BRISTOL BAY RED KING CRAB STOCK ASSESSMENT IN SPRING 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 2019/20 was approximately 3.9 million lb (1,775 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.
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 1985-2009 with mature females being about three times more abundant in 2009 than in 1985 and mature males being about two times more abundant in 2009 than in 1985. Estimated mature abundance has steadily declined since 2009.
4. Recruitment: Estimated recruitment was high during the 1970s and early 1980s and has generally been low since 1985 (1979-year class). During 1984-2019, 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. Estimated recruitment for 2020 is not reliable due to the lack of trawl survey data.
5. Management performance:

Status and catch specifications (1,000 t) (model 19.3):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2016/17	12.53^A	25.81^A	3.84	3.92	4.37	6.64	5.97
2017/18	12.74^B	24.86^B	2.99	3.09	3.60	5.60	5.04
2018/19	10.62^C	16.92^C	1.95	2.03	2.65	5.34	4.27
2019/20	12.72^D	14.24^D	1.72	1.78	2.22	3.40	2.72
2020/21		14.93^D				2.14	1.61*

The stock was above MSST in 2019/20 and hence was not overfished. Since total catch was below OFL, overfishing did not occur. 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
2016/17	27.6^A	56.9^A	8.47	8.65	9.63	14.63	13.17
2017/18	28.1^B	54.8^B	6.60	6.82	7.93	12.35	11.11
2018/19	23.4^C	37.3^C	4.31	4.31	5.85	11.76	9.41
2019/20	28.0^D	31.4^D	3.80	3.91	4.89	7.50	6.00
2020/21		32.9^D				4.72	3.54*

Notes:

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2017
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2018
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2019
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2020
*ABC is calculated applying a buffer of 25% to OFL

6. Basis for the OFL: Values in 1,000 t (model 19.3):

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2016/17	3b	25.8	24.0	0.93	0.27	1984-2016	0.18
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

Basis for the OFL: Values in million lb:

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2016/17	3b	56.8	52.9	0.93	0.27	1984-2016	0.18
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

A. Summary of Major Changes

1. Changes to management of the fishery: None.

2. Changes to the input data:

a. No trawl survey was conducted in 2020.

b. Updated directed pot fishery catch and bycatch data through 2019 (i.e., completed 2019/20 fishery) (occurred in September 2020), and updated/standardized observer biomass estimates in the directed pot fishery and Tanner crab fishery from 1990 to 2019 (occurred in May 2021) (Appendix D).

c. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery were available 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 2014-2019(occurred in September 2020).

3. Changes to the assessment methodology:

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

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

19.3: the base model adopted by the CPT and SSC in September 2020. This model has a constant *M* being estimated for males during 1980-1984, while maintaining a constant (base) *M* of 0.18 for males during 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.

19.3c: the same as model 19.3 except for updating/standardizing the observer data in the directed pot and Tanner crab fisheries. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery were available 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 included.

19.3d: the same as model 19.3c except for changing the maximum cap of effective sample size from 100 to 150 for the retained catch and total males in the directed pot fishery. The computed implied effective sample sizes for these two datasets 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.

19.3f: the same as model 19.3e except for doubling the CV of the prior for trawl survey catchability.

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.

19.3i: the same as model 19.3g except for an additional CV is estimated for NMFS trawl survey biomass.

19.6: the same as model 19.3d except for base *M* is estimated from newly updated equation from Then et al. (2015) as 0.257 ($M = 4.899\ t_{max}^{-0.916}$ with max age t_{max} = 25). Conjunction with this model, a negative log likelihood profile is computed with a base *M* ranging from 0.10 to 0.4 for males.

4. Changes to assessment results:

Eight model scenarios are compared in this draft report. 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 eight models, model 19.3c is model 19.3 with updated pot fishery observer data, and model 19.3d is model 19.3c with a better cap of effective sample sizes for retained catch and total males. These three models fit the data similarly and have similar results. Thus, model 19.3d is preferred over models 19.3 and 19.3c. Model 19.3e has different NMFS survey catchabilities for males and females, thus with one additional estimated parameter over model 19.3d. Both models 19.3d and 19.3e fit the data similarly and have similar model results. The high CV value for the NMFS survey catchability prior for model 19.3f results in estimated NMFS survey catchability > 1.0 for females. Therefore, model 19.3d is preferred over models 19.3e and 19.3f. VAST-estimated NMFS survey biomasses are generally lower than area-swept estimates until 2014 (Figure 6) and higher during 2014-2019, and thus VAST models 19.3g and 19.3i result in higher mature male biomass estimates than the other models in recent years. With the declining biomass trend during recent years, higher mature male biomass during recent years with VAST models 19.3g and 19.3i would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 19.6 is like a sensitivity study, and the very high base natural mortality would result in an extremely high $F_{35\%}$ value. Overall, we recommend model 19.3d as the base model for OFL and ABC determination in September 2021.

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 2020):

"Given the above discussion, the CPT selected model 19.3 as the priority model (in addition to the status quo model, 19.0a) for presentation in September, understanding that time schedules for producing data used in the assessment may be compressed as a result of the global pandemic. Model 19.3 estimated male natural mortality in an early block (1980-1984) and then specified M as 0.18 thereafter. Female natural mortality was estimated as an offset from males in both periods. Survey selectivity was estimated separately for sexes, but a single catchability was estimated (still with a strong prior). If time allows, a model building from 19.3 in which the prior on catchability is relaxed and estimated separately by sex (and revisited in light of the catchability implied by the BSFRF data) would be useful for comparison."

Response: We used model 19.3b to examine the sensitivity of trawl survey catchability estimate when the CV of the prior on catchability was doubled in September 2020. The resulting catchability estimate was greater than 1.0. Different catchabilities for males and females in the NMFS survey were examined in model 19.5 in May 2020 with both sexes having the same survey selectivities. In this report (May 2021), we add model 19.3e with the same prior and model 19.3f with doubled CV value of the prior to examine different survey catchabilities between sexes. BSFRF survey data are used in the model, so we do not use them to estimate a prior for NMFS survey catchabilities.

"Produce the empirical survey selectivity diagnostics that were produced for Tanner crab at this meeting, but for BBRKC. Specifically, display the ratio of NMFS to BSFRF (rather than NMFS/(NMFS+BSFRF)) numbers at size to provide a direct comparison to estimated survey selectivity."

Response: Ratios of NMFS to BSFRF numbers at size are plotted in Figure 7 (a, b, and c). Note that the ratios are from combined all haul data due to small amount of crab caught. The abundance-weighted average ratio is 0.891 for crab ≥135 mm carapace length from all four years (2013-2016) of data, about the same as the double-bag experiment (0.896 at 162.5 mm carapace length), although the ratios changed greatly from year to year.

"Describe how the sex ratios for OFL calculations were averaged. It is the same as the recruitments, but was difficult to confirm in the document."

Response: We added text to explain the sex ratios for OFL calculations in Appendix A (B (b) (2) The proxy for B_{MSY}).

"Check the calculation of total male directed fishery catch as inputted to GMACS to ensure accounting for discard mortality is appropriate. Check the tables for correct numbers and that they match the .DAT files provided. Consider splitting the tables needed by the State of Alaska from those presenting the data used in the assessment. CPT suggests that the methodology for how total catches are calculated should be added to the terms of reference for all assessments."

Response: Total male directed fishery catch data in the GMACS input data file are correct. Table 2 is added to include all observer catch and discard data. Methods of bycatch estimation are added to Table 1a caption.

"Highlight the 'PriorDensity' row in the table listing the contribution of likelihoods to the objective function value. Make sure that it is clear that differences in likelihood comparability are well represented in the tables. It appears that modifications will need to be made to the way that GMACS includes or does not include prior densities so that the objective function values from models with different numbers of parameters (but fitting to identical data) are comparable."

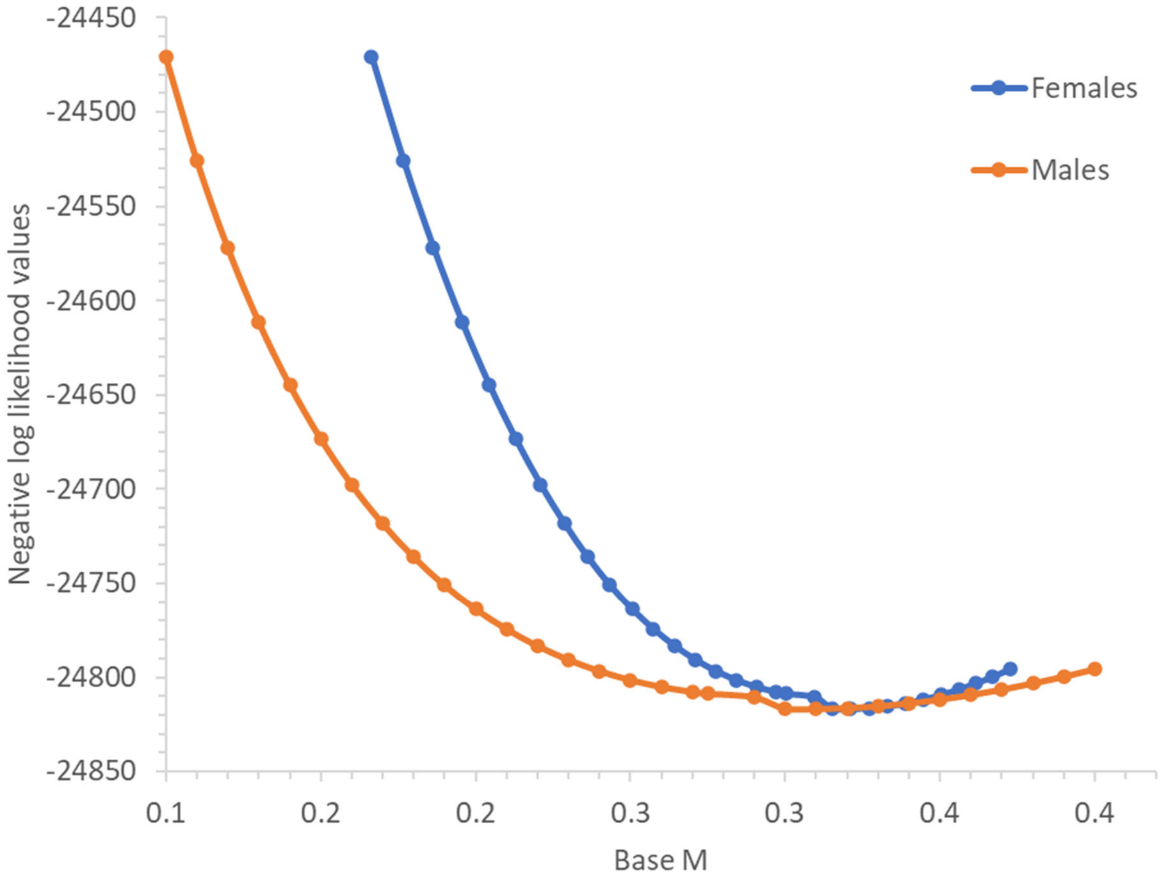
Response: The "PriorDensity" row is highlighted, and a new row is added for total negative log likelihood values without prior densities for easy comparison.

"Include diagnostics for VAST indices of abundance and provide rationale for accepting or rejecting the index in future iterations (but not for September 2020)."

Response: Diagnostics for VAST indices are illustrated in Appendix E.

"Provide justification for the assumed natural mortality for males of 0.18 yr-1. How does the 1% rule assumed in the assessment compare to empirical studies on natural mortality and longevity (e.g. Then et al. 2015)?"

Response: The 1% rule was accepted after very long, several year difficult discussions among the crab overfishing working group, CPT, and SSC. The base M for females is also higher than 0.18 for model 19.3 and the related models. Model 19.6 uses male base M of 0.257 estimated by Then et al. (2015), and we also examine a likelihood profile of base M from 0.1 to 0.4 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.

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 8.

"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 (7 years), (2) average of the period used to estimate $B_{35\%}$, (3) increase in the weight on annual recruitment variation. 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 2020):

"The SSC agrees with the CPT's model recommendations for September. Though promising, it is advisable to postpone the use of VAST estimates for this stock assessment until diagnostics for VAST can be more fully analyzed and better-fitting error distributions identified. The SSC also supports the other recommendations on this assessment offered by the CPT."

Response: We follow these suggestions.

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 and will include it September 2021 assessment document.

"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 2010-2020 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 this report (May 2021).

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. No trawl survey was conducted in 2020.

b. Updated directed pot fishery catch and bycatch data through 2019 (i.e., completed 2019/20 fishery) (occurred in September 2020), and updated/standardized observer biomass estimates in the directed pot fishery and Tanner crab fishery from 1990 to 2019 (occurred in May 2021) (Appendix D).

c. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery were available 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 2014-2019.

Data types and ranges 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 2019 (Tables 1a and 1b). Bycatch data are available starting from 1990 and were obtained from the ADF&G observer database and reports (Gaeuman 2013) (Tables 2a and 2b). Sample sizes for catch by length and shell condition are summarized in Tables 3a and 3b. 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 legal retained and discarded catch 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 1975-2019 were provided by NMFS.

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 2019. 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 2017 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 and 2012) 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 2020.

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, selectivities, catches, and bycatch of the 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) 1982-2020, 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 1994-2020) 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 of 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. 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):

19.3: the base model adopted by the CPT and SSC in September 2020. 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, 100 for males from the pot fishery and 50 for females from the pot fishery and for both males and females from the 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 (during cold years) for females.

(8) Estimating initial year length compositions.

(9) Using the 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.

19.3c: the same as model 19.3 except for updating/standardizing the observer data in the directed pot and Tanner crab fishery. Fishing effort data used to estimate red king crab bycatch in years before the observer data in the Tanner crab fishery were available 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 included.

19.3d: the same as model 19.3c except for changing the maximum cap (N) of effective sample size from 100 to 150 for the retained catch and total males in the directed pot fishery. The computed implied effective sample sizes for these two datasets 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.

19.3f: the same as model 19.3e except for doubling the CV of the prior for trawl survey catchability.

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.

19.3i: the same as model 19.3g except for an additional CV is estimated for NMFS trawl survey biomass.

19.6: the same as model 19.3d except for base M is estimated from newly updated equation from Then et al. (2015) as 0.257 ($M = 4.899\ t_{max}^{-0.916}$ with max age $t_{max} = 25$). Conjunction with this model, a negative log likelihood profile is computed with a base M ranging from 0.10 to 0.4 for males.

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 Tables 3a and 3b.

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 19.3, 19.3c, and 19.3d 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, and 6b for all eight models.

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

iii. Area-swept estimates of mature female abundance and model estimates of effective spawning biomass (Zheng et al. 1995b) during 2010-2020 for groundfish fisheries bycatch calculation are provided in Table 8.

iv. Abundance and biomass time series are provided in Tables 9a and 9b for models 19.3 and 19.3d.

v. Recruitment time series for models 19.3 and 19.3d are provided in Tables 9a and 9b.

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 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 and 9b). 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 for male retained catch and bycatch (Tables 6a and 6b for models 19.3 and 19.3d).

c. Graphs of estimates.

   i. Estimated selectivities and molting probabilities by length are provided in Figures 8a, 8b, 8c, 8d, and 8e and 9a and 9b for models 19.3 and 19.3d.

      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. Estimated survey selectivities in Figures 8a, 8b, and 8c 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 19.3f with doubled NMFS survey biomass CV values has the highest selectivities, while model 19.6 with high natural mortality results in lowest selectivities.

      For all models, estimated molting probabilities during 1975-2020 (Figures 9a and 9b) 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 10a1, 10a2, and 10a3) and BSFRF surveys (Figures 10b and 10c). Absolute mature male biomasses are illustrated in Figures 11a and 11b.

      The population biomass estimates in 2020 are slightly higher than those in 2019. Estimated population biomass increased dramatically in the mid-1970s then decreased precipitously in the early 1980s. Estimated biomass had increased during 1985-2009, declined since 2009, and then have steadily declined since the late 2000s (Figures 10a-10c, 11a, and 11b). Absolute mature male biomasses for all models have a similar trend over time (Figures 11a and 11b). Among the eight models, model estimated relative NMFS survey biomasses are similar, especially for models 19.3, 19.3c, 19.3d, 19.3e, 19.3f, and 19.3g. Absolute mature male biomass estimates are higher for model 19.6 with a high base natural mortality than for the other models and higher for models 19.3g and 19.3i (VAST model scenarios) during recent years. As expected, model 19.3f estimates a higher trawl survey catchability (>1.0 for females), thus resulting in overall lower absolute biomass estimates. All eight models fit the catch and bycatch biomasses very well.

      The fit to BSFRF survey data and estimated survey selectivities are illustrated in Figures 10b-10f.

Among the eight models, model 19.3c is model 19.3 with updated pot fishery observer data, and model 19.3d is model 19.3c with a better cap of effective sample sizes for retained and total male catches. These three models fit the data similarly and have similar model results. Thus, model 19.3d is preferred over models 19.3 and 19.3c. Model 19.3e has different NMFS survey catchabilities for males and females, thus with one additional estimated parameter over model 19.3d. Both models 19.3d and 19.3e fit the data similarly and have similar model results. The high CV value for the NMFS survey catchability prior for model 19.3f results in estimated NMFS survey catchability > 1.0 for females. Therefore, model 19.3d is preferred over models 19.3e and 19.3f. VAST-estimated NMFS survey biomasses are generally lower than area-swept estimates until 2014 (Figure 6) and higher during 2014-2019, and thus VAST models 19.3g and 19.3i result in higher mature male biomass estimates than the other models in recent years. With the declining biomass trend during recent years, higher mature male biomass during recent years with VAST models 19.3g and 19.3i would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 19.6 is like a sensitivity study, and the very high base natural mortality would result in extremely high $F_{35\%}$. Overall, we recommend model 19.3d as the base model for overfishing definition determination in September 2021.

Like the results of model 19.0 in September 2019, the terminal year recruitment analysis with model 19.3 also 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 19.3 and 19.3d. Recruitment is estimated at the end of year in GMACS and is moved up one year for the beginning of next year.

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 19.3 and 19.3d.

The average of estimated male recruits from 1984 to 2019 (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 19.3 and 19.3d, but below the $F_{35\%}$ limits in the other post-1995 years.

For model 19.3, estimated full pot fishing mortalities ranged from 0.00 to 2.24 during 1975-2019, with estimated values over 0.40 during 1975-1976, 1978-1982, 1984-1987, 1990-1991, 1993, 1998 and 2007-2008 (Table 6a, Figure 13a). For model 19.3a, estimated full pot fishing mortalities ranged from 0.00 to 2.13 during 1975-2019, with estimated values over 0.40 in the same years as model 19.3 (Table 6b, Figure 13b).

Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally less than 0.07.

For model 19.3, estimated *M* values are 0.8966 during 1980-1984 and 0.18 for the other years for males, and 1.1802 during 1980-1984 and 0.2369 for the other years for females, with estimated female *M* values equaling to 1.3163 times male *M* values (Figure 13c). For model 19.3d, estimated *M* values are 0.9069 during 1980-1984 and 0.18 for the other years for males, and 1.1894 during 1980-1984 and 0.2361 for the other years for females, with estimated female *M* values equaling to 1.3117 times male *M* values (Figure 13c). 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.

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 and 17b for models 19.3 and 19.3d.

   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 eight models fit the fishery biomass data well and the survey biomass reasonably well (Figures 10 and 16). Because the model estimates annual fishing mortality for directed pot male catch, pot female bycatch, and trawl and fixed gear bycatch, the deviations of observed and predicted (estimated) fishery biomass are mainly due to size composition differences. Models 19.3, 19.3c and 19.3d fit the NMFS area-swept biomass data almost identical (Figure 10a1).

The 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 19.3 and 19.3d (Figures 17a and 17b). Generally, residuals of proportions of survey males and females appear to be random over length and year for models 19.3 and 19.3d (Figures 25a, 25b, 26a, and 26b).

e. Retrospective and historic analyses.

Two kinds of retrospective analyses were conducted for this report: (1) the 2020 model (model 19.3) hindcast results and (2) historical results. The 2020 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 2020 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 2020 model includes sequentially excluding one-year of data. Models 19.3 and 19.3d produced some upward biases during 2009-2019 with higher terminal year estimates of mature male biomass in 2009-2010 and 2014-2019 (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. The biases for total abundance are much smaller than mature male biomass.

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 2020 assessment model results (Figure 29). 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 (Figure 29).

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 (Figure 29).

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 (Figure 29).

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 2020 model results (retrospective analysis) performed reasonably well. No great overestimates or underestimates occurred as was observed in 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 2020 as a function of number of years estimated in the model show converging to 1.0 as the number of years increases (Figure 28). Standard deviations of the ratios drop sharply from one year estimated in the model to two years (Figure 28), 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 19.3 and 19.3d. Estimated standard deviations of mature male biomass are listed in Table 9.
  ii. Probabilities for mature male biomass and OFL in 2020 were illustrated in Figures 30a and 30b for model 19.3 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 2020 were plotted in Figure 31for model 19.3d 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 rates.
  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 (May 2021), eight models are compared. For negative likelihood value comparisons (Tables 5b and 5c), model 19.6 has a higher total likelihood value than the other models due to the high base natural mortality. In fact, the highest total likelihood value is resulted from a base $M = 0.31$ for males. Between two pairs of models (models 19.3e and 19.3f and models 19.3g and 19.3i), either estimating additional CV for NMFS biomass or increased the CV value for the NMFS survey catchability prior increases the total likelihood value. Model 19.3d has similar total likelihood value to those of models 19.3e and 19.3f.

Among the eight models, model 19.3c is model 19.3 with updated pot fishery observer data, and model 19.3d is model 19.3c with a better cap of effective sample sizes for retained and total male catches. These three models fit the data similarly and have close model results. Thus, model 19.3d is preferred over models 19.3 and 19.3c. Model 19.3e has different NMFS survey catchabilities for males and females, thus with one additional estimated parameter over model 19.3d. Both models 19.3d and 19.3e fit the data similarly and have similar model results. The high CV value for the NMFS survey catchability prior for model 19.3f results in estimated NMFS survey catchability >1.0 for females. Therefore, model 19.3d is preferred over models 19.3e and 19.3f. VAST-estimated NMFS survey biomasses are generally lower than area-swept estimates until 2014 (Figure 6) and higher during 2014-2019, and thus VAST models 19.3g and 19.3i result in higher mature male biomass estimates than the other models in recent years. With the declining biomass trend during recent years, higher mature male biomass during recent years with VAST models 19.3g and 19.3i would increase the risk of overfishing the stock. Thus, we suggest not adopting VAST models now. Model 19.6 is like a sensitivity study, and the very high base natural mortality would result in an extremely high $F_{35\%}$ value. Overall, we recommend model 19.3d as the base model for overfishing definition determination in September 2021.

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 2015 to 2019 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 2014-2019 are used for per recruit analysis and projections. For the models in 2020, the averages are the same since they are constant over time during at least last 15 years.

Average recruitment during 1984-2019 is used to estimate $B_{35\%}$ (Figure 12a). Estimated $B_{35\%}$ is compared with historical mature male biomass in Figure 13a. The period of 1984-2019 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 2020 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 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 model 19.3d are used for estimating the probability of estimated mature male biomass below the minimum threshold (0.5*$B_{35\%}$) (Figure 31). The probability (converted to a percentage) is estimated to be about 10.1%.

Status and catch specifications (1,000 t) (model 19.3):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2016/17	12.53^A	25.81^A	3.84	3.92	4.37	6.64	5.97
2017/18	12.74^B	24.86^B	2.99	3.09	3.60	5.60	5.04
2018/19	10.62^C	16.92^C	1.95	2.03	2.65	5.34	4.27
2019/20	12.72^D	14.24^D	1.72	1.78	2.22	3.40	2.72
2020/21		14.93^D				2.14	1.61

The stock was above MSST in 2019/20 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):

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2016/17	27.6[A]	56.9[A]	8.47	8.65	9.63	14.63	13.17
2017/18	28.1[B]	54.8[B]	6.60	6.82	7.93	12.35	11.11
2018/19	23.4[C]	37.3[C]	4.31	4.31	5.85	11.76	9.41
2019/20	28.0[D]	31.4[D]	3.80	3.91	4.89	7.50	6.00
2020/21		32.9[D]				4.72	3.54

Notes:

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2017

B – Calculated from the assessment reviewed by the Crab Plan Team in September 2018

C – Calculated from the assessment reviewed by the Crab Plan Team in September 2019

D – Calculated from the assessment reviewed by the Crab Plan Team in September 2020

Basis for the OFL: Values in 1,000 t (model 19.3):

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2016/17	3b	25.8	24.0	0.93	0.27	1984-2016	0.18
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

Basis for the OFL: Values in million lb:

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	Natural Mortality
2016/17	3b	56.8	52.9	0.93	0.27	1984-2016	0.18
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

4. Based on the $B_{35\%}$ estimated from the average male recruitment during 1984-2019, the biological reference points and OFL are illustrated in Table 4.

5. 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).

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 2012-2019, 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 corresponds to estimated F_{ofl} in 2020. MCMC runs with 400,000 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 due to low recruitments (Table 10; Figure 32). Due to the poor recruitment in recent years, the projected biomass and retained catch are expected to decline during the next few years with fishing mortalities of 0.167 and 0.25.

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 2012-2019 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 2016-2019 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 (19.3). 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. 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 results were estimated in 2020.

Year	Retained Catch				Pot Bycatch		Trawl Bycatch	Fixed Bycatch	Tanner Fishery Bycatch	Total Catch
	U.S.	Cost-Recovery	Foreign	Total	Males	Females				
1953	1331.3		4705.6	6036.9						6036.9
1954	1149.9		3720.4	4870.2						4870.2
1955	1029.2		3712.7	4741.9						4741.9
1956	973.4		3572.9	4546.4						4546.4
1957	339.7		3718.1	4057.8						4057.8
1958	3.2		3541.6	3544.8						3544.8
1959	0.0		6062.3	6062.3						6062.3
1960	272.2		12200.7	12472.9						12472.9
1961	193.7		20226.6	20420.3						20420.3
1962	30.8		24618.7	24649.6						24649.6
1963	296.2		24930.8	25227.0						25227.0
1964	373.3		26385.5	26758.8						26758.8
1965	648.2		18730.6	19378.8						19378.8
1966	452.2		19212.4	19664.6						19664.6
1967	1407.0		15257.0	16664.1						16664.1
1968	3939.9		12459.7	16399.6						16399.6
1969	4718.7		6524.0	11242.7						11242.7
1970	3882.3		5889.4	9771.7						9771.7
1971	5872.2		2782.3	8654.5						8654.5
1972	9863.4		2141.0	12004.3						12004.3
1973	12207.8		103.4	12311.2						12311.2
1974	19171.7		215.9	19387.6						19387.6
1975	23281.2		0	23281.2						23281.2
1976	28993.6		0	28993.6			682.8			29676.4
1977	31736.9		0	31736.9			1249.9			32986.8
1978	39743.0		0	39743.0			1320.6			41063.6
1979	48910.0		0	48910.0			1331.9			50241.9
1980	58943.6		0	58943.6			1036.5			59980.1
1981	15236.8		0	15236.8			219.4			15456.2
1982	1361.3		0	1361.3			574.9			1936.2
1983	0.0		0	0.0			420.4			420.4
1984	1897.1		0	1897.1			1094.0			2991.1
1985	1893.8		0	1893.8			390.1			2283.8
1986	5168.2		0	5168.2			200.6			5368.8
1987	5574.2		0	5574.2			186.4			5760.7
1988	3351.1		0	3351.1			598.4			3949.4
1989	4656.0		0	4656.0			175.2			4831.2
1990	9236.2	36.6	0	9272.8	526.9	648.0	259.9			10707.6
1991	7791.8	93.4	0	7885.1	407.8	47.3	349.4		1401.8	10091.5
1992	3648.2	33.6	0	3681.8	552.0	400.2	293.5		244.4	5172.0
1993	6635.4	24.1	0	6659.6	763.2	634.9	401.4		54.6	8513.6
1994	0.0	42.3	0	42.3			87.3		10.8	146.2
1995	0.0	36.4	0	36.4			82.1		0.0	123.3

1996	3812.7	49.0	0	3861.7	164.6	1.0	90.8	41.4	0.0	4159.6
1997	3971.9	70.2	0	4042.1	244.7	37.0	57.5	22.5	0.0	4403.7
1998	6693.8	85.4	0	6779.2	959.7	579.4	186.1	18.5	0.0	8522.8
1999	5293.5	84.3	0	5377.9	314.2	5.6	150.5	50.1	0.0	5898.3
2000	3698.8	39.1	0	3737.9	360.8	166.7	81.7	4.7	0.0	4351.9
2001	3811.5	54.6	0	3866.2	417.9	122.3	192.8	35.3	0.0	4634.4
2002	4340.9	43.6	0	4384.5	442.7	9.2	151.2	29.2	0.0	5016.8
2003	7120.0	15.3	0	7135.3	918.9	360.9	136.9	12.7	0.0	8564.7
2004	6915.2	91.4	0	7006.7	345.5	174.6	173.5	15.2	0.0	7715.5
2005	8305.0	94.7	0	8399.7	1359.5	410.3	124.7	19.9	0.0	10314.1
2006	7005.3	137.9	0	7143.2	563.8	37.5	151.7	19.6	3.8	7919.6
2007	9237.9	66.1	0	9303.9	1001.3	163.3	154.1	32.3	1.8	10656.8
2008	9216.1	0.0	0	9216.1	1165.5	146.9	136.6	15.6	4.0	10684.6
2009	7226.9	45.5	0	7272.5	888.1	93.7	95.1	5.8	1.6	8356.9
2010	6728.5	33.0	0	6761.5	797.5	121.8	83.3	2.4	0.0	7766.5
2011	3553.3	53.8	0	3607.1	395.0	24.7	56.3	10.9	0.0	4093.9
2012	3560.6	61.1	0	3621.7	205.2	12.0	34.2	18.4	0.0	3891.5
2013	3901.1	89.9	0	3991.0	310.6	102.9	67.1	55.5	28.5	4555.5
2014	4530.0	8.6	0	4538.6	584.7	72.4	34.8	118.8	42.0	5391.3
2015	4522.3	91.4	0	4613.7	266.1	216.3	45.3	77.4	84.2	5303.1
2016	3840.4	83.4	0	3923.9	237.4	105.4	67.3	28.9	0.0	4362.9
2017	2994.1	99.6	0	3093.7	225.2	53.3	91.8	127.6	0.0	3591.6
2018	1954.1	72.4	0	2026.5	279.6	114.8	78.3	148.0	0.0	2647.2
2019	1719.8	55.5	0	1775.3	273.8	43.3	80.8	45.1	0.0	2218.3

Table 1a (19.3d). 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 and are used for models 19.3c-19.6 in 2021.

Year	Retained Catch				Pot Bycatch	Trawl Bycatch	Fixed Bycatch	Tanner Fishery Bycatch
	U.S.	Cost-Recovery	Foreign	Total	Females			
1953	1331.3		4705.6	6036.9				
1954	1149.9		3720.4	4870.2				
1955	1029.2		3712.7	4741.9				
1956	973.4		3572.9	4546.4				
1957	339.7		3718.1	4057.8				
1958	3.2		3541.6	3544.8				
1959	0.0		6062.3	6062.3				
1960	272.2		12200.7	12472.9				
1961	193.7		20226.6	20420.3				
1962	30.8		24618.7	24649.6				
1963	296.2		24930.8	25227.0				
1964	373.3		26385.5	26758.8				
1965	648.2		18730.6	19378.8				
1966	452.2		19212.4	19664.6				
1967	1407.0		15257.0	16664.1				
1968	3939.9		12459.7	16399.6				
1969	4718.7		6524.0	11242.7				
1970	3882.3		5889.4	9771.7				
1971	5872.2		2782.3	8654.5				
1972	9863.4		2141.0	12004.3				
1973	12207.8		103.4	12311.2				
1974	19171.7		215.9	19387.6				
1975	23281.2		0	23281.2				
1976	28993.6		0	28993.6		682.8		
1977	31736.9		0	31736.9		1249.9		
1978	39743.0		0	39743.0		1320.6		
1979	48910.0		0	48910.0		1331.9		
1980	58943.6		0	58943.6		1036.5		
1981	15236.8		0	15236.8		219.4		
1982	1361.3		0	1361.3		574.9		
1983	0.0		0	0.0		420.4		
1984	1897.1		0	1897.1		1094.0		
1985	1893.8		0	1893.8		390.1		
1986	5168.2		0	5168.2		200.6		
1987	5574.2		0	5574.2		186.4		
1988	3351.1		0	3351.1		598.4		
1989	4656.0		0	4656.0		175.2		
1990	9236.2	36.6	0	9272.8	648.0	259.9		
1991	7791.8	93.4	0	7885.1	47.3	349.4		1401.8
1992	3648.2	33.6	0	3681.8	400.2	293.5		244.4

1993	6635.4	24.1	0	6659.6	634.9	401.4		54.6
1994	0.0	42.3	0	42.3		87.3		10.8
1995	0.0	36.4	0	36.4		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	37.0	57.5	22.5	0.0
1998	6693.8	85.4	0	6779.2	579.4	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	166.7	81.7	4.7	0.0
2001	3811.5	54.6	0	3866.2	122.3	192.8	35.3	0.0
2002	4340.9	43.6	0	4384.5	9.2	151.2	29.2	0.0
2003	7120.0	15.3	0	7135.3	360.9	136.9	12.7	0.0
2004	6915.2	91.4	0	7006.7	174.6	173.5	15.2	0.0
2005	8305.0	94.7	0	8399.7	410.3	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	163.3	154.1	32.3	1.8
2008	9216.1	0.0	0	9216.1	146.9	136.6	15.6	4.0
2009	7226.9	45.5	0	7272.5	93.7	95.1	5.8	1.6
2010	6728.5	33.0	0	6761.5	121.8	83.3	2.4	0.0
2011	3553.3	53.8	0	3607.1	24.7	56.3	10.9	0.0
2012	3560.6	61.1	0	3621.7	12.0	34.2	18.4	0.0
2013	3901.1	89.9	0	3991.0	102.9	67.1	55.5	28.5
2014	4530.0	8.6	0	4538.6	72.4	34.8	118.8	42.0
2015	4522.3	91.4	0	4613.7	216.3	45.3	77.4	84.2
2016	3840.4	83.4	0	3923.9	105.4	67.3	28.9	0.0
2017	2994.1	99.6	0	3093.7	53.3	91.8	127.6	0.0
2018	1954.1	72.4	0	2026.5	114.8	78.3	148.0	0.0
2019	1719.8	55.5	0	1775.3	43.3	80.8	45.1	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					0.015		
1995					0.014		
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

Table 2a (19.3). Total observer catch and bycatch (metric ton) of Bristol Bay red king crab. No handling mortality rates are applied. These results were estimated in 2020.

	Total	Pot Bycatch		Trawl	Fixed	Tanner
Year	Males	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	11,782.900	2,634.570	3,240.200	324.883		
1991	9,974.000	2,039.120	236.600	436.783		5,607.344
1992	6,013.700	2,760.045	2,001.200	366.816		977.750
1993	9,667.700	3,815.785	3,174.400	501.770		218.570
1994	42.300	19.060	9.383	109.129		43.366
1995	36.400	16.369	8.058	102.623		0.000
1996	3,902.300	823.180	5.200	113.495	82.859	0.000
1997	3,847.200	1,223.435	184.800	71.862	44.979	0.000
1998	17,681.400	4,798.560	2,897.100	232.580	36.916	0.000
1999	12,245.200	1,570.855	28.200	188.101	100.242	0.000
2000	6,672.300	1,804.165	833.700	102.161	9.446	0.000
2001	5,797.000	2,089.375	611.400	241.011	70.553	0.000
2002	7,065.300	2,213.290	46.100	189.018	58.382	0.000
2003	12,300.600	4,594.290	1,804.700	171.114	25.351	0.000
2004	10,816.800	1,727.745	873.000	216.889	30.422	0.000
2005	13,753.300	6,797.650	2,051.400	155.924	39.802	0.000
2006	9,170.400	2,818.755	187.700	189.660	39.134	15.232
2007	13,956.600	5,006.550	816.700	192.571	64.655	7.169
2008	15,068.700	5,827.550	734.400	170.754	31.158	15.938
2009	12,300.300	4,440.620	468.500	118.906	11.616	6.499
2010	10,087.400	3,987.380	609.200	104.086	4.736	0.000
2011	5,732.600	1,974.810	123.400	70.419	21.706	0.000
2012	4,568.100	1,025.775	59.800	42.786	36.895	0.000
2013	5,260.700	1,552.895	514.300	83.868	110.970	113.848
2014	8,312.700	2,923.280	362.200	43.460	237.651	168.080
2015	6,706.400	1,330.705	1,081.600	56.686	154.810	336.715
2016	5,557.200	1,187.083	527.000	84.127	57.896	0.000
2017	4,075.760	1,126.025	266.546	114.784	255.155	0.000
2018	3,060.344	1,398.089	574.045	97.891	295.916	0.000
2019	3,143.250	1,369.039	216.739	101.001	90.109	0.000

Table 2b (19.3d). 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 and are used for models 19.3c-19.6 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	11,621.800	3,196.200	324.883		
1991	9,792.900	233.900	436.783		5,580.843
1992	5,916.200	1,976.300	366.816		962.846
1993	9,516.800	3,141.500	501.770		218.112
1994			109.129		39.395
1995			102.623		0.000
1996	3,845.200	5.100	113.495	82.859	0.000
1997	3,758.800	182.700	71.862	44.979	0.000
1998	15,644.800	2,769.300	232.580	36.916	0.000
1999	12,112.300	28.000	188.101	100.242	0.000
2000	6,579.700	821.900	102.161	9.446	0.000
2001	5,711.500	604.000	241.011	70.553	0.000
2002	6,961.400	45.600	189.018	58.382	0.000
2003	12,166.500	1,784.400	171.114	25.351	0.000
2004	10,692.000	859.200	216.889	30.422	0.000
2005	13,615.900	2,027.100	155.924	39.802	0.000
2006	9,254.000	187.400	189.660	39.134	15.217
2007	13,871.900	799.400	192.571	64.655	7.142
2008	14,895.900	723.000	170.754	31.158	16.070
2009	12,215.600	441.100	118.906	11.616	6.499
2010	10,092.100	592.200	104.086	4.736	0.000
2011	5,668.700	124.700	70.419	21.706	0.000
2012	4,506.400	55.800	42.786	36.895	0.000
2013	5,317.900	490.200	83.868	110.970	113.063
2014	8,113.800	424.300	43.460	237.651	137.786
2015	6,734.900	1,193.000	56.686	154.810	639.573
2016	5,651.800	617.200	84.127	57.896	0.000
2017	4,077.200	266.900	114.784	255.155	0.000

2018	3,423.200	750.400	97.891	295.916	0.000
2019	3,144.600	218.000	101.001	90.109	0.000

Table 3a (19.3). 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. The data were compiled in 2020.

Year	Trawl Survey		Retained Catch	Pot Total	Pot Bycatch	Trawl & Fixed Gear Bycatch		Tanner Fishery Bycatch	
	Males	Females		Males	Females	Males	Females	Males	Females
1975	2,815	2,042	29,570						
1976	2,699	1,466	26,450			676	2,327		
1977	2,734	2,424	32,596			689	14,014		
1978	2,735	2,793	27,529			1,456	8,983		
1979	1,158	1,456	27,900			2,821	7,228		
1980	1,917	1,301	34,747			39,689	47,463		
1981	591	664	18,029			49,634	42,172		
1982	1,911	1,948	11,466			47,229	84,240		
1983	1,343	733	0			104,910	204,464		
1984	1,209	778	4,404			147,134	357,981		
1985	790	414	4,582			30,693	169,767		
1986	959	341	5,773			1,199	927		
1987	1,123	1,011	4,230			723	275		
1988	708	478	9,833			437	194		
1989	764	403	32,858			3,140	1,566		
1990	729	535	7,218	2,571	1,416	756	375		
1991	1,180	490	36,820	5,024	366	236	90	885	2,198
1992	509	357	23,552	4,769	3,238	212	228	280	685
1993	725	576	32,777	10,334	6,187	24	3	232	265
1994	416	239	0	0	0	327	245		
1995	685	407	0	0	0	120	40		
1996	755	753	8,896	1,778	11	1,035	971		
1997	1,280	702	15,747	11,089	939	1,200	445		
1998	1,067	1,123	16,131	31,432	10,236	1,623	913		
1999	765	618	17,666	13,519	57	2,025	843		
2000	734	730	14,091	32,711	8,470	957	661		
2001	599	736	12,854	26,460	5,474	3,444	2,406		
2002	972	826	15,932	32,612	714	3,262	1,435		
2003	1,360	1,250	16,212	45,583	12,971	1,518	1,008		
2004	1,852	1,271	20,038	38,782	6,667	1,656	1,508		
2005	1,198	1,563	21,938	94,794	26,824	1,814	1,871		
2006	1,178	1,432	18,027	66,529	3,646	1,461	1,979		
2007	1,228	1,305	22,387	111,575	12,457	1,018	1,099		
2008	1,228	1,183	14,567	90,331	8,737	1,794	979		
2009	837	941	16,708	92,616	6,050	1,424	853		
2010	708	1,004	20,137	66,659	6,862	612	843		
2011	531	912	10,706	40,226	1,752	563	1,071		
2012	585	707	8,956	20,161	562	1,507	1,752		
2013	647	569	10,197	30,261	6,070	4,806	4,198	218	596
2014	1,107	1,257	9,618	28,540	1,953	1,966	2,580	256	381
2015	615	681	11,746	22,022	5,927	1,150	3,731	726	2,163

2016	378	812	10,811	26,510	4,315	1,935	3,011
2017	385	508	9,867	27,219	3,834	996	1,137
2018	285	359	7,626	22,480	7,386	2,806	3,389
2019	273	299	8,034	21,712	2,819	713	909

Table 3b (19.3d). 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	2,483	696	1,131		
1991	1,180	490	36,928	4,693	375	326		3,086
1992	509	357	25,550	4,747	2,379	440		965
1993	725	576	32,942	10,199	5,944	27		497
1994	416	239	0	0	0	572		13
1995	685	407	0	0	0	160		
1996	755	753	8,896	642	11	1,226	780	
1997	1,280	702	16,143	9,971	903	349	1,296	
1998	1,067	1,123	17,116	24,479	9,600	1,445	1,091	
1999	765	618	18,685	6,887	40	643	2,225	
2000	734	730	14,143	32,709	8,470	734	884	
2001	599	736	13,735	25,135	5,435	802	5,048	
2002	972	826	16,837	32,315	705	1,142	3,555	
2003	1,360	1,250	18,178	44,600	12,473	525	2,001	
2004	1,852	1,271	22,465	38,738	6,666	666	2,498	
2005	1,198	1,563	27,971	94,591	26,775	1,043	2,642	
2006	1,178	1,432	18,451	73,112	3,980	1,180	2,260	140
2007	1,228	1,305	22,809	115,364	12,661	1,265	852	53
2008	1,228	1,183	24,997	89,765	8,488	1,609	1,164	144
2009	837	941	19,336	97,574	6,039	1,188	1,089	193
2010	708	1,004	20,347	69,264	6,868	907	548	
2011	531	912	10,904	43,012	1,920	443	1,191	
2012	585	707	9,084	21,364	563	282	2,977	
2013	647	569	10,396	32,474	6,030	481	8,523	814
2014	1,107	1,257	9,718	31,192	2,663	261	4,285	637
2015	615	681	11,971	24,589	7,422	409	4,472	2,889
2016	378	812	11,003	30,005	5,734	617	4,329	

2017	385	508	10,067	29,821	3,939	718	1,415
2018	285	359	7,825	25,573	9,718	893	5,302
2019	273	299	8,134	25,991	2,879	713	909

Table 4. Comparison of harmonic means of implied sample sizes and maximum caps (N) of effective sample sizes for models 19.3, 19.3c and 19.3d.

	Model 19.3		Model 19.3c		Model 19.3d	
	Harmonic mean	N	Harmonic mean	N	Harmonic mean	N
Retained catch	177.9	100	182.5	100	190.7	150
Pot total males	199.2	100	225.7	100	238.4	150
Pot total females	30.4	50	30.0	50	30.0	50
Trawl bycatch	62.0	50	61.7	50	61.7	50
Tanner fishery bycatch	65.6	50	25.5	50	25.4	50
Fixed gear bycatch	46.0	50	46.8	50	46.8	50
NMFS survey	181.1	200	180.6	200	179.4	200
BSFRF survey	133.5	200	133.4	200	132.1	200

Table 5a. Number of parameters for the model (Models 19.3, 19.3c, 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6). Red values indicate different values among models.

Parameter counts	**19.3**	**19.3c**	**19.3d**	**19.3e**	**19.3f**	**19.3g**	**19.3i**	**19.6**
Fixed growth parameters	9	9	9	9	9	9	9	9
Fixed recruitment parameters	2	2	2	2	2	2	2	2
Fixed length-weight relationship parameters	6	6	6	6	6	6	6	6
Fixed mortality parameters	4	4	4	4	4	4	4	4
Fixed survey catchability parameter	1	1	1	1	1	1	1	1
Fixed high grading parameters	0	0	0	0	0	0	0	0
Total number of fixed parameters	22	22	22	22	22	22	22	22
Free survey catchability parameter	1	1	1	2	2	1	1	1
Free growth parameters	6	6	6	6	6	6	6	6
Initial abundance (1975)	1	1	1	1	1	1	1	1
Recruitment-distribution parameters	2	2	2	2	2	2	2	2
Mean recruitment parameters	1	1	1	1	1	1	1	1
Male recruitment deviations	45	45	45	45	45	45	45	45
Female recruitment deviations	45	45	45	45	45	45	45	45
Natural mortality parameters	2	2	2	2	2	2	2	2
Mean & offset fishing mortality parameters	6	6	6	6	6	6	6	6
Pot male fishing mortality deviations	45	45	45	45	45	45	45	45
Bycatch mortality from the Tanner crab fishery	50	50	50	50	50	50	50	50
Pot female bycatch fishing mortality deviations	30	30	30	30	30	30	30	30
Trawl bycatch fishing mortality deviations	44	44	44	44	44	44	44	44
Fixed gear bycatch fishing mortality deviations	24	24	24	24	24	24	24	24
Initial (1975) length compositions	35	35	35	35	35	35	35	35
Survey extra CV	1	1	1	1	1	1	2	1
Free selectivity parameters	28	28	28	28	28	28	28	28
Total number of free parameters	366	366	366	367	367	366	367	366
Total number of fixed and free parameters	388	388	388	389	389	388	389	388

Table 5b. Negative log likelihood components for Models 119.3, 19.3c, 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6 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							
	19.3	19.3c	19.3d	19.3e	19.3f	19.3g	19.3i	19.6
Pot-ret-catch	-59.87	-58.38	-57.32	-57.03	-57.67	-54.05	-56.74	-59.19
Pot-totM-catch	25.90	28.58	30.61	31.17	29.99	32.61	31.40	28.20
Pot-F-discC	-52.21	-52.21	-52.21	-52.21	-52.21	-52.19	-52.21	-52.23
Trawl-discC	-60.98	-60.98	-60.98	-60.98	-60.98	-60.97	-60.98	-60.98
Tanner-M-discC	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54
Tanner-F-discC	-43.49	-43.47	-43.47	-43.48	-43.47	-43.44	-43.48	-43.51
Fixed-discC	-33.27	-33.27	-33.27	-33.27	-33.27	-33.26	-33.27	-33.27
Traw-suv-bio	-33.82	-33.68	-33.38	-30.19	-30.59	104.60	-61.31	-35.71
BSFRF-sur-bio	-4.80	-4.71	-4.59	-3.02	-3.84	-6.19	-5.81	-6.56
Pot-ret-comp	-3643.89	-3645.56	-3787.11	-3787.12	-3787.02	-3789.11	-3788.56	-3793.65
Pot-totM-comp	-2150.62	-2150.73	-2223.64	-2223.09	-2224.19	-2219.77	-2224.48	-2224.66
Pot-discF-comp	-1353.14	-1346.66	-1346.70	-1346.68	-1346.74	-1345.73	-1346.88	-1346.10
Trawl-disc-comp	-5583.78	-5583.87	-5582.35	-5582.80	-5583.19	-5586.35	-5589.49	-5588.38
TC-disc-comp	-790.17	-1272.75	-1273.08	-1272.84	-1273.43	-1271.77	-1274.29	-1276.23
Fixed-disc-comp	-3168.76	-3171.53	-3171.32	-3171.47	-3170.67	-3169.04	-3171.91	-3171.00
Trawl-sur-comp	-6717.35	-6714.06	-6710.20	-6708.68	-6711.97	-6696.49	-6701.23	-6715.51
BSFRF-sur-comp	-851.44	-851.60	-851.13	-850.76	-851.97	-852.22	-852.22	-858.23
Recruit-dev	67.03	67.22	67.11	67.05	67.09	67.93	65.71	68.79
Recruit-sex-R	73.72	73.71	73.73	73.74	73.74	73.87	73.75	73.74
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	44.12	44.27	44.41	44.38	44.41	44.92	44.76	40.00
Sex-specific-R	0.06	0.05	0.05	0.05	0.05	0.08	0.01	0.00
Ini-size-struct.	31.46	31.11	31.65	31.42	31.80	30.90	32.68	38.29
PriorDensity	297.16	291.06	290.91	284.87	289.53	286.97	285.37	255.70
Tot-likelihood	-24051.7	-24531.0	-24735.8	-24737.4	-24739.6	-24582.2	-24770.4	-24804.0
Tot-likeli-no-PD	-24348.9	-24822.1	-25026.7	-25022.3	-25029.1	-24869.2	-25055.8	-25059.7
Tot-parameter	366	366	366	367	367	366	367	366
MMB35%	25444.7	25283.9	25220.6	25550.9	24790.2	25533.8	25571.1	21577.5
MMB-terminal	14928.4	14743.0	14802.0	15366.3	14152.8	16538.3	17876.8	12866.6
F35%	0.291	0.292	0.293	0.293	0.292	0.293	0.293	0.443
Fofl	0.157	0.157	0.158	0.163	0.153	0.178	0.195	0.244
OFL	2140.72	2099.17	2114.53	2266.73	1950.18	1950.18	3120.54	2714.94
ABC	1605.54	1574.38	1585.90	1700.05	1462.63	1462.63	2340.41	2036.21
Q-male	0.959	0.958	0.962	0.921	0.987	0.949	0.937	0.930
Q-female	0.959	0.958	0.962	0.945	1.027	0.949	0.937	0.930

Table 5c. Differences of negative log likelihood components and some management quantities between model 19.3 and models 19.3c and 19.3d, and between model 19.3d and models 19.3c, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6. Highlighted cells in red color show values not comparable to the other models.

	19.3 - 19.3c	19.3 - 19.3d	19.3d - 19.3c	19.3d-19.3e	19.3d-19.3f	19.3d-19.3g	19.3d-19.3i	19.3d-19.6
Pot-ret-catch	-1.49	-2.54	1.05	-0.29	0.35	-3.28	-0.59	1.86
Pot-totM-catch	-2.68	-4.71	2.03	-0.56	0.62	-2.00	-0.79	2.41
Pot-F-discC	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.02
Trawl-discC	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00
Tanner-M-discC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tanner-F-discC	-0.01	-0.01	0.00	0.00	-0.01	-0.03	0.00	0.04
Fixed-discC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Traw-suv-bio	-0.14	-0.44	0.30	-3.19	-2.79	-137.98	27.93	2.33
BSFRF-sur-bio	-0.09	-0.20	0.12	-1.57	-0.75	1.60	1.22	1.97
Pot-ret-comp	1.67	143.22	-141.55	0.01	-0.09	2.00	1.45	6.54
Pot-totM-comp	0.11	73.02	-72.91	-0.55	0.55	-3.87	0.84	1.02
Pot-discF-comp	-6.48	-6.44	-0.04	-0.02	0.04	-0.97	0.18	-0.60
Trawl-disc-comp	0.09	-1.43	1.52	0.45	0.84	4.00	7.14	6.03
Tanner-disc-comp	482.58	482.91	-0.33	-0.24	0.35	-1.31	1.21	3.15
Fixed-disc-comp	2.77	2.56	0.21	0.15	-0.65	-2.28	0.59	-0.32
Trawl-sur-comp	-3.29	-7.15	3.86	-1.52	1.77	-13.71	-8.97	5.31
BSFRF-sur-comp	0.16	-0.32	0.47	-0.36	0.85	1.09	1.10	7.11
Recruit-dev	-0.20	-0.09	-0.11	0.06	0.02	-0.82	1.40	-1.68
Recruit-sex-R	0.01	-0.01	0.02	-0.01	-0.01	-0.14	-0.03	-0.01
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	-0.15	-0.29	0.14	0.04	0.00	-0.51	-0.35	4.41
Sex-specific-R	0.02	0.02	0.00	0.00	0.00	-0.03	0.04	0.05
Ini-size-structure	0.36	-0.19	0.54	0.23	-0.15	0.76	-1.02	-6.63
PriorDensity	6.09	6.25	-0.16	6.04	1.38	3.93	5.53	35.21
Tot-likelihood	479.3	684.1	-47.6	1.60	3.80	-153.60	34.60	68.20
Tot-like-no-PD	473.2	677.8	-52.3	-4.44	2.42	-157.53	29.07	32.99
Tot-parameter	0	0	0	-1	-1	0	-1	0
MMB35%	160.79	224.03	-63.25	-330.27	430.40	-313.18	-350.45	3643.18
MMB-terminal	185.36	126.40	58.96	-564.33	649.25	-1736.3	-3074.8	1935.36
F35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.15
Fofl	0.00	0.00	0.00	-0.01	0.01	-0.02	-0.04	-0.09
OFL	41.55	26.19	15.36	-152.20	164.35	164.35	-1006.0	-600.41
ABC	31.16	19.64	11.52	-114.15	123.27	123.27	-754.51	-450.31
Q-male	0.00	0.00	0.00	0.04	-0.02	0.01	0.03	0.03
Q-female	0.00	0.00	0.00	0.02	-0.06	0.01	0.03	0.03

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

index	name	value	std.dev	index	name	value	std.dev
1	theta[2]	0.2749	0.0173	47	log_slx_pars[1]	4.7444	0.0083
2	theta[4]	19.8860	0.0569	48	log_slx_pars[2]	2.1890	0.0583
3	theta[5]	16.3000	0.1429	49	log_slx_pars[3]	4.5081	0.0295
4	theta[7]	0.6590	0.1257	50	log_slx_pars[4]	2.0856	0.1812
5	theta[9]	-0.4401	0.2572	51	log_slx_pars[5]	5.1519	0.0566
6	theta[13]	0.9628	0.3826	52	log_slx_pars[6]	2.8465	0.0460
7	theta[14]	0.6174	0.4329	53	log_slx_pars[7]	4.6374	0.0651
8	theta[15]	0.8052	0.3219	54	log_slx_pars[8]	2.1786	0.6064
9	theta[16]	0.6510	0.3010	55	log_slx_pars[9]	4.5128	0.0168
10	theta[17]	0.4889	0.2941	56	log_slx_pars[10]	0.9159	0.4156
11	theta[18]	0.4465	0.2788	57	log_slx_pars[11]	4.7991	0.0261
12	theta[19]	0.3027	0.2819	58	log_slx_pars[12]	2.3519	0.0920
13	theta[20]	0.3306	0.2712	59	log_slx_pars[13]	4.0859	0.5844
14	theta[21]	0.3533	0.2661	60	log_slx_pars[14]	3.1951	1.5504
15	theta[22]	0.1478	0.2865	61	log_slx_pars[15]	4.1851	0.2052
16	theta[23]	0.1432	0.2807	62	log_slx_pars[16]	3.1842	0.3813
17	theta[24]	0.0240	0.2912	63	log_slx_pars[17]	4.0735	0.2493
18	theta[25]	0.0904	0.2740	64	log_slx_pars[18]	2.1854	0.4853
19	theta[26]	-0.0117	0.2182	65	log_slx_pars[19]	3.7549	236.6700
20	theta[27]	-0.2226	0.2111	66	log_slx_pars[20]	0.3179	410.7200
21	theta[28]	-0.3853	0.2138	67	log_slx_pars[21]	4.3551	0.0450
22	theta[29]	-0.7165	0.2288	68	log_slx_pars[22]	2.3047	0.1459
23	theta[30]	-1.1582	0.2498	69	log_slx_pars[23]	4.4858	0.0145
24	theta[31]	-1.1849	0.2518	70	log_slx_pars[24]	2.4915	0.0696
25	theta[52]	1.2533	0.9311	71	log_slx_pars[25]	4.9217	0.0016
26	theta[53]	1.5687	0.5268	72	log_slx_pars[26]	0.6855	0.0650
27	theta[54]	1.5399	0.4050	73	log_slx_pars[27]	4.9283	0.0022
28	theta[55]	1.2891	0.3561	74	log_slx_pars[28]	0.6763	0.1275
29	theta[56]	1.1377	0.3118	75	log_fbar[1]	-1.5043	0.0428
30	theta[57]	0.6097	0.3388	76	log_fbar[2]	-4.2897	0.0775
31	theta[58]	0.2224	0.3645	77	log_fbar[3]	-5.4585	0.0989
32	theta[59]	-0.0187	0.3664	78	log_fbar[4]	-6.6075	0.0837
33	theta[60]	-0.2084	0.3541	79	log_fdev[1]	0.6427	0.1226
34	theta[61]	-0.5465	0.3714	80	log_fdev[1]	0.6494	0.0929
35	theta[62]	-0.9352	0.3819	81	log_fdev[1]	0.5870	0.0750
36	theta[63]	-1.1947	0.3863	82	log_fdev[1]	0.7065	0.0617
37	theta[64]	-1.4263	0.3848	83	log_fdev[1]	0.9335	0.0553
38	theta[65]	-1.8059	0.3740	84	log_fdev[1]	1.8165	0.0614
39	theta[66]	-1.9123	0.3701	85	log_fdev[1]	2.3108	0.1365
40	theta[67]	-1.8529	0.3494	86	log_fdev[1]	0.6701	0.1759
41	Grwth[21]	0.8870	0.1854	87	log_fdev[1]	-9.0309	0.1185
42	Grwth[42]	1.4192	0.1224	88	log_fdev[1]	1.0063	0.1052
43	Grwth[85]	140.970	1.7806	89	log_fdev[1]	1.1137	0.0932
44	Grwth[86]	0.0596	0.0103	90	log_fdev[1]	1.2936	0.0756
45	Grwth[87]	140.110	0.6511	91	log_fdev[1]	0.8411	0.0661

46	Grwth[88]	0.0729	0.0037
93	log_fdev[1]	0.0275	0.0490
94	log_fdev[1]	0.6682	0.0405
95	log_fdev[1]	0.6733	0.0433
96	log_fdev[1]	0.1482	0.0476
97	log_fdev[1]	0.8191	0.0517
98	log_fdev[1]	-4.3245	0.0493
99	log_fdev[1]	-4.7230	0.0425
100	log_fdev[1]	-0.2379	0.0413
101	log_fdev[1]	-0.1767	0.0419
102	log_fdev[1]	0.7894	0.0451
103	log_fdev[1]	0.3819	0.0438
104	log_fdev[1]	-0.2162	0.0423
105	log_fdev[1]	-0.3014	0.0417
106	log_fdev[1]	-0.1917	0.0406
107	log_fdev[1]	0.2737	0.0393
108	log_fdev[1]	0.2300	0.0393
109	log_fdev[1]	0.5087	0.0397
110	log_fdev[1]	0.2488	0.0388
111	log_fdev[1]	0.6134	0.0388
112	log_fdev[1]	0.7772	0.0409
113	log_fdev[1]	0.5760	0.0419
114	log_fdev[1]	0.4312	0.0421
115	log_fdev[1]	-0.2039	0.0416
116	log_fdev[1]	-0.2809	0.0412
117	log_fdev[1]	-0.1157	0.0419
118	log_fdev[1]	0.2040	0.0440
119	log_fdev[1]	0.2318	0.0486
120	log_fdev[1]	0.1762	0.0559
121	log_fdev[1]	0.0390	0.0652
122	log_fdev[1]	-0.2324	0.0743
123	log_fdev[1]	-0.2629	0.0820
124	log_fdev[2]	0.1418	0.1261
125	log_fdev[2]	0.6032	0.1168
126	log_fdev[2]	0.6008	0.1111
127	log_fdev[2]	0.6844	0.1094
128	log_fdev[2]	1.3961	0.1135
129	log_fdev[2]	1.1126	0.1313
130	log_fdev[2]	2.3962	0.1289
131	log_fdev[2]	2.1357	0.1170
132	log_fdev[2]	3.3701	0.1155
133	log_fdev[2]	2.1852	0.1123
134	log_fdev[2]	1.1270	0.1121
135	log_fdev[2]	0.6761	0.1096
136	log_fdev[2]	1.4522	0.1052
137	log_fdev[2]	0.0183	0.1042
138	log_fdev[2]	0.4656	0.1043
139	log_fdev[2]	0.8772	0.1056
140	log_fdev[2]	0.7061	0.1056
92	log_fdev[1]	-0.0909	0.0545
143	log_fdev[2]	-0.8520	0.1036
144	log_fdev[2]	-0.7779	0.1038
145	log_fdev[2]	-1.2343	0.1037
146	log_fdev[2]	0.0863	0.1042
147	log_fdev[2]	-0.1993	0.1040
148	log_fdev[2]	-0.9709	0.1032
149	log_fdev[2]	-0.2103	0.1031
150	log_fdev[2]	-0.5125	0.1028
151	log_fdev[2]	-0.6062	0.1026
152	log_fdev[2]	-0.3762	0.1025
153	log_fdev[2]	-0.6571	0.1024
154	log_fdev[2]	-0.4930	0.1021
155	log_fdev[2]	-0.4231	0.1022
156	log_fdev[2]	-0.4598	0.1025
157	log_fdev[2]	-0.8254	0.1027
158	log_fdev[2]	-0.9867	0.1029
159	log_fdev[2]	-1.4550	0.1028
160	log_fdev[2]	-1.9816	0.1032
161	log_fdev[2]	-1.2798	0.1037
162	log_fdev[2]	-1.8574	0.1045
163	log_fdev[2]	-1.5055	0.1061
164	log_fdev[2]	-1.0216	0.1086
165	log_fdev[2]	-0.6217	0.1119
166	log_fdev[2]	-0.7132	0.1150
167	log_fdev[2]	-0.6279	0.1185
168	log_fdev[3]	-0.0389	0.0685
169	log_fdev[3]	-0.0388	0.0685
170	log_fdev[3]	1.7536	0.0685
171	log_fdev[3]	1.4488	0.0685
172	log_fdev[3]	1.6753	0.0685
173	log_fdev[3]	2.5538	0.0685
174	log_fdev[3]	1.4425	0.0685
175	log_fdev[3]	1.6003	0.0685
176	log_fdev[3]	-0.2471	0.0685
177	log_fdev[3]	0.9278	0.0685
178	log_fdev[3]	0.4542	0.0685
179	log_fdev[3]	0.9392	0.0685
180	log_fdev[3]	1.6522	0.0685
181	log_fdev[3]	1.6600	0.0685
182	log_fdev[3]	2.9993	0.0720
183	log_fdev[3]	1.0492	0.0729
184	log_fdev[3]	0.3264	0.0792
185	log_fdev[3]	-2.9934	0.0685
186	log_fdev[3]	-3.9508	0.0685
187	log_fdev[3]	-3.7276	0.0685
188	log_fdev[3]	-3.7276	0.0685
189	log_fdev[3]	-4.6439	0.0685
190	log_fdev[3]	-1.1276	0.0702

141	log_fdev[2]	1.1851	0.1081	191	log_fdev[3]	-0.2264	0.0723
142	log_fdev[2]	-0.5717	0.1051	192	log_fdev[3]	0.2395	0.0772
193	log_fdev[4]	0.6887	0.1037	243	log_fdov[1]	-0.3031	0.0796
194	log_fdev[4]	0.0364	0.1022	244	log_fdov[1]	0.8545	0.0812
195	log_fdev[4]	-0.1681	0.1028	245	log_fdov[1]	0.2983	0.0841
196	log_fdev[4]	0.7408	0.1019	246	log_fdov[1]	-0.1485	0.0875
197	log_fdev[4]	-1.6971	0.1013	247	log_fdov[1]	0.9944	0.0918
198	log_fdev[4]	0.2552	0.1009	248	log_fdov[1]	0.1632	0.0959
199	log_fdev[4]	-0.0024	0.1005	249	log_fdov[3]	-0.0002	0.0967
200	log_fdev[4]	-0.8381	0.1004	250	log_fdov[3]	-0.0004	0.0967
201	log_fdev[4]	-0.6665	0.1001	251	log_fdov[3]	0.0002	0.0967
202	log_fdev[4]	-0.3943	0.0999	252	log_fdov[3]	0.0006	0.0967
203	log_fdev[4]	-0.4464	0.0996	253	log_fdov[3]	0.0006	0.0967
204	log_fdev[4]	0.0951	0.0996	254	log_fdov[3]	-0.0016	0.0966
205	log_fdev[4]	-0.6118	0.1001	255	log_fdov[3]	-0.0007	0.0967
206	log_fdev[4]	-1.6194	0.0999	256	log_fdov[3]	-0.0003	0.0967
207	log_fdev[4]	-2.5090	0.0995	257	log_fdov[3]	-0.0005	0.0967
208	log_fdev[4]	-0.9955	0.0992	258	log_fdov[3]	0.0002	0.0967
209	log_fdev[4]	-0.4479	0.0993	259	log_fdov[3]	0.0003	0.0967
210	log_fdev[4]	0.6876	0.0995	260	log_fdov[3]	0.0015	0.0967
211	log_fdev[4]	1.5158	0.1000	261	log_fdov[3]	0.0026	0.0967
212	log_fdev[4]	1.1726	0.1010	262	log_fdov[3]	0.0038	0.0967
213	log_fdev[4]	0.2879	0.1025	263	log_fdov[3]	0.5057	0.0988
214	log_fdev[4]	1.8747	0.1047	264	log_fdov[3]	0.7525	0.0978
215	log_fdev[4]	2.0949	0.1067	265	log_fdov[3]	-0.4482	0.1022
216	log_fdev[4]	0.9467	0.1090	266	log_fdov[3]	-0.0006	0.0967
217	log_foff[1]	-2.8529	0.0537	267	log_fdov[3]	-0.0006	0.0967
218	log_foff[3]	0.5009	0.0929	268	log_fdov[3]	-0.0006	0.0967
219	log_fdov[1]	2.0679	0.0841	269	log_fdov[3]	-0.0006	0.0967
220	log_fdov[1]	-0.5974	0.0832	270	log_fdov[3]	-0.0006	0.0967
221	log_fdov[1]	2.0825	0.0847	271	log_fdov[3]	0.0182	0.0966
222	log_fdov[1]	1.9121	0.0858	272	log_fdov[3]	-0.7141	0.0973
223	log_fdov[1]	-0.3400	0.0844	273	log_fdov[3]	-0.1175	0.0997
224	log_fdov[1]	-0.1270	0.0827	274	rec_dev_est	1.0794	0.2976
225	log_fdov[1]	-3.6240	0.0827	275	rec_dev_est	0.7311	0.2950
226	log_fdov[1]	-0.2733	0.0845	276	rec_dev_est	1.1263	0.2445
227	log_fdov[1]	1.4941	0.0829	277	rec_dev_est	1.7291	0.2113
228	log_fdov[1]	-2.7279	0.0813	278	rec_dev_est	1.9904	0.2231
229	log_fdov[1]	1.2165	0.0805	279	rec_dev_est	1.1519	0.2681
230	log_fdov[1]	0.9443	0.0805	280	rec_dev_est	2.3399	0.1690
231	log_fdov[1]	-1.8064	0.0798	281	rec_dev_est	1.3687	0.1839
232	log_fdov[1]	1.2767	0.0805	282	rec_dev_est	0.9960	0.1708
233	log_fdov[1]	0.4918	0.0809	283	rec_dev_est	-0.8590	0.2556
234	log_fdov[1]	1.0262	0.0796	284	rec_dev_est	0.2556	0.1674
235	log_fdov[1]	-1.1644	0.0791	285	rec_dev_est	-0.8849	0.2447
236	log_fdov[1]	-0.1117	0.0793	286	rec_dev_est	-1.3230	0.2789
237	log_fdov[1]	-0.3832	0.0795	287	rec_dev_est	-1.1210	0.2339
238	log_fdov[1]	-0.5928	0.0798	288	rec_dev_est	-0.1322	0.1713
239	log_fdov[1]	-0.1359	0.0803	289	rec_dev_est	-0.5997	0.1933

240	log_fdov[1]	-1.0767	0.0793
241	log_fdov[1]	-1.7165	0.0787
242	log_fdov[1]	0.3028	0.0788
293	rec_dev_est	0.9320	0.1518
294	rec_dev_est	-1.0433	0.2655
295	rec_dev_est	-1.6231	0.3342
296	rec_dev_est	-0.6536	0.2037
297	rec_dev_est	0.3285	0.1611
298	rec_dev_est	-0.5955	0.2220
299	rec_dev_est	-0.5981	0.2419
300	rec_dev_est	0.7746	0.1599
301	rec_dev_est	-0.7101	0.2737
302	rec_dev_est	-0.6874	0.2618
303	rec_dev_est	0.5600	0.1615
304	rec_dev_est	-0.1755	0.1895
305	rec_dev_est	-0.5592	0.1953
306	rec_dev_est	-1.1078	0.2414
307	rec_dev_est	-1.0323	0.2465
308	rec_dev_est	-0.0045	0.1799
309	rec_dev_est	-0.5554	0.2233
310	rec_dev_est	-0.9540	0.2248
311	rec_dev_est	-1.3618	0.2286
312	rec_dev_est	-1.9292	0.2923
313	rec_dev_est	-1.4162	0.2269
314	rec_dev_est	-0.8414	0.1882
315	rec_dev_est	-1.6911	0.2850
316	rec_dev_est	-1.2456	0.2701
317	rec_dev_est	-1.8541	0.4577
318	rec_dev_est	-0.2405	1.3063
319	logit_rec_prop_es	-0.1738	0.4779
320	logit_rec_prop_es	-0.7552	0.4696
321	logit_rec_prop_es	-0.2946	0.3618
322	logit_rec_prop_es	-0.5530	0.2706
323	logit_rec_prop_es	-0.0626	0.2743
324	logit_rec_prop_es	0.0951	0.3784
325	logit_rec_prop_es	0.3407	0.1569
326	logit_rec_prop_es	0.3958	0.2409
327	logit_rec_prop_es	-0.0992	0.1810
328	logit_rec_prop_es	0.5050	0.4900
329	logit_rec_prop_es	-0.4662	0.1645
330	logit_rec_prop_es	0.2581	0.4222
331	logit_rec_prop_es	-0.0528	0.4617
332	logit_rec_prop_es	0.4767	0.4221
333	logit_rec_prop_es	-0.1924	0.1754
334	logit_rec_prop_es	0.1362	0.2614
335	logit_rec_prop_es	0.9226	0.8947
336	logit_rec_prop_es	0.0337	0.2920
337	logit_rec_prop_es	-0.0668	0.8645
338	logit_rec_prop_es	-0.2947	0.0904
290	rec_dev_est	-2.0873	0.3716
291	rec_dev_est	-1.0340	0.2076
292	rec_dev_est	-2.3004	0.5003
339	logit_rec_prop_es	1.4330	0.7775
340	logit_rec_prop_es	0.6054	0.6934
341	logit_rec_prop_es	0.4621	0.3267
342	logit_rec_prop_es	-0.1146	0.1462
343	logit_rec_prop_es	0.2329	0.3548
344	logit_rec_prop_es	-0.4851	0.3715
345	logit_rec_prop_es	-0.5161	0.1317
346	logit_rec_prop_es	-0.3856	0.4374
347	logit_rec_prop_es	-0.0832	0.4245
348	logit_rec_prop_es	-0.4556	0.1413
349	logit_rec_prop_es	-0.0760	0.2474
350	logit_rec_prop_es	0.1947	0.2815
351	logit_rec_prop_es	-0.2368	0.3697
352	logit_rec_prop_es	-0.3192	0.3748
353	logit_rec_prop_es	-0.8485	0.1925
354	logit_rec_prop_es	-0.3224	0.3105
355	logit_rec_prop_es	-0.5481	0.3173
356	logit_rec_prop_es	-0.0122	0.3469
357	logit_rec_prop_es	-0.2385	0.4730
358	logit_rec_prop_es	-0.1864	0.3287
359	logit_rec_prop_es	0.2586	0.2467
360	logit_rec_prop_es	0.6521	0.5618
361	logit_rec_prop_es	0.4341	0.4426
362	logit_rec_prop_es	0.7423	0.9166
363	logit_rec_prop_es	-0.3395	1.6742
364	m_dev_est[1]	1.6056	0.0288
365	survey_q[1]	0.9592	0.0280
366	log_add_cv[2]	-0.9615	0.2885
367	sd_rbar	16133000	521640
368	sd_ssbF0	72699.0	2135.60
369	sd_Bmsy	25445.0	747.440
370	sd_depl	0.5867	0.0405
371	sd_fmsy	0.2907	0.0043
372	sd_fmsy	0.0059	0.0006
373	sd_fmsy	0.0011	0.0001
374	sd_fmsy	0.0059	0.0006
375	sd_fmsy	0.0000	0.0000
376	sd_fmsy	0.0000	0.0000
377	sd_fofl	0.1572	0.0137
378	sd_fofl	0.0059	0.0006
379	sd_fofl	0.0011	0.0001
380	sd_fofl	0.0059	0.0006
381	sd_fofl	0.0000	0.0000
382	sd_fofl	0.0000	0.0000
383	sd_ofl	2140.7000	334.4400

Table 6b. 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]	0.2713	0.0165	47	log_slx_pars[1]	4.7479	0.0081
2	theta[4]	19.8670	0.0559	48	log_slx_pars[2]	2.2543	0.0497
3	theta[5]	16.2910	0.1432	49	log_slx_pars[3]	4.5086	0.0178
4	theta[7]	0.7335	0.1388	50	log_slx_pars[4]	2.0335	0.1184
5	theta[9]	-0.5733	0.2506	51	log_slx_pars[5]	5.1395	0.0538
6	theta[13]	0.9402	0.3912	52	log_slx_pars[6]	2.8479	0.0466
7	theta[14]	0.6093	0.4306	53	log_slx_pars[7]	4.7220	0.2127
8	theta[15]	0.8111	0.3206	54	log_slx_pars[8]	2.1621	0.3066
9	theta[16]	0.6681	0.3000	55	log_slx_pars[9]	4.7306	0.0827
10	theta[17]	0.5109	0.2958	56	log_slx_pars[10]	0.9006	0.3030
11	theta[18]	0.4734	0.2811	57	log_slx_pars[11]	4.7990	0.0259
12	theta[19]	0.3232	0.2825	58	log_slx_pars[12]	2.3573	0.0916
13	theta[20]	0.3634	0.2686	59	log_slx_pars[13]	3.9746	1.0975
14	theta[21]	0.3963	0.2617	60	log_slx_pars[14]	3.3182	2.1299
15	theta[22]	0.1712	0.2840	61	log_slx_pars[15]	4.1815	0.2231
16	theta[23]	0.1494	0.2788	62	log_slx_pars[16]	3.2184	0.4120
17	theta[24]	0.0433	0.2876	63	log_slx_pars[17]	4.0719	0.2606
18	theta[25]	0.1593	0.2629	64	log_slx_pars[18]	2.1911	0.4900
19	theta[26]	-0.0195	0.2031	65	log_slx_pars[19]	3.7377	504.3600
20	theta[27]	-0.2475	0.1962	66	log_slx_pars[20]	0.0455	125.5900
21	theta[28]	-0.4033	0.1987	67	log_slx_pars[21]	4.3563	0.0479
22	theta[29]	-0.7501	0.2122	68	log_slx_pars[22]	2.3193	0.1469
23	theta[30]	-1.2101	0.2328	69	log_slx_pars[23]	4.4799	0.0138
24	theta[31]	-1.2592	0.2357	70	log_slx_pars[24]	2.4654	0.0688
25	theta[52]	1.1907	1.0092	71	log_slx_pars[25]	4.9207	0.0015
26	theta[53]	1.5700	0.5376	72	log_slx_pars[26]	0.6739	0.0546
27	theta[54]	1.5415	0.4094	73	log_slx_pars[27]	4.9284	0.0019
28	theta[55]	1.2870	0.3571	74	log_slx_pars[28]	0.6713	0.1075
29	theta[56]	1.1298	0.3124	75	log_fbar[1]	-1.5066	0.0423
30	theta[57]	0.5999	0.3396	76	log_fbar[2]	-4.3132	0.0774
31	theta[58]	0.2168	0.3652	77	log_fbar[3]	-5.6295	0.2865
32	theta[59]	-0.0212	0.3670	78	log_fbar[4]	-6.6052	0.0828
33	theta[60]	-0.2077	0.3547	79	log_fdev[1]	0.7046	0.1204
34	theta[61]	-0.5434	0.3722	80	log_fdev[1]	0.6733	0.0932
35	theta[62]	-0.9300	0.3828	81	log_fdev[1]	0.5896	0.0759
36	theta[63]	-1.1896	0.3872	82	log_fdev[1]	0.6931	0.0616
37	theta[64]	-1.4206	0.3857	83	log_fdev[1]	0.9156	0.0548
38	theta[65]	-1.7988	0.3748	84	log_fdev[1]	1.7859	0.0579
39	theta[66]	-1.9047	0.3708	85	log_fdev[1]	2.2615	0.1249
40	theta[67]	-1.8438	0.3499	86	log_fdev[1]	0.6253	0.1754
41	Grwth[21]	0.9570	0.1887	87	log_fdev[1]	-9.0439	0.1260
42	Grwth[42]	1.4224	0.1232	88	log_fdev[1]	1.0441	0.1054
43	Grwth[85]	141.940	1.9324	89	log_fdev[1]	1.1367	0.0906
44	Grwth[86]	0.0601	0.0115	90	log_fdev[1]	1.2979	0.0748
45	Grwth[87]	139.920	0.6309	91	log_fdev[1]	0.8366	0.0646

46	Grwth[88]	0.0722	0.0035	92	log_fdev[1]	-0.0937	0.0532
93	log_fdev[1]	0.0288	0.0477	143	log_fdev[2]	-0.8531	0.1034
94	log_fdev[1]	0.6777	0.0393	144	log_fdev[2]	-0.7854	0.1035
95	log_fdev[1]	0.6884	0.0423	145	log_fdev[2]	-1.2510	0.1034
96	log_fdev[1]	0.1656	0.0471	146	log_fdev[2]	0.0443	0.1037
97	log_fdev[1]	0.8265	0.0518	147	log_fdev[2]	-0.2317	0.1035
98	log_fdev[1]	-4.3296	0.0490	148	log_fdev[2]	-0.9867	0.1029
99	log_fdev[1]	-4.7351	0.0421	149	log_fdev[2]	-0.2155	0.1027
100	log_fdev[1]	-0.2623	0.0407	150	log_fdev[2]	-0.5144	0.1025
101	log_fdev[1]	-0.2142	0.0412	151	log_fdev[2]	-0.6076	0.1022
102	log_fdev[1]	0.6965	0.0437	152	log_fdev[2]	-0.3746	0.1022
103	log_fdev[1]	0.3470	0.0428	153	log_fdev[2]	-0.6544	0.1021
104	log_fdev[1]	-0.2342	0.0412	154	log_fdev[2]	-0.4890	0.1018
105	log_fdev[1]	-0.3126	0.0407	155	log_fdev[2]	-0.4192	0.1020
106	log_fdev[1]	-0.2014	0.0395	156	log_fdev[2]	-0.4581	0.1024
107	log_fdev[1]	0.2645	0.0382	157	log_fdev[2]	-0.8253	0.1026
108	log_fdev[1]	0.2250	0.0382	158	log_fdev[2]	-0.9851	0.1027
109	log_fdev[1]	0.5092	0.0386	159	log_fdev[2]	-1.4506	0.1025
110	log_fdev[1]	0.2568	0.0380	160	log_fdev[2]	-1.9746	0.1028
111	log_fdev[1]	0.6169	0.0381	161	log_fdev[2]	-1.2702	0.1032
112	log_fdev[1]	0.7783	0.0406	162	log_fdev[2]	-1.8469	0.1040
113	log_fdev[1]	0.5769	0.0417	163	log_fdev[2]	-1.4889	0.1057
114	log_fdev[1]	0.4348	0.0414	164	log_fdev[2]	-0.9955	0.1082
115	log_fdev[1]	-0.2041	0.0402	165	log_fdev[2]	-0.5893	0.1115
116	log_fdev[1]	-0.2814	0.0396	166	log_fdev[2]	-0.6744	0.1148
117	log_fdev[1]	-0.1055	0.0403	167	log_fdev[2]	-0.5933	0.1184
118	log_fdev[1]	0.2040	0.0424	168	log_fdev[3]	-0.1164	0.0682
119	log_fdev[1]	0.2487	0.0471	169	log_fdev[3]	0.6699	0.0682
120	log_fdev[1]	0.2098	0.0548	170	log_fdev[3]	1.2285	0.0682
121	log_fdev[1]	0.0761	0.0647	171	log_fdev[3]	1.0928	0.0682
122	log_fdev[1]	-0.1508	0.0745	172	log_fdev[3]	1.3825	0.0682
123	log_fdev[1]	-0.2265	0.0828	173	log_fdev[3]	1.4242	0.0682
124	log_fdev[2]	0.1597	0.1266	174	log_fdev[3]	0.9927	0.0682
125	log_fdev[2]	0.6029	0.1178	175	log_fdev[3]	0.4764	0.0682
126	log_fdev[2]	0.5869	0.1114	176	log_fdev[3]	-0.9874	0.0682
127	log_fdev[2]	0.6622	0.1093	177	log_fdev[3]	-0.5788	0.0682
128	log_fdev[2]	1.3565	0.1121	178	log_fdev[3]	-1.0994	0.0682
129	log_fdev[2]	1.0729	0.1297	179	log_fdev[3]	-0.2563	0.0682
130	log_fdev[2]	2.3685	0.1291	180	log_fdev[3]	0.9401	0.0682
131	log_fdev[2]	2.1245	0.1173	181	log_fdev[3]	1.4181	0.0682
132	log_fdev[2]	3.3721	0.1147	182	log_fdev[3]	3.2775	0.0763
133	log_fdev[2]	2.1828	0.1117	183	log_fdev[3]	1.3179	0.0948
134	log_fdev[2]	1.1189	0.1114	184	log_fdev[3]	0.6099	0.1163
135	log_fdev[2]	0.6688	0.1088	185	log_fdev[3]	-0.7287	0.0836
136	log_fdev[2]	1.4501	0.1045	186	log_fdev[3]	-2.1053	0.0733
137	log_fdev[2]	0.0231	0.1036	187	log_fdev[3]	-2.9662	0.0939
138	log_fdev[2]	0.4773	0.1038	188	log_fdev[3]	-2.4001	0.1114
139	log_fdev[2]	0.8991	0.1051	189	log_fdev[3]	-3.4930	0.0747
140	log_fdev[2]	0.7312	0.1053	190	log_fdev[3]	-0.8825	0.0927

141	log_fdev[2]	1.2002	0.1080
142	log_fdev[2]	-0.5674	0.1049
193	log_fdev[4]	0.6684	0.1033
194	log_fdev[4]	0.0117	0.1020
195	log_fdev[4]	-0.1961	0.1024
196	log_fdev[4]	0.7253	0.1016
197	log_fdev[4]	-1.7057	0.1011
198	log_fdev[4]	0.2495	0.1007
199	log_fdev[4]	-0.0069	0.1003
200	log_fdev[4]	-0.8407	0.1002
201	log_fdev[4]	-0.6675	0.1000
202	log_fdev[4]	-0.3952	0.0998
203	log_fdev[4]	-0.4466	0.0995
204	log_fdev[4]	0.0948	0.0995
205	log_fdev[4]	-0.6123	0.1000
206	log_fdev[4]	-1.6191	0.0998
207	log_fdev[4]	-2.5074	0.0993
208	log_fdev[4]	-0.9934	0.0991
209	log_fdev[4]	-0.4455	0.0992
210	log_fdev[4]	0.6916	0.0993
211	log_fdev[4]	1.5223	0.0999
212	log_fdev[4]	1.1855	0.1009
213	log_fdev[4]	0.3079	0.1024
214	log_fdev[4]	1.8971	0.1046
215	log_fdev[4]	2.1179	0.1067
216	log_fdev[4]	0.9641	0.1091
217	log_foff[1]	-2.8291	0.0410
218	log_foff[3]	-0.1444	0.4096
219	log_fdov[1]	2.0327	0.0834
220	log_fdov[1]	-0.6368	0.0826
221	log_fdov[1]	2.0434	0.0838
222	log_fdov[1]	1.8857	0.0855
223	log_fdov[1]	-0.3437	0.0840
224	log_fdov[1]	-0.1185	0.0821
225	log_fdov[1]	-3.6226	0.0810
226	log_fdov[1]	-0.2549	0.0816
227	log_fdov[1]	1.5335	0.0816
228	log_fdov[1]	-2.7064	0.0808
229	log_fdov[1]	1.2151	0.0801
230	log_fdov[1]	0.9380	0.0800
231	log_fdov[1]	-1.8108	0.0795
232	log_fdov[1]	1.2680	0.0796
233	log_fdov[1]	0.4680	0.0797
234	log_fdov[1]	1.0025	0.0792
235	log_fdov[1]	-1.1823	0.0788
236	log_fdov[1]	-0.1450	0.0788
237	log_fdov[1]	-0.4078	0.0793
238	log_fdov[1]	-0.6609	0.0795
239	log_fdov[1]	-0.1740	0.0793
191	log_fdev[3]	-0.1832	0.1092
192	log_fdev[3]	0.9667	0.1313
243	log_fdov[1]	-0.1534	0.0787
244	log_fdov[1]	0.9281	0.0800
245	log_fdov[1]	0.4190	0.0826
246	log_fdov[1]	-0.1885	0.0863
247	log_fdov[1]	1.1760	0.0910
248	log_fdov[1]	0.1268	0.0953
249	log_fdov[3]	0.0000	0.0962
250	log_fdov[3]	0.0001	0.0962
251	log_fdov[3]	0.0001	0.0963
252	log_fdov[3]	0.0001	0.0963
253	log_fdov[3]	0.0003	0.0963
254	log_fdov[3]	0.0000	0.0963
255	log_fdov[3]	-0.0002	0.0963
256	log_fdov[3]	-0.0002	0.0962
257	log_fdov[3]	-0.0001	0.0962
258	log_fdov[3]	-0.0001	0.0962
259	log_fdov[3]	-0.0001	0.0962
260	log_fdov[3]	0.0001	0.0962
261	log_fdov[3]	0.0003	0.0962
262	log_fdov[3]	0.0009	0.0963
263	log_fdov[3]	1.5183	0.1436
264	log_fdov[3]	1.8010	0.1185
265	log_fdov[3]	0.5805	0.1378
266	log_fdov[3]	-3.4377	0.1091
267	log_fdov[3]	-2.1784	0.1506
268	log_fdov[3]	-0.8048	0.1228
269	log_fdov[3]	0.0265	0.1317
270	log_fdov[3]	0.3755	0.1025
271	log_fdov[3]	0.9644	0.1531
272	log_fdov[3]	0.2010	0.1418
273	log_fdov[3]	0.9525	0.1650
274	rec_dev_est	1.0748	0.2984
275	rec_dev_est	0.6922	0.3000
276	rec_dev_est	1.1259	0.2437
277	rec_dev_est	1.7307	0.2120
278	rec_dev_est	1.9814	0.2295
279	rec_dev_est	1.1071	0.2866
280	rec_dev_est	2.3693	0.1684
281	rec_dev_est	1.4016	0.1834
282	rec_dev_est	0.9997	0.1712
283	rec_dev_est	-0.8854	0.2601
284	rec_dev_est	0.2307	0.1682
285	rec_dev_est	-0.9147	0.2478
286	rec_dev_est	-1.3290	0.2777
287	rec_dev_est	-1.1097	0.2310
288	rec_dev_est	-0.1255	0.1684
289	rec_dev_est	-0.5981	0.1890

240	log_fdov[1]	-1.0739	0.0784	290	rec_dev_est	-2.1159	0.3754
241	log_fdov[1]	-1.7957	0.0781	291	rec_dev_est	-0.9618	0.2016
242	log_fdov[1]	0.2344	0.0782	292	rec_dev_est	-2.1549	0.4556
293	rec_dev_est	0.9043	0.1523	339	logit_rec_prop_e	1.4632	0.7644
294	rec_dev_est	-1.0234	0.2681	340	logit_rec_prop_e	0.4894	0.6837
295	rec_dev_est	-1.6638	0.3460	341	logit_rec_prop_e	0.4657	0.3258
296	rec_dev_est	-0.6549	0.2034	342	logit_rec_prop_e	-0.0656	0.1443
297	rec_dev_est	0.3338	0.1606	343	logit_rec_prop_e	0.2439	0.3668
298	rec_dev_est	-0.6347	0.2267	344	logit_rec_prop_e	-0.5694	0.3816
299	rec_dev_est	-0.6209	0.2440	345	logit_rec_prop_e	-0.4877	0.1275
300	rec_dev_est	0.7884	0.1591	346	logit_rec_prop_e	-0.3932	0.4268
301	rec_dev_est	-0.6835	0.2685	347	logit_rec_prop_e	-0.0418	0.4555
302	rec_dev_est	-0.7679	0.2740	348	logit_rec_prop_e	-0.4050	0.1395
303	rec_dev_est	0.5593	0.1610	349	logit_rec_prop_e	-0.0713	0.2434
304	rec_dev_est	-0.1849	0.1880	350	logit_rec_prop_e	0.2583	0.2816
305	rec_dev_est	-0.5628	0.1939	351	logit_rec_prop_e	-0.2074	0.3698
306	rec_dev_est	-1.1264	0.2405	352	logit_rec_prop_e	-0.4067	0.3604
307	rec_dev_est	-1.0074	0.2403	353	logit_rec_prop_e	-0.8321	0.1907
308	rec_dev_est	0.0006	0.1796	354	logit_rec_prop_e	-0.3538	0.3122
309	rec_dev_est	-0.5645	0.2254	355	logit_rec_prop_e	-0.4678	0.3372
310	rec_dev_est	-1.0624	0.2319	356	logit_rec_prop_e	-0.0856	0.3281
311	rec_dev_est	-1.3591	0.2231	357	logit_rec_prop_e	-0.2073	0.4597
312	rec_dev_est	-1.9157	0.2840	358	logit_rec_prop_e	-0.1264	0.3249
313	rec_dev_est	-1.4057	0.2237	359	logit_rec_prop_e	0.3055	0.2409
314	rec_dev_est	-0.8047	0.1861	360	logit_rec_prop_e	0.6063	0.5625
315	rec_dev_est	-1.7289	0.2892	361	logit_rec_prop_e	0.4574	0.4302
316	rec_dev_est	-1.2117	0.2639	362	logit_rec_prop_e	0.6559	0.8912
317	rec_dev_est	-1.8569	0.4579	363	logit_rec_prop_e	-0.5496	1.6529
318	rec_dev_est	-0.1160	1.3557	364	m_dev_est[1]	1.6170	0.0286
319	logit_rec_prop_e	-0.1714	0.4778	365	survey_q[1]	0.9624	0.0288
320	logit_rec_prop_e	-0.8295	0.4885	366	log_add_cv[2]	-0.9397	0.2873
321	logit_rec_prop_e	-0.2797	0.3623	367	sd_rbar	15908000	510700
322	logit_rec_prop_e	-0.5324	0.2808	368	sd_ssbF0	72059.000	2094.400
323	logit_rec_prop_e	-0.0809	0.2779	369	sd_Bmsy	25221.000	733.0500
324	logit_rec_prop_e	0.0175	0.3949	370	sd_depl	0.5869	0.0408
325	logit_rec_prop_e	0.3783	0.1533	371	sd_fmsy	0.2926	0.0040
326	logit_rec_prop_e	0.4141	0.2366	372	sd_fmsy	0.0059	0.0006
327	logit_rec_prop_e	-0.0631	0.1821	373	sd_fmsy	0.0019	0.0004
328	logit_rec_prop_e	0.4733	0.4895	374	sd_fmsy	0.0060	0.0006
329	logit_rec_prop_e	-0.4640	0.1683	375	sd_fmsy	0.0000	0.0000
330	logit_rec_prop_e	0.2745	0.4305	376	sd_fmsy	0.0000	0.0000
331	logit_rec_prop_e	-0.0788	0.4568	377	sd_fofl	0.1583	0.0139
332	logit_rec_prop_e	0.4625	0.4087	378	sd_fofl	0.0059	0.0006
333	logit_rec_prop_e	-0.0551	0.1691	379	sd_fofl	0.0019	0.0004
334	logit_rec_prop_e	0.1730	0.2465	380	sd_fofl	0.0060	0.0006
335	logit_rec_prop_e	0.9104	0.8664	381	sd_fofl	0.0000	0.0000
336	logit_rec_prop_e	0.1949	0.2840	382	sd_fofl	0.0000	0.0000
337	logit_rec_prop_e	-0.1169	0.7766	383	sd_ofl	2114.5000	333.3800
338	logit_rec_prop_e	-0.3015	0.0939	384	sd_log_recruits	17.2760	0.2115

Table 7. Natural mortality estimates for eight model scenarios.

Model	Sex	Year 1975-1979, 1985-2020	1980-1984
19.3	Males	0.180	0.897
	Females	0.237	1.180
19.3c	Males	0.180	0.902
	Females	0.237	1.185
19.3d	Males	0.180	0.907
	Females	0.236	1.189
19.3e	Males	0.180	0.906
	Females	0.236	1.186
19.3f	Males	0.180	0.907
	Females	0.237	1.193
19.3g	Males	0.180	0.925
	Females	0.234	1.200
19.3i	Males	0.180	0.919
	Females	0.233	1.189
19.6	Males	0.257	1.081
	Females	0.289	1.215

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 2010-2020 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

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 19.3 during 1975-2020. Mature male biomass for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length. The highlighted cell shows a very unreliable recruitment estimate.

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	57.510	30.033	88.074	9.093	57.640		233.362	202.731
1976	66.807	36.605	102.546	8.584	91.349	70.625	272.161	331.868
1977	73.512	41.868	114.496	7.479	124.005	49.849	294.567	375.661
1978	78.735	46.378	120.111	5.979	128.207	74.012	299.709	349.545
1979	69.672	47.182	100.043	4.316	123.110	135.246	291.714	167.627
1980	52.117	37.842	30.293	1.835	126.594	175.629	280.477	249.322
1981	15.211	8.130	6.866	1.141	55.764	75.931	112.334	132.669
1982	7.114	2.252	6.873	0.927	24.830	249.089	69.540	143.740
1983	6.447	2.252	7.689	0.680	15.709	94.311	59.842	49.320
1984	6.169	2.354	5.258	0.465	14.618	64.973	51.154	155.312
1985	7.520	1.854	9.605	0.671	9.902	10.165	34.527	34.535
1986	12.079	4.594	14.870	1.005	13.818	30.986	45.010	48.158
1987	14.241	6.584	20.087	1.220	17.184	9.906	50.786	70.263
1988	14.314	8.328	24.736	1.292	21.684	6.391	54.268	55.372
1989	15.555	9.606	27.738	1.255	20.408	7.822	57.078	55.941
1990	15.152	10.379	24.181	1.188	18.069	21.026	57.209	60.321
1991	11.710	8.694	18.709	1.122	17.428	13.175	52.137	85.055
1992	9.364	6.555	17.471	1.079	18.700	2.976	47.443	37.687
1993	10.405	6.199	15.788	1.128	17.408	8.533	46.767	53.703
1994	10.172	5.936	21.438	1.224	14.799	2.405	41.945	32.335
1995	10.677	7.764	24.504	1.215	13.665	60.942	47.884	38.396
1996	10.786	8.388	22.669	1.155	19.834	8.454	57.153	44.649
1997	10.056	7.500	21.044	1.132	29.204	4.734	63.220	85.277
1998	15.657	7.336	23.885	1.358	25.554	12.482	67.192	85.176
1999	16.755	9.402	27.888	1.542	21.571	33.329	65.731	65.604
2000	14.529	10.426	28.358	1.544	23.110	13.230	67.546	68.102
2001	14.323	10.074	28.833	1.513	26.337	13.196	71.214	53.188
2002	17.013	10.241	32.689	1.538	25.600	52.068	76.387	69.786
2003	17.939	11.804	32.330	1.510	31.356	11.798	82.650	116.794
2004	16.252	11.448	30.031	1.436	38.727	12.068	84.330	131.910
2005	18.170	10.707	30.673	1.410	35.976	42.013	85.769	107.341
2006	17.287	11.331	31.150	1.379	36.928	20.136	86.267	95.676
2007	15.646	11.114	26.295	1.299	41.524	13.719	88.489	104.841
2008	16.198	9.486	25.265	1.346	39.154	7.926	85.461	114.430
2009	16.245	9.567	26.531	1.435	34.624	8.548	79.898	91.673
2010	15.168	9.939	26.053	1.425	30.370	23.889	75.264	81.642
2011	12.925	9.459	25.889	1.359	29.952	13.771	71.252	67.053
2012	11.643	8.947	24.502	1.283	32.030	9.244	70.123	61.248
2013	11.670	8.256	23.728	1.241	30.405	6.148	67.944	62.410
2014	11.658	8.069	22.187	1.225	27.191	3.486	63.732	114.103
2015	10.360	7.575	19.786	1.220	23.252	5.823	57.246	64.240
2016	8.772	6.674	17.238	1.224	19.789	10.346	50.807	61.231
2017	7.197	5.709	14.783	1.214	17.900	4.423	45.776	52.922
2018	6.362	4.800	13.580	1.226	16.240	6.906	42.167	28.932
2019	6.983	4.493	14.237	1.348	14.118	3.758	39.853	28.744
2020	7.305	4.896	14.928	1.185	12.471	18.867		

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 19.3d during 1975-2020. Mature male biomass for year *t* is on Feb. 15, year *t*+1. Size measurements are mm carapace length. The highlighted cell shows a very unreliable recruitment estimate.

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	56.540	28.706	85.209	8.897	56.435		231.627	202.731
1976	66.313	35.957	101.126	8.640	89.457	69.644	270.954	331.868
1977	73.140	41.714	114.504	7.601	121.229	47.506	293.353	375.661
1978	78.167	46.593	120.570	6.130	126.064	73.296	299.720	349.545
1979	69.198	47.378	100.952	4.330	121.678	134.204	292.939	167.627
1980	51.700	38.048	31.062	1.800	125.782	172.433	283.215	249.322
1981	15.239	8.202	7.167	1.165	55.535	71.933	113.178	132.669
1982	7.205	2.325	7.034	0.984	24.495	254.141	69.794	143.740
1983	6.296	2.276	7.529	0.659	15.406	96.563	60.212	49.320
1984	6.104	2.281	5.144	0.452	14.348	64.609	51.301	155.312
1985	7.492	1.834	9.544	0.674	9.664	9.808	34.397	34.535
1986	12.107	4.578	14.926	1.009	13.476	29.943	44.799	48.158
1987	14.257	6.613	20.203	1.221	16.717	9.525	50.438	70.263
1988	14.290	8.353	24.800	1.286	21.095	6.294	53.798	55.372
1989	15.390	9.609	27.622	1.243	19.919	7.838	56.540	55.941
1990	14.924	10.297	23.869	1.173	17.822	20.971	56.818	60.321
1991	11.516	8.557	18.311	1.109	17.197	13.073	51.949	85.055
1992	9.274	6.417	17.192	1.078	18.384	2.865	47.367	37.687
1993	10.555	6.146	15.932	1.151	17.113	9.087	46.945	53.703
1994	10.402	6.039	21.799	1.265	14.544	2.756	42.434	32.335
1995	10.901	7.917	24.937	1.266	13.495	58.729	48.557	38.396
1996	11.154	8.569	23.391	1.213	19.460	8.544	57.831	44.649
1997	10.627	7.790	22.173	1.187	28.542	4.503	63.737	85.277
1998	15.835	7.765	24.912	1.399	25.011	12.351	67.488	85.176
1999	16.835	9.661	28.460	1.556	21.175	33.196	66.182	65.604
2000	14.577	10.534	28.717	1.548	22.662	12.603	67.813	68.102
2001	14.406	10.138	29.131	1.510	25.768	12.777	71.317	53.188
2002	17.145	10.331	33.035	1.532	25.033	52.299	76.434	69.786
2003	17.975	11.902	32.546	1.496	30.829	12.003	82.756	116.794
2004	16.250	11.484	30.130	1.420	38.340	11.031	84.464	131.910
2005	18.202	10.741	30.798	1.403	35.599	41.592	85.872	107.341
2006	17.370	11.365	31.286	1.376	36.213	19.761	86.329	95.676
2007	15.714	11.159	26.428	1.306	40.650	13.543	88.462	104.841
2008	16.288	9.550	25.452	1.365	38.326	7.708	85.370	114.430
2009	16.312	9.638	26.699	1.444	33.843	8.682	79.778	91.673
2010	15.221	9.991	26.181	1.412	29.765	23.790	75.160	81.642
2011	12.967	9.497	25.999	1.335	29.538	13.519	71.181	67.053
2012	11.674	8.981	24.581	1.257	31.686	8.217	70.003	61.248
2013	11.693	8.289	23.753	1.214	29.949	6.107	67.677	62.410
2014	11.591	8.078	22.120	1.195	26.582	3.500	63.268	114.103
2015	10.211	7.534	19.491	1.186	22.785	5.830	56.700	64.240
2016	8.556	6.554	16.759	1.188	19.373	10.633	50.152	61.231
2017	7.005	5.539	14.291	1.179	17.541	4.220	45.170	52.922
2018	6.272	4.651	13.142	1.201	15.966	7.078	41.712	28.932
2019	6.965	4.393	14.003	1.340	13.889	3.713	39.442	28.744
2020	7.293	4.861	14.802	1.186	12.325	21.170		

Table 10. Comparison of projected mature male biomass (1000 t) on Feb. 15 and their 95% limits with four levels of fishing mortality during 2020-2030. Parameter estimates with model 19.3a are used for the projection with recruitments randomly drawn from estimated recruitments from 2012 to 2019. Fishing mortality of 0.167 is about estimated F_{ofl} for Model 19.3a for 2020.

	F=0			F=0.083		
	Mean	2.5% limit	97.5% limit	Mean	2.5% limit	97.5% limit
2020	16.559	15.055	17.985	15.562	14.142	16.896
2021	18.365	16.408	20.181	16.365	14.543	18.058
2022	19.274	17.074	21.720	16.340	14.399	18.530
2023	19.876	17.551	22.607	16.136	14.145	18.508
2024	20.567	18.082	23.657	16.154	13.986	18.811
2025	21.251	18.268	24.662	16.273	13.670	19.145
2026	21.883	18.439	25.880	16.425	13.441	19.680
2027	22.451	18.484	26.760	16.579	13.304	20.149
2028	22.906	18.886	27.598	16.678	13.385	20.426
2029	23.305	19.103	28.054	16.772	13.439	20.390
2030	23.677	19.278	28.473	16.881	13.420	20.644

	F=0.167			F=0.250		
	Mean	2.5% limit	97.5% limit	Mean	2.5% limit	97.5% limit
2020	14.638	13.299	15.885	13.780	12.514	14.939
2021	14.629	12.942	16.223	13.122	11.551	14.613
2022	13.950	12.205	15.930	11.996	10.410	13.832
2023	13.267	11.564	15.364	11.051	9.580	12.925
2024	12.951	10.999	15.183	10.597	8.846	12.625
2025	12.833	10.581	15.242	10.409	8.396	12.557
2026	12.809	10.170	15.613	10.346	8.016	12.819
2027	12.829	10.086	15.747	10.340	7.946	12.939
2028	12.821	10.045	15.907	10.314	7.852	12.899
2029	12.833	10.068	15.891	10.312	7.945	12.854
2030	12.877	10.035	16.016	10.346	7.908	12.898

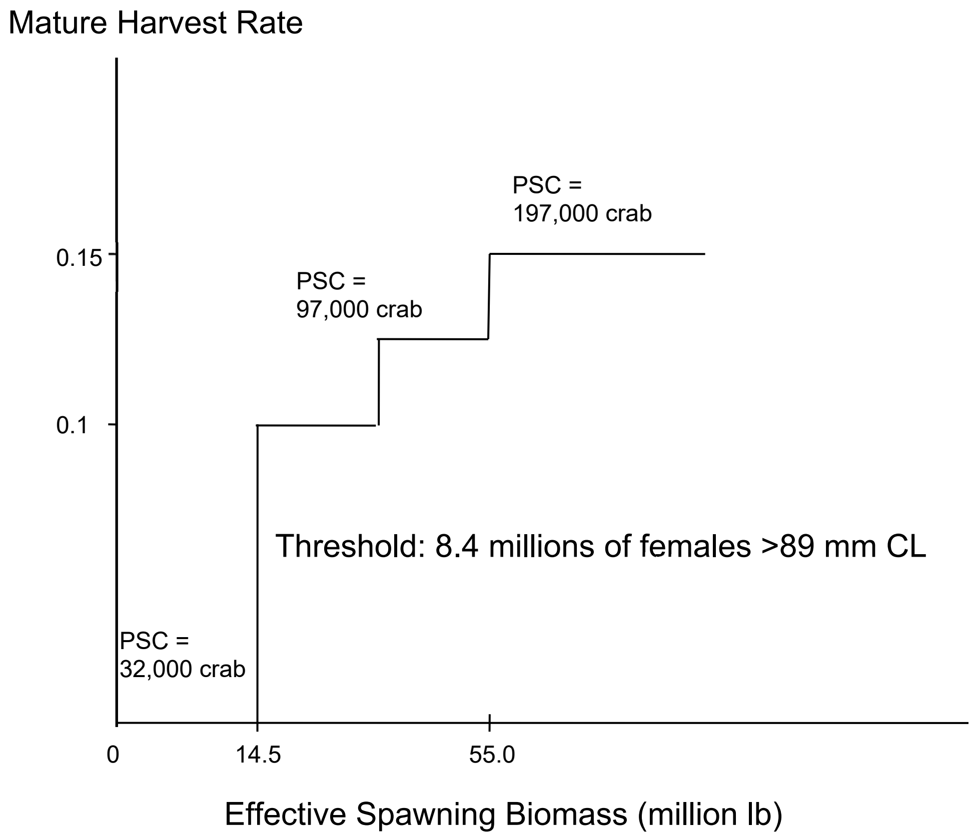


Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crab) of Bristol Bay red king crab in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of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

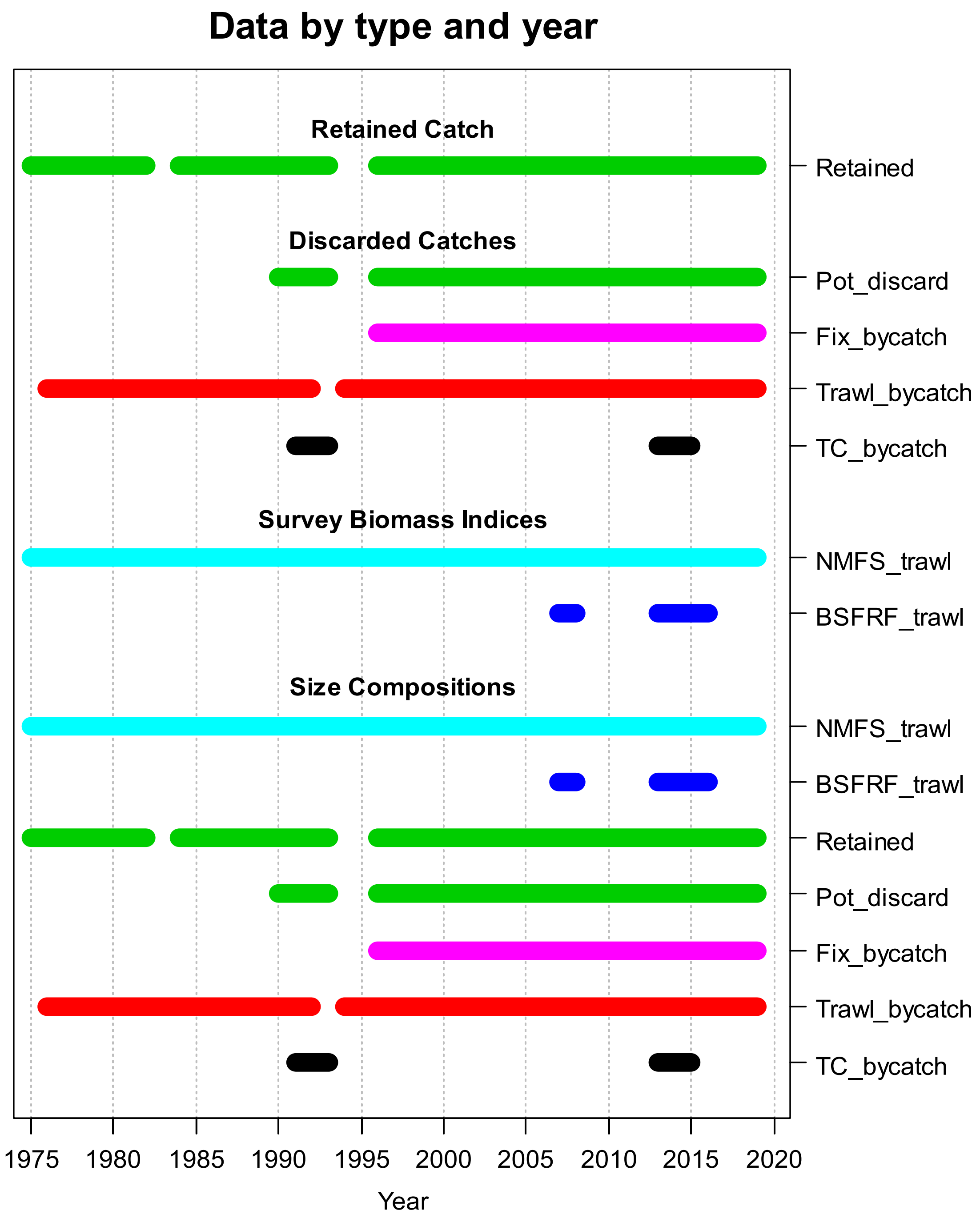


Figure 2a. Data types and ranges used for the stock assessment with model 19.3.

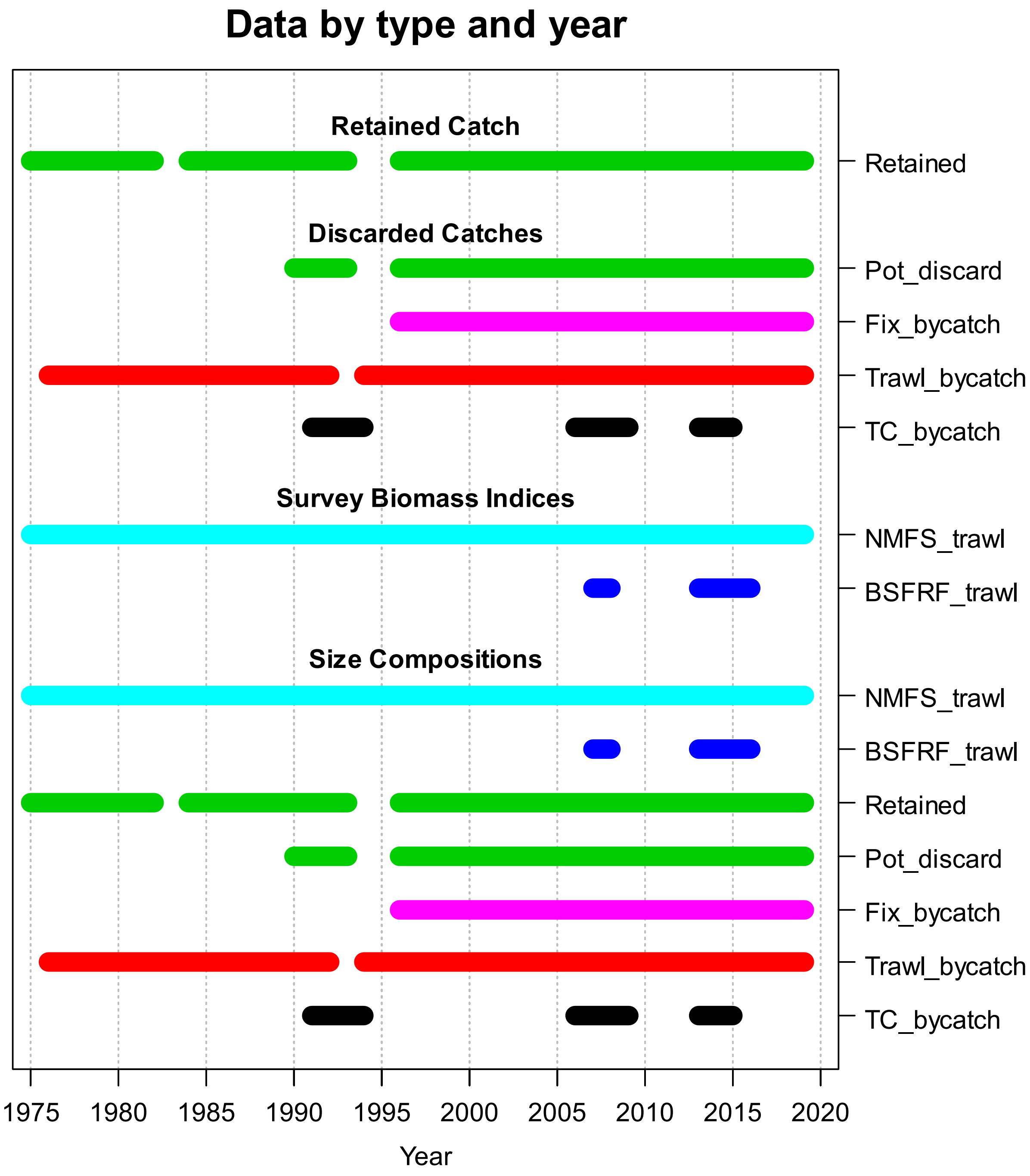


Figure 2b. Data types and ranges used for the stock assessment with the other seven models (19.3c-19.6).

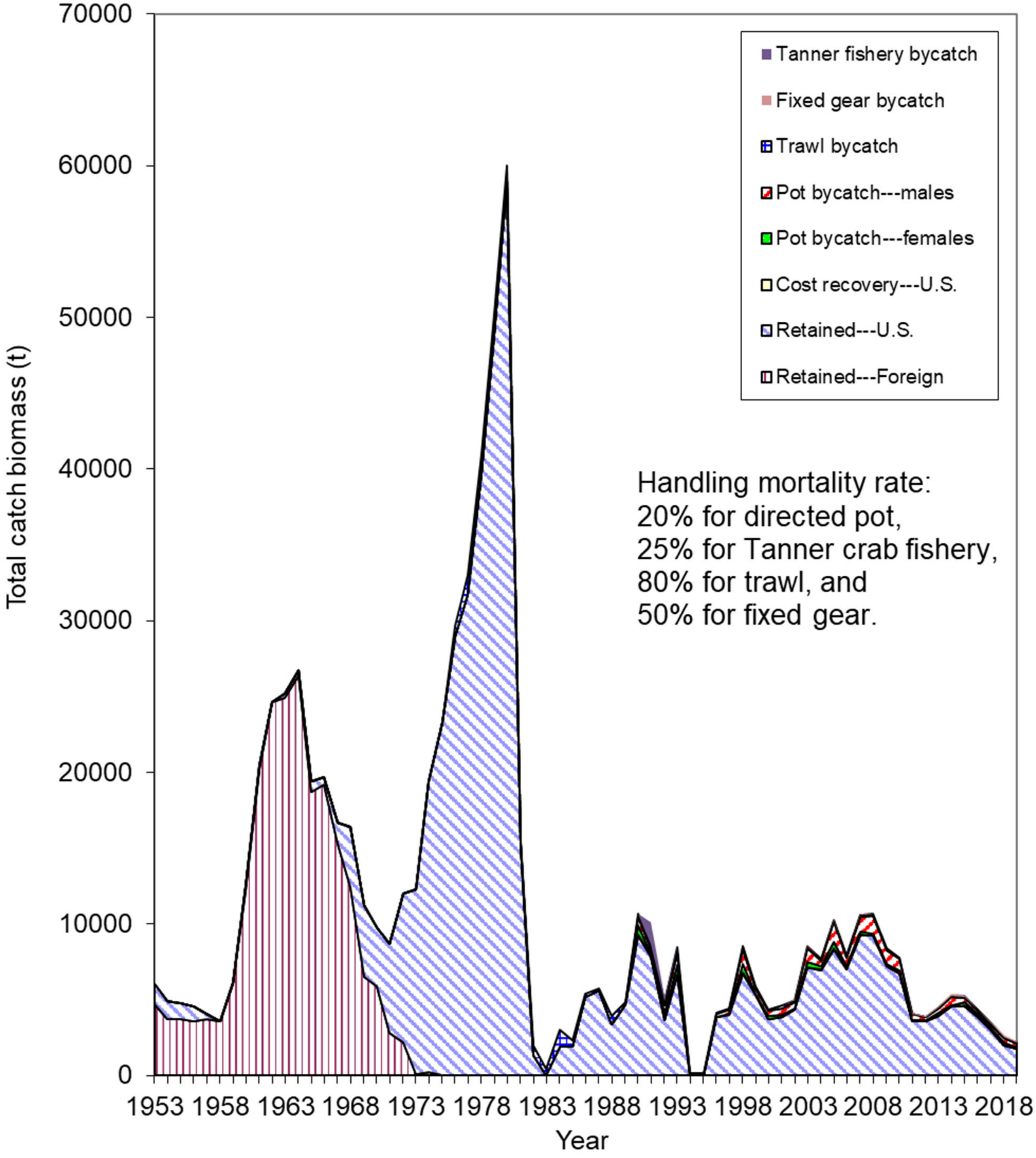


Figure 3. Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1953 to 2019. Directed pot bycatch data were not available from the observer program before 1990 and are not included in this figure.

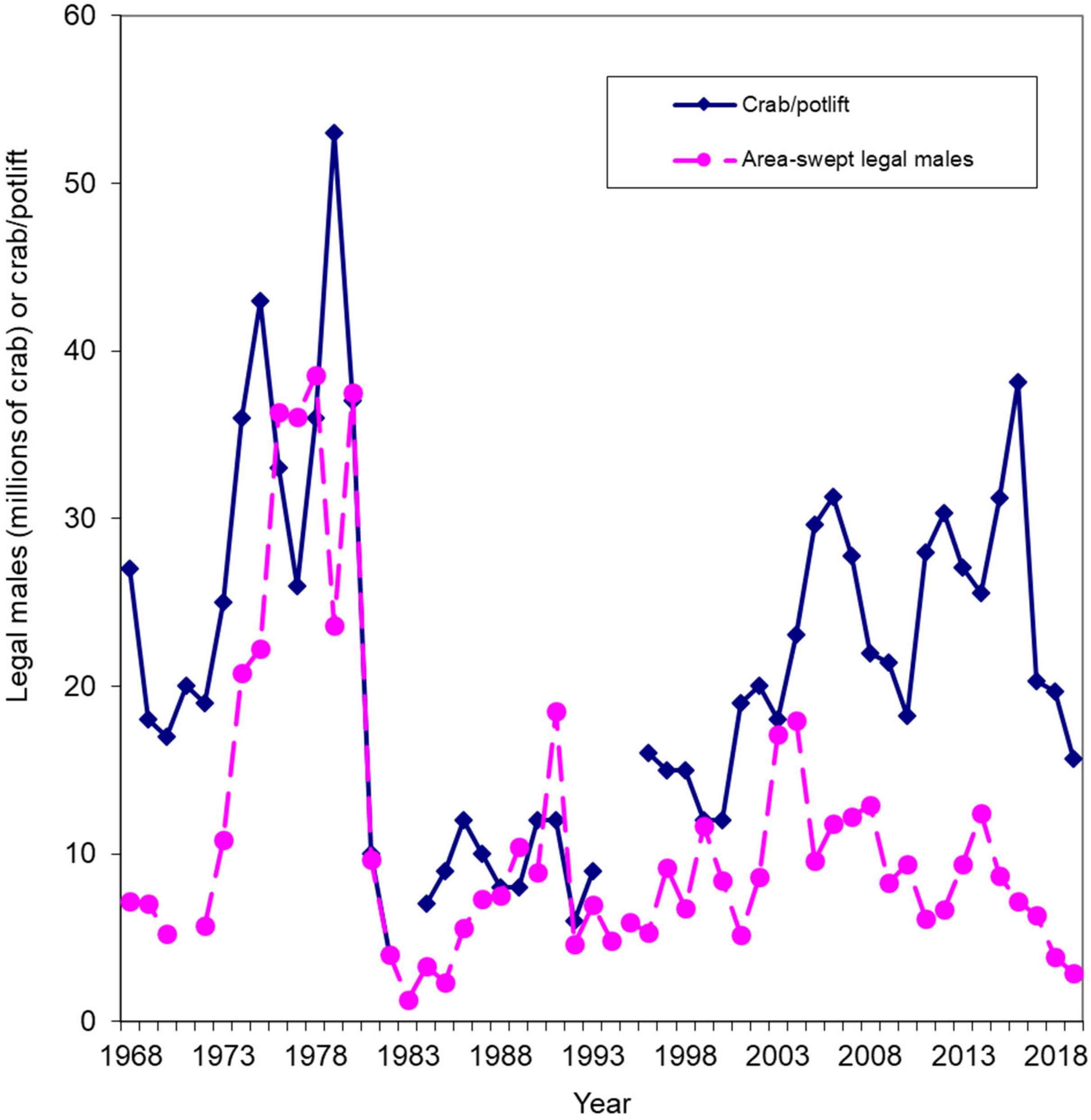


Figure 4. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2019.

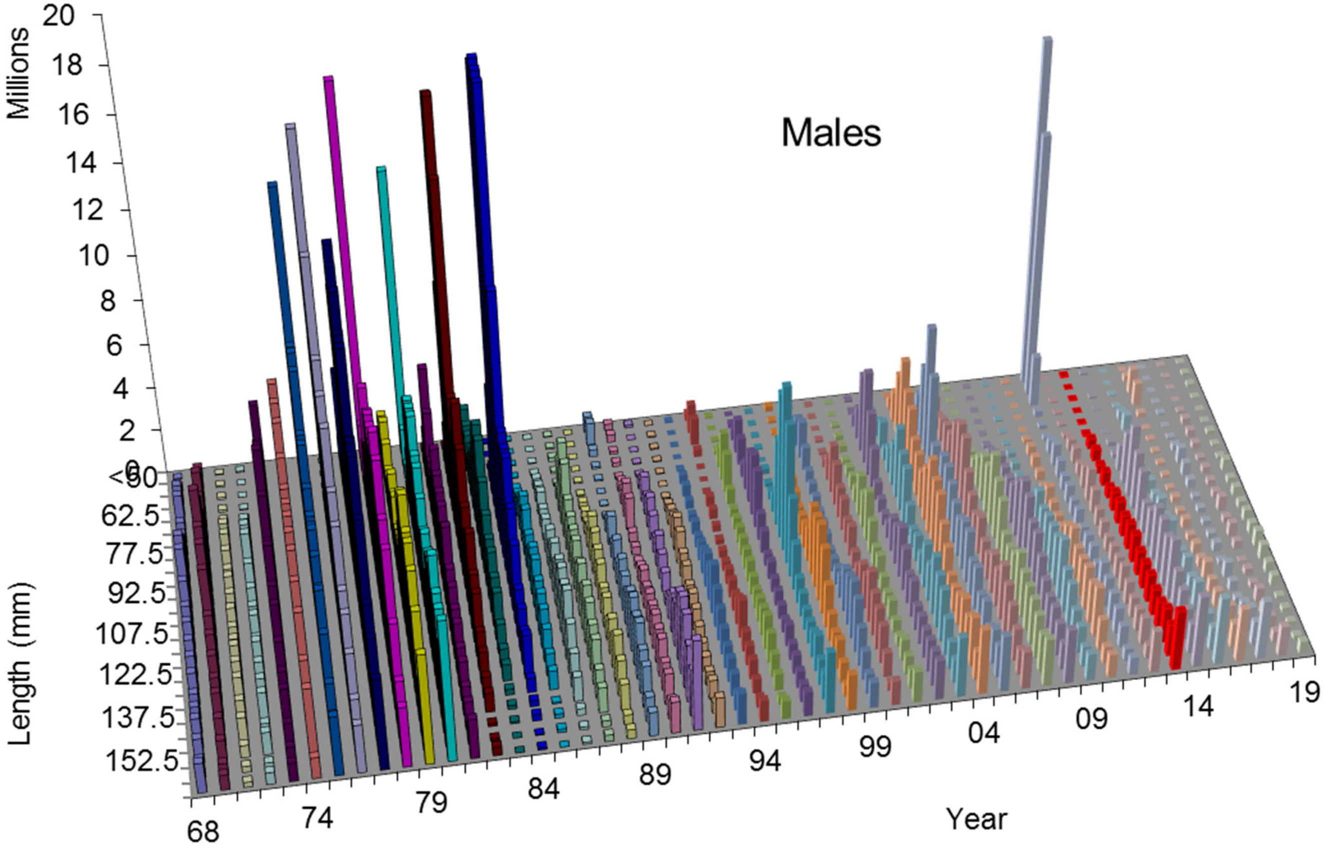


Figure 5a. Survey abundances by 5-mm carapace length bin for male Bristol Bay red king crab from 1968 to 2019.

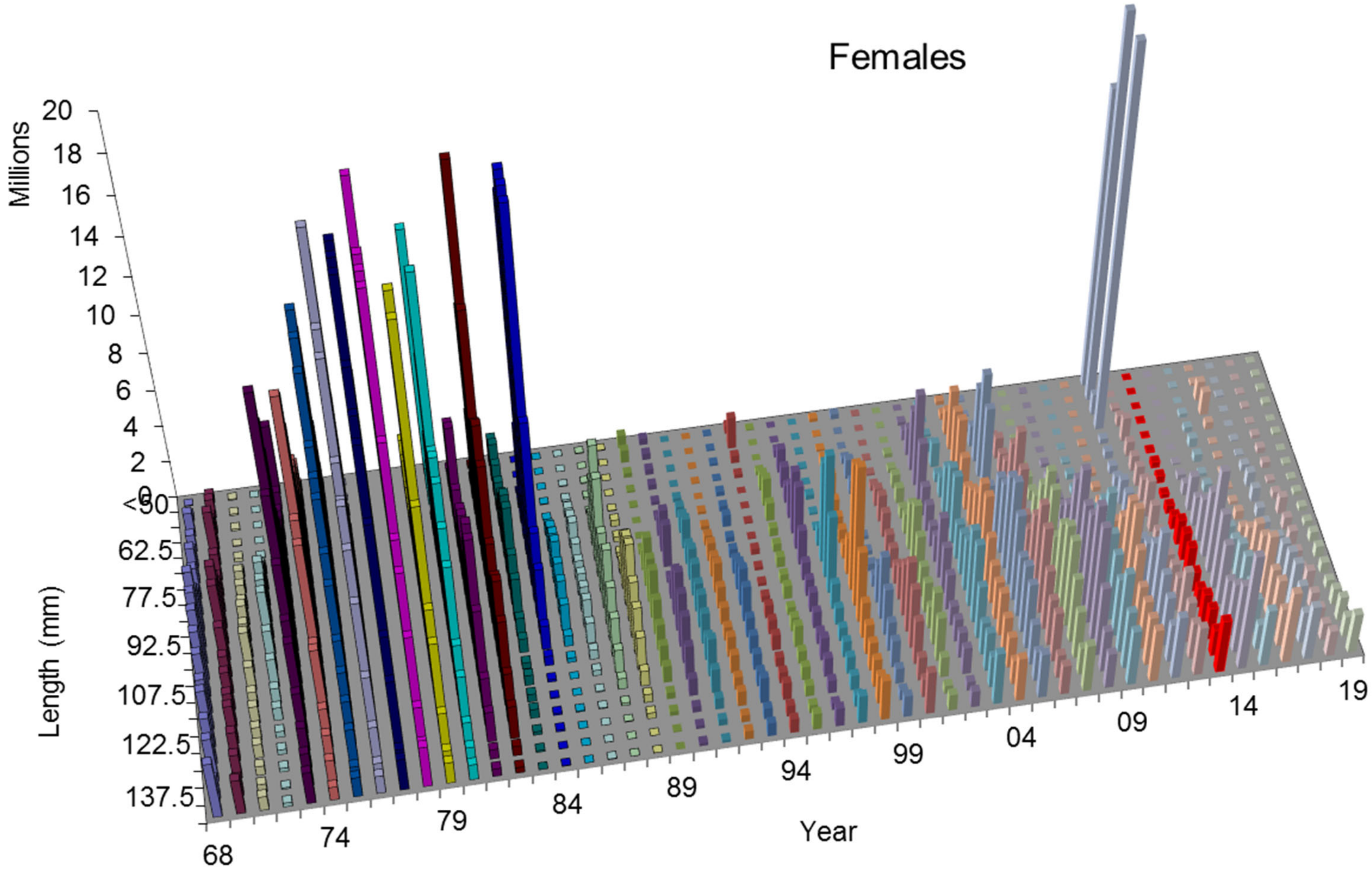


Figure 5b. Survey abundances by 5 mm carapace length bin for female Bristol Bay red king crab from 1968 to 2019.

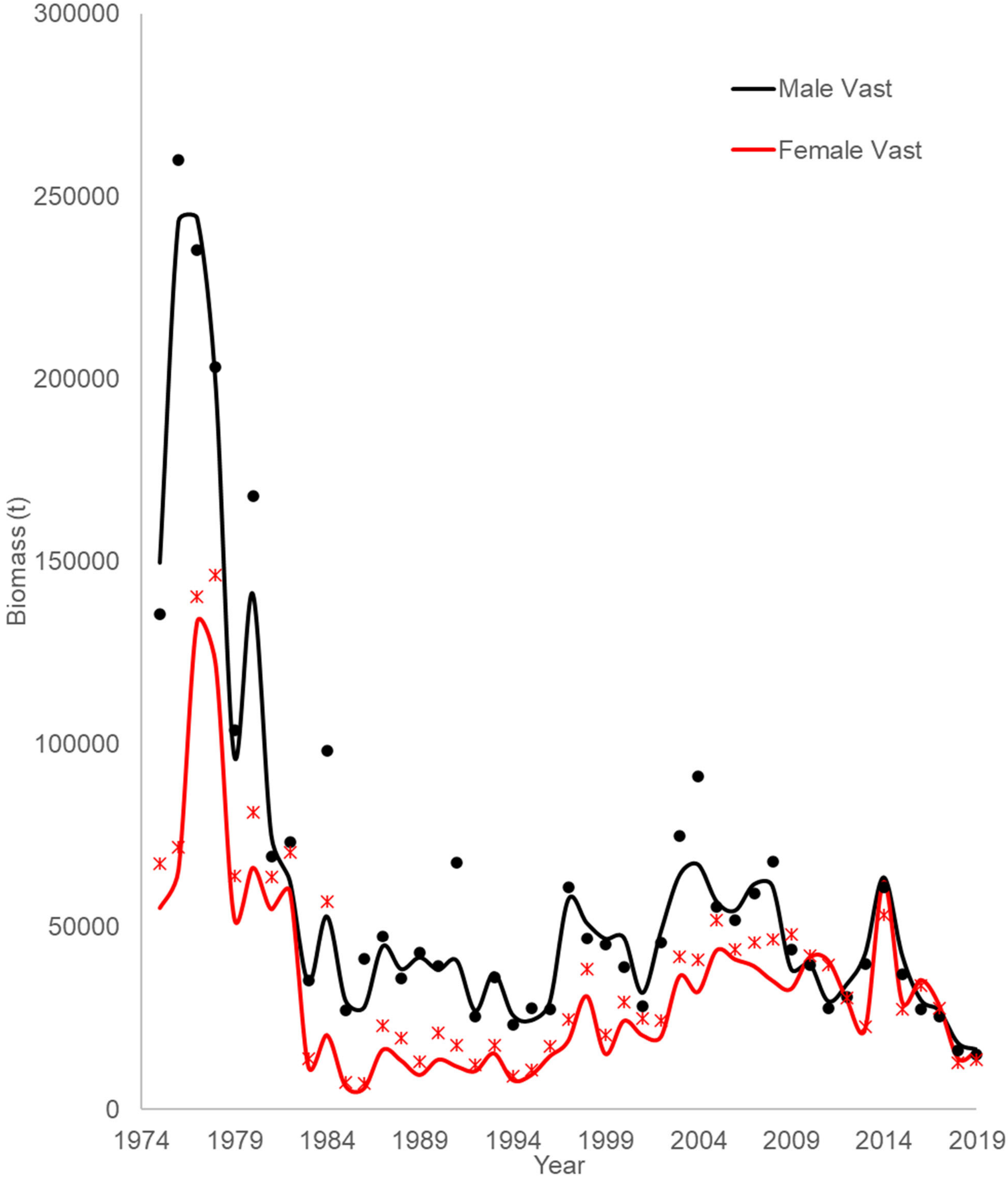
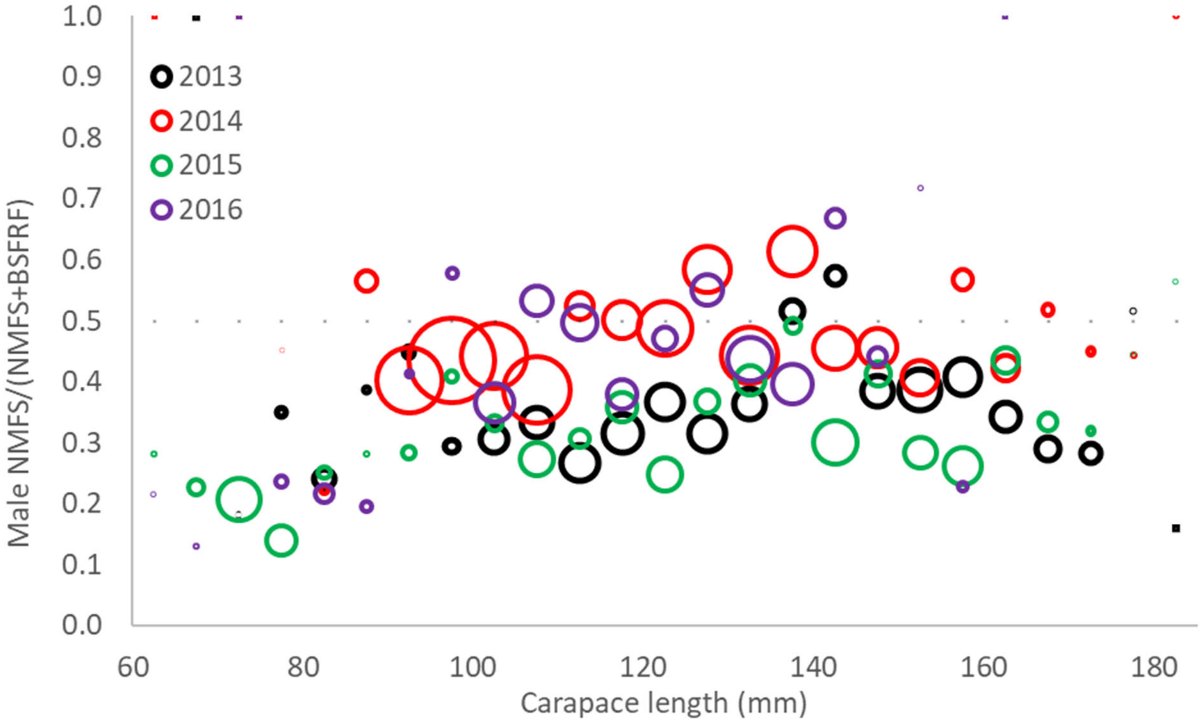


Figure 6. Comparison of area-swept and VAST-estimated survey biomasses for Bristol Bay red king crab from 1975 to 2019.



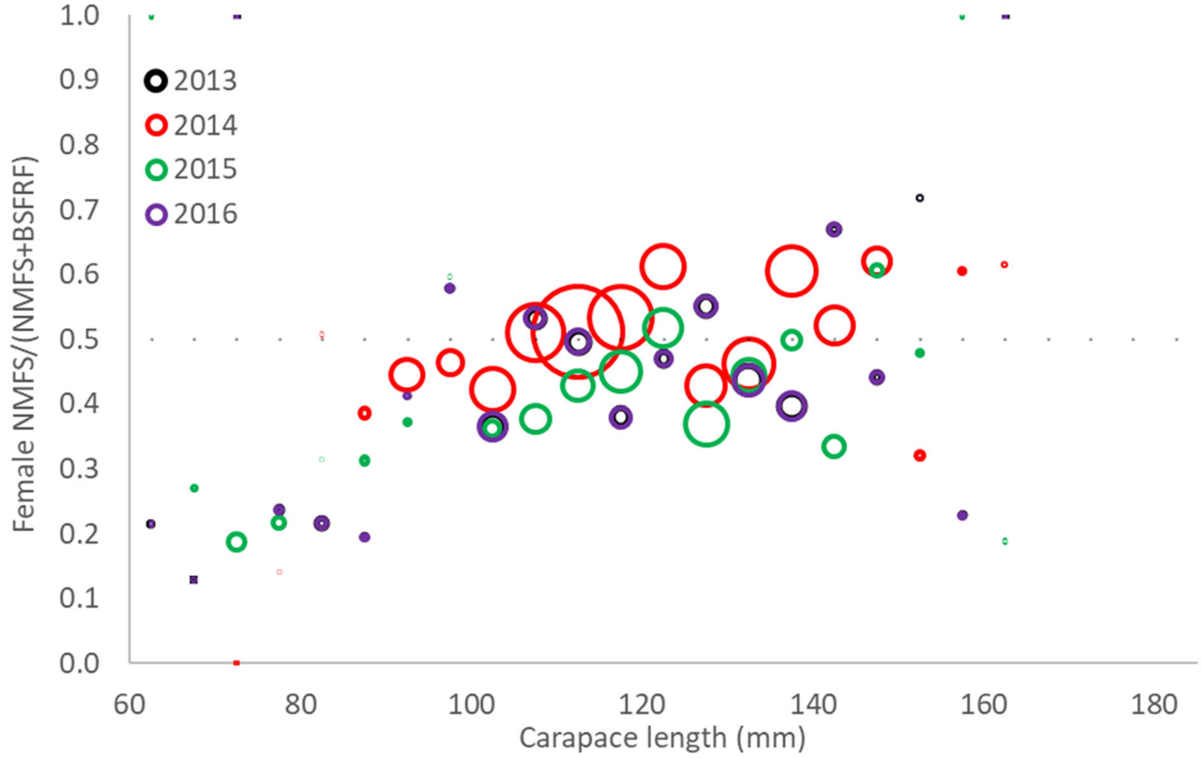


Figure 7a. Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

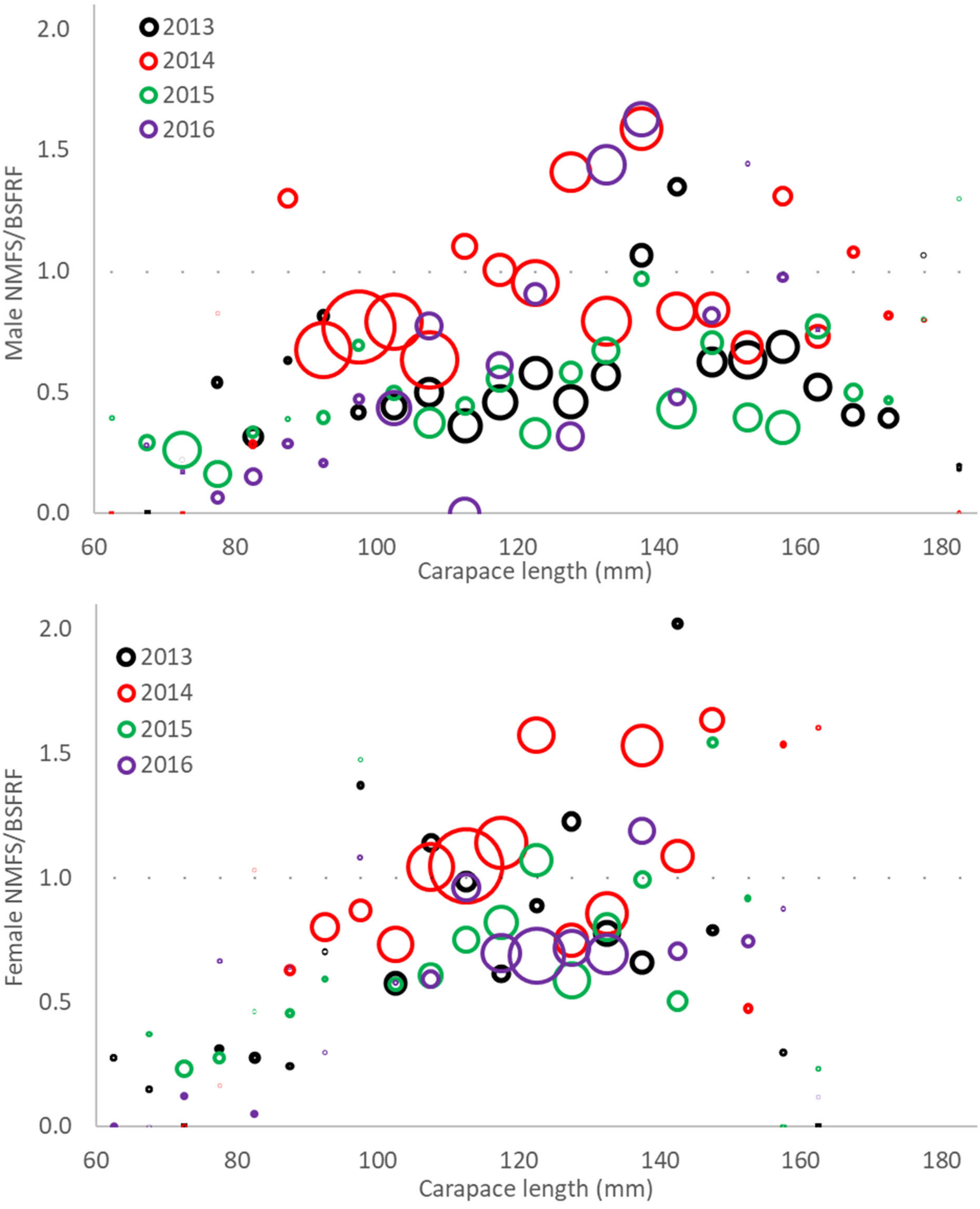


Figure 7b. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

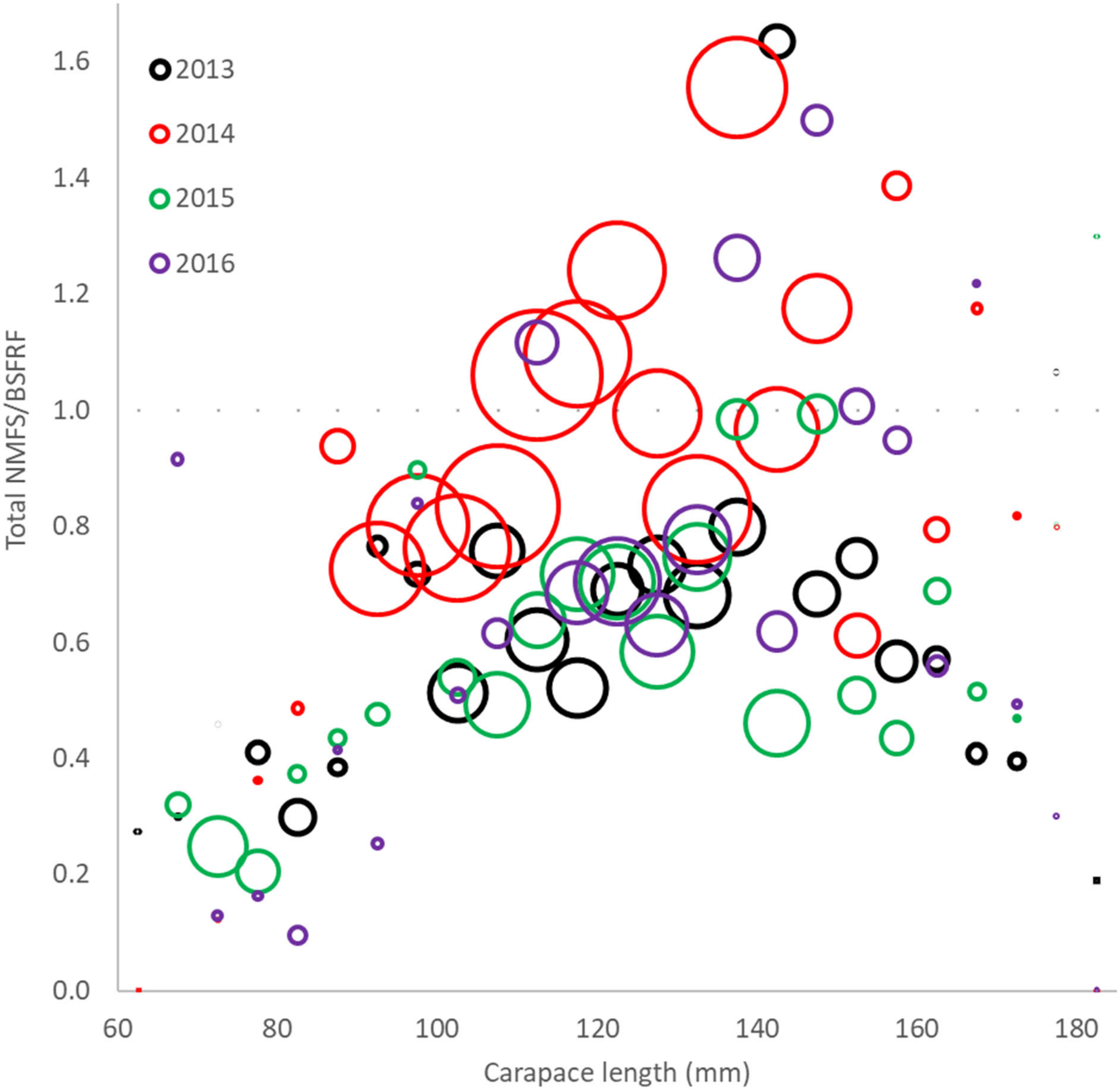


Figure 7c. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances. The abundance-weighted average ratio is 0.891 for crab ≥135 mm carapace length from all four years of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

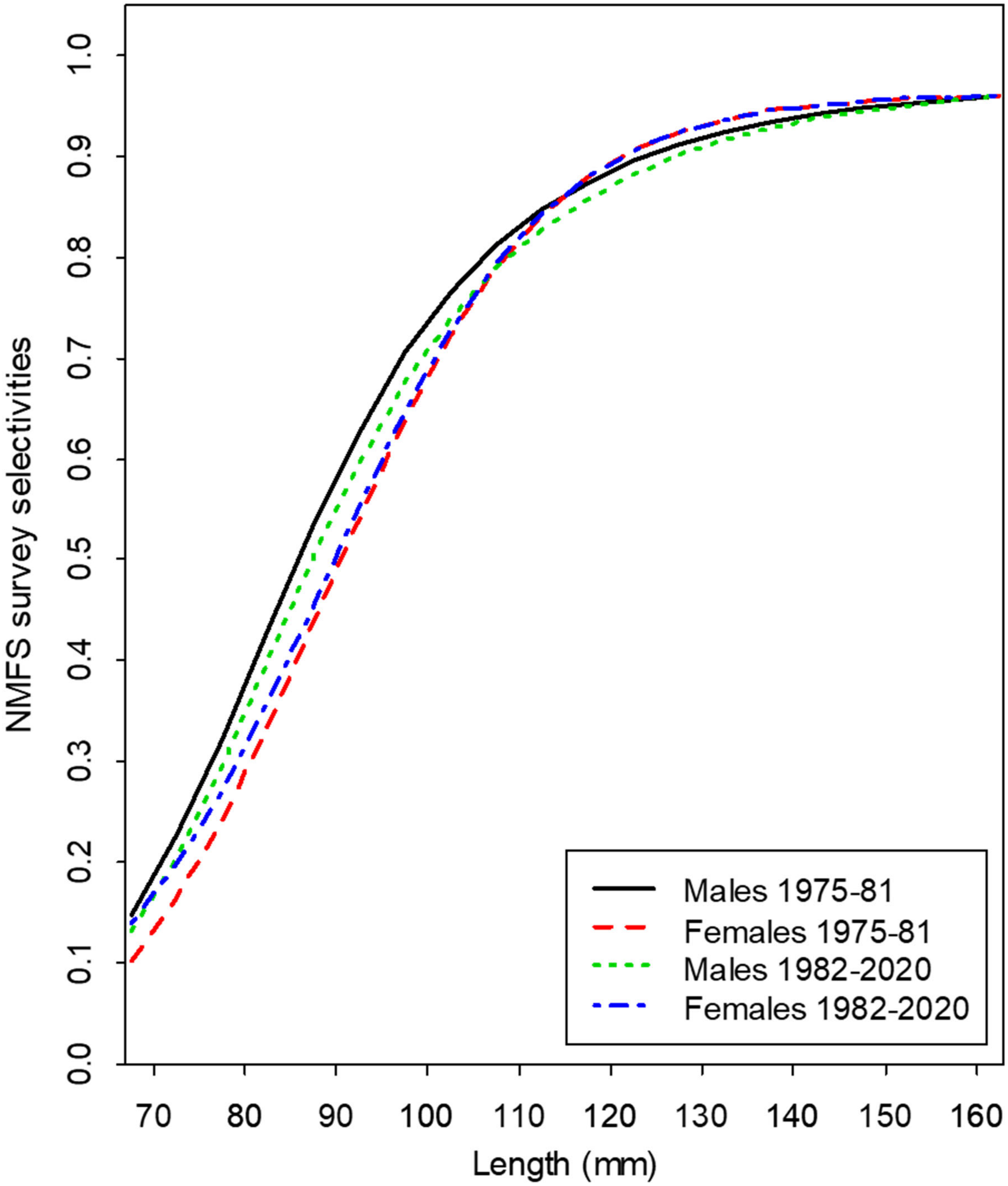


Figure 8a. Estimated NMFS trawl survey selectivities under model 19.3.

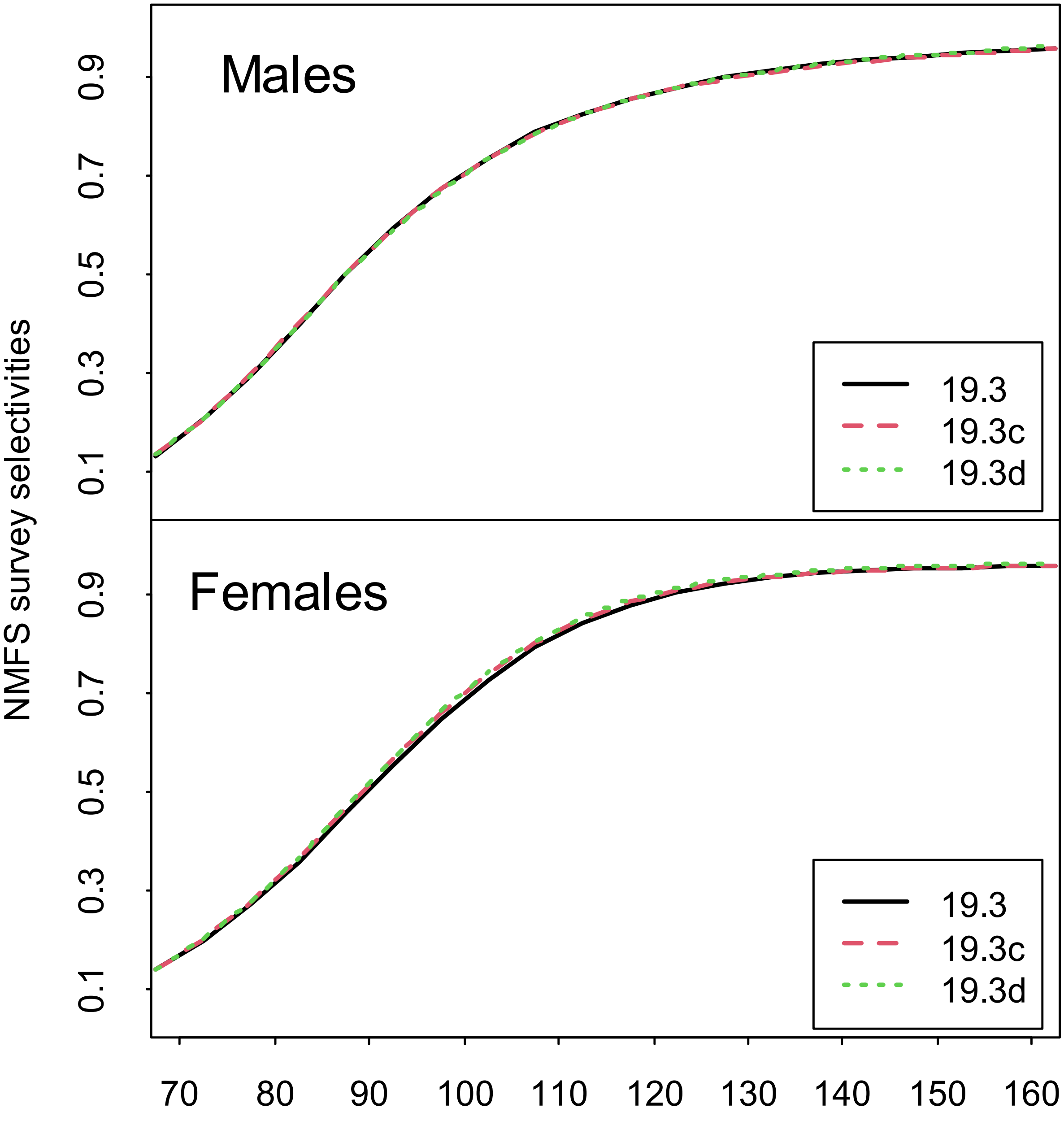


Figure 8b. Comparisons of estimated NMFS survey selectivities with models 19.3, 19.3c, and 19.3d during 1982-2020.

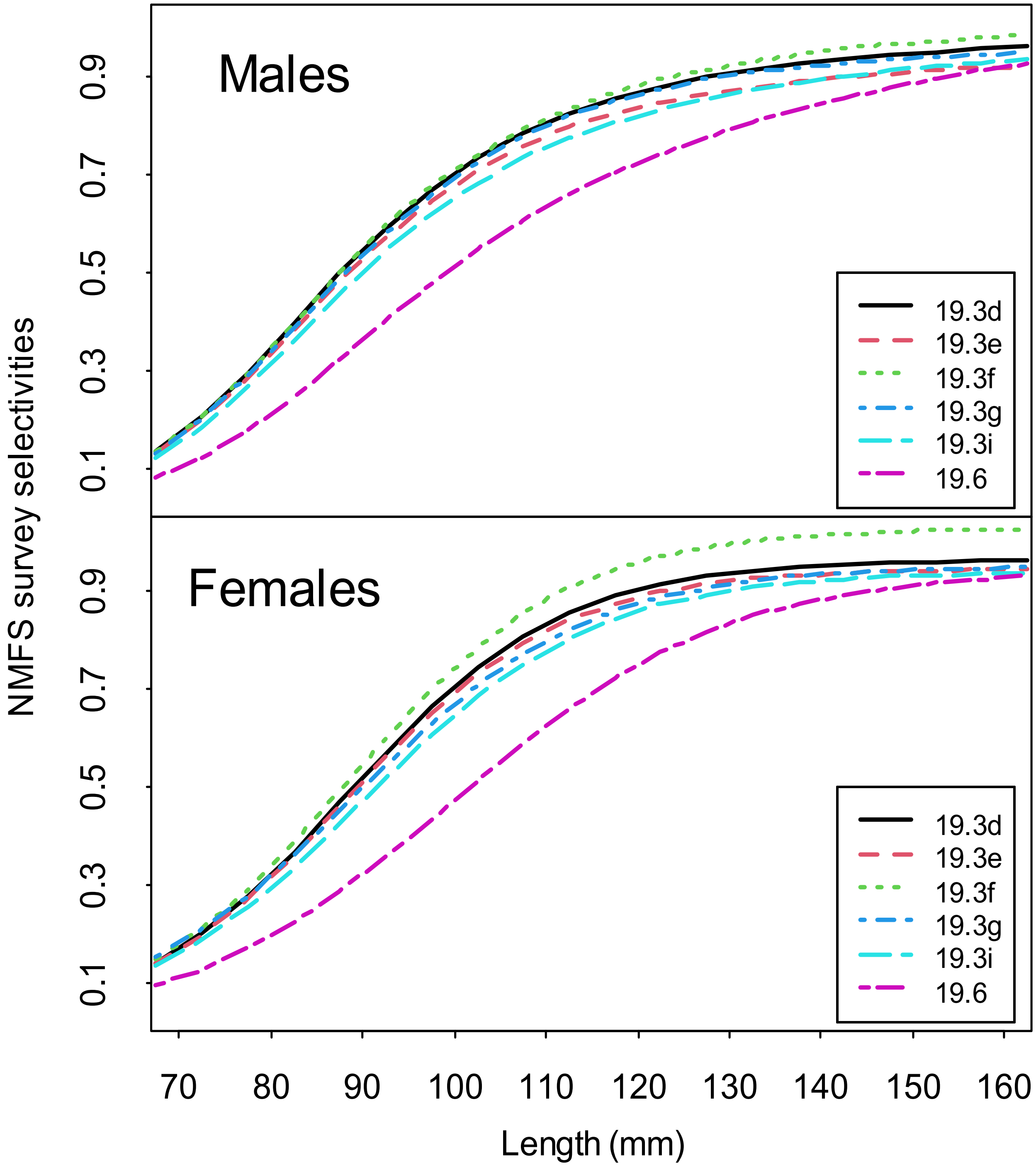


Figure 8c. Comparisons of estimated NMFS survey selectivities with models 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6 during 1982-2020.

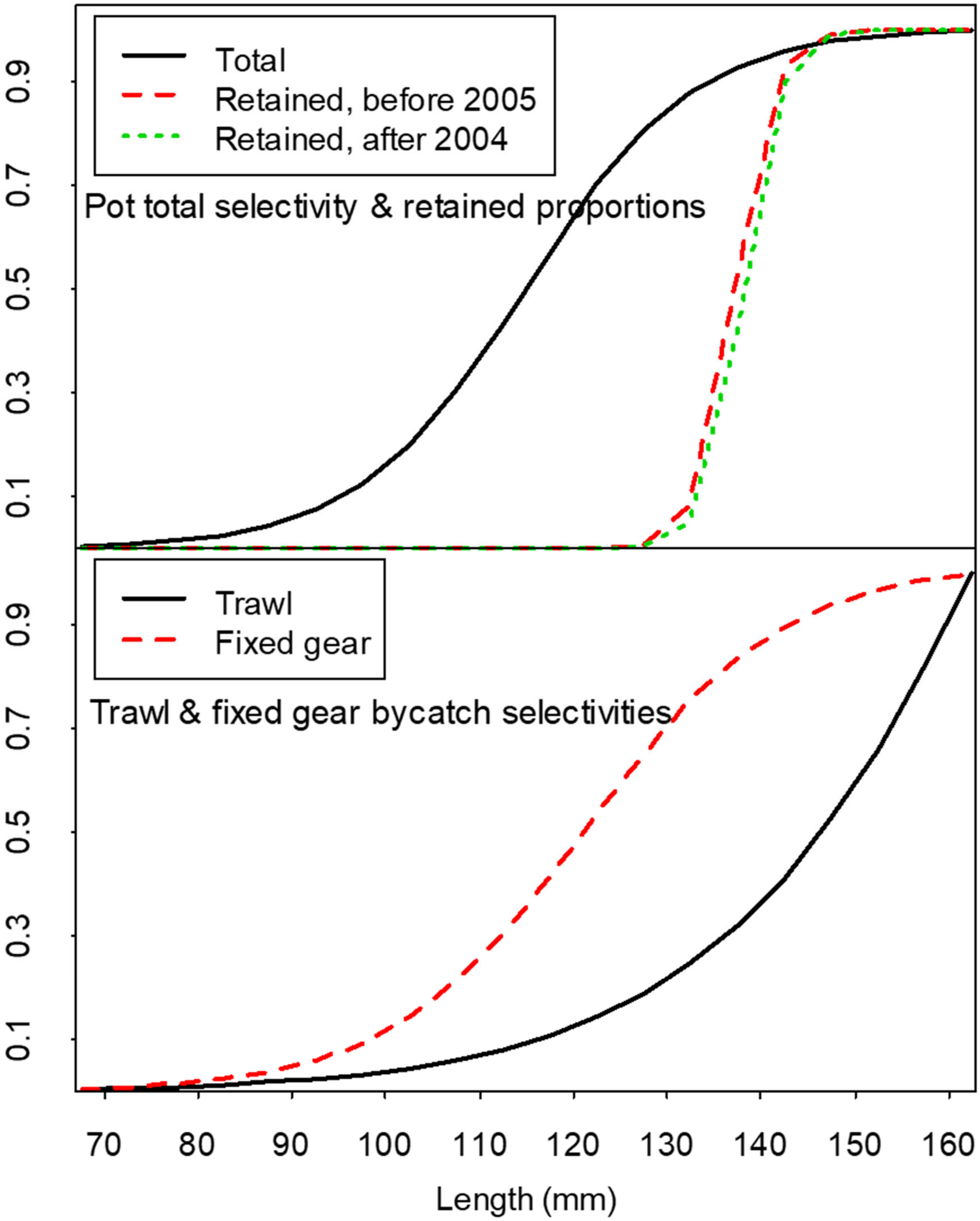


Figure 8d. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 19.3.

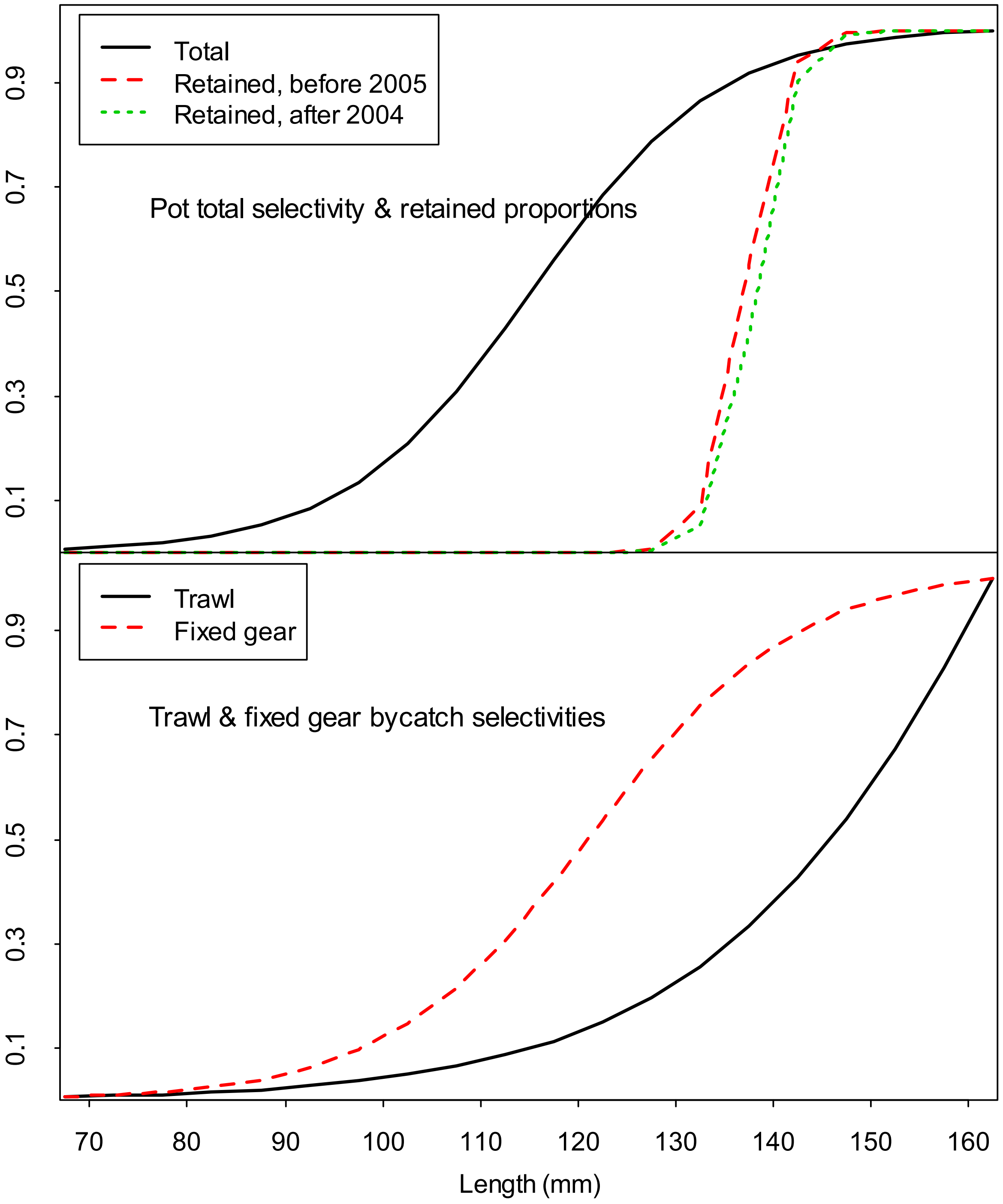


Figure 8e. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 19.3d.

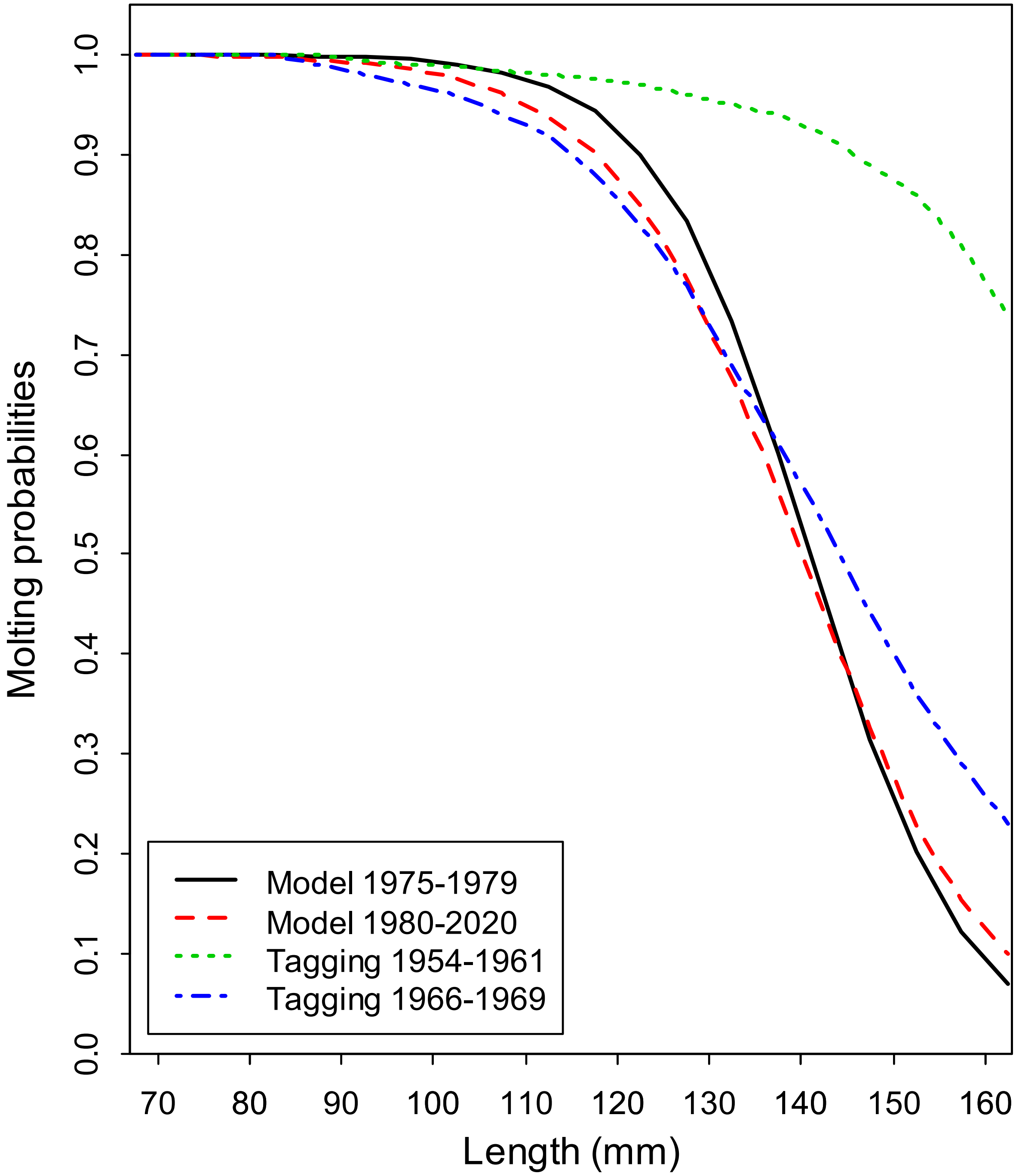


Figure 9a. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 19.3. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2020 were estimated with a length-based model.

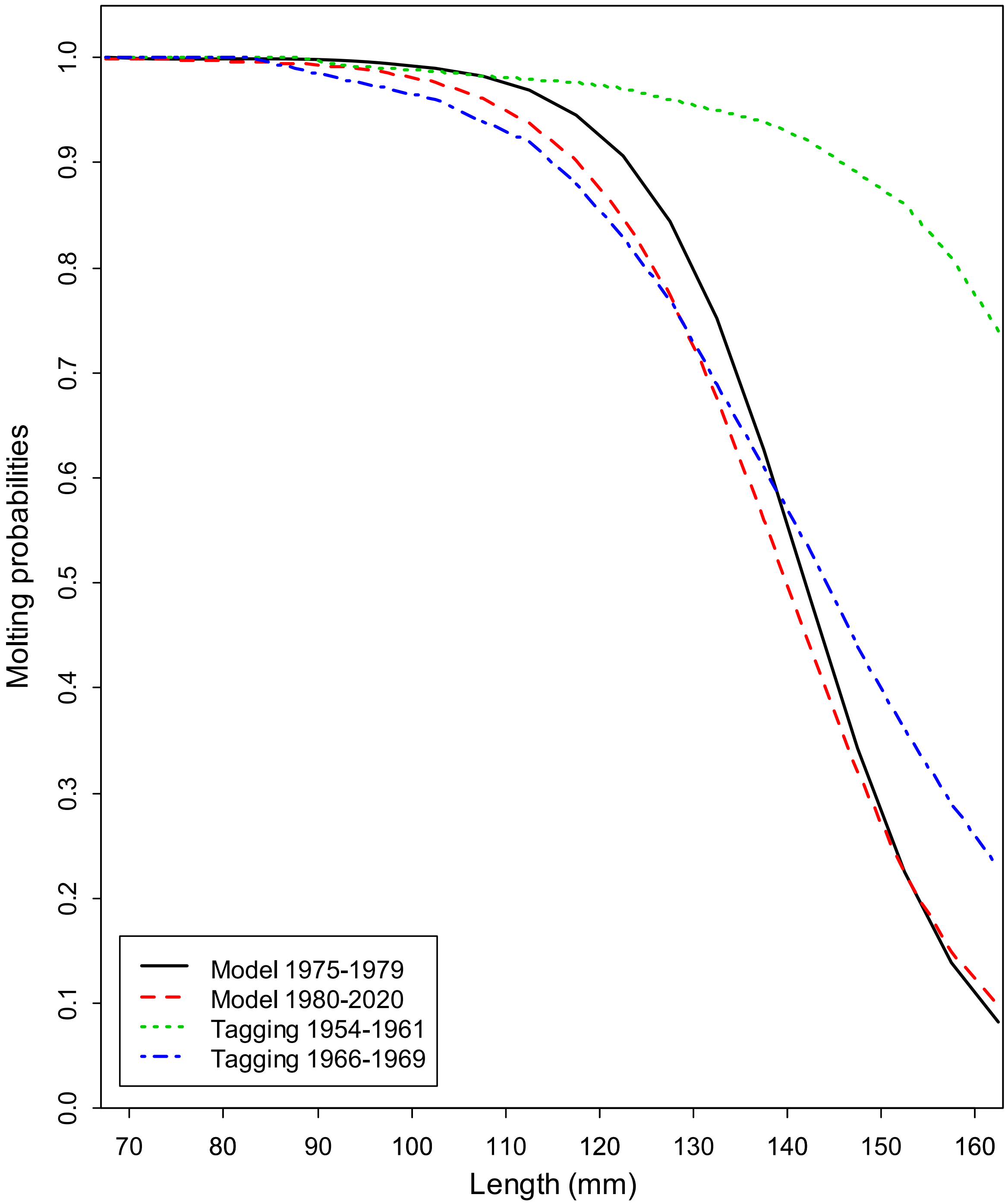


Figure 9b. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 19.3d. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2020 were estimated with a length-based model.

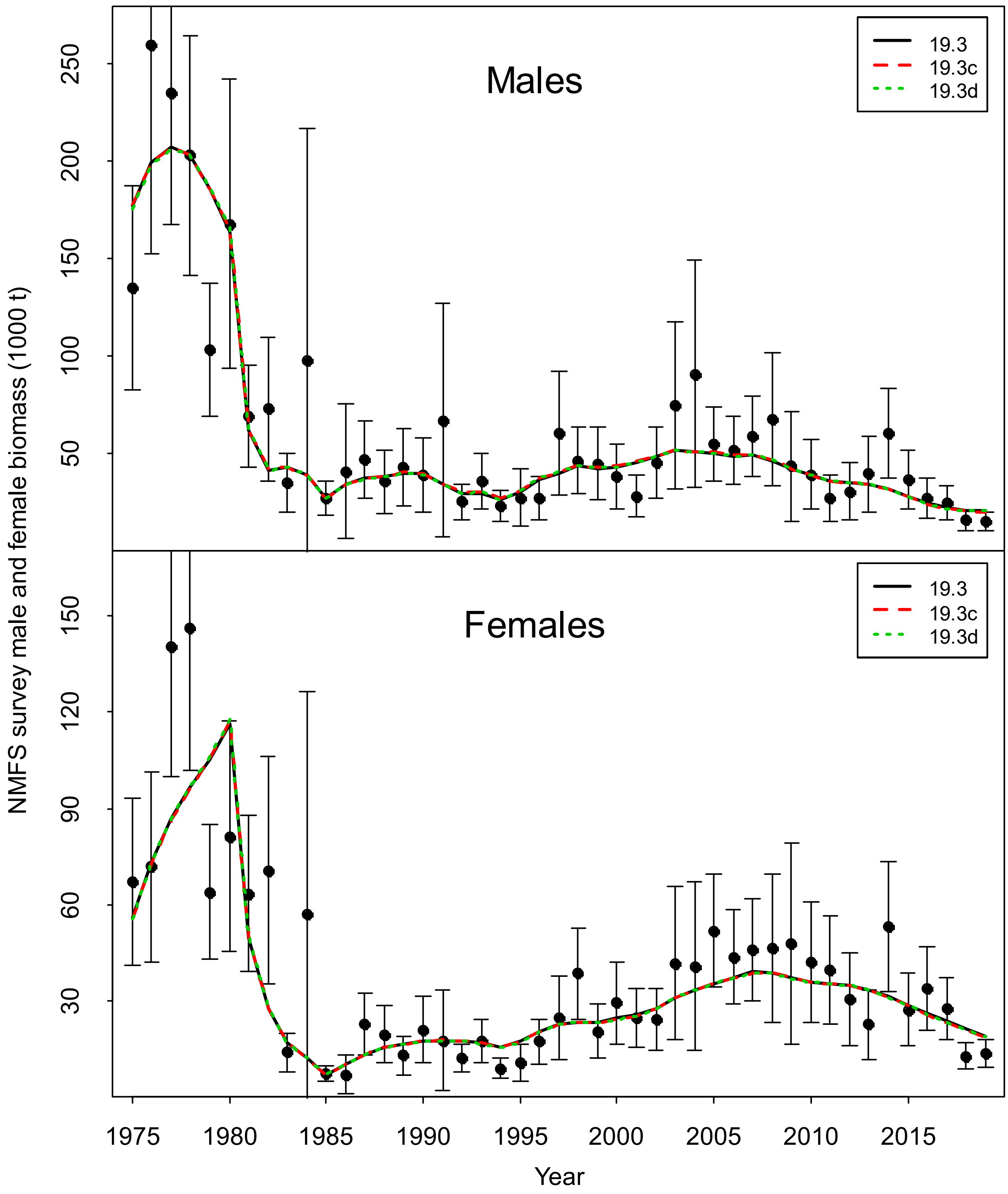


Figure 10a1. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2020 under models 19.3, 19.3c, and 19.3d. The error bars are plus and minus 2 standard deviations of model 19.3.

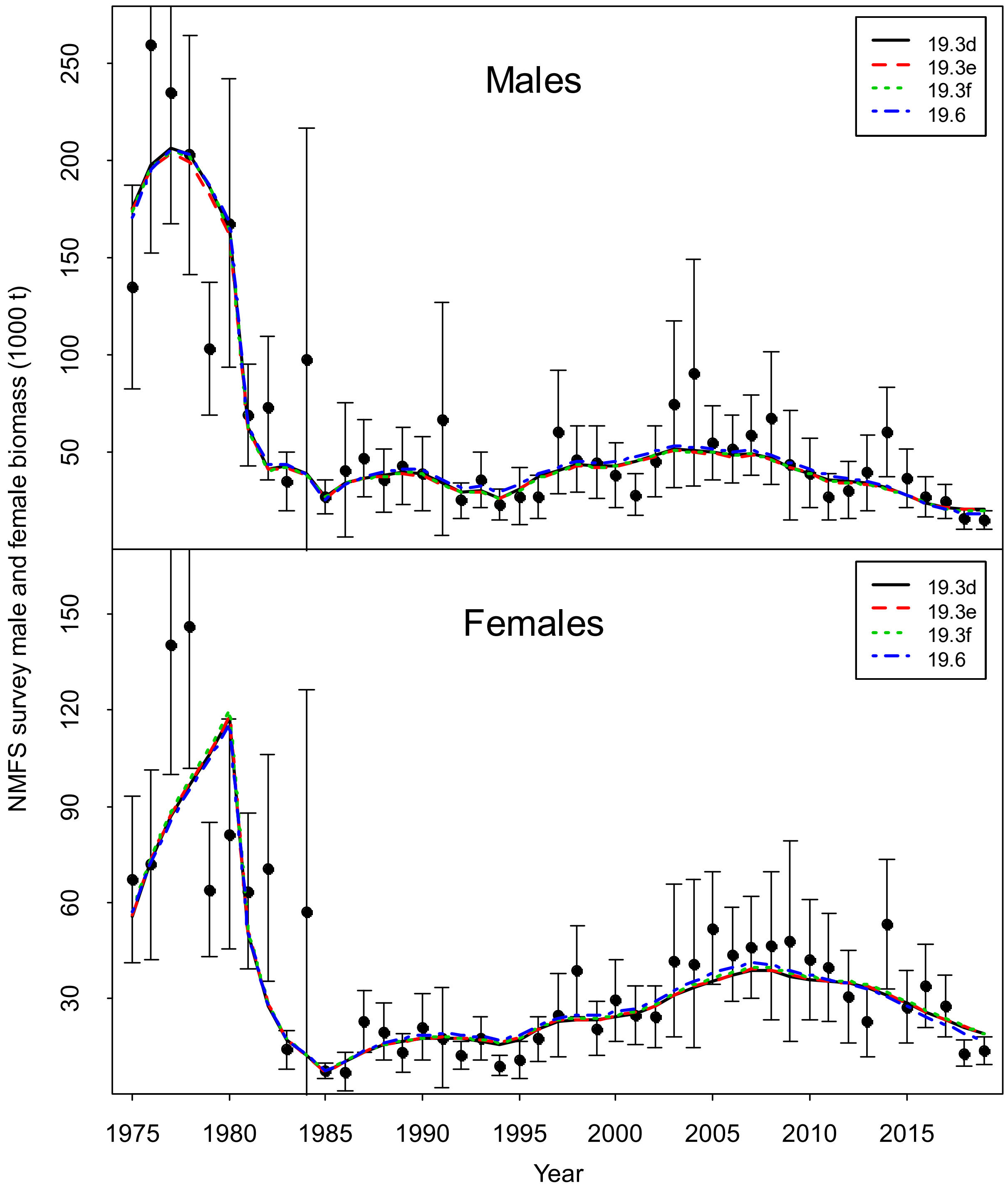


Figure 10a2. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2020 under models 19.3d, 19.3e, 19.3f, and 19.6. The error bars are plus and minus 2 standard deviations of model 19.3d.

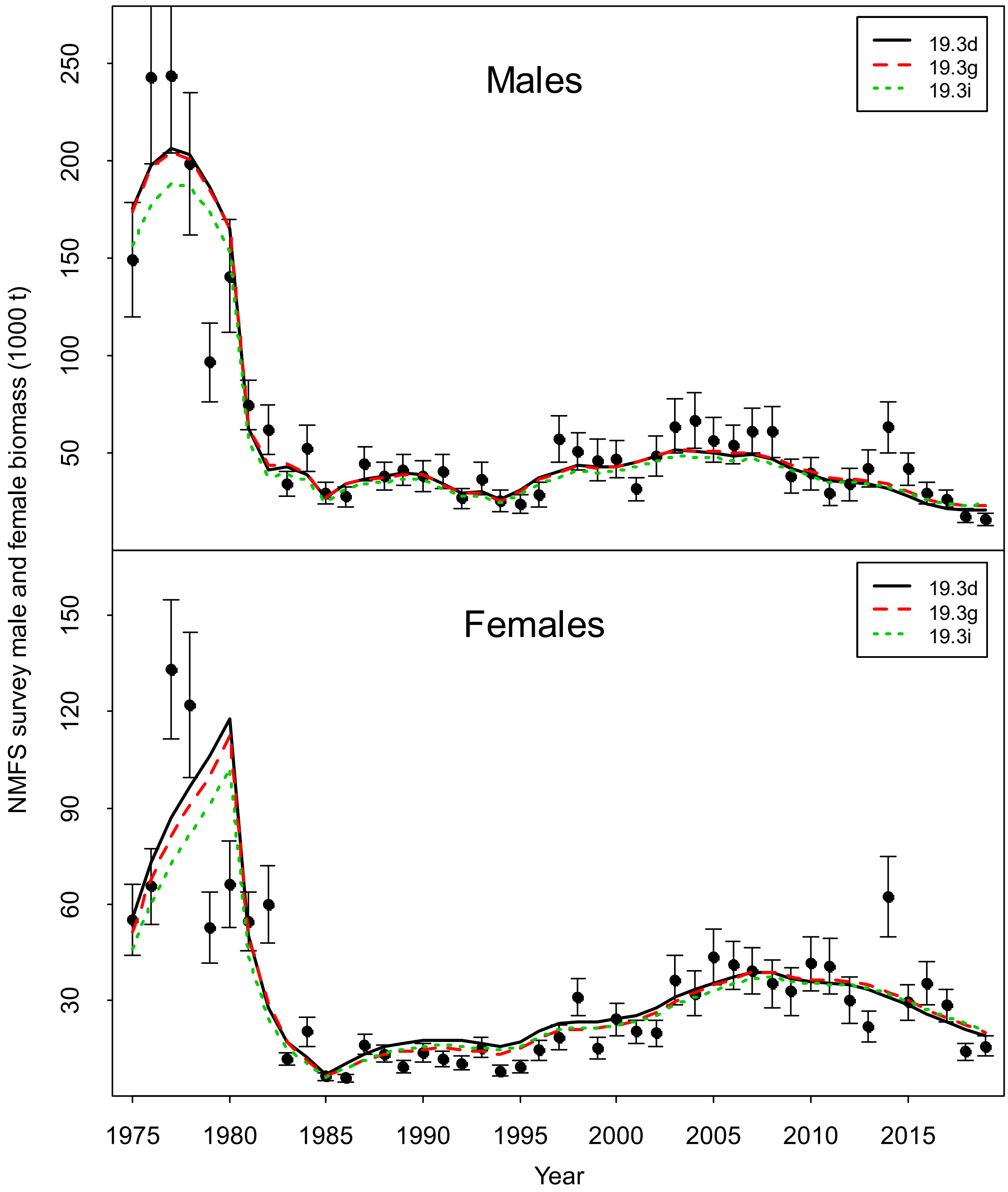


Figure 10a3. Comparisons of VAST estimates of total NMFS survey biomass and model prediction for model estimates in 2020 under models 19.3d, 19.3g, and 19.3i. The error bars are plus and minus 2 standard deviations of model 19.3g.

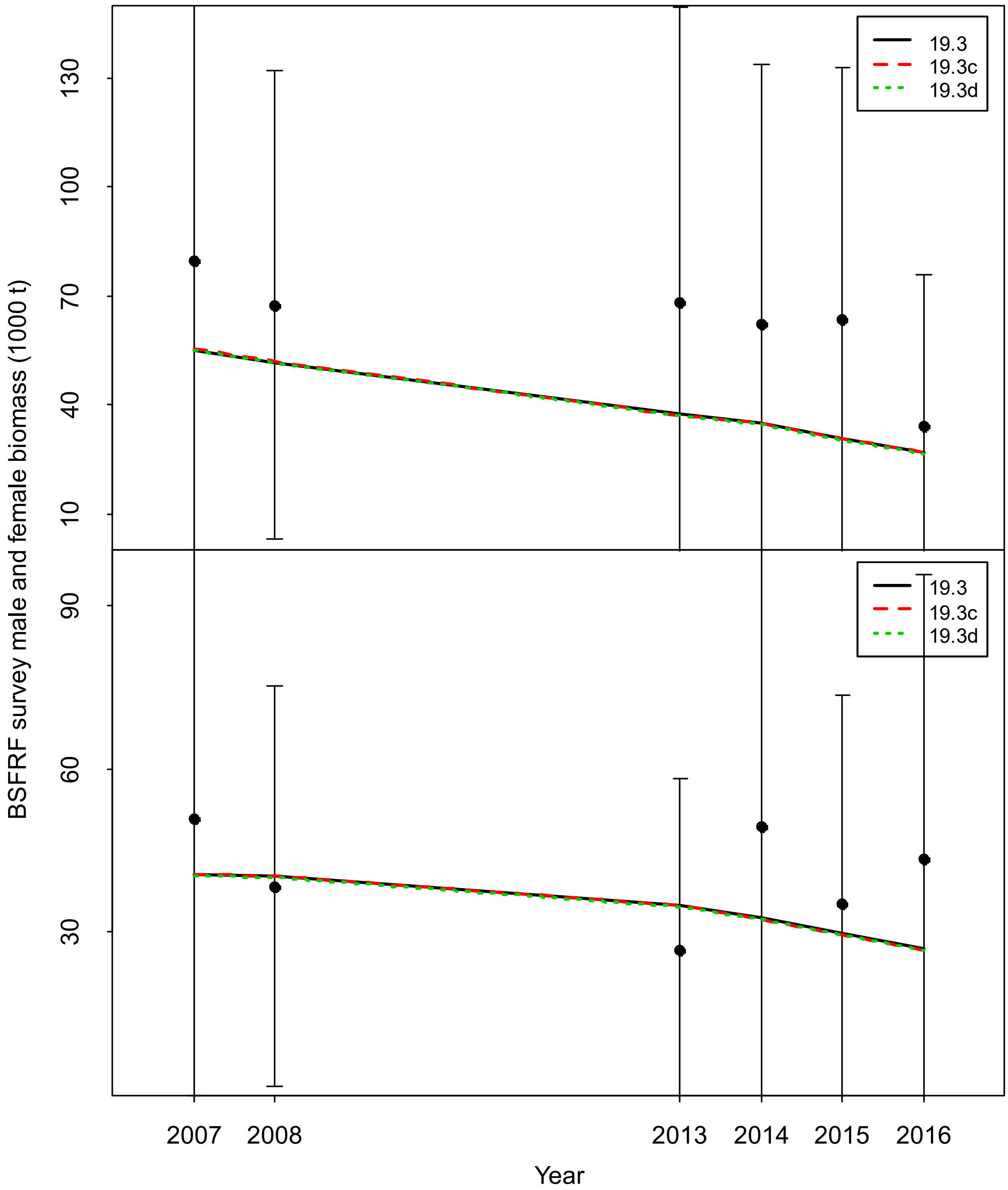


Figure 10b. Comparisons of survey biomass estimates by sex (upper plot for males and lower plot for females) by the BSFRF survey and the model for model estimates in 2020 (models 19.3, 19.3c, and 19.3d). The error bars are plus and minus 2 standard deviations of model 19.3.

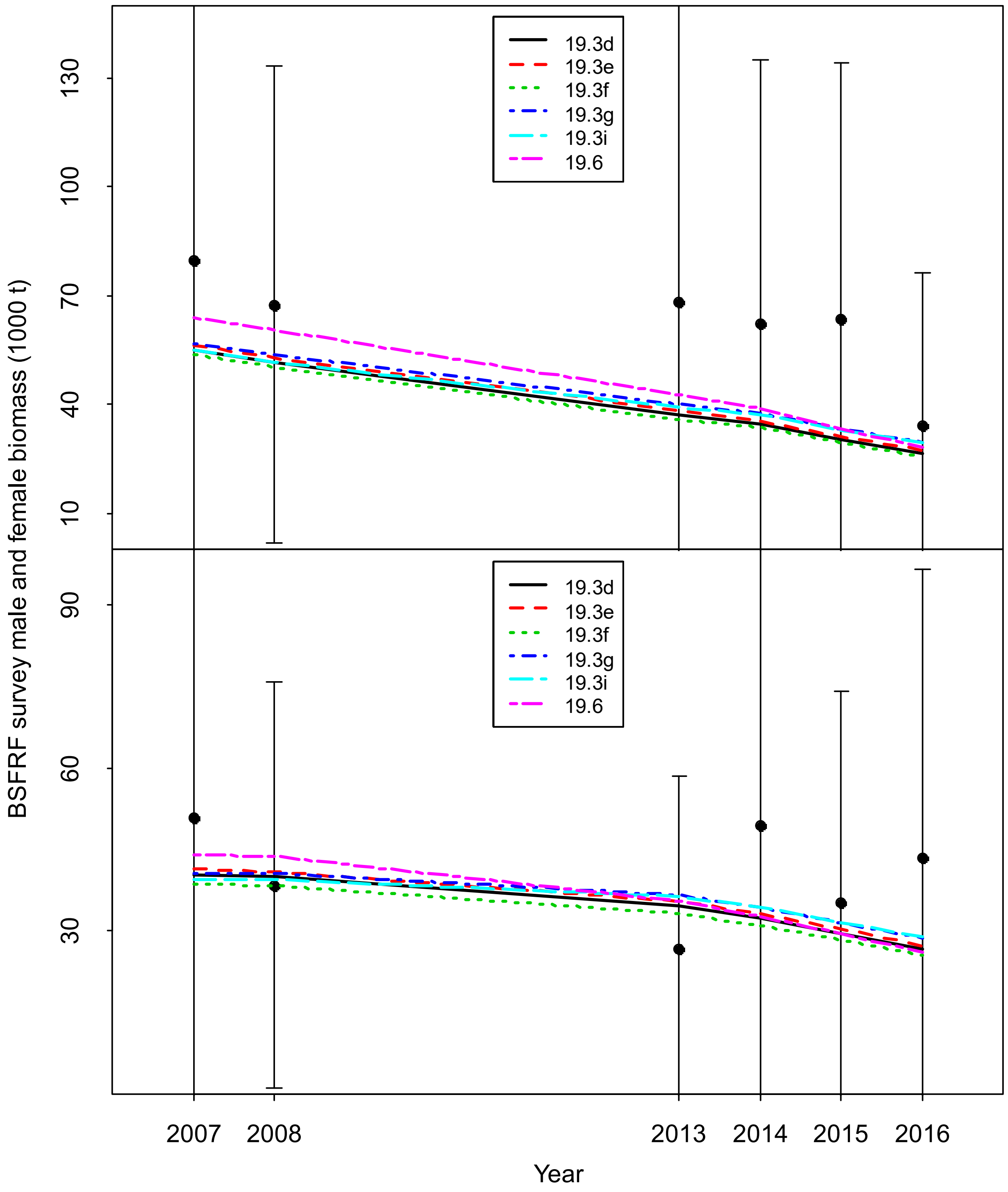


Figure 10c. Comparisons of survey biomass estimates by sex (upper plot for males and lower plot for females) by the BSFRF survey and the model for model estimates in 2020 (models 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6). The error bars are plus and minus 2 standard deviations of model 19.3d.

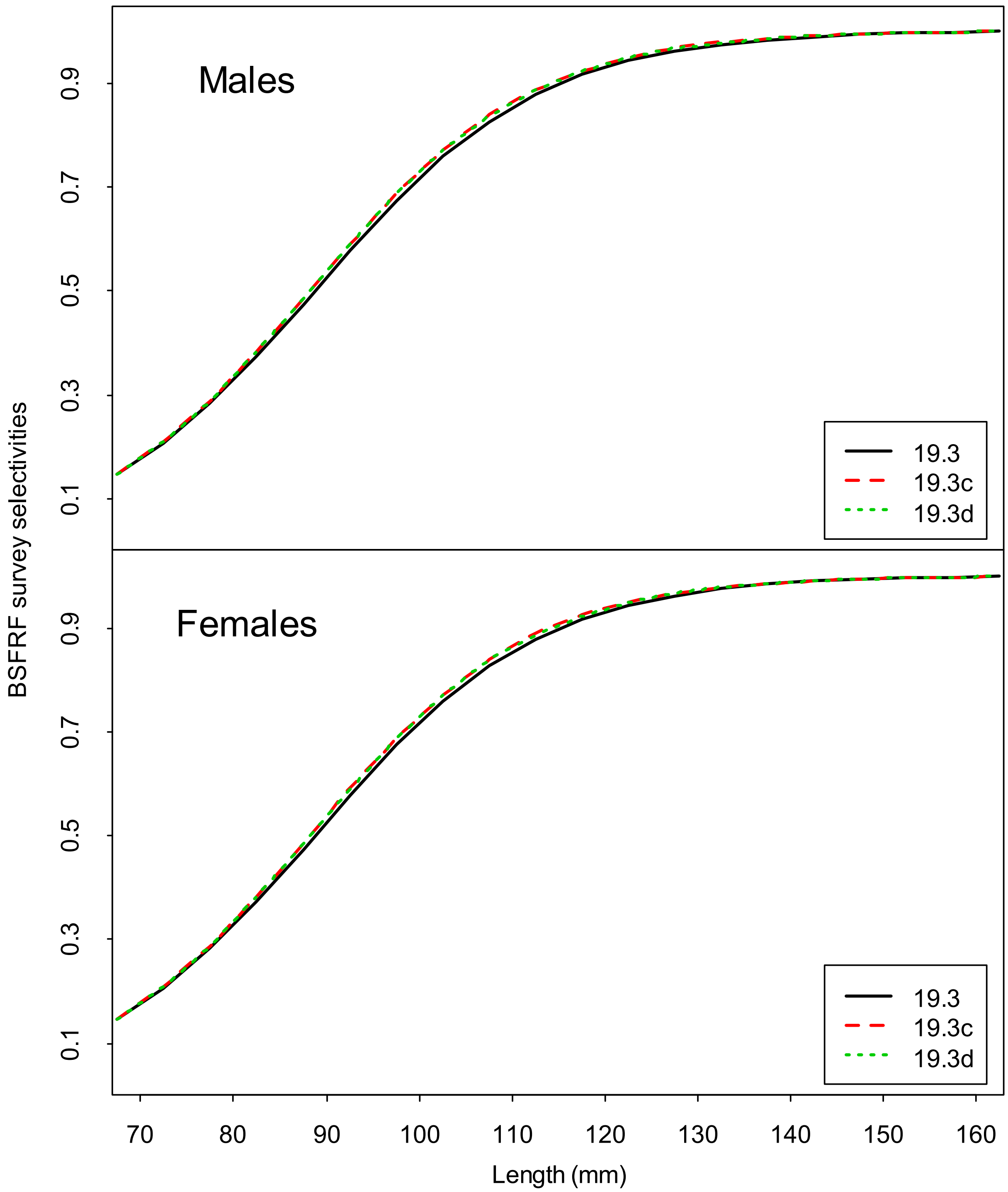


Figure 10d. Comparisons of estimated BSFRF survey selectivities with models 19.3, 19.3c, and 19.3d. The catchability is assumed to be 1.0.

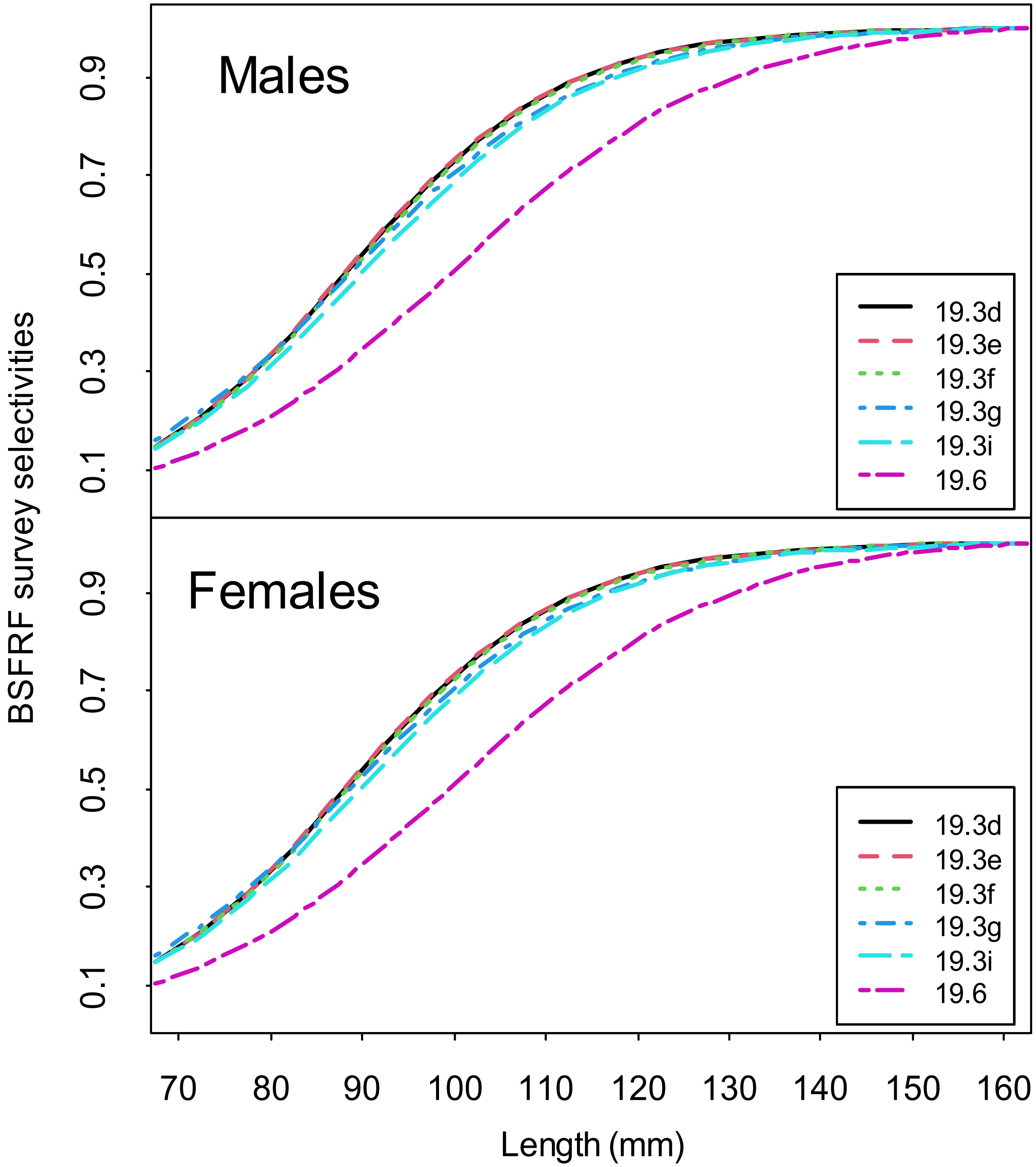


Figure 10d. Comparisons of estimated BSFRF survey selectivities with models 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6. The catchability is assumed to be 1.0.

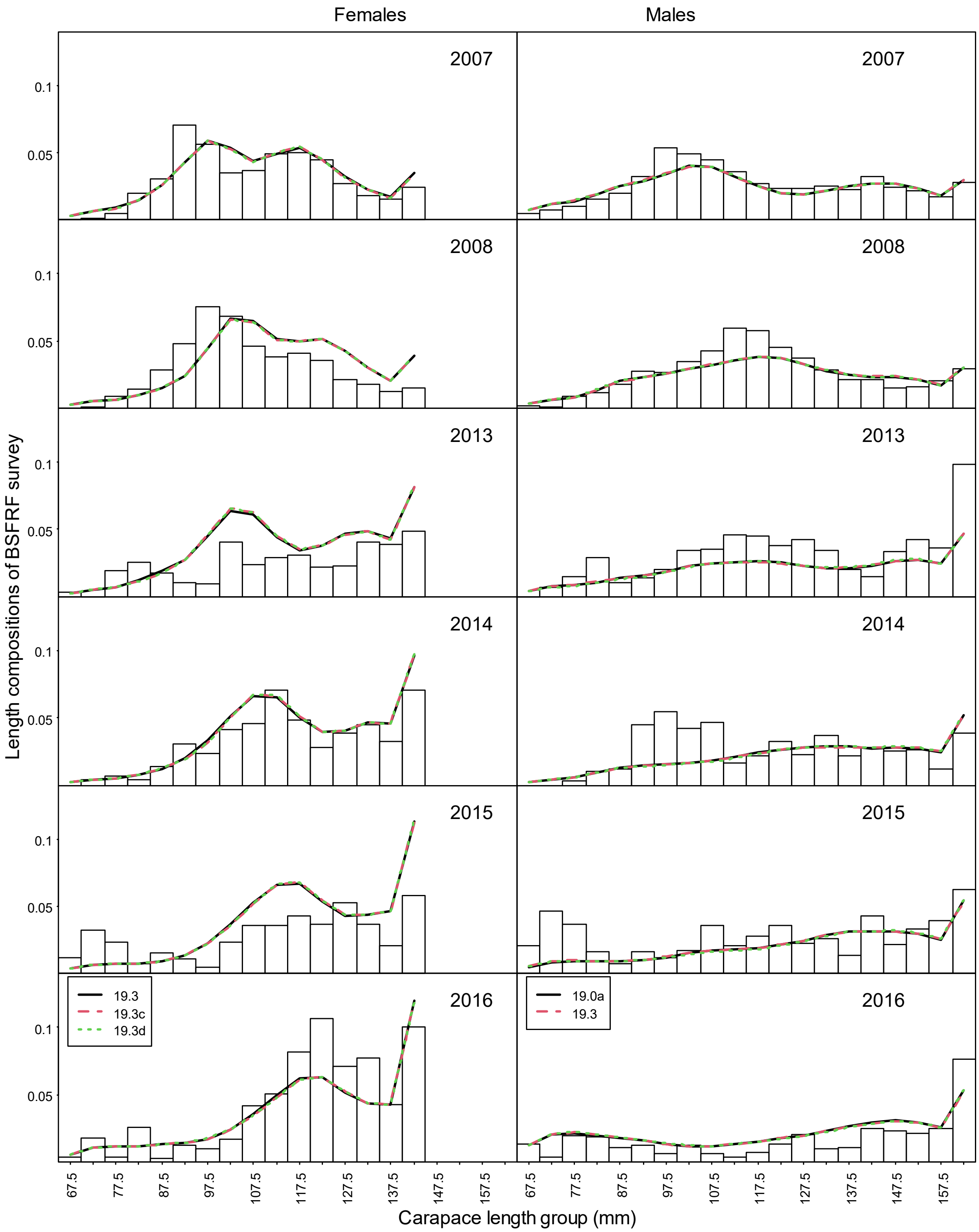


Figure 10f. Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 with models 19.3, 19.3c, and 19.3d.

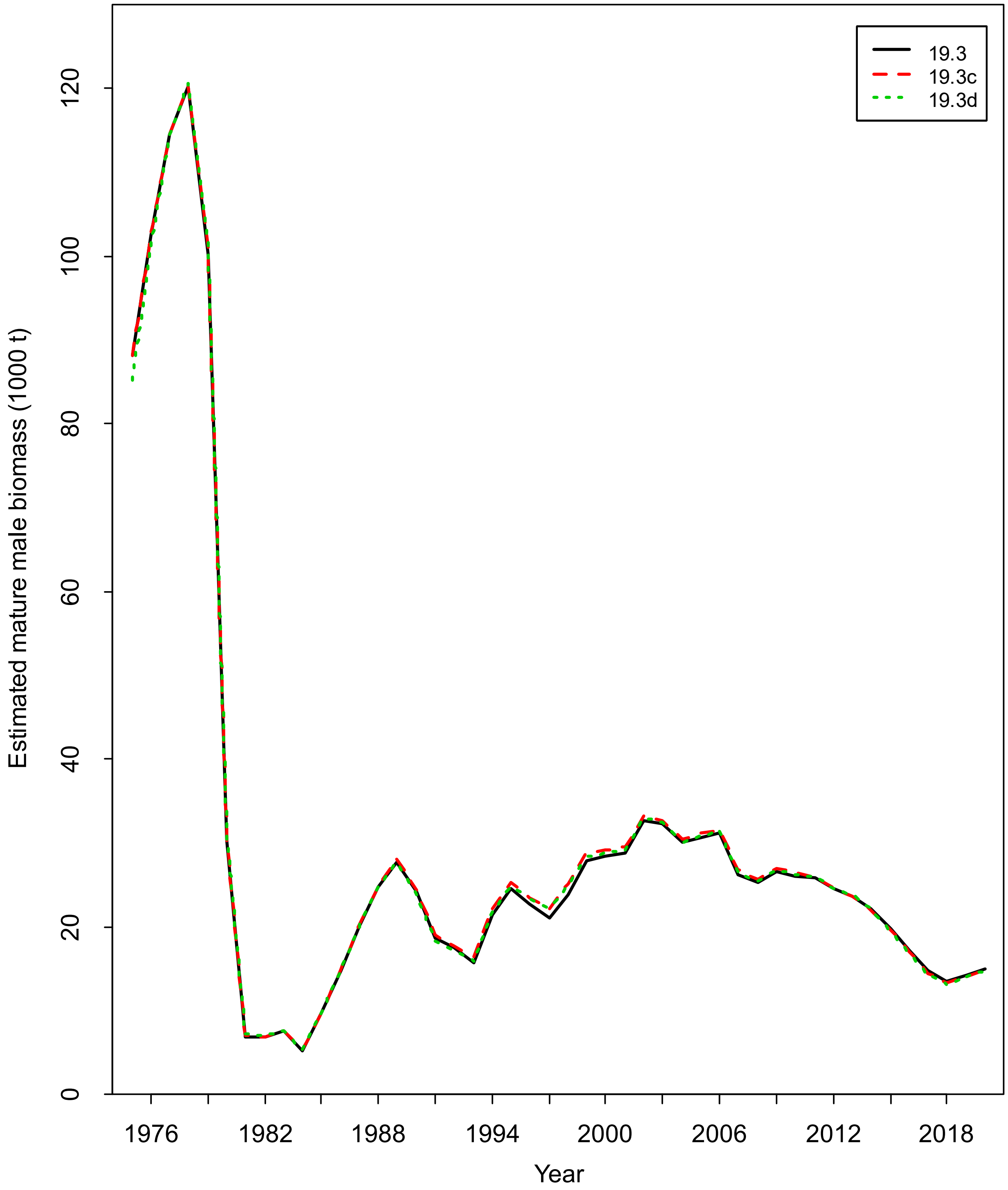


Figure 11a. Estimated absolute mature male biomasses during 1975-2020 for models 19.3, 19.3c, and 19.3d.

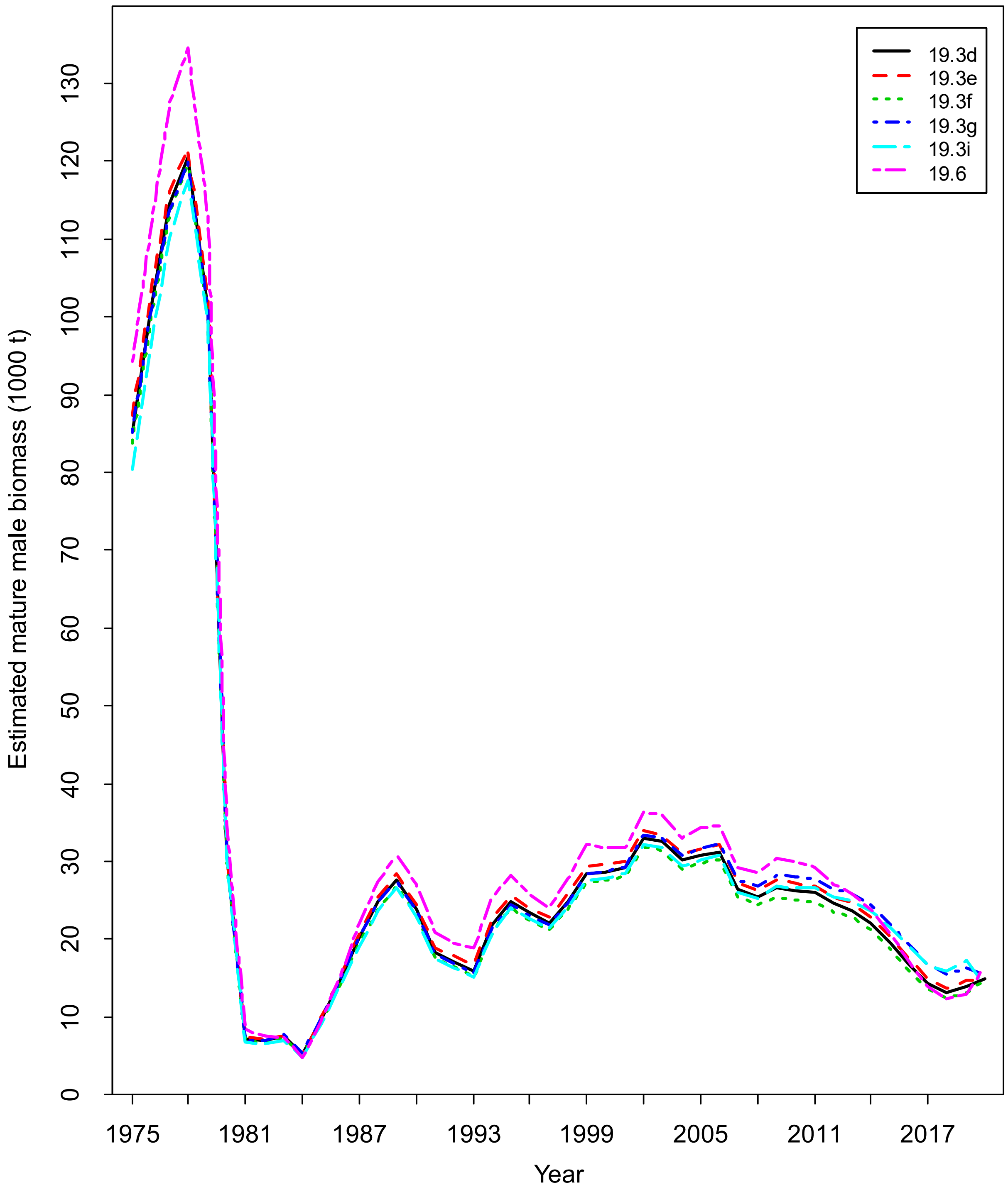


Figure 11b. Estimated absolute mature male biomasses during 1975-2020 for models 19.3d, 19.3e, 19.3f, 19.3g, 19.3i, and 19.6.

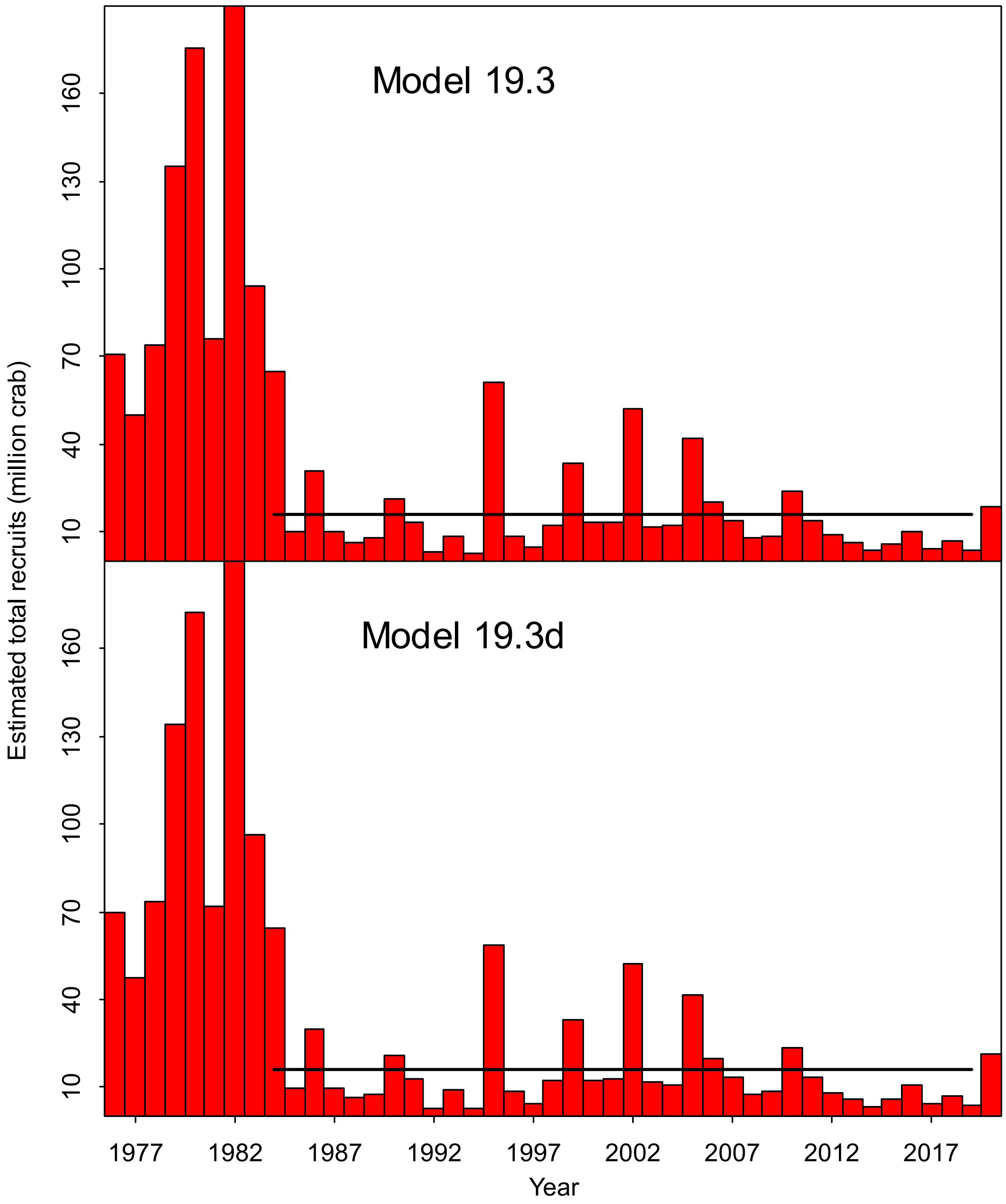


Figure 12a. Estimated recruitment time series during 1976-2020 with models 19.3 and 19.3d. Mean male recruits during 1984-2019 was used to estimate *B35%*.

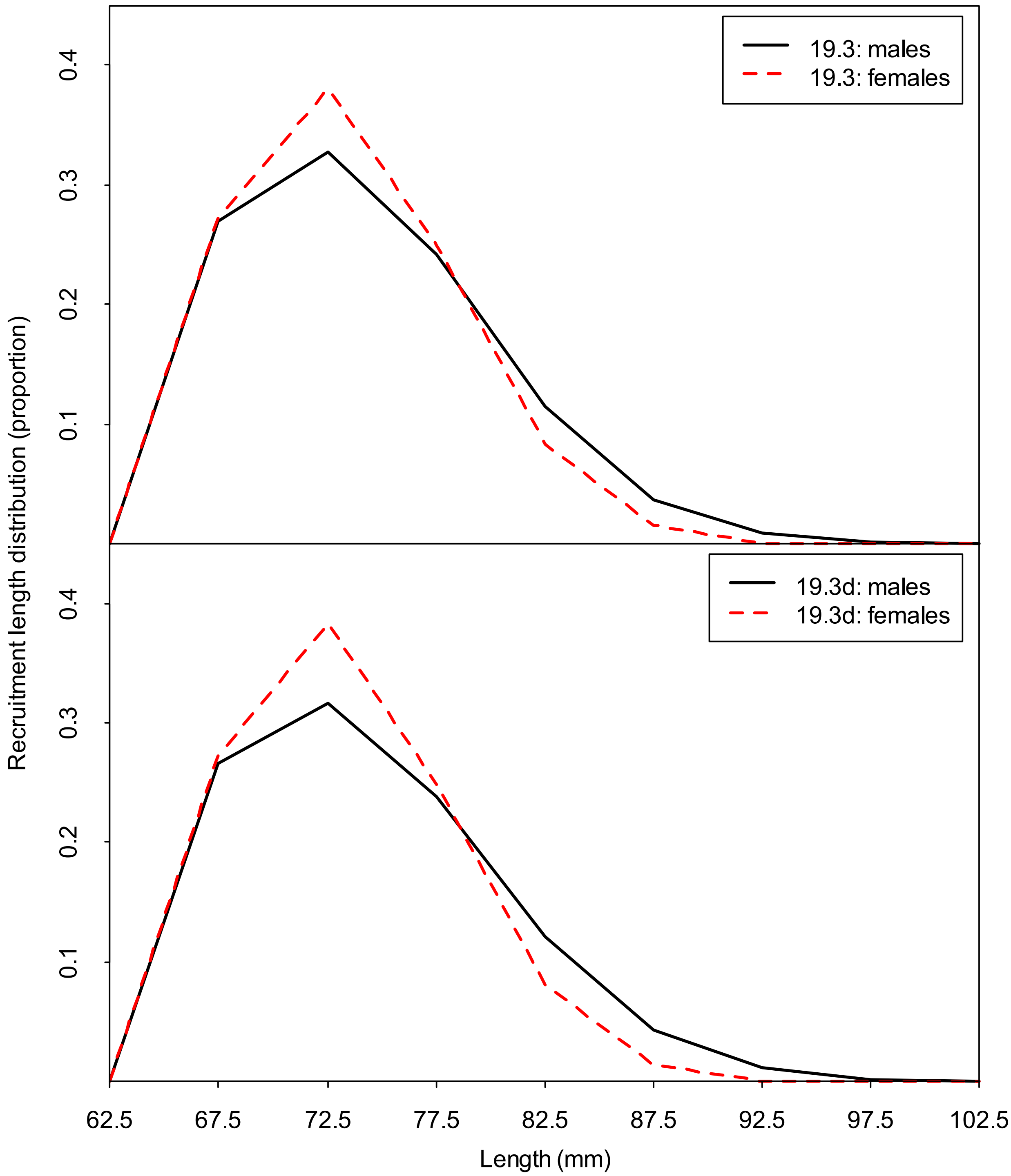


Figure 12b. Estimated recruitment length distributions with models 19.3 and 19.3d.

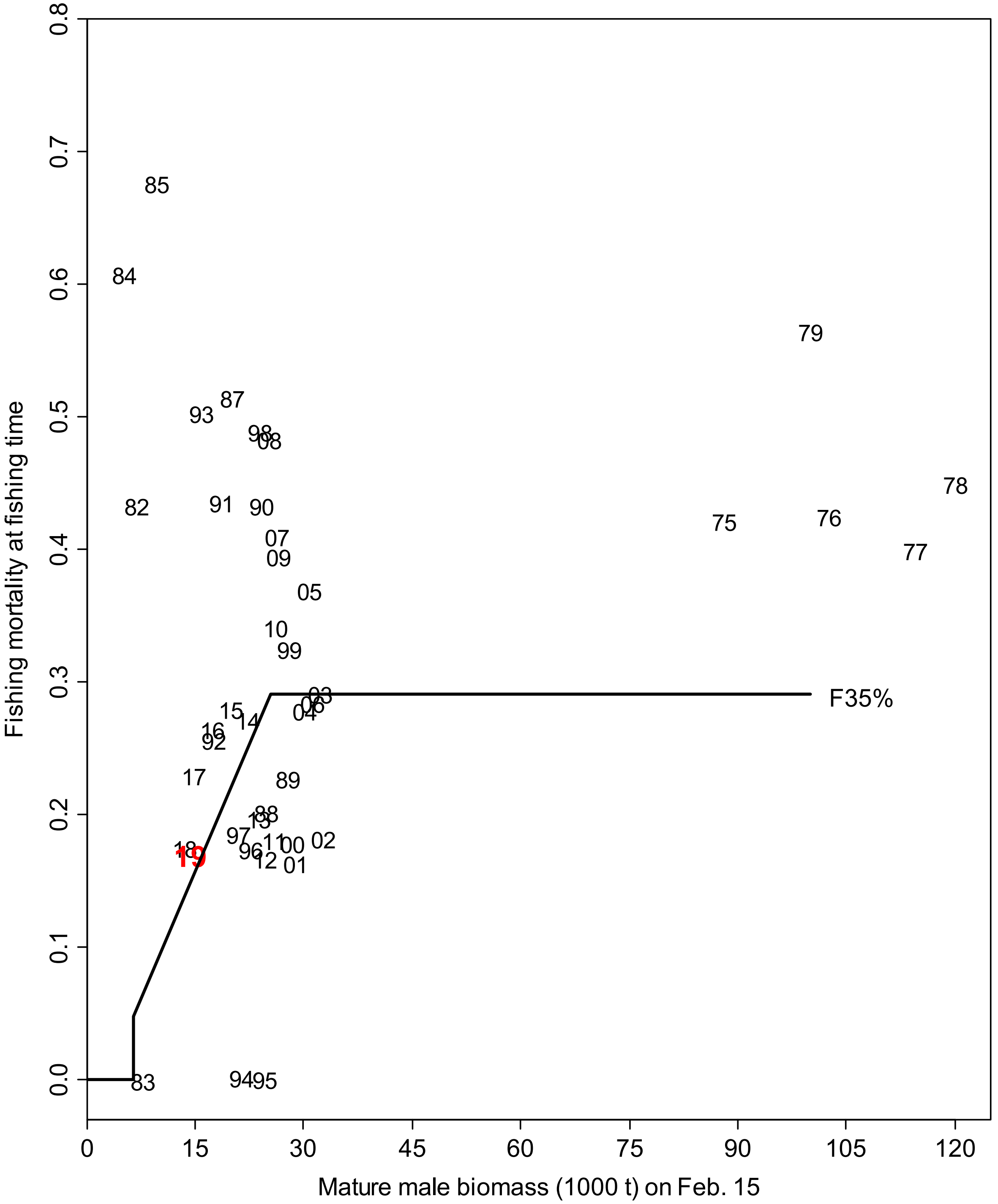


Figure 13a. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2019 under model 19.3. Average of recruitment from 1984 to 2019 was used to estimate $B_{35\%}$.

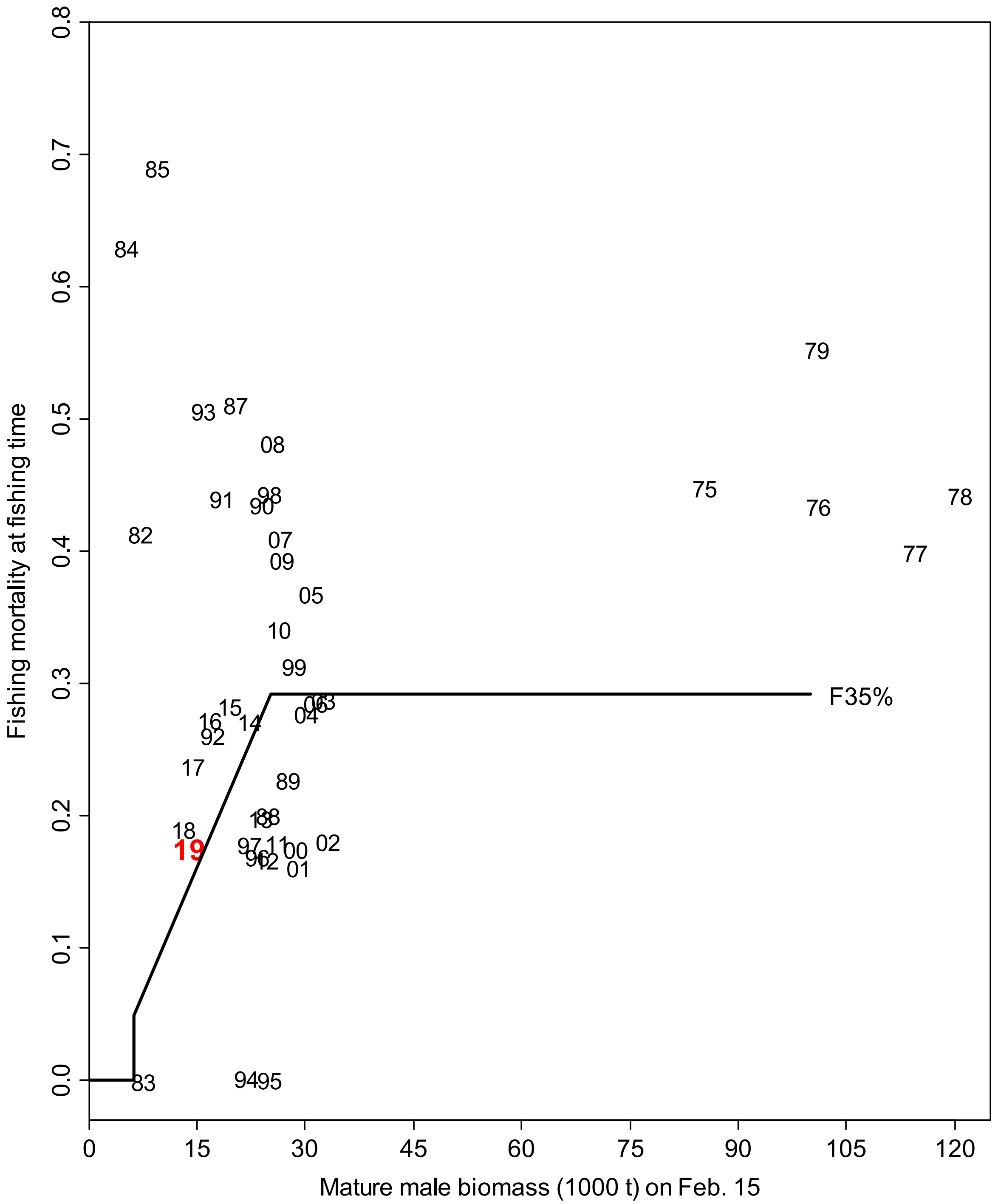


Figure 13b. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2019 under model 19.3d. Average of recruitment from 1984 to 2019 was used to estimate $B_{35\%}$.

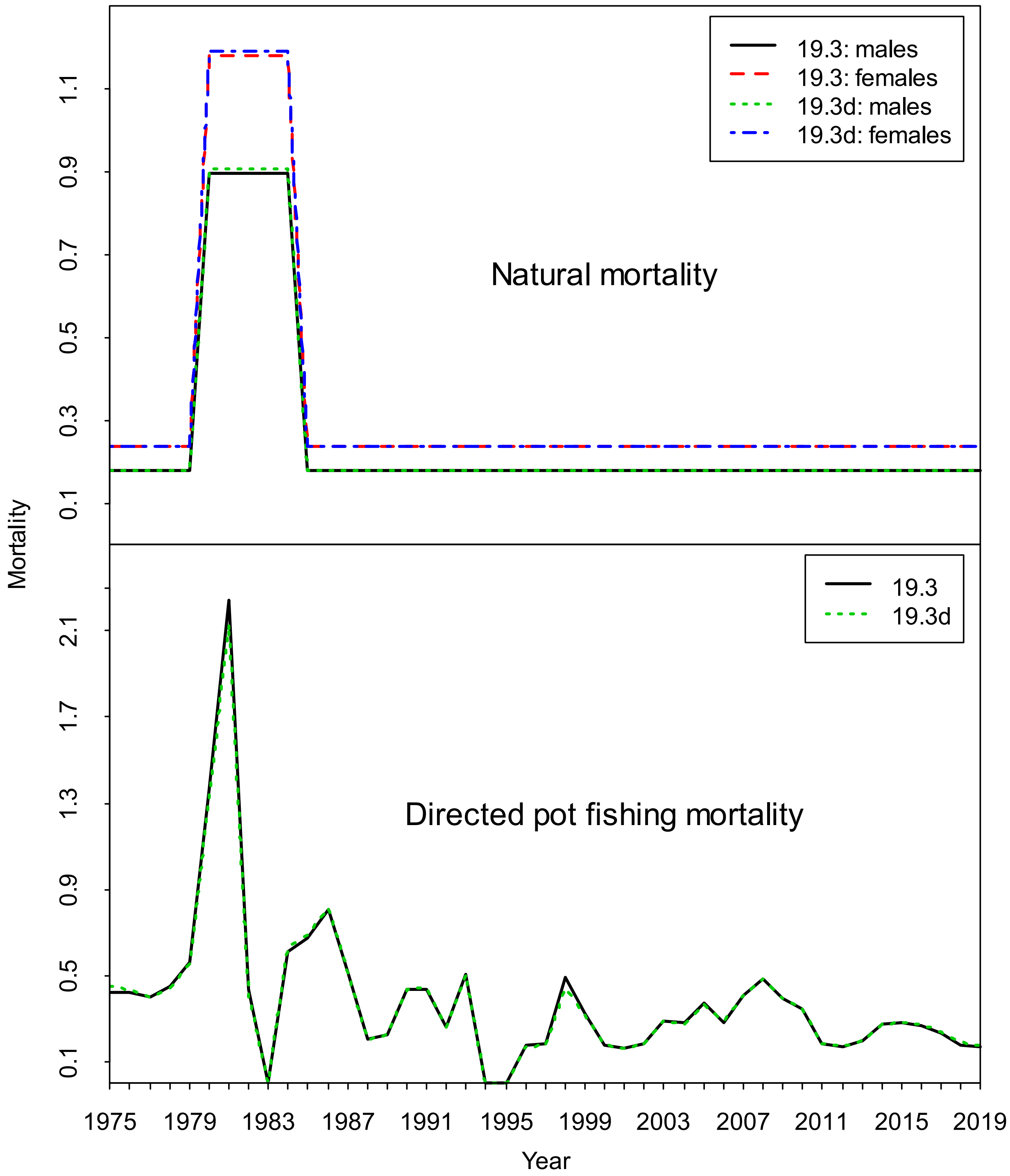


Figure 13c. Comparison of estimated natural mortality and directed pot fishing mortality for models 19.3 and 19.3d.

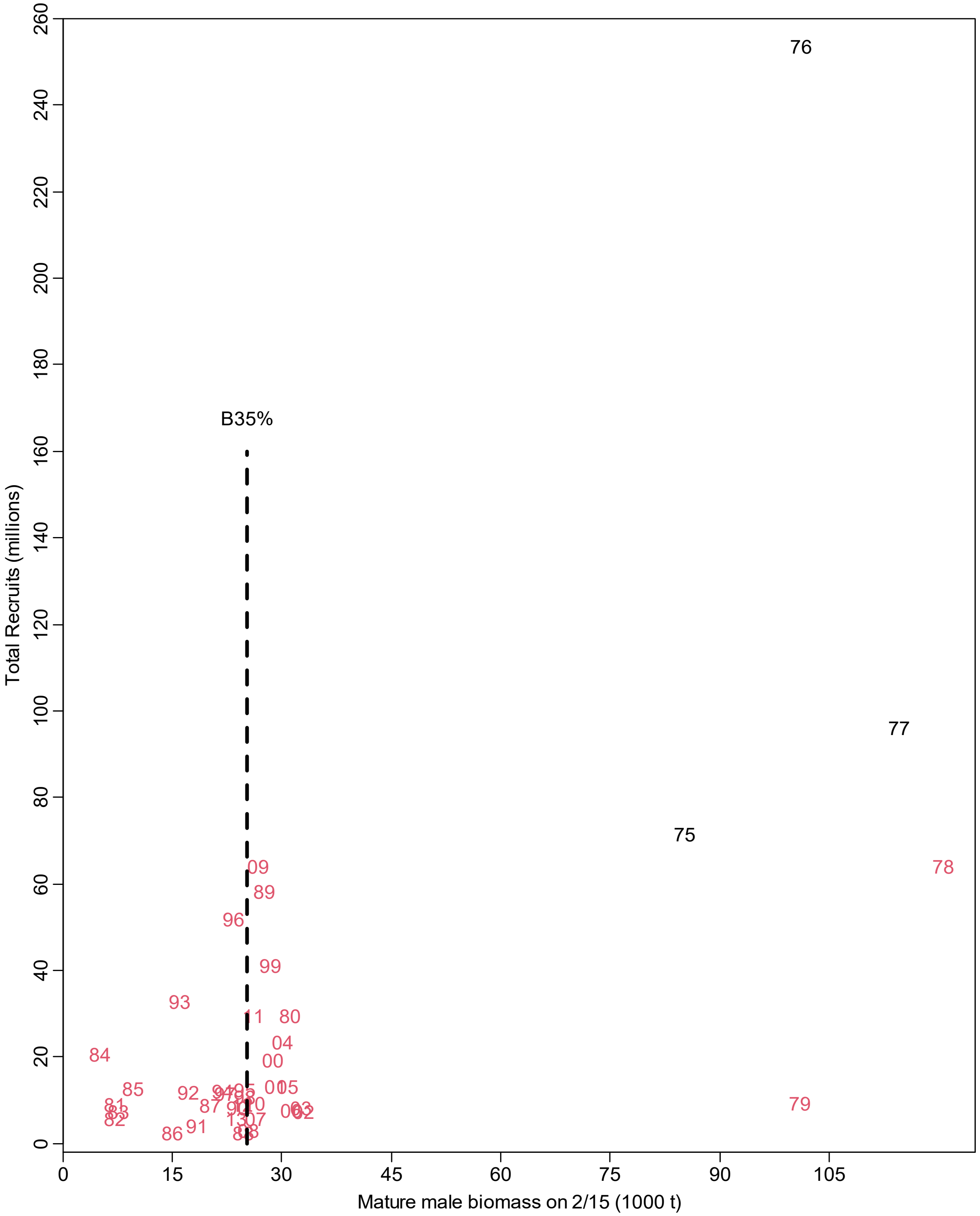


Figure 14a. Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6-year time lag) for Bristol Bay red king crab under model 19.3d. Numerical labels are years of mating, and the vertical dotted line is the estimated $B_{35\%}$ based on the mean recruitment level during 1984 to 2019.

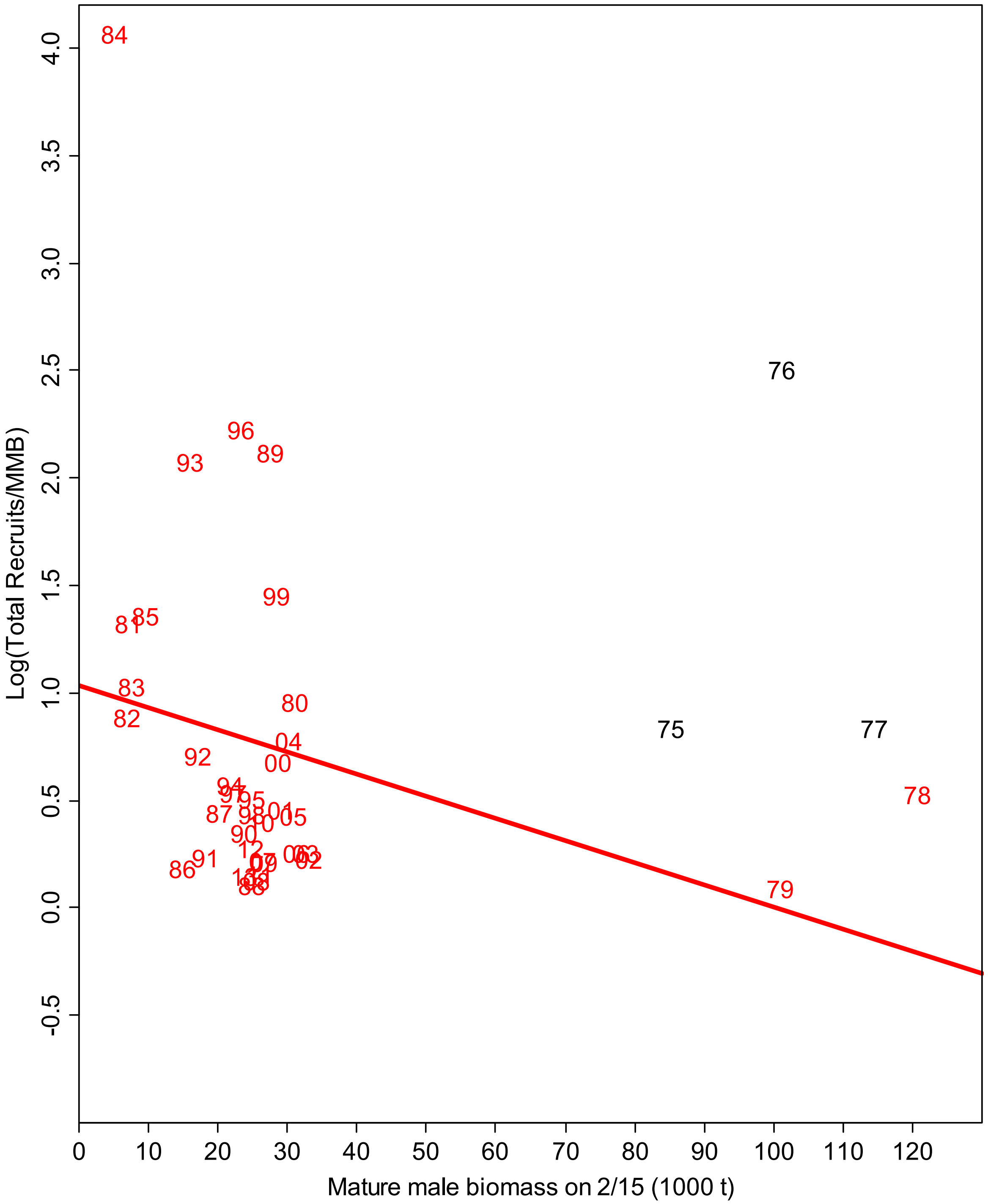


Figure 14b. Relationships between log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab under model 19.3d. Numerical labels are years of mating, and the line is the regression line for data of 1978-2013.

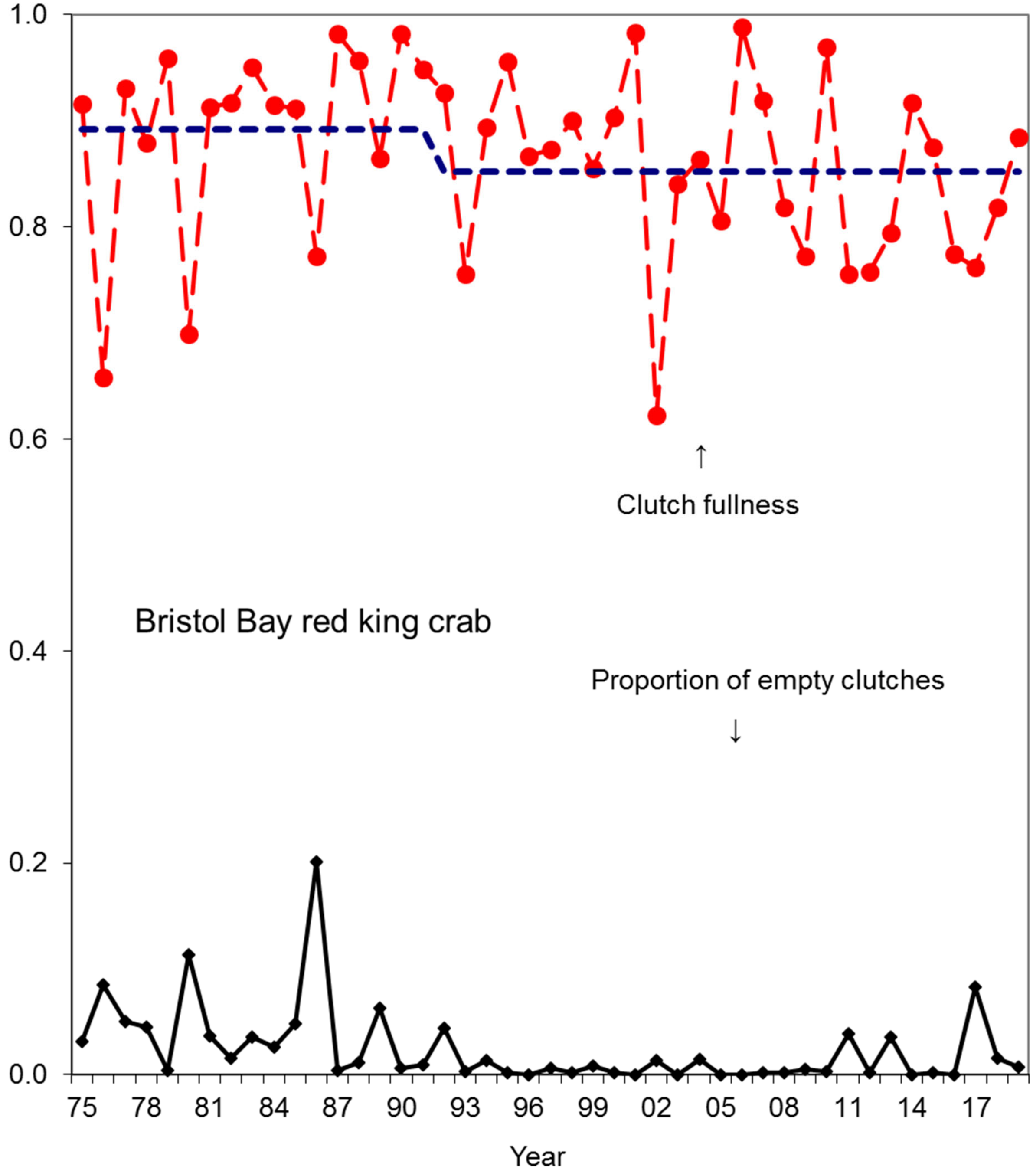


Figure 15. Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2019 from survey data. Oldshell females were excluded. The blue dashed line is the mean clutch fullness during two periods before 1992 and after 1991.

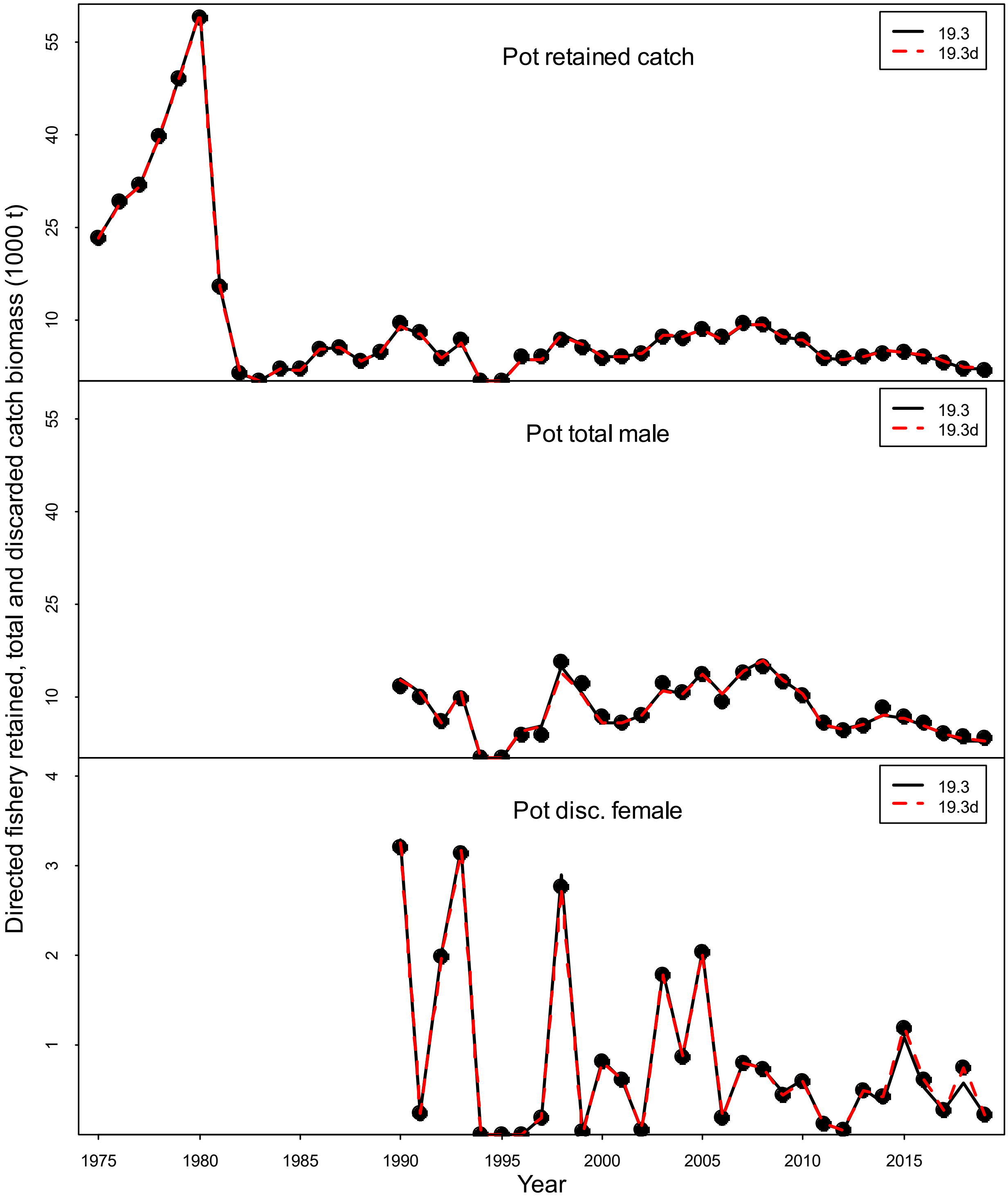


Figure 16a. Observed (dots) and predicted (lines) RKC catch and bycatch biomass under models 19.3 and 19.3d. The observed discarded catch biomass is from model 19.3d.

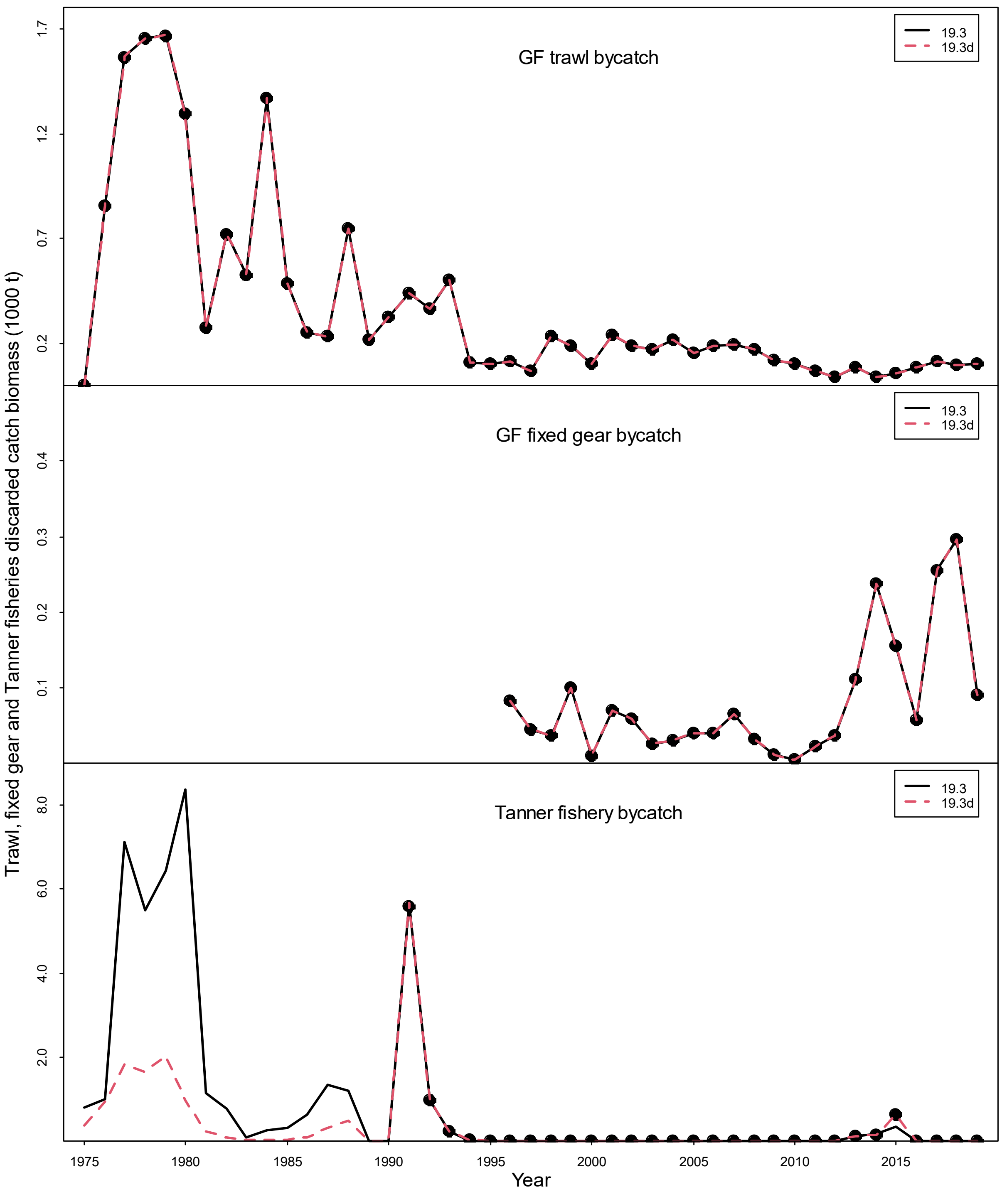


Figure 16b. Observed (dots) and predicted (lines) RKC bycatch biomass from groundfish fisheries and the Tanner crab fishery under models 19.3 and 19.3d. The observed discarded catch biomass from the Tanner crab fishery is from model 19.3d. Trawl bycatch biomass was 0 before 1976.

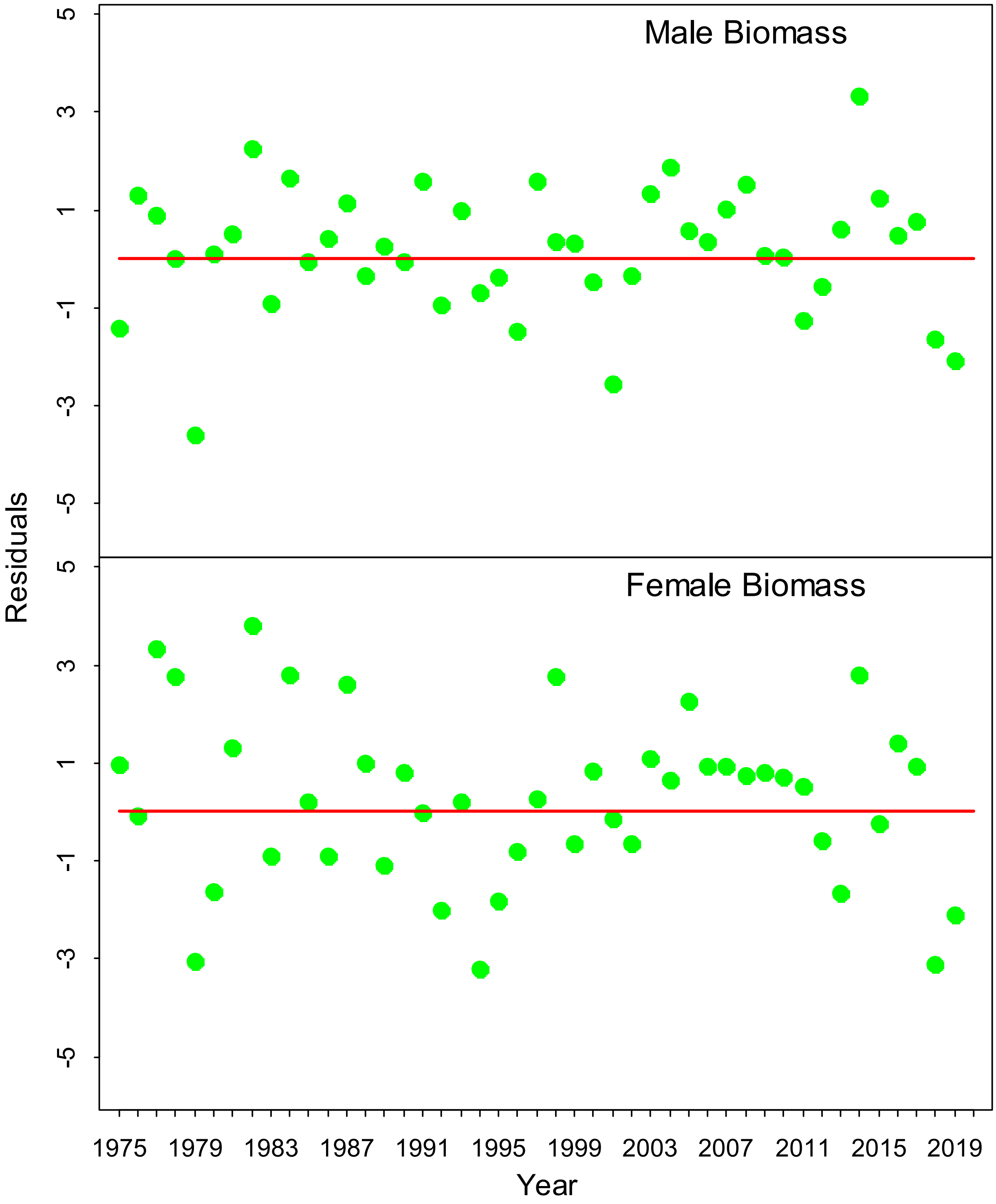


Figure 17a. Standardized residuals of NMFS survey biomass under model 19.3.

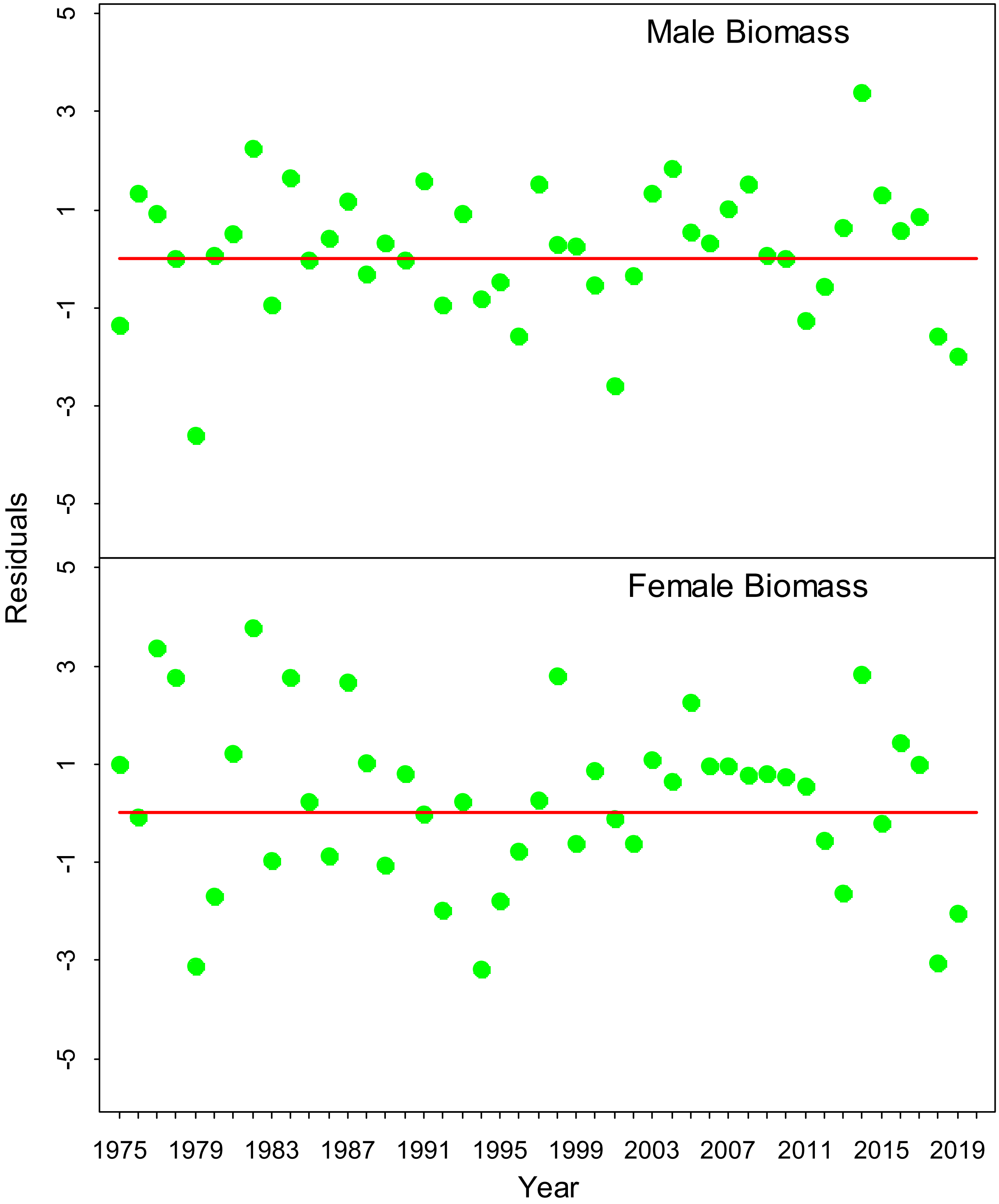


Figure 17b. Standardized residuals of NMFS survey biomass under model 19.3d.

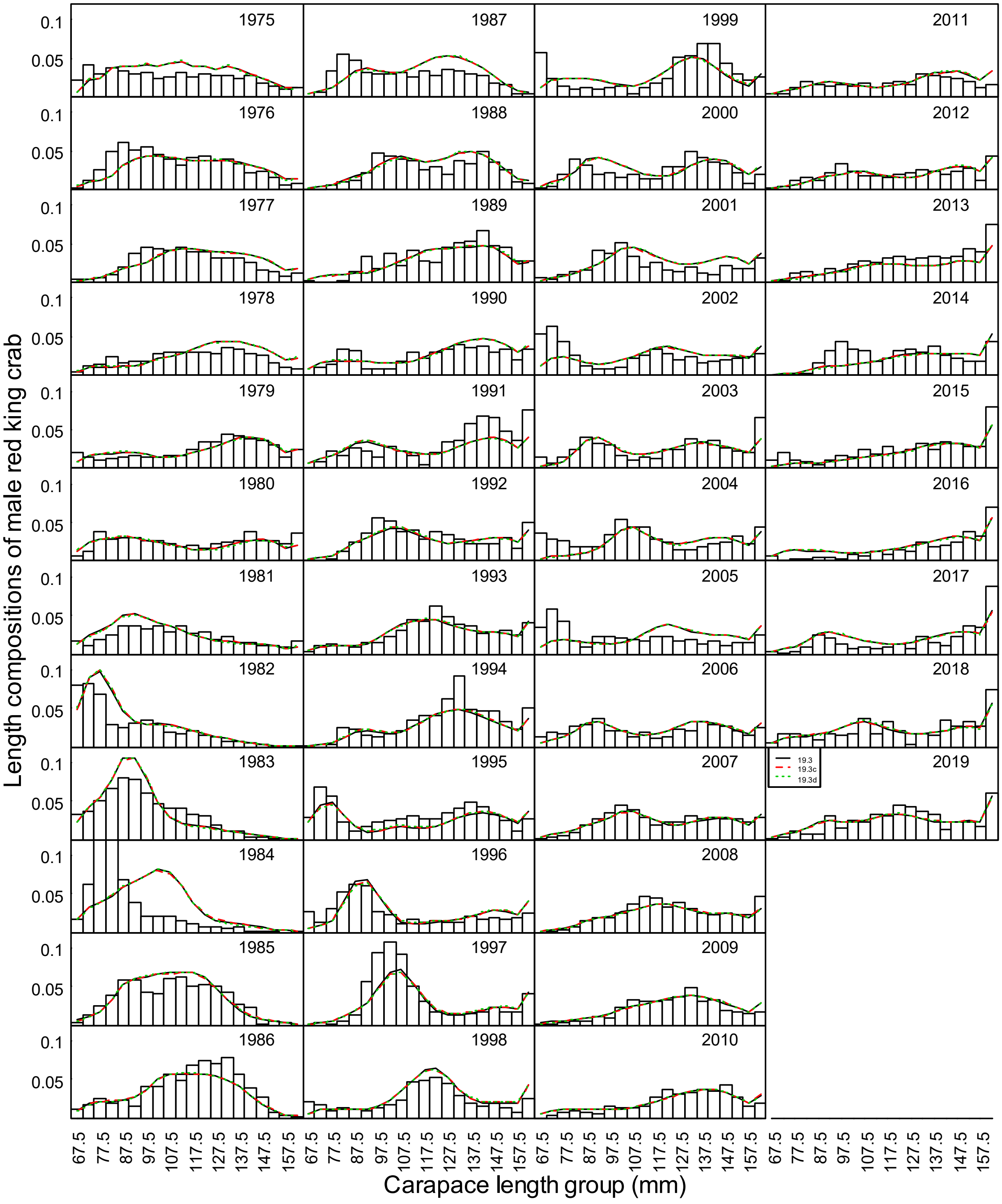


Figure 18. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under models 19.3, 19.3c, and 19.3d.

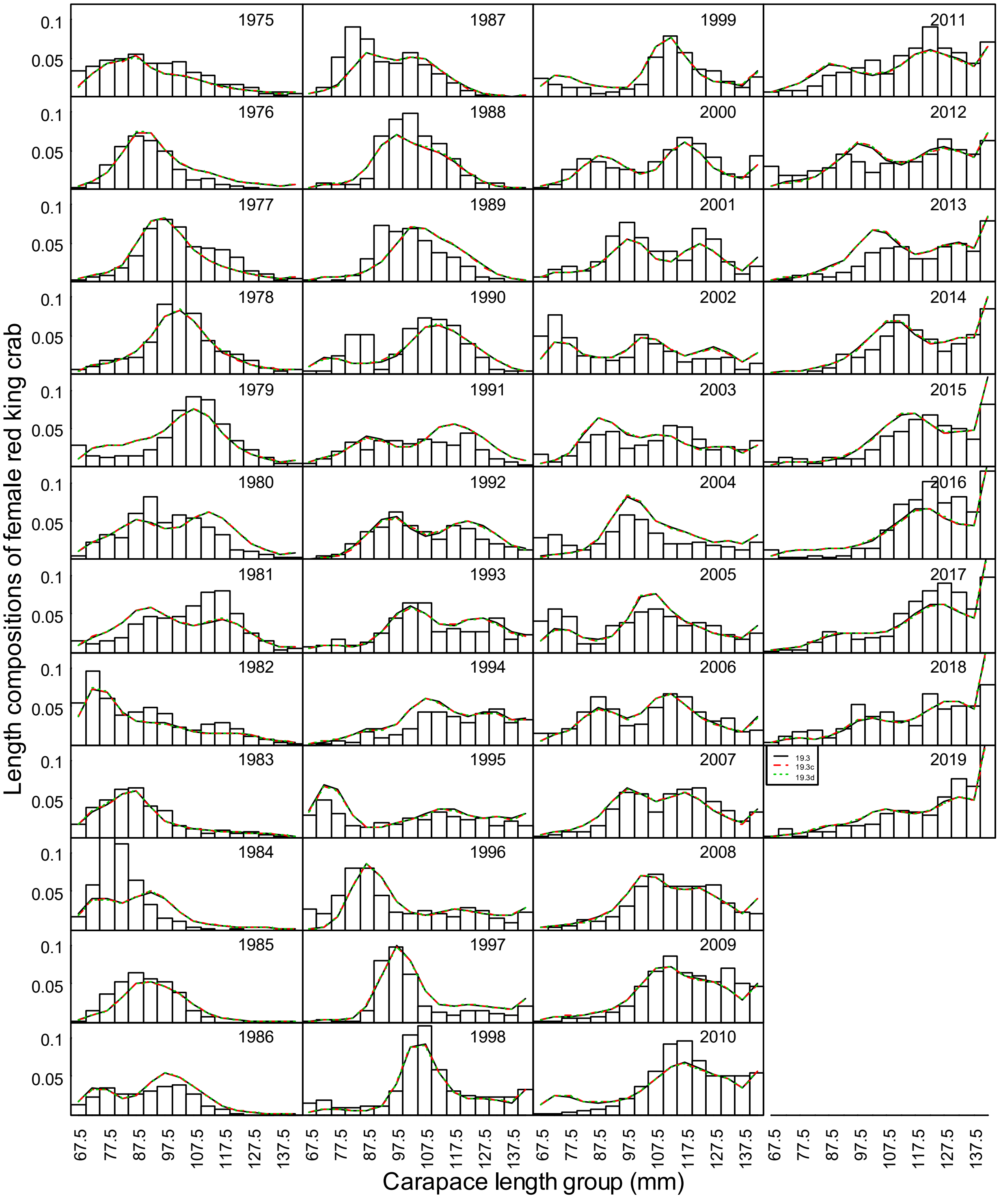


Figure 19. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year under models 19.3, 19.3c, and 19.3d.

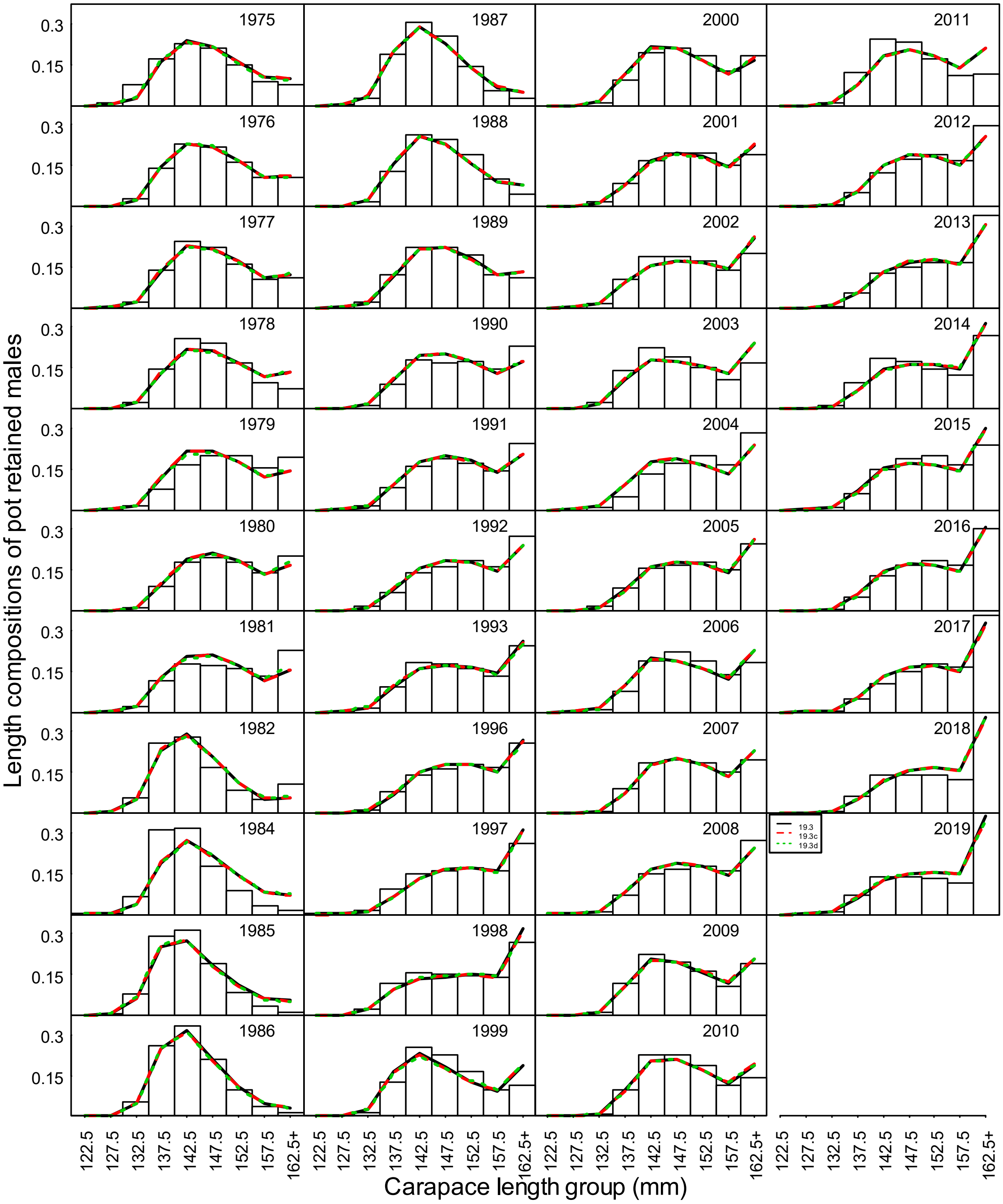


Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.3, 19.3c, and 19.3d.

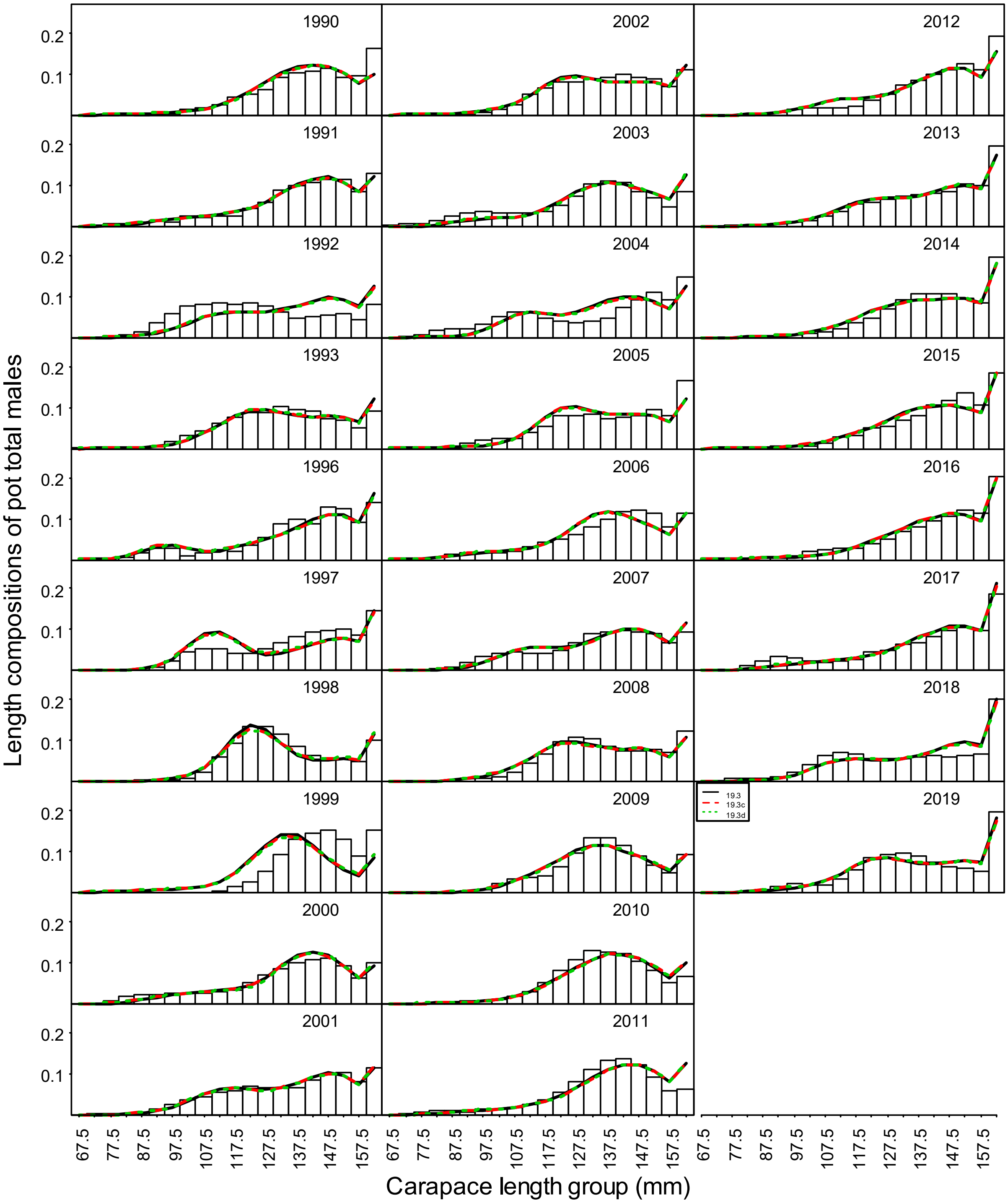


Figure 21. Comparison of observer and model estimated total observer length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.3, 19.3c, and 19.3d. The observed length composition data are from model 19.3d.

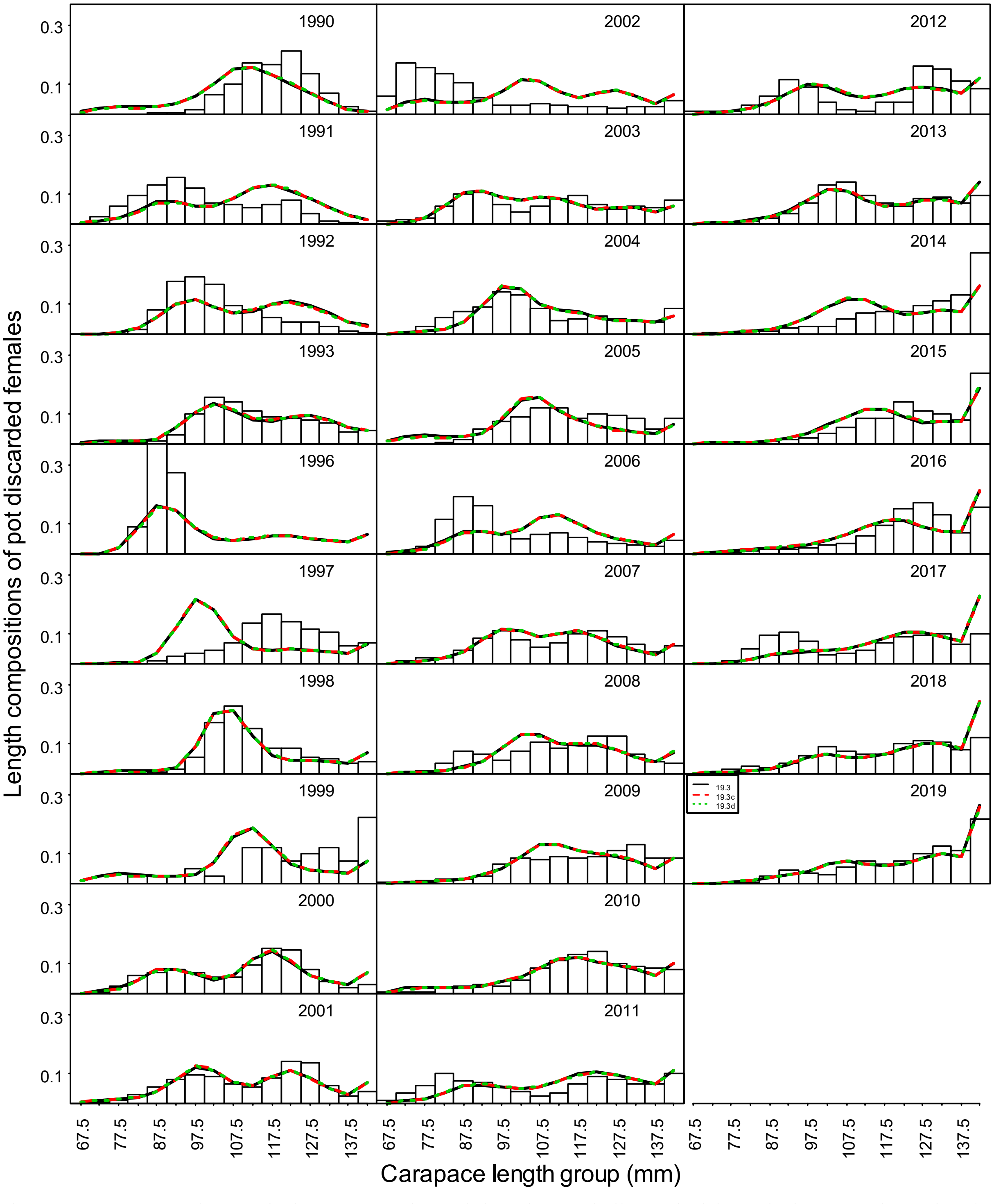


Figure 22. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the directed pot fishery under models 19.3, 19.3c, and 19.3d. The observed length composition data are from model 19.3d.

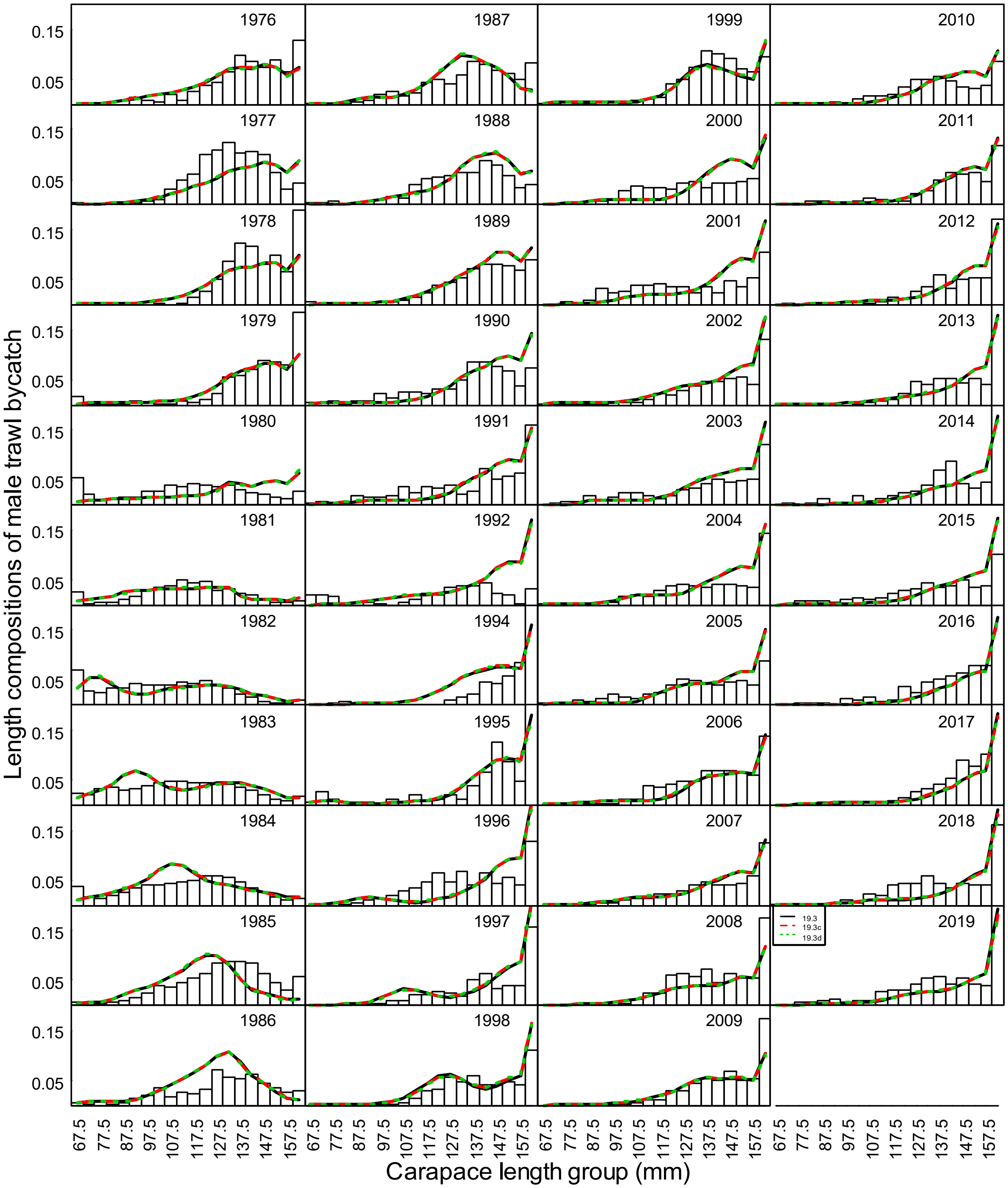


Figure 23a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish trawl fisheries under models 19.3, 19.3c, and 19.3d.

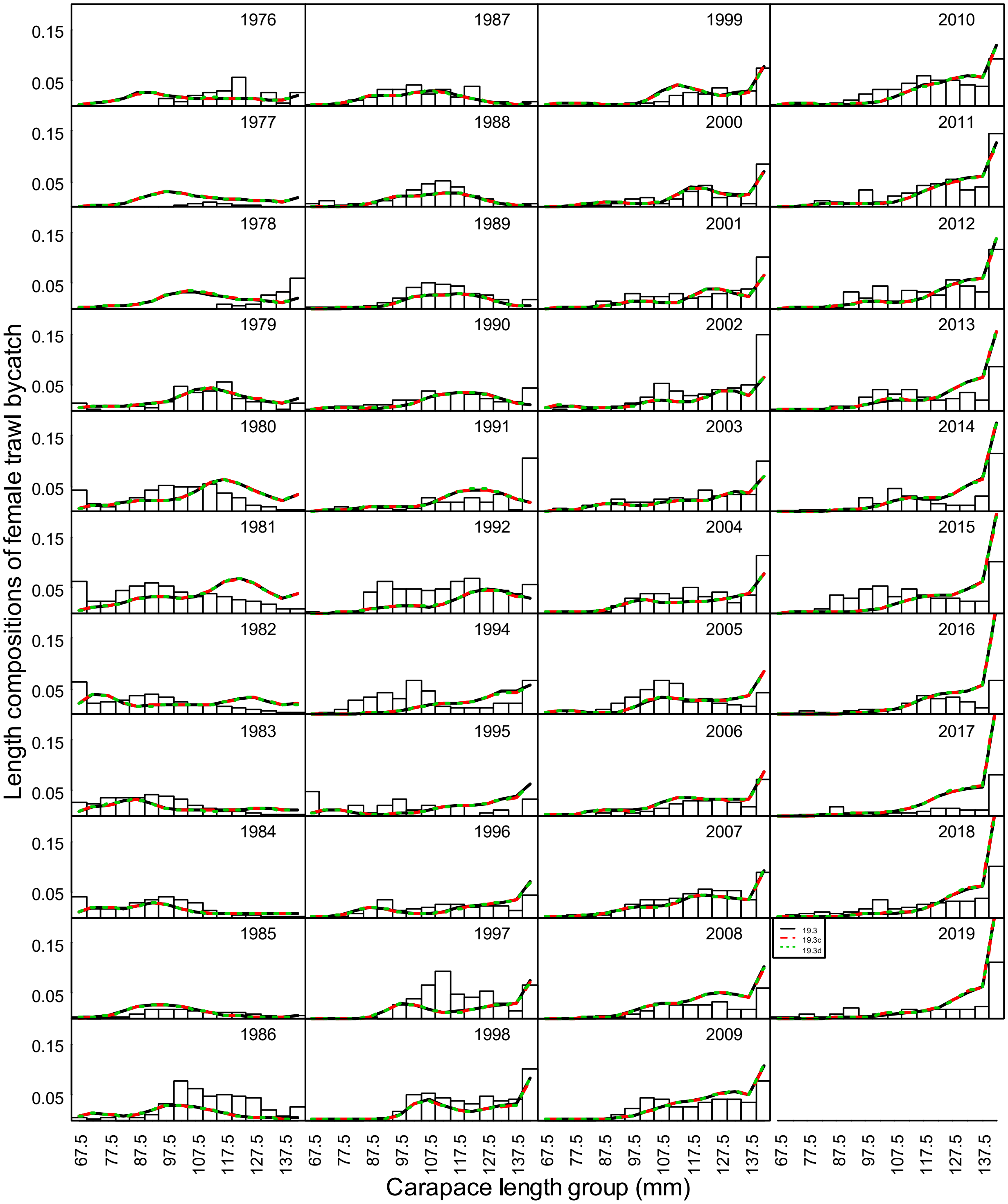


Figure 23b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish trawl fisheries under models 19.3, 19.3c, and 19.3d.

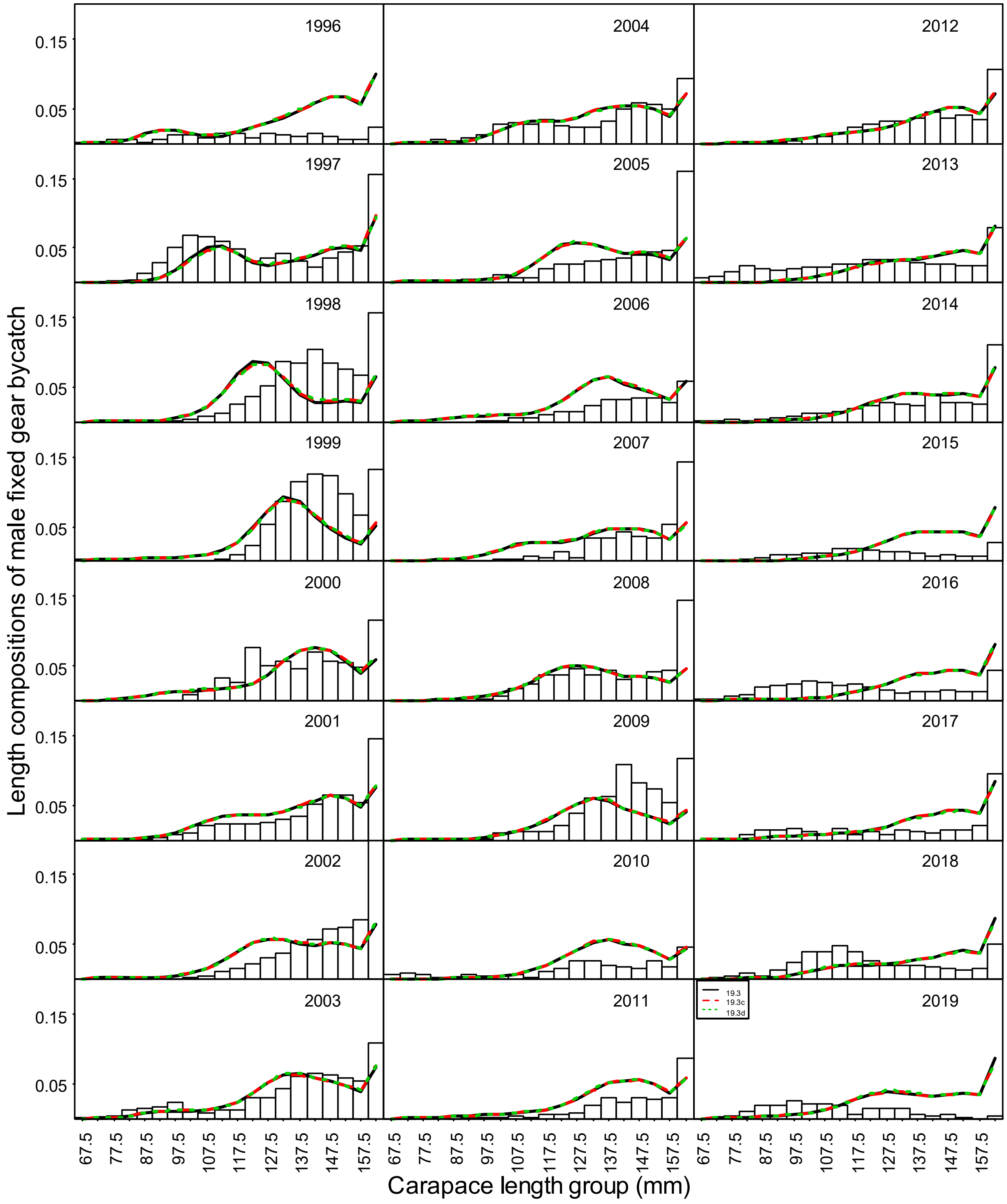


Figure 24a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish fixed gear fisheries under models 19.3, 19.3c, and 19.3d.

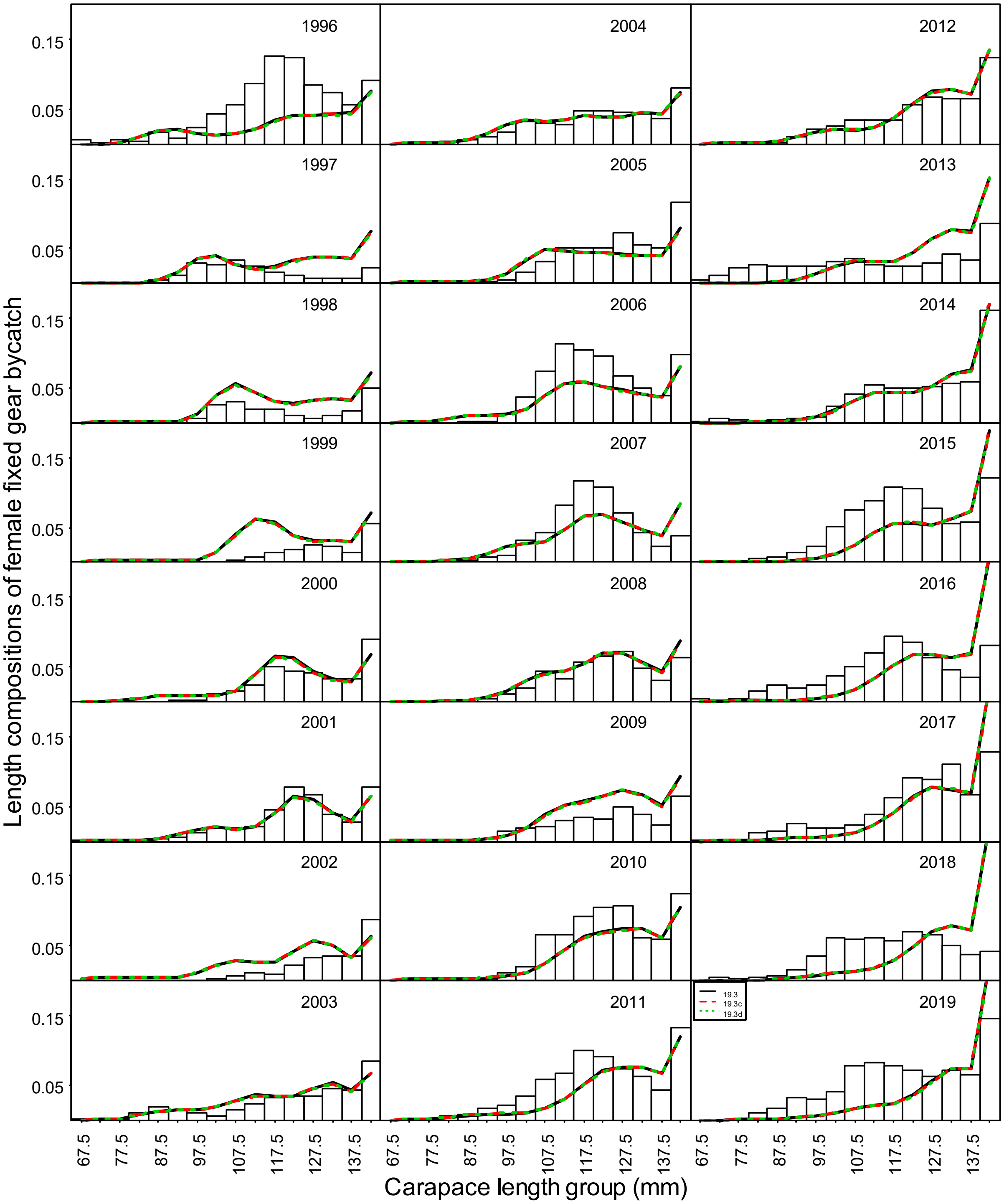


Figure 24b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish fixed gear fisheries under models 19.3, 19.3c, and 19.3d.

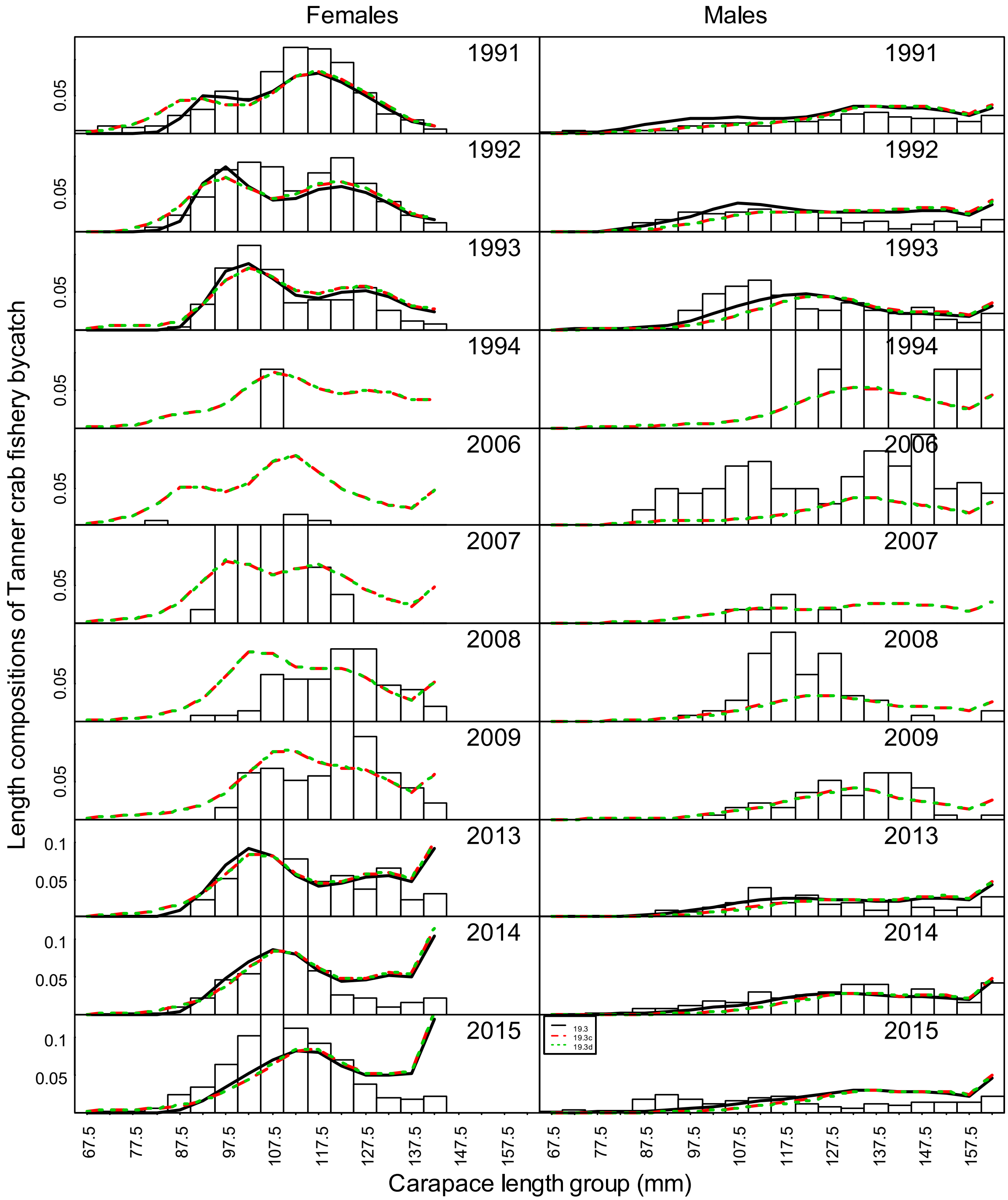


Figure 24c. Comparison of observer and model estimated discarded length frequencies of Bristol Bay red king crab by year in the Tanner crab fishery under models 19.3, 19.3c, and 19.3d. The observed length composition data are from model 19.3d. Length composition data during 1994-2009 are not used in model 19.3.

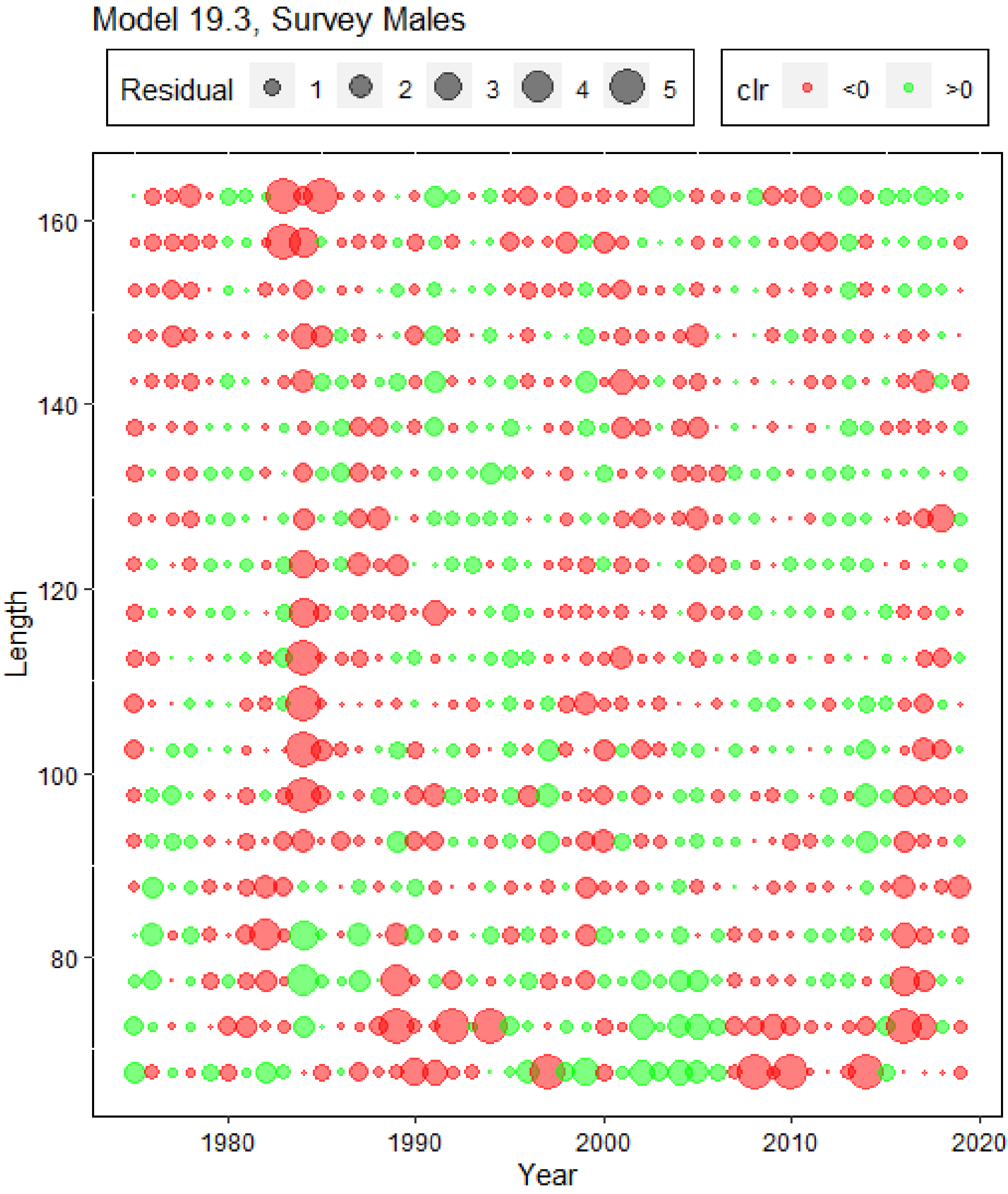


Figure 25a. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.3. Green circles are positive residuals, and red circles are negative residuals.

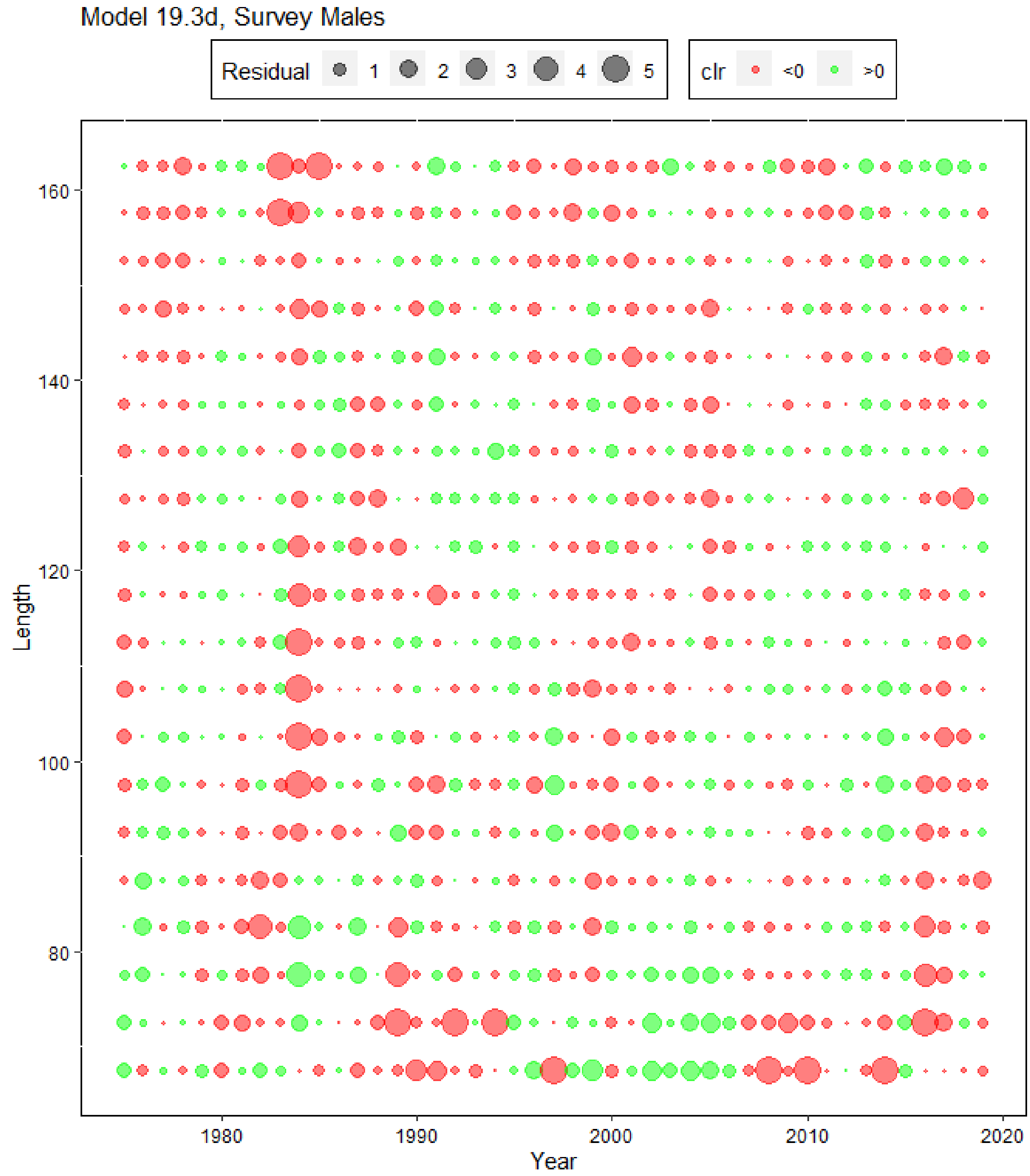


Figure 25b. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.3d. Green circles are positive residuals, and red circles are negative residuals.

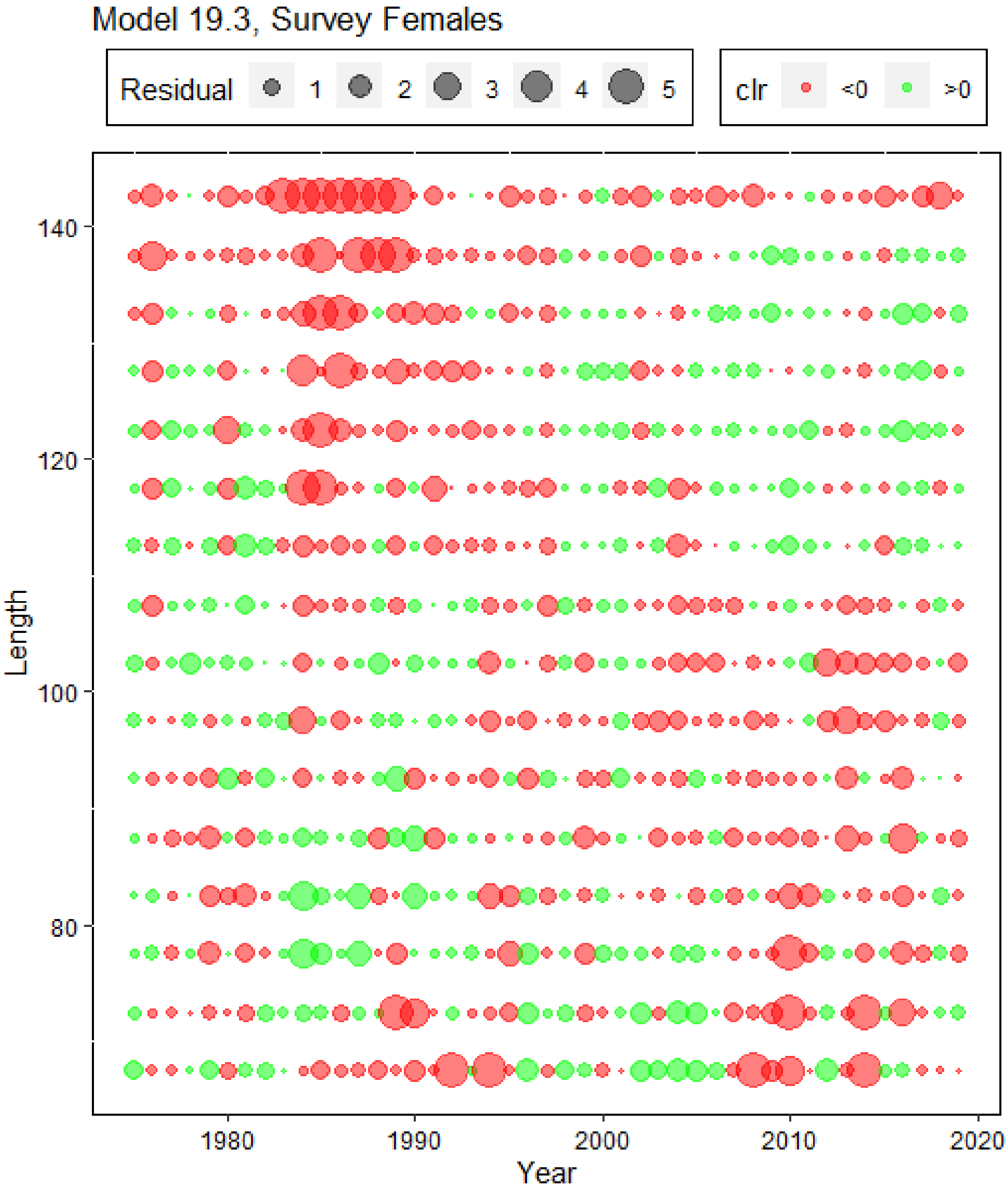


Figure 26a. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.3. Green circles are positive residuals, and red circles are negative residuals.

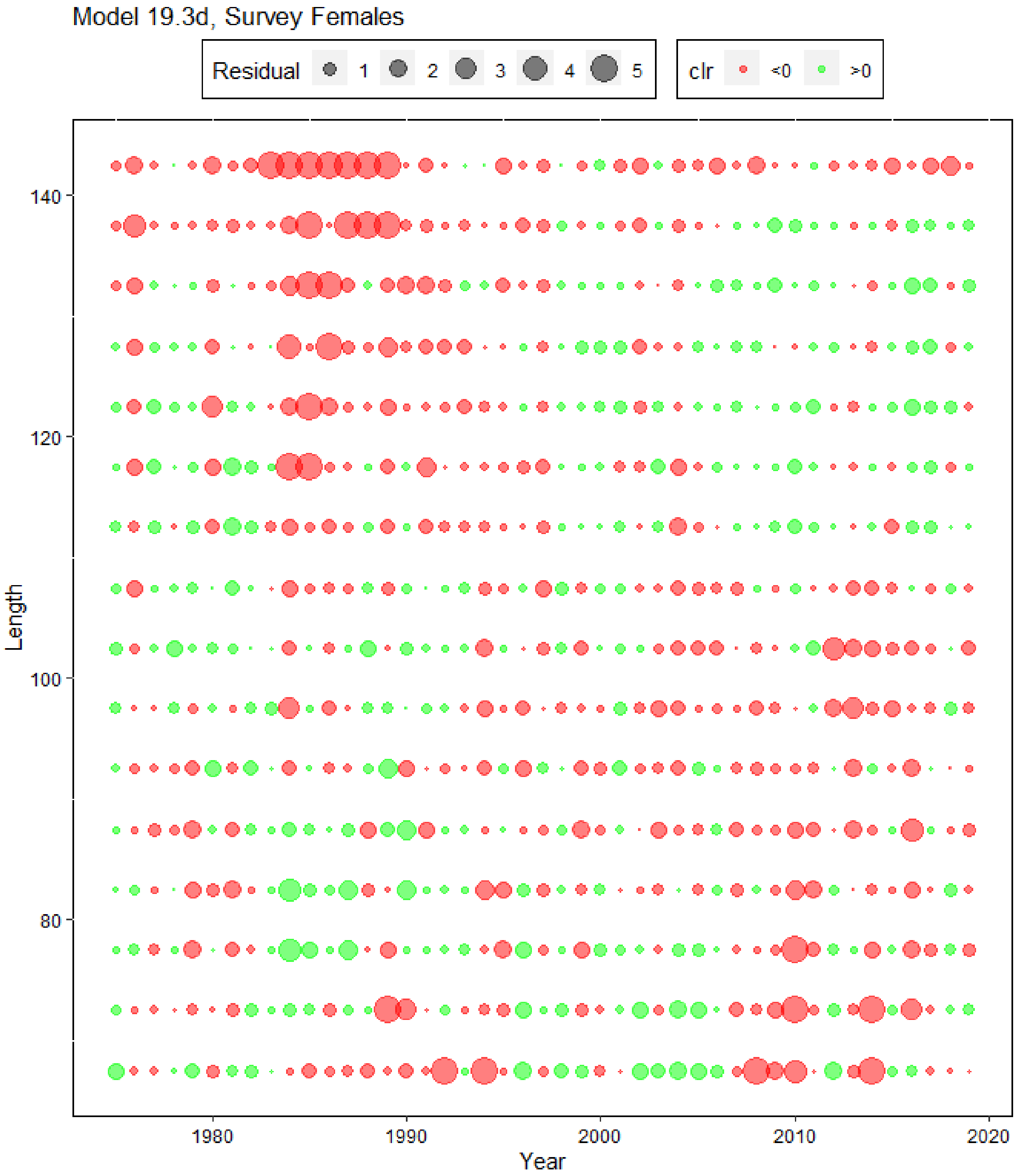


Figure 26b. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.3d. Green circles are positive residuals, and red circles are negative residuals.

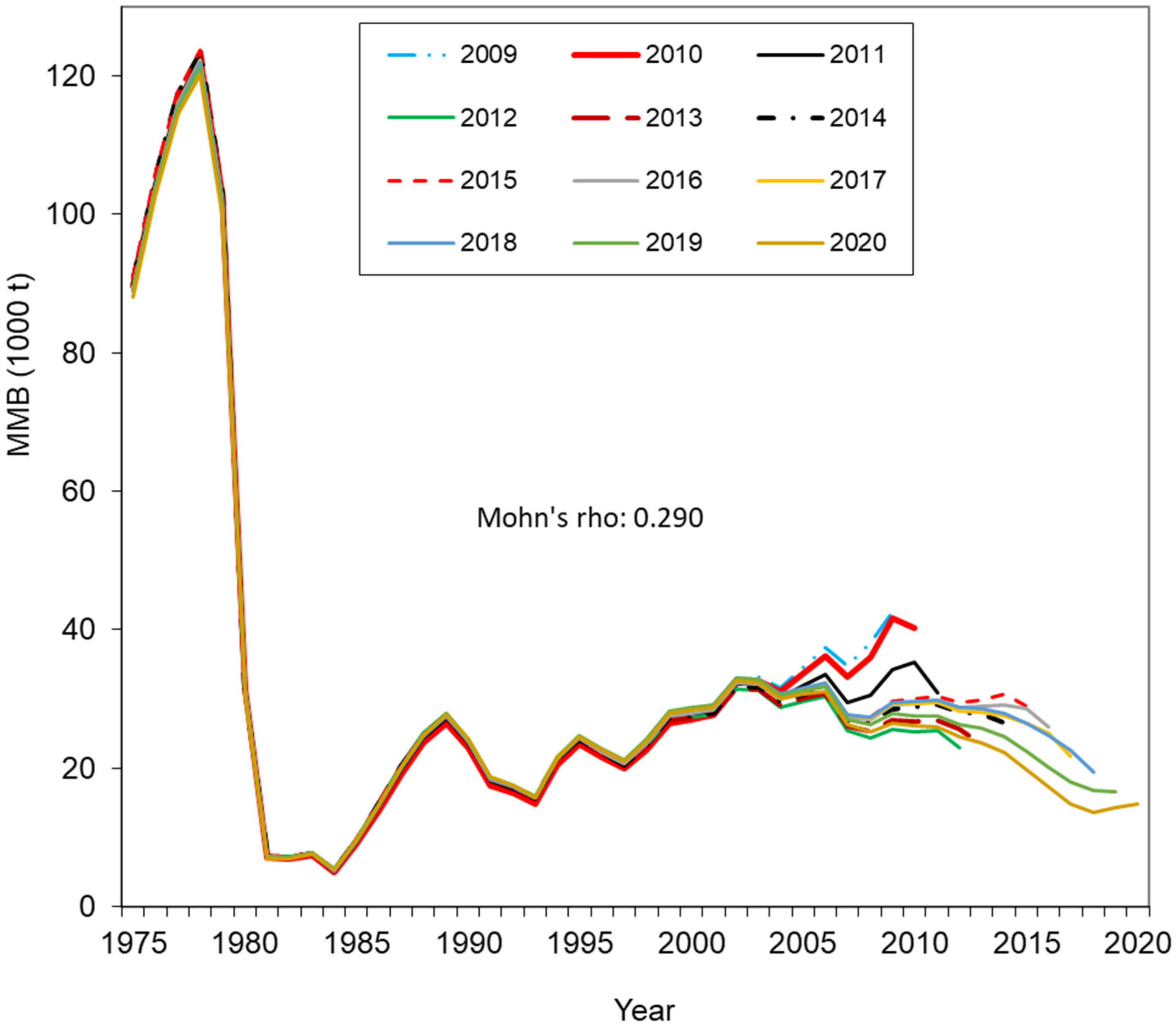


Figure 27a. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2020 made with terminal years 2009-2020 with model 19.3. These are results of the 2020 model. Legend shows the terminal year.

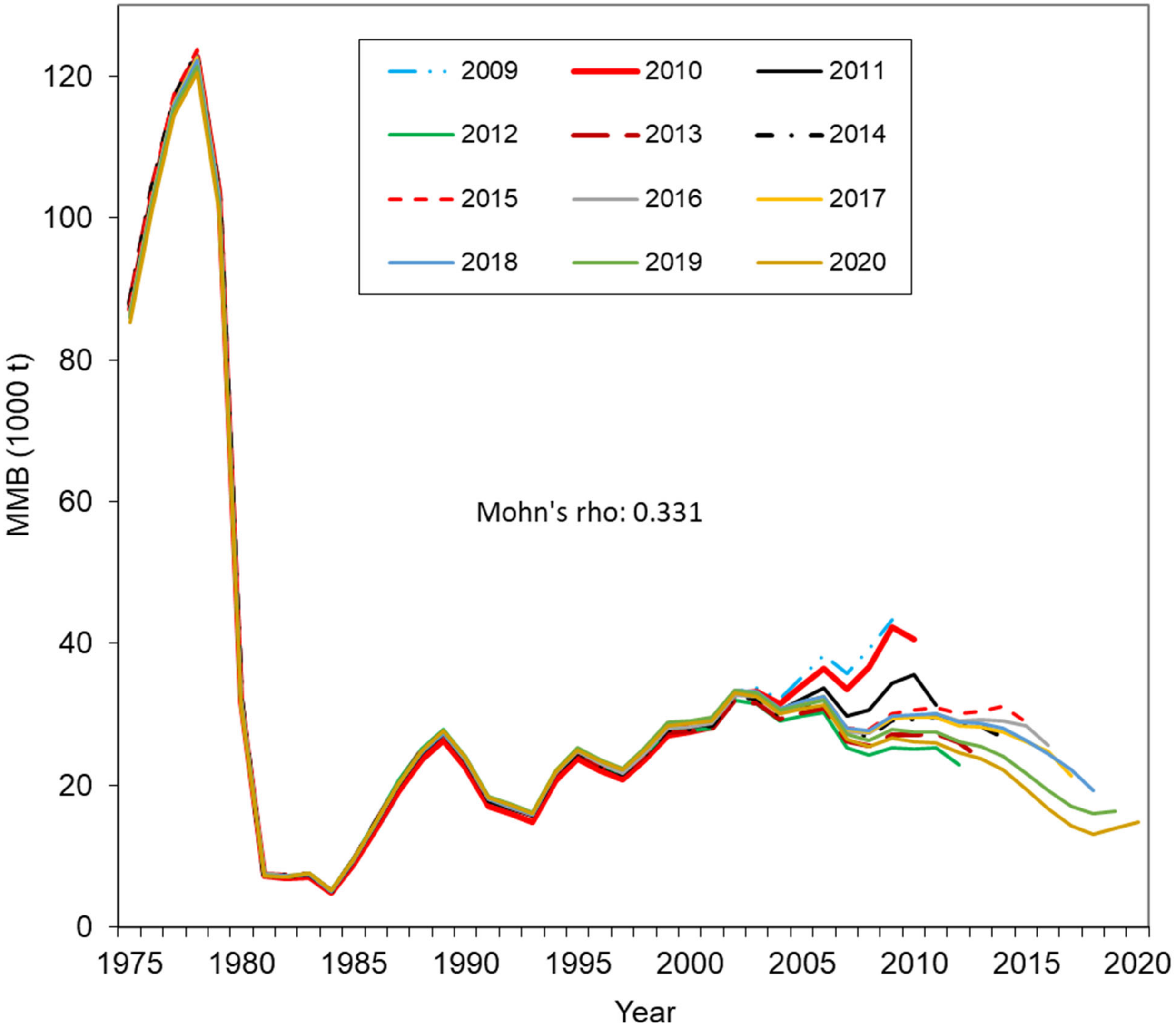


Figure 27b. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2020 made with terminal years 2009-2020 with model 19.3d. These are results of the 2020 model. Legend shows the terminal year.

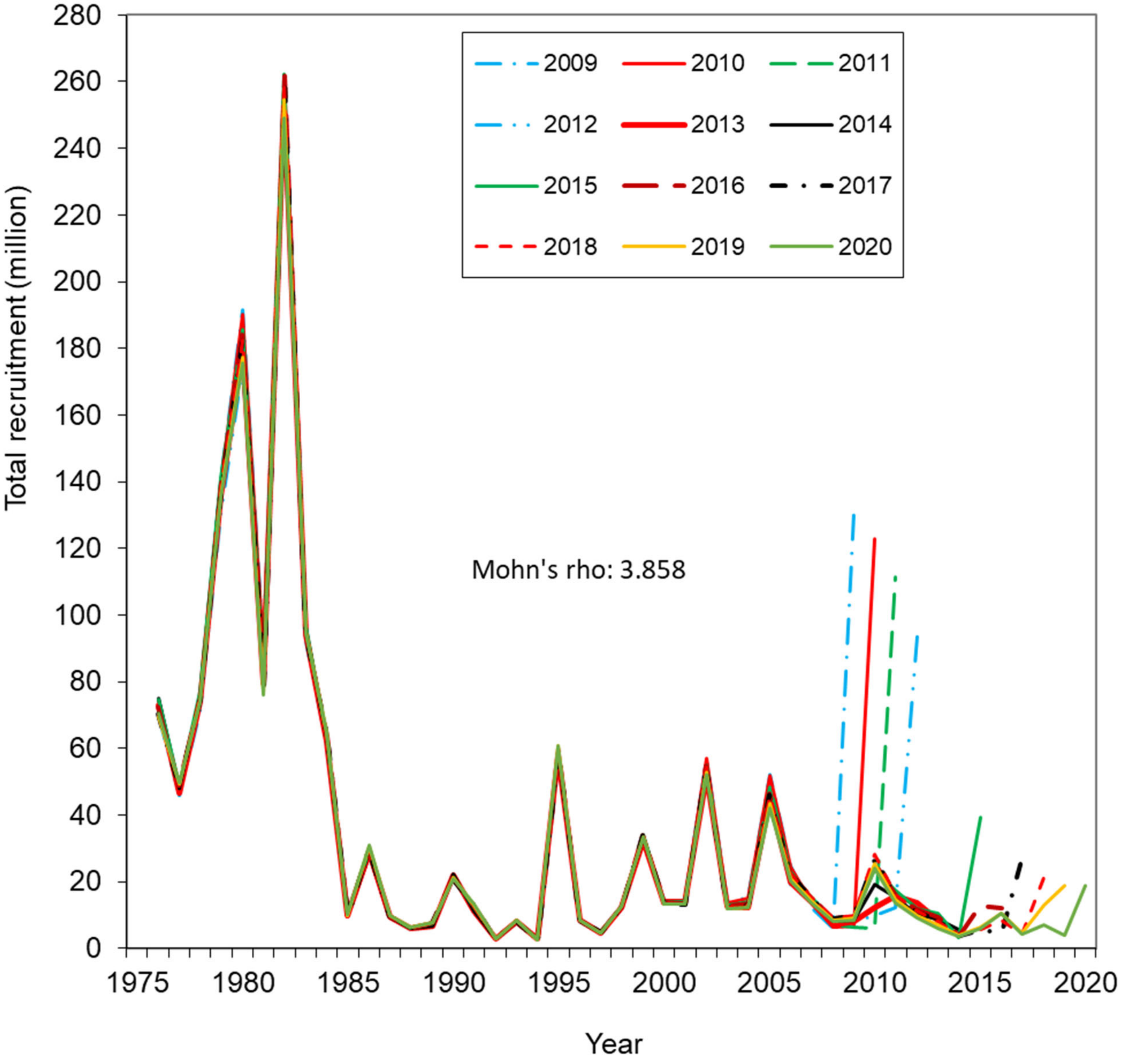


Figure 28a. Comparison of hindcast estimates of total recruitment for model 19.3 of Bristol Bay red king crab from 1976 to 2020 made with terminal years 2009-2020. These are results of the 2020 model. Legend shows the terminal year.

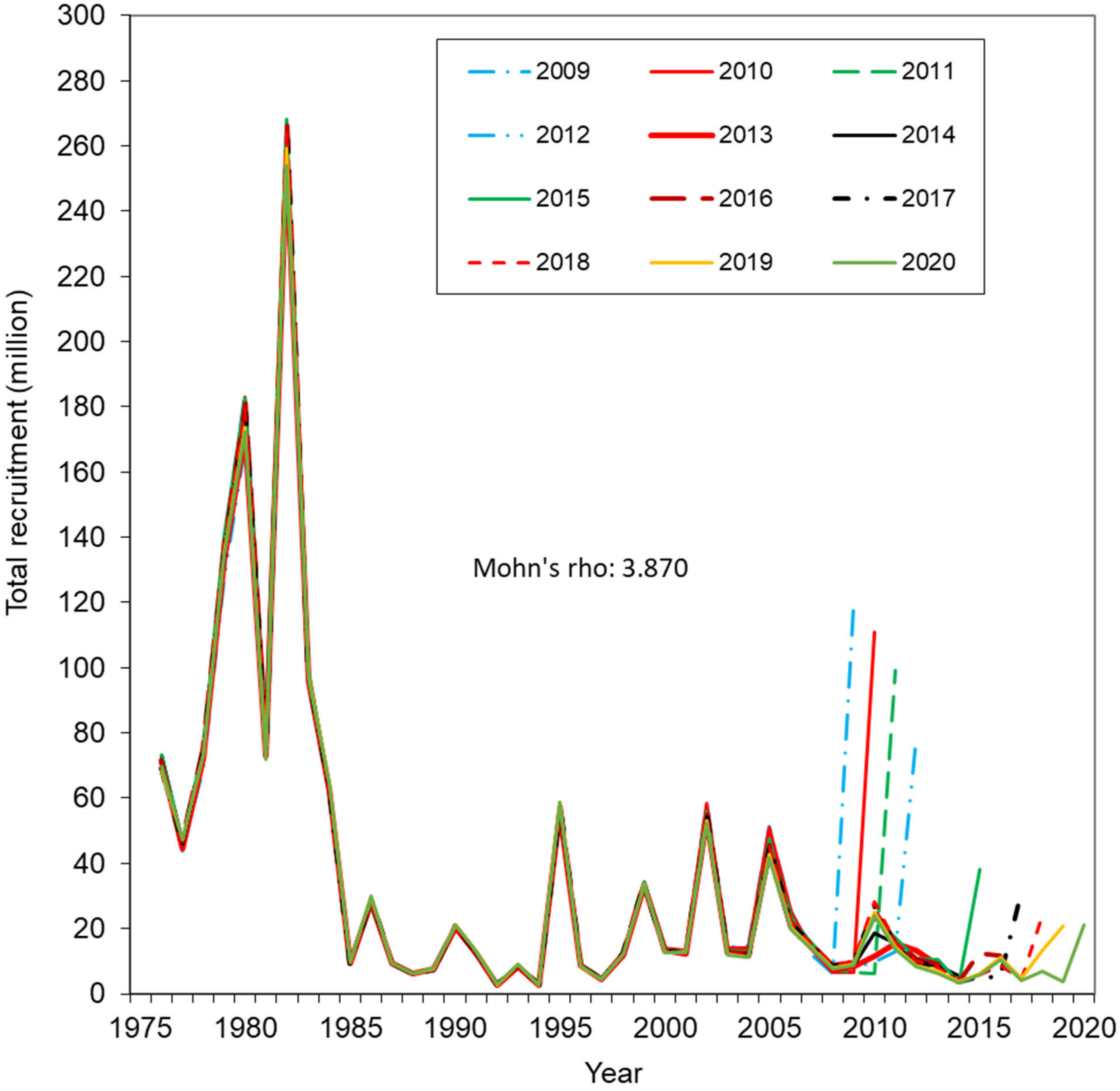


Figure 28b. Comparison of hindcast estimates of total recruitment for model 19.3d of Bristol Bay red king crab from 1976 to 2020 made with terminal years 2009-2020. These are results of the 2020 model. Legend shows the terminal year.

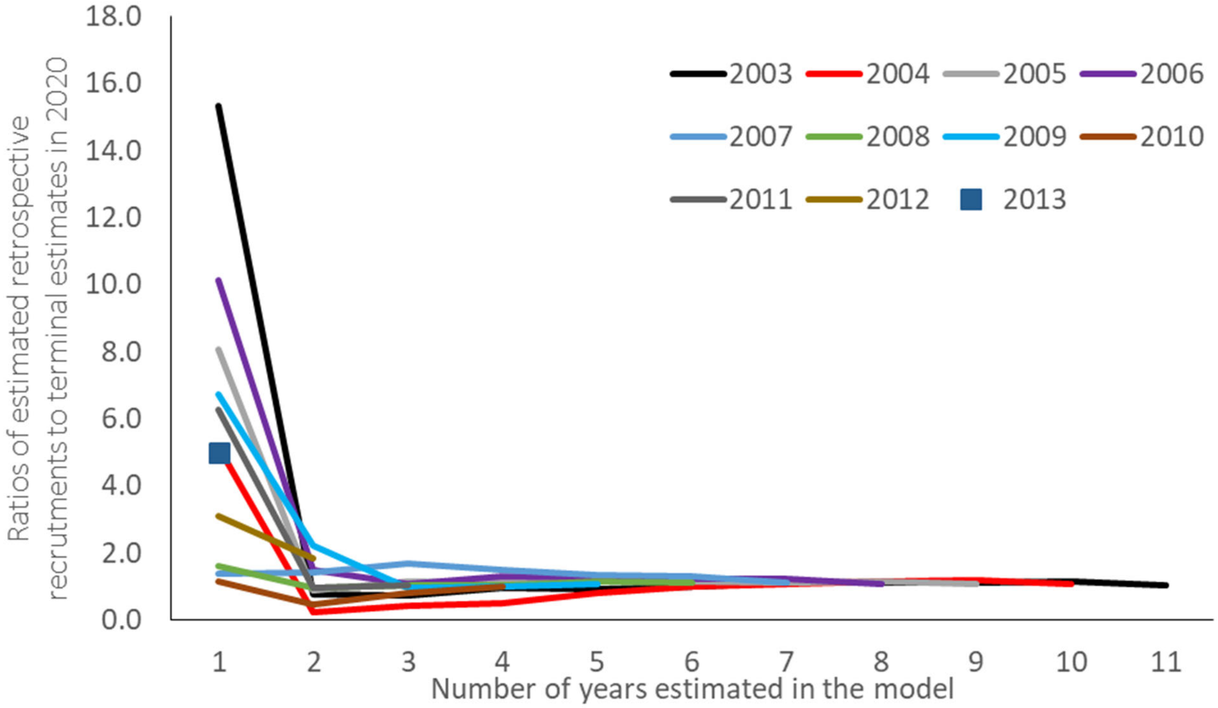


Figure 28c. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 19.3.

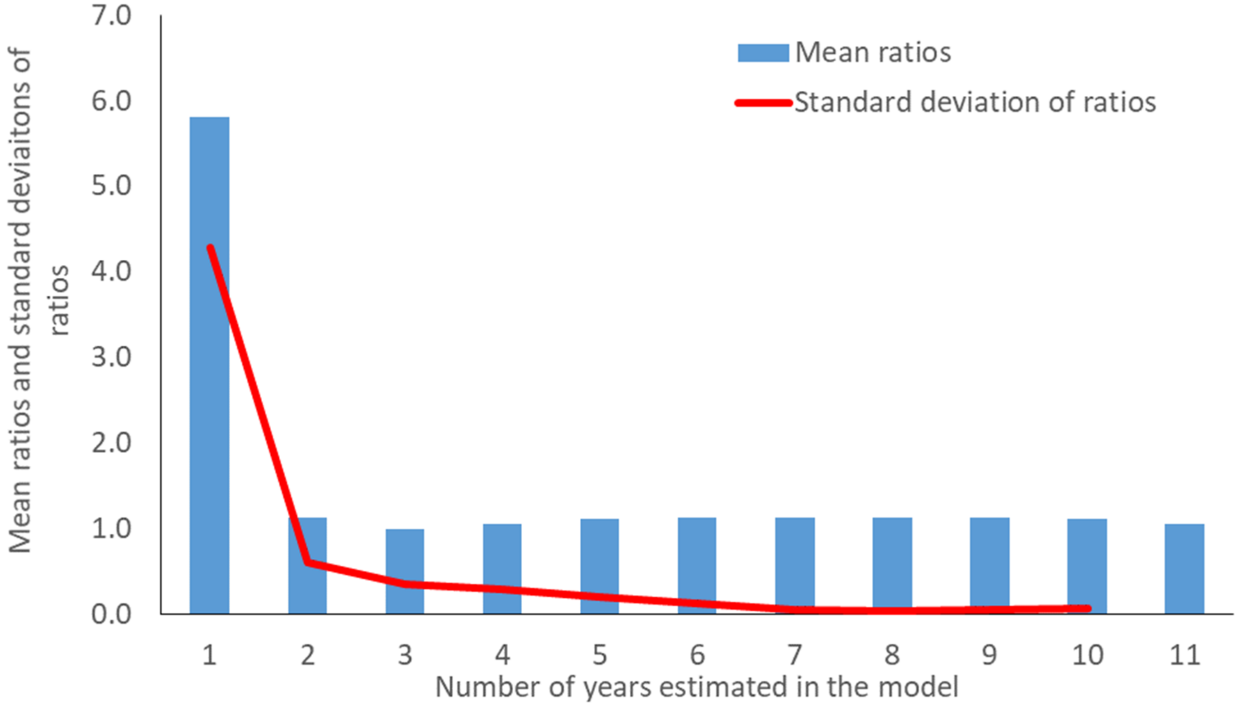


Figure 28d. Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2020) and standard deviations of the ratios as a function of the number of years in the model for model 19.3.

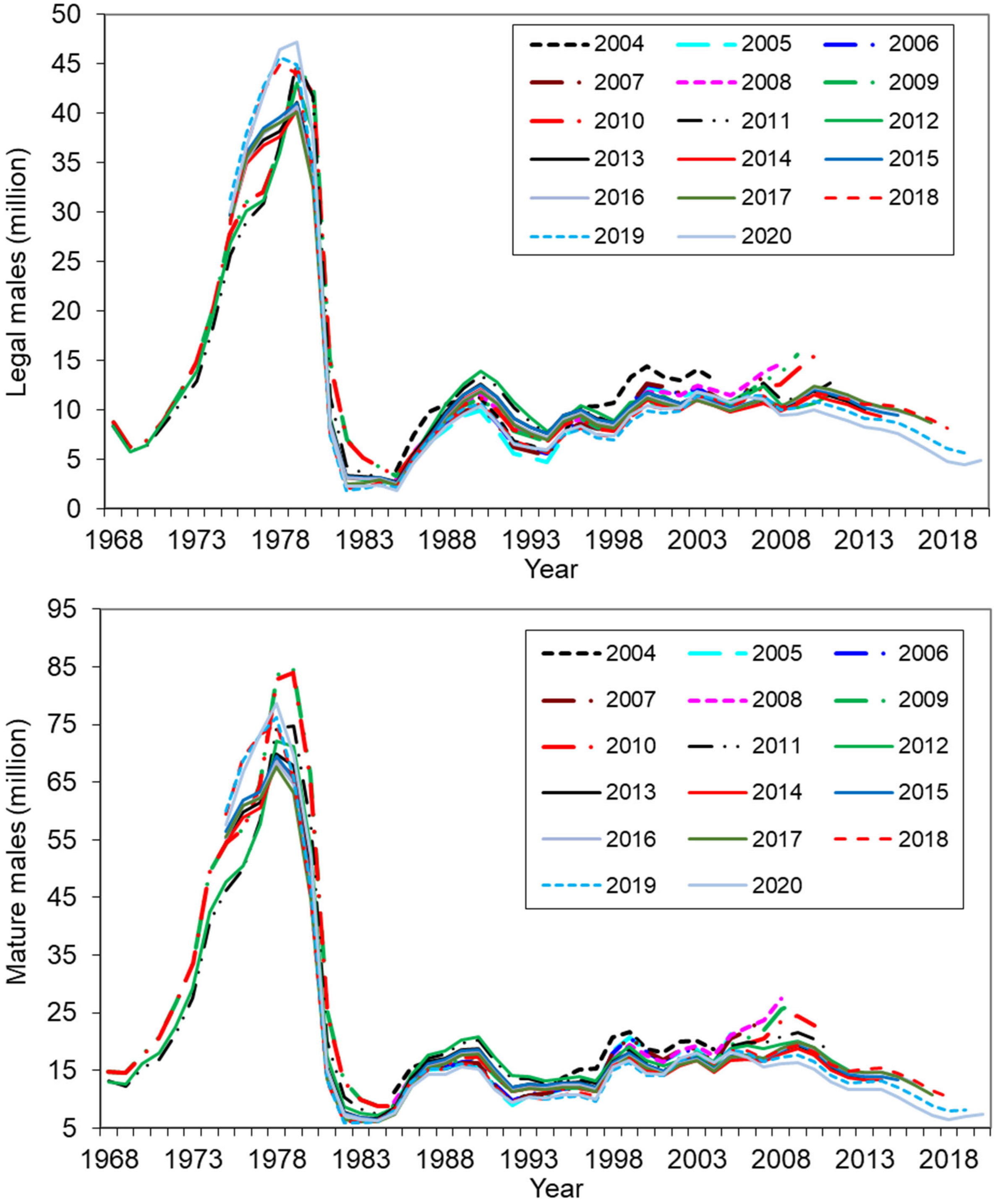


Figure 29. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2020 made with terminal years 2004-2020 with the base models. Model 19.3 is used for 2020. These are results of historical assessments. Legend shows the year in which the assessment was conducted.

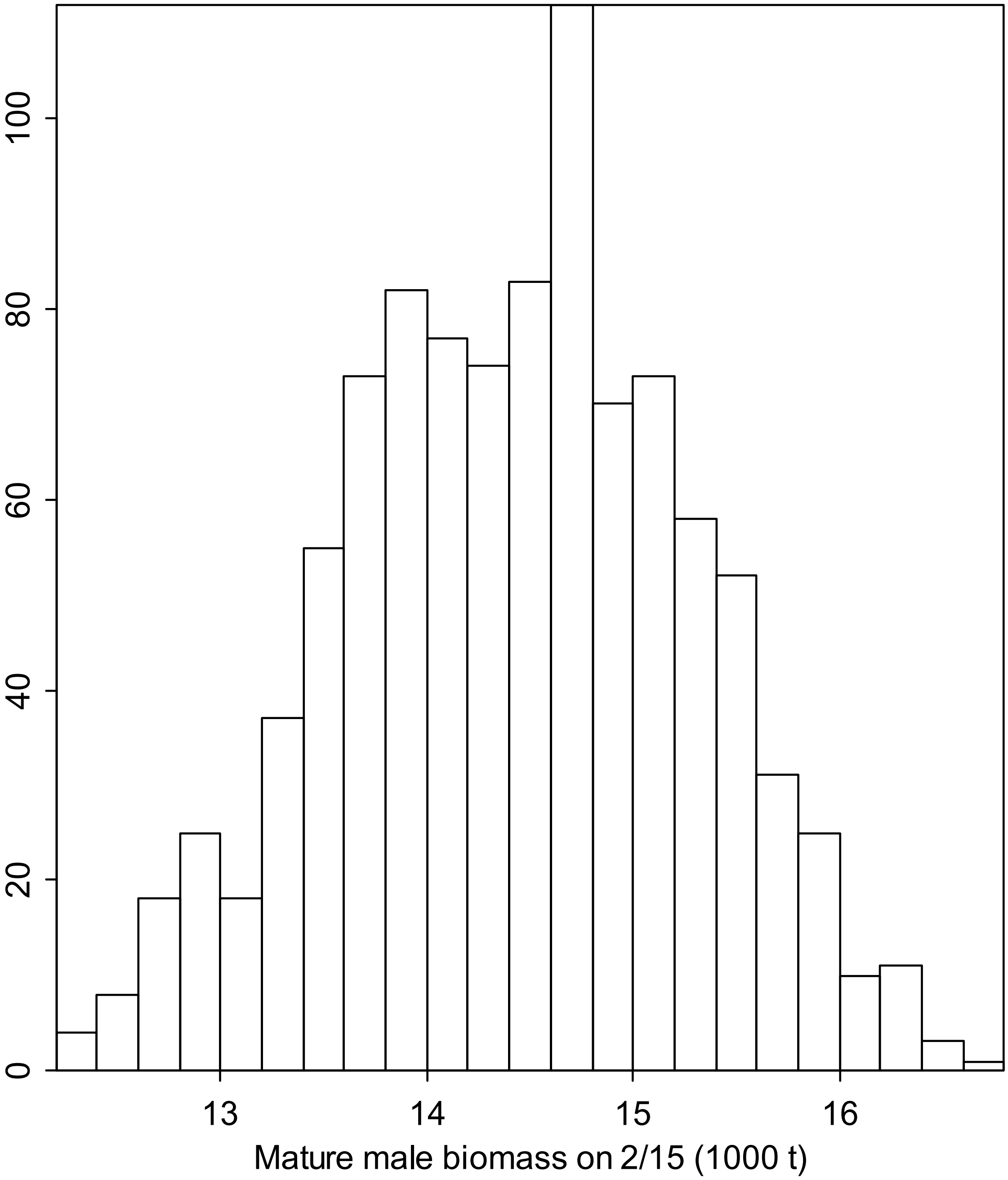


Figure 30a. Histogram of estimated mature male biomass on Feb. 15, 2021 under model 19.3 with the MCMC approach.

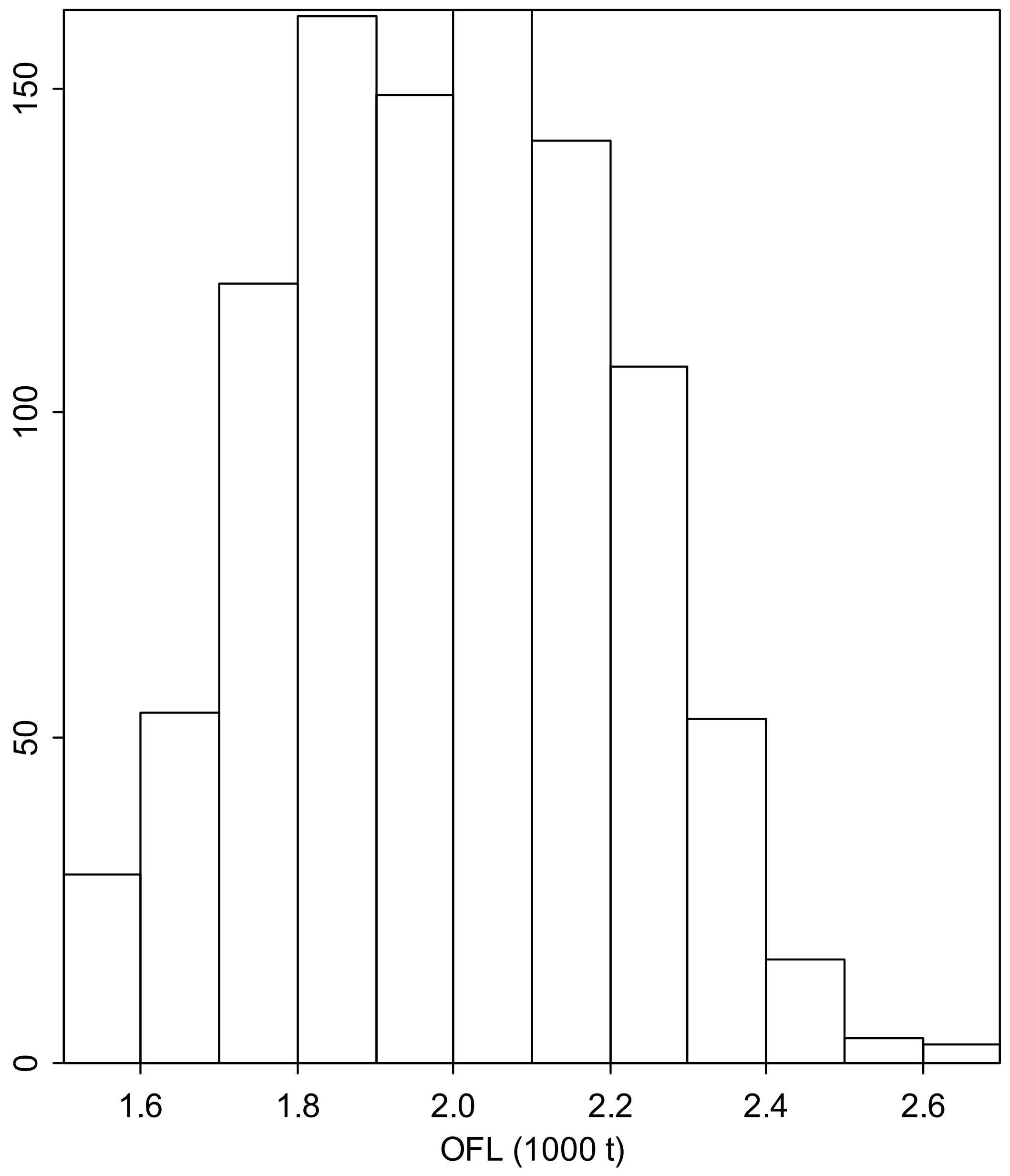


Figure 30b. Histogram of the 2020 estimated OFL under model 19.3 with the MCMC approach.

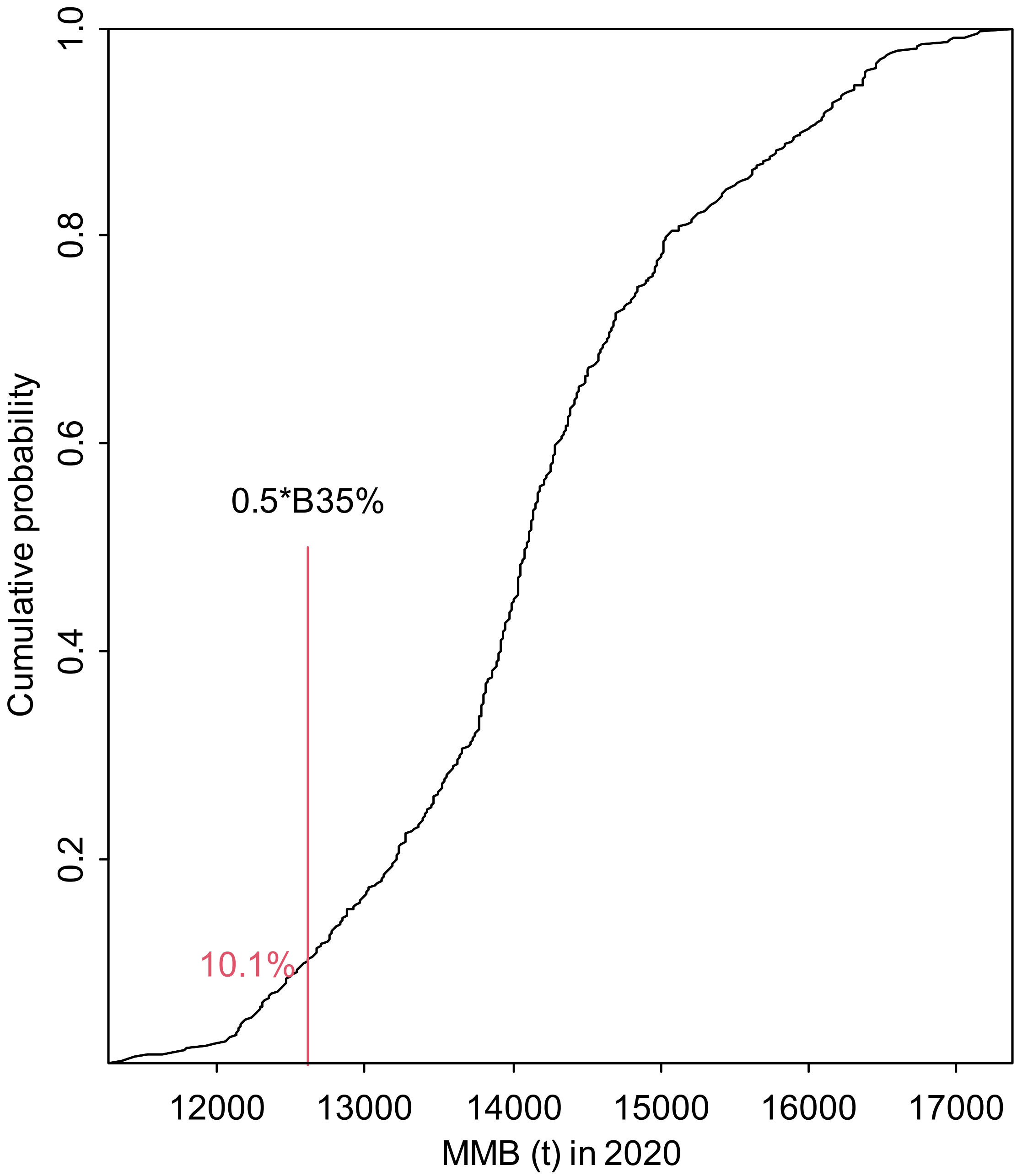


Figure 31. Cumulative probabilities of estimated mature male biomass (MMB) in 2020 under model 19.3d with the MCMC approach. About 10.1% probability is below the minimum threshold.

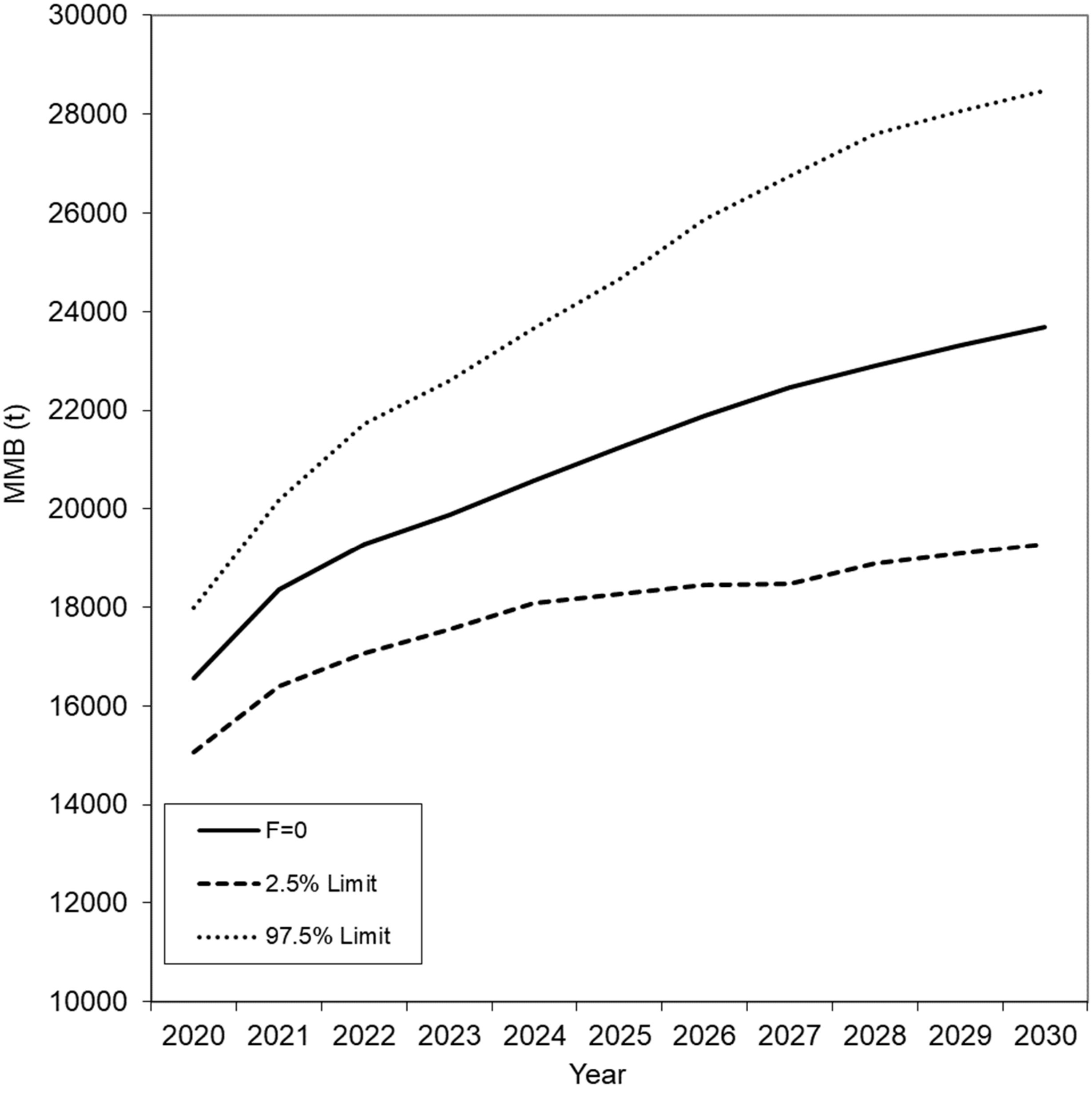


Figure 32a. Projected mature male biomass on Feb. 15 with *F* = 0 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

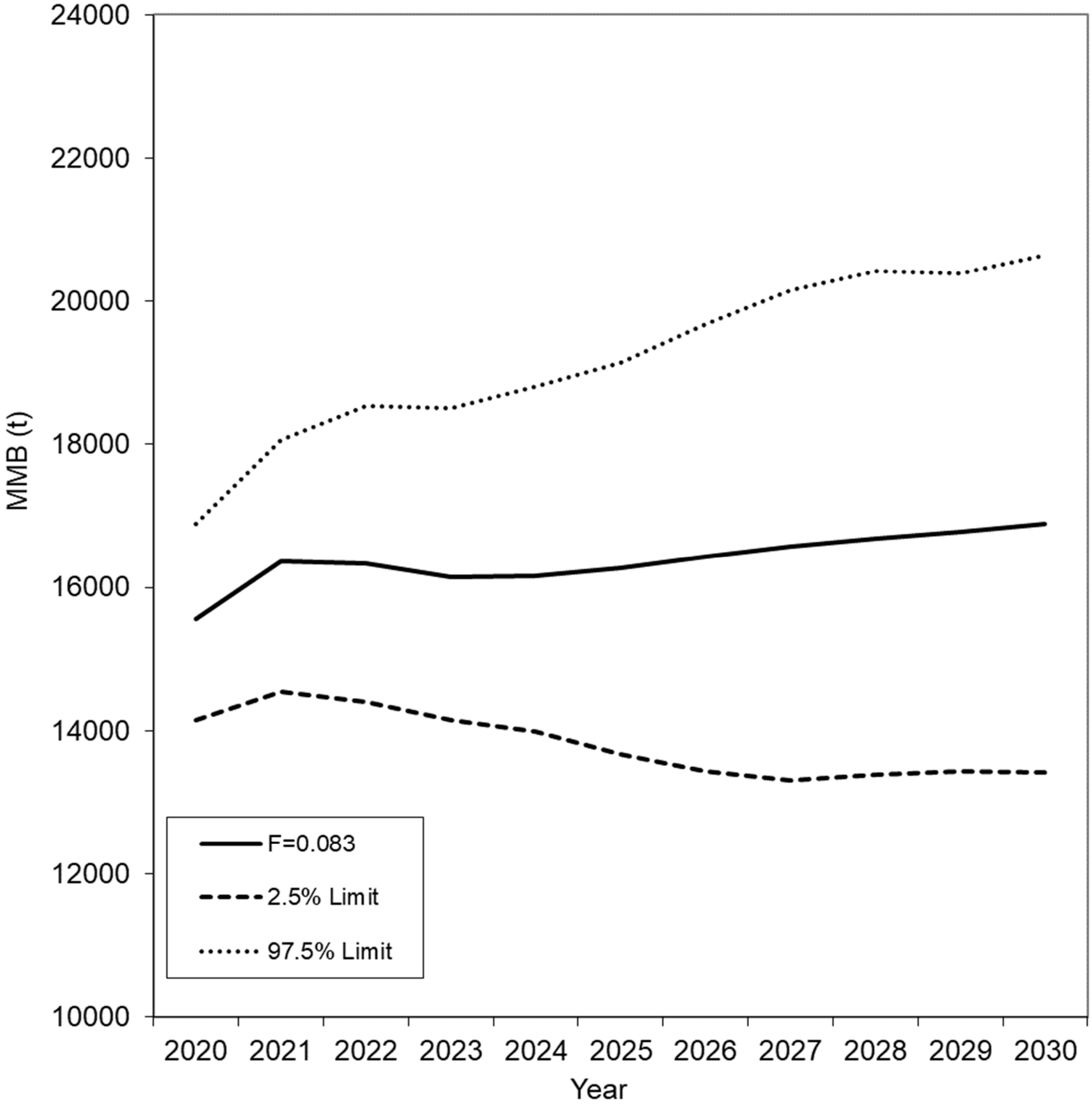


Figure 32b. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

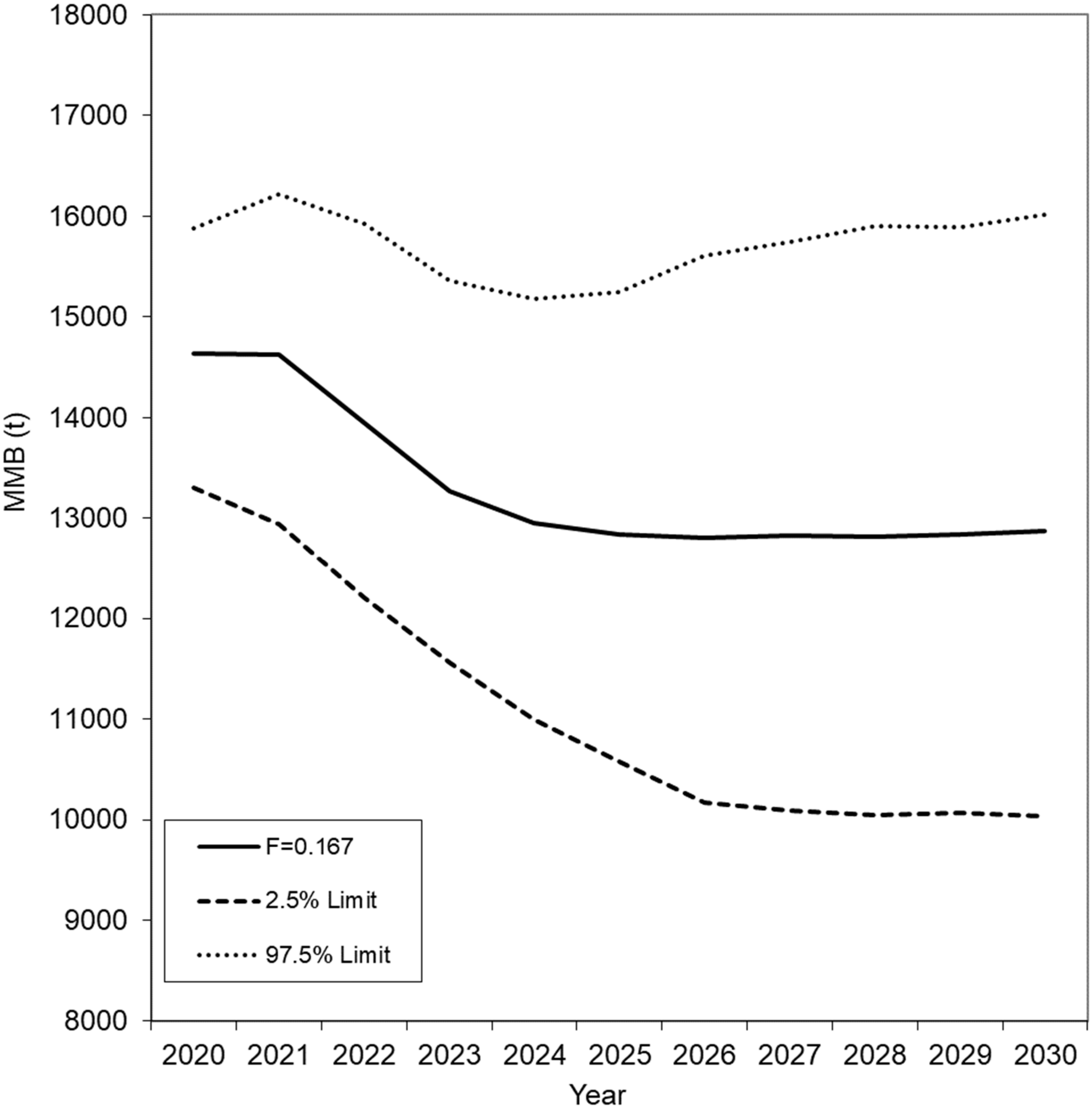


Figure 32c. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

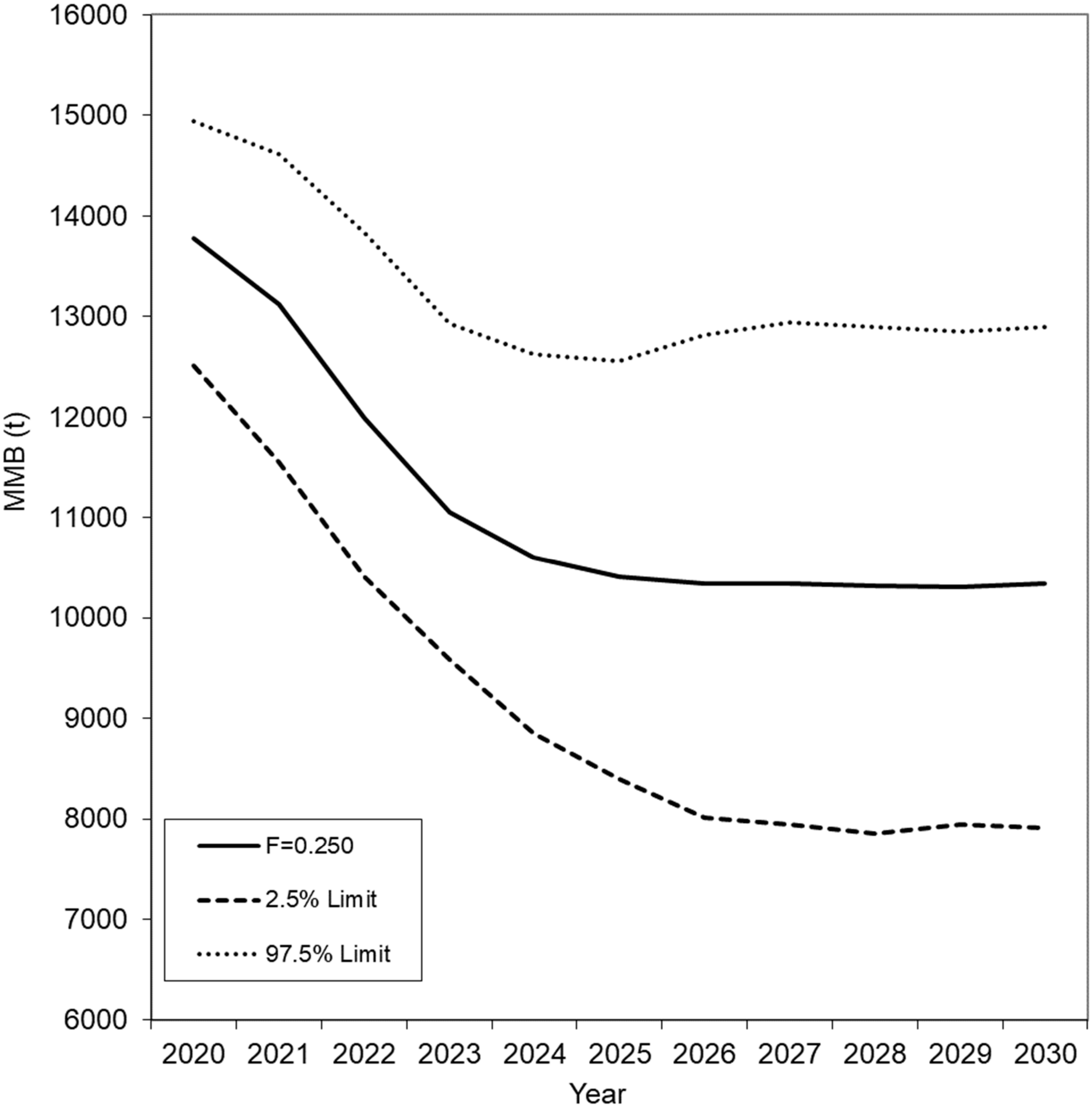


Figure 32d. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

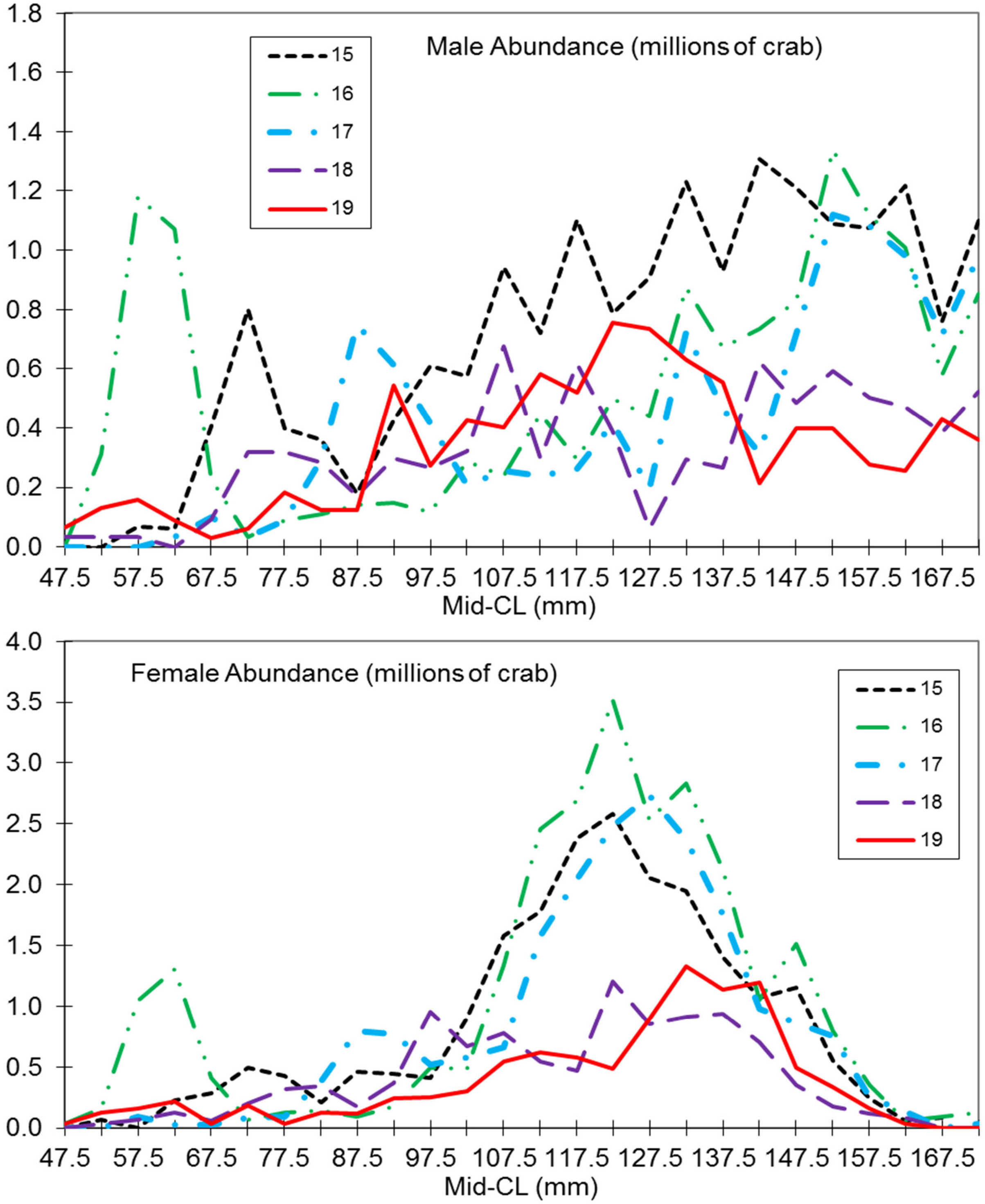


Figure 33. Length frequency distributions of male (top panel) and female (bottom panel) red king crab in Bristol Bay from NMFS trawl surveys during 2015-2019. For purposes of these graphs, abundance estimates are based on area-swept methods.

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.:

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

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

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

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

c. Total mortality / probability of encountering the gear

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

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

where $\rho^{\text{M}}_{y,t}$ 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:

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

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

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 $\xi_{y,t}^{f,g}$ are the annual deviation of fully-selected fishing mortality for fleet *f* (by gender).

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

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

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

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

d. Landings, discards, total catch

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

Landed catch
$$C_{y,t,l}^{\text{Land},f,g} = \frac{\lambda_{y,t,l}^{f,g} S_{y,t,l}^{f,g} F_{y,t}^{f,g}}{Z_{y,t,l}^g} N_{y,t,l}^{f,g} (1 - e^{-Z_{y,t,l}^g}) \tag{A.11}$$

Discards
$$C_{y,t,l}^{\text{Disc},f,g} = \frac{(1-\lambda_{y,t,l}^{f,g}) S_{y,t,l}^{f,g} F_{y,t}^{f,g}}{Z_{y,t,l}^g} N_{y,t,l}^{f,g} (1 - e^{-Z_{y,t,l}^g}) \tag{A.12}$$

Total catch
$$C_{y,t,l}^{\text{Total},f,g} = \frac{S_{y,t,l}^{f,g} F_{y,t}^{f,g}}{Z_{y,t,l}^g} N_{y,t,l}^{f,g} (1 - e^{-Z_{y,t,l}^g}) \tag{A.13}$$

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

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

$$C_{y,t}^{\text{Land},g,f} = \sum_l C_{y,t,l}^{\text{Land},g,f} w_{y,l}^g \; ; \; C_{y,t}^{\text{Disc},g,f} = \sum_l C_{y,t,l}^{\text{Disc},g,f} w_{y,l}^g \; ; \; C_{y,t}^{\text{Total},g,f} = \sum_l C_{y,t,l}^{\text{Total},g,f} w_{y,l}^g \tag{A.14}$$

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

e. Selectivity / retention

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

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

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

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

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

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

f. Growth

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

(1) Molt probability

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

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

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

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

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

(2) Size-transition

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

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

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

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

B. Outputs, Projections and OFL Calculation

a. Core model outputs

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

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

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

Definition of model outputs:

(1) Biomass: two population biomass measurements are used in this report: total survey biomass (crab >64 mm CL) and mature male biomass (males >119 mm CL). Mating time is assumed to Feb. 15.
(2) Recruitment: new entry of number of males in the 1st seven length classes (65- 99 mm CL) and new entry of number of females in the 1st five length classes (65-89 mm CL).
(3) Fishing mortality: full-selected instantaneous annual fishing mortality rate at the time of fishery.

b. Biological reference points

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

(1) The proxy for F_{MSY}

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

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

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

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

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:

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

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.:

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

      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.:

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

      where R_0 is unfished recruitment (i.e.. $SSB_0 / SSBPR(\underline{0})$).
- The control rule used to set fully-selected fishing mortality for the directed fisheries. The options are available

- Pre-specified values for fully-selected fishing mortality for each fishery.
- Pre-specified values subject to the dead catch not exceeding that corresponding to the OFL.
- Pre-specified values subject to the dead catch not exceeding that corresponding to the OFL and the landed catch not exceeding that corresponding to the State of Alaska harvest control rule.

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

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

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

C. Parameter Estimation

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

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

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

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

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

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

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

b. Likelihood Components

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

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

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

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

The weighted negative log likelihood functions are:

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

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

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

c. Population State in Year 1.

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

d. Parameter estimation framework:

(1) Parameters estimated independently

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

i. Natural Mortality

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

ii. Length-weight Relationship

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

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

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. 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.

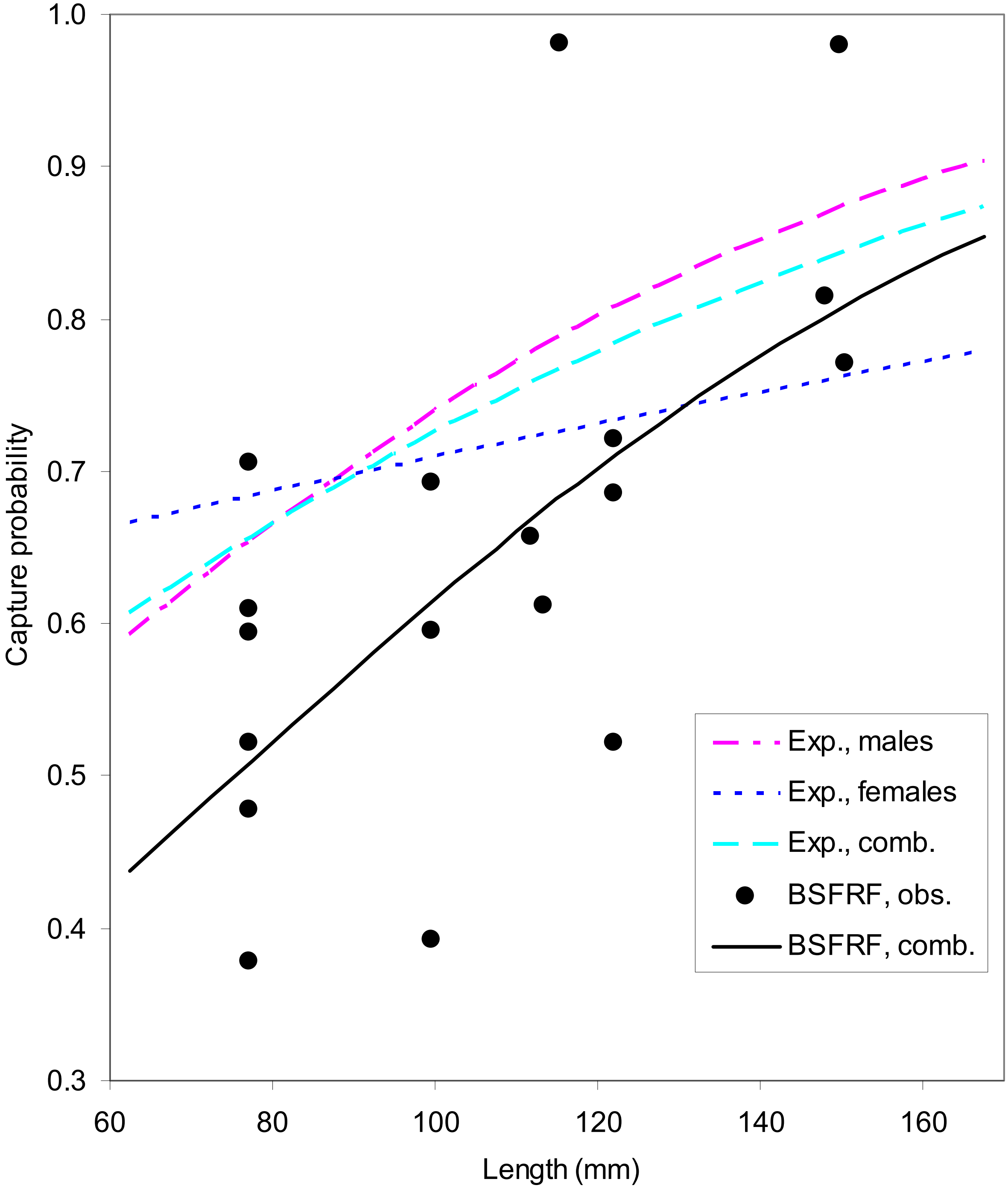
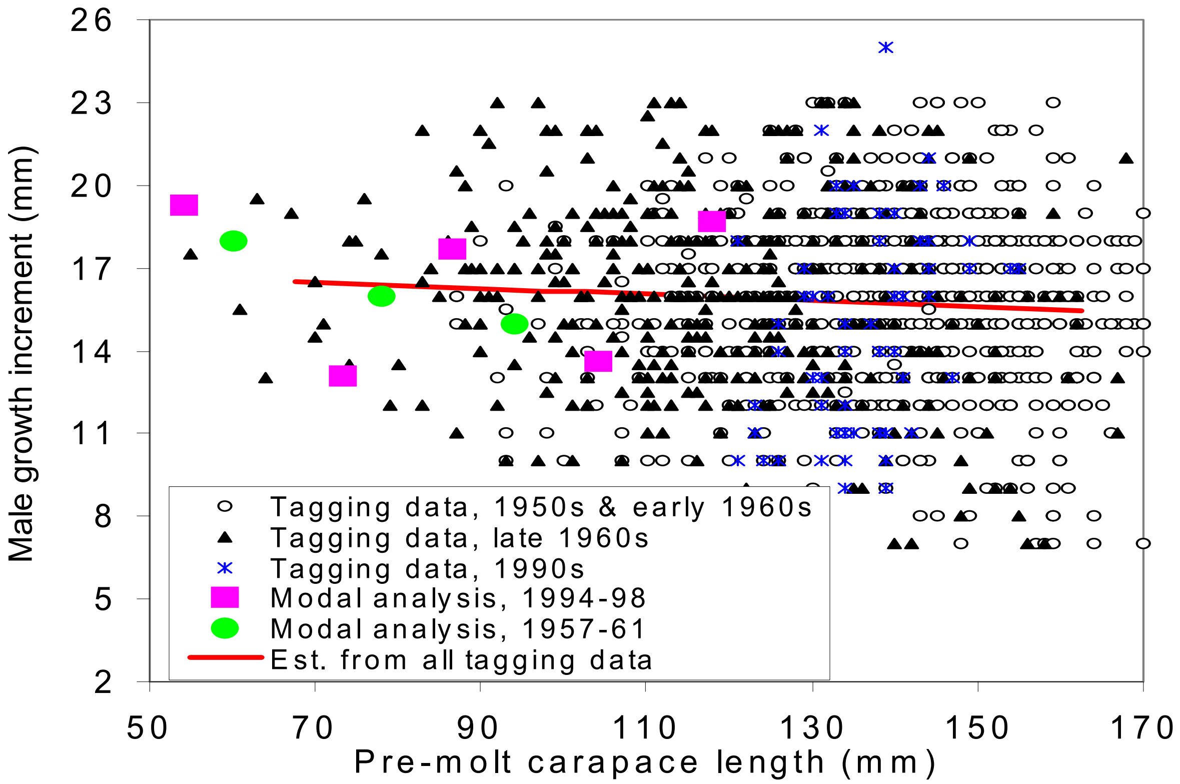


Figure A1. Estimated capture probabilities for NMFS Bristol Bay red king crab trawl surveys by Weinberg et al. (2004) and the Bering Sea Fisheries Research Foundation surveys.



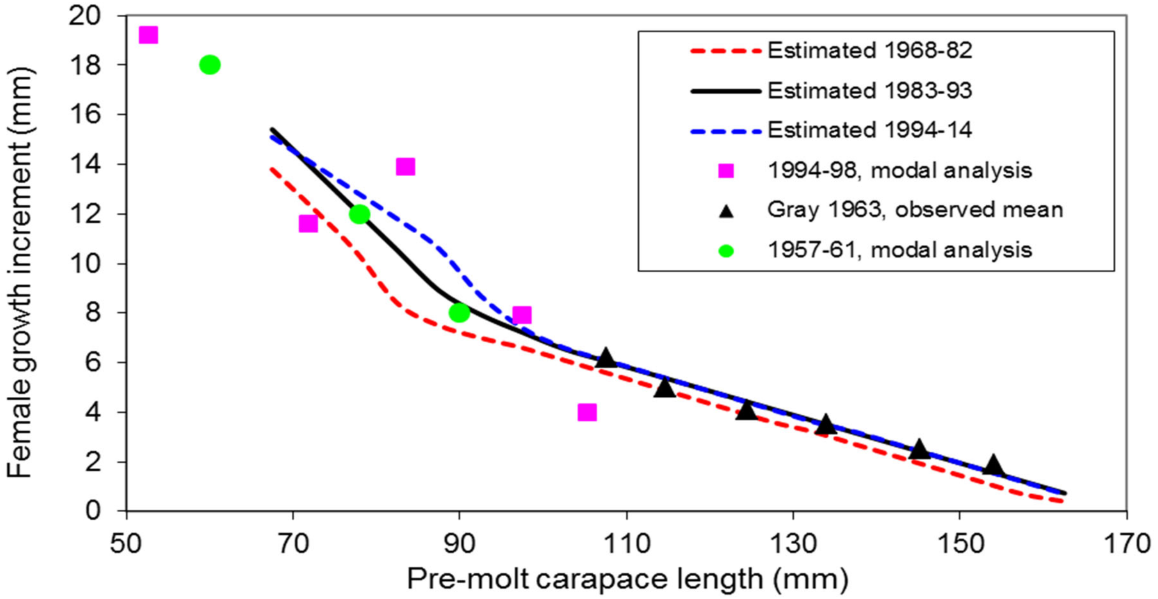


Figure A2. Mean growth increments per molt for Bristol Bay red king crab. Note: "tagging"---based on tagging data; "mode"---based on modal analysis. The female growth increments per molt are for different model scenarios.

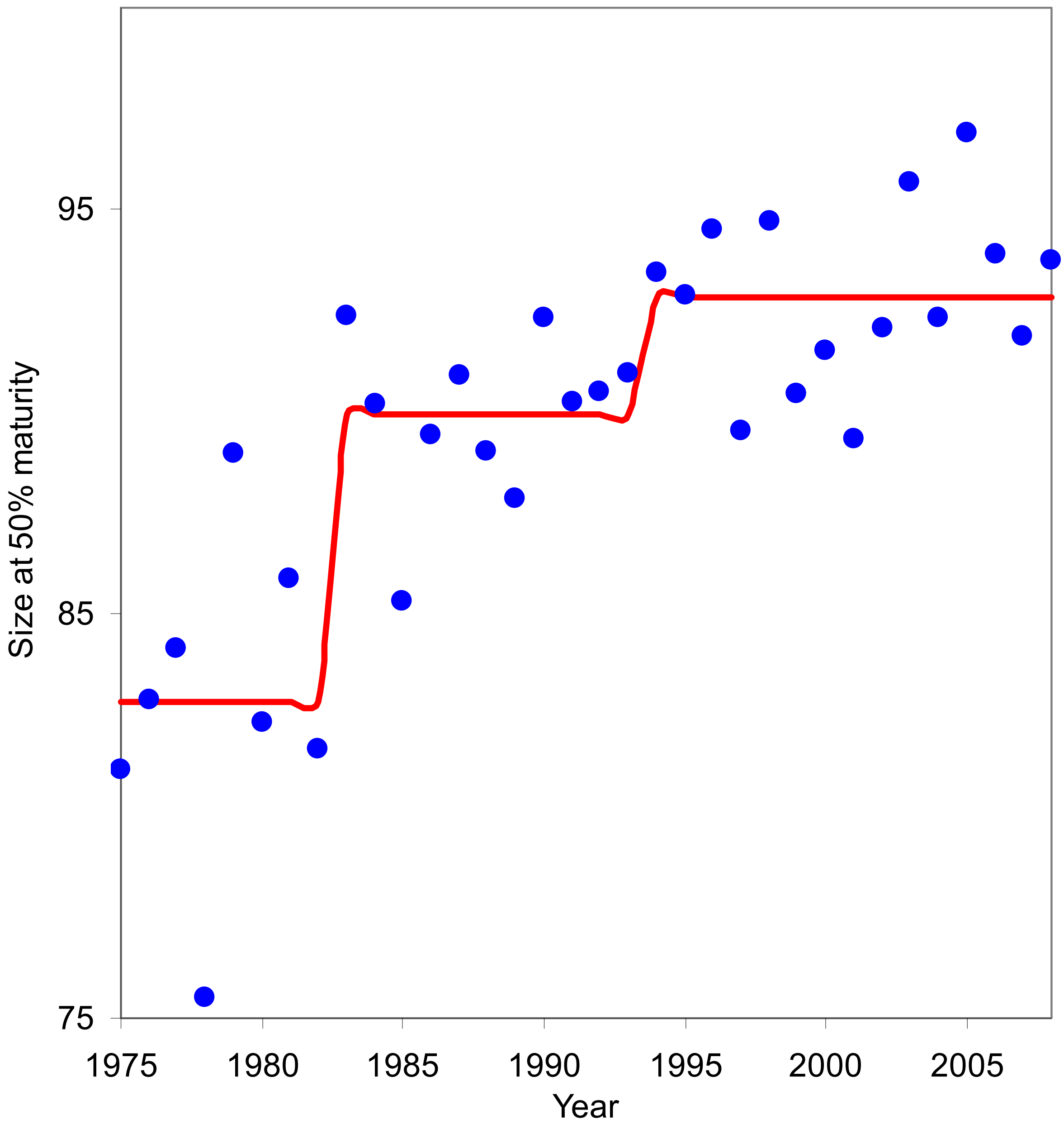


Figure A3. Estimated sizes at 50% maturity for Bristol Bay female red king crab from 1975 to 2008. Averages for three periods (1975-82, 1983-93, and 1994-08) are plotted with a line.

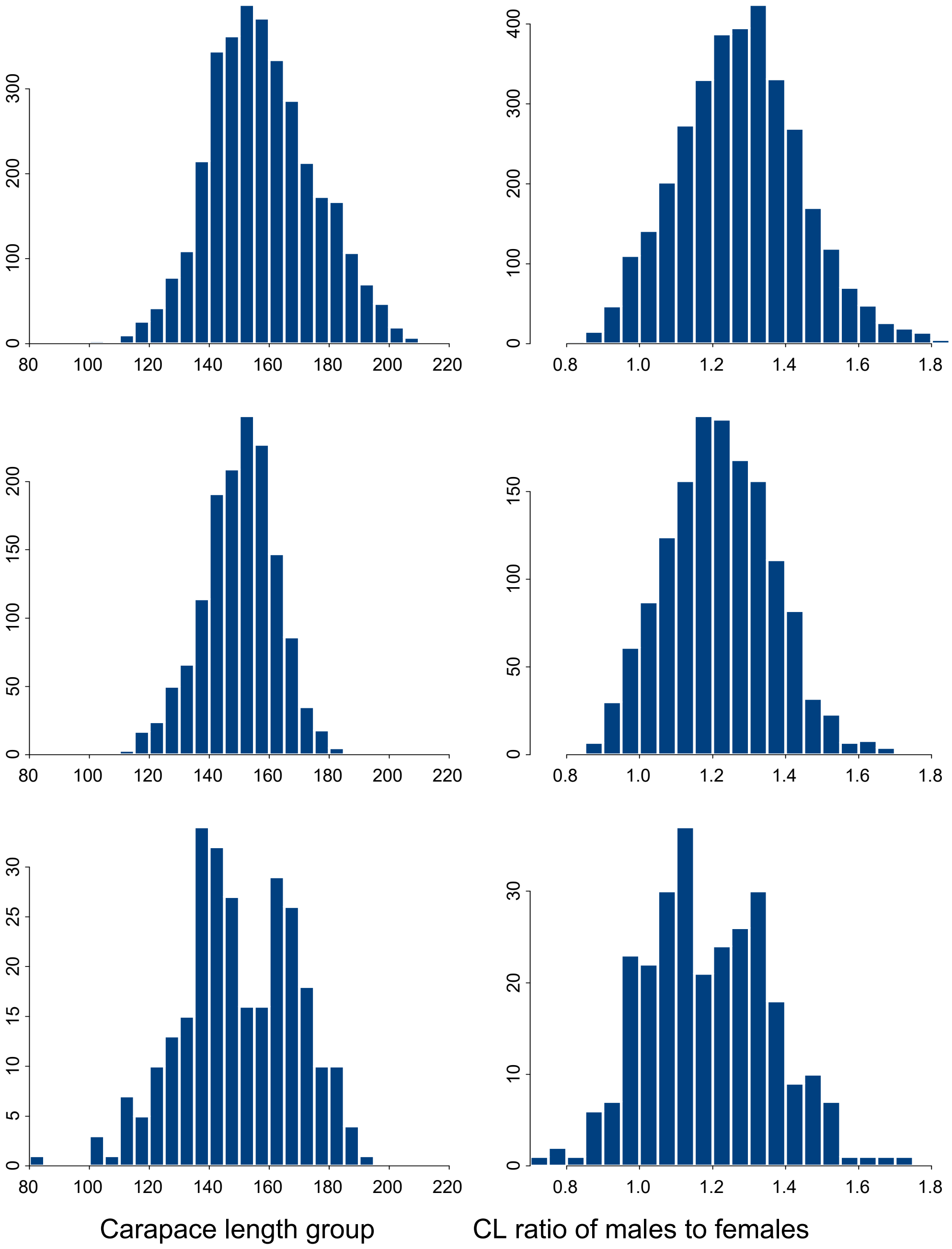


Figure A4. Histograms of carapace lengths (CL) and CL ratios of males to females for male shell ages ≤13 months of red king crab males in grasping pairs; Powell's Kodiak data. Upper plot: all locations and years pooled; middle plot: location 11; lower plot: locations 4 and 13. Sizes at maturity for Kodiak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

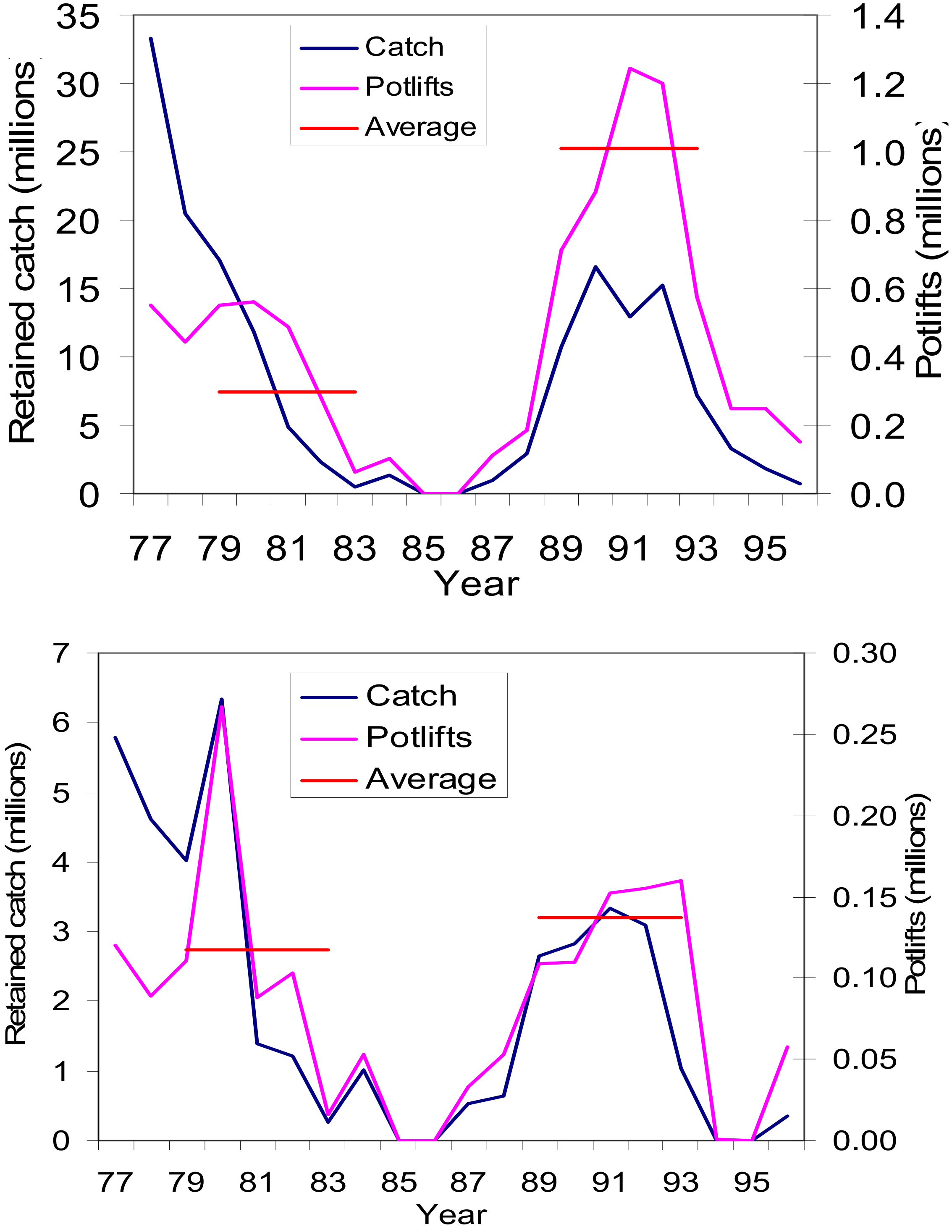


Figure A5. Retained catch and potlifts for total eastern Bering Sea Tanner crab fishery (upper plot) and the Tanner crab fishery east of 163° W (bottom).

Appendix B. Input Data File for Model 19.3

```
#=================================================================

#	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
2019	# 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

# 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
45      30      30      44      25      25     24
##      ——————————————————————————————————————————————————————————————— ##
##      CATCH         DATA
##      Type of       catch: 1 = retained, 2   = discard, 0 =   total
##      Units of catch:  1 = biomass, 2 = numbers
##      for BBRKC Units       are in 1000 mt  for landed & discards.
##      ————————————————————————————————————————————————————————————    ##
##      Male    retained        pot     fishery (tonnes)
#year   seas    fleet   sex     obs     cv      type    units   mult    effort  discard_mortality
1975    3       1       1       23281.2         0.03    1       1       1       0       0.2
1976    3       1       1       28993.6         0.03    1       1       1       0       0.2
1977    3       1       1       31736.9         0.03    1       1       1       0       0.2
1978    3       1       1       39743  0.03     1       1       1       0       0.2
1979    3       1       1       48910  0.03     1       1       1       0       0.2
1980    3       1       1       58943.6         0.03    1       1       1       0       0.2
1981    3       1       1       15236.8         0.03    1       1       1       0       0.2
1982    3       1       1       1361.3 0.03     1       1       1       0       0.2
1983    3       1       1       0.1     0.03    1       1       1       0       0.2     #AEP
1984    3       1       1       1897.1 0.03     1       1       1       0       0.2
1985    3       1       1       1893.8 0.03     1       1       1       0       0.2
1986    3       1       1       5168.2 0.03     1       1       1       0       0.2
1987    3       1       1       5574.2 0.03     1       1       1       0       0.2
1988    3       1       1       3351.1 0.03     1       1       1       0       0.2
1989    3       1       1       4656    0.03    1       1       1       0       0.2
1990    3       1       1       9272.8 0.03     1       1       1       0       0.2
1991    3       1       1       7885.1 0.03     1       1       1       0       0.2
1992    3       1       1       3681.8 0.03     1       1       1       0       0.2
1993    3       1       1       6659.6 0.03     1       1       1       0       0.2
1994    3       1       1       42.3    0.03    1       1       1       0       0.2
1995    3       1       1       36.4    0.03    1       1       1       0       0.2
1996    3       1       1       3861.7 0.03     1       1       1       0       0.2
1997    3       1       1       4042.1 0.03     1       1       1       0       0.2
1998    3       1       1       6779.2 0.03     1       1       1       0       0.2
1999    3       1       1       5377.9 0.03     1       1       1       0       0.2
2000    3       1       1       3737.9 0.03     1       1       1       0       0.2
2001    3       1       1       3866.2 0.03     1       1       1       0       0.2
2002    3       1       1       4384.5 0.03     1       1       1       0       0.2
2003    3       1       1       7135.3 0.03     1       1       1       0       0.2
```

```
2004    3       1       1       7006.7  0.03    1       1       1       0       0.2
2005    3       1       1       8399.7  0.03    1       1       1       0       0.2
2006    3       1       1       7143.2  0.03    1       1       1       0       0.2
2007    3       1       1       9303.9  0.03    1       1       1       0       0.2
2008    3       1       1       9216.1  0.03    1       1       1       0       0.2
2009    3       1       1       7272.5  0.03    1       1       1       0       0.2
2010    3       1       1       6761.5  0.03    1       1       1       0       0.2
2011    3       1       1       3607.1  0.03    1       1       1       0       0.2
2012    3       1       1       3621.7  0.03    1       1       1       0       0.2
2013    3       1       1       3991    0.03    1       1       1       0       0.2
2014    3       1       1       4538.6  0.03    1       1       1       0       0.2
2015    3       1       1       4613.7  0.03    1       1       1       0       0.2
2016    3       1       1       3923.9  0.03    1       1       1       0       0.2
2017    3       1       1       3093.7  0.03    1       1       1       0       0.2
2018    3       1       1       2026.5  0.03    1       1       1       0       0.2
2019    3       1       1       1775.3  0.03    1       1       1       0       0.2

##      Total Male      pot     fishery (t)
#year   seas    fleet   sex     obs     cv      type    units   mult    effort  discard_mortality
1990    3       1       1       11782.9         0.04    0       1       1       0       0.2
1991    3       1       1       9974    0.04    0       1       1       0       0.2
1992    3       1       1       6013.7  0.04    0       1       1       0       0.2
1993    3       1       1       9667.7  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       3902.3  0.04    0       1       1       0       0.2
1997    3       1       1       3847.2  0.04    0       1       1       0       0.2
1998    3       1       1       17681.4         0.04    0       1       1       0       0.2
1999    3       1       1       12245.2         0.04    0       1       1       0       0.2
2000    3       1       1       6672.3  0.04    0       1       1       0       0.2
2001    3       1       1       5797    0.04    0       1       1       0       0.2
2002    3       1       1       7065.3  0.04    0       1       1       0       0.2
2003    3       1       1       12300.6         0.04    0       1       1       0       0.2
2004    3       1       1       10816.8         0.04    0       1       1       0       0.2
2005    3       1       1       13753.3         0.04    0       1       1       0       0.2
2006    3       1       1       9170.4  0.04    0       1       1       0       0.2
2007    3       1       1       13956.6         0.04    0       1       1       0       0.2
2008    3       1       1       15068.7         0.04    0       1       1       0       0.2
2009    3       1       1       12300.3         0.04    0       1       1       0       0.2
2010    3       1       1       10087.4         0.04    0       1       1       0       0.2
2011    3       1       1       5732.6  0.04    0       1       1       0       0.2
2012    3       1       1       4568.1  0.04    0       1       1       0       0.2
2013    3       1       1       5260.7  0.04    0       1       1       0       0.2
```

```
2014    3       1       1       8312.7 0.04     0       1       1       0       0.2
2015    3       1       1       6706.4 0.04     0       1       1       0       0.2
2016    3       1       1       5557.2 0.04     0       1       1       0       0.2
2017    3       1       1       4075.76         0.04    0       1       1       0       0.2
2018    3       1       1       3060.34         0.04    0       1       1       0       0.2
2019    3       1       1       3143.25 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       3240.20 0.07    0       1       1       0       0.2
1991    3       1       2       236.600         0.07    0       1       1       0       0.2
1992    3       1       2       2001.20 0.07    0       1       1       0       0.2
1993    3       1       2       3174.40 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       5.200   0.07    0       1       1       0       0.2
1997    3       1       2       184.800         0.07    0       1       1       0       0.2
1998    3       1       2       2897.10 0.07    0       1       1       0       0.2
1999    3       1       2       28.200 0.07     0       1       1       0       0.2
2000    3       1       2       833.700         0.07    0       1       1       0       0.2
2001    3       1       2       611.400         0.07    0       1       1       0       0.2
2002    3       1       2       46.100 0.07     0       1       1       0       0.2
2003    3       1       2       1804.70 0.07    0       1       1       0       0.2
2004    3       1       2       873.000         0.07    0       1       1       0       0.2
2005    3       1       2       2051.40 0.07    0       1       1       0       0.2
2006    3       1       2       187.700         0.07    0       1       1       0       0.2
2007    3       1       2       816.700         0.07    0       1       1       0       0.2
2008    3       1       2       734.400         0.07    0       1       1       0       0.2
2009    3       1       2       468.500         0.07    0       1       1       0       0.2
2010    3       1       2       609.200         0.07    0       1       1       0       0.2
2011    3       1       2       123.400         0.07    0       1       1       0       0.2
2012    3       1       2       59.800 0.07     0       1       1       0       0.2
2013    3       1       2       514.300         0.07    0       1       1       0       0.2
2014    3       1       2       362.200         0.07    0       1       1       0       0.2
2015    3       1       2       1081.60 0.07    0       1       1       0       0.2
2016    3       1       2       527.000         0.07    0       1       1       0       0.2
2017    3       1       2       266.546         0.07    0       1       1       0       0.2
2018    3       1       2       574.047         0.07    0       1       1       0       0.2
2019    3       1       2       216.739 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	84.127	0.10	2	1	1	0	0.8
2017	5	2	0	114.784	0.10	2	1	1	0	0.8
2018	5	2	0	97.891	0.10	2	1	1	0	0.8
2019	5	2	0	101.001	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       20      0.25
1976    5       3       1       0       0.07    2       1       1       20      0.25
1977    5       3       1       0       0.07    2       1       1       120.031         0.25
1978    5       3       1       0       0.07    2       1       1       88.489  0.25
1979    5       3       1       0       0.07    2       1       1       110.989         0.25
1980    5       3       1       0       0.07    2       1       1       267.154         0.25
1981    5       3       1       0       0.07    2       1       1       87.951  0.25
1982    5       3       1       0       0.07    2       1       1       102.987         0.25
1983    5       3       1       0       0.07    2       1       1       16.239  0.25
1984    5       3       1       0       0.07    2       1       1       52.598  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       32.75   0.25
1988    5       3       1       0       0.07    2       1       1       53.203  0.25
1989    5       3       1       0       0.07    2       1       1       108.519         0.25
1990    5       3       1       0       0.07    2       1       1       109.371         0.25
1991    5       3       1       1890.9  0.07    2       1       1       152.541         0.25
1992    5       3       1       269.526         0.07    2       1       1       154.976         0.25
1993    5       3       1       117.643         0.07    2       1       1       159.922         0.25
1994    5       3       1       0       0.07    2       1       1       1.042   0.25
#1995   5       3       1       0       0.07    2       1       1       0.0001  0.25
#1996   5       3       1       0       0.07    2       1       1       0.0001  0.25
#1997   5       3       1       0       0.07    2       1       1       0.0001  0.25
#1998   5       3       1       0       0.07    2       1       1       0.0001  0.25
#1999   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2000   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2001   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2002   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2003   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2004   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2005   5       3       1       0       0.07    2       1       1       0.0001  0.25
2006    5       3       1       0       0.07    2       1       1       0.4     0.25
2007    5       3       1       0       0.07    2       1       1       0.5     0.25
2008    5       3       1       0       0.07    2       1       1       0.5     0.25
2009    5       3       1       0       0.07    2       1       1       0.2     0.25
#2010   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2011   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2012   5       3       1       0       0.07    2       1       1       0.0001  0.25
2013    5       3       1       37.4687         0.07    2       1       1       2       0.25
2014    5       3       1       83.5014         0.07    2       1       1       2       0.25
2015    5       3       1       116.404         0.07    2       1       1       139.171         0.25
```

```
#2016   5       3       1       0       0.07    2       1       1       0.0001  0.25
#2017   5       3       1       0       0.07    2       1       1       0.0001  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       20      0.25
1976    5       3       2       0       0.07    2       1       1       20      0.25
1977    5       3       2       0       0.07    2       1       1       120.031         0.25
1978    5       3       2       0       0.07    2       1       1       88.489  0.25
1979    5       3       2       0       0.07    2       1       1       110.989         0.25
1980    5       3       2       0       0.07    2       1       1       267.154         0.25
1981    5       3       2       0       0.07    2       1       1       87.951  0.25
1982    5       3       2       0       0.07    2       1       1       102.987         0.25
1983    5       3       2       0       0.07    2       1       1       16.239  0.25
1984    5       3       2       0       0.07    2       1       1       52.598  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       32.75   0.25
1988    5       3       2       0       0.07    2       1       1       53.203  0.25
1989    5       3       2       0       0.07    2       1       1       108.519         0.25
1990    5       3       2       0       0.07    2       1       1       109.371         0.25
1991    5       3       2       3716.45         0.07    2       1       1       152.541         0.25
1992    5       3       2       708.223         0.07    2       1       1       154.976         0.25
1993    5       3       2       100.927         0.07    2       1       1       159.922         0.25
1994    5       3       2       0       0.07    2       1       1       1.042   0.25
#1995   5       3       2       0       0.07    2       1       1       0.0001  0.25
#1996   5       3       2       0       0.07    2       1       1       0.0001  0.25
#1997   5       3       2       0       0.07    2       1       1       0.0001  0.25
#1998   5       3       2       0       0.07    2       1       1       0.0001  0.25
#1999   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2000   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2001   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2002   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2003   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2004   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2005   5       3       2       0       0.07    2       1       1       0.0001  0.25
2006    5       3       2       0       0.07    2       1       1       0.4     0.25
2007    5       3       2       0       0.07    2       1       1       0.5     0.25
2008    5       3       2       0       0.07    2       1       1       0.5     0.25
2009    5       3       2       0       0.07    2       1       1       0.2     0.25
#2010   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2011   5       3       2       0       0.07    2       1       1       0.0001  0.25
#2012   5       3       2       0       0.07    2       1       1       0.0001  0.25
2013    5       3       2       76.3798         0.07    2       1       1       2       0.25
```

```
2014    5   3   2   84.5793     0.07    2   1   1   2   0.25
2015    5   3   2   220.311     0.07    2   1   1   139.171     0.25
#2016   5   3   2   0   0.07    2   1   1   0.0001  0.25
#2017   5   3   1   0   0.07    2   1   1   0.0001  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   57.896  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   295.916     0.10    2   1   1   0   0.5
2019    5   4   0    90.1090.10    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
102
#   Survey data (abundance  indices,units   are 1000    mt)
#Index Year    Season Fleet    Sex Abundance   CV  Units
```

1	1975	1	5	1	0	135463.3	0.193	1
1	1976	1	5	1	0	260149.5	0.207	1
1	1977	1	5	1	0	235411.4	0.144	1
1	1978	1	5	1	0	203192.7	0.152	1
1	1979	1	5	1	0	103715.0	0.164	1
1	1980	1	5	1	0	168047.2	0.221	1
1	1981	1	5	1	0	69161.2	0.190	1
1	1982	1	5	1	0	73232.9	0.251	1
1	1983	1	5	1	0	35368.0	0.214	1
1	1984	1	5	1	0	98281.5	0.606	1
1	1985	1	5	1	0	27203.7	0.159	1
1	1986	1	5	1	0	41113.6	0.420	1
1	1987	1	5	1	0	47410.5	0.209	1
1	1988	1	5	1	0	35852.6	0.228	1
1	1989	1	5	1	0	42967.7	0.232	1
1	1990	1	5	1	0	39271.6	0.242	1
1	1991	1	5	1	0	67458.4	0.443	1
1	1992	1	5	1	0	25442.5	0.176	1
1	1993	1	5	1	0	36217.5	0.198	1
1	1994	1	5	1	0	23285.5	0.174	1
1	1995	1	5	1	0	27670.5	0.266	1
1	1996	1	5	1	0	27277.5	0.203	1
1	1997	1	5	1	0	60719.6	0.264	1
1	1998	1	5	1	0	46693.7	0.182	1
1	1999	1	5	1	0	45126.5	0.204	1
1	2000	1	5	1	0	38787.8	0.216	1
1	2001	1	5	1	0	28367.5	0.187	1
1	2002	1	5	1	0	45597.0	0.202	1
1	2003	1	5	1	0	74997.9	0.283	1
1	2004	1	5	1	0	91090.1	0.321	1
1	2005	1	5	1	0	55471.4	0.171	1
1	2006	1	5	1	0	51948.6	0.169	1
1	2007	1	5	1	0	59064.2	0.174	1
1	2008	1	5	1	0	67945.7	0.249	1
1	2009	1	5	1	0	43692.8	0.326	1
1	2010	1	5	1	0	39555.6	0.223	1
1	2011	1	5	1	0	27529.9	0.213	1
1	2012	1	5	1	0	30830.4	0.237	1
1	2013	1	5	1	0	39833.2	0.244	1
1	2014	1	5	1	0	60859.1	0.191	1
1	2015	1	5	1	0	36919.3	0.208	1
1	2016	1	5	1	0	27302.6	0.194	1
1	2017	1	5	1	0	25344.0	0.173	1

1	2018	1	5	1	0	16064.2	0.161	1
1	2019	1	5	1	0	15127.4	0.157	1
1	1975	1	5	2	0	67267.3	0.193	1
1	1976	1	5	2	0	71718.0	0.207	1
1	1977	1	5	2	0	140249.6	0.144	1
1	1978	1	5	2	0	146351.8	0.152	1
1	1979	1	5	2	0	63911.7	0.164	1
1	1980	1	5	2	0	81275.0	0.221	1
1	1981	1	5	2	0	63507.9	0.190	1
1	1982	1	5	2	0	70506.7	0.251	1
1	1983	1	5	2	0	13951.7	0.214	1
1	1984	1	5	2	0	57030.0	0.606	1
1	1985	1	5	2	0	7330.8	0.159	1
1	1986	1	5	2	0	7044.8	0.420	1
1	1987	1	5	2	0	22852.7	0.209	1
1	1988	1	5	2	0	19519.6	0.228	1
1	1989	1	5	2	0	12973.6	0.232	1
1	1990	1	5	2	0	21049.2	0.242	1
1	1991	1	5	2	0	17596.5	0.443	1
1	1992	1	5	2	0	12244.8	0.176	1
1	1993	1	5	2	0	17485.5	0.198	1
1	1994	1	5	2	0	9049.4	0.174	1
1	1995	1	5	2	0	10725.7	0.266	1
1	1996	1	5	2	0	17371.1	0.203	1
1	1997	1	5	2	0	24557.1	0.264	1
1	1998	1	5	2	0	38482.0	0.182	1
1	1999	1	5	2	0	20477.3	0.204	1
1	2000	1	5	2	0	29314.2	0.216	1
1	2001	1	5	2	0	24820.6	0.187	1
1	2002	1	5	2	0	24188.9	0.202	1
1	2003	1	5	2	0	41796.1	0.283	1
1	2004	1	5	2	0	40819.8	0.321	1
1	2005	1	5	2	0	51869.8	0.171	1
1	2006	1	5	2	0	43727.8	0.169	1
1	2007	1	5	2	0	45777.1	0.174	1
1	2008	1	5	2	0	46484.5	0.249	1
1	2009	1	5	2	0	47980.0	0.326	1
1	2010	1	5	2	0	42086.5	0.223	1
1	2011	1	5	2	0	39523.3	0.213	1
1	2012	1	5	2	0	30417.8	0.237	1
1	2013	1	5	2	0	22576.6	0.244	1
1	2014	1	5	2	0	53243.9	0.191	1
1	2015	1	5	2	0	27320.8	0.208	1

```
1       2016    1       5       2       0       33928.4         0.194   1
1       2017    1       5       2       0       27577.5         0.173   1
1       2018    1       5       2       0       12868.2         0.161   1
1       2019    1       5       2       0       13616.4         0.157   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
13
## Number of rows in each matrix
42      28      28      43      43      6       6       24      24      45      45      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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     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       100     0       0       0       0       0
                0       0       0       0       0       0       0.0003  0       0.0146  0.0887  0.1801
                0.1707  0.1728  0.1431  0.2297
1991    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0.0001  0.0005  0.0141  0.0848  0.1651
```

```
            0.179  0.1739 0.1432 0.2392
1992  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0.0003 0.0002 0.0005 0.0095 0.0638 0.1317
            0.1673 0.1747 0.1636 0.2886
1993  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0      0      0.0014 0.0138 0.094  0.1789
            0.1739 0.1596 0.1331 0.2453
1996  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0      0.0006 0.0006 0.0129 0.0779 0.1407
            0.162  0.1771 0.1671 0.2612
1997  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0      0.0004 0.0003 0.0138 0.0899 0.1486
            0.1603 0.1699 0.1588 0.258
1998  3     1      1      1      0      0      100    0      0      0      0      0
            0      0.0001 0.0001 0.0001 0.0001 0.0004 0.0002 0.0008 0.0225 0.1187 0.1596
            0.149  0.1432 0.1394 0.266
1999  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0.0001 0      0.0001 0.0147 0.1313 0.2575
            0.2292 0.1624 0.0961 0.1087
2000  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0.0001 0.0001 0      0.0001 0.0003 0.0111 0.0931 0.1945
            0.2111 0.1822 0.1247 0.1826
2001  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0.0001 0.0001 0.0001 0.0002 0.0002 0.0012 0.0181 0.0836 0.1681
            0.1986 0.1953 0.1506 0.1838
2002  3     1      1      1      0      0      100    0      0      0      0      0
            0      0.0001 0      0.0001 0.0001 0.0001 0      0.0002 0.0151 0.108  0.1884
            0.1915 0.1683 0.1334 0.1948
2003  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0.0001 0.0001 0.0002 0.0009 0.0243 0.1464 0.232
            0.1871 0.1497 0.0994 0.1597
2004  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0      0      0.0002 0.0064 0.0514 0.1302
            0.1702 0.1971 0.1632 0.2812
2005  3     1      1      1      0      0      100    0      0      0      0      0
            0      0.0001 0      0      0      0.0001 0.0001 0.0008 0.015  0.0859 0.1543
            0.1661 0.1783 0.1516 0.2475
2006  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0.0001 0.0001 0.0004 0.0102 0.0739 0.1905
            0.2203 0.1887 0.137  0.1787
2007  3     1      1      1      0      0      100    0      0      0      0      0
            0      0      0      0      0      0      0.0002 0.0003 0.0067 0.0871 0.1833
            0.1934 0.1846 0.1472 0.1973
```

```
2008    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0.0001  0.0002  0.01    0.0746  0.1457
                0.1619  0.179   0.1625  0.2659
2009    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0       0.0002  0.0108  0.1152  0.2215
                0.1968  0.1588  0.1084  0.1882
2010    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0       0.0003  0.0091  0.0986  0.2244
                0.2238  0.1861  0.1144  0.1433
2011    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0.0003  0.0001  0.0003  0.0114  0.118   0.2436
                0.2292  0.1725  0.1077  0.1169
2012    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0.0001  0       0.0001  0       0       0.0044  0.0499  0.1249
                0.173   0.1886  0.1654  0.2937
2013    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0.0001  0.0001  0       0       0.0001  0.0001  0.0054  0.0525  0.1271
                0.1484  0.1657  0.1632  0.3374
2014    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0       0.0004  0.0117  0.0964  0.1831
                0.1696  0.1454  0.1246  0.2689
2015    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0.0001  0.0003  0.0067  0.0616  0.1473
                0.1864  0.1947  0.1634  0.2397
2016    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0       0.0002  0.0062  0.0489  0.127
                0.166   0.1822  0.1689  0.3006
2017    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0.0001  0.0001  0       0       0       0.0044  0.0453  0.1055
                0.1441  0.1781  0.1664  0.356
2018    3       1       1       1       0       0       100     0       0       0       0       0
                0       0       0       0       0       0       0       0.0001  0.0052  0.0593  0.1370
                0.1406  0.1386  0.1239  0.3951
2019    3       1       1       1       0       0       100 0   0       0       0       0       0
                0       0       0       0       0       0.0000  0.0004  0.0086  0.0678  0.1360  0.1338
                0.1276  0.1139  0.4119

#Total  males
#Year   Season Fleet Sex    Type    Shell   Maturity        Nsamp DataVec
1990    3       1       1       0       0       0       100     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
1991    3       1       1       0       0       0       100     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
1992   3      1      1      0      0      0      100    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
1993   3      1      1      0      0      0      100    0.0008 0.0024 0.0031 0.003  0.004
              0.0073 0.0176 0.0325 0.0455 0.062  0.0745 0.0854 0.0832 0.0991 0.0909 0.0898
              0.0749 0.0725 0.0567 0.0946
1996   3      1      1      0      0      0      100    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
1997   3      1      1      0      0      0      100    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
1998   3      1      1      0      0      0      100    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 0.1122 0.0476 0.0117
              0.0386 0.0565 0.0525 0.2052
1999   3      1      1      0      0      0      100    0      0      0      0.0013 0.0013
              0.0006 0.0017 0.0013 0.0025 0.006  0.0138 0.0264 0.0537 0.0923 0.1302 0.1444
              0.1518 0.1301 0.091  0.1515
2000   3      1      1      0      0      0      100    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 0.1001 0.1083
              0.1114 0.0943 0.0638 0.0988
2001   3      1      1      0      0      0      100    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
2002   3      1      1      0      0      0      100    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
2003   3      1      1      0      0      0      100    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
2004   3      1      1      0      0      0      100    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
2005   3      1      1      0      0      0      100    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
2006   3      1      1      0      0      0      100    0.0001 0.0006 0.0019 0.0065 0.014
              0.0171 0.0166 0.0154 0.02   0.0334 0.0412 0.0506 0.0611 0.0815 0.098  0.1153
              0.1191 0.113  0.0806 0.1138
2007   3      1      1      0      0      0      100    0.0006 0.0021 0.0034 0.0051 0.0089
              0.0191 0.0341 0.044  0.0477 0.044  0.0423 0.0513 0.0676 0.0899 0.0952 0.0974
```

```
                0.0929 0.0907 0.0691 0.0946
2008    3       1      1      0      0      0      100    0.0001 0.0002 0.0007 0.0025 0.0059
                0.0078 0.0088 0.0118 0.0242 0.0444 0.0697 0.0985 0.1095 0.1038 0.0868 0.0768
                0.0766 0.0772 0.0703 0.1244
2009    3       1      1      0      0      0      100    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 0.1354 0.1172
                0.0895 0.0659 0.0499 0.0931
2010    3       1      1      0      0      0      100    0.0004 0.0006 0.0013 0.0028 0.0044
                0.0061 0.0077 0.0113 0.0179 0.0286 0.0504 0.0807 0.107  0.1302 0.1264 0.121
                0.1031 0.0821 0.0512 0.067
2011    3       1      1      0      0      0      100    0.0008 0.0031 0.0055 0.0096 0.0099
                0.0089 0.0128 0.0147 0.0192 0.0264 0.0358 0.0564 0.0822 0.1114 0.1321 0.1357
                0.1212 0.0926 0.0583 0.0633
2012    3       1      1      0      0      0      100    0.0002 0.0003 0.0008 0.0014 0.0037
                0.0088 0.014  0.0188 0.0178 0.0192 0.0236 0.0359 0.0519 0.0746 0.0861 0.099
                0.112  0.1276 0.1127 0.1915
2013    3       1      1      0      0      0      100    0.0001 0.0007 0.0017 0.0022 0.0047
                0.0059 0.0097 0.0152 0.0261 0.0381 0.0546 0.0609 0.0673 0.0742 0.0761 0.0826
                0.0842 0.1033 0.0981 0.1944
2014    3       1      1      0      0      0      100    0.0003 0.0006 0.0008 0.0012 0.0017
                0.0038 0.0063 0.0111 0.0155 0.0206 0.0345 0.0474 0.0701 0.0902 0.1051 0.108
                0.1051 0.0972 0.0846 0.196
2015    3       1      1      0      0      0      100    0.0001 0.0002 0.0008 0.0017 0.0038
                0.0059 0.0063 0.007  0.012  0.0272 0.0337 0.0492 0.0541 0.0675 0.0799 0.107
                0.117  0.137  0.1056 0.1841
2016    3       1      1      0      0      0      100    0.0001 0.0002 0.0015 0.0034 0.0046
                0.0064 0.0111 0.0188 0.0225 0.028  0.0295 0.04   0.0509 0.0675 0.0814 0.0938
                0.1068 0.1214 0.1118 0.2005
2017    3       1      1      0      0      0      100    0.0003 0.0006 0.0034 0.012  0.0258
                0.0362 0.0313 0.0248 0.0207 0.0259 0.0306 0.047  0.0505 0.0641 0.0671 0.0809
                0.097  0.1032 0.0949 0.1839
2018    3       1      1      0      0      0      100    0.0004 0.0017 0.0065 0.0074 0.0060
                0.0100 0.0217 0.0402 0.0630 0.0704 0.0659 0.0551 0.0560 0.0565 0.0621 0.0649
                0.0632 0.0669 0.0698 0.2124
2019    3       1      1      0      0      0      100 0.0000      0.0001 0.0002 0.0021 0.0094
                0.0186 0.0241 0.0214 0.0212 0.0383 0.0591 0.0896 0.0975 0.0981 0.0889 0.0736
                0.0608 0.0588 0.0503 0.1879

#Total  females
#Year   Season Fleet Sex    Type   Shell  Maturity      Nsamp DataVec
1990    3       1      2      0      0      0      50     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
1991    3       1      2      0      0      0      37.5   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
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
1993	3	1	2	0	0	0	50	0.0013	0.0023	0.0047	0.006	0.0137
		0.033	0.1017	0.1606	0.1446	0.1136	0.09	0.0849	0.0829	0.0735	0.043	0.0442
1996	3	1	2	0	0	0	1.1	0	0	0	0.0909	0.6364
		0.2727	0	0	0	0	0	0	0	0	0	0
1997	3	1	2	0	0	0	50	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
1998	3	1	2	0	0	0	50	0.0002	0.0004	0.0009	0.0024	0.0062
		0.0165	0.0519	0.168	0.2191	0.1527	0.0862	0.0853	0.0578	0.0533	0.0362	0.0628
1999	3	1	2	0	0	0	3.6	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
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
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
2002	3	1	2	0	0	0	30.2	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
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
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
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
2006	3	1	2	0	0	0	50	0.0003	0.004	0.0256	0.1183	0.1939
		0.1616	0.0692	0.0519	0.0672	0.0704	0.0576	0.0403	0.0358	0.0323	0.0256	0.0461
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
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
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
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
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
2012	3	1	2	0	0	0	50	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
2013	3	1	2	0	0	0	50	0.0005	0.0017	0.0083	0.0109	0.0187
		0.037	0.0716	0.1327	0.1428	0.0967	0.0716	0.0637	0.0851	0.0904	0.0731	0.0952
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

```
2015  3      1      2      0      0      0      50     0      0.0011 0.0018 0.0051 0.012
             0.0164 0.0197 0.0354 0.0556 0.0869 0.0889 0.1404 0.1126 0.1031 0.0833 0.2377
2016  3      1      2      0      0      0      50     0      0.0003 0.0073 0.0122 0.0187
             0.0181 0.0213 0.0312 0.0377 0.0617 0.0994 0.1535 0.1739 0.1341 0.0712 0.1594
2017  3      1      2      0      0      0      50     0.0005 0.003  0.0137 0.0526 0.0983
             0.1093 0.0806 0.0333 0.0371 0.0497 0.0747 0.0959 0.0991 0.0937 0.0655 0.0929
2018  3      1      2      0      0      0      50     0.0003 0.0046 0.0171 0.0233 0.0221
             0.0338 0.0542 0.0839 0.0766 0.0658 0.0674 0.1078 0.1178 0.1126 0.0839 0.1288
2019  3      1      2      0      0      0      50  0.0000    0.0000 0.0018 0.0053 0.0263
             0.0458 0.0362 0.0337 0.0564 0.0777 0.0702 0.0770 0.1057 0.1302 0.1153 0.2185

#Trawl bycatch      male
#Year Season Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
1976  5      2      1      0.0    0      0      50     0.0000 0.0000 0.0000 0.0000 0.0000
             0.0130 0.0087 0.0043 0.0216 0.0087 0.0260 0.0390 0.0433 0.0649 0.0996 0.0866
             0.0736 0.0909 0.0649 0.1299
1977  5      2      1      0.0    0      0      50     0.0036 0.0009 0.0009 0.0009 0.0026
             0.0035 0.0079 0.0097 0.0317 0.0485 0.0599 0.0996 0.1084 0.1251 0.1040 0.1057
             0.1004 0.0634 0.0326 0.0441
1978  5      2      1      0.0    0      0      50     0.0000 0.0000 0.0000 0.0000 0.0000
             0.0000 0.0000 0.0025 0.0012 0.0025 0.0149 0.0274 0.0511 0.0872 0.1245 0.1158
             0.0797 0.0984 0.0672 0.1880
1979  5      2      1      0.0    0      0      50     0.0178 0.0013 0.0025 0.0013 0.0025
             0.0076 0.0038 0.0025 0.0013 0.0063 0.0051 0.0114 0.0228 0.0556 0.0582 0.0708
             0.0898 0.0860 0.0809 0.1858
1980  5      2      1      0.0    0      0      50     0.0531 0.0207 0.0096 0.0135 0.0142
             0.0163 0.0274 0.0263 0.0380 0.0375 0.0422 0.0394 0.0368 0.0377 0.0313 0.0231
             0.0207 0.0142 0.0131 0.0265
1981  5      2      1      0.0    0      0      50     0.0262 0.0028 0.0045 0.0066 0.0112
             0.0175 0.0279 0.0349 0.0386 0.0504 0.0434 0.0480 0.0287 0.0334 0.0241 0.0212
             0.0112 0.0064 0.0051 0.0087
1982  5      2      1      0.0    0      0      50     0.0701 0.0268 0.0247 0.0326 0.0356
             0.0443 0.0409 0.0403 0.0401 0.0475 0.0426 0.0479 0.0405 0.0326 0.0218 0.0153
             0.0084 0.0052 0.0038 0.0099
1983  5      2      1      0.0    0      0      50     0.0231 0.0214 0.0336 0.0344 0.0311
             0.0319 0.0377 0.0445 0.0473 0.0471 0.0457 0.0437 0.0409 0.0414 0.0371 0.0283
             0.0204 0.0129 0.0096 0.0180
1984  5      2      1      0.0    0      0      50     0.0366 0.0156 0.0147 0.0199 0.0270
             0.0342 0.0399 0.0407 0.0431 0.0476 0.0511 0.0596 0.0594 0.0563 0.0473 0.0355
             0.0264 0.0170 0.0109 0.0146
1985  5      2      1      0.0    0      0      50     0.0051 0.0014 0.0034 0.0059 0.0100
             0.0164 0.0256 0.0396 0.0357 0.0446 0.0538 0.0636 0.0843 0.0862 0.0883 0.0843
             0.0638 0.0455 0.0299 0.0578
```

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1986  5   2      1      0.0    0      0      50     0.0038 0.0019 0.0085 0.0019 0.0056
          0.0136 0.0193 0.0357 0.0160 0.0249 0.0221 0.0320 0.0710 0.0555 0.0527 0.0635
          0.0456 0.0362 0.0259 0.0282
1987  5   2      1      0.0    0      0      49.9   0.0020 0.0000 0.0010 0.0020 0.0050
          0.0080 0.0190 0.0271 0.0170 0.0220 0.0441 0.0491 0.0401 0.0581 0.0852 0.0812
          0.0671 0.0611 0.0511 0.0842
1988  5   2      1      0.0    0      0      31.55  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
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
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            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
```

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               0.0513 0.0342 0.0391 0.1002
2016    5      2      1      0.0    0      0      30.85  0.0000 0.0016 0.0032 0.0049 0.0032
               0.0016 0.0130 0.0097 0.0162 0.0065 0.0113 0.0357 0.0243 0.0470 0.0519 0.0583
               0.0632 0.0794 0.0778 0.2107
2017    5      2      1      0.0    0      0      35.9   0.0000 0.0000 0.0000 0.0000 0.0056
               0.0042 0.0056 0.0056 0.0070 0.0056 0.0084 0.0153 0.0265 0.0320 0.0418 0.0529
               0.0891 0.0766 0.1017 0.3231
2018    5      2      1      0.0    0      0      44.65  0.0011 0.0000 0.0022 0.0000 0.0022
               0.0045 0.0112 0.0045 0.0213 0.0202 0.0403 0.0426 0.0437 0.0594 0.0448 0.0336
               0.0448 0.0403 0.0403 0.1601
2019    5      2      1      0.0    0      0      38.0   0.0013 0.0013 0.0053 0.0079 0.0092
               0.0118 0.0053 0.0092 0.0092 0.0276 0.0303 0.0316 0.0434 0.0553 0.0566 0.0434
               0.0539 0.0421 0.0395 0.2132

#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
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                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
```

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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 0.0097 0.0097 0.0097 0.0227 0.0373 0.0324 0.0340 0.0243 0.0130 0.0665
2017  5  2  2  0  0  0  0  0.0000  0.0000 0.0028 0.0028 0.0181
         0.0056 0.0070 0.0028 0.0056 0.0070 0.0097 0.0153 0.0153 0.0125 0.0125 0.0822
2018  5  2  2  0  0  0  0  0.0000  0.0045 0.0067 0.0112 0.0078
         0.0112 0.0157 0.0347 0.0168 0.0202 0.0246 0.0291 0.0314 0.0325 0.0370 0.0997
2019  5  2  2  0  0  0  0  0.0026  0.0026 0.0105 0.0039 0.0092
         0.0211 0.0079 0.0105 0.0105 0.0171 0.0158 0.0171 0.0184 0.0197 0.0237 0.1118

#Tanner crab bycatch Male (male and female combined compositons are normalized to be 1)
#Year Season Fleet Sex Type Shell Maturity Nsamp DataVec

1991  5  3  1  0.000  0  0  50     0.0026 0.0049 0.0029 0.0042 0.0052
         0.0042 0.0104 0.0143 0.0146 0.0110 0.0159 0.0169 0.0181 0.0269 0.0292 0.0230
         0.0211 0.0201 0.0169 0.0249
1992  5  3  1  0.000  0  0  48.25  0.0000 0.0000 0.0010 0.0031 0.0114
         0.0166 0.0259 0.0238 0.0259 0.0301 0.0270 0.0270 0.0187 0.0124 0.0145 0.0052
         0.0104 0.0135 0.0073 0.0166
1993  5  3  1  0.000  0  0  24.85  0.0000 0.0000 0.0000 0.0000 0.0040
         0.0020 0.0261 0.0483 0.0584 0.0664 0.0463 0.0282 0.0261 0.0362 0.0261 0.0221
         0.0302 0.0141 0.0101 0.0221
2013  5  3  1  0.000  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
2014  5  3  1  0.000  0  0  31.85  0.0000 0.0000 0.0016 0.0000 0.0078
         0.0078 0.0126 0.0188 0.0157 0.0314 0.0220 0.0267 0.0314 0.0408 0.0408 0.0251
         0.0345 0.0251 0.0173 0.0424
2015  5  3  1  0.000  0  0  50     0.0017 0.0038 0.0017 0.0024 0.0180
         0.0246 0.0176 0.0114 0.0152 0.0201 0.0215 0.0118 0.0086 0.0066 0.0121 0.0104
         0.0135 0.0142 0.0149 0.0211
#Tanner crab bycatch female


#Year Season Fleet Sex Type Shell Maturity Nsamp DataVec
```

```
1991   5      3      2      0      0      0      0      0.0052 0.0107 0.0097 0.0103 0.0243
              0.0331 0.0567 0.0463 0.0839 0.1160 0.1134 0.0956 0.0548 0.0269 0.0188 0.0071

1992   5      3      2      0      0      0      0      0.0000 0.0000 0.0011 0.0062 0.0228
              0.0456 0.0818 0.0933 0.0870 0.0539 0.0777 0.0995 0.0653 0.0404 0.0228 0.0124

1993   5      3      2      0      0      0      0      0.0000 0.0000 0.0000 0.0000 0.0040
              0.0342 0.0825 0.1127 0.0805 0.0362 0.0403 0.0403 0.0564 0.0262 0.0121 0.0081

2013   5      3      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 0.0368 0.0651 0.0234 0.0307

2014   5      3      2      0      0      0      0      0.0000 0.0000 0.0016 0.0031 0.0110
              0.0220 0.0471 0.0550 0.1428 0.1586 0.0581 0.0267 0.0220 0.0110 0.0173 0.0220

2015   5      3      2      0      0      0      0      0.0004 0.0013 0.0028 0.0052 0.0239
              0.0346 0.0637 0.1032 0.1440 0.1115 0.0921 0.0689 0.0374 0.0201 0.0170 0.0228

# 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
              0.0171 0.0235 0.0107 0.0075 0.0117 0.0128 0.0299 0.0309 0.0421 0.0597 0.0645
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                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 0.0430
2017    5       4      1      0      0      0      50     0.0000 0.0014 0.0000 0.0071 0.0141
                0.0148 0.0163 0.0120 0.0071 0.0163 0.0085 0.0120 0.0078 0.0141 0.0113 0.0092
                0.0148 0.0141 0.0205 0.0961
```

```
2018   5      4      1      0      0      0      50     0.0009 0.0021 0.0040 0.0081 0.0045
              0.0126 0.0241 0.0396 0.0406 0.0475 0.0390 0.0258 0.0204 0.0206 0.0207 0.0181
              0.0153 0.0141 0.0164 0.0507
2019   5      4      1      0      0      0      43.1 0.0000   0.0023 0.0046 0.0104 0.0186
              0.0197 0.0255 0.0209 0.0209 0.0197 0.0070 0.0139 0.0139 0.0139 0.0058 0.0035
              0.0058 0.0012 0.0000 0.0046

# Fixed gear  crab   bycatch       female
#Year  Season Fleet  Sex    Type   Shell  Maturity      Nsamp DataVec
# ERROR CHECK
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
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
```

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                0.0104 0.0215 0.0262 0.0339 0.0346 0.0339 0.0571 0.0668 0.0648 0.0658 0.1236
2013    5       4      2      0      0      0      0      0.0056 0.0108 0.0224 0.0266 0.0243
                0.0245 0.0249 0.0316 0.0354 0.0272 0.0251 0.0241 0.0296 0.0412 0.0334 0.0853
2014    5       4      2      0      0      0      0      0.0023 0.0061 0.0049 0.0014 0.0042
                0.0056 0.0084 0.0229 0.0422 0.0537 0.0497 0.0502 0.0511 0.0560 0.0597 0.1624
2015    5       4      2      0      0      0      0      0.0002 0.0002 0.0002 0.0045 0.0072
                0.0132 0.0228 0.0512 0.0745 0.0879 0.1082 0.1064 0.0767 0.0557 0.0586 0.1216
2016    5       4      2      0      0      0      0      0.0037 0.0028 0.0044 0.0162 0.0245
                0.0208 0.0231 0.0370 0.0499 0.0695 0.0931 0.0845 0.0640 0.0464 0.0342 0.0815
2017    5       4      2      0      0      0      0      0.0007 0.0007 0.0021 0.0127 0.0155
                0.0261 0.0184 0.0184 0.0240 0.0382 0.0615 0.0912 0.0876 0.1110 0.0671 0.1272
2018    5       4      2      0      0      0      0      0.0006 0.0040 0.0026 0.0049 0.0066
                0.0164 0.0349 0.0621 0.0592 0.0605 0.0573 0.0711 0.0654 0.0507 0.0366 0.0417
2019    5       4      2      0      0      0      0      0.0000 0.0000 0.0012 0.0104 0.0174
                0.0313 0.0290 0.0406 0.0789 0.0824 0.0789 0.0719 0.0638 0.0708 0.0650 0.1462

#NMFS           males  combined
#Year   Season  Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
1975    1       5      1      0.000  0      0      200    0.0222 0.0411 0.0299 0.0379 0.0342
                0.0299 0.0309 0.0246 0.0264 0.0314 0.0268 0.0292 0.0284 0.0273 0.0244 0.0270
                0.0183 0.0134 0.0097 0.0113
1976    1       5      1      0.000  0      0      200    0.0025 0.0127 0.0268 0.0503 0.0623
                0.0522 0.0559 0.0449 0.0392 0.0329 0.0409 0.0438 0.0369 0.0392 0.0335 0.0221
                0.0236 0.0154 0.0070 0.0077
1977    1       5      1      0.000  0      0      200    0.0040 0.0043 0.0065 0.0102 0.0199
                0.0376 0.0453 0.0441 0.0414 0.0450 0.0409 0.0409 0.0311 0.0324 0.0322 0.0259
                0.0166 0.0140 0.0084 0.0121
1978    1       5      1      0.000  0      0      200    0.0043 0.0120 0.0136 0.0240 0.0172
                0.0191 0.0178 0.0279 0.0296 0.0297 0.0300 0.0304 0.0291 0.0367 0.0346 0.0283
                0.0260 0.0173 0.0108 0.0091
1979    1       5      1      0.000  0      0      200    0.0206 0.0154 0.0103 0.0123 0.0144
                0.0163 0.0137 0.0155 0.0164 0.0157 0.0235 0.0338 0.0333 0.0432 0.0415 0.0378
                0.0359 0.0298 0.0136 0.0235
1980    1       5      1      0.000  0      0      200    0.0067 0.0133 0.0376 0.0287 0.0295
                0.0296 0.0265 0.0262 0.0224 0.0192 0.0208 0.0165 0.0231 0.0251 0.0264 0.0378
                0.0266 0.0268 0.0216 0.0357
1981    1       5      1      0.000  0      0      200    0.0160 0.0113 0.0182 0.0240 0.0366
                0.0362 0.0331 0.0367 0.0291 0.0356 0.0261 0.0285 0.0194 0.0221 0.0156 0.0145
                0.0112 0.0106 0.0085 0.0176
1982    1       5      1      0.000  0      0      200    0.0792 0.0811 0.0682 0.0287 0.0240
                0.0310 0.0353 0.0287 0.0197 0.0171 0.0198 0.0141 0.0131 0.0079 0.0066 0.0043
                0.0039 0.0005 0.0004 0.0018
1983    1       5      1      0.000  0      0      200    0.0325 0.0356 0.0497 0.0665 0.0801
```

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              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
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
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            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
            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
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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

#NMFS          female
#Year  Season  Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
1975   1       5      2      0.000  0      0      0      0.0331 0.0401 0.0481 0.0494 0.0564
               0.0439 0.0444 0.0454 0.0326 0.0289 0.0162 0.0158 0.0116 0.0035 0.0029 0.0034
1976   1       5      2      0.000  0      0      0      0.0029 0.0092 0.0313 0.0563 0.0688
               0.0628 0.0494 0.0269 0.0121 0.0137 0.0066 0.0049 0.0023 0.0015 0.0003 0.0011
1977   1       5      2      0.000  0      0      0      0.0026 0.0068 0.0079 0.0193 0.0337
               0.0701 0.0808 0.0715 0.0453 0.0435 0.0415 0.0316 0.0151 0.0100 0.0033 0.0046
1978   1       5      2      0.000  0      0      0      0.0060 0.0111 0.0187 0.0201 0.0233
               0.0418 0.0920 0.1212 0.0791 0.0440 0.0301 0.0267 0.0176 0.0089 0.0045 0.0075
1979   1       5      2      0.000  0      0      0      0.0286 0.0154 0.0121 0.0147 0.0148
               0.0230 0.0381 0.0734 0.0922 0.0876 0.0565 0.0336 0.0215 0.0123 0.0043 0.0057
1980   1       5      2      0.000  0      0      0      0.0048 0.0219 0.0322 0.0292 0.0597
               0.0820 0.0487 0.0581 0.0540 0.0424 0.0315 0.0130 0.0110 0.0059 0.0035 0.0020
1981   1       5      2      0.000  0      0      0      0.0152 0.0113 0.0151 0.0190 0.0366
               0.0456 0.0443 0.0472 0.0600 0.0774 0.0804 0.0510 0.0252 0.0143 0.0028 0.0042
1982   1       5      2      0.000  0      0      0      0.0536 0.0954 0.0603 0.0378 0.0423
               0.0482 0.0398 0.0232 0.0190 0.0257 0.0281 0.0203 0.0114 0.0063 0.0024 0.0009
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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

#BSFRF          males
#Year   Season  Fleet  Sex    Type   Shell  Maturity      Nsamp  DataVec
2007    1       6      1      0      0      0      200    0.0045 0.0074 0.0103 0.0155 0.0198
                0.0321 0.0532 0.0491 0.0443 0.0354 0.0268 0.0231 0.0236 0.0256 0.0223 0.032
                0.0246 0.0218 0.017  0.0278
2008    1       6      1      0      0      0      200    0.0017 0.001  0.0093 0.0119 0.0175
                0.0279 0.0267 0.0348 0.0428 0.0596 0.0581 0.0455 0.0371 0.0284 0.0218 0.0211
                0.0156 0.0157 0.0202 0.0294
2013    1       6      1      0      0      0      75.75  0      0.0073 0.0145 0.0291 0.0102
                0.0136 0.0205 0.0341 0.0357 0.0458 0.0448 0.0383 0.042  0.0348 0.0206 0.0149
                0.0337 0.0426 0.0358 0.0986
```

```
2014    1       6       1       0       0       0       105.75  0       0       0.003   0.0101  0.0118
                0.0448  0.0546  0.0423  0.047   0.0164  0.0221  0.0321  0.0226  0.0369  0.022   0.0282
                0.0257  0.026   0.0116  0.039
2015    1       6       1       0       0       0       98.75   0.0208  0.0463  0.037   0.0162  0.0069
                0.0162  0.0119  0.0174  0.0355  0.0206  0.0274  0.0357  0.0228  0.0262  0.0131  0.0428
                0.0215  0.0327  0.0396  0.0627
2016    1       6       1       0       0       0       73.5    0.0138  0.0039  0.02    0.0193  0.0104
                0.0122  0.0064  0.0126  0.0062  0.0034  0.0068  0.0134  0.0204  0.01    0.011   0.0254
                0.023   0.0215  0.0249  0.0774

#BSFRF  females
#Year   Season  Fleet   Sex     Type    Shell   Maturity        Nsamp   DataVec
2007    1       6       2       0       0       0       000     0.0007  0.0016  0.0044  0.0198  0.0302
                0.0705  0.0563  0.0345  0.0364  0.0493  0.0501  0.0448  0.0272  0.0183  0.0152  0.0243
2008    1       6       2       0       0       0       000     0.0004  0.0013  0.0088  0.0142  0.0286
                0.0483  0.0754  0.0687  0.0463  0.0386  0.0411  0.0357  0.021   0.0179  0.0126  0.015
2013    1       6       2       0       0       0       000     0.0035  0       0.0191  0.0258  0.0176
                0.0105  0.0094  0.0407  0.024   0.0291  0.0308  0.0216  0.0232  0.0403  0.0392  0.0483
2014    1       6       2       0       0       0       000     0       0.0037  0.0071  0.0037  0.014
                0.031   0.0238  0.0415  0.0457  0.0708  0.0481  0.0279  0.0385  0.0448  0.0324  0.0707
2015    1       6       2       0       0       0       000     0.0116  0.0324  0.0231  0.0069  0.0153
                0.0112  0.0042  0.0231  0.0361  0.0358  0.0427  0.0364  0.0528  0.0366  0.0208  0.0575
2016    1       6       2       0       0       0       000     0.0039  0.0178  0.0039  0.0263  0.003
                0.0124  0.0096  0.0168  0.0422  0.0514  0.0826  0.1077  0.072   0.078   0.0429  0.1016
##      Growthdata
# Type of growth increment (1=growth increment with a CV;2=size-at-release; size-at)
0
#       nobs_growth
0
##      Note    SM      used    loewss  regression      for     males   BBRKC           data
##      and     cubic   spine   to      interpolate     3       sets    of      female  BBRK    data
# MidPoint Sex  Increment       CV
#67.5   2       14.766667       10000000000000000000
# MidPoint Sex  MidPoint   Time-at-liberty Size-trans matrix Number of points
# Release       Recapture
##      eof
9999
```

Appendix C. Control File for Models 19.3, 19.3c, 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
#1.38403  0.5      3.7        7         0          0          999                  # Males (beta)
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
#1.38403   0.5      3.0        7        0          0          999                  # Females (beta)
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)
#1.38403    0.5   3.7      -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)
#1.38403    0.5   3.7      -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
 # 9      2       2       2       2       2       # male selectivity type
  2       2       2       2       2       2       # male selectivity type
  2       2       2       2       2       2       # female selectivity type
  0       0       0       0       6       0  #6    # within another gear
 # 5      0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
  0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
  0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, females
## Gear-1   Gear-2   Gear-3   Gear-4   Gear-5   Gear-6
  2       1       1       1       1       1       # retention periods
  1       0       0       0       0       0       # sex specific retention
  2       6       6       6       6       6       # male   retention type
  6       6       6       6       6       6       # female retention type
  1       0       0       0       0       0       # male   retention flag (0 = no, 1 = yes)
  0       0       0       0       0       0       # female retention flag (0 = no, 1 = yes)
  0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, males
  0       0       0       0       0       0       #-NEW: extra parameters for each pattern by fleet, females

## ————————————————————————————————————————————————————————————— ##
## gear  par   sel                                        start  end        ##
## index index par sex  ival  lb    ub    prior   p1   p2     phz   period period     ##
## ————————————————————————————————————————————————————————————— ##
  # Gear-1
  1     1   1   1    125.0000    5   190    0      1    999    4     1975   2019  #4
  1     2   2   1      8.0      0.1   20    0      1    999    4     1975   2019  #4
 # Gear-1
#  1     1   1   1     67.5      0   200    0      1    999   -999    1975   2018  #4        #parameters for cubic spine
```

```
# 1     2   2   1     87.5      0   200    0      1    999   -999     1975   2018  #4
# 1     3   3   1     97.5      0   200    0      1    999   -999     1975   2018  #4
# 1     4   4   1    112.5      0   200    0      1    999   -999     1975   2018  #4
# 1     5   5   1    162.5      0   200    0      1    999   -999     1975   2018  #4
# 1     6   6   1    0.001      0.00001  0.99999   0      1    999    4     1975   2018  #4
# 1     6   7   1    0.1        0.00001  0.99999   0      1    999    4     1975   2018  #4
# 1     6   8   1    0.3        0.00001  0.99999   0      1    999    4    1975   2018  #4
# 1     6   9   1    0.7        0.00001  0.99999   0      1    999    4     1975   2018  #4
# 1     6  10   1    0.99999    0.00001  1.01      0      1    999   -4     1975   2018  #4
  1     3   1  2    84.00     5    150    0      1    999    4     1975   2019
  1     4   2  2     4.0000    0.1   20    0      1    999    4     1975   2019
# Gear-2
   2     5   1   0   165.0       5    190    0      1    999    4     1975   2019
   2     6   2   0    15.0000    0.1   25    0      1    999    4     1975   2019
# Gear-3-9
   3     7   1   1   115.0       5    190    0      1    999    4     1975   2019
   3     8   2   1    15.0      0.1   25    0      1    999    4     1975   2019
   3     9   1   2    95.0       5    190    0      1    999    4     1975   2019  # dummy
   3    10   2   2     2.5      0.1   25    0      1    999    4     1975   2019
# Gear-4
   4    11   1   0   115.0       5    190    0      1    999    4     1975   2019  # dummy
   4    12   2   0    9.0       0.1   25    0      1    999    4     1975   2019
# 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   2020  #5
   5    16   2   1    10.0      1     50    0      1    999    5     1982   2020  #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   2020  #5
   5    20   2   2     4.00     1.0   50    0      1    999    5     1982   2020  #5
# Gear-6
   6    21   1   1    75.0       1   180    0      1    999    5     1975   2020  # 5
   6    22   2   1     8.5       1    50    0      1    999    5     1975   2020  # 5
   6    23   1   2    85.0       1   180    0      1    999    5     1975   2020  # 5
   6    24   2   2    10.0       1    50    0      1    999    5     1975   2020  # 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   2019
  -1    28    2   1    2.5    1     20    0      1    999    4     2005   2019
  -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   2019
# Gear-2
  -2    31    1   0    595    1    999    0      1    999   -3     1975   2019
# Gear-3
```

```
 -3    32    1   0    595    1    999    0      1    999   -3     1975   2019    #Dummy
# Gear-4
 -4    33    1   0    595    1    999    0      1    999   -3     1975   2019
# Gear-5
 -5    34    1   0    590    1    999    0      1    999   -3     1975   2020
# Gear-6
 -6    35    1   0    580    1    999    0      1    999   -3     1975   2020
## ——————————————————————————————————————————————————————————————— ##

# Number of asyptotic parameters
1
# Fleet   Sex     Year       ival  lb   ub    phz
      1     1     1975   0.000001   0    1     -3
#     1     1     2006   0.044000   0    1     -3
#     1     1     2007   0.019700   0    1     -3
#     1     1     2008   0.019875   0    1     -3
#     1     1     2009   0.032750   0    1     -3
#     1     1     2010   0.015320   0    1     -3
#     1     1     2011   0.011250   0    1     -3
#     1     1     2012   0.024045   0    1     -3
#     1     1     2013   0.063200   0    1     -3
#     1     1     2014   0.160500   0    1     -3
#     1     1     2015   0.070950   0    1     -3
#     1     1     2016   0.082600   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
2019       # 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           #(10000)
## EOF
9999
```

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)

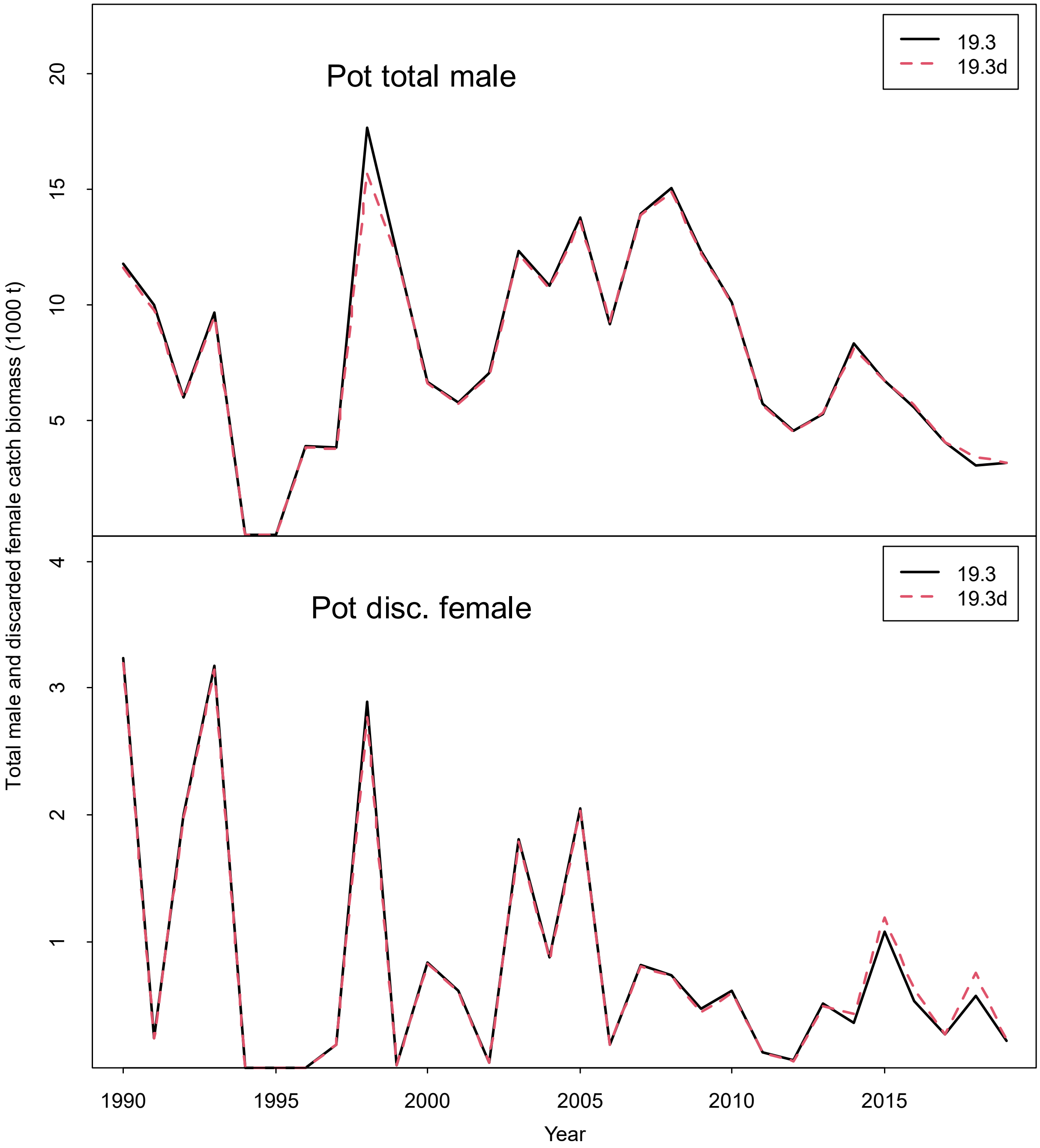


Figure D1. Comparison of observer total male and discarded female biomass in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer total male and discarded female biomass used in models 19.3c-19.6 in 2021.

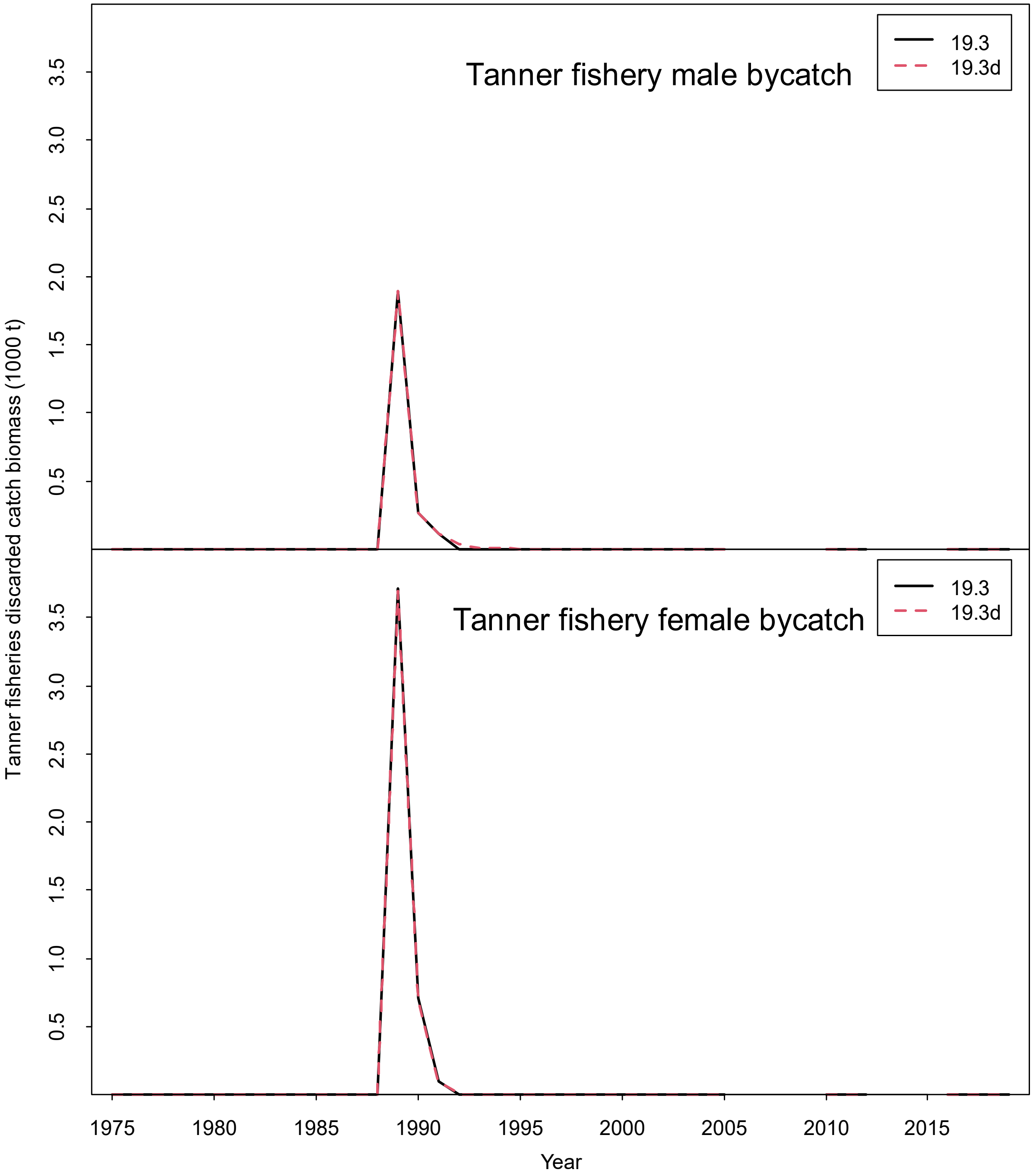


Figure D2. Comparison of observer discarded red king crab biomass in the Tanner crab fishery used in model 19.3 in 2020 and updated/standardized observer discarded red king crab biomass used in models 19.3c-19.6 in 2021.

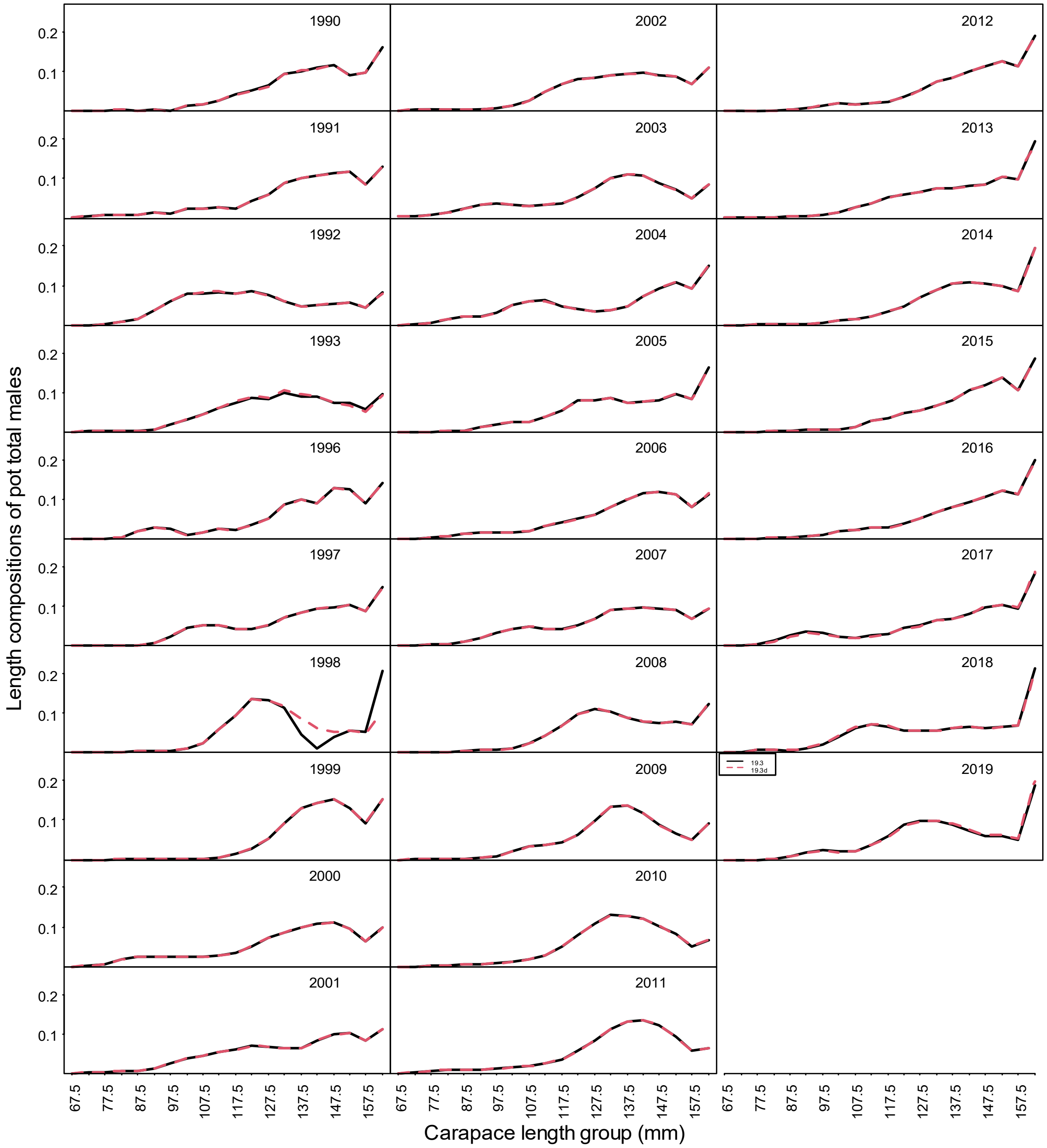


Figure D3. Comparison of observer length compositions of total males in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021. There are some differences in 1998.

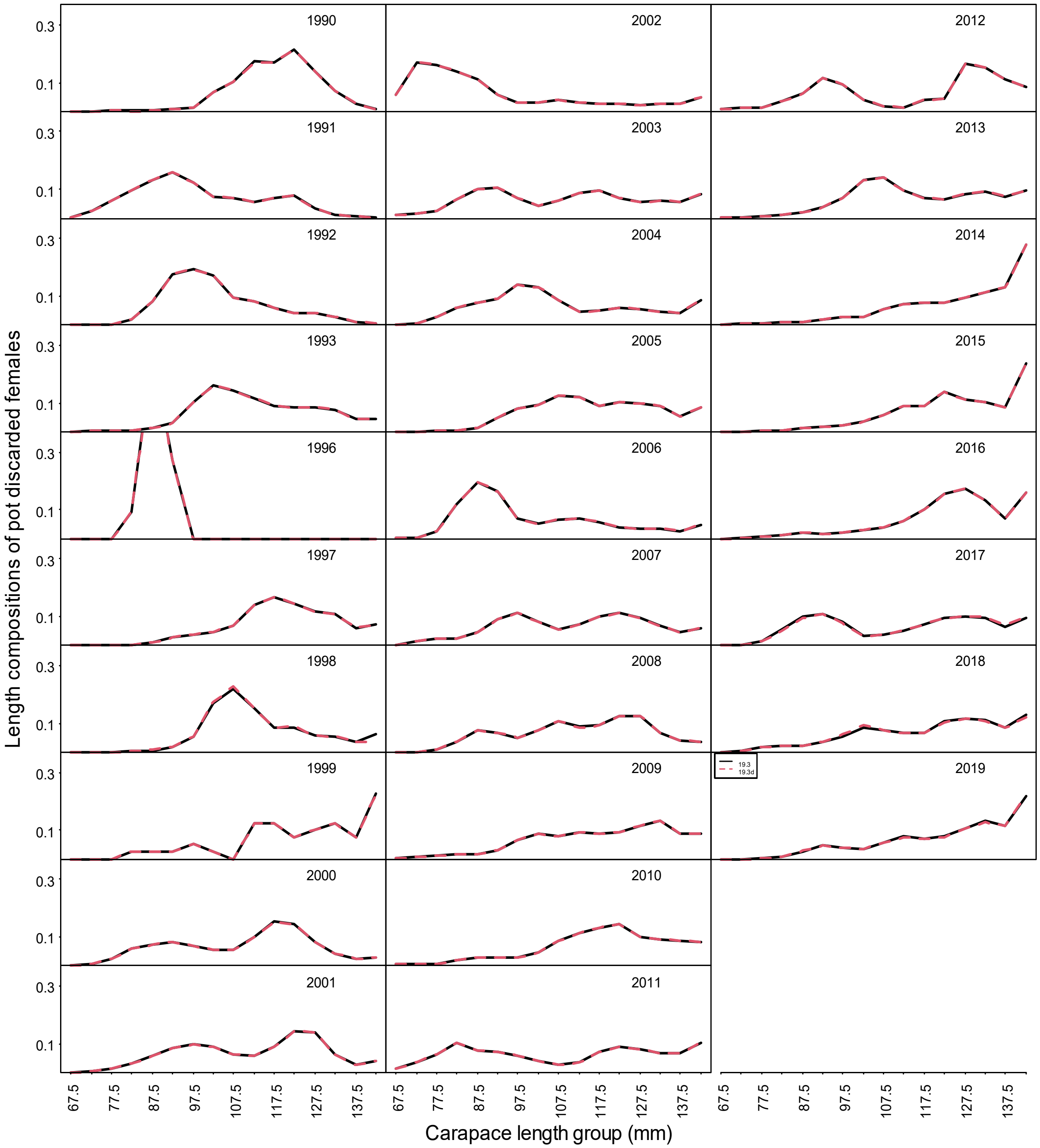


Figure D4. Comparison of observer length compositions of discarded females in the directed pot fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021.

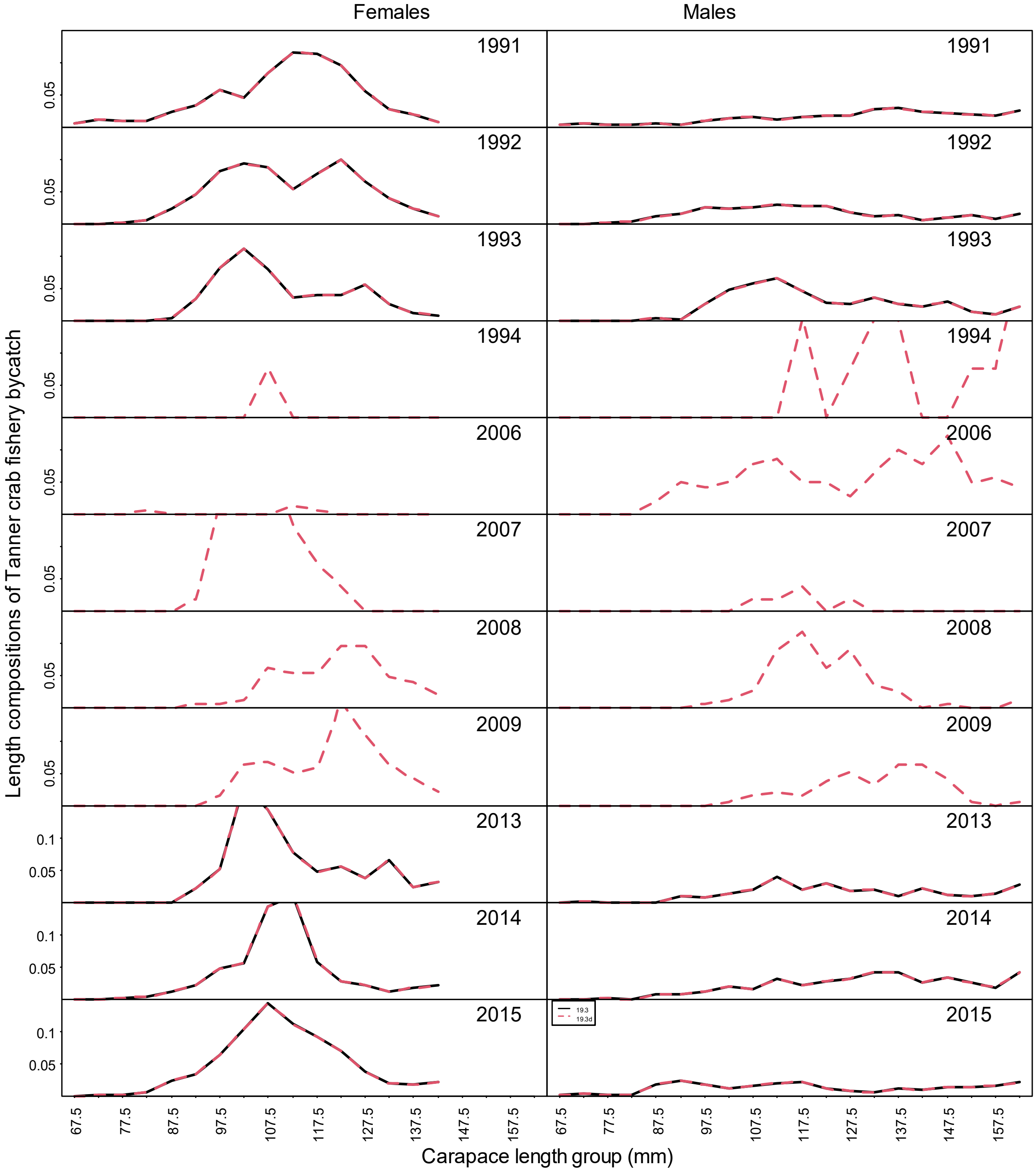


Figure D5. Comparison of observer length compositions of discarded red king crab in the Tanner crab fishery used in model 19.3 in 2020 and updated/standardized observer length compositions used in models 19.3c-19.6 in 2021.

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
   0.4246770    0.1948351    3.2347503    3.1788151    4.3519778    3.5321435
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   2.7613550    2.9545170    2.8214412    2.1871557    2.4178124    1.4982557
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   1.3854900    1.3534917    1.8200897    1.6132997    1.9960421    1.4271915
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   1.0699988    1.1797730    0.5309809    0.3140438    0.5200696    0.6612359
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   1.0289110    1.2053710    1.0209494    1.6926730    1.2784559    0.8561469
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   1.6035744    1.1021394    1.0458219    1.7856805    1.6218819    2.2656588
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
   1.3288600    1.1019269    1.0663150    1.2415754    1.1563799    1.5410823
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft   L_omega1_z
   1.6878197    1.3703371    1.6042728    1.3028284    1.1667935    1.3480184
L_epsilon1_z    logkappa1     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.0495714   -4.3388659    1.5340859    1.5460340    0.9699323    1.2962917
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.3172601    1.0338801    1.1155396    1.1662783    0.6576483    1.2016665
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   0.9830857    0.6621450    1.0850035    1.1362303    0.8017747    1.3811555
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.5272657    1.2876578    1.7433139    1.4644895    1.2669372    1.4267320
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.4516482    1.4677695    1.1041354    0.9524132    1.1605098    1.5874892
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.0521914    1.7108559    2.1826606    1.4280594    1.7164466    0.9810639
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
   1.4394978    1.2622499    1.3979922    1.3106862    1.4290399    1.5194971
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft   L_omega2_z
   1.3870550    1.3922920    1.4670261    1.2116351    1.0194797    0.4350181
L_epsilon2_z    logkappa2   logSigmaM
   0.5071955   -3.4301660   -0.3651867
```

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     0.4246770   -50  0.4246770    50  -5.510007e-09
2  ln_H_input     0.1948362   -50  0.1948351    50  -3.723925e-10
3     beta1_ft     3.2347437   -50  3.2347503    50  -7.993961e-11
4     beta1_ft     3.1788096   -50  3.1788151    50  -1.463718e-11
5     beta1_ft     4.3519711   -50  4.3519778    50   4.783729e-12
6     beta1_ft     3.5321295   -50  3.5321435    50  -1.176659e-11
7     beta1_ft     2.7613474   -50  2.7613550    50  -1.469735e-11
8     beta1_ft     2.9545091   -50  2.9545170    50   2.546408e-12
9     beta1_ft     2.8214352   -50  2.8214412    50  -1.211564e-11
10    beta1_ft     2.1871483   -50  2.1871557    50  -1.672529e-11
11    beta1_ft     2.4178073   -50  2.4178124    50  -2.058931e-11
12    beta1_ft     1.4982417   -50  1.4982557    50  -4.633494e-11
13    beta1_ft     1.3854818   -50  1.3854900    50  -1.053335e-11
14    beta1_ft     1.3534817   -50  1.3534917    50  -1.266365e-11
15    beta1_ft     1.8200752   -50  1.8200897    50  -5.952128e-12
16    beta1_ft     1.6132877   -50  1.6132997    50  -9.197088e-13
17    beta1_ft     1.9960279   -50  1.9960421    50   2.807532e-11
18    beta1_ft     1.4271749   -50  1.4271915    50   2.178813e-11
19    beta1_ft     1.0699726   -50  1.0699988    50   1.539879e-12
20    beta1_ft     1.1797563   -50  1.1797730    50   3.896258e-12
21    beta1_ft     0.5309600   -50  0.5309809    50  -2.937894e-11
22    beta1_ft     0.3140216   -50  0.3140438    50   2.928346e-11
23    beta1_ft     0.5200480   -50  0.5200696    50   3.566680e-11
24    beta1_ft     0.6612178   -50  0.6612359    50   7.180034e-12
25    beta1_ft     1.0288928   -50  1.0289110    50   3.251888e-11
26    beta1_ft     1.2053544   -50  1.2053710    50   1.784350e-11
27    beta1_ft     1.0209341   -50  1.0209494    50   2.645439e-11
28    beta1_ft     1.6926627   -50  1.6926730    50   4.311485e-11
29    beta1_ft     1.2784425   -50  1.2784559    50   1.059597e-12
30    beta1_ft     0.8561281   -50  0.8561469    50   3.409117e-11
31    beta1_ft     1.6035631   -50  1.6035744    50  -5.771561e-11
32    beta1_ft     1.1021215   -50  1.1021394    50   7.861045e-12
33    beta1_ft     1.0457969   -50  1.0458219    50  -1.166498e-10
34    beta1_ft     1.7856635   -50  1.7856805    50   1.387646e-11
35    beta1_ft     1.6218647   -50  1.6218819    50   3.509681e-11
36    beta1_ft     2.2656546   -50  2.2656588    50  -6.827428e-12
37    beta1_ft     1.3288438   -50  1.3288600    50   9.374945e-12
38    beta1_ft     1.1019075   -50  1.1019269    50   7.519851e-11
39    beta1_ft     1.0662975   -50  1.0663150    50  -7.817413e-12
```

```
40     beta1_ft      1.2415596   -50  1.2415754    50   4.209832e-11
41     beta1_ft      1.1563633   -50  1.1563799    50   2.644884e-11
42     beta1_ft      1.5410700   -50  1.5410823    50  -1.294875e-11
43     beta1_ft      1.6878073   -50  1.6878197    50   5.561773e-12
44     beta1_ft      1.3703229   -50  1.3703371    50  -8.080314e-12
45     beta1_ft      1.6042561   -50  1.6042728    50  -1.702249e-11
46     beta1_ft      1.3028170   -50  1.3028284    50  -8.401502e-12
47     beta1_ft      1.1667806   -50  1.1667935    50  -2.232214e-12
48   L_omega1_z      1.3480175   -50  1.3480184    50  -3.410241e-08
49 L_epsilon1_z      1.0495711   -50  1.0495714    50   3.175782e-08
50    logkappa1     -4.3388672   -50 -4.3388659    50  -1.977969e-08
51     beta2_ft      1.5341043   -50  1.5340859    50   3.518412e-10
52     beta2_ft      1.5460373   -50  1.5460340    50  -5.931078e-11
53     beta2_ft      0.9699340   -50  0.9699323    50  -1.117861e-10
54     beta2_ft      1.2963031   -50  1.2962917    50   1.640679e-10
55     beta2_ft      1.3172619   -50  1.3172601    50   3.246647e-11
56     beta2_ft      1.0338814   -50  1.0338801    50  -7.904788e-13
57     beta2_ft      1.1155412   -50  1.1155396    50  -1.348788e-11
58     beta2_ft      1.1662823   -50  1.1662783    50   4.388667e-11
59     beta2_ft      0.6576525   -50  0.6576483    50   1.387850e-10
60     beta2_ft      1.2016876   -50  1.2016665    50   1.584439e-10
61     beta2_ft      0.9830891   -50  0.9830857    50  -7.694823e-11
62     beta2_ft      0.6621540   -50  0.6621450    50   6.455103e-11
63     beta2_ft      1.0850082   -50  1.0850035    50   1.288001e-10
64     beta2_ft      1.1362362   -50  1.1362303    50   1.506884e-11
65     beta2_ft      0.8017748   -50  0.8017747    50  -1.619149e-11
66     beta2_ft      1.3811546   -50  1.3811555    50   3.703882e-11
67     beta2_ft      1.5272671   -50  1.5272657    50   2.245697e-10
68     beta2_ft      1.2876523   -50  1.2876578    50  -9.385914e-11
69     beta2_ft      1.7433179   -50  1.7433139    50   8.517631e-13
70     beta2_ft      1.4644727   -50  1.4644895    50  -3.728475e-10
71     beta2_ft      1.2669226   -50  1.2669372    50  -2.471312e-10
72     beta2_ft      1.4267394   -50  1.4267320    50  -2.875122e-11
73     beta2_ft      1.4516377   -50  1.4516482    50  -2.348370e-10
74     beta2_ft      1.4677741   -50  1.4677695    50  -1.358451e-10
75     beta2_ft      1.1041345   -50  1.1041354    50  -3.897860e-11
76     beta2_ft      0.9524004   -50  0.9524132    50   8.397194e-11
77     beta2_ft      1.1605144   -50  1.1605098    50   2.014122e-11
78     beta2_ft      1.5874896   -50  1.5874892    50  -3.676179e-10
79     beta2_ft      1.0522170   -50  1.0521914    50   5.131540e-10
80     beta2_ft      1.7108621   -50  1.7108559    50   5.035528e-11
81     beta2_ft      2.1826575   -50  2.1826606    50  -4.469785e-10
82     beta2_ft      1.4280642   -50  1.4280594    50  -6.323830e-13
```

```
83    beta2_ft     1.7164473   -50  1.7164466    50  -1.287486e-10
84    beta2_ft     0.9810607   -50  0.9810639    50   9.283063e-11
85    beta2_ft     1.4395046   -50  1.4394978    50   1.569846e-10
86    beta2_ft     1.2622405   -50  1.2622499    50  -1.901315e-10
87    beta2_ft     1.3979906   -50  1.3979922    50  -2.015126e-10
88    beta2_ft     1.3106768   -50  1.3106862    50  -2.468337e-11
89    beta2_ft     1.4290416   -50  1.4290399    50  -5.722267e-11
90    beta2_ft     1.5195095   -50  1.5194971    50   5.287148e-11
91    beta2_ft     1.3870574   -50  1.3870550    50  -9.208190e-11
92    beta2_ft     1.3922933   -50  1.3922920    50   3.860734e-11
93    beta2_ft     1.4670285   -50  1.4670261    50   5.575718e-11
94    beta2_ft     1.2116363   -50  1.2116351    50   1.250289e-11
95    beta2_ft     1.0194761   -50  1.0194797    50   1.003171e-10
96   L_omega2_z      0.4350162   -50  0.4350181    50  -3.462810e-08
97 L_epsilon2_z      0.5071939   -50  0.5071955    50  -1.597902e-08
98    logkappa2    -3.4301683   -50 -3.4301660    50   5.049451e-09
99   logSigmaM    -0.3651849   -50 -0.3651867    50   1.536594e-08
```

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.

```
sdreport(.) result
            Estimate Std. Error
ln_H_input   0.4246770 0.07175141
ln_H_input   0.1948351 0.07075685
beta1_ft     3.2347503 0.98598816
beta1_ft     3.1788151 0.96204976
beta1_ft     4.3519778 0.98044580
beta1_ft     3.5321435 0.96715144
beta1_ft     2.7613550 0.95535058
beta1_ft     2.9545170 0.95854249
beta1_ft     2.8214412 0.96092257
beta1_ft     2.1871557 0.97049350
beta1_ft     2.4178124 0.96559370
beta1_ft     1.4982557 0.97948194
beta1_ft     1.3854900 0.98157659
```

```
beta1_ft      1.3534917 0.98313774
beta1_ft      1.8200897 0.96971598
beta1_ft      1.6132997 0.97605663
beta1_ft      1.9960421 0.97095317
beta1_ft      1.4271915 0.97695256
beta1_ft      1.0699988 0.98285002
beta1_ft      1.1797730 0.97948649
beta1_ft      0.5309809 0.99510650
beta1_ft      0.3140438 1.00611924
beta1_ft      0.5200696 0.99842720
beta1_ft      0.6612359 0.99068226
beta1_ft      1.0289110 0.98695021
beta1_ft      1.2053710 0.98129312
beta1_ft      1.0209494 0.98241836
beta1_ft      1.6926730 0.98578980
beta1_ft      1.2784559 0.98379663
beta1_ft      0.8561469 0.99119474
beta1_ft      1.6035744 0.97978802
beta1_ft      1.1021394 0.98098954
beta1_ft      1.0458219 0.98341788
beta1_ft      1.7856805 0.97135368
beta1_ft      1.6218819 0.97184158
beta1_ft      2.2656588 0.96722132
beta1_ft      1.3288600 0.97521230
beta1_ft      1.1019269 0.98542684
beta1_ft      1.0663150 0.98647406
beta1_ft      1.2415754 0.98209885
beta1_ft      1.1563799 0.98193858
beta1_ft      1.5410823 0.97442937
beta1_ft      1.6878197 0.96955325
beta1_ft      1.3703371 0.97086086
beta1_ft      1.6042728 0.96785576
beta1_ft      1.3028284 0.97409384
beta1_ft      1.1667935 0.97335629
L_omega1_z    1.3480184 0.12672906
L_epsilon1_z  1.0495714 0.05392381
logkappa1    -4.3388659 0.07526483
beta2_ft      1.5340859 0.31380413
beta2_ft      1.5460340 0.25826648
beta2_ft      0.9699323 0.29855034
beta2_ft      1.2962917 0.27567715
beta2_ft      1.3172601 0.22749975
beta2_ft      1.0338801 0.24021826
```

```
beta2_ft      1.1155396 0.24680901
beta2_ft      1.1662783 0.25702944
beta2_ft      0.6576483 0.23968352
beta2_ft      1.2016665 0.25398620
beta2_ft      0.9830857 0.27264083
beta2_ft      0.6621450 0.27889136
beta2_ft      1.0850035 0.24285709
beta2_ft      1.1362303 0.27053944
beta2_ft      0.8017747 0.25426739
beta2_ft      1.3811555 0.23795941
beta2_ft      1.5272657 0.27223595
beta2_ft      1.2876578 0.25558165
beta2_ft      1.7433139 0.27706276
beta2_ft      1.4644895 0.28293733
beta2_ft      1.2669372 0.27829613
beta2_ft      1.4267320 0.26106650
beta2_ft      1.4516482 0.28463490
beta2_ft      1.4677695 0.28049025
beta2_ft      1.1041354 0.27579598
beta2_ft      0.9524132 0.30819295
beta2_ft      1.1605098 0.27117420
beta2_ft      1.5874892 0.26760315
beta2_ft      1.0521914 0.28911940
beta2_ft      1.7108559 0.27343301
beta2_ft      2.1826606 0.26693434
beta2_ft      1.4280594 0.26239635
beta2_ft      1.7164466 0.25616433
beta2_ft      0.9810639 0.25549577
beta2_ft      1.4394978 0.25061561
beta2_ft      1.2622499 0.28717869
beta2_ft      1.3979922 0.26310657
beta2_ft      1.3106862 0.25337096
beta2_ft      1.4290399 0.26411222
beta2_ft      1.5194971 0.25246006
beta2_ft      1.3870550 0.24774184
beta2_ft      1.3922920 0.24364574
beta2_ft      1.4670261 0.23134243
beta2_ft      1.2116351 0.23711445
beta2_ft      1.0194797 0.23724664
L_omega2_z    0.4350181 0.05009772
L_epsilon2_z  0.5071955 0.05981017
logkappa2    -3.4301660 0.15228072
logSigmaM    -0.3651867 0.02666241
```

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	149694.07	0.1250	14893.04
1976	243213.67	0.1125	22185.23
1977	244253.54	0.1012	19842.72
1978	198849.35	0.1135	18384.09
1979	96948.79	0.1265	10137.37
1980	141227.09	0.1244	14389.63
1981	75148.06	0.1023	6280.34
1982	62630.07	0.1227	6305.11
1983	34793.88	0.1114	3170.05
1984	52885.67	0.1388	6064.20
1985	29806.52	0.1123	2755.04
1986	27837.03	0.1186	2726.34
1987	44587.78	0.1197	4394.82
1988	38356.05	0.1174	3679.79
1989	41524.81	0.1193	4036.95
1990	38238.90	0.1239	3912.78
1991	40659.87	0.1286	4375.64
1992	26985.11	0.1217	2728.76
1993	37224.67	0.1290	4028.61
1994	25929.52	0.1306	2806.57
1995	24342.68	0.1233	2497.26
1996	29169.79	0.1298	3134.58
1997	57406.43	0.1262	5970.87
1998	51070.83	0.1161	4868.88
1999	46760.71	0.1382	5303.24
2000	47046.16	0.1276	4843.37
2001	31843.12	0.1099	2880.93
2002	48766.52	0.1278	5142.17
2003	64156.55	0.1313	6922.62
2004	67077.30	0.1325	7343.99
2005	56965.66	0.1177	5692.17
2006	54484.19	0.1106	4947.51
2007	61615.97	0.1136	5740.37
2008	61267.67	0.1288	6415.29
2009	38473.47	0.1406	4423.66
2010	39918.25	0.1259	4100.62
2011	29627.11	0.1303	3195.76
2012	34137.89	0.1475	4111.55
2013	42483.94	0.1351	4692.96
2014	63561.97	0.1233	6403.00
2015	42093.12	0.1170	4038.71
2016	29974.28	0.1120	2799.15
2017	26980.51	0.1050	2385.28
2018	18221.41	0.1117	1714.26
2019	16416.89	0.1162	1597.58

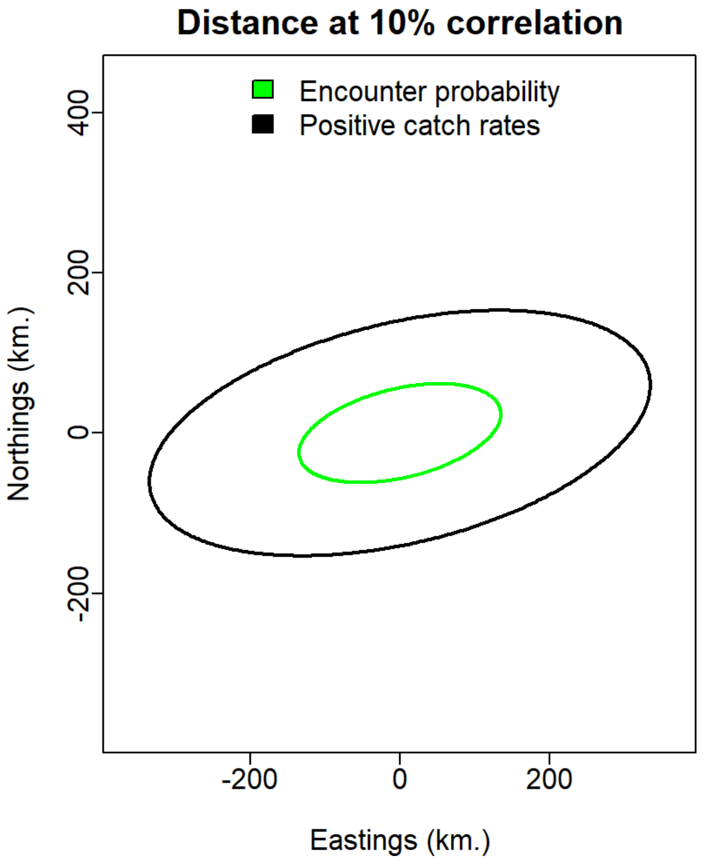


Figure E1 (file = Aniso.png). Geometric anisotropy for males GE65mm. Geometric anisotropy represents the tendency for correlations to decline faster in some directions than others. An ellipse with a major (long) axis pointed northeast-southwest will have correlations that decline slower along this axis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

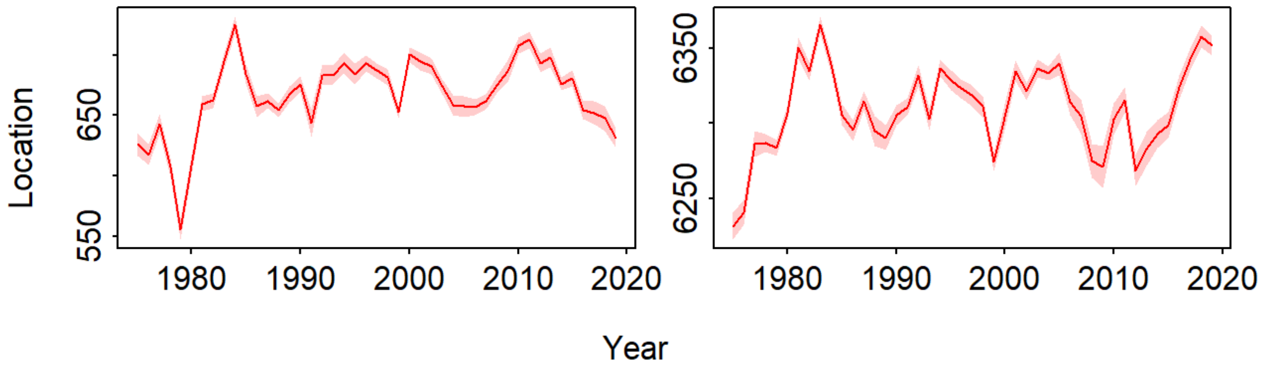


Figure E2 (file = center_of_gravity.png). Center of gravity for males GE65 mm: a.) Eastings (km) and b.) Northings (km). These figures indicate that the population has been shifting slightly to the northwest in recent years.

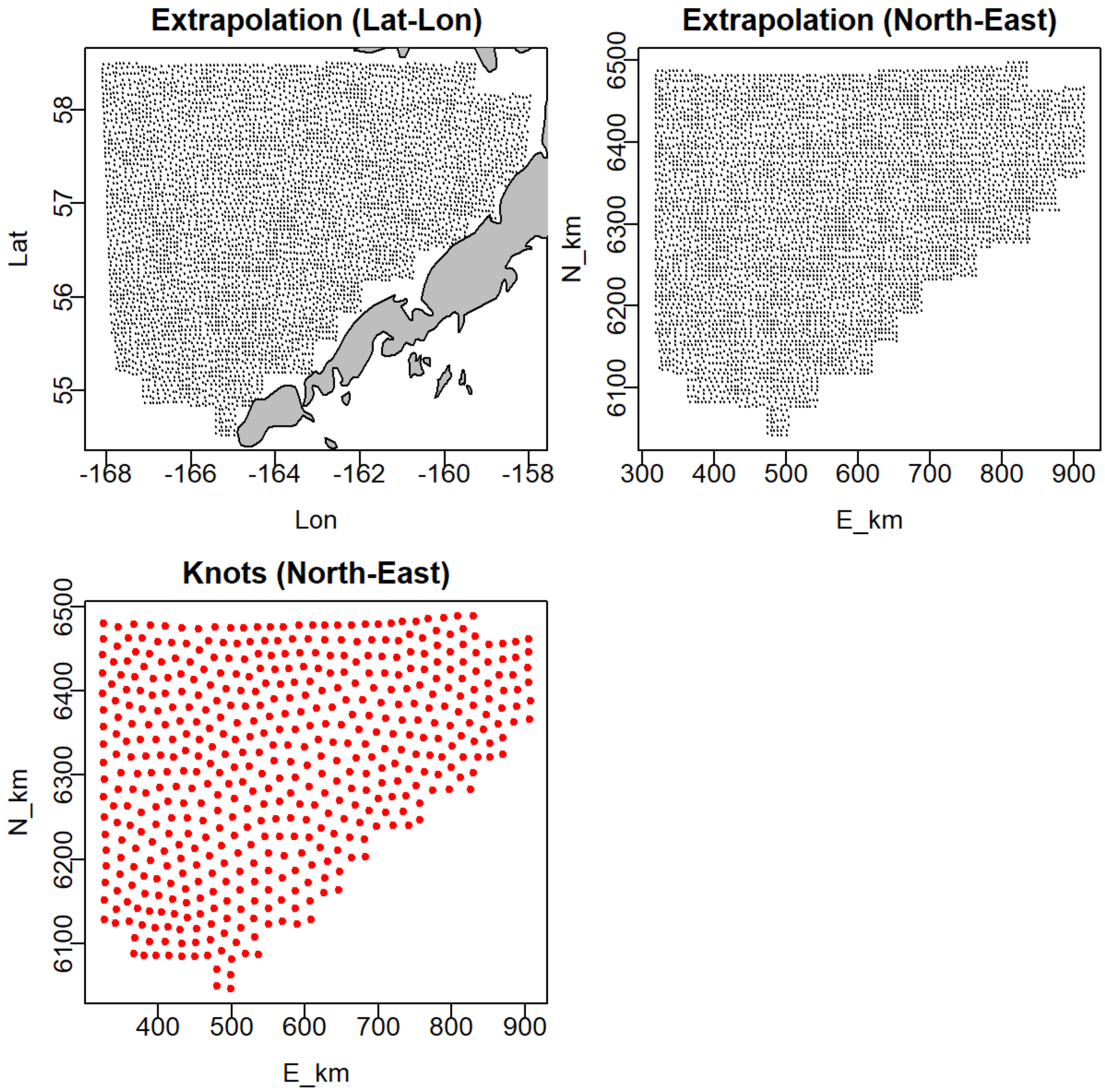


Figure E3 (file = Data_and_knots.png). Extrapolation maps for males GE65 mm: a.) Extrapolation grids by latitude and longitude, b.) Extrapolation grid by Northings/Eastings (in km), and c.) Knots used to define spatial mesh for population estimation.

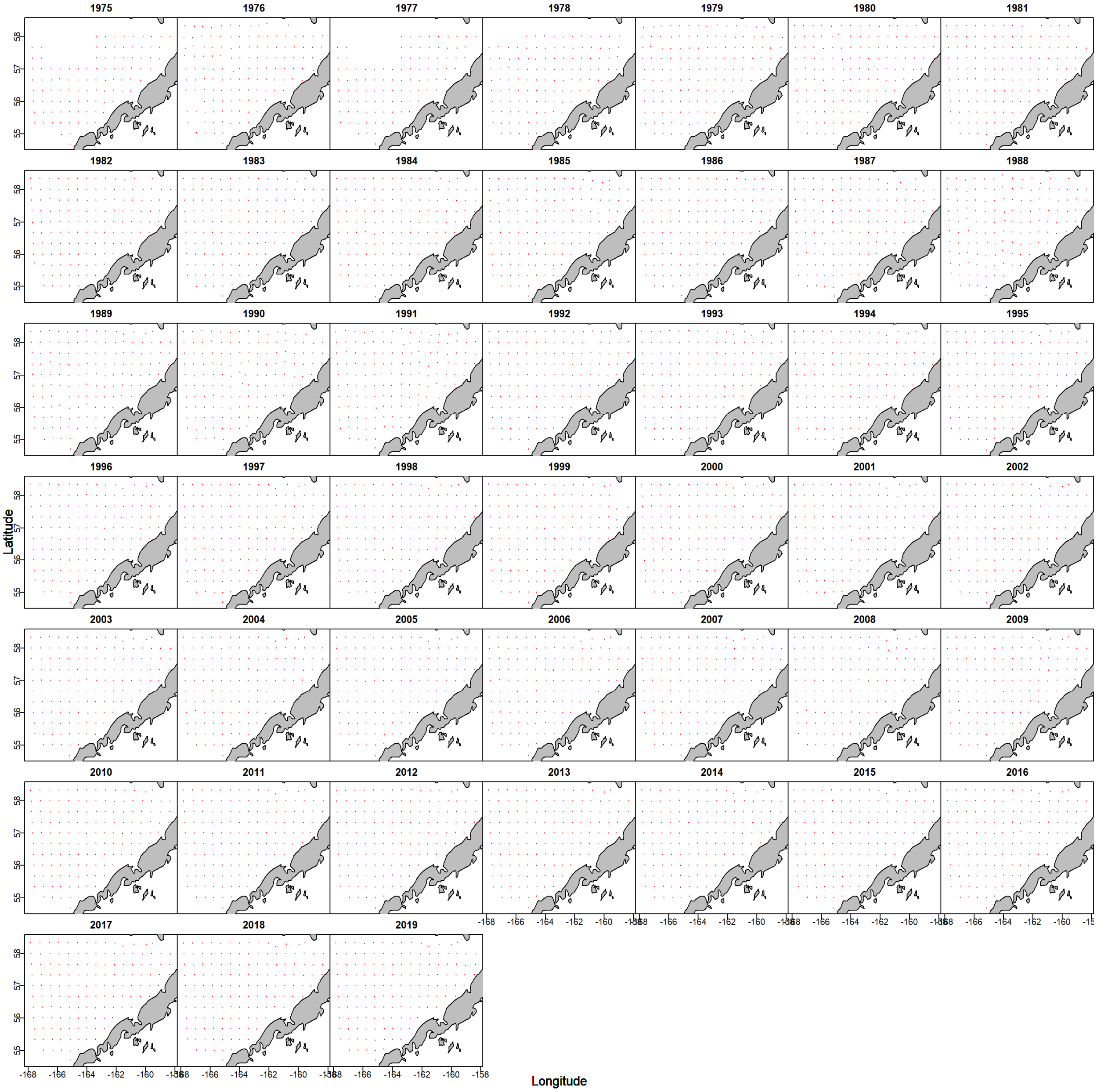


Figure E4 (file = Data_by_year.png). Data sampling locations by year for males GE65 mm. Note standardization of survey area in this subregion of the Bering Sea by 1980.

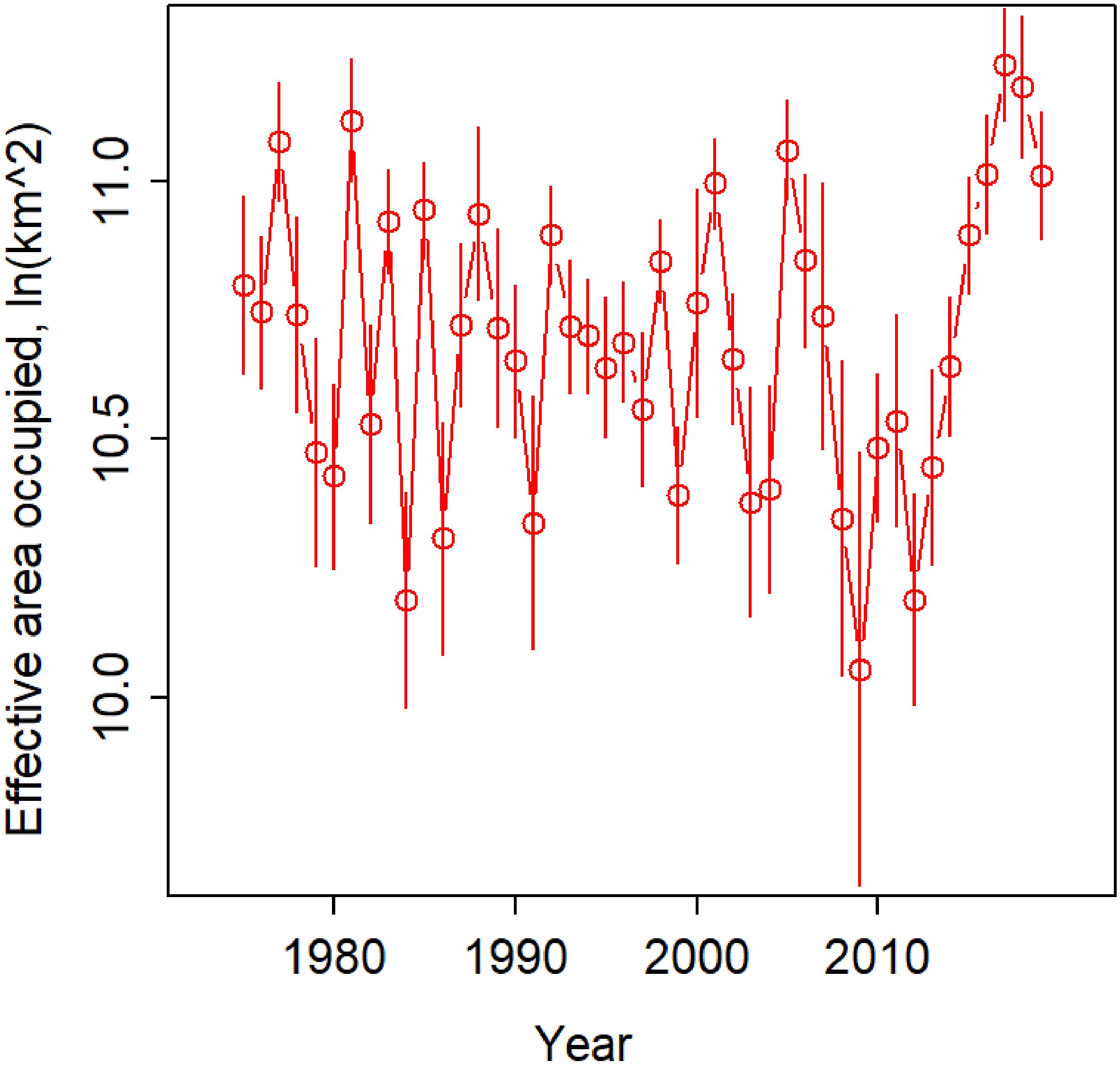


Figure E5 (file = Effective_Area.png). Effective area occupied, in ln(km2) for males GE65 mm. Note modest expansion in area occupied in recent years, despite low population sizes.

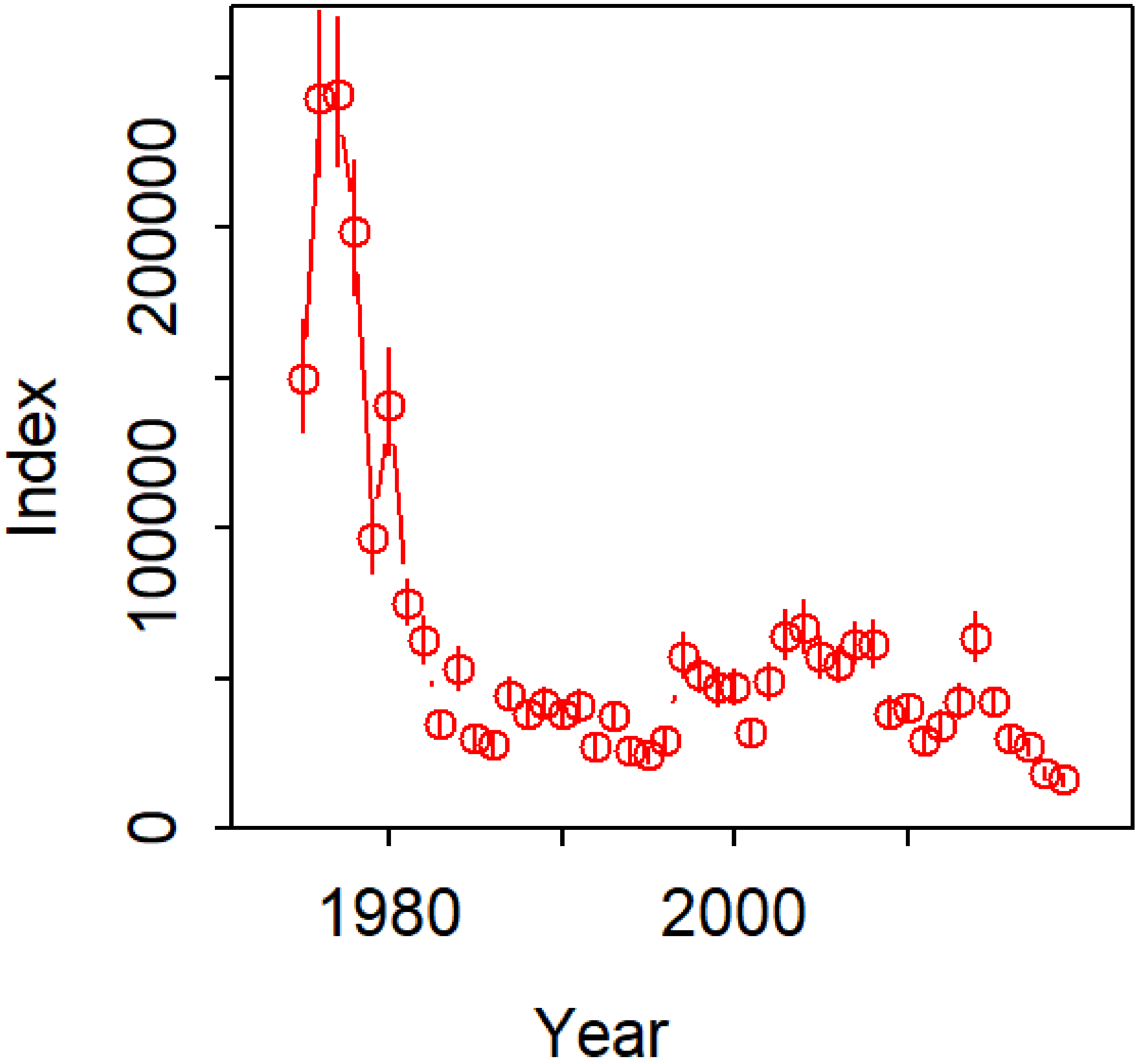


Figure E6 (file = Index-Biomass.png). Biomass estimates by year, with +/- 1SD error bars for males GE65 mm.

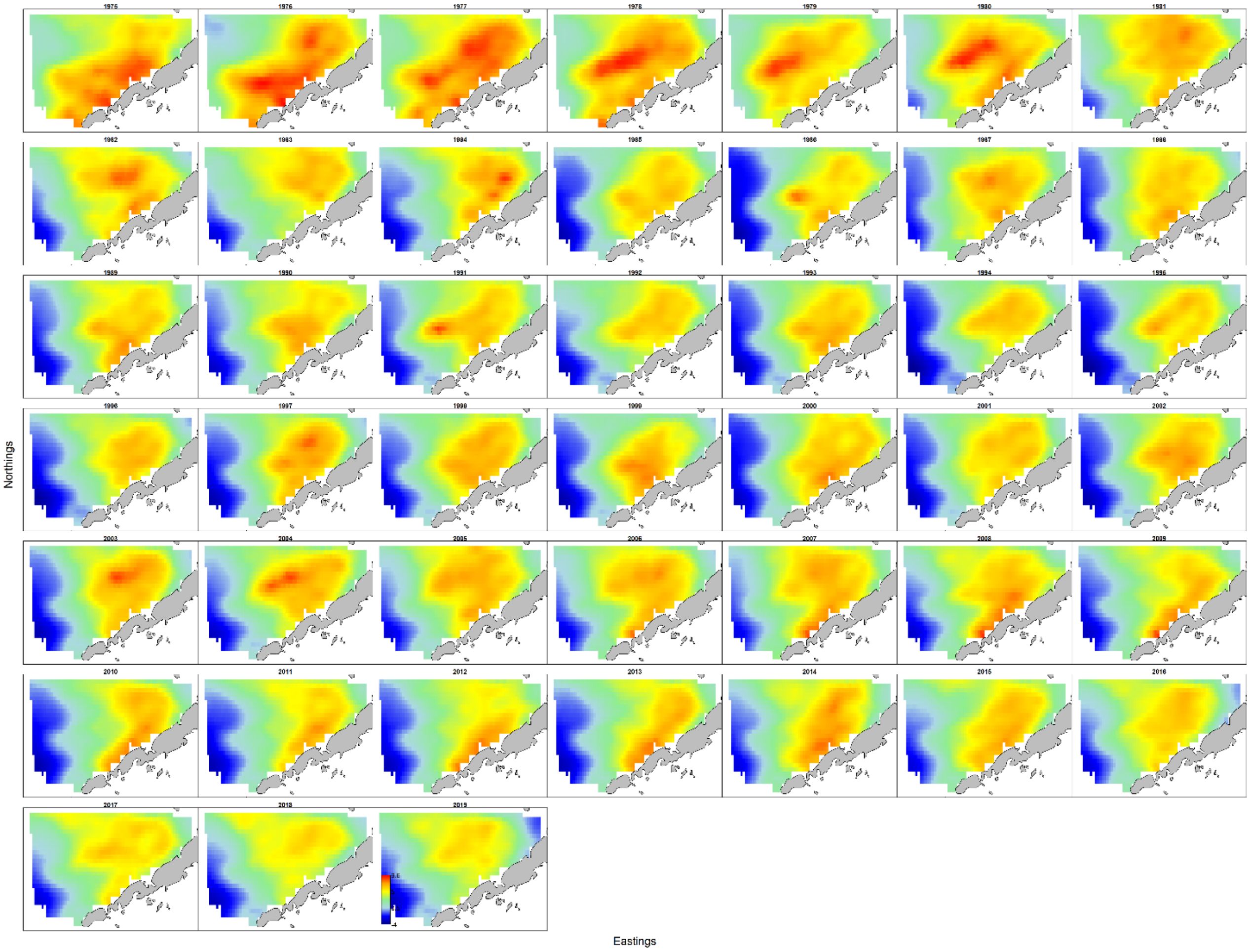


Figure E7 (file = ln_density-predicted.png). Annual log-density maps for males GE65 mm in ln(kg)/km^2.

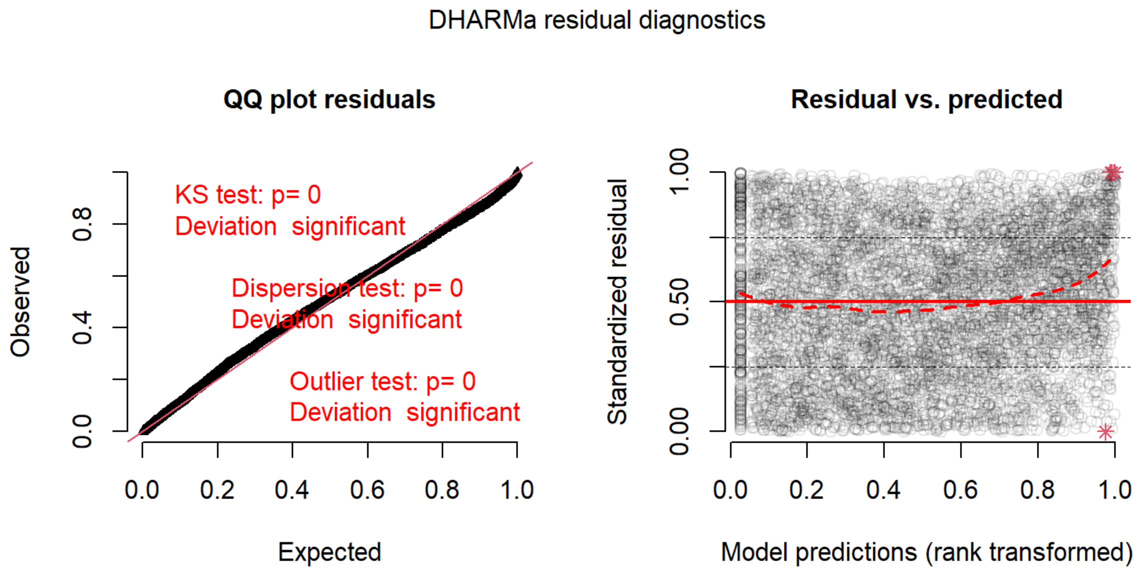


Figure E8 (file = quantile_residuals). DHARMa residual output for males GE65 mm. a.) Q-Q plot of residuals with p-values for statistical test applied automatically by DHARMa package. These p-values have no meaning here and should be ignored. This figure indicates excellent model performance. b.) Rank-transformed model predictions vs. standardized residuals. Note an indication of a trend in residuals for largest model predictions, as indicated by the dashed red line.

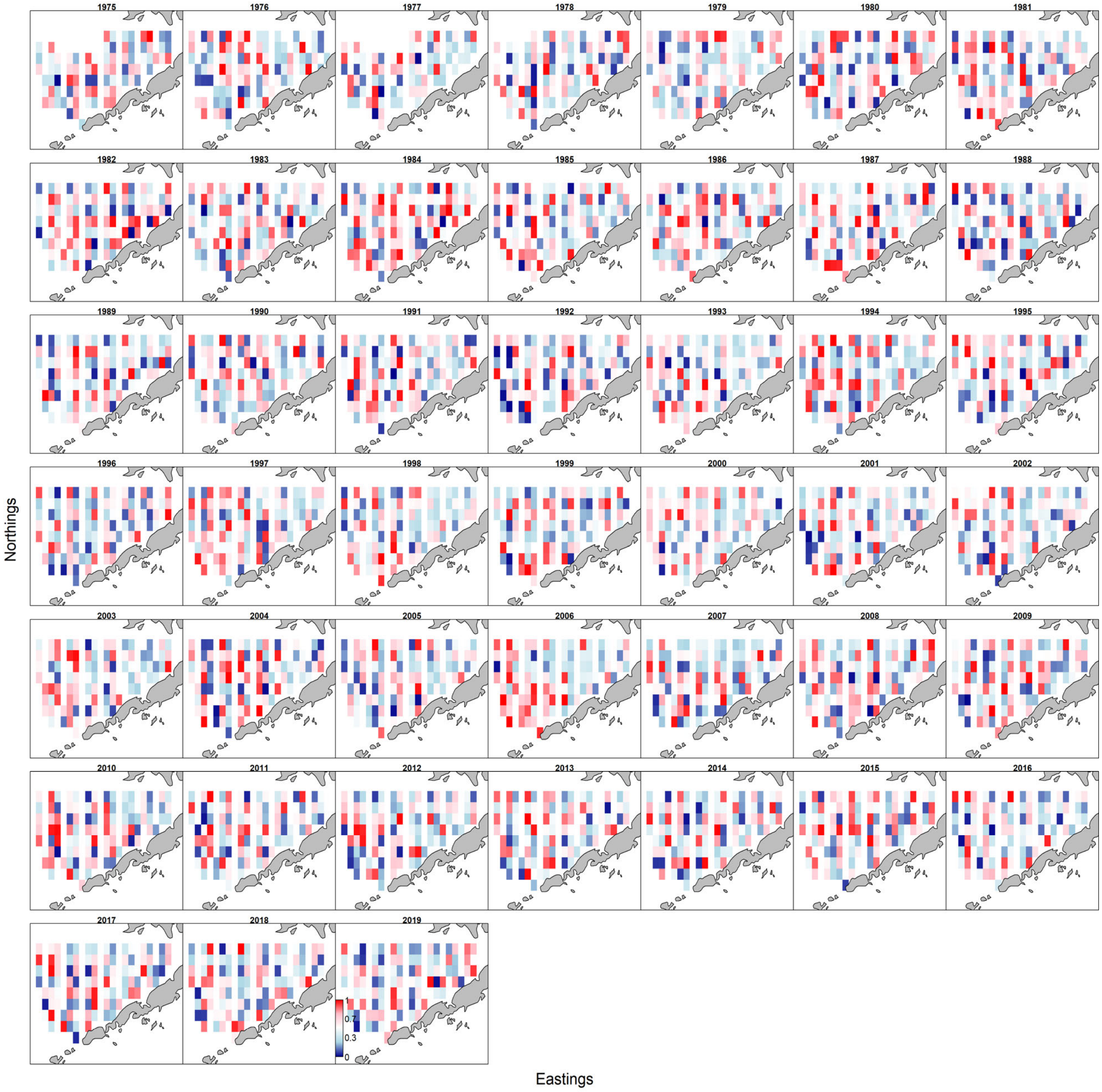
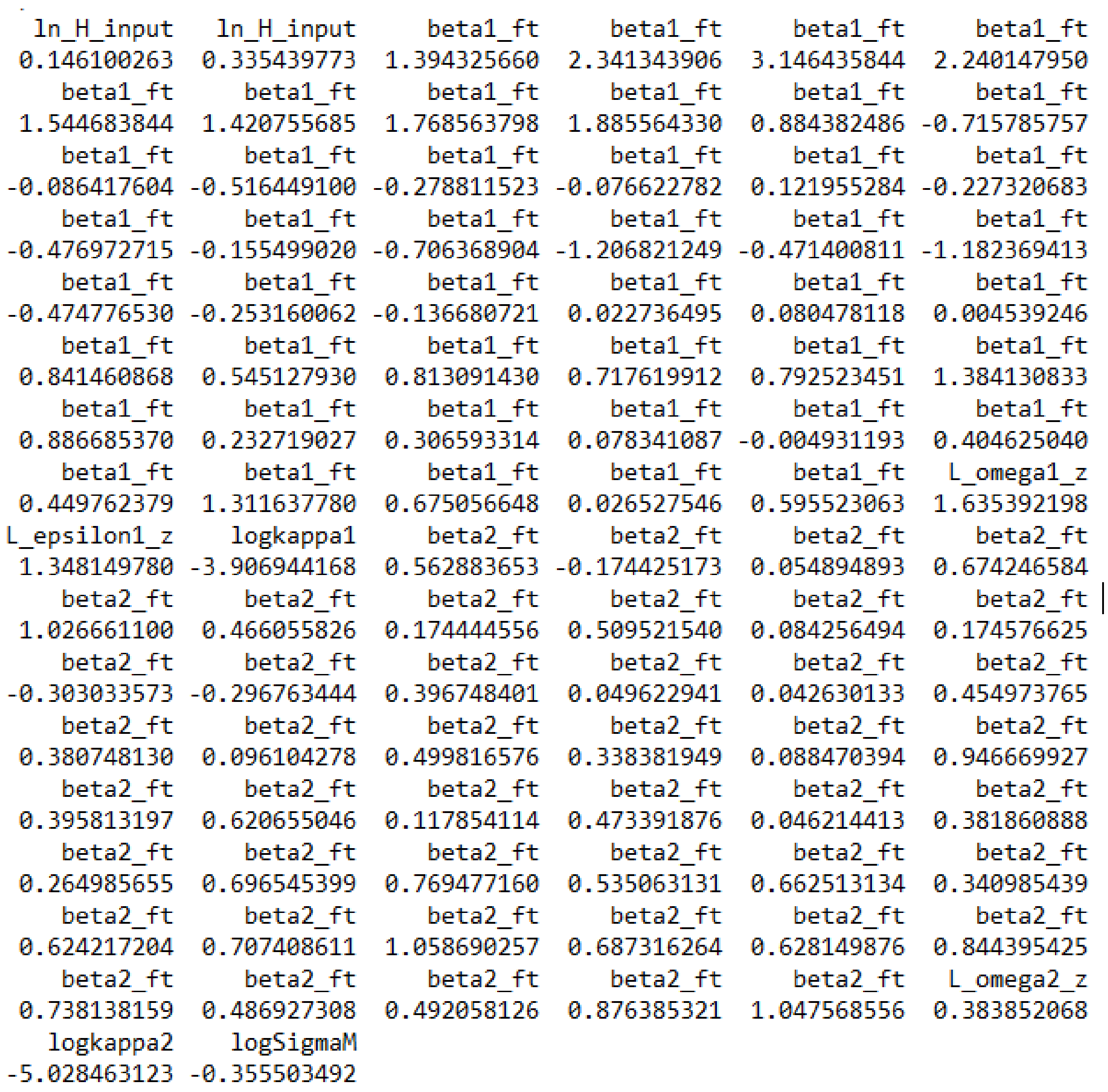


Figure E9 (file = quantile_residuals_on_map.png). Spatial quantile residuals for males GE65 mm with residual "blocks" enlarged for easier viewing. Mapped quantile residuals used to assess for spatial-temporal trends in residuals.

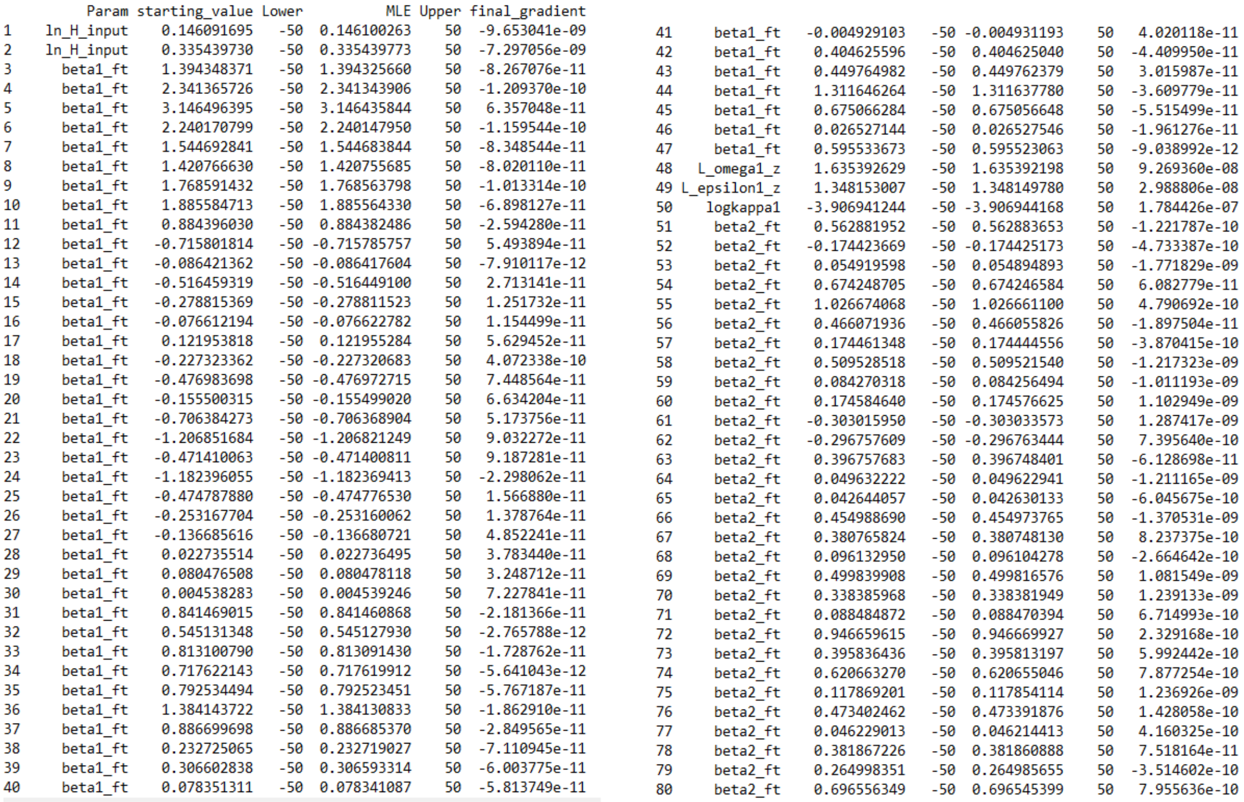
B. Results and diagnostics for females GE65 mm.

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
 0.146100263  0.335439773  1.394325660  2.341343906  3.146435844  2.240147950
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
 1.544683844  1.420755685  1.768563798  1.885564330  0.884382486 -0.715785757
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
-0.086417604 -0.516449100 -0.278811523 -0.076622782  0.121955284 -0.227320683
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
-0.476972715 -0.155499020 -0.706368904 -1.206821249 -0.471400811 -1.182369413
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
-0.474776530 -0.253160062 -0.136680721  0.022736495  0.080478118  0.004539246
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
 0.841460868  0.545127930  0.813091430  0.717619912  0.792523451  1.384130833
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft
 0.886685370  0.232719027  0.306593314  0.078341087 -0.004931193  0.404625040
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft   L_omega1_z
 0.449762379  1.311637780  0.675056648  0.026527546  0.595523063  1.635392198
L_epsilon1_z    logkappa1     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 1.348149780 -3.906944168  0.562883653 -0.174425173  0.054894893  0.674246584
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 1.026661100  0.466055826  0.174444556  0.509521540  0.084256494  0.174576625
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
-0.303033573 -0.296763444  0.396748401  0.049622941  0.042630133  0.454973765
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 0.380748130  0.096104278  0.499816576  0.338381949  0.088470394  0.946669927
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 0.395813197  0.620655046  0.117854114  0.473391876  0.046214413  0.381860888
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 0.264985655  0.696545399  0.769477160  0.535063131  0.662513134  0.340985439
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft
 0.624217204  0.707408611  1.058690257  0.687316264  0.628149876  0.844395425
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft   L_omega2_z
 0.738138159  0.486927308  0.492058126  0.876385321  1.047568556  0.383852068
   logkappa2    logSigmaM
-5.028463123 -0.355503492
```

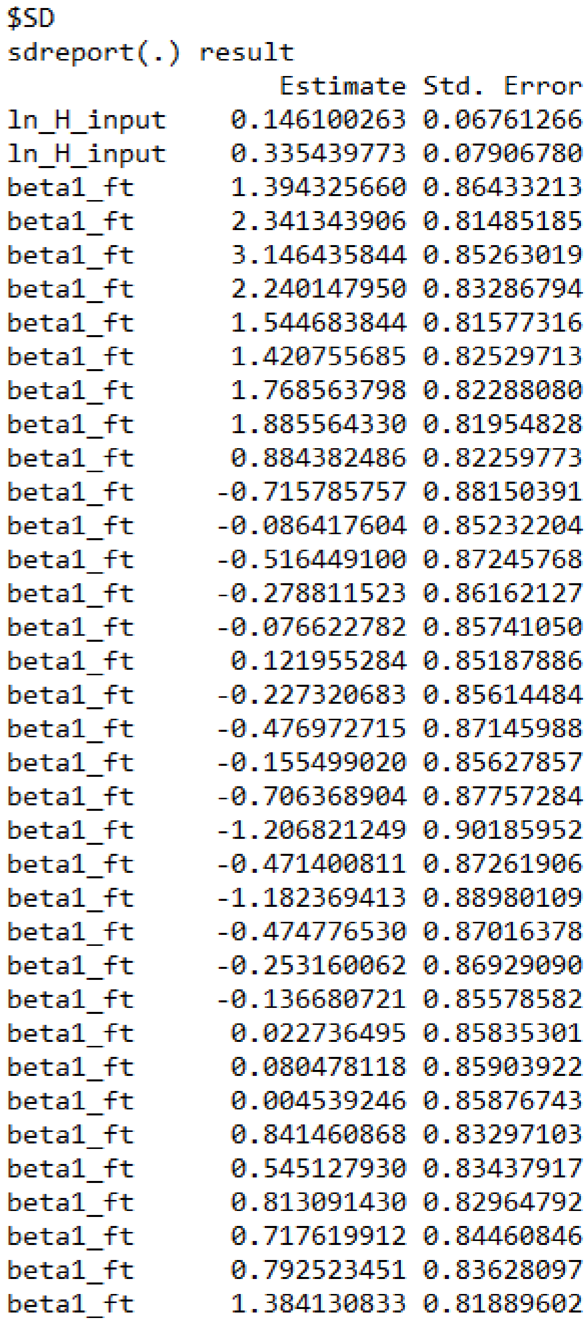
Table E6 (extracted from parameter_estimates.txt). Model parameter estimate diagnostic output for females GE65mm. Starting values for model parameters, upper and lower bounds, MLE, and final gradients for parameters.



```
          Param starting_value Lower          MLE Upper final_gradient
1    ln_H_input    0.146091695   -50  0.146100263    50  -9.653041e-09
2    ln_H_input    0.335439730   -50  0.335439773    50  -7.297056e-09
3      beta1_ft    1.394348371   -50  1.394325660    50  -8.267076e-11
4      beta1_ft    2.341365726   -50  2.341343906    50  -1.209370e-10
5      beta1_ft    3.146496395   -50  3.146435844    50   6.357048e-11
6      beta1_ft    2.240170799   -50  2.240147950    50  -1.159544e-10
7      beta1_ft    1.544692841   -50  1.544683844    50  -8.348544e-11
8      beta1_ft    1.420766630   -50  1.420755685    50  -8.020110e-11
9      beta1_ft    1.768591432   -50  1.768563798    50  -1.013314e-10
10     beta1_ft    1.885584713   -50  1.885564330    50  -6.898127e-11
11     beta1_ft    0.884396030   -50  0.884382486    50  -2.594280e-11
12     beta1_ft   -0.715801814   -50 -0.715785757    50   5.493894e-11
13     beta1_ft   -0.086421362   -50 -0.086417604    50  -7.910117e-12
14     beta1_ft   -0.516459319   -50 -0.516449100    50   2.713141e-11
15     beta1_ft   -0.278815369   -50 -0.278811523    50   1.251732e-11
16     beta1_ft   -0.076612194   -50 -0.076622782    50   1.154499e-11
17     beta1_ft    0.121953818   -50  0.121955284    50   5.629452e-11
18     beta1_ft   -0.227323362   -50 -0.227320683    50   4.072338e-10
19     beta1_ft   -0.476983698   -50 -0.476972715    50   7.448564e-11
20     beta1_ft   -0.155500315   -50 -0.155499020    50   6.634204e-11
21     beta1_ft   -0.706384273   -50 -0.706368904    50   5.173756e-11
22     beta1_ft   -1.206851684   -50 -1.206821249    50   9.032272e-11
23     beta1_ft   -0.471410063   -50 -0.471400811    50   9.187281e-11
24     beta1_ft   -1.182396055   -50 -1.182369413    50  -2.298062e-11
25     beta1_ft   -0.474787880   -50 -0.474776530    50   1.566880e-11
26     beta1_ft   -0.253167704   -50 -0.253160062    50   1.378764e-11
27     beta1_ft   -0.136685616   -50 -0.136680721    50   4.852241e-11
28     beta1_ft    0.022735514   -50  0.022736495    50   3.783440e-11
29     beta1_ft    0.080476508   -50  0.080478118    50   3.248712e-11
30     beta1_ft    0.004538283   -50  0.004539246    50   7.227841e-11
31     beta1_ft    0.841469015   -50  0.841460868    50  -2.181366e-11
32     beta1_ft    0.545131348   -50  0.545127930    50  -2.765788e-12
33     beta1_ft    0.813100790   -50  0.813091430    50  -1.728762e-11
34     beta1_ft    0.717622143   -50  0.717619912    50  -5.641043e-12
35     beta1_ft    0.792534494   -50  0.792523451    50  -5.767187e-11
36     beta1_ft    1.384143722   -50  1.384130833    50  -1.862910e-11
37     beta1_ft    0.886699698   -50  0.886685370    50  -2.849565e-11
38     beta1_ft    0.232725065   -50  0.232719027    50  -7.110945e-11
39     beta1_ft    0.306602838   -50  0.306593314    50  -6.003775e-11
40     beta1_ft    0.078351311   -50  0.078341087    50  -5.813749e-11
```

```
41     beta1_ft   -0.004929103   -50 -0.004931193    50   4.020118e-11
42     beta1_ft    0.404625596   -50  0.404625040    50  -4.409950e-11
43     beta1_ft    0.449764982   -50  0.449762379    50   3.015987e-11
44     beta1_ft    1.311646264   -50  1.311637780    50  -3.609779e-11
45     beta1_ft    0.675066284   -50  0.675056648    50  -5.515499e-11
46     beta1_ft    0.026527144   -50  0.026527546    50  -1.961276e-11
47     beta1_ft    0.595533673   -50  0.595523063    50  -9.038992e-12
48   L_omega1_z    1.635392629   -50  1.635392198    50   9.269360e-08
49 L_epsilon1_z    1.348153007   -50  1.348149780    50   2.988806e-08
50    logkappa1   -3.906941244   -50 -3.906944168    50   1.784426e-07
51     beta2_ft    0.562881952   -50  0.562883653    50  -1.221787e-10
52     beta2_ft   -0.174423669   -50 -0.174425173    50  -4.733387e-10
53     beta2_ft    0.054919598   -50  0.054894893    50  -1.771829e-09
54     beta2_ft    0.674248705   -50  0.674246584    50   6.082779e-11
55     beta2_ft    1.026674068   -50  1.026661100    50   4.790692e-10
56     beta2_ft    0.466071936   -50  0.466055826    50  -1.897504e-11
57     beta2_ft    0.174461348   -50  0.174444556    50  -3.870415e-10
58     beta2_ft    0.509528518   -50  0.509521540    50  -1.217323e-09
59     beta2_ft    0.084270318   -50  0.084256494    50  -1.011193e-09
60     beta2_ft    0.174584640   -50  0.174576625    50   1.102949e-09
61     beta2_ft   -0.303015950   -50 -0.303033573    50   1.287417e-09
62     beta2_ft   -0.296757609   -50 -0.296763444    50   7.395640e-10
63     beta2_ft    0.396757683   -50  0.396748401    50  -6.128698e-11
64     beta2_ft    0.049632222   -50  0.049622941    50  -1.211165e-09
65     beta2_ft    0.042644057   -50  0.042630133    50  -6.045675e-10
66     beta2_ft    0.454988690   -50  0.454973765    50  -1.370531e-09
67     beta2_ft    0.380765824   -50  0.380748130    50   8.237375e-10
68     beta2_ft    0.096132950   -50  0.096104278    50  -2.664642e-10
69     beta2_ft    0.499839908   -50  0.499816576    50   1.081549e-09
70     beta2_ft    0.338385968   -50  0.338381949    50   1.239133e-09
71     beta2_ft    0.088484872   -50  0.088470394    50   6.714993e-10
72     beta2_ft    0.946659615   -50  0.946669927    50   2.329168e-10
73     beta2_ft    0.395836436   -50  0.395813197    50   5.992442e-10
74     beta2_ft    0.620663270   -50  0.620655046    50   7.877254e-10
75     beta2_ft    0.117869201   -50  0.117854114    50   1.236926e-09
76     beta2_ft    0.473402462   -50  0.473391876    50   1.428058e-10
77     beta2_ft    0.046229013   -50  0.046214413    50   4.160325e-10
78     beta2_ft    0.381867226   -50  0.381860888    50   7.518164e-11
79     beta2_ft    0.264998351   -50  0.264985655    50  -3.514602e-10
80     beta2_ft    0.696556349   -50  0.696545399    50   7.955636e-10
```

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.



```
$SD
sdreport(.) result
                Estimate Std. Error
ln_H_input    0.146100263 0.06761266
ln_H_input    0.335439773 0.07906780
beta1_ft      1.394325660 0.86433213
beta1_ft      2.341343906 0.81485185
beta1_ft      3.146435844 0.85263019
beta1_ft      2.240147950 0.83286794
beta1_ft      1.544683844 0.81577316
beta1_ft      1.420755685 0.82529713
beta1_ft      1.768563798 0.82288080
beta1_ft      1.885564330 0.81954828
beta1_ft      0.884382486 0.82259773
beta1_ft     -0.715785757 0.88150391
beta1_ft     -0.086417604 0.85232204
beta1_ft     -0.516449100 0.87245768
beta1_ft     -0.278811523 0.86162127
beta1_ft     -0.076622782 0.85741050
beta1_ft      0.121955284 0.85187886
beta1_ft     -0.227320683 0.85614484
beta1_ft     -0.476972715 0.87145988
beta1_ft     -0.155499020 0.85627857
beta1_ft     -0.706368904 0.87757284
beta1_ft     -1.206821249 0.90185952
beta1_ft     -0.471400811 0.87261906
beta1_ft     -1.182369413 0.88980109
beta1_ft     -0.474776530 0.87016378
beta1_ft     -0.253160062 0.86929090
beta1_ft     -0.136680721 0.85578582
beta1_ft      0.022736495 0.85835301
beta1_ft      0.080478118 0.85903922
beta1_ft      0.004539246 0.85876743
beta1_ft      0.841460868 0.83297103
beta1_ft      0.545127930 0.83437917
beta1_ft      0.813091430 0.82964792
beta1_ft      0.717619912 0.84460846
beta1_ft      0.792523451 0.83628097
beta1_ft      1.384130833 0.81889602
```

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	55086.37	0.1718	6972.55
1976	65470.34	0.1420	6845.61
1977	133213.32	0.1311	12833.68
1978	122010.88	0.1338	12174.59
1979	52499.74	0.1174	4772.99
1980	66102.64	0.1614	8010.32
1981	54748.46	0.1400	5805.62
1982	59697.72	0.1354	6146.47
1983	11724.42	0.1363	1232.76
1984	20266.61	0.1945	3059.97
1985	6368.07	0.1520	746.18
1986	5701.93	0.1574	692.78
1987	16230.06	0.1606	2014.92
1988	13305.71	0.1982	2041.40
1989	9390.61	0.1584	1141.87
1990	13575.18	0.1825	1913.29
1991	11706.97	0.1618	1463.03
1992	10441.13	0.1505	1205.25
1993	15263.61	0.1642	1917.22
1994	8029.10	0.1607	1002.58
1995	9336.25	0.1517	1085.74
1996	14420.95	0.1601	1796.38
1997	18651.36	0.1707	2444.73
1998	30921.92	0.1458	3426.45
1999	15125.41	0.1804	2074.79
2000	24137.86	0.1887	3438.51
2001	20193.73	0.1635	2491.42
2002	19796.89	0.1601	2402.94
2003	36323.13	0.1470	4055.72
2004	32061.21	0.1453	3526.41
2005	43414.57	0.1410	4673.71
2006	40916.80	0.1505	4682.61
2007	39118.91	0.1378	4089.42
2008	35149.98	0.1674	4413.73
2009	32823.63	0.1509	3719.33
2010	41408.02	0.1580	4961.70
2011	40670.43	0.1553	4859.63
2012	30134.93	0.1924	4449.19
2013	21878.24	0.1930	3172.41
2014	62170.19	0.1728	8065.27
2015	29304.10	0.1784	3951.88
2016	35323.78	0.1519	4100.59
2017	28353.57	0.1384	2989.85
2018	13977.81	0.1479	1633.91
2019	15791.49	0.1251	1582.16

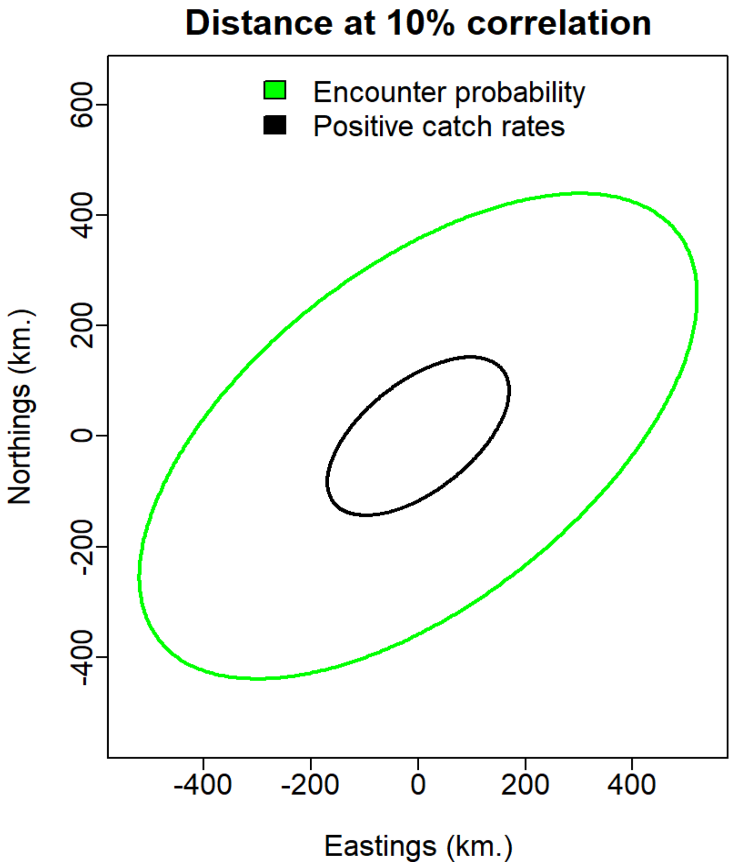


Figure E10 (file = Aniso.png). Geometric anisotropy for females GE65mm. Geometric anisotropy represents the tendency for correlations to decline faster in some directions than others. An ellipse with a major (long) axis pointed northeast-southwest will have correlations that decline slower along this axis than movement northwest-southeast.

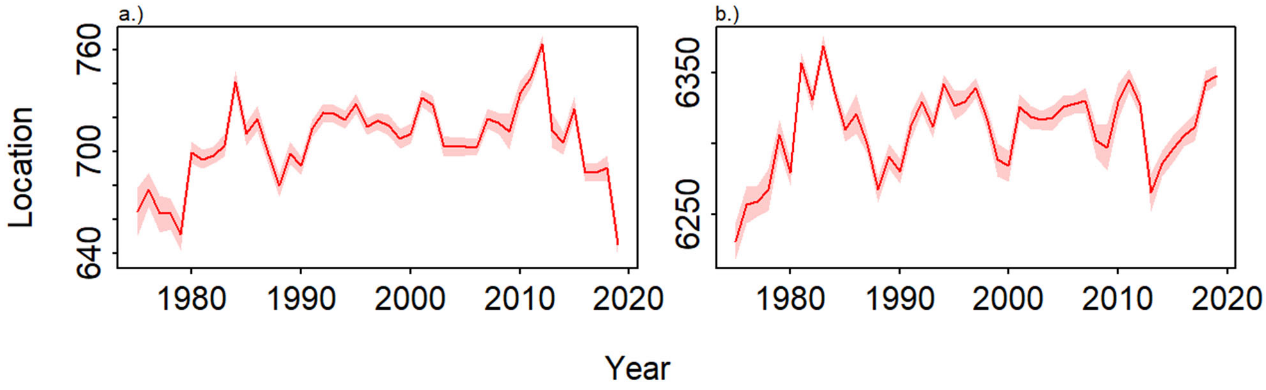


Figure E11 (file = center_of_gravity.png). Center of gravity for females GE65 mm: a.) Eastings (km) and b.) Northings (km). These figures indicate that the population has been shifting slightly to the northwest in recent years.

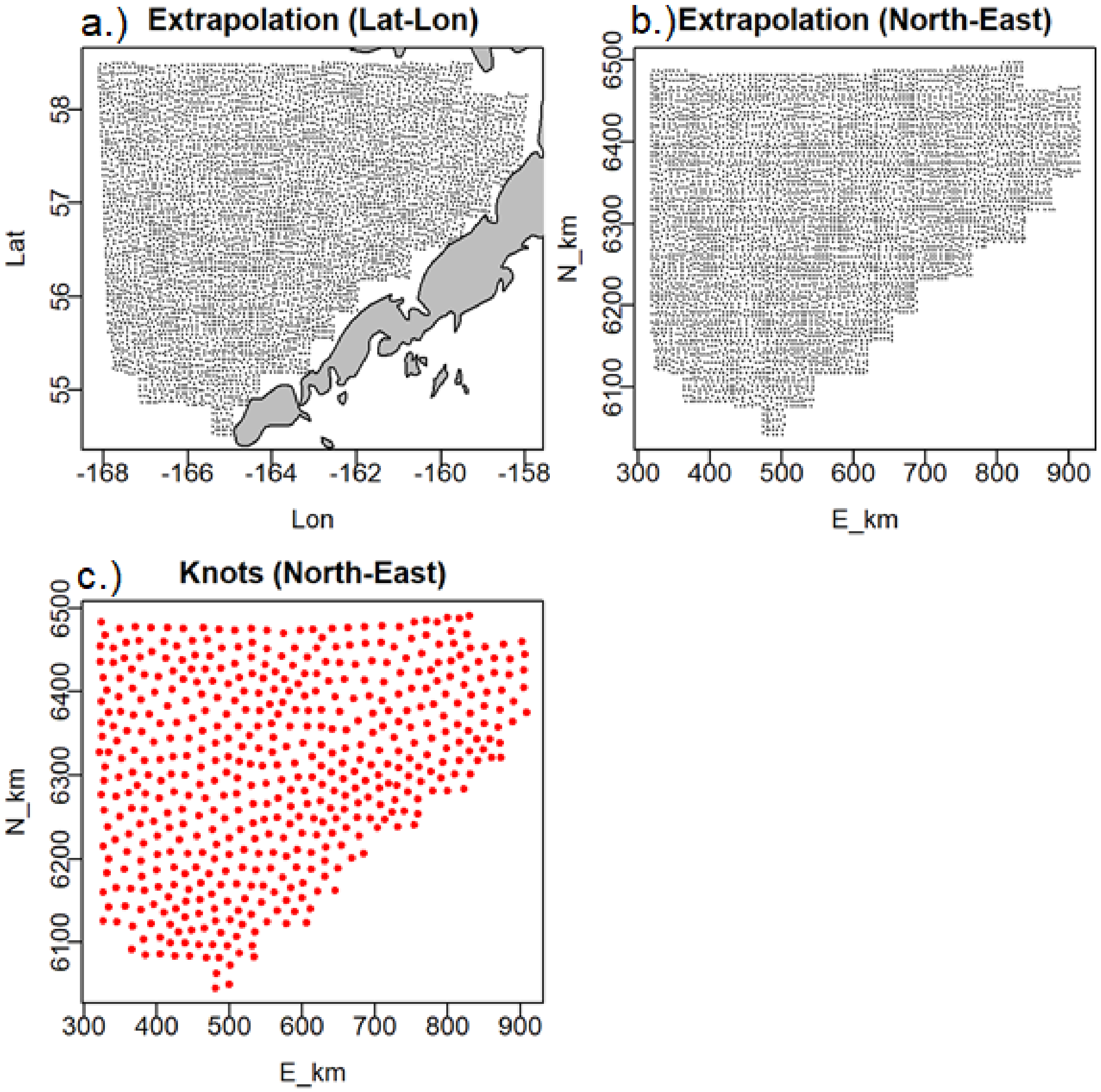


Figure E12 (file = Data_and_knots.png). Extrapolation maps for females GE65 mm: a.) Extrapolation grids by latitude and longitude, b.) Extrapolation grid by Northings/Eastings (in km), and c.) Knots used to define spatial mesh for population estimation.

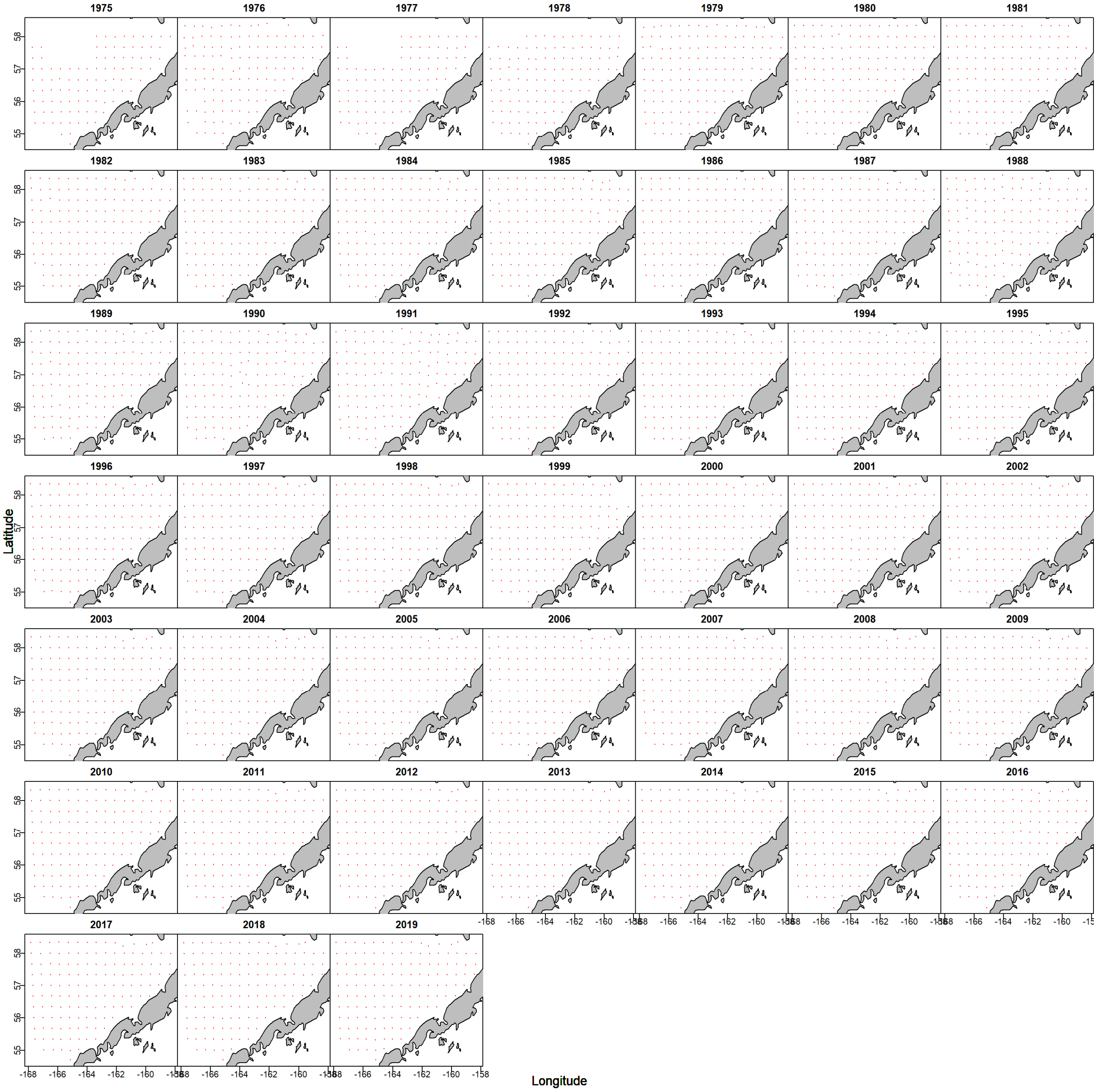


Figure E13 (file = Data_by_year.png). Data sampling locations by year for females GE65 mm. Note standardization of survey area in this subregion of the Bering Sea by 1980.

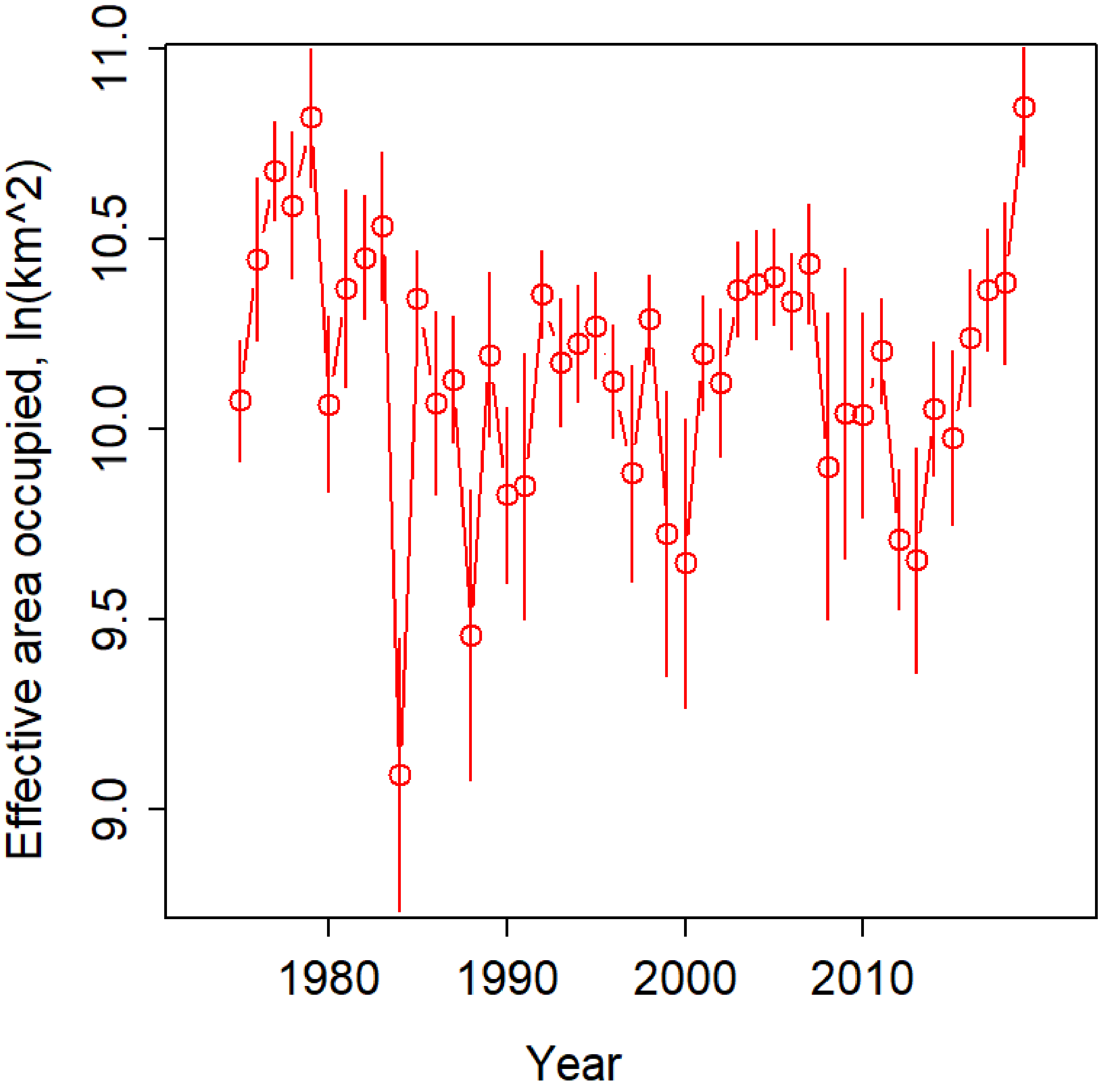


Figure E14 (file = Effective_Area.png). Effective area occupied, in ln(km2) for females GE65 mm. Note modest expansion in area occupied in recent years, despite low population sizes.

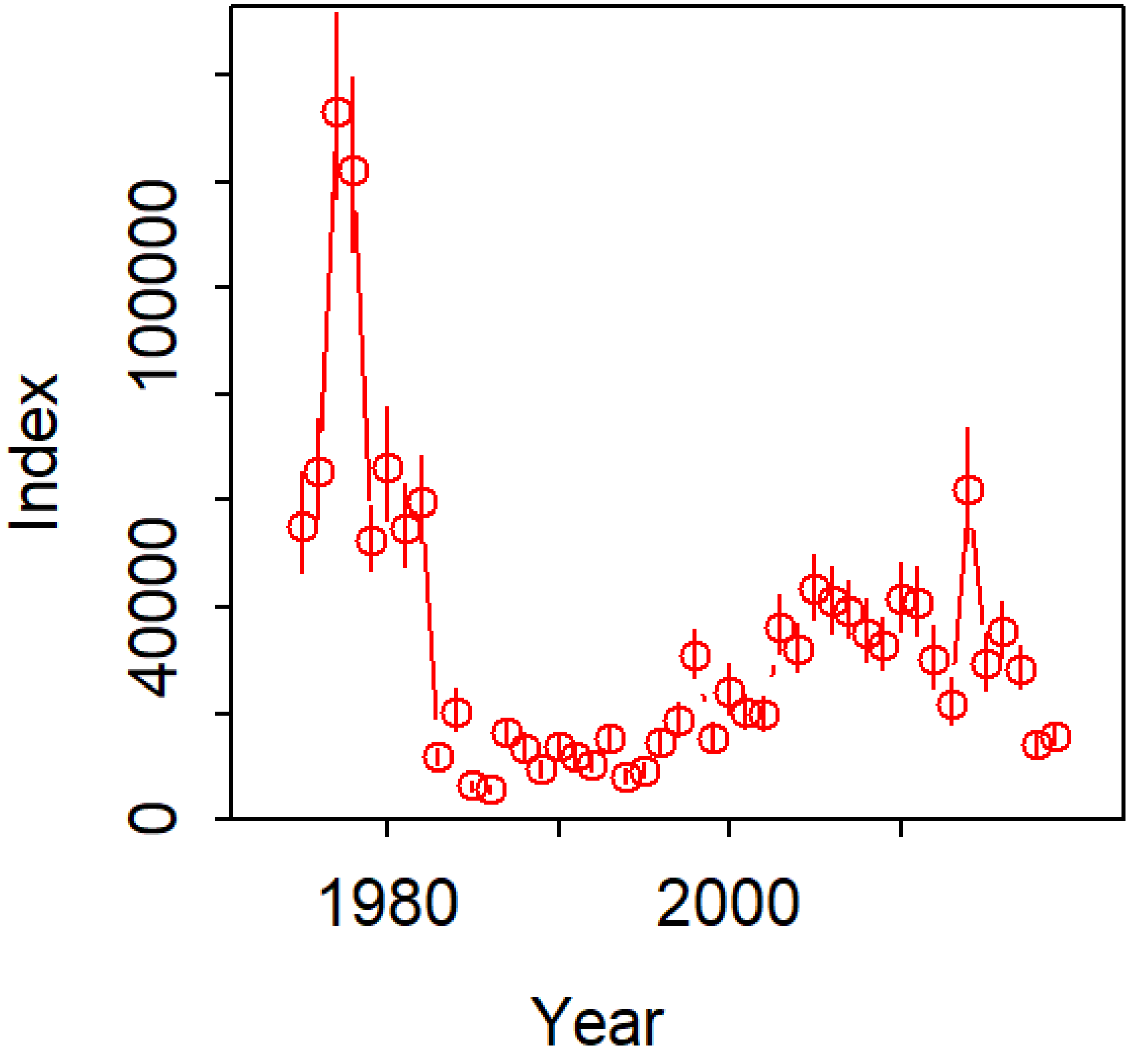


Figure E15 (file = Index-Biomass.png). Biomass estimates by year, with +/- 1SD error bars for females GE65 mm.

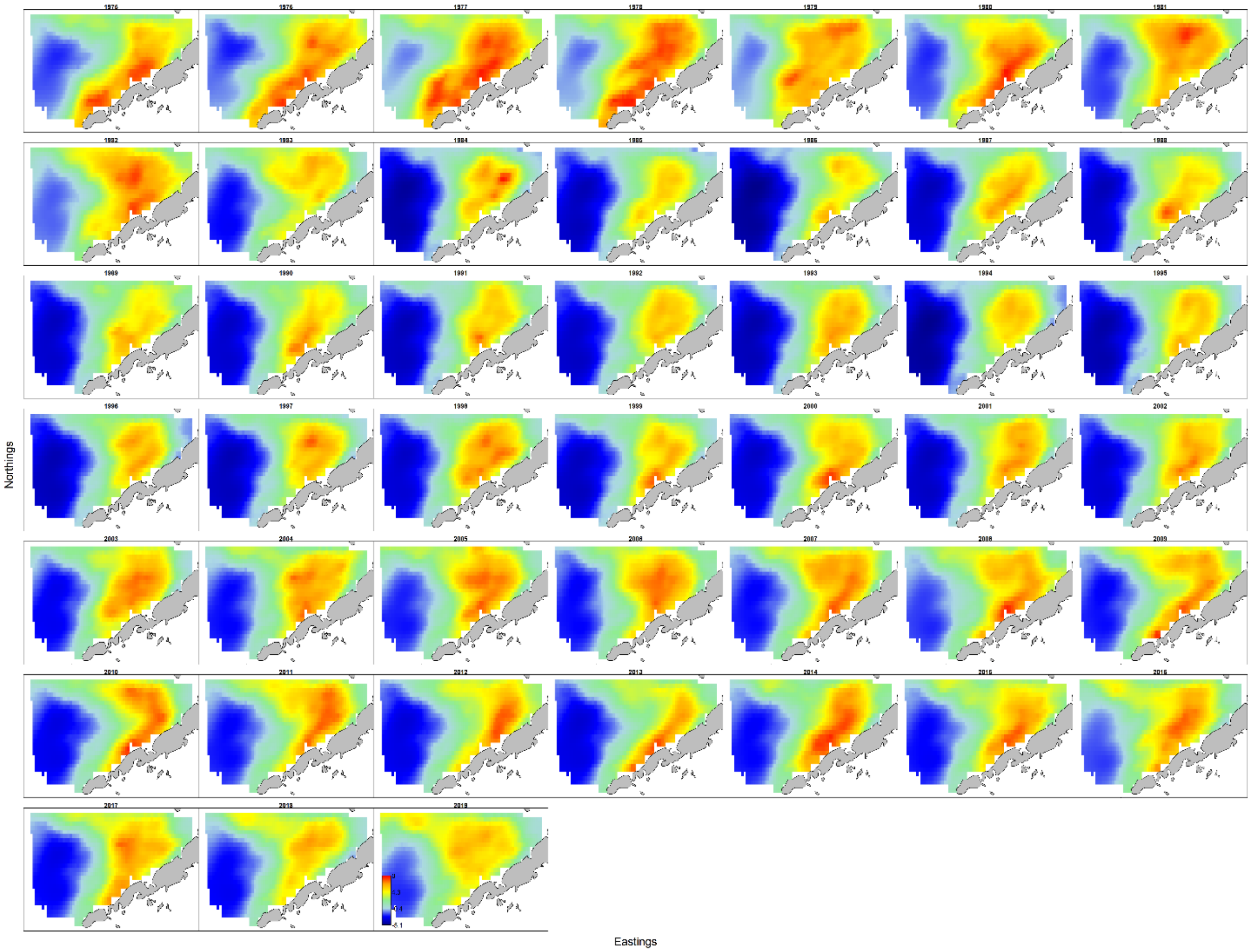


Figure E16 (file = ln_density-predicted.png). Annual log-density maps for females GE65 mm in ln(kg)/km^2.

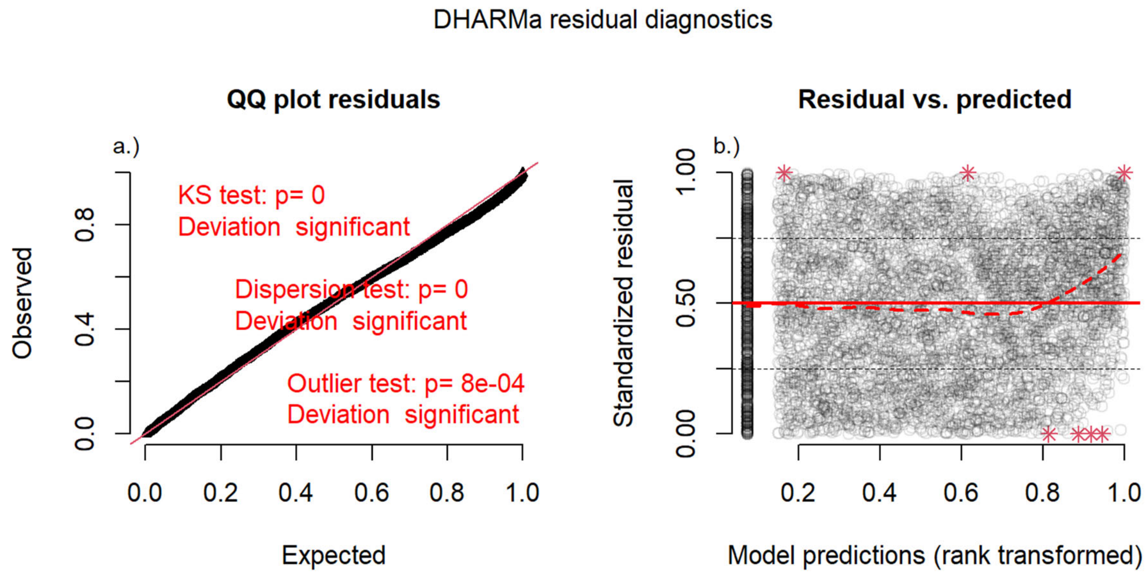


Figure E17 (file = quantile_residuals). DHARMa residual output for females GE65 mm. a.) Q-Q plot of residuals with p-values for statistical test applied automatically by DHARMa package. These p-values have no meaning here and should be ignored. This figure indicates excellent model performance. b.) Rank-transformed model predictions vs. standardized residuals. Note an indication of a trend in residuals for largest model predictions, as indicated by the dashed red line.

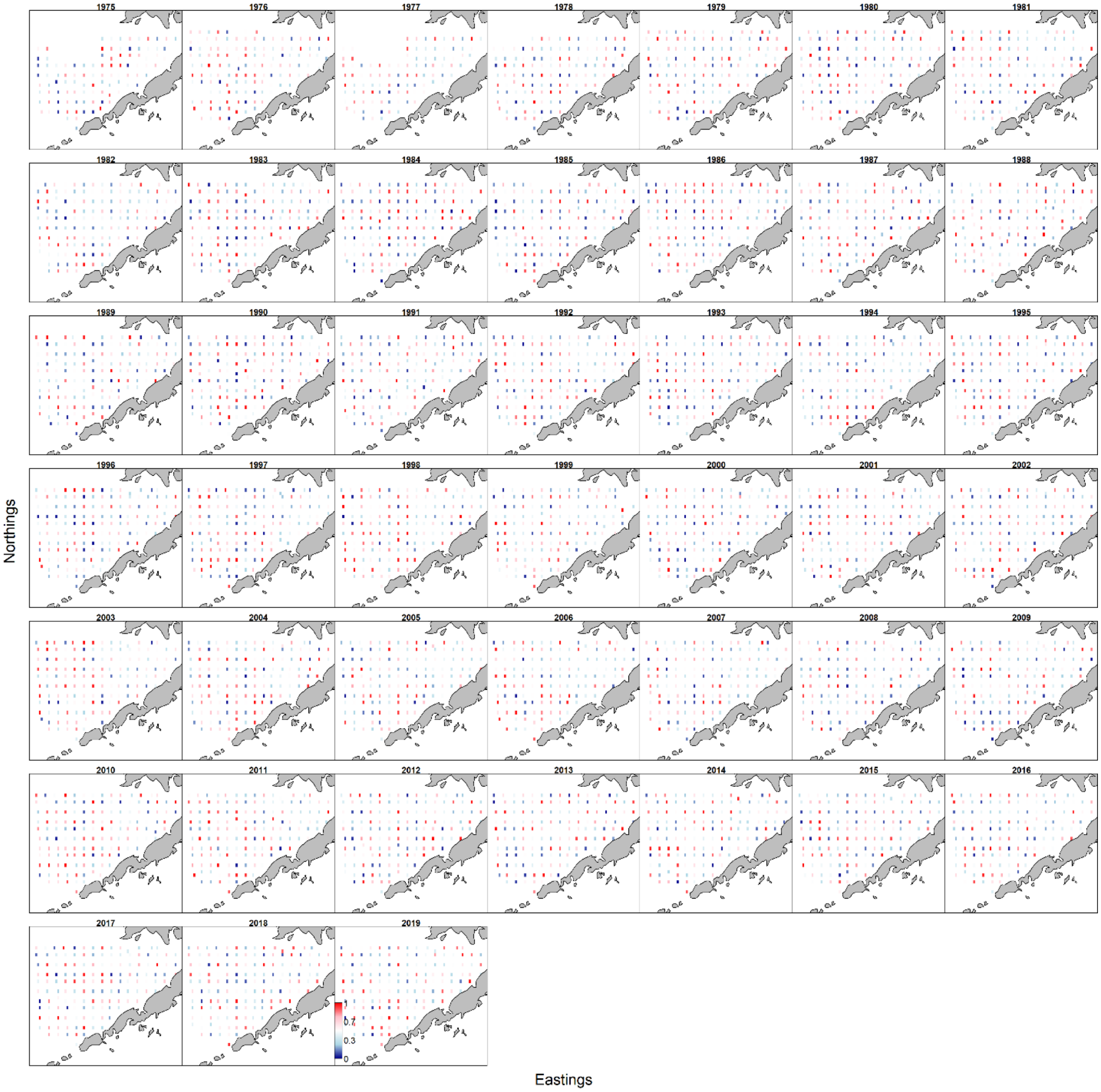


Figure E18 (file = quantile_residuals_on_map.png). Spatial quantile residuals for females GE65 mm. Mapped quantile residuals used to assess for spatial-temporal trends in residuals. While difficult to read here, an absence of notable trends may be observed at higher resolutions. Work is underway to implement code to improve this graphic, please see Figure E9 for an example.

C. Results and diagnostics for total GE65 mm.

Table E9 (extracted from parameter_estimates.txt). Model parameter estimates for total 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 
  0.43677326   0.18710855   0.54829502   0.17235147   0.81963778   0.49439896 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -0.35855266  -0.31378110  -0.09204112  -0.40514673  -0.57961487  -1.66383056 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -1.40809570  -1.78732456  -1.11514733  -1.38214691  -1.15824325  -1.62861091 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -1.95352757  -1.92301581  -2.52265776  -2.75288338  -2.60297078  -2.53035173 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -2.03379254  -1.77293178  -1.65093602  -1.39177173  -1.81340767  -2.02357425 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -1.23998442  -1.67968188  -1.66557964  -1.10576545  -1.26197607  -0.57466328 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft 
 -1.27234779  -1.71376421  -1.89174877  -1.66812545  -1.84010008  -1.25664492 
    beta1_ft     beta1_ft     beta1_ft     beta1_ft     beta1_ft   L_omega1_z 
 -1.12845900  -1.00601021  -0.85921221  -1.58563801  -1.70131456   1.48548278 
L_epsilon1_z    logkappa1     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  1.00890543  -4.36665192   4.40098145   4.73447557   4.71953602   4.68484113 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  4.93175596   4.60228232   4.21029499   4.23650101   3.82847586   4.37133805 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  3.88486157   3.85357327   4.05994729   4.23289071   4.04901240   4.57177581 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  4.56746814   4.52603655   4.82937481   4.46522311   4.53038262   4.73236058 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  4.66785284   4.54915366   4.10873769   4.23099596   4.39171184   4.63861582 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  4.14067821   4.76548445   5.08584612   4.61494732   5.00157015   4.21858149 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft 
  4.50883301   4.38801650   4.73283330   4.51147788   4.60625284   4.56997068 
    beta2_ft     beta2_ft     beta2_ft     beta2_ft     beta2_ft   L_omega2_z 
  4.49295268   4.16123810   4.20421448   4.35722994   4.38539795   0.48545691 
L_epsilon2_z    logkappa2   logSigmaM 
 -0.61385674  -3.45977764  -0.35926265 
```

Table E10 (extracted from parameter_estimates.txt). Model parameter estimate diagnostic output for total 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    0.43677362   -50  0.43677326    50  -8.597976e-09
2  ln_H_input    0.18710868   -50  0.18710855    50   8.751693e-10
3    beta1_ft    0.54827929   -50  0.54829502    50   4.760459e-11
4    beta1_ft    0.17235040   -50  0.17235147    50   4.587708e-11
5    beta1_ft    0.81965636   -50  0.81963778    50   3.157297e-11
6    beta1_ft    0.49442039   -50  0.49439896    50  -1.043610e-11
7    beta1_ft   -0.35854516   -50 -0.35855266    50   1.415312e-11
8    beta1_ft   -0.31377513   -50 -0.31378110    50   2.559020e-11
9    beta1_ft   -0.09203195   -50 -0.09204112    50   1.211653e-11
10   beta1_ft   -0.40515826   -50 -0.40514673    50   6.784440e-11
11   beta1_ft   -0.57961383   -50 -0.57961487    50   2.593126e-11
12   beta1_ft   -1.66381926   -50 -1.66383056    50  -1.858336e-11
13   beta1_ft   -1.40808852   -50 -1.40809570    50   1.607336e-11
14   beta1_ft   -1.78731605   -50 -1.78732456    50   1.014122e-11
15   beta1_ft   -1.11514222   -50 -1.11514733    50   1.630784e-11
16   beta1_ft   -1.38214218   -50 -1.38214691    50   2.212186e-11
17   beta1_ft   -1.15823712   -50 -1.15824325    50   1.974598e-11
18   beta1_ft   -1.62860092   -50 -1.62861091    50  -7.965184e-12
19   beta1_ft   -1.95353975   -50 -1.95352757    50  -3.131204e-10
20   beta1_ft   -1.92300256   -50 -1.92301581    50  -2.252110e-11
21   beta1_ft   -2.52264980   -50 -2.52265776    50  -1.291367e-11
22   beta1_ft   -2.75287439   -50 -2.75288338    50  -6.977086e-12
23   beta1_ft   -2.60295438   -50 -2.60297078    50  -4.847767e-11
24   beta1_ft   -2.53034889   -50 -2.53035173    50   1.385647e-11
25   beta1_ft   -2.03378203   -50 -2.03379254    50  -6.157741e-12
26   beta1_ft   -1.77292701   -50 -1.77293178    50   2.082690e-11
27   beta1_ft   -1.65092759   -50 -1.65093602    50   8.383516e-12
28   beta1_ft   -1.39176733   -50 -1.39177173    50   1.655742e-11
29   beta1_ft   -1.81340264   -50 -1.81340767    50   1.128697e-11
30   beta1_ft   -2.02356864   -50 -2.02357425    50   9.623857e-12
31   beta1_ft   -1.23998109   -50 -1.23998442    50   1.440981e-11
32   beta1_ft   -1.67967173   -50 -1.67968188    50   2.169820e-11
33   beta1_ft   -1.66556065   -50 -1.66557964    50  -5.094236e-11
34   beta1_ft   -1.10575082   -50 -1.10576545    50  -3.726797e-12
35   beta1_ft   -1.26196297   -50 -1.26197607    50   7.757350e-12
36   beta1_ft   -0.57464545   -50 -0.57466328    50  -2.125589e-11
37   beta1_ft   -1.27233402   -50 -1.27234779    50  -1.682121e-11
38   beta1_ft   -1.71375878   -50 -1.71376421    50   1.617195e-11
```

```
39     beta1_ft    -1.89174362   -50 -1.89174877    50  -1.006306e-11
40     beta1_ft    -1.66812166   -50 -1.66812545    50   1.604361e-11
41     beta1_ft    -1.84009411   -50 -1.84010008    50   9.063861e-12
42     beta1_ft    -1.25664125   -50 -1.25664492    50   2.242828e-11
43     beta1_ft    -1.12845190   -50 -1.12845900    50   6.816769e-12
44     beta1_ft    -1.00598923   -50 -1.00601021    50  -3.577316e-11
45     beta1_ft    -0.85919644   -50 -0.85921221    50  -3.243628e-12
46     beta1_ft    -1.58563531   -50 -1.58563801    50   2.014167e-11
47     beta1_ft    -1.70130979   -50 -1.70131456    50   9.175549e-12
48   L_omega1_z     1.48548338   -50  1.48548278    50  -3.586138e-08
49 L_epsilon1_z    1.00890614   -50  1.00890543    50   2.264434e-08
50    logkappa1    -4.36665182   -50 -4.36665192    50  -3.174932e-08
51     beta2_ft     4.40099140   -50  4.40098145    50   1.024958e-11
52     beta2_ft     4.73446957   -50  4.73447557    50   3.198810e-10
53     beta2_ft     4.71955493   -50  4.71953602    50  -5.154011e-10
54     beta2_ft     4.68484262   -50  4.68484113    50  -5.099388e-11
55     beta2_ft     4.93176019   -50  4.93175596    50  -7.858070e-11
56     beta2_ft     4.60227752   -50  4.60228232    50   3.593552e-10
57     beta2_ft     4.21030675   -50  4.21029499    50  -3.163372e-10
58     beta2_ft     4.23650814   -50  4.23650101    50  -9.772450e-11
59     beta2_ft     3.82848617   -50  3.82847586    50  -1.657128e-10
60     beta2_ft     4.37134647   -50  4.37133805    50  -2.012817e-10
61     beta2_ft     3.88487619   -50  3.88486157    50  -3.851337e-10
62     beta2_ft     3.85356909   -50  3.85357327    50   2.813163e-10
63     beta2_ft     4.05995021   -50  4.05994729    50   9.005774e-11
64     beta2_ft     4.23289750   -50  4.23289071    50  -1.068905e-10
65     beta2_ft     4.04901962   -50  4.04901240    50  -1.221689e-10
66     beta2_ft     4.57178778   -50  4.57177581    50  -2.042349e-10
67     beta2_ft     4.56747924   -50  4.56746814    50   5.318981e-10
68     beta2_ft     4.52604992   -50  4.52603655    50  -4.666472e-10
69     beta2_ft     4.82938703   -50  4.82937481    50  -2.455396e-10
70     beta2_ft     4.46522435   -50  4.46522311    50   1.497131e-10
71     beta2_ft     4.53040008   -50  4.53038262    50  -4.307434e-10
72     beta2_ft     4.73234464   -50  4.73236058    50   6.076863e-10
73     beta2_ft     4.66785179   -50  4.66785284    50   1.187459e-10
74     beta2_ft     4.54915140   -50  4.54915366    50   1.475424e-10
75     beta2_ft     4.10875137   -50  4.10873769    50  -1.811760e-10
76     beta2_ft     4.23100237   -50  4.23099596    50  -7.147882e-11
77     beta2_ft     4.39172456   -50  4.39171184    50  -1.877449e-10
78     beta2_ft     4.63862457   -50  4.63861582    50  -1.289262e-10
79     beta2_ft     4.14068722   -50  4.14067821    50  -1.351488e-10
80     beta2_ft     4.76546374   -50  4.76548445    50   7.154171e-10
81     beta2_ft     5.08588056   -50  5.08584612    50  -2.155015e-09
```

```
82    beta2_ft    4.61496308  -50  4.61494732   50  -6.560317e-10
83    beta2_ft    5.00157949  -50  5.00157015   50  -3.255085e-10
84    beta2_ft    4.21857503  -50  4.21858149   50   4.254943e-10
85    beta2_ft    4.50883858  -50  4.50883301   50   1.476863e-11
86    beta2_ft    4.38801013  -50  4.38801650   50   2.635065e-10
87    beta2_ft    4.73285249  -50  4.73283330   50  -3.754783e-10
88    beta2_ft    4.51147972  -50  4.51147788   50   1.122276e-10
89    beta2_ft    4.60625707  -50  4.60625284   50   2.724576e-11
90    beta2_ft    4.56997268  -50  4.56997068   50   1.009717e-10
91    beta2_ft    4.49296250  -50  4.49295268   50  -2.314771e-10
92    beta2_ft    4.16123304  -50  4.16123810   50   3.339302e-10
93    beta2_ft    4.20421884  -50  4.20421448   50  -1.521059e-10
94    beta2_ft    4.35722779  -50  4.35722994   50   3.761693e-10
95    beta2_ft    4.38540426  -50  4.38539795   50   1.736034e-11
96   L_omega2_z    0.48545775  -50  0.48545691   50  -2.974647e-08
97 L_epsilon2_z   -0.61385663  -50 -0.61385674   50   9.579793e-09
98   logkappa2   -3.45977963  -50 -3.45977764   50   2.510703e-08
99   logSigmaM   -0.35926334  -50 -0.35926265   50   5.326118e-08
```

Table E11 (extracted from parameter_estimates.txt). Model parameter estimates with parameter standard errors for total 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.

```
              Estimate Std. Error
ln_H_input    0.43677326 0.07125020
ln_H_input    0.18710855 0.06922590
beta1_ft      0.54829502 1.06521177
beta1_ft      0.17235147 1.03844497
beta1_ft      0.81963778 1.05499567
beta1_ft      0.49439896 1.04101278
beta1_ft     -0.35855266 1.02911677
beta1_ft     -0.31378110 1.03316275
beta1_ft     -0.09204112 1.03492621
beta1_ft     -0.40514673 1.04348530
beta1_ft     -0.57961487 1.03701595
beta1_ft     -1.66383056 1.05150023
beta1_ft     -1.40809570 1.04970992
beta1_ft     -1.78732456 1.05496242
beta1_ft     -1.11514733 1.04197956
```

```
beta1_ft     -1.38214691 1.04995339
beta1_ft     -1.15824325 1.04378422
beta1_ft     -1.62861091 1.04885595
beta1_ft     -1.95352757 1.04978080
beta1_ft     -1.92301581 1.04899738
beta1_ft     -2.52265776 1.06603223
beta1_ft     -2.75288338 1.07208896
beta1_ft     -2.60297078 1.06748590
beta1_ft     -2.53035173 1.06195500
beta1_ft     -2.03379254 1.05593722
beta1_ft     -1.77293178 1.05178834
beta1_ft     -1.65093602 1.04937519
beta1_ft     -1.39177173 1.05685647
beta1_ft     -1.81340767 1.05474695
beta1_ft     -2.02357425 1.05961781
beta1_ft     -1.23998442 1.04981667
beta1_ft     -1.67968188 1.04968985
beta1_ft     -1.66557964 1.04971036
beta1_ft     -1.10576545 1.04521784
beta1_ft     -1.26197607 1.04266897
beta1_ft     -0.57466328 1.04123777
beta1_ft     -1.27234779 1.04645734
beta1_ft     -1.71376421 1.05315626
beta1_ft     -1.89174877 1.05686101
beta1_ft     -1.66812545 1.05363784
beta1_ft     -1.84010008 1.05262940
beta1_ft     -1.25664492 1.04380201
beta1_ft     -1.12845900 1.04114926
beta1_ft     -1.00601021 1.03886168
beta1_ft     -0.85921221 1.04181062
beta1_ft     -1.58563801 1.04356583
beta1_ft     -1.70131456 1.04450095
L_omega1_z    1.48548278 0.14028785
L_epsilon1_z  1.00890543 0.04759218
logkappa1    -4.36665192 0.06735172
beta2_ft      4.40098145 0.36978347
beta2_ft      4.73447557 0.30669709
beta2_ft      4.71953602 0.33380265
beta2_ft      4.68484113 0.31147675
beta2_ft      4.93175596 0.26781540
beta2_ft      4.60228232 0.27236877
beta2_ft      4.21029499 0.28164418
beta2_ft      4.23650101 0.29997743
```

```
beta2_ft     3.82847586 0.26230395
beta2_ft     4.37133805 0.27831774
beta2_ft     3.88486157 0.30528643
beta2_ft     3.85357327 0.31035370
beta2_ft     4.05994729 0.27289567
beta2_ft     4.23289071 0.31367090
beta2_ft     4.04901240 0.27860818
beta2_ft     4.57177581 0.27073996
beta2_ft     4.56746814 0.28284895
beta2_ft     4.52603655 0.28098105
beta2_ft     4.82937481 0.30868137
beta2_ft     4.46522311 0.31411678
beta2_ft     4.53038262 0.30774403
beta2_ft     4.73236058 0.29177052
beta2_ft     4.66785284 0.30782346
beta2_ft     4.54915366 0.30490868
beta2_ft     4.10873769 0.30264172
beta2_ft     4.23099596 0.33309644
beta2_ft     4.39171184 0.30104200
beta2_ft     4.63861582 0.30324470
beta2_ft     4.14067821 0.32568258
beta2_ft     4.76548445 0.29983933
beta2_ft     5.08584612 0.29810572
beta2_ft     4.61494732 0.29704305
beta2_ft     5.00157015 0.28203320
beta2_ft     4.21858149 0.29024624
beta2_ft     4.50883301 0.29251135
beta2_ft     4.38801650 0.30436965
beta2_ft     4.73283330 0.29987888
beta2_ft     4.51147788 0.28929694
beta2_ft     4.60625284 0.28942773
beta2_ft     4.56997068 0.28169234
beta2_ft     4.49295268 0.27141072
beta2_ft     4.16123810 0.28022206
beta2_ft     4.20421448 0.28669247
beta2_ft     4.35722994 0.27178128
beta2_ft     4.38539795 0.27256156
L_omega2_z    0.48545691 0.05618568
L_epsilon2_z -0.61385674 0.04007210
logkappa2    -3.45977764 0.11475488
logSigmaM    -0.35926265 0.02454837
Maximum gradient component: 5.326118e-08
```

Table E12 (file = Table_for_SS3a.csv). Population index output. Biomass estimates for total GE65 mm, in metric tons, log-SD and SD in metric tons.

Year	Estimate metric tons	SD log	SD mt
1975	218754.39	0.1358	23271.11
1976	314111.29	0.1152	28865.53
1977	386129.11	0.1045	31892.88
1978	329878.97	0.1055	27723.90
1979	156699.97	0.1073	13620.71
1980	207590.45	0.1113	18672.42
1981	128568.60	0.1119	11563.99
1982	122784.92	0.1212	12023.72
1983	47552.03	0.1156	4445.68
1984	77405.14	0.1497	9475.66
1985	37762.70	0.1156	3521.08
1986	33697.07	0.1186	3269.71
1987	64163.18	0.1206	6275.24
1988	55005.67	0.1277	5634.27
1989	51208.71	0.1249	5137.01
1990	54859.72	0.1305	5797.54
1991	48655.55	0.1466	6050.62
1992	38260.57	0.1232	3852.48
1993	52436.90	0.1324	5693.26
1994	34174.79	0.1316	3661.82
1995	33740.79	0.1223	3394.04
1996	43935.26	0.1339	4801.85
1997	76636.25	0.1303	8126.61
1998	83045.51	0.1205	8106.89
1999	71976.39	0.1365	7922.89
2000	81405.59	0.1479	9571.48
2001	53605.54	0.1195	5176.42
2002	71258.23	0.1292	7461.41
2003	104859.91	0.1263	10741.51
2004	101626.77	0.1241	10273.17
2005	99198.04	0.1144	9302.95
2006	108514.28	0.1183	10348.81
2007	115708.62	0.1109	10352.46
2008	112276.57	0.1277	11469.91
2009	81248.65	0.1296	8415.20
2010	81562.84	0.1270	8332.95
2011	69928.79	0.1293	7323.51
2012	67635.30	0.1422	7715.65
2013	65508.40	0.1421	7464.34
2014	124659.81	0.1322	13263.56
2015	72566.87	0.1270	7419.99
2016	63672.67	0.1153	5944.26
2017	57769.97	0.1111	5184.21
2018	32083.29	0.1157	3049.00
2019	32470.03	0.1134	3019.25

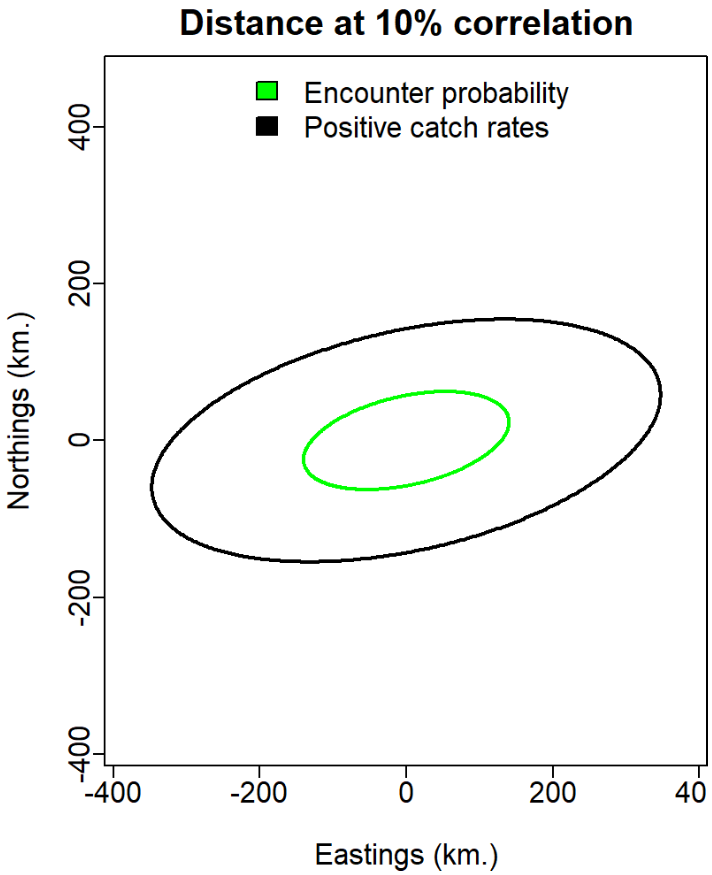


Figure E19 (file = Aniso.png). Geometric anisotropy for total GE65mm. Geometric anisotropy represents the tendency for correlations to decline faster in some directions than others. An ellipse with a major (long) axis pointed northeast-southwest will have correlations that decline slower along this axis than movement northwest-southeast.

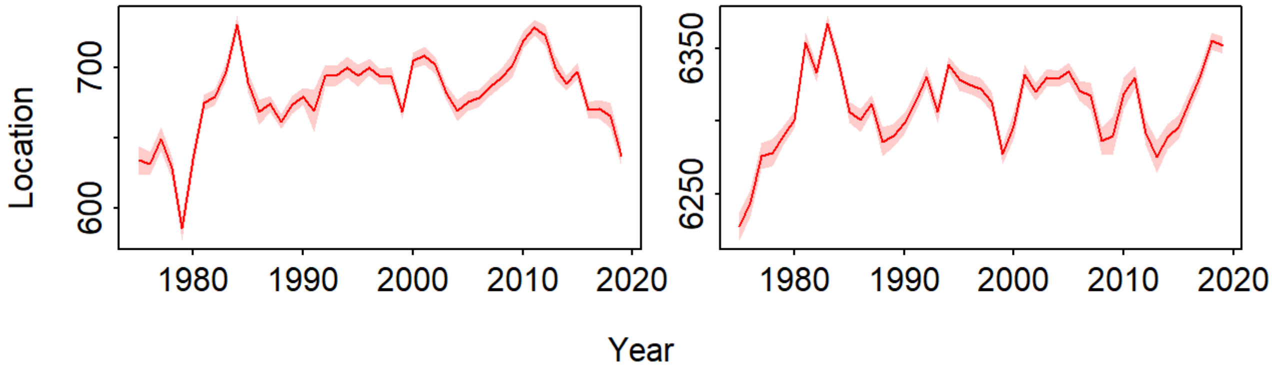


Figure E20 (file = center_of_gravity.png). Center of gravity for total GE65 mm: a.) Eastings (km) and b.) Northings (km). These figures indicate that the population has been shifting slightly to the northwest in recent years.

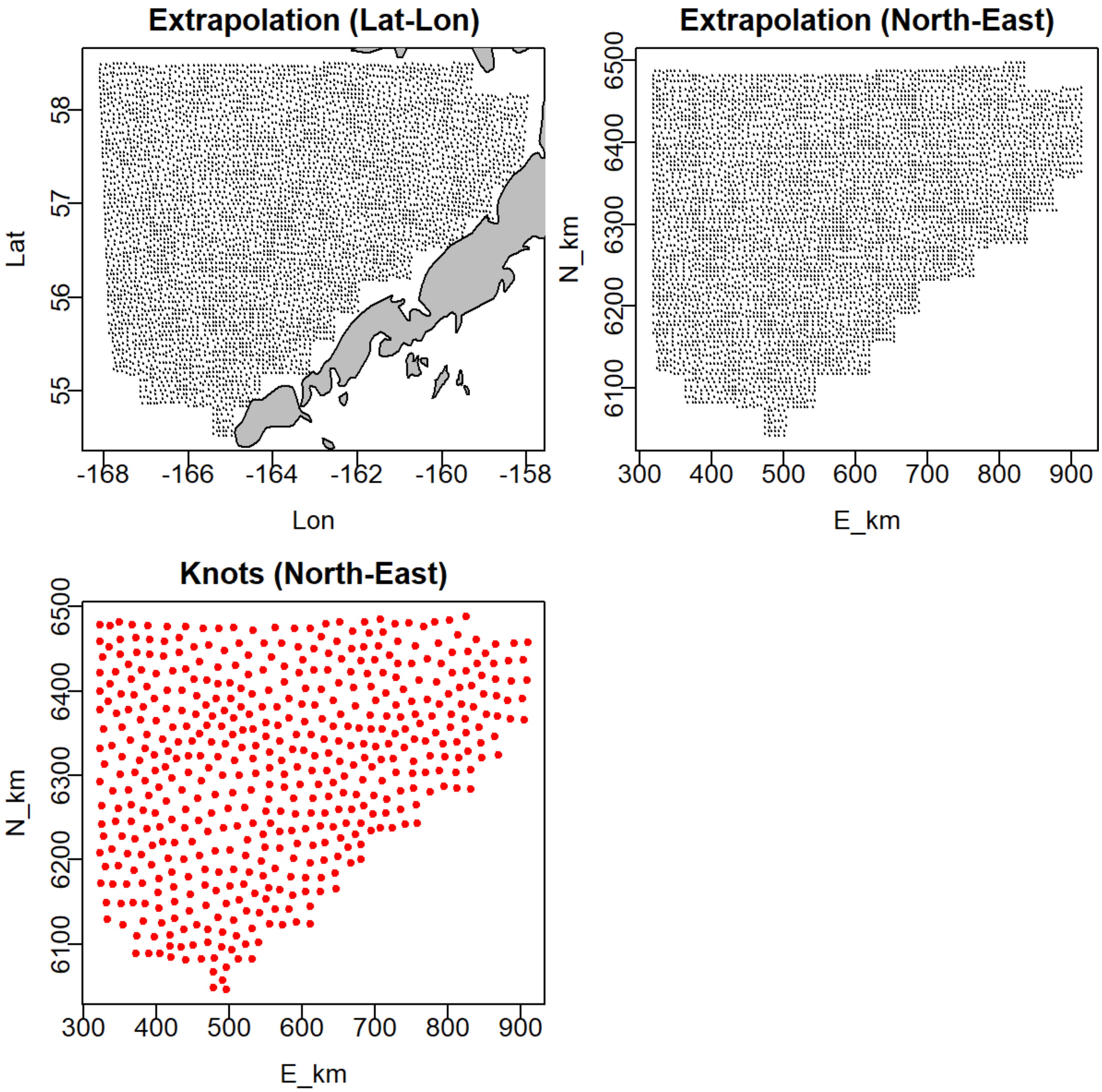


Figure E21 (file = Data_and_knots.png). Extrapolation maps for total GE65 mm: a.) Extrapolation grids by latitude and longitude, b.) Extrapolation grid by Northings/Eastings (in km), and c.) Knots used to define spatial mesh for population estimation.

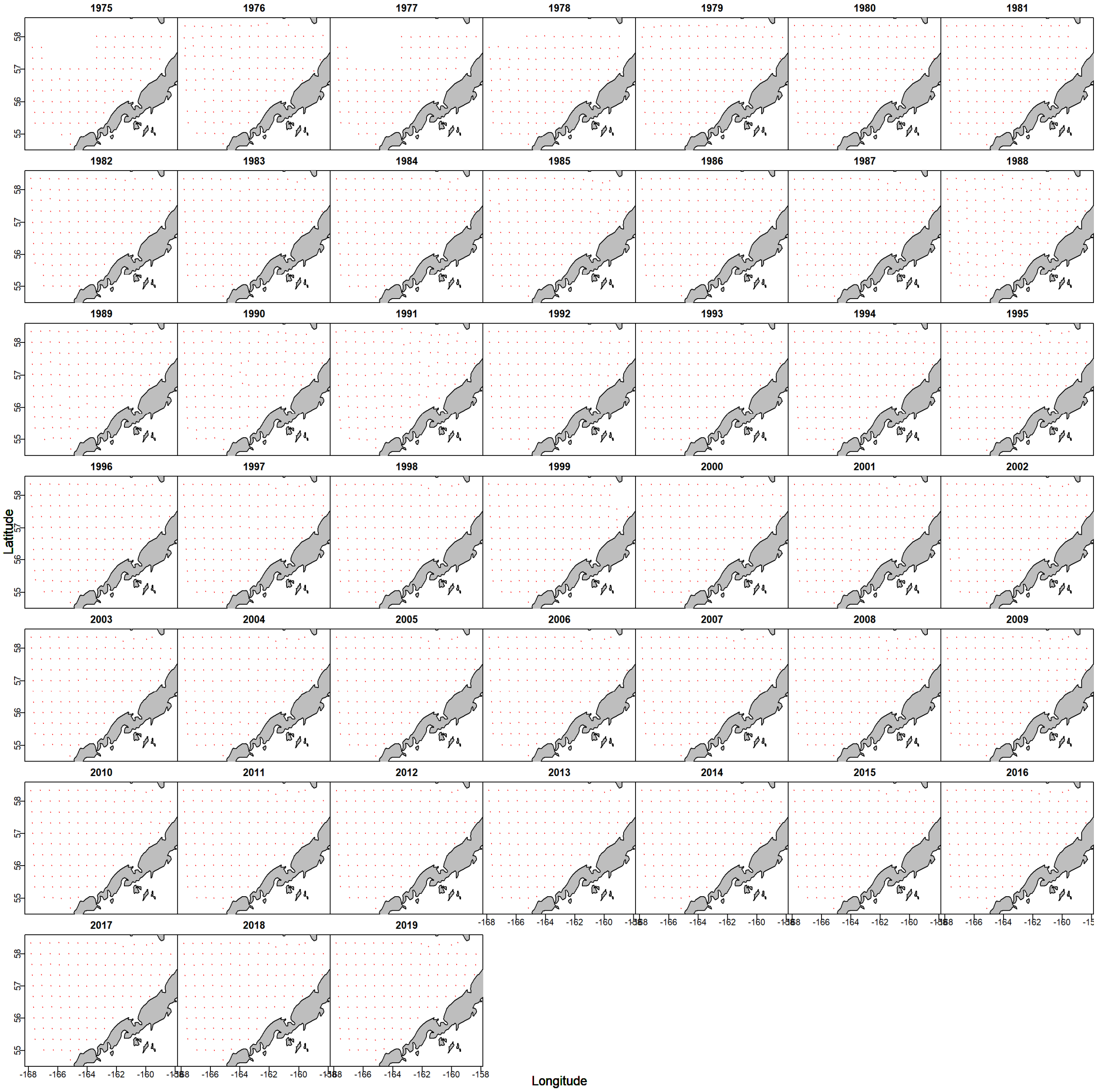


Figure E22 (file = Data_by_year.png). Data sampling locations by year for total GE65 mm. Note standardization of survey area in this subregion of the Bering Sea by 1980.

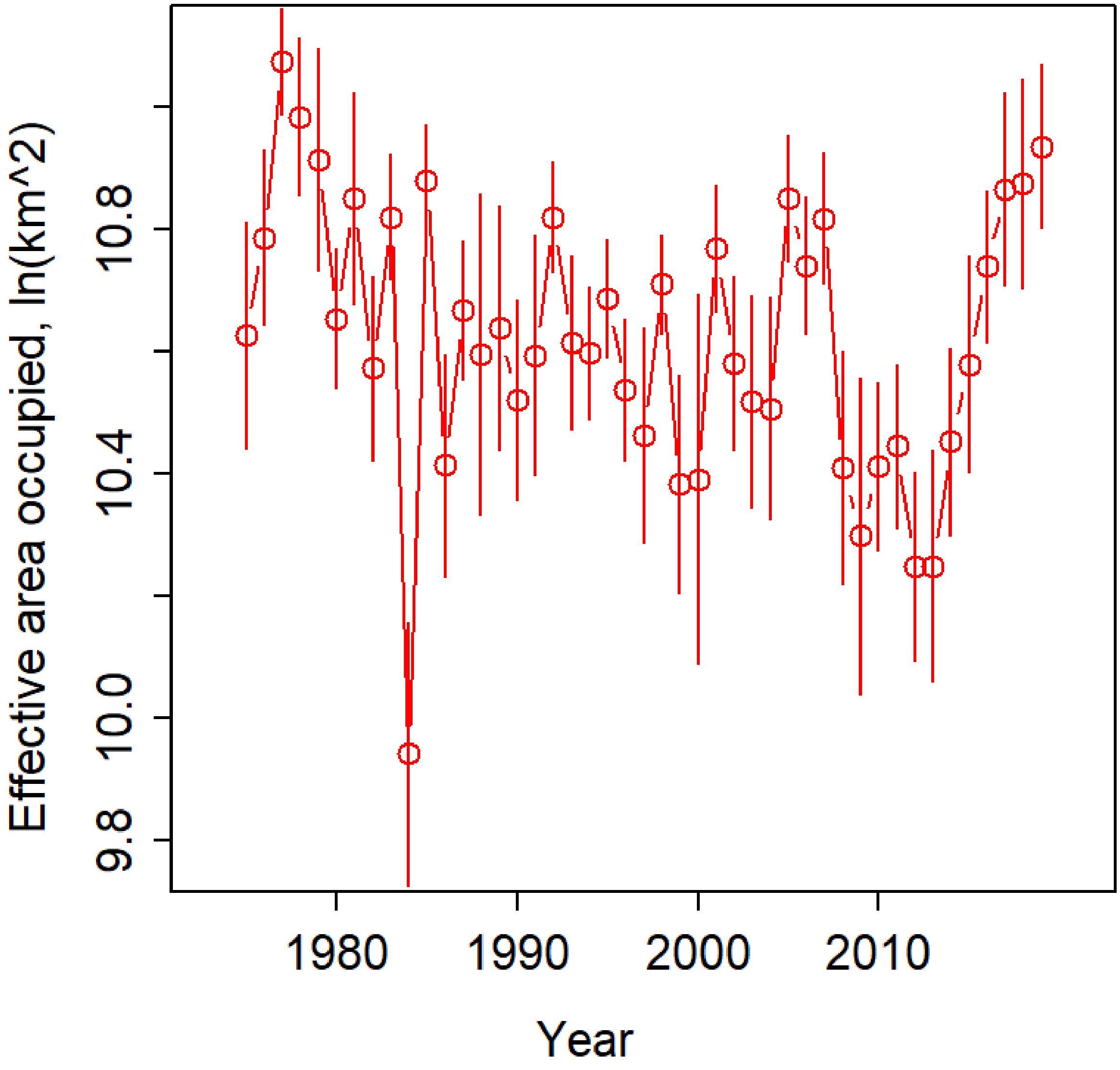


Figure E23 (file = Effective_Area.png). Effective area occupied, in ln(km2) for total GE65 mm. Note modest expansion in area occupied in recent years, despite low population sizes.

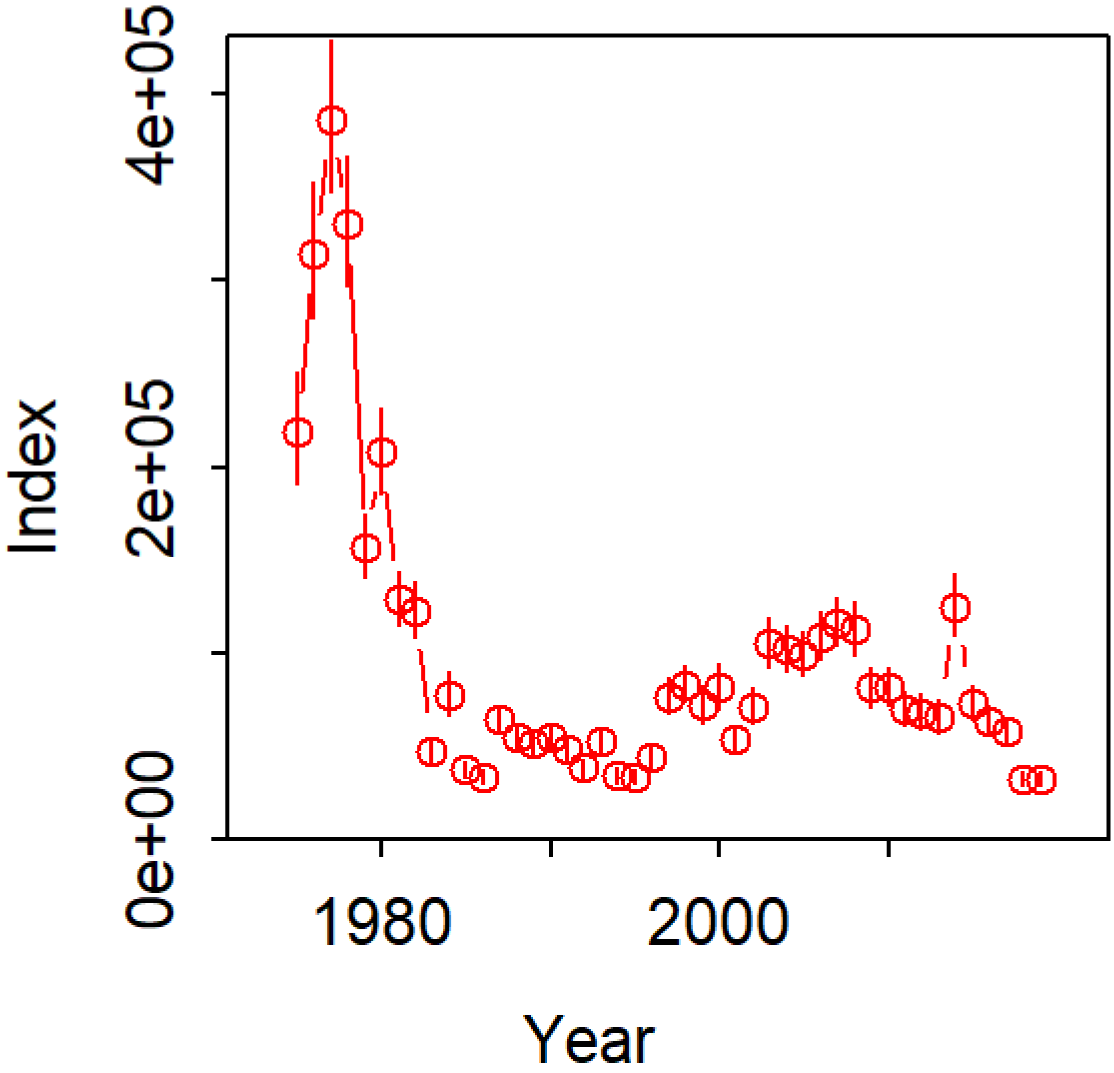


Figure E24 (file = Index-Biomass.png). Biomass estimates by year, with +/- 1SD error bars for total GE65 mm.

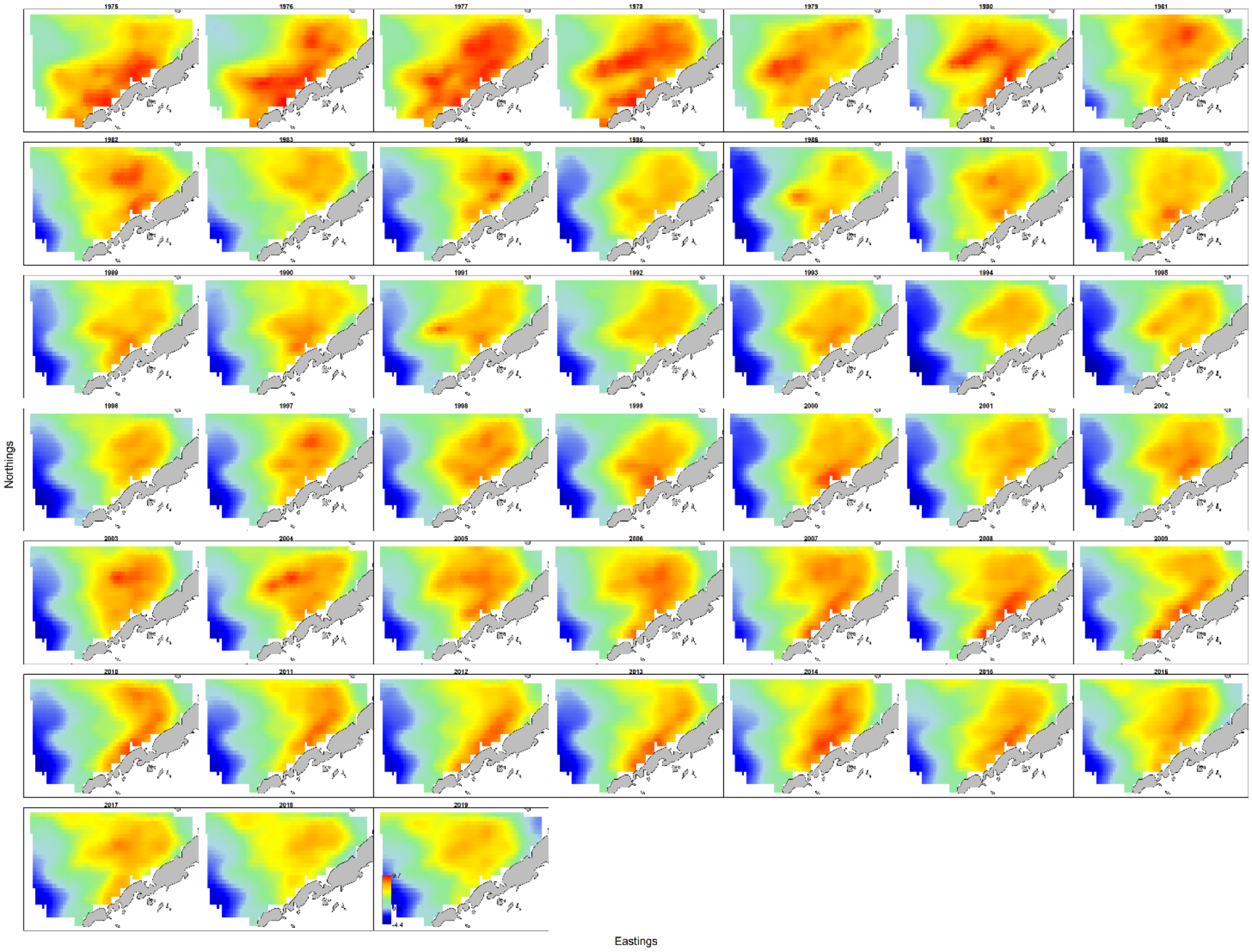


Figure E25 (file = ln_density-predicted.png). Annual log-density maps for total GE65 mm in ln(kg)/km^2.

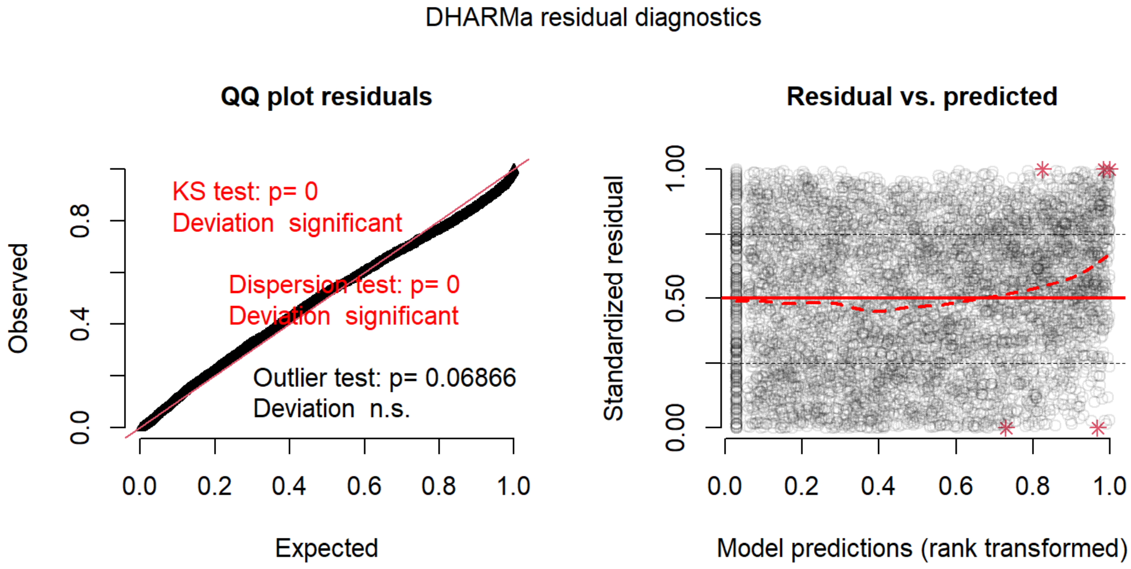


Figure E26 (file = quantile_residuals). DHARMa residual output for total GE65 mm. a.) Q-Q plot of residuals with p-values for statistical test applied automatically by DHARMa package. These p-values have no meaning here and should be ignored. This figure indicates excellent model performance. b.) Rank-transformed model predictions vs. standardized residuals. Note an indication of a trend in residuals for largest model predictions, as indicated by the dashed red line.

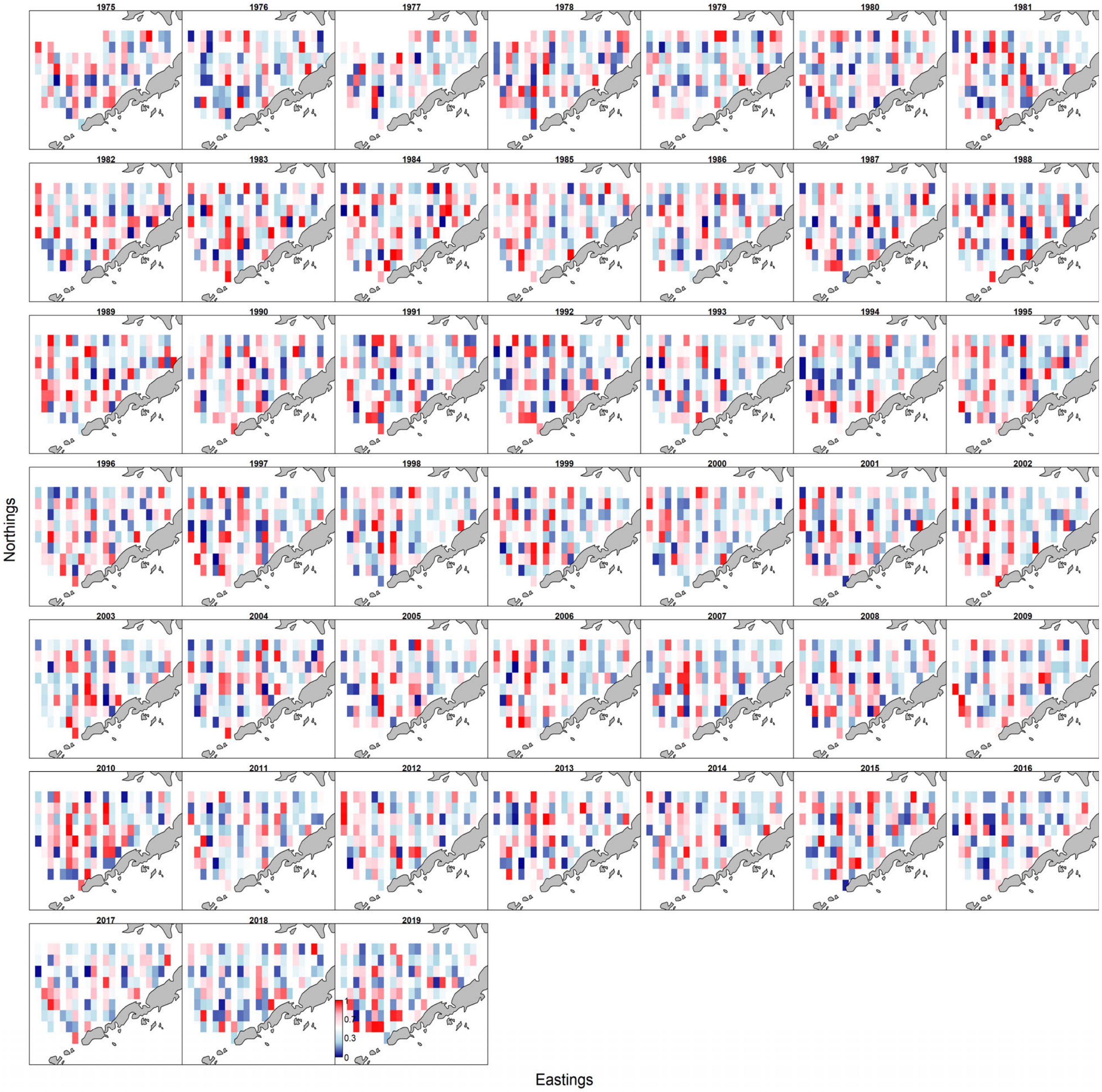


Figure E27 (file = quantile_residuals_on_map.png). Spatial quantile residuals for total GE65 mm with residual “blocks” enlarged for easier viewing. Mapped quantile residuals used to assess for spatial-temporal trends in residuals.