# 2019 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

1. *Stock:* Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus*.
2. *Catches:* Retained catches have not occurred since 1998/1999. Bycatch has been relatively small in recent years. Bycatch mortality in the crab (e.g., Tanner crab, snow crab) fisheries that incidentally take PIBKC was 0.020 t in 2018/19 . Bycatch mortality for PIBKC in

these fisheries was 0.166 t (0.0004 million lbs) in 2015/16, but this was the first non-zero bycatch mortality in the crab fisheries since 2010/11; the 5-year average was 0.020 t. Most bycatch mortality for PIBKC occurs in the BSAI groundfish fixed gear (pot and hook-and-line) fisheries (5-year average: 0.040 t) and trawl fisheries (5-year average: 0.086 t). In 2018/19, the estimated PIBKC bycatch mortality was 0.005 t in the groundfish fixed gear fisheries and 0.385 t in the groundfish trawl fisheries.

3. *Stock biomass:* Stock biomass decreased between the 1995 and 2008 surveys, and continues to fluctuate at low abundances in all size classes. Any short-term trends are questionable given the high uncertainty associated with recent survey results.

4. *Recruitment:* Recruitment indices are not well understood for Pribilof Islands blue king crab. Pre-recruits may not be well-assessed by the survey, but have remained consistently low over the past 10 years.

5. *Management performance:* The stock is below MSST and consequently is overfished. Overfishing did not occur. The following results are based on determining $B_{MSY}$/MSST by averaging the MMB-at-mating time series estimated using the smoothed survey data from a random effects model; the current (2019/20) MMB-at-mating is also based on the smoothed survey data. [Note: MSST changed substantially between 2013/14 and 2014/15 as a result of changes to the NMFS EBS trawl survey dataset used to calculate the proxy $B_{MSY}$. MSST has changed slightly since 2014/15 due to small differences in the random effects model results with the addition of each new year of survey data.]

Table 1: Management performance, all units in metric tons. The OFL is a total catch OFL for each year.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch Mortality | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 2,058 A | 361 A | closed | 0 | 1.18 | 1.16 | 0.87 |
| 2016/17 | 2,053 A | 232 A | closed | 0 | 0.38 | 1.16 | 0.87 |
| 2017/18 | 2,053 A | 230 A | closed | 0 | 0.33 | 1.16 | 0.87 |
| 2018/19 | 2,053 A | 230 A | closed | 0 | 0.41 | 1.16 | 0.87 |
| 2019/20 | -- | 175 B | -- | -- | -- | 1.16 | 0.87 |

Table 2: Management performance, all units in the table are million pounds.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch Mortality | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 4.537 A | 0.796 A | closed | 0 | 0.0026 | 0.0026 | 0.002 |
| 2016/17 | 4.526 A | 0.511 A | closed | 0 | 0.0008 | 0.0026 | 0.002 |
| 2017/18 | 4.526 A | 0.507 A | closed | 0 | 0.0007 | 0.0026 | 0.002 |
| 2018/19 | 4.526 A | 0.507 A | closed | 0 | 0.0009 | 0.0026 | 0.002 |
| 2019/20 | -- | 0.386 B | -- | -- | -- | 0.0026 | 0.002 |

Notes: A – Based on data available to the Crab Plan Team at the time of the assessment following the end of the crab fishing year. B – Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

6. *Basis for the 2019/20 OFL:* The OFL was based on Tier 4 considerations. The ratio of estimated 2016/17 MMB-at-mating to $B_{MSY}$ is less than $\beta$ (0.25) for the $F_{OFL}$ Control Rule, so directed fishing is not allowed. As per the rebuilding plan (NPFMC, 2014a), the OFL is based on a Tier 5 calculation of average bycatch mortalities between 1999/2000 and 2005/2006, which is a time period thought to adequately reflect the conservation needs associated with this stock and to acknowledge existing non-directed catch mortality. Using this approach, the OFL was determined to be 1.16 t for 2019/20. The following results are based on determining $B_{MSY}$/MSST by averaging the MMB-at-mating time series estimated using the smoothed survey data from a random effects model; the current (2019/20) MMB-at-mating is also based on the smoothed survey data.

Table 3: Management performance, all units in metric tons. The OFL is a total catch OFL for each year.

| Year | Tier | $B_{MSY}$ | Current $MMB_{mating}$ | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality | P* |
|---|---|---|---|---|---|---|---|---|
| 2015/16 | 4c | 4,109 | 361 | 0.09 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2016/17 | 4c | 4,116 | 232 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2017/18 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2018/19 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2019/20 | 4c | 4,106 | 175 | 0.04 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |

Table 4: Management performance, all units in the table are million pounds.

| Year | Tier | $B_{MSY}$ | Current $MMB_{mating}$ | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality | P* |
|---|---|---|---|---|---|---|---|---|
| 2015/16 | 4c | 9.06 | 0.795 | 0.09 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2016/17 | 4c | 9.07 | 0.511 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2017/18 | 4c | 9.05 | 0.507 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2018/19 | 4c | 9.05 | 0.507 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2019/20 | 4c | 9.05 | 0.385 | 0.04 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |

7. *Probability density function for the OFL:* Not applicable for this stock.

8. *ABC:* The ABC was calculated using a 25% buffer on the OFL, as in the previous assessments since 2015. The ABC is thus 0.87 t (= 0.25x1.16 t).

9. *Rebuilding analyses results summary:* In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet a rebuilding horizon of 2014. A preliminary assessment model developed by NMFS (not used in this assessment) suggested that rebuilding could occur within 50 years due to random recruitment (NPFMC, 2014a).

Subsequently, Amendment 43 to the King and Tanner Crab Fishery Management Plan (Crab FMP) and Amendment 103 to the Bering Sea and Aleutian Islands Groundfish FMP (BSAI Groundfish FMP) to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. The function of these amendments is to promote bycatch reduction on PIBKC by closing the Pribilof Islands Habitat Conservation Zone to pot fishing for Pacific cod. No pot fishing for Pacific cod occurred within the Pribilof Islands Habitat Conservation Zone in 2015/16.

# A. Summary of Major Changes:

## 1. Management

In 2002, NMFS notified the NPFMC that the PIBKC stock was overfished. A rebuilding plan was implemented in 2003 that included the closure of the stock to directed fishing until the stock was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the Crab FMP and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. Amendment 103 closed the Pribilof Islands Habitat Conservation Zone to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amended the prior rebuilding plan to incorporate new information on the likely rebuilding timeframe for the stock, taking into account environmental conditions and the status and population biology of the stock. No pot fishing for Pacific cod has occurred within the Pribilof Islands Habitat Conservation Zone since 2015/16.

## 2. Input data

Retained and discard catch time series were updated with 2017/18 and 2018/19 data from the crab and groundfish fisheries. Abundance and biomass for PIBKC in the annual summer NMFS EBS bottom trawl survey were updated for the 2018 survey.

## 3. Assessment methodology

With the 2017 assessment, PIBKC was moved to a triennial schedule for full assessments following stock prioritization (CPT, 2017). Thus, only a partial assessment was conducted in 2018 (Stockhausen, 2018). However, the NMFS Alaska Regional Office noted that there was a biennial requirement to review the rebuilding status for PIBKC and that it was sensible to have the assessment and report on the same biennial basis. Consequently, the 2019 assessment is a full assessment. In addition, the timing for the 2019 (and subsequent) full assessment was changed from September to May. This change in timing has required the use of several alternative estimates for quantities used in the assessment model. These include survey MMB in the year of the assessment, as well as retained catch and bycatch quantities in the fishery year prior to the assessment. The NMFS EBS Shelf Survey is typically conducted June-August, so biomass estimates from the survey in the year of the assessment are no longer available and a value projected by the random effects model used to smooth survey MMB is used as a substitute to calculate MMB-at-mating for the assessment year (see Appendix C for more details). Also, the crab fishery year runs (by convention) from July 1 to June 30 so estimates of retained catch in the directed fishery and bycatch in the directed and other fisheries are incomplete at the time of the May assessment. For 2019, the directed fishery was closed and thus there will be no retained catch or bycatch for 2018/19. PIBKC bycatch did occur, though, in the Tanner crab and groundfish fisheries prior to April 1, 2019 when the author accessed in-season bycatch records (Tanner crab: Ben Daly, ADFG, pers. comm.; groundfish fisheries: AKFIN Answers databases). The values for bycatch obtained at this time were used as estimates for the 2018/19 year-end values to determine MMB-at-mating for 2018/19. Although these values are probably underestimates of the final values, given the overall small scale of bycatch in recent years this approximation is likely to have no effect on the determination of "overfished"" status while the determination of "overfishing" will be revisited by the NPFMC Crab Plan Team and Science and Statistical Committee in Septemtber with the end-of-year bycatch numbers for 2018/19.

Otherwise, the methodology is the same as in the 2018/19 assessment. The Tier 4 approach used in this assessment for status determination, based on smoothing the raw survey biomass time series using a random effects model, is identical to that adopted by the CPT and SSC in 2015 and used in the 2015 and 2016 assessments (Stockhausen, 2015, 2016).

### 4. Assessment results

Total catch mortality in 2018/19 was 0.411 t, which did not exceed the OFL (1.16 t). Consequently, overfishing did not occur in 2018/19. The projected MMB-at-mating for 2019/20 decreased slightly from that in 2018/19 but remained below the MSST. Consequently, the stock remains overfished and a directed fishery is prohibited in 2019/20. The OFL, based on average catch, and ABC are identical to last year's values.

## B. Responses to SSC and CPT Comments

### CPT comments September 2015:

*Specific remarks pertinent to this assessment*

Use results from the random effects smoothing model to calculate both $B_{MSY}$ and current $B$ for status determination.

*Responses to CPT Comments:*

Results from the random effects model were used to calculate both $B_{MSY}$ and current $B$ for status determination.

### SSC comments October 2015:

*Specific remarks pertinent to this assessment*

none

**CPT comments May 2016:**

*Specific remarks pertinent to this assessment*

none

**SSC comments June 2016:**

*Specific remarks pertinent to this assessment*

none

**CPT comments September 2017:**

*Specific remarks pertinent to this assessment*

Information regarding the model used for status determination criteria (in Appendix C) should be incorporated into the main assessment section. Additionally, more information should be included in the presentation to the CPT (such as parameter tables and process error) in order to fully evaluate model performance.

*Responses to CPT Comments:*

Information regarding the model used for status determination criteria remains in Appendix C for this assessment. This appendix is produced using an R Markdown script that runs the assessment model and produces the appendix document simultaneously. The main assessment document, previously compsed as a Microsoft Word document, has now been converted to an R Markdown script as well. It may be possible to merge these two documents more fully in the future, but the main assessment document currently contains tables that depend on the results presented in Appendix C and that are formatted in a completely independent step using Microsoft Excel. The two documents can be merged once producing the tables is formulated in R Markdown (a nontrivial task).

As requested, the author will include parameter tables and the estimated process error in his presentation.

**SSC comments October 2017:**

*Specific remarks pertinent to this assessment*

none

**CPT comments May 2018:**

*Specific remarks pertinent to this assessment*

none

### SSC comments June 2018:

*Specific remarks pertinent to this assessment*

none

### CPT comments September 2018:

*Specific remarks pertinent to this assessment*

none

### SSC comments October 2018:

*Specific remarks pertinent to this assessment*

none

# C. Introduction

## 1. Stock

Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus*.

## 2. Distribution

Blue king crab 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 are found in widely-separated populations across the North Pacific (Figure 1). In the western Pacific, blue king crabs occur off Hokkaido in Japan and isolated populations have been observed in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are found in 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, blue king crabs are found in the Gulf of Alaska in widely-separated populations that are frequently associated with fjord-like bays (Figure 1). The 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 (Armstrong et al 1985, 1987; Somerton, 1985).

## 3. Stock structure

Stock structure of blue king crab in the North Pacific is largely unknown. Samples were collected in 2009-2011 by a graduate student at the University of Alaska to support a genetic study on blue king crab population structure. Aspects of blue king crab harvest and abundance trends, phenotypic characteristics, behavior, movement, and genetics will be evaluated by the author following the guidelines in the AFSC report entitled "Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans" by P. Spencer (unpublished report).

The potential for species interactions between blue king crab and red king crab as a potential reason for PIBKC shifts in abundance and distribution were addressed in a previous assessment (Foy, 2013). Foy (2013) compared the spatial extent of both speices in the Pribilof Islands from 1975 to 2009 and found that, in the early 1980's when red king crab first became abundant, blue king crab males and females dominated the 1 to 7 stations where the species co-occurred in the Pribilof Islands District. Spatially, the stations with co-occurance were all dominated by blue king crab and broadly distributed around the Pribilof Islands. In the 1990's, the red king crab population biomass increased substantially as the blue king crab population biomass decreased. During this time period, the number of stations with co-occurance remained around a maximum of 8, but they were equally dominated by both blue king crab and red king crab—sugggesting a direct overlap in distribution at the scale of a survey station. During this time period, the stations dominated by red king crab were dispersed around the Pribilof Islands. Between 2001 and 2009 the blue king crab population decreased dramatically while the red king crab fluctuated. The number of stations dominated by blue king crab in 2001-2009 was similar to that for stations dominated by red king crab for both males and females, suggesting continued competition for similar habitat. The only stations dominated by blue king crab in the latter period are to the north and east of St. Paul Island. Although blue king crab protection measures also afford protection for the red king crab in this region, red king crab stocks continue to fluctuate (more so than simply accounted for by the uncertainty in the survey).

During the years when the fishery was active (1973-1989, 1995-1999), the Pribilof Islands blue king crab (PIBKC) were managed under the Bering Sea king crab Registration Area Q Pribilof District. The southern boundary of this district is formed by 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., while its northern boundary is a line at the latitude of Cape Newenham (58 39' N lat.), its eastern boundary is 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 its western boundary is 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). For assessment purposes, the Pribilof District as defined in Figure 2, with the addition of a 20 nm mile strip to the east of the District (bounded by the dotted red line in Figure 2), is considered to define the stock boundary for PIBKC.

## 4. 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). 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. 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, upon 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 at six years of age (NPFMC 2003). Female size at 50% maturity for Pribilof blue king crab is estimated to be 96-mm carapace length (CL) and size at maturity for males, estimated from chela height relative to CL, is estimated to be 108-mm CL (Somerton and MacIntosh 1983). Skip molting occurs with increasing probability for those males larger than 100 mm CL (NMFS 2005).

Longevity is unknown for this 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 $yr^{-1}$ for all king crab species was adopted in the federal crab fishery management plan for the BSAI areas (Siddeek et al. 2002). A rate of 0.18 $yr^{-1}$ is currently used for PIBKC.

## 5. Management history

The blue king crab fishery in the Pribilof District began in 1973 with a reported catch of 590 t by eight vessels (Table 9; Figure 3). Landings increased during the 1970s and peaked at a harvest of 5,000 t in the 1980/81 season (Table 9; Figure 3), with an associated increase in effort to 110 vessels (ADFG 2008). The fishery occurred September through January, but usually lasted less than 6 weeks (Otto and Cummiskey 1990; ADFG 2008). The fishery was male only, and legal size was >16.5 cm carapace width (NPFMC 1994). Guideline harvest levels (GHL) were 10 percent of the abundance of mature males or 20 percent of the number of legal males (ADFG 2006).

PIBKC have occurred as bycatch in the eastern Bering Sea snow crab (*Chionoecetes opilio*) fishery, the western Bering Sea Tanner crab (*Chionoecetes bairdi*) fishery, the Bering Sea hair crab (*Erimacrus isenbeckii*) fishery, and the Pribilof red and blue king crab fisheries (Tables 10 and 11). In addition, blue king crab have been taken as bycatch in groundfish fisheries by both fixed and trawl gear, primarily those targeting Pacific cod, flathead sole and yellowfin sole (Tables 10-12).

Amendment 21a to the BSAI Groundfish FMP prohibits the use of trawl gear in the Pribilof Islands Habitat Conservation Area (subsequently renamed the Pribilof Islands Habitat Conservation Zone in Amendment 43; Figure 4), which the amendment also established (NPFMC 1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from the impact from trawl gear.

Declines in the PIBKC stock after 1995 resulted in a closure of directed fishing from 1999 to the present. The stock was declared overfished in September 2002, and ADFG developed a rebuilding harvest strategy as part of the NPFMC comprehensive rebuilding plan for the stock. The rebuilding plan also included the closure of the stock to directed fishing until it was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the King and Tanner Crab Fishery Management Plan (FMP) and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. Amendment 103 closes the Pribilof Islands Habitat Conservation Zone (Figure 4) to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amends the prior rebuilding plan to incorporate new information on the likely rebuilding timeframe for the stock, taking into account environmental conditions and the status and population biology of the stock (NPFMC 2014a).

# D. Data

## 1. Summary of new information

The time series of retained and discarded catch in the crab fisheries was updated for 2018/19 from ADFG data (no retained catch, no bycatch mortality; Tables 10 and 11). The time series of discards in the groundfish pot and trawl fisheries (Tables 10 and 11) were updated for 2009/10 -2018/19 using NMFS Alaska Regional Office (AKRO) estimates obtained from the AKFIN database (as updated on April 1, 2019). Results from the 2018 NMFS EBS bottom trawl survey were added to the assessment (Tables 15 and 16), based on the "new" standardization described in the 2015 assessment (Stockhausen, 2015).

## 2. Fishery data

### 2.a. Retained catch

Retained pot fishery catches (live and deadloss landings data) are provided for 1973/74 to 2015/16 (Table 9, Figure 3), including the 1973/74 to 1987/88 and 1995/96 to 1998/99 seasons when blue king crab were targeted in the Pribilof Islands District. In the 1995/96 to 1998/99 seasons, blue king crab and red king crab were fished under the same Guideline Harvest Level (GHL). Total allowable catch (TAC) for a directed fishery has been set at zero since 1999/2000; there was no retained catch in the 2018/19 crab fishing season.

### 2.b. Bycatch and discards:

*Crab pot fisheries*

Non-retained (directed and non-directed) pot fishery catches are provided for sublegal males ($<$ 138 mm CL), legal males ($\geq$ 138 mm CL), and females based on data collected by onboard observers in the crab fisheries (Table 10). Catch weight was calculated by first determining the mean weight (in grams) for crabs in each of three categories: legal non-retained, sublegal, and female. The average weight for each category was then calculated from length frequency tables, where the carapace length ($z$; in mm) was converted to weight ($w$; in g) using the following equation:

$$w = \alpha \cdot z^{\beta} \tag{1}$$

Values for the length-to-weight conversion parameters $\alpha$ and $\beta$ were applied across the time period: males) $\alpha$=0.000508, $\beta$=3.106409; females) $\alpha$=0.02065, $\beta$=2.27 (Daly et al. 2014). Average weights ($\overline{W}$) for each category were calculated using the following equation:

$$\overline{W} = \frac{\sum w_z \cdot n_z}{\sum n_z} \tag{2}$$

where $w_z$ is crab weight-at-size $z$ (i.e., carapace length) using Equation 1, and $n_z$ is the number of crabs observed at that size in the category. Finally, estimated total non-retained weights for each crab fishery were the product of average weight ($\overline{W}$), CPUE based on observer data, and total effort (pot lifts) in each fishery.

Historical non-retained catch data are available from 1996/97 to present from the snow crab general, snow crab CDQ, and Tanner crab fisheries (Table 10, Bowers et al. 2011), although data may be incomplete for some of these fisheries. Prior to 1998/99, limited observer data exists (for catcher-processor vessels only), so non-retained catch before this date is not included here. For this assessment, a 20% handling mortality rate was applied to the bycatch estimates to calculate non-retained crab mortality in these pot fisheries (Table 11). In assessments priot to 2017, a handling mortality rate of 50% was applied to bycatch in the pot fisheries. The revised value used here is now consistent with the rates used in other king crab assessments (e.g., Zheng et al., 2016).

Bycatch mortality in the crab fisheries in 2018/19 consisted of 1 observed sublegal male, amounting to 0.020 t in expanded mortality.

*Groundfish fisheries*

The AKRO estimates of non-retained catch from all groundfish fisheries in 2018/19, as available through the AKFIN database (accessed Aug. 30, 2019), are included in this report (Tables 10-12). Updated estimates for 2009/10-2018/19 were obtained through the AKFIN database.

Groundfish bycatch data from before 1999 are available only in INPFC reports and are not included in this assessment. Non-retained crab catch data in the groundfish fisheries are available from 1991/92 to present. Between 1991 and December 2001, bycatch was estimated using the "blend method." From January 2003 to December 2007, bycatch was estimated using the Catch Accounting System (CAS), based on substantially different methods than the "blend." Starting in January 2008, the groundfish observer program changed the method in which they speciate crab to better reflect their hierarchal sampling method and to account for broken crab that in the past were only identified to genus. In addition, the haul-level weights collected by observers were used to estimate the crab weights through CAS instead of applying an annual (global) weight factor to convert numbers to biomass. Spatial resolution was at the NMFS statistical area. Beginning in January 2009, ADFG statistical areas ($1^o$ longitude x $0.5^o$ latitude) were included in groundfish production reports and allowed an increase in the spatial resolution of bycatch estimates from the NMFS statistical areas to the state statistical areas. Bycatch estimates (2009-present) based on the state statistical areas were first provided in the 2013 assessment, and improved methods for aggregating observer data were used in the 2014 and 2015 assessments (see Stockhausen, 2015). The estimates obtained this year are based on the same methods as those used in the 2014-2016 assessments. Detailed results from this process are presented in Appendix A.

To assess crab mortalities in the groundfish fisheries, an 80% handling mortality rate was applied to estimates of bycatch in trawl fisheries, and a 20% handling mortality rate was applied to fixed gear fisheries using pot and hook and line gear (Tables 10-11).

In 2018/19, fisheries targeting yellowfin sole (*Limanda aspera*) accounted for 95% of the bycatch of PIBKC in the groundfish fisheries, with fisheries targeting Pacific cod (*Gadus microcephalus*) accounting for 5%. In contrast, fisheries targeting flathead sole (*Hippoglossoides elassodon*) and northern rock sole (*Lepidopsetta polyxystra*) accounted for 60% and 68% in 2017/18 and 2016/17 respectively (Table 12).

Since the 2009/10 crab fishing season, Pribilof Islands blue king crab have been taken as bycatch in the groundfish fisheries only by hook and line and non-pelagic trawl gear (Table 13). Starting in 2015, as a consequence of Amendment 43 to the BSAI Groundfish FMP, the Pribilof Islands Habitat Conservation Area was formally closed to pot fishing for Pacific cod in order to promote recovery of the PIBKC stock. In 2018/19, non-pelagic trawl gear was estimated to account for 95% (by weight) of PIBKC bycatch in the groundfish fisheries. In 2015/16, by contrast, non-pelagic trawl gear accounted for only 52% the bycatch. In 2018/19, hook-and-line gear accounted for only 5% of PIBKC bycatch in the groundfish fisheries, although in 2013/14 and 2014/15 this gear type accounted for the total bycatch of PIBKC. Although these appear to be large interannual changes, the actual bycatch amounts involved are fairly small and interannual variability is consequently expected to be rather high.

### 2.c. Catch-at-length

Not applicable.

## 3. Survey data

The 2018 NMFS EBS bottom trawl survey was conducted in June and July. Survey results for PIBKC are based on the stock area first defined in the 2013 assessment (Foy, 2013), which includes the Pribilof District and a 20 nm strip adjacent to the eastern edge of the District (Figure 2). The adjacent area was defined as a result of the new rebuilding plan and the concern that crab outside the Pribilof District were not being accounted for in the assessment.

In 2018, the survey caught 16 blue king crab in 86 stations across the stock area, while 28, 33, and 23 crab were caught across the same stations in the 2015-2017 surveys, respectively (Table 14). Six immature males were caught in 2018, similar to numbers caught in 2015-2017 (4, 5 and 4, respectively). Three mature males (all legal size) were caught in 2018, compared with 13, 3 and 4 in 2015-2017, respectively. One immature female was caught in 2018; none were caught in 2015, while five were caught in 2016 and seven in 2017. Finally, six mature females were caught in 2018, compared with 11 in 2015, 19 in 2016,and 8 in 2017.

The area-swept estimate of mature male abundance in the stock area at the time of the 2018 survey was 56 thousand crab (cv: 0.56), representing a decrease from 91 thousand crab (cv: 0.50) in 2017 (Table 15). The abundance estimate for immature males in 2018 was 110 thousand crab (cv: 0.57), while it was 68 thousand in 2017. The area-swept estimate for immature female abundance in 2018 was 76 thousand crab (cv: 0.59), smaller than the 188 thousand crab (cv: 0.75) in 2017, while that for mature females was only 58 thousand crab (cv: 1.0), smaller than that of 162 thousand (cv:

0.53) in 2017. Given the large uncertainties associated with the estimates, none of the changes were statistically significant.

The area-swept estimate of mature male biomass in the stock area at the time of the 2018 survey was 154 t (cv: 0.57), while it was 253 t (cv: 0.51) in 2017 (Table 16). The biomass estimate for immature males in 2018 was 96 t (cv: 0.54), compared to 45 t (cv: 0.77) in 2017. The area-swept estimate for immature female biomass in 2018 was 45 t (cv: 0.58); in 2017 it was 107 t (cv: 0.81). For mature females, the estimated swept-area biomass was 76 t (cv: 1.00) ; in 2018 it was 152 t (cv: 0.56).

One feature that characterizes survey-based estimates of abundance and biomass for PIBKC is the large uncertainty (cv's on the order of 0.5-1) associated with the estimates, which complicates the interpretation of sometimes large interannual swings in estimates (Tables 15 and 16, Figures 5-8). Estimated total abundance of male PIBKC from the NMFS EBS bottom trawl survey declined from ~24 million crab in 1975, the first year of the "standardized" survey, to ~150,000 in 2016 (the lowest estimated abundance since 2004, which was the minimum for the time series; Table 15, Figures 5 and 6). Following a general decline to a low-point in 1985 (~500,000 males), abundance increased by a factor of 10 in the early 1990s, then generally declined (with small amplitude oscillations superimposed) to the present. Estimated female abundance generally followed a similar trend. It spiked at 180 million crab in 1980, from ~13 million crab in 1975 and only ~1 million in 1979, then returned to more typical levels in 1981 (~6 million crab). More recently, abundance has fluctuated around 200,000 females. Estimated biomass for both males and females have followed trends similar to those in abundance (Table 16, Figures 7 and 8).

Size frequencies for males by shell condition from recent surveys (2015-2018) are illustrated in Figure 9. Size frequencies for all males across the time series are shown in Figure 10. While Figure 10 suggested a recent trend toward larger sizes in 2014-15, this does not appear to have continued in 2016. These plots provide little evidence of recent recruitment.

Size frequencies for females by shell condition are presented in Figure 11 from recent surveys (2015-2018). Size frequencies for all females are shown in 12. These also provide little indication of recent recruitment.

The small numbers of crab caught in recent surveys make it difficult to draw firm conclusions regarding spatial patterns (see figures in Appendix B). That said, the spatial pattern of PIBKC abundance in recent surveys is generally centered fairly compactly within the Pribilof District to the east of St. Paul Island (although 2015 is an exception) and north of St. George Island, within a 60 nm radius of St. Paul.

# E. Analytic Approach

## 1. History of modeling approaches

A catch survey analysis has been used for assessing the stock in the past, although it is not currently in use. In October 2013, the SSC concurred with the CPT that the PIBKC stock falls under Tier 4 for status determination but it recommended that the OFL be calculated using a Tier 5 approach, with ABC based on a 10% buffer. Subsequently, a 25% buffer has been used to calculate ABC.

In the 2013 and 2014 assessments (Foy 2013; Stockhausen 2014), "current" MMB-at-mating was projected from the time of the latest survey using an inverse-variance averaging approach to smoothing annual survey biomass estimates because the uncertainties associated with the annual estimates are extremely large. In the 2015 assessment (Stockhausen, 2015), an alternative approach to smoothing based on a Random Effects model was presented and subsequently adopted by the CPT and SSC to use in estimating $B_{MSY}$ and "current" MMB-at-mating. The Random Effects model (Appendix C) is used in this assessment.

Since the 2017 assessment, assessments for PIBKC have been moved to an odd-year biennial schedule. The timing of the assessment was also moved from September to May, which has required that several data inputs to the model (assessment year MMB at the time of the survey and retained catch and bycatch values from the crab fishery year prior to the assessment year) be estimated in some fashion. For this (2019) assessment, MMB at the time of survey (July, 2019) was estimated from the observed time series using the random effects as a 1-step ahead prediction–i.e., it is the same value as that from the 2018 survey. The values of year-to-date bycatch in the crab and groundfish fisheries on April 1, 2019 were taken as estimates of the 2018/19 year-end values. Because the directed fishery was closed, retained catch and bycatch in the directed fishery would necessarily be zero.

### 2. Model Description

See Appendix C.

### 3. Model Selection and Evaluation

Not applicable

### 4. Results

See Appendix C.

## F. Calculation of the OFL

### 1. Tier Level:

Based on available data, the author recommended classification for this stock is Tier 4 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 2008a).

In Tier 4, stock status is based on the ratio of "current" spawning stock biomass ($B$) to $B_{MSY}$ (or a proxy thereof, $B_{MSY_{proxy}}$, also referred to as $B_{REF}$). MSY (maximum sustained 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. The fishing mortality that, if applied over the long-term, would result in MSY is $F_{MSY}$. $B_{MSY}$ is the long-term average stock size when fished at FMSY, and is based on mature male biomass at the time of 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. Although $B_{MSY}$

cannot be calculated for a Tier 4 stock, a proxy value ($B_{MSY_{proxy}}$ or $B_{REF}$) is defined as the average biomass over a specified time period that satisfies the conditions under which $B_{MSY}$ would occur (i.e., equilibrium biomass yielding MSY under an applied $F_{MSY}$).

The time period for establishing $B_{MSY_{proxy}}$ is assumed to be representative of the stock being fished at an average rate near $F_{MSY}$ and fluctuating around $B_{MSY}$. The SSC has endorsed using the time periods 1980-84 and 1990-97 to calculate $B_{MSY_{proxy}}$ for Pribilof Islands blue king crab to avoid time periods of low abundance possibly caused by high fishing pressure. Alternative time periods (e.g., 1975 to 1979) have also been considered but rejected (Foy 2013). Considerations for choosing the current time periods included:

### A. Production potential

1) Between 2006 and 2013 the stock appeared to be below a threshold for responding to increased production based on the lack of response of the adult stock biomass to slight fluctuations in recruitment (male crab 120-134 mm) (Figure 20 in Foy 2013).

2) An estimate of surplus production using the equation

$$ASP_t = MMB_{t+1} - MMB_t + C_t$$

where $C_t$ denotes total catch mortality in year $t$ suggested that meaningful surplus production existed only in the late 1970s and early 1980s while minor surplus production in the early 1990s may have led to the increases in biomass observed in the late 1990s.

3) Although climate regime shifts where temperature and current patterns change are likely to impact blue king crab larval dispersal and subsequent juvenile crab distribution, no apparent trends in production before or after 1978 were observed (Foy 2013). There are few empirical data to identify trends that may indicate a production shift.

### B. Exploitation rates

Exploitation rates fluctuated during the open fishery periods from 1975 to 1987 and 1995 to 1998 (Figure 20 in Foy 2013) while total catch increased until 1980, then decreased until the fishery was closed in 1987 (Figure 3). Following the re-opening of the fishery in 1995, total catch declined annually until the fishery was closed again in 1999 (Figure 3). The current $F_{MSY_{proxy}} = M$ is 0.18 $yr^{-1}$, so time periods with greater exploitation rates should not be considered to represent periods with average rates of fishery removals.

### C. Recruitment

Subsequent to increases in exploitation rates in the late 1980s and 1990s, the quantity ln(recruits/MMB) dropped, suggesting that exploitation rates at the levels of $F_{MSY_{proxy}} = M$ were not sustainable.

$MMB_{mating}$ is the basis for calculating $B_{MSY_{proxy}}$. The formulas used to calculate $MMB_{mating}$ from MMB at the time of the survey ($MMB_{survey}$) are documented in Appendix C. For this stock,

$B_{MSY_{proxy}}$ was calculated using the random effects model-smoothed estimates for $MMB_{survey}$ from the survey time series (Table 17) in the formula for $MMB_{mating}$. $B_{MSY_{proxy}}$ is the average of $MMB_{mating}$ for the years 1980/81-1984/85 and 1990/91-1997/98 (Table 18) and was calculated as 4106 t.

In this assessment, "current B" ($B$) is the $MMB_{mating}$ projected for 2019/20. Details of this calculation are also provided in Appendix C. For 2019/20, $B$ = 175 t.

Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, $F_{OFL}$, which would result in a total catch greater than the OFL. For Tier 4 stocks, a minimum stock size threshold (MSST) is specified as $0.5 \cdot B_{MSY_{proxy}}$. If $B$ drops below the MSST, the stock is considered to be overfished.

## 2. Parameters and stock sizes

- $B_{MSY_{proxy}}$ ($B_{REF}$) = 4106 t
- $M = 0.18\ yr^{-1}$
- $B$ = 175 t

## 3. OFL specification

### 3.a. Stock status level

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 Tier 4 $F_{OFL}$ is derived using the $F_{OFL}$ Control Rule (Figure 13), where the Stock Status Level (level a, b or c; equations 3-5) is based on the relationship of $B$ to $B_{MSY_{proxy}}$.

Stock Status Level $F_{OFL}$

$$a. \quad B/B_{MSY_{proxy}} > 1.0 \quad F_{OFL} = \gamma \cdot M \tag{3}$$

$$b. \quad \beta < B/B_{MSY_{proxy}} \leq 1.0 \quad F_{OFL} = \gamma \cdot M[(B/B_{MSY_{proxy}} - \alpha)/(1-\alpha)] \tag{4}$$

$$c. \quad B/B_{MSY_{proxy}} \leq \beta \quad F_{directed} = 0, \quad F_{OFL} \leq F_{MSY} \tag{5}$$

When B/$B_{MSY_{proxy}}$ is greater than 1 (Stock Status Level a), $F_{OFL_{proxy}}$ is given by the product of a scalar ($\gamma$=1.0, nominally) and $M$. When $B/B_{MSY_{proxy}}$ is less than 1 and greater than the critical threshold $\beta$ (=0.25) (Stock Status Level b), the scalar $\alpha$ (= 0.1) determines the slope of the non-constant portion of the control rule for $F_{OFL_{proxy}}$. Directed fishing mortality is set to zero when the ratio $B/B_{MSY_{proxy}}$ drops below $\beta$ (Stock Status Level c). Values for $\alpha$ and $\beta$ are based on a sensitivity analysis of the effects on $B/B_{MSY_{proxy}}$ (NPFMC 2008a).

### 3.b. Basis for MMB-at-mating

The basis for projecting MMB from the survey to the time of mating is discussed in detail in Appendix C.

### 3.c. Specification of $F_{OFL}$, OFL and other applicable measures

Table 5: Basis for the OFL (Table 3 repeated). All units in metric tons.

| Year | Tier | $B_{MSY}$ | Current $MMB_{mating}$ | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality | P* |
|---|---|---|---|---|---|---|---|---|
| 2015/16 | 4c | 4,109 | 361 | 0.09 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2016/17 | 4c | 4,116 | 232 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2017/18 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2018/19 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2019/20 | 4c | 4,106 | 175 | 0.04 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |

Table 6: Basis for the OFL (Table 4 repeated). All units in millions lbs.

| Year | Tier | $B_{MSY}$ | Current $MMB_{mating}$ | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality | P* |
|---|---|---|---|---|---|---|---|---|
| 2015/16 | 4c | 9.06 | 0.795 | 0.09 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2016/17 | 4c | 9.07 | 0.511 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2017/18 | 4c | 9.05 | 0.507 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2018/19 | 4c | 9.05 | 0.507 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2019/20 | 4c | 9.05 | 0.385 | 0.04 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |

## 4. Specification of the retained catch portion of the total catch OFL

The retained portion of the catch for this stock is zero (0 t).

## 5. Recommendations:

**For 2019/20, $B_{MSY_{proxy}} = 4106$ t, derived as the mean $MMB_{mating}$ from 1980/81 to 1984/85 and 1990/91 to 1997/98 using the random effects model-smoothed survey time series.** The stock demonstrated highly variable levels of MMB during both of these periods, likely leading to uncertain approximations for $B_{MSY}$. Crabs were highly concentrated during the

EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to limited numbers of tows with crab catches.

$MMB_{mating}$ for 2019/20 was estimated at 175 t. The $B/B_{MSY_{proxy}}$ ratio corresponding to the biomass reference is 0.06. $B/B_{MSY_{proxy}}$ is $< \beta$, therefore the stock status level is c, $F_{directed} = 0$, and $F_{OFL} \leq F_{MSY}$ (as determined in the Pribilof Islands District blue king crab rebuilding plan). Total catch OFL calculations were explored in 2008 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality (NPFMC 2008a). The preferred method was a total catch OFL equivalent to the average catch mortalities between 1999/2000 and 2005/06. This period was after the targeted fishery was closed and did not include recent changes to the groundfish fishery that led to increased blue king crab bycatch. The OFL for 2019/20, based on an average catch mortality, is 1.16 t.

## G. Calculation of the ABC

To calculate an Annual Catch Limit (ACL) to account for scientific uncertainty in the OFL, an acceptable biological catch (ABC) control rule was developed such that ACL=ABC. For Tier 3 and 4 stocks, the ABC is set below the OFL by a proportion based a predetermined probability that the ABC would exceed the OFL (P*). Currently, P* is set at 0.49 and represents a proportion of the OFL distribution that accounts for within assessment uncertainty ($\sigma_w$) in the OFL to establish the maximum permissible ABC ($ABC_{max}$). Any additional uncertainty to account for uncertainty outside of the assessment methods ($\sigma_b$) is considered as a recommended ABC below $ABC_{max}$. Additional uncertainty is included in the application of the ABC by adding the uncertainty components as $\sigma_{total} = \sqrt{\sigma_w^2 + \sigma_b^2}$. For the PIBKC stock, the CPT has recommended, and the SSC has approved, a constant buffer of 25% to the OFL (NPFMC, 2014b).

### 1. Specification of the probability distribution of the OFL used in the ABC

The OFL was set based on a Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/06 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality. As such, the OFL does not have an associated probability distribution.

### 2. List of variables related to scientific uncertainty considered in the OFL probability distribution

None. The OFL is based on a Tier 5 calculation and does not have an associated probability distribution. However, compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands blue king crab is very high due to insufficient data and the small spatial extent of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass from the surveys for the most recent year (2018) is 0.5710464, and has ranged between 0.17 and 1.00 since the 1980 peak in biomass.

## 3. List of additional uncertainties considered for alternative $\sigma_b$ 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 rather are pre-specified.
- $F_{MSY}$ is assumed to be equal to $\gamma \cdot M$ when applying the OFL control rule, where the proportionality constant $\gamma$ is assumed to be equal to 1 and $M$ is assumed to be known.
- 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. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1973-1987 and 1995-1998 so considerable uncertainty exists with this estimate of $B_{MSY}$.

## 4. Recommendations:

For 2019/20, $F_{directed} = 0$ and the total catch OFL is based on catch biomass would maintain the conservation needs with this stock and acknowledge the existing non-directed catch mortality. In this case, the $ABC$ based on a 25% buffer of the average catch between 1999/2000 and 2005/2006 would be 0.87 t.

Table 7: Management performance (Table). All units in metric tons. The OFL is a total catch OFL for each year.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch Mortality | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 2,058 A | 361 A | closed | 0 | 1.18 | 1.16 | 0.87 |
| 2016/17 | 2,053 A | 232 A | closed | 0 | 0.38 | 1.16 | 0.87 |
| 2017/18 | 2,053 A | 230 A | closed | 0 | 0.33 | 1.16 | 0.87 |
| 2018/19 | 2,053 A | 230 A | closed | 0 | 0.41 | 1.16 | 0.87 |
| 2019/20 | -- | 175 B | -- | -- | -- | 1.16 | 0.87 |

Notes:

A – Based on data available to the Crab Plan Team at the time of the assessment following the end of the crab fishing year.

B – Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

Table 8: Management performance (Table 2 repeated). All units in the table are million pounds.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch Mortality | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 4.537 A | 0.796 A | closed | 0 | 0.0026 | 0.0026 | 0.002 |
| 2016/17 | 4.526 A | 0.511 A | closed | 0 | 0.0008 | 0.0026 | 0.002 |
| 2017/18 | 4.526 A | 0.507 A | closed | 0 | 0.0007 | 0.0026 | 0.002 |
| 2018/19 | 4.526 A | 0.507 A | closed | 0 | 0.0009 | 0.0026 | 0.002 |
| 2019/20 | -- | 0.386 B | -- | -- | -- | 0.0026 | 0.002 |

## H. Rebuilding Analyses

Rebuilding analyses results summary: A revised rebuilding plan analysis was submitted to the U.S. Secretary of Commerce in 2014 because NMFS determined that the stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. The Secretary approved the plan in 2015, as well as the two amendments that implement it (Amendment 43 to the King and Tanner Crab Fishery Management Plan and Amendment 103 to the BSAI Groundfish Fishery Management Plan). These amendments impose a closure to all fishing for Pacific cod with pot gear in the Pribilof Islands Habitat Conservation Zone. This measure was designed to protect the main concentration of the stock from the fishery with the highest observed rates of bycatch (NPFMC, 2014a). The area has been closed to trawling since 1995.

## I. Data Gaps and Research Priorities

Given the large CVs associated with the survey abundance and biomass estimates for the Pribilof Islands blue king crab stock, assessment of this species might benefit from additional surveys using alternative gear at finer spatial resolution. Jared Weems, a PhD student at University of Alaska, Fairbanks, is conducting research on alternative survey designs, including visual censuses, drop camera, and collector traps to better quantify PIBKC in a study funded by NPRB. Other data gaps include stock-specific natural mortality rates and a lack of understanding regarding processes apparently preventing successful recruitment to the Pribilof District. Jonathan Reum (AFSC) and colleagues are developing a qualitative network model that described important biological interactions that may influence the productivity of PIBKC. The purpose is to explore the potential efficacy of different management interventions that include new policies on fisheries that target the predators/competitors of PIBKC, as well as out-stocking of benthic PIBKC juveniles assuming implementation of a hatchery program.

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## Tables

Table 9: Total retained catches from directed fisheries for Pribilof Islands District blue king crab (Bowers et al. 2011; D. Pengilly and J. Webb, ADFG, personal communications).

| Year | Retained Catch | | Avg. CPUE |
|---|---|---|---|
| | Abundance | Biomass (t) | legal crabs/pot |
| 1973/1974 | 174,420 | 579 | 26 |
| 1974/1975 | 908,072 | 3,224 | 20 |
| 1975/1976 | 314,931 | 1,104 | 19 |
| 1976/1977 | 855,505 | 2,999 | 12 |
| 1977/1978 | 807,092 | 2,929 | 8 |
| 1978/1979 | 797,364 | 2,901 | 8 |
| 1979/1980 | 815,557 | 2,719 | 10 |
| 1980/1981 | 1,497,101 | 4,976 | 9 |
| 1981/1982 | 1,202,499 | 4,119 | 7 |
| 1982/1983 | 587,908 | 1,998 | 5 |
| 1983/1984 | 276,364 | 995 | 3 |
| 1984/1985 | 40,427 | 139 | 3 |
| 1985/1986 | 76,945 | 240 | 3 |
| 1986/1987 | 36,988 | 117 | 2 |
| 1987/1988 | 95,130 | 318 | 2 |
| 1988/1989 | 0 | 0 | -- |
| 1989/1990 | 0 | 0 | -- |
| 1990/1991 | 0 | 0 | -- |
| 1991/1992 | 0 | 0 | -- |
| 1992/1993 | 0 | 0 | -- |
| 1993/1994 | 0 | 0 | -- |
| 1994/1995 | 0 | 0 | -- |
| 1995/1996 | 190,951 | 628 | 5 |
| 1996/1997 | 127,712 | 425 | 4 |
| 1997/1998 | 68,603 | 232 | 3 |
| 1998/1999 | 68,419 | 234 | 3 |
| 1999/2000 - 2018/2019 | 0 | 0 | -- |

Table 10: Total bycatch (non-retained catch) from the directed and non-directed fisheries for Pribilof Islands District blue king crab. Crab fishery bycatch data is not available prior to 1996/1997 (Bowers et al. 2011; D. Pengilly ADFG). Gear-specific groundfish fishery data is not available prior to 1991/1992 (J. Mondragon, NMFS).

| fishery year | crab (pot) fisheries (t) | | | groundfish fisheries (t) | |
|---|---|---|---|---|---|
| | females | legal males | sublegal males | fixed gear | trawl gear |
| 1991/92 | -- | -- | -- | 0.067 | 6.199 |
| 1992/93 | -- | -- | -- | 0.879 | 60.791 |
| 1993/94 | -- | -- | -- | 0.000 | 34.232 |
| 1994/95 | -- | -- | -- | 0.035 | 6.856 |
| 1995/96 | -- | -- | -- | 0.108 | 1.284 |
| 1996/97 | 0.000 | 0.000 | 0.807 | 0.031 | 0.067 |
| 1997/98 | 0.000 | 0.000 | 0.000 | 1.462 | 0.130 |
| 1998/99 | 3.715 | 2.295 | 0.467 | 19.800 | 0.079 |
| 1999/00 | 1.969 | 3.493 | 4.291 | 0.795 | 0.020 |
| 2000/01 | 0.000 | 0.000 | 0.000 | 0.116 | 0.023 |
| 2001/02 | 0.000 | 0.000 | 0.000 | 0.833 | 0.029 |
| 2002/03 | 0.000 | 0.000 | 0.000 | 0.071 | 0.297 |
| 2003/04 | 0.000 | 0.000 | 0.000 | 0.345 | 0.227 |
| 2004/05 | 0.000 | 0.000 | 0.000 | 0.816 | 0.002 |
| 2005/06 | 0.050 | 0.000 | 0.000 | 0.353 | 1.339 |
| 2006/07 | 0.104 | 0.000 | 0.000 | 0.138 | 0.074 |
| 2007/08 | 0.136 | 0.000 | 0.000 | 3.993 | 0.132 |
| 2008/09 | 0.000 | 0.000 | 0.000 | 0.141 | 0.473 |
| 2009/10 | 0.000 | 0.000 | 0.000 | 0.216 | 0.207 |
| 2010/11 | 0.000 | 0.000 | 0.186 | 0.044 | 0.056 |
| 2011/12 | 0.000 | 0.000 | 0.000 | 0.112 | 0.007 |
| 2012/13 | 0.000 | 0.000 | 0.000 | 0.170 | 0.669 |
| 2013/14 | 0.000 | 0.000 | 0.000 | 0.065 | 0.000 |
| 2014/15 | 0.000 | 0.000 | 0.000 | 0.144 | 0.000 |
| 2015/16 | 0.103 | 0.000 | 0.230 | 0.744 | 0.808 |
| 2016/17 | 0.000 | 0.000 | 0.000 | 0.090 | 0.455 |
| 2017/18 | 0.064 | 0.000 | 0.000 | 0.000 | 0.397 |
| 2018/19 | 0.000 | 0.000 | 0.101 | 0.026 | 0.482 |

Table 11: Total bycatch (discard) mortality from directed and non-directed fisheries for Pribilof Islands District blue king crab. Gear-specific handling mortalities were applied to estimates of non-retained catch from Table 2 for fixed gear (i.e., pot and hook/line; 0.2) and trawl gear (0.8).

| fishery year | crab (pot) fisheries (t) | | | groundfish fisheries (t) | | total bycatch mortality (t) |
|---|---|---|---|---|---|---|
| | females | legal males | sublegal males | fixed gear | trawl gear | |
| 1991/92 | -- | -- | -- | 0.013 | 4.959 | 4.973 |
| 1992/93 | -- | -- | -- | 0.176 | 48.633 | 48.809 |
| 1993/94 | -- | -- | -- | 0.000 | 27.386 | 27.386 |
| 1994/95 | -- | -- | -- | 0.007 | 5.485 | 5.492 |
| 1995/96 | -- | -- | -- | 0.022 | 1.027 | 1.049 |
| 1996/97 | 0.000 | 0.000 | 0.161 | 0.006 | 0.054 | 0.221 |
| 1997/98 | 0.000 | 0.000 | 0.000 | 0.292 | 0.104 | 0.396 |
| 1998/99 | 0.743 | 0.459 | 0.093 | 3.960 | 0.063 | 5.319 |
| 1999/00 | 0.394 | 0.699 | 0.858 | 0.159 | 0.016 | 2.125 |
| 2000/01 | 0.000 | 0.000 | 0.000 | 0.023 | 0.018 | 0.042 |
| 2001/02 | 0.000 | 0.000 | 0.000 | 0.167 | 0.023 | 0.190 |
| 2002/03 | 0.000 | 0.000 | 0.000 | 0.014 | 0.238 | 0.252 |
| 2003/04 | 0.000 | 0.000 | 0.000 | 0.069 | 0.182 | 0.251 |
| 2004/05 | 0.000 | 0.000 | 0.000 | 0.163 | 0.002 | 0.165 |
| 2005/06 | 0.010 | 0.000 | 0.000 | 0.071 | 1.071 | 1.152 |
| 2006/07 | 0.021 | 0.000 | 0.000 | 0.028 | 0.059 | 0.108 |
| 2007/08 | 0.027 | 0.000 | 0.000 | 0.799 | 0.106 | 0.931 |
| 2008/09 | 0.000 | 0.000 | 0.000 | 0.028 | 0.378 | 0.407 |
| 2009/10 | 0.000 | 0.000 | 0.000 | 0.043 | 0.165 | 0.209 |
| 2010/11 | 0.000 | 0.000 | 0.037 | 0.009 | 0.045 | 0.091 |
| 2011/12 | 0.000 | 0.000 | 0.000 | 0.022 | 0.006 | 0.028 |
| 2012/13 | 0.000 | 0.000 | 0.000 | 0.034 | 0.535 | 0.569 |
| 2013/14 | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 | 0.013 |
| 2014/15 | 0.000 | 0.000 | 0.000 | 0.029 | 0.000 | 0.029 |
| 2015/16 | 0.021 | 0.000 | 0.046 | 0.149 | 0.646 | 0.862 |
| 2016/17 | 0.000 | 0.000 | 0.000 | 0.018 | 0.364 | 0.382 |
| 2017/18 | 0.013 | 0.000 | 0.000 | 0.000 | 0.317 | 0.330 |
| 2018/19 | 0.000 | 0.000 | 0.020 | 0.005 | 0.385 | 0.411 |

Table 12: Bycatch (in kg) of PIBKC in the groundfish fisheries, by target type.

| Crab Fishery Year | % bycatch (biomass) by trip target | | | | total bycatch (# crabs) |
|---|---|---|---|---|---|
| | yellowfin sole | Pacific cod | flathead sole | rock sole | |
| | % | % | % | % | |
| 2003/04 | 47 | 22 | 31 | < 1 | 252 |
| 2004/05 | < 1 | 100 | < 1 | < 1 | 259 |
| 2005/06 | < 1 | 97 | 3 | < 1 | 757 |
| 2006/07 | 54 | 20 | < 1 | 26 | 96 |
| 2007/08 | 3 | 96 | 1 | < 1 | 2,950 |
| 2008/09 | 77 | 23 | < 1 | < 1 | 295 |
| 2009/10 | 31 | 51 | 17 | < 1 | 281 |
| 2010/11 | < 1 | 39 | 59 | < 1 | 48 |
| 2011/12 | < 1 | 100 | < 1 | < 1 | 62 |
| 2012/13 | 77 | 20 | 3 | < 1 | 410 |
| 2013/14 | < 1 | 99 | < 1 | < 1 | 39 |
| 2014/15 | < 1 | 99 | < 1 | < 1 | 64 |
| 2015/16 | 43 | 48 | 9 | < 1 | 609 |
| 2016/17 | 16 | 16 | <1 | 68 | 580 |
| 2017/18 | 40 | <1 | 60 | <1 | 278 |
| 2018/19 | 95 | 5 | <1 | <1 | 415 |

Table 13: Bycatch (in kg) of PIBKC in the groundfish fisheries, by gear type.

| Crab Fishery Year | % bycatch (biomass) by gear type | | | | total bycatch (# crabs) |
|---|---|---|---|---|---|
| | non-pelagic trawl % | pelagic trawl % | hook and line % | pot % | |
| 2003/04 | 79 | 0 | 21 | 0 | 252 |
| 2004/05 | 1 | 0 | 99 | 0 | 259 |
| 2005/06 | 3 | 0 | 18 | 79 | 757 |
| 2006/07 | 20 | 0 | 20 | 0 | 96 |
| 2007/08 | 3 | 0 | 1 | 95 | 2,950 |
| 2008/09 | 77 | 0 | 23 | 0 | 295 |
| 2009/10 | 49 | 0 | 7 | 44 | 281 |
| 2010/11 | 59 | 0 | 41 | 0 | 48 |
| 2011/12 | 6 | 0 | 94 | 0 | 62 |
| 2012/13 | 80 | 0 | 20 | 0 | 410 |
| 2013/14 | 0 | 0 | 100 | 0 | 39 |
| 2014/15 | 0 | 0 | 100 | 0 | 64 |
| 2015/16 | 52 | 0 | 48 | 0 | 609 |
| 2016/17 | 84 | 0 | 16 | 0 | 580 |
| 2017/18 | 100 | 0 | 0 | 0 | 278 |
| 2018/19 | 95 | 0 | 5 | 0 | 415 |

Table 14: Summary of recent NMFS annual EBS bottom trawl surveys for the Pribilof Islands District blue king crab by stock component.

| year | Stock Component | Number of tows in District | Tows with crab | Number of crab measured |
|---|---|---|---|---|
| 2018 | Immature male | 86 | 4 | 6 |
| | Mature male | 86 | 3 | 3 |
| | Legal male | 86 | 3 | 3 |
| | Immature female | 86 | 1 | 1 |
| | Mature female | 86 | 3 | 6 |
| 2017 | Immature male | 86 | 2 | 4 |
| | Mature male | 86 | 4 | 4 |
| | Legal male | 86 | 3 | 3 |
| | Immature female | 86 | 3 | 7 |
| | Mature female | 86 | 4 | 8 |
| 2016 | Immature male | 86 | 4 | 5 |
| | Mature male | 86 | 3 | 3 |
| | Legal male | 86 | 1 | 1 |
| | Immature female | 86 | 4 | 5 |
| | Mature female | 86 | 7 | 19 |
| 2015 | Immature male | 86 | 2 | 4 |
| | Mature male | 86 | 8 | 13 |
| | Legal male | 86 | 5 | 7 |
| | Immature female | 86 | 0 | 0 |
| | Mature female | 86 | 4 | 11 |
| 2014 | Immature male | 86 | 3 | 5 |
| | Mature male | 86 | 2 | 5 |
| | Legal male | 86 | 2 | 5 |
| | Immature female | 86 | 1 | 1 |
| | Mature female | 86 | 3 | 4 |

Table 15: Abundance time series for Pribilof Islands blue king crab from the NMFS annual EBS bottom trawl survey.

| Year | Males | | | | | | | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | immature | | mature | | legal | | total | | immature | | mature | | total | |
| | abundance | cv | abundance | cv | abundance | cv | abundance | cv | abundance | cv | abundance | cv | abundance | cv |
| 1975 | 8,475,781 | 0.57 | 15,288,169 | 0.50 | 9,051,486 | 0.50 | 23,763,950 | 0.47 | 0 | 0.00 | 13,147,587 | 0.61 | 13,147,587 | 0.61 |
| 1976 | 4,959,559 | 0.95 | 4,782,105 | 0.45 | 4,012,289 | 0.47 | 9,741,664 | 0.59 | 7,369,388 | 0.97 | 769,150 | 0.51 | 8,138,538 | 0.91 |
| 1977 | 4,215,865 | 0.46 | 13,043,983 | 0.74 | 11,768,927 | 0.77 | 17,259,848 | 0.63 | 851,601 | 0.82 | 13,880,051 | 0.86 | 14,731,651 | 0.86 |
| 1978 | 2,421,458 | 0.50 | 6,140,638 | 0.50 | 3,922,874 | 0.62 | 8,562,096 | 0.43 | 60,923 | 1.00 | 5,926,514 | 0.66 | 5,987,437 | 0.66 |
| 1979 | 79,355 | 0.70 | 4,107,868 | 0.33 | 3,017,119 | 0.31 | 4,187,222 | 0.32 | 142,416 | 0.72 | 1,168,935 | 0.81 | 1,311,351 | 0.77 |
| 1980 | 2,732,728 | 0.47 | 7,842,342 | 0.41 | 6,244,058 | 0.42 | 10,575,070 | 0.40 | 781,224 | 0.77 | 182,902,919 | 0.98 | 183,684,143 | 0.98 |
| 1981 | 2,099,475 | 0.32 | 3,834,431 | 0.18 | 3,245,951 | 0.18 | 5,933,906 | 0.21 | 826,524 | 0.41 | 5,433,491 | 0.44 | 6,260,015 | 0.42 |
| 1982 | 1,371,283 | 0.28 | 2,353,813 | 0.18 | 2,071,468 | 0.19 | 3,725,096 | 0.17 | 876,256 | 0.51 | 7,837,004 | 0.65 | 8,713,260 | 0.63 |
| 1983 | 1,030,732 | 0.36 | 1,851,301 | 0.19 | 1,321,395 | 0.17 | 2,882,033 | 0.22 | 463,726 | 0.54 | 9,307,969 | 0.78 | 9,771,695 | 0.76 |
| 1984 | 517,574 | 0.40 | 770,643 | 0.22 | 558,226 | 0.25 | 1,288,217 | 0.21 | 465,473 | 0.52 | 2,769,190 | 0.38 | 3,234,663 | 0.37 |
| 1985 | 67,765 | 0.60 | 428,076 | 0.28 | 270,242 | 0.29 | 495,841 | 0.27 | 260,081 | 0.54 | 486,184 | 0.44 | 746,266 | 0.36 |
| 1986 | 18,904 | 1.00 | 480,198 | 0.31 | 460,311 | 0.31 | 499,102 | 0.30 | 36,684 | 0.70 | 2,101,932 | 0.90 | 2,138,616 | 0.88 |
| 1987 | 621,541 | 0.83 | 903,180 | 0.41 | 830,151 | 0.42 | 1,524,721 | 0.43 | 401,530 | 0.74 | 670,479 | 0.58 | 1,072,008 | 0.48 |
| 1988 | 1,238,053 | 0.84 | 237,868 | 0.51 | 237,868 | 0.51 | 1,475,921 | 0.71 | 897,629 | 0.87 | 465,463 | 0.48 | 1,363,093 | 0.64 |
| 1989 | 3,514,764 | 0.59 | 239,948 | 0.62 | 239,948 | 0.62 | 3,754,712 | 0.58 | 2,636,099 | 0.74 | 1,141,756 | 0.66 | 3,777,855 | 0.58 |
| 1990 | 2,449,864 | 0.60 | 1,470,419 | 0.63 | 571,708 | 0.54 | 3,920,283 | 0.58 | 2,177,329 | 0.91 | 2,045,839 | 0.55 | 4,223,169 | 0.56 |
| 1991 | 1,920,443 | 0.37 | 2,014,086 | 0.36 | 1,237,558 | 0.44 | 3,934,529 | 0.34 | 805,451 | 0.46 | 2,767,448 | 0.42 | 3,572,899 | 0.35 |
| 1992 | 2,435,796 | 0.59 | 1,935,278 | 0.42 | 1,154,465 | 0.45 | 4,371,074 | 0.48 | 1,797,343 | 0.93 | 2,149,519 | 0.49 | 3,946,863 | 0.52 |
| 1993 | 1,483,524 | 0.52 | 1,875,500 | 0.31 | 1,114,301 | 0.30 | 3,359,024 | 0.34 | 880,672 | 0.61 | 1,782,657 | 0.45 | 2,663,329 | 0.38 |
| 1994 | 638,520 | 0.37 | 1,294,263 | 0.34 | 935,269 | 0.34 | 1,932,783 | 0.33 | 144,763 | 0.57 | 5,047,215 | 0.44 | 5,191,978 | 0.44 |
| 1995 | 1,146,803 | 0.89 | 3,101,712 | 0.60 | 2,186,409 | 0.62 | 4,248,514 | 0.67 | 658,479 | 0.92 | 4,038,556 | 0.52 | 4,697,035 | 0.49 |
| 1996 | 719,430 | 0.63 | 1,712,015 | 0.28 | 1,269,275 | 0.26 | 2,431,445 | 0.33 | 275,735 | 0.42 | 5,045,822 | 0.48 | 5,321,557 | 0.46 |
| 1997 | 467,234 | 0.53 | 1,201,296 | 0.29 | 932,852 | 0.28 | 1,668,530 | 0.34 | 320,344 | 0.67 | 2,614,374 | 0.42 | 2,934,717 | 0.39 |
| 1998 | 949,447 | 0.46 | 967,098 | 0.25 | 797,187 | 0.25 | 1,916,545 | 0.31 | 500,241 | 0.43 | 1,829,509 | 0.44 | 2,329,750 | 0.37 |
| 1999 | 159,536 | 0.37 | 617,258 | 0.33 | 452,740 | 0.34 | 776,794 | 0.33 | 0 | 0.00 | 2,755,976 | 0.49 | 2,755,976 | 0.49 |
| 2000 | 163,835 | 0.56 | 725,051 | 0.30 | 527,589 | 0.30 | 888,885 | 0.31 | 0 | 0.00 | 1,363,070 | 0.46 | 1,363,070 | 0.46 |
| 2001 | 92,918 | 0.65 | 522,239 | 0.71 | 445,863 | 0.74 | 615,157 | 0.69 | 18,516 | 1.00 | 1,697,465 | 0.75 | 1,715,981 | 0.74 |
| 2002 | 0 | 0.00 | 225,476 | 0.47 | 207,146 | 0.49 | 225,476 | 0.47 | 18,729 | 1.00 | 1,221,852 | 0.79 | 1,240,582 | 0.78 |
| 2003 | 45,271 | 0.72 | 228,897 | 0.39 | 213,572 | 0.40 | 274,168 | 0.34 | 67,329 | 0.48 | 1,120,254 | 0.76 | 1,187,583 | 0.72 |
| 2004 | 87,651 | 0.59 | 47,905 | 0.56 | 15,584 | 1.00 | 135,556 | 0.42 | 98,059 | 0.63 | 70,035 | 0.60 | 168,094 | 0.51 |
| 2005 | 1,981,338 | 0.96 | 91,932 | 0.71 | 91,932 | 0.71 | 2,073,270 | 0.92 | 2,268,113 | 1.00 | 289,197 | 0.56 | 2,557,310 | 0.89 |
| 2006 | 138,118 | 0.49 | 55,579 | 0.56 | 38,242 | 0.70 | 193,697 | 0.42 | 113,047 | 0.55 | 429,541 | 0.77 | 542,588 | 0.62 |
| 2007 | 246,165 | 0.72 | 110,080 | 0.85 | 54,403 | 0.75 | 356,245 | 0.64 | 122,483 | 0.73 | 165,763 | 0.90 | 288,245 | 0.59 |
| 2008 | 233,919 | 0.93 | 18,256 | 1.00 | 18,256 | 1.00 | 252,174 | 0.86 | 342,119 | 0.90 | 437,369 | 0.66 | 779,488 | 0.75 |
| 2009 | 267,717 | 0.63 | 248,626 | 0.73 | 68,117 | 0.59 | 516,343 | 0.68 | 152,290 | 0.61 | 477,095 | 0.82 | 629,385 | 0.76 |
| 2010 | 101,151 | 0.84 | 130,465 | 0.49 | 64,703 | 0.48 | 231,616 | 0.61 | 165,632 | 0.56 | 249,027 | 0.69 | 414,660 | 0.62 |
| 2011 | 0 | 0.00 | 165,525 | 0.79 | 129,098 | 0.87 | 165,525 | 0.79 | 18,089 | 1.00 | 36,512 | 0.70 | 54,601 | 0.56 |
| 2012 | 194,522 | 1.00 | 272,233 | 0.80 | 164,165 | 0.68 | 466,755 | 0.88 | 34,683 | 1.00 | 312,095 | 0.76 | 346,777 | 0.70 |
| 2013 | 76,351 | 1.00 | 104,361 | 0.86 | 68,726 | 0.80 | 180,712 | 0.64 | 45,344 | 0.70 | 150,300 | 0.63 | 195,644 | 0.53 |
| 2014 | 90,990 | 0.59 | 91,856 | 0.71 | 91,856 | 0.71 | 182,846 | 0.57 | 27,721 | 1.00 | 74,368 | 0.60 | 102,088 | 0.51 |
| 2015 | 75,575 | 0.77 | 233,630 | 0.37 | 124,592 | 0.45 | 309,205 | 0.41 | 0 | 0.00 | 202,464 | 0.65 | 202,464 | 0.65 |
| 2016 | 94,022 | 0.52 | 55,852 | 0.56 | 19,345 | 1.00 | 149,874 | 0.49 | 131,689 | 0.50 | 322,760 | 0.52 | 454,450 | 0.50 |
| 2017 | 68,238 | 0.77 | 90,645 | 0.50 | 71,937 | 0.59 | 158,884 | 0.46 | 187,860 | 0.75 | 161,799 | 0.53 | 349,659 | 0.54 |
| 2018 | 110,361 | 0.57 | 55,776 | 0.56 | 55,776 | 0.56 | 166,136 | 0.52 | 75,906 | 0.59 | 57,873 | 1.00 | 133,779 | 0.54 |

Table 16: Biomass time series for Pribilof Islands blue king crab from the NMFS annual EBS bottom trawl survey.

| Year | Males | | | | | | | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | immature | | mature | | legal | | total | | immature | | mature | | total | |
| | biomass (t) | cv | biomass (t) | cv | biomass (t) | cv | biomass (t) | cv | biomass (t) | cv | biomass (t) | cv | biomass (t) | cv |
| 1975 | 8,341 | 0.52 | 38,054 | 0.50 | 27,016 | 0.50 | 46,395 | 0.47 | 0 | 0.00 | 12,442 | 0.64 | 12,442 | 0.64 |
| 1976 | 4,129 | 0.94 | 14,059 | 0.45 | 12,649 | 0.47 | 18,188 | 0.45 | 4,968 | 0.97 | 824 | 0.53 | 5,792 | 0.89 |
| 1977 | 3,713 | 0.44 | 42,618 | 0.77 | 40,366 | 0.78 | 46,332 | 0.73 | 419 | 0.83 | 13,154 | 0.88 | 13,572 | 0.87 |
| 1978 | 2,765 | 0.51 | 17,370 | 0.56 | 13,517 | 0.64 | 20,135 | 0.51 | 76 | 1.00 | 6,416 | 0.72 | 6,492 | 0.72 |
| 1979 | 61 | 0.79 | 10,959 | 0.32 | 9,040 | 0.31 | 11,021 | 0.31 | 92 | 0.73 | 1,097 | 0.79 | 1,189 | 0.76 |
| 1980 | 2,084 | 0.49 | 23,553 | 0.43 | 20,679 | 0.45 | 25,637 | 0.42 | 699 | 0.86 | 211,604 | 0.98 | 212,303 | 0.98 |
| 1981 | 1,704 | 0.30 | 11,628 | 0.17 | 10,554 | 0.17 | 13,332 | 0.18 | 497 | 0.41 | 5,987 | 0.47 | 6,484 | 0.46 |
| 1982 | 1,152 | 0.23 | 7,389 | 0.19 | 6,893 | 0.19 | 8,541 | 0.17 | 553 | 0.57 | 8,824 | 0.68 | 9,377 | 0.67 |
| 1983 | 962 | 0.36 | 5,409 | 0.18 | 4,474 | 0.17 | 6,371 | 0.19 | 258 | 0.61 | 9,990 | 0.79 | 10,248 | 0.78 |
| 1984 | 130 | 0.36 | 2,216 | 0.23 | 1,824 | 0.25 | 2,345 | 0.22 | 15 | 0.69 | 3,070 | 0.38 | 3,085 | 0.38 |
| 1985 | 39 | 0.73 | 1,055 | 0.27 | 756 | 0.28 | 1,094 | 0.26 | 5 | 0.46 | 520 | 0.45 | 525 | 0.44 |
| 1986 | 4 | 1.00 | 1,505 | 0.30 | 1,473 | 0.31 | 1,508 | 0.30 | 11 | 0.73 | 2,420 | 0.90 | 2,431 | 0.90 |
| 1987 | 191 | 0.78 | 2,923 | 0.41 | 2,781 | 0.41 | 3,115 | 0.40 | 119 | 0.86 | 795 | 0.58 | 913 | 0.53 |
| 1988 | 170 | 0.71 | 842 | 0.53 | 842 | 0.53 | 1,012 | 0.46 | 190 | 0.79 | 528 | 0.49 | 718 | 0.47 |
| 1989 | 1,275 | 0.62 | 828 | 0.64 | 828 | 0.64 | 2,102 | 0.55 | 801 | 0.67 | 945 | 0.58 | 1,746 | 0.50 |
| 1990 | 2,004 | 0.66 | 3,078 | 0.60 | 1,514 | 0.52 | 5,082 | 0.61 | 1,118 | 0.93 | 1,810 | 0.51 | 2,929 | 0.49 |
| 1991 | 1,377 | 0.39 | 4,690 | 0.39 | 3,326 | 0.45 | 6,067 | 0.37 | 343 | 0.48 | 2,433 | 0.41 | 2,776 | 0.38 |
| 1992 | 1,801 | 0.51 | 4,391 | 0.42 | 3,035 | 0.45 | 6,192 | 0.43 | 802 | 0.96 | 1,848 | 0.48 | 2,649 | 0.46 |
| 1993 | 1,089 | 0.54 | 4,556 | 0.31 | 3,203 | 0.30 | 5,644 | 0.30 | 444 | 0.62 | 1,647 | 0.46 | 2,092 | 0.40 |
| 1994 | 619 | 0.39 | 3,410 | 0.34 | 2,806 | 0.35 | 4,029 | 0.34 | 87 | 0.57 | 4,806 | 0.45 | 4,893 | 0.44 |
| 1995 | 968 | 0.86 | 8,360 | 0.60 | 6,787 | 0.62 | 9,328 | 0.63 | 331 | 0.90 | 3,948 | 0.52 | 4,279 | 0.50 |
| 1996 | 745 | 0.61 | 4,641 | 0.27 | 3,873 | 0.27 | 5,386 | 0.28 | 177 | 0.42 | 5,408 | 0.50 | 5,585 | 0.49 |
| 1997 | 381 | 0.55 | 3,233 | 0.28 | 2,765 | 0.27 | 3,614 | 0.29 | 194 | 0.66 | 2,835 | 0.43 | 3,028 | 0.41 |
| 1998 | 692 | 0.41 | 2,798 | 0.25 | 2,510 | 0.25 | 3,490 | 0.25 | 267 | 0.42 | 1,914 | 0.44 | 2,182 | 0.39 |
| 1999 | 161 | 0.40 | 1,729 | 0.34 | 1,426 | 0.35 | 1,890 | 0.33 | 0 | 0.00 | 2,868 | 0.47 | 2,868 | 0.47 |
| 2000 | 113 | 0.68 | 2,091 | 0.30 | 1,746 | 0.31 | 2,205 | 0.30 | 0 | 0.00 | 1,462 | 0.46 | 1,462 | 0.46 |
| 2001 | 87 | 0.76 | 1,599 | 0.73 | 1,461 | 0.76 | 1,686 | 0.73 | 0 | 1.00 | 1,816 | 0.72 | 1,817 | 0.72 |
| 2002 | 0 | 0.00 | 680 | 0.51 | 647 | 0.52 | 680 | 0.51 | 0 | 1.00 | 1,401 | 0.78 | 1,401 | 0.78 |
| 2003 | 19 | 0.98 | 702 | 0.40 | 671 | 0.41 | 721 | 0.39 | 21 | 0.67 | 1,286 | 0.75 | 1,307 | 0.73 |
| 2004 | 36 | 0.65 | 107 | 0.58 | 48 | 1.00 | 143 | 0.46 | 25 | 0.82 | 98 | 0.60 | 123 | 0.50 |
| 2005 | 326 | 0.94 | 344 | 0.71 | 344 | 0.71 | 670 | 0.59 | 477 | 1.00 | 370 | 0.57 | 847 | 0.61 |
| 2006 | 87 | 0.58 | 166 | 0.60 | 139 | 0.70 | 253 | 0.46 | 38 | 0.60 | 538 | 0.76 | 576 | 0.71 |
| 2007 | 197 | 0.74 | 306 | 0.80 | 206 | 0.73 | 503 | 0.66 | 59 | 0.79 | 223 | 0.88 | 282 | 0.71 |
| 2008 | 212 | 0.95 | 46 | 1.00 | 46 | 1.00 | 258 | 0.80 | 222 | 0.90 | 450 | 0.64 | 672 | 0.70 |
| 2009 | 254 | 0.68 | 497 | 0.71 | 187 | 0.60 | 751 | 0.70 | 80 | 0.66 | 545 | 0.85 | 625 | 0.82 |
| 2010 | 92 | 0.85 | 303 | 0.46 | 190 | 0.48 | 395 | 0.52 | 84 | 0.58 | 310 | 0.66 | 394 | 0.63 |
| 2011 | 0 | 0.00 | 461 | 0.84 | 399 | 0.89 | 461 | 0.84 | 3 | 1.00 | 34 | 0.73 | 37 | 0.67 |
| 2012 | 165 | 1.00 | 644 | 0.74 | 459 | 0.64 | 809 | 0.79 | 9 | 1.00 | 229 | 0.66 | 237 | 0.64 |
| 2013 | 15 | 1.00 | 250 | 0.80 | 190 | 0.75 | 265 | 0.75 | 12 | 0.72 | 154 | 0.70 | 166 | 0.65 |
| 2014 | 83 | 0.62 | 233 | 0.70 | 233 | 0.70 | 317 | 0.57 | 16 | 1.00 | 91 | 0.60 | 108 | 0.53 |
| 2015 | 82 | 0.75 | 622 | 0.39 | 428 | 0.46 | 703 | 0.39 | 0 | 0.00 | 160 | 0.66 | 160 | 0.66 |
| 2016 | 70 | 0.49 | 129 | 0.61 | 68 | 1.00 | 199 | 0.52 | 72 | 0.47 | 329 | 0.50 | 401 | 0.48 |
| 2017 | 45 | 0.77 | 253 | 0.51 | 223 | 0.57 | 298 | 0.47 | 107 | 0.81 | 152 | 0.56 | 259 | 0.53 |
| 2018 | 96 | 0.54 | 154 | 0.57 | 154 | 0.57 | 249 | 0.52 | 45 | 0.58 | 76 | 1.00 | 121 | 0.65 |

Table 17: Smoothed mature male biomass (MMB) at the time of the survey for Pribilof Islands blue king crab using using the Random Effects Model.

| year | raw | | | RE-smoothed | | |
|---|---|---|---|---|---|---|
| | biomass (t) | lower CI (t) | upper CI (t) | biomass (t) | lower CI (t) | upper CI (t) |
| 1975 | 38,054 | 20,760 | 69,754 | 26,882 | 16,821 | 42,960 |
| 1976 | 14,059 | 8,104 | 24,391 | 19,930 | 13,395 | 29,653 |
| 1977 | 42,618 | 17,814 | 101,958 | 21,252 | 13,592 | 33,229 |
| 1978 | 17,370 | 8,912 | 33,852 | 16,972 | 11,337 | 25,408 |
| 1979 | 10,959 | 7,386 | 16,262 | 13,333 | 9,748 | 18,236 |
| 1980 | 23,553 | 13,894 | 39,925 | 15,594 | 11,031 | 22,045 |
| 1981 | 11,628 | 9,321 | 14,507 | 11,421 | 9,355 | 13,944 |
| 1982 | 7,389 | 5,825 | 9,374 | 7,448 | 6,052 | 9,167 |
| 1983 | 5,409 | 4,316 | 6,778 | 5,080 | 4,155 | 6,211 |
| 1984 | 2,216 | 1,659 | 2,959 | 2,348 | 1,842 | 2,993 |
| 1985 | 1,055 | 754 | 1,476 | 1,351 | 1,021 | 1,787 |
| 1986 | 1,505 | 1,030 | 2,199 | 1,556 | 1,157 | 2,091 |
| 1987 | 2,923 | 1,761 | 4,853 | 1,927 | 1,352 | 2,747 |
| 1988 | 842 | 446 | 1,591 | 1,429 | 948 | 2,154 |
| 1989 | 828 | 392 | 1,749 | 1,601 | 1,030 | 2,489 |
| 1990 | 3,078 | 1,513 | 6,261 | 2,603 | 1,718 | 3,942 |
| 1991 | 4,690 | 2,910 | 7,556 | 3,810 | 2,677 | 5,423 |
| 1992 | 4,391 | 2,612 | 7,382 | 4,180 | 2,940 | 5,943 |
| 1993 | 4,556 | 3,100 | 6,694 | 4,328 | 3,200 | 5,853 |
| 1994 | 3,410 | 2,220 | 5,240 | 4,018 | 2,908 | 5,550 |
| 1995 | 8,360 | 4,091 | 17,086 | 4,939 | 3,336 | 7,312 |
| 1996 | 4,641 | 3,309 | 6,509 | 4,383 | 3,316 | 5,793 |
| 1997 | 3,233 | 2,284 | 4,575 | 3,322 | 2,524 | 4,372 |
| 1998 | 2,798 | 2,043 | 3,833 | 2,705 | 2,086 | 3,508 |
| 1999 | 1,729 | 1,136 | 2,631 | 1,977 | 1,452 | 2,691 |
| 2000 | 2,091 | 1,443 | 3,031 | 1,836 | 1,358 | 2,482 |
| 2001 | 1,599 | 689 | 3,710 | 1,264 | 830 | 1,925 |
| 2002 | 680 | 369 | 1,254 | 784 | 529 | 1,163 |
| 2003 | 702 | 428 | 1,150 | 549 | 382 | 788 |
| 2004 | 107 | 53 | 214 | 279 | 180 | 432 |
| 2005 | 344 | 152 | 780 | 266 | 169 | 419 |
| 2006 | 166 | 81 | 339 | 225 | 143 | 354 |
| 2007 | 306 | 125 | 753 | 230 | 142 | 374 |
| 2008 | 46 | 16 | 134 | 211 | 126 | 351 |
| 2009 | 497 | 219 | 1,130 | 294 | 186 | 466 |
| 2010 | 303 | 173 | 532 | 321 | 214 | 481 |
| 2011 | 461 | 180 | 1,180 | 371 | 232 | 595 |
| 2012 | 644 | 277 | 1,496 | 398 | 247 | 640 |
| 2013 | 250 | 102 | 615 | 343 | 214 | 552 |
| 2014 | 233 | 104 | 524 | 336 | 215 | 523 |
| 2015 | 622 | 382 | 1,011 | 391 | 270 | 568 |
| 2016 | 129 | 62 | 265 | 246 | 161 | 375 |
| 2017 | 253 | 136 | 470 | 228 | 149 | 347 |
| 2018 | 154 | 78 | 303 | 194 | 117 | 321 |
| 2019 | - | - | - | 194 | 68 | 558 |

Table 18: Estimates of mature male biomass (MMB) at the time of mating for Pribilof Islands blue king crab using: (1) the "raw" survey biomass time series and (2) the survey biomass time series smoothed using the Random Effects Model. Shaded rows signify averaging time period for $B_{MSY}$/MSST. The 2019/20 estimates are projected values (see Appendix C).

| year | RE Model MMB (t) |
|---|---|
| 1975/76 | 23,164 |
| 1976/77 | 15,120 |
| 1977/78 | 16,374 |
| 1978/79 | 12,547 |
| 1979/80 | 9,441 |
| 1980/81 | 9,354 |
| 1981/82 | 6,404 |
| 1982/83 | 4,822 |
| 1983/84 | 3,638 |
| 1984/85 | 1,981 |
| 1985/86 | 990 |
| 1986/87 | 1,289 |
| 1987/88 | 1,436 |
| 1988/89 | 1,286 |
| 1989/90 | 1,441 |
| 1990/91 | 2,343 |
| 1991/92 | 3,428 |
| 1992/93 | 3,740 |
| 1993/94 | 3,884 |
| 1994/95 | 3,615 |
| 1995/96 | 3,856 |
| 1996/97 | 3,544 |
| 1997/98 | 2,773 |
| 1998/99 | 2,211 |
| 1999/00 | 1,779 |
| 2000/01 | 1,653 |
| 2001/02 | 1,138 |
| 2002/03 | 706 |
| 2003/04 | 494 |
| 2004/05 | 251 |
| 2005/06 | 239 |
| 2006/07 | 203 |
| 2007/08 | 207 |
| 2008/09 | 189 |
| 2009/10 | 265 |
| 2010/11 | 289 |
| 2011/12 | 334 |
| 2012/13 | 358 |
| 2013/14 | 309 |
| 2014/15 | 302 |
| 2015/16 | 352 |
| 2016/17 | 221 |
| 2017/18 | 205 |
| 2018/19 | 175 |
| 2019/20* | 175 |

## Figures

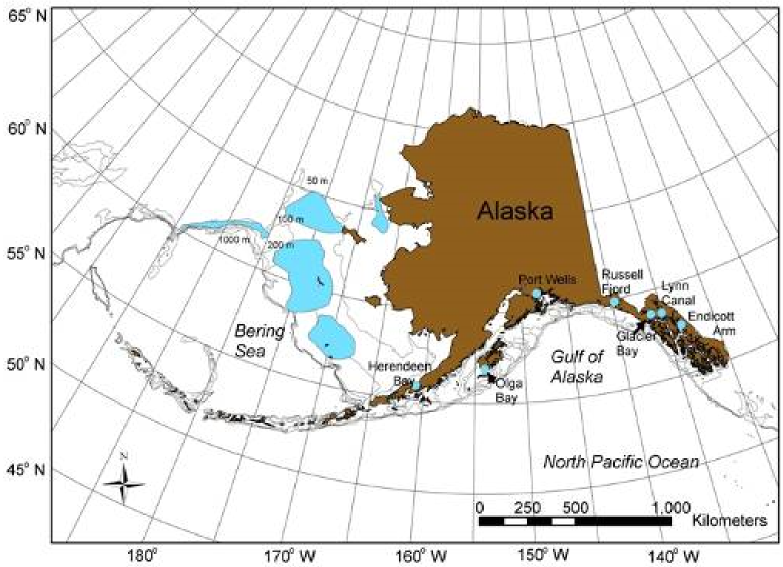


Figure 1: Distribution of blue king crab, *Paralithodes platypus*, in Alaskan waters.

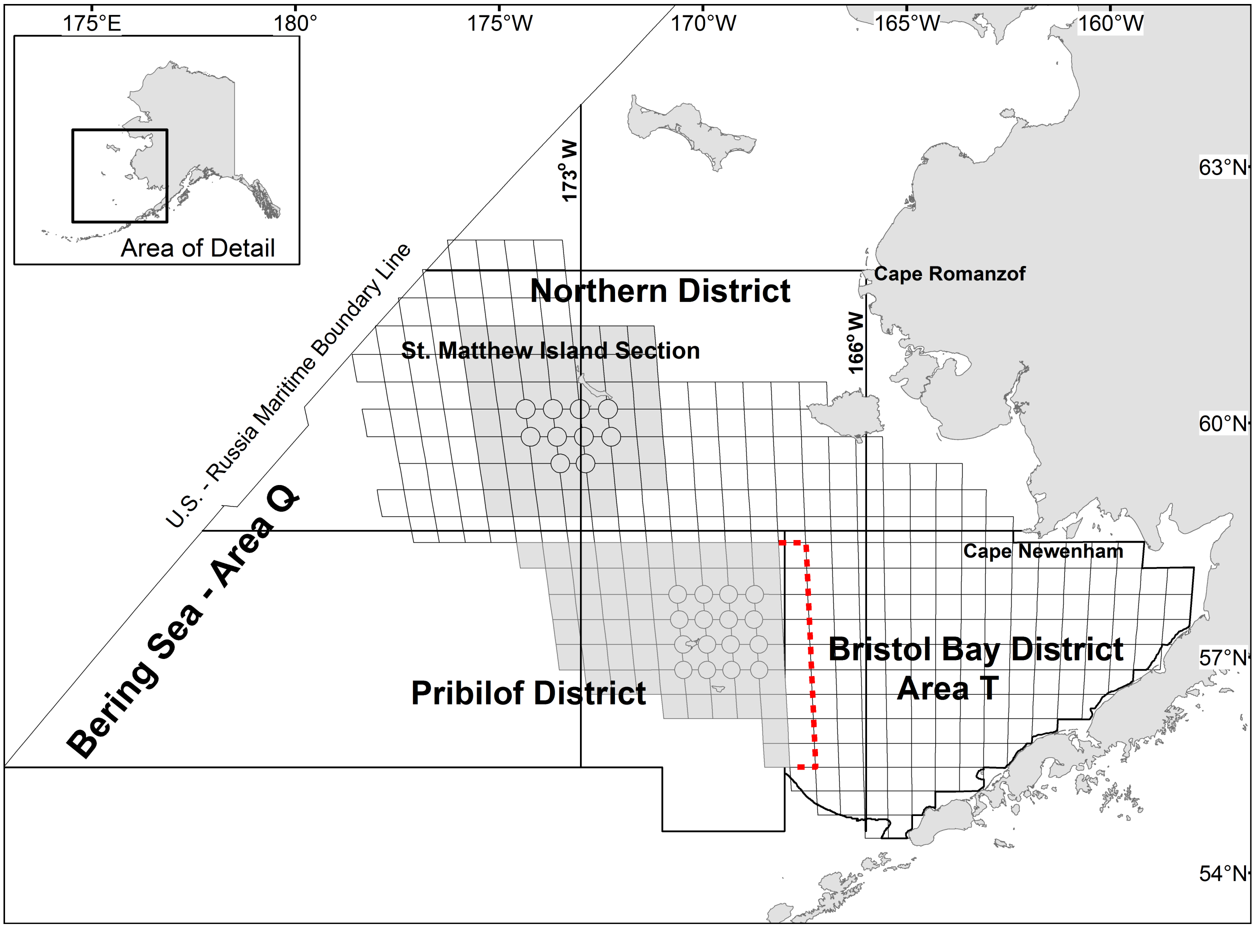


Figure 2: Map of the ADFG King Crab Registration Area Q (Bering Sea), showing (among others) the Pribilof District, which constitutes the stock boundary for PIBKC. The figure also indicates the additional 20nm strip (red dotted line) added in 2013 for calculating biomass and catch data in the Pribilof District.

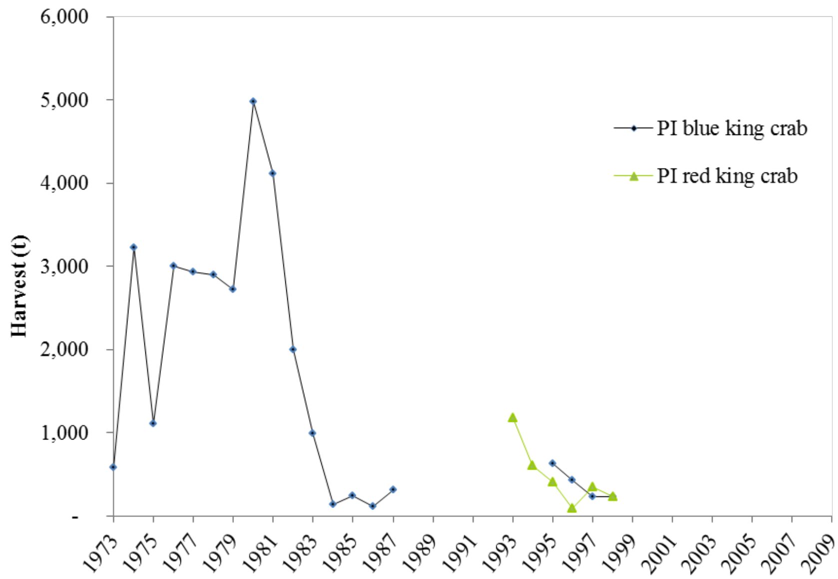


Figure 3: Historical harvests and Guideline Harvest Levels (GHLs) for Pribilof Islands red and blue king crab (from Bowers et al., 2011).

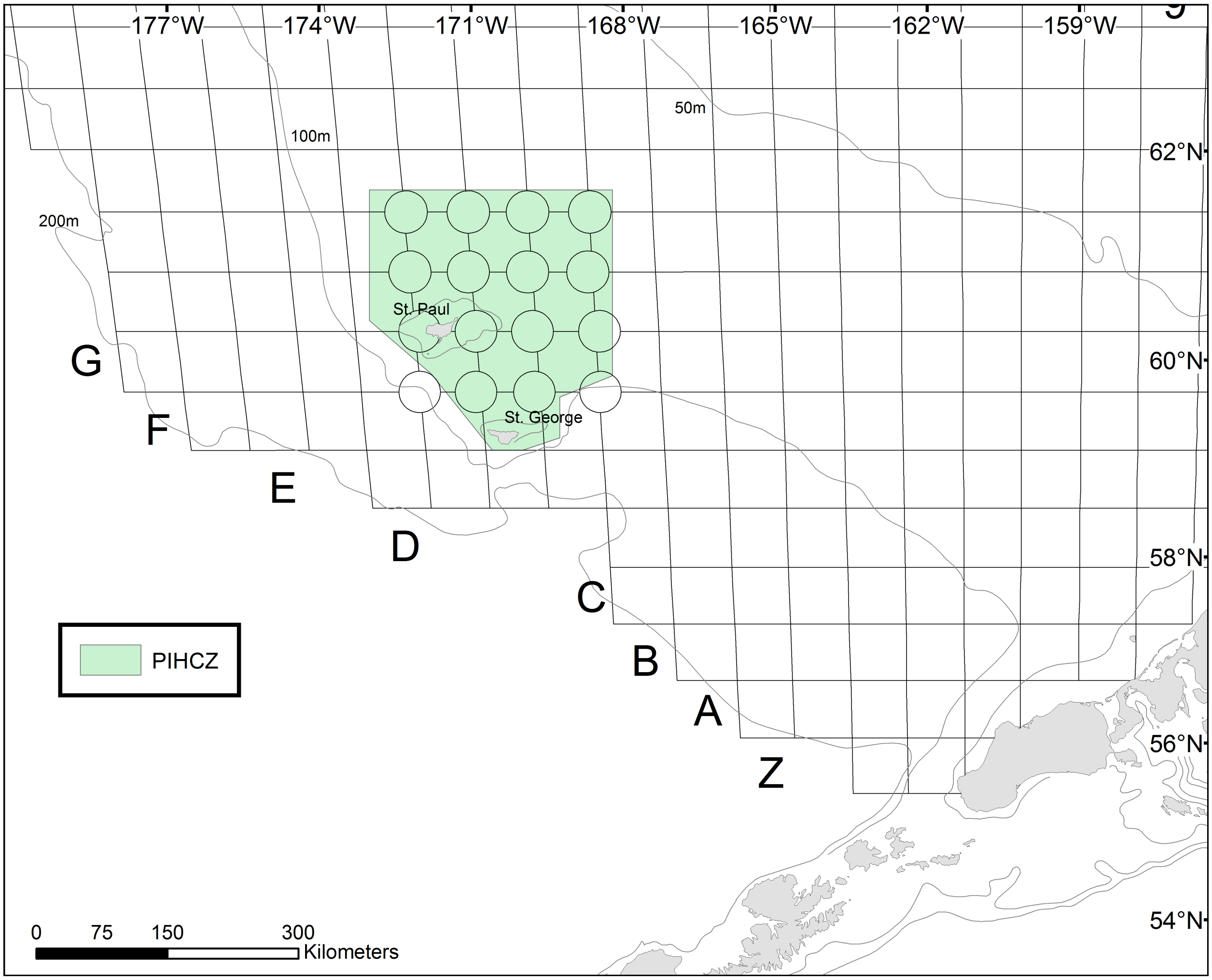


Figure 4: The shaded area shows the Pribilof Islands Habitat Conservation Zone (PIHCZ). Trawl fishing is prohibited year-round in this zone (as of 1995), as is pot fishing for Pacific cod (as of 2015). Also shown is a portion of the NMFS annual EBS bottom trawl survey grid.

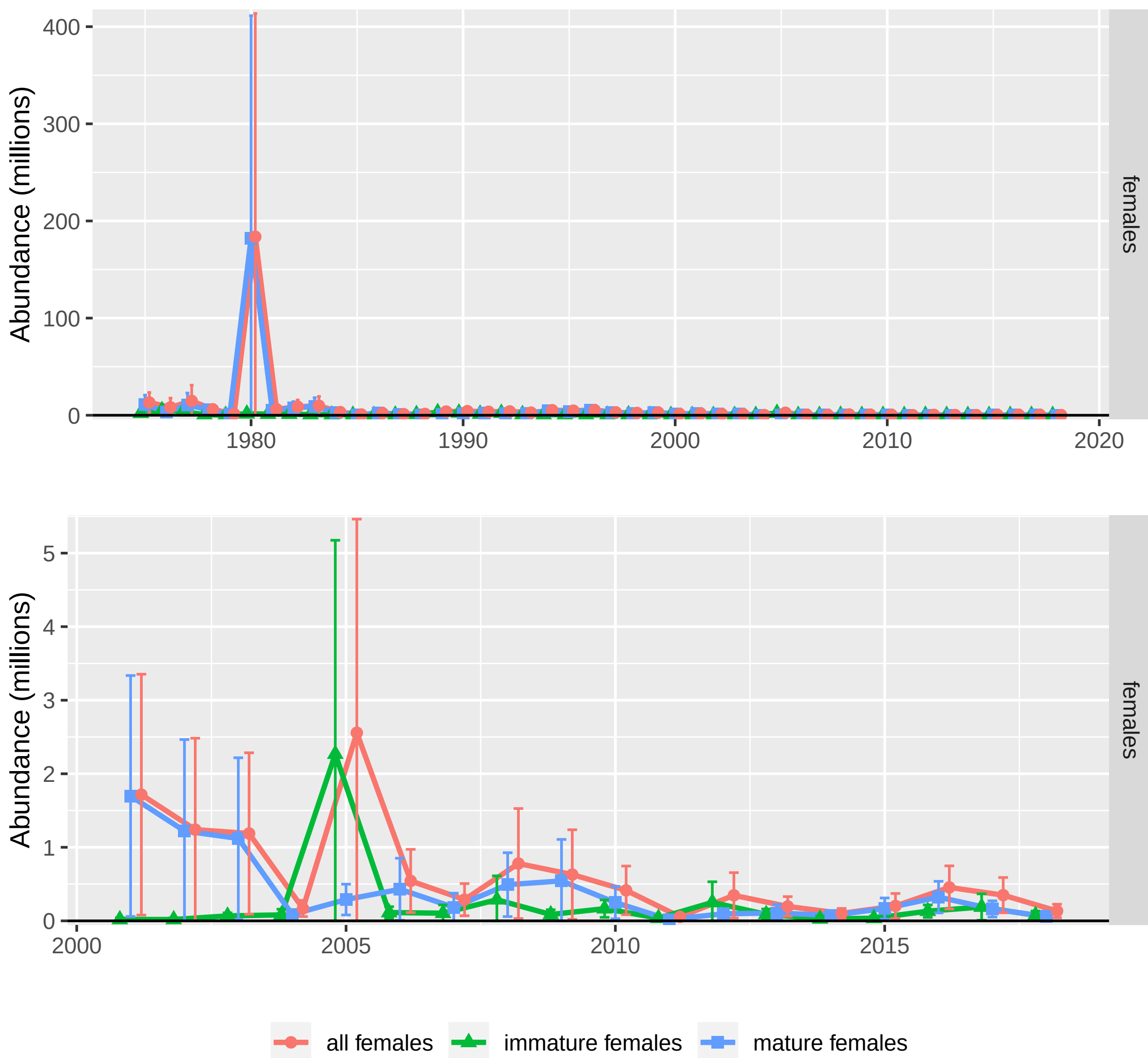


Figure 5: Time series of survey abundance for females (immature, mature, and total).

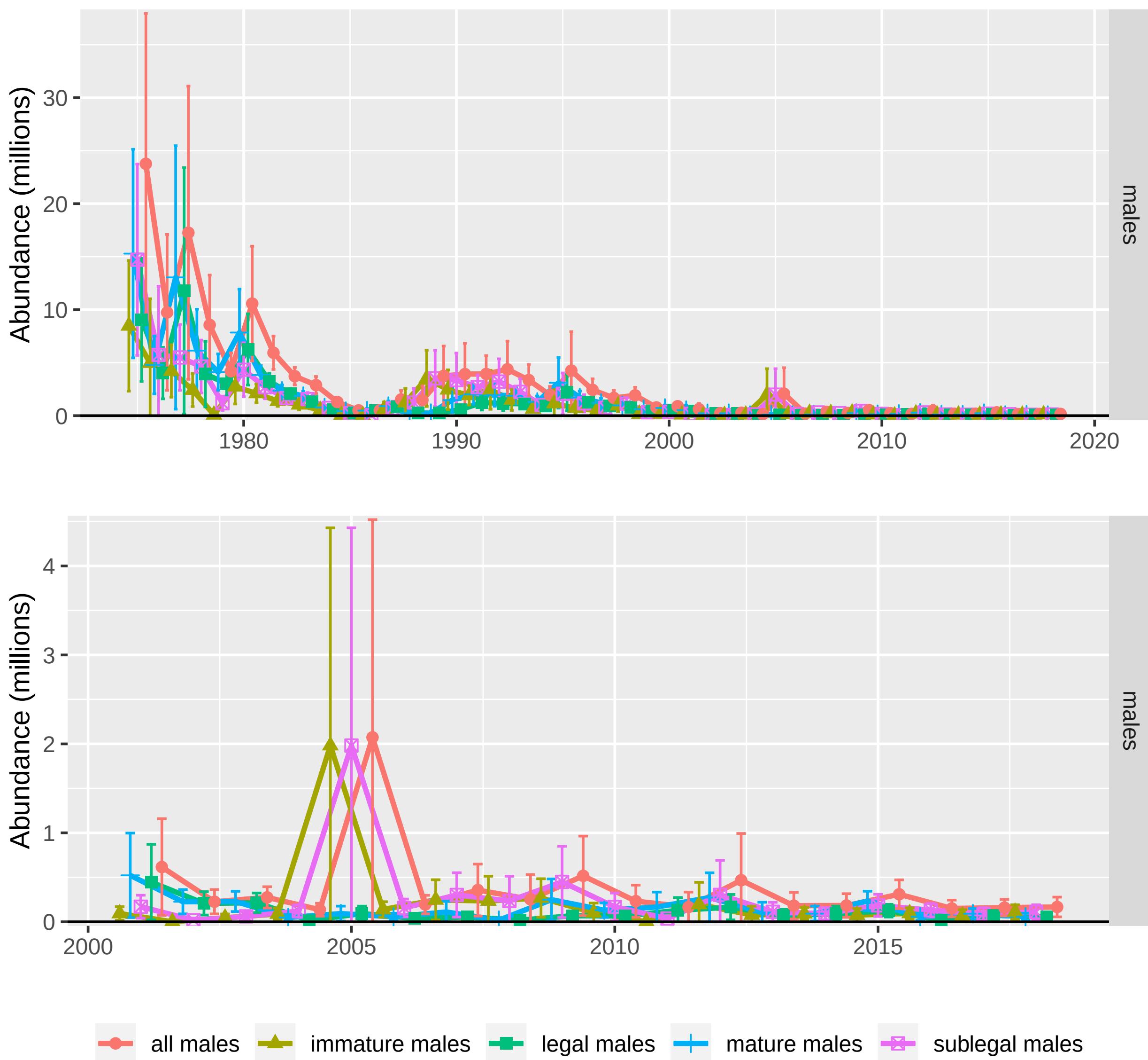


Figure 6: Time series of survey abundance for males in several categories (immature, mature, sublegal, legal and total).

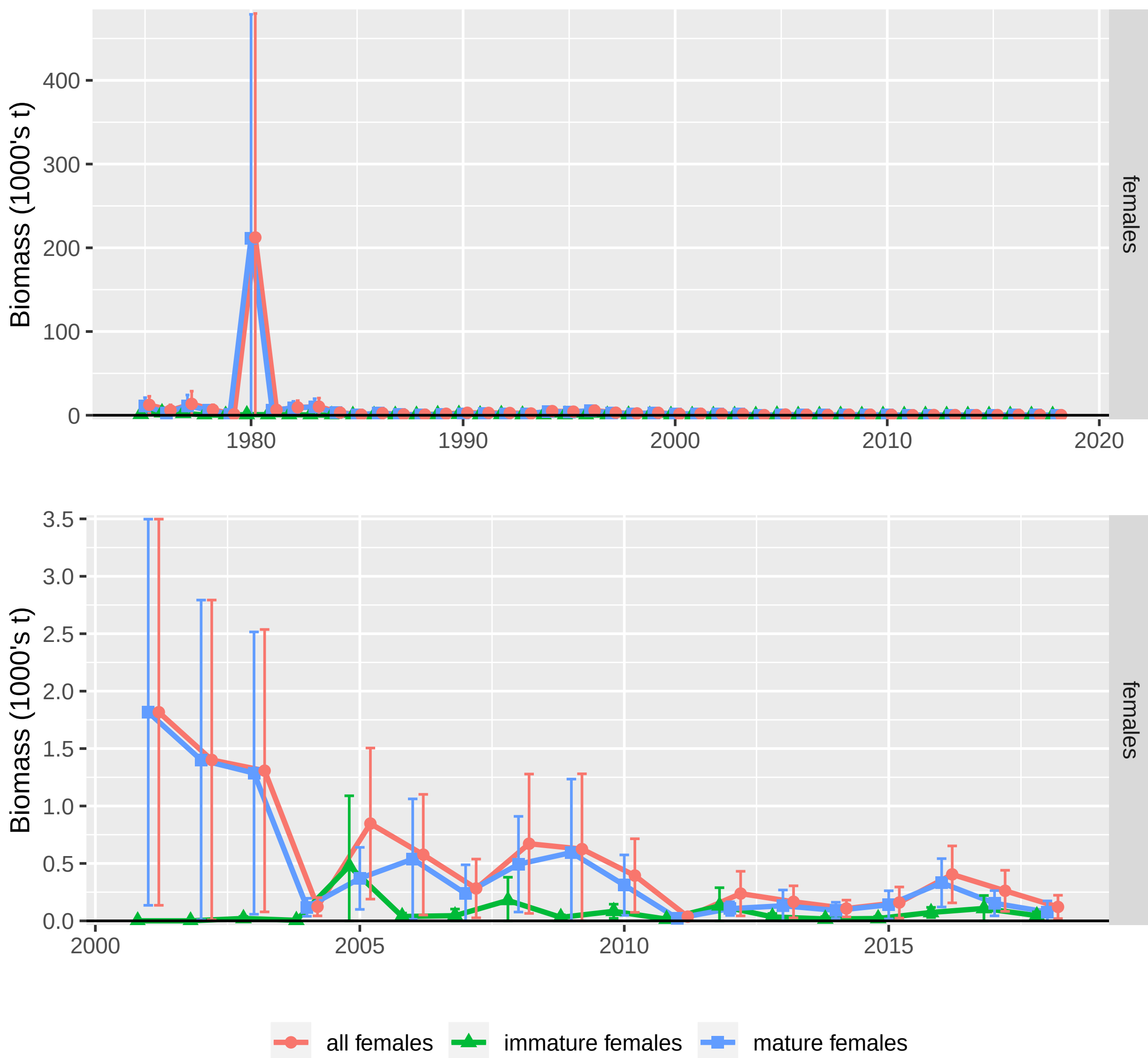


Figure 7: Time series of survey abundance for females (immature, mature, and total).

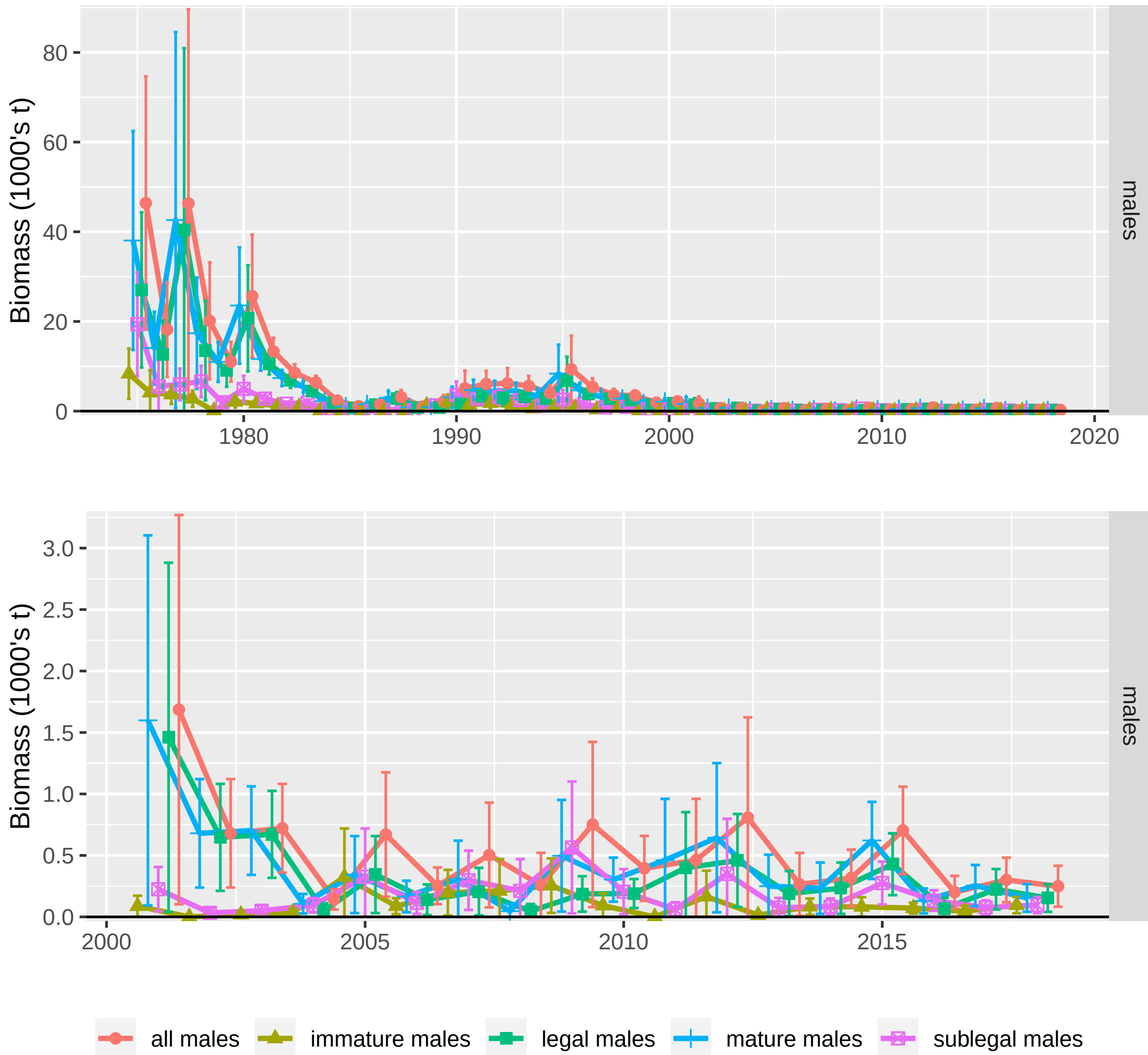


Figure 8: Time series of survey biomass for males in several categories (immature, mature, sublegal, legal and total).

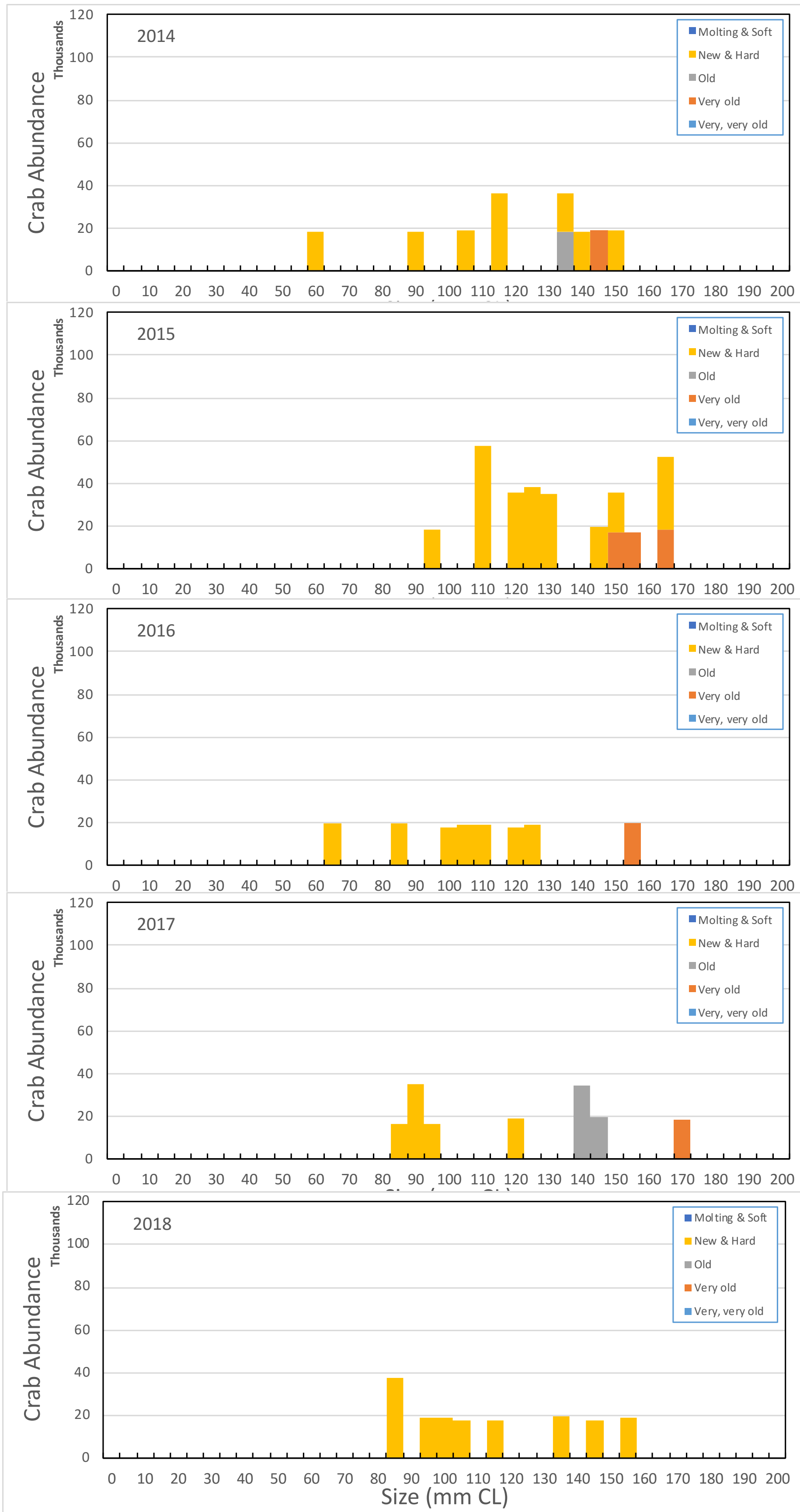


Figure 9: Size frequencies by shell condition for male Pribilof Island blue king crab in 5 mm length bins from recent NMFS EBS bottom trawl surveys.

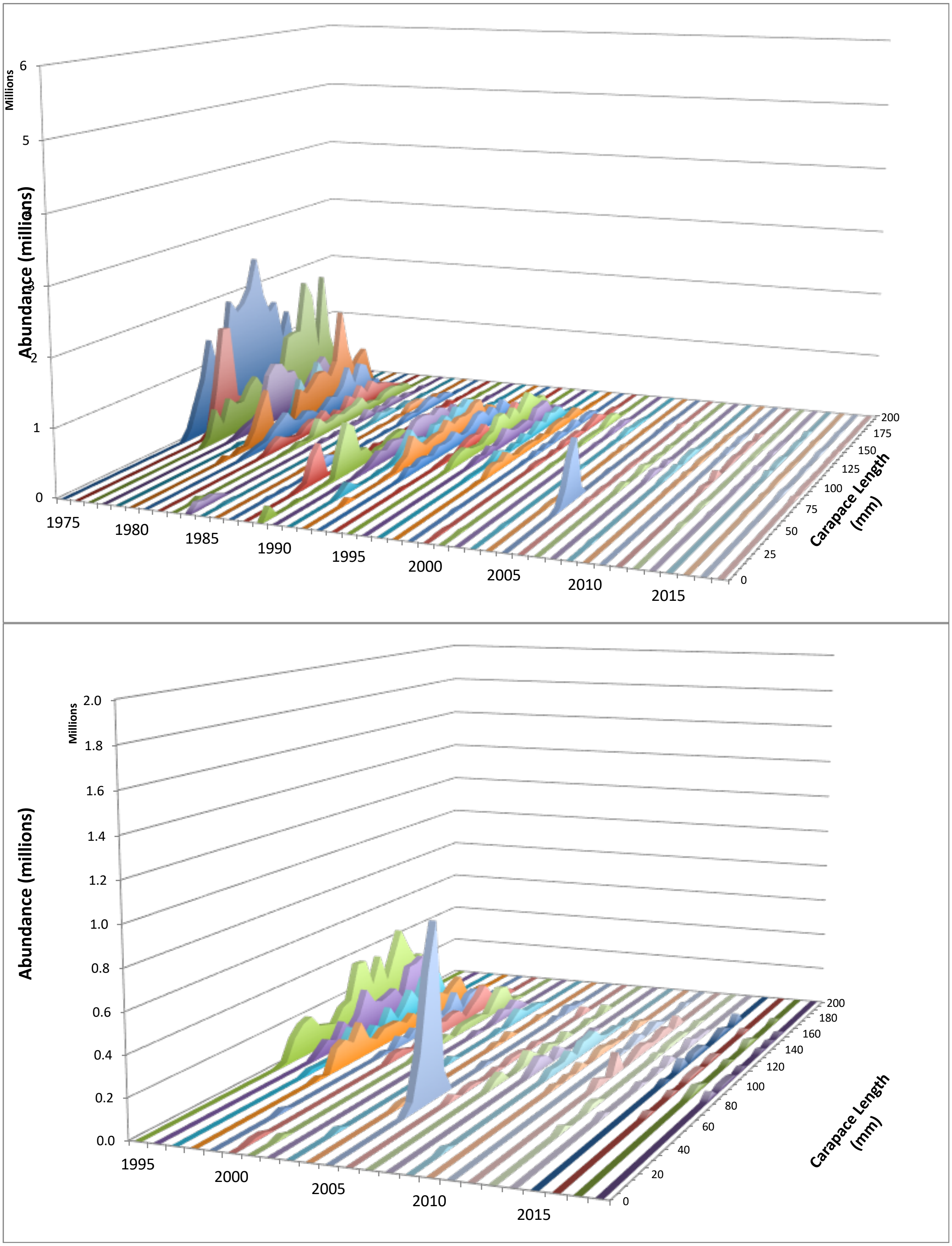


Figure 10: Size frequencies from the annual NMSF bottom trawl survey for male Pribilof Islands blue king crab by 5 mm length bins. The top row shows the entire time series, the bottom shows the size compositions since 1995.

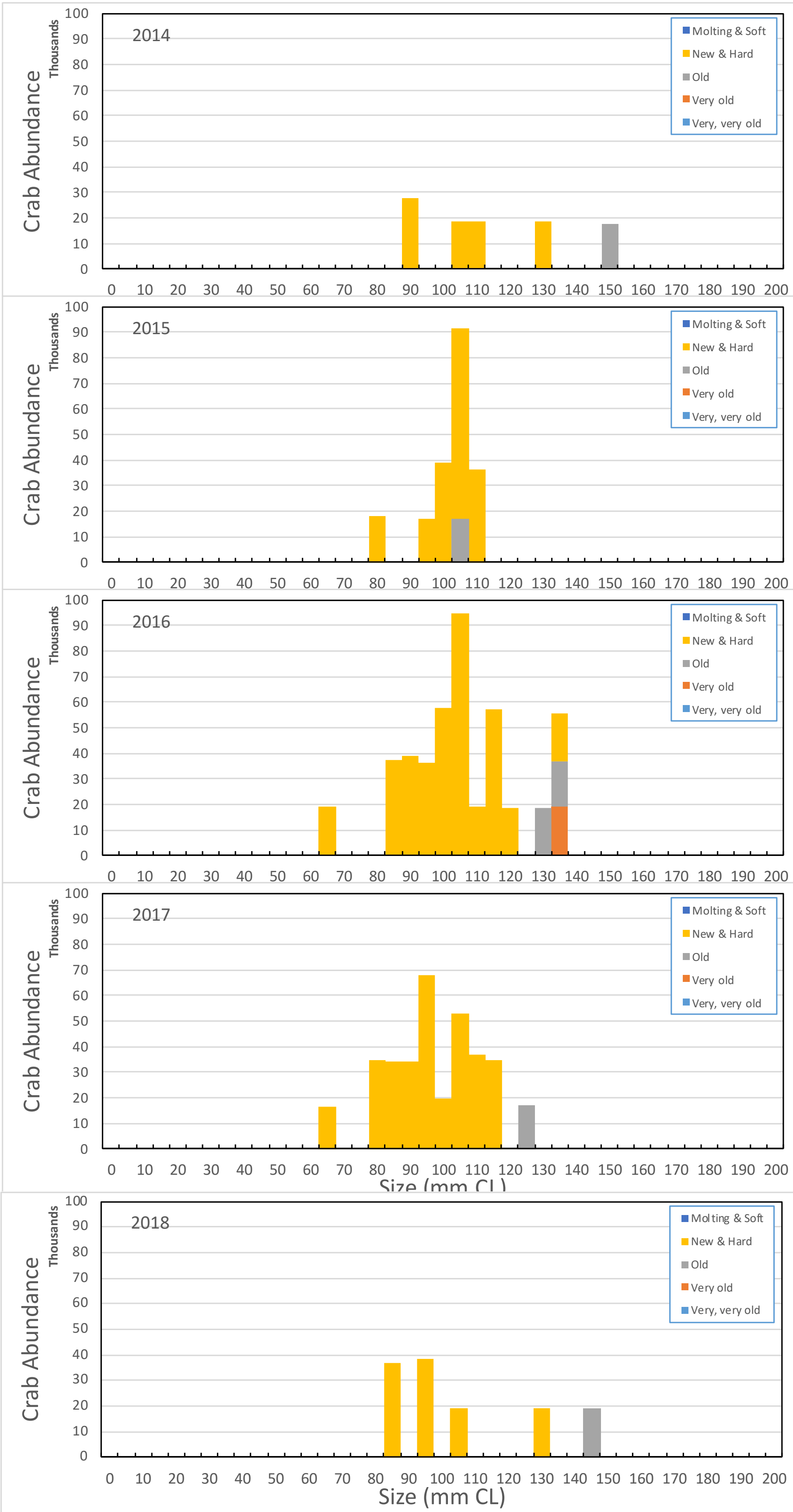


Figure 11: Size frequencies by shell condition for male Pribilof Island blue king crab in 5 mm length bins from recent NMFS EBS bottom trawl surveys.

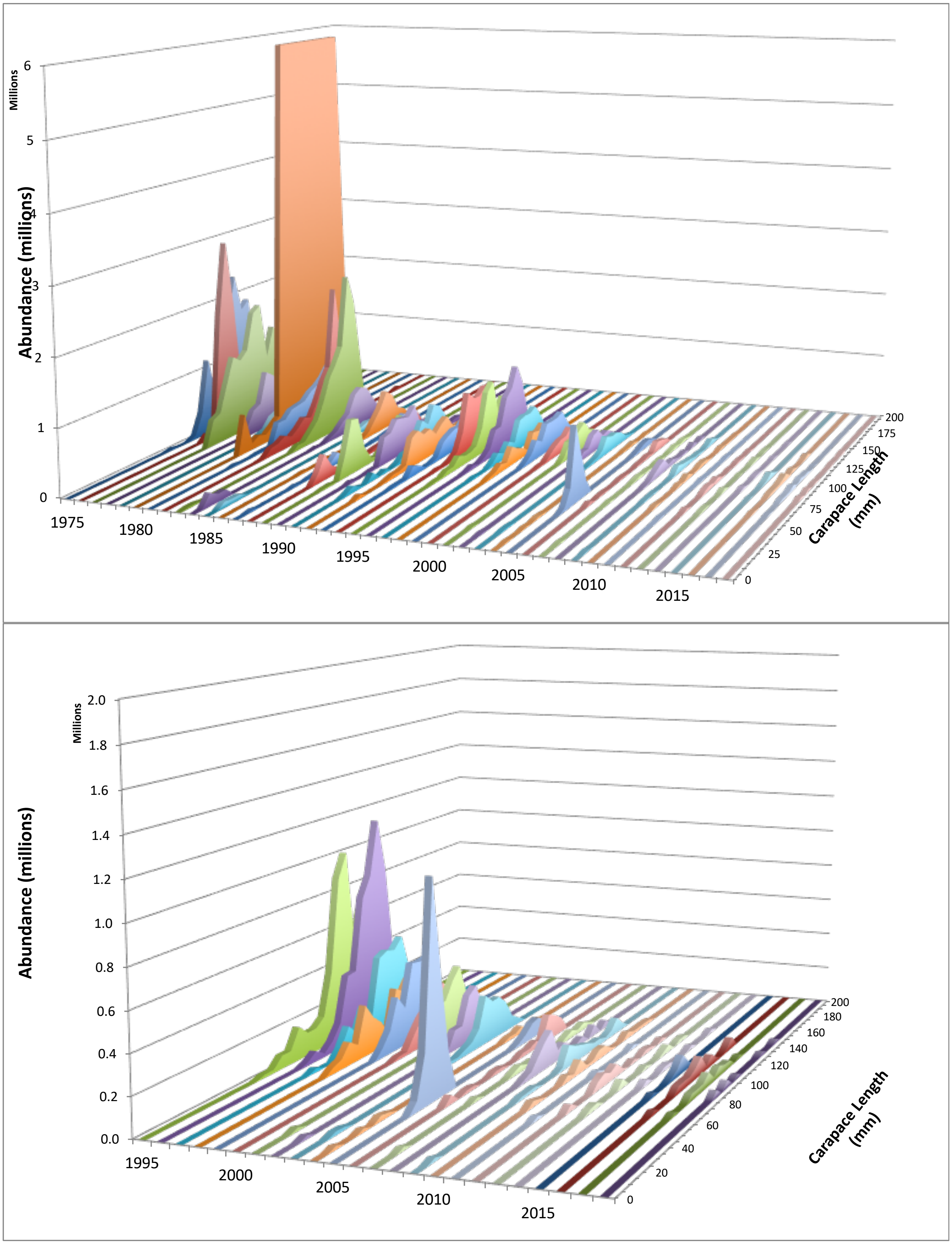


Figure 12: Size frequencies from the annual NMSF bottom trawl survey for male Pribilof Islands blue king crab by 5 mm length bins. The top row shows the entire time series, the bottom shows the size compositions since 1995.

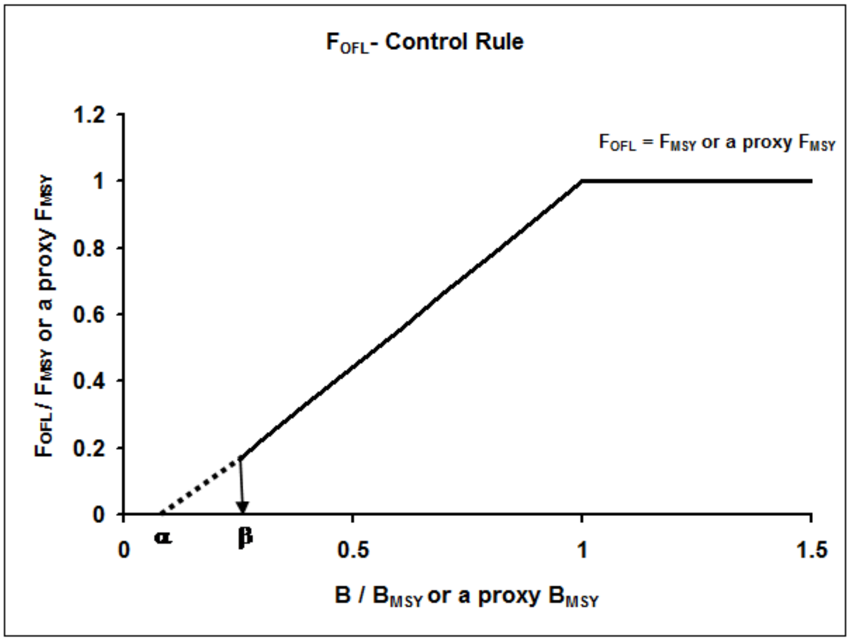


Figure 13: $F_{OFL}$ Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below $\beta$ (= 0.25).