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

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Fishery Update: 2015
All data were finalized for use in 2016 SAFE assessment model.

Winter commercial and subsistence fishery:

The winter commercial fishery harvest of 41,046 crabs (98,750 lb.) was the highest observed in the history of the stock and subsistence crab catch was 7,651 (15,302 lb.). (Table 2)

Summer commercial fishery:

The commercial fishery opened June 29 and closed on July 24 due to meeting the GHL. This was the shortest summer commercial fishery opening in the history of the stock. A total of 144,255 crabs (401,115 lb.) were harvested (Table 1). The standardized CPUE was 1.53 (se: 0.05), continuing an increasing trend since 2012 (Table 1, Appendix A).

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

Fishery Data Update: 2015

Winter commercial:

A total of 576 samples of length-shell composition data were collected for the first time in the history. The data may be incorporated into the assessment model as more data are collected.

Summer commercial:

A total of 4163 samples of length-shell composition data were collected (Table 3)

Summer commercial discards:

Observer survey was conducted. A total of 1506 samples were collected for discards length proportion (Table 4).

Tag recovery

A total of 330 tagged crabs were recovered through commercial – subsistence fisheries (Table 5).

2016 and beyond

Triennial trawl survey funding provided by NOAA was terminated for 2017, and possibly beyond. ADF&G is committed to find funding (source not identified) to continue the survey (no guarantee).

CPT and SSC recommendations and author responses.

Neither CPT nor SSC recommended any major model revision-improvements for 2016 NSRKC SAFE model.

CPT Jan 16 2015

- *Provide trawl survey documentation*

  Trawl survey report will be published in fall 2015 (Close to final report is provided).

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

  In SAFE report guide 072612.doc, under section 4, results (best model), list 4, Evaluation of the fit to the data, item f, says:

  f. Plots of implied versus input effective sample sizes and time-series of implied effective sample sizes.

  Unfortunately, no sample figures and captions were provided. We greatly appreciate CPT's instructions for desired plots (with legends) and captions.

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

  See Appendix A.

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

Alternative model.

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

  Combined with SSC's comment
- *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.*

SSC Oct 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.*

  There seems to be mixed responses regarding moving the Norton Sound red king crab to the Tier 3 status. CPT and SSC's comments boil down to a question "How much stock-specific information is needed to move up to the Tier 3 status?" We greatly appreciate CPT and SSC's consensus on a list of stock-specific information needed and expertise on research protocols to collect those information.

Preliminary 2016 SAFE model assessment

Upon receiving no model change/improvement requests from CPT and SSC, we conducted preliminary model assessment (final 2016 SAFE is Jan 2016). Model considered were: (1) baseline 2015SAFE assessment model (alternative model 6), and (2) fix trawl survey selectivity 1.0.

Summary of negative log-likelihood :

Scenario	Baseline	Alt 1
Parameters	58	57
Total NLL	302.5	302.5
TBA	9.6	9.7
CCPUE	-21.4	-21.4
TLP (N)	-20.3	-19.6
TLP (O)	119.2	118.7
WLP (N)	2.2	2.1
WLP (O)	33.4	33.4
CLP (N)	68.2	68.3
CLP (O)	-4.5	-4.5
OBS (N)	2.3	2.3
OBS (O)	46.4	46.4
REC	12.4	12.3
TAG	54.9	54.9
MMB (2015)	5.33	5.42

TBA: Trawl survey abundance
CCPUE: Summer commercial catch standardized cpue
TLP: Trawl survey length composition: (N: for newshell, O: for oldshell)
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

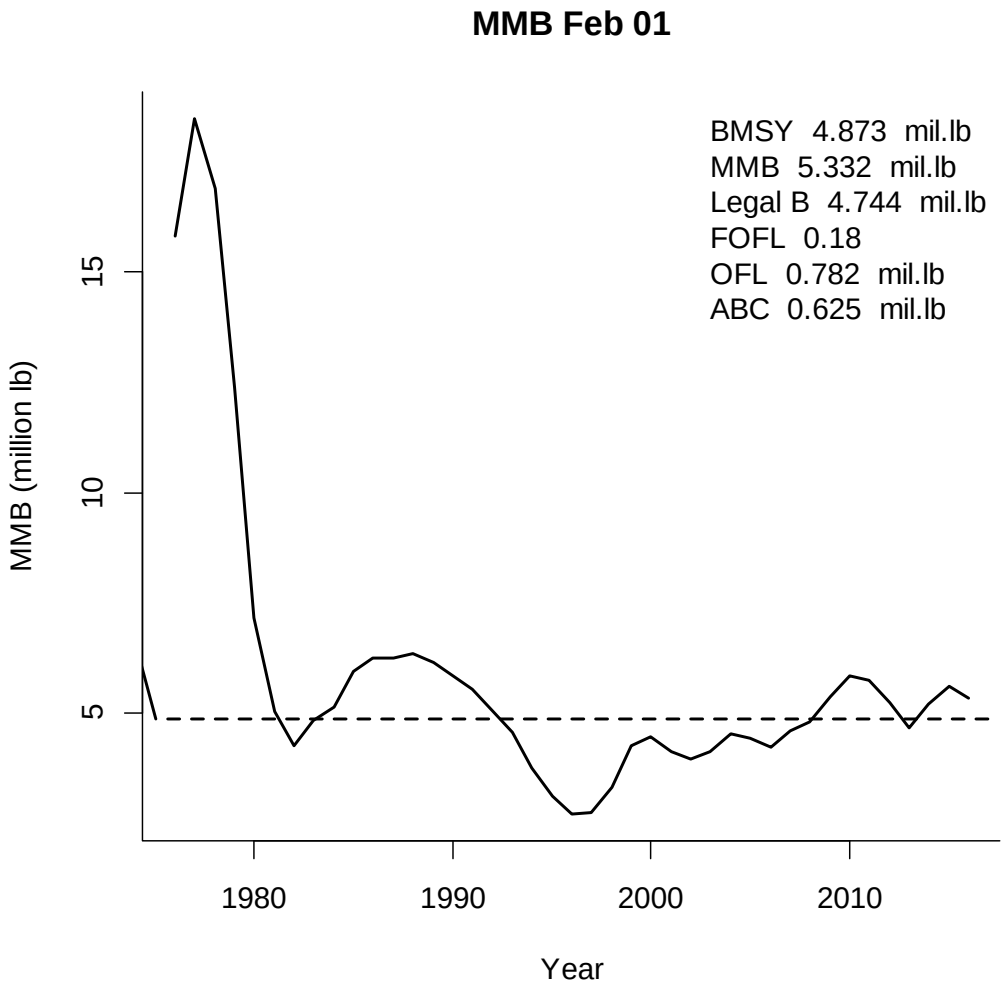


Figure 1: Estimate of MMB trends for baseline model

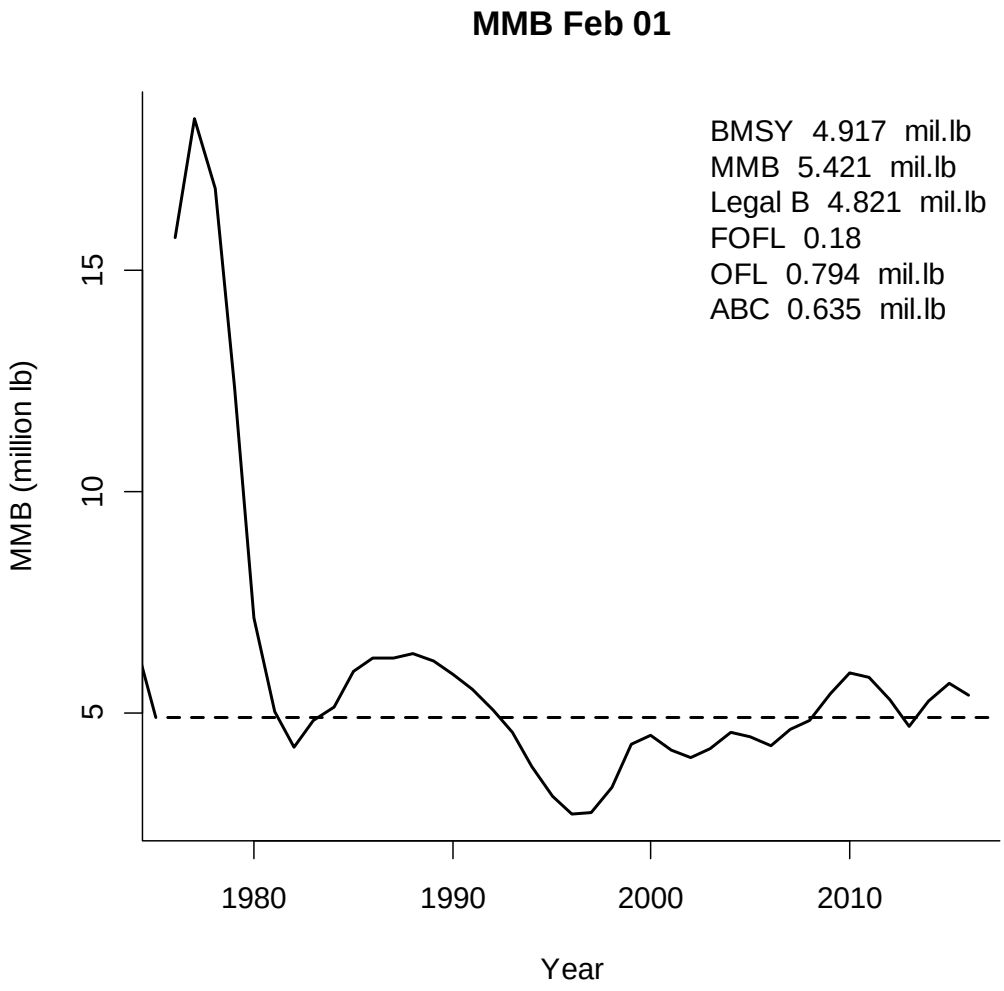


Figure 2: Estimate of MMB trends for alternative 1 model

With updated data, overall there was little difference between the two models. Estimate of trawl selectivity was also 1.0 for the baseline model. Fixing the trawl selectivity slightly changed estimates of MMB projections.

Table 1. 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				
Model Year	Year[a]	# of Fishers	# of Crab Harvested	Winter[b]	Permits			Total Crab	
					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 2. 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.

	Guideline Harvest Level	Commercial Harvest (lb) [a, b]		Total Number (Open Access)				Total Pots		ST CPUE		Season Length		Mid-day from July 1
Year	(lb) [b]	Open Access	CDQ	**Harvest**	Vessels	Permits	Landings	Registered	Pulls	**CPUE**	**SD**	Days	Dates	
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 3. 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).

		New Shell						Old Shell					
Year	Sample	74-83	84-93	94-103	104-113	114-123	124+	74-83	84-93	94-103	104-113	114-123	124+
1977	1549	0	0	0.0032	0.4196	0.3422	0.1220	0	0	0	0.0626	0.040	0.0103
1978	389	0	0	0.0103	0.1851	0.473	0.3059	0	0	0	0.0051	0.0103	0.0103
1979	1660	0	0	0.0253	0.2325	0.3831	0.3217	0	0	0	0.0253	0.0006	0.0114
1980	1068	0	0	0.0037	0.0983	0.3062	0.5543	0	0	0	0.0028	0.0112	0.0234
1981	1748	0	0	0.0039	0.0734	0.1541	0.5090	0	0	0	0.0045	0.0504	0.2046
1982	1093	0	0	0.0421	0.1921	0.1647	0.5050	0	0	0.0037	0.0128	0.022	0.0576
1983	802	0	0	0.0387	0.4127	0.3579	0.0973	0	0	0.0037	0.0362	0.010	0.0436
1984	963	0	0	0.0966	0.4195	0.2804	0.0717	0	0	0.0104	0.0654	0.0488	0.0073
1985	2691	0	0.0004	0.0643	0.3122	0.3716	0.1747	0	0	0.0026	0.0334	0.0312	0.0097
1986	1138	0	0	0.029	0.3559	0.3937	0.1353	0	0	0.0018	0.0202	0.0378	0.0264
1987	1542	0	0	0.0166	0.1788	0.2912	0.3798	0	0	0.0025	0.0267	0.0650	0.0393
1988	1522	0.0007	0	0.0237	0.2004	0.3003	0.2181	0	0	0.0059	0.0644	0.0972	0.0894
1989	2595	0	0	0.0127	0.1643	0.3185	0.2148	0	0	0.0042	0.0555	0.1215	0.1084
1990	1289	0	0	0.0147	0.1435	0.3468	0.3251	0	0	0.0008	0.0372	0.0737	0.0582
1991													
1992	2566	0	0	0.0172	0.201	0.2662	0.2244	0	0	0.0027	0.0792	0.1292	0.080
1993	1813	0	0	0.0142	0.2312	0.3939	0.263	0	0	0.0004	0.0173	0.0437	0.0362
1994	404	0	0	0.0248	0.0941	0.0817	0.0891	0	0	0.0248	0.1881	0.25	0.2475
1995	1174	0	0	0.0392	0.2615	0.2853	0.207	0	0	0.0077	0.0486	0.0741	0.0767
1996	787	0	0	0.0318	0.2236	0.2389	0.141	0	0	0.014	0.1194	0.136	0.0953
1997	1198	0	0	0.0292	0.3656	0.3414	0.1244	0	0	0.0033	0.0559	0.0417	0.0384
1998	1055	0	0	0.0284	0.2332	0.2427	0.1071	0	0	0.0218	0.1118	0.1431	0.1118
1999	561	0	0	0.0026	0.2434	0.2698	0.3836	0	0	0	0	0.0423	0.0582
2000	17213	0	0	0.0194	0.2991	0.3917	0.1249	0	0	0.0028	0.0531	0.0654	0.0436
2001	20030	0	0	0.0243	0.2232	0.3691	0.2781	0	0	0.0008	0.0241	0.0497	0.0304
2002	5198	0	0	0.0442	0.2341	0.2814	0.3253	0	0	0.0046	0.0282	0.0419	0.0402
2003	5220	0	0	0.0232	0.3680	0.3197	0.1523	0	0	0.0011	0.0218	0.0465	0.0674
2004	9605	0	0	0.0087	0.3811	0.3880	0.1395	0	0	0.0004	0.0255	0.0347	0.0221
2005	5360	0	0	0.0022	0.2539	0.4709	0.1823	0	0	0	0.0205	0.0451	0.025
2006	6707	0	0	0.0021	0.1822	0.3484	0.199	0	0	0.0003	0.0498	0.1375	0.0807
2007	6125	0	0	0.0111	0.3574	0.3407	0.1714	0	0	0.0008	0.0247	0.0573	0.0366
2008	5766	0	0	0.0047	0.3512	0.3476	0.0668	0	0	0.0014	0.0895	0.0928	0.0461
2009	6026	0	0	0.0105	0.3445	0.3294	0.1339	0	0	0.0012	0.0768	0.0795	0.0242
2010	5902	0	0	0.0053	0.3855	0.3617	0.1095	0	0	0.0019	0.0546	0.0546	0.0271
2011	2552	0	0	0.0043	0.3170	0.3969	0.1387	0	0	0.0020	0.0611	0.0588	0.0212
2012	5056	0	0	0.0026	0.2421	0.4620	0.2067	0	0	0.0002	0.0259	0.0423	0.0182
2013	4203	0	0	0.0044	0.2388	0.3710	0.3020	0	0	0.0003	0.0140	0.0422	0.0272
2014	4682	0	0	0.0085	0.2828	0.2360	0.2565	0	0	0.0002	0.0412	0.0865	0.0882
2015	4163	0	0	0.0139	0.4762	0.2821	0.1294	0	0	0.0007	0.0237	0.0328	0.0412

Table 4. Summer commercial1987-1994, 2012-2015 observer discards size/shell compositions

		New Shell						Old Shell					
Year	Sample	74-83	84-93	94-103	104-113	114-123	124+	74-83	84-93	94-103	104-113	114-123	124+
1987	1076	0.2026	0.3625	0.3522	0.0344	0	0	0	0	0.0437	0.0046	0	0
1988	712	0.052	0.184	0.4831	0.139	0	0	0	0	0.0969	0.0449	0	0
1989	911	0.2492	0.3392	0.2371	0.0274	0	0	0	0	0.1196	0.0274	0	0
1990	459	0.2702	0.3203	0.3028	0.0414	0	0	0	0	0.0588	0.0065	0	0
1992	515	0.2175	0.3592	0.332	0.0369	0	0	0	0	0.0447	0.0097	0	0
1994	726	0.1556	0.303	0.1736	0.0262	0	0	0	0	0.2824	0.0592	0	0
2012	1632	0.0867	0.1428	0.2478	0.1198	0.0590	0.0212	0.0018	0.0088	0.0478	0.1121	0.1150	0.0372
2013	1725	0.4388	0.2365	0.2470	0.0655	0.0035	0.0012	0.0006	0.0006	0.0041	0.0012	0.0012	0
2014	1675	0.1044	0.2745	0.4320	0.1235	0.0084	0.0024	0.0024	0.0089	0.0298	0.0113	0.0018	0.0006
2015	1501	0.0790	0.1846	0.4635	0.2012	0.0252	0.0106	0	0.0013	0.0159	0.0113	0.0040	0.0033

Table 5. The number of tagged data released and recovered after 1 year (Y1) – 6 year (Y6) by the summer commercial fishery during 1980-1992 and 1993-2015 periods. The two periods were assumed to have different catch selectivity.

Release Length Class	Recap Length Class	1980-1992						1993-2014					
		Y1	Y2	Y3	Y4	Y5	Y6	Y1	Y2	Y3	Y4	Y5	Y6
1	1	0	0	0	0	0	0	0	0	0	0	0	0
1	2	0	0	0	0	0	0	8	0	0	0	0	0
1	3	0	0	0	0	0	0	13	1	0	0	0	0
1	4	0	2	0	0	0	0	3	29	3	0	0	0
1	5	0	0	1	0	2	0	0	2	0	1	0	0
1	6	0	0	0	0	0	0	0	0	0	1	0	0
2	2	0	0	0	0	0	0	0	0	0	0	0	0
2	3	5	0	0	0	0	0	22	2	0	0	0	0
2	4	10	2	0	1	0	0	39	13	3	0	0	0
2	5	0	1	1	1	0	0	3	23	38	2	2	0
2	6	0	0	0	1	1	0	0	1	1	2	1	1
3	3	2	0	0	0	0	0	0	0	0	0	0	0
3	4	32	1	1	0	0	0	77	10	1	0	0	0
3	5	26	3	3	0	0	0	24	3	7	0	0	0
3	6	1	0	2	1	1	0	0	6	2	0	1	0
4	4	15	0	0	0	0	0	8	0	0	0	0	0
4	5	34	14	0	0	0	0	25	0	3	0	1	0
4	6	8	6	3	2	0	0	4	1	1	0	0	1
5	5	15	2	0	0	0	0	19	0	0	0	0	0
5	6	31	10	2	1	0	0	20	1	0	0	0	0
6	6	41	10	3	0	0	0	14	0	0	1	0	0

Length class: 1: 74-83mm, 2:84-93mm, 3:94-103mm, 4:104-113mm, 5:114-123mm, and 6: 124mm+

Appendix A: Norton Sound Red King Crab CPUE Standardization

This is an update of the report by G. Bishop (SAFE 2013). There was no change in the model methodology itself. Only changes are data.

Methods

Data Source & Cleaning

Commercial fishery harvest data were obtained from a fish ticket database, which included: Landing Date, Fish Ticket Number, Vessel Number, Permit Fishery ID, Statistical Area(s) fished, Effort, and Number and Pounds of Crab harvested (Table A1). Fish ticket database may have multiple entries of identical Fish Ticket Number, Vessel Number, Permit Fishery ID, and Statistical Area . In those cases, at least one Effort data are missing or zero with the Number and Pounds of Crab harvested. These entries indicate that crabs were either retained from commercial fishery (i.e., not sold), or dead loss.

Following data cleaning and combining methods were conducted.

1. Sum crab number and efforts by Fish Ticket Number, Vessel Number, Permit Fishery ID, Statistical Area
2. Remove data of missing or zero Efforts, Number of Crab, Pounds of Crab (Those are considered as true missing data)
3. Calculate CPUE as Number of Crab/Effort

The data were separated into two periods: 1977-1992 and 1993-2015. The two periods represents before and after super exclusive status enacted since 1993.

Data Censoring

We first investigated distribution of fishing vessels by frequency of deliveries and years of operation (Figure A2, Tables A3,A4). The number of vessels operated ranged from 2 (1988) to 48 (1995). None of vessels operated consecutively from 1977 to 2015, and many vessels operated only 1 year.
During 1977-92 period, vessels of 1 year of operation and/or 1 delivery per year harvested 20-90% of crabs (Table A3). For instance, all vessels did only 1 delivery in 1989, and in 1988 64% of crabs were harvested by 1 vessel that did only 1 delivery. On the other hand, during 1993-2015 period of post super-exclusive fishery status, the majority of commercial crab fishery and harvest was done by vessels with more than 5 years of operations and more than 5 deliveries per year.
For 1977 – 1992, censoring was made for vessels of more than 2 years of operations. Increasing deliveries to more than one would result in no estimates for some years. Further increasing years of operation would also limit the number of vessel to only 1 or 2. For 1993 – 2015, censoring was made for vessels of more than 5 years of operations and 5 deliveries per year.

Analyses

A GLM was constructed as

$$\ln(CPUE) = YR + VSL + MSA + WOY + PF$$

Where YR: Year, VSL: Vessel, MSA: Modified Statistical Area, WOY: Week of Year, PF: Week of Year (Table 1). All variables were treated as categorical. Inclusion of interaction terms were not considered because they were absent (SAFE 2013).

For selection of the best model, forward and backward stepwise selection was conducted. (R step function)

```
fit <- glm(L.CPUE.NO ~ factor(YR) + factor(VSL) + factor(WOY) + factor(MSA) +
factor(PF),data=NSdata.C)
step <- step(fit, direction='both', trace = 10)
best.glm<-glm(formula(step), data=NSdata.C)
```

The analyses were conducted for both censored and full data.

Results

Of the five variables included, the final model included four variables for 1977-1992, and all variables remained for 1993-2015 (Tables A4). The selected variables were identical with Bishop, and no major difference was observed for results of model diagnoses (SAFE 2013).

Model estimated standardized and observed CPUE differed for 1977-1980 period, but similar for 1981 to 2015 (Figure A3, Tables A5, A6). During 1977-1980 period, censored data model showed decline in 1978 and increase in 1979-1980, full data model showed steady decline from 1977 to 1980, and observed CPUE showed a peak in 1978 (Figure A3). Other notable difference was in 1989 when model estimated CPUE showed an increase while the observed CPUE showed a decline. Since 1977-1980 periods had only few vessels, data censoring had greater effects on standardized CPUE. On the other hand, fisheries since 1993 consisted of many vessels with similar characteristics, so that data censoring had little effects. For the assessment model, we used standardized CPUE with censored data.

Table A1. List of variables in the fish ticket database. Variables in bold face were used for generalized linear modeling.

Variable	Description
YR	Year of commercial fishery
VSL	Unique vessel identification number
Fish Ticket Number	Unique delivery to a processor by a vessel.
PF	Unique Permit Fishery categories **(see Table A2)**
Statistical Area	Unique fishery area.
MOA	Modified statistical area, combining each statistical area into 4 larger areas: Inner, Mid, Outer, Outer North **(see Appendix A3, Figure A1)**
Fishing beginning date	Date of pots set
Landing date	Date of crab landed to processor
WOY	Week of Landing Date **(calculated)**
Effort	The number of pot lift
Crab Numbers	Total number of crabs harvested from pots
Crab Pounds	Total pounds of crab harvested from pots
ln(CPUE)	ln(Crab Numbers/Effort) **(calculated)**

Table A2. Permit fisheries, descriptions, and years with deliveries for Norton Sound summer commercial red king crab harvest data.

Permit fishery	Type	Description	Years
K09Q	Open access	KING CRAB , POT GEAR VESSEL UNDER 60', BERING SEA	1994–2002
K09Z	Open access	KING CRAB , POT GEAR VESSEL UNDER 60', NORTON SOUND	1992–2015
K09ZE	CDQ	KING CRAB , POT GEAR VESSEL UNDER 60', NORTON SOUND CDQ, NSEDC	2000–2015
K09ZF	CDQ	KING CRAB , POT GEAR VESSEL UNDER 60', NORTON SOUND CDQ, YDFDA	2002–2004
K91Q	Open access	KING CRAB , POT GEAR VESSEL 60' OR OVER, BERING SEA	1978–1989
K91Z	Open access	KING CRAB , POT GEAR VESSEL 60' OR OVER, NORTON SOUND	1982–1994

Table A3. Modified statistical area definitions used for analysis of Norton Sound summer commercial red king crab harvest data.

Modified statistical area	Statistical areas included
Inner	616331, 616401, 626331, 626401, 626402
Mid	636330, 636401, 636402, 646301, 646330, 646401, 646402
Outer	656300, 656330, 656401, 656402, 666230, 666300, 666330, 666401
Outer North	666402, 666431, 676300, 676330 ,676400, 676430, 676501, 686330

Table A4. The number of vessels by the number of years operated and deliveries made per year.

Years	1					2					3					4					>5					Total
Deliveries	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5	
1977	4							1					1					1									7
1978	1					1	1			1		1		1	1					2				1		10
1979	6	6	1		1	4	3	1		1	2	2		1		1	1		1	1	1	1				34
1980		1	1		1			1		1										1		1				7
1981	2	1	8	3	3	2	4	2		1	1	1	2		1	1	1				1			1	1	36
1982	1	1	1	1				2						1					1		1			2		11
1983	8					6	1				3	1				1					2	1				23
1984	1		2			1							1						1				2			8
1985	1				1	1				1					1										1	6
1986						1															2					3
1987			5	1												1					2					9
1988	1						1																			2
1989	5					2										1					2					10
1990	2																				1	1				4
1992	10	1				6										2					1					20
1993	3				4			1							3					1					5	17
1994	1	2	3		2		1			1					7					4		3			11	35
1995		2			9	1				9					5			1		4			1	1	15	48
1996		1		1	4	2		2	1	4	2	2			3					3	3	2	1		10	41
1997					2				1						1					2	1		1		5	13
1998										1	1				1						1				4	8
1999					1						1		1			1					1		2		3	10
2000					1					1			1		1							1		1	9	15
2001			1		2					1					1				1	2			1	1	20	30
2002		2			1	1				1					2	1				1	1	3	2	1	16	32
2003							1																1		23	25
2004	1		1																	1			2	3	18	26
2005												1			1				1		1	1	1		24	30
2006	2												1		1					1			1		22	28
2007	2														2					1	2		3		20	30
2008						1														1	1			1	18	22
2009																		1					1		21	23
2010															1									1	21	23
2011														1							1				22	24
2012											1				1			1				1			25	29
2013											1				3					1					28	33
2014										2					3					1		1	2		24	33
2015		1	1							2				1	4					1				3	23	36

Table A5. Proportion of red king crab harvest by the number of years operated and deliveries made per year.

Years	1					2					3					4					>5				
Deliveries	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5	1	2	3	4	>5
1977	0.25	0	0	0	0	0	0	0.29	0	0	0	0	0.29	0	0	0	0	0.17	0	0	0	0	0	0	0
1978	0	0	0	0	0	0.04	0.04	0	0	0.2	0	0.08	0	0.15	0.09	0	0	0	0	0.26	0	0	0	0.13	0
1979	0.11	0.17	0.01	0	0.05	0.08	0.11	0.02	0	0.09	0.03	0.1	0	0.04	0	0.02	0.02	0	0.02	0.02	0.01	0.08	0	0	0
1980	0	0.04	0	0	0.19	0	0	0.24	0	0.19	0	0	0	0	0	0	0	0	0	0.13	0	0.2	0	0	0
1981	0.01	0.01	0.18	0.05	0.17	0.02	0.06	0.07	0	0.02	0	0.03	0.03	0	0.09	0.04	0.02	0	0	0	0.07	0	0	0.08	0.05
1982	0.01	0.04	0.03	0.03	0	0	0	0.07	0	0	0	0	0	0.06	0	0	0	0	0.04	0	0.32	0	0	0.4	0
1983	0.24	0	0	0	0	0.22	0.02	0	0	0	0.13	0.03	0	0	0	0.09	0	0	0	0	0.21	0.06	0	0	0
1984	0.01	0	0.11	0	0	0.19	0	0	0	0	0	0	0.08	0	0	0	0	0	0.17	0	0	0	0.44	0	0
1985	0.14	0	0	0	0.24	0.06	0	0	0	0.19	0	0	0	0	0.15	0	0	0	0	0	0	0	0	0	0.21
1986	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.93	0	0	0	0
1987	0	0	0.25	0.09	0	0	0	0	0	0	0	0	0	0	0	0.24	0	0	0	0	0.41	0	0	0	0
1988	0.64	0	0	0	0	0	0.36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0.54	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0	0.11	0	0	0	0	0.27	0	0	0	0
1990	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.28	0.32	0	0	0
1992	0.51	0.17	0	0	0	0.21	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0.09	0	0	0	0
1993	0.01	0	0	0	0.4	0	0	0.01	0	0	0	0	0	0	0.28	0	0	0	0	0	0	0	0	0	0.29
1994	0	0	0.01	0	0.1	0	0	0	0	0.01	0	0	0	0	0.31	0	0	0	0	0.12	0	0	0	0	0.45
1995	0	0	0	0	0.17	0	0	0	0	0.25	0	0	0	0	0.07	0	0	0	0	0.09	0	0	0	0	0.41
1996	0	0	0	0	0.1	0	0	0	0.02	0.26	0	0.01	0	0	0.2	0	0	0	0	0.06	0.01	0	0.01	0	0.33
1997	0	0	0	0	0.11	0	0	0	0.06	0	0	0	0	0	0.09	0	0	0	0	0.12	0.02	0	0.04	0	0.56
1998	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0.08	0	0	0	0	0	0.01	0	0	0	0.82
1999	0	0	0	0	0.39	0	0	0	0	0	0	0	0.15	0	0	0.03	0	0	0	0	0	0	0.12	0	0.31
2000	0	0	0	0	0.1	0	0	0	0	0.02	0	0	0.01	0	0.1	0	0	0	0	0	0	0	0	0.01	0.77
2001	0	0	0.01	0	0.07	0	0	0	0	0.02	0	0	0	0	0.06	0	0	0	0.03	0.05	0	0	0.03	0	0.72
2002	0	0.01	0	0	0.05	0	0	0	0	0.07	0	0	0	0	0.04	0	0	0	0	0.04	0	0.04	0.02	0.01	0.72
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2004	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0.03	0.05	0.87
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0.02	0.02	0	0.93
2006	0.01	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0.04	0	0	0.01	0	0.92
2007	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0.06	0.01	0	0.05	0	0.85
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0.01	0.93
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0.99
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01	0.98
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.99
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.01	0	0	0.98
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0.02	0	0	0	0	0.91
2014	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0.07	0	0	0	0	0.03	0	0	0.01	0	0.81
2015	0	0	0	0	0	0	0	0	0	0.08	0	0	0	0.01	0.07	0	0	0	0	0.04	0	0	0	0.05	0.75

Table A4. Final generalized linear model formulae and associated R^2 selected for Norton Sound summer commercial red king crab fishery. The dependent variable is ln(CPUE) in numbers.

Time series	Years	Deliveries	Explanatory variables	Null dev.	Null df	Resid. dev.	Resid. df	AIC	R^2
1977–1992	All	All	YR+VSL+WOY+MSA	1163.1	797	445.4	653	2091	0.68
	≥2	≥1	YR+VSL+WOY+MSA	703.7	483	379.9	420	1188	0.60
1993–2015	All	All	YR+VSL+WOY+MSA+PF	5363.0	6309	3050.3	6127	13688	0.50
	≥5	≥5	YR+VSL+WOY+MSA+PF	3374.1	4767	2175.0	4678	9971	0.46

Table A5. Standardized (Censored/full data), and scaled arithmetic observed CPUE indices from 1977–1992.

	Censored		**Full data**		**Observed**
Year	**CPUE**	**SE**	**CPUE**	**SE**	**CPUE**
1977	4.18	0.34	3.43	0.34	2.08
1978	2.21	0.23	2.83	0.23	3.73
1979	3.09	0.18	2.59	0.17	1.62
1980	3.03	0.26	2.43	0.25	1.80
1981	0.89	0.19	0.74	0.17	0.64
1982	0.11	0.25	0.13	0.25	0.33
1983	1.00	0.22	0.90	0.22	0.68
1984	0.94	0.23	1.09	0.23	0.83
1985	0.34	0.20	0.37	0.21	0.62
1986	0.76	0.41	1.00	0.43	2.20
1987	0.57	0.32	0.63	0.32	0.58
1988	1.44	0.67	1.51	0.71	1.88
1989	1.80	0.32	1.61	0.33	0.89
1990	1.13	0.40	1.18	0.42	1.10
1991	NA	NA	NA	NA	NA
1992	0.30	0.31	0.26	0.31	0.25

Table A6. Standardized (Censored/full data), and scaled arithmetic observed CPUE indices from 1993–2015.

	Censored		Full data		Observed
Year	**CPUE**	**SE**	**CPUE**	**SE**	**CPUE**
1993	0.91	0.10	0.90	0.08	1.38
1994	0.81	0.06	0.80	0.05	0.79
1995	0.43	0.05	0.47	0.04	0.48
1996	0.51	0.08	0.44	0.06	0.60
1997	0.85	0.10	0.86	0.08	0.92
1998	0.80	0.13	0.74	0.12	0.56
1999	0.93	0.13	0.77	0.11	0.45
2000	1.26	0.06	1.24	0.06	1.49
2001	0.66	0.05	0.70	0.04	0.70
2002	1.25	0.06	1.21	0.06	1.13
2003	0.88	0.05	0.89	0.05	0.93
2004	1.37	0.05	1.36	0.05	1.27
2005	1.26	0.05	1.30	0.05	1.33
2006	1.38	0.05	1.43	0.05	1.46
2007	1.07	0.05	1.13	0.05	1.02
2008	1.42	0.05	1.46	0.05	1.39
2009	0.89	0.04	0.92	0.04	1.02
2010	1.27	0.04	1.31	0.04	1.30
2011	1.62	0.05	1.63	0.05	1.75
2012	1.34	0.04	1.38	0.04	1.35
2013	0.69	0.04	0.70	0.04	0.73
2014	1.16	0.05	1.18	0.04	1.08
2015	1.53	0.05	1.57	0.05	1.46

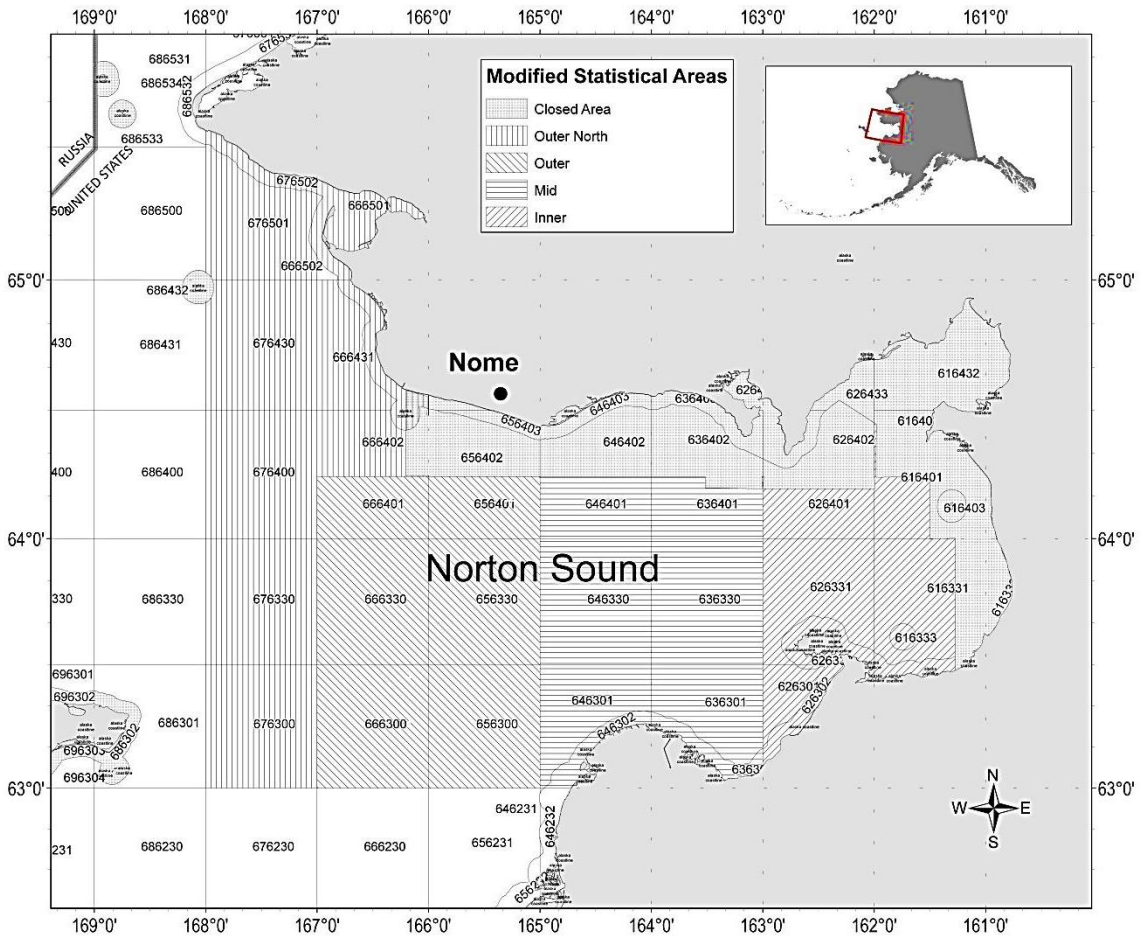
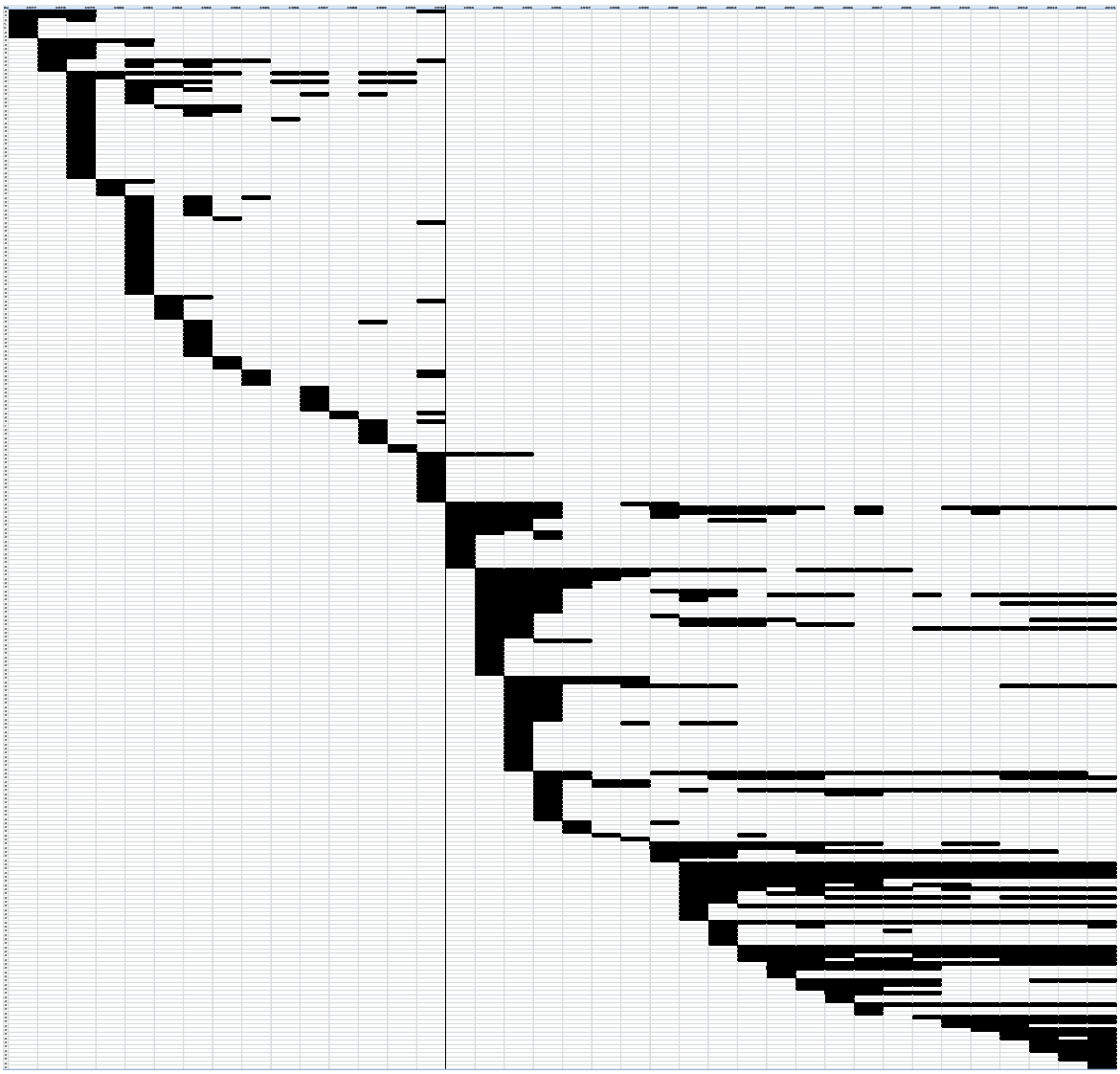


Figure A1. Closed area and statistical area boundaries used for reporting commercial harvest information for red king crab in Registration Area Q, Northern District, Norton Sound Section and boundaries of the new *Modified Statistical Areas* used in this analysis.

Figure A2. Distribution of unique vessel from 1976 (left) to 2015 (right). Each row indicates unique vessel, and each black represents the year vessel was operated. Vertical black line shows division between 1992 and 1993.



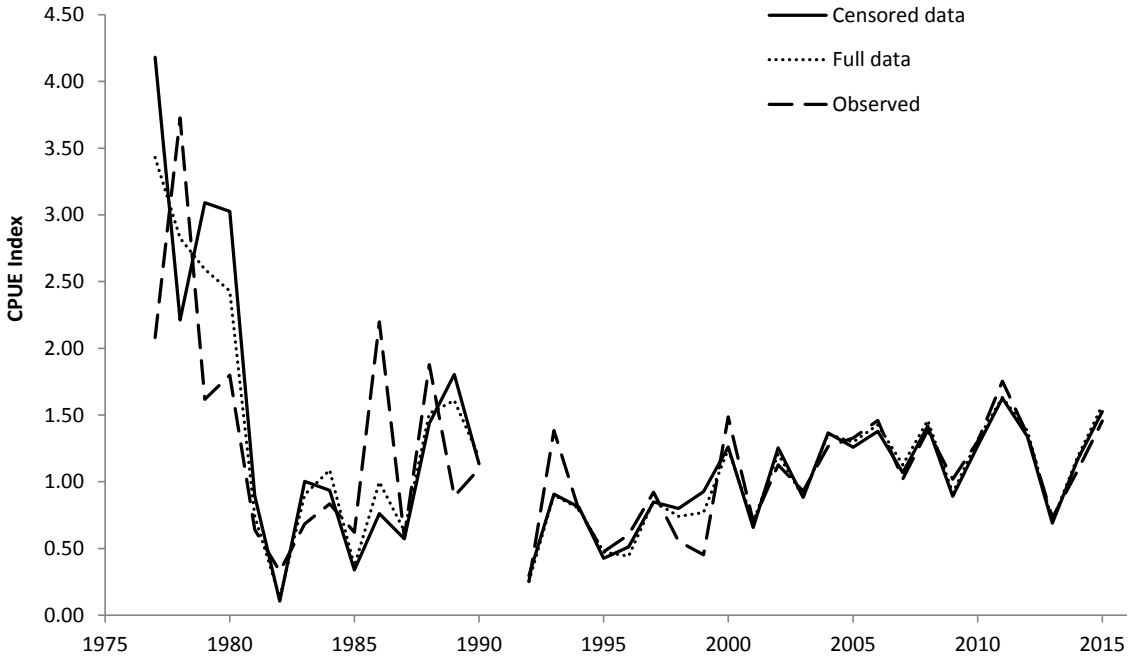


Figure A3. Comparison of CPUE among Observed, Standardized (censored data), and Standardized (full data) in 1977-2015.

Appendix B: Summary of recent investigations on Norton Sound red king crab

Jenefer Bell: Alaska Department of Fish and Game, Nome

Maturity

Size at maturity for male red king crabs is estimated at 50–59 mm CL (Paul et al. 1991) using the presence of spermataphores to indicate physical maturity. However, the authors urge caution because of the potential for a difference in carapace length between physical maturity and functional maturity: the carapace length at which male red king crab can grasp and hold a female.

From data collected during spring 2012–2014 and summer 2015 pot surveys, size at maturity for female red king crab appears to be between 64 and 72mm CL (Figure B1). This is consistent with earlier research stating size at maturity is 71.4 mm CL (Otto et al. 1990).

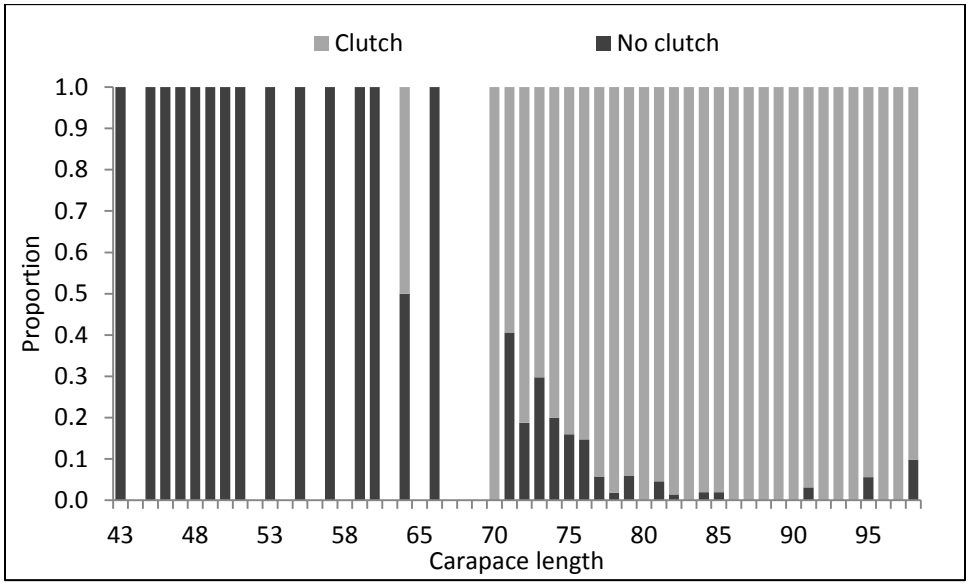


Figure B1.–Proportion of female red king crab with clutches and no clutches collected in pots in June 2012–2014 and August 2015.

Molt timing and growth

Molting in crustaceans is regulated by ecdysteroids, specifically 20-Hydroxyecdysone and ecdysone (Chang and O'Connor 1977). Molting hormones in the hemolymph begin to increase 2 to several months prior to molting and decrease abruptly 1–3 weeks before molting (3 weeks for Tanner crab, 1 week for Dungeness crab, unknown for Red king crab; Tamone et al. 2005, 2007, Thomton et al. 2006). After molting, hormones remain low throughout the intermolt period, approximately 9 months.

Hemolymph was collected from Norton Sound red king crab from April to September in 2014. The data suggest molt timing of Norton Sound red king crab is late summer for sublegal (immature) and after August for legal (mature) crab (Figure B2). This is consistent with increased incidents of double-shelled (molting) crab in late August–September commercial

catches (Joyce Soong, ADF&G, personal communication). Hemolymph cannot be collected during the months of November–January and May (i.e., no or poor sea ice conditions) therefore it may be difficult to definitively determine molt timing with this method. Additional hemolymph samples were collected in 2015 attempting to fill in data gaps from the first year of the project. Those samples will be processed in November 2015.

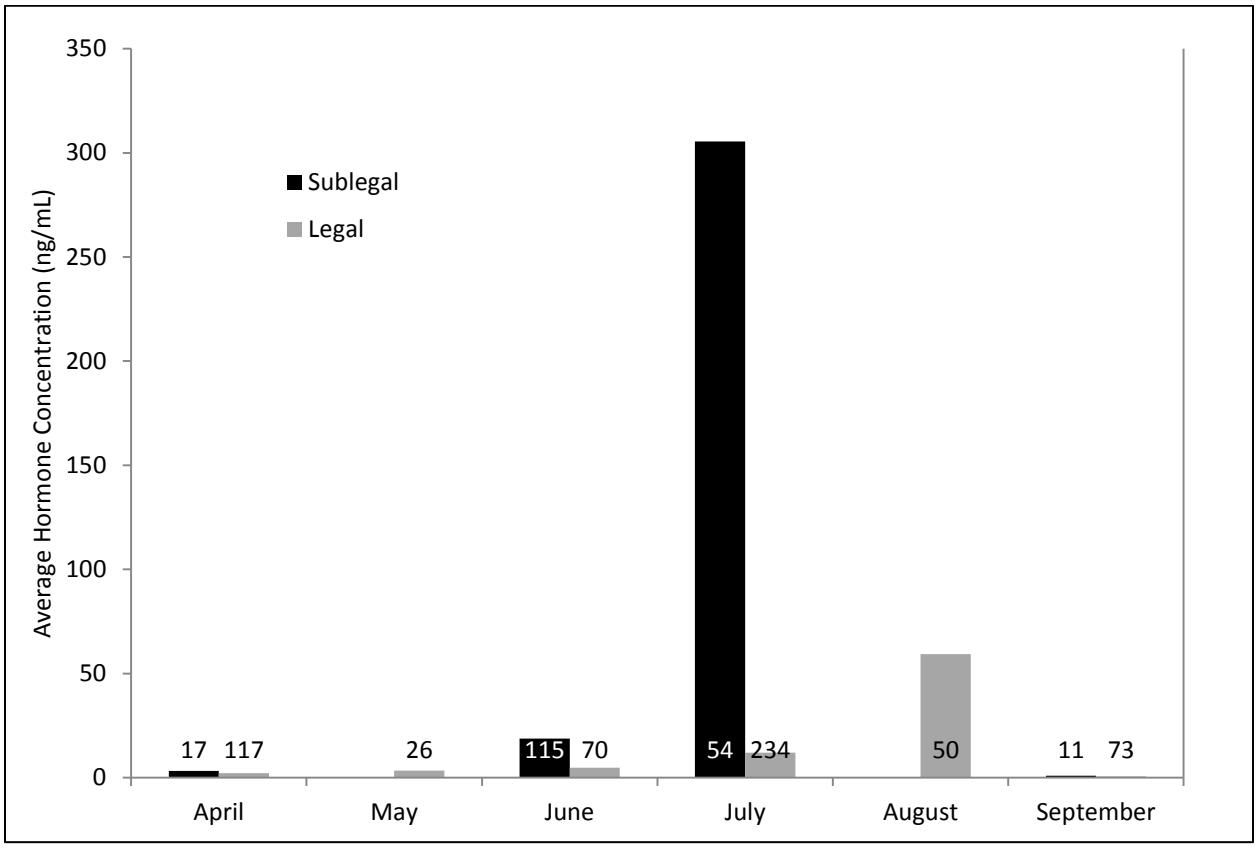


Figure B2.–Average hormone level by month for legal and sublegal red king crab. *Note*: number on bar indicates sample size.

Molt increment analysis from red king crab captured during a tagging study (2012–2014) suggests Red king crab molting from sublegal to larger sublegal or to legal crab was larger than red king crab molting from legal to larger legal crab (t-test with unequal variance: t=10.1, df=211, p<0.0001). Red king crab starting as sublegal had an average molt increment of 14.0 mm (SD=2.1) and red king crab starting as legal had an average molt increment of 11.0 mm (SD=2.1). Additionally, this study found new shell legal red king crab had a larger molt increment than old shell legal red king crab (t-test with unequal variance: t=3.5, df=23.7, p=0.002). Legal new shell crab had an average molt increment of 12.7 mm (SD=2.3) and old shell crab had an average of 10.7 mm (SD=1.9) molt increment. The molt increment disparity between shell conditions was not apparent in sublegal red king crab. New shell sublegal red king crab had a larger average molt increment (14.0 mm, SD=2.1) than new shell legal red king crab (12.7 mm (SD=2.3); t-test with unequal variance: t=2.4, df=24.5, p=0.03; Figure B3).

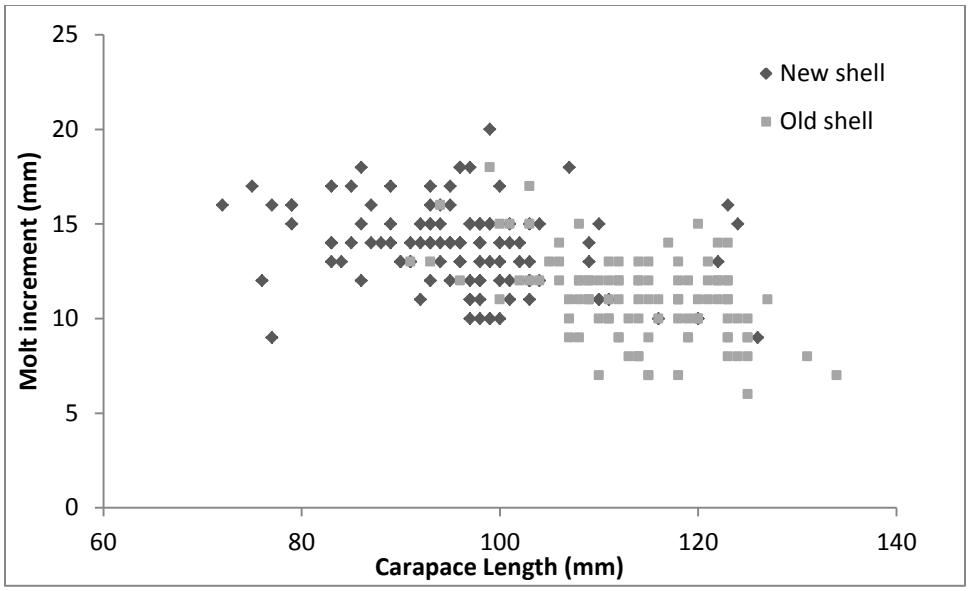


Figure B3.–Red king crab molt increment by carapace length and shell condition (at time of tagging).

Inshore-offshore movements

In 2012–2014 spring (mid-June) red king crab were tagged 5 and 10 miles from the coast east of Nome and were recaptured during summer commercial fisheries (late June–September). Tag recapture data show offshore movement tends to be to the southwest (Figures B4, B5). However, tag recovery is limited to areas open to commercial fishing therefore complete movement patterns remain unknown. Red king crab had an average rate of travel of 1.6–2.0 km day^{-1} and had an average of 30–36 days at large.

Red king crab were tagged and recaptured in the commercial fisheries. Tags recaptured in the fishery immediately after tagging were in proportions similar to proportions of red king crab harvest by statistical area indicating dispersal of nearshore crab in all areas of the offshore commercial fishery (Table B1). This suggests red king crab mix throughout Norton Sound and crab harvested in each statistical area may originate from several nearshore locations.

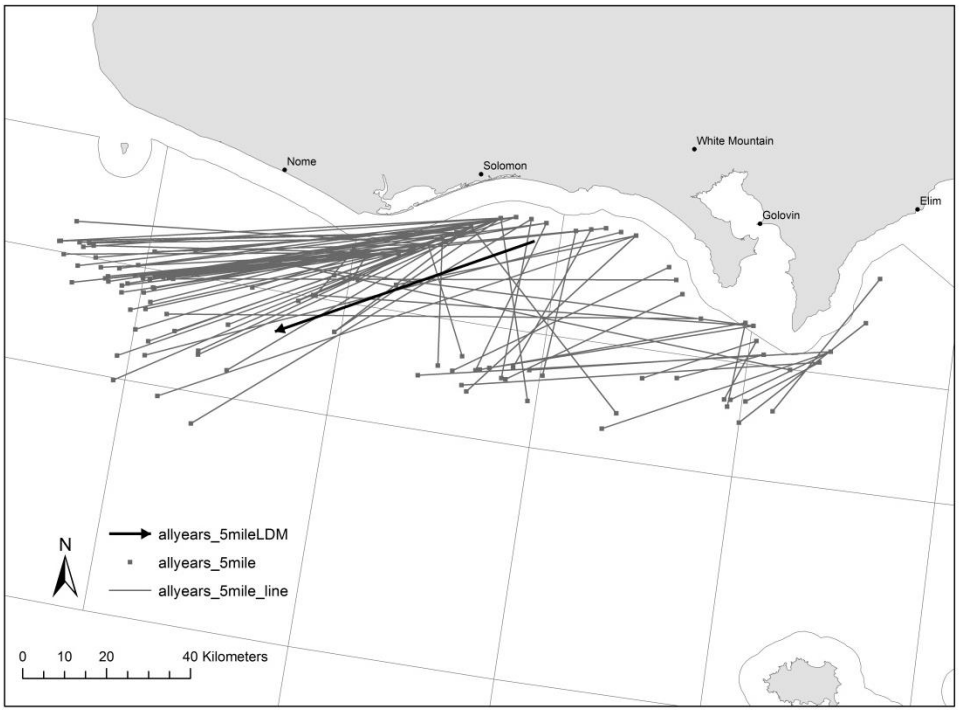


Figure B4.–Straight line direction of red king crab tagged on the 5 mile transect and recaptured in the commercial fisheries. *Note*: The heavy black arrow represents linear directional mean.

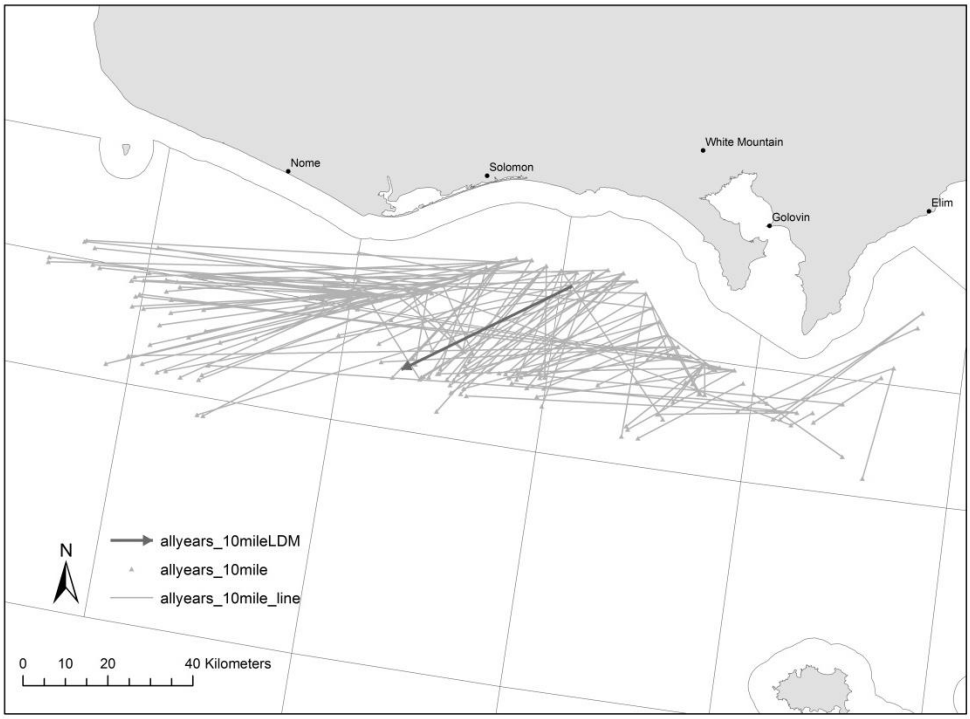


Figure B5.–Straight line direction of red king crab tagged on the 10 mile transect and recaptured in the commercial fisheries. *Note*: The heavy black arrow represents linear directional mean.

Table B1.–Distribution of commercial harvest and recaptured red king crab in the commercial fishery by statistical area.

Statistical area	Number of crab harvested	Percent of harvest	Number of recaptured crab	Percent of recaptures
616331	1,763	0.4%	0	0.0%
616401	4,278	1.0%	2	0.3%
626331	230	0.1%	0	0.0%
626401	74,669	17.7%	135	22.1%
636330	7,189	1.7%	4	0.7%
636401	87,718	20.8%	119	19.5%
646330	3,657	0.9%	1	0.2%
646401	65,948	15.7%	93	15.2%
646402	1,803	0.4%	11	1.8%
656330	5,387	1.3%	5	0.8%
656401	118,624	28.2%	121	19.8%
656402	12,623	3.0%	56	9.2%
666330	331	0.1%	1	0.2%
666401	28,618	6.8%	39	6.4%
666402	6,786	1.6%	22	3.6%
666431	1,749	0.4%	2	0.3%

Size composition

Size composition of Norton Sound red king crab was collected in spring (mid-June, before the commercial fishery, 5 & 10 miles from coast, east of Nome) and fall (mid-Sept, after the commercial fishery, 3–30 miles offshore of Nome) pot surveys in 2013 and 2014.

The size composition of crab captured in the spring surveys was variable over the 3 year project with legal red king crab making up the majority in 2012 and smaller pre-recruit red king crab making larger contributions in 2013 and 2014. This pattern of size classes within nearshore waters may be an indication of upcoming legal red king crab available to the fishery as evidenced by the peak of pre-recruit 3 (74–83 mm CL) red king crab in 2013 reappearing as pre-recruit 2 (84–93 mm CL) and 1 (94–103 mm CL) red king crab in 2014 (Figure B6), typically the time it takes to molt at least one size class. The abrupt appearance of pre-recruit 3 crab within this project is likely an artefact of the pots used in this study; pots were designed to retain crab >70 mm CL and thus we would not expect to see a pre-recruit 4 spike in 2012 preceding that cohort being detected in 2013. Alternatively, if the habitat sampled in transects was not suitable for small crab, this appearance of the pre-recruit 3 cohort in 2013 may signal an ontogenetic shift into the transect habitat. The high number of legal red king crab coincident with few small crabs in 2012 and the appearance of small crabs in 2013 may also indicate a 3–4 year lag between abundant year classes available to the fishery.

The size composition of red king crab captured in the fall pot surveys was consistent in both years with crabs >100 mm CL making up the largest portion within each year. Interestingly, red king crab between the sizes of 80–95 mm CL were captured less frequently than smaller and larger crab in both years suggesting a spatial heterogeneity between size classes.

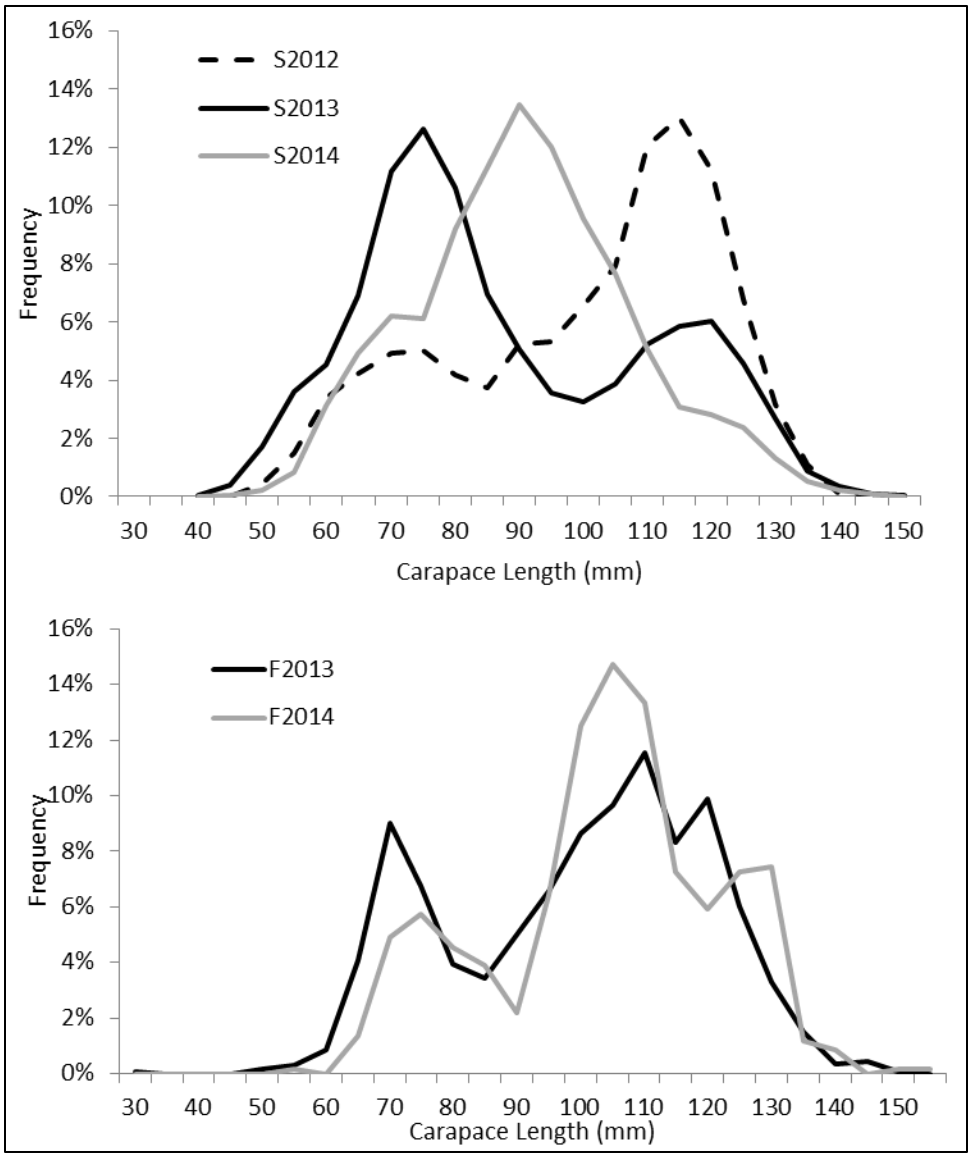


Figure B6.–Length frequency distribution of red king crab captured in spring (top) and fall (bottom) pot surveys.

Commercial harvest monitoring

Of all red king crab captured in the pots sampled by observers from 2012–2014, 7,032 were non-target crabs and 5,593 were legal crabs. Further, locations within the commercial fishing area were identified as having higher catches of non-target red king crab (Figure B7). Overall, non-crab bycatch is minimal within the summer commercial fisheries (Table B2).

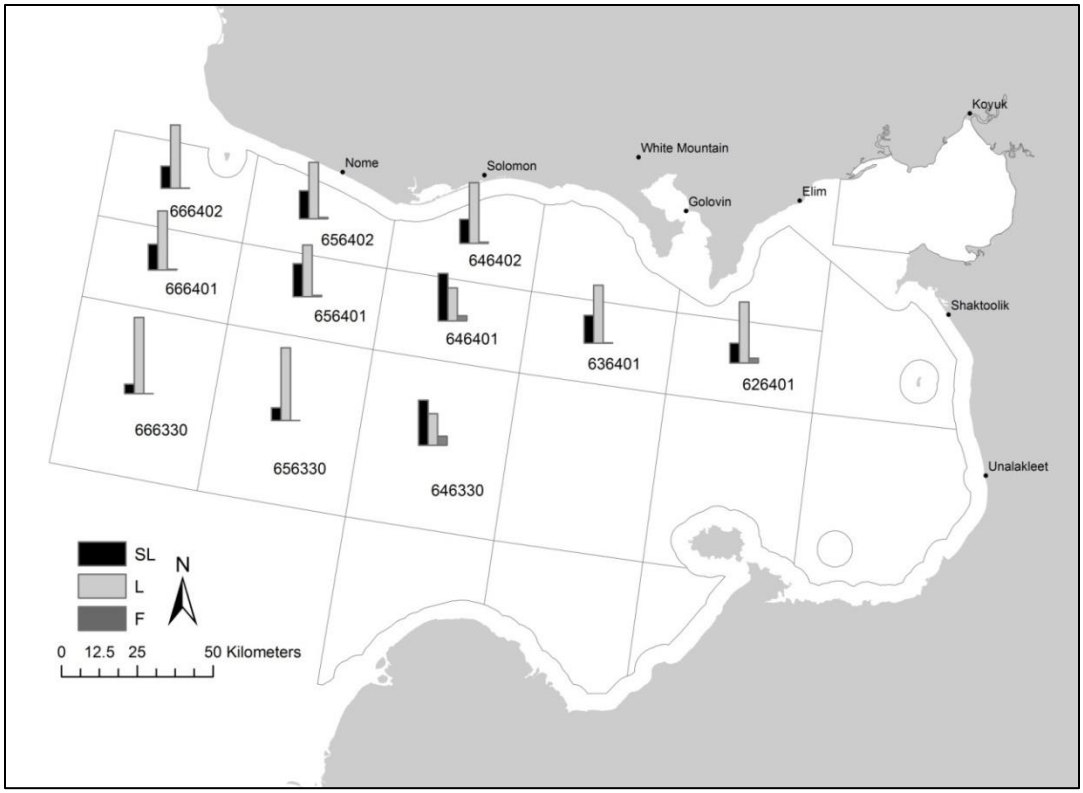


Figure B7.–Proportion by length class of red king crab captured in observer sampled pots in each statistical area. *Note:* sublegal (SL), legal (L), and female (F).

Table B2.–Species and number found in all observer pots during the 2012–2014 summer commercial fisheries, Norton Sound, AK.

Common Name	Species	Number
Red king crab	*Paralithodes camtschaticus*	12,773
Purple orange sea star	*Asterias amurensis*	4,629
Opilio crab	*Chionocetes* sp.	110
Circumboreal toad crab	*Hyas coarctatus*	88
Helmet crab	*Telmessus cheiragonus*	62
Hermit crab	*Pagurus* sp.	36
Pacific halibut	*Hippoglossus stenolepis*	29
Starry flounder	*Platichthys stellatus*	28
Basket star	*Gorgonocephalus* sp.	25
Northern neptune/Fat whelk	*Neptunea* sp.	25
Pacific cod	*Gadus macrocephalus*	23
Arctic sea star	*Leptasterias* sp.	21
Yellowfin sole	*Limanda aspera*	10
Green sea urchin	*Strongylocentratus droebachiensis*	8
Sculpin	*Enophrys* sp. / *Myoxocephalus* sp.	3

Jellyfish		3
Blue king crab	*Paralithodes platypus*	1
Spiny king crab	*Paralithodes brevipes*	2
Misc. invertebrates		6
Misc. sea star		5
Misc. fish		3

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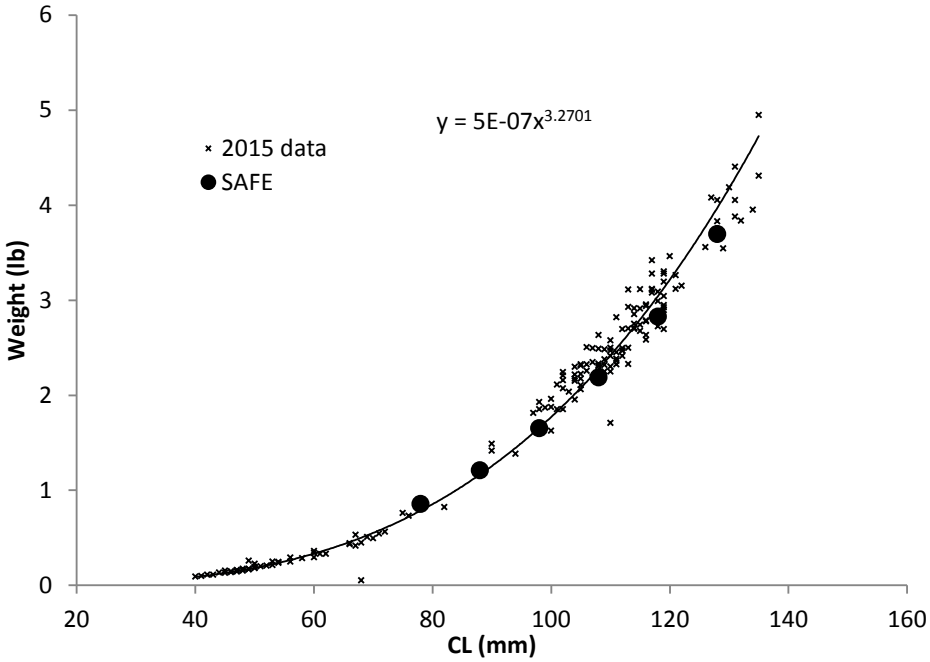
Appendix C. Application of recent findings on current NSRKC model assumptions.

Length-Weight relationship

The 2015 length-weight relationship was similar to current SAFE assumptions of average weight at each age class. This shows model assumption is appropriate.



Size-at-maturity

No new information was obtained in 2015. The current NSRKC assumption of size-at-maturity is CL > 94 mm. We were lacked time to measure chela heights in this year's survey.

Molt timing

The new finding is consistent with model assumption: molting occurs after summer fishery.

Molting probability

We isolated crabs tagged in spring and recaptured in summer next year (after molting period) by size class.

Release Class	Shell	number	Recap New	Recap Old	Molting P	Model
1	New Old	21 0	21	0	1.0	1.0
2	New Old	28 2	28 2	0 0	1.0 1.0	1.0
3	New Old	54 7	49 7	5 (0) 0	0.91 1.0	0.97
4	New Old	30 29	14 26	16 (16) 3 (1)	0.47 0.90	0.87
5	New Old	23 52	10 47	13 (12) 5 (3)	0.30 0.90	0.56
6	New Old	19 19	3 14	16 (16) 5(5)	0.15 0.74	0.2

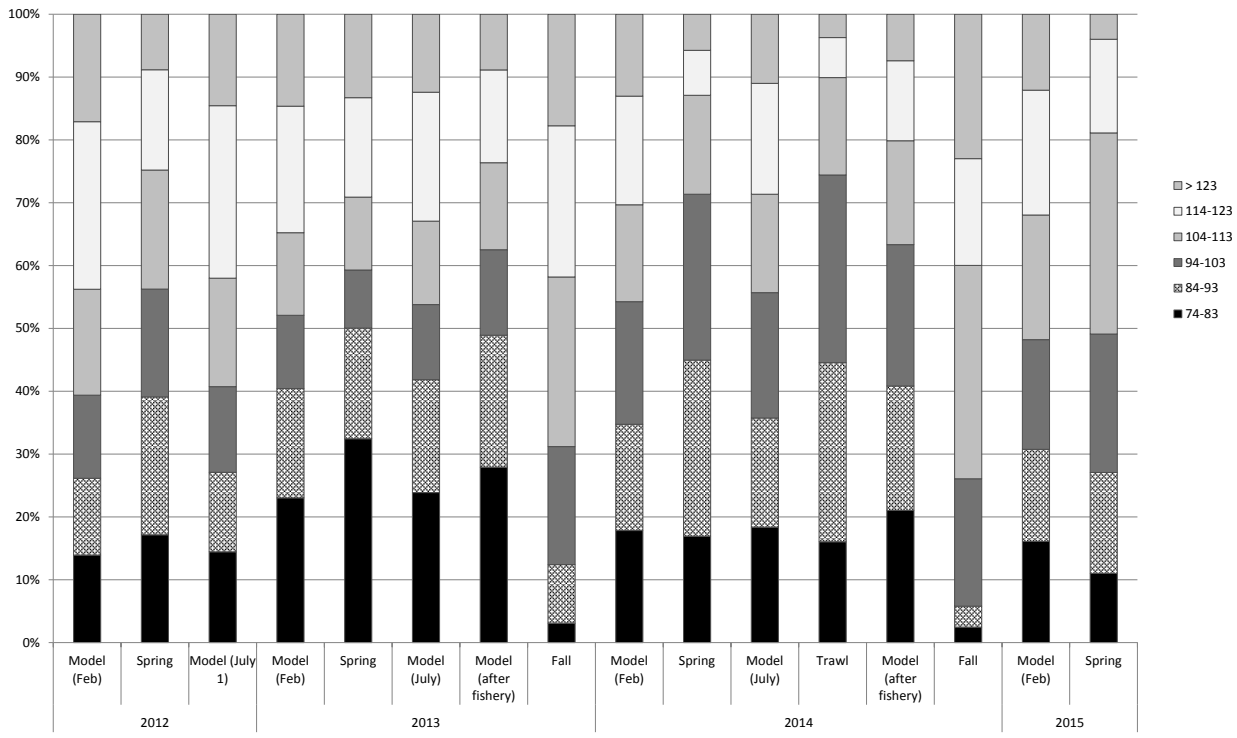
The numbers in parenthesis: oldshell in the same length class.
The model assumes identical molting probability for both new and old shells.

The assessment model assumes (1) same molting probability for new and old shells, and (2) unmolted crab remains in the same length class. The first assumption does not seem consistent with data. The data suggest different molting probability for new and old shell. On the other hand, the second assumption is consistent with the data.

Spring-Summer Inshore offshore movements

Model has no assumption of movement.

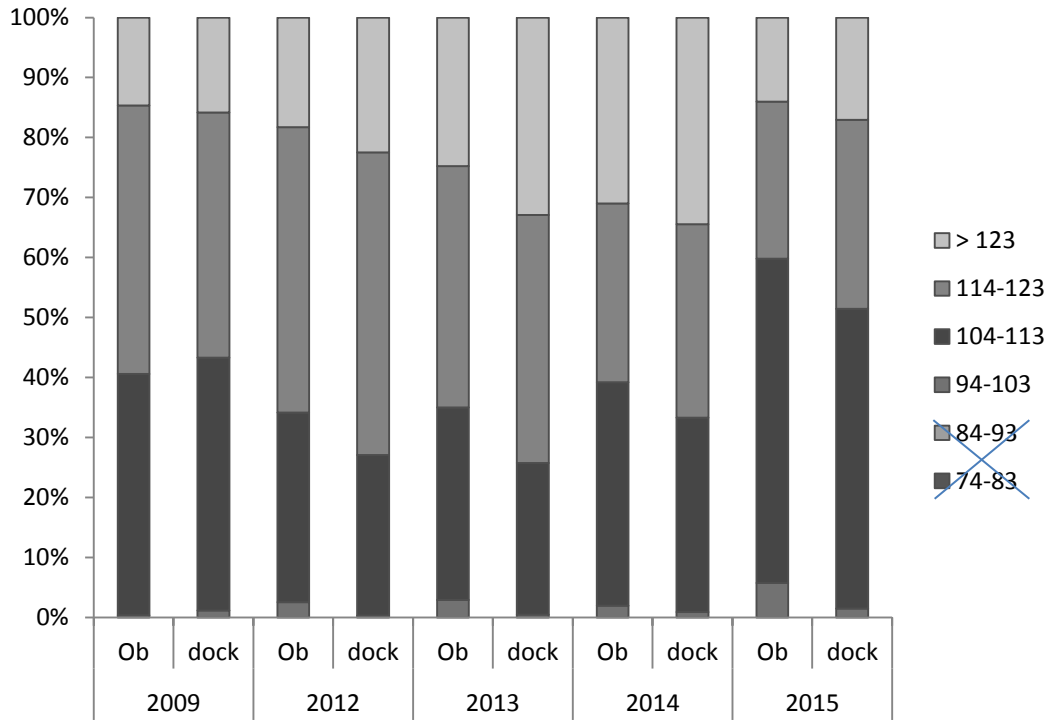
Spring and fall survey size composition



The above figure compares 2015 SAFE model lengths composition with 2012-15 spring and fall survey (not included in the model). Compared to the model prediction, spring survey show higher proportion of immature crab, and fall survey show higher proportion of mature crab than model prediction. Thus far, the model explained this with inverse logistic winter pot selectivity (i.e., hiding larger crabs or assuming that large crabs stay offshore). Since both spring and fall surveys used identical pots, selectivity should be the same between spring and fall survey. This suggests that the population observed in spring and fall is dramatically different. It could be the case that many immature crabs have not returned to the nearshore area in September.

Representativeness of observer data

ADF&G has been collecting commercial catch discard length composition data through an opportunistic fishery observer program since 2009. It has been questioned whether the data are sufficiently representative to directly estimate the number of discards. Here, we compared retained catch between observer and dock sampling.



The data show that observer sampling had a higher proportion of smaller crabs than dockside sampling. The discrepancy is probably due to: (1) smaller crabs retained for personal use or (2) smaller crabs being sold directly as catcher-seller. Since those crabs did not make to commercial processing dock where samples were taken, their lengths were not surveyed. Catches of those crabs are reported, and their proportion is less than 2% of total commercial catch. Surveyors indicated that the fishermen with observer tend to catch more smaller crabs than others.

Possible future assessment model modifications

1. Different molting probability functions for New and Old shells?

2. Include spring and fall survey data to the model?

We may not continue this project, due to funding cuts. Does model need more length composition data?

3. Keep observer data even though samples may not be representative?

4. Changing length classes from 10mm interval to 5 mm interval?

The major issue is that we do not have enough sample, especially for oldshell crabs. Change likelihood calculation for oldshell crab (e.g., 10mm interval for trawl and 5mm interval for others, fit proportion of oldshell rather than oldshell by length class?)