Norton Sound Red King Crab Stock Assessment for the fishing year 2016

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Executive Summary

1. Stock. Red king crab, *Paralithodes camtschaticus*, in Norton Sound, Alaska.

2. Catches. This stock supports three main fisheries: summer commercial, winter commercial, and winter subsistence fisheries. Of those, the summer commercial fishery accounts for more than 90% of total harvest. The summer commercial fishery started in 1977, and catch peaked in the late 1970s with retained catch of over 2.9 million pounds. Since 1982, retained catches have been below 0.5 million pounds, averaging 0.275 million pounds, including several low years in the 1990s. Retained catches have increased to about 0.4 million pounds in recent years coincident with increases in estimated abundance,.

3. Stock Biomass. Following a peak in 1977, abundance or the stock collapsed to a historic low in 1982. Estimated mature male biomass (MMB) has shown an increasing trend since 1997. However, uncertainty in historical biomass is high due in part to infrequent trawl surveys (every 3 to 5 years) and limited winter pot surveys.

4. Recruitment. Model estimated recruitment was weak during the late 1970s and high during the early 1980s, with a slight 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 Catch	Total Catch	OFL	ABC
2012/13	1.76[A]	4.59	0.47	0.47	0.47	0.53[A]	0.48
2013/14	2.06[B]	5.00	0.50	0.35	0.35	0.58[B]	0.52
2014/15	2.11[C]	3.71	0.38	0.39	0.39	0.46[C]	0.42
2015	2.41[D]	5.13	0.39	0.40	0.52	0.72[D]	0.58
2016	2.26[E]	5.87	TBD	TBD	TBD	0.71[E]	0.57

Status and catch specifications (1000t)

Year	MSST	Biomass (MMB)	GHL	Retained Catch	Total Catch	OFL	ABC
2012/13	0.80[A]	1.93	0.21	0.21	0.21	0.24[A]	0.22
2013/14	0.93[B]	2.27	0.23	0.16	0.16	0.26[B]	0.24
2014/15	0.96[C]	1.68	0.17	0.18	0.18	0.21[C]	0.19
2015	1.09[D]	2.33	0.18	0.18	0.24	0.33[D]	0.26
2016	1.03	2.66	TBD	TBD	TBD	0.32 [E]	0.26

Notes:
MSST was calculated as $B_{MSY}/2$
A-Calculated from the assessment reviewed by the Crab Plan Team in May 2012
B-Calculated from the assessment reviewed by the Crab Plan Team in May 2013
C-Calculated from the assessment reviewed by the Crab Plan Team in May 2014
D-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2015
E-Calculated from the assessment reviewed by the Crab Plan Team in Jan 2016
Conversion to Metric ton: 1 Metric ton = 2.2046× 1000 lb

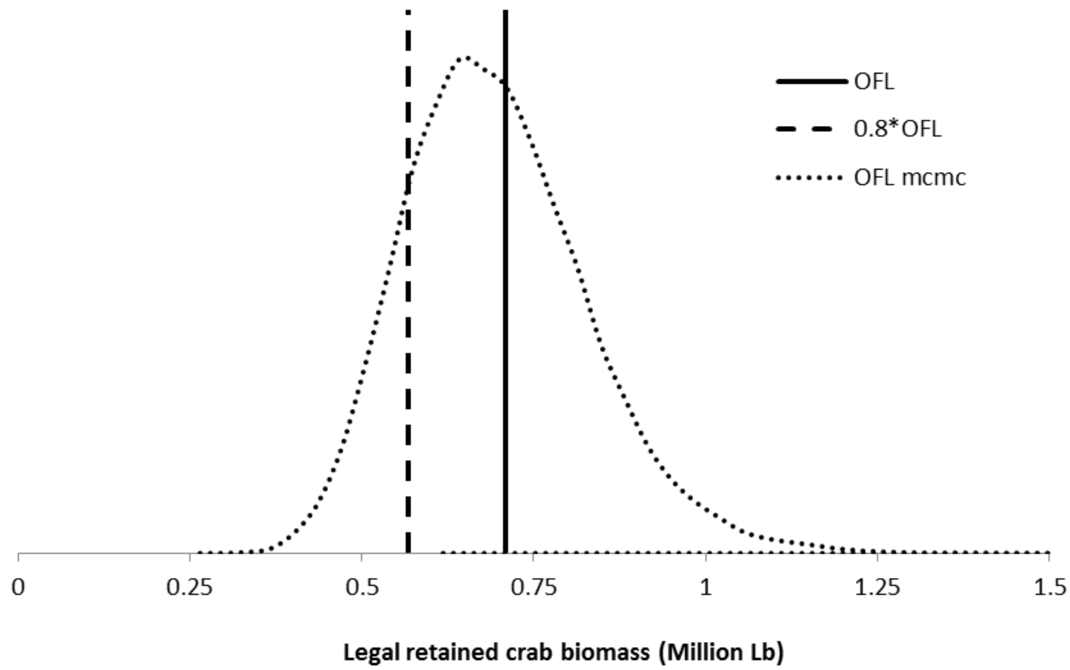
Biomass in millions of pounds

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	M	1-Buffer	ABC
2012/13	4a	3.51	4.59	1.2	0.18	1980-2012	0.18	0.9	0.48
2013/14	4b	4.12	5.00	1.2	0.18	1980-2013	0.18	0.9	0.52
2014/15	4b	4.19	3.71	0.9	0.16	1980-2014	0.18	0.9	0.42
2015	4a	4.81	5.13	1.1	0.18	1980-2015	0.18	0.8	0.58
2016	4a	4.53	5.87	1.3	0.18	1980-2016	0.18	0.8	0.57

Biomass in 1000t

Year	Tier	B_{MSY}	Current MMB	B/B_{MSY} (MMB)	F_{OFL}	Years to define B_{MSY}	M	1-Buffer	ABC
2012/13	4a	1.59	1.93	1.2	0.18	1980-2012	0.18	0.9	0.22
2013/14	4a	1.86	2.27	1.2	0.18	1980-2013	0.18	0.9	0.24
2014/15	4b	1.90	1.68	0.9	0.16	1980-2014	0.18	0.9	0.19
2015	4a	2.18	2.33	1.1	0.18	1980-2015	0.18	0.8	0.26
2016	4a	2.06	2.66	1.3	0.18	1980-2016	0.18	0.8	0.26

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



7. The basis for the ABC recommendation

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

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

   N/A

A. *Summary of Major Changes in 2015*

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

   None

2. Changes to the input data

   a. Data update: 2015 summer commercial fishery (total catch, catch length comp, discards length comp), 2014/2015 winter commercial and subsistence catch

   b. Data update: 1977-2015 standardized commercial catch CPUE and CV. No changes in standardization methodology (SAFE 2013).

3. Changes to the assessment methodology:

   None

4. Changes to the assessment results.

   None

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

Crab Plan Team - Jan 16 2015

- Provide trawl survey documentation

  Trawl survey report is published as ADFG report. The report is available at http://www.adfg.alaska.gov/FedAidPDFs/FDS15-40.pdf

- Provide an explanation and legend for figures comparing input sample sizes with effective sample.

  Done

- Provide the documentation on the survey CPUE standardization as an Appendix

  Included in the Appendix B.

- Fix trawl survey selectivity parameter to 1.0 (i.e., do not estimate)

  Not conducted because selectivity was not always 1.0.

- Provide stock-specific maturity information for possible move to Tier 3.

  Author's reply:
  Assumed male size at (functional) maturity of the NSRKC (CL 94 mm) was determined by adjusting that of Tier 3 BBRKC (CL 120mm) reflecting their slower growth and smaller size. However, male size at (functional) maturity of Tier 3 BBRKC is also assumed (Zheng et al. 2014). For BBRKC male size at maturity is 103 mm CL by chelae allometry (Somerton 1980), 50-59 mm CL by spermatophore presence (Paul et al. 1991). Functional size-at-functional maturity is likely greater than physiological or morphological maturity based on *in situ* grasping pair morphometry was estimated at 120 to 130mm CL for Kodiak Island red king crab (Powell et al. 2002, Webb 2014).

- Include a discussion of the relative uncertainty in model parameters and data employed in the model as well as relative weightings in model configuration for use in best approximating the uncertainty in the OFL.

  Author's reply:
  Tagging data weighting issue has been discussed in SAFE 2015 and effects of input sample size for length composition have been discussed at modeling workshop in 2013

and 2014. We would gladly examine if there is a request for examining effects of specific data set.

SSC Feb 2-4 2015

- The SSC identified the fate of large males as the major uncertainty and hopes that this can be resolved through further research. The competing hypotheses of localized depletion, high natural mortality, or migration to a refuge from fishing have very different implications for OFL and ABC. Until this is resolved, the SSC felt that moving this stock to Tier 3 status would be problematic.

  Author's reply:

  The CPT (Sept 17 2015) commented that the fate of large males is not really a tier 3 question, although does need more investigation.

  Regarding the SSC's hypotheses of localized depletion, high natural mortality, or migration to a refuge from fishing; we examined the available data and suggest the following:

  Trawl survey did not show any pattern that higher number of larger crab being caught at edge of survey boundaries. Spring survey 2012-2015 also did not see higher proportion of large crabs along the coastal area. On the other hand, fall surveys in 2013-2014 consistently showed higher proportion (17% in 2013, 23% in 2014) of the largest size class (> 123mm CL) crab. Those larger crabs were absent in spring survey conducted 8 months later (5% in 2014, 3.5% in 2015). Winter commercial catch length composition did not show high large crab proportion (11 % in Jan-May 2015). These results do not seem to support the hypotheses of localized depletion or migration to a refuge from fishing.

  Regarding the high natural mortality, see section 3.c: Model selection and evaluation – search for balance.

- The SSC prefers that OFL and ABC be consistently presented in units of tons.

  Author's reply:

  We agree to SSC about using of tons as standard metric, international standard. Unfortunately, however, pounds is the customary unit of the US public. We prefer our report to be easily readable to the US public, including crab fishermen, by using the US customary units.

CPT Sept 17 2015

- Explore iterative data reweighting after guidance from the data weighting workshop.

  Author's reply:
  As of preparation of this report (Nov. 2015), no specific recommendations of exploring iterative re-weighting procedures have been provided by the time of NSRKC assessment. We look forward implementing the recommendations for January 2017 assessment.

- Maturity data on males is needed before moving NSRKC to tier 3.

  Author's reply:
  Assumed male size at (functional) maturity of the NSRKC (CL 94 mm) was determined by adjusting that of Tire 3 BBRKC (CL 120mm) reflecting their slower growth and smaller size. However, male size at (functional) maturity of Tire 3 BBRKC is also assumed (Zheng et al. 2014). For BBRKC male size at maturity is CL 103 mm by chelae allometry (Somerton 1980), 50-59 mm CL by spermatophore presence (Paul et al. 1991). Estimated size at functional maturity is only available for one red king crab stock in Alaska (Webb 2014) in which the 5th percentile of the size frequency distribution of males observed in grasping pairs near Kodiak Island was ~ 120 mm CL (Powell et al. 2002).

SSC Oct 5-7 2015

- The SSC supports the plan team's recommendations of exploring iterative re-weighting procedures after the Center for the Advancement of Population Assessment Methodology (CAPAM) data-weighting workshop in late October 2015.

  Author's reply:
  As of preparation of this report (Nov. 2015), no specific recommendations of exploring iterative re-weighting procedures have been provided by the time of NSRKC assessment. We look forward implementing the recommendations for January 2017 assessment.

- The SSC also recommends that the author follow the terms of reference and provide retrospective estimates of spawning stock biomass and the appropriate statistics (e.g., Mohns' rho).

  Author's reply:
  Mohns' rho (Mohn 1999) was calculated, as $\rho = \sum (B_{(1976y),y+1} - B_{(19762015),y+1}) / B_{(1976y),y+1}$,

  only for the author preferred model. Mohns' rho has NO statistical range criteria of whether an assessment model is deemed acceptable/ unacceptable. We appreciate SSC providing a list of appropriate statistics to be reported for assessment model evaluations, and guidance how each statistics are weighed for selecting the best assessment model.

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 been made on possible stock separation within the putative stock known as Norton Sound red king crab.
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 (Jennifer 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 (Jennifer Bell, ADF&G, personal communication). Timing of molting is unknown but is considered to occur in late August – September, based on increase catches of fresh-molted crab later in the fishing season (August- September) (Joyce Soong, ADF&G personal communication); however, blood hormonal studies suggested an April-May molting season (Jennifer Bell, ADF&G, personal communication), which is consistent with Powell et al. (1983). Recent observations indicate biennial mating (Robert Foy, NOAA, personal communication). Trawl surveys show that crab distribution is dynamic. Recent surveys show high abundance on the southeast side of the 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 is harvested offshore during the summer commercial fishery, whereas most of the winter subsistence fishery harvest occurs nearshore.

<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 was 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. Regulation changes and location of buyers resulted in harvest distribution moving eastward 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 started accepting only legal crab of ≥ 5 inch CW.

Not all Norton Sound area is open for commercial fisheries. Since the beginning of the commercial fisheries in 1977, approximately 5-10 miles off the shore 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.

<u>CDQ Fishery</u>

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 who decides how their crab quota is to be harvested. During the March 2002 BOF meeting, new regulations for the CDQ crab fishery were adopted that affected; closed-water boundaries were relaxed in eastern Norton Sound and waters west of Sledge Island. In March 2008, the BOF changed the start date of the Norton Sound open-access portion of the fishery to be opened by emergency order as early as June 15. The CDQ fishery may open at any time (as soon as ice is out), by emergency order.

<u>Winter Commercial Fishery</u>

The winter commercial crab fishery is a small fishery using hand lines and pots through the nearshore ice. On average 10 permit holders harvested 2,500 crabs during 1978-2009. From 2007 to 2015 the winter commercial catch increased from 3,000 crabs to over 40,000 (Table 2). In 2015 winter commercial catch reached 20% of total crab catch. The BOF responded in May 2015 by amending regulations to allocate 8% of the total commercial guideline harvest level (GHL) to the winter commercial fishery. 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 will be in effect for the 2016 season.

Subsistence Fishery

While the 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 during winter 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. Subsistence fishery has no size or sex limit; however, the majority of retained catches are males of near legal crab size. The subsistence fishery catch is influenced not only by crab abundance, but also by changes in distribution, changes in gear (e.g., more use of pots instead of hand lines since 1980s), and ice conditions (e.g., reduced catch due to unstable ice conditions: 1987-88, 1988-89, 1992-93, 2000-01, 2003-04, 2004-05, and 2006-07).

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

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

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

In 2012 a revised GHL for the summer commercial fishery was implemented: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.25 million lb; (2) ≤ 7% of legal male abundance when the estimated legal biomass falls within the range 1.25-2.0 million lb; (3) ≤ 13% of legal male abundance when the estimated legal biomass falls within the range 2.0-3.0 million lb; and (3) ≤ 15% of legal male biomass when estimated legal biomass >3.0 million lb.

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

1. Revised GHL to include all fisheries (winter, summer, commercial, and subsistence).
2. Set guideline harvest level for winter commercial fishery (GHL_w) at 8% of the total GHL (i.e., GHL_w = 0.08 x GHL), and summer commercial guideline harvest level (GHL_s) be remainder of total GHL (i.e., GHL_s = GHL - winter comm. harvest - winter subsistence harvest).
3. Date of the winter red king crab commercial fishing season is from January 15 to April 30.

Year	Notable historical management changes
1976	The abundance survey started
1977	Large vessel commercial fisheries began

1991	Fishery closed due to staff constraints
1994	Super exclusive designation went into effect. The end of large vessel commercial fishery operation. The majority of commercial fishery subsequently shifted to east of 164^{o}W longitude.
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 ≥ 4-3/4 inch CW to ≥ 5 inch CW
2006	The Statistical area Q3 section expanded (Figure 1)
2008	Start date of the open access fishery changed from July1 to after June 15 by emergency order. Pot configuration requirement: at least 4 escape rings (>4½ 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 > 6½ inches.
2012	The Board of Fisheries adopted a revised GHL for summer fishery.
2016	Winter GHL for commercial fisheries was established and modified winter fishing season dates were implemented.

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

NSRKC is a Tier4 crab stock. Direct estimation of the B_{MSY} is not possible. The B_{MSY} proxy is calculated as mean model estimated mature male biomass (MMB) from 1980 to present. Choice of this period was based on a hypothesized shift in stock productivity a due to a climatic regime shift indexed by the Pacific Decadal Oscillation (PDO) in 1976-77. Stock status of the NSRKC was Tier 4a until 2013. In 2014 the stock fell to Tier 4b, but came back to Tire 4a in 2015.

D. Data

1. Summary of new information:

Trawl survey:

Trawl survey report is published as ADFG report. The report is available at http://www.adfg.alaska.gov/FedAidPDFs/FDS15-40.pdf

Winter commercial and subsistence fishery:

Winter commercial fishery catch in 2015 was 41,046 crabs (98,750 lb.), which was the highest harvest record since development of its fishery. Subsistence crab catch was 7,651 (15,302 lb., Table 2).

Summer commercial fishery:

The summer commercial fishery opened on June 29 and closed on July 24 due to meeting the GHL. This was the shortest fishery in the history. A total of 144,255 crabs (401,115 lb.) were harvested (Table 1).

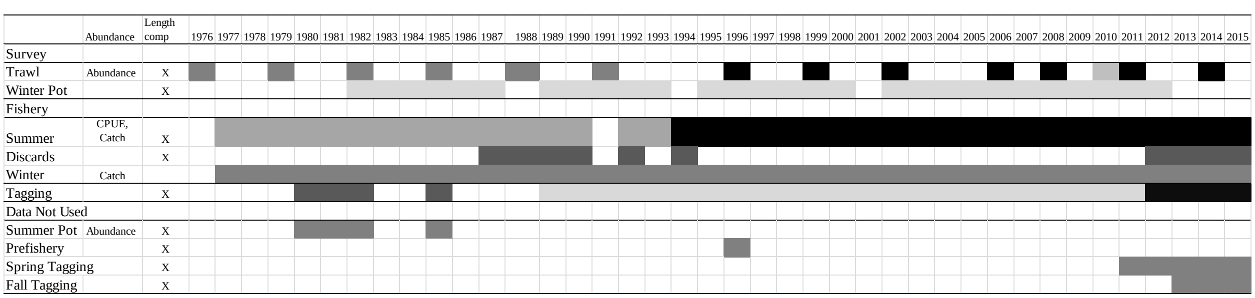
Total harvest for 2015 season was 192,952 crabs (515,167 lb.) and did not exceed the 2015 ABC of 0.58 million lb.

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	Abundance Length proportion	3 5, Figure 3
Winter pot survey	81-87, 89-91,93,95-00,02-12	Length proportion	6, Figure 3
Summer commercial fishery	76-90,92-15	Retained catch Standardized CPUE, Length proportion	1 1 4, Figure 3
Summer commercial Discards	87-90,92,94, 2012-2014	Length proportion (sublegal only)	7, Figure 3
Winter subsistence fishery	76-15	Total catch Retained catch	2 2
Winter commercial fishery	78-15	Retained catch	2
Tag recovery	80-15	Recovered tagged crab	8

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, Length	Not reliable due to ice conditions
Winter Commercial	2015	Length proportion	Years of data too short
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, no other crab, groundfish, or shellfish fisheries exist.

	Fishery	Data availability
Bycatch in other crab fisheries	Does not exist	NA
Bycatch in groundfish pot	Does not exist	NA
Bycatch in groundfish trawl	Does not exist	NA
Bycatch in the scallop fishery	Does not exist	NA

3. Other miscellaneous data:

   Spring offshore migration distance and direction (2013-2015)

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

Data aggregated:

   Proportion of legal size crab, estimated from trawl survey and observer data. (Table 11)

Data estimated outside the model:

   Summer commercial catch standardized CPUE (Table 1)

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 the largest size class of crab than in seen in data. This problem was further exasperated when natural mortality *M* was set as 0.18 from previous *M* = 0.3 in 2011 (SAFE 2011). This problem was examined and resolved by increasing *M* of the largest length crabs to 3.6×*M* or *M* = 0.648 (SAFE 2012). Profile likelihood analyses have been conducted several times, which resulted in **the lowest likelihood at *M* = 0.34** (SAFE 2012, 2013). However, even at this higher *M*, the model was not able to resolve poor fits to the commercial catch. Profile likelihood of commercial catch was lowest around M = 0.5 or greater.

From 2013 to 2014, the NSRKC model was thoroughly examined by the CPT during the modeling workshop. The workshop improved the model fit thorough excluding some data (summer pot survey), revising the trawl survey abundance estimates, standardizing commercial catch CPUE, including tag recovery data to estimate the growth transition matrix within the model, and changing weights in the likelihood. However, the issue of *M* was not addressed in this workshop. For the 2016 assessment we again examined the influence of *M* on model performance.

Historical Model configuration progression:

2011 (SAFE 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 (SAFE 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 (SAFE 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 (SAFE 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 (SAFE 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

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).

b-f. See Appendix A.

g. Critical assumptions of the model:

i. Male crab mature at CL length 94mm.

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

ii. Molting events in fall after the fishery

iii. Instantaneous natural mortality *M* is 0.18 for all length classes, except for the last length group (> 123mm) where *M* is 3.6 times higher (0.648). *M* is constant over time.

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

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

This assumption is based on the fact that low proportion of large crabs caught in nearshore area where the winter surveys occur. Causes of this have been argued: (1) large crab do not migrate into nearshore 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 former was more likely the cause (Jennifer Bell, ADFG, personal communication).

vi. Summer commercial fisheries selectivity is an asymptotic logistic function of 1.0 at the length class CL 124mm. While fishery changed greatly between the periods of 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 two periods were examined in 2015, which showed no difference between the two models (SAFE 2015). For model parsimony, the two were combined.

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

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

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

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

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

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

xii. Discards handling mortality for all fisheries is 20%.
No empirical estimate is available.

xiii. Annual retained catch is measured without error.

xiv. All legal size crab (≥ 4-3/4 inch CW) are retained.

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 for length class 4. However, the model was not sensitive to this change (SAFE 2013).

xv. All sublegal size crab or commercially unacceptable size crab (< 5 inch CW, since 2005) are discarded.

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

h. Changes of assumptions since last assessment:

None.

i. Code validation
The model code was reviewed at the CPT modeling workshop in 2013 and 2014. It is available from the authors.

3. Model Selection and Evaluation

a. Description of alternative model configurations.

CPT did not recommend any future model modifications in Jan 2015, except for fixing the trawl survey selectivity parameter. Here, we examined 3 major model scenarios: (1) estimate multiplier of the last length class natural mortality multiplier (*ms*) from the model, (2) estimate *M* equal for all length classes from the model, and (3) estimate *M* and *ms* from the model. For data input, we examined 3 scenarios: (1) expand length classes (2) change growth increment interval from 10 mm to 5 mm, and (3) both (1) and (2). Increasing length ranges or reducing growth increment interval increases use of data. This may increase the number of parameters to be estimated, but may also improve model fit.

List of model scenarios considered.

Scenario	Length Range	Length Interval	M	ms (> 123mm)
0 (Default)	74-124	10	0.18	3.6
1			0.18	Est
2			Est	1.0
3			Est	Est
4	64-134	10	0.18	3.6
5			0.18	Est
6			Est	1.0
7			Est	Est
8	74-124	5	0.18	3.6
9			0.18	Est
10			Est	1.0
11			Est	Est
12	64-134	5	0.18	3.6
13			0.18	Est
14			Est	1.0
15			Est	Est

Est: model estimated.

b. Evaluation of alternative models results:

For model 1 to 15

Model	Number of Parameters	Total	TSA	St. CPUE	TLP	WLP	CLP	OBS	REC	TAG
0	59	310.9	9.7	-21.7	124.5	44.6	59.7	33.5	12.0	48.6
1	60	310.8	9.6	-21.7	124.2	44.6	60.1	33.5	12.1	48.4
2	60	324.2	9.3	-21.2	120.1	44.8	72.1	34.4	11.2	53.4
3	61	310.7	9.6	-21.6	123.6	44.3	60.5	33.5	11.9	48.8
4	61	292.9	10.0	-21.1	102.0	42.3	58.0	29.8	12.3	59.5
5	62	293.0	10.0	-21.0	102.0	42.3	58.2	29.8	12.3	59.5
6	62	314.0	9.9	-20.9	103.3	45.1	69.7	31.4	11.4	64.1
7	63	292.6	9.9	-21.1	102.6	42.2	57.9	29.5	12.4	59.2
8	60	353.2	9.8	-22.1	119.4	43.7	63.4	30.5	11.6	96.8
9	61	353.1	9.8	-22.1	119.1	43.6	63.8	30.4	11.6	96.8
10	61	366.3	9.5	-21.7	116.7	46.3	71.2	32.1	11.0	101.2
11	62	352.8	9.8	-22.1	118.3	43.8	63.7	30.7	11.5	97.0
12	64	354.8	10.3	-21.3	101.9	44.7	62.5	28.0	12.3	116.3
13	65	354.8	10.3	-21.3	101.9	44.7	62.5	28.0	12.3	116.3
14	65	378.4	10.2	-21.2	104.6	49.0	73.3	29.8	11.6	121.0
15	66	354.3	10.2	-21.3	102.1	44.3	62.9	27.6	12.4	116.1

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 catch length composition
REC: Recruitment deviation

OBS: Summer Commercial catch Observer discards length composition
TAG: Tagging recovery data composition

Estimated *M*, *ms*, MMB (2016) and OFL. Bold fonts are model estimate.

Model	*M*	*ms*	MMB(2016)	OFL
0	0.18	3.6	5.99	0.85
1	0.18	**3.42**	5.78	0.82
2	**0.42**	1	6.15	1.74
3	**0.21**	**2.96**	6.03	0.78
4	0.18	3.6	5.88	0.77
5	0.18	**3.56**	5.87	0.77
6	**0.4**	1	5.81	1.42
7	**0.14**	**4.61**	6.54	0.81
8	0.18	3.6	6.50	0.86
9	0.18	**3.45**	6.46	0.85
10	**0.41**	1	6.63	1.64
11	**0.22**	**2.78**	6.54	1.02
12	0.18	3.6	6.17	0.76
13	0.18	**3.60**	6.17	0.76
14	**0.39**	1	6.16	1.33
15	**0.14**	**4.82**	6.05	0.59

c. Search for balance:

Diagnostics and output from alternative models are detailed in Appendices C1 (model 0) to C16 (model 15) Among all alternative models, major differences are: estimate *M* of the largest length class, estimate M for all lengths equal, estimate *M* and the largest length class, increase range of length classes, and decrease increments length class. Estimating *M* multiplier of the largest length class (*ms*) did not change model fit (Model 0 vs. Model 1), indicating that *ms* = 3.6 is still a valid assumption. Estimating *M* (Model 0 vs. Model 2) improved fits of trawl survey length composition, but worsened fit of commercial fishery length composition and tag recovery. The model tends to overestimate commercial catch proportion of largest length class or underestimate that of middle length crabs. We also attempted to estimate selectivity of the largest length class as separate parameter, which allows model to choose dome shaped selectivity. However, the estimate was 1.0. Estimate of *M* was 0.42 that was more than twice higher than the default assumption of *M* = 0.18. Profile analyses showed that each likelihood components had different information about *M* (Appendix B1); however, except for winter pot and observer length comp, all other likelihood components were minimized at *M* ranging 0.3 to 0.6. This suggests that under the assumption of constant natural mortality across length classes and current model configurations, the data do not support the assumption of *M* = 0.18. Estimating both *M* and that of the largest length class (Model 0 vs. Model 3) did not change model fit. Estimated *M* was 0.21 for all and 0.617 (*ms* = 2.96) for the largest length class, similar to model assumption. This suggests that given available data and model configuration, assuming higher mortality for the largest length classes is the best option. This also suggests that if M = 0.18 across all length classes is true then model structure may need to be re-examined. Increasing the length classes (Model 0 vs. Model 4) or decreasing length category interval from 10 mm to 5 mm (Model 0 vs. Model 8) can increase use of more data and thus may yield better estimates for selectivities and molting probability. Regardless, all models had similar fit to trawl survey abundance and standardized CPUE.

Projected MMB for 2016 was similar across models ranging from 5.8 to 6.6 million lb. On the other hand, estimates of OFL differed greatly across the models because of differences in M. Considering all factors, we initially considered alternative models 0, 1, 5, and 13 for the 2016 assessment. Among the 4 models, Model 5 had the lowest Mohn's rho (Model 0: -0.482, Model 1: -0.556, Model 5: 0.115, Model 13: 0.924). While Mohn's rho has no cut-off criteria to which a model is deemed unacceptable, a model with Mohn's roh closer to 0 is generally considered a better model. Thus, we recommend the Model 5 for the 2016 assessment model.

4. Results

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

"Implied" effective sample sizes were calculated as

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

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

Maximum sample size for length proportion:

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

2. Tables of estimates.

   a. Model parameter estimates (Tables 10, 11, 12, 13).

   b. Abundance and biomass time series (Table 14)

c. Recruitment time series (Table 14).

d. Time series of catch/biomass (Tables 14 and 15)

3. Graphs of estimates.

a. Molting probability and trawl/pot selectivity (Figure 5)

b. Trawl survey and model estimated trawl survey abundance (Figure 6)

c. Estimated male abundances (recruits, legal, and total) (Figure 7)

d. Estimated mature male biomass (Figure 8)

e. Time series of standardized cpue for the summer commercial fishery (Figure 9).

f. Time series of catch and estimated harvest rate (Figure 10).

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; however fits of cpue are available (Figures 9, 11).

b. Model fits to survey numbers (Figures 6, 11).

All model estimated abundances of total crab were within the 95% confidence interval of the survey observed abundance, except for 1976 and 1979, where model estimates were higher than the observed abundances.

c. Fits of catch proportions by lengths (Figures 12, 13).

d. Model fits to catch and survey proportions by length (Figures 12, 14, 15, 16).

e. Marginal distribution for the fits to the composition data

f. Plots of implied versus input effective sample sizes and time-series of implied effective sample size (Figure 4).

g. Tables of RMSEs for the indices:

Trawl survey: 0.36
Summer commercial standardized CPUE: 0.5.

h. QQ plots and histograms of residuals (Figure 11).

5. Retrospective and prospective analyses (Figure 17,18).
6. Uncertainty and sensitivity analyses.

   See Sections 2 and 5.

F. Calculation of the OFL

1. Specification of the Tier level and stock status.

The Norton Sound red king crab stock is placed in Tier 4. It is not possible to estimate the spawner-recruit relationship, but some abundance and harvest estimates are available to build a computer simulation model that captures the essential population dynamics. Tier 4 stocks are assumed to have reliable estimates of current survey biomass and instantaneous *M*; however, the estimates for the Norton Sound red king crab stock are uncertain. Survey biomass is based on triennial trawl surveys with CVs ranging from 15-42% (Table 4).

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	$\beta < B/B_{MSY^{prox}} \leq 1$	$F_{OFL} = \gamma M\,(B/B_{MSY^{prox}} - \alpha)/(1-\alpha)$
c	$B/B_{MSY^{prox}} \leq \beta$	$F_{OFL} = bycatch\ mortality\ \&\ directed\ \ fishery\ F = 0$

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 1980-2016

Predicted mature male biomass in 2016 in February 01 is:

Mature male biomass : 5.87 (SD 1.12) million lb.

Estimated B_{MSY} proxy is:

4.53 million lb.

Since projected MMB is greater than B_{MSY} proxy, **Norton Sound red king crab stock status is Tire 4 a.**

2. Calculation of OFL.

The OFL was calculated for retained, unretained, and total male catch, in which OFL is calculated by applying F_{OFL} control rule to crab abundance estimates.

$$OFL = (1 - \exp(-F_{OFL}))Legal\_B$$

Legal_B, biomass of legal crab subject to fisheries is calculated as : Projected abundance by length crab × fishing selectivity by length crab × Proportion of legal crab per length class × Average lb per length class (Appendix A)

The Norton Sound red king crab fishery consists of a small (1-17% of total catch biomass) winter subsistence and commercial fishery from January to May and summer commercial fishery (83-99% of total catch biomass) from mid-June to September. The two fisheries use different fishing gears and thus have different catch selectivities (Figure 5, Table 11).

In determination of OFL, *Legal_B* should be biomass right before the majority of fisheries occur that is July 01, which is calculated as: (Feb 1st abundance – winter fishery harvests – winter fishery discards × handling mortality) × natural mortality from Feb 1st to June 30th. However, because model assessment is based on February 01 population, and winter fishery is yet to occur, predicted July 01 population cannot be calculated directly.

Hence, under the direction of the CPT (Jan 12, 2016), the crab abundance (*Legal_B*) used for calculation of the OFL the July 01 *Legal_B* was calculated as: Projected legal abundance (Feb 1st) × Commercial pot selectivity × Proportion of legal crab per length class × average lb per length class × natural mortality from February 1st to July 1st.

$$Legal\_B = (\sum_{l}(N_{w,l,} + O_{w,l,})S_{s,l}L_l wm_l)e^{-0.42M}$$

$$OFL_r = (1 - \exp(-F_{OFL}))Legal\_B$$

For next year (2017) calculation of (*Legal_B*) will be updated to incorporate projected winter fishery removal.

The unretained OFL is a sub-legal crab biomass catchable to summer commercial pot fisheries calculated as: Projected legal abundance (Feb 1st) × Commercial pot selectivity × Proportion of sub-legal crab per length class × Average lb per length class × handling mortality.

$$OFL_{nr} = (1 - \exp(-F_{OFL})) \sum_{l} (N_{s,l,} + O_{s,l,}) S_{s,l} (1 - L_l) wm_l \; hm$$

where $N_{s,l}$ and $O_{s,l}$ are summer abundances of newshell and oldshell crab in length class *l* in the terminal year, L_l is the proportion of legal males in length class *l*, $S_{s,l}$ is summer commercial catch selectivity, wm_l is average weight in length class *l* and *hm* is handling mortality rate. .

The total male OFL is

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

For calculation of the OFL 2016

Legal male biomass (July 01): 4.31 (SD 0.89) million lb
OFL_r = 0.710 million lb.
OFL_{nr} = 0.180 million lb.
OFL_T = 0.890 million lb.

G. Calculation of the ABC

1. Specification of the probability distribution of the OFL.

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

Retained ABC for legal male crab is 80% of OFL

ABC = 0.710× 0.8 = 0.568 million lb.

H. Rebuilding Analyses

Not applicable

I. Data Gaps and Research Priorities

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

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Table 1. Historical summer commercial red king crab fishery economic performance, Norton Sound Section, eastern Bering Sea, 1977-2014. 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	Harvest	Total Number (Open Access) Vessels	Permits	Landings	Total Pots Registered	Pulls	ST CPUE CPUE	SD	Season Length Days	Dates	Mid-day from July 1
1977	[c]	0.52		**195,877**	7	7	13		5,457	**4.18**	**0.34**	60	[c]	**0.03**
1978	3.00	2.09		**660,829**	8	8	54		10,817	**2.21**	**0.23**	60	6/07-8/15	**0.03**
1979	3.00	2.93		**970,962**	34	34	76		34,773	**3.09**	**0.18**	16	7/15-7/31	**0.063**
1980	1.00	1.19		**329,778**	9	9	50		11,199	**3.03**	**0.26**	16	7/15-7/31	**0.063**
1981	2.50	1.38		**376,313**	36	36	108		33,745	**0.89**	**0.19**	38	7/15-8/22	**0.093**
1982	0.50	0.23		**63,949**	11	11	33		11,230	**0.11**	**0.25**	23	8/09-9/01	**0.14**
1983	0.30	0.37		**132,205**	23	23	26	3,583	11,195	**1.00**	**0.22**	3.8	8/01-8/05	**0.093**
1984	0.40	0.39		**139,759**	8	8	21	1,245	9,706	**0.94**	**0.23**	13.6	8/01-8/15	**0.107**
1985	0.45	0.43		**146,669**	6	6	72	1,116	13,209	**0.34**	**0.20**	21.7	8/01-8/23	**0.132**
1986	0.42	0.48		**162,438**	3	3		578	4,284	**0.76**	**0.41**	13	8/01-8/25	**0.153**
1987	0.40	0.33		**103,338**	9	9		1,430	10,258	**0.57**	**0.32**	11	8/01-8/12	**0.118**
1988	0.20	0.24		**76,148**	2	2		360	2,350	**1.44**	**0.67**	9.9	8/01-8/11	**0.115**
1989	0.20	0.25		**79,116**	10	10		2,555	5,149	**1.80**	**0.32**	3	8/01-8/04	**0.096**
1990	0.20	0.19		**59,132**	4	4		1,388	3,172	**1.13**	**0.40**	4	8/01-8/05	**0.099**
1991	0.34			**0**	No Summer Fishery									
1992	0.34	0.07		**24,902**	27	27		2,635	5,746	**0.30**	**0.31**	2	8/01-8/03	**0.093**
1993	0.34	0.33		**115,913**	14	20	208	560	7,063	**0.91**	**0.10**	52	7/01-8/28	**0.09**
1994	0.34	0.32		**108,824**	34	52	407	1,360	11,729	**0.81**	**0.06**	31	7/01-7/31	**0.044**
1995	0.34	0.32		**105,967**	48	81	665	1,900	18,782	**0.43**	**0.05**	67	7/01-9/05	**0.066**
1996	0.34	0.22		**74,752**	41	50	264	1,640	10,453	**0.51**	**0.08**	57	7/01-9/03	**0.096**
1997	0.08	0.09		**32,606**	13	15	100	520	2,982	**0.85**	**0.10**	44	7/01-8/13	**0.101**
1998	0.08	0.03	0.00	**10,661**	8	11	50	360	1,639	**0.80**	**0.13**	65	7/01-9/03	**0.088**
1999	0.08	0.02	0.00	**8,734**	10	9	53	360	1,630	**0.93**	**0.13**	66	7/01-9/04	**0.101**
2000	0.33	0.29	0.01	**111,728**	15	22	201	560	6,345	**1.26**	**0.06**	91	7/01- 9/29	**0.11**
2001	0.30	0.28	0.00	**98,321**	30	37	319	1,200	11,918	**0.66**	**0.05**	97	7/01- 9/09	**0.085**
2002	0.24	0.24	0.01	**86,666**	32	49	201	1,120	6,491	**1.25**	**0.06**	77	6/15-9/03	**0.074**
2003	0.25	0.25	0.01	**93,638**	25	43	236	960	8,494	**0.88**	**0.05**	68	6/15-8/24	**0.079**
2004	0.35	0.31	0.03	**120,289**	26	39	227	1,120	8,066	**1.37**	**0.05**	51	6/15-8/08	**0.063**
2005	0.37	0.37	0.03	**138,926**	31	42	255	1,320	8,867	**1.26**	**0.05**	73	6/15-8/27	**0.071**
2006	0.45	0.42	0.03	**150,358**	28	40	249	1,120	8,867	**1.38**	**0.05**	68	6/15-8/22	**0.09**
2007	0.32	0.29	0.02	**110,344**	38	30	251	1,200	9,118	**1.07**	**0.05**	52	6/15-8/17	**0.063**
2008	0.41	0.36	0.03	**143,337**	23	30	248	920	8,721	**1.42**	**0.05**	73	6/23-9/03	**0.063**
2009	0.38	0.37	0.03	**143,485**	22	27	359	920	11,934	**0.89**	**0.04**	98	6/15-9/20	**0.1**
2010	0.40	0.39	0.03	**149,822**	23	32	286	1,040	9,698	**1.27**	**0.04**	58	6/28-8/24	**0.096**
2011	0.36	0.37	0.03	**141,626**	24	25	173	1,040	6,808	**1.62**	**0.05**	33	6/28-7/30	**0.038**
2012	0.47	0.44	0.03	**161,113**	40	29	312	1,200	10,041	**1.34**	**0.04**	72	6/29-9/08	**0.077**
2013	0.50	0.37	0.02	**130,603**	37	33	460	1,420	15,058	**0.69**	**0.04**	74	7/3-9/14	**0.107**
2014	0.38	0.36	0.03	**129,657**	52	33	309	1,560	10,127	**1.16**	**0.05**	52	6/25-8/15	**0.052**
2015	0.39	0.37	0.03	**144,255**	42	36	251	1,480	8,356	**1.53**	**0.05**	26	6/29-7/24	**0.030**

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

Table 2. Historical winter commercial and subsistence red king crab fisheries, Norton Sound Section, eastern Bering Sea, 1977-2015. 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	**41,046**	2014/15	155	153	107	**9,840**	**7,651**

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. Trawl survey abundance estimate is based on 10×10 nmil^2 grid, except for 2010 (20×20 nmil^2).

Year	Dates	Survey Agency	Survey method	Survey coverage			Abundance ≥74 mm	
				surveyed stations	Stations w/ NSRKC	n mile^2 covered		CV
1976	9/02 - 9/05	NMFS	Trawl	103	62	10260	**4247.5**	**0.31**
1979	7/26 - 8/05	NMFS	Trawl	85	22	8421	**1417.2**	**0.20**
1980	7/04 - 7/14	ADFG	Pots				2092.3	N/A
1981	6/28 - 7/14	ADFG	Pots				2153.4	N/A
1982	7/06 - 7/20	ADFG	Pots				1140.5	N/A
1982	9/05 - 9/11	NMFS	Trawl	58	37	5721	**2791.7**	**0.29**
1985	7/01 - 7/14	ADFG	Pots				2320.4	0.083
1985	9/16 -10/01	NMFS	Trawl	78	49	7688	**2306.3**	**0.25**
1988	8/16 - 8/30	NMFS	Trawl	78	41	7721	**2263.4**	**0.29**
1991	8/22 - 8/30	NMFS	Trawl	52	38	5183	**3132.5**	**0.43**
1996	8/07 - 8/18	ADFG	Trawl	50	30	4938	**1264.7**	**0.317**
1999	7/28 - 8/07	ADFG	Trawl	53	31	5221	**2276.1**	**0.194**
2002	7/27 - 8/06	ADFG	Trawl	57	37	5621	**1747.6**	**0.125**
2006	7/25 - 8/08	ADFG	Trawl	101	45	10008	**2549.7**	**0.288**
2008	7/24 - 8/11	ADFG	Trawl	74	44	7330	**2707.1**	**0.164**
2010[a]	7/27 - 8/09	NMFS	Trawl	35	15	13749	**2041.0**	**0.455**
2011	7/18 - 8/15	ADFG	Trawl	65	34	6447	**2701.7**	**0.133**
2014	7/18 - 7/30	ADFG	Trawl	47	34	4700	**5481.5**	**0.486**

Table 4. Summer commercial catch size/shell compositions. Sizes in this and Tables 5-10 and 12 are mm carapace length. Legal size (4.75 inch carapace width is approximately equal to 124 mm carapace length.

Model 5 data

		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

Model 13 data

		New Shell														
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1977	1549	0	0	0	0	0.00	0.00	0.00	0.00	0.15	0.27	0.22	0.12	0.05	0.02	0.05
1978	389	0	0	0	0	0.00	0.00	0.00	0.01	0.04	0.14	0.23	0.24	0.17	0.10	0.04
1979	1660	0	0	0	0	0.00	0.00	0.00	0.03	0.09	0.14	0.20	0.19	0.16	0.10	0.07
1980	1068	0	0	0	0	0.00	0.00	0.00	0.00	0.04	0.05	0.12	0.18	0.19	0.18	0.18
1981	1784	0	0	0	0	0.00	0.00	0.00	0.00	0.03	0.05	0.06	0.09	0.13	0.15	0.23
1982	1093	0	0	0	0	0.00	0.00	0.00	0.04	0.09	0.10	0.07	0.09	0.10	0.12	0.29
1983	802	0	0	0	0	0.00	0.00	0.00	0.04	0.16	0.25	0.23	0.13	0.04	0.02	0.03
1984	963	0	0	0	0	0.00	0.00	0.01	0.09	0.21	0.21	0.16	0.12	0.04	0.02	0.01
1985	2691	0	0	0	0	0.00	0.00	0.00	0.06	0.14	0.17	0.19	0.19	0.11	0.05	0.02
1986	1138	0	0	0	0	0.00	0.00	0.00	0.03	0.14	0.22	0.23	0.16	0.08	0.04	0.02
1987	1985	0	0	0	0	0.00	0.00	0.00	0.02	0.05	0.13	0.14	0.15	0.14	0.13	0.11
1988	1522	0	0	0	0	0.00	0.00	0.00	0.02	0.06	0.14	0.16	0.15	0.10	0.08	0.04
1989	2595	0	0	0	0	0.00	0.00	0.00	0.01	0.07	0.10	0.15	0.16	0.11	0.06	0.05
1990	1289	0	0	0	0	0.00	0.00	0.00	0.01	0.05	0.09	0.17	0.18	0.16	0.10	0.07
1991																
1992	2566	0	0	0	0	0.00	0.00	0.00	0.02	0.08	0.12	0.14	0.12	0.08	0.05	0.09
1993	17804	0	0	0	0	0.00	0.00	0.00	0.01	0.09	0.14	0.19	0.20	0.15	0.08	0.03
1994	404	0	0	0	0	0.00	0.00	0.00	0.02	0.04	0.05	0.03	0.05	0.04	0.03	0.02
1995	1167	0	0	0	0	0.00	0.00	0.00	0.04	0.10	0.17	0.15	0.14	0.09	0.06	0.05
1996	787	0	0	0	0	0.00	0.00	0.00	0.03	0.10	0.12	0.13	0.11	0.05	0.04	0.05
1997	1198	0	0	0	0	0.00	0.00	0.00	0.03	0.13	0.24	0.22	0.13	0.07	0.03	0.03
1998	1055	0	0	0	0	0.00	0.00	0.00	0.02	0.08	0.16	0.14	0.11	0.05	0.03	0.03
1999	562	0	0	0	0	0.00	0.00	0.00	0.06	0.13	0.17	0.12	0.12	0.11	0.08	0.09
2000	17213	0	0	0	0	0.00	0.00	0.00	0.02	0.10	0.19	0.23	0.16	0.08	0.03	0.02
2001	20030	0	0	0	0	0.00	0.00	0.00	0.02	0.09	0.14	0.21	0.16	0.13	0.07	0.07
2002	5219	0	0	0	0	0.00	0.00	0.00	0.04	0.10	0.13	0.13	0.15	0.15	0.10	0.07
2003	5226	0	0	0	0	0.00	0.00	0.00	0.02	0.14	0.23	0.20	0.12	0.07	0.05	0.03
2004	9606	0	0	0	0	0.00	0.00	0.00	0.01	0.11	0.28	0.24	0.15	0.07	0.04	0.03
2005	5360	0	0	0	0	0.00	0.00	0.00	0.00	0.05	0.20	0.26	0.21	0.12	0.04	0.02
2006	6707	0	0	0	0	0.00	0.00	0.00	0.00	0.04	0.14	0.18	0.17	0.12	0.06	0.02
2007	6125	0	0	0	0	0.00	0.00	0.00	0.01	0.13	0.23	0.19	0.15	0.09	0.05	0.03
2008	5766	0	0	0	0	0.00	0.00	0.00	0.00	0.10	0.25	0.23	0.12	0.04	0.01	0.01
2009	6026	0	0	0	0	0.00	0.00	0.00	0.01	0.12	0.22	0.19	0.14	0.08	0.04	0.02
2010	5902	0	0	0	0	0.00	0.00	0.00	0.01	0.11	0.28	0.23	0.13	0.07	0.03	0.01
2011	2552	0	0	0	0	0.00	0.00	0.00	0.00	0.09	0.23	0.25	0.15	0.08	0.04	0.02
2012	5056	0	0	0	0	0.00	0.00	0.00	0.00	0.06	0.18	0.25	0.21	0.13	0.05	0.02
2013	6072	0	0	0	0	0.00	0.00	0.00	0.00	0.07	0.16	0.19	0.18	0.15	0.10	0.06
2014	4682	0	0	0	0	0.00	0.00	0.00	0.01	0.11	0.17	0.13	0.11	0.09	0.09	0.07
2015	4173	0	0	0	0	0.00	0.00	0.00	0.01	0.19	0.28	0.19	0.10	0.06	0.04	0.03

Model 13 data

						Old Shell										
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1977	1549	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.04	0.03	0.01	0.01	0.00	0.00
1978	389	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
1979	1660	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01
1980	1068	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
1981	1784	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.05	0.07	0.09
1982	1093	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.03
1983	802	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.01	0.02
1984	963	0	0	0	0	0.00	0.00	0.00	0.01	0.04	0.03	0.03	0.02	0.00	0.00	0.00
1985	2691	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.00	0.00
1986	1138	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.00
1987	1985	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.02	0.01	0.01
1988	1522	0	0	0	0	0.00	0.00	0.00	0.01	0.03	0.04	0.05	0.05	0.05	0.02	0.02
1989	2595	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.03	0.06	0.06	0.06	0.03	0.02
1990	1289	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.03	0.03	0.02	0.01
1991																
1992	2566	0	0	0	0	0.00	0.00	0.00	0.00	0.03	0.05	0.07	0.06	0.03	0.03	0.02
1993	17804	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.01
1994	404	0	0	0	0	0.00	0.00	0.00	0.02	0.09	0.10	0.10	0.15	0.11	0.09	0.05
1995	1167	0	0	0	0	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.03	0.01
1996	787	0	0	0	0	0.00	0.00	0.00	0.01	0.05	0.07	0.08	0.06	0.04	0.03	0.02
1997	1198	0	0	0	0	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.02	0.02	0.01	0.01
1998	1055	0	0	0	0	0.00	0.00	0.00	0.02	0.05	0.06	0.08	0.06	0.05	0.04	0.03
1999	562	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.02	0.04	0.01	0.00
2000	17213	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.03	0.02	0.01	0.01
2001	20030	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.02	0.01	0.01
2002	5219	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.01	0.01
2003	5226	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.02	0.01
2004	9606	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01
2005	5360	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.02	0.01	0.01	0.01
2006	6707	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.07	0.05	0.02	0.01
2007	6125	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.02	0.01	0.01
2008	5766	0	0	0	0	0.00	0.00	0.00	0.00	0.03	0.06	0.05	0.04	0.02	0.01	0.01
2009	6026	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.05	0.05	0.03	0.01	0.01	0.01
2010	5902	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.04	0.03	0.02	0.02	0.01	0.00
2011	2552	0	0	0	0	0.00	0.00	0.00	0.00	0.02	0.04	0.03	0.02	0.01	0.00	0.00
2012	5056	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.00
2013	6072	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.00
2014	4682	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.05	0.04	0.03	0.02
2015	4173	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.01	0.01

Table 5. Summer Trawl Survey size/shell compositions.

Model 5 data

		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+
1976	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	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	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	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	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	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	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	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	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	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	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	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	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	391	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

Model 13 data

							New Shell									
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1976	1326	0.00	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.16	0.18	0.13	0.05	0.02	0.01	0.00
1979	220	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.02	0.03	0.02	0.01	0.01
1982	327	0.14	0.08	0.04	0.03	0.06	0.10	0.09	0.14	0.10	0.06	0.02	0.01	0.00	0.00	0.00
1985	350	0.05	0.06	0.05	0.05	0.08	0.11	0.09	0.08	0.08	0.08	0.03	0.03	0.01	0.00	0.00
1988	366	0.09	0.08	0.10	0.09	0.06	0.06	0.07	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.00
1991	340	0.09	0.09	0.06	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.03	0.00	0.01	0.01	0.01
1996	269	0.09	0.20	0.10	0.11	0.07	0.06	0.06	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.01
1999	283	0.02	0.01	0.00	0.01	0.03	0.07	0.10	0.19	0.14	0.12	0.09	0.04	0.03	0.00	0.01
2002	244	0.07	0.03	0.07	0.05	0.06	0.07	0.07	0.05	0.01	0.00	0.01	0.02	0.02	0.00	0.01
2006	373	0.08	0.11	0.12	0.14	0.11	0.10	0.06	0.06	0.04	0.02	0.01	0.03	0.01	0.01	0.00
2008	275	0.07	0.06	0.07	0.08	0.11	0.11	0.05	0.06	0.06	0.04	0.03	0.00	0.01	0.01	0.01
2010	69	0.00	0.01	0.01	0.03	0.04	0.01	0.09	0.09	0.03	0.03	0.00	0.03	0.00	0.00	0.00
2011	315	0.05	0.08	0.09	0.03	0.04	0.05	0.05	0.06	0.07	0.11	0.08	0.06	0.03	0.01	0.01
2014	391	0.04	0.04	0.06	0.09	0.10	0.14	0.11	0.07	0.06	0.03	0.01	0.01	0.01	0.01	0.01

Model 13 data

							Old Shell									
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1976	1326	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.00	0.01	0.01
1979	220	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.04	0.10	0.16	0.24	0.12	0.07	0.03
1982	327	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.03
1985	350	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.02	0.01
1988	366	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.03	0.03	0.04	0.03	0.02	0.03
1991	340	0.01	0.02	0.04	0.02	0.01	0.01	0.04	0.04	0.08	0.08	0.07	0.07	0.05	0.04	0.02
1996	269	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
1999	283	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.02	0.02	0.01	0.02	0.00	0.00
2002	244	0.00	0.01	0.01	0.02	0.02	0.05	0.06	0.05	0.05	0.04	0.05	0.04	0.03	0.02	0.02
2006	373	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.01	0.00	0.00
2008	275	0.00	0.00	0.00	0.01	0.02	0.03	0.02	0.04	0.03	0.05	0.00	0.01	0.01	0.02	0.00
2010	69	0.00	0.00	0.03	0.00	0.04	0.04	0.07	0.13	0.06	0.13	0.07	0.00	0.01	0.01	0.01
2011	315	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.05	0.04	0.02	0.03	0.01	0.02	0.00
2014	391	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.05	0.02	0.03	0.03	0.01	0.01	0.00	0.00

Table 6. Winter pot survey size/shell compositions.

Model 5 data

			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

Model 13 data

			New Shell														
Year	CPUE	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1981/82	NA	719	0.00	0.00	0.03	0.07	0.09	0.13	0.12	0.09	0.04	0.03	0.01	0.01	0.01	0.01	0.00
1982/83	24.2	2583	0.01	0.02	0.03	0.06	0.12	0.16	0.14	0.14	0.11	0.10	0.05	0.02	0.01	0.00	0.00
1983/84	24.0	1677	0.00	0.01	0.05	0.11	0.14	0.11	0.12	0.11	0.09	0.06	0.04	0.02	0.00	0.00	0.00
1984/85	24.5	789	0.01	0.01	0.03	0.06	0.09	0.16	0.21	0.14	0.10	0.05	0.04	0.02	0.00	0.00	0.00
1985/86	19.2	594	0.01	0.03	0.06	0.07	0.07	0.10	0.13	0.12	0.09	0.10	0.06	0.02	0.01	0.00	0.00
1986/87	5.8	144	0.00	0.00	0.02	0.03	0.06	0.10	0.09	0.10	0.03	0.04	0.03	0.01	0.00	0.00	0.00
1987/88																	
1988/89	13.0	500	0.00	0.01	0.05	0.08	0.10	0.05	0.06	0.08	0.10	0.09	0.11	0.06	0.02	0.01	0.00
1989/90	21.0	2076	0.00	0.00	0.01	0.04	0.08	0.13	0.14	0.12	0.09	0.09	0.06	0.06	0.04	0.02	0.01
1990/91	22.9	1283	0.00	0.00	0.01	0.00	0.03	0.06	0.12	0.17	0.15	0.11	0.07	0.03	0.01	0.00	0.00
1992/93	5.5	181	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.02	0.06	0.07	0.09	0.03	0.02	0.01	0.00
1993/94																	
1994/95	6.2	858	0.00	0.01	0.02	0.04	0.04	0.04	0.05	0.05	0.11	0.15	0.14	0.10	0.05	0.03	0.01
1995/96	9.9	1580	0.02	0.05	0.06	0.07	0.08	0.12	0.11	0.09	0.07	0.05	0.03	0.03	0.02	0.01	0.00
1996/97	2.9	398	0.01	0.06	0.11	0.11	0.12	0.10	0.06	0.05	0.06	0.09	0.06	0.05	0.02	0.03	0.01
1997/98	10.9	881	0.00	0.00	0.03	0.11	0.19	0.22	0.16	0.10	0.04	0.02	0.02	0.01	0.00	0.00	0.00
1998/99	10.7	1307	0.00	0.00	0.01	0.01	0.04	0.08	0.14	0.22	0.22	0.14	0.06	0.02	0.01	0.00	0.00
1999/00	6.2	575	0.01	0.01	0.04	0.05	0.04	0.06	0.07	0.09	0.15	0.18	0.12	0.06	0.03	0.00	0.00
2000/01	3.1	44															
2001/02	13.0	828	0.01	0.04	0.13	0.17	0.14	0.12	0.10	0.07	0.04	0.03	0.03	0.03	0.03	0.01	0.01
2002/03	9.6	824	0.01	0.01	0.04	0.06	0.09	0.13	0.16	0.12	0.10	0.08	0.04	0.02	0.01	0.01	0.00
2003/04	3.7	296	0.00	0.00	0.00	0.01	0.04	0.12	0.12	0.14	0.14	0.18	0.10	0.04	0.01	0.01	0.00
2004/05	4.4	405	0.00	0.00	0.03	0.04	0.06	0.08	0.08	0.10	0.11	0.10	0.11	0.08	0.04	0.03	0.00
2005/06	6.0	512	0.00	0.00	0.04	0.10	0.12	0.11	0.12	0.09	0.09	0.07	0.03	0.03	0.02	0.00	0.00
2006/07	7.3	159	0.03	0.04	0.04	0.09	0.03	0.16	0.19	0.16	0.09	0.04	0.02	0.03	0.00	0.00	0.00
2007/08	25.0	3552	0.00	0.01	0.04	0.11	0.12	0.13	0.09	0.08	0.07	0.07	0.04	0.02	0.00	0.00	0.00
2008/09	21.9	525	0.00	0.00	0.02	0.05	0.04	0.09	0.15	0.20	0.13	0.07	0.05	0.03	0.01	0.00	0.00
2009/10	25.3	578	0.00	0.01	0.01	0.03	0.04	0.09	0.09	0.12	0.12	0.12	0.08	0.03	0.01	0.01	0.00
2010/11	22.1	596	0.00	0.02	0.02	0.05	0.07	0.07	0.09	0.12	0.08	0.09	0.07	0.06	0.03	0.02	0.00
2011/12	29.4	675	0.00	0.02	0.05	0.06	0.11	0.12	0.10	0.09	0.07	0.05	0.06	0.07	0.03	0.01	0.00

Model 13 data

					Old Shell												
Year	CPUE	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1981/82	NA	719	0.00	0.00	0.02	0.03	0.05	0.07	0.06	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.00
1982/83	24.2	2583	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01
1983/84	24.0	1677	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.01
1984/85	24.5	789	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.01	0.00	0.00	0.00
1985/86	19.2	594	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.02	0.02	0.01	0.00	0.00
1986/87	5.8	144	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.02	0.15	0.15	0.08	0.03	0.02	0.01	0.00
1987/88																	
1988/89	13.0	500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.04	0.02	0.01	0.00
1989/90	21.0	2076	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.01	0.01	0.00
1990/91	22.9	1283	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.07	0.04	0.03	0.02
1992/93	5.5	181	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.14	0.10	0.17	0.06	0.05	0.05
1993/94																	
1994/95	6.2	858	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.03	0.03	0.02
1995/96	9.9	1580	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.04	0.03	0.02	0.01	0.01
1996/97	2.9	398	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.01	0.00	0.01
1997/98	10.9	881	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01
1998/99	10.7	1307	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
1999/00	6.2	575	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.02	0.01	0.00	0.01	0.00
2000/01	3.1	44															
2001/02	13.0	828	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
2002/03	9.6	824	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
2003/04	3.7	296	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.01	0.00	0.01	0.01	0.01
2004/05	4.4	405	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.04	0.02	0.01	0.00	0.00
2005/06	6.0	512	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.03	0.02	0.01	0.01
2006/07	7.3	159	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.03	0.01	0.00	0.00	0.00
2007/08	25.0	3552	0.00	0.01	0.01	0.03	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00
2008/09	21.9	525	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.04	0.00	0.00	0.00
2009/10	25.3	578	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.03	0.03	0.01	0.00	0.00
2010/11	22.1	596	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.05	0.06	0.03	0.02	0.01	0.00	0.00
2011/12	29.4	675	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.03	0.03	0.02	0.01	0.00

Table 7. Summer commercial1987-1994, 2012-2015 observer discards size/shell compositions
Model 5 data

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

Model 13 data

		New Shell														
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1987	1146	0.02	0.04	0.08	0.11	0.13	0.19	0.18	0.15	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1988	722	0.00	0.01	0.01	0.03	0.06	0.09	0.21	0.26	0.12	0.02	0.00	0.00	0.00	0.00	0.00
1989	1000	0.02	0.05	0.10	0.09	0.10	0.14	0.13	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1990	507	0.03	0.05	0.09	0.13	0.14	0.13	0.16	0.11	0.02	0.01	0.00	0.00	0.00	0.00	0.00
1992	580	0.04	0.07	0.07	0.10	0.14	0.15	0.15	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1994	850	0.03	0.05	0.02	0.04	0.04	0.06	0.08	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2012	939	0.11	0.10	0.06	0.05	0.09	0.10	0.15	0.17	0.09	0.01	0.01	0.00	0.00	0.00	0.00
2013	2617	0.14	0.20	0.17	0.12	0.08	0.08	0.08	0.08	0.04	0.01	0.00	0.00	0.00	0.00	0.00
2014	1755	0.01	0.03	0.04	0.06	0.10	0.16	0.19	0.22	0.10	0.02	0.01	0.00	0.00	0.00	0.00
2015	824	0.00	0.01	0.02	0.06	0.07	0.11	0.15	0.29	0.19	0.04	0.01	0.01	0.00	0.00	0.00

Model 13 data

		Old Shell														
Year	Sample	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
1987	1146	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	722	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.04	0.01	0.00	0.00	0.00	0.00	0.00
1989	1000	0.01	0.01	0.01	0.02	0.03	0.04	0.06	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1990	507	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1992	580	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1994	850	0.03	0.04	0.03	0.04	0.07	0.08	0.12	0.12	0.04	0.01	0.00	0.00	0.00	0.00	0.00
2012	939	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2013	2617	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	1755	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2015	824	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Table 8 The number of tagged data released and recovered after 1 year (Y1) – 3 year (Y3) during 1980-1992 and 1993-2015 periods.

Model 5 data

Release Length Class	Recap Length Class	1980-1992			1993-2014		
		Y1	Y2	Y3	Y1	Y2	Y3
64 – 73	64 – 73						
64 – 73	74 - 83	1					
64 – 73	84 - 93	1			3	1	
64 – 73	94 - 103		1			4	
64 – 73	104 – 113					4	1
64 – 73	114 – 123						2
64 – 73	124 – 133						
64 – 73	134+						
74 - 83	74 - 83						
74 - 83	84 - 93				21		
74 - 83	94 - 103				22	10	
74 - 83	104 – 113		2		4	68	3
74 - 83	114 – 123			2		3	2
74 - 83	124 – 133						
74 - 83	134+						
84 - 93	84 - 93						
84 - 93	94 - 103	5			42	4	
84 - 93	104 – 113	10	2		80	20	6
84 - 93	114 – 123		1	1	7	37	2
84 - 93	124 – 133				1	1	2
84 - 93	134+						
94 - 103	94 - 103	3			6	1	
94 - 103	104 – 113	31	1	1	144	19	
94 - 103	114 – 123	26	1	3	71	7	10
94 - 103	124 – 133	2		1		8	6
94 - 103	134+				1		
104 – 113	104 – 113	16			44	2	
104 – 113	114 – 123	34	13		73	22	4
104 – 113	124 – 133	7	6	3	12	4	7
104 – 113	134+						
114 – 123	114 – 123	16	2		62	4	
114 – 123	124 – 133	26	9	1	59	28	3
114 – 123	134+	5	1		19	4	2
124 – 133	124 – 133	15			36	6	
124 – 133	134+	10	4	2	10	8	4
134+	134+	15	6	1	8		

Model 13 data

Release Length Class	Recap Length Class	1980-1992			1993-2014		
		Y1	Y2	Y3	Y1	Y2	Y3
64-68	64-68						
64-68	69-73						
64-68	74-78	1					
64-68	79-83						
64-68	84-88						
64-68	89-93						
64-68	94-98						
64-68	99-103						
64-68	104-108					1	
64-68	109-113						
64-68	114-118						
64-68	119-123						
64-68	123-128						
64-68	129-133						
64-68	134+						
69-73	69-73						
69-73	74-78						
69-73	79-83						
69-73	84-88	1			3		
69-73	89-93					1	
69-73	94-98					2	
69-73	99-103		1			2	
69-73	104-108					2	
69-73	109-113					1	1
69-73	114-118						1
69-73	119-123						
69-73	123-128						
69-73	129-133						
69-73	134+						
74-78	74-78						
74-78	79-83						
74-78	84-88				5		
74-78	89-93				10		
74-78	94-98				1	1	
74-78	99-103					7	
74-78	104-108		1			10	
74-78	109-113					3	
74-78	114-118						2
74-78	119-123			2			

74-78	123-128						
74-78	129-133						
74-78	134+						
79-83	79-83						
79-83	84-88				1		
79-83	89-93				5		
79-83	94-98				17	1	
79-83	99-103				4	1	
79-83	104-108		1		3	20	1
79-83	109-113				1	35	2
79-83	114-118					3	
79-83	119-123						
79-83	123-128						
79-83	129-133						
79-83	134+						
84-88	84-88						
84-88	89-93						
84-88	94-98				5		
84-88	99-103				25	3	
84-88	104-108	2			8	1	
84-88	109-113		2		2	15	4
84-88	114-118					22	1
84-88	119-123						
84-88	123-128						
84-88	129-133					1	
84-88	134+						
89-93	89-93						
89-93	94-98						
89-93	99-103	5			12	1	
89-93	104-108	5			58		1
89-93	109-113	3			12	4	1
89-93	114-118		1	1		7	1
89-93	119-123				5	6	
89-93	123-128				1		1
89-93	129-133						1
89-93	134+						
94-98	94-98						
94-98	99-103				1		
94-98	104-108	5			32	6	
94-98	109-113	14			84	7	
94-98	114-118	4			10		3
94-98	119-123		1	3		4	5
94-98	123-128	1		1		6	1

94-98	129-133	1					
94-98	134+				1		
99-103	99-103	3			5	1	
99-103	104-108				4		
99-103	109-113	12	1	1	24	6	
99-103	114-118	19			59	2	1
99-103	119-123	3			2	1	1
99-103	123-128					2	2
99-103	129-133						3
99-103	134+						
104-108	104-108	10			7		
104-108	109-113	1			4	1	
104-108	114-118	10	2		21	6	1
104-108	119-123	15	3		20	4	
104-108	123-128	3	1	2	2	2	1
104-108	129-133			1		1	3
104-108	134+						
109-113	109-113				29		
109-113	114-118	5			1		1
109-113	119-123		2		31	12	2
109-113	123-128	9	6		10	1	1
109-113	129-133	4	5				2
109-113	134+						
114-118	114-118				24		
114-118	119-123	3			18	2	
114-118	123-128		2		22	7	2
114-118	129-133	10	4		8	2	1
114-118	134+	2			1	1	
119-123	119-123	1			20		
119-123	123-128	12			5	4	
119-123	129-133	1			24	15	
119-123	134+	13	5	1	18	3	2
123-128	123-128	4	1		19	1	
123-128	129-133	3			6	1	
123-128	134+	4	2	1	8	5	3
129-133	129-133	12			11	4	
129-133	134+	6	2	1	2	3	1
134+	134+	15	6	1	8		

Table 9. 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	Equation Number in Appendix A	Lower	Upper
log_q_1	Commercial fishery catchability (1977-92)	(20)	-32.5	8.5
log_q_2	Commercial fishery catchability (1993-2014)	(20)	-32.5	10.0
log_N_{76}	Initial abundance	(1)	2.0	15.0
R_0	Mean Recruit	(13)	2.0	12.0
$log\_\sigma_R^2$	Recruit standard deviation	(13)	-20.0	20.0
a_1	Parameter for intimal length proportion	(2)	-5.0	5.0
a_2	Parameter for intimal length proportion	(2)	-5.0	5.0
a_3	Parameter for intimal length proportion	(2)	-5.0	5.0
a_4	Parameter for intimal length proportion	(2)	-5.0	5.0
a_5	Parameter for intimal length proportion	(2)	-5.0	5.0
r	Proportion of length class 1 for recruit	(14)	0.5	0.9
log_α	Inverse logistic molting parameter	(15)	-5.5	-2.0
log_ϕ_{st1}	Logistic trawl selectivity parameter (NMFS)	(16)	-15.0	-1.0
log_ϕ_{st2}	Logistic trawl selectivity parameter (ADF&G)	(16)	-15.0	-1.0
log_ϕ_w	Logistic winter pot selectivity parameter Or Inverse logistic winter pot selectivity parameter	(15,16)	-10.0	10.0
Sw_6 / Sw_1	Winter pot selectivity of length class 6 (logistic), length class 1 (inverse logistic)	(15,16)	0.1	1.0
log_ϕ_1	Logistic commercial catch selectivity parameter (1977-92)	(16)	-5.0	-1.0
log_ϕ_2	Logistic commercial catch selectivity parameter (1993-2014)	(16)	-5.0	-1.0
w_t^2	Additional varince for standard CPUE	(31)	0.0	6.0
q	Survey q for NMFS trawl 1976-91	(31)	0.1	1.0
σ	Growth transition sigma	(17)	0.0	30.0
β_1	Growth transition mean	(17)	0.0	20.0
β_2	Growth transition increment	(17)	0.0	20.0

Table 10 . Summary of parameter estimates and standard deviations of Norton Sound red king crab. Model 5

	Estimate	std.dev
log_q_1	-6.9259	0.1906
log_q_2	-6.7761	0.11195
log_N_{76}	9.1231	0.15299
R_0	6.4911	0.090086
$log\_\sigma_R^2$	0.027945	0.44393
log_R_{77}	-0.56982	0.37063
log_R_{78}	-0.71447	0.35474
log_R_{79}	0.24017	0.32398
log_R_{80}	0.34399	0.29828
log_R_{81}	0.31351	0.27449
log_R_{82}	0.40028	0.31875
log_R_{83}	0.58749	0.28078
log_R_{84}	0.061908	0.31094
log_R_{85}	0.45028	0.28276
log_R_{86}	-0.008591	0.30533
log_R_{87}	-0.008095	0.26231
log_R_{88}	0.010236	0.2729
log_R_{89}	-0.39646	0.29694
log_R_{90}	-0.28167	0.26238
log_R_{91}	-0.54566	0.2904
log_R_{92}	-0.74061	0.31228
log_R_{93}	-0.61466	0.29318
log_R_{94}	-0.37182	0.26754
log_R_{95}	-0.086911	0.24029
log_R_{96}	0.53258	0.21708
log_R_{97}	-0.20834	0.31568
log_R_{98}	-0.66352	0.31794
log_R_{99}	-0.17289	0.31294
log_R_{00}	0.14649	0.26868
log_R_{01}	0.16903	0.25699
log_R_{02}	0.006718	0.30956
log_R_{03}	-0.31276	0.33503
log_R_{04}	0.28697	0.24744
log_R_{05}	0.3216	0.24164
log_R_{06}	0.48335	0.24985
log_R_{07}	0.485	0.24724
log_R_{08}	0.11161	0.29966
log_R_{09}	-0.31992	0.30542
log_R_{10}	0.050226	0.25402
log_R_{11}	0.2479	0.2958
log_R_{12}	0.95366	0.26511

name	Estimate	std.dev
log_R_{13}	-0.064742	0.36781
log_R_{14}	-0.14998	0.44671
a_1	2.5859	4.3418
a_2	2.6678	4.2709
a_3	4.003	4.0705
a_4	4.2557	4.0567
a_5	4.4771	4.0493
a_6	3.6832	4.0742
a_7	2.0469	4.2894
r1	14.988	63.407
r2	14.626	63.407
log_α	-2.0122	0.016911
log_ϕ_{st1}	-2.6268	0.35705
log_ϕ_w	-2.0465	0.050315
Sw_1	0.070758	0.034013
Sw_2	0.44402	0.10674
log_ϕ_l	-2.0887	0.057957
w^2_t	0.075056	0.023717
q	0.74645	0.13422
σ	4.3015	0.26533
β_1	10.292	0.80362
β_2	8.1997	0.20266
M		
ms	3.5552	0.31672

Model 13

	Estimate	std.dev
log_q_1	-6.915	0.1882
log_q_2	-6.7478	0.10959
log_N_{76}	9.1446	0.15016
R_0	6.4965	0.087764
$log\_\sigma_R^2$	-0.017897	0.4288
log_R_{77}	-0.6057	0.35732
log_R_{78}	-0.70196	0.34304
log_R_{79}	0.34168	0.27485
log_R_{80}	0.26841	0.27664
log_R_{81}	0.33319	0.25218
log_R_{82}	0.48945	0.27443
log_R_{83}	0.48783	0.26815
log_R_{84}	0.11651	0.28101
log_R_{85}	0.46689	0.25099
log_R_{86}	-0.051417	0.27787
log_R_{87}	-0.007842	0.24367
log_R_{88}	0.024252	0.2508
log_R_{89}	-0.44084	0.27779
log_R_{90}	-0.29302	0.24642
log_R_{91}	-0.5423	0.27091
log_R_{92}	-0.74135	0.29141
log_R_{93}	-0.53768	0.2666
log_R_{94}	-0.4061	0.25618
log_R_{95}	-0.087755	0.22817
log_R_{96}	0.54883	0.19138
log_R_{97}	-0.31011	0.2923
log_R_{98}	-0.62355	0.29992
log_R_{99}	-0.16896	0.28657
log_R_{00}	0.18266	0.24043
log_R_{01}	0.18352	0.23424
log_R_{02}	-0.068791	0.29021
log_R_{03}	-0.2684	0.30106
log_R_{04}	0.32018	0.22461
log_R_{05}	0.26825	0.23038
log_R_{06}	0.53006	0.21792
log_R_{07}	0.44263	0.22501
log_R_{08}	0.10561	0.26684
log_R_{09}	-0.27795	0.27491
log_R_{10}	0.027615	0.24224
log_R_{11}	0.34476	0.27238
log_R_{12}	0.91115	0.26265

name	Estimate	std.dev
log_R_{13}	-0.080906	0.35931
log_R_{14}	-0.16095	0.44919
a_1	2.5616	4.089
a_2	1.8895	4.5519
a_3	1.3861	4.7425
a_4	2.2245	4.1301
a_5	2.9176	3.9276
a_6	3.1745	3.8839
a_7	3.4127	3.8627
a_8	3.3869	3.8586
a_9	3.4946	3.8463
a_{10}	3.4981	3.8466
a_{11}	3.1417	3.8613
a_{12}	2.1496	3.9518
a_{13}	1.7873	4.1704
a_{14}	0.30529	5.1112
r1	14.967	135.17
r2	14.943	135.17
r3	14.885	135.17
r4	14.347	135.17
r5	-6.8084	17901
log_α	-2.0597	0.012815
log_ϕ_{st1}	-2.5495	0.27329
log_ϕ_w	-2.0929	0.049215
Sw_1	0.032224	0.034442
Sw_2	0.10802	0.061776
Sw_3	0.2926	0.11008
Sw_4	0.52251	0.15919
log_ϕ_1	-2.0581	0.060299
w^2_t	7.38E-02	0.023578
q	0.743	0.13223
σ	3.5999	0.31154
β_1	2.7995	0.12141
β_2	13.289	0.4609
M		
ms	3.5999	0.31154

Table 11. Estimated selectivities, molting probabilities, and proportions of legal crab by length (mm CL) class for Norton Sound male red king crab.

Model 5

Length Class	Legal Proportion	Mean weight (lb)	Selectivity ADFG/ NOAA	Selectivity Winter Pot	Selectivity Summer Fishery	Molting Probability
64 - 73	0.00	0.434	0.86	0.07	0.15	1.00
74 - 83	0.00	0.855	0.93	0.44	0.37	1.00
84 - 93	0.00	1.313	0.96	0.99	0.67	0.99
94 - 103	0.13	1.823	0.98	0.95	0.88	0.95
104 - 113	0.87	2.387	0.99	0.85	0.96	0.83
114 - 123	1.00	3.064	1.00	0.61	0.99	0.56
124 - 133	1.00	3.840	1.00	0.30	1.00	0.25
134+	1.00	4.649	1.00	0.11	1.00	0.08

Model 13

Length Class	Legal Proportion	Mean weight (lb)	Selectivity ADFG/ NOAA	Selectivity Winter Pot	Selectivity Summer Fishery	Molting Probability
64-68	0.00	0.332	0.81	0.03	0.12	1.00
69-73	0.00	0.537	0.86	0.11	0.20	1.00
74-78	0.00	0.747	0.90	0.29	0.32	1.00
79-83	0.00	0.965	0.93	0.52	0.47	0.99
84-88	0.00	1.194	0.95	0.99	0.63	0.99
89-93	0.00	1.435	0.97	0.98	0.76	0.98
94-98	0.02	1.691	0.98	0.96	0.86	0.96
99-103	0.23	1.958	0.98	0.93	0.92	0.92
104-108	0.77	2.239	0.99	0.88	0.96	0.86
109-113	0.97	2.543	0.99	0.80	0.98	0.76
114-118	1.00	2.882	1.00	0.68	0.99	0.63
119-123	1.00	3.252	1.00	0.53	0.99	0.47
123-128	1.00	3.641	1.00	0.38	1.00	0.32
129-133	1.00	4.041	1.00	0.25	1.00	0.20
134+	1.00	4.446	1.00	0.15	1.00	0.12

Table 12: Estimated molting probability incorporated transition matrix.

Model 5: without molting probability

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	0.001	0.208	0.726	0.065	0.000	0.000	0.000	0.000
74 - 83		0.003	0.344	0.626	0.027	0.000	0.000	0.000
84 - 93			0.011	0.499	0.480	0.009	0.000	0.000
94 - 103				0.030	0.641	0.326	0.003	0.000
104 – 113					0.072	0.734	0.194	0.001
114 – 123						0.148	0.752	0.100
124 – 133							0.277	0.723
134+								1.000

Model 5: with molting probability

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	0.002	0.207	0.726	0.065	0.000	0.000	0.000	0.00
74 - 83		0.007	0.343	0.624	0.027	0.000	0.000	0.00
84 - 93			0.025	0.492	0.474	0.009	0.000	0.00
94 - 103				0.081	0.608	0.309	0.003	0.00
104 - 113					0.233	0.606	0.160	0.00
114 - 123						0.527	0.418	0.06
124 - 133							0.821	0.18
134+								1.00

Model 13: without molting probability

Pre-molt Length Class	Post-molt Length Class														
	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
64-68	0.000	0.000	0.034	0.451	0.474	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69-73		0.000	0.000	0.057	0.525	0.394	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74-78			0.000	0.001	0.091	0.584	0.312	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79-83				0.000	0.002	0.137	0.619	0.235	0.006	0.000	0.000	0.000	0.000	0.000	0.000
84-88					0.000	0.004	0.196	0.627	0.169	0.003	0.000	0.000	0.000	0.000	0.000
89-93						0.000	0.009	0.268	0.607	0.115	0.001	0.000	0.000	0.000	0.000
94-98							0.000	0.016	0.347	0.561	0.075	0.001	0.000	0.000	0.000
99-103								0.000	0.029	0.429	0.495	0.046	0.000	0.000	0.000
104-108									0.000	0.050	0.506	0.416	0.027	0.000	0.000
109-113										0.001	0.080	0.570	0.334	0.015	0.000
114-118											0.002	0.123	0.612	0.255	0.008
119-123												0.004	0.179	0.631	0.187
123-128													0.008	0.284	0.708
129-133														0.041	0.959
134+															1.000

Model 13: with molting probability

Pre-molt Length Class	Post-molt Length Class														
	64-68	79-73	74-78	79-83	84-88	89-93	94-98	99-103	104-108	109-113	114-118	119-123	124-128	129-133	134+
64-68	0.001	0.000	0.034	0.451	0.474	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69-73		0.002	0.000	0.057	0.525	0.393	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74-78			0.004	0.001	0.090	0.582	0.311	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79-83				0.007	0.002	0.136	0.615	0.234	0.006	0.000	0.000	0.000	0.000	0.000	0.000
84-88					0.013	0.004	0.194	0.620	0.167	0.003	0.000	0.000	0.000	0.000	0.000
89-93						0.024	0.008	0.261	0.593	0.113	0.001	0.000	0.000	0.000	0.000
94-98							0.044	0.016	0.332	0.536	0.071	0.001	0.000	0.000	0.000
99-103								0.080	0.027	0.395	0.455	0.042	0.000	0.000	0.000
104-108									0.141	0.043	0.435	0.358	0.023	0.000	0.000
109-113										0.237	0.061	0.435	0.255	0.011	0.000
114-118											0.371	0.077	0.386	0.161	0.005
119-123												0.528	0.085	0.299	0.088
123-128													0.680	0.092	0.228
129-133														0.807	0.193
134+															1.000

Table 13. Annual abundance estimates (million crab) and mature male biomass (MMB, million lb) for Norton Sound red king crab estimated by a length-based analysis from 1976 to 2014

Model 5.

	Abundance			Legal (≥ 104 mm)				MMB	
Year	Recruits	Total (≥ 74 mm)	Mature (≥ 94 mm)	Abundance	S.D	Biomass	S.D	Biomass	S.D.
1976	2.610	9.165	6.554	4.250	1.036	11.262	2.929	15.667	3.424
1977	1.175	8.041	6.866	5.580	0.960	16.221	2.908	18.739	3.087
1978	0.797	6.368	5.571	5.024	0.738	15.872	2.402	16.957	2.437
1979	0.566	4.383	3.817	3.485	0.505	11.589	1.723	12.235	1.751
1980	1.039	3.126	2.087	1.878	0.339	6.373	1.186	6.776	1.218
1981	1.426	2.929	1.504	1.216	0.236	4.109	0.824	4.650	0.887
1982	1.467	2.787	1.319	0.890	0.211	2.746	0.679	3.553	0.802
1983	1.544	3.129	1.585	1.097	0.225	3.249	0.688	4.173	0.825
1984	1.791	3.537	1.746	1.239	0.246	3.659	0.745	4.620	0.887
1985	1.427	3.375	1.948	1.376	0.270	4.078	0.813	5.161	0.975
1986	1.488	3.554	2.065	1.537	0.296	4.576	0.894	5.584	1.052
1987	1.280	3.294	2.013	1.531	0.299	4.666	0.924	5.583	1.050
1988	1.075	3.121	2.046	1.577	0.291	4.837	0.905	5.731	1.031
1989	1.072	3.006	1.934	1.551	0.272	4.840	0.856	5.573	0.951
1990	0.856	2.674	1.817	1.450	0.244	4.582	0.776	5.281	0.861
1991	0.782	2.464	1.682	1.363	0.217	4.324	0.692	4.935	0.762
1992	0.690	2.232	1.542	1.269	0.184	4.073	0.592	4.596	0.641
1993	0.557	1.956	1.400	1.150	0.155	3.712	0.501	4.189	0.544
1994	0.554	1.714	1.160	0.958	0.131	3.091	0.425	3.479	0.458
1995	0.673	1.638	0.965	0.779	0.110	2.510	0.357	2.863	0.388
1996	0.881	1.750	0.869	0.657	0.098	2.077	0.313	2.477	0.350
1997	1.491	2.418	0.927	0.655	0.096	2.004	0.299	2.517	0.355
1998	1.211	2.439	1.228	0.796	0.111	2.361	0.332	3.171	0.409
1999	0.696	2.268	1.571	1.113	0.141	3.241	0.407	4.113	0.497
2000	0.775	2.320	1.545	1.256	0.148	3.812	0.447	4.372	0.492
2001	1.098	2.448	1.350	1.100	0.131	3.471	0.417	3.949	0.449
2002	1.245	2.584	1.339	1.002	0.119	3.150	0.375	3.786	0.422
2003	1.146	2.595	1.449	1.043	0.120	3.184	0.367	3.951	0.424
2004	0.898	2.419	1.521	1.123	0.126	3.388	0.381	4.144	0.445
2005	1.185	2.651	1.466	1.136	0.136	3.457	0.407	4.089	0.474
2006	1.436	2.851	1.415	1.056	0.137	3.251	0.420	3.930	0.473
2007	1.629	3.170	1.541	1.082	0.140	3.253	0.425	4.120	0.499
2008	1.726	3.467	1.741	1.219	0.151	3.618	0.453	4.605	0.528
2009	1.399	3.339	1.940	1.371	0.162	4.049	0.485	5.128	0.565
2010	0.949	2.972	2.023	1.514	0.170	4.512	0.513	5.485	0.585
2011	1.001	2.859	1.858	1.490	0.165	4.562	0.509	5.270	0.568
2012	1.265	2.911	1.646	1.318	0.151	4.142	0.478	4.766	0.520
2013	2.227	3.801	1.574	1.177	0.139	3.670	0.437	4.422	0.505
2014	1.639	3.477	1.838	1.208	0.163	3.642	0.480	4.821	0.633
2015	0.994	3.174	2.179	1.541	0.253	4.477	0.702	5.694	0.933

Model 13.

	Abundance			Legal (≥ 104 mm)				MMB	
Year	Recruits	Total (≥ 64 mm)	Mature (≥ 94 mm)	Abundance	S.D	Biomass	S.D	Biomass	S.D.
1976	2.921	9.364	6.443	4.072	0.994	10.830	2.831	15.270	3.283
1977	1.440	8.167	6.727	5.487	0.950	15.861	2.855	18.277	3.015
1978	0.824	6.449	5.624	4.975	0.737	15.708	2.391	16.945	2.410
1979	0.580	4.432	3.852	3.509	0.500	11.646	1.709	12.305	1.736
1980	1.153	3.243	2.090	1.886	0.334	6.420	1.171	6.806	1.201
1981	1.474	2.952	1.479	1.192	0.228	4.072	0.803	4.593	0.861
1982	1.502	2.818	1.316	0.860	0.200	2.647	0.647	3.494	0.779
1983	1.702	3.254	1.552	1.068	0.218	3.151	0.664	4.054	0.792
1984	1.801	3.535	1.735	1.204	0.237	3.546	0.716	4.534	0.860
1985	1.470	3.415	1.945	1.362	0.264	4.015	0.791	5.104	0.957
1986	1.567	3.609	2.042	1.510	0.290	4.489	0.874	5.492	1.025
1987	1.331	3.314	1.983	1.503	0.292	4.584	0.903	5.477	1.024
1988	1.094	3.137	2.043	1.548	0.283	4.739	0.880	5.671	1.011
1989	1.122	3.030	1.909	1.535	0.268	4.786	0.842	5.490	0.931
1990	0.883	2.673	1.790	1.420	0.238	4.500	0.759	5.191	0.842
1991	0.789	2.457	1.668	1.337	0.211	4.238	0.675	4.864	0.746
1992	0.717	2.227	1.510	1.246	0.180	4.006	0.580	4.500	0.623
1993	0.579	1.952	1.373	1.118	0.149	3.619	0.486	4.097	0.527
1994	0.602	1.739	1.138	0.932	0.126	3.007	0.410	3.394	0.442
1995	0.699	1.645	0.946	0.756	0.106	2.437	0.345	2.790	0.374
1996	0.901	1.758	0.856	0.639	0.094	2.015	0.301	2.419	0.340
1997	1.550	2.449	0.899	0.631	0.093	1.932	0.288	2.427	0.339
1998	1.243	2.416	1.173	0.750	0.105	2.233	0.312	3.009	0.386
1999	0.703	2.266	1.563	1.070	0.131	3.085	0.378	4.018	0.475
2000	0.804	2.329	1.525	1.246	0.146	3.758	0.437	4.289	0.477
2001	1.166	2.488	1.322	1.080	0.128	3.420	0.409	3.871	0.437
2002	1.324	2.628	1.304	0.962	0.113	3.042	0.359	3.673	0.407
2003	1.154	2.584	1.430	1.005	0.115	3.058	0.351	3.851	0.411
2004	0.928	2.435	1.507	1.103	0.123	3.305	0.369	4.065	0.431
2005	1.257	2.701	1.444	1.115	0.130	3.388	0.391	4.007	0.453
2006	1.468	2.848	1.381	1.026	0.131	3.169	0.402	3.824	0.452
2007	1.708	3.221	1.513	1.041	0.133	3.127	0.404	4.005	0.479
2008	1.780	3.470	1.690	1.170	0.144	3.469	0.431	4.434	0.503
2009	1.432	3.342	1.910	1.324	0.154	3.891	0.460	4.986	0.543
2010	1.006	2.999	1.993	1.477	0.163	4.381	0.492	5.355	0.562
2011	1.026	2.870	1.844	1.467	0.159	4.476	0.492	5.191	0.547
2012	1.388	3.009	1.621	1.300	0.147	4.088	0.463	4.686	0.502
2013	2.269	3.816	1.547	1.137	0.132	3.562	0.419	4.321	0.482
2014	1.696	3.479	1.783	1.161	0.154	3.504	0.451	4.646	0.601
2015	1.005	3.172	2.167	1.484	0.238	4.274	0.654	5.568	0.901

Table 14. Summary of catch and estimated discards (million lb) for Norton Sound red king crab. Assumed average crab weight is 2.5 lb for the winter commercial catch, 2.0 lb for the subsistence catch, and 1.0 lb for Winter subsistence discards. Summer and winter commercial discards were estimated from the model.

Model 5.

Year	Summer Com	Winter Com	Winter Sub	Discards Summer	Discards Winter Sub	Discards Winter com	Total	Catch/ MMB
1977	0.52	0.000	0.000	0.020	0.000	0.000	0.54	0.029
1978	2.09	0.024	0.025	0.038	0.008	0.000	2.185	0.129
1979	2.93	0.001	0.000	0.049	0.000	0.000	2.98	0.244
1980	1.19	0.000	0.000	0.025	0.000	0.000	1.215	0.179
1981	1.38	0.000	0.001	0.069	0.000	0.000	1.45	0.312
1982	0.23	0.000	0.003	0.020	0.001	0.000	0.254	0.071
1983	0.37	0.001	0.021	0.036	0.006	0.000	0.434	0.104
1984	0.39	0.002	0.022	0.036	0.005	0.000	0.455	0.098
1985	0.43	0.003	0.017	0.037	0.002	0.000	0.489	0.095
1986	0.48	0.005	0.014	0.031	0.004	0.000	0.534	0.096
1987	0.33	0.003	0.012	0.020	0.002	0.000	0.367	0.066
1988	0.24	0.001	0.005	0.013	0.001	0.000	0.26	0.045
1989	0.25	0.001	0.012	0.012	0.002	0.000	0.277	0.050
1990	0.19	0.009	0.024	0.009	0.004	0.000	0.236	0.045
1991	0	0.010	0.015	0.000	0.002	0.000	0.027	0.005
1992	0.07	0.019	0.023	0.003	0.003	0.001	0.119	0.026
1993	0.33	0.004	0.002	0.014	0.000	0.000	0.35	0.084
1994	0.32	0.014	0.008	0.014	0.001	0.001	0.358	0.103
1995	0.32	0.019	0.011	0.016	0.002	0.001	0.369	0.129
1996	0.22	0.004	0.003	0.016	0.001	0.000	0.244	0.099
1997	0.09	0.000	0.001	0.010	0.001	0.000	0.102	0.041
1998	0.03	0.002	0.017	0.004	0.012	0.000	0.065	0.020
1999	0.02	0.007	0.015	0.002	0.003	0.000	0.047	0.011
2000	0.3	0.008	0.011	0.014	0.004	0.000	0.337	0.077
2001	0.28	0.003	0.001	0.015	0.000	0.000	0.299	0.076
2002	0.25	0.006	0.004	0.019	0.003	0.000	0.282	0.074
2003	0.26	0.017	0.008	0.022	0.005	0.001	0.313	0.079
2004	0.34	0.001	0.002	0.024	0.001	0.000	0.368	0.089
2005	0.4	0.005	0.008	0.024	0.003	0.000	0.44	0.108
2006	0.45	0.000	0.002	0.035	0.001	0.000	0.488	0.124
2007	0.31	0.008	0.021	0.030	0.011	0.001	0.381	0.092
2008	0.39	0.014	0.019	0.039	0.009	0.001	0.472	0.102
2009	0.4	0.012	0.010	0.035	0.002	0.001	0.46	0.090
2010	0.42	0.012	0.014	0.027	0.002	0.001	0.476	0.087
2011	0.4	0.008	0.013	0.020	0.003	0.000	0.444	0.084
2012	0.47	0.023	0.015	0.027	0.004	0.001	0.54	0.113
2013	0.35	0.057	0.015	0.032	0.014	0.005	0.473	0.107
2014	0.39	0.037	0.007	0.044	0.002	0.004	0.484	0.100
2015	0.40	0.103	0.019	0.030	0.005	0.006	0.563	0.099

Model 13

Year	Summer Com	Winter Com	Winter Sub	Discards Summer	Discards Winter Sub	Discards Winter com	Total	Catch/ MMB
1977	0.52	0.000	0.000	0.021	0.000	0.000	0.541	0.030
1978	2.09	0.024	0.025	0.044	0.008	0.000	2.191	0.129
1979	2.93	0.001	0.000	0.052	0.000	0.000	2.983	0.242
1980	1.19	0.000	0.000	0.026	0.000	0.000	1.216	0.179
1981	1.38	0.000	0.001	0.077	0.000	0.000	1.458	0.317
1982	0.23	0.000	0.003	0.022	0.001	0.000	0.256	0.073
1983	0.37	0.001	0.021	0.039	0.006	0.000	0.437	0.108
1984	0.39	0.002	0.022	0.040	0.005	0.000	0.459	0.101
1985	0.43	0.003	0.017	0.038	0.002	0.000	0.49	0.096
1986	0.48	0.005	0.014	0.034	0.004	0.000	0.537	0.098
1987	0.33	0.003	0.012	0.021	0.002	0.000	0.368	0.067
1988	0.24	0.001	0.005	0.014	0.001	0.000	0.261	0.046
1989	0.25	0.001	0.012	0.012	0.002	0.000	0.277	0.050
1990	0.19	0.009	0.024	0.010	0.004	0.000	0.237	0.046
1991	0	0.010	0.015	0.000	0.002	0.000	0.027	0.006
1992	0.07	0.019	0.023	0.003	0.003	0.001	0.119	0.026
1993	0.33	0.004	0.002	0.016	0.000	0.000	0.352	0.086
1994	0.32	0.014	0.008	0.015	0.001	0.001	0.359	0.106
1995	0.32	0.019	0.011	0.018	0.002	0.001	0.371	0.133
1996	0.22	0.004	0.003	0.018	0.001	0.000	0.246	0.102
1997	0.09	0.000	0.001	0.011	0.001	0.000	0.103	0.042
1998	0.03	0.002	0.017	0.004	0.012	0.000	0.065	0.022
1999	0.02	0.007	0.015	0.002	0.003	0.000	0.047	0.012
2000	0.3	0.008	0.011	0.015	0.004	0.000	0.338	0.079
2001	0.28	0.003	0.001	0.016	0.000	0.000	0.3	0.078
2002	0.25	0.006	0.004	0.022	0.003	0.001	0.286	0.078
2003	0.26	0.017	0.008	0.025	0.005	0.001	0.316	0.082
2004	0.34	0.001	0.002	0.026	0.001	0.000	0.37	0.091
2005	0.4	0.005	0.008	0.026	0.003	0.000	0.442	0.110
2006	0.45	0.000	0.002	0.038	0.001	0.000	0.491	0.128
2007	0.31	0.008	0.021	0.033	0.011	0.001	0.384	0.096
2008	0.39	0.014	0.019	0.043	0.009	0.001	0.476	0.107
2009	0.4	0.012	0.010	0.038	0.002	0.001	0.463	0.093
2010	0.42	0.012	0.014	0.029	0.002	0.001	0.478	0.089
2011	0.4	0.008	0.013	0.021	0.003	0.000	0.445	0.086
2012	0.47	0.023	0.015	0.028	0.004	0.001	0.541	0.115
2013	0.35	0.057	0.015	0.037	0.014	0.005	0.478	0.111
2014	0.39	0.037	0.007	0.048	0.002	0.004	0.488	0.105
2015	0.40	0.103	0.019	0.033	0.005	0.006	0.566	0.102

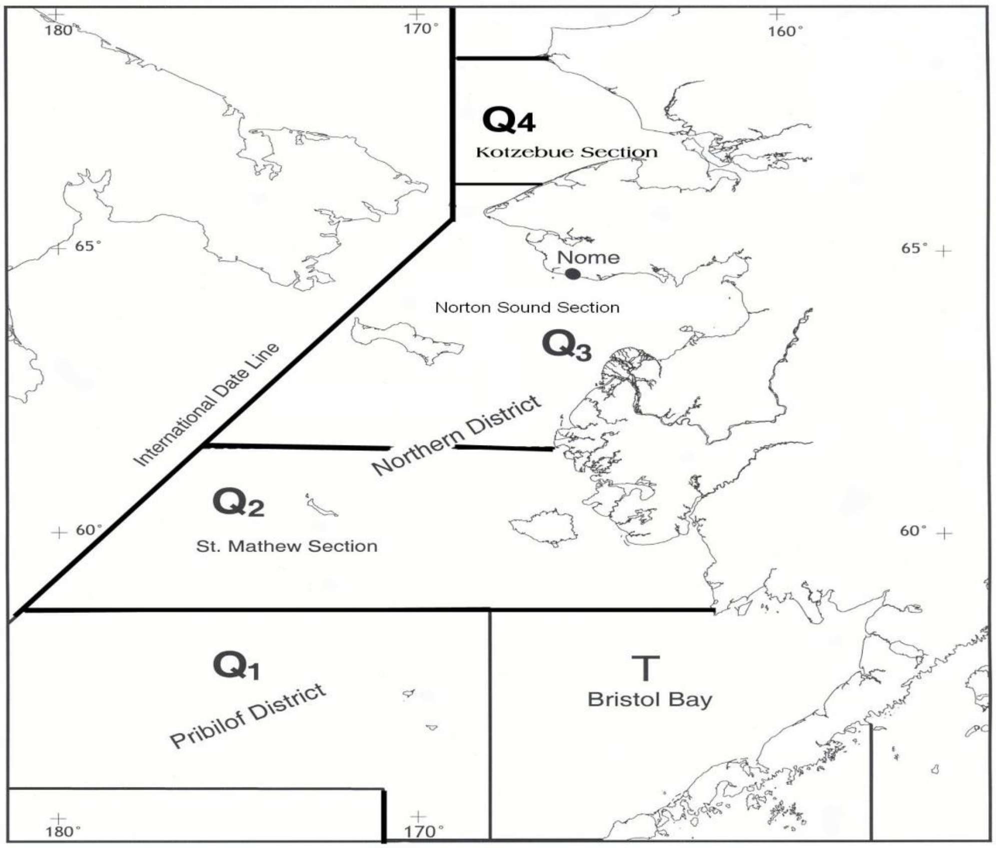

Figure 1. King crab fishing districts and sections of Statistical Area Q.

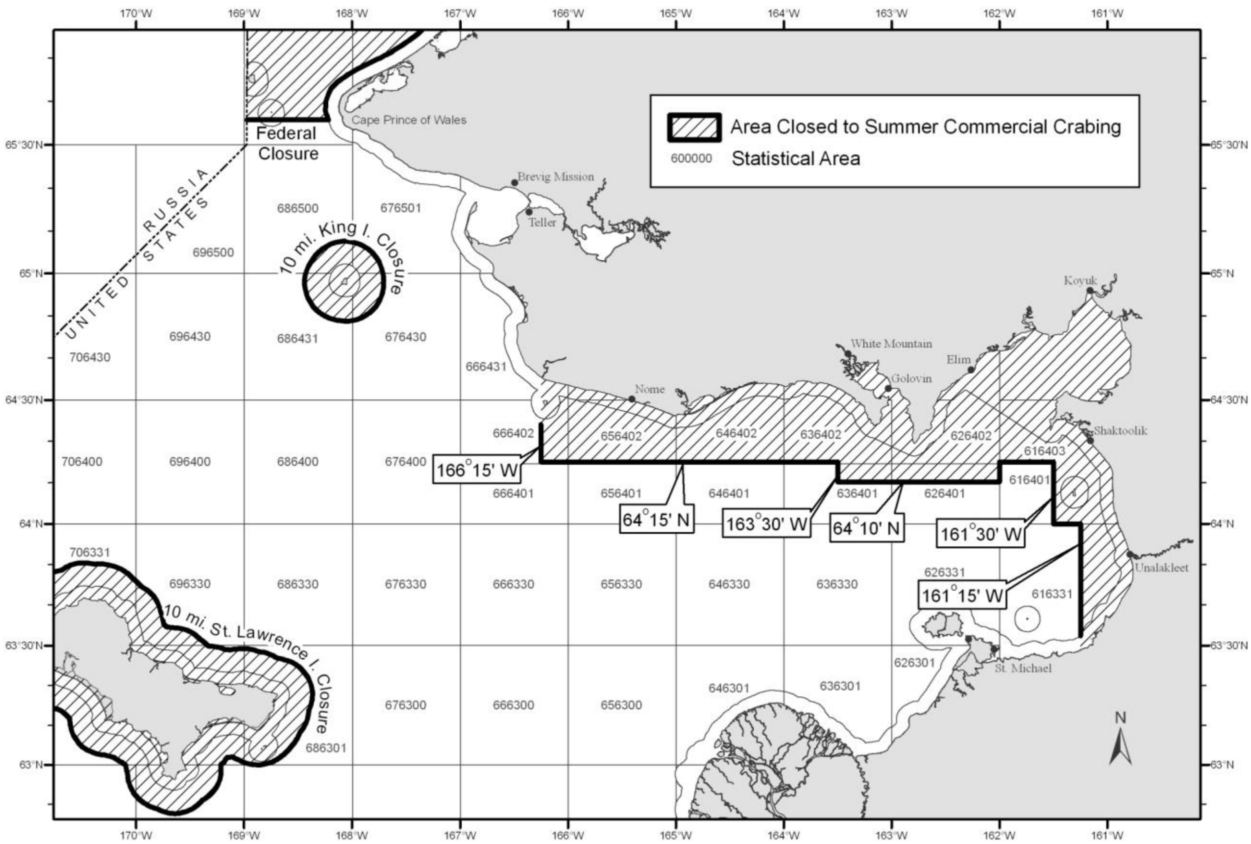

Figure 2. Closed water regulations in effect for the Norton Sound commercial crab fishery.

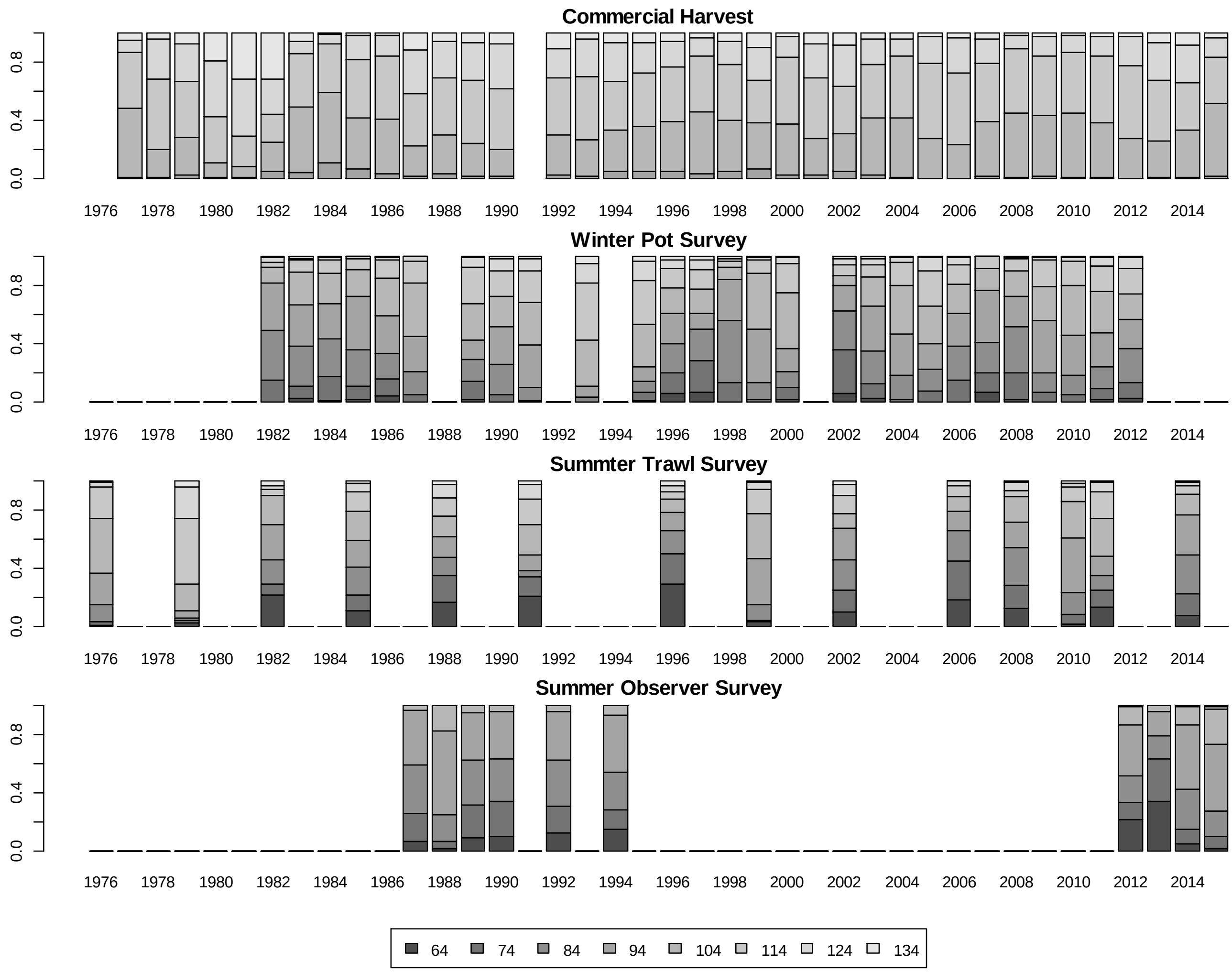

Figure 3. Observed length compositions 1976-2015.

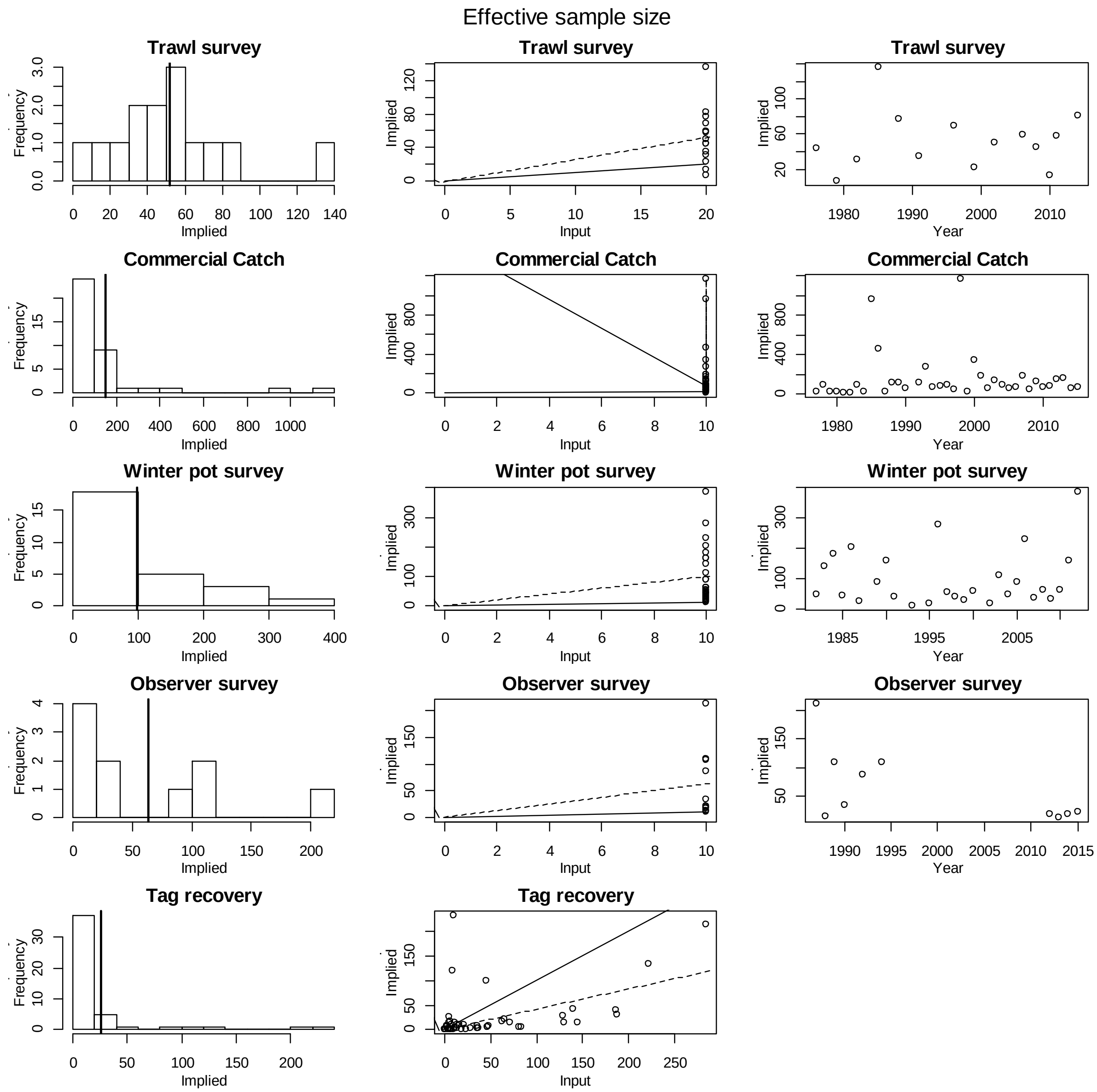

Figure 4. Effective sample size vs. implied sample size. Figures in the first column show effective sample size (x-axis) vs. frequency (y-axis). Vertical solid line is the implied sample size. Figures in the second column show implied sample size (x-axis) vs. effective sample size (y-axis). Dashed line indicates linear regression slope, and solid line is 1:1 line. Figures in the third column show year (x-axis) vs. effective sample size (y-axis).

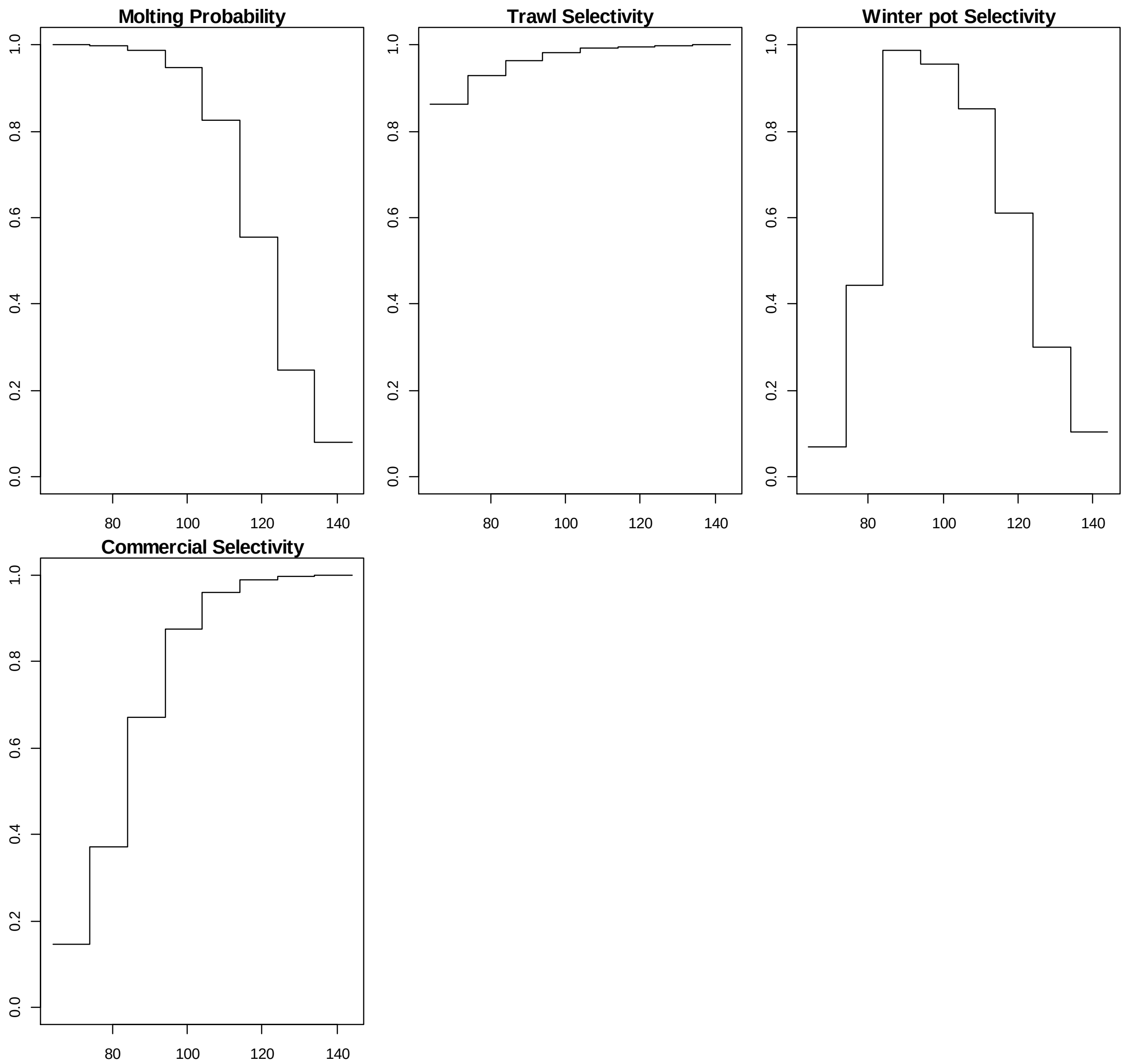

Figure 5. Molting probability and trawl/pot selectivities.

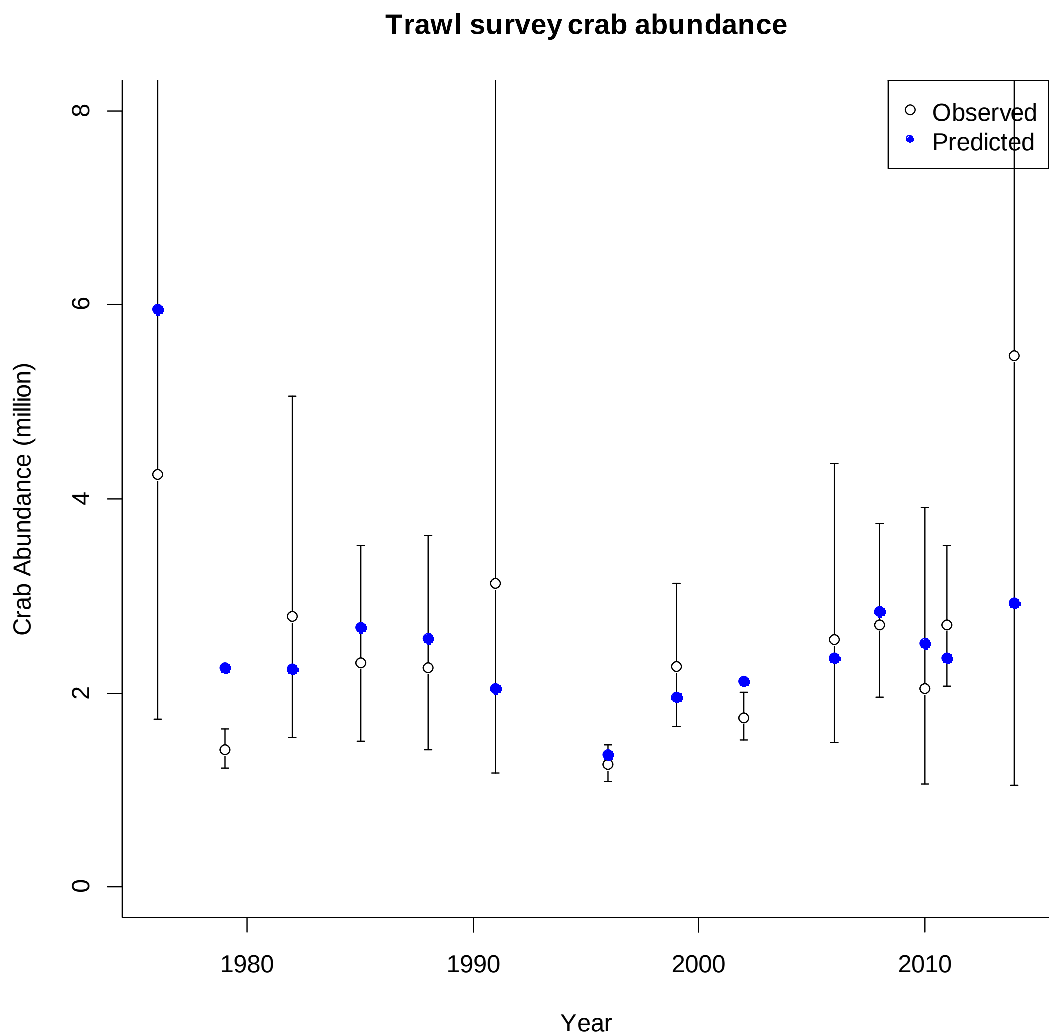

Figure 6. Estimated trawl survey male abundance with 95% lognormal Confidence Interval (crab ≥ 74 mm CL).

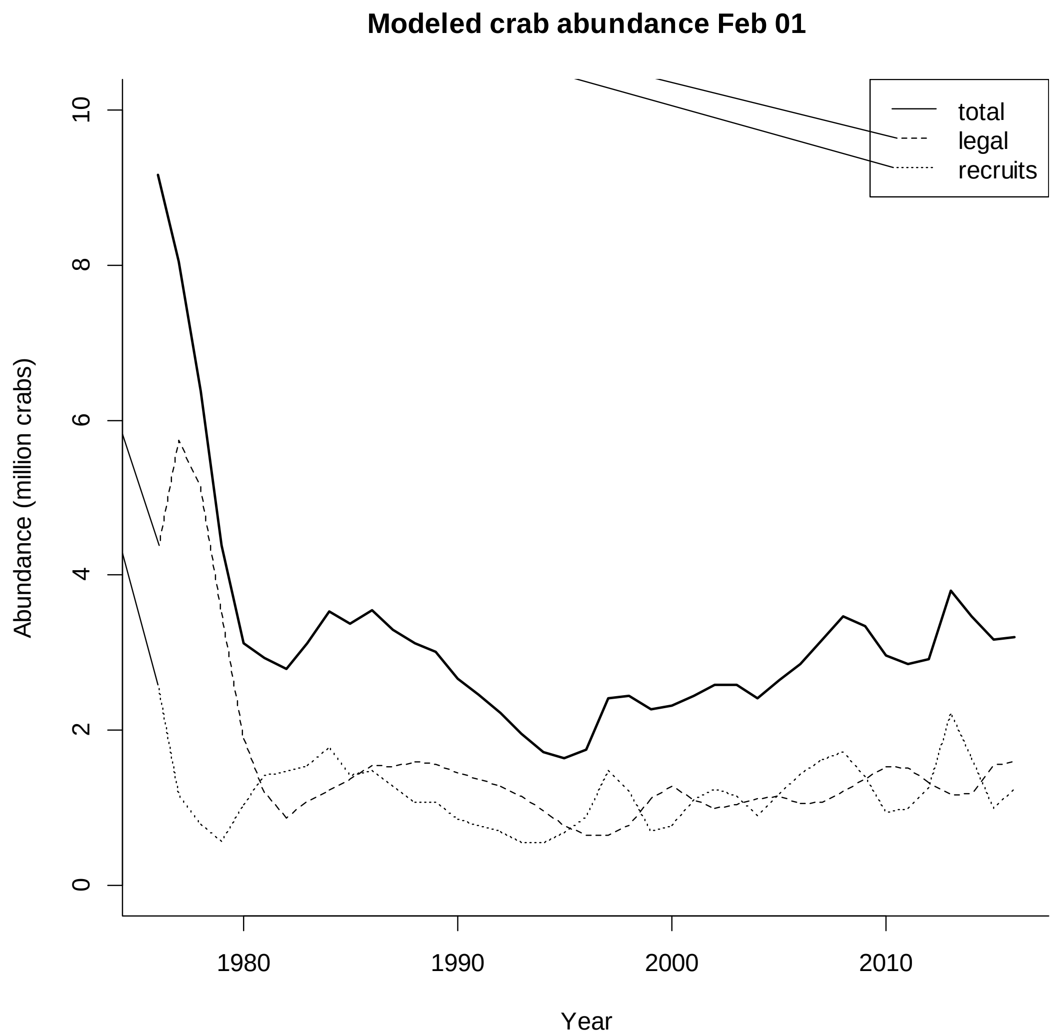

Figure 7. Estimated abundances of legal and recruits males from 1976-2015.

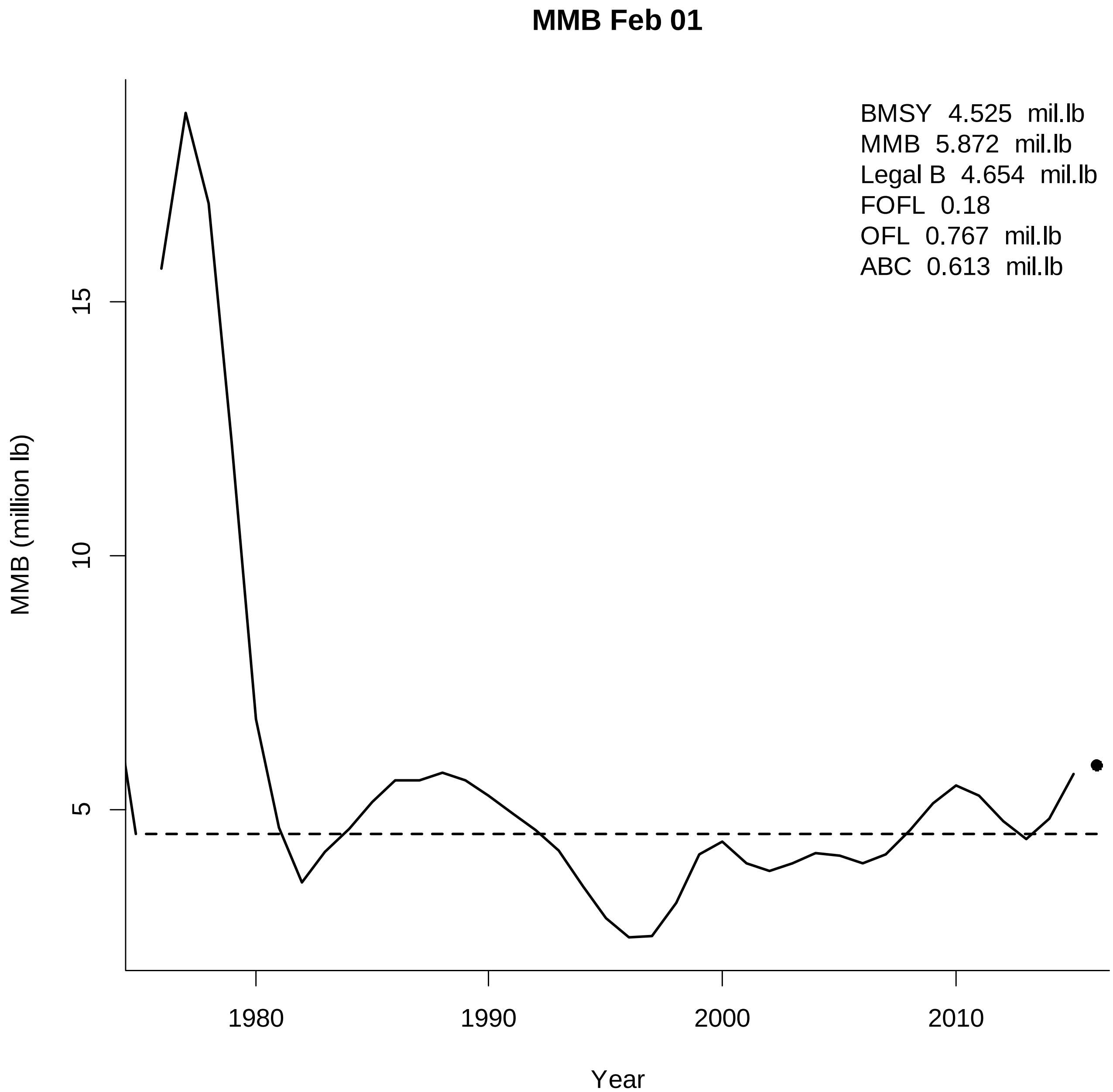

Figure 8. Estimated MMB from 1976-2015. Dash line shows Bmsy (Average MMB of 1980-2016). Black points indicate projected MMB of 2016.

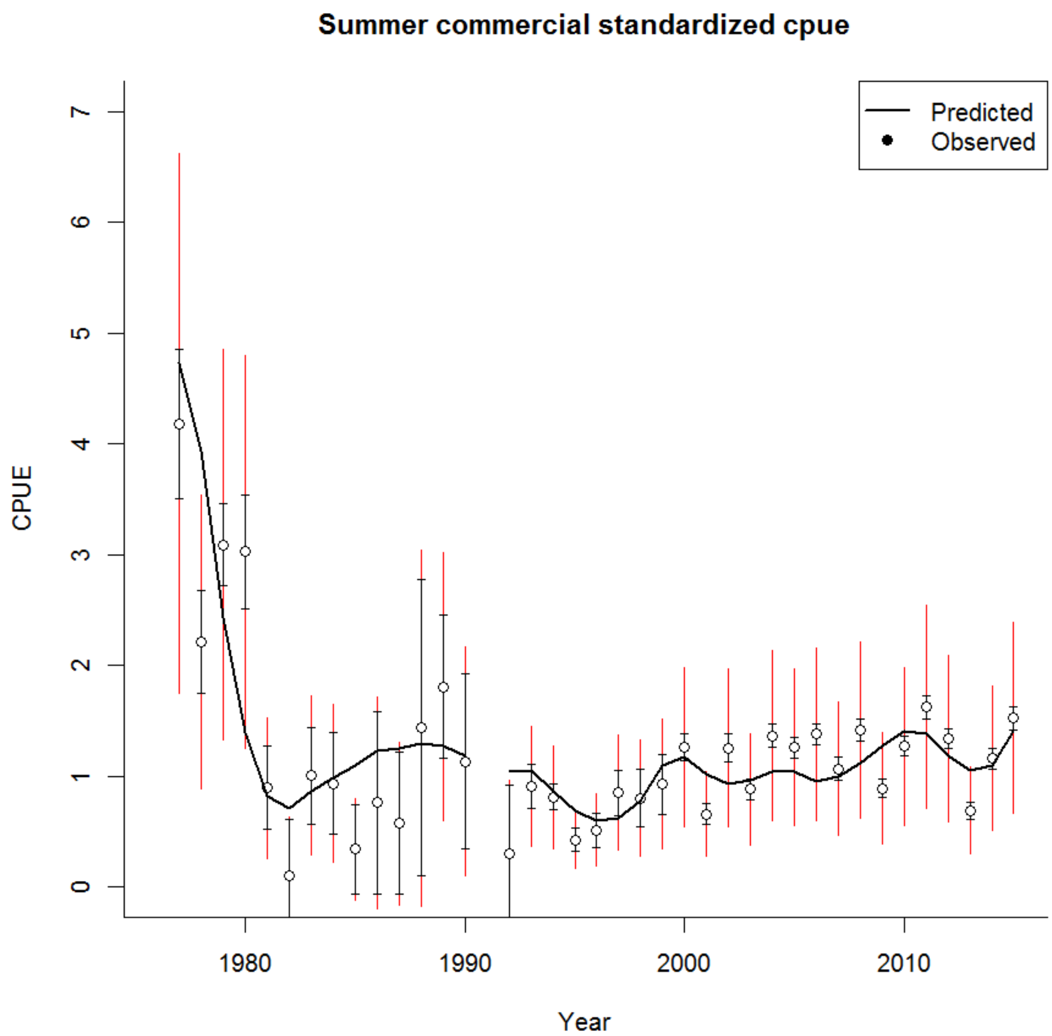

Figure 9. Summer commercial standardized cpue. Black line is input SD and red line is input and estimated additional SD.

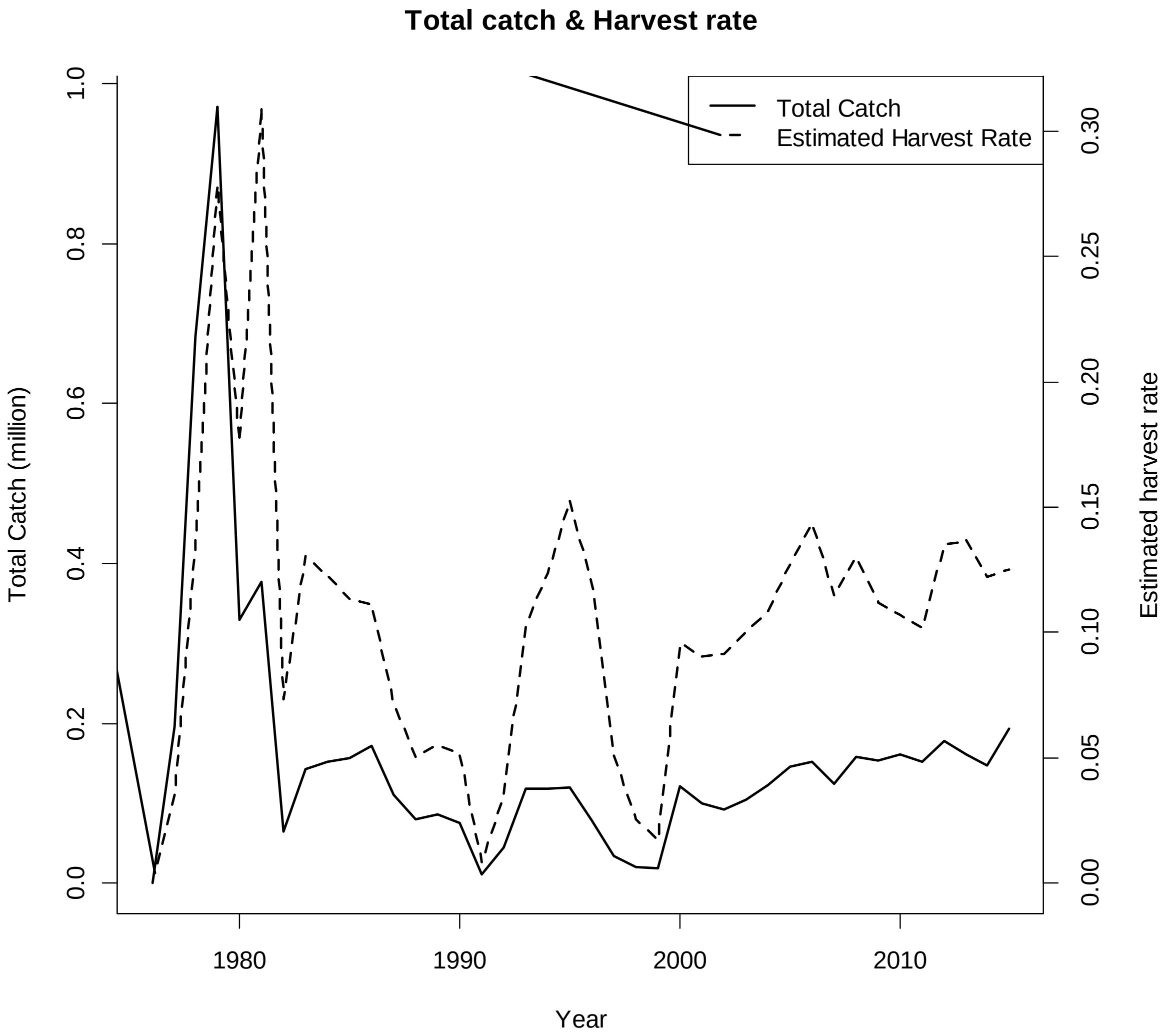

Figure 10. Commercial Catch and estimated harvest rate of legal male.

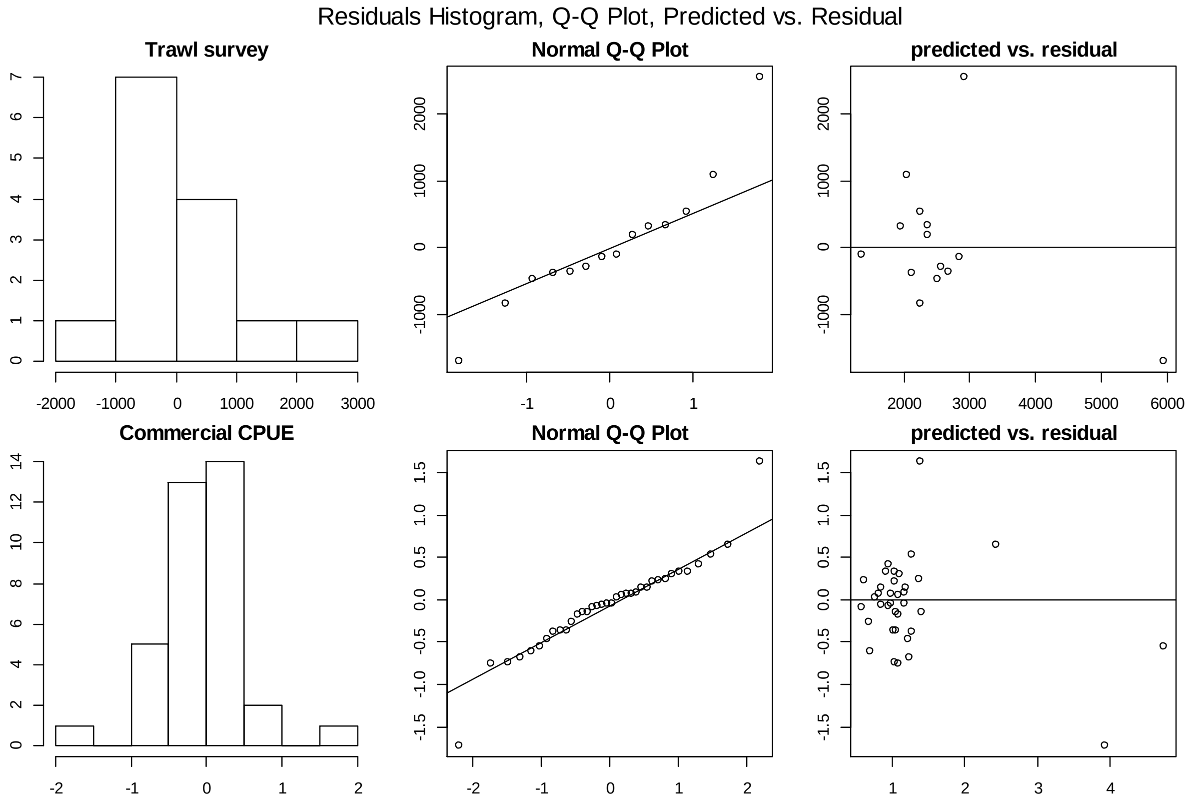

Figure 11. Residual and QQ plot.

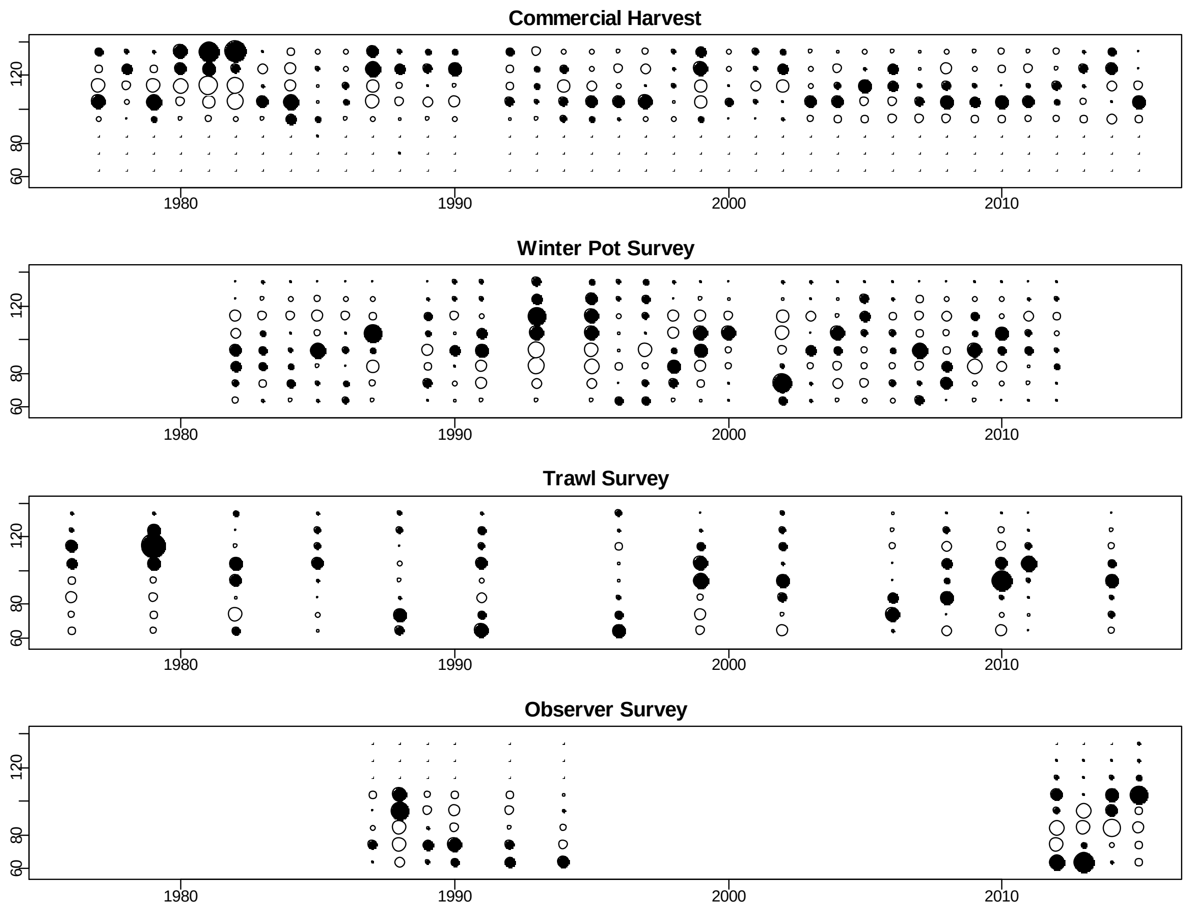

Figure 12. Bubble plot of predicted and observed length proportion (Alternative model 0). Black circle indicates model estimates lower than observed, white circle indicates model estimates higher than observed. Size of circle indicate degree of deviance (larger circle = larger deviance).

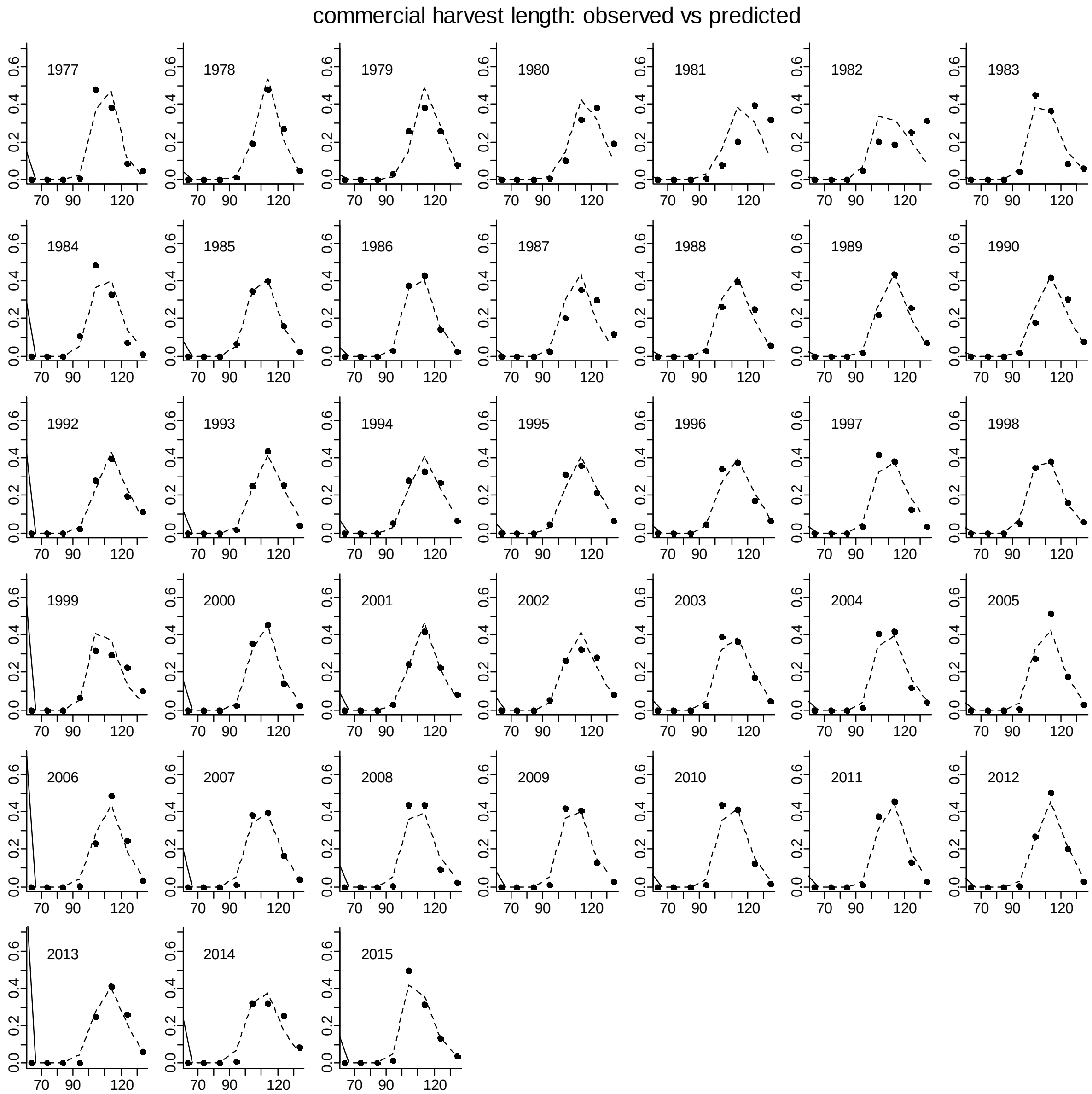

Figure 13. Predicted (dashed line) vs. observed (black dots) length class proportion for the summer commercial catch.

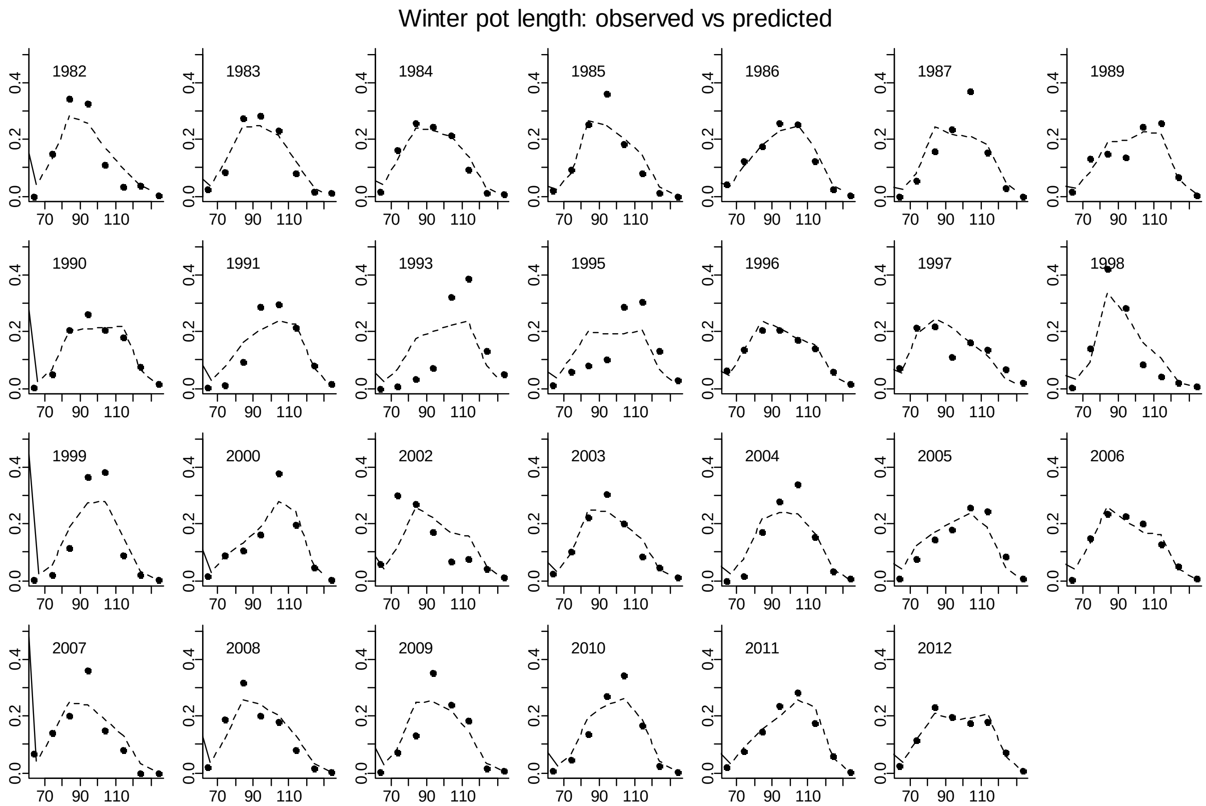

Figure 14. Predicted vs. observed length class proportion for winter pot survey.

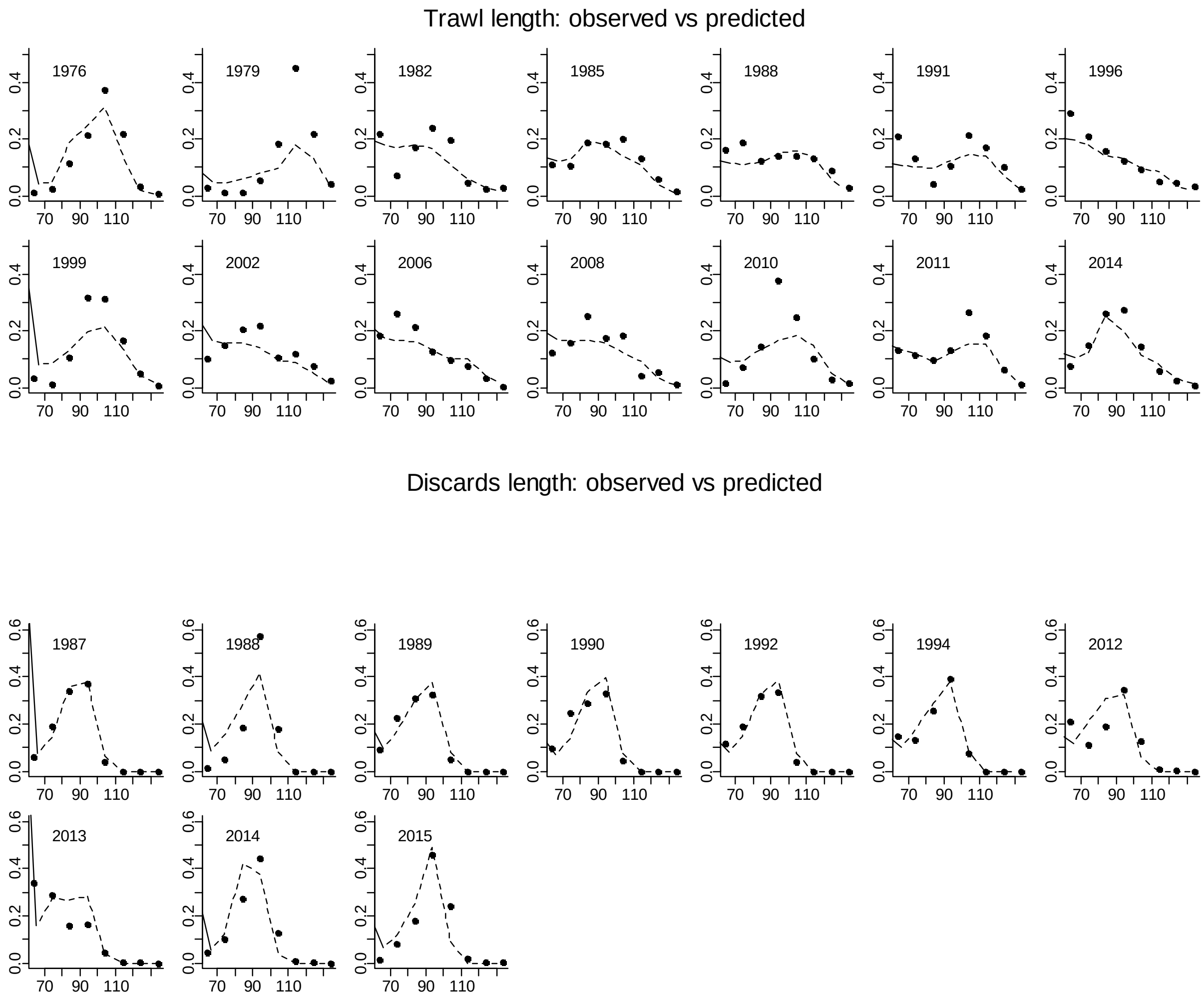

Figure 15. Predicted vs. observed length class proportion for trawl survey and commercial observer.

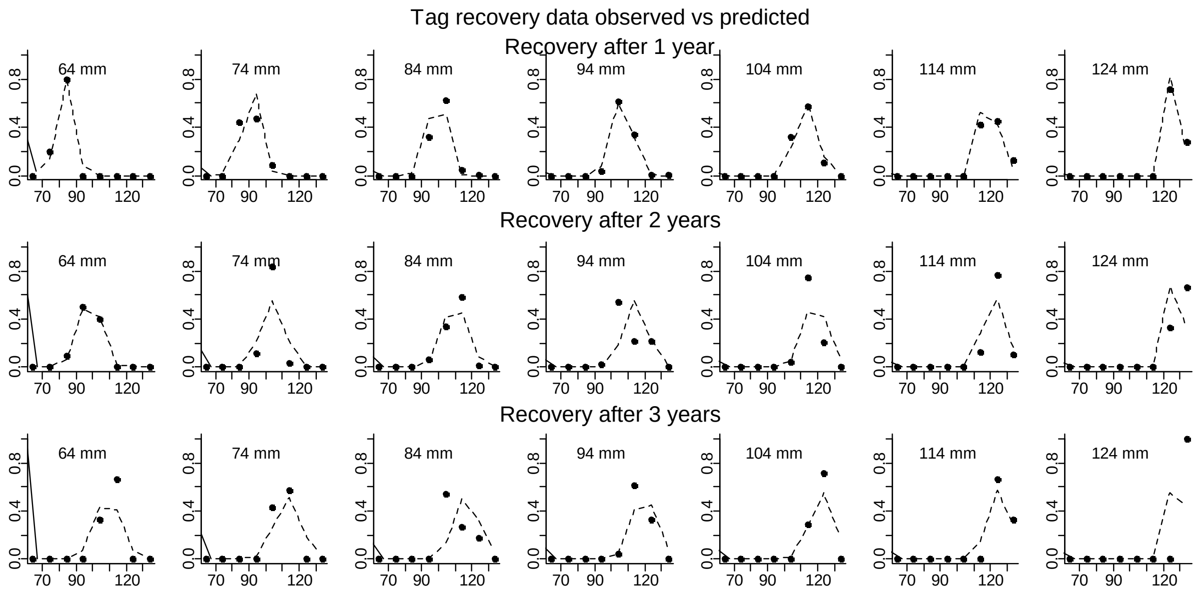

Figure 16. Predicted vs. observed length class proportion for tag recovery data 1980-1992, and 1993-2014.

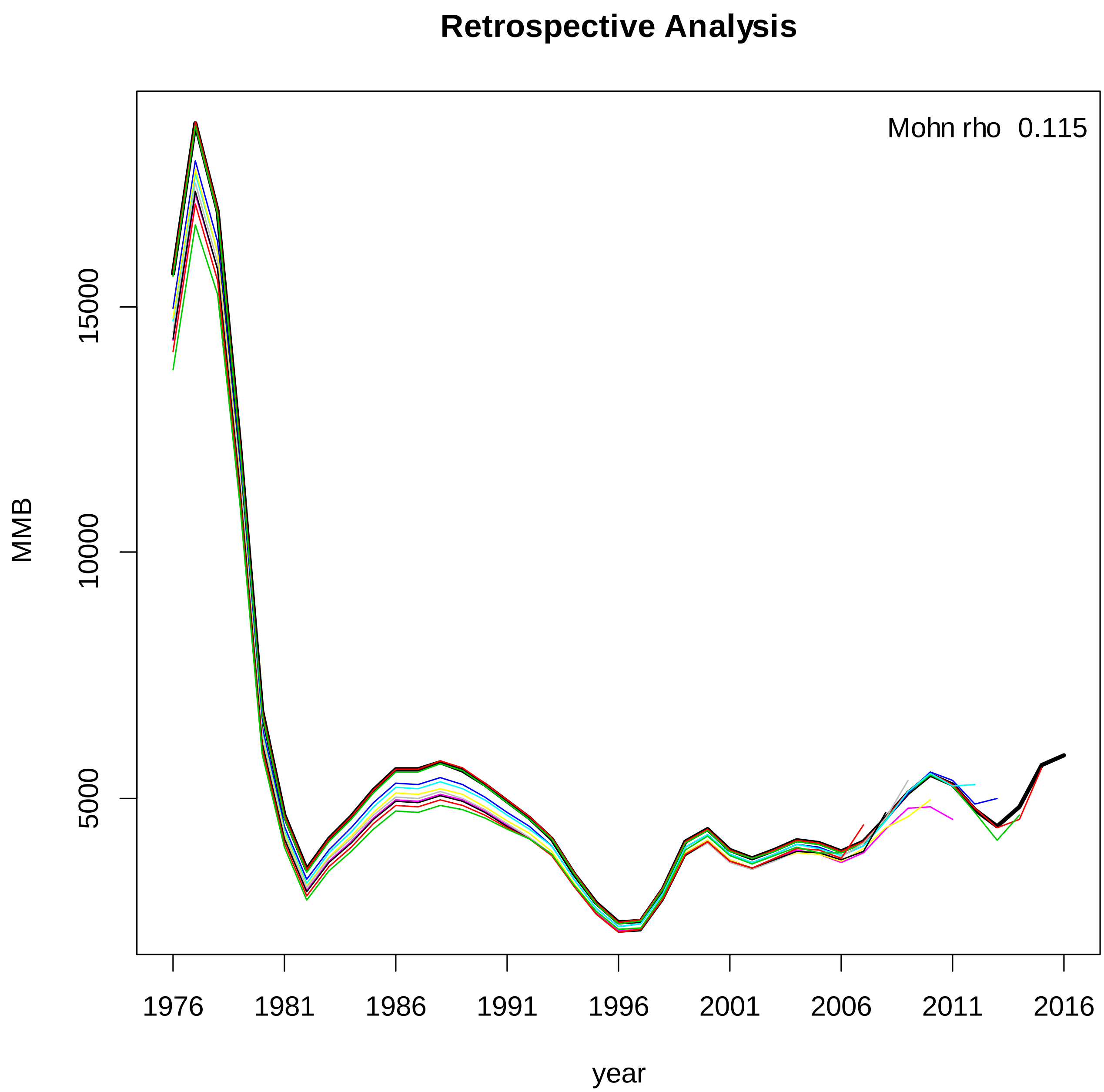

Figure 17. Retrospective analyses. Each line shows retrospective MMB. Model 5

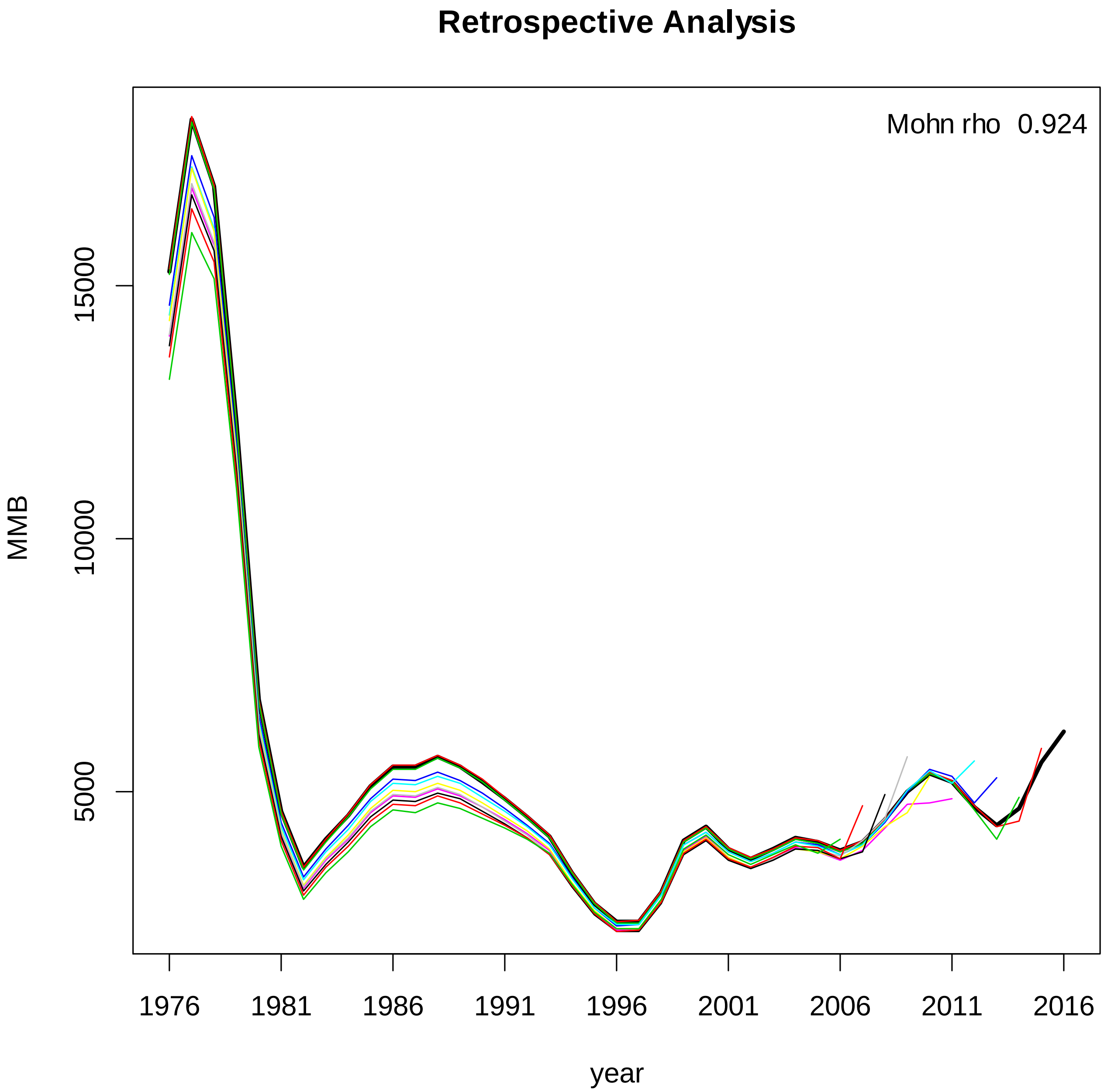

Figure 18. Retrospective analyses. Each line shows retrospective MMB. Model 13