Draft 2014 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 and discards have been relatively small in recent years, with most bycatch mortality occurring in the BSAI groundfish trawl fisheries (5-year average: 0.12 t [0.0003 million lbs]) and pot fisheries (5-year average: 0.03 t [0.0001 million lbs]). In 2013/14, the estimated crab bycatch mortality was zero in the groundfish trawl fisheries and 0.03 t (0.0001 million lbs) in the groundfish pot fisheries. The estimated bycatch mortality for Pribilof Islands blue king crab in other crab fisheries was zero in 2013/14.
3. Stock biomass: Stock biomass in recent years decreased between the 1995 and 2008 surveys, and continues to fluctuate at low abundance 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 blue king crab. Pre-recruits have remained consistently low in the past 10 years, although these may not be well assessed with the survey.
5. Management performance: The stock is below MSST and consequently is overfished. Overfishing did not occur during the 2013/2014 fishing year.

All units are tons of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2010/11	4,420 [A]	286 [A]	0	0	0.18	1.81	
2011/12	2,247 [A]	365 [A]	0	0	0.36	1.16	1.04
2012/13	1,994 [A]	579 [A]	0	0	0.61	1.16	1.04
2013/14	2,001 [A]	225 [A]	0	0	0.03	1.16	1.04
2014/15	--	218 [B]	--	--	--	1.16	1.04

All units are million pounds of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2010/11	9.74 [A]	0.63 [A]	0	0	0.0004	0.004	
2011/12	4.95 [A]	0.80 [A]	0	0	0.0008	0.003	0.002
2012/13	4.39 [A]	1.09 [A]	0	0	0.0013	0.003	0.002
2013/14	4.41 [A]	0.50 [A]	0	0	0.0001	0.003	0.002
2014/15	--	0.48 [B]	--	--	--	0.003	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 2014/2015 OFL: The OFL was set following Tier 4 considerations. The ratio of the estimate of current (2014/15) MMB at mating to B_{MSY} is less than 0.25, so directed fishing is not allowed. As a consequence, the OFL is based on a Tier 5 calculation of average bycatch mortalities between 1999/2000 and 2005/2006 to adequately reflect the conservation needs with this stock and to acknowledge existing non-directed catch mortality. Using this approach, the OFL was determined to be 1.16 t (0.0003 million lbs) for 2014/15.

All weights in t.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2010/11	4c	4,209	286	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2011/12	4c	4,209	365	0.09	1	1975/76-1984/85 &1990/91-1997/98	0.18	10% buffer
2012/13	4c	4,494	496	0.11	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2013/14	4c	3,988	278	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	4,002	218	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer

All weights in million lbs.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2010/11	4c	9.28	0.63	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2011/12	4c	9.28	0.80	0.09	1	1975/76-1984/85 &1990/91-1997/98	0.18	10% buffer
2012/13	4c	9.91	1.09	0.11	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2013/14	4c	8.79	0.61	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	8.82	0.48	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer

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

8. The ABC_{max} was calculated using a 10% buffer similar to that of the Tier 5 ABC control rule. The ABC_{max} was thus estimated to be 1.04 t.

9. Rebuilding analyses results summary: Proposed Crab FMP and regulatory amendments were submitted for review by the Secretary in early 2013 because NMFS determined that the stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. These amendments are still under review.

A. Summary of Major Changes:

1. Management: There were no major changes to the 2013/2014 management of the fishery.
2. Input data: Retained and discard catch time series were updated with 2013/2014 data from the crab and groundfish fisheries. A new methodology for estimating discard catch for the groundfish fisheries based on ADF&G state statistical areas was used for 2009/10-2013/14, replacing the previous estimates. This new methodology corrected some deficiencies in a similar approach used in the previous assessment. Abundance, biomass and size frequencies were estimated from the 2014 NMFS crab and groundfish summer bottom trawl survey data using the same methodology as in 2013, as well.
3. Assessment methodology: The time series of MMB-at-mating to determine B_{MSY} for this stock was estimated using a 3-year centered, running average, weighted by the inverse variance. The MMB-at-mating for 2014/15 was calculated by projecting a simple average of MMB-at-survey for this year and last year forward to mating, using a 3-year average estimator for the ratio of bycatch mortality to MMB-at-fishery to estimate the projected bycatch mortality for 2014/15.
4. Assessment results: The projected MMB decreased somewhat from that in 2013/14 and remained below the MSST. Consequently, the OFL remains low with no directed fishery. Total catch mortality in 2013/2014 was 0.03 t.

B. Responses to SSC and CPT Comments

<u>SSC comments October 2013:</u>

Specific remarks pertinent to this assessment

The SSC recommends a modified Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/2006, resulting in a total catch OFL of 0.00116 kt.

The SSC supports using a 10% buffer for the ABC calculation, resulting in an ABC_{max} of 0.00104 kt.

Responses to SSC Comments: The authors have followed the SSC's recommendations for OFL and ABC calculations. Because these are based on catch mortalities over a fixed time period, the resulting OFL and ABC values are identical to those the SSC recommended last year.

<u>SSC comments June 2014:</u>

Specific remarks pertinent to this assessment

none

<u>CPT comments September 2013:</u>

Specific remarks pertinent to this assessment

The CPT expressed interest in seeing information about whether the amount of observer coverage has changed since the new groundfish observer program was implemented in 2013.

The CPT would like to see the spatial distribution of bycatch by State statistical area.

Responses to CPT Comments: This will be addressed at the May 2015 CPT meeting.

<u>CPT comments May 2014:</u>

Specific remarks pertinent to this assessment

none

C. Introduction

1. **Blue king crabs,** *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 that are frequently associated with fjord-like bays (Figure 1). In the western Pacific, blue king crabs occur off Hokkaido in Japan, and isolated populations have been observed n 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 (Somerton 1985; Armstrong et al 1985, 1987).

   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 occupied the waters adjacent to and northeast of the Pribilof Islands (Armstrong et al. 1987).

3. **Stock structure -** Stock structure of blue king crabs in the North Pacific is largely unknown. Samples were collected in 2009-2011 to support a genetic study on blue king crab population structure by a graduate student at the University of Alaska. Aspects of blue king crab harvest and abundance trends, phenotypic characteristics, behavior, movement, and genetics will also be evaluated by the authors 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.

   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 the previous assessment (Foy, 2013). R. Foy 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 ands 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 i 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 exist 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).

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 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 (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 for all king crab species was adopted in the federal crab fishery management plan for the BSAI areas (Siddeek et. al 2002).

5. **Management history -** The king crab fishery in the Pribilof District began in 1973 with a reported catch of 590 t by eight vessels (Figure 3). Landings increased during the 1970s and peaked at a harvest of 5,000 t in the 1980/81 season, with an associated increase in effort to 110 vessels (ADF&G 2008). The fishery occurred September through January, but usually lasted less than 6 weeks (Otto and Cummiskey 1990, ADF&G 2008). The fishery was male only, and legal size was >16.5 cm carapace width (NOAA 1995). Guideline harvest level (GHL) was 10 percent of the abundance of mature male or 20 percent of the number of legal males (ADF&G 2006). Following 1995, declines in the stock resulted in a closure of directed fishing from 1999 to present. The Pribilof Islands blue king crab stock was declared overfished in September, 2002 and the Alaska Department of Fish and Game (ADFG) developed a rebuilding harvest strategy as part of the North Pacific Fishery Management Council's (NPFMC) comprehensive rebuilding plan for the stock.

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

   Blue king crab in the Pribilof District can occur as bycatch in the following crab fisheries: the eastern Bering Sea snow crab (*Chionoecetes opilio*), the eastern Bering Sea Tanner crab (*Chionoecetes bairdi*), the Bering Sea hair crab (*Erimacrus isenbeckii*), and the Pribilof red and blue king crab. In addition, blue king crab are caught in flatfish, sablefish, halibut, pollock, and Pacific cod fisheries.

D. Data

1. *Summary of new information:* The standard survey time series data, including an additional (as of 2013) 20 nm strip on the eastern portion of the Pribilof District, was recalculated and updated through 2014. The time series of discards in the groundfish pot and trawl fisheries was recalculated and updated through the 2013/14 crab fishery season (July 1-June 30). The time series of retained and discarded catch in the crab fisheries was also updated with 2013/2014 data.

2. *a. Total catch:*

   <u>Crab pot fisheries</u>

   Retained pot fishery catches (live and deadloss landings data) are provided for 1973/1974 to 2012/2013 (Table 1), including the 1973/1974 to 1987/1988 and 1995/1996 to 1998/1999 seasons when blue king crab were targeted in the Pribilof Islands District. In the 1995/1996 to 1998/1999 seasons, blue king crab and red king crab were fished under the same GHL. Total allowable catch (TAC) for a directed fishery was set at zero in 2013/14 and there was consequently no retained catch in the 2013/2014 crab fishing season *b. Bycatch and discards:*

Crab pot fisheries

Non-retained (directed and non-directed) pot fishery catches are provided for sub-legal males (≤138 mm CL), legal males (>138 mm CL), and females based on data collected by onboard observers in the crab fisheries. 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 (*CL*; in mm) was converted to weight (*W*; in g) using the following equation:

$$W = \alpha \cdot CL^{\beta} \qquad (1)$$

Values for the length-to-weight conversion parameters α and β were available for two time periods: 1973-2009 (males: α =0.000329, β =3.175; females: α =0.114389, β =1.9192) and 2010-2011 (both sexes: α =0.000508, β =3.106). Average weights ($\overline{W}$) for each category were calculated using the following equation:

$$\overline{W} = \frac{\sum_z W_z \cdot n_z}{\sum_z n_z} \qquad (2)$$

where W_z is crab weight-at-size *z* (i.e., carapace length) using Eq. 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. A 50% handling mortality rate was applied to these bycatch estimates to estimate crab mortality in these pot fisheries.

Historical non-retained catch data are available from 1996/1997 to present from the snow crab general, snow crab CDQ, and Tanner crab fisheries (Table 2, Bowers et al. 2011), although data may be incomplete for some of these fisheries. Prior to 1998, limited observer data exists (for catcher-processor vessels only), so non-retained catch before this date is not included here.

In 2013/2014, there were no Pribilof Islands blue king crab incidentally caught in the crab fisheries (Table 2).

Groundfish pot, trawl, and hook and line fisheries

NOAA Fisheries Alaska Regional Office (AKRO; J. Gasper, NMFS, pers. comm.) estimates of non-retained catch from all groundfish fisheries in 2013/14 are included in this SAFE report. Revised estimates for 2009/10-2012/13, based on an improved approach to handling unobserved catches, are also included (Table 2 and 3).

Prior to 1991, groundfish bycatch data are available only in INPFC reports and are not included in this assessment. Historical non-retained groundfish catch data are available from 1991/1992 to present (J. Mondragon, NMFS, personal communication). 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 federal reporting area. Starting in January 2009, ADF&G (state) statistical areas were included in groundfish production reports and allowed an increase in the spatial resolution of bycatch estimates from the federal reporting areas to the state statistical areas. Bycatch estimates (2009-present) based on the state statistical areas were first provided in the 2013 assessment. For this assessment (2014), these estimates have been recalculated based on improved methods for aggregating observer data. More information on crab bycatch estimates in the groundfish fisheries, and changes between 2013 and 2014, is provided in Appendix A.

To assess crab mortalities in the groundfish fisheries, an 80% handling mortality rate was applied to estimates of bycatch using trawl fisheries and a 50% handling mortality rate was applied to fisheries using pot and hook and line gear (Table 2, 3). Changes in these results from the 2013 assessment for 2009/10-2012/13 are summarized in the following table (units are t):

year	2013 estimates		2014 estimates		% change	
	fixed gear	trawl gear	fixed gear	trawl gear	fixed gear	trawl gear
2009/10	1.04	0.17	0.11	0.17	-89	0
2010/11	0.05	0.05	0.02	0.05	-60	0
2011/12	0.06	0.01	0.06	0.01	0	0
2012/13	0.08	0.54	0.08	0.54	0	0

While changes in estimates from fixed gear were substantial in a relative sense for 2009/10 and 2010/11, they were small in an absolute sense (< 1 t).

In 2013/14, bycatch of Pribilof Islands blue king crab occurred almost exclusively in fisheries targeting Pacific cod (*Gadus macrocephalus*; 99.2% by weight, Table 3). In 2012/13, fisheries targeting Pacific cod accounted for 20% of the bycatch while those targeting yellowfin sole (*Limanda aspera*) accounted for 77.2%. The flathead sole (*Hippoglossoides elasodon*) fishery also accounted for a substantial fraction of the bycatch in 2010/11 (26%).

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 4). In 2013/14, hook and line gear accounted for the total bycatch of Pribilof Islands blue king crab. In the previous year, it accounted for only 20% of the bycatch (by weight) whereas non-pelagic trawl gear accounted for 80%.

c. Catch-at-length: NA

d. Survey biomass:

The 2014 NMFS EBS bottom trawl survey results (Daly et al. in press) included in this SAFE report are based on the new Pribilof Islands blue king crab stock area definition first used in the 2013 assessment. This stock area definition includes the Pribilof District and a 20 nm strip adjacent to the eastern edge of the District. This new area was defined as a result of the new rebuilding plan and the concern that crab outside of the Pribilof District were not being accounted for in the assessment. The addition of the 20 nm strip resulted in a small effect on the time series (Foy, 2013). Annual differences between the previous time series and the new time series ranged from 0 to 9% (Foy, 2013). Historical survey data were available from 1975 to the present (Tables 6 and 7).

Abundance estimates for male and female crab were calculated by shell condition using 5 mm size (CL) bins. Weight-at-size (Eq. 1) schedules and cutpoint maturity criteria (females: immature < 90 mm CL, mature ≥ 90 mmCL; males: immature < 120 mm CL, mature ≥ 120 mm CL) were applied to these abundance-at-size estimates and summed across relevant sizes to calculate mature male, female, and legal male biomass.

A total of 15 blue king crab were caught at 6 of the 86 stations in the Pribilof District; 10 males were caught at 4 stations and 5 females were caught at 4 stations (Table 5). Males and females were caught together at two of these stations.

Five mature males were caught at 2 stations. All were legal-sized. The 2014 area-swept biomass estimate (± 95% CI) for mature/legal-sized males was 233 ± 320 t, while the 2014 abundance estimate was 0.09 ± 0.13 million crab (Table 6, Figure 5). Also, five immature males were caught at 3 stations. The 2014 biomass estimate for immature males was 83 ± 102 t, while the 2014 abundance estimate was 0.09 ± 0.11 million crab (Table 6, Figure 5).

For mature males, the 2014 survey represents a 7% decrease in biomass and a 12% decrease in abundance over 2013; both are well below the 1990-2013 averages of 1,888 t for biomass and 0.81 million for abundance. For legal males, the changes represent a 22% increase in biomass and a 34% increase in abundance over 2013, but both are well below the 1990-2013 averages of 1,456 t for biomass and 0.53 million for abundance. For immature males, the changes represent a 472% increase in biomass and a 19% increase in abundance over 2013, but both are well below the 1990-2013 averages of 445 t for biomass and 0.69 million for abundance.

Four mature females were caught at 3 stations. The 2014 area-swept biomass estimate (± 95% CI) for mature females was 91 ± 108 t, while the 2014 abundance estimate was 0.07 ± 0.09 million crab (Table 6, Figure 5). One immature female was caught. The 2014 area-swept biomass estimate (± 95% CI) for immature females was 16 ± 32 t, while the 2014 abundance estimate was 0.03 ± 0.05 million crab (Table 6, Figure 5).

For mature females, the 2014 survey represents a 30% decrease in biomass and a 12% decrease in abundance over 2013; both are well below the 1990-2013 averages of 1,590 t for biomass and 1.5 million for abundance. For immature females, the changes represent a 53% decrease in biomass and a 69% increase in abundance over 2013, but both are well below the 1990-2013 averages of 270 t for biomass and 0.68 million for abundance.

Given the large confidence intervals and CVs involved in these area-swept biomass and abundance estimates (Table 7), none of the changes from 2013 to 2014 is statistically significant. To smooth out some of the interannual variability in survey results associated with sampling uncertainty, a centered 3-year running average with inverse variance weighting was applied to the time series of abundance and biomass estimates in Table 6 (Table 8). The smoothed trends suggest that mature male biomass (MMB; Figure 6) and male recruit biomass (Figure 7) trends have been relatively stable since 2010.

Size frequencies for males by shell condition from the 3 most recent surveys (2012-2014) are illustrated in Figure 8, while size frequencies for all males are shown in Figure 9.

Size frequencies for females by shell condition, egg condition, and clutch fullness are illustrated in Figure 10 for the 2014 survey. Size frequencies for all females are shown in Figure 11.

Spatial patterns found in the 2014 survey are contrasted with those from the 2013 survey in Figures 12-14.

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.

2. *Model Desciption: Not applicable.*

3. *Model Selection and Evaluation: Not applicable*
4. *Results: Not applicable*

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 2008).

In Tier 4, stock status is based on the ratio of current B to B_{MSY} (or a proxy thereof, B_{MSY}^{proxy}, also referred to as B_{REF}). MSY 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}. The MSY stock size (B_{MSY}) 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}^{proyx} or B_{REF}) is defined as the average biomass over a specified period that satisfies the conditions under which B_{MSY} would occur (i.e., equilibrium biomass yielding MSY by 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} 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. Considerations for choosing the current time periods included:

A. Production potential

1) Between 2006 and 2013 the stock does appears 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).

2) An estimate of surplus production (ASP = MMB_{t+1} – MMB_t + total catch_t) suggested that only meaningful surplus existed 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 a climate regime shift where temperature and current structure changes are likely to impact blue king crab larval dispersal and subsequent juvenile crab distribution, no apparent trends in production before and after 1978 were observed. There are few empirical data to identify trends that may allude to a production shift. However, further analysis is warranted given the paucity of surplus production and recruitment subsequent to 1981 and the spikes in recruits (male crab 120-134 mm) /spawner (MMB) observed in the early 1990s and 2009 (Figure 21).

B. Exploitation rates fluctuated during the open fishery periods from 1975 to 1987 and 1995 to 1998 (Figure 20) while total catch increased until 1980 before the fishery was closed in 1987 and increased again in 1995 before again closing in 1999 (Figure 22). The current $F_{\mathrm{MSY}}^{\mathrm{proxy}}$ assume F=M is 0.18 so time periods with greater exploitation rates should not be considered to represent a period with an average rate of fishery removals.

C. Subsequent to increases in exploitation rates in the late 1980s and 1990s, the ln (recruits/MMB) dropped, suggesting that exploitation rates at the levels of MMB present were not sustainable.

Thus, 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 B. For this stock, B_{MSY}^{proxy} was calculated using "raw" (unsmoothed) estimates for MMB_{survey} in the formula for MMB_{mating}. B_{MSY}^{proxy} is the average of MMB_{mating} for the years 1980-84 and 1990-97 (see Table 6) and was calculated as 4002 t.

In this assessment, "current B" is the MMB_{mating} projected for 2014/15. Details of this calculation are provided in Appendix B. For 2014/15, current B =

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 B_{MSY}^{proxy} and if the current MMB (projected to the time of mating) drops below the MSST, the stock is considered to be overfished.

2. *List of parameter and stock sizes:*

- B_{MSY}^{proxy} (B_{REF}) = 4,002 t
- M = 0.18 yr^{-1}

3. *OFL specification:*

a. In the Tier 4 OFL-setting approach, the "total catch OFL" and the "retained catch OFL" are calculated by applying the F_{OFL} to all crab at the time of the fishery (total catch OFL) or to the mean retained catch determined for a specified period of time (retained catch OFL). The Tier 4 F_{OFL} Control Rule is illustrated in Figure 15.

The Tier 4 F_{OFL} is derived using the F_{OFL} Control Rule (Figure 15), where Stock Status Level (level a, b or c; equations 6-8) is based on the relationship of current MMB (B) to B_{MSY}^{proxy}:

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

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

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

c. Specification of F_{OFL}, OFL and other applicable measures:

All weights in t.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2010/11	4c	4,209	286	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2011/12	4c	4,209	365	0.09	1	1975/76-1984/85 &1990/91-1997/98	0.18	10% buffer
2012/13	4c	4,494	496	0.11	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2013/14	4c	3,988	278	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	4,002	218	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer

All weights in million lbs.

Year	Tier	B_{MSY}	Current MMB_{mating}	B/B_{MSY} (MMB_{mating})	γ	Years to define B_{MSY}	Natural Mortality	P*
2010/11	4c	9.28	0.63	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2011/12	4c	9.28	0.80	0.09	1	1975/76-1984/85 &1990/91-1997/98	0.18	10% buffer
2012/13	4c	9.91	1.09	0.11	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2013/14	4c	8.79	0.61	0.07	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer
2014/15	4c	8.82	0.48	0.05	1	1980/81-1984/85 &1990/91-1997/98	0.18	10% buffer

4. *Specification of the retained catch portion of the total catch OFL:*

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

5. *Recommendations:*

   For 2014/2015, *B_{MSY}^{proxy} = 4002 t, derived as the mean MMB_{mating} from 1980 to 1984 and 1990 to 1997*. The stock demonstrated highly variable levels of MMB during both of these periods likely leading to uncertain approximations of B_{MSY}. Crabs were highly concentrated during the EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to a limited number of tows with crab catches.

   MMB_{mating} for 2014/15 was estimated at 218 t for B_{MSY}^{prxyy}. The B/B_{MSY}^{proxy} ratio corresponding to the biomass reference is 0.05. B/B_{MSY}^{proxy} is < β, 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 2008). The preferred method was a total catch OFL equivalent to the average catch mortalities between 1999/2000 and 2005/2006. 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 author recommended OFL for 2014/15, 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 (σ_w) in the OFL to establish the maximum permissible ABC (ABC_{max}). Any additional uncertainty to account for uncertainty outside of the assessment methods (σ_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 $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$. For a Tier 5 stock a constant buffer of 10% is applied to the OFL.

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 2005/2006 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 is 0.70 and has ranged between 0.17 and 0.80 since the 1980 peak in biomass.

3. *List of additional uncertainties considered for alternative σ_b applications to the ABC.*

   Several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:

   - Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.

   - F_{msy} is assumed to be equal to γM when applying the OFL control rule while γ is assumed to be equal to 1 and M is assumed to be known.

   - The 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 2014/2015, $F_{directed}$ = 0 and the total catch OFL 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_{max}* based on a 10% buffer of the average catch between 1999/2000 and 2005/2006 would be 1.04 t.**

All units are tons of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2010/11	4,420 [A]	286 [A]	0	0	0.18	1.81	
2011/12	2,247 [A]	365 [A]	0	0	0.36	1.16	1.04
2012/13	1,994 [A]	579 [A]	0	0	0.61	1.16	1.04
2013/14	2,001 [A]	225 [A]	0	0	0.03	1.16	1.04
2014/15	--	218 [B]	--	--	--	1.16	1.04

All units are million pounds of crab and the OFL is a total catch OFL for each year:

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2010/11	9.74 [A]	0.63 [A]	0	0	0.0004	0.004	
2011/12	4.95 [A]	0.80 [A]	0	0	0.0008	0.003	0.002
2012/13	4.39 [A]	1.09 [A]	0	0	0.0013	0.003	0.002
2013/14	4.41 [A]	0.50 [A]	0	0	0.0001	0.003	0.002
2014/15	--	0.48 [B]	--	--	--	0.003	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.

H. Rebuilding Analyses

3Rebuilding analyses results summary: Proposed Crab FMP and regulatory amendments were submitted for review by the Secretary in early 2013 since NMFS determined that the stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014.

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. Further data gaps include a lack of understanding regarding processes apparently preventing successful recruitment to the Pribilof District.

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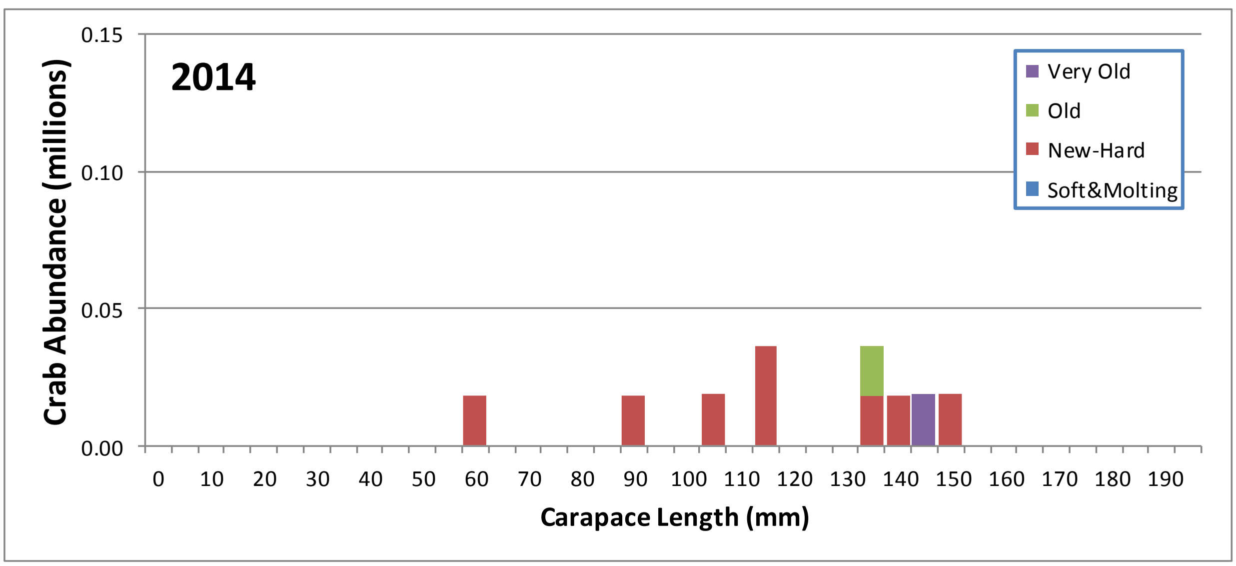


Figure 13. 2013 (left) and 2014 (right) EBS bottom trawl survey size class distribution of blue king crab in the Pribilof District.

Figure 14. 2013 (left) and 2014 (right) EBS bottom trawl survey frequency of occurrence of mature male blue king crab in the Pribilof District.

Figure 15. F_{OFL} Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β (= 0.25).

Tables

Table 1. Total retained catches from directed fisheries for Pribilof Islands District blue king crab (Bowers et al. 2011; D. Pengilly, ADF&G, personal communications).

Year	Retained Catch		Avg. CPUE
	Abundance	Biomass (t)	legal crabs/pot
1973/1974	174,420	579	26
1974/1975	908,072	3224	20
1975/1976	314,931	1104	19
1976/1977	855,505	2999	12
1977/1978	807,092	2929	8
1978/1979	797,364	2901	8
1979/1980	815,557	2719	10
1980/1981	1,497,101	4976	9
1981/1982	1,202,499	4119	7
1982/1983	587,908	1998	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	0
1989/1990	0	0	0
1990/1991	0	0	0
1991/1992	0	0	0
1992/1993	0	0	0
1993/1994	0	0	0
1994/1995	0	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 - 2013/2014	0	0	0

Table 2. Total non-retained catch (bycatch/discard) mortalities from directed and non-directed fisheries for Pribilof Islands District blue king crab. Handling mortalities (pot and hook/line= 0.5, trawl = 0.8) were applied to estimates of non-retained catch based on observer data in the crab and groundfish fisheries. Crab bycatch data is not available prior to 1996/1997 (Bowers et al. 2011; D. Pengilly ADF&G). Gear-specific groundfish fishery data is not available prior to 1991/1992 (J. Mondragon, NMFS).

Year	Crab pot fisheries			Groundfish fisheries	
	Non-retained legal male (t)	Sublegal male (t)	Female (t)	Fixed gear (t)	Trawl gear (t)
1991/1992	NA	NA	NA	0.03	4.96
1992/1993	NA	NA	NA	0.44	48.63
1993/1994	NA	NA	NA	0.00	27.39
1994/1995	NA	NA	NA	0.02	5.48
1995/1996	NA	NA	NA	0.05	1.03
1996/1997	0	0.4	0	0.02	0.05
1997/1998	0	0	0	0.73	0.10
1998/1999	1.15	0.23	1.86	9.90	0.06
1999/2000	1.75	2.15	0.99	0.40	0.02
2000/2001	0	0	0	0.06	0.02
2001/2002	0	0	0	0.42	0.02
2002/2003	0	0	0	0.04	0.24
2003/2004	0	0	0	0.17	0.18
2004/2005	0	0	0	0.41	0.00
2005/2006	0	0	0.05	0.18	1.07
2006/2007	0	0	0.05	0.07	0.06
2007/2008	0	0	0.05	2.00	0.11
2008/2009	0	0	0	0.07	0.38
2009/2010	0	0	0	0.11	0.17
2010/2011	0	0.09	0	0.02	0.05
2011/2012	0	0	0	0.06	0.01
2012/2013	0	0	0	0.08	0.54
2013/2014	0	0	0	0.03	0.00

Table 3. Proportion by weight of the Pribilof Islands blue king crab bycatch in the groundfish fisheries among trip targets For the 2003/2004-2008/2009 crab fishing seasons, these were calculated using bycatch from NMFS Statistical Area 513. For 2009/10-2013/14, these were calculated using the AKRO Catch Accounting System, with data reported from State of Alaska statistical areas that encompass the newly-defined Pribilof Islands Blue King Crab District. Groundfish fishery target species that caught blue king crab but made up less than 1% of the blue king crab bycatch across all years are not shown in the table. These include pollock-bottom trawl, pollock-midwater trawl, halibut, Greenland halibut, and arrowtooth flounder.

Crab Fishery Year	% bycatch by trip target					total bycatch (# crabs)
	yellowfin sole %	Pacific cod %	flathead sole %	rocksole %	sablefish %	
2003/2004	47.0	22.0	31.0	0.0	0.0	252
2004/2005	0.0	100.0	0.0	0.0	0.0	259
2005/2006	0.0	97.0	3.0	0.0	0.0	757
2006/2007	54.0	20.0	0.0	26.0	0.0	96
2007/2008	3.0	96.0	1.0	0.0	0.0	2,950
2008/2009	77.0	23.0	0.0	0.0	0.0	295
2009/2010	30.5	51.1	16.8	0.0	<1	281
2010/2011	<1	38.5	59.0	0.0	<1	48
2011/2012	<1	99.8	<1	0.0	<1	63
2012/2013	77.2	20.0	2.9	0.0	<1	410
2013/2014	<1	99.2	<1	0.0	<1	26

Table 4. Proportion by weight of the Pribilof Islands blue king crab bycatch in the groundfish fisheries among gear types. For the 2003/2004-2008/2009 crab fishing seasons, these were calculated using bycatch from NMFS Statistical Area 513. For 2009/10-20134/14, these were calculated using the AKRO Catch Accounting System, with data reported from State of Alaska statistical areas that encompass the newly-defined Pribilof Islands Blue King Crab District.

Crab Fishery Year	% bycatch by gear type				total bycatch (# crabs)
	hook and line %	non-pelagic trawl %	pot %	pelagic trawl %	
2003/04	21	79	0	0	252
2004/05	99	1	0	0	259
2005/06	18	3	79	0	757
2006/07	20	20	0	0	96
2007/08	1	3	95	0	2,950
2008/09	23	77	0	0	295
2009/10	7	49	44	0	281
2010/11	41	59	0	0	48
2011/12	94	6	0	0	63
2012/13	20	80	0	0	410
2013/14	100	0	0	0	26

Table 5. Summary of 2014 NMFS annual EBS bottom trawl survey for Pribilof Islands District blue king crab by stock component.

Stock Component	Number of tows in District 2014	Tows with crab 2014	Number of crab measured 2014	Number of crab crab caught 2014	Abundance (millions)	Biomass (mt)
Immature male	86	3	5	5	0.091	83
Mature male	86	2	5	5	0.092	233
Legal male	86	2	5	5	0.092	233
Immature female	86	1	1	1	0.028	16
Mature female	86	3	4	4	0.074	91

Table 6. Pribilof Islands District blue king crab abundance, mature biomass, legal male biomass, and totals estimated based on the NMFS annual EBS bottom trawl survey. These data are estimated using the new stock boundaries established in 2012, which included a 20 nm column to the east of the previous stock boundary definition. Running averages were not done. NA = Not Available.

Year	@ time of survey					@ mating time
	Mature male abundance	Mature male biomass (t)	Legal male biomass (t)	Total male biomass (t)	Total female biomass (t)	Mature male biomass (t)
1975/1976	14,955,818	33,862	24,037	41,292	12,172	29,447
1976/1977	3,568,103	9,573	8,585	13,333	5,770	5,795
1977/1978	13,043,983	38,756	36,706	42,137	13,573	32,135
1978/1979	6,140,638	15,798	12,291	18,315	6,492	11,491
1979/1980	5,232,918	12,974	10,843	14,275	4,097	9,119
1980/1981	5,432,065	14,253	12,163	16,050	63,713	8,146
1981/1982	3,921,734	10,744	9,686	13,014	9,911	5,794
1982/1983	2,344,203	6,691	6,241	7,740	9,376	4,142
1983/1984	1,851,301	4,919	4,069	5,795	10,248	3,492
1984/1985	674,376	1,761	1,446	1,860	2,580	1,454
1985/1986	428,076	959	687	995	523	638
1986/1987	480,198	1,368	1,340	1,372	2,431	1,121
1987/1988	903,180	2,659	2,529	2,833	913	2,094
1988/1989	237,868	766	766	921	717	690
1989/1990	239,948	752	752	1,914	1,745	677
1990/1991	1,738,237	3,259	1,549	5,376	3,811	2,934
1991/1992	2,014,086	4,266	3,025	5,521	2,776	3,839
1992/1993	1,935,278	3,995	2,761	5,635	2,649	3,574
1993/1994	1,875,500	4,144	2,913	5,136	2,092	3,718
1994/1995	1,263,447	3,028	2,491	3,578	4,858	2,724
1995/1996	3,139,328	7,753	6,365	8,616	4,844	6,388
1996/1997	1,712,015	4,221	3,522	4,899	5,585	3,400
1997/1998	1,201,296	2,940	2,515	3,288	3,028	2,428
1998/1999	967,097	2,545	2,283	3,175	2,182	2,065
1999/2000	617,258	1,573	1,297	1,719	2,868	1,414
2000/2001	725,050	1,902	1,588	2,005	1,462	1,712
2001/2002	522,239	1,454	1,329	1,533	1,817	1,309
2002/2003	225,476	618	588	618	1,401	557
2003/2004	228,897	638	610	656	1,307	575
2004/2005	47,905	97	44	130	123	87
2005/2006	91,932	313	313	610	847	281
2006/2007	50,638	137	115	210	558	124
2007/2008	100,295	254	170	417	257	228
2008/2009	18,256	42	42	235	672	37
2009/2010	248,626	452	170	684	625	407
2010/2011	138,787	322	202	420	440	290
2011/2012	165,525	461	399	461	37	415
2012/2013	272,233	644	459	809	237	579
2013/2014	104,361	250	190	265	166	225
2014/2015	91,856	233	233	317	108	NA

Table 7. CVs for Pribilof Islands District blue king crab abundance, mature biomass, legal male biomass, and totals estimated based on the NMFS annual EBS bottom trawl survey. These data are estimated using the new stock boundaries established in 2012 which included a 20 nm column to the east of the previous stock boundary definition. Running averages were not done.

Year	@ time of survey				
	Mature male abundance	Mature male biomass	Legal male biomass	Total male biomass	Total female biomass
1975/1976	0.503	0.501	0.500	0.476	0.637
1976/1977	0.418	0.413	0.421	0.468	0.893
1977/1978	0.743	0.768	0.784	0.729	0.874
1978/1979	0.496	0.558	0.643	0.506	0.717
1979/1980	0.266	0.256	0.247	0.275	0.441
1980/1981	0.319	0.300	0.285	0.310	0.894
1981/1982	0.173	0.168	0.169	0.173	0.452
1982/1983	0.181	0.187	0.192	0.175	0.669
1983/1984	0.186	0.178	0.175	0.187	0.781
1984/1985	0.229	0.233	0.254	0.227	0.385
1985/1986	0.281	0.267	0.283	0.263	0.446
1986/1987	0.305	0.303	0.307	0.302	0.896
1987/1988	0.414	0.411	0.414	0.397	0.526
1988/1989	0.509	0.529	0.529	0.457	0.473
1989/1990	0.624	0.637	0.637	0.551	0.497
1990/1991	0.439	0.425	0.381	0.433	0.375
1991/1992	0.363	0.385	0.450	0.373	0.376
1992/1993	0.420	0.423	0.446	0.432	0.463
1993/1994	0.310	0.307	0.301	0.305	0.399
1994/1995	0.341	0.346	0.352	0.344	0.436
1995/1996	0.540	0.539	0.544	0.564	0.423
1996/1997	0.281	0.269	0.265	0.279	0.491
1997/1998	0.294	0.276	0.271	0.294	0.407
1998/1999	0.246	0.249	0.255	0.252	0.392
1999/2000	0.334	0.337	0.347	0.333	0.467
2000/2001	0.296	0.296	0.305	0.304	0.460
2001/2002	0.710	0.735	0.759	0.733	0.722
2002/2003	0.473	0.506	0.525	0.506	0.775
2003/2004	0.389	0.400	0.411	0.390	0.734
2004/2005	0.563	0.583	1.000	0.455	0.504
2005/2006	0.712	0.710	0.710	0.589	0.606
2006/2007	0.565	0.604	0.700	0.462	0.671
2007/2008	0.854	0.799	0.734	0.662	0.708
2008/2009	1.000	1.000	1.000	0.797	0.705
2009/2010	0.732	0.713	0.604	0.698	0.818
2010/2011	0.484	0.459	0.481	0.521	0.604
2011/2012	0.792	0.843	0.886	0.843	0.674
2012/2013	0.797	0.735	0.643	0.786	0.637
2013/2014	0.862	0.797	0.752	0.754	0.654
2014/2015	0.710	0.699	0.699	0.567	0.529

Table 8. Three-year weighted (inverse variance), centered running averages of Pribilof Islands District blue king crab mature male abundance and biomass, legal male biomass, total male biomass, total female biomass, and mature male biomass at mating time based on the NMFS annual EBS bottom trawl survey. NA = Not Available.

Year	@ time of survey					@ mating time
	Mature male abundance	Mature male biomass (t)	Legal male biomass (t)	Total male biomass (t)	Total female biomass (t)	Mature male biomass (t)
1975/1976	NA	NA	NA	NA	NA	NA
1976/1977	4,200,609	11,280	10,247	16,841	8,410	6,633
1977/1978	4,234,074	11,020	9,579	15,638	6,747	6,699
1978/1979	5,517,339	13,598	11,191	15,260	4,592	9,575
1979/1980	5,404,179	13,645	11,402	15,289	4,463	8,838
1980/1981	4,311,444	11,615	10,304	13,691	4,960	6,507
1981/1982	2,898,311	8,353	7,783	9,494	9,950	4,980
1982/1983	2,300,630	6,214	5,253	7,353	9,819	4,152
1983/1984	1,017,736	2,686	2,291	2,792	2,857	2,209
1984/1985	614,303	1,401	1,030	1,420	639	955
1985/1986	508,803	1,223	925	1,266	650	856
1986/1987	475,461	1,133	853	1,167	614	776
1987/1988	369,370	1,165	1,153	1,259	809	1,011
1988/1989	278,353	901	902	1,249	872	818
1989/1990	261,166	879	931	1,176	992	792
1990/1991	362,449	1,250	1,206	3,042	2,461	1,126
1991/1992	1,897,982	3,766	1,941	5,508	2,980	3,385
1992/1993	1,930,678	4,139	2,897	5,351	2,422	3,713
1993/1994	1,550,754	3,575	2,714	4,372	2,516	3,210
1994/1995	1,547,448	3,632	2,816	4,342	2,762	3,265
1995/1996	1,521,470	3,713	3,085	4,321	5,015	3,188
1996/1997	1,428,799	3,480	2,952	3,947	3,779	2,855
1997/1998	1,136,930	2,943	2,590	3,505	2,650	2,399
1998/1999	838,049	2,166	1,848	2,414	2,546	1,867
1999/2000	752,767	1,948	1,639	2,135	1,890	1,714
2000/2001	648,723	1,696	1,422	1,815	1,758	1,526
2001/2002	336,836	954	905	944	1,504	859
2002/2003	237,187	658	628	668	1,457	592
2003/2004	72,140	138	71	172	132	124
2004/2005	67,024	134	70	168	138	120
2005/2006	52,721	119	68	161	144	107
2006/2007	60,960	171	147	256	364	154
2007/2008	29,890	67	67	233	353	60
2008/2009	23,986	57	70	329	342	51
2009/2010	28,621	69	80	343	518	61
2010/2011	154,495	357	195	465	42	322
2011/2012	153,347	364	238	461	45	327
2012/2013	139,469	337	259	342	48	304
2013/2014	105,996	267	238	315	132	NA
2014/2015	NA	NA	NA	NA	NA	NA

Figures

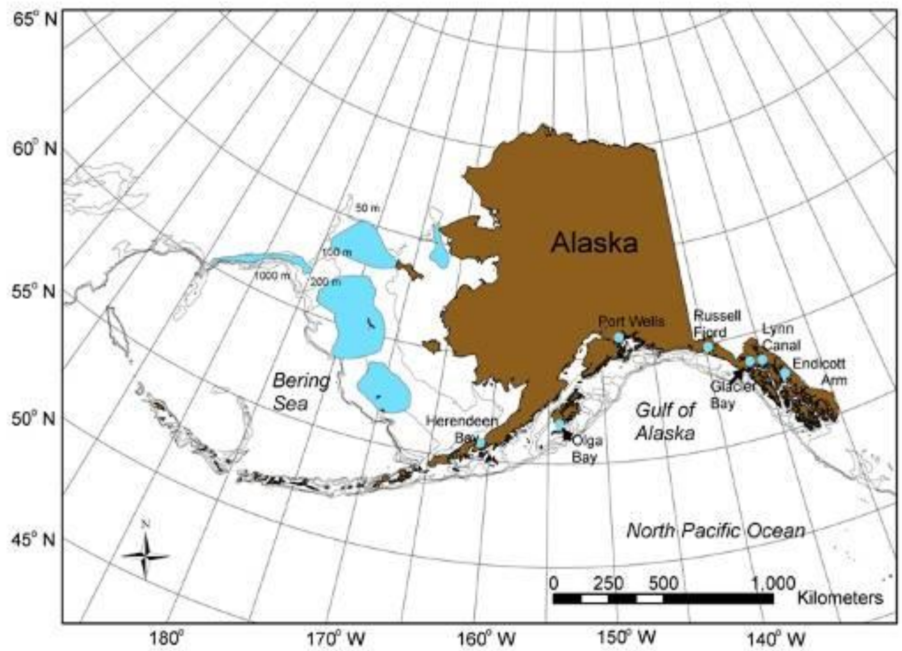


Figure 1. Distribution of blue king crab (*Paralithodes platypus*) in Alaskan waters.

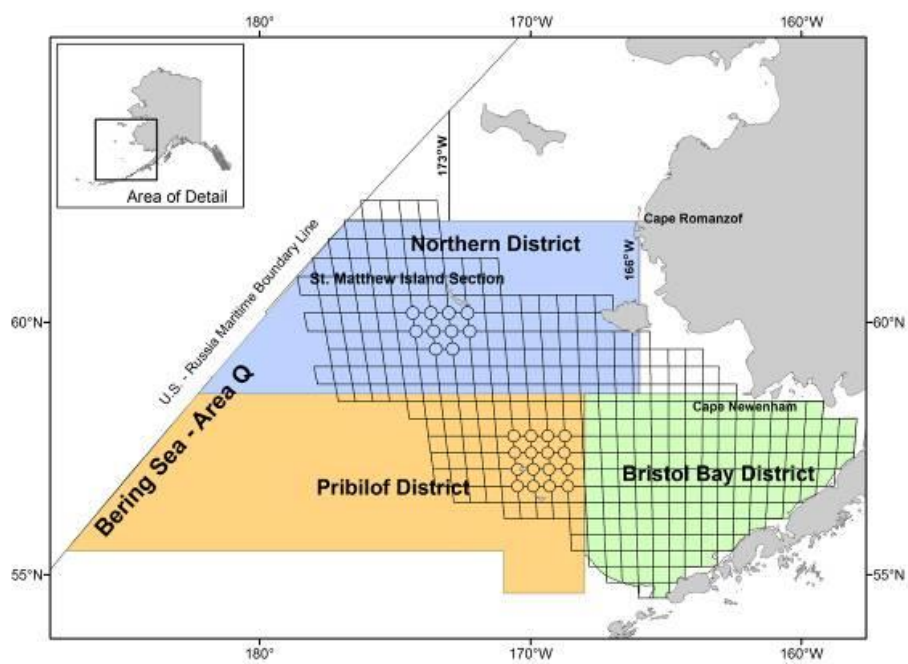


Figure 2. King crab Registration Area Q (Bering Sea) showing the Pribilof District. This figure does not show the additional 20 nm strip considered starting in 2013 year for biomass and catch data in the Pribilof District.

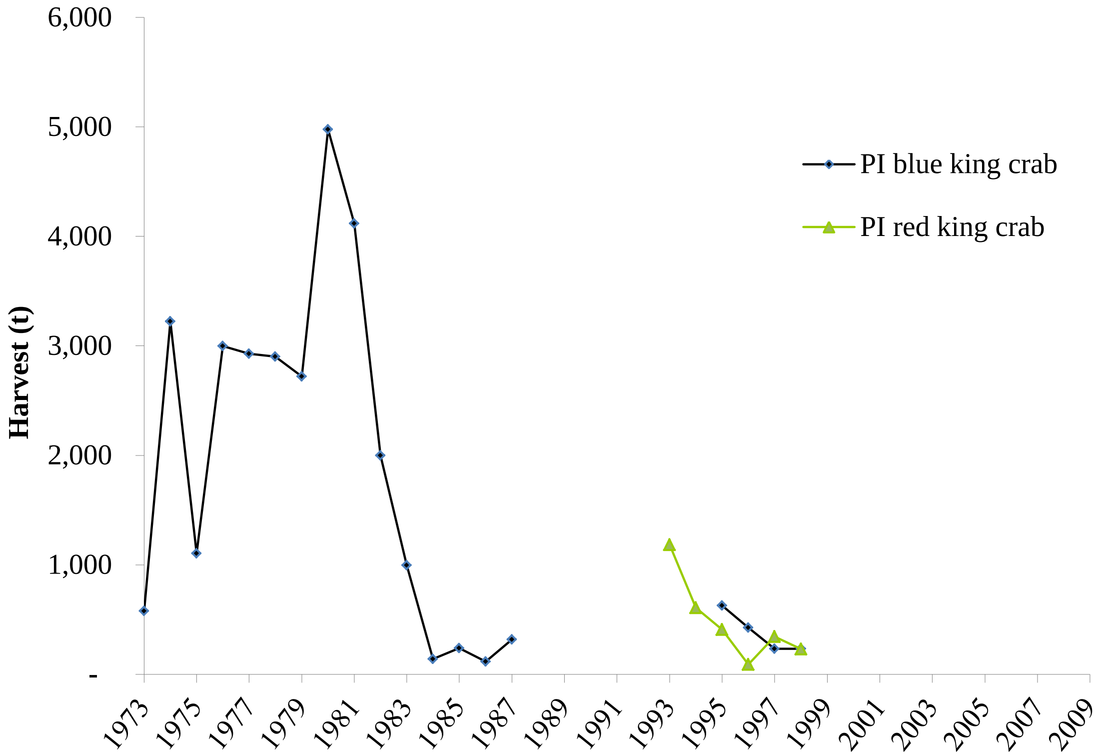


Figure 3. Historical harvests (t) and GHLs for Pribilof Island blue and red king crab (Bowers et al. 2011).

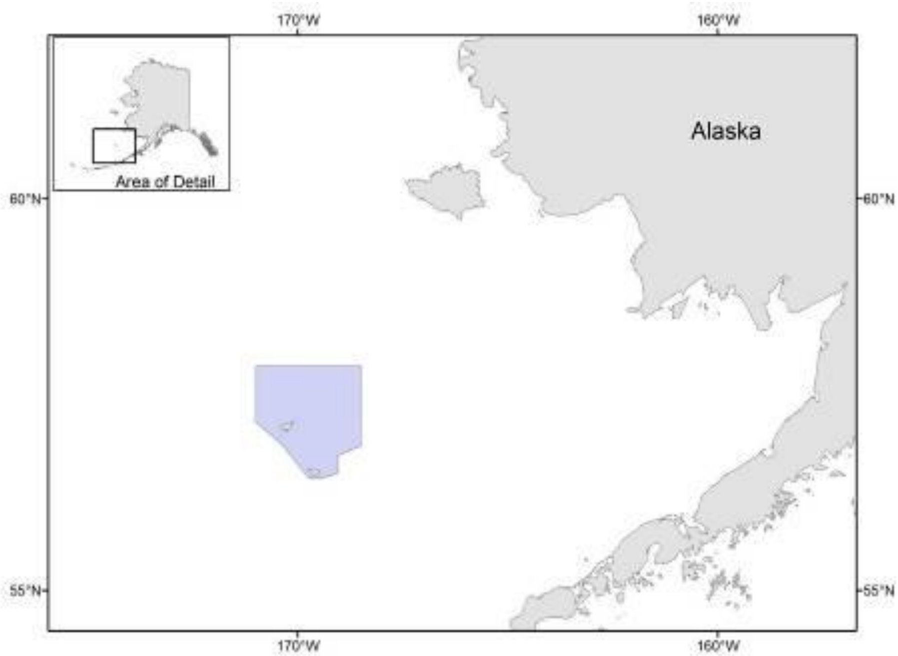
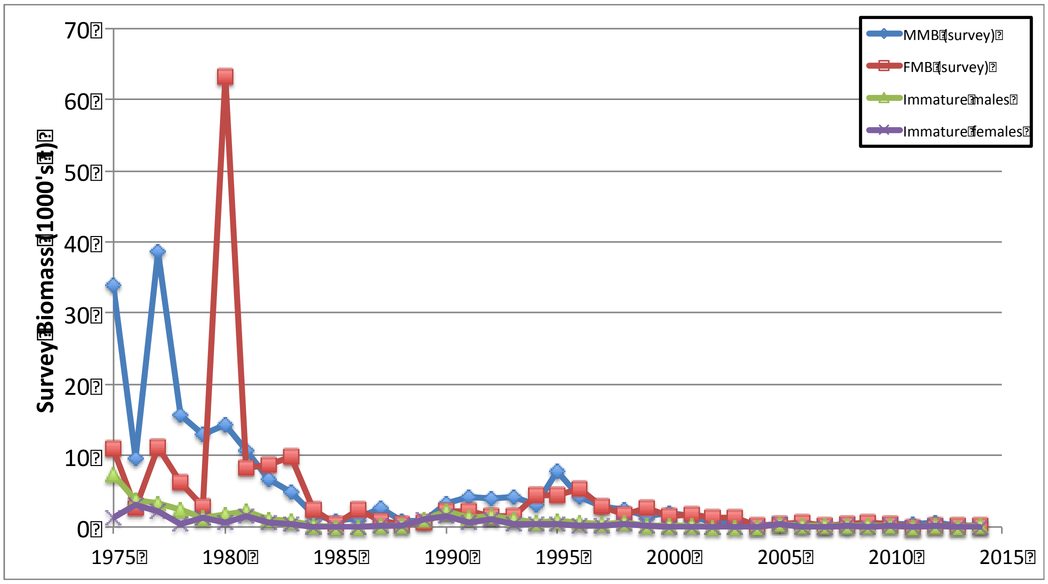


Figure 4. The shaded area shows the Pribilof Islands Habitat Conservation area. Trawl fishing is prohibited year-round in this zone.



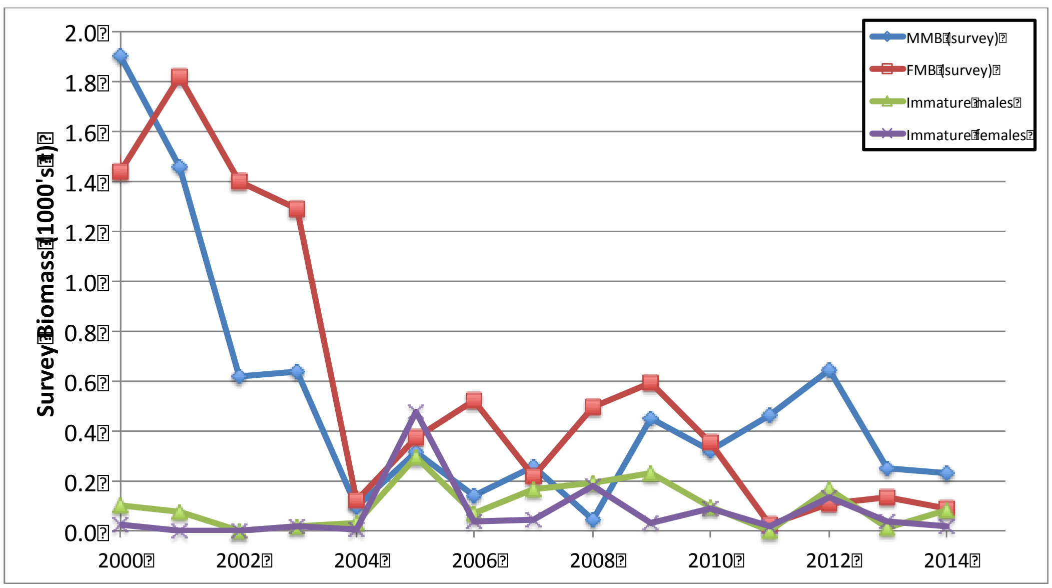


Figure 5. Time series for various stock components of Pribilof Islands blue king crab estimated from the NMFS annual EBS bottom trawl survey. Upper graph: 1975-2014. Lower graph: 2000-2014.

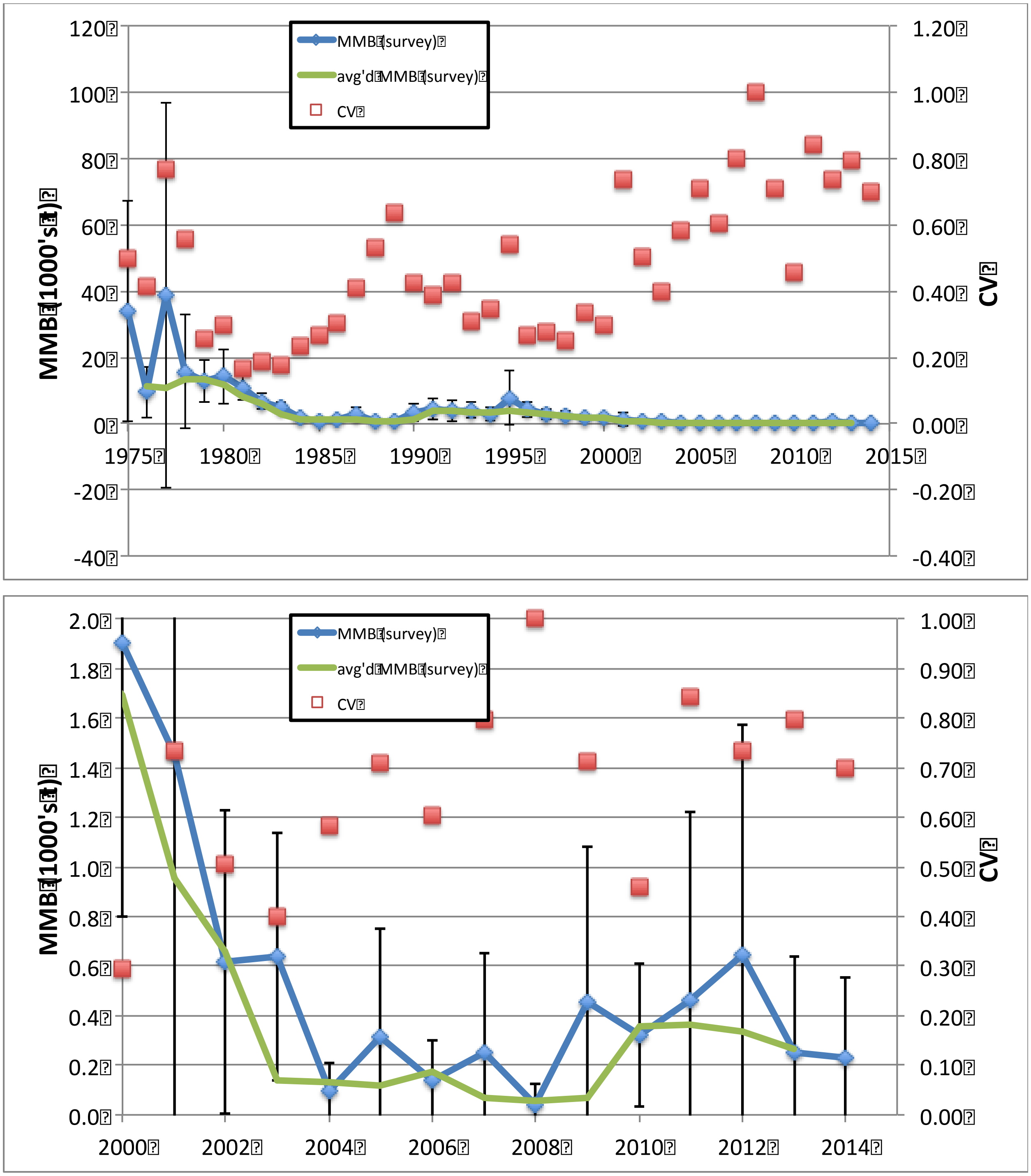


Figure 6. Time series for mature male biomass (MMB) estimated from the NMFS annual EBS bottom trawl survey. Upper graph: 1975-2014. Lower graph: 2000-2014. Blue line: "raw" time series. Red line: 3-year center-averaged using inverse-variance weighting. Error bars are 95% CIs.

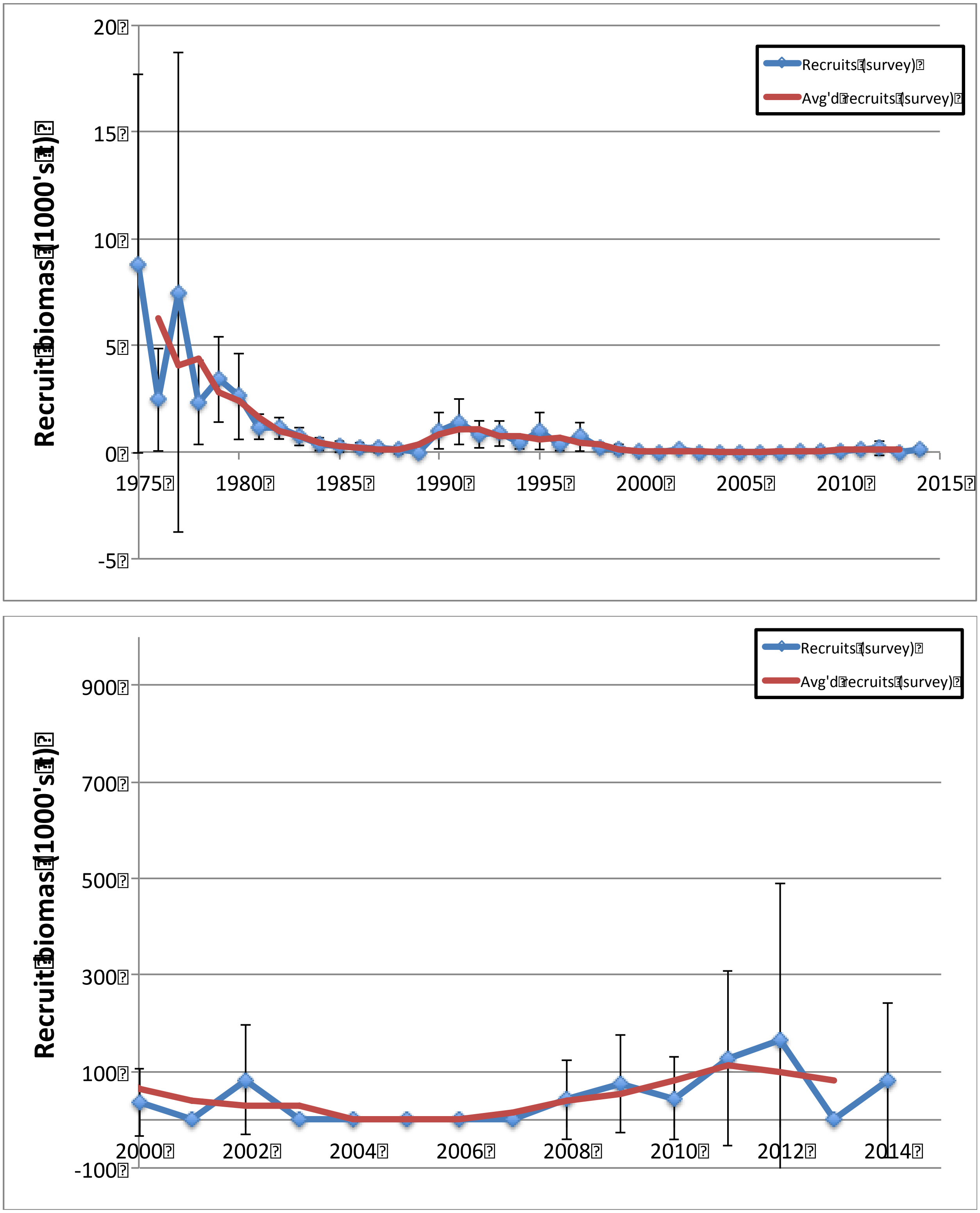


Figure 7. Time series for male recruits (120-134 mm CL) estimated from the NMFS annual EBS bottom trawl survey. Upper graph: 1975-2014. Lower graph: 2000-2014. Blue line: "raw" time series. Red line: 3-year center-averaged using inverse-variance weighting. Error bars are 95% CIs.

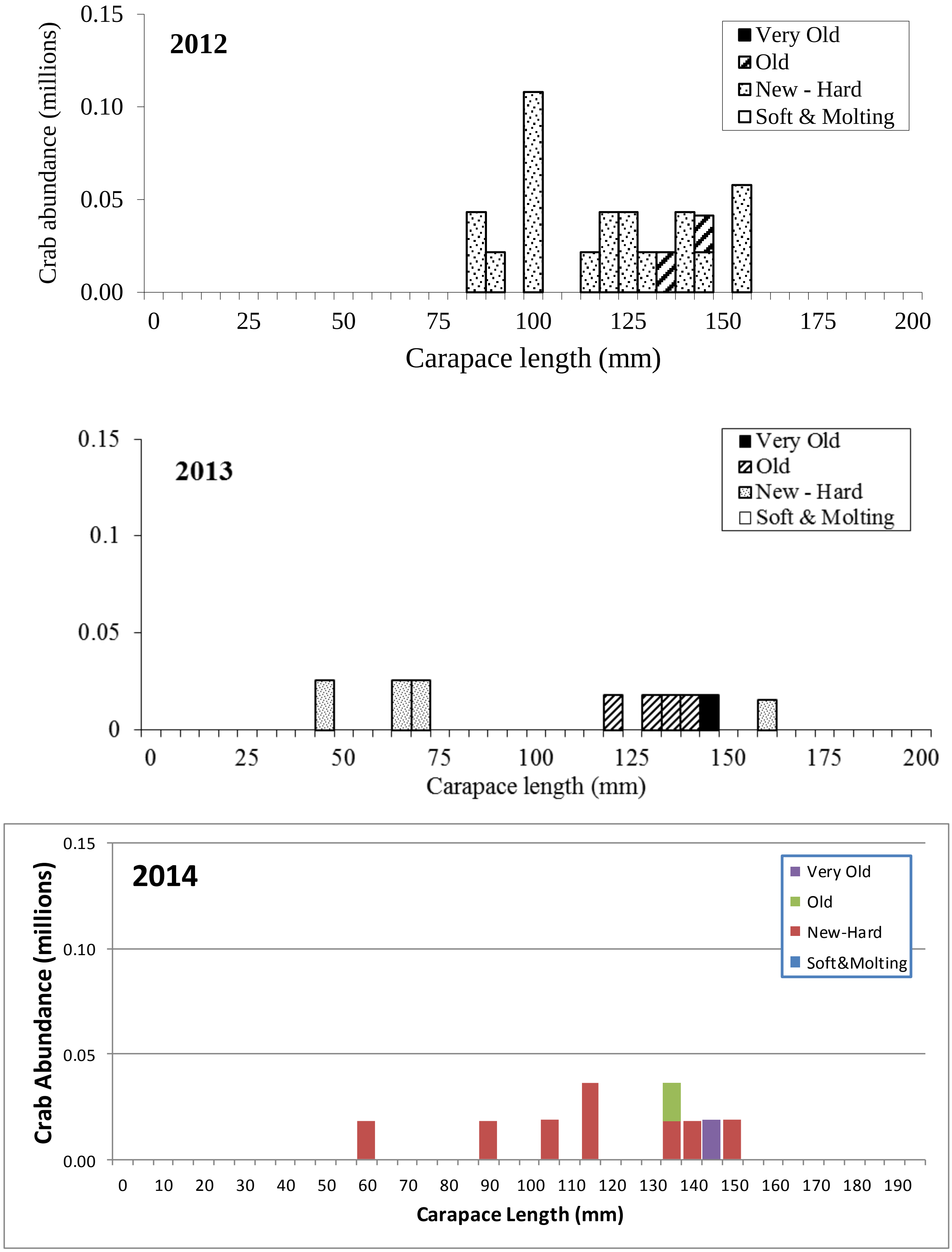


Figure 8. Size frequencies by shell condition for male Pribilof Island blue king crab in 5 mm length bins from the last 3 surveys.

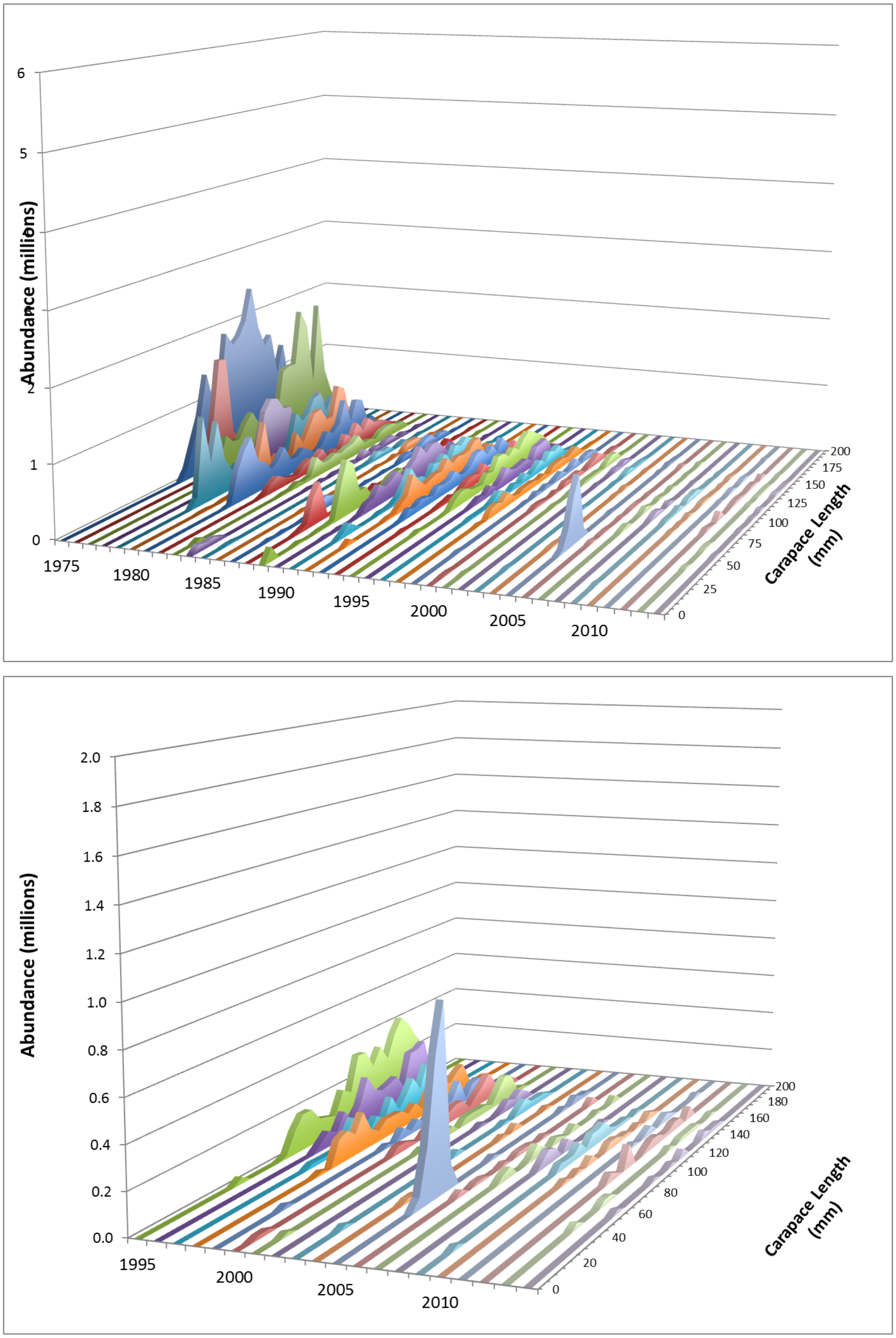


Figure 9. Size frequencies from the annual NMSF bottom trawl survey for male Pribilof Islands blue king crab from 1975 to 2014 (upper graph) and from 1995 to 2014 (lower graph) by 5 mm length classes.

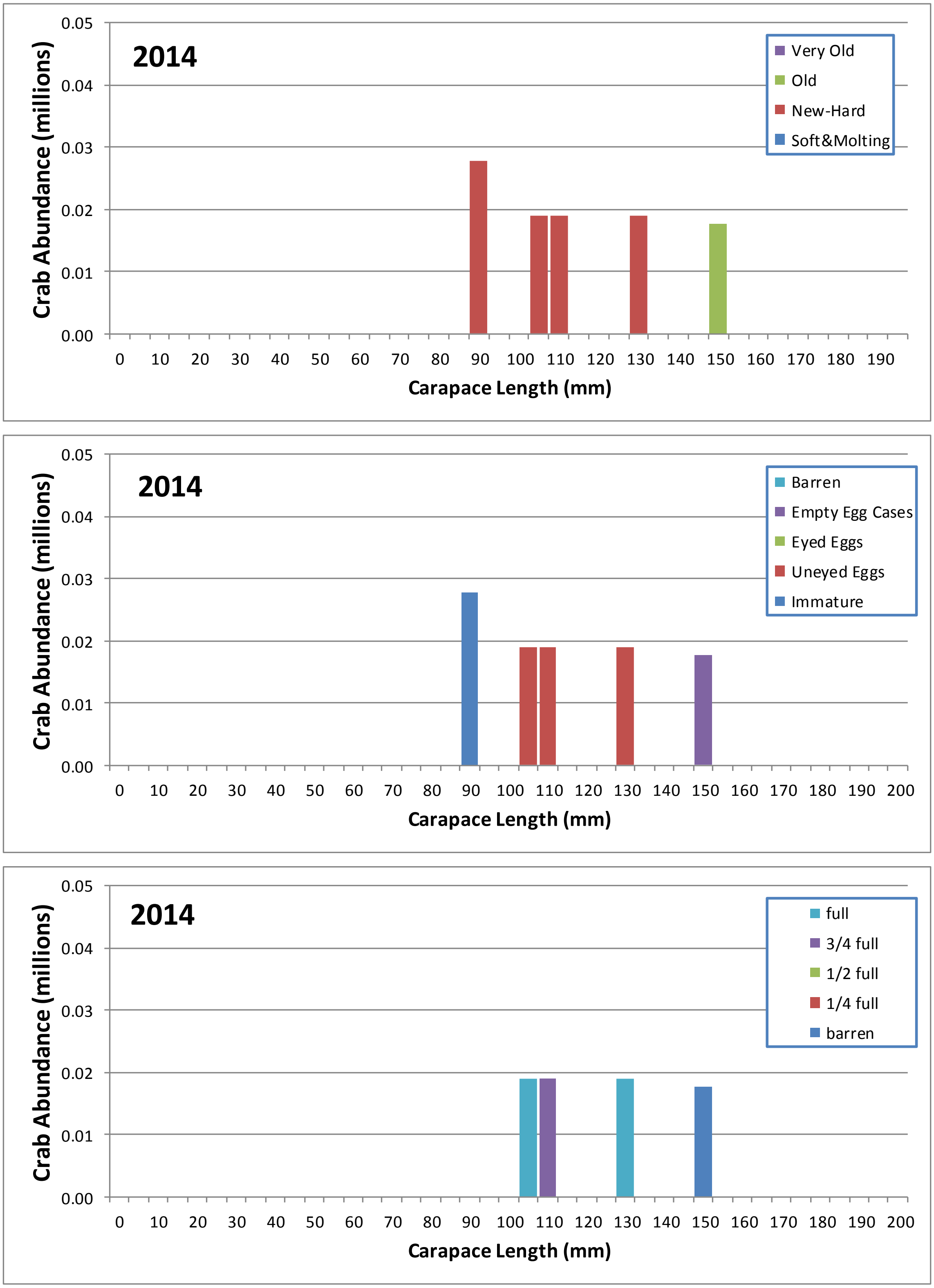


Figure 10. Size-frequencies by shell condition, egg condition, and clutch fullness for female Pribilof Island blue king crab by 5 mm length bins from the 2014 NMFS bottom trawl survey.

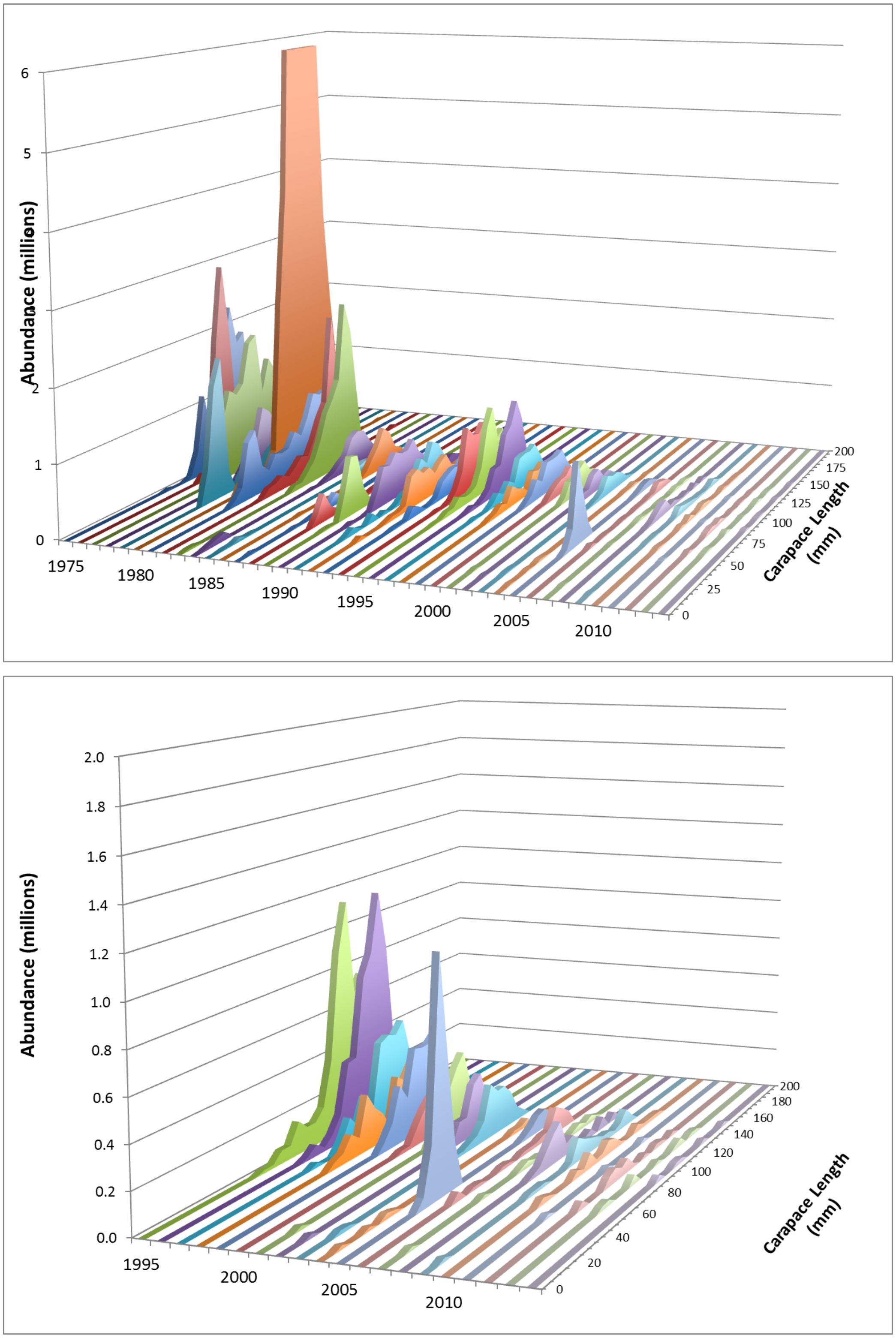


Figure 11. Size frequencies from the annual NMSF bottom trawl survey for female Pribilof Islands blue king crab from 1975 to 2014 (upper graph) and from 1995 to 2014 (lower graph) by 5 mm length classes.

2013 2014

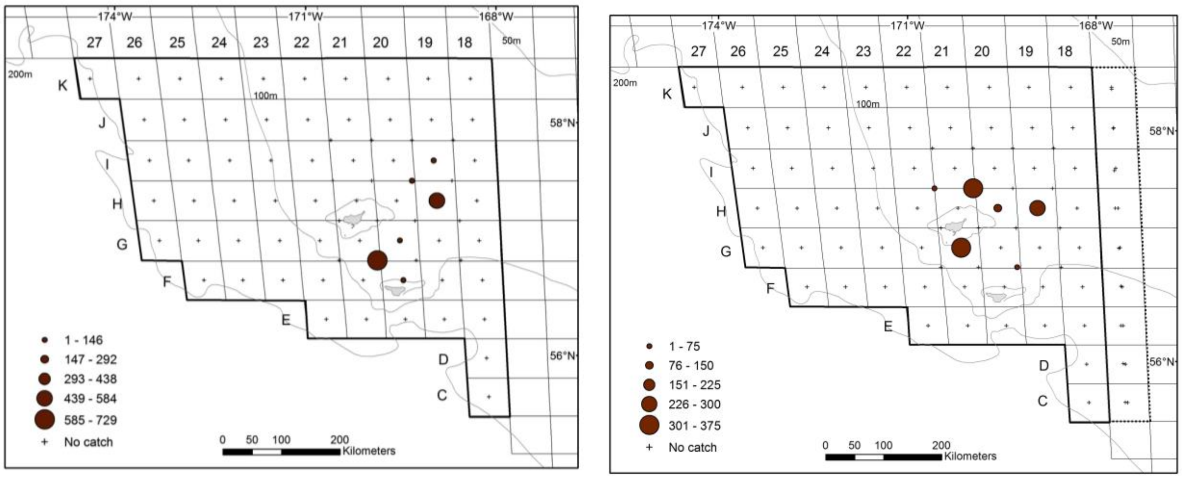


Figure 12. Total density (number/nm^2) of blue king crab in the Pribilof District in the 2013 (left) and 2014 (right) EBS bottom trawl survey.

2013 2014

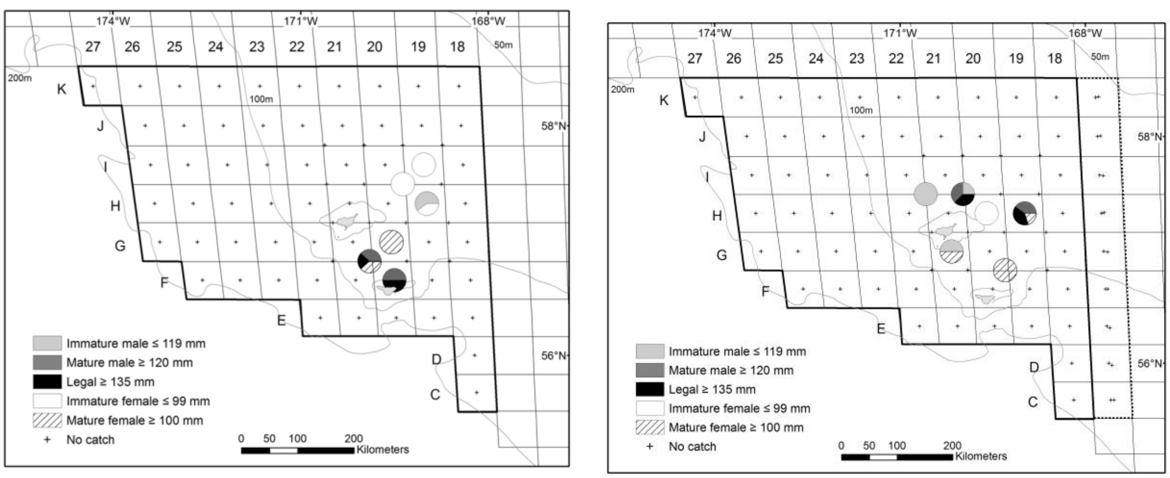


Figure 13. 2013 (left) and 2014 (right) EBS bottom trawl survey size class distribution of blue king crab in the Pribilof District.

2013 2014

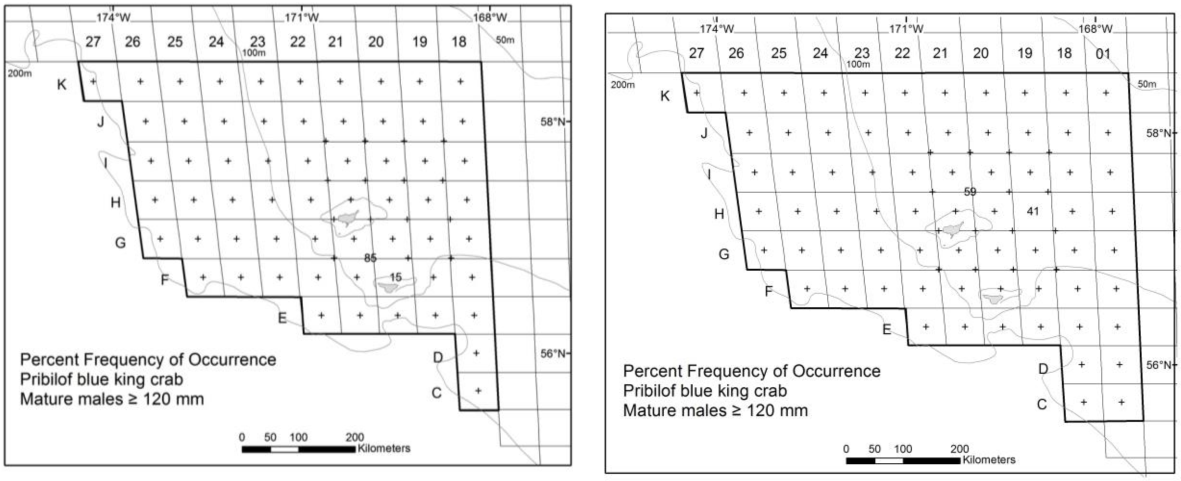


Figure 14. 2013 (left) and 2014 (right) EBS bottom trawl survey frequency of occurrence of mature male blue king crab in the Pribilof District.

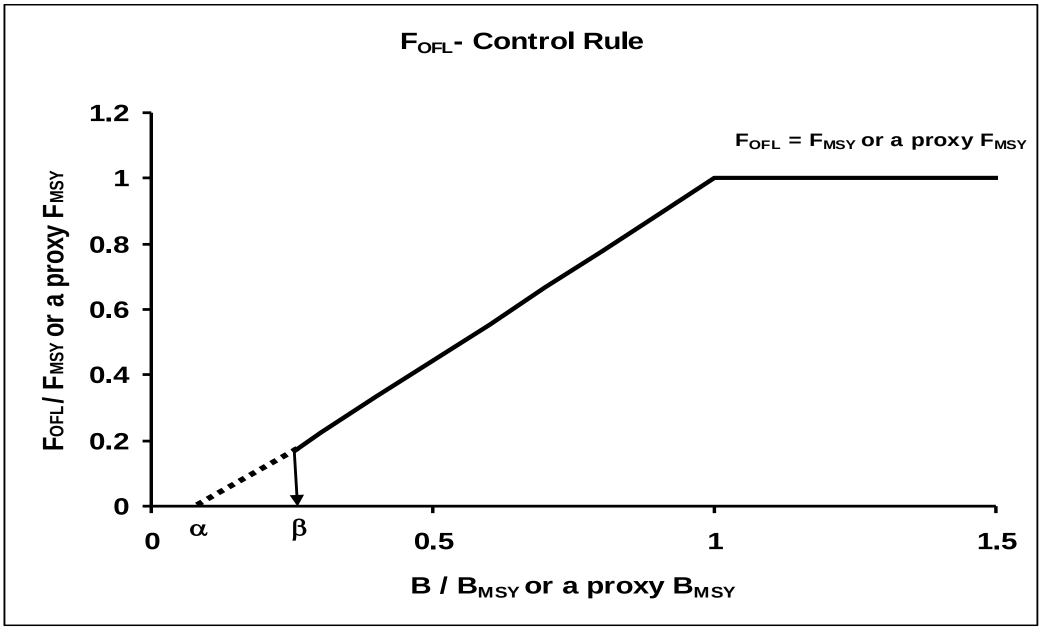


Figure 15. F_{OFL} Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β (= 0.25).

Appendix A: Estimating crab bycatch in the groundfish fisheries

This appendix provides a brief overview regarding estimation of crab bycatch in the groundfish fisheries, as conducted by the NMFS Alaska Regional Office (AKRO) and the Alaska Fisheries Information Network (AKFIN). It represents a merging of two memos provided by J. Gaspar (AKRO) discussing these details.

Data availability:

Pre 1991: Data available in INPFC reports only.

1991-December 2002: Bycatch estimates use the "blend method". The blend process combined data from industry production reports and observer reports to make the best, comprehensive accounting of groundfish catch. For shoreside processors, Weekly Production Reports (WPR) submitted by industry were the best source of data for retained groundfish landings. All fish delivered to shoreside processors were weighed on scales, and these weights were used to account for retained catch. Observer data from catcher vessels provided the best data on at-sea discards of groundfish by vessels delivering to shoreside processors. Discard rates from these observer data were applied to the shoreside groundfish landings to estimate total at-sea discards from both observed and unobserved catcher vessels. For observed catcher/processors and motherships, the WPR and the Observer Reports recorded estimates of total catch (retained catch plus discards). If both reports were available, one of them were selected during the "blend" process for incorporation into the catch database. If the vessel was unobserved, only the WPR was available.

January 2003 –December 2007: A new database structure named the Catch Accounting System (CAS) led to large method change. Bycatch estimates were derived from a combination of observer and landing (catcher vessels/production data). Production data included CPs and catcher vessels delivering to motherships. To obtain fishery level estimates, CAS uses a ratio estimator derived from observer data (counts of crab/kg groundfish) that is applied to production/landing information (see http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-205.pdf). Estimates of crab are in numbers because the Prohibited Species Catch (PSC) is managed on numbers. There were two issues with this dataset that required estimation work outside of CAS:

1) The estimated number of crab had to be converted to weights. An average weight was calculated using groundfish observer data. This weight was specific to crab year, crab species, and fixed or trawl gear. This average was applied to the estimated number of crab for crab year by federal reporting area.

2) In some situations crab estimates were identified and grouped in the observed data to the genus level. These crabs were apportioned to the species level using the identified crab.

January 2008-2012: The 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, haul-level weights collected by the observers were used to estimate the weight of crab through CAS instead of applying an annual (global) weight factor. Spatial resolution was at the federal reporting area.

NEW Data January 2009 – 2013: A new data set was made available in August 2013. The level of spatial resolution in CAS was formerly at the federal reporting area because this was the highest spatial resolution at which observer data was aggregated to create bycatch rates. The federal reporting area does not follow crab stock boundaries, particular for species with small stock areas such as the Pribilof Islands or St. Matthew Island stocks, so the new data was provided at the State reporting areas. This method uses a weight-based ratio estimator (wieght crab/weight groundfish) applied to groundfish reported on production/landing reports. Where possible, this dataset aggregates observer data to the stock area level to create bycatch estimates at the stock area. There are instances where no observer data is available and aggregation could go outside of a stock area, but this practice is greatly reduced compared with the pre-2009 data, which at-best was at the Federal reporting area level.

AKFIN/AKR created this new data set using observer data and eLandings information: landing reports and production reports. 2009 is the start of the data set because it is the first year that identification of state statistical areas was required on groundfish production reports. This allowed the use of a ratio estimator created from observer data to be applied to state statistical area landings/production.

Changes in 2014

Changes in estimates of crab bycatch in the groundfish fisheries, beginning in 2009, occurred between spring 2013 and fall of 2014 due to improvements made to the database and methods.

Background

The Alaska Region historically provided estimates of crab bycatch in groundfish fisheries at the federal reporting area level. Ratio estimation (weight of crab/total groundfish) methods were used to estimate crab catch by species. Generally speaking, there are two steps in this estimation method: 1) a ratio estimator is created by post-stratifying (aggregating) observer information; and 2) the ratio estimator is then applied to landings or production information that have the same post-strata characteristics as in 1 (e.g., both the landings and observer data were collected from area 541 for pot gear during the same week). Details on the estimation routines used in the Catch Accounting System (CAS) are in Cahalan et al. (2010), with an updated Technical Memorandum currently in review.

Spatial scale is an important component in the post-strata criteria. There are two spatial scales associated with industry reports of groundfish catch: 1) the federal reporting area and 2) the groundfish FMP area; the latter being an aggregation of federal reporting areas. Estimates of crab bycatch from CAS are specific to a federal reporting area if at-sea observer data is available; however, in federal reporting areas that have commercial landings and no corresponding observer data (defined by the post-stratification criteria), the ratio estimator is derived from an aggregation of observer information across the entire Bering Sea and Aleutian Islands FMP area. These post-stratification procedures result in bycatch estimates that may include at-sea observer information from outside a crab stock area[1].

Changes to estimation

In 2013, the NMFS Alaska Regional Office (AKRO) and Alaska Fisheries Information Network (AKFIN) created a new estimation method to generate estimates crab catch (in weight) in the groundfish fisheries by crab stock area. This required modifying the CAS Prohibited Species Catch (PSC) calculation methods so that the post-strata definitions were specific to a crab stock area and crab species (or state statistical area within a crab stock area). ***The stock-area specific estimates (in weight) are available through AKFIN starting in the 2009/2010 crab year.***

A flaw in the estimation method was identified in 2013 after the September Plan Team. This flaw allowed observer data from outside a stock area boundary to be used for stock-area specific estimation if there was little observer data available within the stock area. Correcting this issue was especially important for crab stocks that bisect reporting areas, such as the Pribilof Islands, St. Mathews Islands, and Bristol Bay, but it also affected the estimates for most stocks throughout the Bering Sea and Aleutian Islands. As expected, large changes were observed for the St. Mathews and the Pribilof Islands stock areas since observer data had incorrectly been aggregated across these areas. For example, observer information from the St.

[1] Note that post-strata definitions also including gear, vessel, week ending date, trip target, and observer selection method (based on deployment rates in the ADP). The intent of this appendix is not to provide detail on the estimation methods, but instead to highlight large changes in methodology.

Mathew stock area was used in the ratio estimators for the Pribilof Islands.

In 2014, AKFIN and AKRO staff conducted further review of the crab estimation routines. This review resulted in several programming changes that affected some estimates:

- There were errors in the mapping of State of Alaska statistical areas with the crab stock area boundaries that were found and corrected. This correction affected some estimates, particularly Pribilof Island estimates where the eastern extension of the stock area boundary for blue king crab was incorrectly applied to red and golden king crab (which also changed the Bristol Bay area slightly).

- The procedures used to determine if a trip has corresponding observer data were improved. This improvement results in a lower percentage of trips that are incorrectly marked as unobserved, which means more estimates are specific to observed trips. The impact on estimation due to this change was minor.

- A post stratum was added to the estimation process. This post stratum is only used when observer data are unavailable for landings of a specific gear type (with the exception of jig gear since it is never observed), stock area, and calendar year. The impact on crab estimates due to this change was minor (mainly a few vessels in the Aleutian Islands): nearly all ratio estimates use observer data that is of the same gear type as the vessels making a landing.

In addition, updates to observer information occur when observers are debriefed and data quality verified. Debriefings can result in changes to data values or cause deletions of incorrectly collected data.

References

Cahalan J., Mondragon J., and J. Gasper. 2010. Catch sampling and estimation in the federal groundfish fisheries off Alaska. NOAA Tech. Mem. NMFS AFSC-205. 42 pp.

Appendix B: MMB Calculations

MMBsurvey

MMB at the time of each survey (MMB_{survey}; Figure 6, Table 6) is calculated from NMFS trawl survey estimates of male numbers-at-size z (n_z) by summing the product of weight-at-size (W_z, Eq. 1), maturity-at-size ($P_z = 0 \; or \; 1$, depending on whether z<120 mm CL or z≥120 mm CL), and n_z over all sizes, as in:

$$MMB_{survey} = \sum_z P_z \cdot W_z \cdot n_z \qquad \text{(B1)}$$

To reduce the effects of large uncertainty in these survey-based estimates, the time series of MMB_{survey} is also smoothed using a 3-year centered, inverse variance-weighted, running average (denoted $\langle MMB_{survey} \rangle$, Table 8). The “raw” and 3-year running average estimates for MMB are compared in Figure 14.

MMB$_{mating}$

The estimates for MMB_{survey} (“raw” or averaged) are projected forward to mating time each year (MMB_{mating}; Table 8) based on an assumed rate for natural mortality (M = 0.18 yr^{-1}), retained (R) and non-retained (NR) fishing mortalities for that year (based on Tables 1 and 2), and assumed time intervals between the survey and fishing activity (t_{sf} = 3 months) and between the fishing activity and mating (t_{fm} = 5 months) using the following equation:

$$MMB_{mating} = \left(MMB_{survey} \cdot e^{-M \cdot t_{sf}} - R - NR\right) \cdot e^{-M \cdot t_{fm}} \qquad \text{(B2)}$$

Current B: Projected MMB$_{mating}$

The “current B” used in status determination and OFL setting is the projected MMB_{mating} for the current year (2014/15 for the 2014 assessment) calculated using Eq. B2. To reduce year-to-year variability in this quantity due simply to sampling uncertainty in the survey, the value used in the equation for MMB_{survey} is the average of MMB_{survey} from the last two surveys (2013 and 2014, denoted here as $\langle MMB_{survey} \rangle$). For this year, $\langle MMB_{survey} \rangle$ = 241.76 t. Note that the projected MMB_{mating} (= current B) is necessarily less than or equal to $\langle MMB_{survey} \rangle$. Consequently, because B_{MSY}^{proxy} (B_{REF}) = 4002 t, $B/ B_{MSY}^{proxy} \leq 0.06 < \beta$ = 0.25, the stock is in Tier 4c, and directed fishing in 2014/15 will not be allowed under any circumstances and R in Eq. B2 is zero.

An estimate of the projected NR (non-retained mortality, NR_p) to use in eq. B2 for the projected MMB_{mating} is based on multiplying an estimator (θ) for the ratio of bycatch mortality to MMB just prior to fishing ($MMB_{fishing}$). Thus, $NR_p = \theta \cdot MMB_{fishing}$, where $MMB_{fishing} = \langle MMB_{survey} \rangle \cdot e^{-M \cdot t_{sf}}$. The estimator θ is taken as the ratio of the average mature male bycatch mortality to the average actual MMB_{mating}, where the averages are taken over the last 3 years (i.e., 2011/12-2013/14).

Putting this all together,

$$Projected\ MMB_{mating} = \left(\langle MMB_{survey} \rangle \cdot e^{-M \cdot t_{sf}} - R - NR_P\right) \cdot e^{-M \cdot t_{fm}}$$

$$Projected\ MMB_{mating} = \left(\langle MMB_{survey} \rangle \cdot e^{-M \cdot t_{sf}} - 0 - \theta \cdot \langle MMB_{survey} \rangle \cdot e^{-M \cdot t_{sf}}\right) \cdot e^{-M \cdot t_{fm}}$$

$$Projected\ MMB_{mating} = \left(\langle MMB_{survey} \rangle \cdot e^{-M \cdot t_{sf}}\right)(1 - \theta) \cdot e^{-M \cdot t_{fm}} \qquad \text{(B3)}$$