dev_est	-1.0472	0.3449
316	logit_rec_prop_es	-0.1537	0.4241
317	logit_rec_prop_es	-0.8269	0.5351
318	logit_rec_prop_es	-0.2454	0.3725
319	logit_rec_prop_es	-0.4789	0.2696
320	logit_rec_prop_es	0.0458	0.2626
321	logit_rec_prop_es	0.2147	0.3178
322	logit_rec_prop_es	0.3249	0.1395
323	logit_rec_prop_es	0.3912	0.2255
324	logit_rec_prop_es	-0.0991	0.1714
325	logit_rec_prop_es	0.3898	0.4264
326	logit_rec_prop_es	-0.4722	0.1647
327	logit_rec_prop_es	0.1454	0.3904
328	logit_rec_prop_es	-0.1364	0.4400
329	logit_rec_prop_es	0.4216	0.3754
330	logit_rec_prop_es	-0.1024	0.1704
331	logit_rec_prop_es	0.1521	0.2406
332	logit_rec_prop_es	0.5851	0.6677
333	logit_rec_prop_es	0.2041	0.2778
334	logit_rec_prop_es	-0.3668	0.6482
335	logit_rec_prop_es	-0.3068	0.0877
336	logit_rec_prop_es	1.1230	0.5842
337	logit_rec_prop_es	0.3580	0.6072
338	logit_rec_prop_es	0.4235	0.3046
339	logit_rec_prop_es	-0.0680	0.1391
340	logit_rec_prop_es	0.1172	0.3485
341	logit_rec_prop_es	-0.5841	0.3619
342	logit_rec_prop_es	-0.5302	0.1245
343	logit_rec_prop_es	-0.4682	0.4292
344	logit_rec_prop_es	-0.1430	0.4047
345	logit_rec_prop_es	-0.5048	0.1467
346	logit_rec_prop_es	0.0642	0.3135
347	logit_rec_prop_es	0.2232	0.2962
348	logit_rec_prop_es	-0.2550	0.3886
349	logit_rec_prop_es	-0.4102	0.3688
350	logit_rec_prop_es	-0.8147	0.2022
351	logit_rec_prop_es	-0.5773	0.2823
352	logit_rec_prop_es	-0.5034	0.3835
353	logit_rec_prop_es	-0.5008	0.3384
354	logit_rec_prop_es	-0.0955	0.4563
355	logit_rec_prop_es	-0.3949	0.3547
356	logit_rec_prop_es	0.4524	0.2320
357	logit_rec_prop_es	0.5043	0.4838
358	logit_rec_prop_es	0.5141	0.2984
359	logit_rec_prop_es	0.7067	0.6437
360	logit_rec_prop_es	1.4153	0.7380
361	logit_rec_prop_es	0.2622	0.5675
362	m_dev_est[1]	1.5908	0.0301
363	survey_q[1]	0.9637	0.0248

Table 7. Natural mortality estimates for nine model scenarios during different year blocks. Rows denoted with "base" indicate the estimate defaulted to the base value in the first column or third column.

Model	Sex	1975-1979, 1985-2014, 2019-2021	1980-1984	1985-2014 2019-2021	2015-2018
21.1b	Males	0.180	0.890		base
	Females	0.238	1.179		base
22.0	Males			0.180	base
	Females			0.232	base
22.0a	Males			0.226	base
	Females			0.261	base
22.0b	Males			0.225	base
	Females			0.261	base
22.0c	Males			0.223	base
	Females			0.260	base
22.0d	Males			0.180	base
	Females			0.231	base
22.0e	Males			0.180	0.333
	Females			0.220	0.406
22.1	Males	0.180	0.883		base
	Females	0.239	1.172		base
22.1a	Males	0.180	0.909		0.304
	Females	0.231	1.164		0.389

Table 8. Area-swept estimates of mature female abundance (million crab) and model estimates of effective spawning biomass (ESB, Zheng et al. 1995b) (1000 t) during 2011-2021 for groundfish fisheries bycatch (PSC) calculation. (*mature female abundance in 2020 is the model projected value). Note that PSC limits apply to previous-year ESB.

Year	Mature female abundance	Effective spawning biomass
2011	28.520	19.541
2012	21.121	20.029
2013	15.694	22.382
2014	38.580	23.272
2015	18.666	21.098
2016	22.633	19.147
2017	18.497	18.042
2018	9.106	15.093
2019	8.587	12.705
2020	9.668*	11.394
2021	6.432	9.463

Table 9a. Annual abundance estimates (million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) for red king crab in Bristol Bay estimated by length-based model 21.1b during 1975-2021. MMB for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length.

Year (t)	Males				Females	Total Recruits	Total Survey Biomass	
	Mature (>119 mm)	Legal (>134mm)	MMB (>119 mm)	SD MMB	Mature (>89 mm)		Model Est. (>64 mm)	Area-Swept (>64 mm)
1975	55.779	28.331	83.664	8.376	55.337	NA	234.431	199.643
1976	65.460	35.634	99.538	8.075	83.991	66.359	274.253	327.615
1977	72.725	41.413	113.562	6.993	111.559	41.176	295.812	371.223
1978	78.087	46.637	120.474	5.574	116.044	66.361	299.272	343.189
1979	68.622	47.610	100.604	3.925	111.446	117.547	288.137	165.449
1980	50.197	37.923	30.473	1.617	113.805	155.108	273.337	247.226
1981	14.486	8.034	6.579	1.065	49.851	70.412	109.208	131.145
1982	6.815	2.170	6.588	0.940	21.908	244.482	65.467	141.898
1983	6.206	2.176	7.428	0.687	14.387	94.472	57.631	48.476
1984	6.178	2.294	5.247	0.438	14.146	64.509	50.393	152.607
1985	7.555	1.888	9.682	0.657	9.765	10.439	34.563	34.138
1986	12.172	4.642	15.068	0.994	13.745	30.154	45.218	47.434
1987	14.380	6.682	20.434	1.197	17.142	9.679	50.963	69.245
1988	14.459	8.460	25.136	1.252	21.551	6.247	54.335	54.597
1989	15.556	9.747	27.995	1.200	20.386	8.154	57.010	55.136
1990	15.029	10.437	24.161	1.128	18.256	20.869	57.108	59.451
1991	11.553	8.654	18.456	1.065	17.617	13.166	52.065	83.892
1992	9.280	6.463	17.239	1.039	18.726	3.143	47.435	37.334
1993	10.512	6.159	15.869	1.114	17.435	9.116	47.008	52.906
1994	10.380	6.022	21.743	1.223	14.876	3.119	42.492	32.104
1995	10.873	7.903	24.867	1.224	13.821	59.371	48.548	38.068
1996	11.148	8.553	23.334	1.169	19.858	8.874	57.789	43.959
1997	10.587	7.785	22.064	1.148	28.932	4.544	63.872	84.030
1998	15.933	7.755	24.988	1.359	25.499	12.607	67.780	84.101
1999	17.003	9.743	28.740	1.506	21.639	33.776	66.443	64.754
2000	14.665	10.659	28.925	1.498	23.050	12.714	68.075	67.381
2001	14.482	10.220	29.306	1.459	26.134	13.086	71.709	52.455
2002	17.354	10.417	33.406	1.477	25.463	52.053	76.829	69.086
2003	18.189	12.067	32.979	1.443	31.154	12.007	82.992	115.760
2004	16.378	11.649	30.462	1.365	38.459	11.420	84.573	130.556
2005	18.311	10.864	31.080	1.336	35.760	40.111	85.681	105.727
2006	17.436	11.471	31.495	1.301	36.120	19.461	85.666	94.477
2007	15.722	11.230	26.489	1.226	40.099	13.171	87.354	103.327
2008	16.166	9.571	25.270	1.261	37.668	7.396	83.917	113.082
2009	16.074	9.565	26.262	1.317	33.053	8.540	78.084	90.547
2010	14.989	9.835	25.648	1.286	29.016	22.572	73.193	80.501
2011	12.728	9.326	25.407	1.215	28.643	13.079	68.892	66.408
2012	11.369	8.791	23.859	1.134	30.518	7.641	67.398	60.697
2013	11.321	8.055	22.875	1.081	28.857	5.565	64.796	62.217
2014	11.098	7.788	20.992	1.050	25.524	3.497	60.153	113.135
2015	9.607	7.151	18.101	1.029	21.839	5.418	53.424	64.175
2016	7.876	6.086	15.144	1.023	18.590	10.799	46.812	60.958
2017	6.329	5.009	12.588	1.014	16.797	4.424	41.918	52.935
2018	5.585	4.111	11.379	1.024	15.262	8.457	38.852	28.805
2019	6.457	3.857	12.485	1.161	13.446	3.587	37.177	28.539
2020	6.986	4.447	14.114	1.322	12.097	3.869		
2021	7.654	5.012	15.118	1.168	10.294	7.848	35.532	28.476

Table 9b. Annual abundance estimates (million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) for red king crab in Bristol Bay estimated by length-based model 22.0 during 1975-2021. MMB for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length.

Year (t)	Males				Females	Total Recruits	Total Survey Biomass	
	Mature (>119 mm)	Legal (>134mm)	MMB (>119 mm)	SD MMB	Mature (>89 mm)		Model Est. (>64 mm)	Area-Swept (>64 mm)
1985	8.568	2.347	11.665	0.975	8.498	NA	34.678	34.138
1986	13.006	5.351	17.174	1.193	12.005	30.922	44.488	47.434
1987	14.434	7.312	21.392	1.324	15.732	9.388	49.918	69.245
1988	14.460	8.698	25.621	1.332	20.615	6.070	53.162	54.597
1989	15.575	9.797	28.250	1.266	19.716	8.357	55.680	55.136
1990	15.124	10.479	24.427	1.188	17.805	20.541	55.718	59.451
1991	11.631	8.727	18.669	1.118	17.308	13.098	50.886	83.892
1992	9.379	6.526	17.459	1.088	18.427	3.082	46.574	37.334
1993	10.646	6.227	16.149	1.166	17.247	9.276	46.309	52.906
1994	10.567	6.118	22.108	1.282	14.834	3.254	42.036	32.104
1995	11.011	8.034	25.186	1.279	13.920	58.602	47.824	38.068
1996	11.322	8.658	23.698	1.224	19.837	8.770	56.984	43.959
1997	10.676	7.913	22.325	1.197	28.681	4.581	63.277	84.030
1998	16.209	7.816	25.494	1.428	25.471	12.679	67.301	84.101
1999	17.338	9.940	29.407	1.588	21.766	33.332	65.981	64.754
2000	14.915	10.893	29.516	1.573	23.152	12.686	67.632	67.381
2001	14.704	10.411	29.847	1.528	26.212	13.146	71.308	52.455
2002	17.622	10.582	33.994	1.548	25.669	50.699	76.193	69.086
2003	18.463	12.262	33.592	1.512	31.180	12.039	82.220	115.760
2004	16.587	11.850	30.989	1.429	38.277	11.431	83.904	130.556
2005	18.572	11.016	31.649	1.407	35.847	39.559	84.969	105.727
2006	17.682	11.662	32.059	1.372	36.229	19.249	85.000	94.477
2007	15.918	11.408	26.979	1.295	40.168	13.422	86.822	103.327
2008	16.431	9.718	25.837	1.340	37.929	7.350	83.674	113.082
2009	16.354	9.755	26.876	1.403	33.513	8.721	78.107	90.547
2010	15.298	10.040	26.321	1.375	29.629	22.164	73.300	80.501
2011	13.013	9.557	26.072	1.299	29.254	13.519	69.112	66.408
2012	11.602	9.007	24.449	1.212	31.132	7.531	67.744	60.697
2013	11.574	8.238	23.478	1.159	29.670	5.716	65.291	62.217
2014	11.359	7.981	21.611	1.129	26.346	3.637	60.786	113.135
2015	9.849	7.349	18.697	1.108	22.706	5.547	54.198	64.175
2016	8.106	6.274	15.721	1.102	19.462	11.206	47.701	60.958
2017	6.544	5.191	13.142	1.090	17.674	4.621	42.953	52.935
2018	5.794	4.282	11.918	1.097	16.174	8.758	40.017	28.805
2019	6.730	4.022	13.112	1.238	14.353	3.648	38.429	28.539
2020	7.280	4.656	14.801	1.401	12.999	3.822		
2021	7.974	5.236	15.480	1.199	11.193	7.956	36.668	28.476

Table 9c. Annual abundance estimates (million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) for red king crab in Bristol Bay estimated by length-based model 22.0d during 1975-2021. MMB for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length.

Year (t)	Males				Females	Total Recruits	Total Survey Biomass	
	Mature (>119 mm)	Legal (>134mm)	MMB (>119 mm)	SD MMB	Mature (>89 mm)		Model Est. (>64 mm)	Area-Swept (>64 mm)
1985	8.399	2.311	11.393	0.940	8.404	NA	34.267	34.138
1986	12.769	5.261	16.748	1.160	11.915	30.433	44.126	47.434
1987	14.191	7.183	20.908	1.295	15.579	9.403	49.474	69.245
1988	14.235	8.558	25.141	1.305	20.372	6.025	52.759	54.597
1989	15.364	9.658	27.785	1.238	19.490	8.286	55.406	55.136
1990	14.937	10.352	24.000	1.159	17.600	20.217	55.499	59.451
1991	11.466	8.610	18.282	1.090	17.103	12.978	50.562	83.892
1992	9.234	6.414	17.104	1.061	18.230	3.097	46.189	37.334
1993	10.475	6.124	15.762	1.138	17.070	9.248	46.000	52.906
1994	10.369	6.006	21.675	1.254	14.686	3.207	41.733	32.104
1995	10.833	7.914	24.777	1.251	13.805	58.216	47.605	38.068
1996	11.163	8.539	23.320	1.197	19.758	8.816	56.554	43.959
1997	10.522	7.805	21.959	1.173	28.703	4.615	62.943	84.030
1998	15.995	7.699	25.031	1.401	25.483	12.754	67.204	84.101
1999	17.091	9.820	28.885	1.559	21.802	33.469	65.971	64.754
2000	14.693	10.755	29.026	1.545	23.303	12.691	67.595	67.381
2001	14.517	10.268	29.407	1.503	26.469	13.476	71.431	52.455
2002	17.460	10.456	33.599	1.525	25.963	51.259	76.566	69.086
2003	18.299	12.174	33.216	1.490	31.721	12.040	82.634	115.760
2004	16.451	11.763	30.670	1.408	39.059	12.113	84.559	130.556
2005	18.434	10.933	31.338	1.383	36.614	40.129	85.932	105.727
2006	17.544	11.598	31.760	1.349	37.384	16.176	85.818	94.477
2007	15.805	11.344	26.719	1.270	41.084	14.145	87.321	103.327
2008	16.135	9.641	25.307	1.298	37.982	7.651	83.822	113.082
2009	15.786	9.559	25.865	1.335	33.750	8.415	78.073	90.547
2010	14.730	9.673	25.149	1.286	29.863	21.253	73.094	80.501
2011	12.572	9.172	24.996	1.205	29.211	14.649	68.729	66.408
2012	11.232	8.678	23.478	1.119	31.148	6.664	67.324	60.697
2013	11.186	7.947	22.507	1.056	29.954	5.941	64.898	62.217
2014	10.977	7.691	20.653	1.013	26.535	3.751	60.373	113.135
2015	9.429	7.064	17.693	0.982	23.033	5.153	53.731	64.175
2016	7.615	5.954	14.590	0.967	19.699	11.387	47.155	60.958
2017	6.122	4.826	12.066	0.962	17.860	4.386	42.318	52.935
2018	5.383	3.953	10.865	0.975	16.338	8.860	39.401	28.805
2019	6.371	3.701	12.136	1.144	14.465	3.683	37.862	28.539
2020	6.946	4.380	13.894	1.337	13.094	3.969		
2021	7.695	4.981	14.905	1.184	11.256	7.983	36.376	28.476

Table 9d. Annual abundance estimates (million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) for red king crab in Bristol Bay estimated by length-based model 22.0e during 1975-2021. MMB for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length.

Year (t)	Males				Females	Total Recruits	Total Survey Biomass	
	Mature (>119 mm)	Legal (>134mm)	MMB (>119 mm)	SD MMB	Mature (>89 mm)		Model Est. (>64 mm)	Area-Swept (>64 mm)
1985	8.449	2.398	11.444	0.925	8.046	NA	33.156	34.138
1986	12.748	5.278	16.739	1.140	11.497	29.019	42.799	47.434
1987	14.160	7.162	20.851	1.274	15.008	9.129	47.973	69.245
1988	14.196	8.519	25.038	1.284	19.632	5.826	51.228	54.597
1989	15.329	9.612	27.669	1.218	18.919	8.233	54.007	55.136
1990	14.912	10.308	23.900	1.140	17.262	19.896	54.276	59.451
1991	11.449	8.577	18.191	1.072	16.923	12.815	49.515	83.892
1992	9.225	6.388	17.030	1.045	18.148	3.119	45.344	37.334
1993	10.494	6.108	15.743	1.124	17.140	9.179	45.401	52.906
1994	10.408	6.005	21.704	1.243	14.895	3.233	41.408	32.104
1995	10.883	7.928	24.832	1.243	14.129	57.521	47.295	38.068
1996	11.212	8.567	23.383	1.191	19.979	8.878	56.049	43.959
1997	10.594	7.833	22.065	1.172	28.960	4.621	62.508	84.030
1998	16.172	7.754	25.316	1.415	25.947	12.964	67.134	84.101
1999	17.324	9.929	29.316	1.584	22.452	34.064	66.283	64.754
2000	14.924	10.905	29.501	1.576	24.168	12.968	68.162	67.381
2001	14.787	10.436	29.968	1.542	27.658	13.849	72.339	52.455
2002	17.844	10.662	34.371	1.583	27.371	53.722	77.950	69.086
2003	18.750	12.451	34.162	1.565	33.756	12.760	84.541	115.760
2004	16.935	12.090	31.730	1.498	42.099	13.124	87.242	130.556
2005	19.120	11.310	32.758	1.511	39.999	44.278	89.617	105.727
2006	18.322	12.106	33.459	1.512	41.548	18.579	90.664	94.477
2007	16.654	11.929	28.630	1.464	46.519	16.438	93.548	103.327
2008	17.339	10.317	27.858	1.563	43.799	9.228	91.509	113.082
2009	17.376	10.489	29.240	1.692	39.618	10.164	87.100	90.547
2010	16.617	10.894	29.296	1.727	35.654	27.706	83.455	80.501
2011	14.575	10.635	29.650	1.704	35.886	19.456	80.604	66.408
2012	13.294	10.254	28.470	1.658	39.642	9.346	80.824	60.697
2013	13.591	9.609	28.198	1.680	38.988	8.536	79.877	62.217
2014	13.855	9.612	27.348	1.762	35.257	5.431	76.480	113.135
2015	12.544	9.326	23.076	1.489	31.204	7.763	70.577	64.175
2016	9.217	7.166	16.990	1.050	22.661	14.274	54.262	60.958
2017	6.587	5.189	12.125	0.825	17.524	4.692	42.112	52.935
2018	4.988	3.670	9.078	0.756	13.647	8.229	33.517	28.805
2019	4.951	2.867	8.964	0.894	10.246	3.059	27.310	28.539
2020	5.248	3.259	10.038	1.068	9.508	3.347		
2021	5.765	3.639	11.506	1.029	8.339	6.638	26.465	28.476

Table 9e. Annual abundance estimates (million crab), mature male biomass (MMB, 1000 t), and total survey biomass (1000 t) for red king crab in Bristol Bay estimated by length-based model 22.1 during 1975-2021. MMB for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length.

Year (t)	Males				Females	Total Recruits	Total Survey Biomass	
	Mature (>119 mm)	Legal (>134mm)	MMB (>119 mm)	SD MMB	Mature (>89 mm)		Model Est. (>64 mm)	Area-Swept (>64 mm)
1975	56.764	28.767	85.536	8.397	53.666	NA	243.232	199.643
1976	66.218	36.302	101.388	7.997	79.498	64.993	283.276	327.615
1977	72.537	41.885	114.040	6.895	105.033	38.674	303.193	371.223
1978	77.648	46.521	120.081	5.442	109.015	60.888	303.434	343.189
1979	68.105	47.256	99.634	3.829	104.297	111.476	289.357	165.449
1980	49.669	37.493	29.831	1.549	106.280	146.788	272.931	247.226
1981	14.050	7.915	6.120	0.962	47.125	75.677	110.267	131.145
1982	6.403	2.038	6.107	0.835	21.138	237.345	63.003	141.898
1983	5.927	2.043	7.081	0.624	14.229	90.920	55.348	48.476
1984	6.107	2.221	5.127	0.421	13.977	64.019	48.994	152.607
1985	7.477	1.866	9.533	0.639	9.681	10.401	33.915	34.138
1986	11.991	4.599	14.772	0.967	13.682	29.876	44.624	47.434
1987	14.161	6.588	20.032	1.167	17.005	9.704	50.290	69.245
1988	14.255	8.343	24.721	1.224	21.384	6.235	53.714	54.597
1989	15.366	9.625	27.590	1.173	20.233	8.115	56.560	55.136
1990	14.860	10.324	23.781	1.101	18.103	20.705	56.741	59.451
1991	11.404	8.549	18.110	1.039	17.461	13.111	51.569	83.892
1992	9.153	6.362	16.926	1.013	18.616	3.146	46.872	37.334
1993	10.361	6.068	15.525	1.087	17.344	9.171	46.571	52.906
1994	10.204	5.921	21.358	1.195	14.798	3.070	42.106	32.104
1995	10.714	7.796	24.503	1.196	13.767	59.401	48.244	38.068
1996	11.012	8.447	23.005	1.142	19.859	8.874	57.078	43.959
1997	10.437	7.692	21.723	1.123	29.107	4.566	63.193	84.030
1998	15.741	7.642	24.567	1.331	25.630	12.867	67.462	84.101
1999	16.789	9.635	28.280	1.477	21.765	34.077	66.295	64.754
2000	14.469	10.538	28.491	1.469	23.307	12.641	67.819	67.381
2001	14.322	10.094	28.925	1.433	26.493	13.592	71.588	52.455
2002	17.232	10.311	33.090	1.453	25.830	53.030	77.005	69.086
2003	18.055	12.003	32.676	1.420	31.831	11.896	83.094	115.760
2004	16.270	11.581	30.209	1.343	39.448	12.333	84.896	130.556
2005	18.201	10.800	30.833	1.313	36.675	41.187	86.417	105.727
2006	17.324	11.423	31.258	1.280	37.500	16.443	86.245	94.477
2007	15.638	11.182	26.295	1.204	41.324	14.034	87.633	103.327
2008	15.911	9.515	24.824	1.224	37.986	7.804	83.955	113.082
2009	15.570	9.396	25.375	1.258	33.537	8.225	78.047	90.547
2010	14.492	9.511	24.626	1.209	29.441	22.179	73.063	80.501
2011	12.361	8.991	24.497	1.134	28.815	14.223	68.598	66.408
2012	11.072	8.517	23.061	1.054	30.840	6.973	67.069	60.697
2013	11.014	7.820	22.094	0.992	29.404	5.919	64.543	62.217
2014	10.805	7.559	20.244	0.949	25.975	3.624	59.947	113.135
2015	9.284	6.934	17.326	0.917	22.390	5.182	53.214	64.175
2016	7.489	5.840	14.263	0.903	19.013	11.244	46.559	60.958
2017	6.005	4.726	11.763	0.898	17.172	4.230	41.589	52.935
2018	5.276	3.860	10.584	0.913	15.596	8.732	38.581	28.805
2019	6.244	3.620	11.838	1.082	13.706	3.653	37.001	28.539
2020	6.818	4.284	13.591	1.272	12.330	4.146		
2021	7.552	4.885	14.852	1.155	10.470	7.816	35.701	28.476

Table 10a. Comparison of projected mature male biomass (1000 t) on Feb. 15 and their 95% limits with four levels of fishing mortality during 2021-2031. Parameter estimates with model 21.1b are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 21.1b for 2021 is 0.173 and MSST is 12162 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	16.730	14.353	19.219	15.759	13.528	18.110
2022	18.719	16.026	21.302	16.698	14.311	19.023
2023	19.819	16.915	22.889	16.839	14.375	19.600
2024	21.124	17.563	25.008	17.210	14.203	20.734
2025	21.984	18.111	26.964	17.478	14.113	21.782
2026	22.753	18.220	28.619	17.616	13.680	22.795
2027	23.463	18.180	30.102	17.660	13.255	23.385
2028	23.979	18.229	31.340	17.771	12.951	23.859
2029	24.305	18.151	32.063	17.776	12.802	24.040
2030	24.717	18.602	32.662	17.881	12.894	24.216
2031	25.065	18.828	33.101	17.892	12.913	24.302

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	14.867	12.740	17.067	14.056	12.007	16.101
2022	14.994	12.834	17.110	13.474	11.499	15.364
2023	14.457	12.298	16.892	12.481	10.587	14.670
2024	14.270	11.644	17.287	11.986	9.699	14.725
2025	14.147	11.168	17.986	11.681	8.968	15.306
2026	13.973	10.575	18.581	11.388	8.350	15.564
2027	13.871	10.048	18.814	11.205	7.868	15.820
2028	13.770	9.645	19.082	11.083	7.459	15.728
2029	13.653	9.492	18.990	10.950	7.374	15.612
2030	13.684	9.498	18.896	10.986	7.431	15.549
2031	13.682	9.449	19.042	10.994	7.331	15.664

Table 10b. Comparison of projected mature male biomass (1000 t) on Feb. 15 and their 95% limits with four levels of fishing mortality during 2021-2031. Parameter estimates with model 22.0 are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 22.0 for 2021 is 0.200 and MSST is 11070 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	17.056	14.515	20.058	16.081	13.692	18.919
2022	19.136	16.353	22.574	17.097	14.576	20.201
2023	20.130	17.029	23.836	17.135	14.407	20.356
2024	21.169	17.459	25.416	17.257	14.105	20.845
2025	21.902	17.410	27.578	17.279	13.524	22.391
2026	22.595	17.443	29.649	17.383	12.978	23.692
2027	23.311	17.441	31.536	17.539	12.692	24.837
2028	23.788	17.516	32.773	17.601	12.442	25.316
2029	24.176	17.448	33.974	17.626	12.173	26.004
2030	24.750	17.532	34.674	17.825	12.079	25.721
2031	25.249	17.591	34.935	18.075	12.125	25.883

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	15.182	12.899	17.853	14.322	12.167	16.863
2022	15.342	13.052	18.093	13.814	11.716	16.299
2023	14.707	12.296	17.529	12.688	10.552	15.167
2024	14.245	11.451	17.533	11.922	9.433	14.880
2025	13.927	10.593	18.525	11.468	8.430	15.666
2026	13.815	9.895	19.433	11.247	7.801	16.401
2027	13.704	9.511	20.085	11.020	7.390	16.851
2028	13.590	9.322	20.335	10.890	7.148	16.863
2029	13.554	8.953	20.589	10.882	6.911	16.974
2030	13.651	8.946	20.210	10.928	6.940	16.816
2031	13.752	8.830	20.404	11.085	6.800	16.848

Table 10c. Comparison of projected mature male biomass (1000 t) on Feb. 15 and their 95% limits with four levels of fishing mortality during 2021-2031. Parameter estimates with model 22.0d are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 22.0d for 2021 is 0.191 and MSST is 11036 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	17.056	14.515	20.058	16.081	13.692	18.919
2022	19.136	16.353	22.574	17.097	14.576	20.201
2023	20.130	17.029	23.836	17.135	14.407	20.356
2024	21.169	17.459	25.416	17.257	14.105	20.845
2025	21.902	17.410	27.578	17.279	13.524	22.391
2026	22.595	17.443	29.649	17.383	12.978	23.692
2027	23.311	17.441	31.536	17.539	12.692	24.837
2028	23.788	17.516	32.773	17.601	12.442	25.316
2029	24.176	17.448	33.974	17.626	12.173	26.004
2030	24.750	17.532	34.674	17.825	12.079	25.721
2031	25.249	17.591	34.935	18.075	12.125	25.883

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	15.182	12.899	17.853	14.322	12.167	16.863
2022	15.342	13.052	18.093	13.814	11.716	16.299
2023	14.707	12.296	17.529	12.688	10.552	15.167
2024	14.245	11.451	17.533	11.922	9.433	14.880
2025	13.927	10.593	18.525	11.468	8.430	15.666
2026	13.815	9.895	19.433	11.247	7.801	16.401
2027	13.704	9.511	20.085	11.020	7.390	16.851
2028	13.590	9.322	20.335	10.890	7.148	16.863
2029	13.554	8.953	20.589	10.882	6.911	16.974
2030	13.651	8.946	20.210	10.928	6.940	16.816
2031	13.752	8.830	20.404	11.085	6.800	16.848

Table 10d. Comparison of projected mature male biomass (1000 t) on Feb. 15 and their 95% limits with four levels of fishing mortality during 2021-2031. Parameter estimates with model 22.1 are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 22.1 for 2021 is 0.184 and MSST is 11189 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	16.633	14.163	19.102	15.694	13.342	17.979
2022	18.809	15.993	21.700	16.828	14.317	19.466
2023	20.154	17.117	23.338	17.201	14.572	20.006
2024	21.568	17.946	25.622	17.771	14.504	21.343
2025	22.714	18.190	27.698	18.132	14.174	22.497
2026	23.576	18.455	29.882	18.215	14.030	23.783
2027	24.096	18.389	31.751	18.246	13.571	24.727
2028	24.593	18.441	32.849	18.142	13.256	25.231
2029	24.933	18.386	33.528	18.201	12.977	25.269
2030	25.373	18.592	33.583	18.306	12.865	25.359
2031	25.715	18.761	34.679	18.413	12.796	25.530

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	14.815	12.593	16.956	13.992	11.895	15.997
2022	15.096	12.900	17.484	13.585	11.594	15.714
2023	14.773	12.465	17.253	12.782	10.732	14.970
2024	14.794	11.908	17.938	12.495	9.922	15.368
2025	14.729	11.331	18.678	12.180	9.182	15.780
2026	14.525	10.901	19.456	11.920	8.629	16.351
2027	14.258	10.360	20.167	11.571	8.101	16.868
2028	14.084	9.982	20.204	11.356	7.790	16.726
2029	13.956	9.635	19.975	11.220	7.536	16.478
2030	13.998	9.491	19.923	11.237	7.408	16.413
2031	14.003	9.318	20.088	11.263	7.299	16.474

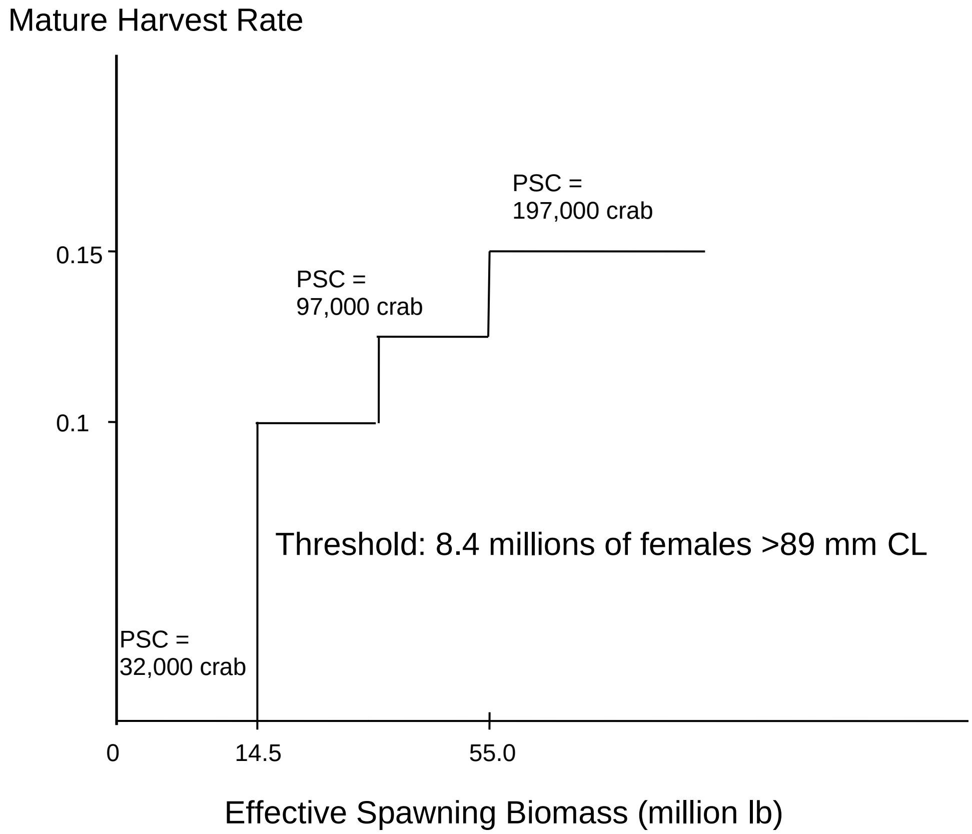


Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crab) of Bristol Bay red king crab in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of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

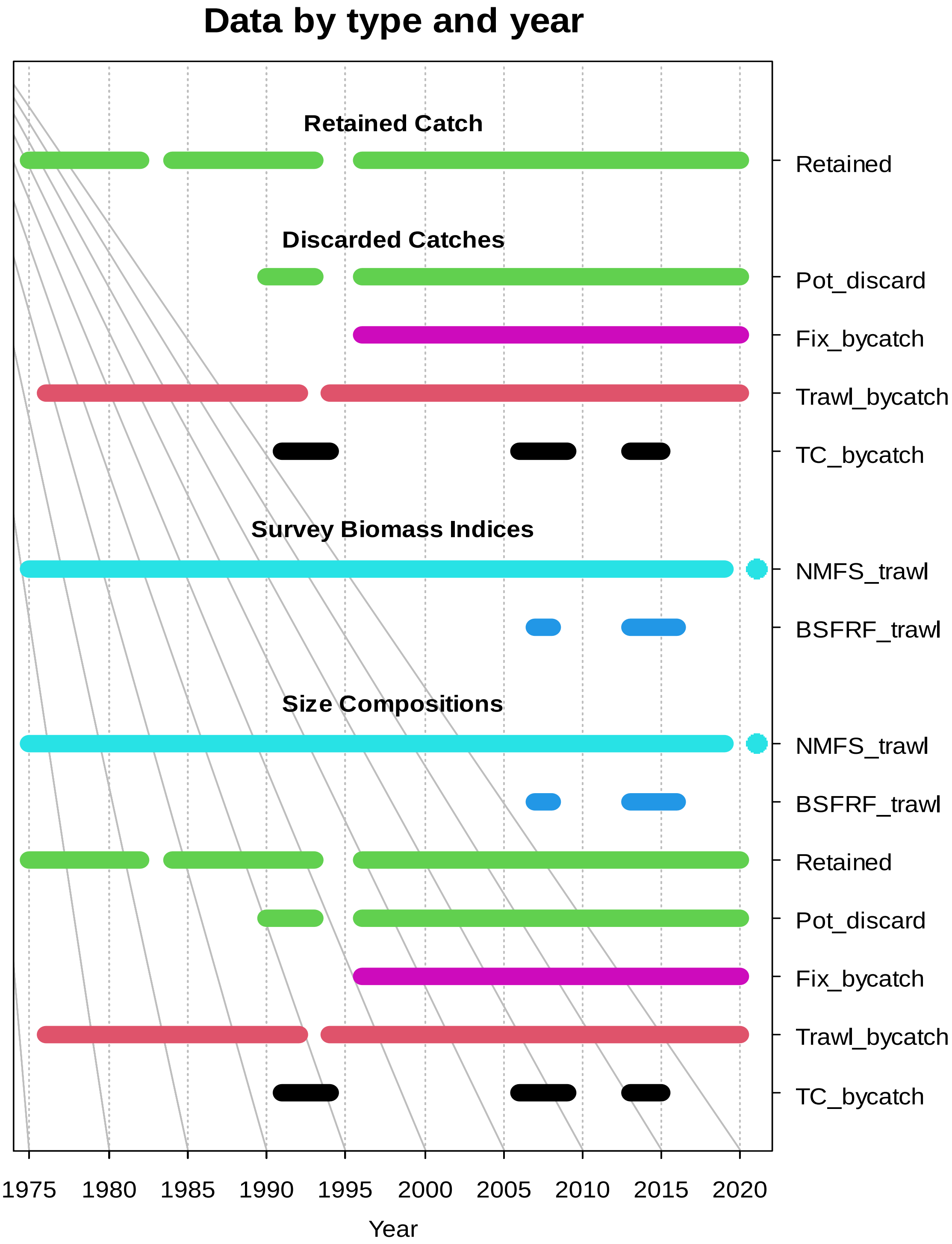


Figure 2. Data types and ranges used for the stock assessment.

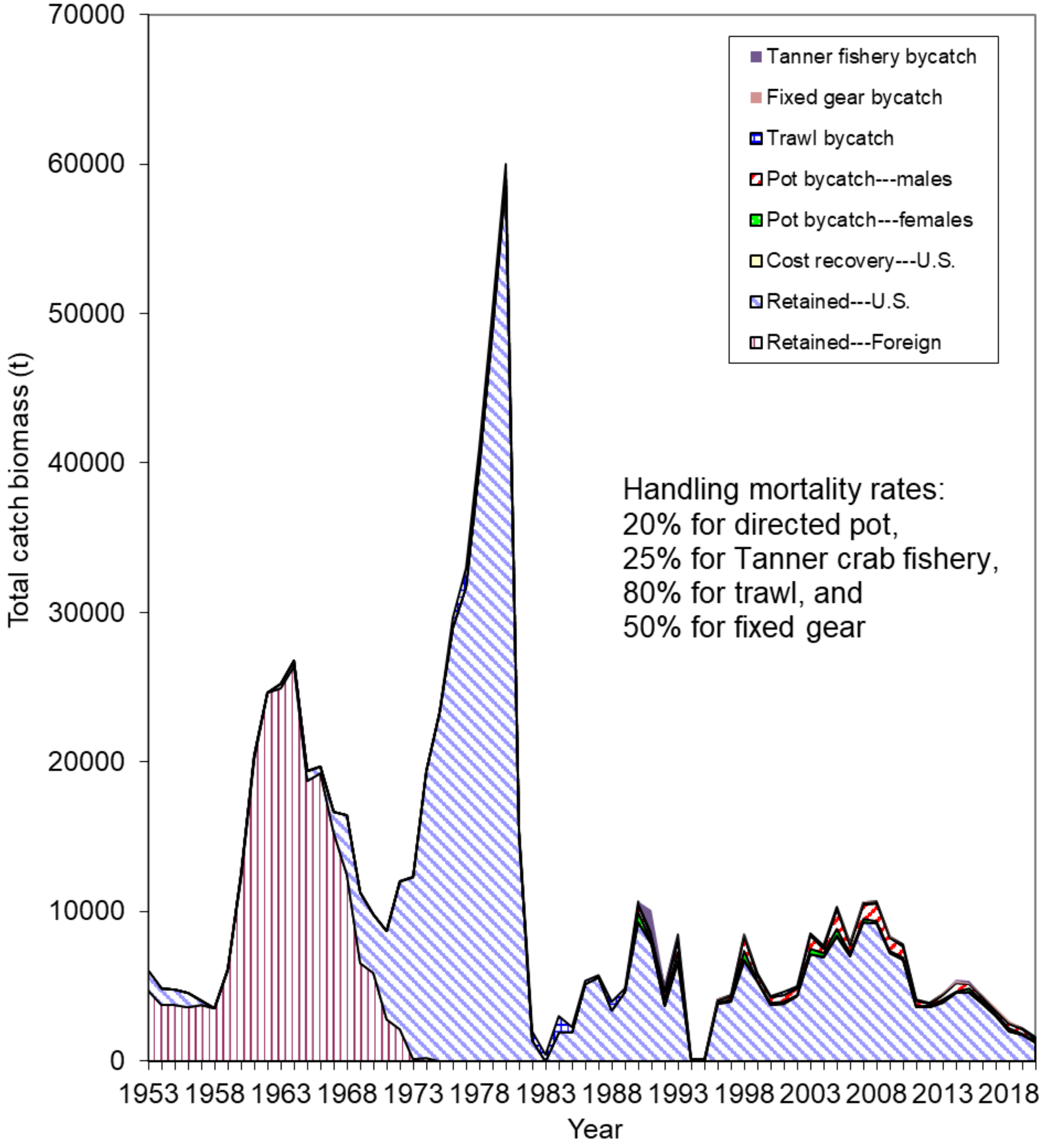


Figure 3. Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1953 to 2020. Directed pot bycatch data were not available from the observer program before 1990 and are not included in this figure.

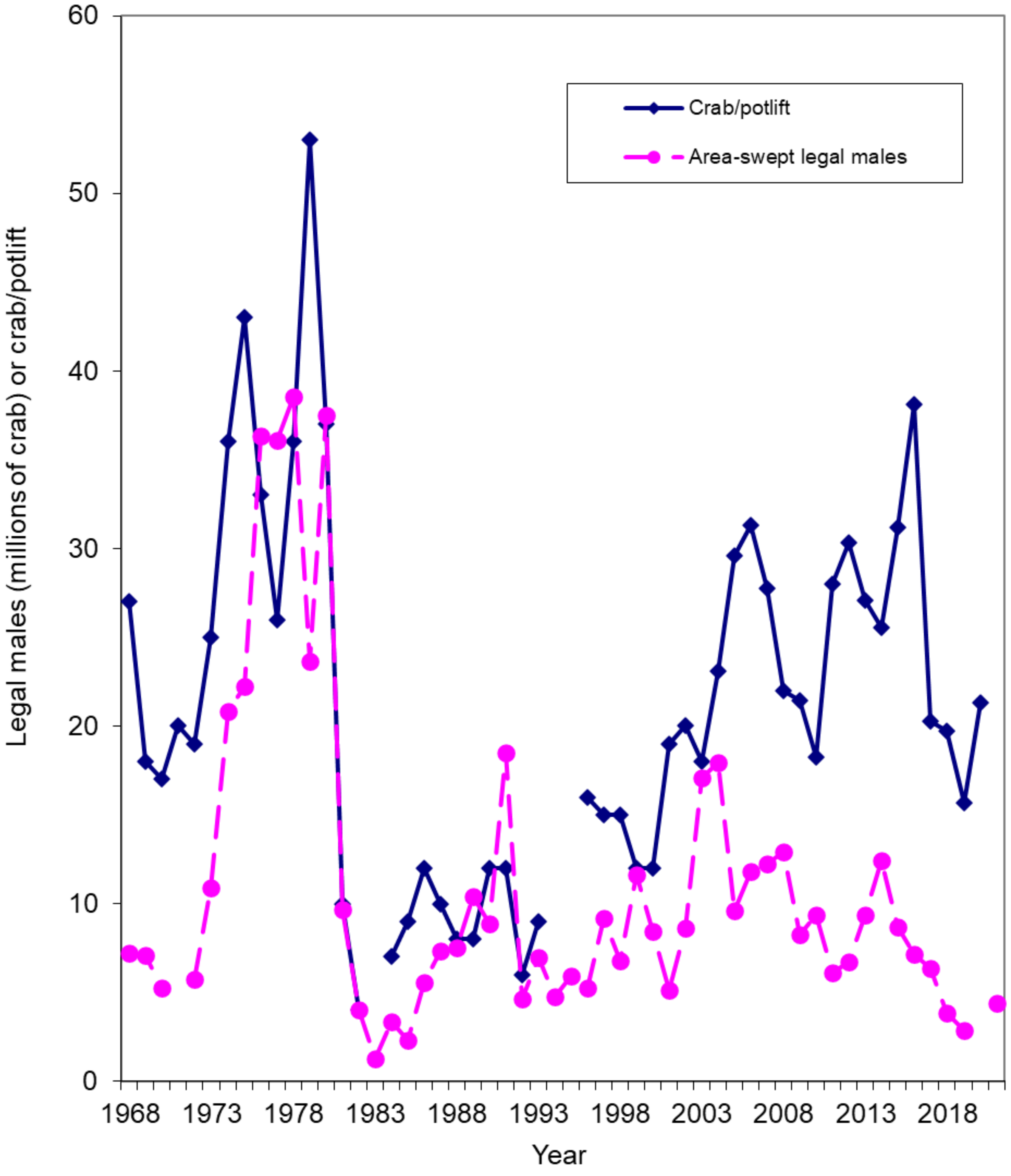


Figure 4. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2021.

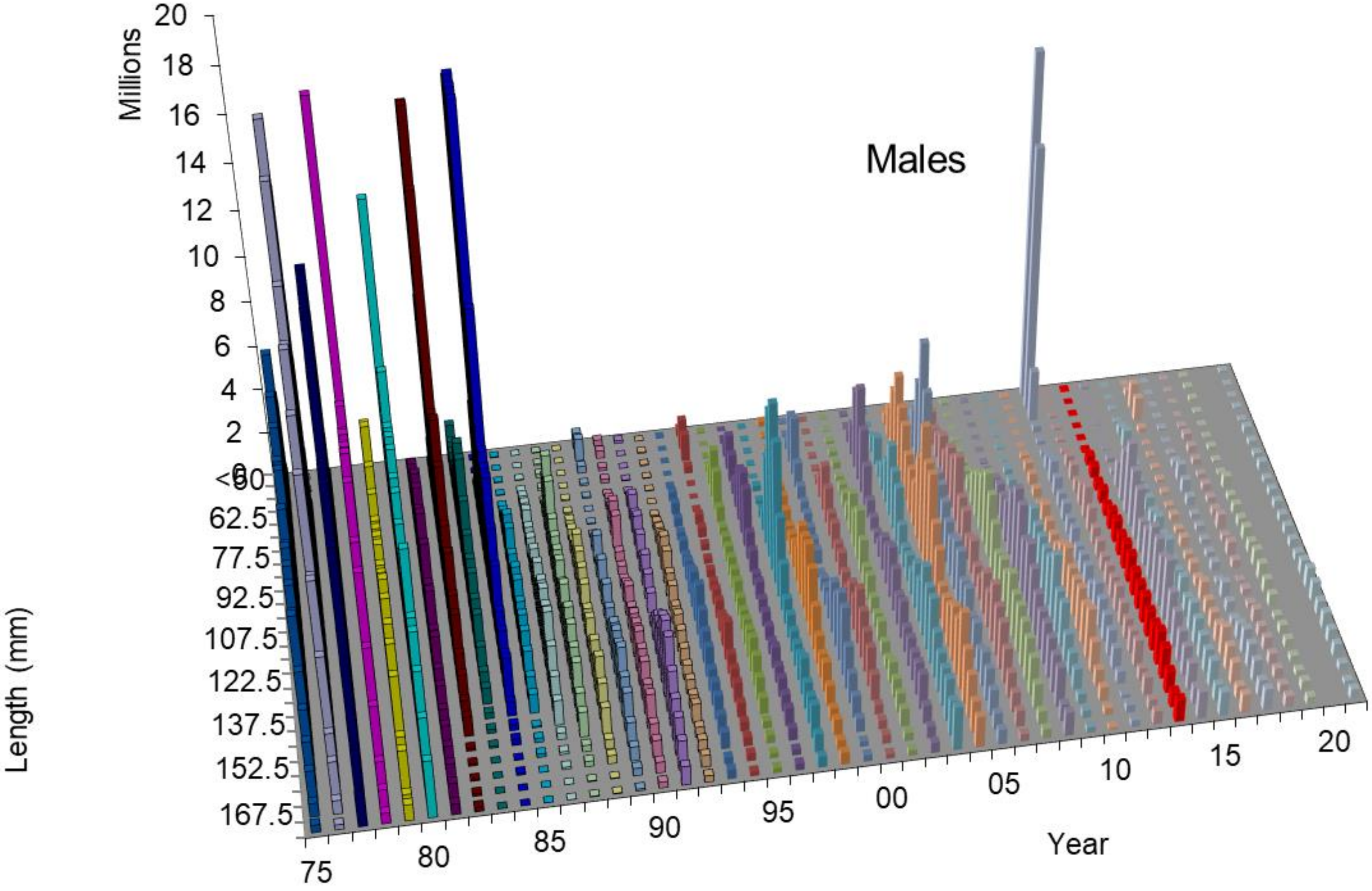


Figure 5a. Survey abundances by 5-mm carapace length bin for male Bristol Bay red king crab from 1975 to 2021.

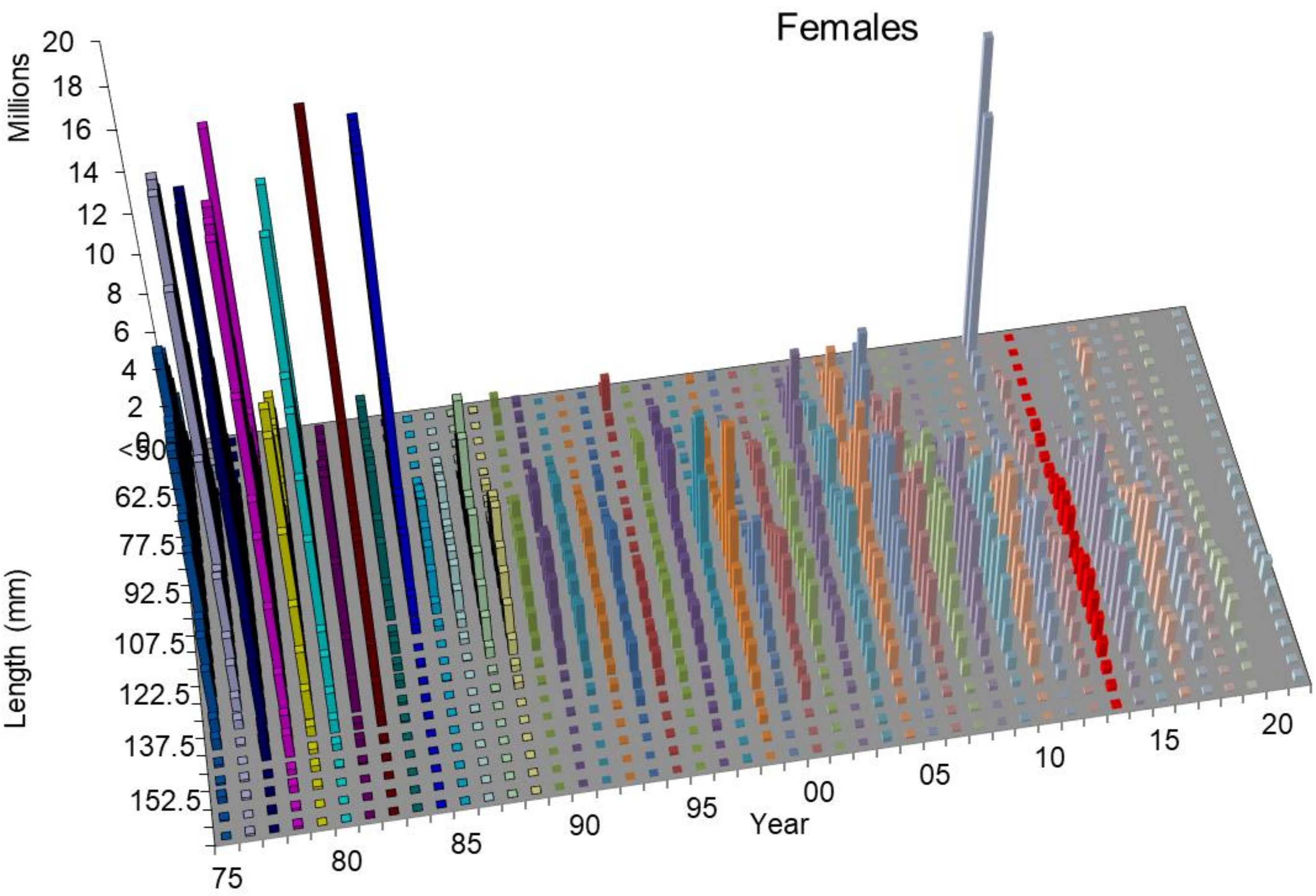


Figure 5b. Survey abundances by 5 mm carapace length bin for female Bristol Bay red king crab from 1975 to 2021.

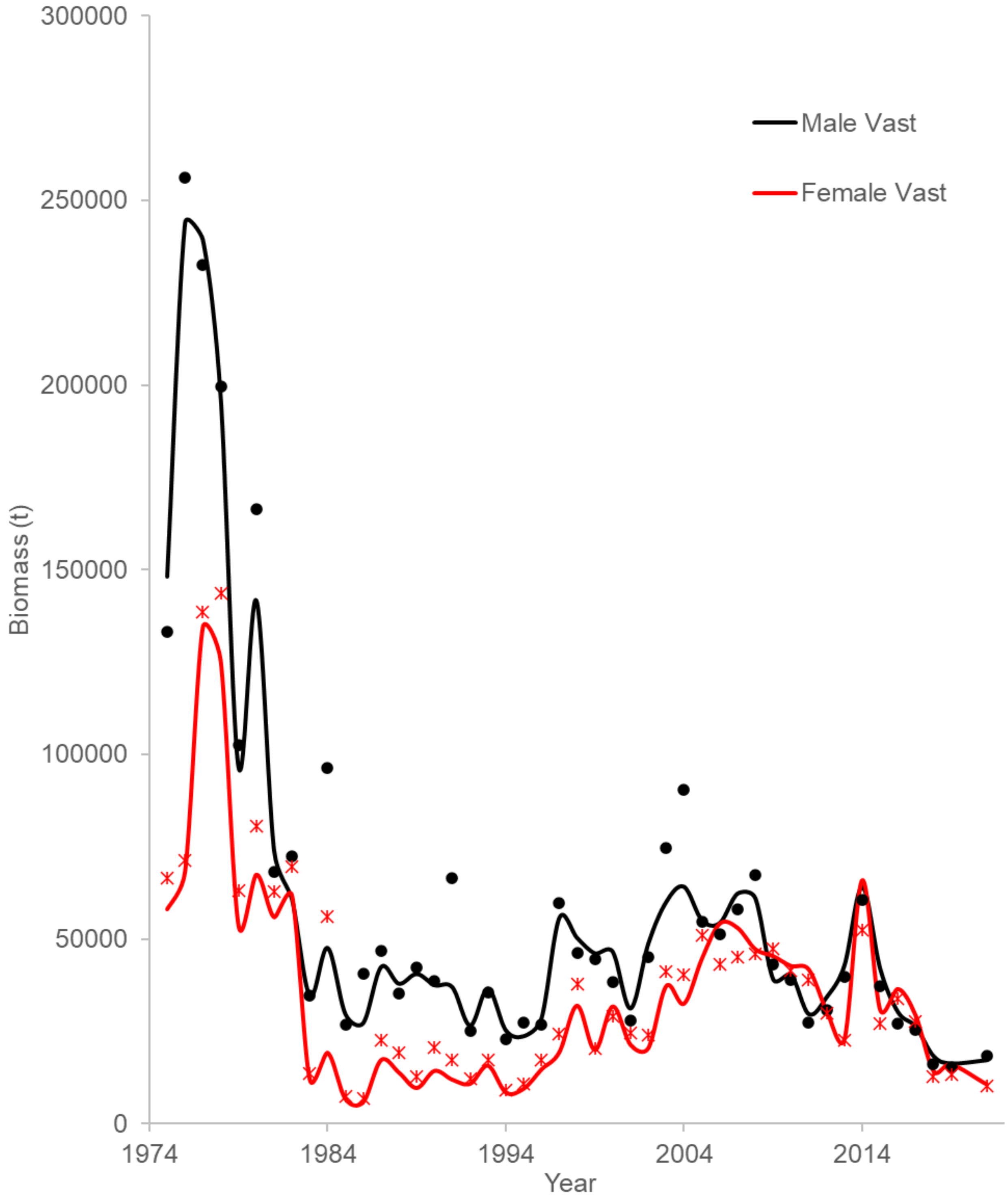


Figure 6. Comparison of area-swept and VAST-estimated survey biomasses for Bristol Bay red king crab from 1975 to 2021.

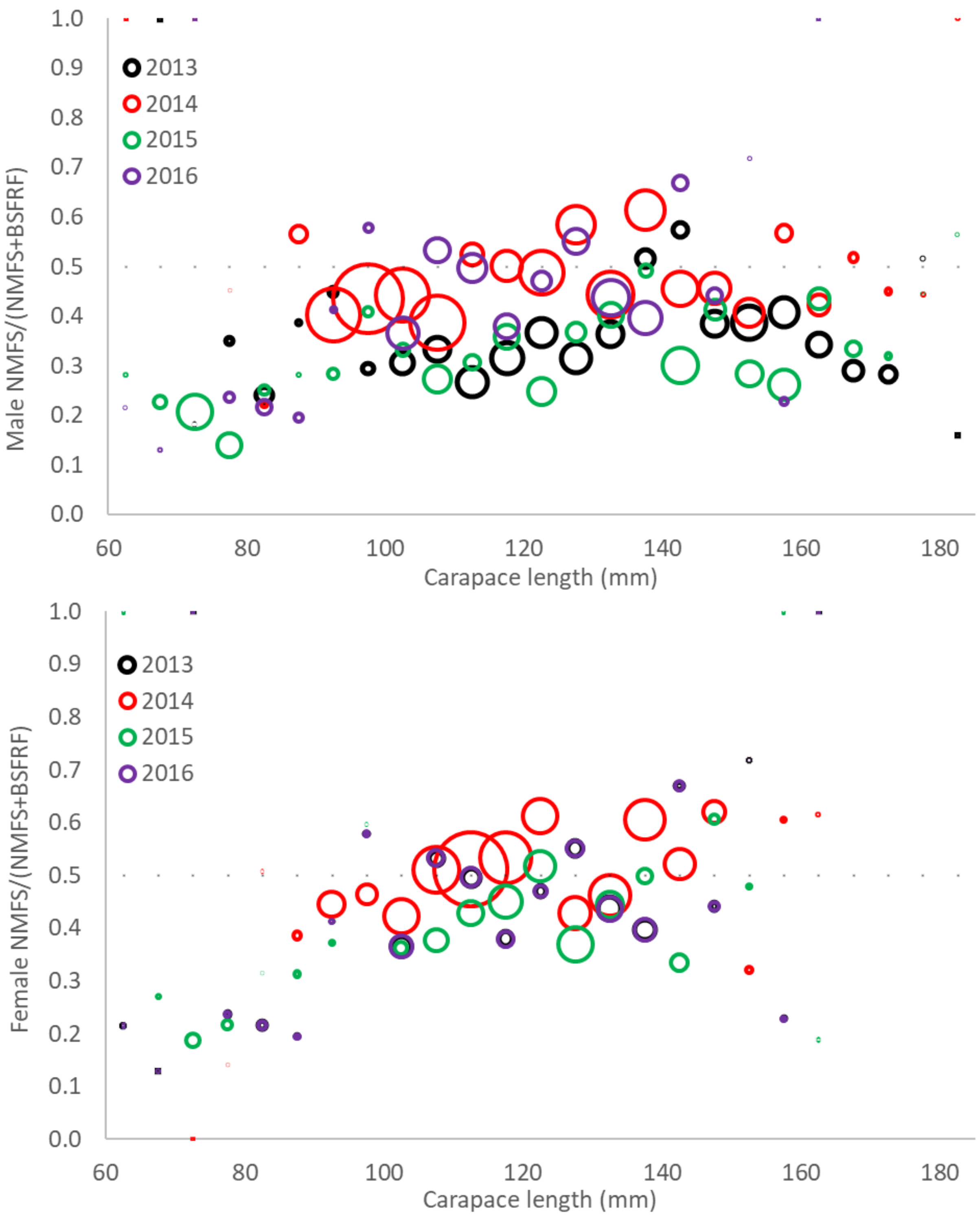


Figure 7a. Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

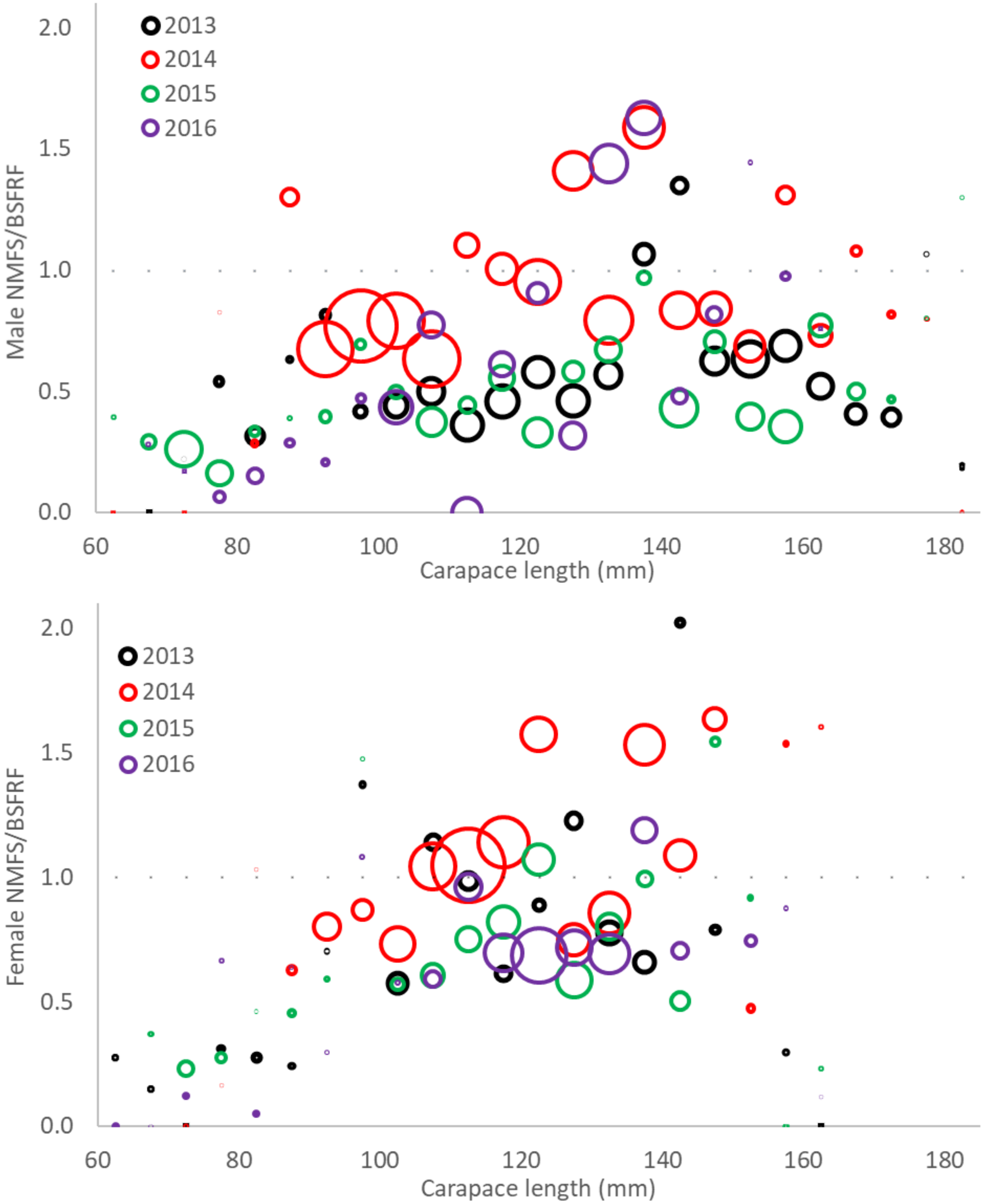


Figure 7b. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

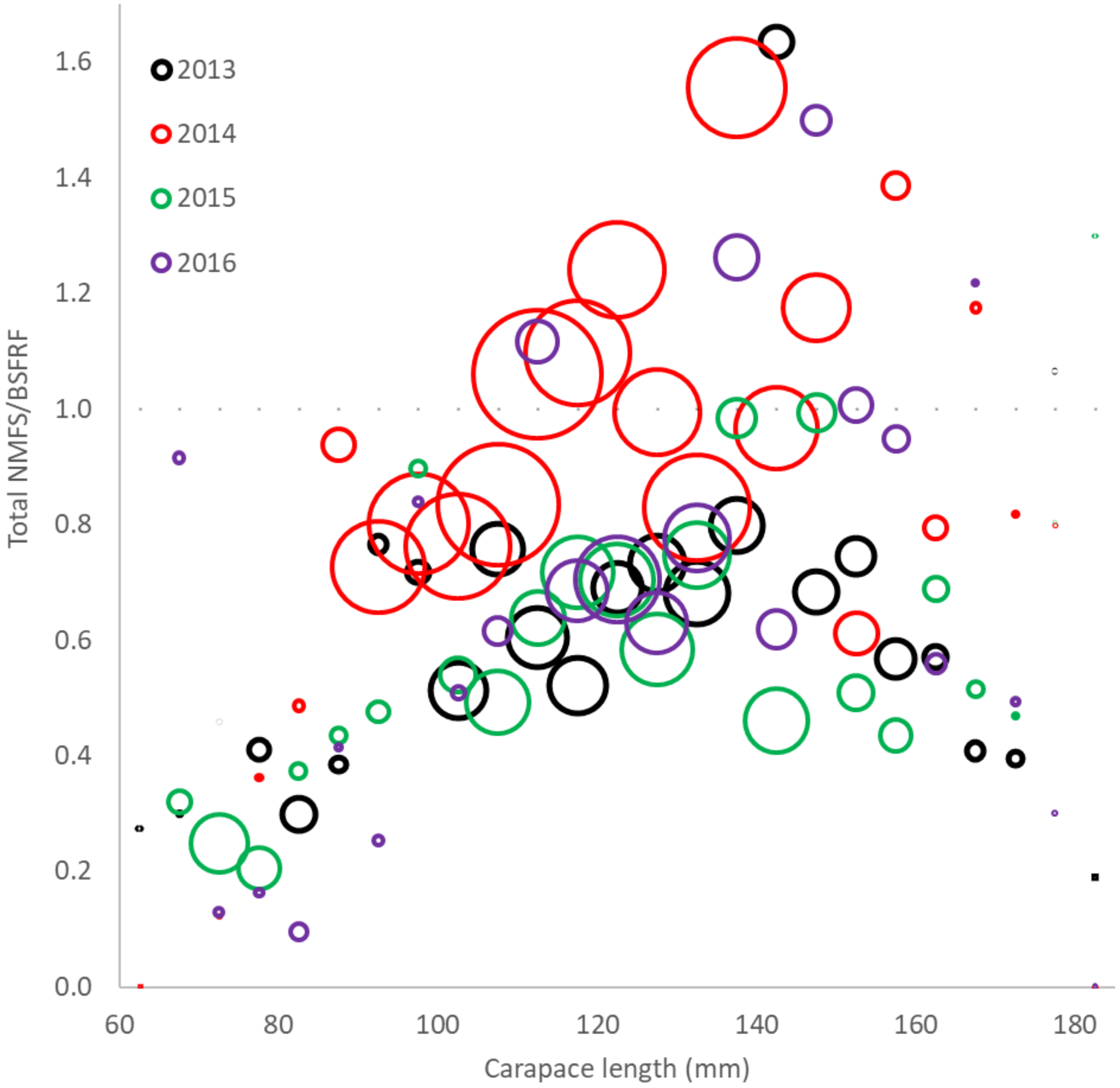


Figure 7c. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances. The abundance-weighted average ratio is 0.891 for crab ≥135 mm carapace length from all four years of data. The approach to compute this overall ratio is documented in section D. Data, 4. Bering Sea Fisheries Research Foundation Survey Data.

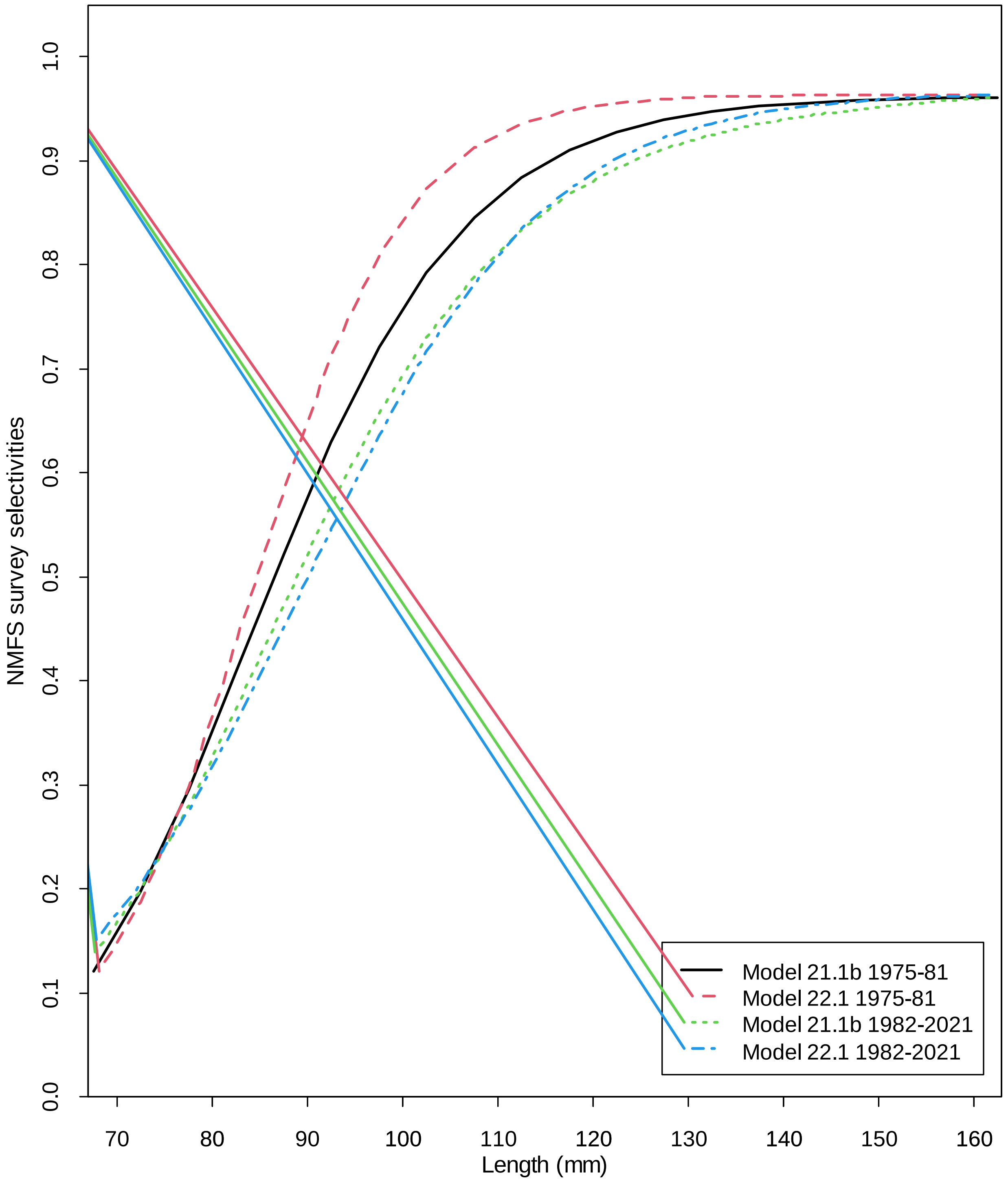


Figure 8a. Estimated NMFS trawl survey selectivities under models 21.1b and 22.1.

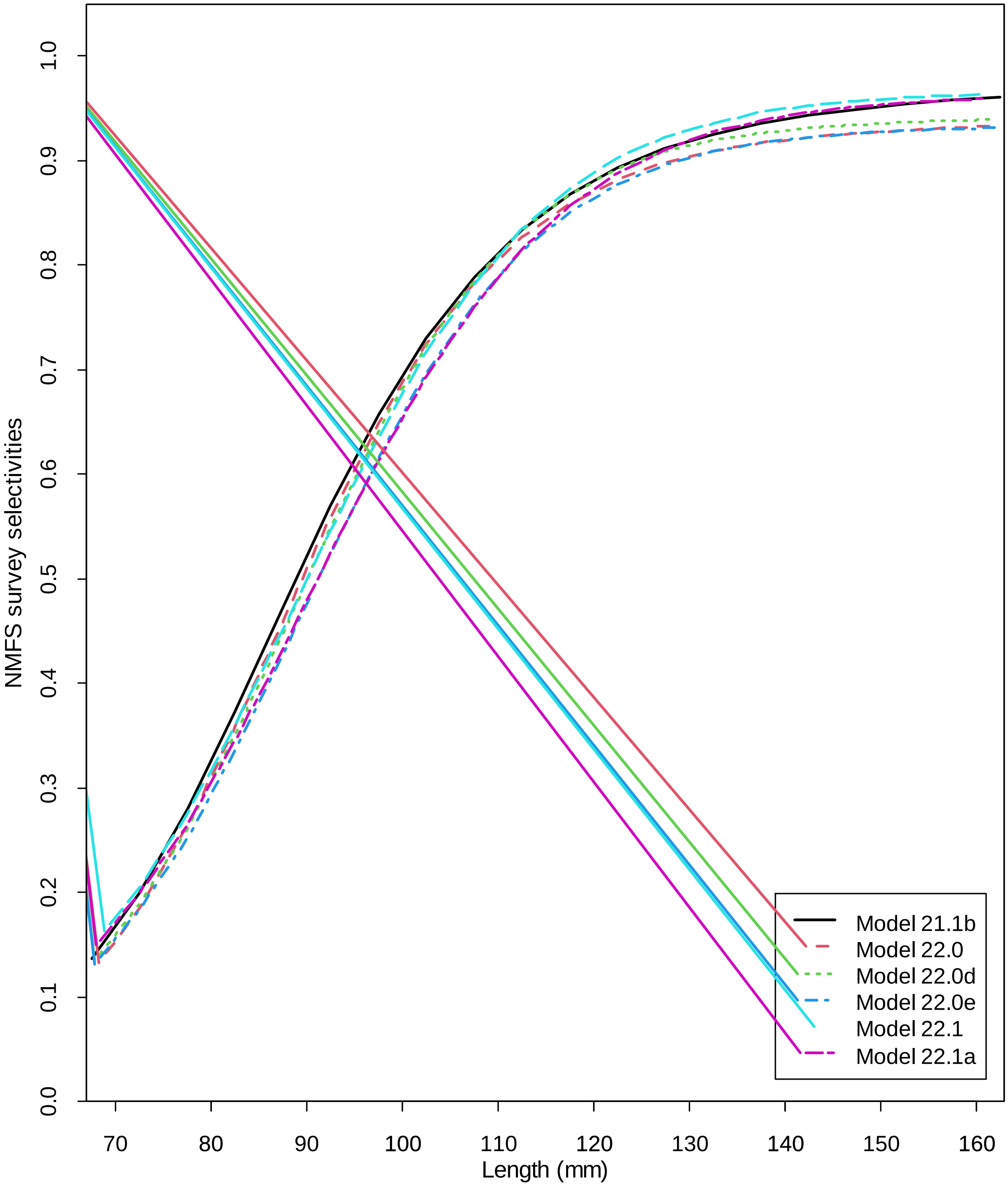


Figure 8b. Comparisons of estimated NMFS trawl survey selectivities with models 21.1b, 22.0, 22.0d, 22.0e, 22.1, and 22.1a during 1982-2021.

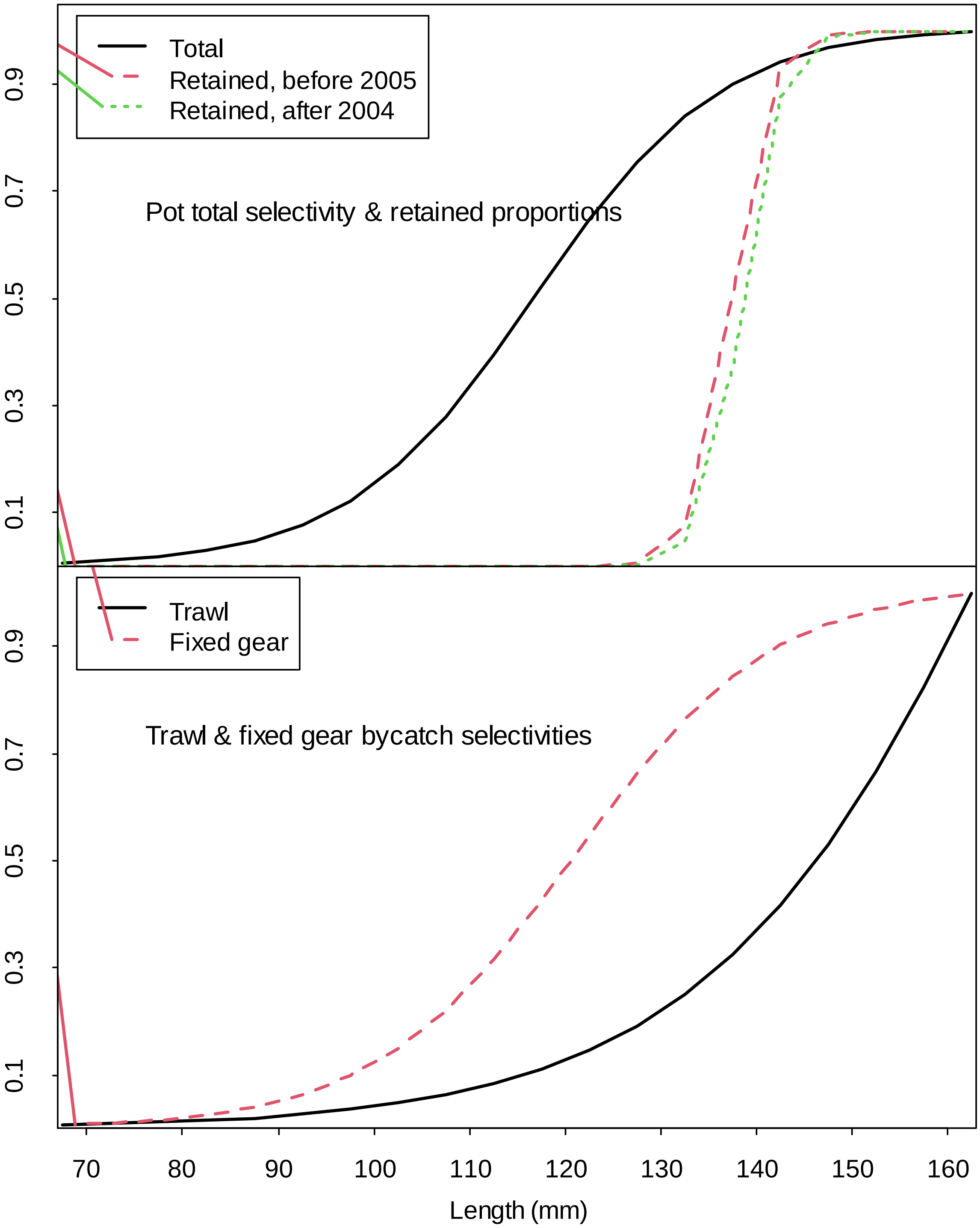


Figure 8c. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 21.1b.

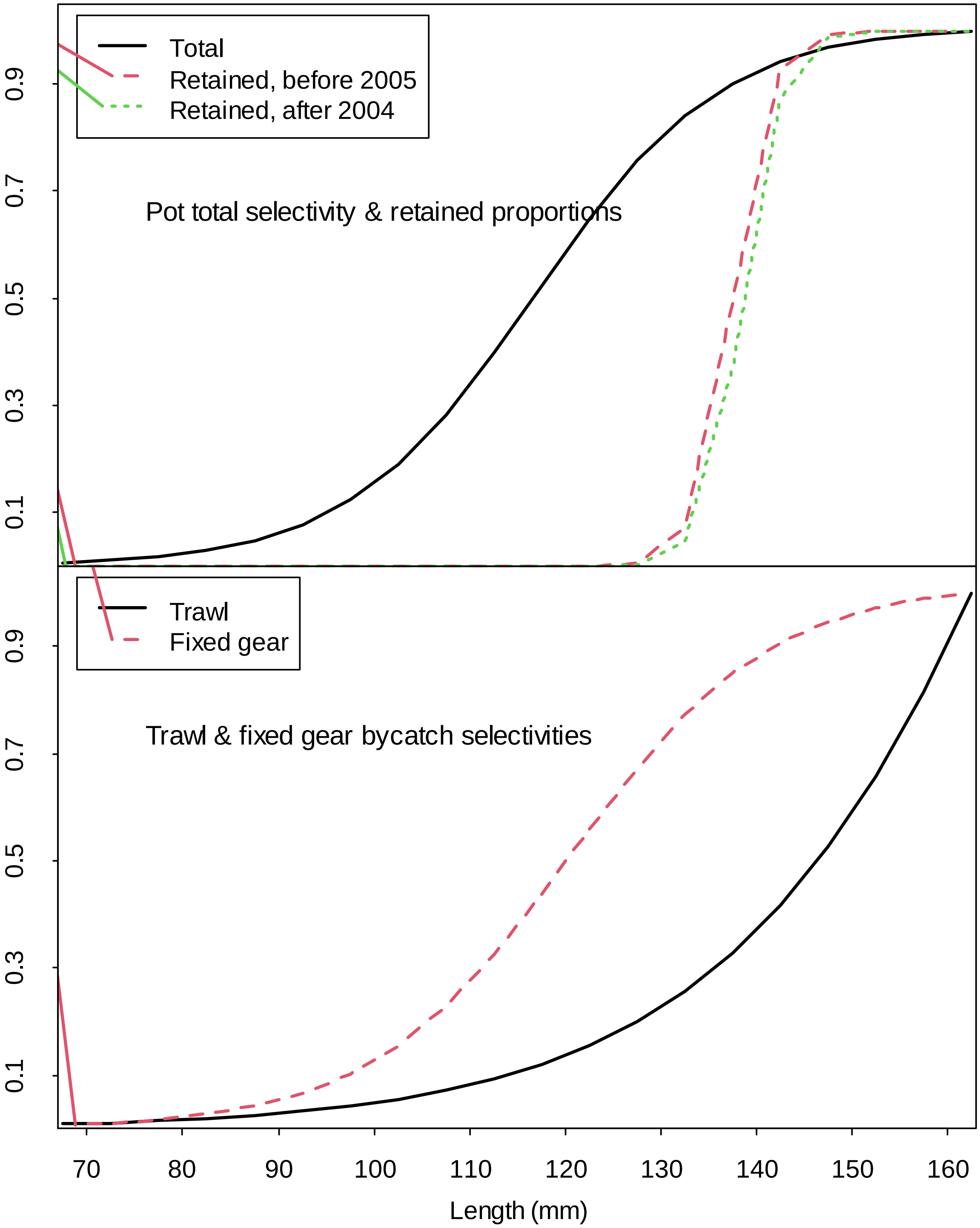


Figure 8d. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 22.0.

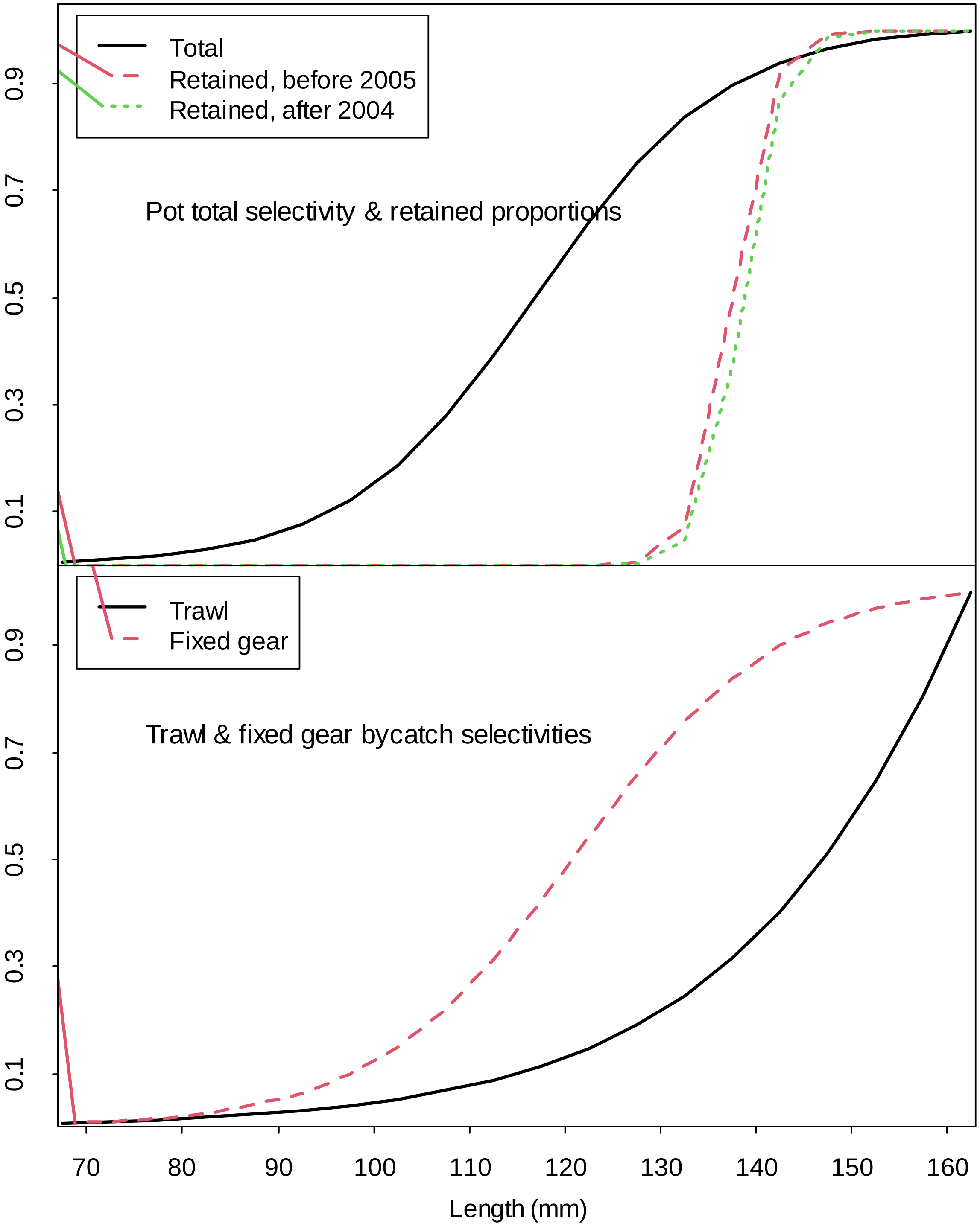


Figure 8e. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 22.0d.

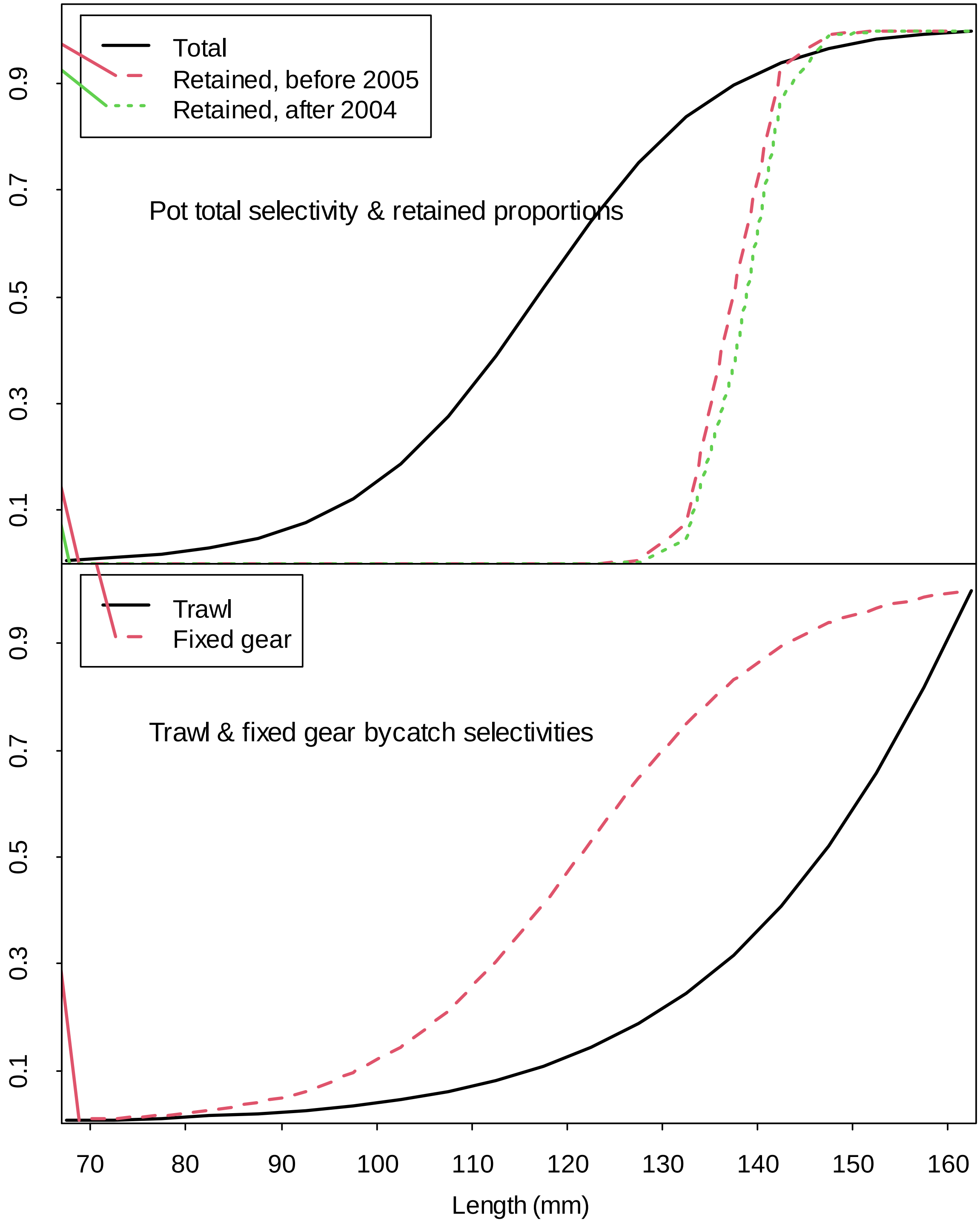


Figure 8f. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 22.1.

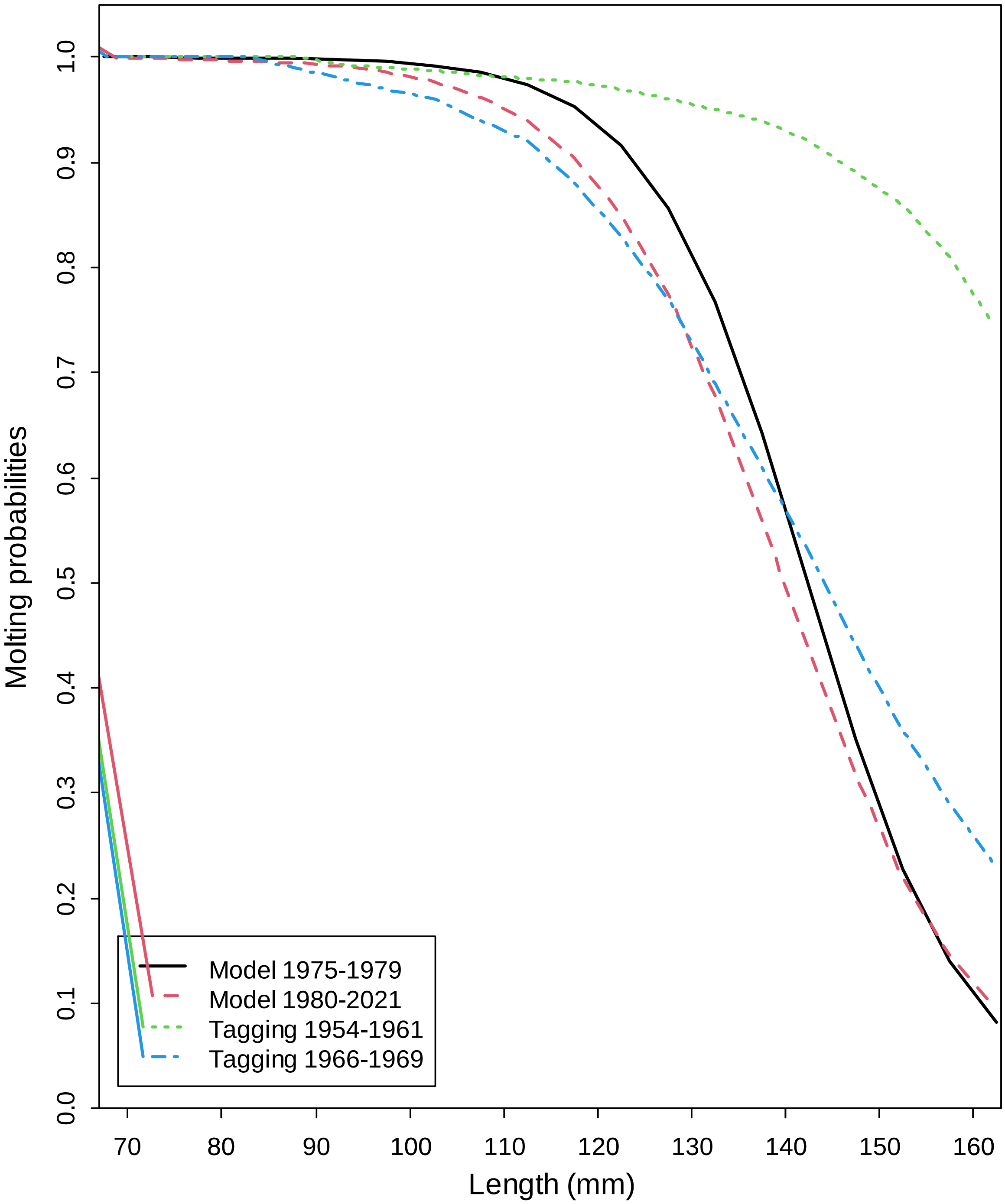


Figure 9a. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 21.1b. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2021 were estimated with a length-based model.

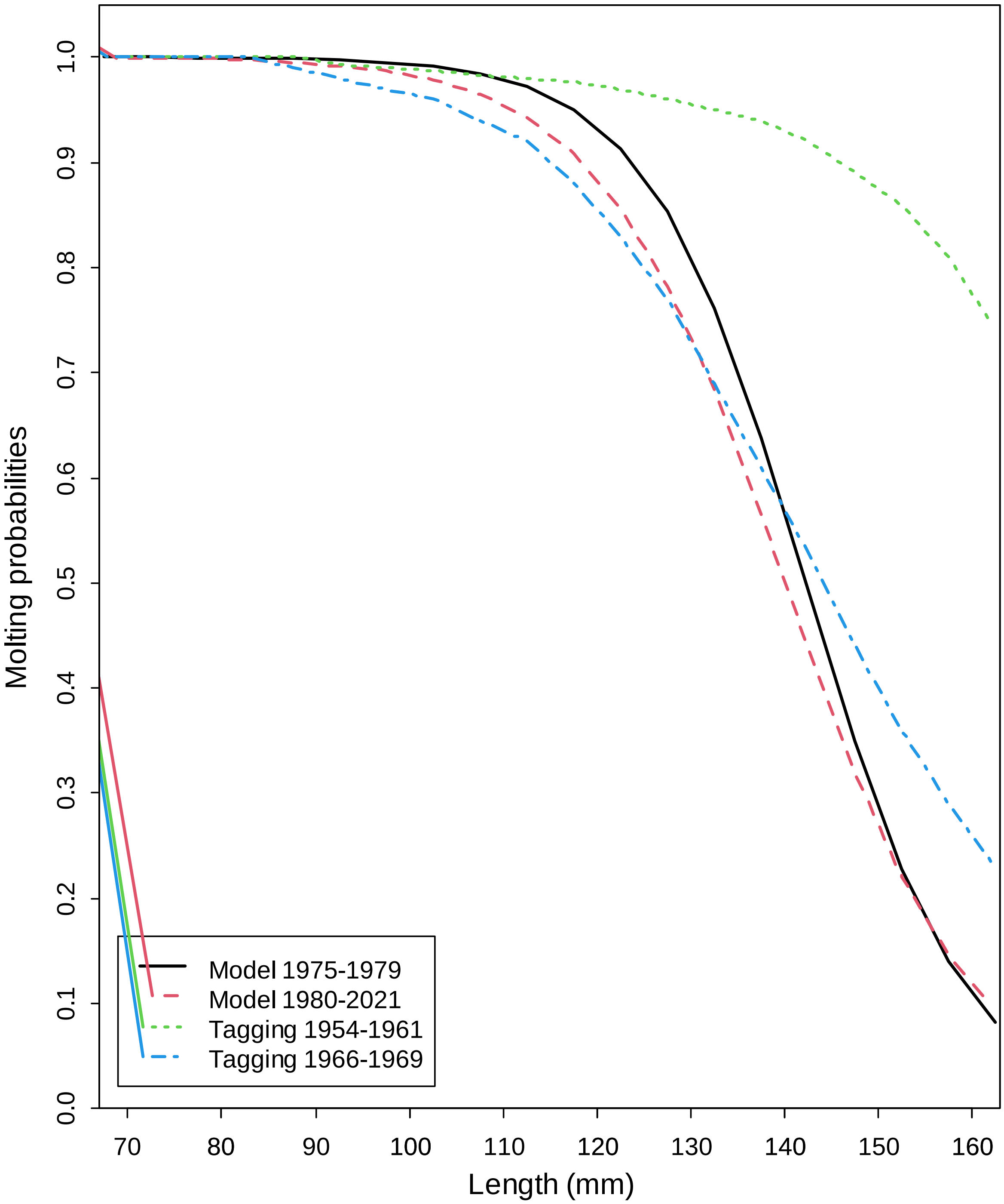


Figure 9b. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 22.1. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2021 were estimated with a length-based model.

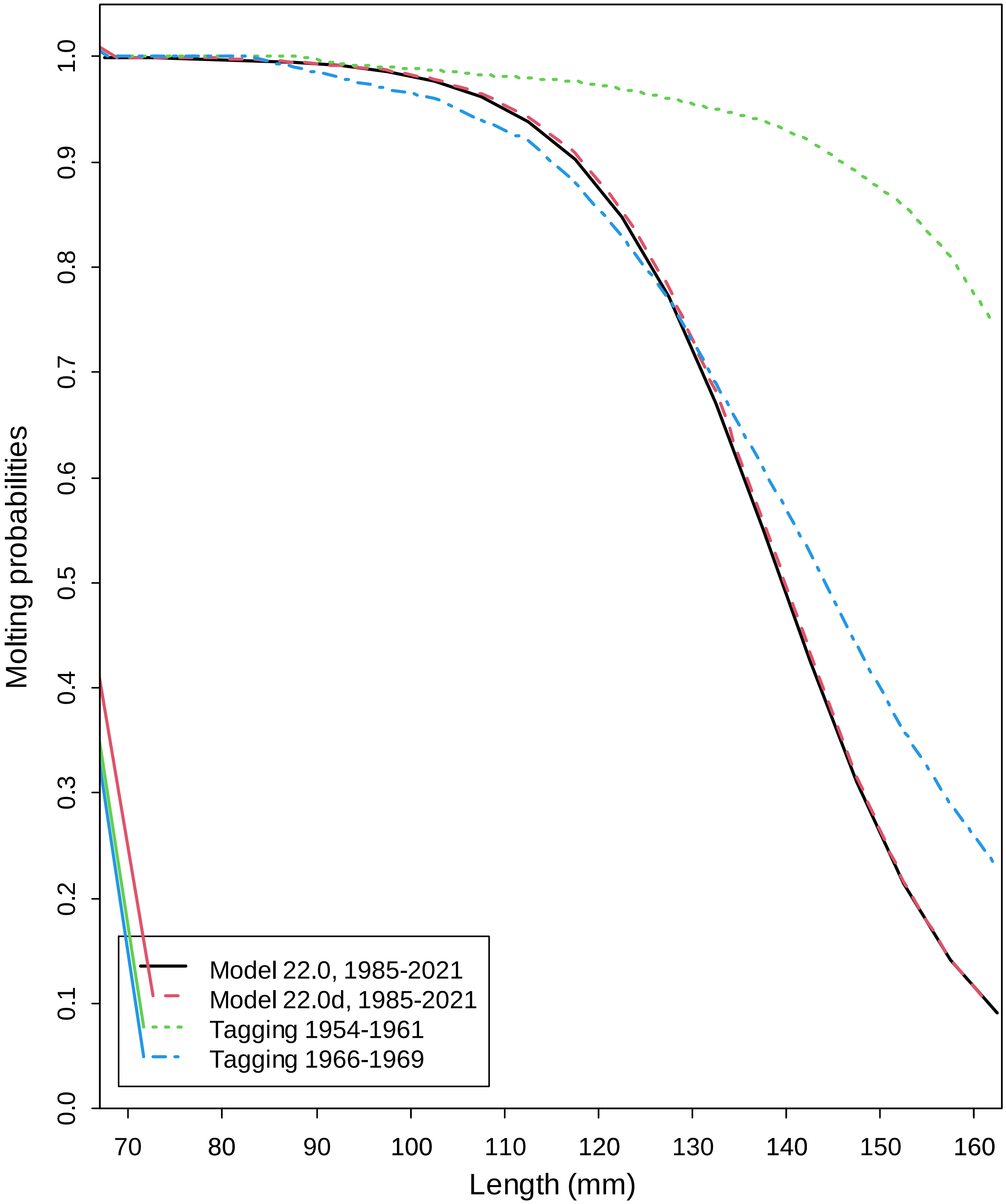


Figure 9c. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with models 22.0 and 22.0d during 1985-2021. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data.

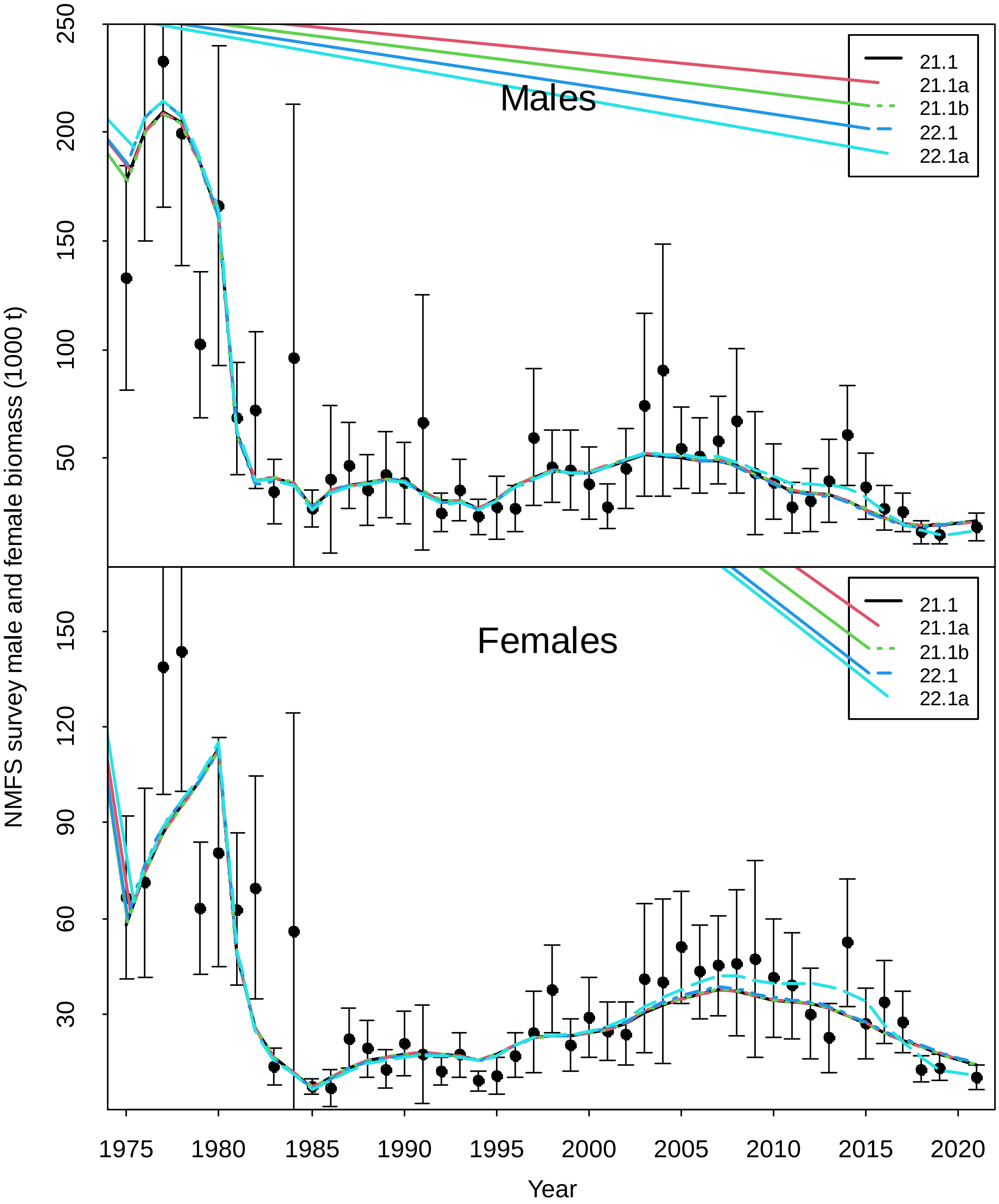


Figure 10a. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2021 under models 21.1, 21.1a, 21.1b, 22.1, and 22.1a. The error bars are plus and minus 2 standard deviations of model 21.1b.

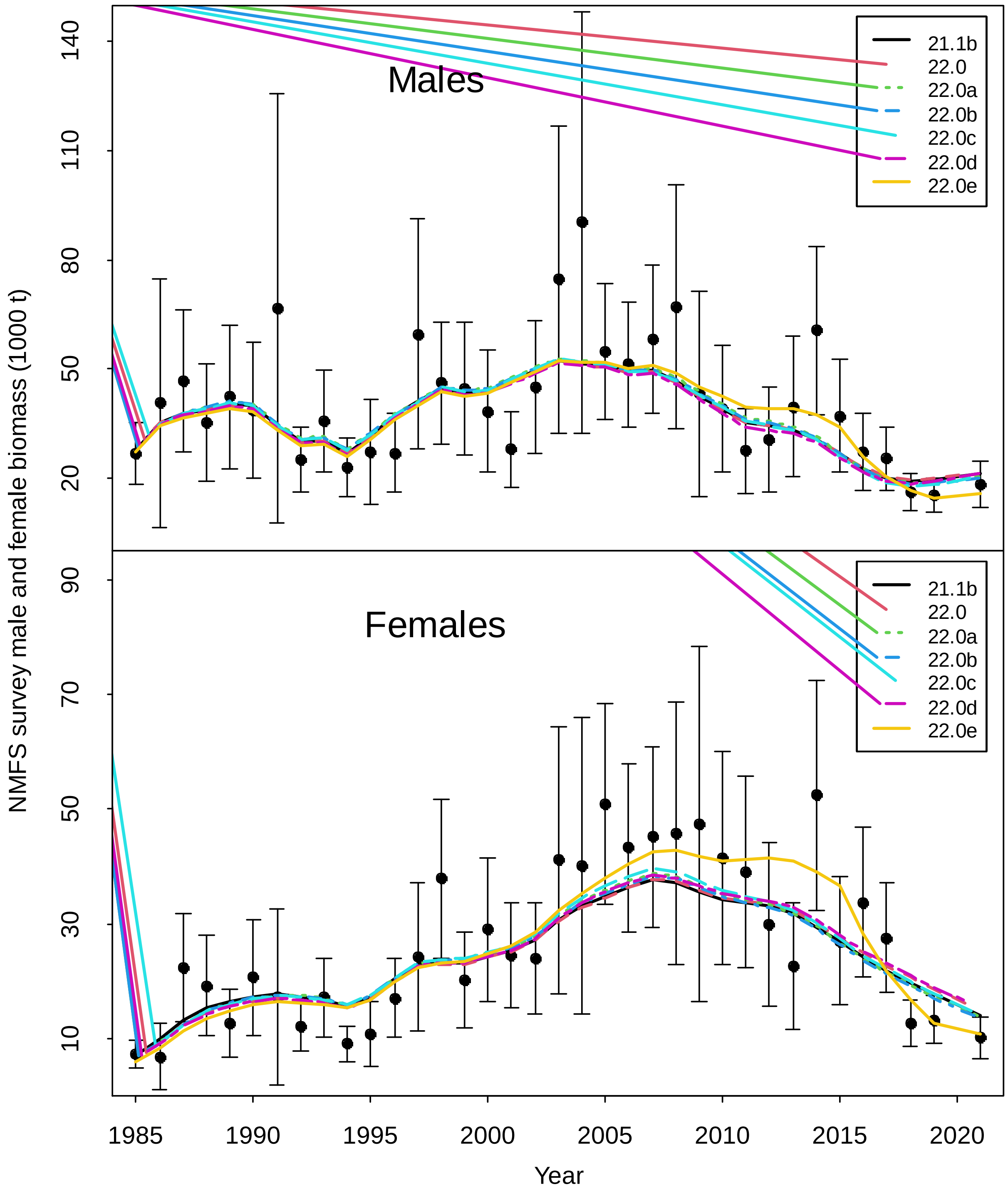


Figure 10b. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2021 under models 21.1b, 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e. The error bars are plus and minus 2 standard deviations of model 22.0.

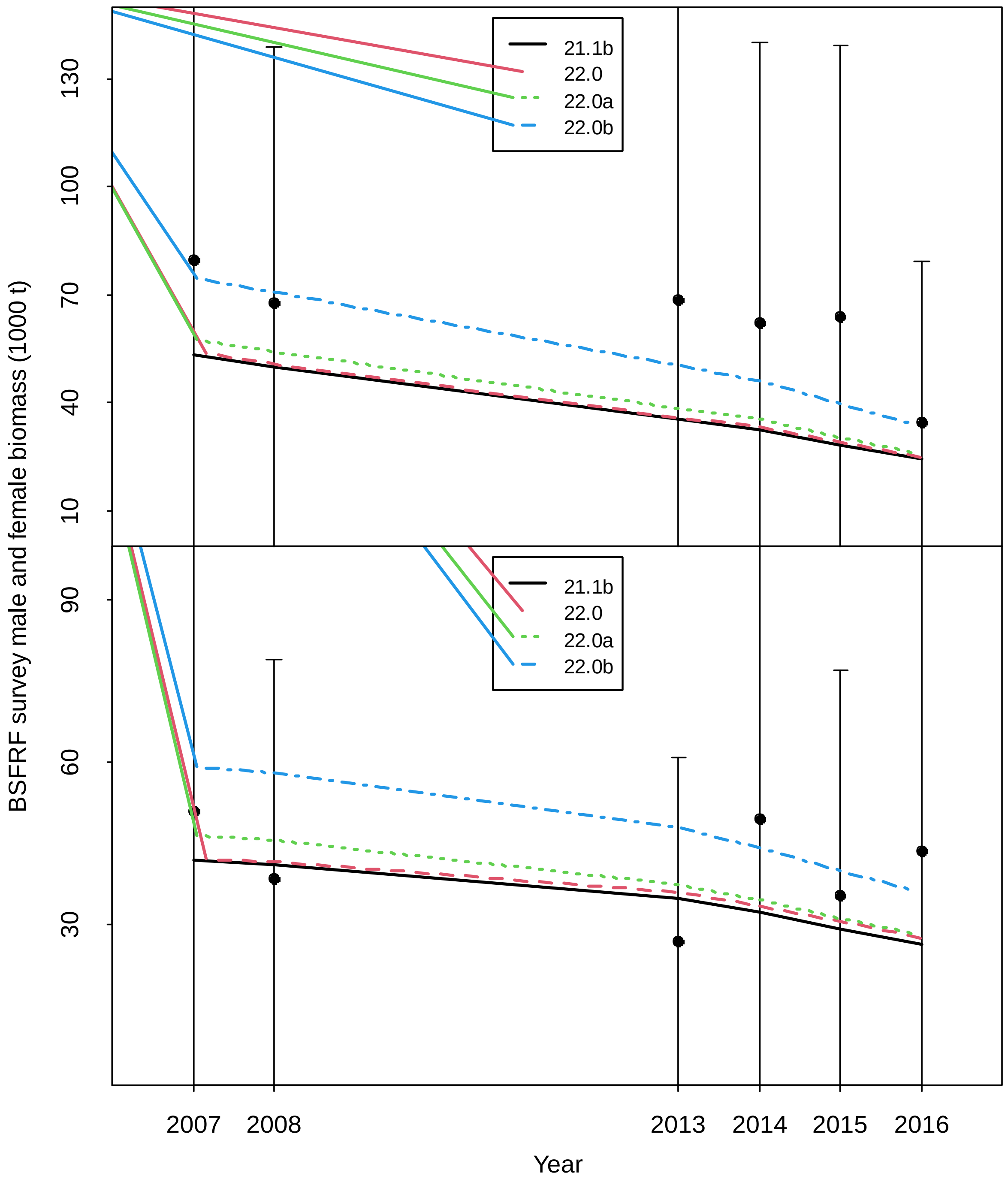


Figure 10c. Comparisons of survey biomass estimates by sex (upper plot for males and lower plot for females) by the BSFRF survey and the model for model estimates in 2021 (models 21.1b, 22.0, 22.0a, and 22.0b). The error bars are plus and minus 2 standard deviations of model 21.1b. The BSFRF survey catchability is assumed to be 1.0 for all models except for model 22.0b which estimates the catchability.

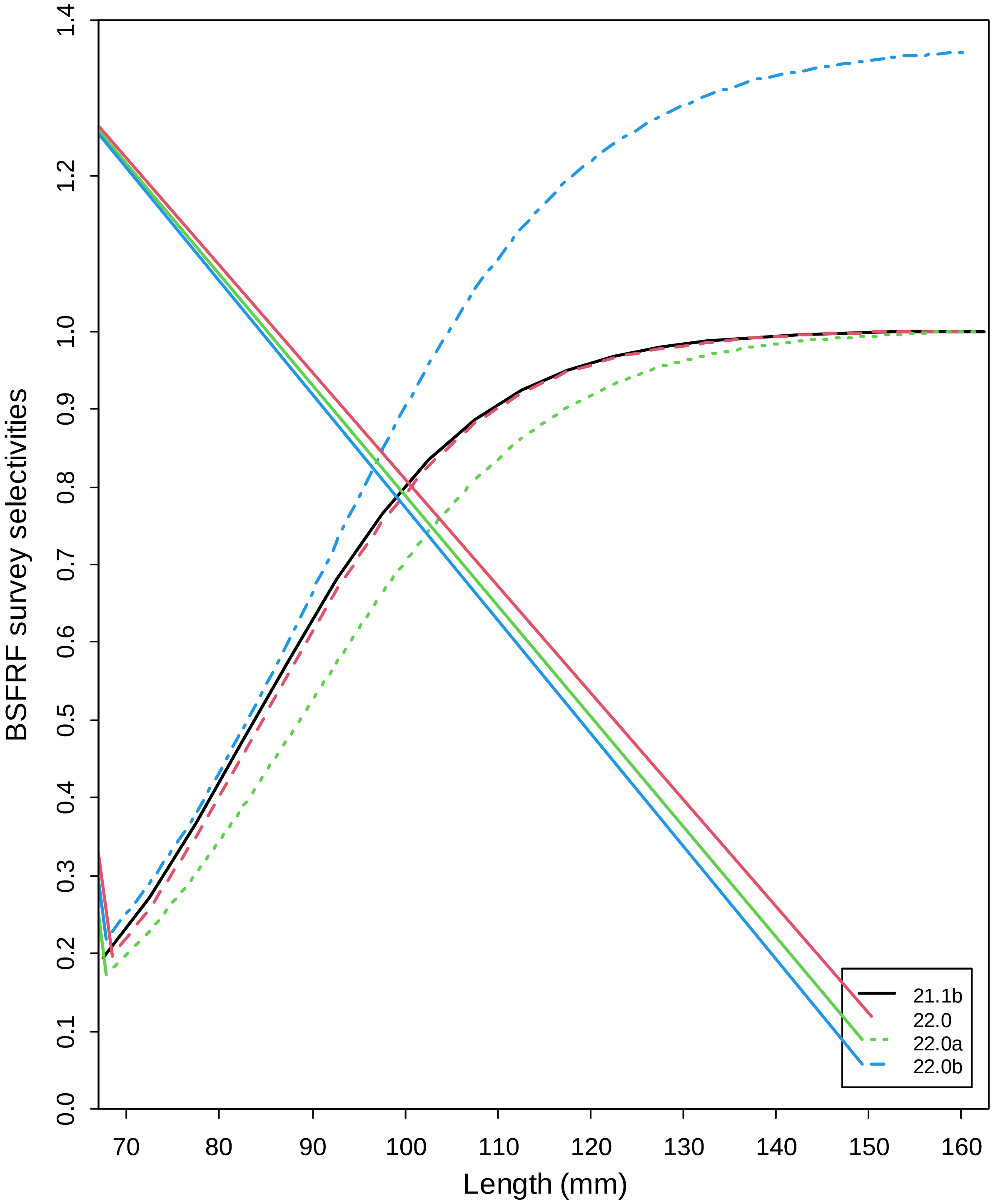


Figure 10d. Comparisons of estimated BSFRF survey selectivities with models 21.1b, 22.0, 22.0a, and 22.0b. The BSFRF survey catchability is assumed to be 1.0 for all models except for model 22.0b which estimates the catchability.

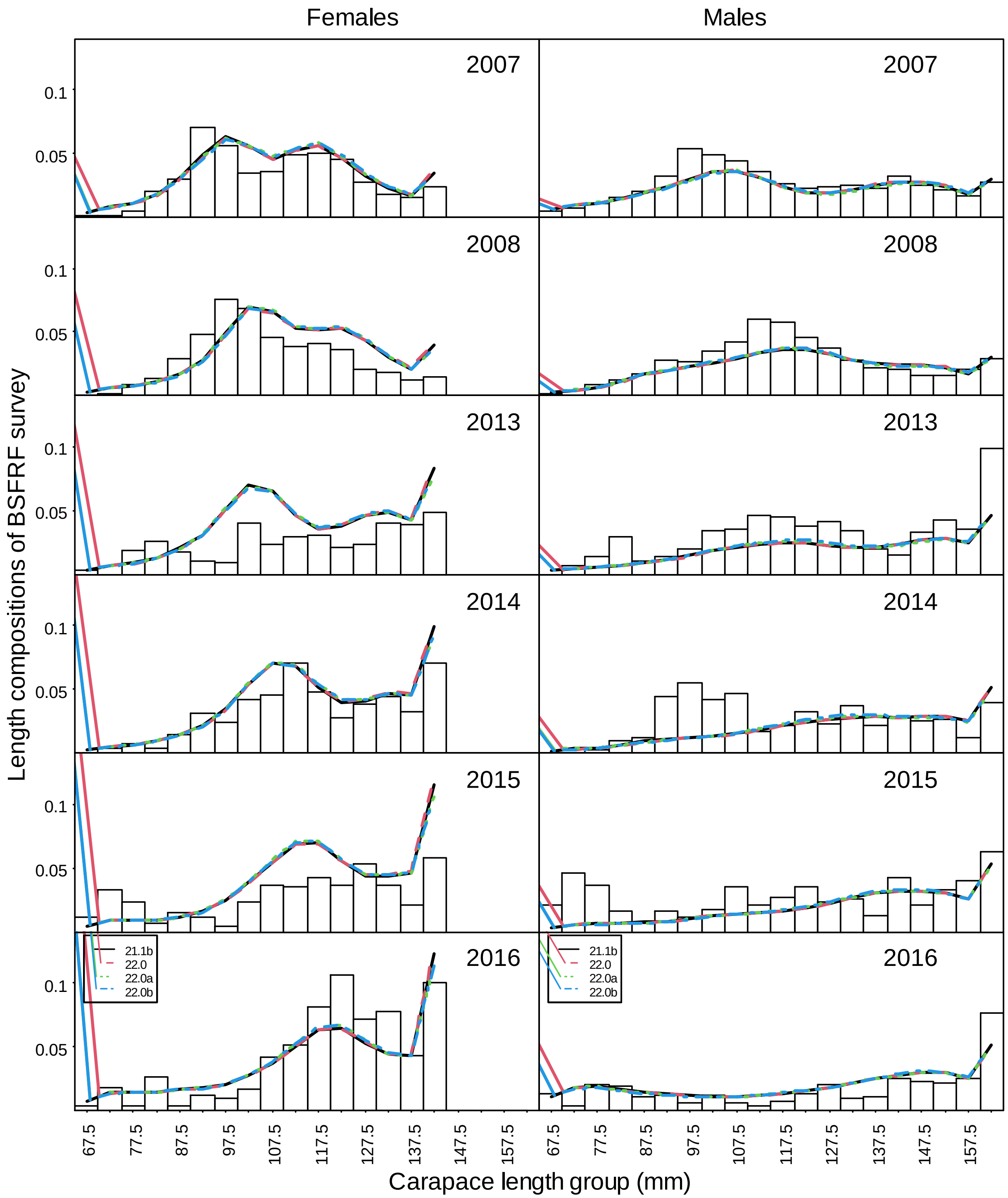


Figure 10e. Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 with models 21.1b, 22.0, 22.0a, and 22.0b.

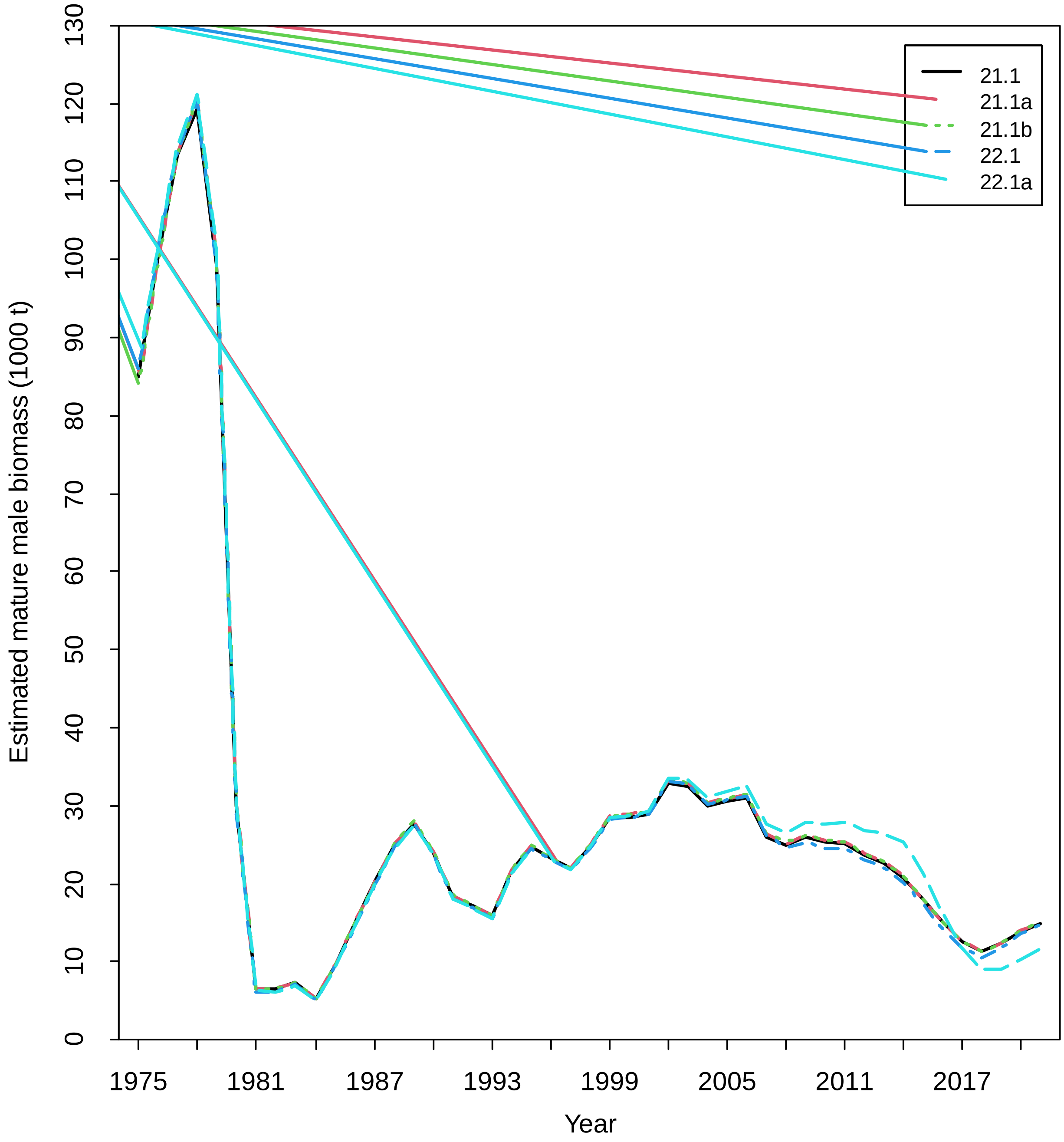


Figure 11a. Estimated absolute mature male biomasses during 1975-2021 for models 21.1, 21.1a, 21.1b, 22.1, and 22.1a. Mature male biomass is estimated on Feb. 15, year+1.

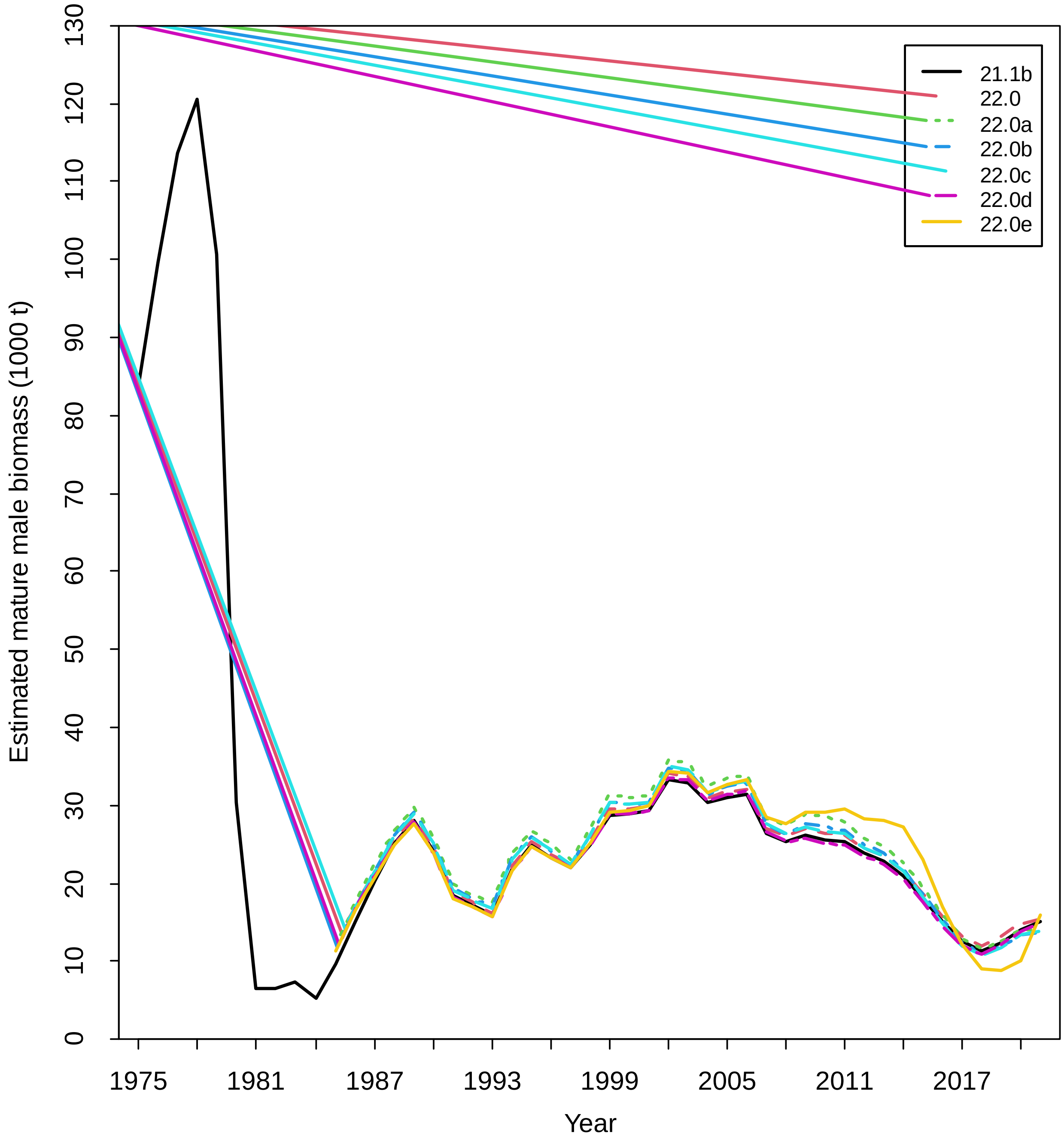


Figure 11b. Estimated absolute mature male biomasses during 1975-2021 for models 21.1b, 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e. Mature male biomass is estimated on Feb. 15, year+1.

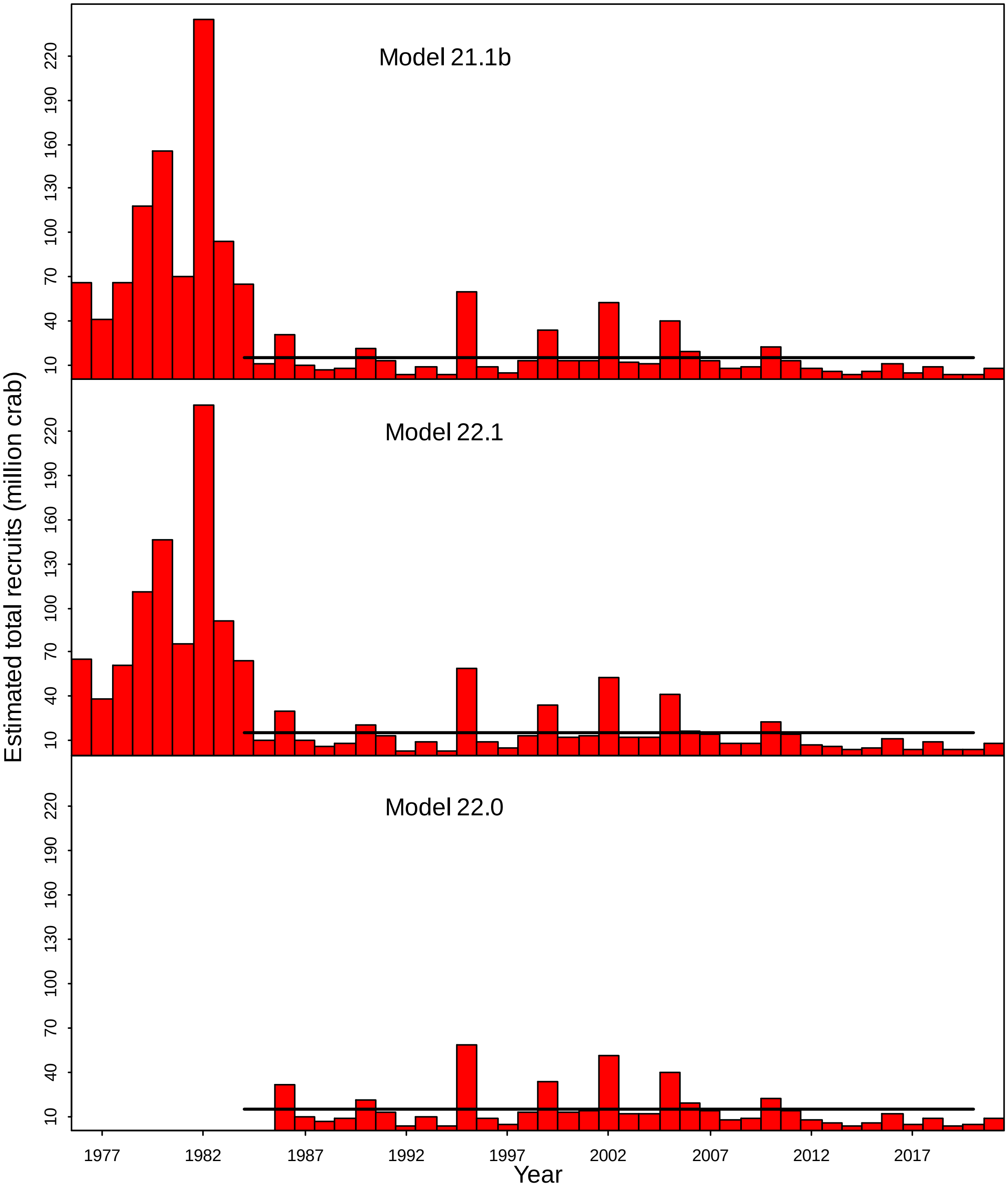


Figure 12a. Estimated recruitment time series during 1976-2021 with models 21.1b, 22.1, and 22.0. Mean male recruits during 1984-2020 was used to estimate $B_{35\%}$. Recruitment estimates in the terminal year (2021) are unreliable.

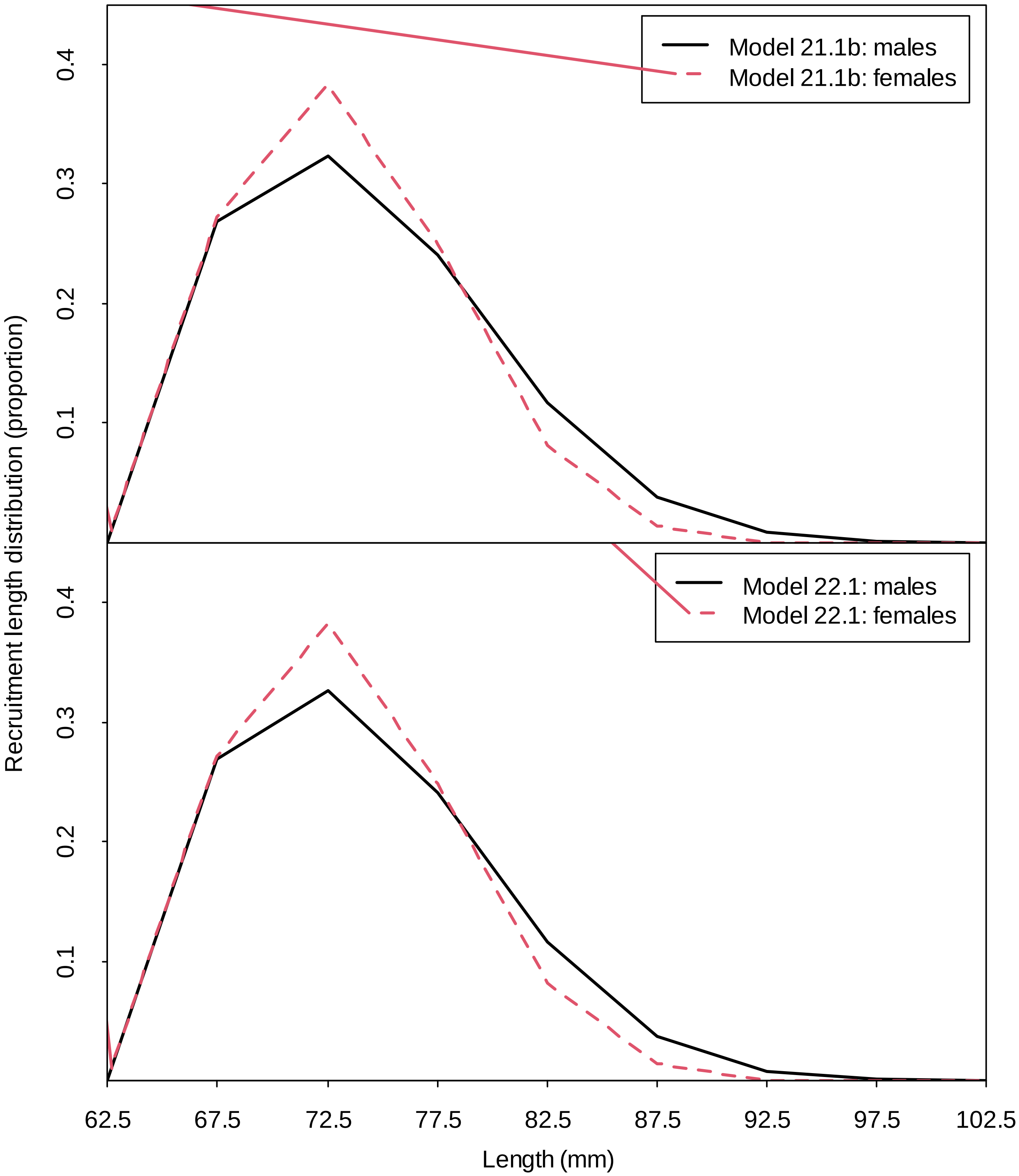


Figure 12b. Estimated recruitment length distributions with models 21.1b and 22.1.

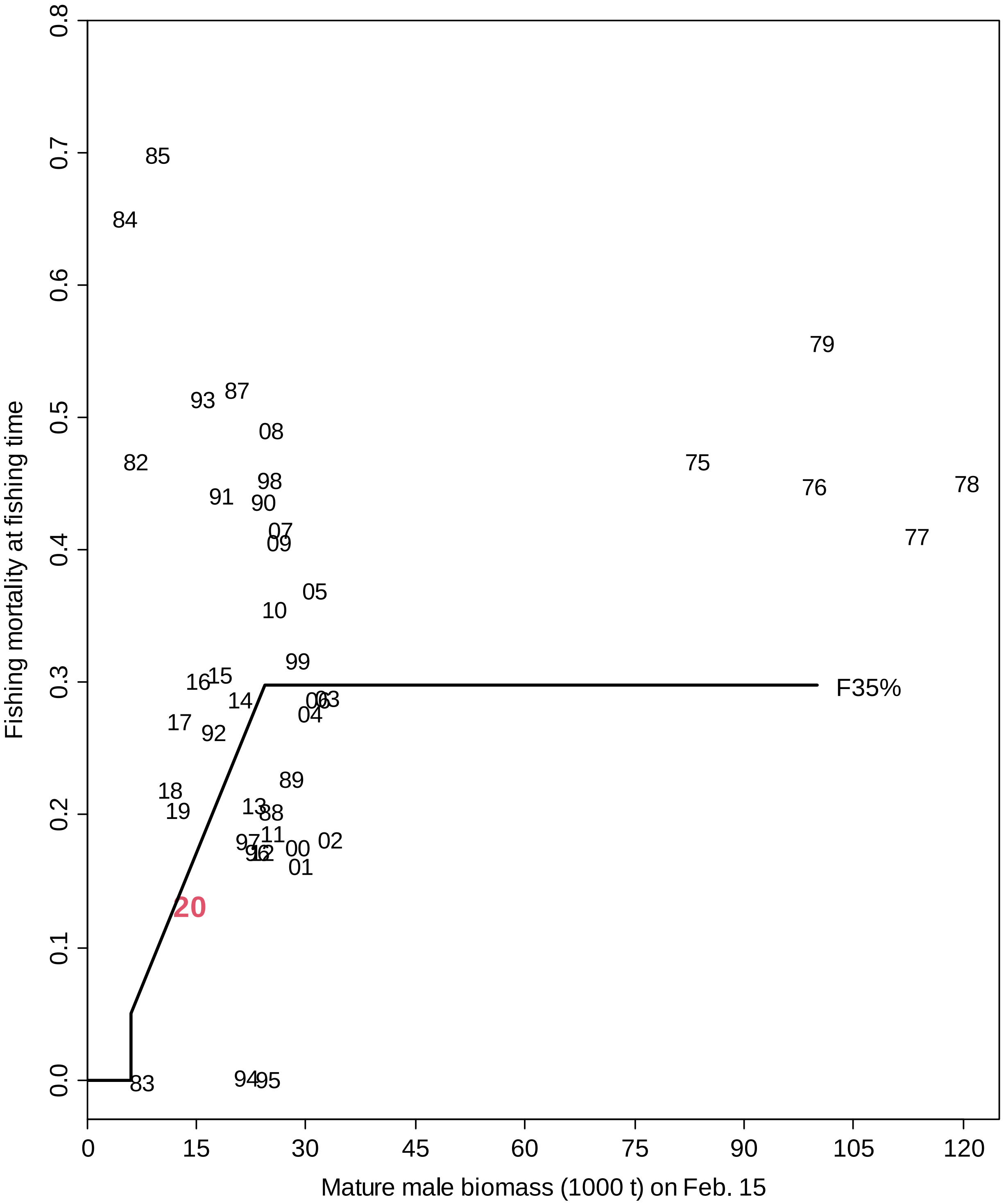


Figure 13a. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2020 under model 21.1b. Average of recruitment from 1984 to 2020 was used to estimate $B_{35\%}$.

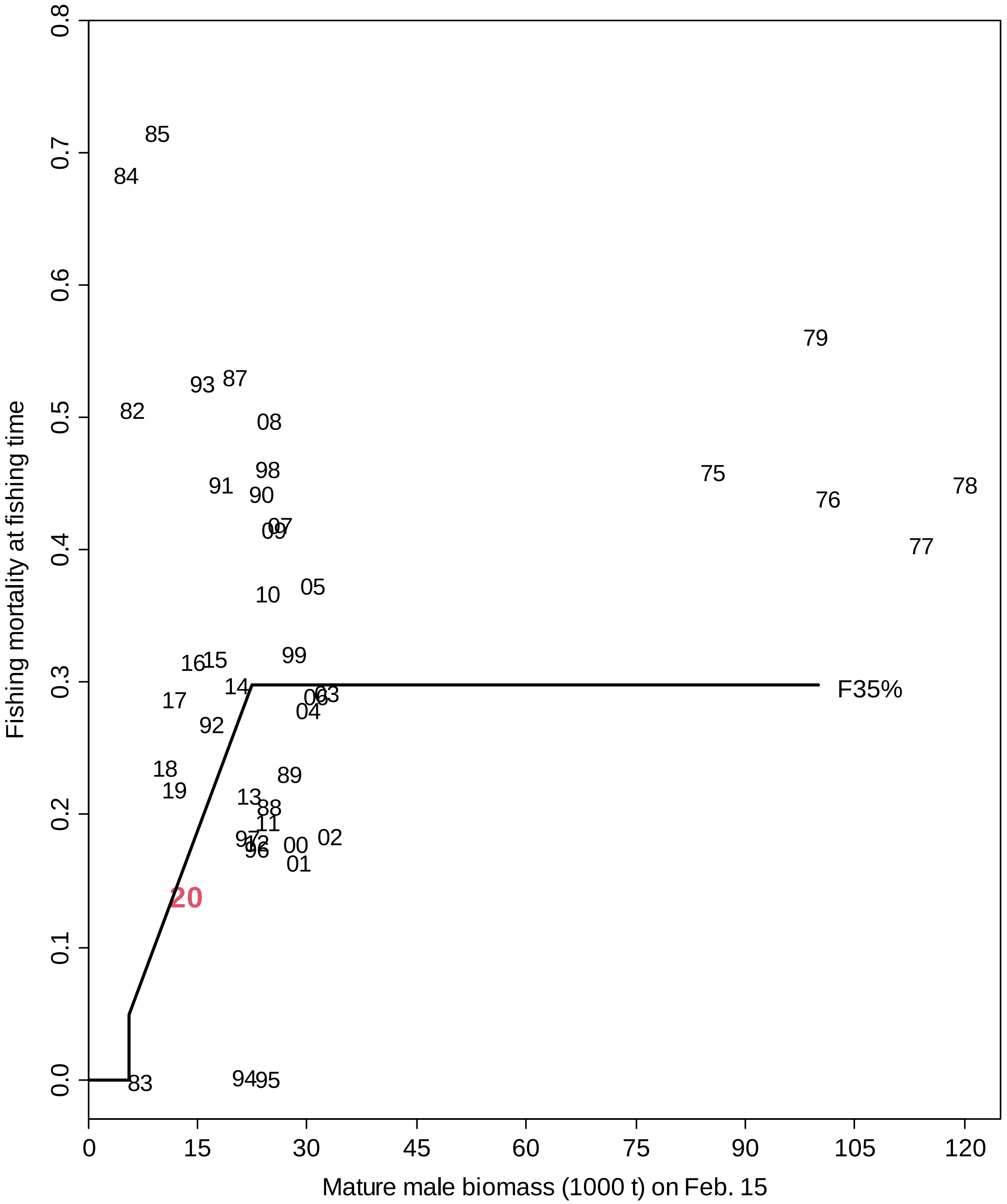


Figure 13b. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2020 under model 22.1. Average of recruitment from 1984 to 2020 was used to estimate $B_{35\%}$.

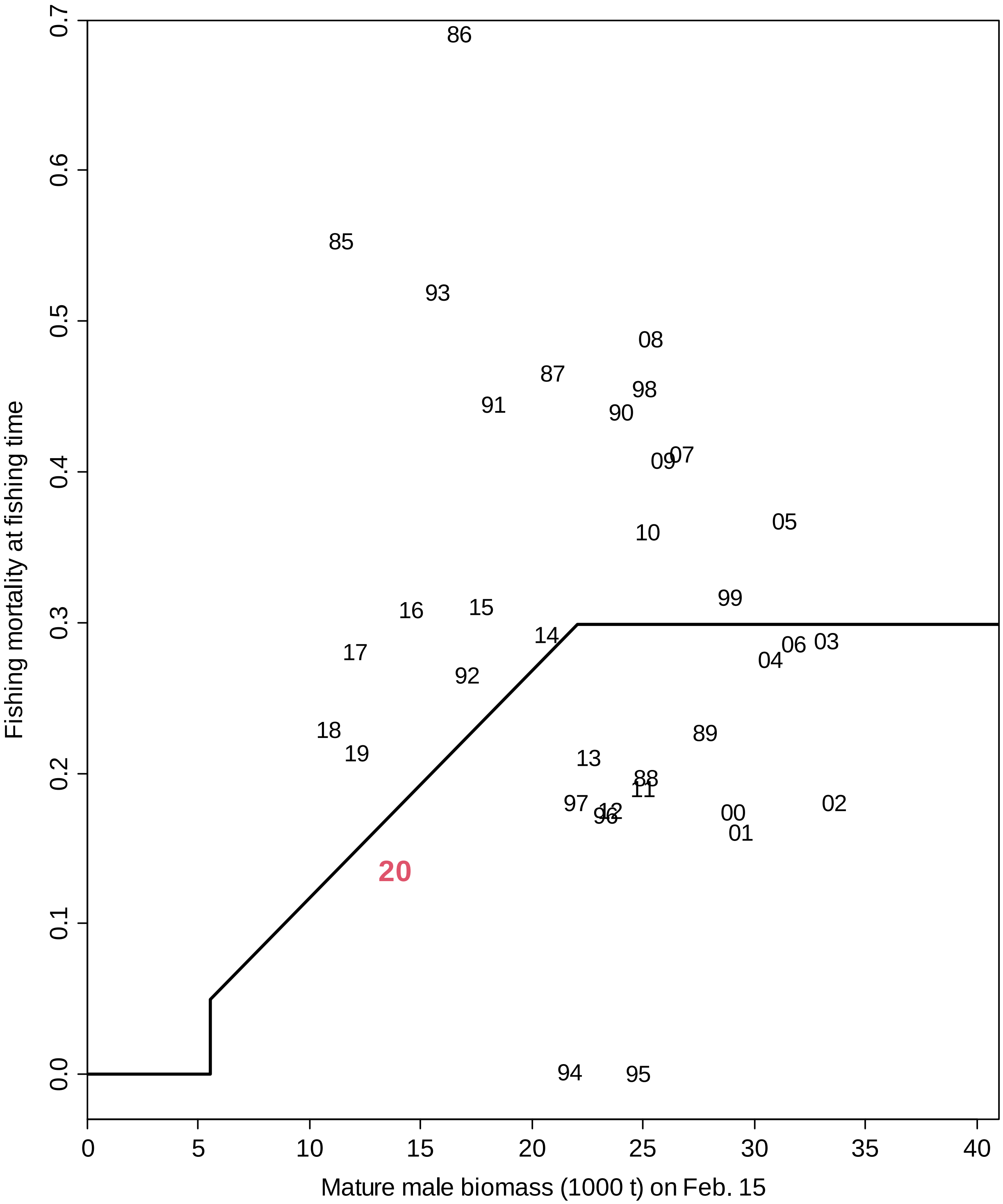


Figure 13c. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1985-2020 under model 22.0d. Average of recruitment from 1986 to 2020 was used to estimate $B_{35\%}$.

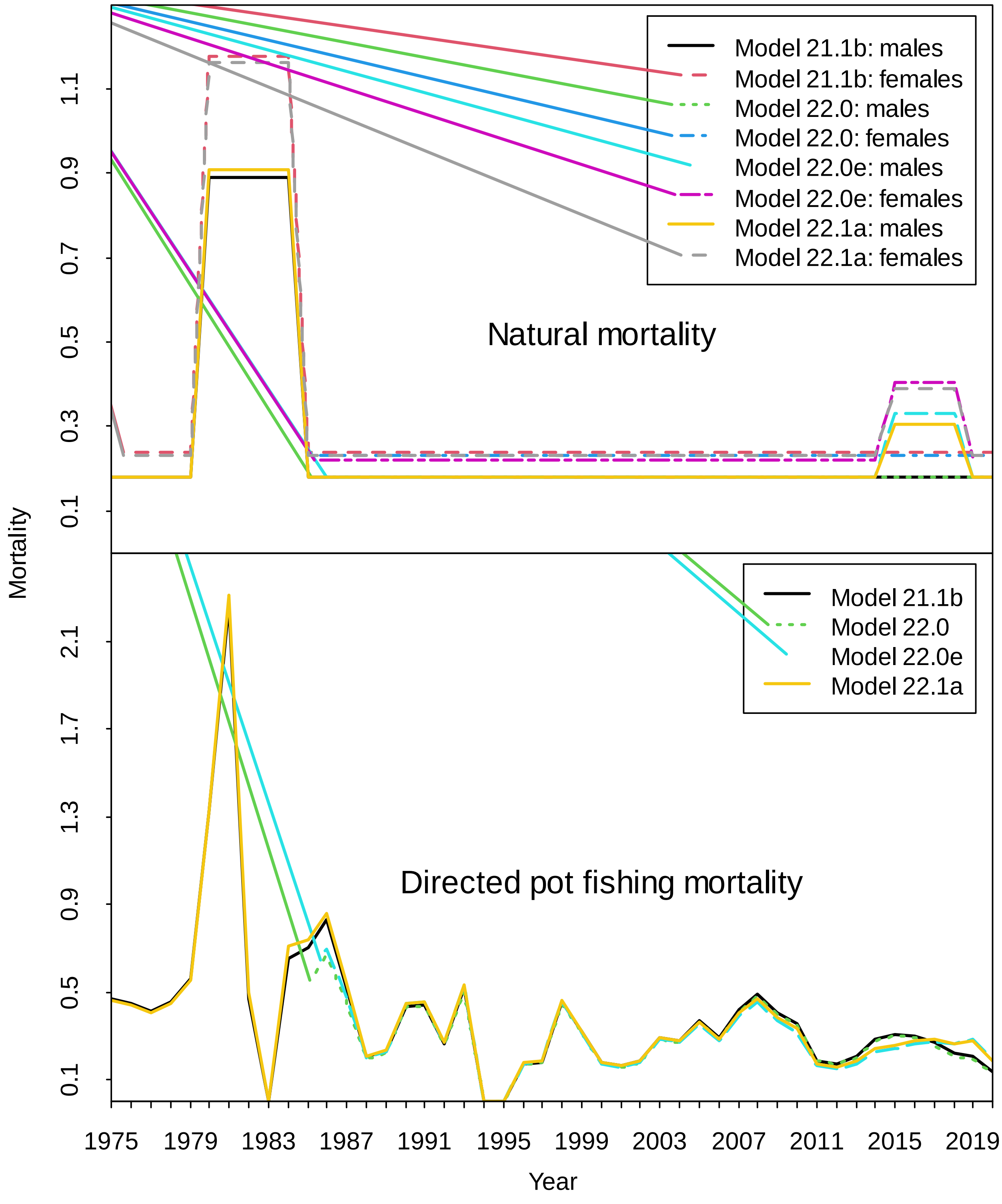


Figure 13d. Comparison of estimated natural mortality and directed pot fishing mortality for models 21.1b, 22.0, 22.0e, and 22.1a.

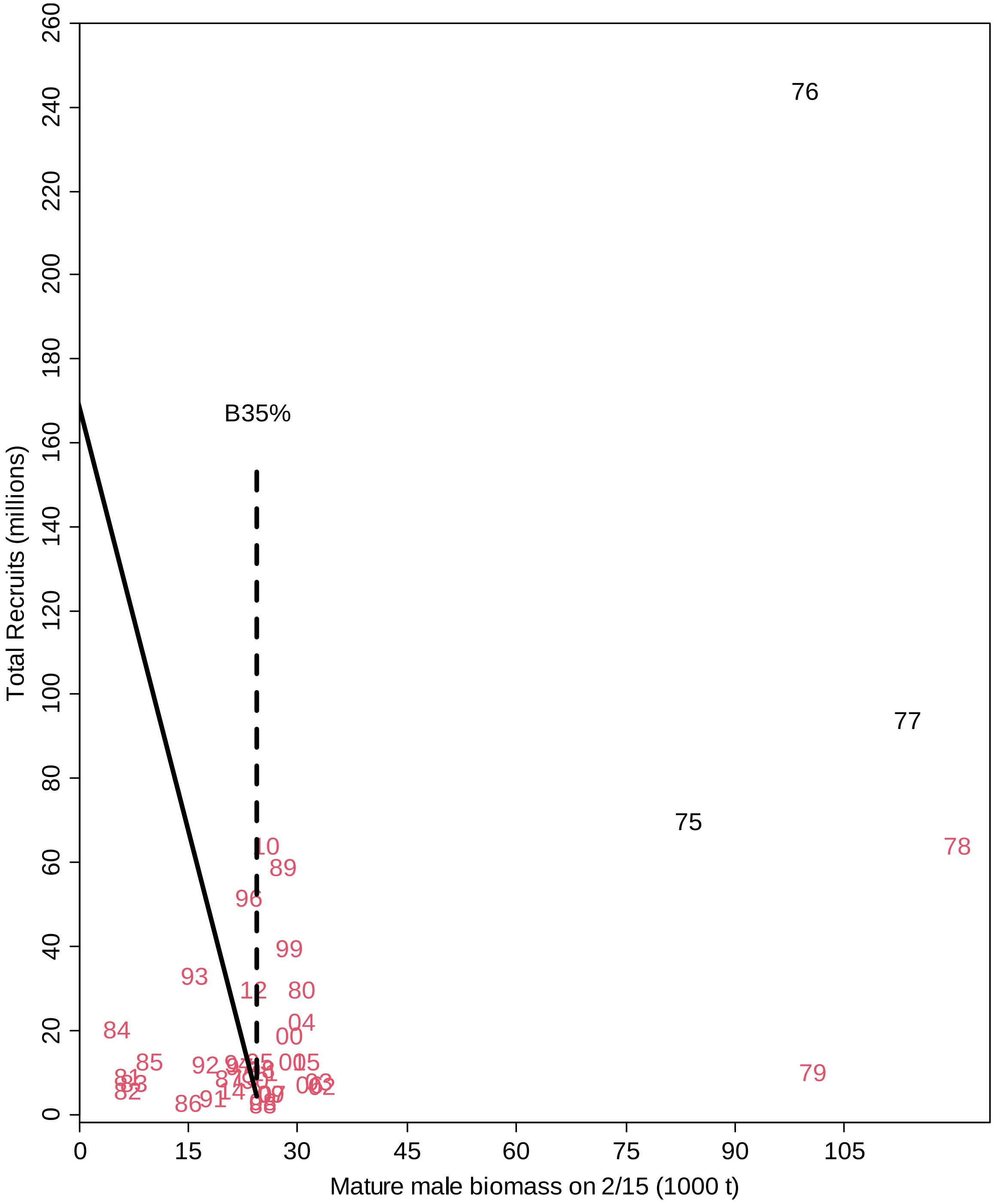


Figure 14a. Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6-year time lag) for Bristol Bay red king crab under model 21.1b. Numerical labels are years of mating, and the vertical dotted line is the estimated $B_{35\%}$ based on the mean recruitment level during 1984 to 2020.

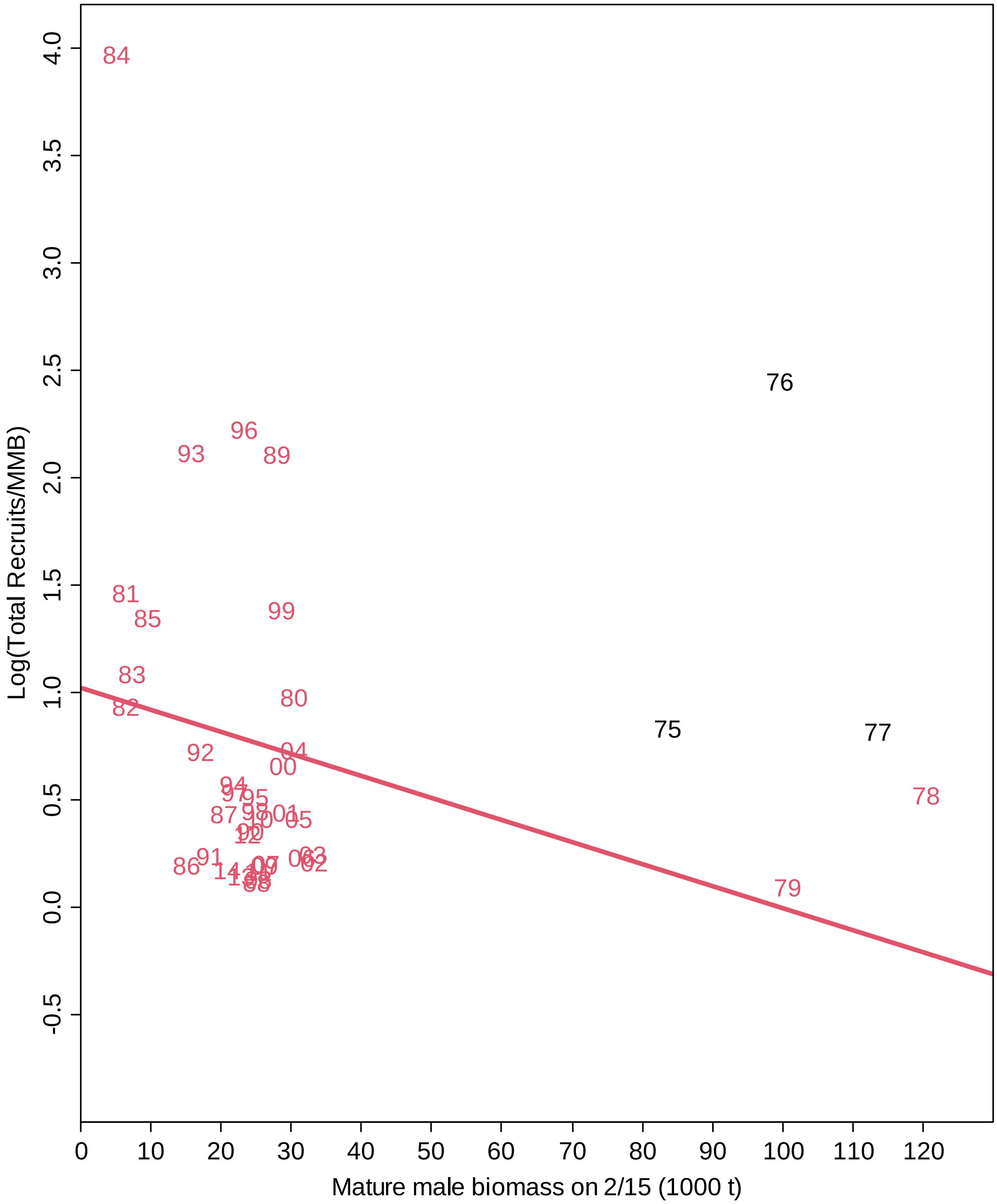


Figure 14b. Relationships between log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab under model 21.1b. Numerical labels are years of mating, and the line is the regression line for data of 1978-2014.

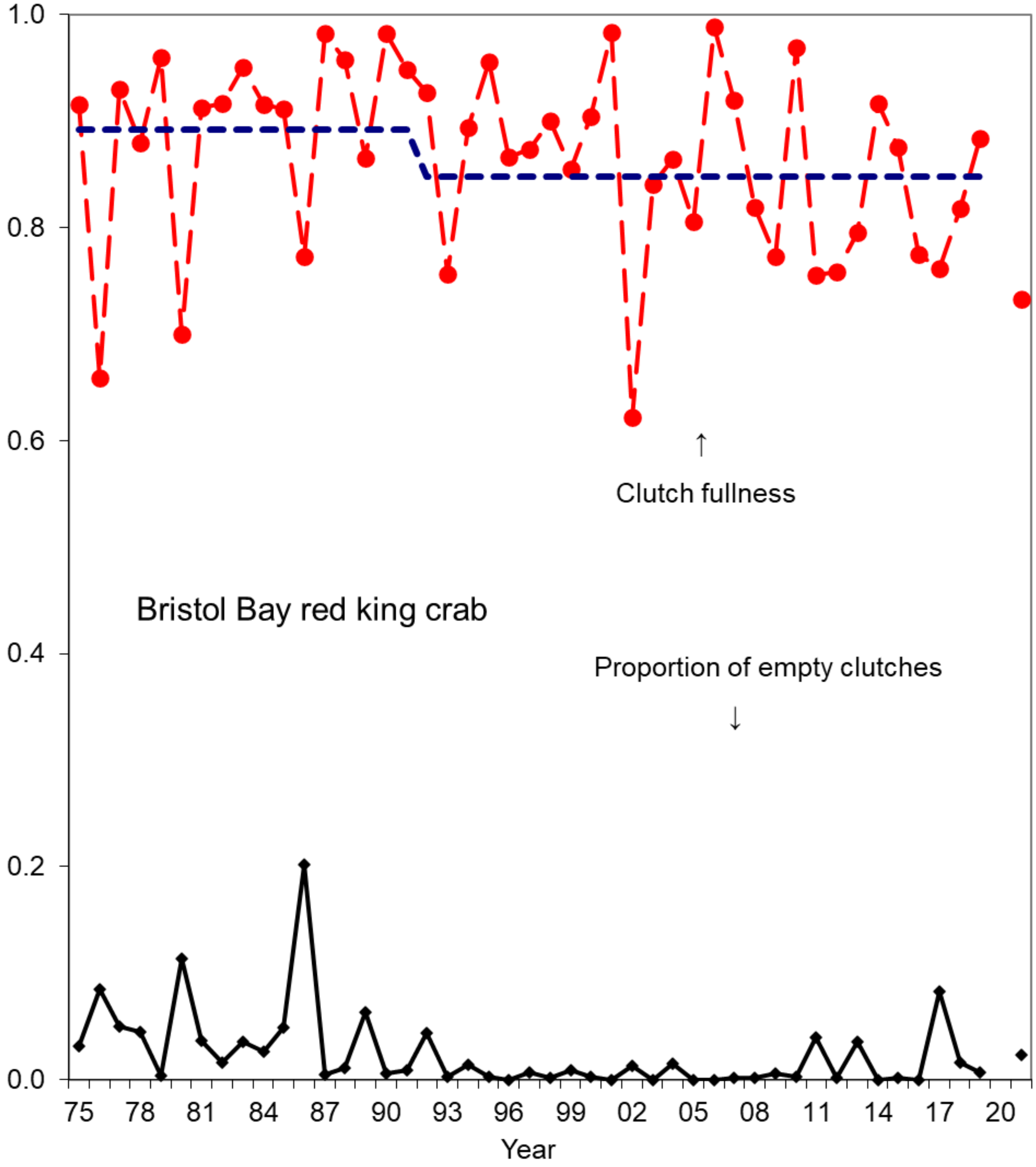


Figure 15. Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2021 from survey data. Oldshell females were excluded. The blue dashed line is the mean clutch fullness during two periods before 1992 and after 1991.

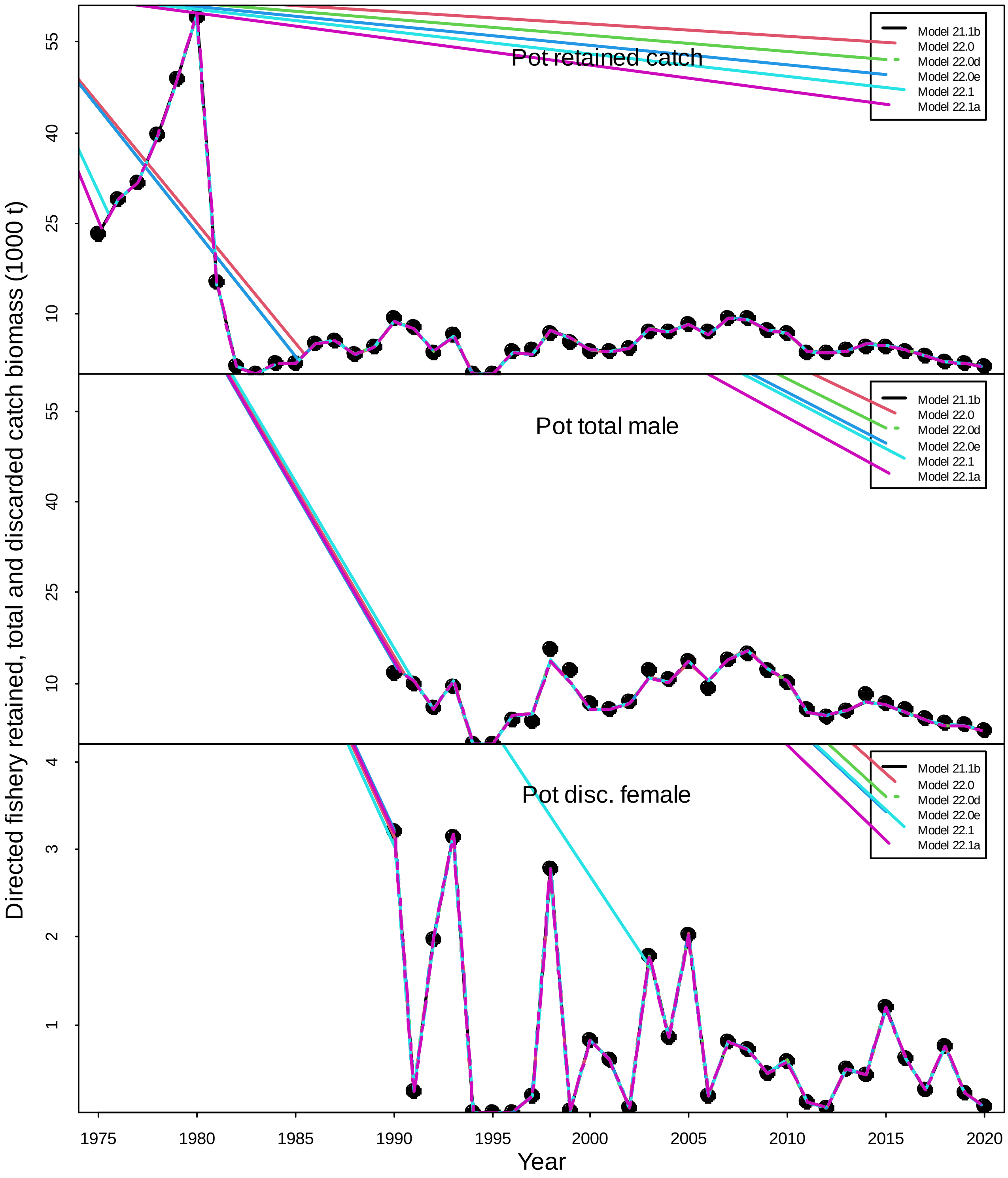


Figure 16a. Observed (dots) and predicted (lines) RKC catch and bycatch biomass under models 21.1b, 22.0, 22.0d, 22.0e, 22.1, and 22.1a.

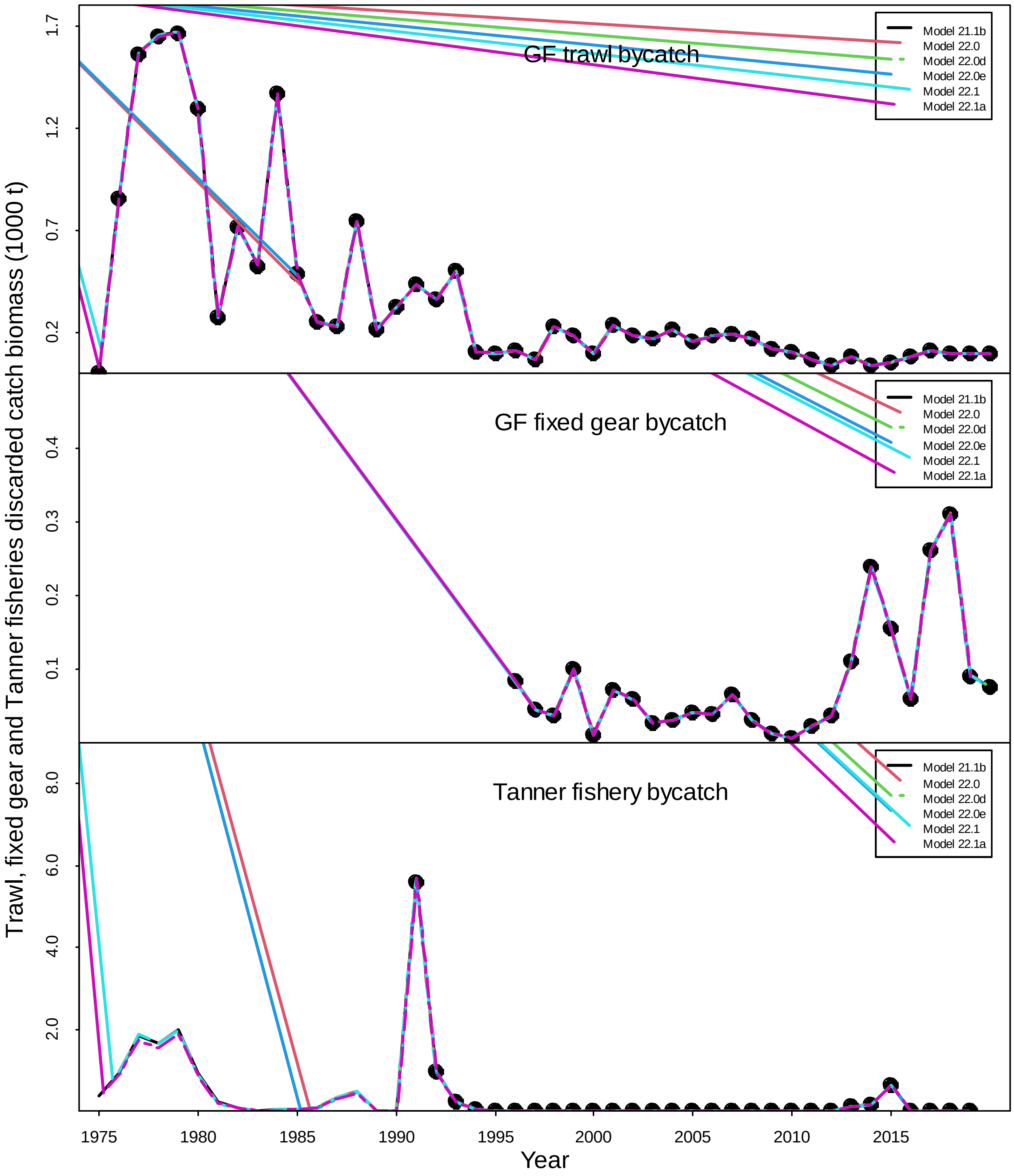


Figure 16b. Observed (dots) and predicted (lines) RKC bycatch biomass from groundfish fisheries and the Tanner crab fishery under models 21.1b, 22.0, 22.0d, 22.0e, 22.1, and 22.1a. Trawl bycatch biomass was 0 before 1976.

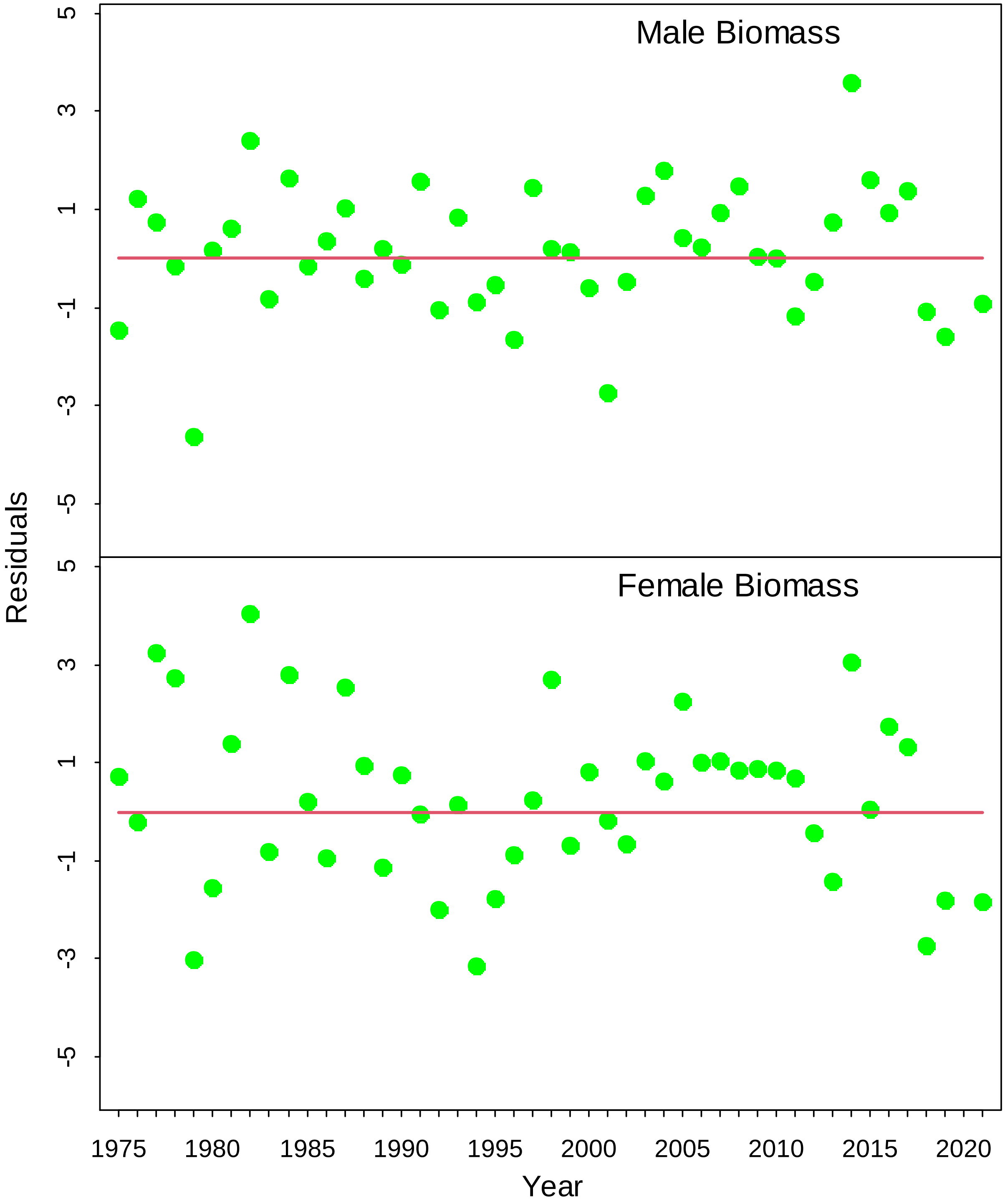


Figure 17a. Standardized residuals of NMFS survey biomass under model 21.1b.

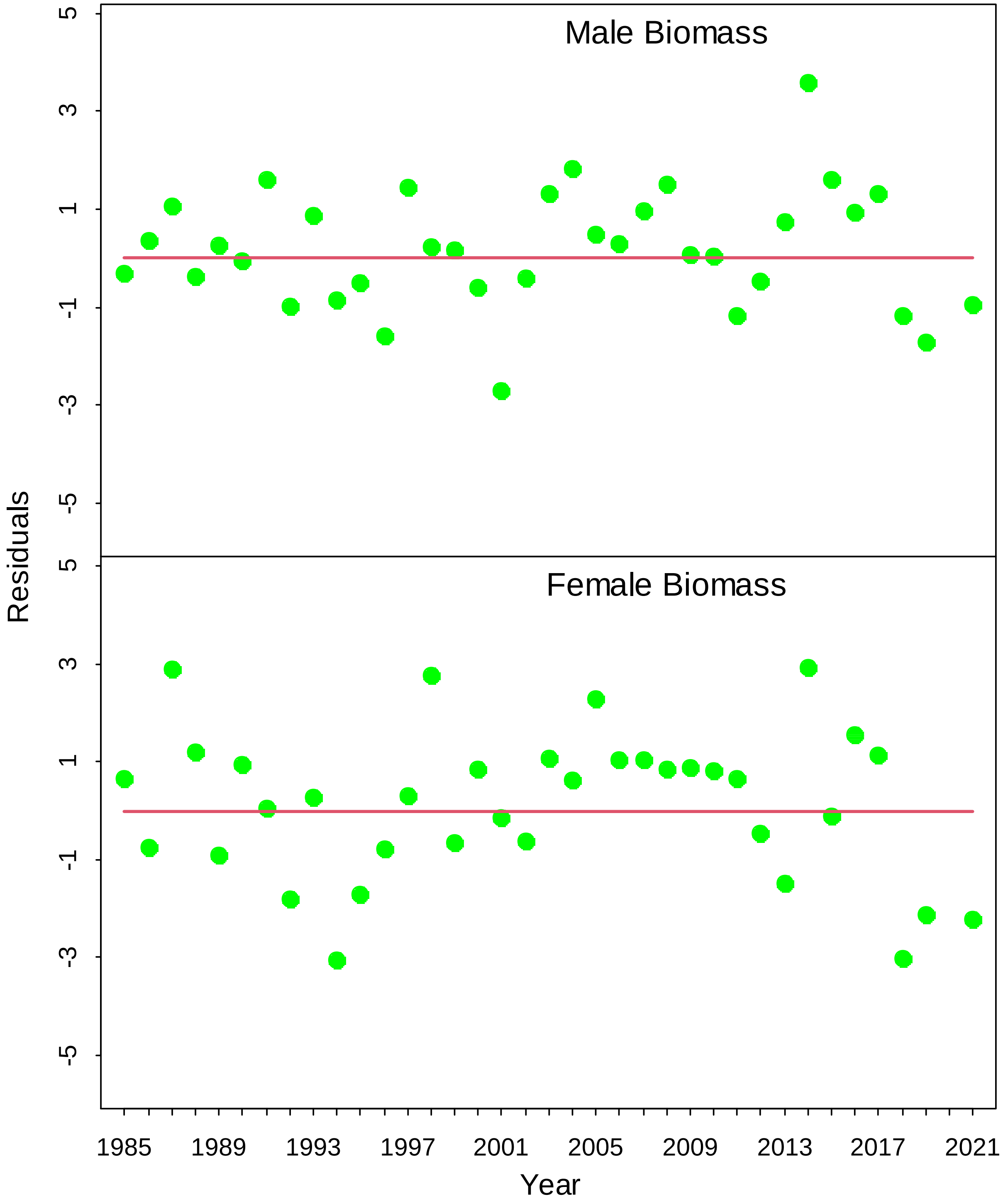


Figure 17b. Standardized residuals of NMFS survey biomass under model 22.0.

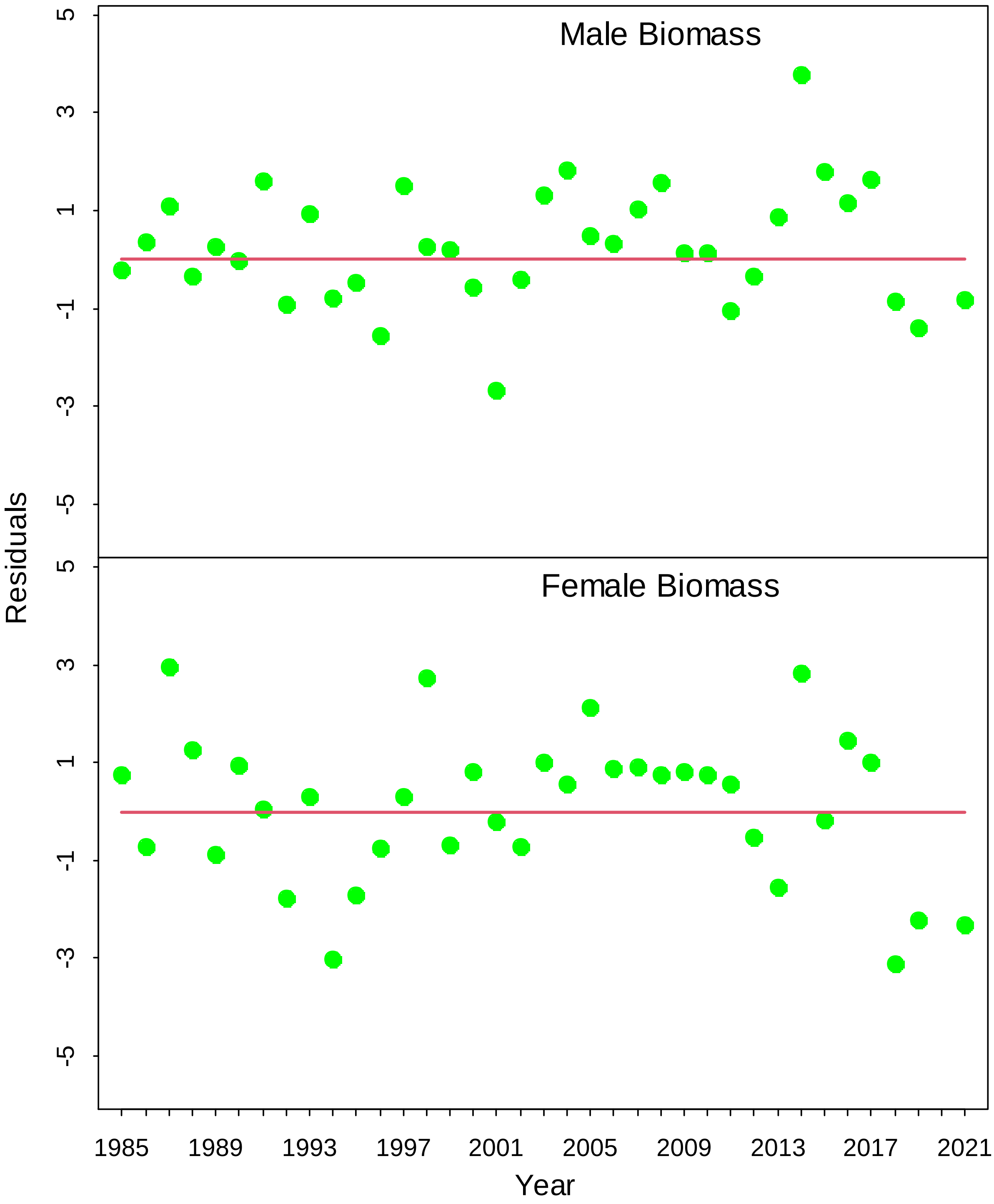


Figure 17c. Standardized residuals of NMFS survey biomass under model 22.0d.

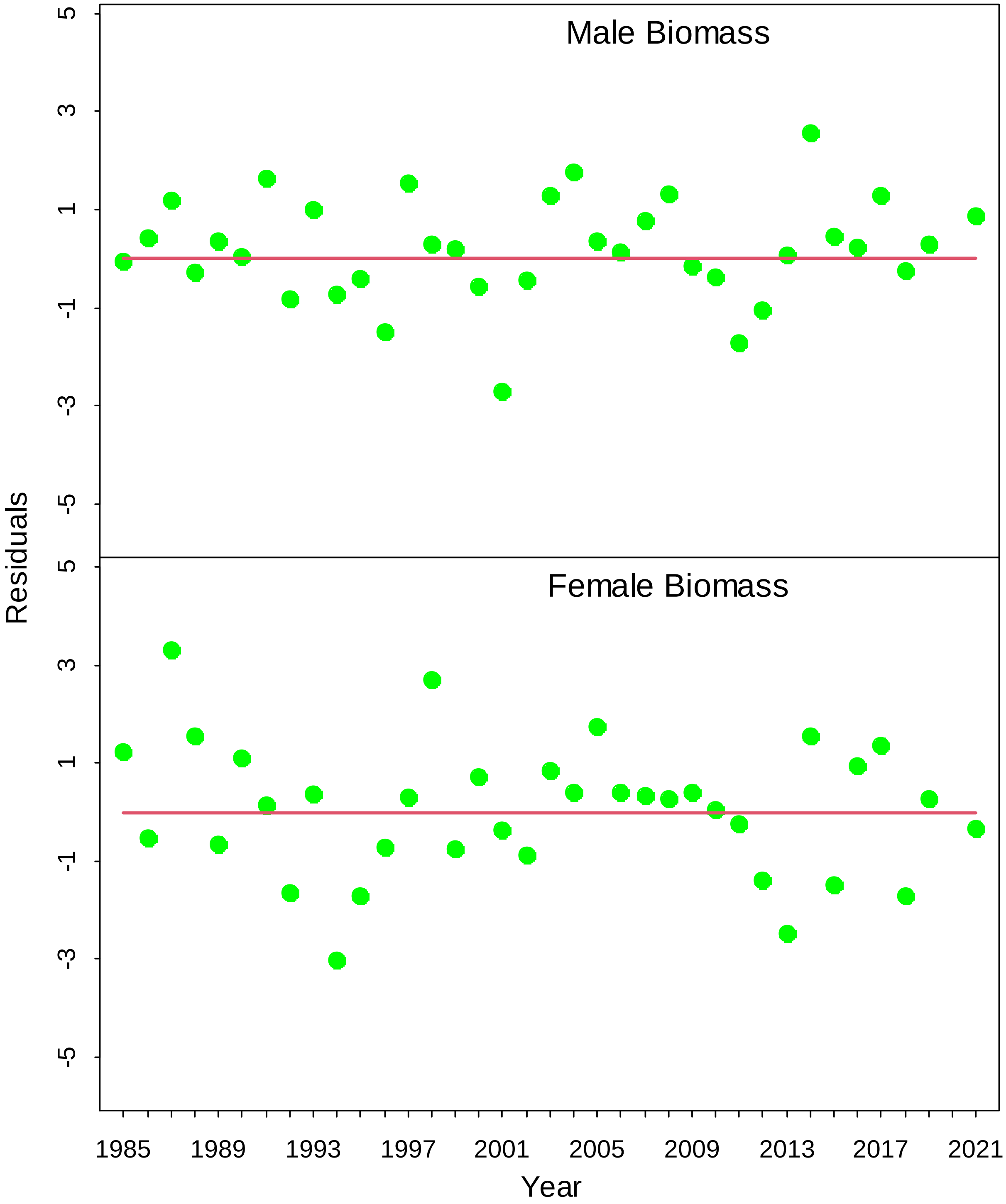


Figure 17d. Standardized residuals of NMFS survey biomass under model 22.0e.

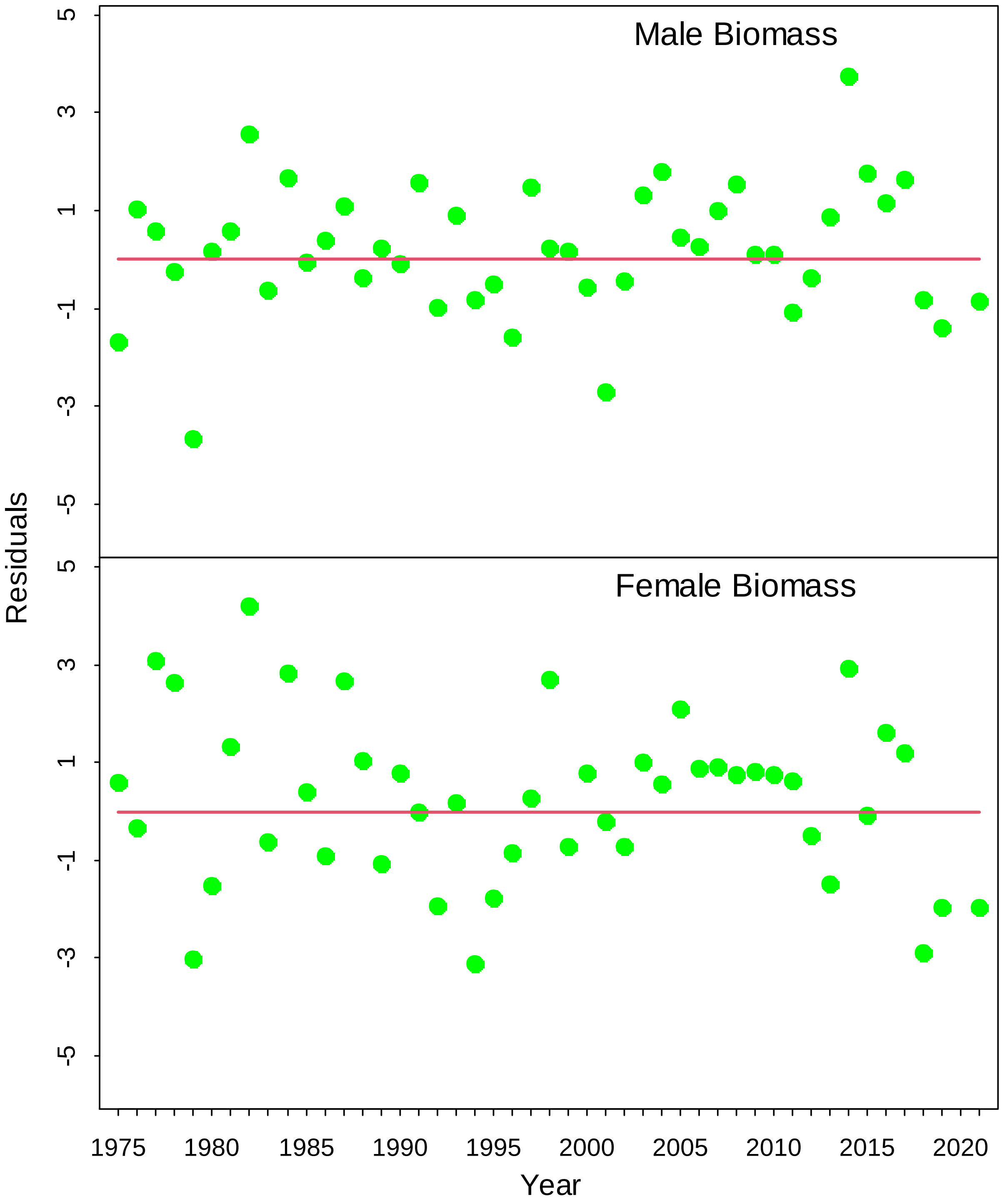


Figure 17e. Standardized residuals of NMFS survey biomass under model 22.1.

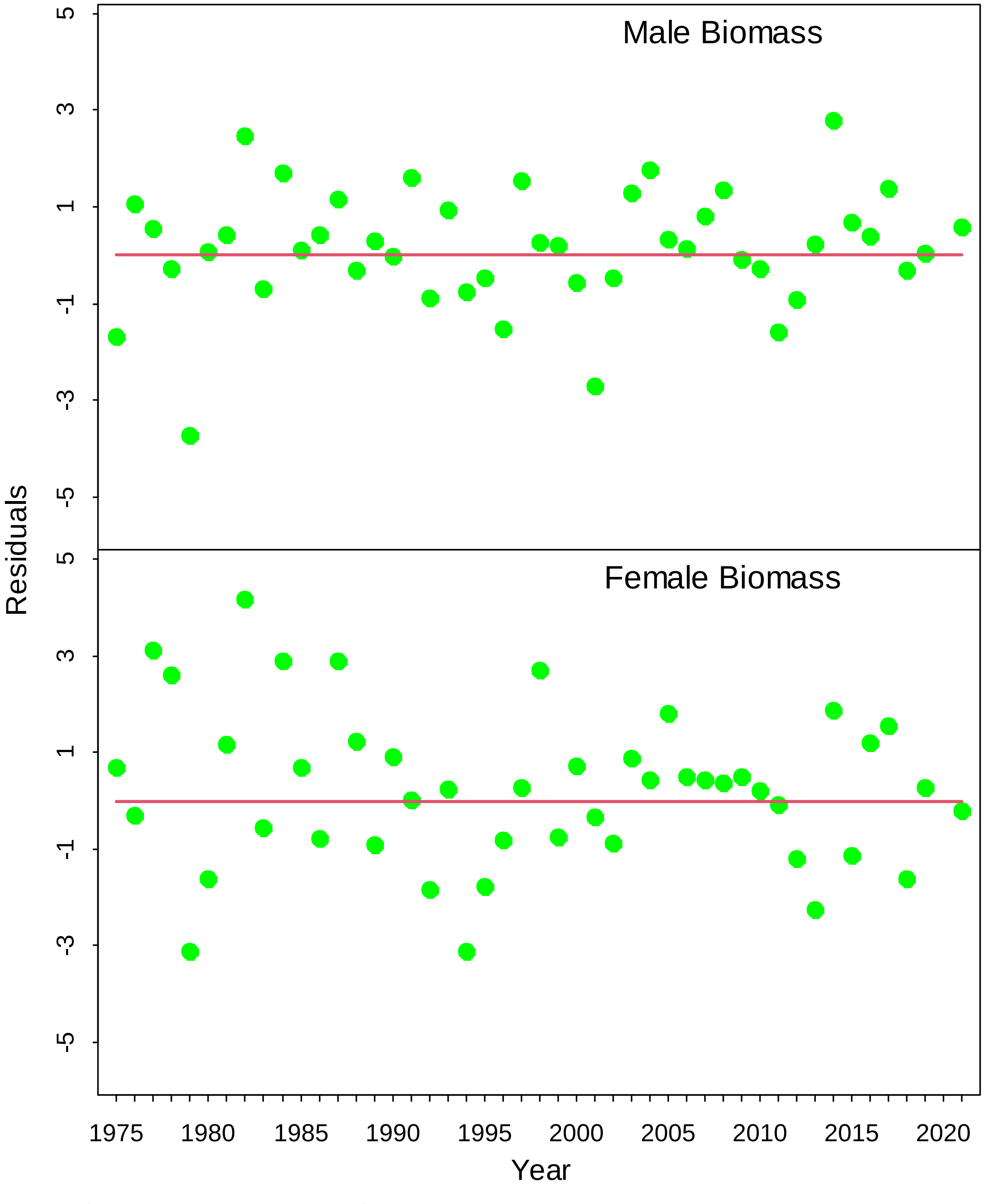


Figure 17f. Standardized residuals of NMFS survey biomass under model 22.1a.

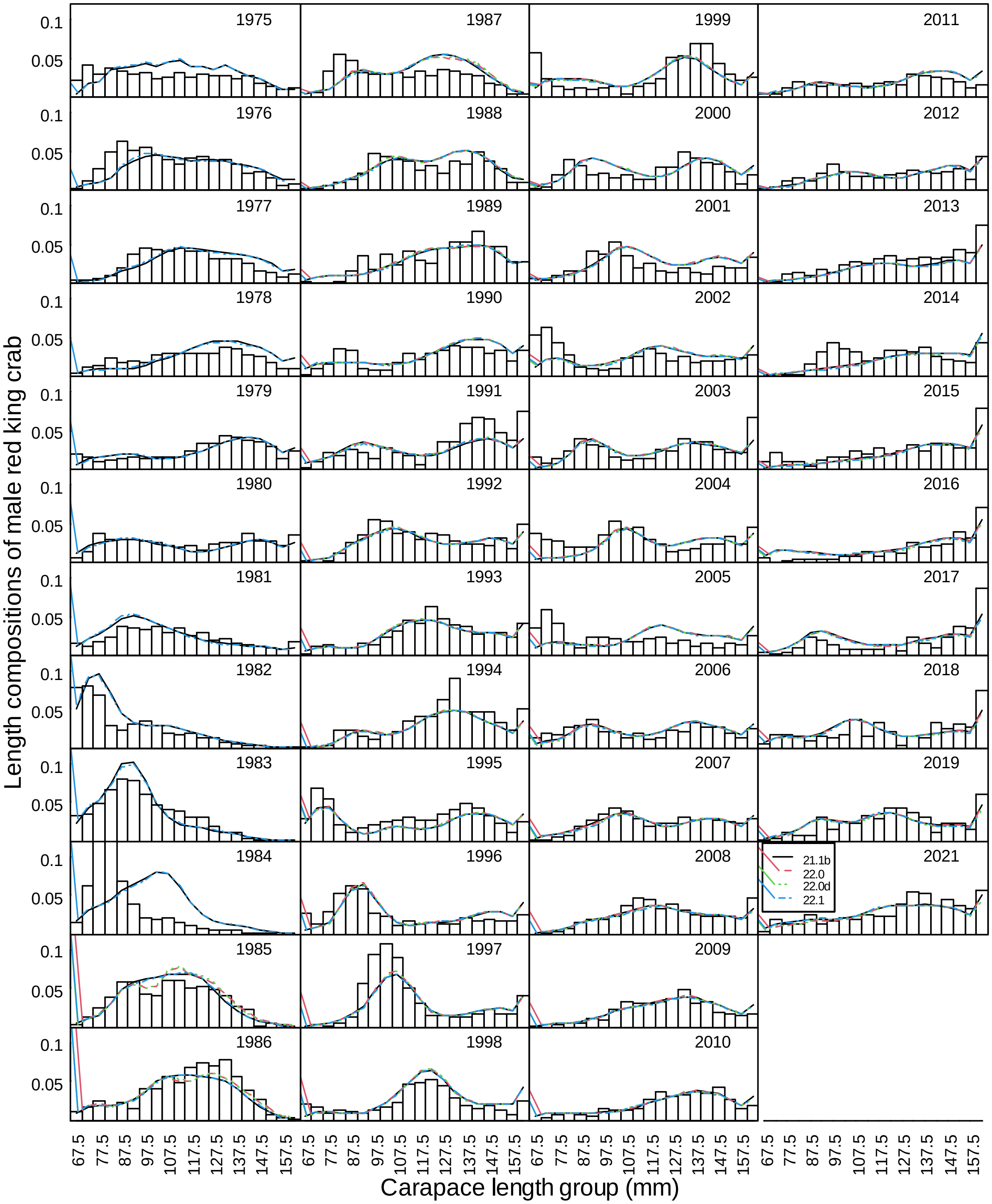


Figure 18. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under models 21.1b, 22.0, 22.0d, and 22.1.

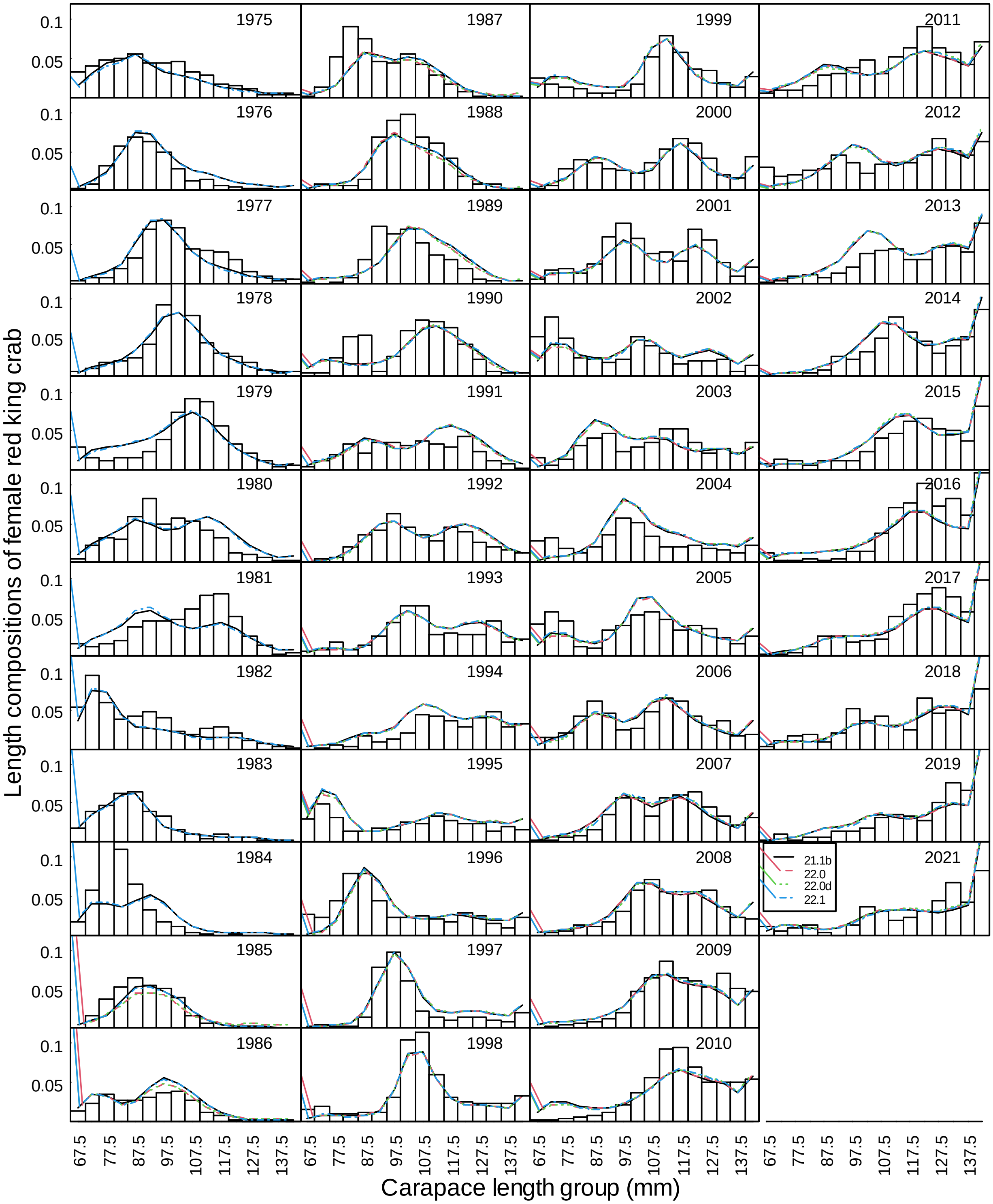


Figure 19. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year under models 21.1b, 22.0, 22.0d, and 22.1.

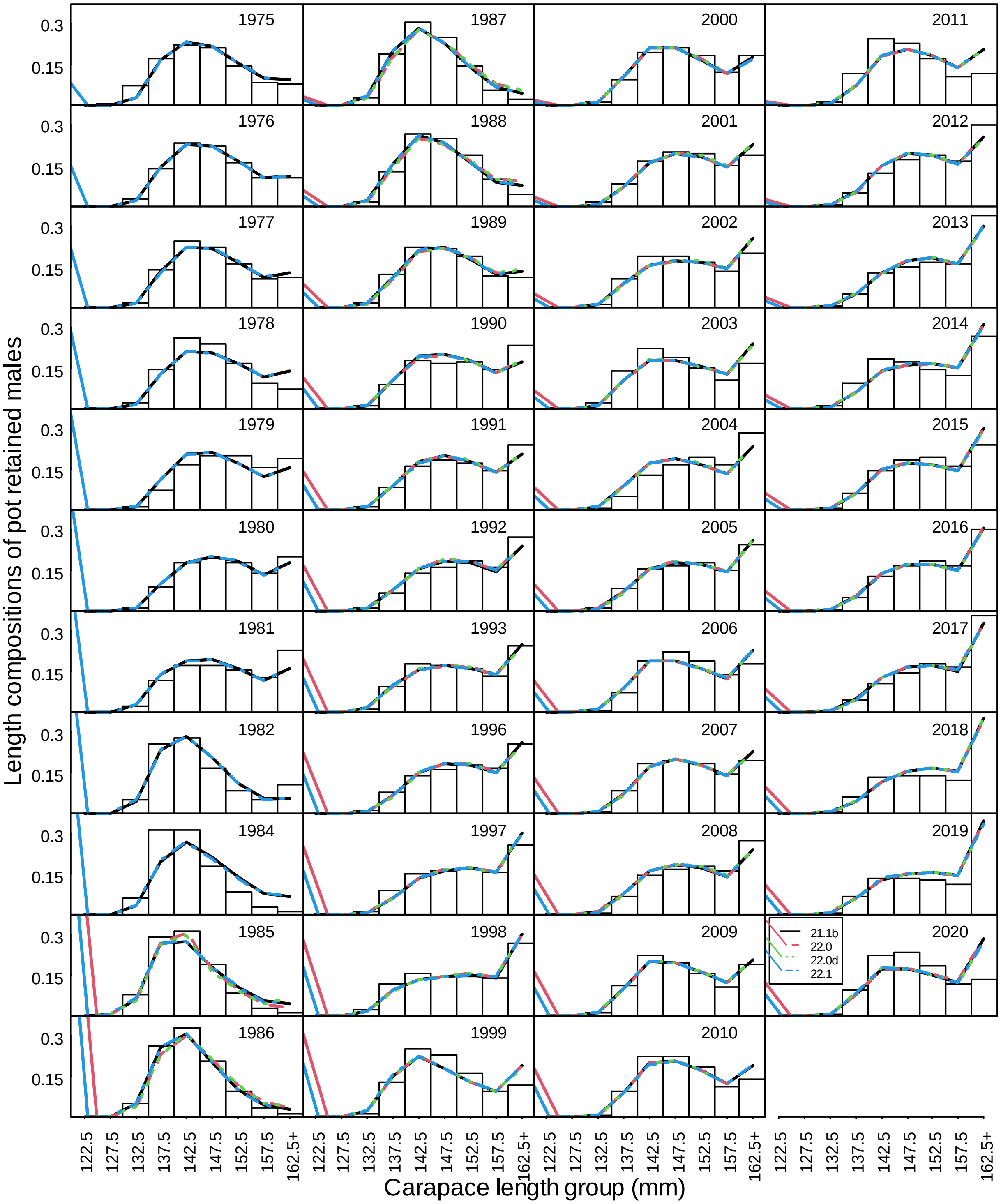


Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 21.1b, 22.0, 22.0d, and 22.1.

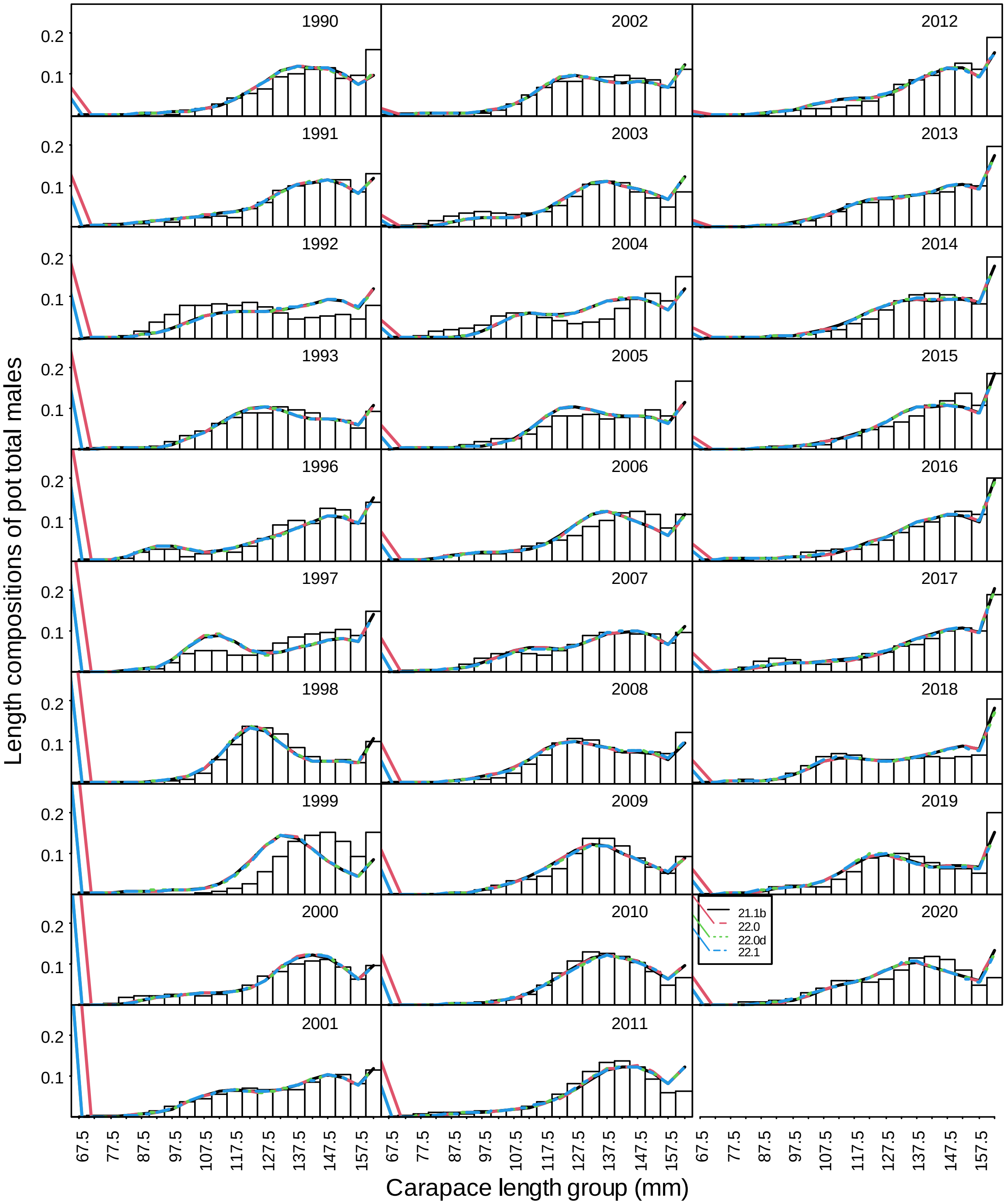


Figure 21. Comparison of observer and model estimated total observer length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 21.1b, 22.0, 22.0d, and 22.1.

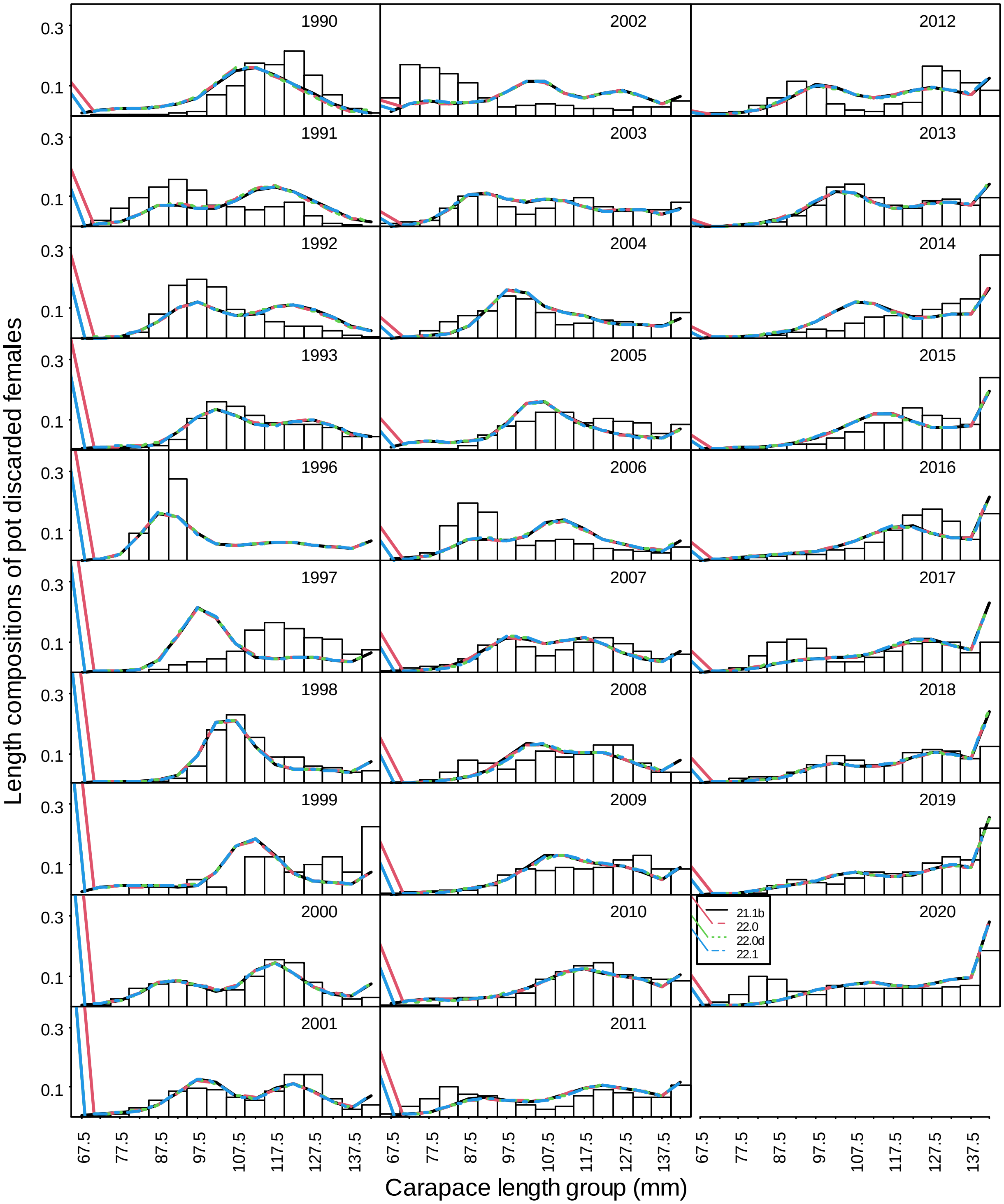


Figure 22. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the directed pot fishery under models 21.1b, 22.0, 22.0d, and 22.1.

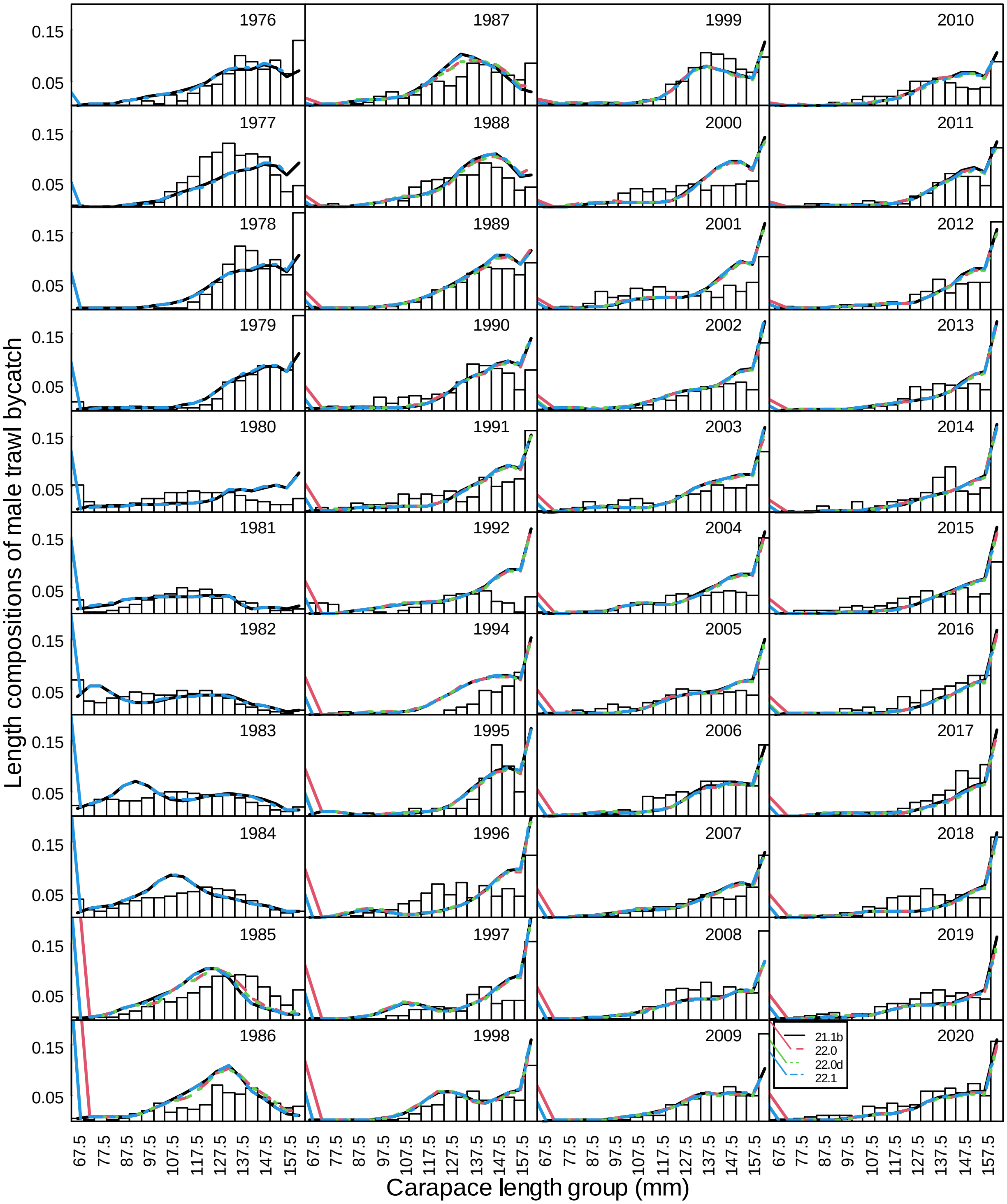


Figure 23a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish trawl fisheries under models 21.1b, 22.0, 22.0d, and 22.1.

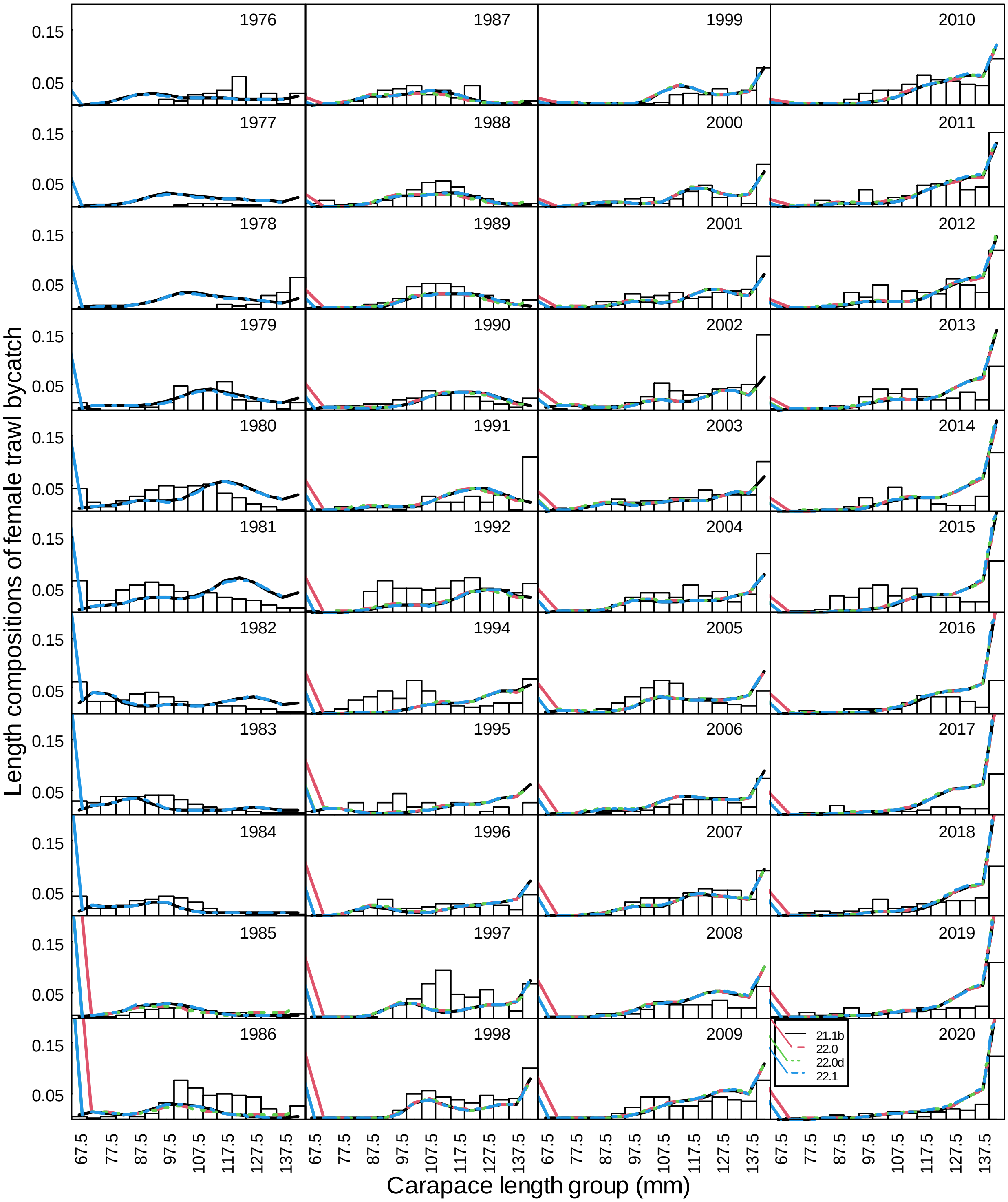


Figure 23b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish trawl fisheries under models 21.1b, 22.0, 22.0d, and 22.1.

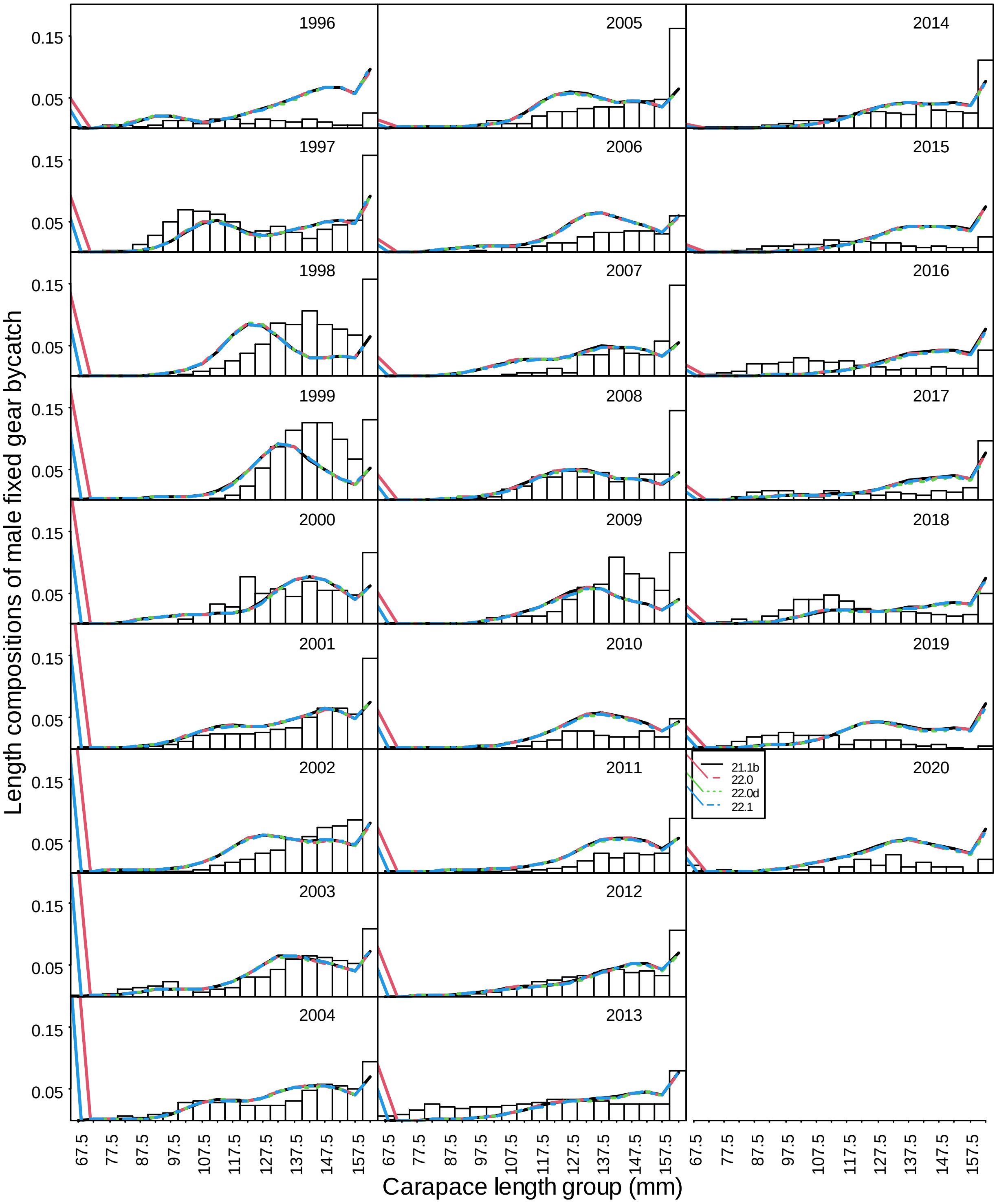


Figure 24a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish fixed gear fisheries under models 21.1b, 22.0, 22.0d, and 22.1.

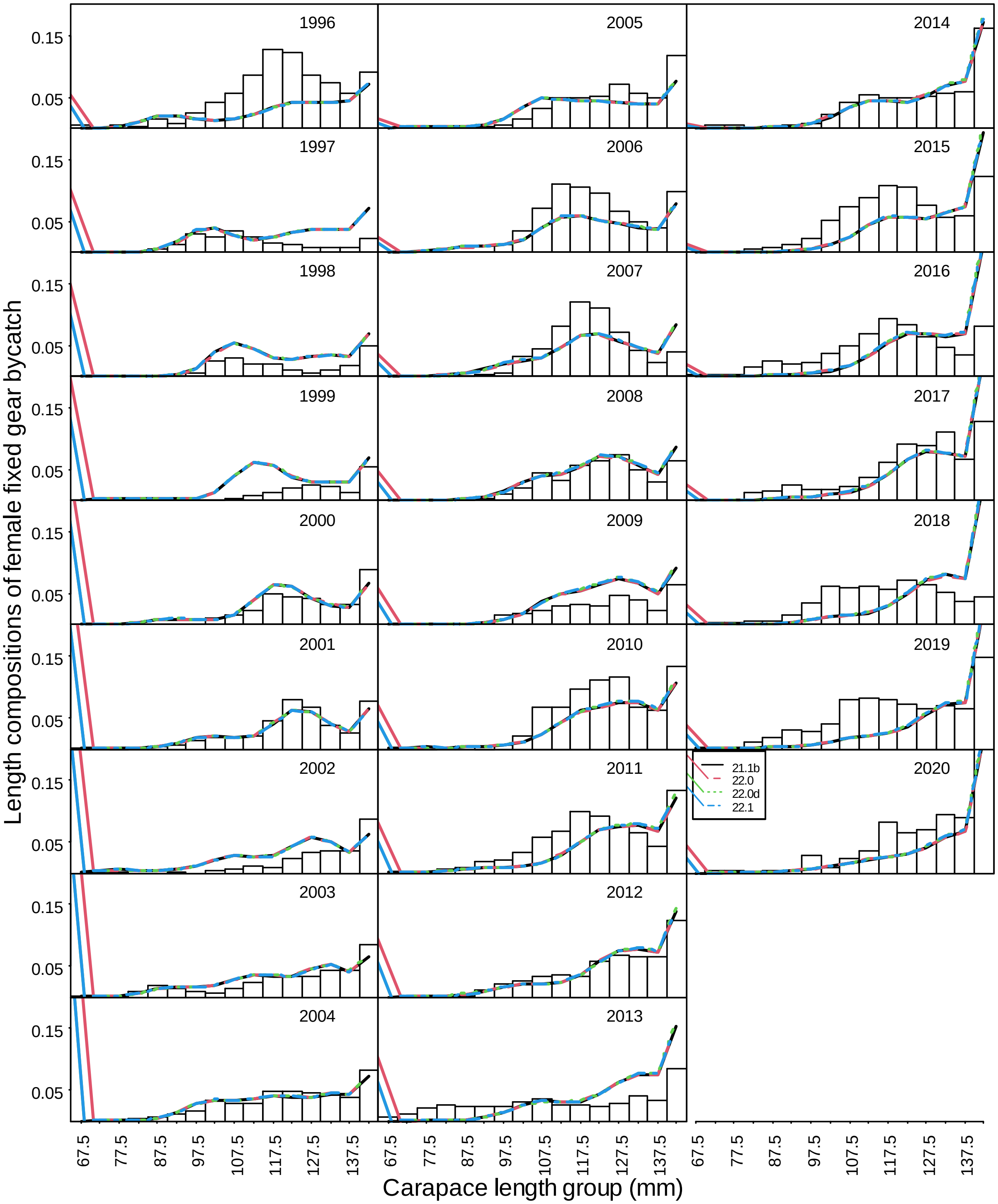


Figure 24b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish fixed gear fisheries under models 21.1b, 22.0, 22.0d, and 22.1.

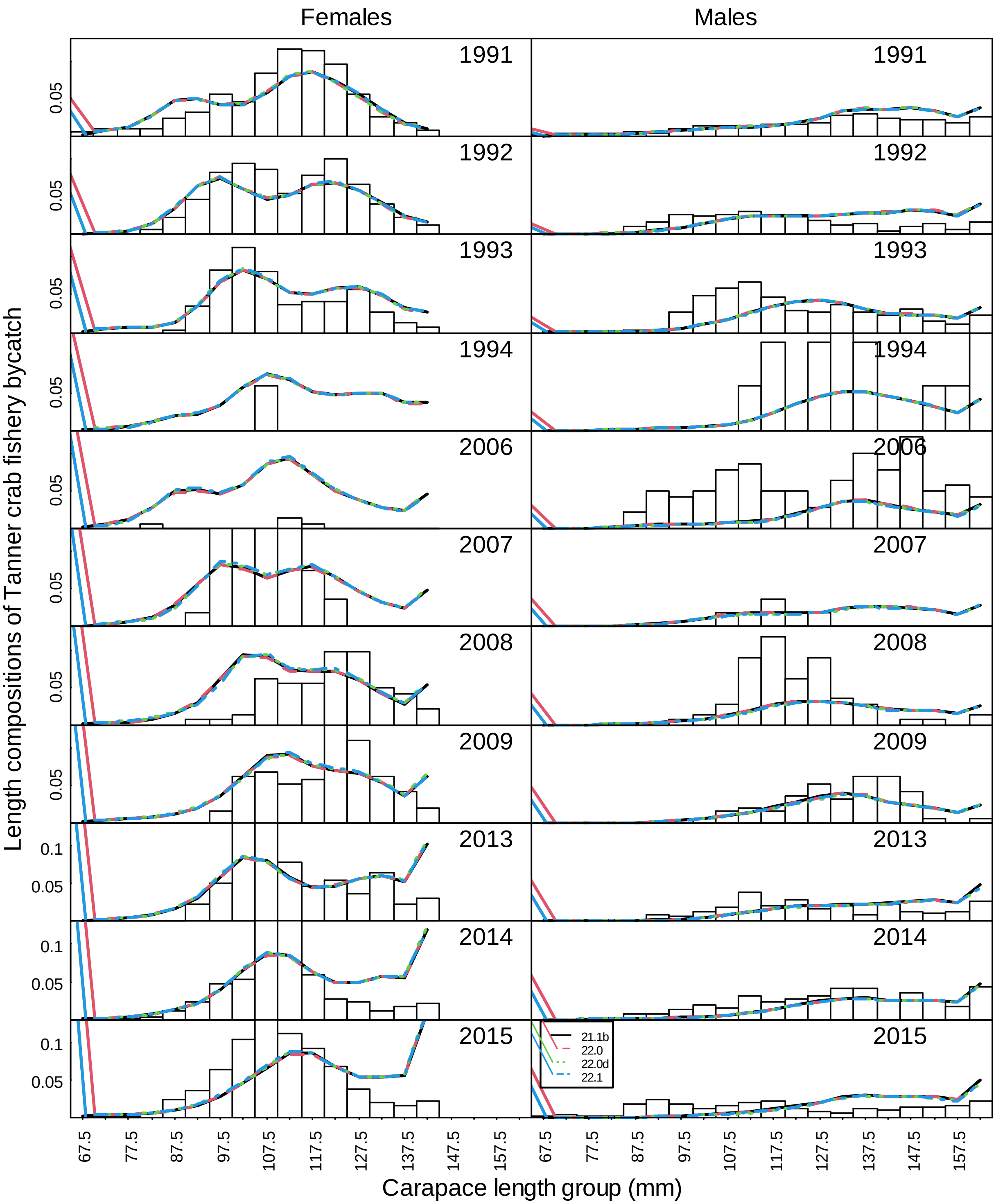


Figure 24c. Comparison of observer and model estimated discarded length frequencies of Bristol Bay red king crab by year in the Tanner crab fishery under models 21.1b, 22.0, 22.0d, and 22.1. Length composition data during 1994-2009 were not used before 2021.

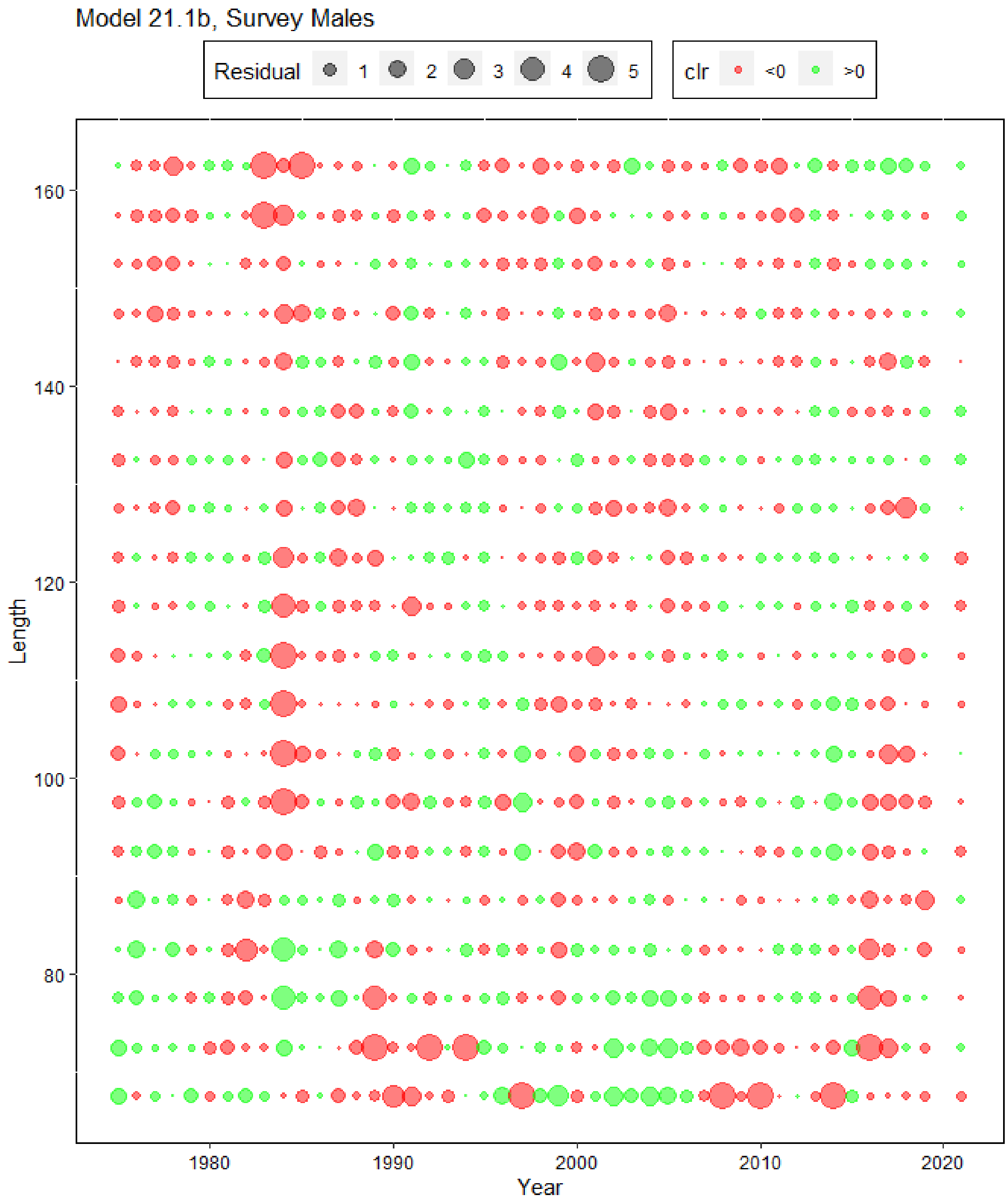


Figure 25a. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 21.1b. Green circles are positive residuals, and red circles are negative residuals.

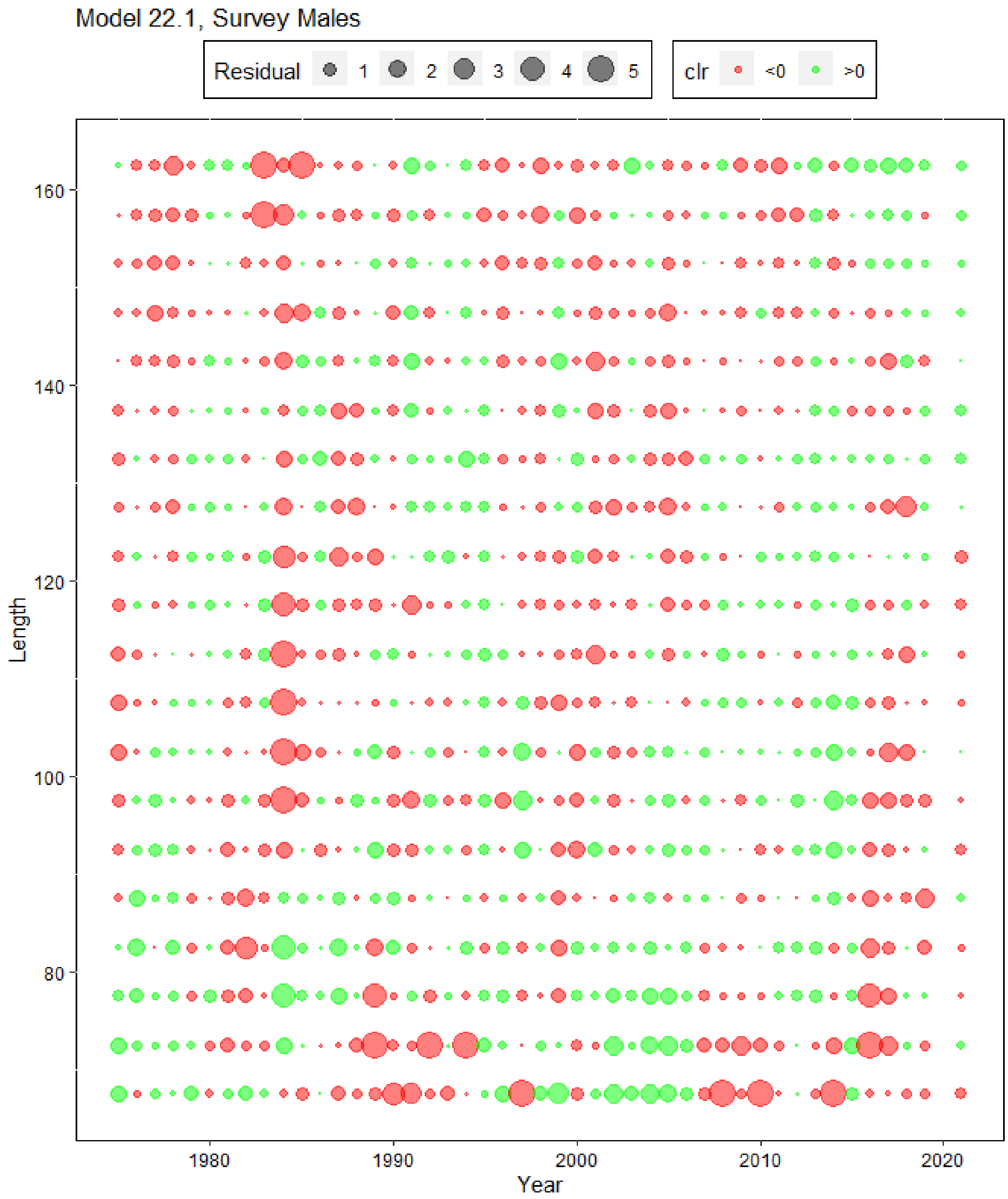


Figure 25b. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 22.1. Green circles are positive residuals, and red circles are negative residuals.

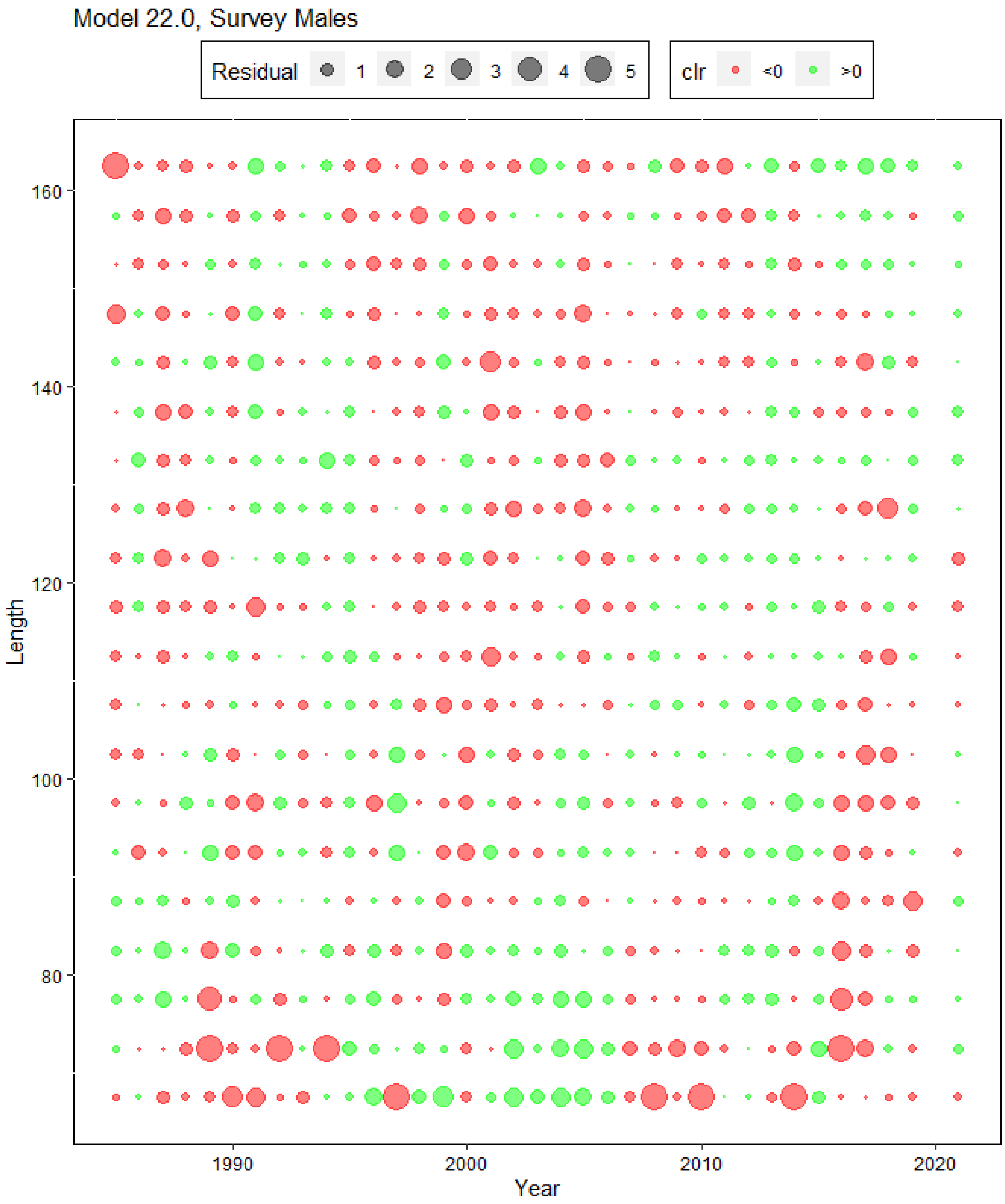


Figure 25c. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 22.0. Green circles are positive residuals, and red circles are negative residuals.

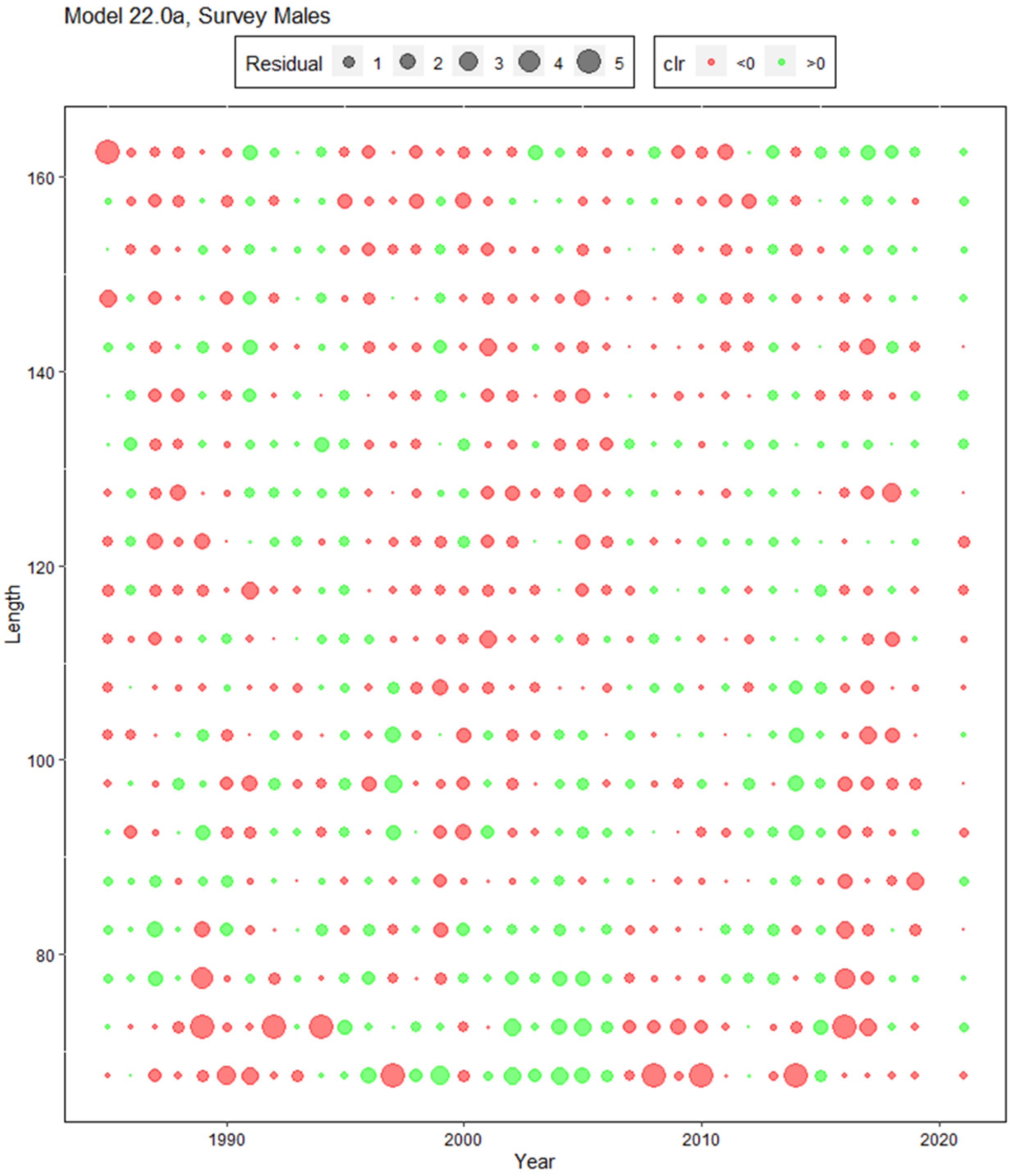


Figure 25d. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 22.0a. Green circles are positive residuals, and red circles are negative residuals.

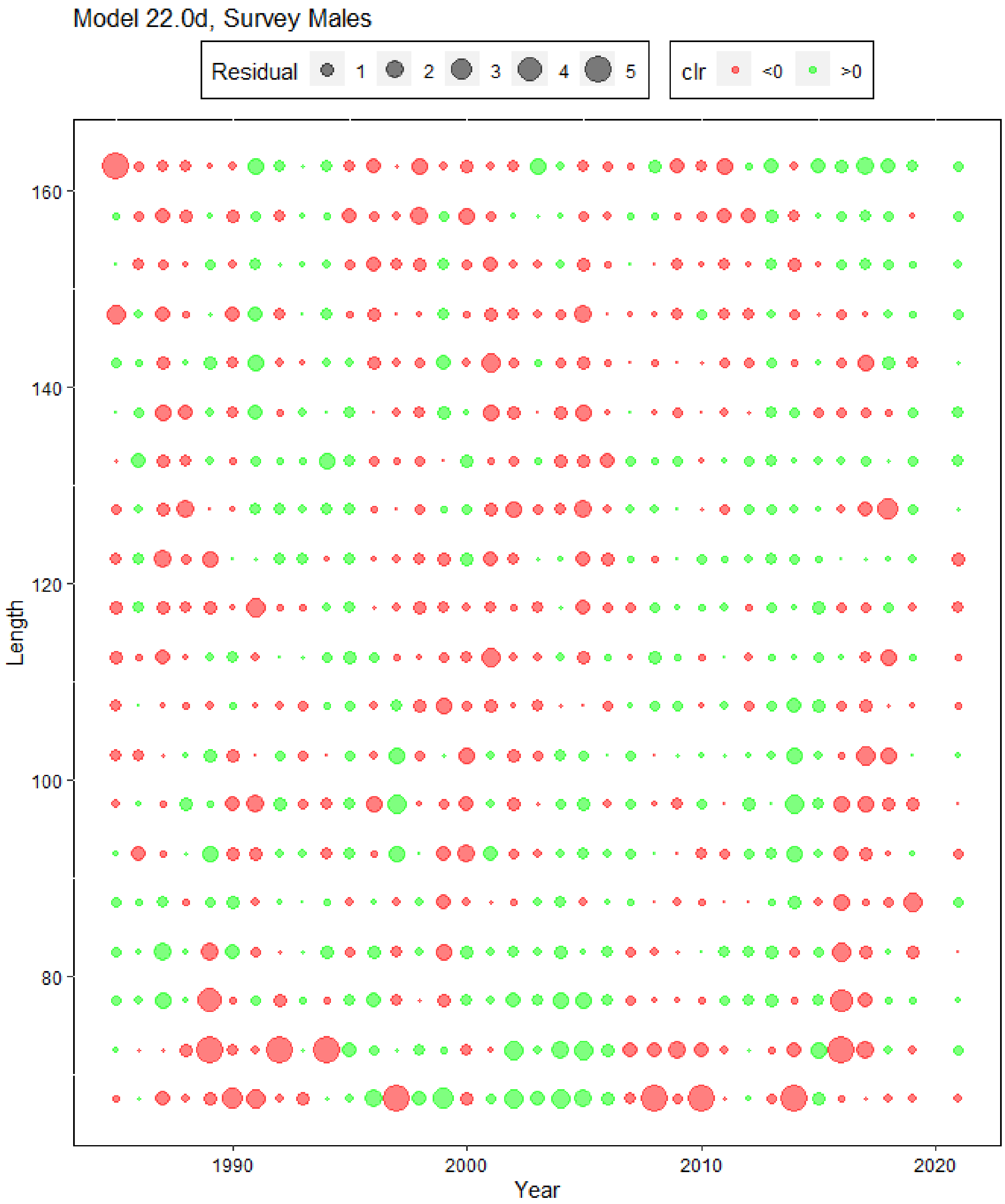


Figure 25e. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 22.0d. Green circles are positive residuals, and red circles are negative residuals.

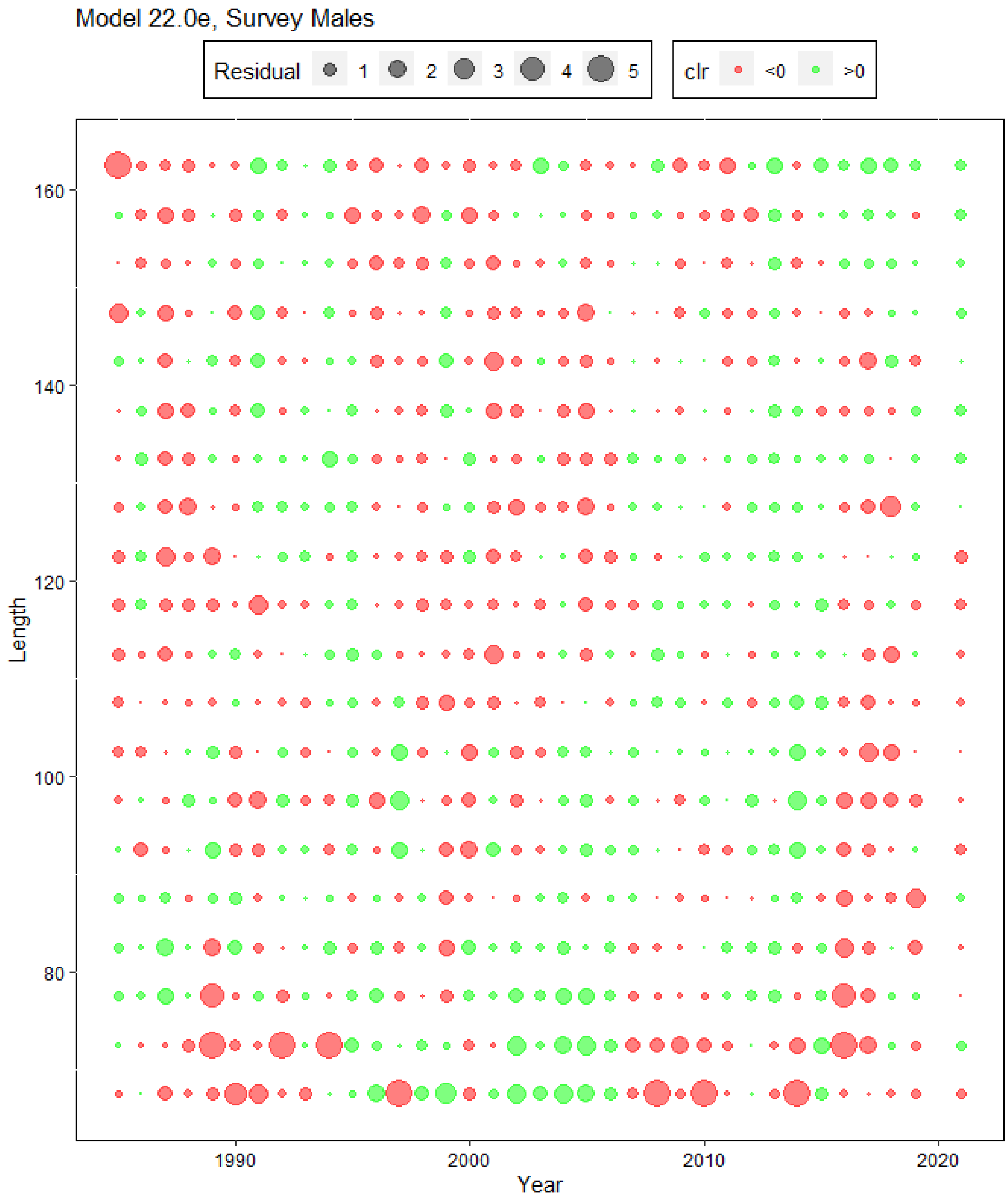


Figure 25f. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 22.0e. Green circles are positive residuals, and red circles are negative residuals.

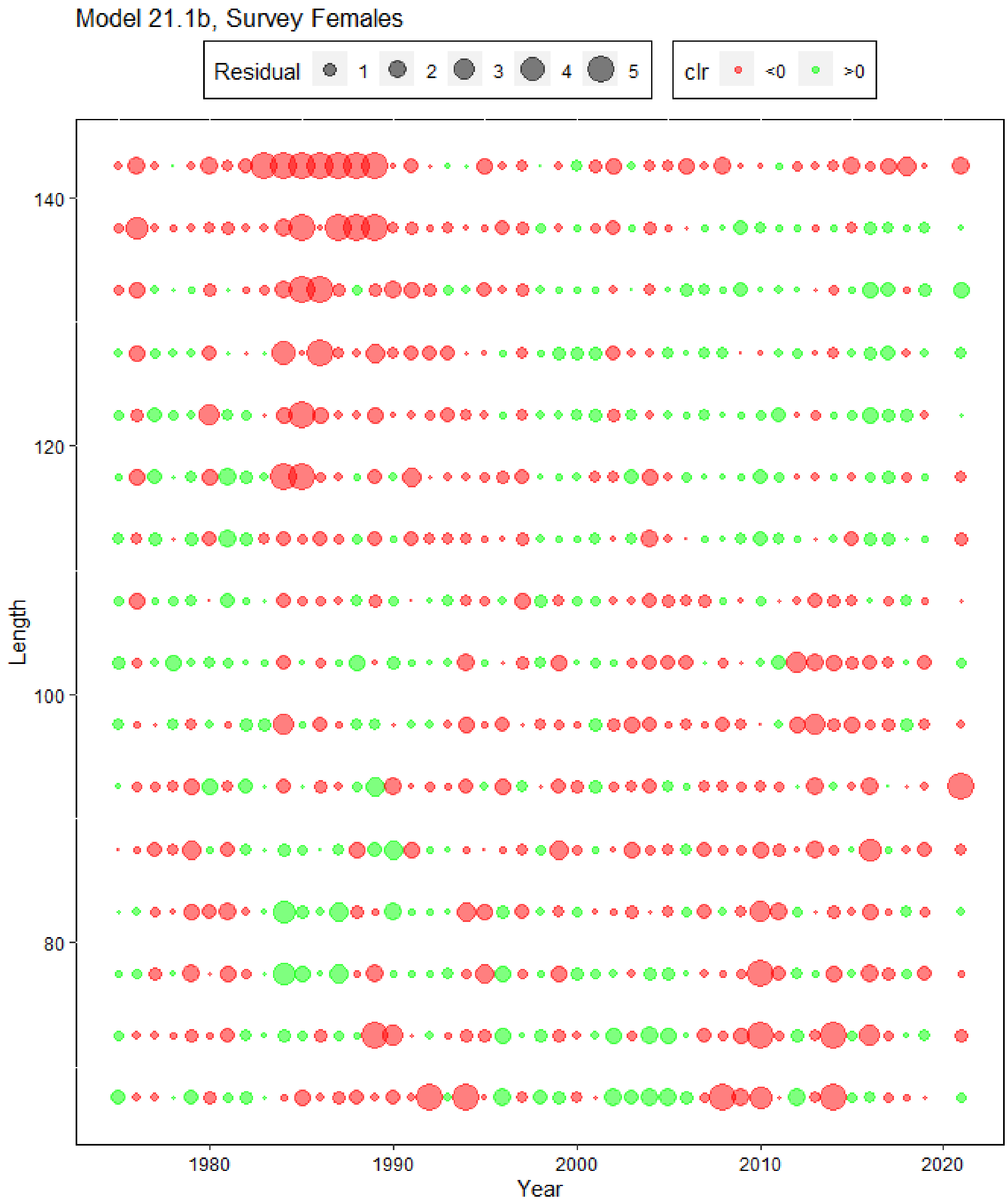


Figure 26a. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 21.1b. Green circles are positive residuals, and red circles are negative residuals.

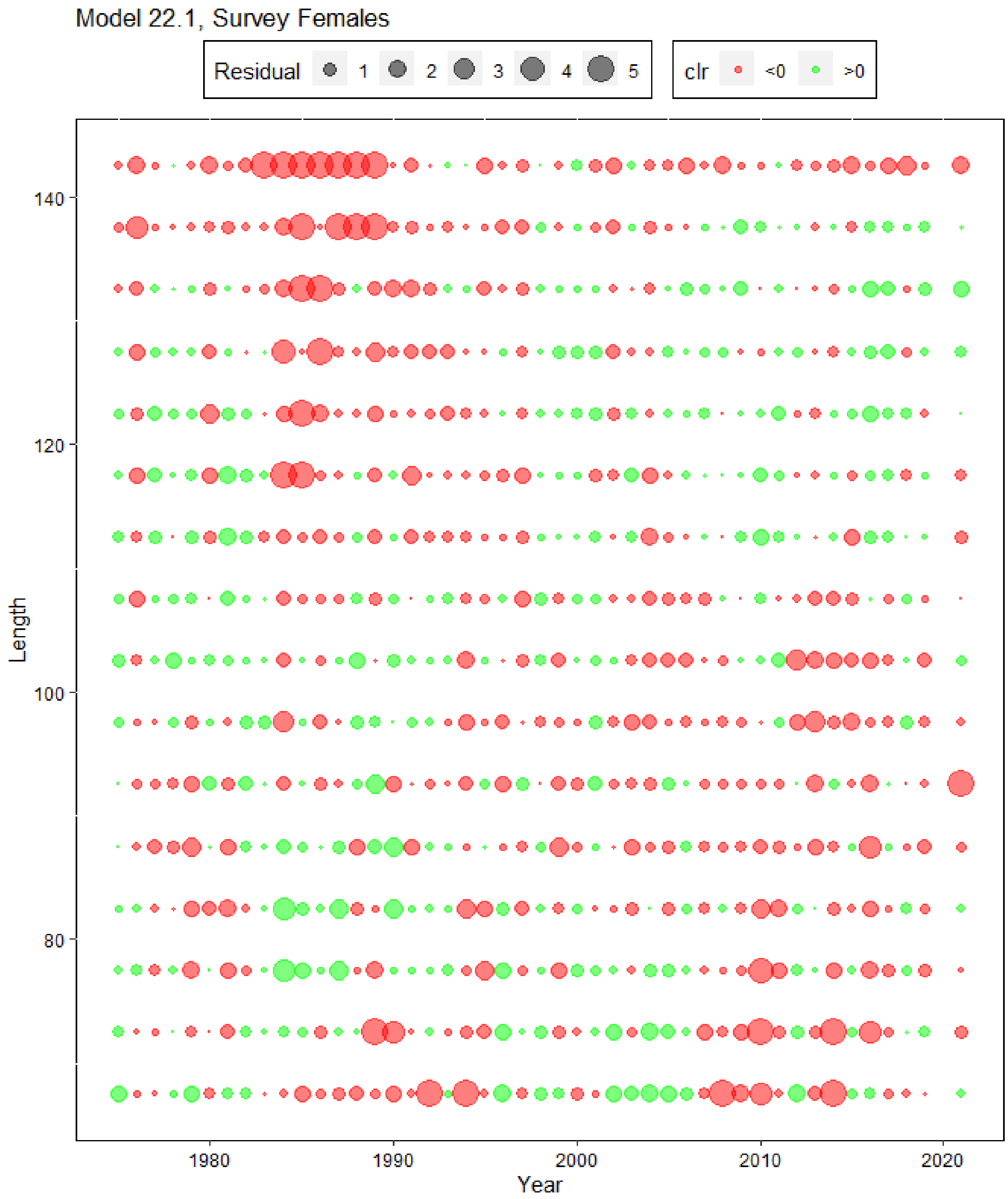


Figure 26b. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 22.1. Green circles are positive residuals, and red circles are negative residuals.

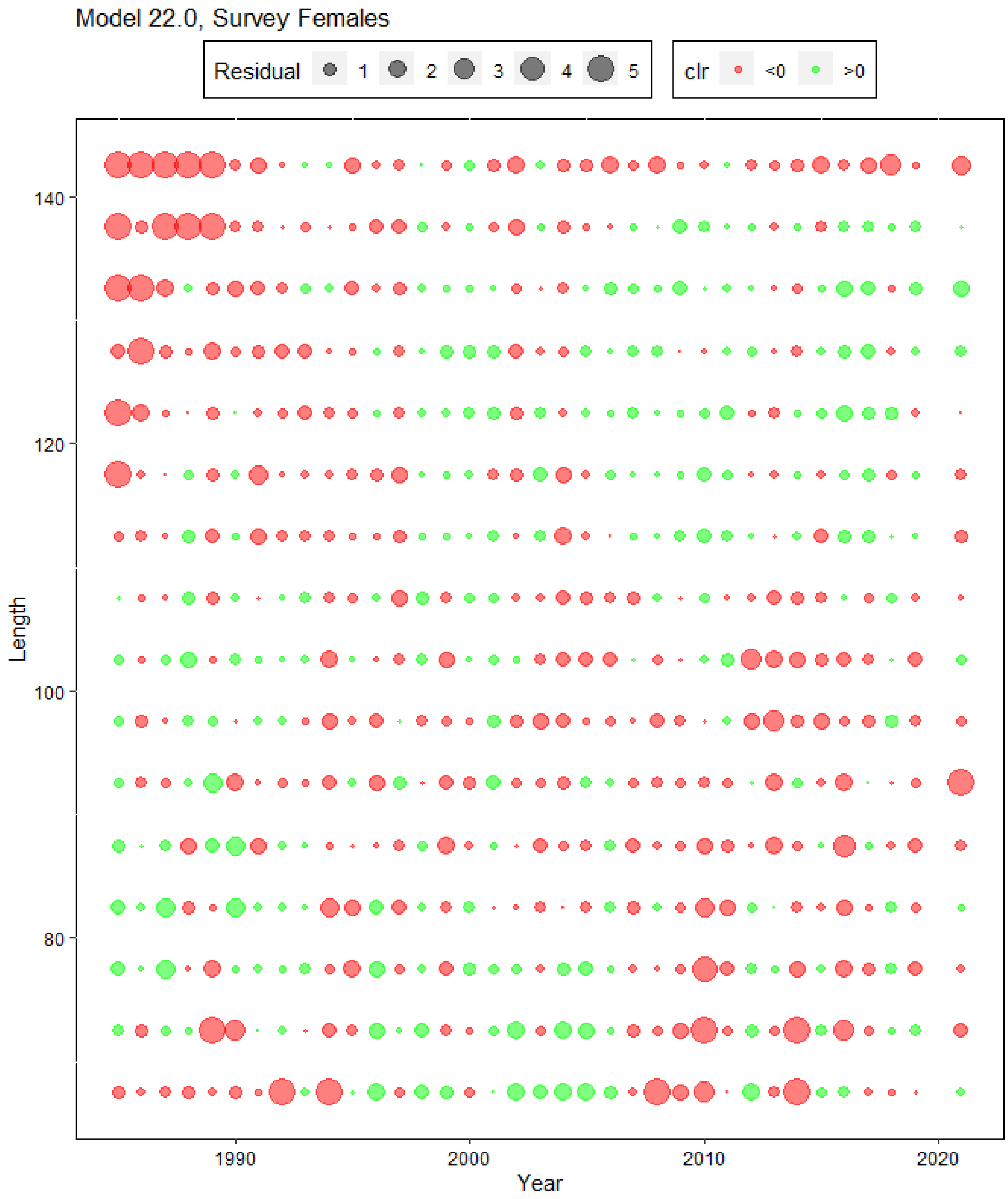


Figure 26c. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 22.0. Green circles are positive residuals, and red circles are negative residuals.

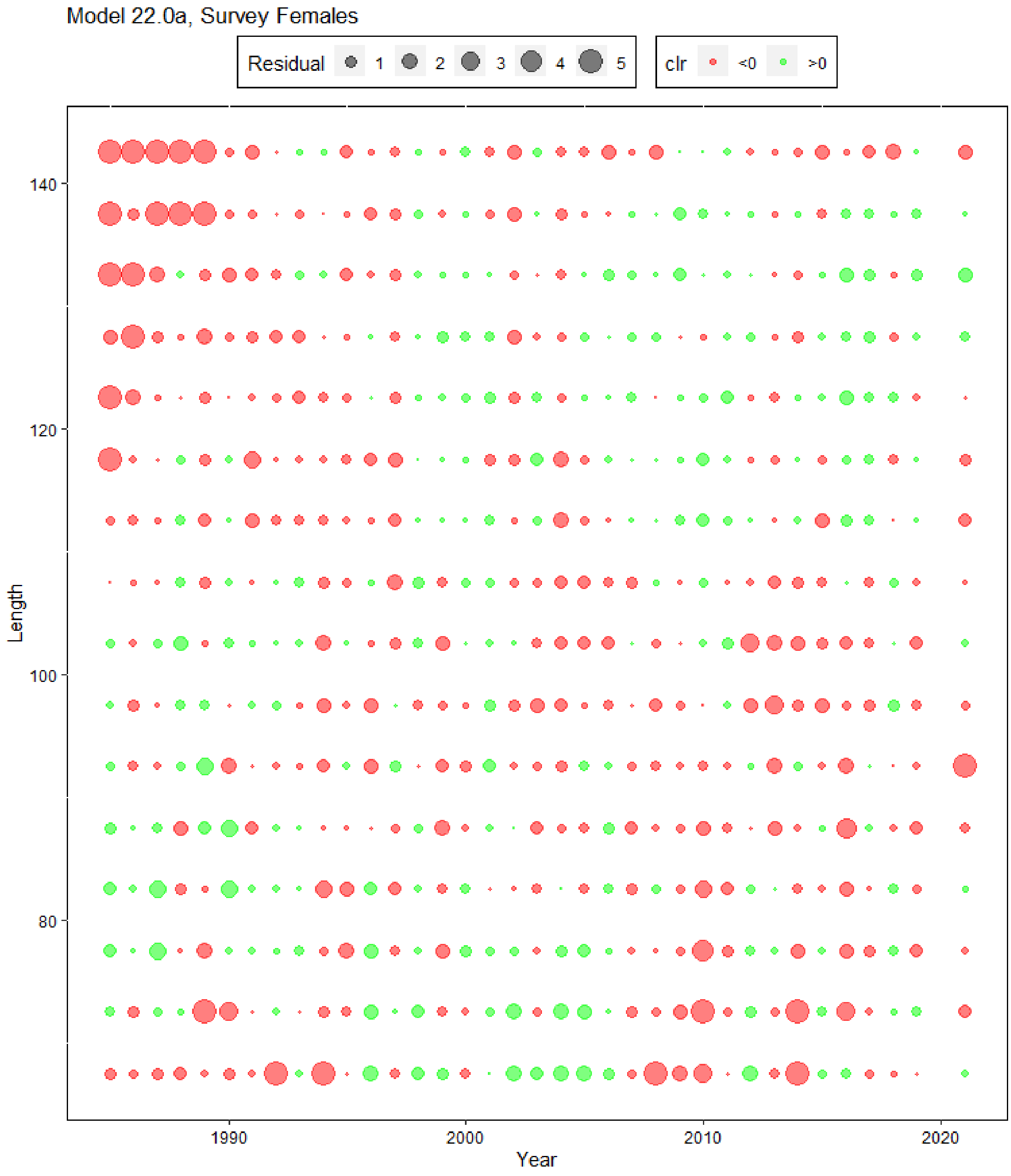


Figure 26d. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 22.0a. Green circles are positive residuals, and red circles are negative residuals.

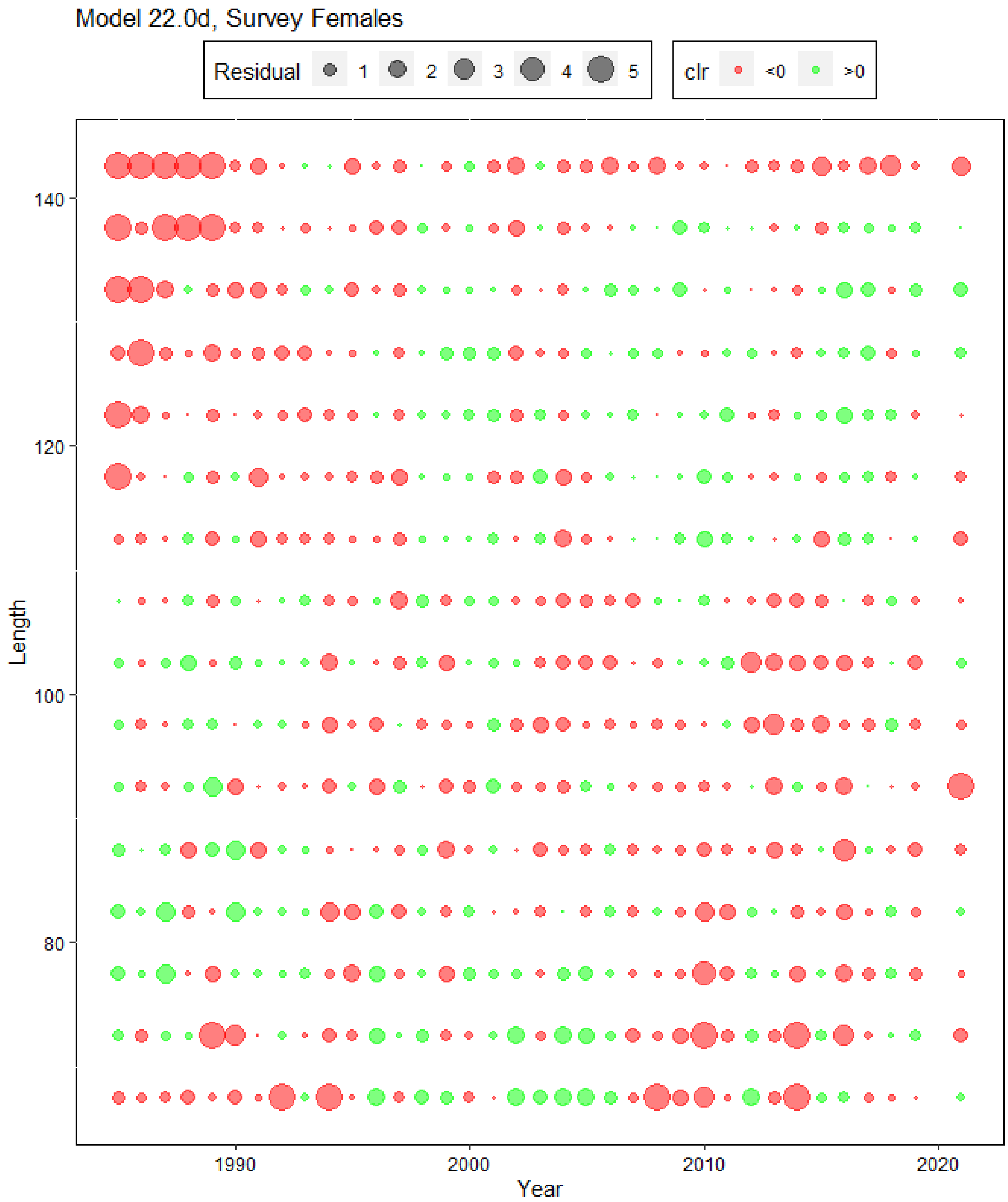


Figure 26e. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 22.0d. Green circles are positive residuals, and red circles are negative residuals.

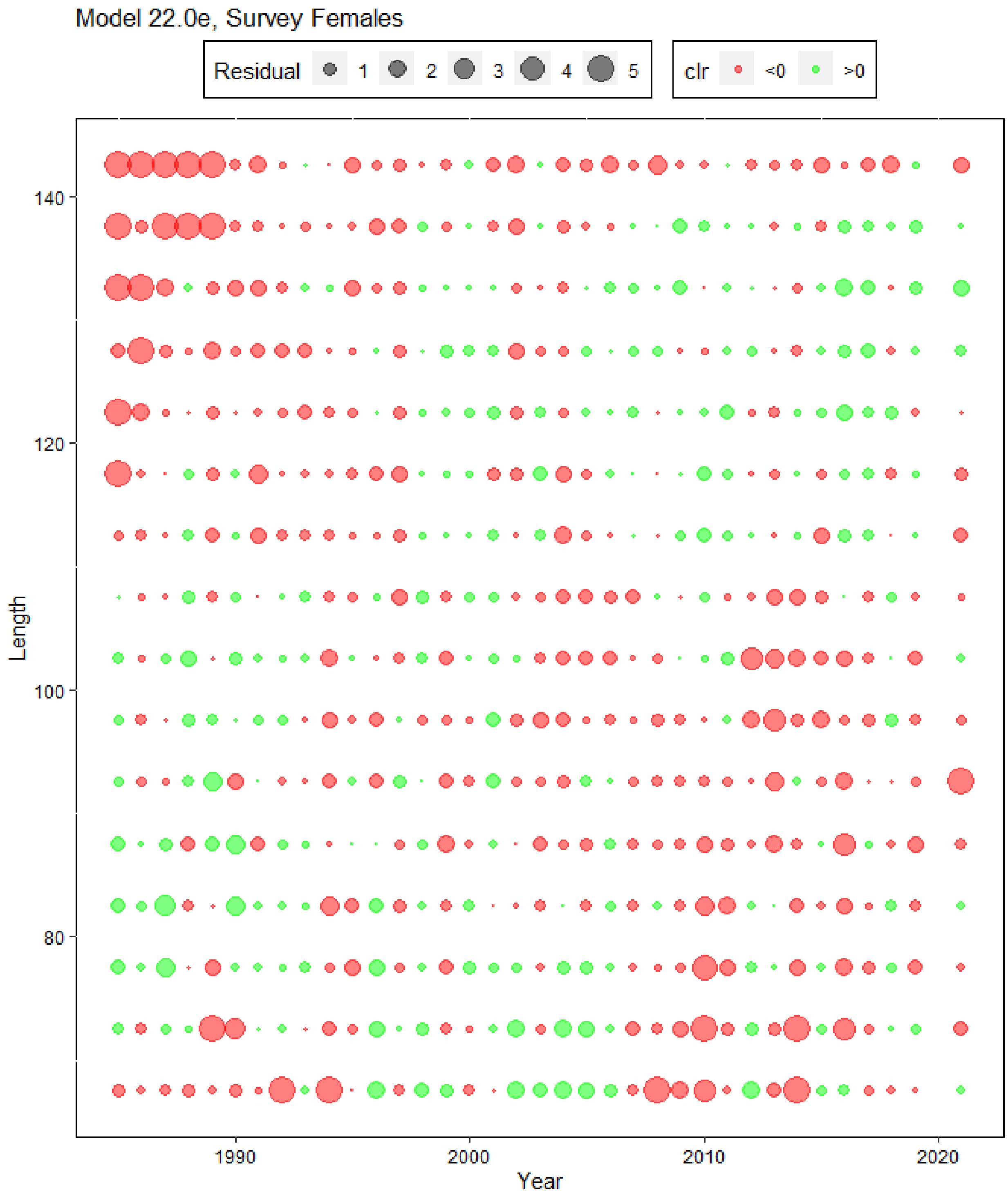


Figure 26f. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 22.0e. Green circles are positive residuals, and red circles are negative residuals.

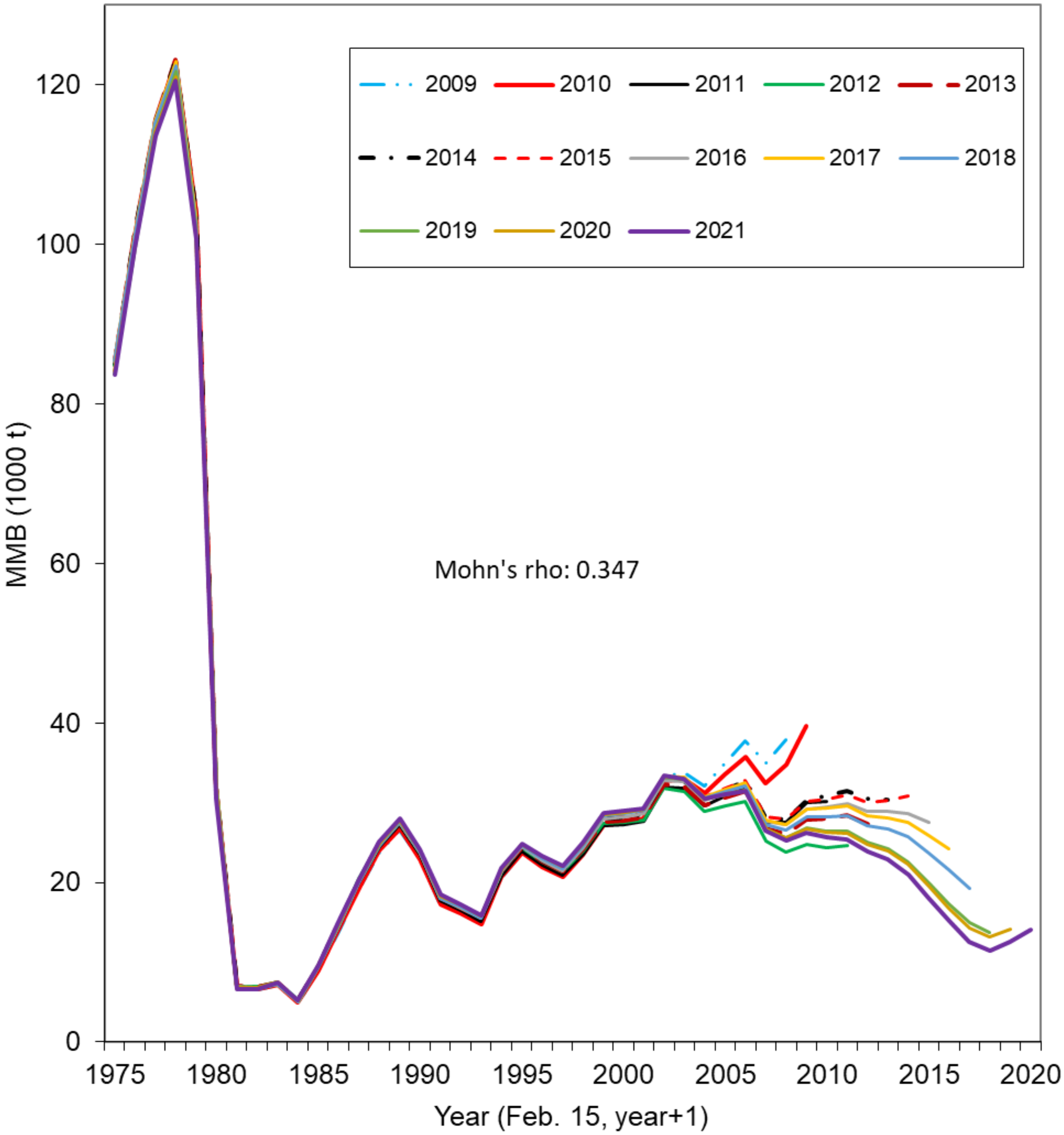


Figure 27a. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 21.1b. These are results of the 2021 model. Legend shows the terminal year.

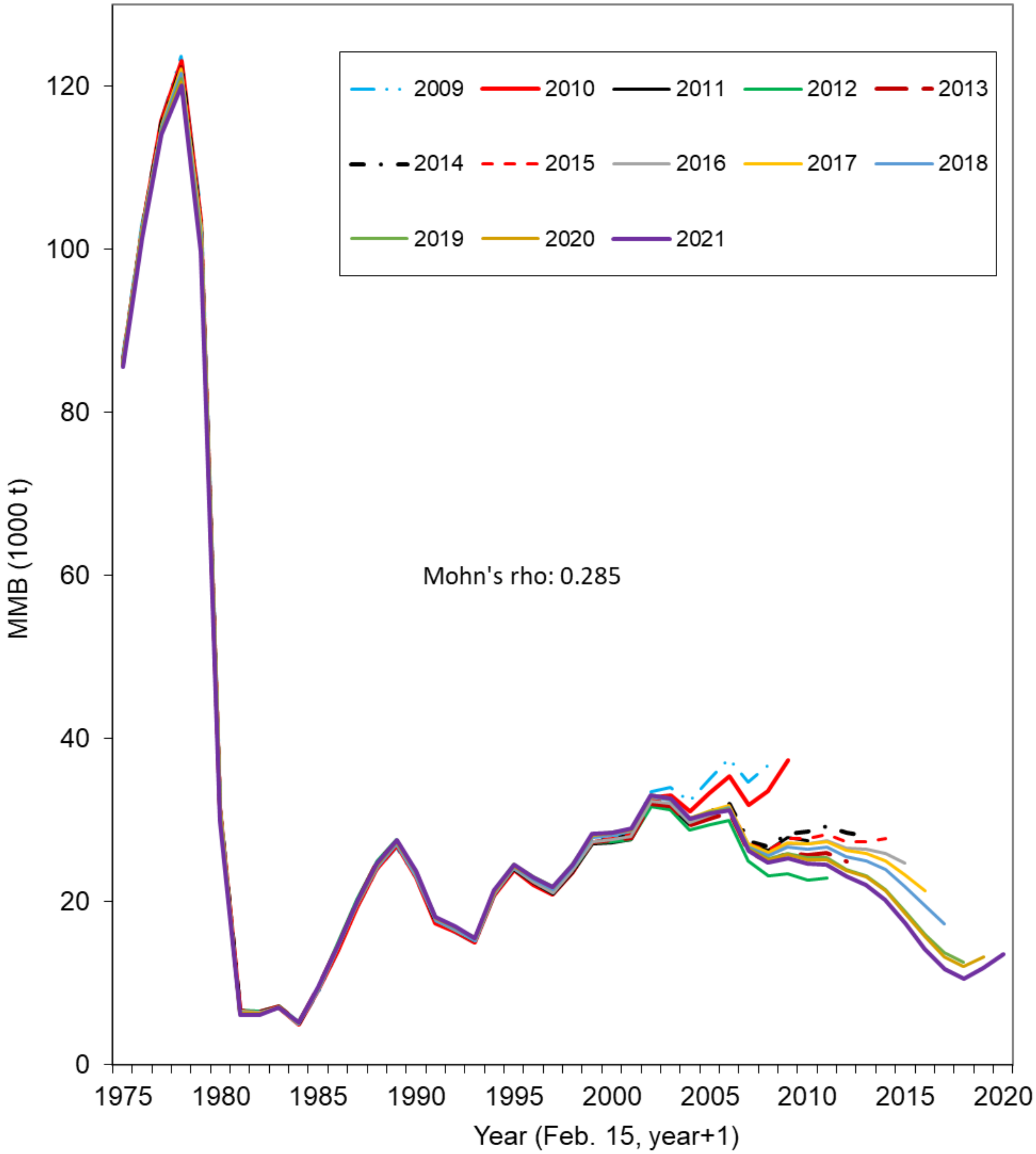


Figure 27b. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.1. These are results of the 2021 model. Legend shows the terminal year.

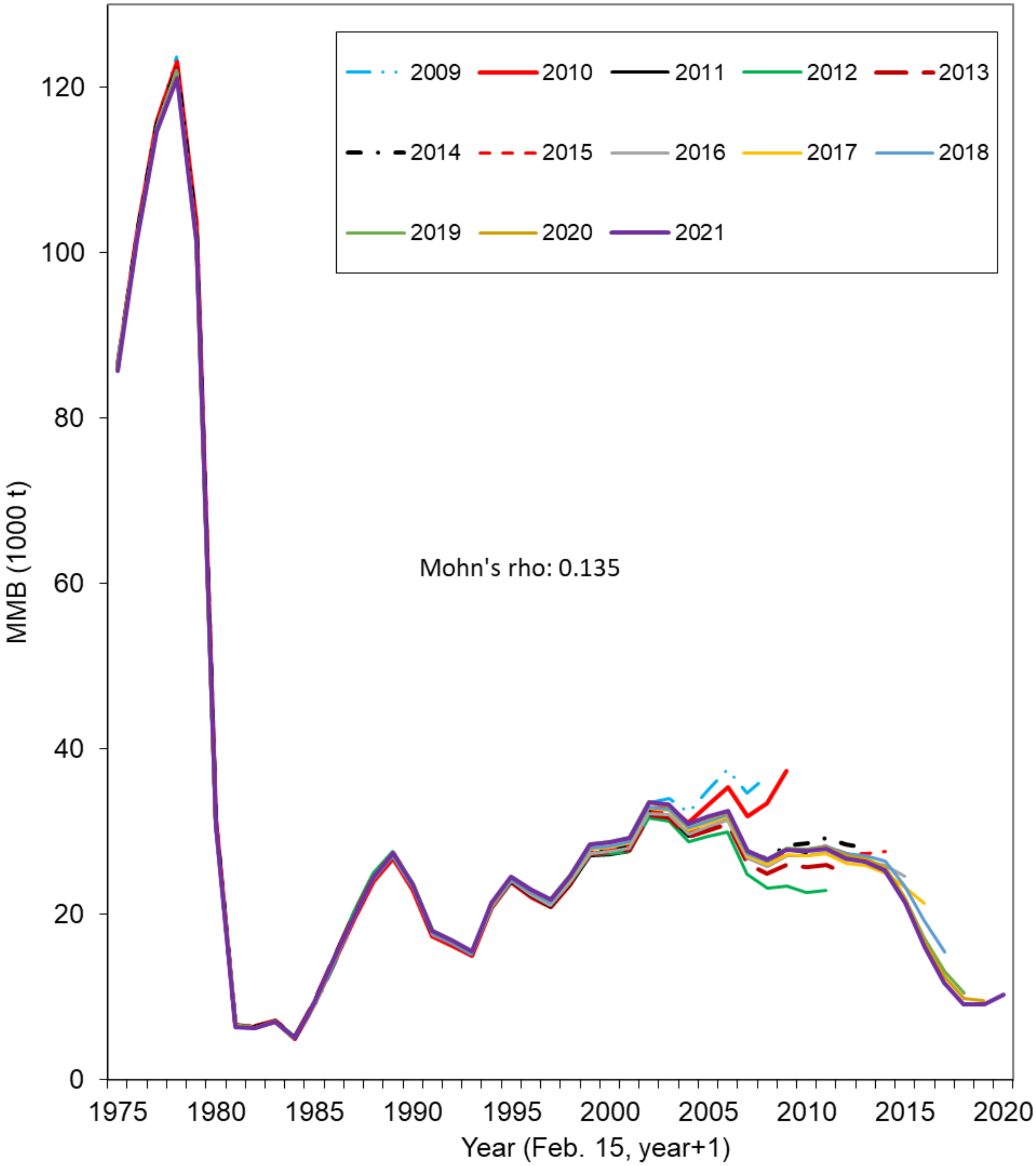


Figure 27c. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.1a. These are results of the 2021 model. Legend shows the terminal year.

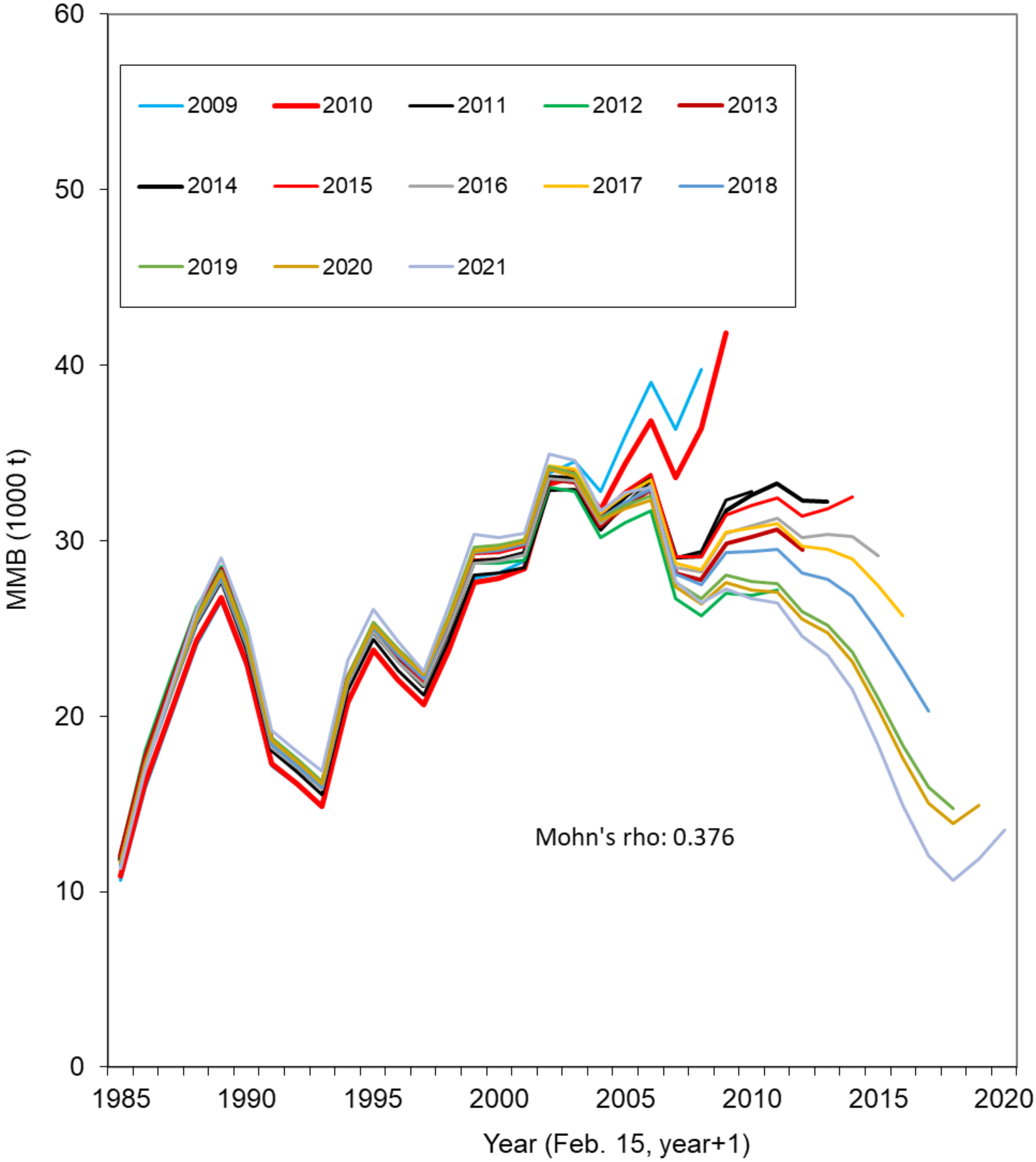


Figure 27d. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.0. These are results of the 2021 model. Legend shows the terminal year.

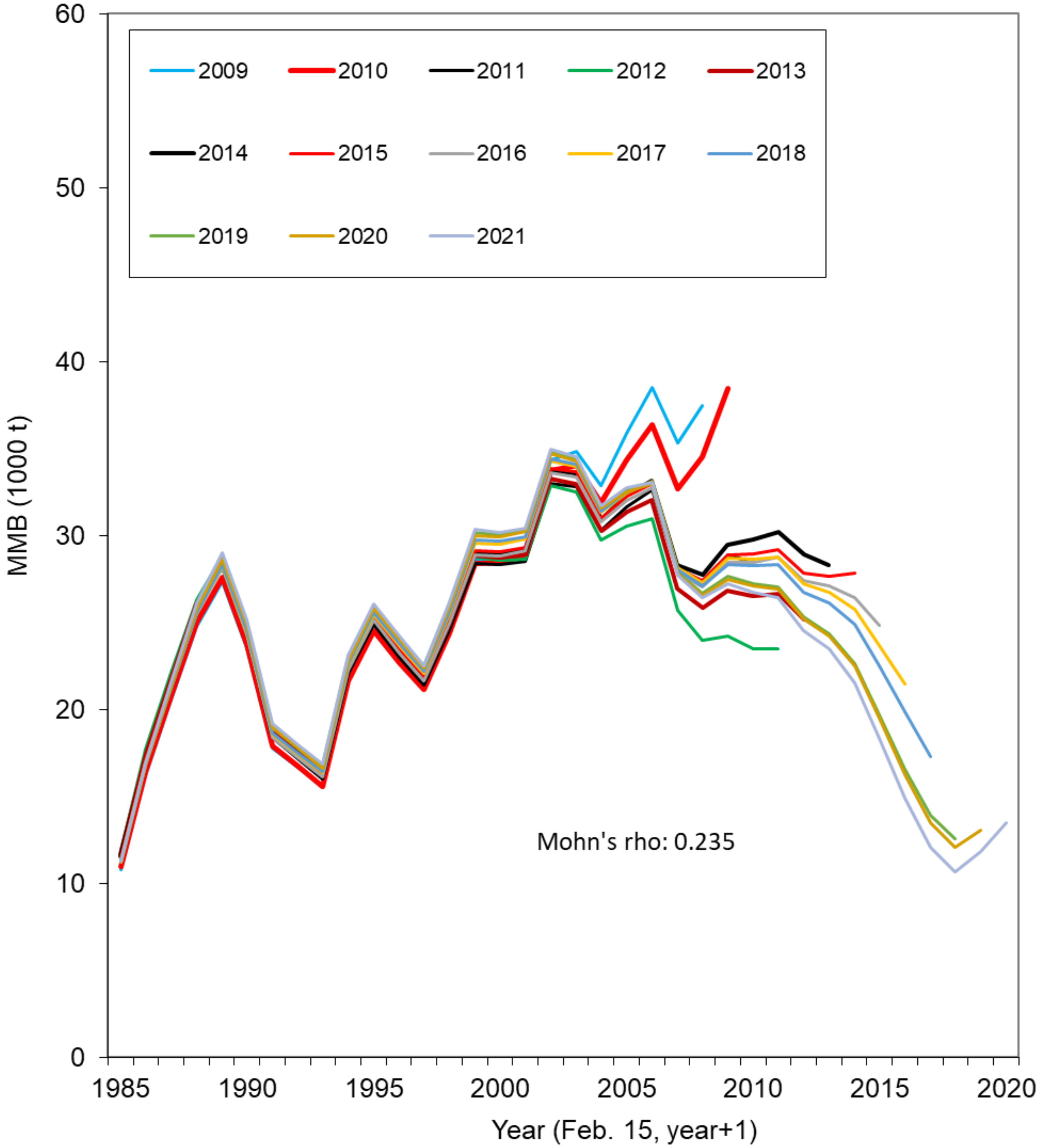


Figure 27e. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.0c. These are results of the 2021 model. Legend shows the terminal year.

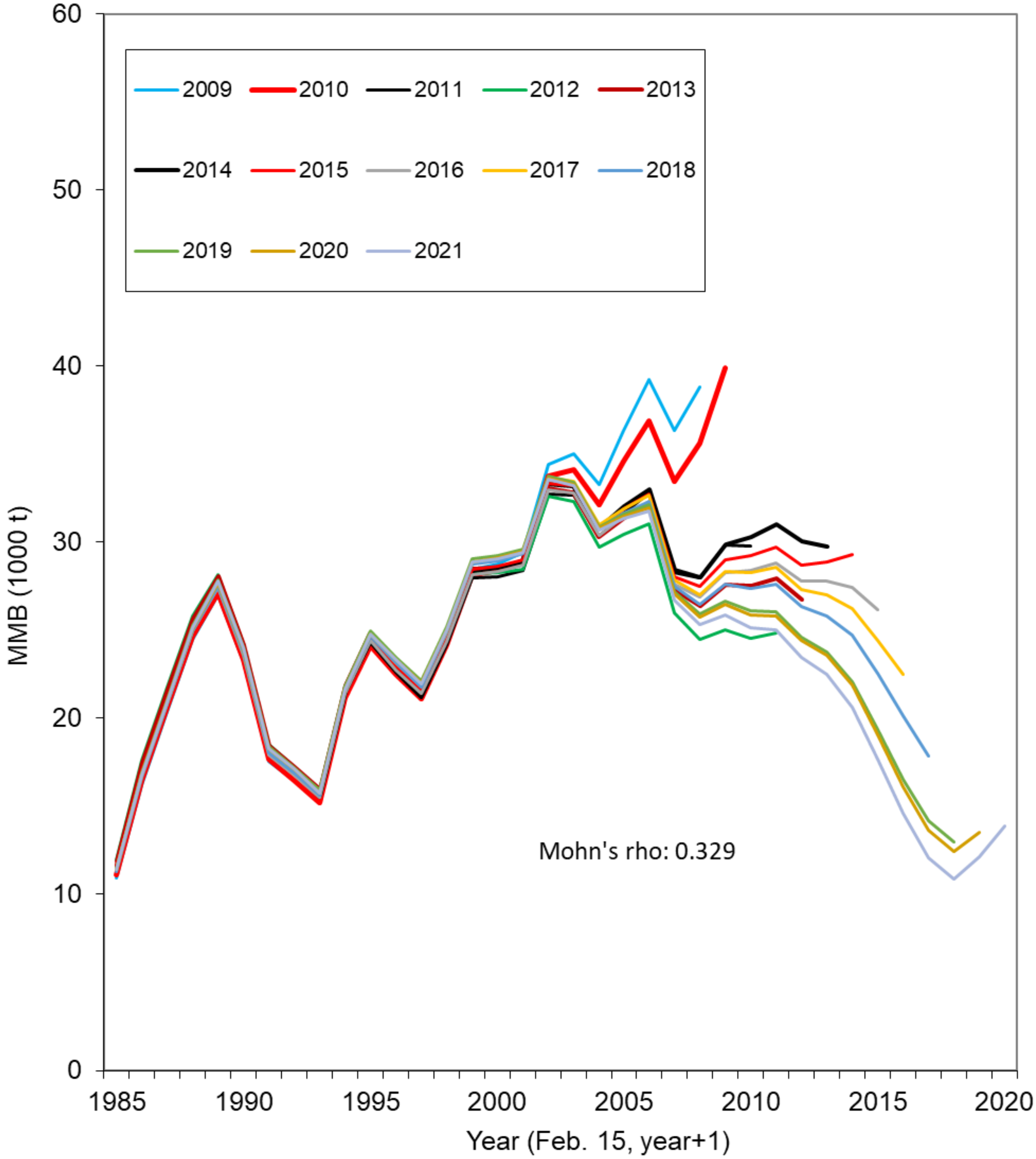


Figure 27f. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.0d. These are results of the 2021 model. Legend shows the terminal year.

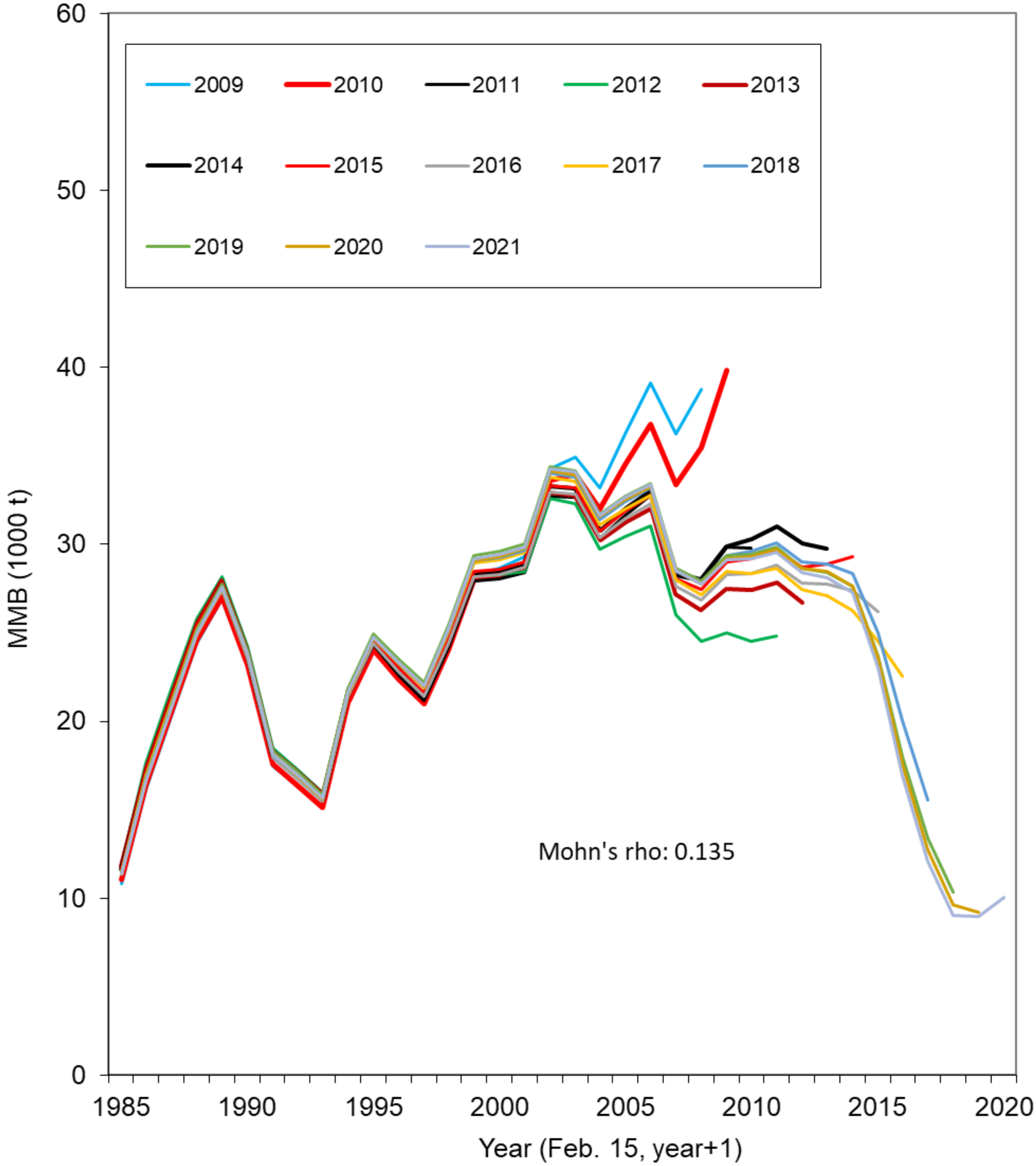


Figure 27g. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 22.0e. These are results of the 2021 model. Legend shows the terminal year.

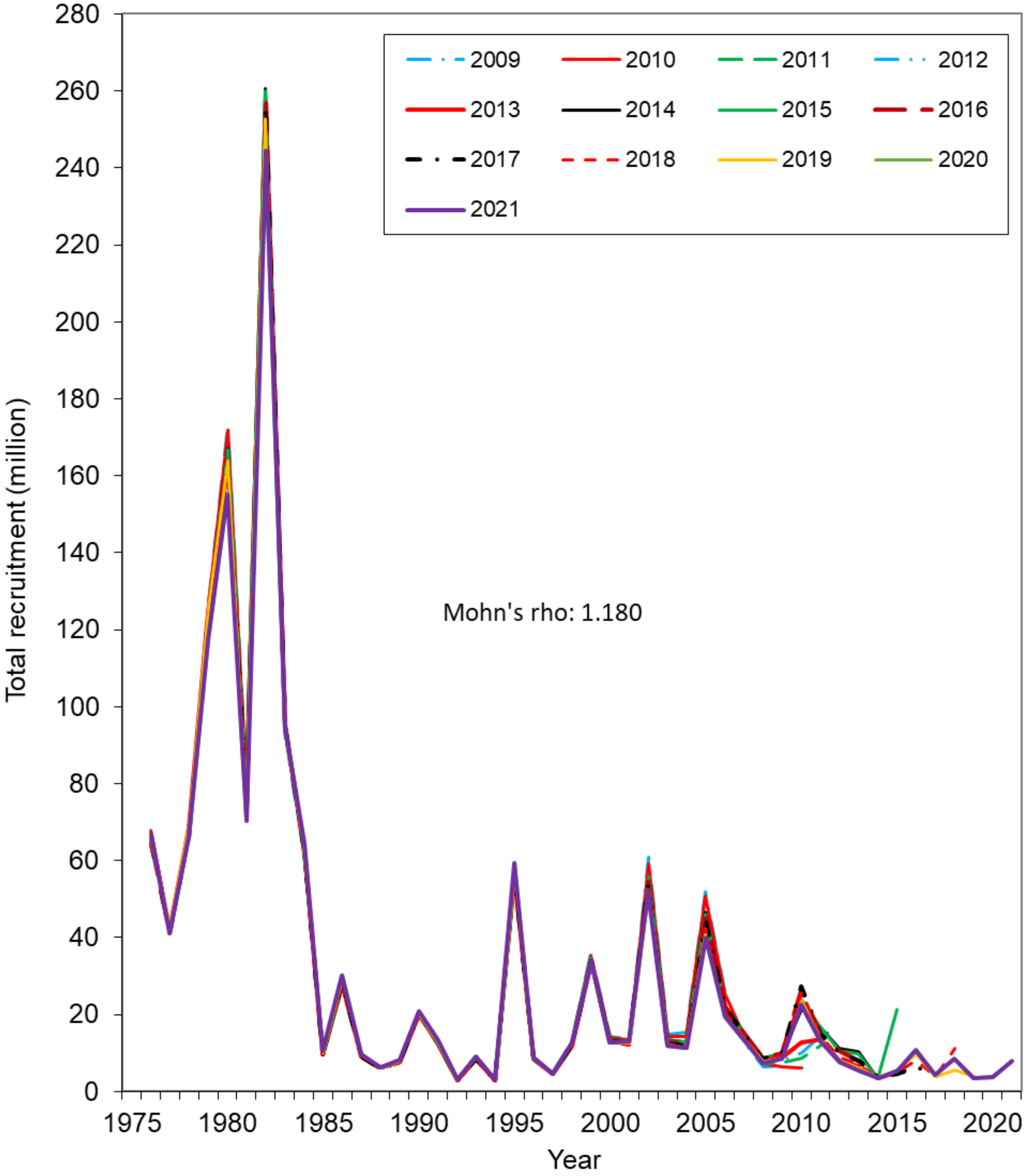


Figure 28a. Comparison of hindcast estimates of total recruitment for model 21.1b of Bristol Bay red king crab from 1976 to 2021 made with terminal years 2009-2021. These are results of the 2021 model. Legend shows the terminal year.

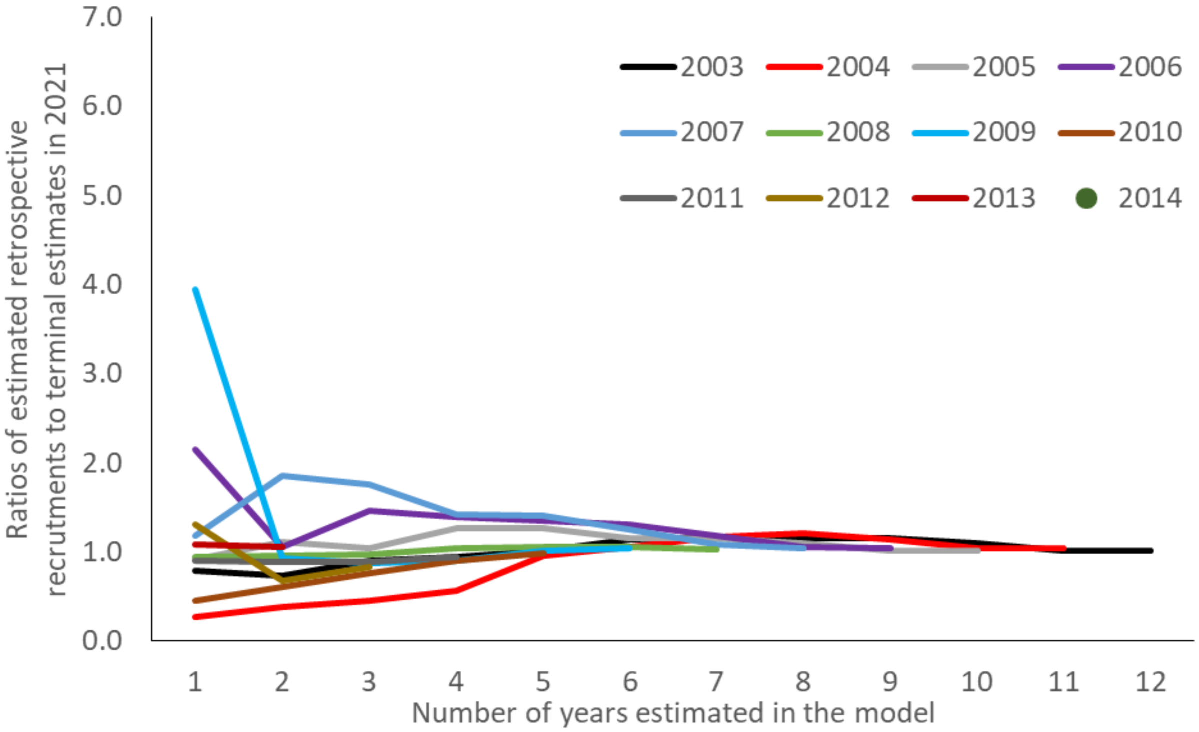


Figure 28b. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 21.1b.

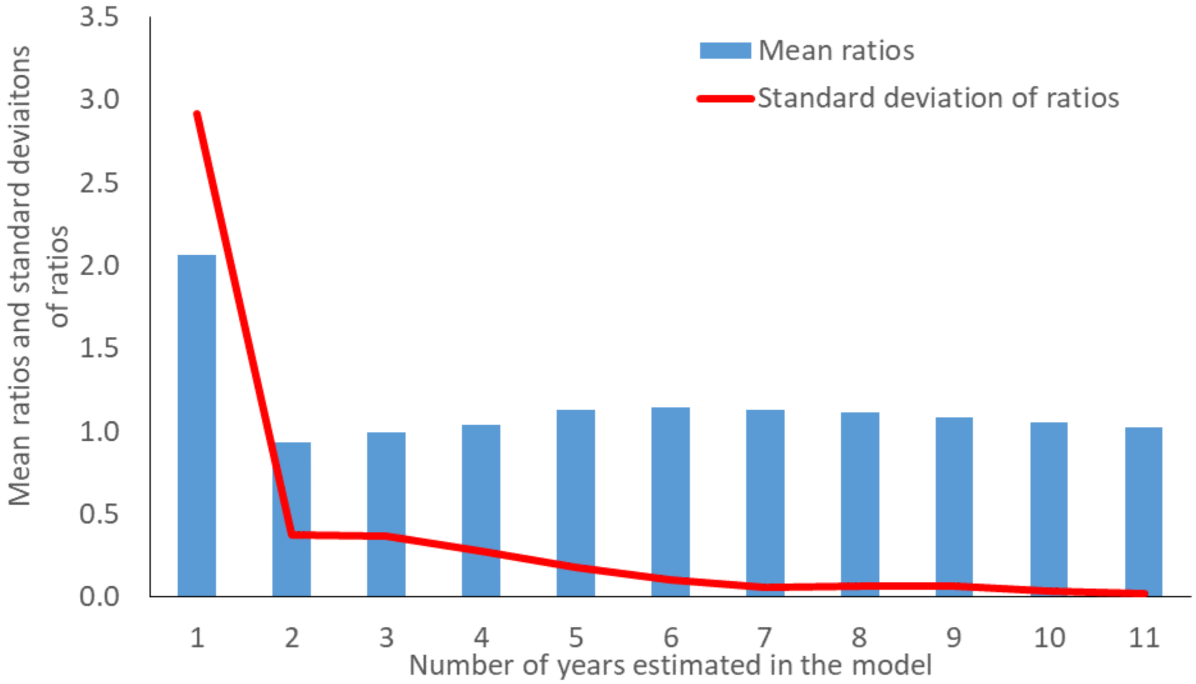


Figure 28c. Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2021) and standard deviations of the ratios as a function of the number of years in the model for model 21.1b.

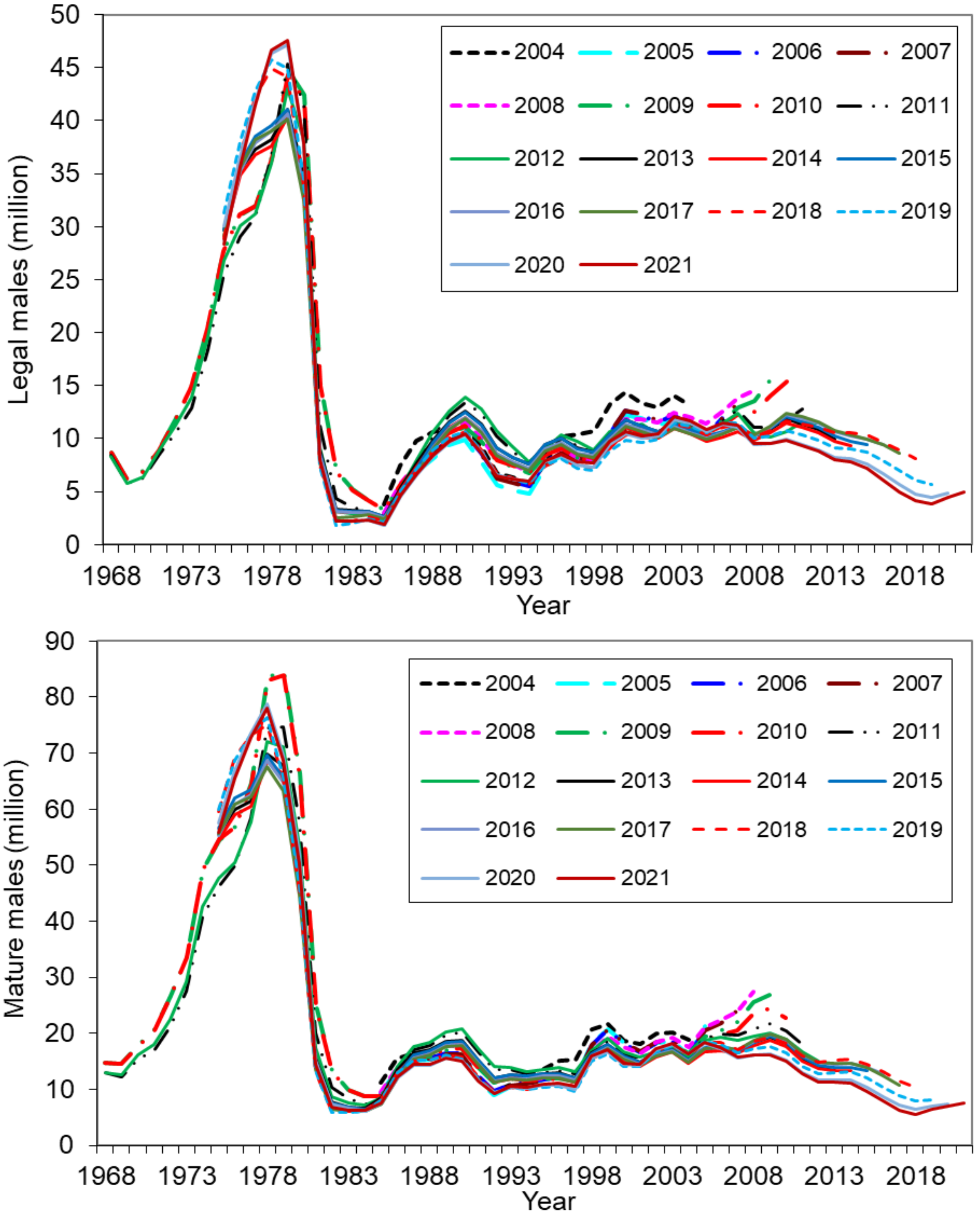


Figure 29a. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2021 made with terminal years 2004-2021 with the base models. Model 21.1b is used for 2021. These are results of historical assessments. Legend shows the year in which the assessment was conducted.

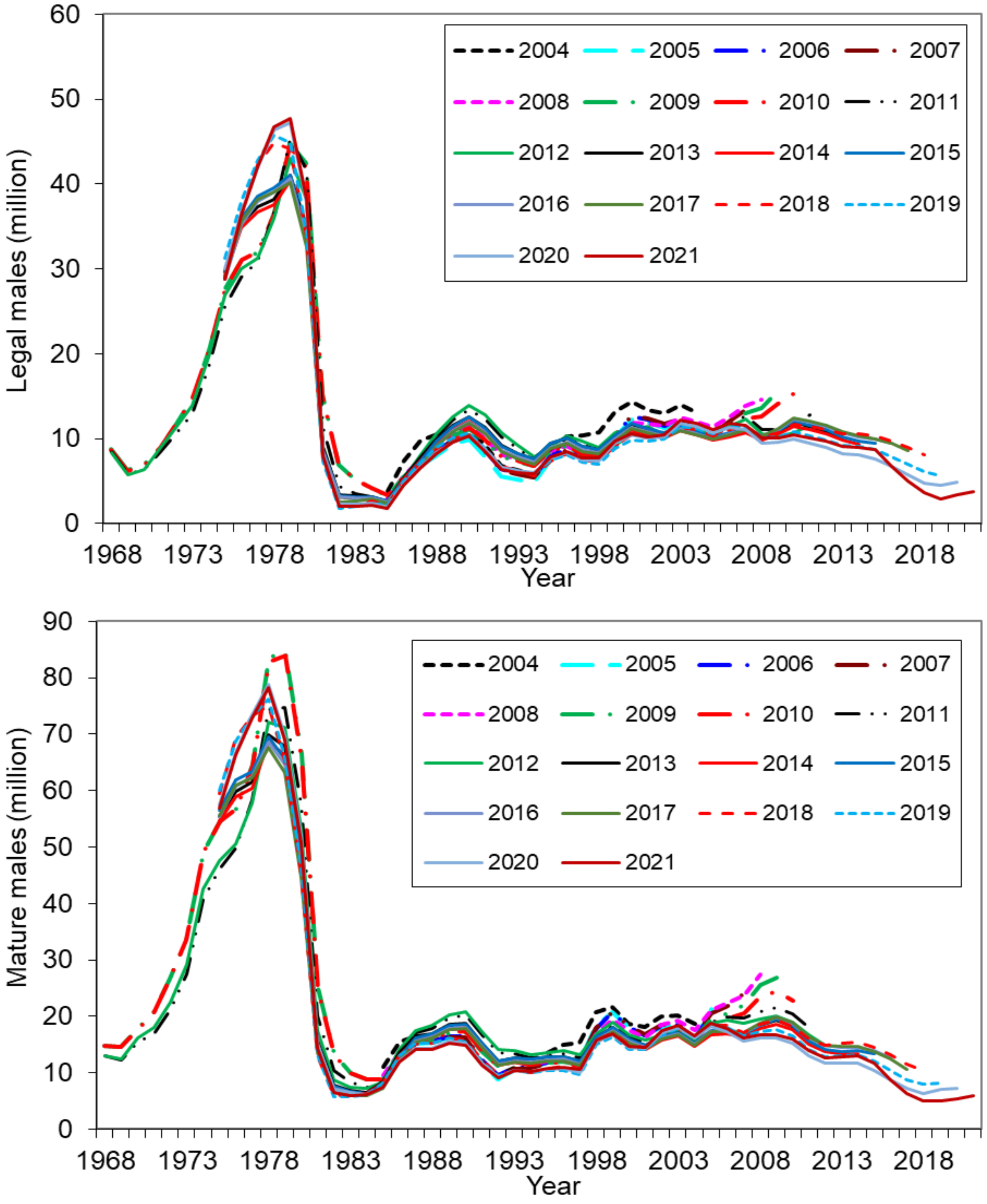


Figure 29b. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2021 made with terminal years 2004-2021 with the base models. Model 22.1a is used for 2021. These are results of historical assessments. Legend shows the year in which the assessment was conducted.

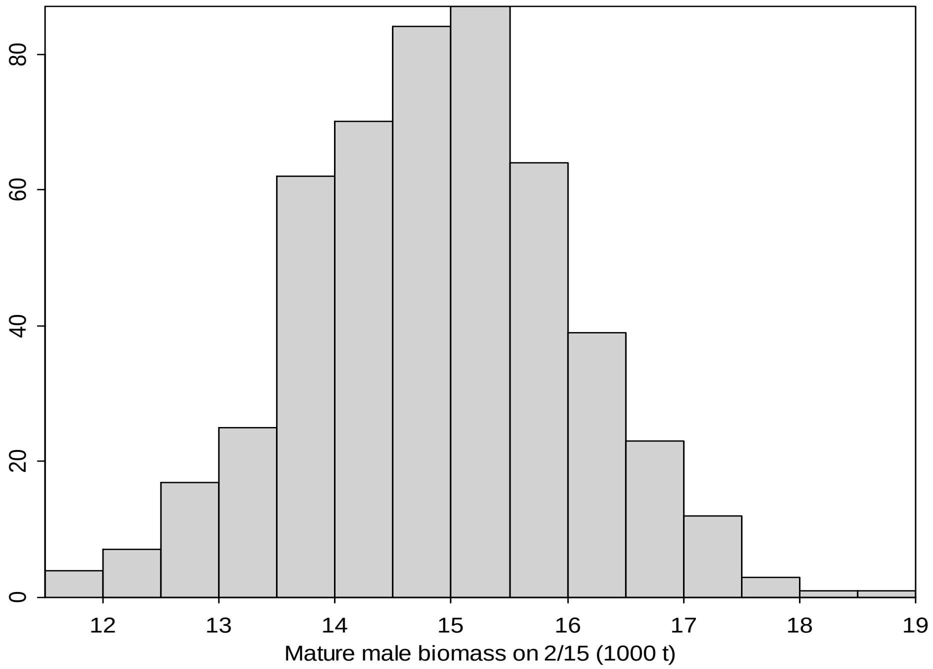


Figure 30a. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 21.1b with the MCMC approach.

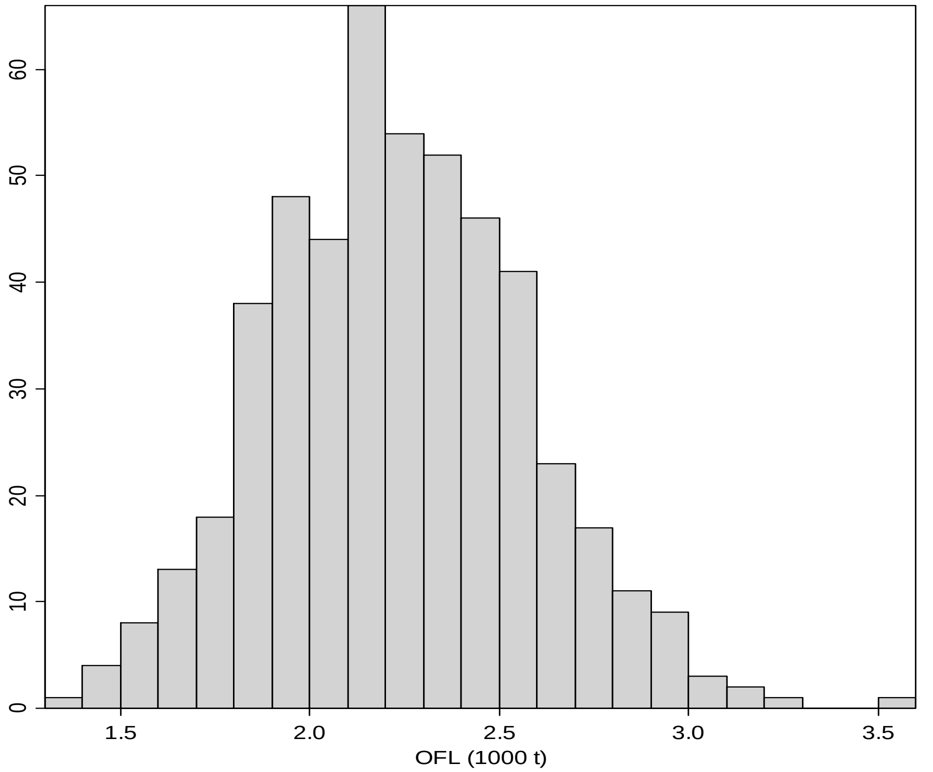


Figure 30b. Histogram of the 2021 estimated OFL under model 21.1b with the MCMC approach.

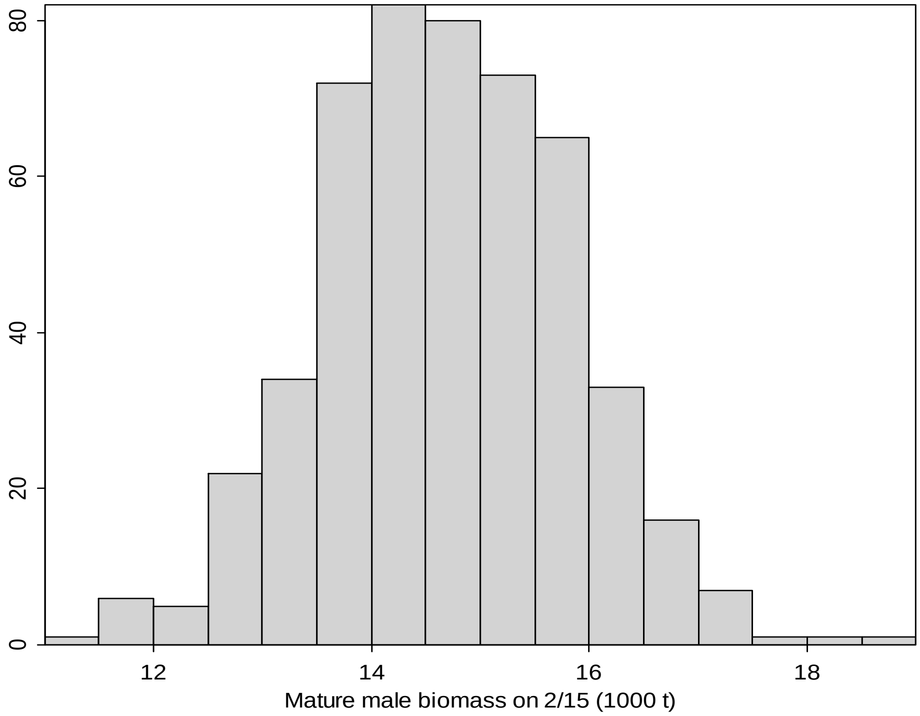


Figure 30c. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 22.0 with the MCMC approach.

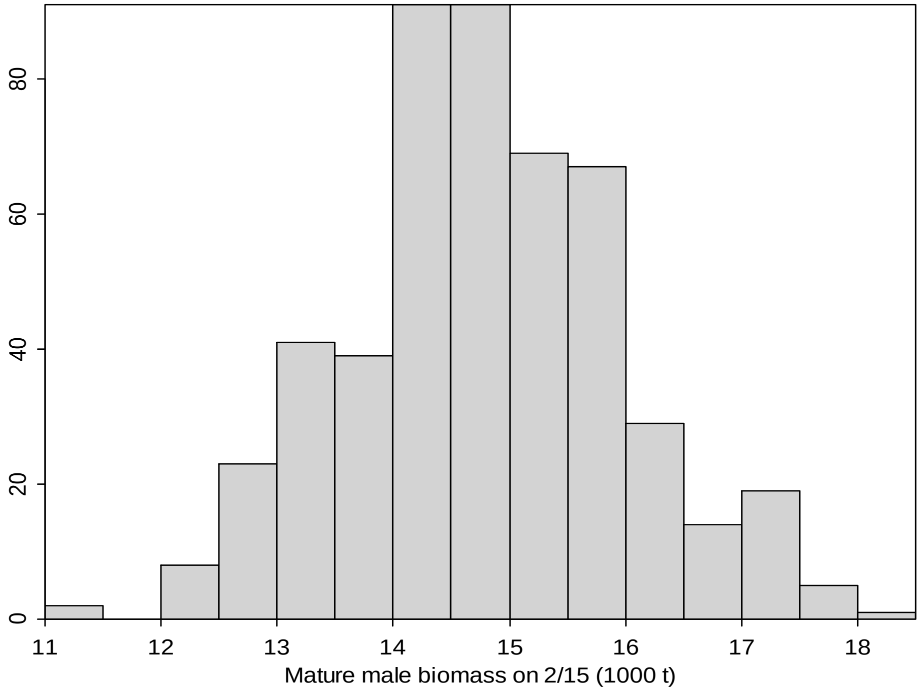


Figure 30d. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 22.0d with the MCMC approach.

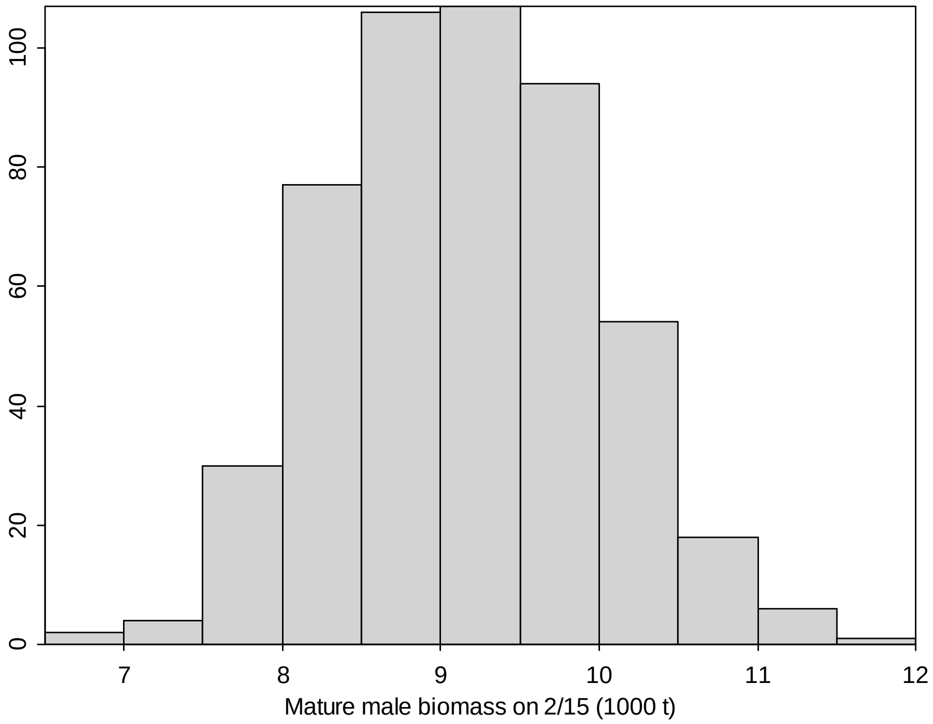


Figure 30e. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 22.0e with the MCMC approach.

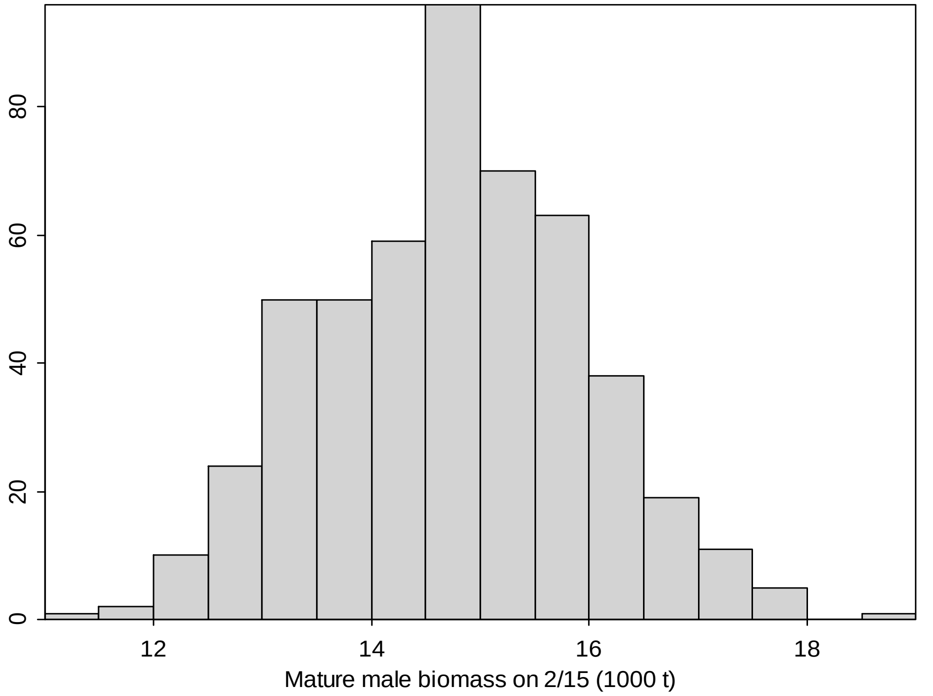


Figure 30f. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 22.1 with the MCMC approach.

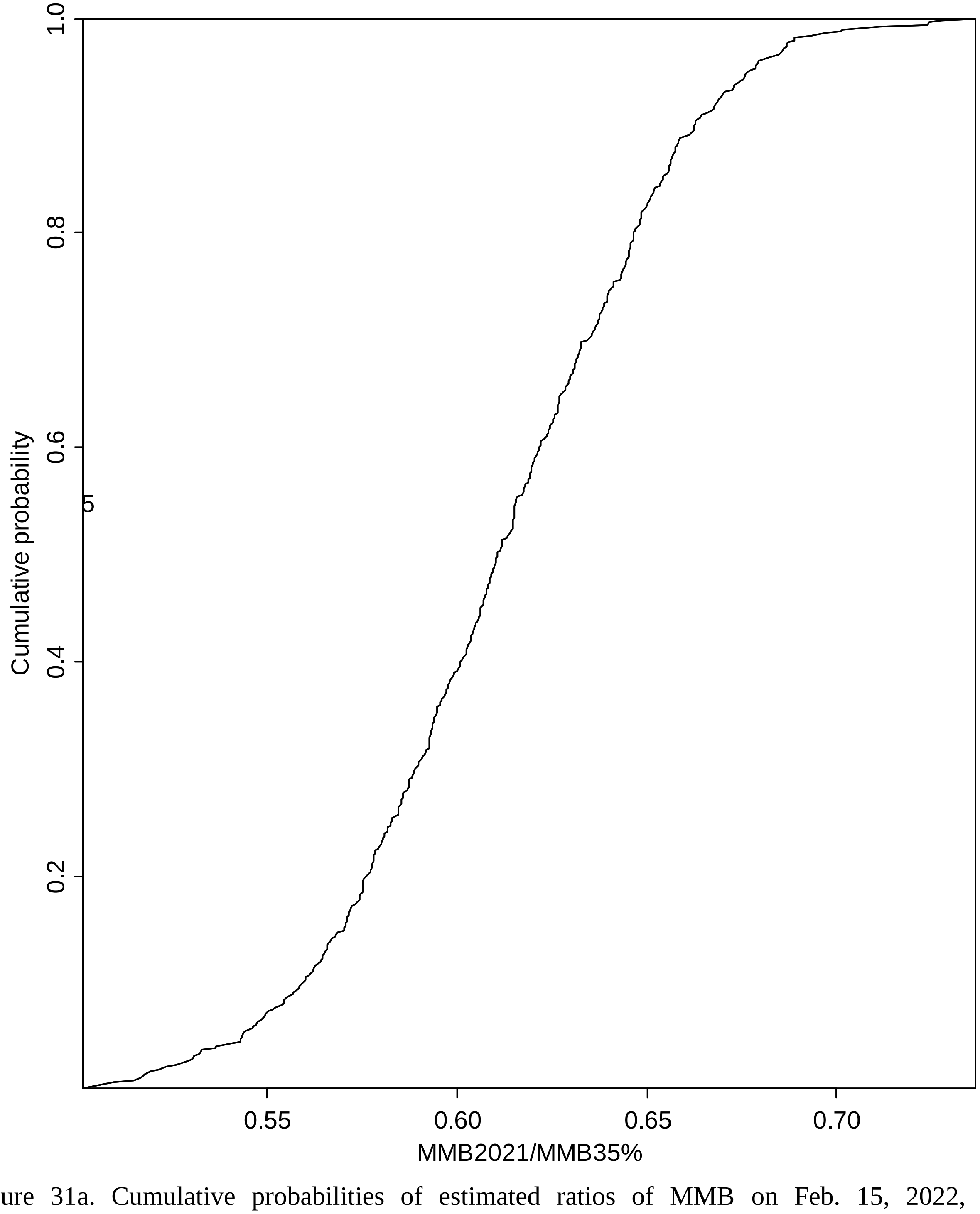


Figure 31a. Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values under model 21.1b with the MCMC approach. Zero probability is below the estimated minimum thresholds.

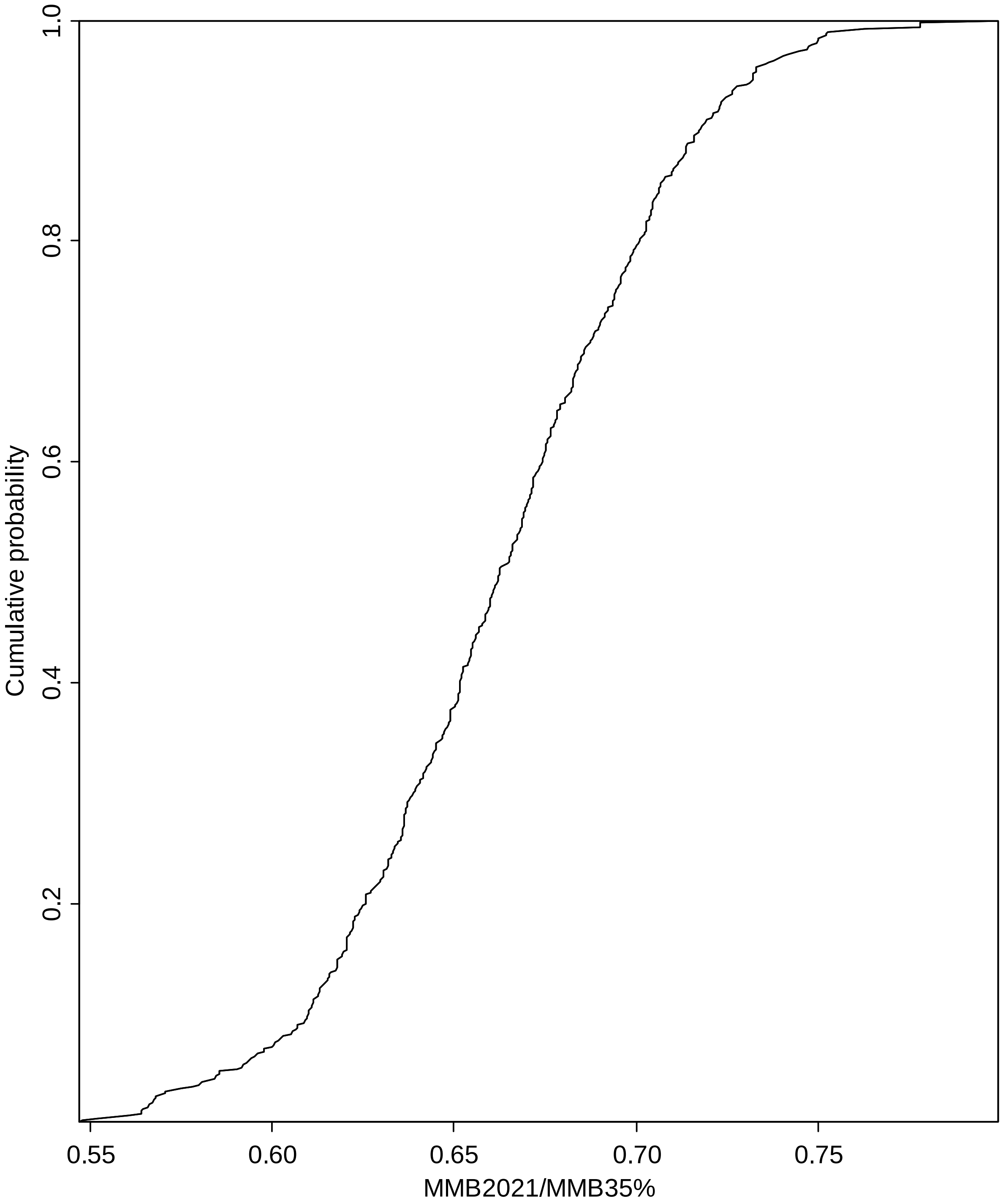


Figure 31b. Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values under model 22.0 with the MCMC approach. Zero probability is below the estimated minimum thresholds.

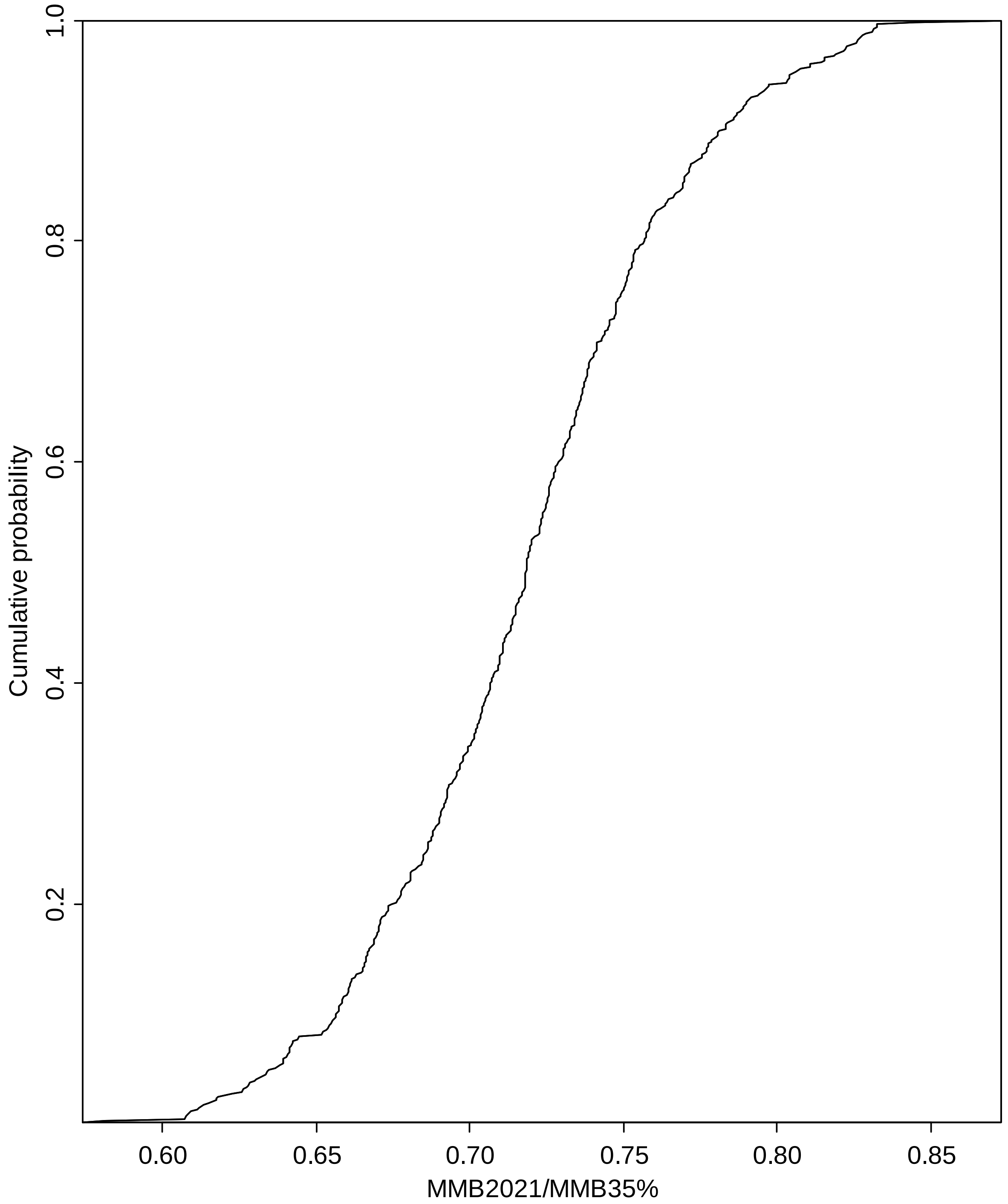


Figure 31c. Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values under model 22.0d with the MCMC approach. About 0.6% probability is below the estimated minimum thresholds.

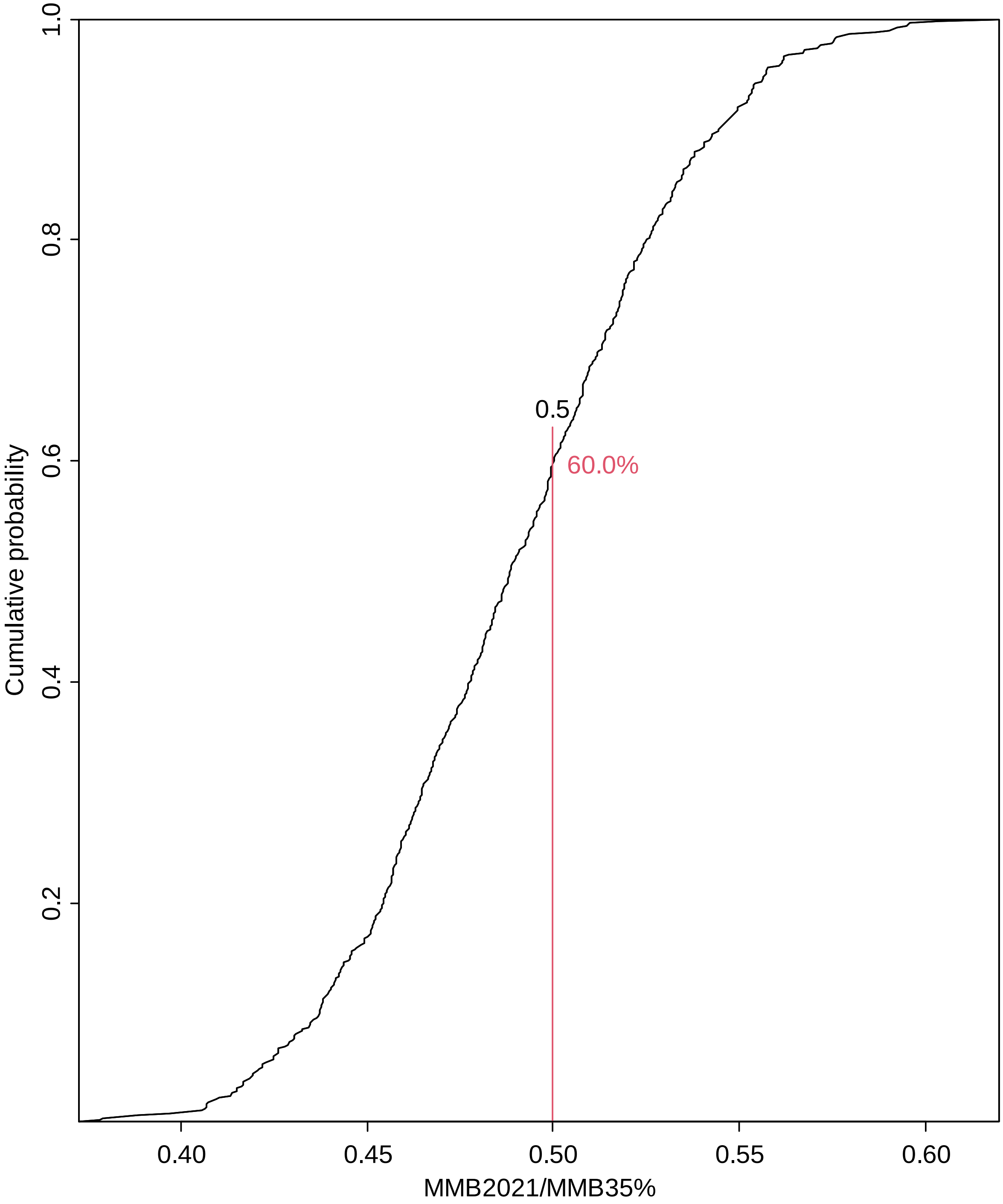


Figure 31d. Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values under model 22.0e with the MCMC approach. About 60.0% probability is below the estimated minimum thresholds.

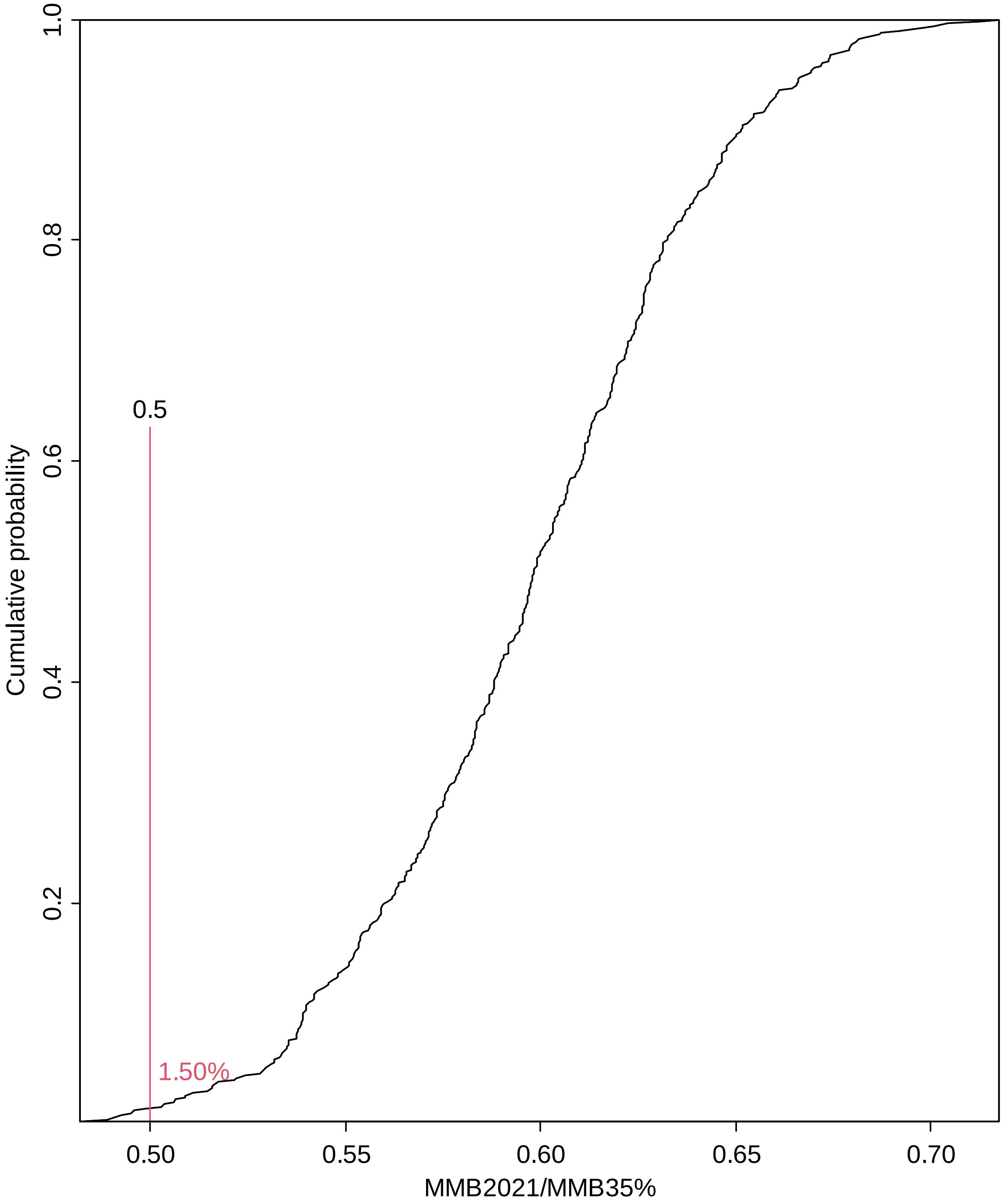


Figure 31e. Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values under model 22.1 with the MCMC approach. About 1.5% probability is below the estimated minimum thresholds.

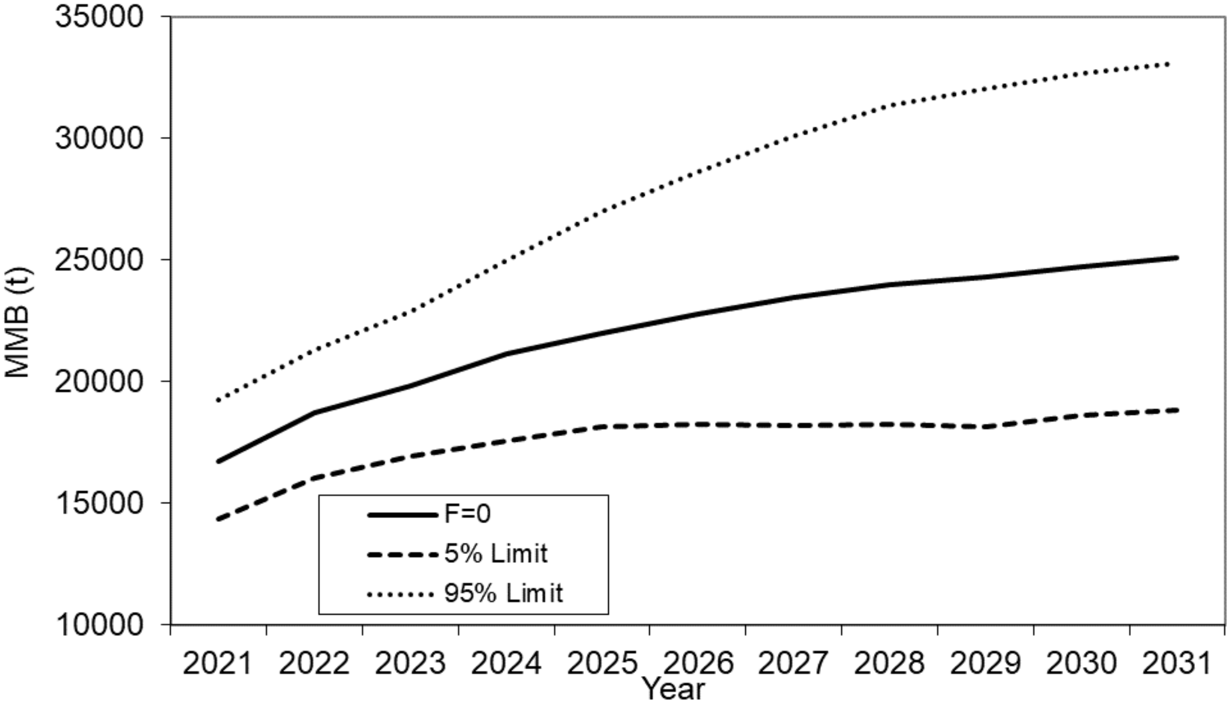


Figure 32a. Projected mature male biomass on Feb. 15 with *F* = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1b. Crab year “2021” represents Feb. 15, 2022.

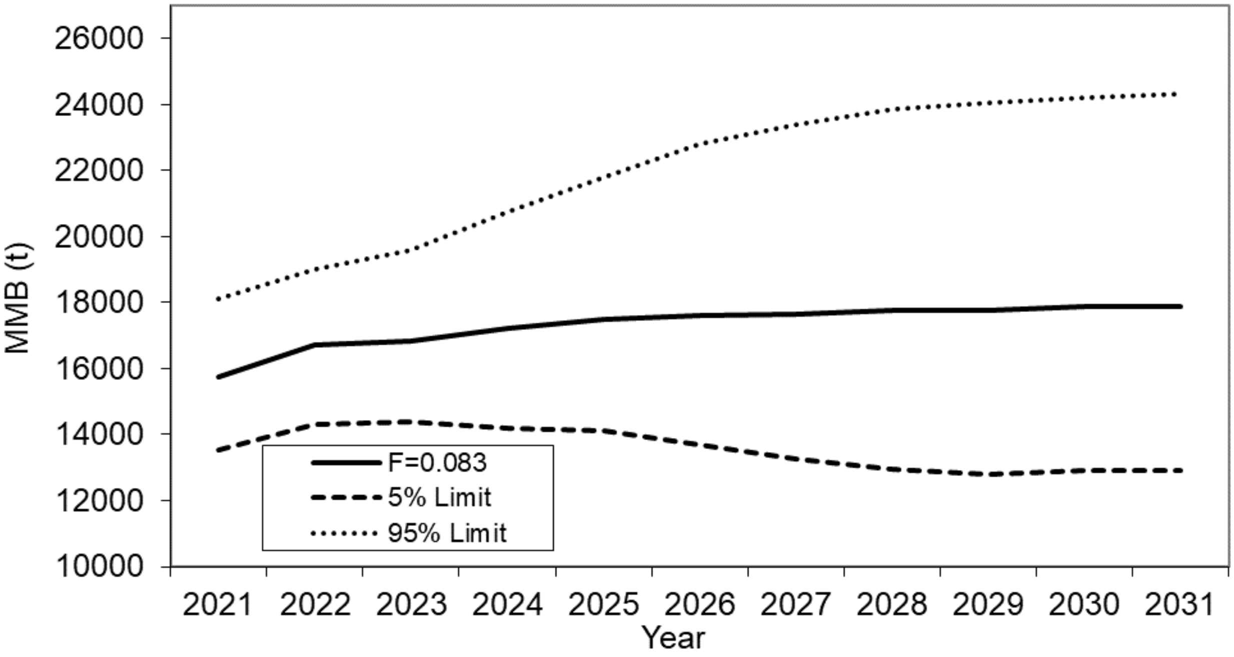


Figure 32b. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1b. Crab year “2021” represents Feb. 15, 2022.

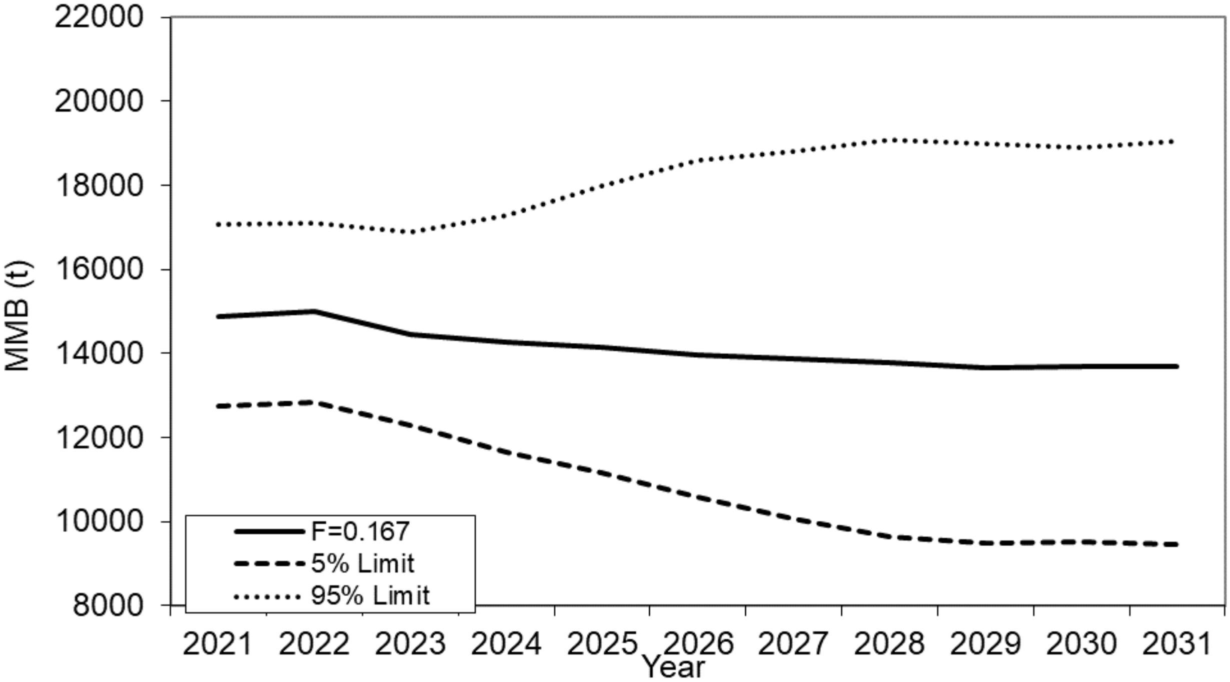


Figure 32c. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1b. Crab year "2021" represents Feb. 15, 2022.

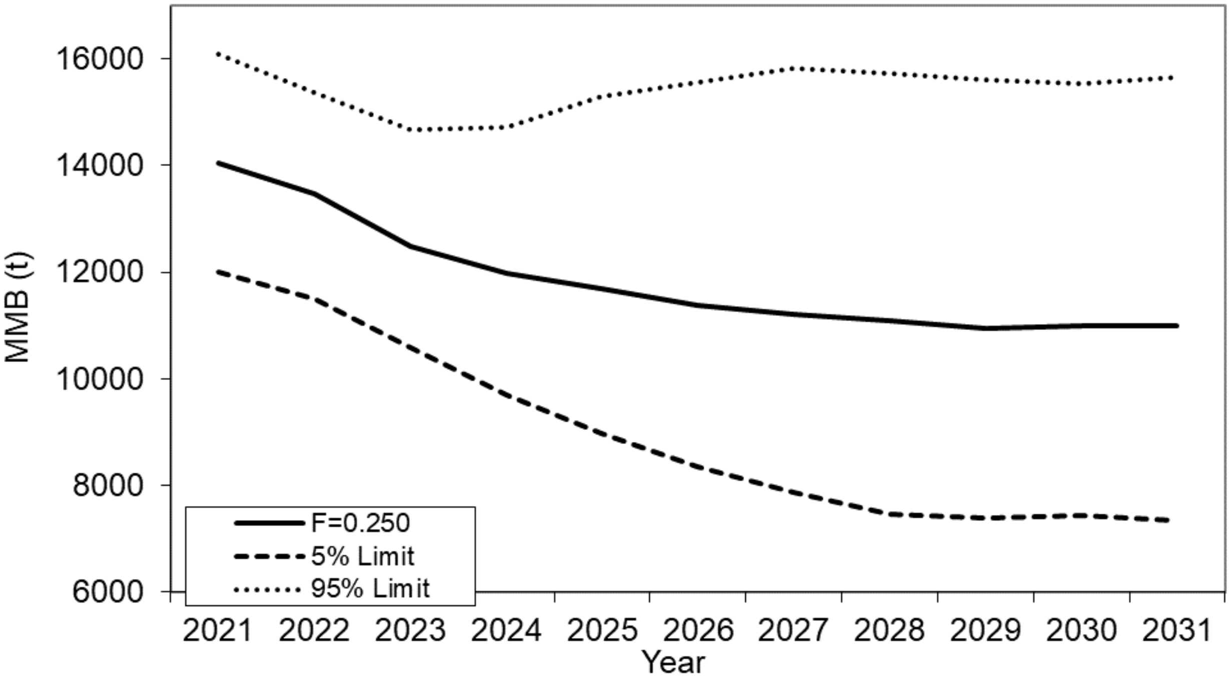


Figure 32d. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1b. Crab year "2021" represents Feb. 15, 2022.

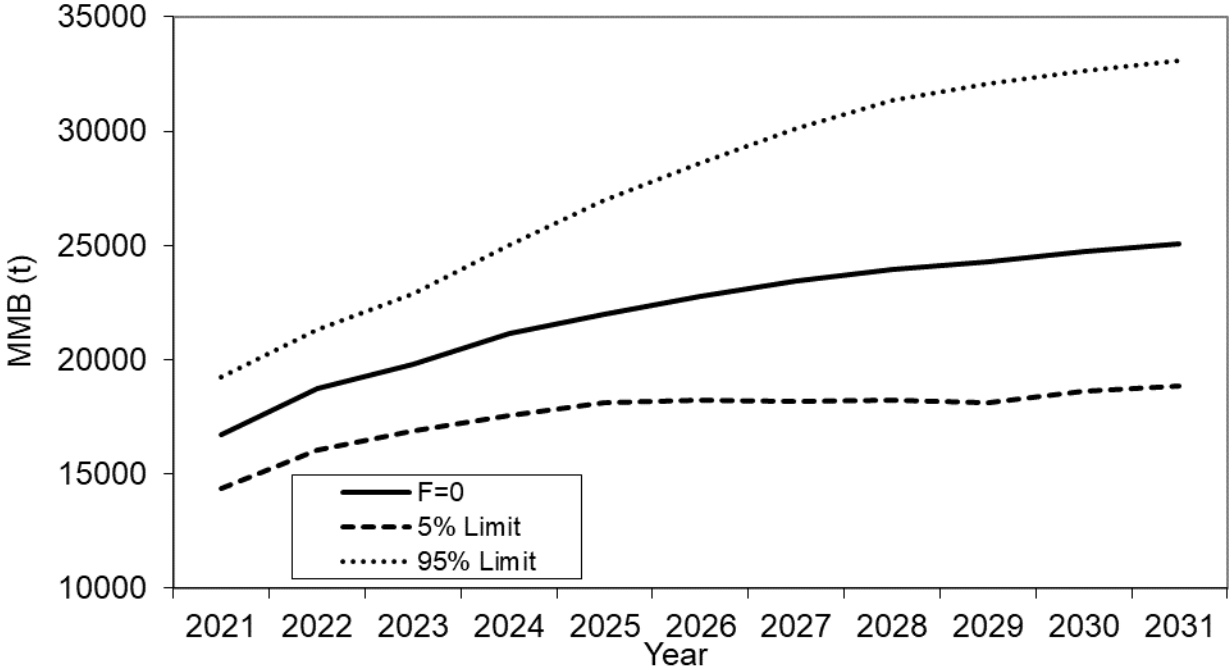


Figure 32e. Projected mature male biomass on Feb. 15 with F = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0. Crab year “2021” represents Feb. 15, 2022.

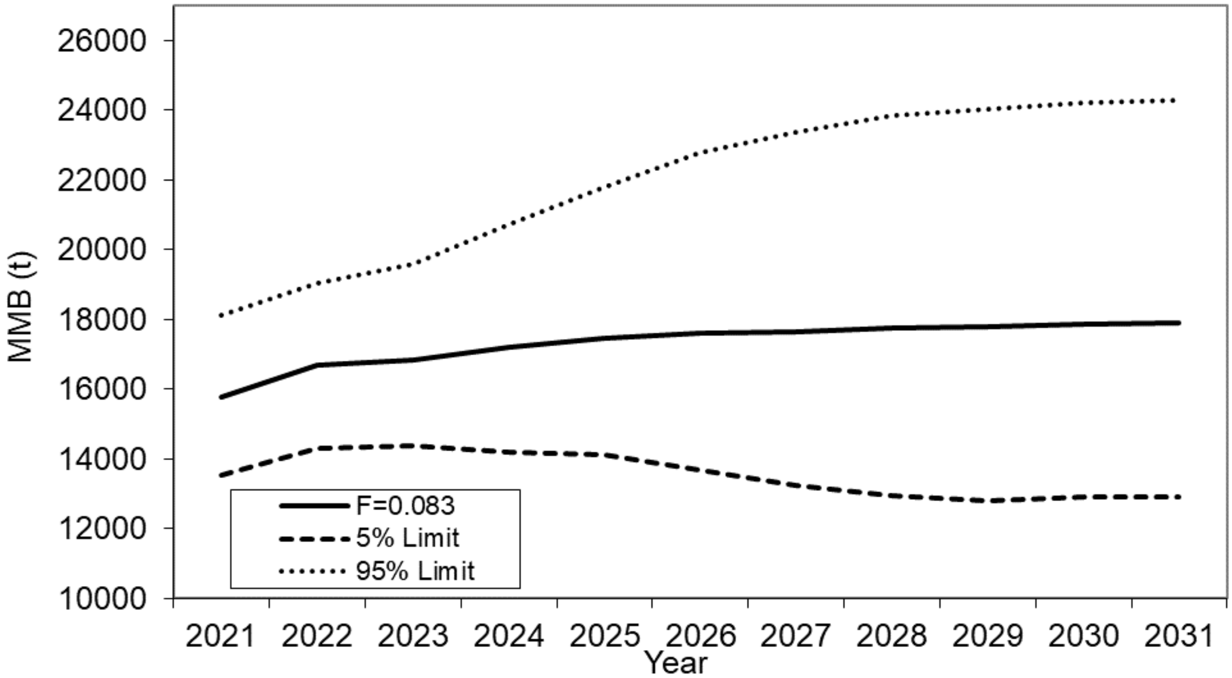


Figure 32f. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0. Crab year “2021” represents Feb. 15, 2022.

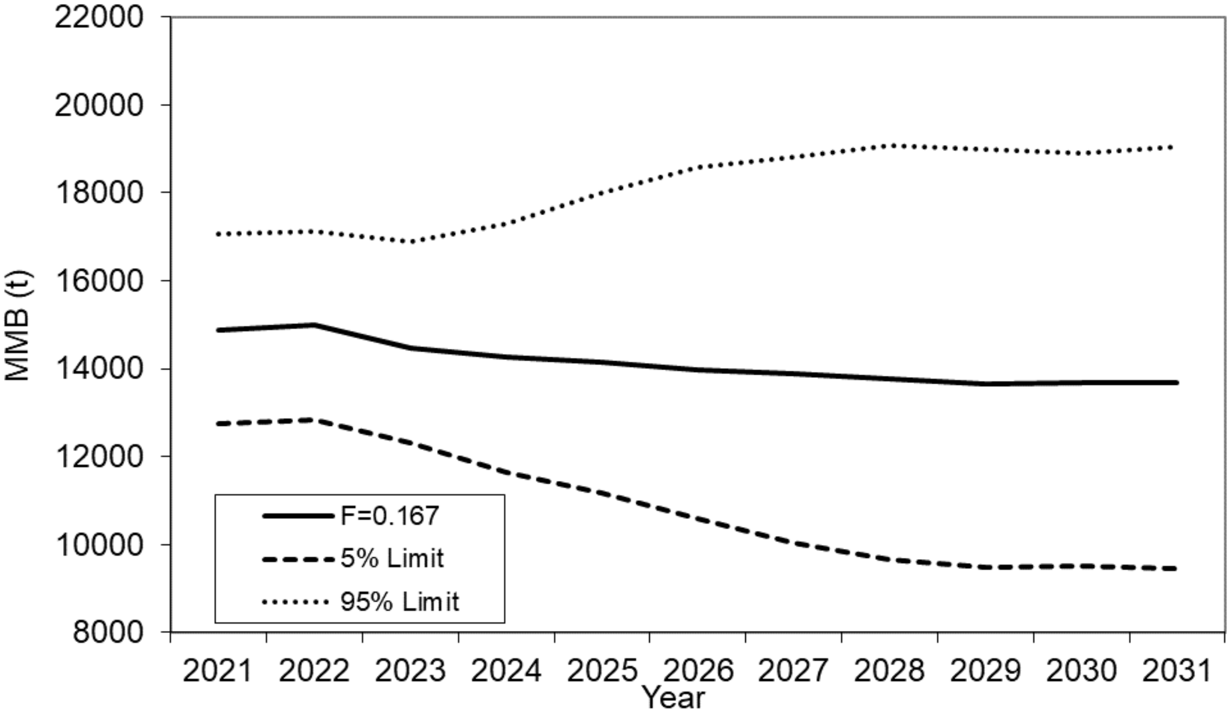


Figure 32g. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0. Crab year "2021" represents Feb. 15, 2022.

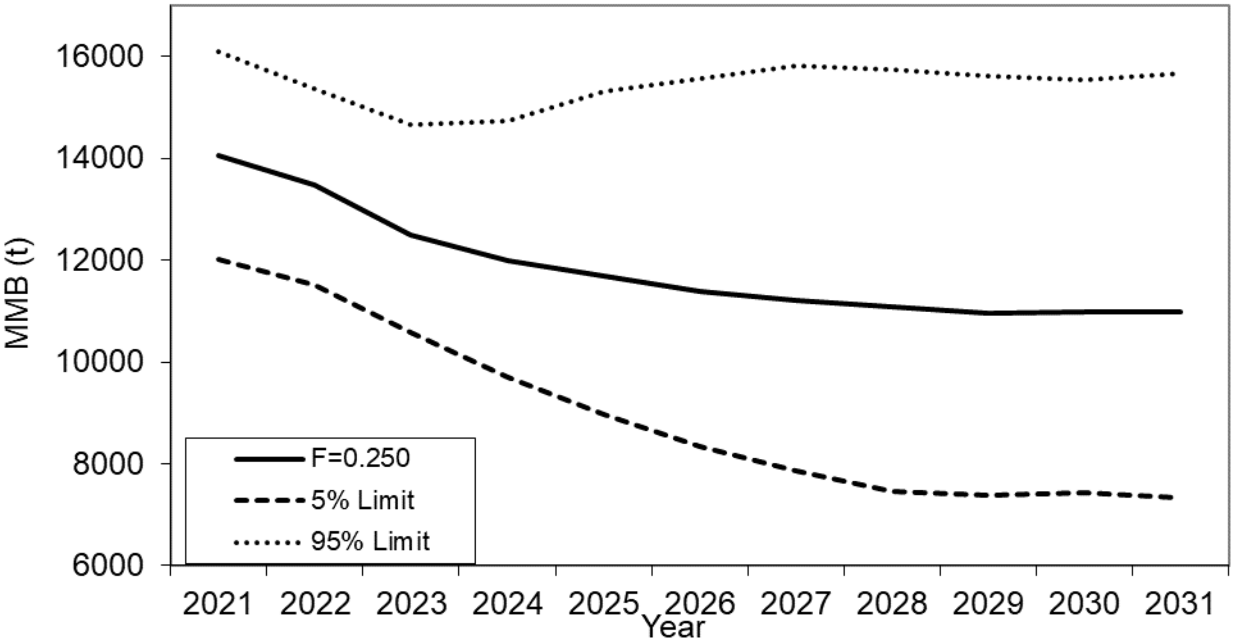


Figure 32h. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0. Crab year "2021" represents Feb. 15, 2022.

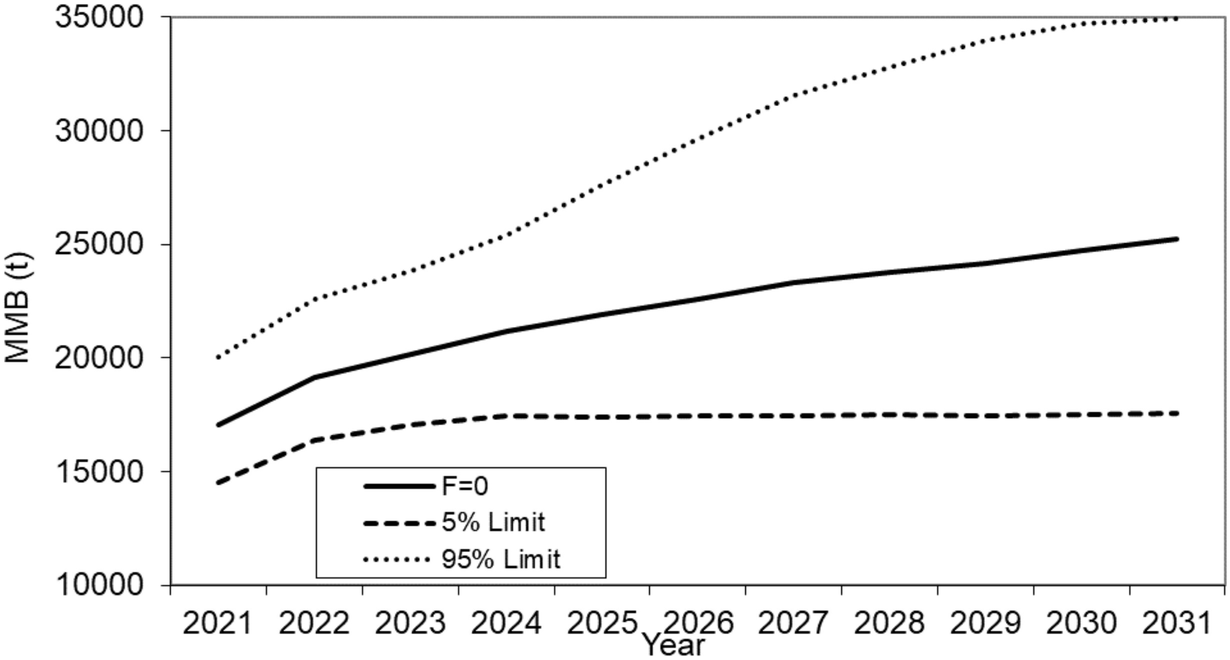


Figure 32i. Projected mature male biomass on Feb. 15 with F = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0d. Crab year "2021" represents Feb. 15, 2022.

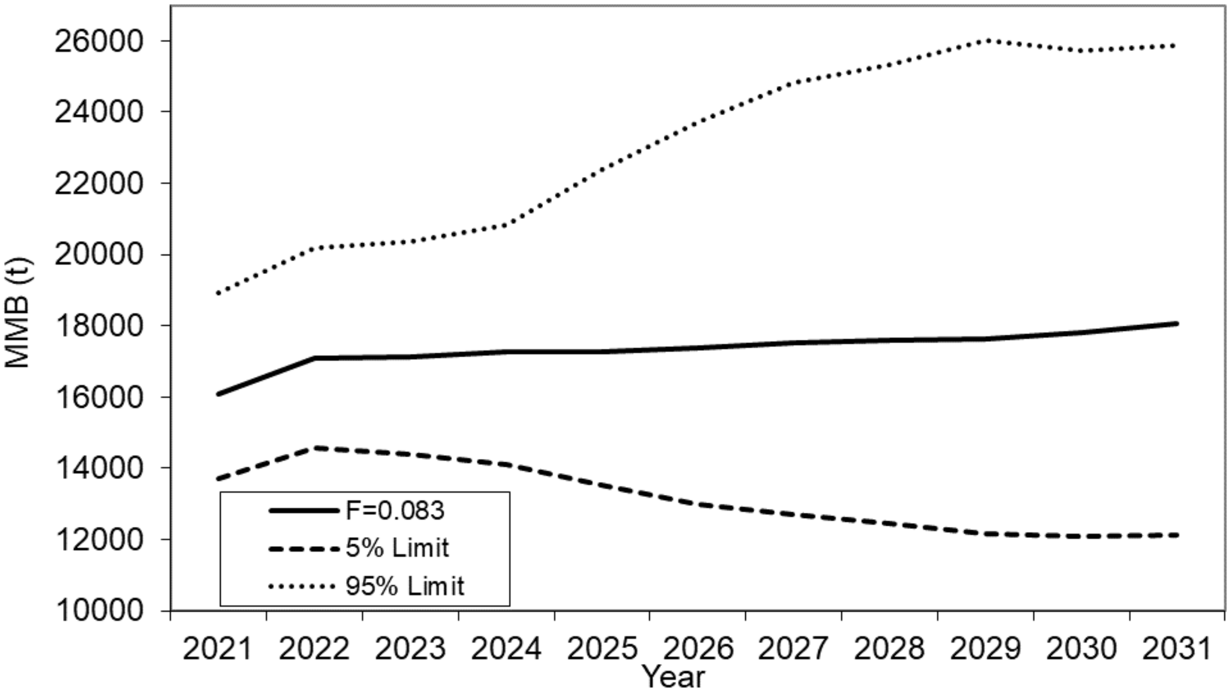


Figure 32j. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0d. Crab year "2021" represents Feb. 15, 2022.

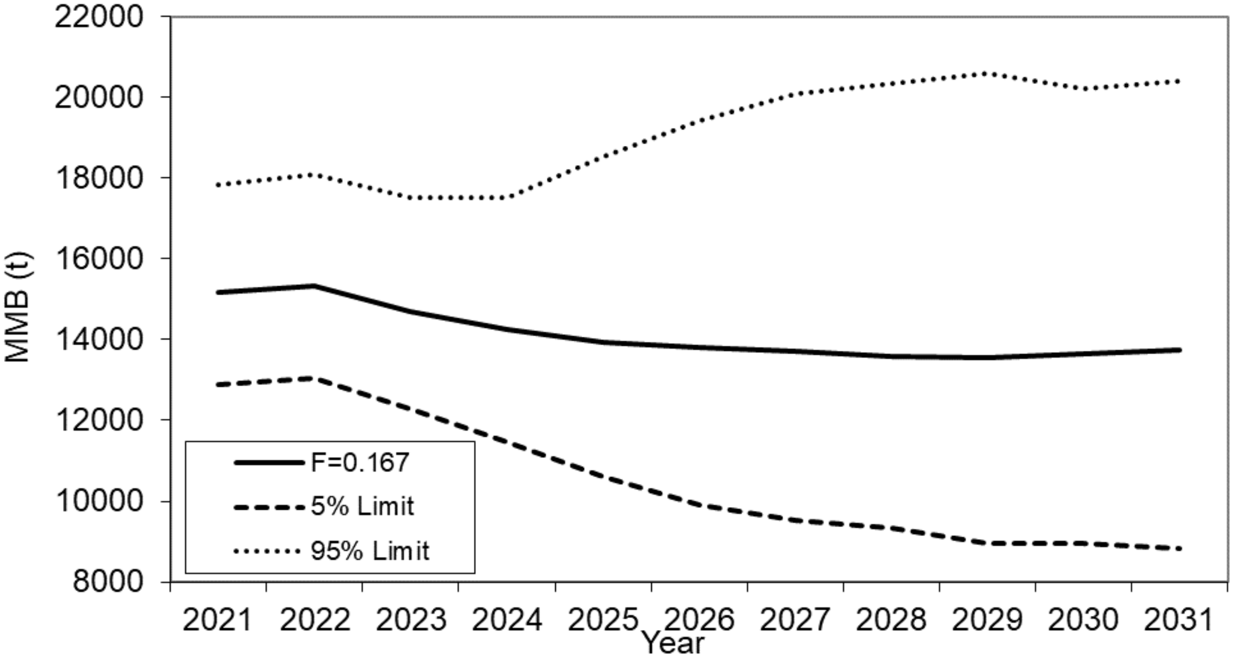


Figure 32k. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0d. Crab year “2021” represents Feb. 15, 2022.

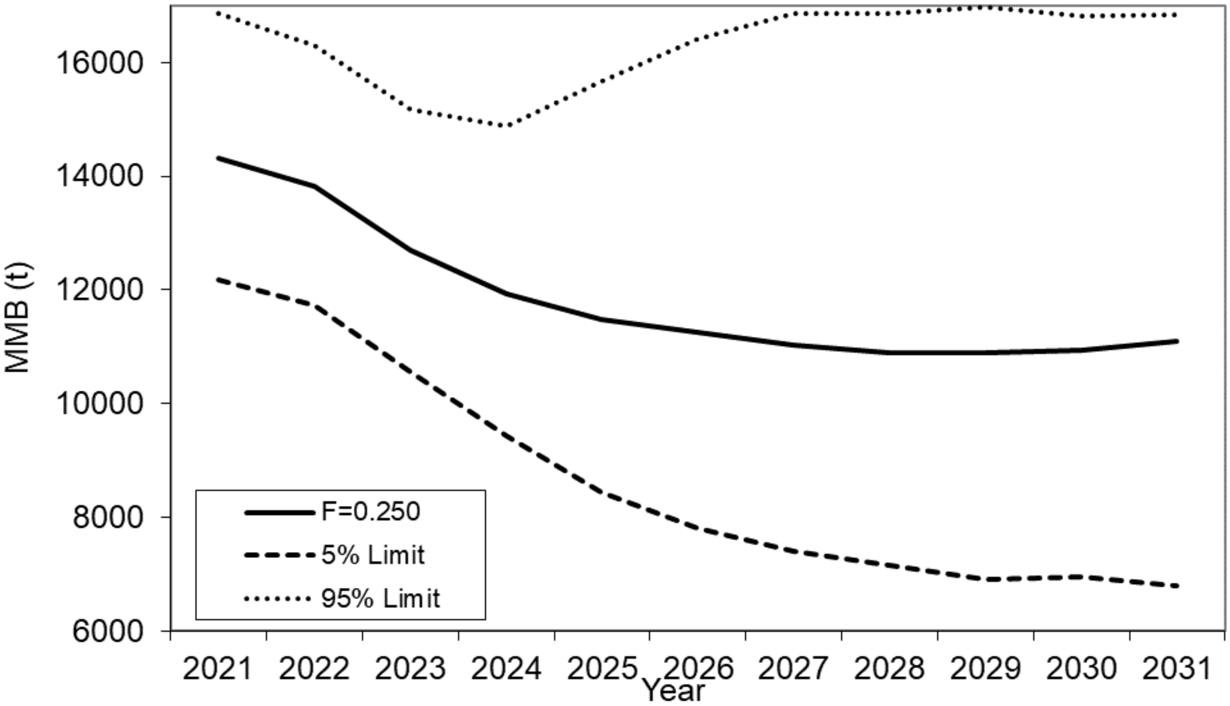


Figure 32l. Projected mature male biomass on Feb. 15 with F = 0.25 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.0d. Crab year “2021” represents Feb. 15, 2022.

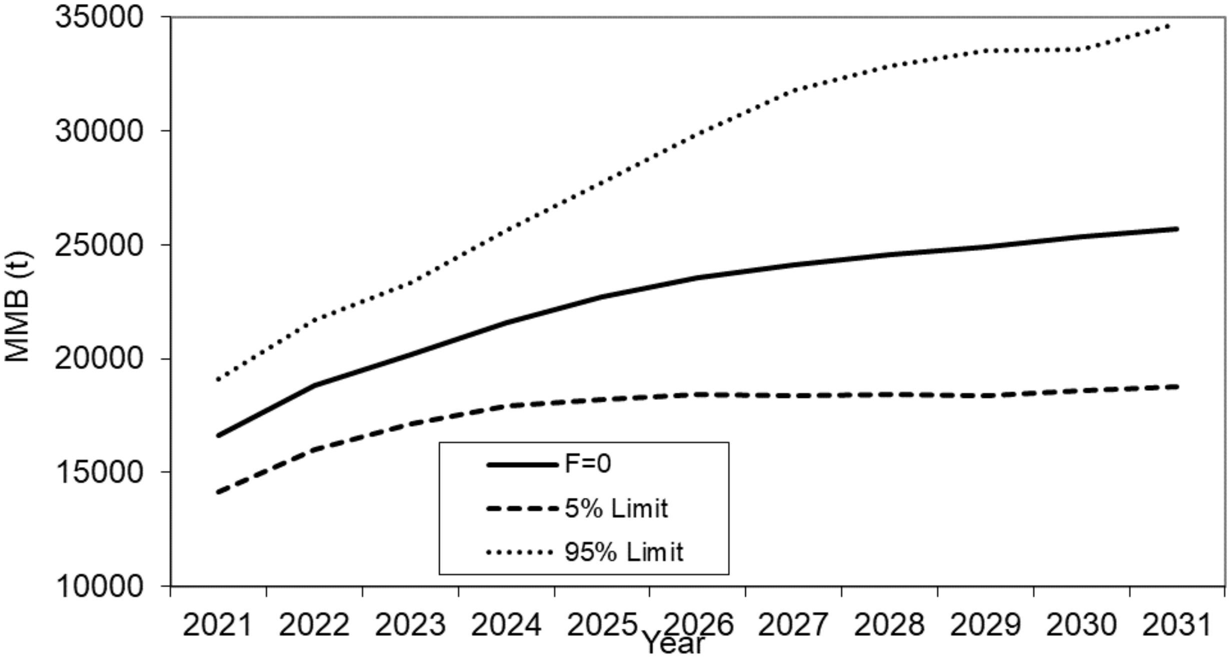


Figure 32i. Projected mature male biomass on Feb. 15 with F = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.1. Crab year “2021” represents Feb. 15, 2022.

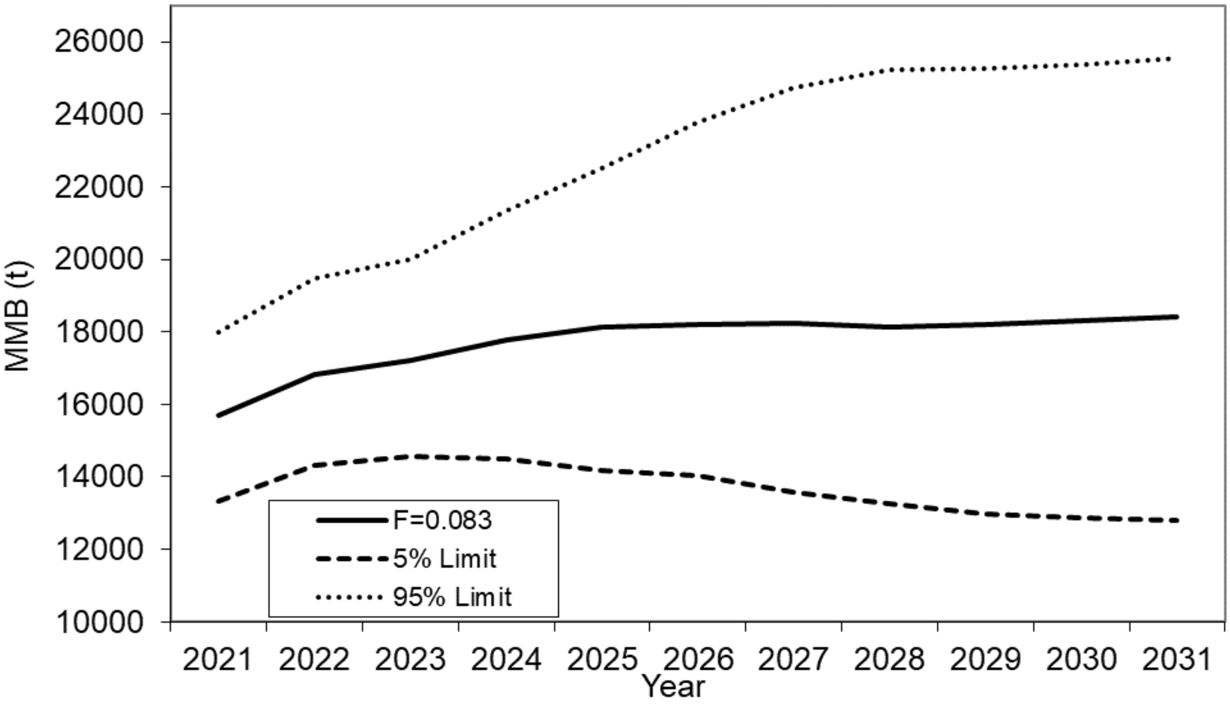


Figure 32j. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.1. Crab year “2021” represents Feb. 15, 2022.

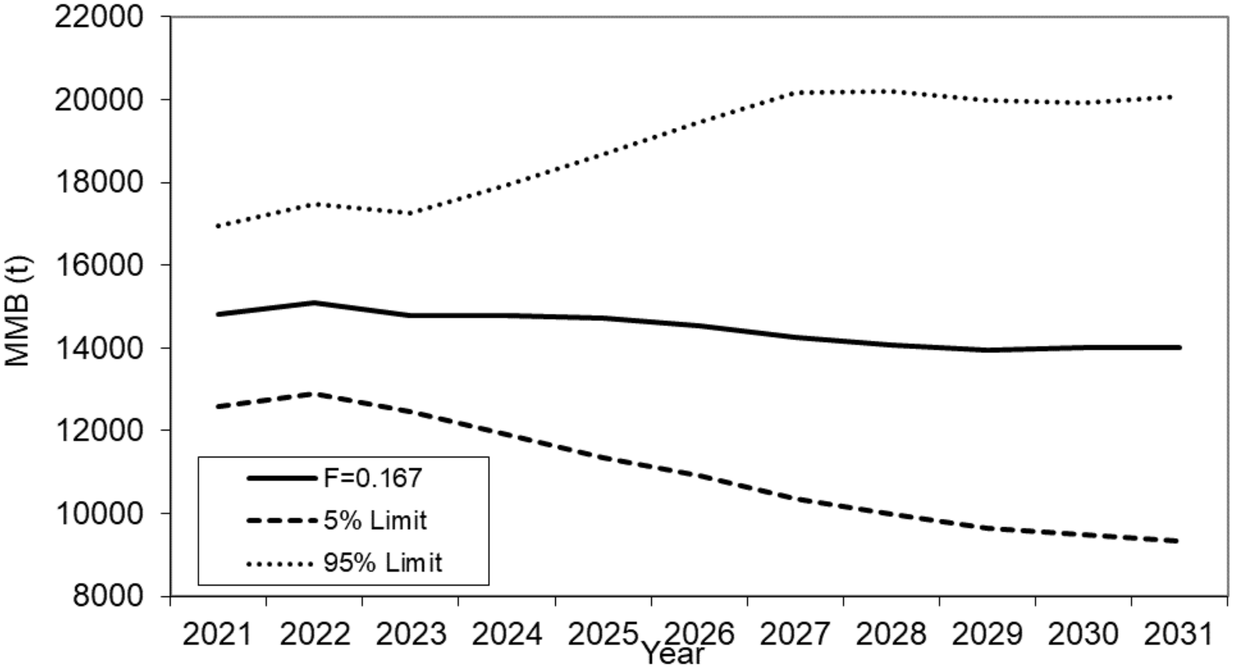


Figure 32k. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.1. Crab year "2021" represents Feb. 15, 2022.

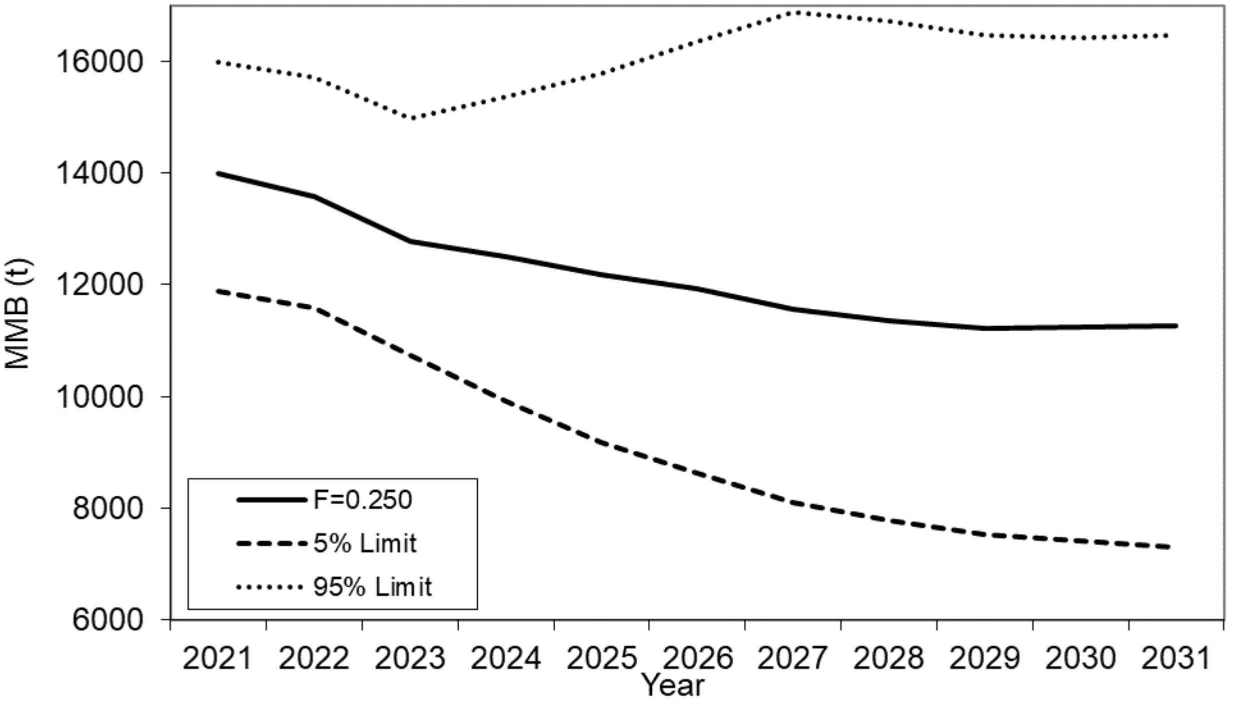


Figure 32l. Projected mature male biomass on Feb. 15 with F = 0.25 harvest strategy during 2021-2031. Input parameter estimates are based on model 22.1. Crab year "2021" represents Feb. 15, 2022.

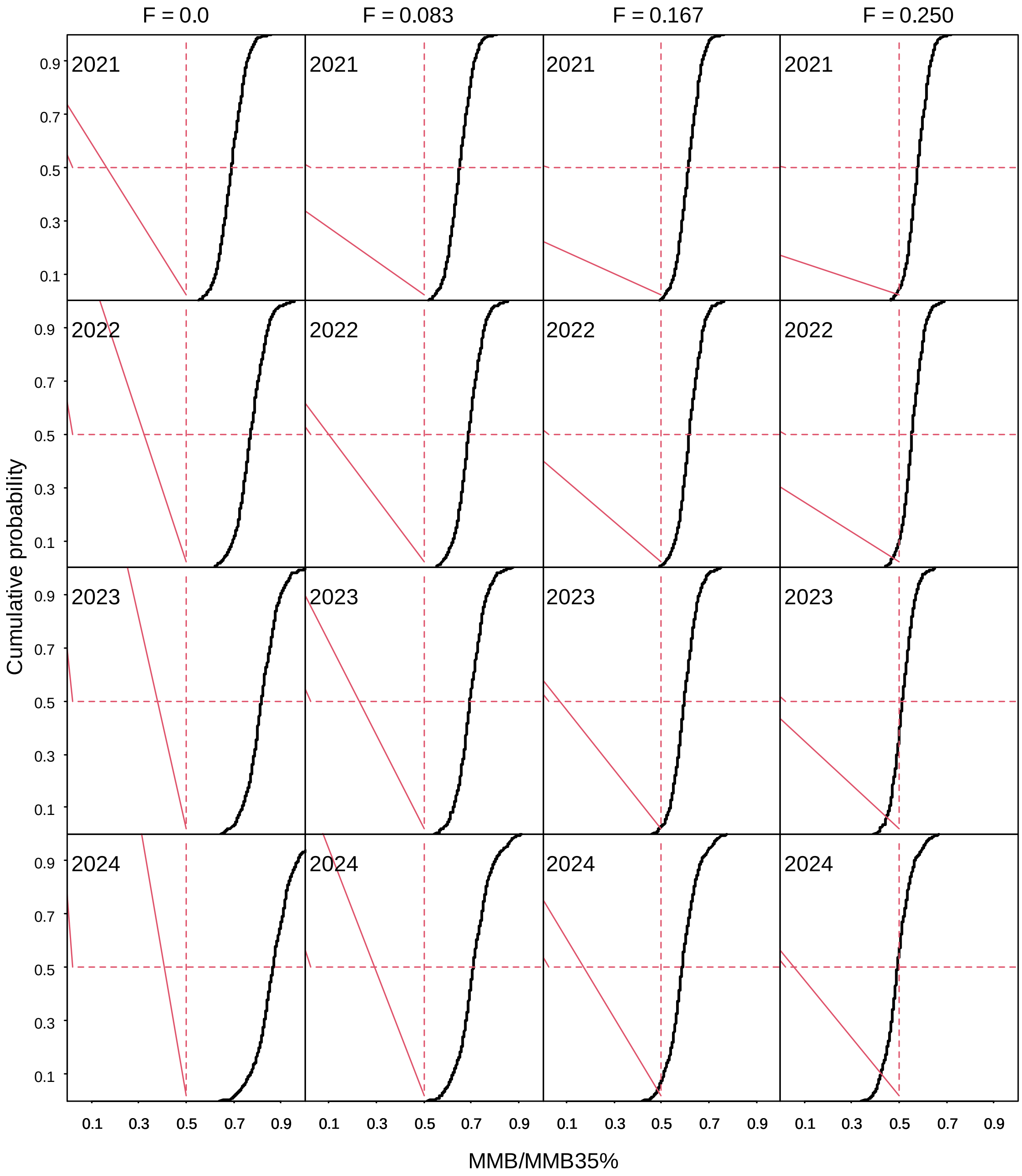


Figure 33a. Cumulative probabilities of estimated ratios of MMB during 2021-2024 to corresponding estimated $B_{35\%}$ values under model 21.1b with the MCMC approach and four fishing mortality values. Crab year "2021" represents Feb. 15, 2022.

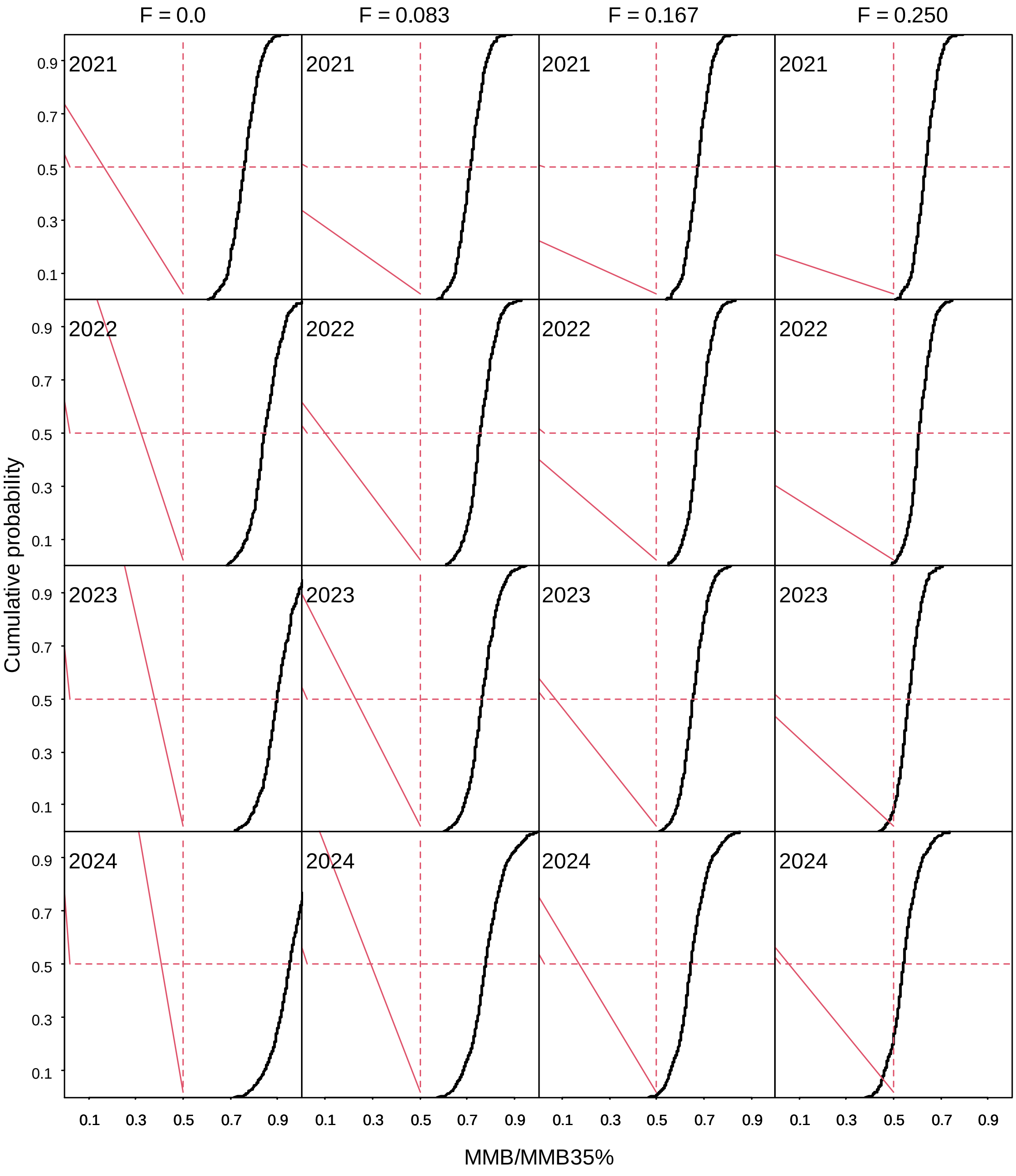


Figure 33b. Cumulative probabilities of estimated ratios of MMB during 2021-2024 to corresponding estimated $B_{35\%}$ values under model 22.0 with the MCMC approach and four fishing mortality values. Crab year “2021” represents Feb. 15, 2022.

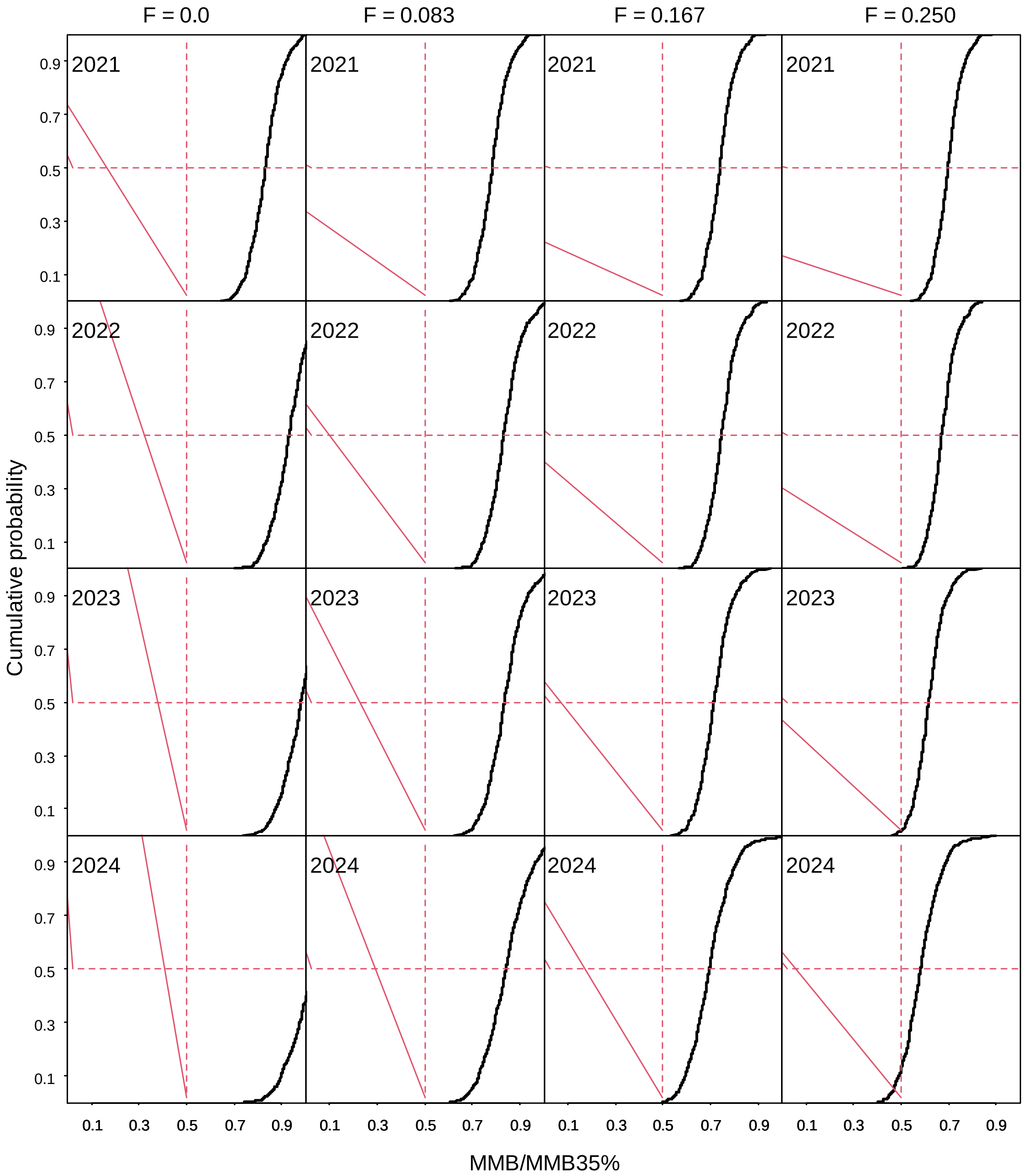


Figure 33c. Cumulative probabilities of estimated ratios of MMB during 2021-2024 to corresponding estimated $B_{35\%}$ values under model 22.0d with the MCMC approach and four fishing mortality values. Crab year "2021" represents Feb. 15, 2022.

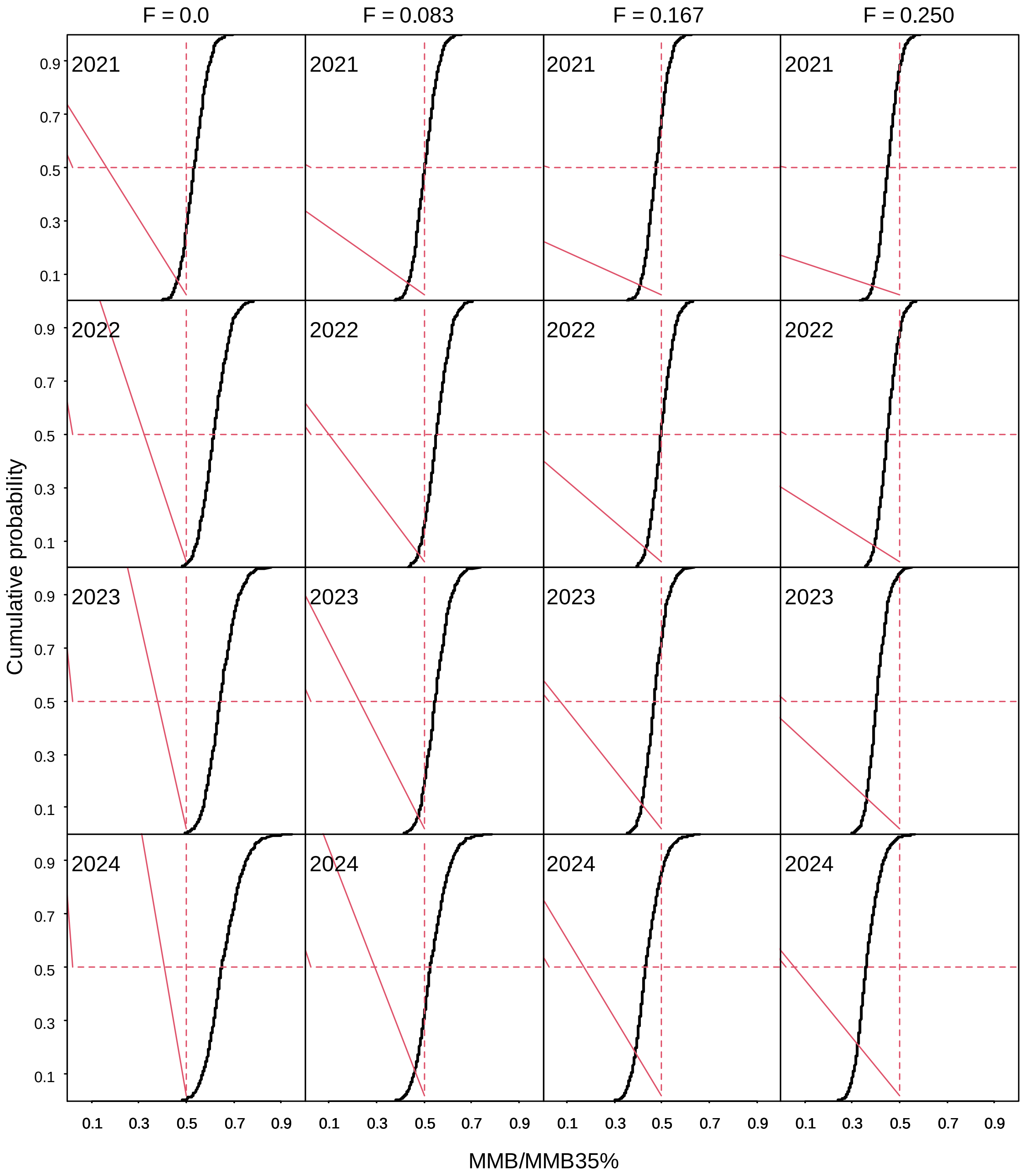


Figure 33d. Cumulative probabilities of estimated ratios of MMB during 2021-2024 to corresponding estimated $B_{35\%}$ values under model 22.0e with the MCMC approach and four fishing mortality values. Crab year "2021" represents Feb. 15, 2022.

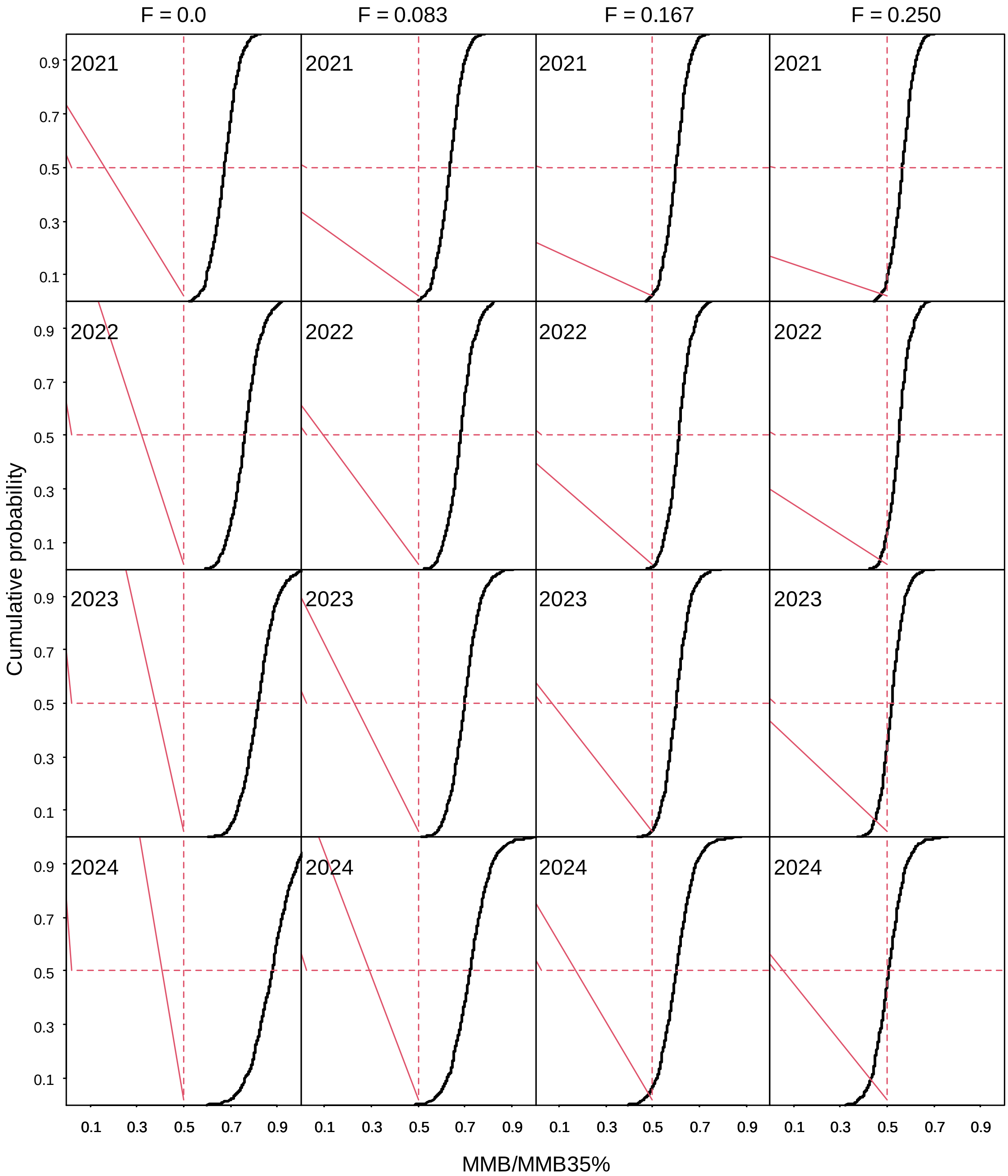


Figure 33e. Cumulative probabilities of estimated ratios of MMB during 2021-2024 to corresponding estimated $B_{35\%}$ values under model 22.1 with the MCMC approach and four fishing mortality values. Crab year “2021” represents Feb. 15, 2022.

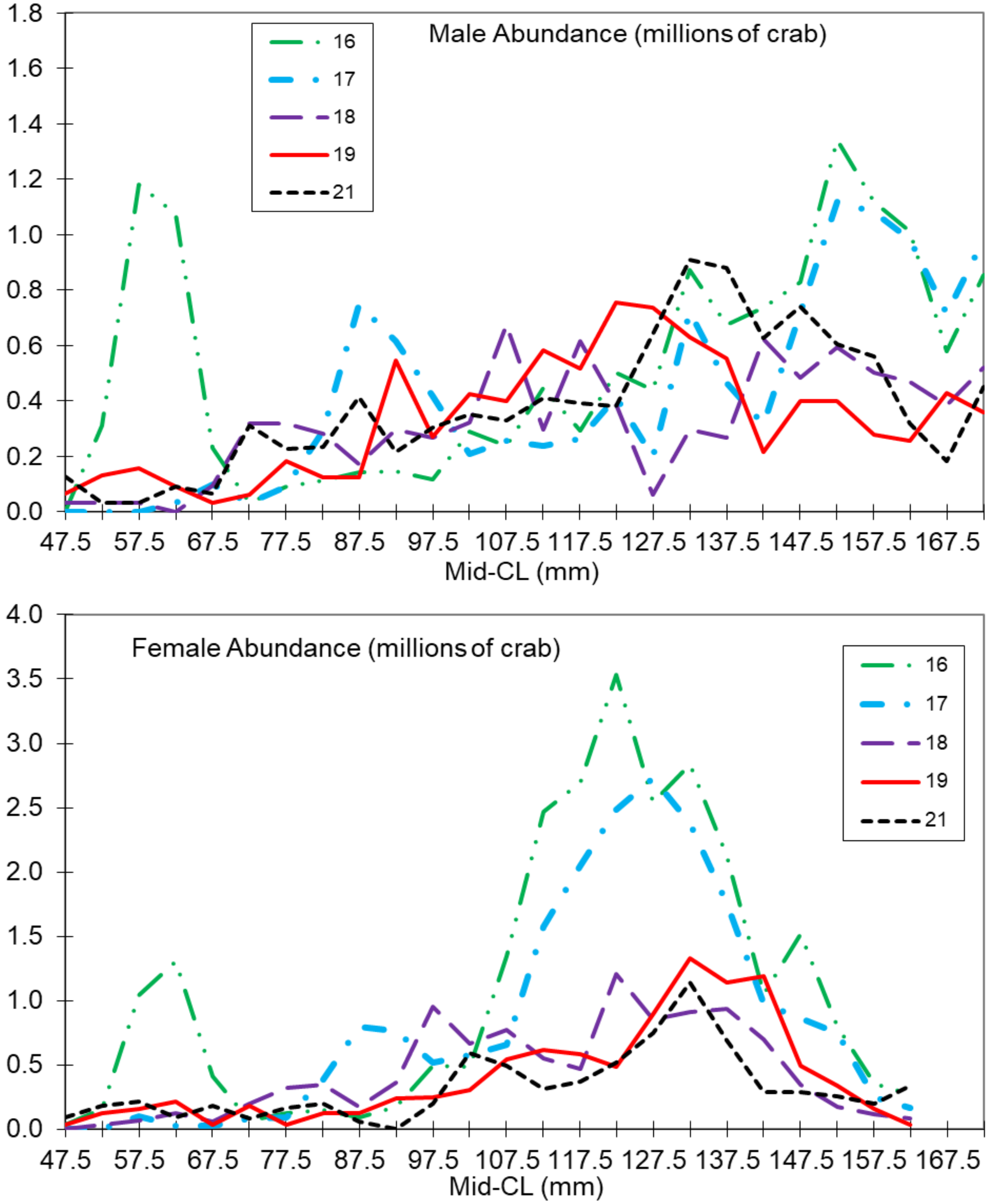
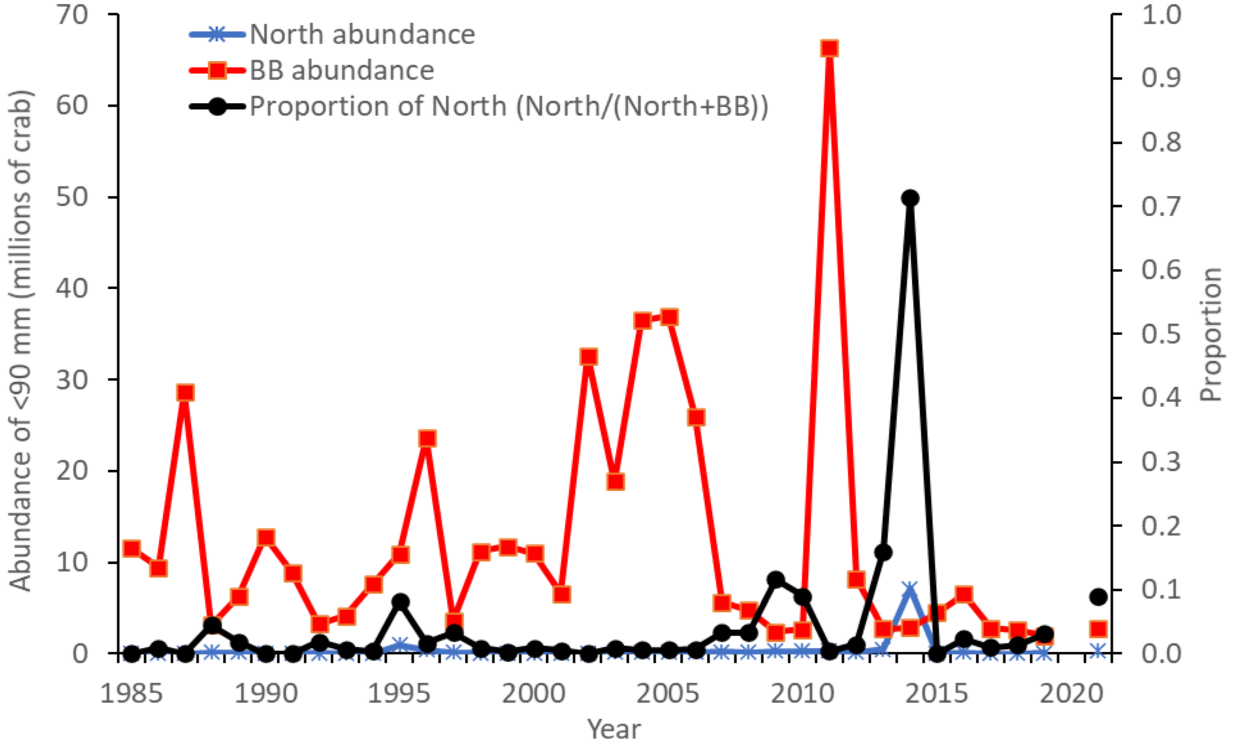


Figure 34. Length frequency distributions of male (top panel) and female (bottom panel) red king crab in Bristol Bay from NMFS trawl surveys during 2016-2021. For purposes of these graphs, abundance estimates are based on area-swept methods.



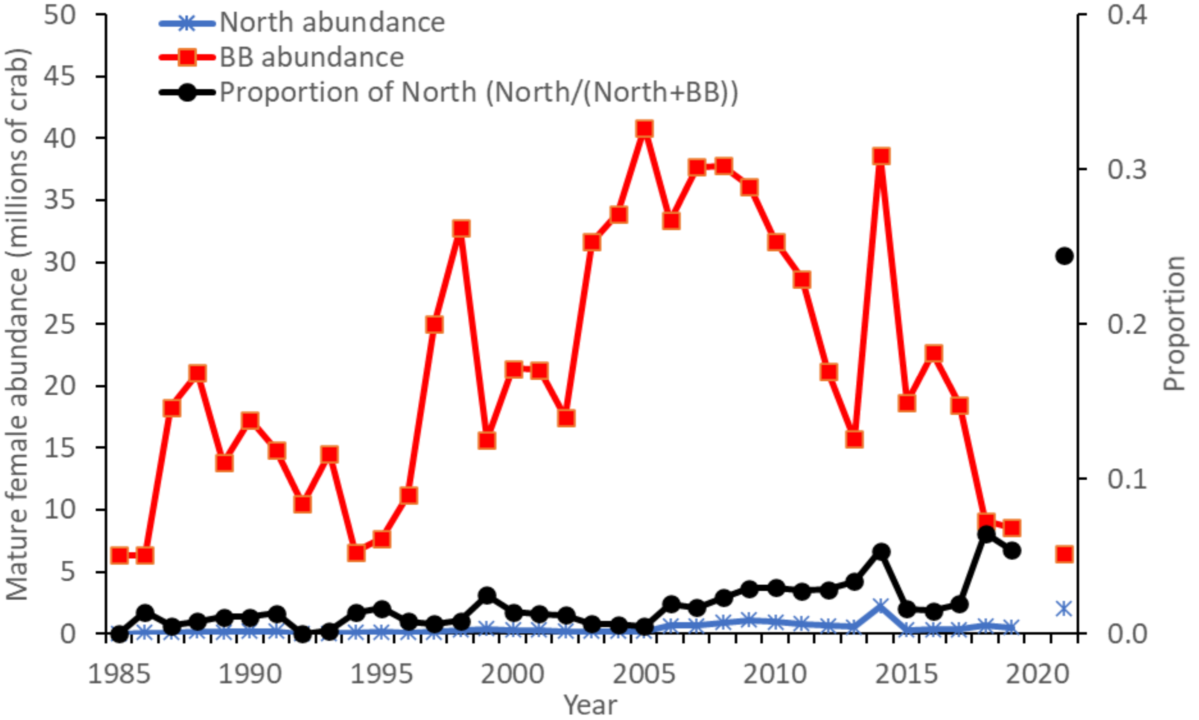


Figure 35a. Comparisons of NMFS survey area-swept estimates of total crab <90 mm CL and mature female abundances in Bristol Bay area (BB) and north of Bristol Bay area (North) during 1985-2021.

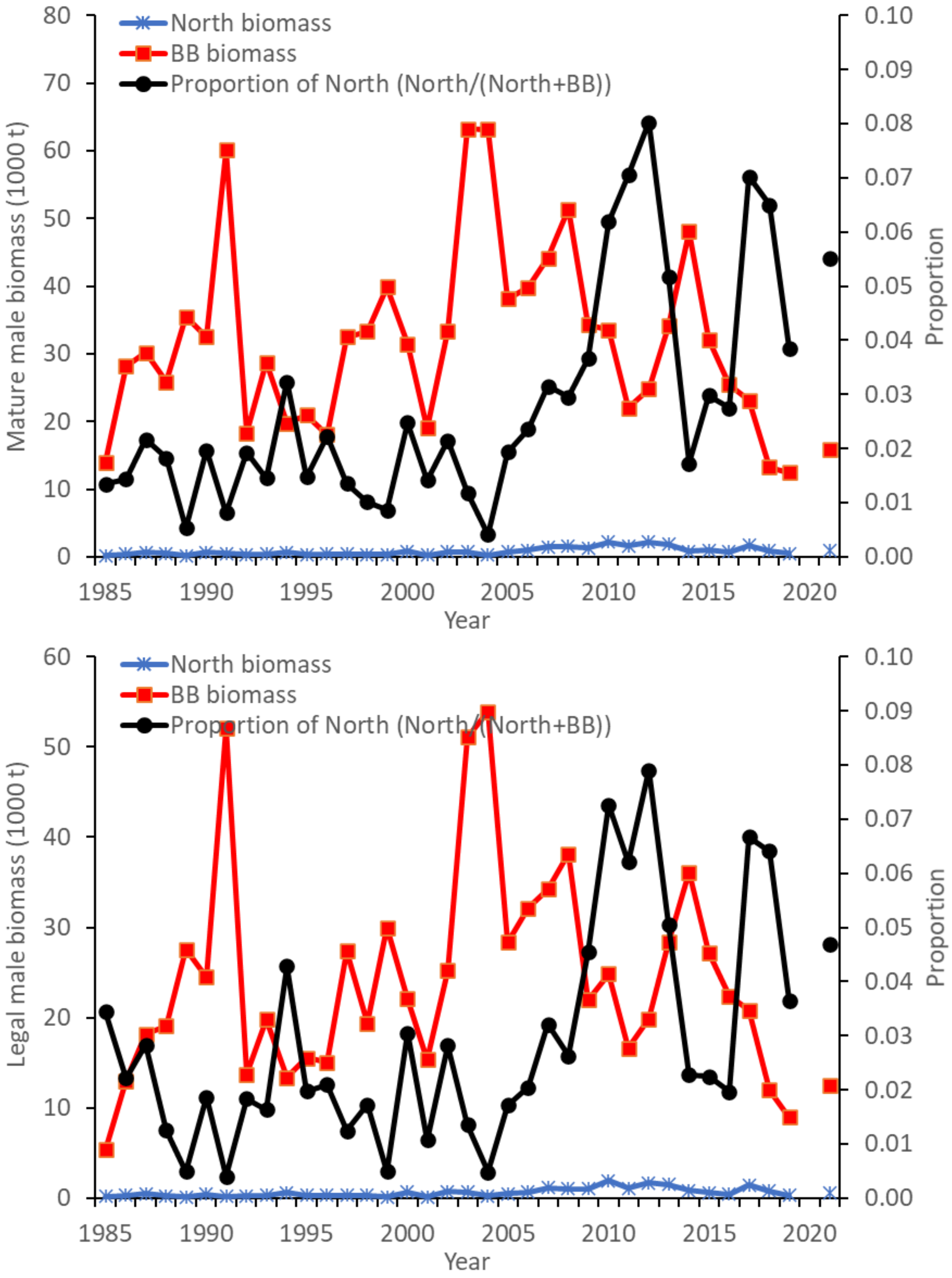


Figure 35b. Comparisons of NMFS survey area-swept estimates of mature and legal male abundances in Bristol Bay area (BB) and north of Bristol Bay area (North) during 1985-2021.

Appendix A. Description of GMACS with Bristol Bay Red King Crab Options (mainly from the GMACS document)

A. Model Description

a. Population model

The basic dynamics account for growth, mortality, maturity state and shell condition (although most of the equations below do not explicitly refer to maturity state and shell condition). For the case in which shell condition is not distinguished:

$$\underline{N}^g_{y,t} = ((\mathbf{I}-\mathbf{P}^g_{y,t-1}) + \mathbf{X}^g_{y,t-1}\mathbf{P}^g_{y,t-1})\mathbf{S}^g_{y,t-1}\,\underline{N}^g_{y,t-1} + \underline{\tilde{R}}^g_{y,t} \qquad \text{(A.1)}$$

where $\underline{N}^g_{y,t}$ is the number of animals by size-class of gender *g* at the start of season *t* of year *y*, $\mathbf{P}^g_{y,t}$ is a matrix with diagonals given by vector of molting probabilities for animals of gender *g* at the start of season *t* of year *y*, $\mathbf{S}^g_{y,t}$ is a matrix with diagonals given by the vector of probabilities of surviving for animals of gender *g* during time-step *t* of year *y* (which may be of zero duration):

$$S^g_{y,t,l,l} = \exp\left(-Z^g_{y,t,l}\right) \qquad \text{(A.2)}$$

$\mathbf{X}^g_{y,t}$ is the size-transition matrix (probability of growing from one size-class to each of the other size-classes or remains in the same size class) for animals of gender *g* during season *t* of year *y*, $\underline{\tilde{R}}^g_{y,t}$ is the recruitment (by size-class) to gear *g* during season *t* of year *y* (which will be zero except for one season – the recruitment season), and $Z^g_{y,t,l}$ is the total mortality for animals of gender *g* in size-class *l* during season *t* of year *y*. Note that mortality is continuous across a time-step.

The initial conditions for the model (i.e., the numbers-at-size at the start of the first year, y_1) is specified with an overall total recruitment multiplied by offsets for each size-class, i.e.:

$$N^g_{y_1,l} = R_{\text{Init}}\, e^{\delta^g_{y_1,l}} \Big/ \sum_{g'}\sum_{l'} e^{\delta^{g'}_{y_1,l'}} \qquad \text{(A.3)}$$

The minimum carapace length for both males and females is set at 65 mm, and crab abundance is modeled with a length-class interval of 5 mm. The last length class includes all crab ≥160-mm CL for males and ≥140-mm CL for females. Thus, length classes/groups are 20 for males and 16 for females.

b. Recruitment

Recruitment occurs once during each year. Recruitment by sex and size-class is the product of total recruitment, the split of the total recruitment to sex and the assignment of sex-specific recruitment to size-classes, i.e.:

$$\tilde{R}^{g}_{y,t,l} = \bar{R}e^{\varepsilon_y} \begin{cases} (1+e^{\phi_y})^{-1}\, p_l^{\mathrm{r,mal}} & \text{if } g\text{=males} \\ \phi_y (1+e^{\phi_y})^{-1}\, p_l^{\mathrm{r,fem}} & \text{if } g\text{=females} \end{cases} \tag{A.4}$$

where $\bar{R}$ is median recruitment, ϕ_y determines the sex ratio of recruitment during year *y*, and $p_l^{r,g}$ is the proportion of the recruitment (by gender and year) that recruits to size-class *l*:

$$p_l^{r,g} = \int\limits_{L_l^{\mathrm{low}}}^{L_l^{\mathrm{hi}}} \tfrac{1}{\Gamma(\alpha^{r,g}/\beta^{r,g})} (l/\beta^{r,g})^{((\alpha^{r,g}/\beta^{r,g})-1)} e^{-l/\beta^{r,g}}\, dl \tag{A.5}$$

where $\alpha^{r,g}$ and $\beta^{r,g}$ are the parameters that define a gamma function for the distribution of recruits to size-class. Equation A.5 can be restricted to a subset of size-classes, in which case the results from Equation A.5 are normalized to sum to 1 over the selected size-classes.

c. Total mortality / probability of encountering the gear

Total mortality is the sum of fishing mortality and natural mortality, i.e.:

$$Z^{g}_{y,t,l} = \rho^{\mathrm{M}}_{y,t} M^{g}_{y} \tilde{M}_l + \sum_f S^{f,g}_{y,t,l} (\lambda^{f,g}_{y,t,l} + \Omega^{f,g}_{y,t,l}(1-\lambda^{f,g}_{y,t,l})) F^{f,g}_{y,t} \tag{A.6}$$

where $\rho^{\mathrm{M}}_{y,t}$ is the proportion of natural mortality that occurs during season *t* for year *y*, M^{g}_{y} is the rate of natural mortality for year *y* for animals of gender *g* (applies to animals for which $\tilde{M}_l = 1$), $\tilde{M}_l$ is the relative natural mortality for size-class *l* , $S^{f,g}_{y,t,l}$ is the (capture) selectivity for animals of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, $\lambda^{f,g}_{y,t,l}$ is the probability of retention for animals of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, $\Omega^{f,g}_{y,t,l}$ is the mortality rate for discards of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, and $F^{f,g}_{y,t}$ is the fully-selected fishing mortality for animals of gender *g* by fleet *f* during season *t* of year *y*.

The probability of encountering the gear (occurs instantaneously) is given by:

$$\tilde{Z}^{g}_{y,t,l} = \sum_f S^{f,g}_{y,t,l} F^{f,g}_{y,t} \tag{A.7}$$

Note that Equation A.7 is computed under the premise that fishing is instantaneous and hence that there is no natural mortality during season *t* of year *y*.

The logarithms of the fully-selected fishing mortalities by season are modelled as:

$$\ell\mathrm{n}F^{f,\mathrm{mal}}_{y,t} = \ell\mathrm{n}F^{f,\mathrm{mal}} + \xi^{f,\mathrm{mal}}_{y,t} \tag{A.8}$$

$$\ell\mathrm{n}F^{f,\mathrm{fem}}_{y,t} = \ell\mathrm{n}F^{f,\mathrm{mal}}_{y,t} + \phi^{f} + \xi^{f,\mathrm{fem}}_{y,t} \tag{A.9}$$

where $F^{f,\text{mal}}$ is the reference fully-selected fishing mortality rate for fleet *f*, ϕ^f is the offset between female and male fully-selected fishing mortality for fleet *f*, and $\xi^{f,g}_{y,t}$ are the annual deviation of fully-selected fishing mortality for fleet *f* (by gender).

Natural mortality can depend on time with blocked natural mortality (individual parameters). This option estimates natural mortality as parameters by block, i.e.:

$$M_y^g = e^{\psi_y^g} \tag{A.10}$$

where $M_{y_1}^g$ is the rate of natural mortality for gender *g* for the first year of the model, and ψ_y^g is the annual change in natural mortality and changes in blocks of years.

It is possible to 'mirror' the values for the ψ_y^g parameters (between genders and between blocks), which allows male and female natural mortality to be the same, and for natural mortality to be the same for discontinuous blocks (based on Equation A.10). It is also possible to estimate a ratio of natural mortality between genders. The deviations in natural mortality can also be penalized to avoid unrealistic changes in natural mortality to fit 'quirks' in the data.

d. Landings, discards, total catch

The model keeps track of (and can be fitted to) landings, discards, total catch by fleet in season with continuous mortality:

Landed catch

$$C^{\text{Land},f,g}_{y,t,l} = \frac{\lambda^{f,g}_{y,t,l}\, S^{f,g}_{y,t,l} F^{f,g}_{y,t}}{Z^g_{y,t,l}} N^{f,g}_{y,t,l}(1-e^{-Z^g_{y,t,l}}) \tag{A.11}$$

Discards

$$C^{\text{Disc},f,g}_{y,t,l} = \frac{(1-\lambda^{f,g}_{y,t,l})\, S^{f,g}_{y,t,l} F^{f,g}_{y,t}}{Z^g_{y,t,l}} N^{f,g}_{y,t,l}(1-e^{-Z^g_{y,t,l}}) \tag{A.12}$$

Total catch

$$C^{\text{Total},f,g}_{y,t,l} = \frac{S^{f,g}_{y,t,l} F^{f,g}_{y,t}}{Z^g_{y,t,l}} N^{f,g}_{y,t,l}(1-e^{-Z^g_{y,t,l}}) \tag{A.13}$$

Landings, discards, and total catches by fleet can be aggregated over gender (e.g., when fitting to removals reported as gender-combined). Equations A.11-13 are extended naturally for the case in which the population is represented by shell condition and/or maturity status (given the assumption that fishing mortality, retention and discard mortality depend on gender and time, but not on shell condition nor maturity status).

Landings, discards, and total catches by fleet can be reported in numbers (Equations A.11–13) or in terms of weight. For example, the landings, discards, and total catches by fleet, season, year, and gender for the total (over size-class) removals are computed as:

$$C^{\text{Land},g,f}_{y,t} = \sum_l C^{\text{Land},g,f}_{y,t,l}\, w^g_{y,l}\ ;\ C^{\text{Disc},g,f}_{y,t} = \sum_l C^{\text{Disc},g,f}_{y,t,l}\, w^g_{y,l}\ ;\ C^{\text{Total},g,f}_{y,t} = \sum_l C^{\text{Total},g,f}_{y,t,l}\, w^g_{y,l} \tag{A.14}$$

where $C_{y,t}^{\text{Land},g,f}$, $C_{y,t}^{\text{Disc},g,f}$, and $C_{y,t}^{\text{Total},g,f}$ are respectively the landings, discards, and total catches in weight by fleet, season, year, and gender for the total (over size-class) removals, and $w_{y,l}^{g}$ is the weight of an animal of gender *g* in size-class *l* during year *y*.

e. Selectivity / retention

Selectivity (the probability of encountering the gear) and retention (the probability of being landed given being captured) are logistic function:

$$S_l = 1 - \left(1 + \frac{exp((\bar{L}_l - S_{50})}{\sigma^S}\right))^{-1} \tag{A.15}$$

where S_{50} is the size corresponding to 50% selectivity, σ^S is the "standard deviation" of the selectivity curve, and $\bar{L}_l$ is the midpoint of size-class *l*.

It is possible to assume that selectivity for one fleet is the product of two of the selectivity patterns. This option is used to model cases in which one survey (NMFS trawl survey) is located within the footprint of another survey (BSFRF trawl survey).

The options to model retention are the same as those for selectivity, except that it is possible to estimate an asymptotic parameter, which allows discard of animals that would be "fully retained" according to the standard options for (capture) selectivity.

Selectivity and retention can be defined for blocks of contiguous years. Two blocks are used for NMFS survey selectivity (before 1982 and after 1981) due to gear modifications and two blocks are used for the directed pot fishery retention (before 2005 and after 2004) due to the fishery rationalization.

f. Growth

Growth is a key component of any size-structured model. It is modelled in terms of molt probability and the size-transition matrix (the probability of growing from each size-class to each of the other size-classes, constrained to be zero for sizes less than the current size). Note that the size-transition matrix has entries on its diagonal, which represent animals that molt but do not change size-classes.

(1) Molt probability

There are two options for modelling the probability of molting as a function of size, $P_{l,l}$:

- Constant probability (1 for females)
- Logistic probability (for males), i.e.:

$$P_{l,l} = 1 - (1 + \exp((\bar{L}_l - P_{50}) / \sigma^P))^{-1} \tag{A.16}$$

where P_{50} is the size at which the probability of molting is 0.5, and σ^S is the "standard deviation" of the molt probability function.

Molt probability is specified by gender and can change in blocks (one block before 1981 and one block after 1980 for males).

(2) Size-transition

The proportion of animals in size-class *j* that grow to be in size-class *i* ($X_{i,j}$) can be pre-specified as gamma-distributed size-increments:

$$X_{i,j} = \int_{L_j^{\text{low}}}^{L_j^{\text{hi}}} \frac{1}{\Gamma(I_i/\tilde{\beta})}((l-\bar{L}_i)/\tilde{\beta})^{(I_i/\tilde{\beta})-1} e^{-(l-\bar{L}_i)/\tilde{\beta}} dl \tag{A.17}$$

where I_i is the ‘expected’ growth increment for an animal in size-class *i* (a linear function of the mid-point of size-class *i*), $\tilde{\beta}$ determines the variation in growth among individuals, and L_j^{low} and L_j^{hi} are respectively the lower and upper bounds of size-class *j*.

The size-transition matrix is specified by gender and can change in blocks (one block for males and three blocks for females (1975-1982, 1983-1993, and 1994-present based on changes in sizes at maturity).

B. Outputs, Projections and OFL Calculation

a. Core model outputs

The core model outputs are the N-matrix, the matrix of fully-selected fishing mortalities, the time-series of spawning stock biomass, mature male biomass (SSB), the values for the model parameters, and the predictions related to the observations. The spawning stock biomass (and hence mature male biomass) is defined according to:

$$SSB_y = \sum_g p^{\text{SSB},g} \sum_l N_{y,t^*,l}^g \tag{A.18}$$

where $p^{\text{SSB},g}$ is the relative contribution of gender *g* to spawning biomass ($p^{\text{SSB,mal}} = 1$; $p^{\text{SSB,fem}} = 0$ corresponds to spawning stock biomass equating to mature male biomass), and *t** is the season in which spawning takes place (spawning occurs at the start of the season).

Definition of model outputs:

(1) Biomass: two population biomass measurements are used in this report: total survey biomass (crab >64 mm CL) and mature male biomass (males >119 mm CL). Mating time is assumed to Feb. 15.

(2) Recruitment: new entry of number of males in the 1st seven length classes (65- 99 mm CL) and new entry of number of females in the 1st five length classes (65-89 mm CL).

(3) Fishing mortality: full-selected instantaneous annual fishing mortality rate at the time of fishery.

b. Biological reference points

The key biological reference points are the proxy for F_{MSY}, the proxy for B_{MSY} and the Overfishing Level (OFL).

(1) The proxy for F_{MSY}

The specification for the proxy for F_{MSY} depends on the tier in which the stock is placed. BBRKC belongs to Tier 3, and the proxy for F_{MSY} is $F_{35\%}$, the value of a multiplier on the fully-selected fishing mortality rates for directed fisheries in the final year of the assessment such that spawning biomass-per-recruit is 35% of the unfished level. The fully-selected fishing mortality rates for non-directed fisheries are set to recent averages (recent 5 years for BBRKC). The unfished spawning biomass-per-recruit, $SSBPR(\underline{0})$, is calculated by projecting the population model forward where fishing mortality is zero for all fleets, and recruitment is constant (and ideally equal to 1). $F_{35\%}$ is then computed (using Newtons' method) such that:

$$SSBPR(\underline{\alpha}\underline{\bar{F}}) = 0.35\, SSBPR(\underline{0}) \tag{A.19}$$

where $\underline{\bar{F}}$ is the vector of recent average fully-selected fishing mortalities, and $\underline{\alpha}$ is a vector with 1 for the non-directed fisheries and a calculated constant for the directed fisheries.

(2) The proxy for B_{MSY}

The specification for the proxy for B_{MSY} depends on the tier in which the stock is placed. For stocks in Tier 4, the proxy for B_{MSY} is the average spawning stock biomass over a pre-specified number of years. For Tier 3, the proxy for B_{MSY} is $0.35\, SSBPR(\underline{0})$ multiplied by the mean recruitment over a pre-specified number of years. GMACS estimates annual recruitments by sex through estimating annual recruitment deviations and annual recruitment proportions by sex. Pre-specified numbers of years are needed in the control file for recruitment average and for mean recruitment sex ratio, respectively.

(3) Calculating the OFL

The OFL is the total catch (in weight) encountered by the gear that dies either due to being landed or due to being discarded when fully-selected fishing mortality is computed using the OFL control rule. The total catch

$$OFL = \sum_g \sum_t w^g_{y_2,l} \frac{S^{f,g}_{y_2,t,l}(\lambda^{f,g}_{y_2,t,l} + \Omega^{f,g}_{y_2,t,l}(1-\lambda^{f,g}_{y_2,t,l})S^{f,g}_{y_2,t,l})\alpha^{*,f}\bar{F}^{f,g}_t}{Z^g_{y_2+1,t,l}} N^{f,g}_{y_2+1,t,l}(1-e^{-Z^g_{y_2+1,t,l}}) \tag{A.20}$$

where y_2 is the final year of the assessment, $\alpha^{*,f}$ is the multiplier on average fully-selected fishing mortality for fleet *f* (1 for non-directed fisheries and a value computed from the OFL control rule for the directed fisheries), $\bar{F}^{f,g}_t$ is recent average fully-selected fishing mortality for fleet *f* and gender *g* during season *t*, and $Z^g_{y_2+1,t,l}$ is the total mortality on animals of gender *g* in size-class *l* during season *t* of year y_2+1:

$$Z^g_{y_2+1,t,l} = \rho^{\mathrm{M}}_{y_2,t} M^g_{y_2} \tilde{M}_l + \sum_f S^{f,g}_{y_2,t,l} (\lambda^{f,g}_{y_2,t,l} + \Omega^{f,g}_{y_2,t,l}(1-\lambda^{f,g}_{y_2,t,l}))\alpha^{*,f} \bar{F}^{f,g}_t \tag{A.21}$$

The values for entries of the vector α^* for the directed fisheries are determined using the OFL control rule:

- If the projected spawning stock biomass in year y2+1 when $\underline{\alpha}^* = \underline{\alpha}$ exceeds the proxy for B_{MSY}, then $\alpha^{*,f} = \alpha^f$.
- If the projected spawning stock biomass in year y2+1 when $\underline{\alpha}^* = \underline{\alpha}$ is less than 25% of the proxy for B_{MSY}, then $\alpha^{*,f} = 0$.
- If the projected spawning stock biomass in year y2+1, $SSB^*_{y_2}$ when $\underline{\alpha}^* = \underline{\alpha}$ lies between less than 25% and 100% of the proxy for B_{MSY}, then $\alpha^{*,f}$ is tuned according to $\alpha^{*,f} = \dfrac{\alpha^f\left(\frac{SSB^*_{y_2}}{B_{MSY}} - 0.1\right)}{0.9}$ until convergence.

c. Projections

The specifications for the projections relate to:

- The duration of the projection.
- Whether the fully-selected fishing mortalities for the non-directed fisheries are set to zero or to recent averages by fleet.
- The way in which future recruitment is generated. The options available are:
    - Select a recruitment from a set of historical recruitments at random.
    - Generate a future recruitment from a Ricker stock-recruitment relationship, i.e.:

      $$R^g_y = SSB_{y-a*} / SSB_0 e^{-1.25 \ell n h(SSB_{y-a*}/SSB_0 - 1)} e^{\varepsilon_y - \sigma_R^2/2} \,;\; \varepsilon_y \sim N(0;\sigma^2) \tag{A.22}$$

      where $a*$ is the time-lag between spawning and entering the first size-class in the model, SSB_0 is unfished spawning stock biomass, h is the steepness of the stock-recruitment relationship, σ_R is the variation in recruitment about the stock-recruitment relationship.
    - Generate a future recruitment from a Beverton-Holt stock-recruitment relationship, i.e.:

      $$R^g_y = \frac{4R_0\, SSB_{y-a*} / SSB_0}{(1-h) + (5h-1) SSB_{y-a*} / SSB_0} e^{\varepsilon_y - \sigma_R^2/2} \quad \varepsilon_y \sim N(0;\sigma^2) \tag{A.23}$$

      where R_0 is unfished recruitment (i.e.. $SSB_0 / SSBPR(\underline{0})$).
- The control rule used to set fully-selected fishing mortality for the directed fisheries. The options are available
    - Pre-specified values for fully-selected fishing mortality for each fishery.
    - Pre-specified values subject to the dead catch not exceeding that corresponding to the OFL.

- Pre-specified values subject to the dead catch not exceeding that corresponding to the OFL and the landed catch not exceeding that corresponding to the State of Alaska harvest control rule.

The value for the steepness of the stock-recruitment relationship is computed such that the maximum sustainable yield occurs at $F_{35\%}$, i.e.:

$$\left.\frac{dC(\underline{F})}{dF}\right|_{\underline{F}=\underline{\alpha}^{*}\bar{F}} \tag{A.24}$$

where $C(\underline{F})$ is the equilibrium landed catch when the population model is projected forward deterministically under one of the two stock-recruitment relationships.

C. Parameter Estimation

a. *Estimating Bycatch Fishing Mortalities for Years without Observer Data*

Observer data are not available for the directed pot fishery before 1990 and the Tanner crab fishery before 1991. There are also extremely low observed bycatches in the Tanner crab fishery in 1994 and during 2006-2009. Bycatch fishing mortalities for male and females during 1975-1989 in the directed pot fishery were estimated as

$$F_t^{disc,s} = r^s \; F_t^{dir} \tag{A.25}$$

where r^s is the mean ratio of estimated bycatch discard fishing mortalities to the estimated directed pot fishing mortalities during 1990-2004 for sex s. Directed pot fishing practice has changed after 2004 due to fishery rationalization.

We used pot fishing effort (potlifts) east of 163° W in the Tanner crab fishery to estimate red king crab bycatch discard fishing mortalities in that fishery when observer data are not available (1975-1990, 1994, 2006-2009):

$$F_t^{Tanner,s} = a^s \; E_t \tag{A.26}$$

where a^s is the mean ratio of estimated Tanner crab fishery bycatch fishing mortalities to fishing efforts during 1991-1993 for sex s, and E_t is Tanner crab fishery fishing efforts east of 163° W in year t. Due to fishery rationalization after 2004, we used the data only during 1991-1993 to estimate the ratio.

b. Likelihood Components

A maximum likelihood approach was used to estimate parameters. For length compositions ($p_{l,t,s,sh}$), the likelihood functions are :

$$Rf = \prod_{l=1}^{L} \prod_{t=1}^{T} \coprod_{s=1}^{2} \prod_{sh=1}^{2} \frac{\left\{ exp\left[-\frac{\left(p_{l,t,s,sh} - \hat{p}_{l,t,s,sh}\right)^2}{2\sigma_{l,t,s,sh}^2} \right] + 0.01 \right\}}{\sqrt{2\pi\sigma_{l,t,s,sh}^2}} \tag{A.27}$$

$$\sigma_{l,t,s,sh}^2 = \frac{\left[p_{l,t,s,sh}\left(1 - p_{l,t,s,sh}\right) + \frac{0.1}{L}\right]}{n_t}$$

where L is the number of length groups, T the number of years, and n_t the effective sample size in year t, which was estimated for trawl survey, pot retained catch, total directed pot male catch, directed pot female discard, groundfish trawl discard, groundfish fixed gear discard, and Tanner crab fishery discard length composition data. $p_{l,t,s,sh}$ is the observed proportion of crab in length-class l, year t, sex s and shell condition sh, and $\hat{p}_{l,t,s,sh}$ is the model-estimate corresponding to $p_{l,t,s,sh}$.

The weighted negative log likelihood functions are:

$$\begin{gathered}
Length\ compositions\text{:}\ -\sum \ln\left(Rf_i\right) \\
Catch\ and\ bycatch\ biomasses\text{:}\ \sum\left[ln\left(\frac{C_t}{\hat{C}_t}\right)^2 / \left(2\ln\left(cv_t^2 + 1\right)\right) \right] \\
NMFS\ survey\ biomass\text{:}\ \sum\left[ln\left(ln\left(CV_t{}^2 + 1\right)\right)^{0.5} + \frac{ln\left(\frac{B_t}{\hat{B}_t}\right)^2}{\left(2ln\left(CV_t{}^2 + 1\right)\right)} \right] \\
BSFRF\ survey\ biomass\text{:}\ \sum\left[ln\left(ln\left(CV_t{}^2 + AV^2 + 1\right)\right)^{0.5} + \frac{ln\left(\frac{B_t}{\hat{B}_t}\right)^2}{\left(2ln\left(CV_t{}^2 + AV^2 + 1\right)\right)} \right] \\
R\ variation\text{:}\ \lambda_R \sum\left[ln\left(\frac{R_t}{\bar{R}}\right)^2 \right] \\
R\ sex\ ratio\text{:}\ \lambda_s \sum\left[ln\left(\frac{\bar{R}_M}{\bar{R}_F}\right)^2 \right] \\
Groundfish\ bycatch\ fishing\ mortalities\text{:}\ \lambda_t \sum\left[ln\left(\frac{F_{t,gf}}{\bar{F}_{gf}}\right)^2 \right] \\
Pot\ female\ bycatch\ fishing\ mortalities\text{:}\ \lambda_p \sum\left[ln\left(\frac{F_{t,f}}{\bar{F}_f}\right)^2 \right] \\
Trawl\ survey\ catchability\text{:}\ \frac{(Q - \hat{Q})^2}{2\sigma^2}
\end{gathered} \tag{A.28}$$

where R_t is the recruitment in year t, $\bar{R}$ the mean recruitment, $\bar{R}_M$ the mean male recruitment, $\bar{R}_F$ the mean female recruitment, AV is additional CV and estimated in the model, $\bar{F}_{gf}$ the mean groundfish bycatch fishing mortality (this is separated into trawl and fixed gear fishery bycatch), $\bar{F}_f$ the mean pot female bycatch fishing mortality, Q summer trawl survey catchability, and σ the estimated standard deviation of Q (all models).

Weights λ_j are assumed to be 2 for recruitment variation, 10 for recruitment sex ratio, 0.2 for pot female bycatch fishing mortality, and 0.1 for trawl bycatch fishing mortality. These λ_j values correspond to CV values of 0.53, 0.23, 3.34, and 12.14, respectively.

c. Population State in Year 1.

The total abundance and proportions for the first year are estimated in the model.

d. Parameter estimation framework:

(1) Parameters estimated independently

Basic natural mortality, length-weight relationships, and mean growth increments per molt were estimated independently outside of the model. Mean length of recruits to the model depends on growth and was assumed to be 72.5 for both males and females. Handling mortality rates were set to 0.2 for the directed pot fishery, 0.25 for the Tanner crab fishery, 0.5 for the groundfish fixed gear fishery, and 0.8 for the groundfish trawl fishery.

i. Natural Mortality

Based on an assumed maximum age of 25 years and the 1% rule (Zheng 2005), a base M was estimated to be 0.18 for males.

ii. Length-weight Relationship

Length-weight relationships for males and females were as follows:

Immature Females: $W = 0.000408\, L^{3.127956}$

Ovigerous Females: $W = 0.003593\, L^{2.666076}$ (A.29)

Males: $W = 0.0004031\, L^{3.141334}$

where W is weight in grams, and L CL in mm.

iii. Growth Increment per Molt

A variety of data are available to estimate male mean growth increment per molt for Bristol Bay RKC. Tagging studies were conducted during the 1950s, 1960s and 1990s, and mean growth increment per molt data from these tagging studies in the 1950s and 1960s were analyzed by Weber and Miyahara (1962) and Balsiger (1974). Modal analyses were conducted for the data during 1957-1961 and the 1990s (Weber 1967; Loher et al. 2001). Mean growth increment per molt may be a function of body size and shell condition and vary over time (Balsiger 1974; McCaughran and Powell 1977); however, for simplicity, mean growth increment per molt was assumed to be only a function of body size in the models. Tagging data were used to estimate mean growth increment per molt as a function of pre-molt length for males (Figure A2). The results from modal analyses of 1957-1961 and the 1990s were used to estimate mean growth increment per molt for immature females during 1975-1993 and 1994-2020, respectively, and the data presented in Gray (1963) were used to estimate those for mature females for model scenarios (Figure A2). To make a smooth transition of growth increment per molt from immature to mature females, weighted growth increment averages of 70% and 30% at 92.5 mm CL pre-molt length and 90% and 10% at 97.5 mm CL were used, respectively, for mature and immature females during 1983-1993. These percentages are roughly close to the composition of maturity. During 1975-1982, females matured at a smaller size, so the growth increment per molt as a function of length was shifted to smaller increments. Likewise, during 1994-2021, females matured at a slightly higher size, so the growth increment per molt was shifted to high increments for immature crab (Figure A2). Once mature, the growth increment per molt for male crab decreases slightly and annual molting probability decreases, whereas the growth increment for female crab decreases dramatically but annual molting probability remains constant at 1.0 (Powell 1967).

iv. Sizes at Maturity for Females

The NMFS collected female reproductive condition data during the summer trawl surveys. Mature females are separated from immature females by a presence of egg clutches or egg cases. Proportions of mature females at 5-mm length intervals were summarized and a logistic curve was fitted to the data each year to estimate sizes at 50% maturity. Sizes at 50% maturity are illustrated in Figure A3 with mean values for three different periods (1975-82, 1983-93, and 1994-2021).

v. Sizes at Maturity for Males

Although size at sexual maturity for Bristol Bay red king crab males has been estimated (Paul et al. 1991), there are no data for estimating size of functional maturity collected in the natural environment. Sizes at functional maturity for Bristol Bay male RKC have been assumed to be 120 mm CL (Schmidt and Pengilly 1990). This is based on mating pair data collected off Kodiak Island (Figure A4). Sizes at maturity for Bristol Bay female RKC are about 90 mm CL, about 15 mm CL less than Kodiak female RKC (Pengilly et al. 2002). The size ratio of mature males to females is 1.3333 at sizes at maturity for Bristol Bay RKC, and since mature males grow at much larger increments than mature females, the mean size ratio of mature males to females is most likely larger than this ratio. Size ratios of the large majority of Kodiak mating pairs were less than 1.3333, and in some bays, only a small proportion of mating pairs had size ratios above 1.3333 (Figure A4).

In the laboratory, male RKC as small as 80 mm CL from Kodiak and Southeast Alaska can successfully mate with females (Paul and Paul 1990). But few males less than 100 mm CL were observed to mate with females in the wild. Based on the size ratios of males to females in the Kodiak mating pair data, setting 120 mm CL as a minimum size of functional maturity for Bristol Bay male RKC is proper in terms of managing the fishery.

vi. Potential Reasons for High Mortality during the Early 1980s

Bristol Bay red king crab abundance had declined sharply during the early 1980s. Many factors have been speculated for this decline: (i) completely wiped out by fishing: the directed pot fishery, the other directed pot fishery (Tanner crab fishery), and bottom trawling; and (ii) high fishing and natural mortality. With the survey abundance, harvest rates in 1980 and 1981 were among the highest, thus the directed fishing definitely had a big impact on the stock decline, especially legal and mature males. However, for the sharp decline during 1980-1984 for males, 3 out of 5 years had low mature harvest rates. During the 1981-1984 decline for females, 3 out of 4 years had low mature harvest rates. Also pot catchability for females and immature males are generally much lower than for legal males, so the directed pot fishing alone cannot explain the sharp decline for all segments of the stock during the early 1980s.

Red king crab bycatch in the eastern Bering Sea Tanner crab fishery is another potential factor (Griffin et al. 1983). The main overlap between Tanner crab and Bristol Bay red king crab is east of 163^o W. No absolute red king crab bycatch estimates are available until 1991. So there are insufficient data to fully evaluate the impact. Tanner crab retained catch and potlifts from the eastern Bering Sea Tanner crab fishery are illustrated in Figure A5. The observed red king crab bycatch in the Tanner crab fishery during 1991-2015 and total potlifts east of 166^o W during 1975 to 2015 were used to estimate the bycatch mortality in the current model. Because winter sea surface temperatures and air temperatures were warmer (which means a lower handling mortality rate) and there were fewer potlifts during the early 1980s than during the early 1990s, bycatch in the Tanner crab fishery is unlikely to have been a main factor for the sharp decline of Bristol Bay red king crab.

Several factors may have caused increases in natural mortality. Crab diseases in the early 1980s were documented by Sparks and Morado (1985), but inadequate data were collected to examine their effects on the stock. Stevens (1990) speculated that senescence may be a factor because many crab in the early 1980s were very old due to low temperatures in the 1960s and early 1970s. The biomass of the main crab predator, Pacific cod, increased about 10 times during the late 1970s and early 1980s. Yellowfin sole biomass also increased substantially during this period. Predation is primarily on juvenile and molting/softshell crab. But we lack stomach samples in shallow waters (juvenile habitat) and during the period when red king crab molt. Also cannibalism occurs during molting periods for red king crab. High crab abundance in the late 1970s and early 1980s may have increased the occurrence of cannibalism.

Overall, the likely causes for the sharp decline in the early 1980s are combinations of the above factors, such as pot fisheries on legal males, bycatch, and predation on females and juvenile and sublegal males, senescence for older crab, and disease for all crab. In our model, we estimated one mortality parameter for males and another for females during 1980-1984. We also estimated a mortality parameter for females during 1976-1979 and 1985-1993. These three mortality parameters are additional to the basic natural mortality of 0.18yr^{-1}, all directed fishing mortality, and non-directed fishing mortality. These three mortality parameters could be attributed to natural mortality as well as undocumented non-directed fishing mortality. The model fit the data much better with these three parameters than without them.

(2) Parameters estimated conditionally

The following model parameters were estimated for male and female crab: total recruits for each year (year class strength R_t for t = 1975 to 2020), total abundance in the first year (1975), growth parameter β, and recruitment parameter β_r for males and females separately. Molting probability parameters β and L_{50} were also estimated for male crab. Estimated parameters also include different sets of β and L_{50} for total selectivity and retained proportions, β and L_{50} for pot-discarded female selectivity, β and L_{50} for pot-discarded male and female selectivities from the eastern Bering Sea Tanner crab fishery, β and L_{50} for groundfish trawl and fixed gear discarded selectivities, and different sets of β

and L_{50} for NMFS trawl survey male and female selectivities separately. The NMFS survey catchabilities Q for some models were also estimated. Different sets of β and L_{50} for selectivity parameters were estimated for the survey data from the Bering Fisheries Research Foundation. Annual fishing mortalities were also estimated for the directed pot fishery for males (1975-2020), pot-discarded females from the directed fishery (1990-2020), pot-discarded males and females from the eastern Bering Sea Tanner crab fishery (1991-93, 2013-15), groundfish trawl discarded males and females (1976-2020), and groundfish fixed gear discarded males and females (1996-2020). One additional mortality parameter for years 1980-1984 for males and a constant to multiply male natural mortality for estimating female natural mortality were also estimated. Some estimated parameters were constrained in the model. For example, male and female recruitment estimates were forced to be close to each other for a given year.

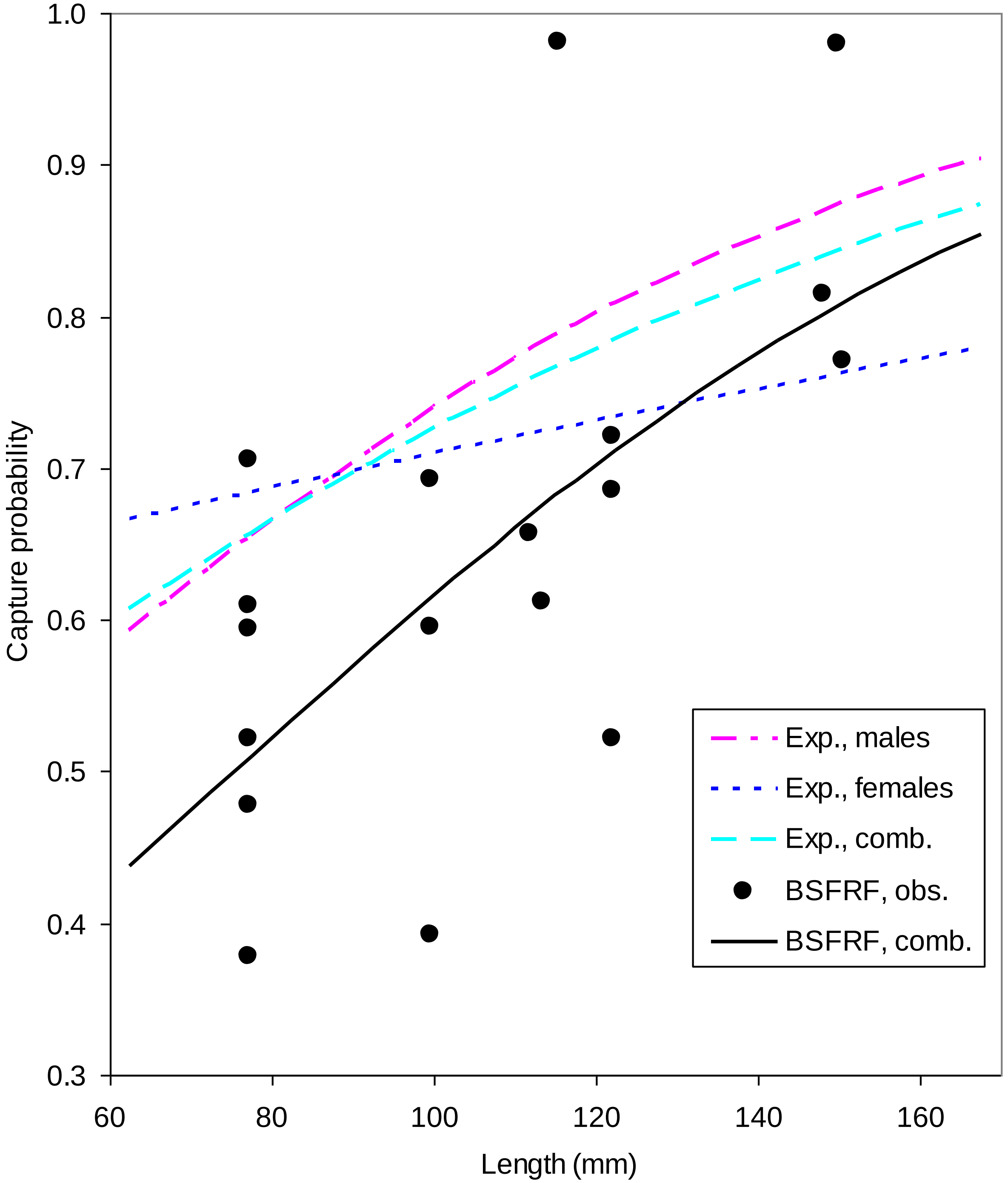


Figure A1. Estimated capture probabilities for NMFS Bristol Bay red king crab trawl surveys by Weinberg et al. (2004) and the Bering Sea Fisheries Research Foundation surveys.

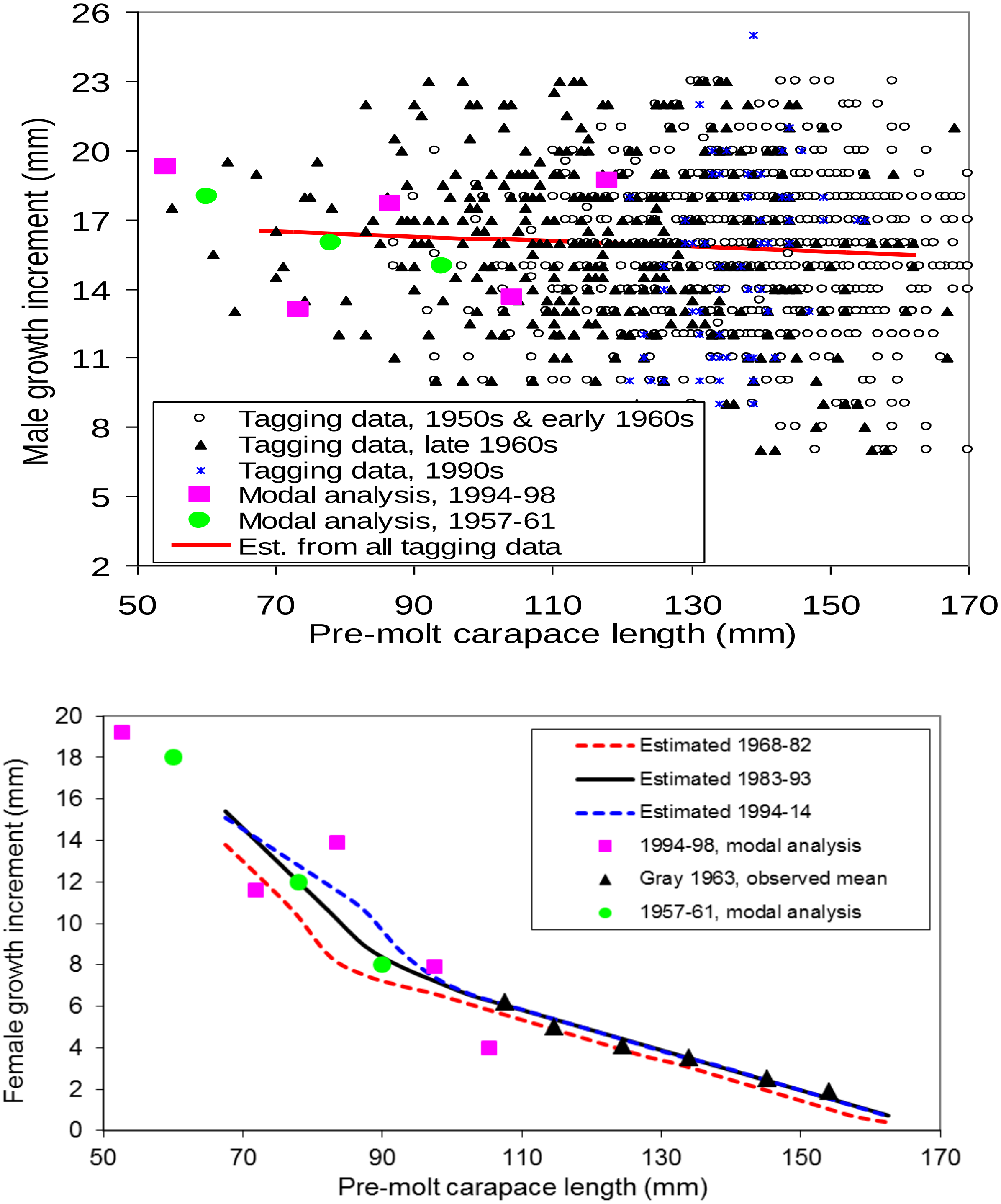


Figure A2. Mean growth increments per molt for Bristol Bay red king crab. Note: “tagging”---based on tagging data; “mode”---based on modal analysis. The female growth increments per molt are for different model scenarios.

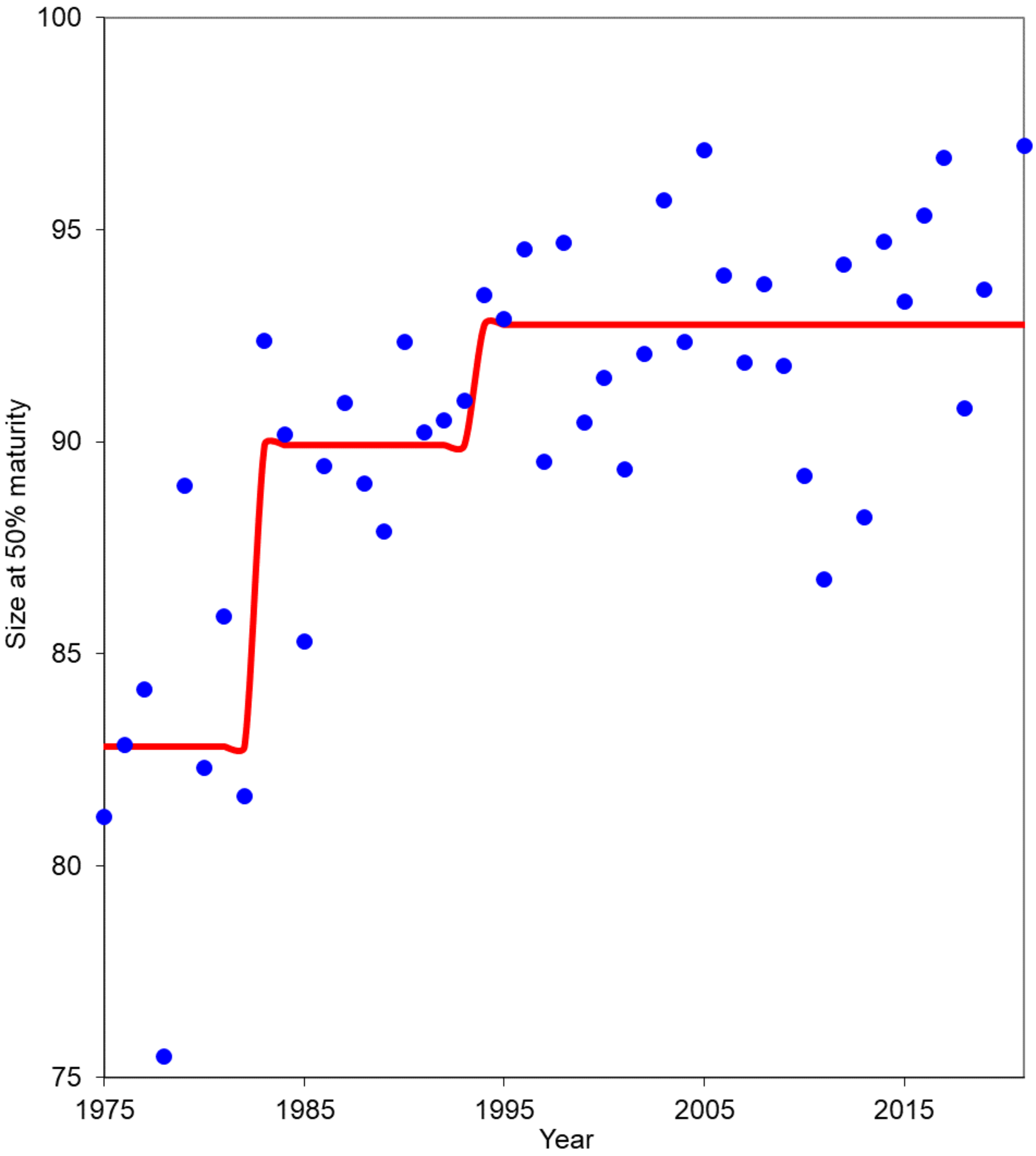


Figure A3. Estimated sizes at 50% maturity for Bristol Bay female red king crab from 1975 to 2021. Averages for three periods (1975-82, 1983-93, and 1994-2021) are plotted with a line.

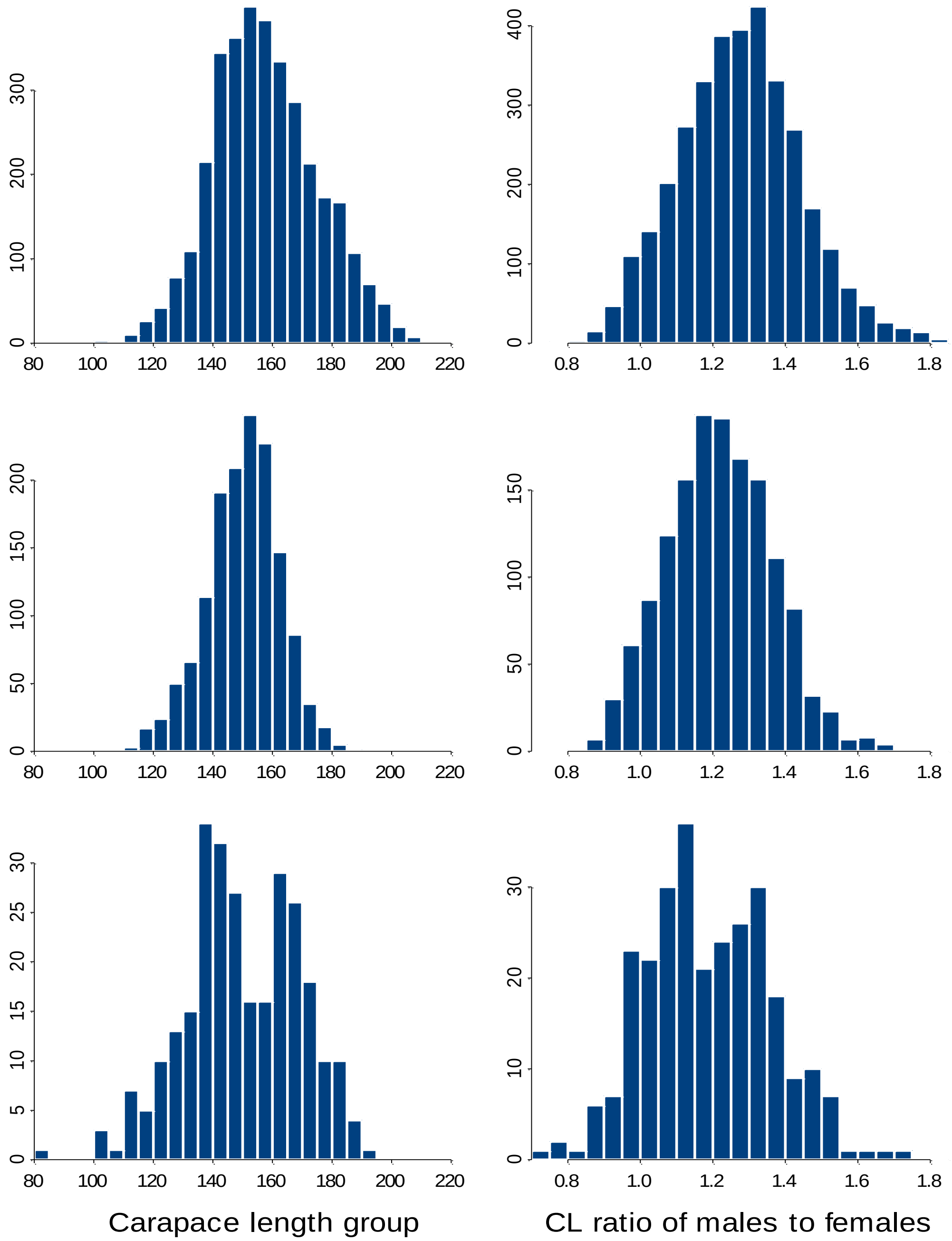


Figure A4. Histograms of carapace lengths (CL) and CL ratios of males to females for male shell ages ≤13 months of red king crab males in grasping pairs; Powell's Kodiak data. Upper plot: all locations and years pooled; middle plot: location 11; lower plot: locations 4 and 13. Sizes at maturity for Kodiak red king crab are about 15 mm larger than those for Bristol Bay red king crab. (Doug Pengilly, ADF&G, pers. comm.).

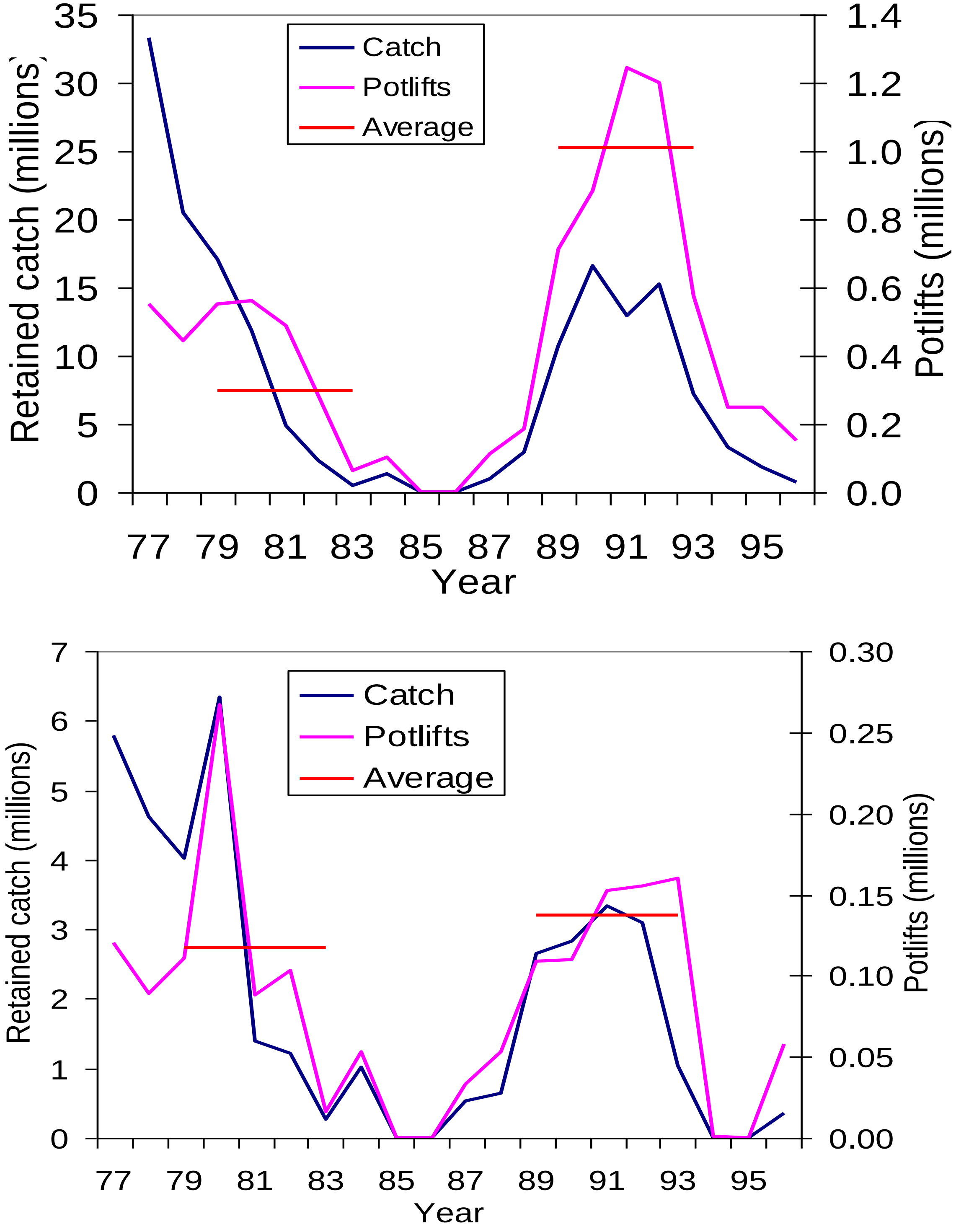


Figure A5. Tanner crab retained catch and potlifts for total eastern Bering Sea Tanner crab fishery (upper plot) and the Tanner crab fishery east of 163° W (bottom).

Appendix B. Input Data File for Model 21.1b

```
#===============================================================
#       Gmacs Main  Data   File   Version      1.1:   BBRKC        Example
#       GEAR_INDEX         DESCRIPTION
#       1       :   Pot    fishery retained    catch.
#       1       :   Pot    fishery with   discarded    catch.
#       2       :   Trawl  bycatch
#       3       :   Tanner bycatch
#       4       :   fixed gear bycatch
#       5       :   Trawl  survey
#       6       :    BSFRF survey
#       Fisheries:  1      Pot    Fishery,     2      Pot    Discard,     3      Trawl
                by-catch,  4      Tanner bycatch 5 fixed gear
#       Surveys:    6      NMFS Trawl  Survey,7    BSFRFSurvey
#==================================================================
1975    # Start  year
2020    # End  year
7       # Number of seasons
6       # Number of fleets (fishing fleets and surveys)
2       # Number of sexes
2       # Number of shell condition types
1       # Number of maturity types
20      # Number of size-classes in the      model
7       # Season recruitment occurs
7       # Season molting and growth occurs
6       # Season to calculate SSB
1       # Season for N output
# maximum size-class (males then females)
20 16
#       size_breaks (a  vector  giving  the    break  points  between     size   intervals,
                dim=nclass+1)
65      70      75      80      85      90      95      100     105     110     115     120     125
                130     135     140     145     150     155     160     165
#       Natural mortality       per     season  input   type    (1      =       vector  by      season,
                2       =       matrix  by      season/year)
2
#       Proportion of the total  natural  mortality to be  applied each    season
0.0000  0.2329 0.0000 0.2671 0.000  0.194  0.306  #1975
0.0000  0.2795 0.0000 0.2205 0.000  0.194  0.306   #1976
0.0000  0.3233 0.0000  0.1767 0.000  0.194  0.306   #1977
0.0000  0.2548 0.0000  0.2452 0.000  0.194  0.306   #1978
0.0000  0.2493 0.0000 0.2507 0.000  0.194  0.306   #1979
0.0000  0.2493 0.0000 0.2507 0.000  0.194  0.306   #1980
0.0000  0.2493 0.0000 0.2507 0.000  0.194  0.306   #1981
```

```
0.0000  0.2356 0.0000 0.2644 0.000   0.194  0.306   #1982
0.0000  0.2400 0.0000  0.2600 0.000  0.194  0.306   #1983
0.0000  0.2712 0.0000 0.2288 0.000   0.194  0.306   #1984
0.0000  0.2438 0.0000 0.2562 0.000   0.194  0.306   #1985
0.0000  0.2521 0.0000 0.2479 0.000   0.194  0.306   #1986
0.0000  0.2493 0.0000 0.2507 0.000   0.194  0.306   #1987
0.0000  0.2438 0.0000 0.2562 0.000   0.194  0.306   #1988
0.0000  0.2493 0.0000 0.2507 0.000   0.194  0.306   #1989
0.0000  0.3507 0.0000 0.1493 0.000   0.194  0.306   #1990
0.0000  0.3425 0.0000 0.1575 0.000   0.194  0.306   #1991
0.0000  0.3425 0.0000 0.1575 0.000   0.194  0.306   #1992
0.0000  0.3452 0.0000 0.1548 0.000   0.194  0.306   #1993
0.0000  0.3400 0.0000  0.1600 0.000  0.194  0.306   #1994
0.0000  0.3400 0.0000 0.1600 0.000   0.194  0.306   #1995
0.0000  0.3400 0.0000  0.1600 0.000  0.194  0.306   #1996
0.0000  0.3400 0.0000  0.1600 0.000  0.194  0.306   #1997
0.0000  0.3400 0.0000  0.1600 0.000  0.194  0.306   #1998
0.0000  0.3000  0.0000  0.2000 0.000 0.194  0.306   #1999
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2000
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2001
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2002
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2003
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2004
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2005
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2006
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2007
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2008
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2009
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2010
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2011
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2012
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2013
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2014
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2015
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2016
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2017
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2018
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2019
0.0000  0.3000 0.0000  0.2000 0.000  0.194  0.306   #2020
# Fishing fleet  names (delimited with: no spaces in names)

Pot_Fishery Trawl_Bycatch Bairdi_Fishery_Bycatch Fixed_Gear
# Survey names (delimited with: no spaces in names)
NMFS_Trawl BSFRF
```

```
# Are the seasons instantaneous (0) or continuous (1)
1 1 1 1 1 1 1
# Number of catch data frames
7
# Number of rows in each data frame
46      31      31      45      25      25      25
##      ------------------------------------------------------------------------------------------##
##      CATCH           DATA
##      Type of         catch: 1 = retained, 2   = discard, 0 =  total
##      Units of catch: 1 = biomass, 2 = numbers
##      for BBRKC Units         are in 1000 mt  for landed & discards.
##      -------------------------------------------------------------------------------------     ##
##      Male    retained        pot     fishery (tonnes)
#year   seas    fleet   sex     obs     cv      type    units   mult    effort  discard_mortality
1975    3       1       1       23281.2         0.03    1       1       1       0       0.2
1976    3       1       1       28993.6         0.03    1       1       1       0       0.2
1977    3       1       1       31736.9         0.03    1       1       1       0       0.2
1978    3       1       1       39743   0.03    1       1       1       0       0.2
1979    3       1       1       48910   0.03    1       1       1       0       0.2
1980    3       1       1       58943.6         0.03    1       1       1       0       0.2
1981    3       1       1       15236.8         0.03    1       1       1       0       0.2
1982    3       1       1       1361.3  0.03    1       1       1       0       0.2
1983    3       1       1       0.1     0.03    1       1       1       0       0.2     #AEP
1984    3       1       1       1897.1  0.03    1       1       1       0       0.2
1985    3       1       1       1893.8  0.03    1       1       1       0       0.2
1986    3       1       1       5168.2  0.03    1       1       1       0       0.2
1987    3       1       1       5574.2  0.03    1       1       1       0       0.2
1988    3       1       1       3351.1  0.03    1       1       1       0       0.2
1989    3       1       1       4656    0.03    1       1       1       0       0.2
1990    3       1       1       9272.8  0.03    1       1       1       0       0.2
1991    3       1       1       7885.1  0.03    1       1       1       0       0.2
1992    3       1       1       3681.8  0.03    1       1       1       0       0.2
1993    3       1       1       6659.6  0.03    1       1       1       0       0.2
1994    3       1       1       42.3    0.03    1       1       1       0       0.2
1995    3       1       1       36.4    0.03    1       1       1       0       0.2
1996    3       1       1       3861.7  0.03    1       1       1       0       0.2
1997    3       1       1       4042.1  0.03    1       1       1       0       0.2
1998    3       1       1       6779.2  0.03    1       1       1       0       0.2
1999    3       1       1       5377.9  0.03    1       1       1       0       0.2
2000    3       1       1       3737.9  0.03    1       1       1       0       0.2
2001    3       1       1       3866.2  0.03    1       1       1       0       0.2
2002    3       1       1       4384.5  0.03    1       1       1       0       0.2
2003    3       1       1       7135.3  0.03    1       1       1       0       0.2
2004    3       1       1       7006.7  0.03    1       1       1       0       0.2
```

```
2005    3       1       1       8399.7  0.03    1       1       1       0       0.2
2006    3       1       1       7143.2  0.03    1       1       1       0       0.2
2007    3       1       1       9303.9  0.03    1       1       1       0       0.2
2008    3       1       1       9216.1  0.03    1       1       1       0       0.2
2009    3       1       1       7272.5  0.03    1       1       1       0       0.2
2010    3       1       1       6761.5  0.03    1       1       1       0       0.2
2011    3       1       1       3607.1  0.03    1       1       1       0       0.2
2012    3       1       1       3621.7  0.03    1       1       1       0       0.2
2013    3       1       1       3991    0.03    1       1       1       0       0.2
2014    3       1       1       4538.6  0.03    1       1       1       0       0.2
2015    3       1       1       4613.7  0.03    1       1       1       0       0.2
2016    3       1       1       3923.9  0.03    1       1       1       0       0.2
2017    3       1       1       3093.7  0.03    1       1       1       0       0.2
2018    3       1       1       2026.5  0.03    1       1       1       0       0.2
2019    3       1       1       1775.3  0.03    1       1       1       0       0.2
2020    3       1       1       1256.98 0.03    1       1       1       0       0.2
##      Total Male      pot     fishery (t)
#year   seas    fleet   sex     obs     cv      type    units   mult    effort  discard_mortality
1990    3       1       1       11621.8         0.04    0       1       1       0       0.2
1991    3       1       1       9792.9  0.04    0       1       1       0       0.2
1992    3       1       1       5916.2  0.04    0       1       1       0       0.2
1993    3       1       1       9516.8  0.04    0       1       1       0       0.2
1994    3       1       1       62.3    0.04    0       1       1       0       0.2
1995    3       1       1       52.8    0.04    0       1       1       0       0.2
1996    3       1       1       3845.2  0.04    0       1       1       0       0.2
1997    3       1       1       3758.8  0.04    0       1       1       0       0.2
1998    3       1       1       15644.8         0.04    0       1       1       0       0.2
1999    3       1       1       12112.3         0.04    0       1       1       0       0.2
2000    3       1       1       6579.7  0.04    0       1       1       0       0.2
2001    3       1       1       5711.5  0.04    0       1       1       0       0.2
2002    3       1       1       6961.4  0.04    0       1       1       0       0.2
2003    3       1       1       12166.5         0.04    0       1       1       0       0.2
2004    3       1       1       10692.0         0.04    0       1       1       0       0.2
2005    3       1       1       13615.9         0.04    0       1       1       0       0.2
2006    3       1       1       9254.0  0.04    0       1       1       0       0.2
2007    3       1       1       13871.9         0.04    0       1       1       0       0.2
2008    3       1       1       14894.9         0.04    0       1       1       0       0.2
2009    3       1       1       12218.8         0.04    0       1       1       0       0.2
2010    3       1       1       10095.4         0.04    0       1       1       0       0.2
2011    3       1       1       5665.3  0.04    0       1       1       0       0.2
2012    3       1       1       4495.5  0.04    0       1       1       0       0.2
2013    3       1       1       5305.9  0.04    0       1       1       0       0.2
2014    3       1       1       8113.8  0.04    0       1       1       0       0.2
2015    3       1       1       6726.8  0.04    0       1       1       0       0.2
```

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2016	3	1	1	5651.8	0.04	0	1	1	0	0.2
2017	3	1	1	4077.2	0.04	0	1	1	0	0.2
2018	3	1	1	3423.2	0.04	0	1	1	0	0.2
2019	3	1	1	3144.6	0.04	0	1	1	0	0.2
2020	3	1	1	2299.7	0.04	0	1	1	0	0.2
##	Female	discards	Pot	fishery
#year seas fleet sex obs	cv	type units	mult effort	discard_mortality
1990	3	1	2	3196.2	0.07	0	1	1	0	0.2
1991	3	1	2	233.9	0.07	0	1	1	0	0.2
1992	3	1	2	1976.3	0.07	0	1	1	0	0.2
1993	3	1	2	3141.5	0.07	0	1	1	0	0.2
1994	3	1	2	1.877	0.07	0	1	1	0	0.2
1995	3	1	2	1.612	0.07	0	1	1	0	0.2
1996	3	1	2	5.1	  0.07	0	1	1	0	0.2
1997	3	1	2	182.7	0.07	0	1	1	0	0.2
1998	3	1	2	2769.3	0.07	0	1	1	0	0.2
1999	3	1	2	28.0	0.07	0	1	1	0	0.2
2000	3	1	2	821.9	0.07	0	1	1	0	0.2
2001	3	1	2	604.0	0.07	0	1	1	0	0.2
2002	3	1	2	45.6	0.07	0	1	1	0	0.2
2003	3	1	2	1784.4	0.07	0	1	1	0	0.2
2004	3	1	2	859.2	0.07	0	1	1	0	0.2
2005	3	1	2	2027.1	0.07	0	1	1	0	0.2
2006	3	1	2	187.4	0.07	0	1	1	0	0.2
2007	3	1	2	799.4	0.07	0	1	1	0	0.2
2008	3	1	2	724.2	0.07	0	1	1	0	0.2
2009	3	1	2	441.3	0.07	0	1	1	0	0.2
2010	3	1	2	592.6	0.07	0	1	1	0	0.2
2011	3	1	2	124.8	0.07	0	1	1	0	0.2
2012	3	1	2	55.9	0.07	0	1	1	0	0.2
2013	3	1	2	490.7	0.07	0	1	1	0	0.2
2014	3	1	2	424.3	0.07	0	1	1	0	0.2
2015	3	1	2	1195.6	0.07	0	1	1	0	0.2
2016	3	1	2	617.2	0.07	0	1	1	0	0.2
2017	3	1	2	266.9	0.07	0	1	1	0	0.2
2018	3	1	2	750.4	0.07	0	1	1	0	0.2
2019	3	1	2	218.0	0.07	0	1	1	0	0.2
2020	3	1	2	76.1	0.07	0	1	1	0	0.2
##	Trawl	fishery	discards (t, without applying to handling mortality rate)
#year	seas	fleet	sex	obs	cv	type	units	mult	effort	discard_mortality
1976	5	2	0	853.494		  0.10	2	1	1	0	0.8
1977	5	2	0	1562.313	0.10	2	1	1	0	0.8
1978	5	2	0	1650.775	0.10	2	1	1	0	0.8
1979	5	2	0	1664.925	0.10	2	1	1	0	0.8
```

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1980    5       2       0       1295.625        0.10    2       1       1       0       0.8
1981    5       2       0       274.229            0.10 2       1       1       0       0.8
1982    5       2       0       718.610            0.10 2       1       1       0       0.8
1983    5       2       0       525.554            0.10 2       1       1       0       0.8
1984    5       2       0       1367.550        0.10    2       1       1       0       0.8
1985    5       2       0       487.576            0.10 2       1       1       0       0.8
1986    5       2       0       250.758            0.10 2       1       1       0       0.8
1987    5       2       0       233.045            0.10 2       1       1       0       0.8
1988    5       2       0       747.996            0.10 2       1       1       0       0.8
1989    5       2       0       219.023            0.10 2       1       1       0       0.8
1990    5       2       0       324.883            0.10 2       1       1       0       0.8
1991    5       2       0       436.783            0.10 2       1       1       0       0.8
1992    5       2       0       366.816            0.10 2       1       1       0       0.8
1993    5       2       0       501.770            0.10 2       1       1       0       0.8
1994    5       2       0       109.129            0.10 2       1       1       0       0.8
1995    5       2       0       102.623            0.10 2       1       1       0       0.8
1996    5       2       0       113.495            0.10 2       1       1       0       0.8
1997    5       2       0       71.862     0.10 2       1       1       0       0.8
1998    5       2       0       232.580            0.10 2       1       1       0       0.8
1999    5       2       0       188.101            0.10 2       1       1       0       0.8
2000    5       2       0       102.161            0.10 2       1       1       0       0.8
2001    5       2       0       241.011            0.10 2       1       1       0       0.8
2002    5       2       0       189.018            0.10 2       1       1       0       0.8
2003    5       2       0       171.114            0.10 2       1       1       0       0.8
2004    5       2       0       216.889            0.10 2       1       1       0       0.8
2005    5       2       0       155.924            0.10 2       1       1       0       0.8
2006    5       2       0       189.660            0.10 2       1       1       0       0.8
2007    5       2       0       192.571            0.10 2       1       1       0       0.8
2008    5       2       0       170.561            0.10 2       1       1       0       0.8
2009    5       2       0       118.672            0.10 2       1       1       0       0.8
2010    5       2       0       104.005            0.10 2       1       1       0       0.8
2011    5       2       0       70.286     0.10 2       1       1       0       0.8
2012    5       2       0       42.641     0.10 2       1       1       0       0.8
2013    5       2       0       83.613     0.10 2       1       1       0       0.8
2014    5       2       0       43.129     0.10 2       1       1       0       0.8
2015    5       2       0       56.410     0.10 2       1       1       0       0.8
2016    5       2       0       84.127     0.10 2       1       1       0       0.8
2017    5       2       0       114.624            0.10 2       1       1       0       0.8
2018    5       2       0       97.561     0.10 2       1       1       0       0.8
2019    5       2       0       100.915     0.10       2       1       1       0       0.8
2020    5       2       0       100.842     0.10       2       1       1       0       0.8
# Tanner crab fishery discards males
#year   seas    fleet   sex     obs     cv      type    units   mult    potlifts discard_mortality
1975    5       3       1       0       0.07    2       1       1       106.445         0.25
```

```
1976    5       3       1       0       0.07    2       1       1       233.667         0.25
1977    5       3       1       0       0.07    2       1       1       408.437         0.25
1978    5       3       1       0       0.07    2       1       1       356.594         0.25
1979    5       3       1       0       0.07    2       1       1       476.410         0.25
1980    5       3       1       0       0.07    2       1       1       496.751         0.25
1981    5       3       1       0       0.07    2       1       1       322.634         0.25
1982    5       3       1       0       0.07    2       1       1       192.538         0.25
1983    5       3       1       0       0.07    2       1       1       44.546          0.25
1984    5       3       1       0       0.07    2       1       1       67.037          0.25
#1985   5       3       1       0       0.07    2       1       1       0.0001          0.25
#1986   5       3       1       0       0.07    2       1       1       0.0001          0.25
1987    5       3       1       0       0.07    2       1       1       39.827          0.25
1988    5       3       1       0       0.07    2       1       1       92.551          0.25
1989    5       3       1       0       0.07    2       1       1       306.175         0.25
1990    5       3       1       0.000   0.07    2       1       1       493.82  0.25
1991    5       3       1       1890.540 0.07   2       1       1       360.864         0.25
1992    5       3       1       263.854 0.07    2       1       1       508.922         0.25
1993    5       3       1       118.614 0.07    2       1       1       286.62  0.25
1994    5       3       1       38.907  0.07    2       1       1       228.254         0.25
#1995   5       3       1       0.000   0.07    2       1       1       201.988         0.25
#1996   5       3       1       0.000   0.07    2       1       1       64.989  0.25
#1997   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#1998   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#1999   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2000   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2001   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2002   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2003   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2004   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2005   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
2006    5       3       1       14.334  0.07    2       1       1       15.273  0.25
2007    5       3       1       5.536   0.07    2       1       1       26.441  0.25
2008    5       3       1       9.245   0.07    2       1       1       19.401  0.25
2009    5       3       1       3.089   0.07    2       1       1       6.635   0.25
#2010   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2011   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2012   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
2013    5       3       1       37.426  0.07    2       1       1       16.633  0.25
2014    5       3       1       68.588  0.07    2       1       1       72.768  0.25
2015    5       3       1       189.229 0.07    2       1       1       130.302         0.25
#2016   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2017   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2018   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
#2019   5       3       1       0.000   0.07    2       1       1       1e-4    0.25
```

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#2020   5       3       1       0.000   0.07    2       1       1       1e-4    0.25

#       Tanner crab     fishery discards        females
#year   seas    fleet   sex     obs     cv      type    units   mult    potlifts discard_mortality
1975    5       3       2       0       0.07    2       1       1       106.445         0.25
1976    5       3       2       0       0.07    2       1       1       233.667         0.25
1977    5       3       2       0       0.07    2       1       1       408.437         0.25
1978    5       3       2       0       0.07    2       1       1       356.594         0.25
1979    5       3       2       0       0.07    2       1       1       476.410         0.25
1980    5       3       2       0       0.07    2       1       1       496.751         0.25
1981    5       3       2       0       0.07    2       1       1       322.634         0.25
1982    5       3       2       0       0.07    2       1       1       192.538         0.25
1983    5       3       2       0       0.07    2       1       1       44.546 0.25
1984    5       3       2       0       0.07    2       1       1       67.037 0.25
#1985   5       3       2       0       0.07    2       1       1       0.0001 0.25
#1986   5       3       2       0       0.07    2       1       1       0.0001 0.25
1987    5       3       2       0       0.07    2       1       1       39.827 0.25
1988    5       3       2       0       0.07    2       1       1       92.551 0.25
1989    5       3       2       0       0.07    2       1       1       306.175         0.25
1990    5       3       2       0.000   0.07    2       1       1       493.82 0.25
1991    5       3       2       3690.303 0.07 2         1       1       360.864         0.25
1992    5       3       2       698.992         0.07    2       1       1       508.922         0.25
1993    5       3       2       99.498 0.07     2       1       1       286.62 0.25
1994    5       3       2       0.488   0.07    2       1       1       228.254         0.25
#1995   5       3       2       0.000   0.07    2       1       1       201.988         0.25
#1996   5       3       2       0.000   0.07    2       1       1       64.989 0.25
#1997   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#1998   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#1999   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2000   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2001   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2002   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2003   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2004   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2005   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
2006    5       3       2       0.883   0.07    2       1       1       15.273 0.25
2007    5       3       2       1.606   0.07    2       1       1       26.441 0.25
2008    5       3       2       6.825   0.07    2       1       1       19.401 0.25
2009    5       3       2       3.410   0.07    2       1       1       6.635   0.25
#2010   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2011   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
#2012   5       3       2       0.000   0.07    2       1       1       1e-4    0.25
2013    5       3       2       75.637 0.07     2       1       1       16.633 0.25
2014    5       3       2       68.907 0.07     2       1       1       72.768 0.25
```

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2015   5   3   2   449.020      0.07   2   1   1   130.302      0.25
#2016  5   3   2   0.000   0.07   2   1   1   1e-4   0.25
#2017  5   3   2   0.000   0.07   2   1   1   1e-4   0.25
#2018  5   3   2   0.000   0.07   2   1   1   1e-4   0.25
#2019  5   3   2   0.000   0.07   2   1   1   1e-4   0.25
#2020  5   3   2   0.000   0.07   2   1   1   1e-4   0.25

##     Fixed gear   crab   fishery discards   (t, without applying to handling mortality
       rate)
1996   5   4   0   82.859 0.10   2   1   1   0   0.5
1997   5   4   0   44.979 0.10   2   1   1   0   0.5
1998   5   4   0   36.916 0.10   2   1   1   0   0.5
1999   5   4   0   100.242      0.10   2   1   1   0   0.5
2000   5   4   0   9.446   0.10   2   1   1   0   0.5
2001   5   4   0   70.553 0.10   2   1   1   0   0.5
2002   5   4   0   58.382 0.10   2   1   1   0   0.5
2003   5   4   0   25.351 0.10   2   1   1   0   0.5
2004   5   4   0   30.422 0.10   2   1   1   0   0.5
2005   5   4   0   39.802 0.10   2   1   1   0   0.5
2006   5   4   0   39.134 0.10   2   1   1   0   0.5
2007   5   4   0   64.655 0.10   2   1   1   0   0.5
2008   5   4   0   31.158 0.10   2   1   1   0   0.5
2009   5   4   0   11.614 0.10   2   1   1   0   0.5
2010   5   4   0   4.944   0.10   2   1   1   0   0.5
2011   5   4   0   21.726 0.10   2   1   1   0   0.5
2012   5   4   0   36.897 0.10   2   1   1   0   0.5
2013   5   4   0   110.208      0.10   2   1   1   0   0.5
2014   5   4   0   237.374      0.10   2   1   1   0   0.5
2015   5   4   0   154.775      0.10   2   1   1   0   0.5
2016   5   4   0   59.418 0.10   2   1   1   0   0.5
2017   5   4   0   260.011      0.10   2   1   1   0   0.5
2018   5   4   0   309.415      0.10   2   1   1   0   0.5
2019   5   4   0   90.291 0.10   2   1   1   0   0.5
2020   5   4   0   75.130 0.10   2   1   1   0   0.5
##     ————————————————————————————————————————————————————     ##
##     RELATIVE   ABUNDANCE   DATA
##     Units   of   Abundance:   1   =   biomass,   2   =   numbers
##     TODO:add   column for   maturity   for   terminal   molt   life-histories
##     for   BBRKC   Units   are   in   1000   mt.
##     ————————————————————————————————————————————————————     ##
##     Number   of   relative abundance   indicies
2
# Data type (1=total selectivity; 2=retention*selectivity)
 1 1
```

```
##      Number          of      rows    in      each    index
104
#       Survey data     (abundance      indices,units   are     1000    mt)
#Index  Year    Season  Fleet   Sex     Abundance       CV      Units
1       1975    1       5       1       0       133084.0        0.193   1  0
1       1976    1       5       1       0       256362.2        0.207   1  0
1       1977    1       5       1       0       232538.7        0.144   1  0
1       1978    1       5       1       0       199542.2        0.152   1  0
1       1979    1       5       1       0       102448.2        0.164   1  0
1       1980    1       5       1       0       166524.3        0.221   1  0
1       1981    1       5       1       0       68294.4         0.190   1  0
1       1982    1       5       1       0       72296.3         0.251   1  0
1       1983    1       5       1       0       34761.9         0.214   1  0
1       1984    1       5       1       0       96418.3         0.606   1  0
1       1985    1       5       1       0       26819.4         0.159   1  0
1       1986    1       5       1       0       40549.3         0.420   1  0
1       1987    1       5       1       0       46769.1         0.209   1  0
1       1988    1       5       1       0       35373.6         0.228   1  0
1       1989    1       5       1       0       42357.7         0.232   1  0
1       1990    1       5       1       0       38727.8         0.242   1  0
1       1991    1       5       1       0       66528.0         0.443   1  0
1       1992    1       5       1       0       25096.2         0.176   1  0
1       1993    1       5       1       0       35670.6         0.198   1  0
1       1994    1       5       1       0       23002.5         0.174   1  0
1       1995    1       5       1       0       27251.9         0.266   1  0
1       1996    1       5       1       0       26815.7         0.203   1  0
1       1997    1       5       1       0       59638.3         0.264   1  0
1       1998    1       5       1       0       46208.6         0.182   1  0
1       1999    1       5       1       0       44528.7         0.204   1  0
1       2000    1       5       1       0       38390.7         0.216   1  0
1       2001    1       5       1       0       27942.7         0.187   1  0
1       2002    1       5       1       0       45139.9         0.202   1  0
1       2003    1       5       1       0       74641.0         0.283   1  0
1       2004    1       5       1       0       90354.3         0.321   1  0
1       2005    1       5       1       0       54789.5         0.171   1  0
1       2006    1       5       1       0       51215.2         0.169   1  0
1       2007    1       5       1       0       58144.3         0.174   1  0
1       2008    1       5       1       0       67214.4         0.249   1  0
1       2009    1       5       1       0       43170.4         0.326   1  0
1       2010    1       5       1       0       39020.6         0.223   1  0
1       2011    1       5       1       0       27385.1         0.213   1  0
1       2012    1       5       1       0       30655.4         0.237   1  0
1       2013    1       5       1       0       39650.2         0.244   1  0
1       2014    1       5       1       0       60649.4         0.191   1  0
```

1	2015	1	5	1	0	37085.3	0.208	1	0
1	2016	1	5	1	0	27184.9	0.194	1	0
1	2017	1	5	1	0	25335.3	0.173	1	0
1	2018	1	5	1	0	16034.2	0.161	1	0
1	2019	1	5	1	0	15169.9	0.157	1	0
1	2021	1	5	1	0	18235.4	0.177	1	0
1	1975	1	5	2	0	66558.7	0.193	1	0
1	1976	1	5	2	0	71252.4	0.207	1	0
1	1977	1	5	2	0	138684.3	0.144	1	0
1	1978	1	5	2	0	143646.6	0.152	1	0
1	1979	1	5	2	0	63000.5	0.164	1	0
1	1980	1	5	2	0	80701.3	0.221	1	0
1	1981	1	5	2	0	62850.4	0.190	1	0
1	1982	1	5	2	0	69601.4	0.251	1	0
1	1983	1	5	2	0	13713.6	0.214	1	0
1	1984	1	5	2	0	56188.5	0.606	1	0
1	1985	1	5	2	0	7318.7	0.159	1	0
1	1986	1	5	2	0	6884.6	0.420	1	0
1	1987	1	5	2	0	22475.5	0.209	1	0
1	1988	1	5	2	0	19223.7	0.228	1	0
1	1989	1	5	2	0	12778.0	0.232	1	0
1	1990	1	5	2	0	20722.8	0.242	1	0
1	1991	1	5	2	0	17363.5	0.443	1	0
1	1992	1	5	2	0	12238.2	0.176	1	0
1	1993	1	5	2	0	17235.1	0.198	1	0
1	1994	1	5	2	0	9101.7	0.174	1	0
1	1995	1	5	2	0	10816.3	0.266	1	0
1	1996	1	5	2	0	17143.2	0.203	1	0
1	1997	1	5	2	0	24392.1	0.264	1	0
1	1998	1	5	2	0	37892.7	0.182	1	0
1	1999	1	5	2	0	20225.3	0.204	1	0
1	2000	1	5	2	0	28990.5	0.216	1	0
1	2001	1	5	2	0	24512.6	0.187	1	0
1	2002	1	5	2	0	23946.5	0.202	1	0
1	2003	1	5	2	0	41118.5	0.283	1	0
1	2004	1	5	2	0	40201.7	0.321	1	0
1	2005	1	5	2	0	50937.4	0.171	1	0
1	2006	1	5	2	0	43262.1	0.169	1	0
1	2007	1	5	2	0	45183.0	0.174	1	0
1	2008	1	5	2	0	45867.2	0.249	1	0
1	2009	1	5	2	0	47376.6	0.326	1	0
1	2010	1	5	2	0	41480.2	0.223	1	0
1	2011	1	5	2	0	39023.0	0.213	1	0
1	2012	1	5	2	0	30042.0	0.237	1	0

```
1       2013    1       5       2       0       22566.7         0.244   1  0
1       2014    1       5       2       0       52485.7         0.191   1  0
1       2015    1       5       2       0       27089.5         0.208   1  0
1       2016    1       5       2       0       33773.1         0.194   1  0
1       2017    1       5       2       0       27599.3         0.173   1  0
1       2018    1       5       2       0       12770.5         0.161   1  0
1       2019    1       5       2       0       13368.6         0.157   1  0
1       2021    1       5       2       0       10240.7     0.177       1  0
        #       BSFRF
2       2007    1       6       1       0       79542  0.116   1  0
2       2008    1       6       1       0       67569  0.094   1  0
2       2013    1       6       1       0       68384  0.209   1  0
2       2014    1       6       1       0       62327  0.192   1  0
2       2015    1       6       1       0       63709  0.161   1  0
2       2016    1       6       1       0       34417  0.22    1  0
2       2007    1       6       2       0       50811  0.116   1  0
2       2008    1       6       2       0       38472  0.094   1  0
2       2013    1       6       2       0       26633  0.209   1  0
2       2014    1       6       2       0       49414  0.192   1  0
2       2015    1       6       2       0       35244  0.161   1  0
2       2016    1       6       2       0       43399  0.22    1  0

## Number of length frequency matrices
13
## Number of rows in each matrix
43      29      29      44      44      11      11      25      25      46      46      6       6
##      Number          of      bins    in      each    matrix  (columns        of      size    data)
20      20      16      20      16      20      16      20      16      20      16      20      16
##      SIZE COMPOSITION DATA FOR ALL FLEETS
##      ———————————————————————————————————————————————————————————————————————— ##
##      SIZE    COMP LEGEND
##      Sex: 1  = male, 2 = female, 0   = both sexes combined
##      Type of         composition: 1 = retained, 2 = discard, 0 = total composition
##      Maturity        state:  1       =       immature,       2       =       mature, 0       =
                both    states  combined
##      Shell   condition:      1       =       new     shell,  2       =       old     shell,  0
                =       both    shell   types   combined
##      ——————————————————————————————————————————————————————————————————————          ##
#Retained       males
#Year   Season Fleet    Sex     Type    Shell   Maturity        Nsamp DataVec
1975    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0071 0.0741 0.1721 0.2239
                0.2122 0.1464 0.0858 0.0785
1976    3       1       1       1       0       0       150     0       0       0       0       0
```

```
                0       0       0       0       0       0       0       0.0016  0.029   0.1418  0.2316
                0.2199  0.1635  0.1071  0.1055
1977    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0017  0.0192  0.1382  0.2442
                0.2226  0.1605  0.104   0.1096
1978    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0012  0.0209  0.1441  0.2588
                0.2401  0.1673  0.0966  0.0711
1979    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0013  0.0119  0.0747  0.1649
                0.1998  0.2004  0.1556  0.1914
1980    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0008  0.0138  0.0919  0.1771
                0.195   0.1792  0.1404  0.2019
1981    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0006  0.0225  0.1164  0.1743
                0.1711  0.1584  0.1284  0.2283
1982    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0       0.0544  0.2576  0.2802
                0.1667  0.0837  0.0508  0.1067
1984    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0.0003  0.0023  0.0654  0.311   0.3135
                0.1763  0.0846  0.0321  0.0145
1985    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0.0005  0.0044  0.079   0.2869  0.3098
                0.1898  0.086   0.0306  0.0129
1986    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0016  0.0531  0.2613  0.3289
                0.2084  0.0978  0.0352  0.0137
1987    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0013  0.0284  0.1895  0.3045
                0.2522  0.1421  0.0565  0.0255
1988    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0       0.0202  0.1294  0.2646
                0.2471  0.1876  0.1033  0.0477
1989    3       1       1       1       0       0       150     0       0       0       0       0
                0       0       0       0       0       0       0       0.0005  0.0187  0.1211  0.2209
                0.219   0.1908  0.1197  0.1094
1990    3    1    1    1    0    0    150    0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0003  0.0003  0.0143  0.0884  0.1783  0.1699
        0.1737  0.1438  0.2311  #7218
1991    3    1    1    1    0    0    150    0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0001  0.0000  0.0000  0.0001  0.0005  0.0138  0.0830  0.1613  0.1854
        0.1721  0.1431  0.2404  #36928
```

```
1992  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0002 0.0001 0.0001 0.0001 0.0002 0.0002 0.0006 0.0150 0.0699 0.1388 0.1606
      0.1817 0.1592 0.2733 #25550
1993  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0001 0.0001 0.0002 0.0002 0.0009 0.0140 0.0944 0.1790 0.1741
      0.1597 0.1327 0.2447 #32942
1996  3   1   1   1   0   0   150  0.0000 0.0000 0.0001 0.0000 0.0001 0.0000
      0.0000 0.0001 0.0001 0.0002 0.0000 0.0001 0.0006 0.0129 0.0786 0.1419 0.1628
      0.1768 0.1673 0.2584 #8896
1997  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0001 0.0001 0.0001 0.0000 0.0001 0.0003 0.0135 0.0893 0.1489 0.1610
      0.1702 0.1585 0.2579 #16143
1998  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0001
      0.0000 0.0001 0.0001 0.0001 0.0004 0.0002 0.0008 0.0220 0.1171 0.1586 0.1482
      0.1435 0.1405 0.2685 #17116
1999  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0000 0.0000 0.0001 0.0000 0.0002 0.0140 0.1272 0.2531 0.2271
      0.1641 0.0985 0.1158 #18685
2000  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0001 0.0000 0.0001
      0.0000 0.0000 0.0001 0.0001 0.0000 0.0001 0.0003 0.0110 0.0930 0.1940 0.2116
      0.1827 0.1245 0.1824 #14143
2001  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0001 0.0001 0.0001 0.0001 0.0002 0.0002 0.0012 0.0175 0.0820 0.1677 0.1979
      0.1940 0.1509 0.1880 #13735
2002  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0001 0.0000 0.0001 0.0001 0.0001 0.0000 0.0002 0.0146 0.1056 0.1865 0.1888
      0.1683 0.1352 0.2006 #16837
2003  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0001 0.0002
      0.0001 0.0001 0.0000 0.0001 0.0001 0.0002 0.0008 0.0222 0.1381 0.2251 0.1889
      0.1527 0.1049 0.1666 #18178
2004  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0003 0.0061 0.0503 0.1285 0.1698
      0.1959 0.1655 0.2834 #22465
2005  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0001
      0.0000 0.0000 0.0000 0.0000 0.0001 0.0001 0.0008 0.0150 0.0858 0.1543 0.1661
      0.1785 0.1517 0.2474 #27971
2006  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0000 0.0000 0.0001 0.0001 0.0004 0.0101 0.0731 0.1893 0.2204
      0.1893 0.1378 0.1794 #18451
2007  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0000 0.0000 0.0000 0.0002 0.0003 0.0066 0.0867 0.1830 0.1936
      0.1846 0.1477 0.1974 #22809
2008  3   1   1   1   0   0   150  0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
      0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0001 0.0081 0.0695 0.1466 0.1665
```

```
        0.1771  0.1599  0.2720  #24997
2009    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0001  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0002  0.0109  0.1150  0.2216  0.1965
        0.1591  0.1084  0.1884  #19336
2010    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0003  0.0090  0.0991  0.2245  0.2235
        0.1858  0.1147  0.1430  #20347
2011    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0001
        0.0000  0.0000  0.0000  0.0000  0.0003  0.0001  0.0003  0.0113  0.1178  0.2429  0.2291
        0.1730  0.1085  0.1167  #10904
2012    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0001  0.0000  0.0001  0.0000  0.0000  0.0043  0.0493  0.1245  0.1721
        0.1877  0.1652  0.2967  #9084
2013    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0001  0.0001  0.0000  0.0000  0.0001  0.0001  0.0054  0.0524  0.1272  0.1483
        0.1663  0.1632  0.3368  #10396
2014    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0004  0.0116  0.0966  0.1824  0.1703
        0.1453  0.1244  0.2689  #9718
2015    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0001  0.0003  0.0066  0.0613  0.1472  0.1859
        0.1960  0.1635  0.2392  #11971
2016    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0002  0.0063  0.0495  0.1276  0.1660
        0.1820  0.1690  0.2994  #11003
2017    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0001  0.0001  0.0000  0.0000  0.0000  0.0044  0.0450  0.1056  0.1452
        0.1782  0.1661  0.3553  #10067
2018    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0001  0.0000  0.0000  0.0000  0.0001  0.0000  0.0001  0.0056  0.0604  0.1373  0.1403
        0.1385  0.1238  0.3936  #7825
2019    3   1   1   1   0   0   150   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0004  0.0085  0.0675  0.1356  0.1343
        0.1282  0.1143  0.4112  #8134
2020    3   1   1   1   0   0   150   0   0   0   0   0   0   0   0   0   0
        0   0   0   0.0078  0.0948  0.2247  0.2325  0.1855  0.1174  0.1374  #3850

#Total  males
#Year   Season Fleet   Sex   Type   Shell   Maturity   Nsamp DataVec
1990    3   1   1   0   0   0   127.2  0   0   0.0004  0.0028  0.0016  0.0043  0.0024
        0.013   0.0173  0.0263  0.0421  0.0523  0.0641  0.0943  0.1018  0.1108  0.1156  0.0924
        0.0971  0.1616  #2544
1991    3   1   1   0   0   0   150   0.0009  0.0038  0.0075  0.0081  0.0092  0.0149
        0.0124  0.0241  0.0236  0.0262  0.0243  0.0428  0.0605  0.0884  0.1014  0.1069  0.1152
```

```
        0.1161  0.085   0.129   #4696
1992    3   1   1   0   0   0   150   0   0.0006  0.0008  0.0075  0.0151  0.0375
        0.0591  0.0777  0.0806  0.0838  0.0806  0.0852  0.0756  0.0603  0.0477  0.0503  0.0538
        0.0578  0.0448  0.081   #4775
1993    3   1   1   0   0   0   150   0.0009  0.0025  0.0032  0.0028  0.0035  0.007
        0.0177  0.0325  0.0445  0.0615  0.0761  0.088   0.087   0.1039  0.0946  0.0902  0.0723
        0.0683  0.0512  0.0922  #10200
1996    3   1   1   0   0   0   32.1   0   0   0   0.0047  0.0187  0.0296  0.0265
        0.0109  0.0171  0.0249  0.0218  0.0358  0.053   0.0872  0.0981  0.0888  0.1277  0.1246
        0.0903  0.1402  #642
1997    3   1   1   0   0   0   150   0   0.0001  0.0002  0.0003  0.0006  0.0081
        0.0227  0.0446  0.0519  0.0534  0.0422  0.041   0.0522  0.0701  0.0832  0.0938  0.0967
        0.1035  0.0886  0.1467  #10016
1998    3   1   1   0   0   0   150   0.0001  0.0002  0.0004  0.0021  0.0037  0.0054
        0.0056  0.0104  0.0246  0.0588  0.0946  0.1362  0.1335  0.1177  0.0861  0.0628  0.0524
        0.0552  0.0498  0.1004  #24537
1999    3   1   1   0   0   0   150   0   0   0   0.0013  0.0013  0.0006  0.0017
        0.0013  0.0025  0.0059  0.0138  0.0264  0.0537  0.0923  0.1302  0.1445  0.1518  0.13
        0.091   0.1518  #6892
2000    3   1   1   0   0   0   150   0.0002  0.002   0.0071  0.0185  0.0234  0.0242
        0.0256  0.0262  0.0254  0.0291  0.0349  0.0507  0.0718  0.0843  0.1002  0.1083  0.1113
        0.0943  0.0638  0.0988  #32709
2001    3   1   1   0   0   0   150   0.0004  0.0023  0.0037  0.005   0.0066  0.0139
        0.0249  0.0381  0.0447  0.0539  0.0605  0.0696  0.0659  0.0647  0.0652  0.0843  0.0982
        0.1023  0.0824  0.1133  #25135
2002    3   1   1   0   0   0   150   0.0017  0.0046  0.0044  0.0051  0.0043  0.0054
        0.0066  0.0151  0.0272  0.0504  0.0684  0.0822  0.083   0.0901  0.0939  0.0985  0.0913
        0.0881  0.0689  0.1108  #32317
2003    3   1   1   0   0   0   150   0.0034  0.0053  0.0065  0.0144  0.0257  0.0323
        0.0355  0.0335  0.0315  0.0322  0.036   0.0526  0.0756  0.1021  0.1115  0.108   0.0867
        0.0715  0.0494  0.0863  #44600
2004    3   1   1   0   0   0   150   0.0001  0.0019  0.0061  0.016   0.021   0.0231
        0.0316  0.0519  0.0613  0.0616  0.0486  0.0411  0.035   0.0389  0.0474  0.0731  0.0927
        0.1087  0.0917  0.1482  #38772
2005    3   1   1   0   0   0   150   0.0001  0.0005  0.0008  0.0017  0.0044  0.0128
        0.0199  0.0243  0.0264  0.0383  0.0556  0.0801  0.0806  0.0849  0.0723  0.0769  0.0794
        0.0949  0.0818  0.1643  #94622
2006    3   1   1   0   0   0   150   0.0001  0.0006  0.0019  0.0065  0.014   0.0171
        0.0166  0.0154  0.02    0.0333  0.0412  0.0506  0.0611  0.0815  0.098   0.1153  0.1191
        0.113   0.0806  0.1138  #73315
2007    3   1   1   0   0   0   150   0.0006  0.0021  0.0034  0.0051  0.0089  0.0191
        0.034   0.044   0.0477  0.044   0.0422  0.0512  0.0676  0.0898  0.0952  0.0974  0.0929
        0.0907  0.0692  0.0948  #115507
2008    3   1   1   0   0   0   150   0.0001  0.0002  0.0007  0.0026  0.0059  0.0078
```

```
          0.0088  0.0118  0.0243  0.0445  0.0698  0.0986  0.1096  0.1039  0.0869  0.0768  0.0765
          0.0771  0.0703  0.1242  #89771
2009      3      1      1      0      0      0      150     0.0002  0.0005  0.0009  0.0016  0.0021  0.0038
          0.0093  0.0213  0.033   0.0371  0.0428  0.0638  0.0978  0.1348  0.1355  0.1172  0.0895
          0.0658  0.0499  0.0931  #97868
2010      3      1      1      0      0      0      150     0.0004  0.0006  0.0013  0.0028  0.0044  0.0061
          0.0077  0.0113  0.0179  0.0286  0.0504  0.0806  0.1071  0.1302  0.1264  0.121   0.1031
          0.0821  0.0512  0.067   #69276
2011      3      1      1      0      0      0      150     0.0008  0.0031  0.0055  0.0097  0.01    0.0089
          0.0129  0.0147  0.0193  0.0265  0.0358  0.0565  0.0822  0.111   0.132   0.1355  0.1212
          0.0927  0.0583  0.0635  #42931
2012      3      1      1      0      0      0      150     0.0002  0.0003  0.0008  0.0014  0.0037  0.0088
          0.0141  0.0189  0.018   0.0192  0.0236  0.036   0.0519  0.0748  0.0859  0.0992  0.1117
          0.1276  0.1124  0.1915  #21404
2013      3      1      1      0      0      0      150     0.0001  0.0007  0.0017  0.0022  0.0047  0.0058
          0.0096  0.015   0.0257  0.0378  0.0545  0.0607  0.0672  0.0741  0.076   0.0828  0.0844
          0.1035  0.0983  0.1952  #32332
2014      3      1      1      0      0      0      150     0.0003  0.0006  0.0008  0.0012  0.0017  0.0038
          0.0063  0.0111  0.0155  0.0206  0.0344  0.0473  0.0701  0.0901  0.105   0.1081  0.105
          0.0974  0.0847  0.1961  #31216
2015      3      1      1      0      0      0      150     0.0001  0.0002  0.0008  0.0017  0.0038  0.0059
          0.0063  0.007   0.012   0.0271  0.0336  0.049   0.0541  0.0673  0.0799  0.1071  0.1171
          0.1372  0.1058  0.184   #24533
2016      3      1      1      0      0      0      150     0.0001  0.0002  0.0015  0.0034  0.0046  0.0064
          0.0111  0.0188  0.0225  0.0279  0.0294  0.0399  0.0508  0.0675  0.0813  0.0938  0.1068
          0.1214  0.1119  0.2006  #30030
2017      3      1      1      0      0      0      150     0.0002  0.0006  0.0031  0.0115  0.0241  0.0341
          0.0294  0.0235  0.0197  0.0248  0.0291  0.0456  0.0497  0.0644  0.0674  0.0825  0.0997
          0.1049  0.0978  0.1879  #30002
2018      3      1      1      0      0      0      150     0.0004  0.0027  0.0072  0.0082  0.0067  0.011
          0.0232  0.0432  0.0643  0.0723  0.0676  0.057   0.0557  0.0563  0.0621  0.0649  0.0622
          0.0647  0.0674  0.2028  #25635
2019      3      1      1      0      0      0      150     0       0.0001  0.0002  0.0019  0.0084  0.017   0.0218
          0.0194  0.0196  0.0356  0.056   0.0866  0.094   0.0978  0.0907  0.0755  0.0641  0.0617
          0.0527  0.1971  #25999
2020      3      1      1      0      0      0      150     0       0.0007  0.0034  0.0075  0.0101  0.0142
          0.0177  0.03    0.0426  0.0589  0.0607  0.0573  0.0633  0.0859  0.1139  0.1189  0.1129
          0.087   0.0491  0.0661  #16650

#Total    females
#Year     Season Fleet  Sex    Type   Shell  Maturity       Nsamp  DataVec
1990      3      1      2      0      0      0      34.95   0       0.0014  0.0029  0.0029  0.0057  0.0072
          0.0143  0.0672  0.1016  0.1731  0.1688  0.2132  0.1359  0.0715  0.0243  0.01    #699
1991      3      1      2      0      0      0      18.75   0.0027  0.024   0.0613  0.096   0.1333  0.16
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        0.1227  0.072   0.0693  0.056   0.0693  0.08    0.0347  0.0107  0.0053  0.0027  #375
1992    3       1       2       0       0       0       50      0       0.0013  0.0029  0.0177  0.0803  0.1765  0.195
        0.1698  0.0958  0.0815  0.0572  0.0404  0.0395  0.0256  0.0118  0.0046  #2379
1993    3       1       2       0       0       0       50      0.0013  0.0024  0.0044  0.0059  0.013   0.0326
        0.1011  0.1598  0.1443  0.1139  0.0905  0.0853  0.0834  0.074   0.0434  0.0446  #5944
1996    3       1       2       0       0       0       0.55    0       0       0       0.0909  0.6364  0.2727  0       0
        0       0       0       0       0       0       0       0       #11
1997    3       1       2       0       0       0       45.3    0       0       0.0011  0.0011  0.0099  0.0265  0.0364
        0.0464  0.0695  0.1391  0.1667  0.1435  0.117   0.1082  0.0607  0.074   #906
1998    3       1       2       0       0       0       50      0.0002  0.0004  0.0009  0.0026  0.0066  0.0174
        0.055   0.1755  0.2268  0.1521  0.0863  0.0883  0.059   0.0532  0.0352  0.0403  #9655
1999    3       1       2       0       0       0       2       0       0       0       0.025   0.025   0.025   0.05    0.025
        0       0.125   0.125   0.075   0.1     0.125   0.075   0.225   #40
2000    3       1       2       0       0       0       50      0       0.0044  0.0256  0.0607  0.0744  0.0816  0.0701
        0.0543  0.055   0.0998  0.1541  0.146   0.0799  0.042   0.0224  0.0296  #8470
2001    3       1       2       0       0       0       50      0.0007  0.0042  0.0129  0.0307  0.0568  0.0844
        0.0986  0.0909  0.0646  0.0568  0.0883  0.1407  0.14    0.0638  0.0269  0.0396  #5436
2002    3       1       2       0       0       0       35.3    0.0595  0.1714  0.1601  0.1388  0.1091  0.0581
        0.0297  0.0326  0.0382  0.0326  0.0241  0.0241  0.0198  0.0269  0.0283  0.0467  #706
2003    3       1       2       0       0       0       50      0.012   0.0164  0.0231  0.0635  0.102   0.1075
        0.0682  0.043   0.06    0.0866  0.0984  0.0675  0.054   0.0596  0.0572  0.0811  #12474
2004    3       1       2       0       0       0       50      0.0003  0.0056  0.0258  0.0575  0.0774  0.0918
        0.1413  0.1308  0.0876  0.0449  0.0503  0.0611  0.0531  0.0446  0.0431  0.0851  #6666
2005    3       1       2       0       0       0       50      0.0004  0.0013  0.0022  0.005   0.0146  0.05
        0.0788  0.0931  0.1233  0.1212  0.0871  0.1021  0.0958  0.0885  0.0519  0.0848  #26782
2006    3       1       2       0       0       0       50      0.0003  0.004   0.0256  0.1183  0.1939  0.1616
        0.0692  0.0519  0.0672  0.0704  0.0576  0.0403  0.0358  0.0323  0.0256  0.0461  #3991
2007    3       1       2       0       0       0       50      0.0029  0.0124  0.0214  0.0235  0.0461  0.0886
        0.1116  0.0832  0.0556  0.0739  0.1005  0.1146  0.0942  0.0671  0.0437  0.0604  #12691
2008    3       1       2       0       0       0       50      0.0004  0.0018  0.0097  0.0362  0.0775  0.0662
        0.0472  0.0772  0.1071  0.0871  0.0954  0.126   0.1254  0.067   0.0391  0.0368  #8564
2009    3       1       2       0       0       0       50      0.0036  0.0083  0.0099  0.0144  0.0164  0.0282
        0.0652  0.0867  0.0803  0.0912  0.0857  0.09    0.1141  0.1308  0.0875  0.0877  #6055
2010    3       1       2       0       0       0       50      0.0036  0.0051  0.0052  0.0199  0.0276  0.0292
        0.0269  0.0444  0.0882  0.1135  0.1315  0.1423  0.1011  0.0917  0.0879  0.0816  #6872
2011    3       1       2       0       0       0       50      0.013   0.037   0.0604  0.101   0.076   0.0698  0.0583
        0.0411  0.0266  0.0359  0.0693  0.0911  0.0823  0.0667  0.0672  0.1042  #1920
2012    3       1       2       0       0       0       28.15   0.0089  0.0107  0.0124  0.0337  0.0604  0.1155
        0.0941  0.0391  0.0178  0.0124  0.0409  0.0426  0.1652  0.151   0.1101  0.0853  #563
2013    3       1       2       0       0       0       50      0.0005  0.0017  0.0083  0.0107  0.0188  0.0365
        0.0714  0.1329  0.1423  0.0972  0.0717  0.0636  0.0854  0.0906  0.0732  0.0952  #6051
2014    3       1       2       0       0       0       50      0.0011  0.0053  0.0068  0.0086  0.0086  0.021
        0.0282  0.0274  0.0526  0.0713  0.0755  0.0762  0.0965  0.1142  0.1303  0.2764  #2663
2015    3       1       2       0       0       0       50      0       0.0011  0.0019  0.0052  0.0122  0.0166  0.0196
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        0.0357  0.0559  0.0869  0.0886  0.1401  0.1121  0.1031  0.0834  0.2375  #7457
2016    3    1    2    0    0    0    50    0    0.0003  0.0072  0.0122  0.0183  0.0189  0.0213
        0.0346  0.0388  0.0636  0.0998  0.1519  0.1718  0.1331  0.0701  0.1581  #5832
2017    3    1    2    0    0    0    50    0.0007  0.0032  0.0148  0.0544  0.0992  0.1096
        0.0769  0.0317  0.0354  0.0477  0.07    0.093   0.0979  0.0982  0.0665  0.1007  #4043
2018    3    1    2    0    0    0    50    0.0005  0.0054  0.0182  0.0241  0.0237  0.0371
        0.0627  0.0942  0.0774  0.0647  0.065   0.1019  0.1139  0.1069  0.0824  0.1217  #9840
2019    3    1    2    0    0    0    50    0    0    0.0017  0.0059  0.0287  0.0491  0.038
        0.0342  0.0549  0.0757  0.0691  0.0757  0.1047  0.1275  0.1137  0.2211  #2894
2020    3    1    2    0    0    0    48.05    0    0.0114  0.0375  0.0978  0.0874  0.0499
        0.0385  0.0708  0.0572  0.0583  0.0562  0.0593  0.0593  0.0656  0.0666  0.1842  #961

#Trawl  bycatch         male
#Year   Season  Fleet   Sex     Type    Shell   Maturity        Nsamp   DataVec
1976    5       2       1       0.0     0       0       50      0.0000 0.0000 0.0000 0.0000 0.0000
                0.0130 0.0087 0.0043 0.0216 0.0087 0.0260 0.0390 0.0433 0.0649 0.0996 0.0866
                0.0736 0.0909 0.0649 0.1299
1977    5       2       1       0.0     0       0       50      0.0036 0.0009 0.0009 0.0009 0.0026
                0.0035 0.0079 0.0097 0.0317 0.0485 0.0599 0.0996 0.1084 0.1251 0.1040 0.1057
                0.1004 0.0634 0.0326 0.0441
1978    5       2       1       0.0     0       0       50      0.0000 0.0000 0.0000 0.0000 0.0000
                0.0000 0.0000 0.0025 0.0012 0.0025 0.0149 0.0274 0.0511 0.0872 0.1245 0.1158
                0.0797 0.0984 0.0672 0.1880
1979    5       2       1       0.0     0       0       50      0.0178 0.0013 0.0025 0.0013 0.0025
                0.0076 0.0038 0.0025 0.0013 0.0063 0.0051 0.0114 0.0228 0.0556 0.0582 0.0708
                0.0898 0.0860 0.0809 0.1858
1980    5       2       1       0.0     0       0       50      0.0531 0.0207 0.0096 0.0135 0.0142
                0.0163 0.0274 0.0263 0.0380 0.0375 0.0422 0.0394 0.0368 0.0377 0.0313 0.0231
                0.0207 0.0142 0.0131 0.0265
1981    5       2       1       0.0     0       0       50      0.0262 0.0028 0.0045 0.0066 0.0112
                0.0175 0.0279 0.0349 0.0386 0.0504 0.0434 0.0480 0.0287 0.0334 0.0241 0.0212
                0.0112 0.0064 0.0051 0.0087
1982    5       2       1       0.0     0       0       50      0.0701 0.0268 0.0247 0.0326 0.0356
                0.0443 0.0409 0.0403 0.0401 0.0475 0.0426 0.0479 0.0405 0.0326 0.0218 0.0153
                0.0084 0.0052 0.0038 0.0099
1983    5       2       1       0.0     0       0       50      0.0231 0.0214 0.0336 0.0344 0.0311
                0.0319 0.0377 0.0445 0.0473 0.0471 0.0457 0.0437 0.0409 0.0414 0.0371 0.0283
                0.0204 0.0129 0.0096 0.0180
1984    5       2       1       0.0     0       0       50      0.0366 0.0156 0.0147 0.0199 0.0270
                0.0342 0.0399 0.0407 0.0431 0.0476 0.0511 0.0596 0.0594 0.0563 0.0473 0.0355
                0.0264 0.0170 0.0109 0.0146
1985    5       2       1       0.0     0       0       50      0.0051 0.0014 0.0034 0.0059 0.0100
                0.0164 0.0256 0.0396 0.0357 0.0446 0.0538 0.0636 0.0843 0.0862 0.0883 0.0843
                0.0638 0.0455 0.0299 0.0578
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1986    5    2    1    0.0    0    0    50    0.0038  0.0019  0.0085  0.0019  0.0056
        0.0136  0.0193  0.0357  0.0160  0.0249  0.0221  0.0320  0.0710  0.0555  0.0527  0.0635
        0.0456  0.0362  0.0259  0.0282
1987    5    2    1    0.0    0    0    49.9    0.0020  0.0000  0.0010  0.0020
        0.0050  0.0080  0.0190  0.0271  0.0170  0.0220  0.0441  0.0491  0.0401  0.0581  0.0852
        0.0812  0.0671  0.0611  0.0511  0.0842
1988    5    2    1    0.0    0    0    31.5    0.0048  0.0048  0.0063  0.0016
        0.0032  0.0000  0.0095  0.0175  0.0127  0.0397  0.0524  0.0540  0.0571  0.0635  0.0651
        0.0889  0.0794  0.0587  0.0349  0.0397
1989    5    2    1    0.0    0    0    50    0.0047  0.0024  0.0019  0.0006
        0.0019  0.0019  0.0045  0.0047  0.0097  0.0142  0.0237  0.0379  0.0437  0.0534  0.0711
        0.0810  0.0799  0.0784  0.0679  0.0899
1990    5    2    1    0.0    0    0    45.4    0.0055  0.0044  0.0077  0.0022
        0.0077  0.0077  0.0253  0.0154  0.0253  0.0286  0.0220  0.0308  0.0352  0.0551  0.0914
        0.0881  0.0826  0.0738  0.0407  0.0804
1991    5    2    1    0.0    0    0    13.75    0.0036  0.0073  0.0036  0.0073
        0.0182  0.0145  0.0145  0.0182  0.0364  0.0255  0.0364  0.0327  0.0400  0.0218  0.0291
        0.0691  0.0509  0.0582  0.0655  0.1600
1992    5    2    1    0.0    0    0    16.65    0.0210  0.0210  0.0180  0.0000
        0.0060  0.0060  0.0030  0.0000  0.0060  0.0120  0.0240  0.0210  0.0360  0.0390  0.0390
        0.0450  0.0240  0.0210  0.0030  0.0330
1994    5    2    1    0.0    0    0    28.55    0.0000  0.0000  0.0035  0.0070
        0.0018  0.0000  0.0000  0.0000  0.0000  0.0000  0.0018  0.0018  0.0088  0.0158  0.0210
        0.0473  0.0438  0.0578  0.0841  0.2785
1995    5    2    1    0.0    0    0    6    0.0000  0.0000  0.0000  0.0000
        0.0000  0.0083  0.0000  0.0083  0.0083  0.0167  0.0000  0.0167  0.0167  0.0167  0.0333
        0.0750  0.1417  0.1000  0.0500  0.2833
1996    5    2    1    0.0    0    0    50    0.0000  0.0008  0.0000  0.0017
        0.0050  0.0116  0.0149  0.0174  0.0281  0.0347  0.0480  0.0662  0.0463  0.0695  0.0397
        0.0645  0.0430  0.0571  0.0422  0.1241
1997    5    2    1    0.0    0    0    16.95    0.0000  0.0000  0.0000  0.0000
        0.0029  0.0029  0.0029  0.0088  0.0088  0.0206  0.0206  0.0265  0.0236  0.0177  0.0501
        0.0649  0.0324  0.0383  0.0383  0.1534
1998    5    2    1    0.0    0    0    50    0.0007  0.0007  0.0007  0.0000
        0.0000  0.0000  0.0035  0.0028  0.0056  0.0133  0.0280  0.0315  0.0566  0.0476  0.0580
        0.0420  0.0420  0.0469  0.0406  0.1098
1999    5    2    1    0.0    0    0    31.45    0.0016  0.0016  0.0000  0.0016
        0.0032  0.0000  0.0064  0.0016  0.0079  0.0127  0.0127  0.0413  0.0493  0.0747  0.1065
        0.1017  0.0922  0.0715  0.0668  0.0954
2000    5    2    1    0.0    0    0    36.45    0.0000  0.0000  0.0014  0.0014
        0.0014  0.0069  0.0096  0.0288  0.0370  0.0316  0.0357  0.0302  0.0425  0.0466  0.0343
        0.0425  0.0439  0.0466  0.0521  0.2277
2001    5    2    1    0.0    0    0    39.75    0.0000  0.0000  0.0050  0.0025
        0.0101  0.0340  0.0226  0.0264  0.0403  0.0377  0.0428  0.0352  0.0352  0.0252  0.0352
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       0.0226  0.0478  0.0352  0.0528  0.1031
2002   5       2       1       0.0     0       0       50      0.0009  0.0009  0.0009  0.0009
       0.0018  0.0026  0.0061  0.0044  0.0061  0.0105  0.0219  0.0193  0.0281  0.0369  0.0457
       0.0457  0.0518  0.0571  0.0404  0.1326
2003   5       2       1       0.0     0       0       25.8    0.0019  0.0039  0.0058  0.0078
       0.0194  0.0097  0.0155  0.0233  0.0252  0.0174  0.0136  0.0194  0.0310  0.0349  0.0426
       0.0523  0.0465  0.0484  0.0523  0.1202
2004   5       2       1       0.0     0       0       31.8    0.0016  0.0000  0.0000  0.0016
       0.0016  0.0047  0.0047  0.0157  0.0220  0.0173  0.0220  0.0346  0.0393  0.0346  0.0346
       0.0409  0.0440  0.0409  0.0362  0.1494
2005   5       2       1       0.0     0       0       50      0.0029  0.0038  0.0019  0.0087
       0.0077  0.0135  0.0212  0.0154  0.0125  0.0231  0.0260  0.0394  0.0510  0.0481  0.0423
       0.0413  0.0462  0.0481  0.0404  0.0885
2006   5       2       1       0.0     0       0       50      0.0000  0.0000  0.0000  0.0000
       0.0017  0.0026  0.0026  0.0128  0.0111  0.0394  0.0360  0.0428  0.0488  0.0462  0.0685
       0.0702  0.0693  0.0659  0.0591  0.1404
2007   5       2       1       0.0     0       0       50      0.0000  0.0000  0.0000  0.0016
       0.0024  0.0033  0.0049  0.0114  0.0122  0.0131  0.0237  0.0220  0.0294  0.0384  0.0465
       0.0392  0.0384  0.0424  0.0596  0.1241
2008   5       2       1       0.0     0       0       50      0.0000  0.0000  0.0006  0.0000
       0.0025  0.0025  0.0019  0.0025  0.0132  0.0257  0.0257  0.0595  0.0620  0.0570  0.0721
       0.0464  0.0652  0.0545  0.0539  0.1754
2009   5       2       1       0.0     0       0       50      0.0000  0.0000  0.0000  0.0000
       0.0009  0.0026  0.0026  0.0034  0.0068  0.0103  0.0111  0.0308  0.0308  0.0427  0.0556
       0.0530  0.0684  0.0513  0.0504  0.1726
2010   5       2       1       0.0     0       0       45.05   0.0000  0.0000  0.0022  0.0022
       0.0022  0.0055  0.0033  0.0122  0.0189  0.0178  0.0200  0.0322  0.0499  0.0488  0.0544
       0.0455  0.0366  0.0344  0.0377  0.0866
2011   5       2       1       0.0     0       0       21.95   0.0000  0.0000  0.0023  0.0068
       0.0068  0.0023  0.0023  0.0068  0.0137  0.0091  0.0068  0.0068  0.0228  0.0273  0.0501
       0.0661  0.0615  0.0615  0.0433  0.1185
2012   5       2       1       0.0     0       0       14.05   0.0000  0.0036  0.0000  0.0000
       0.0000  0.0036  0.0071  0.0071  0.0036  0.0071  0.0142  0.0107  0.0285  0.0356  0.0569
       0.0320  0.0498  0.0534  0.0534  0.1708
2013   5       2       1       0.0     0       0       24.05   0.0000  0.0021  0.0000  0.0021
       0.0021  0.0000  0.0000  0.0021  0.0042  0.0083  0.0104  0.0229  0.0457  0.0395  0.0520
       0.0499  0.0437  0.0520  0.0395  0.2599
2014   5       2       1       0.0     0       0       13.05   0.0000  0.0038  0.0000  0.0038
       0.0115  0.0038  0.0000  0.0192  0.0038  0.0115  0.0192  0.0230  0.0268  0.0383  0.0690
       0.0881  0.0421  0.0345  0.0460  0.2069
2015   5       2       1       0.0     0       0       20.45  0.0000  0.0000  0.0073  0.0073  0.0073
       0.0049  0.0122  0.0147  0.0122  0.0147  0.0220  0.0293  0.0318  0.0440  0.0342  0.0391
       0.0513  0.0342  0.0391  0.1002
2016   5       2       1       0.0     0       0       30.85  0.0000  0.0016  0.0032  0.0049  0.0032
```

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        0.0016  0.0130  0.0097  0.0162  0.0065  0.0113  0.0357  0.0243  0.0470  0.0519  0.0583
        0.0632  0.0794  0.0778  0.2107
2017    5       2       1       0.0     0       0       35.9   0.0000  0.0000  0.0000  0.0000  0.0056
        0.0042  0.0056  0.0056  0.0070  0.0056  0.0084  0.0153  0.0265  0.0320  0.0418  0.0529
        0.0891  0.0766  0.1017  0.3231
2018    5       2       1       0.0     0       0       44.65  0.0011  0.0000  0.0022  0.0000  0.0022
        0.0045  0.0112  0.0045  0.0213  0.0202  0.0403  0.0426  0.0437  0.0594  0.0448  0.0336
        0.0448  0.0403  0.0403  0.1601
2019    5       2       1       0.0     0       0       41.15  0.0012  0.0024  0.0049  0.0073  0.0122
        0.0134  0.0049  0.0109  0.0097  0.0267  0.0304  0.0316  0.0401  0.0535  0.0583  0.0450
        0.0510  0.0425  0.0401  0.2151
2020    5       2       1       0.0     0       0 38.2   0.0026  0.0000  0.0039  0.0079  0.0105
        0.0118  0.0118  0.0092  0.0288  0.0249  0.0340  0.0301  0.0314  0.0589  0.0589  0.0641
        0.0550  0.0733  0.0510  0.1571

#Trawl  bycatch         female
#Year   Season  Fleet   Sex     Type    Shell   Maturity        Nsamp   DataVec
1976    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0000 0.0000
                0.0000 0.0130 0.0087 0.0216 0.0260 0.0303 0.0563 0.0130 0.0260 0.0043 0.0260
1977    5       2       2       0       0       0       0       0.0000 0.0009 0.0009 0.0000 0.0000
                0.0009 0.0026 0.0053 0.0070 0.0088 0.0062 0.0053 0.0044 0.0026 0.0009 0.0009
1978    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0000 0.0000
                0.0000 0.0000 0.0000 0.0000 0.0000 0.0075 0.0050 0.0075 0.0262 0.0324 0.0610
1979    5       2       2       0       0       0       0       0.0130 0.0013 0.0000 0.0000 0.0063
                0.0038 0.0152 0.0468 0.0354 0.0392 0.0544 0.0215 0.0164 0.0177 0.0013 0.0139
1980    5       2       2       0       0       0       0       0.0433 0.0160 0.0096 0.0189 0.0281
                0.0409 0.0497 0.0472 0.0489 0.0525 0.0362 0.0265 0.0134 0.0081 0.0039 0.0040
1981    5       2       2       0       0       0       0       0.0612 0.0245 0.0245 0.0437 0.0540
                0.0608 0.0525 0.0425 0.0315 0.0383 0.0312 0.0267 0.0240 0.0158 0.0093 0.0086
1982    5       2       2       0       0       0       0       0.0631 0.0235 0.0237 0.0285 0.0379
                0.0413 0.0332 0.0246 0.0190 0.0177 0.0156 0.0144 0.0104 0.0080 0.0034 0.0049
1983    5       2       2       0       0       0       0       0.0281 0.0233 0.0351 0.0363 0.0358
                0.0407 0.0392 0.0316 0.0222 0.0154 0.0100 0.0087 0.0065 0.0042 0.0030 0.0041
1984    5       2       2       0       0       0       0       0.0400 0.0156 0.0155 0.0211 0.0298
                0.0344 0.0399 0.0359 0.0287 0.0151 0.0085 0.0060 0.0042 0.0031 0.0019 0.0029
1985    5       2       2       0       0       0       0       0.0034 0.0013 0.0024 0.0046 0.0096
                0.0171 0.0195 0.0193 0.0163 0.0128 0.0119 0.0111 0.0108 0.0057 0.0025 0.0066
1986    5       2       2       0       0       0       0       0.0038  0.0014  0.0038  0.0000
        0.0038  0.0099  0.0329  0.0762  0.0630  0.0470  0.0494  0.0466  0.0428  0.0202  0.0085
        0.0268
1987    5       2       2       0       0       0       0       0.0020  0.0020  0.0030  0.0100
        0.0180  0.0311  0.0331  0.0401  0.0220  0.0311  0.0160  0.0391  0.0080  0.0080  0.0030
        0.0090
1988    5       2       2       0       0       0       0       0.0079  0.0143  0.0032  0.0079
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       0.0063 0.0127 0.0222 0.0333 0.0476 0.0524 0.0397 0.0222 0.0175 0.0079 0.0048
       0.0063
1989   5      2      2      0      0      0      0      0.0026 0.0024 0.0013 0.0022
       0.0065 0.0108 0.0205 0.0429 0.0502 0.0480 0.0435 0.0295 0.0256 0.0170 0.0065
       0.0168
1990   5      2      2      0      0      0      0      0.0022 0.0044 0.0077 0.0088
       0.0121 0.0121 0.0198 0.0220 0.0374 0.0297 0.0308 0.0264 0.0165 0.0099 0.0055
       0.0242
1991   5      2      2      0      0      0      0      0.0000 0.0036 0.0073 0.0036
       0.0000 0.0073 0.0036 0.0073 0.0291 0.0182 0.0182 0.0291 0.0182 0.0327 0.0036
       0.1055
1992   5      2      2      0      0      0      0      0.0030 0.0000 0.0000 0.0030
       0.0420 0.0631 0.0480 0.0480 0.0450 0.0480 0.0631 0.0691 0.0480 0.0450 0.0390
       0.0571
1994   5      2      2      0      0      0      0      0.0000 0.0035 0.0088 0.0280
       0.0333 0.0438 0.0298 0.0665 0.0455 0.0175 0.0140 0.0123 0.0140 0.0210 0.0210
       0.0683
1995   5      2      2      0      0      0      0      0.0083 0.0000 0.0000 0.0250
       0.0083 0.0250 0.0417 0.0167 0.0250 0.0000 0.0250 0.0000 0.0083 0.0167 0.0000
       0.0250
1996   5      2      2      0      0      0      0      0.0000 0.0000 0.0008 0.0091
       0.0207 0.0339 0.0149 0.0165 0.0182 0.0248 0.0256 0.0190 0.0240 0.0215 0.0141
       0.0422
1997   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0000
       0.0029 0.0000 0.0265 0.0383 0.0678 0.0944 0.0472 0.0413 0.0560 0.0295 0.0147
       0.0678
1998   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0007
       0.0014 0.0042 0.0182 0.0503 0.0545 0.0441 0.0392 0.0322 0.0469 0.0371 0.0399
       0.1014
1999   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0016
       0.0000 0.0000 0.0048 0.0048 0.0079 0.0207 0.0254 0.0223 0.0350 0.0238 0.0302
       0.0747
2000   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0027
       0.0041 0.0082 0.0151 0.0192 0.0082 0.0151 0.0316 0.0425 0.0178 0.0233 0.0082
       0.0837
2001   5      2      2      0      0      0      0      0.0000 0.0000 0.0025 0.0025
       0.0138 0.0126 0.0289 0.0226 0.0252 0.0302 0.0201 0.0239 0.0302 0.0340 0.0377
       0.1019
2002   5      2      2      0      0      0      0      0.0000 0.0009 0.0000 0.0018
       0.0035 0.0079 0.0149 0.0272 0.0527 0.0369 0.0281 0.0316 0.0395 0.0430 0.0492
       0.1484
2003   5      2      2      0      0      0      0      0.0000 0.0058 0.0039 0.0116
       0.0155 0.0233 0.0174 0.0194 0.0213 0.0271 0.0252 0.0426 0.0310 0.0329 0.0329
       0.0988
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2004   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0016
       0.0016 0.0142 0.0299 0.0377 0.0393 0.0299 0.0535 0.0330 0.0409 0.0220 0.0346
       0.1164
2005   5      2      2      0      0      0      0      0.0010 0.0058 0.0077 0.0048
       0.0087 0.0212 0.0346 0.0500 0.0673 0.0596 0.0260 0.0308 0.0221 0.0192 0.0154
       0.0442
2006   5      2      2      0      0      0      0      0.0000 0.0000 0.0009 0.0009
       0.0043 0.0094 0.0068 0.0103 0.0154 0.0231 0.0300 0.0308 0.0342 0.0257 0.0171
       0.0736
2007   5      2      2      0      0      0      0      0.0000 0.0000 0.0016 0.0016
       0.0033 0.0139 0.0269 0.0359 0.0359 0.0376 0.0465 0.0563 0.0522 0.0506 0.0343
       0.0906
2008   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0006
       0.0063 0.0044 0.0075 0.0169 0.0307 0.0269 0.0263 0.0269 0.0338 0.0194 0.0188
       0.0608
2009   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0000
       0.0017 0.0120 0.0231 0.0453 0.0427 0.0256 0.0274 0.0342 0.0436 0.0393 0.0350
       0.0769
2010   5      2      2      0      0      0      0      0.0011 0.0011 0.0011 0.0011
       0.0044 0.0122 0.0244 0.0322 0.0322 0.0433 0.0599 0.0511 0.0488 0.0433 0.0400
       0.0932
2011   5      2      2      0      0      0      0      0.0000 0.0000 0.0046 0.0137
       0.0091 0.0068 0.0342 0.0091 0.0205 0.0228 0.0433 0.0456 0.0524 0.0342 0.0410
       0.1481
2012   5      2      2      0      0      0      0      0.0000 0.0000 0.0000 0.0000
       0.0036 0.0320 0.0214 0.0463 0.0142 0.0356 0.0320 0.0285 0.0569 0.0463 0.0320
       0.1139
2013   5      2      2      0      0      0      0      0.0021 0.0000 0.0021 0.0000
       0.0083 0.0062 0.0249 0.0416 0.0333 0.0395 0.0249 0.0187 0.0229 0.0353 0.0187
       0.0852
2014   5      2      2      0      0      0      0 0.0000 0.0000 0.0038 0.0038 0.0038
       0.0077 0.0268 0.0153 0.0460 0.0307 0.0268 0.0153 0.0115 0.0115 0.0307 0.1149
2015   5      2      2      0      0      0      0 0.0000 0.0024 0.0024 0.0073 0.0342
       0.0293 0.0465 0.0538 0.0318 0.0465 0.0367 0.0293 0.0293 0.0220 0.0220 0.1002
2016   5      2      2      0      0      0      0 0.0000 0.0000 0.0065 0.0049 0.0016
       0.0081 0.0097 0.0097 0.0097 0.0227 0.0373 0.0324 0.0340 0.0243 0.0130 0.0665
2017   5      2      2      0      0      0      0 0.0000 0.0000 0.0028 0.0028 0.0181
       0.0056 0.0070 0.0028 0.0056 0.0070 0.0097 0.0153 0.0153 0.0125 0.0125 0.0822
2018   5      2      2      0      0      0      0 0.0000 0.0045 0.0067 0.0112 0.0078
       0.0112 0.0157 0.0347 0.0168 0.0202 0.0246 0.0291 0.0314 0.0325 0.0370 0.0997
2019   5      2      2      0      0      0      0 0.0024 0.0024 0.0097 0.0036 0.0085
       0.0194 0.0073 0.0109 0.0122 0.0170 0.0182 0.0170 0.0207 0.0182 0.0231 0.1081
2020   5      2      2      0      0      0      0 0.0000 0.0026 0.0026 0.0026 0.0092
       0.0052 0.0105 0.0079 0.0131 0.0105 0.0065 0.0131 0.0209 0.0157 0.0301 0.1243
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#Tanner       crab    bycatch       Male    (male and female combined compositons are
        normalized to be 1)
#Year   Season Fleet    Sex     Type    Shell   Maturity        Nsamp DataVec
1991    5   1   1   0   0   0   50    0.0026  0.0048  0.0029  0.0042  0.0051  0.0042
        0.0102  0.0141  0.0144  0.0112  0.0156  0.0166  0.0182  0.0271  0.0300  0.0236  0.0217
        0.0217  0.0169  0.0252  #3131
1992    5   1   1   0   0   0   48.25   0.0000  0.0000  0.0010  0.0031  0.0114  0.0166
        0.0259  0.0238  0.0259  0.0301  0.0269  0.0269  0.0187  0.0124  0.0145  0.0052  0.0104
        0.0135  0.0073  0.0166  #965
1993    5   1   1   0   0   0   24.85   0.0000  0.0000  0.0000  0.0000  0.0040  0.0020
        0.0262  0.0483  0.0584  0.0664  0.0463  0.0282  0.0262  0.0362  0.0262  0.0221  0.0302
        0.0141  0.0101  0.0221  #497
1994    5   1   1   0   0   0   0.85   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0588  0.1176  0.0000  0.1176  0.2353  0.1176  0.0000  0.0000
        0.0588  0.0588  0.1765  #17
2006    5   1   1   0   0   0   7     0.0000  0.0000  0.0000  0.0000  0.0214  0.0500
        0.0429  0.0500  0.0786  0.0857  0.0500  0.0500  0.0286  0.0643  0.1000  0.0786  0.1214
        0.0500  0.0571  0.0429  #140
2007    5   1   1   0   0   0   2.65   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0189  0.0189  0.0377  0.0000  0.0189  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  #53
2008    5   1   1   0   0   0   7.25   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0069  0.0138  0.0276  0.0897  0.1172  0.0621  0.0897  0.0345  0.0276  0.0000  0.0069
        0.0069  0.0000  0.0138  #145
2009    5   1   1   0   0   0   9.65   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0052  0.0155  0.0207  0.0155  0.0363  0.0518  0.0311  0.0622  0.0622  0.0415
        0.0052  0.0000  0.0052  #193
2013    5   1   1   0   0   0   40.7   0.0000  0.0012  0.0000  0.0000  0.0000  0.0086
        0.0074  0.0135  0.0184  0.0393  0.0197  0.0295  0.0172  0.0197  0.0086  0.0221  0.0123
        0.0098  0.0135  0.0270  #814
2014    5   1   1   0   0   0   31.55   0.0000  0.0000  0.0016  0.0000  0.0079  0.0079
        0.0127  0.0190  0.0158  0.0317  0.0222  0.0269  0.0317  0.0412  0.0412  0.0254  0.0349
        0.0254  0.0174  0.0428  #631
2015    5   1   1   0   0   0   50    0.0017  0.0038  0.0017  0.0024  0.0181  0.0247
        0.0178  0.0115  0.0153  0.0205  0.0219  0.0118  0.0087  0.0066  0.0122  0.0104  0.0136
        0.0143  0.0150  0.0212  #2872
#Tanner       crab    bycatch       female
#Year   Season Fleet    Sex     Type    Shell   Maturity        Nsamp DataVec
1991    5   1   2   0   0   0   0    0.0051  0.0105  0.0096  0.0102  0.0240  0.0326
        0.0565  0.0466  0.0827  0.1150  0.1137  0.0952  0.0556  0.0265  0.0188  0.0070  #3131
1992    5   1   2   0   0   0   0    0.0000  0.0000  0.0010  0.0062  0.0228  0.0456
        0.0819  0.0933  0.0870  0.0539  0.0777  0.0995  0.0653  0.0404  0.0228  0.0124  #965
1993    5   1   2   0   0   0   0    0.0000  0.0000  0.0000  0.0000  0.0040  0.0342
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        0.0825  0.1127  0.0805  0.0362  0.0402  0.0402  0.0563  0.0262  0.0121  0.0080  #497
1994    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0588  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  #17
2006    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0071  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0143  0.0071  0.0000  0.0000  0.0000  0.0000  0.0000  #140
2007    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0000  0.0000  0.0189
        0.1698  0.2264  0.2453  0.1321  0.0755  0.0377  0.0000  0.0000  0.0000  0.0000  #53
2008    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0000  0.0000  0.0069
        0.0069  0.0138  0.0621  0.0552  0.0552  0.0966  0.0966  0.0483  0.0414  0.0207  #145
2009    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
        0.0155  0.0622  0.0674  0.0518  0.0570  0.1606  0.1088  0.0622  0.0415  0.0208  #193
2013    5     1      2      0      0      0      0      0.0000  0.0000  0.0000  0.0000  0.0000  0.0221
        0.0504  0.1806  0.1437  0.0774  0.0467  0.0553  0.0369  0.0651  0.0233  0.0307  #814
2014    5     1      2      0      0      0      0      0.0000  0.0000  0.0016  0.0032  0.0111  0.0222
        0.0475  0.0539  0.1442  0.1537  0.0586  0.0269  0.0222  0.0111  0.0174  0.0206  #631
2015    5     1      2      0      0      0      0      0.0003  0.0014  0.0028  0.0052  0.0240  0.0348
        0.0637  0.1031  0.1445  0.1114  0.0912  0.0682  0.0373  0.0198  0.0167  0.0219  #2872
# Fixed gear    crab    bycatch         Male
#Year   season  Fleet   Sex     Type    Shell   Maturity        Nsamp DataVec
1996    5       4       1       0       0       0       37.8    0.0026  0.0013  0.0066  0.0053
        0.0026  0.0053  0.0132  0.0132  0.0079  0.0146  0.0146  0.0079  0.0146  0.0132  0.0106
        0.0146  0.0106  0.0066  0.0066  0.0238
1997    5       4       1       0       0       0       50      0.0000  0.0000  0.0024  0.0024
        0.0134  0.0284  0.0504  0.0686  0.0654  0.0607  0.0496  0.0315  0.0347  0.0418  0.0315
        0.0221  0.0362  0.0441  0.0528  0.1560
1998    5       4       1       0       0       0       50      0.0000  0.0000  0.0000  0.0000
        0.0000  0.0019  0.0019  0.0039  0.0077  0.0125  0.0251  0.0367  0.0521  0.0869  0.0849
        0.1052  0.0840  0.0772  0.0666  0.1564
1999    5       4       1       0       0       0       50      0.0031  0.0006  0.0019  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0000  0.0025  0.0094  0.0218  0.0524  0.0868  0.1142
        0.1255  0.1242  0.0980  0.0674  0.1311
2000    5       4       1       0       0       0       29.55   0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0085  0.0169  0.0321  0.0271  0.0761  0.0508  0.0575  0.0457
        0.0694  0.0558  0.0541  0.0474  0.1151
2001    5       4       1       0       0       0       50      0.0000  0.0002  0.0006  0.0004
        0.0016  0.0044  0.0074  0.0111  0.0201  0.0221  0.0239  0.0233  0.0257  0.0298  0.0340
        0.0513  0.0652  0.0638  0.0547  0.1456
2002    5       4       1       0       0       0       50      0.0000  0.0000  0.0000  0.0003
        0.0009  0.0017  0.0003  0.0020  0.0049  0.0111  0.0151  0.0220  0.0305  0.0365  0.0520
        0.0582  0.0722  0.0748  0.0854  0.2880
2003    5       4       1       0       0       0       50      0.0011  0.0000  0.0032  0.0118
        0.0150  0.0171  0.0235  0.0107  0.0075  0.0118  0.0128  0.0299  0.0310  0.0422  0.0598
        0.0646  0.0630  0.0582  0.0534  0.1095
2004    5       4       1       0       0       0       50      0.0000  0.0005  0.0018  0.0055
```

```
        0.0037  0.0092  0.0114  0.0284  0.0307  0.0288  0.0343  0.0247  0.0243  0.0243  0.0321
        0.0485  0.0586  0.0559  0.0499  0.0934
2005    5       4       1       0       0       0       50      0.0005  0.0000  0.0014  0.0000
        0.0005  0.0042  0.0009  0.0116  0.0075  0.0075  0.0205  0.0266  0.0266  0.0312  0.0336
        0.0349  0.0410  0.0433  0.0457  0.1603
2006    5       4       1       0       0       0       50      0.0000  0.0000  0.0000  0.0000
        0.0000  0.0005  0.0027  0.0016  0.0070  0.0070  0.0107  0.0161  0.0155  0.0246  0.0321
        0.0321  0.0353  0.0359  0.0289  0.0600
2007    5       4       1       0       0       0       39.25   0.0000  0.0000  0.0000  0.0000
        0.0013  0.0000  0.0000  0.0013  0.0025  0.0051  0.0051  0.0140  0.0051  0.0344  0.0344
        0.0446  0.0369  0.0344  0.0561  0.1478
2008    5       4       1       0       0       0       50      0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0026  0.0069  0.0172  0.0232  0.0369  0.0378  0.0464  0.0369  0.0438
        0.0309  0.0344  0.0421  0.0430  0.1452
2009    5       4       1       0       0       0       50      0.0000  0.0000  0.0000  0.0000
        0.0009  0.0009  0.0009  0.0101  0.0129  0.0129  0.0129  0.0202  0.0395  0.0606  0.0634
        0.1093  0.0817  0.0735  0.0542  0.1166
2010    5       4       1       0       0       0       25.65   0.0000  0.0000  0.0019  0.0000
        0.0000  0.0019  0.0019  0.0000  0.0019  0.0039  0.0117  0.0136  0.0273  0.0273  0.0214
        0.0195  0.0175  0.0292  0.0195  0.0487
2011    5       4       1       0       0       0       50      0.0000  0.0000  0.0008  0.0017
        0.0000  0.0025  0.0017  0.0025  0.0042  0.0025  0.0050  0.0067  0.0076  0.0185  0.0303
        0.0235  0.0303  0.0286  0.0303  0.0866
2012    5       4       1       0       0       0       50      0.0000  0.0000  0.0003  0.0007
        0.0013  0.0010  0.0047  0.0074  0.0114  0.0138  0.0225  0.0269  0.0316  0.0326  0.0376
        0.0443  0.0376  0.0417  0.0343  0.1058
2013    5       4       1       0       0       0       50      0.0073  0.0097  0.0153  0.0253
        0.0210  0.0185  0.0211  0.0215  0.0232  0.0264  0.0275  0.0327  0.0340  0.0303  0.0300
        0.0265  0.0272  0.0256  0.0250  0.0798
2014    5       4       1       0       0       0       50      0.0019  0.0026  0.0040  0.0026
        0.0033  0.0054  0.0089  0.0128  0.0121  0.0145  0.0191  0.0238  0.0285  0.0261  0.0233
        0.0390  0.0289  0.0273  0.0250  0.1102
2015    5       4       1       0       0       0       50      0.0007  0.0011  0.0007  0.0022
        0.0063  0.0098  0.0107  0.0130  0.0125  0.0192  0.0177  0.0170  0.0150  0.0143  0.0110
        0.0076  0.0103  0.0083  0.0074  0.0262
2016    5       4       1       0       0       0       50      0.0018  0.0032  0.0062  0.0090
        0.0192  0.0210  0.0240  0.0291  0.0261  0.0229  0.0247  0.0189  0.0155  0.0118  0.0127
        0.0132  0.0159  0.0127  0.0134  0.0430
2017    5       4       1       0       0       0       50      0.0000  0.0014  0.0000  0.0071
        0.0141  0.0148  0.0163  0.0120  0.0071  0.0163  0.0085  0.0120  0.0078  0.0141  0.0113
        0.0092  0.0148  0.0141  0.0205  0.0961
2018    5       4       1       0       0       0       50      0.0009  0.0020  0.0041  0.0080
        0.0045  0.0126  0.0242  0.0392  0.0399  0.0470  0.0385  0.0255  0.0201  0.0203  0.0204
        0.0178  0.0151  0.0139  0.0162  0.0500
```

```
2019    5       4       1       0       0       0       43.15 0.0000  0.0023  0.0046  0.0104  0.0185
        0.0197  0.0255  0.0209  0.0209  0.0197  0.0070  0.0139  0.0139  0.0139  0.0058  0.0035
        0.0058  0.0012  0.0000  0.0046
2020    5       4       1       0       0       0 12.3  0.0122  0.0000  0.0041  0.0000  0.0000
        0.0000  0.0000  0.0041  0.0081  0.0000  0.0081  0.0203  0.0122  0.0285  0.0081  0.0163
        0.0081  0.0081  0.0000  0.0203

# Fixed gear    crab    bycatch         female
#Year   Season Fleet    Sex     Type    Shell   Maturity        Nsamp DataVec
1996    5       4       2       0       0       0       0       0.0066  0.0013  0.0053  0.0040
        0.0159  0.0079  0.0238  0.0423  0.0556  0.0860  0.1270  0.1230  0.0847  0.0741  0.0556
        0.0913
1997    5       4       2       0       0       0       0       0.0000  0.0000  0.0008  0.0008
        0.0047  0.0126  0.0299  0.0260  0.0339  0.0252  0.0165  0.0126  0.0071  0.0071  0.0079
        0.0229
1998    5       4       2       0       0       0       0       0.0000  0.0000  0.0010  0.0000
        0.0000  0.0000  0.0068  0.0251  0.0309  0.0193  0.0203  0.0097  0.0058  0.0106  0.0174
        0.0502
1999    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0000  0.0000  0.0000  0.0000  0.0031  0.0075  0.0131  0.0194  0.0256  0.0237  0.0137
        0.0549
2000    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0000  0.0017  0.0017  0.0102  0.0152  0.0237  0.0508  0.0440  0.0423  0.0321  0.0321
        0.0897
2001    5       4       2       0       0       0       0       0.0004  0.0002  0.0000  0.0016
        0.0028  0.0066  0.0127  0.0195  0.0177  0.0205  0.0441  0.0787  0.0678  0.0380  0.0266
        0.0777
2002    5       4       2       0       0       0       0       0.0000  0.0003  0.0009  0.0000
        0.0000  0.0006  0.0000  0.0029  0.0060  0.0106  0.0086  0.0226  0.0340  0.0348  0.0354
        0.0876
2003    5       4       2       0       0       0       0       0.0011  0.0005  0.0011  0.0101
        0.0198  0.0150  0.0091  0.0069  0.0150  0.0240  0.0331  0.0337  0.0342  0.0438  0.0427
        0.0839
2004    5       4       2       0       0       0       0       0.0005  0.0000  0.0023  0.0032
        0.0055  0.0114  0.0174  0.0330  0.0293  0.0284  0.0476  0.0481  0.0458  0.0426  0.0375
        0.0815
2005    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0005
        0.0005  0.0023  0.0056  0.0149  0.0322  0.0503  0.0499  0.0517  0.0718  0.0555  0.0499
        0.1174
2006    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0011  0.0016  0.0123  0.0348  0.0717  0.1108  0.1055  0.0964  0.0675  0.0498  0.0396
        0.0990
2007    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0000  0.0038  0.0064  0.0318  0.0446  0.0815  0.1197  0.1108  0.0726  0.0433  0.0229
```

```
        0.0395
2008    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0000  0.0043  0.0120  0.0198  0.0438  0.0335  0.0576  0.0653  0.0730  0.0490  0.0301
        0.0644
2009    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0000
        0.0000  0.0028  0.0147  0.0184  0.0220  0.0294  0.0340  0.0312  0.0487  0.0395  0.0239
        0.0652
2010    5       4       2       0       0       0       0       0.0000  0.0000  0.0000  0.0019
        0.0039  0.0000  0.0058  0.0214  0.0663  0.0682  0.0975  0.1111  0.1150  0.0663  0.0624
        0.1326
2011    5       4       2       0       0       0       0       0.0000  0.0017  0.0008  0.0067
        0.0076  0.0176  0.0202  0.0336  0.0580  0.0664  0.1000  0.0908  0.0739  0.0639  0.0429
        0.1328
2012    5       4       2       0       0       0       0       0.0000  0.0000  0.0010  0.0027
        0.0020  0.0104  0.0215  0.0262  0.0339  0.0346  0.0339  0.0571  0.0668  0.0648  0.0658
        0.1236
2013    5       4       2       0       0       0       0       0.0056  0.0108  0.0224  0.0266
        0.0243  0.0245  0.0249  0.0316  0.0354  0.0272  0.0251  0.0241  0.0296  0.0412  0.0334
        0.0853
2014    5       4       2       0       0       0       0       0.0023  0.0061  0.0049  0.0014
        0.0042  0.0056  0.0084  0.0229  0.0422  0.0537  0.0497  0.0502  0.0511  0.0560  0.0597
        0.1624
2015    5       4       2       0       0       0       0       0.0002  0.0002  0.0002  0.0045
        0.0072  0.0132  0.0228  0.0512  0.0745  0.0879  0.1082  0.1064  0.0767  0.0557  0.0586
        0.1216
2016    5       4       2       0       0       0       0       0.0037  0.0028  0.0044  0.0162
        0.0245  0.0208  0.0231  0.0370  0.0499  0.0695  0.0931  0.0845  0.0640  0.0464  0.0342
        0.0815
2017    5       4       2       0       0       0       0       0.0007  0.0007  0.0021  0.0127
        0.0155  0.0261  0.0184  0.0184  0.0240  0.0382  0.0615  0.0912  0.0876  0.1110  0.0671
        0.1272
2018    5       4       2       0       0       0       0       0.0006  0.0039  0.0026  0.0050
        0.0067  0.0162  0.0344  0.0613  0.0585  0.0615  0.0574  0.0713  0.0654  0.0520  0.0385
        0.0446
2019    5       4       2       0       0       0       0       0.0000  0.0000  0.0012  0.0104
        0.0174  0.0313  0.0290  0.0406  0.0788  0.0823  0.0788  0.0718  0.0637  0.0707  0.0649
        0.1472
2020    5       4       2       0       0       0       0 0.0000  0.0041  0.0041  0.0000  0.0041
        0.0041  0.0285  0.0081  0.0244  0.0366  0.0813  0.0650  0.0691  0.0935  0.0894  0.3293

#NMFS           males   combined
#Year   Season  Fleet   Sex     Type    Shell   Maturity        Nsamp   DataVec
1975    1       5       1       0.000   0       0       200     0.0222  0.0411  0.0299  0.0379  0.0342
                0.0299  0.0309  0.0246  0.0264  0.0314  0.0268  0.0292  0.0284  0.0273  0.0244  0.0270
```

```
                0.0183 0.0134 0.0097 0.0113
1976    1       5      1      0.000  0      0      200    0.0025 0.0127 0.0268 0.0503 0.0623
                0.0522 0.0559 0.0449 0.0392 0.0329 0.0409 0.0438 0.0369 0.0392 0.0335 0.0221
                0.0236 0.0154 0.0070 0.0077
1977    1       5      1      0.000  0      0      200    0.0040 0.0043 0.0065 0.0102 0.0199
                0.0376 0.0453 0.0441 0.0414 0.0450 0.0409 0.0409 0.0311 0.0324 0.0322 0.0259
                0.0166 0.0140 0.0084 0.0121
1978    1       5      1      0.000  0      0      200    0.0043 0.0120 0.0136 0.0240 0.0172
                0.0191 0.0178 0.0279 0.0296 0.0297 0.0300 0.0304 0.0291 0.0367 0.0346 0.0283
                0.0260 0.0173 0.0108 0.0091
1979    1       5      1      0.000  0      0      200    0.0206 0.0154 0.0103 0.0123 0.0144
                0.0163 0.0137 0.0155 0.0164 0.0157 0.0235 0.0338 0.0333 0.0432 0.0415 0.0378
                0.0359 0.0298 0.0136 0.0235
1980    1       5      1      0.000  0      0      200    0.0067 0.0133 0.0376 0.0287 0.0295
                0.0296 0.0265 0.0262 0.0224 0.0192 0.0208 0.0165 0.0231 0.0251 0.0264 0.0378
                0.0266 0.0268 0.0216 0.0357
1981    1       5      1      0.000  0      0      200    0.0160 0.0113 0.0182 0.0240 0.0366
                0.0362 0.0331 0.0367 0.0291 0.0356 0.0261 0.0285 0.0194 0.0221 0.0156 0.0145
                0.0112 0.0106 0.0085 0.0176
1982    1       5      1      0.000  0      0      200    0.0792 0.0811 0.0682 0.0287 0.0240
                0.0310 0.0353 0.0287 0.0197 0.0171 0.0198 0.0141 0.0131 0.0079 0.0066 0.0043
                0.0039 0.0005 0.0004 0.0018
1983    1       5      1      0.000  0      0      200    0.0325 0.0356 0.0497 0.0665 0.0801
                0.0783 0.0598 0.0468 0.0402 0.0398 0.0320 0.0309 0.0190 0.0119 0.0107 0.0037
                0.0025 0.0012 0.0000 0.0000
1984    1       5      1      0.000  0      0      200    0.0161 0.0626 0.1229 0.1327 0.0682
                0.0389 0.0206 0.0202 0.0208 0.0154 0.0119 0.0072 0.0063 0.0050 0.0065 0.0021
                0.0009 0.0009 0.0001 0.0003
1985    1       5      1      0.000  0      0      200    0.0026 0.0128 0.0244 0.0395 0.0589
                0.0582 0.0424 0.0403 0.0602 0.0614 0.0513 0.0523 0.0497 0.0418 0.0279 0.0237
                0.0018 0.0051 0.0042 0.0000
1986    1       5      1      0.000  0      0      200    0.0112 0.0179 0.0248 0.0201 0.0232
                0.0156 0.0408 0.0400 0.0559 0.0485 0.0675 0.0734 0.0700 0.0788 0.0563 0.0385
                0.0275 0.0073 0.0029 0.0023
1987    1       5      1      0.000  0      0      200    0.0012 0.0071 0.0340 0.0546 0.0469
                0.0317 0.0290 0.0291 0.0310 0.0253 0.0332 0.0270 0.0363 0.0345 0.0290 0.0284
                0.0183 0.0154 0.0038 0.0039
1988    1       5      1      0.000  0      0      200    0.0013 0.0013 0.0066 0.0110 0.0133
                0.0215 0.0469 0.0430 0.0405 0.0374 0.0262 0.0308 0.0210 0.0371 0.0331 0.0495
                0.0368 0.0268 0.0094 0.0093
1989    1       5      1      0.000  0      0      200    0.0017 0.0000 0.0009 0.0024 0.0149
                0.0348 0.0184 0.0376 0.0232 0.0412 0.0288 0.0253 0.0450 0.0523 0.0535 0.0665
                0.0483 0.0466 0.0283 0.0278
1990    1       5      1      0.000  0      0      200    0.0013 0.0106 0.0151 0.0348 0.0329
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                0.0094 0.0080 0.0084 0.0182 0.0296 0.0219 0.0298 0.0341 0.0401 0.0369 0.0382
                0.0299 0.0344 0.0196 0.0342
1991    1       5      1      0.000  0      0      200    0.0011 0.0090 0.0224 0.0168 0.0265
                0.0217 0.0137 0.0274 0.0221 0.0172 0.0053 0.0198 0.0347 0.0364 0.0588 0.0674
                0.0658 0.0482 0.0369 0.0757
1992    1       5      1      0.000  0      0      200    0.0010 0.0000 0.0020 0.0127 0.0252
                0.0355 0.0552 0.0528 0.0382 0.0399 0.0291 0.0378 0.0348 0.0280 0.0234 0.0233
                0.0219 0.0307 0.0169 0.0496
1993    1       5      1      0.000  0      0      200    0.0021 0.0110 0.0137 0.0105 0.0095
                0.0157 0.0142 0.0235 0.0309 0.0443 0.0417 0.0627 0.0479 0.0390 0.0371 0.0269
                0.0288 0.0298 0.0242 0.0411
1994    1       5      1      0.000  0      0      163.75 0.0016 0.0000 0.0031 0.0237 0.0235
                0.0152 0.0124 0.0173 0.0213 0.0354 0.0412 0.0403 0.0627 0.0907 0.0474 0.0461
                0.0468 0.0327 0.0229 0.0504
1995    1       5      1      0.000  0      0      200    0.0283 0.0683 0.0557 0.0220 0.0110
                0.0169 0.0222 0.0255 0.0275 0.0305 0.0263 0.0268 0.0343 0.0402 0.0490 0.0433
                0.0323 0.0238 0.0108 0.0262
1996    1       5      1      0.000  0      0      200    0.0278 0.0135 0.0298 0.0529 0.0632
                0.0594 0.0276 0.0225 0.0117 0.0179 0.0140 0.0150 0.0139 0.0130 0.0218 0.0165
                0.0190 0.0171 0.0183 0.0252
1997    1       5      1      0.000  0      0      200    0.0000 0.0036 0.0022 0.0052 0.0127
                0.0564 0.0943 0.1070 0.0910 0.0515 0.0301 0.0162 0.0149 0.0132 0.0142 0.0168
                0.0234 0.0168 0.0173 0.0402
1998    1       5      1      0.000  0      0      200    0.0209 0.0174 0.0103 0.0127 0.0120
                0.0101 0.0135 0.0169 0.0226 0.0467 0.0485 0.0523 0.0451 0.0291 0.0183 0.0153
                0.0196 0.0135 0.0080 0.0245
1999    1       5      1      0.000  0      0      200    0.0583 0.0244 0.0134 0.0104 0.0120
                0.0110 0.0121 0.0148 0.0047 0.0132 0.0182 0.0233 0.0520 0.0536 0.0700 0.0688
                0.0435 0.0303 0.0221 0.0252
2000    1       5      1      0.000  0      0      200    0.0018 0.0047 0.0195 0.0396 0.0310
                0.0200 0.0228 0.0163 0.0201 0.0147 0.0134 0.0296 0.0294 0.0489 0.0416 0.0360
                0.0343 0.0229 0.0085 0.0196
2001    1       5      1      0.000  0      0      200    0.0069 0.0050 0.0106 0.0149 0.0156
                0.0421 0.0372 0.0523 0.0346 0.0200 0.0253 0.0166 0.0140 0.0202 0.0132 0.0112
                0.0219 0.0191 0.0192 0.0327
2002    1       5      1      0.000  0      0      200    0.0534 0.0638 0.0436 0.0272 0.0119
                0.0091 0.0076 0.0106 0.0229 0.0266 0.0347 0.0290 0.0203 0.0252 0.0170 0.0193
                0.0195 0.0222 0.0242 0.0274
2003    1       5      1      0.000  0      0      200    0.0149 0.0069 0.0142 0.0236 0.0392
                0.0320 0.0301 0.0165 0.0112 0.0143 0.0133 0.0251 0.0236 0.0386 0.0348 0.0364
                0.0254 0.0216 0.0212 0.0666
2004    1       5      1      0.000  0      0      200    0.0371 0.0289 0.0268 0.0195 0.0187
                0.0187 0.0350 0.0535 0.0436 0.0445 0.0293 0.0238 0.0142 0.0150 0.0179 0.0232
                0.0240 0.0327 0.0232 0.0447
```

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2005   1      5      1      0.000  0      0      200    0.0353 0.0586 0.0419 0.0160 0.0098
              0.0228 0.0234 0.0215 0.0184 0.0171 0.0219 0.0233 0.0159 0.0189 0.0125 0.0158
              0.0103 0.0155 0.0144 0.0252
2006   1      5      1      0.000  0      0      200    0.0133 0.0197 0.0173 0.0276 0.0291
              0.0369 0.0210 0.0208 0.0129 0.0188 0.0116 0.0128 0.0236 0.0205 0.0329 0.0280
              0.0271 0.0200 0.0144 0.0246
2007   1      5      1      0.000  0      0      200    0.0017 0.0025 0.0053 0.0084 0.0196
              0.0271 0.0345 0.0436 0.0386 0.0288 0.0187 0.0233 0.0236 0.0315 0.0273 0.0288
              0.0277 0.0262 0.0229 0.0290
2008   1      5      1      0.000  0      0      200    0.0000 0.0008 0.0038 0.0068 0.0149
              0.0188 0.0194 0.0239 0.0372 0.0470 0.0453 0.0328 0.0382 0.0317 0.0249 0.0226
              0.0242 0.0236 0.0222 0.0467
2009   1      5      1      0.000  0      0      200    0.0010 0.0005 0.0037 0.0053 0.0053
              0.0104 0.0096 0.0225 0.0330 0.0301 0.0315 0.0328 0.0363 0.0479 0.0312 0.0329
              0.0198 0.0163 0.0148 0.0169
2010   1      5      1      0.000  0      0      200    0.0000 0.0033 0.0080 0.0094 0.0077
              0.0054 0.0161 0.0134 0.0130 0.0153 0.0270 0.0363 0.0302 0.0325 0.0367 0.0348
              0.0423 0.0262 0.0145 0.0200
2011   1      5      1      0.000  0      0      200    0.0036 0.0044 0.0125 0.0204 0.0169
              0.0138 0.0168 0.0151 0.0182 0.0132 0.0181 0.0203 0.0161 0.0295 0.0275 0.0257
              0.0242 0.0204 0.0115 0.0165
2012   1      5      1      0.000  0      0      200    0.0025 0.0040 0.0120 0.0159 0.0128
              0.0227 0.0336 0.0247 0.0174 0.0174 0.0153 0.0196 0.0217 0.0264 0.0234 0.0209
              0.0232 0.0281 0.0132 0.0434
2013   1      5      1      0.000  0      0      200    0.0008 0.0025 0.0123 0.0145 0.0101
              0.0174 0.0134 0.0235 0.0280 0.0261 0.0323 0.0348 0.0303 0.0319 0.0344 0.0324
              0.0340 0.0431 0.0395 0.0749
2014   1      5      1      0.000  0      0      200    0.0000 0.0005 0.0026 0.0030 0.0160
              0.0313 0.0437 0.0348 0.0313 0.0192 0.0231 0.0326 0.0336 0.0309 0.0372 0.0258
              0.0224 0.0189 0.0180 0.0439
2015   1      5      1      0.000  0      0      200    0.0105 0.0207 0.0103 0.0093 0.0047
              0.0110 0.0158 0.0149 0.0244 0.0187 0.0285 0.0203 0.0235 0.0318 0.0240 0.0338
              0.0313 0.0282 0.0278 0.0796
2016   1      5      1      0.000  0      0      200    0.0066 0.0009 0.0026 0.0032 0.0041
              0.0043 0.0034 0.0083 0.0069 0.0129 0.0085 0.0145 0.0127 0.0254 0.0195 0.0213
              0.0241 0.0389 0.0324 0.0709
2017   1      5      1      0.000  0      0      200    0.0032 0.0011 0.0029 0.0095 0.0243
              0.0199 0.0135 0.0068 0.0083 0.0077 0.0086 0.0134 0.0064 0.0234 0.0150 0.0102
              0.0233 0.0363 0.0351 0.0868
2018   1      5      1      0.000  0      0      161    0.0051 0.0173 0.0173 0.0153 0.0093
              0.0161 0.0144 0.0174 0.0367 0.0160 0.0334 0.0210 0.0033 0.0160 0.0145 0.0338
              0.0262 0.0321 0.0272 0.0746
2019   1      5      1      0.000  0      0      143    0.0017 0.0036 0.0106 0.0071 0.0071
              0.0314 0.0157 0.0244 0.0231 0.0336 0.0299 0.0436 0.0424 0.0363 0.0319 0.0124
```

```
                0.0229 0.0230 0.0160 0.0602
2021    1       5      1      0.000  0      0  142.75 0.0038     0.0187 0.0136 0.0140 0.0248
                0.0129 0.0183 0.0211 0.0198 0.0245 0.0236 0.0229 0.0384 0.0546 0.0527 0.0377
                0.0444 0.0362 0.0337 0.0572

#NMFS           female
#Year   Season  Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
1975    1       5      2      0.000  0      0      0      0.0331 0.0401 0.0481 0.0494 0.0564
                0.0439 0.0444 0.0454 0.0326 0.0289 0.0162 0.0158 0.0116 0.0035 0.0029 0.0034
1976    1       5      2      0.000  0      0      0      0.0029 0.0092 0.0313 0.0563 0.0688
                0.0628 0.0494 0.0269 0.0121 0.0137 0.0066 0.0049 0.0023 0.0015 0.0003 0.0011
1977    1       5      2      0.000  0      0      0      0.0026 0.0068 0.0079 0.0193 0.0337
                0.0701 0.0808 0.0715 0.0453 0.0435 0.0415 0.0316 0.0151 0.0100 0.0033 0.0046
1978    1       5      2      0.000  0      0      0      0.0060 0.0111 0.0187 0.0201 0.0233
                0.0418 0.0920 0.1212 0.0791 0.0440 0.0301 0.0267 0.0176 0.0089 0.0045 0.0075
1979    1       5      2      0.000  0      0      0      0.0286 0.0154 0.0121 0.0147 0.0148
                0.0230 0.0381 0.0734 0.0922 0.0876 0.0565 0.0336 0.0215 0.0123 0.0043 0.0057
1980    1       5      2      0.000  0      0      0      0.0048 0.0219 0.0322 0.0292 0.0597
                0.0820 0.0487 0.0581 0.0540 0.0424 0.0315 0.0130 0.0110 0.0059 0.0035 0.0020
1981    1       5      2      0.000  0      0      0      0.0152 0.0113 0.0151 0.0190 0.0366
                0.0456 0.0443 0.0472 0.0600 0.0774 0.0804 0.0510 0.0252 0.0143 0.0028 0.0042
1982    1       5      2      0.000  0      0      0      0.0536 0.0954 0.0603 0.0378 0.0423
                0.0482 0.0398 0.0232 0.0190 0.0257 0.0281 0.0203 0.0114 0.0063 0.0024 0.0009
1983    1       5      2      0.000  0      0      0      0.0174 0.0383 0.0475 0.0629 0.0647
                0.0398 0.0341 0.0152 0.0107 0.0042 0.0090 0.0056 0.0061 0.0022 0.0013 0.0000
1984    1       5      2      0.000  0      0      0      0.0174 0.0585 0.1229 0.1105 0.0647
                0.0325 0.0159 0.0119 0.0038 0.0017 0.0000 0.0004 0.0001 0.0002 0.0001 0.0000
1985    1       5      2      0.000  0      0      0      0.0009 0.0155 0.0377 0.0521 0.0643
                0.0555 0.0516 0.0397 0.0161 0.0068 0.0000 0.0000 0.0015 0.0000 0.0000 0.0000
1986    1       5      2      0.000  0      0      0      0.0124 0.0224 0.0355 0.0274 0.0263
                0.0313 0.0362 0.0388 0.0274 0.0113 0.0072 0.0008 0.0000 0.0000 0.0008 0.0000
1987    1       5      2      0.000  0      0      0      0.0013 0.0124 0.0525 0.0918 0.0761
                0.0462 0.0445 0.0569 0.0414 0.0292 0.0179 0.0079 0.0018 0.0004 0.0000 0.0000
1988    1       5      2      0.000  0      0      0      0.0006 0.0076 0.0064 0.0062 0.0139
                0.0695 0.0910 0.0979 0.0697 0.0600 0.0407 0.0184 0.0077 0.0077 0.0000 0.0000
1989    1       5      2      0.000  0      0      0      0.0017 0.0000 0.0017 0.0082 0.0310
                0.0740 0.0646 0.0692 0.0531 0.0376 0.0315 0.0194 0.0064 0.0041 0.0000 0.0000
1990    1       5      2      0.000  0      0      0      0.0041 0.0052 0.0235 0.0513 0.0525
                0.0071 0.0256 0.0601 0.0732 0.0708 0.0633 0.0410 0.0215 0.0062 0.0037 0.0037
1991    1       5      2      0.000  0      0      0      0.0042 0.0115 0.0196 0.0320 0.0218
                0.0344 0.0343 0.0310 0.0366 0.0329 0.0281 0.0431 0.0232 0.0110 0.0069 0.0027
1992    1       5      2      0.000  0      0      0      0.0000 0.0053 0.0074 0.0197 0.0364
                0.0414 0.0625 0.0448 0.0353 0.0273 0.0450 0.0407 0.0265 0.0212 0.0162 0.0122
1993    1       5      2      0.000  0      0      0      0.0066 0.0080 0.0175 0.0085 0.0131
```

		0.0248	0.0437	0.0647	0.0639	0.0269	0.0300	0.0268	0.0271	0.0445	0.0175	0.0219
1994	1	5	2	0.000	0	0	0	0.0000	0.0016	0.0044	0.0030	0.0169
		0.0092	0.0124	0.0213	0.0431	0.0416	0.0362	0.0280	0.0395	0.0469	0.0292	0.0321
1995	1	5	2	0.000	0	0	0	0.0294	0.0482	0.0316	0.0145	0.0139
		0.0182	0.0163	0.0254	0.0234	0.0334	0.0272	0.0234	0.0240	0.0145	0.0203	0.0155
1996	1	5	2	0.000	0	0	0	0.0260	0.0219	0.0436	0.0794	0.0796
		0.0436	0.0226	0.0218	0.0245	0.0202	0.0161	0.0285	0.0244	0.0156	0.0087	0.0236
1997	1	5	2	0.000	0	0	0	0.0004	0.0037	0.0016	0.0020	0.0146
		0.0791	0.0969	0.0616	0.0212	0.0137	0.0095	0.0146	0.0143	0.0109	0.0084	0.0208
1998	1	5	2	0.000	0	0	0	0.0145	0.0196	0.0101	0.0088	0.0111
		0.0116	0.0303	0.1040	0.1153	0.0594	0.0303	0.0252	0.0225	0.0235	0.0232	0.0336
1999	1	5	2	0.000	0	0	0	0.0243	0.0169	0.0125	0.0115	0.0044
		0.0055	0.0093	0.0164	0.0512	0.0800	0.0583	0.0358	0.0340	0.0199	0.0123	0.0268
2000	1	5	2	0.000	0	0	0	0.0018	0.0067	0.0269	0.0403	0.0357
		0.0272	0.0255	0.0226	0.0358	0.0524	0.0676	0.0603	0.0419	0.0208	0.0167	0.0433
2001	1	5	2	0.000	0	0	0	0.0056	0.0168	0.0195	0.0136	0.0259
		0.0598	0.0779	0.0579	0.0395	0.0398	0.0291	0.0691	0.0560	0.0262	0.0103	0.0205
2002	1	5	2	0.000	0	0	0	0.0506	0.0769	0.0485	0.0247	0.0222
		0.0176	0.0225	0.0520	0.0399	0.0296	0.0163	0.0206	0.0205	0.0221	0.0071	0.0136
2003	1	5	2	0.000	0	0	0	0.0163	0.0059	0.0143	0.0314	0.0414
		0.0464	0.0239	0.0292	0.0351	0.0533	0.0526	0.0356	0.0219	0.0265	0.0220	0.0349
2004	1	5	2	0.000	0	0	0	0.0279	0.0327	0.0194	0.0132	0.0199
		0.0369	0.0577	0.0514	0.0334	0.0204	0.0196	0.0232	0.0184	0.0166	0.0127	0.0225
2005	1	5	2	0.000	0	0	0	0.0405	0.0561	0.0457	0.0116	0.0099
		0.0336	0.0386	0.0521	0.0567	0.0468	0.0336	0.0383	0.0347	0.0227	0.0165	0.0246
2006	1	5	2	0.000	0	0	0	0.0143	0.0139	0.0198	0.0425	0.0615
		0.0462	0.0254	0.0259	0.0481	0.0656	0.0619	0.0415	0.0301	0.0352	0.0167	0.0186
2007	1	5	2	0.000	0	0	0	0.0015	0.0023	0.0064	0.0078	0.0155
		0.0356	0.0574	0.0560	0.0325	0.0570	0.0614	0.0641	0.0459	0.0343	0.0210	0.0323
2008	1	5	2	0.000	0	0	0	0.0000	0.0027	0.0054	0.0136	0.0116
		0.0167	0.0303	0.0570	0.0724	0.0560	0.0555	0.0562	0.0575	0.0355	0.0234	0.0216
2009	1	5	2	0.000	0	0	0	0.0005	0.0019	0.0050	0.0055	0.0081
		0.0122	0.0206	0.0466	0.0656	0.0866	0.0645	0.0603	0.0523	0.0705	0.0514	0.0470
2010	1	5	2	0.000	0	0	0	0.0018	0.0006	0.0037	0.0048	0.0069
		0.0116	0.0213	0.0365	0.0565	0.0927	0.0955	0.0700	0.0509	0.0497	0.0508	0.0545
2011	1	5	2	0.000	0	0	0	0.0058	0.0085	0.0092	0.0141	0.0284
		0.0310	0.0384	0.0484	0.0299	0.0530	0.0637	0.0905	0.0635	0.0571	0.0430	0.0710
2012	1	5	2	0.000	0	0	0	0.0293	0.0180	0.0191	0.0250	0.0281
		0.0461	0.0351	0.0220	0.0331	0.0355	0.0365	0.0461	0.0663	0.0521	0.0462	0.0633
2013	1	5	2	0.000	0	0	0	0.0008	0.0027	0.0093	0.0112	0.0067
		0.0125	0.0202	0.0384	0.0429	0.0450	0.0304	0.0302	0.0455	0.0491	0.0405	0.0786
2014	1	5	2	0.000	0	0	0	0.0000	0.0000	0.0012	0.0040	0.0091
		0.0258	0.0219	0.0320	0.0499	0.0770	0.0569	0.0456	0.0307	0.0399	0.0516	0.0859
2015	1	5	2	0.000	0	0	0	0.0074	0.0129	0.0110	0.0055	0.0120

```
              0.0114 0.0107 0.0234 0.0408 0.0461 0.0616 0.0668 0.0531 0.0503 0.0362 0.0819
2016   1      5      2      0.000  0      0      0      0.0120 0.0019 0.0036 0.0043 0.0026
              0.0051 0.0143 0.0141 0.0390 0.0714 0.0782 0.1023 0.0737 0.0823 0.0617 0.1158
2017   1      5      2      0.000  0      0      0      0.0010 0.0028 0.0030 0.0126 0.0258
              0.0248 0.0167 0.0188 0.0214 0.0511 0.0665 0.0804 0.0885 0.0769 0.0569 0.0973
2018   1      5      2      0.000  0      0      0      0.0031 0.0109 0.0172 0.0186 0.0094
              0.0198 0.0516 0.0362 0.0421 0.0296 0.0254 0.0652 0.0462 0.0495 0.0509 0.0773
2019   1      5      2      0.000  0      0      0      0.0017 0.0105 0.0018 0.0070 0.0070
              0.0140 0.0143 0.0174 0.0312 0.0355 0.0335 0.0279 0.0515 0.0766 0.0656 0.1276
2021   1      5      2      0.000  0      0      0      0.0107 0.0051 0.0100 0.0121 0.0033
              0.0000 0.0120 0.0356 0.0296 0.0189 0.0224 0.0309 0.0446 0.0684 0.0413 0.0825

#BSFRF        males
#Year  Season Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
2007   1      6      1      0      0      0      200    0.0045 0.0074 0.0103 0.0155 0.0198
              0.0321 0.0532 0.0491 0.0443 0.0354 0.0268 0.0231 0.0236 0.0256 0.0223 0.032
              0.0246 0.0218 0.017  0.0278
2008   1      6      1      0      0      0      200    0.0017 0.001  0.0093 0.0119 0.0175
              0.0279 0.0267 0.0348 0.0428 0.0596 0.0581 0.0455 0.0371 0.0284 0.0218 0.0211
              0.0156 0.0157 0.0202 0.0294
2013   1      6      1      0      0      0      75.75  0      0.0073 0.0145 0.0291 0.0102
              0.0136 0.0205 0.0341 0.0357 0.0458 0.0448 0.0383 0.042  0.0348 0.0206 0.0149
              0.0337 0.0426 0.0358 0.0986
2014   1      6      1      0      0      0      105.75 0      0      0.003  0.0101 0.0118
              0.0448 0.0546 0.0423 0.047  0.0164 0.0221 0.0321 0.0226 0.0369 0.022  0.0282
              0.0257 0.026  0.0116 0.039
2015   1      6      1      0      0      0      98.75  0.0208 0.0463 0.037  0.0162 0.0069
              0.0162 0.0119 0.0174 0.0355 0.0206 0.0274 0.0357 0.0228 0.0262 0.0131 0.0428
              0.0215 0.0327 0.0396 0.0627
2016   1      6      1      0      0      0      73.5   0.0138 0.0039 0.02   0.0193 0.0104
              0.0122 0.0064 0.0126 0.0062 0.0034 0.0068 0.0134 0.0204 0.01   0.011  0.0254
              0.023  0.0215 0.0249 0.0774

#BSFRF        females
#Year  Season Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
2007   1      6      2      0      0      0      000    0.0007 0.0016 0.0044 0.0198 0.0302
              0.0705 0.0563 0.0345 0.0364 0.0493 0.0501 0.0448 0.0272 0.0183 0.0152 0.0243
2008   1      6      2      0      0      0      000    0.0004 0.0013 0.0088 0.0142 0.0286
              0.0483 0.0754 0.0687 0.0463 0.0386 0.0411 0.0357 0.021  0.0179 0.0126 0.015
2013   1      6      2      0      0      0      000    0.0035 0      0.0191 0.0258 0.0176
              0.0105 0.0094 0.0407 0.024  0.0291 0.0308 0.0216 0.0232 0.0403 0.0392 0.0483
2014   1      6      2      0      0      0      000    0      0.0037 0.0071 0.0037 0.014
              0.031  0.0238 0.0415 0.0457 0.0708 0.0481 0.0279 0.0385 0.0448 0.0324 0.0707
2015   1      6      2      0      0      0      000    0.0116 0.0324 0.0231 0.0069 0.0153
```

```
                0.0112 0.0042 0.0231 0.0361 0.0358 0.0427 0.0364 0.0528 0.0366 0.0208 0.0575
2016    1       6      2      0      0      0      000    0.0039 0.0178 0.0039 0.0263 0.003
                0.0124 0.0096 0.0168 0.0422 0.0514 0.0826 0.1077 0.072  0.078  0.0429 0.1016
##      Growthdata
# Type of growth increment (1=growth increment with a CV;2=size-at-release; size-at)
0
#       nobs_growth
0
##      Note    SM     used   loewss regression    for    males  BBRKC         data
##      and     cubic  spine  to     interpolate   3      sets   of     female BBRKCdata
# MidPoint Sex  Increment     CV
#67.5   2       14.766667     10000000000000000000000
# MidPoint Sex  MidPoint   Time-at-liberty Size-trans matrix Number of points
# Release      Recapture
##      eof
9999
```

Appendix C1. Control File for Models 21.1b

```
## ———————————————————————————————————————————————————————————————— ##
## LEADING PARAMETER CONTROLS                                          ##
##    Controls for leading parameter vector (theta)                 ##
## LEGEND                                                    ##
##    prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma        ##
## ———————————————————————————————————————————————————————————————————— ##
## ntheta
  91
## ———————————————————————————————————————————————————————————————————— ##
## ival       lb       ub       phz   prior     p1      p2        # parameter      ##
## —————————————————————————————————————————————————————————————————— ##
   0.18       0.15    0.2        -4       2    0.18    0.04       # M
 # 0.18       0.15    0.4         4       2    0.18    0.03       # M
   0.0       -0.4    0.4         4      1    0.0     0.03       # M
  16.5      -10       18        -2      0  -10.0    20.0       # logR0
  19.5      -10       25         3       0   10.0    25.0       # logRini, to estimate if NOT initialized at
unfished (n68)
  16.5      -10       25         1       0   10.0    20.0   #1      # logRbar, to estimate if NOT initialized
at unfished      #1
  72.5        55       100         -4       1   72.5     7.25        # recruitment expected value (males or
combined)
   0.726149   0.32      1.64       3       0    0.1     5.0        # recruitment scale (variance component)
(males or combined)
   0.00      -5        5        -4       0   0.0     20.00       # recruitment expected value (females)
   0.00      -1.69      0.40       3       0    0.0    20.0        # recruitment scale (variance component)
(females)
  -0.10536     -10        0.75      -4       0  -10.0     0.75       # ln(sigma_R)
  #-0.10       -5        5.0       4       0   -10.0     10.0       # ln(sigma_R)
   0.75       0.20      1.00      -2       3    3.0     2.00       # steepness
   0.01       0.00      1.00      -3       3    1.01    1.01       # recruitment autocorrelation
#   0.00      -10        4         2       0   10.0    20.00       # Deviation for size-class 1 (normalization
class)
   1.107962885630     -10        4         9       0   10.0    20.00       # Deviation for size-class 2
   0.563229168219     -10        4         9       0   10.0    20.00       # Deviation for size-class 3
   0.681928313426     -10        4         9       0   10.0    20.00       # Deviation for size-class 4
   0.491057364532     -10        4         9       0   10.0    20.00       # Deviation for size-class 5
```

```
  0.407911777560     -10        4         9      0   10.0    20.00       # Deviation for size-class 6
  0.436516142684     -10        4         9      0   10.0    20.00       # Deviation for size-class 7
  0.40612675395550     -10        4         9      0   10.0    20.00       # Deviation for size-class 8
  0.436145974880     -10        4         9      0   10.0    20.00       # Deviation for size-class 9
  0.40494522852708     -10        4         9      0   10.0    20.00       # Deviation for size-class 10
  0.30401970466854     -10        4         9      0   10.0    20.00       # Deviation for size-class 11
  0.2973752673022     -10        4         9      0   10.0    20.00       # Deviation for size-class 12
  0.1746800712364   -10        4         9      0   10.0    20.00       # Deviation for size-class 13
  0.0845298456942     -10        4         9      0   10.0    20.00       # Deviation for size-class 14
  0.0107462399193     -10        4         9      0   10.0    20.00       # Deviation for size-class 15
  -0.190468322904     -10        4         9      0   10.0    20.00       # Deviation for size-class 16
  -0.376312503735     -10        4         9      0   10.0    20.00       # Deviation for size-class 17
  -0.699162895473     -10        4         9      0   10.0    20.00       # Deviation for size-class 18
  -1.15881771530     -10        4         9      0   10.0    20.00       # Deviation for size-class 19
  -1.17311583316     -10        4         9      0   10.0    20.00       # Deviation for size-class 20
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 1
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 2
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 3
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 4
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 5
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 6
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 7
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 8
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 9
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 10
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 11
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 12
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 13
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 14
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 15
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 16
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 17
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 18
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 19
-100.00      -101        5        -2      0   10.0    20.00       # Deviation for size-class 20
  0.425704202053     -10        4         9      0   10.0    20.00       # Deviation for size-class 1
  2.268408592660     -10        4         9      0   10.0    20.00       # Deviation for size-class 2
  1.810451373080     -10        4         9      0   10.0    20.00       # Deviation for size-class 3
  1.37035725111     -10        4         9      0   10.0    20.00       # Deviation for size-class 4
  1.158258087990     -10        4         9      0   10.0    20.00       # Deviation for size-class 5
  0.596196784439     -10        4         9      0   10.0    20.00       # Deviation for size-class 6
  0.225756761257     -10        4         9      0   10.0    20.00       # Deviation for size-class 7
  -0.0247857565368     -10        4         9      0   10.0    20.00       # Deviation for size-class 8
  -0.214045895269     -10        4         9      0   10.0    20.00       # Deviation for size-class 9
```

```
   -0.560539577780    -10      4      9    0  10.0   20.00     # Deviation for size-class 10
   -0.974218300021    -10      4      9    0  10.0   20.00     # Deviation for size-class 11
   -1.24580072031     -10      4      9    0  10.0   20.00     # Deviation for size-class 12
   -1.49292897450     -10      4      9    0  10.0   20.00     # Deviation for size-class 13
   -1.94135821253     -10      4      9    0  10.0   20.00     # Deviation for size-class 14
   -2.05101560679     -10      4      9    0  10.0   20.00     # Deviation for size-class 15
   -1.94956606430     -10      4      9    0  10.0   20.00     # Deviation for size-class 16
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 17
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 18
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 19
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 20
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 1
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 2
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 3
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 4
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 5
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 6
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 7
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 8
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 9
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 10
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 11
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 12
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 13
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 14
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 15
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 16
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 17
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 18
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 19
 -100.00     -101     5     -2    0  10.0   20.00     # Deviation for size-class 20
#        weight-at-length input       method(1 = allometry [w_l = a*l^b], 2 = vector by sex)
2
##       Males
0.000224781  0.000281351  0.000346923  0.000422209  0.000507927  0.000604802
         0.000713564         0.00083495   0.0009697    0.00111856   0.00128229
         0.00146163  0.00165736   0.00187023   0.00210101   0.00235048   0.00261942
         0.00290861  0.00321882   0.0039059
##       Females
0.0002151      0.00026898   0.00033137   0.00040294   0.00048437   0.00062711
         0.0007216   0.00082452   0.00093615   0.00105678   0.00118669   0.00132613
         0.00147539  0.00163473   0.00180441   0.00218315   0.00218315   0.00218315
         0.00218315  0.0021831
# Proportion mature by sex
```

```
0       0   0    0    0    0    0    0    0    0    0    1    1
        1   1    1    1    1    1    1
0       0   0    0    0    1    1    1    1    1    1    1    1
        1   1    1    1    1    1    1
# Proportion legal by sex
0       0   0    0    0    0    0    0    0    0    0    1    1
        1   1    1    1    1    1    1
0       0   0    0    0    0    0    0    0    0    0    0    0
        0   0    0    0    0    0    0
## ———————————————————————————————————————————————————— ##
## ———————————————————————————————————————————————————— ##
## GROWTH PARAMETER CONTROLS                                        ##
##    Two lines for each parameter if split sex, one line if not         ##
## ———————————————————————————————————————————————————— ##
# Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-
transition; 3=gamma distribution for size-increment; 4=gamma distribution for size after
increment)
3
# growth increment model (1=alpha/beta; 2=estimated by size-class;3=pre-specified/emprical)
3
# molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
# Maximum size-class for recruitment(males then females)
7 5
## number of size-increment periods
1 3
## Year(s) size-incremnt period changes (blank if no changes)
1983 1994
## number of molt periods
2 2
## Year(s) molt period changes (blank if no changes)
1980 1980
## Beta parameters are relative (1=Yes;0=no)
1
## ——————————————————————————————————————————————————— ##
## ival    lb    ub     phz   prior   p1    p2      # parameter    ##
## ———————————————————————————————————————————————————— ##
16.5    0   20    -33   0     0     999       # Males
16.5    0   20    -33   0     0     999       # Males
16.4    0   20    -33   0     0     999       # Males
16.3    0   20    -33   0     0     999       # Males
16.3    0   20    -33   0     0     999       # Males
16.2    0   20    -33   0     0     999       # Males
16.2    0   20    -33   0     0     999       # Males
```

```
16.1    0     20    -33    0    0    999         # Males
16.1    0     20    -33    0    0    999         # Males
16         0  20    -33    0    0    999         # Males
16         0  20    -33    0    0    999         # Males
15.9    0     20    -33    0    0    999         # Males
15.8    0     20    -33    0    0    999         # Males
15.8    0     20    -33    0    0    999         # Males
15.7    0     20    -33    0    0    999         # Males
15.7    0     20    -33    0    0    999         # Males
15.6    0     20    -33    0    0    999         # Males
15.6    0     20    -33    0    0    999         # Males
15.5    0     20    -33    0    0    999         # Males
15.5    0     20    -33    0    0    999         # Males
1.0    0.5    3.0    6      0   0    999         # Males (beta)
13.8    0     20    -33    0    0    999         # Females
12.2    0     20    -33    0    0    999         # Females
10.5    0     20    -33    0    0    999         # Females
8.4     0     20    -33    0    0    999         # Females
7.5     0     20    -33    0    0    999         # Females
7       0     20    -33    0    0    999         # Females
6.6     0     20    -33    0    0    999         # Females
6.1     0     20    -33    0    0    999         # Females
5.6     0     20    -33    0    0    999         # Females
5.1     0     20    -33    0    0    999         # Females
4.6     0     20    -33    0    0    999         # Females
4.1     0     20    -33    0    0    999         # Females
3.6     0     20    -33    0    0    999         # Females
3.2     0     20    -33    0    0    999         # Females
2.7     0     20    -33    0    0    999         # Females
2.2     0     20    -33    0    0    999         # Females
1.7     0     20    -33    0    0    999         # Females
1.2     0     20    -33    0    0    999         # Females
0.7     0     20    -33    0    0    999         # Females
0.4     0     20    -33    0    0    999         # Females
1.5     0.5   3.0    6     0    0    999         # Females (beta)
15.4    0     20    -33    0    0    999         # Females
13.8    0     20    -33    0    0    999         # Females
12.2    0     20    -33    0    0    999         # Females
10.5    0     20    -33    0    0    999         # Females
8.9     0     20    -33    0    0    999         # Females
7.9     0     20    -33    0    0    999         # Females
7.2     0     20    -33    0    0    999         # Females
6.6     0     20    -33    0    0    999         # Females
6.1     0     20    -33    0    0    999         # Females
```

```
5.6       0     20     -33     0      0      999           # Females
5.1       0     20     -33     0      0      999           # Females
4.6       0     20     -33     0      0      999           # Females
4.1       0     20     -33     0      0      999           # Females
3.6       0     20     -33     0      0      999           # Females
3.2       0     20     -33     0      0      999           # Females
2.7       0     20     -33     0      0      999           # Females
2.2       0     20     -33     0      0      999           # Females
1.7       0     20     -33     0      0      999           # Females
1.2       0     20     -33     0      0      999           # Females
0.7       0     20     -33     0      0      999           # Females
0.0     -1.0    1.0     -7     0      0      999           # Females (beta)
15.1      0     20     -33     0      0      999           # Females
14        0     20     -33     0      0      999           # Females
12.9      0     20     -33     0      0      999           # Females
11.8      0     20     -33     0      0      999           # Females
10.6      0     20     -33     0      0      999           # Females
8.7       0     20     -33     0      0      999           # Females
7.4       0     20     -33     0      0      999           # Females
6.6       0     20     -33     0      0      999           # Females
6.1       0     20     -33     0      0      999           # Females
5.6       0     20     -33     0      0      999           # Females
5.1       0     20     -33     0      0      999           # Females
4.6       0     20     -33     0      0      999           # Females
4.1       0     20     -33     0      0      999           # Females
3.6       0     20     -33     0      0      999           # Females
3.2       0     20     -33     0      0      999           # Females
2.7       0     20     -33     0      0      999           # Females
2.2       0     20     -33     0      0      999           # Females
1.7       0     20     -33     0      0      999           # Females
1.2       0     20     -33     0      0      999           # Females
0.7       0     20     -33     0      0      999           # Females
0.0     -1.0    1.0     -7     0      0      999           # Females (beta)
## ———————————————————————————————————————————————————————————————————— ##
## —————————————————————————————————————————————————————————————————————— ##
## MOLTING PROBABILITY CONTROLS                                          ##
##    Two lines for each parameter if split sex, one line if not     ##
## ———————————————————————————————————————————————————————————————————————— ##
## ival      lb       ub       phz   prior    p1     p2        # parameter      ##
## —————————————————————————————————————————————————————————————————————— ##
## males and combined
  145.0386     100.     500.0       3      0    0.0    999.0       # molt_mu males
    0.053036     0.02     2.0       3      0    0.0    999.0       # molt_cv males
  145.0386     100.     500.0       3      0    0.0    999.0       # molt_mu males
```

```
   0.053036    0.02    2.0      3      0    0.0    999.0       # molt_cv males
## females
  300.0000      5.    500.0     -4      0    0.0    999.0       # molt_mu females (molt every year)
   0.01        0.001    9.0     -4      0    0.0    999.0       # molt_cv females (molt every year)
  300.0000      5.    500.0     -4      0    0.0    999.0       # molt_mu females (molt every year)
   0.01        0.001    9.0     -4      0    0.0    999.0       # molt_cv females (molt every year)
## ———————————————————————————————————————————————————————————————————————— ##
# The custom growth-increment matrix

# custom molt probability matrix

## ——————————————————————————————————————————————————————————————————— ##
## SELECTIVITY CONTROLS                                                   ##
##    Selectivity P(capture of all sizes). Each gear must have a selectivity and a    ##
##    retention selectivity. If a uniform prior is selected for a parameter then the   ##
##    lb and ub are used (p1 and p2 are ignored)                          ##
## LEGEND                                                         ##
##    sel type: 0 = parametric, 1 = coefficients (NIY), 2 = logistic, 3 = logistic95,  ##
##            4 = double normal (NIY)                                  ##
##    gear index: use +ve for selectivity, -ve for retention                  ##
##    sex dep: 0 for sex-independent, 1 for sex-dependent                       ##
## —————————————————————————————————————————————————————————————————
Gear-2   Gear-3   Gear-4   Gear-5   Gear-6
## PotFshry TrawlByc TCFshry  FixedGr  NMFS     BSFRF
   1       1       1       1       2       1       # selectivity periods
   1       0       1       0       0       0       # sex specific selectivity
   2       2       2       2       2       2       # male selectivity type
   2       2       2       2       2       2       # female selectivity type
   0       0       0       0       6       0   #6     # within another gear
  # 5       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0       0      #-NEW: extra parameters for each pattern by fleet, females
## Gear-1   Gear-2   Gear-3   Gear-4   Gear-5   Gear-6
   2       1       1       1       1       1       # retention periods
   1       0       0       0       0       0       # sex specific retention
   2       6       6       6       6       6       # male   retention type
   6       6       6       6       6       6       # female retention type
   1       0       0       0       0       0       # male   retention flag (0 = no, 1 = yes)
   0       0       0       0       0       0       # female retention flag (0 = no, 1 = yes)
   0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0       0      #-NEW: extra parameters for each pattern by fleet, females
## ———————————————————————————————————————————————————————————————————————— ##
## gear  par   sel                                  start  end        ##
## index index par sex  ival  lb    ub     prior   p1   p2     phz   period period      ##
```

```
## ——————————————————————————————————————————————————————————————— ##
   # Gear-1
   1     1    1   1    125.0000    5   190    0      1    999    4     1975   2020  #4
   1     2    2   1      8.0      0.1   20    0      1    999    4     1975   2020  #4
  1     3    1   2    84.00      5    150    0      1    999    4     1975   2020
  1     4    2   2     4.0000    0.1   20    0      1    999    4     1975   2020
# Gear-2
   2     5    1   0    165.0       5    190    0      1    999    4     1975   2020
   2     6    2   0     15.0000    0.1   25    0      1    999    4     1975   2020
# Gear-3-9
  3     7    1   1    103.275      5    190    1      103.275    30.98  4     1975   2020
  3     8    2   1     8.834       0.1   25    1      8.834      2.65   4     1975   2020
  3     9    1   2    91.178       5    190    1      91.178     27.35  4     1975   2020
  3    10    2   2     2.5         0.1   25    1      2.5        0.75   4     1975   2020
# Gear-4
   4    11    1   0    115.0       5    190    0      1    999    4     1975   2020  # dummy
   4    12    2   0    9.0        0.1   25    0      1    999    4     1975   2020
# Gear-5
   5    13    1   0     75.0      30   190    0      1    999    5     1975   1981  #5
   5    14    2   0      5.0      1     50    0      1    999    5     1975   1981  #5
   5    15    1   0     80.0      30   190    0      1    999    5     1982   2021  #5
   5    16    2   0      10.0     1     50    0      1    999    5     1982   2021  #5
# Gear-6
   6    17    1   0     75.0      1    180    0      1    999    5     1975   2021  # 5
  6    18    2   0     8.5       1     50    0      1    999    5     1975   2021  # 5
## ————————————————————————————————————————————————————————————————— ##
## Retained                                                     ##
## gear  par   sel                                       start  end        ##
## index index par sex  ival  lb    ub     prior   p1   p2     phz   period period      ##
## ——————————————————————————————————————————————————————————————##
# Gear-1
  -1     25    1   1    135    1    999    0      1    999    4     1975   2004
  -1     26    2   1    2.0    1     20    0      1    999    4     1975   2004
  -1     27    1   1    140    1    999    0      1    999    4     2005   2020
  -1     28    2   1    2.5    1     20    0      1    999    4     2005   2020
  -1     29    1   2    591    1    999    0      1    999   -3     1975   2004
  -1     30    1   2    591    1    999    0      1    999   -3     2005   2020
# Gear-2
  -2     31    1   0    595    1    999    0      1    999   -3     1975   2020
# Gear-3
  -3     32    1   0    595    1    999    0      1    999   -3     1975   2020    #Dummy
# Gear-4
  -4     33    1   0    595    1    999    0      1    999   -3     1975   2020
# Gear-5
```

```
 -5    34   1  0   590   1   999   0     1   999  -3    1975  2021
# Gear-6
 -6    35   1  0   580   1   999   0     1   999  -3    1975  2021
## ———————————————————————————————————————————————————— ##
# Number of asyptotic parameters
1
# Fleet   Sex    Year      ival  lb   ub   phz
     1     1    1975  0.000001   0   1    -3
## —————————————————————————————————————————————————— ##
## PRIORS FOR CATCHABILITY
##    If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##    and p2 are ignored). ival must be > 0                                  ##
## LEGEND                                                  ##
##    prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma              ##
## —————————————————————————————————————————————————— ##
## ival     lb      ub    phz   prior  p1       p2     Analytic?   LAMBDA Emphasis
   0.896    0       2     6    1     0.896    0.03   0          1            1
   1.0      0       5    -6    0     0.001    5.00   0          1            1   # BSFRF
## ———————————————————————————————————————————————————— ##
## ———————————————————————————————————————————————————— ##
## ADDITIONAL CV FOR SURVEYS/INDICES                                        ##
##    If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##    and p2 are ignored). ival must be > 0                                  ##
## LEGEND                                                  ##
##    prior type: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma         ##
## —————————————————————————————————————————————————— ##
## ival        lb       ub       phz   prior     p1      p2
   0.0001      0.00001   10.0      -4    4        1.0     100   # NMFS
   0.25     0.00001   10.0       10   0        0.001   1.00   # BSFRF
## ————————————————————————————————————————————————##
### Pointers to how the the additional CVs are used (0 ignore; >0 link to one of the parameters
1 2
## ———————————————————————————————————————————————————— ##
## PENALTIES FOR AVERAGE FISHING MORTALITY RATE FOR EACH GEAR
## —————————————————————————————————————————————————— ##
## Mean_F   Female Offset STD_PHZ1   STD_PHZ2   PHZ_M   PHZ_F
   0.22313        0.0505      0.5      45.50      1       1     -12      4    -10   2.95     -10    10  # Pot
   0.0183156         1.0      0.5      45.50      1      -1     -12      4    -10     10     -10    10   # Trawl
   0.011109          1.0      0.5      45.50      1       1     -12      4    -10     10     -10    10   # Tanner (-1 -5)
   0.011109          1.0      0.5      45.50      1      -1     -12      4    -10     10     -10    10   # Fixed
   0.00              0.0     2.00      20.00     -1      -1     -12      4    -10     10     -10    10   # NMFS trawl survey (0 catch)
   0.00              0.0     2.00      20.00     -1      -1     -12      4    -10     10     -10    10   # BSFRF (0)
```

```
## ——————————————————————————————————————————————————— ##
## ——————————————————————————————————————————————————— ##
## OPTIONS FOR SIZE COMPOSTION DATA                               ##
##    One column for each data matrix                      ##
## LEGEND                                          ##
##    Likelihood: 1 = Multinomial with estimated/fixed sample size          ##
##              2 = Robust approximation to multinomial              ##
##              3 = logistic normal (NIY)                   ##
##              4 = multivariate-t (NIY)                   ##
##              5 = Dirichlet                      ##
## AUTO TAIL COMPRESSION                                ##
##    pmin is the cumulative proportion used in tail compression          ##
## ——————————————————————————————————————————————————— ##
#  Pot        Trawl   Tanner  Fixed   NMFS    BSFRF
   2   2   2   2   2   2   2   2   2   2   2   2  2   # Type of likelihood
   0   0   0   0   0   0   0   0   0   0   0   0  0   # Auto tail compression (pmin)
   1   1   1   1   1   1   1   1   1   1   1   1  1   # Initial value for effective sample size multiplier
  -4  -4  -4  -4  -4  -4  -4  -4  -4  -4  -4  -4 -4   # Phz for estimating effective sample size (if appl.)
   1   2   3   4   4   5   5   6   6   7   7   8  8   # Composition aggregator
  #1   2   3   4   5   6   7   8   9  10  11  12 13   # Composition aggregator
   1   1   1   1   1   1   1   1   1   2   2   2  2   # Set to 2 for survey-like predictions; 1 for catch-like
predictions !!!NEW 1/2022
   1   1   1   1   1   1   1   1   1   1   1   1  1   # LAMBDA
   1   1   1   1   1   1   1   1   1   1   1   1  1   # Emphasis AEP
## ——————————————————————————————————————————————————— ##
## ——————————————————————————————————————————————————— ##
## TIME VARYING NATURAL MORTALIIY RATES                              ##
## LEGEND                                          ##
## Type: 0 = constant natural mortality                   ##
##      1 = Random walk (deviates constrained by variance in M)          ##
##      2 = Cubic Spline (deviates constrained by nodes & node-placement)        ##
##      3 = Blocked changes (deviates constrained by variance at specific knots)     ##
##      4 = Time blocks                                  ##
## ———————————————————————————————————————————————— ##
## Type
6
## M is relative (YES=1; NO=0)
1
## Phase of estimation
3
## STDEV in m_dev for Random walk
0.25
## Number of nodes for cubic spline or number of step-changes for option 3
2
```

```
2
## Year position of the knots (vector must be equal to the number of nodes)
1980 1985
1980 1985
# number of breakpoints in M by size
0
## Specific initial values for the natural mortality devs (0-no, 1=yes)
1
## ———————————————————————————————————————————————— ##
## ival       lb       ub       phz   extra    prior     p1      p2        # parameter     ##
## ————————————————————————————————————————————##
 1.7342575      0        2         8      0
 0.000000     -2         2       -99      0
1.780586      0         2         8     -1
0.000000     -2         2       -99      0
## ———————————————————————————————————————————————— ##
##  ??????????????????????????????????????????? ##
##  TAGGING controls  CONTROLS                    !!!NEW 1/2022
##  ??????????????????????????????????????????? ##
1         # emphasis on tagging data
## ———————————————————————————————————————————— ##
## OTHER CONTROLS
## ——————————————————————————————————————————##
1975      # First rec_dev
2020      # last rec_dev
   2      # Estimated rec_dev phase
   2      # Estimated sex_ratio
 0.5      # initial sex-ratio
  -3      # Estimated rec_ini phase
   1      # VERBOSE FLAG (0 = off, 1 = on, 2 = objective func; 3 diagnostics)
   3      # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters, 3 = Free
parameters (revised))
   1      # Lambda (proportion of mature male biomass for SPR reference points).
   0      # Stock-Recruit-Relationship (0 = none, 1 = Beverton-Holt)
   10     # Maximum phase (stop the estimation after this phase).
   -1     # Maximum number of function calls
   1      # Calculate reference points (0=no)      !!!NEW 1/2022
   200    # Year to compute equilibria            !!!NEW 1/2022
## ———————————————————————————————————————————————— ##
## EMPHASIS FACTORS (CATCH)
## ———————————————————————————————————————————————— ##
#Ret_male    Disc_male    Disc_female    Disc_trawl    Disc_Tanner_male    Disc_Tanner_female
Disc_fixed
       1        1          1         1              1                1         1
```

```
#     500       100         100         50              100                100        50
## EMPHASIS FACTORS (Priors) by fleet: fdev_total, Fdov_total, Fdev_year, Fdov_year
1 1 0 0 # Pot fishery
1 1 0 0 # Trawl   by-catch
1 1 0 0 # Tanner  by-catch
1 1 0 0 # Fixed  by-catch
1 1 0 0 # Trawl survey
1 1 0 0 # BSFRF survey
## ———————————————————————————————————————————— ##
## EMPHASIS FACTORS (Priors)
## ————————————————————————————————————————————— ##
# Log_fdevs    meanF        Mdevs   Rec_devs  Initial_devs  Fst_dif_dev  Mean_sex-Ratio     Fvecs
Fdovs (!!!NEW for the last two 1/2022)
     10000       0        1.0         2            0            0            10       0     0
## EOF
9999
```

Appendix C2. Control File for Model 22.0e

```
## ————————————————————————————————————————————————————— ##
## LEADING PARAMETER CONTROLS                                              ##
##     Controls for leading parameter vector (theta)                  ##
## LEGEND                                                    ##
##     prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma              ##
## ————————————————————————————————————————————————————— ##
```

```
## ntheta
  91
## ———————————————————————————————————————————————————————————————————————————— ##
## ival      lb      ub      phz   prior    p1     p2       # parameter      ##
## —————————————————————————————————————————————————————————————————————————————— ##
   0.18       0.10    0.5        -4       2    0.18    0.04       # M
   0.0       -0.4    0.4         4      1    0.0     0.03       # M
  15.8      -10       25        -2      0  -10.0    20.0        # logR0
  17.8      -10       25         3      0   10.0    25.0       # logRini, to estimate if NOT initialized at unfished (n68)
  15.8       -10       25         1      0   10.0    20.0   #1      # logRbar, to estimate if NOT initialized at unfished      #1
  72.5       55      100        -4      1   72.5     7.25       # recruitment expected value (males or combined)
   0.67     0.32     1.64       3      0    0.1     5.0        # recruitment scale (variance component) (males or combined)
   0.00      -5        5       -4      0   0.0     20.00       # recruitment expected value (females)
   0.00      -1.69     0.40      3      0   0.0    20.0        # recruitment scale (variance component) (females)
  -0.10536    -10         0.75      -4      0  -10.0     0.75       # ln(sigma_R)
   0.75       0.20     1.00     -2      3    3.0     2.00       # steepness
   0.01       0.00     1.00     -3      3    1.01    1.01        # recruitment autocorrelation
#   0.00      -10        4         2      0   10.0    20.00       # Deviation for size-class 1 (normalization class)
  8.1126e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 2
  7.8104e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 3
  1.1268e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 4
  1.3185e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 5
  1.2508e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 6
  9.8376e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 7
  9.4073e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 8
  1.1977e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 9
  1.1885e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 10
  1.0060e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 11
  9.5158e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 12
  8.0902e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 13
  4.7857e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 14
  3.5835e-02     -10        4        9      0   10.0    20.00       # Deviation for size-class 15
 -4.3686e-01     -10        4        9      0   10.0    20.00       # Deviation for size-class 16
 -1.0925e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 17
 -1.6729e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 18
 -2.3508e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 19
 -2.0125e+00      -10        4        9      0   10.0    20.00       # Deviation for size-class 20
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 1
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 2
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 3
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 4
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 5
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 6
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 7
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 8
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 9
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 10
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 11
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 12
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 13
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 14
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 15
 -100.00      -101        5       -2      0   10.0    20.00       # Deviation for size-class 16
```

```
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 17
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 18
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 19
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 20
 -1.0795e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 1
  4.0114e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 2
  8.7356e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 3
  1.0721e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 4
  1.2198e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 5
  1.0467e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 6
  8.2774e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 7
  3.6531e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 8
 -3.7105e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 9
 -8.1969e-01   -10         4          9       0   10.0    20.00        # Deviation for size-class 10
 -1.5243e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 11
 -1.6193e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 12
 -1.5513e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 13
 -1.7739e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 14
 -1.9128e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 15
 -1.8794e+00   -10         4          9       0   10.0    20.00        # Deviation for size-class 16
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 17
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 18
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 19
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 20
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 1
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 2
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 3
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 4
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 5
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 6
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 7
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 8
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 9
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 10
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 11
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 12
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 13
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 14
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 15
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 16
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 17
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 18
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 19
 -100.00      -101         5         -2       0   10.0    20.00        # Deviation for size-class 20
#           weight-at-length input    method  (1 = allometry      [w_l = a*l^b],      2 = vector by sex)

##          Males
0.000224781      0.000281351      0.000346923      0.000422209      0.000507927      0.000604802
            0.000713564   0.00083495      0.0009697       0.00111856      0.00128229      0.00146163
            0.00165736    0.00187023      0.00210101      0.00235048      0.00261942      0.00290861
            0.00321882    0.0039059
##          Females
```

```
0.0002151 0.00026898   0.00033137   0.00040294   0.00048437   0.00062711   0.0007216
          0.00082452   0.00093615   0.00105678   0.00118669   0.00132613   0.00147539
          0.00163473   0.00180441   0.00218315   0.00218315   0.00218315   0.00218315
          0.0021831
# Proportion mature by sex
0         0     0     0     0     0     0     0     0     0     0     1     1
          1     1     1     1     1     1     1
0         0     0     0     0     1     1     1     1     1     1     1     1
          1     1     1     1     1     1     1
# Proportion legal by sex
0         0     0     0     0     0     0     0     0     0     0     1     1
          1     1     1     1     1     1     1
0         0     0     0     0     0     0     0     0     0     0     0     0
          0     0     0     0     0     0     0
## ——————————————————————————————————————————————————————————————————— ##
## ——————————————————————————————————————————————————————————————————— ##
## GROWTH PARAMETER CONTROLS                                          ##
##     Two lines for each parameter if split sex, one line if not     ##
## ——————————————————————————————————————————————————————————————————— ##
# Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-transition; 3=gamma distribution for size-increment; 4=gamma distribution for size after increment)
3
# growth increment model (1=alpha/beta; 2=estimated by size-class;3=pre-specified/emprical)
3
# molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
# Maximum size-class for recruitment(males then females)
7 5
## number of size-increment periods
1 2
## Year(s) size-incremnt period changes (blank if no changes)
1994
## number of molt periods
1 1
## Year(s) molt period changes (blank if no changes)
#1980 1980
## Beta parameters are relative (1=Yes;0=no)
1

## ————————————————————————————————————————————————————————————————— ##
## ival      lb     ub     phz   prior   p1    p2      # parameter   ##
## ——————————————————————————————————————————————————————————————##
16.5      0      20     -33    0       0     999           # Males
16.5      0      20     -33    0       0     999           # Males
16.4      0      20     -33    0       0     999           # Males
16.3      0      20     -33    0       0     999           # Males
16.3      0      20     -33    0       0     999           # Males
16.2      0      20     -33    0       0     999           # Males
16.2      0      20     -33    0       0     999           # Males
16.1      0      20     -33    0       0     999           # Males
16.1      0      20     -33    0       0     999           # Males
16          0    20     -33    0       0     999           # Males
16          0    20     -33    0       0     999           # Males
```

```
15.9    0     20    -33   0   0   999       # Males
15.8    0     20    -33   0   0   999       # Males
15.8    0     20    -33   0   0   999       # Males
15.7    0     20    -33   0   0   999       # Males
15.7    0     20    -33   0   0   999       # Males
15.6    0     20    -33   0   0   999       # Males
15.6    0     20    -33   0   0   999       # Males
15.5    0     20    -33   0   0   999       # Males
15.5    0     20    -33   0   0   999       # Males
1.0     0.5   3.0   6     0   0   999       # Males (beta)
15.4    0     20    -33   0   0   999       # Females
13.8    0     20    -33   0   0   999       # Females
12.2    0     20    -33   0   0   999       # Females
10.5    0     20    -33   0   0   999       # Females
8.9     0     20    -33   0   0   999       # Females
7.9     0     20    -33   0   0   999       # Females
7.2     0     20    -33   0   0   999       # Females
6.6     0     20    -33   0   0   999       # Females
6.1     0     20    -33   0   0   999       # Females
5.6     0     20    -33   0   0   999       # Females
5.1     0     20    -33   0   0   999       # Females
4.6     0     20    -33   0   0   999       # Females
4.1     0     20    -33   0   0   999       # Females
3.6     0     20    -33   0   0   999       # Females
3.2     0     20    -33   0   0   999       # Females
2.7     0     20    -33   0   0   999       # Females
2.2     0     20    -33   0   0   999       # Females
1.7     0     20    -33   0   0   999       # Females
1.2     0     20    -33   0   0   999       # Females
0.7     0     20    -33   0   0   999       # Females
1.5     0.5   3.0   6     0   0   999       # Females (beta)
15.1    0     20    -33   0   0   999       # Females
14      0     20    -33   0   0   999       # Females
12.9    0     20    -33   0   0   999       # Females
11.8    0     20    -33   0   0   999       # Females
10.6    0     20    -33   0   0   999       # Females
8.7     0     20    -33   0   0   999       # Females
7.4     0     20    -33   0   0   999       # Females
6.6     0     20    -33   0   0   999       # Females
6.1     0     20    -33   0   0   999       # Females
5.6     0     20    -33   0   0   999       # Females
5.1     0     20    -33   0   0   999       # Females
4.6     0     20    -33   0   0   999       # Females
4.1     0     20    -33   0   0   999       # Females
3.6     0     20    -33   0   0   999       # Females
3.2     0     20    -33   0   0   999       # Females
2.7     0     20    -33   0   0   999       # Females
2.2     0     20    -33   0   0   999       # Females
1.7     0     20    -33   0   0   999       # Females
1.2     0     20    -33   0   0   999       # Females
0.7     0     20    -33   0   0   999       # Females
0.0     -1.0  1.0   -7    0   0   999       # Females (beta)
## ———————————————————————————————————————————————————————— ##
```

```
## ——————————————————————————————————————————————————————————————————————— ##
## MOLTING PROBABILITY CONTROLS                                              ##
##     Two lines for each parameter if split sex, one line if not          ##
## ————————————————————————————————————————————————————————————————————##
## ival       lb       ub       phz   prior     p1      p2        # parameter      ##
## ——————————————————————————————————————————————————————————————————————— ##
## males and combined
  145.0386     100.     500.0      3      0    0.0    999.0        # molt_mu males
    0.053036     0.02     2.0      3      0    0.0    999.0        # molt_cv males
## females
  300.0000       5.    500.0     -4      0    0.0    999.0        # molt_mu females (molt every year)
    0.01        0.001    9.0     -4      0    0.0    999.0        # molt_cv females (molt every year)
## ——————————————————————————————————————————————————————————————————————— ##
# The custom growth-increment matrix

# custom molt probability matrix

## ——————————————————————————————————————————————————————————————————————— ##
## SELECTIVITY CONTROLS                                                  ##
##     Selectivity P(capture of all sizes). Each gear must have a selectivity and a     ##
##     retention selectivity. If a uniform prior is selected for a parameter then the   ##
##     lb and ub are used (p1 and p2 are ignored)                              ##
## LEGEND                                                      ##
##     sel type: 0 = parametric, 1 = coefficients (NIY), 2 = logistic, 3 = logistic95,  ##
##              4 = double normal (NIY)                                 ##
##     gear index: use +ve for selectivity, -ve for retention                   ##
##     sex dep: 0 for sex-independent, 1 for sex-dependent                       ##
## ——————————————————————————————————————————————————————————————————————— ##
## Gear-1   Gear-2   Gear-3   Gear-4   Gear-5   Gear-6
## PotFshry TrawlByc TCFshry  FixedGr  NMFS     BSFRF
   1       1       1       1       1              # selectivity periods
   1       0       1       0       0              # sex specific selectivity
   2       2       2       2       2              # male selectivity type
   2       2       2       2       2              # female selectivity type
   0       0       0       0       0       #6     # within another gear
  # 5       0       0       0       0             #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0              #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0              #-NEW: extra parameters for each pattern by fleet, females
## Gear-1   Gear-2   Gear-3   Gear-4   Gear-5   Gear-6
   2       1       1       1       1              # retention periods
   1       0       0       0       0              # sex specific retention
   2       6       6       6       6              # male   retention type
   6       6       6       6       6              # female retention type
   1       0       0       0       0              # male   retention flag (0 = no, 1 = yes)
   0       0       0       0       0              # female retention flag (0 = no, 1 = yes)
   0       0       0       0       0              #-NEW: extra parameters for each pattern by fleet, males
   0       0       0       0       0              #-NEW: extra parameters for each pattern by fleet, females
  1       1       1       1       1              # determines if maximum selectivity at size is forced to equal 1 or not
## ————————————————————————————————————————————————————————————————————— ##
## gear  par   sel                                            start  end        ##
## index index par sex  ival  lb    ub     prior   p1   p2     phz   period period      ##
## ——————————————————————————————————————————————————————————————————————— ##
   # Gear-1
```

```
  1    1   1   1    125.0000    5   190    0      1    999    4     1985   2020  #4
  1    2   2   1      8.0      0.1   20    0      1    999    4     1985   2020  #4
 # Gear-1
 1    3   1   2     84.00      5    150    0      1    999    4     1985   2020
 1    4   2   2      4.0000    0.1   20    0      1    999    4     1985   2020
# Gear-2
  2    5   1   0    165.0       5    190    0      1    999    4     1985   2020
  2    6   2   0     15.0000    0.1   25    0      1    999    4     1985   2020
# Gear-3
 3    7   1   1    103.275      5    190    1      103.275    30.98  4     1985   2020
 3    8   2   1      8.834      0.1   25    1      8.834      2.65   4     1985   2020
 3    9   1   2     91.178      5    190    1      91.178     27.35  4     1985   2020
 3   10   2   2      2.5        0.1   25    1      2.5        0.75   4     1985   2020
# Gear-4
  4   11   1   0    115.0       5    190    0      1    999    4     1985   2020  # dummy
  4   12   2   0    9.0        0.1   25    0      1    999    4     1985   2020
# Gear-5
  5   13   1   0     80.0      30   190    0      1    999    5     1985   2021  #5
  5   14   2   0     10.0      1    50    0      1    999    5     1985   2021  #5
## ---------------------------------------------------------------------------- ##
## Retained                                                  ##
## gear  par   sel                                   start  end        ##
## index index par sex  ival  lb    ub     prior   p1   p2     phz   period period      ##
## ---------------------------------------------------------------------------- ##
# Gear-1
  -1    25    1   1    135    1    999    0     1    999    4     1985   2004
  -1    26    2   1    2.0    1     20    0     1    999    4     1985   2004
  -1    27    1   1    140    1    999    0     1    999    4     2005   2020
  -1    28    2   1    2.5    1     20    0     1    999    4     2005   2020
  -1    29    1   2    591    1    999    0     1    999   -3     1985   2004
  -1    30    1   2    591    1    999    0     1    999   -3     2005   2020
# Gear-2
  -2    31    1   0    595    1    999    0     1    999   -3     1985   2020
# Gear-3
  -3    32    1   0    595    1    999    0     1    999   -3     1985   2020    #Dummy
# Gear-4
  -4    33    1   0    595    1    999    0     1    999   -3     1985   2020
# Gear-5
  -5    34    1   0    590    1    999    0     1    999   -3     1985   2021
## ---------------------------------------------------------------------------- ##
# Number of asyptotic parameters
1
# Fleet   Sex     Year       ival  lb   ub    phz
     1     1     1985   0.000001   0    1     -3
## ---------------------------------------------------------------------------- ##
## PRIORS FOR CATCHABILITY
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0                                  ##
## LEGEND                                                         ##
##     prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma              ##
## ---------------------------------------------------------------------------- ##
## ival     lb       ub    phz   prior  p1        p2    Analytic?   LAMBDA Emphasis
  0.896     0        2     6    1      0.896     0.03   0           1            1
```

```
## ———————————————————————————————————————————————————————————————————————— ##
## ———————————————————————————————————————————————————————————————————————— ##
## ADDITIONAL CV FOR SURVEYS/INDICES                                        ##
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0                               ##
## LEGEND                                                            ##
##     prior type: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma         ##
##  ————————————————————————————————————————————————————————————————————————————
##
## ival       lb       ub       phz   prior     p1      p2
   0.0001     0.00001   10.0     -4    4        1.0     100   # NMFS
## ——————————————————————————————————————————————————————————————————————————##
### Pointers to how the the additional CVs are used (0 ignore; >0 link to one of the parameters  !!!NEW 1/2022
1
## —————————————————————————————————————————————————————————————————————————————##
## PENALTIES FOR AVERAGE FISHING MORTALITY RATE FOR EACH GEAR
## ———————————————————————————————————————————————————————————————————————— ##
## Mean_F   Female Offset STD_PHZ1   STD_PHZ2   PHZ_M   PHZ_F
 # 0.22313        0.0505      0.5      45.50      1       1   # Pot
 # 0.0183156         1.0      0.5      45.50      1       -1   # Trawl
 # 0.011109          1.0      0.5      45.50      1       1   # Tanner (-1 -5)
 # 0.011109          1.0      0.5      45.50      1       -1   # Fixed
 # 0.00              0.0     2.00      20.00     -1      -1   # NMFS trawl survey (0 catch)
 # 0.00              0.0     2.00      20.00     -1      -1   # BSFRF (0)
 # 2.95                                       # Upper bound value for male directed fishig mortality deviations
   0.22313        0.0505      0.5      45.50      1       1     -12      4    -10   2.95     -10    10  # Pot
   0.0183156         1.0      0.5      45.50      1      -1     -12      4    -10     10     -10    10   # Trawl
   0.011109          1.0      0.5      45.50      1       1     -12      4    -10     10     -10    10   # Tanner (-1 -5)
   0.011109          1.0      0.5      45.50      1      -1     -12      4    -10     10     -10    10   # Fixed
   0.00              0.0     2.00      20.00     -1      -1     -12      4    -10     10     -10    10   # NMFS trawl survey (0 catch)
## ———————————————————————————————————————————————————————————————————————— ##
## ———————————————————————————————————————————————————————————————————————— ##
## OPTIONS FOR SIZE COMPOSTION DATA                                           ##
##     One column for each data matrix                                    ##
## LEGEND                                                            ##
##     Likelihood: 1 = Multinomial with estimated/fixed sample size                  ##
##               2 = Robust approximation to multinomial                      ##
##               3 = logistic normal (NIY)                               ##
##               4 = multivariate-t (NIY)                               ##
##               5 = Dirichlet                                     ##
## AUTO TAIL COMPRESSION                                                 ##
##     pmin is the cumulative proportion used in tail compression                    ##
## ———————————————————————————————————————————————————————————————————————— ##
#  Pot        Trawl   Tanner  Fixed   NMFS    BSFRF
   2   2   2   2   2   2   2   2   2   2   2   # Type of likelihood
   0   0   0   0   0   0   0   0   0   0   0   # Auto tail compression (pmin)
   1   1   1   1   1   1   1   1   1   1   1   # Initial value for effective sample size multiplier
  -4  -4  -4  -4  -4  -4  -4  -4  -4  -4  -4   # Phz for estimating effective sample size (if appl.)
   1   2   3   4   4   5   5   6   6   7   7   # Composition aggregator
   1   1   1   1   1   1   1   1   1   2   2   # Set to 2 for survey-like predictions; 1 for catch-like predictions !!!NEW 1/2022
   1   1   1   1   1   1   1   1   1   1   1   # LAMBDA
   1   1   1   1   1   1   1   1   1   1   1   # Emphasis AEP
## ——————————————————————————————————————————————————————————————————————##
```

```
## ———————————————————————————————————————————————————————————————— ##
## TIME VARYING NATURAL MORTALIIY RATES                                    ##
## LEGEND                                              ##
## Type: 0 = constant natural mortality                        ##
##      1 = Random walk (deviates constrained by variance in M)           ##
##      2 = Cubic Spline (deviates constrained by nodes & node-placement)        ##
##      3 = Blocked changes (deviates constrained by variance at specific knots)     ##
##      4 = Time blocks                                    ##
## ——————————————————————————————————————————————————————————————————— ##
## Type
6
## M is relative (YES=1; NO=0)
1
## Phase of estimation
3
## STDEV in m_dev for Random walk
0.25
## Number of nodes for cubic spline or number of step-changes for option 3
2
2
## Year position of the knots (vector must be equal to the number of nodes)
2015 2019
2015 2019
# number of breakpoints in M by size
0
## Specific initial values for the natural mortality devs (0-no, 1=yes)
1
## —————————————————————————————————————————————————————————————————— ##
## ival       lb       ub       phz   extra    prior    p1      p2        # parameter     ##
## —————————————————————————————————————————————————————————————————— ##
 0.40          0         2        8      0
 0.000000     -2         2       -99      0
 0.400         0         2        8      -1
 0.000000     -2         2       -99      0
## —————————————————————————————————————————————————————————————————— ##
##  ???????????????????????????????????????????? ##
##  TAGGING controls  CONTROLS                    !!!NEW 1/2022
##  ???????????????????????????????????????????? ##
1         # emphasis on tagging data
# maturity specific natural mortality? (yes = 1; no = 0; only for use if nmature > 1)
0
## ————————————————————————————————————————————————————————————————##
## ——————————————————————————————————————————————————————————##
## OTHER CONTROLS
## ——————————————————————————————————————————————————————————————————— ##
1985       # First rec_dev
2020       # last rec_dev
   2       # Estimated rec_dev phase
   2       # Estimated sex_ratio
 0.5       # initial sex-ratio
  -3       # Estimated rec_ini phase
   1       # VERBOSE FLAG (0 = off, 1 = on, 2 = objective func; 3 diagnostics)
   3      # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters, 3 = Free parameters (revised))
```

```
  1      # Lambda (proportion of mature male biomass for SPR reference points).
  0      # Stock-Recruit-Relationship (0 = none, 1 = Beverton-Holt)
  10      # Maximum phase (stop the estimation after this phase).
  -1      # Maximum number of function calls
  1      # Calculate reference points (0=no)      !!!NEW 1/2022
  200     # Year to compute equilibria             !!!NEW 1/2022
## ————————————————————————————————————————————————————————————————##
## EMPHASIS FACTORS (CATCH)
## ————————————————————————————————————————————————————————————————##
#Ret_male Disc_male Disc_female Disc_trawl Disc_Tanner_male Disc_Tanner_female Disc_fixed
      1        1          1         1              1                1         1
## EMPHASIS FACTORS (Priors) by fleet: fdev_total, Fdov_total, Fdev_year, Fdov_year   !!!NEW 1/2022
1 1 0 0 # Pot fishery
1 1 0 0 # Trawl   by-catch
1 1 0 0 # Tanner  by-catch
1 1 0 0 # Fixed  by-catch
1 1 0 0 # Trawl survey
## ————————————————————————————————————————————————————————————————##
## EMPHASIS FACTORS (Priors)
## ——————————————————————————————————————————————————————————————————————— ##
# Log_fdevs   meanF      Mdevs  Rec_devs Initial_devs Fst_dif_dev Mean_sex-Ratio    Fvecs Fdovs (!!!NEW for the
last two 1/2022)
     10000      0       1.0        2           0          0            10      0    0    0    0    0
## EOF
9999
```

Appendix D. Summary of the CIE Review of BBRKC in 2021

The virtual CIE review of the stock assessments for Bristol Bay red king crab and eastern Bering Sea snow crab was held online during March 22-26, 2021. The review was conducted by three independent experts: Drs. Yong Chen, Nick Caputi, and Billy Ernst. The review reports are at the end of this SAFE report. The followings are a brief summary of recommendations and plan to address these recommendations.

1. *Identifying the possible sources of the large retrospective patterns and/or develop alternative approaches to provide catch advice if retrospective patterns persistent and biased errors are too large for the assessments to be considered reliable. Conducted more studies to identify temporal trends and/or time blocks of parameters, such as natural mortality and survey catchability, to be incorporated in future stock assessments.*

Reply: Temporal changes in parameters may play an important role for the large retrospective patterns, and some data conflict between NMFS surveys and 2007-2008 and 2013-2016 BSFRF surveys also contributes to them. We used model 21.2 to add another time block (2018-2019) of natural mortality. The Mohn's rho value for mature male biomass decreases from 0.347 for model 19.3d to 0.223 for model 21.2. We will further examine the retrospective patterns and develop alternative model scenarios to reduce the retrospective patterns for the CPT meeting in January/May 2022. Potential changes in natural mortality over time play a big role for the large retrospective patterns during recent years, and additional time blocks of parameters for recent years will be further evaluated.

2. *Survey performance/efficacy and selectivity curve evaluations in term of changes in distributions over time, and the stock area evaluation.*

   Reply: We would like to examine red king crab north of the management area of Bristol Bay sometime in the future to see whether they are part of the BBRKC stock. Hopefully, a tagging study can be conducted to examine the link between red king crab in these two areas. We have not seen the need for evaluating different kinds of survey selectivity curves now since large-size crab are generally inside the survey area. Some limited genetic and larval transport studies were conducted on the stock area in the past.

3. *Surveying the red king crab juvenile crab abundance in nearshore locations may provide an estimate of younger juvenile abundance where the year-class is better defined.*

   Reply: We second this and have advocated this for a long time.

4. *Examining VAST results on effects on the stock assessment model.*

   Reply: We will continue to use VAST results as a model scenario to compare it to the other model scenarios.

5. *Evaluating commercial catch, effort, and CPUE for crab distributions, fishery performance, and population abundance relative to the trawl survey results and on impacts on survey timing and survey availability, and standardizing the CPUE for improvement, and conducting a depletion analysis.*

   Reply: Catch and bycatch are used in the model, the commercial CPUE is used to compare to the survey legal male abundance but not in the model, and fishing distributions and CPUE are often examined by ADF&G. The fishing season has been very short in the most years, so the depletion analysis may not be much useful. Trawl surveys generally cover all red king crab distribution areas except for nearshore areas. We just started CPUE standardization work and will try to incorporate the standardized CPUE in the assessment model in 2022.

6. *Extending estimates of sizes-at-50% maturity for females and examining the impacts of changes on mature female biomass estimates. Conducting a sensitivity study to examine impacts of changes at sizes-at-maturity for males on mature male biomass estimates.*

   Reply: We will update the estimates of sizes-at-50% maturity for females. Since the harvest strategy defines the sizes of mature females and males and the growth increments of males is not affected by changes in sizes-at-maturity, impacts of changes at sizes-at-maturity for males on mature male biomass estimates do not occur for the harvest strategy. The current defined size-at-maturity for males is for functional maturity and is much larger than the physiological mature sizes.

7. *A model run just using data from 1985 to avoid high natural mortality during the early 1980s.*

   Reply: We have planned to do this in 2022.

8. *Examining biological, environmental, and vessel performance data on the 2014 NMFS trawl survey to assess the survey abundance outlier and conducting a sensitivity study without the 2014 NMFS trawl survey data.*

   Reply: During the CIE review, we conducted this sensitivity study. The NMFS and BSFRF have examined biological, environmental, and vessel performance data on the 2014 NMFS trawl survey extensively. It is unlikely that we would drop this data point in the stock assessments since there are several data points in the survey time series that are as unexpected as the 2014 data.

9. *Important to continue environmental SAFE reports.*

   Reply: We agree and hopefully it will be updated annually.

10. *Besides overfished and overfishing, using MMB, recruitment, trends in commercial catch and CPUE, legal-size abundance and total survey biomass, and the projections and near future outlook to summarize the stock status.*

    Reply: We will add these in our summary of the stock status.

11. *Modeling double bag experiment and BSFRF side-by-side survey data to improve the catchability prior.*

Reply: This is a good suggestion. However, we do not use BSFRF side-by-side survey data to estimate the NMFS trawl catchability prior because we do not want to use these data twice since they are used in the model already.

12. *Conducting new tagging study to update the outdated tagging/return data used in the assessments.*

    Reply: We agree with this recommendation. Hopefully, tagging study will be conducted for BBRKC in the future.