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

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## *Executive Summary*

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## Introduction

*Scientific name and description of general distribution*

Blue king crab (*Paralithodes platypus*) are anomurans in the family Lithodidae which also includes the red king crab (*Paralithodes camtschaticus*) and golden or brown king crab (*Lithodes aequispinus*) in Alaska. Blue king crabs occur off Hokkaido in Japan, with disjunct populations occurring in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are known from the Diomede Islands, Point Hope, outer Kotzebue Sound, King Island, and the outer parts of Norton Sound. In the remainder of the Bering Sea, they are found in the waters off St. Matthew Island and the Pribilof Islands. In more southerly areas as far as southeastern Alaska in the Gulf of Alaska, blue king crabs are found in widely-separated populations that are frequently associated with fjord-like bays (Figure 1). This disjunct, insular distribution of blue king crab relative to the similar but more broadly distributed red king crab is likely the result of post-glacial period increases in water temperature that have limited the distribution of this cold-water adapted species (Somerton 1985). Factors that may be directly responsible for limiting the distribution include the physiological requirements for reproduction, competition with the more warm-water adapted red king crab, exclusion by warm-water predators, or habitat requirements for settlement of larvae (Somerton 1985; Armstrong et al 1985, 1987).

*Description of management units*

During the years when the fishery was active (1973-1989, 1995-1999), the Pribilof Islands blue king crab were managed under the Bering Sea king crab Registration Area Q Pribilof District, which has as its southern boundary a line from 54° 36’ N lat., 168° W long., to 54° 36’ N lat., 171°

W long., to 55° 30' N lat., 171° W. long., to 55° 30' N lat., 173° 30' E long., as its northern boundary the latitude of Cape Newenham (58° 39' N lat.), as its eastern boundary a line from 54° 36' N lat., 168° W long., to 58° 39' N lat., 168° W long., to Cape Newenham (58° 39' N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991 (ADF&G 2008) (Figure 2). In the Pribilof District, blue king crab occupy the waters adjacent to and northeast of the Pribilof Islands (Armstrong et al. 1987) (Figure 3). The Pribilof Islands consist of the islands of St. Paul and St. George.

*Stock structure*

Based on catch-survey analysis from the 2007 NMFS trawl survey, the estimated total mature biomass of 1.3-million pounds is the second lowest on record, exceeding only that of 0.6-million pounds in 2004. Estimated 2007 abundance of 0.1-million mature-sized male is the second lowest on record, whereas estimates of 0.1-million legal males and 0.3-million mature-sized females are the lowest on record. A continued decline in mature male and female abundances is anticipated for at least two years. Although relatively high numbers of small crabs (< 70 mm-CL) were caught, mainly at one haul, during the 2005 NMFS trawl survey, there was very little representation of juvenile crabs in the 2006 and 2007 surveys. The Pribilof blue king crab stock continues to show no indications of near-term recovery (NPFMC 2007).

*Life history*

Blue king crab are similar in size and appearance, except for color, to the more widespread red king crab, but are typically biennial spawners with lesser fecundity and somewhat larger sized (*ca.* 1.2 mm) eggs (Somerton and Macintosh 1983; 1985; Jensen et al. 1985; Jensen and Armstrong 1989; Selin and Fedotov 1996). Red king crab are annual spawners with relatively higher fecundity and smaller sized (*ca.* 1.0 mm) eggs. Blue king crab fecundity increases with size, from approximately 100,000 embryos for a 100-110 mm CL female to approximately 200,000 for a female >140-mm CL (Somerton and MacIntosh 1985). Blue king crab have a biennial ovarian cycle with embryos developing over a 12 or 13-month period depending on whether or not the female is primiparous or multiparous, respectively (Stevens 2006a). Armstrong et al. (1985, 1987), however, estimated the embryonic period for Pribilof blue king crab at 11-12 months, regardless of previous reproductive history and Somerton and MacIntosh (1985) placed development at 14-15 months. It may not be possible for large female blue king crabs to support the energy requirements for annual ovary development, growth, and egg extrusion due to limitations imposed by their habitat, such as poor quality or low abundance of food or reduced feeding activity due to cold water (Armstrong et al. 1987, Jensen and Armstrong 1989). Both the large size reached by Pribilof Islands blue king crab and the generally high productivity of the Pribilof area, however, argue against such environmental constraints. Development of the fertilized embryos occurs in the egg cases attached to the pleopods beneath the abdomen of the female crab and hatching occurs February through April (Stevens 2006b). After larvae are released, large female Pribilof blue king crab will molt, mate, and extrude their clutches the following year in late March through mid April (Armstrong et al. 1987).

Female crabs require an average of 29 days to release larvae, and release an average of 110,033 larvae (Stevens 2006b). Larvae are pelagic and pass through four zoeal larval stages which last about 10 days each, with length of time being dependent on temperature; the colder the temperature the slower the development and vice versa (Stevens et al 2008). Stage I zoeae must

find food within 60 hours as starvation reduces their ability to capture prey (Paul and Paul 1980) and successfully molt. Zoeae consume phytoplankton, the diatom *Thalassiosira* spp. in particular, and zooplankton. The fifth larval stage is the non-feeding (Stevens et al. 2008) and transitional glaucothoe stage in which the larvae take on the shape of a small crab but retain the ability to swim by using their extended abdomen as a tail. This is the stage at which the larvae searches for appropriate settling substrate, and once finding it, molts to the first juvenile stage and henceforth remains benthic. The larval stage is estimated to last for 2.5 to 4 months and larvae metamorphose and settle during July through early September (Armstrong et al. 1987, Stevens et al. 2008).

Blue king crab molt frequently as juveniles, growing a few mm in size with each molt. Unlike red king crab juveniles, blue king crab juveniles are not known to form pods. Female king crabs typically reach sexual maturity at approximately five years of age while males may reach maturity one year later, at six years of age (NPFMC 2003). Female size at 50% maturity for Pribilof blue king crab is estimated at 96-mm carapace length (CL) and size at maturity for males, as estimated from size of chela relative to CL, is estimated at 108-mm CL (Somerton and MacIntosh 1983). Skip molting occurs with increasing probability for those males larger than 100 mm CL (NOAA 2005).

Longevity is unknown for the species, due to the absence of hard parts retained through molts with which to age crabs. Estimates of 20 to 30 years in age have been suggested (Blau 1997). Natural mortality for male Pribilof blue king crabs has been estimated at 0.34-0.94 with a mean of 0.79 (Otto and Cummiskey 1990) and a range of 0.16 to 0.35 for Pribilof and St. Matthew Island stocks combined (Zheng et al. 1997). An annual natural mortality of 0.2 for all king crab species was adopted in the federal crab fishery management plan for the BSAI areas (Siddeek at al 2002).

**Fishery**

*Description of fishery*

The Pribilof blue king crab fishery has been closed since 1999. The fishery occurred September through January, but usually lasted less than 6 weeks (Otto and Cummiskey 1990, ADF&G 2008). The fishery used mesh covered steel box-shaped pots set on single lines (NOAA 1995). Standard commercial king crab pots are rectangular with length and width dimensions ranging from 150 to 240 cm and height from 67 to 99 cm. The pot has two tunnels at opposite ends, two side panels, one top panel and one bottom panel. Fish are placed inside as bait and the pot is sunk to the sea floor. The king crab are sorted once they are brought to the surface, and any not meeting the regulation requirements are thrown back. The fishery was male only, and legal size was >16.5 cm carapace width (NOAA 1995). The king crab are then typically stored live in a holding tank until the boat reaches shore, where they are sold and processed. TAC was 10 percent of the abundance of mature male or 20 percent of the number of legal males (ADF&G 2006).

The Pribilof Islands Area Habitat Conservation Zone was established in 1995, under authority of the Magnuson-Stevens Fishery Conservation and Management Act. Trawl fishing has been prohibited year-round in the Pribilof Island Habitat Conservation Area since (Figure 4).

*Information on bycatch and discards*
Bycatch in the blue king crab fisheries consist almost entirely of non-legal blue king crabs (NOAA 1995). State regulations prescribe gear modifications to inhibit the bycatch of small crab, female crab, and other species of crab. Gear modifications include escape rings, tunnel size, and a requirement that crab pots be fitted with a degradable escape mechanism.

Blue king crab in the Pribilof District can occur as bycatch in the following crab fisheries: the eastern Bering Sea snow crab fishery, the eastern Bering Sea Tanner crab fishery, the Bering Sea hair crab (*Erimacrus isenbeckii*) fishery, and the Pribilof red and blue king crab fisheries. Of those fisheries, only the eastern Bering Sea snow crab fishery has remained open; the eastern Bering Sea Tanner crab fishery closed from 1997-2004, the Pribilof red and blue king crab fisheries have been closed since 1999, and the Bering Sea hair crab fishery has been closed since 2001. Although St. Matthew blue king crab account for the majority of blue king crab captured in the snow crab fishery (D. Barnard, ADF&G, Kodiak, personal communication), the total bycatch of blue king crab in the snow crab fishery is relatively low (estimated at <25,000 crabs annually during 1995-2002). It should be noted that only limited data is available for estimating bycatch in the Pribilof king crab fisheries that occurred during 1995-1998. Bycatch of blue king crab in groundfish fisheries is small relative to total population abundance (NPFMC 2003).

*Summary of historical catch distributions*
The king crab fishery in the Pribilof District began in 1973 with a reported catch of 1.3 million pounds by eight vessels. Landings increased during the 1970s and peaked at a harvest of 11.0 million pounds in the 1980/81 season with an associated increase in effort to 110 vessels (ADF&G 2008). A decline in landings followed, and by 1988 the fishery was closed. In 1993 new regulations set pot limits based on vessel length for crab fisheries in the Bering Sea. In the Pribilof District pot limits were set at 50 vessels over 125 feet overall length and 40 pots for vessels at or under 125 feet in overall length.

In 1995, an increase in blue king crab abundance and a continued harvestable surplus of red king crabs resulted in a combined red and blue king crab GHL of 2.5 million pounds (ADF&G 2008). The fishery was reopened and a total of 1,154,386 pounds was landed in that year. Following 1995, declines in the stock resulted in a closure from 1999 to present. The Pribilof blue king crab stock was declared overfished in September of 2002 and the Alaska Department of Fish and Game developed a rebuilding harvest strategy as part of the Council's comprehensive rebuilding plan for the stock (Zheng and Pengilly 2003).

**Data**
*Length at age*
Carapace length for mature female Pribilof blue king crab is estimated at 96 mm and CL for mature males, as estimated from size of chela relative to CL, is estimated at 108 mm (Somerton and MacIntosh 1983).

Total catch for the Pribilof District blue king crab fishery is summarized in Table 1. Bycatch loss is summarized in Table 2. Survey biomass estimates for mature male and female biomass and legal male biomass are in Table 3.

*Growth per molt*
For adult male blue king crabs, in the Pribilof District, carapace length increases 14.3 mm (Standard Error = 0.3) per molt (Otto and Cummiskey 1990). Skip molting occurs with increasing probability for those males larger than 100-mm CL (NOAA 2005).

**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 blue 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 is set as the limit for the directed fishery given the expected non-retained losses.

***OFL-Setting Results***

The 2007/08 OFLs:
For 2007, two levels of $B_{REF}$ are defined. $B_{REF1}$=7.08 million pounds of mature male biomass derived as the mean of 1980-1997. $B_{REF2}$=8.96 million pounds derived mean of 1980-84 plus 1990-97 and is the authors recommendation. The stock demonstrated widely varying levels of mature male biomass as well as prominent instability as reflected by periods of stock collapse. Substantial uncertainty exists in these data and the suitability of these time periods for estimating a proxy for equilibrium stock biomass $B_{MSY}$. Both of these $B_{REF}$ proxies likely underestimate the capacity of this stock to persist at $B_{MSY}$ and provide maximum sustainable yield to the fisheries. It is not obvious that any grouping of years from these data provide a more satisfactory solution to this uncertainty. 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 0.615 million pounds therefore the stock status level is c. For the directed fishery, both $B_{REF1}$ and $B_{REF2}$, the 2007 estimate of MMB is below $\beta$=0.25 $B_{REF}$, therefore F=0 for both scenarios. No directed fishery is permitted and the $F_{OFL}$ for the non-directed catch would be $\leq F_{MSY}$ as determined in the revision to the rebuilding plan.

**Ecosystem Considerations**
***Ecosystem Effects on Stock***
*1) Prey availability/abundance trends*
Blue king crab diet varies with life stage. The four planktonic larval zoeal stages consume phytoplankton and zooplankton, the fifth larval glaucothoe stage is non-feeding, and the early juveniles feed on benthic organisms such as diatoms, protozoa, hydroids, and crab. Juveniles and adults are opportunistic omnivorous scavengers. Based on stomach-content analysis, juvenile crabs consume diatoms, foraminifera, algae, sponge spicules, bryozoans, polychaetes, copepods, and sediment; detritus may also be a major component of their diet (Feder et al. 1980). At age 1+, crabs will eat many different foods, including bivalves, worms, seastars, barnacles, polychaetes, snails, Tanner crab, echinoids, and hydroids (Feder and Jewett 1981). The adult diet includes crustaceans, worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, fish parts, and algae. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. With regards to larval stages, plankton abundance is effected by climatic conditions; strong vertical mixing and an unstable water column associated with a strong Aleutian Low inhibits growth of *Thalassiosira* spp diatoms which provide important nutrients to zoeal king crabs (Zheng and Kruse 2000).

*2) Predator population trends*
During each life stage, crab are consumed by different predators; however, minimal data exists on predation of blue king crab. NMFS stomach analysis records show only 34 stomachs from the EBS that contained blue king crab as prey (NPFMC 2003).
Mean prey weights were as follows:

Pacific cod (2) *Gadus macrocephalus* 303.524 g/crab
Walleye pollock (25) *Theragra chalcogramma* 0.005 g/crab
Yellowfin sole (8) *Pleuronectes asper* 0.007 g/crab

These observations were taken from June to August during the NMFS summer bottom trawl survey for crab and groundfish in the eastern Bering Sea (NPFMC 2003). Additionally, Pacific cod have been observed to feed on molting adult female blue king crabs in February (NPFMC 2003). The size of crabs in stomachs of yellowfin sole and walleye pollock indicates that they prey on larvae and very early juveniles and cod appear to prey on juveniles and adults (NPFMC 2003). Sampling has been limited for blue king crab, but it seems very likely that the same set of species that prey on other king crabs would prey on blue king crab. This would include red king crab predators, such as skates (*Raja* spp), several sculpins (cottidae), northern rock sole (*Lepidopsetta polyxystra*), Alaska plaice (*Pleuronectes quadratuburculatus*), flathead sole (*Hippoglossoides elassodon*) and Pacific halibut (*Hippoglossus stenolepis*), as predators of blue king crabs. Juveniles may additionally fall prey to yellowfin sole (*Limanda aspera*), and arrowtooth flounder (*Atheresthes stomias*), Irish lords (*Hemilepidotus* sp), snailfish (*Liparis* sp.), and octopus (*Enteroctopus dofleini*) (Livingston et al. 1983). As crabs grow older however, they begin to exceed the mouth gape of many of these predators (NPFMC 2003). Juvenile red king crab suffer mortality due to cannibalism by older red king crab and this is likely the case with blue king crab juveniles as well (Stevens and Swiney 2005).

Coincident with the stock decline of Pribilof blue king in the early 1980s, the abundance of cod and flatfishes increased dramatically in the late 1970s and early 1980s and has generally been high ever since; the influx of rock sole in the Pribilof Islands area has been particularly high (NPFMC 2003). A cause and effect relationship between the decline in Pribilof blue king crab stock and the increase in the stocks of groundfish that are predators of and competitors with blue king crab remains speculative, however. Time series analysis of year classes of blue king crab and selected EBS fish stocks (Pacific cod, yellowfin sole, rockfish) have not revealed any correlation between groundfish predation or competition and the decline in blue king crab stocks (Zheng and Kruse 2000).

Mortality is also ascribed to ghost fishing of lost crab pots and groundfish pots. The term ghost fishing describes continued fishing by lost or derelict gear. Crab caught in ghost or lost pots may die of starvation; however, the impact of ghost fishing on crab stocks remains unknown. To reduce starvation mortality in lost pots, crab pots have been required to be fitted with degradable escape mechanisms such as cotton thread or twine since 1977. Pots without escape mechanisms could continue to catch and kill crabs for many years and High and Worlund (1979) estimated an effective fishing life of 15 years for king crab pots. Testimony from crabbers and pot manufacturers indicate that all pots currently fished in Bering Sea crab fisheries contain escape mechanisms (NPFMC 2007).

*3) Changes in habitat quality*

Blue king crab larvae spend three and a half to four months in pelagic larval stages before settling to the benthic life stage. Larvae are found in waters of depths between 40 to 60 m. Release of larvae in the nearshore areas and local current patterns and eddies may increase the chances for settlement and metamorphosis of glaucothoe in the nearshore “shell hash ” (a mixture of broken bivalve and gastropod shells) habitat. However, conditions that would transport larvae away from the nearshore habitat probably occur at least occasionally, and such events would be expected to drastically reduce post-settlement survivorship (Armstrong et al.

1987). Additionally, conditions that affect the production of plankton will impact larval survival. Strong vertical mixing and an unstable water column associated with a strong Aleutian Low inhibit the growth of the *Thalassiosira* spp diatoms that provide important nutrients to zoeal king crabs (Zheng and Kruse 2000). In spring 2007, Bering Sea ice lasted for almost two months just to the north of the Pribilof Islands, contrasting with previous years since 2000 (ADF&G 2008). The presence of sea ice together with below normal ocean temperatures likely resulted in the first ice edge primary production bloom since 1999 (ADF&G 2008). Increased primary production could result in increased prey items for king crab larvae.

Juveniles occur primarily on substratum of gravel and/or cobble overlaid with shell hash (Armstrong et al. 1985). These habitat areas have been found at depths of 40-60 m around the Pribilof Islands and exist within 10-15 km of St. Paul Island and on a narrow ridge just east of St. George Island (Armstrong et al. 1985, 1987). This association suggests a habitat requirement for juvenile blue king crab in the Bering Sea that is limiting to the species' distribution. Shell hash habitat may be important to juveniles as a refuge from predators; juvenile blue king crab lack the long spines present on juvenile red king crabs and may have a greater requirement for the cover afforded by shell hash (Armstrong et al. 1985; 1987; Palacios et al. 1985). Blue king crab juveniles in their first year of life often have white carapaces that blend in with shell hash. Later juvenile stages have a mottled color pattern that blends into the background epifauna. Survival is linked to the abundance of shells of certain mollusk species, including mussels *(Modiolus modiolus),* scallops *(Chlamys sp.),* rock oysters *(Pododesmus macrochisma),* and hairy tritons *(Fusitriton oregonensis)* (Palacios et al. 1985). Such material is scarce in offshore, sandy environments. Over 80 percent of juveniles live at depths < 50 m, and >90 percent live between 0-1°C (Armstrong et al. 1985).

Adult blue king crabs in the Pribilof Islands do not show the same restrictions to the nearshore habitat as juveniles (Palacios et al. 1985, Armstrong et al. 1987). Instead, adults show a seasonal distribution, with a high density in the nearshore areas to the east of St. Paul Island in spring and a more dispersed distribution in the offshore areas in the summer (Armstrong et al. 1987). The spring aggregations indicate a shoreward migration for egg hatching and mating and suggest the importance of the nearshore habitat around St. Paul Island for those purposes (NPFMC 2003). Adult female blue king crab prefer substratum of sandy mud (in 95 percent of samples) with gastropod shells, at depths of 40-80 m (Armstrong et al. 1985). Over 90 percent of legal males and mature females live at depths >50 m (Armstrong et al. 1985). 65 percent of adults live between 2-3°C, the remainder live at temperatures <2°C.
Blue king crab are a cold-adapted species. Bottom temperature in the Pribilof Habitat Conservation Area during EBS summer survey catches of blue king crab range between 1.5 and 7.7 ˚C with an average of 3.08 C (NMFS, unpublished data). Laboratory studies have shown a temperature effect on hatching timing, embryonic development, larval growth and survival (Stevens 2006b). Rising water temperatures could further limit habitat range by increasing competition from the more warm-water adapted red king crab and exclusion by warm-water predators (Somerton 1985, Armstrong et al 1985; 1987). Movement of the cold pool of bottom water northward with warming is thought be causing a reorganization of Bering Sea biogeography (Mueter and Litzow 2008). This is cause for possible concern for Pribilof Islands blue king crab.

The increasing acidification of the oceans' waters may also impact blue king crab at various life stages. Crabs use calcite (a stable form of $CaCO_3$) to harden chitinous exoskeletons and may be exposed to conditions of calcite undersaturation in areas where seawater pH has decreased. Currently, acidification research has only been conducted on larval blue king crab. Preliminary studies have indicated that a decrease in pH of 0.3 to 0.5 units from ambient (7.95) negatively affects growth, survival, and calcium mass (NMFS, unpublished data). However, Nakanishi (1987) found that survival of all zoeal stages was 100 percent at pH values from 6.5 to 8.0, and was very poor at pH values below 6.

*4) Disease*
Blue king crab may contract two potentially fatal diseases including a herpes-type viral disease of the bladder and systemic infections by a microsporidian of the genus *Thelohania* (Sparks and Morado 1985). Prevalence of these diseases during the early 1980s, as well as their general nature, suggests that they could cause considerable mortalities (ADF&G 2003). Although there is a high prevalence of parasitic barnacles (rhizocephalans) identified as *Briarosaccus callosum* in blue king crab populations in southeastern Alaska (Shirley et al 1995; Hawkes et al 1985), there is no record of rhizocephalan infections of blue king crab in the eastern Bering Sea (ADF&G 2003).

***Fishery Effects on the Ecosystem***
1) *Fishery-specific contribution to bycatch of prohibited species, forage (including herring and juvenile pollock), HAPC biota*
There has been no fishery for blue king crab since 1999; however, benthic species that may be caught as bycatch in the crab fishery include fish, gastropods (snails), coral, echinoderms (stars and sea urchin), non-FMP crab, and other invertebrates (sponges, octopus, anemone, and jelly fish). Fish, including a number of crab predators, especially Pacific cod, halibut, yellowfin sole, and sculpin (*Myoxocephalus* spp.) account for the greatest proportion of estimated crab pot bycatch. These species are widely distributed and highly abundant representatives of the greater groundfish community (NPFMC 2003). The fishery does not occur in any areas designated as HAPC (NPFMC 2003).

NMFS Sustainable Fisheries concluded that the effects of the crab fisheries prosecuted under the FMP are not likely to (1) result in the direct take or compete for the prey of the seven large protected whale species, Northern Right Whale (*Balaena glacialis*), Bowhead Whale (*Balaena mysticetus*), Sei Whale (*Balaenoptera borealis*), Blue Whale (*Balaenoptera musculus*), Fin Whale (*Balaenoptera physalus*), Humpback Whale (*Megaptera novaeangliae*), Sperm Whale, (*Physeter acrocephalus*), or the western and eastern population of Steller sea lions (*Eumetopias jubatus*) or (2) destroy or adversely modify designated Steller sea lion critical habitat (ADF&G 2003).

*2) Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components.*
The blue king crab fishery occurred in the area of highest large male abundance, northeast of the Pribilof Islands. The season for the Pribilof Islands blue king crab fisheries opened September 15 and lasted until the GHL was harvested, which was usually about a week. Relative to predator needs in space and time, the fishery targeted large males which are not known to be a common

prey item. Mating occurs in late March through mid-April so the fishery would have had no impact except to reduce the number of mature males available to mate.

3) *Fishery-specific effects on amount of large size target fish.*
The fishery may have had an effect on reducing the amount of large size target crab in the population; however there are no studies conclusive on the fishery being the cause behind the decline in the population.

4) *Fishery-specific contribution to discards and offal production.*
Discards would have consisted of undersized king crabs (NMFS 1995).

5) *Fishery-specific effects on age-at-maturity and fecundity of the target species.*
It is unknown what effect the fishery may have had on age-at-maturity and fecundity. It is probable that the fishery did not affect age-at-maturity but it is possible that the loss of mature male crabs to the fishery could have created an absence of mates for mature female crabs, thus decreasing fecundity.

6) *Fishery-specific effects on EFH non-living substrate (using gear specific fishing effort as a proxy for amount of possible substrate disturbance).*
It is unknown what effect the setting and retrieval of pots from the sea floor has on EFH non-living substrate. Bottom trawls and dredges could disrupt nursery and adult feeding areas (NMFS 1995).

Ecosystem effects on the eastern Bering Sea Tanner crab stocks and fishery effects on the ecosystem are interpreted and evaluated in Table 4.

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Table 1. Legal crab biomass (LBS x $10^6$) landed (directed OA/IFQfishery).

| Year | Landed crab |
|---|---|
| 1980 | 10.98 |
| 1981 | 9.08 |
| 1982 | 4.41 |
| 1983 | 2.19 |
| 1984 | 0.31 |
| 1985 | 0.53 |
| 1986 | 0.26 |
| 1987 | 0.70 |
| 1988 | 0.00 |
| 1989 | 0.00 |
| 1990 | 0.00 |
| 1991 | 0.00 |
| 1992 | 0.00 |
| 1993 | 2.60 |
| 1994 | 1.34 |
| 1995 | 1.27 |
| 1996 | 0.94 |
| 1997 | 0.51 |
| 1998 | 0.52 |
| 1999 | 0.00 |
| 2000 | 0.00 |
| 2001 | 0.00 |
| 2002 | 0.00 |
| 2003 | 0.00 |
| 2004 | 0.00 |
| 2005 | 0.00 |
| 2006 | 0.00 |
| 2007 | 0.00 |

Table 2. Legal blue king crab biomass (LBS x $10^6$) discard/bycatch loss in EBS pot and groundfish fisheries. Groundfish fishery values reported for combined golden king crab and Pribilof Islands blue king crab from 1992 to 2002 (AKRO blend estimate). Catch data from all NOAA Fisheries Bering Sea regulatory and reporting areas except 514, 521, and 524 reported here. 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 | | 0.166 | 0.166 |
| 1993 | | 0.196 | 0.196 |
| 1994 | | 0.124 | 0.124 |
| 1995 | | 0.026 | 0.026 |
| 1996 | | 0.026 | 0.027 |
| 1997 | | 0.043 | 0.043 |
| 1998 | 0.0082 | 0.068 | 0.072 |
| 1999 | 0.0043 | 0.123 | 0.131 |
| 2000 | | 0.040 | 0.040 |
| 2001 | | 0.028 | 0.028 |
| 2002 | | 0.102 | 0.102 |
| 2003 | | 0.002 | 0.002 |
| 2004 | | 0.003 | 0.003 |
| 2005 | 0.0001 | 0.002 | 0.002 |
| 2006 | | 0.004 | 0.004 |
| 2007 | | 0.060 | 0.060 |

Table 3. 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 | 7.46 | 103.00 | 5.63 | 101.00 | 32.63 | 260.14 | 28.00 |
| 1981 | 10.40 | 15.00 | 5.63 | 10.80 | 32.19 | 27.56 | 27.56 |
| 1982 | 4.09 | 9.35 | 3.00 | 8.23 | 16.95 | 20.86 | 14.57 |
| 1983 | 2.73 | 9.36 | 2.19 | 8.87 | 11.51 | 21.32 | 8.66 |
| 1984 | 0.95 | 3.12 | 0.86 | 3.05 | 4.92 | 7.56 | 3.97 |
| 1985 | 0.50 | 0.52 | 0.48 | 0.52 | 2.51 | 1.23 | 1.93 |
| 1986 | 0.47 | 1.89 | 0.45 | 1.85 | 2.84 | 4.72 | 2.80 |
| 1987 | 1.34 | 0.95 | 0.82 | 0.57 | 5.27 | 1.53 | 4.96 |
| 1988 | 1.25 | 1.20 | 0.20 | 0.38 | 1.40 | 0.99 | 1.39 |
| 1989 | 3.32 | 3.57 | 0.42 | 0.95 | 2.02 | 1.81 | 1.59 |
| 1990 | 3.46 | 4.48 | 1.72 | 2.04 | 6.17 | 4.19 | 2.29 |
| 1991 | 3.30 | 3.34 | 2.04 | 2.39 | 8.80 | 4.92 | 5.53 |
| 1992 | 3.67 | 3.32 | 2.24 | 1.65 | 9.17 | 3.28 | 5.51 |
| 1993 | 2.78 | 2.50 | 1.88 | 1.88 | 8.73 | 3.90 | 5.78 |
| 1994 | 1.57 | 4.32 | 1.30 | 3.95 | 6.24 | 8.51 | 4.63 |
| 1995 | 3.95 | 4.47 | 3.18 | 3.80 | 16.49 | 8.27 | 12.74 |
| 1996 | 2.27 | 4.71 | 1.96 | 4.48 | 9.94 | 10.71 | 7.63 |
| 1997 | 1.50 | 2.54 | 1.18 | 2.31 | 6.11 | 5.53 | 4.96 |
| 1998 | 2.09 | 2.35 | 1.31 | 1.74 | 6.75 | 4.12 | 5.45 |
| 1999 | 0.77 | 2.54 | 0.72 | 2.42 | 3.73 | 5.71 | 2.93 |
| 2000 | 0.82 | 1.42 | 0.73 | 1.38 | 4.14 | 3.31 | 3.37 |
| 2001 | 0.56 | 1.62 | 0.54 | 1.61 | 3.17 | 3.84 | 2.78 |
| 2002 | 0.22 | 1.24 | 0.22 | 1.23 | 1.36 | 3.17 | 1.29 |
| 2003 | 0.25 | 1.11 | 0.22 | 1.08 | 1.34 | 2.76 | 1.28 |
| 2004 | 0.15 | 0.12 | 0.07 | 0.10 | 0.29 | 0.29 | 0.11 |
| 2005 | 2.15 | 2.65 | 0.10 | 0.31 | 0.76 | 0.88 | 0.76 |
| 2006 | 0.16 | 0.53 | 0.08 | 0.45 | 0.39 | 1.21 | 0.28 |
| 2007 | 0.36 | 0.27 | 0.17 | 0.20 | 0.76 | 0.55 | 0.41 |

**Table 4. Ecosystem effects on Pribilof blue king crab**

| Indicator | Observation | Interpretation | Evaluation |
|---|---|---|---|
| *Prey availability or abundance trends* | | | |
| Zooplankton, phytoplankton, benthic infauna | Stomach contents, plankton surveys | Stable, though phytoplankton varies inter-annually | Possible concern |
| *Predator population trends* | | | |
| Marine mammals (Sea otters) | Population trends vary by location | Not likely to affect surveyed stock | No concern |
| Birds | NA | NA | No concern |
| Fish (Pollock, Pacific cod, halibut) | Stable | stable | Possible concern |
| *Changes in habitat quality* | | | |
| Temperature regime | Cold-water restricted species so warming trends could limit population | Likely to affect surveyed stock | Definite concern |
| Winter-spring environmental conditions | Affects larval survival | Affects timing of larval release and timing of molt intervals | Definite concern |
| Production | Affects larval survival | Inter-annual variability dependent on a number of climatic conditions | Definite concern |

**Pribilof blue king crab effects on ecosystem**

| Indicator | Observation | Interpretation | Evaluation |
|---|---|---|---|
| *Fishery contribution to bycatch* | | | |
| Prohibited species | Likely minor impact | Minor contribution to mortality | No concern |
| Forage (including herring, Atka mackerel, cod, and pollock) | Likely minor impact | Bycatch levels small relative to forage biomass | No concern |
| HAPC biota | Low bycatch levels of (spp) | Bycatch levels small relative to HAPC biota | No concern |
| Marine mammals and birds | No impact | Safe | No concern |
| Sensitive non-target species | Likely minor impact | Data limited, likely to be safe | No concern |

| | | | |
|---|---|---|---|
| *Fishery concentration in space and time* | Low exploitation rate by predators; possible impact on fecundity | Little detrimental effect on predators; possible impact on fecundity | No concern for predators; possible concern for fecundity |
| *Fishery effects on amount of large size target fish* | High exploitation rate | Natural fluctuation | Definite concern |
| *Fishery contribution to discards and offal production* | unknown | data limited | Possible concern |
| *Fishery effects on age-at-maturity and fecundity* | unknown | NA | Possible concern |

Figure 1. Distribution of blue king crab (*Paralithodes platypus*) in Alaskan waters.

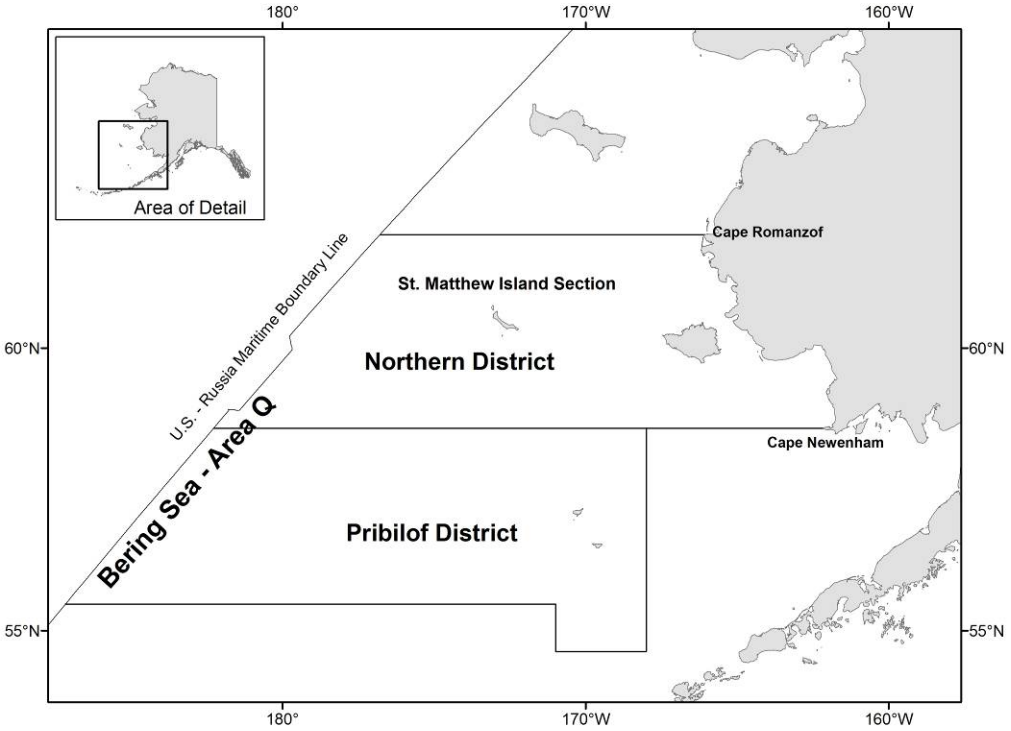


Figure 2. Blue king crab management district.

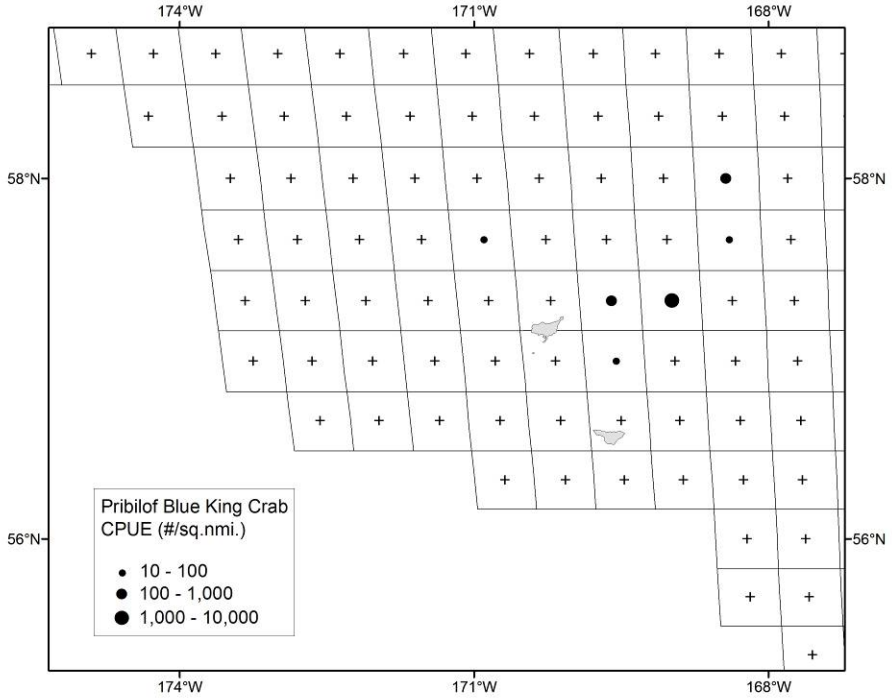


Figure 3. Location of blue king crab populations northeast of Pribilof Islands (2007 NMFS survey data).

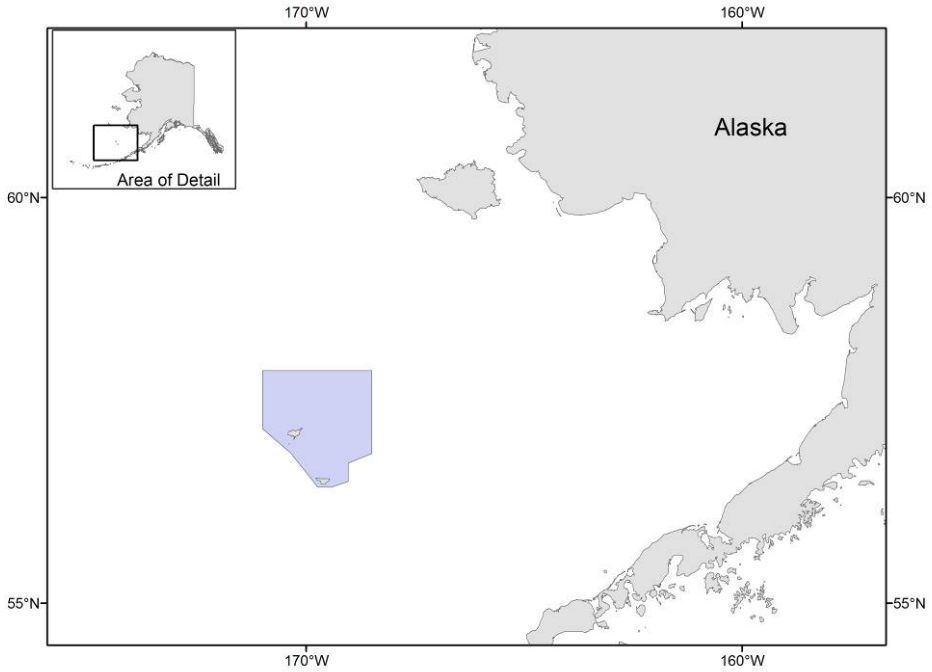


Figure 4. The Pribilof Islands Area Habitat Conservation Zone. Trawl fishing is prohibited year-round in this zone.

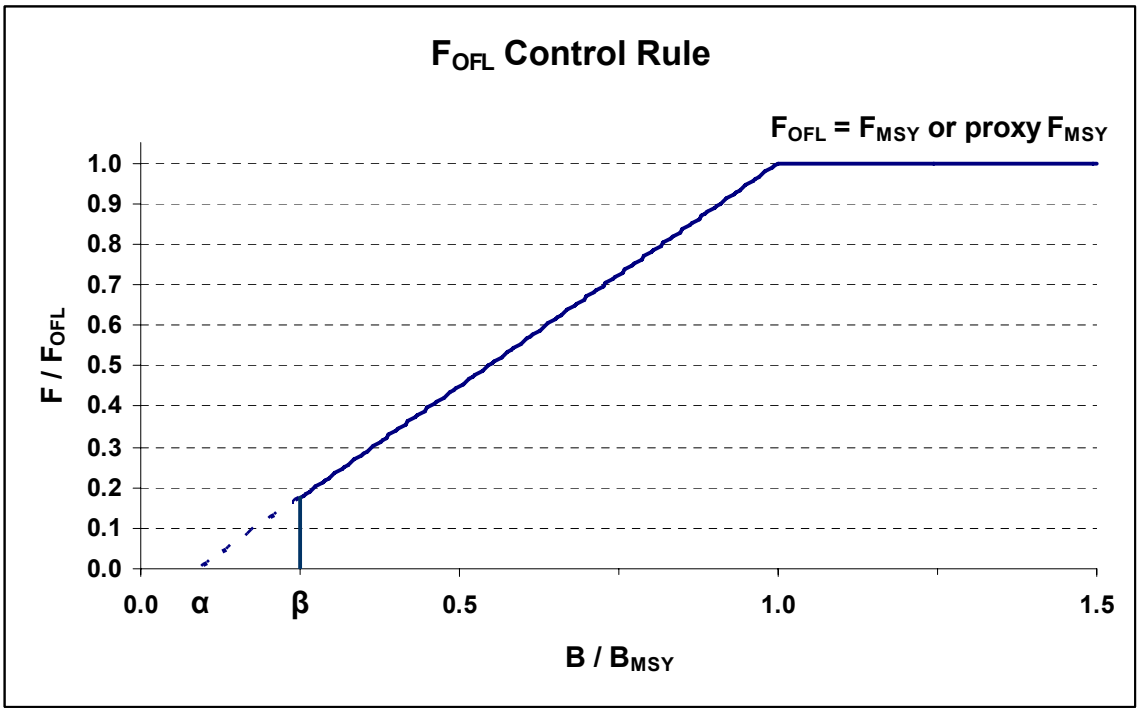


Figure 5. $F_{OFL}$ Control Rule for Tier-4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set 0 below β.