1. Norton Sound Red King Crab Stock Assessment for the fishing year 2019

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Executive Summary

1. Stock. Red king crab, *Paralithodes camtschaticus*, in Norton Sound, Alaska.
2. Catches. This stock supports three important fisheries: summer commercial, winter commercial, and winter subsistence fisheries. Of those, the summer commercial fishery accounts for 85% of total harvest. The summer commercial fishery started in 1977. Catch peaked in the late 1970s with retained catch of over 2.9 million pounds. Since 1994, Norton Sound Crab fishery operated as super exclusive. For 2018 fishery season, Norton Sound Red King Crab harvest consisted of: 9,189 crab (20,118 lb.) by winter commercial, 4,424 (8,848 lb.) by winter subsistence, and 89,613 crab (298,396 lb.) by summer commercial, totaling 103,217 crab (338,574 lb.) below ABC of 0.35 million lb.
3. Stock Biomass. Norton Sound Red King Crab stock has been monitored by triennial survey since 1976 by NOAA (1976-1991) and ADF&G (1996-present), ranged from 1.41 million to 5.9 million crab. In 2018, abundance by trawl survey was 1.11 million crab with CV 0.25.
4. Recruitment. Model estimated recruitment was weak during the late 1970s and high during the early 1980s, with a slightly downward trend from 1983 to 1993. Estimated recruitment has been highly variable but on an increasing trend in recent years.
5. Management performance.

Status and catch specifications (million lb.)

Year	MSST	Biomass (MMB)	GHL	Retained Commercial Catch	Total Retained Catch	Retained OFL	Retained ABC
2015	2.41[A]	5.13	0.39	0.40	0.52	0.72[A]	0.58
2016	2.26[B]	5.87	0.52	0.51	0.52	0.71[B]	0.57
2017	2.31[C]	5.14	0.50	0.49	0.50	0.67 [C]	0.54
2018	2.41[D]	4.08	0.30	0.31	0.34	0.43[D]	0.35
2019	2.24[E]	3.12	TBD	TBD	TBD	0.24[E]	0.19

Status and catch specifications (1000t)

Year	MSST	Biomass (MMB)	GHL	Retained Commercial Catch	Total Retained Catch	Retained OFL	Retained ABC
2015	1.09[A]	2.33	0.18	0.18	0.24	0.33[A]	0.26
2016	1.03[B]	2.66	0.24	0.23	0.24	0.32[B]	0.26
2017	1.05[C]	2.33	0.23	0.22	0.24	0.30[C]	0.24
2018	1.09 [D]	1.85	0.13	0.14	0.15	0.20 [D]	0.16
2019	1.03 [E]	1.41	TBD	TBD	TBD	0.11 [E]	0.09

Notes:
MSST was calculated as $B_{MSY}/2$
A-Calculated from the assessment reviewed by the Crab Plan Team in May 2015
B-Calculated from the assessment reviewed by the Crab Plan Team in May 2016
C-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2017
D-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2018
E-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2019
Conversion to Metric ton: 1 Metric ton (t) = 2.2046×1000 lb.

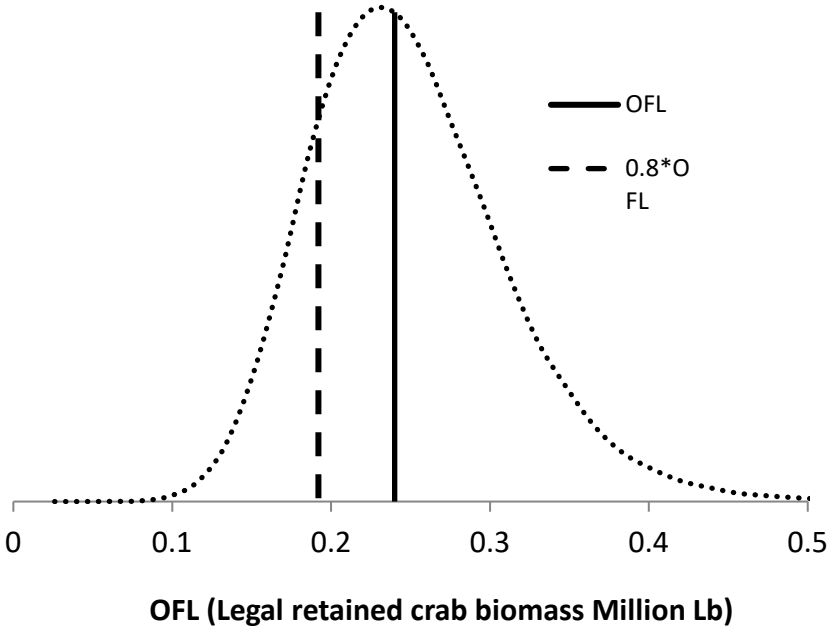
Biomass in millions of pounds

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	M	1-Buffer	Retained ABC
2015	4a	4.81	5.13	1.1	0.18	1980-2015	0.18	0.8	0.58
2016	4a	4.53	5.87	1.3	0.18	1980-2016	0.18	0.8	0.57
2017	4a	4.62	5.14	1.1	0.18	1980-2017	0.18	0.8	0.54
2018	4b	4.82	4.08	0.9	0.15	1980-2018	0.18	0.8	0.35
2019	4b	4.57	3.12	0.7	0.12	1980-2019	0.18	0.8	0.19

Biomass in 1000t

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	M	1-Buffer	Retained ABC
2015	4a	2.18	2.33	1.1	0.18	1980-2015	0.18	0.8	0.26
2016	4a	2.06	2.66	1.3	0.18	1980-2016	0.18	0.8	0.26
2017	4a	2.10	2.33	1.1	0.18	1980-2017	0.18	0.8	0.24
2018	4b	2.18	1.85	0.9	0.15	1980-2018	0.18	0.8	0.16
2019	4b	2.06	1.41	0.7	0.12	1980-2019	0.18	0.8	TBD

6. Probability Density Function of the OFL, OFL profile, and mcmc estimates.



7. The basis for the ABC recommendation

   For Tier 4 stocks, the default maximum ABC is based on P*=49% that is essentially identical to the OFL. Accounting for uncertainties in assessment and model results, the SSC chose to use 90% OFL (10% Buffer) for the Norton Sound red king crab stock from 2011 to 2014. In 2015, the buffer was increased to 20% (ABC = 80% OFL).

8. A summary of the results of any rebuilding analyses.

   N/A

A. Summary of Major Changes in 2018

1. Changes to the management of the fishery**:**

   None

2. Changes to the input data
   a. Data update:
      i. 1977-2018 standardized commercial catch CPUE and CV. No changes in standardization methodology (NPFMC 2013).
      ii. Winter and Summer fishery harvest, discards, and length composition data
      iii. Tag recovery data
      iv. Trawl survey: abundance, length-shell composition

b. New data:

i. Winter commercial retained length-shell data

3. Changes to the assessment methodology:

None

4. Changes to the assessment results.

None

B. Response to SSC and CPT Comments

Crab Plan Team – January 9, 2018

- Evaluate methods to improved ADF&G bottom trawl survey biomass estimation, including model-based approaches.

  Authors' reply:

  VAST modeling approach has been considered. However, validity of the application of this method need to be evaluated before this approach is used for model assessment.

- Quantitatively evaluate the representativeness of observer sampling.

  Authors' reply:

  From 2012 to 2017 distribution of samples taken by stat area differed greatly from those of commercial fishery. Further analyses are needed to examine spatial difference in length-shell composition.

- Estimate fishery retention curve. Consider alternative (2-parameter and 1-parameter) curves for both retention and selectivity

  Authors' reply:

  Retention curve can be estimated by estimating total catch selectivity (fitting to total catch length/shell distribution) and multiples of total catch selectivity with retention curve (fitting to retained catch length/shell distribution). In Norton Sound, total catch data are available only for 7 years from 2012 to 2018. During 1986-1995 samples of retained and discarded crabs were collected independently (600~1000 for each). Total number of retained and discarded catch are unknown during the 1986-1995 surveys. Thus, **only 2012-2018 data were used to estimate total catch selectivity**, and **1987-1994 discards data were removed from the mode.**

  Inclusion of retained curve also changed observer data. In the base lime model,

Model and Data configuration

Model	Observer data	Available Years	Likelihood Commercial Retained	Likelihood Observer
Baseline	Discards length-shell comp	1986-1995, 2012-2018	TS *PL	TS *(1-PL)
Retention selectivity	Total catch length-shell comp	2012-2018	TS*RS	TS
	Discards length-shell comp	1986-1995	TS*RS	TS*(1-RS)

TS: Total catch selectivity, PL: observed legal proportion by length class, RS: Retention selectivity

- Provide Tier 3 calculations and evaluate its suitability for Tier 3 status.

  Author's reply

  We calculated F35% for base model that resulted to 1.86 with B35% of 1.22 million lb.

  Based on 2019 projected MMB of 3.11 million lb. and legal biomass of 2.50 million lb., OFL retained legal biomass by Tier 3 calculation is 1.86 million lb. that was 7.75 times higher than Tier 4 OFL of 0.24 million lb.

SSC – February 5, 2018

- Requests more information on the evidence of biennial mating and some consideration of the implications, if any, on fishery harvest strategy.

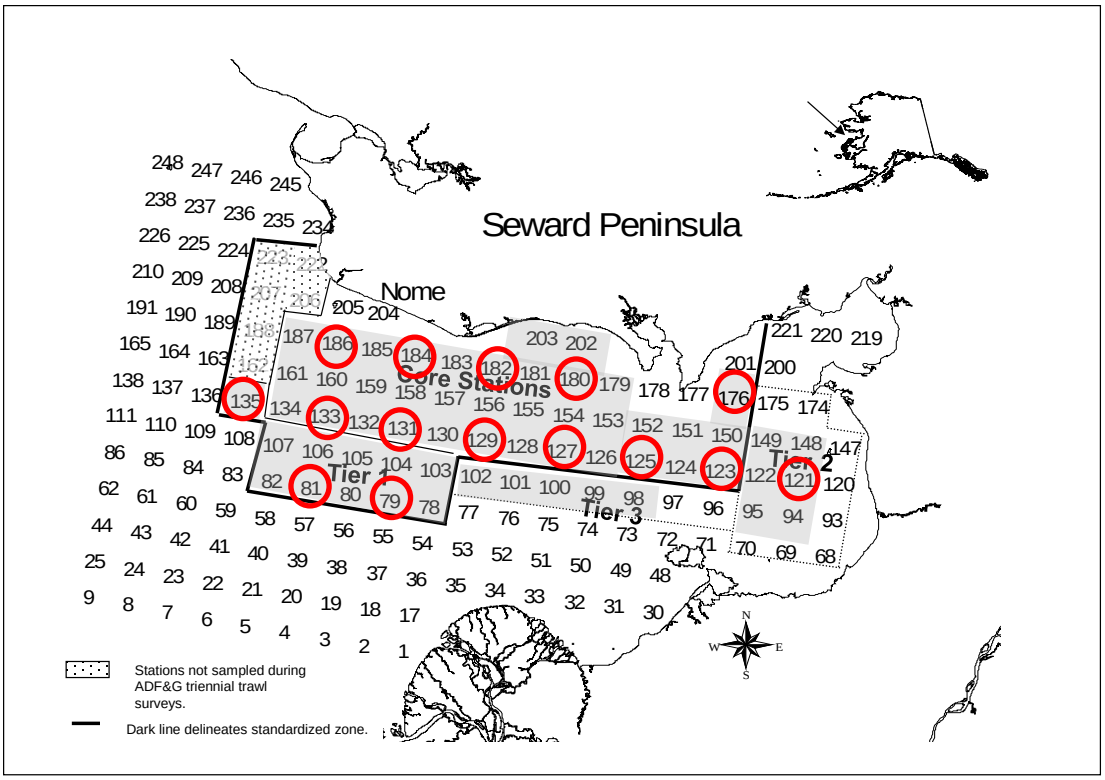
  Author Reply

  Further researches are needed to confirm.

- Recommend a spatial comparison of the ADFG and NMFS trawl survey 2017.

  Author Reply

  12 stations were surveyed by both ADFG and NMFS trawl survey in 2017. On average, swept area of NMFS survey (0.042 km^2) was about twice of ADFG (0.023 km^2). Average CPUE (# of crabs/km^2) of males of CL greater and equal to 64mm of ADFG (91.7) was about twice of NMFS (47.3). CPUE of ADFG trawl was also higher for small males. On the other hand, NMFS trawl caught more than 3-time higher females (58.5) than ADFG (17.7). Simultaneously, there was high variations among stations.



Gray shaded area is standard stations. Red circles are NMFS trawl survey stations.

Table: Comparison of CPUE between ADFG and NMFS trawl survey in 2017.

	Female		Male < 64mm CL		Male ≥ 64mm CL	
Station	ADFG	NOAA	ADFG	NOAA	ADFG	NOAA
79	0	0	0	0	0	0
81	0	42.96	0	0	44.29	21.48
121	0	0	0	0	0	0
123	44.28	381.53	44.29	178.05	88.58	50.87
125	132.86	259.80	221.44	129.90	88.58	0
127	0	0	88.58	0		0
129	0	22.94	0	0	88.58	0
131	44.29	0	0	27.16	88.58	81.47
133	0	22.21	132.86	22.21	708.60	111.04
135	0	0	0	0	0	125.47
176	0	48.34	44.29	120.84	0	0
180	44.29	99.67	0	124.58	0	224.24
182	0	0	0	0	0	0
184	0	0	265.73	0	88.58	24.07
186	0	0	0	0	88.58	23.85
Average	17.72	58.50	56.94	40.18	91.74	47.32

- Consider whether switch of commercial buyers in 2005 may have affected the apparent CPUE and its standardization.

  Authors' reply:

  In the standardization of commercial CPUE (Appendix B), variable "Year of commercial fishery" was identified as the most influential factor. The variable, in effect, addresses any deviations associated with particular year of fishing, including changes in regulation.

- Request to include Quantitative Baseline of Annual Community Engagement and Dependency.

  Author's reply: This will be done by Economic SAFE, but not in this chapter.

CIE-Review: June

Crab Plan Team – September 12, 2018

- Limit the January discussion to Tier 3 vs. Tier 4. The CPT does not need to see all of the model description again.

  Author Reply: Model results with updated data were included in the report. However, the results would not be presented at the CPT.

- A key concern is determining if Tier 3 status is appropriate for NSRKC. A thorough examination of the understanding (based on NSRKC-specific studies) of the processes that determine F35% is needed to make this determination.

  Author Reply: We concur with CPT.

- The CPT suggests comparing the calculated OFLs when the increased natural mortality on the plus group is included when computing a Tier 4 OFL to support the decision between Tier 3 vs. 4 status. A relevant question is what would happen if the stock was fished at *M* uniformly, as there is no assumed selectivity in Tier 4 rules. The basic thrust of these questions is to ensure that the OFLs presented for Tier 3 and Tier 4 are fair comparisons.

  Author Reply: Tier 4 OFL* based on increased M on the large group is presented. OFL* (0.44 mil lb.) was higher than CPT specified OFL (0.24 mil lb.), but still lower than Tier 3 OFL (1.55-1.64 mil lb.) (See Model selection and Evaluation section).

- A summary slide of the pros and cons of Tier 3 vs. Tier 4 for this stock would be useful.

  Author Reply: The slide is provided:

  Tier 3:
  Pro: Harvest limit based entirely on biological process.
  Con: High uncertainties about model assumed/estimated biological process.
  Tier 4:
  Pro: Conventional
  Con: *Ad hoc* harvest limit rule that may not be biologically justifiable.

  Impacts on fishery

  Tier 4 OFL/ABC is generally lower than GHL, and thus current fishery harvest is limited by Tier 4 ABC. Under Tier 3 OFL/ABC harvest will more likely be limited by GHL. For example, under model 18.0, the maximum allowable harvest under GHL will be 0.32 million lb. (up to 13% of projected legal catchable crab biomass of 2.50 million lb.,). This GHL is higher than Tier 4b OFL of 0.24 mil lb. but lower than Tier 3 OFL of 1.55 mil lb.

- Perform sensitivities to the assumed knife-edge cutoff for maturity. Search out data to inform the appropriateness of the assumptions about maturity.

  Author Reply: While information about maturity size is biologically important, because the model does not include spawner-recruit relationship (i.e., Recruitment = f(matured)), maturity **information is used solely for calculation of MMB, B_{MSY}, B_{pred}, (B_{pred}/B_{MSY}), and ultimately FOFL**.

  FOFL is very little affected by the change of maturity criteria.

  (Example, default model 18.0)

Maturity criteria	B_{MSY}	B_{pred}	B_{pred}/B_{MSY}	FOFL
Default (≥94mm)	4.58	3.14	0.68	0.65γM
Alt 1 (≥104mm)	3.87	2.61	0.67	0.64γM
Alt 2 (≥84mm)	5.04	3.53	0.71	0.68γM
Alt 3 (Alt 1+ .5·94mm)	4.23	2.87	0.68	0.64γM
Alt 4 (Default+ .5·84mm)	4.81	3.33	0.69	0.66γM

C. Introduction

1. Species: red king crab (*Paralithodes camtschaticus*) in Norton Sound, Alaska.
2. General Distribution: Norton Sound red king crab is one of the northernmost red king crab populations that can support a commercial fishery (Powell et al. 1983). It is distributed throughout Norton Sound with a westward limit of 167-168º W. longitude, depths less than 30 m, and summer bottom temperatures above 4ºC. The Norton Sound red king crab management area consists of two units: Norton Sound Section (Q3) and Kotzebue Section (Q4) (Menard et al. 2011). The Norton Sound Section (Q3) consists of all waters in Registration Area Q north of the latitude of Cape Romanzof, east of the International Dateline, and south of 66°N latitude (Figure 1). The Kotzebue Section (Q4) lies immediately north of the Norton Sound Section and includes Kotzebue Sound. Commercial fisheries have not occurred regularly in the Kotzebue Section. This report deals with the Norton Sound Section of the Norton Sound red king crab management area.
3. Evidence of stock structure: Thus far, no studies have investigated possible stock separation within the putative Norton Sound red king crab stock.
4. Life history characteristics relevant to management: One of the unique life-history traits of Norton Sound red king crab is that they spend their entire lives in shallow water since Norton Sound is generally less than 40 m in depth. Distribution and migration patterns of Norton Sound red king crab have not been well studied. Based on the 1976-2006 trawl surveys, red king crab in Norton Sound are found in areas with a mean depth range of 19 ± 6 (SD) m and bottom temperatures of 7.4 ± 2.5 (SD) ºC during summer. Norton Sound red king crab are consistently abundant offshore of Nome.

   Norton Sound red king crab migrate between deeper offshore and inshore shallow waters. Timing of the inshore mating migration is unknown but is assumed to be during late fall to winter (Powell et al. 1983). Offshore migration occurs in late May - July (Jenefer Bell, ADF&G, personal communication). The results from a study funded by North Pacific Research Board (NPRB) during 2012-2014 suggest that older/large crab (> 104mm CL) stay

offshore in winter, based on findings that large crab are not found nearshore during spring offshore migration periods (Jenefer Bell, ADF&G, personal communication). Molt timing is unknown but likely occurs in late August – September, based on increase catches of newly-molted crab late in the fishing season (August- September) (Joyce Soong, ADF&G personal communication) and evaluation of molting hormone profiles in the hemolymph (Jenefer Bell, ADF&G, personal communication). Recent observations also indicate that mating may be biennial (Robert Foy, NOAA, personal communication). Trawl surveys show that crab distribution is dynamic with recent surveys showing high abundance on the southeast side of Norton Sound, offshore of Stebbins and Saint Michael.

5. Brief management history: Norton Sound red king crab fisheries consist of commercial and subsistence fisheries. The commercial red king crab fishery started in 1977 and occurs in summer (June – August) and winter (December – May). The majority of red king crab harvest occurs offshore during the summer commercial fishery, whereas the winter commercial and subsistence fisheries occur nearshore through ice.

   Summer Commercial Fishery

   A large-vessel summer commercial crab fishery started in 1977 in the Norton Sound Section (Table 1) and continued from 1977 through 1990. No summer commercial fishery occurred in 1991 because there were no staff to manage the fishery. In March 1993, the Alaska Board of Fisheries (BOF) limited participation in the fishery to small boats. Then on June 27, 1994, a super-exclusive designation went into effect for the fishery. This designation stated that a vessel registered for the Norton Sound crab fishery may not be used to take king crabs in any other registration areas during that registration year. A vessel moratorium was put into place before the 1996 season. This was intended to precede a license limitation program. In 1998, Community Development Quota (CDQ) groups were allocated a portion of the summer harvest; however, no CDQ harvest occurred until the 2000 season. On January 1, 2000 the North Pacific License Limitation Program (LLP) went into effect for the Norton Sound crab fishery. The program dictates that a vessel which exceeds 32 feet in length overall must hold a valid crab license issued under the LLP by the National Marine Fisheries Service. Changes in regulations and the location of buyers resulted in eastward movement of the harvest distribution in Norton Sound in the mid-1990s. In Norton Sound, a legal crab is defined as ≥ 4-3/4-inch carapace width (CW, Menard et al. 2011), which is approximately equivalent to ≥ 104 mm carapace length mm CL. Since 2005, commercial buyers (Norton Sound Economic Development Corporation) started accepting only legal crab of ≥ 5-inch CW. This may have increased discards; however, because discards have not been monitored until 2012, impact of this change on discards is unknown. This issue was also examined in assessment model selection, which showed no difference in estimates of selectivity functions before and after 2005 (NPFMC 2016).

   Portions of Norton Sound area are closed to commercial fishing for red king crab. Since the beginning of the commercial fisheries in 1977, waters approximately 5-10 miles offshore of southern Seward Peninsula from Port Clarence to St. Michael have been closed to protect crab nursery grounds during the summer commercial crab fishery (Figure 2). The spatial extent of closed waters has varied historically.

CDQ Fishery

The Norton Sound and Lower Yukon CDQ groups divide the CDQ allocation. Only fishers designated by the Norton Sound and Lower Yukon CDQ groups are allowed to participate in this portion of the king crab fishery. Fishers are required to have a CDQ fishing permit from the Commercial Fisheries Entry Commission (CFEC) and register their vessel with the Alaska Department of Fish and Game (ADF&G) before begin fishing. Fishers operate under the authority of each CDQ group. The CDQ fishery may open at any time by emergency order. CDQ harvest share is 7.5% of total projected harvest.

Winter Commercial Fishery

The winter commercial crab fishery is a small fishery using hand lines and pots through the nearshore ice. On average 10 permit holders harvested 2,500 crabs during 1978-2009. From 2007 to 2015 the winter commercial catch increased from 3,000 crabs to over 40,000 (Table 2). In 2015 winter, commercial catch reached 20% of total crab catch. The BOF responded in May 2015 by amending regulations to allocate 8% of the total commercial guideline harvest level (GHL) to the winter commercial fishery, which became in effect since 2017 season. The winter red king crab commercial fishing season was also set from January 15 to April 30, unless changed by emergency order. The new regulation became in effect since the 2016 season.

Subsistence Fishery

While the winter subsistence fishery has a long history, harvest information is available only since the 1977/78 season. The majority of the subsistence crab fishery harvest occurs using hand lines and pots through nearshore ice. Average annual winter subsistence harvest was 5,400 crab (1977-2010). Subsistence harvesters need to obtain a permit before fishing and record daily effort and catch. There are no size or sex specific harvest limits; however, the majority of retained catches are males of near legal size. The subsistence fishery catch is influenced not only by crab abundance, but also by changes in distribution, changes in gear (e.g., more use of pots instead of hand lines since 1980s), and ice conditions (e.g., reduced catch due to unstable ice conditions: 1987-88, 1988-89, 1992-93, 2000-01, 2003-04, 2004-05, and 2006-07).

The summer subsistence crab fishery harvest has been monitored since 2004 with an average harvest of 712 crab per year. Since this harvest is very small, the summer subsistence fishery was not included in the assessment model.

6. Brief description of the annual ADF&G harvest strategy

Since 1997 Norton Sound red king crab has been managed based on a guideline harvest level (GHL). From 1999 to 2011 the GHL for the summer commercial fishery was determined by a prediction model and the model estimated predicted biomass: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.5 million lb.; (2) ≤ 5% of legal male abundance when the estimated legal biomass falls within the range 1.5-2.5 million lb.; and (3) ≤ 10% of legal male when estimated legal biomass >2.5 million lb.

In 2012 a revised GHL for the summer commercial fishery was implemented: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.25 million lb.; (2) ≤ 7% of legal male abundance when the estimated legal biomass falls within the range 1.25-2.0 million lb.; (3) ≤ 13% of legal male abundance when the estimated legal biomass falls within the range 2.0-3.0

million lb.; and (3) ≤ 15% of legal male biomass when estimated legal biomass >3.0 million lb.

In 2015 the Alaska Board of Fisheries passed the following regulations regarding winter commercial fisheries:

1. Revised GHL to include summer and winter commercial fisheries.
2. Set guideline harvest level for winter commercial fishery (GHL_w) at 8% of the total GHL
3. Dates of the winter red king crab commercial fishing season are from January 15 to April 30.

Year	Notable historical management changes
1976	The abundance survey started
1977	**Large vessel commercial fisheries began (Legal size ≥ 5 inch CW)**
1978	**Legal size changes to ≥ 4.75 inch CW**
1991	Fishery closed due to staff constraints
1994	Super exclusive designation went into effect. The end of large vessel commercial fishery operation.
1998	Community Development Quota (CDQ) allocation went into effect
1999	Guideline Harvest Level (GHL) went into effect
2000	North Pacific License Limitation Program (LLP) went into effect.
2002	Change in closed water boundaries (Figure 2)
2005	**Commercially accepted legal crab size changed from ≥ 5 inch CW**
2006	The Statistical area Q3 section expanded (Figure 1)
2008	Start date of the open access fishery changed from July 1 to after June 15 by emergency order. **Pot configuration requirement: at least 4 escape rings (>4.5 inch diameter) per pot located within one mesh of the bottom of the pot, or at least ½ of the vertical surface of a square pot or sloping side-wall surface of a conical or pyramid pot with mesh size > 6.5 inches.**
2012	The Board of Fisheries adopted a revised GHL for summer fishery.
2016	Winter GHL for commercial fisheries was established and modified winter fishing season dates were implemented.

7. Summary of the history of the $B_{MSY.}$

NSRKC is a Tier 4 crab stock. Direct estimation of the B_{MSY} is not possible. The B_{MSY} proxy is calculated as mean model estimated mature male biomass (MMB) from 1980 to present. Choice of this period was based on a hypothesized shift in stock productivity a due to a climatic regime shift indexed by the Pacific Decadal Oscillation (PDO) in 1976-77. Stock status of the NSRKC was Tier 4a until 2013. In 2014 the stock fell to Tier 4b, but came back to Tier 4a for the 2015-2017 seasons. In 2018 the stock again fell to Tier 4b.

D. Data

1. Summary of new information:

Winter commercial and subsistence fishery:

Winter commercial fishery catch in 2018 was 9,189 crab (20,118 lb.). Subsistence retained crab catch was 4,424 and unretained was 1,343 or 23 % of total catch (Table 2).

Summer commercial fishery:

The summer commercial fishery opened on 6/25/2018 d closed on 7/28/2018. Total of 89,613 crab (298,396 lb.) were harvested (Table 1).

Total retained harvest for 2018 season was 103,217 crab (338,574 lb.) and did not exceed the 2018 ABC of 0.35 million lb.

Summer Trawl abundance survey ADFG (7/22-7/29).

Abundance estimated by ADFG survey was 1108.9 (x 1000) crab with CV 25% (Table 3).

2. Available survey, catch, and tagging data

	Years	Data Types	Tables
Summer trawl survey	76,79,82,85,88,91,96, 99, 02,06,08,10,11,14,17, 18	Abundance Length-shell comp	3 6
Winter pot survey	81-87, 89-91,93,95-00,02-12	Length-shell comp	7
Summer commercial fishery	77-90,92-18	Retained catch Standardized CPUE, Length-shell comp	1 1 4
Summer Com total catch	12-18	Length-shell comp	9
Summer Com Discards	87-90,92,94, 2012-2018	Length-shell comp	8
Winter subsistence fishery	76-18	Total & Retained catch	2
Winter commercial fishery	78-18	Retained catch	2
	15-18	Retained Length-Shell	5
Tag recovery	80-18	Recovered tagged crab	10

Data available but not used for assessment

Data	Years	Data Types	Reason for not used
Summer pot survey	80-82,85	Abundance Length proportion	Uncertainties on how estimates were made.
Summer preseason survey	95	Length proportion	Just one year of data
Summer subsistence fishery	2005-2013	retained catch	Too few catches compared to commercial
Winter Pot survey	87, 89-91,93,95-00,02-12	CPUE	CPUE data Not reliable due to ice conditions
Preseason Spring pot survey	2011-15	CPUE, Length proportion	Years of data too short
Postseason Fall pot survey	2013-15	CPUE, Length proportion	Years of data too short

Time series of available data. Different shades indicate that survey agency, survey methods, or type of data collected differ among years.

	Survey		Harvests			Tag	Data Not Used[3]				
	S. Trawl	W. Pot	S.Com	S.Com Discards	W. Com, Sub	Tag recovery	S. Pot	Pre fish	Sp. Tag	F. Tag,	W. Com
N[1]	N		H, CPUE		H		N				
Length[2]	X	X	X	X		X	X	X	X	X	X
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1: Index of abundance data: N: Abundance, H: Harvest, CPUE: Catch cpue,
2: Length/shell proportion data available
3: Data were not used for the assessment model because of short term data.
4: Different colors indicate changes in fishery characteristics, survey methodologies, or different survey agencies.

Catches in other fisheries

In Norton Sound, directed Pacific Cod pot fishery was issued in 2018 under the CDQ permit. However, the fishery did not occur. This fishery may develop in the future.

	Fishery	Data availability
Other crab fisheries	Does not exist	NA
Groundfish pot	Pacific Cod (Planned, but not executed)	NA
Groundfish trawl	Does not exist	NA
Scallop fishery	Does not exist	NA

3. Other miscellaneous data:

   Satellite tag migration tracking (NOAA 2016)

   Spring offshore migration distance and direction (2012-2015)

   Monthly blood hormone level (indication of molting timing) (2014-2015)

Data aggregated:

Proportion of legal-size crab, estimated from trawl survey and observer data. (Table 13)

Data estimated outside the model:

Summer commercial catch standardized CPUE (Table 1, Appendix B)

E. Analytic Approach

1. History of the modeling approach.

The Norton Sound red king crab stock was assessed using a length-based synthesis model (Zheng et al. 1998). Since adoption of the model, the major challenge is a conflict between model projection and data, specifically the model projects higher abundance-proportion of large size class (> 123mm CL) of crab than observed. This problem was further exasperated when natural mortality *M* was set to 0.18 from previous *M* = 0.3 in 2011 (NPFMC 2011). This issue has been resolved by assuming (3-4 times) higher *M* for the length crabs (i.e., *M* = 1.8 for length classes ≤ 123mm, and higher M for > 123mm) (NPFMC 2012, 2013, 2014, 2015, 2016, 2017, 2018). Alternative assumptions have been explored, such as changing molting probability (i.e., crab matured quicker or delayed maturation), higher natural mortality, and dorm shaped selectivity (i.e., large crab are not caught, or moved out of fishery/survey grounds). However, those alternative assumptions did not produce better model fits. Model estimated length specific molting probability was similar to inverse logistic curve, and did not improve model fit (NPFMC 2016). Constant *M* across all length classes resulted in higher *M* (0.3-0.45) (NPFMC 2013, 2017). Dome shaped selectivity (i.e., assume large crabs were not caught/not surveyed/moved out of survey and fishing area) increased MMB twicer higher than other models. A model with gradual increase of *M* across length classes resulted in *M* increase staring at size 94mm. However, this did not improve

overall model fit and was rejected for model consideration (NPFMC 2018). With addition of total catch length data in summer and retention length data in winter commercial fisheries, 2019 model specification examined estimation of retention curve for both summer and winter fishery, and evaluation of OFL under Tier 3 formula.

Historical Model configuration progression:

2011 (NPFMC 2011)
1. M =0.18
2. M of the last length class = 0.288
3. Include summer commercial discards mortality = 0.2
4. Weight of fishing effort = 20,
5. The maximum effective sample size for commercial catch and winter surveys = 100,

2012 (NPFMC 2012)
1. M of the last length class = 3.6×M
2. The maximum effective sample size for commercial catch and winter surveys = 50,
3. Weight of fishing effort = 50.

2013 (NPFMC 2013)
1. Standardize commercial catch cpue and replace likelihood of commercial catch efforts to standardized commercial catch cpue with weight = 1.0
2. Eliminate summer pot survey data from likelihood
3. Estimate survey q of 1976-1991 NMFS survey with maximum of 1.0
4. The maximum effective sample size for commercial catch and winter surveys = 20.

2014 (NPFMC 2014)
1. Modify functional form of selectivity and molting probability to improve parameter estimates (2 parameter logistic to 1 parameter logistic)
2. Include additional variance for the standardized cpue.
3. Include winter pot survey cpue (But was removed from the final model due to lack of fit)
4. Estimate growth transition matrix from tagged recovery data.

2015 (NPFMC 2015)
1. Winter pot survey selectivity is an inverse logistic, estimating selectivity of the smallest length group independently
2. Reduce Weight of tag-recovery: W = 0.5
3. Model parsimony: one trawl survey selectivity and one commercial pot selectivity

2016 (NPFMC 2016)

1. Length range extended from 74mm – 124mm above to 64mm – 134mm above.
2. Estimate multiplier for the largest (> 123mm) length classes.

2017 (NPFMC 2017)

1. Change molting probability function from 1 to 2 parameter logistic. Assume molting probability not reaching 1 for the smallest length class.

2018 (NPFMC 2018)

1. No model changes. Same as 2017 model configuration

2. Model Description

a. Description of overall modeling approach:

The model is a male-only size structured model that combines multiple sources of survey, catch, and mark-recovery data using a maximum likelihood approach to estimate abundance, recruitment, catchability of the commercial pot gear, and parameters for selectivity and molting probabilities (See Appendix A for full model description).

Unlike other crab assessment models, NSRK modeling year is starts from February 1st to January 31st of the following year. This schedule was selected because Norton Sound winter crab fisheries can start when Norton Sound ice become thick enough to operate fishery safely, which can be as earliest as mid-late January.

b-f. See Appendix A.

g. Critical assumptions of the model:

i. Male crab mature at CL length 94mm.

Size at maturity of NSRKC (CL 94 mm) was determined by adjusting that of BBRKC (CL 120mm) reflect the slower growth and smaller size of NSRKC.

ii. Molting occurs in the fall after the summer fishery

iii. Instantaneous natural mortality *M* is 0.18 for all length classes, except for the last length group (> 123mm).

iv. Trawl survey selectivity is a logistic function with 1.0 for length classes 5-6. Selectivity is constant over time.

v. Winter pot survey selectivity is a dome shaped function: Reverse logistic function of 1.0 for length class CL 84mm, and model estimate for CL < 84mm length classes. Selectivity is constant over time.

This assumption is based on the fact that a low proportion of large crab are caught in the nearshore area where winter surveys occur. Causes of this pattern may be that (1) large crab do not migrate into nearshore waters in winter or (2) large crab are fished out by winter fisheries where the survey occurs (i.e., local depletion).

Recent studies suggest that the first explanation is more likely than second (Jenefer Bell, ADFG, personal communication).

vi. Summer commercial fisheries selectivity is an asymptotic logistic function of 1.0 at the length class CL 134mm. While the fishery changed greatly between the periods (1977-1992 and 1993-present) in terms of fishing vessel composition and pot configuration, the selectivity of each period was assumed to be identical. Model fits of separating and combining the two periods were examined in 2015, and showed no difference between the two models (NPFMC 2015). For model parsimony, the two were combined.

vii. Summer trawl survey selectivity is an asymptotic logistic function of 1.0 at the length of CL 124mm. While the survey changed greatly between NOAA (1976-1991) and ADF&G (1996-present) in terms of survey vessel and trawl net structure, selectivity of both periods was assumed to be identical. Model fits separating and combining the two surveys were examined in 2015. No differences between the two models were observed (NPFMC 2015) and for model parsimony the two were combined.

viii. Winter commercial and subsistence fishery selectivity and length-shell conditions are the same as those of the winter pot survey. All winter commercial and subsistence harvests occur February 1st.

Winter commercial king crab pots can be any dimension (5AAC 34.925(d)). No length composition data exists for crab harvested in the winter commercial or subsistence fisheries. However, because commercial fishers are also subsistence fishers, it is reasonable to assume that the commercial fishers used crab pots that they use for subsistence harvest, and hence both fisheries have the same selectivity.

ix. Growth increments are a function of length, are constant over time, estimated from tag recovery data.

x. Molting probability is an inverse logistic function of length for males.

xi. A summer fishing season for the directed fishery is short. All summer commercial harvests occur July 1st.

xii. Discards handling mortality rate for all fisheries is 20%.

No empirical estimate is available.

xiii. Annual retained catch is measured without error.

xiv. All legal-size crab (≥ 4-3/4-inch CW) are retained, and sublegal size crab or commercially unacceptable size crab (< 5-inch CW, since 2005) are discarded

Since 2005, buyers announced that only legal crab with ≥ 5-inch CW are acceptable for purchase. Since samples are taken at a commercial dock, it was anticipated that this change would lower the proportion of legal crab. However, the model was not sensitive to this change (NPFMC 2013, 2017).

xv. Length compositions have a multinomial error structure and abundance has a log-normal error structure.

h. Changes of assumptions since last assessment:

None.

3. Model Selection and Evaluation

a. Description of alternative model configurations.

For 2019 assessment, we incorporated newly available data: summer commercial total catch length-shell comp data 2012 – 2018 (Model 18.1x), and winter commercial retained length-shell comp data 2015 – 2018 (Model 18.2x). Because winter data were short, our modeling strategy was evaluating effectiveness of summer data (Model 18.1x) first, and then add winter data (Model 18.2x).

Baseline model assumes fixed retention selectivity and uses retention and discards length-shell data to estimate catch selectivity. Combination of total and retention length-shell data is used to estimate fishery catch and retention selectivity. Simultaneously, this poses question of using 1986 – 95 discards only shell-length data. One option (Model, 18.1a) is not using data, second (Model, 18.1b) is separately fitting discards length-shell likelihood. Further option is separating retention selectivity (Model 18.1c) or total catch selectivity (Model 18.1d) into two periods (pre and post super-exclusive).

In similar way, use of winter commercial retention data will be used to estimate retention selectivity for winter commercial. We examined 3 alternatives of model specifications with winter data: 1) to default model (Model 18.0), 2) to Model 18.1a, and 3) to Model 18.1b.

We examined alternative models of

Model 18.0: Baseline: assumed retention selectivity: fit discards lengths comp (1987 - 1994, 2012 – 2018)

Model 18.1a: Summer commercial retention curve estimated: fit total catch length comp (2012 – 2018)

Model 18.1b: Model 18.1a and fit discards length comp (1987 – 1994)

Model 18.1c: Model 18.1b with 2 retention selectivity

Model 18.1d: Model 18.1b with 2 total catch selectivity

Model 18.2: Model 18.0 + winter commercial retention

Model 18.2a: Model 18.1a + winter commercial retention

Model 18.2b: Model 18.1b + winter commercial retention

b. Evaluation of negative log-likelihood alternative models results:

Model	Model 18.0	Model 18.1a	Model 18.1b	Model 18.1c	Model 18.1d	Model 18.2	Model 18.2a	Model 18.2b
Additional Parameters		+2	+2	+4	+4	+2	+4	+4
Total	301.0	273.9	289.4	289.0	298.7	304.0	276.6	292.3
TSA	9.5	9.6	9.5	9.5	9.6	9.6	9.7	9.5
St.CPUE	-29.2	-29.2	-29.4	-29.5	-29.5	-29.5	-29.1	-29.3
TLP	103.7	104.1	104.0	103.9	103.4	105.7	106.1	105.9
WLP	38.7	38.5	38.8	38.8	38.8	39.0	38.9	39.1
CLP	52.0	49.8	49.7	49.3	49.7	50.1	48.1	47.9
OBS	30.7	**8.0**	**20.6**	**20.6**	**21.1**	30.5	**7.7**	**20.3**
REC	14.6	15.1	14.9	14.9	15.1	14.7	15.2	15.1
TAG	81.1	**77.8**	81.3	81.3	90.5	80.9	**77.6**	81.1
WN						2.5	2.4	2.5
MMB(mil.lb)	3.12	3.10	3.11	3.11	3.11	2.93	3.11	3.12
Legal crab Catchable (mil.lb)	2.50	2.47	2.50	2.50	2.50	2.50	2.50	2.51
OFL (mil.lb)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
OFL* (mil.lb)	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
B35%(mil.lb)	1.22	1.38	1.21	1.21	1.21	1.24	1.21	1.22
F35%	1.87	2.34	1.85	1.87	2.1	1.91	2.42	1.89
F40%	1.19	1.34	1.18	1.18	1.27	1.21	1.36	1.20
OFL: F35%	1.55	1.72	1.54	1.55	1.64	1.57	1.75	1.56
OFL: F40%	1.19	1.28	1.18	1.18	1.24	1.20	1.29	1.20

TSA: Trawl Survey Abundance
St. CPUE: Summer commercial catch standardized CPUE
TLP: Trawl survey length composition:
WLP: Winter pot survey length composition
CLP: Summer commercial retention catch length composition
REC: Recruitment deviation
OBS: Summer commercial catch observer discards (Baseline) or total catch (Alternative models) length composition
TAG: Tagging recovery data composition
WN: Winter Commercial length-shell composition
OFL*: Tier 4 OFL where F_{OFL} is size dependent (i.e. higher F_{OFL} for the last two length classes).
See Appendix C1-C3 for standard output figures and estimated parameters.

a. Search for balance:

It should be noted that comparison of total and Observer (OBS) likelihood among Model 18.0, 18.1x, 18.2x are in appropriate because data set and likelihood calculations differ. Examining other likelihoods, estimating retention selectivity did not change fit to population dynamics (TSA, st.CPUE), but improved fits of commercial retention (CLP) and tag recovery data (TAG) that inform transition matrix and molt probability. Difference between the model 18.1a and 18.1b is, whether to utilize historical 1987-1994 discards length composition data. Since the historical data were collected during the period of large-scale fishery, the data would be expected to differentiate catch or retention selectivity if they differed between the two fishery periods. However, separating catch or retention selectivity (Model 18.1c, 18.1d) did not improve model.

Given that summer total catch and winter retention data will be collected annually, incorporating those two datasets (Model 18.2a, b) is desirable, although estimating winter retention selectivity did not improve model fit of winter retention (WIN). This is probably because winter retention selectivity was similar to assumed selectivity (Figure 3). As for consequences of alternative models in management parameters, all models estimated nearly similar projected MMB, and OFL.

This leaves choice between 18.2a and 18.2b, or whether to fit 1987-1994 data even though the data had little effects. **In the absence of compelling reason to remove the data, we recommend 18.2b for an assessment of 2019 OFL and ABC.** The other difference between the two models is Tier 3 calculation of F35% and F40%. This is due to difference in the shape of commercial catch selectivity. Selectivity of Model 18.2a are generally lower than 18.0 and 18.2b (Figure 3), which resulted in higher F for 18.0a.

4. Results:

1. List of effective sample sizes and weighting factors (Figure 4)

"Implied" effective sample sizes were calculated as

$$n = \sum_l \hat{P}_{y,l}(1-\hat{P}_{y,l}) \Big/ \sum_l (P_{y,l} - \hat{P}_{y,l})^2$$

Where $P_{y,l}$ and $\hat{P}_{y,l}$ are observed and estimated length compositions in year *y* and length group *l*, respectively. Estimated effective sample sizes vary greatly over time.

Maximum sample sizes for length proportions:

Survey data	Sample size
Summer commercial, winter pot, and summer observer	minimum of 0.1 × actual sample size or 10
Summer trawl and pot survey	minimum of 0.5 × actual sample size or 20
Tag recovery	0.5× actual sample size

Weighting factor

Recruitment SD 0.5

2. Tables of estimates.
   a. Model parameter estimates (Tables 11, 12).
   b. Abundance and biomass time series (Table 15)
   c. Recruitment time series (Table 15).
   d. Time series of catch/biomass (Tables 16)
3. Graphs of estimates.

a. Molting probability and trawl/pot selectivity (Figure 3)

b. Estimated male abundances (recruits, legal, and total) (Figure 4)

c. Estimated mature male biomass (Figure 5)

e. Time series of catch and estimated harvest rate (Figure 6).

4. Evaluation of the fit to the data.

a. Fits to observed and model predicted catches.

Not applicable. Catch is assumed to be measured without error.

b.Model fits to survey numbers.

1. Time series of trawl survey (Figure 7).
2. Time series of standardized cpue for the summer commercial fishery (Figure 8).

d. Model fits to catch and survey proportions by length (Figures 9-14).

e. Marginal distribution for the fits to the composition data

f. Plots of implied versus input effective sample sizes and time-series of implied effective sample size (Figure 15).

g. RMSEs of trawl survey and standardized CPUE (Figure 16)

h. QQ plots and histograms of residuals of trawl survey and standardized CPUE (Figure 16).

5. Retrospective analyses (Figure 17). Will be presented on Jan 2019 final assessment.

6. Uncertainty and sensitivity analyses.

See Sections 2 and 5.

F. Calculation of the OFL

1. Specification of the Tier level and stock status.

The Norton Sound red king crab stock is placed in Tier 4. It is not possible to estimate the spawner-recruit relationship, but some abundance and harvest estimates are available to build a computer simulation model that captures the essential population dynamics. Tier 4 stocks are assumed to have reliable estimates of current survey biomass and instantaneous *M*; however, the estimates for the Norton Sound red king crab stock are uncertain.

Tire 4 level and the OFL are determined by the F_{MSY} proxy, B_{MSY} proxy, and estimated legal male abundance and biomass:

Level	Criteria	F_{OFL}
a	$B / B_{MSY\,prox} > 1$	$F_{OFL} = \gamma M$
b	$\beta < B / B_{MSY\,prox} \le 1$	$F_{OFL} = \gamma M\,(B / B_{MSY\,prox} - \alpha)/(1-\alpha)$

c	$B / B_{MSY\,prox} \le \beta$	$F_{OFL} = bycatch\ mortality\ \&\ directed\ \ fishery\ F = 0$

where B is a mature male biomass (MMB), B_{MSY} proxy is average mature male biomass over a specified time period, M = 0.18, $\gamma = 1$, $\alpha = 0.1$, and $\beta = 0.25$

For Norton Sound red king crab, MMB is defined as the biomass of males > 94 mm CL on February 01 (Appendix A)**.** B_{MSY} proxy is

B_{MSY} proxy = average model estimated MMB from 1980-2019

Estimated B_{MSY} proxy is: 4.57 million lb.

Predicted mature male biomass in 2019 on February 01

Mature male biomass: 3.12 (SE 0.39) million lb.

Since projected MMB is less than B_{MSY} proxy,

Norton Sound red king crab stock status is Tier 4b

When FOFL is calculated by

$$F_{OFL} = \gamma M\ (B / B_{MSY\,prox} - \alpha) / (1 - \alpha)$$

FOFL of 0.118 for all length classes

2. Calculation of OFL.

OFL was calculated for retained (OFL_r), un-retained (OFL_{ur}), and total (OFL_T) for legal sized crab, *Legal_B*, by applying F_{OFL}.

Legal_B is a biomass of legal crab subject to fisheries and is calculated as: Projected abundance by length crab × fishing selectivity by length class × Proportion of legal crab per length class × Average lb per length class.

For the Norton Sound red king crab assessment, *Legal_B* was defined as winter biomass catchable to summer commercial pot fishery gear $Legal\_B_w$, as

$$Legal\_B_w = \sum_l (N_{w,l,} + O_{w,l,}) S_{s,l} P_{lg,l} wm_l$$

The Norton Sound red king crab fishery consists of two distinct fisheries: winter and summer. The two fisheries are discontinuous with 5 months between the two fisheries during which natural mortalities occur. To incorporate this fishery, the CPT in 2016 recommended the following formula:

$$Legal\_B_s = Legal\_B_w (1 - \exp(-x \cdot F_{OFL})) e^{-0.42M}$$
$$OFL_r = (1 - \exp(-(1-x) \cdot F_{OFL})) Legal\_B_s$$

And $$p = \frac{Legal\_B_w (1 - \exp(-x \cdot F_{OFL}))}{OFL_r}$$

Where p is a specific proportion of winter crab harvest to total (winter + summer) harvest.

Solving x of the above, a revised retained OFL is

$$OFL = Legal\_B_w\left(1-e^{-(F_{OFl}+0.42M)}-(1-e^{-0.42M})\left(\frac{1-p\cdot(1-e^{-(F_{OFL}+0.42M)})}{1-p\cdot(1-e^{-0.42M})}\right)\right)$$

Accounting for difference in length specific natural mortality

$$OFL_r=\sum_l\left[Legal\_B_{w,l}\left(1-e^{-(F_{OF,l}+0.42M_l)}-(1-e^{-0.42M_l})\left(\frac{1-p\cdot(1-e^{-(F_{OFL,l}+0.42M_l)})}{1-p\cdot(1-e^{-0.42M_l})}\right)\right)\right]$$

Unretained OFL (OFL_{ur}) is a sub-legal crab biomass catchable to summer commercial pot fisheries calculated as: Projected legal abundance (Feb 1st) × Commercial pot selectivity × Proportion of sub-legal crab per length class × Average lb per length class × handling mortality (hm =0.2)

$$OFL_{ur}=\sum_l\left[Sub\_legal\_B_{w,l}\left(1-e^{-(F_{OFL,l}+0.42M_l)}-(1-e^{-0.42M_l})\left(\frac{1-p\cdot(1-e^{-(F_{OFL,l}+0.42M_l)})}{1-p\cdot(1-e^{-0.42M_l})}\right)\right)\right]\cdot hm$$

The total male OFL is

$$OFL_T = OFL_r + OFL_{ur}$$

For calculation of the OFL 2019, we specified p = 0.16.

Legal male biomass catchable to fishery (Feb 01): 2.49 (SE: 0.37) million lb.
OFL_r = 0.24 million lb. or 0.11 kMT
OFL_{nr} = 0.07 million lb. or 0. 03 kMT
OFL_T = 0.31 million lb. or 0.14 kMT

G. Calculation of the ABC

1. Specification of the probability distribution of the OFL.

Probability distribution of the OFL was determined based on the CPT recommendation in January 2015 of 20% buffer:

Retained ABC for legal male crab is 80% of OFL

ABC = 0.19 million lb. or 0.09 kMT

H. Rebuilding Analyses

Not applicable

I. Data Gaps and Research Priorities

The major data gap is the fate of crab greater than 123 mm.

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Table 1. Historical summer commercial red king crab fishery economic performance, Norton Sound Section, eastern Bering Sea, 1977-2017. Bold type shows data that are used for the assessment model.

	Guideline Harvest Level	Commercial Harvest (lb) [a, b]		**Number**	Total Number (Open Access)			Total Pots		**ST CPUE**		Season Length		**Mid-day from July**
Year	(lb) [b]	Open Access	CDQ	**Harvest**	Vessels	Permits	Landings	Registered	Pulls	**CPUE**	**SD**	Days	Dates	
										3.32	**0.67**			
1977	[c]	517.787		**195,877**	7	7	13		5,457			60	[c]	**0.049**
1978	3,000.000	2,091.961		**660,829**	8	8	54		10,817	**4.72**	**0.64**	60	6/07-8/15	**0.142**
1979	3,000.000	2,931.672		**970,962**	34	34	76		34,773	**2.89**	**0.63**	16	7/15-7/31	**0.088**
1980	1,000.000	1,186.596		**329,778**	9	9	50		11,199	**3.11**	**0.64**	16	7/15-7/31	**0.066**
1981	2,500.000	1,379.014		**376,313**	36	36	108		33,745	**0.87**	**0.62**	38	7/15-8/22	**0.096**
1982	500.000	228.921		**63,949**	11	11	33		11,230	**0.20**	**0.61**	23	8/09-9/01	**0.151**
1983	300.000	368.032		**132,205**	23	23	26	3,583	11,195	**0.90**	**0.64**	3.8	8/01-8/05	**0.096**
\1984	400.000	387.427		**139,759**	8	8	21	1,245	9,706	**1.61**	**0.64**	13.6	8/01-8/15	**0.110**
1985	450.000	427.011		**146,669**	6	6	72	1,116	13,209	**0.50**	**0.65**	21.7	8/01-8/23	**0.118**
1986	420.000	479.463		**162,438**	3	3		578	4,284	**1.79**	**0.69**	13	8/01-8/25	**0.153**
1987	400.000	327.121		**103,338**	9	9		1,430	10,258	**0.62**	**0.63**	11	8/01-8/12	**0.107**
1988	200.000	236.688		**76,148**	2	2		360	2,350	**2.39**	**0.84**	9.9	8/01-8/11	**0.110**
1989	200.000	246.487		**79,116**	10	10		2,555	5,149	**1.21**	**0.60**	3	8/01-8/04	**0.096**
1990	200.000	192.831		**59,132**	4	4		1,388	3,172	**1.09**	**0.67**	4	8/01-8/05	**0.099**
1991	340.000			**0**	No Summer Fishery									
1992	340.000	74.029		**24,902**	27	27		2,635	5,746	**0.17**	**0.59**	2	8/01-8/03	**0.093**
1993	340.000	335.790		**115,913**	14	20	208	560	7,063	**0.85**	**0.35**	52	7/01-8/28	**0.093**
1994	340.000	327.858		**108,824**	34	52	407	1,360	11,729	**0.75**	**0.34**	31	7/01-7/31	**0.044**
1995	340.000	322.676		**105,967**	48	81	665	1,900	18,782	**0.39**	**0.34**	67	7/01-9/05	**0.093**
1996	340.000	224.231		**74,752**	41	50	264	1,640	10,453	**0.48**	**0.35**	57	7/01-9/03	**0.101**
1997	80.000	92.988		**32,606**	13	15	100	520	2,982	**0.79**	**0.36**	44	7/01-8/13	**0.074**
1998	80.000	29.684	0.00	**10,661**	8	11	50	360	1,639	**0.74**	**0.37**	65	7/01-9/03	**0.110**
1999	80.000	23.553	0.00	**8,734**	10	9	53	360	1,630	**0.86**	**0.37**	66	7/01-9/04	**0.104**
2000	336.000	297.654	14.87	**111,728**	15	22	201	560	6,345	**1.17**	**0.34**	91	7/01- 9/29	**0.126**
2001	303.000	288.199	0	**98,321**	30	37	319	1,200	11,918	**0.60**	**0.34**	97	7/01- 9/09	**0.104**
2002	248.000	244.376	15.226	**86,666**	32	49	201	1,120	6,491	**1.16**	**0.34**	77	6/15-9/03	**0.060**
2003	253.000	253.284	13.923	**93,638**	25	43	236	960	8,494	**0.80**	**0.34**	68	6/15-8/24	**0.058**
2004	326.500	314.472	26.274	**120,289**	26	39	227	1,120	8,066	**1.20**	**0.34**	51	6/15-8/08	**0.033**
2005	370.000	370.744	30.06	**138,926**	31	42	255	1,320	8,867	**1.13**	**0.34**	73	6/15-8/27	**0.058**
2006	454.000	419.191	32.557	**150,358**	28	40	249	1,120	8,867	**1.23**	**0.34**	68	6/15-8/22	**0.052**
2007	315.000	289.264	23.611	**110,344**	38	30	251	1,200	9,118	**0.97**	**0.34**	52	6/15-8/17	**0.036**
2008	412.000	364.235	30.9	**143,337**	23	30	248	920	8,721	**1.25**	**0.34**	73	6/23-9/03	**0.079**
2009	375.000	369.462	28.125	**143,485**	22	27	359	920	11,934	**0.79**	**0.34**	98	6/15-9/20	**0.090**
2010	400.000	387.304	30	**149,822**	23	32	286	1,040	9,698	**1.14**	**0.34**	58	6/28-8/24	**0.074**
2011	358.000	373.990	26.851	**141,626**	24	25	173	1,040	6,808	**1.48**	**0.34**	33	6/28-7/30	**0.038**
2012	465.450	441.080	34.91	**161,113**	40	29	312	1,200	10,041	**1.22**	**0.34**	72	6/29-9/08	**0.093**
2013	495.600	373.278	18.585	**130,603**	37	33	460	1,420	15,058	**0.63**	**0.34**	74	7/3-9/14	**0.110**
2014	382.800	360.860	28.148	**129,657**	52	33	309	1,560	10,127	**1.06**	**0.34**	52	6/25-8/15	**0.052**
2015	394.600	371.520	29.595	**144,255**	42	36	251	1,480	8,356	**1.37**	**0.34**	26	6/29-7/24	**0.033**
2016	517.200	416.576	3,583	**138,997**	36	37	220	1,520	8,009	**1.20**	**0.34**	25	6/27-7/21	**0.025**
2017	496,800	411,736	0	**135,322**	36	36	270	1,640	9,401	**1.06**	**0.34**	30	6/26-7/25	**0.027**
2018	290,282	298,396	0	**89,613**	34	34	256	1,400	8,797	**0.62**	**0.34**	35	6/24-7/29	**0.038**

[a] Deadloss included in total. [b] Millions of pounds. [c] Information not available.

Table 2. Historical winter commercial and subsistence red king crab fisheries, Norton Sound Section, eastern Bering Sea, 1977-2016. Bold typed data are used for the assessment model.

		Commercial			Subsistence				
Model Year	Year[a]	# of Fishers	# of Crab Harvested	Winter[b]	Permits Issued	Permits Returned	Permits Fished	Total Crab Caught[c]	Total Crab Retained[d]
1978	1978	37	**9,625**	1977/78	290	206	149	**NA**	**12,506**
1979	1979	1[f]	**221**[f]	1978/79	48	43	38	**NA**	**224**
1980	1980	1[f]	**22**[f]	1979/80	22	14	9	**NA**	**213**
1981	1981	0	**0**	1980/81	51	39	23	**NA**	**360**
1982	1982	1[f]	**17**[f]	1981/82	101	76	54	**NA**	**1,288**
1983	1983	5	**549**	1982/83	172	106	85	**NA**	**10,432**
1984	1984	8	**856**	1983/84	222	183	143	**15,923**	**11,220**
1985	1985	9	**1,168**	1984/85	203	166	132	**10,757**	**8,377**
1986	1985/86	5	**2,168**	1985/86	136	133	107	**10,751**	**7,052**
1987	1986/87	7	**1,040**	1986/87	138	134	98	**7,406**	**5,772**
1988	1987/88	10	**425**	1987/88	71	58	40	**3,573**	**2,724**
1989	1988/89	5	**403**	1988/89	139	115	94	**7,945**	**6,126**
1990	1989/90	13	**3,626**	1989/90	136	118	107	**16,635**	**12,152**
1991	1990/91	11	**3,800**	1990/91	119	104	79	**9,295**	**7,366**
1992	1991/92	13	**7,478**	1991/92	158	105	105	**15,051**	**11,736**
1993	1992/93	8	**1,788**	1992/93	88	79	37	**1,193**	**1,097**
1994	1993/94	25	**5,753**	1993/94	118	95	71	**4,894**	**4,113**
1995	1994/95	42	**7,538**	1994/95	166	131	97	**7,777**	**5,426**
1996	1995/96	9	**1,778**	1995/96	84	44	35	**2,936**	**1,679**
1997	1996/97	2[f]	**83**[f]	1996/97	38	22	13	**1,617**	**745**
1998	1997/98	5	**984**	1997/98	94	73	64	**20,327**	**8,622**
1999	1998/99	5	**2,714**	1998/99	95	80	71	**10,651**	**7,533**
2000	1999/00	10	**3,045**	1999/00	98	64	52	**9,816**	**5,723**
2001	2000/01	3	**1,098**	2000/01	50	27	12	**366**	**256**
2002	2001/02	11	**2,591**	2001/02	114	61	45	**5,119**	**2,177**
2003	2002/03	13	**6,853**	2002/03	107	70	61	**9,052**	**4,140**
2004	2003/04	2[f]	**522**[f]	2003/04[g]	96	77	41	**1,775**	**1,181**
2005	2004/05	4	**2,091**	2004/05	170	98	58	**6,484**	**3,973**
2006	2005/06	1[f]	**75**[f]	2005/06	98	97	67	**2,083**	**1,239**
2007	2006/07	8	**3,313**	2006/07	129	127	116	**21,444**	**10,690**
2008	2007/08	9	**5,796**	2007/08	139	137	108	**18,621**	**9,485**
2009	2008/09	7	**4,951**	2008/09	105	105	70	**6,971**	**4,752**
2010	2009/10	10	**4,834**	2009/10	125	123	85	**9,004**	**7,044**
2011	2010/11	5	**3,365**	2010/11	148	148	95	**9,183**	**6,640**
2012	2011/12	35	**9,157**	2011/12	204	204	138	**11,341**	**7,311**
2013	2012/13	26	**22,639**	2012/13	149	148	104	**21,524**	**7,622**
2014	2013/14	21	**14,986**	2013/14	103	103	75	**5,421**	**3,252**
2015	2014/15	44	**41,062**	2014/15	155	153	107	**9,840**	**7,651**
2016	2015/16	25	**29,792**	2015/16	139	97	64	**6,468**	**5,340**
2017	2017	43	**26,008**	2017	163	163	109	**7,185**	**6,039**
2018	2018	28	**9,180**	2018	123	120	82	**5,767**	**4,424**

a Prior to 1985 the winter commercial fishery occurred from January 1 - April 30. As of March 1985, fishing may occur from November 15 - May 15.

b The winter subsistence fishery occurs during months of two calendar years (as early as December, through May).

c The number of crab actually caught; some may have been returned.

d The number of crab retained is the number of crab caught and kept.

f Confidentiality was waived by the fishers.

h Prior to 2005, permits were only given out of the Nome ADF&G office. Starting with the 2004-5 season, permits were given out in Elim, Golovin, Shaktoolik, and White Mountain.

Table 3. Summary of triennial trawl survey Norton Sound male red king crab abundance estimates (CL ≥ 64mm) . Trawl survey abundance estimate is based on 10×10 nm^2 grid, except for 2010 and 2017 (20×20 nm^2). Bold typed data are used for the assessment model.

				Survey coverage			Abundance ≥74 mm (1982-1991) ≥64 mm (1996- 2007)	
Year	Dates	Survey Agency	Survey method	Total surveyed stations	Stations w/ NSRKC	n mile^2 covered		CV
1976	9/02 – 9/25	NMFS	Trawl	103	62	10260	**4247.5**	**0.31**
1979	7/26 - 8/05	NMFS	Trawl	85	22	8421	**1417.2**	**0.20**
1980	7/04 - 7/14	ADFG	Pots				2092.3	N/A
1981	6/28 - 7/14	ADFG	Pots				2153.4	N/A
1982	7/06 - 7/20	ADFG	Pots				1140.5	N/A
1982	9/05 - 9/11	NMFS	Trawl	58	37	5721	**2791.7**	**0.29**
1985	7/01 - 7/14	ADFG	Pots				2320.4	0.083
1985	9/16 -10/01	NMFS	Trawl	78	49	7688	**2306.3**	**0.25**
1988	8/16 - 8/30	NMFS	Trawl	78	41	7721	**2263.4**	**0.29**
1991	8/22 - 8/30	NMFS	Trawl	52	38	5183	**3132.5**	**0.43**
1996	8/07 - 8/18	ADFG	Trawl	50	30	4938	**1283.0**	**0.25**
1999	7/28 - 8/07	ADFG	Trawl	52	31	5221	**2608.0**	**0.24**
2002	7/27 - 8/06	ADFG	Trawl	57	37	5621	**2056.0**	**0.36**
2006	7/25 - 8/08	ADFG	Trawl	114	45	10008	**3336.0**	**0.39**
2008	7/24 - 8/11	ADFG	Trawl	86	44	7330	**2894.2**	**0.31**
2010[a]	7/27 - 8/09	NMFS	Trawl	35	15	5841	**1980.1**	**0.44**
2011	7/18 - 8/15	ADFG	Trawl	65	34	6447	**3209.3**	**0.29**
2014	7/18 - 7/30	ADFG	Trawl	47	34	4700	**5934.6**	**0.47**
2017	7/28 - 8/08	ADFG	Trawl	60	41	6000	**1762.1**	**0.22**
2017	8/18 - 8/29	NMFS	Trawl	35	18	5841	**1035.8**	**0.40**
2018	7/22 - 7/29	ADFG	Trawl	60	34	6000	**1108.9**	**0.25**

Table 4. Summer commercial retained catch length-shell compositions.

		New Shell								Old Shell							
Year	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
1977	1549	0	0	0	0.00	0.42	0.34	0.08	0.05	0	0	0	0.00	0.06	0.04	0.01	0.00
1978	389	0	0	0	0.01	0.19	0.47	0.26	0.04	0	0	0	0.00	0.01	0.01	0.01	0.00
1979	1660	0	0	0	0.03	0.23	0.38	0.26	0.07	0	0	0	0.00	0.03	0.00	0.00	0.01
1980	1068	0	0	0	0.00	0.10	0.31	0.37	0.18	0	0	0	0.00	0.00	0.01	0.02	0.01
1981	1784	0	0	0	0.00	0.07	0.15	0.28	0.23	0	0	0	0.00	0.00	0.05	0.12	0.09
1982	1093	0	0	0	0.04	0.19	0.16	0.22	0.29	0	0	0	0.00	0.01	0.02	0.03	0.03
1983	802	0	0	0	0.04	0.41	0.36	0.06	0.03	0	0	0	0.00	0.04	0.01	0.02	0.02
1984	963	0	0	0	0.10	0.42	0.28	0.06	0.01	0	0	0	0.01	0.07	0.05	0.01	0.00
1985	2691	0	0	0.00	0.06	0.31	0.37	0.15	0.02	0	0	0	0.00	0.03	0.03	0.01	0.00
1986	1138	0	0	0	0.03	0.36	0.39	0.12	0.02	0	0	0	0.00	0.02	0.04	0.02	0.00
1987	1985	0	0	0	0.02	0.18	0.29	0.27	0.11	0	0	0	0.00	0.03	0.06	0.03	0.01
1988	1522	0	0.00	0	0.02	0.20	0.30	0.18	0.04	0	0	0	0.01	0.06	0.10	0.07	0.02
1989	2595	0	0	0	0.01	0.16	0.32	0.17	0.05	0	0	0	0.00	0.06	0.12	0.09	0.02
1990	1289	0	0	0	0.01	0.14	0.35	0.26	0.07	0	0	0	0.00	0.04	0.07	0.05	0.01
1991																	
1992	2566	0	0	0	0.02	0.20	0.27	0.14	0.09	0	0	0	0.00	0.08	0.13	0.06	0.02
1993	17804	0	0	0	0.01	0.23	0.39	0.23	0.03	0	0	0	0.00	0.02	0.04	0.03	0.01
1994	404	0	0	0	0.02	0.09	0.08	0.07	0.02	0	0	0	0.02	0.19	0.25	0.20	0.05
1995	1167	0	0	0	0.04	0.26	0.29	0.15	0.05	0	0	0	0.01	0.05	0.07	0.06	0.01
1996	787	0	0	0	0.03	0.22	0.24	0.09	0.05	0	0	0	0.01	0.12	0.14	0.08	0.02
1997	1198	0	0	0	0.03	0.37	0.34	0.10	0.03	0	0	0	0.00	0.06	0.04	0.03	0.01
1998	1055	0	0	0	0.03	0.23	0.24	0.08	0.03	0	0	0	0.02	0.11	0.14	0.08	0.03
1999	562	0	0	0	0.06	0.29	0.24	0.18	0.09	0	0	0	0.00	0.02	0.05	0.04	0.00
2000	17213	0	0	0	0.02	0.30	0.39	0.11	0.02	0	0	0	0.00	0.05	0.07	0.04	0.01
2001	20030	0	0	0	0.02	0.22	0.37	0.21	0.07	0	0	0	0.00	0.02	0.05	0.02	0.01
2002	5219	0	0	0	0.04	0.23	0.28	0.25	0.07	0	0	0	0.00	0.03	0.04	0.03	0.01
2003	5226	0	0	0	0.02	0.37	0.32	0.12	0.03	0	0	0	0.00	0.02	0.05	0.05	0.01
2004	9606	0	0	0	0.01	0.38	0.39	0.11	0.03	0	0	0	0.00	0.03	0.03	0.01	0.01
2005	5360	0	0	0	0.00	0.25	0.47	0.16	0.02	0	0	0	0.00	0.02	0.05	0.02	0.01
2006	6707	0	0	0	0.00	0.18	0.35	0.17	0.02	0	0	0	0.00	0.05	0.14	0.07	0.01
2007	6125	0	0	0	0.01	0.36	0.34	0.14	0.03	0	0	0	0.00	0.02	0.06	0.03	0.01
2008	5766	0	0	0	0.00	0.35	0.35	0.06	0.01	0	0	0	0.00	0.09	0.09	0.04	0.01
2009	6026	0	0	0	0.01	0.34	0.33	0.11	0.02	0	0	0	0.00	0.08	0.08	0.02	0.01
2010	5902	0	0	0	0.01	0.39	0.36	0.10	0.01	0	0	0	0.00	0.05	0.05	0.02	0.00
2011	2552	0	0	0	0.00	0.32	0.40	0.12	0.02	0	0	0	0.00	0.06	0.06	0.02	0.00
2012	5056	0	0	0	0.00	0.24	0.46	0.18	0.02	0	0	0	0.00	0.03	0.04	0.02	0.00
2013	6072	0	0	0	0.00	0.24	0.37	0.24	0.06	0	0	0	0.00	0.01	0.04	0.02	0.00
2014	4682	0	0	0	0.01	0.28	0.24	0.18	0.07	0	0	0	0.00	0.04	0.09	0.07	0.02
2015	4173	0	0	0	0.01	0.48	0.28	0.10	0.03	0	0	0	0.00	0.02	0.03	0.03	0.01
2016	1543	0	0	0	0.00	0.25	0.47	0.16	0.03	0	0	0	0.00	0.02	0.02	0.03	0.01
2017	3412	0	0	0	0.00	0.18	0.39	0.21	0.03	0	0	0	0.01	0.03	0.12	0.05	0.01
2018	2609	0	0	0	0.00	0.11	0.32	0.32	0.08	0	0	0	0	0.01	0.08	0.08	0.02

Table 5. Winter commercial catch length-shell compositions.

		New Shell								Old Shell							
Year	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
2015	576	0	0	0	0.07	0.50	024	0.06	0.01	0	0	0	0.01	0.04	0.03	0.03	0.01
2016	1016	0	0	0	0.03	0.45	0.31	0.03	0.00	0	0	0	0.01	0.09	0.04	0.02	0.01
2017	540	0	0	0	0.00	0.20	0.30	0.13	0.02	0	0	0	0.00	0.08	0.19	0.06	0.02
2018	401	0	0	0	0.00	0.11	0.25	0.27	0.05	0	0	0	0	0.04	0.16	0.10	0.02

Table 6. Summer Trawl Survey length-shell compositions.

			New Shell								Old Shell							
Year	Survey	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
1976	NMFS	1326	0.01	0.02	0.10	0.19	0.34	0.18	0.02	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.01	0.01
1979	NMFS	220	0.01	0.01	0.00	0.02	0.05	0.05	0.03	0.01	0.01	0.00	0.01	0.04	0.14	0.40	0.19	0.03
1982	NMFS	327	0.22	0.07	0.16	0.23	0.17	0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.02	0.03
1985	NMFS	350	0.11	0.11	0.19	0.17	0.16	0.06	0.01	0.00	0.00	0.00	0.00	0.02	0.05	0.08	0.05	0.01
1988	NMFS	366	0.16	0.19	0.12	0.13	0.11	0.06	0.03	0.00	0.00	0.00	0.01	0.01	0.03	0.07	0.05	0.03
1991	NMFS	340	0.18	0.08	0.02	0.03	0.06	0.03	0.01	0.01	0.03	0.06	0.02	0.08	0.16	0.14	0.09	0.02
1996	ADFG	269	0.29	0.21	0.13	0.09	0.05	0.00	0.00	0.01	0.00	0.00	0.03	0.03	0.04	0.04	0.04	0.03
1999	ADFG	283	0.03	0.01	0.10	0.29	0.26	0.13	0.03	0.01	0.00	0.00	0.00	0.03	0.05	0.04	0.02	0.00
2002	ADFG	244	0.09	0.12	0.14	0.11	0.02	0.03	0.02	0.01	0.01	0.03	0.07	0.10	0.09	0.09	0.05	0.02
2006	ADFG	373	0.18	0.26	0.21	0.11	0.06	0.04	0.02	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.01	0.00
2008	ADFG	275	0.12	0.15	0.21	0.11	0.10	0.03	0.02	0.01	0.00	0.01	0.04	0.06	0.08	0.01	0.04	0.00
2010	NMFS	69	0.01	0.04	0.06	0.17	0.06	0.03	0.00	0.00	0.00	0.03	0.09	0.20	0.19	0.07	0.03	0.01
2011	ADFG	315	0.13	0.11	0.09	0.11	0.18	0.14	0.03	0.01	0.00	0.00	0.01	0.02	0.09	0.04	0.03	0.00
2014	ADFG	387	0.08	0.15	0.24	0.18	0.09	0.02	0.01	0.01	0.00	0.00	0.03	0.10	0.05	0.04	0.01	0.00
2017	ADFG	116	0.14	0.12	0.05	0.09	0.10	0.04	0.00	0.00	0.01	0.02	0.02	0.02	0.07	0.18	0.04	0.00
2017	NMFS	58	0.09	0.10	0.14	0.05	0.05	0.05	0.05	0.03	0.03	0.00	0.03	0.05	0.03	0.19	0.05	0.03
2018	ADFG	73	0.37	0.10	0.11	0.03	0.01	0.03	0.04	0.01	0	0.07	0.01	0.04	0.03	0.03	0.10	0.03

Table 7. Winter pot survey length-shell compositions.

			New Shell								Old Shell							
Year	CPUE	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
1981/82	NA	719	0.00	0.10	0.23	0.21	0.07	0.02	0.02	0.00	0.00	0.05	0.11	0.11	0.04	0.02	0.02	0.00
1982/83	24.2	2583	0.03	0.08	0.28	0.28	0.21	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01
1983/84	24.0	1677	0.01	0.16	0.26	0.23	0.15	0.06	0.01	0.00	0.00	0.00	0.00	0.02	0.06	0.03	0.01	0.01
1984/85	24.5	789	0.02	0.09	0.25	0.35	0.16	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.00
1985/86	19.2	594	0.04	0.12	0.17	0.24	0.19	0.08	0.01	0.00	0.00	0.00	0.00	0.01	0.06	0.04	0.01	0.00
1986/87	5.8	144	0.00	0.06	0.15	0.19	0.07	0.04	0.00	0.00	0.00	0.00	0.01	0.04	0.30	0.11	0.03	0.00
1987/88																		
1988/89	13.0	500	0.02	0.13	0.15	0.13	0.19	0.17	0.03	0.00	0.00	0.00	0.00	0.00	0.05	0.08	0.03	0.00
1989/90	21.0	2076	0.00	0.05	0.21	0.26	0.18	0.12	0.06	0.01	0.00	0.00	0.00	0.00	0.03	0.06	0.02	0.00
1990/91	22.9	1283	0.00	0.01	0.09	0.29	0.27	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.07	0.02
1992/93	5.5	181	0.00	0.01	0.03	0.06	0.13	0.12	0.03	0.00	0.00	0.00	0.00	0.02	0.19	0.27	0.10	0.05
1993/94																		
1994/95	6.2	858	0.01	0.06	0.08	0.10	0.26	0.23	0.07	0.01	0.00	0.00	0.00	0.00	0.03	0.07	0.06	0.02
1995/96	9.9	1580	0.06	0.14	0.20	0.19	0.11	0.07	0.03	0.00	0.00	0.00	0.00	0.01	0.06	0.07	0.03	0.01
1996/97	2.9	398	0.07	0.21	0.22	0.11	0.15	0.11	0.05	0.01	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.01
1997/98	10.9	881	0.00	0.14	0.41	0.27	0.05	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.02	0.01
1998/99	10.7	1307	0.00	0.02	0.12	0.36	0.36	0.08	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.00
1999/00	6.2	575	0.02	0.09	0.10	0.16	0.33	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.01	0.00
2000/01	3.1	44																
2001/02	13.0	828	0.05	0.29	0.26	0.17	0.06	0.06	0.04	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00
2002/03	9.6	824	0.02	0.10	0.22	0.28	0.18	0.06	0.02	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.02	0.01
2003/04	3.7	296	0.00	0.02	0.16	0.26	0.32	0.14	0.01	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.02	0.01
2004/05	4.4	405	0.00	0.07	0.14	0.18	0.22	0.19	0.07	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.01	0.00
2005/06	6.0	512	0.00	0.14	0.23	0.21	0.16	0.05	0.02	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.03	0.01
2006/07	7.3	159	0.07	0.14	0.19	0.35	0.13	0.04	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.00	0.00
2007/08	25.0	3552	0.01	0.14	0.25	0.17	0.14	0.07	0.01	0.00	0.01	0.04	0.07	0.03	0.03	0.01	0.01	0.00
2008/09	21.9	525	0.00	0.07	0.13	0.35	0.20	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.10	0.00	0.00
2009/10	25.3	578	0.01	0.05	0.13	0.21	0.24	0.11	0.02	0.00	0.00	0.00	0.01	0.06	0.10	0.05	0.01	0.00
2010/11	22.1	596	0.02	0.08	0.13	0.20	0.17	0.13	0.05	0.00	0.00	0.00	0.01	0.03	0.11	0.05	0.01	0.00
2011/12	29.4	675	0.03	0.11	0.23	0.19	0.12	0.13	0.04	0.00	0.00	0.00	0.00	0.01	0.05	0.05	0.03	0.00

Table 8. Summer commercial1987-1994, 2012-2017 observer discards length-shell compositions.

		New Shell								Old Shell							
Year	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
1987	1146	0.06	0.19	0.32	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00
1988	722	0.01	0.04	0.15	0.48	0.14	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.04	0.00	0.00	0.00
1989	1000	0.07	0.19	0.24	0.22	0.03	0.00	0.00	0.00	0.02	0.03	0.07	0.11	0.03	0.00	0.00	0.00
1990	507	0.08	0.23	0.27	0.27	0.04	0.00	0.00	0.00	0.02	0.02	0.02	0.05	0.01	0.00	0.00	0.00
1992	580	0.11	0.17	0.30	0.29	0.03	0.00	0.00	0.00	0.01	0.02	0.02	0.04	0.01	0.00	0.00	0.00
1994	850	0.07	0.06	0.11	0.15	0.02	0.00	0.00	0.00	0.07	0.07	0.15	0.24	0.05	0.00	0.00	0.00
2012	939	0.21	0.11	0.19	0.32	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00
2013	2617	0.34	0.29	0.16	0.16	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	1755	0.05	0.10	0.26	0.41	0.12	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.00	0.00
2015	824	0.01	0.08	0.18	0.44	0.23	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00
2016	426	0.04	0.05	0.17	0.50	0.17	0.02	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00
2017	544	0.10	0.16	0.13	0.31	0.26	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
2018	532	0.10	0.17	0.36	0.30	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00

Table 9. Summer commercial1 2012-2018 observer total catch length-shell compositions.

		New Shell								Old Shell							
Year	Sample	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
2012	3055	0.10	0.05	0.08	0.15	0.15	0.17	0.06	0.01	0.00	0.00	0.00	0.03	0.08	0.09	0.03	0.00
2013	4762	0.19	0.16	0.09	0.10	0.16	0.16	0.09	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00
2014	3506	0.02	0.05	0.13	0.22	0.22	0.12	0.08	0.03	0.00	0.00	0.00	0.02	0.03	0.03	0.02	0.01
2015	1671	0.01	0.04	0.09	0.23	0.37	0.14	0.05	0.01	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.00
2016	2114	0.01	0.01	0.03	0.12	0.29	0.36	0.08	0.02	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.00
2017	2748	0.02	0.03	0.03	0.06	0.19	0.33	0.18	0.02	0.00	0.00	0.00	0.00	0.02	0.07	0.03	0.01
2018	1628	0.03	0.06	0.12	0.11	0.09	0.17	0.18	0.04	0.00	0.00	0.01	0.01	0.15	0.07	0.08	0.02

Table 10. The number of tagged data released and recovered after 1 year (Y1) – 3 year (Y3) during 1980-1992 and 1993-2017 periods.

Release Length Class	Recap Length Class	1980-1992			1993-2018		
		Y1	Y2	Y3	Y1	Y2	Y3
64 – 73	64 – 73						
64 – 73	74 - 83	1					
64 – 73	84 - 93	1	1		3		
64 – 73	94 - 103		1			5	
64 – 73	104 – 113		1			4	11
64 – 73	114 – 123						11
64 – 73	124 – 133						
64 – 73	134+						
74 - 83	74 - 83						
74 - 83	84 - 93	3			21		
74 - 83	94 - 103	7			22	12	
74 - 83	104 – 113		13		4	94	19
74 - 83	114 – 123		1	2		5	46
74 - 83	124 – 133						6
74 - 83	134+						
84 - 93	84 - 93						
84 - 93	94 - 103	15	1		41	5	2
84 - 93	104 – 113	19	5	1	81	34	14
84 - 93	114 – 123		5	2	7	69	27
84 - 93	124 – 133				1	3	9
84 - 93	134+						6
94 - 103	94 - 103	4	1		7	2	
94 - 103	104 – 113	53	5	1	165	33	2
94 - 103	114 – 123	31	5	7	82	38	32
94 - 103	124 – 133	2	2	2		19	13
94 - 103	134+				1		
104 – 113	104 – 113	18			59	7	
104 – 113	114 – 123	38	15	3	109	64	9
104 – 113	124 – 133	7	8	4	15	18	18
104 – 113	134+						
114 – 123	114 – 123	17	2		72	9	
114 – 123	124 – 133	27	10	2	72	38	10
114 – 123	134+	5	1		19	6	3
124 – 133	124 – 133	15			41	9	1
124 – 133	134+	10	4	2	15	12	7
134+	134+	15	6	1	11	2	

Table 11. Summary of initial input parameter values and bounds for a length-based population model of Norton Sound red king crab. Parameters with "log_" indicate log scaled parameters.

Parameter	Parameter description	Lower	Upper
$\log\_q_{1,2}$	Commercial fishery catchability (1977-92, 1993-2017)	-20.5	20
$\log\_N_{76}$	Initial abundance	2.0	15.0
R_0	Mean Recruit	2.0	12.0
$\log\ \sigma_R^2$	Recruit standard deviation	-40.0	40.0
$a_{1\text{-}7}$	Intimal length proportion	0	10.0
r_1	Proportion of length class 1 for recruit	0	10.0
$\log\_\alpha$	Inverse logistic molting parameter	-5.0	-1.0
$\log\_\beta$	Inverse logistic molting parameter	1.0	5.5
$\log\_\phi_{st1}$	Logistic trawl selectivity parameter	-5.0	1.0
$\log\_\phi_{wa}$	Inverse logistic winter pot selectivity parameter	-5.0	1.0
$\log\_\phi_{wb}$	Inverse logistic winter pot selectivity parameter	0.0	6.0
$Sw_{1,2}$	Winter pot selectivity of length class 1,2	0.1	1.0
$\log\_\phi_1$	Logistic commercial catch selectivity parameter	-5.0	1.0
$\log\_\phi_2$	Logistic commercial catch selectivity parameter	0.0	6.0
log_acr	Logistic summer commercial retention selectivity parameter	-5.0	1.0
log_bcr	Logistic summer commercial retention selectivity parameter	0.0	6.0
log_awr	Logistic winter commercial retention selectivity parameter	-5.0	1.0
log_bwr	Logistic winter commercial retention selectivity parameter	0.0	6.0
w^2_t	Additional variance for standard CPUE	0.0	6.0
ms	Natural mortality multipliers	0.5	5.0
q	Survey q for NMFS trawl 1976-91	0.1	1.0
σ	Growth transition sigma	0.0	30.0
β_1	Growth transition mean	0.0	20.0
β_2	Growth transition increment	0.0	20.0

Table 12. Summary of parameter estimates and standard deviations of Norton Sound red king crab. (Model 18.2b)

name	Estimate	std.dev
$\log\_q_1$	-7.002	0.171
$\log\_q_2$	-6.826	0.112
$\log\_N_{76}$	9.048	0.131
R_0	6.439	0.081
$\log\_R_{76}$	0.021	0.418
$\log\_R_{77}$	-0.533	0.370
$\log\_R_{78}$	-0.719	0.354
$\log\_R_{79}$	0.375	0.318
$\log\_R_{80}$	0.526	0.282
$\log\_R_{81}$	0.416	0.263
$\log\_R_{82}$	0.380	0.316
$\log\_R_{83}$	0.568	0.275
$\log\_R_{84}$	0.175	0.292
$\log\_R_{85}$	0.461	0.280
$\log\_R_{86}$	0.076	0.287
$\log\_R_{87}$	0.026	0.248
$\log\_R_{88}$	0.028	0.259
$\log\_R_{89}$	-0.317	0.279
$\log\_R_{90}$	-0.282	0.255
$\log\_R_{91}$	-0.520	0.284
$\log\_R_{92}$	-0.699	0.305
$\log\_R_{93}$	-0.576	0.289
$\log\_R_{94}$	-0.288	0.256
$\log\_R_{95}$	-0.065	0.225
$\log\_R_{96}$	0.569	0.218
$\log\_R_{97}$	-0.011	0.292
$\log\_R_{98}$	-0.631	0.319
$\log\_R_{99}$	-0.002	0.308
$\log\_R_{00}$	0.299	0.263
$\log\_R_{01}$	0.394	0.239
$\log\_R_{02}$	-0.007	0.313
$\log\_R_{03}$	-0.283	0.329
$\log\_R_{04}$	0.286	0.240
$\log\_R_{05}$	0.417	0.220
$\log\_R_{06}$	0.446	0.241
$\log\_R_{07}$	0.518	0.228

name	Estimate	std.dev
$\log\_R_{09}$	-0.397	0.289
$\log\_R_{10}$	0.020	0.244
$\log\_R_{11}$	0.288	0.275
$\log\_R_{12}$	0.926	0.182
$\log\_R_{13}$	-0.111	0.288
$\log\_R_{14}$	-0.653	0.310
$\log\_R_{15}$	-0.745	0.276
$\log\_R_{16}$	-0.452	0.239
$\log\_R_{17}$	-0.006	0.282
a_1	1.476	4.534
a_2	2.291	4.214
a_3	3.740	4.021
a_4	4.025	4.006
a_5	4.273	3.997
a_6	3.515	4.027
a_7	2.083	4.300
r1	10.000	0.798
r2	9.704	0.818
log_a	-2.685	0.091
log_b	4.835	0.016
$\log\_\phi_{st1}$	-5.000	0.082
$\log\_\phi_{wa}$	-2.224	0.308
$\log\_\phi_{wb}$	4.796	0.033
Sw1	0.073	0.035
Sw2	0.483	0.123
$\log\_\phi_1$	-2.085	0.056
log_acr	-0.781	0.129
log_bcr	4.645	0.008
log_awr	-0.781	0.129
log_bwr	4.645	0.008
w^2_t	0.051	0.016
q	0.754	0.130
σ	3.891	0.208
β_1	12.496	0.695
β_2	7.636	0.170
ms78	3.206	0.265

log_R_{08}	0.083	0.284

Table 13. Estimated selectivity, mortality, molting probabilities, and proportions of legal crab by length class (mm CL) for Norton Sound male red king crab (Model 18.2b).

						Selectivity			
Length Class	Legal Proportion	Summer Com Retention	Winter Com Retention	Mean weight (lb)	Natural mortality (*M*)	Trawl	Winter Pot	Summer Fishery	Molting Probability
64 - 73	0.00	0.00	0.00	0.44	0.18	1.00	0.07	0.14	0.98
74 - 83	0.00	0.00	0.00	0.87	0.18	1.00	0.48	0.36	0.96
84 - 93	0.00	0.00	0.00	1.31	0.18	1.00	0.97	0.67	0.93
94 - 103	0.14	0.07	0.08	1.80	0.18	1.00	0.92	0.87	0.87
104 - 113	0.88	0.88	0.79	2.37	0.18	1.00	0.79	0.96	0.77
114 - 123	1.00	1.00	0.99	3.04	0.18	1.00	0.57	0.99	0.62
124 - 133	1.00	1.00	1.00	3.80	0.58	1.00	0.31	1.00	0.45
134+	1.00	1.00	1.00	4.60	0.58	1.00	0.13	1.00	0.30

Table 14. Estimated molting probability incorporated transition matrix (Model 18.2b).

Pre-molt Length Class	Post-molt Length Class							
	64-73	74-83	84-93	94-103	104-113	114-123	124-133	134+
64 - 73	0.02	0.09	0.79	0.10	0.00	0.00	0.00	0.00
74 - 83		0.04	0.23	0.70	0.03	0.00	0.00	0.00
84 - 93			0.08	0.42	0.49	0.00	0.00	0.00
94 - 103				0.15	0.58	0.27	0.00	0.00
104 - 113					0.29	0.61	0.10	0.00
114 - 123						0.50	0.47	0.03
124 - 133							0.73	0.27
134+								1.00

Table 15. Annual abundance estimates (million crab) and mature male biomass (Feb 01) (MMB, million lb) for Norton Sound red king crab estimated by a length-based analysis from 1976 to 2018.

	Abundance			Legal (≥ 104 mm)		MMB
Year	Recruits	Total (≥ 64 mm)	Mature (≥ 94 mm)	Abundance	Biomass	Biomass
1976	2.11	8.50	6.39	4.13	11.02	15.25
1977	0.94	7.49	6.54	5.30	15.23	17.63
1978	0.73	6.00	5.28	4.74	14.76	15.81
1979	0.53	4.18	3.65	3.31	10.89	11.53
1980	1.09	3.09	2.00	1.78	5.97	6.39
1981	1.55	3.07	1.52	1.17	3.90	4.56
1982	1.54	2.97	1.43	0.90	2.73	3.70
1983	1.46	3.22	1.76	1.17	3.41	4.50
1984	1.63	3.55	1.91	1.34	3.92	4.99
1985	1.37	3.43	2.07	1.45	4.30	5.44
1986	1.44	3.57	2.13	1.57	4.68	5.72
1987	1.23	3.34	2.10	1.56	4.71	5.73
1988	1.05	3.16	2.11	1.61	4.89	5.83
1989	1.02	3.03	2.02	1.59	4.90	5.71
1990	0.83	2.73	1.90	1.50	4.68	5.44
1991	0.74	2.50	1.75	1.41	4.43	5.08
1992	0.64	2.26	1.62	1.32	4.19	4.76
1993	0.53	1.99	1.46	1.19	3.83	4.33
1994	0.53	1.75	1.21	0.99	3.19	3.61
1995	0.67	1.69	1.02	0.81	2.60	2.99
1996	0.85	1.78	0.93	0.69	2.16	2.61
1997	1.43	2.43	0.99	0.68	2.09	2.66
1998	1.23	2.53	1.31	0.81	2.41	3.32
1999	0.71	2.35	1.63	1.13	3.28	4.22
2000	0.83	2.47	1.63	1.30	3.88	4.52
2001	1.19	2.67	1.48	1.16	3.61	4.20
2002	1.40	2.92	1.52	1.10	3.40	4.19
2003	1.15	2.84	1.69	1.17	3.54	4.50
2004	0.84	2.61	1.77	1.30	3.87	4.75
2005	1.11	2.76	1.65	1.29	3.91	4.59
2006	1.41	2.98	1.57	1.17	3.61	4.36
2007	1.51	3.18	1.67	1.16	3.50	4.45
2008	1.61	3.46	1.85	1.28	3.80	4.85
2009	1.28	3.28	2.00	1.39	4.12	5.25
2010	0.83	2.87	2.04	1.51	4.49	5.48
2011	0.89	2.74	1.84	1.47	4.47	5.17
2012	1.19	2.82	1.63	1.29	4.01	4.65
2013	2.05	3.61	1.57	1.14	3.53	4.33
2014	1.43	3.28	1.85	1.16	3.49	4.75
2015	0.70	2.78	2.08	1.47	4.26	5.40
2016	0.50	2.30	1.80	1.46	4.37	5.02
2017	0.57	2.02	1.44	1.22	3.83	4.25
2018	0.85	2.01	1.16	0.95	3.03	3.44

Table 16. Summary of catch and estimated discards (million lb) for Norton Sound red king crab. Assumed average crab weight is 2.0 lb for winter subsistence catch and 1.0 lb for Winter subsistence discards. Summer and winter commercial discards were estimated from the model.

Year	Summer Com	Winter Com	Winter Sub	Modeled Discards Summer	Discards Winter Sub	Modeled Discards Winter Com	Total	Catch/ MMB
1977	0.52	0.000	0.000	0.019	0	0.000	0.539	0.035
1978	2.09	0.024	0.025	0.037	0.008	0.001	2.186	0.124
1979	2.93	0.001	0.000	0.050	0	0.000	2.981	0.189
1980	1.19	0.000	0.000	0.027	0	0.000	1.217	0.106
1981	1.38	0.000	0.001	0.078	0	0.000	1.459	0.228
1982	0.23	0.000	0.003	0.022	0.001	0.000	0.256	0.056
1983	0.37	0.001	0.021	0.036	0.006	0.000	0.435	0.117
1984	0.39	0.002	0.022	0.033	0.005	0.000	0.453	0.101
1985	0.43	0.003	0.017	0.034	0.002	0.001	0.486	0.097
1986	0.48	0.005	0.014	0.031	0.004	0.001	0.535	0.098
1987	0.33	0.003	0.012	0.020	0.002	0.000	0.367	0.064
1988	0.24	0.001	0.005	0.012	0.001	0.000	0.260	0.045
1989	0.25	0.000	0.012	0.012	0.002	0.000	0.277	0.047
1990	0.19	0.010	0.024	0.009	0.004	0.001	0.237	0.041
1991	0	0.010	0.015	0.000	0.002	0.001	0.028	0.005
1992	0.07	0.021	0.023	0.003	0.003	0.002	0.120	0.024
1993	0.33	0.005	0.002	0.014	0	0.001	0.350	0.074
1994	0.32	0.017	0.008	0.013	0.001	0.002	0.358	0.083
1995	0.32	0.022	0.011	0.016	0.002	0.003	0.371	0.103
1996	0.22	0.005	0.003	0.016	0.001	0.001	0.245	0.082
1997	0.09	0.000	0.001	0.009	0.001	0.000	0.102	0.039
1998	0.03	0.002	0.017	0.004	0.012	0.001	0.066	0.025
1999	0.02	0.007	0.015	0.002	0.003	0.001	0.048	0.014
2000	0.3	0.008	0.011	0.015	0.004	0.001	0.339	0.080
2001	0.28	0.003	0.001	0.017	0	0.001	0.301	0.067
2002	0.25	0.007	0.004	0.020	0.003	0.002	0.285	0.068
2003	0.26	0.017	0.008	0.023	0.005	0.004	0.317	0.076
2004	0.34	0.001	0.002	0.022	0.001	0.000	0.366	0.081
2005	0.4	0.006	0.008	0.022	0.003	0.001	0.439	0.092
2006	0.45	0.000	0.002	0.032	0.001	0.000	0.485	0.106
2007	0.31	0.008	0.021	0.028	0.011	0.002	0.380	0.087
2008	0.39	0.015	0.019	0.036	0.009	0.003	0.472	0.106
2009	0.4	0.012	0.010	0.034	0.002	0.003	0.460	0.095
2010	0.42	0.012	0.014	0.026	0.002	0.002	0.476	0.091
2011	0.4	0.009	0.013	0.019	0.003	0.001	0.444	0.081
2012	0.47	0.025	0.015	0.026	0.004	0.004	0.542	0.105
2013	0.35	0.061	0.015	0.033	0.014	0.016	0.484	0.104
2014	0.39	0.035	0.007	0.044	0.002	0.012	0.492	0.114
2015	0.40	0.099	0.019	0.028	0.005	0.015	0.570	0.120
2016	0.42	0.080	0.011	0.016	0.001	0.007	0.535	0.099
2017	0.41	0.078	0.012	0.014	0.001	0.007	0.521	0.104
2018	0.30	0.029	0.008	0.019	0	0.000	0.539	0.035

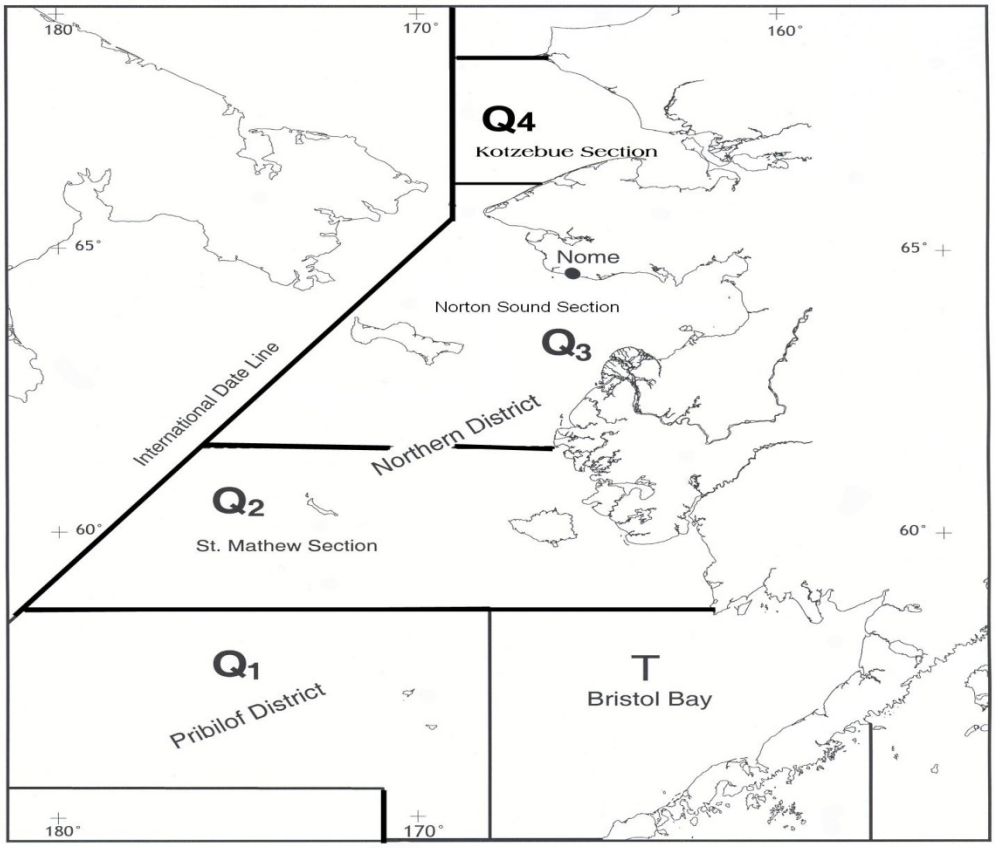


Figure 1. King crab fishing districts and sections of Statistical Area Q.

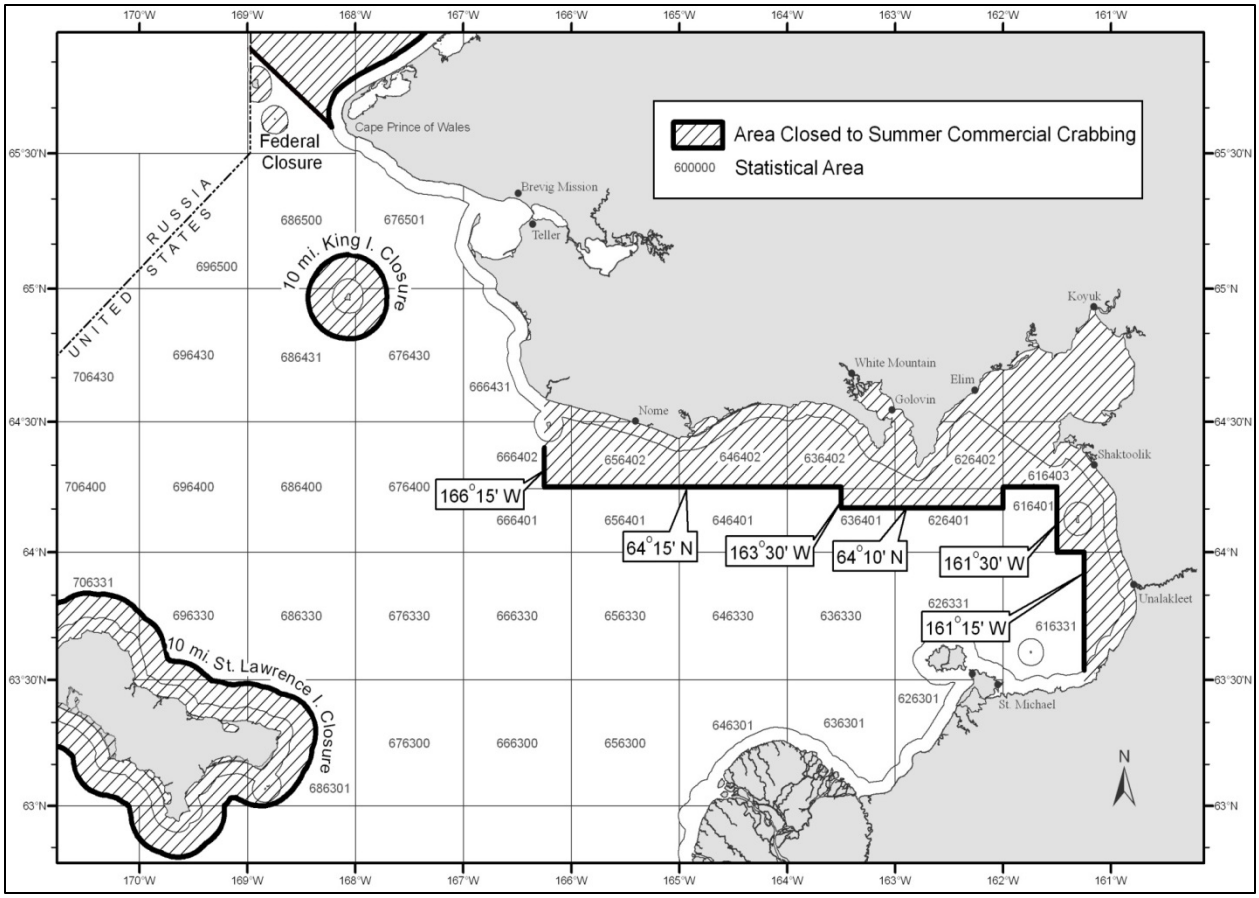


Figure 2. Closed water regulations in effect for the Norton Sound commercial crab fishery. Line around the coastline delineates the 3-mil3 state waters zone.

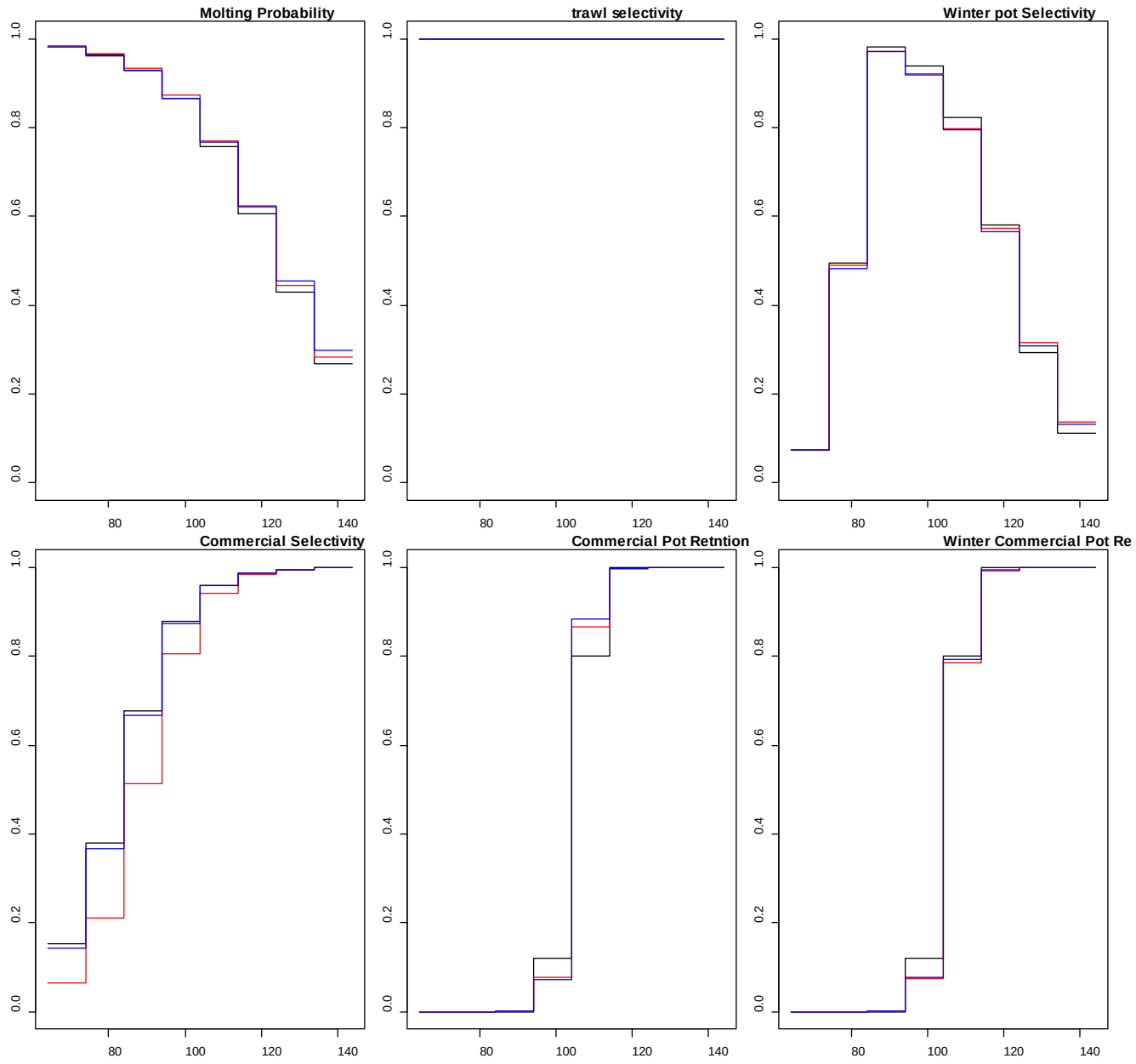


Figure 3. Model estimated annual molting probability, and selectivity for trawl survey, winter pot survey, summer commercial fishery, and summer and winter commercial retention. X-axis is carapace length (mm). Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

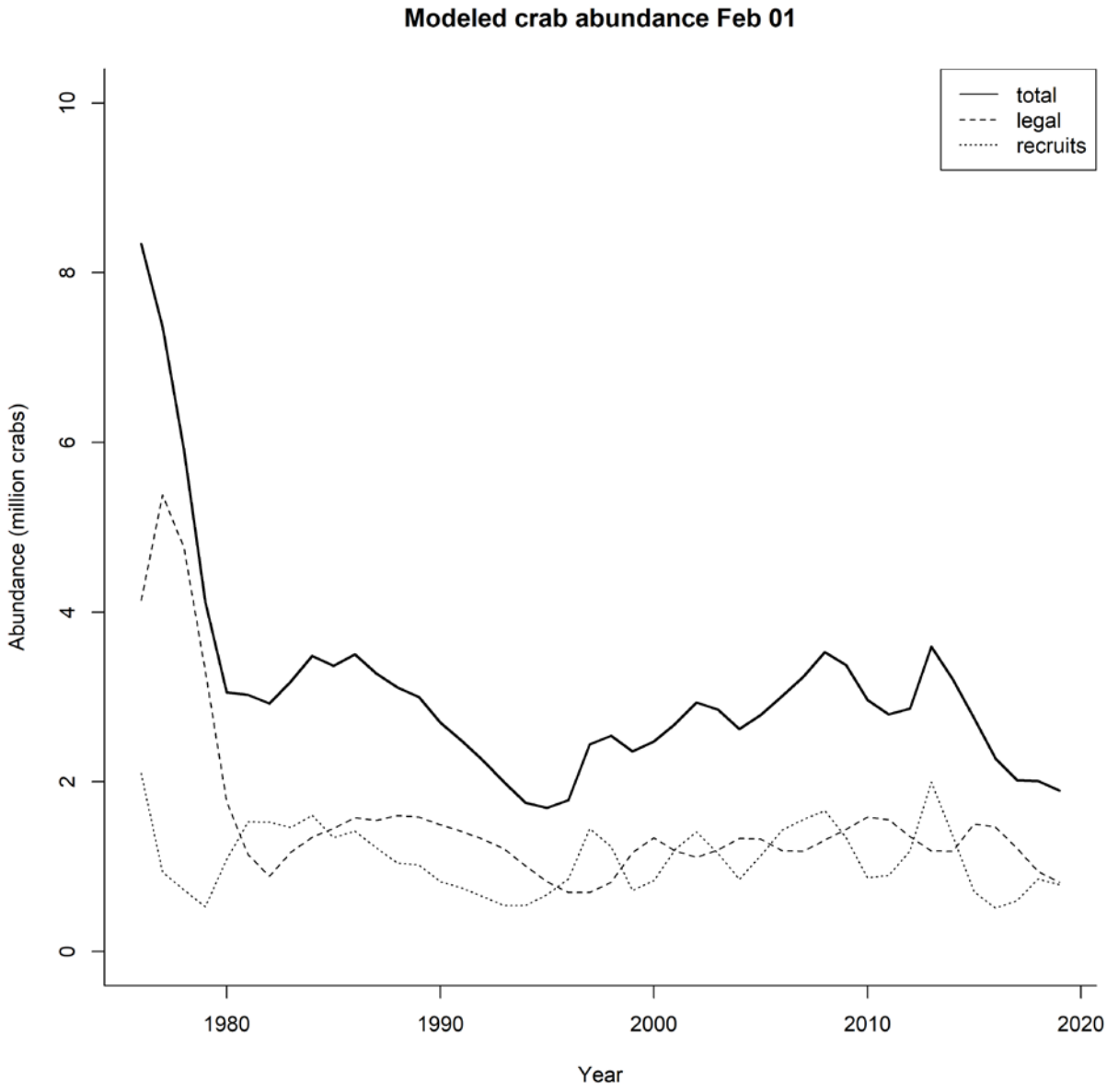


Figure 4. Model estimated abundances of total, legal (CL>104mm) and recruit (CL 64-94nn) males during1976-2018.

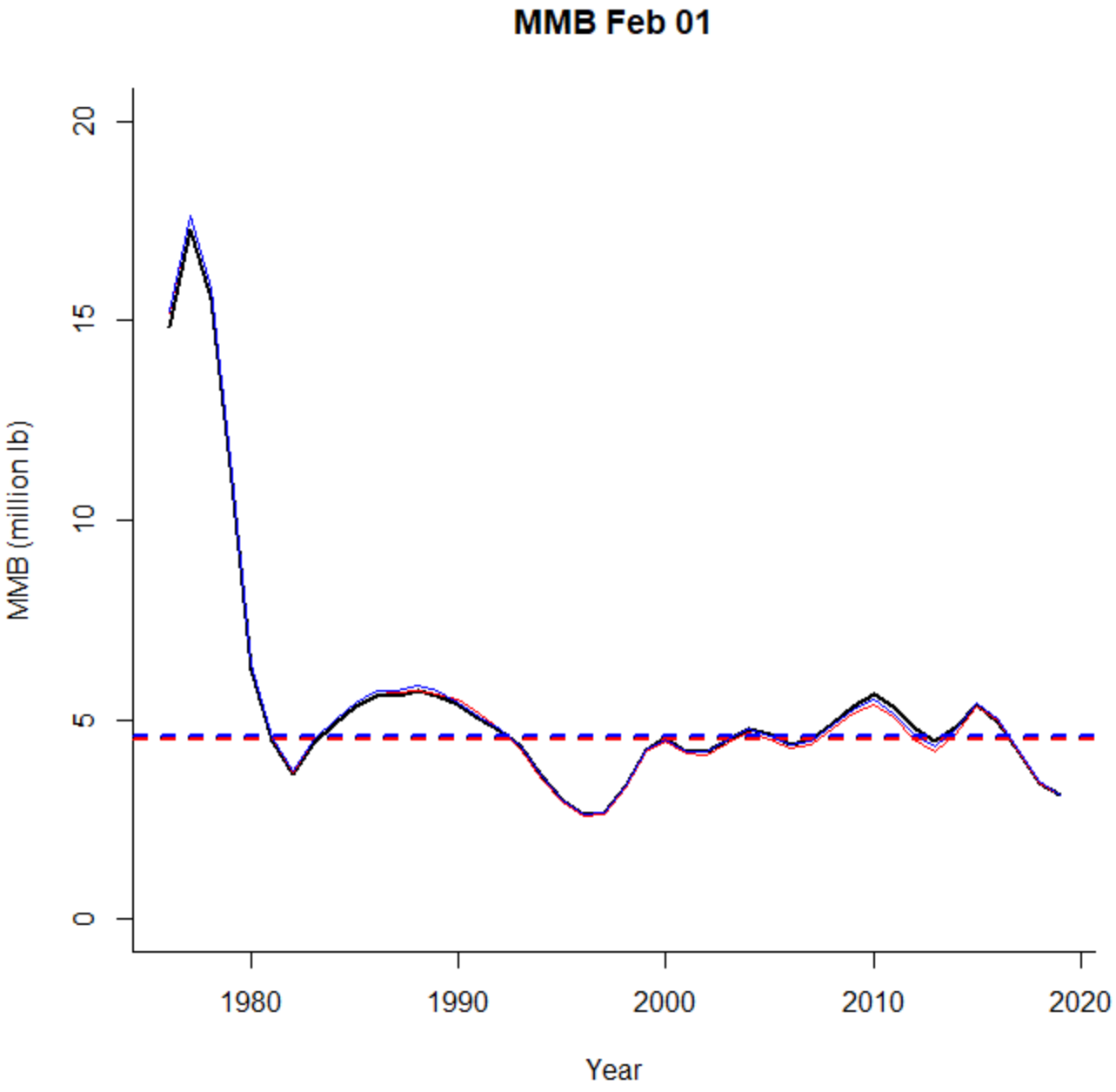


Figure 5. Estimated MMB during 1976-2018. Dash line shows Bmsy (Average MMB of 1980-2018). The black point indicates the projected MMB of 2018. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

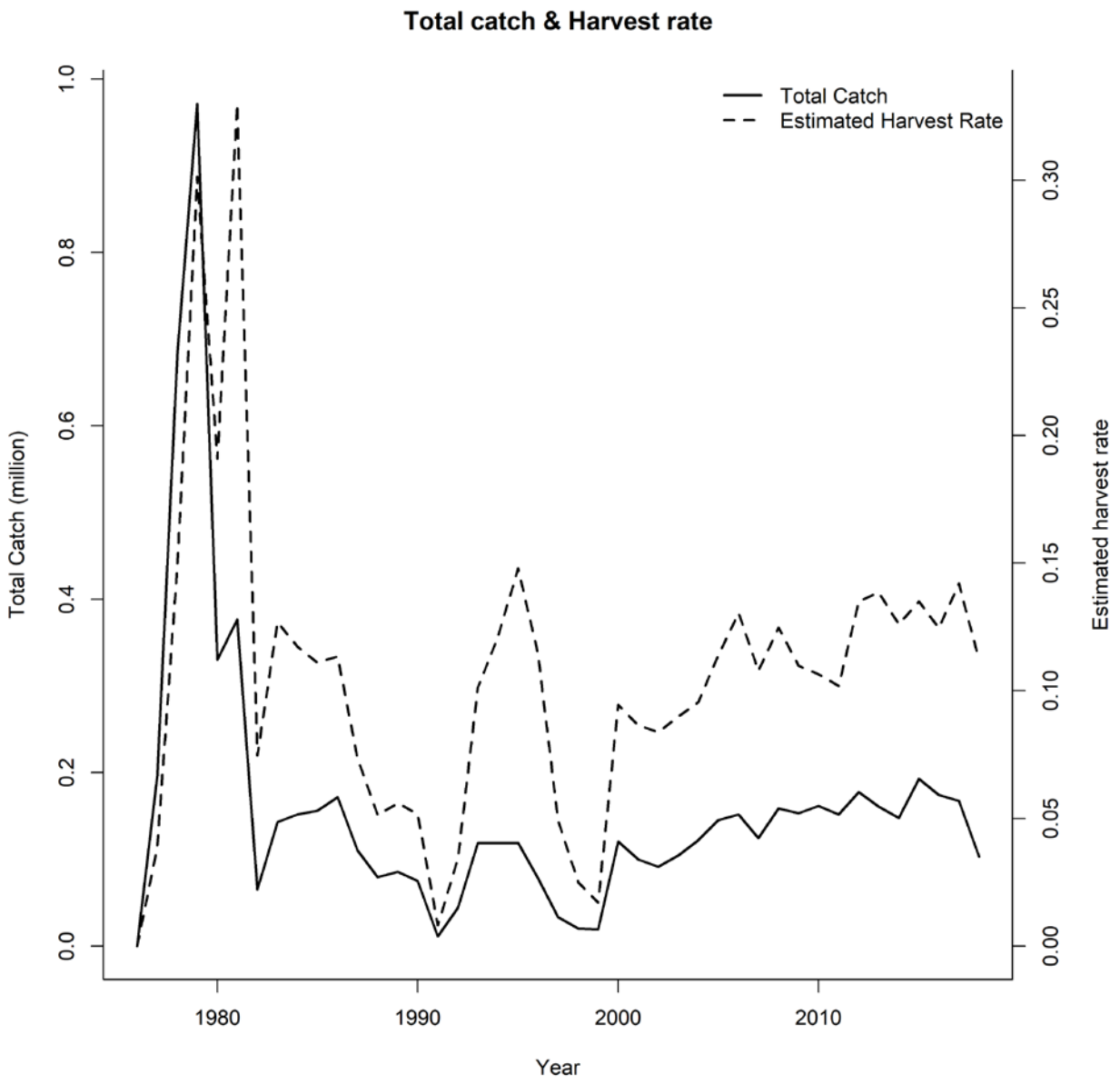


Figure 6. Commercial catch and estimated harvest rates of legal males over time.

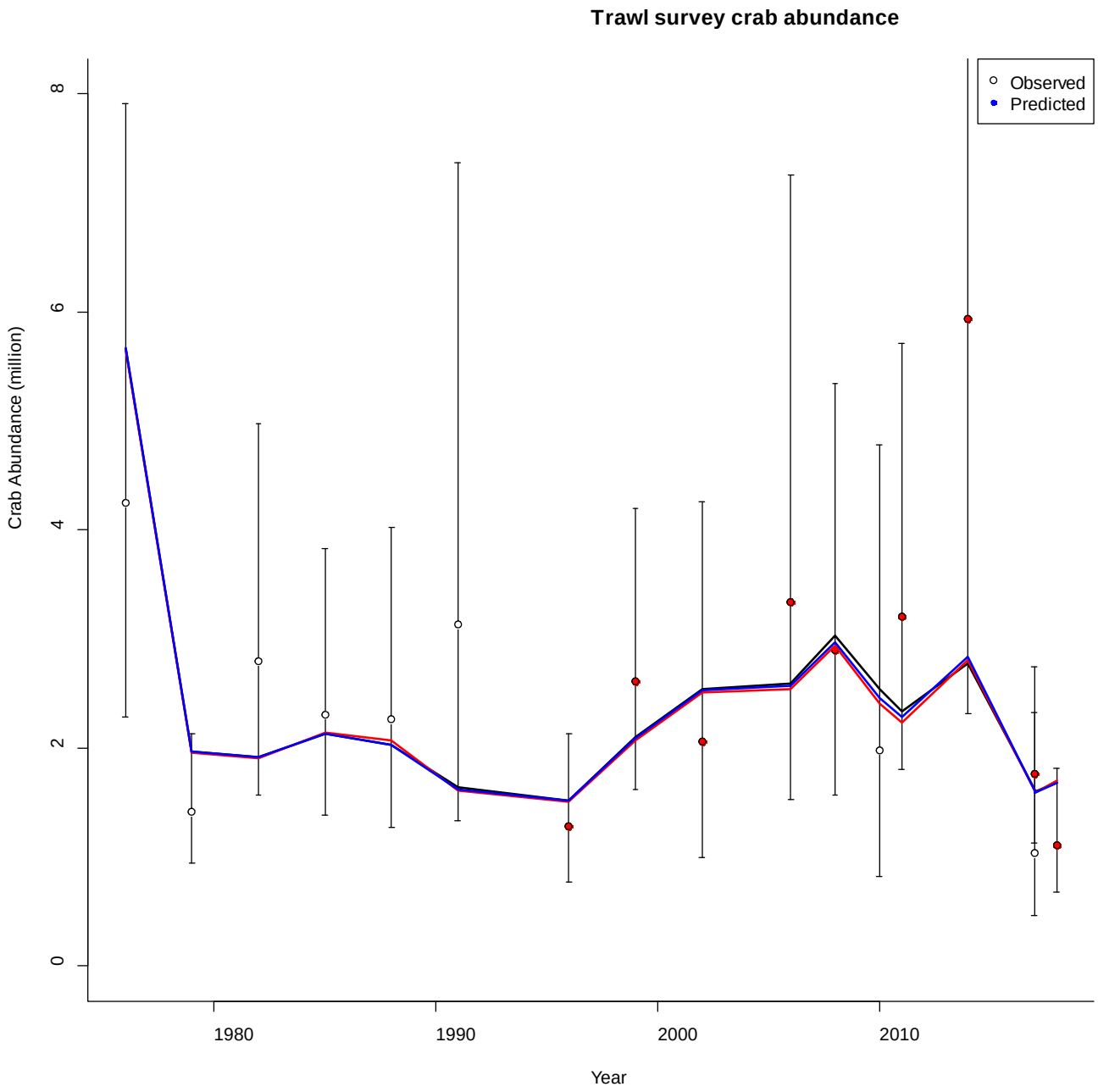


Figure 7. Observed (open circle) (White: NMFS, Red ADF&G) and model estimated (dots) trawl survey male abundances with 95% lognormal Confidence Intervals (1976-1991:crab ≥ 74 mm CL, 1996-2017:crab ≥ 64 mm CL) Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

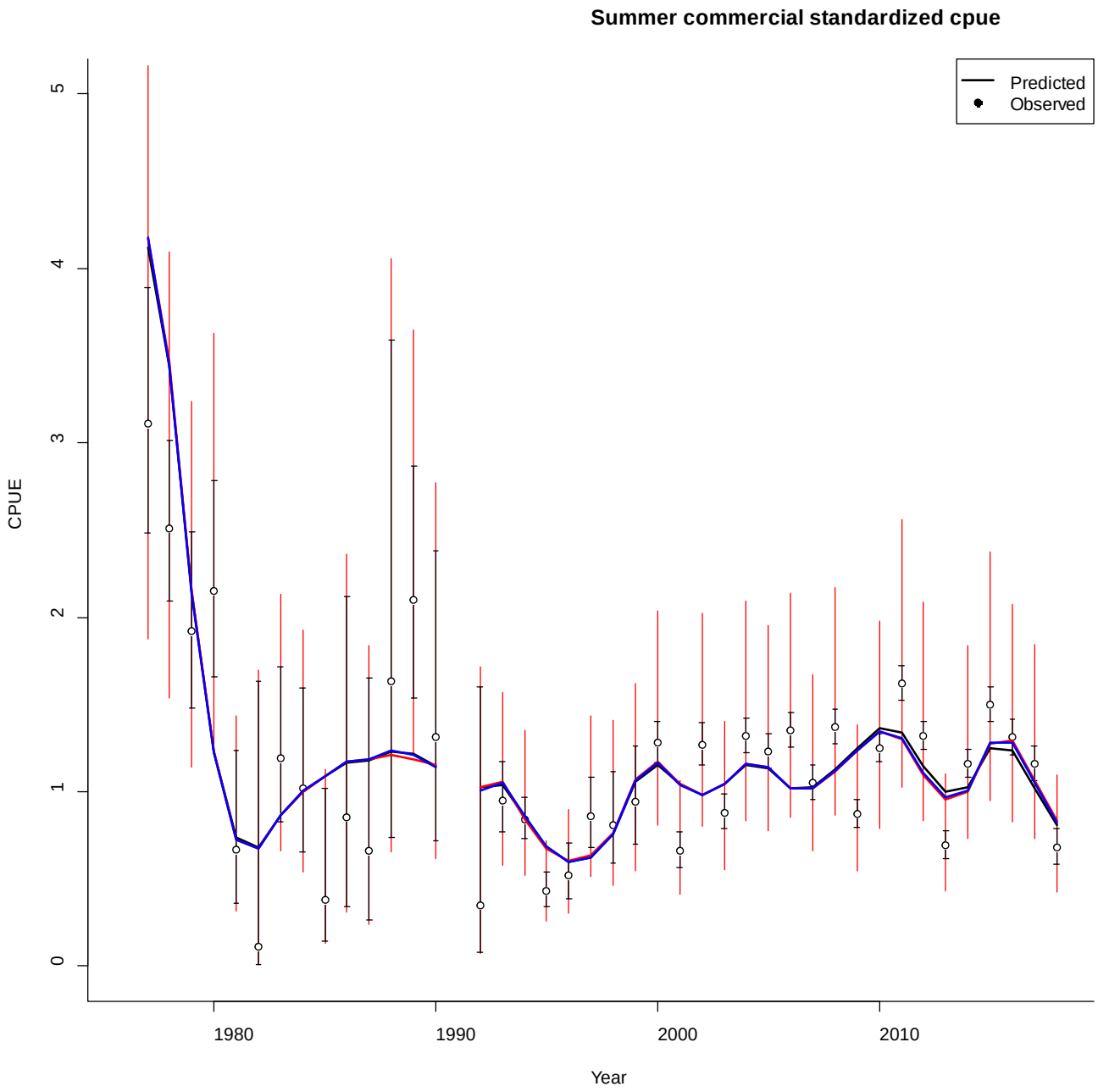


Figure 8. Summer commercial fishery standardized cpue. Vertical black lines are input SD and red lines are input and estimated additional SD. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

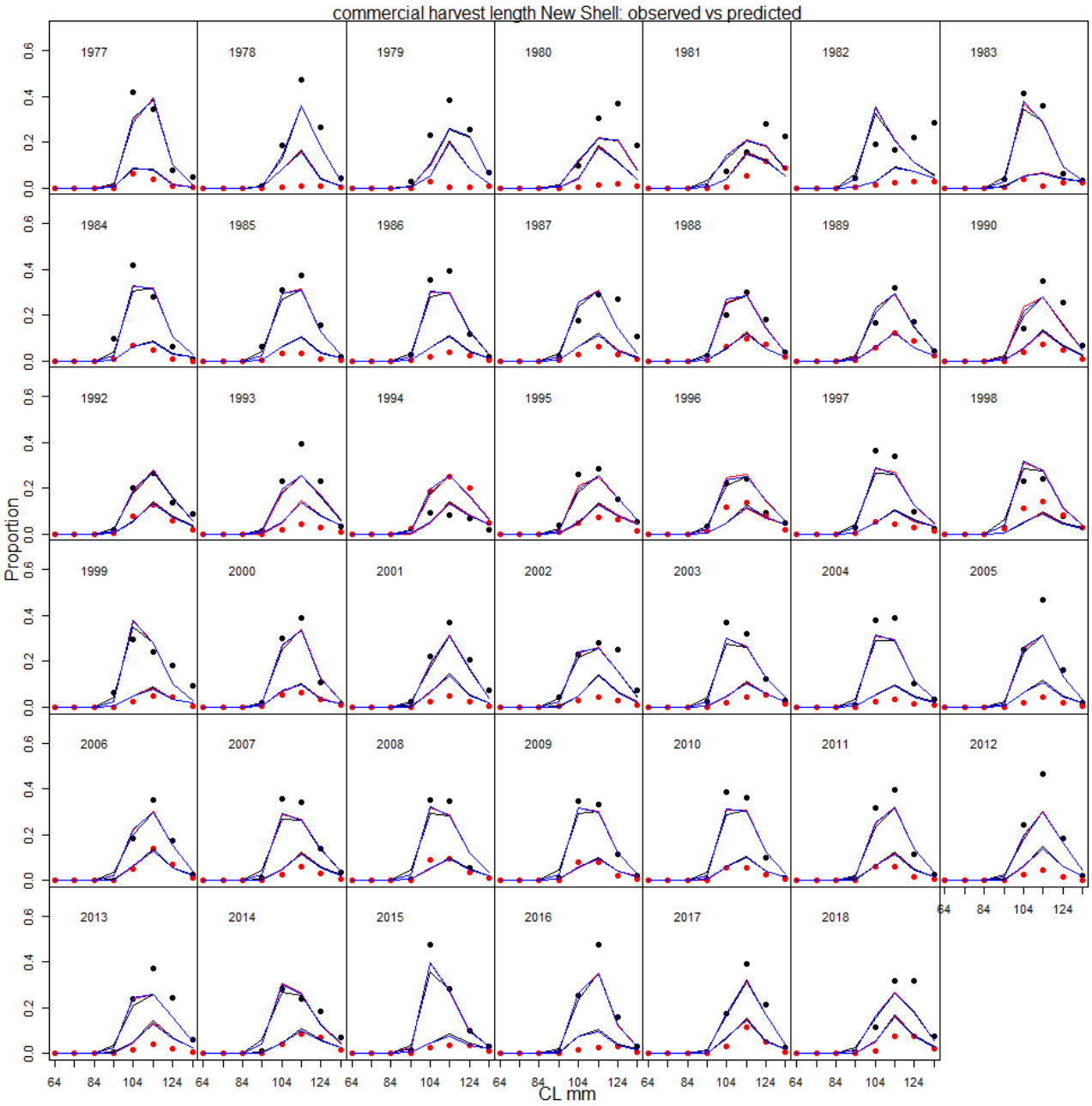


Figure 9. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for the summer commercial catch. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

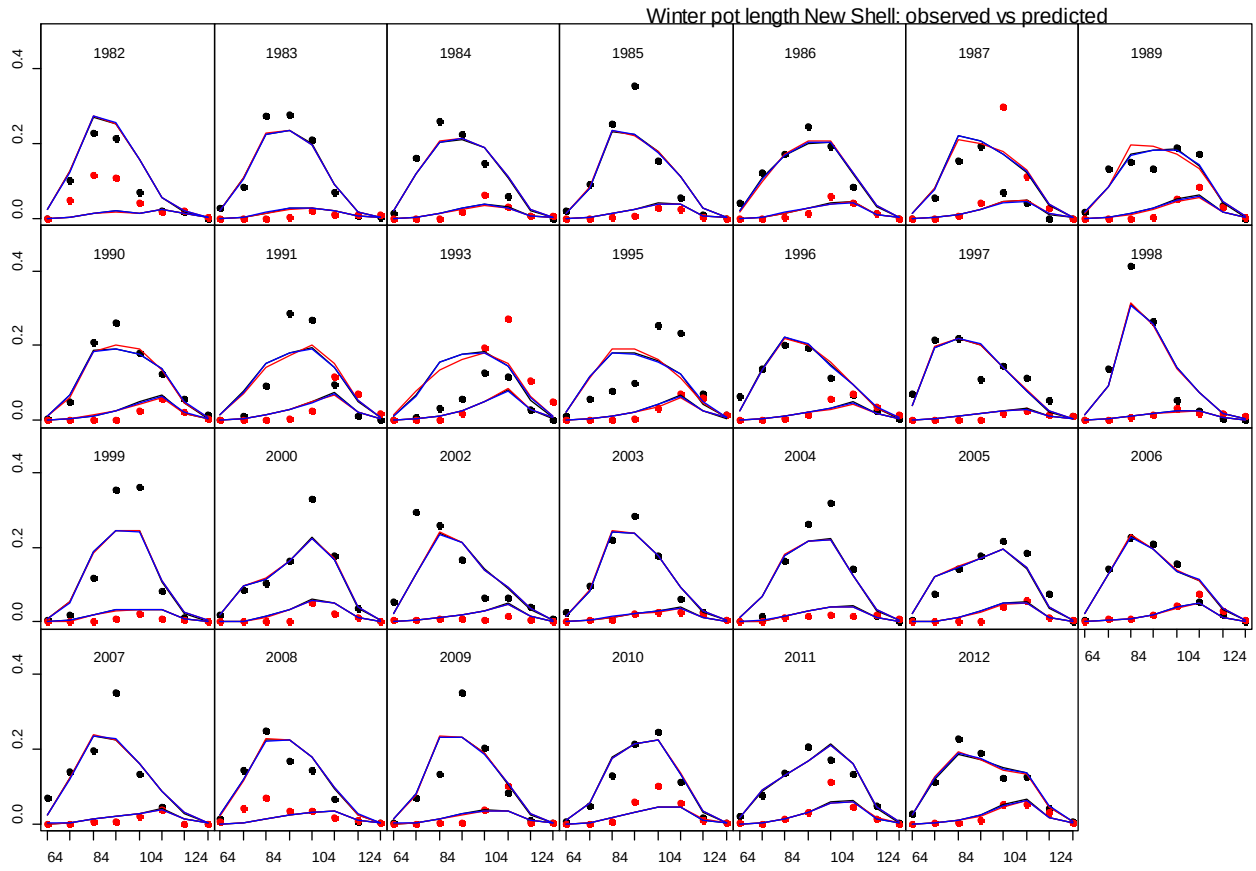


Figure 10. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for winter pot survey. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

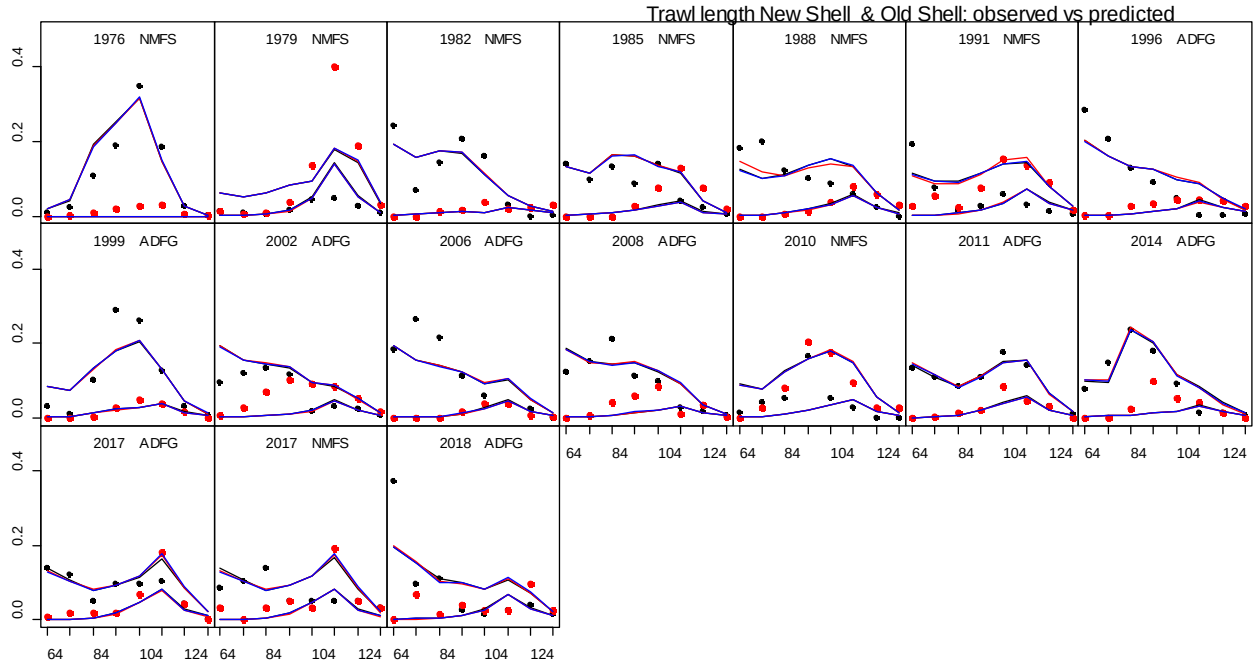
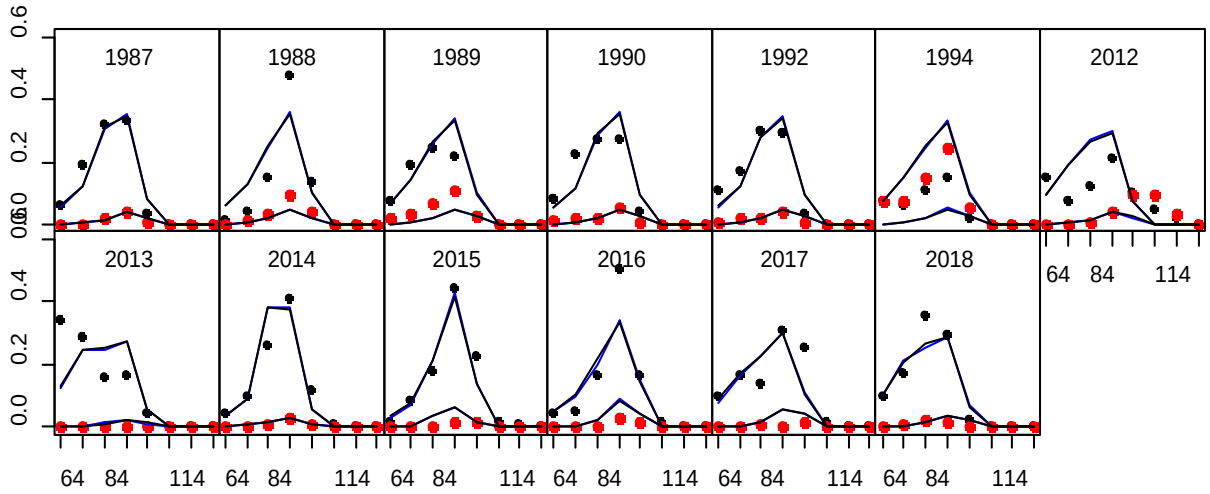


Figure 11. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for trawl survey. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

a



b

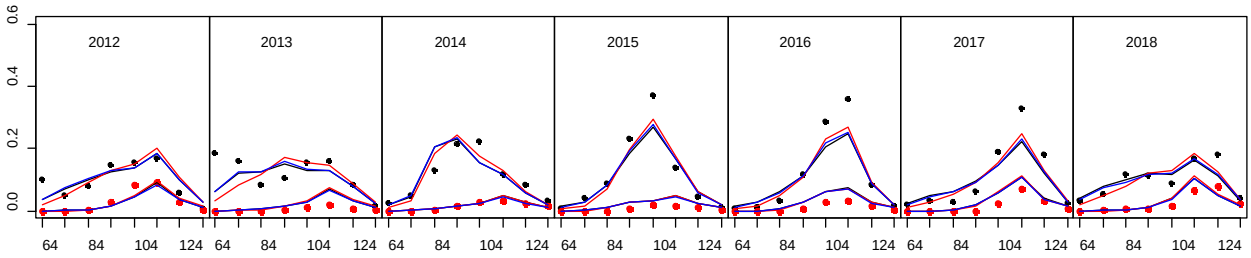


Figure 12 . Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for observer discard (a) and total catch (b) data. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

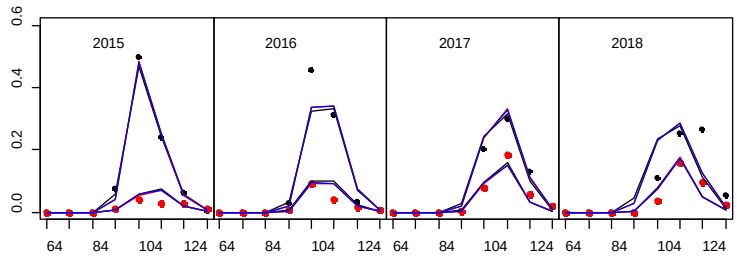


Figure 13. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for winter commercial retained catch data. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

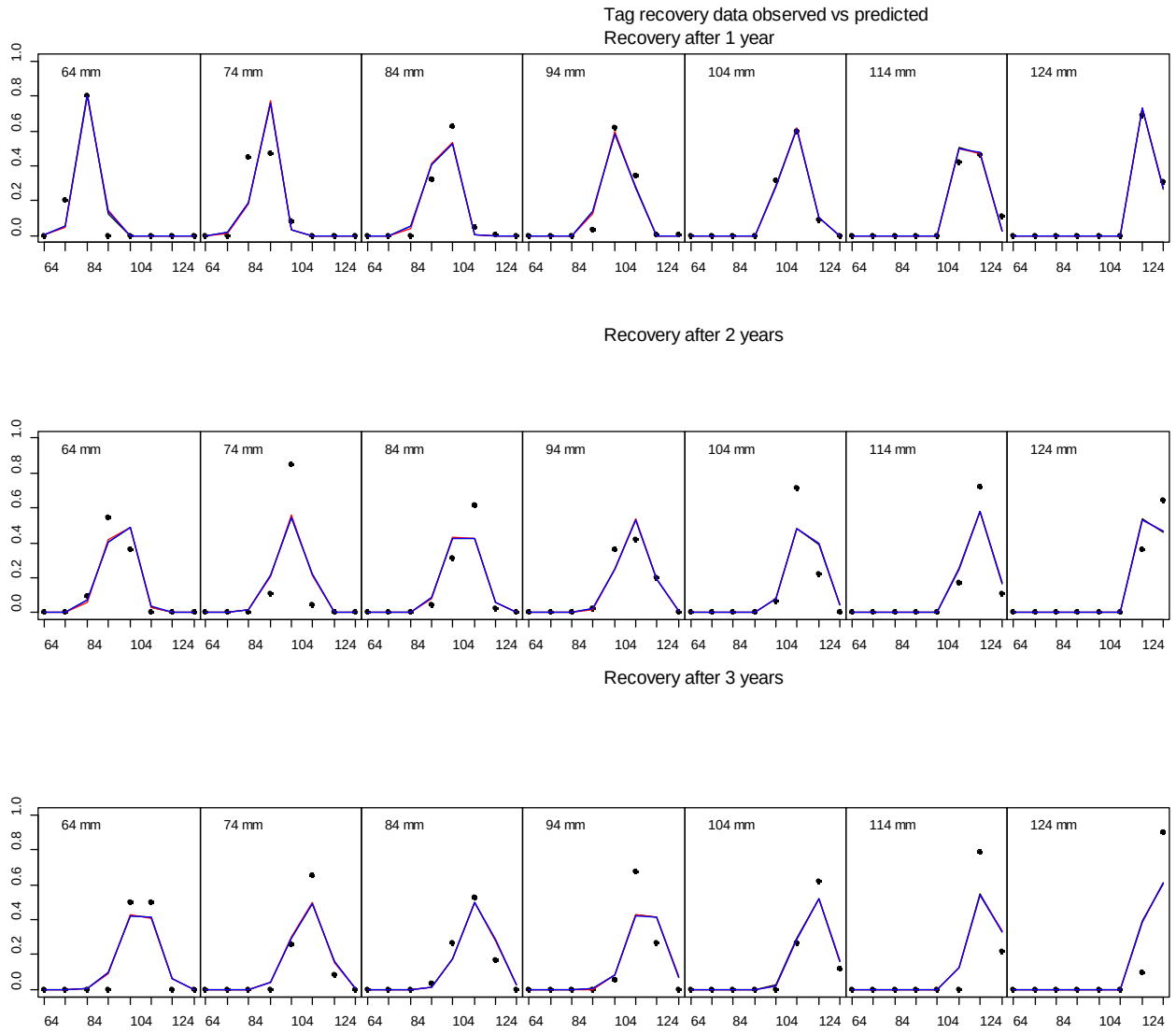


Figure 14. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions tag recovery data. Line colors black, red, and blue correspond to model 18.0, model 18.2a, and model 18.2b, respectively.

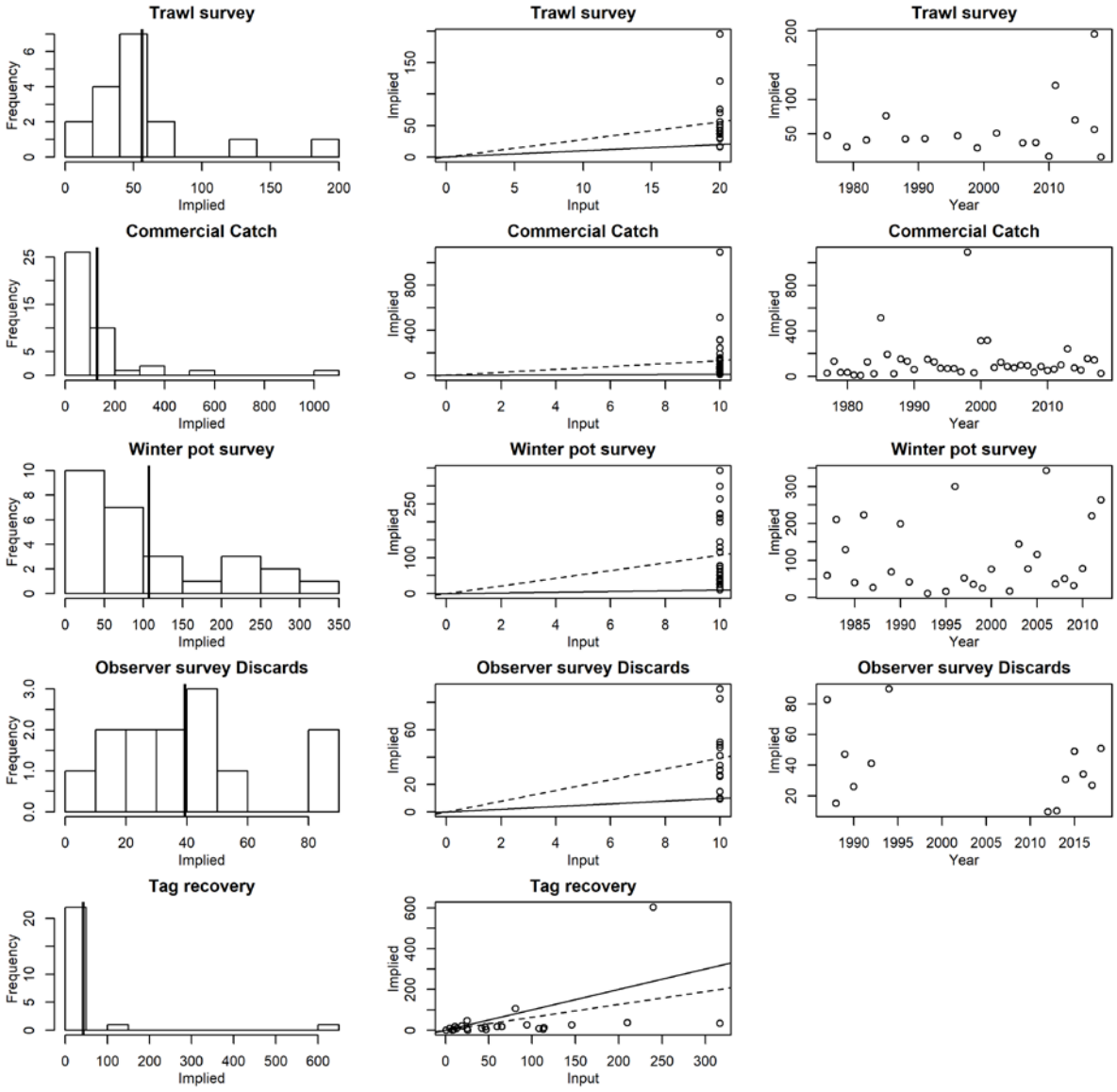


Figure 15. Input vs. model implied effective sample size. Figures in the first column show implied effective sample size (x-axis) vs. frequency (y-axis). Vertical solid line is the implied sample size. Figures in the second column show input sample sizes (x-axis) vs. implied effective sample sizes (y-axis). Dashed line indicates the linear regression slope, and solid line is 1:1 line. Figures in the third column show years (x-axis) vs. implied effective sample sizes (y-axis).

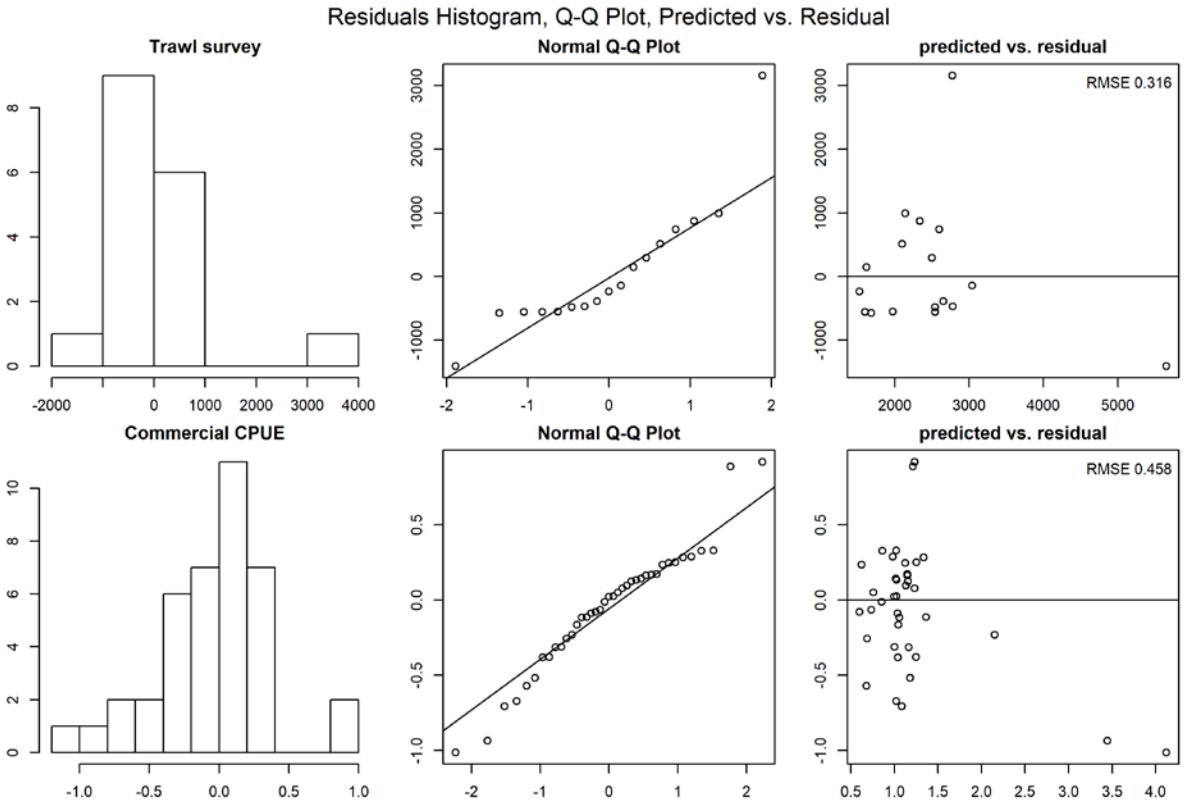
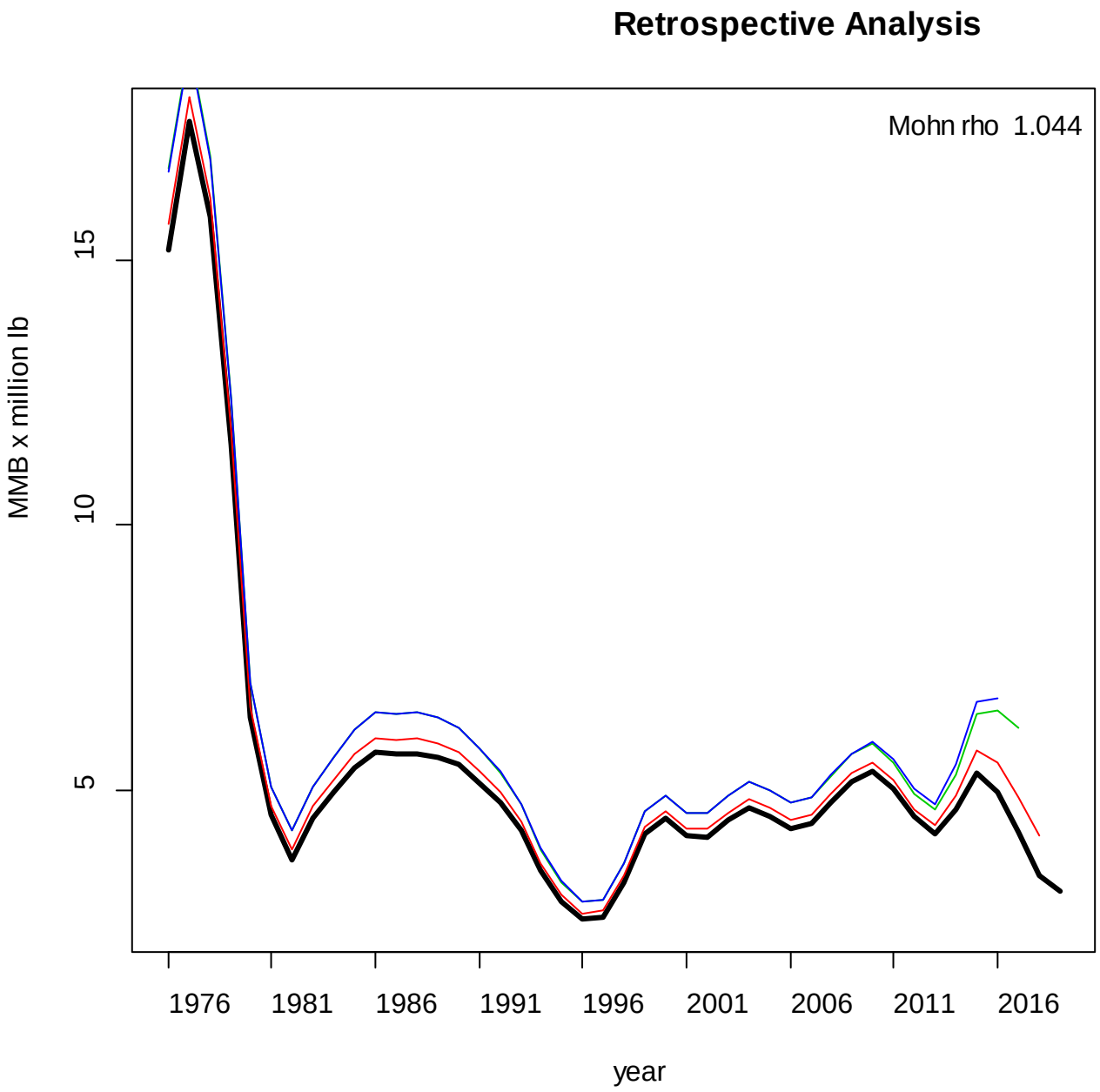


Figure 16. QQ plots of trawl survey abundance and commercial CPUE residuals.

Model 18.2a


Retrospective Analysis
Mohn rho 1.044
MMB x million lb
5
10
15
1976
1981
1986
1991
1996
2001
2006
2011
2016
year

Model 18.2b

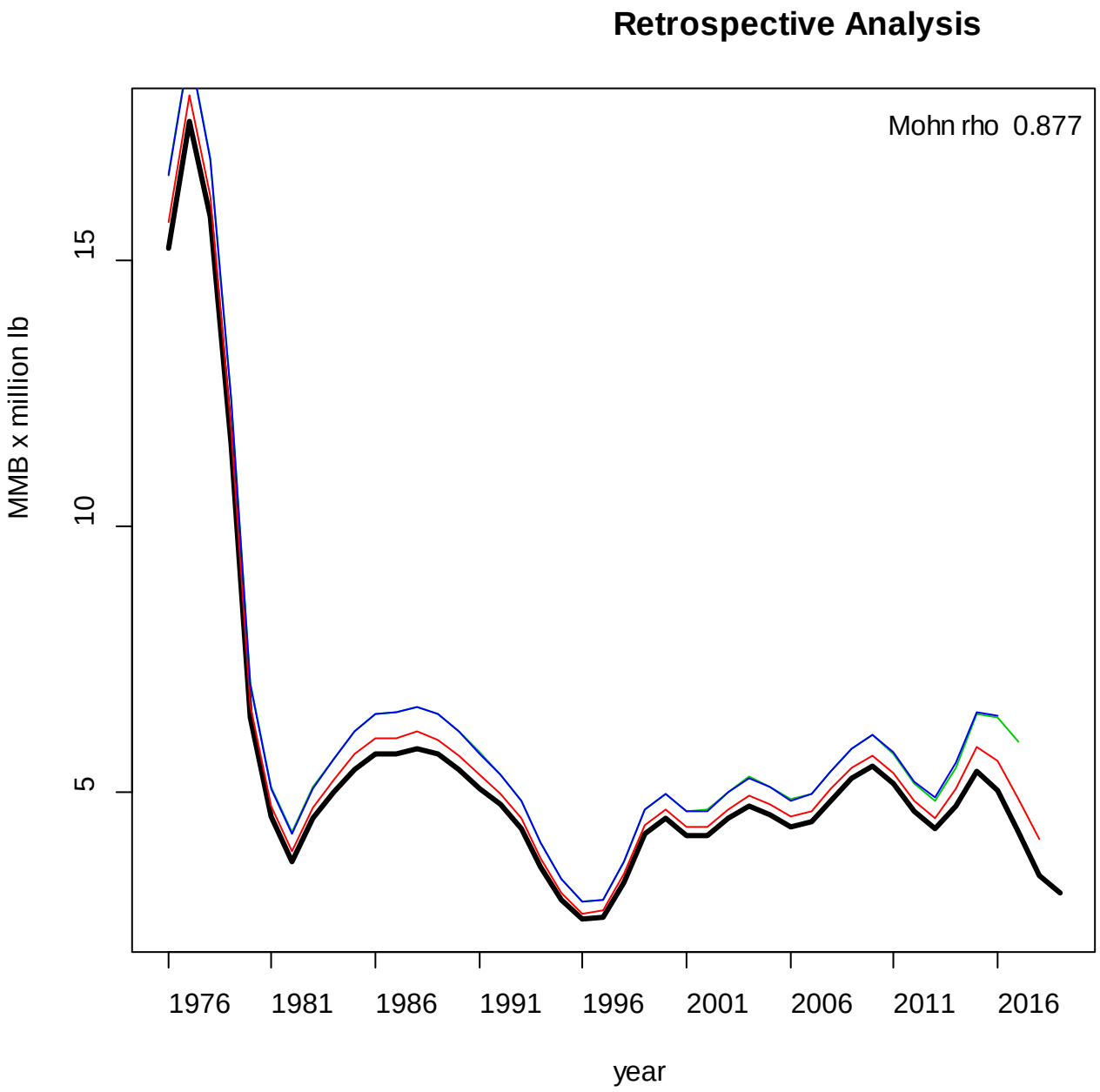


Figure 17. Retrospective analyses of model 18.2a and 18.2b. Each line shows a series of retrospective MMB.