BRISTOL BAY RED KING CRAB STOCK ASSESSMENT IN FALL 2021

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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 and 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/potlift (CUPE) has been much less than the retained catch, 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 and decreased precipitously in the early 1980s. Estimated mature crab abundance had 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 is below the state of Alaska harvest strategy threshold of 8.4 million of crab for 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	1.67

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 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.

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	3.68

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 NMFS trawl survey data through 2021.

b. Updated directed pot fishery catch and bycatch data through 2020 (i.e., completed 2020/21 fishery), and updated/standardized observer biomass estimates in the directed pot fishery and Tanner crab fishery from 1990 to 2020 (Appendix D).

c. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery are changed from east of 163^0 W to east of 166^0 W, which covers about the whole Bristol Bay red king crab stock. Five more years of length composition data with relatively small observed sample sizes from the Tanner crab fishery are also added (occurred in May 2021) (Appendix D).

d. Updated groundfish fisheries bycatch data during 2014-2020.

3. Changes to the assessment methodology:

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

b. Six models are compared in this report (See Section E.3.a for details) (the first four models are requested by the CPT and SSC and the last two models are added by the authors):

19.3d: the same as the base model 19.3 in September 2020 except for updating/standardizing the observer data in the directed pot and Tanner crab fisheries and changing the maximum cap of effective sample size from 100 to 150 for the retained catch and total males in the directed pot fishery. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery are changed from east of 163^0 W to east of 166^0 W, which covers about the whole Bristol Bay red king crab stock. Five more years of length composition data with relatively small observed sample sizes from the Tanner crab fishery are also included. The computed implied effective sample sizes for the retained catch and total males in the directed pot fishery in models 19.3 and 19.3c are close to 200 (Table 4).

19.3e: the same as model 19.3d except for males and females to have different NMFS trawl survey catchabilities. This model is similar to model 19.5 in May 2020 except for changes in model 19.3, 19.3c and 19.3d.

19.3g: the same as model 19.3d except for VAST-estimated NMFS survey trawl biomass and CV are used. This model is similar to model 19.4a in May 2020 except for the changes in models 19.3, 19.3c and 19.3d.

21.0 (suggested by the SSC): the same as model 19.3d except for estimating 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. For consistence, one selectivity curve is estimated for the BSFRF trawl survey as well.

21.1: the same as model 19.3d except for one shared catchability and selectivity curve for the NMFS trawl survey to help make several selectivity parameters better defined. For consistence, one selectivity curve is estimated for the BSFRF trawl survey as well.

21.2: the same as model 21.1 except for estimating additional time block (2018-2019) of natural mortality parameter. There is only one additional estimated parameter since the female natural mortality is relative to the male natural mortality.

4. Changes to assessment results:

Six model scenarios are compared in this draft report. As shown in May 2021, newly updated and standardized bycatch biomass and length composition estimates from the crab pot fisheries generally have only very minor impacts on the model results, and the minor impacts are likely caused by increasing length composition data from six years to eleven years and use of fishing effort from east of 163^0 W to east of 166^0 W in the Tanner crab fishery. Increasing the caps of effective sample sizes from 100 to 150 for retained and total male length compositions also affect very little on the model results.

Among the six models, models 19.3d, 19.3e, and 21.1 are very similar in terms of model results. Model 19.3e has different NMFS survey catchability parameters by sex, so one more parameter than model 19.3d. But model 19.3e does not statistically significantly improve the fit to the data.

Model 21.1 shares the same survey selectivity curves between sex and thus has six parameters less than model 19.3d. Model 21.1 fits the data just as good as model 19.3d. The VAST version of the model, model 19.3g, greatly reduces survey biomass CVs and has similar model results for most years as models 19.3d, 19.3e, 21.1, and 21.2, but results in higher estimated population biomasses during recent years than these four models due to higher estimates of NMFS survey biomasses by VAST. The 2014 NMFS survey seems to be an outlier (biased high); however, VAST results even bias higher. With the declining biomass trend during recent years, higher mature male biomass estimates during recent years with VAST model 19.3g would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 21.0, with a constant natural mortality over time and sex and one less parameter than model 21.1 and seven less than model 19.3d, generally fits the data poorly. With a sharp decline in survey abundance during the early 1980s, it is difficult to fit the data without increase in natural mortality for that period because the abundance decrease occurred for all size groups of crab and fishing selectivity was very low for small crab. Model 21.2 addresses the survey abundance decline during 2018-2019 through adding a time block of natural mortality and reduces the retrospective bias (Mohn's rho from 0.347 on mature male biomass for models 19.3d and 21.1 to 0.223 for model 21.2). Based on above consideration, we recommend model 21.1 as the base model for overfishing definition determination in September 2021 due to less parameters, less confounding, and acceptable data fittings.

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 October 2019):

"The SSC reminds authors to use the model numbering protocols that allows the SSC to understand the year in which a particular version of the model was first introduced. Also, when reporting bycatch in tables in each SAFE chapter, the SSC requests authors to be clear whether they report bycatch or bycatch mortality (DMRs have been applied). Further, when reporting bycatch mortality, it would be helpful to report the DMR values used."

Response: We have followed these recommendations.

"The SSC requests that the CPT consider developing a standard approach for projecting the upcoming year's biomass that does not include removing the entire OFL for stocks where recent mortality has been substantially below the OFL. This may appreciably change the projected biomass levels for stocks such as Tanner crab, where actual catch mortality has been less than 10% of the OFL."

Response: Agree to this request and will follow the standard approach developed by the CPT.

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 will 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.

"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. We will examine the retrospective patterns further in May 2022.

"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 B35% 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 2020):
“Include a table in the assessment document providing estimates of M for all scenarios.”

Response: Included them in Table 7.

“Include a table in the assessment document that provide the differences in likelihood values between the base model and each alternative model scenario considered a candidate for status determination.”

Response: Done (Table 5c).

“Evaluate different approaches to constraining the terminal year estimate of recruitment for the purpose of developing projections.”

Response: We plan to compare three approaches to constraining the terminal year estimate of recruitment for the purpose of developing projections: (1) average of recent low recruitment period excluding the terminal year (8 years), (2) average of the period used to estimate $B_{35\%}$, (3) increase in the weight on annual recruitment variation and sex ratio. Since the current GMACS version cannot carry work on (1) and (2), we examine only (3) in this report. As shown in the table below with model 19.3d, increasing weight on sex ratio (forcing them close to 50% each year) has some minor impacts on recruitment estimates in the terminal year, while increasing penalty on annual variation seems not to affect the model results. Overall, changes in penalties on recruitment deviation and sex ratio have very minor impacts on terminal recruitment estimates.

	Penalty values								
Scenario	Deviation	Sex ratio	Total Neg. LL	$B_{35\%}$	B_{2020}/ $B_{35\%}$	Male R_{2020}	Female R_{2020}	R neg. value	log.like. value
Base	2	10	-24735.8	25220.6	0.587	7747253	13422716	67.11	73.73
1	4	10	-24735.8	25220.6	0.587	7747255	13422727	67.11	73.73
2	4	20	-24735.8	25193.9	0.587	7691424	13404168	67.14	73.72
3	4	40	-24735.7	25149.4	0.588	7593412	13360860	67.19	73.70
4	8	10	-24735.8	25220.6	0.587	7747255	13422727	67.11	73.73
5	8	20	-24735.8	25193.9	0.587	7691424	13404168	67.14	73.72
6	8	40	-24735.7	25149.4	0.588	7593412	13360860	67.19	73.70
7	16	10	-24735.8	25220.6	0.587	7747255	13422727	67.11	73.73
8	16	20	-24735.8	25193.9	0.587	7691424	13404168	67.14	73.72
9	16	40	-24735.7	25149.4	0.588	7593412	13360860	67.19	73.70

10	2	100	-24735.5	25058.7	0.590	7376448	13239983	67.31	73.66
11	2	500	-24735.2	24874.1	0.594	6866432	12923606	67.61	73.61

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

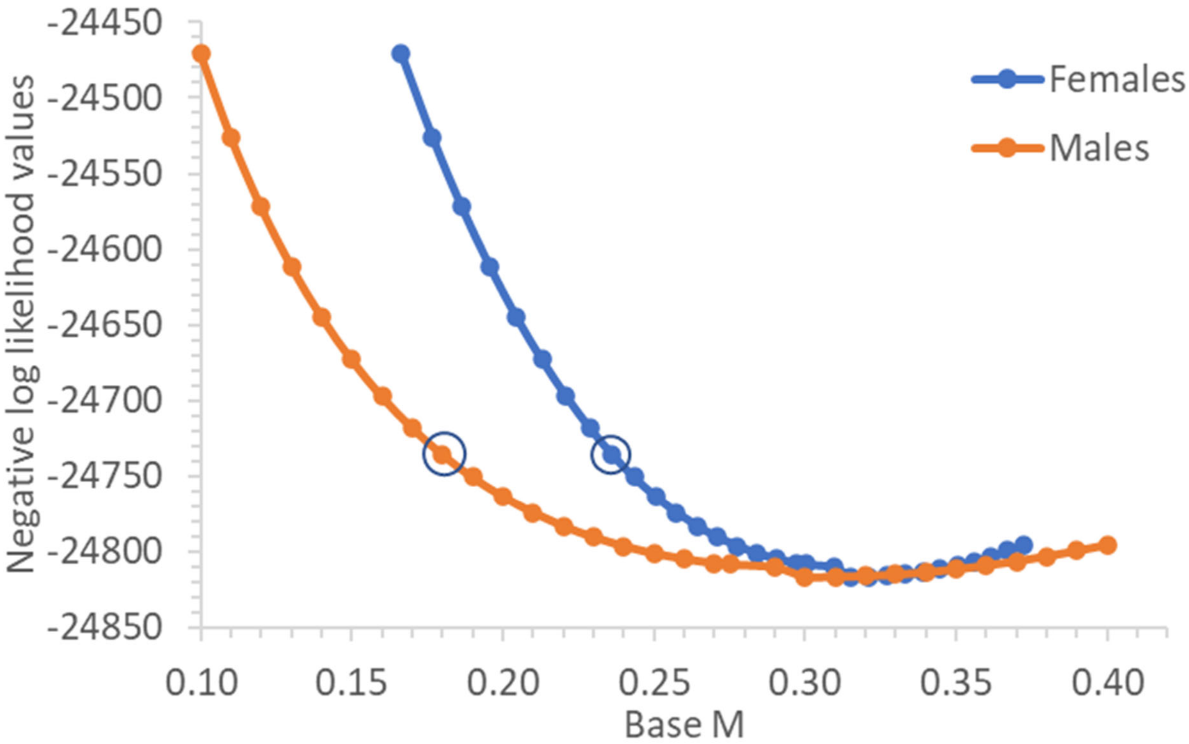
"The SSC supports exploring more modern methods for estimating natural mortality, but notes that this method still relies strongly on the maximum age for BBRKC. The SSC recommends continued research to validate the ages for this stock."

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, 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. We will conduct a retrospective analysis for model 19.6 and present compositional fit results in May 2022. 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 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 F.

Response to SSC Comments specific to this assessment (from October 2020):

"Next year's assessment should estimate the probability that the stock is currently in the overfished condition."

Response: Included it in Figure 31.

"Information should be provided on the prevalence of crab bycatch excluders being used in the pot cod fishery, and whether the excluders influence the length composition of bycatch."

Response: Will try to collect these data and analyze them in the future. Right now, very limited data are available.

"The SSC also endorses the Alaska Bering Sea Crabber's request to include raw numbers used for PSC limits in a table in the BBRKC SAFE consistent with EBS snow crab (see Table 11 in the EBS snow crab SAFE), if it is practical to do so."

Response: Included it in this report for years 2010-2021 in Table 8.

"The SSC looks forward to future analyses of the use of VAST estimates for this stock assessment including diagnostics and better-fitting error distributions."

Response: Included VAST results and diagnostics in Appendix E and used VAST-estimated survey biomass in two model scenarios (model 19.3g and 19.3i) in May 2021 and model 19.3g in September 2021. Comparison of area-swept and VAST estimates are summarized in Tables 3b and 3c.

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, historical guideline harvest levels (GHL) were 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 carapace length, 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, and 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 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 NMFS trawl survey data through 2021.

b. Updated directed pot fishery catch and bycatch data through 2020 (i.e., completed 2020/21 fishery), and updated/standardized observer biomass estimates in the directed pot fishery and Tanner crab fishery from 1990 to 2020 (Appendix D).

c. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery are changed from east of 163^0 W to east of 166^0 W, which covers the whole Bristol Bay red king crab stock. Five more years of length composition data with relatively small observed sample sizes from the Tanner crab fishery are also added (occurred in May 2021) (Appendix D).

d. Updated groundfish fisheries bycatch data during 2014-2020.

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 for 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 re-surveyed 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. 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. 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 carapace length 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, 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 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 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 carapace length 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):

19.3d: the same as the base model 19.3 in September 2020 except for updating/standardizing the observer data in the directed pot and Tanner crab fisheries and changing the maximum cap of effective sample size from 100 to 150 for the retained catch and total males in the directed pot fishery. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery are changed from east of 163^0 W to east of 166^0 W, which covers about the whole Bristol Bay red king crab stock. Five more years of length composition data with relatively small observed sample sizes from the Tanner crab fishery are also included. The computed implied effective sample sizes for the retained catch and total males in the directed pot fishery in four models are close to 200 (Table 4).

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.

19.3e: the same as model 19.3d except for males and females to have different NMFS trawl survey catchabilities. This model is similar to model 19.5 in May 2020 except for changes in model 19.3, 19.3c and 19.3d.

19.3g: the same as model 19.3d except for VAST-estimated NMFS survey trawl biomass and CV are used. This model is similar to model 19.4a in May 2020 except for the changes in models 19.3, 19.3c and 19.3d.

21.0: the same as model 19.3d except for estimating 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. For consistence, one selectivity curve is estimated for the BSFRF trawl survey as well.

21.1: the same as model 19.3d except for one shared catchability and selectivity curve for the NMFS trawl survey to help make several selectivity parameters better defined. For consistence, one selectivity curve is estimated for the BSFRF trawl survey as well.

21.2: the same as model 21.1 except for estimating additional time block (2018-2019) of natural mortality parameter. There is only one additional estimated parameter since the female natural mortality is relative to the male natural mortality.

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 *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 19.3d, 19.3e, 19.3g, 21.1, and 21.2 are summarized in Table 4.

b. Tables of estimates.

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

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

iii. Area-swept estimates of mature female abundance and model estimates of effective spawning biomass (Zheng et al. 1995b) during 2010-2021 for groundfish fisheries bycatch calculation are provided in Table 8.

iv. Abundance and biomass time series are provided in Tables 9a, 9b, 9c, and 9d for models 19.3d, 19.3g, 21.1, and 21.2.

v. Recruitment time series for models 19.3d, 19.3g, 21.1, and 21.2 are provided in Tables 9a, 9b, 9c, and 9d.

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, and 9d). 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 19.3d, 21.1, and 21.2).

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 19.3d, 21.1, and 21.2.

    One of the most important results is estimated trawl survey selectivity (Figures 8a, 8b, and 8c). 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. Among the models, model 21.0 with the highest estimated natural mortality in the large majority of years has the lowest NMFS survey selectivities, while the other five models have similar estimated survey selectivities.

    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 1985-2007, declined since 2007, and then have steadily declined since the late 2000s (Figures 10a-10c, 11a, and 11b). Absolute mature male biomasses for all models except for model 21.0 have a similar trend over time (Figures 11a and 11b). Among the six models, model estimated relative NMFS survey biomasses are similar for four models 19.3d, 19.3e, 21.1, and 21.2. Model 19.3g (VAST) has higher relative biomasses than these four models during the recent 20 years due to higher VAST estimates. Model 21.0 does not fit the survey biomass as well as the other five models. Absolute mature male biomass estimates are higher for model 21.0 during the late 1980s-mid-2010s and higher for model 19.3g during the recent 20 years than the other four models. As expected, model 21.2 has relatively low absolute mature male biomass estimates after 2017 due to high natural mortality during 2018-19. All six 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.

Among the six models, models 19.3d, 19.3e, and 21.1 are very similar in terms of model results. Model 19.3e has different NMFS survey catchability parameters by sex, so one more parameter than model 19.3d. But model 19.3e does not statistically significantly improve the fit to the data. Model 21.1 shares the same survey selectivity curves between sex and thus has six parameters less than model 19.3d. Model 21.1 fits the data just as good as model 19.3d. The VAST version of the model, model 19.3g, greatly reduces survey biomass CVs and has similar model results for most years as models 19.3d, 19.3e, 21.1, and 21.2, but results in higher estimated population biomasses during recent years than the other four models due to higher estimates of NMFS survey biomasses by VAST. The 2014 NMFS survey seems to be an outlier (biased high); however, VAST results even bias higher. With the declining biomass trend during recent years, higher mature male biomasses during recent years with VAST model 19.3g would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 21.0, with a constant natural mortality over time and sex and one less parameter than model 21.1 and seven less than model 19.3d, generally fits the data poorly. With a sharp decline in survey abundance during the early 1980s, it is difficult to fit the data without increase in natural mortality for that period because the abundance decrease occurred for all size groups of crab and fishing selectivity was very low for small crab. Model 21.2 addresses the survey abundance decline during 2018-2019 through adding a time block of natural mortality and reduces the retrospective bias (Mohn's rho from 0.347 on mature male biomass for models 19.3d and 21.1 to 0.223 for model 21.2). Based on above consideration, we recommend model 21.1 as the base model for overfishing definition determination in September 2021 due to less parameters, less confounding, and acceptable data fittings.

Like the results of model 19.3 in September 2020, the terminal year recruitment analysis with model 19.3d 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 19.3d, 21.1, and 21.0. 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 19.3d and 21.1 are similar and differ greatly from those for model 21.0 due to differences in natural morality. Estimated recruitments among models 19.3d, 19.3e, 19.3g, 21.1, and 21.2 are also similar.

iv. Estimated fishing mortality rates are plotted against mature male biomass in Figures 13a and 13b and estimated *M* and directed pot fishing mortality values over time are illustrated in Figure 13c for models 19.3d, 21.0, 21.1, and 21.2.

The average of estimated male recruits from 1984 to 2020 (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 and 13b). 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 19.3d and 21.1, but below the $F_{35\%}$ limits in the other post-1995 years.

For model 19.3d, estimated full pot fishing mortalities ranged from 0.00 to 2.18 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 21.1, estimated full pot fishing mortalities ranged from 0.00 to 2.27 during 1975-2020, with estimated values over 0.40 in the same years as model 19.3d. Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally small and less than 0.07.

For model 19.3d, estimated *M* values are 0.896 during 1980-1984 and 0.18 for the other years for males, and 1.200 during 1980-1984 and 0.241 for the other years for females, with estimated female *M* values equaling to 1.340 times male *M* values (Figure 13c). For model 21.1, estimated *M* values are 0.888 during 1980-1984 and 0.18 for the other years for males, and 1.178 during 1980-1984 and 0.239 for the other years for females, with estimated female *M* values equaling to 1.326 times male *M* values. Biologically, females mature earlier than males and likely have higher *M* values.

v. Estimated mature male biomass and recruitment are plotted to illustrate their relationships with model 19.3d (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.

   ii. Model fits to NMFS survey biomass are shown in Figure 10 with a standardized residual plot in Figures 17a, 17b, 17c, 17d, and 17e for models 19.3d, 19.3g, 21.0, 21.1, and 21.2.

   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 except for model 21.0 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 19.3d, 19.3e and 21.1 fit the NMFS area-swept biomass data almost identical (Figure 10a).

These five 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 models 19.3d, 19.3e, 19.3g, 21.1, and 21.2 (Figures 17a, 17b, 17c, 17d and 17e). Generally, residuals of proportions of survey males and females appear to be random over length and year for the above five models (Figures 25a, 25b, 25c, 25d, 26a, 26b, 26c, and 26d).

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. Models 19.3d and 21.1 have about the same patterns and produce some upward biases during 2009-2020 with higher terminal year estimates of mature male biomass in 2009-2010 and 2014-2020 (Figures 27-28). 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. 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

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 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. Model 21.2 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 (Figures 28d and 28f). Standard deviations of the ratios drop sharply from one year estimated in the model to two years (Figures 28e and 28g), 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 Table 6 for models 19.3d, 21.1, and 21.2. 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, 30b, 30c, 30d, 30e, 30f, 30g, and 30h for models 19.3d, 19.3g, 21.1 and 21.2 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 Figure 31 for models 19.3d, 19.3g, 21.1 and 21.2 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 model 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 (September 2021), six models are compared. For negative likelihood value comparisons (Tables 5b and 5c), model 21.2 has the highest total likelihood value due to the additional high natural morality block during 2018-2019, while the highest likelihood value without prior density is resulted from model 19.3d with a relatively high number of parameters. Model 21.0 does not fit the NMFS survey data well with a very low likelihood value. Model 19.3d has similar total likelihood value to model 19.3e.

Among the six models, models 19.3d, 19.3e, and 21.1 are very similar in terms of model results. Model 19.3e has different NMFS survey catchability parameters by sex, so one more parameter than model 19.3d. But model 19.3e does not statistically significantly improve the fit to the data. Model 21.1 shares the same survey selectivity curves between sex and thus has six parameters less than model 19.3d. Model 21.1 fits the data just as good as model 19.3d. The VAST version of the model, model 19.3g, greatly reduces survey biomass CVs and has similar model results for most years as models 19.3d, 19.3e, 21.1, and 21.2, but results in higher estimated population biomasses during recent years than these four models due to higher estimates of NMFS survey biomasses by VAST. The 2014 NMFS survey seems to be an outlier (biased high); however, VAST results even bias higher. With the declining biomass trend during recent years, higher mature male biomasses during recent years with VAST model 19.3g would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 21.0, with a constant natural mortality over time and sex and one less parameter than model 21.1 and seven less than model 19.3d, generally fits the data poorly. With a sharp decline in survey abundance during the early 1980s, it is difficult to fit the data without increase in natural mortality for that period because the abundance decrease occurred for all size groups of crab and fishing selectivity was very low for small crab. Model 21.2 addresses the survey abundance decline during 2018-2019 through adding a time block of natural mortality and reduces the retrospective bias (Mohn's rho from 0.347 on mature male biomass for models 19.3d and 21.1 to 0.223 for model 21.2). Based on above consideration, we recommend model 21.1 as the base model for overfishing definition determination in September 2021 due to less parameters, less confounding, and acceptable data fittings.

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

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

c) $\frac{B}{B^*} \le \beta$ $\quad$ 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 $0 \le \alpha \le \beta$. A default value of 0.1 is used.

Because trawl bycatch fishing mortality is not related to pot fishing mortality, average trawl bycatch fishing mortality during 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 last 15 years.

Average recruitment during 1984-2020 is used to estimate $B_{35\%}$ (Figure 12a). Estimated $B_{35\%}$ is compared with historical mature male biomass in Figure 13a. 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 current spawning stock is mainly in the middle of Bristol Bay. The 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 distribution of MMB in 2021 is illustrated in Figure 30. 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 close to overfished condition and lack of survey in 2020, the CPT recommended additional 5% buffer in September 2020, resulting in ABC = 0.75*OFL for 2020.

MCMC runs with 500,000 replicates and 500 draws with models 19.3d, 19.3g, 21.1, and 21.2 are used for estimating the probabilities of estimated mature male biomass below the minimum threshold (0.5*$B_{35\%}$) (Figure 31). The probabilities (converted to a percentage) is estimated to be about 0%, 0%, 0%, and 38.1%, respectively for these four 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	1.67

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 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	3.68

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 B35% 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% for 2020 due to lack of survey by the CPT, ABC = 0.75*OFL (Table 4). The 2020/21 buffer was used 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. Fishing mortality of 0.167 is about the same as the estimated F_{ofl} of 0.168 in 2021 with model 21.1. MCMC runs with 500,000 replicates and 500 draws are used for 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 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 19.3d, 19.3e, 19.3g, 21.1, and 21.2 (Table 10; Figure 32). A constant fishing mortality of 0.167 may increase the risk of "approaching an overfished condition" for model 21.2. With additional low recruitment used to compute $B_{35\%}$, the estimated MSST would decline further in 2022.

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 33). 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 33). No strong cohorts were observed in the survey data after this cohort through 2010 (Figure 33). 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 abundance 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 33). 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.

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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			
	U.S.	Cost-Recovery	Foreign	Total	Females	Trawl Bycatch	Fixed Bycatch	Tanner Fishery Bycatch
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	95.1	5.8	1.6
2010	6728.5	33.0	0	6761.5	118.5	83.3	2.4	0.0
2011	3553.3	53.8	0	3607.1	25.0	56.3	10.9	0.0
2012	3560.6	61.1	0	3621.7	11.2	34.2	18.4	0.0
2013	3901.1	89.9	0	3991.0	98.1	67.1	55.5	28.5
2014	4530.0	8.6	0	4538.6	84.9	34.8	118.8	42.0
2015	4522.3	91.4	0	4613.7	239.1	45.3	77.4	84.2
2016	3840.4	83.4	0	3923.9	123.4	67.5	28.9	0.0
2017	2994.1	99.6	0	3093.7	53.4	91.8	127.6	0.0
2018	1954.1	72.4	0	2026.5	150.1	78.4	148.1	0.0
2019	1719.8	55.5	0	1775.3	43.3	80.8	45.3	0.0
2020	1200.6	56.4	0	1257.0	15.2	82.5	8.8	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	118.906	11.616	6.499
2010	10095.400	592.600	104.086	4.736	0.000
2011	5665.300	124.800	70.419	21.706	0.000
2012	4495.500	55.900	42.786	36.895	0.000
2013	5305.900	490.700	83.868	110.970	113.063
2014	8113.800	424.300	43.460	237.651	137.786
2015	6726.800	1195.600	56.686	154.810	639.573
2016	5651.800	617.200	84.338	57.888	0.000
2017	4077.200	266.900	114.782	255.155	0.000
2018	3423.200	750.400	97.998	296.188	0.000
2019	3144.600	218.000	100.999	90.567	0.000
2020	2299.700	76.100	103.098	17.517	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			631		
1989	764	403	32,858			4,706		
1990	729	535	7,218	2,544	696	1,131		
1991	1,180	490	36,928	4,696	375	326		3,131
1992	509	357	25,550	4,775	2,379	440		965
1993	725	576	32,942	10,200	5,944	27		497
1994	416	239	0	0	0	572		17
1995	685	407	0	0	0	160		
1996	755	753	8,896	642	11	1,226	780	
1997	1,280	702	16,143	10,016	906	349	1,296	
1998	1,067	1,123	17,116	24,537	9,655	1,445	1,091	
1999	765	618	18,685	6,892	40	643	2,225	
2000	734	730	14,143	32,709	8,470	734	884	
2001	599	736	13,735	25,135	5,436	802	5,048	
2002	972	826	16,837	32,317	706	1,142	3,555	
2003	1,360	1,250	18,178	44,600	12,474	525	2,001	
2004	1,852	1,271	22,465	38,772	6,666	666	2,498	
2005	1,198	1,563	27,971	94,622	26,782	1,043	2,642	
2006	1,178	1,432	18,451	73,315	3,991	1,180	2,260	140
2007	1,228	1,305	22,809	115,507	12,691	1,265	852	53
2008	1,228	1,183	24,997	89,771	8,564	1,609	1,164	145
2009	837	941	19,336	97,868	6,055	1,188	1,089	193
2010	708	1,004	20,347	69,276	6,872	907	548	
2011	531	912	10,904	42,931	1,920	443	1,191	
2012	585	707	9,084	21,404	563	282	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	614	4,332	
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	822	864	
2020			3,850	16,650	961	622	251	
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 19.3d, 19.3g, 21.1, and 21.2.

	Model 193d		Model 193.g		Model 21.1		Model 21.2	
	Harm.S	N	Harm.S	N	Harm.S	N	Harm.S	N
Retained catch	166.7	150	165.0	150	169.6	150	170.6	150
Pot total males	231.5	150	217.1	150	232.4	150	232.7	150
Pot total females	28.8	50	28.5	50	28.8	50	28.9	50
Trawl bycatch	60.9	50	61.9	50	60.5	50	61.7	50
Tanner fishery bycatch	25.8	50	25.9	50	25.7	50	25.8	50
Fixed gear bycatch	45.8	50	44.9	50	45.5	50	45.7	50
NMFS survey	179.0	200	175.6	200	177.3	200	177.2	200
BSFRF survey	129.7	200	129.9	200	120.8	200	120.3	200

Table 5a. Number of parameters for the model (Models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2). Red values indicate different values among models.

Parameter counts	**19.3d**	**19.3e**	**19.3g**	**21.0**	**21.1**	**21.2**
Fixed growth parameters	9	9	9	9	9	9
Fixed recruitment parameters	2	2	2	2	2	2
Fixed length-weight relationship parameters	6	6	6	6	6	6
Fixed mortality parameters	5	5	5	4	5	5
Fixed survey catchability parameter	1	1	1	1	1	1
Fixed high grading parameters	0	0	0	0	0	0
Total number of fixed parameters	23	23	23	22	23	23
Free survey catchability parameter	1	2	1	1	1	1
Free growth parameters	6	6	6	6	6	6
Initial abundance (1975)	1	1	1	1	1	1
Recruitment-distribution parameters	2	2	2	2	2	2
Mean recruitment parameters	1	1	1	1	1	1
Male recruitment deviations	46	46	46	46	46	46
Female recruitment deviations	46	46	46	46	46	46
Natural mortality parameters	2	2	2	1	2	3
Mean & offset fishing mortality parameters	6	6	6	6	6	6
Pot male fishing mortality deviations	46	46	46	46	46	46
Bycatch mortality from the Tanner crab fishery	50	50	50	50	50	50
Pot female bycatch fishing mortality deviations	31	31	31	31	31	31
Trawl bycatch fishing mortality deviations	45	45	45	45	45	45
Fixed gear bycatch fishing mortality deviations	25	25	25	25	25	25
Initial (1975) length compositions	35	35	35	35	35	35
Survey extra CV	1	1	1	1	1	1
Free selectivity parameters	28	28	28	22	22	22
Total number of free parameters	372	373	372	365	366	367
Total number of fixed and free parameters	395	396	395	387	389	390

Table 5b. Negative log likelihood components for Models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2 and some management quantities. Highlighted cells in yellow color show prior density values and total negative likelihood values without prior density. Highlighted cells in red color show values not comparable to the other models.

	Models					
	19.3d	19.3e	19.3g	20.0	21.1	21.2
Pot-ret-catch	-59.59	-59.21	-52.90	-60.47	-59.74	-59.73
Pot-totM-catch	27.90	28.68	32.44	20.47	27.61	27.60
Pot-F-discC	-53.95	-53.96	-53.94	-53.90	-53.95	-53.95
Trawl-discC	-62.37	-62.37	-62.35	-61.78	-62.36	-62.36
Tanner-M-discC	-43.54	-43.54	-43.54	-43.53	-43.54	-43.54
Tanner-F-discC	-43.48	-43.48	-43.47	-21.47	-43.48	-43.47
Fixed-discC	-34.65	-34.65	-34.65	-34.65	-34.65	-34.65
Traw-suv-bio	-34.66	-30.57	117.60	82.38	-34.10	-38.81
BSFRF-sur-bio	-3.43	-3.84	-5.79	-3.85	-3.40	-4.08
Pot-ret-comp	-3871.79	-3872.05	-3873.16	-3876.30	-3872.23	-3872.84
Pot-totM-comp	-2301.77	-2301.08	-2297.08	-2300.31	-2302.59	-2302.64
Pot-discF-comp	-1395.01	-1394.97	-1393.02	-1387.87	-1394.84	-1395.02
Trawl-disc-comp	-5712.62	-5712.65	-5716.18	-5598.54	-5714.29	-5716.37
TC-disc-comp	-1275.92	-1275.68	-1273.77	-1277.98	-1275.74	-1275.91
Fixed-disc-comp	-3291.18	-3291.12	-3285.99	-3274.23	-3290.39	-3289.60
Trawl-sur-comp	-6855.26	-6853.95	-6848.57	-6587.49	-6847.63	-6844.54
BSFRF-sur-comp	-850.21	-849.64	-849.69	-790.02	-844.38	-843.74
Recruit-dev	68.69	68.62	69.30	56.81	69.20	69.32
Recruit-sex-R	75.61	75.66	75.65	76.01	75.35	75.36
Log_fdev=0	0.00	0.00	0.00	0.18	0.00	0.00
M-deviation	44.09	44.06	44.44	0.00	43.88	45.68
Sex-specific-R	0.13	0.14	0.20	0.13	0.01	0.01
Ini-size-struct.	31.86	31.62	31.08	28.73	30.60	30.67
PriorDensity	297.95	293.59	295.23	233.24	267.59	265.61
Tot-likelihood	-25343.2	-25344.5	-25168.1	-24874.4	-25363.1	-25367.0
Tot-likeli-no-PD	-25641.2	-25638.1	-25463.3	-25107.6	-25630.7	-25632.6
Tot-parameter	372	373	372	365	366	367
MMB$_{35\%}$	24707.6	25067.8	25449.3	16606.1	24236.5	24450.2
MMB-terminal	14874.0	15466.8	16791.5	9345.92	14946.7	12631.0
F$_{35\%}$	0.292	0.293	0.294	0.730	0.293	0.292
F$_{ofl}$	0.163	0.169	0.183	0.375	0.168	0.135
OFL	2151.73	2311.14	2768.39	2655.35	2225.06	1518.38
ABC	1613.80	1733.36	2076.29	1991.51	1668.80	1138.79
Q-male	0.967	0.925	0.957	0.998	0.964	0.963
Q-female	0.967	0.944	0.957	0.998	0.964	0.963

Table 5c. Differences of negative log likelihood components and some management quantities between model 19.3d and models 19.3e, 19.3g, 21.0, 21.1, and 21.2, and between models 21.1 and 21.2. Highlighted cells in red color show values not comparable to the other models.

	19.3d-19.3e	19.3d-19.3g	19.3d-21.0	19.3d-21.1	19.3d-21.2	21.1-21.2
Pot-ret-catch	-0.38	-6.69	0.87	0.15	0.14	-0.02
Pot-totM-catch	-0.78	-4.54	7.43	0.29	0.30	0.01
Pot-F-discC	0.00	-0.01	-0.05	0.00	-0.01	0.00
Trawl-discC	0.00	-0.02	-0.59	0.00	0.00	0.00
Tanner-M-discC	0.00	0.00	-0.01	0.00	0.00	0.00
Tanner-F-discC	0.00	-0.01	-22.01	0.00	-0.01	-0.01
Fixed-discC	0.00	0.00	0.00	0.00	0.00	0.00
Traw-suv-bio	-4.09	-152.26	-117.04	-0.55	4.15	4.71
BSFRF-sur-bio	0.42	2.37	0.42	-0.03	0.66	0.69
Pot-ret-comp	0.26	1.37	4.51	0.44	1.05	0.61
Pot-totM-comp	-0.69	-4.69	-1.46	0.82	0.87	0.05
Pot-discF-comp	-0.04	-1.99	-7.14	-0.17	0.01	0.18
Trawl-disc-comp	0.03	3.56	-114.08	1.67	3.75	2.08
Tanner-disc-comp	-0.24	-2.15	2.06	-0.18	-0.01	0.17
Fixed-disc-comp	-0.06	-5.19	-16.95	-0.79	-1.58	-0.79
Trawl-sur-comp	-1.31	-6.69	-267.77	-7.63	-10.72	-3.09
BSFRF-sur-comp	-0.57	-0.52	-60.19	-5.83	-6.47	-0.65
Recruit-dev	0.07	-0.61	11.88	-0.52	-0.64	-0.12
Recruit-sex-R	-0.04	-0.04	-0.40	0.26	0.25	-0.01
Log_fdev=0	0.00	0.00	-0.18	0.00	0.00	0.00
M-deviation	0.02	-0.35	44.09	0.21	-1.59	-1.80
Sex-specific-R	0.00	-0.07	0.00	0.12	0.13	0.00
Ini-size-structure	0.24	0.78	3.13	1.26	1.19	-0.07
PriorDensity	4.36	2.72	64.71	30.37	32.35	1.98
Tot-likelihood	1.30	-175.10	-468.80	19.90	23.80	3.90
Tot-like-no-PD	-3.06	-177.82	-533.51	-10.47	-8.55	1.92
Tot-parameter	-1.00	0.00	7.00	6.00	5.00	-1.00
MMB$_{35\%}$	-360.16	-741.74	8101.48	471.08	257.35	-213.72
MMB-terminal	-592.83	-1917.50	5528.05	-72.69	2242.98	2315.67
F$_{35\%}$	0.00	0.00	-0.44	0.00	0.00	0.00
F$_{ofl}$	-0.01	-0.02	-0.21	0.00	0.03	0.03
OFL	-159.41	-616.66	-503.62	-73.33	633.35	706.68
ABC	-119.56	-462.49	-377.71	-55.00	475.01	530.01
Q-male	0.04	0.01	-0.03	0.00	0.00	0.00
Q-female	0.02	0.01	-0.03	0.00	0.00	0.00

Table 6a. Summary of estimated model parameter values and standard deviations for model 19.3d for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2926	0.0148	47	log_slx_pars[1]	4.7482	0.0080
2	theta[4]	19.8760	0.0557	48	log_slx_pars[2]	2.2575	0.0483
3	theta[5]	16.2370	0.1399	49	log_slx_pars[3]	4.5114	0.0174
4	theta[7]	0.7454	0.1418	50	log_slx_pars[4]	2.0532	0.1144
5	theta[9]	-0.5692	0.2507	51	log_slx_pars[5]	5.1580	0.0588
6	theta[13]	0.9493	0.3725	52	log_slx_pars[6]	2.8564	0.0460
7	theta[14]	0.5946	0.4189	53	log_slx_pars[7]	4.7184	0.2133
8	theta[15]	0.7985	0.3162	54	log_slx_pars[8]	2.1621	0.3066
9	theta[16]	0.6615	0.2973	55	log_slx_pars[9]	4.7278	0.0841
10	theta[17]	0.5082	0.2935	56	log_slx_pars[10]	0.9009	0.3028
11	theta[18]	0.4730	0.2790	57	log_slx_pars[11]	4.7980	0.0244
12	theta[19]	0.3238	0.2801	58	log_slx_pars[12]	2.3530	0.0879
13	theta[20]	0.3638	0.2662	59	log_slx_pars[13]	3.4992	1.0849
14	theta[21]	0.3957	0.2608	60	log_slx_pars[14]	3.9120	0.0103
15	theta[22]	0.1695	0.2835	61	log_slx_pars[15]	4.1659	0.1878
16	theta[23]	0.1440	0.2789	62	log_slx_pars[16]	3.2632	0.3175
17	theta[24]	0.0349	0.2885	63	log_slx_pars[17]	4.0974	0.2321
18	theta[25]	0.1530	0.2616	64	log_slx_pars[18]	2.1856	0.4630
19	theta[26]	-0.0298	0.2027	65	log_slx_pars[19]	3.7443	250.10
20	theta[27]	-0.2606	0.1963	66	log_slx_pars[20]	0.3169	424.23
21	theta[28]	-0.4176	0.1988	67	log_slx_pars[21]	4.3622	0.0360
22	theta[29]	-0.7644	0.2123	68	log_slx_pars[22]	2.3230	0.1225
23	theta[30]	-1.2234	0.2328	69	log_slx_pars[23]	4.4918	0.0127
24	theta[31]	-1.2741	0.2356	70	log_slx_pars[24]	2.4909	0.0654
25	theta[52]	1.0452	1.2012	71	log_slx_pars[25]	4.9208	0.0015
26	theta[53]	1.6257	0.5396	72	log_slx_pars[26]	0.6757	0.0540
27	theta[54]	1.5979	0.3992	73	log_slx_pars[27]	4.9290	0.0019
28	theta[55]	1.3262	0.3490	74	log_slx_pars[28]	0.6636	0.1041
29	theta[56]	1.1438	0.3137	75	log_fbar[1]	-1.4921	0.0417
30	theta[57]	0.6034	0.3443	76	log_fbar[2]	-4.2775	0.0762
31	theta[58]	0.2245	0.3669	77	log_fbar[3]	-5.6050	0.2824
32	theta[59]	-0.0114	0.3666	78	log_fbar[4]	-6.5973	0.0780
33	theta[60]	-0.1981	0.3532	79	log_fdev[1]	0.7021	0.1195
34	theta[61]	-0.5366	0.3705	80	log_fdev[1]	0.6712	0.0928
35	theta[62]	-0.9254	0.3809	81	log_fdev[1]	0.5850	0.0753
36	theta[63]	-1.1852	0.3856	82	log_fdev[1]	0.6872	0.0605
37	theta[64]	-1.4168	0.3842	83	log_fdev[1]	0.9102	0.0544
38	theta[65]	-1.7989	0.3735	84	log_fdev[1]	1.7839	0.0580
39	theta[66]	-1.9049	0.3696	85	log_fdev[1]	2.2712	0.1220
40	theta[67]	-1.8446	0.3484	86	log_fdev[1]	0.6368	0.1635
41	Grwth[21]	0.9493	0.1862	87	log_fdev[1]	-9.0468	0.1127
42	Grwth[42]	1.4119	0.1220	88	log_fdev[1]	1.0334	0.1039
43	Grwth[85]	141.920	1.7585	89	log_fdev[1]	1.1238	0.0891
44	Grwth[86]	0.0605	0.0108	90	log_fdev[1]	1.2820	0.0733
45	Grwth[87]	139.890	0.6148	91	log_fdev[1]	0.8216	0.0639

46	Grwth[88]	0.0721	0.0034	92	log_fdev[1]	-0.1073	0.0529
93	log_fdev[1]	0.0161	0.0476	143	log_fdev[2]	-0.5765	0.1049
94	log_fdev[1]	0.6651	0.0392	144	log_fdev[2]	-0.8645	0.1035
95	log_fdev[1]	0.6765	0.0420	145	log_fdev[2]	-0.7979	0.1036
96	log_fdev[1]	0.1555	0.0465	146	log_fdev[2]	-1.2627	0.1035
97	log_fdev[1]	0.8185	0.0510	147	log_fdev[2]	0.0371	0.1038
98	log_fdev[1]	-4.3369	0.0484	148	log_fdev[2]	-0.2369	0.1036
99	log_fdev[1]	-4.7432	0.0419	149	log_fdev[2]	-0.9938	0.1030
100	log_fdev[1]	-0.2703	0.0406	150	log_fdev[2]	-0.2239	0.1028
101	log_fdev[1]	-0.2217	0.0409	151	log_fdev[2]	-0.5223	0.1026
102	log_fdev[1]	0.6901	0.0433	152	log_fdev[2]	-0.6140	0.1023
103	log_fdev[1]	0.3405	0.0423	153	log_fdev[2]	-0.3799	0.1023
104	log_fdev[1]	-0.2408	0.0409	154	log_fdev[2]	-0.6561	0.1022
105	log_fdev[1]	-0.3189	0.0404	155	log_fdev[2]	-0.4881	0.1019
106	log_fdev[1]	-0.2073	0.0393	156	log_fdev[2]	-0.4138	0.1020
107	log_fdev[1]	0.2585	0.0380	157	log_fdev[2]	-0.4450	0.1022
108	log_fdev[1]	0.2199	0.0381	158	log_fdev[2]	-0.8056	0.1023
109	log_fdev[1]	0.5074	0.0385	159	log_fdev[2]	-0.9602	0.1024
110	log_fdev[1]	0.2570	0.0379	160	log_fdev[2]	-1.4240	0.1022
111	log_fdev[1]	0.6198	0.0378	161	log_fdev[2]	-1.9452	0.1024
112	log_fdev[1]	0.7876	0.0398	162	log_fdev[2]	-1.2345	0.1028
113	log_fdev[1]	0.5935	0.0405	163	log_fdev[2]	-1.7998	0.1033
114	log_fdev[1]	0.4572	0.0398	164	log_fdev[2]	-1.4273	0.1046
115	log_fdev[1]	-0.1781	0.0388	165	log_fdev[2]	-0.9149	0.1068
116	log_fdev[1]	-0.2521	0.0383	166	log_fdev[2]	-0.4943	0.1099
117	log_fdev[1]	-0.0691	0.0387	167	log_fdev[2]	-0.5662	0.1129
118	log_fdev[1]	0.2528	0.0402	168	log_fdev[2]	-0.4815	0.1162
119	log_fdev[1]	0.3142	0.0441	169	log_fdev[2]	-0.4855	0.1184
120	log_fdev[1]	0.2975	0.0513	170	log_fdev[3]	-0.1164	0.0682
121	log_fdev[1]	0.1879	0.0613	171	log_fdev[3]	0.6699	0.0682
122	log_fdev[1]	-0.0209	0.0715	172	log_fdev[3]	1.2285	0.0682
123	log_fdev[1]	-0.0919	0.0793	173	log_fdev[3]	1.0928	0.0682
124	log_fdev[1]	-0.5185	0.0822	174	log_fdev[3]	1.3825	0.0682
125	log_fdev[2]	0.1562	0.1258	175	log_fdev[3]	1.4242	0.0682
126	log_fdev[2]	0.5977	0.1170	176	log_fdev[3]	0.9927	0.0682
127	log_fdev[2]	0.5807	0.1107	177	log_fdev[3]	0.4764	0.0682
128	log_fdev[2]	0.6570	0.1090	178	log_fdev[3]	-0.9874	0.0682
129	log_fdev[2]	1.3588	0.1122	179	log_fdev[3]	-0.5788	0.0682
130	log_fdev[2]	1.0902	0.1293	180	log_fdev[3]	-1.0994	0.0682
131	log_fdev[2]	2.3832	0.1277	181	log_fdev[3]	-0.2563	0.0682
132	log_fdev[2]	2.1294	0.1163	182	log_fdev[3]	0.9401	0.0682
133	log_fdev[2]	3.3709	0.1149	183	log_fdev[3]	1.4181	0.0682
134	log_fdev[2]	2.1781	0.1116	184	log_fdev[3]	3.2520	0.0757
135	log_fdev[2]	1.1123	0.1113	185	log_fdev[3]	1.2924	0.0951
136	log_fdev[2]	0.6597	0.1088	186	log_fdev[3]	0.5855	0.1150
137	log_fdev[2]	1.4380	0.1046	187	log_fdev[3]	-0.7515	0.0836
138	log_fdev[2]	0.0089	0.1037	188	log_fdev[3]	-2.1204	0.0732
139	log_fdev[2]	0.4625	0.1038	189	log_fdev[3]	-2.9780	0.0945
140	log_fdev[2]	0.8846	0.1051	190	log_fdev[3]	-2.4063	0.1108

141	log_fdev[2]	0.7178	0.1053	191	log_fdev[3]	-3.4926	0.0744
142	log_fdev[2]	1.1912	0.1079	192	log_fdev[3]	-0.8564	0.0925
193	log_fdev[3]	-0.1406	0.1091	243	log_fdov[1]	-1.0473	0.0784
194	log_fdev[3]	1.0289	0.1305	244	log_fdov[1]	-1.7660	0.0781
195	log_fdev[4]	0.6645	0.1033	245	log_fdov[1]	0.2600	0.0781
196	log_fdev[4]	0.0076	0.1021	246	log_fdov[1]	-0.1384	0.0784
197	log_fdev[4]	-0.2006	0.1025	247	log_fdov[1]	0.9314	0.0794
198	log_fdev[4]	0.7212	0.1018	248	log_fdov[1]	0.3999	0.0817
199	log_fdev[4]	-1.7089	0.1013	249	log_fdov[1]	-0.2297	0.0855
200	log_fdev[4]	0.2468	0.1009	250	log_fdov[1]	1.1187	0.0904
201	log_fdev[4]	-0.0092	0.1005	251	log_fdov[1]	0.0635	0.0942
202	log_fdev[4]	-0.8419	0.1004	252	log_fdov[1]	-0.4509	0.0959
203	log_fdev[4]	-0.6674	0.1002	253	log_fdov[3]	0.0000	0.0962
204	log_fdev[4]	-0.3933	0.1000	254	log_fdov[3]	0.0001	0.0962
205	log_fdev[4]	-0.4425	0.0998	255	log_fdov[3]	0.0001	0.0963
206	log_fdev[4]	0.1030	0.0997	256	log_fdov[3]	0.0001	0.0963
207	log_fdev[4]	-0.5993	0.1001	257	log_fdov[3]	0.0003	0.0963
208	log_fdev[4]	-1.6013	0.0999	258	log_fdov[3]	0.0000	0.0963
209	log_fdev[4]	-2.4841	0.0994	259	log_fdov[3]	-0.0002	0.0963
210	log_fdev[4]	-0.9657	0.0991	260	log_fdov[3]	-0.0002	0.0962
211	log_fdev[4]	-0.4127	0.0992	261	log_fdov[3]	-0.0001	0.0962
212	log_fdev[4]	0.7310	0.0993	262	log_fdov[3]	-0.0001	0.0962
213	log_fdev[4]	1.5714	0.0996	263	log_fdov[3]	-0.0001	0.0962
214	log_fdev[4]	1.2464	0.1003	264	log_fdov[3]	0.0001	0.0962
215	log_fdev[4]	0.3815	0.1016	265	log_fdov[3]	0.0003	0.0962
216	log_fdev[4]	1.9834	0.1035	266	log_fdov[3]	0.0009	0.0963
217	log_fdev[4]	2.2116	0.1052	267	log_fdov[3]	1.5178	0.1410
218	log_fdev[4]	1.0573	0.1071	268	log_fdov[3]	1.8067	0.1190
219	log_fdev[4]	-0.5991	0.1094	269	log_fdov[3]	0.5874	0.1363
220	log_foff[1]	-2.8599	0.0410	270	log_fdov[3]	-3.4319	0.1094
221	log_foff[3]	-0.1593	0.4089	271	log_fdov[3]	-2.1715	0.1520
222	log_fdov[1]	2.0545	0.0836	272	log_fdov[3]	-0.7962	0.1228
223	log_fdov[1]	-0.6139	0.0828	273	log_fdov[3]	0.0340	0.1312
224	log_fdov[1]	2.0658	0.0841	274	log_fdov[3]	0.3805	0.1022
225	log_fdov[1]	1.9068	0.0857	275	log_fdov[3]	0.9653	0.1529
226	log_fdov[1]	-0.3216	0.0843	276	log_fdov[3]	0.1832	0.1422
227	log_fdov[1]	-0.0967	0.0823	277	log_fdov[3]	0.9234	0.1654
228	log_fdov[1]	-3.6002	0.0812	278	rec_dev_est	1.1669	0.2917
229	log_fdov[1]	-0.2323	0.0819	279	rec_dev_est	0.7591	0.2997
230	log_fdov[1]	1.5548	0.0819	280	rec_dev_est	1.1895	0.2428
231	log_fdov[1]	-2.6847	0.0811	281	rec_dev_est	1.7932	0.2106
232	log_fdov[1]	1.2390	0.0804	282	rec_dev_est	2.0362	0.2257
233	log_fdov[1]	0.9637	0.0803	283	rec_dev_est	1.1490	0.2708
234	log_fdov[1]	-1.7842	0.0798	284	rec_dev_est	2.4162	0.1658
235	log_fdov[1]	1.2972	0.0799	285	rec_dev_est	1.4612	0.1808
236	log_fdov[1]	0.4990	0.0800	286	rec_dev_est	1.0698	0.1682
237	log_fdov[1]	1.0319	0.0795	287	rec_dev_est	-0.8083	0.2560
238	log_fdov[1]	-1.1514	0.0790	288	rec_dev_est	0.3026	0.1652
239	log_fdov[1]	-0.1123	0.0790	289	rec_dev_est	-0.8287	0.2429

240	log_fdov[1]	-0.3763	0.0794	290	rec_dev_est	-1.2703	0.2778
241	log_fdov[1]	-0.6345	0.0796	291	rec_dev_est	-1.0311	0.2272
242	log_fdov[1]	-0.1496	0.0793	292	rec_dev_est	-0.0598	0.1652
293	rec_dev_est	-0.5276	0.1859	339	logit_rec_prop_es	0.1389	0.2440
294	rec_dev_est	-2.0275	0.3677	340	logit_rec_prop_es	0.7356	0.7742
295	rec_dev_est	-0.8966	0.1992	341	logit_rec_prop_es	0.1703	0.2833
296	rec_dev_est	-2.0573	0.4365	342	logit_rec_prop_es	-0.2939	0.7188
297	rec_dev_est	0.9723	0.1488	343	logit_rec_prop_es	-0.3295	0.0930
298	rec_dev_est	-0.9394	0.2626	344	logit_rec_prop_es	1.3175	0.6817
299	rec_dev_est	-1.6030	0.3420	345	logit_rec_prop_es	0.4167	0.6537
300	rec_dev_est	-0.5926	0.2010	346	logit_rec_prop_es	0.4297	0.3208
301	rec_dev_est	0.3973	0.1575	347	logit_rec_prop_es	-0.0901	0.1436
302	rec_dev_est	-0.5653	0.2236	348	logit_rec_prop_es	0.2065	0.3604
303	rec_dev_est	-0.5643	0.2432	349	logit_rec_prop_es	-0.6116	0.3847
304	rec_dev_est	0.8497	0.1557	350	logit_rec_prop_es	-0.5063	0.1271
305	rec_dev_est	-0.6220	0.2660	351	logit_rec_prop_es	-0.4408	0.4245
306	rec_dev_est	-0.7113	0.2707	352	logit_rec_prop_es	-0.0889	0.4469
307	rec_dev_est	0.6014	0.1582	353	logit_rec_prop_es	-0.4127	0.1403
308	rec_dev_est	-0.1367	0.1853	354	logit_rec_prop_es	-0.1075	0.2415
309	rec_dev_est	-0.5230	0.1920	355	logit_rec_prop_es	0.2423	0.2812
310	rec_dev_est	-1.0926	0.2398	356	logit_rec_prop_es	-0.2391	0.3712
311	rec_dev_est	-0.9704	0.2383	357	logit_rec_prop_es	-0.4650	0.3594
312	rec_dev_est	0.0054	0.1807	358	logit_rec_prop_es	-0.8243	0.1979
313	rec_dev_est	-0.5290	0.2233	359	logit_rec_prop_es	-0.4356	0.3083
314	rec_dev_est	-1.0526	0.2314	360	logit_rec_prop_es	-0.5369	0.3396
315	rec_dev_est	-1.3474	0.2211	361	logit_rec_prop_es	-0.2063	0.3241
316	rec_dev_est	-1.8813	0.2775	362	logit_rec_prop_es	-0.3278	0.4434
317	rec_dev_est	-1.3975	0.2217	363	logit_rec_prop_es	-0.2591	0.3210
318	rec_dev_est	-0.7540	0.1782	364	logit_rec_prop_es	0.3393	0.2298
319	rec_dev_est	-1.6443	0.2626	365	logit_rec_prop_es	0.6528	0.5172
320	rec_dev_est	-0.9975	0.2105	366	logit_rec_prop_es	0.4453	0.3131
321	rec_dev_est	-1.8343	0.3549	367	logit_rec_prop_es	0.8179	0.6939
322	rec_dev_est	-1.8062	0.3881	368	logit_rec_prop_es	1.5042	0.8324
323	rec_dev_est	-1.0517	0.3445	369	logit_rec_prop_es	0.3286	0.5847
324	logit_rec_prop_es	-0.2590	0.4559	370	m_dev_est[1]	1.6045	0.0286
325	logit_rec_prop_es	-0.8972	0.4918	371	survey_q[1]	0.9675	0.0257
326	logit_rec_prop_es	-0.3495	0.3571	372	log_add_cv[2]	-0.8134	0.2770
327	logit_rec_prop_es	-0.6025	0.2678	373	sd_rbar	15664000	445630
328	logit_rec_prop_es	-0.1758	0.2726	374	sd_ssbF0	70593	1871
329	logit_rec_prop_es	-0.1152	0.3760	375	sd_Bmsy	24708	655
330	logit_rec_prop_es	0.3275	0.1509	376	sd_depl	0.6020	0.0410
331	logit_rec_prop_es	0.3316	0.2284	377	sd_fmsy	0.2925	0.0040
332	logit_rec_prop_es	-0.1175	0.1799	378	sd_fmsy	0.0078	0.0008
333	logit_rec_prop_es	0.3966	0.4674	379	sd_fmsy	0.0000	0.0000
334	logit_rec_prop_es	-0.4881	0.1679	380	sd_fmsy	0.0058	0.0006
335	logit_rec_prop_es	0.1975	0.4120	381	sd_fmsy	0.0000	0.0000
336	logit_rec_prop_es	-0.1202	0.4573	382	sd_fmsy	0.0000	0.0000
337	logit_rec_prop_es	0.3891	0.3917	383	sd_fofl	0.1631	0.0139
338	logit_rec_prop_es	-0.0876	0.1676	384	sd_fofl	0.0078	0.0008

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

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2825	0.0140	47	log_slx_pars[1]	4.7476	0.0079
2	theta[4]	19.8240	0.0493	48	log_slx_pars[2]	2.2552	0.0481
3	theta[5]	16.2300	0.1401	49	log_slx_pars[3]	4.5075	0.0171
4	theta[7]	0.6744	0.1321	50	log_slx_pars[4]	2.0391	0.1150
5	theta[9]	-0.4821	0.2373	51	log_slx_pars[5]	5.1527	0.0567
6	theta[13]	0.9098	0.4463	52	log_slx_pars[6]	2.8514	0.0451
7	theta[14]	0.6595	0.4739	53	log_slx_pars[7]	4.7154	0.2168
8	theta[15]	0.8572	0.3377	54	log_slx_pars[8]	2.1631	0.3062
9	theta[16]	0.7008	0.3095	55	log_slx_pars[9]	4.7310	0.0823
10	theta[17]	0.5350	0.2988	56	log_slx_pars[10]	0.9004	0.3030
11	theta[18]	0.4920	0.2799	57	log_slx_pars[11]	4.7961	0.0243
12	theta[19]	0.3340	0.2795	58	log_slx_pars[12]	2.3509	0.0884
13	theta[20]	0.3718	0.2653	59	log_slx_pars[13]	4.1240	0.1575
14	theta[21]	0.4065	0.2594	60	log_slx_pars[14]	2.2314	0.3610
15	theta[22]	0.1822	0.2816	61	log_slx_pars[15]	3.7231	0.6756
16	theta[23]	0.1648	0.2769	62	log_slx_pars[16]	3.3294	0.4270
17	theta[24]	0.0631	0.2867	63	log_slx_pars[17]	4.4306	0.0292
18	theta[25]	0.1805	0.2615	64	log_slx_pars[18]	2.4521	0.0711
19	theta[26]	0.0043	0.2022	65	log_slx_pars[19]	4.9206	0.0015
20	theta[27]	-0.2194	0.1957	66	log_slx_pars[20]	0.6719	0.0542
21	theta[28]	-0.3740	0.1981	67	log_slx_pars[21]	4.9290	0.0019
22	theta[29]	-0.7206	0.2116	68	log_slx_pars[22]	0.6621	0.1040
23	theta[30]	-1.1831	0.2326	69	log_fbar[1]	-1.4945	0.0415
24	theta[31]	-1.2307	0.2353	70	log_fbar[2]	-4.2811	0.0762
25	theta[52]	1.2165	0.7443	71	log_fbar[3]	-5.6118	0.2830
26	theta[53]	1.4734	0.4674	72	log_fbar[4]	-6.6079	0.0775
27	theta[54]	1.4116	0.3684	73	log_fdev[1]	0.6892	0.1181
28	theta[55]	1.1801	0.3366	74	log_fdev[1]	0.6613	0.0902
29	theta[56]	1.0932	0.2945	75	log_fdev[1]	0.5846	0.0735
30	theta[57]	0.6113	0.3173	76	log_fdev[1]	0.6887	0.0601
31	theta[58]	0.2234	0.3511	77	log_fdev[1]	0.9156	0.0544
32	theta[59]	-0.0165	0.3595	78	log_fdev[1]	1.7939	0.0580
33	theta[60]	-0.2062	0.3522	79	log_fdev[1]	2.3122	0.1251
34	theta[61]	-0.5420	0.3721	80	log_fdev[1]	0.6904	0.1694
35	theta[62]	-0.9294	0.3841	81	log_fdev[1]	-9.0153	0.1174
36	theta[63]	-1.1888	0.3890	82	log_fdev[1]	1.0259	0.1037
37	theta[64]	-1.4183	0.3878	83	log_fdev[1]	1.0916	0.0871
38	theta[65]	-1.7906	0.3762	84	log_fdev[1]	1.2685	0.0732
39	theta[66]	-1.8954	0.3724	85	log_fdev[1]	0.8145	0.0640
40	theta[67]	-1.8369	0.3520	86	log_fdev[1]	-0.1111	0.0531
41	Grwth[21]	0.9926	0.1889	87	log_fdev[1]	0.0141	0.0477
42	Grwth[42]	1.4088	0.1212	88	log_fdev[1]	0.6637	0.0394
43	Grwth[85]	141.920	1.7259	89	log_fdev[1]	0.6753	0.0421
44	Grwth[86]	0.0594	0.0104	90	log_fdev[1]	0.1552	0.0466
45	Grwth[87]	139.820	0.6096	91	log_fdev[1]	0.8174	0.0510

46	Grwth[88]	0.0720	0.0034	92	log_fdev[1]	-4.3381	0.0485
93	log_fdev[1]	-4.7437	0.0420	143	log_fdev[2]	-0.9986	0.1030
94	log_fdev[1]	-0.2701	0.0407	144	log_fdev[2]	-0.2275	0.1029
95	log_fdev[1]	-0.2216	0.0411	145	log_fdev[2]	-0.5256	0.1026
96	log_fdev[1]	0.6902	0.0435	146	log_fdev[2]	-0.6180	0.1024
97	log_fdev[1]	0.3381	0.0425	147	log_fdev[2]	-0.3839	0.1023
98	log_fdev[1]	-0.2431	0.0410	148	log_fdev[2]	-0.6602	0.1022
99	log_fdev[1]	-0.3198	0.0406	149	log_fdev[2]	-0.4923	0.1020
100	log_fdev[1]	-0.2083	0.0395	150	log_fdev[2]	-0.4177	0.1020
101	log_fdev[1]	0.2567	0.0382	151	log_fdev[2]	-0.4489	0.1023
102	log_fdev[1]	0.2183	0.0383	152	log_fdev[2]	-0.8104	0.1024
103	log_fdev[1]	0.5064	0.0387	153	log_fdev[2]	-0.9661	0.1024
104	log_fdev[1]	0.2559	0.0381	154	log_fdev[2]	-1.4309	0.1022
105	log_fdev[1]	0.6195	0.0381	155	log_fdev[2]	-1.9526	0.1025
106	log_fdev[1]	0.7880	0.0400	156	log_fdev[2]	-1.2417	0.1028
107	log_fdev[1]	0.5931	0.0407	157	log_fdev[2]	-1.8070	0.1034
108	log_fdev[1]	0.4555	0.0401	158	log_fdev[2]	-1.4344	0.1047
109	log_fdev[1]	-0.1824	0.0390	159	log_fdev[2]	-0.9216	0.1069
110	log_fdev[1]	-0.2576	0.0385	160	log_fdev[2]	-0.5005	0.1100
111	log_fdev[1]	-0.0739	0.0389	161	log_fdev[2]	-0.5723	0.1131
112	log_fdev[1]	0.2490	0.0404	162	log_fdev[2]	-0.4884	0.1163
113	log_fdev[1]	0.3111	0.0444	163	log_fdev[2]	-0.4942	0.1186
114	log_fdev[1]	0.2953	0.0517	164	log_fdev[3]	-0.1164	0.0682
115	log_fdev[1]	0.1868	0.0617	165	log_fdev[3]	0.6699	0.0682
116	log_fdev[1]	-0.0222	0.0720	166	log_fdev[3]	1.2285	0.0682
117	log_fdev[1]	-0.0940	0.0798	167	log_fdev[3]	1.0928	0.0682
118	log_fdev[1]	-0.5248	0.0828	168	log_fdev[3]	1.3825	0.0682
119	log_fdev[2]	0.1568	0.1249	169	log_fdev[3]	1.4242	0.0682
120	log_fdev[2]	0.6040	0.1165	170	log_fdev[3]	0.9927	0.0682
121	log_fdev[2]	0.5918	0.1107	171	log_fdev[3]	0.4764	0.0682
122	log_fdev[2]	0.6753	0.1093	172	log_fdev[3]	-0.9874	0.0682
123	log_fdev[2]	1.3937	0.1126	173	log_fdev[3]	-0.5788	0.0682
124	log_fdev[2]	1.1460	0.1305	174	log_fdev[3]	-1.0994	0.0682
125	log_fdev[2]	2.4232	0.1294	175	log_fdev[3]	-0.2563	0.0682
126	log_fdev[2]	2.1478	0.1172	176	log_fdev[3]	0.9401	0.0682
127	log_fdev[2]	3.3723	0.1153	177	log_fdev[3]	1.4181	0.0682
128	log_fdev[2]	2.1684	0.1115	178	log_fdev[3]	3.2533	0.0755
129	log_fdev[2]	1.1041	0.1113	179	log_fdev[3]	1.2929	0.0963
130	log_fdev[2]	0.6532	0.1089	180	log_fdev[3]	0.5847	0.1149
131	log_fdev[2]	1.4333	0.1046	181	log_fdev[3]	-0.7503	0.0842
132	log_fdev[2]	0.0056	0.1037	182	log_fdev[3]	-2.1190	0.0733
133	log_fdev[2]	0.4592	0.1038	183	log_fdev[3]	-2.9771	0.0957
134	log_fdev[2]	0.8811	0.1051	184	log_fdev[3]	-2.4066	0.1116
135	log_fdev[2]	0.7146	0.1052	185	log_fdev[3]	-3.4939	0.0747
136	log_fdev[2]	1.1862	0.1078	186	log_fdev[3]	-0.8583	0.0932
137	log_fdev[2]	-0.5812	0.1049	187	log_fdev[3]	-0.1416	0.1106
138	log_fdev[2]	-0.8681	0.1034	188	log_fdev[3]	1.0291	0.1322
139	log_fdev[2]	-0.8006	0.1036	189	log_fdev[4]	0.6660	0.1032
140	log_fdev[2]	-1.2649	0.1035	190	log_fdev[4]	0.0089	0.1021

141	log_fdev[2]	0.0335	0.1038	191	log_fdev[4]	-0.2013	0.1025
142	log_fdev[2]	-0.2422	0.1035	192	log_fdev[4]	0.7207	0.1018
193	log_fdev[4]	-1.7079	0.1013	243	log_fdov[1]	-0.2264	0.0857
194	log_fdev[4]	0.2480	0.1009	244	log_fdov[1]	1.1215	0.0906
195	log_fdev[4]	-0.0084	0.1005	245	log_fdov[1]	0.0656	0.0944
196	log_fdev[4]	-0.8412	0.1004	246	log_fdov[1]	-0.4468	0.0961
197	log_fdev[4]	-0.6667	0.1002	247	log_fdov[3]	0.0000	0.0962
198	log_fdev[4]	-0.3932	0.1000	248	log_fdov[3]	0.0001	0.0962
199	log_fdev[4]	-0.4417	0.0997	249	log_fdov[3]	0.0001	0.0963
200	log_fdev[4]	0.1039	0.0997	250	log_fdov[3]	0.0001	0.0963
201	log_fdev[4]	-0.5990	0.1001	251	log_fdov[3]	0.0003	0.0963
202	log_fdev[4]	-1.6014	0.0999	252	log_fdov[3]	0.0000	0.0963
203	log_fdev[4]	-2.4851	0.0994	253	log_fdov[3]	-0.0002	0.0963
204	log_fdev[4]	-0.9668	0.0991	254	log_fdov[3]	-0.0002	0.0962
205	log_fdev[4]	-0.4134	0.0992	255	log_fdov[3]	-0.0001	0.0962
206	log_fdev[4]	0.7306	0.0992	256	log_fdov[3]	-0.0001	0.0962
207	log_fdev[4]	1.5711	0.0996	257	log_fdov[3]	-0.0001	0.0962
208	log_fdev[4]	1.2464	0.1003	258	log_fdov[3]	0.0001	0.0962
209	log_fdev[4]	0.3818	0.1015	259	log_fdov[3]	0.0004	0.0962
210	log_fdev[4]	1.9838	0.1034	260	log_fdov[3]	0.0009	0.0963
211	log_fdev[4]	2.2114	0.1052	261	log_fdov[3]	1.5192	0.1457
212	log_fdev[4]	1.0553	0.1072	262	log_fdov[3]	1.8016	0.1196
213	log_fdev[4]	-0.6021	0.1095	263	log_fdov[3]	0.5807	0.1363
214	log_foff[1]	-2.8656	0.0396	264	log_fdov[3]	-3.4391	0.1096
215	log_foff[3]	-0.1517	0.4063	265	log_fdov[3]	-2.1672	0.1499
216	log_fdov[1]	2.0502	0.0836	266	log_fdov[3]	-0.7939	0.1242
217	log_fdov[1]	-0.6193	0.0828	267	log_fdov[3]	0.0366	0.1317
218	log_fdov[1]	2.0593	0.0840	268	log_fdov[3]	0.3853	0.1022
219	log_fdov[1]	1.9006	0.0856	269	log_fdov[3]	0.9673	0.1548
220	log_fdov[1]	-0.3290	0.0842	270	log_fdov[3]	0.1852	0.1438
221	log_fdov[1]	-0.1047	0.0821	271	log_fdov[3]	0.9230	0.1658
222	log_fdov[1]	-3.6065	0.0811	272	rec_dev_est	1.1192	0.2572
223	log_fdov[1]	-0.2354	0.0818	273	rec_dev_est	0.6411	0.2897
224	log_fdov[1]	1.5521	0.0819	274	rec_dev_est	1.1186	0.2355
225	log_fdov[1]	-2.6852	0.0811	275	rec_dev_est	1.6624	0.2073
226	log_fdov[1]	1.2384	0.0804	276	rec_dev_est	1.9396	0.2172
227	log_fdov[1]	0.9616	0.0803	277	rec_dev_est	1.1352	0.2581
228	log_fdov[1]	-1.7871	0.0797	278	rec_dev_est	2.3898	0.1661
229	log_fdov[1]	1.2957	0.0799	279	rec_dev_est	1.4421	0.1795
230	log_fdov[1]	0.4985	0.0800	280	rec_dev_est	1.0527	0.1677
231	log_fdov[1]	1.0315	0.0795	281	rec_dev_est	-0.7733	0.2461
232	log_fdov[1]	-1.1508	0.0790	282	rec_dev_est	0.2986	0.1641
233	log_fdov[1]	-0.1111	0.0790	283	rec_dev_est	-0.8199	0.2357
234	log_fdov[1]	-0.3745	0.0794	284	rec_dev_est	-1.2705	0.2694
235	log_fdov[1]	-0.6307	0.0795	285	rec_dev_est	-0.9981	0.2191
236	log_fdov[1]	-0.1445	0.0792	286	rec_dev_est	-0.0608	0.1649
237	log_fdov[1]	-1.0408	0.0783	287	rec_dev_est	-0.5339	0.1848
238	log_fdov[1]	-1.7592	0.0780	288	rec_dev_est	-1.9610	0.3477
239	log_fdov[1]	0.2659	0.0780	289	rec_dev_est	-0.9005	0.1971

240	log_fdov[1]	-0.1328	0.0783	290	rec_dev_est	-1.9704	0.3885
241	log_fdov[1]	0.9366	0.0794	291	rec_dev_est	0.9694	0.1483
242	log_fdov[1]	0.4042	0.0818	292	rec_dev_est	-0.9339	0.2589
293	rec_dev_est	-1.5721	0.3233	339	logit_rec_prop_es	0.3221	0.5794
294	rec_dev_est	-0.5771	0.1964	340	logit_rec_prop_es	0.4656	0.3070
295	rec_dev_est	0.3964	0.1567	341	logit_rec_prop_es	-0.0533	0.1398
296	rec_dev_est	-0.5610	0.2199	342	logit_rec_prop_es	0.1480	0.3426
297	rec_dev_est	-0.5368	0.2356	343	logit_rec_prop_es	-0.6035	0.3749
298	rec_dev_est	0.8439	0.1552	344	logit_rec_prop_es	-0.4694	0.1234
299	rec_dev_est	-0.6302	0.2599	345	logit_rec_prop_es	-0.5132	0.4238
300	rec_dev_est	-0.6805	0.2562	346	logit_rec_prop_es	-0.0912	0.4166
301	rec_dev_est	0.5914	0.1572	347	logit_rec_prop_es	-0.3696	0.1371
302	rec_dev_est	-0.1315	0.1812	348	logit_rec_prop_es	-0.1194	0.2301
303	rec_dev_est	-0.5285	0.1884	349	logit_rec_prop_es	0.3417	0.2703
304	rec_dev_est	-1.1061	0.2334	350	logit_rec_prop_es	-0.2394	0.3634
305	rec_dev_est	-0.9610	0.2308	351	logit_rec_prop_es	-0.4883	0.3506
306	rec_dev_est	0.0035	0.1767	352	logit_rec_prop_es	-0.7978	0.1909
307	rec_dev_est	-0.5277	0.2202	353	logit_rec_prop_es	-0.4360	0.3039
308	rec_dev_est	-1.0681	0.2270	354	logit_rec_prop_es	-0.5149	0.3379
309	rec_dev_est	-1.3838	0.2191	355	logit_rec_prop_es	-0.1618	0.3246
310	rec_dev_est	-1.8584	0.2611	356	logit_rec_prop_es	-0.2949	0.4182
311	rec_dev_est	-1.4159	0.2200	357	logit_rec_prop_es	-0.2601	0.3197
312	rec_dev_est	-0.7376	0.1771	358	logit_rec_prop_es	0.4402	0.2236
313	rec_dev_est	-1.6315	0.2556	359	logit_rec_prop_es	0.4901	0.4537
314	rec_dev_est	-0.9895	0.2081	360	logit_rec_prop_es	0.5034	0.3032
315	rec_dev_est	-1.8372	0.3537	361	logit_rec_prop_es	0.6528	0.6252
316	rec_dev_est	-1.7602	0.3906	362	logit_rec_prop_es	1.2804	0.7030
317	rec_dev_est	-1.0535	0.3458	363	logit_rec_prop_es	0.1718	0.5651
318	logit_rec_prop_es	-0.1188	0.4012	364	m_dev_est[1]	1.5962	0.0295
319	logit_rec_prop_es	-0.8490	0.5272	365	survey_q[1]	0.9640	0.0253
320	logit_rec_prop_es	-0.2056	0.3444	366	log_add_cv[2]	-0.8098	0.2771
321	logit_rec_prop_es	-0.4593	0.2679	367	sd_rbar	15560000	419900
322	logit_rec_prop_es	0.0569	0.2518	368	sd_ssbF0	69247.0	1685.1
323	logit_rec_prop_es	0.1812	0.3291	369	sd_Bmsy	24237.0	589.8
324	logit_rec_prop_es	0.3369	0.1408	370	sd_depl	0.6167	0.0415
325	logit_rec_prop_es	0.3666	0.2236	371	sd_fmsy	0.2925	0.0040
326	logit_rec_prop_es	-0.0944	0.1751	372	sd_fmsy	0.0077	0.0008
327	logit_rec_prop_es	0.3248	0.4249	373	sd_fmsy	0.0000	0.0000
328	logit_rec_prop_es	-0.4618	0.1654	374	sd_fmsy	0.0057	0.0006
329	logit_rec_prop_es	0.1620	0.3870	375	sd_fmsy	0.0000	0.0000
330	logit_rec_prop_es	-0.1455	0.4409	376	sd_fmsy	0.0000	0.0000
331	logit_rec_prop_es	0.3964	0.3648	377	sd_fofl	0.1679	0.0141
332	logit_rec_prop_es	-0.0667	0.1658	378	sd_fofl	0.0077	0.0008
333	logit_rec_prop_es	0.1675	0.2408	379	sd_fofl	0.0000	0.0000
334	logit_rec_prop_es	0.4681	0.6368	380	sd_fofl	0.0057	0.0006
335	logit_rec_prop_es	0.2394	0.2807	381	sd_fofl	0.0000	0.0000
336	logit_rec_prop_es	-0.5440	0.6349	382	sd_fofl	0.0000	0.0000
337	logit_rec_prop_es	-0.2772	0.0873	383	sd_ofl	2225.1	340.2
338	logit_rec_prop_es	1.1193	0.5582	384			

Table 6c. Summary of estimated model parameter values and standard deviations for model 21.2 for Bristol Bay red king crab.

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2741	0.0143	47	log slx pars[1]	4.7480	0.0079
2	theta[4]	19.8240	0.0494	48	log_slx_pars[2]	2.2552	0.0480
3	theta[5]	16.2400	0.1402	49	log_slx_pars[3]	4.5093	0.0171
4	theta[7]	0.6802	0.1325	50	log_slx_pars[4]	2.0474	0.1139
5	theta[9]	-0.4899	0.2366	51	log_slx_pars[5]	5.1538	0.0570
6	theta[13]	0.9123	0.4472	52	log_slx_pars[6]	2.8523	0.0450
7	theta[14]	0.6628	0.4743	53	log_slx_pars[7]	4.7153	0.2173
8	theta[15]	0.8606	0.3380	54	log_slx_pars[8]	2.1632	0.3061
9	theta[16]	0.7037	0.3098	55	log_slx_pars[9]	4.7312	0.0822
10	theta[17]	0.5377	0.2989	56	log_slx_pars[10]	0.9003	0.3031
11	theta[18]	0.4943	0.2800	57	log_slx_pars[11]	4.7960	0.0240
12	theta[19]	0.3354	0.2795	58	log_slx_pars[12]	2.3515	0.0876
13	theta[20]	0.3726	0.2653	59	log_slx_pars[13]	4.1210	0.1578
14	theta[21]	0.4067	0.2593	60	log_slx_pars[14]	2.2254	0.3670
15	theta[22]	0.1821	0.2815	61	log_slx_pars[15]	3.6988	0.7080
16	theta[23]	0.1645	0.2768	62	log_slx_pars[16]	3.3546	0.4375
17	theta[24]	0.0625	0.2866	63	log_slx_pars[17]	4.4333	0.0286
18	theta[25]	0.1793	0.2615	64	log_slx_pars[18]	2.4580	0.0708
19	theta[26]	0.0040	0.2022	65	log_slx_pars[19]	4.9206	0.0015
20	theta[27]	-0.2199	0.1957	66	log_slx_pars[20]	0.6722	0.0541
21	theta[28]	-0.3746	0.1981	67	log_slx_pars[21]	4.9290	0.0019
22	theta[29]	-0.7213	0.2116	68	log_slx_pars[22]	0.6614	0.1042
23	theta[30]	-1.1837	0.2326	69	log_fbar[1]	-1.4978	0.0416
24	theta[31]	-1.2313	0.2353	70	log_fbar[2]	-4.2832	0.0764
25	theta[52]	1.2139	0.7441	71	log_fbar[3]	-5.6280	0.2837
26	theta[53]	1.4717	0.4681	72	log_fbar[4]	-6.6113	0.0771
27	theta[54]	1.4134	0.3693	73	log_fdev[1]	0.6936	0.1182
28	theta[55]	1.1828	0.3372	74	log_fdev[1]	0.6654	0.0903
29	theta[56]	1.0948	0.2950	75	log_fdev[1]	0.5881	0.0736
30	theta[57]	0.6108	0.3180	76	log_fdev[1]	0.6908	0.0601
31	theta[58]	0.2226	0.3515	77	log_fdev[1]	0.9157	0.0544
32	theta[59]	-0.0175	0.3595	78	log_fdev[1]	1.7913	0.0581
33	theta[60]	-0.2068	0.3519	79	log_fdev[1]	2.3075	0.1254
34	theta[61]	-0.5435	0.3718	80	log_fdev[1]	0.6876	0.1705
35	theta[62]	-0.9306	0.3837	81	log_fdev[1]	-9.0118	0.1189
36	theta[63]	-1.1907	0.3887	82	log_fdev[1]	1.0368	0.1057
37	theta[64]	-1.4199	0.3875	83	log_fdev[1]	1.1012	0.0874
38	theta[65]	-1.7926	0.3760	84	log_fdev[1]	1.2738	0.0732
39	theta[66]	-1.8971	0.3722	85	log_fdev[1]	0.8191	0.0640
40	theta[67]	-1.8386	0.3518	86	log_fdev[1]	-0.1065	0.0531
41	Grwth[21]	0.9967	0.1898	87	log_fdev[1]	0.0184	0.0478
42	Grwth[42]	1.3997	0.1204	88	log_fdev[1]	0.6676	0.0395
43	Grwth[85]	141.930	1.7256	89	log_fdev[1]	0.6792	0.0422
44	Grwth[86]	0.0593	0.0104	90	log_fdev[1]	0.1590	0.0466
45	Grwth[87]	139.780	0.6078	91	log_fdev[1]	0.8207	0.0509

46	Grwth[88]	0.0720	0.0034	92	log_fdev[1]	-4.3353	0.0484
93	log_fdev[1]	-4.7411	0.0420	143	log_fdev[2]	-1.0003	0.1030
94	log_fdev[1]	-0.2677	0.0407	144	log_fdev[2]	-0.2295	0.1029
95	log_fdev[1]	-0.2194	0.0411	145	log_fdev[2]	-0.5281	0.1026
96	log_fdev[1]	0.6916	0.0435	146	log_fdev[2]	-0.6216	0.1024
97	log_fdev[1]	0.3389	0.0425	147	log_fdev[2]	-0.3886	0.1023
98	log_fdev[1]	-0.2424	0.0410	148	log_fdev[2]	-0.6668	0.1022
99	log_fdev[1]	-0.3194	0.0406	149	log_fdev[2]	-0.5003	0.1020
100	log_fdev[1]	-0.2083	0.0395	150	log_fdev[2]	-0.4284	0.1021
101	log_fdev[1]	0.2560	0.0382	151	log_fdev[2]	-0.4636	0.1025
102	log_fdev[1]	0.2169	0.0383	152	log_fdev[2]	-0.8286	0.1027
103	log_fdev[1]	0.5038	0.0388	153	log_fdev[2]	-0.9880	0.1028
104	log_fdev[1]	0.2520	0.0381	154	log_fdev[2]	-1.4549	0.1027
105	log_fdev[1]	0.6139	0.0382	155	log_fdev[2]	-1.9794	0.1030
106	log_fdev[1]	0.7790	0.0403	156	log_fdev[2]	-1.2727	0.1036
107	log_fdev[1]	0.5802	0.0413	157	log_fdev[2]	-1.8446	0.1045
108	log_fdev[1]	0.4388	0.0409	158	log_fdev[2]	-1.4807	0.1062
109	log_fdev[1]	-0.2021	0.0401	159	log_fdev[2]	-0.9781	0.1090
110	log_fdev[1]	-0.2799	0.0397	160	log_fdev[2]	-0.5683	0.1125
111	log_fdev[1]	-0.1000	0.0405	161	log_fdev[2]	-0.5758	0.1124
112	log_fdev[1]	0.2167	0.0426	162	log_fdev[2]	-0.3428	0.1287
113	log_fdev[1]	0.2694	0.0474	163	log_fdev[2]	-0.2680	0.1474
114	log_fdev[1]	0.2413	0.0554	164	log_fdev[3]	-0.1164	0.0682
115	log_fdev[1]	0.1182	0.0658	165	log_fdev[3]	0.6699	0.0682
116	log_fdev[1]	-0.0641	0.0712	166	log_fdev[3]	1.2285	0.0682
117	log_fdev[1]	-0.0047	0.0847	167	log_fdev[3]	1.0928	0.0682
118	log_fdev[1]	-0.3297	0.1113	168	log_fdev[3]	1.3825	0.0682
119	log_fdev[2]	0.1599	0.1249	169	log_fdev[3]	1.4242	0.0682
120	log_fdev[2]	0.6061	0.1165	170	log_fdev[3]	0.9927	0.0682
121	log_fdev[2]	0.5922	0.1107	171	log_fdev[3]	0.4764	0.0682
122	log_fdev[2]	0.6732	0.1093	172	log_fdev[3]	-0.9874	0.0682
123	log_fdev[2]	1.3873	0.1127	173	log_fdev[3]	-0.5788	0.0682
124	log_fdev[2]	1.1369	0.1310	174	log_fdev[3]	-1.0994	0.0682
125	log_fdev[2]	2.4168	0.1298	175	log_fdev[3]	-0.2563	0.0682
126	log_fdev[2]	2.1465	0.1176	176	log_fdev[3]	0.9400	0.0682
127	log_fdev[2]	3.3755	0.1157	177	log_fdev[3]	1.4181	0.0682
128	log_fdev[2]	2.1731	0.1115	178	log_fdev[3]	3.2693	0.0758
129	log_fdev[2]	1.1081	0.1113	179	log_fdev[3]	1.3085	0.0969
130	log_fdev[2]	0.6571	0.1089	180	log_fdev[3]	0.5996	0.1153
131	log_fdev[2]	1.4371	0.1046	181	log_fdev[3]	-0.7355	0.0845
132	log_fdev[2]	0.0095	0.1038	182	log_fdev[3]	-2.1113	0.0734
133	log_fdev[2]	0.4628	0.1039	183	log_fdev[3]	-2.9720	0.0957
134	log_fdev[2]	0.8843	0.1051	184	log_fdev[3]	-2.4051	0.1113
135	log_fdev[2]	0.7173	0.1052	185	log_fdev[3]	-3.4959	0.0746
136	log_fdev[2]	1.1881	0.1078	186	log_fdev[3]	-0.8742	0.0934
137	log_fdev[2]	-0.5800	0.1049	187	log_fdev[3]	-0.1652	0.1110
138	log_fdev[2]	-0.8670	0.1034	188	log_fdev[3]	0.9948	0.1328
139	log_fdev[2]	-0.7998	0.1036	189	log_fdev[4]	0.6659	0.1032
140	log_fdev[2]	-1.2647	0.1035	190	log_fdev[4]	0.0083	0.1021

141	log_fdev[2]	0.0326	0.1038	191	log_fdev[4]	-0.2028	0.1025
142	log_fdev[2]	-0.2438	0.1035	192	log_fdev[4]	0.7188	0.1018
193	log_fdev[4]	-1.7102	0.1013	243	log_fdov[1]	-0.2136	0.0852
194	log_fdev[4]	0.2454	0.1009	244	log_fdov[1]	1.1509	0.0899
195	log_fdev[4]	-0.0116	0.1005	245	log_fdov[1]	0.1219	0.0955
196	log_fdev[4]	-0.8455	0.1004	246	log_fdov[1]	-0.3874	0.0983
197	log_fdev[4]	-0.6721	0.1002	247	log_fdov[3]	0.0000	0.0962
198	log_fdev[4]	-0.4003	0.1000	248	log_fdov[3]	0.0000	0.0962
199	log_fdev[4]	-0.4503	0.0998	249	log_fdov[3]	0.0001	0.0963
200	log_fdev[4]	0.0926	0.0998	250	log_fdov[3]	0.0001	0.0963
201	log_fdev[4]	-0.6138	0.1002	251	log_fdov[3]	0.0003	0.0963
202	log_fdev[4]	-1.6193	0.1001	252	log_fdov[3]	0.0000	0.0963
203	log_fdev[4]	-2.5063	0.0997	253	log_fdov[3]	-0.0002	0.0963
204	log_fdev[4]	-0.9906	0.0996	254	log_fdov[3]	-0.0002	0.0962
205	log_fdev[4]	-0.4403	0.0997	255	log_fdov[3]	-0.0001	0.0962
206	log_fdev[4]	0.6995	0.1000	256	log_fdov[3]	-0.0001	0.0962
207	log_fdev[4]	1.5337	0.1006	257	log_fdov[3]	-0.0001	0.0962
208	log_fdev[4]	1.2014	0.1018	258	log_fdov[3]	0.0001	0.0962
209	log_fdev[4]	0.3282	0.1035	259	log_fdov[3]	0.0004	0.0962
210	log_fdev[4]	1.9205	0.1059	260	log_fdov[3]	0.0009	0.0963
211	log_fdev[4]	2.2150	0.1048	261	log_fdov[3]	1.5222	0.1446
212	log_fdev[4]	1.2076	0.1217	262	log_fdov[3]	1.8027	0.1199
213	log_fdev[4]	-0.3737	0.1403	263	log_fdov[3]	0.5810	0.1368
214	log_foff[1]	-2.8632	0.0396	264	log_fdov[3]	-3.4401	0.1096
215	log_foff[3]	-0.1550	0.4069	265	log_fdov[3]	-2.1718	0.1493
216	log_fdov[1]	2.0514	0.0835	266	log_fdov[3]	-0.7981	0.1242
217	log_fdov[1]	-0.6200	0.0827	267	log_fdov[3]	0.0339	0.1315
218	log_fdov[1]	2.0580	0.0839	268	log_fdov[3]	0.3836	0.1021
219	log_fdov[1]	1.8981	0.0855	269	log_fdov[3]	0.9667	0.1536
220	log_fdov[1]	-0.3336	0.0841	270	log_fdov[3]	0.1878	0.1426
221	log_fdov[1]	-0.1101	0.0820	271	log_fdov[3]	0.9308	0.1647
222	log_fdov[1]	-3.6091	0.0810	272	rec_dev_est	1.1127	0.2568
223	log_fdov[1]	-0.2375	0.0817	273	rec_dev_est	0.6365	0.2897
224	log_fdov[1]	1.5494	0.0818	274	rec_dev_est	1.1173	0.2352
225	log_fdov[1]	-2.6895	0.0810	275	rec_dev_est	1.6637	0.2072
226	log_fdov[1]	1.2336	0.0803	276	rec_dev_est	1.9460	0.2167
227	log_fdov[1]	0.9559	0.0803	277	rec_dev_est	1.1399	0.2582
228	log_fdov[1]	-1.7936	0.0797	278	rec_dev_est	2.3936	0.1661
229	log_fdov[1]	1.2896	0.0798	279	rec_dev_est	1.4360	0.1796
230	log_fdov[1]	0.4914	0.0800	280	rec_dev_est	1.0377	0.1679
231	log_fdov[1]	1.0231	0.0795	281	rec_dev_est	-0.7863	0.2464
232	log_fdov[1]	-1.1602	0.0790	282	rec_dev_est	0.2801	0.1645
233	log_fdov[1]	-0.1215	0.0790	283	rec_dev_est	-0.8346	0.2361
234	log_fdov[1]	-0.3847	0.0795	284	rec_dev_est	-1.2862	0.2703
235	log_fdov[1]	-0.6403	0.0796	285	rec_dev_est	-1.0091	0.2193
236	log_fdov[1]	-0.1537	0.0793	286	rec_dev_est	-0.0731	0.1648
237	log_fdov[1]	-1.0507	0.0784	287	rec_dev_est	-0.5452	0.1849
238	log_fdov[1]	-1.7707	0.0780	288	rec_dev_est	-1.9703	0.3484
239	log_fdov[1]	0.2539	0.0781	289	rec_dev_est	-0.9117	0.1974

240	log_fdov[1]	-0.1429	0.0784	290	rec_dev_est	-1.9806	0.3893
241	log_fdov[1]	0.9315	0.0794	291	rec_dev_est	0.9565	0.1483
242	log_fdov[1]	0.4069	0.0816	292	rec_dev_est	-0.9416	0.2590
293	rec_dev_est	-1.5839	0.3248	339	logit_rec_prop_es	0.3185	0.5817
294	rec_dev_est	-0.5859	0.1967	340	logit_rec_prop_es	0.4663	0.3078
295	rec_dev_est	0.3889	0.1567	341	logit_rec_prop_es	-0.0502	0.1401
296	rec_dev_est	-0.5680	0.2203	342	logit_rec_prop_es	0.1532	0.3439
297	rec_dev_est	-0.5455	0.2364	343	logit_rec_prop_es	-0.6112	0.3776
298	rec_dev_est	0.8403	0.1552	344	logit_rec_prop_es	-0.4683	0.1235
299	rec_dev_est	-0.6314	0.2601	345	logit_rec_prop_es	-0.5209	0.4249
300	rec_dev_est	-0.6806	0.2568	346	logit_rec_prop_es	-0.1011	0.4173
301	rec_dev_est	0.5953	0.1572	347	logit_rec_prop_es	-0.3744	0.1372
302	rec_dev_est	-0.1208	0.1810	348	logit_rec_prop_es	-0.1297	0.2294
303	rec_dev_est	-0.5163	0.1884	349	logit_rec_prop_es	0.3291	0.2693
304	rec_dev_est	-1.0874	0.2332	350	logit_rec_prop_es	-0.2522	0.3629
305	rec_dev_est	-0.9404	0.2310	351	logit_rec_prop_es	-0.5058	0.3513
306	rec_dev_est	0.0345	0.1765	352	logit_rec_prop_es	-0.8191	0.1901
307	rec_dev_est	-0.4914	0.2212	353	logit_rec_prop_es	-0.4471	0.3042
308	rec_dev_est	-1.0277	0.2272	354	logit_rec_prop_es	-0.5256	0.3376
309	rec_dev_est	-1.3325	0.2189	355	logit_rec_prop_es	-0.1597	0.3224
310	rec_dev_est	-1.8040	0.2609	356	logit_rec_prop_es	-0.2917	0.4167
311	rec_dev_est	-1.3531	0.2222	357	logit_rec_prop_es	-0.2726	0.3218
312	rec_dev_est	-0.6657	0.1790	358	logit_rec_prop_es	0.4292	0.2230
313	rec_dev_est	-1.5494	0.2560	359	logit_rec_prop_es	0.4591	0.4464
314	rec_dev_est	-0.9036	0.2097	360	logit_rec_prop_es	0.4584	0.2993
315	rec_dev_est	-1.8696	0.3468	361	logit_rec_prop_es	0.6194	0.6120
316	rec_dev_est	-1.9205	0.3818	362	logit_rec_prop_es	1.3088	0.6927
317	rec_dev_est	-1.2220	0.3418	363	logit_rec_prop_es	0.2045	0.5462
318	logit_rec_prop_es	-0.1141	0.4010	364	m_dev_est[1]	1.6036	0.0295
319	logit_rec_prop_es	-0.8454	0.5277	365	m_dev_est[3]	0.5251	0.1564
320	logit_rec_prop_es	-0.1983	0.3443	366	survey_q[1]	0.9630	0.0254
321	logit_rec_prop_es	-0.4496	0.2682	367	log_add_cv[2]	-0.8831	0.2817
322	logit_rec_prop_es	0.0691	0.2514	368	sd_rbar	15726000	428670
323	logit_rec_prop_es	0.1915	0.3294	369	sd_ssbF0	69858	1712
324	logit_rec_prop_es	0.3559	0.1411	370	sd_Bmsy	24450	599
325	logit_rec_prop_es	0.3870	0.2255	371	sd_depl	0.5166	0.0502
326	logit_rec_prop_es	-0.0708	0.1763	372	sd_fmsy	0.2924	0.0040
327	logit_rec_prop_es	0.3291	0.4257	373	sd_fmsy	0.0082	0.0009
328	logit_rec_prop_es	-0.4466	0.1662	374	sd_fmsy	0.0000	0.0000
329	logit_rec_prop_es	0.1737	0.3889	375	sd_fmsy	0.0058	0.0006
330	logit_rec_prop_es	-0.1365	0.4430	376	sd_fmsy	0.0000	0.0000
331	logit_rec_prop_es	0.3956	0.3646	377	sd_fmsy	0.0000	0.0000
332	logit_rec_prop_es	-0.0564	0.1655	378	sd_fofl	0.1354	0.0167
333	logit_rec_prop_es	0.1732	0.2410	379	sd_fofl	0.0082	0.0009
334	logit_rec_prop_es	0.4731	0.6384	380	sd_fofl	0.0000	0.0000
335	logit_rec_prop_es	0.2394	0.2815	381	sd_fofl	0.0058	0.0006
336	logit_rec_prop_es	-0.5479	0.6353	382	sd_fofl	0.0000	0.0000
337	logit_rec_prop_es	-0.2680	0.0874	383	sd_fofl	0.0000	0.0000
338	logit_rec_prop_es	1.1295	0.5600	384	sd_ofl	1518.4	327.1600

Table 7. Natural mortality estimates for six model scenarios.

Model	Sex	Year 1975-1979, 1985-2017, 2020-2021	1980-1984	2018-2019
19.3d	Males	0.180	0.896	0.180
	Females	0.241	1.200	0.241
19.3e	Males	0.180	0.895	0.180
	Females	0.241	1.196	0.241
19.3g	Males	0.180	0.908	0.180
	Females	0.240	1.209	0.240
21.0	Males	0.363	0.363	0.363
	Females	0.363	0.363	0.363
21.1	Males	0.180	0.888	0.180
	Females	0.239	1.178	0.239
21.2	Males	0.180	0.895	0.304
	Females	0.237	1.177	0.400

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 2010-2021 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
2010	31.603	30.573
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 19.3d 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	56.223	28.458	84.469	8.658	57.015	NA	229.011	199.643
1976	66.108	35.664	100.427	8.288	90.983	72.343	267.806	327.615
1977	72.940	41.472	113.822	7.057	123.242	48.120	289.889	371.223
1978	77.927	46.342	119.831	5.570	127.717	74.000	296.306	343.189
1979	68.893	47.122	100.123	4.024	123.167	135.336	289.530	165.449
1980	51.184	37.740	30.578	1.731	127.377	172.562	279.108	247.226
1981	15.036	8.119	6.964	1.082	56.066	71.060	110.788	131.145
1982	7.075	2.277	6.910	0.893	24.698	252.326	68.226	141.898
1983	6.202	2.249	7.458	0.646	15.551	97.100	59.057	48.476
1984	6.043	2.269	5.113	0.434	14.520	65.653	50.778	152.607
1985	7.515	1.834	9.572	0.656	9.838	10.037	34.351	34.138
1986	12.120	4.590	14.953	0.987	13.766	30.483	44.793	47.434
1987	14.253	6.621	20.204	1.190	17.097	9.834	50.457	69.245
1988	14.273	8.351	24.772	1.251	21.522	6.324	53.852	54.597
1989	15.380	9.597	27.592	1.207	20.296	8.032	56.629	55.136
1990	14.912	10.288	23.832	1.136	18.115	21.216	56.900	59.451
1991	11.486	8.544	18.249	1.072	17.488	13.289	51.966	83.892
1992	9.237	6.395	17.108	1.042	18.663	2.965	47.327	37.334
1993	10.508	6.116	15.824	1.112	17.348	9.188	46.888	52.906
1994	10.350	6.001	21.674	1.220	14.735	2.879	42.352	32.104
1995	10.844	7.876	24.796	1.221	13.661	59.551	48.449	38.068
1996	11.097	8.524	23.241	1.164	19.808	8.804	57.648	43.959
1997	10.566	7.743	22.014	1.145	28.991	4.534	63.541	84.030
1998	15.765	7.714	24.737	1.346	25.363	12.453	67.319	84.101
1999	16.756	9.605	28.265	1.491	21.421	33.509	65.982	64.754
2000	14.487	10.470	28.497	1.484	22.893	12.798	67.534	67.381
2001	14.312	10.066	28.894	1.445	25.972	12.811	70.977	52.455
2002	17.047	10.255	32.782	1.459	25.176	52.680	75.996	69.086
2003	17.871	11.822	32.280	1.423	30.972	12.093	82.144	115.760
2004	16.128	11.399	29.831	1.347	38.410	11.059	83.719	130.556
2005	18.055	10.642	30.452	1.321	35.564	41.098	84.958	105.727
2006	17.190	11.249	30.871	1.287	36.018	19.645	85.127	94.477
2007	15.502	11.018	25.943	1.213	40.191	13.351	86.970	103.327
2008	16.006	9.383	24.835	1.249	37.762	7.553	83.650	113.082
2009	15.950	9.417	25.907	1.301	33.197	8.535	77.878	90.547
2010	14.815	9.710	25.250	1.270	29.094	22.645	73.017	80.501
2011	12.544	9.177	24.978	1.204	28.673	13.271	68.703	66.408
2012	11.227	8.642	23.483	1.127	30.529	7.861	67.218	60.697
2013	11.180	7.928	22.516	1.075	28.848	5.854	64.677	62.217
2014	10.983	7.666	20.679	1.044	25.548	3.433	60.130	113.135
2015	9.538	7.052	17.873	1.024	21.874	5.568	53.483	64.175
2016	7.843	6.019	15.002	1.017	18.590	10.597	46.911	60.958
2017	6.296	4.970	12.480	1.007	16.827	4.351	41.988	52.935
2018	5.562	4.079	11.307	1.016	15.274	8.306	38.794	28.805
2019	6.339	3.826	12.278	1.141	13.382	3.597	36.979	28.539
2020	6.837	4.355	13.828	1.290	12.003	3.700		
2021	7.482	4.899	14.874	1.148	10.120	7.868	35.168	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 19.3g 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	55.728	28.455	83.919	7.485	57.578	NA	226.769	206.199
1976	65.307	35.574	99.372	7.106	92.549	76.664	265.711	312.109
1977	72.115	41.177	112.468	6.285	124.182	45.746	287.986	373.797
1978	77.152	46.015	118.437	5.159	127.884	71.063	293.553	322.142
1979	68.164	46.778	99.300	3.771	122.593	147.103	285.487	150.320
1980	50.715	37.562	30.796	1.640	127.062	219.400	278.000	209.070
1981	14.895	8.050	6.806	1.112	58.169	98.005	114.449	129.840
1982	7.155	2.207	6.879	0.960	27.683	267.220	73.066	122.494
1983	6.619	2.247	7.814	0.670	17.708	86.822	61.358	46.543
1984	6.512	2.385	5.550	0.428	14.784	63.130	51.116	66.781
1985	7.727	1.946	10.007	0.623	9.090	9.174	33.792	36.287
1986	12.213	4.722	15.307	0.899	12.558	28.033	43.694	33.034
1987	14.307	6.694	20.418	1.056	15.311	9.357	48.793	59.592
1988	14.271	8.371	24.815	1.102	19.143	5.751	51.697	51.717
1989	15.340	9.561	27.508	1.052	18.034	7.618	54.167	50.171
1990	14.880	10.224	23.734	0.983	16.077	20.168	54.262	51.793
1991	11.449	8.493	18.124	0.923	15.527	12.714	49.246	48.816
1992	9.160	6.341	16.911	0.893	16.670	2.917	44.593	37.343
1993	10.399	6.034	15.568	0.943	15.566	8.881	44.217	52.256
1994	10.233	5.892	21.357	1.029	13.231	2.794	39.843	33.654
1995	10.730	7.752	24.441	1.033	12.327	60.739	46.140	33.100
1996	11.022	8.408	22.941	0.990	18.787	9.463	55.532	43.148
1997	10.516	7.660	21.778	0.987	28.626	4.598	61.848	74.997
1998	15.891	7.654	24.819	1.183	25.323	13.053	66.179	82.230
1999	17.034	9.647	28.653	1.325	21.563	34.717	65.440	66.045
2000	14.773	10.613	28.987	1.334	23.353	13.538	67.441	78.239
2001	14.599	10.243	29.452	1.314	26.829	13.925	71.364	52.519
2002	17.440	10.452	33.546	1.350	26.307	57.437	77.167	69.265
2003	18.363	12.083	33.275	1.339	33.076	13.008	84.125	97.293
2004	16.695	11.736	31.020	1.289	41.834	12.353	86.566	96.644
2005	18.861	11.055	32.083	1.291	39.055	45.297	88.732	99.749
2006	18.071	11.816	32.769	1.281	39.973	21.232	89.759	108.431
2007	16.372	11.652	27.907	1.225	44.935	14.176	92.292	115.304
2008	17.054	10.038	27.102	1.271	42.264	8.191	89.435	108.292
2009	17.129	10.184	28.513	1.331	37.161	9.344	83.887	84.476
2010	16.006	10.581	28.014	1.291	32.573	25.597	79.228	83.035
2011	13.678	10.082	27.763	1.211	32.180	14.286	75.082	71.417
2012	12.335	9.530	26.273	1.126	34.372	8.938	73.720	64.814
2013	12.374	8.811	25.458	1.060	32.424	6.407	71.210	65.675
2014	12.258	8.602	23.776	1.006	28.814	3.701	66.571	130.051
2015	10.789	8.035	20.979	0.959	24.677	6.235	59.694	72.884
2016	9.019	6.992	18.021	0.924	20.990	11.105	52.807	66.727
2017	7.365	5.897	15.330	0.893	18.912	4.690	47.519	55.483
2018	6.579	4.936	14.034	0.885	17.035	8.354	43.953	32.517
2019	7.370	4.643	14.987	0.964	14.839	3.566	41.728	32.251
2020	7.853	5.171	16.498	1.071	13.193	3.803		
2021	8.393	5.697	16.791	0.934	11.092	7.860	38.981	27.761

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 21.1 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	56.355	28.732	85.018	18.164	55.294	NA	235.729	199.643
1976	65.761	35.872	100.332	51.274	83.915	68.515	274.956	327.615
1977	72.641	41.390	113.493	32.835	111.484	42.476	296.139	371.223
1978	77.507	46.277	119.259	86.217	116.071	68.477	299.706	343.189
1979	68.394	46.879	99.248	87.761	111.559	117.956	289.031	165.449
1980	50.507	37.431	29.978	15.585	114.004	155.638	274.648	247.226
1981	14.737	7.973	6.615	0.590	49.994	69.623	109.808	131.145
1982	6.842	2.183	6.630	0.474	21.991	244.122	65.446	141.898
1983	6.210	2.183	7.445	0.416	14.444	94.633	57.564	48.476
1984	6.147	2.293	5.233	0.228	14.199	64.109	50.365	152.607
1985	7.526	1.877	9.654	0.367	9.799	10.325	34.540	34.138
1986	12.133	4.616	15.034	0.801	13.778	30.158	45.137	47.434
1987	14.282	6.645	20.293	3.316	17.155	9.855	50.828	69.245
1988	14.301	8.374	24.851	3.468	21.541	6.280	54.182	54.597
1989	15.412	9.618	27.669	2.373	20.387	8.247	56.888	55.136
1990	14.942	10.309	23.904	1.844	18.261	21.054	57.038	59.451
1991	11.492	8.561	18.282	1.138	17.627	13.118	52.040	83.892
1992	9.246	6.401	17.136	1.006	18.729	3.148	47.464	37.334
1993	10.524	6.126	15.863	0.820	17.434	9.092	47.084	52.906
1994	10.381	6.014	21.735	0.965	14.877	3.119	42.558	32.104
1995	10.862	7.893	24.841	0.950	13.826	58.983	48.573	38.068
1996	11.126	8.537	23.296	0.965	19.812	8.793	57.719	43.959
1997	10.535	7.761	21.986	1.120	28.799	4.645	63.716	84.030
1998	15.812	7.706	24.806	1.309	25.384	12.564	67.569	84.101
1999	16.830	9.637	28.402	1.721	21.543	33.257	66.129	64.754
2000	14.509	10.508	28.570	1.377	22.916	12.768	67.618	67.381
2001	14.328	10.084	28.944	1.223	25.952	13.080	71.169	52.455
2002	17.108	10.275	32.894	1.419	25.308	52.028	76.241	69.086
2003	17.922	11.861	32.392	1.468	30.994	11.914	82.366	115.760
2004	16.144	11.429	29.892	1.425	38.277	11.330	83.948	130.556
2005	18.105	10.661	30.554	1.413	35.592	40.419	85.085	105.727
2006	17.223	11.281	30.957	1.424	35.978	19.617	85.123	94.477
2007	15.498	11.036	25.965	1.158	39.996	13.189	86.917	103.327
2008	16.023	9.387	24.873	1.001	37.602	7.403	83.605	113.082
2009	15.987	9.429	25.978	1.045	32.995	8.558	77.854	90.547
2010	14.915	9.736	25.422	1.057	28.974	22.454	72.999	80.501
2011	12.653	9.244	25.197	1.014	28.601	13.200	68.707	66.408
2012	11.290	8.717	23.651	0.924	30.461	7.689	67.232	60.697
2013	11.226	7.980	22.650	0.994	28.813	5.608	64.666	62.217
2014	11.026	7.705	20.797	0.975	25.485	3.489	60.062	113.135
2015	9.567	7.083	17.961	0.838	21.803	5.431	53.365	64.175
2016	7.854	6.040	15.052	0.693	18.555	10.701	46.761	60.958
2017	6.308	4.980	12.520	0.546	16.762	4.377	41.852	52.935
2018	5.559	4.088	11.320	0.485	15.223	8.318	38.750	28.805
2019	6.403	3.831	12.383	0.516	13.404	3.563	37.027	28.539
2020	6.903	4.400	13.964	0.591	12.049	3.849		
2021	7.543	4.946	14.947	1.158	10.261	7.802	35.295	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 21.2 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	56.311	28.712	84.933	43.404	55.231	NA	234.901	199.643
1976	65.742	35.852	100.284	29.014	84.075	68.767	274.281	327.615
1977	72.698	41.391	113.574	82.107	111.955	42.714	295.827	371.223
1978	77.648	46.337	119.517	105.684	116.765	69.081	299.890	343.189
1979	68.599	47.002	99.677	51.821	112.444	119.316	289.790	165.449
1980	50.772	37.604	30.208	2.694	115.132	158.227	276.177	247.226
1981	14.819	8.006	6.683	0.478	50.561	70.661	110.516	131.145
1982	6.889	2.197	6.664	0.372	22.271	247.557	65.822	141.898
1983	6.228	2.187	7.441	0.324	14.580	95.014	57.721	48.476
1984	6.163	2.285	5.221	0.198	14.267	63.796	50.287	152.607
1985	7.527	1.871	9.642	0.514	9.773	10.296	34.335	34.138
1986	12.132	4.612	15.026	2.456	13.710	29.906	44.884	47.434
1987	14.279	6.640	20.283	2.831	17.060	9.810	50.544	69.245
1988	14.301	8.367	24.841	2.130	21.422	6.246	53.903	54.597
1989	15.413	9.614	27.661	2.134	20.297	8.240	56.642	55.136
1990	14.945	10.307	23.898	1.487	18.215	21.007	56.828	59.451
1991	11.496	8.560	18.279	1.073	17.610	13.103	51.863	83.892
1992	9.252	6.402	17.137	0.886	18.731	3.151	47.328	37.334
1993	10.537	6.129	15.879	0.705	17.464	9.082	46.999	52.906
1994	10.398	6.021	21.762	0.832	14.928	3.119	42.524	32.104
1995	10.881	7.903	24.873	1.030	13.897	58.822	48.528	38.068
1996	11.141	8.549	23.323	1.188	19.853	8.814	57.621	43.959
1997	10.559	7.771	22.026	1.163	28.841	4.637	63.629	84.030
1998	15.849	7.725	24.873	1.507	25.455	12.580	67.545	84.101
1999	16.875	9.661	28.490	1.373	21.645	33.345	66.163	64.754
2000	14.555	10.538	28.665	1.211	23.052	12.808	67.685	67.381
2001	14.378	10.117	29.049	1.254	26.139	13.099	71.285	52.455
2002	17.173	10.314	33.026	1.497	25.521	52.368	76.416	69.086
2003	17.997	11.908	32.549	1.551	31.290	12.021	82.602	115.760
2004	16.223	11.483	30.064	1.390	38.720	11.444	84.297	130.556
2005	18.211	10.723	30.773	1.416	36.082	40.988	85.577	105.727
2006	17.340	11.358	31.212	1.393	36.569	20.031	85.776	94.477
2007	15.624	11.123	26.247	1.056	40.783	13.487	87.768	103.327
2008	16.195	9.487	25.237	1.016	38.467	7.619	84.668	113.082
2009	16.211	9.561	26.452	1.100	33.857	8.825	79.109	90.547
2010	15.173	9.906	25.990	1.046	29.827	23.395	74.443	80.501
2011	12.920	9.442	25.821	1.009	29.599	13.828	70.358	66.408
2012	11.559	8.927	24.306	1.067	31.721	8.088	69.095	60.697
2013	11.530	8.197	23.378	1.097	30.128	5.963	66.714	62.217
2014	11.382	7.948	21.632	1.010	26.743	3.721	62.248	113.135
2015	9.951	7.363	18.882	0.870	22.957	5.841	55.643	64.175
2016	8.257	6.344	16.041	0.700	19.622	11.615	49.136	60.958
2017	6.716	5.301	13.548	0.581	17.834	4.800	44.354	52.935
2018	5.997	4.416	11.577	0.482	16.309	9.156	41.432	28.805
2019	6.127	3.675	10.999	0.465	12.288	3.485	34.514	28.539
2020	5.782	3.674	11.445	0.523	9.462	3.312		
2021	6.253	4.067	12.631	1.293	8.115	6.659	28.528	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 19.3d are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 19.3d for 2021 is 0.163 and MSST is 12354 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	16.658	14.841	18.633	15.673	13.963	17.519
2022	18.909	16.411	20.931	16.892	14.627	18.671
2023	20.679	17.201	22.720	17.677	14.609	19.351
2024	22.320	18.124	24.902	18.363	14.734	20.690
2025	23.477	18.776	27.097	18.659	14.763	21.901
2026	24.251	18.839	28.785	18.701	14.341	22.782
2027	24.690	19.103	30.241	18.534	14.156	23.370
2028	25.149	19.033	31.288	18.542	13.835	23.670
2029	25.488	19.162	32.052	18.583	13.530	23.891
2030	25.880	19.182	32.492	18.568	13.534	23.895
2031	26.190	19.570	33.098	18.625	13.730	23.987

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	14.764	13.150	16.498	13.909	12.391	15.554
2022	15.143	13.078	16.726	13.603	11.729	15.021
2023	15.213	12.488	16.697	13.141	10.725	14.490
2024	15.297	12.157	17.387	12.910	10.205	14.808
2025	15.131	11.840	17.987	12.557	9.666	15.107
2026	14.882	11.132	18.473	12.122	8.967	15.414
2027	14.426	10.772	18.687	11.642	8.512	15.436
2028	14.303	10.459	18.699	11.483	8.222	15.263
2029	14.229	10.199	18.695	11.336	7.966	15.230
2030	14.134	9.935	18.612	11.263	7.855	15.254
2031	14.095	10.208	18.618	11.228	7.994	15.054

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 19.3g are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 19.3g for 2021 is 0.183 and MSST is 12725 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	19.022	17.206	20.721	17.878	16.131	19.469
2022	20.876	18.337	22.952	18.544	16.232	20.444
2023	22.336	18.733	24.936	18.924	15.757	21.247
2024	24.176	19.522	26.665	19.822	15.760	21.977
2025	25.395	20.008	28.864	20.075	15.597	23.245
2026	25.942	20.135	30.521	19.941	15.220	23.958
2027	26.430	20.247	32.057	19.818	14.838	24.739
2028	26.828	20.219	33.184	19.630	14.449	25.206
2029	27.054	20.256	34.166	19.619	14.179	25.153
2030	27.326	20.223	34.438	19.393	14.094	25.227
2031	27.614	20.415	35.009	19.437	14.116	25.357

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	16.812	15.148	18.308	15.805	14.220	17.229
2022	16.531	14.412	18.322	14.773	12.835	16.439
2023	16.178	13.338	18.241	13.929	11.372	15.781
2024	16.455	12.936	18.325	13.838	10.741	15.578
2025	16.256	12.438	19.103	13.425	10.086	15.984
2026	15.744	11.835	19.320	12.842	9.417	16.051
2027	15.430	11.266	19.737	12.390	8.861	16.205
2028	15.089	10.856	19.857	12.134	8.516	16.224
2029	14.954	10.563	19.642	11.912	8.314	16.008
2030	14.746	10.477	19.620	11.727	8.162	15.950
2031	14.664	10.458	19.628	11.607	8.122	15.938

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 21.1 are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 21.1 for 2021 is 0.168 and MSST is 12119 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	16.717	14.132	19.353	15.716	13.293	18.178
2022	18.563	15.770	21.280	16.547	14.112	18.955
2023	19.717	16.861	22.603	16.744	14.280	19.199
2024	20.865	17.454	24.341	16.985	14.096	20.132
2025	21.748	17.673	26.538	17.157	13.685	21.464
2026	22.437	17.873	28.468	17.237	13.445	22.559
2027	23.110	18.036	30.224	17.360	13.127	23.392
2028	23.628	18.094	31.126	17.452	12.851	23.609
2029	24.052	18.156	31.928	17.529	12.798	24.072
2030	24.440	18.351	32.734	17.543	12.750	24.173
2031	24.817	18.569	33.152	17.652	12.752	24.259

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	14.795	12.501	17.099	13.948	11.766	16.105
2022	14.773	12.669	16.930	13.242	11.325	15.213
2023	14.267	12.180	16.486	12.282	10.494	14.245
2024	14.008	11.488	16.868	11.737	9.540	14.384
2025	13.873	10.788	17.598	11.418	8.647	14.834
2026	13.701	10.371	18.303	11.096	8.206	15.312
2027	13.531	9.875	18.685	10.901	7.702	15.616
2028	13.461	9.603	18.766	10.796	7.434	15.608
2029	13.444	9.500	18.941	10.776	7.388	15.519
2030	13.384	9.380	18.937	10.697	7.268	15.432
2031	13.382	9.317	18.690	10.726	7.182	15.329

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 21.2 are used for the projection with recruitments randomly drawn from estimated recruitments from 2013 to 2020. Estimated F_{ofl} for Model 21.2 for 2021 is 0.135 and MSST is 12225 t.

	F=0			F=0.083		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	13.969	11.516	16.666	13.135	10.850	15.689
2022	15.750	13.014	18.691	14.076	11.589	16.686
2023	16.756	13.952	20.023	14.237	11.790	16.963
2024	17.826	14.726	21.702	14.617	11.932	17.908
2025	19.198	15.219	24.092	15.213	11.929	19.570
2026	20.361	15.687	26.253	15.798	11.872	21.175
2027	21.461	16.057	28.557	16.384	11.858	22.533
2028	22.571	16.549	30.358	17.032	11.958	23.550
2029	23.369	16.907	31.543	17.234	12.149	24.280
2030	23.979	17.395	32.515	17.545	12.296	24.759
2031	24.704	17.950	33.533	17.817	12.550	24.911

	F=0.167			F=0.250		
	Median	5% limit	95% limit	Median	5% limit	95% limit
2021	12.373	10.231	14.783	11.678	9.656	13.943
2022	12.602	10.362	14.972	11.316	9.297	13.478
2023	12.170	9.975	14.624	10.477	8.580	12.722
2024	12.124	9.785	15.042	10.193	8.153	12.822
2025	12.402	9.500	16.241	10.274	7.697	13.795
2026	12.589	9.211	17.460	10.333	7.364	14.713
2027	13.006	9.029	18.407	10.637	7.222	15.519
2028	13.343	9.055	19.059	10.804	7.142	15.890
2029	13.442	9.058	19.309	10.865	7.081	16.041
2030	13.583	9.180	19.800	11.029	7.218	16.393
2031	13.672	9.256	19.779	11.098	7.257	16.217

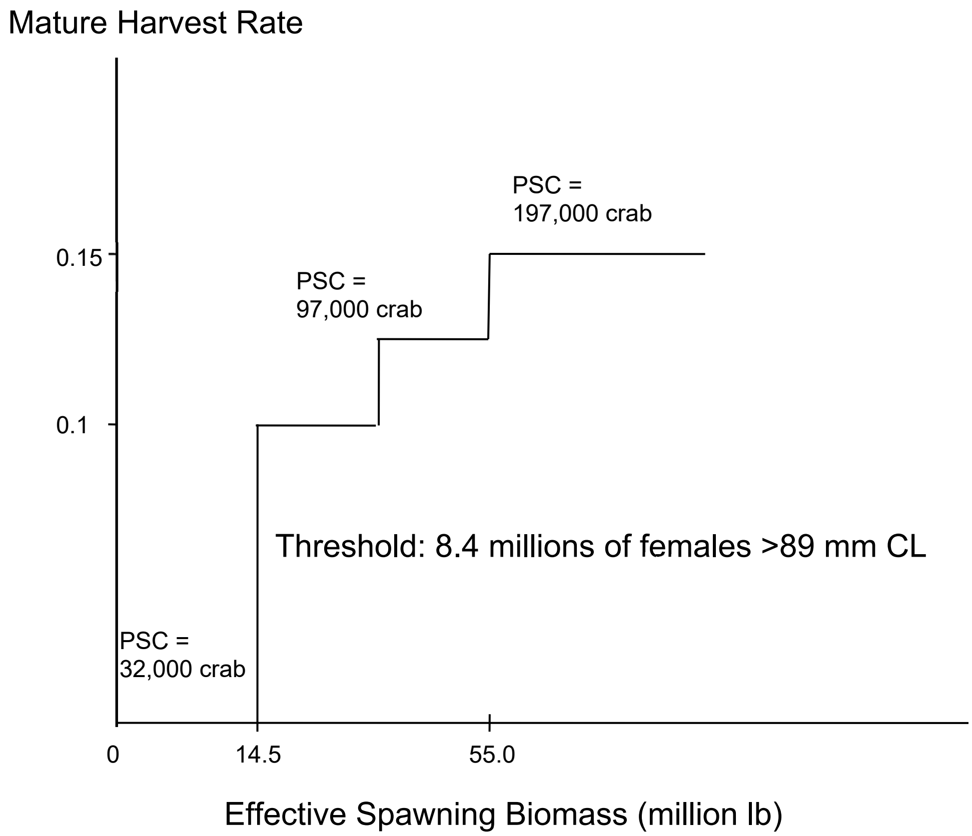


Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crab) of Bristol Bay red king crab in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of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

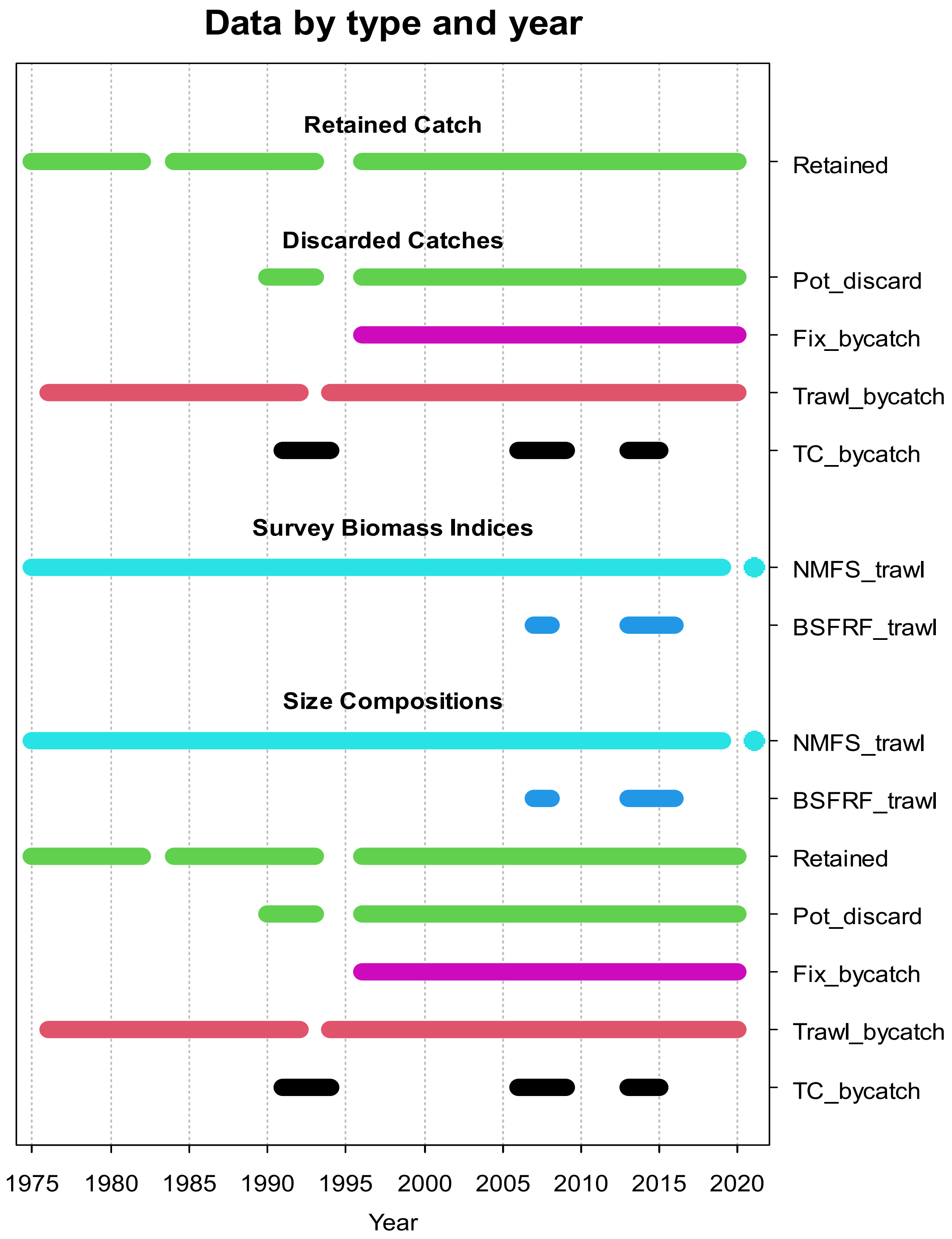


Figure 2. Data types and ranges used for the stock assessment.

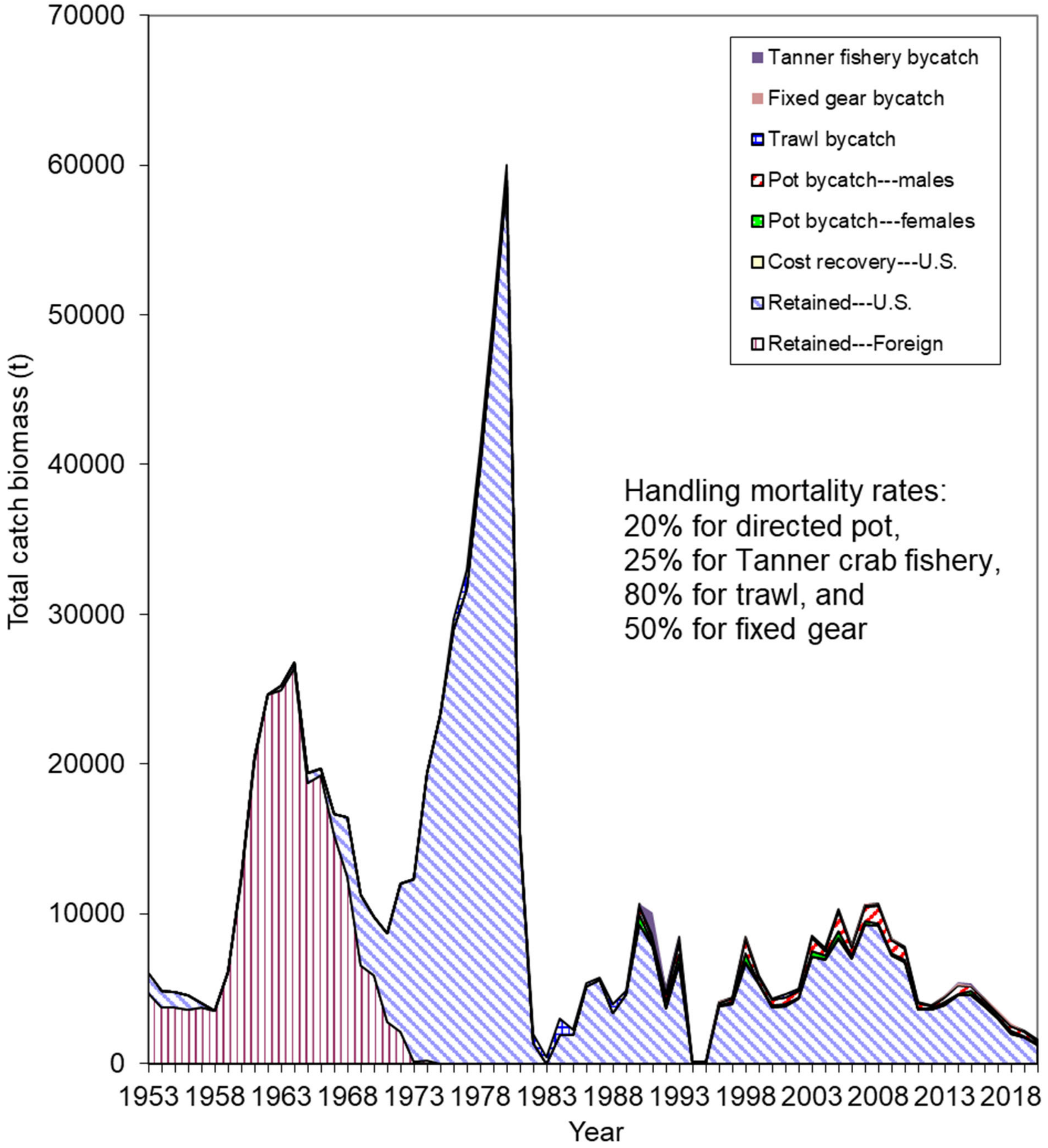


Figure 3. Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1953 to 2020. Directed pot bycatch data were not available from the observer program before 1990 and are not included in this figure.

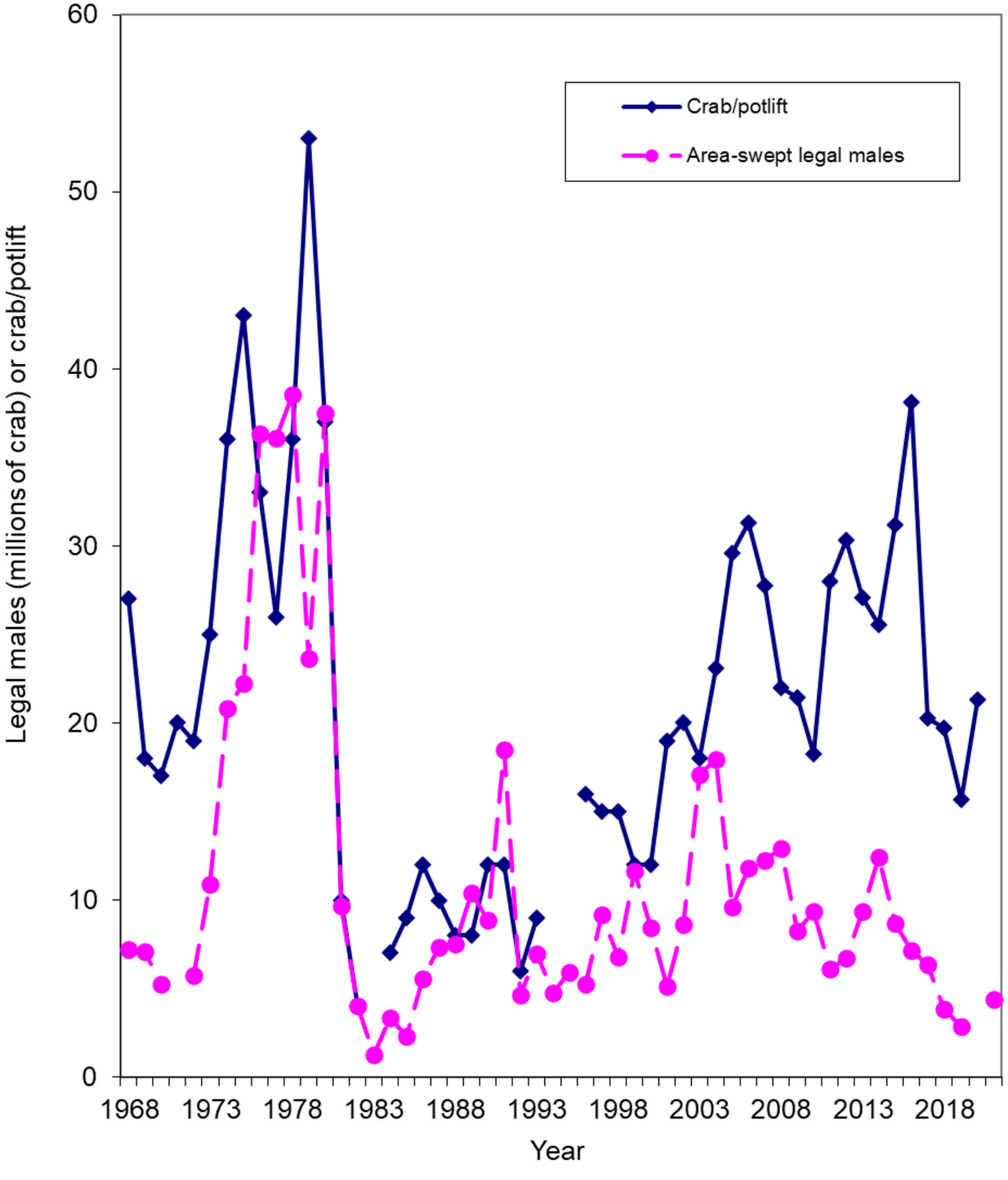


Figure 4. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2021.

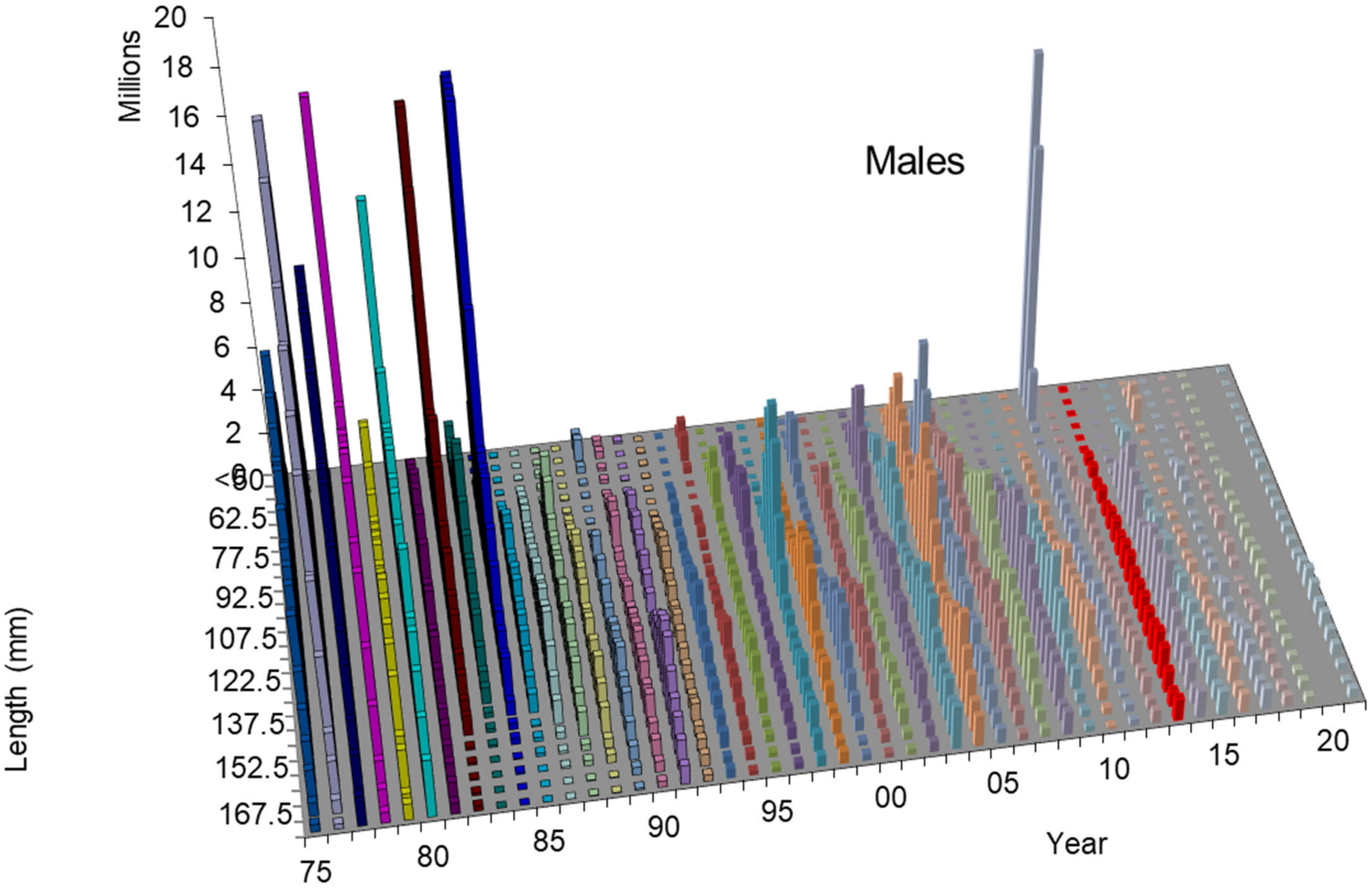


Figure 5a. Survey abundances by 5-mm carapace length bin for male Bristol Bay red king crab from 1975 to 2021.

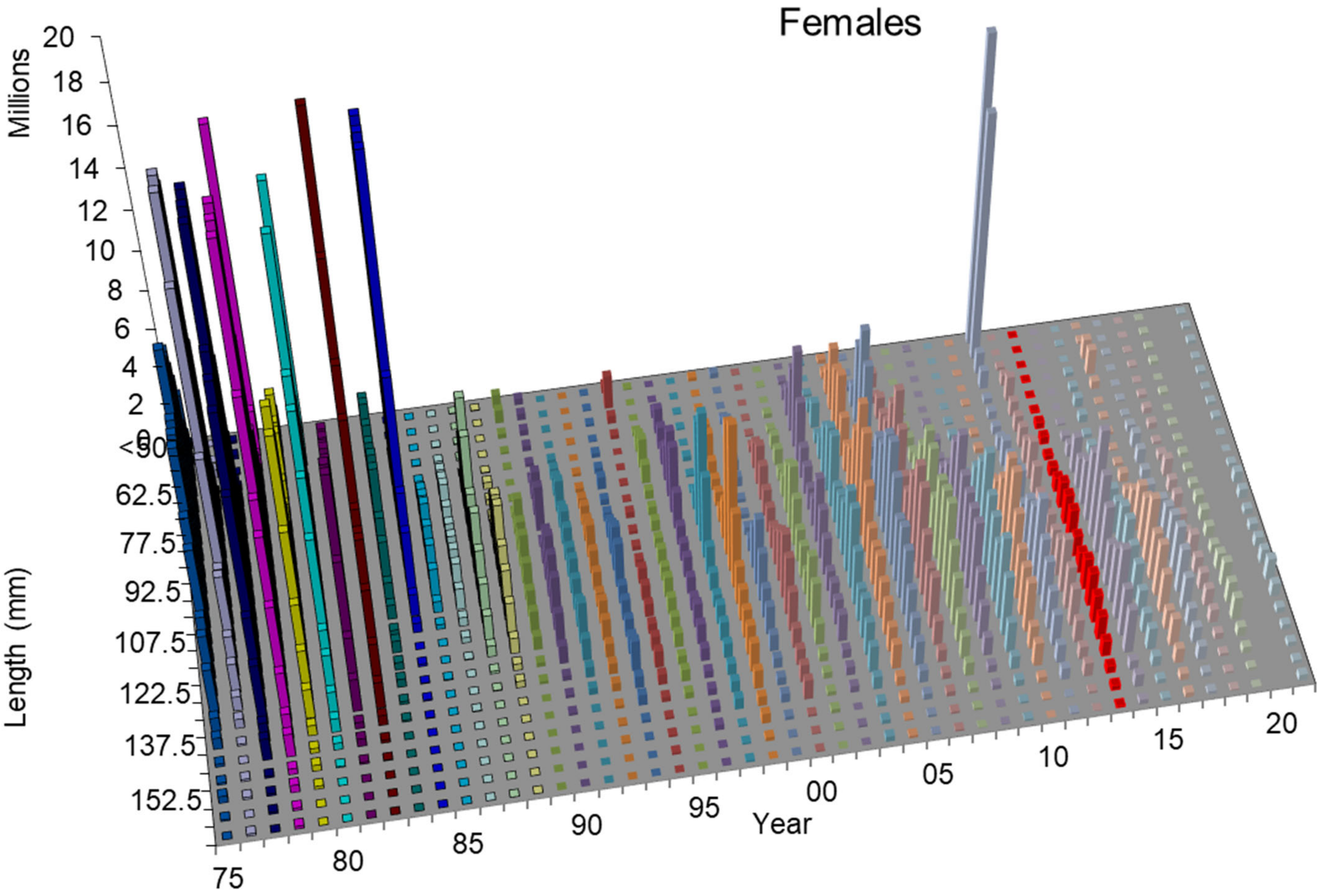


Figure 5b. Survey abundances by 5 mm carapace length bin for female Bristol Bay red king crab from 1975 to 2021.

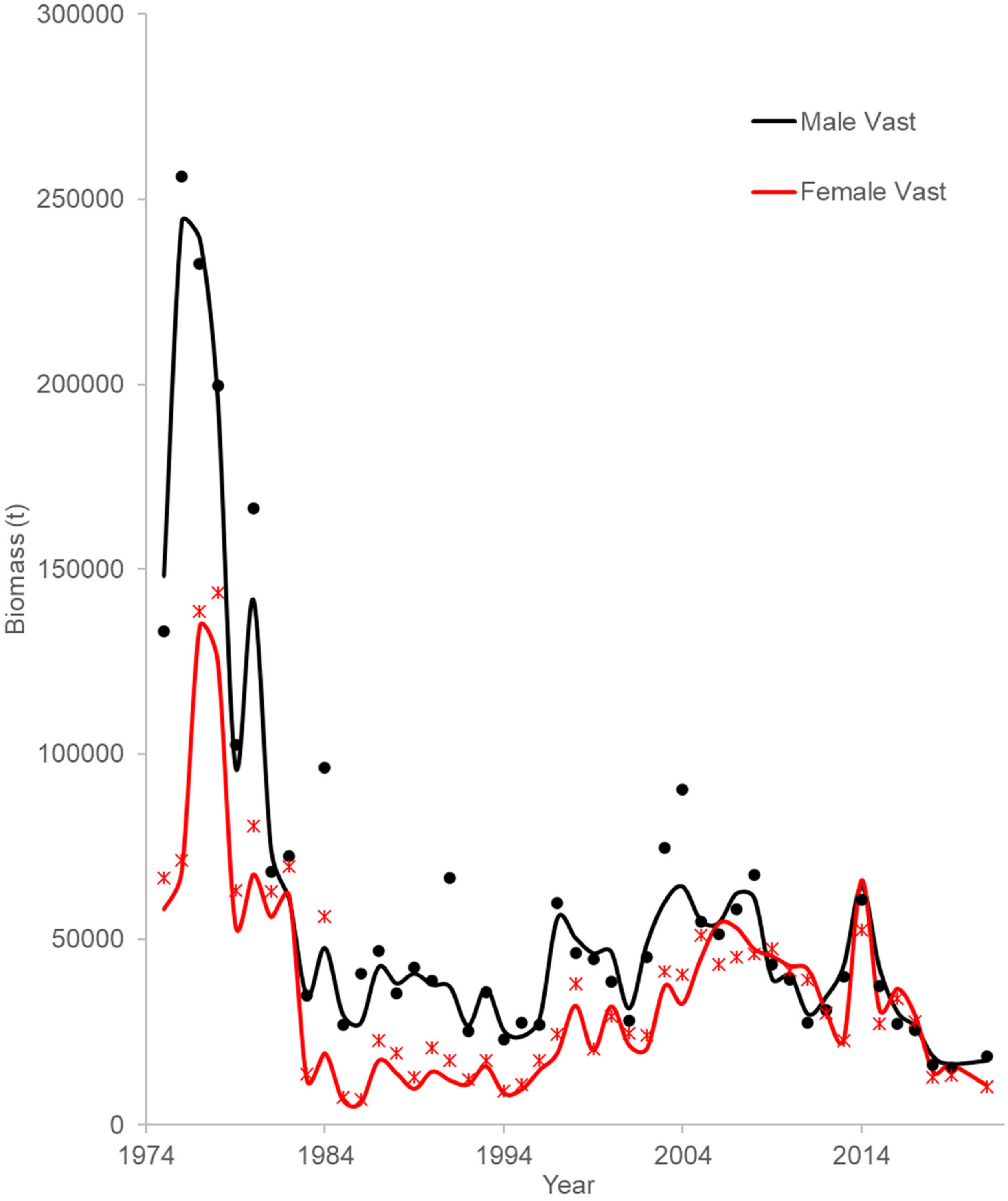


Figure 6. Comparison of area-swept and VAST-estimated survey biomasses for Bristol Bay red king crab from 1975 to 2021.

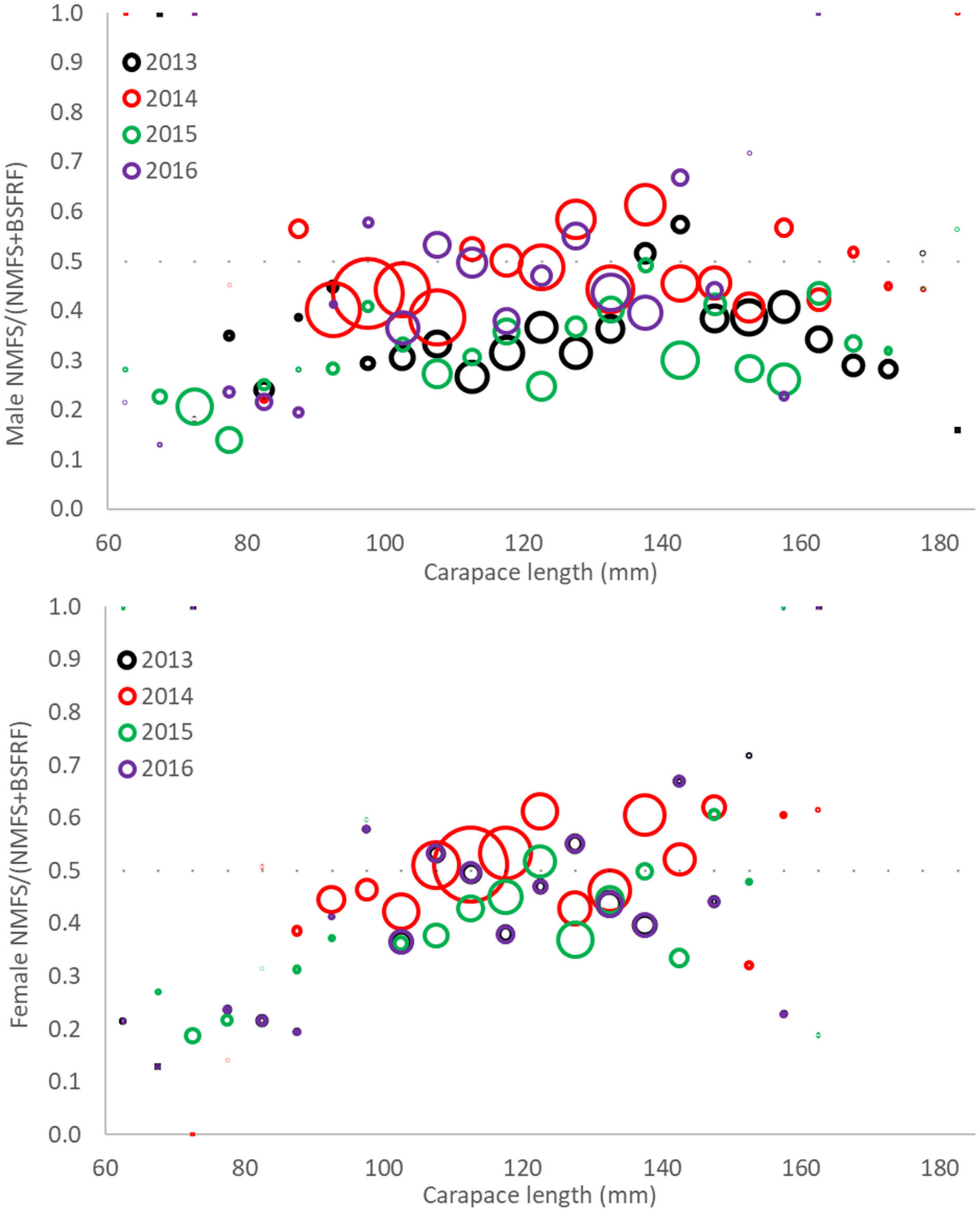
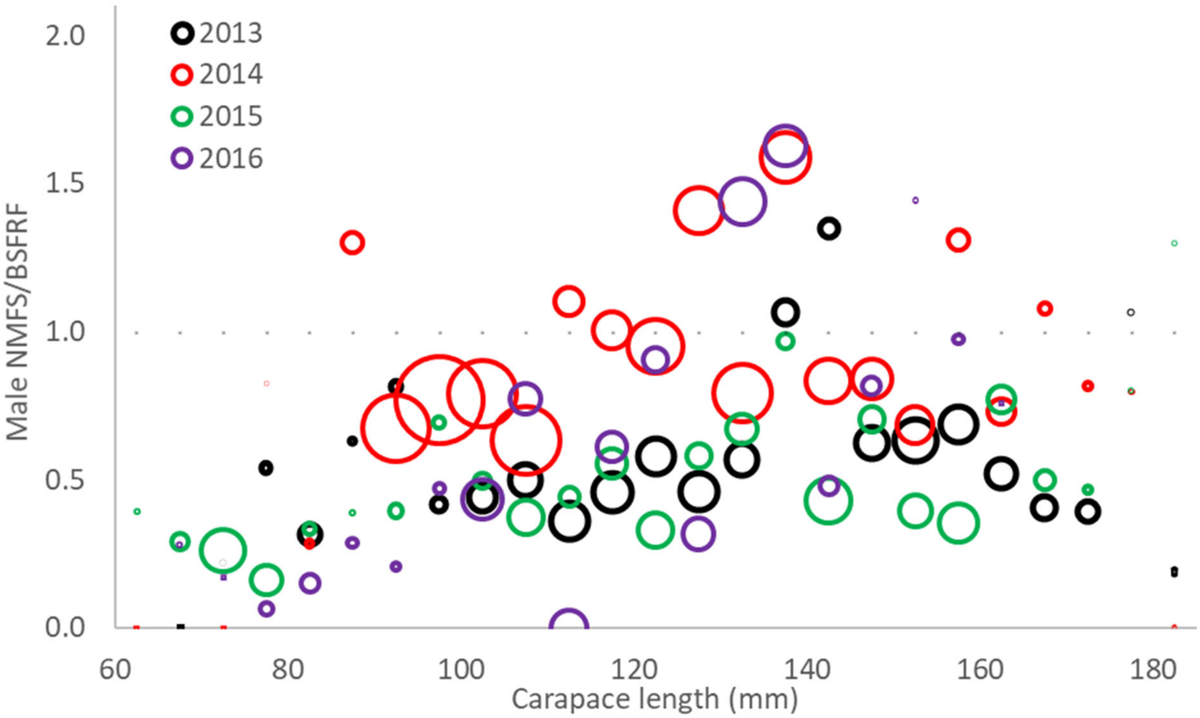


Figure 7a. Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.



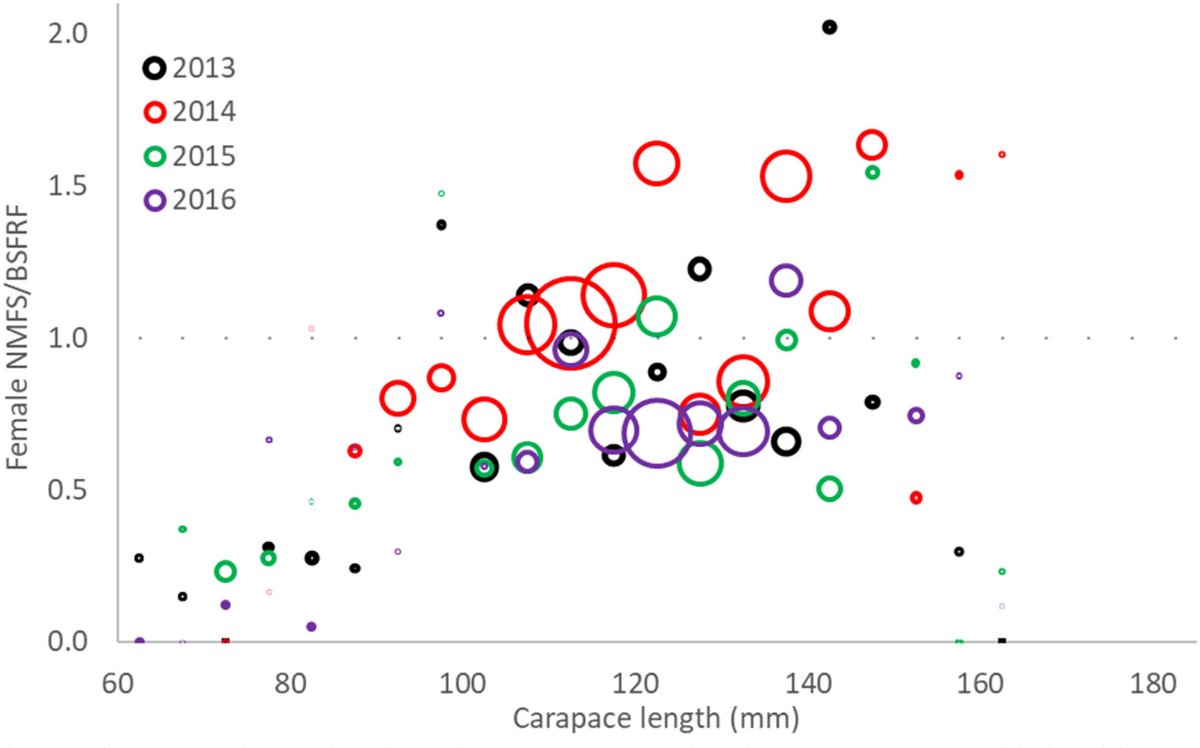


Figure 7b. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

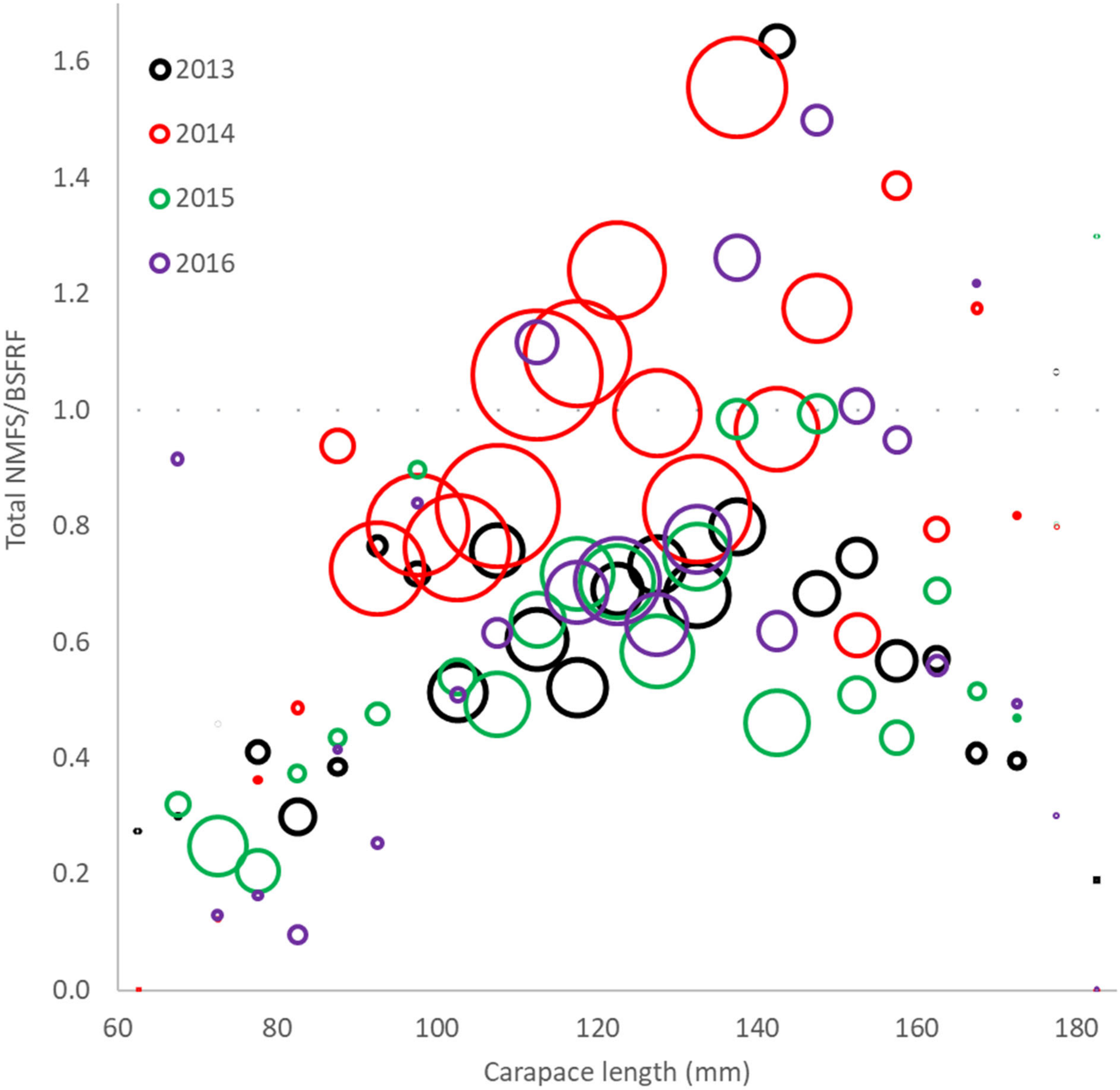


Figure 7c. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances. The abundance-weighted average ratio is 0.891 for crab ≥135 mm carapace length from all four years of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

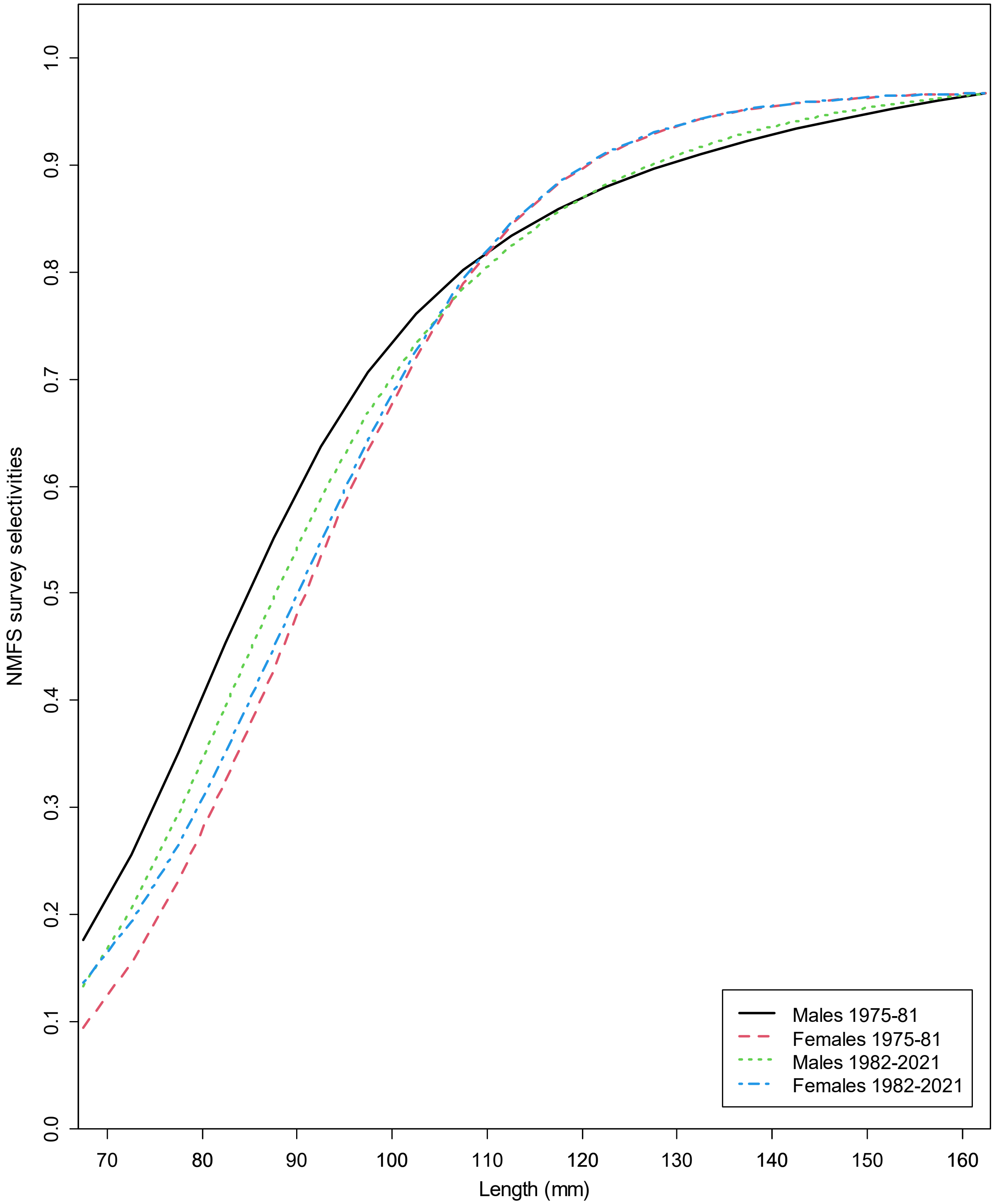


Figure 8a. Estimated NMFS trawl survey selectivities under model 19.3d.

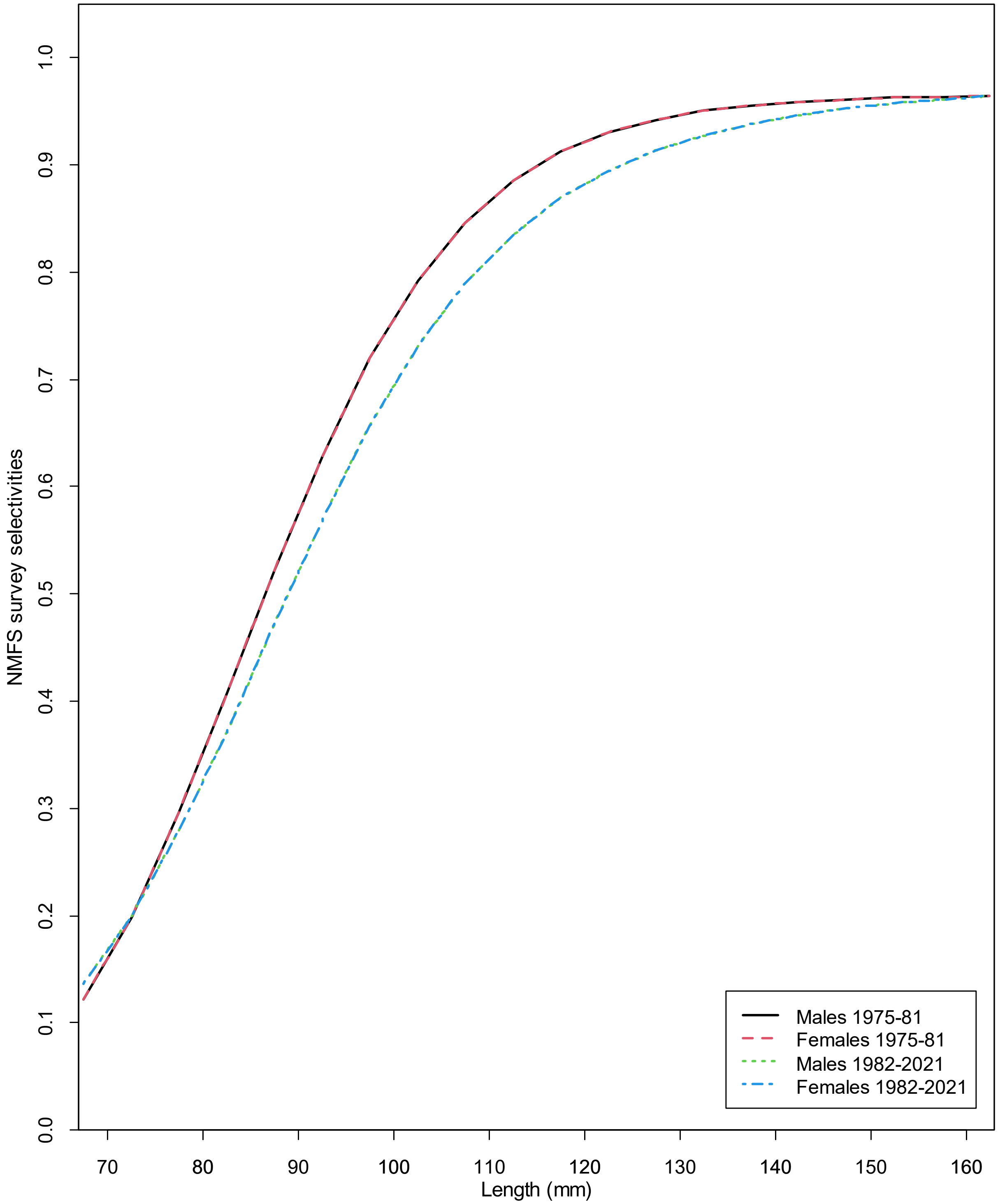


Figure 8b. Estimated NMFS trawl survey selectivities under model 21.1.

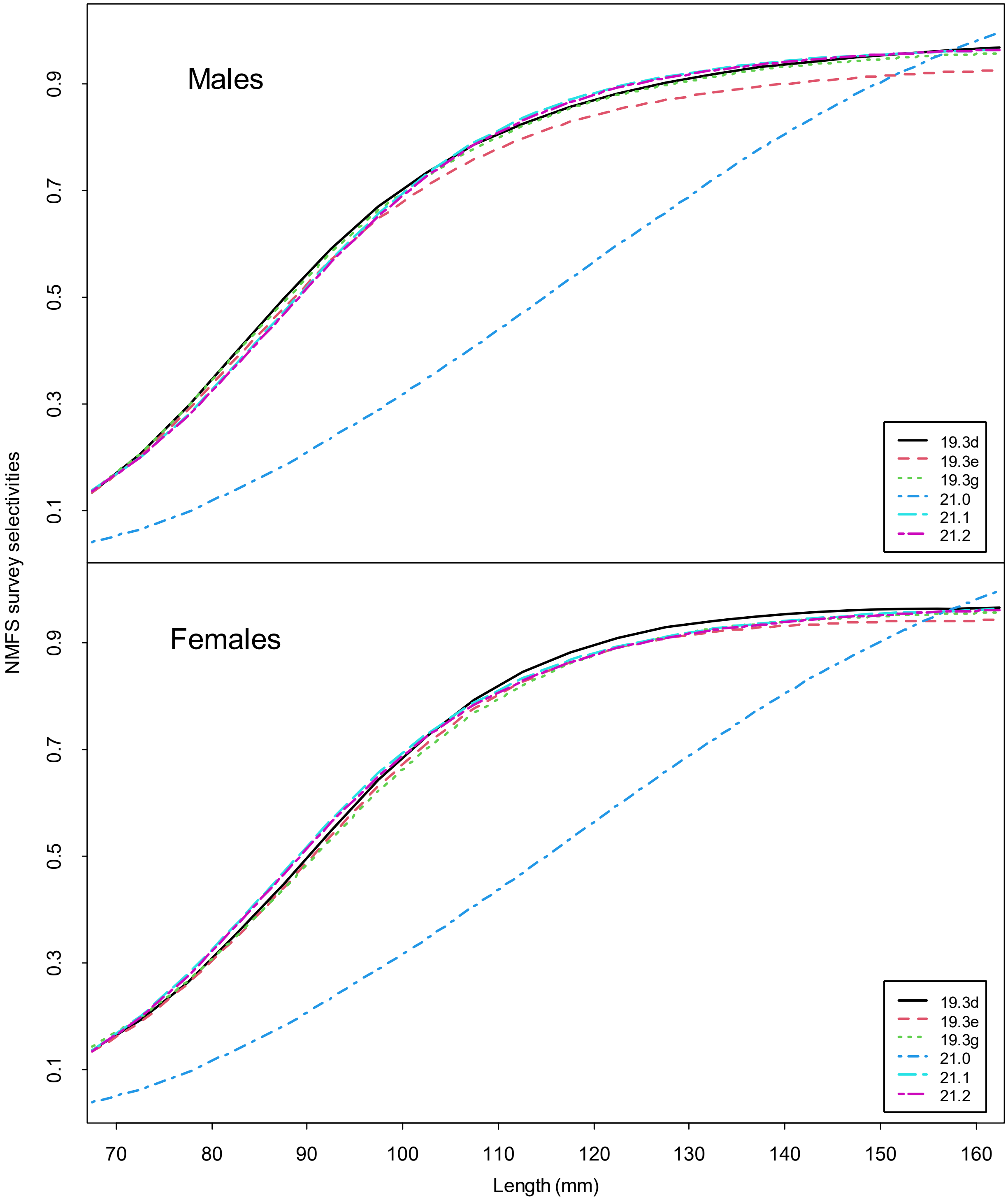


Figure 8c. Comparisons of estimated NMFS survey selectivities with models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2 during 1982-2021.

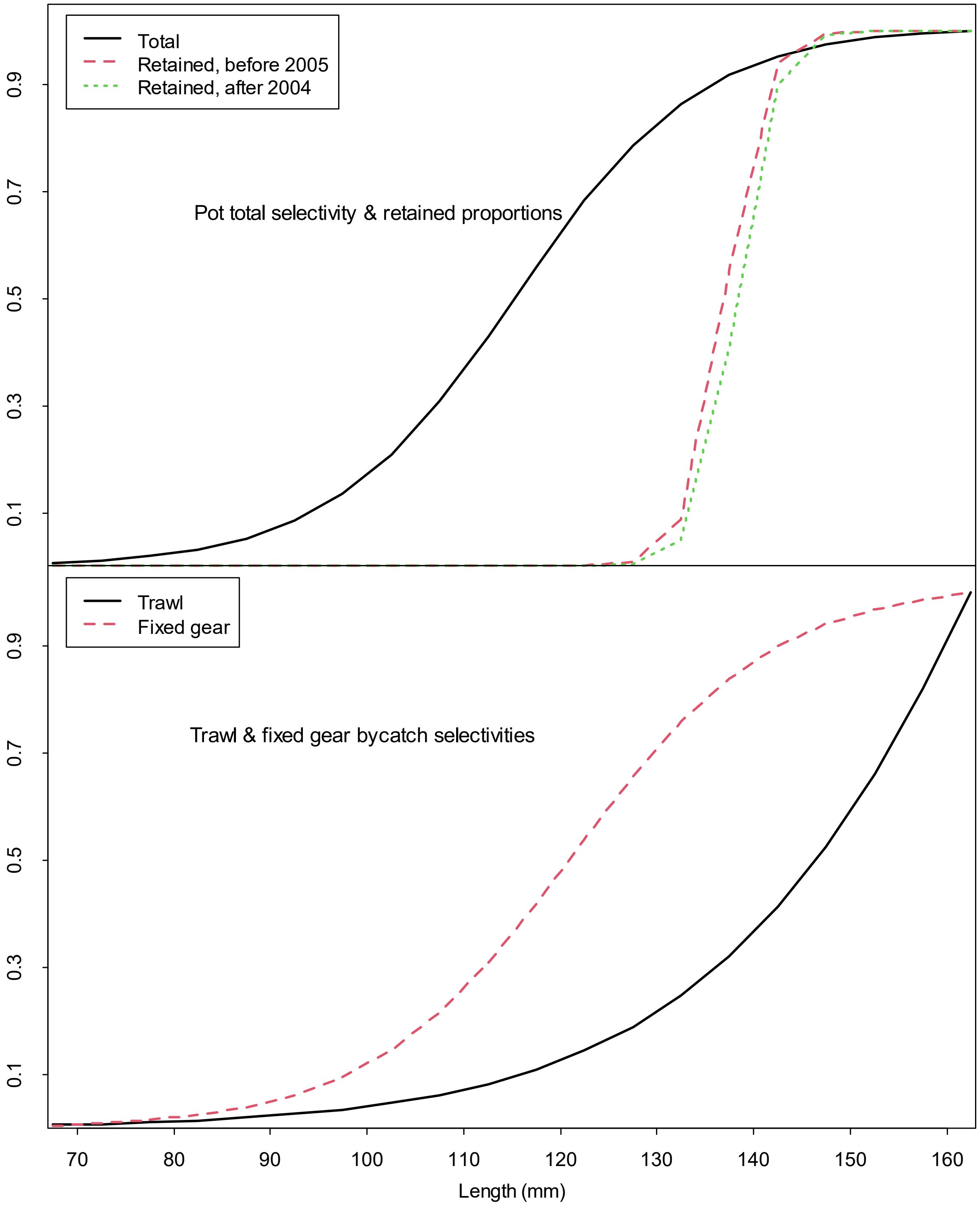


Figure 8d. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 19.3d.

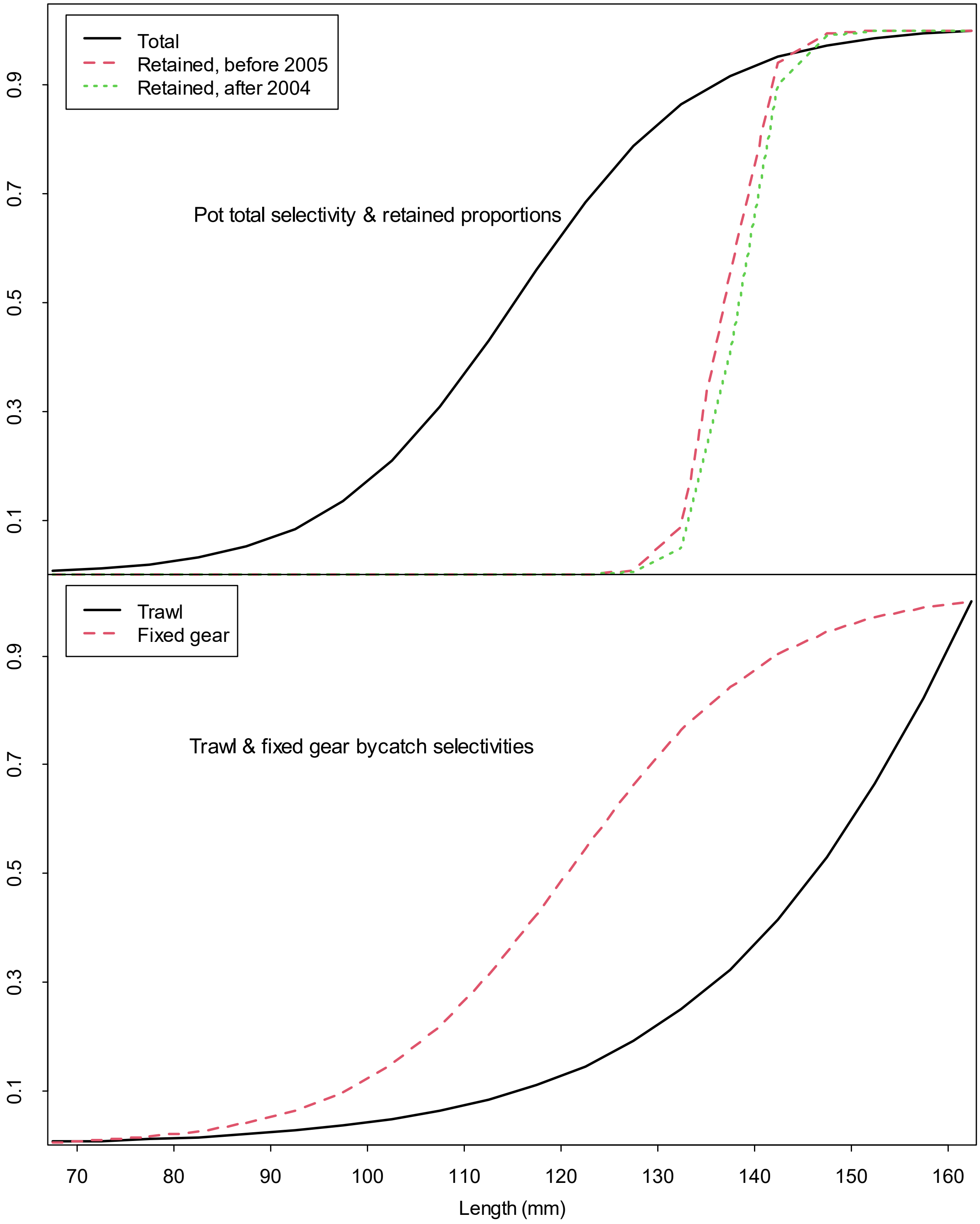


Figure 8e. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 21.1.

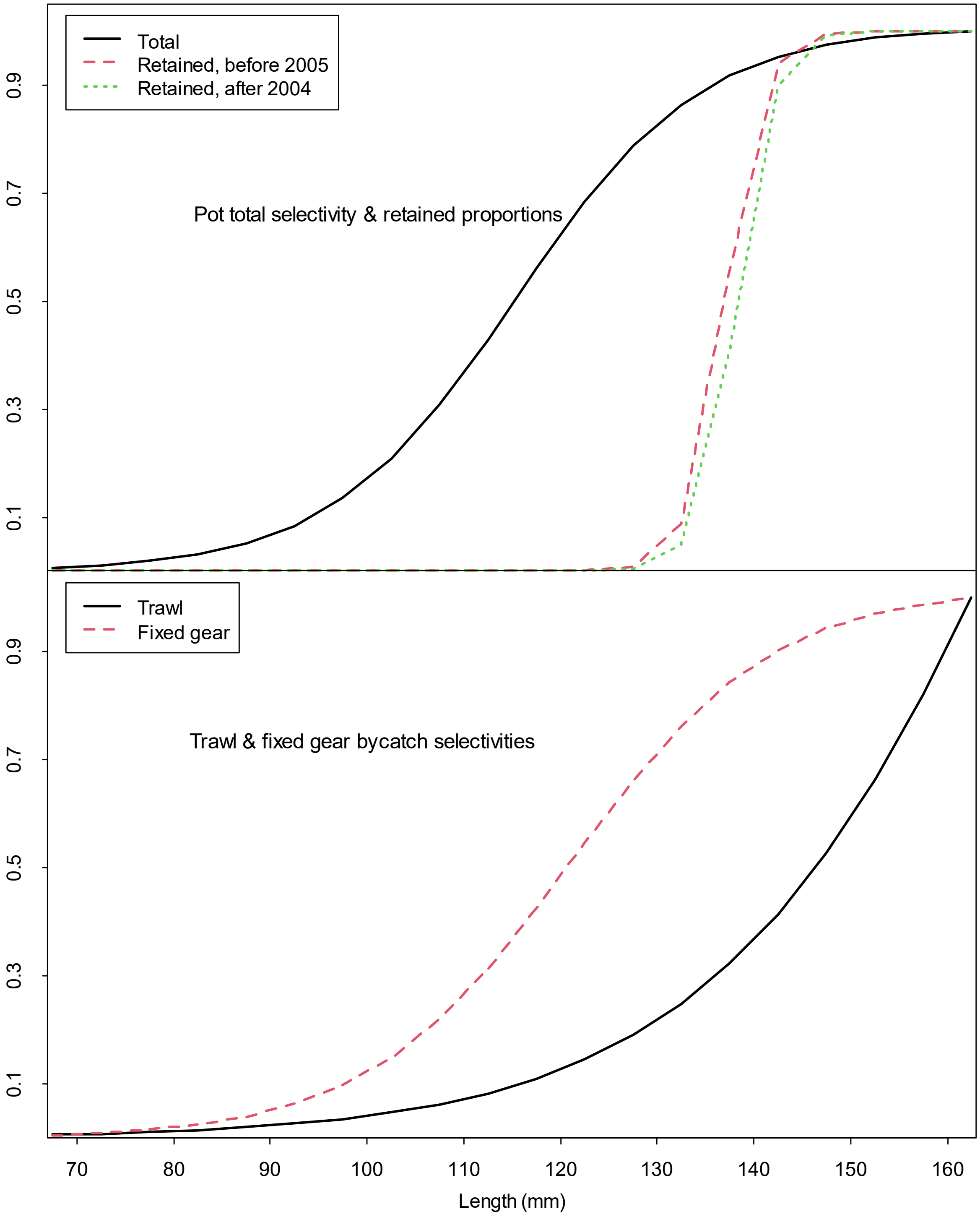


Figure 8f. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 21.2.

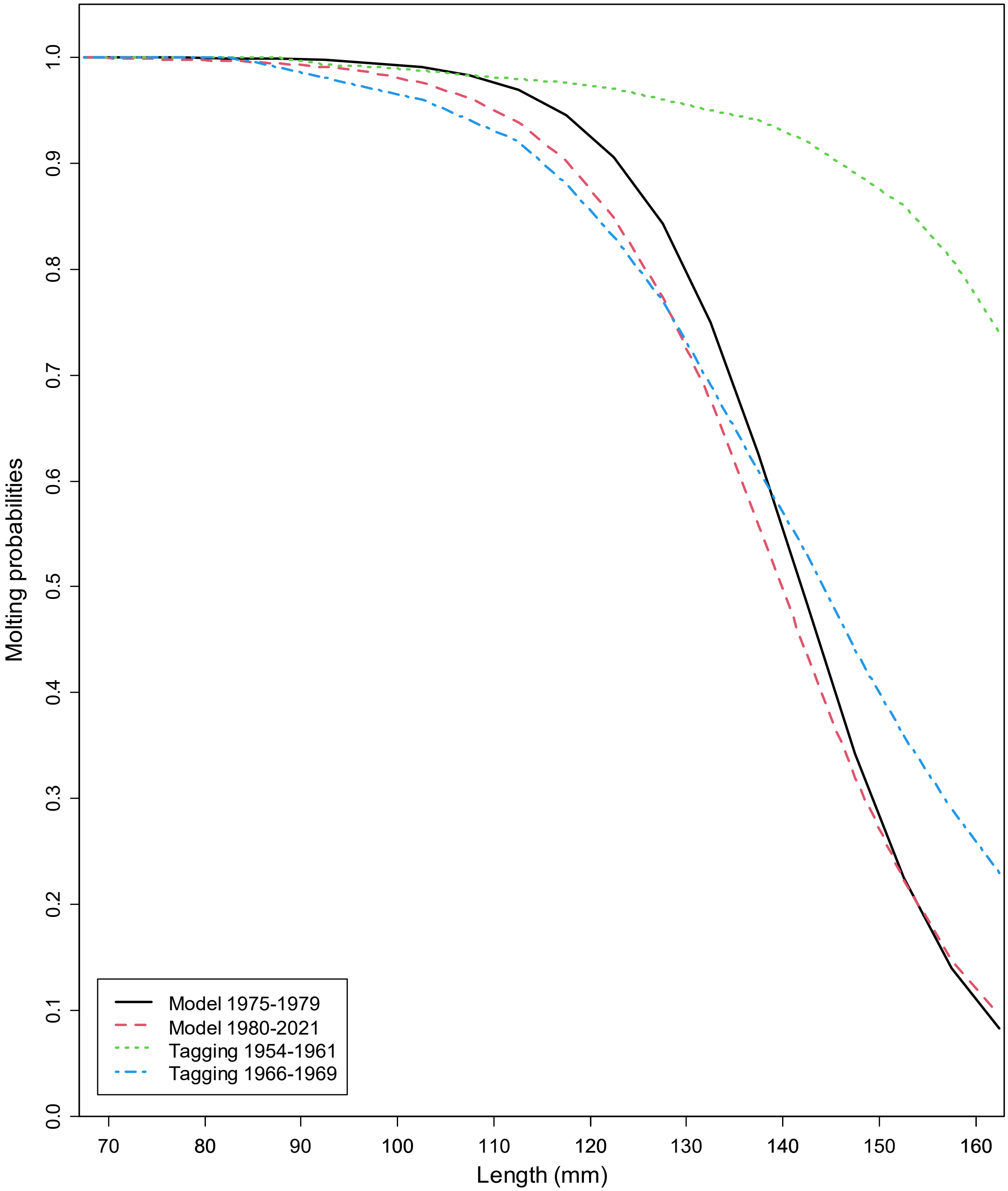


Figure 9a. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 19.3d. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2021 were estimated with a length-based model.

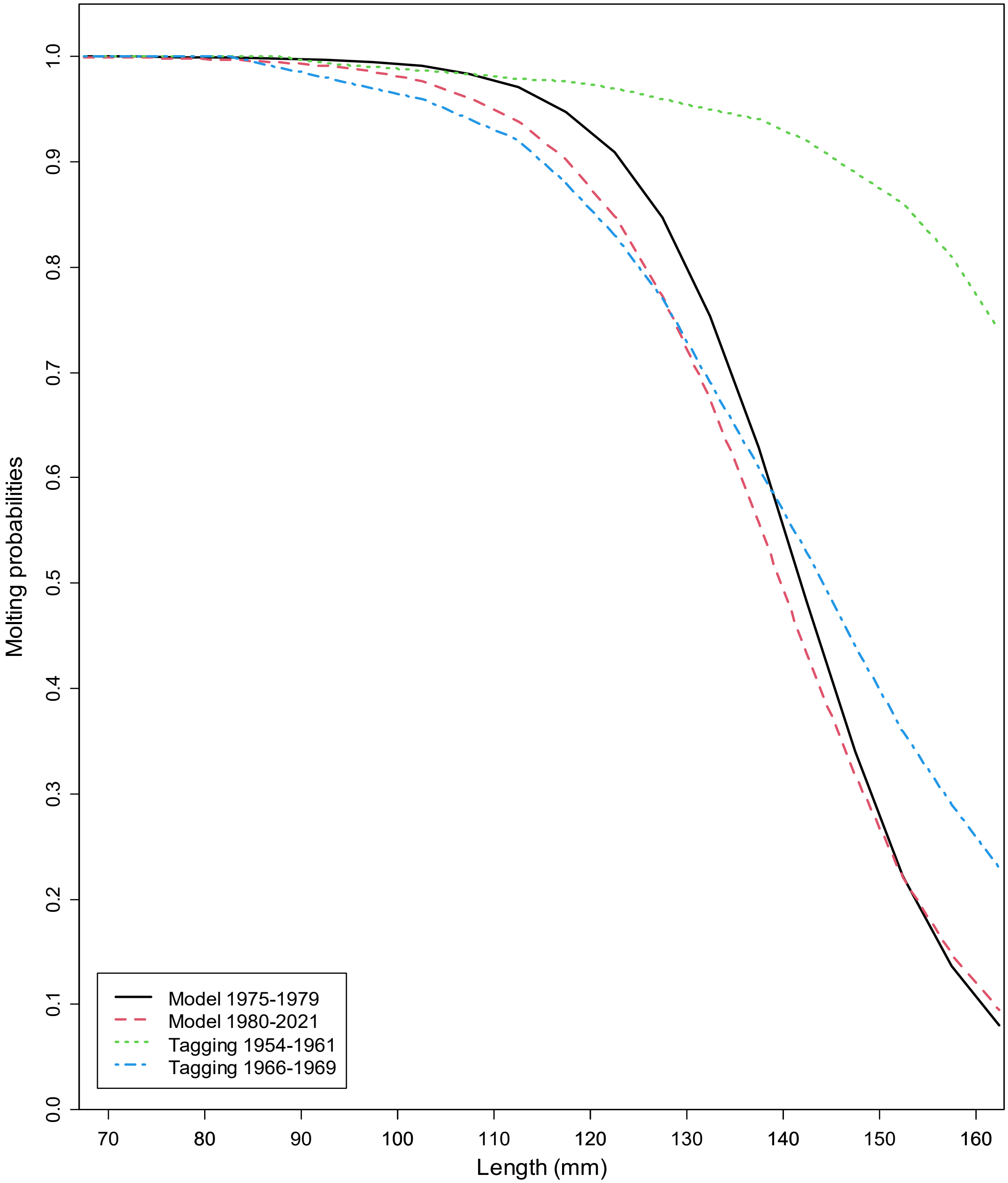


Figure 9b. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 21.1. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2021 were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

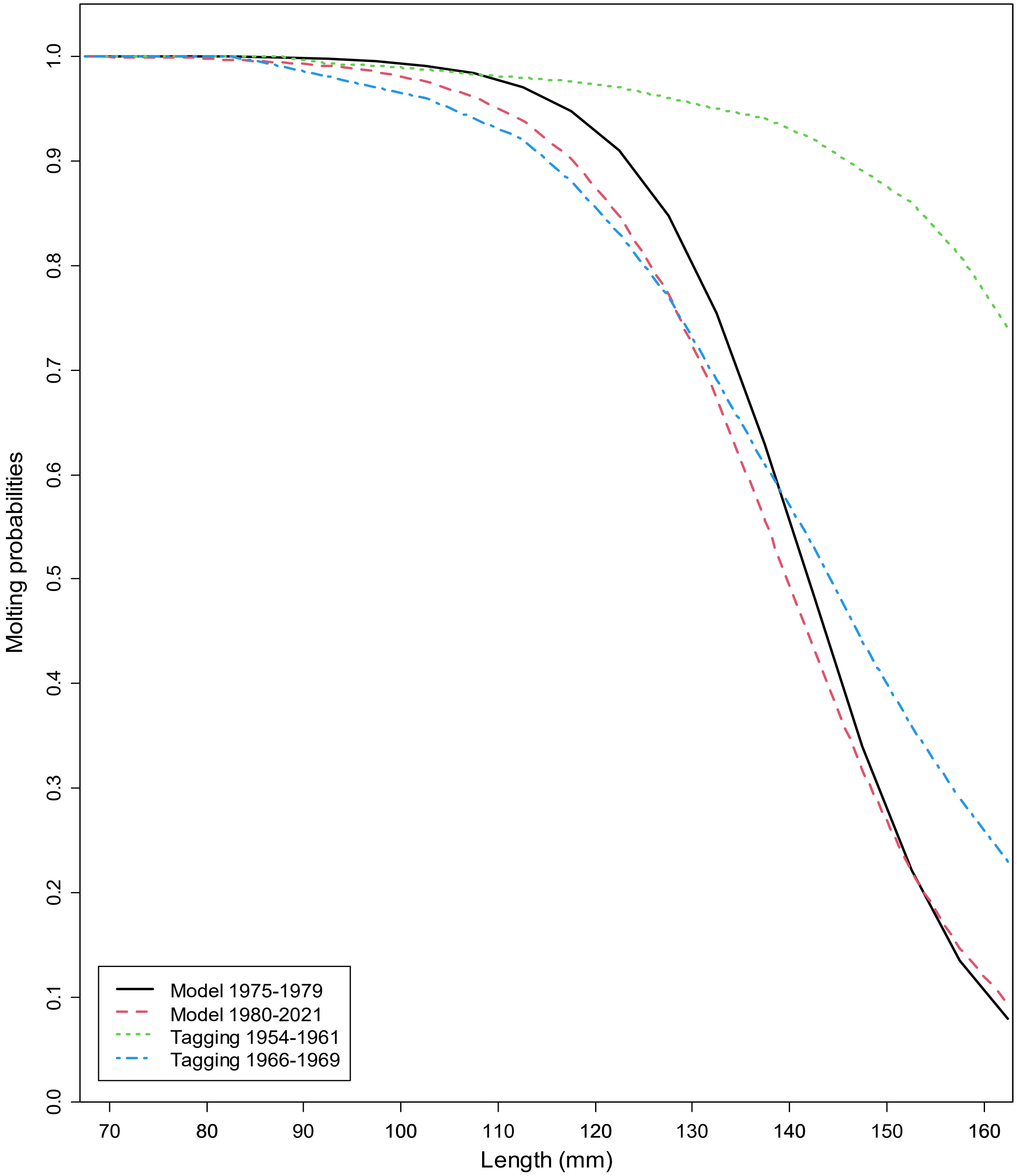


Figure 9c. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 21.2. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2021 were estimated with a length-based model.

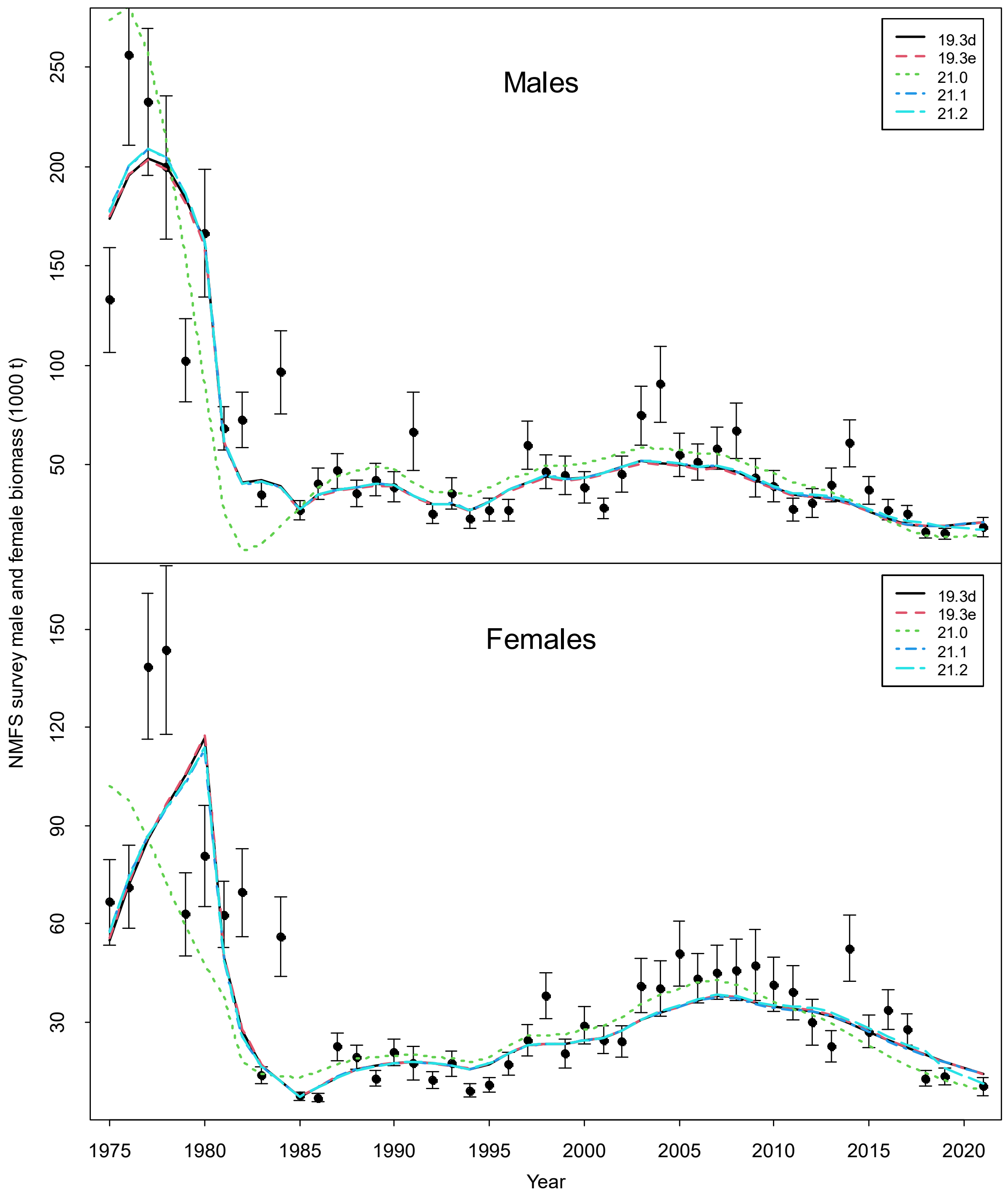


Figure 10a. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2021 under models 19.3d, 19.3e, 21.0, 21.1, and 21.2. The error bars are plus and minus 2 standard deviations of model 19.3d.

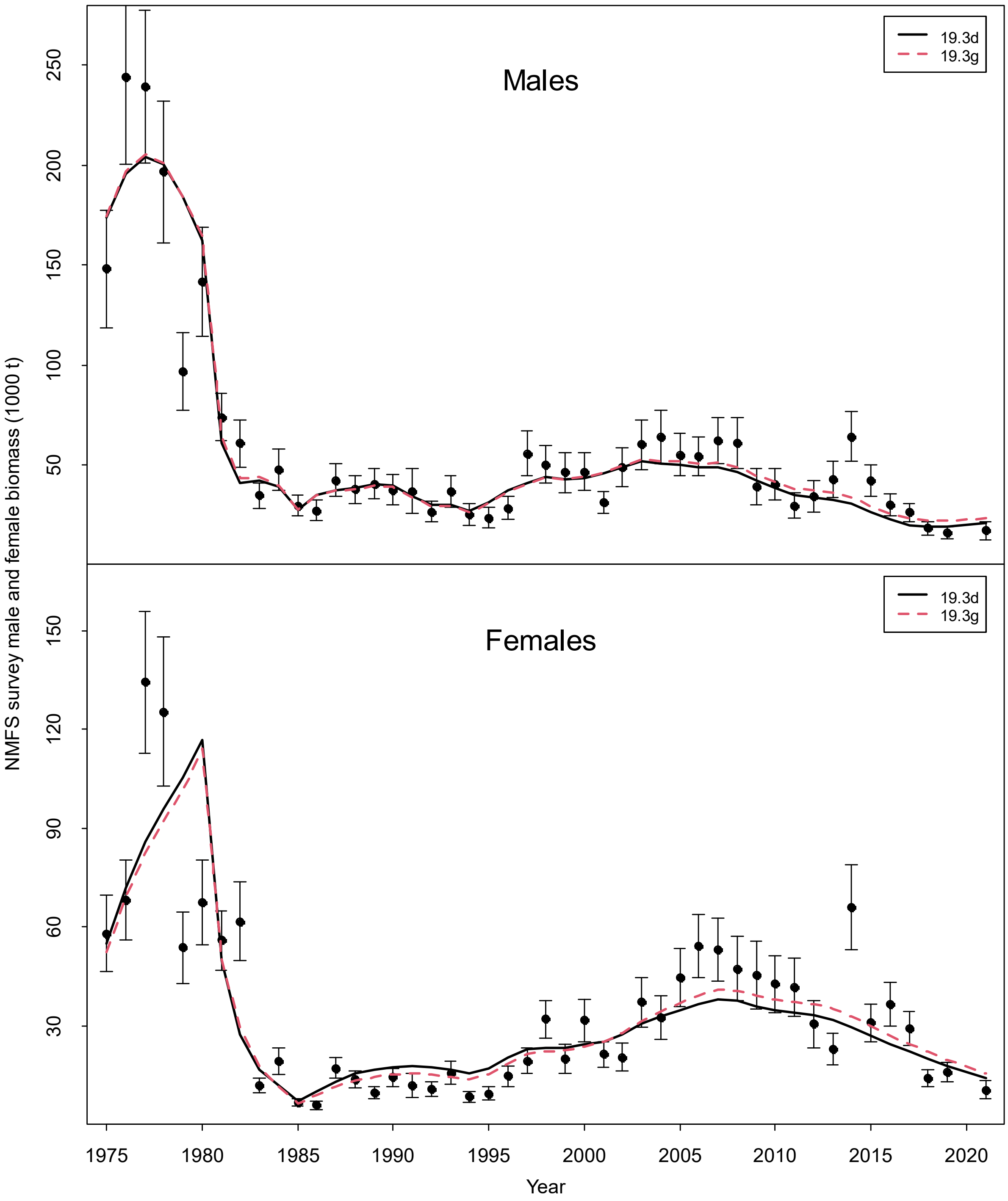


Figure 10b. Comparisons of VAST estimates of total NMFS survey biomass and model prediction for model estimates in 2021 under models 19.3d and 19.3g. The error bars are plus and minus 2 standard deviations of model 19.3g. Note that model 19.3d fits area-swept biomasses, not these VAST biomasses.

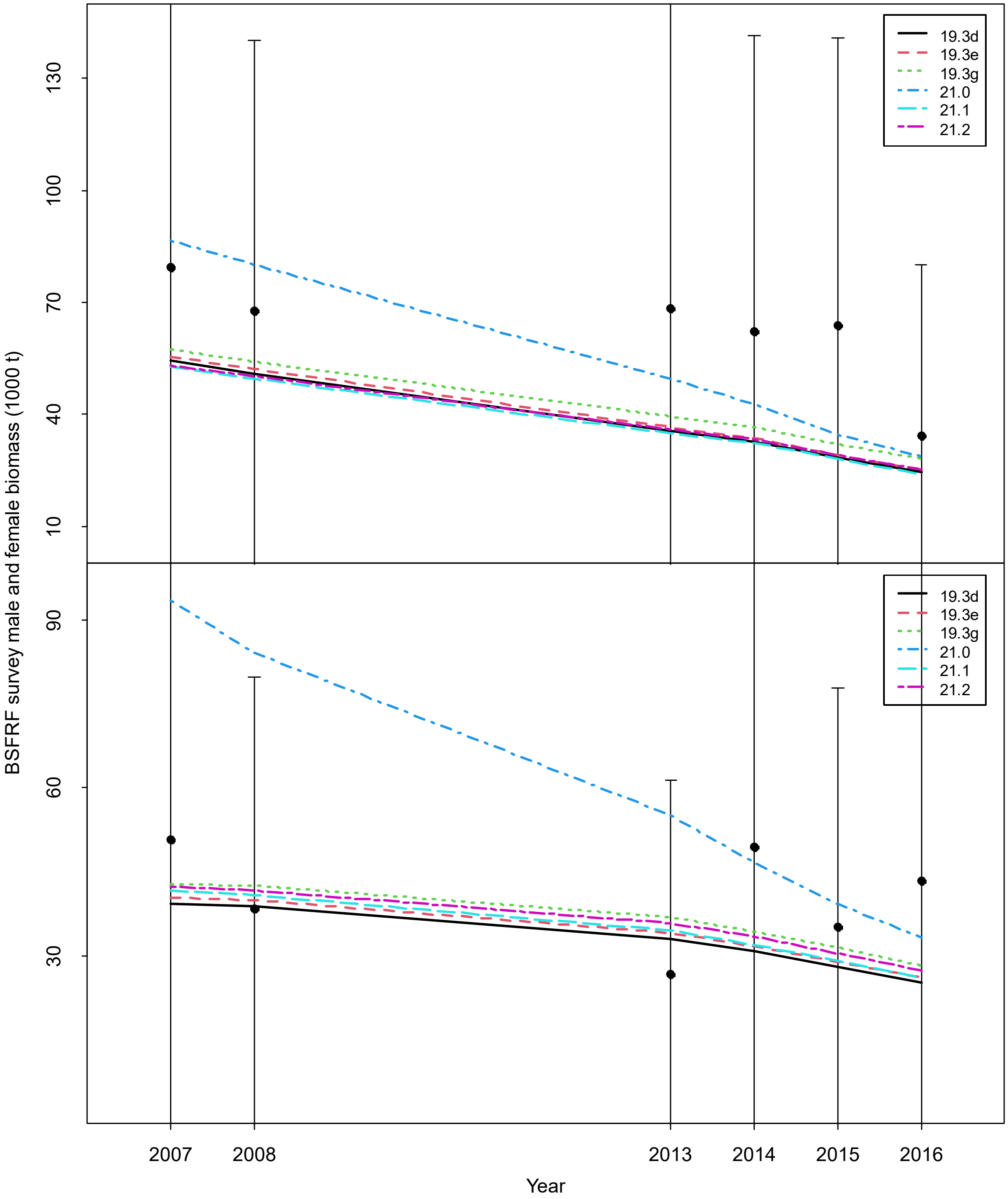


Figure 10c. Comparisons of survey biomass estimates by sex (upper plot for males and lower plot for females) by the BSFRF survey and the model for model estimates in 2021 (models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2). The error bars are plus and minus 2 standard deviations of model 19.3d.

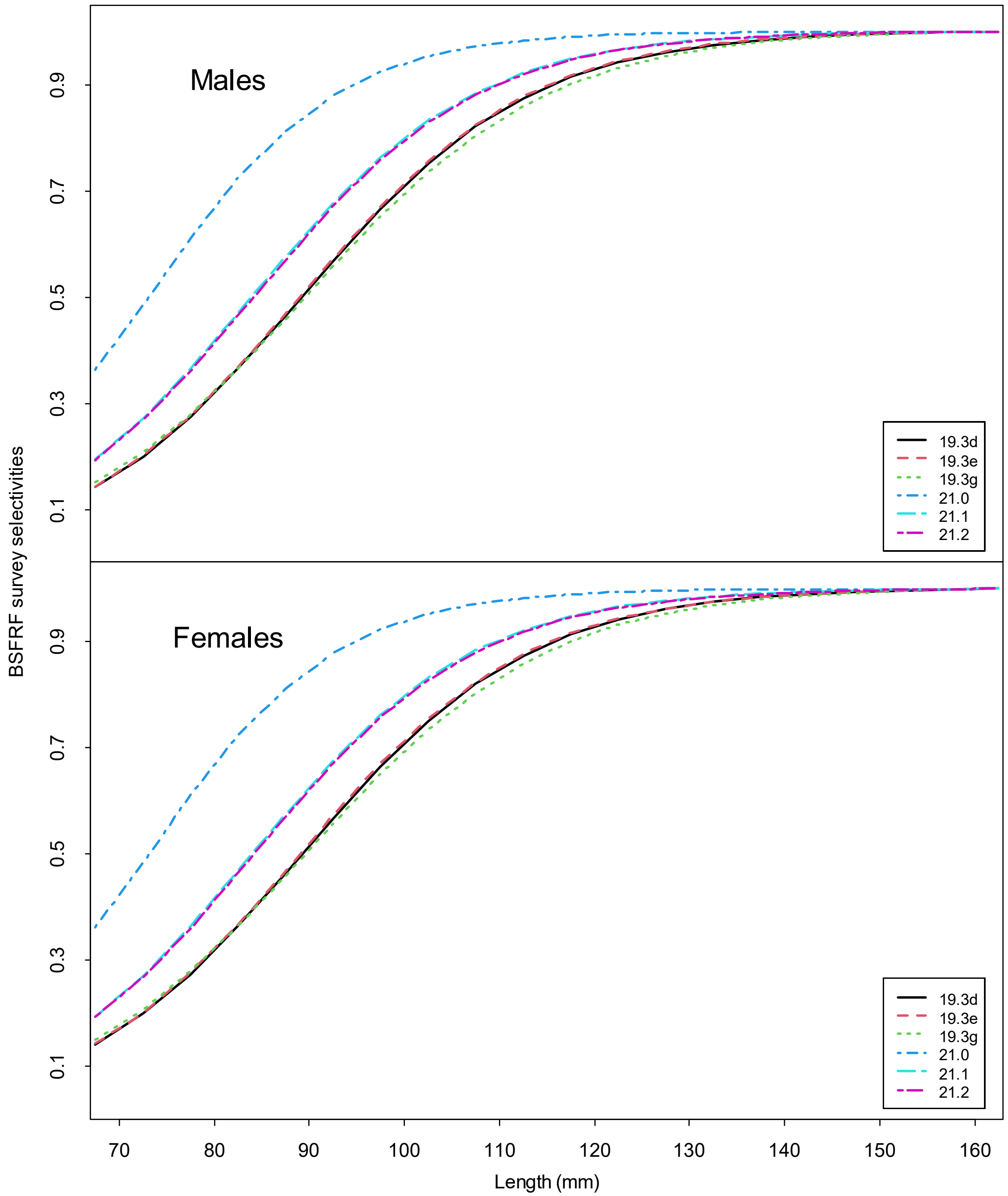


Figure 10d. Comparisons of estimated BSFRF survey selectivities with models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2. The catchability is assumed to be 1.0.

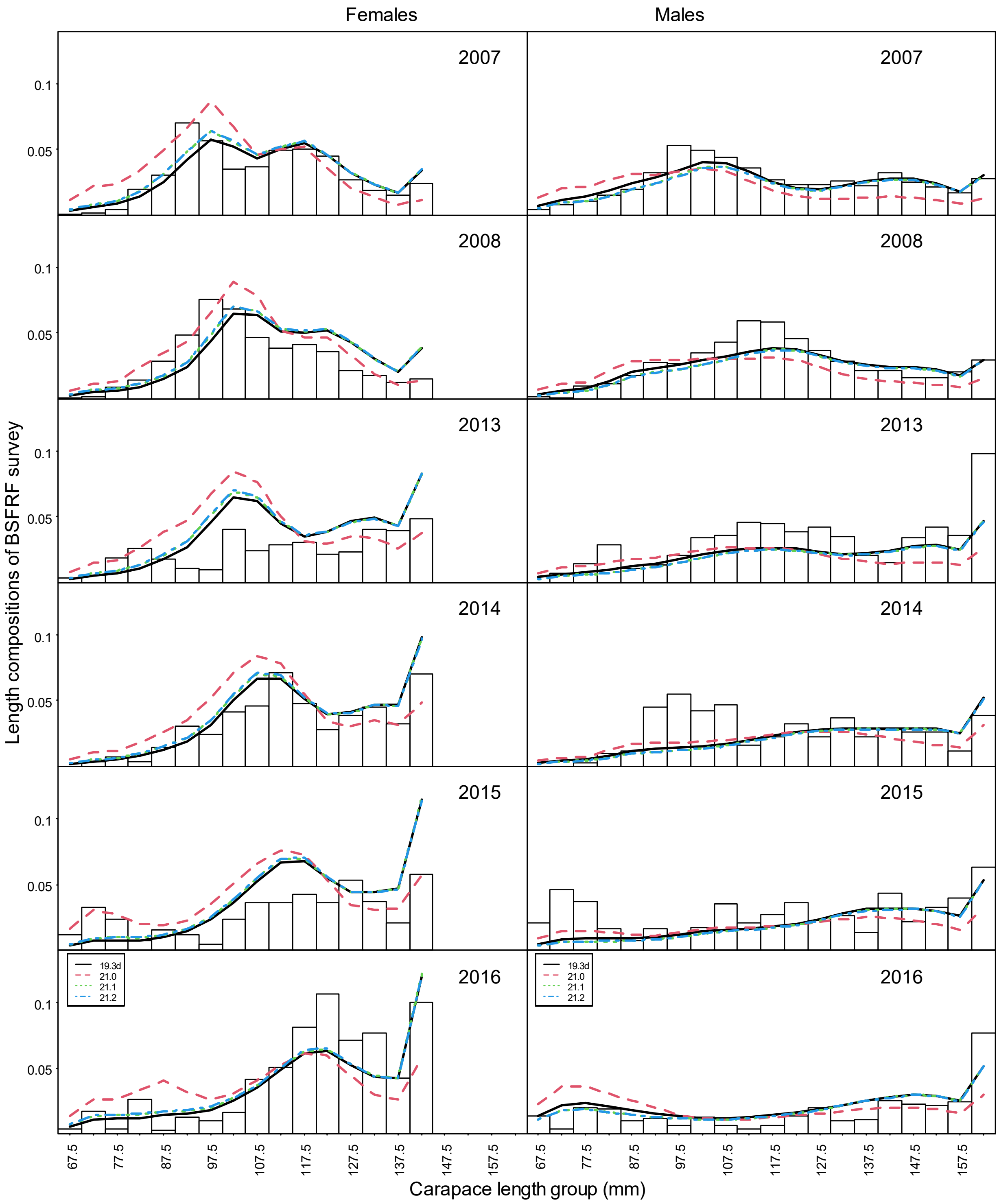


Figure 10e. Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 with models 19.3d, 21.0, 21.1, and 21.2.

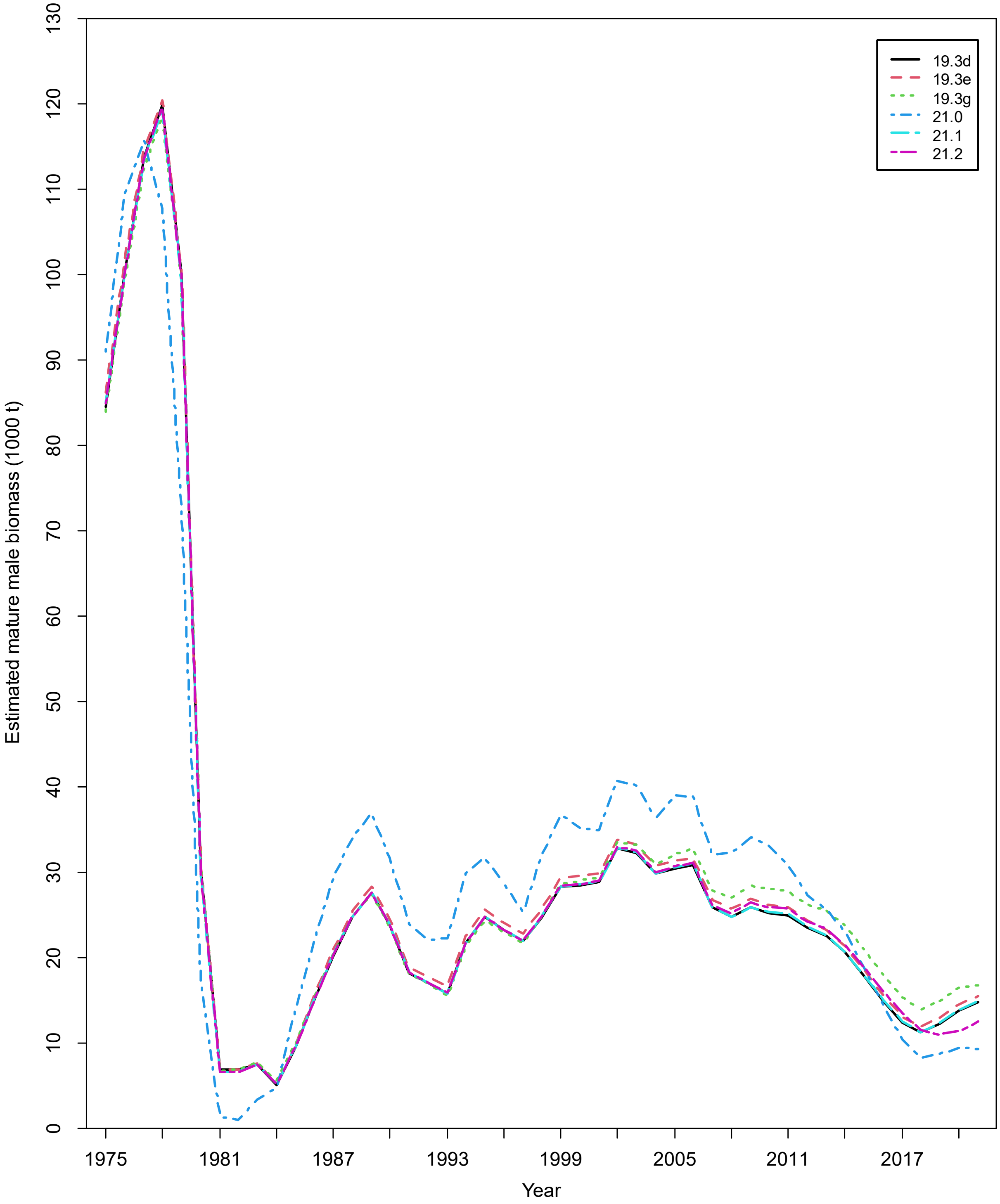


Figure 11. Estimated absolute mature male biomasses during 1975-2021 for models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2.

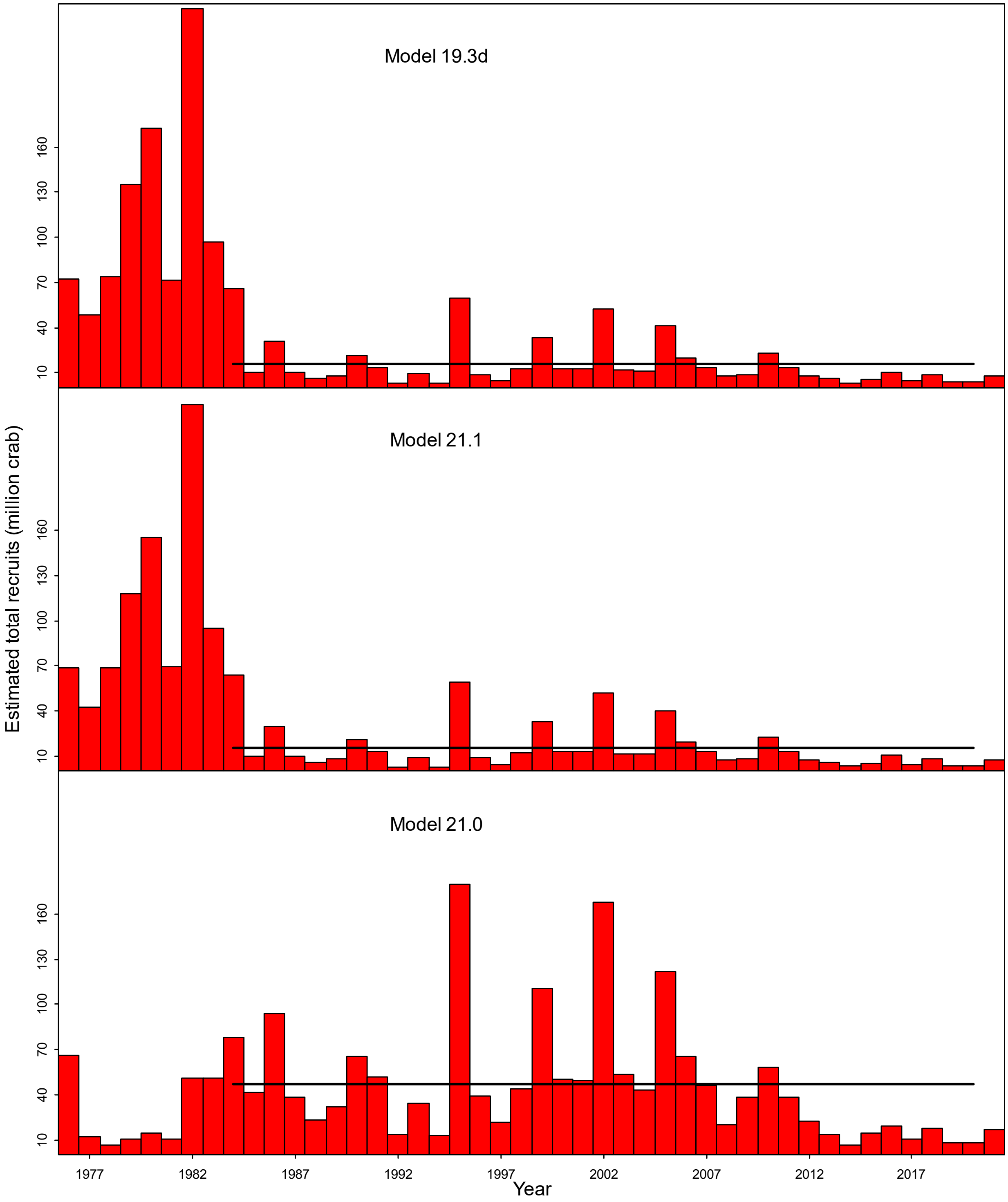


Figure 12a. Estimated recruitment time series during 1976-2021 with models 19.3d, 21.1, and 21.0. Mean male recruits during 1984-2020 was used to estimate $B_{35\%}$. Recruitment estimates in the terminal year (2021) are unreliable.

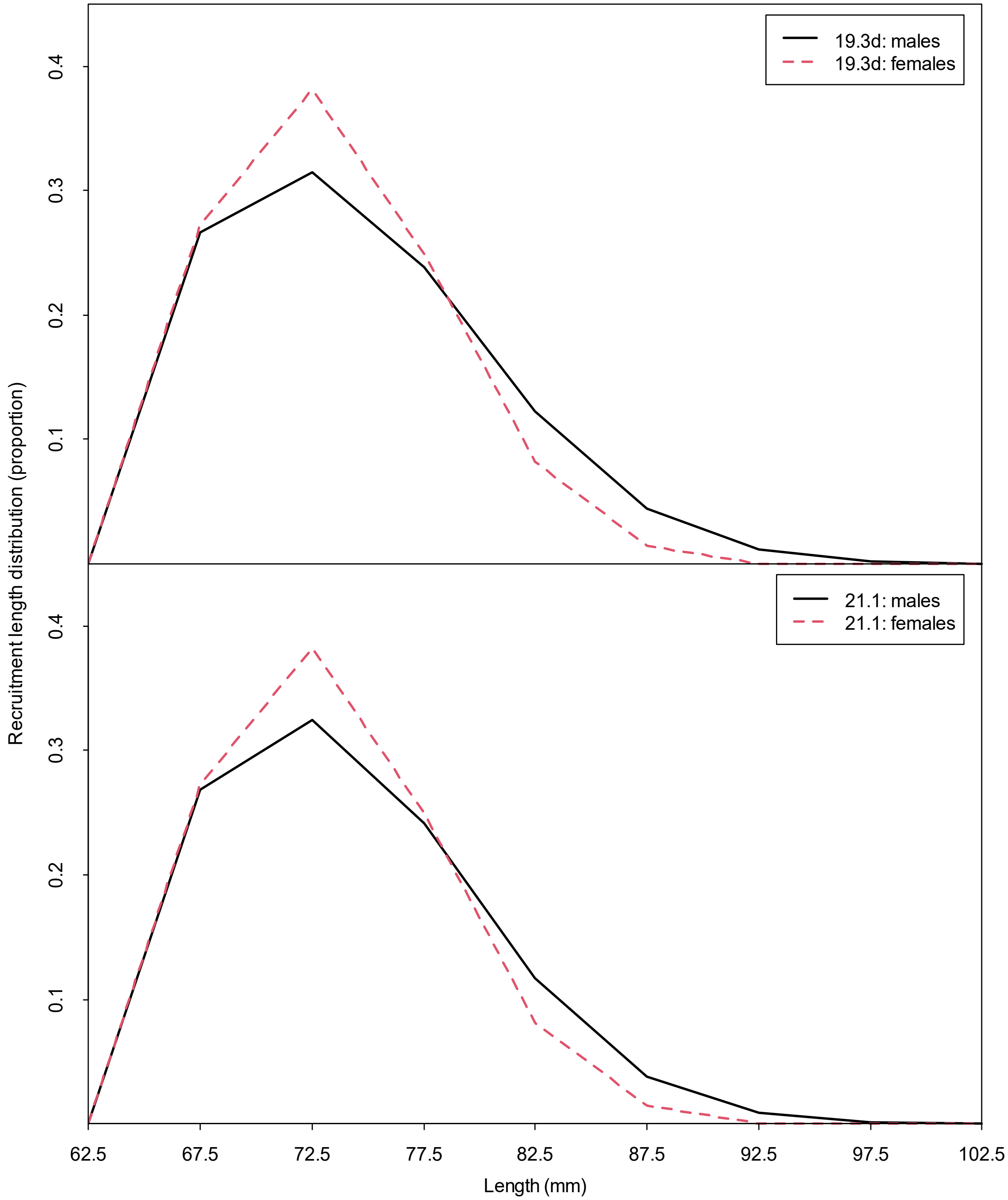


Figure 12b. Estimated recruitment length distributions with models 19.3d and 21.1.

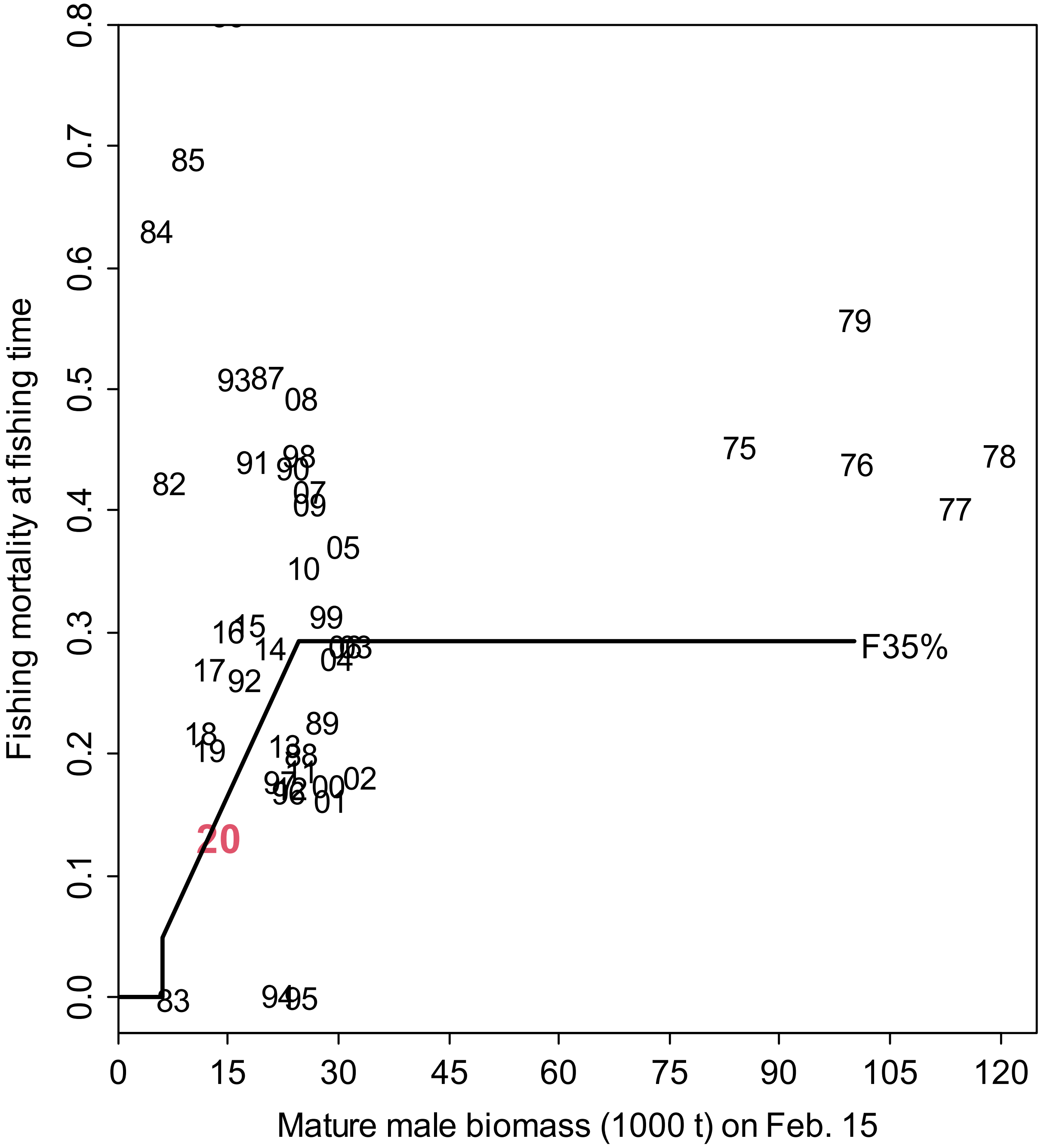


Figure 13a. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2020 under model 19.3d. Average of recruitment from 1984 to 2020 was used to estimate $B_{35\%}$.

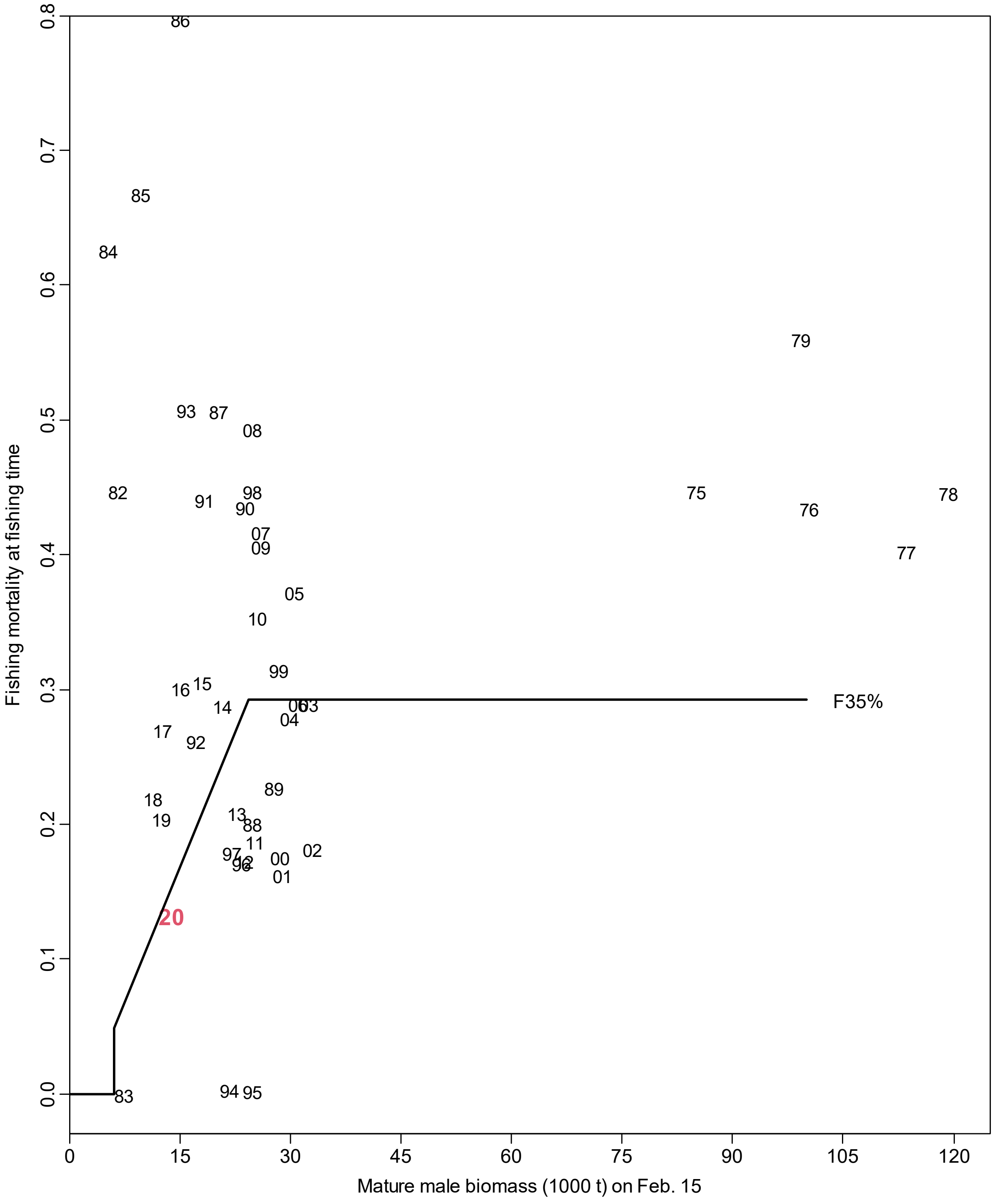


Figure 13b. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2020 under model 21.1. Average of recruitment from 1984 to 2020 was used to estimate $B_{35\%}$.

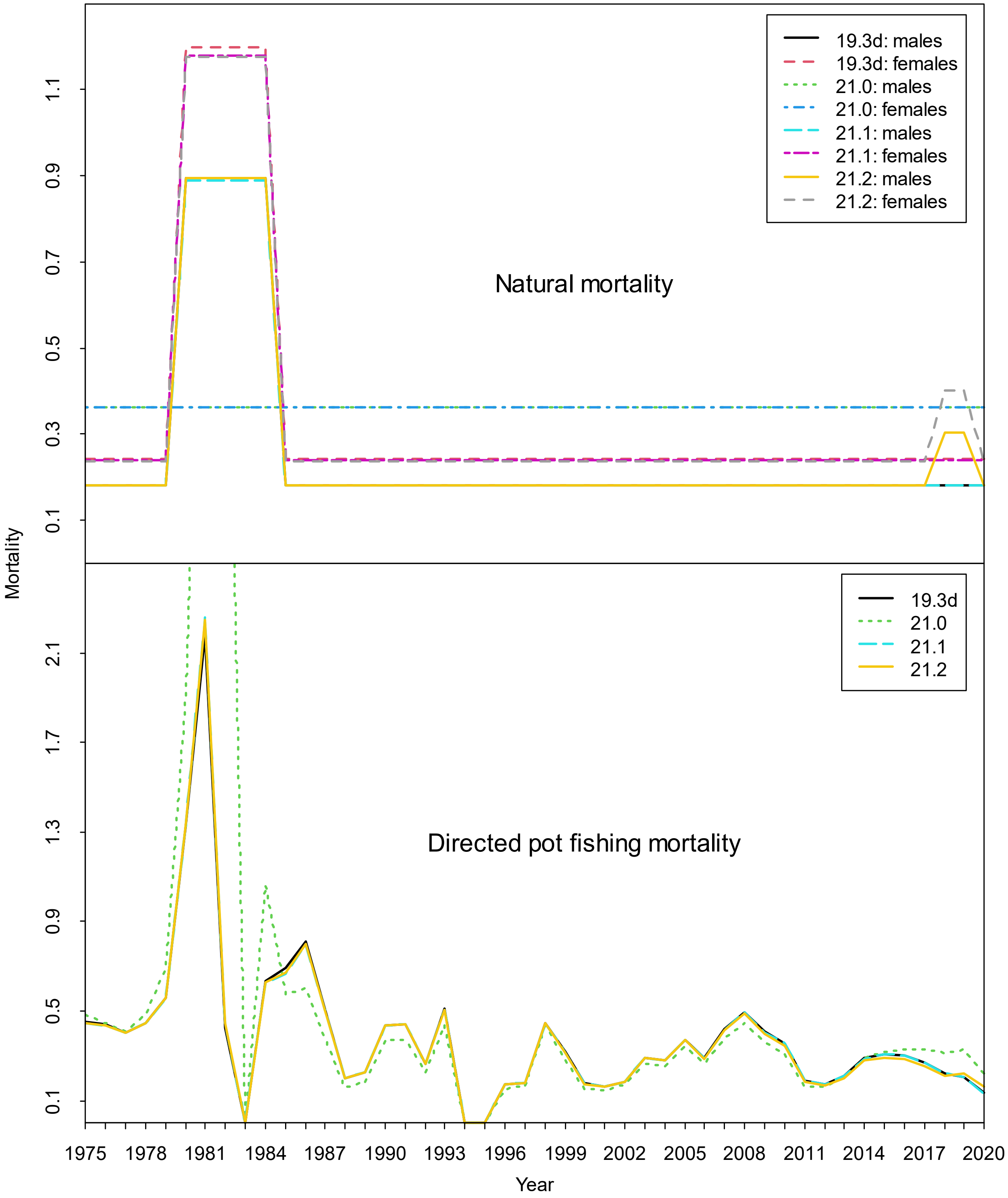


Figure 13c. Comparison of estimated natural mortality and directed pot fishing mortality for models 19.3d, 21.0, 21.1, and 21.2.

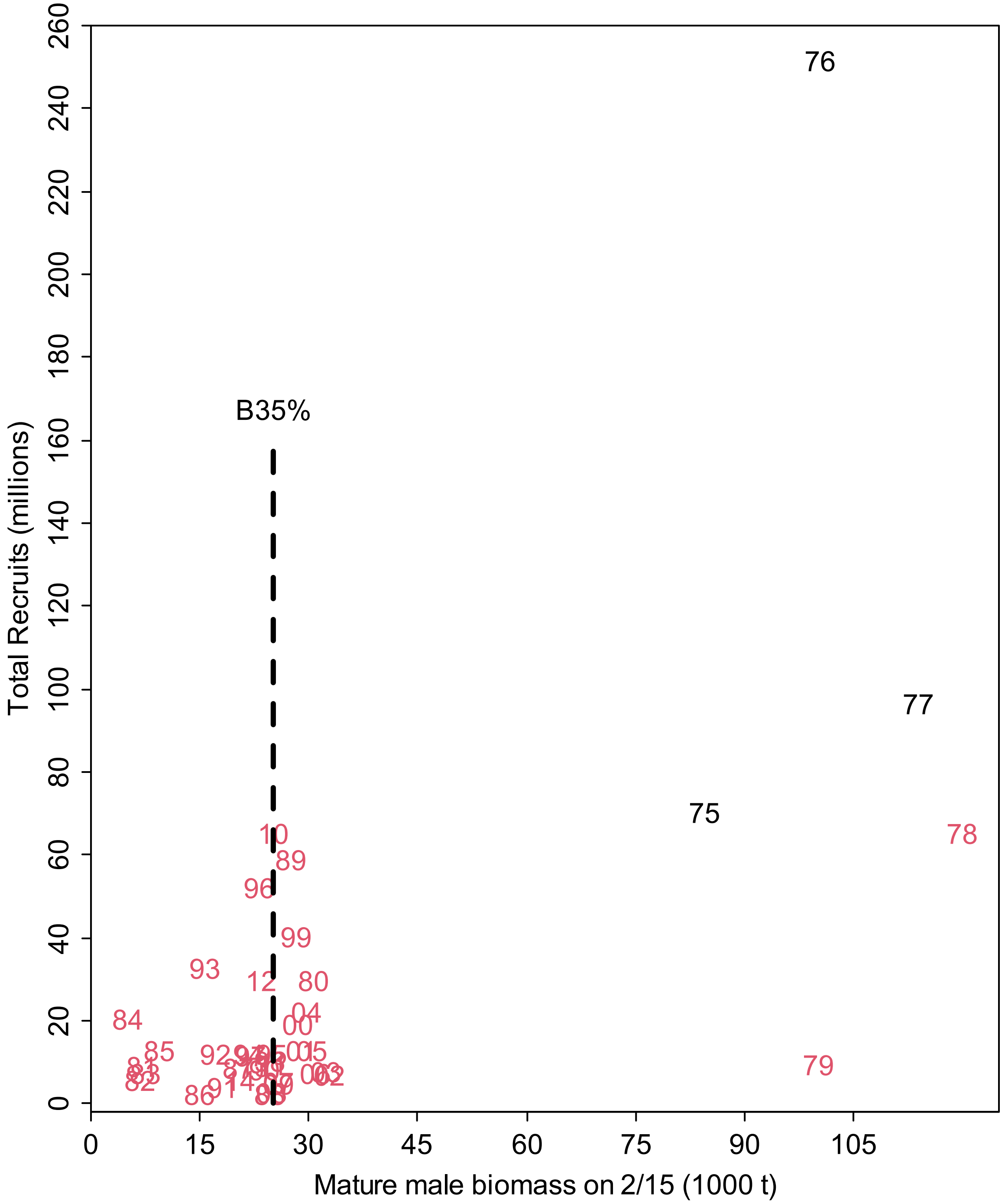


Figure 14a. Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6-year time lag) for Bristol Bay red king crab under model 19.3d. Numerical labels are years of mating, and the vertical dotted line is the estimated *B35%* based on the mean recruitment level during 1984 to 2020.

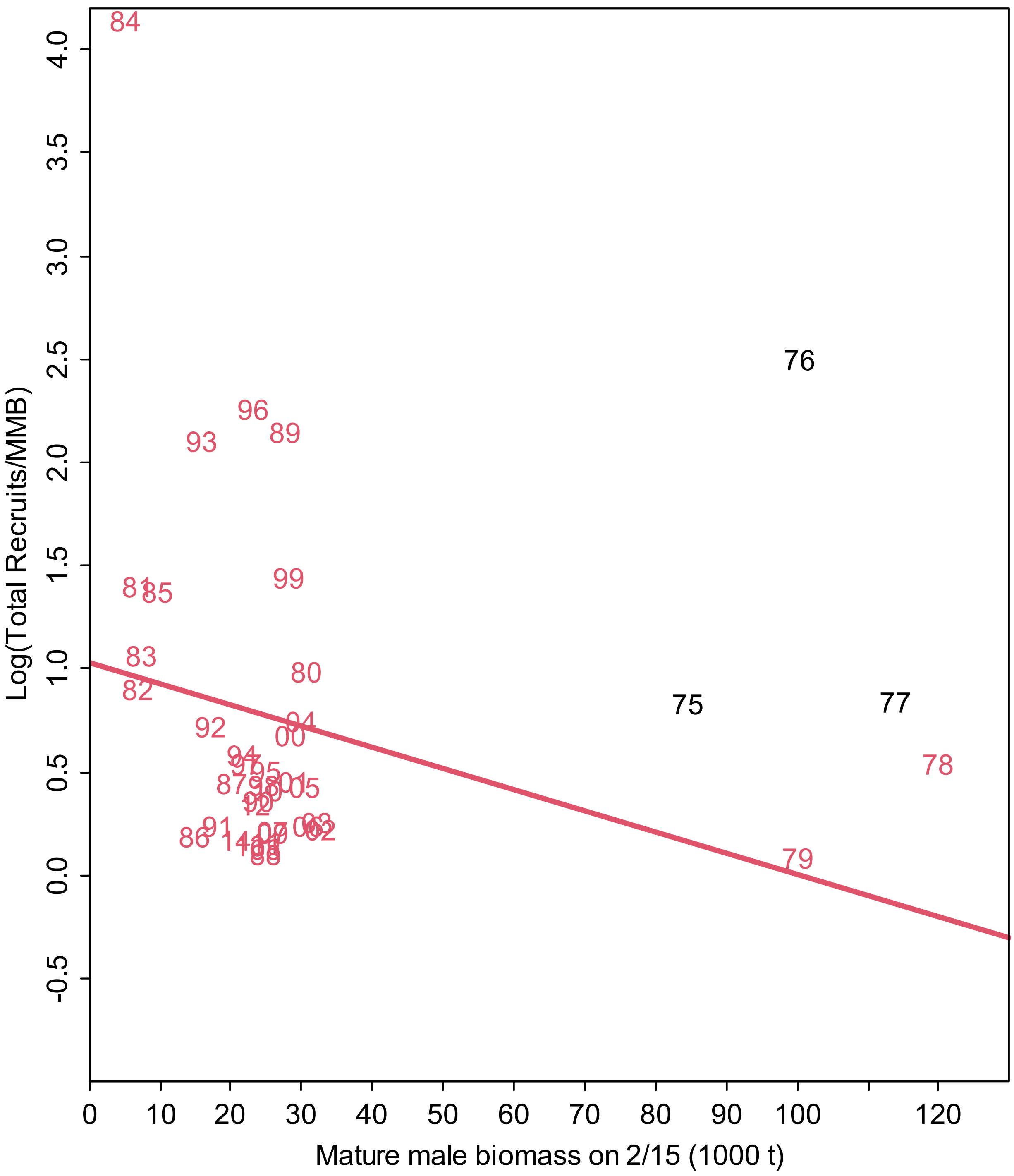


Figure 14b. Relationships between log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab under model 19.3d. Numerical labels are years of mating, and the line is the regression line for data of 1978-2014.

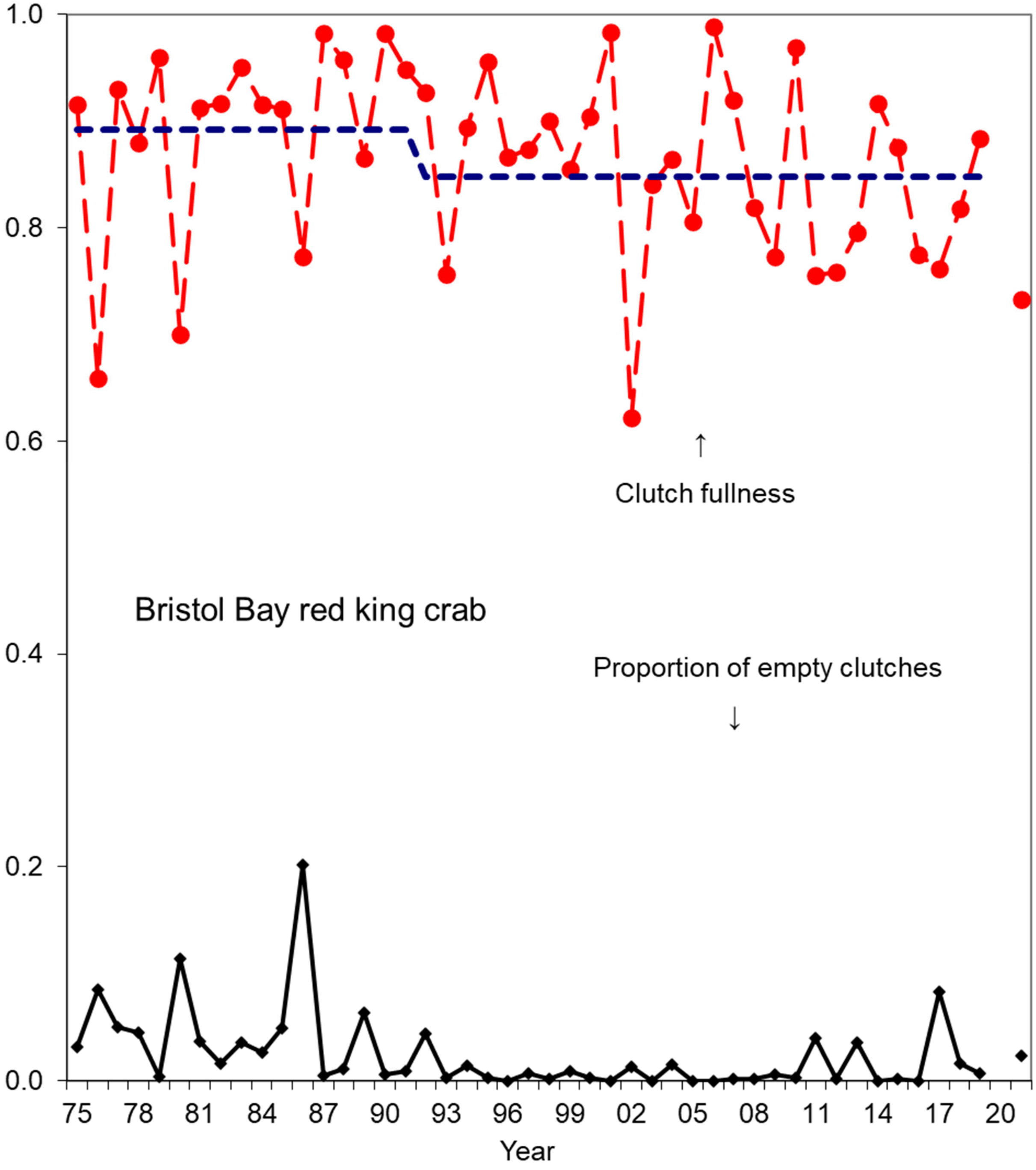


Figure 15. Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2021 from survey data. Oldshell females were excluded. The blue dashed line is the mean clutch fullness during two periods before 1992 and after 1991.

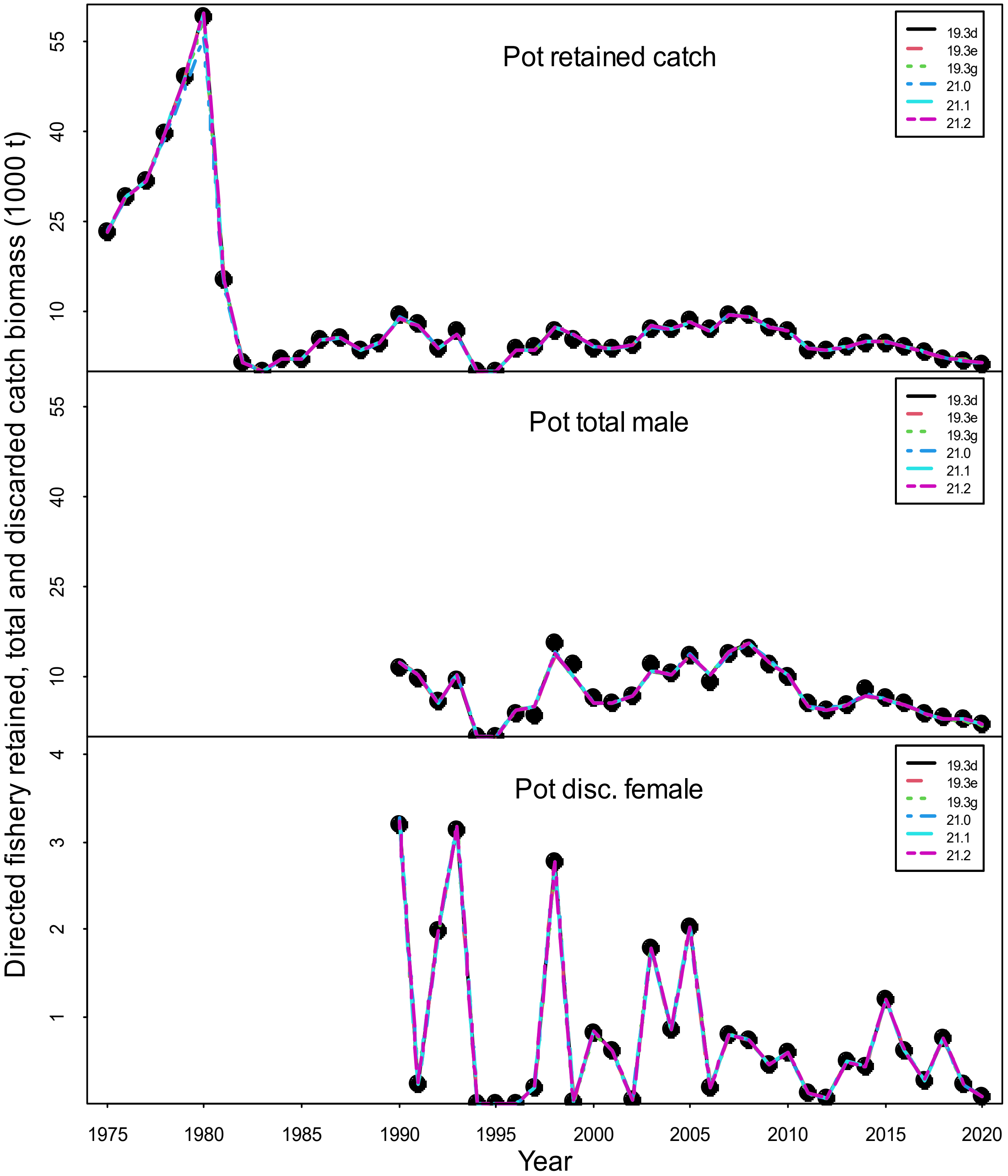


Figure 16a. Observed (dots) and predicted (lines) RKC catch and bycatch biomass under models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2.

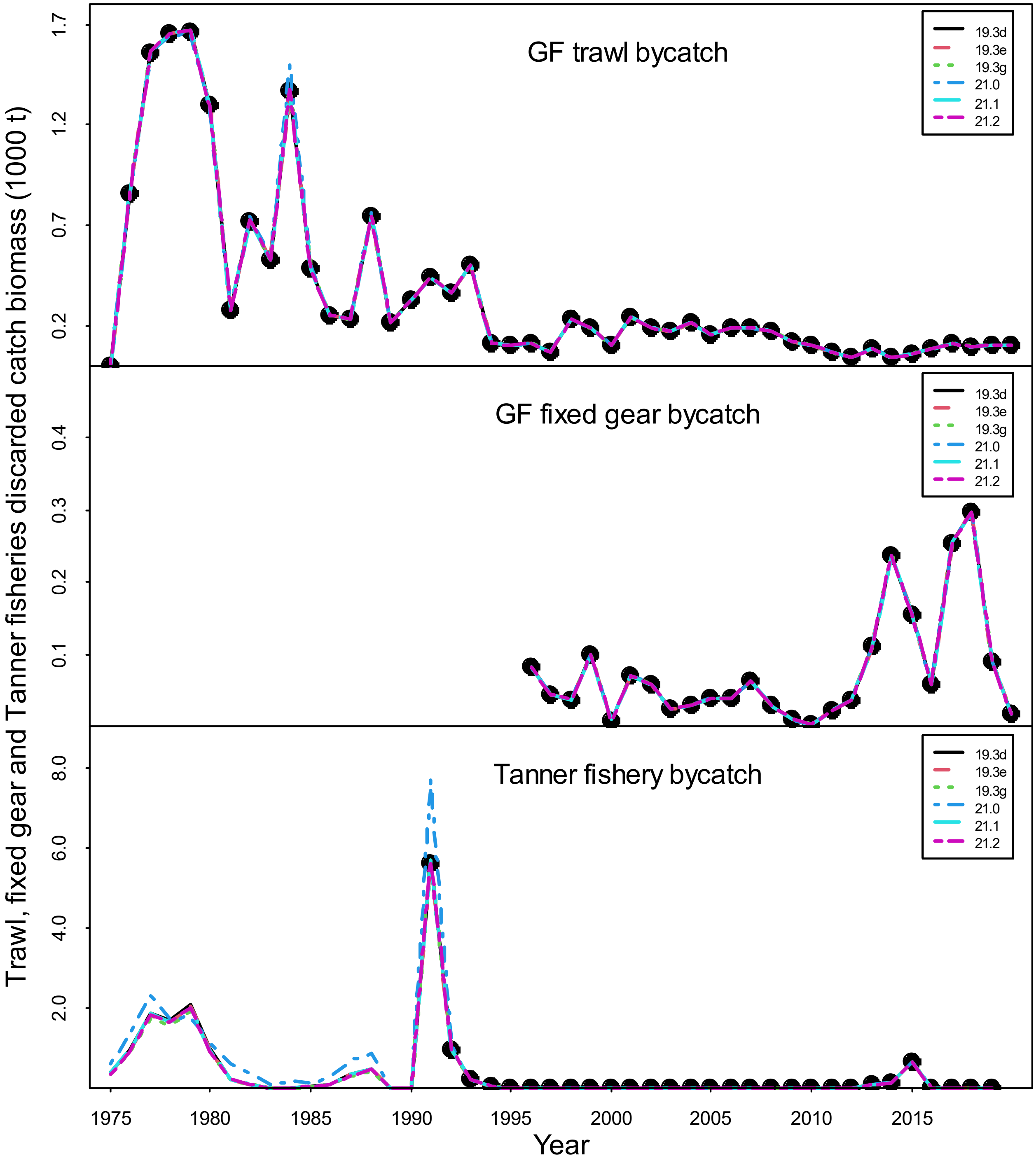


Figure 16b. Observed (dots) and predicted (lines) RKC bycatch biomass from groundfish fisheries and the Tanner crab fishery under models 19.3d, 19.3e, 19.3g, 21.0, 21.1, and 21.2. Trawl bycatch biomass was 0 before 1976.

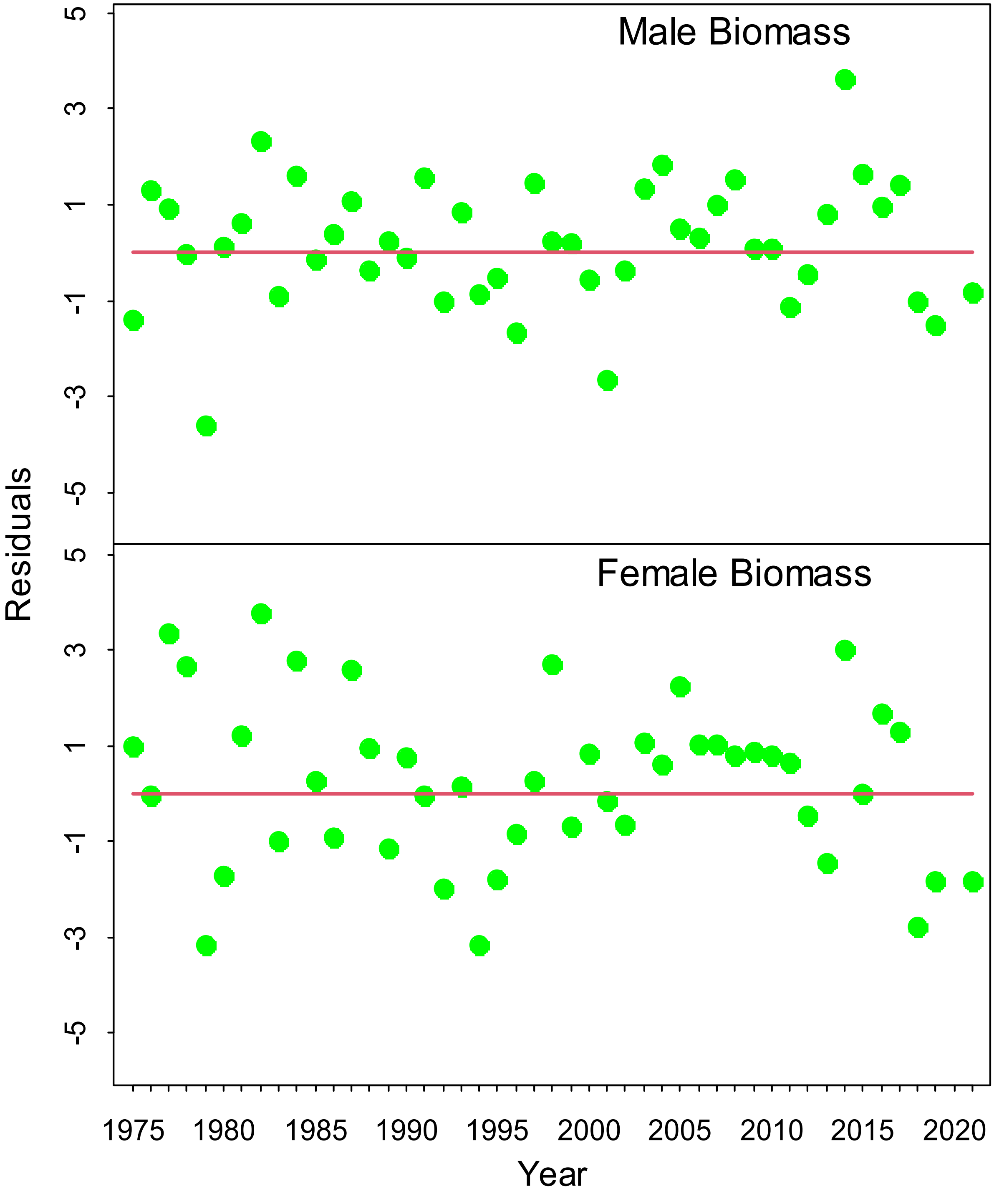


Figure 17a. Standardized residuals of NMFS survey biomass under model 19.3d.

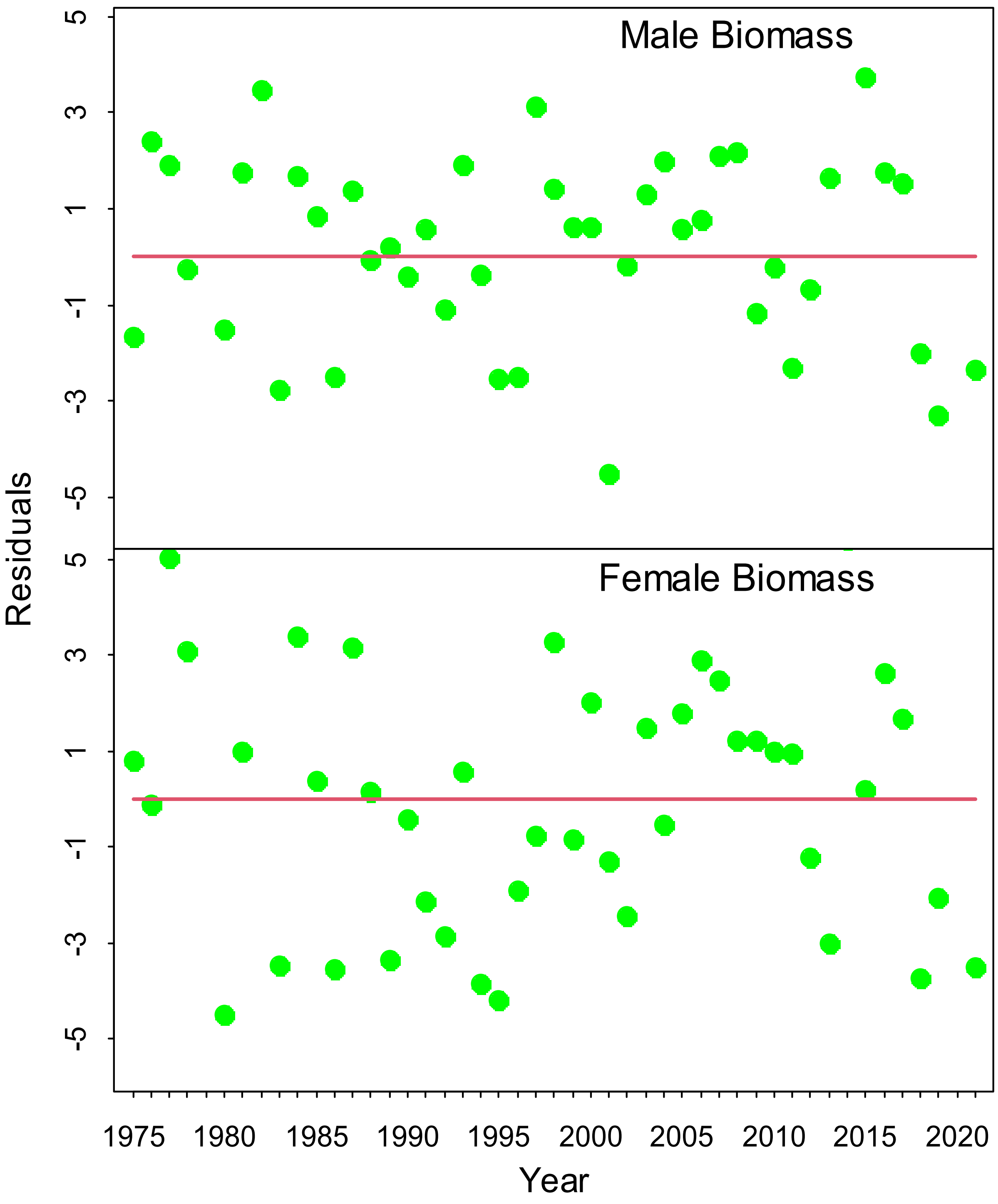


Figure 17b. Standardized residuals of NMFS survey biomass under model 19.3g.

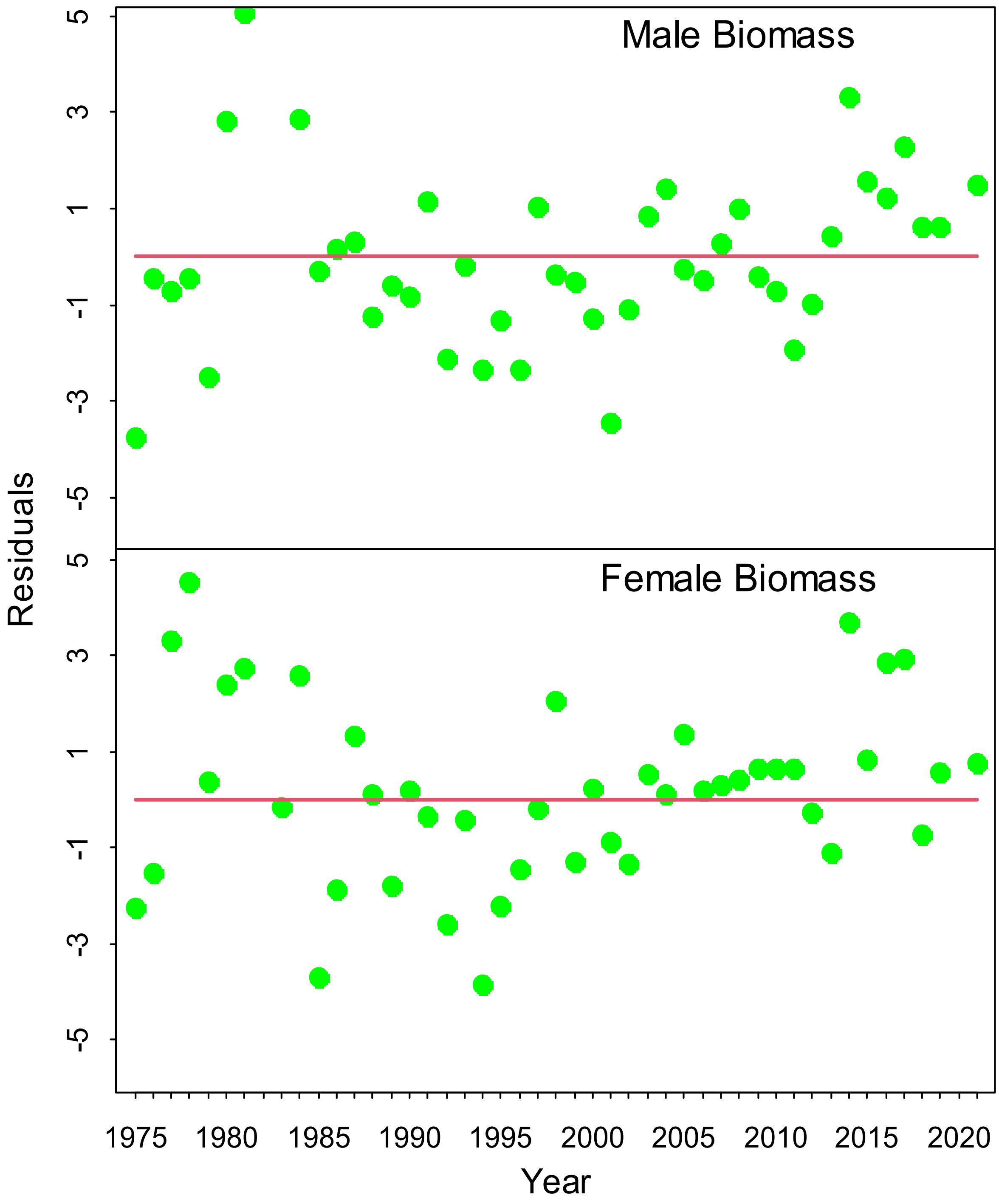


Figure 17c. Standardized residuals of NMFS survey biomass under model 21.0.

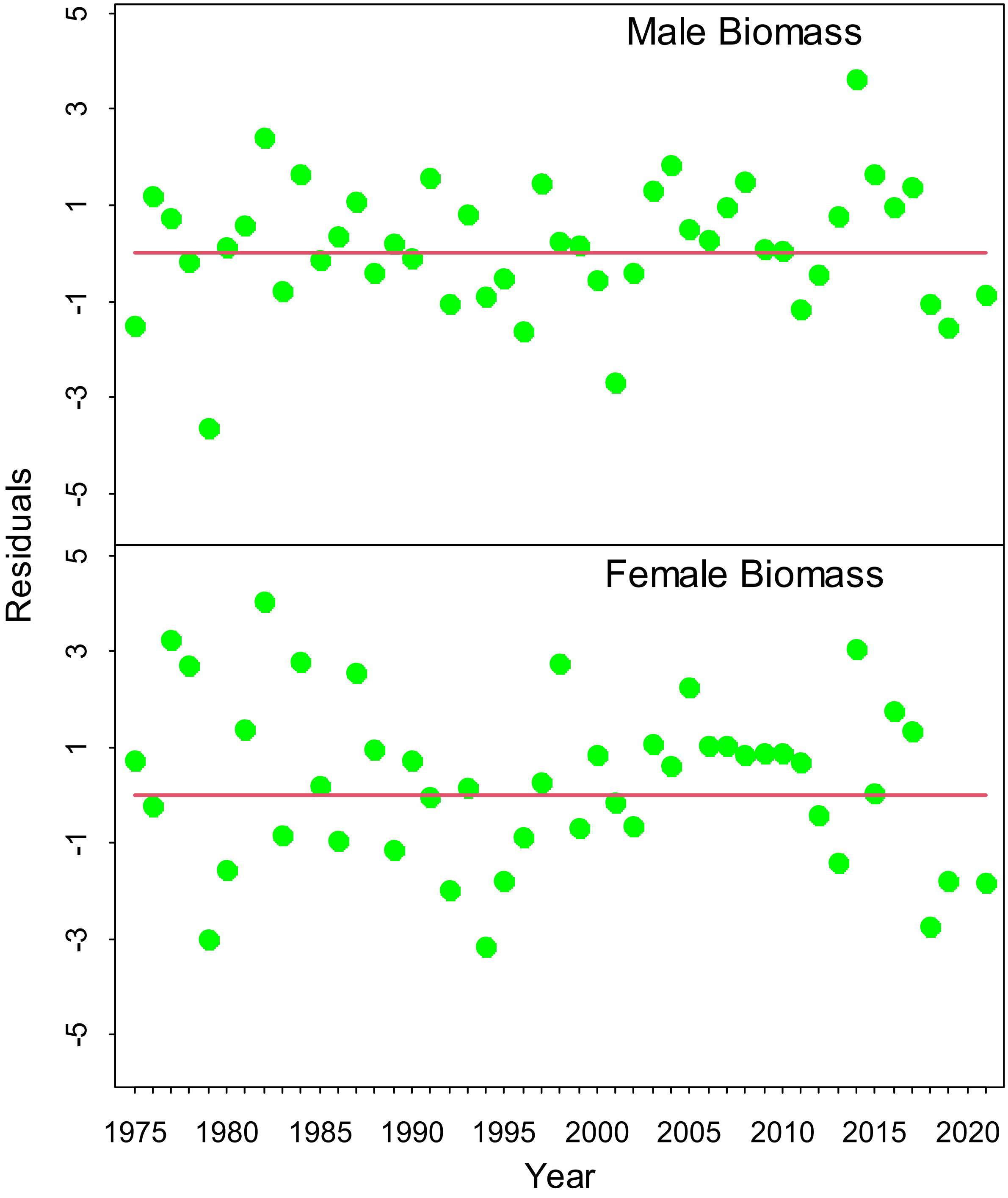


Figure 17d. Standardized residuals of NMFS survey biomass under model 21.1.

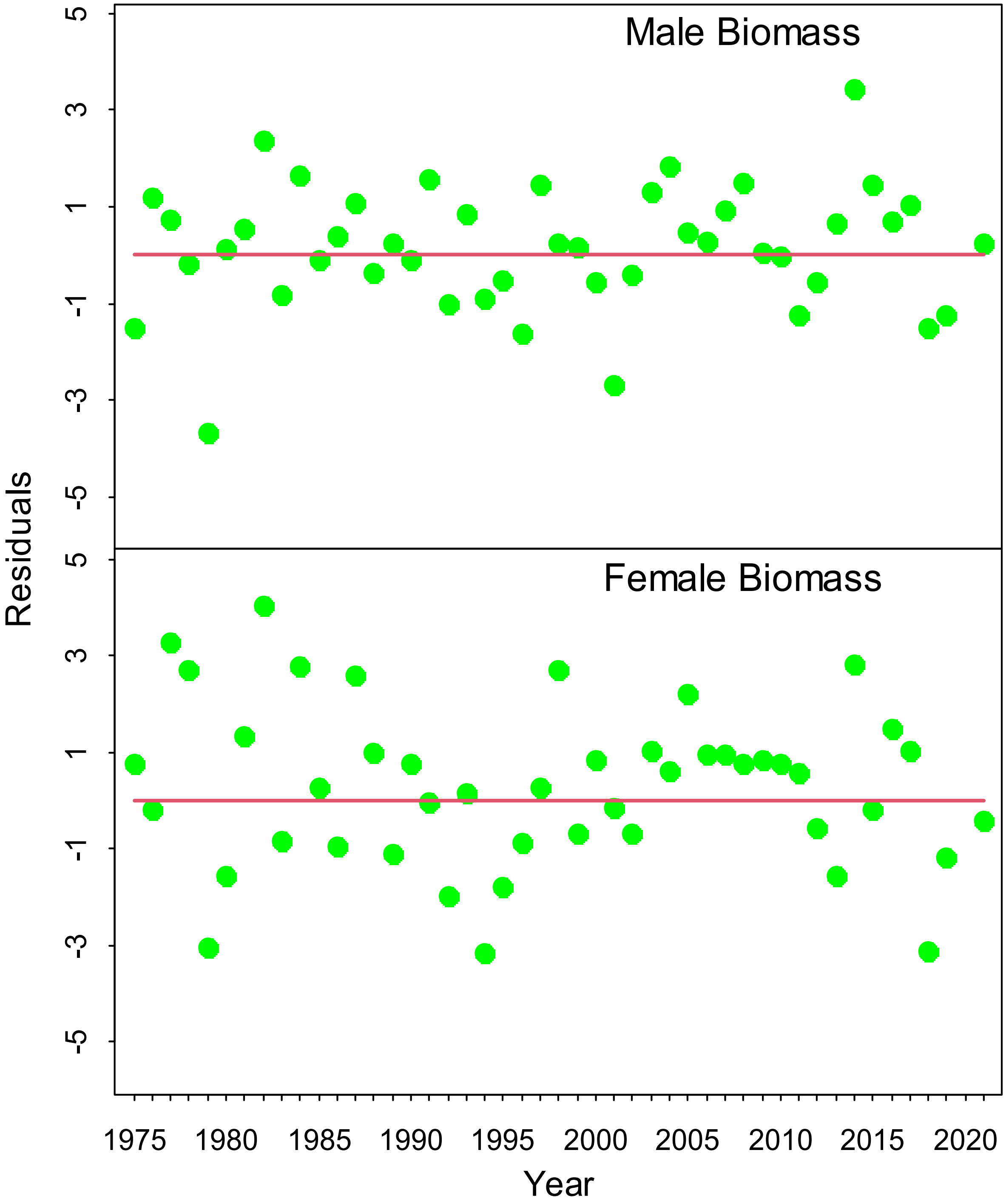


Figure 17e. Standardized residuals of NMFS survey biomass under model 21.2.

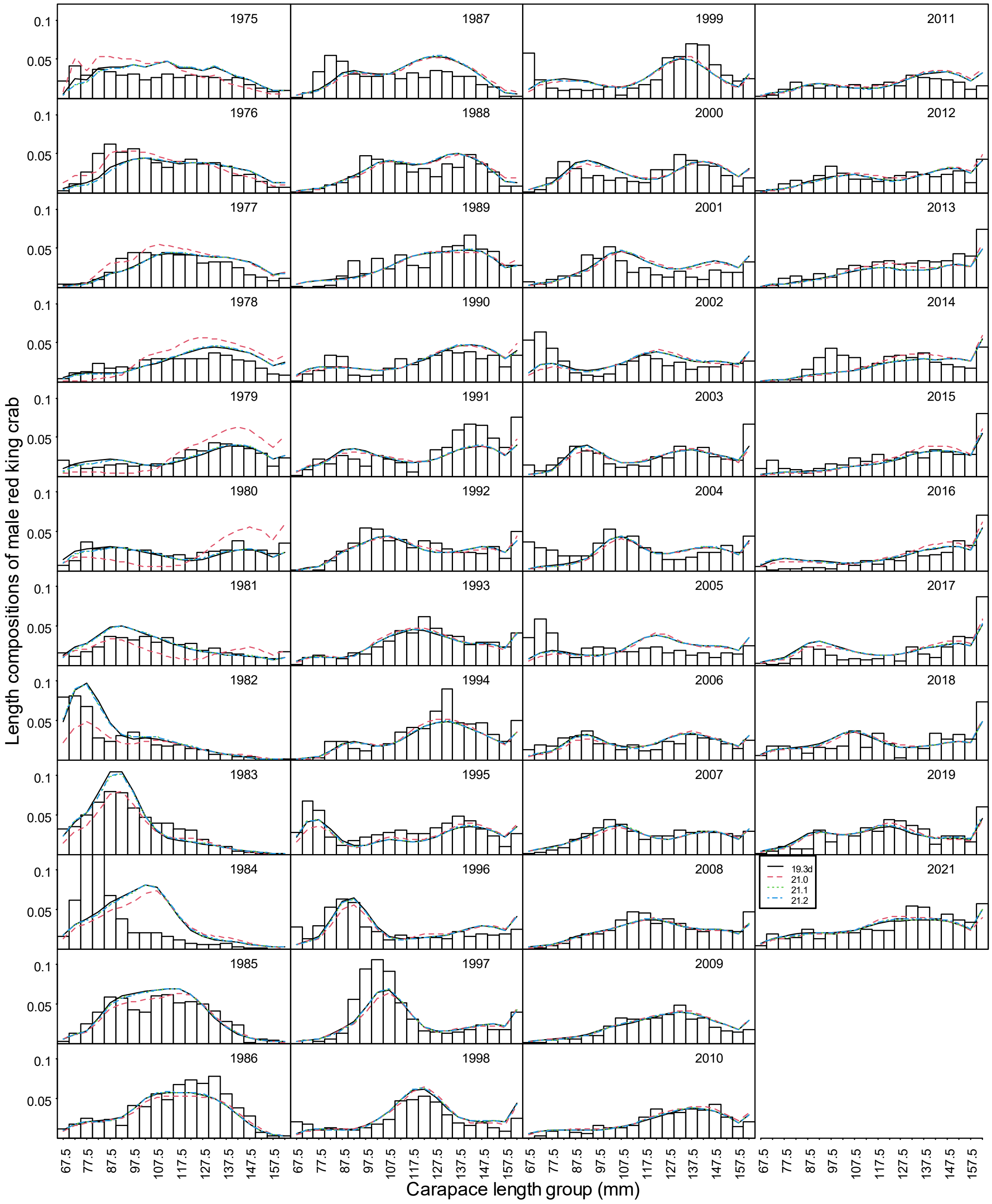


Figure 18. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under models 19.3d, 21.0, 21.1, and 21.2.

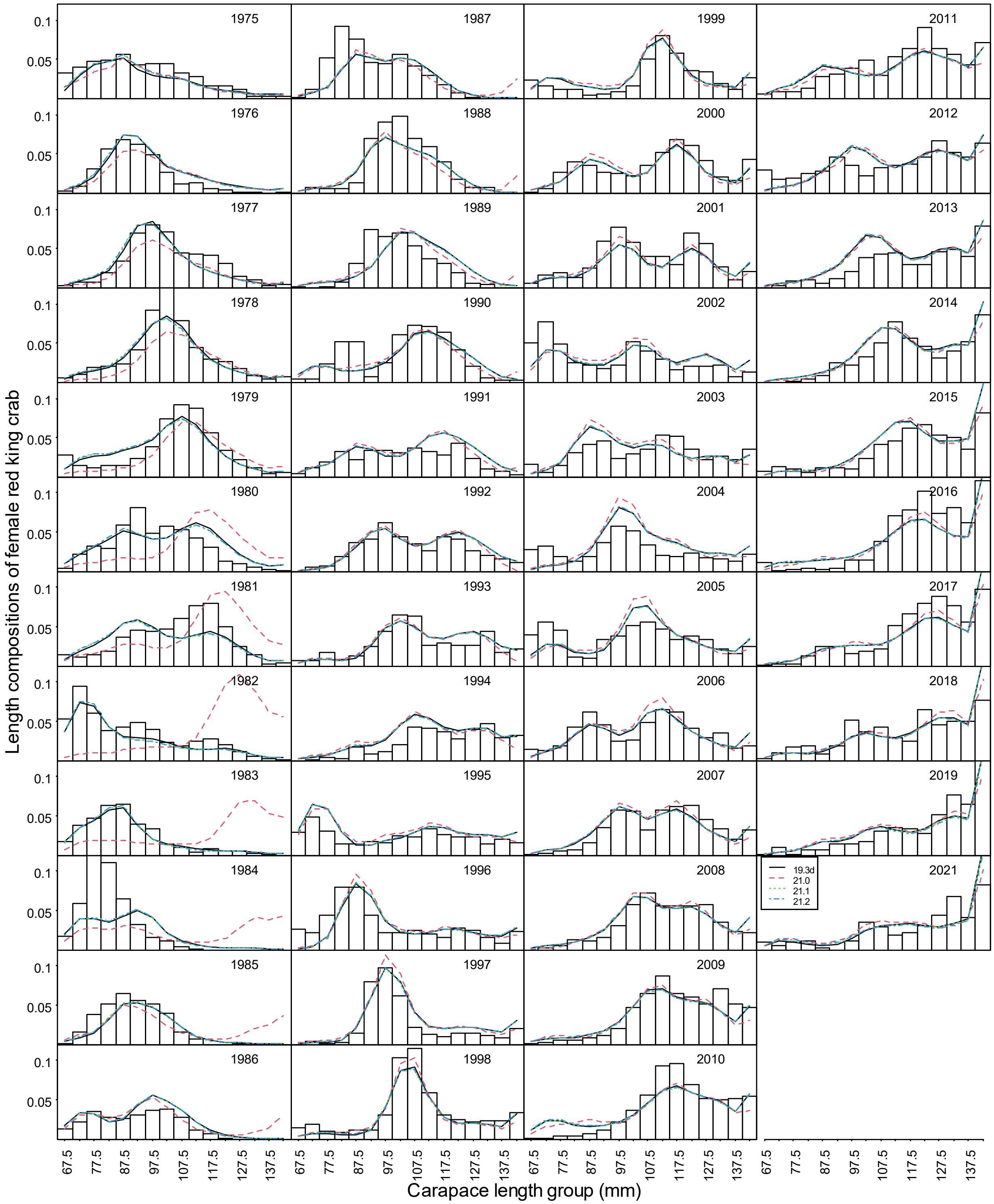


Figure 19. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year under models 19.3d, 21.0, 21.1, and 21.2.

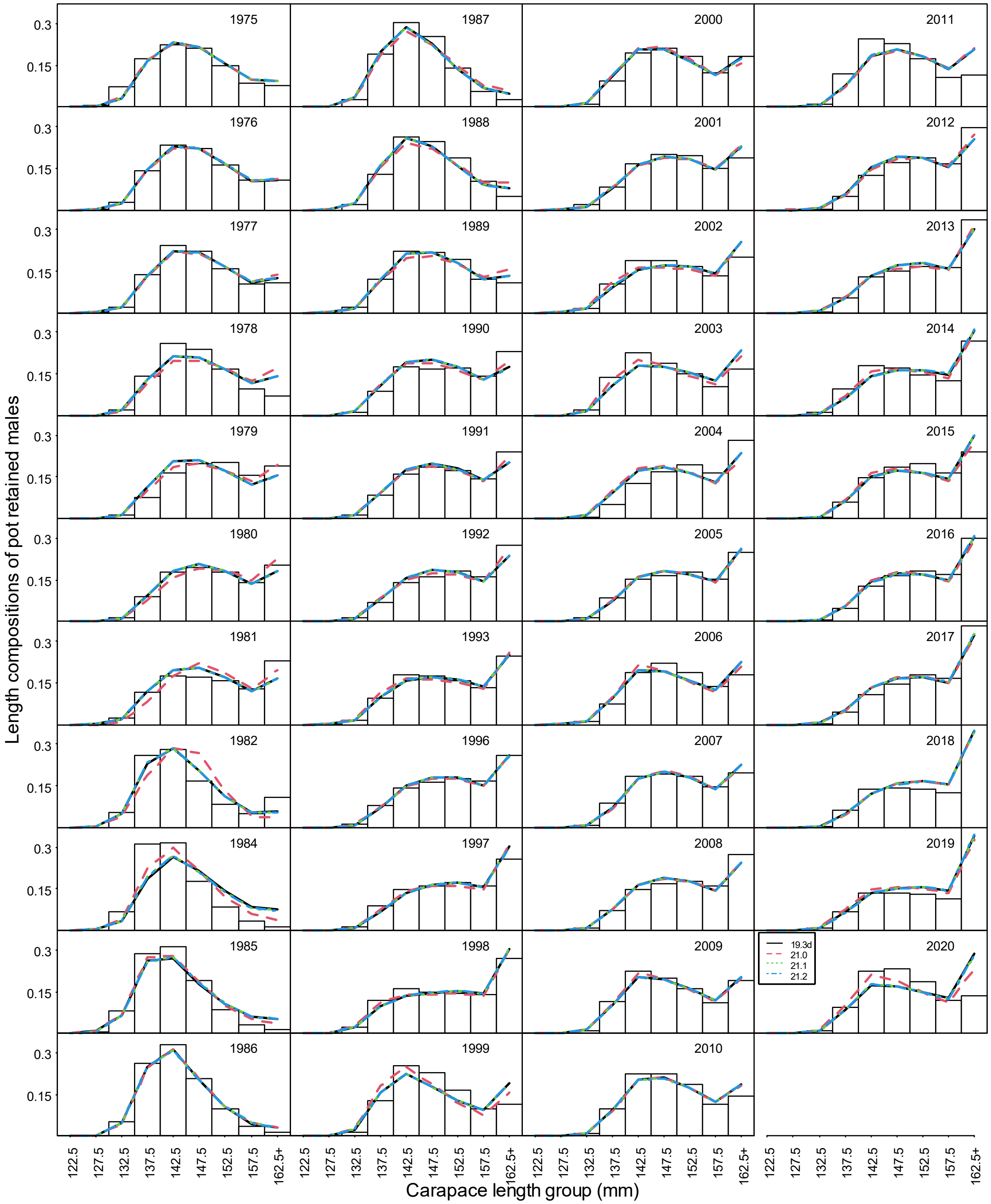


Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.3d, 21.0, 21.1, and 21.2.

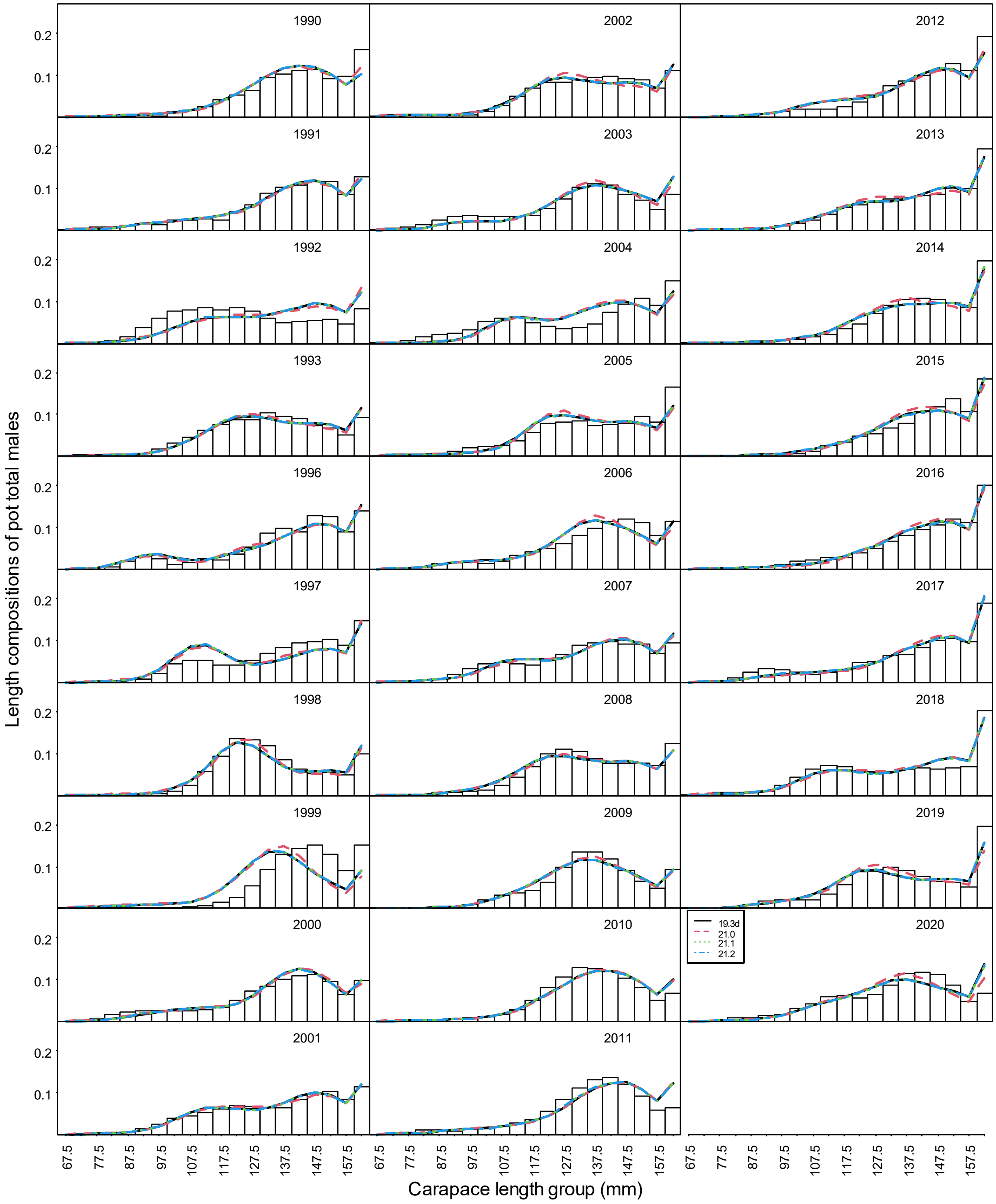


Figure 21. Comparison of observer and model estimated total observer length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.3d, 21.0, 21.1, and 21.2.

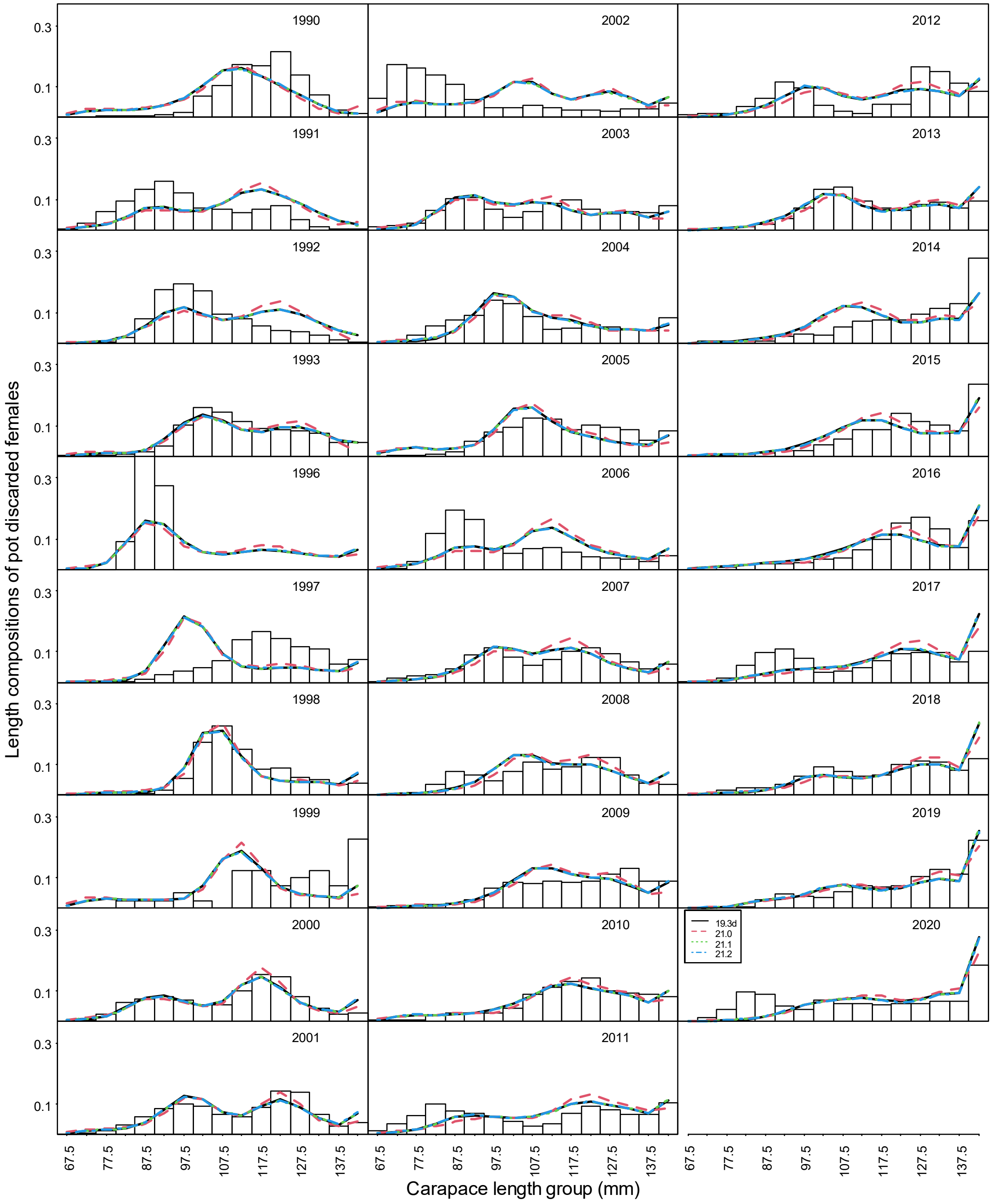


Figure 22. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the directed pot fishery under models 19.3d, 21.0, 21.1, and 21.2.

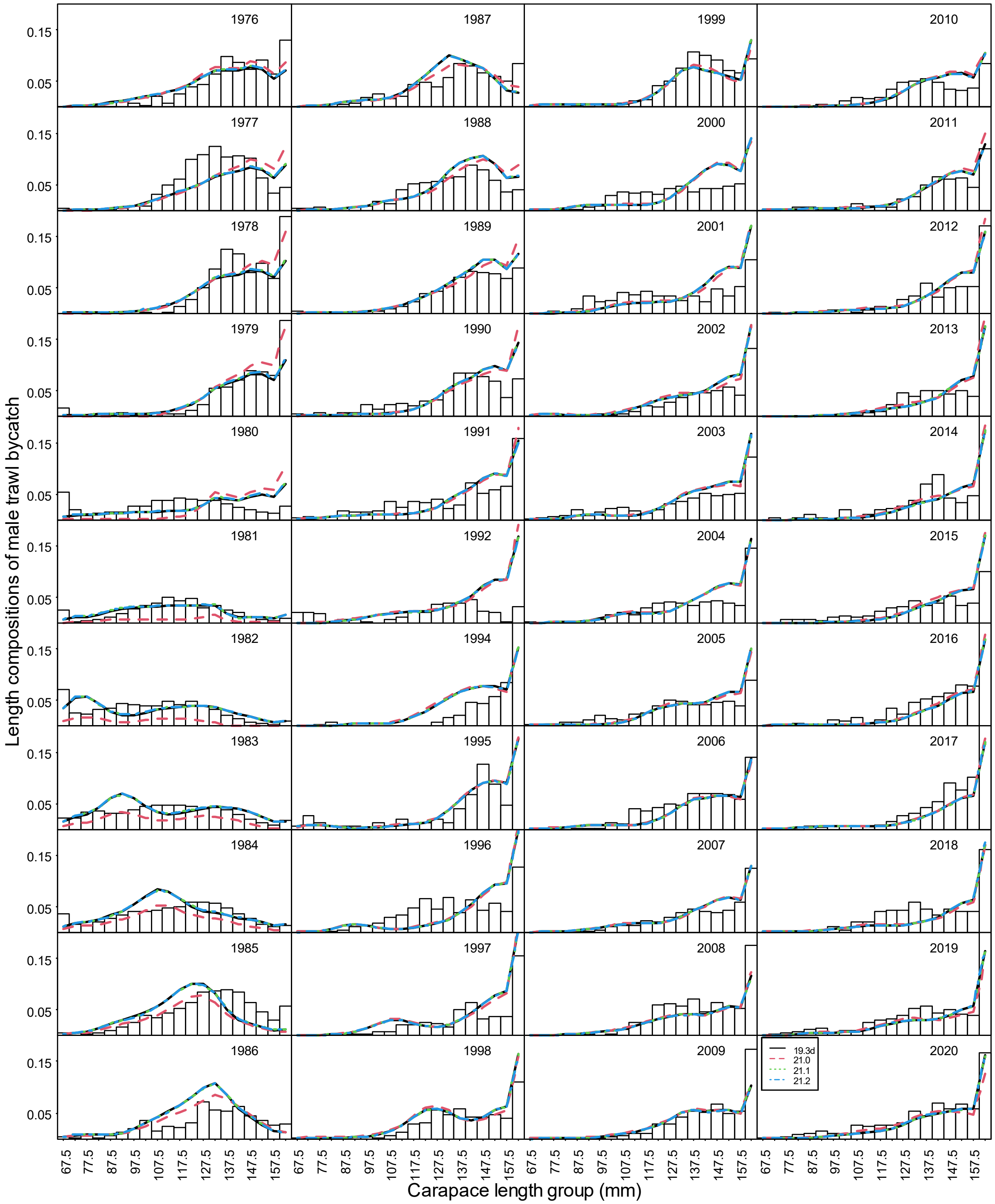


Figure 23a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish trawl fisheries under models 19.3d, 21.0, 21.1, and 21.2.

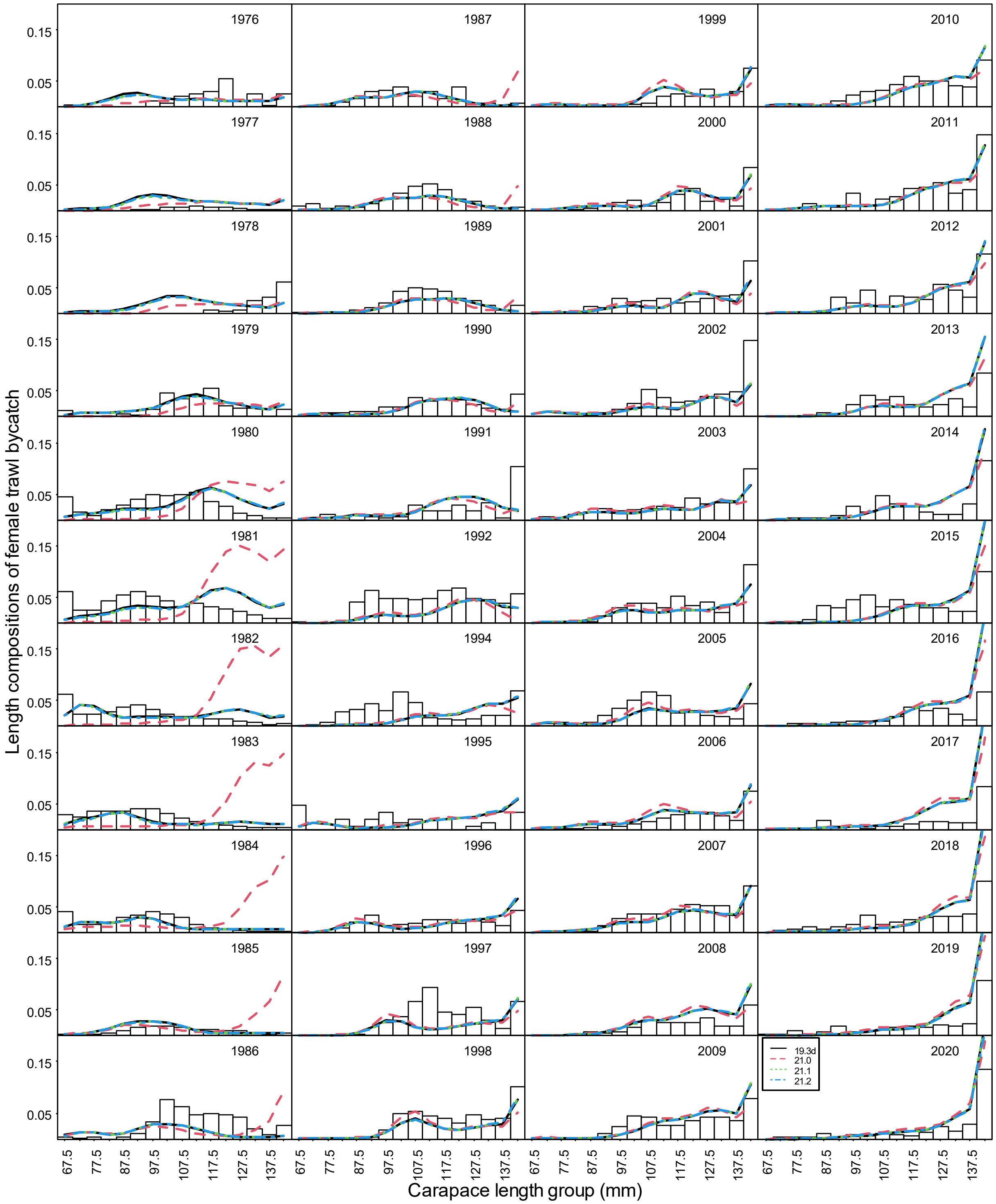


Figure 23b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish trawl fisheries under models 19.3d, 21.0, 21.1, and 21.2.

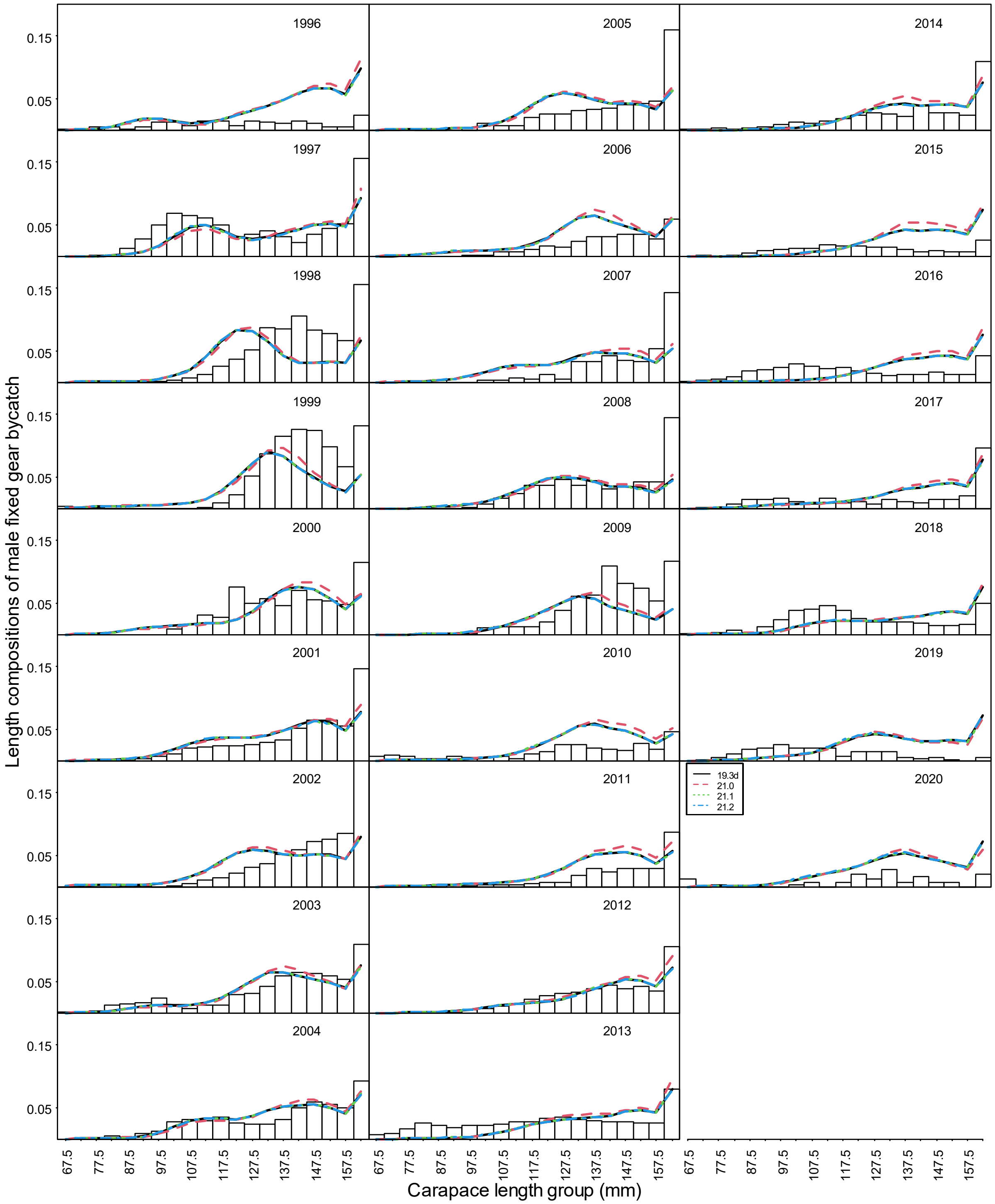


Figure 24a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish fixed gear fisheries under models 19.3d, 21.0, 21.1, and 21.2.

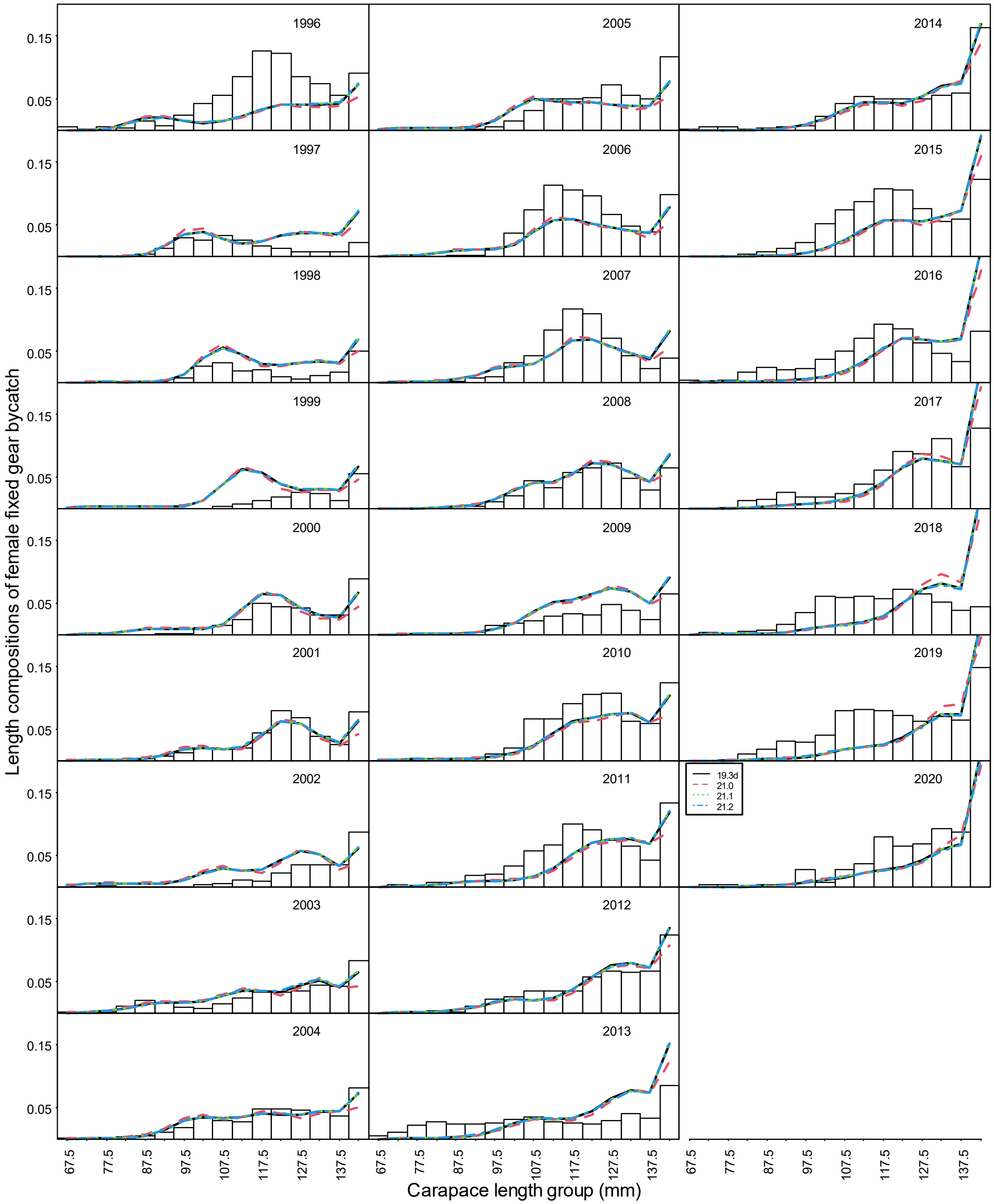


Figure 24b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish fixed gear fisheries under models 19.3d, 21.0, 21.1, and 21.2.

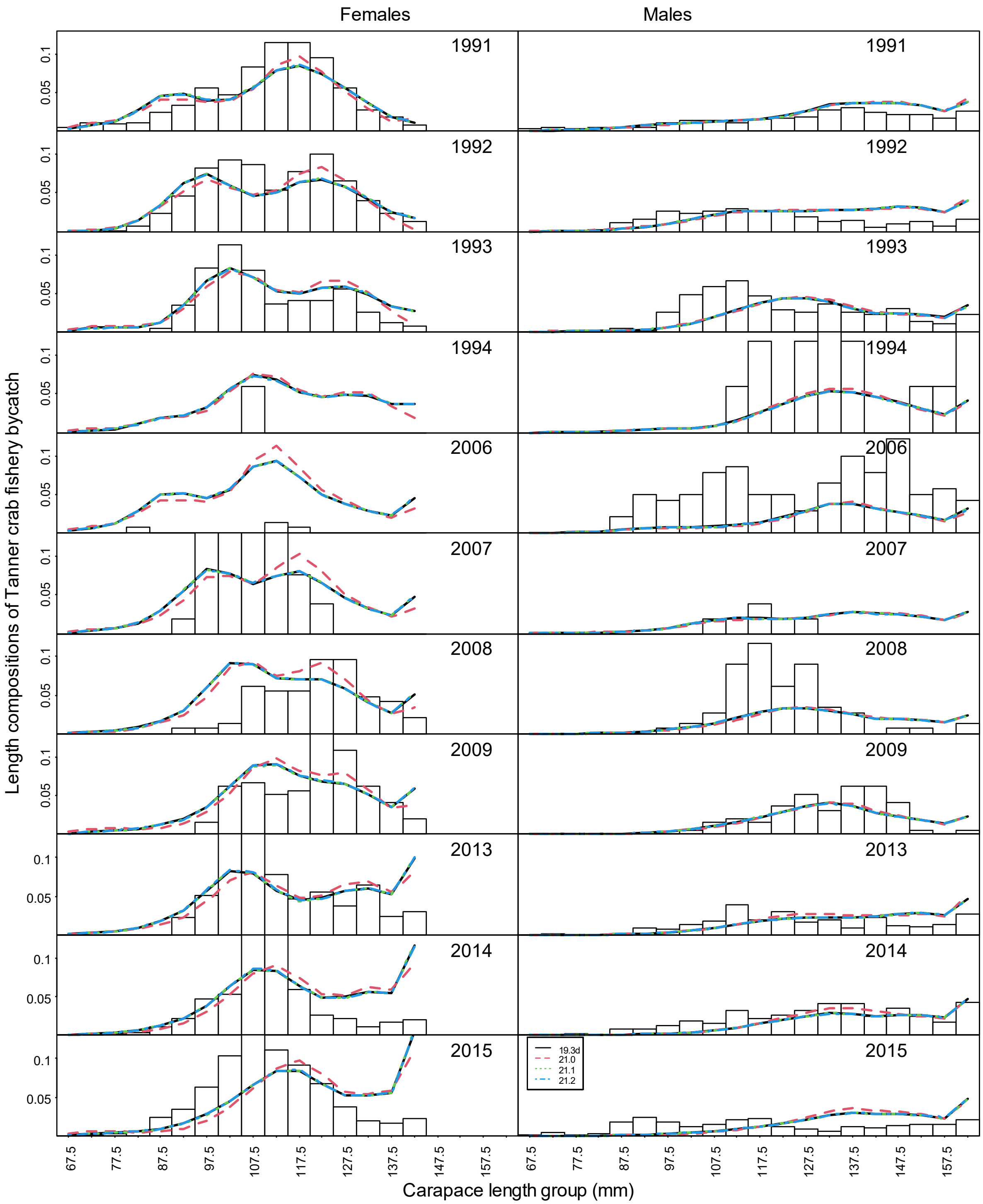


Figure 24c. Comparison of observer and model estimated discarded length frequencies of Bristol Bay red king crab by year in the Tanner crab fishery under models 19.3d, 21.0, 21.1, and 21.2. Length composition data during 1994-2009 were not used before 2021.

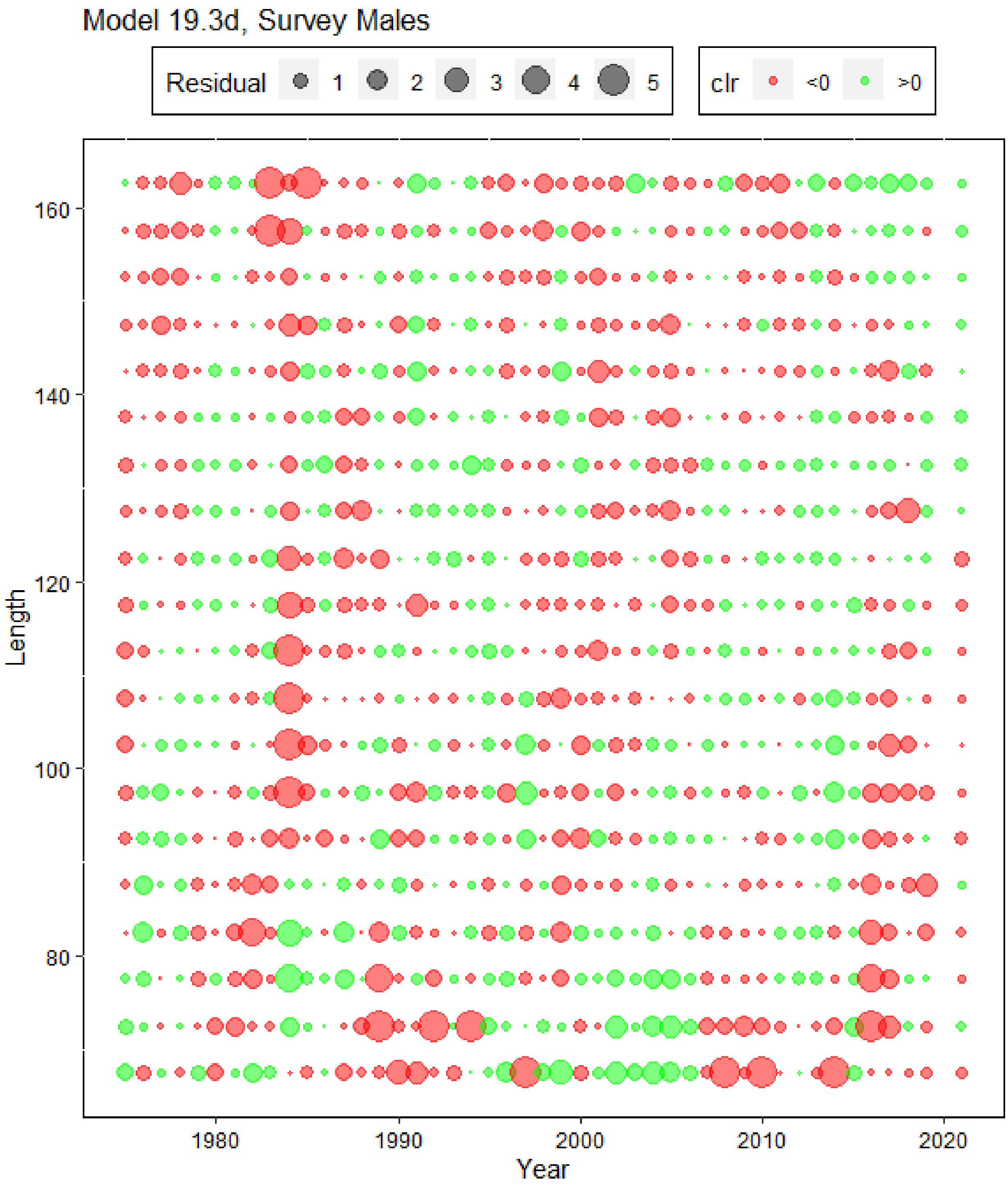


Figure 25a. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.3d. Green circles are positive residuals, and red circles are negative residuals.

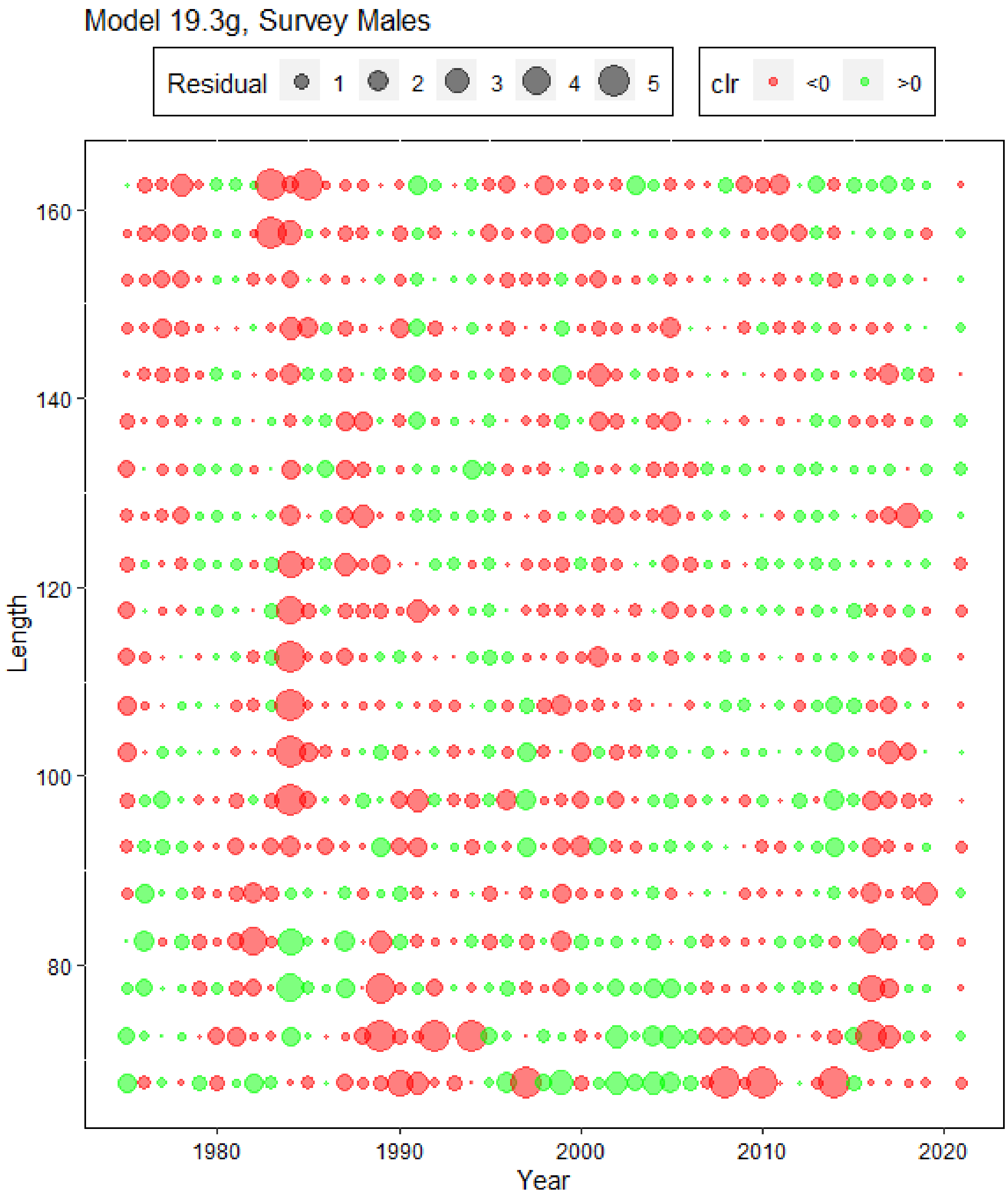


Figure 25b. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.3g. Green circles are positive residuals, and red circles are negative residuals.

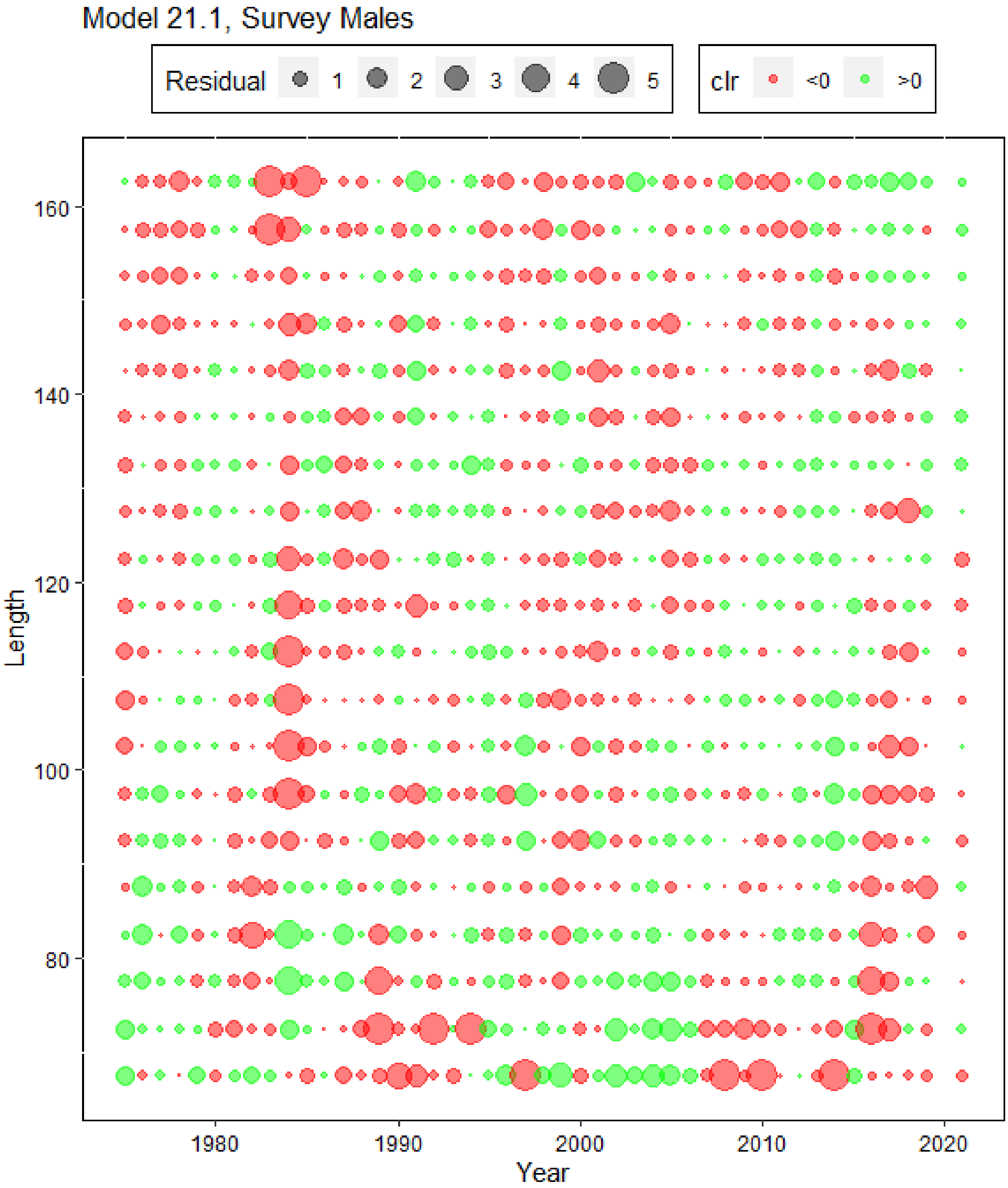


Figure 25c. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 21.1. Green circles are positive residuals, and red circles are negative residuals.

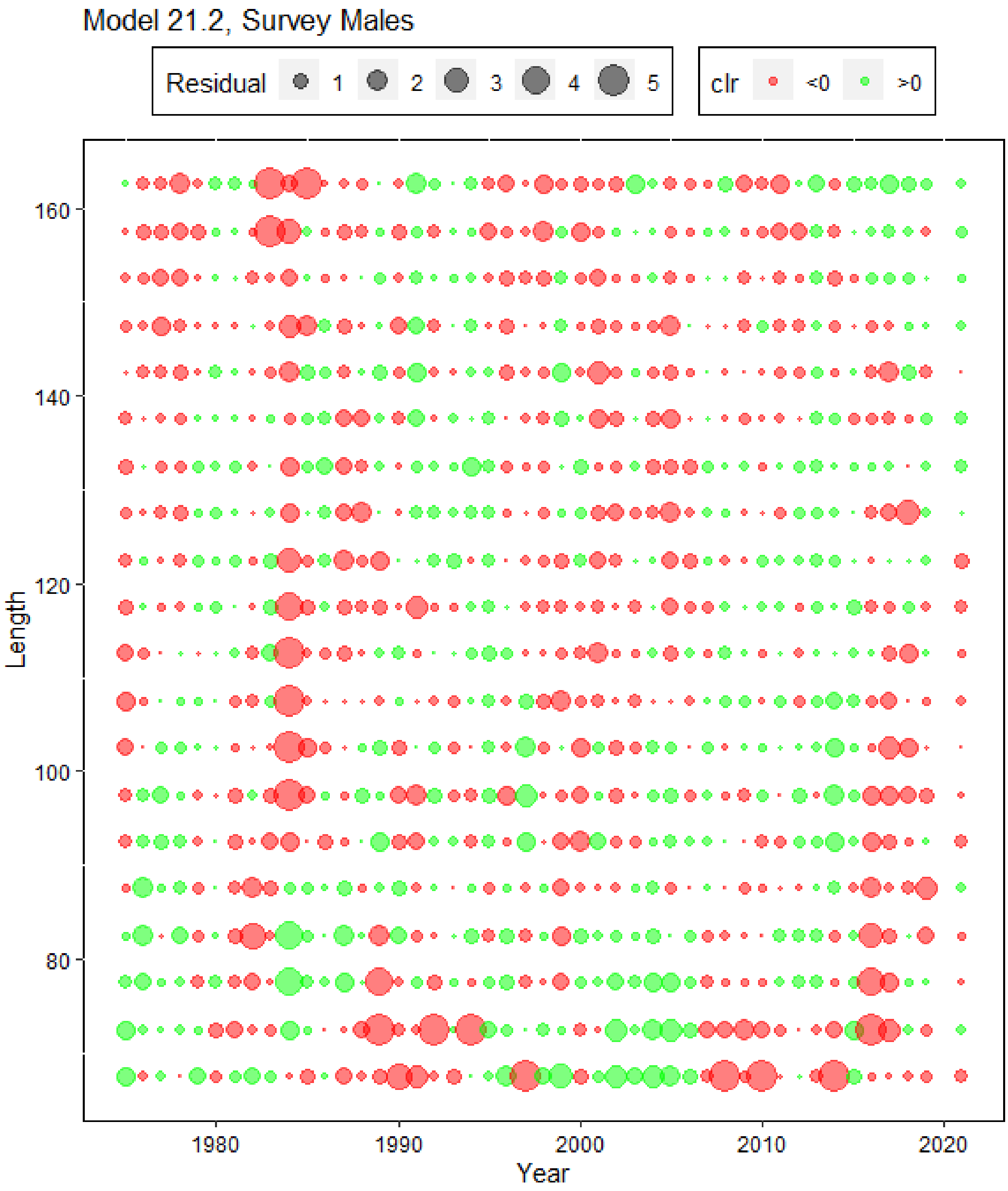


Figure 25d. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 21.2. Green circles are positive residuals, and red circles are negative residuals.

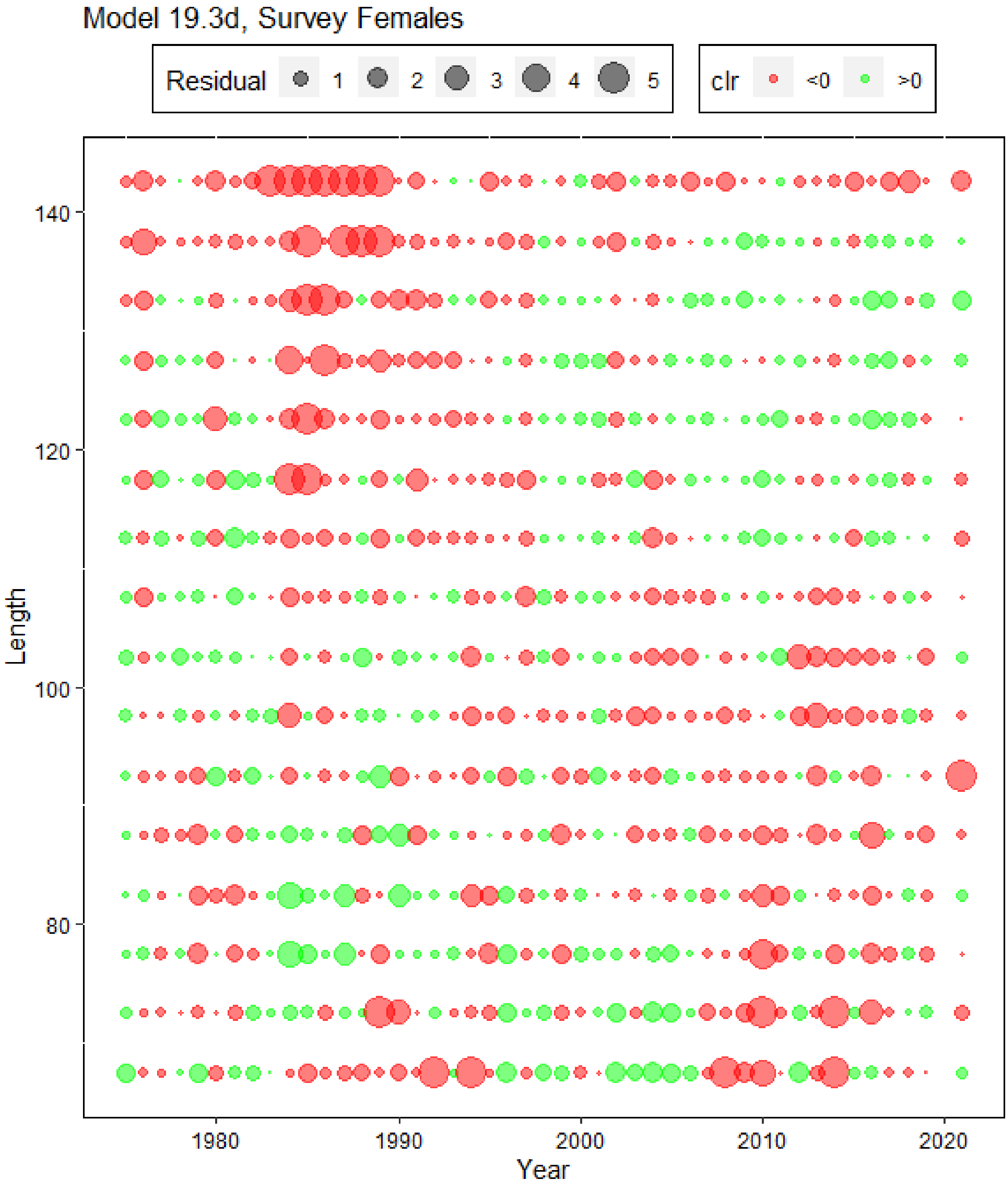


Figure 26a. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.3d. Green circles are positive residuals, and red circles are negative residuals.

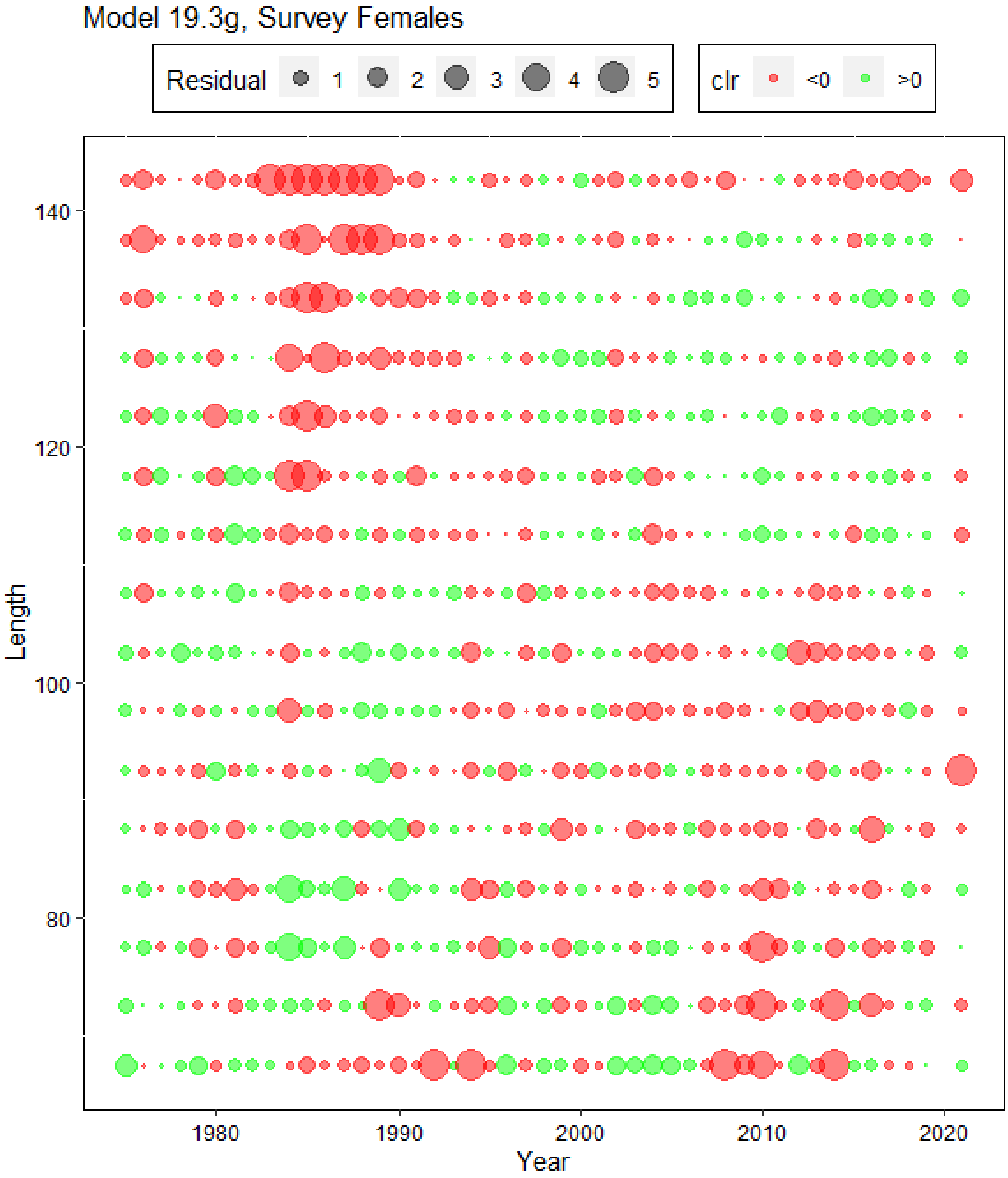


Figure 26b. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.3g. Green circles are positive residuals, and red circles are negative residuals.

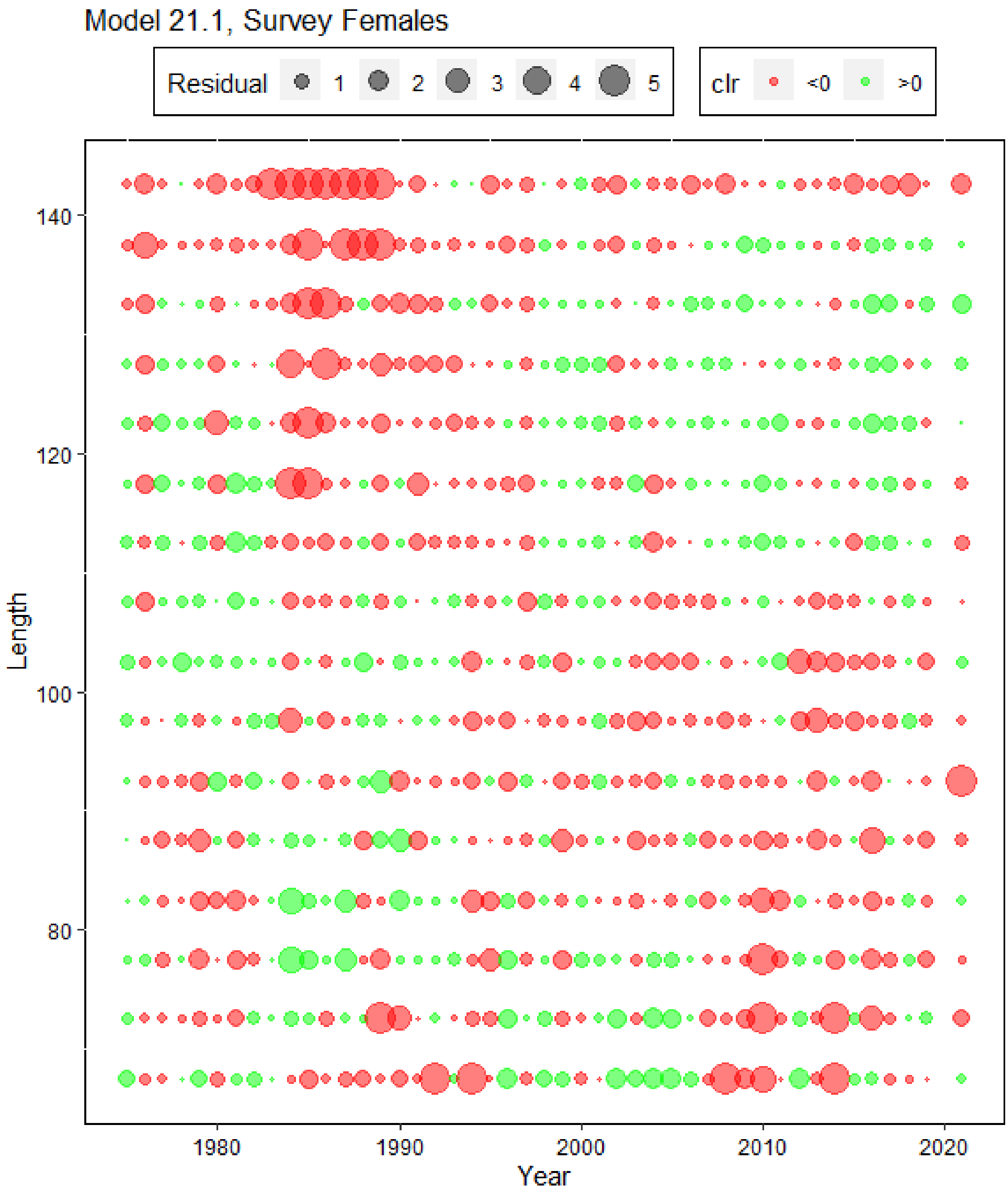


Figure 26c. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 21.1. Green circles are positive residuals, and red circles are negative residuals.

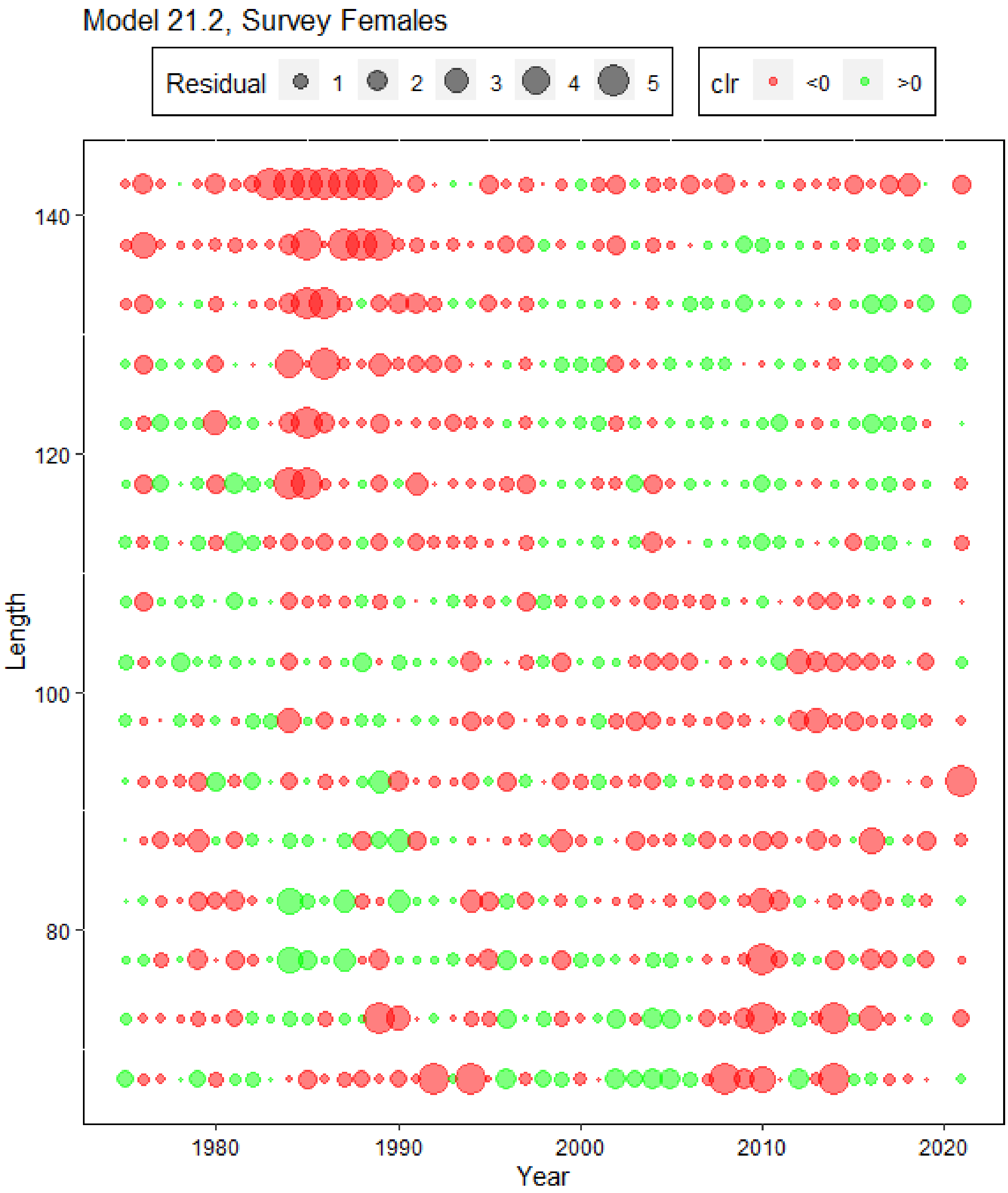


Figure 26d. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 21.2. Green circles are positive residuals, and red circles are negative residuals.

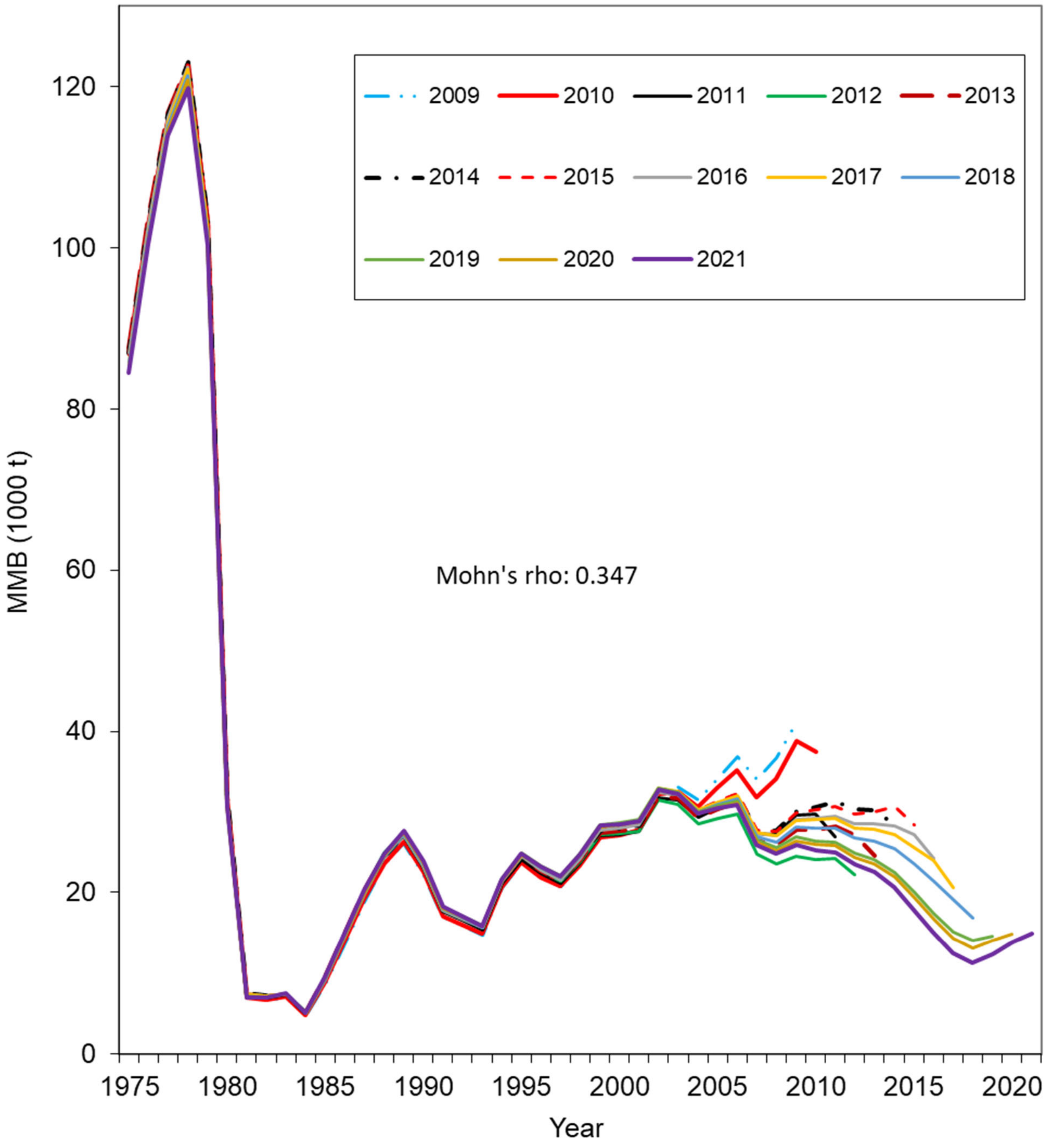


Figure 27a. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 19.3d. These are results of the 2021 model. Legend shows the terminal year.

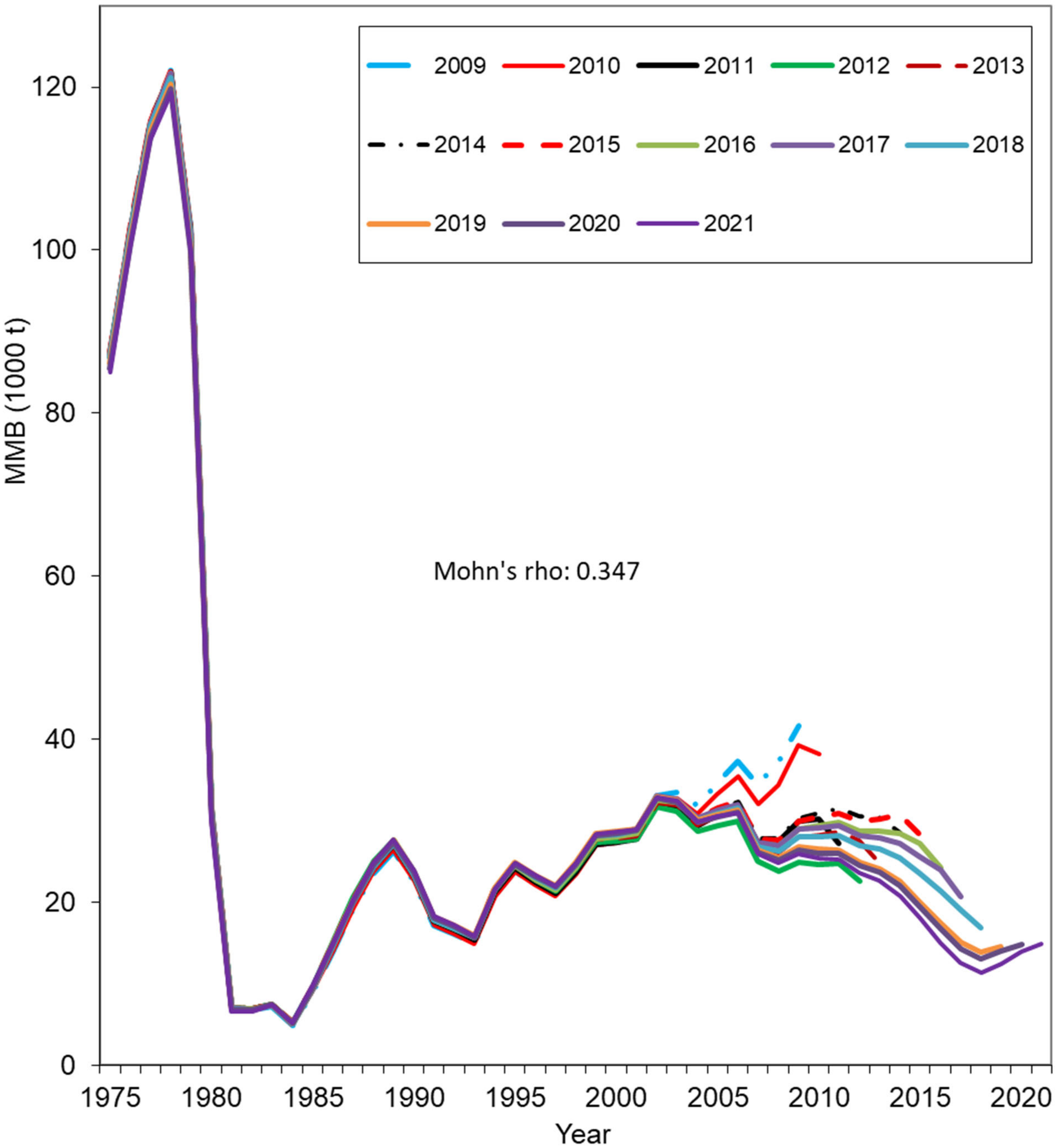


Figure 27b. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 21.1. These are results of the 2021 model. Legend shows the terminal year.

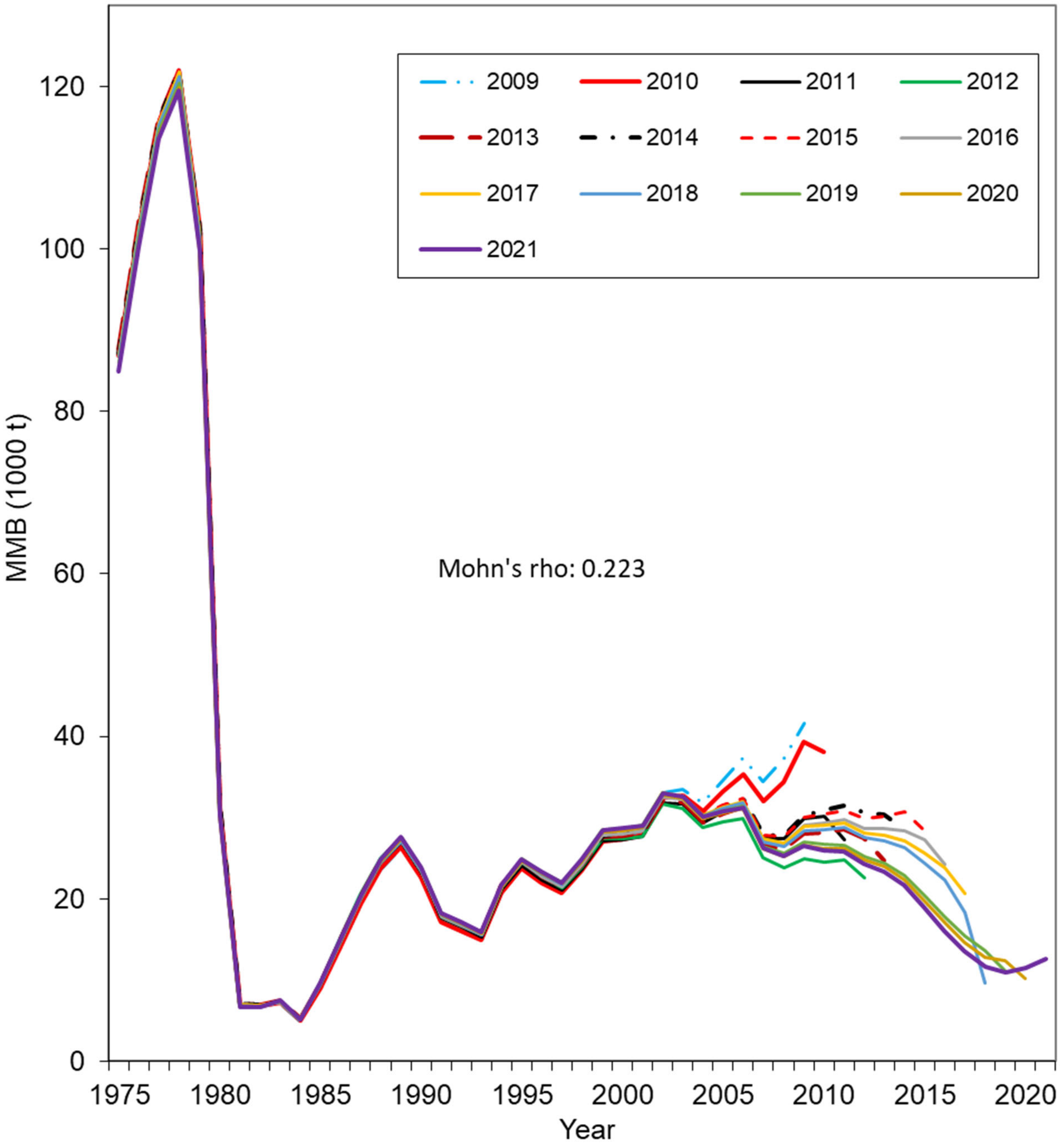


Figure 27c. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2021 made with terminal years 2009-2021 with model 21.2. These are results of the 2021 model. Legend shows the terminal year.

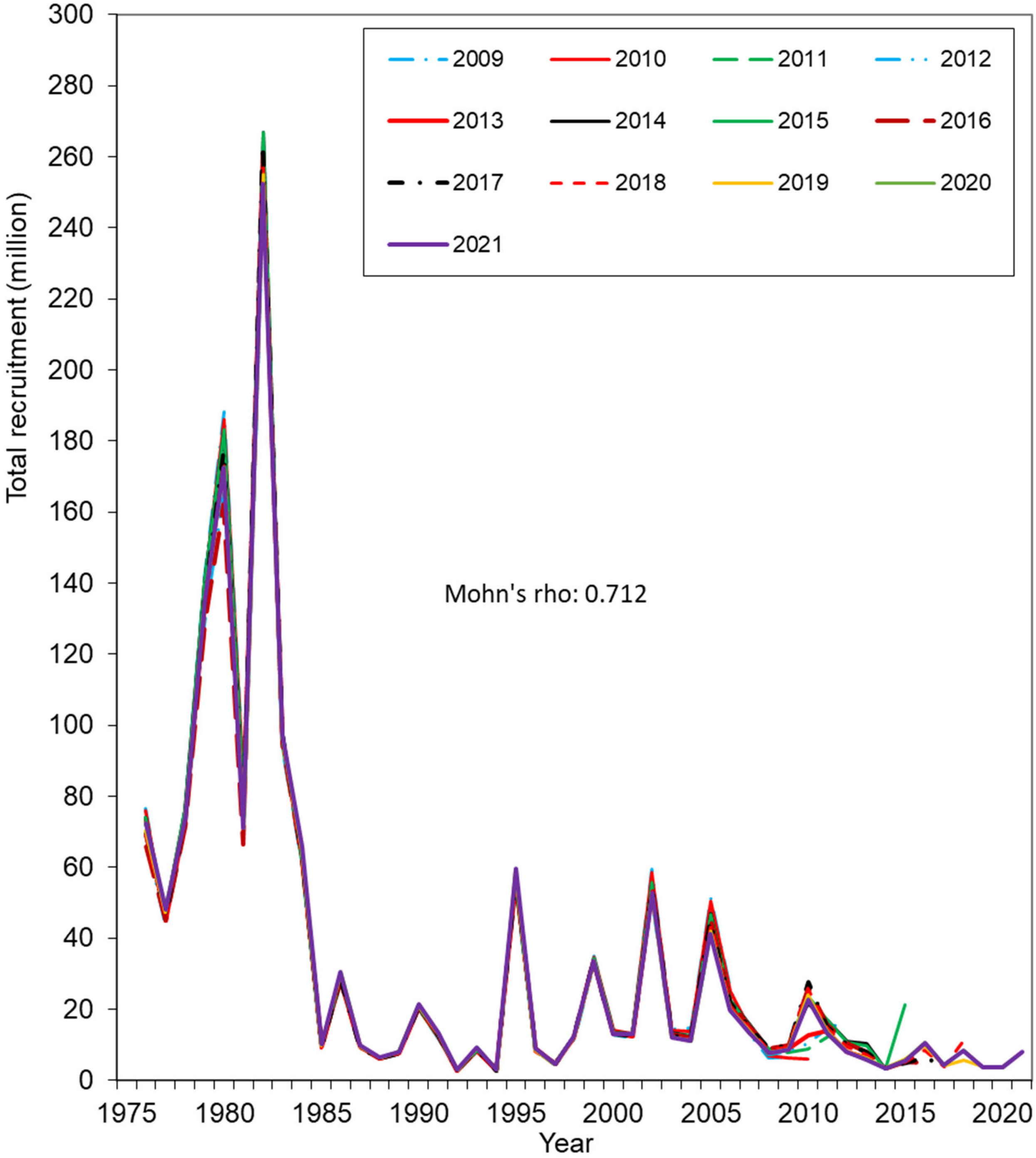


Figure 28a. Comparison of hindcast estimates of total recruitment for model 19.3d of Bristol Bay red king crab from 1976 to 2021 made with terminal years 2009-2021. These are results of the 2021 model. Legend shows the terminal year.

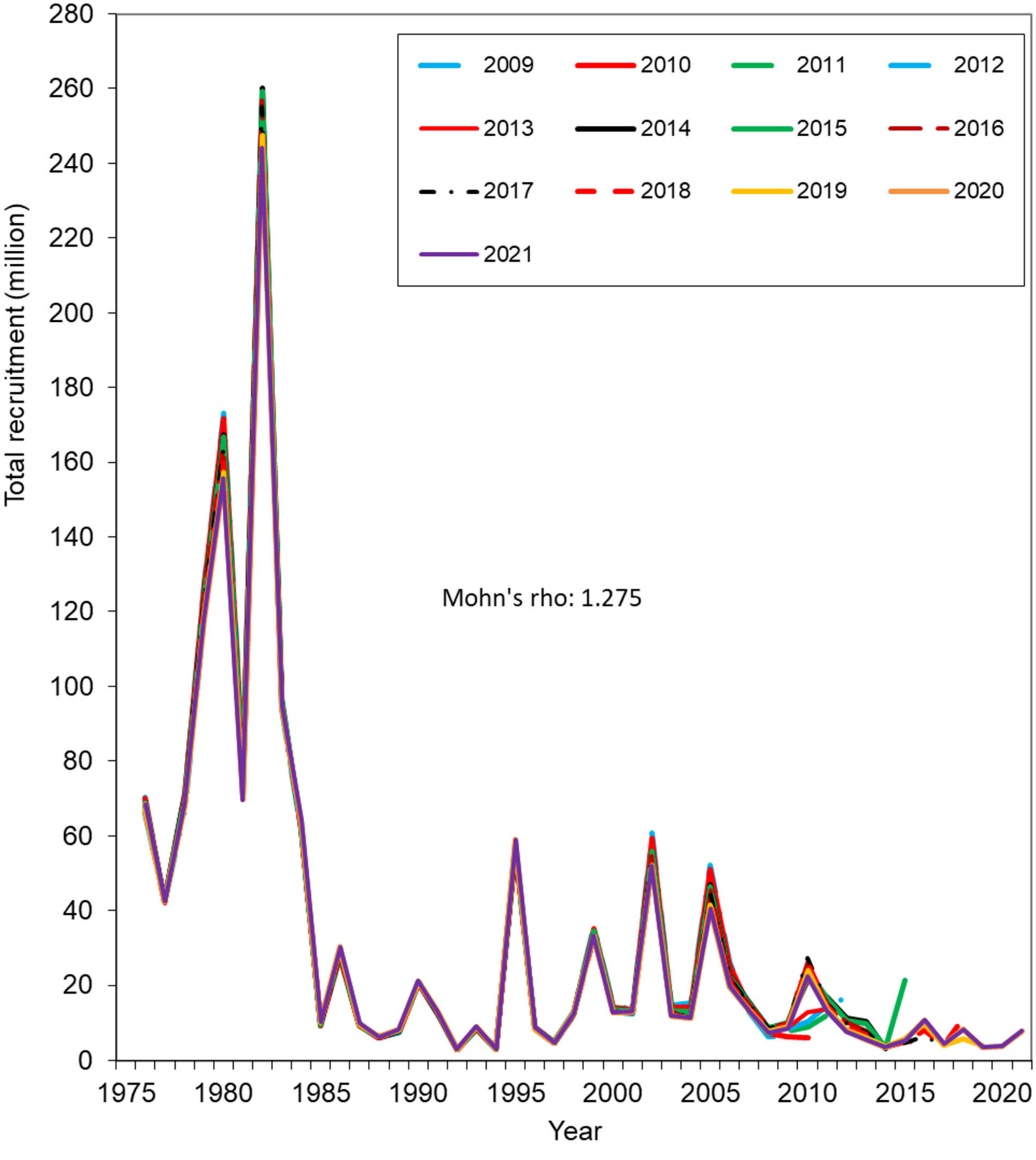


Figure 28b. Comparison of hindcast estimates of total recruitment for model 21.1 of Bristol Bay red king crab from 1976 to 2021 made with terminal years 2009-2021. These are results of the 2021 model. Legend shows the terminal year.

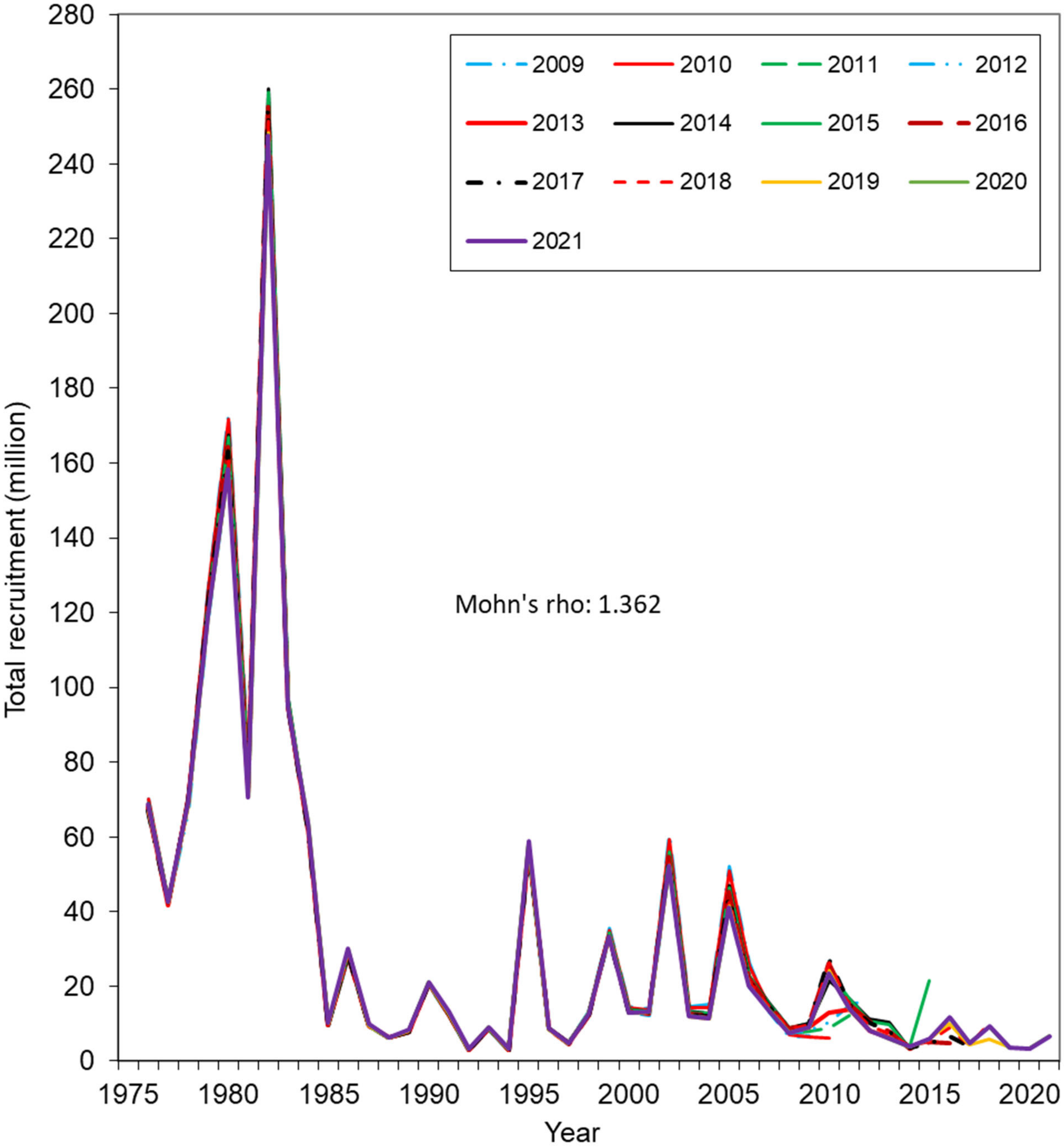


Figure 28c. Comparison of hindcast estimates of total recruitment for model 21.2 of Bristol Bay red king crab from 1976 to 2021 made with terminal years 2009-2021. These are results of the 2021 model. Legend shows the terminal year.

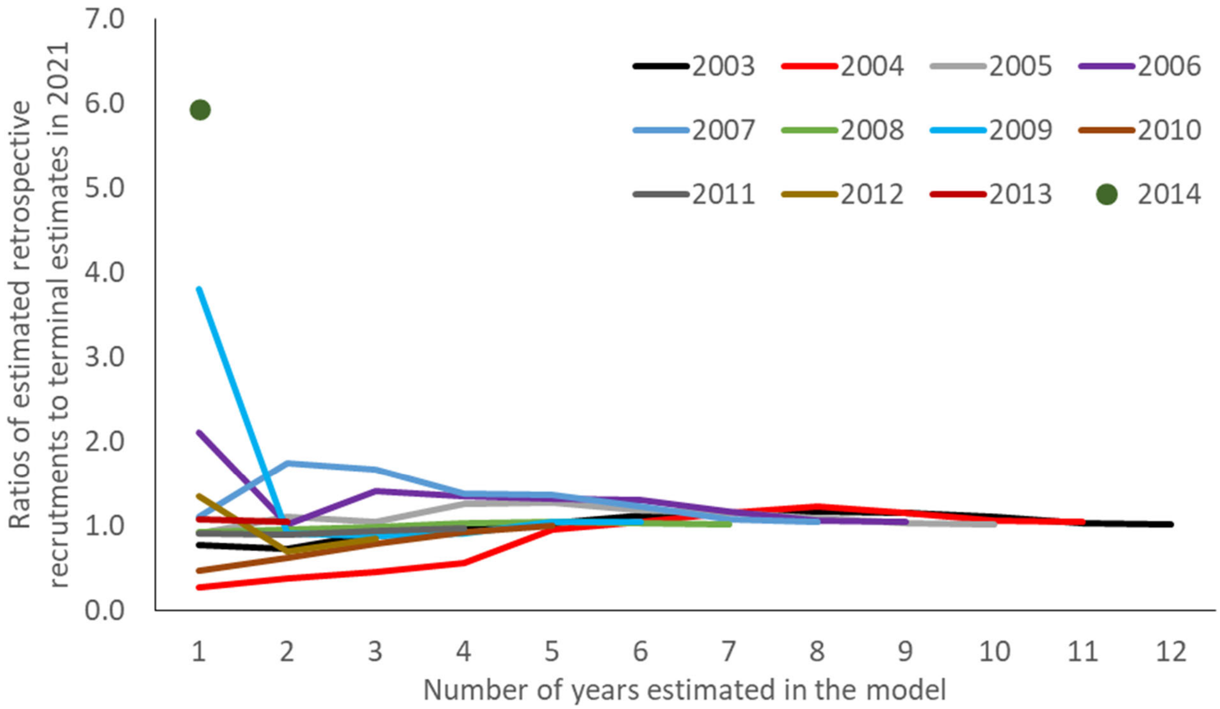


Figure 28d. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 19.3d.

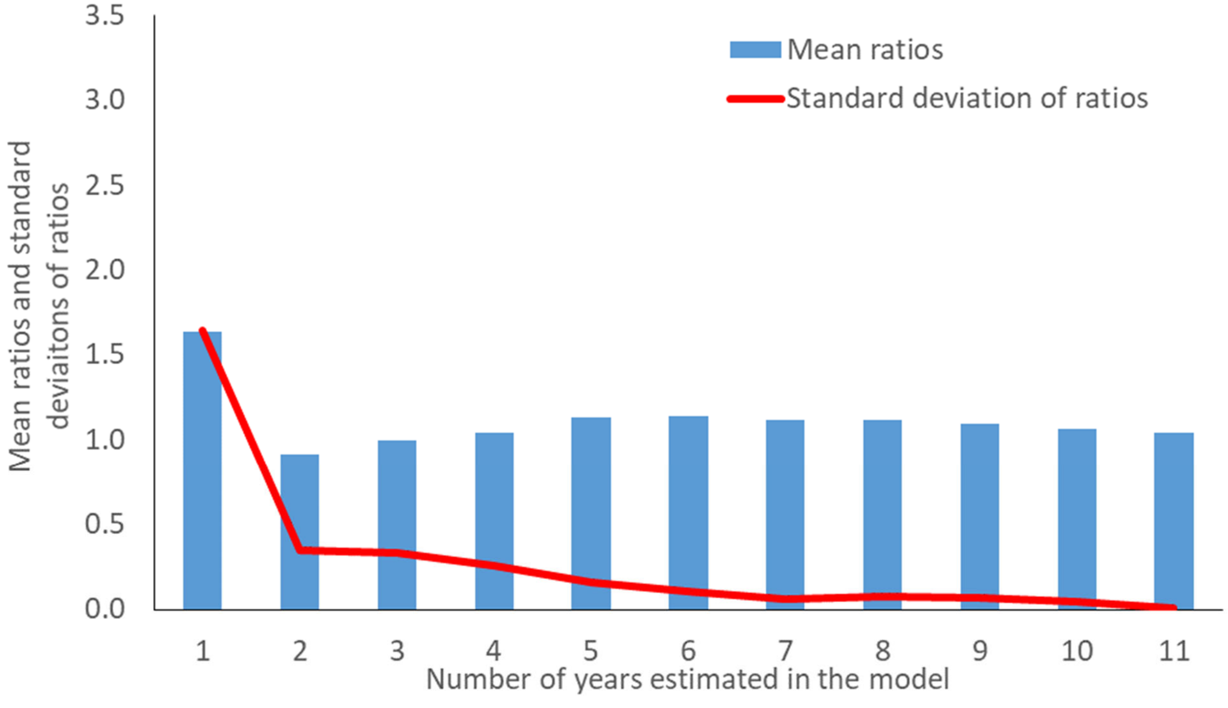


Figure 28e. Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2021) and standard deviations of the ratios as a function of the number of years in the model for model 19.3d.

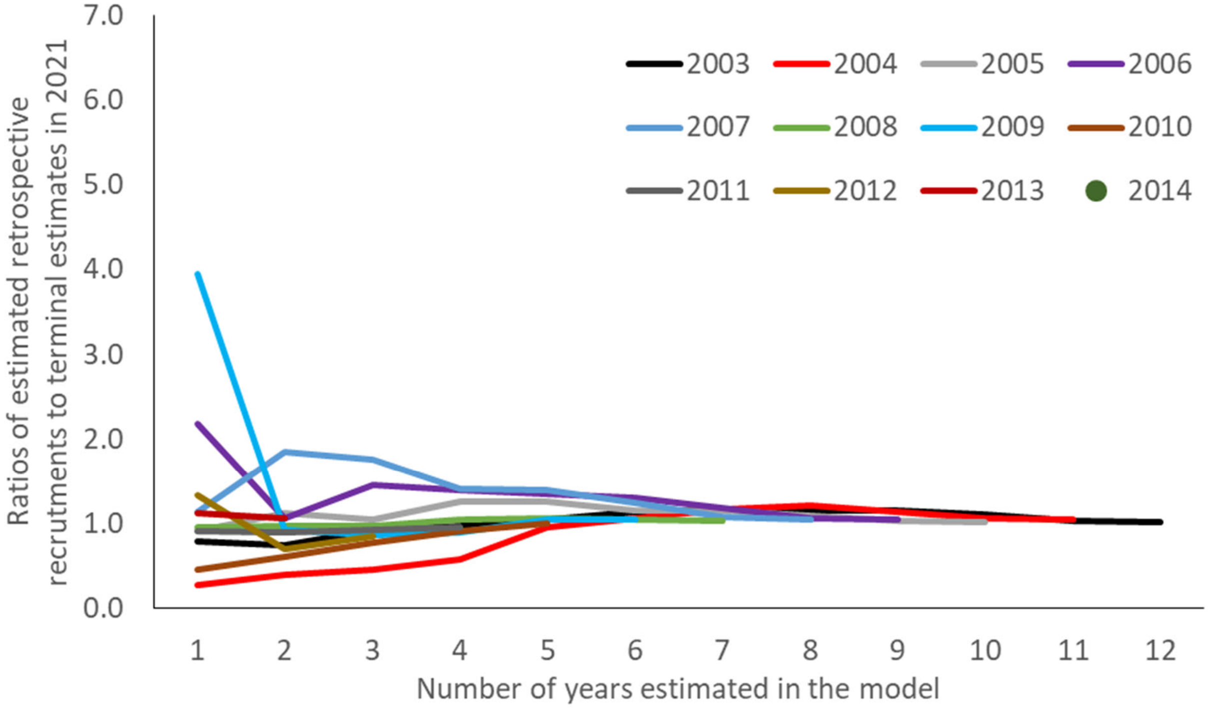


Figure 28f. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 21.1.

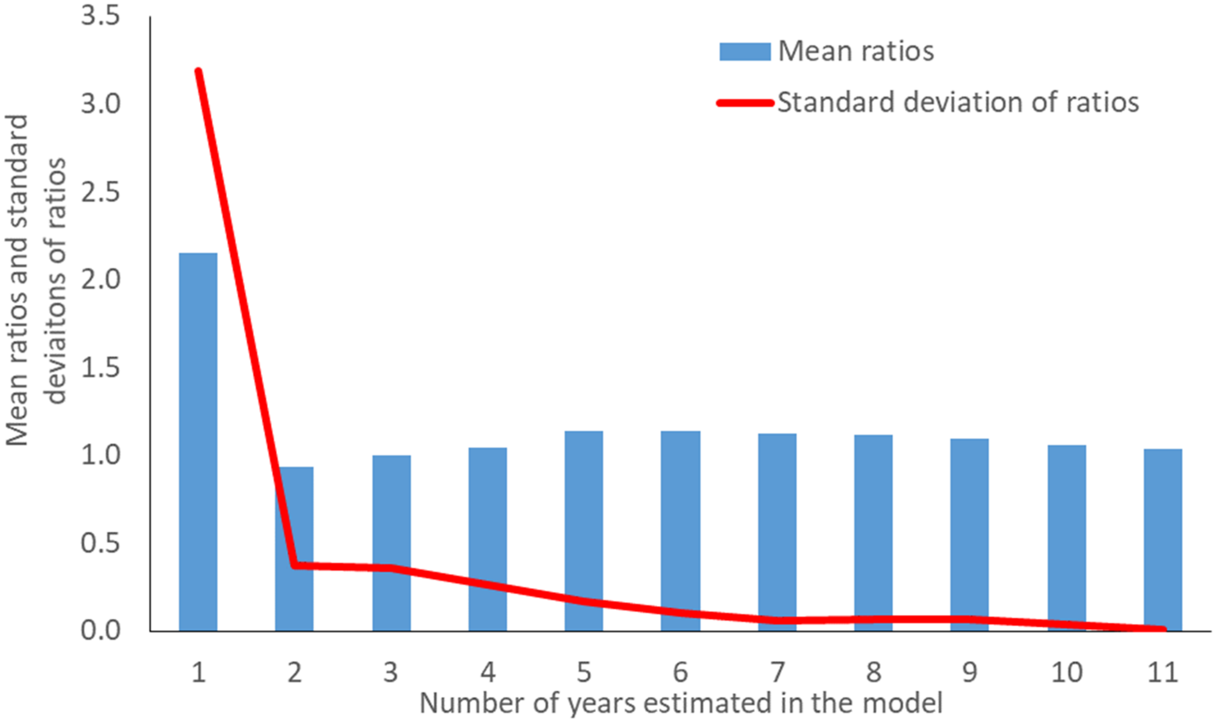


Figure 28g. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 21.1.

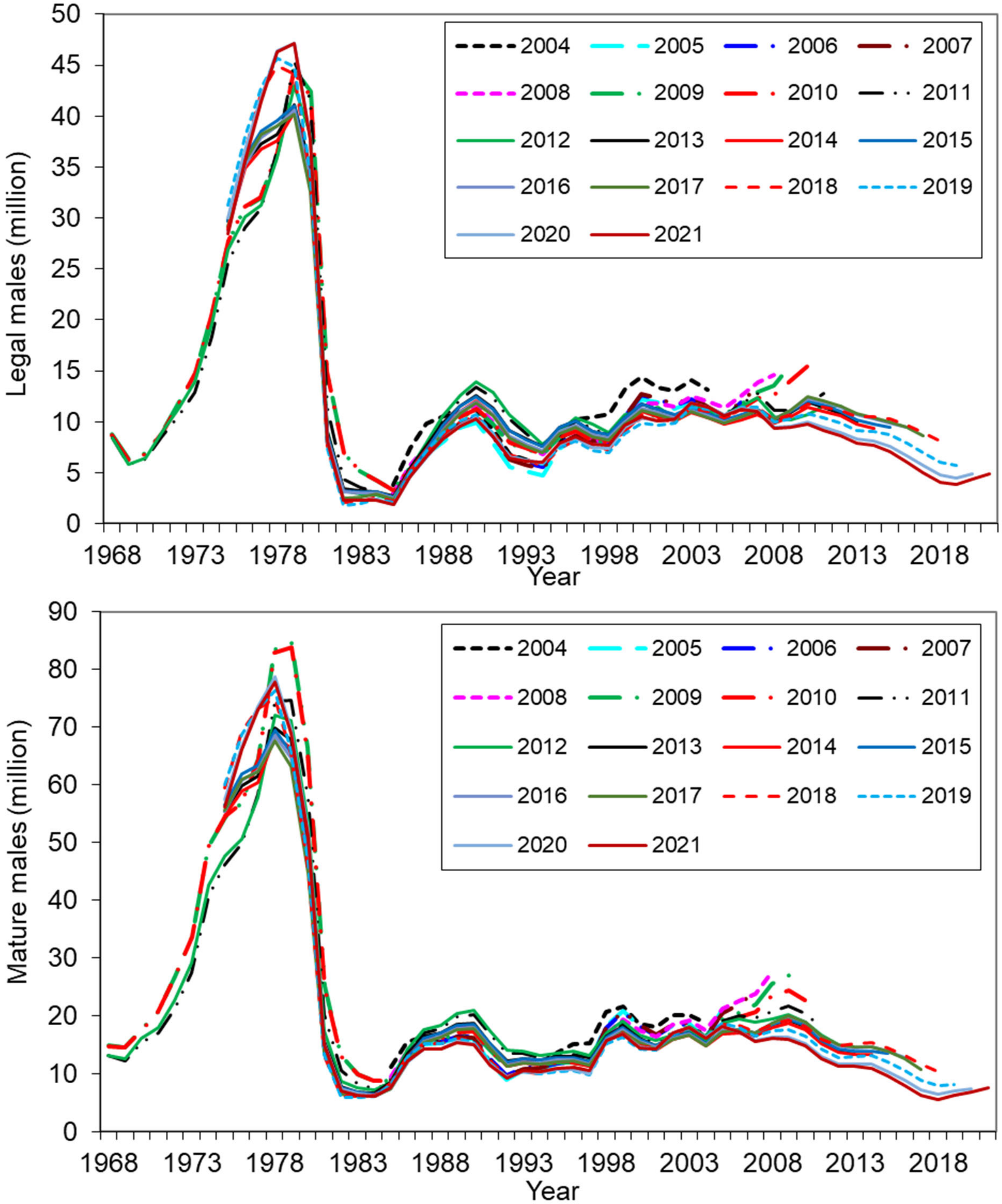


Figure 29a. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2021 made with terminal years 2004-2021 with the base models. Model 19.3d is used for 2021. These are results of historical assessments. Legend shows the year in which the assessment was conducted.

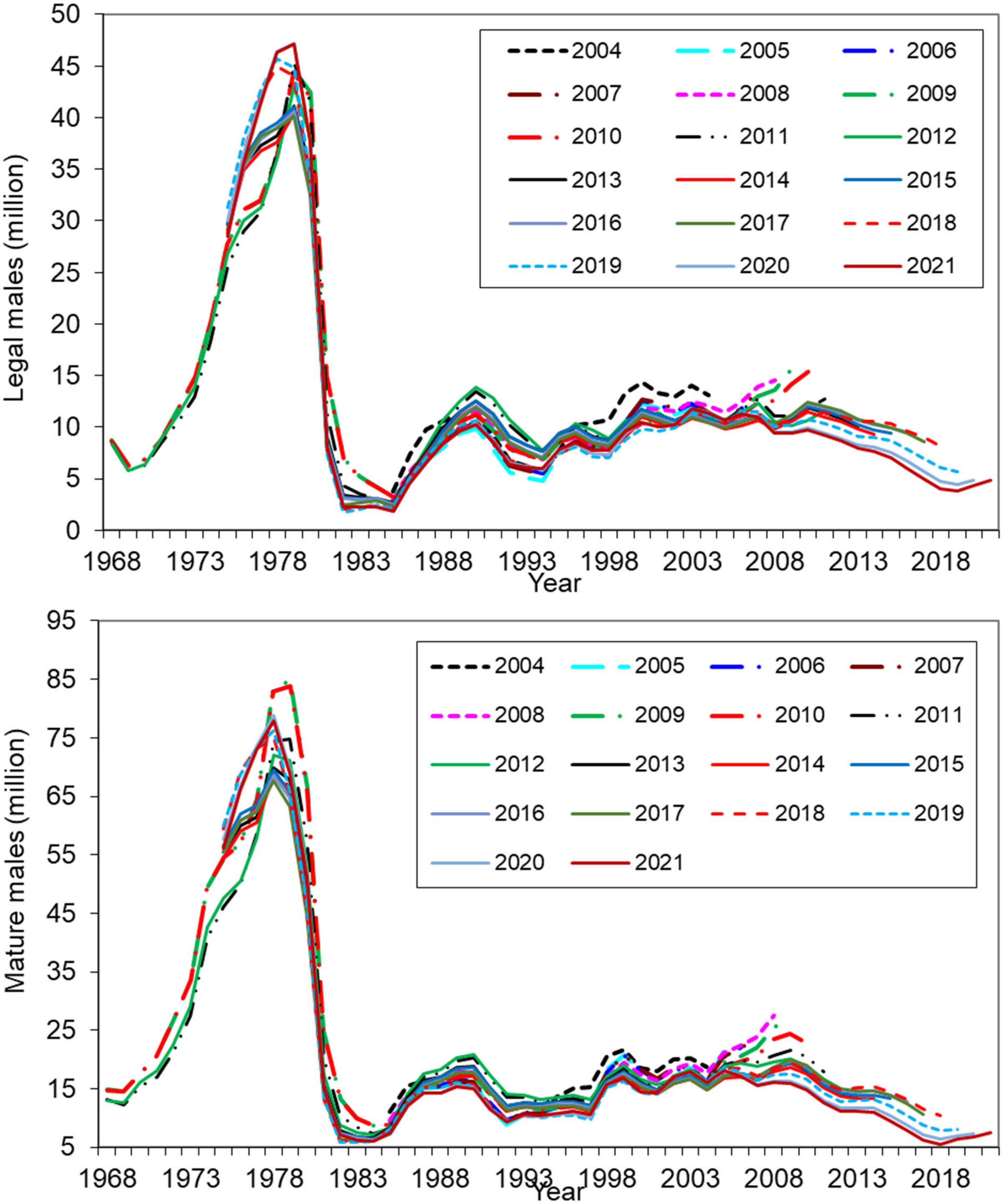


Figure 29b. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2021 made with terminal years 2004-2021 with the base models. Model 21.1 is used for 2021. These are results of historical assessments. Legend shows the year in which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

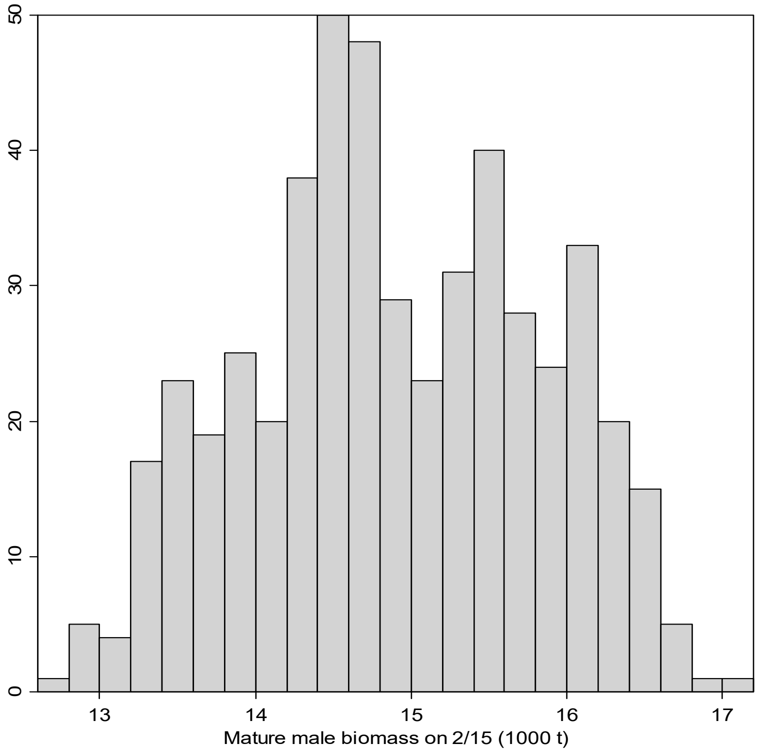


Figure 30a. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 19.3d with the MCMC approach.

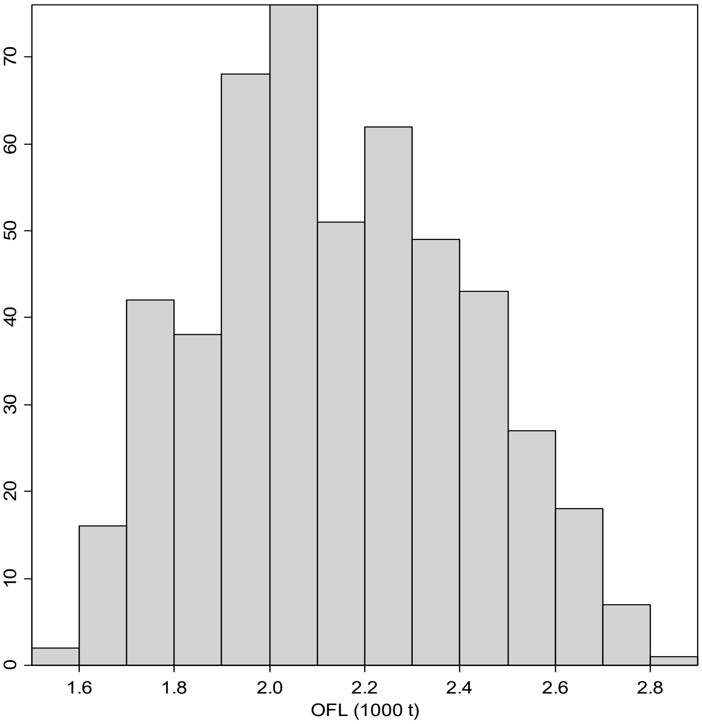


Figure 30b. Histogram of the 2021 estimated OFL under model 19.3d with the MCMC approach.

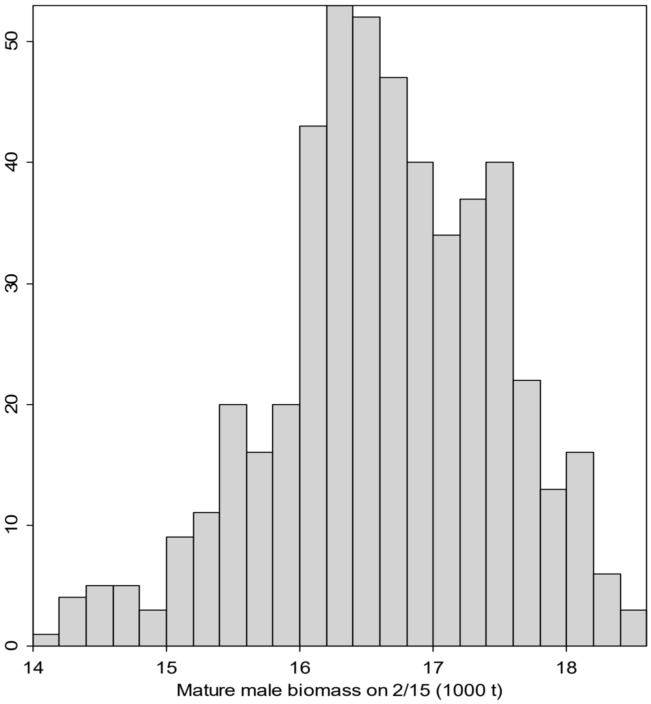


Figure 30c. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 19.3g with the MCMC approach.

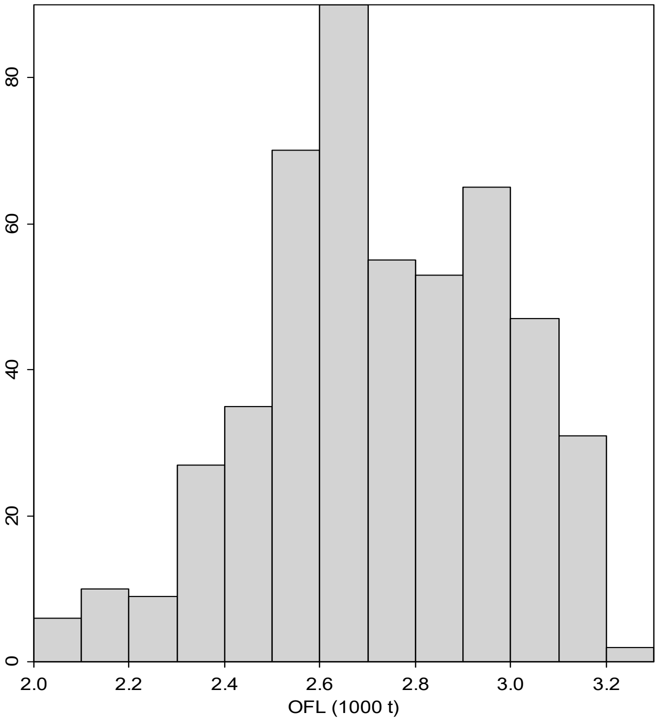


Figure 30d. Histogram of the 2021 estimated OFL under model 19.3g with the MCMC approach.

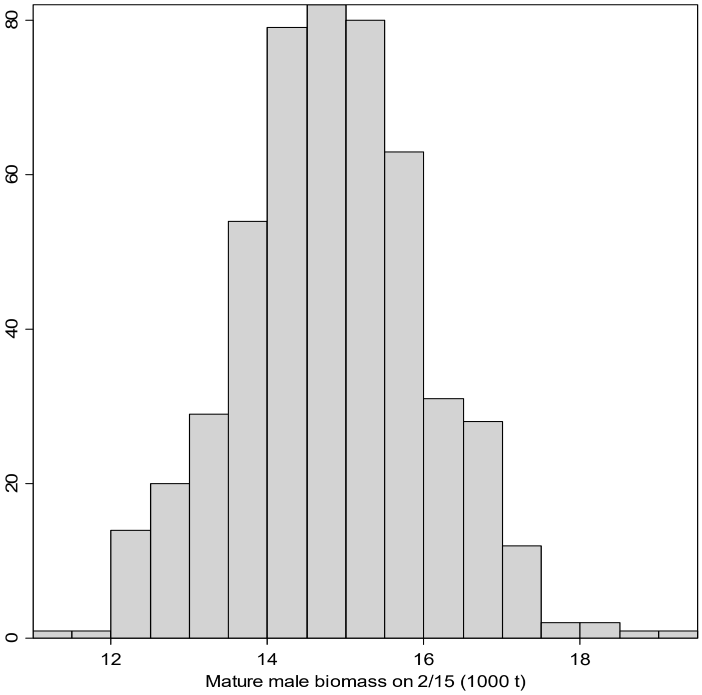


Figure 30e. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 21.1 with the MCMC approach.

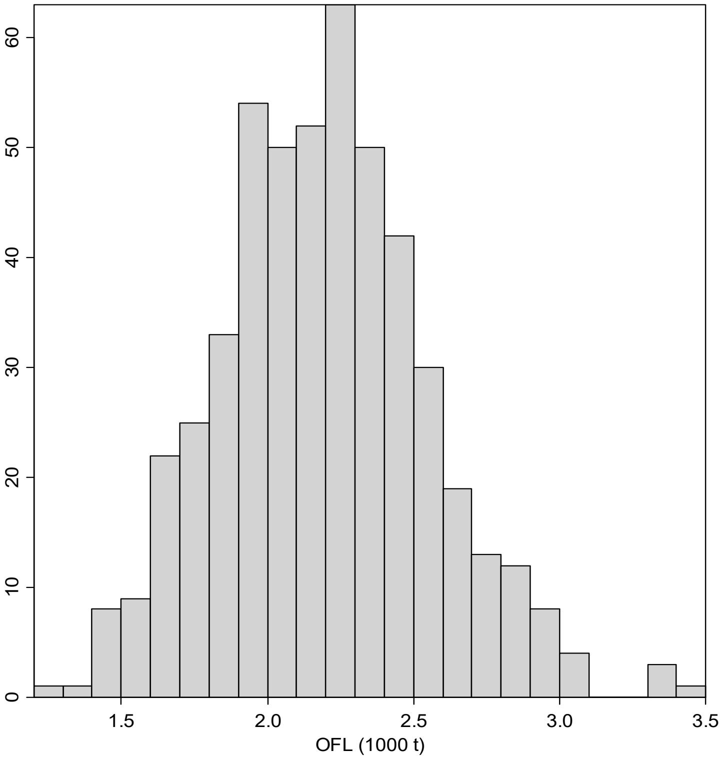


Figure 30f. Histogram of the 2021 estimated OFL under model 21.1 with the MCMC approach.

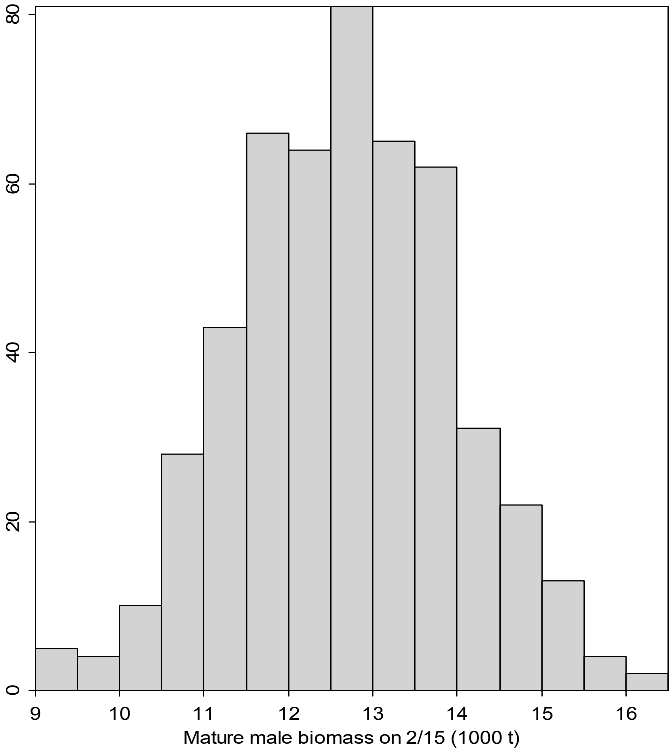


Figure 30g. Histogram of estimated mature male biomass on Feb. 15, 2022, under model 21.2 with the MCMC approach.

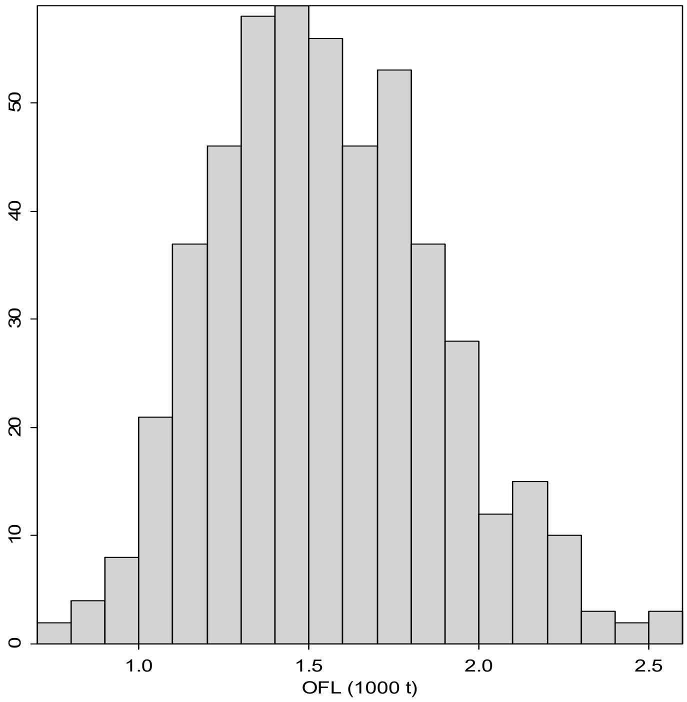


Figure 30h. Histogram of the 2021 estimated OFL under model 21.2 with the MCMC approach.

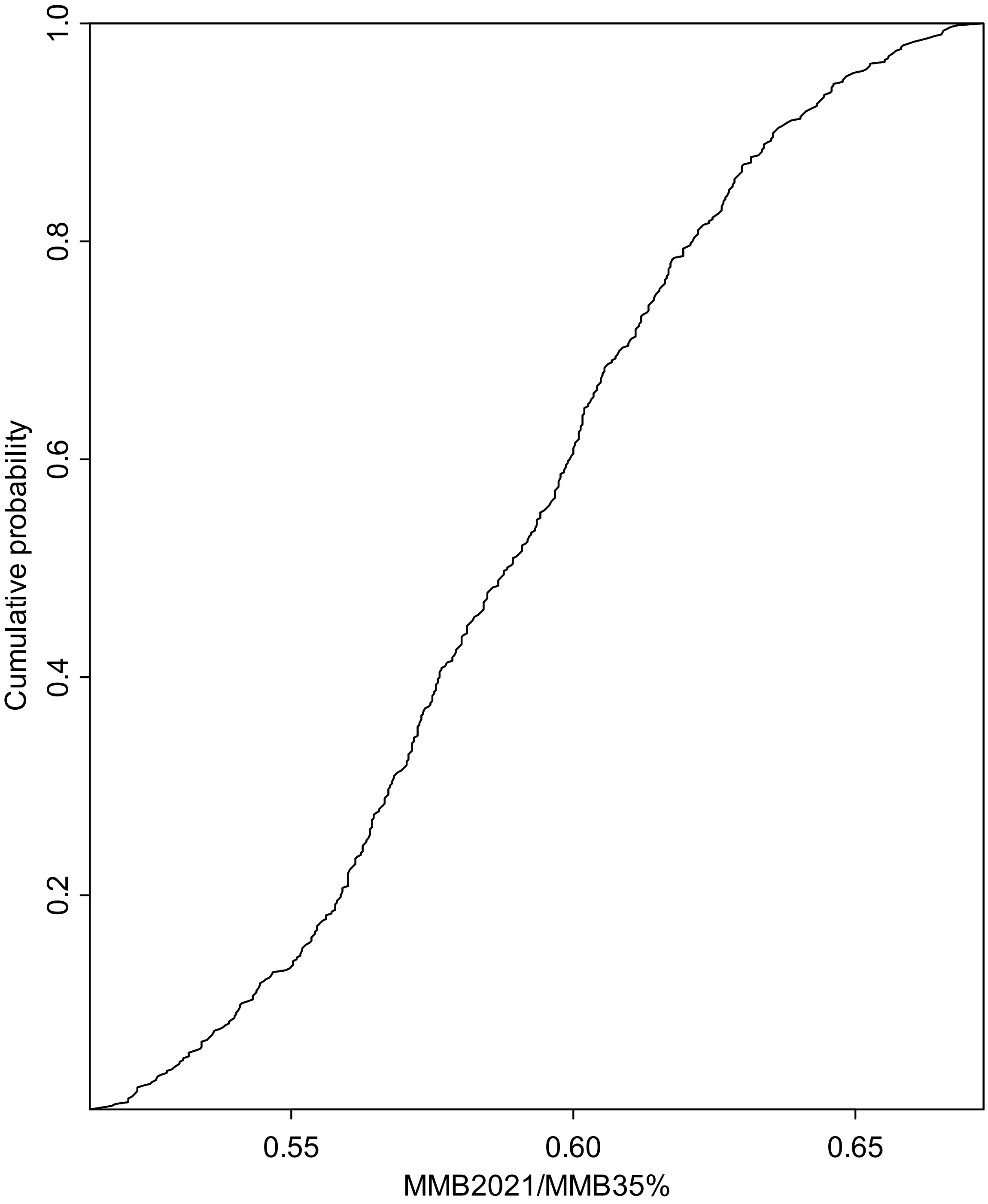


Figure 31a. Cumulative probabilities of estimated ratios of MMB in 2021 to corresponding estimated $B_{35\%}$ values under model 19.3d with the MCMC approach. Zero probability is below the estimated minimum thresholds.

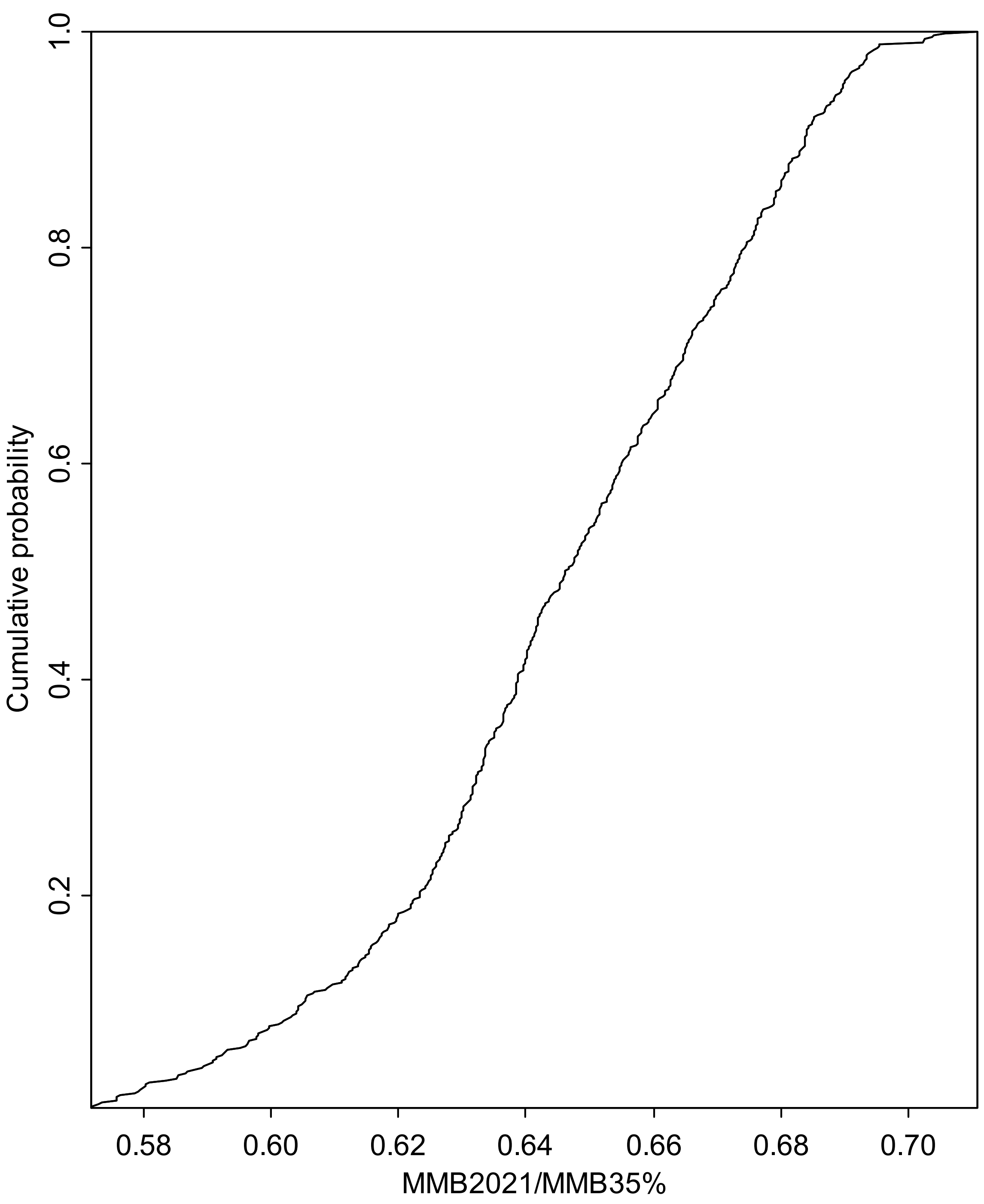


Figure 31b. Cumulative probabilities of estimated ratios of MMB in 2021 to corresponding estimated B35% values under model 19.3g with the MCMC approach. Zero probability is below the estimated minimum thresholds.

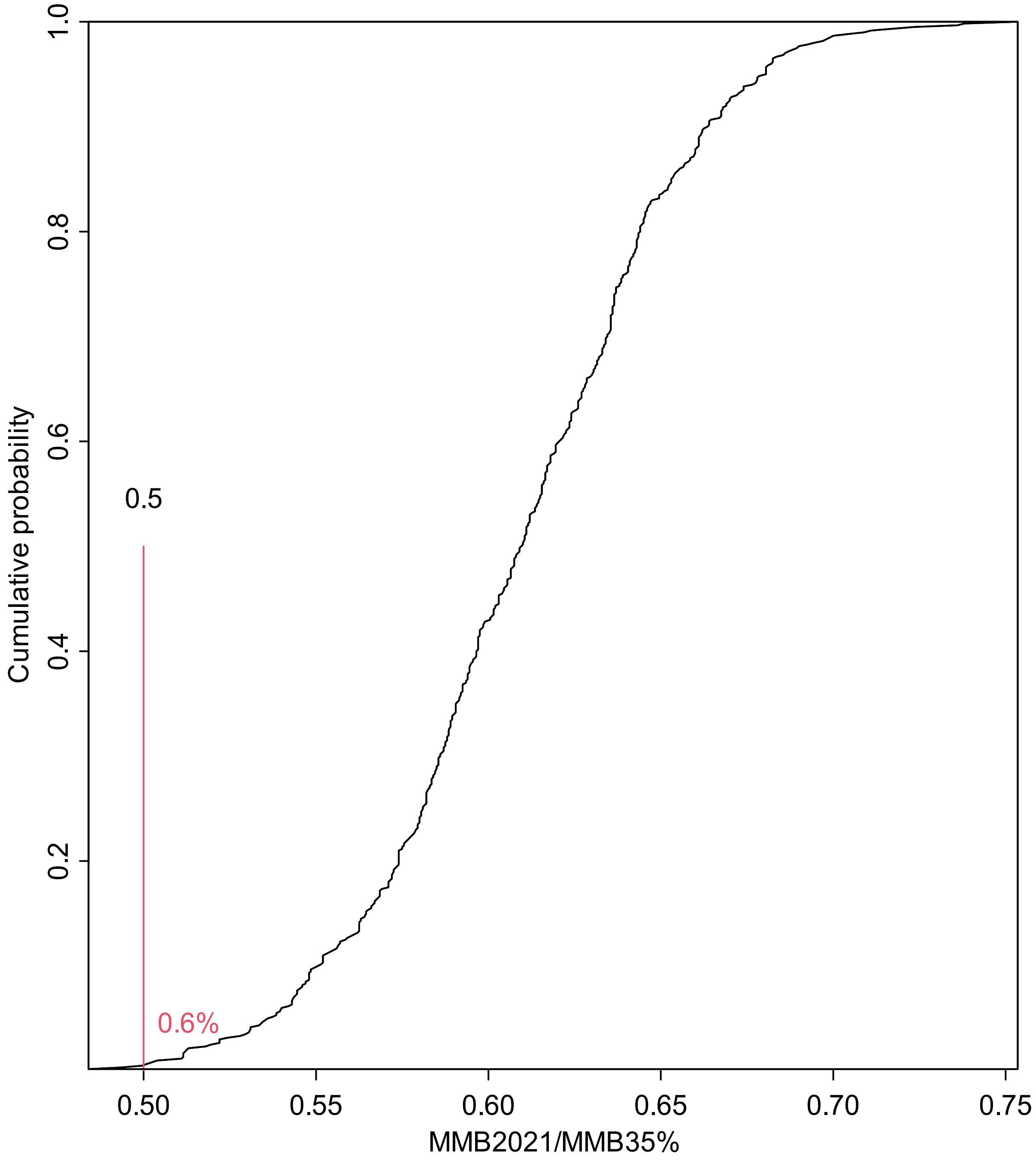


Figure 31c. Cumulative probabilities of estimated ratios of MMB in 2021 to corresponding estimated B35% values under model 21.1 with the MCMC approach. About 0.6% probability is below the estimated minimum thresholds.

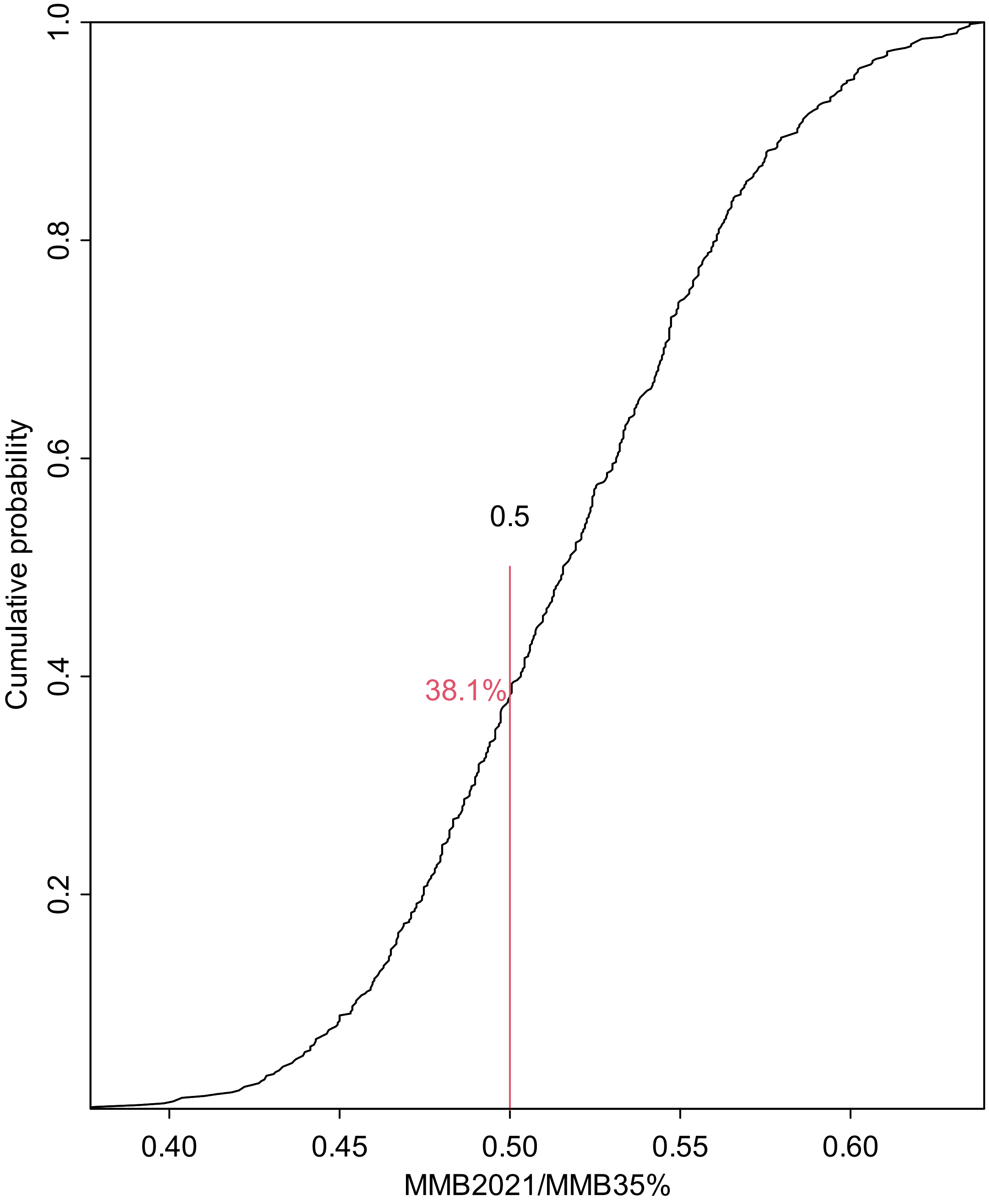


Figure 31d. Cumulative probabilities of estimated ratios of MMB in 2021 to corresponding estimated B35% values under model 21.2 with the MCMC approach. About 38.08% probability is below the estimated minimum thresholds.

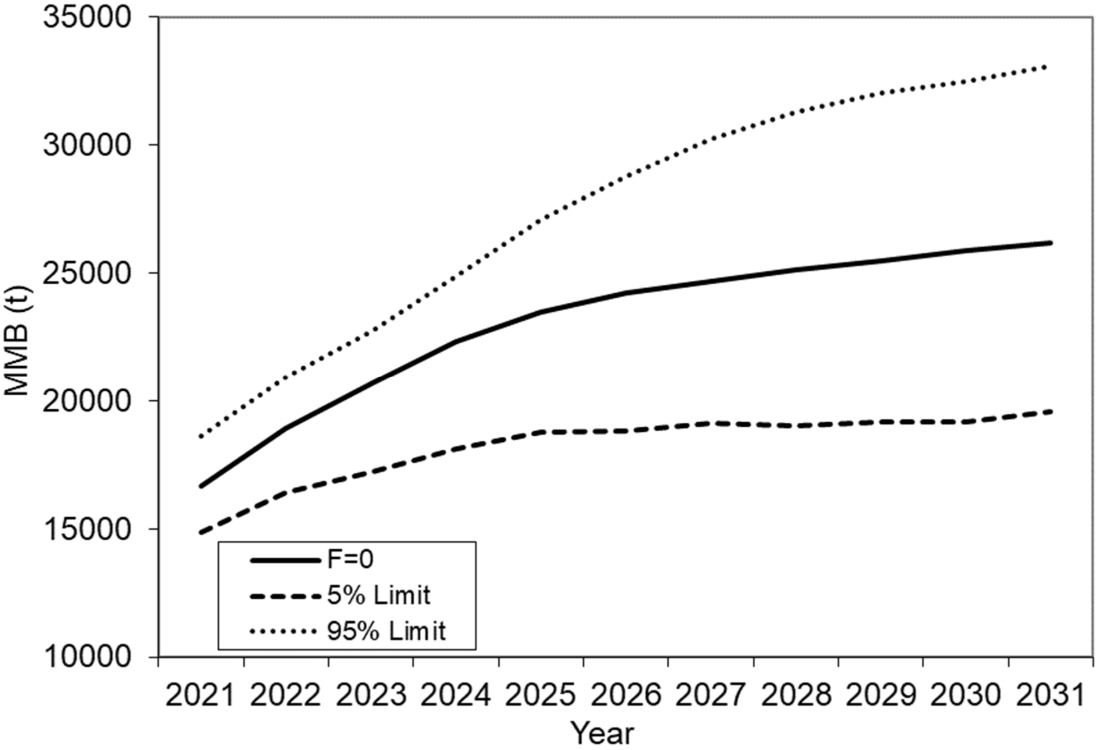


Figure 32a. Projected mature male biomass on Feb. 15 with *F* = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 19.3d.

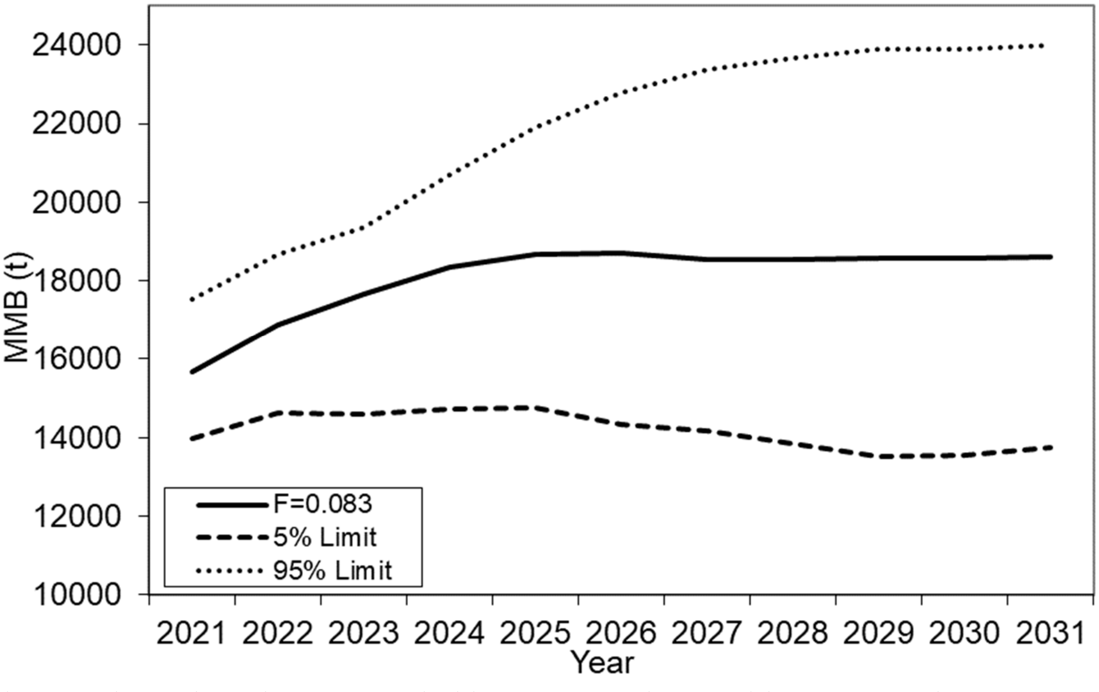


Figure 32b. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 19.3d.

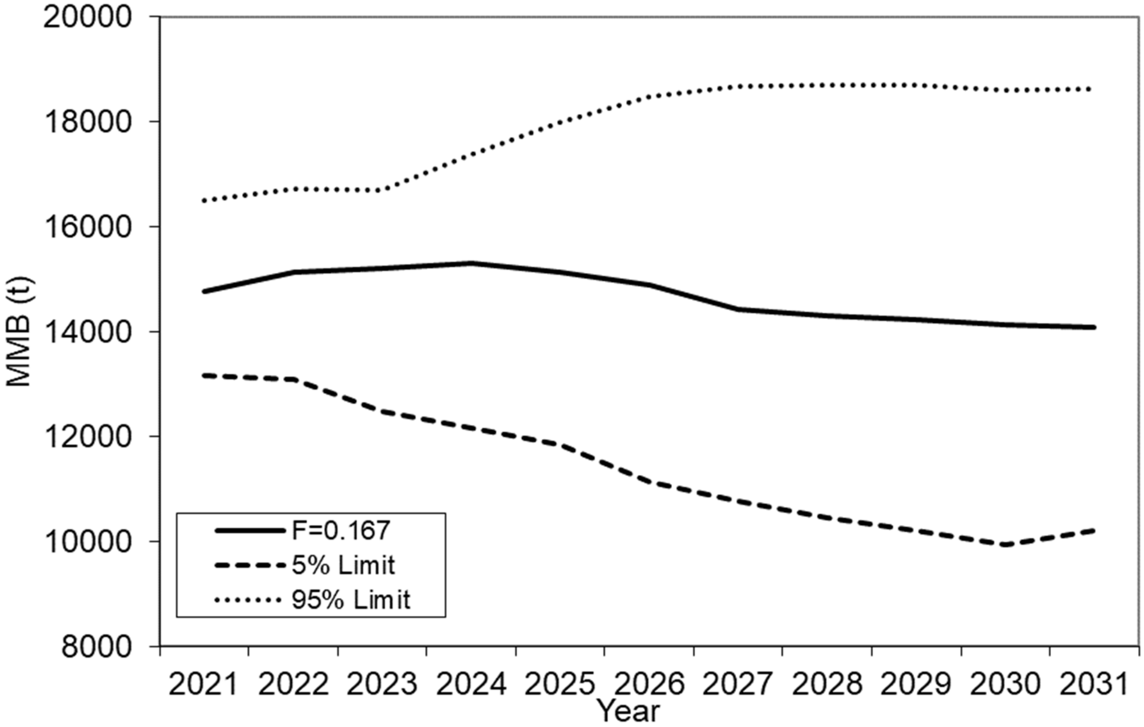


Figure 32c. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 19.3d.

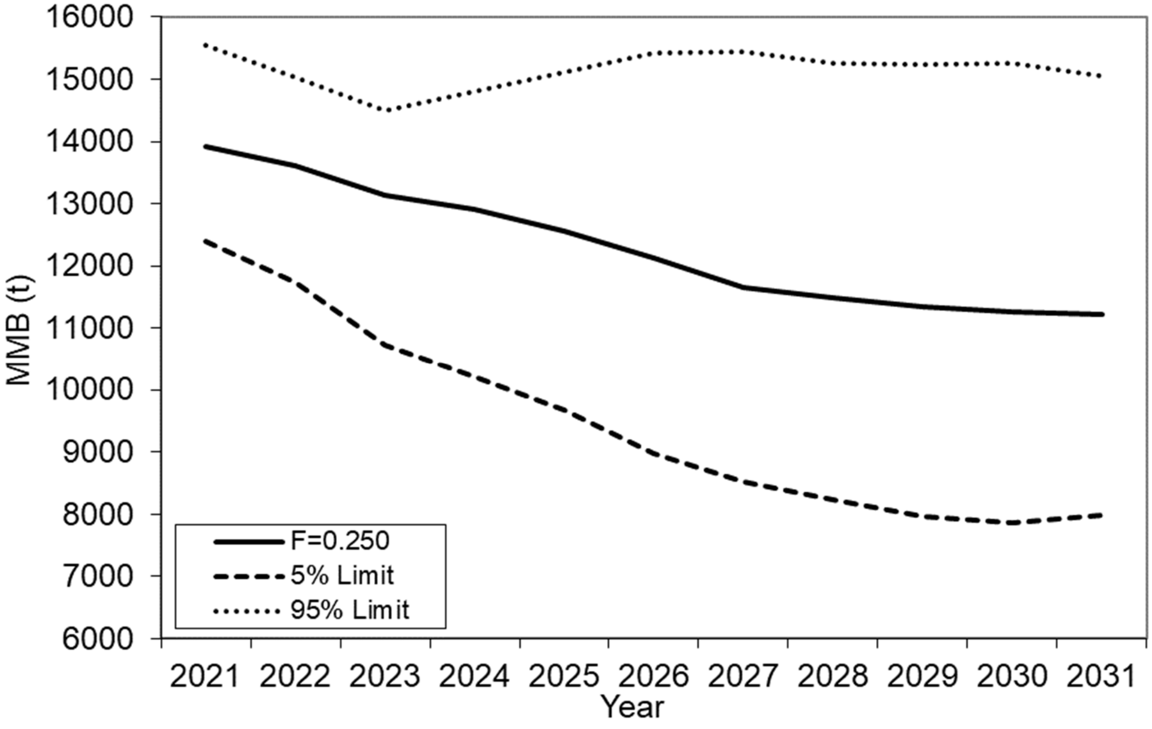


Figure 32d. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2021-2031. Input parameter estimates are based on model 19.3d.

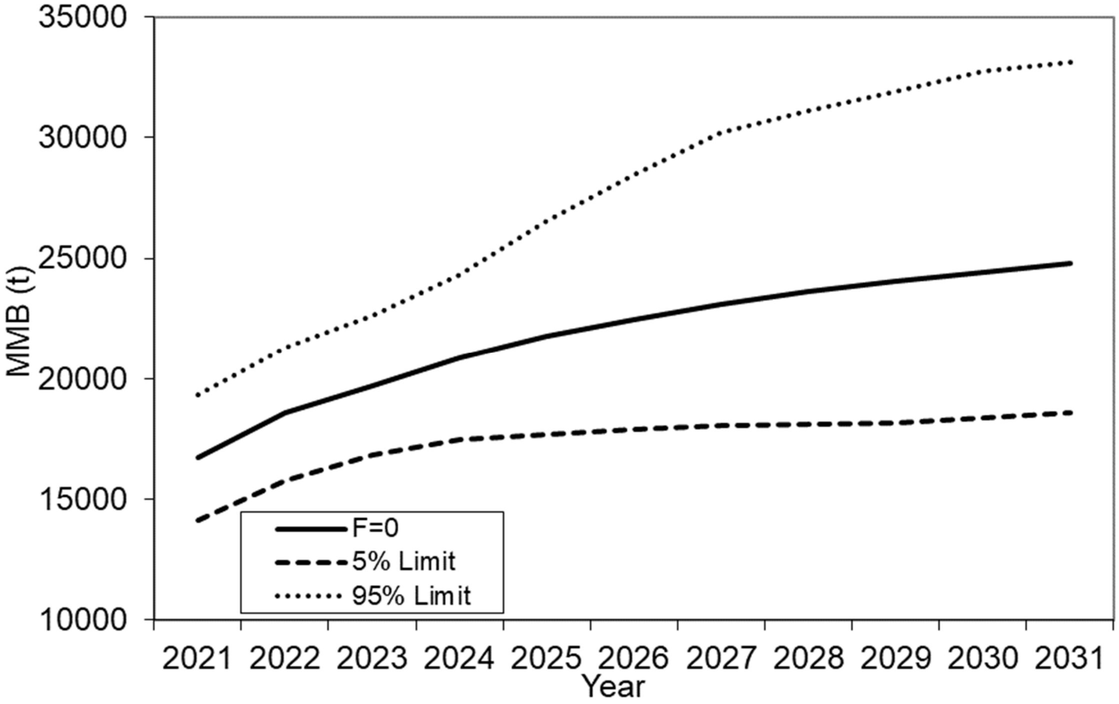


Figure 32e. Projected mature male biomass on Feb. 15 with F = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1.

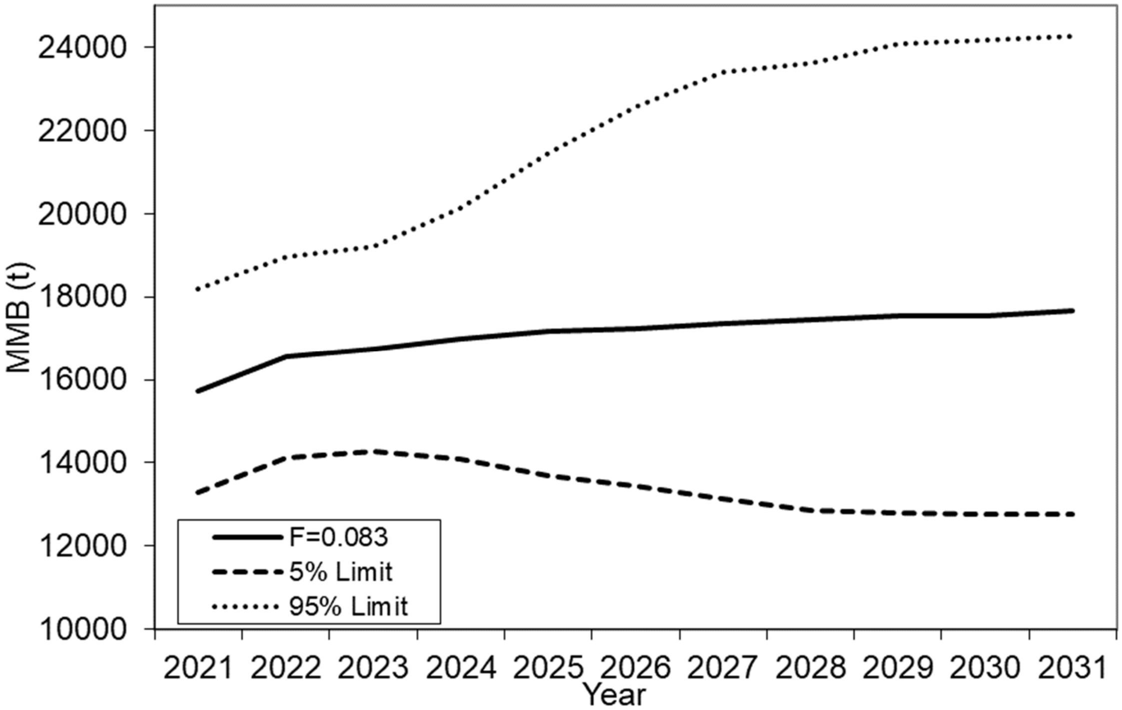


Figure 32f. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1.

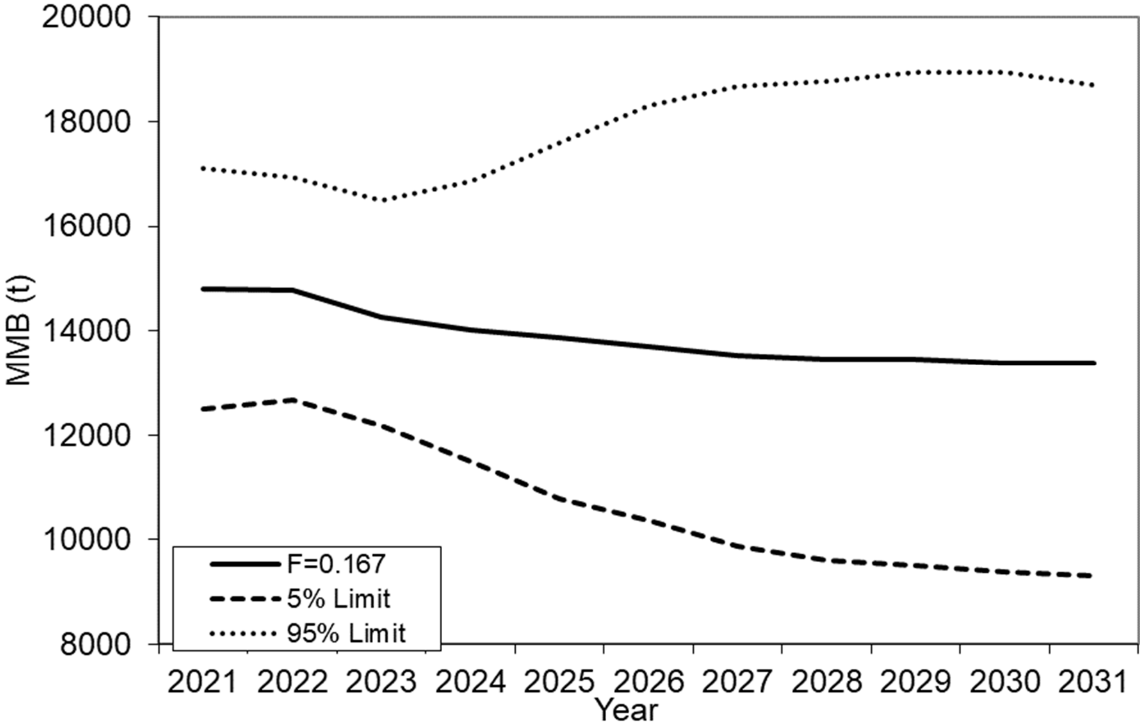


Figure 32g. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1.

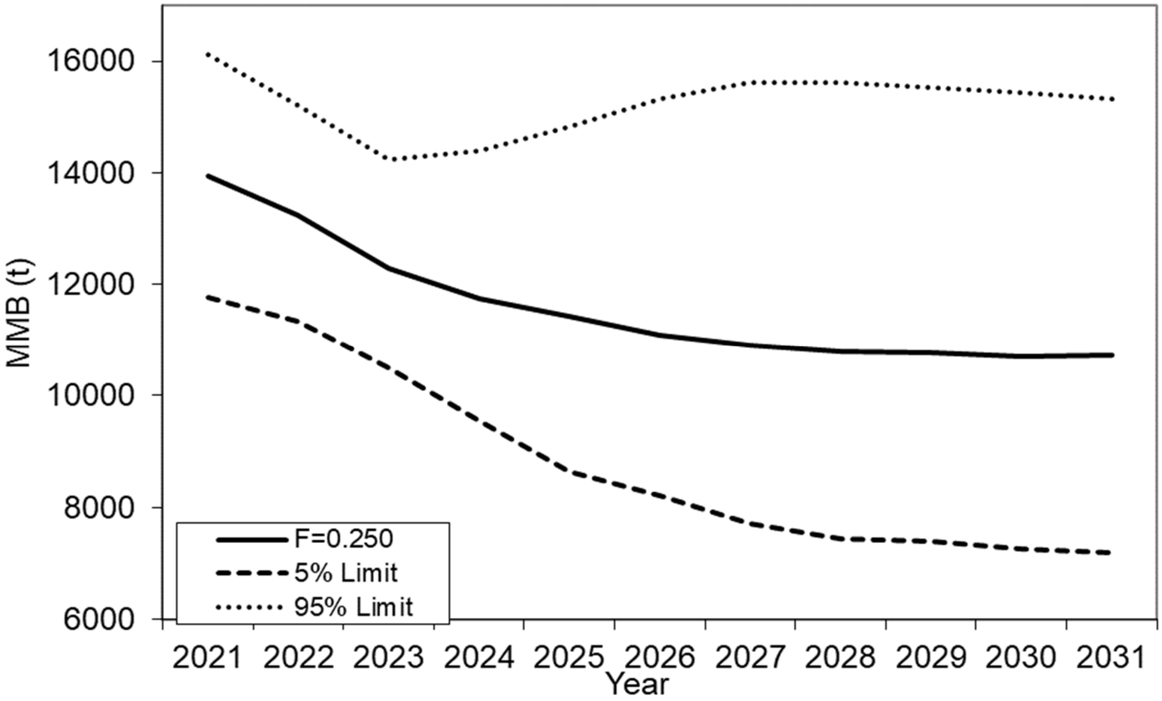


Figure 32h. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.1.

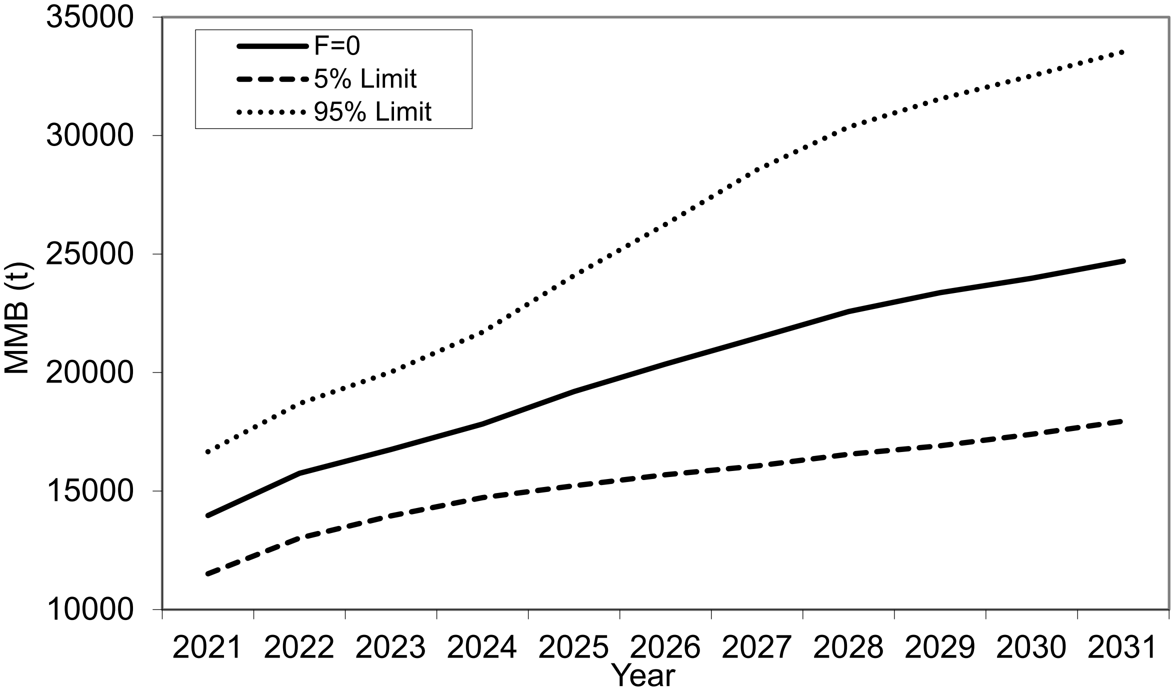


Figure 32i. Projected mature male biomass on Feb. 15 with F = 0 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.2.

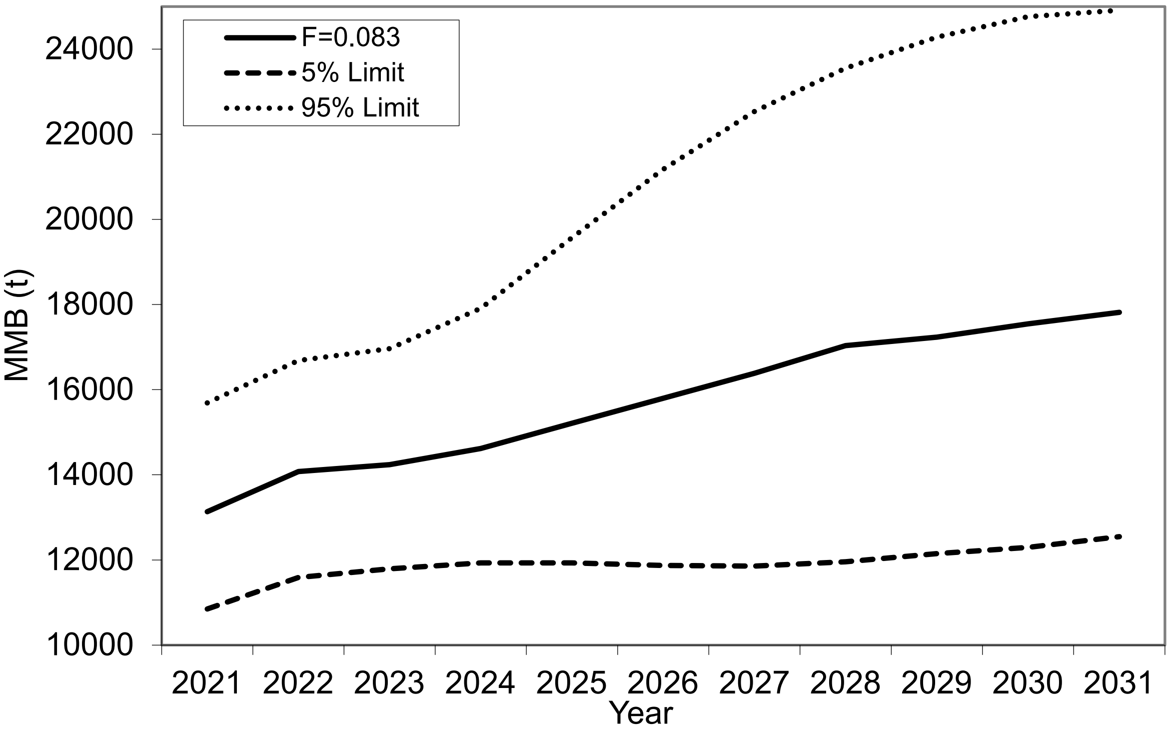


Figure 32j. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.2.

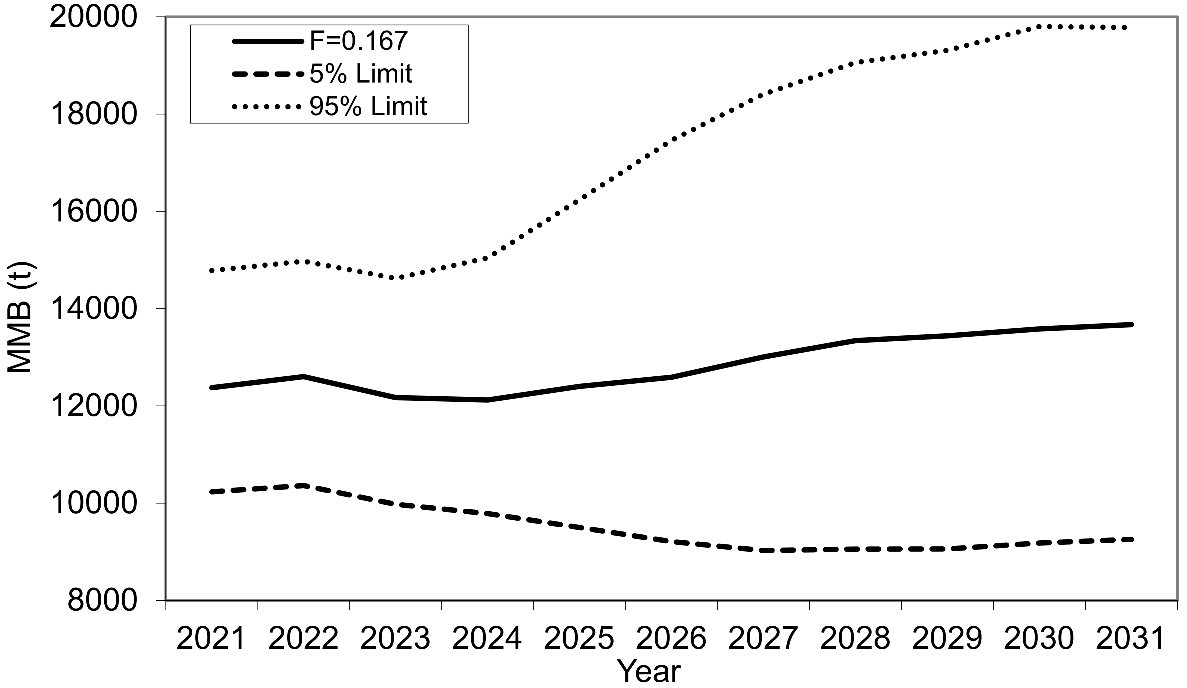


Figure 32k. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.2.

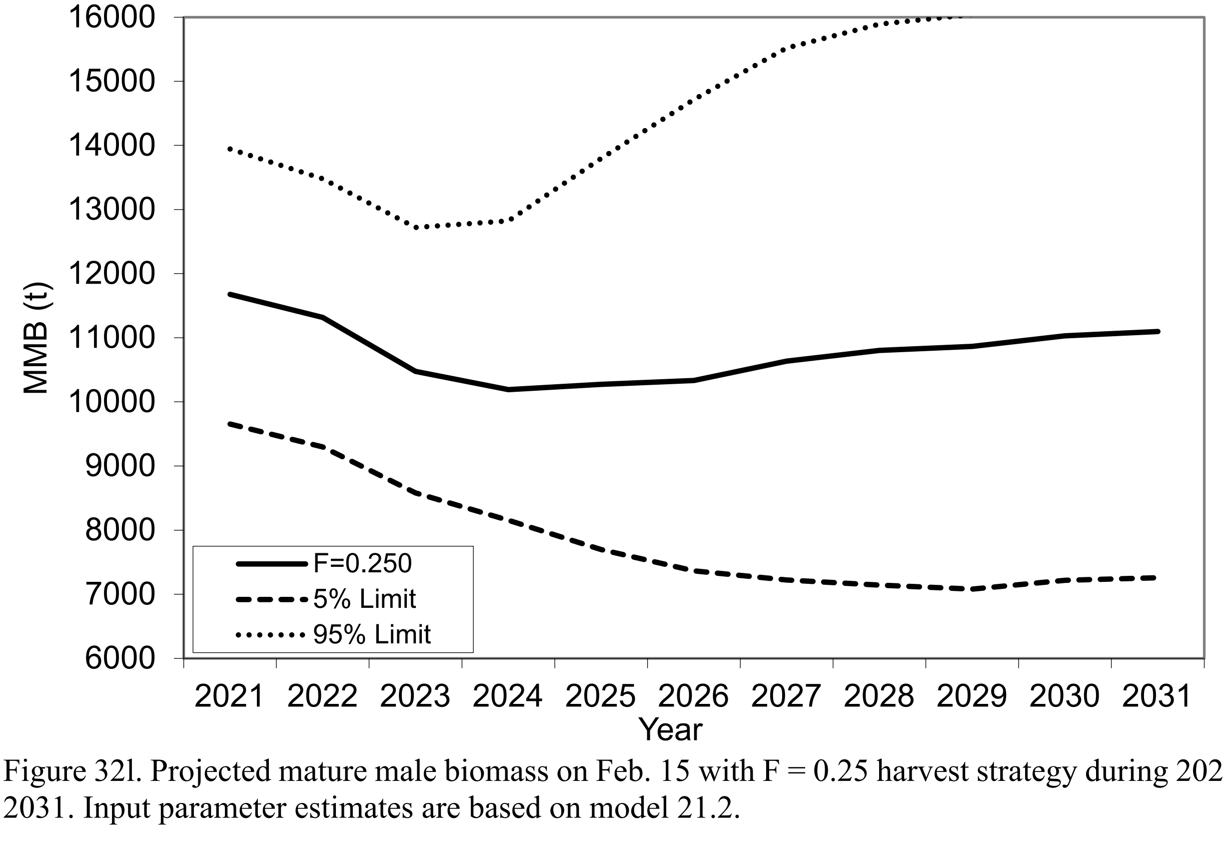
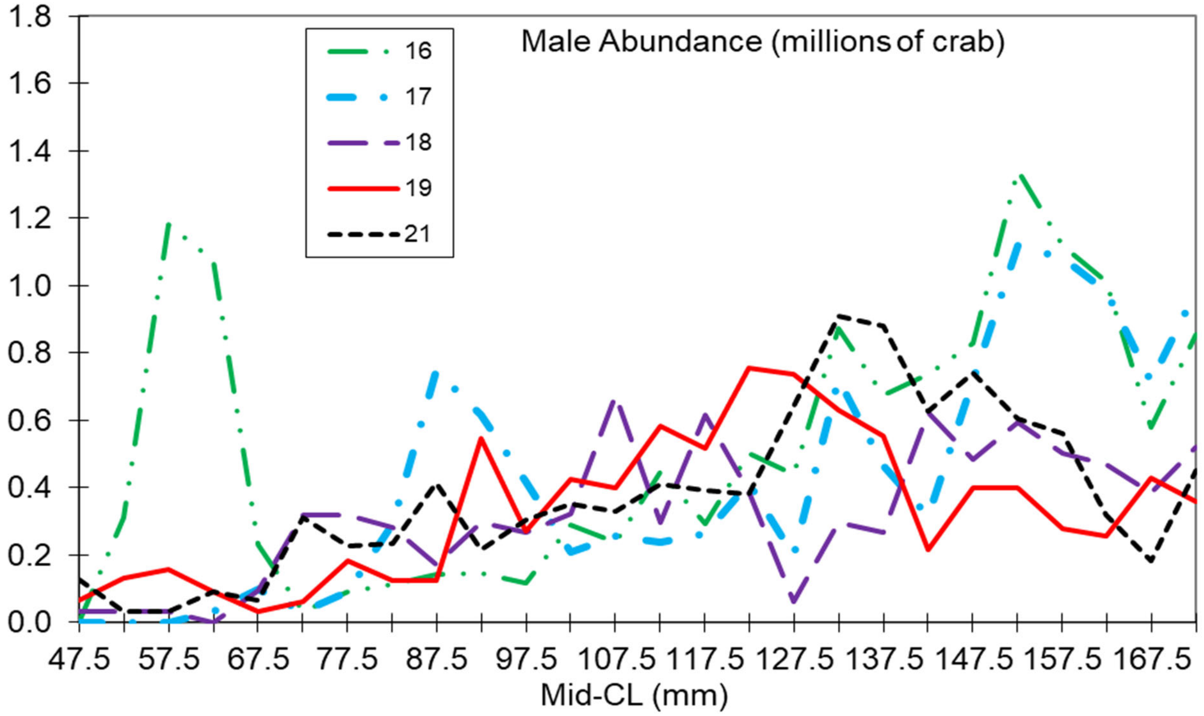


Figure 32l. Projected mature male biomass on Feb. 15 with F = 0.25 harvest strategy during 2021-2031. Input parameter estimates are based on model 21.2.



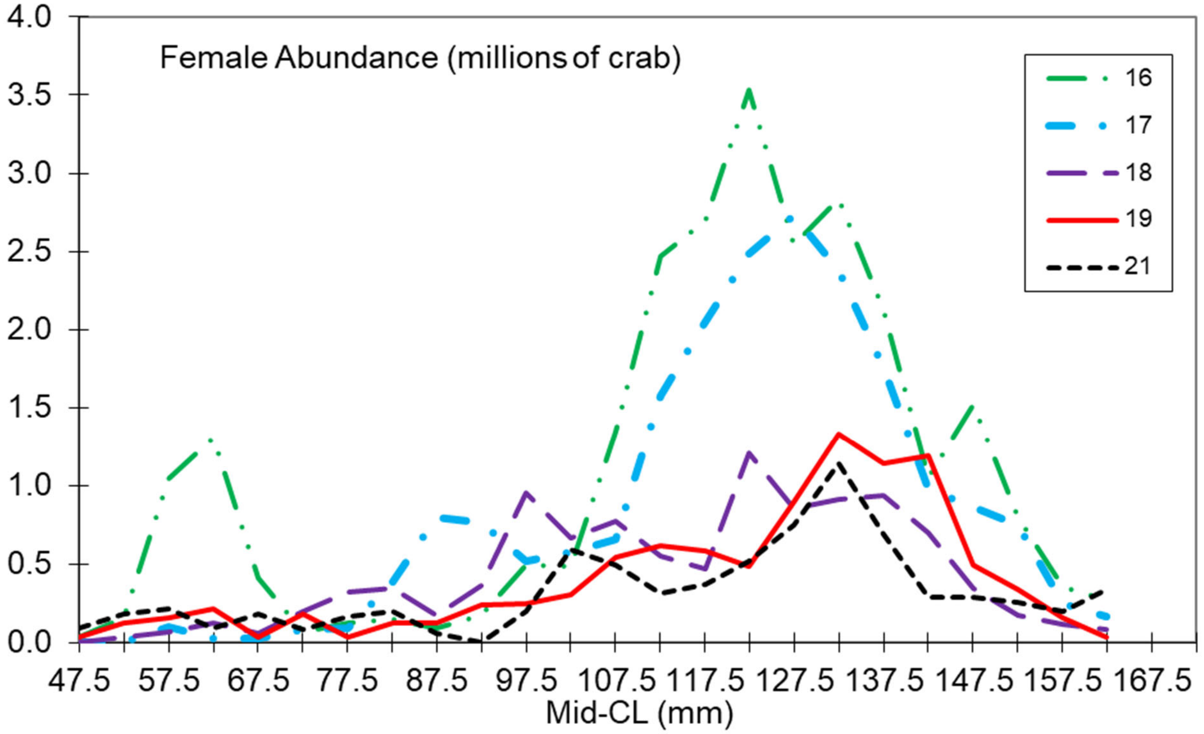


Figure 33. Length frequency distributions of male (top panel) and female (bottom panel) red king crab in Bristol Bay from NMFS trawl surveys during 2016-2021. For purposes of these graphs, abundance estimates are based on area-swept methods.

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:

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

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):

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

$\mathbf{X}^g_{y,t}$ 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.:

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

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:

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

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.:

$$M^g_y = e^{\psi^g_y} \qquad \text{(A.10)}$$

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

It is possible to 'mirror' the values for the ψ^g_y 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

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

Discards

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

Total catch

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

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:

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

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:

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

where S_{50} is the size corresponding to 50% selectivity, σ^S is the "standard deviation" of the selectivity curve, and $\overline{L}_l$ 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.:

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

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:

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

> 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:

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

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 $\alpha^{*,f} = \frac{\alpha^f \left(\frac{SSB^*_{y_2}}{B_{MSY}} - 0.1 \right)}{0.9}$ 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.:

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

      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 :

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

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

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:

$$Length\ compositions:\ -\sum \ln\left(Rf_i\right)$$

$$Catch\ and\ bycatch\ biomasses:\ \sum\left[ln\left(\frac{C_t}{\hat{C}_t}\right)^{2}/\left(2\ln\left(cv_t^{2}+1\right)\right)\right]$$

$$NMFS\ survey\ biomass:\ \sum\left[ln\left(ln\left({CV_t}^{2}+1\right)\right)^{0.5}+\frac{ln\left(\frac{B_t}{\hat{B}_t}\right)^{2}}{\left(2ln\left({CV_t}^{2}+1\right)\right)}\right]$$

$$BSFRF\ survey\ biomass:\ \sum\left[ln\left(ln\left({CV_t}^{2}+AV^{2}+1\right)\right)^{0.5}+\frac{ln\left(\frac{B_t}{\hat{B}_t}\right)^{2}}{\left(2ln\left({CV_t}^{2}+AV^{2}+1\right)\right)}\right]$$

$$R\ variation:\ \lambda_R\sum\left[ln\left(\frac{R_t}{\bar{R}}\right)^{2}\right] \qquad \text{(A.28)}$$

$$R\ sex\ ratio:\ \lambda_s\sum\left[ln\left(\frac{\bar{R}_M}{\bar{R}_F}\right)^{2}\right]$$

$$Groundfish\ bycatch\ fishing\ mortalities:\ \lambda_t\sum\left[ln\left(\frac{F_{t,gf}}{\overline{F_{gf}}}\right)^{2}\right]$$

$$Pot\ female\ bycatch\ fishing\ mortalities:\ \lambda_p\sum\left[ln\left(\frac{F_{t,f}}{\overline{F_f}}\right)^{2}\right]$$

$$Trawl\ survey\ catchability:\ \frac{\left(Q-\hat{Q}\right)^{2}}{2\sigma^{2}}$$

where R_t is the recruitment in year t, $\overline{R}$ 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:

$$\begin{aligned} &\text{Immature Females:} && W = 0.000408\, L^{3.127956} \\ &\text{Ovigerous Females:} && W = 0.003593\, L^{2.666076} \\ &\text{Males:} && W = 0.0004031\, L^{3.141334} \end{aligned} \qquad \text{(A.29)}$$

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 1994-2020, 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 1994-2020).

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° 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° 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 $t = 1976$ 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 (1975-2019), pot-discarded females from the directed fishery (1990-2019), pot-discarded males and females from the eastern Bering Sea Tanner crab fishery (1991-93, 2013-15), groundfish trawl discarded males and females (1976-2019), and groundfish fixed gear discarded males and females (1996-2019). 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.

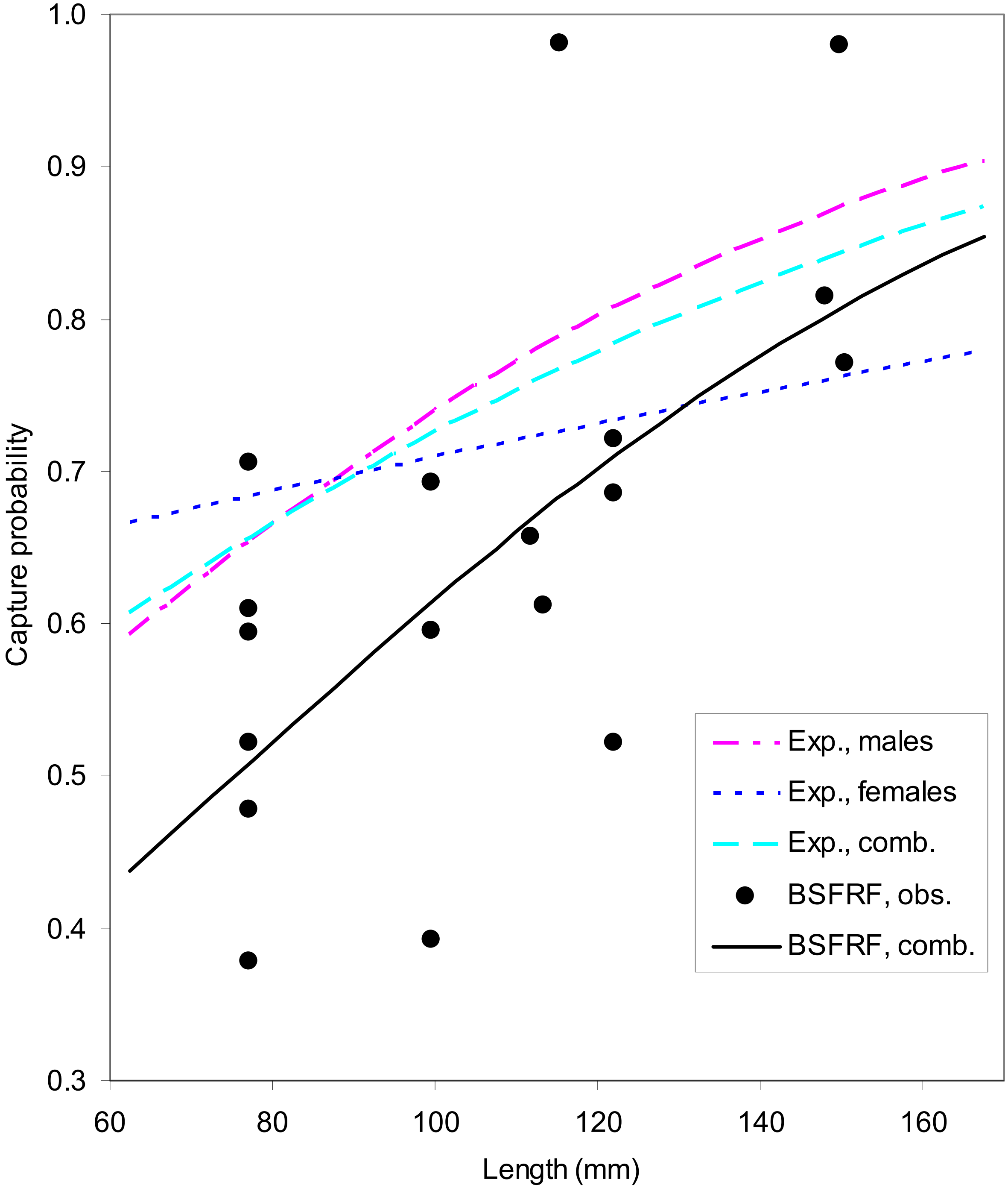
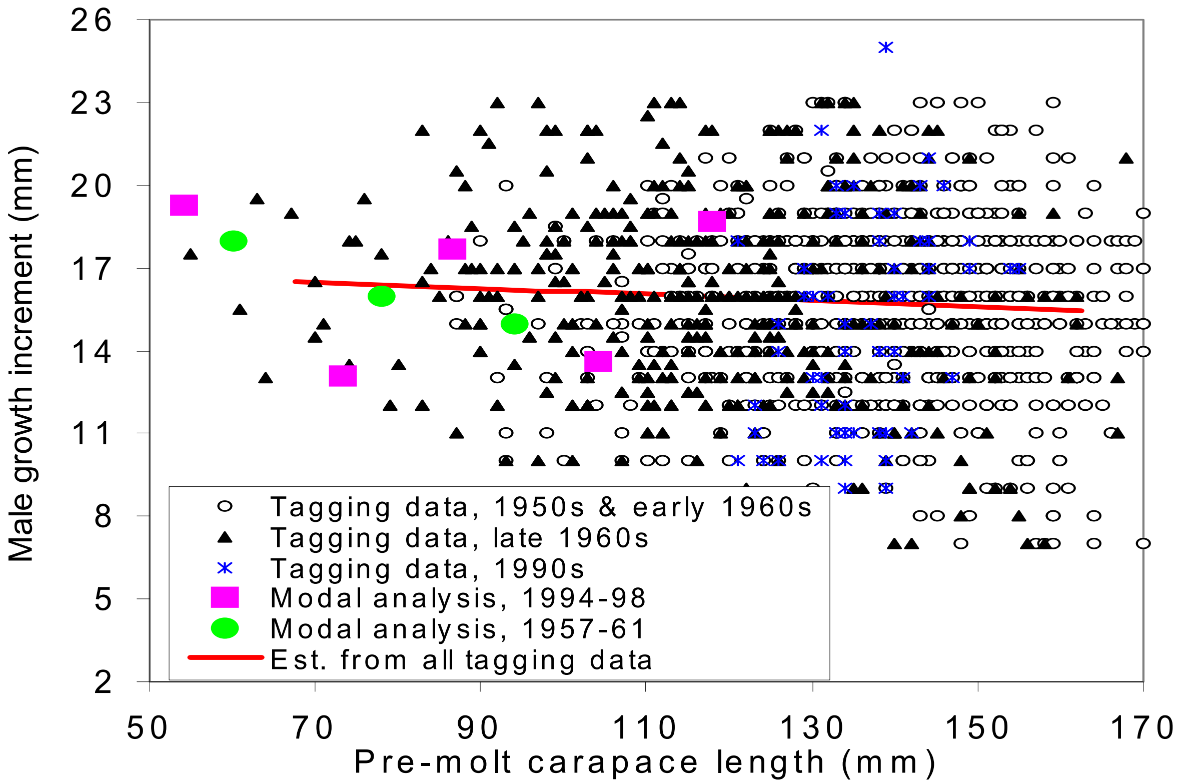


Figure A1. Estimated capture probabilities for NMFS Bristol Bay red king crab trawl surveys by Weinberg et al. (2004) and the Bering Sea Fisheries Research Foundation surveys.



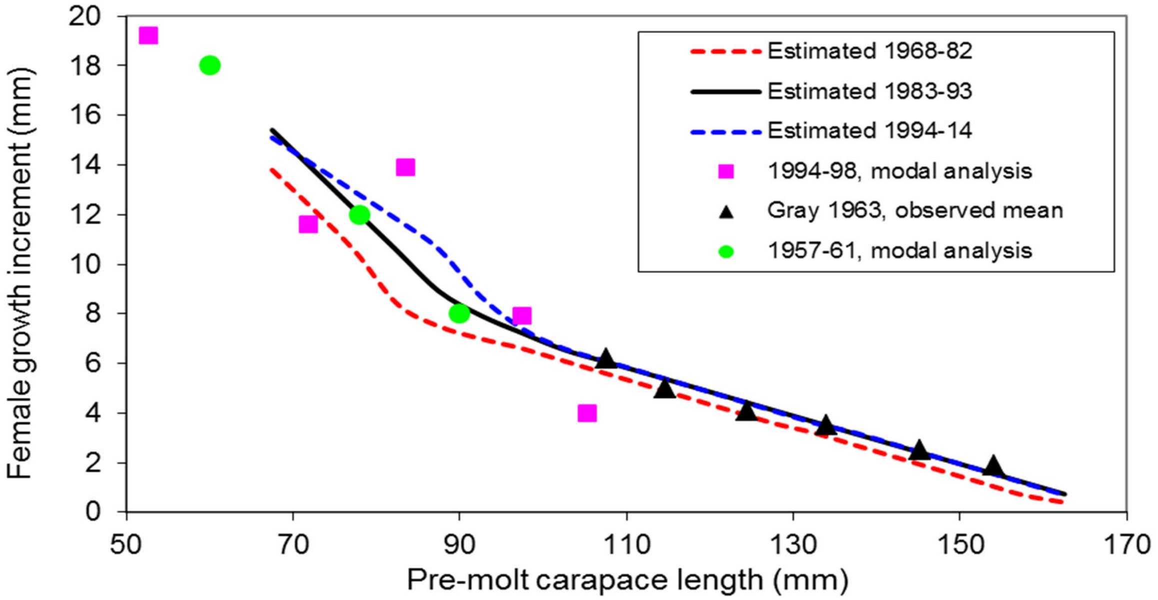


Figure A2. Mean growth increments per molt for Bristol Bay red king crab. Note: “tagging”---based on tagging data; “mode”---based on modal analysis. The female growth increments per molt are for different model scenarios.

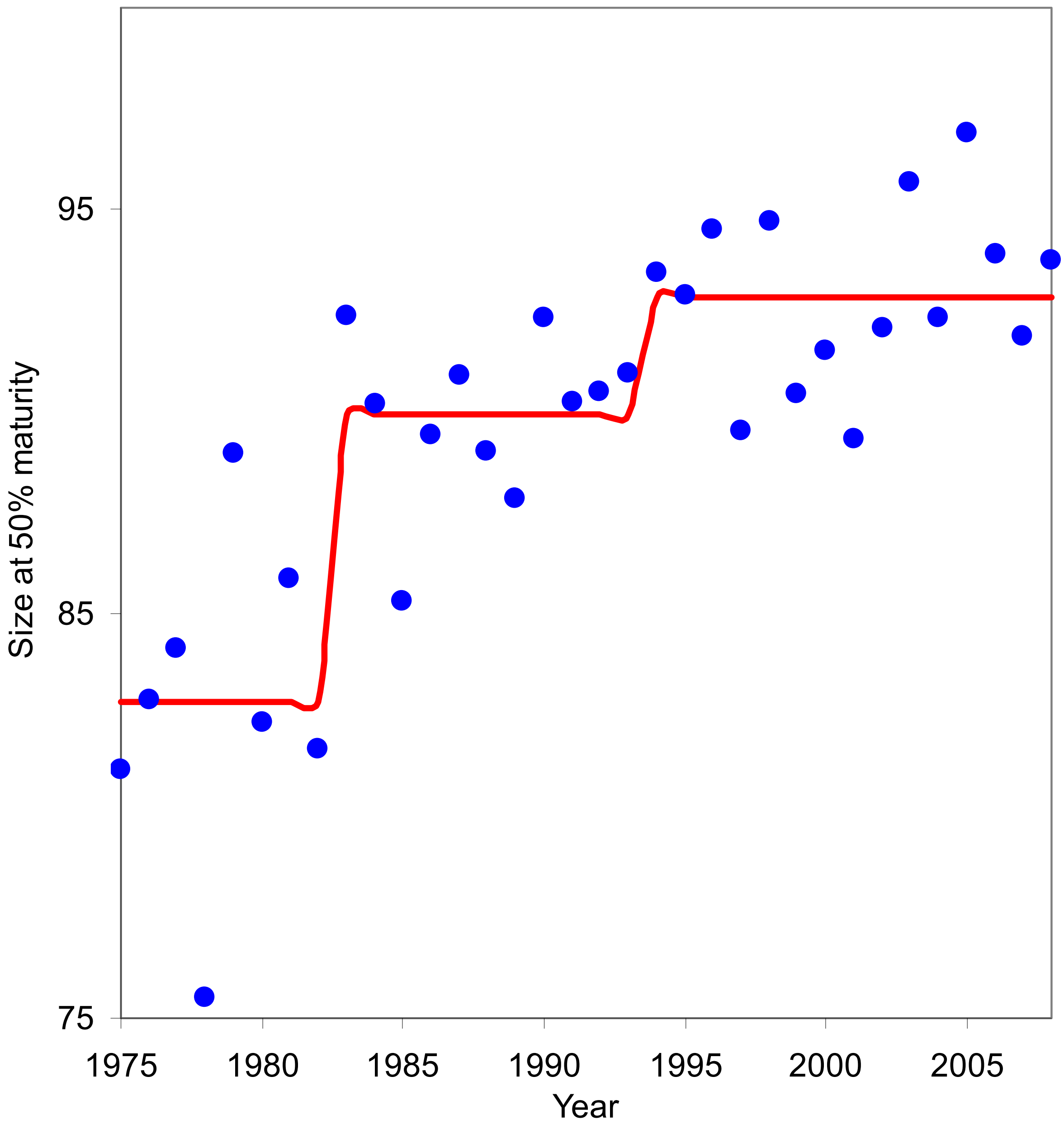


Figure A3. Estimated sizes at 50% maturity for Bristol Bay female red king crab from 1975 to 2008. Averages for three periods (1975-82, 1983-93, and 1994-08) are plotted with a line.

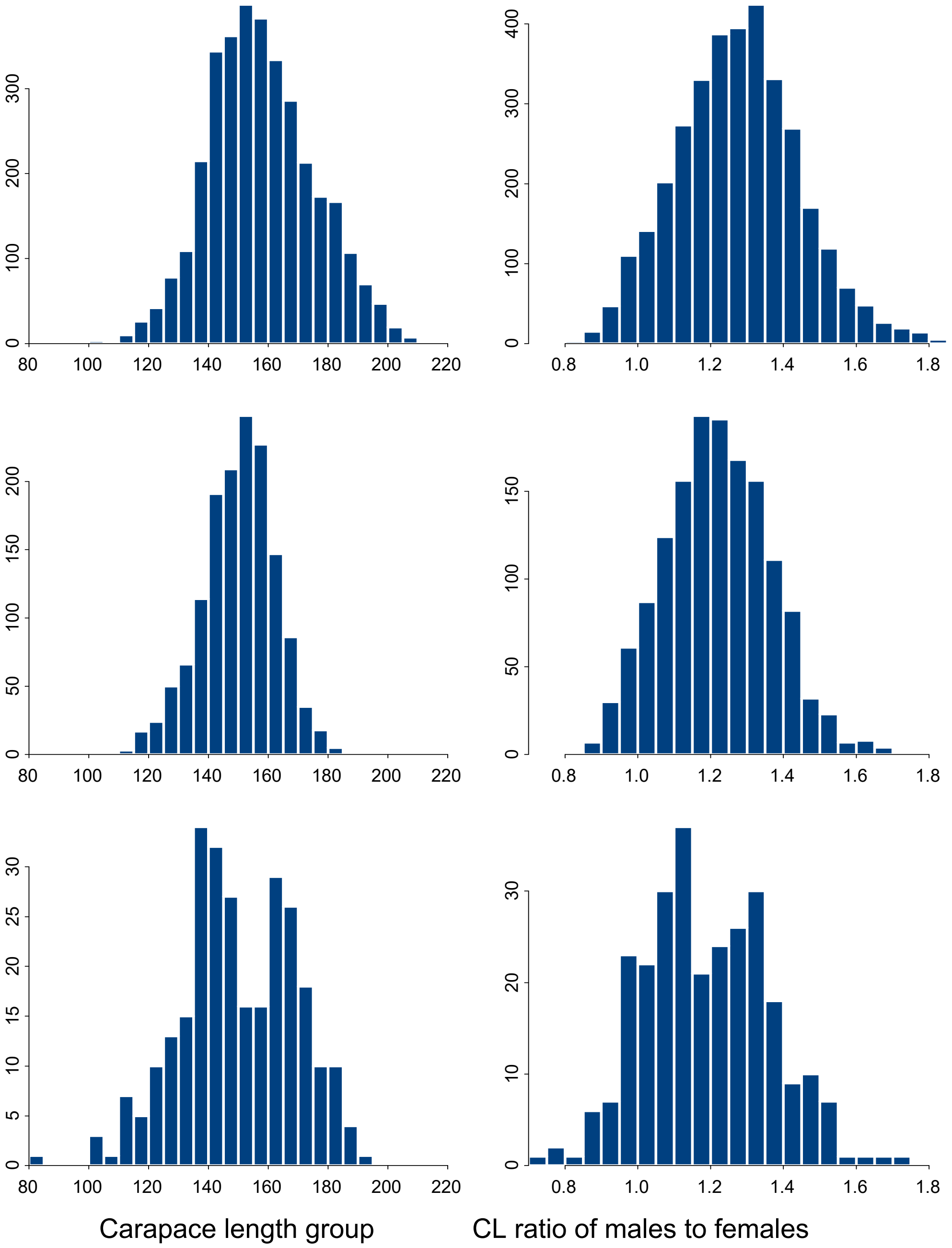
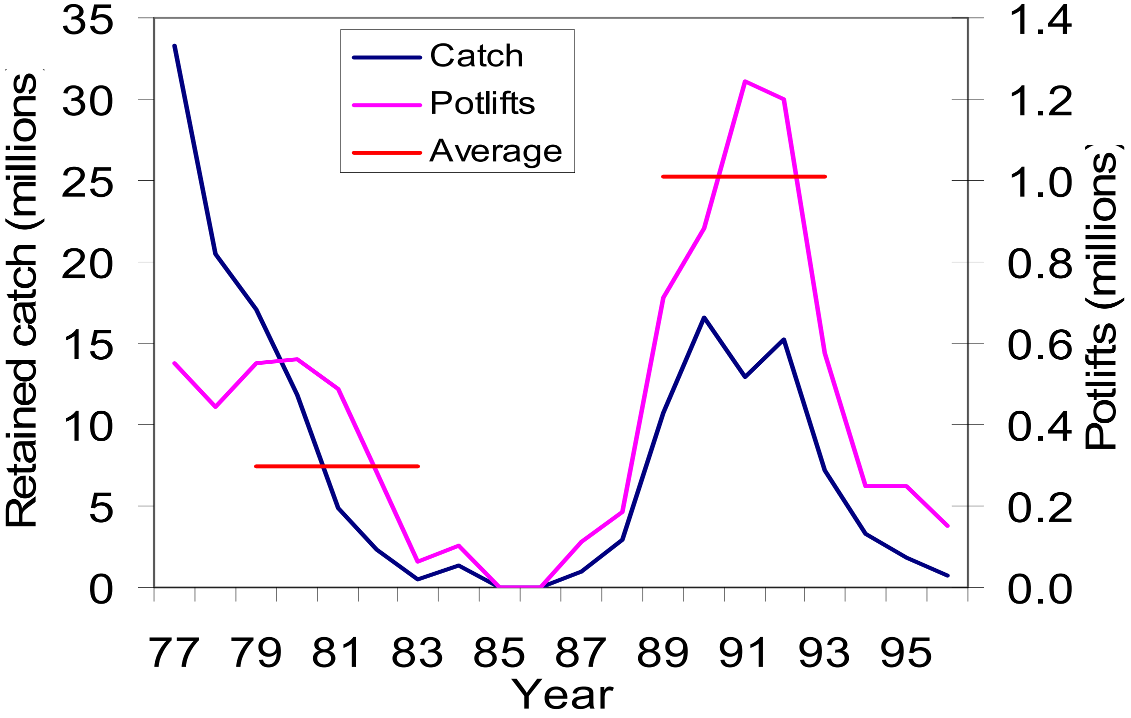


Figure A4. Histograms of carapace lengths (CL) and CL ratios of males to females for male shell ages ≤13 months of red king crab males in grasping pairs; Powell's Kodiak data. Upper plot: all locations and years pooled; middle plot: location 11; lower plot: locations 4 and 13. Sizes at maturity for Kodiak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



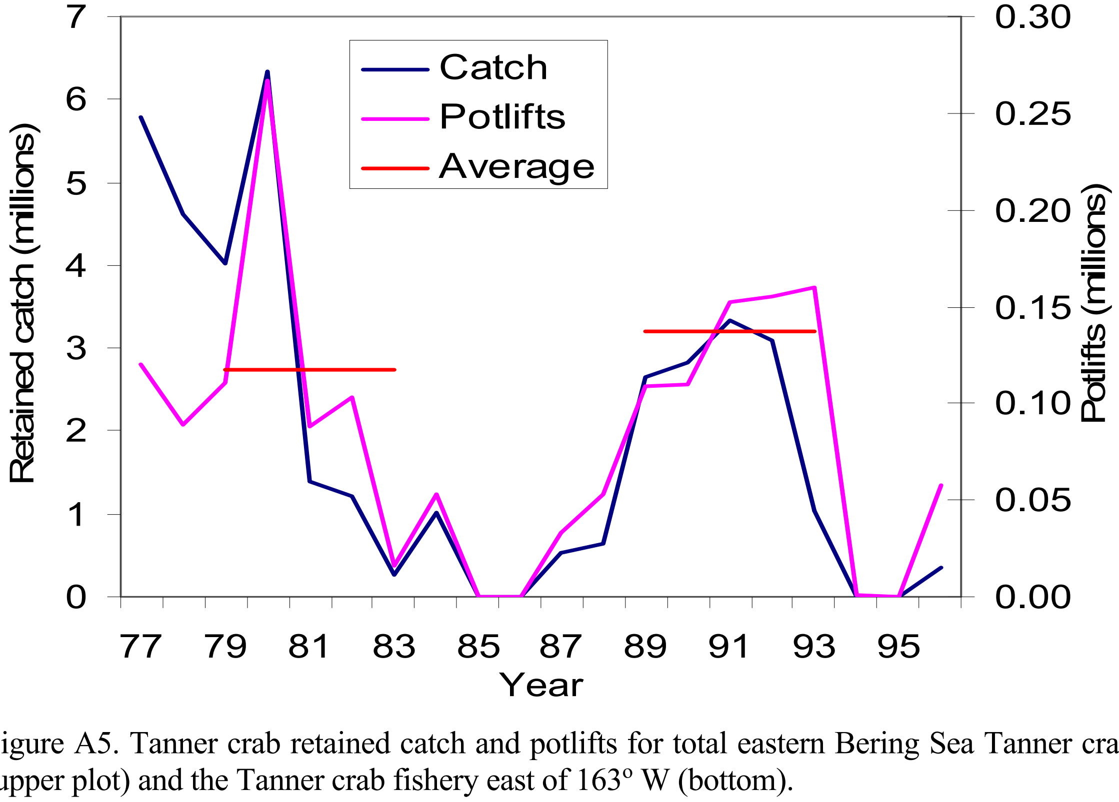


Figure A5. Tanner crab retained catch and potlifts for total eastern Bering Sea Tanner crab fishery (upper plot) and the Tanner crab fishery east of 163° W (bottom).

Appendix B. Input Data File for Models 19.3d, 21.0, 21.1, and 21.2

```
#========================================================================
#       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       :    Trawl  survey
#       Fisheries:   1      Pot    Fishery,     2      Pot    Discard,      3      Trawl
                by-catch,   4      Tanner bycatch 5 fixed gear
#       Surveys:     6      NMFS Trawl  Survey,7      BSFRF Survey
#==========================================================================

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
```

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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
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
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	118.906	0.10	2	1	1	0	0.8
2010	5	2	0	104.086	0.10	2	1	1	0	0.8
2011	5	2	0	70.419	0.10	2	1	1	0	0.8
2012	5	2	0	42.786	0.10	2	1	1	0	0.8
2013	5	2	0	83.868	0.10	2	1	1	0	0.8
2014	5	2	0	43.460	0.10	2	1	1	0	0.8
2015	5	2	0	56.686	0.10	2	1	1	0	0.8
2016	5	2	0	84.338	0.10	2	1	1	0	0.8

```
2017   5      2      0      114.782        0.10 2      1      1      0      0.8
2018   5      2      0       97.998   0.10 2      1      1      0      0.8
2019   5      2      0      100.999   0.10        2      1      1      0      0.8
2020   5      2      0      103.098   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
#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
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   11.616  0.10    2   1   1   0   0.5
2010    5   4   0   4.736   0.10    2   1   1   0   0.5
2011    5   4   0   21.706  0.10    2   1   1   0   0.5
2012    5   4   0   36.895  0.10    2   1   1   0   0.5
2013    5   4   0   110.970         0.10    2   1   1   0       0.5
2014    5   4   0   237.651         0.10    2   1   1   0       0.5
2015    5   4   0   154.810         0.10    2   1   1   0       0.5
2016    5   4   0   57.888  0.10    2   1   1   0   0.5
2017    5   4   0   255.155         0.10    2   1   1   0       0.5
2018    5   4   0   296.188         0.10    2   1   1   0       0.5
2019    5   4   0    90.5670.10     2   1   1   0   0.5
2020    5   4   0    17.5170.10     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
## 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
1 1976 1 5 1 0 256362.2 0.207 1
1 1977 1 5 1 0 232538.7 0.144 1
1 1978 1 5 1 0 199542.2 0.152 1
1 1979 1 5 1 0 102448.2 0.164 1
1 1980 1 5 1 0 166524.3 0.221 1
1 1981 1 5 1 0 68294.4 0.190 1
1 1982 1 5 1 0 72296.3 0.251 1
1 1983 1 5 1 0 34761.9 0.214 1
1 1984 1 5 1 0 96418.3 0.606 1
1 1985 1 5 1 0 26819.4 0.159 1
1 1986 1 5 1 0 40549.3 0.420 1
1 1987 1 5 1 0 46769.1 0.209 1
1 1988 1 5 1 0 35373.6 0.228 1
1 1989 1 5 1 0 42357.7 0.232 1
1 1990 1 5 1 0 38727.8 0.242 1
1 1991 1 5 1 0 66528.0 0.443 1
1 1992 1 5 1 0 25096.2 0.176 1
1 1993 1 5 1 0 35670.6 0.198 1
1 1994 1 5 1 0 23002.5 0.174 1
1 1995 1 5 1 0 27251.9 0.266 1
1 1996 1 5 1 0 26815.7 0.203 1
1 1997 1 5 1 0 59638.3 0.264 1
1 1998 1 5 1 0 46208.6 0.182 1
1 1999 1 5 1 0 44528.7 0.204 1
1 2000 1 5 1 0 38390.7 0.216 1
1 2001 1 5 1 0 27942.7 0.187 1
1 2002 1 5 1 0 45139.9 0.202 1
1 2003 1 5 1 0 74641.0 0.283 1
1 2004 1 5 1 0 90354.3 0.321 1
1 2005 1 5 1 0 54789.5 0.171 1
```

1	2006	1	5	1	0	51215.2	0.169	1
1	2007	1	5	1	0	58144.3	0.174	1
1	2008	1	5	1	0	67214.4	0.249	1
1	2009	1	5	1	0	43170.4	0.326	1
1	2010	1	5	1	0	39020.6	0.223	1
1	2011	1	5	1	0	27385.1	0.213	1
1	2012	1	5	1	0	30655.4	0.237	1
1	2013	1	5	1	0	39650.2	0.244	1
1	2014	1	5	1	0	60649.4	0.191	1
1	2015	1	5	1	0	37085.3	0.208	1
1	2016	1	5	1	0	27184.9	0.194	1
1	2017	1	5	1	0	25335.3	0.173	1
1	2018	1	5	1	0	16034.2	0.161	1
1	2019	1	5	1	0	15169.9	0.157	1
1	2021	1	5	1	0	18235.4	0.177	1
1	1975	1	5	2	0	66558.7	0.193	1
1	1976	1	5	2	0	71252.4	0.207	1
1	1977	1	5	2	0	138684.3	0.144	1
1	1978	1	5	2	0	143646.6	0.152	1
1	1979	1	5	2	0	63000.5	0.164	1
1	1980	1	5	2	0	80701.3	0.221	1
1	1981	1	5	2	0	62850.4	0.190	1
1	1982	1	5	2	0	69601.4	0.251	1
1	1983	1	5	2	0	13713.6	0.214	1
1	1984	1	5	2	0	56188.5	0.606	1
1	1985	1	5	2	0	7318.7	0.159	1
1	1986	1	5	2	0	6884.6	0.420	1
1	1987	1	5	2	0	22475.5	0.209	1
1	1988	1	5	2	0	19223.7	0.228	1
1	1989	1	5	2	0	12778.0	0.232	1
1	1990	1	5	2	0	20722.8	0.242	1
1	1991	1	5	2	0	17363.5	0.443	1
1	1992	1	5	2	0	12238.2	0.176	1
1	1993	1	5	2	0	17235.1	0.198	1
1	1994	1	5	2	0	9101.7	0.174	1
1	1995	1	5	2	0	10816.3	0.266	1
1	1996	1	5	2	0	17143.2	0.203	1
1	1997	1	5	2	0	24392.1	0.264	1
1	1998	1	5	2	0	37892.7	0.182	1
1	1999	1	5	2	0	20225.3	0.204	1
1	2000	1	5	2	0	28990.5	0.216	1
1	2001	1	5	2	0	24512.6	0.187	1
1	2002	1	5	2	0	23946.5	0.202	1

```
1       2003    1       5       2       0       41118.5         0.283   1
1       2004    1       5       2       0       40201.7         0.321   1
1       2005    1       5       2       0       50937.4         0.171   1
1       2006    1       5       2       0       43262.1         0.169   1
1       2007    1       5       2       0       45183.0         0.174   1
1       2008    1       5       2       0       45867.2         0.249   1
1       2009    1       5       2       0       47376.6         0.326   1
1       2010    1       5       2       0       41480.2         0.223   1
1       2011    1       5       2       0       39023.0         0.213   1
1       2012    1       5       2       0       30042.0         0.237   1
1       2013    1       5       2       0       22566.7         0.244   1
1       2014    1       5       2       0       52485.7         0.191   1
1       2015    1       5       2       0       27089.5         0.208   1
1       2016    1       5       2       0       33773.1         0.194   1
1       2017    1       5       2       0       27599.3         0.173   1
1       2018    1       5       2       0       12770.5         0.161   1
1       2019    1       5       2       0       13368.6         0.157   1
1       2021    1       5       2       0       10240.7         0.177   1
        #       BSFRF
2       2007    1       6       1       0       79542   0.116   1
2       2008    1       6       1       0       67569   0.094   1
2       2013    1       6       1       0       68384   0.209   1
2       2014    1       6       1       0       62327   0.192   1
2       2015    1       6       1       0       63709   0.161   1
2       2016    1       6       1       0       34417   0.22    1
2       2007    1       6       2       0       50811   0.116   1
2       2008    1       6       2       0       38472   0.094   1
2       2013    1       6       2       0       26633   0.209   1
2       2014    1       6       2       0       49414   0.192   1
2       2015    1       6       2       0       35244   0.161   1
2       2016    1       6       2       0       43399   0.22    1

## Number of length frequency matrices
## 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
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        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
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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
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        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   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
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       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
       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
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            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
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      31.55  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 0.0026 0.0019 0.0006 0.0019
            0.0019 0.0045 0.0047 0.0097 0.0142 0.0237 0.0379 0.0439 0.0534 0.0710 0.0809
            0.0798 0.0783 0.0678 0.0897
1990   5    2      1      0.0    0      0      50     0.0051 0.0041 0.0071 0.0020 0.0081
            0.0071 0.0234 0.0142 0.0244 0.0264 0.0224 0.0305 0.0325 0.0508 0.0843 0.0843
            0.0772 0.0681 0.0376 0.0742
1991   5    2      1      0.0    0      0      16.3   0.0036 0.0072 0.0036 0.0072 0.0181
            0.0144 0.0144 0.0181 0.0361 0.0253 0.0361 0.0325 0.0397 0.0217 0.0289 0.0722
            0.0505 0.0578 0.0650 0.1588
1992   5    2      1      0.0    0      0      22     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      28.6   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
```

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1995  5   2      1      0.0    0      0      8      0.0067 0.0267 0.0133 0.0067 0.0067
          0.0067 0.0000 0.0133 0.0067 0.0200 0.0000 0.0133 0.0200 0.0133 0.0400 0.0667
          0.1267 0.0867 0.0467 0.2467
1996  5   2      1      0.0    0      0      50     0.0000 0.0008 0.0000 0.0016 0.0049
          0.0114 0.0147 0.0188 0.0294 0.0343 0.0474 0.0662 0.0466 0.0686 0.0392 0.0645
          0.0425 0.0564 0.0417 0.1266
1997  5   2      1      0.0    0      0      17.45  0.0000 0.0000 0.0000 0.0000 0.0029
          0.0029 0.0029 0.0088 0.0088 0.0206 0.0206 0.0265 0.0235 0.0176 0.0500 0.0647
          0.0324 0.0382 0.0382 0.1559
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 0.0314 0.0566 0.0475 0.0580 0.0419
          0.0419 0.0475 0.0405 0.1097
1999  5   2      1      0.0    0      0      32.15  0.0016 0.0016 0.0000 0.0016 0.0031
          0.0000 0.0063 0.0031 0.0079 0.0126 0.0142 0.0409 0.0504 0.0756 0.1071 0.1008
          0.0913 0.0709 0.0661 0.0945
2000  5   2      1      0.0    0      0      36.7   0.0000 0.0000 0.0014 0.0014 0.0014
          0.0068 0.0095 0.0286 0.0368 0.0327 0.0354 0.0313 0.0422 0.0463 0.0354 0.0422
          0.0436 0.0463 0.0518 0.2262
2001  5   2      1      0.0    0      0      40.1   0.0000 0.0000 0.0050 0.0025 0.0100
          0.0339 0.0226 0.0263 0.0402 0.0376 0.0427 0.0351 0.0351 0.0251 0.0351 0.0226
          0.0477 0.0351 0.0527 0.1041
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 0.0280 0.0368 0.0464 0.0455
          0.0517 0.0569 0.0412 0.1322
2003  5   2      1      0.0    0      0      26.25  0.0019 0.0039 0.0058 0.0077 0.0193
          0.0097 0.0154 0.0232 0.0251 0.0174 0.0135 0.0193 0.0309 0.0347 0.0425 0.0521
          0.0463 0.0483 0.0521 0.1216
2004  5   2      1      0.0    0      0      33.3   0.0015 0.0000 0.0000 0.0015 0.0015
          0.0045 0.0060 0.0166 0.0211 0.0166 0.0302 0.0392 0.0407 0.0377 0.0347 0.0407
          0.0422 0.0392 0.0347 0.1448
2005  5   2      1      0.0    0      0      50     0.0029 0.0038 0.0019 0.0086 0.0077
          0.0134 0.0211 0.0154 0.0125 0.0230 0.0259 0.0393 0.0509 0.0480 0.0422 0.0413
          0.0461 0.0480 0.0403 0.0883
2006  5   2      1      0.0    0      0      50     0.0000 0.0000 0.0000 0.0000 0.0017
          0.0025 0.0025 0.0127 0.0110 0.0391 0.0365 0.0425 0.0484 0.0467 0.0688 0.0697
          0.0688 0.0671 0.0586 0.1393
2007  5   2      1      0.0    0      0      50     0.0000 0.0000 0.0000 0.0016 0.0024
          0.0032 0.0048 0.0112 0.0128 0.0136 0.0233 0.0217 0.0289 0.0393 0.0457 0.0401
          0.0393 0.0425 0.0586 0.1252
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 0.0131 0.0255 0.0255 0.0597 0.0622 0.0566 0.0715 0.0466
          0.0646 0.0547 0.0541 0.1753
2009  5   2      1      0.0    0      0      50     0.0000 0.0000 0.0000 0.0000 0.0008
```

```
          0.0025 0.0025 0.0033 0.0066 0.0108 0.0116 0.0298 0.0298 0.0431 0.0547 0.0514
          0.0671 0.0497 0.0530 0.1740
2010  5   2   1   0.0   0   0   45.95  0.0000 0.0000 0.0022 0.0022 0.0022
          0.0054 0.0033 0.0120 0.0185 0.0174 0.0196 0.0348 0.0490 0.0501 0.0566 0.0479
          0.0359 0.0337 0.0370 0.0860
2011  5   2   1   0.0   0   0   22.3   0.0000 0.0000 0.0022 0.0067 0.0067
          0.0022 0.0022 0.0067 0.0135 0.0090 0.0067 0.0067 0.0224 0.0269 0.0493 0.0650
          0.0605 0.0628 0.0448 0.1188
2012  5   2   1   0.0   0   0   14.15  0.0000 0.0035 0.0000 0.0000 0.0000
          0.0035 0.0071 0.0071 0.0035 0.0071 0.0141 0.0106 0.0283 0.0353 0.0601 0.0318
          0.0495 0.0530 0.0530 0.1696
2013  5   2   1   0.0   0   0   24.2   0.0000 0.0021 0.0000 0.0021 0.0021
          0.0000 0.0000 0.0021 0.0041 0.0083 0.0103 0.0227 0.0455 0.0393 0.0517 0.0517
          0.0434 0.0517 0.0393 0.2624
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   30.7  0.0000  0.0016  0.0033  0.0049  0.0033
      0.0016  0.0130  0.0098  0.0163  0.0065  0.0114  0.0358  0.0244  0.0472  0.0521  0.0586
      0.0635  0.0798  0.0782  0.2117
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   41.1  0.0012  0.0024  0.0049  0.0073  0.0122
      0.0134  0.0049  0.0109  0.0097  0.0268  0.0304  0.0316  0.0401  0.0535  0.0584  0.0450
      0.0511  0.0426  0.0401  0.2153
2020  5   2   1   0.0   0   0 31.1 0.0016 0.0000 0.0048 0.0096 0.0113 0.0145
      0.0113  0.0080  0.0257  0.0241  0.0273  0.0257  0.0322  0.0547  0.0450  0.0707  0.0579
      0.0675  0.0579  0.1672

#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	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	0.0028	0.0024	0.0015	0.0022	0.0065
		0.0108	0.0204	0.0430	0.0504	0.0480	0.0435	0.0295	0.0256	0.0170	0.0065	0.0168
1990	5	2	2	0	0	0	0	0.0020	0.0041	0.0071	0.0081	0.0112
		0.0112	0.0183	0.0203	0.0366	0.0305	0.0335	0.0325	0.0234	0.0173	0.0152	0.0447
1991	5	2	2	0	0	0	0	0.0000	0.0036	0.0108	0.0036	0.0000
		0.0072	0.0036	0.0072	0.0289	0.0181	0.0181	0.0289	0.0181	0.0325	0.0036	0.1047
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	0.0467	0.0000	0.0000	0.0200	0.0067
		0.0200	0.0333	0.0133	0.0200	0.0000	0.0200	0.0000	0.0067	0.0133	0.0000	0.0333
1996	5	2	2	0	0	0	0	0.0000	0.0000	0.0008	0.0090	0.0204
		0.0335	0.0147	0.0163	0.0188	0.0253	0.0253	0.0188	0.0237	0.0212	0.0139	0.0425
1997	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0029
		0.0000	0.0265	0.0382	0.0676	0.0941	0.0471	0.0412	0.0559	0.0294	0.0147	0.0676
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	0.0440	0.0391	0.0321	0.0468	0.0370	0.0398	0.1013
1999	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0016	0.0000
		0.0000	0.0047	0.0047	0.0079	0.0205	0.0252	0.0220	0.0346	0.0236	0.0299	0.0756
2000	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0027	0.0041
		0.0082	0.0150	0.0191	0.0082	0.0163	0.0313	0.0422	0.0177	0.0232	0.0082	0.0845

```
2001    5       2       2       0       0       0       0       0.0000 0.0000 0.0025 0.0025 0.0138
                0.0125 0.0289 0.0226 0.0251 0.0301 0.0201 0.0238 0.0301 0.0351 0.0376 0.1016
2002    5       2       2       0       0       0       0       0.0000 0.0009 0.0000 0.0018 0.0035
                0.0079 0.0149 0.0271 0.0525 0.0368 0.0280 0.0315 0.0394 0.0438 0.0490 0.1480
2003    5       2       2       0       0       0       0       0.0000 0.0058 0.0039 0.0116 0.0154
                0.0232 0.0174 0.0193 0.0232 0.0270 0.0251 0.0425 0.0309 0.0328 0.0328 0.0985
2004    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0015 0.0015
                0.0136 0.0287 0.0377 0.0392 0.0287 0.0513 0.0332 0.0407 0.0211 0.0362 0.1131
2005    5       2       2       0       0       0       0       0.0010 0.0058 0.0077 0.0048 0.0086
                0.0211 0.0355 0.0499 0.0672 0.0605 0.0259 0.0307 0.0221 0.0192 0.0154 0.0441
2006    5       2       2       0       0       0       0       0.0000 0.0000 0.0008 0.0008 0.0051
                0.0093 0.0068 0.0102 0.0153 0.0229 0.0297 0.0306 0.0340 0.0272 0.0178 0.0731
2007    5       2       2       0       0       0       0       0.0000 0.0000 0.0032 0.0016 0.0032
                0.0144 0.0265 0.0353 0.0353 0.0369 0.0457 0.0554 0.0514 0.0514 0.0353 0.0899
2008    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0006 0.0068
                0.0044 0.0081 0.0168 0.0305 0.0267 0.0267 0.0267 0.0342 0.0199 0.0186 0.0609
2009    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0000 0.0017
                0.0116 0.0232 0.0456 0.0414 0.0257 0.0273 0.0348 0.0423 0.0414 0.0365 0.0779
2010    5       2       2       0       0       0       0       0.0011 0.0011 0.0011 0.0011 0.0044
                0.0120 0.0239 0.0316 0.0326 0.0435 0.0598 0.0511 0.0501 0.0424 0.0392 0.0914
2011    5       2       2       0       0       0       0       0.0000 0.0000 0.0045 0.0135 0.0090
                0.0067 0.0336 0.0090 0.0224 0.0269 0.0426 0.0448 0.0538 0.0336 0.0404 0.1457
2012    5       2       2       0       0       0       0       0.0000 0.0000 0.0000 0.0000 0.0035
                0.0318 0.0212 0.0459 0.0141 0.0353 0.0318 0.0283 0.0565 0.0459 0.0318 0.1166
2013    5       2       2       0       0       0       0       0.0021 0.0000 0.0021 0.0000 0.0083
                0.0062 0.0248 0.0413 0.0331 0.0393 0.0248 0.0186 0.0227 0.0351 0.0186 0.0847
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  0.0098  0.0098  0.0098  0.0195  0.0375  0.0309  0.0342  0.0244  0.0130  0.0668
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
        0.0195  0.0073  0.0109  0.0122  0.0170  0.0182  0.0170  0.0207  0.0182  0.0231  0.1071
2020    5       2       2       0       0       0       0   0.0000  0.0032  0.0032  0.0032  0.0113
        0.0032  0.0080  0.0064  0.0113  0.0096  0.0064  0.0129  0.0241  0.0161  0.0289  0.1350
#Tanner         crab    bycatch         Male    (male   and     female  combined        compositons     are
        normalized to be 1)
#Year   Season Fleet    Sex     Type    Shell   Maturity        Nsamp DataVec
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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 0.0825
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         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       39      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       44.2    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 0.0117 0.0149
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          0.0171 0.0235 0.0107 0.0075 0.0117 0.0128 0.0299 0.0309 0.0421 0.0597 0.0645
          0.0629 0.0581 0.0533 0.1093
2004  5   4      1      0      0      0      50     0.0000 0.0005 0.0023 0.0059 0.0036
          0.0091 0.0123 0.0282 0.0310 0.0287 0.0346 0.0246 0.0241 0.0241 0.0319 0.0492
          0.0583 0.0556 0.0497 0.0929
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 0.0026 0.0016 0.0069 0.0069 0.0106 0.0159 0.0154 0.0244 0.0318 0.0318
          0.0349 0.0355 0.0286 0.0593
2007  5   4      1      0      0      0      42.6   0.0000 0.0000 0.0000 0.0000 0.0037
          0.0000 0.0000 0.0037 0.0037 0.0074 0.0062 0.0136 0.0049 0.0333 0.0333 0.0432
          0.0358 0.0333 0.0543 0.1432
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      27.4   0.0073 0.0091 0.0073 0.0036 0.0036
          0.0073 0.0055 0.0000 0.0073 0.0036 0.0109 0.0146 0.0255 0.0255 0.0201 0.0182
          0.0164 0.0274 0.0182 0.0456
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 0.0302 0.0235
          0.0302 0.0285 0.0302 0.0865
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  0.0429
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
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        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       43.2  0.0000  0.0023  0.0046  0.0104  0.0185
        0.0197  0.0255  0.0208  0.0208  0.0197  0.0069  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 12.55 0.0120 0.0000 0.0040 0.0000 0.0000 0.0000
        0.0000  0.0040  0.0080  0.0000  0.0080  0.0199  0.0120  0.0279  0.0080  0.0159  0.0080
        0.0080  0.0000  0.0199

# 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 0.0197
                0.0155 0.0096 0.0069 0.0149 0.0240 0.0331 0.0336 0.0341 0.0443 0.0427 0.0837
2004    5       4       2       0       0       0       0       0.0005 0.0005 0.0023 0.0032 0.0055
                0.0114 0.0173 0.0328 0.0292 0.0282 0.0474 0.0483 0.0456 0.0428 0.0374 0.0811
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 0.0122 0.0371 0.0736 0.1128 0.1053 0.0969 0.0667 0.0492 0.0392 0.0979
2007    5       4       2       0       0       0       0       0.0000 0.0012 0.0012 0.0012 0.0025
                0.0074 0.0099 0.0321 0.0432 0.0827 0.1173 0.1086 0.0704 0.0420 0.0222 0.0383
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 0.0036 0.0036
                0.0036 0.0109 0.0201 0.0657 0.0657 0.0912 0.1058 0.1077 0.0620 0.0584 0.1241
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2011   5      4      2      0      0      0      0      0.0000 0.0025 0.0008 0.0067 0.0076
              0.0176 0.0202 0.0336 0.0579 0.0663 0.0999 0.0907 0.0739 0.0638 0.0428 0.1327
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  0.0369  0.0499  0.0699  0.0930  0.0847  0.0639  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  0.0289  0.0405  0.0787  0.0822  0.0787  0.0718  0.0637  0.0706  0.0648  0.1481
2020   5      4      2      0      0      0      0 0.0000   0.0040   0.0040   0.0000   0.0040
       0.0040  0.0279  0.0080  0.0279  0.0359  0.0797  0.0637  0.0677  0.0916  0.0876  0.3386

#NMFS         males
#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
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                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
                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
```

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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
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
```

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                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
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                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
##       eof
9999
```

Appendix C1. Control File for Models 19.3d and 19.3g

```
## ———————————————————————————————————————————————————————————————————————————— ##
## 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-1   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       1       1        # 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
   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
   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  1    75.0     30   190   0     1   999   5    1975   1981  #5
  5   14   2  1     5.0     1    50   0     1   999   5    1975   1981  #5
  5   15   1  1    80.0     30   190   0     1   999   5    1982   2021  #5
  5   16   2  1    10.0     1    50   0     1   999   5    1982   2021  #5
  5   17   1  2    70.0     30   180   0     1   999   5    1975   1981  #5
  5   18   2  2     9.0     1    50   0     1   999   5    1975   1981  #5
  5   19   1  2    70.0     30   180   0     1   999   5    1982   2021  #5
  5   20   2  2    4.00    1.0   50   0     1   999   5    1982   2021  #5
# Gear-6
  6   21   1  1    75.0     1   180   0     1   999   5    1975   2021  # 5
  6   22   2  1     8.5     1    50   0     1   999   5    1975   2021  # 5
  6   23   1  2    85.0     1   180   0     1   999   5    1975   2021  # 5
  6   24   2  2    10.0     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      9    0        0.001   1.00  # BSFRF
## ------------------------------------------------------------------------------------------ ##

## ------------------------------------------------------------------------------------------ ##
## PENALTIES FOR AVERAGE FISHING MORTALITY RATE FOR EACH GEAR
## ------------------------------------------------------------------------------------------ ##
## Mean_F   Female Offset STD_PHZ1   STD_PHZ2   PHZ_M   PHZ_F
                                                # 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)
   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   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
## ———————————————————————————————————————————————————————————————— ##

## ———————————————————————————————————————————————————————————————— ##
## 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
## ———————————————————————————————————————————————————————————————————————— ##
## 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)
## ———————————————————————————————————————————————————————————————————————— ##
# Log_fdevs   meanF      Mdevs  Rec_devs Initial_devs Fst_dif_dev Mean_sex-Ratio
    10000       0         1.0              2            0            0           10
## EOF
9999
```

Appendix C2. Control File for Model 21.1

 # Model 21.1 has the same control file as models 19.3d and 19.3g above except for the selectivity controls below:

```
## ———————————————————————————————————————————————————————————————————————##
## 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       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
       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
 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   2     10.0       1    50    0      1    999    5     1975   2021  # 5
```

Appendix D. Comparison of Observer Biomass and Length Composition Estimates of Crab Pot Fisheries in 2020 (model 19.3) and Updated/standardized Estimates in 2021 (models 19.3c-19.6)

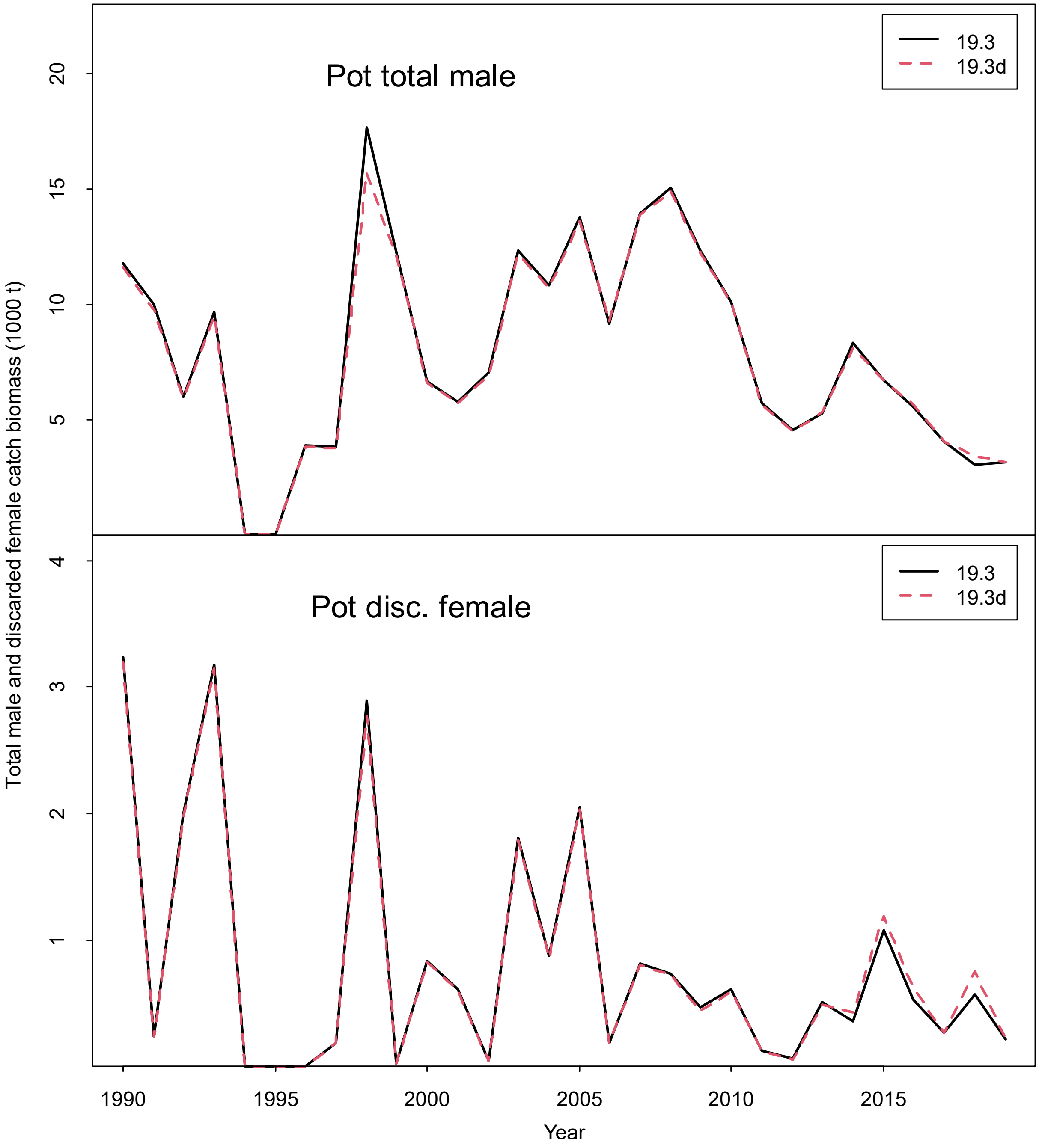

Figure D1. Comparison of observer total male and discarded female biomass in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer total male and discarded female biomass used in models 19.3c-19.6 in 2021.

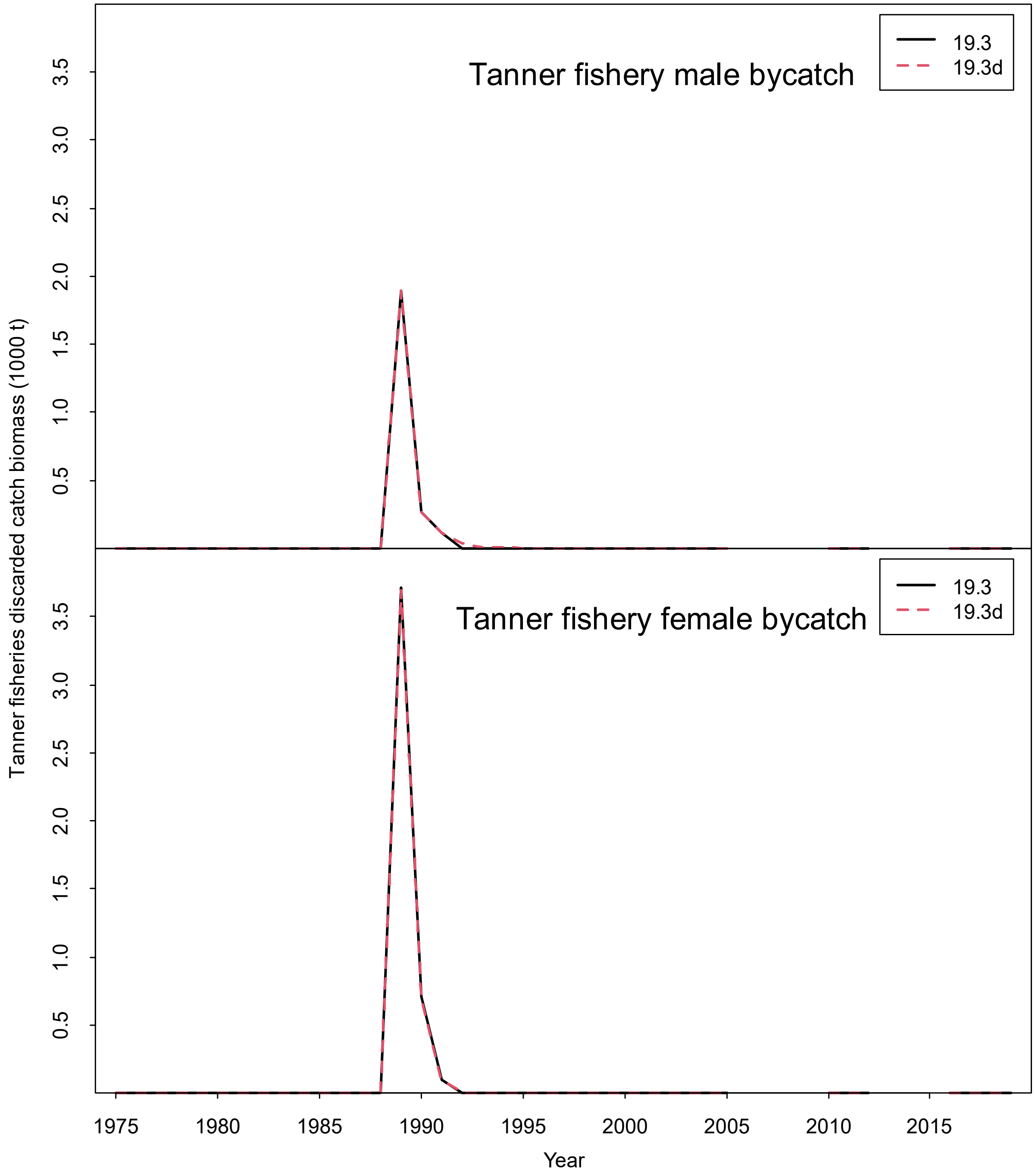

Figure D2. Comparison of observer discarded red king crab biomass in the Tanner crab fishery used in model 19.3 in 2020 and updated/standardized observer discarded red king crab biomass used in models 19.3c-19.6 in 2021.

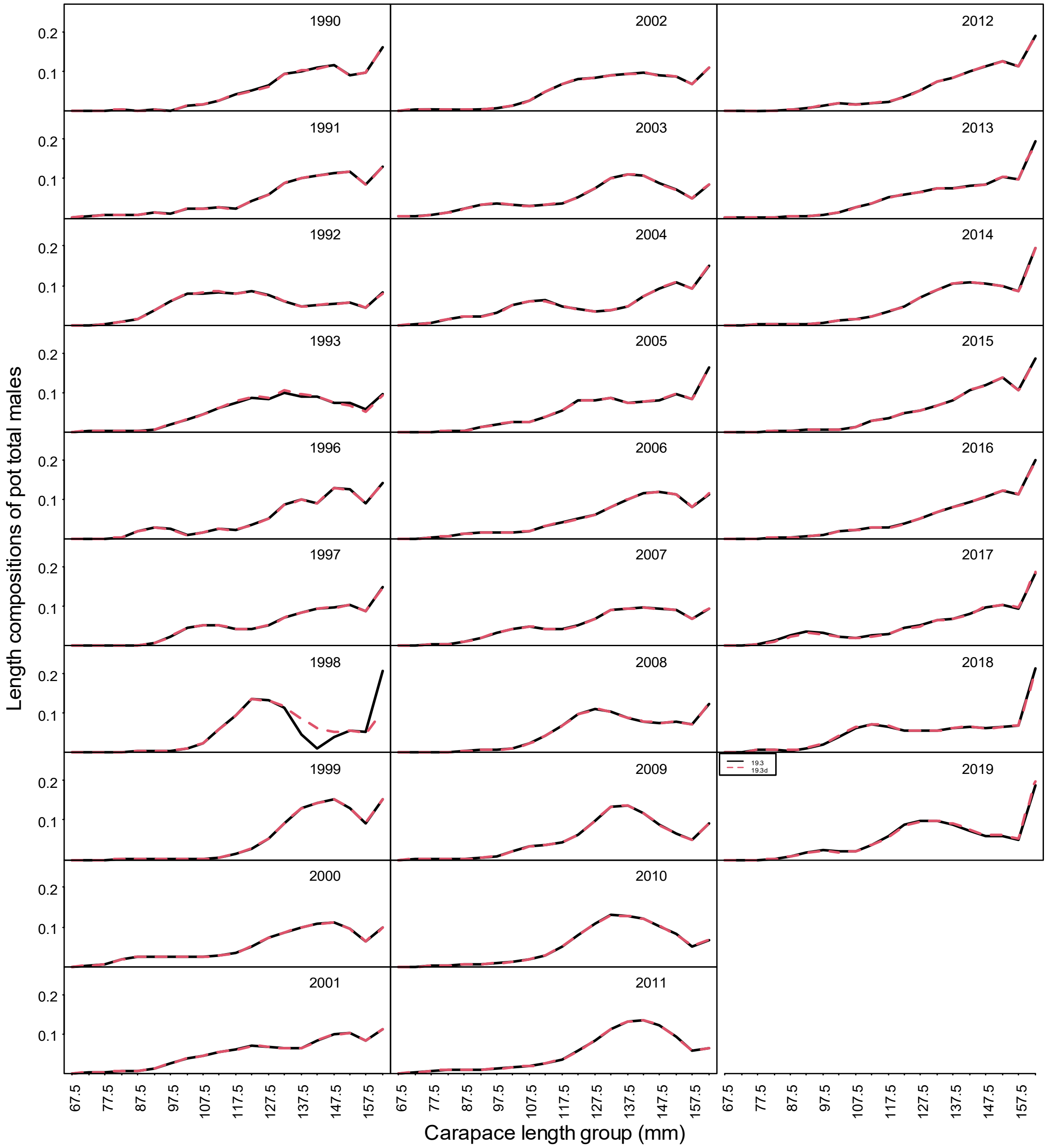

Figure D3. Comparison of observer length compositions of total males in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021. There are some differences in 1998.

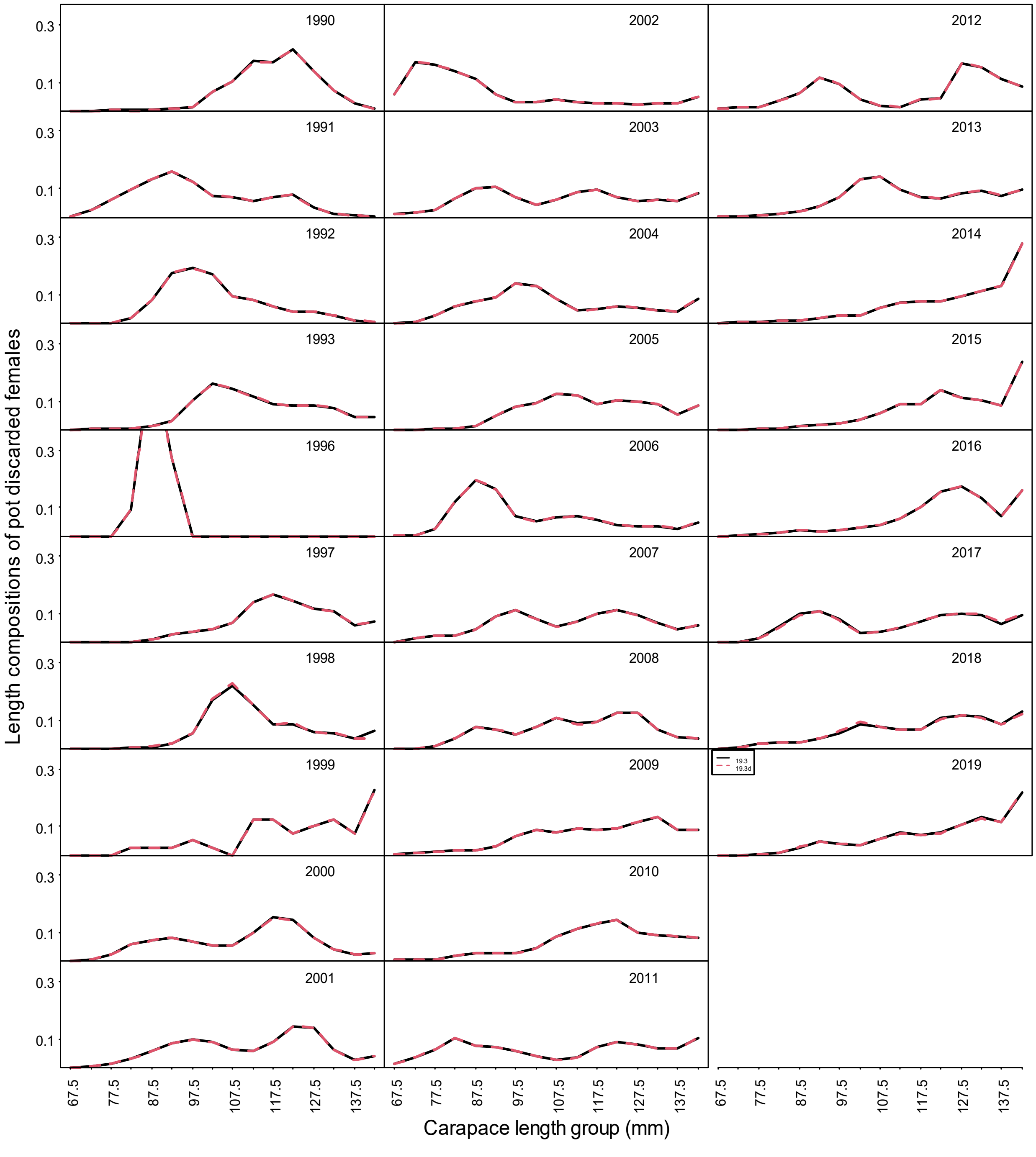

Figure D4. Comparison of observer length compositions of discarded females in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021.

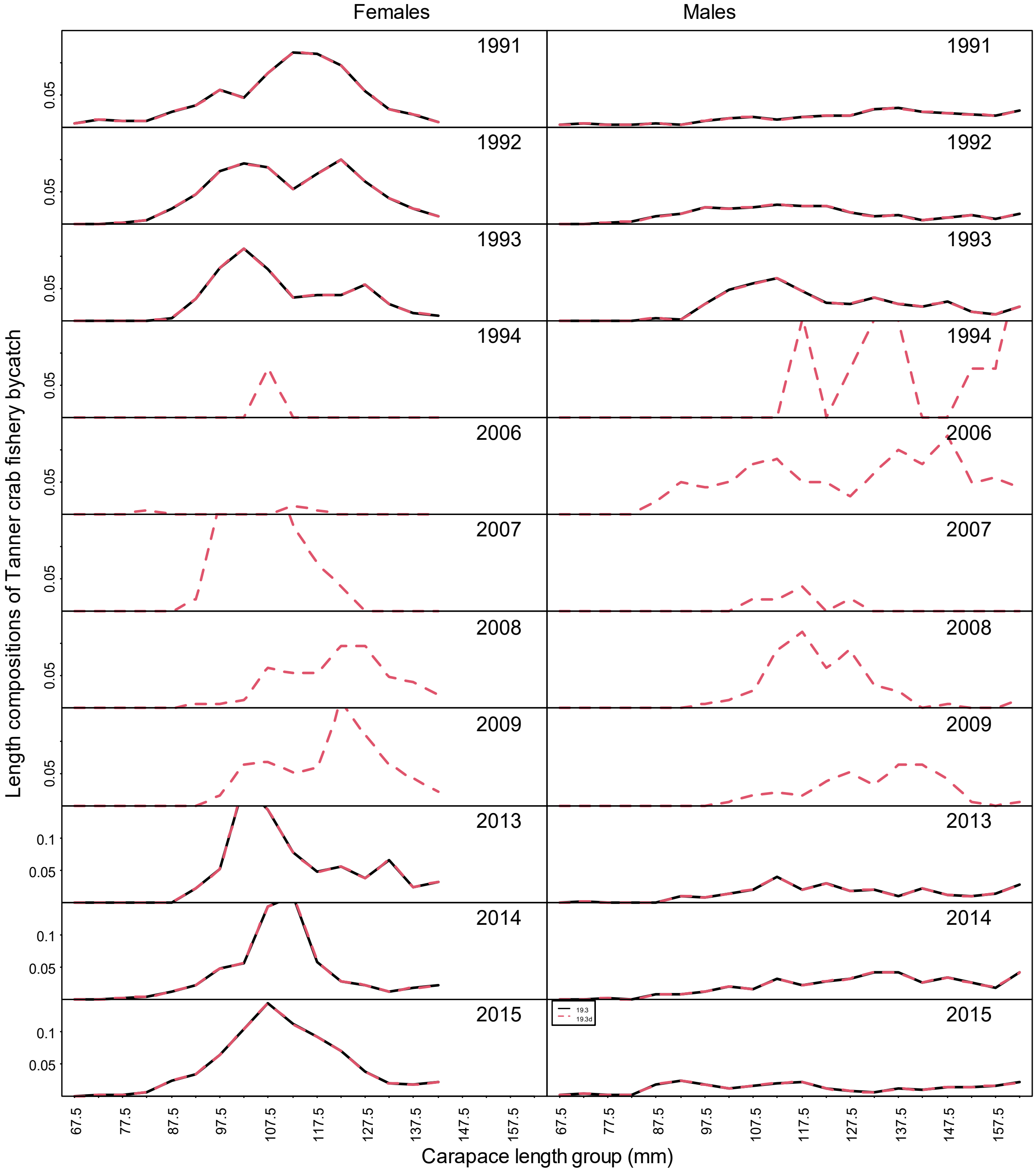

Figure D5. Comparison of observer length compositions of discarded red king crab in the Tanner crab fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021.

Appendix E. VAST Results and Diagnostics by Jon Richar, NMFS

Overall, VAST performed very well for the Bristol Bay red king crab (BBRKC) stock. Best diagnostic performance was in the total GE65 model, while the female GE65 model was difficult to get to converge and had the most issues of the BBRKC models. Population trends tracked current survey estimates well, with no obvious indications of bias when model estimates are compared against area swept estimates. The one concern here is a divergence in trends between VAST estimates and area swept estimates observed for the female GE65 component from 2006-2009. The cause of this divergence is not currently well-understood, and it is still being investigated. Center of gravity and effective area occupied output suggest that the female GE65 population segment is modestly increasing its range, while shifting somewhat to the northwest, while the male GE65 component is contracting its range while also shifting somewhat to the northwest. The new DHARMa residual-based diagnostics were encouraging, with Q-Q plots indicating that total, male and female biomass models performed well, and were able to adequately capture observed population variability. The plots for rank-transformed model predictions vs. standardized residuals did however indicate that the models had some difficulty with the very highest observations, as positive trends in residuals may be observed these in plots for all models at the larger values/higher ranks. Spatial quantile residual plots do not suggest presence of any concerning trends in residuals in either space or time. In conclusion, I am now much more comfortable supporting use of VAST in the stock assessment process than I was last year.

A. Results and diagnostics for males GE65 mm

Table E1 (extracted from parameter_estimates.txt). Model parameter estimates for males GE65 mm. Note that L_epsilon2_z, the parameter for spatio-temporal variation in biomass only is disabled for this model, due to insufficient variability.

```
 ln_H_input  ln_H_input    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  0.4391878   0.2362784   3.1870833   3.1482178   4.2975626   3.5055616 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  2.7546938   2.9387418   2.8090674   2.1975491   2.3903317   1.4759950 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  1.4115011   1.3560671   1.7933598   1.6488495   1.9902657   1.4207743 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  0.9449223   1.1595817   0.5447065   0.3425239   0.5197206   0.6925863 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  1.0448458   1.2189155   1.0389659   1.7046963   1.3129525   0.8759443 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  1.6165848   1.1155201   1.0583272   1.7829058   1.6289998   2.2660369 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  1.3293630   1.0980179   1.0735500   1.2421947   1.1682093   1.5588999 
   beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft    beta1_ft 
  1.6884189   1.4101422   1.6256154   1.3309061   1.2015305   0.8184543 
 L_omega1_z L_epsilon1_z   logkappa1    beta2_ft    beta2_ft    beta2_ft 
  1.4004117   0.9844877  -4.4128177   1.5602333   1.5934981   1.0509342 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.3621967   1.3742022   1.0756192   1.1483564   1.1630868   0.6761904 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.2142167   0.9502871   0.6792951   1.1115024   1.1334183   0.8304728 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.4176535   1.6200684   1.3310675   1.7552726   1.4731987   1.3053098 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.4425218   1.4619022   1.4917258   1.1545082   0.9501476   1.1356627 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.5995770   1.0884986   1.7198370   2.1385707   1.4645905   1.7529291 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.0044478   1.4574191   1.3365247   1.4029822   1.3431484   1.4455134 
   beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft    beta2_ft 
  1.5414561   1.3948492   1.4169171   1.4475720   1.2218920   1.0103108 
   beta2_ft  L_omega2_z L_epsilon2_z  logkappa2  logSigmaM 
  1.5264481   0.4624250   0.6196889  -3.2598081  -0.3985383 
```

Table E2 (extracted from parameter_estimates.txt). Model parameter estimate diagnostic output for males GE65mm. Starting values for model parameters, upper and lower bounds, MLE, and final gradients for parameters.

```
         Param starting_value Lower       MLE Upper final_gradient
1    ln_H_input     0.4391867   -50  0.4391878    50  -9.951311e-08
2    ln_H_input     0.2362819   -50  0.2362784    50   3.004268e-08
3      beta1_ft     3.1870395   -50  3.1870833    50   1.111093e-10
4      beta1_ft     3.1482769   -50  3.1482178    50  -7.063106e-10
5      beta1_ft     4.2975254   -50  4.2975626    50   1.293898e-10
6      beta1_ft     3.5055801   -50  3.5055616    50  -2.174545e-10
7      beta1_ft     2.7547269   -50  2.7546938    50  -5.261835e-10
8      beta1_ft     2.9388218   -50  2.9387418    50  -1.392814e-09
9      beta1_ft     2.8091291   -50  2.8090674    50  -1.016497e-09
10     beta1_ft     2.1975525   -50  2.1975491    50  -6.418217e-10
11     beta1_ft     2.3903774   -50  2.3903317    50  -1.373203e-09
12     beta1_ft     1.4759576   -50  1.4759950    50  -5.036691e-10
13     beta1_ft     1.4114883   -50  1.4115011    50  -4.239684e-10
14     beta1_ft     1.3560457   -50  1.3560671    50  -1.561702e-10
15     beta1_ft     1.7933563   -50  1.7933598    50  -5.946967e-10
16     beta1_ft     1.6488450   -50  1.6488495    50  -3.097540e-10
17     beta1_ft     1.9902873   -50  1.9902657    50  -5.559713e-10
18     beta1_ft     1.4207534   -50  1.4207743    50  -4.039453e-10
19     beta1_ft     0.9449147   -50  0.9449223    50   4.307640e-09
20     beta1_ft     1.1595515   -50  1.1595817    50  -3.064133e-10
21     beta1_ft     0.5446761   -50  0.5447065    50   2.771938e-11
22     beta1_ft     0.3425045   -50  0.3425239    50  -2.264033e-10
23     beta1_ft     0.5196904   -50  0.5197206    50   2.450040e-12
24     beta1_ft     0.6925625   -50  0.6925863    50  -4.936118e-10
25     beta1_ft     1.0448108   -50  1.0448458    50  -2.439142e-10
26     beta1_ft     1.2188867   -50  1.2189155    50  -3.681846e-10
27     beta1_ft     1.0389426   -50  1.0389659    50  -5.351439e-10
28     beta1_ft     1.7046632   -50  1.7046963    50  -2.388374e-10
29     beta1_ft     1.3129275   -50  1.3129525    50  -3.662821e-10
30     beta1_ft     0.8759045   -50  0.8759443    50  -1.882459e-10
31     beta1_ft     1.6165638   -50  1.6165848    50  -5.810286e-11
32     beta1_ft     1.1154768   -50  1.1155201    50  -3.789955e-10
33     beta1_ft     1.0582582   -50  1.0583272    50  -2.963479e-10
34     beta1_ft     1.7828887   -50  1.7829058    50  -1.317346e-11
35     beta1_ft     1.6289807   -50  1.6289998    50  -1.388951e-10
36     beta1_ft     2.2660619   -50  2.2660369    50  -7.813679e-10
37     beta1_ft     1.3293432   -50  1.3293630    50  -3.254761e-10
38     beta1_ft     1.0979752   -50  1.0980179    50   6.896794e-11
39     beta1_ft     1.0735260   -50  1.0735500    50  -4.733853e-10
```

```
40     beta1_ft     1.2421676  -50  1.2421947   50  -5.893286e-11
41     beta1_ft     1.1681796  -50  1.1682093   50  -2.945697e-10
42     beta1_ft     1.5588815  -50  1.5588999   50  -3.485408e-10
43     beta1_ft     1.6884179  -50  1.6884189   50  -7.526464e-10
44     beta1_ft     1.4101243  -50  1.4101422   50  -7.845189e-10
45     beta1_ft     1.6256086  -50  1.6256154   50  -6.127483e-10
46     beta1_ft     1.3308939  -50  1.3309061   50  -8.829494e-10
47     beta1_ft     1.2015257  -50  1.2015305   50  -5.506894e-10
48     beta1_ft     0.8183886  -50  0.8184543   50   1.455554e-08
49   L_omega1_z      1.4004052  -50  1.4004117   50  -1.643575e-07
50  L_epsilon1_z     0.9844882  -50  0.9844877   50   3.294941e-07
51    logkappa1     -4.4128183  -50 -4.4128177   50   4.975118e-08
52     beta2_ft     1.5602487  -50  1.5602333   50   1.025834e-09
53     beta2_ft     1.5935201  -50  1.5934981   50  -7.958167e-10
54     beta2_ft     1.0509267  -50  1.0509342   50   3.753193e-10
55     beta2_ft     1.3622446  -50  1.3621967   50   4.691980e-10
56     beta2_ft     1.3742177  -50  1.3742022   50   1.557668e-09
57     beta2_ft     1.0755727  -50  1.0756192   50   1.209907e-09
58     beta2_ft     1.1483634  -50  1.1483564   50   1.023270e-10
59     beta2_ft     1.1630824  -50  1.1630868   50   2.385937e-09
60     beta2_ft     0.6762126  -50  0.6761904   50   2.803054e-09
61     beta2_ft     1.2141951  -50  1.2142167   50  -1.121785e-09
62     beta2_ft     0.9502955  -50  0.9502871   50   3.649783e-09
63     beta2_ft     0.6793103  -50  0.6792951   50  -1.805287e-09
64     beta2_ft     1.1115363  -50  1.1115024   50   3.641606e-09
65     beta2_ft     1.1334277  -50  1.1334183   50  -1.157829e-10
66     beta2_ft     0.8304767  -50  0.8304728   50   4.839720e-10
67     beta2_ft     1.4176728  -50  1.4176535   50   2.385172e-09
68     beta2_ft     1.6200584  -50  1.6200684   50  -1.685979e-08
69     beta2_ft     1.3310893  -50  1.3310675   50   1.716716e-09
70     beta2_ft     1.7552963  -50  1.7552726   50  -3.104388e-10
71     beta2_ft     1.4731839  -50  1.4731987   50  -1.029665e-10
72     beta2_ft     1.3053207  -50  1.3053098   50  -1.898480e-09
73     beta2_ft     1.4425045  -50  1.4425218   50  -1.681499e-10
74     beta2_ft     1.4619044  -50  1.4619022   50   4.673222e-10
75     beta2_ft     1.4917213  -50  1.4917258   50  -1.245564e-09
76     beta2_ft     1.1545156  -50  1.1545082   50   4.842198e-10
77     beta2_ft     0.9501949  -50  0.9501476   50   1.886896e-09
78     beta2_ft     1.1356828  -50  1.1356627   50   1.449099e-09
79     beta2_ft     1.5996048  -50  1.5995770   50   1.199237e-09
80     beta2_ft     1.0884536  -50  1.0884986   50  -2.382119e-09
81     beta2_ft     1.7198674  -50  1.7198370   50   1.006131e-09
82     beta2_ft     2.1385716  -50  2.1385707   50  -4.514268e-09
```

```
83     beta2_ft     1.4645415  -50  1.4645905   50  -3.775469e-09
84     beta2_ft     1.7529134  -50  1.7529291   50  -1.660291e-09
85     beta2_ft     1.0044774  -50  1.0044478   50   3.438657e-09
86     beta2_ft     1.4574307  -50  1.4574191   50   5.531273e-10
87     beta2_ft     1.3365173  -50  1.3365247   50  -3.125194e-09
88     beta2_ft     1.4029968  -50  1.4029822   50   9.920731e-10
89     beta2_ft     1.3431527  -50  1.3431484   50  -5.822489e-10
90     beta2_ft     1.4455255  -50  1.4455134   50   1.259603e-09
91     beta2_ft     1.5414456  -50  1.5414561   50  -3.650555e-10
92     beta2_ft     1.3948450  -50  1.3948492   50   1.131374e-09
93     beta2_ft     1.4169299  -50  1.4169171   50   3.835869e-09
94     beta2_ft     1.4475652  -50  1.4475720   50   3.151732e-09
95     beta2_ft     1.2218954  -50  1.2218920   50   4.572616e-09
96     beta2_ft     1.0103148  -50  1.0103108   50   4.749075e-09
97     beta2_ft     1.5264675  -50  1.5264481   50  -4.029581e-08
98   L_omega2_z     0.4624244  -50  0.4624250   50  -8.535374e-07
99  L_epsilon2_z    0.6196891  -50  0.6196889   50  -5.273847e-09
100    logkappa2   -3.2598058  -50 -3.2598081   50  -3.899256e-08
101    logSigmaM   -0.3985396  -50 -0.3985383   50   6.683992e-07
```

Table E3 (extracted from parameter_estimates.txt). Model parameter estimates with parameter standard errors for maleGE65 mm. Note often large sizes of standard errors relative to estimates. Although final model converged and fit observations well, convergence was problematic to achieve, requiring some model simplification via removal of terms. Large standard errors suggest further simplification in future runs may be beneficial. Male and Total GE65 mm models had much larger parameter estimates relative to the standard errors.

```
             Estimate Std. Error
ln_H_input  0.4391878 0.07250751
ln_H_input  0.2362784 0.07380400
beta1_ft    3.1870833 1.05632614
beta1_ft    3.1482178 1.03439359
beta1_ft    4.2975626 1.05173995
beta1_ft    3.5055616 1.03884342
beta1_ft    2.7546938 1.02792307
beta1_ft    2.9387418 1.03056883
beta1_ft    2.8090674 1.03285049
beta1_ft    2.1975491 1.04121576
beta1_ft    2.3903317 1.03693303
beta1_ft    1.4759950 1.04903794
beta1_ft    1.4115011 1.05064963
beta1_ft    1.3560671 1.05250173
beta1_ft    1.7933598 1.04017804
beta1_ft    1.6488495 1.04528687
```

```
beta1_ft      1.9902657 1.04121334
beta1_ft      1.4207743 1.04646779
beta1_ft      0.9449223 1.05919461
beta1_ft      1.1595817 1.04959847
beta1_ft      0.5447065 1.06249726
beta1_ft      0.3425239 1.07217645
beta1_ft      0.5197206 1.06647010
beta1_ft      0.6925863 1.05823715
beta1_ft      1.0448458 1.05503033
beta1_ft      1.2189155 1.05025870
beta1_ft      1.0389659 1.05091265
beta1_ft      1.7046963 1.05426591
beta1_ft      1.3129525 1.05212256
beta1_ft      0.8759443 1.05870165
beta1_ft      1.6165848 1.04860760
beta1_ft      1.1155201 1.04984874
beta1_ft      1.0583272 1.05192767
beta1_ft      1.7829058 1.04209071
beta1_ft      1.6289998 1.04187899
beta1_ft      2.2660369 1.03777729
beta1_ft      1.3293630 1.04507352
beta1_ft      1.0980179 1.05437982
beta1_ft      1.0735500 1.05518342
beta1_ft      1.2421947 1.05142084
beta1_ft      1.1682093 1.05089598
beta1_ft      1.5588999 1.04412934
beta1_ft      1.6884189 1.04026788
beta1_ft      1.4101422 1.04054635
beta1_ft      1.6256154 1.03841779
beta1_ft      1.3309061 1.04379751
beta1_ft      1.2015305 1.04286866
beta1_ft      0.8184543 1.08613444
L_omega1_z    1.4004117 0.13640182
L_epsilon1_z  0.9844877 0.04868669
logkappa1    -4.4128177 0.07047106
beta2_ft      1.5602333 0.30988181
beta2_ft      1.5934981 0.25705696
beta2_ft      1.0509342 0.29757122
beta2_ft      1.3621967 0.27265516
beta2_ft      1.3742022 0.22561398
beta2_ft      1.0756192 0.23919191
beta2_ft      1.1483564 0.24519643
beta2_ft      1.1630868 0.25794122
```

```
beta2_ft      0.6761904 0.23801805
beta2_ft      1.2142167 0.25171407
beta2_ft      0.9502871 0.27392505
beta2_ft      0.6792951 0.27992569
beta2_ft      1.1115024 0.23826975
beta2_ft      1.1334183 0.26947238
beta2_ft      0.8304728 0.25151095
beta2_ft      1.4176535 0.23613589
beta2_ft      1.6200684 0.26106892
beta2_ft      1.3310675 0.25440218
beta2_ft      1.7552726 0.27443753
beta2_ft      1.4731987 0.28294323
beta2_ft      1.3053098 0.27695785
beta2_ft      1.4425218 0.26077392
beta2_ft      1.4619022 0.28399585
beta2_ft      1.4917258 0.27849220
beta2_ft      1.1545082 0.27553009
beta2_ft      0.9501476 0.30666442
beta2_ft      1.1356627 0.27217156
beta2_ft      1.5995770 0.26777963
beta2_ft      1.0884986 0.28597732
beta2_ft      1.7198370 0.27163552
beta2_ft      2.1385707 0.26515755
beta2_ft      1.4645905 0.25980767
beta2_ft      1.7529291 0.25364988
beta2_ft      1.0044478 0.25361267
beta2_ft      1.4574191 0.25045537
beta2_ft      1.3365247 0.28376119
beta2_ft      1.4029822 0.26204314
beta2_ft      1.3431484 0.25354669
beta2_ft      1.4455134 0.26337971
beta2_ft      1.5414561 0.25125528
beta2_ft      1.3948492 0.24639492
beta2_ft      1.4169171 0.24233905
beta2_ft      1.4475720 0.22997147
beta2_ft      1.2218920 0.23653622
beta2_ft      1.0103108 0.23700722
beta2_ft      1.5264481 0.22935320
L_omega2_z    0.4624250 0.05100366
L_epsilon2_z  0.6196889 0.04160007
logkappa2    -3.2598081 0.12477628
logSigmaM    -0.3985383 0.02794715
```

Table E4 (file = Table_for_SS3a.csv). Population index output. Biomass estimates for males GE65 mm, in metric tons, log-SD and SD in metric tons.

Year	Estimate (t)	SD_log	SD_mt
1975	148118.51	0.1242	14597.16
1976	243853.38	0.1105	21797.56
1977	239346.32	0.1004	19213.93
1978	196698.38	0.1105	17725.22
1979	96579.00	0.1224	9742.04
1980	141622.12	0.1172	13629.73
1981	73903.45	0.0987	5952.58
1982	60766.35	0.1173	5849.65
1983	34590.17	0.1074	3039.05
1984	47589.76	0.1307	5118.82
1985	29606.91	0.1095	2661.95
1986	27199.54	0.1186	2666.60
1987	42383.68	0.1158	4025.94
1988	37873.87	0.1124	3472.83
1989	40526.89	0.1151	3794.14
1990	37491.75	0.1196	3702.28
1991	36915.81	0.1643	5486.35
1992	26546.36	0.1199	2637.30
1993	36553.61	0.1296	3966.76
1994	25229.51	0.1269	2647.21
1995	23645.86	0.1230	2431.36
1996	28476.14	0.1255	2949.09
1997	55682.39	0.1219	5602.94
1998	50276.81	0.1120	4622.09
1999	46095.23	0.1330	5023.98
2000	46505.33	0.1253	4697.93
2001	31181.06	0.1074	2738.90
2002	48795.86	0.1229	4939.07
2003	60035.03	0.1237	6084.77
2004	64126.34	0.1253	6640.56
2005	55097.49	0.1161	5379.38
2006	54276.96	0.1073	4782.39
2007	62256.43	0.1117	5688.58
2008	61024.12	0.1266	6279.65
2009	39090.98	0.1387	4416.07
2010	40328.62	0.1234	4055.32
2011	29640.33	0.1290	3150.55
2012	34231.62	0.1437	4008.44
2013	42819.06	0.1294	4510.26
2014	64111.48	0.1186	6208.43
2015	42029.58	0.1140	3919.17
2016	30229.92	0.1090	2736.35
2017	26252.33	0.1028	2256.08
2018	18269.63	0.1097	1670.39
2019	16261.62	0.1120	1520.07
2021	17184.63	0.1416	2286.36

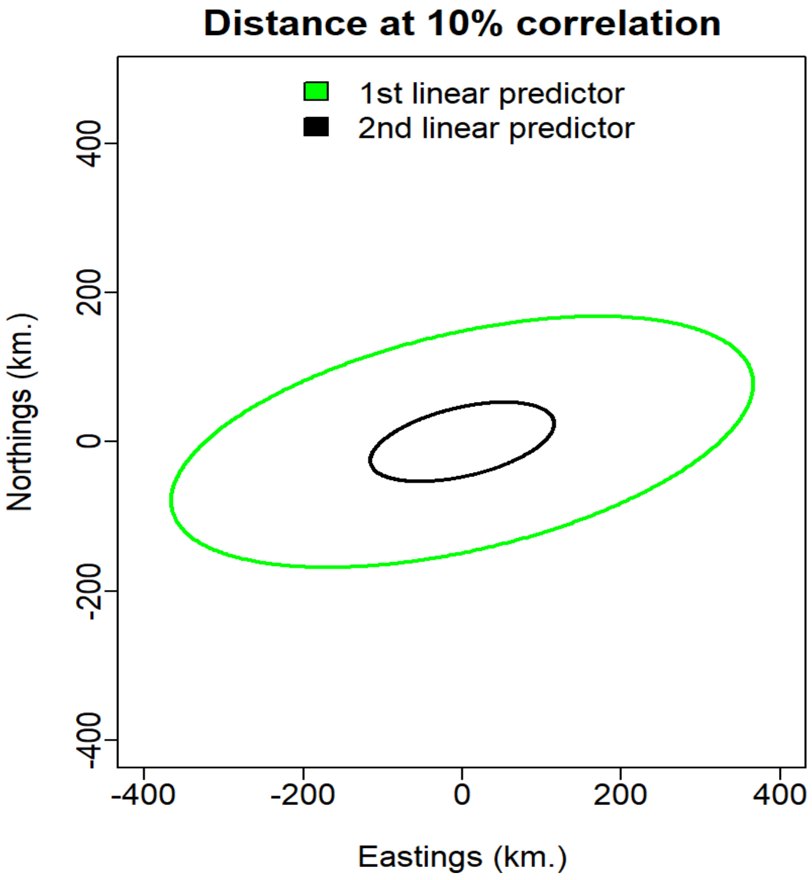

Figure E1 (file = Aniso.png). Geometric anisotropy for males GE65mm. Geometric anisotropy represents the tendency for correlations to decline faster in some directions than others. An ellipse with a major (long) axis pointed northeast-southwest will have correlations that decline slower along this axis than movement northwest-southeast.

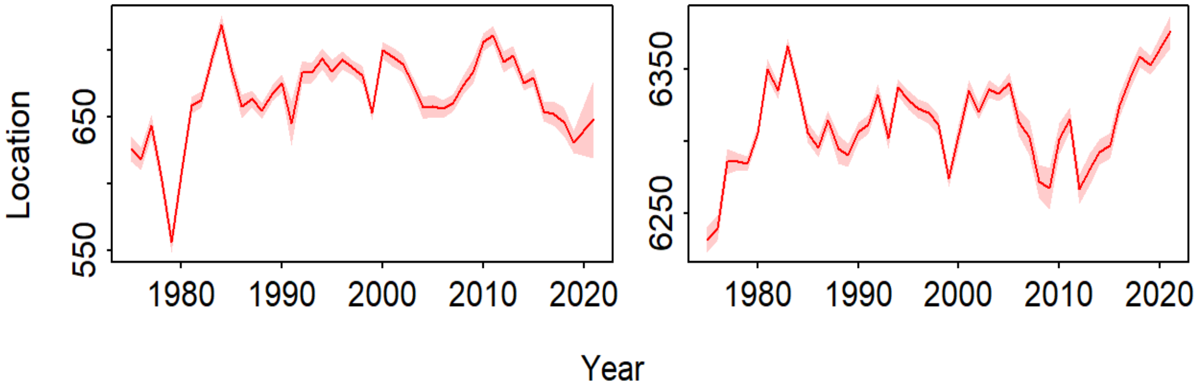

Figure E2 (file = center_of_gravity.png). Center of gravity for males GE65 mm: a.) Eastings (km) and b.) Northings (km). These figures indicate that the population has been shifting slightly to the northwest in recent years.

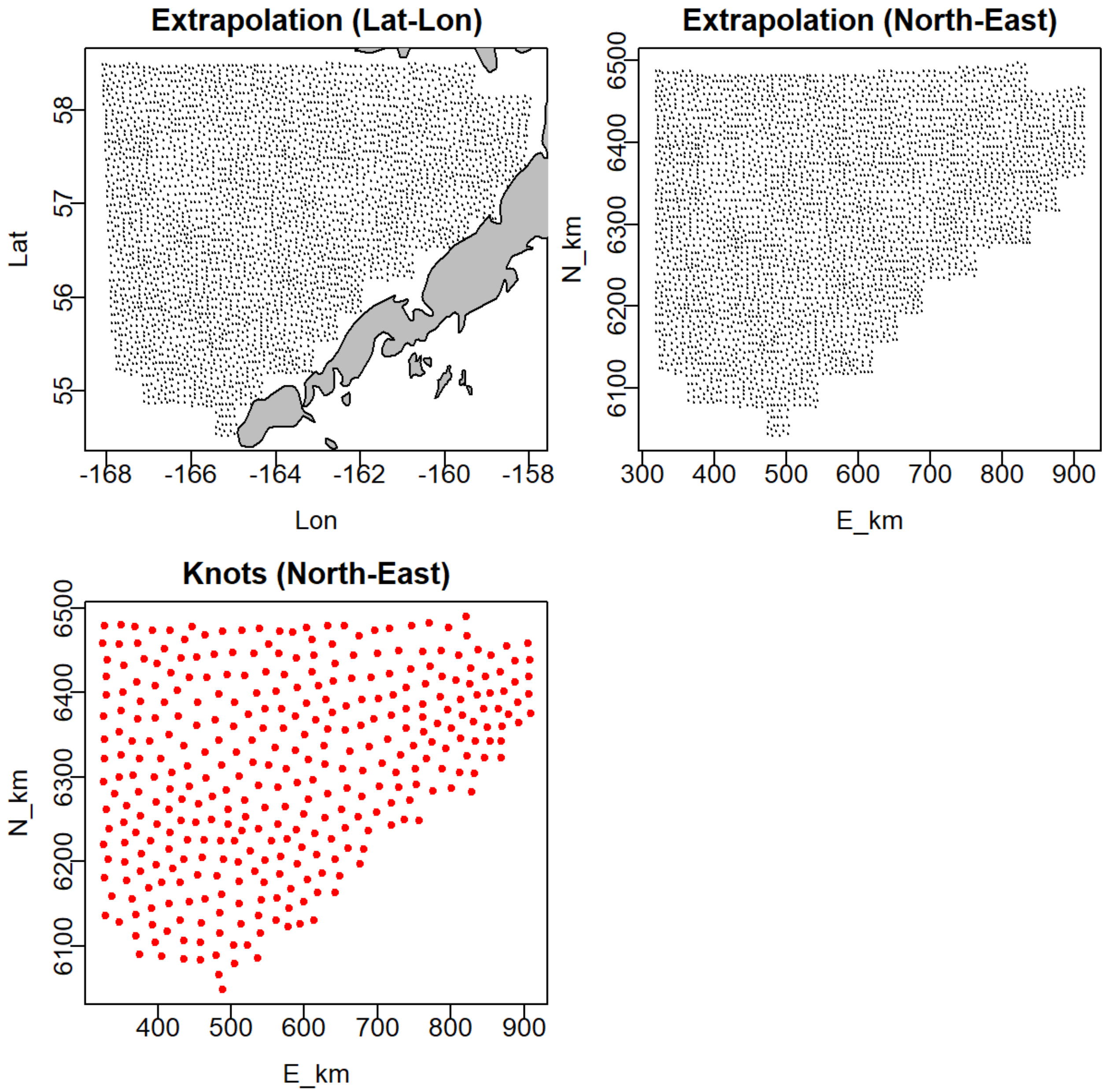

Figure E3 (file = data_and_knots.png). Extrapolation maps for males GE65 mm: a.) Extrapolation grids by latitude and longitude, b.) Extrapolation grid by Northings/Eastings (in km), and c.) Knots used to define spatial mesh for population estimation.

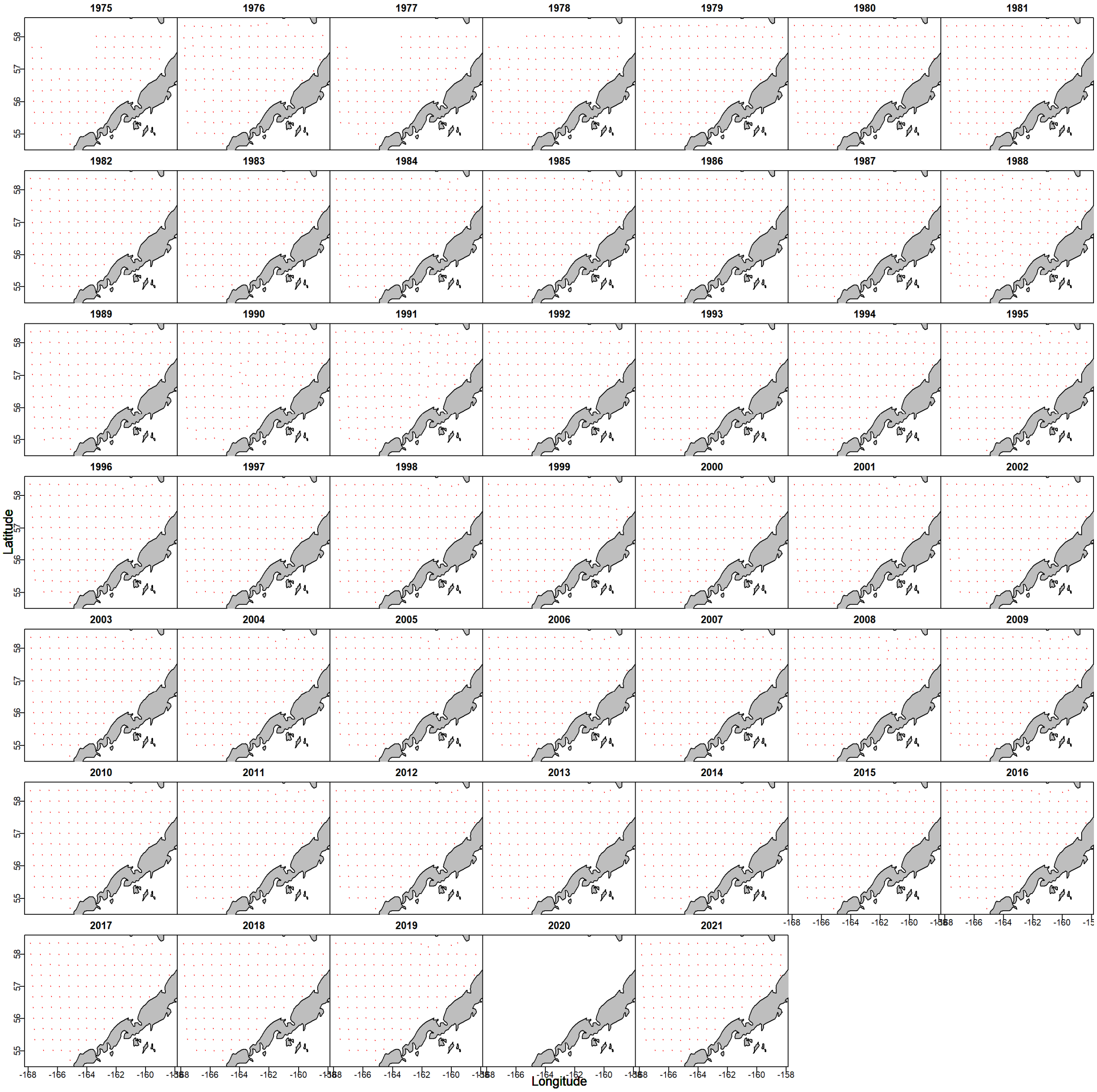

Figure E4 (file = data_by_year.png). Data sampling locations by year for males GE65 mm. Note standardization of survey area in this subregion of the Bering Sea by 1980.

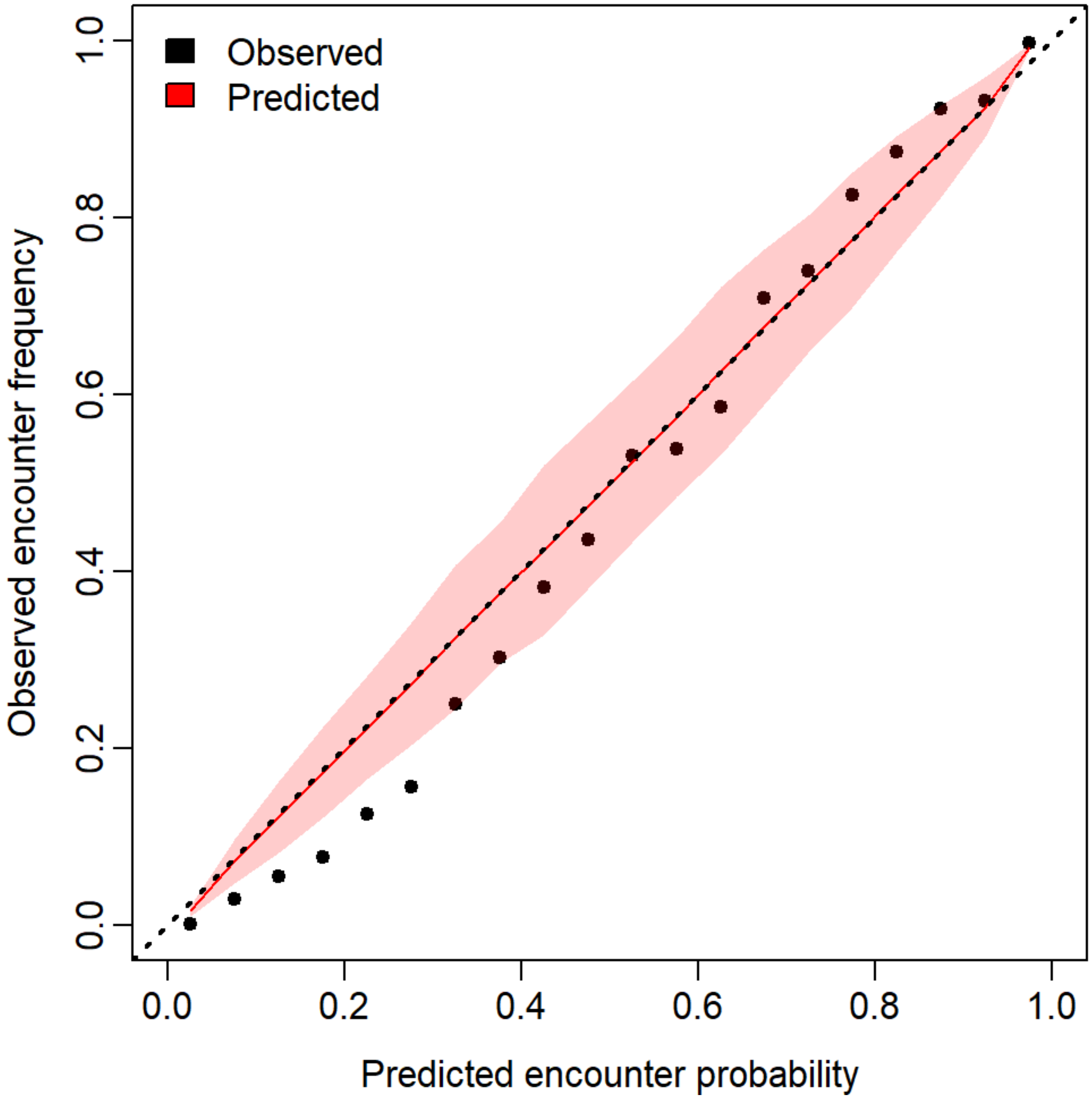

Figure E5 (file = diag--encounter_prob.png). Diagnostic plot of model predicted encounter probability vs. observed encounter frequency for male GE 65 biomass model. Shaded region is confidence interval. Results here indicate excellent model performance t high encounter rates, but poor performance at the lowest encounter rates, suggesting the model may have some difficulty with females in peripheral habitat regions.

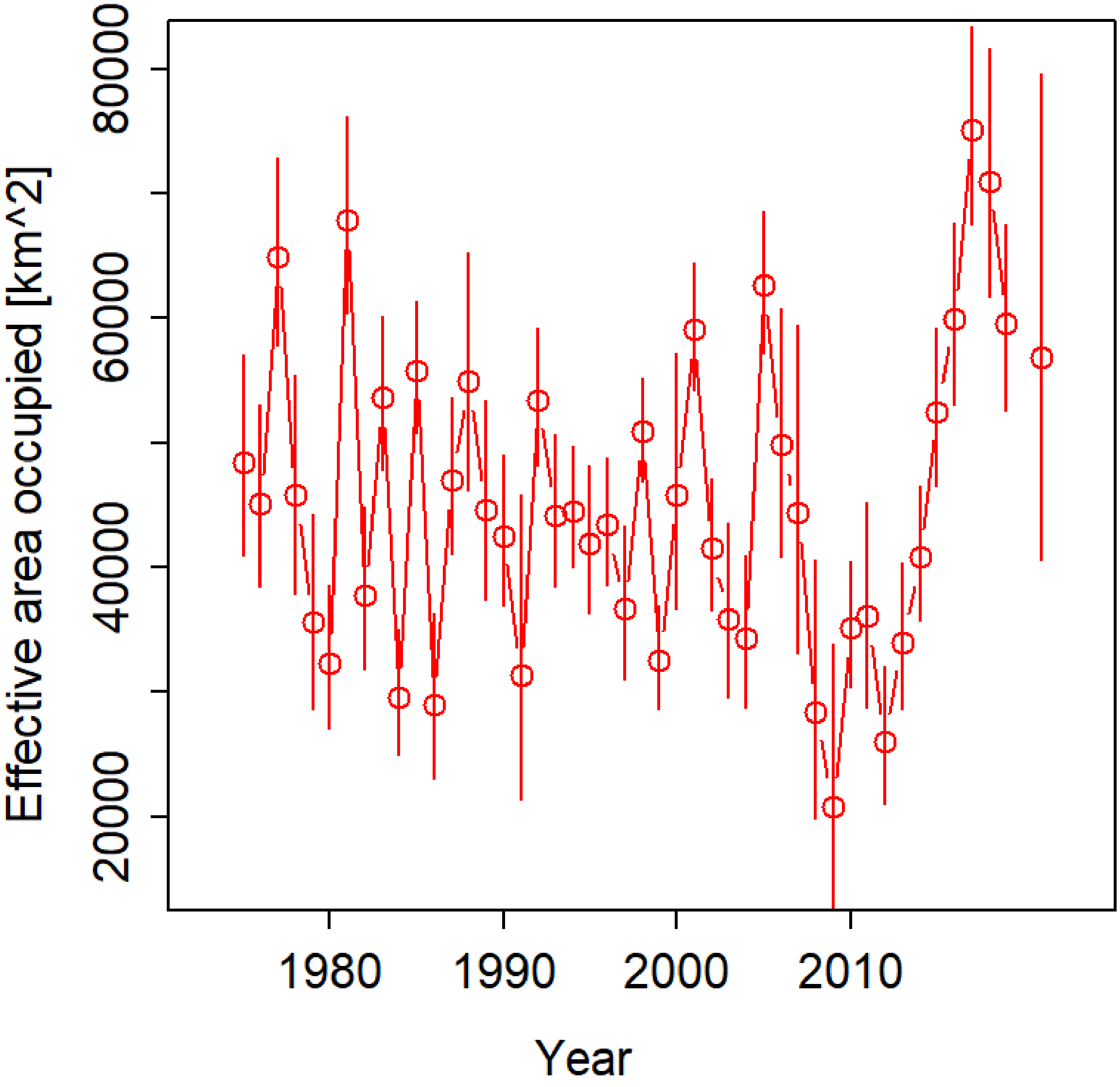

Figure E6 (file = effective_area.png). Effective area occupied, in ln(km2) for males GE65 mm. Note modest expansion in area occupied in recent years, despite low population sizes.

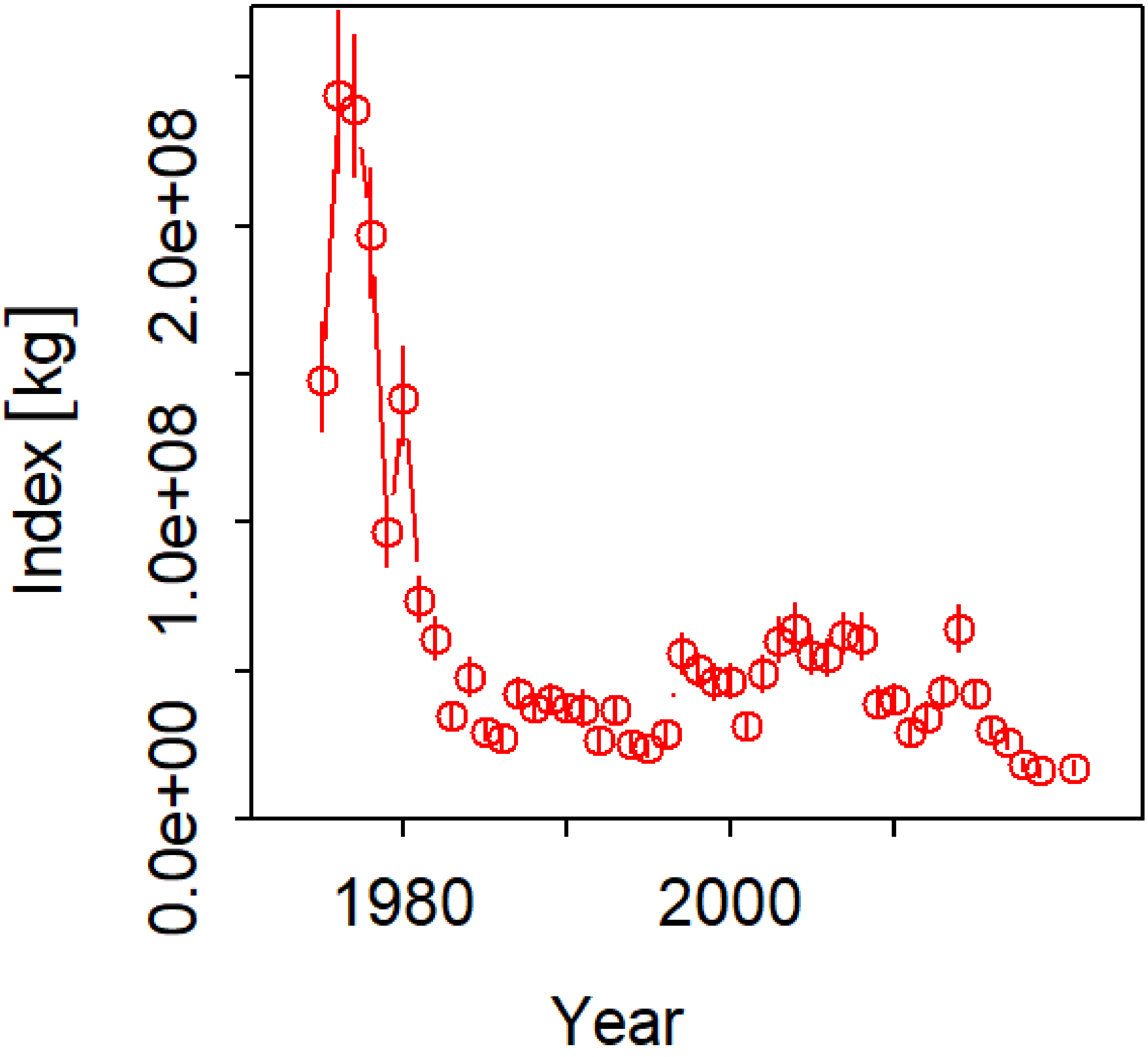

Figure E7 (file = index-biomass.png). Biomass estimates by year, with +/- 1SD error bars for males GE65 mm.

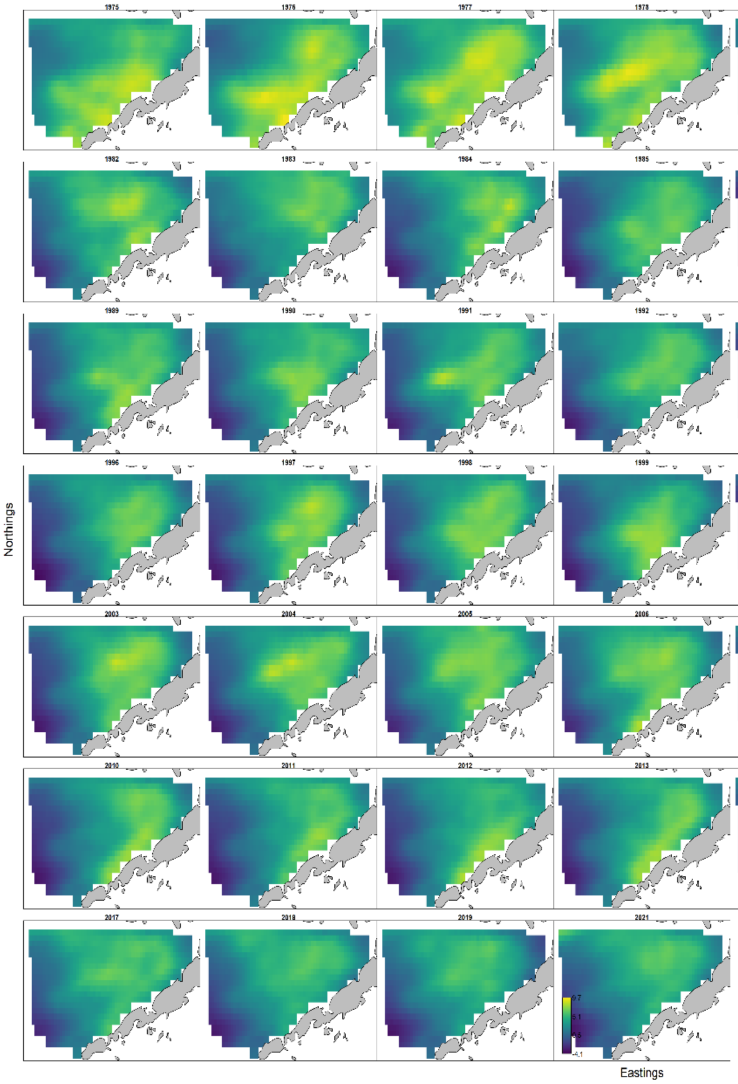

Figure E8 (file = ln_density-predicted.png). Annual log-density maps for males GE65 mm in ln(kg)/km^2.

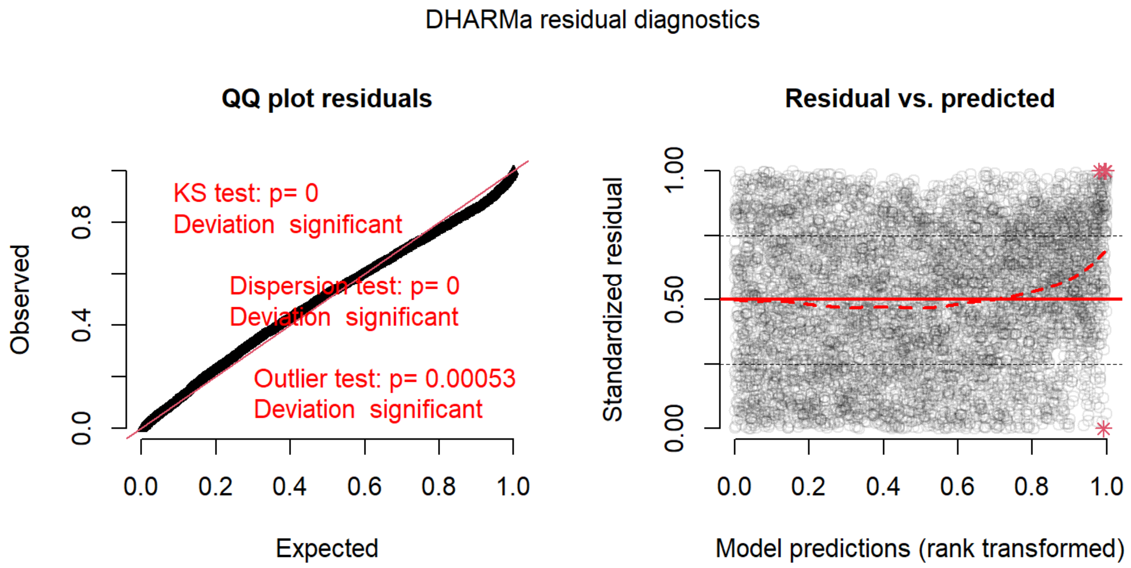

Figure E9 (file = quantile_residuals.png). DHARMa residual output for males GE65 mm. a.) Q-Q plot of residuals with p-values for statistical test applied automatically by DHARMa package. These p-values have no meaning here and should be ignored. This figure indicates excellent model performance. b.) Rank-transformed model predictions vs. standardized residuals. Note an indication of a trend in residuals for largest model predictions, as indicated by the dashed red line.

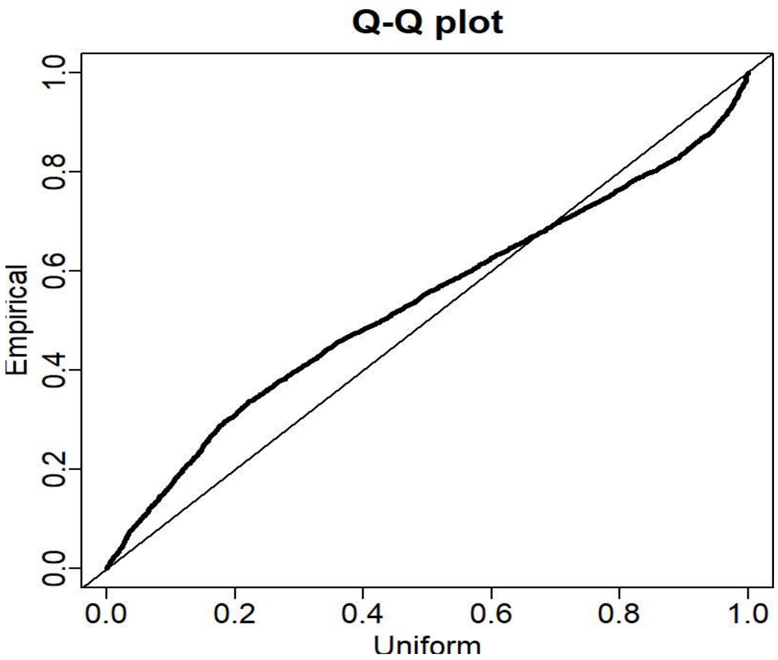

Figure E10 (file = posterior_predictive-histogram-1.png). Catch rate Q-Q plot for male GE 65 biomass model. Results indicate that relative to the observation model employed, data distribution was thin tailed and slightly right skewed.

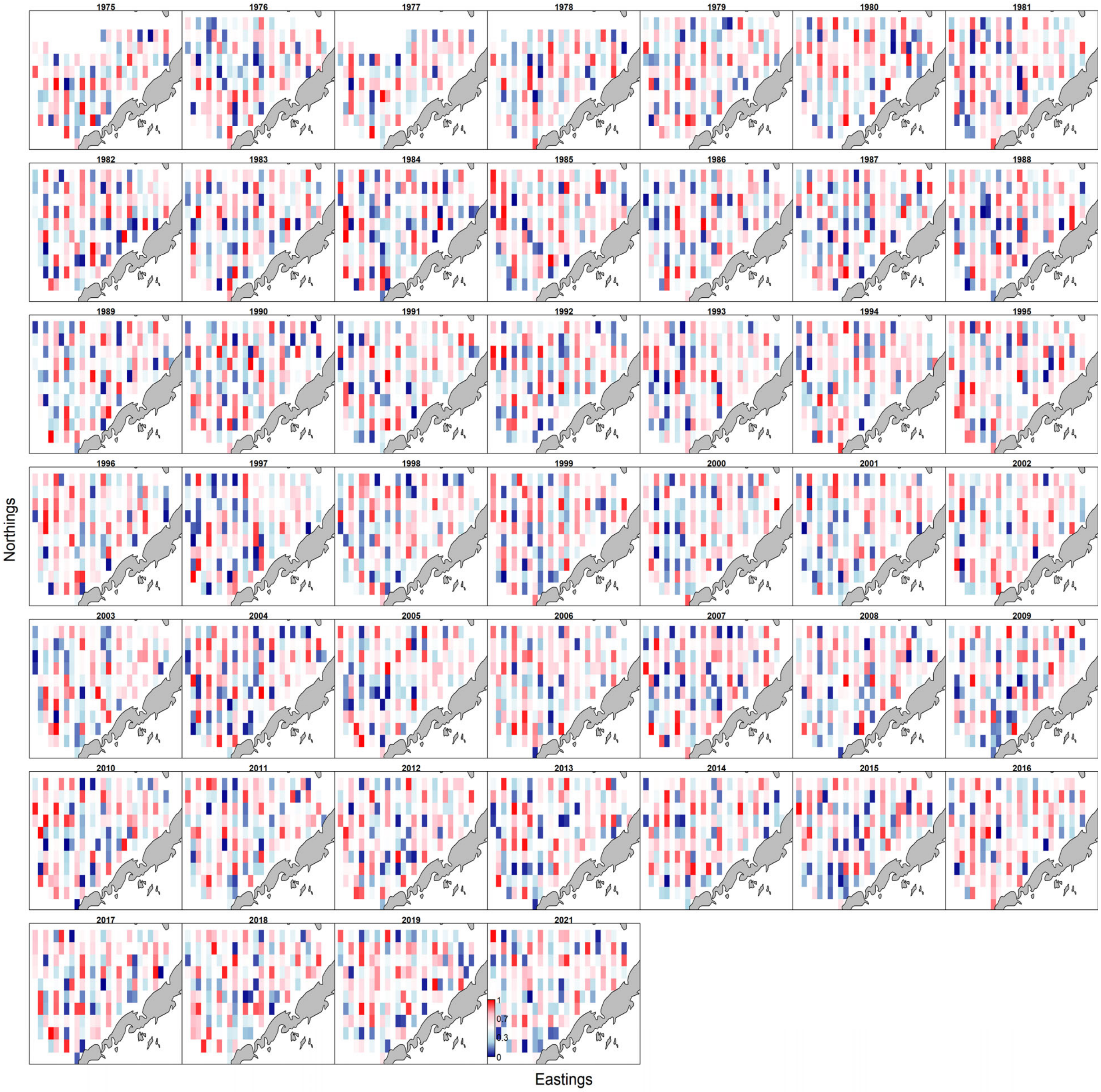

Figure E11 (file = quantile_residuals_on_map_enlarged.png). Spatial quantile residuals for males GE65 mm with residual "blocks" enlarged for easier viewing. Mapped quantile residuals used to assess for spatial-temporal trends in residuals.

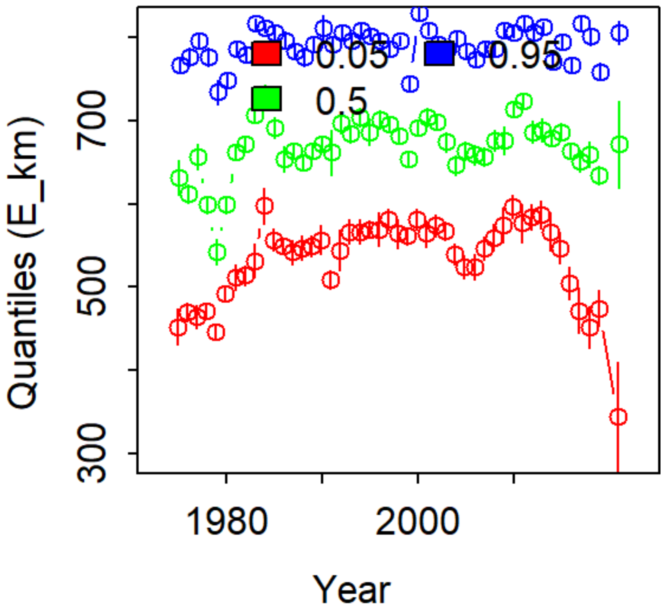

Figure E12 (file = rangeedge_E_km.png). Eastern range edge calculated for male biomass w/retow data, GE65. Blue is the eastern limit (by default the 95% quantile), green is middle (50%) and red is the western limit (by default 5%). All are calculated using methods described here: https://doi.org/10.1111/gcb.15614 . SEs are done via sampling from the joint precision of random and fixed effects.

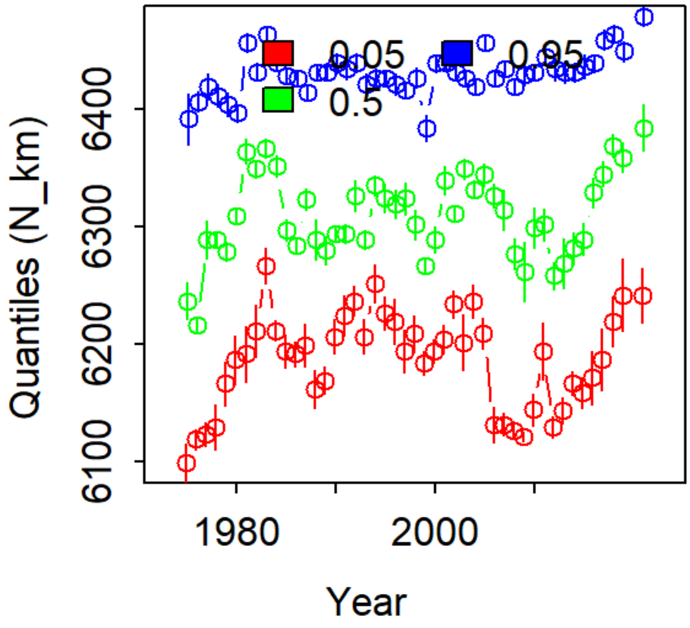

Figure E13 (file = rangeedge_N_km.png). Northern range edge calculated for male biomass w/retow data, GE65. Blue is the northern limit (by default the 95% quantile), green is middle (50%) and red is southern limit (by default 5%). All are calculated using methods described here: https://doi.org/10.1111/gcb.15614 . SEs are done via sampling from the joint precision of random and fixed effects.

B. Results and diagnostics for females GE65 mm.

Table E5 (extracted from parameter_estimates.txt). Model parameter estimates for females GE65 mm. Note that L_epsilon2_z, the parameter for spatio-temporal variation in biomass only is disabled for this model, due to insufficient variability.

```
  ln_H_input   ln_H_input     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 0.160319048  0.271418625  1.450071259  2.359112117  3.158210263  2.252701604 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 1.539839955  1.424845488  1.759473622  1.852824961  0.863620038 -0.732605213 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
-0.100451396 -0.514062102 -0.245282732 -0.066888152  0.132344420 -0.223000584 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
-0.482409069 -0.161380318 -0.721750141 -1.220168764 -0.499522827 -1.190233224 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
-0.499483655 -0.261091858 -0.160360197  0.006155899  0.067690769 -0.015087528 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 0.827870979  0.514657485  0.766915171  0.715961435  0.759103378  1.353224830 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 0.848470067  0.202927023  0.277598796  0.074341366 -0.016502549  0.395170355 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 0.447428936  1.280986865  0.656823269 -0.007286607  0.563164987  0.206001490 
  L_omega1_z L_epsilon1_z    logkappa1     beta2_ft     beta2_ft     beta2_ft 
 1.661931366  1.361796896 -3.898065712  0.546198698 -0.184657301  0.063063258 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.698025431  1.032318915  0.468683992  0.157577917  0.528002170  0.090902958 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.179414554 -0.294593216 -0.307097111  0.369726505  0.032860328  0.029836959 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.467593854  0.362152935  0.090835004  0.496201160  0.359593156  0.096346731 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.949320577  0.415567314  0.601753448  0.364664215  0.722762944  0.059180827 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.393680615  0.261684265  0.713244439  0.778461280  0.788628502  0.988123668 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.662460508  0.956565861  0.717436291  1.074119736  0.691110266  0.642991660 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
 0.875937229  0.747572149  0.499004706  0.507505405  0.880717251  1.029050810 
    beta2_ft   L_omega2_z    logkappa2   logSigmaM 
 1.033244781  0.386033108 -5.013687862 -0.351555387 
```

Table E6 (extracted from parameter_estimates.txt). Model parameter estimate diagnostic output for females GE65mm. Starting values for model parameters, upper and lower bounds, MLE, and final gradients for parameters.

```
        Param starting_value Lower          MLE Upper final_gradient
1  ln_H_input    0.160321507   -50  0.160319048    50  -2.946783e-08
2  ln_H_input    0.271421548   -50  0.271418625    50  -1.101310e-08
3    beta1_ft    1.450038669   -50  1.450071259    50   4.105920e-10
4    beta1_ft    2.359171061   -50  2.359112117    50  -1.009385e-09
5    beta1_ft    3.158205400   -50  3.158210263    50   8.558487e-11
6    beta1_ft    2.252669352   -50  2.252701604    50   3.638050e-10
7    beta1_ft    1.539831295   -50  1.539839955    50   1.060909e-10
8    beta1_ft    1.424804816   -50  1.424845488    50   5.620999e-10
9    beta1_ft    1.759496270   -50  1.759473622    50  -4.545866e-10
10   beta1_ft    1.852848536   -50  1.852824961    50  -3.045066e-10
11   beta1_ft    0.863600906   -50  0.863620038    50   2.800649e-10
12   beta1_ft   -0.732623970   -50 -0.732605213    50   2.229235e-10
13   beta1_ft   -0.100450281   -50 -0.100451396    50  -1.291574e-10
14   beta1_ft   -0.514074394   -50 -0.514062102    50   9.066514e-11
15   beta1_ft   -0.245314046   -50 -0.245282732    50   3.016238e-10
16   beta1_ft   -0.066920565   -50 -0.066888152    50   1.632836e-10
17   beta1_ft    0.132331355   -50  0.132344420    50   4.986522e-11
18   beta1_ft   -0.223050554   -50 -0.223000584    50   7.994432e-10
19   beta1_ft   -0.482414975   -50 -0.482409069    50   7.726948e-11
20   beta1_ft   -0.161378024   -50 -0.161380318    50  -3.958822e-11
21   beta1_ft   -0.721733757   -50 -0.721750141    50  -2.730757e-10
22   beta1_ft   -1.220161076   -50 -1.220168764    50  -2.275063e-10
23   beta1_ft   -0.499532587   -50 -0.499522827    50   1.169787e-10
24   beta1_ft   -1.190266977   -50 -1.190233224    50   3.704019e-10
25   beta1_ft   -0.499492367   -50 -0.499483655    50   3.442868e-11
26   beta1_ft   -0.261098080   -50 -0.261091858    50   2.867750e-11
27   beta1_ft   -0.160336027   -50 -0.160360197    50  -3.991290e-10
28   beta1_ft    0.006149657   -50  0.006155899    50   1.571651e-10
29   beta1_ft    0.067710191   -50  0.067690769    50  -2.874461e-10
30   beta1_ft   -0.015098594   -50 -0.015087528    50   1.238120e-10
31   beta1_ft    0.827931199   -50  0.827870979    50  -1.212716e-09
32   beta1_ft    0.514627006   -50  0.514657485    50   4.864467e-10
33   beta1_ft    0.766964949   -50  0.766915171    50  -9.087208e-10
34   beta1_ft    0.715914493   -50  0.715961435    50   6.061405e-10
35   beta1_ft    0.759050283   -50  0.759103378    50   7.215220e-10
36   beta1_ft    1.353253337   -50  1.353224830    50  -5.250868e-10
37   beta1_ft    0.848386123   -50  0.848470067    50   1.330065e-09
38   beta1_ft    0.202907692   -50  0.202927023    50   2.758409e-10
```

```
39      beta1_ft    0.277578294   -50  0.277598796    50   3.177425e-10
40      beta1_ft    0.074243154   -50  0.074341366    50   7.362799e-10
41      beta1_ft   -0.016531301   -50 -0.016502549    50   4.123426e-10
42      beta1_ft    0.395202445   -50  0.395170355    50  -6.180896e-10
43      beta1_ft    0.447458225   -50  0.447428936    50  -6.370828e-10
44      beta1_ft    1.280911654   -50  1.280986865    50   8.573653e-10
45      beta1_ft    0.656786913   -50  0.656823269    50   5.457850e-10
46      beta1_ft   -0.007236384   -50 -0.007286607    50  -1.216769e-09
47      beta1_ft    0.563208701   -50  0.563164987    50  -1.468933e-09
48      beta1_ft    0.206029346   -50  0.206001490    50  -8.274839e-10
49    L_omega1_z    1.661938456   -50  1.661931366    50  -1.857808e-08
50  L_epsilon1_z    1.361801728   -50  1.361796896    50   6.898941e-08
51     logkappa1   -3.898065326   -50 -3.898065712    50   2.200006e-07
52      beta2_ft    0.546186500   -50  0.546198698    50   2.305161e-10
53      beta2_ft   -0.184669378   -50 -0.184657301    50  -2.645320e-09
54      beta2_ft    0.063040802   -50  0.063063258    50   2.842810e-10
55      beta2_ft    0.698020534   -50  0.698025431    50   5.253575e-10
56      beta2_ft    1.032308346   -50  1.032318915    50   1.394877e-09
57      beta2_ft    0.468677716   -50  0.468683992    50   1.167098e-09
58      beta2_ft    0.157574538   -50  0.157577917    50  -6.309619e-10
59      beta2_ft    0.527982770   -50  0.528002170    50   2.452849e-09
60      beta2_ft    0.090901657   -50  0.090902958    50  -3.464731e-10
61      beta2_ft    0.179404394   -50  0.179414554    50   4.494387e-10
62      beta2_ft   -0.294597861   -50 -0.294593216    50   1.371064e-09
63      beta2_ft   -0.307094622   -50 -0.307097111    50  -1.093072e-10
64      beta2_ft    0.369726073   -50  0.369726505    50  -2.071854e-10
65      beta2_ft    0.032850820   -50  0.032860328    50  -4.469438e-10
66      beta2_ft    0.029836668   -50  0.029836959    50   7.177965e-10
67      beta2_ft    0.467593906   -50  0.467593854    50  -4.048775e-09
68      beta2_ft    0.362148373   -50  0.362152935    50   5.675469e-10
69      beta2_ft    0.090834064   -50  0.090835004    50  -2.260148e-10
70      beta2_ft    0.496194718   -50  0.496201160    50   1.886411e-10
71      beta2_ft    0.359592228   -50  0.359593156    50   5.641221e-10
72      beta2_ft    0.096341930   -50  0.096346731    50   1.687432e-10
73      beta2_ft    0.949320127   -50  0.949320577    50   8.174972e-10
74      beta2_ft    0.415561028   -50  0.415567314    50   1.796598e-10
75      beta2_ft    0.601746836   -50  0.601753448    50   3.441514e-10
76      beta2_ft    0.364662552   -50  0.364664215    50  -5.591856e-10
77      beta2_ft    0.722744581   -50  0.722762944    50  -1.245372e-09
78      beta2_ft    0.059173537   -50  0.059180827    50  -2.789378e-10
79      beta2_ft    0.393681973   -50  0.393680615    50  -8.707772e-10
80      beta2_ft    0.261673919   -50  0.261684265    50  -5.762590e-11
81      beta2_ft    0.713241352   -50  0.713244439    50   4.110188e-10
```

```
82     beta2_ft   0.778458246  -50  0.778461280   50  -2.589707e-09
83     beta2_ft   0.788622200  -50  0.788628502   50   1.595954e-09
84     beta2_ft   0.988112519  -50  0.988123668   50  -1.232189e-09
85     beta2_ft   0.662455987  -50  0.662460508   50  -7.822551e-10
86     beta2_ft   0.956564236  -50  0.956565861   50  -2.381394e-09
87     beta2_ft   0.717426581  -50  0.717436291   50   9.443379e-11
88     beta2_ft   1.074111747  -50  1.074119736   50  -1.949649e-10
89     beta2_ft   0.691123335  -50  0.691110266   50  -5.628475e-11
90     beta2_ft   0.642994266  -50  0.642991660   50  -1.511843e-09
91     beta2_ft   0.875935178  -50  0.875937229   50  -5.541052e-10
92     beta2_ft   0.747564215  -50  0.747572149   50  -4.720722e-10
93     beta2_ft   0.499006739  -50  0.499004706   50   2.084447e-09
94     beta2_ft   0.507500495  -50  0.507505405   50  -3.059739e-10
95     beta2_ft   0.880702766  -50  0.880717251   50   1.355153e-09
96     beta2_ft   1.029043671  -50  1.029050810   50   4.222546e-09
97     beta2_ft   1.033242380  -50  1.033244781   50  -4.228071e-10
98    L_omega2_z   0.386033762  -50  0.386033108   50  -6.568901e-07
99     logkappa2  -5.013669518  -50 -5.013687862   50  -2.564786e-07
100    logSigmaM  -0.351556071  -50 -0.351555387   50   1.103371e-07
```

Table E7 (extracted from parameter_estimates.txt). Model parameter estimates with parameter standard errors for female GE65 mm. Note often large sizes of standard errors relative to estimates. Although final model converged and fit observations well, convergence was problematic to achieve, requiring some model simplification via removal of terms. Large standard errors suggest further simplification in future runs may be beneficial. Male and Total GE65 mm models had much larger parameter estimates relative to the standard errors.

```
sdreport(.) result
                Estimate Std. Error
ln_H_input   0.160319048 0.06765087
ln_H_input   0.271418625 0.07668538
beta1_ft     1.450071259 0.86741525
beta1_ft     2.359112117 0.81806650
beta1_ft     3.158210263 0.85623571
beta1_ft     2.252701604 0.83693403
beta1_ft     1.539839955 0.81929566
beta1_ft     1.424845488 0.82899195
beta1_ft     1.759473622 0.82718491
beta1_ft     1.852824961 0.82346294
beta1_ft     0.863620038 0.82691551
beta1_ft    -0.732605213 0.88497696
beta1_ft    -0.100451396 0.85590935
beta1_ft    -0.514062102 0.87544471
beta1_ft    -0.245282732 0.86532763
beta1_ft    -0.066888152 0.86299153
beta1_ft     0.132344420 0.85571896
beta1_ft    -0.223000584 0.85785530
beta1_ft    -0.482409069 0.87527875
beta1_ft    -0.161380318 0.86030554
beta1_ft    -0.721750141 0.88139096
beta1_ft    -1.220168764 0.90544726
beta1_ft    -0.499522827 0.87648005
beta1_ft    -1.190233224 0.89351079
beta1_ft    -0.499483655 0.87438102
beta1_ft    -0.261091858 0.87269102
beta1_ft    -0.160360197 0.85992557
beta1_ft     0.006155899 0.86248965
beta1_ft     0.067690769 0.86287582
beta1_ft    -0.015087528 0.86255811
beta1_ft     0.827870979 0.83691641
beta1_ft     0.514657485 0.83899572
beta1_ft     0.766915171 0.83435968
beta1_ft     0.715961435 0.84889798
```

```
beta1_ft      0.759103378 0.84062535
beta1_ft      1.353224830 0.82311634
beta1_ft      0.848470067 0.83521602
beta1_ft      0.202927023 0.85235700
beta1_ft      0.277598796 0.84721714
beta1_ft      0.074341366 0.85950160
beta1_ft     -0.016502549 0.85234305
beta1_ft      0.395170355 0.84357865
beta1_ft      0.447428936 0.84169429
beta1_ft      1.280986865 0.81691450
beta1_ft      0.656823269 0.84033782
beta1_ft     -0.007286607 0.84185934
beta1_ft      0.563164987 0.83130155
beta1_ft      0.206001490 0.83640022
L_omega1_z    1.661931366 0.14292152
L_epsilon1_z  1.361796896 0.05316551
logkappa1    -3.898065712 0.05696260
beta2_ft      0.546198698 0.49251485
beta2_ft     -0.184657301 0.47125254
beta2_ft      0.063063258 0.54210518
beta2_ft      0.698025431 0.48938973
beta2_ft      1.032318915 0.46645210
beta2_ft      0.468683992 0.46735725
beta2_ft      0.157577917 0.47831690
beta2_ft      0.528002170 0.46476340
beta2_ft      0.090902958 0.46279860
beta2_ft      0.179414554 0.48378447
beta2_ft     -0.294593216 0.46122150
beta2_ft     -0.307097111 0.47120434
beta2_ft      0.369726505 0.47575778
beta2_ft      0.032860328 0.46124305
beta2_ft      0.029836959 0.46261642
beta2_ft      0.467593854 0.45063159
beta2_ft      0.362152935 0.47588641
beta2_ft      0.090835004 0.46833496
beta2_ft      0.496201160 0.48793621
beta2_ft      0.359593156 0.48986747
beta2_ft      0.096346731 0.47262253
beta2_ft      0.949320577 0.48529677
beta2_ft      0.415567314 0.48952225
beta2_ft      0.601753448 0.50247400
beta2_ft      0.364664215 0.47316410
beta2_ft      0.722762944 0.47049439
```

```
beta2_ft      0.059180827 0.47772716
beta2_ft      0.393680615 0.46570696
beta2_ft      0.261684265 0.47738136
beta2_ft      0.713244439 0.47707256
beta2_ft      0.778461280 0.46933027
beta2_ft      0.788628502 0.48537776
beta2_ft      0.988123668 0.46856712
beta2_ft      0.662460508 0.45835594
beta2_ft      0.956565861 0.46431313
beta2_ft      0.717436291 0.49271866
beta2_ft      1.074119736 0.47182797
beta2_ft      0.691110266 0.46013636
beta2_ft      0.642991660 0.46293518
beta2_ft      0.875937229 0.48068697
beta2_ft      0.747572149 0.45944714
beta2_ft      0.499004706 0.45742000
beta2_ft      0.507505405 0.46923253
beta2_ft      0.880717251 0.46471206
beta2_ft      1.029050810 0.45957985
beta2_ft      1.033244781 0.45219695
L_omega2_z    0.386033108 0.12607370
logkappa2    -5.013687862 0.51876426
logSigmaM    -0.351555387 0.02737774
```

Table E8 (file = Table_for_SS3a.csv). Population index output. Biomass estimates for females GE65 mm, in metric tons, log-SD and SD in metric tons.

Year	Estimate metric tons	SD log	SD mt
1975	58080.69	0.1734	7379.55
1976	68255.39	0.1440	7204.52
1977	134450.17	0.1320	12992.14
1978	125443.86	0.1341	12464.46
1979	53741.43	0.1176	4873.17
1980	67447.85	0.1574	7957.52
1981	55936.58	0.1425	5995.00
1982	61728.03	0.1362	6366.36
1983	11952.85	0.1390	1270.98
1984	19190.71	0.2010	2960.00
1985	6680.11	0.1516	778.15
1986	5834.67	0.1588	710.70
1987	17207.90	0.1619	2146.76
1988	13842.67	0.1988	2121.22
1989	9644.14	0.1588	1170.14
1990	14301.23	0.1803	1980.01
1991	11900.16	0.1614	1474.64
1992	10796.96	0.1519	1252.65
1993	15701.93	0.1668	1992.73
1994	8424.75	0.1633	1062.35
1995	9453.76	0.1535	1108.13
1996	14671.88	0.1629	1845.51
1997	19314.71	0.1715	2529.85
1998	31953.64	0.1493	3609.00
1999	19950.19	0.1822	2753.96
2000	31733.78	0.1892	4530.78
2001	21337.56	0.1631	2622.23
2002	20468.70	0.1621	2506.55
2003	37258.37	0.1500	4234.11
2004	32517.85	0.1440	3529.75
2005	44651.26	0.1433	4857.68
2006	54154.41	0.1494	6121.50
2007	53047.20	0.1384	5547.94
2008	47267.85	0.1649	5849.62
2009	45384.83	0.1604	5443.56
2010	42706.17	0.1568	5068.13
2011	41776.86	0.1582	5066.74
2012	30581.91	0.1955	4574.54
2013	22856.03	0.1943	3322.44
2014	65939.18	0.1723	8518.40
2015	30854.14	0.1769	4113.03
2016	36497.51	0.1498	4166.54
2017	29230.75	0.1398	3091.11
2018	14247.39	0.1489	1666.16
2019	15988.89	0.1254	1594.13
2021	10576.47	0.1359	1155.91

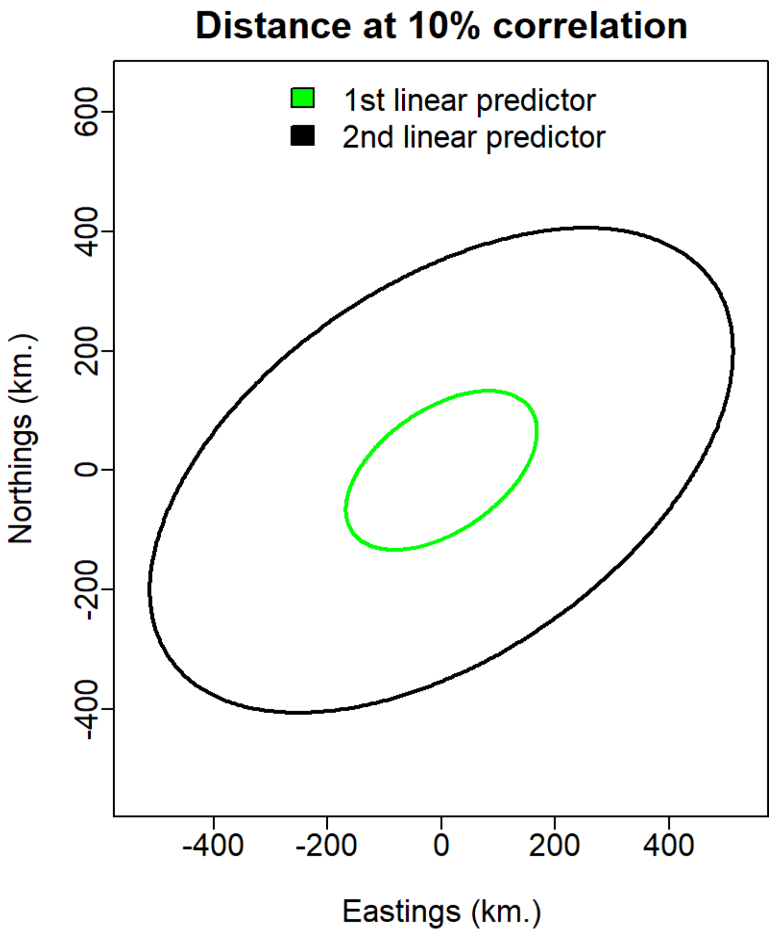

Figure E14 (file = Aniso.png). Geometric anisotropy for females GE65mm. Geometric anisotropy represents the tendency for correlations to decline faster in some directions than others. An ellipse with a major (long) axis pointed northeast-southwest will have correlations that decline slower along this axis than movement northwest-southeast.

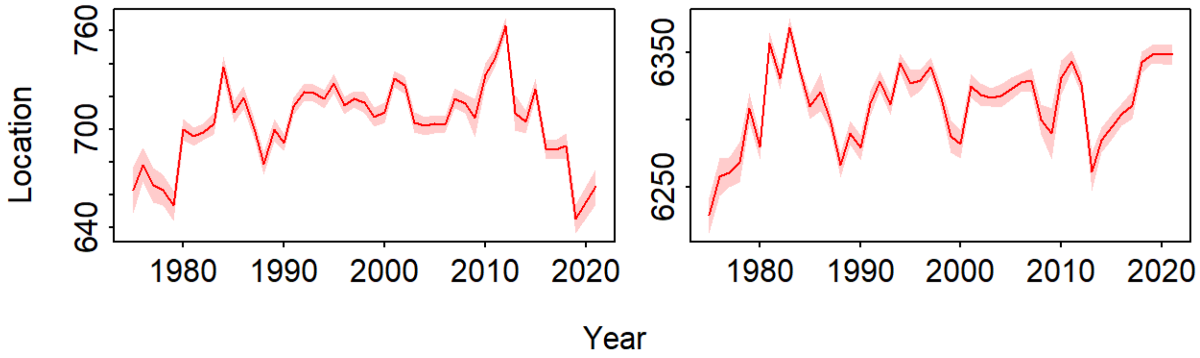

Figure E15 (file = center_of_gravity.png). Center of gravity for females GE65 mm: a.) Eastings (km) and b.) Northings (km). These figures indicate that the population has been shifting slightly to the northwest in recent years.

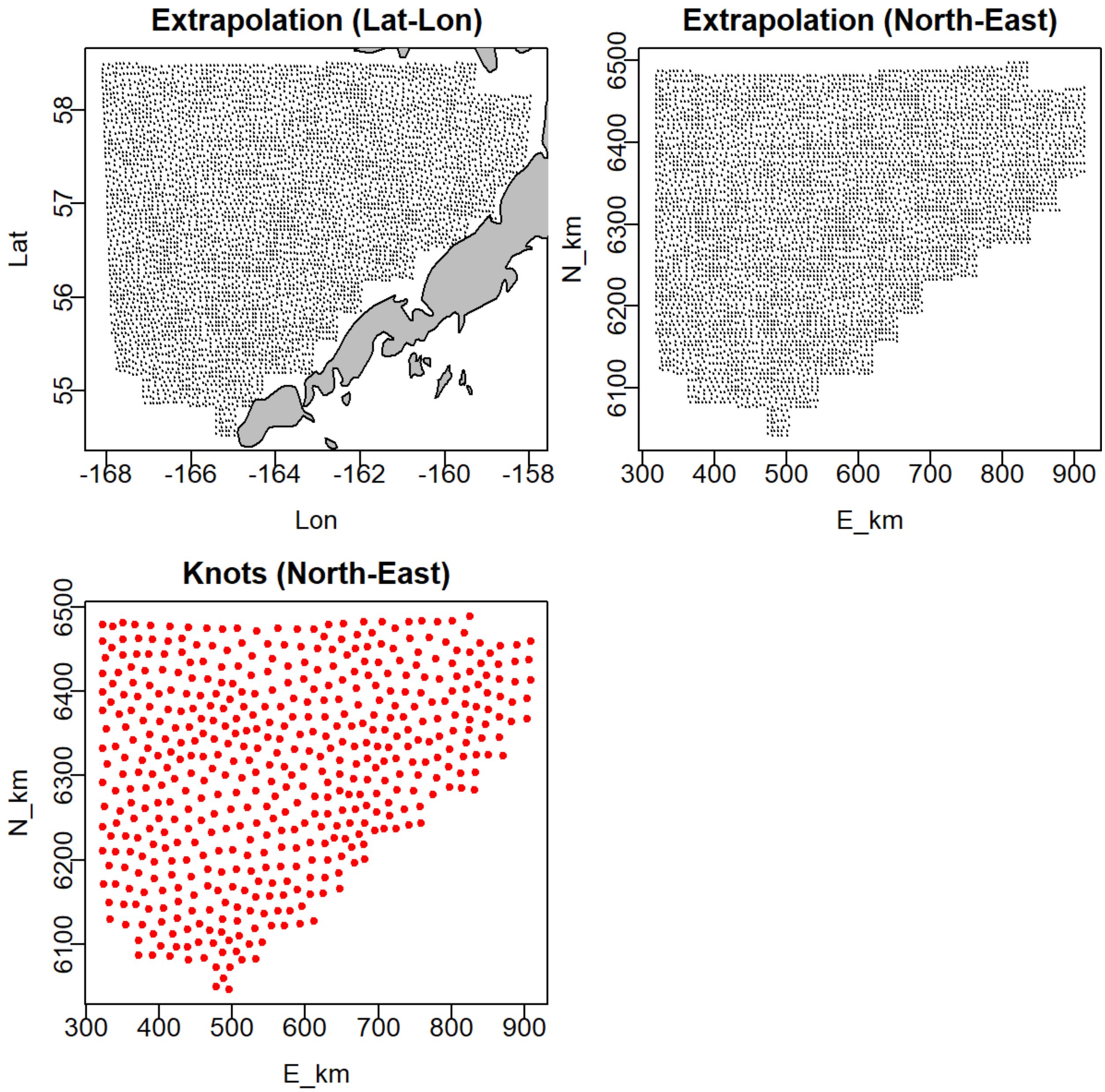

Figure E16 (file = Data_and_knots.png). Extrapolation maps for females GE65 mm: a.) Extrapolation grids by latitude and longitude, b.) Extrapolation grid by Northings/Eastings (in km), and c.) Knots used to define spatial mesh for population estimation.

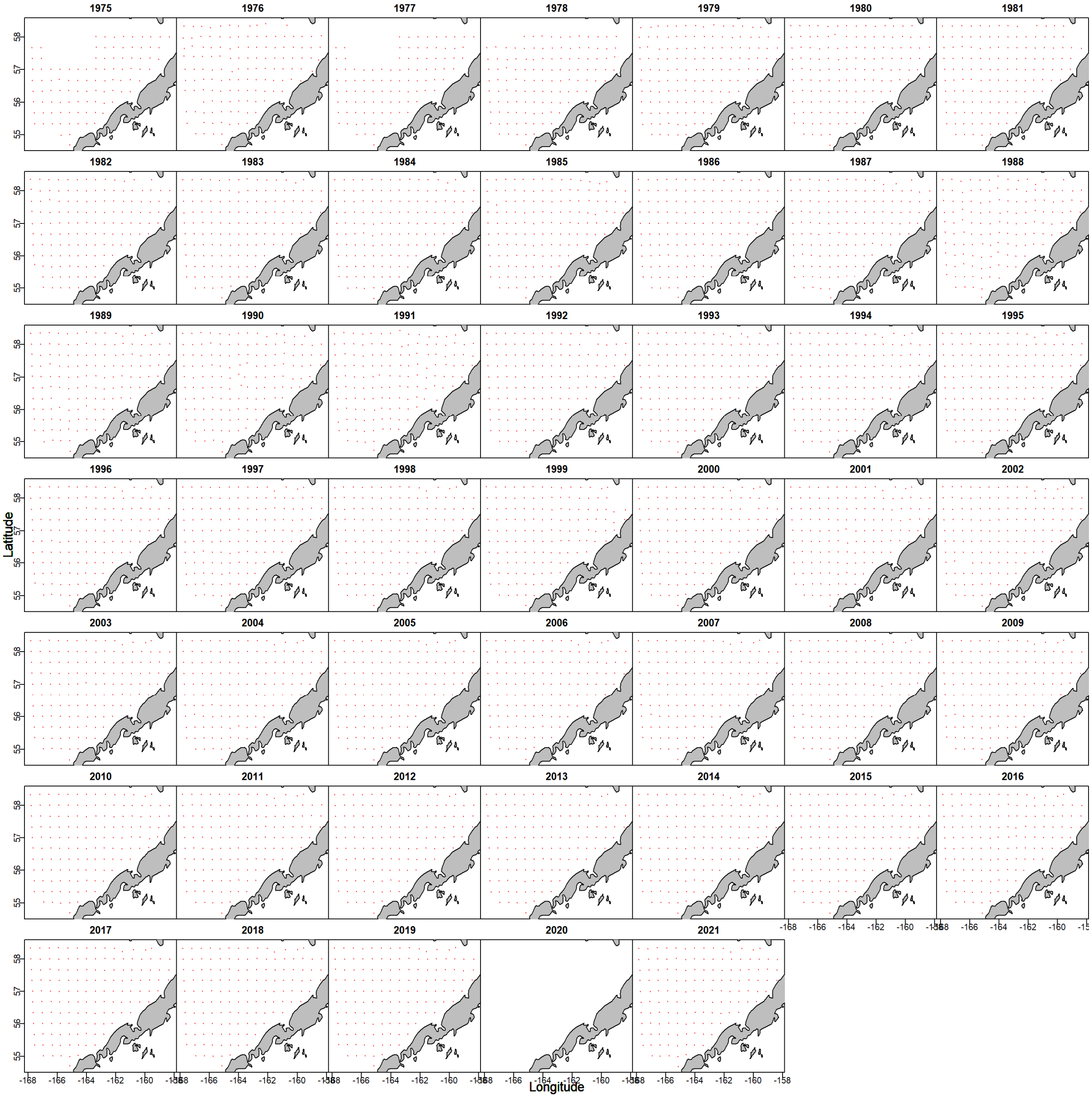

Figure E17 (file = Data_by_year.png). Data sampling locations by year for females GE65 mm. Note standardization of survey area in this subregion of the Bering Sea by 1980.

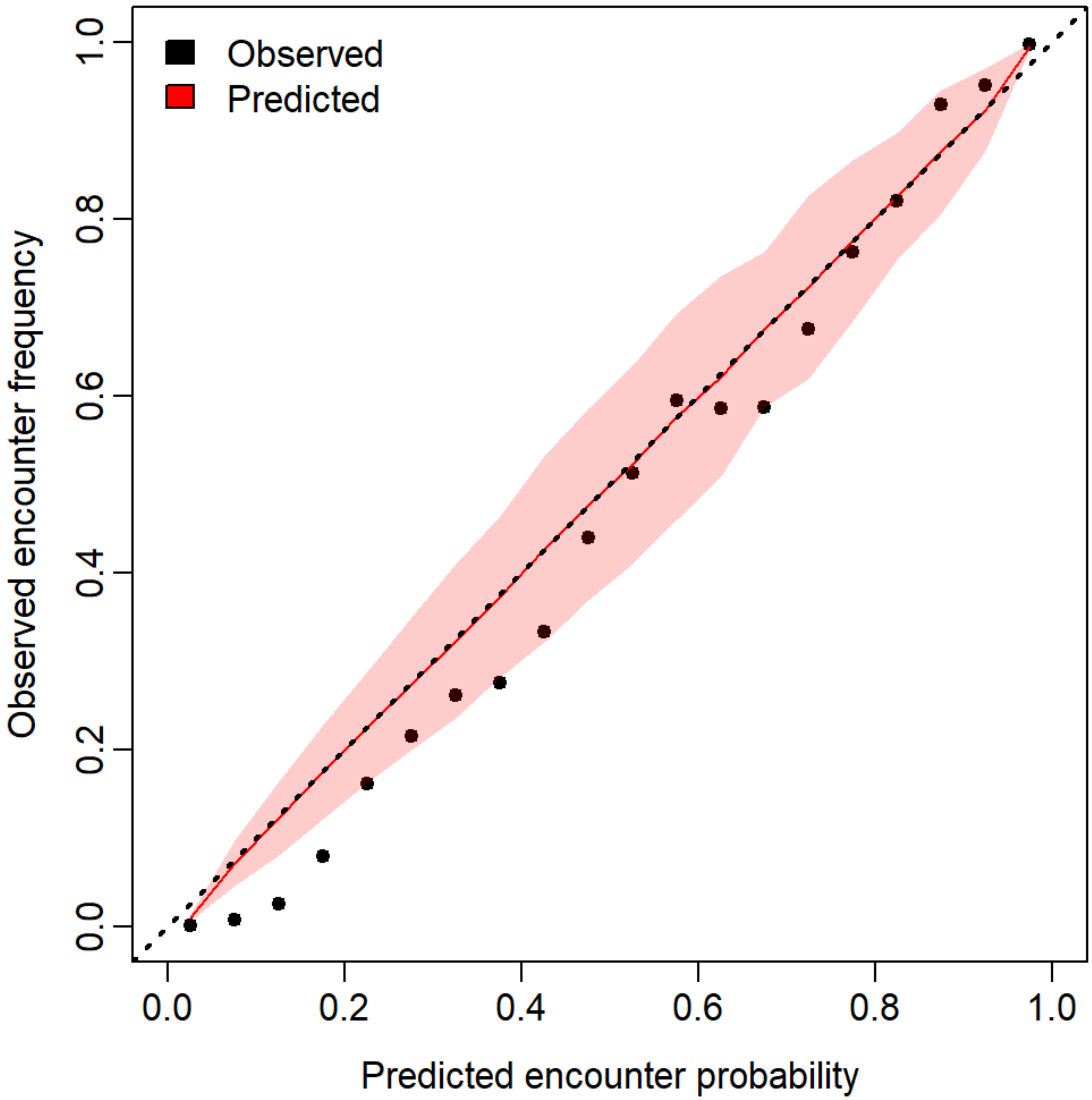

Figure E18 (file =diag--encounter_prob.png). Diagnostic plot of model predicted encounter probability vs. observed encounter frequency for female GE 65 biomass model. Shaded region is confidence interval. Results here indicate excellent model performance t high encounter rates, but poor performance at the lowest encounter rates, suggesting the model may have some difficulty with females in peripheral habitat regions.

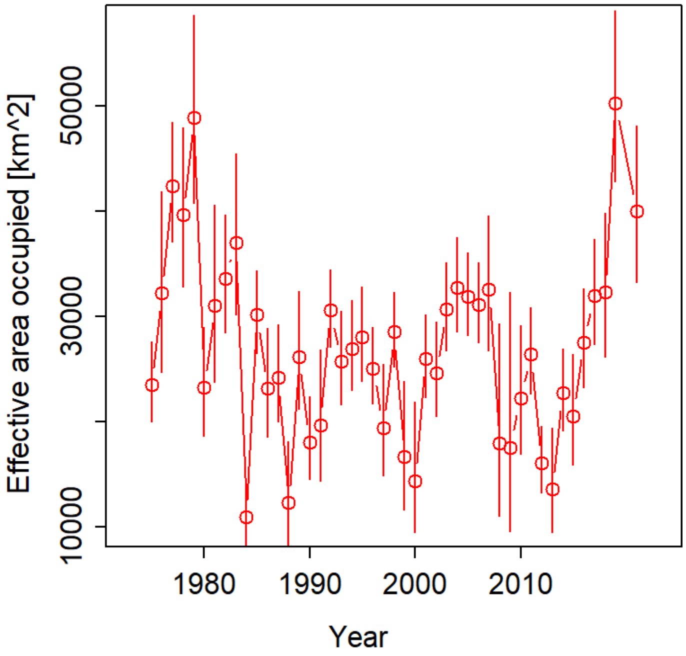

Figure E19 (file = Effective_Area.png). Effective area occupied, in ln(km2) for females GE65 mm. Note modest expansion in area occupied in recent years, despite low population sizes.

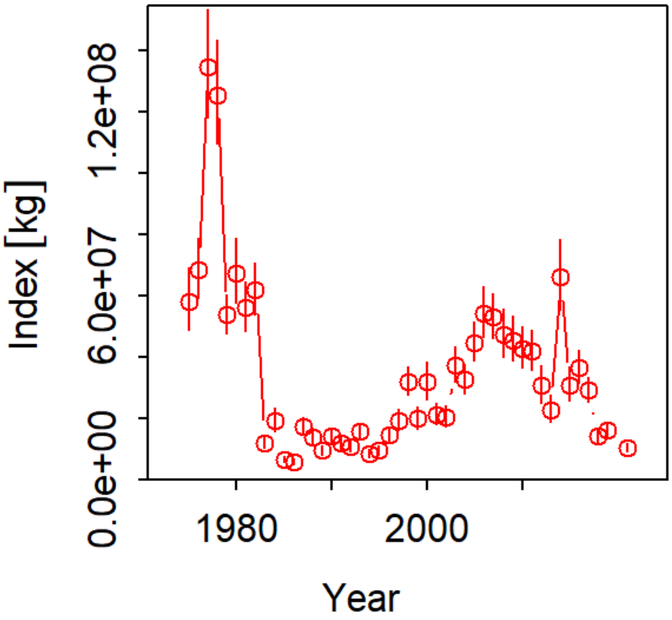

Figure E20 (file = Index-Biomass.png). Biomass estimates by year, with +/- 1SD error bars for females GE65 mm.

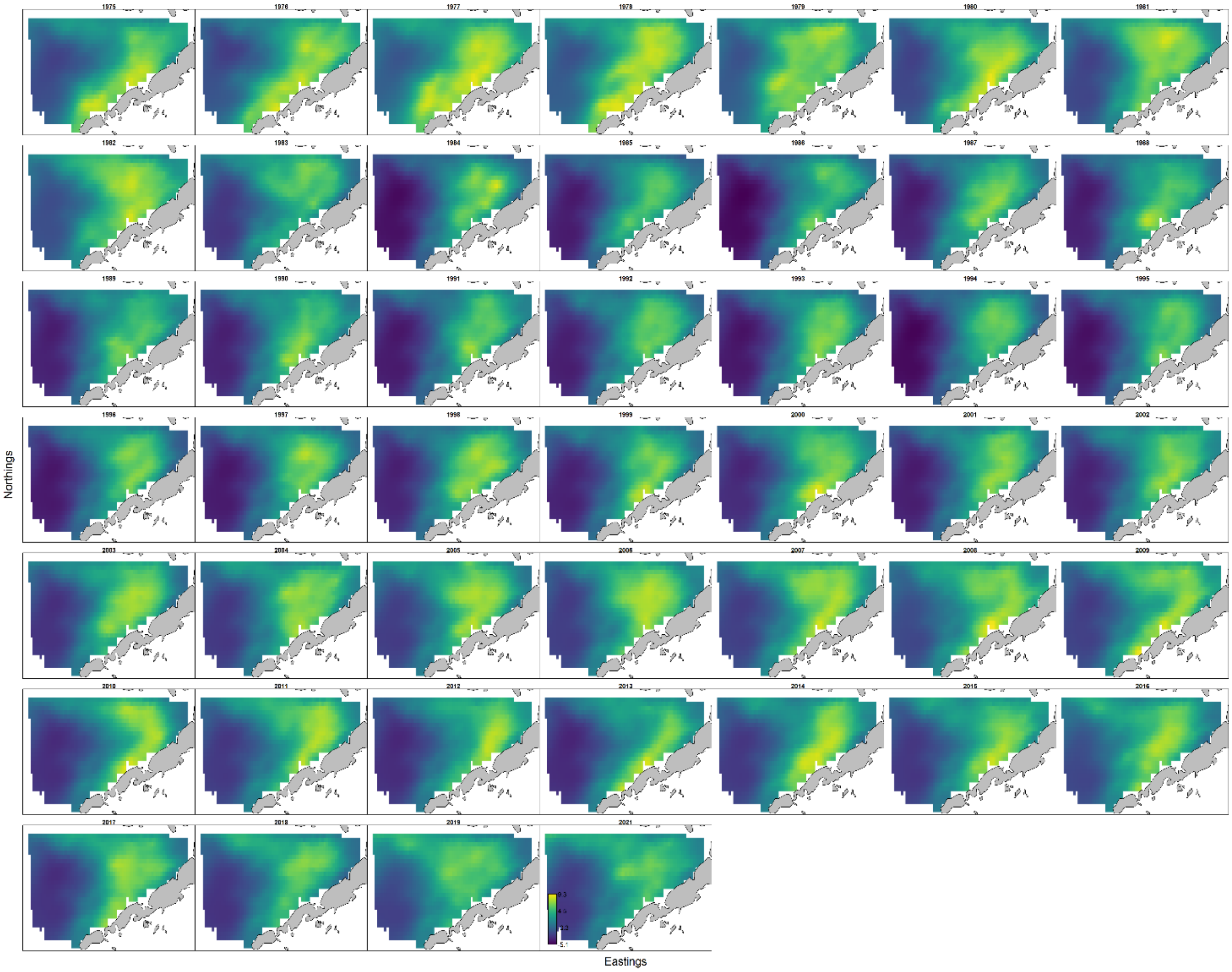

Figure E21 (file = ln_density-predicted.png). Annual log-density maps for females GE65 mm in ln(kg)/km^2.

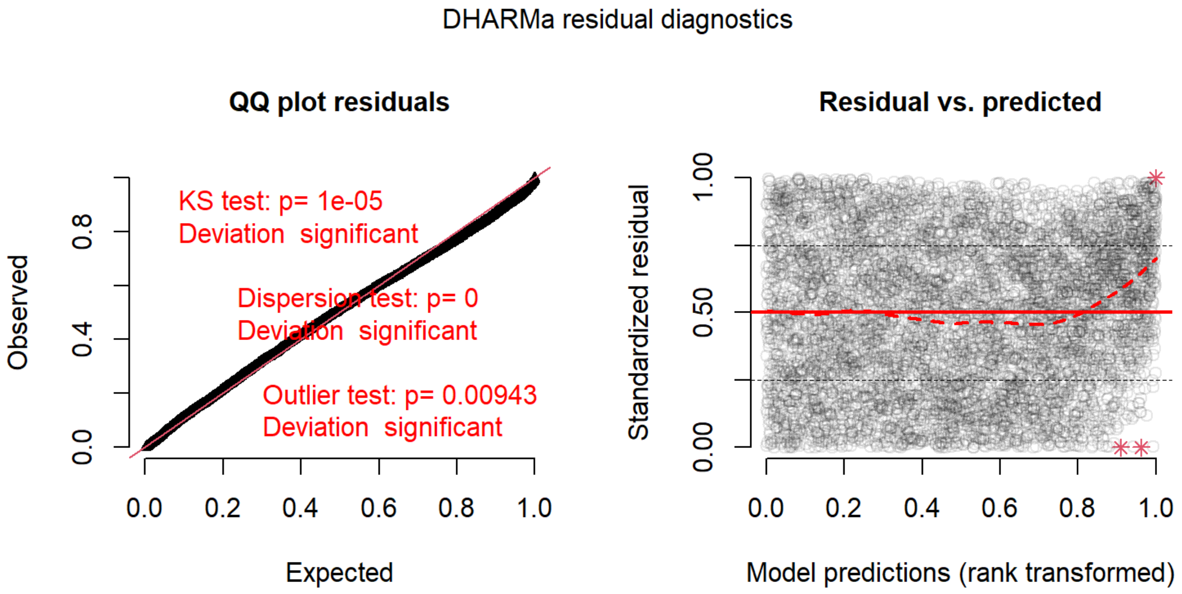

Figure E22 (file = quantile_residuals). DHARMa residual output for females GE65 mm. a.) Q-Q plot of residuals with p-values for statistical test applied automatically by DHARMa package. These p-values have no meaning here and should be ignored. This figure indicates excellent model performance. b.) Rank-transformed model predictions vs. standardized residuals. Note an indication of a trend in residuals for largest model predictions, as indicated by the dashed red line.

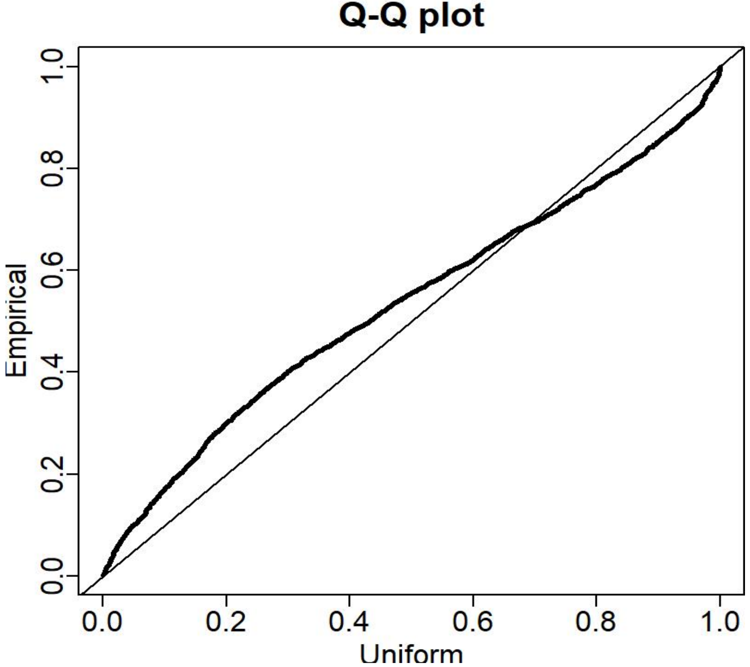

Figure E23 (file = posterior_predictive-histogram-1.png). Catch rate Q-Q plot for female GE 65 biomass model. Results indicate that relative to the observation model employed, data distribution was thin tailed and slightly right skewed.

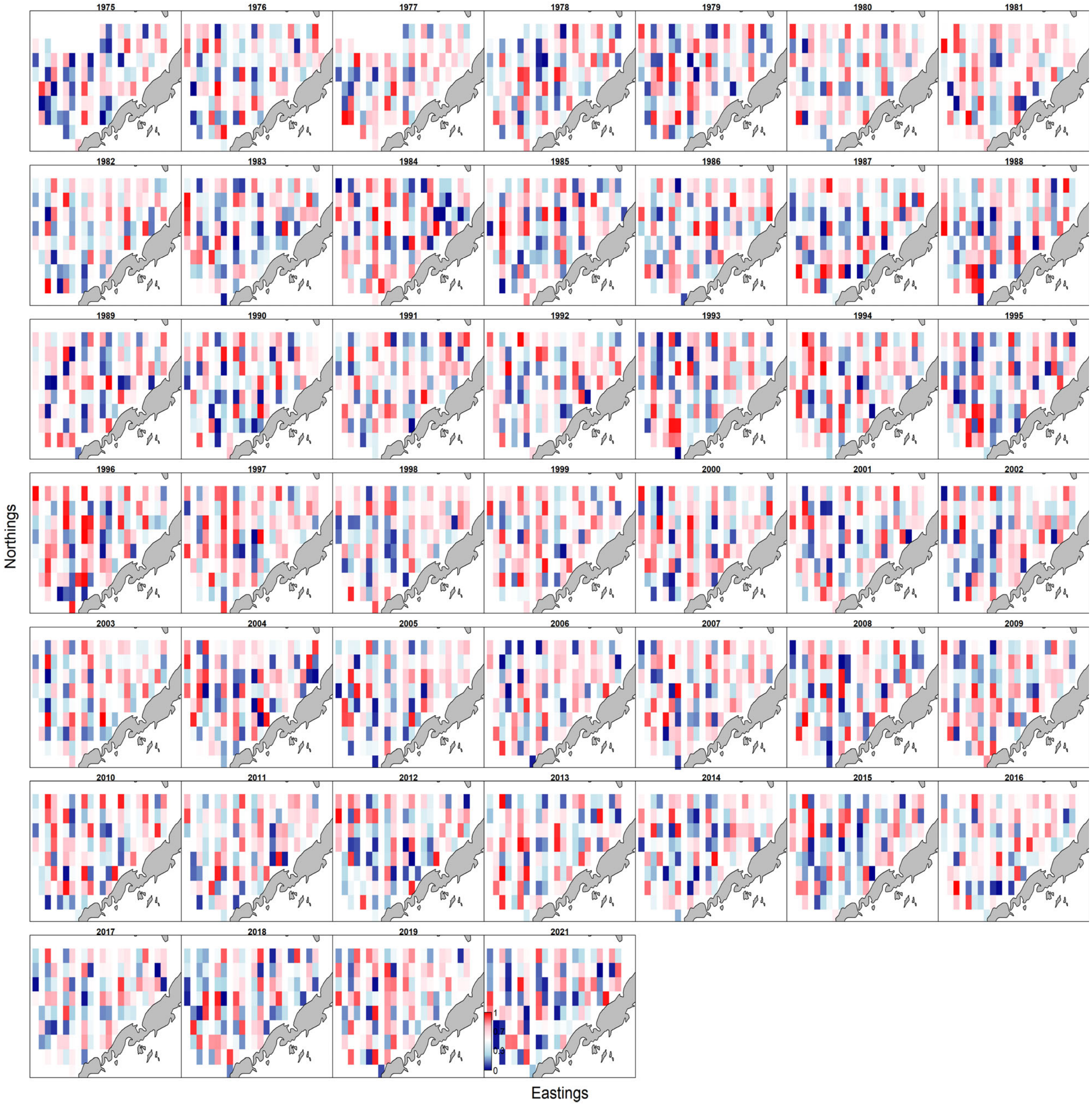

Figure E24 (file = quantile_residuals_on_map_enlarged.png). Spatial quantile residuals for females GE65 mm. Mapped quantile residuals used to assess for spatial-temporal trends in residuals. While difficult to read here, an absence of notable trends may be observed at higher resolutions. Work is underway to implement code to improve this graphic, please see Figure E9 for an example.

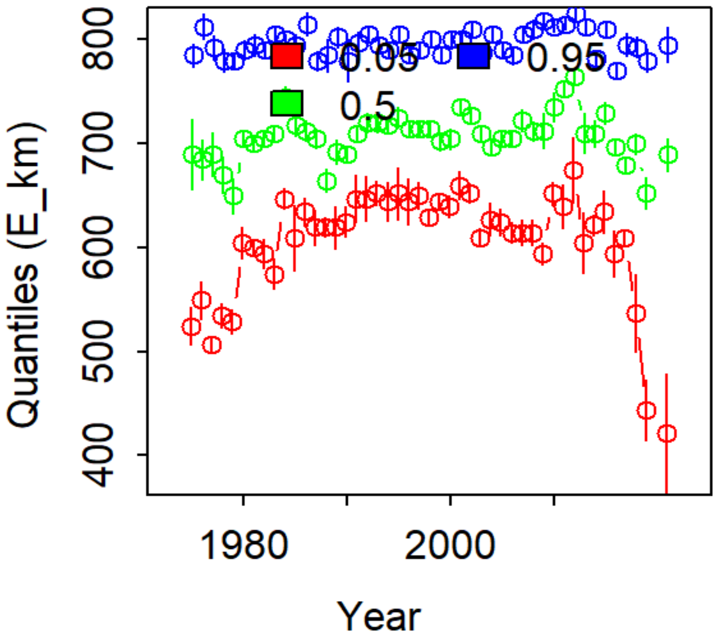

Figure E25 (file = rangeedge_E_km.png). Eastern range edge calculated for female biomass w/retow data, GE65. Blue is the eastern limit (by default the 95% quantile), green is middle (50%) and red is the western limit (by default 5%). All are calculated using methods described here: https://doi.org/10.1111/gcb.15614 . SEs are done via sampling from the joint precision of random and fixed effects.

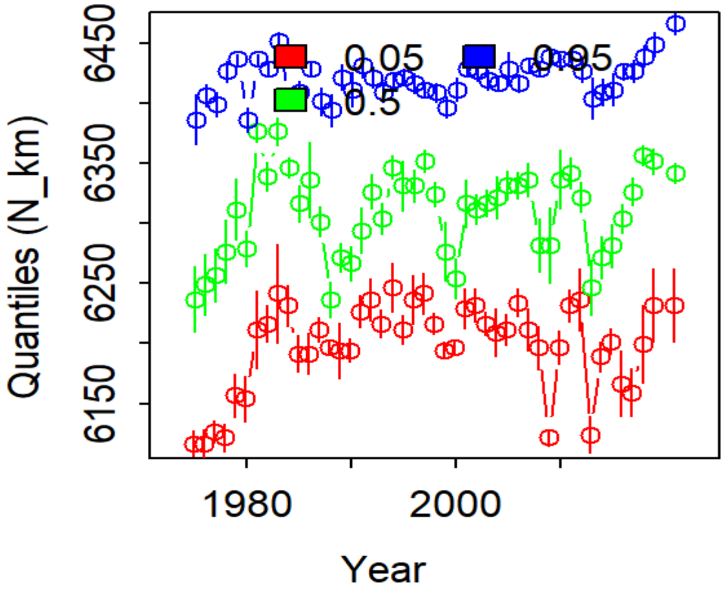

Figure E26 (file = rangeedge_N_km.png). Northern range edge calculated for female biomass w/retow data, GE65. Blue is the northern limit (by default the 95% quantile), green is middle (50%) and red is southern limit (by default 5%). All are calculated using methods described here: https://doi.org/10.1111/gcb.15614 . SEs are done via sampling from the joint precision of random and fixed effects.

Appendix F. 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.

Appendix G. Preliminary Bristol Bay Red King Crab CPUE Standardization by M.S.M. Siddeek, Tyler Jackson, and Jie Zheng

Observer data have been collected since 1990 (Zheng and Siddeek 2021), but data were not comprehensive in the initial years, so a shorter time series of data for the period 1997/98–2020/21 was selected for this analysis. The observer CPUE data collection improved over the years and the data since 1995/96 are more reliable (Siddeek *et al.* 2020). But fishery closures in 1994 and 1995 and unusually low soak time (an important predictor variable for CPUE standardization) recorded in 1996 persuaded us to consider a restricted time series 1997/98–2020/21 for standardization. Onboard observers sample several ‘count pots’ per day and categorize catch as females, sublegal males, retained legal males, and legal (unknown retained) males. Previously, observers sub-categorized legal males as retained and non-retained, though uncertainty in retention status has resulted in those subcategories being dropped prior to the 2018/19 season. As a result, we considered total number of legal male crab (i.e., retained-legal + non-retained legal + legal-unknown-retained) as the dependent variable for CPUE standardization. In addition to crab tallies, observers also record vessel, sequential pot number, sample date, Alaska Department of Fish and Game (ADF&G) statistical area, longitude, latitude, soak time (hrs), depth (fa), and biotwine status (intact / failed) for each pot sampled. Pot dimensions are inferred from a subsample of pots measured by observers during the fishing trip, assuming that the subsample is representative of all pots fished during the trip.

Data Preparation

The 1990/91–2020/21 observer database consists of 20,739 records and that of 1997/98–2020/21 contains 20,453 records after removing unusual gear (e.g., non-rectangular pots) and NAs entry in gear records. For CPUE standardization, these data were further reduced by 5% cutoff of Soak time and 1% cutoff of Depth on both ends of the variable range to remove unreliable data or data from dysfunctional pot operations and restricting to vessels to “core vessels,” which have made **three trips per year for at least three years** during 1997/98–2020/21. The cutoff points were determined separately for pre- and post-rationalization periods. We grouped the entire observer sampling locations (Figure 1) into rectangular grids identified by an AreaGP code. There are a total of 26 grids (1 to 26 AreaGp codes). We restricted the data to only grids with more than 50 observer pot samples. We considered three trips per year to capture at least a few vessels in pre- and post- rationalization periods. Out of 402 total number of vessels fished during the 1997/98–2020/21 fishing period, there were 52 core vessels in total, 25 of which fished during the pre-rationalized period and 47 of which fished during the post-rationalization period. The total number of records for core vessels reduced to 11,957 (consisting of 1,017 for pre- and 10,940 for post-rationalization periods). Figure 2 compares the CPUE trends between the observer “core vessel” and that of fishery CPUE. The trends are similar.

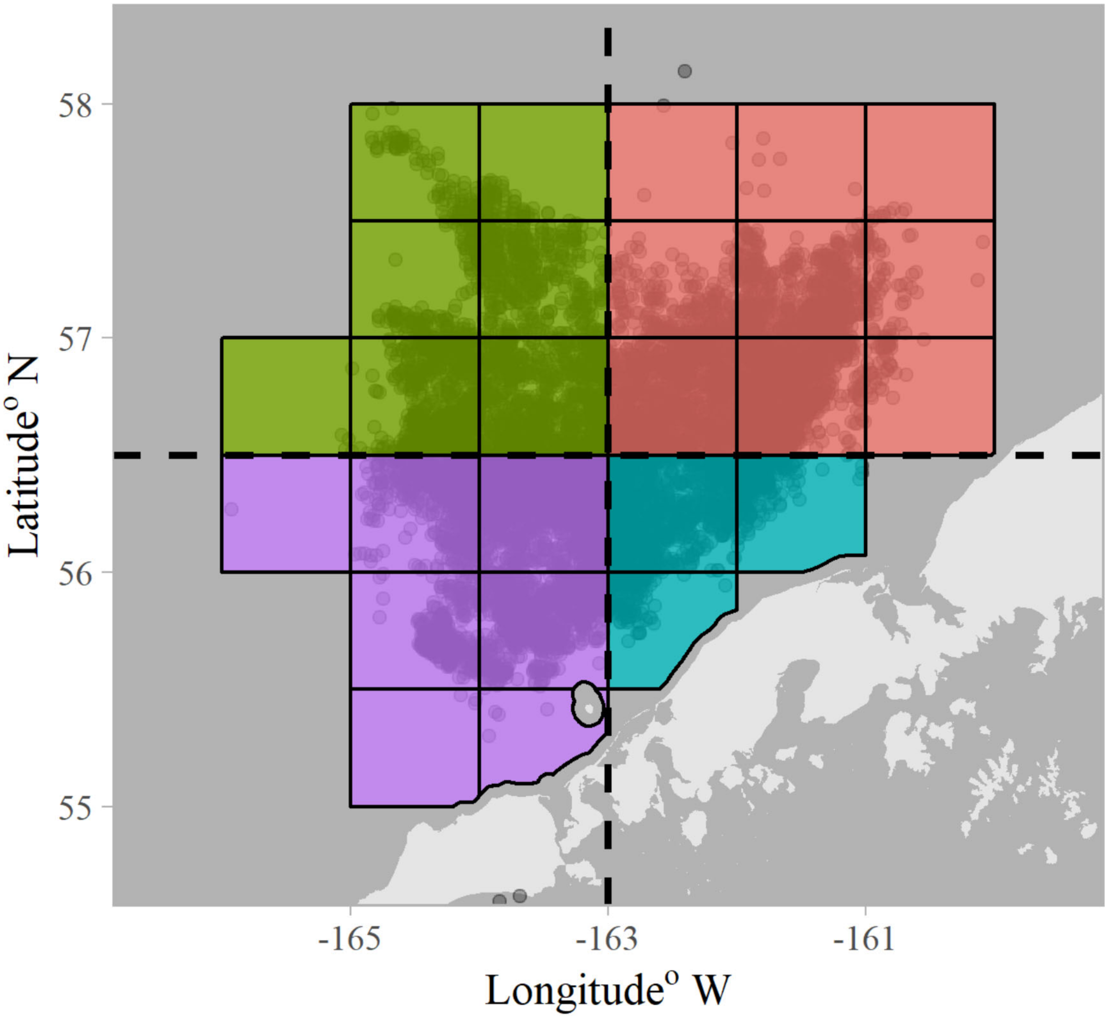

Figure 1. Map of statistical areas fishing throughout the time series (grids) for Bristol Bay red king crab. Black dots in the background indicate observer pot locations. Each grid on the map was identified by an AreaGp code (a total of 26 grids).

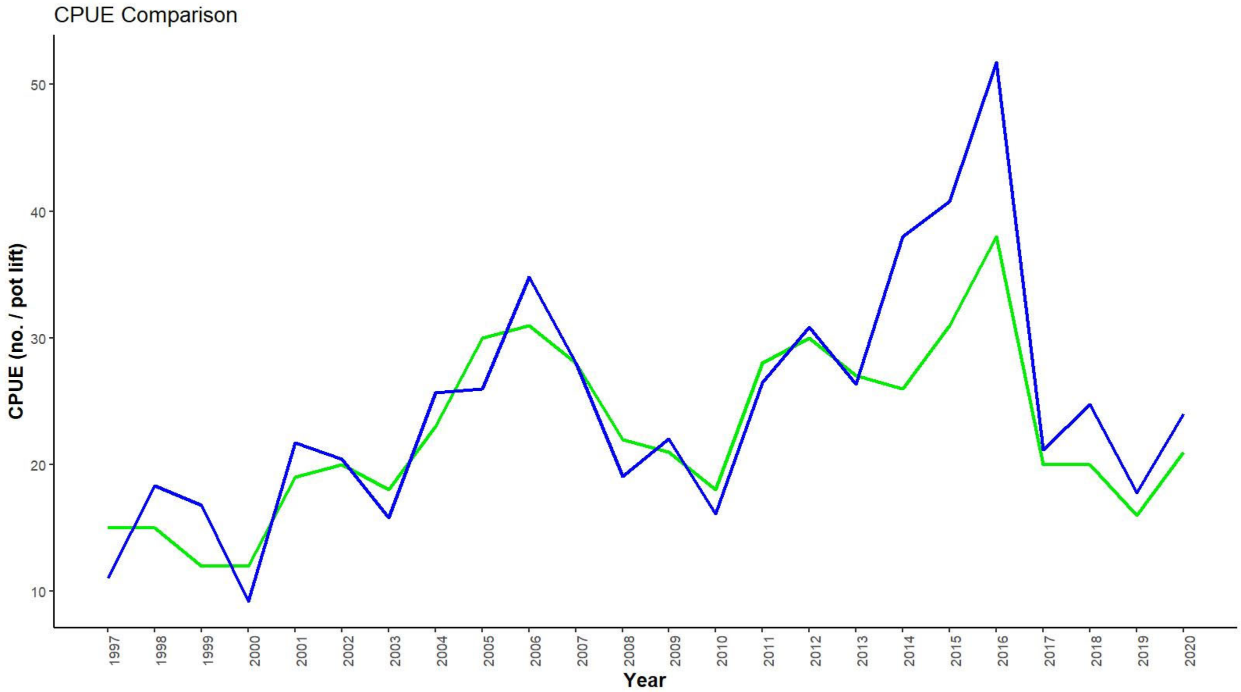

Figure 2. Comparison of observer core vessel predicted CPUE (blue line) and fishery CPUE (green line) for 1997–2020 (Zheng and Siddeek, 2021).

Month was extracted from sample date. Observers have sampled pots from September - January, though September only appears in 2006 (59 pots) and 2009 (31 pots), and January only appears in 2007 (12 pots), 2017 (12 pots), 2018 (14 pots), and 2019 (24 pots). More pots were sampled in December, though these are still proportionately very few (2005, 193 pots; 2007, 69 pots; 2008, 41 pots). Captain code was devised from permit holder names reported in fish tickets. There were 29 captains during the pre-rationalized period and 74 captains during the post rationalized period.

There was a significant change in fishing practice due to changes in management regulations before and after crab rationalization (crab rationalization was implemented in 2005). This change prompted us to consider two separate observer CPUE time series, 1997/98–2004/05 and 2005/06–2020/21, to estimate CPUE indices.

GLM Parameterization

The CPUE standardization followed the GLM fitting procedure (Maunder and Punt 2004; Starr 2012; Siddeek *et al*. 2016). We considered the negative binomial GLM on positive and zero catches to select the explanatory variables. The response variable CPUE is the observer sample total number of legal crab record for a pot haul. The negative binomial model uses the log link function for the GLM fit.

We assumed the null model to be:

$$\ln(\mathrm{CPUE_i}) = \mathrm{Year_{y_i}}$$
(1)

where Year is a factorial variable.

The maximum set of model terms offered to the stepwise selection procedure was:

$$\ln(\mathrm{CPUE_I}) = \mathrm{Year_{y_i}} + \mathrm{ns}(\mathrm{Soak_{si}}, \mathrm{df}) + \mathrm{Month_{m_i}} + \mathrm{Vessel_{vi}} + \mathrm{Captain_{ci}} + \mathrm{Area_{ai}} + \mathrm{Gear_{gi}} + \mathrm{ns}(\mathrm{Depth_{di}}, \mathrm{df}).$$
(2)

where Soak is in unit of hours and is numeric; Month, Area (AreaGP) code, Vessel code, Captain code, and Gear code are factorial variables; Depth in fathom is a numeric variable; ns = cubic spline, and df = degree of freedom. We assigned numeric codes to captain for this analysis.

We used a log link function and a dispersion parameter (θ) in the GLM fitting process. We used the R^2 criterion for predictor variable selection (Siddeek *et al*. 2016).

We calculated appropriate degrees of freedom and dispersion parameters by calculating AICs for a range of values and locating the best values at the minimum AIC. We further reduced the number of degrees of freedom of the cubic spline based on significant GLM fit of individual degree of freedom (results are available with the first author).

The final main effect models were:

Final model selection by stepCPUE:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 3) + Area \qquad (3)$$

for the 1997/98–2004/05 period [θ=1.76, $\mathrm{R}^2 = 0.2654$]

Final selection by stepCPUE:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 5) + Area \qquad (4)$$

for the 2005/06–2020/21 period [$\mathrm{q} = 1.91,\ \mathrm{R}^2 = 0.1862$].

Collinearity test by the GVIF statistics was performed on the final models (Fox and Weisberg, 2019). The GVIF values after accounting for degrees of freedom were small (< 2.5) indicating non-collinearity among predictor variables (Table 1). Note that the GVIF analysis suggested to remove the “Month” variable from the final model for the 2005/06–2020/21 data set and accordingly this variable was removed for the final GLM fit.

Table 1. Estimates of GVIF for predictor variables in the final models for pre- and post-rationalization periods for Bristol Bay red king crab.

Predictor Variable	GVIF	Df	GVIF^(1/(2*Df))

1997-2004:			
Year	2501.605	7	1.748759
Captain	86126.25	28	1.224976
ns(Soak, df = 3)	2.785245	3	1.186162
Area	342.268	13	1.251629
2005-2020:			
Year	12779.75	15	1.370516
Captain	59071.66	73	1.078154
ns(Soak, df = 5)	1.971867	5	1.070256
Area	132.2133	24	1.107116

Figures 3 and 4 compare the standardized CPUE index with that of non-standardized index for the pre- and post-rationalization periods. Figure 5 depicts the influence plot to explain the sharp rise of the index in 2001. It is influenced largely by the inclusion of Captain variable in the model which included 3 of 6 captains that fished in no other years in the pre-rationalized time series.

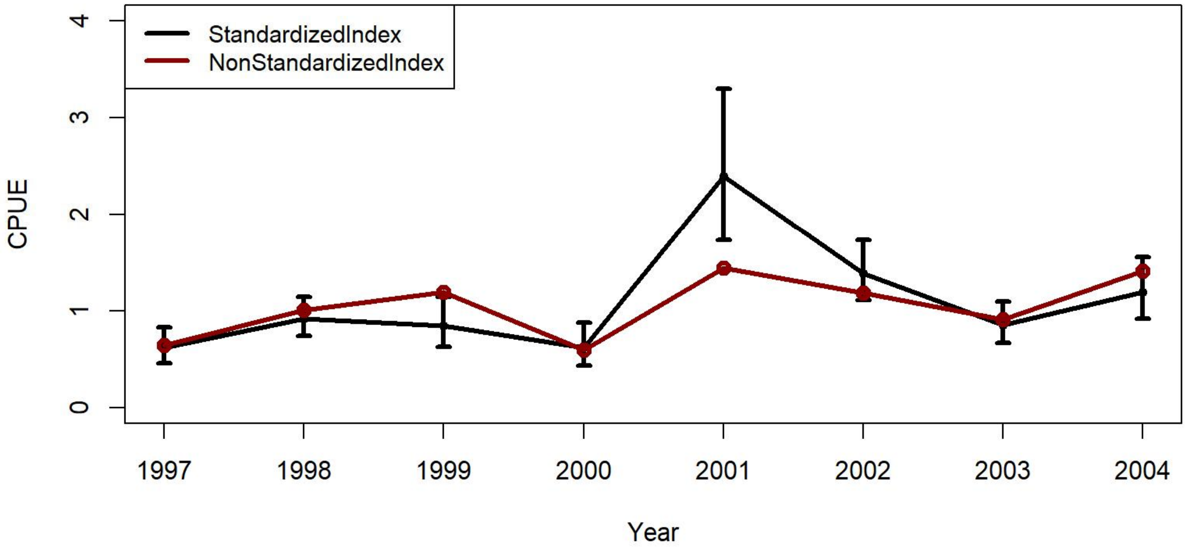

Figure 3. Comparison of standardized (black line) and non-standardized (red line) CPUE indices for the pre-rationalization period (1997–2004) for Bristol Bay red king crab. The confidence limits are determined with ±2SE for the standardized CPUE.

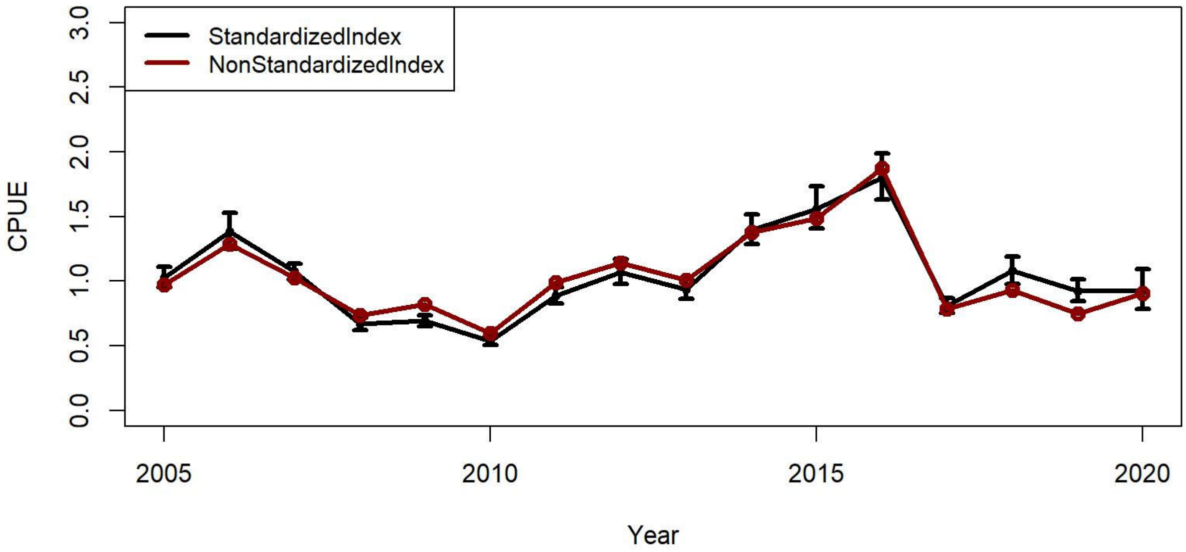

Figure 4. Comparison of standardized (black line) and non-standardized (red line) CPUE indices for the post-rationalization period (2005–2020) for Bristol Bay red king crab. The confidence limits are determined with ±2SE for the standardized CPUE.

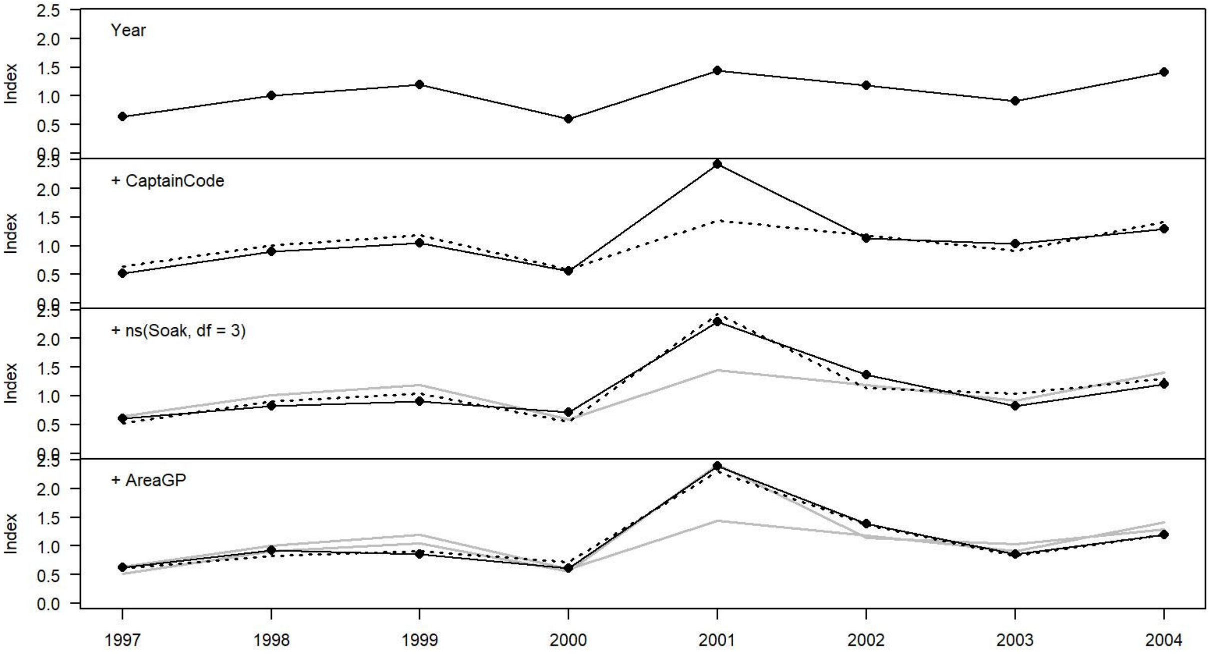

Figure 5. Step plot to demonstrate the influence of addition of each predictor variable on the year index for the 1997–04 period, Bristol Bay red king crab.

Table 2 lists the estimated CPUE indices with standard errors and variances for input to assessment model. Since the indices were estimated separately for pre-and post-rationalization periods, they may be treated differently (perhaps different catchability as in Aleutian Islands golden king crab model) for assessment model fitting.

Table 2. Time series of CPUE indices with standard errors and variances of log CPUE for 1997–2020 for Bristol Bay red king crab.

Year	CPUE Index	SE (log CPUE)	var (log CPUE)
1997	0.618291	0.146825549	0.829324
1998	0.919748	0.108070767	1.141663
1999	0.847569	0.149370374	1.142658
2000	0.61542	0.176281048	0.875563
2001	2.392181	0.160830019	3.299813
2002	1.38512	0.110822854	1.728809
2003	0.853143	0.125964609	1.097572
2004	1.192582	0.131810963	1.552307
2005	1.02907	0.03930311	1.113226
2006	1.382794	0.049456031	1.526562
2007	1.074879	0.02827801	1.137422
2008	0.67021	0.035913094	0.720119
2009	0.69392	0.029487662	0.736075
2010	0.538557	0.028807999	0.570498
2011	0.88784	0.036872467	0.955789
2012	1.071097	0.045109242	1.172223
2013	0.933593	0.040912662	1.013197
2014	1.397332	0.041636546	1.518674
2015	1.561149	0.052130719	1.732704
2016	1.80002	0.049556584	1.987567
2017	0.809307	0.035848265	0.869462
2018	1.078602	0.048973329	1.189595
2019	0.925782	0.045119843	1.01321
2020	0.926531	0.082689971	1.093159

Diagnostic

Figures 6 and 7 depict the Q-Q plots of studentized residuals for the 1997-2004 and 2005–2020 CPUE index fits:

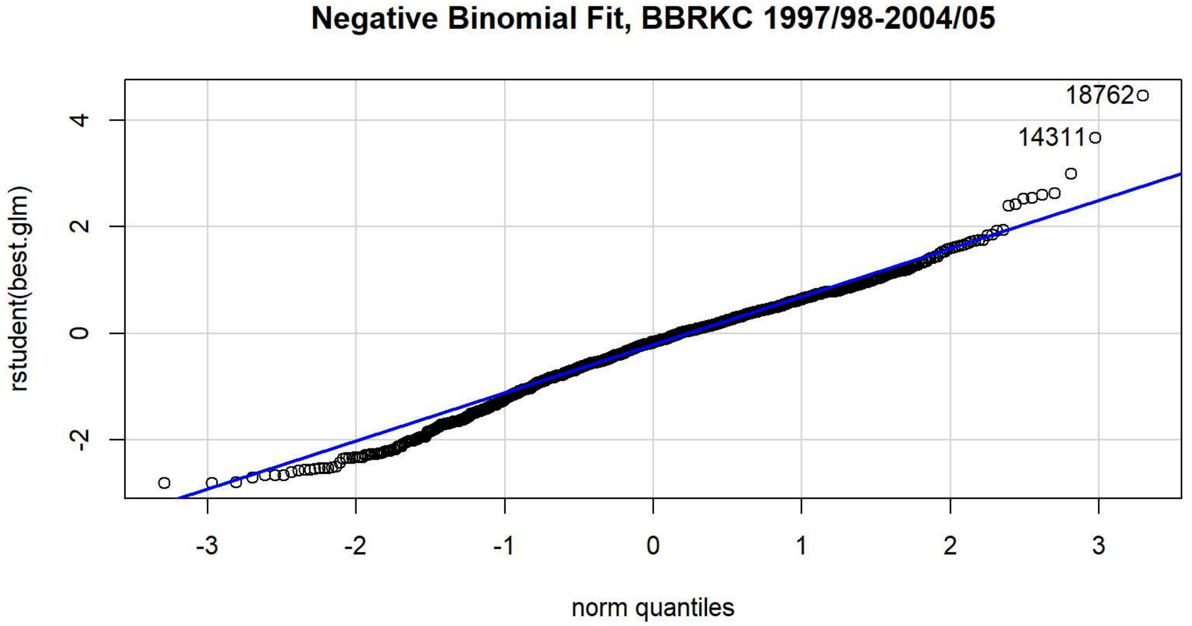

Figure 6. Q-Q plot of studentized residuals of CPUE index fit for pre-rationalization period (1997–2004) for Bristol Bay red king crab.

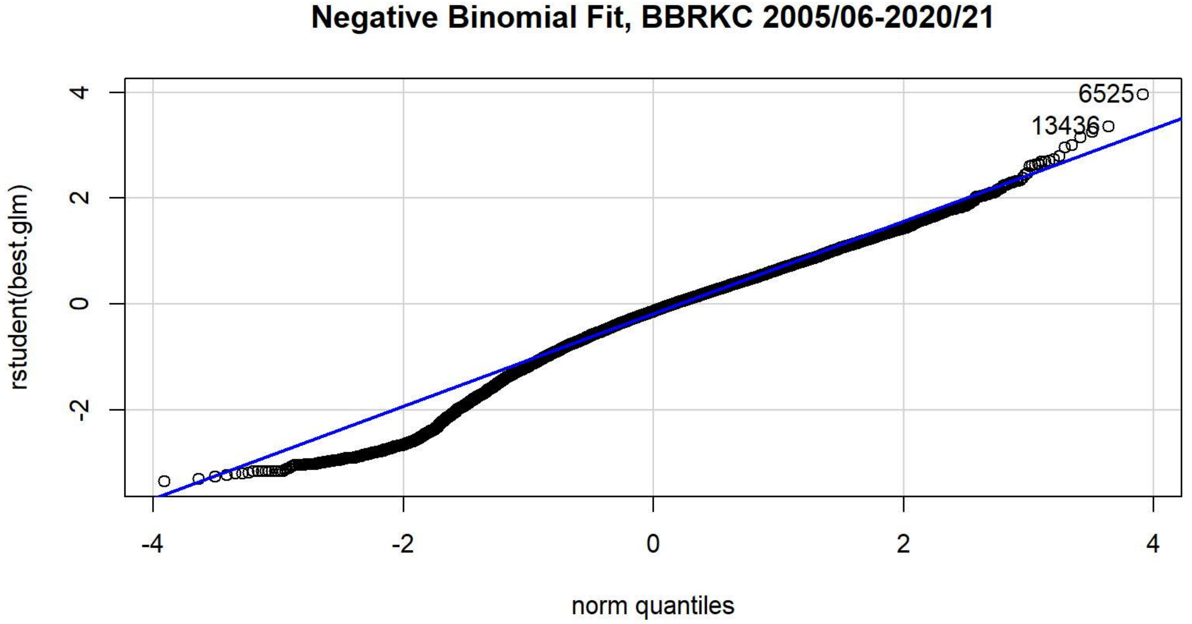

Figure 7. Q-Q plot of studentized residuals of CPUE index fit for post-rationalization period (2005–2020) for Bristol Bay red king crab.

Acknowledgments

We thank Lee Hulbert of ADF&G for helping with coding of captain in the database.

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