

## **Appendix B**

### **Norton Sound Red King Crab CPUE Standardization**

**Note:** This is an update of model by G. Bishop (SAFE 2013).

#### **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 A2-1,2,3, Figure A2-1). 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

##### **Data Censoring**

During 1977-92 period, vessels of 1 year of operation and/or 1 delivery per year harvested 20-90% of crabs (Table A2-5, Figure A2-2). 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 the 1993-2017

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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. For 1993 – 2018, censoring was made for vessels of more than 5 years of operations and 5 deliveries per year.

## Analyses

A GLM was constructed as

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

Where YR: Year, PD: Fishery periods (1977-1992, 1993-2004,2005-2018), VSL: Vessel, MSA: Statistical Area, WOY: Week of Year, PF: Permit vs open fishery (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.

Generally, censoring had little effects on standardized CPUE.

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Table B-1. List of variables in the fish ticket database. Variables in bold face were used for generalized linear modeling.

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

Table B-2. Permit fisheries, descriptions, and years with deliveries for Norton Sound summer commercial red king crab harvest data.

<b>Permit fishery</b>	<b>Type</b>	<b>Description</b>	<b>Years</b>
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	1992–2017
K09ZE	CDQ	KING CRAB , POT GEAR VESSEL UNDER 60', NORTON SOUND CDQ, NSEDC	2000–2017
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 B-3. Modified statistical area definitions used for analysis of Norton Sound summer commercial red king crab harvest data.

<b>Modified statistical area</b>	<b>Statistical areas included</b>
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

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Table B-4. Final generalized linear model formulae and AIC selected for Norton Sound summer commercial red king crab fishery. The dependent variable is ln(CPUE) in numbers.

Data	Explanatory variables	Null dev.	Null df	Resid. dev.	Resid. df	AIC
1977-1992	YR+VSL+MOY+MSA	703.7	483	247.6	418	1183
1993-2018	YR+VSL+WOY+MSA+PF	4024.0	5638	2626.6	5538	11899

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Table B-5. Standardized (Censored/full data), and scaled arithmetic observed CPUE indices from 1977–1992.

Year	Censored		Full data		Observed
	CPUE	SE	CPUE	SE	CPUE
1977	2.31	0.24	3.11	0.35	2.05
1978	4.15	0.13	2.51	0.23	4.77
1979	1.72	0.11	1.92	0.25	1.88
1980	2.14	0.16	2.15	0.28	1.90
1981	0.65	0.09	0.67	0.21	0.71
1982	0.25	0.12	0.11	0.25	0.30
1983	0.55	0.17	1.19	0.22	0.67
1984	1.10	0.18	1.02	0.23	0.97
1985	0.44	0.14	0.38	0.20	0.56
1986	1.63	0.33	0.85	0.41	1.75
1987	0.80	0.29	0.66	0.32	0.66
1988	2.09	0.33	1.63	0.67	1.72
1989	0.90	0.29	2.10	0.33	0.79
1990	1.60	0.41	1.31	0.40	1.31
1991					
1992	0.17	0.25	0.35	0.31	0.18
1993	0.96	0.09	1.03	0.10	1.04
1994	0.63	0.05	0.82	0.07	0.67
1995	0.40	0.05	0.44	0.06	0.42
1996	0.54	0.08	0.52	0.08	0.55
1997	0.76	0.10	0.81	0.10	0.88
1998	0.67	0.13	0.76	0.13	0.63
1999	0.47	0.13	0.96	0.14	0.53
2000	1.35	0.06	1.25	0.06	1.36
2001	0.74	0.05	0.64	0.05	0.67
2002	1.10	0.06	1.32	0.06	1.05
2003	0.90	0.05	0.86	0.05	0.87
2004	1.35	0.05	1.31	0.05	1.37
2005	1.24	0.05	1.23	0.05	1.26
2006	1.45	0.05	1.33	0.05	1.38
2007	1.10	0.05	1.06	0.05	1.00
2008	1.54	0.05	1.35	0.05	1.40
2009	1.04	0.04	0.87	0.04	1.00
2010	1.40	0.04	1.25	0.04	1.29
2011	1.69	0.05	1.64	0.05	1.66
2012	1.58	0.04	1.33	0.04	1.51
2013	0.74	0.04	0.70	0.04	0.82
2014	1.18	0.04	1.18	0.04	1.19
2015	1.55	0.05	1.52	0.05	1.47
2016	1.46	0.05	1.33	0.05	1.50
2017	1.27	0.05	1.16	0.05	1.28
2018	0.81	0.05	0.68	0.05	0.85



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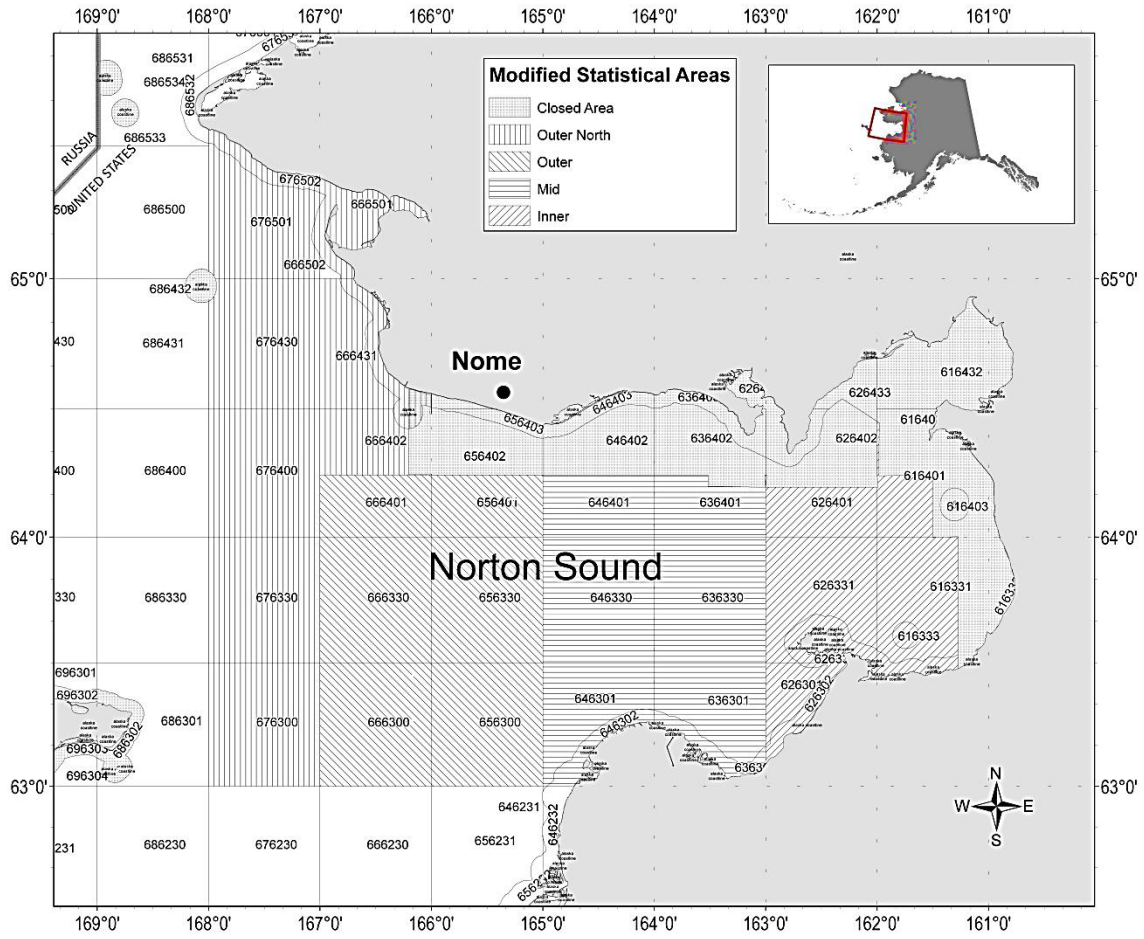


Figure A2-1. Closed area and statistical area boundaries used for reporting commercial harvest information for red king crab in Registration Area Q, Northern District, Norton Sound Section and boundaries of the new *Modified Statistical Areas* used in this analysis.