BRISTOL BAY RED KING CRAB STOCK ASSESSMENT IN FALL 2020

J. Zheng and M.S.M. Siddeek
Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 115526
Juneau, AK 99811-5526, USA
Phone: (907) 465-6102
Fax: (907) 465-2604
Email: jie.zheng@alaska.gov

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_{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

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).

c. Updated groundfish fisheries bycatch data during 2014-2019.

3. Changes to the assessment methodology:

a. Uncertainty of estimated management qualities without trawl survey data in 2020 is examined (Appendix D).

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

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

19.0a: the model 19.0 in September 2019 except with mean recruitment sex ratio during the reference period to estimate $B_{35\%}$. This model replaces the previous GMACS version that had the sex ratio only in the terminal year to estimate $B_{35\%}$.

19.0b: the same as model 19.0a except for fixing the recruitment in the terminal year to be the mean recruitment during the seven years prior to the terminal year.

19.3: the same as model 19.0a except for a constant *M* being estimated for males during 1980-1984, a constant *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.

19.3a: the same as model 19.3 except for fixing the recruitment in the terminal year to be the mean recruitment during the seven years prior to the terminal year.

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

19.3l: the same as model 19.3 except for adding a low trawl survey biomass for 2020 (at 25 percentile) (Appendix D).

19.3h: the same as model 19.3 except for adding a high trawl survey biomass for 2020 (at 75 percentile) (Appendix D).

4. Changes to assessment results:

The population biomass estimates in 2020 are slightly higher than those in 2019. Among the seven models, model estimated relative NMFS survey biomasses and mature biomasses are 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 are higher during recent years than the other five model scenarios. As expected, model 19.3b estimates 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 can largely be explained by different structures of *M*. All seven models fit the catch and bycatch biomasses extremely well. Among the seven models, models 19.0b and 19.3a are respectively models 19.0a and 19.3 with a reasonable terminal year recruitment estimate for potential forward projections. Model 19.3b is just a sensitivity run for a trawl survey catchability prior, and models 19.3l and 19.3h are used for examining the uncertainty without the trawl survey in 2020. Model 19.3 is the preferred model by the CPT in May 2020 and fits the data better with one less parameter than model 19.0a, thus being our preferred model for overfishing definition determination. The CPT adopted GMACS for overfishing definition determination for September 2019.

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 $B_{35\%}$.

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. 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.

"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: Will include this in May 2021.

"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. 2016)?"

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. We will examine it again in May 2021.

Response to CPT Comments (from September 2019):

"Explore the cause of the residual pattern for female fits for the largest size class in the bottom trawl survey."

Response: The patterns could be due to changes in maturities-at-size, growths, and natural mortalities. The patterns have been improved in many models in May 2020 and September 2020.

"Provide a plot of the empirical BSFRF vs. NMFS selectivity values."

Response: We plot NMFS/(NMFS+BSFRF) as well as NMFS/BSFRF in Figure 7.

"Consider a scenario with different catchabilities for males and females in the NMFS survey to address the discrepancies in the respective selectivity curves."

Response: We added model 19.5 with different catchabilities for males and females in the NMFS survey in May 2020.

"Investigate the discrepancies in historical assessment, e.g., by retrospective plots, and estimation of Mohn's rho."

Response: These have been plotted in Figures 27-29 in our SAFE report since September 2019.

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 2019):

"The SSC recommends evaluating the use of one selectivity curve for both sexes, since the selectivity is length based and the gear is the same. If the authors believe that one sex is less available to the survey, please provide evidence. If evidence exists, consider using two catchabilities (as recommended by the CPT) with one selectivity curve."

Response: This is a very good suggestion. New models 19.4, 19.4a, 19.4b and 19.5 have the same selectivity curve for both sexes in May 2020. In model 19.5, different survey catchabilities are used for each sex.

"The SSC requests that these large differences in length predictions between the models be investigated, given what appear to be similar selectivities."

Response: GMACS has been improved since September 2019, including rewriting selectivity function codes, and six out of the current eight models in May 2020 have reasonable fits to these large female length compositions. Models 19.1 and 19.2 do not fit well primarily due to *M* assumptions.

"The SSC recommends that details on the reference point calculations should be investigated and reported on for the next assessment. The SSC also requests that the addition of new data be consistently evaluated by comparing the results from the preceding year to the same model with the addition of new data. Note, these models will retain the same model number (e.g., Model 19.0 with 2019 data and Model 19.0 with 2020 data)."

Response: We found a problem of the previous GMACS version using the sex ratio of recruitment in the terminal year only 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 for the reference point calculation. Details on the reference point calculations are provided in Appendix A. In this SAFE report (September 2020) as well as past reports, we always did retrospective analysis to compare a model with different year's data. We also plot trawl survey biomass estimates under model 19.3 (2020 data) and model 19.3 (2019 data) alone for comparison (Figure 10b).

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 total actual catch 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 the directed pot fishery catch and bycatch data through 2019 (i.e., completed 2019/20 fishery).

c. 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) (Table 2). Sample sizes for catch by length and shell condition are summarized in Table 3. 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 LBA (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 1976-1993. 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 assessments. 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} over sex, 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 and is assumed to not change over time for males. 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 has 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):

19.0a: the model 19.0 in September 2019 except with mean recruitment sex ratio during the reference period to estimate $B_{35\%}$.

Basic features of this model include:

(1) Base M = 0.18yr^{-1}, with an additional mortality level during 1980-1984 for males and two additional mortality levels (one for 1980-1984 and the other for 1976-1979 and 1985-1993) for females. Additional mortalities are estimated in the model.

(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.

19.0b: the same as model 19.0a except for fixing the recruitment in the terminal year to be the mean recruitment during the seven years prior to the terminal year. This model scenario is used for forward projection if needed.

19.3: the same as model 19.0a except for a constant *M* being estimated for males during 1980-1984, a constant *M* of 0.18 for males during the other years, and an estimated constant multiplier being used to multiply male *M* to estimate *M* for females. That is, *M* for females is relative to *M* for males each year.

19.3a: the same as model 19.3 except for fixing the recruitment in the terminal year to be the mean recruitment during the seven years prior to the terminal year. These seven years have the lowest recruitment level. This model scenario is used for forward projection if needed.

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

19.3l: the same as model 19.3 except for adding a low trawl survey biomass for 2020 (25th percentile) (Appendix D).

19.3h: the same as model 19.3 except for adding a high trawl survey biomass for 2020 (75th percentile) (Appendix D).

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

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

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

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

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.

b. Tables of estimates.

i. Negative log-likelihood values and parameter estimates are summarized in Tables 4 and 5 for all seven models.

ii. Abundance and biomass time series are provided in Tables 6a and 6b for models 19.0a and 19.3.

iii. Recruitment time series for models 19.0a and 19.3 are provided in Tables 6a and 6b.

iv. Time series of catch biomass is provided in Table 1.

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 6a and 6b). 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 5a and 5b for models 19.0a and 19.3).

c. Graphs of estimates.

i. Estimated selectivities and molting probabilities by length are provided in Figures 8a and 8b and 9a and 9b for models 19.0a and 19.3.

One of the most important results is estimated trawl survey selectivity (Figures 8a and 8b). Survey selectivity affects not only the fitting of the data but also the absolute abundance estimates. Estimated survey selectivities in Figures 8a and 8b 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.

For all models, estimated molting probabilities during 1975-2020 (Figures 9a ad 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 total survey biomass and mature male and female abundances are shown for NMFS surveys (Figure 10a) and BSFRF surveys (Figure 10c). Absolute mature male biomasses are illustrated in Figure 11.

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 and 11). Absolute mature male biomasses for all models have a similar trend over time (Figure 11). Among the seven models, model estimated relative NMFS survey biomasses and mature biomasses are 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 are higher during recent years than the other 5 model scenarios. As expected, model 19.3b estimates 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 can largely be explained by different structures of natural mortality. All seven models fit the catch and bycatch biomasses very well. Among the seven models, models 19.0b and 19.3a are basically models 19.0a and 19.3 with a reasonable terminal year recruitment estimate for potential forward projections. Model 19.3b is just for a sensitivity run for trawl survey catchability prior, and models 19.3l and 19.3h are used for examining the uncertainty without the trawl survey in 2020. Model 19.3 is the preferred model by the CPT from May 2020 and fits the data better with one less parameter than model 19.0a, thus being our preferred model for overfishing definition determination.

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

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 19.0a and 19.3. 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 19.0a and 19.3.

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 2016-2017 for models 19.0a, and in 1998-1999, 2005, 2007-2010, 2014-2019 for model 19.3, but below the $F_{35\%}$ limits in the other post-1995 years.

For model 19.0a, estimated full pot fishing mortalities ranged from 0.00 to 2.87 during 1975-2019. Estimated values were greater than 0.40 during 1975-1976, 1978-1982, 1984-1987, 1990-1991, 1993, 1998 and 2007-2008 (Table 5a, Figure 13a). 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 in the same years as model 19.0a (Table 5b, Figure 13b). Estimated fishing mortalities for pot female and groundfish fisheries bycatches are generally less than 0.07.

For model 19.0a, estimated *M* values are 0.7459 during 1980-1984 and 0.18 for the other years for males, and 1.172 during 1980-1984 and 0.3124 during 1976-1979 and 1985-1993 and 0.18 for the other years for females (Figure 13c). 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). 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 19.3 (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 total survey biomass are shown in Figure 10 with a standardized residual plot in Figures 17a and 17b for models 19.0a and 19.3.

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 seven 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. Model 19.3 fits the 2019 and 2020 data almost identical (Figure 10b), partly due to lack of trawl survey data in 2020.

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 model 19.3 and showed mostly negative residuals for females during the last eight years for model 19.0a (Figures 17a and 17b). Generally, residuals of proportions of survey males and females appear to be random over length and year for models 19.0a and (Figures 25 and 26).

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. Model 19.3 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 5 for models 19.0a and 19.3. Estimated standard deviations of mature male biomass are listed in Table 6.

ii. Probabilities for mature male biomass and OFL in 2020 were illustrated in Figures 30 and 31 for model 19.3 using the MCMC approach. The confidence intervals are quite narrow.

iii. 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 abundance and mature male biomass were small among these handling mortality rates.

iv. 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 this report (September 2020), seven models are compared. The population biomass estimates in 2020 are slightly higher than those in 2019. Absolute mature male biomasses for all models have a similar trend over time (Figure 11). Among the seven models, model estimated relative NMFS survey biomasses and mature biomasses are 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 are higher during recent years than the other five model scenarios. As expected, model 19.3b estimates 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 can largely be explained by different structures of natural mortality. All seven models fit the catch and bycatch biomasses very well.

For negative likelihood value comparisons (Tables 4b and 4c), models 19.0a and 19.0b have lower likelihood values than the other models. Model 19.3b has the highest likelihood value due to reduced influence of the prior on the trawl survey catchability. Interestingly, model 19.3a with two less parameters has a slightly higher likelihood value than model 19.3, due to the recruitment sex ratio component; however, model 19.3 fits the trawl survey data slightly better. The differences are very small.

Among the seven models, models 19.0b and 19.3a are basically models 19.0a and 19.3 with a reasonable terminal year recruitment estimate for potential forward projections. Model 19.3b is just for a sensitivity run for trawl survey catchability prior, and models 19.3l and 19.3h are used for examining the uncertainty without the trawl survey in 2020. Model 19.3 is the preferred model by the CPT in May 2020 and fits the data better with one less parameter than model 19.0a, thus being our preferred model for overfishing definition determination for September 2020.

F. Calculation of the OFL and ABC

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

   The Tier 3 control rule formula is as follows:

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

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

   c) $\frac{B}{B^*} \le \beta$ $\qquad$ directed 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 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.

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 7; 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.

J. Acknowledgements

Drs. Andre Punt, James Ianelli, and D'Arcy Webber first applied BBRKC data to GMACS for stock assessments and our GMACS model mainly comes from their work. We thank the Crab Plan Team, Ben Daly, William Bechtol, Tyler Jackson, and Katie Palof for reviewing the earlier draft of this manuscript.

K. Literature Cited

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 1a. Bristol Bay red king crab annual catch and bycatch mortality biomass (t) from July 1 to June 30. A handling mortality rate of 20% for the directed pot, 25% for the Tanner fishery, 80% for trawl, and 50% or fixed gear was assumed to estimate bycatch mortality biomass. 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.

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	3.8	1.9	87.3		10.8	146.2
1995	0.0	36.4	0	36.4	3.3	1.6	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 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
	Catch	Crab/tan	Catch	Crab/tan	Catch	Crab/Potlift	Crab/tan
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 2. Total observer catch and bycatch (metric ton) of Bristol Bay red king crab. No handling mortality rates are applied.

Year	Total Males	Pot Bycatch Males	Pot Bycatch Females	Trawl Bycatch	Fixed Bycatch	Tanner 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 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.

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 4a. Number of parameters for the model (Models 19.0a, 19.0b, 19.3, 19.3a, 19.3b, 19.3l, and 19.3h). Red values indicate different values among models.

Parameter counts	**19.0a**	**19.0b**	**19.3**	**19.3a**	**19.3b**	**19.3l**	**19.3h**
Fixed growth parameters	9	9	9	9	9	9	9
Fixed recruitment parameters	2	2	2	2	2	2	2
Fixed length-weight relationship parameters	6	6	6	6	6	6	6
Fixed mortality parameters	4	4	4	4	4	4	4
Fixed survey catchability parameter	1	1	1	1	1	1	1
Fixed high grading parameters	0	0	0	0	0	0	0
Total number of fixed parameters	22	22	22	22	22	22	22
Free survey catchability parameter	1	1	1	1	1	1	1
Free growth parameters	6	6	6	6	6	6	6
Initial abundance (1975)	1	1	1	1	1	1	1
Recruitment-distribution parameters	2	2	2	2	2	2	2
Mean recruitment parameters	1	1	1	1	1	1	1
Male recruitment deviations	45	44	45	44	45	45	45
Female recruitment deviations	45	44	45	44	45	45	45
Natural mortality parameters	3	3	2	2	2	2	2
Mean & offset fishing mortality parameters	6	6	6	6	6	6	6
Pot male fishing mortality deviations	45	45	45	45	45	45	45
Bycatch mortality from the Tanner crab fishery	50	50	50	50	50	50	50
Pot female bycatch fishing mortality deviations	30	30	30	30	30	30	30
Trawl bycatch fishing mortality deviations	44	44	44	44	44	44	44
Fixed gear bycatch fishing mortality deviations	24	24	24	24	24	24	24
Initial (1975) length compositions	35	35	35	35	35	35	35
Survey extra CV	1	1	1	1	1	1	1
Free selectivity parameters	28	28	28	28	28	28	28
Total number of free parameters	367	365	366	364	366	366	366
Total number of fixed and free parameters	389	387	388	386	388	388	388

Table 4b. Negative log likelihood components for Models 19.0a, 19.0b, 19.3, 19.3a, 19.3b, 19.3l, and 19.3h and some management quantities. Highlighted cells in yellow color show prior density values and total negative likelihood values without prior density.

	Models						
	19.0a	19.0b	19.3	19.3a	19.3b	19.3l	19.3h
Pot-ret-catch	-62.15	-62.13	-59.87	-59.88	-60.83	-59.90	-59.84
Pot-totM-catch	23.63	23.71	25.90	25.90	24.03	25.78	25.97
Pot-F-discC	-52.23	-52.23	-52.21	-52.21	-52.20	-52.21	-52.21
Trawl-discC	-60.97	-60.97	-60.98	-60.98	-60.98	-60.98	-60.98
Tanner-M-discC	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54
Tanner-F-discC	-43.54	-43.54	-43.49	-43.49	-43.48	-43.49	-43.49
Fixed-discC	-33.27	-33.27	-33.27	-33.27	-33.27	-33.27	-33.27
Traw-suv-bio	-21.28	-20.05	-33.82	-33.72	-35.18	-36.61	-36.21
BSFRF-sur-bio	-6.55	-6.69	-4.80	-4.83	-3.09	-4.50	-4.97
Pot-ret-comp	-3639.55	-3639.50	-3643.89	-3643.93	-3643.96	-3643.77	-3643.96
Pot-totM-comp	-2147.56	-2147.19	-2150.62	-2150.62	-2151.87	-2150.59	-2150.64
Pot-discF-comp	-1358.90	-1358.34	-1353.14	-1353.08	-1353.04	-1353.20	-1353.11
Trawl-disc-comp	-5565.24	-5565.06	-5583.78	-5583.87	-5583.70	-5583.16	-5584.09
TC-disc-comp	-780.10	-780.35	-790.17	-790.29	-790.83	-789.98	-790.25
Fixed-disc-comp	-3163.15	-3163.84	-3168.76	-3168.87	-3167.87	-3168.68	-3168.83
Trawl-sur-comp	-6723.19	-6722.98	-6717.35	-6717.38	-6720.93	-6718.67	-6716.47
BSFRF-sur-comp	-843.49	-843.11	-851.44	-851.43	-852.66	-851.47	-851.41
Recruit-dev	61.54	62.17	67.03	67.50	67.10	67.28	66.91
Recruit-sex-R	74.99	72.73	73.72	72.08	73.71	73.73	73.73
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	51.88	51.99	44.12	44.11	44.15	44.05	44.16
Sex-specific-R	0.94	0.84	0.06	0.07	0.06	0.06	0.05
Ini-size-struct.	29.81	29.91	31.46	31.48	31.96	31.42	31.49
PriorDensity	258.01	257.81	297.16	297.53	301.13	297.94	296.55
Tot-likelihood	-24043.9	-24043.6	-24051.7	-24052.7	-24055.3	-24053.8	-24054.4
Tot-likeli-no-PD	-24301.9	-24301.4	-24348.9	-24350.2	-24356.4	-24351.7	-24351.0
Tot-parameter	367	365	366	364	366	366	366
MMB35%	25142.33	24961.21	25444.68	25438.31	24559.29	25324.34	25523.27
MMB-terminal	16561.25	16684.07	14928.39	14988.25	13463.40	14422.21	15219.53
F35%	0.295	0.295	0.291	0.291	0.288	0.290	0.291
Fofl	0.183	0.187	0.157	0.158	0.144	0.152	0.160
OFL	2763.44	2831.42	2140.72	2158.13	1766.99	1997.27	2223.67
ABC	2072.58	2123.56	1605.54	1618.60	1325.24	1497.95	1667.76
Q-1982-now	0.940	0.936	0.959	0.958	1.053	0.960	0.959

Table 4c. Differences of negative log likelihood components and some management quantities between model 19.3 and models 19.0a, 19.3b, 19.3l, and 19.3h.

	19.3 - 19.0a	19.3 - 19.3b	19.3 - 19.3l	19.3 - 19.3h
Pot-ret-catch	2.286	0.967	0.029	-0.026
Pot-totM-catch	2.275	1.870	0.124	-0.066
Pot-F-discC	0.020	-0.007	0.001	-0.001
Trawl-discC	-0.014	-0.001	0.000	0.000
Tanner-M-discC	-0.001	0.000	0.000	0.000
Tanner-F-discC	0.051	-0.010	0.002	-0.001
Fixed-discC	0.000	0.000	0.000	0.000
Traw-suv-bio	-12.544	1.354	2.786	2.391
BSFRF-sur-bio	1.758	-1.709	-0.295	0.169
Pot-ret-comp	-4.340	0.070	-0.120	0.070
Pot-totM-comp	-3.060	1.250	-0.030	0.020
Pot-discF-comp	5.760	-0.100	0.060	-0.030
Trawl-disc-comp	-18.540	-0.080	-0.620	0.310
Tanner-disc-comp	-10.071	0.661	-0.186	0.082
Fixed-disc-comp	-5.610	-0.890	-0.080	0.070
Trawl-sur-comp	5.840	3.580	1.320	-0.880
BSFRF-sur-comp	-7.949	1.221	0.032	-0.032
Recruit-dev	5.485	-0.072	-0.252	0.114
Recruit-sex-R	-1.276	0.009	-0.009	-0.010
Log_fdev=0	0.000	0.000	0.000	0.000
M-deviation	-7.757	-0.033	0.066	-0.045
Sex-specific-R	-0.881	0.002	0.003	0.015
Ini-size-structure	1.653	-0.500	0.049	-0.024
PriorDensity	39.151	-3.973	-0.787	0.605
Tot-likelihood	-7.800	3.600	2.100	2.700
Tot-like-no-PD	-46.951	7.573	2.887	2.095
Tot-parameter	-1.000	0.000	0.000	0.000
MMB35%	302.35	885.39	120.34	-78.59
MMB-terminal	-1632.86	1464.99	506.18	-291.13
F35%	-0.004	0.002	0.000	0.000
Fofl	-0.026	0.014	0.006	-0.003
OFL	-622.72	373.73	143.45	-82.95
ABC	-467.04	280.30	107.59	-62.21
Q-1982-now	0.019	-0.094	-0.001	0.000

Table 5a. Summary of estimated model parameter values and standard deviations for model 19.0a 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	92	log_fdev[1]	-0.0909	0.0545
93	log_fdev[1]	0.0275	0.0490	143	log_fdev[2]	-0.8520	0.1036
94	log_fdev[1]	0.6682	0.0405	144	log_fdev[2]	-0.7779	0.1038

95	log_fdev[1]	0.6733	0.0433	145	log_fdev[2]	-1.2343	0.1037
96	log_fdev[1]	0.1482	0.0476	146	log_fdev[2]	0.0863	0.1042
97	log_fdev[1]	0.8191	0.0517	147	log_fdev[2]	-0.1993	0.1040
98	log_fdev[1]	-4.3245	0.0493	148	log_fdev[2]	-0.9709	0.1032
99	log_fdev[1]	-4.7230	0.0425	149	log_fdev[2]	-0.2103	0.1031
100	log_fdev[1]	-0.2379	0.0413	150	log_fdev[2]	-0.5125	0.1028
101	log_fdev[1]	-0.1767	0.0419	151	log_fdev[2]	-0.6062	0.1026
102	log_fdev[1]	0.7894	0.0451	152	log_fdev[2]	-0.3762	0.1025
103	log_fdev[1]	0.3819	0.0438	153	log_fdev[2]	-0.6571	0.1024
104	log_fdev[1]	-0.2162	0.0423	154	log_fdev[2]	-0.4930	0.1021
105	log_fdev[1]	-0.3014	0.0417	155	log_fdev[2]	-0.4231	0.1022
106	log_fdev[1]	-0.1917	0.0406	156	log_fdev[2]	-0.4598	0.1025
107	log_fdev[1]	0.2737	0.0393	157	log_fdev[2]	-0.8254	0.1027
108	log_fdev[1]	0.2300	0.0393	158	log_fdev[2]	-0.9867	0.1029
109	log_fdev[1]	0.5087	0.0397	159	log_fdev[2]	-1.4550	0.1028
110	log_fdev[1]	0.2488	0.0388	160	log_fdev[2]	-1.9816	0.1032
111	log_fdev[1]	0.6134	0.0388	161	log_fdev[2]	-1.2798	0.1037
112	log_fdev[1]	0.7772	0.0409	162	log_fdev[2]	-1.8574	0.1045
113	log_fdev[1]	0.5760	0.0419	163	log_fdev[2]	-1.5055	0.1061
114	log_fdev[1]	0.4312	0.0421	164	log_fdev[2]	-1.0216	0.1086
115	log_fdev[1]	-0.2039	0.0416	165	log_fdev[2]	-0.6217	0.1119
116	log_fdev[1]	-0.2809	0.0412	166	log_fdev[2]	-0.7132	0.1150
117	log_fdev[1]	-0.1157	0.0419	167	log_fdev[2]	-0.6279	0.1185
118	log_fdev[1]	0.2040	0.0440	168	log_fdev[3]	-0.0389	0.0685
119	log_fdev[1]	0.2318	0.0486	169	log_fdev[3]	-0.0388	0.0685
120	log_fdev[1]	0.1762	0.0559	170	log_fdev[3]	1.7536	0.0685
121	log_fdev[1]	0.0390	0.0652	171	log_fdev[3]	1.4488	0.0685
122	log_fdev[1]	-0.2324	0.0743	172	log_fdev[3]	1.6753	0.0685
123	log_fdev[1]	-0.2629	0.0820	173	log_fdev[3]	2.5538	0.0685
124	log_fdev[2]	0.1418	0.1261	174	log_fdev[3]	1.4425	0.0685
125	log_fdev[2]	0.6032	0.1168	175	log_fdev[3]	1.6003	0.0685
126	log_fdev[2]	0.6008	0.1111	176	log_fdev[3]	-0.2471	0.0685
127	log_fdev[2]	0.6844	0.1094	177	log_fdev[3]	0.9278	0.0685
128	log_fdev[2]	1.3961	0.1135	178	log_fdev[3]	0.4542	0.0685
129	log_fdev[2]	1.1126	0.1313	179	log_fdev[3]	0.9392	0.0685
130	log_fdev[2]	2.3962	0.1289	180	log_fdev[3]	1.6522	0.0685
131	log_fdev[2]	2.1357	0.1170	181	log_fdev[3]	1.6600	0.0685
132	log_fdev[2]	3.3701	0.1155	182	log_fdev[3]	2.9993	0.0720
133	log_fdev[2]	2.1852	0.1123	183	log_fdev[3]	1.0492	0.0729
134	log_fdev[2]	1.1270	0.1121	184	log_fdev[3]	0.3264	0.0792
135	log_fdev[2]	0.6761	0.1096	185	log_fdev[3]	-2.9934	0.0685
136	log_fdev[2]	1.4522	0.1052	186	log_fdev[3]	-3.9508	0.0685
137	log_fdev[2]	0.0183	0.1042	187	log_fdev[3]	-3.7276	0.0685
138	log_fdev[2]	0.4656	0.1043	188	log_fdev[3]	-3.7276	0.0685
139	log_fdev[2]	0.8772	0.1056	189	log_fdev[3]	-4.6439	0.0685
140	log_fdev[2]	0.7061	0.1056	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	290	rec_dev_est	-2.0873	0.3716
241	log_fdov[1]	-1.7165	0.0787	291	rec_dev_est	-1.0340	0.2076
242	log_fdov[1]	0.3028	0.0788	292	rec_dev_est	-2.3004	0.5003
293	rec_dev_est	0.9320	0.1518	339	logit_rec_prop_es	1.4330	0.7775
294	rec_dev_est	-1.0433	0.2655	340	logit_rec_prop_es	0.6054	0.6934
295	rec_dev_est	-1.6231	0.3342	341	logit_rec_prop_es	0.4621	0.3267
296	rec_dev_est	-0.6536	0.2037	342	logit_rec_prop_es	-0.1146	0.1462
297	rec_dev_est	0.3285	0.1611	343	logit_rec_prop_es	0.2329	0.3548
298	rec_dev_est	-0.5955	0.2220	344	logit_rec_prop_es	-0.4851	0.3715

299	rec_dev_est	-0.5981	0.2419	345	logit_rec_prop_es	-0.5161	0.1317
300	rec_dev_est	0.7746	0.1599	346	logit_rec_prop_es	-0.3856	0.4374
301	rec_dev_est	-0.7101	0.2737	347	logit_rec_prop_es	-0.0832	0.4245
302	rec_dev_est	-0.6874	0.2618	348	logit_rec_prop_es	-0.4556	0.1413
303	rec_dev_est	0.5600	0.1615	349	logit_rec_prop_es	-0.0760	0.2474
304	rec_dev_est	-0.1755	0.1895	350	logit_rec_prop_es	0.1947	0.2815
305	rec_dev_est	-0.5592	0.1953	351	logit_rec_prop_es	-0.2368	0.3697
306	rec_dev_est	-1.1078	0.2414	352	logit_rec_prop_es	-0.3192	0.3748
307	rec_dev_est	-1.0323	0.2465	353	logit_rec_prop_es	-0.8485	0.1925
308	rec_dev_est	-0.0045	0.1799	354	logit_rec_prop_es	-0.3224	0.3105
309	rec_dev_est	-0.5554	0.2233	355	logit_rec_prop_es	-0.5481	0.3173
310	rec_dev_est	-0.9540	0.2248	356	logit_rec_prop_es	-0.0122	0.3469
311	rec_dev_est	-1.3618	0.2286	357	logit_rec_prop_es	-0.2385	0.4730
312	rec_dev_est	-1.9292	0.2923	358	logit_rec_prop_es	-0.1864	0.3287
313	rec_dev_est	-1.4162	0.2269	359	logit_rec_prop_es	0.2586	0.2467
314	rec_dev_est	-0.8414	0.1882	360	logit_rec_prop_es	0.6521	0.5618
315	rec_dev_est	-1.6911	0.2850	361	logit_rec_prop_es	0.4341	0.4426
316	rec_dev_est	-1.2456	0.2701	362	logit_rec_prop_es	0.7423	0.9166
317	rec_dev_est	-1.8541	0.4577	363	logit_rec_prop_es	-0.3395	1.6742
318	rec_dev_est	-0.2405	1.3063	364	m_dev_est[1]	1.6056	0.0288
319	logit_rec_prop_es	-0.1738	0.4779	365	survey_q[1]	0.9592	0.0280
320	logit_rec_prop_es	-0.7552	0.4696	366	log_add_cv[2]	-0.9615	0.2885
321	logit_rec_prop_es	-0.2946	0.3618	367	sd_rbar	16133000	521640.0
322	logit_rec_prop_es	-0.5530	0.2706	368	sd_ssbF0	72699.0	2135.600
323	logit_rec_prop_es	-0.0626	0.2743	369	sd_Bmsy	25445.0	747.4400
324	logit_rec_prop_es	0.0951	0.3784	370	sd_depl	0.5867	0.0405
325	logit_rec_prop_es	0.3407	0.1569	371	sd_fmsy	0.2907	0.0043
326	logit_rec_prop_es	0.3958	0.2409	372	sd_fmsy	0.0059	0.0006
327	logit_rec_prop_es	-0.0992	0.1810	373	sd_fmsy	0.0011	0.0001
328	logit_rec_prop_es	0.5050	0.4900	374	sd_fmsy	0.0059	0.0006
329	logit_rec_prop_es	-0.4662	0.1645	375	sd_fmsy	0.0000	0.0000
330	logit_rec_prop_es	0.2581	0.4222	376	sd_fmsy	0.0000	0.0000
331	logit_rec_prop_es	-0.0528	0.4617	377	sd_fofl	0.1572	0.0137
332	logit_rec_prop_es	0.4767	0.4221	378	sd_fofl	0.0059	0.0006
333	logit_rec_prop_es	-0.1924	0.1754	379	sd_fofl	0.0011	0.0001
334	logit_rec_prop_es	0.1362	0.2614	380	sd_fofl	0.0059	0.0006
335	logit_rec_prop_es	0.9226	0.8947	381	sd_fofl	0.0000	0.0000
336	logit_rec_prop_es	0.0337	0.2920	382	sd_fofl	0.0000	0.0000
337	logit_rec_prop_es	-0.0668	0.8645	383	sd_ofl	2140.7000	334.4400
338	logit_rec_prop_es	-0.2947	0.0904				

Table 5b. 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	92	log_fdev[1]	-0.0909	0.0545
93	log_fdev[1]	0.0275	0.0490	143	log_fdev[2]	-0.8520	0.1036
94	log_fdev[1]	0.6682	0.0405	144	log_fdev[2]	-0.7779	0.1038

95	log_fdev[1]	0.6733	0.0433	145	log_fdev[2]	-1.2343	0.1037
96	log_fdev[1]	0.1482	0.0476	146	log_fdev[2]	0.0863	0.1042
97	log_fdev[1]	0.8191	0.0517	147	log_fdev[2]	-0.1993	0.1040
98	log_fdev[1]	-4.3245	0.0493	148	log_fdev[2]	-0.9709	0.1032
99	log_fdev[1]	-4.7230	0.0425	149	log_fdev[2]	-0.2103	0.1031
100	log_fdev[1]	-0.2379	0.0413	150	log_fdev[2]	-0.5125	0.1028
101	log_fdev[1]	-0.1767	0.0419	151	log_fdev[2]	-0.6062	0.1026
102	log_fdev[1]	0.7894	0.0451	152	log_fdev[2]	-0.3762	0.1025
103	log_fdev[1]	0.3819	0.0438	153	log_fdev[2]	-0.6571	0.1024
104	log_fdev[1]	-0.2162	0.0423	154	log_fdev[2]	-0.4930	0.1021
105	log_fdev[1]	-0.3014	0.0417	155	log_fdev[2]	-0.4231	0.1022
106	log_fdev[1]	-0.1917	0.0406	156	log_fdev[2]	-0.4598	0.1025
107	log_fdev[1]	0.2737	0.0393	157	log_fdev[2]	-0.8254	0.1027
108	log_fdev[1]	0.2300	0.0393	158	log_fdev[2]	-0.9867	0.1029
109	log_fdev[1]	0.5087	0.0397	159	log_fdev[2]	-1.4550	0.1028
110	log_fdev[1]	0.2488	0.0388	160	log_fdev[2]	-1.9816	0.1032
111	log_fdev[1]	0.6134	0.0388	161	log_fdev[2]	-1.2798	0.1037
112	log_fdev[1]	0.7772	0.0409	162	log_fdev[2]	-1.8574	0.1045
113	log_fdev[1]	0.5760	0.0419	163	log_fdev[2]	-1.5055	0.1061
114	log_fdev[1]	0.4312	0.0421	164	log_fdev[2]	-1.0216	0.1086
115	log_fdev[1]	-0.2039	0.0416	165	log_fdev[2]	-0.6217	0.1119
116	log_fdev[1]	-0.2809	0.0412	166	log_fdev[2]	-0.7132	0.1150
117	log_fdev[1]	-0.1157	0.0419	167	log_fdev[2]	-0.6279	0.1185
118	log_fdev[1]	0.2040	0.0440	168	log_fdev[3]	-0.0389	0.0685
119	log_fdev[1]	0.2318	0.0486	169	log_fdev[3]	-0.0388	0.0685
120	log_fdev[1]	0.1762	0.0559	170	log_fdev[3]	1.7536	0.0685
121	log_fdev[1]	0.0390	0.0652	171	log_fdev[3]	1.4488	0.0685
122	log_fdev[1]	-0.2324	0.0743	172	log_fdev[3]	1.6753	0.0685
123	log_fdev[1]	-0.2629	0.0820	173	log_fdev[3]	2.5538	0.0685
124	log_fdev[2]	0.1418	0.1261	174	log_fdev[3]	1.4425	0.0685
125	log_fdev[2]	0.6032	0.1168	175	log_fdev[3]	1.6003	0.0685
126	log_fdev[2]	0.6008	0.1111	176	log_fdev[3]	-0.2471	0.0685
127	log_fdev[2]	0.6844	0.1094	177	log_fdev[3]	0.9278	0.0685
128	log_fdev[2]	1.3961	0.1135	178	log_fdev[3]	0.4542	0.0685
129	log_fdev[2]	1.1126	0.1313	179	log_fdev[3]	0.9392	0.0685
130	log_fdev[2]	2.3962	0.1289	180	log_fdev[3]	1.6522	0.0685
131	log_fdev[2]	2.1357	0.1170	181	log_fdev[3]	1.6600	0.0685
132	log_fdev[2]	3.3701	0.1155	182	log_fdev[3]	2.9993	0.0720
133	log_fdev[2]	2.1852	0.1123	183	log_fdev[3]	1.0492	0.0729
134	log_fdev[2]	1.1270	0.1121	184	log_fdev[3]	0.3264	0.0792
135	log_fdev[2]	0.6761	0.1096	185	log_fdev[3]	-2.9934	0.0685
136	log_fdev[2]	1.4522	0.1052	186	log_fdev[3]	-3.9508	0.0685
137	log_fdev[2]	0.0183	0.1042	187	log_fdev[3]	-3.7276	0.0685
138	log_fdev[2]	0.4656	0.1043	188	log_fdev[3]	-3.7276	0.0685
139	log_fdev[2]	0.8772	0.1056	189	log_fdev[3]	-4.6439	0.0685
140	log_fdev[2]	0.7061	0.1056	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	290	rec_dev_est	-2.0873	0.3716
241	log_fdov[1]	-1.7165	0.0787	291	rec_dev_est	-1.0340	0.2076
242	log_fdov[1]	0.3028	0.0788	292	rec_dev_est	-2.3004	0.5003
293	rec_dev_est	0.9320	0.1518	339	logit_rec_prop_es	1.4330	0.7775
294	rec_dev_est	-1.0433	0.2655	340	logit_rec_prop_es	0.6054	0.6934
295	rec_dev_est	-1.6231	0.3342	341	logit_rec_prop_es	0.4621	0.3267
296	rec_dev_est	-0.6536	0.2037	342	logit_rec_prop_es	-0.1146	0.1462
297	rec_dev_est	0.3285	0.1611	343	logit_rec_prop_es	0.2329	0.3548
298	rec_dev_est	-0.5955	0.2220	344	logit_rec_prop_es	-0.4851	0.3715

299	rec_dev_est	-0.5981	0.2419	345	logit_rec_prop_es	-0.5161	0.1317
300	rec_dev_est	0.7746	0.1599	346	logit_rec_prop_es	-0.3856	0.4374
301	rec_dev_est	-0.7101	0.2737	347	logit_rec_prop_es	-0.0832	0.4245
302	rec_dev_est	-0.6874	0.2618	348	logit_rec_prop_es	-0.4556	0.1413
303	rec_dev_est	0.5600	0.1615	349	logit_rec_prop_es	-0.0760	0.2474
304	rec_dev_est	-0.1755	0.1895	350	logit_rec_prop_es	0.1947	0.2815
305	rec_dev_est	-0.5592	0.1953	351	logit_rec_prop_es	-0.2368	0.3697
306	rec_dev_est	-1.1078	0.2414	352	logit_rec_prop_es	-0.3192	0.3748
307	rec_dev_est	-1.0323	0.2465	353	logit_rec_prop_es	-0.8485	0.1925
308	rec_dev_est	-0.0045	0.1799	354	logit_rec_prop_es	-0.3224	0.3105
309	rec_dev_est	-0.5554	0.2233	355	logit_rec_prop_es	-0.5481	0.3173
310	rec_dev_est	-0.9540	0.2248	356	logit_rec_prop_es	-0.0122	0.3469
311	rec_dev_est	-1.3618	0.2286	357	logit_rec_prop_es	-0.2385	0.4730
312	rec_dev_est	-1.9292	0.2923	358	logit_rec_prop_es	-0.1864	0.3287
313	rec_dev_est	-1.4162	0.2269	359	logit_rec_prop_es	0.2586	0.2467
314	rec_dev_est	-0.8414	0.1882	360	logit_rec_prop_es	0.6521	0.5618
315	rec_dev_est	-1.6911	0.2850	361	logit_rec_prop_es	0.4341	0.4426
316	rec_dev_est	-1.2456	0.2701	362	logit_rec_prop_es	0.7423	0.9166
317	rec_dev_est	-1.8541	0.4577	363	logit_rec_prop_es	-0.3395	1.6742
318	rec_dev_est	-0.2405	1.3063	364	m_dev_est[1]	1.6056	0.0288
319	logit_rec_prop_es	-0.1738	0.4779	365	survey_q[1]	0.9592	0.0280
320	logit_rec_prop_es	-0.7552	0.4696	366	log_add_cv[2]	-0.9615	0.2885
321	logit_rec_prop_es	-0.2946	0.3618	367	sd_rbar	16133000	521640
322	logit_rec_prop_es	-0.5530	0.2706	368	sd_ssbF0	72699.0	2135.60
323	logit_rec_prop_es	-0.0626	0.2743	369	sd_Bmsy	25445.0	747.440
324	logit_rec_prop_es	0.0951	0.3784	370	sd_depl	0.5867	0.0405
325	logit_rec_prop_es	0.3407	0.1569	371	sd_fmsy	0.2907	0.0043
326	logit_rec_prop_es	0.3958	0.2409	372	sd_fmsy	0.0059	0.0006
327	logit_rec_prop_es	-0.0992	0.1810	373	sd_fmsy	0.0011	0.0001
328	logit_rec_prop_es	0.5050	0.4900	374	sd_fmsy	0.0059	0.0006
329	logit_rec_prop_es	-0.4662	0.1645	375	sd_fmsy	0.0000	0.0000
330	logit_rec_prop_es	0.2581	0.4222	376	sd_fmsy	0.0000	0.0000
331	logit_rec_prop_es	-0.0528	0.4617	377	sd_fofl	0.1572	0.0137
332	logit_rec_prop_es	0.4767	0.4221	378	sd_fofl	0.0059	0.0006
333	logit_rec_prop_es	-0.1924	0.1754	379	sd_fofl	0.0011	0.0001
334	logit_rec_prop_es	0.1362	0.2614	380	sd_fofl	0.0059	0.0006
335	logit_rec_prop_es	0.9226	0.8947	381	sd_fofl	0.0000	0.0000
336	logit_rec_prop_es	0.0337	0.2920	382	sd_fofl	0.0000	0.0000
337	logit_rec_prop_es	-0.0668	0.8645	383	sd_ofl	2140.700	334.4400
338	logit_rec_prop_es	-0.2947	0.0904				

Table 6a. 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 analysis (model 19.0a) 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	59.824	31.215	92.553	9.555	58.594		248.677	202.731
1976	68.579	37.909	106.416	8.908	100.154	76.287	290.527	331.868
1977	73.255	42.679	115.195	7.524	125.875	48.646	302.138	375.661
1978	76.379	45.716	116.397	5.794	120.830	65.402	293.370	349.545
1979	65.788	44.991	92.239	3.980	108.793	115.358	270.123	167.627
1980	46.636	34.415	25.805	1.563	105.213	134.085	241.483	249.322
1981	13.368	7.387	5.145	0.855	47.721	63.839	97.474	132.669
1982	5.883	1.820	5.799	0.782	22.102	183.294	57.006	143.740
1983	5.857	2.034	7.493	0.663	13.924	86.260	51.731	49.320
1984	6.062	2.433	5.719	0.506	13.405	72.749	49.328	155.312
1985	8.088	2.094	10.729	0.750	10.751	11.824	37.416	34.535
1986	12.931	4.990	16.517	1.117	15.488	36.908	48.489	48.158
1987	15.153	7.135	21.972	1.335	18.964	11.309	54.502	70.263
1988	15.108	8.916	26.534	1.386	23.315	7.405	57.188	55.372
1989	16.101	10.128	29.168	1.319	20.984	6.872	58.417	55.941
1990	15.479	10.733	25.099	1.234	17.291	23.484	57.063	60.321
1991	11.917	8.891	19.279	1.157	15.592	11.005	50.829	85.055
1992	9.532	6.679	17.893	1.105	15.987	2.876	44.857	37.687
1993	10.518	6.287	16.053	1.147	13.477	7.534	42.823	53.703
1994	10.167	5.955	21.482	1.226	10.519	2.505	37.024	32.335
1995	10.549	7.689	24.259	1.203	10.436	48.931	42.900	38.396
1996	10.615	8.240	22.253	1.134	15.001	7.606	52.092	44.649
1997	9.823	7.325	20.477	1.102	22.353	4.023	58.159	85.277
1998	15.429	7.117	23.323	1.327	20.545	11.426	62.526	85.176
1999	16.628	9.125	27.396	1.514	18.140	27.734	61.594	65.604
2000	14.404	10.189	27.831	1.516	19.616	11.335	63.927	68.102
2001	14.162	9.876	28.252	1.483	22.355	12.120	68.102	53.188
2002	16.914	10.037	32.202	1.515	22.610	41.904	73.568	69.786
2003	17.932	11.608	32.023	1.496	27.359	10.072	80.213	116.794
2004	16.268	11.321	29.821	1.426	33.334	10.177	82.398	131.910
2005	18.415	10.639	30.879	1.420	32.206	37.840	84.577	107.341
2006	17.644	11.387	31.638	1.401	33.678	16.686	86.182	95.676
2007	16.043	11.263	26.972	1.332	38.705	12.550	89.508	104.841
2008	16.779	9.718	26.327	1.403	37.383	6.747	87.662	114.430
2009	16.961	9.906	27.918	1.510	34.371	7.862	83.287	91.673
2010	15.886	10.368	27.557	1.507	31.285	20.681	79.648	81.642
2011	13.583	9.921	27.373	1.437	31.169	12.733	76.660	67.053
2012	12.260	9.403	25.955	1.360	33.395	7.941	76.409	61.248
2013	12.323	8.704	25.253	1.321	32.456	5.753	75.007	62.410
2014	12.405	8.536	23.881	1.319	29.870	3.258	71.455	114.103
2015	11.132	8.099	21.576	1.330	26.593	5.697	65.526	64.240
2016	9.515	7.229	19.033	1.352	23.537	10.641	59.572	61.231
2017	7.879	6.259	16.525	1.357	21.796	4.455	54.975	52.922
2018	7.070	5.327	15.365	1.387	20.335	7.204	51.678	28.932
2019	7.856	5.047	16.287	1.542	18.337	4.619	49.595	28.744
2020	8.222	5.540	16.561	1.185	16.969	57.313		

Table 6b. 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 analysis (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 7. 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

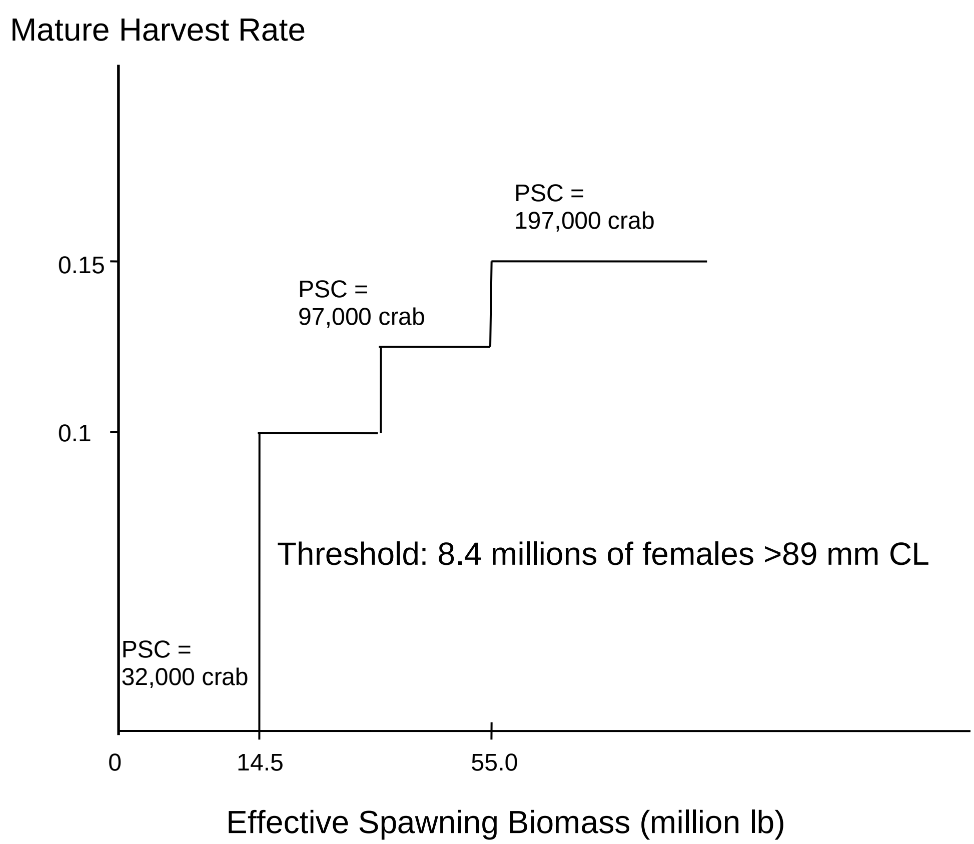


Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crab) of Bristol Bay red king crab in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of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

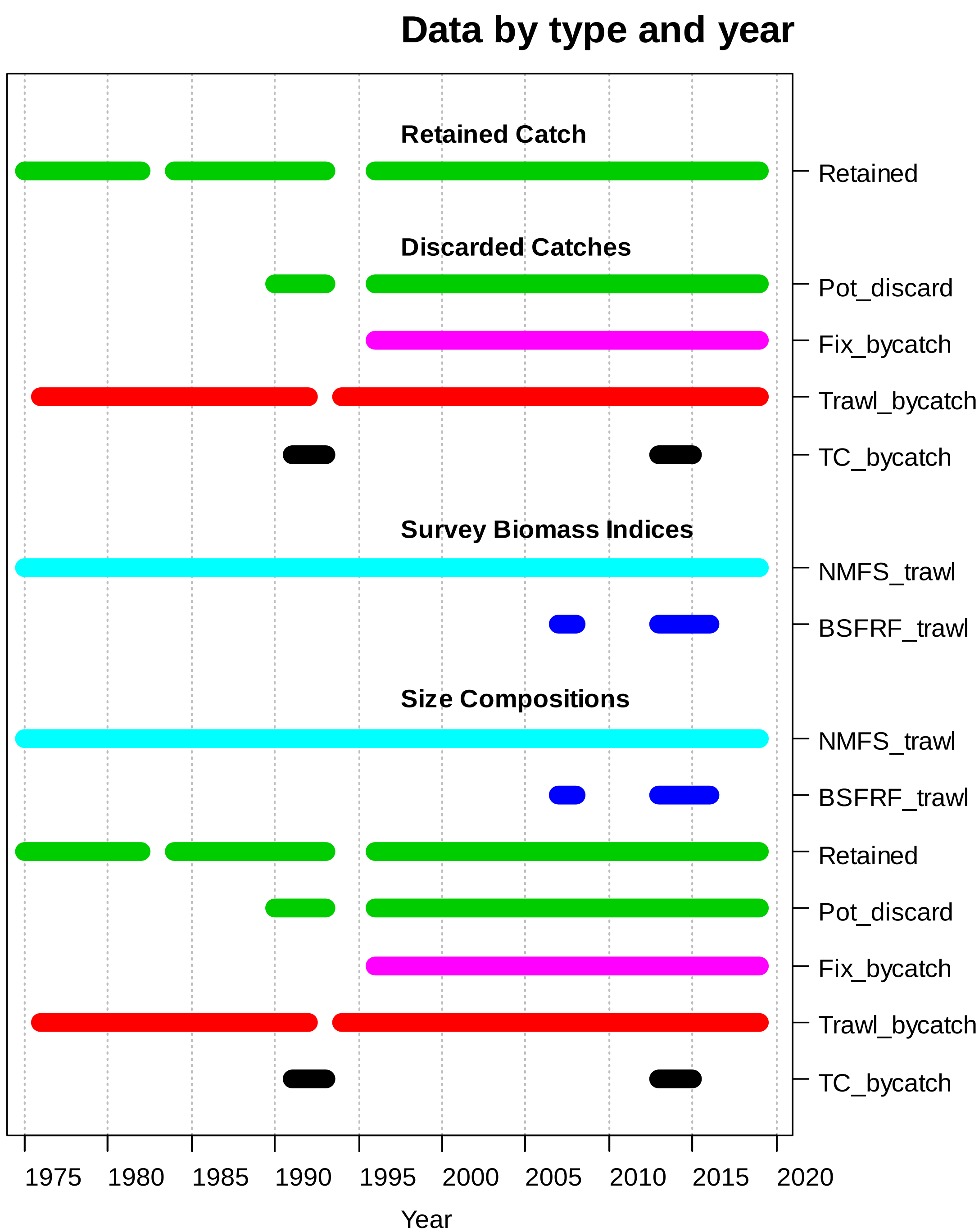


Figure 2. Data types and ranges used for the stock assessment.

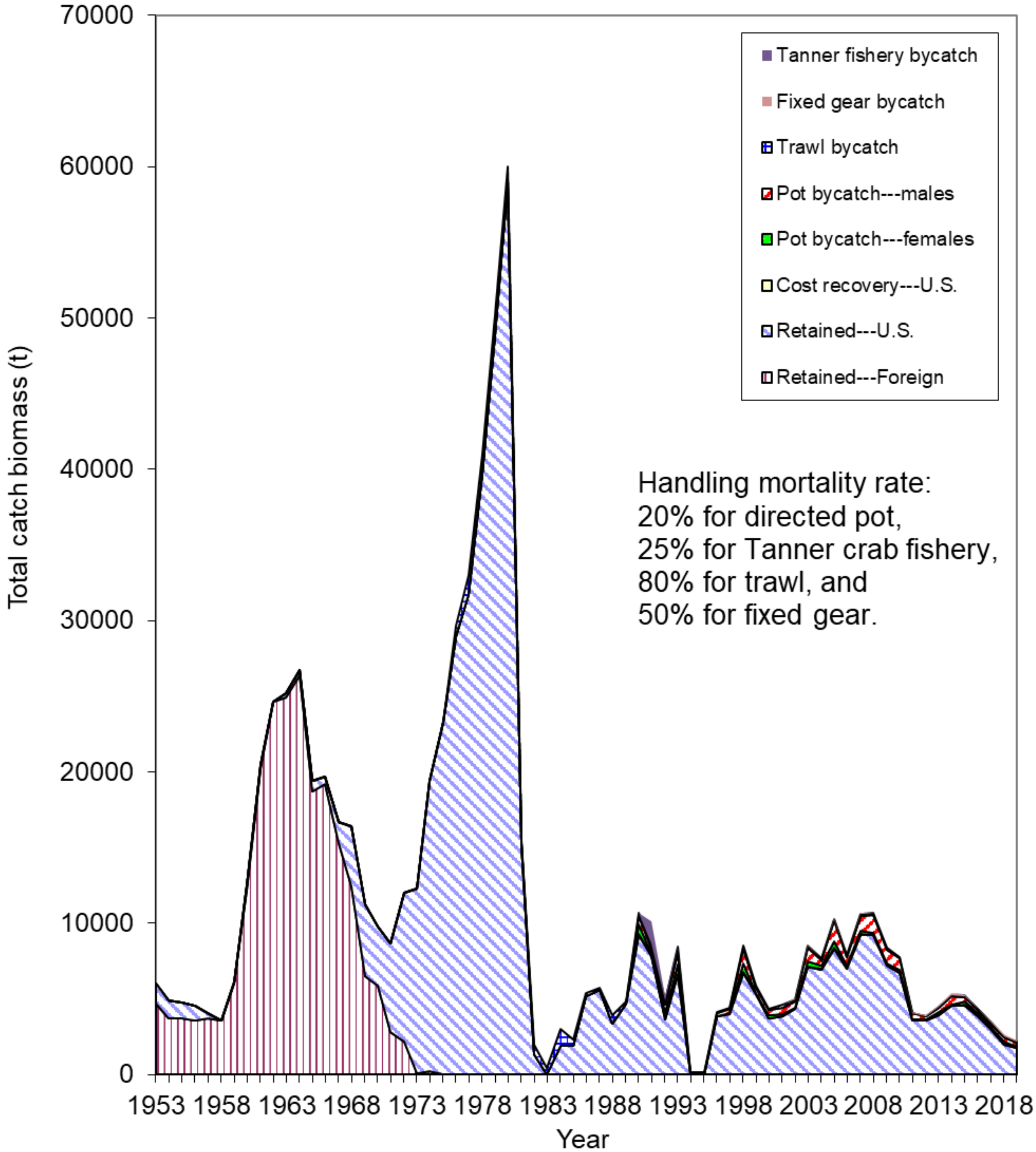


Figure 3. Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1953 to 2019. Directed pot bycatch data were not available from the observer program before 1990 and are not included in this figure.

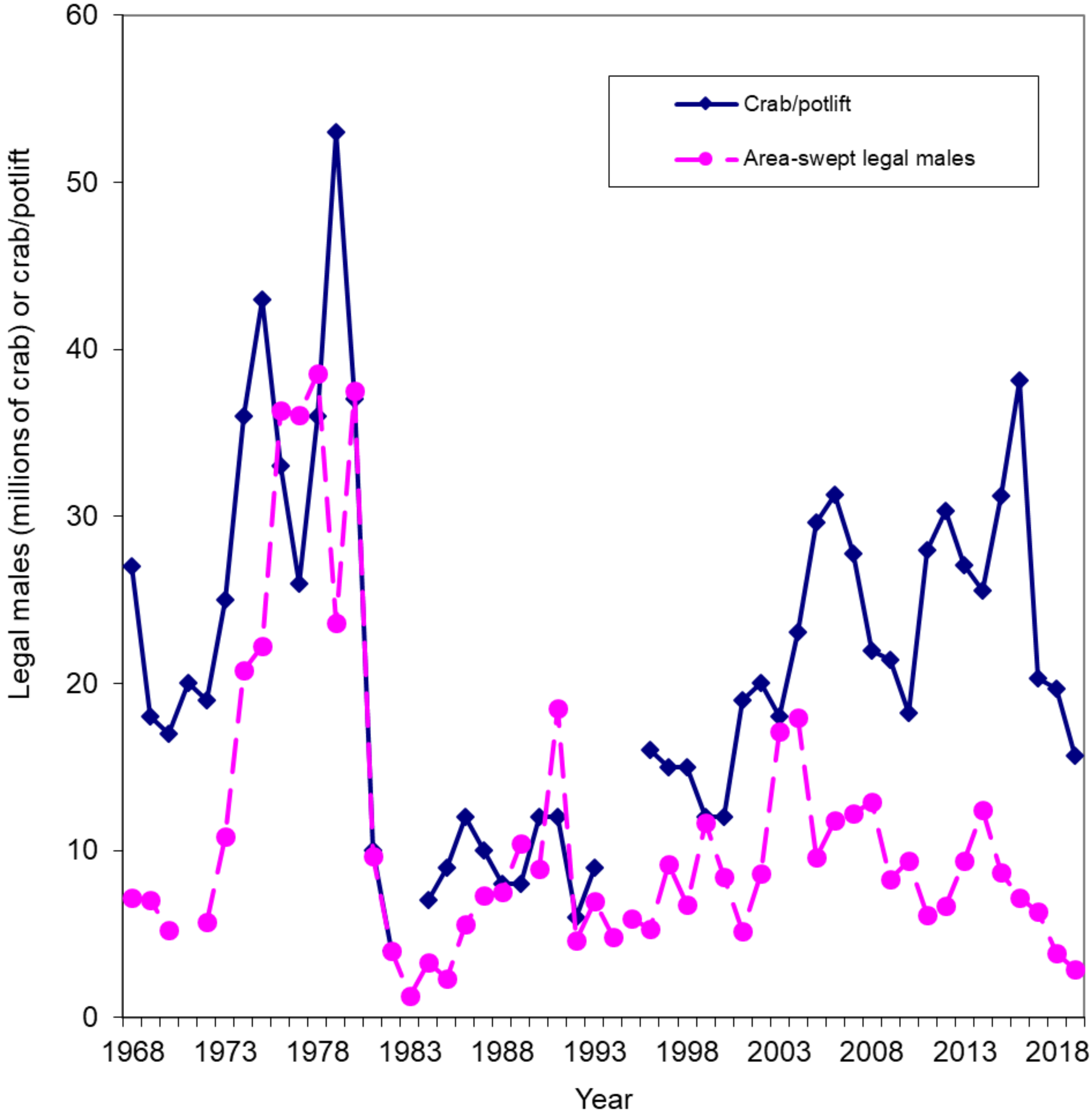


Figure 4. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2019.

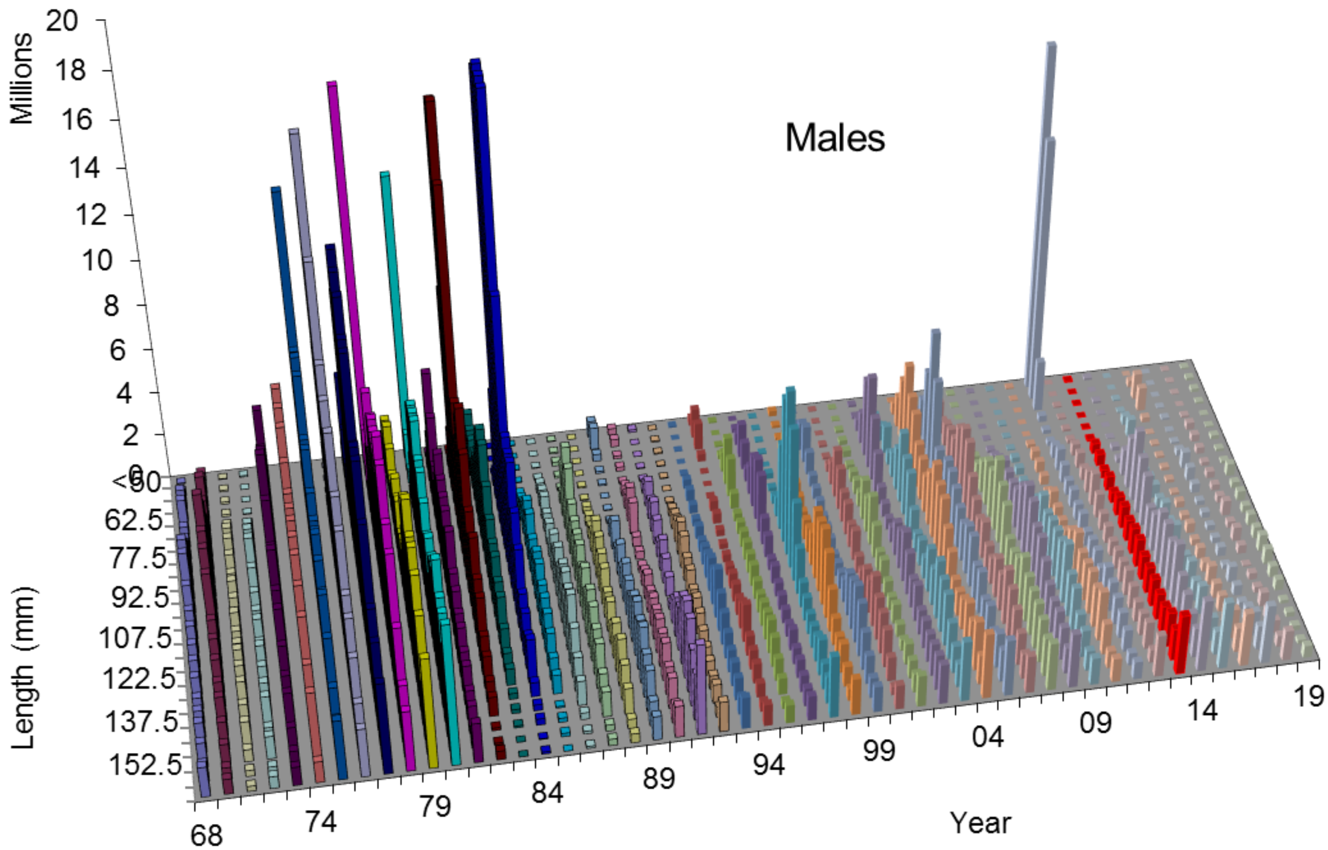


Figure 5a. Survey abundances by 5-mm carapace length bin for male Bristol Bay red king crab from 1968 to 2019.

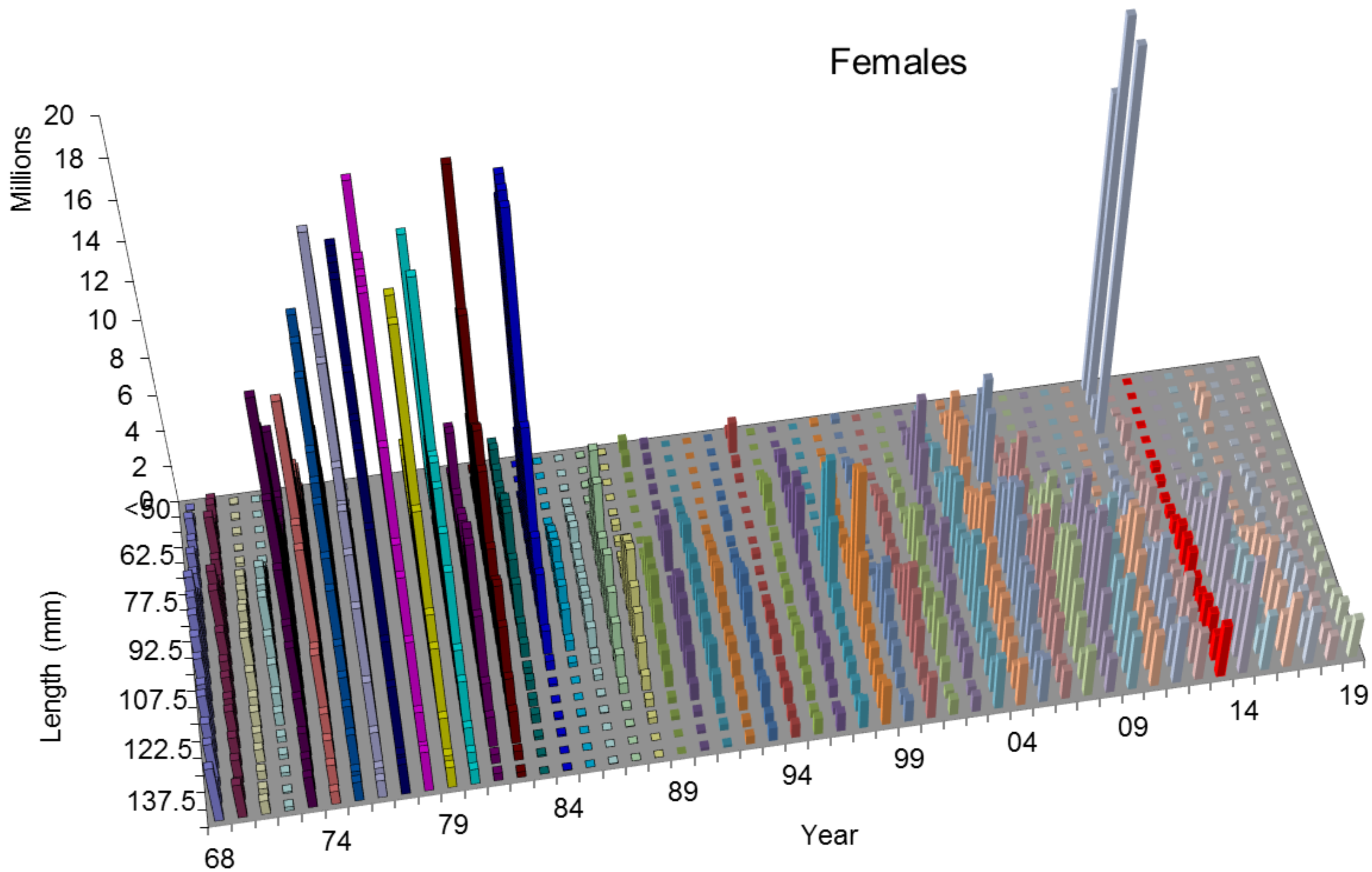


Figure 5b. Survey abundances by 5 mm carapace length bin for female Bristol Bay red king crab from 1968 to 2019.

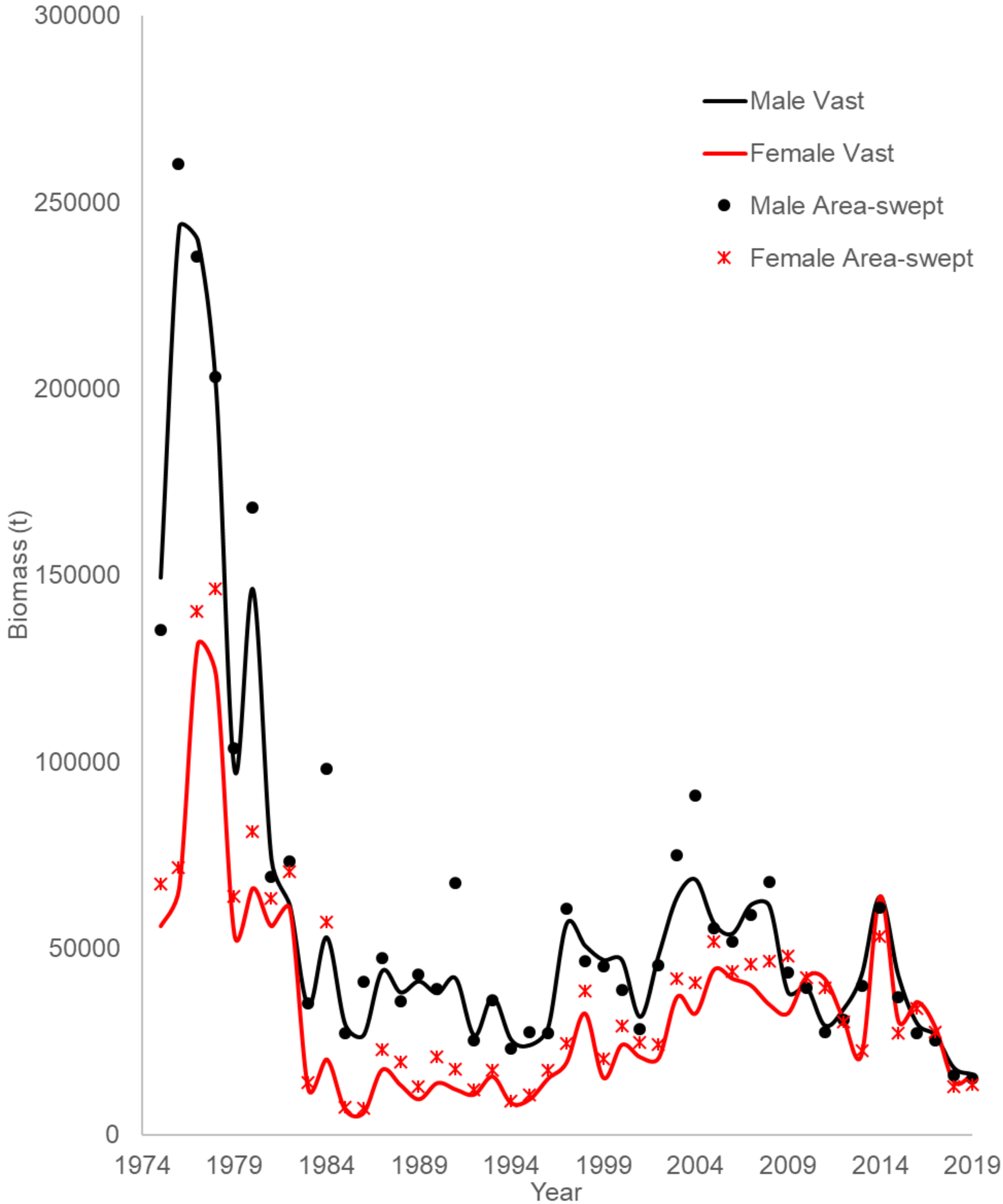


Figure 6. Comparison of area-swept and VAST-estimated survey biomasses for Bristol Bay red king crab from 1975 to 2019.

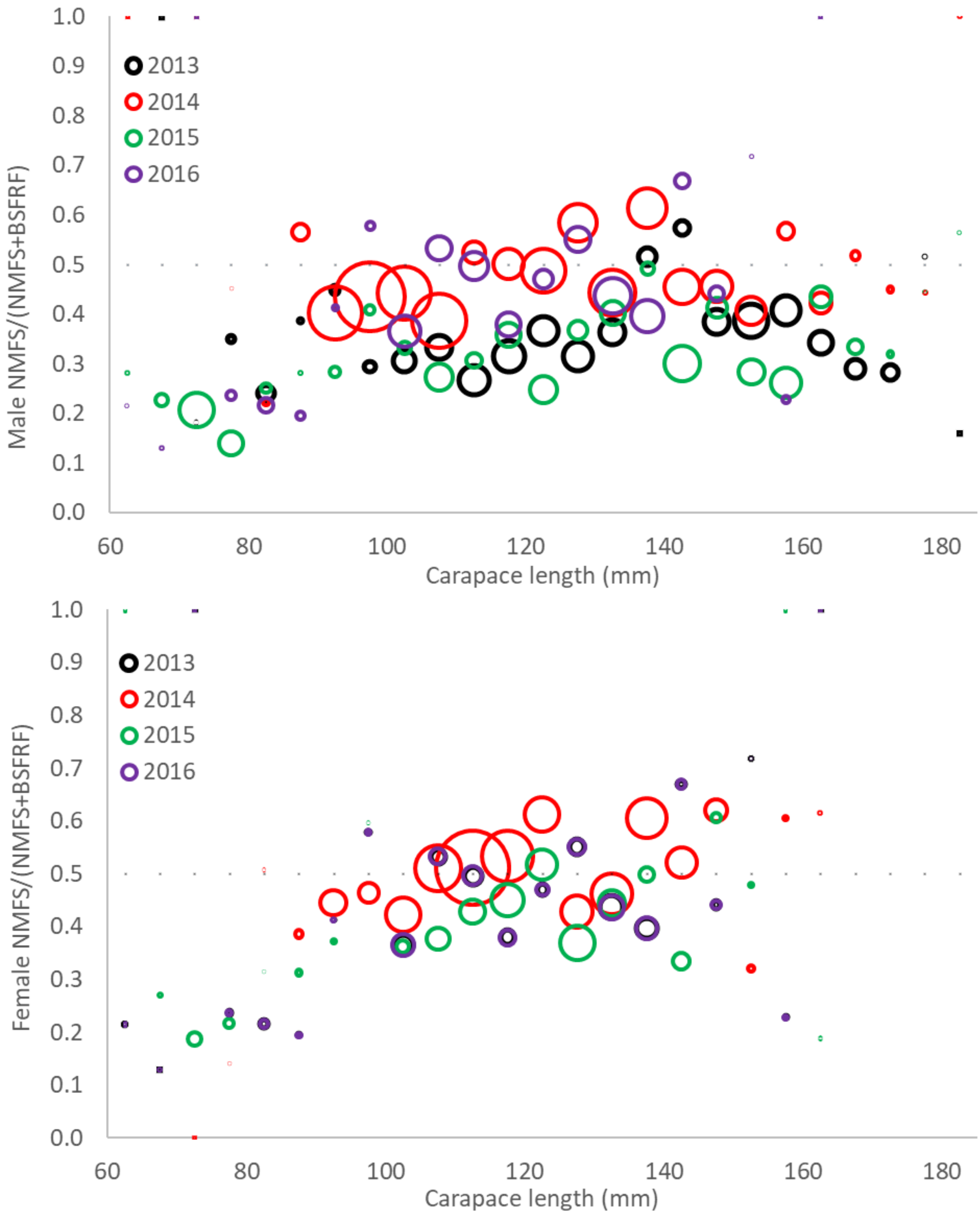


Figure 7a. Comparison of NMFS survey abundance proportions of total NMFS and BSFRF side-by-side trawl surveys during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

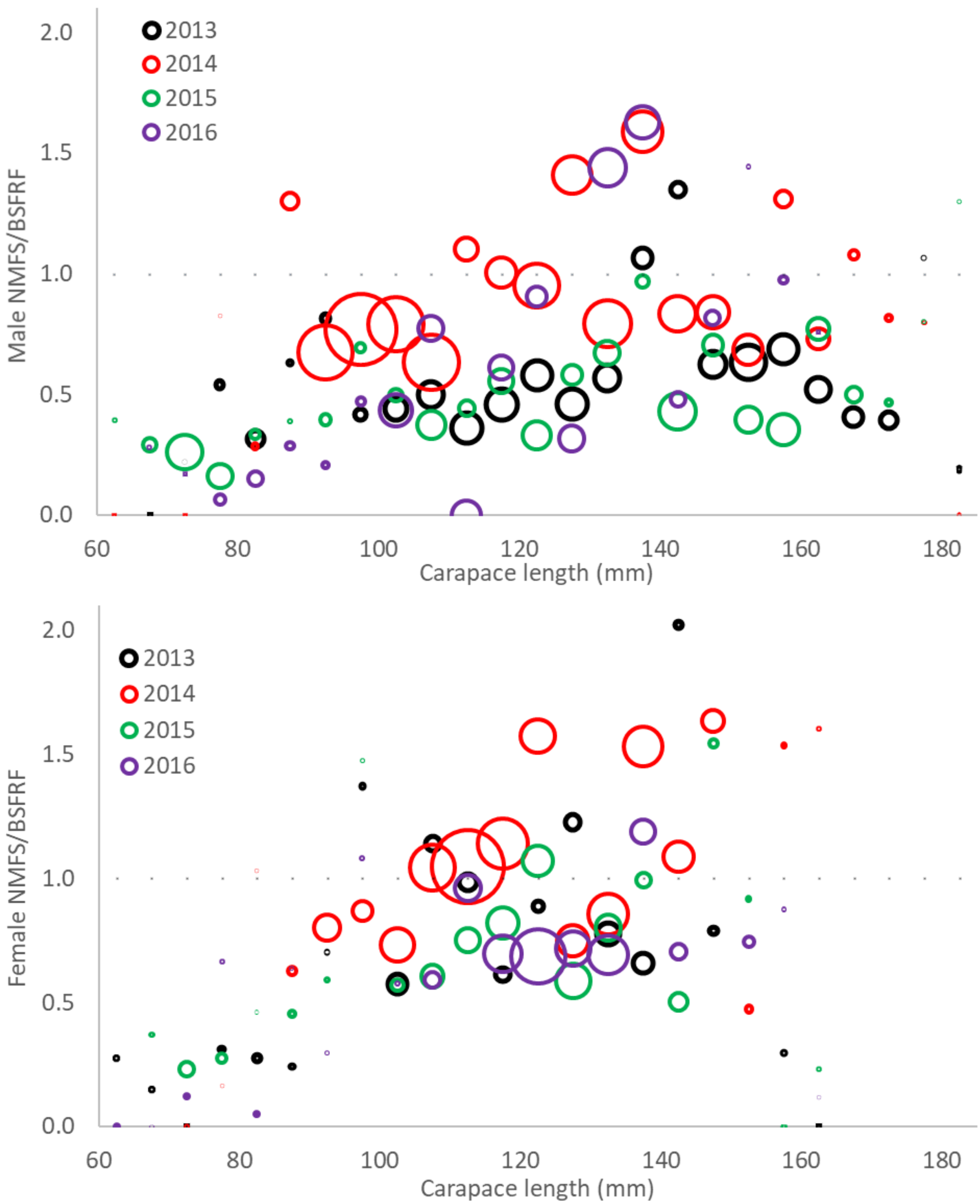


Figure 7b. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances.

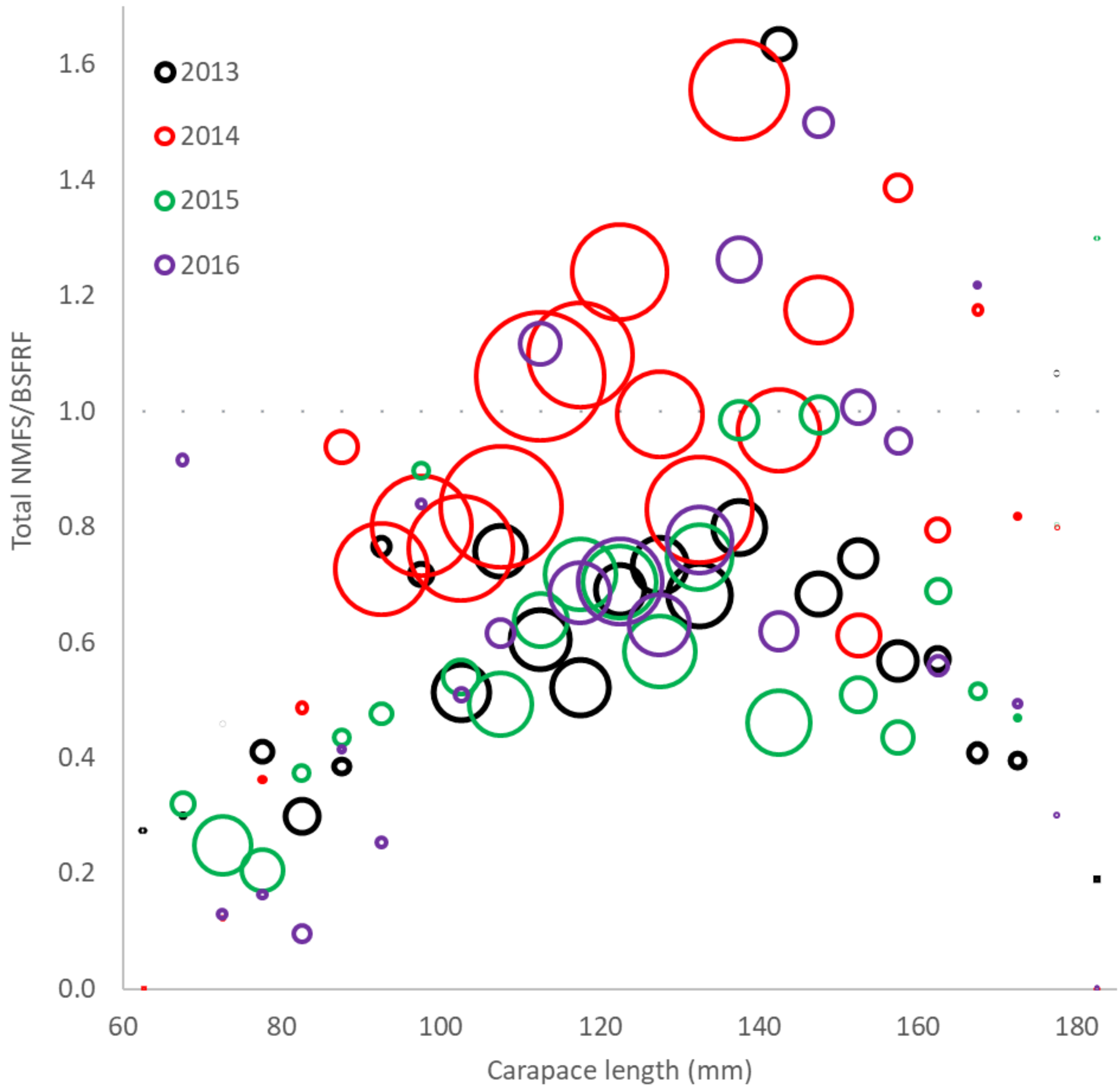


Figure 7c. Comparison of ratios of NMFS survey abundances to BSFRF side-by-side survey abundances during 2013-2016 for Bristol Bay red king crab. Sizes of circles are proportional to total abundances. The abundance-weighted average ratio is 0.891 for crab ≥135 mm carapace length from all four years of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

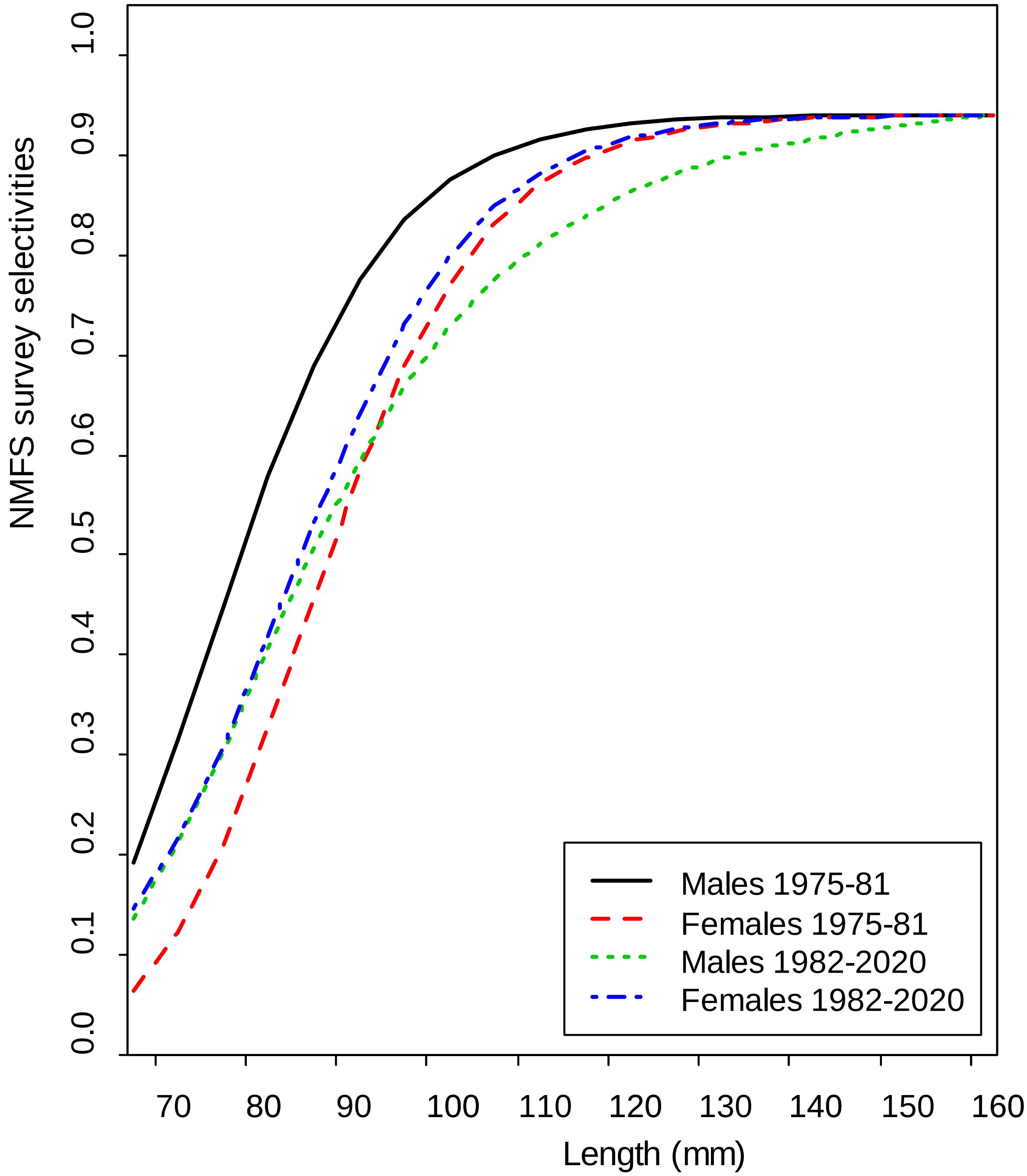


Figure 8a. Estimated NMFS trawl survey selectivities under model 19.0a.

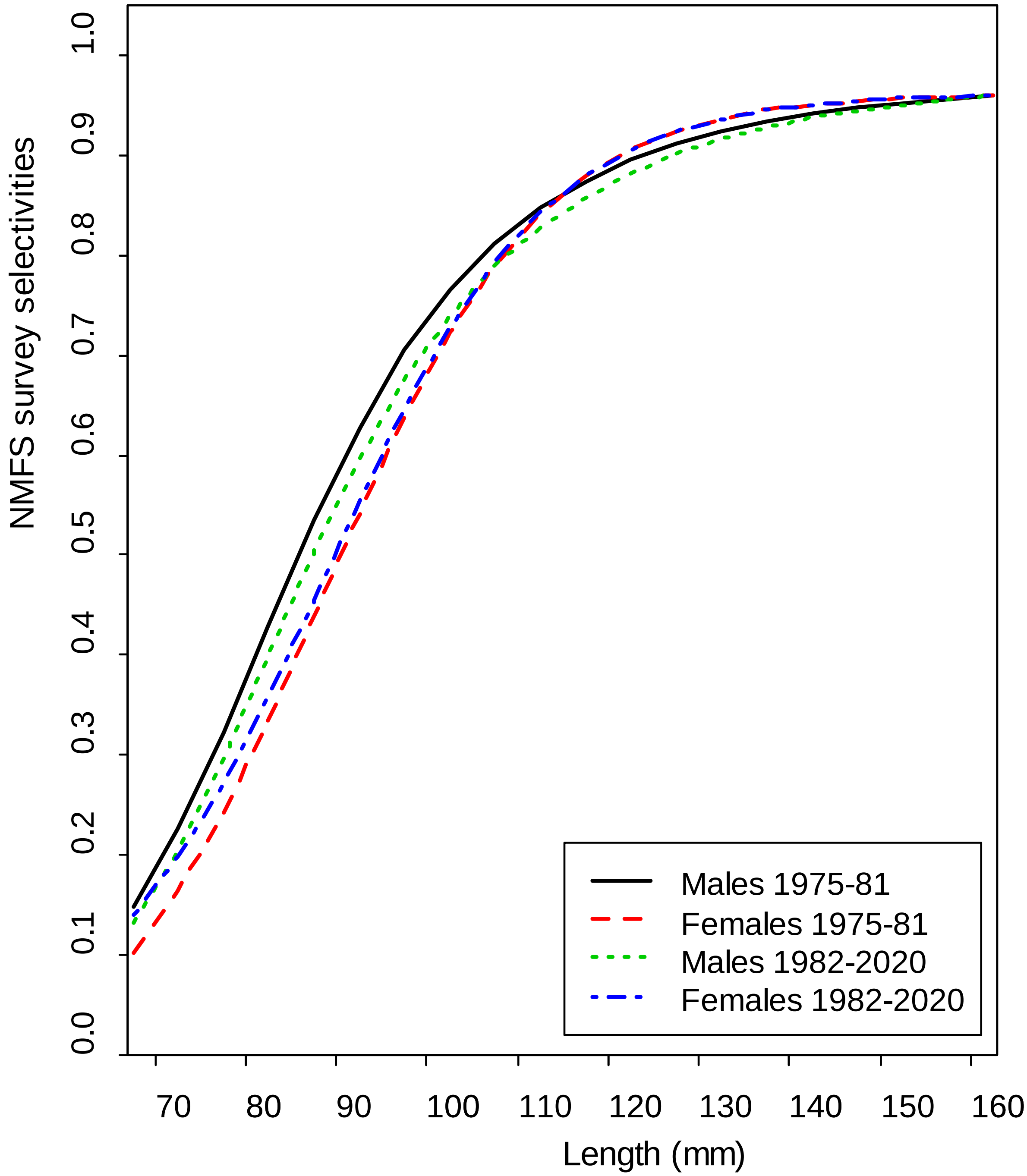


Figure 8b. Estimated NMFS trawl survey selectivities under model 19.3.

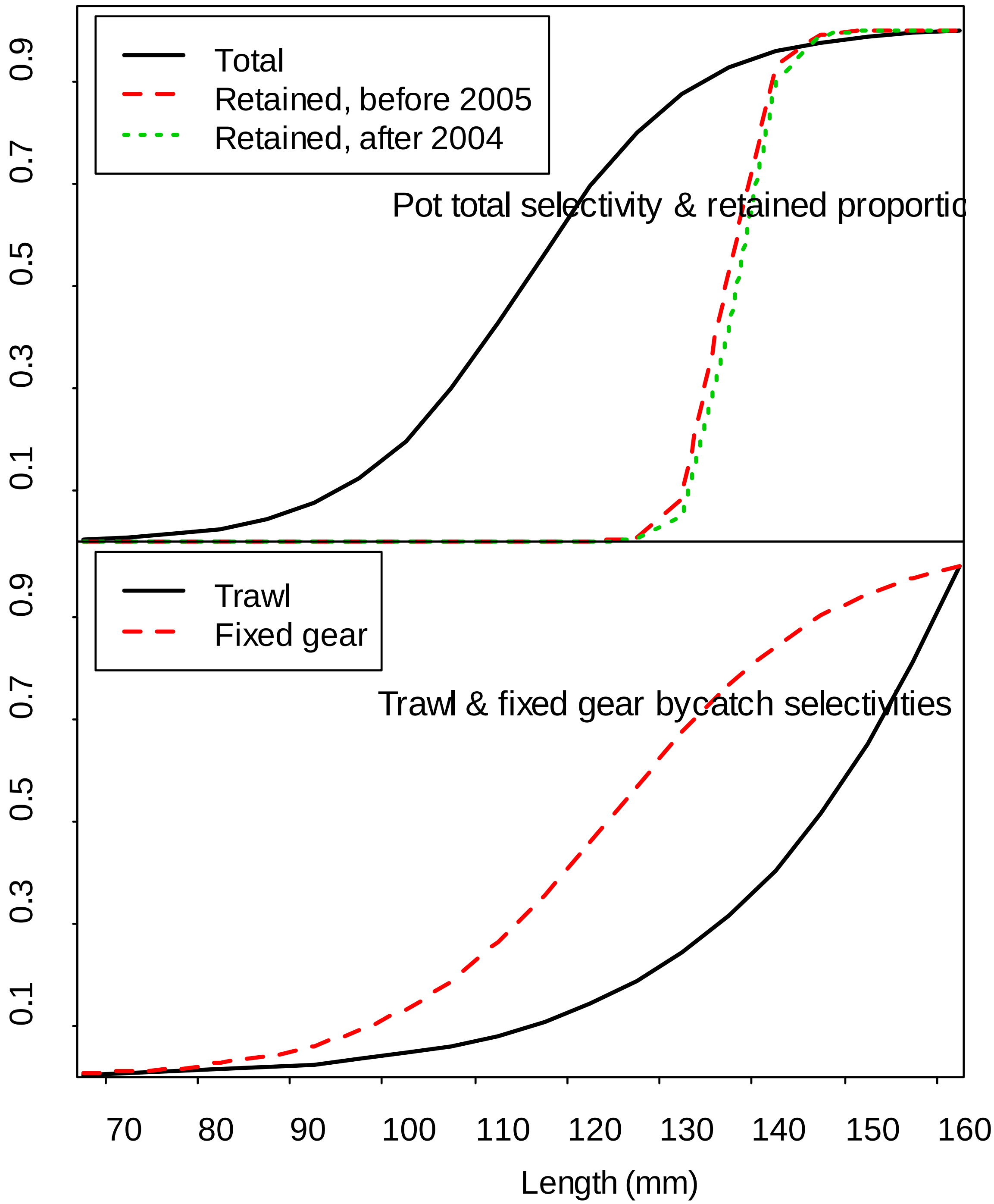


Figure 8c. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 19.0a.

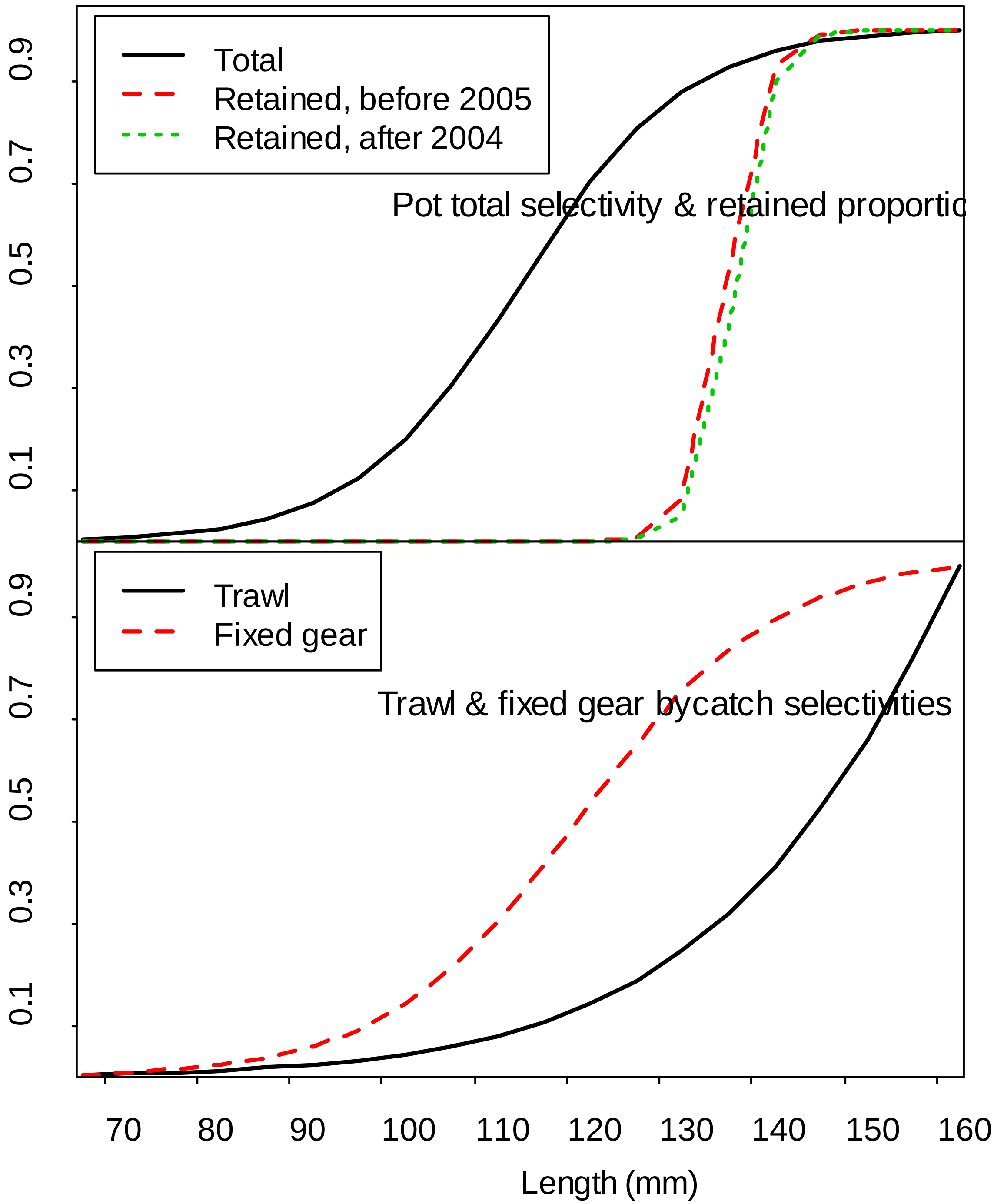


Figure 8d. Estimated total pot fishery selectivities and retained proportions and groundfish fisheries bycatch selectivities under model 19.3.

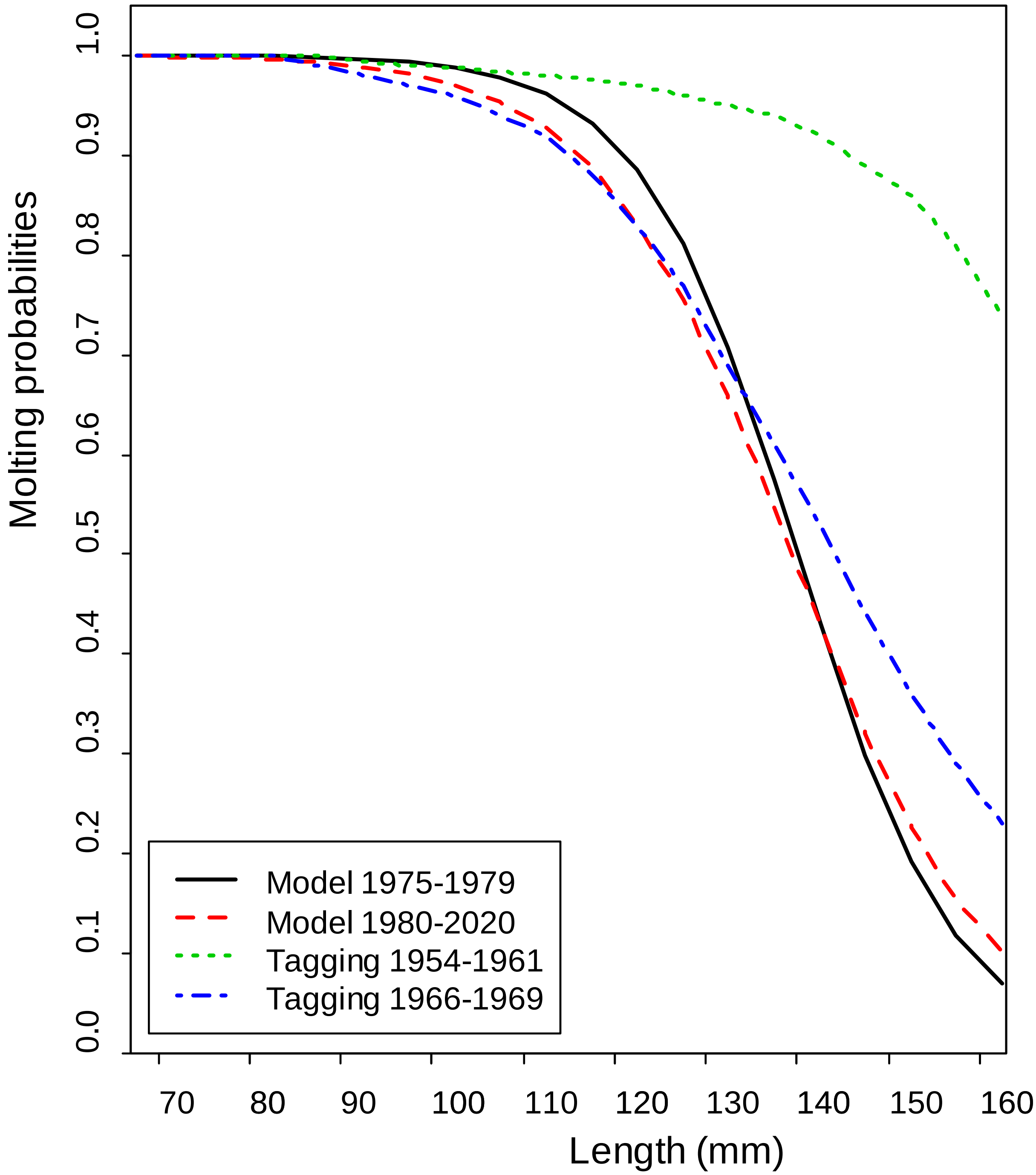


Figure 9a. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 19.0a. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2020 were estimated with a length-based model.

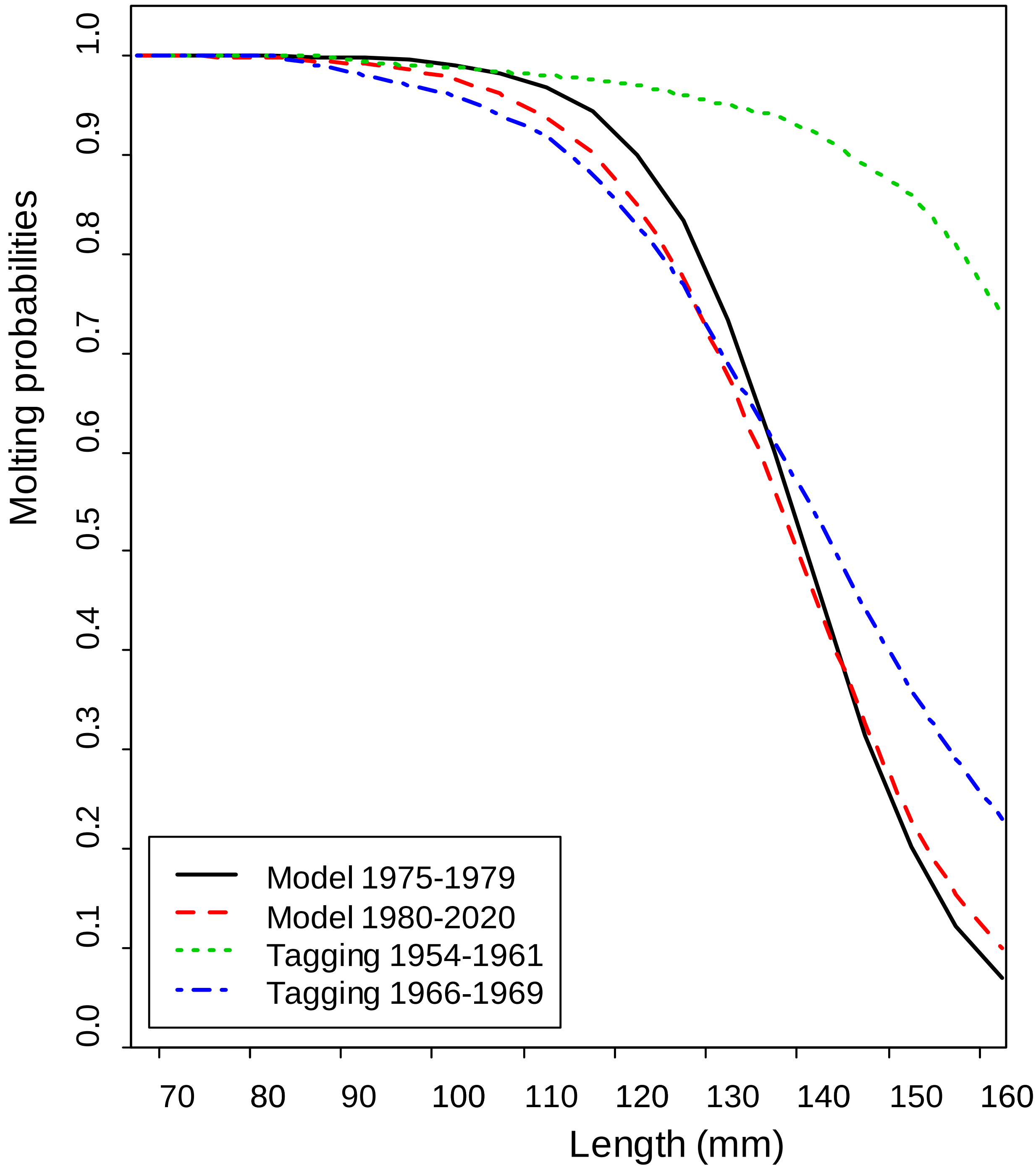


Figure 9b. Comparison of estimated probabilities of molting of male red king crab in Bristol Bay for different periods with model 19.3. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1975-1979 and 1980-2020 were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

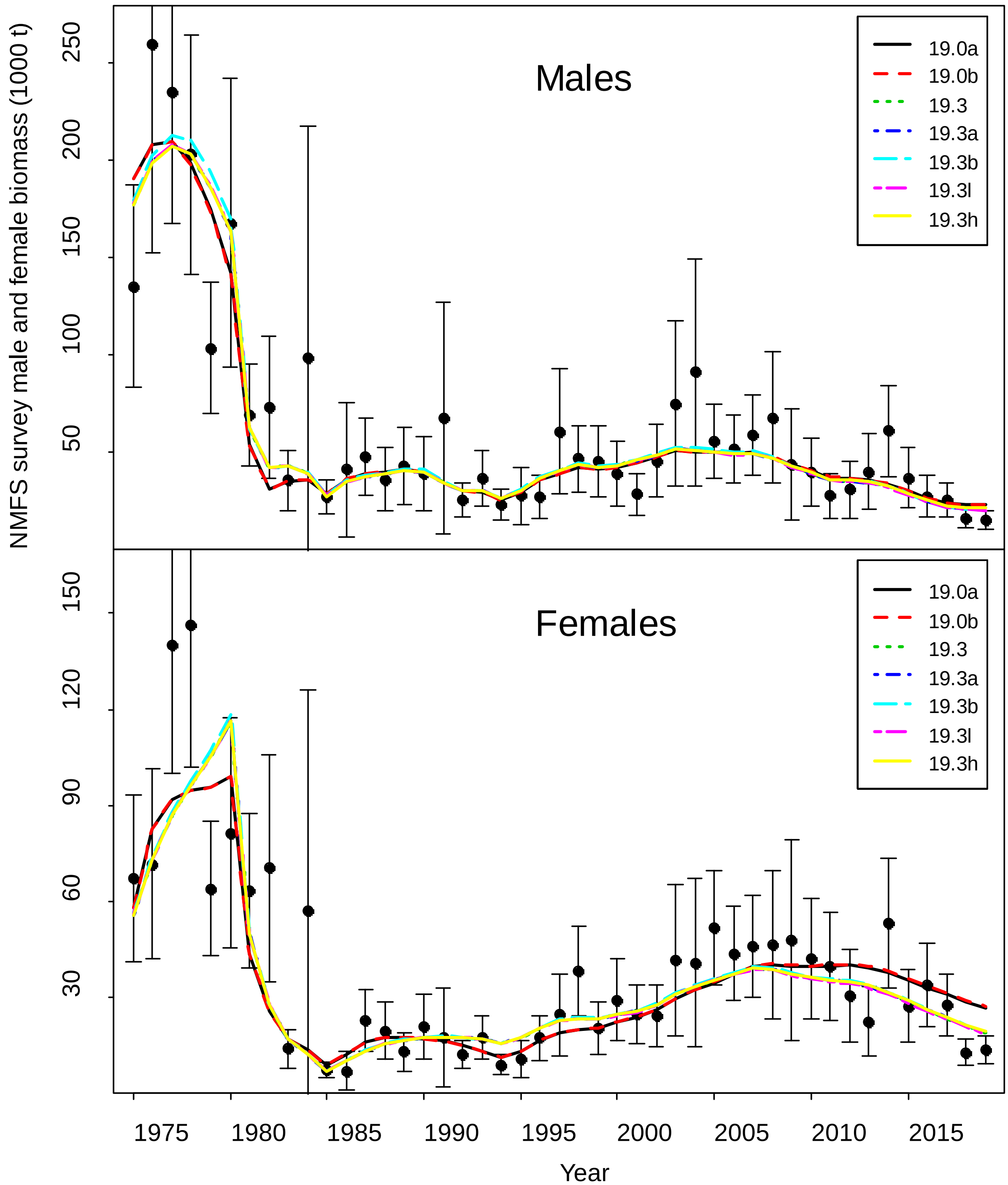


Figure 10a. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2020 under models 19.0a, 19.0b, 19.3, 19.3a, 19.3b, 19.3l, and 19.3h. The error bars are plus and minus 2 standard deviations of model 19.3.

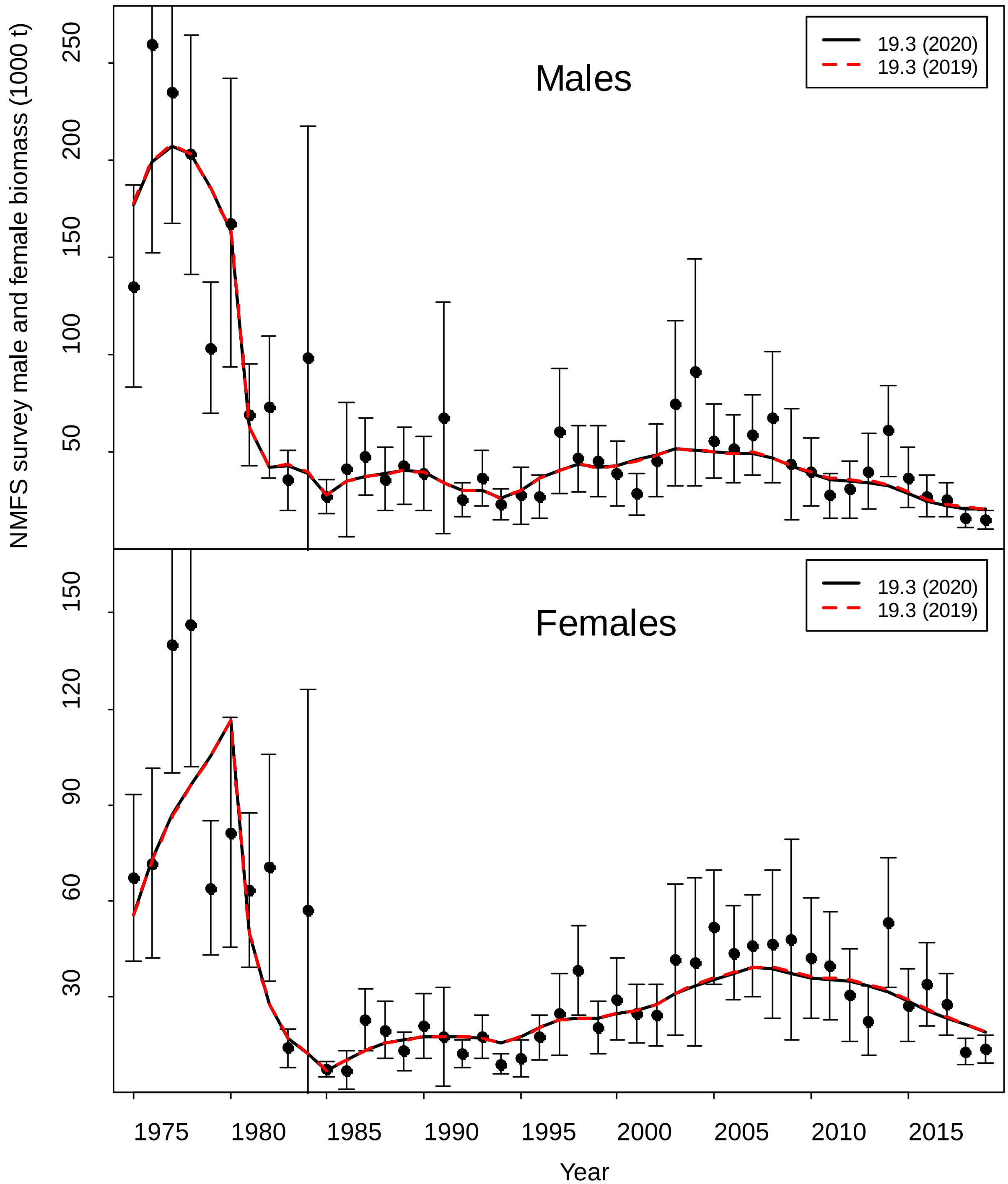


Figure 10b. Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates under model 19.3 (2019 data) and (2020 data). The error bars are plus and minus 2 standard deviations of model 19.3.

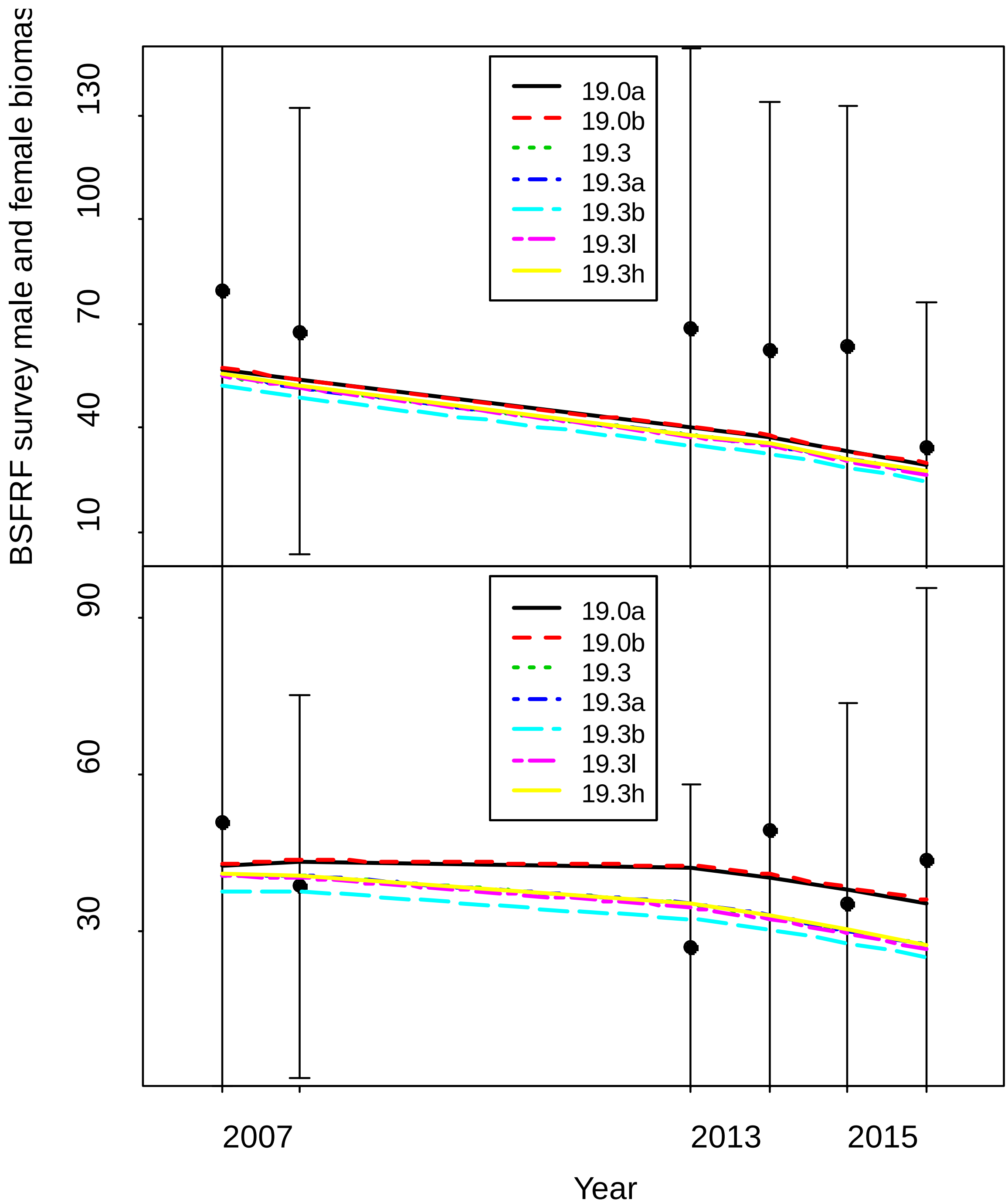


Figure 10c. Comparisons of survey biomass estimates by sex (upper plot for males and lower plot for females) by the BSFRF survey and the model for model estimates in 2020 (models 19.0a, 19.0b, 19.3, 19.3a, 19.3b, 19.3l, and 19.3h). The error bars are plus and minus 2 standard deviations of model 19.3.

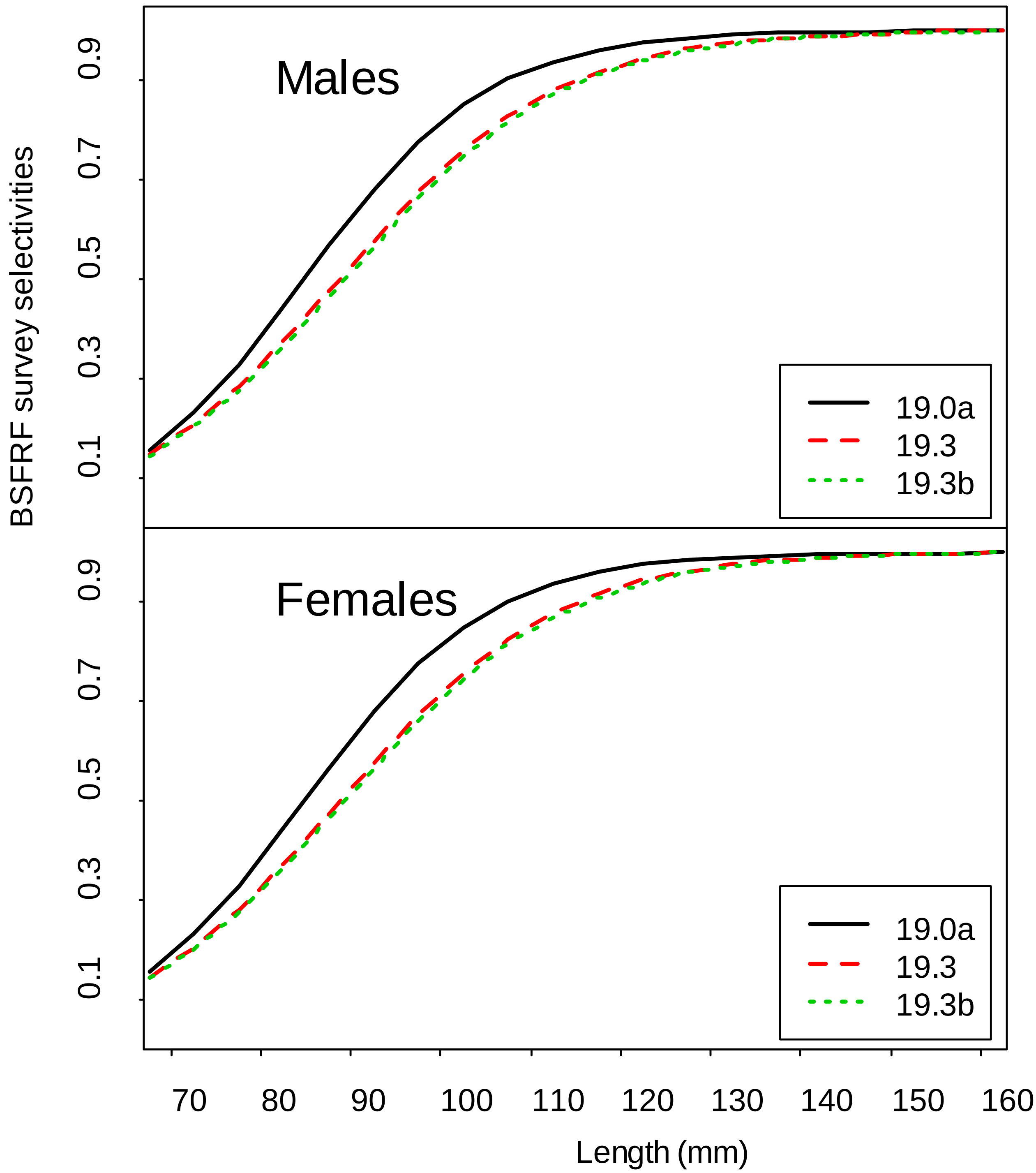


Figure 10d. Comparisons of estimated BSFRF survey selectivities with models 19.0a, 19.3, and 19.3b. The catchability is assumed to be 1.0.

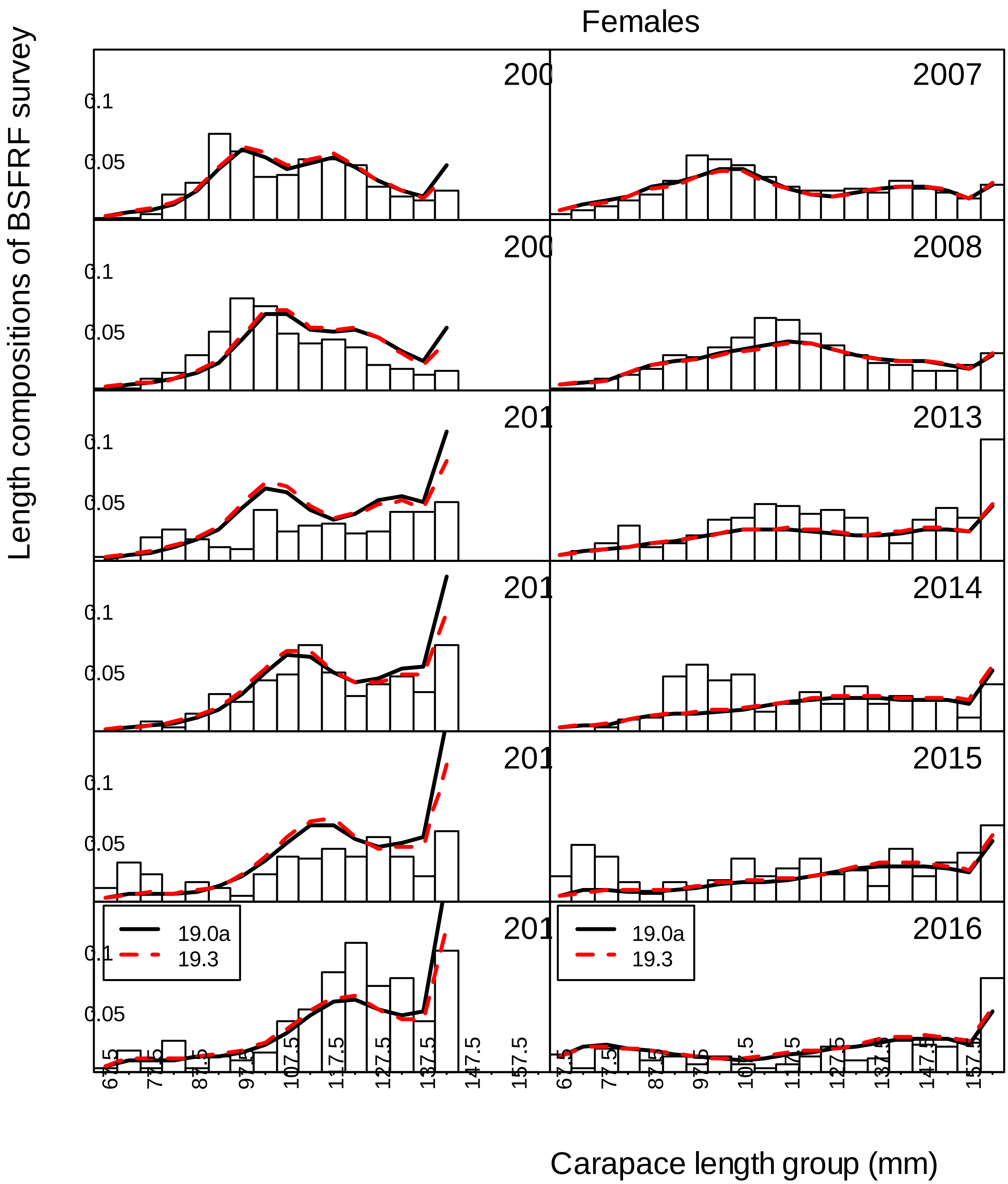


Figure 10e. Comparisons of length compositions by the BSFRF survey and the model estimates during 2007-2008 and 2013-2016 with models 19.0a and 19.3.

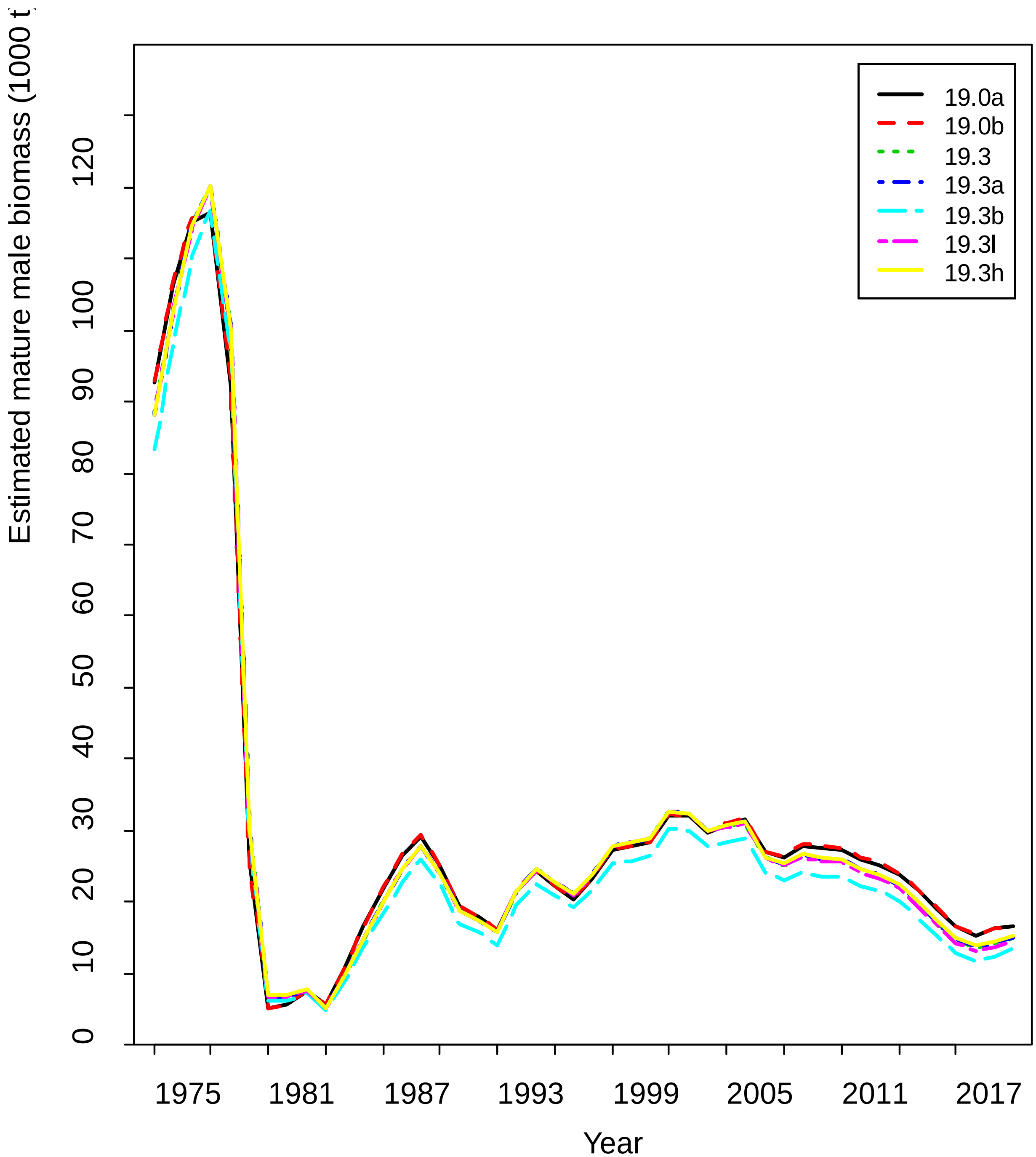


Figure 11. Estimated absolute mature male biomasses during 1975-2020 for models 19.0a, 19.0b, 19.3, 19.3a, 19.3b, 19.3l, and 19.3h.

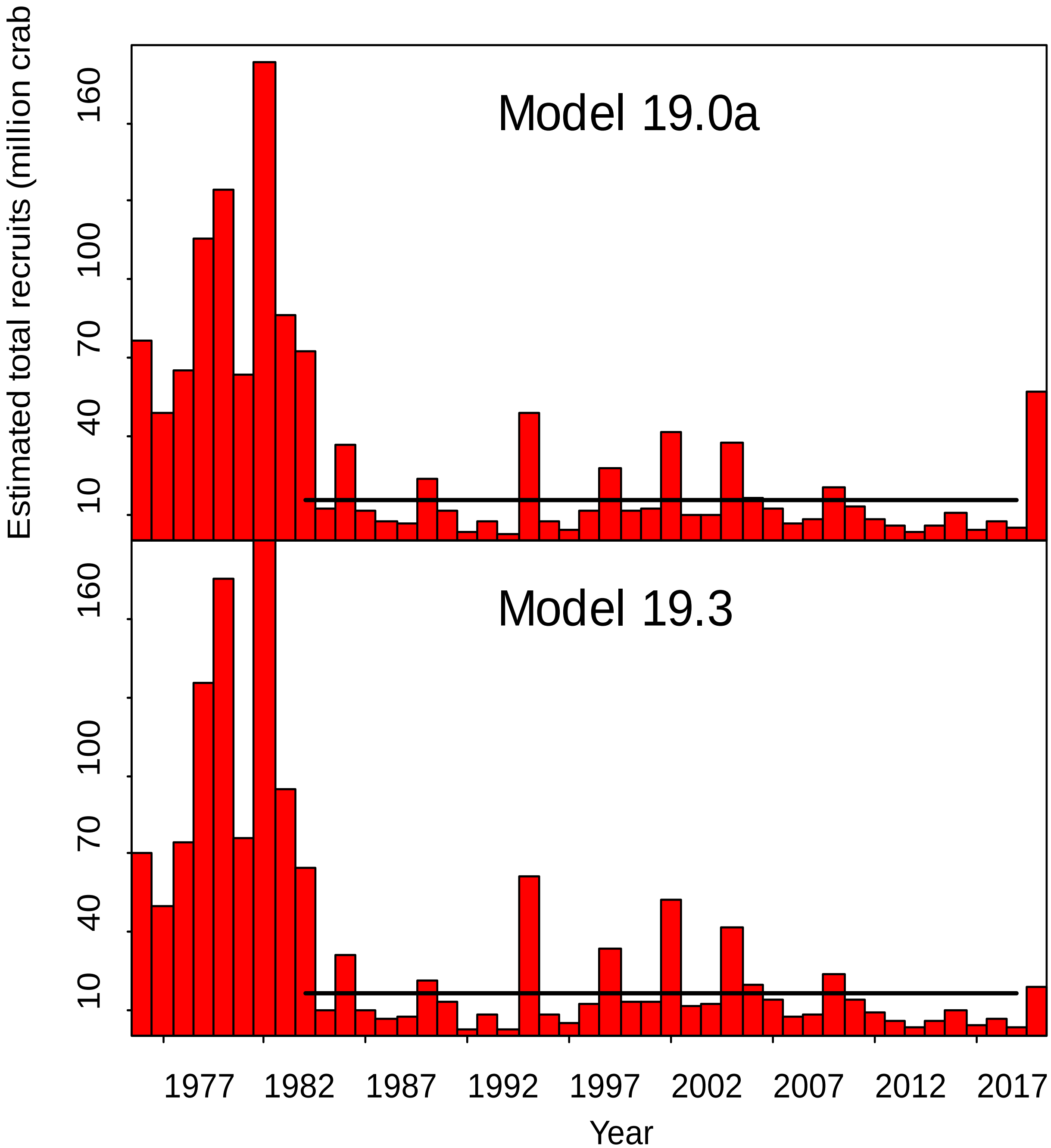


Figure 12a. Estimated recruitment time series during 1976-2020 with models 19.0a and 19.3. Mean male recruits during 1984-2019 was used to estimate $B_{35\%}$.

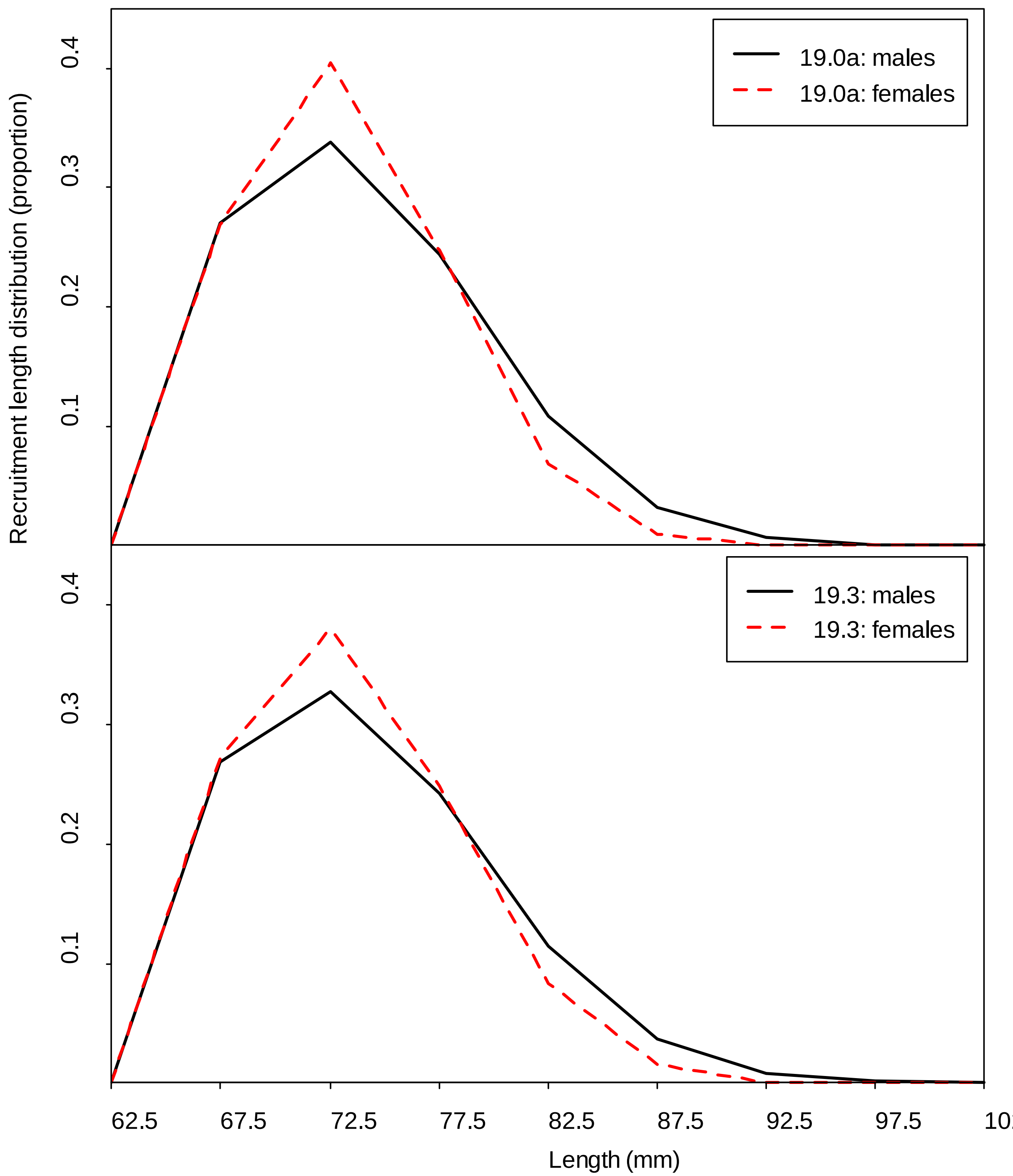


Figure 12b. Estimated recruitment length distributions with models 19.0a and 19.3.

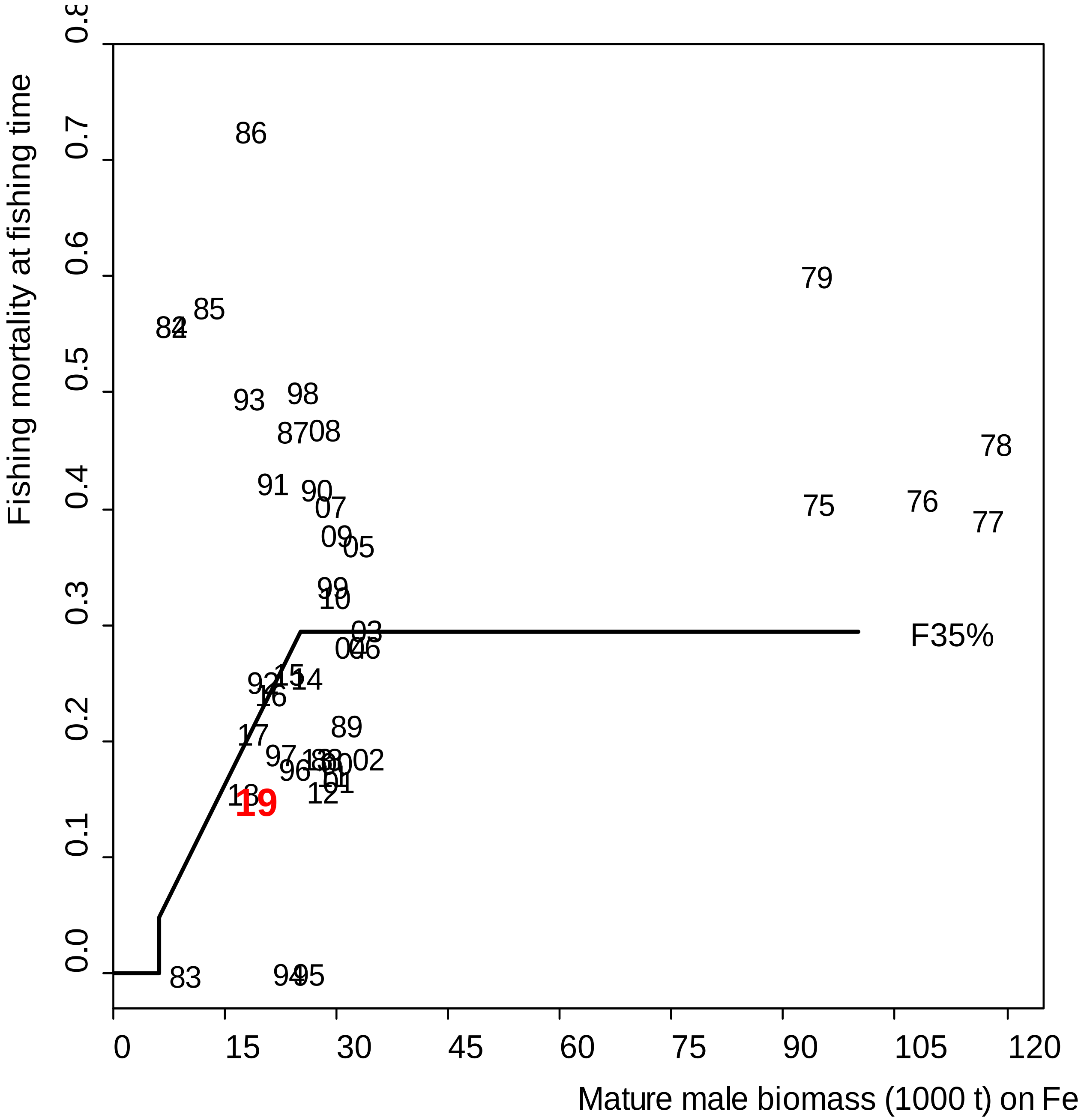


Figure 13a. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2019 under model 19.0a. Average of recruitment from 1984 to 2019 was used to estimate B_{MSY}.

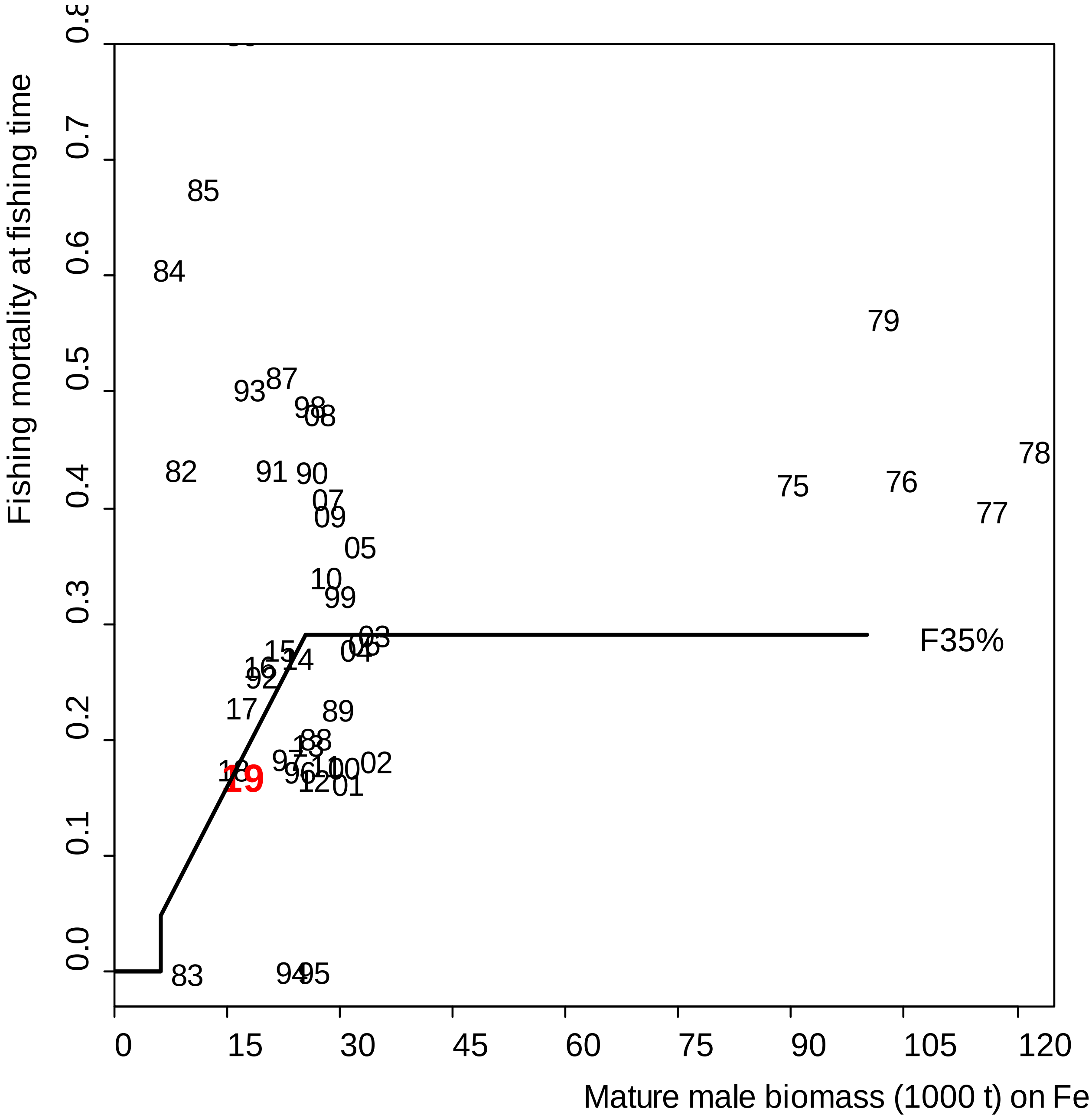


Figure 13b. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1975-2019 under model 19.3. Average of recruitment from 1984 to 2019 was used to estimate B_{MSY}.

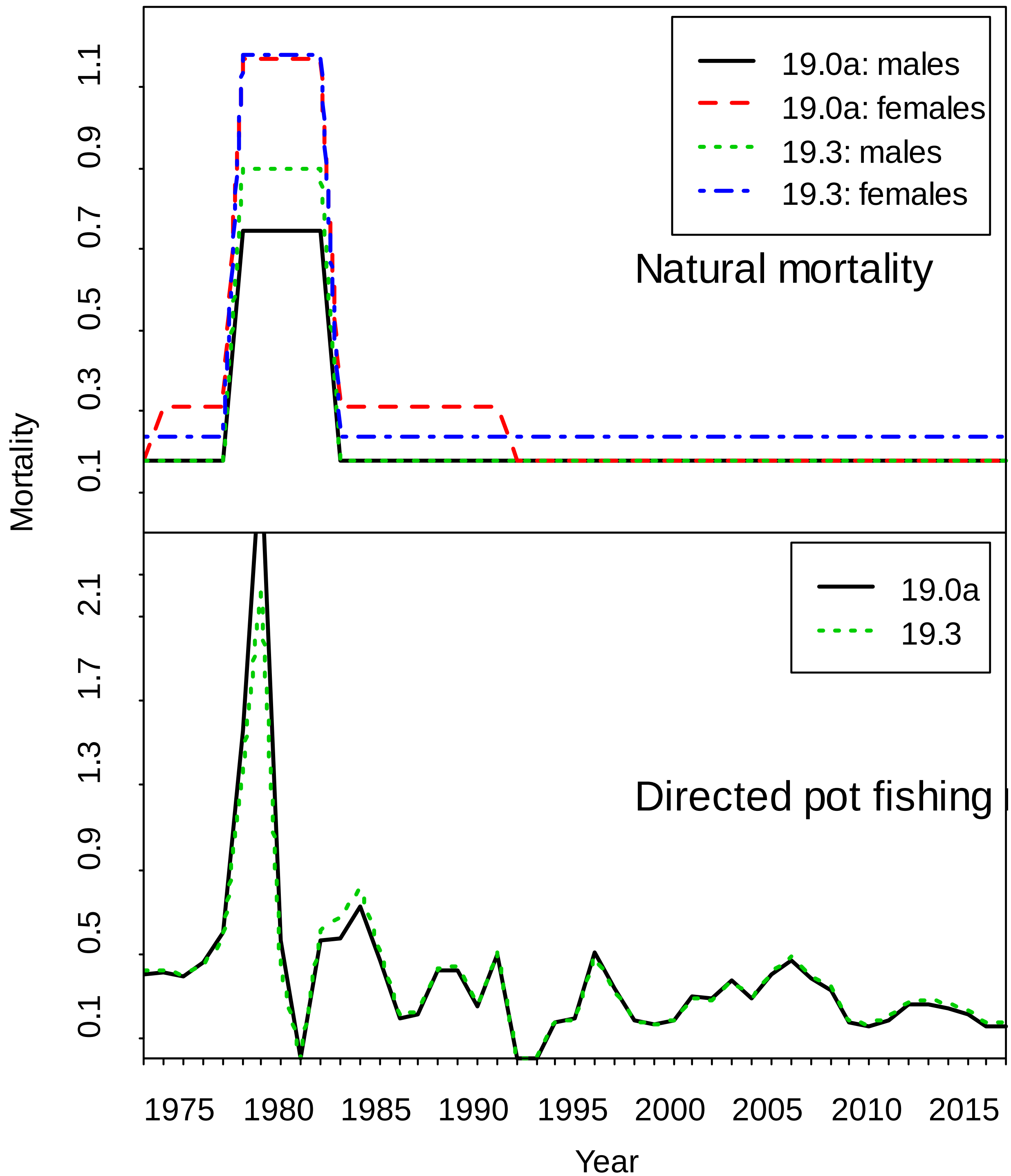


Figure 13c. Comparison of estimated natural mortality and directed pot fishing mortality for models models 19.0a and 19.3.

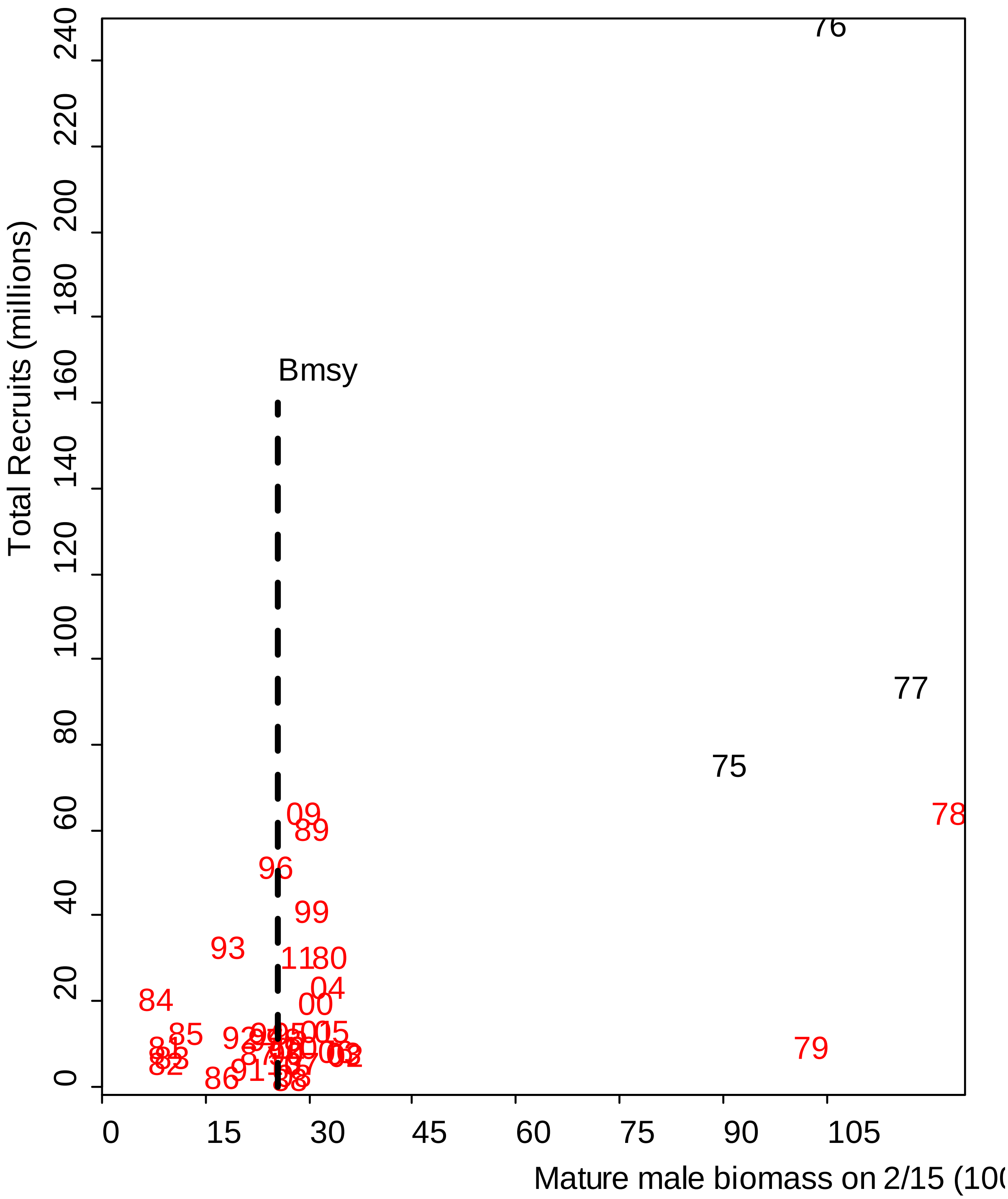


Figure 14a. Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6-year time lag) for Bristol Bay red king crab under model 19.3. Numerical labels are years of mating, and the vertical dotted line is the estimated $B_{35\%}$ based on the mean recruitment level during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

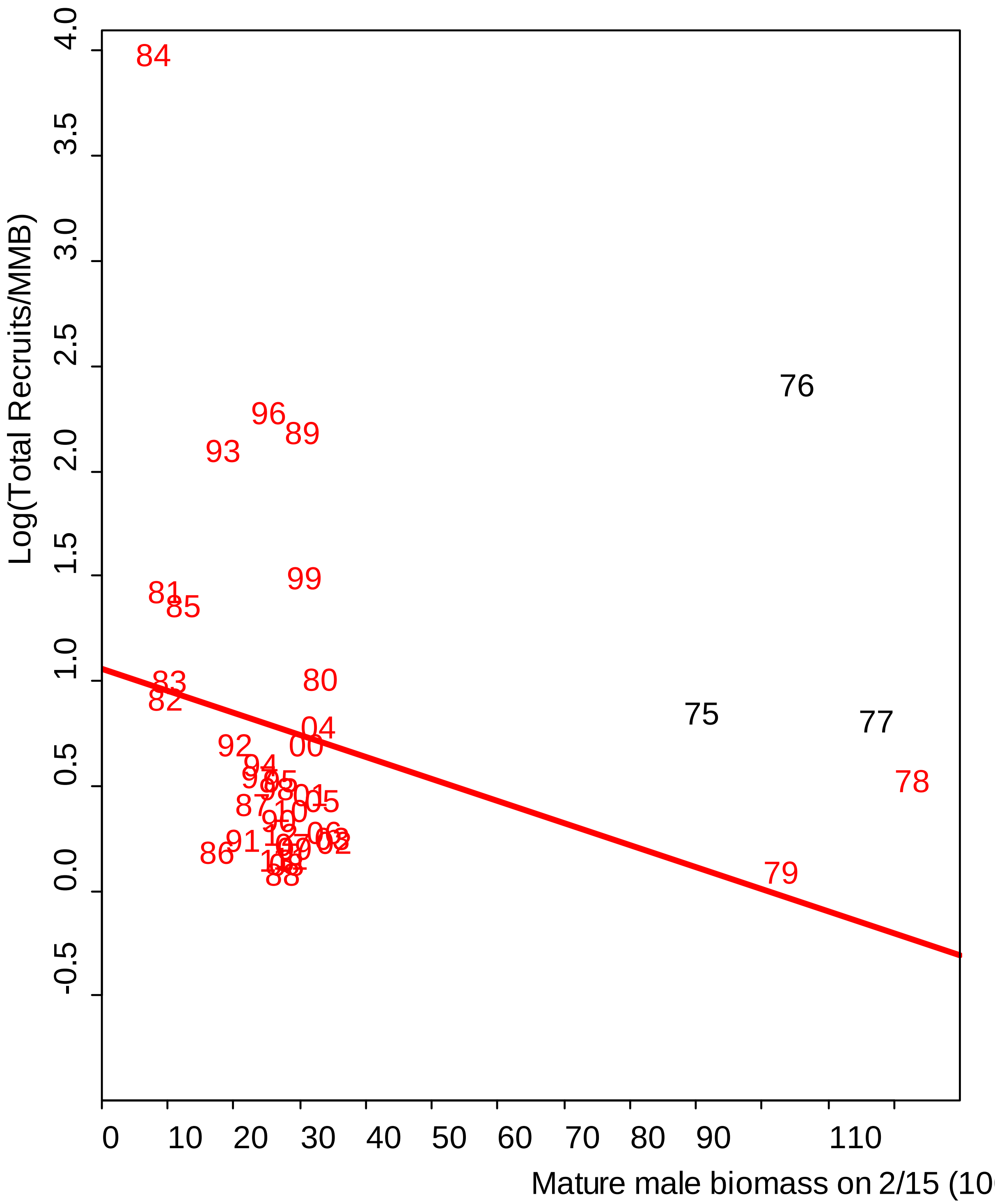


Figure 14b. Relationships between log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab under model 19.3. Numerical labels are years of mating, and the line is the regression line for data of 1978-2013.

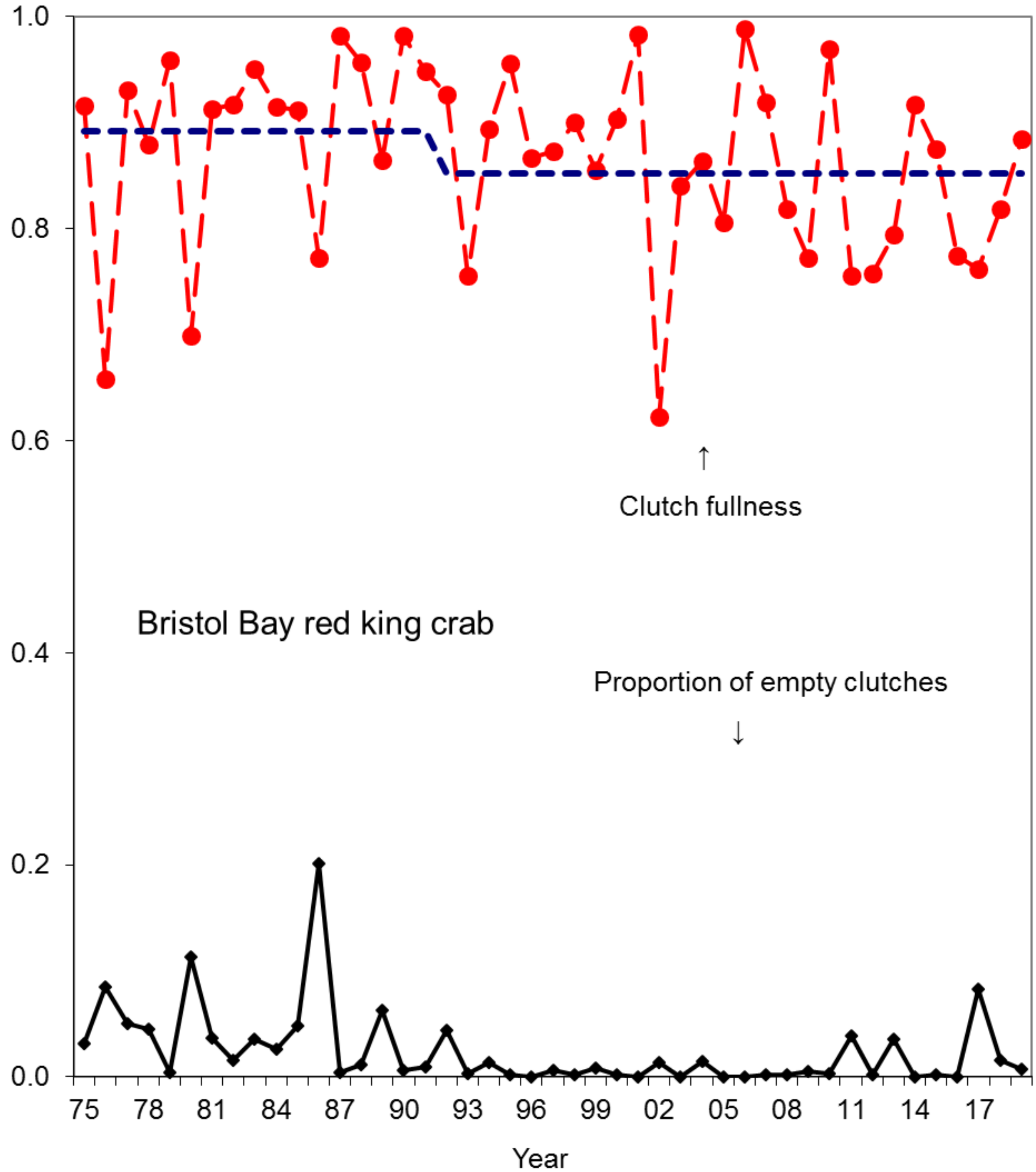


Figure 15. Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crab >89 mm CL from 1975 to 2019 from survey data. Oldshell females were excluded. The blue dashed line is the mean clutch fullness during two periods before 1992 and after 1991.

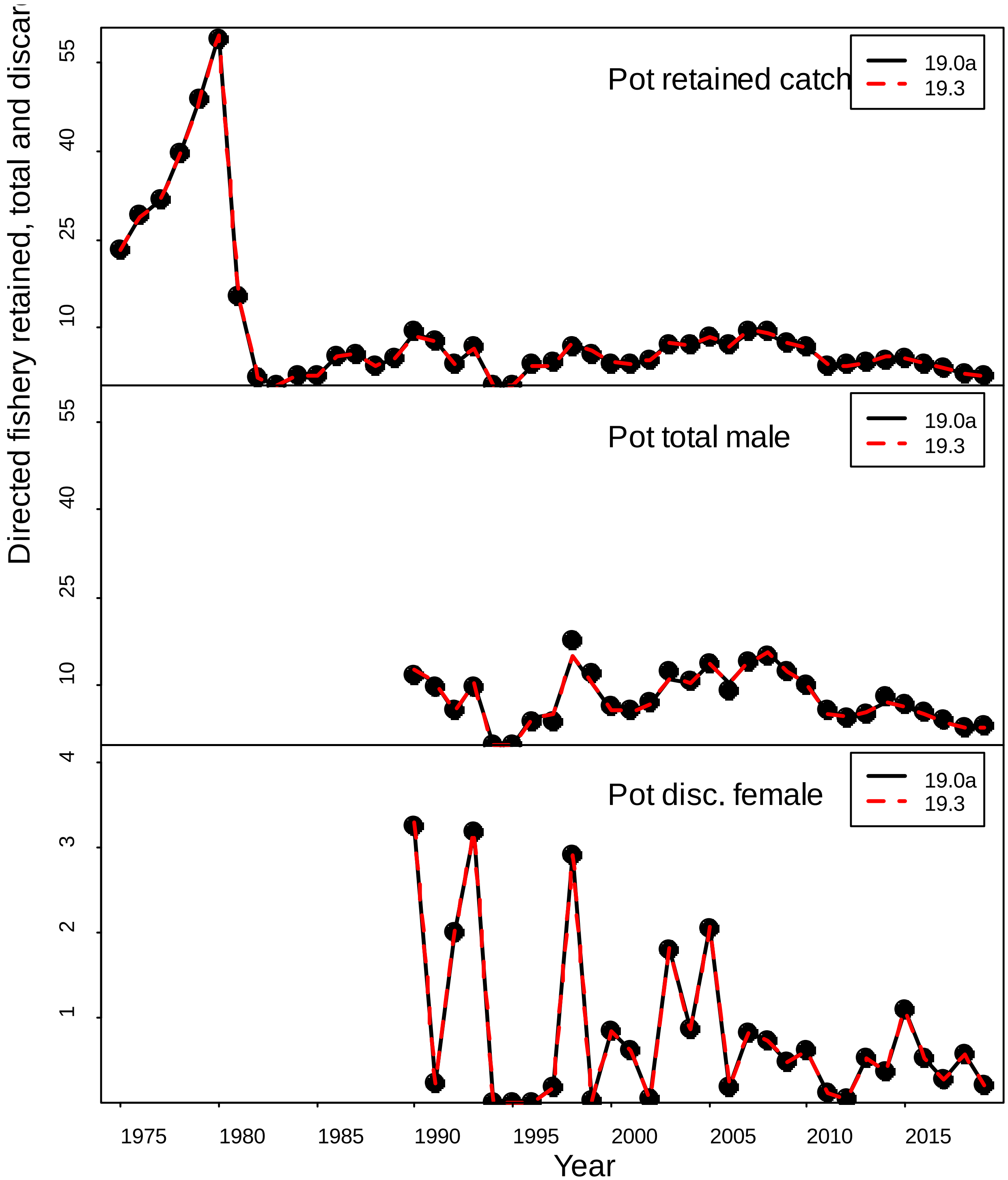


Figure 16a. Observed (dots) and predicted (lines) RKC catch and bycatch biomass under models 19.0a and 19.3.

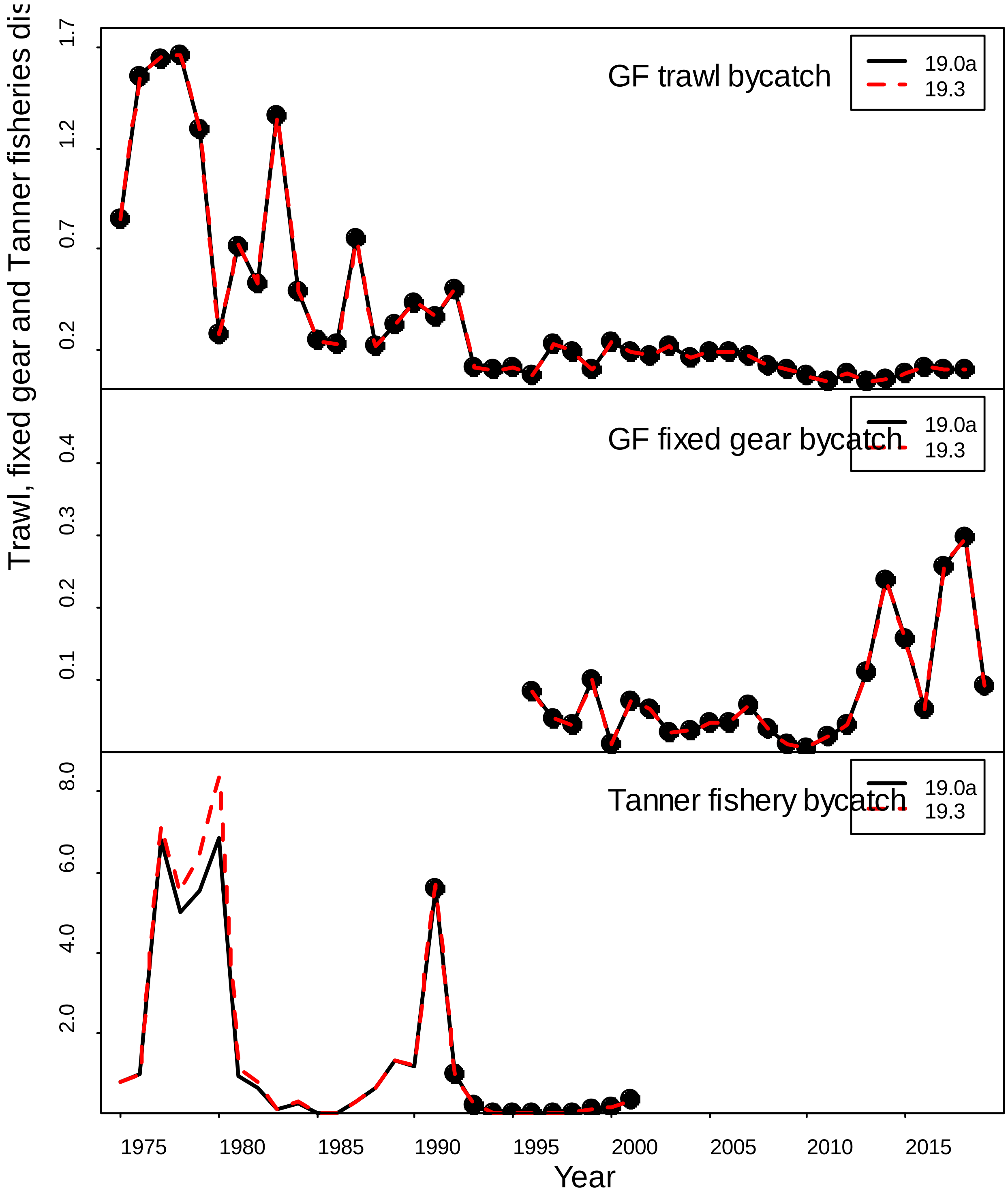


Figure 16b. Observed (dots) and predicted (lines) RKC bycatch biomass from groundfish fisheries and the Tanner crab fishery under models 19.0a and 19.3. Trawl bycatch biomass was 0 before 1976.

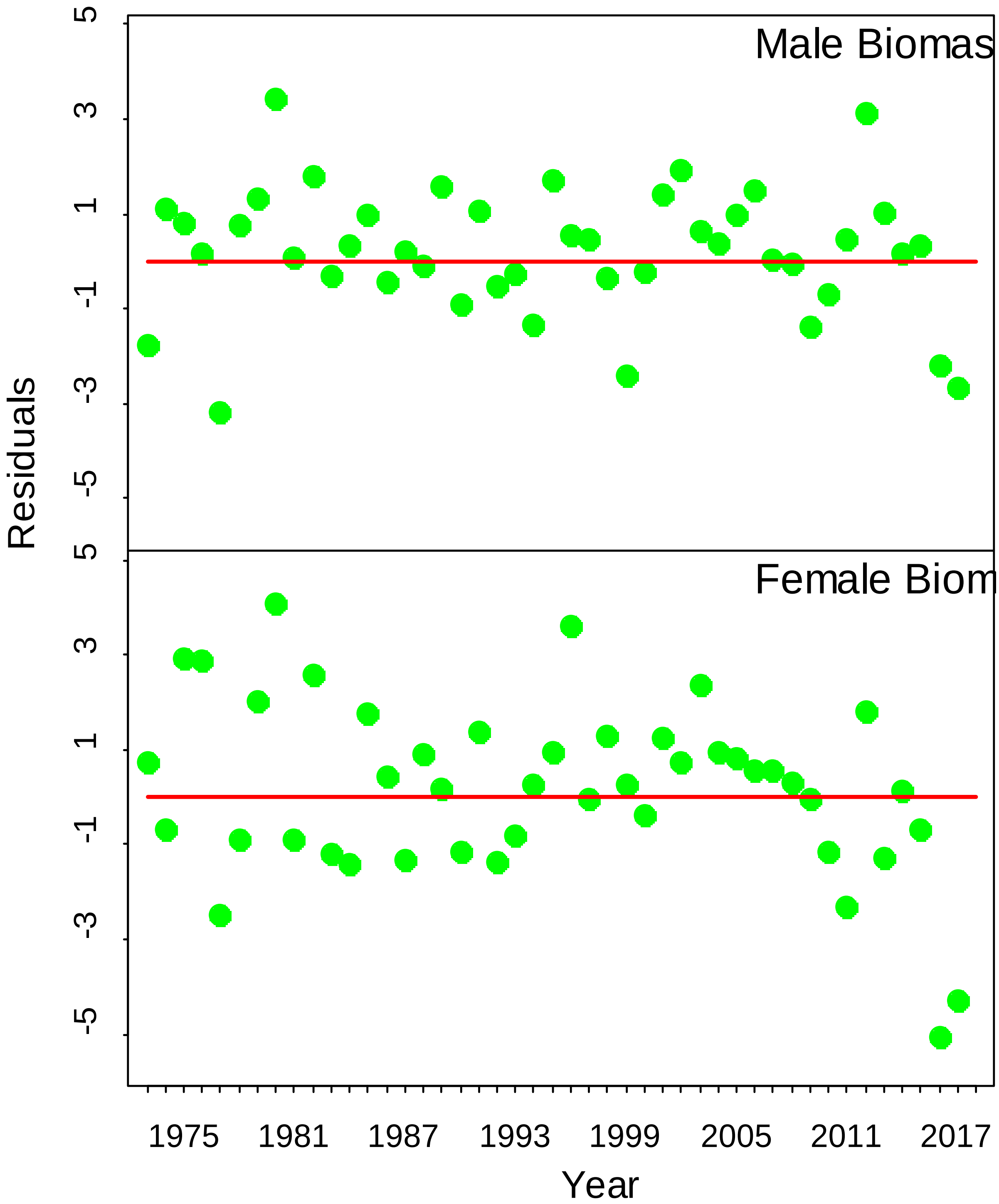


Figure 17a. Standardized residuals of NMFS survey biomass under model 19.0a.

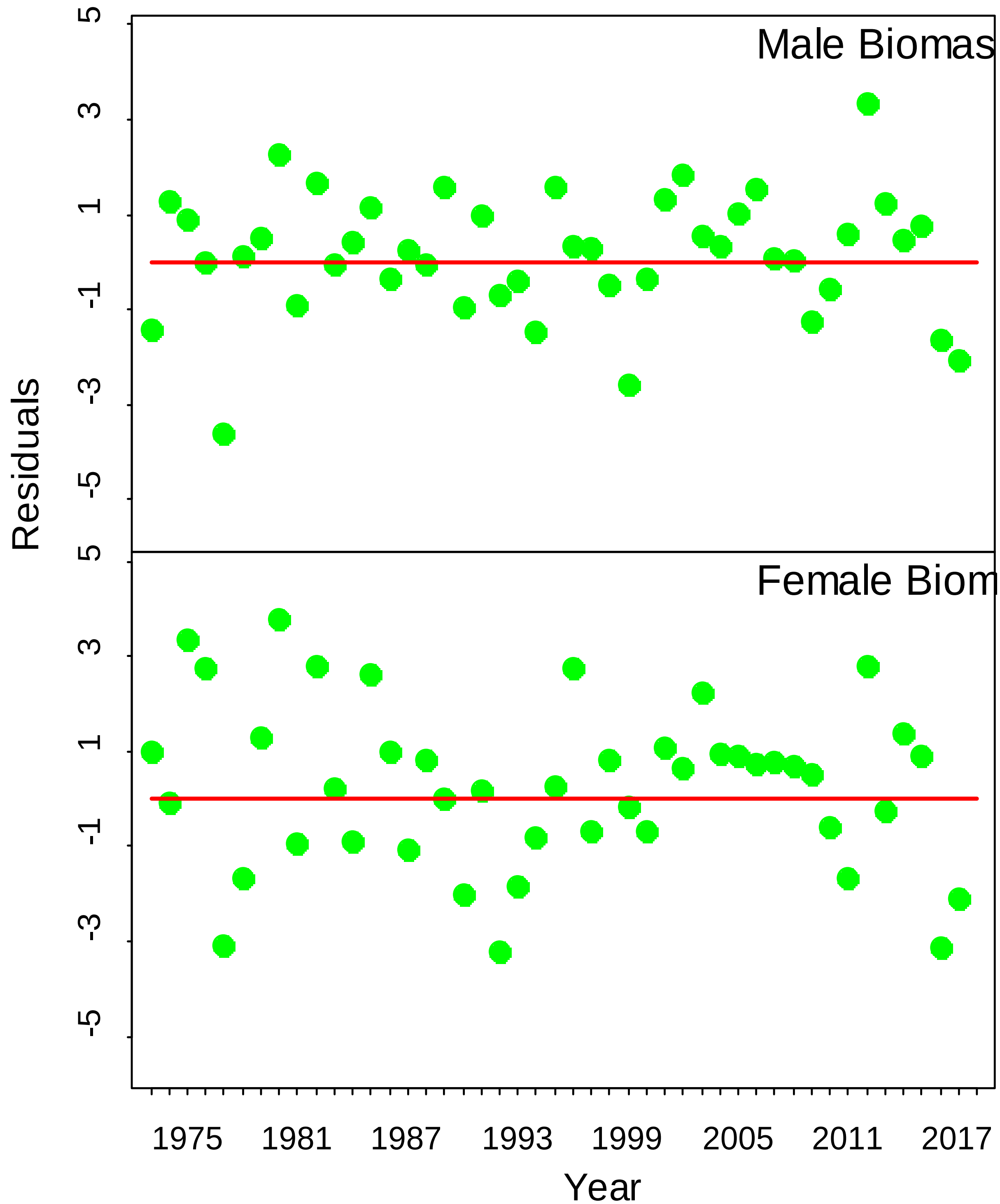


Figure 17b. Standardized residuals of NMFS survey biomass under model 19.3.

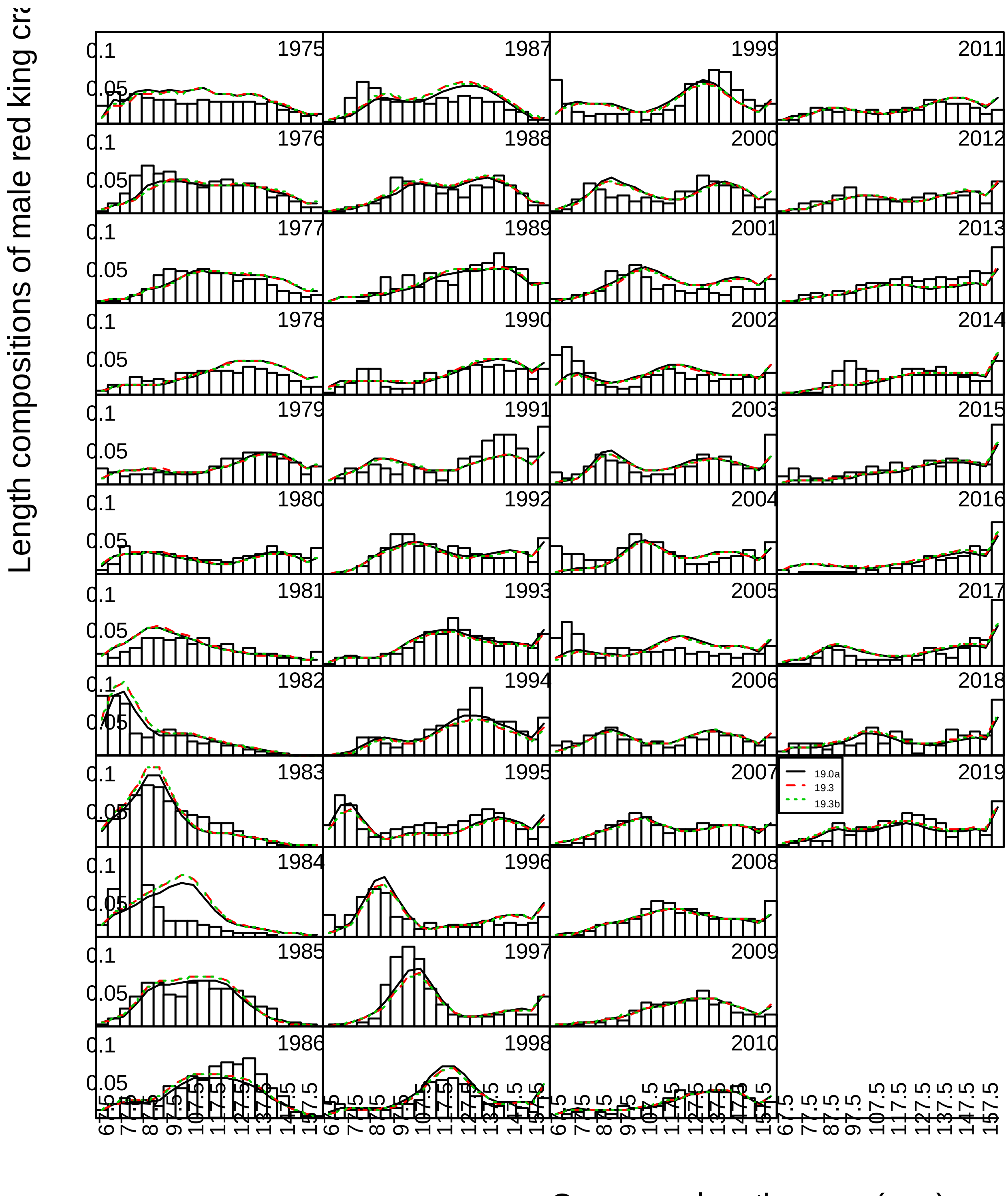


Figure 18. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under models 19.0a, 19.3, and 19.3b.

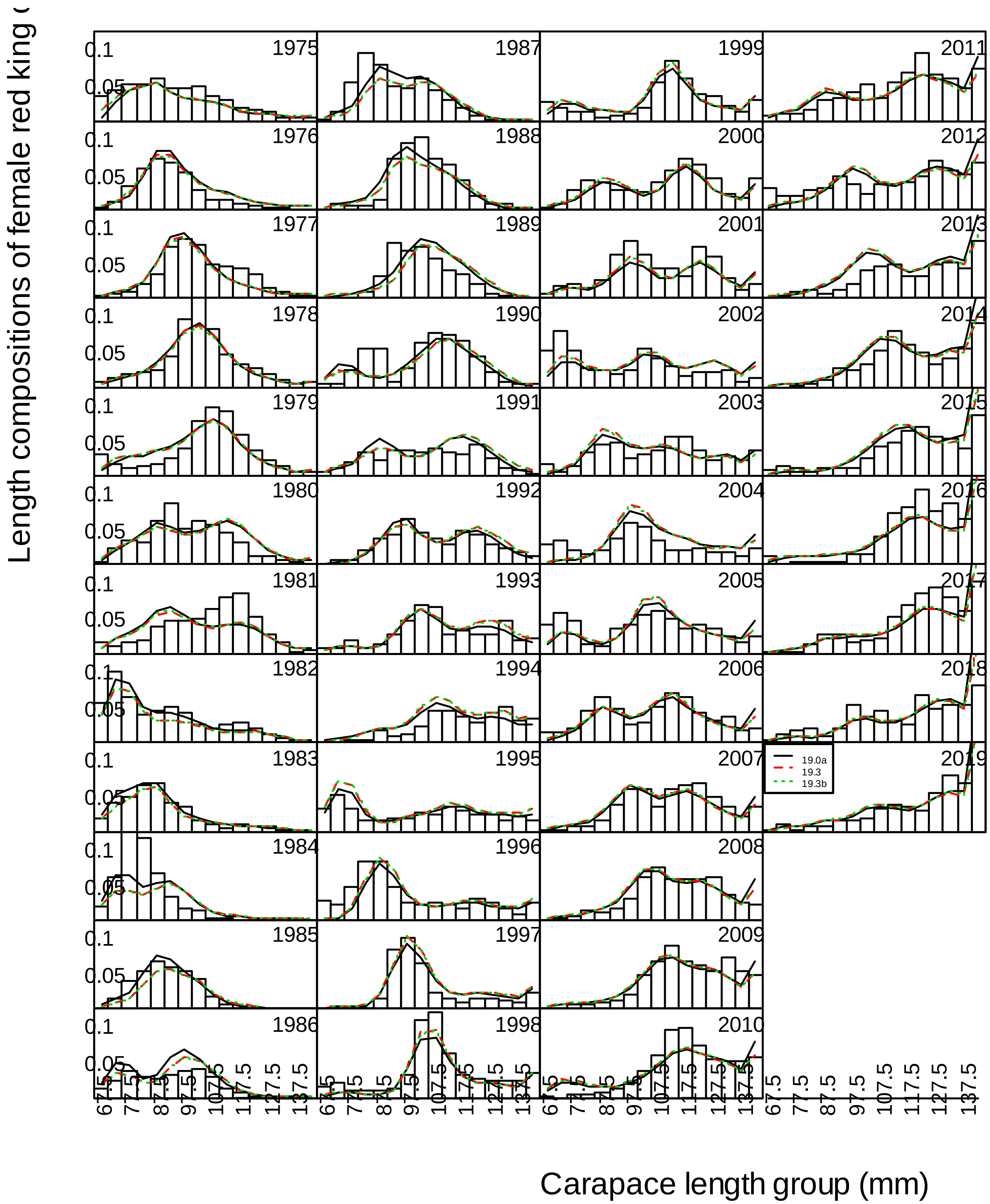


Figure 19. Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay female red king crab by year under models 19.0a, 19.3, and 19.3b.

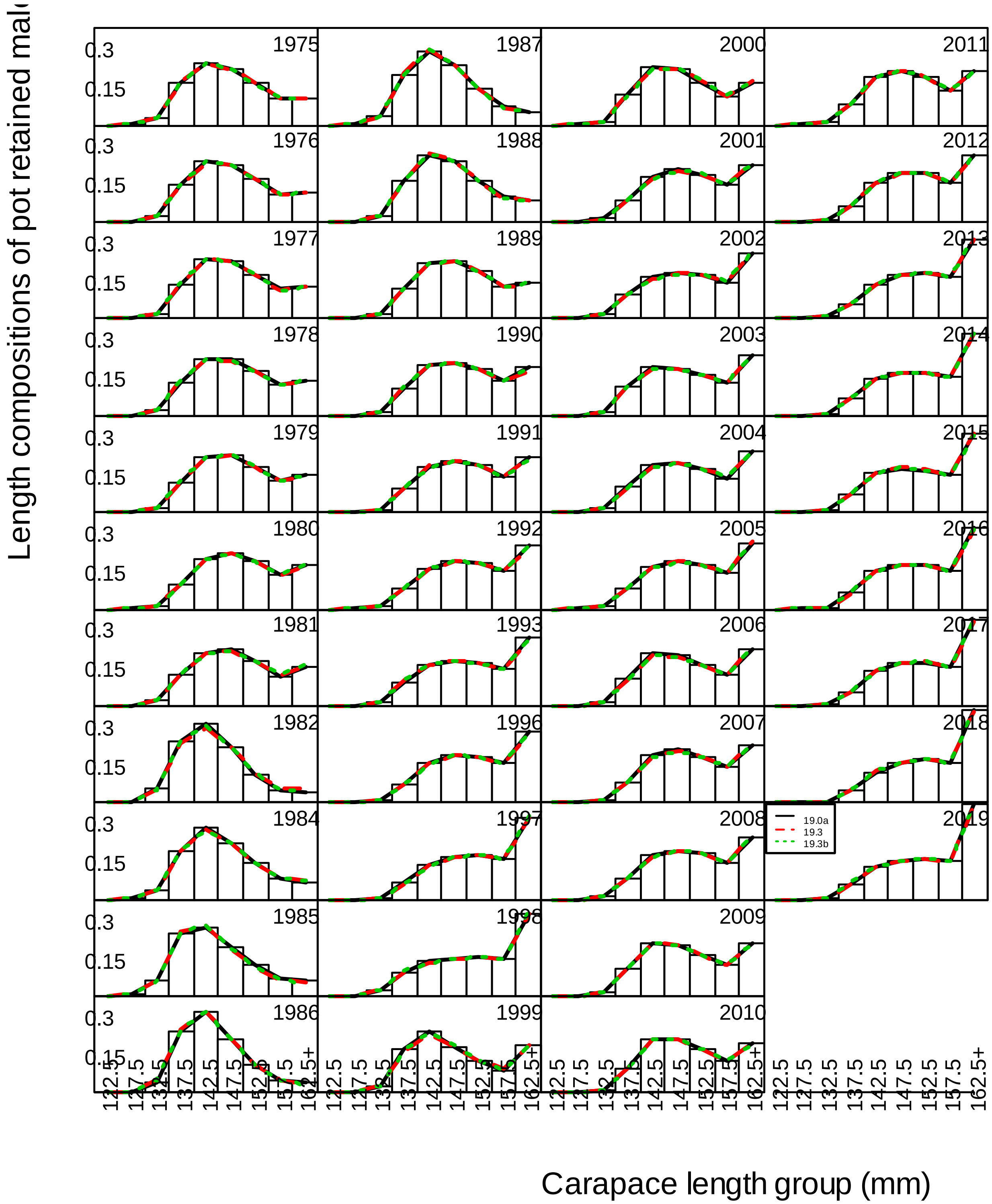


Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.0a, 19.3, and 19.3b.

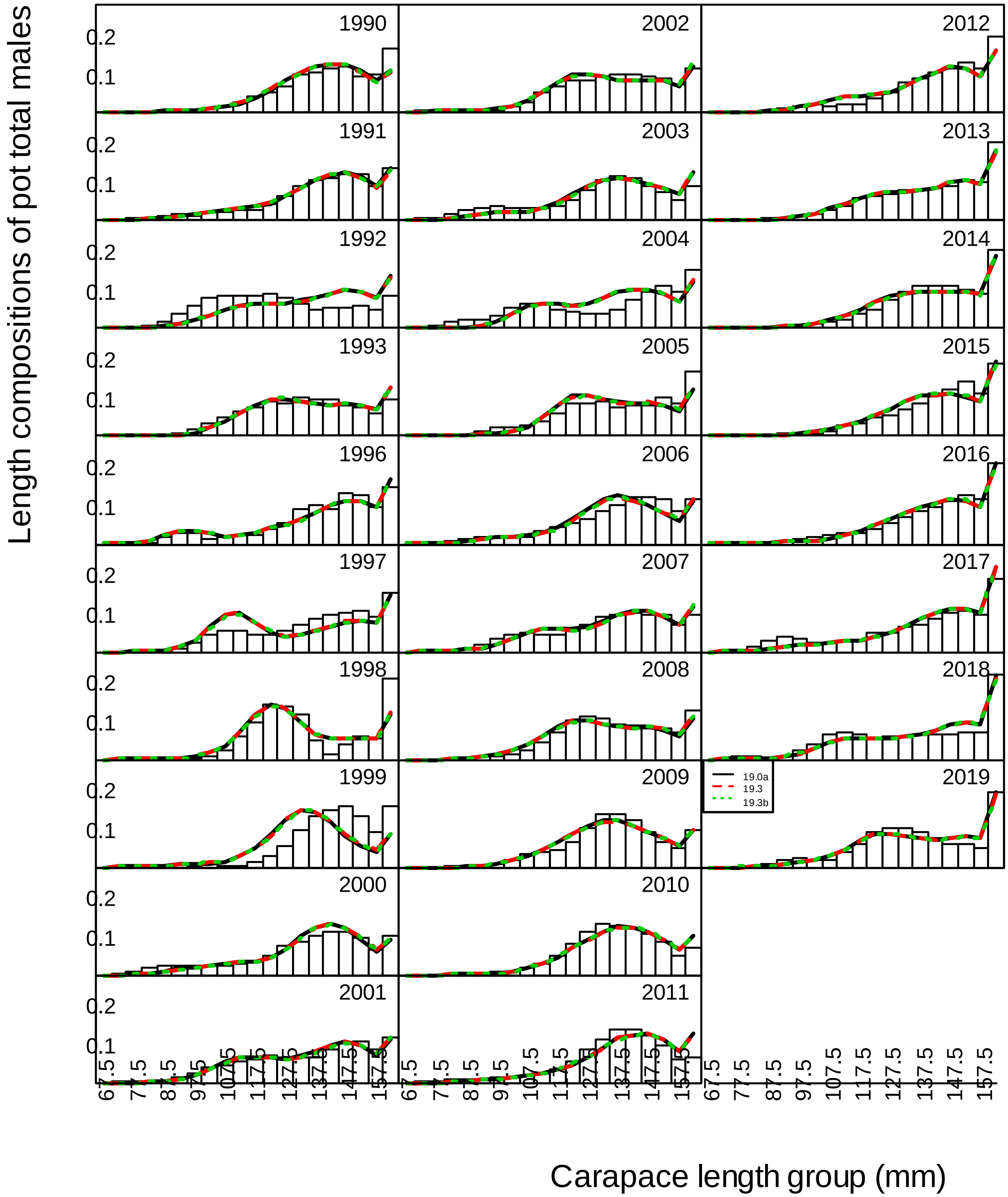


Figure 21. Comparison of observer and model estimated total observer length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 19.0a, 19.3, and 19.3b.

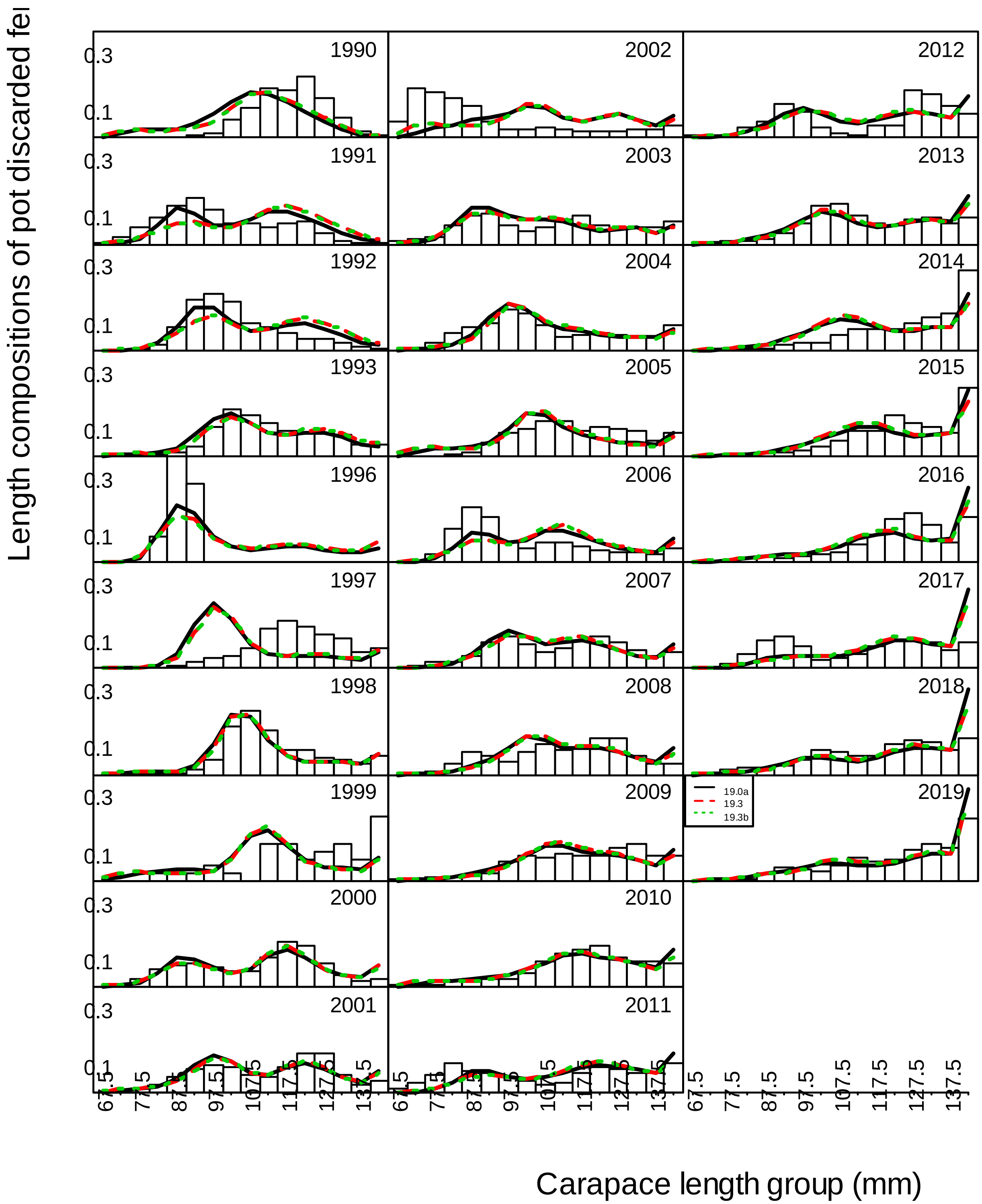


Figure 22. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the directed pot fishery under models 19.0a, 19.3, and 19.3b.

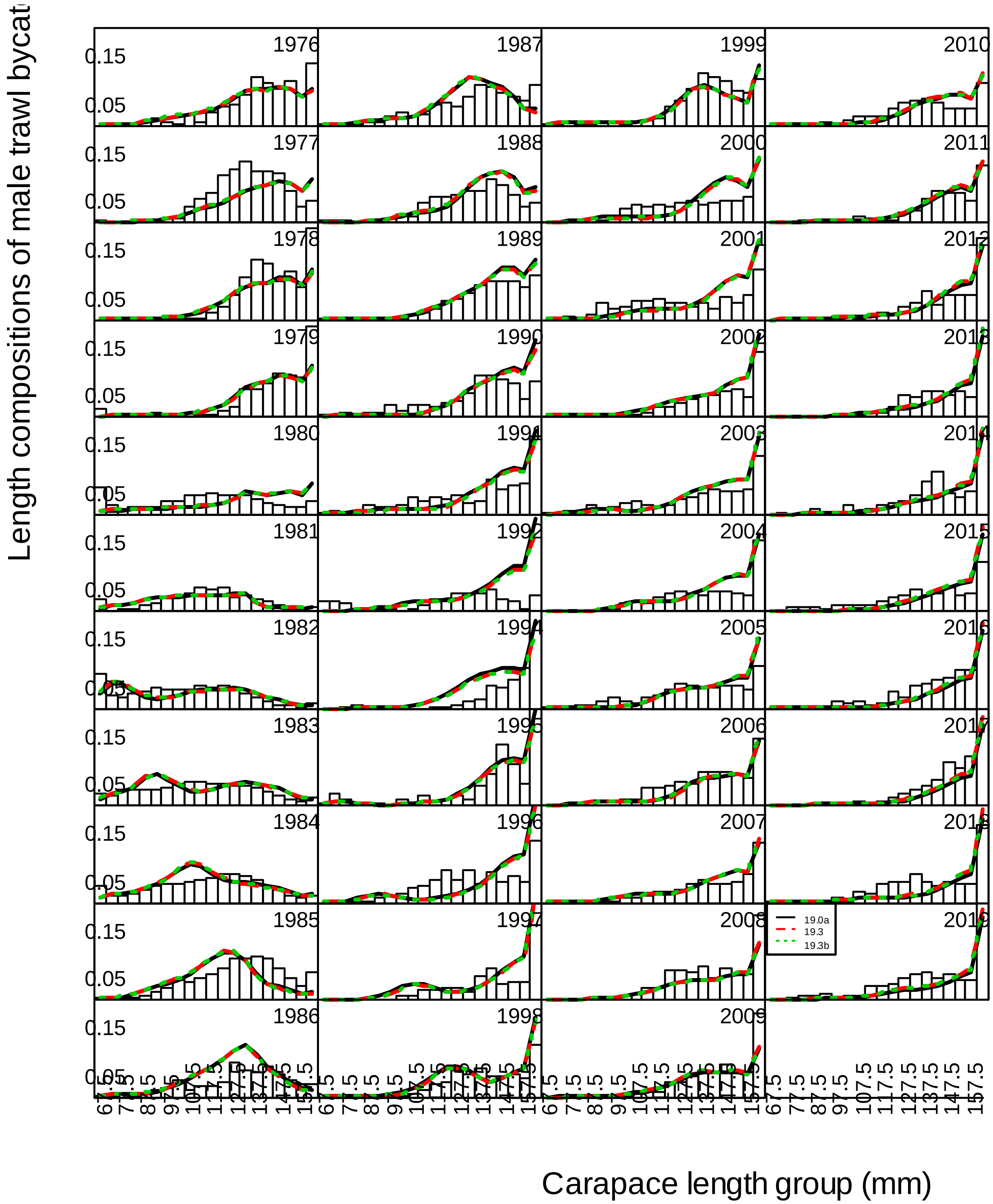


Figure 23a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish trawl fisheries under models 19.0a, 19.3, and 19.3b.

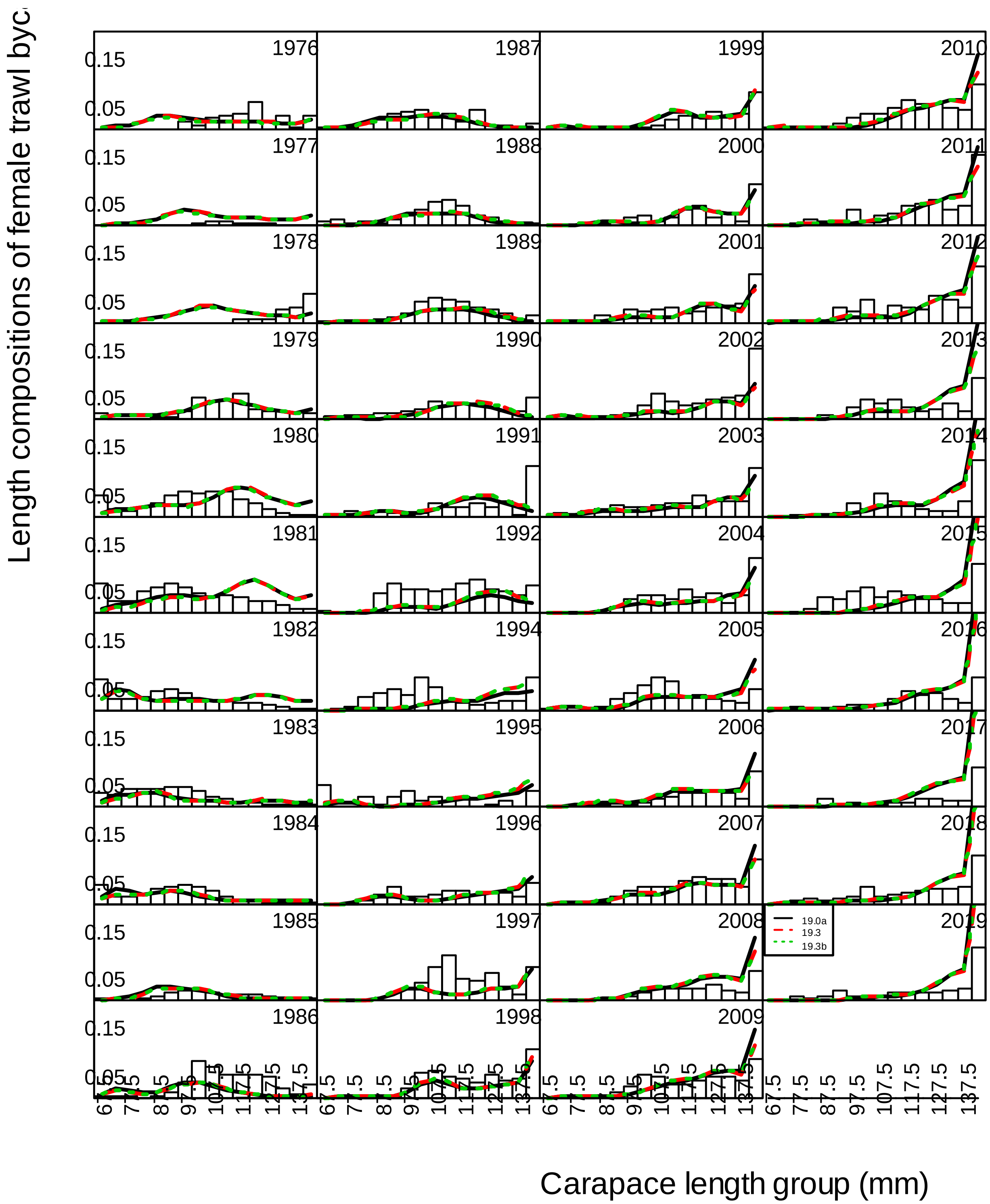


Figure 23b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish trawl fisheries under models 19.0a, 19.3, and 19.3b.

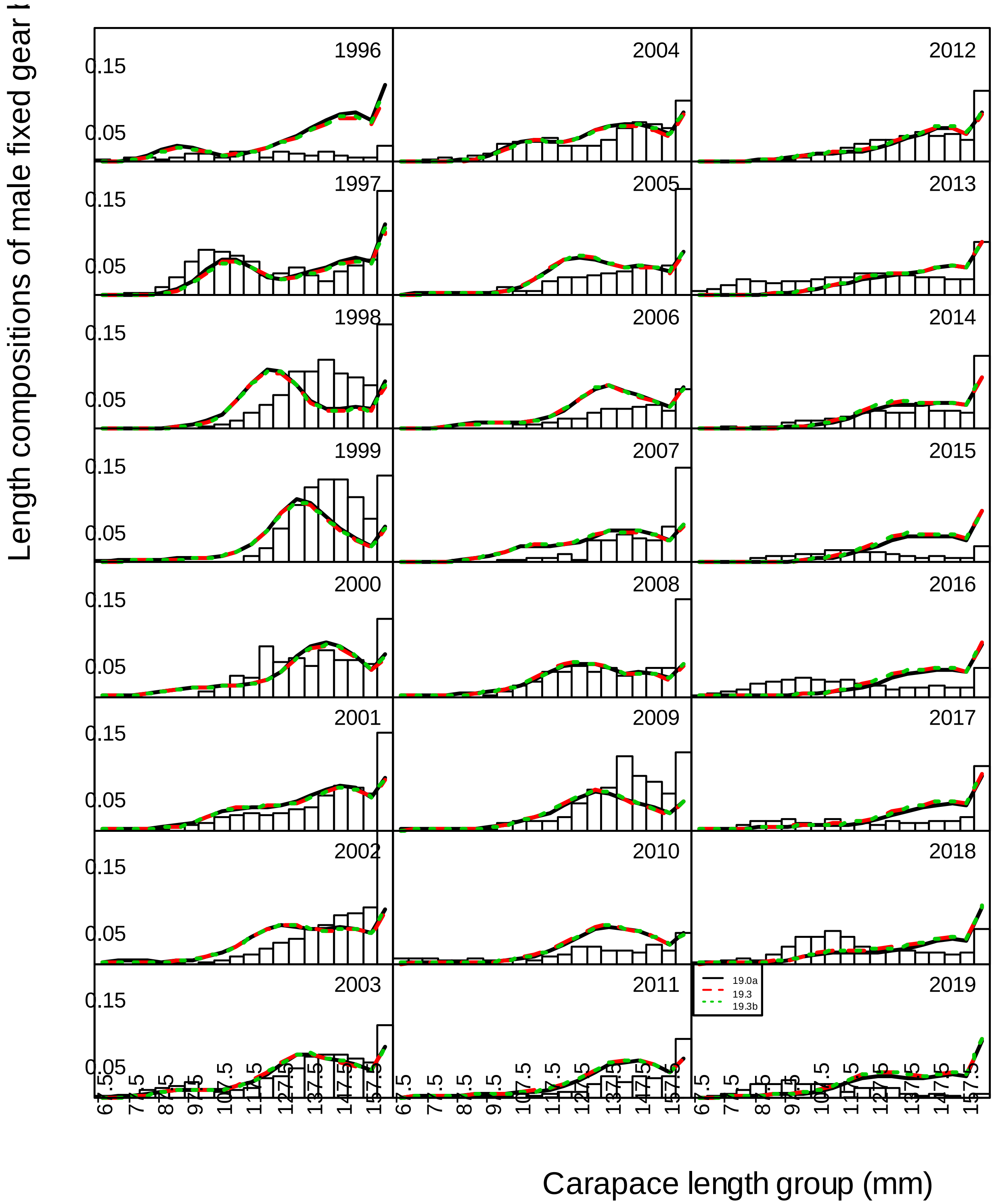


Figure 24a. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crab by year in the groundfish fixed gear fisheries under models 19.0a, 19.3, and 19.3b.

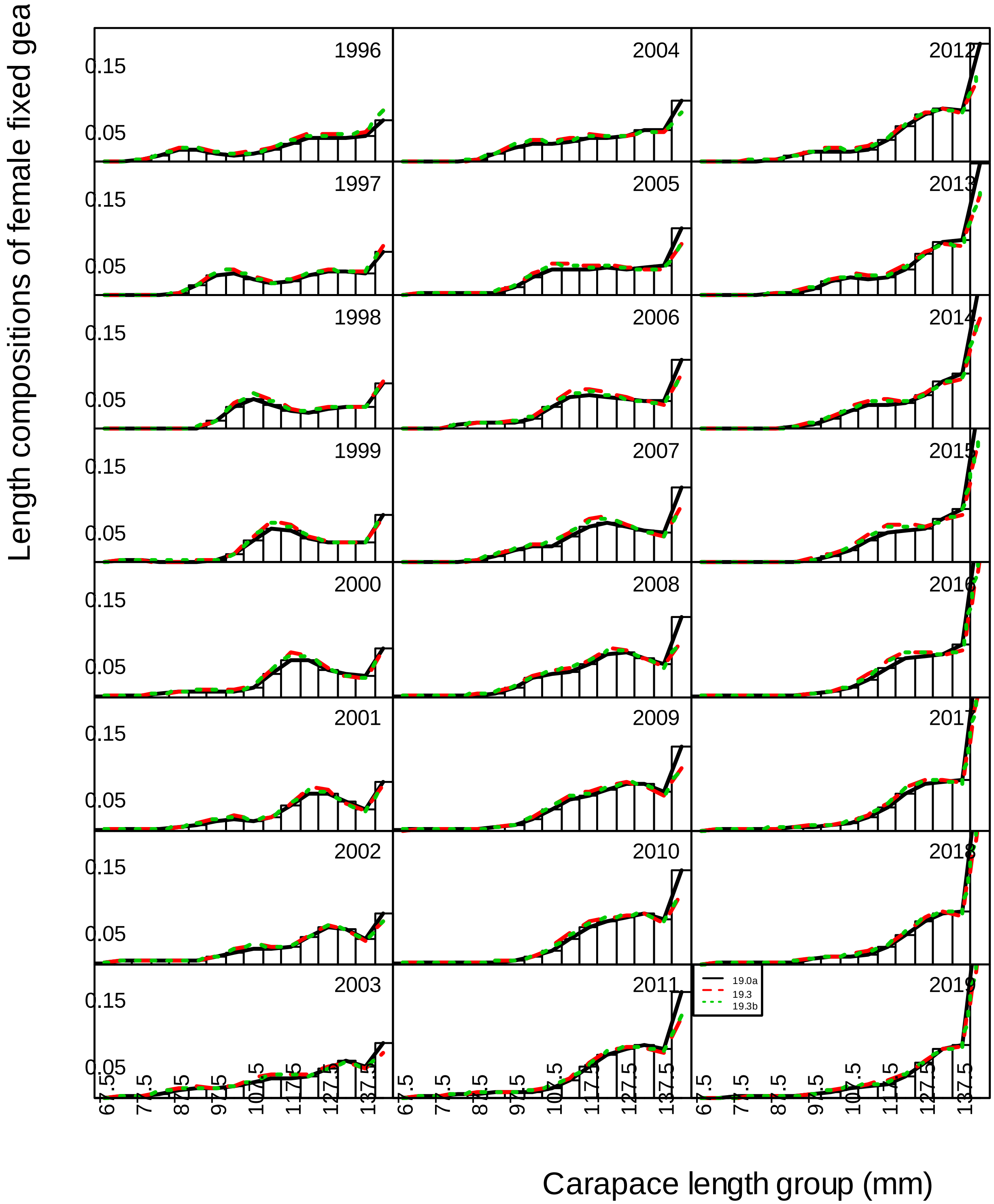


Figure 24b. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crab by year in the groundfish fixed gear fisheries under models 19.0a, 19.3, and 19.3b.

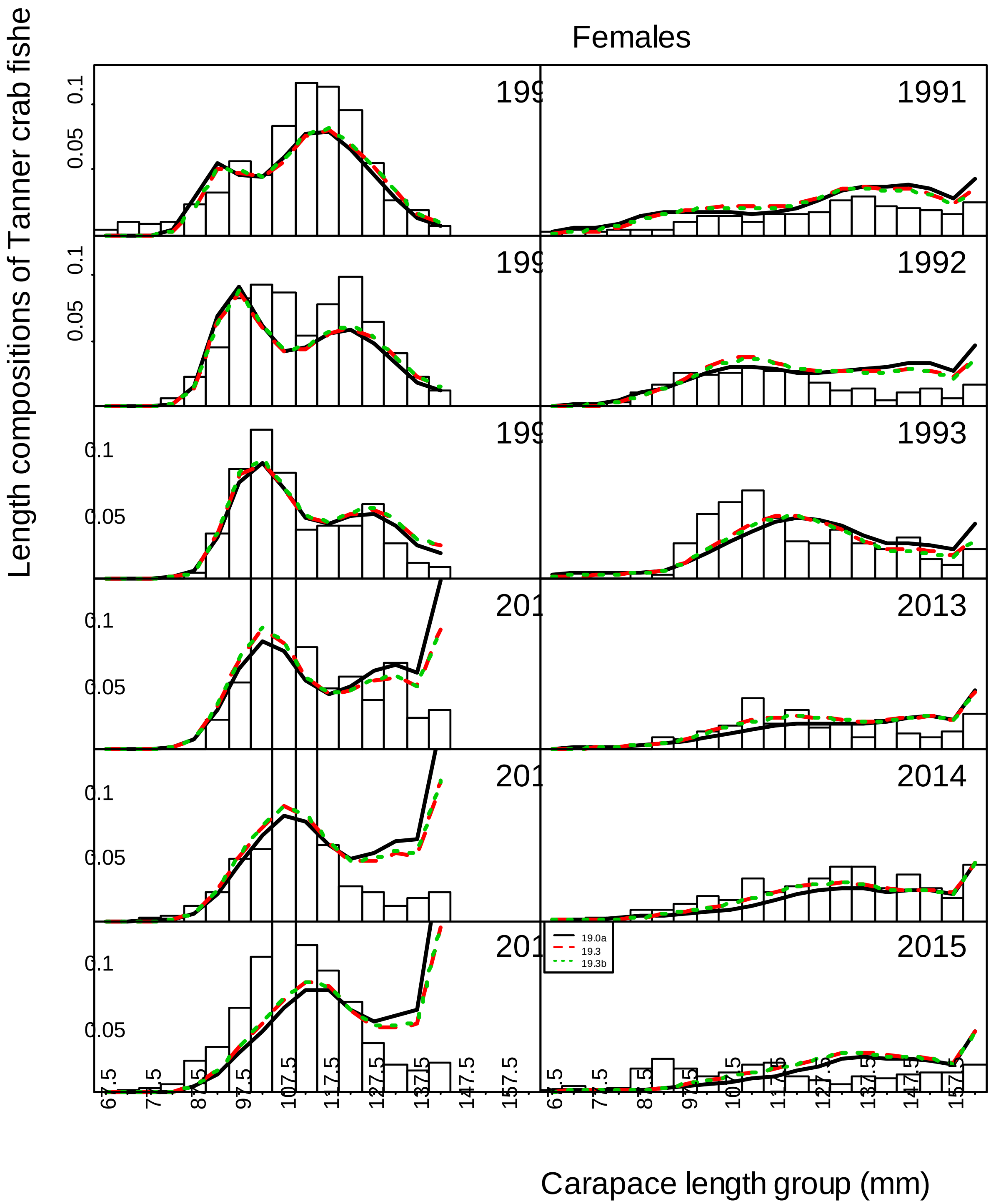


Figure 24c. Comparison of observer and model estimated discarded length frequencies of Bristol Bay red king crab by year in the Tanner crab fishery under models 19.0a, 19.3, and 19.3b.

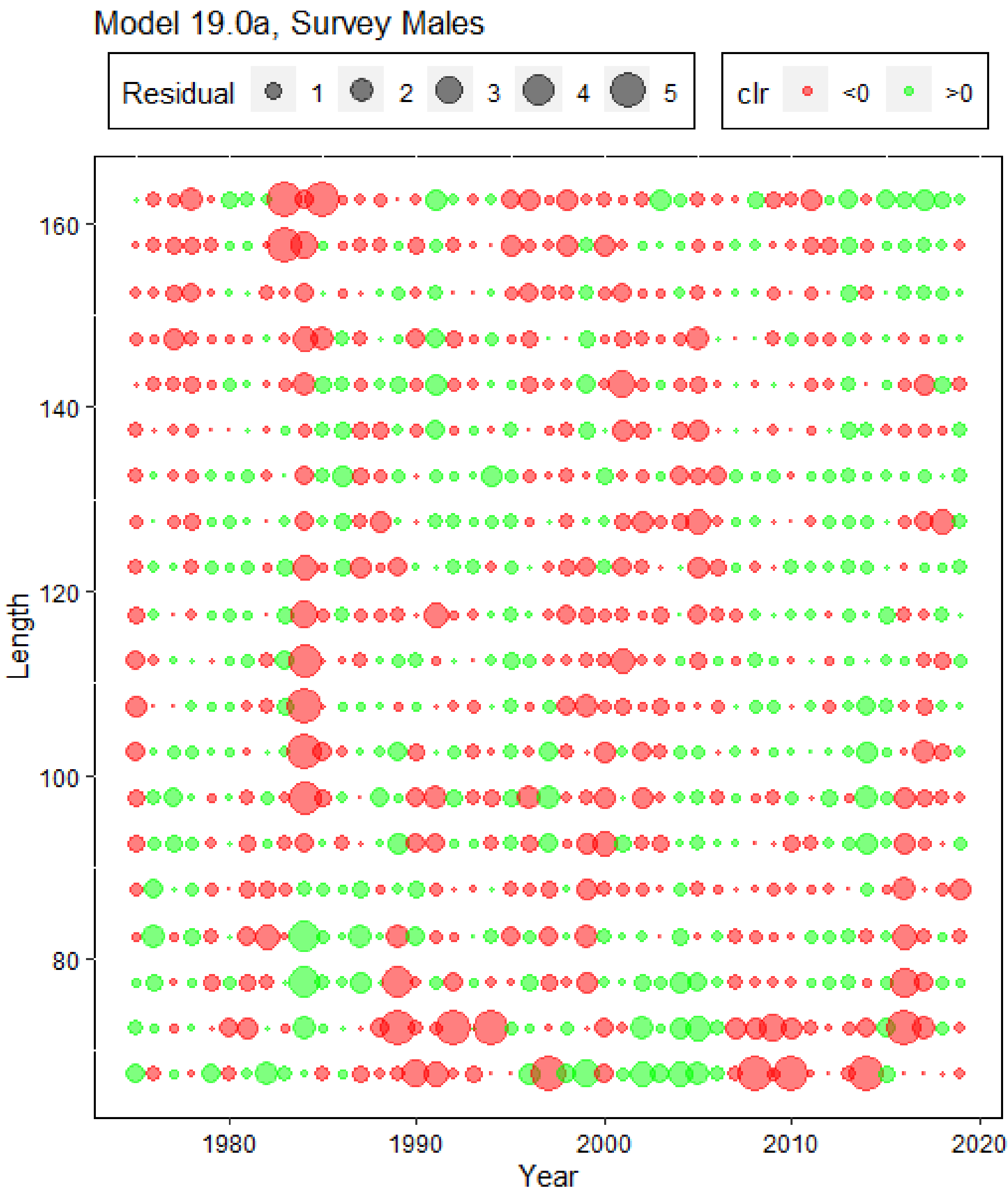


Figure 25a. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.0a. Green circles are positive residuals, and red circles are negative residuals.

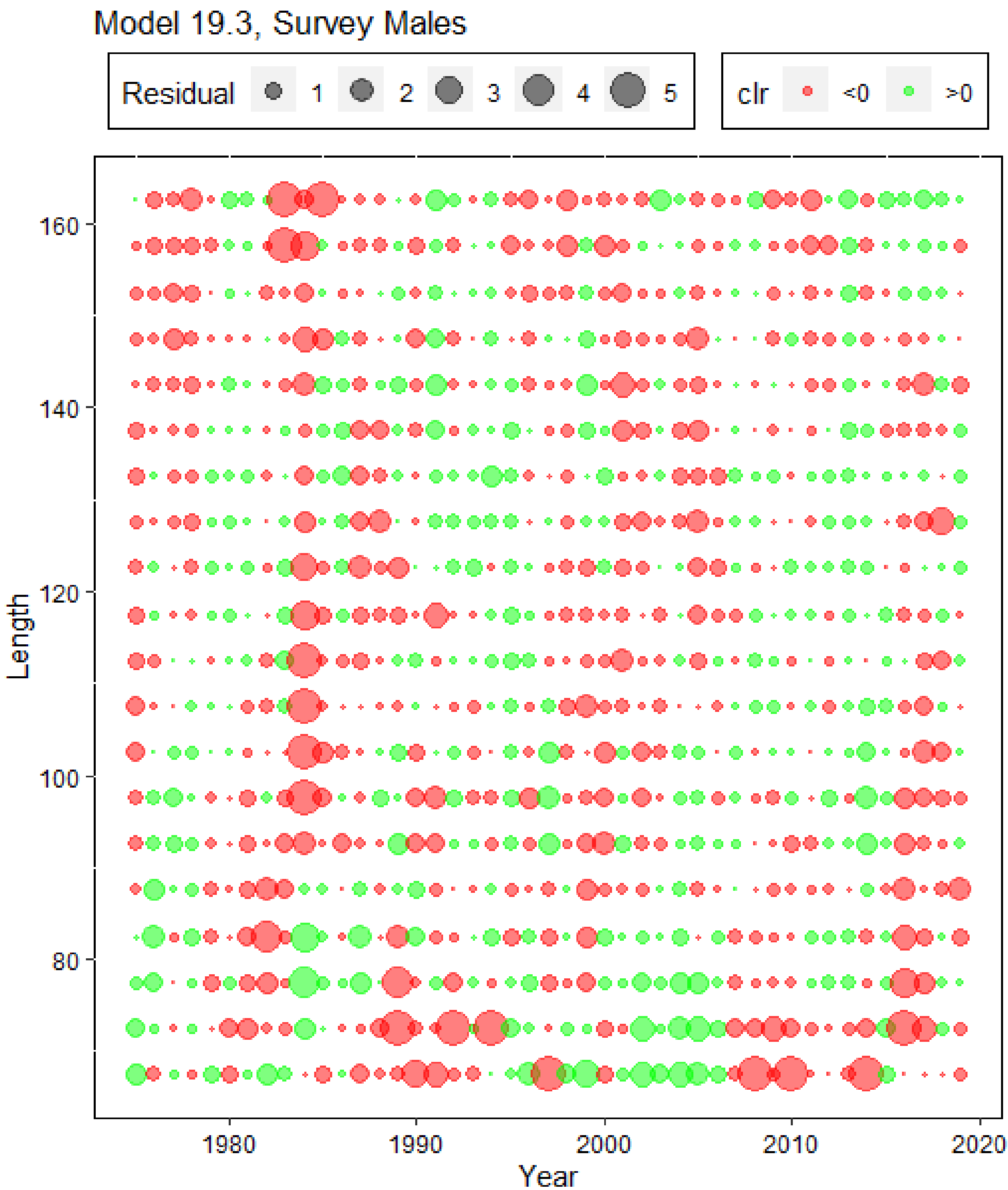


Figure 25b. Residuals of proportions of NMFS survey male red king crab by year and carapace length (mm) under model 19.3. Green circles are positive residuals, and red circles are negative residuals.

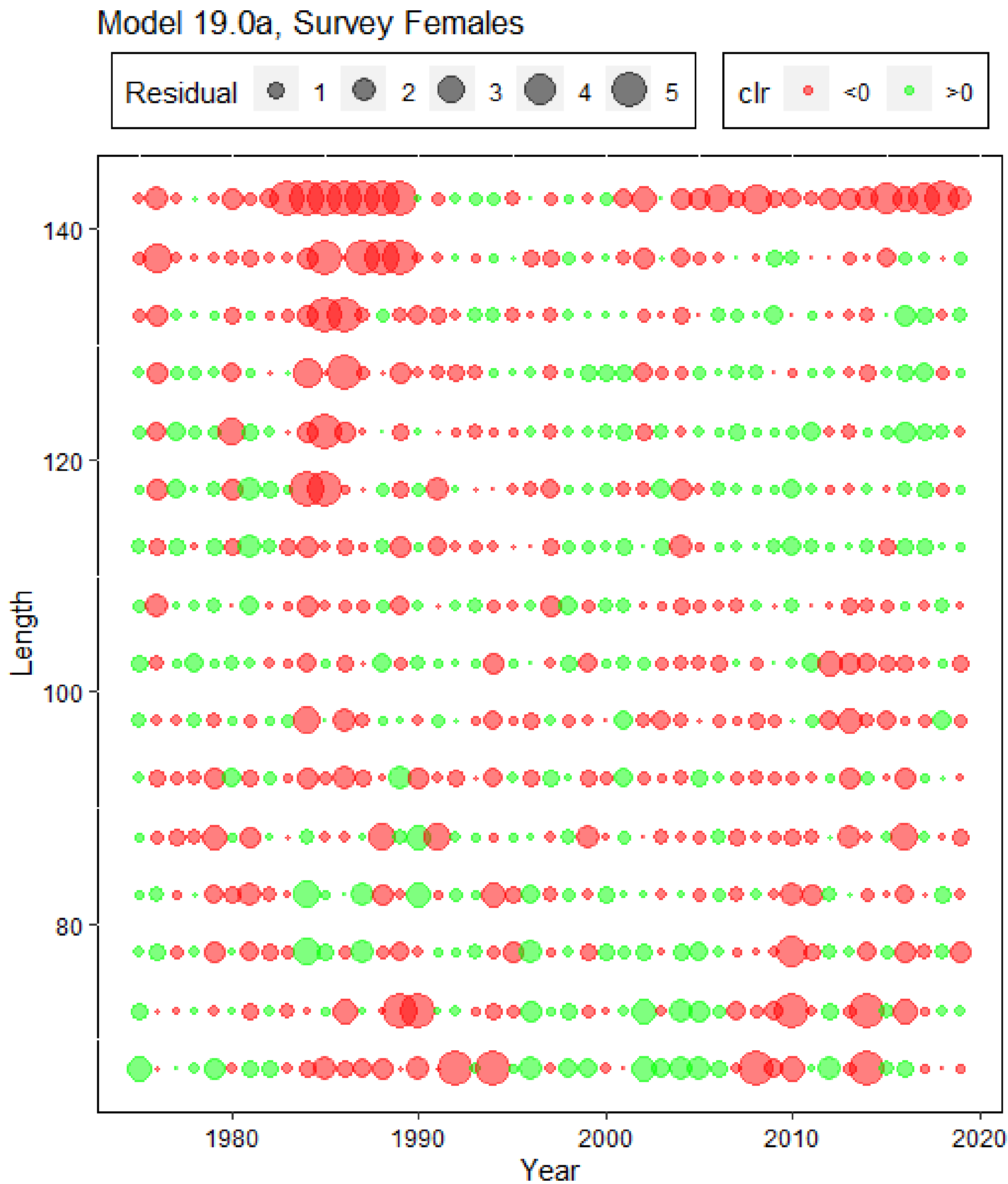


Figure 26a. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.0a. Green circles are positive residuals, and red circles are negative residuals.

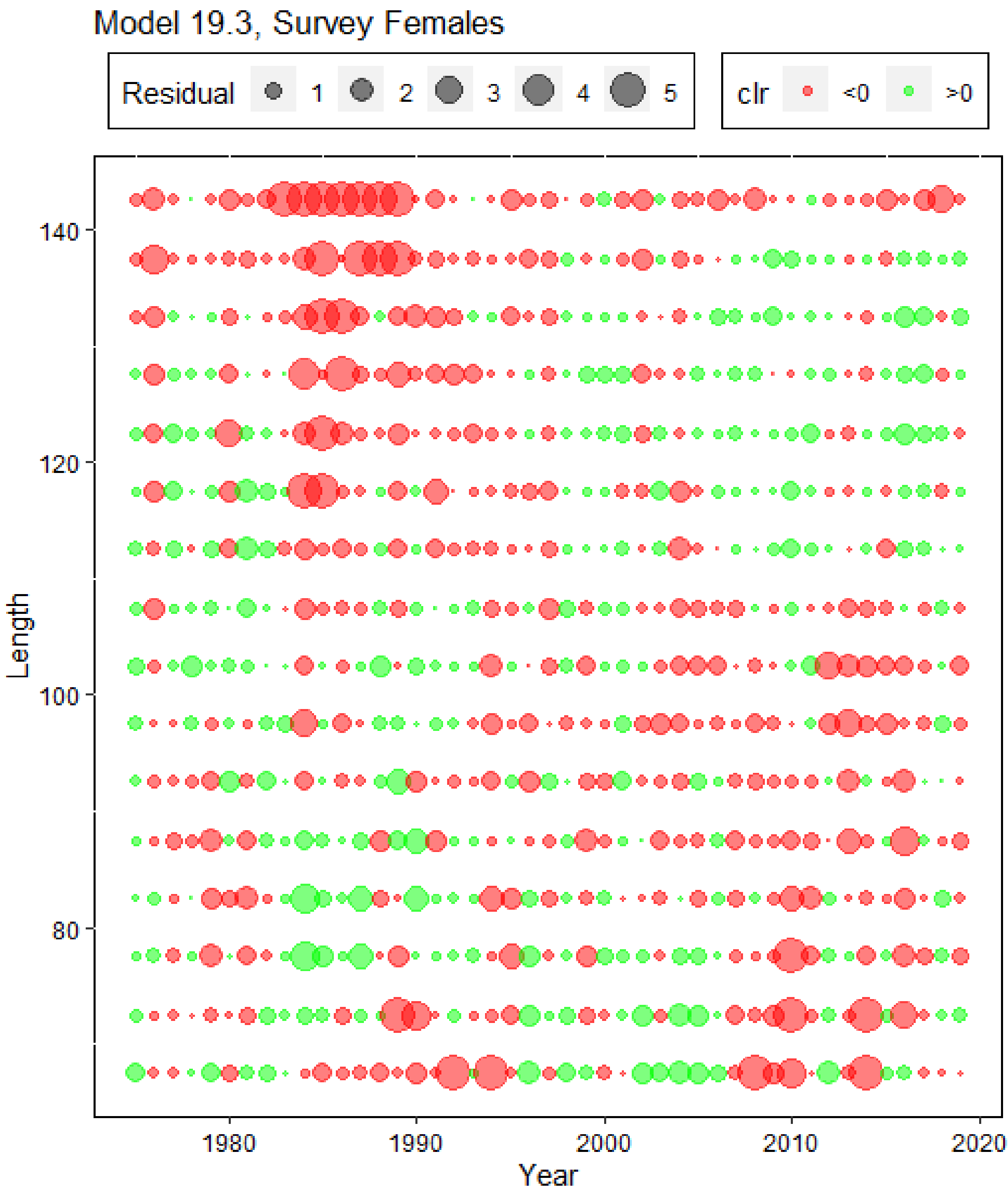


Figure 26b. Residuals of proportions of NMFS survey female red king crab by year and carapace length (mm) under model 19.3. Green circles are positive residuals, and red circles are negative residuals.

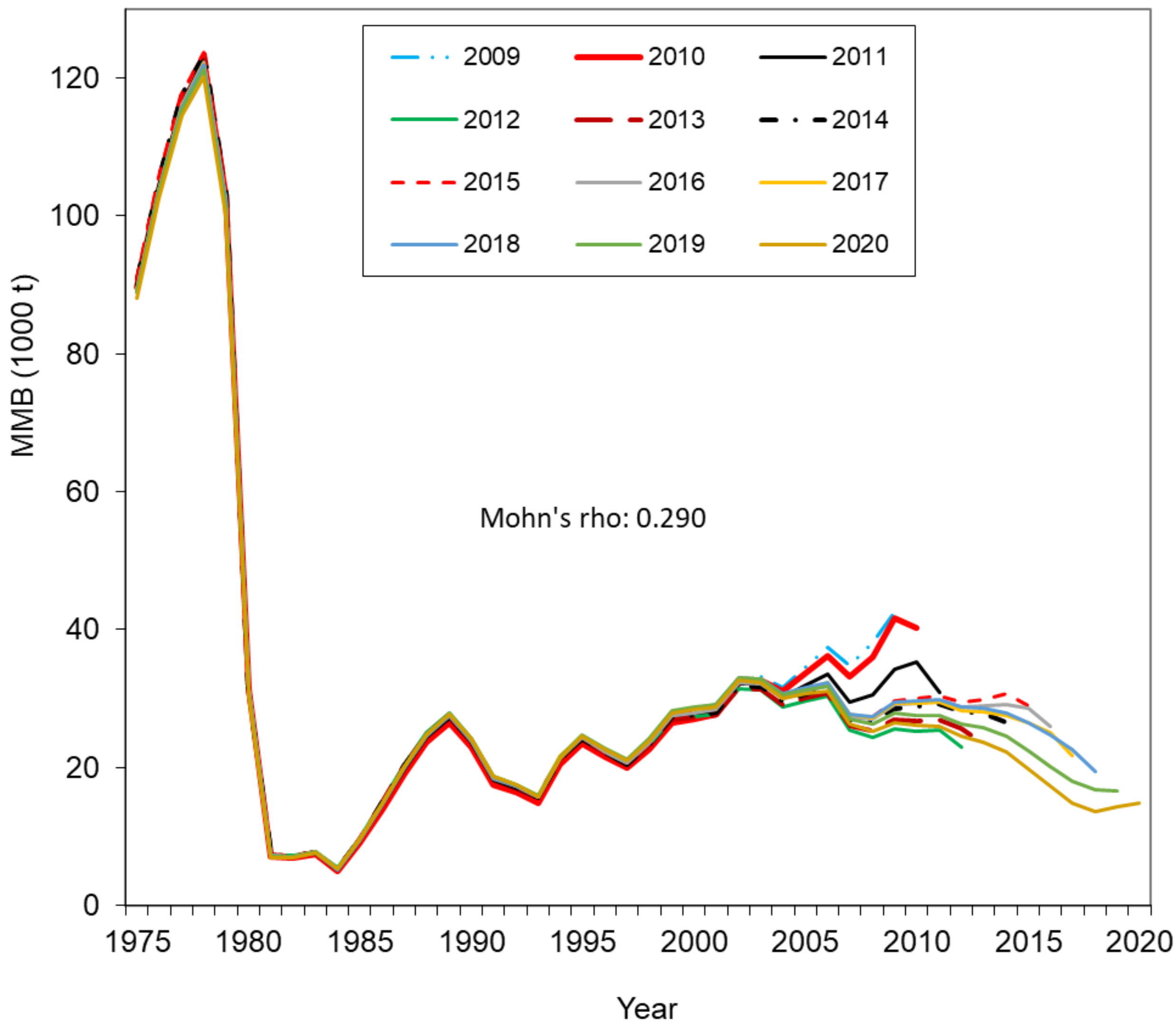


Figure 27. Comparison of hindcast estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2020 made with terminal years 2009-2020 with model 19.3. These are results of the 2020 model. Legend shows the terminal year.

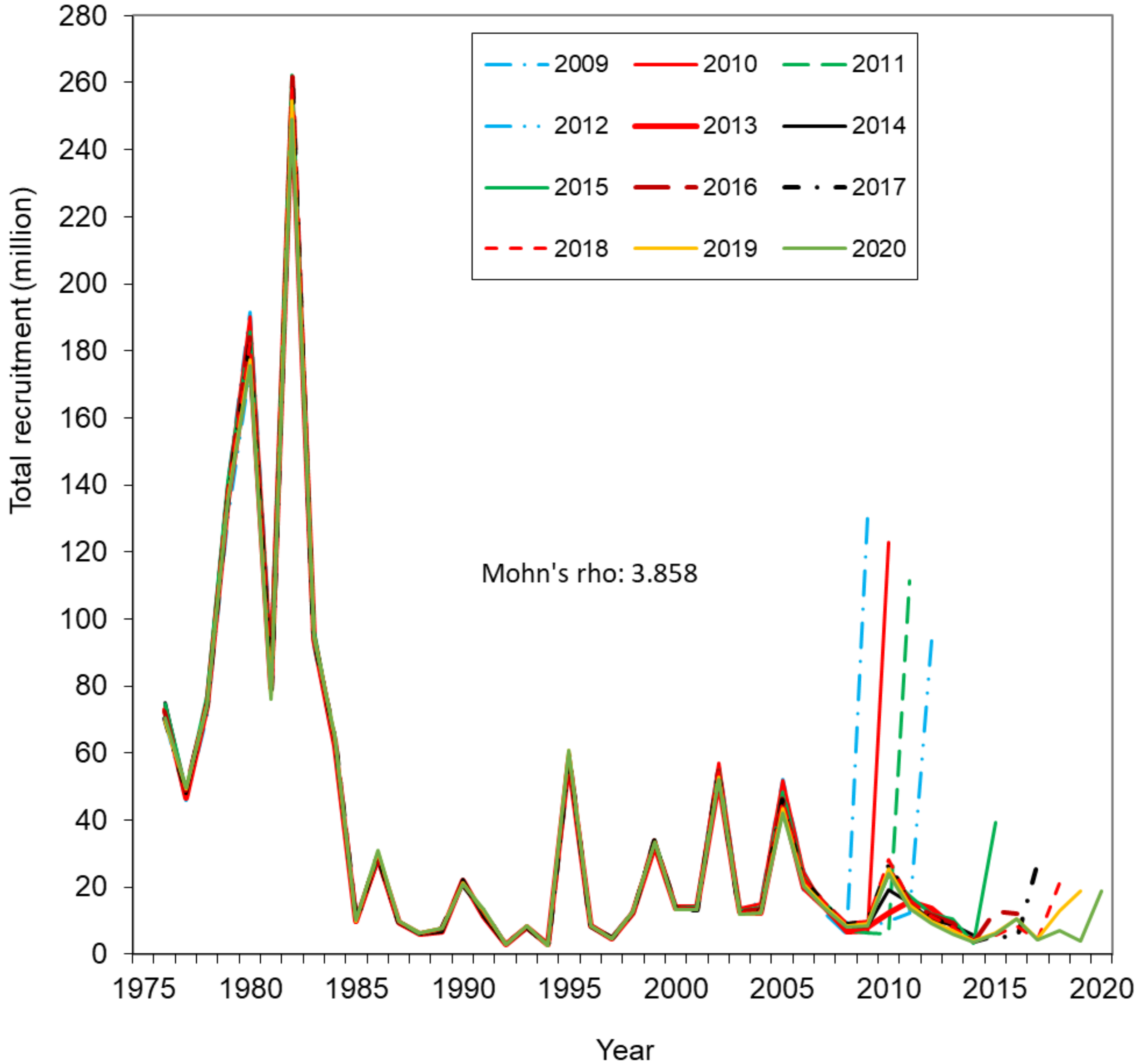


Figure 28a. Comparison of hindcast estimates of total recruitment for model 19.3 of Bristol Bay red king crab from 1976 to 2020 made with terminal years 2009-2020. These are results of the 2020 model. Legend shows the terminal year.

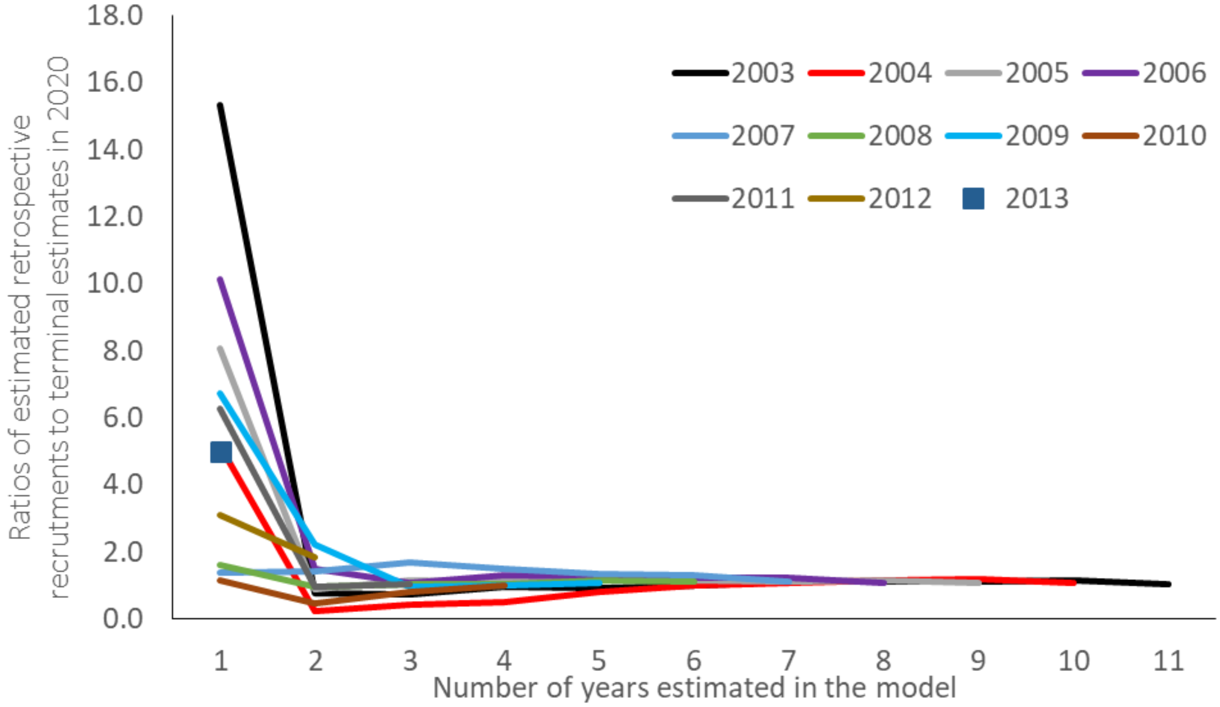


Figure 28b. Evaluation of Bristol Bay red king crab retrospective errors on recruitment estimates as a function of the number of years in the model for model 19.3.

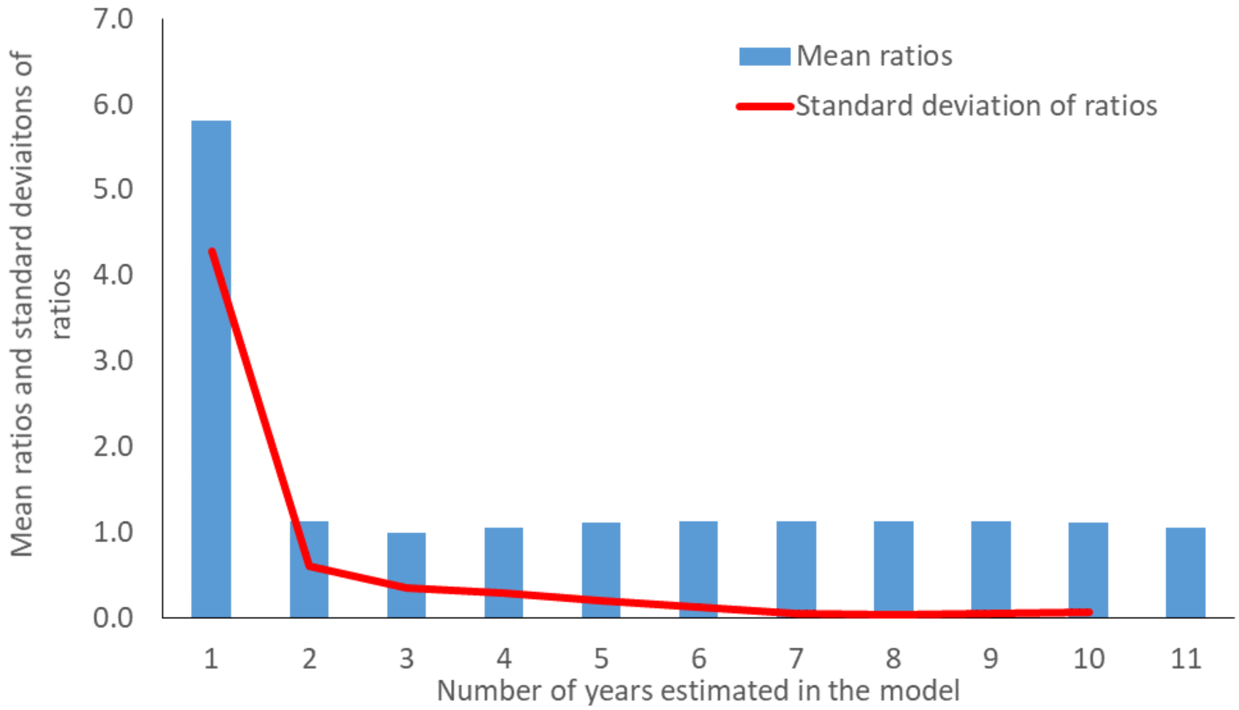


Figure 28c. Mean ratios of retrospective estimates of recruitments to those estimated in the most recent year (2020) and standard deviations of the ratios as a function of the number of years in the model for model 19.3.

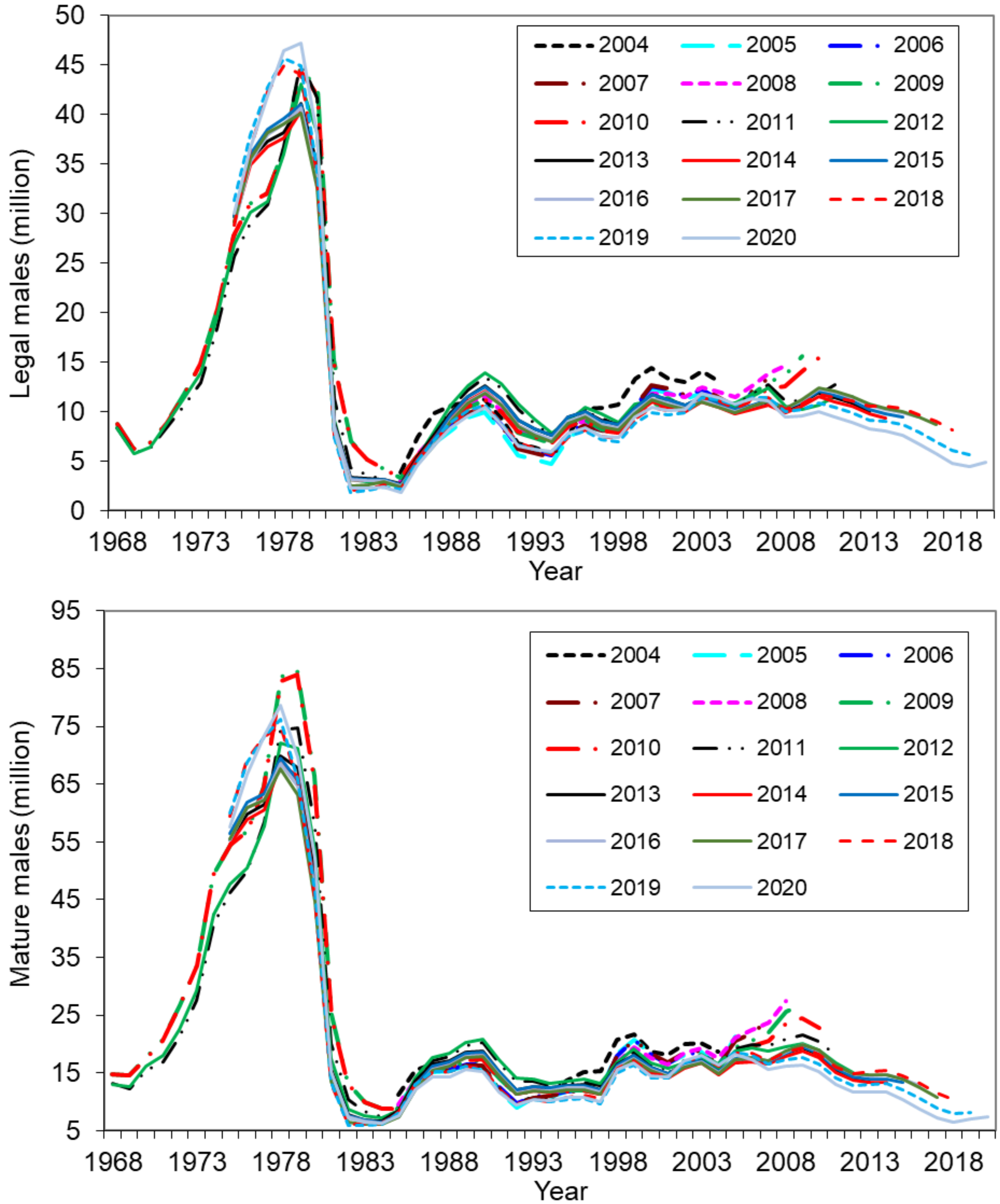


Figure 29. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2020 made with terminal years 2004-2020 with the base models. Model 19.3 is used for 2020. These are results of historical assessments. Legend shows the year in which the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

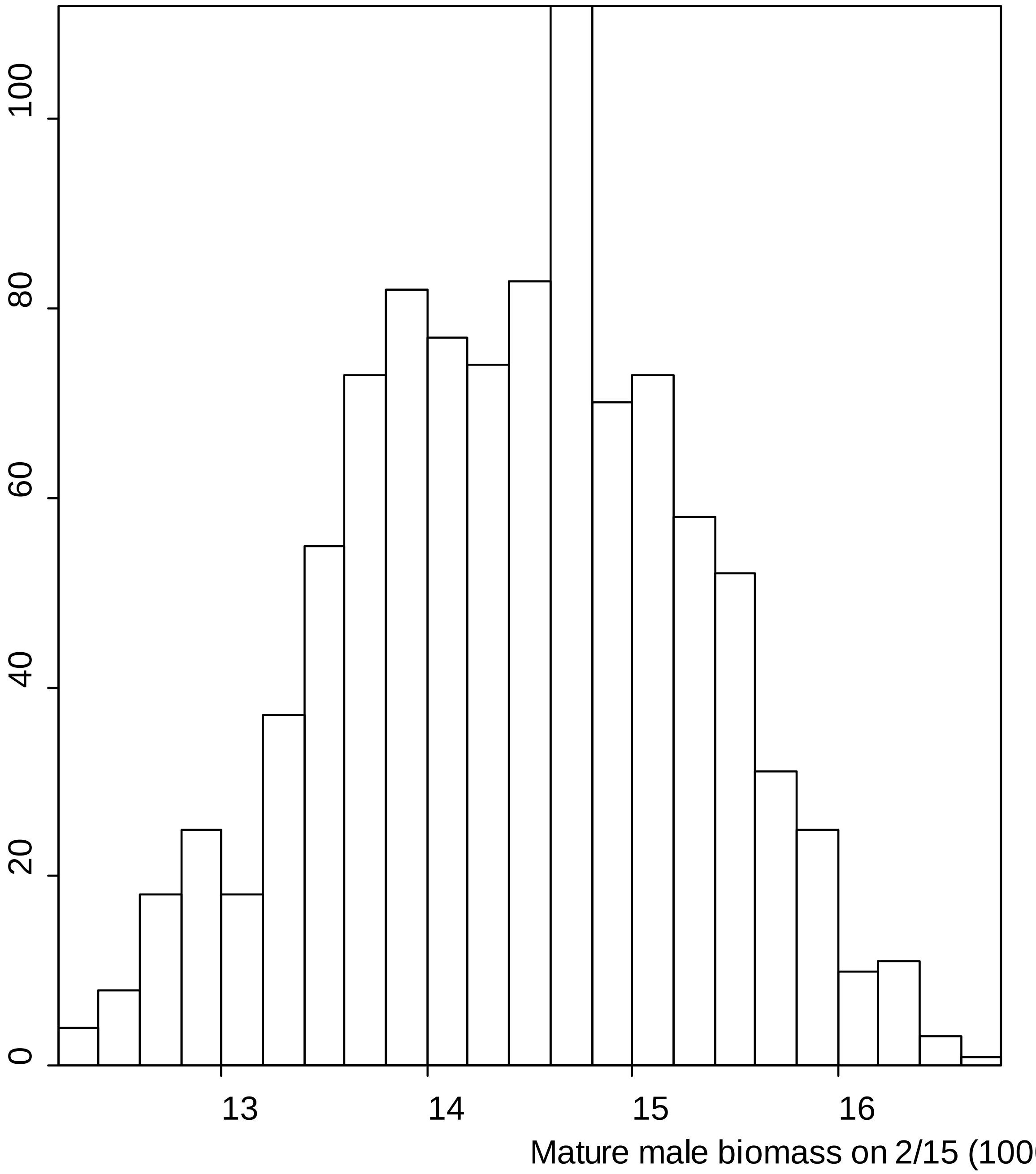


Figure 30. Histogram of estimated mature male biomass on Feb. 15, 2021 under model 19.3 with the MCMC approach.

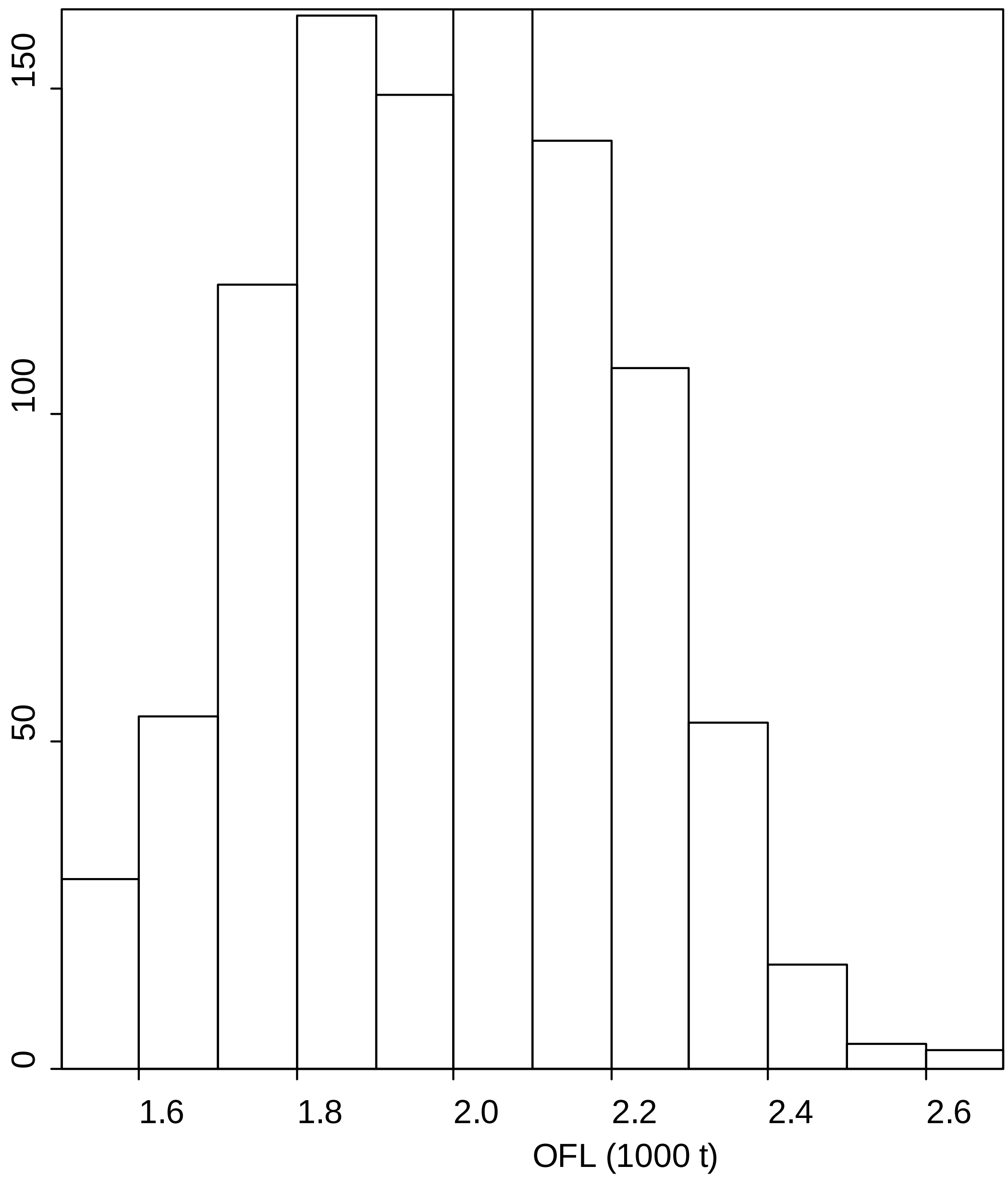


Figure 31. Histogram of the 2020 estimated OFL under model 19.3 with the MCMC approach.

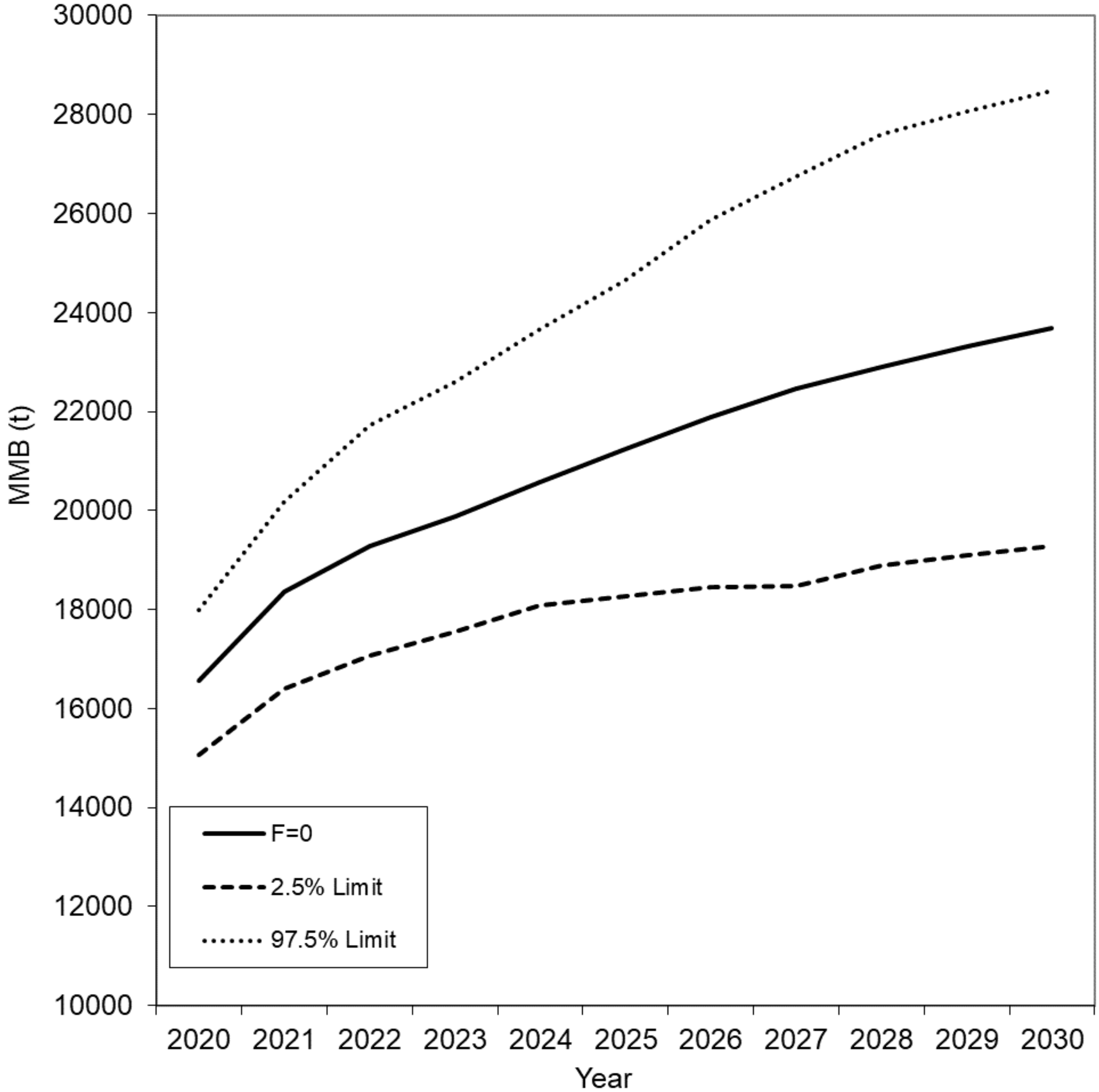


Figure 32a. Projected mature male biomass on Feb. 15 with $F = 0$ harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

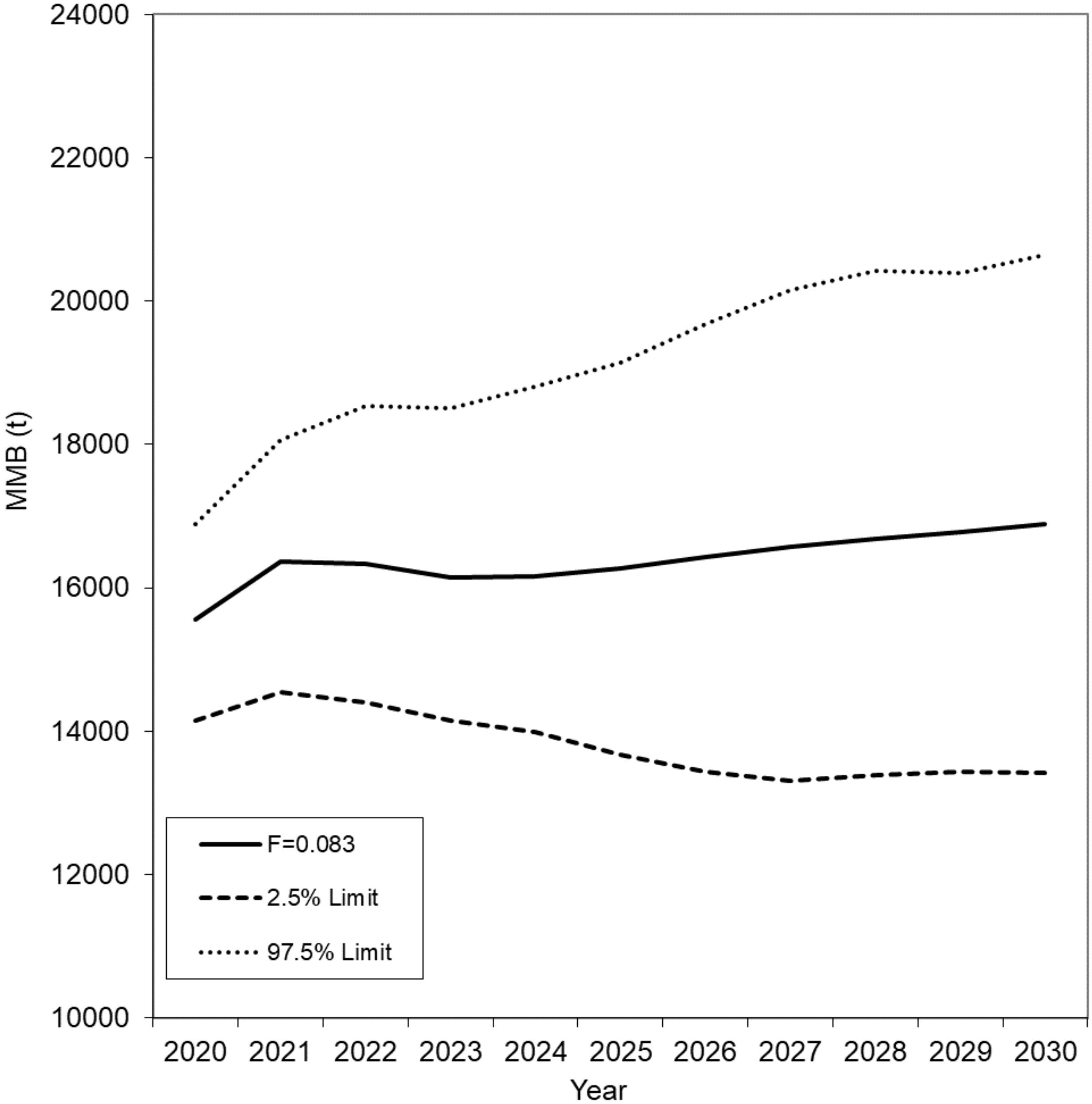


Figure 32b. Projected mature male biomass on Feb. 15 with F = 0.083 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

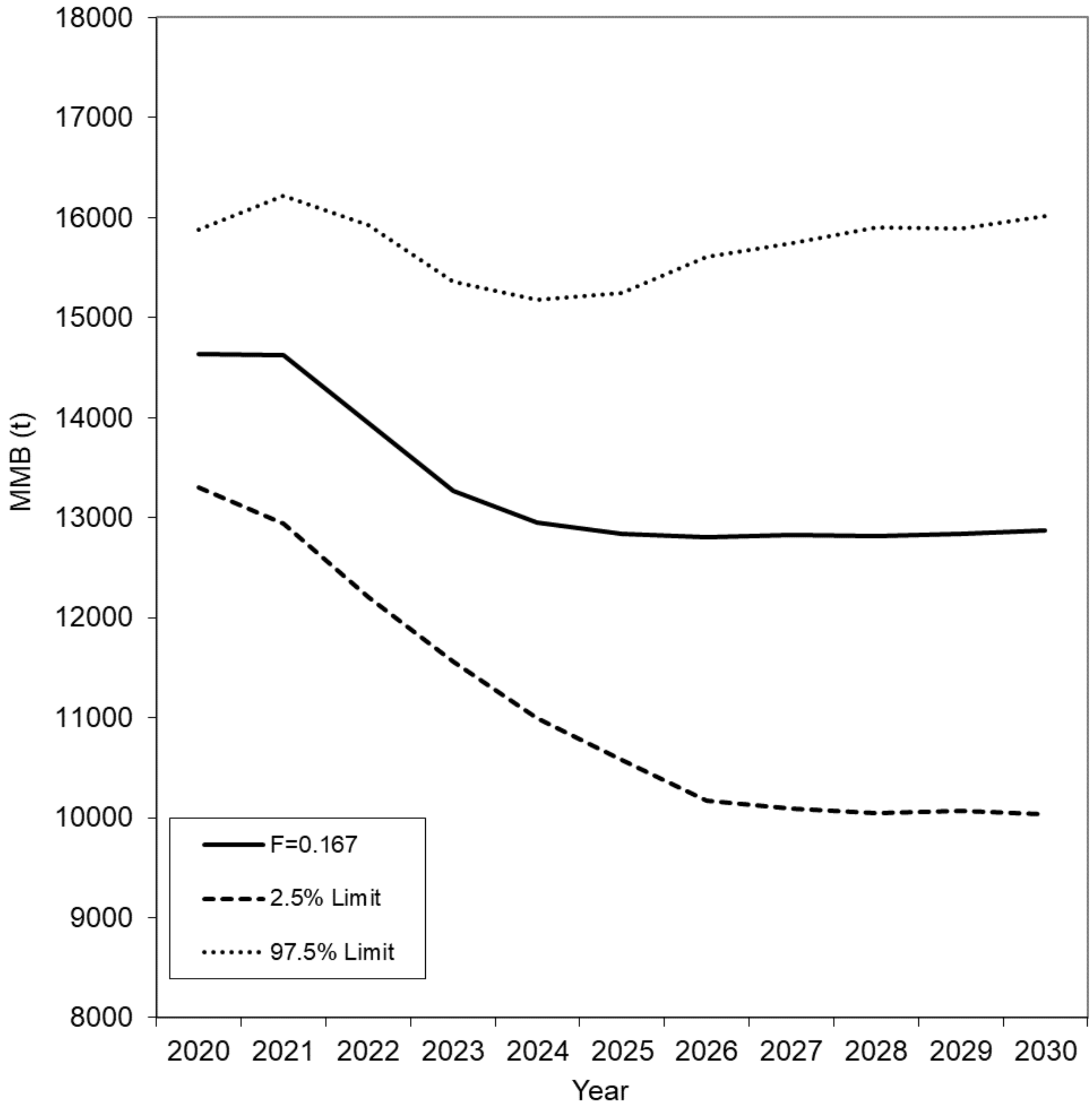


Figure 32c. Projected mature male biomass on Feb. 15 with F = 0.167 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

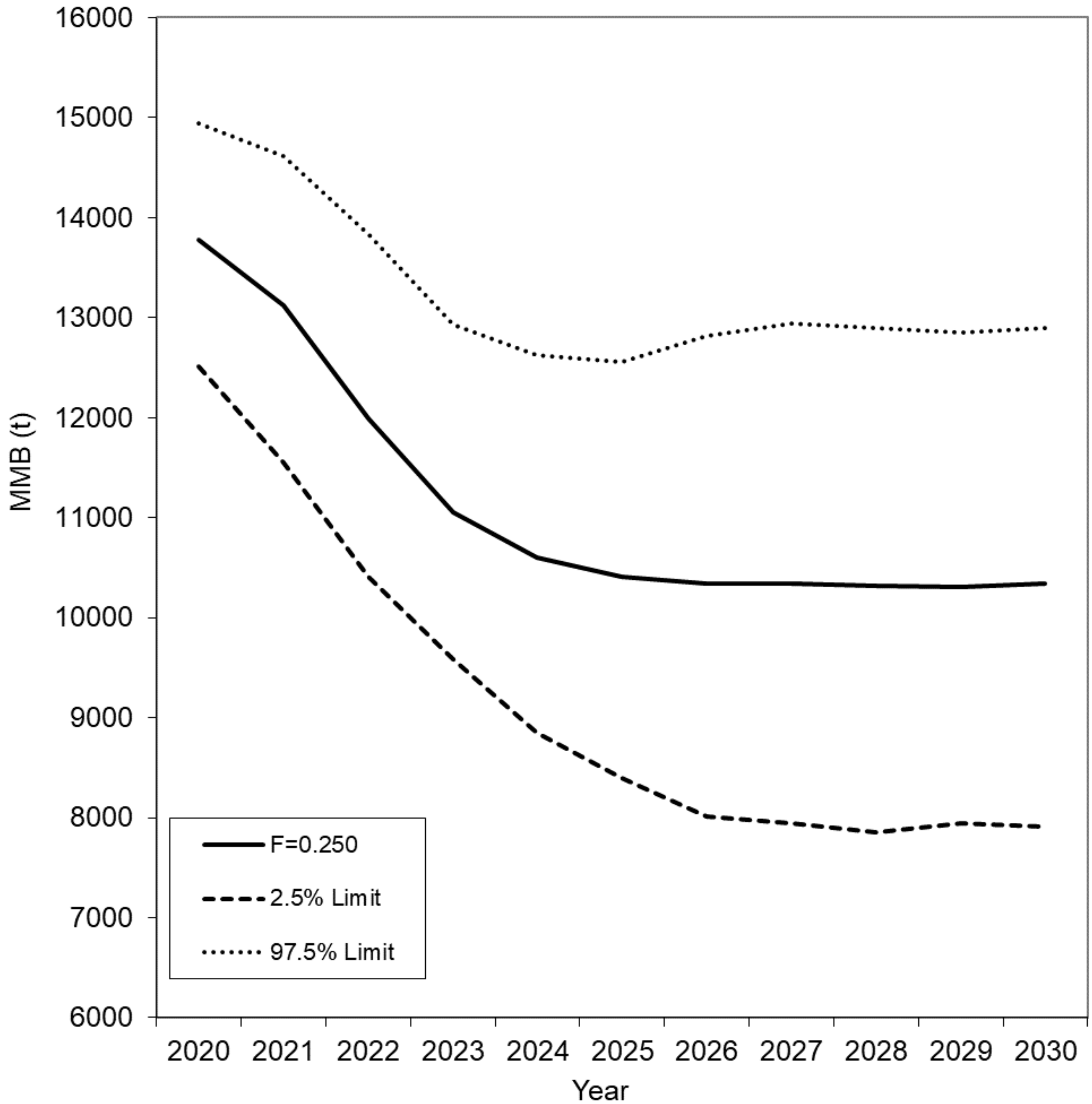


Figure 32d. Projected mature male biomass on Feb. 15 with F = 0.250 harvest strategy during 2020-2030. Input parameter estimates are based on model 19.3a.

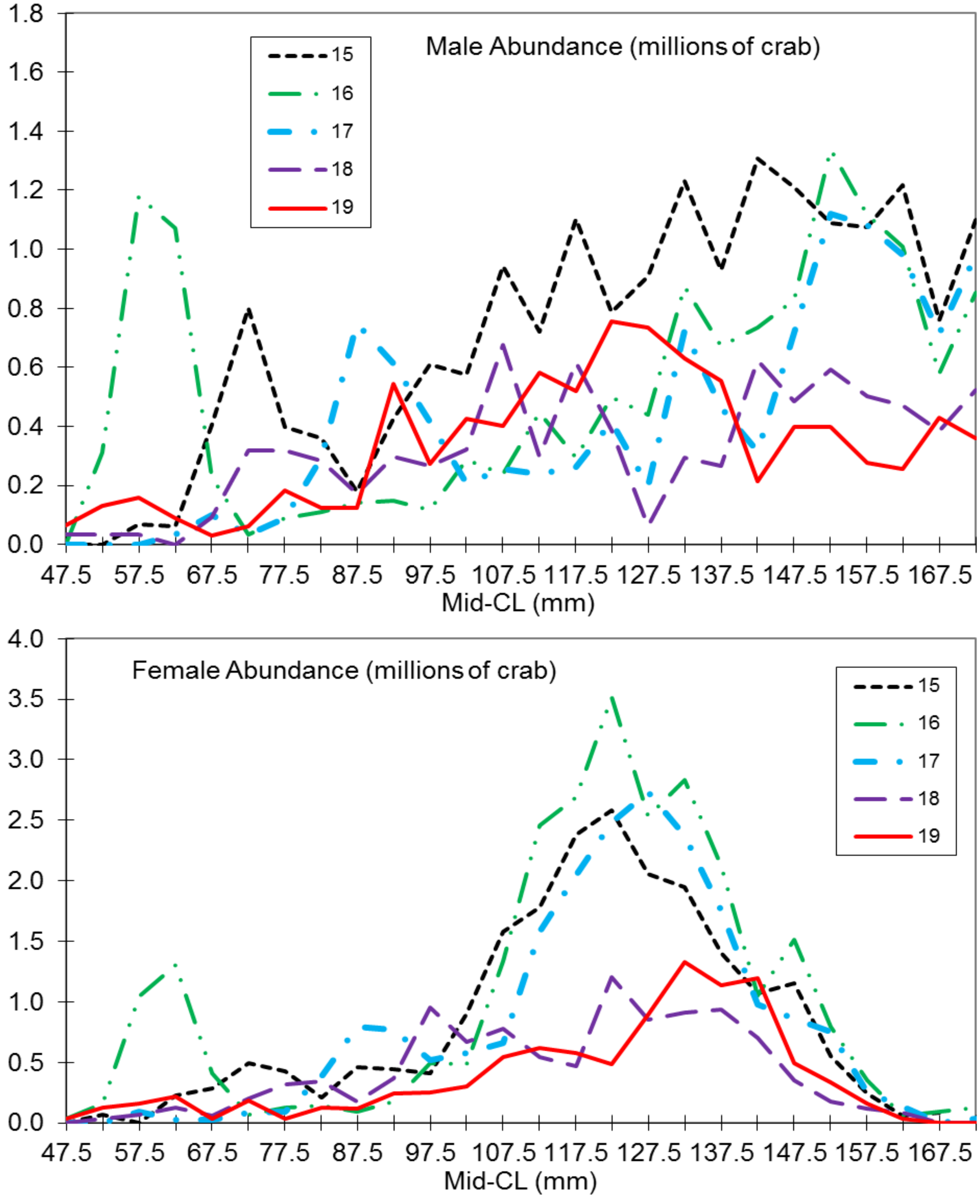


Figure 33. Length frequency distributions of male (top panel) and female (bottom panel) red king crab in Bristol Bay from NMFS trawl surveys during 2015-2019. For purposes of these graphs, abundance estimates are based on area-swept methods.

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:

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

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

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

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

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

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.:

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

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

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

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

c. Total mortality / probability of encountering the gear

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

$$Z_{y,t,l}^{g} = \rho_{y,t}^{\text{M}} M_y^g \tilde{M}_l + \sum_f S_{y,t,l}^{f,g} (\lambda_{y,t,l}^{f,g} + \Omega_{y,t,l}^{f,g}(1-\lambda_{y,t,l}^{f,g})) F_{y,t}^{f,g} \tag{A.6}$$

where $\rho_{y,t}^{\text{M}}$ is the proportion of natural mortality that occurs during season *t* for year *y*, M_y^g 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 , $S_{y,t,l}^{f,g}$ is the (capture) selectivity for animals of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, $\lambda_{y,t,l}^{f,g}$ is the probability of retention for animals of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, $\Omega_{y,t,l}^{f,g}$ is the mortality rate for discards of gender *g* in size-class *l* by fleet *f* during season *t* of year *y*, and $F_{y,t}^{f,g}$ 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:

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

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:

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

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

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:

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

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.:

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

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

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

(2) Size-transition

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

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

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:

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

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

Definition of model outputs:

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

b. Biological reference points

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

(1) The proxy for F_{MSY}

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

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

where $\underline{\overline{F}}$ 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

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

where y_2 is the final year of the assessment, $\alpha^{*,f}$ is the multiplier on average fully-selected fishing mortality for fleet f (1 for non-directed fisheries and a value computed from the OFL control rule for the directed fisheries), $\overline{F}^{f,g}_t$ 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:

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

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

- If the projected spawning stock biomass in year y_2+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 y_2+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 y_2+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 $\alpha^{*,f} = \alpha^f(SSB^*_{y_2}/B_{MSY} - 0.1)/0.9$ 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.:

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

      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.:

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

      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.:

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

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^{o} 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^{o} 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:

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

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), basic M was estimated to be 0.18 for both males and/or females. Natural mortality in a given year, M_t, may equal to $M + Mm_t$ (for males) or $M + Mf_t$ (females), or may be estimated. Different model scenarios estimate Mm_t and Mf_t differently.

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^{o} 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 1991-1993 and total potlifts east of 163^{o} W during 1968 to 2005 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 $0.18 yr^{-1}$, 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). Three additional mortality parameters for Mm_t and Mf_t were also estimated for some model scenarios. 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.

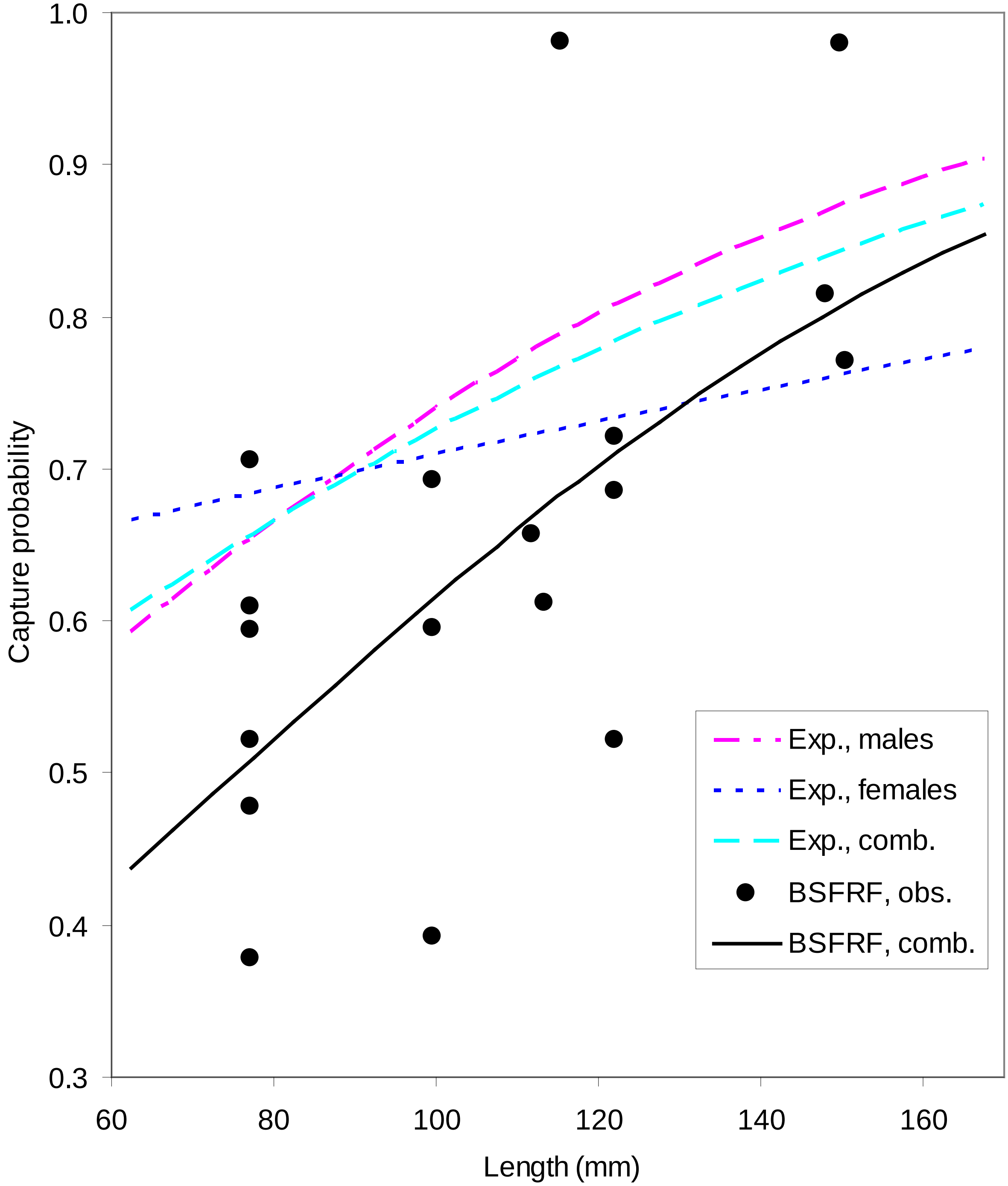
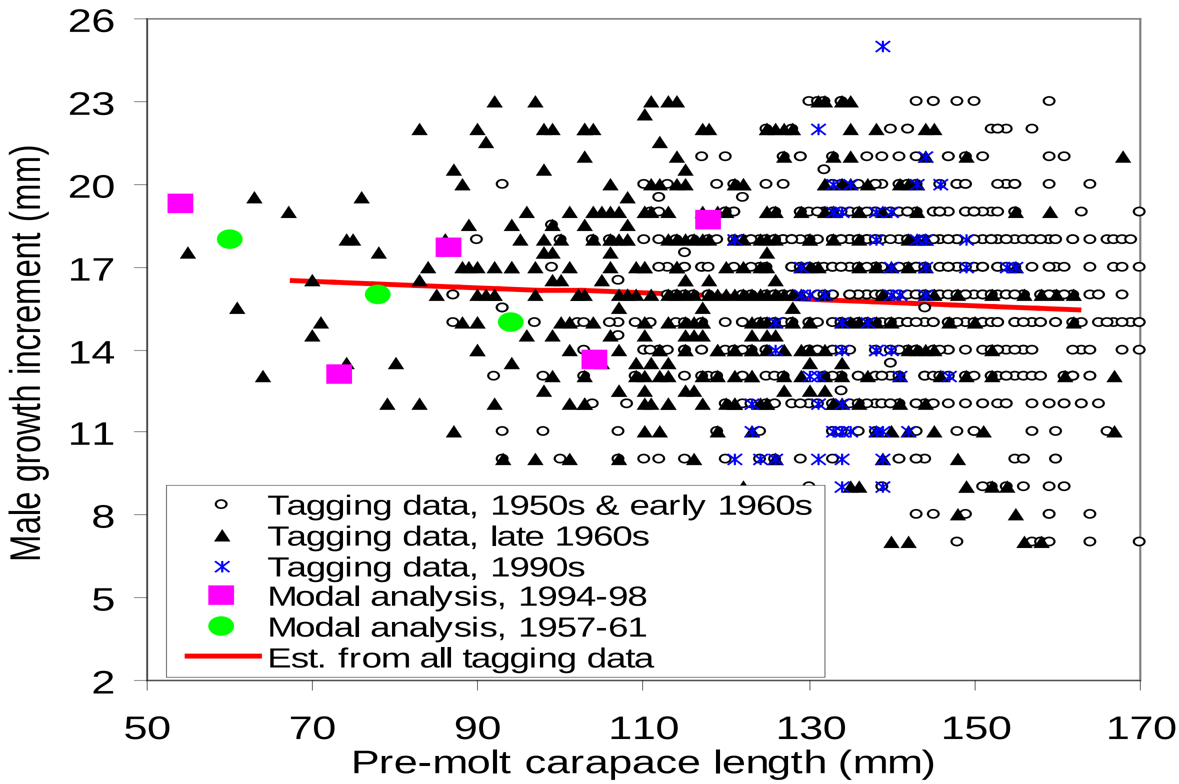


Figure A1. Estimated capture probabilities for NMFS Bristol Bay red king crab trawl surveys by Weinberg et al. (2004) and the Bering Sea Fisheries Research Foundation surveys.



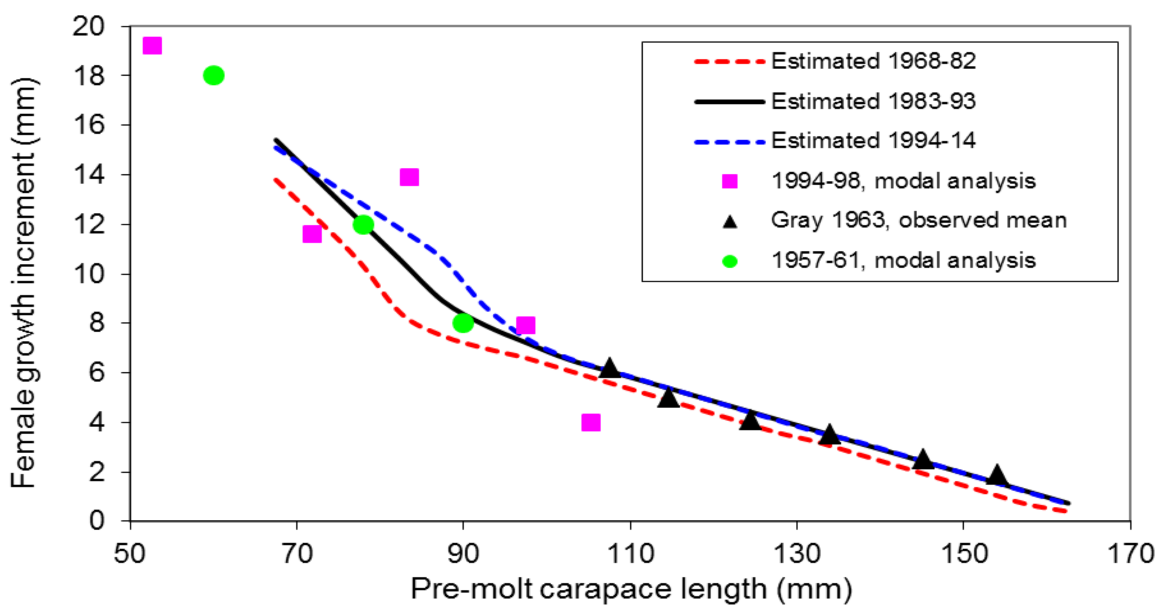


Figure A2. Mean growth increments per molt for Bristol Bay red king crab. Note: “tagging”---based on tagging data; “mode”---based on modal analysis. The female growth increments per molt are for different model scenarios.

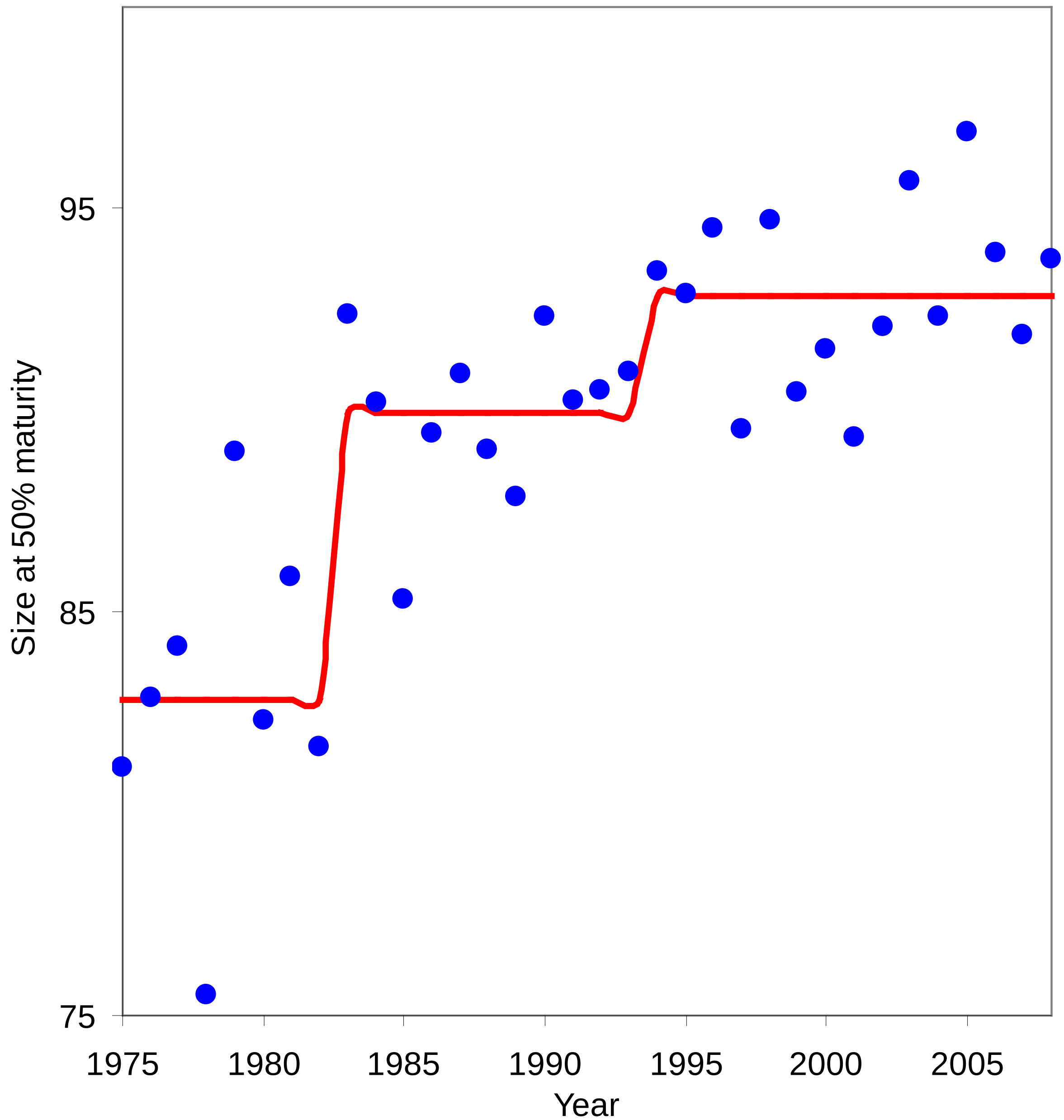


Figure A3. Estimated sizes at 50% maturity for Bristol Bay female red king crab from 1975 to 2008. Averages for three periods (1975-82, 1983-93, and 1994-08) are plotted with a line.

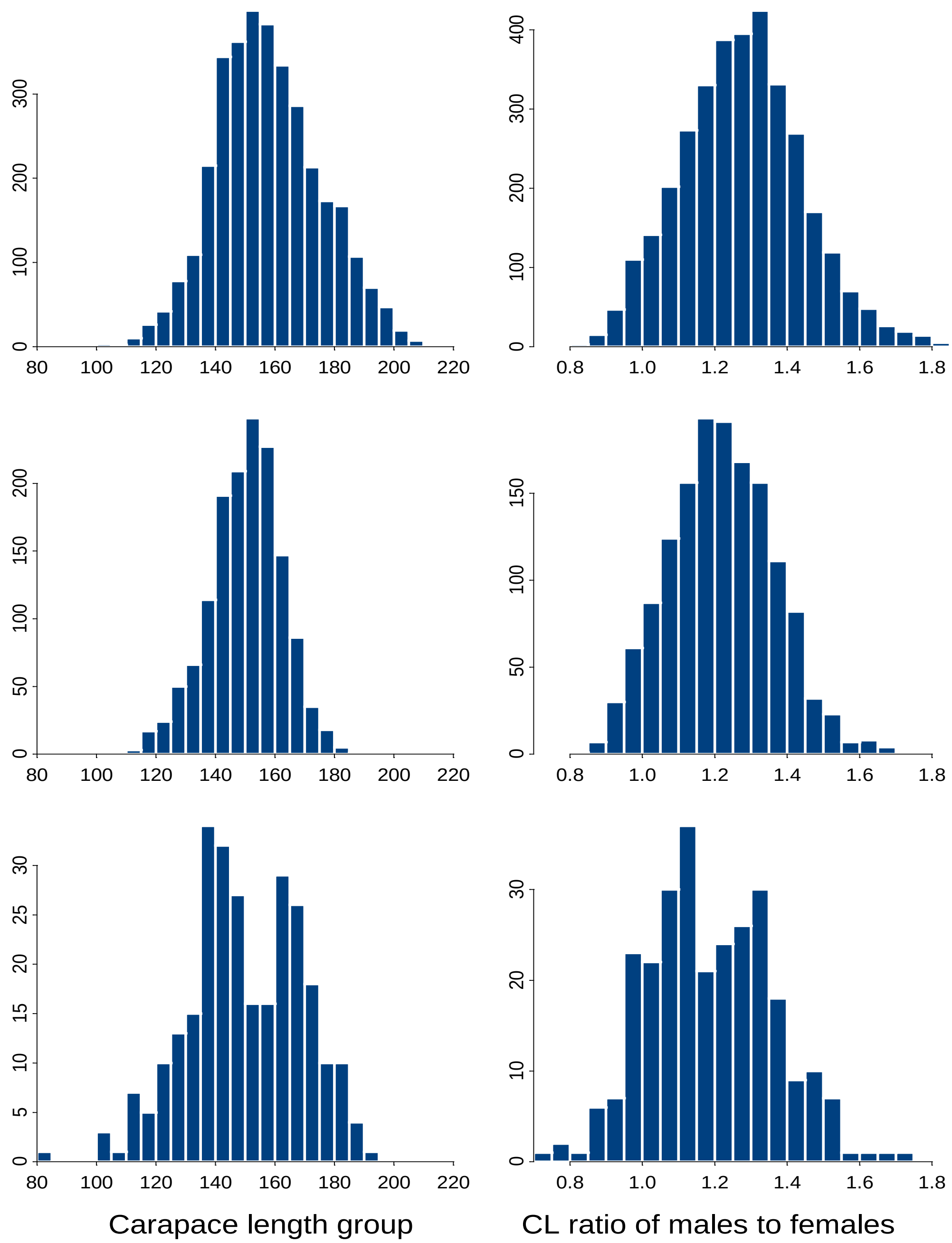


Figure A4. Histograms of carapace lengths (CL) and CL ratios of males to females for male shell ages ≤13 months of red king crab males in grasping pairs; Powell's Kodiak data. Upper plot: all locations and years pooled; middle plot: location 11; lower plot: locations 4 and 13. Sizes at maturity for Kodiak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

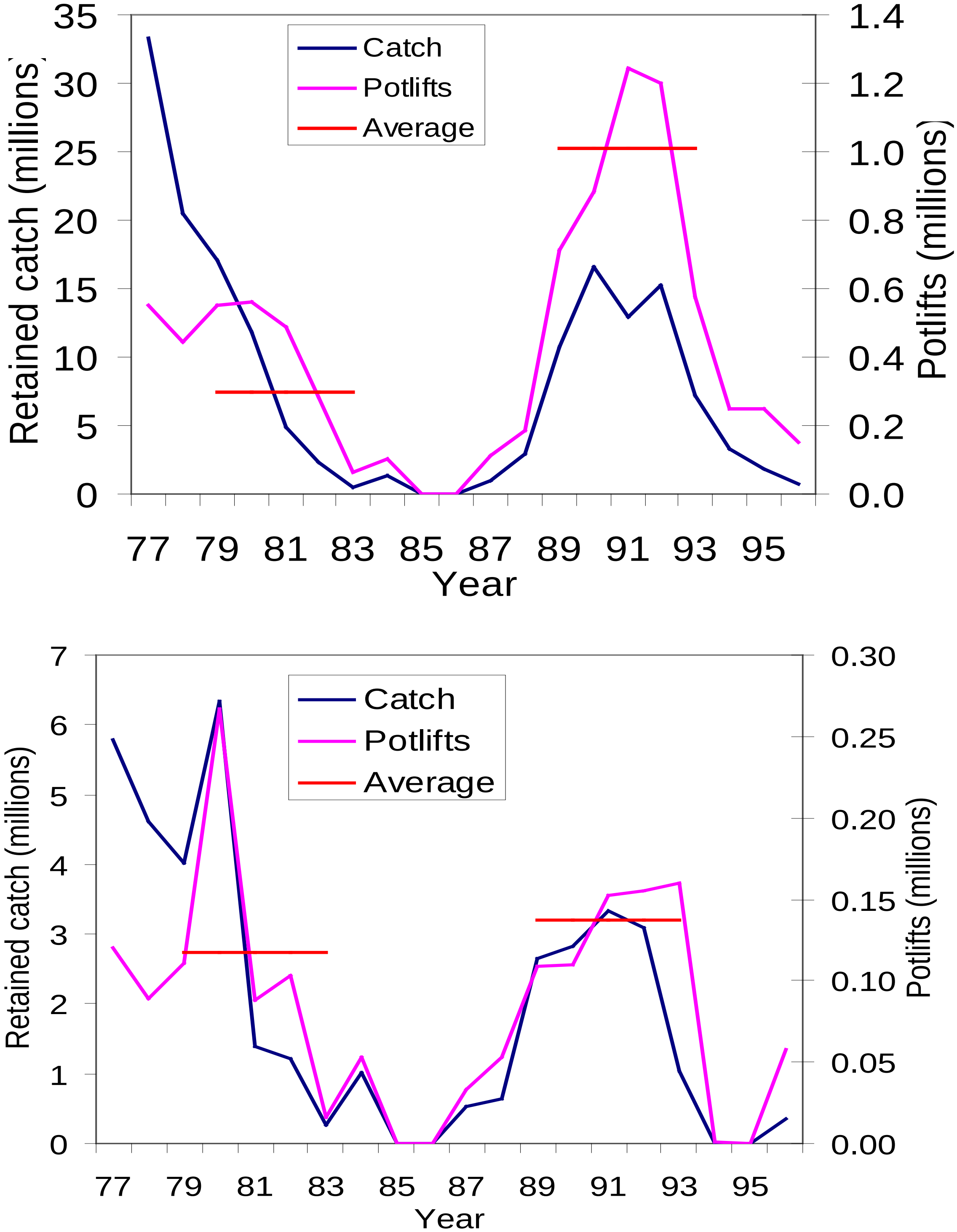


Figure A5. Retained catch and potlifts for total eastern Bering Sea Tanner crab fishery (upper plot) and the Tanner crab fishery east of 163° W (bottom).

Appendix B. Input Data File for Models 19.0a-19.3 (all seven models)

#===

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	90.109	0.10	2	1	1	0	0.5

————————————————————————————
RELATIVE ABUNDANCE DATA
Units of Abundance: 1 = biomass, 2 = numbers
TODO:add column for maturity for terminal molt life-histories
for BBRKC Units are in 1000 mt.
————————————————————————————
Number of relative abundance indicies
2
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
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
		0.0339	0.0226	0.0263	0.0402	0.0376	0.0427	0.0351	0.0351	0.0251	0.0351	0.0226
		0.0477	0.0351	0.0527	0.1041							
2002	5	2	1	0.0	0	0	50	0.0009	0.0009	0.0009	0.0009	0.0018
		0.0026	0.0061	0.0044	0.0061	0.0105	0.0219	0.0193	0.0280	0.0368	0.0464	0.0455
		0.0517	0.0569	0.0412	0.1322							
2003	5	2	1	0.0	0	0	26.25	0.0019	0.0039	0.0058	0.0077	0.0193
		0.0097	0.0154	0.0232	0.0251	0.0174	0.0135	0.0193	0.0309	0.0347	0.0425	0.0521
		0.0463	0.0483	0.0521	0.1216							
2004	5	2	1	0.0	0	0	33.3	0.0015	0.0000	0.0000	0.0015	0.0015
		0.0045	0.0060	0.0166	0.0211	0.0166	0.0302	0.0392	0.0407	0.0377	0.0347	0.0407
		0.0422	0.0392	0.0347	0.1448							
2005	5	2	1	0.0	0	0	50	0.0029	0.0038	0.0019	0.0086	0.0077
		0.0134	0.0211	0.0154	0.0125	0.0230	0.0259	0.0393	0.0509	0.0480	0.0422	0.0413
		0.0461	0.0480	0.0403	0.0883							
2006	5	2	1	0.0	0	0	50	0.0000	0.0000	0.0000	0.0000	0.0017
		0.0025	0.0025	0.0127	0.0110	0.0391	0.0365	0.0425	0.0484	0.0467	0.0688	0.0697
		0.0688	0.0671	0.0586	0.1393							
2007	5	2	1	0.0	0	0	50	0.0000	0.0000	0.0000	0.0016	0.0024
		0.0032	0.0048	0.0112	0.0128	0.0136	0.0233	0.0217	0.0289	0.0393	0.0457	0.0401
		0.0393	0.0425	0.0586	0.1252							
2008	5	2	1	0.0	0	0	50	0.0000	0.0000	0.0006	0.0000	0.0025
		0.0025	0.0019	0.0025	0.0131	0.0255	0.0255	0.0597	0.0622	0.0566	0.0715	0.0466
		0.0646	0.0547	0.0541	0.1753							
2009	5	2	1	0.0	0	0	50	0.0000	0.0000	0.0000	0.0000	0.0008
		0.0025	0.0025	0.0033	0.0066	0.0108	0.0116	0.0298	0.0298	0.0431	0.0547	0.0514
		0.0671	0.0497	0.0530	0.1740							
2010	5	2	1	0.0	0	0	45.95	0.0000	0.0000	0.0022	0.0022	0.0022
		0.0054	0.0033	0.0120	0.0185	0.0174	0.0196	0.0348	0.0490	0.0501	0.0566	0.0479
		0.0359	0.0337	0.0370	0.0860							
2011	5	2	1	0.0	0	0	22.3	0.0000	0.0000	0.0022	0.0067	0.0067
		0.0022	0.0022	0.0067	0.0135	0.0090	0.0067	0.0067	0.0224	0.0269	0.0493	0.0650
		0.0605	0.0628	0.0448	0.1188							
2012	5	2	1	0.0	0	0	14.15	0.0000	0.0035	0.0000	0.0000	0.0000
		0.0035	0.0071	0.0071	0.0035	0.0071	0.0141	0.0106	0.0283	0.0353	0.0601	0.0318
		0.0495	0.0530	0.0530	0.1696							
2013	5	2	1	0.0	0	0	24.2	0.0000	0.0021	0.0000	0.0021	0.0021
		0.0000	0.0000	0.0021	0.0041	0.0083	0.0103	0.0227	0.0455	0.0393	0.0517	0.0517
		0.0434	0.0517	0.0393	0.2624							
2014	5	2	1	0.0	0	0	13.05	0.0000	0.0038	0.0000	0.0038	0.0115
		0.0038	0.0000	0.0192	0.0038	0.0115	0.0192	0.0230	0.0268	0.0383	0.0690	0.0881
		0.0421	0.0345	0.0460	0.2069							
2015	5	2	1	0.0	0	0	20.45	0.0000	0.0000	0.0073	0.0073	0.0073
		0.0049	0.0122	0.0147	0.0122	0.0147	0.0220	0.0293	0.0318	0.0440	0.0342	0.0391
		0.0513	0.0342	0.0391	0.1002							
2016	5	2	1	0.0	0	0	30.85	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
0.0108 0.0204 0.0430 0.0504 0.0480 0.0435 0.0295 0.0256 0.0170 0.0065 0.0168
1990 5 2 2 0 0 0 0 0.0020 0.0041 0.0071 0.0081 0.0112
0.0112 0.0183 0.0203 0.0366 0.0305 0.0335 0.0325 0.0234 0.0173 0.0152 0.0447
1991 5 2 2 0 0 0 0 0.0000 0.0036 0.0108 0.0036 0.0000
0.0072 0.0036 0.0072 0.0289 0.0181 0.0181 0.0289 0.0181 0.0325 0.0036 0.1047

1992	5	2	2	0	0	0	0	0.0030	0.0000	0.0000	0.0030	0.0420
		0.0631	0.0480	0.0480	0.0450	0.0480	0.0631	0.0691	0.0480	0.0450	0.0390	0.0571
1994	5	2	2	0	0	0	0	0.0000	0.0035	0.0088	0.0280	0.0333
		0.0438	0.0298	0.0665	0.0455	0.0175	0.0140	0.0123	0.0140	0.0210	0.0210	0.0683
1995	5	2	2	0	0	0	0	0.0467	0.0000	0.0000	0.0200	0.0067
		0.0200	0.0333	0.0133	0.0200	0.0000	0.0200	0.0000	0.0067	0.0133	0.0000	0.0333
1996	5	2	2	0	0	0	0	0.0000	0.0000	0.0008	0.0090	0.0204
		0.0335	0.0147	0.0163	0.0188	0.0253	0.0253	0.0188	0.0237	0.0212	0.0139	0.0425
1997	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0029
		0.0000	0.0265	0.0382	0.0676	0.0941	0.0471	0.0412	0.0559	0.0294	0.0147	0.0676
1998	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0007	0.0014
		0.0042	0.0182	0.0503	0.0545	0.0440	0.0391	0.0321	0.0468	0.0370	0.0398	0.1013
1999	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0016	0.0000
		0.0000	0.0047	0.0047	0.0079	0.0205	0.0252	0.0220	0.0346	0.0236	0.0299	0.0756
2000	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0027	0.0041
		0.0082	0.0150	0.0191	0.0082	0.0163	0.0313	0.0422	0.0177	0.0232	0.0082	0.0845
2001	5	2	2	0	0	0	0	0.0000	0.0000	0.0025	0.0025	0.0138
		0.0125	0.0289	0.0226	0.0251	0.0301	0.0201	0.0238	0.0301	0.0351	0.0376	0.1016
2002	5	2	2	0	0	0	0	0.0000	0.0009	0.0000	0.0018	0.0035
		0.0079	0.0149	0.0271	0.0525	0.0368	0.0280	0.0315	0.0394	0.0438	0.0490	0.1480
2003	5	2	2	0	0	0	0	0.0000	0.0058	0.0039	0.0116	0.0154
		0.0232	0.0174	0.0193	0.0232	0.0270	0.0251	0.0425	0.0309	0.0328	0.0328	0.0985
2004	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0015	0.0015
		0.0136	0.0287	0.0377	0.0392	0.0287	0.0513	0.0332	0.0407	0.0211	0.0362	0.1131
2005	5	2	2	0	0	0	0	0.0010	0.0058	0.0077	0.0048	0.0086
		0.0211	0.0355	0.0499	0.0672	0.0605	0.0259	0.0307	0.0221	0.0192	0.0154	0.0441
2006	5	2	2	0	0	0	0	0.0000	0.0000	0.0008	0.0008	0.0051
		0.0093	0.0068	0.0102	0.0153	0.0229	0.0297	0.0306	0.0340	0.0272	0.0178	0.0731
2007	5	2	2	0	0	0	0	0.0000	0.0000	0.0032	0.0016	0.0032
		0.0144	0.0265	0.0353	0.0353	0.0369	0.0457	0.0554	0.0514	0.0514	0.0353	0.0899
2008	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0006	0.0068
		0.0044	0.0081	0.0168	0.0305	0.0267	0.0267	0.0267	0.0342	0.0199	0.0186	0.0609
2009	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0017
		0.0116	0.0232	0.0456	0.0414	0.0257	0.0273	0.0348	0.0423	0.0414	0.0365	0.0779
2010	5	2	2	0	0	0	0	0.0011	0.0011	0.0011	0.0011	0.0044
		0.0120	0.0239	0.0316	0.0326	0.0435	0.0598	0.0511	0.0501	0.0424	0.0392	0.0914
2011	5	2	2	0	0	0	0	0.0000	0.0000	0.0045	0.0135	0.0090
		0.0067	0.0336	0.0090	0.0224	0.0269	0.0426	0.0448	0.0538	0.0336	0.0404	0.1457
2012	5	2	2	0	0	0	0	0.0000	0.0000	0.0000	0.0000	0.0035
		0.0318	0.0212	0.0459	0.0141	0.0353	0.0318	0.0283	0.0565	0.0459	0.0318	0.1166
2013	5	2	2	0	0	0	0	0.0021	0.0000	0.0021	0.0000	0.0083
		0.0062	0.0248	0.0413	0.0331	0.0393	0.0248	0.0186	0.0227	0.0351	0.0186	0.0847
2014	5	2	2	0	0	0	0	0.0000	0.0000	0.0038	0.0038	0.0038
		0.0077	0.0268	0.0153	0.0460	0.0307	0.0268	0.0153	0.0115	0.0115	0.0307	0.1149
2015	5	2	2	0	0	0	0	0.0000	0.0024	0.0024	0.0073	0.0342
		0.0293	0.0465	0.0538	0.0318	0.0465	0.0367	0.0293	0.0293	0.0220	0.0220	0.1002

2016 5 2 2 0 0 0 0 0.0000 0.0000 0.0065 0.0049 0.0016
0.0081 0.0097 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
		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
		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
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
		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
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
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
##	Growth data
# 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	1000000000000000000000
# MidPoint Sex	MidPoint	Time-at-liberty Size-trans matrix Number of points
# Release	Recapture
##	eof
9999
```

Appendix C. Control File for Model 19.3

```
## ------------------------------------------------------------------------------ ##
## 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. Assessing Uncertainty of Management Qualities without Trawl Survey in the Terminal Year (2020)

Approaches

Based on the suggestion by a CPT subgroup, three approaches are used to evaluate the loss of the 2020 EBS NMFS survey on crab assessments:

Approach 1: Retrospective analysis with two sets of runs.

"This approach entails doing two sets of retrospective runs. The first set would be simply the standard retrospective analysis in which data are removed from the assessment sequentially one year at a time beginning with the most recent year. The second set of retrospective runs is like the first except that the survey data in the final year are also removed. One set of comparisons would look at the CVs of estimated management quantities such as OFL and MMB based on the usual Hessian approximations provided by ADMB (Fournier et al. 2012). The expectation is that the average CV for the runs with last year of survey data omitted would be higher than the average CV when these data are available. A second kind of analysis would be considered the most recent assessment as the "truth," and look at the mean squared error (MSE) between management quantities estimated in the retrospective runs and the most recent assessment. Again the expectation would be that MSE would be larger for the runs with the missing ending year survey."

Approach 2: Drop the most recent survey.

"This approach would entail dropping the 2019 survey from the 2019 accepted assessment model. Changes in OFL and MMB and their CVs are the main interest."

Approach 3: Sensitivity analysis with high and low proxy surveys.

"This method evaluates the impact of different hypothetical 2020 survey outcomes, and is based on a SSC recommendation in its June minutes. For the survey time series fit in proposed base model for this year, calculate the multiplicative residuals, $\hat{y}_i/y_i$, where y_i is observed survey observation, and $\hat{y}_i$ is the predicated survey observation after fitting the model. Obtain the 25th and the 75th percentiles of the multiplicative residuals (in R: quantile(mresids,prob=c(0.25,.75)). The rationale for the 25th and 75th percentiles is that they are a typical high and low value for the survey. Obtain the predicated survey value for the 2020 by putting in a trial survey value for 2020 with a very high CV, say 100, so that the model does not attempt to fit that observation. Multiply the predicted survey value by the 25th and 75th percentile of the multiplicative residual for a high and a low survey observation for 2020. Assume a CV equal to the median survey CV and fit these values in two model runs to evaluate sensitivity of ending year survey sensitivity. Large changes in management quantities such as OFL and MMB indicate high sensitivity."

Results

The results are summarized below. The second approach is a subset of the first approach.

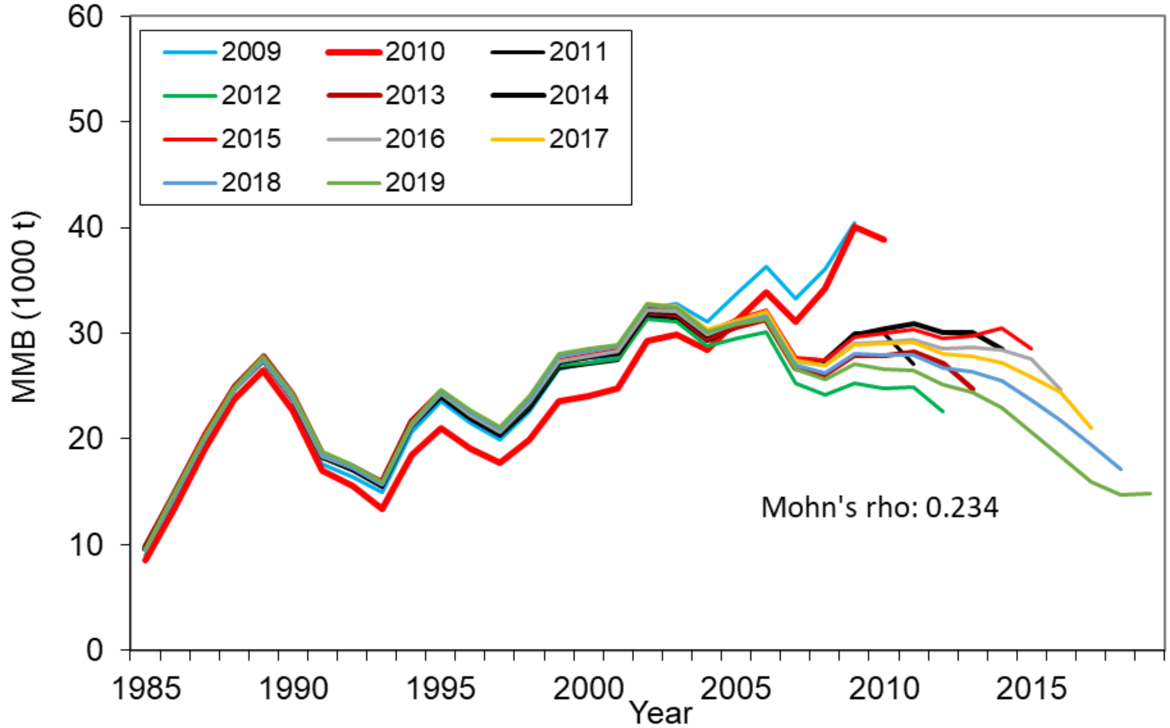
Table D1. Summary of results of two sets of retrospective analyses for mature male biomass in terminal years, OFL and ratio of mature male biomass in terminal years to $B_{35\%}$.

With survey:													
Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean	Abs mean
MMB	40.46	38.90	27.03	22.62	24.68	28.45	28.48	24.70	21.03	17.09	14.85	27.34	
CV	0.07	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	
Relative error	49.68%	46.12%	2.15%	-9.84%	1.29%	24.00%	37.69%	34.98%	31.87%	16.13%		23.41%	27.10%
SE	180.33	150.7	0.32	6.09	0.10	30.32	60.77	40.98	25.84	5.63		50.11	
OFL	9.45	10.33	6.95	5.03	5.97	7.37	7.56	6.09	4.64	3.13	2.18	6.65	
CV	0.07	0.08	0.14	0.15	0.14	0.13	0.12	0.12	0.14	0.14	0.15	0.12	
MMB/ B35%	1.26	1.22	0.93	0.80	0.87	0.96	0.99	0.89	0.77	0.65	0.58	0.93	
CV	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.06	
Without survey:													
MMB	42.49	40.17	30.92	22.94	23.49	26.54	28.91	26.02	21.79	16.73	16.54	26.96	
CV	0.07	0.08	0.09	0.09	0.08	0.07	0.07	0.07	0.08	0.09	0.08	0.08	
Relative error	52.44%	45.39%	12.13%	-12.68%	-8.62%	8.35%	28.90%	28.71%	21.28%	-0.53%		17.54%	21.90%
SE	213.64	157.3	11.19	11.09	4.91	4.18	42.00	33.70	14.62	0.01		49.26	
OFL	9.98	10.45	8.72	5.19	5.45	6.52	7.73	6.56	4.92	3.02	2.70	6.47	
CV	0.07	0.08	0.09	0.17	0.15	0.14	0.13	0.13	0.15	0.17	0.15	0.13	
MMB/ B35%	1.30	1.27	1.03	0.81	0.83	0.92	1.00	0.92	0.79	0.63	0.63	0.92	
CV	0.06	0.06	0.07	0.07	0.06	0.06	0.05	0.05	0.06	0.07	0.07	0.06	
(No survey – survey)/survey													
MMB	5.02%	3.28%	14.40%	1.44%	-4.85%	-6.73%	1.51%	5.35%	3.60%	-2.12%	11.41%	2.94%	5.04%
OFL	5.62%	1.17%	25.51%	3.19%	-8.72%	-11.64%	2.24%	7.76%	6.00%	-3.36%	23.56%	4.67%	8.37%
MMB/ B35%	3.48%	4.53%	10.16%	1.11%	-3.94%	-4.53%	1.13%	3.26%	2.45%	-2.26%	8.38%	-1.35%	4.11%

Table D2. Summary of results for approach 3.

	Model			
	19.3l	19.3	19.3h	(19.3h-19.3l)/19.3
B35%	25.324	25.445	25.523	0.78%
MMB-terminal	14.422	14.928	15.220	5.34%
F35%	0.290	0.291	0.291	0.17%
Fofl	0.152	0.157	0.160	5.66%

OFL	1.997	2.141	2.224	10.58%
MMB/B35%	0.570	0.587	0.596	4.57%



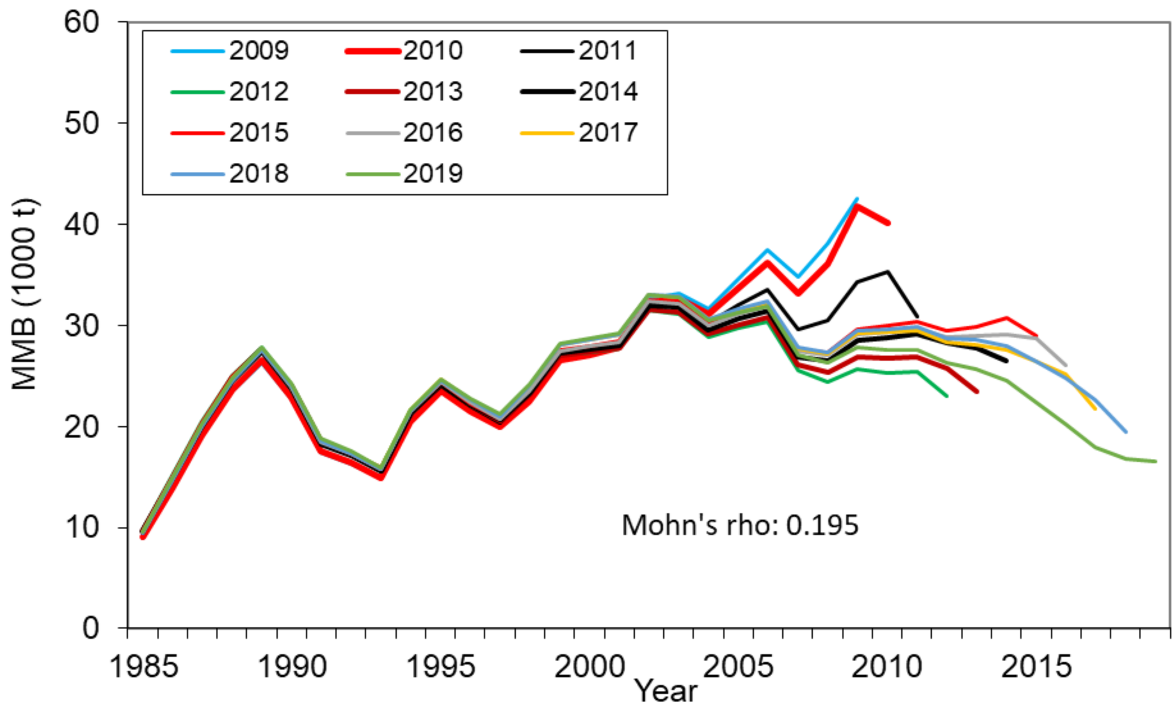


Figure D1. Comparison of hindcast (retrospective) estimates of mature male biomass on Feb. 15 of Bristol Bay red king crab from 1975 to 2019 made with terminal years 2009-2019 with terminal year trawl survey (upper panel) and without terminal year trawl survey (lower panel) with model 19.3. Legend shows the terminal year.

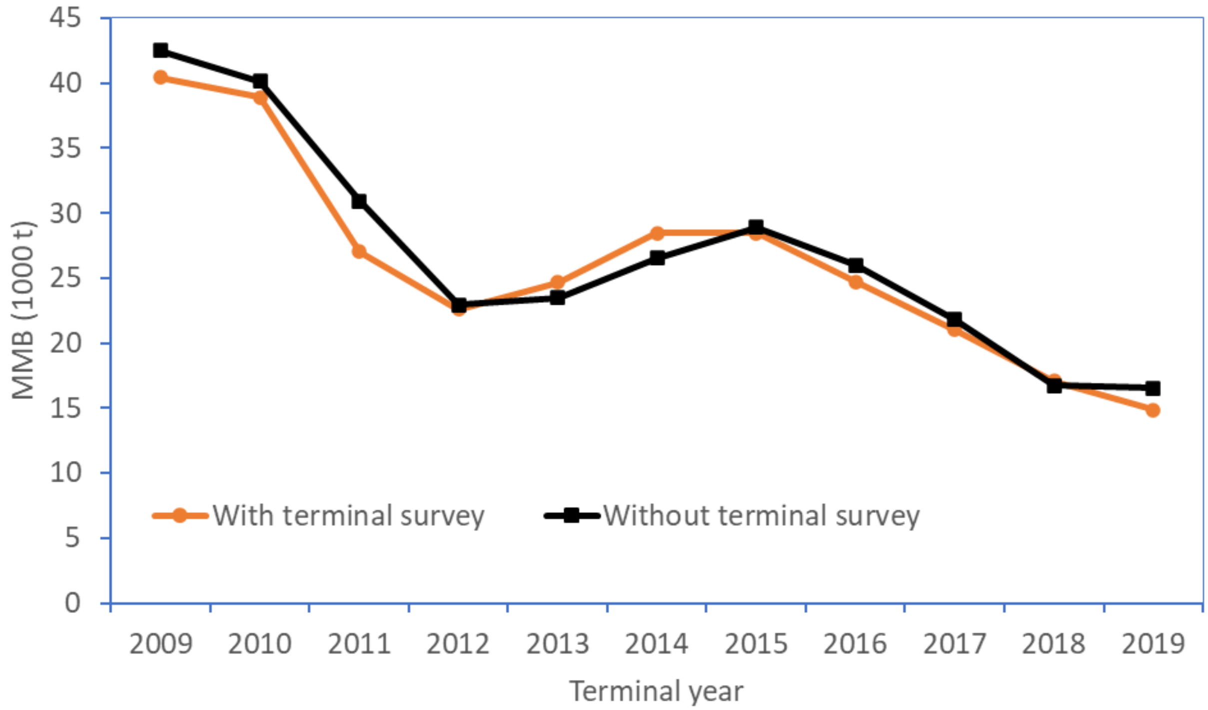


Figure D2. Comparison of estimated mature male biomasses in the terminal years with two sets of retrospective analyses.

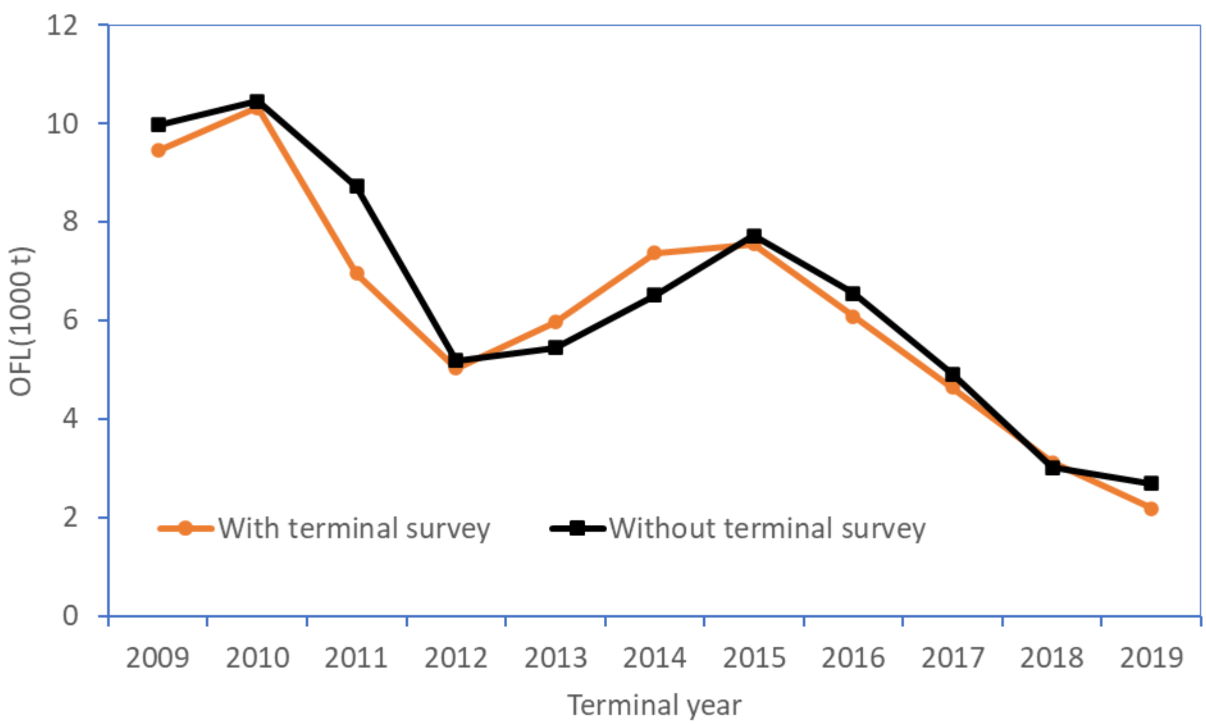


Figure D3. Comparison of estimated OFLs in the terminal years with two sets of retrospective analyses.

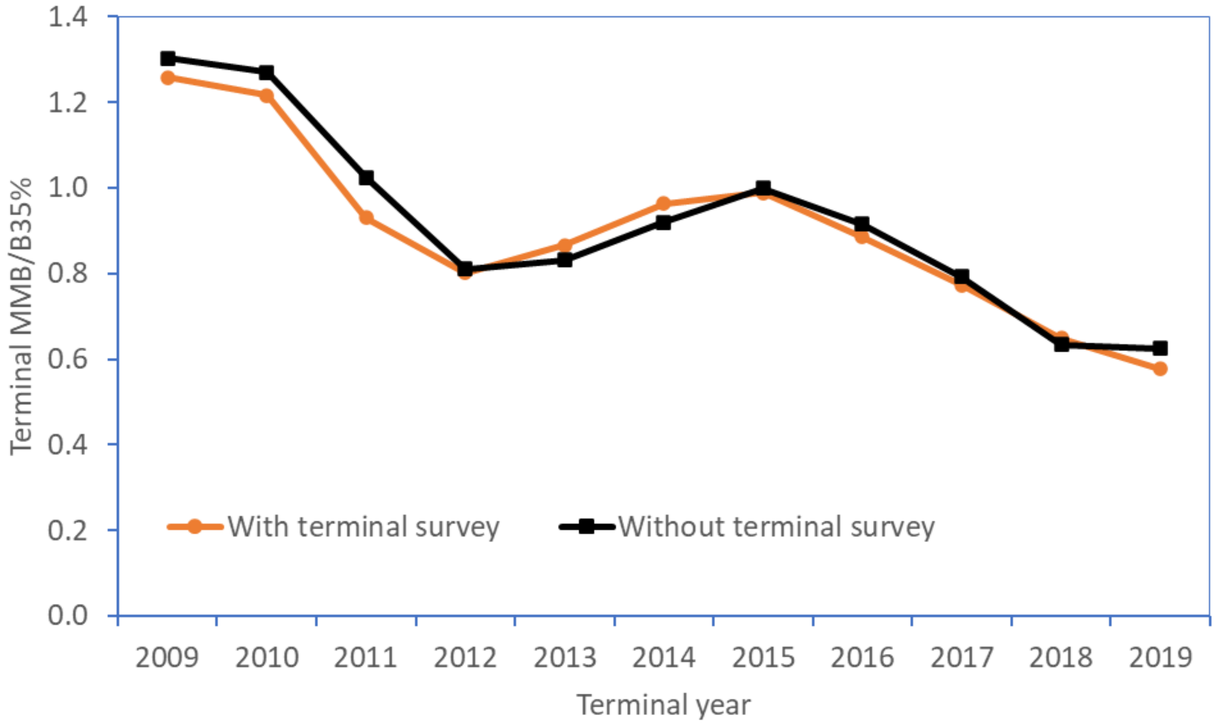


Figure D4. Comparison of estimated ratios of MMB/$B_{35\%}$ in the terminal years with two sets of retrospective analyses.

As expected, CVs for MMB, OFL and ratio of MMB/$B_{35\%}$ in terminal years are generally slightly less with trawl survey in terminal years than those without trawl survey (Table D1). However, retrospective patterns, Mohn's rho, mean relative error, mean absolute relative error, and MSE for MMB are unexpectedly better without trawl survey in the terminal years than with trawl survey (Table D1, Figure D1). It seems that the expectation is reasonable as long as the trawl survey results are as expected. The trawl survey in 2014 results in a much higher than expected crab abundance, and surveys in 2018 and 2019 produce unexpected lower crab abundances. These unexpected trawl survey results are likely the cause for better retrospective patterns for MMB without trawl survey in the terminal years.

Overall, the differences of MMB, OFL and ratio of MMB/ $B_{35\%}$ are small between with and without trawl survey in the terminal years (Table D1, Figures D2, D3 and D4). Mean absolute relative errors are 5.04%, 8.37%, and 4.11%, respectively, for MMB, OFL and ratio of MMB/ $B_{35\%}$ for without survey relative to with survey in the terminal years. The differences of MMB, OFL and ratio of MMB/ $B_{35\%}$ between models 19.3l and 19.3h are 5.34%, 10.58% and 4.57%, respectively (Table D2, Figure D5).

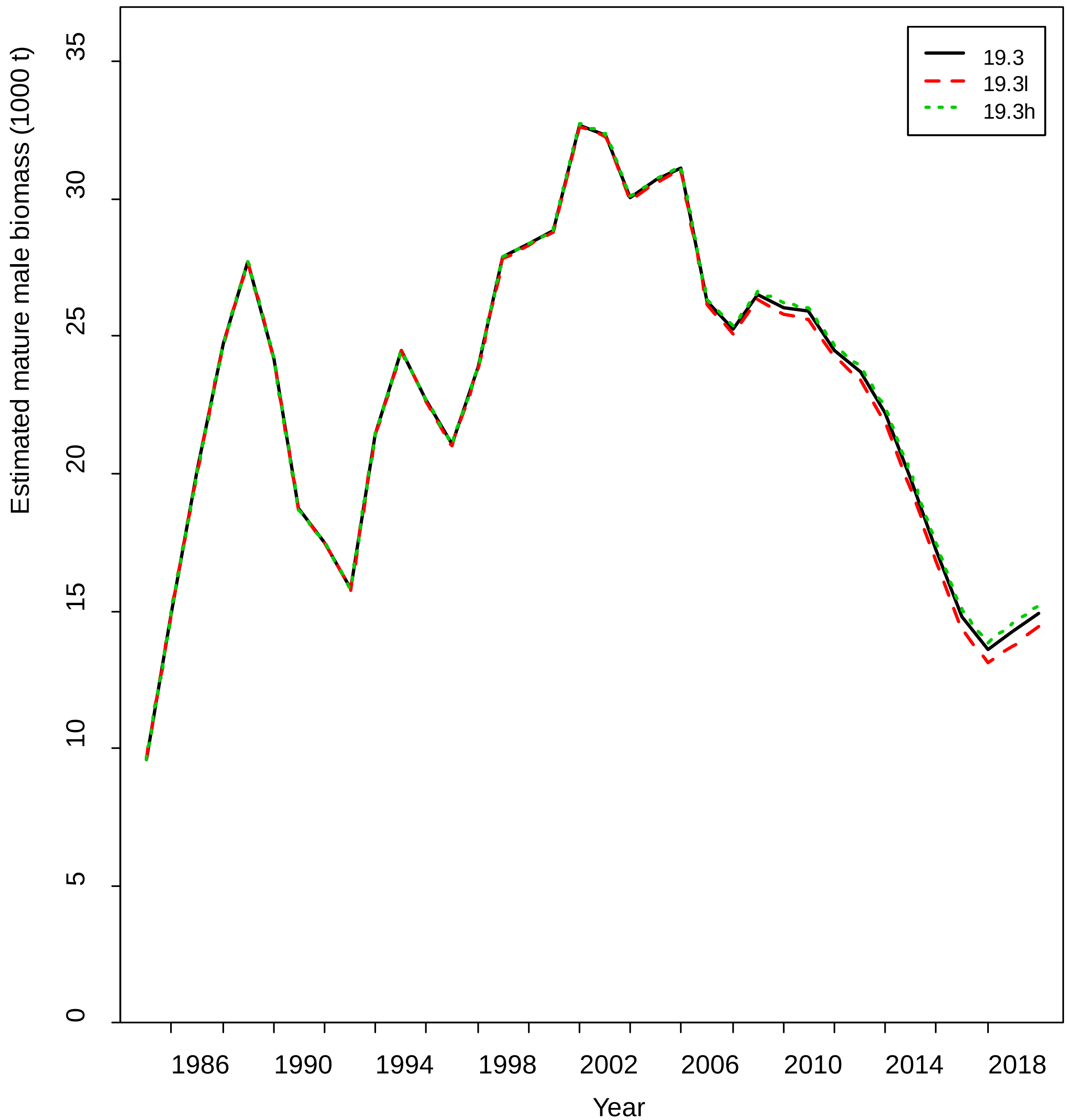


Figure D5. Comparison of estimated mature male biomass under three models (19.3, 19.3l and 19.3h). The results before 1985 are not shown for a better scale.

Appendix E. Ecosystem and Socioeconomic Profile of the Bristol Bay Red King Crab Stock

Erin Fedewa, Brian Garber-Yonts and Kalei Shotwell

September 2020

With Contributions from:

Curry Cunningham, Kelly Kearny, Mike Litzow, Jens Nielsen, Darren Pilcher, Jon Richar, Dale Robinson, Jordan Watson, Ellen Yasumiishi, Leah Zacher, Jie Zheng, and Jean Lee

Executive Summary

National initiative and NPFMC recommendations suggest a high priority for conducting an ecosystem and socioeconomic profile (ESP) for the Bristol Bay red king crab (BBRKC) stock due to recent declines in abundance and poor recruitment. In addition, scores for stock prioritization, habitat prioritization, and data classification analysis were moderate to high. The BBRKC ESP follows the new standardized framework for evaluating ecosystem and socioeconomic considerations, and may be considered a proving ground for potential operational use in the main stock assessment.

We use information from a variety of data streams available for the BBRKC stock and present results of applying the ESP process through a metric and subsequent indicator assessment. Analysis of the ecosystem and socioeconomic metrics for BBRKC by life history stage along with information from the literature identified a suite of indicators for testing and continued monitoring within the ESP. Results of the metric and indicator assessment are summarized below as ecosystem and socioeconomic considerations that can be used for evaluating concerns in the main stock assessment.

Ecosystem Considerations

- Available physical indicators for 2020 show a return to near-average conditions in Bristol Bay. A relatively high positive Arctic Oscillation index in winter 2020 may suggest favorable conditions for BBRKC productivity.
- Persistently low levels of chlorophyll *a* and above-average wind stress in Bristol Bay in combination with substantial increases in juvenile sockeye salmon abundance in the past 5 years could be indicative of poor larval conditions.
- The degree of match or mismatch of first-feeding larval red king crab with preferred diatom prey may be critical for larval survival, and recent fluctuations in spring temperatures during embryo development could impact the synchrony between hatch timing and the spring bloom.
- BBRKC recruitment remains well below the long-term average. Concurrent declines in Pacific cod and benthic invertebrate biomass in the past 5 years coinciding with above-average bottom temperatures and a reduced cold pool may suggest bottom-up climate forcing on Bristol Bay benthic communities.
- Current-year increases in corrosive bottom waters in Bristol Bay have the potential to impact shell formation, growth and survival of BBRKC.

Socioeconomic Considerations

- The numbers of vessels and processors active in the 2018/19 and 2019/20 BBRKC seasons dropped below the lower bounds of their long-term historical range during 2018 and 2019. Both metrics have been in a generally declining trend since the BBRKC fishery was substantially restructured and consolidated following rationalization.
- Ex-vessel price has remained above the long-term average since 2010, partially mitigating some income effects of declining BBRKC production, but the reduced level of participation and employment suggest that reduced economic performance of the BBRKC fishery may have negative distributional effects.
- While aggregate BBRKC ex-vessel value was at a historical low in 2019, BBRKC ex-vessel revenue share on average for active vessels was only moderately below average during 2019. The local quotient for BBRKC catch value of landings to Dutch Harbor also declined to a historical low in 2019.

Introduction

Ecosystem-based science is becoming a component of effective marine conservation and resource management; however, the gap remains between conducting ecosystem research and integrating with the stock assessment. A consistent approach has been lacking for deciding when and how to incorporate ecosystem and socioeconomic information into a stock assessment and how to test the reliability of this information for identifying future change. A new standardized framework termed the ecosystem and socioeconomic profile (ESP) has recently been developed to serve as a proving ground for testing ecosystem and socioeconomic linkages within the stock assessment process (Shotwell et al., *In Review*). The ESP uses data collected from a large variety of national initiatives, literature, process studies, and laboratory analyses in a four-step process to generate a set of standardized products that culminate in a focused, succinct, and meaningful communication of potential drivers on a given stock. The ESP process and products are supported in several strategic documents (Dorn et al., 2018; Lynch et al., 2018) and recommended by the North Pacific Fishery Management Council's (NPFMC) groundfish and crab Plan Teams and the Scientific and Statistical Committee (SSC).

This ESP for Bristol Bay red king crab (hereafter referred to as BBRKC) follows a template for ESPs (Shotwell et al., *In Review*) and replaces the previous ecosystem considerations chapter in the 2011 Bering Sea and Aleutian Islands Crab SAFE document and the stock-specific report cards produced in recent years.

The ESP process consists of the following four steps:

1.) Evaluate national initiative and stock assessment classification scores (Lynch et al., 2018) along with regional research priorities to assess the priority and goals for conducting an ESP.
2.) Perform a metric assessment to identify potential vulnerabilities and bottlenecks throughout the life history of the stock and provide mechanisms to refine indicator selection.
3.) Select a suite of indicators that represent the critical processes identified in the metric assessment and monitor the indicators using statistical tests appropriate for the data availability of the stock.
4.) Generate the standardized ESP report following the guideline template and report ecosystem and socioeconomic considerations, data gaps, caveats, and future research priorities.

Justification

The national initiative stock and habitat prioritization scores for BBRKC are overall high primarily because the distribution of this stock depends greatly on habitat. There is also increasing model development for BBRKC, and the stock is highly vulnerability to the impacts of future ocean acidification. Furthermore, the BBRKC stock has been on a declining trend with subsequent lower total allowable catch in recent years, warranting the Crab Plan Team to request an evaluation of ecosystem factors. Current data availability as well as target data availability for five attributes of stock assessment model input data (i.e. catch, size composition, abundance, life history and ecosystem linkage) were classified for the BBRKC stock in order to identify data gaps and assess the priority for conducting an ESP. BBRKC is currently managed as a Tier 3 crab stock and as such, the new data classification scores characterize the stock as data-moderate with estimates of spawner/recruit relationships currently unavailable. Both current and target data availability attribute levels for the BBRKC stock size composition attribute were classified as a 3, which adequately supports a size-structured stock assessment. However, abundance, life history and ecosystem linkage attributes were highlighted as having gaps between current and target data availability. Research priorities for data classification include improvements in stock specific growth estimates and associated life history information, as well as understanding mechanisms for detecting productivity regimes in the population. These initiative scores and data classification levels suggest a high priority for conducting an ESP for BBRKC.

Data

Initially, information on BBRKC was gathered through a variety of national initiatives that were conducted by AFSC personnel. These include (but are not limited to) stock assessment prioritization, habitat assessment prioritization, climate vulnerability analysis, and stock assessment categorization. A form was submitted to stock assessment authors to gather results from all the initiatives in one location, thus serving as the initial starting point for developing the ESP metrics for groundfish and crab stocks in the BSAI and GOA fishery management plans (FMP).

Data used to generate ecosystem metrics and indicators for the BBRKC ESP were collected from a variety of laboratory studies, remote sensing databases, fisheries surveys, regional reports and fishery observer data collections (Table 1). Results from laboratory studies were specifically used to inform metrics and indicators relating to thermal tolerances, phenology and energetics across RKC life history stages. Larval indicator development utilized datasets from the NOAA Bering Arctic Subarctic Integrated Survey (BASIS) and blended satellite data products from NOAA, NASA and ESA. Data for late-juvenile through adult RKC stages were derived from the annual NOAA eastern Bering Sea bottom trawl survey and fishery observer data collected during the BBRKC fishery. Information on RKC habitat use was derived from essential fish habitat (EFH) model output and maps (Figure 3; Laman et al., 2017) as well as laboratory studies and collaborative RKC tagging efforts. Data from the NOAA Resource Ecology and Ecosystem Modeling (REEM) food habits database were used to determine species compositions of benthic predators on commercial crab species.

Data used to generate socioeconomic metrics and indicators were derived from fishery-dependent sources, including commercial landings data for BBRKC collected in ADFG fish tickets and the BSAI Crab Economic Data Report (EDR) database (both sourced from AKFIN), and effort statistics reported in the most recent ADFG Annual Management Report for BSAI shellfish fisheries estimated from ADF&G Crab Observer program data (Leon et al. 2017).

Metrics Assessment

National Metrics

The national initiative form data were summarized into a metric panel (Figure 1) that acts as a first pass ecosystem and socioeconomic synthesis. Metrics range from estimated values to qualitative scores of population dynamics, life history, or economic data for a given stock (see Shotwell et al., *In Review* for more details). To simplify interpretation, the metrics are rescaled by using a percentile rank for BBRKC relative to all other stocks in the groundfish and crab FMP's. Additionally, some metrics are reversed so that all metrics can be compared on a low to high scale between all stocks in the FMP. These adjustments allow for initial identification of vulnerable (percentile rank value is high) and resilient (percentile rank value is low) traits for BBRKC. Data quality estimates are also provided from the lead stock assessment author (0 or green shaded means no data to support answer, 4 or purple shaded means complete data), and if there are no data available for a particular metric then an "NA" will appear in the panel. The metric panel gives context for how BBRKC relate to other groundfish and crab stocks and highlights the potential vulnerabilities and data gaps for the stock. Threshold values identified from national initiatives (Methot, 2015, Morrison et al., 2015, NMFS, 2011) for select metrics are provided to highlight high levels of vulnerability for a given stock (Figure 1, red dots).

For BBRKC ecosystem metrics, latitude range, reproductive strategy, early life history survival, ocean acidification sensitivity, and habitat specificity indicate high vulnerability via the percentile method when compared to other Alaska groundfish and crab stocks. Additionally, maximum length, recruitment variability, population growth rate, depth range, bottom-up ecosystem value, fecundity, and maximum age were over the thresholds defined by national initiatives. Scores suggest that RKC are habitat specialists and reproductive success may be highly sensitive to specific environmental conditions due to aggregate mating behavior. Additionally, a relatively long larval duration, pelagic predation pressure, and specific habitat requirements following settlement indicate that early life history stages are a criticality in RKC life stages. Initial metric panel results indicate that stage-based information incorporating predation pressures, habitat dependence, ocean acidification and climatic conditions would be valuable for the stock and would assist with subsequent indicator development. For the three applicable socioeconomic metrics, values indicated fairly high commercial importance, indicating that RKC may be increasingly sensitive to targeted fishing.

BBRKC had numerous data gaps for ecosystem metrics including length- and age-based metrics, recruitment variability and natural mortality. Data quality was rated as medium to complete for all metrics with data available, although the prevalence of data gaps for important life history metrics highlight the need for additional research to better understand RKC life history processes.

Ecosystem Processes

Data evaluated over ontogenetic shifts (e.g., egg, larvae, juvenile, adult) may be helpful for identifying specific bottlenecks in productivity and relevant indicators for monitoring. As a first attempt to summarize important processes or potential bottlenecks across RKC life history stages, we include a detailed life history synthesis (Table 2a), an associated summary of relevant ecosystem processes (Table 2b), and a baseline life history conceptual model (Figure 2a). In the life history tables and conceptual model, abiotic and biotic processes were identified by each life stage from the literature, process studies and laboratory rearing experiments. Details on why these processes were highlighted, as well as the potential relationship between ecosystem processes and stock productivity are described below.

Red king crab molt, mate and extrude new egg clutches each spring, after which females brood fertilized eggs externally for up to a year (Stevens and Swiney, 2007). Embryo development is delayed in cold years (Chilton et al., 2010) and laboratory studies suggest that acidified conditions have significant effects on embryogenesis (Long et al., 2013). Following hatch, RKC larval development consists of four zoeal stages and one glaucothoe stage, after which larvae metamorphose and settle as stage C1 benthic juveniles. Zoea larvae feed primarily on diatoms; the chain-forming diatom *Thallasiosira nordenskioldii* is a particularly important larval food source due to its large size and high densities in natural populations (Paul et al., 1989). First-feeding larvae represent a critical bottleneck during development as previous research indicates that chances of survival are greatly reduced if larvae do not feed within 60 hours of hatching (Paul and Paul, 1980). Likewise, because the glaucothoe stage is a non-feeding stage, survival likely depends on nutrition acquired during zoeal stages. Laboratory rearing experiments reported optimal larval survival at 8°C (Nakanishi, 1987), although RKC zoeal stages appear to exhibit an ontogenetic change in thermal tolerance, and ZII larval survival is greatly reduced above 6°C (Shirley and Shirley, 1989). Although first-feeding success of RKC larvae is likely higher for earlier hatch dates coinciding with high densities of *Thallasiosira*, cooler water temperatures slow larval development rates and increase mortality due to both increased offshore transport and larval stage duration (Loher and Armstrong, 2000). Shirley and Shirley (1990) found that the length of the RKC larval period was inversely related to chlorophyll *a* concentrations, and that larval survival was inversely related to larval period length. Likewise, larval advection and dispersal relative to oceanographic conditions and the availability of suitable settlement habitat may be significant drivers of recruitment success in a given year (Daly et al., 2018).

During the early juvenile stages, successful settlement requires shallow, nearshore waters (<50m) and structurally complex habitats due to the reliance on crypsis to evade predation (Loher and Armstrong, 2000; Stevens, 2003). Survival in small juvenile RKC increases with the amount of physical structure in settlement habitats (Stoner, 2009; Pirtle et al., 2012), whereas larger juveniles are often associated with habitats composed of structural invertebrates that likely provide increased foraging opportunities (Pirtle and Stoner, 2010). These results suggest an ontogenetic shift in habitat requirements following the first year of benthic life as RKC juveniles rely less on high-relief habitat, and instead form large pods to evade predators. Juvenile RKC molt several times a year during early benthic instar stages and are especially vulnerable to groundfish predators such as Pacific cod while soft (Livingston, 1989). Overall, juvenile RKC appear to have a broad range of temperature tolerance, indicated by relatively high survival over the range of temperatures tested (2 to 12 °C) in a laboratory experiment (Stoner et al., 2010). This is likely advantageous during the juvenile stage when RKC utilize relatively shallow habitats more prone to temperature fluctuations.

Late juvenile and adult RKC are less reliant on complex substrate and, instead, temperatures appear to drive patterns in spatial distributions and migration timing. Northerly shifts in stock distribution are generally associated with both warmer temperatures and high Pacific Decadal Oscillation values during the summer (Loher and Armstrong, 2005; Zheng and Kruse, 2006), whereas fall distributions during the fishery tend to contract to the center of Bristol Bay during warm years (Zacher et al., 2018). Mature female RKC appear to avoid waters <2 °C (Chilton et al., 2010) and recent tagging efforts suggest that mature males tend to avoid warm waters >4 °C. Historic spawning grounds for RKC have been identified off the western end of the Alaska Peninsula in an area commonly referred to as “Cod Alley”, although in recent years the area has been subject to intense fishing pressure (Dew, 2010). Essential fish habitat for red king crab remains poorly defined and very little is known about the potential effects of bottom trawling on RKC spatial distributions, spawning aggregations and habitat use.

Socioeconomic Processes

As described below, the set of socioeconomic indicators reported in this ESP are categorized as *Fishery Performance, Economic Performance* and *Community Effects* indicators. Fishery Performance indicators are intended to represent processes most directly involved in prosecution of the BBRKC fishery, and thus have the potential to differentially affect the condition of the stock depending on how they influence the timing, spatial distribution, selectivity, and other aspects of fishing pressure. *Economic Performance* and *Community Effects* indicators are intended to capture key dimensions of the economic and social processes through which outputs, benefits and other effects flowing from commercial exploitation of the fishery are generated and distributed. Notwithstanding these categorical distinctions, the social and economic processes that affect, and are affected by, the condition of the stock are complex and interrelated at different time scales. Moreover, these processes are strongly influenced by the institutional structures of fishery management, which develop over time and include both small adjustments in in-season management as well as comprehensive structural changes that induce complex, multidimensional change affecting numerous social and economic processes. Implementation of the Crab Rationalization (CR) Program in 2005 is an example of the latter (a full summary of the management history of the BBRKC fishery is beyond the scope of the ESP; see Nichols, et al., 2019).

Among other changes, rationalization resulted in rapid consolidation of the BBRKC fleet, from a high of 274 vessels in 1998 to 89 during the first year of the CR program, which has subsequently further consolidated to 56 vessels operating in the 2019/20 season. Allocation of tradable crab harvest quota shares, with leasing of annual harvest quota, facilitated fleet consolidation and improved operational and economic efficiency of the fleet, changing the timing of the fishery from short derby seasons to more extended seasons, and inducing extensive and ongoing changes in harvest sector ownership, employment, and income. Crab processing sector provisions of the CR program, including allocation of transferable processing quota shares (PQS) and leasing of annual quota, facilitated similar operational and economic efficiencies in the sector, with more limited consolidation of processing capacity to fewer locations, and fewer plants in those ports (with Unalaska/Dutch Harbor receiving the largest share of BBRKC landings before and after 2005, and Akutan, King Cove, Kodiak, and St. Paul continuing to receive landings to date).

These and other institutional changes continue to influence the geographic and inter-sectoral distribution of benefits produced by the BBRKC fleet, both through direct ownership and labor income in the BBRKC harvest and processing sectors, and indirect social and economic effects on fishery-dependent communities throughout Alaska and greater Pacific Northwest region. The full range of fishery, economic, and social processes cannot be captured within the scope of the ESP framework, and more comprehensive set of metrics and indicators intended to inform BBRKC fishery management and annual harvest specifications are provided in the annual Crab Economic SAFE.

Indicators Assessment

We first provide information on how we selected the indicators for the third step of the ESP process and then provide results on the indicators analysis. Developing and selecting a suite of meaningful indicators necessitates compiling time series data that represent stock vulnerabilities or critical processes, as identified by the metric assessment. These indicators must be useful for stock assessments in that they are regularly updated, reliable, consistent, and long-term. The indicator suite is then monitored in a series of statistical tests that gradually increase in complexity depending on the data availability of the stock (Shotwell et al., *In Review*).

Indicator Suite

Very few studies have effectively linked environmental variables or ecosystem conditions to recruitment of Bering Sea crab stocks, owing primarily to the highly variable nature of crab recruitment. Zheng and Kruse (2000) noted that strong year classes of RKC in the early 1970’s corresponded with low temperatures. However, recruitment trends are not consistently explained by temperatures or decadal-scale environmental variability and weak relationships suggest that climatic conditions alone do not account for all the variability in year class strength. Groundfish predation has been hypothesized as a mechanism driving recruitment variability and previous studies indicate a strong negative relationship between Pacific cod biomass and red king crab recruitment (Zheng and Kruse, 2006; Betchol and Kruse, 2010). Large-scale indices of environmental variation including the Aleutian Low, Pacific Decadal Oscillation and Arctic Oscillation have also been linked to red king crab productivity (Loher and Armstrong, 2005; Zheng and Kruse, 2006; Szuwalski et al., *in review*) , although associated mechanisms remain unclear. In acknowledging the paucity of these mechanistic linkages, we generated a suite of ecosystem and socioeconomic indicators using stock vulnerabilities identified in the metric assessment (Figure 1) in addition to tested driver-response relationships from previously published studies (Table 2b). When selecting a suite of indicators for the BBRKC ESP, efforts were focused on developing spatially explicit indicators bounded by the BBRKC management area, which 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.; ADF&G 2012). The following list of indicators is organized by process, and ecosystem indicators are grouped by RKC life history stage when applicable. Indicator title and a brief description are provided in Table 3a for ecosystem indicators and Table 3b for socioeconomic indicators with references, where possible, for more information.

Ecosystem Indicators:

1. Physical Indicators

- The EBS **cold pool index** (<2°C) is not only important in driving RKC distributions, but also in driving distributions of major predators of RKC. Pacific cod and several flatfish species typically avoid temperatures less than 1° C (Kotwicki and Lauth, 2013), suggesting that cold years when the cold pool extends into Bristol Bay may offer RKC a refuge from predation. The cold pool index was calculated as the fraction of the EBS BT survey area with bottom water less than 2°C on 1 July of each year from Bering10K ROMS model output hindcasts (Kearney et al., 2020).
- **Summer bottom temperatures** in Bristol Bay represent environmental conditions during the summer survey period and drive juvenile and adult RKC distributions (Loher and Armstrong, 2005), timing of the reproductive cycle (Chilton et al., 2010) and larval transport (Daly et al., 2018). Laboratory studies have also shown that temperature is a direct driver of growth, molt duration and feeding ration (Long et al., 2017: Stoner et al., 2013). Summer bottom temperatures were calculated as the average of June-July bottom temperatures within the BBRKC management boundary from ROMS model output (Kearney et al., 2020).
- The **Arctic Oscillation** is a large-scale mode of climate variability; increased red king crab recruitment has been associated with increases in the Arctic Oscillation (Szuwalski et al., *in review*). When the Arctic Oscillation is in its positive phase, strong winds circling the North Pole confine colder air across polar regions. The Arctic Oscillation indicator was determined as the average of Jan-March Arctic Oscillation deviations, developed by NOAA’s Climate Prediction Center.
- A **Corrosivity Index** developed from Bering10K ROMS output was calculated as the percent of the BBRKC management area containing an average bottom aragonite saturation state of < 1 from Feb-April (D. Pilcher, *pers. commun.*, 2020; Pilcher et al., 2019). The corrosivity index represents potential acidified bottom water conditions in Bristol Bay, which would negatively affect RKC physiology. Reductions in RKC larval condition (Long et al., 2013), juvenile growth and survival (Long et al., 2013), and shell hardness (Coffey et al., 2017) have been documented in low pH conditions.
- **Spring bottom temperatures, wind stress** and **chlorophyll *a* biomass** indicators represent environmental conditions and food sources for RKC early life history stages. Temperature-mediated shifts in embryo development, hatch timing and larval duration could subsequently result in RKC larvae mismatches with prey resources, or increase the probability of advection away from favorable nursery grounds. First-feeding success of RKC larvae has also been linked to high diatom abundances, light winds and water column stability (Paul et al., 1989). Spring bottom temperatures were calculated as the average of Feb-March bottom temperatures within the BBRKC management boundary from ROMS model output (Kearney et al., 2020). Wind stress was determined by averaging June ocean surface wind speeds from remote sensing data within the BBRKC management boundary (Zhang et al., 2006, NOAA/NESDIS, CoastWatch). Chlorophyll *a* biomass was calculated as the April-June average chlorophyll-a estimates from MODIS satellites within the Southern Inner Shelf of the Bering Sea (J. Nielsen, *pers. commun.*, 2020).

2. Biological Indicators

- Estimates of **juvenile sockeye salmon abundance** in the EBS and **Pacific cod biomass** in Bristol Bay represent major predators during the larval and juvenile to adult stages, respectively. Sockeye salmon abundance was estimated from NOAA Bering Arctic Subarctic Integrated

Surveys in the EBS (E. Yasumiishi, *pers. commun*., 2020). Estimates of Pacific cod biomass were derived from the EBS bottom trawl survey catch data.

- Species included in the **benthic invertebrate biomass** indicator (i.e. brittle stars, sea stars, sea cucumber, bivalves, non-commercial crab species, shrimp and polychaetes) are important prey sources for BBRKC (Feder et al. 1980; Jewett and Feder, 1982).. Increases in invert biomass may suggest optimal foraging conditions for RKC, although increases in highly mobile benthic foragers such as hermit crabs and sea stars may, instead, may point towards increased competition for benthic resources. Biomass estimates were determined from the EBS bottom trawl survey catch data.
- A **BBRKC recruit biomass** index effectively tracks the number of males that will likely enter the fishery the following year. Small catches of these sub-legal RKC are often a reliable indicator of impending declines in mature male biomass. BBRKC recruit biomass (110-134 mm CL) was estimated from the EBS bottom trawl survey catch data (J. Richar, *pers. commun*., 2020).
- Spatial distribution indicators include summer **area occupied by mature male and female RKC**, as well as male **catch distance from shore** during the fishery. Areas occupied were determined as the minimum area containing 95% of the cumulative BBRKC CPUE from the EBS bottom trawl survey. Catch distance from shore was calculated using fishery observer data as the mean distance legal male RKC were caught from shore during the fishery (L. Zacher, *pers. commun*., 2020). In warm years, RKC tend to aggregate in the center of Bristol Bay (Zacher et al., 2018), which may have implications for the effectiveness of fixed closure areas and RKC bycatch during winter groundfish fisheries.

Socioeconomic Indicators:

1. Fishery Performance Indicators

- CPUE (mean no. of crabs per potlift): Fishing effort efficiency, as measured by estimated mean number of retained BBRKC per potlift.
- Total Potlifts: Fishing effort, as measured by estimated number of crab pots lifted by vessels during the BBRKC fishery.
- Vessels active in fishery: Annual count of crab vessels that delivered commercial landings of BBRKC to processors.
- BBRKC male bycatch biomass: Incidental bycatch biomass estimates of male BBRKC (tons) in trawl and fixed gear fisheries

2. Economic Indicators

- TAC Utilization (%): Percentage of the annual BBRKC TAC (GHL prior to 2005) that was harvested by active vessels, including deadloss discarded at landing.
- Ex-vessel value of BBRKC landings: Aggregate ex-vessel value of BBRKC landings (as adjusted by CFEC to account for post-season adjustments to ex-vessel settlements), summed over all ex-vessel sales reported.
- Ex-vessel price per pound: commercial value per unit (pound) of BBRKC landings (as adjusted by CFEC to account for post-season adjustments to ex-vessel settlements), measured as weighted average value over all ex-vessel sales reported. Ex-vessel prices, combined with vessel operating costs and other factors, determine the economic return to vessels per unit of catch and, considering the availability and expected returns from alternative fishing targets, are a direct driver of the level and intensity of fishing effort.
- BBRKC ex-vessel revenue share (% of total exvessel revenue): BBRKC ex-vessel revenue share as percentage of total calendar year ex-vessel revenue from all commercial landings in Alaska fisheries, mean value over all vessels active in BBRKC during the respective year. Revenue share provides an indicator of the relative income dependence of participating vessels on the BBRKC

fishery, where changes in the fishery that reduce the returns from fishing (e.g., reductions in TAC and/or ex-vessel price) are offset by income produced from alternative fishing targets.

3. Community Indicators

- Processors active in fishery: Total number of crab processors that purchased landings of BBRKC from delivering vessels during the calendar year. This provides an indicator of the level of participation of buyers in the market for BBRKC landings.
- Processing Employment in BBRKC: Crab processing employment generated in BBRKC fishery as measured by total paid hours of labor input by processing employees, summed over all shore-based plants that processed BBRKC landings.
- Local Quotient of BBRKC landed catch in Dutch Harbor: Ex-vessel value share of BBRKC landings to Unalaska/Dutch Harbor, as percentage of total value of commercial landings to processors in the community from all commercial Alaska fisheries, as aggregate percentage over all landings during the respective year. Dutch Harbor is the principal port of landing for the BBRKC fishery, historically, representing between 43% and 58% of annual landings since 2005.

Indicator Analysis

We provide the list and time-series of indicators (Table 3, Figures 4-5) and then monitor the indicators using three stages of statistical tests that gradually increase in complexity depending on the stability of the indicator for monitoring the ecosystem or socioeconomic process and the data availability for the stock (Shotwell et al., *In Review*). At this time, we report the results of the first and second stage statistical tests of the indicator analysis for BBRKC. The third stage will require more indicator development and review of the ESP modeling applications.

Stage 1, Traffic Light Test:

The first stage of the indicator analysis is a simple assessment of the most recent year relative value and a traffic-light evaluation of the most current year where available (Table 3). Both measures are based on one standard deviation from the long-term mean of the time series. A symbol is provided if the most recent year of the time series is greater than (+), less than (-), or within (•) one standard deviation of the long-term mean for the time series. If the most recent year is also the current year then a color fill is provided for the traffic-light ranking based on whether the relative value creates conditions that are good (blue), average (white), or poor (red) for BBRKC (Caddy et al., 2015). The blue or red coloring does not always correspond to a greater than (+) or less than (-) relative value. In many cases the most current year was not available and this demonstrates significant data gaps for evaluating ecosystem and socioeconomic data for BBRKC.

Overall, BBRKC recruitment still remains well below average. EBS bottom trawl survey biomass estimates were not available for 2020, however the 2018 recruitment estimate was the lowest in the 40-year time series, following the lowest previously observed in 2017. Trends in physical ecosystem indicators suggest poor to fair environmental conditions during the past 5 years for the BBRKC stock. The cold pool extent in Bristol Bay was at an all-time low from 2018-2019 while average summer bottom temperatures have exceeded 4°C in three of the past five years. Environmental conditions in 2020 appear to have returned to near-average compared to the long-term mean, with a positive phase Arctic Oscillation coinciding with an increase in the cold pool extent and a nearly 2°C decline in summer bottom temperatures from 2019 to 2020. On the contrary, a nearly 3-fold increase in bottom water corrosivity in Bristol Bay from 2019 to 2020 suggests that over 50% of Bristol Bay bottom waters were below the aragonite saturation threshold ($\Omega arag < 1$) from February to April.

Spring bottom temperatures in 2020 averaged 0.37°C, which suggests that embryo development and hatching may have been delayed due to colder than average bottom temperatures. 2020 spring bottom temperatures were below 2006 and 2007 bottom temperatures when Chilton et al. (2010) noted that stations sampled in May had high numbers of mature female RKC still brooding embryos fertilized the previous season. These results suggest that in 2020, peak hatch timing may have been delayed until June, which could have implications for temporal synchrony between larval RKC and the spring bloom. Furthermore, chlorophyll *a* biomass estimates have remained below-average for the past five years and wind stress in Bristol Bay has been above-average during this time period. Together these conditions may be indicative of declines in diatom abundances and low larval encounter rates due to increased surface mixing. Record high juvenile sockeye salmon abundances since 2014 may be further indicative of increased predation and subsequent poor survival of RKC larval stages in the past 5 years.

Due to the 2020 cancellation of the EBS bottom trawl survey, current-year data are not available for Pacific cod and benthic invert biomass indicators. However, both indicators are on a downward trend and Pacific cod biomass has been below average since 2016 in Bristol Bay. Current year data was also unobtainable for spatial distribution indicators, though recent trends are consistent with documented shifts in spatial distributions during previous warm periods in Bristol Bay (Loher and Armstrong, 2005; Zacher et al., 2018). During warm years in 2018-2019, male RKC were located further from shore during the fishery, and both males and females occupied a larger area during the summer trawl survey in recent years.

Indicators reported for applicable socioeconomic metrics are derived from fishery-dependent sources that are typically available for the prior year or lagged by up to three years (as of the September-November assessment cycle for most Alaska-region FMP crab and groundfish stocks), and as such are limited to providing retrospective information. The metrics reported in Table 3b, therefore, are based on the most current available value of the respective data series, representing conditions in the BBRKC fishery during 2018 or 2019.

Fishery performance metrics related to aggregate fishing effort, including number of active vessels and total number of potlifts, were low relative to the long term averages, but were within the range of recent variation and exhibiting declining trends commensurate with lower TACs following the 2016/17 season. CPUE has declined since 2016, but was slightly below average during 2019.

Metrics for economic and community indicators were more generally negative for 2018-2019. Ex-vessel price remained relatively high over the most recent years, which may have partially mitigated some effects of decreased production, however, aggregate ex-vessel value reached a historical low during 2019, falling below 1 standard deviation of the long-term mean. BBR ex-vessel revenue share declined more modestly during 2019, possibly reflecting distribution of aggregate landings over fewer vessels, as well as a relatively brief BBRKC season allowing more time devoted to other fisheries. Processing employment generated by BBRKC, as measured in aggregate paid processing labor hours, also fell to a historical low. The local quotient of BBRKC catch value in Dutch Harbor fell to 7%, indicating that the decline in BBRKC landing value was somewhat isolated to the fishery, with local landings from other fisheries maintaining value in 2019.

Stage 2, Importance Test:

Bayesian adaptive sampling (BAS) was used for the second stage statistical test to quantify the association between hypothesized predictors and BBRKC mature male biomass (MMB), and to assess the strength of support for each hypothesis. BAS explores model space, or the full range of candidate combinations of predictor variables, to calculate marginal inclusion probabilities for each predictor, model weights for each combination of predictors, and generate Bayesian model averaged predictions for outcomes (Clyde et al., 2011). In this second test, the full set of indicators is first winnowed to the predictors that could directly relate to MMB, and have consistent temporal scales. We then provide the mean relationship between each predictor variable and log MMB over time (Figure 6a), with error bars describing the uncertainty (1 standard deviation) in each estimated effect and the marginal inclusion probabilities for each predictor variable (Figure 6b). A higher probability indicates that the variable is a better candidate predictor of BBRKC MMB. The highest ranked predictor variables (> 0.50 inclusion probability) were: BBRKC recruit biomass, Pacific cod biomass, and the Arctic Oscillation. Unfortunately, due to the nature of the BAS model only being able to fit years with complete observations for each covariate, the final subset of covariates was quite small and creates a significant data gap. Despite this shortcoming, predictive performance of the BAS model appears to generally capture BBRKC MMB trends across the time series (Figure 6d).

Recommendations

The BBRKC ESP follows the standardized framework for evaluating the various ecosystem and socioeconomic considerations for this stock (Shotwell et al., *In Review*). Given the metric and indicator assessment we provide the following set of considerations:

Ecosystem Considerations

- Available physical indicators for 2020 show a return to near-average conditions in Bristol Bay. A relatively high positive Arctic Oscillation index in winter 2020 may suggest favorable conditions for BBRKC productivity.
- Persistently low levels of chlorophyll *a* and above-average wind stress in Bristol Bay in combination with substantial increases in juvenile sockeye salmon abundance in the past 5 years could be indicative of poor larval conditions.
- The degree of match or mismatch of first-feeding larval red king crab with preferred diatom prey may be critical for larval survival, and recent fluctuations in spring temperatures during embryo development could impact the synchrony between hatch timing and the spring bloom.
- BBRKC recruitment remains well below the long-term average. Concurrent declines in Pacific cod and benthic invertebrate biomass in the past 5 years coinciding with above-average bottom temperatures and a reduced cold pool may suggest bottom-up climate forcing on Bristol Bay benthic communities.
- Current-year increases in corrosive bottom waters in Bristol Bay have the potential to impact shell formation, growth and survival of BBRKC.

Economic Considerations

- The numbers of vessels and processors active in the 2018/19 and 2019/20 BBRKC seasons dropped below the lower bounds of their long-term historical range during 2018 and 2019. Both metrics have been in a generally declining trend since the BBRKC fishery was substantially restructured and consolidated following rationalization.
- Ex-vessel price has remained above the long-term average since 2010, partially mitigating some income effects of declining BBRKC production, but the reduced level of participation and employment suggest that reduced economic performance of the BBRKC fishery may have negative distributional effects.
- While aggregate BBRKC ex-vessel value was at a historical low in 2019, BBRKC ex-vessel revenue share on average for active vessels was only moderately below average during 2019. The local quotient for BBRKC catch value of landings to Dutch Harbor also declined to a historical low in 2019.

Data Gaps and Future Research Priorities

Current year data gaps for ecosystem indicators due to the cancellation of the 2020 EBS bottom trawl survey emphasize the necessity of annual surveys for tracking impending ecosystem shifts and potential impacts to BBRKC. Low stock recruitment in the past decade also warrants a better understanding of early life history processes and bottlenecks to aid in developing meaningful larval indicators as early warning signs. Evaluating RKC phenology relative to spring bloom timing may be useful for predicting larval condition and subsequent survival to settlement. Additionally, evaluating larval drift patterns and identifying essential fish habitat for benthic juvenile RKC may support the development of a larval retention or settlement success indicator.

Given the dramatic increase in Bristol Bay sockeye salmon in recent years, we emphasize the importance of understanding predator-prey interactions and spatial overlap. Furthermore, additional groundfish stomach data outside of the summer survey time series would inform predation mortality during the molt when RKC are highly vulnerable. The prevalence of corrosive bottom waters in Bristol Bay also highlights the need for continued research to identify the potential impacts of ocean acidification on RKC physiology. Ongoing efforts to understand the relationship between aragonite saturation states and BBRCK distributions (E. Kennedy, *pers. commun*., 2020) will be particularly important if Bristol Bay continues to experience corrosive water conditions. Overall, we highlight the continued importance of developing a mechanistic understanding of driver-response relationships to facilitate the inclusion of ecosystem indicators in future management strategies for Bering Sea commercial crab stocks.

Socioeconomic indicators of community participation in the BBRKC fishery included in this report are limited to general metrics related to the processing sector (number of active processors, aggregate processing labor hours), and local quotient of landed value in Dutch Harbor. Extensive data resources are available to support development of a wide variety of useful community-related indicators, however, more comprehensive depiction of indicators at the level of individual communities within the ESP is currently constrained by the limited scope and intent of the document. AFSC is currently developing a dedicated annual report to accompany the Crab and Groundfish Economic SAFE reports, focused on providing comprehensive analysis and monitoring of community participation and engagement in groundfish and crab fisheries. The Annual Community Engagement and Participation Overview (ACEPO) will provide detailed, community-level metrics of fishery participation, including income and employment, and ownership of vessel, plant, permit and quota share assets. Development of methods and indices for effectively capturing these and other dimensions of management effects on communities is currently concentrated on producing the ACEPO report. It is expected that this will provide the basis for identifying reduced-form indicators of community effects that will be suitable for incorporation in future ESPs.

Acknowledgements

We would like to thank all contributors and stock assessment authors for their timely response to requests and questions regarding data, report summaries, and manuscripts. We also thank all attendees and presenters at ESP Data workshops (May 2019 and March 2020) for their valuable insight on the development of the BBRKC ESP and future indicator development. Lastly, we thank the Crab Plan Team, North Pacific Fisheries Management Council, and AFSC for supporting the development of this report and future reports.

Literature Cited

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

Bechtol, W. R., and Kruse, G. H. 2010. Factors affecting historical red king crab recruitment around Kodiak Island, Alaska. *In* Biology and Management of Exploited Crab Populations under Climate Change, 25th edn, pp. 413-442. Ed. by G. H. Kruse, G. L. Eckert, R. J. Foy, R. N. Lipcius, B. Sainte-Marie, D. L. Stram, and D. Woodby. Alaska Sea Grant College Program, University of Alaska Fairbanks, Anchorage, AK.

Caddy, J.F. 2015. The traffic light procedure for decision making: its rapid extension from fisheries to other sectors of the economy. Glob. J. of Sci. Front. Res: 1 Mar. Sci. 15(1), 30 pp.

[25]Chilton, E. A., Foy, R. J., and Armistead, C. E. 2010. Temperature effects on assessment of red king crab in Bristol Bay, Alaska. *In* Biology and Management of Exploited Crab Populations under Climate Change, pp. 249-263. Ed. by G. H. Kruse, G. L. Eckert, R. J. Foy, R. N. Lipcius, B. Sainte-Marie, D. L. Stram, and D. Woodby. Alaska Sea Grant, University of Alaska Fairbanks.

Clyde, M. A., J. Ghosh, and M. L. Littman. 2011. Bayesian Adaptive Sampling for Variable Selection and Model Averaging. Journal of Computational and Graphical Statistics 20:80-101.

Coffey, W. D., Yarram, A., Matoke, B., Long, W. C., Swiney, K. M., Foy, R. J., and Dickenson, G. 2017. Ocean acidification leads to altered micromechanical properties of the mineralized cuticle of juvenile red and blue king crabs. Journal of Experimental Marine Biology and Ecology, 495: 1-12.

[22]Daly, B., Eckert, G. L., and White, T. D. 2013. Predation of hatchery-cultured juvenile red king crabs (*Paralithodes camtschaticus*) in the wild. Canadian Journal of Fisheries and Aquatic Sciences, 70: 358-366.

[27]Daly, B., Hermann, A. J., Parada, C., Hinckley, S., Loher, T., and Armstrong, D. 2018. Impacts of climate change on red king crab larval advection in Bristol Bay: implications for recruitment variability. ICES Document NPRB PRoject 1402. 124 pp.

Dew, C. B. 2010. Historical perspective on habitat essential to Bristol Bay red king crab. *In* Biology and Management of Exploited Crab Populations under Climate Change, 25th edn, pp. 377-402. Ed. by G. H. Kruse, G. L. Eckert, R. J. Foy, R. N. Lipcius, B. Sainte-Marie, D. L. Stram, and D. Woodby. Alaska Sea Grant College Program, University of Alaska Fairbanks, Anchorage, AK.

[16]Donaldson, W., Byersdorfer, S., Pengilly, D., and Blau, S. 1992. Growth of red king crab, Paralithodes camtschaticus (Tilesius, 1815), in artificial habitat collectors at Kodiak, Alaska. Journal of Shellfish Research, 11: 85-89.

Dorn, M. W., C. J. Cunningham, M. T. Dalton, B. S. Fadely, B. L. Gerke, A. B. Hollowed, K. K. Holsman, J. H. Moss, O. A. Ormseth, W. A. Palsson, P. A. Ressler, L. A. Rogers, M. A. Sigler, P. J. Stabeno, and M. Szymkowiak. 2018. A climate science regional action plan for the Gulf of Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-376, 58 p.

[15]Feder, H. M., McCumby, K., and Paul, A. J. 1980. The food of post-larval king crab, *Paralithodes camtschatica*, in Kachemak Bay, Alaska (Decapoda, Lithodidae). Crustaceana, 39: 315-318.

Garber-Yonts, B., and Lee, J. 2019. Economic status report summary: BSAI crab fisheries, 2019. 16 pp.

[9]Haynes, E. 1974. Distribution and relative abundance of larvae of king crab, *Paralithodes camtschatica*, in the southeastern Bering Sea, 1969–70. Fishery Bulletin, 72: 804-812.

[19]Jewett, S., and Feder, H. 1982. Food and feeding habits of the king crab *Paralithodes camtschatica* near Kodiak Island, Alaska. Marine Biology, 66: 243-250.

Kearney, K., Hermann, A., Cheng, W., Ortiz, I., and Aydin, K. 2020. A coupled pelagic–benthic–sympagic biogeochemical model for the Bering Sea: documentation and validation of the BESTNPZ model (v2019.08.23) within a high-resolution regional ocean model. Geosci. Model Dev., 13: 597-650.

Kotwicki, S., and Lauth, R. R. 2013. Detecting temporal trends and environmentally-driven changes in the spatial distribution of bottom fishes and crabs on the eastern Bering Sea shelf. Deep Sea Research Part II: Topical Studies in Oceanography, 94: 231-243.

[6]Kuris, A. M. 1991. A review of patterns and causes of crustacean brood mortality. *In* Crustacean issues, pp. 117-141. Ed. by A. W. A. Kuris. A.A. Balkema, Rotterdam.

Laman, E. A., C. N. Rooper, S. C. Rooney, K. A. Turner, D. W. Cooper, and M. Zimmermann. 2017. Model-based essential fish habitat definitions for Bering Sea groundfish species. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-357, 265 p

[23]Lang, G. M., Livingston, P. A., Pacunski, R., Parkhurst, J., and Yang, M.-S. 1991. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986. ICES Document NMFS F/NWC-207. 240 pp.

[13]Livingston, P. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. Fishery Bulletin, 87: 807-827.

[8]Loher, T., and Armstrong, D. A. 2000. Recruitment limitation in Alaskan red king crab (*Paralithodes camtschaticus*): the importance of early life history stages. 81 pp.

[28]Loher, T., and Armstrong, D. A. 2005. Historical changes in the abundance and distribution of ovigerous red king crabs (*Paralithodes camtschaticus*) in Bristol Bay (Alaska), and potential relationship with bottom temperature. Fisheries Oceanography, 14: 292-306.

Long, W. C., and Daly, B. 2017. Upper thermal tolerance in red and blue king crab: sublethal and lethal effects. Marine Biology, 164: 162.

[24]Long, W. C., Swiney, K. M., and Foy, R. J. 2013a. Effects of ocean acidification on the embryos and larvae of red king crab, *Paralithodes camtschaticus*. Marine Pollution Bulletin, 69: 38-47.

Long, W. C., Swiney, K. M., Harris, C., Page, H. N., and Foy, R. J. 2013b. Effects of ocean acidification on juvenile red king crab (*Paralithodes camtschaticus*) and Tanner crab (*Chionoecetes bairdi*) growth, condition, calcification, and survival. PloS one, 8: e60959.

Lynch, P. D., R. D. Methot, and J. S. Link (eds.). 2018. Implementing a Next Generation Stock Assessment Enterprise. An Update to the NOAA Fisheries Stock Assessment Improvement Plan. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-183, 127 p. doi: 10.7755/TMSPO.183

Methot, R. D. Jr. (ed.). 2015. Prioritizing fish stock assessments. NOAA Tech. Memo. NMFS-F/SPO-152, 31 p.

Morrison, W.E., M. W. Nelson, J. F. Howard, E. J. Teeters, J. A. Hare, R. B. Griffis, J.D. Scott, and M.A. Alexander. 2015. Methodology for Assessing the Vulnerability of Marine Fish and Shellfish Species to a Changing Climate. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OSF-3, 48 p.

[3]Nakanishi, T. 1987. Effects of water temperature and hypoxia on the oxygen consumption of eggs of king crab. Bulletin of the Japanese Society of Scientific Fisheries, 53: 235-237.

Nichols, E., J. Shaishnikoff, and M. Westphal. 2019. Annual management report for shellfish fisheries of the Bering Sea–Aleutian Islands Management Area, 2018/19. Alaska Department of Fish and Game, Fishery Management Report No. 19-33, Anchorage.

NMFS. 2011. Habitat Assessment Prioritization. A Report by the Habitat Assessment Prioritization Working Group. Internal Report, NMFS White Paper. Office of Science and Technology, NMFS, NOAA. Silver Spring, MD. 41 p.

Paul, A., and Paul, J. 1980. The effect of early starvation on later feeding success of king crab zoeae. Journal of Experimental Marine Biology and Ecology, 44: 247-251.

[4]Paul, A., Paul, J., and Coyle, K. 1989. Energy sources for first-feeding zoeae of king crab *Paralithodes camtschatica*(Tilesius)(Decapoda, Lithodidae). Journal of Experimental Marine Biology and Ecology, 130: 55-69.

Pilcher, D. J., Naiman, D. M., Cross, J. N., Hermann, A. J., Siedlecki, S. A., Gibson, G. A., and Mathis, J. T. 2019. Modeled Effect of Coastal Biogeochemical Processes, Climate Variability, and Ocean Acidification on Aragonite Saturation State in the Bering Sea. 5.

Pirtle, J. L., Eckert, G. L., and Stoner, A. W. 2012. Habitat structure influences the survival and predator-prey interactions of early juvenile red king crab *Paralithodes camtschaticus*. Marine Ecology Progress Series, 465: 169-184.

[14]Pirtle, J. L., and Stoner, A. W. 2010. Red king crab (*Paralithodes camtschaticus*) early post-settlement habitat choice: Structure, food, and ontogeny. Journal of Experimental Marine Biology and Ecology, 393: 130-137.

[7]Powell, G. C., and Nickerson, R. B. 1965. Reproduction of king crabs, *Paralithodes camtschatica* (Tilesius). Journal of the Fisheries Research Board of Canada, 22: 101-111.

Shirley, S. M., and Shirley, T. C. 1989. Interannual variability in density, timing and survival of Alaskan red king crab *Paralithodes camtschatica* larvae. Marine Ecology Progress Series, 54: 51-59.

Shirley, T. C., and Shirley, S. M. 1990. Planktonic survival of red king crab larvae in a subarctic ecosystem, 1985-1989. *In* APPRISE: Interannual Variability and Fisheries Recruitment, pp. 263-285. Ed. by D. A. Ziemann, and K. W. Fulton-Bennett. School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks.

Shotwell, S.K., K., Blackhart, D., Hanselman, P., Lynch, S., Zador, B., Fissel, P., Spencer, and K., Aydin. *In Review*. Introducing a national framework for including stock-specific ecosystem and socioeconomic considerations within next generation stock assessments.

Stevens, B. G. 2003. Settlement, substratum preference, and survival of red king crab *Paralithodes camtschaticus* (Tilesius, 1815) glaucothoe on natural substrata in the laboratory. Journal of Experimental Marine Biology and Ecology, 283: 63-78.

[2]Stevens, B. G. 2014. Development and biology of king crab larvae. *In* King Crabs of the World: Biology and Fisheries Management, pp. 233-259. Ed. by B. G. Stevens. CRC Press, Boca Raton, FL.

[5]Stevens, B. G., and Swiney, K. M. 2007. Hatch timing, incubation period, and reproductive cycle for captive primiparous and multiparous red king crab, *Paralithodes camtschaticus*. Journal of Crustacean Biology, 27: 37-48.

Stoner, A. W. 2009. Habitat-mediated survival of newly settled red king crab in the presence of a predatory fish: role of habitat complexity and heterogeneity. Journal of Experimental Marine Biology and Ecology, 382: 54-60.

Stoner, A. W., Copeman, L. A., and Ottmar, M. L. 2013. Molting, growth, and energetics of newly-settled blue king crab: Effects of temperature and comparisons with red king crab. Journal of Experimental Marine Biology and Ecology, 442: 10-21.

[18]Stoner, A. W., Ottmar, M. L., and Copeman, L. A. 2010. Temperature effects on the molting, growth, and lipid composition of newly-settled red king crab. Journal of Experimental Marine Biology and Ecology, 393: 138-147.

Szuwalski, C.S., Cheng, W., Foy, R.J., Hermann, A.J., Hollowed, A.B., Holsman, K.H., Lee, J., Stockhausen, W.T., Zheng, J., In review. Climate change and the future productivity and distribution of crab in the Bering Sea. ICES J. Mar. Sci.

[11]Wespestad, V. G., Livingston, P. A., and Reeves, J. 1994. Juvenile sockeye salmon (*Oncorhynchus nerka*) predation on Bering Sea red king crab (*Paralithodes camtschaticus*) larvae as a cause of recruitment variation. ICES CM, 10: 17.

[17]Westphal, M. J., Eckert, G. L., and Tamone, S. L. 2014. Comparison of first year growth among field, hatchery-and laboratory-raised juvenile red king crab, *Paralithodes camtschaticus* (Tilesius, 1815), in Alaska. Journal of Crustacean Biology, 34: 319-325.

[20]Zacher, L. S., Kruse, G. H., and Hardy, S. M. 2018. Autumn distribution of Bristol Bay red king crab using fishery logbooks. PloS one, 13: 22.

[21]Zacher, L. S., Richar, J. I., and Foy, R. J. 2020. The 2019 eastern and northern Bering Sea continental shelf trawl surveys : results for commercial crab species.

Zhang, Y., Rossow, W., and Stackhouse Jr, P. 2006. Comparison of different global information sources used in surface radiative flux calculation: Radiative properties of the surface. Journal of Geophysical Research, 111.

Zheng, J., and Kruse, G. 2000. Recruitment patterns of Alaskan crabs in relation to decadal shifts in climate and physical oceanography. ICES Journal of Marine Science, 57: 438.

Zheng, J., and Kruse, G. H. 2006. Recruitment variation of eastern Bering Sea crabs: Climate-forcing or top-down effects? Progress in Oceanography, 68: 184-204.

[12]Zheng, J., and Siddeek, M. S. M. 2019. Bristol Bay red king crab stock assessment in fall 2019. *In* Stock assessment and fishery evaluation report for the king and Tanner crab fisheries of the Bering Sea and Aleutian Islands regions, pp. 125-266. North Pacific Management Council, 605 W. 4th Avenue, Anchorage AK 99620.

---

[*]Superscript numbers refer to references in Tables 2a and 2b

Table 1. List of data sources used in the Bristol Bay red king crab (BBRKC) ESP evaluation. Please see the BBRKC SAFE document (Zheng et al., 2019), the NOAA EBS Trawl Survey: Results for Commercial Crab Species Technical Memo (Zacher et al., 2020) and the SAFE Economic Status Report (Garber-Yonts and Lee, 2019) for more details.

	Title	Description	Years	Extent
Ecosystem	RACE EBS Bottom Trawl Survey	Bottom trawl survey of groundfish and crab on standardized 376-station grid using an 83-112 Eastern otter trawl	1975-2019	EBS annual
	REEM Food Habits Database	Diet data for key groundfish species collected by the Resource Ecology and Ecosystem Modeling (REEM) Program on the EBS bottom trawl survey	1987-2019	EBS annual
	ADF&G Crab Observer program data	BBRKC catch and effort data reported by ADF&G statistical areas during the fall fishery	2000-2019	EBS annual
	Essential Fish Habitat Models	Habitat suitability MaxEnt models for describing essential fish habitat of groundfish and crab in Alaska, EFH 2017 Update	1970-2017	Alaska
	BASIS survey	Surface/midwater column community survey of forage fish and salmon stocks	2002-2018	EBS, biennial
	ROMS Model Output	High-resolution regional oceanographic model hindcasts from the Bering Sea Regional Ocean Modeling System (ROMS)	1970-2020	EBS variable
	NOAA Climate Model Output	Monthly large-scale climate indices constructed by the National Weather Service’s Climate Prediction Center	1854-2020	North Pacific annual
	Satellite Data	Monthly wind stress and 8-day composite ocean color products from MODIS Aqua and MetOp ASCAP sensors (NOAA NCEI/NOAA NESDIS)	1988-2020	Global annual
Socioeconomic	ADF&G fish ticket database	Volume, value, and port of landing for Alaska crab and groundfish commercial landings; data processed and provided by Alaska Fisheries Information Network	1992-2019	Alaska
	ADF&G Crab Observer program data	BBRKC catch and effort data (number of active vessels, total pots lifted, and CPUE), sourced from ADF&G Annual Fishery Management Report	1980-2019	Alaska
	BSAI Crab Economic Data Report database	Crab processing employment; data processed and provided by Alaska Fisheries Information Network	1998-2018	Alaska

Table 2a: Ecological information by life history stage for Bristol Bay red king crab

Stage	Habitat & Distribution	Phenology	Age, Length, Growth	Energetics	Diet	Predators
Egg	Clutch of embryos brooded under the female's abdomen until hatching[7]	328-365 day embryo incubation, peak hatch in Feb[5]	Egg length 1.16mm[3]	Optimal: 3°C – 8°C[3]	Yolk	Nemertean worms and amphipods feed on egg clutches[6]
Larvae	Pelagic; nearshore along the Alaska Peninsula (40-70m depth)[9]	March-June, Hatch to C1 benthic stage: 130 d at 8°C[3]	1.1 – 2mm CL[2]	Optimal: 5°C – 10°C[2,3]	Phytoplankton-diatoms[4] (glaucothoe: non-feeding)	Planktivorous fish, salmon smolt[11]
Juvenile	Benthic; nearshore complex habitat- boulders, cobble, shell hash, structural invertebrates (<50m depth)[8, 14]	Peak settlement in July[8], 1 to 5-6 years duration for benthic instar stages	Mean size at settlement: 1.91 - 2.18mm CL[16,17]	No effect on survival of C1-C4 juveniles from 1.5°C to 12°C[18]	Sponges, diatoms, foraminifera, crustaceans, polychaetes, bryozoans[15]	Pacific cod[13], flatfish, crab[22]
Adult	Benthic: sand and mud bottoms (50-200m depth)[20, 21]	5-6+ years, Annual molt and mate Jan-June	For management, females >89 mm CL and males >119 mm CL are assumed to be mature[12]	Optimal: 2°C – 4°C[20]	Mollusks, echinoderms, polychaetes, crustaceans, hydroids, sea stars[19]	Pacific cod, halibut, skates[13,23] (primarily during the molt)

Table 2b. Key processes affecting survival by life history stage for Bristol Bay red king crab (BBRKC)

Stage	Processes Affecting Survival	Relationship to BBRKC
Egg	1. Temperature 2. CO_2 concentrations	Cold temperatures extend embryo development[25] while embryo mortality increases at temperatures above 8°C[3]. Exposure to increased $C0_2$ levels delays hatch time and reduces embryo condition[24]
Larvae	1. Spatial and temporal synchrony with spring bloom 2. Diatom abundance in spring/summer 3. Larval transport/retention onshore	RKC peak hatch coinciding with high abundances of *Thallasiosira* ssp. may increase larval survival[4]. Settlement success and benthic survival is likely related to oceanographic conditions that facilitate transport to suitable nearshore nurseries[27].
Juvenile	1. Availability of highly structured habitat 2. Predation	Complex nursery habitats promote the survival of benthic juvenile stages by providing refuge from predators[14]
Adult	1. Bottom temperature 2. Predation	Bottom temperatures are likely responsible for shifts in spatial distribution and migration timing[28]. After molting, adult RKC are highly vulnerable to groundfish predation.

Table 3a. First stage ecosystem indicator analysis for Bristol Bay red king crab (BBRKC), including indicator title and short description. The most recent year relative value (greater than (+), less than (-) or within 1 standard deviation (•) of long-term mean) of the time series is provided. Fill color is based on a traffic light evaluation for BBRKC of the current year conditions relative to 1 standard deviation of the longterm mean (white = average, blue = good, red = poor, no fill = no current year data).

Title	Description	Recent
Cold Pool Index	Fraction of the EBS BT survey area with bottom water less than 2°C on 1 July of each year from Bering10K ROMS model output hindcasts	●
Summer Bottom Temperature	Average of June-July bottom temperatures (° C) within the BBRKC management boundary from the Bering 10K ROMS model output hindcasts	●
Arctic Oscillation	Average of Jan-March Arctic Oscillation Index estimates; constructed by projecting daily 1000mb height anomalies poleward of 20°N onto the loading pattern of the Arctic Oscillation	+
Corrosivity Index	Percent of the BBRKC management area containing an average bottom aragonite saturation state of < 1 from Feb-April	+
Spring Bottom Temperature	Average of Feb-March bottom temperatures (° C) within the BBRKC management boundary from the Bering 10K ROMS model output hindcasts	●
Wind Stress	June ocean surface wind stress within the BBRKC management boundary. Product of NOAA blended winds and MetOp ASCAP sensors from multiple satellites	●
Chlorophyll-a Biomass	April-June average chlorophyll-a biomass within the Southern Inner Shelf of the Bering Sea; calculated with 8-day composite data from MODIS satellites	●
Juvenile sockeye salmon abundance	Estimated September juvenile sockeye salmon biomass from the Bering Arctic Subarctic Integrated Surveys in the EBS	+
Pacific cod biomass	Biomass (1,000t) of Pacific cod within the BBRKC management boundary on the EBS bottom trawl survey	-

Table 3a (cont.). First stage ecosystem indicator analysis for Bristol Bay red king crab (BBRKC), including indicator title and short description. The most recent year relative value (greater than (+), less than (-) or within 1 standard deviation (•) of long-term mean) of the time series is provided. Fill color is based on a traffic light evaluation for BBRKC of the current year conditions relative to 1 standard deviation of the longterm mean (white = average, blue = good, red = poor, no fill = no current year data).

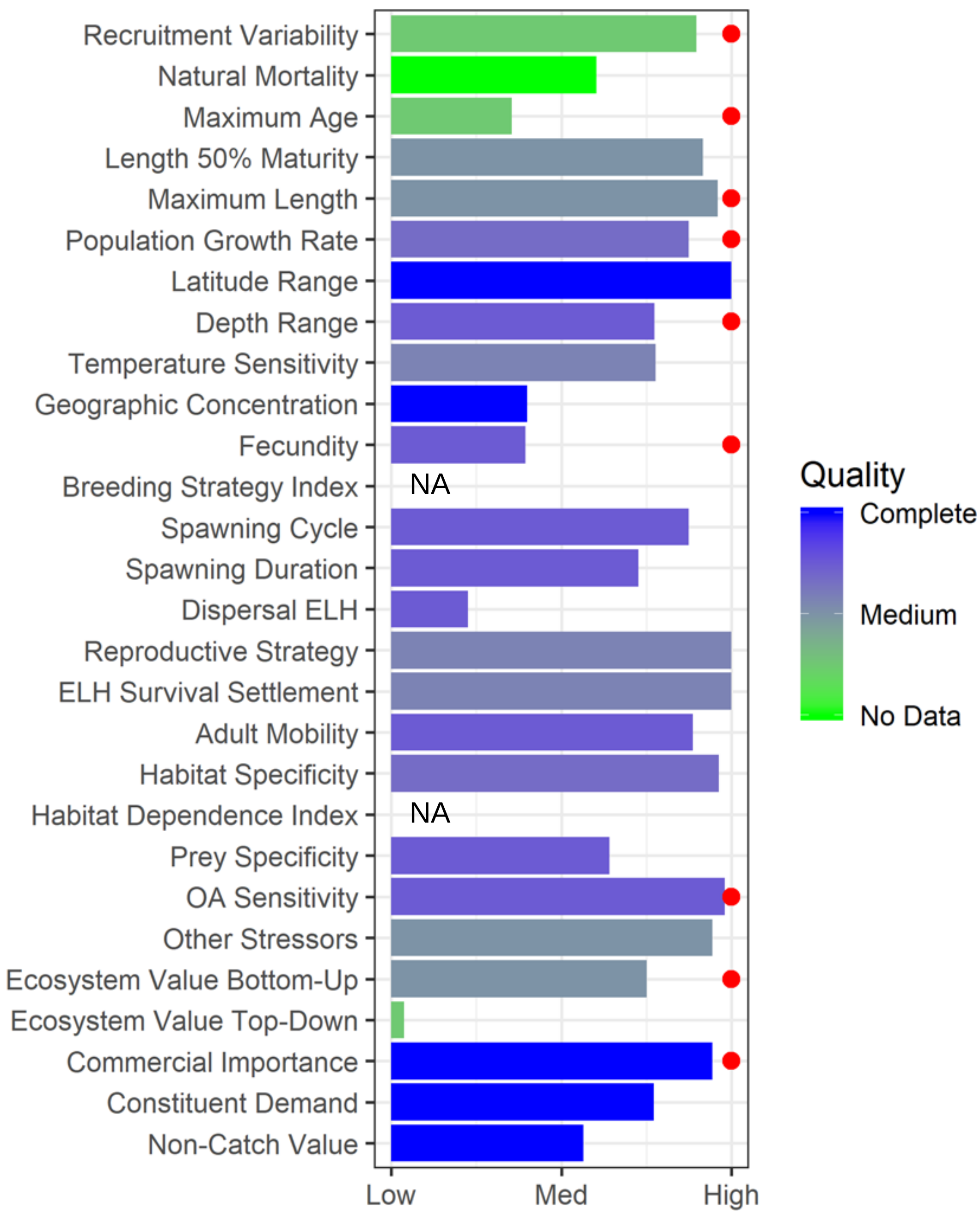
Title	Description	Recent
Benthic invertebrate biomass	Combined biomass (1,000t) of benthic invertebrates within the BBRKC management boundary on the EBS bottom trawl survey	●
BBRKC recruit biomass	Biomass of male red king crab (110-134 mm CL) from the EBS bottom trawl survey that will likely enter the fishery the following year.	-
BBRKC Catch Distance from Shore	Mean distance (km) legal male Bristol Bay red king crab were caught from shore in the autumn fishery (starting Oct. 15th) using observer data.	+
BBRKC mature male area occupied	The minimum area containing 95% of the cumulative CPUE for BBRKC mature males from the EBS bottom trawl survey	+
BBRKC mature female area occupied	The minimum area containing 95% of the cumulative CPUE for BBRKC mature females from the EBS bottom trawl survey	+

Table 3b. First stage socioeconomic indicator analysis for Bristol Bay red king crab (BBRKC), including indicator title and short description. The most recent year relative value (greater than (+), less than (-) or within 1 standard deviation (•) of long-term mean) of the time series is provided. Fill color is based on a traffic light evaluation for BBRKC of the current year conditions relative to 1 standard deviation of the longterm mean (white = average, blue = good, red = poor, no fill = no current year data).

Title	Description	Recent
CPUE	Fishing effort efficiency, as measured by estimated mean number of retained BBRKC per potlift	●
Vessels active in fishery	Annual count of crab vessels that delivered commercial landings of BBRKC to processors[2]	-
Total Potlifts	Fishing effort, as measured by estimated number of crab pots lifted by vessels during the BBRKC fishery	●
BBRKC Male Bycatch in Groundfish Fishery	Incidental bycatch biomass estimates of male BBRKC (tons) in trawl and fixed gear fisheries	●
TAC Utilization	Percentage of the annual BBRKC TAC (GHL prior to 2005) that was harvested by active vessels, including deadloss discarded at landing.	●
Ex-vessel value of BBRKC landings	Aggregate ex-vessel value of BBRKC landings (as adjusted by CFEC to account for post-season adjustments to ex-vessel settlements), summed over all ex-vessel sales reported.	-
Ex-vessel price per pound	Commercial value per unit (pound) of BBRKC landings (as adjusted by CFEC to account for post-season adjustments to ex-vessel settlements), measured as weighted average value over all ex-vessel sales reported.	●
BBRKC ex-vessel revenue share	BBRKC ex-vessel revenue share as percentage of total calendar year ex-vessel revenue from all commercial landings in Alaska fisheries, mean value over all vessels active in BBRKC during the respective year.	-
Processors active in fishery	Total number of crab processors that purchased landings of BBRKC from delivering vessels during the calendar year.	-
Processing Employment in BBRKC	Crab processing employment generated in BBRKC fishery as measured by total paid hours of labor input by processing employees, summed over all shore-based plants that processed BBRKC landings.	-

Local Quotient of BBRKC landed catch in Dutch Harbor	Ex-vessel value share of BBRKC landings to Unalaska/Dutch Harbor, as percentage of total value of commercial landings to processors in the community from all commercial Alaska fisheries, as aggregate percentage over all landings during the respective year.	**-**

Figure 1. Baseline metrics for Bristol Bay red king crab graded as a percentile rank over all groundfish and crab stocks in the FMP. Higher rank values indicate a vulnerability and color of the horizontal bar describes data quality of the metric (see Shotwell et al., *In Review*, for more details on the metric definitions). The red dot is a threshold value based on information collected from national initiatives.



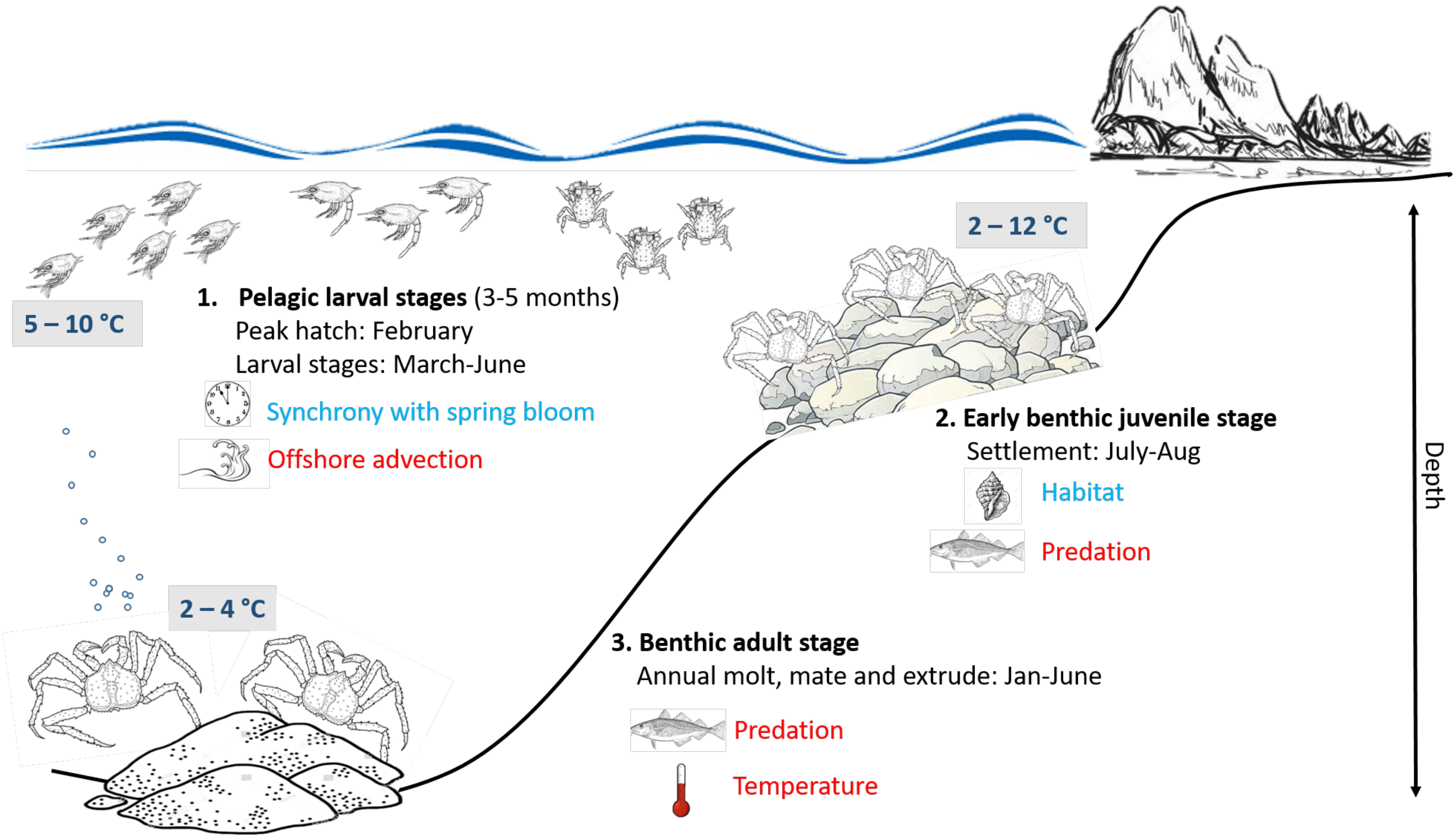


Figure 2a. Conceptual diagram of phenological information by life history stage for Bristol Bay red king crab and processes likely affecting survival in each stage. Thermal requirements by life history stage were determined from RKC laboratory studies.

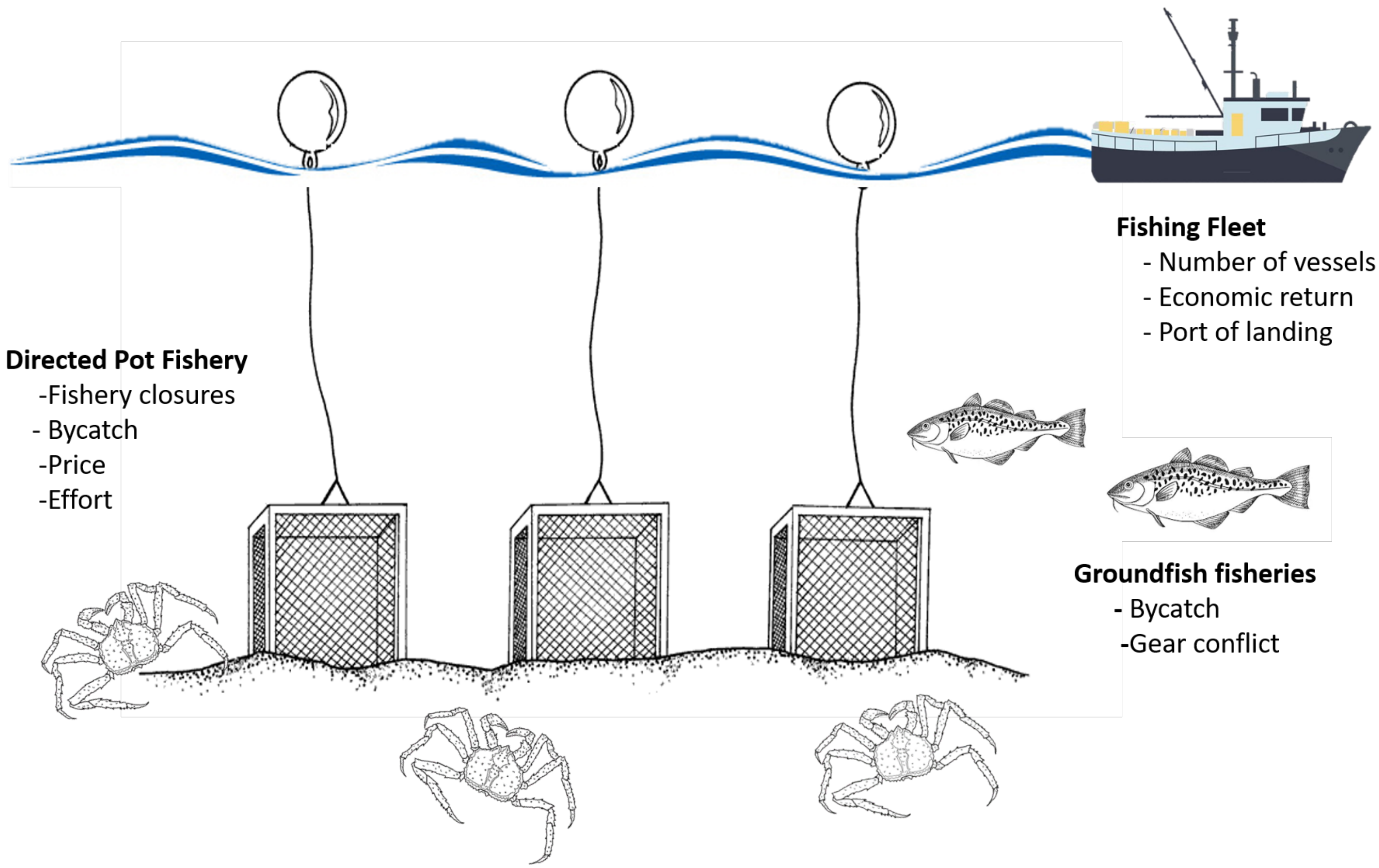


Figure 2b. Conceptual diagram of socioeconomic performance metrics that may identify dominant pressures on the Bristol Bay red king crab stock.

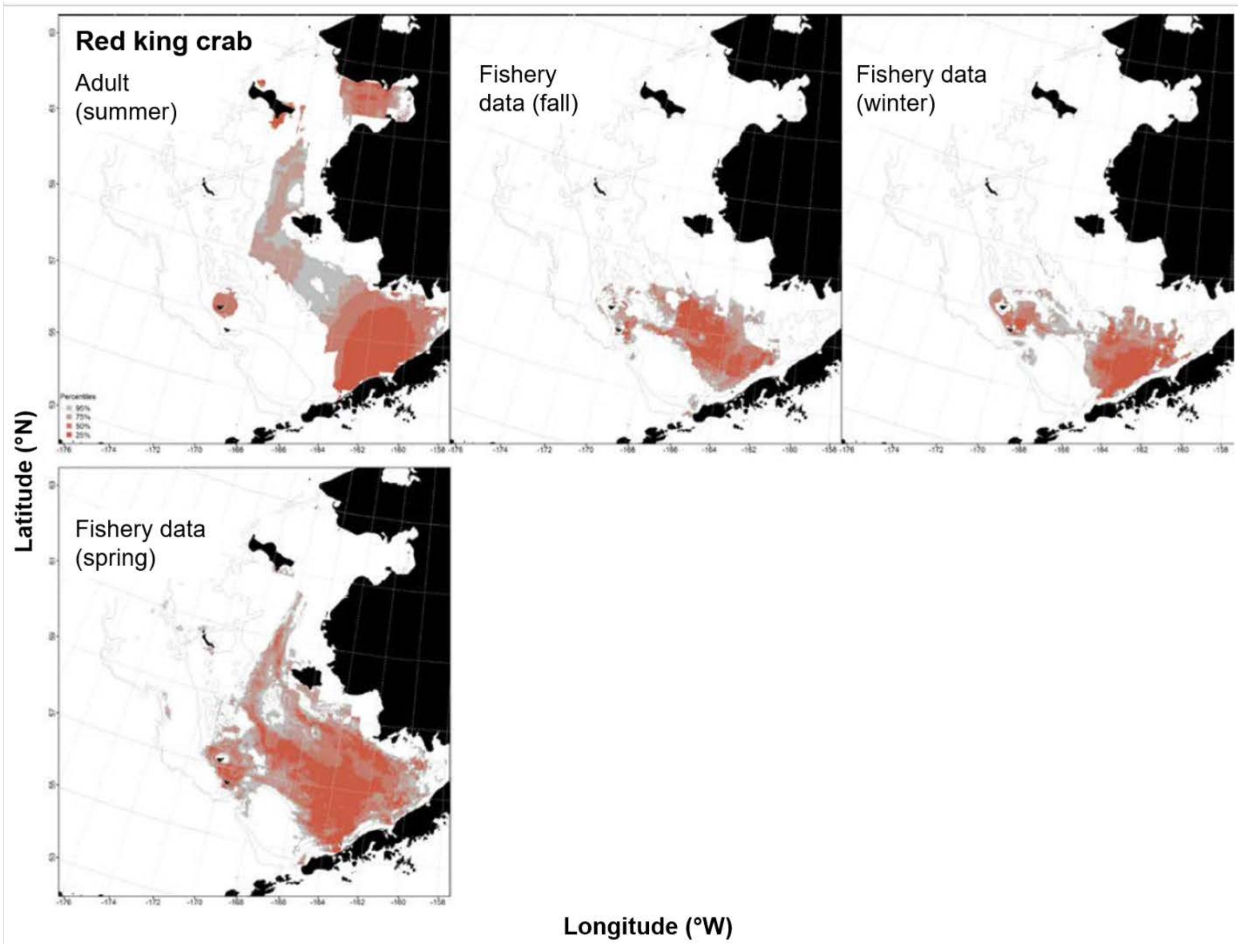


Figure 3. Essential fish habitat (EFH) predicted for red king crab (upper left panel) from RACE-GAP summertime bottom trawl surveys (1982-2014) and predicted from presence in commercial fishery catches (2003-2013) from fall, winter, and spring (remaining three panels) in the eastern Bering Sea. Figure modified from Laman et al., (2017).

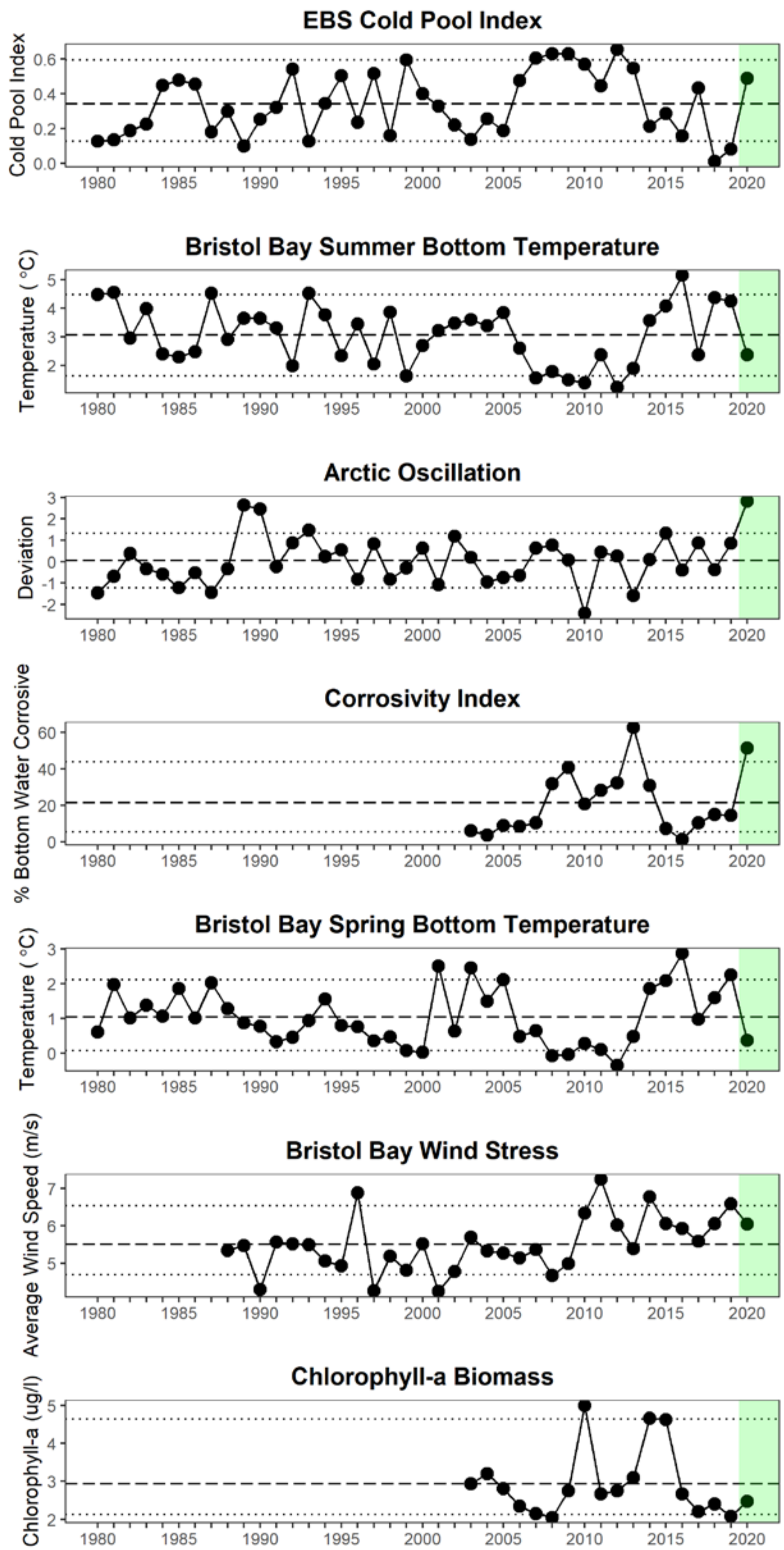


Figure 4. Selected ecosystem indicators for Bristol Bay red king crab with time series ranging from 1980 – 2020. Upper and lower dotted horizontal lines are 90th and 10th percentiles of time series. Dashed horizontal line is the mean of time series. Light green shaded area represents most recent year data for traffic light analysis.

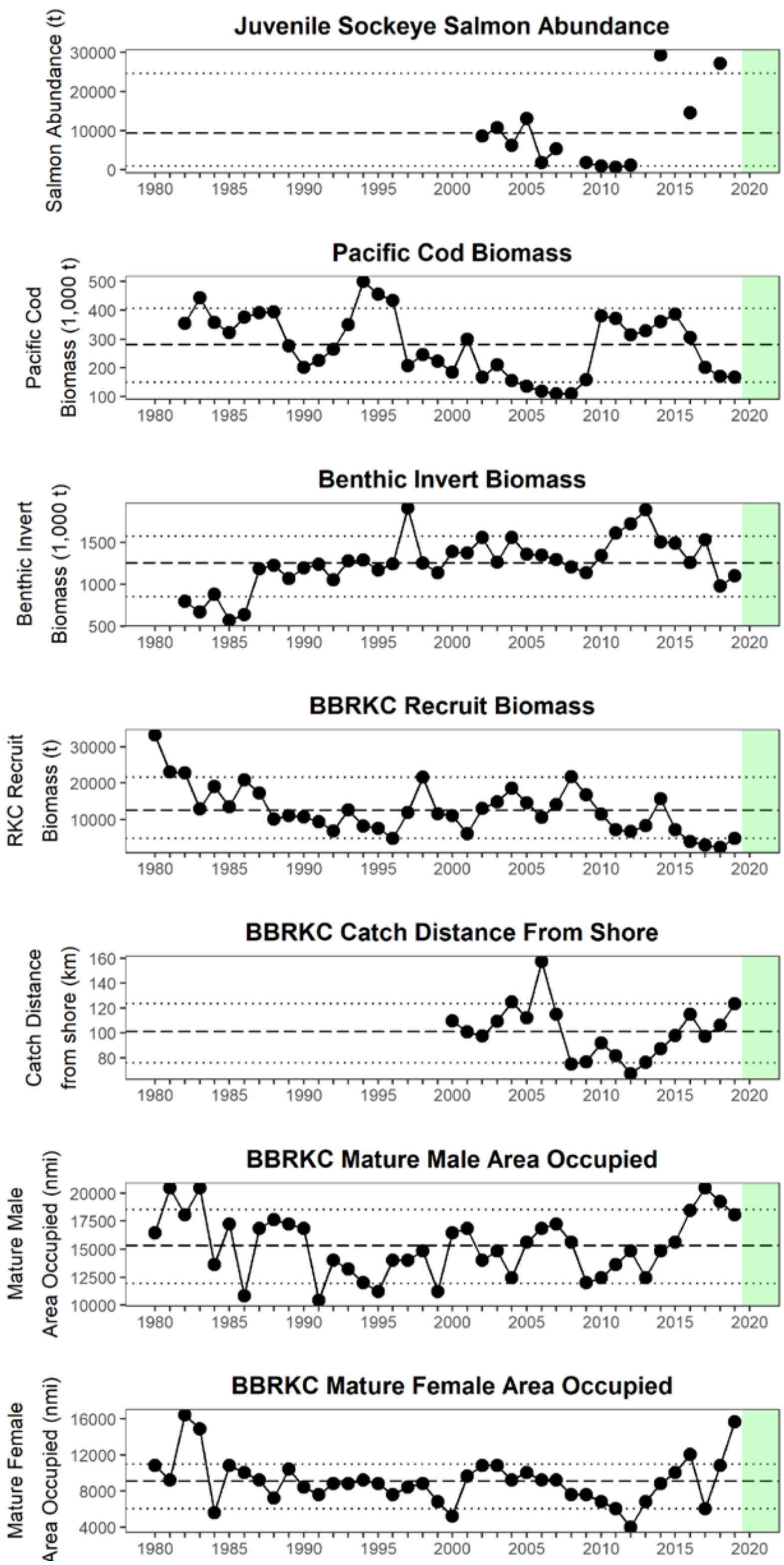


Figure 4 (cont.). Selected ecosystem indicators for Bristol Bay red king crab with time series ranging from 1980 – 2020. Upper and lower dotted horizontal lines are 90th and 10th percentiles of time series. Dashed horizontal line is the mean of time series. Light green shaded area represents most recent year data for traffic light analysis.

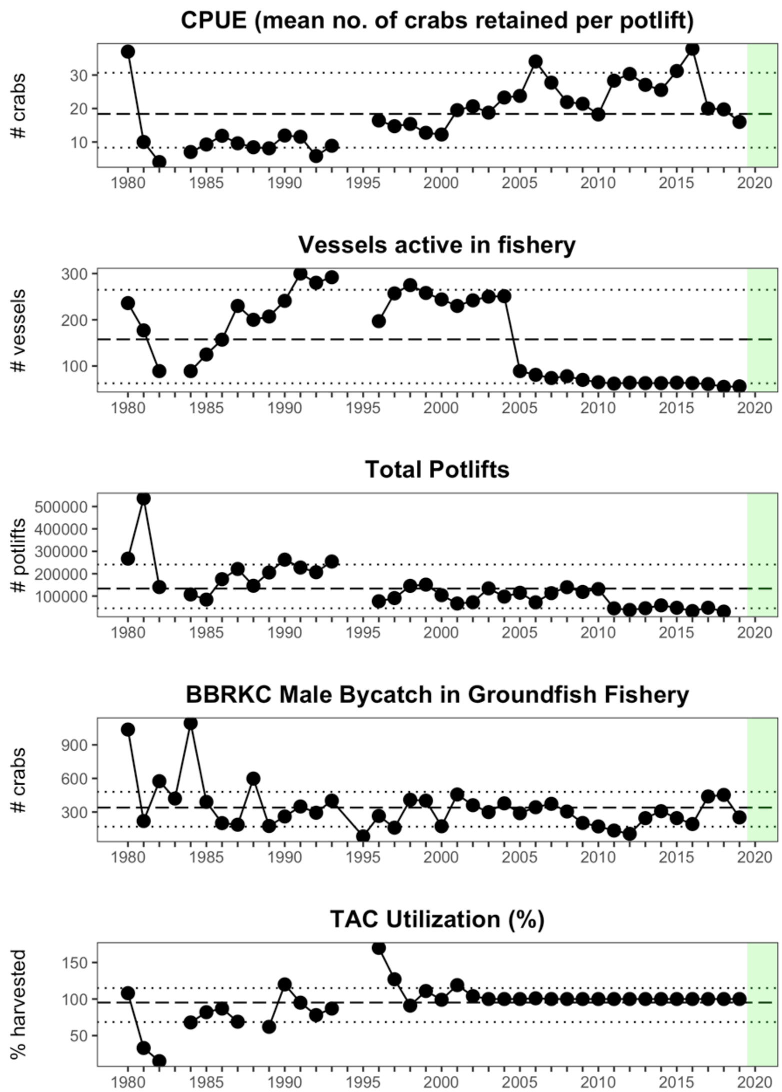


Figure 5. Selected socioeconomic indicators for Bristol Bay red king crab with time series ranging from 1980 – 2019. Upper and lower dotted horizontal lines are 90th and 10th percentiles of time series. Dashed horizontal line is the mean of time series. Light green shaded area represents most recent year data for traffic light analysis.

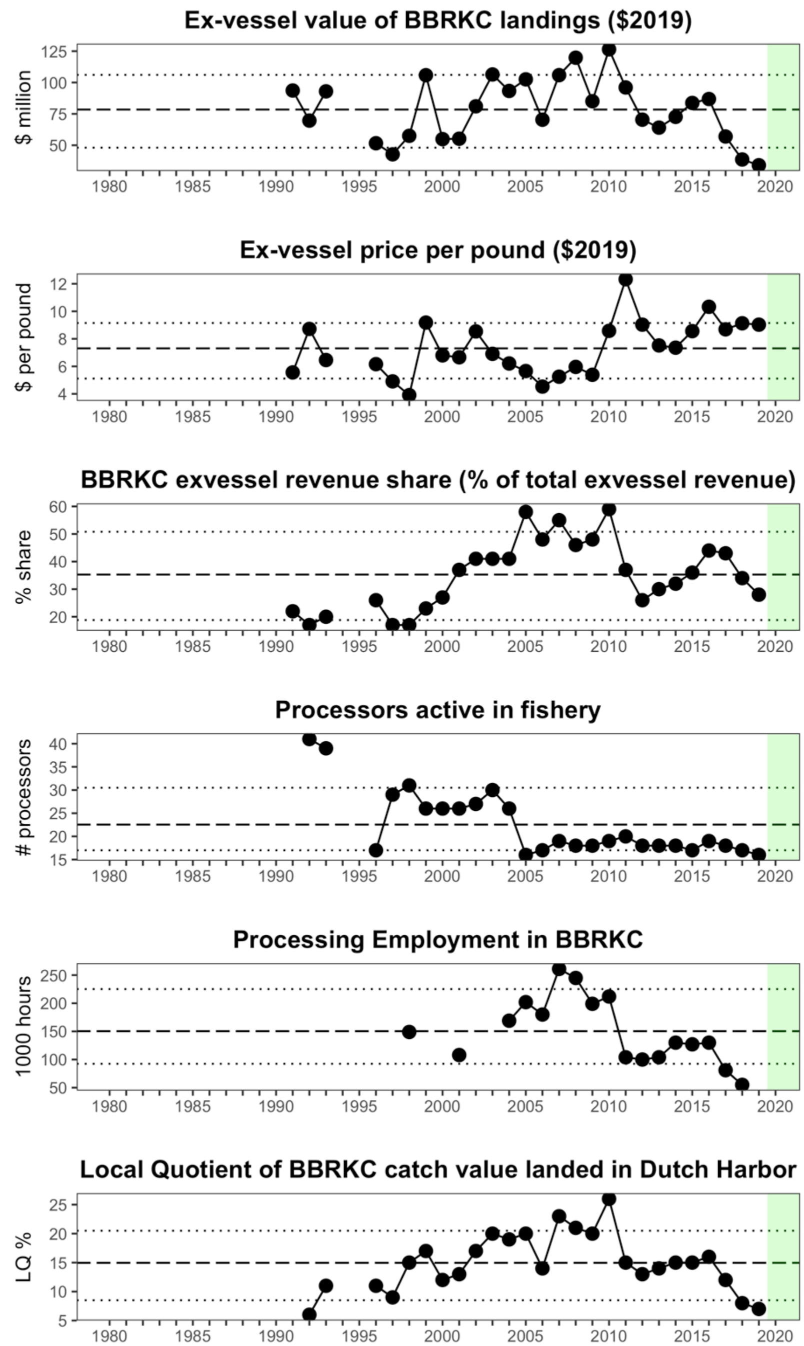


Figure 5. (cont.) Selected socioeconomic indicators for Bristol Bay red king crab with time series ranging from 1980 – 2019. Upper and lower dotted horizontal lines are 90th and 10th percentiles of time series. Dashed horizontal line is the mean of time series. Light green shaded area represents most recent year data for traffic light analysis.

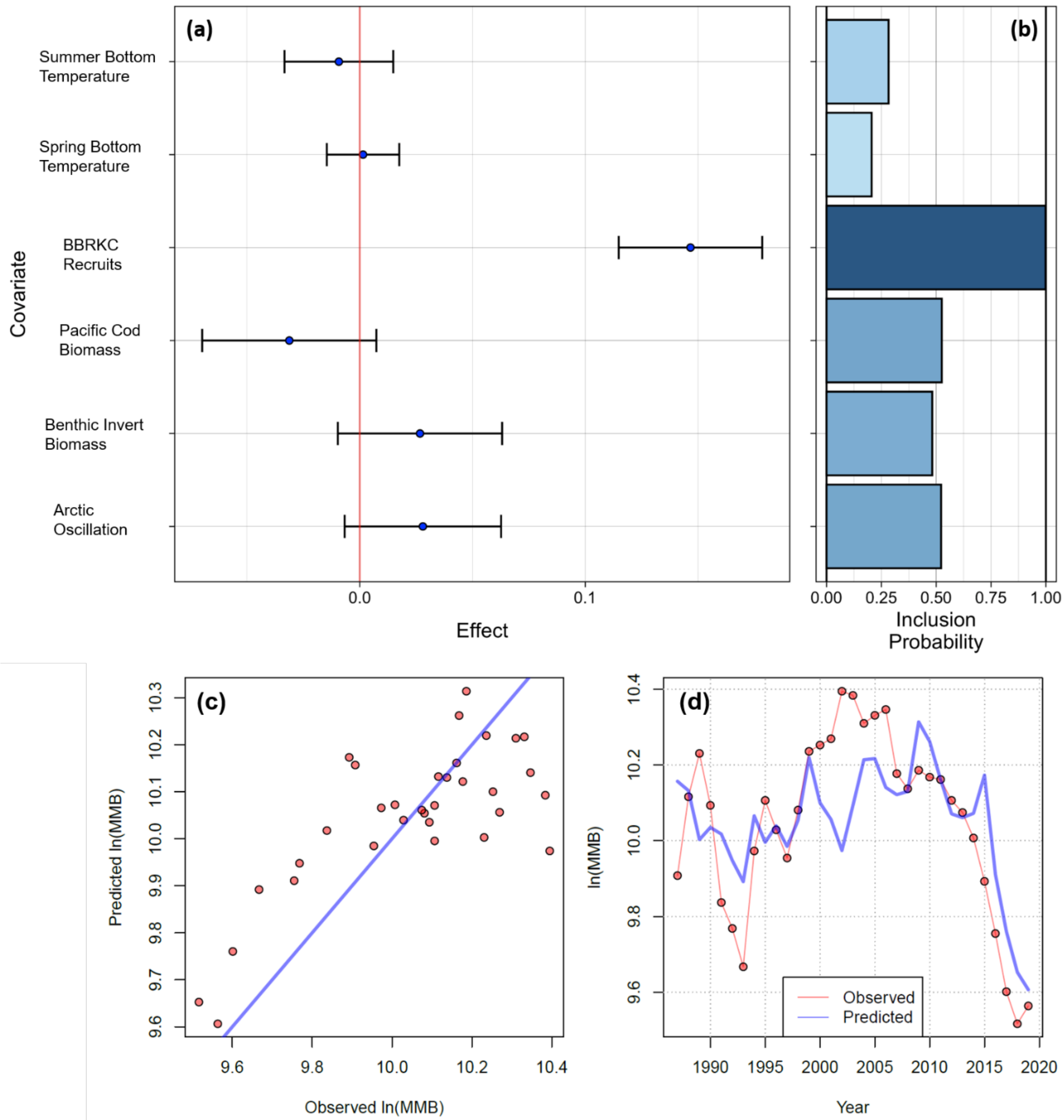


Figure 6. Bayesian adaptive sampling output showing the mean relationship and uncertainty (± 1 SD) with log-transformed Bristol Bay red king crab mature male biomass: a) the estimated effect and b) marginal inclusion probabilities for each predictor variable of the subsetted covariate ecosystem indicator dataset. Output also includes model c) predicted fit (1:1 line) and d) average fit across the MMB time series.