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# 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*

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## Introduction

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

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 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 and summarized that natural mortality estimates based upon tag-recapture data varies from 0.001 to 0.93 for crabs 80-169 mm CL with natural mortality increasing with size and that estimates based upon trawl survey data vary from 0.08 to 1.21 for the size range 85-169 mm CL, but crabs <125 mm CL had higher natural mortality. Utilizing the same data sets, Zheng et al. (1995) concluded natural mortality is bowl shaped over length and varies over time. Using newer tag-recovery data than is reported above, Siddeek et al. (2002) estimated natural mortality of Bristol Bay red king crab males to range from 0.54 to 0.70, however they conclude that these estimates appear high considering the longevity of red king crab. Natural mortality was set at 0.2 for Bering Sea king crab stocks (NPFMC 1998) and will be 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 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 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 red king crabs (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 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).

**Fishery**

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). There is no harvest strategy for the Pribilof district red king crab fishery in State regulation. The king crab fishery in the Pribilof District began in 1973 with blue king crabs *Paralithodes platypus* being targeted. A red king crab fishery in the Pribilof District opened for the first time in September 1993 following an increase in the abundance of red king crabs observed around the Pribilof Islands during the 1993 NMFS summer crab and groundfish trawl survey. For the 1993 fishery a GHL of 3.4 million pounds was set and 2.6 million pounds were harvested and in 1994 the GHL was 2 million pounds and 1.3 million pounds were harvested (Table 1) (Bowers et al. 2008). 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 combined red and blue king crab GHLs from 1996 though 1998 were 2.5, 1.8, 1.5, and 1.25 million pounds and corresponding red king crab harvests were 0.87, 0.20, 0.76, 0.51 million pounds (Table 1) (Bowers et al. 2008). From 1999 to 2006/07 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 (Bowers et al. 2008).

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. The Alaska Department of Fish and Game manages the crab CDQ fisheries and the Central Bering Sea Fishermen's Association (CBSFA) is allocated 100% of the Pribilof red and blue king crab. Due to fishery closures, Pribilof red king crab were only harvested under a CDQ in 1998 where 3.5% of the overall GHL was allocated to the CDQ resulting in 35,958 pounds, harvest data is confidential due to limited participation in the fishery (Table 1) (Bowers et al. 2008).

Amendment 21a to the BSAI groundfish FMP established the Pribilof Islands Habitat Conservation Area (Figure 2) 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 the negative effects of trawl gear.

Pribilof red king crabs occur as bycatch in the eastern Bering Sea snow crab, eastern Bering Sea Tanner crab, Bering Sea hair crab (*Erimacrus isenbeckii*), and Pribilof crab fisheries. Many of these fisheries have been closed or recently re-opened so the opportunity to catch Pribilof red king crab to is limited. The Bering Sea snow crab fishery has remained opened but ADF&G observers have not recorded any red king in their sampled pots during the last two fishing seasons (Barnard and Burt 2007, 2008). The eastern Bering Sea Tanner crab fishery recently re-opened west of 166$^{o}$ longitude (the fishery was closed from 1997-2004). ADF&G observers recorded 1.0 red king crab per sampled pot during the 2005/2006 fishery, but only 0.08 during the 2006/2007 fishery (Barnard and Burt 2007, 2008). The Bering Sea hair crab fishery has been closed since 2001, and the Pribilof blue king crab fishery has been closed since 1999. In addition, Pribilof red king crab have not been caught as bycatch in groundfish trawl fisheries since 1995 because of the Pribilof Islands Habitat Conservation Area trawl closure.

The highest catches of Pribilof red king crab during the last directed fishery occurred in the Alaska Department of Fish and Game statistical area to the east of St. Paul Island. However, red king crabs were also harvested in the statistical areas south, southwest, west and northeast of St. Paul Island (ADFG 1998). Historically, the statistical area east of St. Paul Island had the highest catches, followed by the areas southeast, west and southwest of the Island (personal communication, Robert K. Gish, ADFG).

Pribilof Island red king crab GHL and CDQ allocations, harvests and deadloss are summarized in Table 1.

**Data**

Total catch for the Pribilof District red king crab fishery is summarized in Tables 1 and 2. Fishing effort is summarized in Table 3 and bycatch loss is summarized in Table 4. Survey biomass estimates for mature male and female biomass and legal mal biomass are in Table 5.

Because crabs are difficult to age, length and weight at age information are not available. Weight at length relationships for eastern Bering Sea red king crab and results are (NMFS Shellfish Assessment Program, unpublished data):

Ovigerous females (n = 438, CL range: 79-163 mm): $W = 0.00081138 * CL^{2.697412}$

Nonovigerous females (n = 155, CL range: 18-145 mm): $W = 0.00036852 * CL^{3.081298}$

Males (n = 1026, CL range: 48-198 mm): $W = 0.00033293 * CL^{3.143922}$

**Analytic Approach**

*Tier-4 OFL Control Rule and OFL-Determination*

In the Environmental Assessment for Amendment 24 to the FMP (NPFMC 2008), Tier-4 stocks are characterized as those where essential life-history information and understanding are lacking. Although a full assessment model cannot be specified for Tier-4 stocks, or stock-recruitment relationship defined, sufficient information is available for simulation modeling that captures essential population dynamics of the stock as well as the performance of the fisheries. This

approach provides the annual status determination criteria to assess stock status and to establish harvest control rules.

In Tier-4, a default value of M and a scaler Gamma ($\gamma$) are used in OFL setting. The proxy $B_{MSY}$ represents the equilibrium stock biomass that provides maximum sustainable yield (MSY) to a fishery exploited at $F_{MSY}$. $B_{MSY}$ can be estimated as the average biomass over a specified period that satisfies these conditions (i.e., equilibrium biomass yielding MSY by an applied $F_{MSY}$). We also consider its estimation as a percentage of pristine biomass ($B_0$) of the unfished or lightly exploited stock. In Tier-4, the $F_{OFL}$ is calculated as the product of $\gamma$ and M, where M is the instantaneous rate of natural mortality. The FMP ammendment defines a default value of $\gamma = 1.0$. Gamma is allowed to be less than or greater than unity, resultanting in an overfishing limit that is more or less biologically conservative than fishing at the rate M. Use of the scaler $\gamma$ is intended to allow adjustments in the overfishing definitions to account for differences in the biomass measures used in the EA analyses. However, since Tier-4 stocks are information-poor by definition, the EA states that $\gamma$ should be set to a value that provides more biological conservation and less risk-prone overfishing definitions. The overfishing limit for Tier-4 stocks is the total catch comprised of retained catch plus discard/bycatch losses. For Tier-4 stocks, a minimum stock size threshold (MSST) is specified; if current MMB drops below MSST, the stock is considered to be overfished.

For Tier-4 stocks, the $F_{OFL}$ is derived using a Control Rule (Figure 3) based on whether a current mature stock biomass metric (B) is a member of 1 of 3 stock status levels (a, b or c) in the following algorithm. The stock biomass level beta ($\beta$) represents a minimum threshold below which directed fishing mortality is set to zero. The parameter alpha ($\alpha$) moderates the slope of the non-constant portion of the control rule. For biomass levels levels $\beta < B \leq B_{MSY}$, the $F_{OFL}$ is estimated as a function of the ratio $B/B_{MSY}$. The value of M is 0.18 for eastern Bering Sea red king crab. In the EA analysis for Tier-3 stocks, a $B_{MSY}$ proxy reference value ($B_{REF}$) equal to 35% of the maximum spawning potential of the unfished stock was specified. For Tier-4 stocks, a reference biomass value ($B_{REF}$) must be specified. The OFL algorithm is:

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

***OFL Model Structure***

In this Tier-4 OFL-setting approach:

$$LMB_{Fishery} = LMB_{Survey} \cdot e^{-PM(sf)} \quad (1)$$

$$MMB_{Fishery} = MMB_{Survey} \cdot e^{-PM(sf)} \quad (2)$$

$$MMB_{Mating} = MMB_{Survey} \cdot e^{-PM(sm)} \quad (3)$$

where,

$LMB_{Survey}$ is the legal male biomass at the time of the survey,
$LMB_{Fishery}$ is the legal male biomass at the time of the fishery,

$MMB_{Survey}$ is the mature male biomass at the time of the survey,
$MMB_{Fishery}$ is the mature male biomass at the time of the fishery,
PM(sf) is the partial M from the time of the survey to the fishery (6 months),
PM(sm) is the partial M from the time of the survey to mating (8 months),
$e^{-PM(sf)}$ is the survival rate from the survey to the fishery,
$e^{-PM(sm)}$ is the survival rate from the survey to mating.

The projected catch overfishing limit is calculated as:

$$\text{Catch OFL} = [1-e^{-Fofl}] \cdot LMB_{Fishery} \quad (4)$$

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

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

$$\mu_{LMB} = [\text{Total LMB Losses}] / LMB_{Fishery} \quad (6)$$

$$\mu_{MMB} = [\text{Total MMB Losses}] / MMB_{Fishery} \quad (7)$$

where,
[Total LMB Losses] is the total directed + non-directed losses to LMB,
[Total MMB Losses] is the total directed + non-directed losses to MMB.

Using the $F_{OFL}$ Control Rule (Figure 3), $F_{OFL}$ is determined based on MMB at time of mating after extraction of total catch. Since the ratio of $B/B_{REF}$ is dependent on the magnitude of the extracted catch and the catch OFL upon the estimated $F_{OFL}$, an iterative solution is found that maximizes the $F_{OFL}$ and catch based on the relationship of MMB at mating to $B_{REF}$. The total catch OFL includes all sources of fishery-induced removals from the stock – that is, directed retained catch, directed discards, and non-directed pot and trawl bycatch mortalities. Given specification of all component losses, the retained portion of the catch OFL and/or the retained portion of the buffered catch OFL is set as the limit for the directed fishery given the expected non-retained losses.

***OFL-Setting Results***

<u>The 2007/08 OFLs</u>:

For 2007, two levels of $B_{REF}$ are defined. $B_{REF1}$=8.90 million pounds of male mature biomass derived as the mean of 1991-2007 and is the recommended by the author. $B_{REF2}$=10.32 million pounds derived mean of 1991-95 plus 2000-07. The stock demonstrated widely varying levels of MMB during these periods. The trawl survey found crabs highly concentrated and indices of male biomass are characterized by very poor precision. Survey estimates are highly influenced by the results of a limited number of tows with crab catches. Substantial uncertainty exists in these data and the suitability of these time periods for estimating a proxy for equilibrium stock biomass $B_{MSY}$. It is uncertain if either $B_{REF}$ proxy adequately estimates the capacity of this stock to persist at $B_{MSY}$ and provide maximum sustainable yield to the fisheries.

We used a buffer value of 0.80 to illustrate a level of catch OFL that reduces the risk of exceeding the overfishing limit. For both $B_{REF}$ model scenarios, gamma was set at the default

value of 1.0. Given precautionary fishery management principles, we find no evidence that would justify a gamma in excess of 1.0 or fishing at an $F_{OFL}$ rate greater than M.

Male mature biomass at the time of mating for 2007 is estimated at 12.50 million pounds for both $B_{REF1}$ and $B_{REF2}$ options. The $B/B_{REF}$ ratios and $F_{OFLs}$ corresponding to the two biomass reference options are , respectively, [$B/B_{REF1}$=1.40, $F_{OFL}$=0.18] and [$B/B_{REF2}$=1.21, $F_{OFL}$=0.18]. For the 2007 fishery, we estimated catch OFLs of 2.48 million pounds of legal male biomass for both options. After adjusting for projected discard/bycatch mortalities to LMB, the retained portion of the respective catch OFLs is 2.25 million pounds. The expected exploitation rates on LMB and MMB associated with the $F_{OFL}$ for both options is: $\mu_{LMB}$ = 0.165; $\mu_{MMB}$ = 0.159.

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 biomass estimates, and that unacceptable levels of blue king crab incidental catch and bycatch mortality would occur in a directed Pribilof Islands red king crab fishery. As a result of this and considering the poor blue king crab stock condition, the fishery remains closed.

Reference points for both $B_{REF}$ options (Catch and biomass estimate are in millions of pounds).

| | |
|---|---|
| Projected Catch OFL: | 2.479604 |
| MMB @ Mating: | 12.498942 |
| OFL/MMB @ Fishery: | 0.158815 |
| OFL/Legal Males @ Fishery: | 0.164730 |
| OFL Split: | |
| Retained Part of OFL: | 2.252589 |
| Directed Discards: | 0.002874 |
| Non-Directed Discards: | 0.224141 |

**Ecosystem Considerations**

***Ecosystem effects on the stock***

*Prey availability/abundance trends*

There have been no directed studies of the prey of Pribilof red king crab so the feeding habits can only be inferred from studies of red king populations from other areas. Several food-habit studies summarized in Jewett and Onuf (1988) report that red king crab diet varies with life stage and that red king crab are opportunistic omnivorous feeders, eating a wide variety of microscopic and macroscopic plants and animals. More specifically, red king crab larvae consume diatoms, small planktonic animals and fragments of plants (Bright 1967) and in the Bering Sea, important food items for adult red king crab are bivalve mollusks, gastropod mollusks, sea urchins, sand dollars, polychaete worms, and crustaceans, including other crabs (McLaughlin and Hebard 1961; Feder and Jewett 1981). Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not been re-sampled since. Because red king crab are opportunistic omnivores, it likely that they are not food limited.

*Predator population trends*

Predators of Pribilof Island red king crab have not been specifically studied, but predation on red king crab in the eastern Bering Sea has been studied. Pacific cod (*Gadus macrocephalus)* are the primary predators of red king crab with walleye pollock (*Theragra chalcogramma*), Pacific halibut (*Hippoglossus stenolepis*) and skates (*Raja* sp.) being minor predators (Lang et al. 2005). Larvae and newly settled juveniles are consumed by walleye pollock and yellowfin sole (*Limanda aspera*) (Livingston et al. 1993). Although Pacific cod are the primary predators of red king crab, Livingston (1989) concluded that cod were not the major force behind reduced numbers of female red king crab observed in the eastern Bering Sea from 1981 to 1985.

Pribilof Islands specific predator population trend data is not available so trends for the eastern Bering Sea are presented. Pacific cod biomass increased steadily from 1978 through 1983, remained relatively constant from 1983 through 1988, fluctuated slightly from 1988 through 1994 (the highest observation) and in general has steadily declined since then with 2007 estimates being the lowest estimate in the time series (Thompson et al. 2007). Walleye pollock biomass increased from 1979 to the mid 1980's, is characterized by peaks in the mid 1980s and mid 1990s with a substantial decline by 1991 and stocks are currently facing another low point with the stock projected to drop to the lowest levels since the late 1970s (Ianelli et al. 2007). Halibut biomass was lowest in 1982, fluctuated from 1983 through 1988, peaked in 1988, dropped in 1989 and increased from 1990 through 1996 when the highest biomass of the time series was observed, after 1998 biomass has fluctuated (personal communication, Steven Hare, IPHC). Biomass estimates of all skate species in the eastern Bering Sea are not reported, however biomass has been estimated for the Alaska skate (*Bathyraja parmifera*) since 1982. Estimated biomass for the Alaska skate fluctuated from 1982 through 1986, from 1986 through 1990 biomass in general increased and peaked in 1990, from 1991 through 1999 biomass tended to decrease and beginning in 1999 to the present biomass has been increasing (Ormseth and Matta 2007). Yellowfin sole biomass was at low levels during most of the 1960s and early 1970s after a period of high exploitation after which time biomass increased and peaked by 1984, biomass has been in a slow decline but has remained high and stable in recent years (Wilderbuer et al. 2007).

Pansporoblastic microsporidan (*Thelohania* sp.) and rhizocephalan infections (*Briarosaccus* sp.) were found in red king crab of the northeastern Pacific (Sparks and Morado 1997). In Bristol Bay, red king crabs with rhizocephalan, microporidan, and viral or putative viral diseases were found (Sparks and Morado 1985). The microsporidan disease in red king crabs is almost certainly fatal however rhizocehalan infection appears to be of little importance among red king crab (Sparks and Morado 1990). Otto et al. (1990) found three of 243 red king crab egg clutches from Bristol Bay to contain nemertian worms, which are known predators of embryos.

*Changes in habitat quality*

The past decade has been warmer in the Bering Sea, however winter and spring 2007 surface air temperatures were colder than normal and 2006 was close to normal, but these cold anomalies are not in the range of pre-1977 temperatures (Wang et al. 2008). In the Bering Sea, a northward biogeographical shift is being observed in response to a retreat of cold ocean temperatures and atmospheric forcing (Overland and Stabeno 2004). Distribution changes of Pribilof Islands red king crab has not been studied, however the distribution of ovigerous red king crab in southeastern Bering Sea shifted to the northeast during the late 1970s and early 1980s and this

distribution change coincided with increased early summer near-bottom temperatures (Loher and Armstrong 2005). Water temperature may be important is structuring the distribution of ovigerous red king crab (Loher and Armstrong 2005).

Recruitment trends for red king crabs in Alaska may be partly related to decadal shifts in climate and physical oceanography. Strong year classes for eastern Bering Sea red king crab were observed when temperatures were low and weak year classes occurred when temperatures were high, but temperature alone cannot explain year class strength trends for red king crab (Zheng and Kruse 2000). In Bristol Bay, there is a relationship between red king crab brood strength and the intensity of the Aleutian Low atmospheric pressure system, during low pressure the brood strength is reduced (Tyler and Kruse 1996; Zheng and Kruse 2000). Gish (2006) suggested that the lack of king crab recruitment in the Pribilof Islands area may be the result of a large-scale environmental event affecting abundance and distribution.

Ice cover has changed in the Bering Sea including the area around the Pribilof Islands. In 1972 through 1976, ice cover remained around St. Paul Island for more than a month (Schumacher et al. 2003). Spring 2007 was cold and sea ice lasted for almost 2 months just north of the Pribilof Islands which is close to normal conditions observed from 1979 through 1999 and in contrast to the warm years of 2000-2005 (Wang et al. 2008). In the Bering Sea, if seasonal ice pack were to decrease in extent or melt earlier, a shift from ice-edge blooms to later open-water blooms may cause long-term declines in sediment organic matter (Lovvorn et al. 2005). In these shelf systems, much of the production from spring blooms at the retreating ice edge sink to the bottom with little grazing by zooplankton, therefore supporting abundant benthic communities (Overland and Stabeno 2004; Lovvorn et al. 2005). The importance of this settled phytoplankton to the macrobenthos will partially determine the effects of long-term changes in ice cover (Lovvorn et al. 2005). The presence of sea ice in 2007 along with below normal ocean temperatures likely resulted in the first ice edge bloom since 1999 (Wang et al. 2008). The changes in ice cover on the benthic community of the Pribilof Islands are not well understood.

Unless red king crab distribution around the Pribilof Islands change, the critical habitat that Pribilof Islands red king crab inhabit will not be altered by bottom trawling because the Pribilof Islands Habitat Conservation Area protects the majority of crab habitat in the area (NPFMC 1994).

***Fishery Effects on the Ecosystem***

Bycatch information from the Pribilof district king crab fishery is scant due to limited observer coverage during the years of the fishery. The percent of the fleet observed was 1.8 in 1993, 0.8 in 1995 and 0.0 for every other year (Boyle and Schwenzfeier 2002), therefore it is difficult to estimate the fishery-specific contribution to the bycatch of prohibited and forage species. The Pribilof district king crab fishery does not occur in any areas designated as Habitat Areas of Particular Concern (HAPC) (NPFMC 2003). NMFS conducted Endangered Species Act (ESA) Section 7 Consultations-Biological Assessments on the impact of the Bering Sea and Aleutian Island FMP crab fisheries on marine mammals (NMFS 2000) and on seabirds (NMFS 2002) and concluded that the crab fisheries are not likely to result in the direct take or compete for prey for the protected marine mammal species, destroy or adversely modify designated Steller sea lion critical habitat, adversely affect listed seabirds or destroy or adversely modify designated critical

habitat. The only plausible biological interaction between the crab fisheries and threatened and endangered seabirds identified in the biological assessment is vessel strikes by seabirds, but NMFS (2002) concluded that available evidence is not sufficient to suggest that these interactions occur in today's fisheries and limit recovery of seabirds.

The Pribilof Islands red king crab fishery was only executed for 6 seasons (1993-1998). The stocks and area are not well studied and so information is not available on the effects of fishery removals on predator needs, the effects of the removal of large male crabs from the population, and the effects of the fishery on the age-at maturity and fecundity of the stock. Additionally, information is not available on the fishery-specific contribution to discards and offal production.

The extent that pot gear impacts benthic habitat is not well know and most likely depends on the substrate. It is likely that habitat is affected during both setting and retrieval of pots, but little research has been done. There is no evidence that pot gear adversely affects mud and sandy substrates where red king crab are primarily fished (NMFS 2004). It has been estimated that for each pot set 49 $ft^2$ of substrate is impacted and that the estimated number of sets per year for the Pribilof red and blue king crab fishery would be 28,381 resulting in 1,390,669 $ft^2$ possibly impacted by pot gear which is 0.0% of the Bering Sea shelf (NMFS 2004).

**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.

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. 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.

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.

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.

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.

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.

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

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.

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.

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. 1967. Growth of king crabs in the vicinity of Kodiak Island, Alaska. Informational Leaflet 92, Alaska Department of Fish and Game, 58 p.

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.

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

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.

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. Pribilof District commercial red king crab fishery data, 1993-2007/08 (Bowers et al. 2008)

| **Season** | **GHL[a]** | **Harvest[a,e]** | **CDQ[c,d]** | **Harvest** | **Deadloss[d]** |
|---|---|---|---|---|---|
| 1993 | 3.4[b] | 2.61 | | | 472 |
| 1994 | 2[b] | 1.34 | | | 2,929 |
| 1995 | 2.5[c] | 0.87 | | | 15,348 |
| 1996 | 1.8[c] | 0.20 | | | 319 |
| 1997 | 1.5[c] | 0.76 | | | 18,807 |
| 1998 | 1.25[c] | 0.51 | 35,958 | Confidential | 8,703 |
| 1999-2007/08 | | Fishery Closed | | Fishery Closed | |

[a] Millions of pounds
[b] For red king crab; fishery closed to blue king crab
[c] For combined red and blue king crab
[d] In pounds
[e] Deadloss included

Table 2. Legal crab biomass (LBS x $10^6$) landed (directed fishery).

| Year | Landed crab |
|---|---|
| 1980 | 0.922 |
| 1981 | 1.274 |
| 1982 | 0.470 |
| 1983 | 0.045 |
| 1984 | 0.000 |
| 1985 | 0.000 |
| 1986 | 0.000 |
| 1987 | 0.000 |
| 1988 | 0.000 |
| 1989 | 0.000 |
| 1990 | 0.000 |
| 1991 | 0.000 |
| 1992 | 0.000 |
| 1993 | 0.379 |
| 1994 | 0.168 |
| 1995 | 0.108 |
| 1996 | 0.200 |
| 1997 | 0.800 |
| 1998 | 0.509 |
| 1999 | 0.000 |
| 2000 | 0.000 |
| 2001 | 0.000 |
| 2002 | 0.000 |
| 2003 | 0.000 |
| 2004 | 0.000 |
| 2005 | 0.000 |
| 2006 | 0.000 |
| 2007 | 0.000 |

Table 3. Fishing effort during Pribilof 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 |
| 1999-2007/08 | Fishery Closed | | | |

Table 4. Legal red king crab biomass (LBS x $10^6$) discard/bycatch loss in EBS pot and groundfish fisheries. Total male catch includes mortality of 0.50 for pot fisheries and 0.80 for groundfish fisheries.

| Year | Pot ($10^6$ LB) | Groundfish ($10^6$ LB) | Total ($10^6$ LB) |
|---|---|---|---|
| 1980 | | | |
| 1981 | | | |
| 1982 | | | |
| 1983 | | | |
| 1984 | | | |
| 1985 | | | |
| 1986 | | | |
| 1987 | | | |
| 1988 | | | |
| 1989 | | | |
| 1990 | | | |
| 1991 | | | |
| 1992 | | 0.045 | 0.045 |
| 1993 | | 0.016 | 0.016 |
| 1994 | | 0.006 | 0.006 |
| 1995 | | 0.012 | 0.012 |
| 1996 | | 0.008 | 0.008 |
| 1997 | | 0.003 | 0.003 |
| 1998 | 0.00223 | 0.004 | 0.006 |
| 1999 | 0.00287 | 0.045 | 0.048 |
| 2000 | | 0.005 | 0.005 |
| 2001 | 0.00001 | 0.012 | 0.012 |
| 2002 | | 0.019 | 0.019 |
| 2003 | | 0.006 | 0.006 |
| 2004 | | 0.006 | 0.006 |
| 2005 | 0.00042 | 0.002 | 0.003 |
| 2006 | | 0.010 | 0.010 |
| 2007 | | 0.221 | 0.221 |

Table 5. Mature crab abundance, biomass, and legal male biomass (LBS x $10^6$) based on maturity schedule applied to NOAA Fisheries EBS trawl survey CPUE.

| | Crabs > 39mm ($10^6$ Crab) | | Mature Crabs ($10^6$ Crab) | | Mature Biomass ($10^6$ LB) | | Legal Male Biomass ($10^6$ LB) |
|---|---|---|---|---|---|---|---|
| Year | Male | Female | Male | Female | Male | Female | Male |
| 1980 | 0.77 | 0.39 | 0.73 | 0.39 | 5.82 | 1.07 | 5.82 |
| 1981 | 0.77 | 0.39 | 0.73 | 0.39 | 5.82 | 1.07 | 5.82 |
| 1982 | 0.32 | 0.44 | 0.31 | 0.43 | 2.98 | 1.36 | 2.98 |
| 1983 | 0.11 | 0.14 | 0.09 | 0.13 | 0.77 | 0.42 | 0.70 |
| 1984 | 0.11 | 0.05 | 0.11 | 0.05 | 0.81 | 0.16 | 0.67 |
| 1985 | 0.03 | 0.00 | 0.03 | 0.00 | 0.22 | 0.00 | 0.22 |
| 1986 | 0.03 | 0.04 | 0.03 | 0.04 | 0.27 | 0.11 | 0.27 |
| 1987 | 0.01 | 0.02 | 0.01 | 0.01 | 0.09 | 0.02 | 0.09 |
| 1988 | 1.47 | 1.51 | 0.09 | 0.23 | 0.28 | 0.51 | 0.08 |
| 1989 | 1.73 | 2.76 | 0.70 | 1.04 | 3.11 | 2.05 | 1.77 |
| 1990 | 3.52 | 1.42 | 0.85 | 0.93 | 2.40 | 1.62 | 0.13 |
| 1991 | 2.65 | 4.00 | 2.06 | 3.59 | 8.11 | 7.03 | 2.45 |
| 1992 | 1.77 | 2.78 | 1.36 | 2.37 | 6.81 | 5.22 | 5.22 |
| 1993 | 3.57 | 5.12 | 2.84 | 4.79 | 16.84 | 11.27 | 15.72 |
| 1994 | 2.95 | 2.61 | 2.52 | 2.30 | 16.34 | 5.64 | 14.46 |
| 1995 | 1.51 | 1.15 | 1.24 | 1.01 | 8.51 | 2.54 | 7.65 |
| 1996 | 0.57 | 0.95 | 0.48 | 0.92 | 4.43 | 2.71 | 4.37 |
| 1997 | 2.64 | 1.10 | 1.46 | 0.82 | 11.60 | 2.31 | 10.76 |
| 1998 | 1.15 | 1.06 | 0.81 | 0.95 | 5.07 | 2.56 | 3.79 |
| 1999 | 0.00 | 8.20 | 0.00 | 2.14 | 0.02 | 6.77 | 0.02 |
| 2000 | 1.52 | 0.63 | 1.42 | 0.59 | 8.73 | 1.42 | 7.76 |
| 2001 | 5.61 | 3.98 | 3.49 | 3.38 | 17.44 | 7.96 | 11.51 |
| 2002 | 1.83 | 0.44 | 1.81 | 0.42 | 14.88 | 1.23 | 14.84 |
| 2003 | 1.38 | 1.15 | 1.38 | 1.14 | 11.05 | 3.46 | 10.85 |
| 2004 | 2.31 | 1.76 | 0.88 | 0.61 | 8.55 | 2.09 | 8.55 |
| 2005 | 0.33 | 1.39 | 0.28 | 1.39 | 2.98 | 5.16 | 2.95 |
| 2006 | 1.54 | 0.94 | 1.46 | 0.89 | 15.65 | 3.24 | 14.97 |
| 2007 | 1.98 | 1.74 | 1.75 | 1.63 | 16.58 | 5.69 | 15.98 |

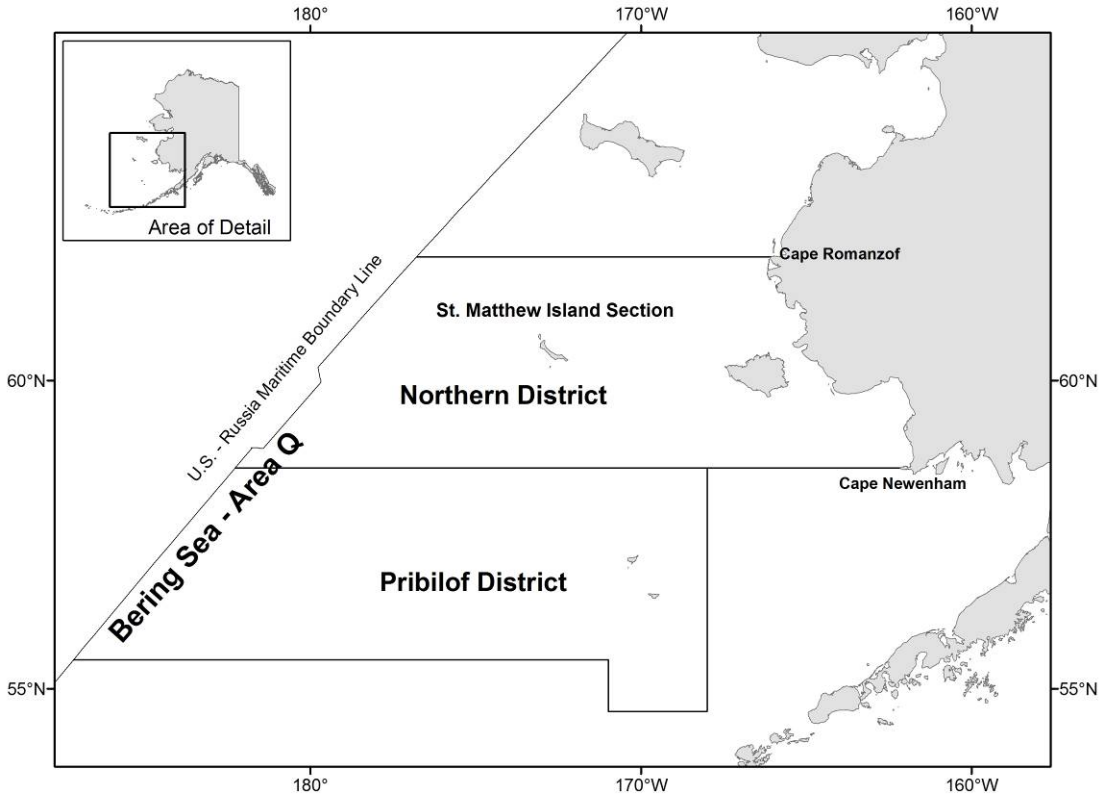


Figure 1. King crab Registration Area Q (Bering Sea) showing the Pribilof District.

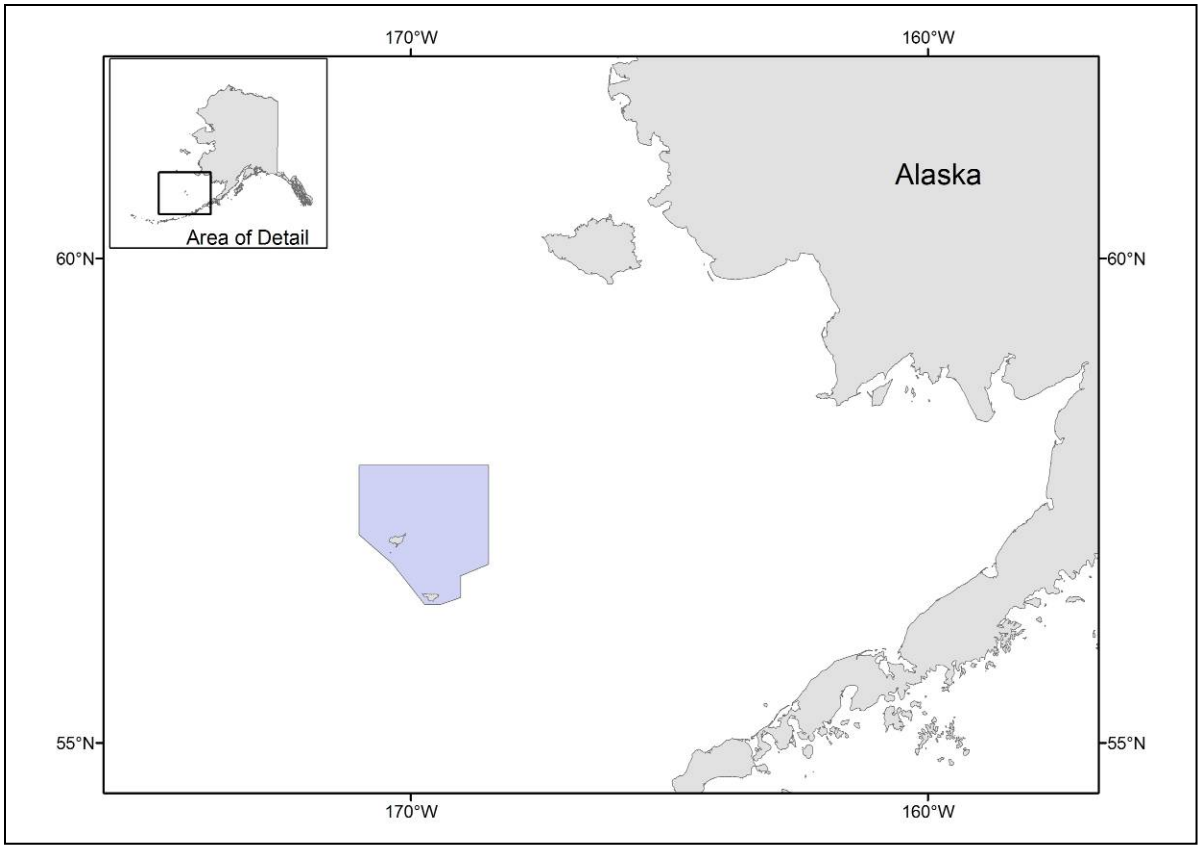


Figure 2. The shaded area shows the Pribilof Islands Habitat Conservation area

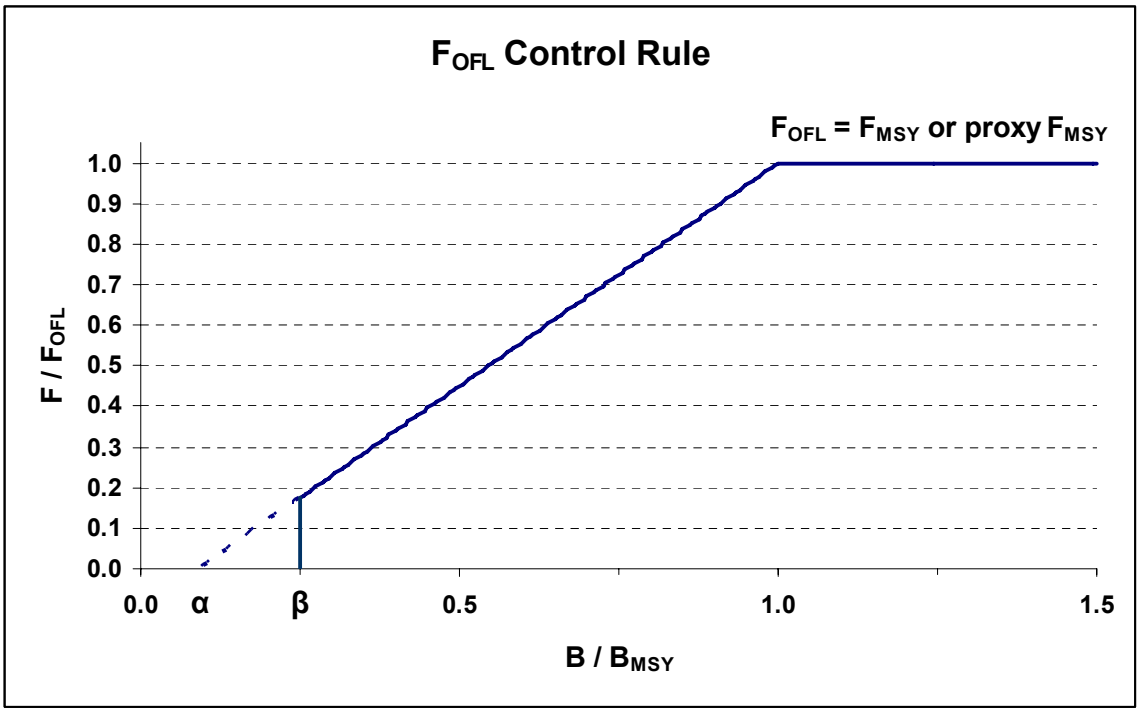


Figure 3. $F_{OFL}$ Control Rule for Tier-4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set 0 below β.