2011 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Red King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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Executive Summary

*highlighted text will be filled in with new survey and catch data prior to the September 2011 meeting.

1. Stock: Pribilof Islands red king crab, *Paralithodes camtschaticus*
2. Catches: Retained catches have not occurred since 1998/1999. Bycatch and discards have been steady or decreased in recent years to current levels with no bycatch.
3. Stock biomass: Stock biomass in recent years has decreased from 2007 to 2009 and increased slightly in all size classes in 2010.
4. Recruitment: Recruitment indices are not well understood for Pribilof red king crab. Pre-recruit have remained relatively consistent in the past 10 years although may not be well assessed with the survey.
5. Management performance:

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2008/09	1,991 (4.39)	5,016[A] (11.06)	0	0	9.5 (0.021)	1,506 (3.32)	
2009/10	1,914 (4.22)	2,023[B] (4.46)	0	0	2.7 (0.006)	227 (0.50)	
2010/11		2,468[C] (5.44)				349 (0.77)	
2011/12		x[D]					

All units are in t (million lbs) of crabs and the OFL is a total catch OFL for each year. The stock was above MSST in 2009/10 and is hence not overfished. Overfishing did not occur during the 2009/10 fishing year.

Notes:
A – Based on survey data available to the Crab Plan Team in September 2008 and updated with 2008/2009 catches
B – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
C – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/2011 catches
D – Based on survey data available to the Crab Plan Team in September 2011

6. Basis for 2011/2012 OFL projection:

Year	Tier	B_{MSY} t (10^6 lbs)	Current MMB_{mating} t (10^6 lbs)	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality yr^{-1}	P*
2009/10	4b	3,828 (8.44)	2,468 (5.44)	0.64	1.0	1991/1992-2009/2010	0.18	

7. The OFL distribution will be developed approximating the log normal distribution.
8. Basis for the ABC recommendation…..Recommended and maxABC.

9. Rebuilding analyses results summary: not applicable

Summary of Major Changes:
Major changes to this DRAFT 2010 stock assessment include removal of ecosystem chapter.

1. Management: There were no major changes to the 2009/2010 management of the fishery.
2. Input data: The crab fishery retained and discard catch time series was updated with 2009/2010 data.
3. Assessment methodology: There were no changes to assessment methodology. A draft catch and survey model was developed in 2010 and is presented as Appendix A. Assessment methodology for ABC calculations was included.
4. Assessment results: The projected MMB and subsequent OFL increased in this assessment. Total catch in 2009/2010 was 2.72 t.

Responses to SSC and CPT Comments

SSC comments June 2010:

General remarks pertinent to this assessment

none

Specific remarks pertinent to this assessment

The SSC agrees with the CPT recommendations for continued management of Pribilof Islands red king crab under Tier 4, setting γ=1, with M=0.18, and using the 1991 through current time series for estimating the proxy for B_{MSY}. In regards to stock structure (SAFE page 314) the SSC suggests consulting Seeb and Smith (2005) as described on SAFE page 554 (Adak red king crab chapter) which describes stock structure of red king crab in waters off Alaska. As stated in SSC minutes from June of 2009, the SSC looks forward to the presentation of a catch-survey analysis for this stock in October 2010.

Responses to CPT Comments: The CSA model is in development and will be ready for review during the winter 2011. Stock structure text added.

SSC comments October 2010:

General remarks pertinent to this assessment

none

Specific remarks pertinent to this assessment

The OFL method and tier determination were approved by the SSC for this stock in June. The SSC appreciates the concise nature of the stock assessment chapter. Based on the CPT's recommendation, we suggest that the author examine an average of recent survey biomasses when computing the OFL and look forward to a presentation of this in June 2011. The SSC continues to look forward to the implementation of a catch-survey analysis for this stock.

Responses to SSC Comments: Methodology for an average biomass from recent years provided. CSA model development provided in Appendix A.

<u>CPT comments May 2010:</u>
General remarks pertinent to this assessment

none

Specific remarks pertinent to this assessment

- *The 'Total Crab @ survey' column in Table 4 is incorrect and needs to be recalculated.*
- *Equation 3 is the same as equation 1 and needs to be corrected for females.*
- *Reorganize the chapter so that it is in standard format of text, tables, and figures.*
- *All tables on page 1 should be updated for final assessment in September 2010.*

Responses to CPT Comments: All points addressed.

<u>CPT comments September 2010:</u>
General remarks pertinent to this assessment

none

Specific remarks pertinent to this assessment

The CPT recommended that the author base MMB estimates on moving averages when computing OFLs owing the high uncertainty associated with the survey estimates.

Responses to CPT Comments: Methodology for an average biomass from recent years provided.

Introduction

1. **Red king crabs, *Paralithodes camtschaticus*** (Tilesius, 1815)

2. **Distribution** - Red king crabs are anomurans in the family lithodidae and are distributed from the Bering Sea south to the Queen Charlotte Islands and to Japan in the western Pacific (Jensen 1995; Figure 1). Red king crabs have also been introduced and become established in the Barents Sea (Jørstad et al. 2002). The Pribilof Islands red king crab stock is located in the Pribilof District of the Bering Sea Management Area Q. The Pribilof District is defined as Bering Sea waters south of the latitude of Cape Newenham (58° 39' N lat.), west of 168° W long., east of the United States – Russian convention line of 1867 as amended in 1991, north of 54° 36' N lat. between 168° 00' N and 171° 00' W. long and north of 55° 30'N lat. between 171° 00' W. long and the U.S.-Russian boundary (Figure 2).

3. **Stock structure –** The only available stock structure of red king crabs in the North Pacific is based on 1,800 microsatellite DNA samples from red king crabs originating from the Sea of Okhotsk to Southeast Alaska (Seeb and Smith 2005). In the Bering Sea Aleutian Island region, samples from Bristol Bay, Port Moller, and the Pribilof Islands were divergent from the Aleutian Islands and Norton Sound.

4. **Life History** - Red king crabs reproduce annually and mating occurs between hard-shelled males and soft-shelled females. Unlike brachyurans, red king crabs do not have spermathecae and cannot store sperm, therefore a female must mate every year to produce a fertilized clutch of eggs (Powell and Nickerson 1965). A pre-mating embrace is formed 3-7 days prior to female ecdysis, the female molts and copulation occurs within hours. During copulation, the male inverts the female so they are abdomen to abdomen and then the male extends his fifth pair of periopods to deposit sperm on the female's gonopores. After copulation, eggs are fertilized as they are extruded through the gonopores located at the ventral surface of the coxopides of the third periopods. The eggs form a spongelike mass, adhering to the setae on the pleopods where they are brooded until hatching (Powell and Nickerson 1965). Fecundity estimates are not available for Pribilof Islands red king crab, but range from 42,736 to 497,306 for Bristol Bay red king crab (Otto et al. 1990). The estimated size at 50 percent maturity of female Pribilof Islands red king crabs is approximately 102 mm carapace length (CL) which is larger than 89 mm CL reported for Bristol Bay and 71 mm CL for Norton Sound (Otto et al. 1990). Size at maturity has not been determined specifically for Pribilof Islands red king crab males, however approximately 103 mm CL is reported for eastern Bering Sea male red king crabs (Somerton 1980). Early studies predicted that red king crab become mature at approximately age 5 (Powell 1967; Weber 1967); however, Stevens (1990) predicted mean age at recruitment in Bristol Bay to be 7 to 12 years, and Loher et al. (2001) predicted age to recruitment to be approximately 8 to 9 years after settlement. Based upon a long-term laboratory study, longevity of red king crab males is approximately 21 years and less for females (Matsuura and Takeshita 1990).
Natural mortality of Bering Sea red king crab stocks is poorly known (Bell 2006) and estimates vary. Siddeek et al. (2002) reviewed natural mortality estimates from various sources. Natural mortality estimates based upon historical tag-recapture data range from 0.001 to 0.93 for crabs 80-169 mm CL with natural mortality increasing with size. Natural mortality estimates based on more recent tag-recovery data for Bristol Bay red king crab males range from 0.54 to 0.70, however the authors noted that these estimates appear high considering the longevity of red king crab. Natural mortality estimates based on trawl survey data vary from 0.08 to 1.21 for the size range 85-169 mm CL, with higher mortality for crabs <125 mm CL. In an earlier analysis that utilized the same data sets, Zheng et al. (1995) concluded natural mortality is dome shaped over length and varies over time. Natural mortality was set at 0.2 for Bering Sea king crab stocks (NPFMC 1998) and was changed to 0.18 with Amendment 24.

The reproductive cycle of Pribilof Islands red king crabs has not been established, however in Bristol Bay, timing of molting and mating of red king crabs is variable and occurs from the end of January through the end of June (Otto et al. 1990). Primiparous Bristol Bay red king crab females (brooding their first egg clutch) extrude eggs on average 2 months earlier in the reproductive season and brood eggs longer than multiparous (brooding their second or subsequent egg clutch) females (Stevens and Swiney 2007a, Otto et al. 1990) resulting in incubation periods that are approximately eleven to twelve months in duration (Stevens and Swiney 2007a, Shirley et al. 1990). Larval hatching among red king crabs is relatively synchronous among stocks and in Bristol Bay occurs March through June with peak hatching in May and June (Otto et al.

1990), however larvae of primiparous females hatch earlier than multiparous females (Stevens and Swiney 2007b, Shirley and Shirley 1989). As larvae, red king crabs exhibit four zoeal stages and a glaucothoe stage (Marukawa 1933).

Growth parameters have not been examined for Pribilof Islands red king crabs; however they have been studied for eastern Bering Sea red king crab. A review by the Center for Independent Experts (CIE) reported that growth parameters are poorly known for all red king crab stocks (Bell 2006). Growth increments of immature southeastern Bering Sea red king crabs are approximately: 23% at 10 mm CL, 27% at 50 mm CL, 20% at 80 mm CL and 16 mm for immature crabs over 69 mm CL (Weber 1967). Growth of males and females is similar up to approximately 85 mm CL, thereafter females grow more slowly than males (Weber 1967; Loher et al. 2001). In a laboratory study, growth of female red king crabs was reported to vary with age, during their pubertal molt (molt to maturity) females grew on average 18.2%, whereas primiparous females grew 6.3% and multiparous females grew 3.8% (Stevens and Swiney, 2007a). Similarly, based upon tag-recapture data from 1955-1965 researchers observed that adult female growth per molt decreases with increased size (Weber 1974). Adult male growth increment is on average 17.5 mm irrespective of size (Weber 1974).

Molting frequency has been studied for Alaskan red king crabs, but Pribilof Islands specific studies have not been conducted. Powell (1967) reports that the time interval between molts increases from a minimum of approximately three weeks for young juveniles to a maximum of four years for adult males. Molt frequency for juvenile males and females is similar and once mature, females molt annually and males molt annually for a few years and then biennially, triennially and quadrennial (Powell 1967). The periodicity of mature male molting is not well understood and males may not molt synchronously like females who molt prior to mating (Stevens 1990).

5. **Management history** - Red king crab stocks in the Bering Sea and Aleutian Islands are managed by the Sate of Alaska through the federal Fishery Management Plan (FMP) for Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 1998). The Alaska Department of Fish and Game (ADF&G) has not published harvest regulations for the Pribilof district red king crab fishery. The king crab fishery in the Pribilof District began in 1973 with blue king crabs *Paralithodes platypus* being targeted (Figure 3). A red king crab fishery in the Pribilof District opened for the first time in September 1993. Beginning in 1995, combined red and blue king crab GHLs were established. Declines in red and blue king crab abundance from 1996 through 1998 resulted in poor fishery performance during those seasons with annual harvests below the fishery GHL. The North Pacific Fishery Management Council (NPFMC) established the Bering Sea Community Development Quota (CDQ) for Bering Sea fisheries including the Pribilof red and blue king crab fisheries which was implemented in 1998. From 1999 to 2008/2009 the Pribilof fishery was not open due to low blue king crab abundance, uncertainty with estimated red king crab abundance, and concerns for blue king crab bycatch associated with a directed red king crab fishery. Pribilof blue king crab was declared overfished in September of 2002 and is still considered overfished. (see Bowers et al. 2008 for complete management history).

Amendment 21a to the BSAI groundfish FMP established the Pribilof Islands Habitat Conservation Area (Figure 4) which prohibits the use of trawl gear in a specified area around the Pribilof Islands year round (NPFMC 1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from impacts from trawl gear.

Pribilof red king crabs occur as bycatch in the eastern Bering Sea snow crab (*Chionocetes opilio*), eastern Bering Sea Tanner crab (*Chionocetes bairdi*), Bering Sea hair crab (*Erimacrus isenbeckii*), and Pribilof blue king crab fisheries. Many of these fisheries have been closed or recently re-opened so the opportunity to catch Pribilof red king crab is limited. Limited non-directed catch exists in crab fisheries and groundfish pot and hook and line fisheries.

Data

1. The standard survey time series data updated through 2010 and the standard groundfish discards time series data updated through 2010 were used in this assessment. The crab fishery retained and discard catch time series was updated with 2009/2010 data.

2. a. Total catch:
   Crab pot fisheries
   Retained pot fishery catches (live and deadloss landings data) are provided for 1993/1994 to 1998/1999 (Table 1 and 2), the seasons when red king crab were targeted in the Pribilof Islands District. In the 1995/1996 to 1998/1999 seasons red king crab and blue king crab were fished under the same Guideline Harvest Level (GHL). There was no GHL and therefore zero retained catch in the 2009/2010 fishing season.

b. Bycatch and discards:

Crab pot fisheries

Non-retained (directed and non-directed) pot fishery catches are provided for sub-legal males (≤138 mm CL), legal males (>138 mm CL), and females based on data collected by onboard observers. Catch weight was calculated by first determining the mean weight (g) for crabs in each of three categories: legal non-retained, sublegal, and female. The average weight for each category was calculated from length frequency tables where the CL (mm) was converted to g (see equation 1: males: A=0.000361, B=3.16; females: A=0.0102, B=2.38849), multiplied by the number of crabs at that CL, summed, and then divided by the total number of crabs (equation 2).

$$\text{Weight (g)} = A * \text{CL(mm)}^{B} \tag{1}$$

$$\text{Mean Weight (g)} = \sum(\text{weight at size} * \text{number at size}) / \sum(\text{crabs}) \tag{2}$$

Finally, weights were the product of average weight, CPUE, and total pot lifts in the fishery. To assess crab mortalities in these pot fisheries a 50% handling mortality rate is applied to these estimates.

Historical non-retained catch data are available from 1998/1999 to present from the snow crab, golden king crab (*Lithodes aequispina*), and Tanner crab fisheries (Table 3) although data may be incomplete for some of these fisheries. Prior to 1998 limited observer data exists for catcher-processor vessels only so non-retained catch before this date is not included here.

In 2009/2010, there were no legal males incidentally caught in the crab fisheries (Table 3).

Groundfish pot, trawl, and hook and line fisheries

The 2009/2010 NOAA Fisheries Regional Office (J. Mondragon, NMFS, personal communication) assessments of non-retained catch from all groundfish fisheries are included in this SAFE report. Groundfish catches of crab are reported for all crab combined by federal reporting areas. Catches from observed fisheries were applied to non-observed fisheries to estimate a total catch. Catch counts were converted to biomass by applying the average weight measured from observed tows from July 2009 to June 2010. For Pribilof Islands red king crab, Areas 513 and 521 are included. It is noted that due to the extent of Area 513 into the Bristol Bay District, groundfish non-retained crab catches for Pribilof Islands red king crab may be overestimated. Current efforts are underway to provide data on a more fine spatial scale to correct this error. To estimate sex ratios for 2010 catches, sex ratios by size and sex from the 2010 EBS bottom trawl survey were applied. To assess crab mortalities in these groundfish fisheries a 50% handling mortality rate was applied to pot and hook and line estimates and an 80% handling mortality rate was applied to trawl estimates.

Historical non-retained groundfish catch data are available from 1991/1992 to present (J. Mondragon, NMFS, personal communication) although sex ratios have not been discriminated by each year's survey proportions (Table 3).

In 2009/2010, 3.63 t of male and female red king crab were caught in groundfish fisheries which is less than half the estimate of non-retained crab catch in 2008/2009 pot, trawl, and hook and line groundfish fisheries. The catch was mostly in non-pelagic trawls (82%) followed by longline (9%), and pot (8%) fisheries. The targeted species in these fisheries were Pacific cod (30%), pelagic pollock (21%), flathead sole (12%), yellowfin sole (12%), bottom pollock (12%) rock sole (3%), and Greenland turbot (3%).

c. Catch-at-length: NA

d. Survey biomass:
The 2010 NOAA Fisheries EBS bottom trawl survey results (Chilton et al. in press) are included in this SAFE report. Abundance estimates of male and female crab are assessed for 5 mm length bins and for total abundances for each EBS stock (Figure 5). Weight (equation 1) and maturity (equation 3) schedules are applied to these abundances and summed to calculate mature male, female, and legal male biomass.

$$\text{Proportion mature male} = 1/(1 + (5.842 * 10^{14}) * e^{((CL(mm)+2.5) * -0.288)}$$
$$\text{Proportion mature female} = 1/(1 + (1.416 * 10^{13}) * e^{((CL(mm)+2.5) * -0.297)} \quad (3)$$

Historical survey data are available from 1980 to the present when survey and data analyses were standardized (Table 4, Figure 6).

Red king crab were caught at 13 of the 41 stations in the Pribilof District high-density sampling area in 2010 (Chilton et al. in press, Figure 7). The density of legal-sized males caught at a station ranged from 66 to 1,854 crab/nmi^2. Legal-sized male red king crab were caught at 11 stations in the Pribilof District high-density sampling area representing 92% of the total male abundance but below the average from the previous 20 years (Figure 8). The majority of the legal-sized males were distributed south and west of St. Paul Island at stations G-21 and GH-2122. Mature males were encountered at 11 of the 41 stations. Mature males were distributed ubiquitously around St. Paul Island in the nearshore shallow water stations. The 2010 size-frequency for red king crab males shows a decrease in the number of oldshell and very oldshell legal-sized males in comparison to the 2008 shell conditions but an increase when compared to 2009. In 2010, one legal-sized male was in softshell condition and caught east of St. Paul Island at depths less than 50 m while 54% of the legal-sized males were evaluated as new hardshell crabs and distributed north and south of St. Paul Island. Forty-five percent of the legal-sized males were in oldshell and very oldshell condition and primarily distributed east of St. Paul Island. The 2010 biomass estimate of mature-sized red king crab females was 467 t, representing 100% of the total female biomass as no immature females were caught on the 2010 survey. None of the mature females were carrying eyed embryos with 85% of the mature females brooding uneyed embryos and 15% were barren or had empty egg cases. The majority of mature females with uneyed embryos were in the130 mm CL to 140 mm CL size class.

Analytic Approach

1. **History of modeling approaches**
2. A catch survey analysis has been used for assessing the stock in the past and has been further developed in Appendix A.

Calculation of the OFL

1. Based on available data, the authors, the Crab Plan Team, and the Science and Statistical Committee all recommend that this stock should be classified as a Tier 4 stock for stock status level determination defined by Amendment 24 to the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 2008).

2. In Tier 4, Maximum Sustainable Yield is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological, and environmental conditions. In Tier 4, the fishing mortality that, if applied over the long-term, would result in MSY is approximated by F_{MSY}^{proxy}. The MSY stock size (B_{MSY}) is based on mature male biomass at mating (MMB_{mating}) which serves as an approximation for egg production. MMB_{mating} is used as a basis for B_{MSY} because of the complicated female crab life history, unknown sex ratios, and male only fishery. The B_{MSY}^{proxy} represents the equilibrium stock biomass that provides maximum sustainable yield (MSY) to a fishery exploited at F_{MSY}^{proxy}.. B_{MSY} can be estimated as the average biomass over a specified period that satisfies these conditions (i.e., equilibrium biomass yielding MSY by an applied F_{MSY}). This is also considered a percentage of pristine biomass (B_0) of the unfished or lightly exploited stock. The current stock biomass reference point for status of stock determination is MMB_{mating}.

   The mature stock biomass ratio β where $B/B_{MSY}^{prox} = 0.25$ represents the critical biomass threshold below which directed fishing mortality is set to zero (Figure 9). The parameter α determines the slope of the non-constant portion of the control rule line and was set to 0.1. Values for α and β where based on sensitivity analysis effects on B/B_{MSY}^{prox} (NPFMC 2008). The F_{OFL} derivation where B is greater than β includes the product of a scalar (**γ**) and M (equations 5 and 6) where the default **γ** value is 1 and M for Bering Sea red king crab is 0.18. The value of **γ** may alternatively be calculated as F_{MSY}/M depending on the availability of data for the stock.

   Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, the F_{OFL} control rule resulting in a total catch greater than the OFL. For Tier 4 stocks, a minimum stock size threshold (MSST) is specified as 0.5 B_{MSY}^{prox}; if current MMB at the time of mating drops below MSST, the stock is considered to be overfished.

3. OFL specification:
   a. In the Tier 4 OFL-setting approach, the "total catch OFL" and the "retained catch OFL" are calculated by applying the F_{OFL} to all crab at the time of the fishery (total catch OFL) or to the mean retained catch determined for a specified period of time (retained

catch OFL). The F_{OFL} is derived using a Maximum Fishing Mortality Threshold (MFMT) or F_{OFL} Control Rule (Figure 8) where Stock Status Level (level a, b or c; equations 4-6) is based on the relationship of current mature stock biomass (B) to B_{MSY}^{proxy}.

Stock Status Level:	F_{OFL}:	
a. $B/B_{MSY}^{prox} > 1.0$	$F_{OFL} = \gamma \cdot M$	(4)
b. $\beta < B/B_{MSY}^{prox} \leq 1.0$	$F_{OFL} = \gamma \cdot M\,[(B/B_{MSY}^{prox} - \alpha)/(1 - \alpha)]$	(5)
c. $B/B_{MSY}^{prox} \leq \beta$	$F_{directed} = 0;\ F_{OFL} \leq F_{MSY}$	(6)

B_{MSY}^{prox} for the 2010 assessment was calculated as the average MMB_{mating} from 1991 to current based on the observation that red king crab were relatively uncommon in the area prior to 1991.

b. The MMB_{Mating} projection is based on application of M from the 2010 NMFS trawl survey (July 15) to mating (February 15) and the removal of estimated retained, bycatch, and discarded catch mortality (equation 7). Catch mortalities are estimated from the proportion of catch mortalities in 2009/2010 to the 2010 survey biomass.

$$MMB_{Survey} \cdot e^{-PM(sm)} - \text{(projected legal male catch OFL)-(projected non-retained catch)} \qquad (7)$$

where, MMB_{Survey} is the mature male biomass at the time of the survey, $e^{-PM(sm)}$ is the survival rate from the survey to mating. PM(sm) is the partial M from the time of the survey to mating (8 months).

c. To project a total catch OFL for the upcoming crab fishing season, the F_{OFL} is estimated by an iterative solution that maximizes the projected F_{OFL} and projected catch based on the relationship of B to B_{MSY}^{prox}. B is approximated by MMB at mating (equation 7).

For a total catch OFL, the annual fishing mortality rate (F_{OFL}) is applied to the total crab biomass at the fishery (equation 8).

$$\text{Projected Total Catch OFL} = [1 - e^{-Fofl}] \cdot \text{Total Crab Biomass}_{Fishery} \qquad (8)$$

where $[1 - e^{-Fofl}]$ is the annual fishing mortality rate.

Exploitation rates on legal male biomass (μ_{LMB}) and mature male biomass (μ_{MMB}) at the time of the fishery are calculated as:

$$\mu_{LMB} = \text{[Total LMB retained and non-retained catch]} / LMB_{Fishery} \qquad (9)$$

$$\mu_{MMB} = [\text{Total MMB retained and non-retained catch}] / MMB_{Fishery} \quad (10)$$

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2008/09	1,991	5,016[A]	0	0	9.5	1,506	
2009/10	1,914	2,023[B]	0	0	2.7	227	
2010/11		2,468[C]				349	
2011/12		x[D]					

All units are in t (million lbs) of crabs and the OFL is a total catch OFL for each year. The stock was above MSST in 2009/10 and is hence not overfished. Overfishing did not occur during the 2009/10 fishing year.

Notes:
A – Based on survey data available to the Crab Plan Team in September 2008 and updated with 2008/2009 catches
B – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
C – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/2011 catches
D – Based on survey data available to the Crab Plan Team in September 2011

4. Recommendations:
   For 2010/2011 B_{MSY}^{prox}=3,828 t of MMB_{mating} derived as the mean of 1991/1992 to 2009/2010 and is recommended by the authors, CPT and SSC. The stock demonstrated highly variable levels of MMB_{mating} during these periods likely leading to uncertain approximations of B_{MSY}. Crabs were highly concentrated during the EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to a limited number of tows with crab catches.

   Male mature biomass at the time of mating for 2010/2011 is estimated at 2,468 t for B_{MSY}^{prox}. The B/B_{MSY}^{prox} =0.64 and F_{OFL}=0.11. The biomass reference option B/B_{MSY}^{prox} is < 1, therefore the stock status level is b (equation 5). For the 2009/2010 fishery, total catch OFL was estimated at 349 t of crab and legal male catch OFL was estimated at 281 t of crab. The projected exploitation rates based on full retained catches up to the OFL for LMB and $MMB_{fishery}$ are 0.12 and 0.11 respectively.

   Red king crabs in the Pribilof Islands have been historically harvested with blue king crabs and are currently the dominant of the two species in this area. There are concerns as to the low reliability of survey biomass estimates, and the high levels of blue king crab incidental catch mortality that would occur in a directed Pribilof Islands red king crab fishery.

Calculation of the ABC

1. Specification of the probability distribution of the OFL used in the ABC: A distribution for the OFL which quantifies uncertainty will be constructed using bootstrapping methods approximating the lognormal distribution. This involves generating values for *M* and annual MMB_{mating} (e.g. by assuming that MMB is log-normally distributed and *M* is normally distributed) and for each simulation calculating the OFL using the standard methods in section 3 of the OFL Specification section above. The OFL distribution for Pribilof Island red king crab is skewed to the right due to the patchy spatial distribution and small abundance which affects the variability of density estimates among trawl

survey stations. This lognormal distribution suggests that use of the mean value (as opposed to the median) of the distribution would be appropriate as it changes with greater variability.

2. List of variables related to scientific uncertainty considered in the OFL probability distribution: Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands red king crab is high due to insufficient data and the small distribution of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass for the most recent year is 0.637 and has ranged between 0.357 and 0.786 since the 1995 peak in biomass. The coefficient of variation for the estimate of mature male biomass for the most recent year from the stock assessment used for the projections is 0.180.

3. List of additional uncertainties considered for alternative σ_b applications to the ABC. Several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:
   - Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.
   - F_{msy} is assumed to be equal to γM when applying the OFL control rule while γ is assumed to be equal to 1 and M is assumed to be known.
   - The model on which the projections are based is still in development and has yet to be reviewed by the CPT.
   - The coefficients of variation for the survey estimates of abundance for this stock are very high.
   - B_{msy} is assumed to be equivalent to average mature male biomass between 1991 and 2008. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1981-1988 and 1993-1999, so considerable uncertainty exists with this estimate of B_{msy}.

   Additional uncertainty will be included in the application of the ABC by adding the uncertainty components as $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$. Given the relative amount of information available for Pribilof Island's red king crab, the author recommended ABC includes an additional σ_b of 0.4.

4. Author recommended ABC and if less than maxABC provide rationale for establishing less than maximum permissible: The maxABC and the author recommended ABC will be provided here.

Average Biomass

Taking an average biomass across previous years to calculate the MMB in the most recent year was considered to reduce the effect of high uncertainty in the survey based area swept estimates (Figure 10). A range of years from 2 to 7 resulted in mean MMB over the time series from 2,724 to 2,773 t (Table 5). Using an average biomass of 5 to 7 years resulted in the highest deviations from 162 to 365 t and dampened the distribution so that biomass peaks were skewed from the observed values. The 3 year average appears to balance the deviations between the observed and averaged while reducing the annual variation in the MMB and is recommended as a new method for calculating MMB each year.

Literature Cited

ADFG. 1998. Annual management report for the shellfish fisheries of the westward region, 1997. Alaska Department of Fish and Game, Regional Information Report. 4K98-39, 308 p.

Barnard, D.R. and R. Burt. 2007. Alaska Department of Fish and Game summary of the 2005/2006 mandatory shellfish observer program database for the rationalized crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 07-02, Anchorage.

Barnard, D.R. and R. Burt. 2008. Alaska Department of Fish and Game summary of the 2006/2007 mandatory shellfish observer program database for the rationalized crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 08-17, Anchorage.

Bell, M. C. 2006. Review of Alaska crab overfishing definitions: Report to University of Miami Independent System for peer reviews. April 24-28, 2006 Seattle, Washington, 35 p.

Bowers, F. R., M. Schwenzfeier, S. Coleman, B. J. Failor-Rounds, K. Milani, K. Herring, M. Salmon, and M. Albert. 2008. Annual management report for the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfish Observer Program, 2006/07. Alaska Department of Fish and Game, Fishery Management Report. No. 08-02, 230 p.

Boyle, L, and M. Schwenzfeier. 2002. Alaska's mandatory shellfish observer program, 1988-2000, p. 693-704. *In* A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley and D. Woodby (editors), Crabs in cold water regions: biology, management, and economics. Alaska Sea Grant College Program, Report No. AK-SG-02-01, University of Alaska, Fairbanks, AK.

Bright, D. B. 1967. Life histories of the king crab, *Paralithodes camtschatica*, and the "Tanner" crab, *Chionoecetes bairdi*, in Cook Inlet, Alaska. Ph.D. Thesis, University of Southern California.

Chilton, E.A., C.E. Armistead, R.J. Foy, and L. Rugolo. In press. The 2010 Eastern Bering Sea Continental Shelf Bottom Trawl Survey: Results for Commercial Crab Species. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-XXX, 195 p.

Feder, H.M., and S.C. Jewett. 1981. Feeding interactions in the eastern Bering Sea with emphasis on the benthos, p. 1229-1261 *In* D.W. Hood and J.A. Calder (editors.), The eastern Bering Sea shelf: oceanography and resources. Vol. 2. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Office of Marine Pollution and Assessment.

Gish, R. K. 2006. The 2005 Pribilof District king crab survey. Alaska Department of Fish and Game, Fishery Management Report. No. 06-60, 49 p.

Haflinger, K. 1981. A survey of benthic infaunal communities of the Southeastern Bering Sea shelf, p. 1091-1104. *In* Hood and Calder (editors), The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 2. Office Mar. Pol. Assess., NOAA. University of Washington Wash. Press, Seattle, WA.

Ianelli, J.N.S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2007. Chapter 1: Eastern Bering Sea walleye Pollock. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, North Pacific Fishery Management Council, Anchorage, p. 41-138.

Jensen, G.C. 1995. Pacific Coast Crabs and Shrimps. Sea Challengers, Monterey, California, 87p.

Jewett, S.C., and C.P. Onuf. 1988. Habitat suitability index models: red king crab. Biological Report, 82(10.153), U.S. Fish and Wildlife Service, 34 p.

Jørstad, K.E., E. Farestveit, H. Rudra, A-L. Agnalt, and S. Olsen. 2002. Studies on red king crab (*Paralithodes camtschaticus*) introduced to the Barents Sea, p. 425-438. *In* A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley and D. Woodby (editors), Crabs in cold water regions: biology, management, and economics. Alaska Sea Grant College Program Report No. AK-SG-02-01, University of Alaska, Fairbanks, AK.

Lang, G.M., P.A. Livingston, and K.A. Dodd. 2005. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1997 through 2001. United States Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-158, 230 p.

Livingston, P. A., A. Ward, G. M. Lang, and M.S. Yang. 1993. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1987 to 1989. United States Department of Commerce, NOAA Technical Memorandum. NMFD-AFSC-11, 192 p.

Livingston, P.A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the Eastern Bering Sea. Fishery Bulletin 87:807-827.

Loher, T. and D.A. Armstrong. 2005. Historical changes in the abundance and distribution of ovigerous red king crabs (*Paralithodes camtschaticus*) in Bristol Bay (Alaska), and potential relationship with bottom temperature. Fisheries Oceanography 14:292-306.

Loher, T., D.A. Armstrong, and B. G. Stevens. 2001. Growth of juvenile red king crab (*Paralithodes camtschaticus*) in Bristol Bay (Alaska) elucidated from field sampling and analysis of trawl-survey data. Fishery Bulletin 99:572-587.

Lovvorn, J.R., L.W. Cooper, M.L. Brooks, C.C. De Ruyck, J.K. Bump, and J.M. Grebmeier. 2005. Organic matter pathways to zooplankton and benthos under pack ice in late winter and open water in late summer in the north-central Bering Sea. Marine Ecology Progress Series 291:135-150.

Marukawa, H. 1933. Biological and fishery research on Japanese king crab *Paralithodes camtschatica* (Tilesius). Fish. Exp. Stn, Tokyo 4:1-152.

Matsuura, S. and Takeshita, K. 1990. Longevity of red king crab, *Paralithodes camtschatica*, revealed by long-term rearing study, p. 65-90. *In* B. Melteff (editor) International Symposium on King and Tanner crabs. Alaska Sea Grant College Program Report No. 90-04, University of Alaska Fairbanks, AK.

McLaughlin, P. A. and J. F. Herberd. 1961. Stomach contents of the Bering Sea king crab. International North Pacific Commission, Bulletin 5:5-8.

NMFS. 2000. Endangered Species Act Section 7 Consultation – Biological Assessment: Crab fisheries authorized under the Fishery Management Plan for Bering Sea/Aleutian Islands king and Tanner crabs. National Marine Fisheries Service, Alaska Region, 14 p.

NMFS. 2002. Endangered Species Act Section 7 Consultation – Biological Assessment: Crab fisheries authorized under the Fishery Management Plan for Bering Sea/Aleutian Islands king and Tanner crabs. National Marine Fisheries Service, Alaska Region, 59 p.

NMFS. 2004. Final Environmental Impact Statement for Bering Sea and Aleutian Islands Crab Fisheries. National Marine Fisheries Service, Alaska Region

NPFMC (North Pacific Fishery Management Council). 1994. Environmental Assessment/Regulatory Impact/Review/Initial Regulatory Flexibility analysis for

Amendment 21a to the Fishery Management Plan for Bering Sea and Aleutian Islands Groundfish. Anchorage, Alaska.
NPFMC (North Pacific Fishery Management Council). 1998. Fishery Management Plan for the Bering Sea/Aleutian Islands king and Tanner crabs. Anchorage, Alaska 105 p.
NPFMC (North Pacific Fishery Management Council). 2003. Environmental Assessment for Amendment 17 to the Fishery Management Plan for the king and Tanner crab fisheries in the Bering Sea/Aleutian Islands: A rebuilding plan for the Pribilof Islands blue king crab stock. Anchorage, Alaska 87 p.
NPFMC (North Pacific Fishery Management Council). 2008. Environmental Assessment for Amendment 24 to the Fishery Management Plan for the king and Tanner crab fisheries in the Bering Sea/Aleutian Islands: to revise overfishing definitions. Anchorage, Alaska 194 p.
Ormseth, O. and B. Matta. 2007. Chapter 17: Bering Sea and Aleutian Islands Skates. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, North Pacific Fishery Management Council, Anchorage 909-1010 p.
Otto R.S., R.A. MacIntosh, and P.A. Cummiskey. 1990. Fecundity and other reproductive parameters of female red king crab (*Paralithodes camtschatica*) in Bristol Bay and Norton Sound, Alaska, p. 65-90 *In* B. Melteff (editor) Proceedings of the International Symposium on King and Tanner crabs. Alaska Sea Grant College Program Report No. 90-04, University of Alaska Fairbanks, AK.
Overland, J.E. and P.J. Stabeno. 2004. Is the climate of the Bering Sea warming and affecting the ecosystem? EOS 85:309-316.
Powell G.C. and R.B. Nickerson. 1965. Reproduction of king crabs, *Paralithodes camtschatica* (Tilesius). Journal of Fisheries Research Board of Canada 22:101-111.
Powell, G.C. 1967. Growth of king crabs in the vicinity of Kodiak Island, Alaska. Informational Leaflet 92, Alaska Department of Fish and Game, 58 p.
Schumacher, J.D., N.A. Bond, R.D. Brodeur, P.A. Livingston, J.M. Napp, and P.J. Stabeno. 2003. Climate change in the southeastern Bering Sea and some consequences for biota, p. 17-40. *In* G. Hempel and K. Sherman (editors.) Large Marine Ecosystems of the World-Trends in Exploitation, Protection and Research. Elsevier Science, Amsterdam.
Shirley, S. M. and T. C. Shirley. 1989. Interannual variability in density, timing and survival of Alaskan red king crab *Paralithodes camtschatica* larvae. Marine Ecology Progress Series 54:51-59.
Shirley, T. C., S. M. Shirley, and S. Korn. 1990. Incubation period, molting and growth of female red king crabs: effects of temperature, p. 51-63. *In* B. Melteff (editor) Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant College Program Report No. 90-04, University of Alaska Fairbanks, AK.
Siddeek, M.S.M, L. J. Watson, S. F. Blau, and H. Moore. 2002. Estimating natural mortality of king crabs from tag recapture data, p. 51-75. *In* A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley and D. Woodby (editors), Crabs in cold water regions: biology, management, and economics. Alaska Sea Grant College Program Report No. AK-SG-02-01, University of Alaska, Fairbanks, AK.
Somerton, D. A. 1980. A computer technique for estimating the size of sexual maturity in crabs. Canadian Journal of Fisheries and Aquatic Science 37: 1488-1494.

Sparks, A.K. and J.F. Morado. 1985. A preliminary report on the diseases of Alaska king crabs, p. 333-339. *In* B.R. Melteff (editor), Proceedings of the International King Crab Symposium. Alaska Sea Grant College Program Report No. 85-12, University of Alaska, Anchorage, AK.

Sparks, A.K. and J.F. Morado. 1997. Some diseases of northeastern Pacific commercial crabs. Journal of Shellfish Research 16:321.

Stevens, B.B. 1990. Temperature-dependent growth of juvenile red king crab (*Paralithodes camtschatica*), and its effects on size-at-age and subsequent recruitment in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences 47:1307-1317.

Stevens, B.G. and K. M. Swiney. 2007b. Growth of female red king crabs *Paralithodes camtshaticus* during pubertal, primiparous, and multiparous molts. Alaska Fisheries Research Bulletin 12:263-270.

Stevens, B.G. and K.M. Swiney. 2007a. Hatch timing, incubation period, and reproductive cycle for primiparous and multiparous red king crab *Paralithodes camtschaticus*. Journal of Crustacean Biology 27:37-48.

Thompson, G. J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007. Chapter 2: Assessment of the Pacific cod stock in the eastern Bering Sea and Aleutian Islands Area. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, North Pacific Fishery Management Council, Anchorage, 209-328 p.

Tyler, A.V. and G.H. Kruse. 1996. Conceptual modeling of brood strength of red king crabs in the Bristol Bay region of the Bering Sea, p. 511-543. *In* High Latitude Crabs: Biology, Management, and Economics. Alaska Sea Grant College Program Report No. 96-02, University of Alaska, Fairbanks, AK.

Wang, M., C. Ladd, J. Overland, P. Stabeno, N. Bond, and S. Salo. Eastern Bering Sea Climate-FOCI. 2008, p. 106-113. *In* J. Boldt (editor) Appendix C: Ecosystem Considerations for 2008. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, North Pacific Fishery Management Council, Anchorage, AK.

Weber, D. D. 1967. Growth of the immature king crab Paralithodes camtschatica (Tilesius). Bulletin No. 21, North Pacific Commission, 53 p.

Weber, D.D. 1974. Observations on growth of southeastern Bering Sea king crab, *Paralithodes camtschatica*, from a tag-recovery study, 1955-65. Data Report 86, National Marine Fisheries Service, 122 p.

Wilderbuer, T.K. D.G. Nichol and J. Ianelli. Chapter 4: Yellowfin sole. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, North Pacific Fishery Management Council, Anchorage 447-512 p.

Zheng, J. and G. H. Kruse. 2000. Recruitment patterns of Alaskan crabs in relation to decadal shifts in climate and physical oceanography. ICES Journal of Marine Science 57:438-451.

Zheng, J. M.C. Murphy, and G.H. Kruse. 1995. A length-based population model and stock-recruitment relationships for red king crab, *Paralithodes camtschaticus*, in Bristol Bay, Alaska. Canadian Journal of Fisheries and Aquatic Science 52:1229-1246.

Table 1. Total retained catches from directed fisheries for Pribilof Islands District red king crab (Bowers et al. 2008; D. Pengilly, ADF&G, personal communications).

Year	Catch (count)	Catch (10^6)	CPUE (legal crab count/pot)
1973/1974	0	0	0
1974/1975	0	0	0
1975/1976	0	0	0
1976/1977	0	0	0
1977/1978	0	0	0
1978/1979	0	0	0
1979/1980	0	0	0
1980/1981	0	0	0
1981/1982	0	0	0
1982/1983	0	0	0
1983/1984	0	0	0
1984/1985	0	0	0
1985/1986	0	0	0
1986/1987	0	0	0
1987/1988	0	0	0
1988/1989	0	0	0
1989/1990	0	0	0
1990/1991	0	0	0
1991/1992	0	0	0
1992/1993	0	0	0
1993/1994	380,286	2.608	11
1994/1995	167,520	1.339	6
1995/1996	110,834	0.898	3
1996/1997	25,383	0.200	<1
1997/1998	90,641	0.757	3
1998/1999	68,129	0.544	3
1999/2000	0	0	0
2000/2001	0	0	0
2001/2002	0	0	0
2002/2003	0	0	0
2003/2004	0	0	0
2004/2005	0	0	0
2005/2006	0	0	0
2006/2007	0	0	0
2007/2008	0	0	0
2008/2009	0	0	0
2009/2010	0	0	0

Table 2. Fishing effort during Pribilof Islands District commercial red king crab fisheries, 1993-2007/08 (Bowers et al. 2008)

Season	Number of Vessels	Number of Landings	Number of Pots Registered	Number of Pots Pulled
1993	112	135	4,860	35,942
1994	104	121	4,675	28,976
1995	117	151	5,400[a]	34,885
1996	66	90	2,730[a]	29,411
1997	53	110	2,230[a]	28,458
1998	57	57	2,398[a]	23,381
1999-2009/10	Fishery Closed			

Table 3. Non-retained total catch mortalities from directed and non-directed fisheries for Pribilof Islands District red king crab. Handling mortalities (pot and hook/line= 0.5, trawl = 0.8) were applied to the catches. (Bowers et al. 2008; D. Pengilly, ADF&G; J. Mondragon, NMFS).

	Crab pot fisheries			Groundfish fisheries	
Year	Legal male (t)	Sublegal male (t)	Female (t)	All fixed (t)	All trawl (t)
1991/1992	0.00	0.00	0.00	0.45	45.81
1992/1993	0.00	0.00	0.00	16.33	175.99
1993/1994	0.00	0.00	0.00	0.45	132.00
1994/1995	0.00	0.00	0.00	0.45	15.42
1995/1996	0.00	0.00	0.00	4.99	6.35
1996/1997	0.00	0.00	0.00	1.81	2.27
1997/1998	0.00	0.00	0.00	4.54	7.71
1998/1999	0.00	0.91	11.34	10.43	6.80
1999/2000	1.36	0.00	8.16	12.25	3.18
2000/2001	0.00	0.00	0.00	2.27	4.54
2001/2002	0.00	0.00	0.00	2.72	6.80
2002/2003	0.00	0.00	0.00	0.45	9.07
2003/2004	0.00	0.00	0.00	0.91	9.98
2004/2005	0.00	0.00	0.00	3.18	3.63
2005/2006	0.00	0.18	1.81	4.54	24.49
2006/2007	1.36	0.14	0.91	6.80	21.32
2007/2008	0.91	0.05	0.09	1.81	2.72
2008/2009	0.09	0.00	0.00	1.81	6.80
2009/2010	0.00	0.00	0.00	0.45	2.27

Table 4. Pribilof Islands District red king crab abundance, mature biomass, and legal male biomass (t), and totals estimated based on the NMFS annual EBS bottom trawl survey.

Year	Mature	Mature	Legal	Total	Total

	males @ survey t	males @ mating t	Males @ survey t	males @ survey t	females @ survey t
1980/1981	2640	1764	2640		
1981/1982	2640	2127	2640		
1982/1983	1352	1175	1352		
1983/1984	349	308	318		
1984/1985	367	327	304		
1985/1986	100	86	100		
1986/1987	122	109	122		
1987/1988	41	36	41		
1988/1989	127	113	36		
1989/1990	1411	1252	803		
1990/1991	1089	966	59		
1991/1992	3679	3239	1111		
1992/1993	3089	2640	2368		
1993/1994	7638	5525	7130		
1994/1995	7412	5956	6559		
1995/1996	3860	3007	3470		
1996/1997	2009	1687	1982		
1997/1998	5262	4314	4881		
1998/1999	2300	1783	1719		
1999/2000	9	0	9		
2000/2001	3960	3506	3520		
2001/2002	7911	7008	5221		
2002/2003	6749	5983	6731		
2003/2004	5012	4436	4921		
2004/2005	3878	3438	3878		
2005/2006	1352	1179	1338		
2006/2007	7099	6278	6790		
2007/2008	7521	6663	7248	7716	2717
2008/2009	5665	5017	5280	6241	3452
2009/2010	2463	2023	2114	2522	553
2010/2011	3107	2468	2880	3139	467

Table 5. Mean, standard deviation (SD) and deviations for alternative average year options for calculating MMB in the most recent year.

	0yr	2yr	3yr	4yr	5yr	7yr
Mean (t)	2724	2744	2766	2773	2766	2770
SD	2224	2023	1857	1740	1646	1496
Mean deviation		12	11	62	162	365
SD deviation		1001	1497	1722	1802	1861
Mean Absolute Deviation		747	1189	1382	1477	1485

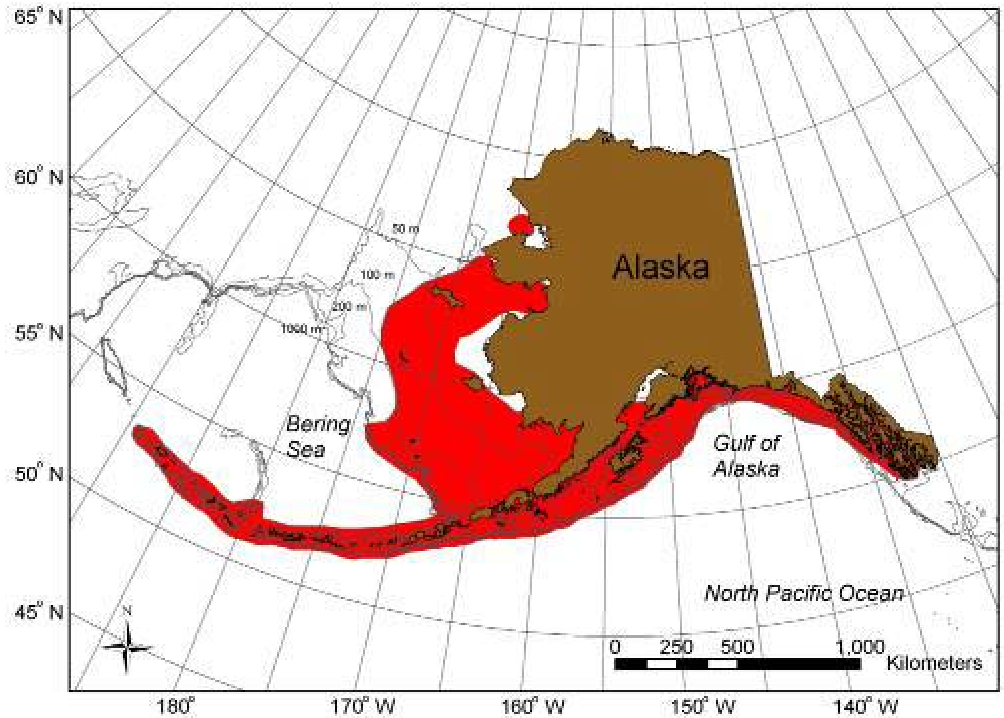

Figure 1. Red king crab distribution.

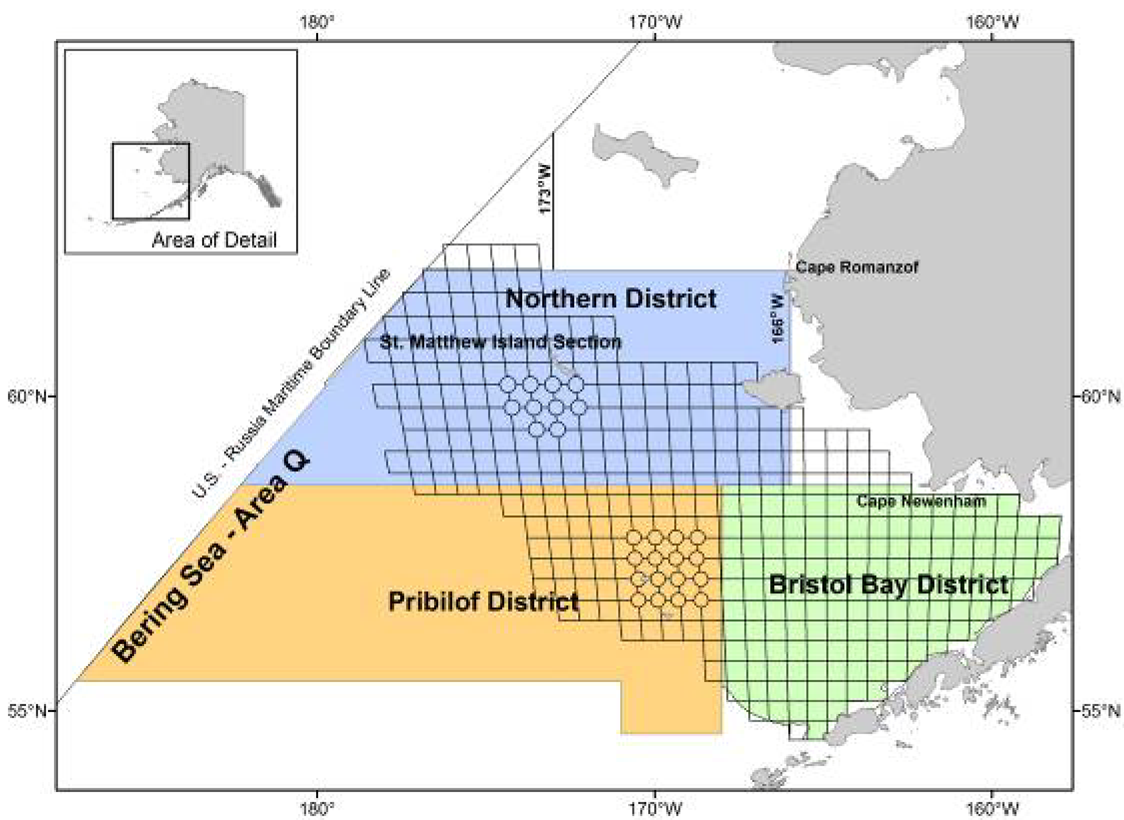

Figure 2. King crab Registration Area Q (Bering Sea) showing the Pribilof District.

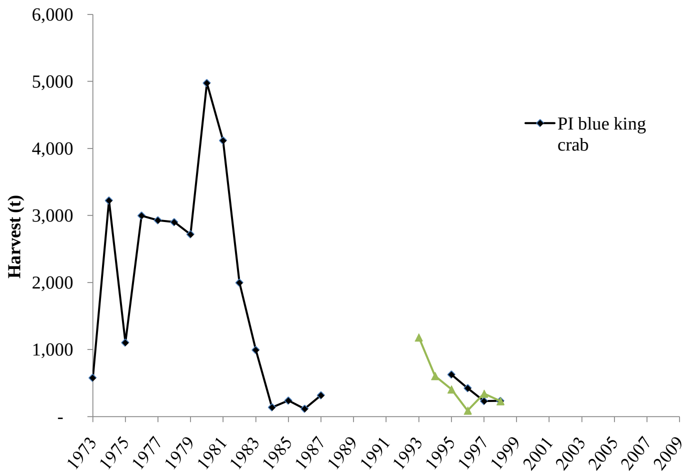

Figure 3. Historical harvests and GHLs for Pribilof Island red king crab (Bowers et al. 2007).

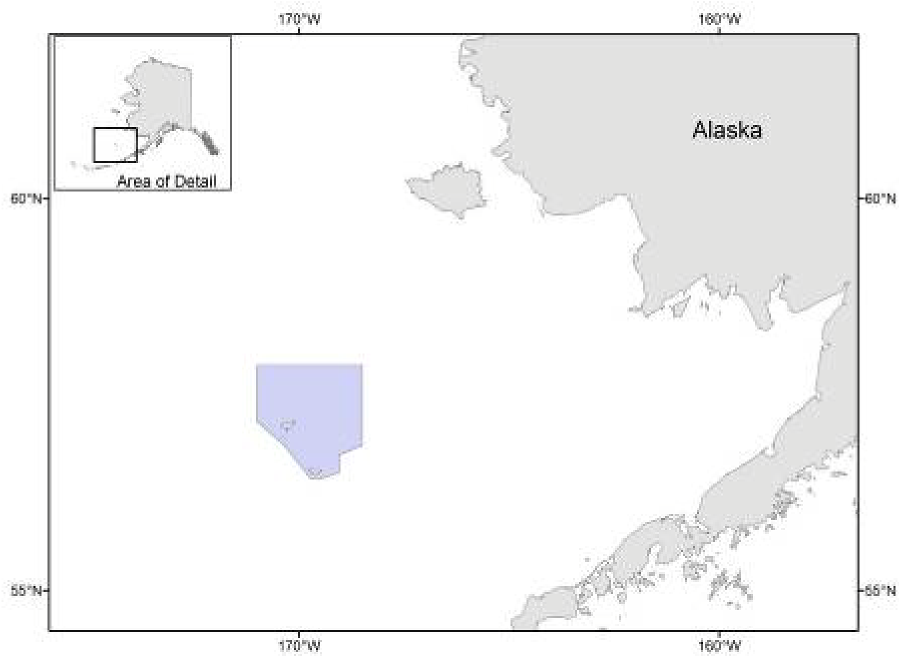

Figure 4. The shaded area shows the Pribilof Islands Habitat Conservation area

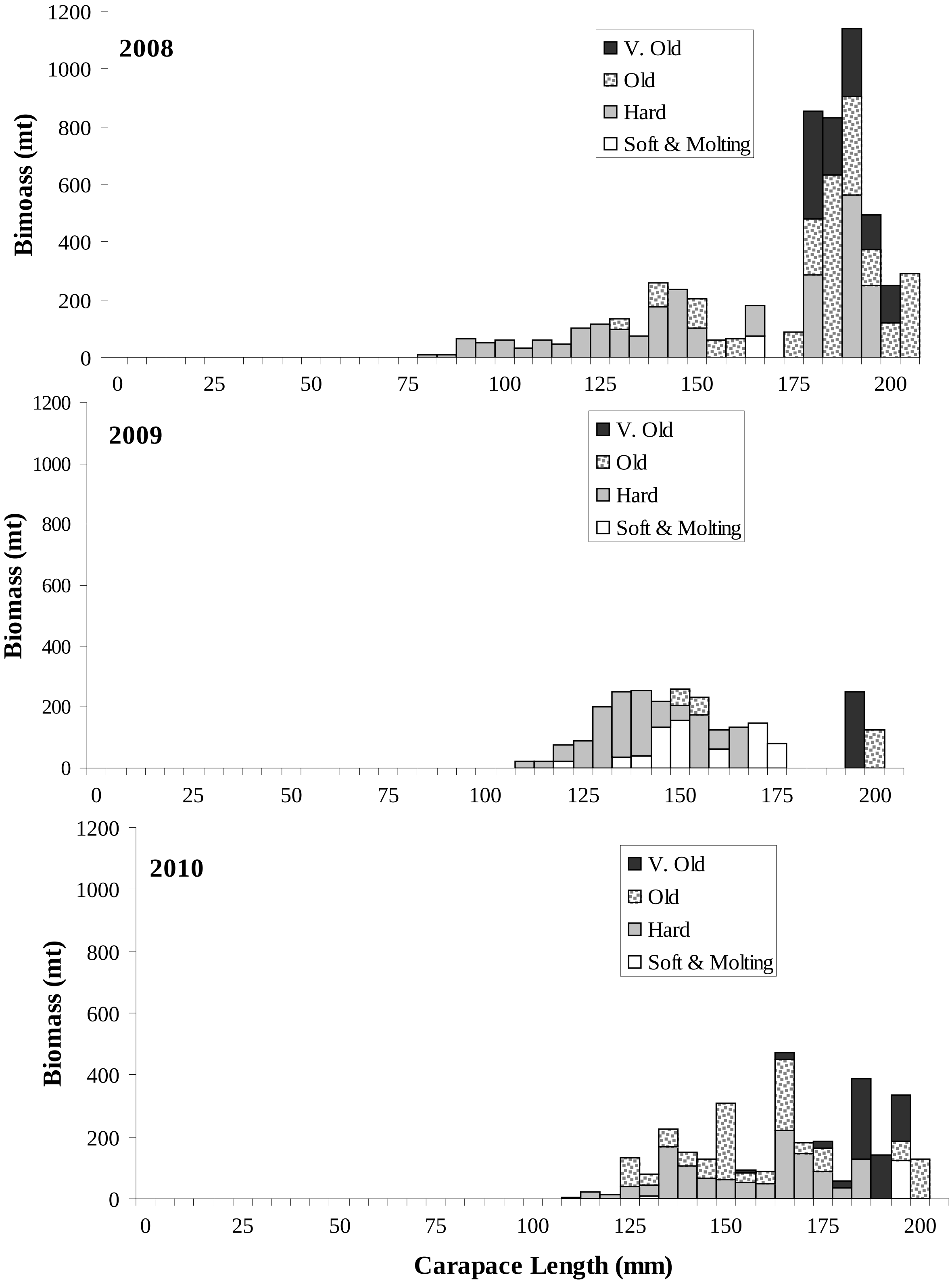

Figure 5. Distribution of Pribilof Island red king crab in 5 mm length bins by shell condition for the last 3 surveys.

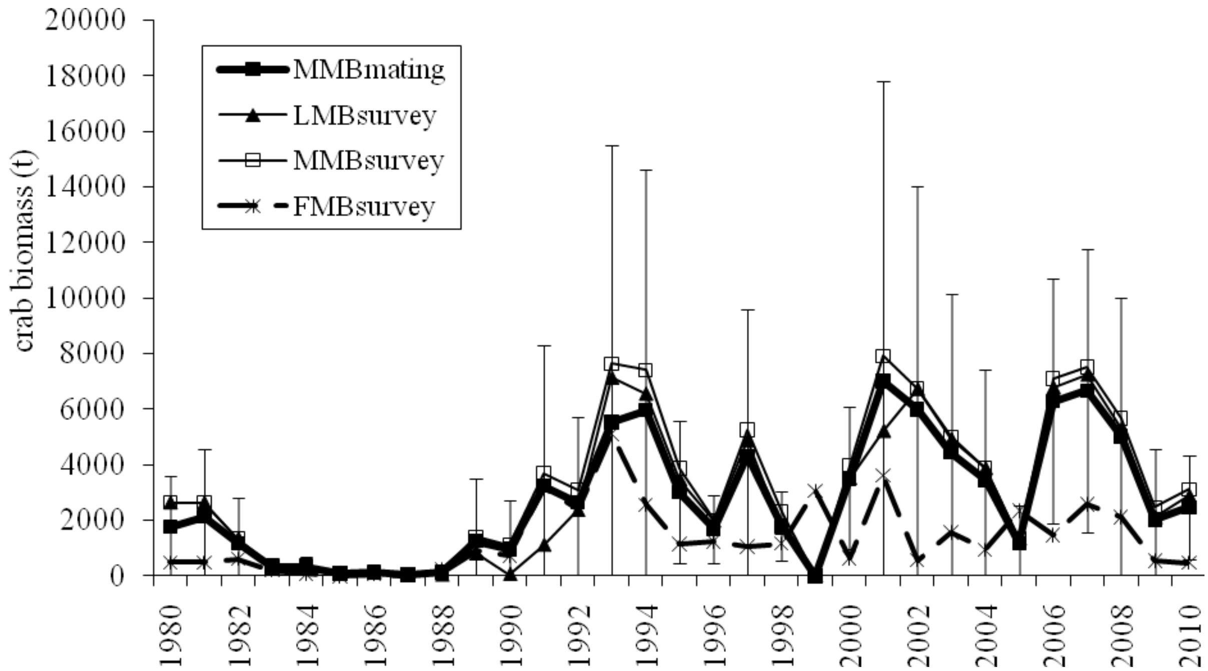

Figure 6. Historical trends of Pribilof Island red king crab mature male biomass (95% C.I.), mature female biomass, and legal male biomass estimated from the NMFS annual EBS bottom trawl survey.

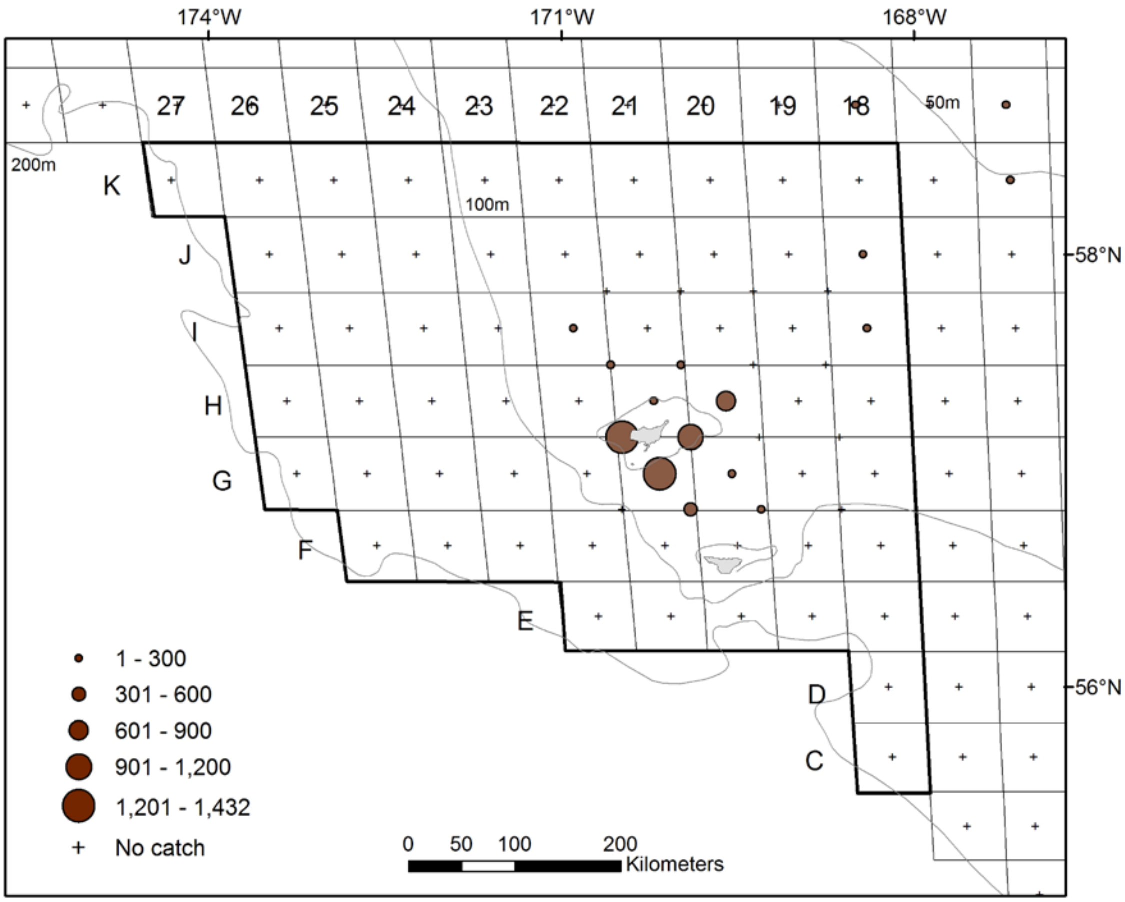

Figure 7. Total density (number/nm^2) of red king crab in the Pribilof District in the 2010 EBS bottom trawl survey.

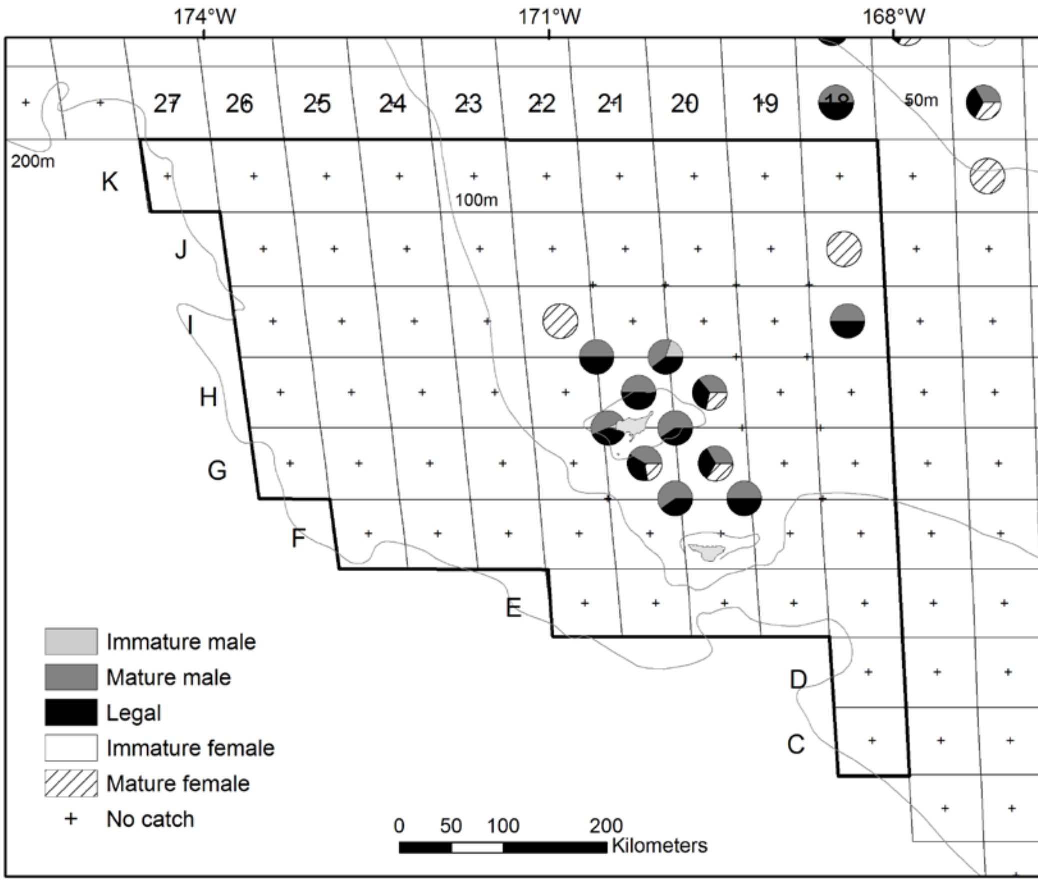

Figure 8. 2010 EBS bottom trawl survey size class distribution of red king crab in the Pribilof District.

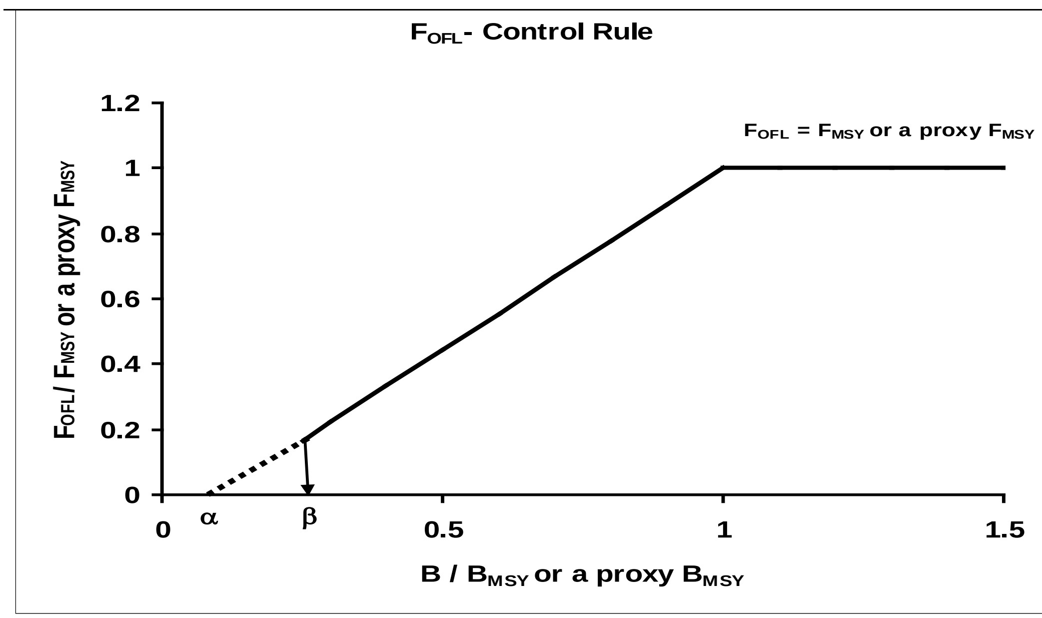

Figure 9. F_{OFL} Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β.

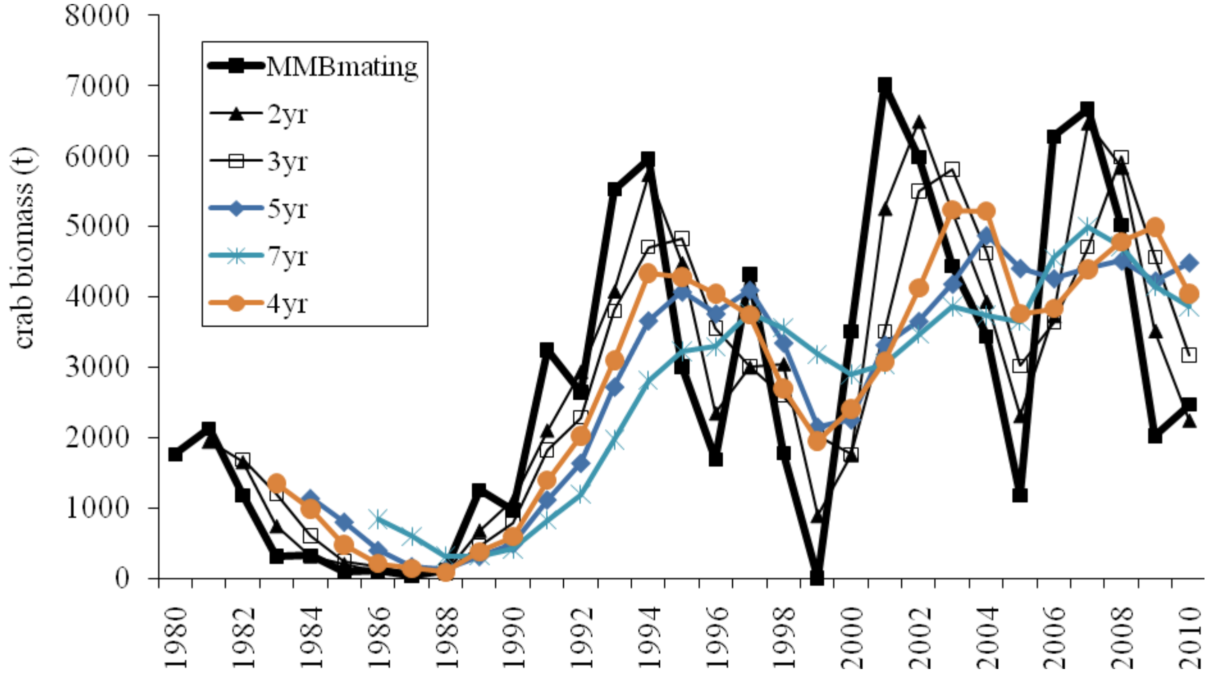

Figure 10. Alternative average biomass options ranging from 2 to 7 year for calculating MMB in the most recent year.