# Norton Sound Red King Crab Stock Assessment for the fishing year 2020

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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, the Norton Sound Crab fishery operated as super exclusive. For the 2019 fishery season, Norton Sound Red King Crab harvest consisted of 1,050 crab (3,295 lb.) by winter commercial, 1,545 crab (3,100 lb) by winter subsistence, and 24,506 crab (75,023 lb) by summer commercial, totaling 27,099 crab (81,418 lb). Total harvests were below ABC of 0.19 million lb. The harvest decline was due to 1) late ice buildup preventing winter fisheries and 2) low catch CPUE and declined summer commercial fishery participation.

3. Stock Biomass. The Norton Sound Red King Crab stock has been monitored by triennial surveys since 1976 by NOAA (1976-1991) and ADF&G (1996-present), with survey catch ranged from 1.41 million to 5.9 million crab. In 2019, abundance by trawl survey by ADF&G was 4.66 million crab with a CV of 0.60, whereas the survey by NMFS was 2.43 million crab with a CV of 0.26. The difference is partially due to 1) ADF&G survey had high crab catch in one station, and 2) high crab catch of NMFS survey occurred outside of the standard survey area.

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 |
|---|---|---|---|---|---|---|---|
| 2016 | 2.26[A] | 5.87 | 0.52 | 0.51 | 0.52 | 0.71[A] | 0.57 |
| 2017 | 2.31[B] | 5.14 | 0.50 | 0.49 | 0.50 | 0.67[B] | 0.54 |
| 2018 | 2.41[C] | 4.08 | 0.30 | 0.31 | 0.34 | 0.43[C] | 0.35 |
| 2019 | 2.24[D] | 3.12 | 0.15 | 0.08 | 0.08 | 0.24[D] | 0.19 |
| 2020 | 2.28[E] | 3.67 | TBD | TBD | TBD | 0.29[E] | 0.22 |

*Status and catch specifications (1000t)*

| Year | MSST | Biomass (MMB) | GHL | Retained Commercial Catch | Total Retained Catch | Retained OFL | Retained ABC |
|---|---|---|---|---|---|---|---|
| 2016 | 1.03[A] | 2.66 | 0.24 | 0.23 | 0.24 | 0.32[A] | 0.26 |
| 2017 | 1.05[B] | 2.33 | 0.23 | 0.22 | 0.24 | 0.30[B] | 0.24 |
| 2018 | 1.09[C] | 1.85 | 0.13 | 0.14 | 0.15 | 0.20[C] | 0.16 |
| 2019 | 1.03[D] | 1.41 | 0.07 | 0.04 | 0.04 | 0.11[D] | 0.09 |
| 2020 | 1.04[E] | 1.66 | TBD | TBD | TBD | 0.13[E] | 0.10 |

Notes:
MSST was calculated as $B_{MSY}/2$
A-Calculated from the assessment reviewed by the Crab Plan Team in May 2016
B-Calculated from the assessment reviewed by the Crab Plan Team in May 2017
C-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2018
D-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2019
E-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2020

Conversion to Metric ton: 1 Metric ton (t) = 2.2046×1000 lb

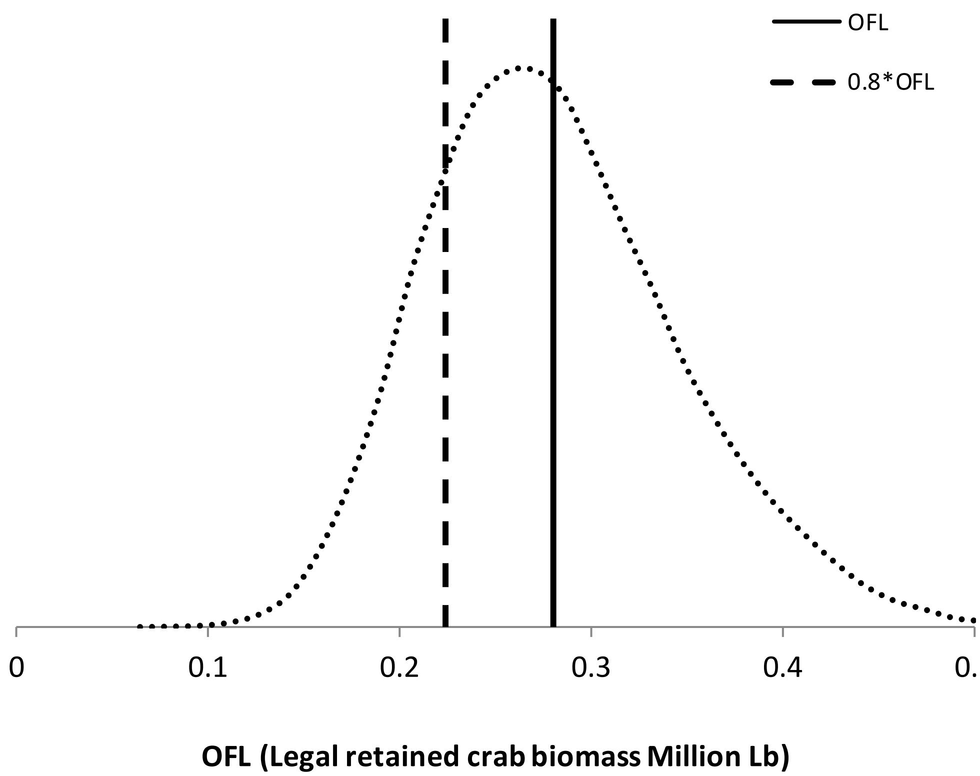
*Biomass in millions of pounds*

| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | M | 1-Buffer | Retained ABC |
|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 2020 | 4b | 4.56 | 3.66 | 0.8 | 0.14 | 1980-2020 | 0.18 | 0.75 | 0.22 |

*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 |
|---|---|---|---|---|---|---|---|---|---|
| 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 | 2.07 | 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 | 0.09 |
| 2020 | 4b | 2.07 | 1.66 | 0.8 | 0.14 | 1980-2020 | 0.18 | 0.75 | 0.10 |

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). In 2020, the buffer was increased to 25% (ABC = 75% OFL) over concern for low CPUE of 2018-2019.

8. A summary of the results of any rebuilding analysis

   N/A

## A. *Summary of Major Changes in 2019*

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

   None

2. Changes to the input data

   a. Data update:

      i. 1977-2019 standardized commercial catch CPUE and CV. Standardized CPUE was calculated for entire dataset, instead of separating two (1977-1993, 1994-2019) time periods.

      ii. Winter and Summer commercial fishery harvest, discards, and length composition data. Retained size composition data were not collected for 2019 winter commercial due to low harvest.

      iii. Tag recovery data 2019 (14 crab).

      iv. Trawl surveys: abundance, length-shell compositions:

      ADFG and NMFS 2019

3. Changes to the assessment methodology:

   None

4. Changes to the assessment results.

   Model estimated mature male biomass increased from 3.12 million lb. in 2019 to 3.73 million lb. in 2020. Estimated OFL also increased from 0.24 million lb. in 2019 to 0.29 million lb. in 2020.

## B. *Response to SSC and CPT Comments*

Crab Plan Team – January 23-25, 2019

- Continue to evaluate methods to improved ADF&G bottom trawl survey biomass estimation, including model based approaches such as VAST.

  Authors' reply: VAST modeling has been applied to historical trawl survey data. However, we were not able to generate estimates. **Authors request experts' instruction and assistance for implementation.**

- Conduct a sensitivity analysis to evaluate the effect of mark-recapture data by fitting the model only marks that are liberty for one year.

  Authors' reply:

  Alternative model:  19.1

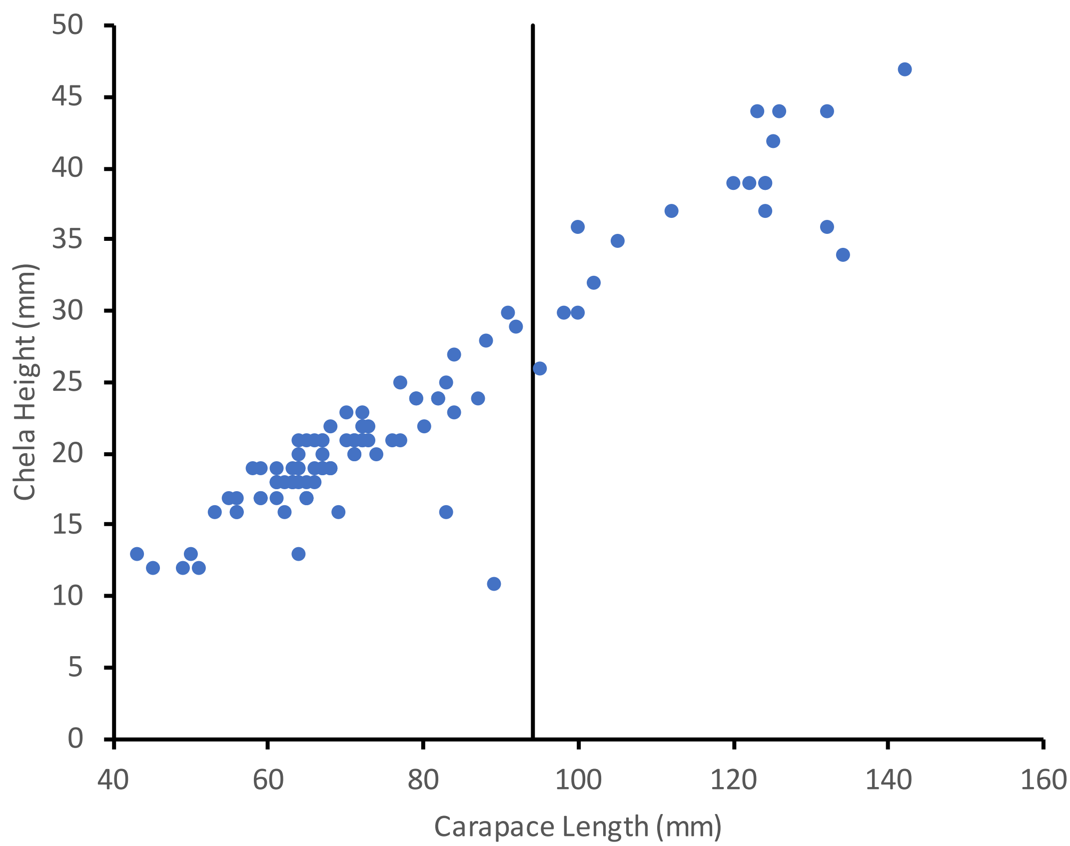
- Evaluate potential differences in survey Q between NOAA and ADFG bottom trawl surveys.

  Authors' reply:  Alternative model 19.2 and 19.3

- Collect more chela-carapace data, especially at the small size ranges, to improve the size at maturity estimate.

  Author's reply

  In 2019 97 male samples were collected during the annual bottom trawl survey.   No distinctive break point has been present.  Solid vertical line shows current cut-off length of 95mm.



SSC – February 4-6 2019

- The model choice does not have much impact on the results, or on the Tier 4 reference points, hence the focus for the stock assessment should be on the input data.

  Authors' reply:

  We fully concur. We are collecting more data as budget allows.

- Bring forward total catch OFLs and ABCs or provide rationale why the retained catch OFL and ABC are still more appropriate at this time.

  Authors' reply:

  Estimating total catch OFL requires estimating the number of discards in summer commercial fisheries. Thus far, no formal estimates of discards have not been established for NSRKC. See Appendix C for 2002-2018 preliminary discards estimates.

- Include options with an estimated constant M across size classes (including the largest class) and a dome-shaped selectivity for the summer commercial fishery and for the summer survey.

  Authors' reply: Alternative model 19.4 and 19.5

- Spatial distribution and modeling. a thorough examination of the spatial distribution of red king crab, in particular spatial differences in size composition, across the northern Bering Sea beyond Norton Sound would be helpful. Available data include the 2010 and 2017-2018 NMFS bottom trawl surveys.

  Authors' reply: We believe that this task is more appropriate for NMFS.

- Spatial modeling: Compare the ADF&G and NMFS surveys using appropriate methods for zero-inflated distributions, such as those offered in various R packages (e.g., pscl, gamlss, INLA, VAST, glmmfields).

  Author's reply:

  We are not familiar with those packages and spatial modeling, including intent of the comparison.

  It should also be noted that ADF&G and NMFS surveys are NOT "paired" (i.e., side-by-side survey). ADF&G and NMFS surveys differ in **survey protocols (e.g., tow distance), trawl gears, survey spatial extent and timing. Itis expected that the two surveys would differ in abundance and spatial distribution.** Changes of distribution and abundances between the two surveys may be due to different survey protocols, movement of crab.

- Survey time series: Explore using two catchability parameters for the differing time blocks of the survey time series shown in Figure 7 which uses a different length range after 1995 to compute the abundance index.

  Author's reply:

  The NMFS survey abundance prior to 1995 were provided by NMFS (NPFMC 2014) when NSRKC model was based on 74mm and above. When this was changed to 64mm and above survey abundances after 1995 were updated by the authors (NPFMC2016), but not for the pre-1995 NMFS surveys. This was because the assessment model was already estimating q (q ~ 0.7) for pre-1995 survey abundance. In this assessment, the pre-1995 survey abundance was updated to 64mm and above. We also included differences in abundance estimation methodologies between pre-1995 NMFS and post 1995 trawl surveys (Table 3). Combining with application of VAST, we will further explore improvement of trawl survey abundance.

- Local and traditional knowledge: Encourage through collaborations at the local level to consider these sources of knowledge

  Author's reply:

  **Authors request SSC and experts' instructions how to collaborate and incorporate local and traditional knowledge into assessment.**

- Male maturity: new maturity studies are clearly needed to improve the assessment. Explore Russian data on maturity if available. Also, the relationship between maturity and temperature across stocks should be explored for potential predictive capability for Norton Sound.

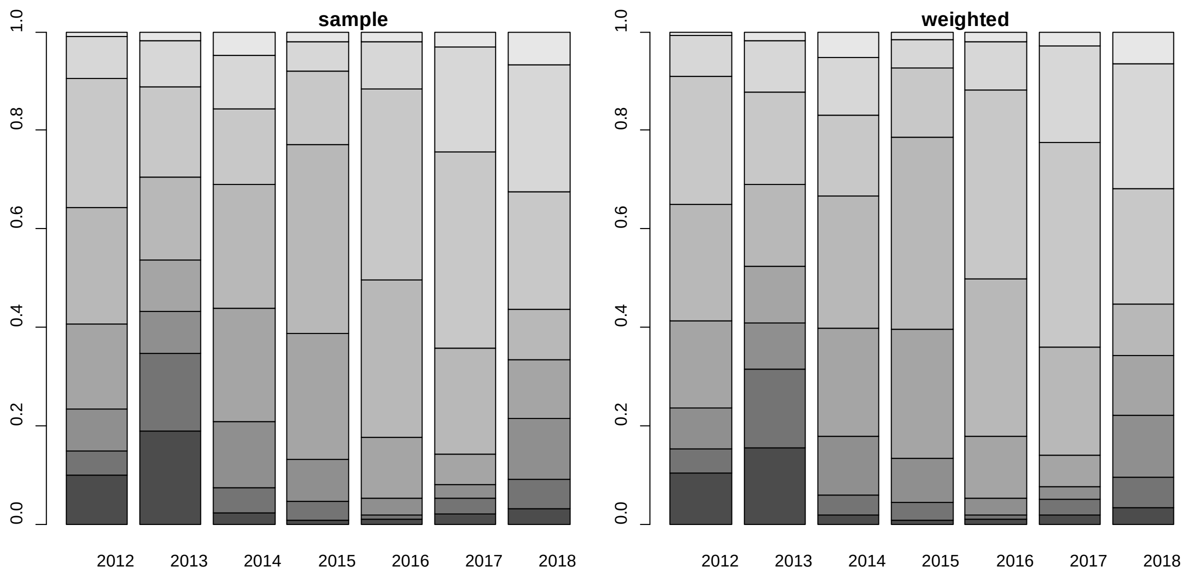
  Authors' reply:

  We are eager to incorporate SSC's suggestions on data weighting; however, we are not familiar with the dataset mentioned. **Authors request experts' instruction and assistance for implementation.**

- Consider estimating observer length composition weighted by catch/strata.

  Authors' reply:

  While weighted length composition is considered more accurate than simple unweighted one, there is little difference between the two.




- Consider data weighting based on iterative tuning, number of hauls, or other approaches.

  Authors' reply:

  Francis' (2011, 2017) iterative weighting was applied for size composition and tag recovery data. However, the calculated weights were greater than current model weights, and application of the weights resulted in lower fits trawl survey abundance data. The number of length classes (8) for NSRKC may also be too few to apply Francis' weighting (André Punt, personal communication).

- Include before/after variables in CPUE standardization to account for a change in commercially acceptable size limit. Clarify if the time series of CPUE is showing different measures of CPUE for the time periods prior to and after 1995.

  Authors' reply:

  In the original CPUE standardization, the CPUE data were separated in two periods: 1976-1992 and 1993-present, and two regressions were run. In this revision, we included time stage variables PD, 1976-1992, 1993-2014, 2015-present, and ran a single regression model. The PD variable turned out to be insignificant and was removed from the final regression model. Furthermore, this also increased model sd, so that model estimated additional variance (advar) became 0.

- Use revised Mohn's rho.

  Authors' reply:

  It was implemented for the final assessment. However, more fundamental note, CPT-SSC has not established standardized criterion for Mohn's rho (e.g., min-max rho value) for selection of the best alternative model, or an adjustment of predicted biomass or determination of OFL/ABC buffer (i.e., what to do when the Mohn's rho of the adopted model exceeded criteria?) The calculated Mohn.Rho of the CPT/SSC recommended model (19.0) based on retrospective analyses of past 4 years was 0.258. This exceeded, guideline range provided by Hurtado-Ferro et al. (2015), of -0.15 to 0.2 for longer lived and -0.22 to 0.30 for shorter lived species. If this is deemed concern, then the model may be rejected or other **Authors appreciate SSC's directive for potential application of revised Mohn's rho for improvement of the NSRKC assessment model.**

- Parameters $r_1$ and log-$phi_{st1}$ hitting bounds.

  Authors' reply:

  $r_1$ is a parameter for normalization for estimating proportion, pi = exp(ri)/[1+sum(exp(r))], (see equation 2 of Appendix A), so that hitting bounds is acceptable. log-$phi_{st1}$ is the trawl survey selectivity curve in log scale (see equation (16) Appendix A). Since trawl selectivity was estimated to be 1.0 across all lengths, hitting bound does not affect results of the assessment model. SSC (NPFMC 2017) suggested setting trawl survey selectivity to 1.0 for all length.

Crab Plan Team – April 29, 2019

- Draft assessment in GMACS will potentially be provided in September 2019.

  Authors' reply:

  We are eager to incorporate SSC's suggestions on data weighting and are working on implementation.

Crab Plan Team – Sept 16-20, 2019

SSC – Sept 30-Oct 2, 2019

- No additional requests.

## *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 167-168$^{o}$ W. longitude, depths less than 30 m, and summer bottom temperatures above 4$^{o}$C. 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) $^{o}$C 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.

   <u>Summer Commercial Fishery</u>

   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. CDQ harvest share is 7.5% of total projected harvest, which can be prosecuted in both summer and winter fisheries season.

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 crab during 1978-2009. From 2007 to 2015 the winter commercial catch increased from 3,000 crab 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.

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.

Note that harvest of both commercial and subsistence winter fisheries is influenced largely by availability of stable ice condition. Regardless of crab abundance, low harvest can occur due to poor ice condition.

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 the winter commercial fisheries:

1) Revised GHL to include summer and winter commercial fisheries.
2) Set guideline harvest level for the 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 $B_{\mathrm{MSY}}$.

NSRKC is a Tier 4 crab stock. Direct estimation of the $B_{\mathrm{MSY}}$ is not possible. The $B_{\mathrm{MSY}}$ 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. Since 2018 the stock has been under Tier 4b status.

## *D. Data*

1. Summary of new information:

Winter commercial and subsistence fisheries:

The winter commercial fishery catch in 2019 was 9,189 crab (20,118 lb.). Subsistence retained crab catch was 4,424 and unretained was 1,343 crab or 23 % of total catch (Table 2).

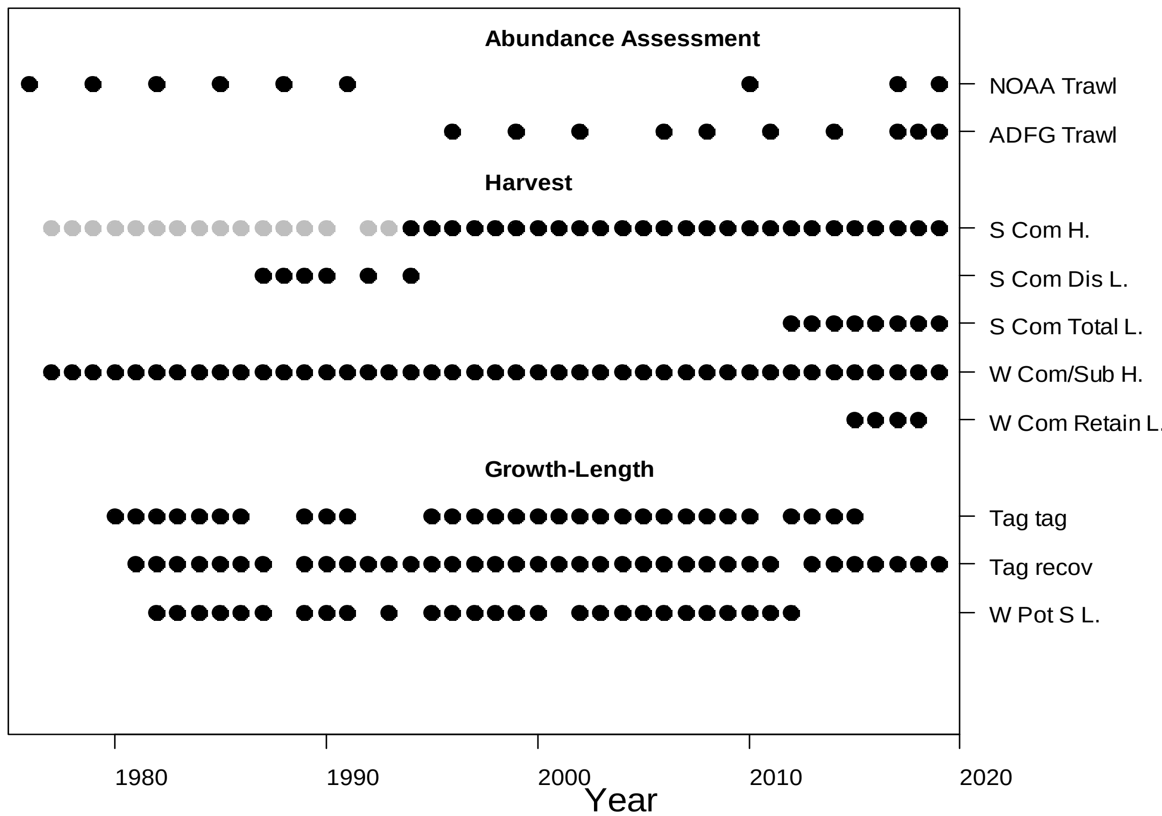
Summer commercial fishery:

The summer commercial fishery opened on 6/25/2019 and closed on 9/03/2019. Total of 75,023 crab (24,506 lb.) were harvested (Table 1). This is the lowest harvest since 2000.

Total retained harvest for 2019 season was 88,646 crab (34,811 lb. or 0.035 million lb) and did not exceed the 2019 ABC of 0.19 million lb.

Summer Trawl abundance survey by ADFG (7/22-7/29) was estimated to be 4.67 million (CV 60%) and that by NMFS (8/4-8/7) was 2.53 million (CV 26%) (Table 3). These discrepancies were also present in 2017 (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, 18,19 | Abundance<br>Length-shell comp | 3<br>6 |
| Winter pot survey | 81-87, 89-91,93,95-00,02-12 | Length-shell comp | 7 |
| Summer commercial fishery | 77-90,92-19 | Retained catch<br>Standardized CPUE,<br>Length-shell comp | 1<br>1<br>4 |
| Summer Com total catch | 12-19 | Length-shell comp | 9 |
| Summer Com Discards | 87-90,92,94 | Length-shell comp | 8 |
| Winter subsistence fishery | 76-19 | Total & Retained catch | 2 |
| Winter commercial fishery | 78-19 | Retained catch | 2 |
| | 15-18 | Retained Length-Shell | 5 |
| Tag recovery | 80-19 | 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 |

Catches in other fisheries

In Norton Sound, the directed Pacific Cod pot fishery was issued in 2018 under the CDQ permit. From 2015 to 2018 fishery seasons a total of 19 kg (12 ~ 14 crab) of NSRKC were taken from the groundfish fisheries (CPT 2019). This is small enough to ignore.

| | Fishery | Data availability |
|---|---|---|
| Other crab fisheries | Does not exist | NA |
| Groundfish pot | Pacific Cod | Y (Confidential) |
| 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:

   Proportions 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* = 0.18 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 crab were not caught/not surveyed/moved out of survey and fishing area) increased MMB twice 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 No model change requests
2019 (NPFMC 2019)
1) Fit total catch length composition and estimate retention probability for summer and winter commercial fishery.
2) Include winter commercial retained length data.

## 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, NSRKC modeling year 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 7-8. 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) fewer large crab 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 the 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 134mm. 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 1$^{st}$.

Winter commercial king crab pots can be any dimension (5AAC 34.925(d)). No length composition data exist for crab harvested in the winter commercial and 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, constant over time and 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 at the day when 50% of harvest occurred.

xii. Discards handling mortality rate for all fisheries is 20%.
No empirical estimates are available.

xiii. Annual retained catch is measured without error.

xiv. Retained catch of crabs are estimated by retained probability function.

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 2020 preliminary assessment, we explored all alternative modeling suggestions by CPT and SSC (See Authors' responses). The baseline model (Model 19.0) is Model 18.2b adopted for the 2019 assessment. Model 19.1 explores the effects of tagging data on molting and growth transition matrix. Models 19.2 and 19.3 reexamine validity of assumptions about trawl survey q set in 2013 (NPFMC 2013). Finally, Model 19.4 reexamines the assumption of size dependent mortality (i.e., higher *M* for larger crab) by estimating natural mortality and dome shape selectivity, which was examined in 2017 (NPFMC 2017). In 2017 model assessment, estimating size invariant M resulted in higher *M*, and dome shaped selectivity resulted in assuming large number of crab never observed and caught by the fisheries. Model 19.4-19.5 combines that two alternatives examined previously. The same selectivity for each size class as 2017 was estimated directly with selectivity of one size class assumed to be 1.0. Smoothing penalty was also included in likelihood.

In September 2019 draft assessment, we examined alternative models of
Model 19.0: Baseline: Model 18.2b
Model 19.1: Model 19.0 + Tag recovery data just for 1 year
Model 19.2: Model 19.0 + NOAA trawl survey Q =1.0, Est: ADFG survey Q
Model 19.3: Model 19.0 + Est survey Qs NOAA and ADFG
Model 19.4: Model 19.0 + Est *M* equal for all lengths + Dome shape selectivity for trawl and summer commercial (max sel 94-103 for trawl, 104-113 for com)
Model 19.5: Model 19.0 + Est *M* equal for all lengths + Dome shape selectivity for trawl and summer commercial (max sel 104-113 for trawl, 114-123 for com)

From those, CPT/SSC recommended Model 19.0 with final updated data for assessment in January 2020.

b. Evaluation of negative log-likelihood values with alternative models:

| | **Jan 2020** | Sept 2019 | | | | | |
|---|---|---|---|---|---|---|---|
| Model | **Model 19.0** | Model 19.0 | Model 19.1 | Model 19.2 | Model 19.3 | Model 19.4 | Model 19.5 |
| Additional Parameters | | | | | +1 | +14 | +14 |
| Total | 315.9 | 306.1 | 254.4 | 306.2 | 305.8 | 296.5 | 288.6 |
| TSA | 10.0 | 9.8 | 9.6 | 9.9 | 9.7 | 8.8 | 9.4 |
| St.CPUE | -24.1 | -24.1 | -24.1 | -24.1 | -23.8 | -23.2 | -23.2 |
| TLP | 115.3 | 110.8 | 109.7 | 110.5 | 110.6 | 108.4 | 105.4 |
| WLP | 38.5 | 39.0 | 39.6 | 38.6 | 38.8 | 41.4 | 42.5 |
| CLP | 49.3 | 48.4 | 48.9 | 48.3 | 48.3 | 54.1 | 50.2 |
| OBS | 24.8 | 20.4 | 19.9 | 20.3 | 20.4 | 19.4 | 20.2 |
| REC | 2.7 | 2.6 | 2.7 | 2.4 | 2.5 | 1.8 | 1.9 |
| WN | 17.8 | 18.1 | 18.3 | 18.1 | 18.1 | 18.8 | 18.8 |
| TAG | 81.5 | 81.2 | 30.0 | 81.2 | 81.2 | 65.0 | 61.8 |
| BMSY(mil.lb) | 4.58 | 4.66 | 4.70 | 3.40 | 4.00 | 6.72 | 5.13 |
| MMB(mil.lb) | 3.73 | 3.98 | 3.87 | 2.86 | 3.35 | 5.45 | 4.66 |
| Legal crab Catchable (mil.lb) | 2.43 | 2.53 | 2.46 | 1.78 | 2.10 | 2.37 | 2.18 |
| OFL(mil.lb) | 0.29 | 0.31 | 0.29 | 0.22 | 0.26 | 0.46 | 0.60 |
| NOAA q | 0.71 | 0.70 | 0.68 | 1 | 0.81 | 0.66 | 0.71 |
| ADFG q | 1 | 1 | 1 | 1.40 | 1.20 | 1 | 1 |
| M | 0.18/0.58 | 018/0.58 | 018/0.64 | 018/0.52 | 018/0.55 | 0.31 | 0.43 |

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

See Appendix C1-C3 for standard output figures and estimated parameters.

Search for balance:

SSC noted in 2019 that model choice does not have much impact on the results, or on the Tier 4 reference points, which was also true for the 2020 assessment. The only meaningful change occurs when we change assumptions about survey and fishery data selectivity and q, natural mortality, and fate of large crab, in other words, changing assumptions and understandings about biology of the NSRKC that are significantly lacking support.

Using only 1st year molting tagged crab (Model 19.0 vs. 19.1) resulted in slight changes in transition matrix (Table 14), and this did not improve model fit, MMB, and likelihood (Figure 4,8,9,11). Thus, including more than 1 years of recovery data appeared to have little effects on estimation of size transition matrix and the NSRKC assessment model. Estimating ADF&G survey q was greater than 1.0 (Models 19.2, 19.3), indicating that ADFG trawl survey overestimates NSRKC abundance (Figure 7). This lowered MMB and OFL from the baseline model (Figure 5). Assuming domed shape selectivity and estimating *M* (Model 19.4, 19.5) resulted in higher natural mortality and higher MMB (Figure 6), indicating that NSRKC having a greater natural mortality than assumed 0.18 and that larger crab exist in Norton Sound that have never been observed or caught by summer trawl survey or summer commercial fishery. Under the Tier 4 harvest control rule, a higher natural mortality results in a higher OFL (though they are lower than Tier 3 OFL (NPFMC 2019)).

Authors recommended Model 19.0 or 19.1 for final assessment. The question to decide between the two models are whether to include tag-recovery data of 2 and 3 years at liberty, given that the data had little/no influence on assessment model results. CPT recommended and authors concurred Model 19.0 with updated data for the final assessment for January 2020.

# 4. **Results**

1. List of effective sample sizes and weighting factors (Figure 15)

   "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 13).

c. Recruitment time series (Table 13).

d. Time series of catch/biomass (Tables 14).

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).

c. Model fits to catch and survey proportions by length (Figures 9-13).

d. Marginal distribution for the fits to the composition data.

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

f. RMSEs of trawl survey and standardized CPUE (Figure 17).

QQ plots and histograms of residuals of trawl survey and standardized CPUE (Figure 17).

5. Retrospective analyses (Figure 18).

   Retrospective analyses was limited to past 4 years because winter commercial length data that was used to estimate retention curve was limited to 4 years of data.

| Year | Predicted MMB (x1000) | Hindcast MMB | Mohn.Rho |
|---|---|---|---|
| 2019 | 3038.92 | 2826.42 | 0.2935 |
| 2018 | 3951.35 | 3190.10 | 0.4161 |
| 2017 | 5662.02 | 4762.69 | 0.2386 |
| 2016 | 6160.35 | 5164.06 | 0.0822 |

   Revised Mohn.Rho 0.258

   Hurtado-Ferro et al. (2015), provided guideline of Mohn's rho exceeding the range of (-0.15 to 0.2) for longer life-history and (-0.22 to 0.30) for shorter lived species, should cause for concern.

6. Uncertainty and sensitivity analyses.

## *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 1980-2020.

**Estimated $B_{MSY}$ proxy is: 4.561 million lb / 2.07 k ton.**

Predicted mature male biomass in 2020 on February 01

**Mature male biomass: 3.664 (SE 0.452) million lb. or 2.07 (SE 0.305) k ton**

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

**Norton Sound red king crab stock status is Tier 4b,**

Where $F_{OFL}$ is calculated by

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

**$F_{OFL}$ of 0.141 for all length classes.**

1. 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 × fishery 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 $p = \dfrac{Legal\_B_w(1-\exp(-x\cdot F_{OFL}))}{OFL_r}$

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 the summer commercial pot fishery 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 2020, we specified $p$ = 0.16.

Legal male biomass catchable to fishery (Feb 01): 2.428 (SE 0.30) million lb or 1.101 k ton
**$OFL_r$ = 0.287 million lb. or 0.104 k ton**

## *G. Calculation of the ABC*

1. Specification of the probability distribution of the OFL.

Probability distribution of the OFL was derived using ADMB's 1 million MCMC.

In 2015 of ABC buffer of Norton Sound Red King Crab was set to 20%, and ABC is calculated as (1-ABC buffer)·OFL

In 2020, CPT recommended the buffer to 25% due to declined CPUE.

Retained ABC for legal male crab is 75% of OFL

**ABC = 0.215 million lb. or 0.098 k ton**

## *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. Bold type shows data that are used for the assessment model.**

| Year | Guideline Harvest Level (lb) [b] | Commercial Harvest (lb) [a, b] Open Access | CDQ | **Number Harvest** | Total Number (Open Access) Vessels | Permits | Landings | Total Pots Registered | Pulls | **ST CPUE CPUE** | **SD** | Season Length Days | Dates | **Mid-day from July** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1977** | [c] | 517.787 | | **195,877** | 7 | 7 | 13 | | 5,457 | **3.29** | **0.68** | 60 | [c] | **0.049** |
| **1978** | 3,000.000 | 2,091.961 | | **660,829** | 8 | 8 | 54 | | 10,817 | **4.68** | **0.65** | 60 | 6/07-8/15 | **0.142** |
| **1979** | 3,000.000 | 2,931.672 | | **970,962** | 34 | 34 | 76 | | 34,773 | **2.87** | **0.64** | 16 | 7/15-7/31 | **0.088** |
| **1980** | 1,000.000 | 1,186.596 | | **329,778** | 9 | 9 | 50 | | 11,199 | **3.07** | **0.65** | 16 | 7/15-7/31 | **0.066** |
| **1981** | 2,500.000 | 1,379.014 | | **376,313** | 36 | 36 | 108 | | 33,745 | **0.86** | **0.64** | 38 | 7/15-8/22 | **0.096** |
| **1982** | 500.000 | 228.921 | | **63,949** | 11 | 11 | 33 | | 11,230 | **0.2** | **0.62** | 23 | 8/09-9/01 | **0.151** |
| **1983** | 300.000 | 368.032 | | **132,205** | 23 | 23 | 26 | 3,583 | 11,195 | **0.9** | **0.65** | 3.8 | 8/01-8/05 | **0.096** |
| **\1984** | 400.000 | 387.427 | | **139,759** | 8 | 8 | 21 | 1,245 | 9,706 | **1.59** | **0.65** | 13.6 | 8/01-8/15 | **0.110** |
| **1985** | 450.000 | 427.011 | | **146,669** | 6 | 6 | 72 | 1,116 | 13,209 | **0.5** | **0.66** | 21.7 | 8/01-8/23 | **0.118** |
| **1986** | 420.000 | 479.463 | | **162,438** | 3 | 3 | | 578 | 4,284 | **1.74** | **0.7** | 13 | 8/01-8/25 | **0.153** |
| **1987** | 400.000 | 327.121 | | **103,338** | 9 | 9 | | 1,430 | 10,258 | **0.61** | **0.64** | 11 | 8/01-8/12 | **0.107** |
| **1988** | 200.000 | 236.688 | | **76,148** | 2 | 2 | | 360 | 2,350 | **2.36** | **0.86** | 9.9 | 8/01-8/11 | **0.110** |
| **1989** | 200.000 | 246.487 | | **79,116** | 10 | 10 | | 2,555 | 5,149 | **1.21** | **0.61** | 3 | 8/01-8/04 | **0.096** |
| **1990** | 200.000 | 192.831 | | **59,132** | 4 | 4 | | 1,388 | 3,172 | **1.08** | **0.68** | 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** | **0.6** | 2 | 8/01-8/03 | **0.093** |
| **1993** | 340.000 | 335.790 | | **115,913** | 14 | 20 | 208 | 560 | 7,063 | **0.9** | **0.35** | 52 | 7/01-8/28 | **0.093** |
| **1994** | 340.000 | 327.858 | | **108,824** | 34 | 52 | 407 | 1,360 | 11,729 | **0.81** | **0.34** | 31 | 7/01-7/31 | **0.044** |
| **1995** | 340.000 | 322.676 | | **105,967** | 48 | 81 | 665 | 1,900 | 18,782 | **0.42** | **0.34** | 67 | 7/01-9/05 | **0.093** |
| **1996** | 340.000 | 224.231 | | **74,752** | 41 | 50 | 264 | 1,640 | 10,453 | **0.51** | **0.34** | 57 | 7/01-9/03 | **0.101** |
| **1997** | 80.000 | 92.988 | | **32,606** | 13 | 15 | 100 | 520 | 2,982 | **0.84** | **0.35** | 44 | 7/01-8/13 | **0.074** |
| **1998** | 80.000 | 29.684 | 0.00 | **10,661** | 8 | 11 | 50 | 360 | 1,639 | **0.79** | **0.36** | 65 | 7/01-9/03 | **0.110** |
| **1999** | 80.000 | 23.553 | 0.00 | **8,734** | 10 | 9 | 53 | 360 | 1,630 | **0.92** | **0.36** | 66 | 7/01-9/04 | **0.104** |
| **2000** | 336.000 | 297.654 | 14.87 | **111,728** | 15 | 22 | 201 | 560 | 6,345 | **1.24** | **0.34** | 91 | 7/01- 9/29 | **0.126** |
| **2001** | 303.000 | 288.199 | 0 | **98,321** | 30 | 37 | 319 | 1,200 | 11,918 | **0.64** | **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 | **1.23** | **0.34** | 77 | 6/15-9/03 | **0.060** |
| **2003** | 253.000 | 253.284 | 13.923 | **93,638** | 25 | 43 | 236 | 960 | 8,494 | **0.85** | **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 | **1.27** | **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 | **1.19** | **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 | **1.31** | **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 | **1.02** | **0.34** | 52 | 6/15-8/17 | **0.036** |
| **2008** | 412.000 | 364.235 | 30.9 | **143,337** | 23 | 30 | 248 | 920 | 8,721 | **1.32** | **0.34** | 73 | 6/23-9/03 | **0.079** |
| **2009** | 375.000 | 369.462 | 28.125 | **143,485** | 22 | 27 | 359 | 920 | 11,934 | **0.84** | **0.34** | 98 | 6/15-9/20 | **0.090** |
| **2010** | 400.000 | 387.304 | 30 | **149,822** | 23 | 32 | 286 | 1,040 | 9,698 | **1.22** | **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 | **1.58** | **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 | **1.29** | **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 | **0.67** | **0.33** | 74 | 7/3-9/14 | **0.110** |
| **2014** | 382.800 | 360.860 | 28.148 | **129,657** | 52 | 33 | 309 | 1,560 | 10,127 | **1.12** | **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 | **1.45** | **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 | **1.27** | **0.34** | 25 | 6/27-7/21 | **0.025** |
| **2017** | 496,800 | 411,736 | 0 | **135,322** | 36 | 36 | 270 | 1,640 | 9,401 | **1.1** | **0.34** | 30 | 6/26-7/25 | **0.027** |
| **2018** | 319,400 | 298,396 | 0 | **89,613** | 34 | 34 | 256 | 1,400 | 8,797 | **0.64** | **0.34** | 35 | 6/24-7/29 | **0.030** |
| **2019** | 150,600 | 73,784 | 1,239 | **24,506** | 24 | 26 | 146 | 1,096 | 5,438 | **0.26** | **0.34** | 62 | 6/25-9/03 | **0.068** |

[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. Bold typed data are used for the assessment model.**

| | Commercial | | | | Subsistence | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Permits | | | Total Crab | |
| **Model Year** | Year[a] | # of Fishers | # of Crab Harvested | Winter[b] | Issued | Returned | Fished | Caught[c] | 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** |
| **2019** | 2019 | 6 | **1,050** | 2019 | 101 | 101 | 60 | **2,080** | **1,545** |

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 ≥64 mm | |
|---|---|---|---|---|---|---|---|---|
| Year | Dates | Survey Agency | Survey method | Total surveyed hauls | Stations w/ NSRKC | n mile$^2$ expaned | | CV |
| 1976 | 9/02 – 9/25 | NMFS | Trawl | 117 | 61 | 7600 | **4301.8** | **0.31** |
| 1979 | 7/26 - 8/05 | NMFS | Trawl | 115 | 33 | 7600 | **1457.4** | **0.22** |
| 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 | 57 | 46 | 7600 | **3548.9** | **0.25** |
| 1985 | 7/01 - 7/14 | ADFG | Pots | | | | 2320.4 | 0.083 |
| 1985 | 9/16 -10/01 | NMFS | Trawl | 78 | 58 | 7600 | **2424.9** | **0.26** |
| 1988 | 8/16 - 8/30 | NMFS | Trawl | 82 | 45 | 7600 | **2702.3** | **0.29** |
| 1991 | 8/22 - 8/30 | NMFS | Trawl | 51 | 38 | 7600 | **4049.1** | **0.40** |
| 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 | 6000 | **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 | 16 | 14 | 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 | 16 | 8 | 5841 | **1035.8** | **0.40** |
| 2018 | 7/22 - 7/29 | ADFG | Trawl | 60 | 34 | 6000 | **1108.9** | **0.25** |
| 2019 | 7/17-7/29 | ADFG | Trawl | 52 | 27 | 5221 | **4660.8** | **0.60** |
| 2019 | 8/04-8/07 | NMFS | Trawl | 16 | 10 | 5841 | **2532.4** | **0.30** |

Abundance of NMFS survey (1976-1991) was estimated by NMFS, multiplying the mean CPUE (# NRKC/NM$^2$) across all hauls (including re-tows) to a standard survey area (7600NM$^2$).
In contrast, abundance of ADFG (1996-2019) and NMFS (2010,2017) survey were estimated by ADFG by multiplying CPUE (# NRKC/NM$^2$) of each station to an area represented by the station (~100NM$^2$) and summing across all surveyed station (ADFG: 4700 – 5200NM$^2$. NOAA 5841 NM$^2$).

**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 |
| 2019 | 1136 | 0 | 0 | 0 | 0.01 | 0.32 | 0.23 | 0.13 | 0.03 | 0 | 0 | 0 | 0 | 0.02 | 0.10 | 0.14 | 0.03 |

**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 |
| 2019 | ADFG | 307 | 0.55 | 0.30 | 0.03 | 0 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0.01 | 0.02 | 0.01 | 0.02 | 0.03 | 0.01 |
| 2019 | NMFS | 135 | 0.36 | 0.30 | 0.08 | 0.04 | 0.01 | 0 | 0.01 | 0.01 | 0.04 | 0.01 | 0.04 | 0.02 | 0.01 | 0.01 | 0.04 | 0.01 |

**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 commercial 1987-1994 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 |

**Table 9. Summer commercial 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 |
| 2019 | 236 | 0.13 | 0.06 | 0.06 | 0.13 | 0.08 | 0.05 | 0.01 | 0.01 | 0 | 0 | 0.00 | 0.04 | 0.11 | 0.14 | 0.14 | 0.05 |

**Table 10. The number of tagged data released and recovered after 1 year (Y1) – 3 year (Y3) during 1980-1992 and 1993-2019 periods.**

| Release Length Class | Recap Length Class | 1980-1992 | | | | | 1993-2019 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Y1 | Y2 | Y3 | Y4 | Y5 | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 |
| 64 – 73 | 64 – 73 | | | | | | | | | | | |
| 64 – 73 | 74 - 83 | 1 | | | | | | | | | | |
| 64 – 73 | 84 - 93 | 1 | 1 | | | | 3 | | | | | |
| 64 – 73 | 94 - 103 | | | | | | | 5 | | | | |
| 64 – 73 | 104 – 113 | | | | 1 | | | 4 | 11 | 3 | 1 | 1 |
| 64 – 73 | 114 – 123 | | | | 1 | | | | 11 | 5 | 1 | |
| 64 – 73 | 124 – 133 | | | | | | | | | 1 | | 1 |
| 64 – 73 | 134+ | | | | | | | | | | 2 | |
| 74 - 83 | 74 - 83 | | | | | | | | | | | |
| 74 - 83 | 84 - 93 | | | | | | 21 | | | | | |
| 74 - 83 | 94 - 103 | | | | | | 22 | 12 | | | | |
| 74 - 83 | 104 – 113 | | 2 | | | | 4 | 94 | 19 | 4 | 1 | |
| 74 - 83 | 114 – 123 | | | 2 | | 2 | | 5 | 46 | 17 | 2 | 1 |
| 74 - 83 | 124 – 133 | | | | | | | | 6 | 11 | 3 | 2 |
| 74 - 83 | 134+ | | | | | | | | | 1 | | |
| 84 - 93 | 84 - 93 | | | | | | | | | | | |
| 84 - 93 | 94 - 103 | 5 | | | | | 42 | 5 | 2 | | | |
| 84 - 93 | 104 – 113 | 10 | 2 | | 1 | | 81 | 34 | 14 | 1 | | |
| 84 - 93 | 114 – 123 | | 1 | 1 | 1 | | 7 | 69 | 27 | 9 | 3 | |
| 84 - 93 | 124 – 133 | | | | 1 | 1 | 1 | 3 | 9 | 12 | 4 | |
| 84 - 93 | 134+ | | | | | | | | | 2 | 1 | |
| 94 - 103 | 94 - 103 | 3 | 1 | 1 | | | 7 | 2 | | | | |
| 94 - 103 | 104 – 113 | 31 | 1 | 3 | | | 165 | 33 | 2 | | | |
| 94 - 103 | 114 – 123 | 26 | | 1 | 1 | | 82 | 38 | 32 | 3 | | |
| 94 - 103 | 124 – 133 | 2 | | | | | | 19 | 13 | 5 | 1 | |
| 94 - 103 | 134+ | | | | | 1 | 1 | | | 1 | 1 | 1 |
| 104 – 113 | 104 – 113 | 16 | | | | | 59 | 7 | | | | |
| 104 – 113 | 114 – 123 | 34 | 13 | | | | 109 | 64 | 9 | 3 | 1 | |
| 104 – 113 | 124 – 133 | 7 | 6 | 3 | 1 | | 15 | 18 | 18 | 9 | 1 | |
| 104 – 113 | 134+ | | | | 1 | | | | 4 | 1 | 1 | 1 |
| 114 – 123 | 114 – 123 | 16 | 2 | | | | 72 | 9 | | | | |
| 114 – 123 | 124 – 133 | 26 | 9 | 1 | | | 72 | 38 | 10 | 1 | 1 | |
| 114 – 123 | 134+ | 5 | 1 | | 1 | | 19 | 6 | 3 | 4 | | |
| 124 – 133 | 124 – 133 | 15 | | | | | 41 | 9 | 1 | | | |
| 124 – 133 | 134+ | 10 | 4 | 2 | | | 15 | 12 | 7 | 1 | | |
| 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 | Est | sd | Lower | Upper |
|---|---|---|---|---|---|
| $log\_q_{1,2}$ | Commercial fishery catchability (1977-92, 1993-2017) | -6.768 | 0.110 | -20.5 | 20 |
| $log\_N_{76}$ | Initial abundance | 9.113 | 0.108 | 2.0 | 15.0 |
| $R_0$ | Mean Recruit | 6.462 | 0.081 | 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 | -2.682 | 0.089 | -5.0 | -1.0 |
| $log\_\beta$ | Inverse logistic molting parameter | 4.831 | 0.015 | 1.0 | 5.5 |
| $log\_\phi_{st1}$ | Logistic trawl selectivity parameter | -5.000 | 0.048 | -5.0 | 1.0 |
| $log\_\phi_{wa}$ | Inverse logistic winter pot selectivity parameter | -2.220 | 0.269 | -5.0 | 1.0 |
| $log\_\phi_{wb}$ | Inverse logistic winter pot selectivity parameter | 4.795 | 0.029 | 0.0 | 6.0 |
| $Sw_{1,2}$ | Winter pot selectivity of length class 1,2 | | | 0.1 | 1.0 |
| $log\_\phi_l$ | Logistic commercial catch selectivity parameter | -2.067 | 0.052 | -5.0 | 1.0 |
| log_acr | Logistic summer commercial retention selectivity parameter | -0.787 | 0.129 | -5.0 | 1.0 |
| log_bcr | Logistic summer commercial retention selectivity parameter | 4.646 | 0.008 | 0.0 | 6.0 |
| log_awr | Logistic winter commercial retention selectivity parameter | -0.954 | 0.536 | -5.0 | 1.0 |
| log_bwr | Logistic winter commercial retention selectivity parameter | 4.656 | 0.037 | 0.0 | 6.0 |
| $w^2_t$ | Additional variance for standard CPUE | 0.000 | 0.000 | 0.0 | 6.0 |
| ms | Natural mortality multipliers | 3.226 | 0.252 | 0.5 | 5.0 |
| q | Survey q for NMFS trawl 1976-91 | 0.710 | 0.114 | 0.1 | 1.0 |
| $\sigma$ | Growth transition sigma | 3.853 | 0.209 | 0.0 | 30.0 |
| $\beta_1$ | Growth transition mean | 12.196 | 0.704 | 0.0 | 20.0 |
| $\beta_2$ | Growth transition increment | 7.713 | 0.173 | 0.0 | 20.0 |

**Table 12. Estimated molting probability incorporated transition matrix.**

| 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 | 0.10 | 0.79 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| 74 - 83 | | 0.04 | 0.24 | 0.70 | 0.03 | 0.00 | 0.00 | 0.00 |
| 84 - 93 | | | 0.08 | 0.43 | 0.49 | 0.01 | 0.00 | 0.00 |
| 94 - 103 | | | | 0.15 | 0.58 | 0.26 | 0.00 | 0.00 |
| 104 - 113 | | | | | 0.29 | 0.61 | 0.10 | 0.00 |
| 114 - 123 | | | | | | 0.50 | 0.47 | 0.03 |
| 124 - 133 | | | | | | | 0.72 | 0.28 |
| 134+ | | | | | | | | 1.00 |

**Table 13. 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.**

| | Abundance | | | Legal (≥ 104mm) | | MMB |
|---|---|---|---|---|---|---|
| Year | Recruits (<94mm) | Total | Mature (≥ 94mm) | Abundance | Biomass | Biomass |
| 1976 | 2.61 | 9.07 | 6.46 | 4.14 | 11.03 | 15.39 |
| 1977 | 1.07 | 7.97 | 6.90 | 5.43 | 15.54 | 18.35 |
| 1978 | 0.77 | 6.41 | 5.64 | 5.01 | 15.51 | 16.74 |
| 1979 | 0.55 | 4.50 | 3.95 | 3.58 | 11.72 | 12.42 |
| 1980 | 1.10 | 3.33 | 2.23 | 1.99 | 6.68 | 7.13 |
| 1981 | 1.59 | 3.25 | 1.66 | 1.31 | 4.43 | 5.07 |
| 1982 | 1.69 | 3.21 | 1.52 | 0.99 | 3.07 | 4.04 |
| 1983 | 1.66 | 3.51 | 1.85 | 1.23 | 3.63 | 4.78 |
| 1984 | 1.71 | 3.76 | 2.05 | 1.43 | 4.17 | 5.34 |
| 1985 | 1.38 | 3.59 | 2.20 | 1.57 | 4.63 | 5.81 |
| 1986 | 1.34 | 3.58 | 2.23 | 1.67 | 4.99 | 6.05 |
| 1987 | 1.15 | 3.28 | 2.13 | 1.62 | 4.94 | 5.89 |
| 1988 | 1.06 | 3.13 | 2.07 | 1.60 | 4.93 | 5.80 |
| 1989 | 1.10 | 3.05 | 1.95 | 1.54 | 4.79 | 5.57 |
| 1990 | 0.92 | 2.78 | 1.86 | 1.45 | 4.54 | 5.32 |
| 1991 | 0.82 | 2.58 | 1.76 | 1.39 | 4.36 | 5.06 |
| 1992 | 0.72 | 2.38 | 1.66 | 1.33 | 4.21 | 4.83 |
| 1993 | 0.58 | 2.10 | 1.52 | 1.23 | 3.93 | 4.47 |
| 1994 | 0.55 | 1.84 | 1.29 | 1.05 | 3.35 | 3.79 |
| 1995 | 0.65 | 1.73 | 1.08 | 0.87 | 2.77 | 3.17 |
| 1996 | 0.85 | 1.81 | 0.96 | 0.73 | 2.30 | 2.73 |
| 1997 | 1.52 | 2.51 | 1.00 | 0.70 | 2.16 | 2.71 |
| 1998 | 1.30 | 2.61 | 1.31 | 0.82 | 2.43 | 3.34 |
| 1999 | 0.75 | 2.42 | 1.66 | 1.15 | 3.32 | 4.29 |
| 2000 | 0.81 | 2.49 | 1.67 | 1.32 | 3.94 | 4.61 |
| 2001 | 1.17 | 2.66 | 1.49 | 1.19 | 3.69 | 4.26 |
| 2002 | 1.35 | 2.85 | 1.50 | 1.10 | 3.43 | 4.18 |
| 2003 | 1.11 | 2.74 | 1.64 | 1.15 | 3.50 | 4.40 |
| 2004 | 0.83 | 2.52 | 1.69 | 1.24 | 3.73 | 4.56 |
| 2005 | 1.13 | 2.70 | 1.57 | 1.22 | 3.72 | 4.37 |
| 2006 | 1.45 | 2.94 | 1.50 | 1.11 | 3.41 | 4.14 |
| 2007 | 1.60 | 3.21 | 1.61 | 1.10 | 3.33 | 4.26 |
| 2008 | 1.63 | 3.45 | 1.82 | 1.24 | 3.66 | 4.73 |
| 2009 | 1.28 | 3.27 | 1.98 | 1.38 | 4.05 | 5.18 |
| 2010 | 0.85 | 2.87 | 2.02 | 1.50 | 4.44 | 5.42 |
| 2011 | 0.92 | 2.75 | 1.83 | 1.45 | 4.42 | 5.12 |
| 2012 | 1.17 | 2.79 | 1.62 | 1.27 | 3.97 | 4.61 |
| 2013 | 1.98 | 3.52 | 1.54 | 1.13 | 3.50 | 4.26 |
| 2014 | 1.40 | 3.17 | 1.77 | 1.13 | 3.41 | 4.59 |
| 2015 | 0.67 | 2.67 | 2.00 | 1.41 | 4.08 | 5.19 |
| 2016 | 0.48 | 2.20 | 1.72 | 1.39 | 4.16 | 4.79 |
| 2017 | 0.55 | 1.91 | 1.36 | 1.15 | 3.61 | 4.01 |
| 2018 | 0.74 | 1.83 | 1.08 | 0.88 | 2.84 | 3.21 |
| 2019 | 2.31 | 3.32 | 1.00 | 0.75 | 2.38 | 2.85 |

**Table 14. 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 | 0.022 | 0 | 0.000 | 0.542 | 0.035 |
| 1978 | 2.09 | 0.024 | 0.025 | 0.040 | 0.008 | 0.001 | 2.188 | 0.141 |
| 1979 | 2.93 | 0.001 | 0.000 | 0.049 | 0 | 0.000 | 2.98 | 0.254 |
| 1980 | 1.19 | 0.000 | 0.000 | 0.024 | 0 | 0.000 | 1.214 | 0.182 |
| 1981 | 1.38 | 0.000 | 0.001 | 0.067 | 0 | 0.000 | 1.448 | 0.327 |
| 1982 | 0.23 | 0.000 | 0.003 | 0.020 | 0.001 | 0.000 | 0.254 | 0.083 |
| 1983 | 0.37 | 0.001 | 0.021 | 0.036 | 0.006 | 0.000 | 0.434 | 0.119 |
| 1984 | 0.39 | 0.002 | 0.022 | 0.033 | 0.005 | 0.000 | 0.452 | 0.108 |
| 1985 | 0.43 | 0.003 | 0.017 | 0.032 | 0.002 | 0.000 | 0.484 | 0.105 |
| 1986 | 0.48 | 0.005 | 0.014 | 0.028 | 0.004 | 0.001 | 0.532 | 0.107 |
| 1987 | 0.33 | 0.003 | 0.012 | 0.018 | 0.002 | 0.000 | 0.365 | 0.074 |
| 1988 | 0.24 | 0.001 | 0.005 | 0.012 | 0.001 | 0.000 | 0.259 | 0.053 |
| 1989 | 0.25 | 0.000 | 0.012 | 0.012 | 0.002 | 0.000 | 0.276 | 0.058 |
| 1990 | 0.19 | 0.010 | 0.024 | 0.009 | 0.004 | 0.001 | 0.238 | 0.052 |
| 1991 | 0 | 0.010 | 0.015 | 0.000 | 0.002 | 0.001 | 0.028 | 0.006 |
| 1992 | 0.07 | 0.021 | 0.023 | 0.003 | 0.003 | 0.002 | 0.122 | 0.029 |
| 1993 | 0.33 | 0.005 | 0.002 | 0.014 | 0 | 0.000 | 0.351 | 0.089 |
| 1994 | 0.32 | 0.017 | 0.008 | 0.013 | 0.001 | 0.001 | 0.36 | 0.108 |
| 1995 | 0.32 | 0.022 | 0.011 | 0.015 | 0.002 | 0.002 | 0.372 | 0.134 |
| 1996 | 0.22 | 0.005 | 0.003 | 0.014 | 0.001 | 0.001 | 0.244 | 0.106 |
| 1997 | 0.09 | 0.000 | 0.001 | 0.009 | 0.001 | 0.000 | 0.101 | 0.047 |
| 1998 | 0.03 | 0.002 | 0.017 | 0.004 | 0.012 | 0.001 | 0.066 | 0.027 |
| 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 | 0.086 |
| 2001 | 0.28 | 0.003 | 0.001 | 0.015 | 0 | 0.000 | 0.299 | 0.081 |
| 2002 | 0.25 | 0.007 | 0.004 | 0.019 | 0.003 | 0.001 | 0.284 | 0.083 |
| 2003 | 0.26 | 0.017 | 0.008 | 0.021 | 0.005 | 0.002 | 0.313 | 0.090 |
| 2004 | 0.34 | 0.001 | 0.002 | 0.022 | 0.001 | 0.000 | 0.366 | 0.098 |
| 2005 | 0.4 | 0.006 | 0.008 | 0.022 | 0.003 | 0.001 | 0.44 | 0.118 |
| 2006 | 0.45 | 0.000 | 0.002 | 0.032 | 0.001 | 0.000 | 0.485 | 0.142 |
| 2007 | 0.31 | 0.008 | 0.021 | 0.029 | 0.011 | 0.001 | 0.38 | 0.114 |
| 2008 | 0.39 | 0.015 | 0.019 | 0.037 | 0.009 | 0.002 | 0.472 | 0.129 |
| 2009 | 0.4 | 0.012 | 0.010 | 0.033 | 0.002 | 0.002 | 0.459 | 0.113 |
| 2010 | 0.42 | 0.012 | 0.014 | 0.026 | 0.002 | 0.001 | 0.475 | 0.107 |
| 2011 | 0.4 | 0.009 | 0.013 | 0.019 | 0.003 | 0.001 | 0.445 | 0.101 |
| 2012 | 0.47 | 0.025 | 0.015 | 0.026 | 0.004 | 0.002 | 0.542 | 0.137 |
| 2013 | 0.35 | 0.061 | 0.015 | 0.031 | 0.014 | 0.009 | 0.48 | 0.137 |
| 2014 | 0.39 | 0.035 | 0.007 | 0.042 | 0.002 | 0.007 | 0.483 | 0.142 |
| 2015 | 0.40 | 0.099 | 0.019 | 0.028 | 0.005 | 0.010 | 0.561 | 0.138 |
| 2016 | 0.42 | 0.080 | 0.011 | 0.016 | 0.001 | 0.005 | 0.533 | 0.128 |
| 2017 | 0.41 | 0.078 | 0.012 | 0.013 | 0.001 | 0.004 | 0.518 | 0.143 |
| 2018 | 0.30 | 0.029 | 0.008 | 0.012 | 0.001 | 0.002 | 0.352 | 0.124 |
| 2019 | 0.08 | 0.032 | 0.003 | 0.006 | 0.001 | 0.006 | 0.128 | 0.054 |

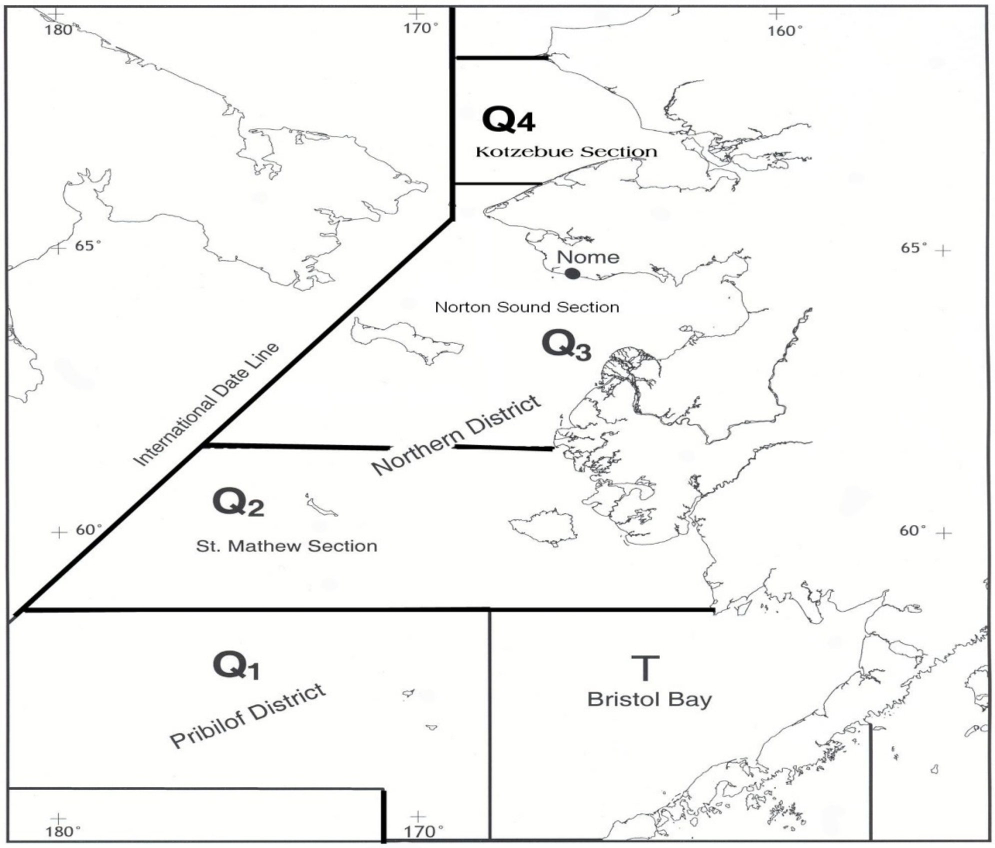



Figure 1. King crab fishing districts and sections of Statistical Area Q.

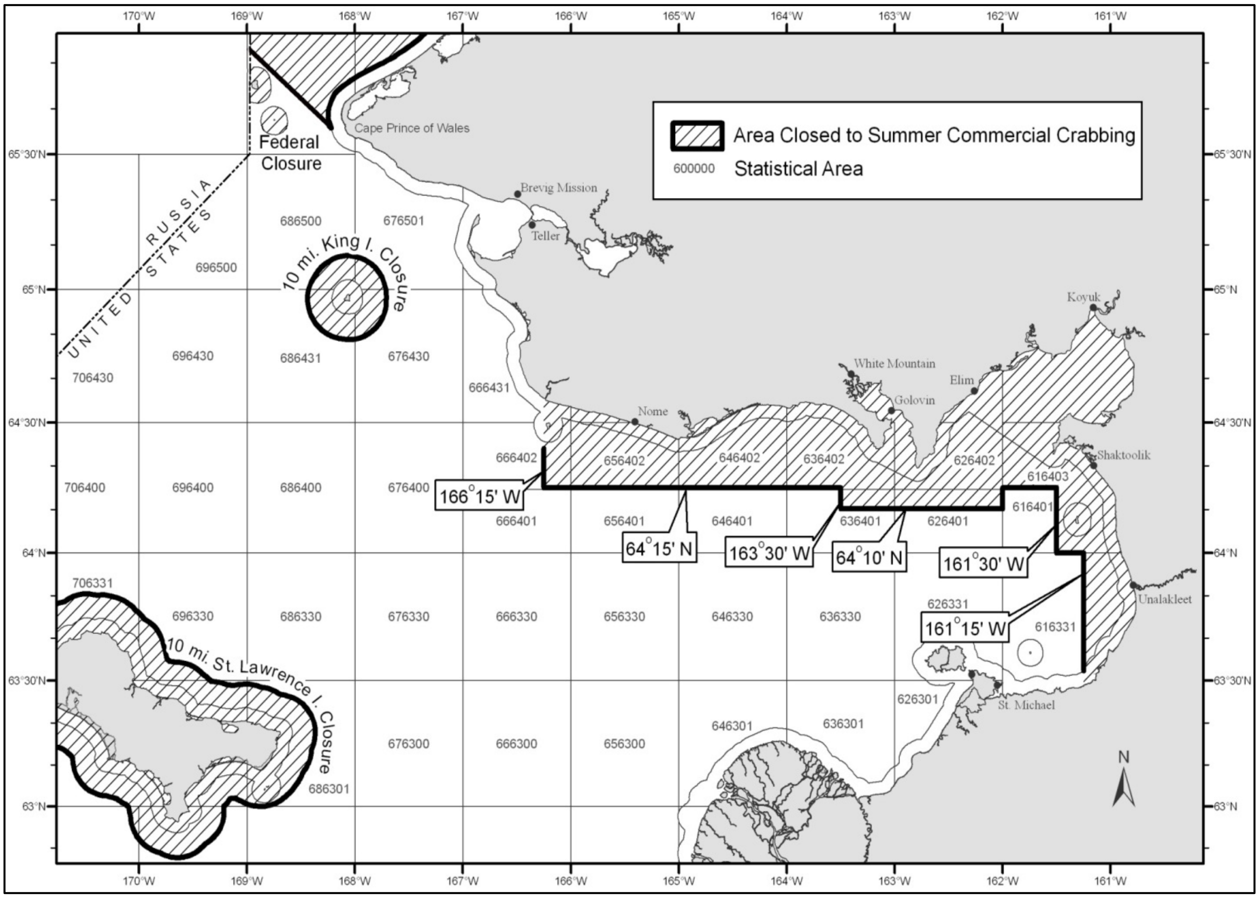



Figure 2. Closed water regulations in effect for the Norton Sound commercial crab fishery. Line around the coastline delineates the 3-mil3 state waters zone.

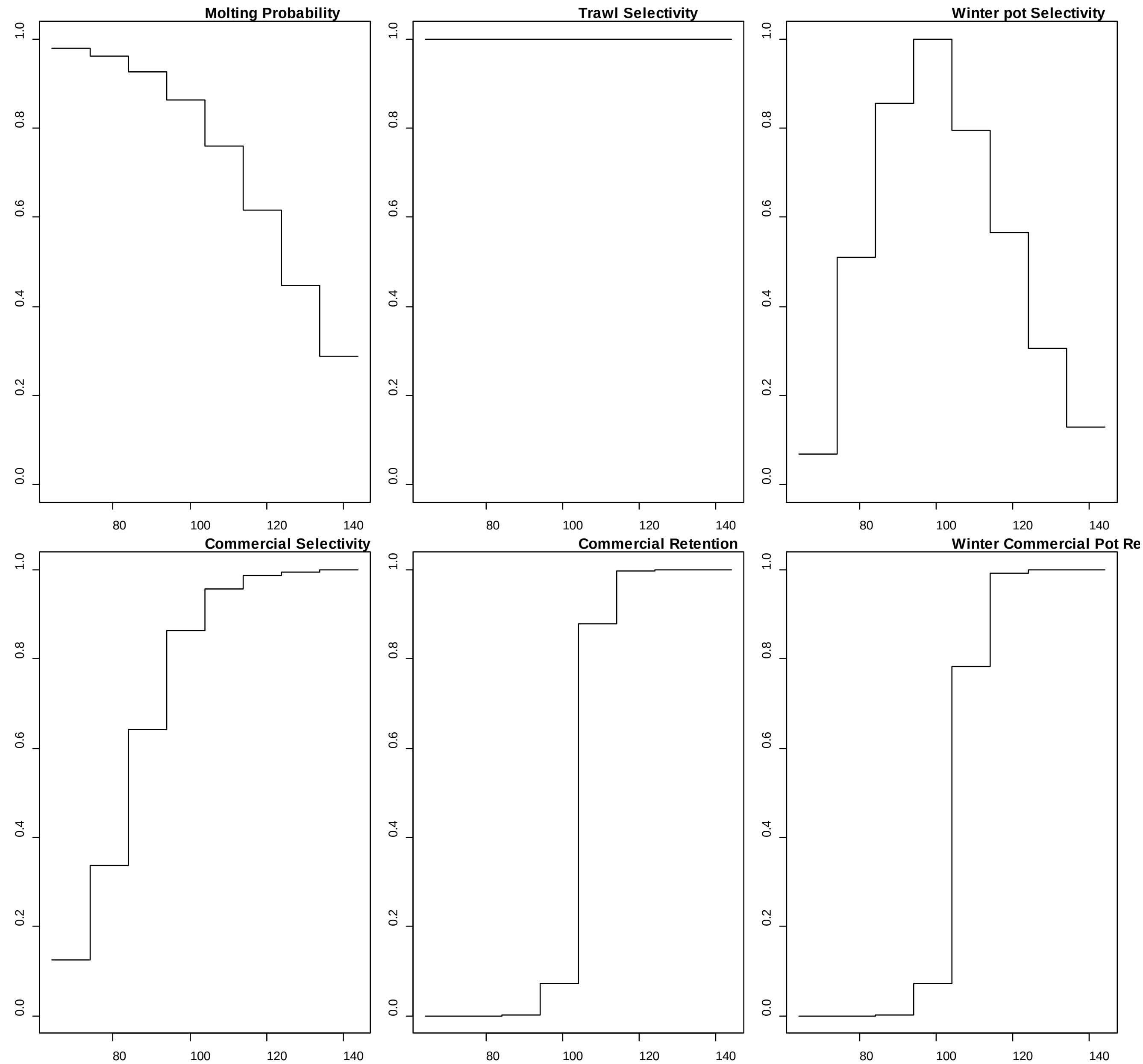



Figure 3. Model estimated annual molting probability, and selectivity for trawl survey, winter pot survey, summer commercial fishery, and summer and winter commercial retention. X-axis is carapace length (mm).

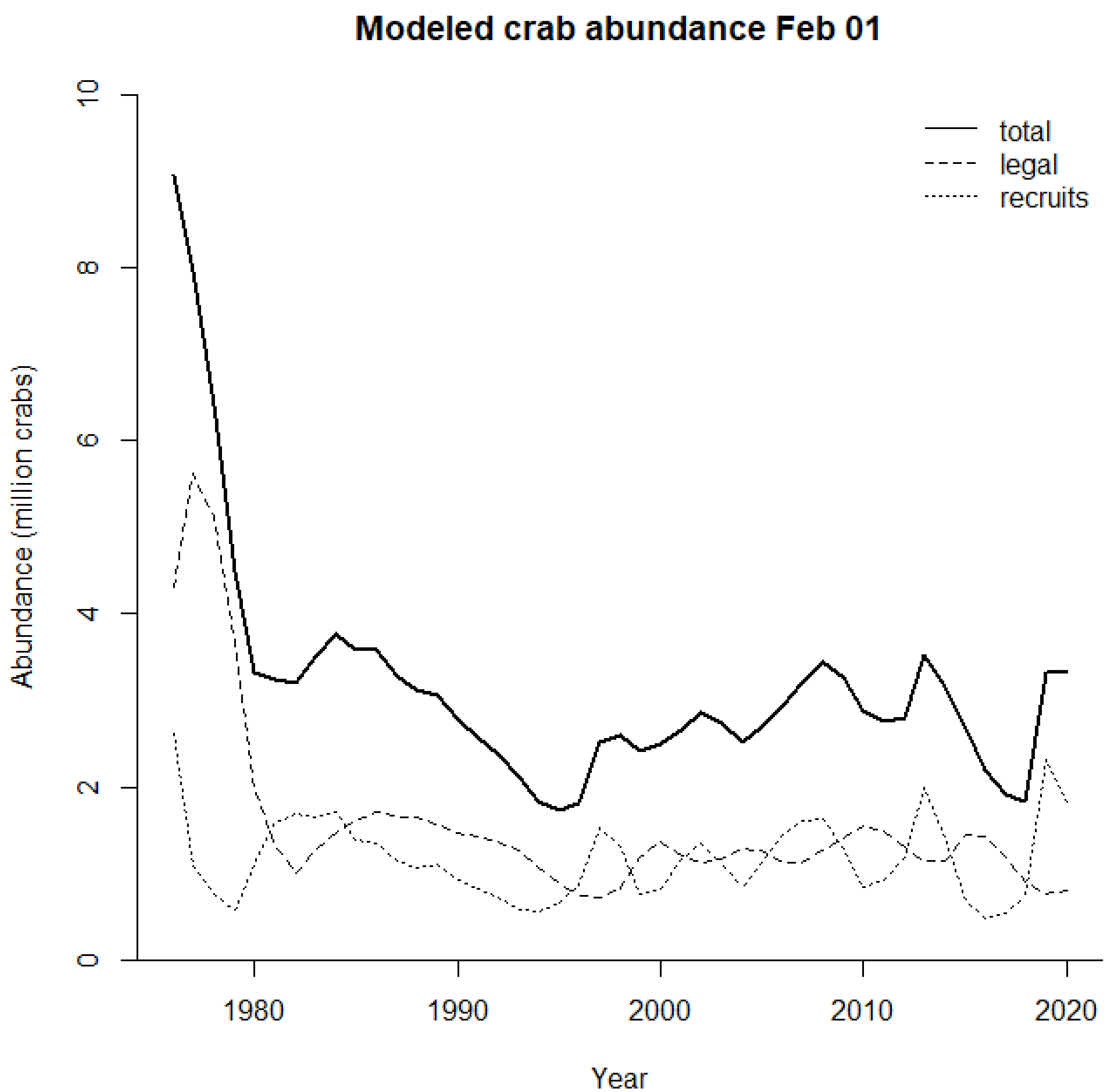



Figure 4. Model estimated abundances of total, legal (CL>104mm) and recruit (CL 64-94nn) males during1976-2019.

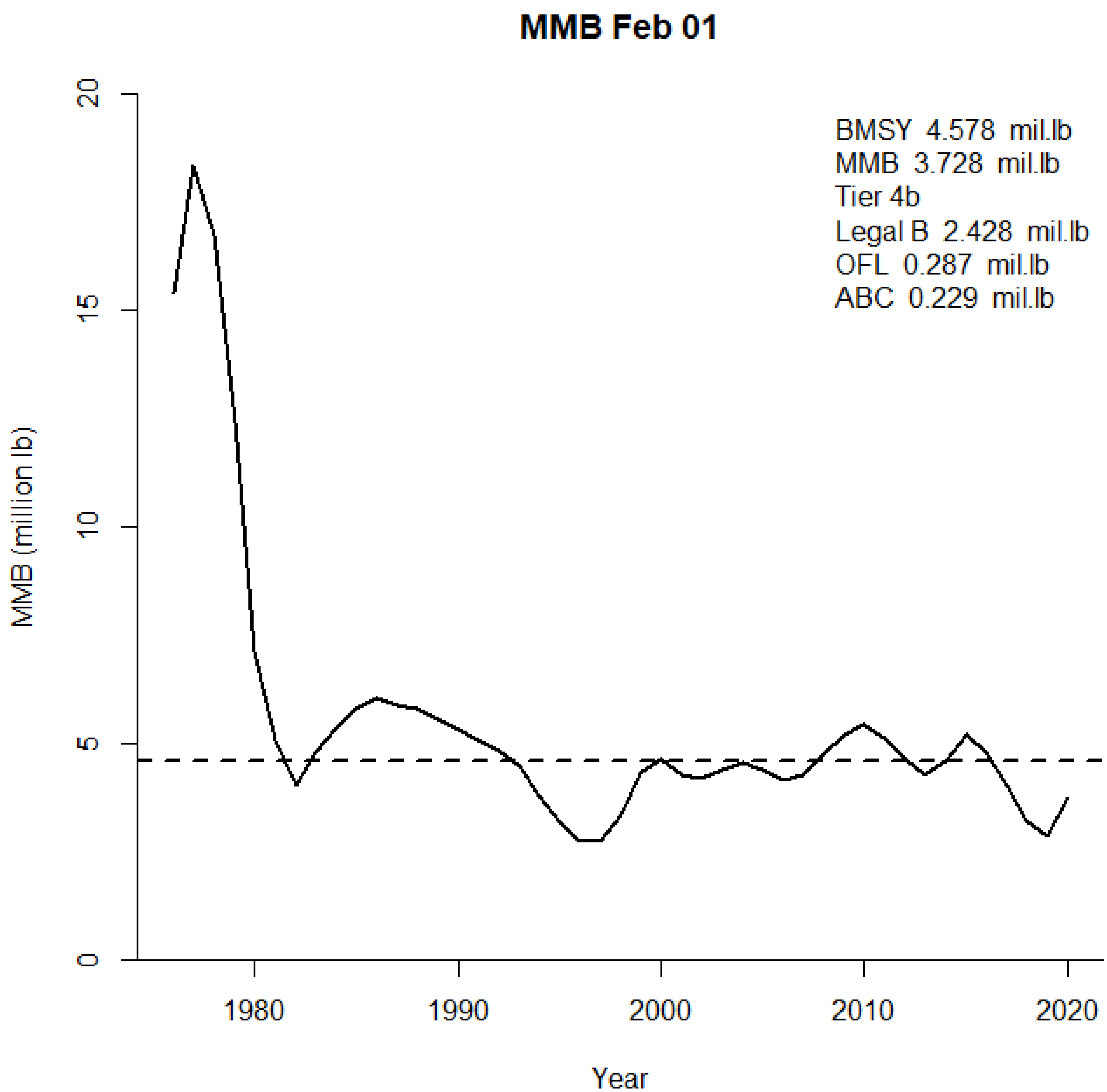



Figure 5. Estimated MMB during 1976-2019. Dash line shows Bmsy (Average MMB of 1980-2020). Dot indicate projected MMB of 2020.

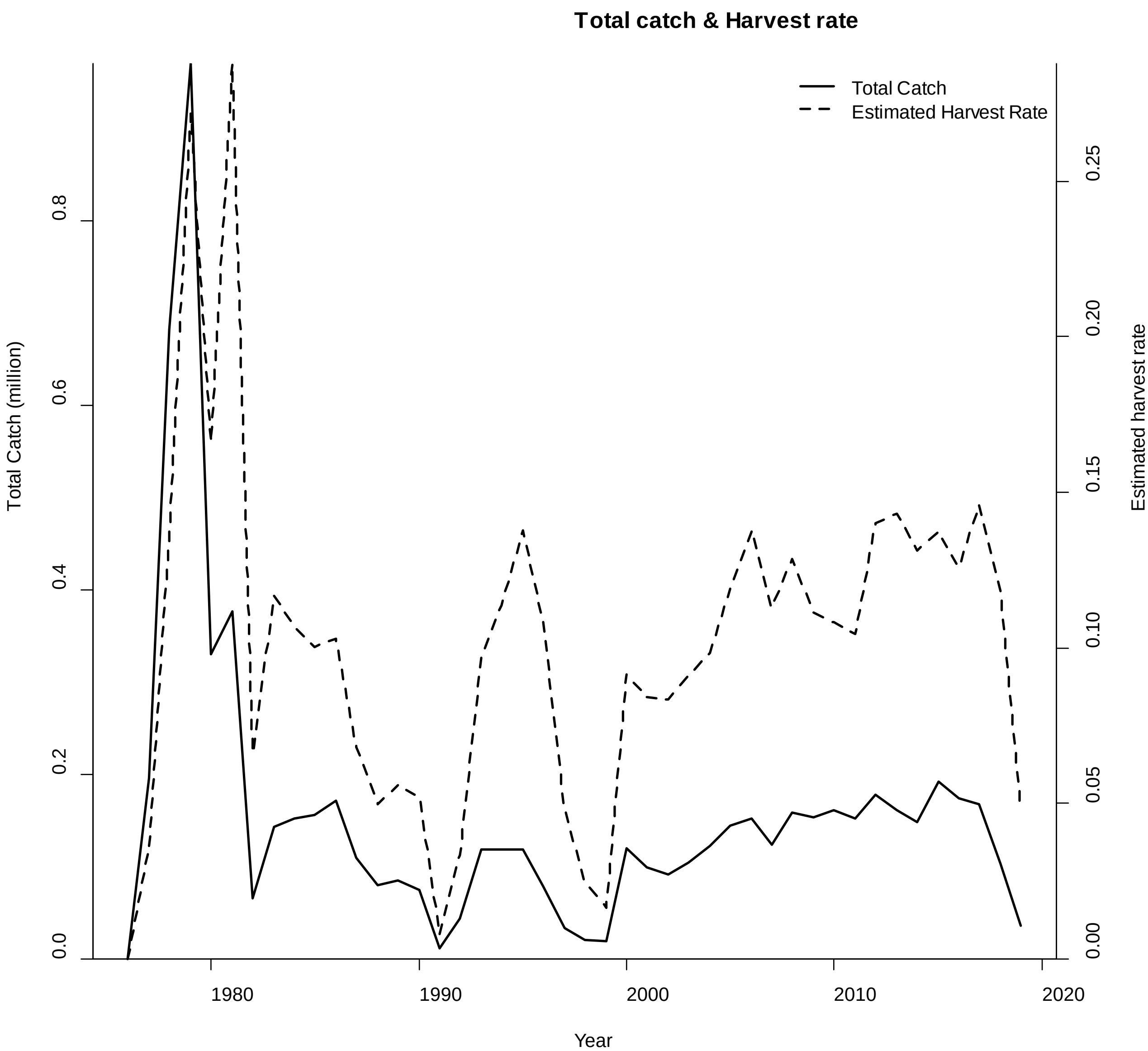



Figure 6. Commercial catch and estimated harvest rates of legal males over time.

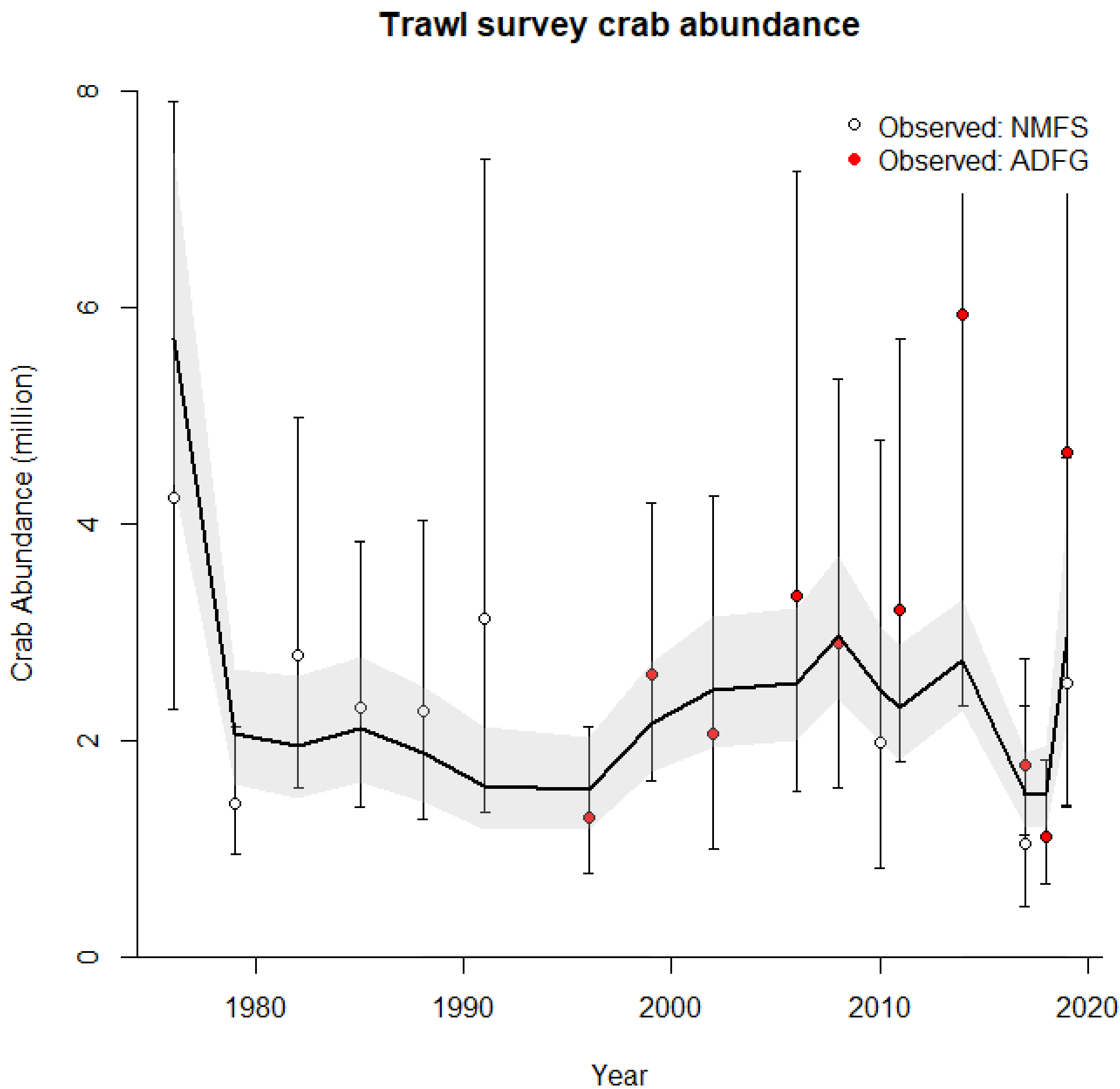



Figure 7. Observed (open circle) (White: NMFS, Red ADF&G) and model estimated (line) trawl survey male abundances with 95% lognormal Confidence Intervals (crab ≥ 64 mm CL). Shaded area indicate 95%CI lognormal CI of the model estimate.

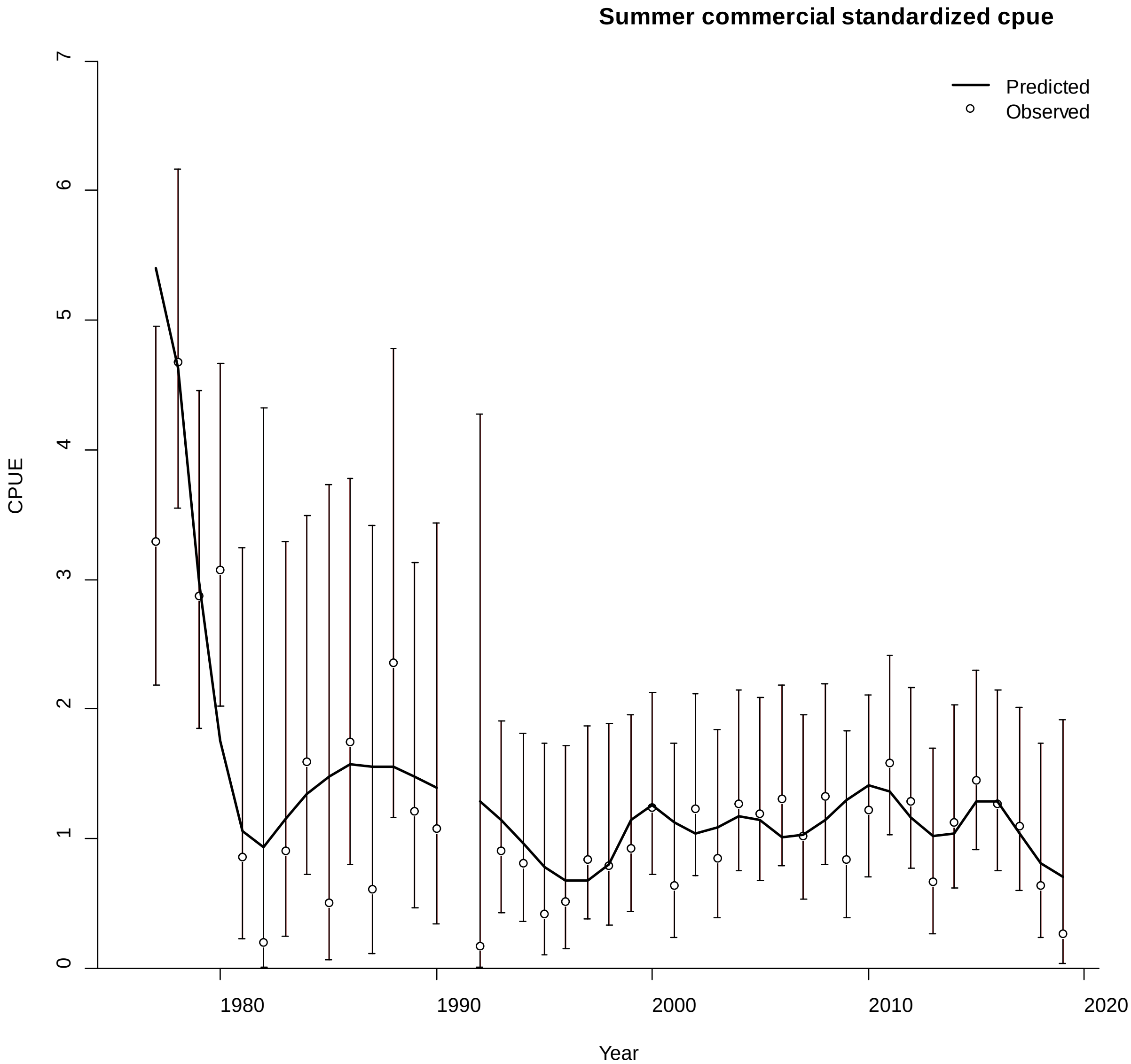



Figure 8. Observed (open circle) with 95% lognormal Confidence Intervals and model estimated (lines) standardized CPUE.

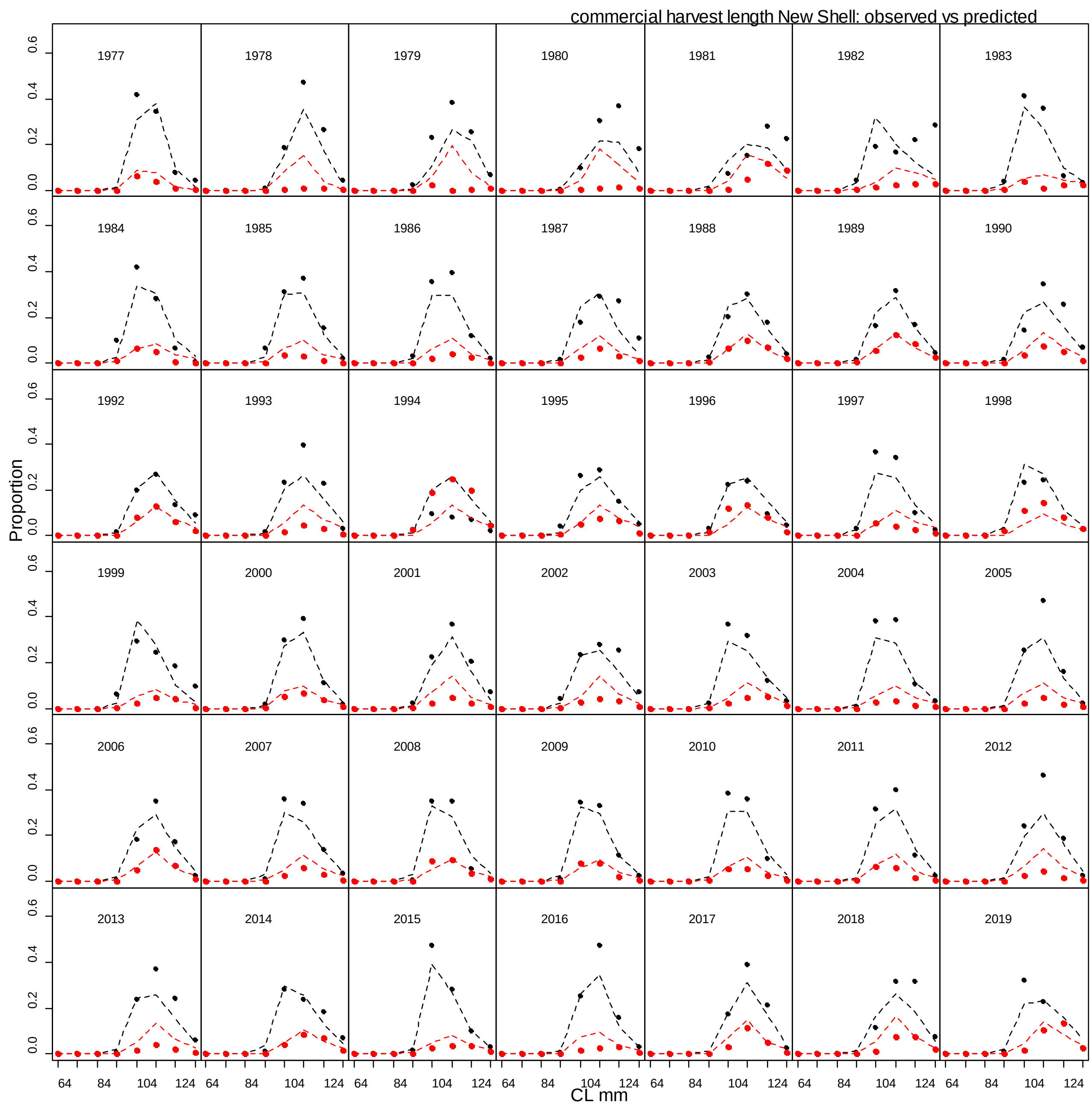
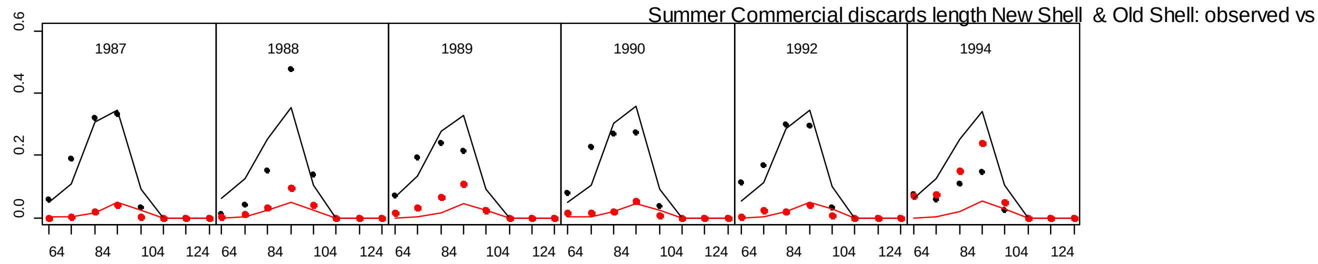



Figure 9. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for the summer commercial harvest 1977-2019.



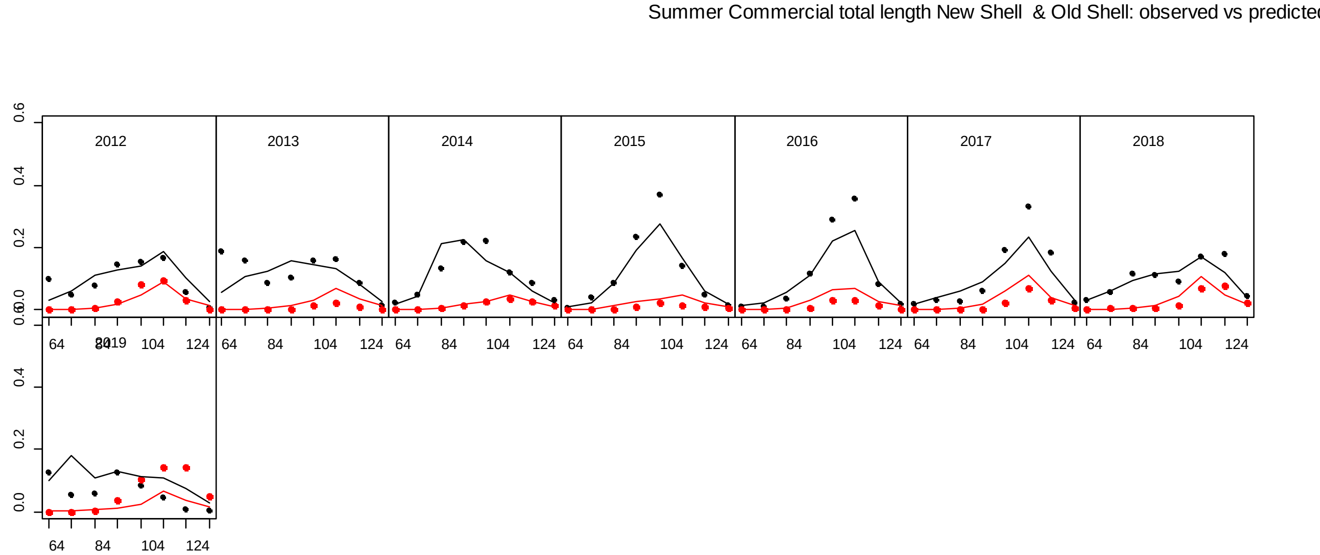




Figure 10. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for summer commercial discards (1987-94) and total catch (2012-2019).

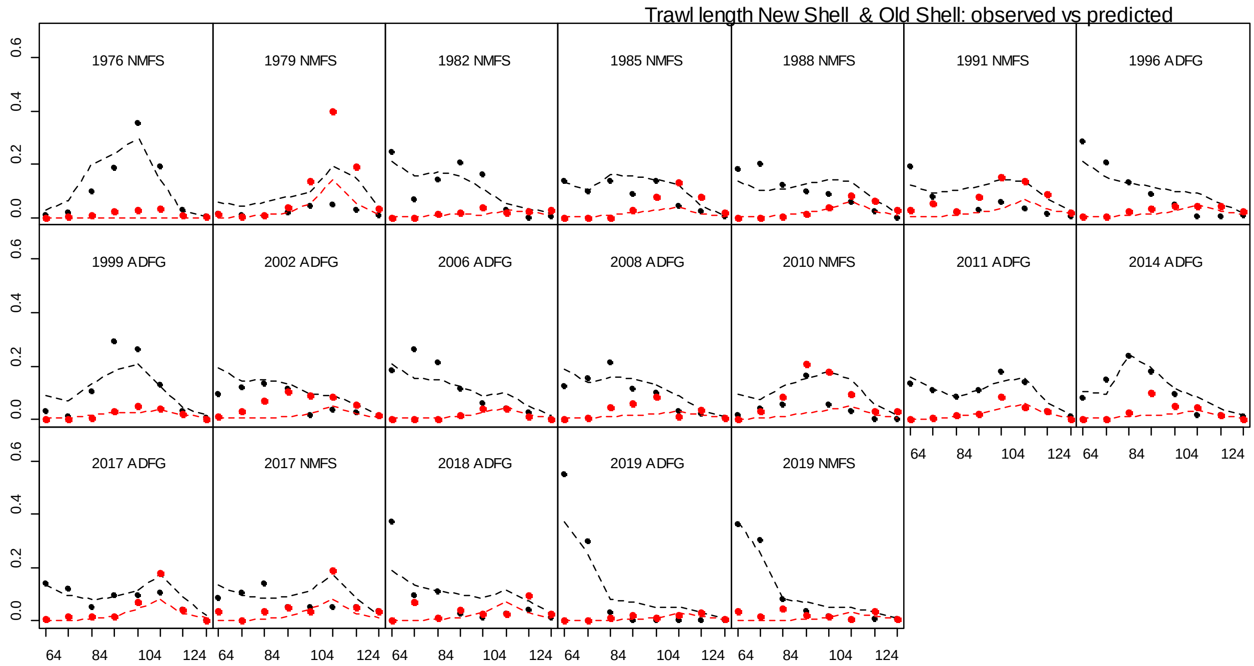



Figure 11. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for summer trawl survey 1976 – 2019

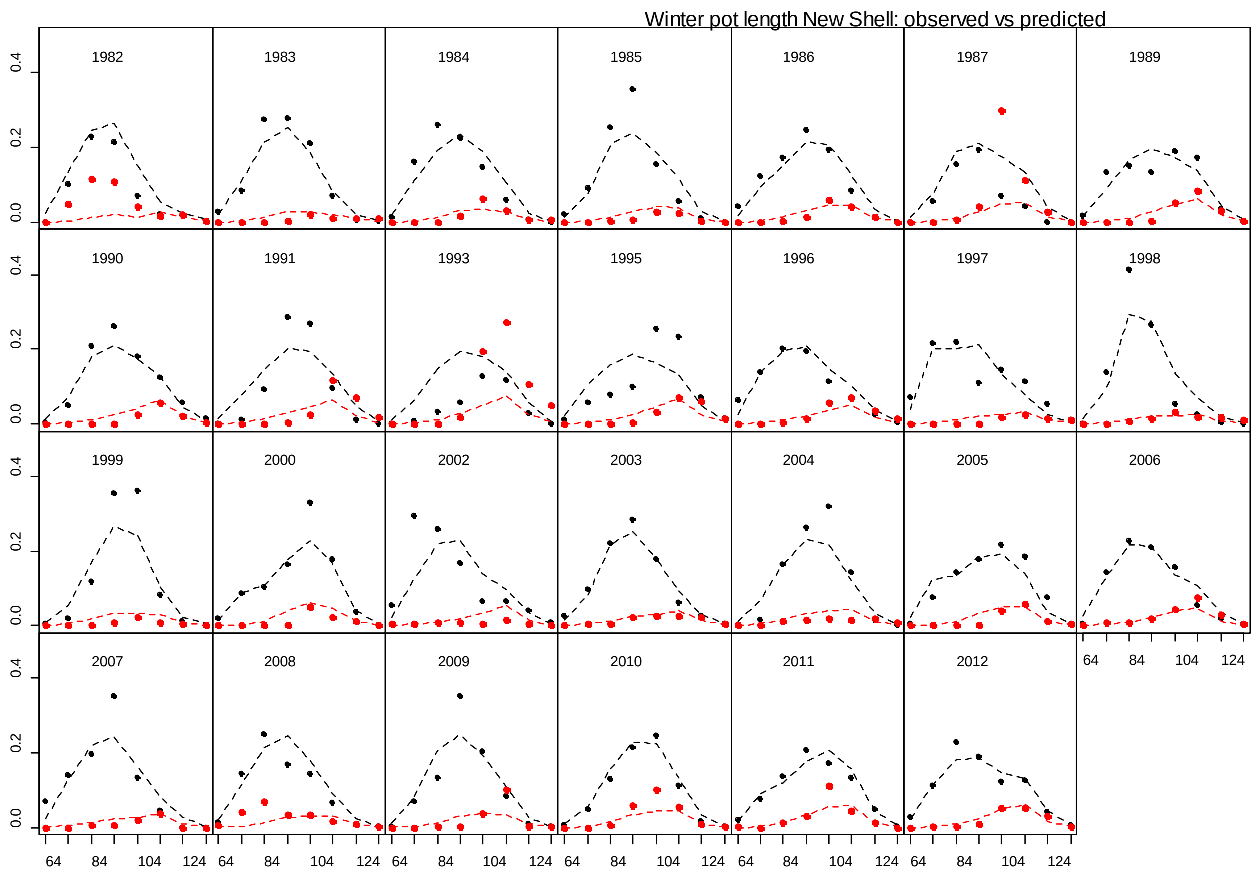



Figure 12. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for winter pot survey 1982 – 2012

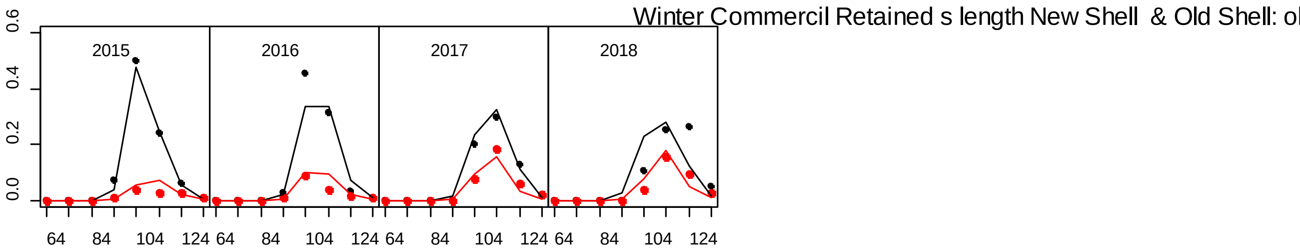



Figure 13. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions for winter commercial fishery 2015-2018

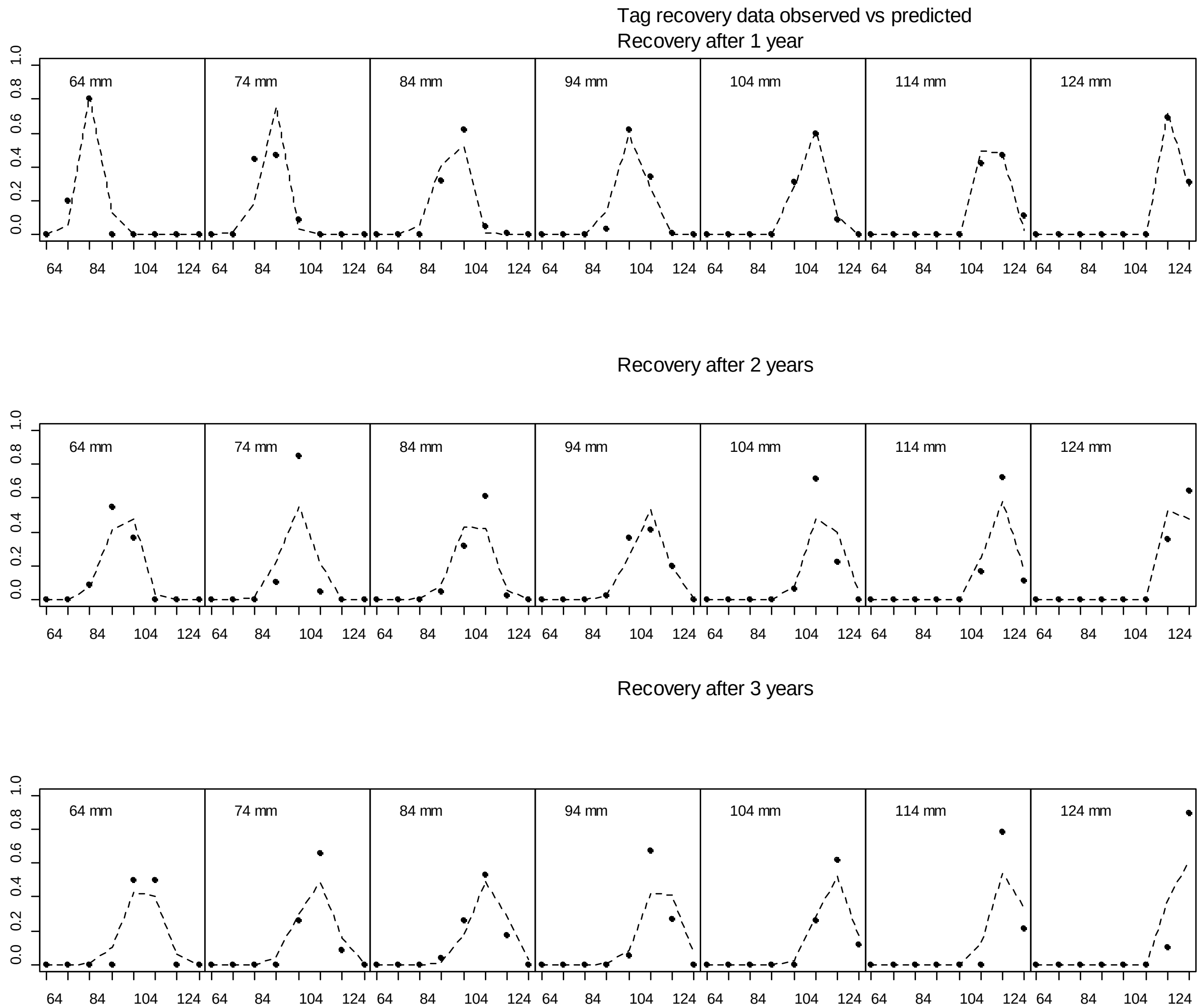



Figure 14. Predicted (line) vs. observed (dots: black New Shell, red Old Shell) length class proportions tag recovery data.

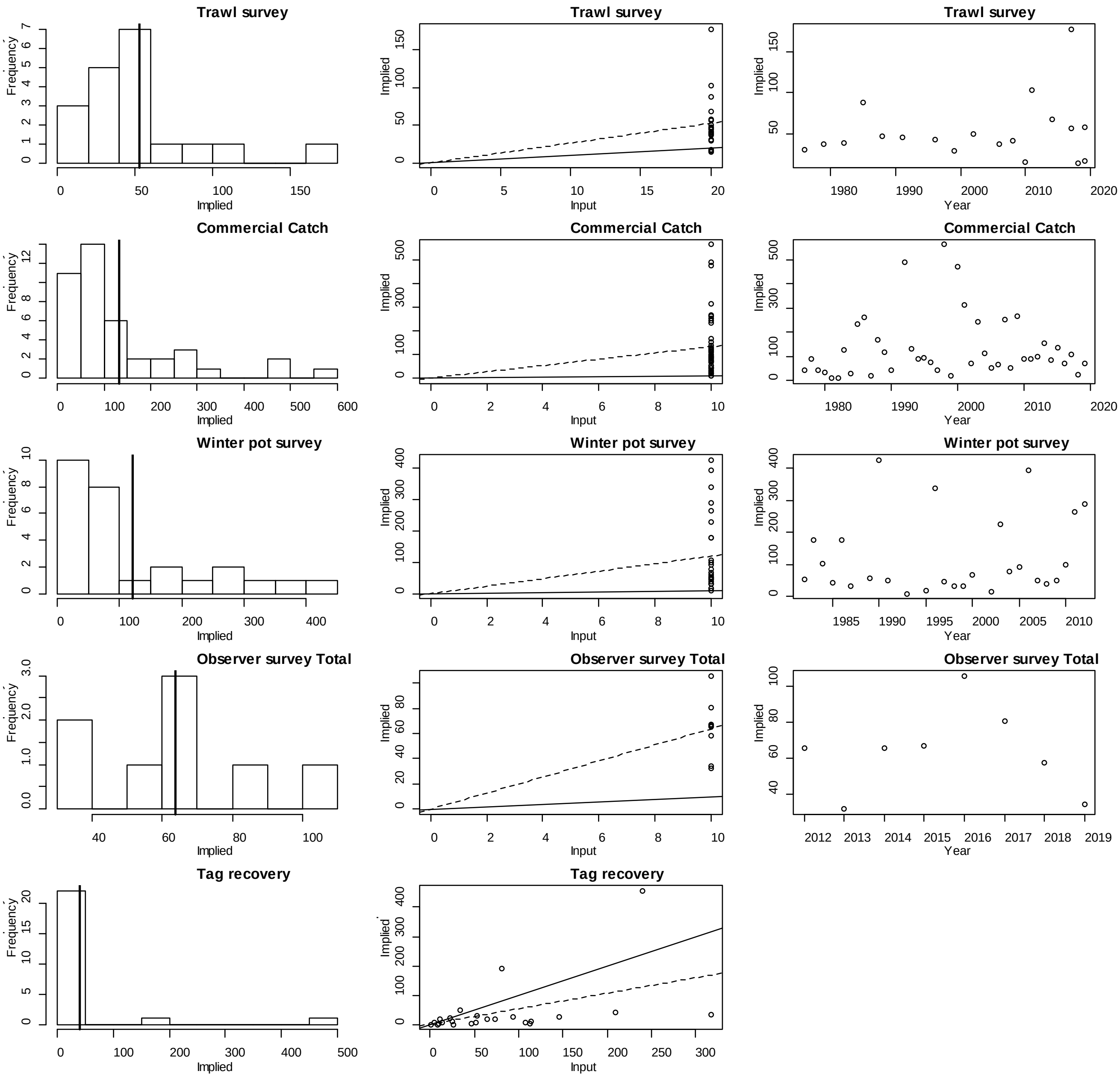



Figure 15. Input vs. model implied effective sample size. Figures in the first column show implied effective sample size (x-axis) vs. frequency (y-axis). Vertical solid line is the implied sample size. Figures in the second column show input sample sizes (x-axis) vs. implied effective sample sizes (y-axis). 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).

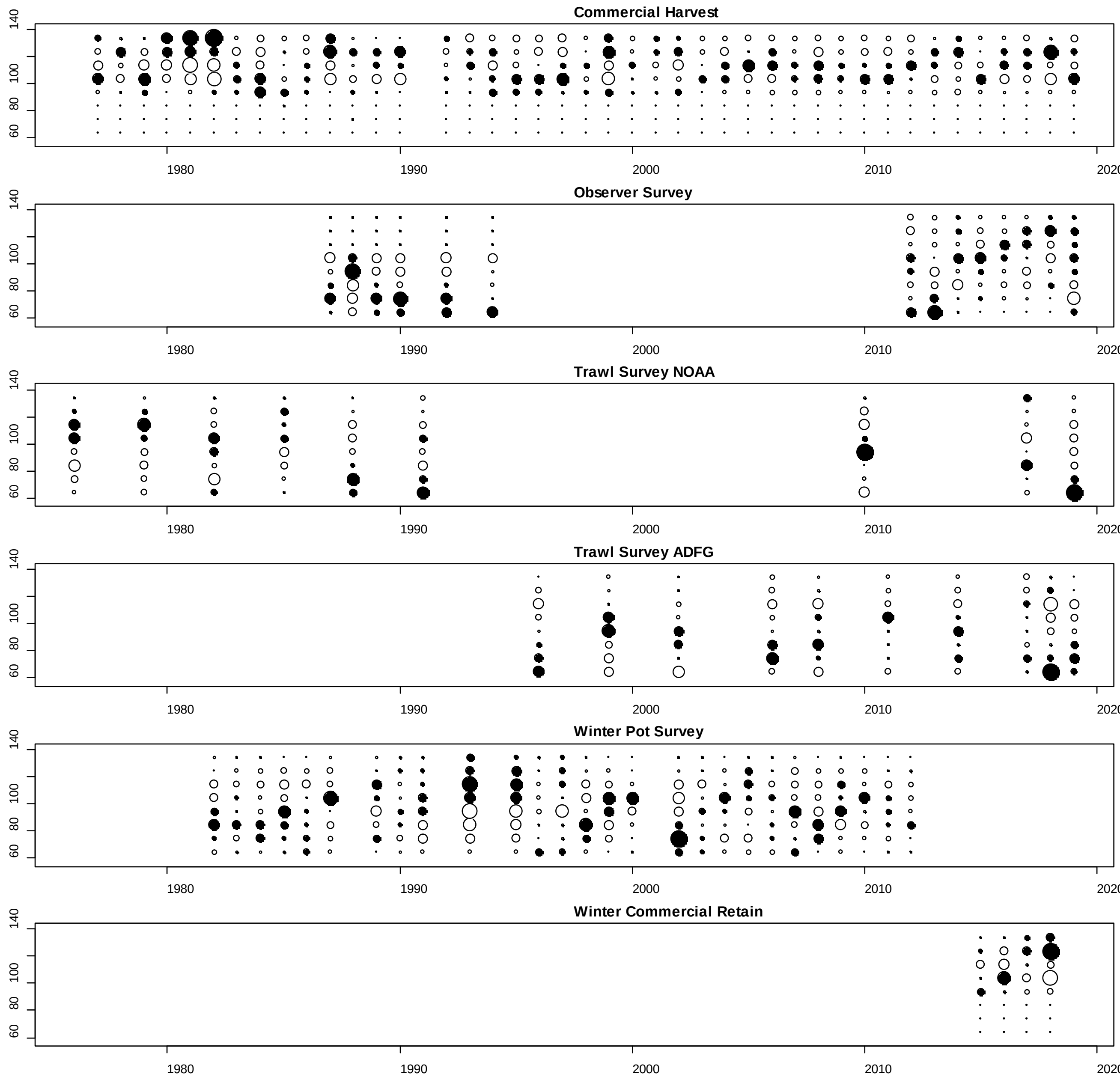



Figure 16. Bubble plots of predicted and observed length proportions.
Black circle indicates model estimates lower than observed, white circle indicates model estimates higher than observed. Size of circle indicates degree of deviance (larger circle = larger deviance).

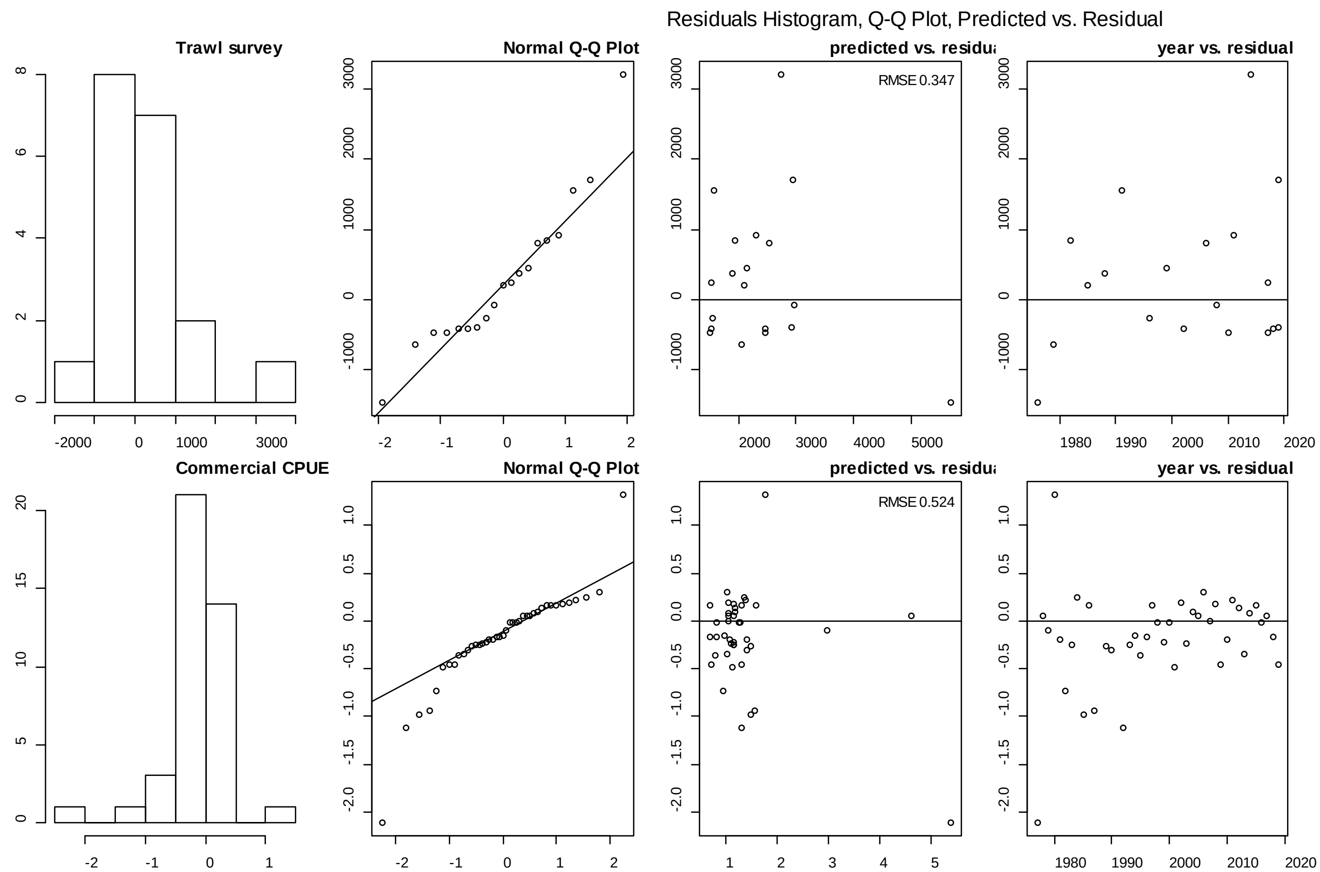



Figure 17. QQ Plot of Trawl survey and Commercial CPUE

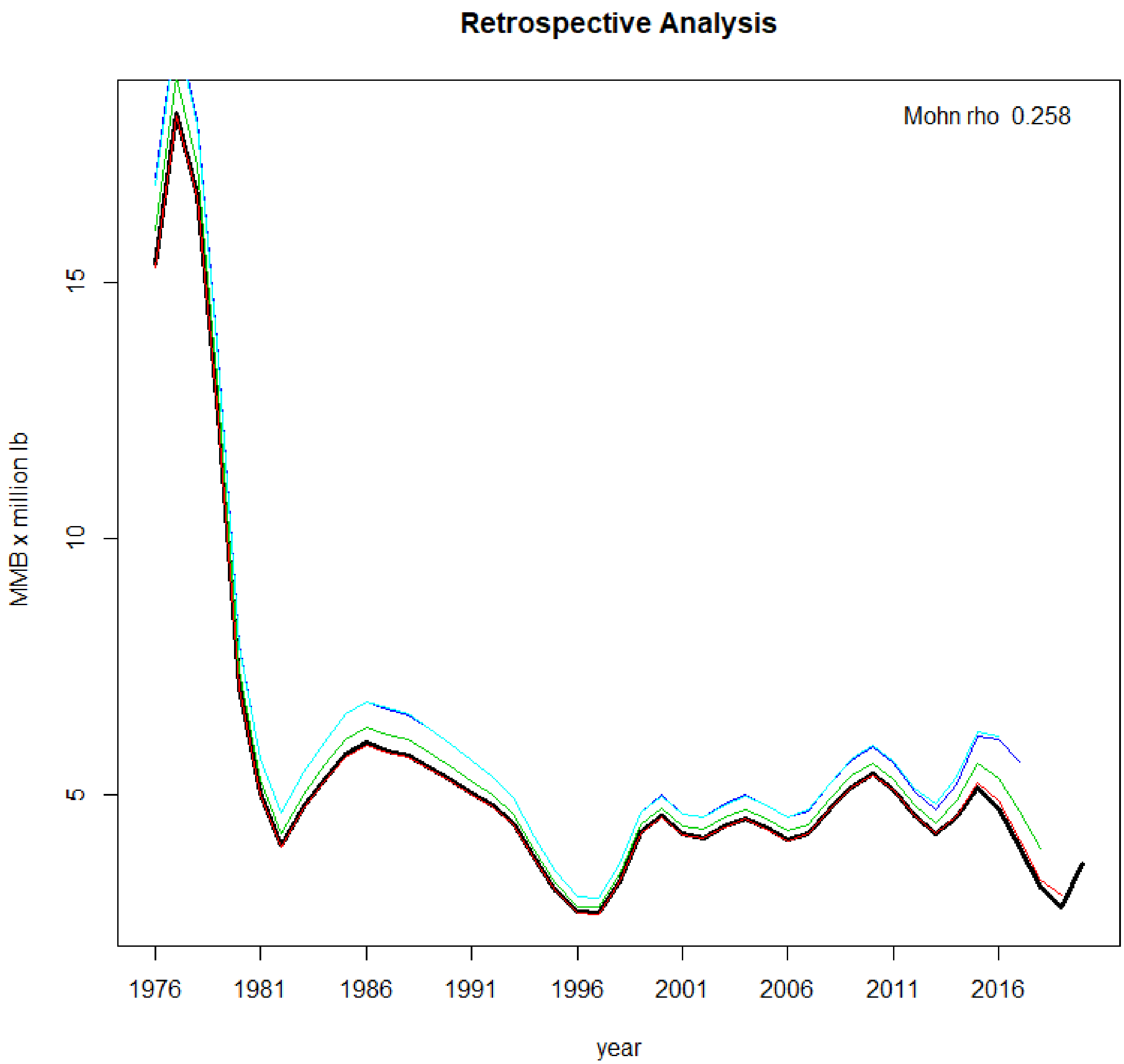



Figure 18. Retrospective Analyses of Norton Sound Red King Crab MMB from 2016 to 2019.