Pribilof Islands Golden King Crab

May 2012 Crab SAFE Report Chapter (25 April 2012 Draft)

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Executive Summary

1. **Stock:** Pribilof Islands (Pribilof District) golden king crab *Lithodes aequispinus*

2. Catches:

Commercial fishing for golden king crab in the Pribilof District has been concentrated in the Pribilof Canyon. The fishing season for this stock has been defined as a calendar year (as opposed to a "crab fishery year") following the close of the 1983/84 season. The domestic fishery developed in the 1982/83 season, although some limited fishing occurred at least as early as 1981/82. Peak harvest occurred in the 1983/84 season with a retained catch of 0.856-million pounds (388 t) by 50 vessels. Since then, participation in the fishery has been sporadic and annually retained catch has been variable, from 0 pounds in the nine years that no vessels participated (1984, 1986, 1990–1992, 2006–2009) up to a maximum of 0.342-million pounds (155 t) in 1995, when seven vessels made landings. The fishery is not rationalized. There is no state harvest strategy in regulation. A guideline harvest level (GHL) was first established for the fishery in 1999 at 0.200-million pounds (91 t) and has been managed towards a GHL of 0.150-million pounds (68 t) since 2000. No vessels participated in the directed fishery and no landings were made during 2006–2009. One vessel landed catch in 2010 and two vessels landed catch in 2011; directed fishery catch cannot be reported in those two years under the confidentiality requirements of Sec. 16.05.815 (SOA statute). Non-retained bycatch occurs in the directed golden king crab fishery, the eastern Bering Sea snow crab fishery, the Bering Sea grooved Tanner crab fishery, and Bering Sea groundfish fisheries. Estimated annual weight of non-retained bycatch in directed and non-directed crab fisheries during calendar years 2001–2011 ranges from 0 pounds to 0.049-million pounds (22 t). Estimates of annual total fishery mortality during calendar years 2001–2011 due to crab fisheries range from 0 to 0.160-million pounds (73 t), with an average of 0.078-million pounds (35 t). Estimates of annually discarded bycatch during Bering Sea groundfish fisheries are reported for crab fishery years. Those estimates range from <0.001-million (<1 t) to 0.027-million pounds (12 t) annually during the 1991/92–2010/11 crab fishery years. Estimates of annual fishery mortality during 1991/92–2010/11 due to groundfish fisheries range from <0.001-million pounds (<1 t) to 0.019-million pounds (9 t), with an average of 0.006-million pounds (3 t).

3. Stock biomass:

Stock biomass (all sizes, both sexes) of golden king crab have been estimated for the Pribilof Canyon area using the area-swept technique applied to data obtained during eastern Bering Sea upper continental slope trawl surveys performed by NMFS-AFSC in 2002, 2004, 2008, and 2010 (Hoff and Britt 2003, 2005, 2009, 2011). The biomass estimate for the Pribilof Canyon area in 2010 was 3.560-million pounds (1,615 t). The biomass estimate for the entire eastern Bering Sea slope survey area in 2010 was 5.071-million pounds (2,300 t).

4. Recruitment:

From data collected during the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental slope surveys biomass of golden king crab (all sizes and both sexes) are estimated to have increased in the surveyed area of eastern Bering Sea. Biomass in the Pribilof Canyon area was estimated to have increased from 1.504-million pounds (682 t) in 2002 to 3.560-million pounds (1,615 t) in 2010; biomass for the entire slope survey area was estimated to have increased from 2.227-million pounds (1,010 t) in 2002 to 5.071-million pounds (2,300 t) in 2010.

5. Management performance:

No overfished determination (i.e., MSST) is possible for this stock given the limited information and analysis on stock biomass; there are presently no estimates of mature male biomass or mature female biomass for this stock. Overfishing did not occur during 2011 (the golden king crab season in the Pribilof District is based on a calendar year); the estimated total catch did not exceed the OFL of 0.18-million pounds (82 t). Retained catch and total-catch mortality in 2011 are confidential under the requirements of Sec. 16.05.815 (SOA statute). No ABC was established for the 2011 season. The 2012 season is currently ongoing. Values given in the tables below for the 2013 OFL and ABC are the author's recommendations.

Year[a]	MSST	Biomass (MMB)	GHL[b]	Retained Catch[c]	Total Catch[c,d]	OFL[c,e]	ABC[c,e]
2009	N/A	N/A	0.150	0	0.001	0.17 R	N/A
2010	N/A	N/A	0.150	Conf.[f]	Conf.[f]	0.17 R	N/A
2011	N/A	N/A	0.150	Conf.[f]	Conf.[f]	0.18 T	N/A
2012	N/A	N/A	0.150	TBD	TBD	0.20 T	0.18 T
2013	N/A	N/A	TBD	TBD	TBD	[0.20 T]	[0.18 T]

a. Season is based on a calendar year.
b. Guideline harvest level expressed in millions of pounds.
c. Millions of pounds.
d. Total retained catch plus estimated bycatch mortality during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
e. Noted as "R" for retained-catch-only OFL and "T" for total-catch OFL and ABC.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season.

Year[a]	MSST	Biomass (MMB)	GHL[b]	Retained Catch[c]	Total Catch[c,d]	OFL[c,e]	ABC[c,e]
2009	N/A	N/A	68	0	0.5	77 R	N/A
2010	N/A	N/A	68	Conf.[f]	Conf.[f]	77 R	N/A
2011	N/A	N/A	68	Conf.[f]	Conf.[f]	82 T	N/A
2012	N/A	N/A	68	TBD	TBD	91 T	82 T
2013	N/A	N/A	TBD	TBD	TBD	[91 T]	[82 T]

a. Season is based on a calendar year.
b. Guideline harvest level expressed in t.
c. Metric tons.
d. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤9 t, with an average of 3 t.
e. Noted as "R" for retained-catch-only OFL and "T" for total-catch OFL and ABC.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season.

6. Basis for the OFL and ABC: The values for 2013 are the author's recommendation.

Year[a]	Tier	Years to define Average catch (OFL)	Natural Mortality	Buffer
2009	5	1993-1999[b]	0.18[e]	N/A
2010	5	1993–1998[b]	0.18[e]	N/A
2011	5	1993–1998[c]	0.18[e]	N/A
2012	5	1993–1998[d]	0.18[e]	10%
2013	5	[1993–1998[d]]	[0.18[e]]	[10%]

a. Season is based on a calendar year.
b. OFL was for retained catch and was determined by the average of the retained catch for these years.
c. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.05 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
d. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.052 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
e. Assumed value for FMP king crab in NPFMC (2007); does not enter into OFL estimation for Tier 5 stock.

7. **PDF of the OFL:** Sampling distribution of the two alternative Tier 5 OFLs was estimated by bootstrapping. The standard deviation of the estimated sampling distribution of the recommended OFL (Alternative 1) is 0.510-million pounds (CV = 0.25). See section G.1.

8. **Basis for the ABC recommendation:** A 10% buffer on the OFL, the default; i.e., ABC = (1-0.1)·OFL.

9. **A summary of the results of any rebuilding analyses:** Not applicable; stock is not under a rebuilding plan.

A. Summary of Major Changes

1. **Changes to the management of the fishery:** None. Fishery continues to be managed under authority of an ADF&G commissioner's permit and with a guideline harvest level (GHL) of 0.150-million pounds. As of this writing, one vessel has registered for the 2012 season, but has not yet begun fishing (H. Fitch, ADF&G, 23 April 2012 email).

2. **Changes to the input data:**
   - Retained catch and bycatch data has been updated with the results for the 2011 directed fishery, during which only two vessels participated in the fishery, rendering the catch data confidential under the requirements of Sec. 16.05.815 (SOA statute).
   - Information on bycatch during other crab fisheries during 1993 (0 bycatch in the snow crab fishery and no data for the grooved Tanner crab fishery) was added.
   - Bycatch estimates have been updated using the data collected from groundfish fisheries during 2010/11.

3. **Changes to the assessment methodology:** None. This assessment follows the methodology recommended by the CPT in May 2011 and the SSC in June 2011.

4. **Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL:**
   - The OFLs for 2009 and 2010 were both established as retained-catch OFLs of 0.17-million pounds. The 2009 OFL was estimated by the average annual retained catch for the period 1993–1999, whereas the 2010 OFL was estimated by the average annual retained catch for the period 1993–1998; in 2009 the CPT and SSC recommended removing the 1999 from the period for computing retained catch because 1999 was the first year that a GHL was established for the fishery.
   - The OFL for 2011 was established as a total-catch OFL of 0.18-million pounds and was estimated as the average retained catch (including deadloss) for the period 1993–1998 times 1.05 plus 0.006-million pounds; i.e.,

$$OFL_{tot,2011} = 1.05 * OFL_{ret,1993\text{-}1998} + 0.006\text{-million pounds.}$$

     $OFL_{ret,1993\text{-}1998}$ is the average annual retained catch in the directed fishery during 1993–1998. The factor of 1.05 was used to account for the crab bycatch mortality in the directed crab fishery and 0.006-million pounds was used to account for the "background level" of bycatch mortality occurring in the groundfish and non-directed crab fisheries, estimated by the average annual bycatch mortality using data available; 2001–2005 for crab fisheries and 1991/92–2008/09 for groundfish fisheries.
   - The OFL for 2012 was a total-catch OFL of 0.20-million pounds and was estimated using 1993–1998 to compute average annual retained catch, an estimate of pounds of bycatch mortality per pound of retained catch during the directed fishery, an estimate of the average annual bycatch mortality due to non-directed crab fisheries during 1994–1998 and an estimate of average annual bycatch mortality due to groundfish fisheries during 1992/93–1998/99; i.e.,

$OFL_{TOT(1),2012} = (1+R_{2001–2010})*RET_{1993-1998} + BM_{NC,1994-1998} + BM_{GF,1992/93–1998/99,}$

where,

- $R_{2001–2010}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained in the directed fishery during 2001–2010
- $RET_{1993-1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998
- $BM_{NC,1994-1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
- $BM_{GF,1992/93–1998/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

- The recommended OFL for 2013 is a total-catch OFL of 0.20-million pounds, estimated by the calculations given for the 2012 OFL.

B. Responses to SSC and CPT Comments

1. **Responses to the most recent two sets of SSC and CPT comments on assessments in general (and relevant to this assessment):**
    - CPT, May 2011: None.
    - SSC, June 2011: None.
    - CPT, September 2011 (via Sept 2011 SAFE):
        - *"The team recommends that analysts provide a list of the parameters (e.g., natural mortality, Q, the appropriateness of F_{MSY} and B_{MSY} proxies), an indication of whether the estimates/assumptions used to compute the OFL is likely wrong in a systematic way (leading to under- or over-estimation of the OFL) and a range for the extent of error. The analysts should then calculate how the OFL would change for the extremes of the ranges."*
        - Response: This is addressed in Section **E.4.*f***.
        - *"The team requests that, to the extent possible, assessments include a listing of the tables and figures in the assessment (i.e., Table of Tables, Table of Figures).*
        - Response: It is done.
    - SSC, October 2011: None.

2. **Responses to the most recent two sets of SSC and CPT comments specific to the assessment:**
    - CPT, May 2011: *"The team concurred with the author's recommendation for the OFL based on Alternative 1. This freezes the time frame to that used previously and provides the retained catch data now available corresponding roughly with that time frame and total fishery mortality estimates over that time frame." "The team concurred with the author's recommendation for an ABC = maximum permissible ABC."*
        - Response: The Alternative 1 OFL and ABC presented here for 2013 are the same as the Alternative 1 OFL and ABC for 2012 that were presented to the CPT in May 2011.

- SSC, June 2011: The SSC recommended: 1) *"… calculating OFL using the average annual ratio of bycatch mortality to retained catch between 2001 and 2010, average annual retained catch from 1993 through 1998, average annual bycatch mortality in non-directed crab fisheries during 1994-1998, and the average annual rate of bycatch mortality in groundfish fisheries over 1992/93-1998/99"*; and 2) *"using the 10% buffer for tier-5 stocks"* to calculate the ABC. The SSC also encouraged the author to explore the eastern Bering Sea upper continental slope survey data *"for their utility to provide estimates of biomass for the Pribilof District"*, giving consideration to *"the distribution of the survey with respect to stock distribution, as well as estimation of survey catchability by size and sex."* The SSC looked forward to the results of that examination.
    - Response: The Alternative 1 OFL and ABC presented here for 2013 are the same as recommended for 2012 by the SSC in June 2011. The assessment presents results for golden king crab (as summarized in the survey report) from the 2010 slope survey and compares with results with the previous surveys in 2000, 2002, and 2008. Distribution of the survey with respect to stock distribution is commented on. No estimates of survey catchability by sex and size are presented here, but some comments are made given what information is presented in the survey reports. See **D.4**.

- CPT, September 2011: None.

- SSC, October 2011: None.

C. Introduction

1. **Scientific name:** *Lithodes aequispinus* J. E. Benedict, 1895

2. **Description of general distribution:** General distribution of golden king crab is summarized by NMFS (2004):

   Golden king crab, also called brown king crab, range from Japan to British Columbia. In the BSAI, golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island passes (pages 3–34).

   Golden, or brown, king crab occur from the Japan Sea to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett et al. 1985). They are typically found on the continental slope at depths of 300–1,000 m on extremely rough bottom. They are frequently found on coral bottom (pages 3–43).

The Pribilof District is part of king crab Registration Area Q (Figure 1). Bowers et al. (2011, pages 87–88) define those boundaries:

> The Bering Sea king crab Registration Area Q 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 Point Hope (68° 21' 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. Area Q is divided into the Pribilof District, which includes waters south of Cape Newenham, and the Northern District, which incorporates all waters north of Cape Newenham.

Results of the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009) and Hoff and Britt (2003, 2005, 2009, 2011) show that the biomass, number, and density (in number per area and in weight per area) of golden king crab on the eastern Bering Sea continental slope are higher in the southern areas than in the northern areas. Highest densities, biomass, and abundance of golden king crab in the Bering Sea occur in the Pribilof Canyon, as does most of the commercial catch of golden king crab (Bowers et al. 2011; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006).

Results of the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009) and Hoff and Britt (2003, 2005, 2009, and 2011) show that majority of golden king crab on the eastern Bering Sea continental slope occurred in the 200–400 m and 400–600 m depth ranges (see section D.2.d). Commercial fishing for golden king crab in the Bering Sea typically occurs at depths of 100–300 fathoms (183–549 m; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006; Gaeuman 2011); average depth of pots fished in the Pribilof golden king crab fishery during the 2002 fishery (the most recently prosecuted fishery for which fishery observer data are not confidential) was 214 fathoms (391 m).

3. **Evidence of stock structure:** I am aware of no data for evaluating stock structure within this stock.

4. **Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology):** The following review of molt timing and reproductive cycle of golden king crab is adapted from Watson et al. (2002):

> Unlike red king crab, golden king crab may have an asynchronous molting cycle (McBride et al. 1982, Otto and Cummiskey 1985, Sloan 1985, Blau and Pengilly 1994). In a sample of male golden king crab 95–155-mm CL and female golden king crab 104–157-mm CL collected from Prince William Sound and held in seawater tanks, Paul and Paul (2000) observed molting in every month of the year, although the highest frequency of molting occurred during May–October. Watson et al. (2002) estimated that only 50% of 139-mm CL male golden king crab in the eastern Aleutian Islands molt annually and that the intermolt period for males ≥150-mm CL averages >1 year.
>
> Female lithodids molt before copulation and egg extrusion (Nyblade 1987). From their observations on embryo development in golden king crab, Otto and Cummiskey's (1985) suggested that time between successive ovipositions was roughly twice that of embryo development and that spawning and molting of mature females occurs approximately every two years. Sloan (1985) also

suggested a reproductive cycle >1 year with a protracted barren phase for female golden king crab. Data from tagging studies on female golden king crab in the Aleutian Islands are generally consistent with a molt period for mature females of 2 years or less and that females carry embryos for less than two years with a prolonged period in which they remain in barren condition (Watson et al 2002). From laboratory studies of golden king crab collected from Prince William Sound, Paul and Paul (2001b) estimated a 20-month reproductive cycle with a 12-month clutch brooding period.

Numerous observations on clutch and embryo condition of mature female golden king crab captured during surveys have been consistent with asynchronous, aseasonal reproduction (Otto and Cummiskey 1985, Hiramoto 1985, Sloan 1985, Somerton and Otto 1986, Blau and Pengilly 1994, Blau et al. 1998, Watson et al. 2002). Based on data from Japan (Hiramoto and Sato 1970), McBride et al. (1982) suggested that spawning of golden king crab in the Bering Sea and Aleutian Islands occurs predominately during the summer and fall.

The success of asynchronous and aseasonal spawning of golden king crab may be facilitated by fully lecithotrophic larval development (i.e., the larvae can develop successfully to juvenile crab without eating; Shirley and Zhou 1997).

Note that asynchronous, aseasonal molting and the prolonged intermolt period (>1 year) of mature female and the larger male golden king crab likely makes scoring shell conditions very difficult and especially difficult to relate to "time post-molt," posing problems for inclusion of shell condition data into assessment models.

5. **Brief summary of management history:** A complete summary of the management history through 2009 is provided in Bowers et al. (2011, pages 92–94).

The first domestic harvest of golden king crab in the Pribilof District was in 1982 when two vessels fished. Peak harvest and participation occurred in the 1983/84 season with a retained catch of 0.856-million pounds landed by 50 vessels. Since 1984 the fishery has been managed with a calendar-year season under authority of a commissioner's permit and landings and participation has been low and sporadic. Retained catch during 1984–2009 has ranged from 0 pounds to 0.342-million pounds and the number of vessels participating annually has ranged from 0 to 8; no vessels registered for the fishery and there was no retained catch in 2006–2009. One vessel fished in the 2010 season and two vessels fished in the 2011 season; catch statistics for those two seasons are confidential under Sec. 16.05.815 of SOA statutes. The fishery is not rationalized and has been managed inseason to a guideline harvest level (GHL) since 1999. The GHL for 1999 was 0.200-million pounds, whereas the GHL for 2000-2012 has been 0.150-million pounds.

A summary of relevant fishery regulations and management actions pertaining to the Pribilof District golden king crab fishery is provided below.

Only males of a minimum legal size may be retained. By State of Alaska regulation (**5 AAC 34.920 (a)**), the minimum legal size limit for Pribilof District golden king crab is 5.5-inches (140

mm) carapace width (CW), including spines. A carapace length (CL) ≥124 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007).

Golden king crab may be commercially fished only with king crab pots (as defined in **5 AAC 34.050**). Pots used to fish for golden king crab in the Pribilof Islands must have at least four escape rings of no less than five and one-half inches inside diameter installed on the vertical plane or at least one-third of one vertical surface of the pot composed of not less than nine-inch stretched mesh webbing to permit escapement of undersized golden king crab (**5 AAC 34.925 (c)**) and the sidewall "…must contain an opening equal to or exceeding 18 inches in length... The opening must be laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 30 thread." (**5 AAC 39.145(1)**). There is a pot limit of 40 pots for vessels ≤125-feet LOA and of 50 pots for vessels >125-feet LOA (**5 AAC 34.925 (e)(1)(B)**).

Golden king crab can be harvested from 1 January through 31 December only under conditions of a permit issued by the commissioner of ADF&G (**5 AAC 34.910 (b)(3)**). Since 2001 those conditions have included the carrying of a fisheries observer.

D. Data

1. <u>Summary of new information</u>:

1. Retained catch and estimated bycatch during the 2011 directed fishery (both of which are confidential), estimated bycatch in non-directed crab fisheries during 2011, and estimated bycatch in groundfish fisheries during the 2010/11 crab fishery year have been added. Available information on bycatch data from the non-directed crab fisheries in 1993 was added, which turned out to be not much information; there were no observers during the 1993 Bering Sea grooved Tanner crab fishery. Published results of 2010 Bering Sea upper continental slope survey are provided and compared with those of the 2002, 2004, and 2008 surveys.

2. <u>Data presented as time series</u>:

a. <u>Total catch</u> and b. <u>Information on bycatch and discards</u>:

- The 1981/82–1983/84, 1984–2011 time series of retained catch (number and pounds of crab harvested, including deadloss), effort (vessels, landings, and pot lifts), average weight of landed crab, average carapace length of landed crab, and CPUE (number of landed crab captured per pot lift) are presented in Table 1.
- The 1993–2011 time series of weight of retained catch, estimated bycatch and estimated weight of fishery mortality of Pribilof golden king crab during commercial crab fisheries are given in Table 2. Bycatch of Pribilof golden king crab occurs mainly in the directed golden king crab fishery, when prosecuted, and to a lesser extent in the Bering Sea snow crab fishery and the Bering Sea grooved Tanner crab fishery. Because the Bering Sea snow crab fishery is prosecuted mainly or entirely between January and May and the Bering Sea grooved Tanner crab fishery is prosecuted with a calendar-year season, bycatch for the crab fisheries can be estimated on a calendar-year basis to align with the season for Pribilof District golden king crab. Observer data on size distributions and estimated catch numbers of non-retained catch were used to estimate the weight of non-retained catch of golden king crab by applying a weight-at-length estimator (see below). Observers were first deployed to collect bycatch data during the Pribilof District golden

king crab fishery in 2001 and during the Bering Sea grooved Tanner crab fishery in 1994. Retained catch or observer data are confidential for at least one of the crab fisheries in 1999–2001, 2003–2005, and 2010−2011. Following Siddeek et al. (2011), the bycatch mortality rate of golden king crab captured and discarded during Aleutian Islands golden king crab fishery was assumed to be 0.2. Following Foy (2011a, b), bycatch mortality rate of king crab during the snow crab fishery was assumed to be 0.5. The bycatch mortality rate during the grooved Tanner crab fishery was also assumed to be 0.5.

- The groundfish fishery data were grouped into crab fishery years, rather than into calendar years. The 1991/92–2010/11 time series of estimated annual weight of bycatch and total fishery mortality of golden king crab in reporting areas 513, 517, and 521 during federal groundfish fisheries by gear type (combining pot and hook-and-line gear as a single "fixed gear" category and combining non-pelagic and pelagic trawl gear as a single "trawl" category) is provided in Table 3. Following Foy (2011a, b), the bycatch mortality of king crab captured by fixed gear during groundfish fisheries was assumed to be 0.5 and of king crab captured by trawls during groundfish fisheries was assumed to be 0.8.

c. ***Catch-at-length:*** Not used in a Tier 5 assessment; none are presented.

d. Survey biomass estimates: Survey biomass estimates are not used in a Tier 5 assessment. However, biomass estimates of golden king crab (all sizes and sexes) by area and depth zone from the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey are presented in Table 4. The survey area is depicted in Figure 2 and catch distribution and density of golden king crab during the 2010 survey is shown in Figure 3. Trends in survey biomass, with the Pribilof Canyon area shown separately, are presented graphically in Figure 4.

e. ***Survey catch at length:*** Survey catch at length data are not used in a Tier 5 assessment. However, size composition by sex of the estimated golden king crab population from the 2004, 2008, and 2010 eastern Bering Sea upper continental slope trawl survey is presented in Figure 5.

f. ***Other data time series:*** See section **D.4** on other time-series data that is available, but not presented here.

3. Data which may be aggregated over time:

a. Growth-per-molt; frequency of molting, etc. (by sex and perhaps maturity state):

The author is not aware of data on growth per molt of Pribilof golden king crab. Growth per molt of juvenile golden king crab, 2–35-mm CL, collected from Prince William Sound have been observed in a laboratory setting and equations describing the increase in CL and intermolt period were estimated from those observations (Paul and Paul 2001a); those results are not provided here. Growth per molt has also been estimated from golden king crab with CL ≥ 90 mm that were tagged in the Aleutian Islands and recovered during subsequent commercial fisheries (Watson et al. 2002); those results are not presented here because growth-per-molt information does not enter into a Tier 5 assessment.

See section **C.4** for discussion of evidence that mature female and the larger male golden king crab exhibit asynchronous, aseasonal molting and a prolonged intermolt period (>1 year).

b. Weight-at length or weight-at-age (by sex):

Parameters (A and B) used for estimating weight (g) from carapace length (CL, mm) of male and female red king crab according to the equation, Weight = $A*CL^B$ (from Table 3-5, NPFMC 2007) are: A = 0.0002988 and B = 3.135 for males and A = 0.001424 and B = 2.781 for females; note that although the estimated parameters, A and B, are those estimated for ovigerous females, those parameters were used to estimate the weight of all females without regard to reproductive status. Estimated weights in grams were converted to pounds by dividing by 453.6.

c. Natural mortality rate:

The default natural mortality rate assumed for king crab species by NPFMC (2007) is M=0.18. Note, however, natural mortality was not used for OFL estimation because this stock belongs to Tier 5.

4. Information on any data sources that were available, but were excluded from the assessment:

Standardized bottom trawl surveys to assess the groundfish and invertebrate resources of the eastern Bering Sea (EBS) upper continental slope have been performed in 2002, 2004, 2008, 2010 (Hoff and Britt 2003, 2005, 2009, 2011; Haaga et al. 2009). The raw data from those surveys have not been accessed for this assessment; only summary of results and stock biomass estimates that have been reported by Hoff and Britt (2003, 2005, 2009, 2011) and reported by Haaga et al. (2009) are presented in this assessment. Access to the raw data from those standardized surveys could allow for "area-swept" estimation of abundance and biomass of golden king crab in the Pribilof District by relevant size, sex, and reproductive-status classes (e.g., mature male biomass, mature female biomass, legal-sized male biomass, etc.). Additionally, a pilot slope survey was also performed in 2000 and triennial surveys using a variety of nets, methods, vessels, and sampling locations were performed during 1979–1991 (Hoff and Britt 2011); no data from those surveys were accessed for, and no results from those surveys were reported on, in this assessment because, according to Hoff and Britt (2011), "Comparisons between the post-2000 surveys and those conducted from 1979–1991 remains confounded due to differences in sampling gear, survey design, sampling methodology, and species identification."

The CPT encouraged that data from the EBS slope survey be included to the extent possible to consider whether that information may be sufficient to move this assessment up to Tier 4 in future years (2009 Crab SAFE, Executive Summary). Although published and unpublished summaries of the EBS slope survey data have been included in recent SAFEs, the author has not acquired the raw survey data, as would be necessary for considering if that data is sufficient for a Tier 4 assessment. With regard to the 2011 SSC's encouragement to explore the eastern Bering Sea upper continental slope survey data "for their utility to provide estimates of biomass for the Pribilof District" and to give consideration to "the distribution of the survey with respect to stock distribution, as well as estimation of survey catchability by size and sex," the author reports the following, generalizing from the 2010 survey report (Hoff and Britt 2011).

The survey samples approximately 200 randomly-chosen locations (stratified by 200 m depth zones) from the areas of 200–1,200 m depth. In 2010, the mean sampling density over the total surveyed area of 32,723 km^2 was one haul per 204.48 km^2; survey tow sampling is denser at depths < 800 m. That sampling density compares to one haul per 400 nmi^2 (1,372 km^2) for the standard stations in the eastern Bering Sea continental shelf survey. Hence the survey design provides a high sampling density within the depth range that golden king crab typically occur and at which the commercial fishery is typically prosecuted. Moreover, the survey area contains all areas at depths of 200–1,200 m within the borders of the Pribilof District and the survey area, extending beyond the north and south borders of the district.

With regard to the survey catchability by size and sex, the survey uses a Poly Nor'eastern high-opening bottom trawl equipped with mud-sweeper roller gear (see Hoff and Britt 2011 for details). The author has no idea how such gear affects survey catchability by size or sex, or how such would compare with that realized by the continental shelf survey, which does not use mud-sweeper roller gear. The author is not aware of any studies that provide data to estimate catchability by size and sex for this survey. Under the survey protocols, sites are considered towable when depth change less than 50 m over a 2-nmi transect and there are no detectable obstacles in the trawl path; that restriction on trawl locations may or may not affect catchability for all sizes and both sexes, depending on habitat preferences. The author notes that a cursory examination of the size/sex frequency distribution of golden king crab captured during the last three biennial surveys (Figure 5), shows that golden king crab <20 mm CL are captured by the survey gear, but that highest frequencies tend to occur at sizes >100 mm CL, consistent with reduced catchability at smaller sizes. Size and sex frequencies of captured golden king crab appear to track poorly across the last three biennial surveys (Figure 4). For example, the catch in 2008 was dominated by males of roughly 90–120 mm CL and the size frequency distribution of females in 2008 was relatively flat, whereas the catch in 2010 was dominated by females of roughly 110–140 mm CL and the size frequency distribution of males in 2010 was relatively flat.

E. Analytic Approach

1. **History of modeling approaches for this stock:** This is a Tier 5 stock; there is no assessment model and no history of assessment modelling approaches for this stock.

2. **Model Description:** *Subsections a–i are not applicable to a Tier 5 sock.*

No assessment model for the Pribilof Islands golden king crab stock exists and none is in development. Accordingly, it has been recommended by NPFMC (2007) and by the CPT and SSC in 2008−2011 that the Pribilof Islands golden king crab stock be managed as a Tier 5 stock. For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST without an estimate of biomass, and "the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock" (NPFMC 2007). Although NPFMC (2007) defined the OFL in terms of the retained catch, total-catch OFLs may be considered for Tier 5 stocks for which nontarget fishery removal data are available (Federal Register/Vol. 73, No. 116, 33926). The CPT (in May 2010) and the SSC (in June 2010) endorsed the use of a total-catch OFL to establish the OFL for this stock. This assessment recommends – and only considers – use of a total-catch OFL for 2013.

Additionally, NPFMC (2007) states that for estimating the OFL of Tier 5 stocks, "The time period selected for computing the average catch, hence the OFL, should be based on the best

scientific information available and provide the required risk aversion for stock conservation and utilization goals." Given that a total-catch OFL is to be used, alternative configurations for the Tier 5 model are limited to: 1) alternative time periods for computing the average total-catch mortality; and 2) alternative approaches for estimating the non-retained component of the total catch mortality during that period.

With regard to choosing from alternative time periods for computing average annual catch to compute the OFL, NPFMC (2007) suggested using the average retained catch over the years 1993 to 1999 as the estimated OFL for Pribilof Islands golden king crab. Years post-1984 were chosen based on an assumed 8-year lag between hatching and growth to legal size after the 1976/77 "regime shift". With regard to excluding data from years 1985 to 1992 and years after 1999, NPFMC (2007) states, "The excluded years are from 1985 to 1992 and from 2000 to 2005 for Pribilof Islands golden king crab when the fishing effort was less than 10% of the average or the GHL was set below the previous average catch." In 2008 the CPT and SSC endorsed the approach of estimating OFL as the average retained catch during 1993–1999 for setting a retained-catch OFL for 2009. However, in May 2009 the CPT setting a retained-catch OFL for 2010, but using the average retained catch during 1993–1998; 1999 was excluded because it was the first year that a preseason GHL was established for the fishery. In May 2010, the CPT established a total-catch OFL computed as a function of the average retained catch during 1993–1998, a ratio-based estimate of the bycatch mortality during the directed fishery of that period, and an estimate of the "background" bycatch mortality due to other fisheries. Other time periods, extending into years post-1999, had been considered for computing the average retained catch in the establishment of the 2009, 2010, 2011 OFLs, but those time periods were rejected by the CPT and the SSC. Hence the period for calculating the retained-catch portion of the Tier 5 total-catch OFL for this stock has been firmly established by the CPT and SSC at 1993–1998 (the CPT said "this freezes the time frame..."). For the 2012 OFL, the CPT and SSC recommended the period 2001–2010 for calculating the ratio-based estimate of the bycatch mortality during the 1993–1998 directed fishery, the period 1994–1998 for calculating the estimated bycatch mortality due to non-directed crab fisheries during 1993–1998, and the period 1992/93–1998/99 for calculating the estimated bycatch mortality due to groundfish fisheries during 1993–1998.

Because no new information has become available since the May 2011 CPT meeting (aside from the confidential catch data from the 2011 Pribilof District golden king crab fishery season, the non-directed crab fishery bycatch estimates for 2011, and the groundfish bycatch estimates for 2009/10 and because both the CPT and the SSC have settled on a time period of 1993–1998 for computing the average retained catch in the calculations of the 2010 –2012 OFLs, the author sees no reason to consider any other time periods besides 1993–1998 for computing the average retained catch in the calculation of the 2013 OFL; those who do see a reason should consult the minutes on this subject from the May 2009 and 2010 CPT meetings. Likewise, in their recommendations for the 2012 OFL, the CPT and SSC have established the periods for estimating bycatch mortality during 1993–1998 due to groundfish fisheries (1992/93–1998/99) and non-directed crab fisheries (1994–1998; insufficient data was collected from other crab fisheries to estimate bycatch mortality in 1993; see Table 1).

With regard to the alternative approaches for estimating the non-retained component of the total catch mortality, an obvious issue is that there are no data on bycatch in the directed fishery

during 1993–1998, so choices must be made on how to best estimate the bycatch mortality during that period.

3. Model Selection and Evaluation:

a. *Description of alternative model configurations*

Two alternatives are presented. Alternative 1 is the status quo approach (i.e., the approach used to establish the 2012 total-catch OFL) and the author's recommended alternative. Alternative 2 is the same as Alternative 1 except that it uses updated bycatch data from crab fisheries in 2011; it is presented to allow the CPT and the SSC to clarify whether the 2013 and subsequent OFLs should be computed using data collected after 2010, or if the time periods for data used to calculate the 2013 and subsequent OFLs should be "frozen" at the years used to calculate the 2012 OFL.

Alternative 1 (status quo and author's recommendation). The recommended OFL is set as a total-catch OFL using 1993–1998 to compute average annual retained catch, an estimate of pounds of bycatch mortality per pound of retained catch during the directed fishery, an estimate of the average annual bycatch mortality due to the non-directed crab fisheries during 1994–1998 and an estimate of average annual bycatch mortality due to the groundfish fisheries during 1992/93–1998/99; i.e.,

$$OFL_{1,\,2013} = (1+R_{2001–2010})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93–98/99,}$$

where,

- $R_{2001–2010}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained catch in the directed fishery during 2001–2010
- $RET_{1993\text{-}1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998
- $BM_{NC,1994\text{-}1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
- $BM_{GF,92/93–98/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

The average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained in the directed fishery during 2001–2010 is used as a factor to estimate bycatch mortality in the directed fishery during 1993–1998 because, whereas there is no data on bycatch for the directed fishery during 1993–1998, there is such data from the directed fishery during 2001–2010 (excluding 2006–2009, when there was no fishery effort).

The estimated average annual bycatch mortality in non-directed fisheries during 1994–1998 is used to estimate the average annual bycatch mortality in non-directed fisheries during 1993–1998 because there is no bycatch data available for the non-directed fisheries during 1993.

The estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99 is used to estimate the average annual bycatch mortality in groundfish fisheries during 1993–1998 because 1992/93–1998/99 is the shortest time period of crab fishery years that encompasses calendar years 1993–1998.

Statistics on the data and estimates used to calculate $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$ are provided in Table 5; the column means in Table 5 are the calculated values of $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$. Using the calculated values of $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$, $OFL_{1,\,2013}$ is,

$$OFL_{1,2013} = (1+0.052)*173{,}722 + 13{,}418 + 8{,}353 = 204{,}611 \text{ lbs (0.20-million lbs).}$$

Alternative 2. Alternative 2 follows the approach as Alternative 1, but uses the updated data on bycatch from the 2011 directed fishery to estimate the ratio of bycatch mortality to retained catch during the 1993–1998 directed fishery; i.e.,

$$OFL_{2,\,2013} = (1+R_{2001–2011})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93–98/99,}$$

where,

- $R_{2001–2011}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained catch in the directed fishery during 2001–2011
- $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93–98/99}$ are as defined for Alternative 1, above.

Statistics on the data and estimates used to calculate, $RET_{1993\text{-}1998}$, $R_{2001\text{-}2011}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93–98/99}$ are provided in Table 6. Using those calculated values, $OFL_{2,\,2013}$ is calculated as,

$$OFL_{2,2013} = (1+0.053)*173{,}722 + 13{,}418 + 8{,}353 = 204{,}700 \text{ lbs (0.20-million lbs).}$$

b. ***Show a progression of results from the previous assessment to the preferred base model by adding each new data source and each model modification in turn to enable the impacts of these changes to be assessed:*** See the table, below.

Model	Retained- vs. Total-catch	Time Period	Resulting OFL (millions of pounds)
Alt. 1 – recommended/status quo	Total-catch	1993–1998	0.20
Alt. 2	Total-catch	1993–1998	0.20

Alternative 1 is recommended and is the status quo; it is recommended as being the best approach with the limited data available. The choice between Alternative 1 and Alternative 2 makes no difference in the 2013 OFL – both round to 0.20 million pounds. The choice here is to decide whether the periods used to calculate the OFL should be "frozen" at the periods chosen to calculate the 2012 OFL or if the period used to estimate the ratio of bycatch mortality to retained catch should be updated each year with the most recent fishery.

c. ***Evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models:***

Both alternatives have the same number of parameters. Both can be seen as equally realistic.

d. ***Convergence status and convergence criteria for the base-case model (or proposed base-case model):*** Not applicable.

e. ***Table (or plot) of the sample sizes assumed for the compositional data:*** Not applicable.

f. ***Do parameter estimates for all models make sense, are they credible?:***
The time period used for determining the OFL was established by the SSC in June 2010, but choice of time period is made difficult due to sporadic, low-effort nature of the fishery. Estimates of total retained catch (pounds) during a season are from fish tickets landings and are assumed here to be correct. Estimates of bycatch from crab fisheries data are generally considered credible (e.g., Byrne and Pengilly 1998, Gaeuman 2011), but may have greater uncertainty in a small, low effort fishery such as the Pribilof golden king crab fishery. Estimates of bycatch mortality are estimates of bycatch times an assumed bycatch mortality rate. Bycatch mortality rates have not been estimated from data.

g. ***Description of criteria used to evaluate the model or to choose among alternative models, including the role (if any) of uncertainty:*** See section E.3.c, above.

h. ***Residual analysis (e.g. residual plots, time series plots of observed and predicted values or other approach):*** Not applicable.

i. ***Evaluation of the model, if only one model is presented; or evaluation of alternative models and selection of final model, if more than one model is presented:*** See section E.3.c, above.

4. Results (best model(s)):

a. List of effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties: Not applicable.

b. Tables of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible; include estimates from previous SAFEs for retrospective comparisons): See Tables 6-8.

c. Graphs of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible): Information requested for this subsection is not applicable to a Tier 5 stock.

d. Evaluation of the fit to the data: Not applicable for Tier 5 stock.

e. Retrospective and historic analyses (retrospective analyses involve taking the "best" model and truncating the time-series of data on which the assessment is based; a historic analysis involves plotting the results from previous assessments): Not applicable for Tier 5 stock.

f. Uncertainty and sensitivity analyses (this section should highlight unresolved problems and major uncertainties, along with any special issues that complicate scientific

assessment, including questions about the best model, etc.): For this assessment, the major uncertainties are:

- Whether the time period is "representative of the production potential of the stock" and if it serves to "provide the required risk aversion for stock conservation and utilization goals." Or whether any such time period exists.
    - Only a period of 6 years is used to compute the OFL, 1993–1998. The SSC has noted its uneasiness with that situation ("6 years of data are very few years upon which to base these catch specifications." June 2011 SSC minutes).
- No data on bycatch due to the directed fishery during the period used to compute the OFL is available. Estimation of the OFL rests on the assumption that data on the ratio of bycatch to retained catch during the post-2000 seasons can be used to accurately estimate that ratio for the 1993–1998 seasons.
- The bycatch mortality rates used in estimation of total catch. Bycatch mortality is unknown and no data that could be used to estimate the bycatch mortality of this stock is known to the author. Hence, only the values that are assumed for other BSAI king crab stock assessments are considered in this assessment. The estimated OFL increases (or decreases) relative to the bycatch mortality rates assumed: doubling the assumed bycatch mortality rates increases the OFL estimate by a factor of 1.15; halving the assumed bycatch mortality rates decreases the OFL estimate by a factor of 0.92.

F. Calculation of the OFL

1. Specification of the Tier level and stock status level for computing the OFL:

- Recommended as Tier 5, total-catch OFL estimated by estimated average total catch over a specified period.
- Recommended time period for computing retained-catch OFL: 1993–1998.
    - This is the time period used to establish OFL for the 2010–2012 seasons. The time period 1993–1998 provides the longest continuous time period through 2011 during which vessels participated in the fishery, retained-catch data can be retrieved that are not confidential, and the retained catch was not constrained by a GHL. Data on bycatch mortality contemporaneous with 1993-1998 to the extent possible is used to calculate the total-catch OFL in the recommended Alternative 1.

2. List of parameter and stock size estimates (or best available proxies thereof) required by limit and target control rules specified in the fishery management plan: Not applicable for Tier 5 stock.

3. Specification of the total-catch OFL:

a. Provide the equations (from Amendment 24) on which the OFL is to be based:

From **Federal Register** / Vol. 73, No. 116, page 33926, "For stocks in Tier 5, the overfishing level is specified in terms of an average catch value over an historical time period, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information." Additionally, "For stocks where nontarget fishery removal data are available, catch includes all fishery removals, including retained catch and discard losses. Discard losses will be determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks where only retained catch information is

available, the overfishing level is set for and compared to the retained catch" (FR/Vol. 73, No. 116, 33926). That compares with the specification of NPFMC (2007) that the OFL "represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock."

b. Basis for projecting MMB to the time of mating: Not applicable for Tier 5 stock.

c. Specification of F_{OFL}, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring: See table below. Although the retained and total catch for 2011 cannot be presented here due to the confidentiality of data, the author can report that total catch in 2011 did not exceed the 2011 OFL. Values for the 2013 OFL and ABC are the author's recommendations.

Year[a]	MSST	Biomass (MMB)	GHL[b]	Retained Catch[c]	Total Catch[c,d]	OFL[c,e]	ABC[c,e]
2009	N/A	N/A	0.150	0	0.001	0.17 R	N/A
2010	N/A	N/A	0.150	Conf.[f]	Conf.[f]	0.17 R	N/A
2011	N/A	N/A	0.150	Conf.[f]	Conf.[f]	0.18 T	N/A
2012	N/A	N/A	0.150	TBD	TBD	0.20 T	0.18 T
2013	N/A	N/A	TBD	TBD	TBD	[0.20 T]	[0.18 T]

a. Season is based on a calendar year.
b. Guideline harvest level expressed in millions of pounds. The Pribilof District golden king crab fishery is not rationalized and a TAC is not established for the fishery.
c. Millions of pounds.
d. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2009/10 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
e. Noted as "R" for retained-catch-only OFL and "T" for total-catch OFL.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season..

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

***a.* Equation for recommended retained-portion of total-catch OFL.**

Retained-catch portion = average retained catch during 1993–1998
= 173,722 pounds (0.17-million pounds).

5. Recommended F_{OFL}, OFL total catch and the retained portion for the coming year: See sections ***F.3*** and ***F.4***, above; no F_{OFL} is recommended for a Tier 5 stock.

G. Calculation of ABC

1. PDF of OFL. Bootstrap estimates of the sampling distributions (assuming no error in estimation of bycatch) of the Alternatives 1 and 2 OFLs are shown in Figure 6 (1,000 samples drawn with replacement independently from each of the four columns of values in Table 5 to calculate $R_{2001\text{-}2010}$, $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, $BM_{GF,92/93\text{-}98/99}$ and $OFL_{1,2013}$; and 1,000 samples drawn with replacement independently from each of the four columns of values in Table 6 to calculate $R_{2001\text{-}2011}$, $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, $BM_{GF,92/93\text{-}98/99}$ and $OFL_{2,2013}$). Table 7 provides statistics on the generated distributions.

2. List of variables related to scientific uncertainty.

- Bycatch mortality rate in each fishery that bycatch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch rate will increase the OFL (and hence the ABC), but has no effect on the retained-catch portion of the OFL or the retained-catch portion of the ABC.
- Estimated bycatch and bycatch mortality for each fishery that bycatch occurred in during 1993–1998.
- The time period to compute the average catch under the assumption of representing "a time period determined to be representative of the production potential of the stock."

3. List of addititional uncertainties for alternative sigma-b. Not applicable to this Tier 5 assessment.

4. Author recommended ABC. (1-0.1)·(204,612 pounds) = 0.18-million pounds.

H. Rebuilding Analyses

Entire section is not applicable; this stock has not been declared overfished.

I. Data Gaps and Research Priorities

Data from the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental shelf trawl surveys have not been examined for their utility in providing reliable estimates of biomass and abundance of golden king crab by size, sex, and reproductive status within the Pribilof District. Survey catchability of golden king crab by sex and size is not estimated.

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Table 1. Harvest history for the Pribilof District golden king crab fishery from the 1981/82 season through 2011 (from 2011 SAFE, updated with 2011 data provided by P. Converse, ADF&G, Kodiak via 17 April 2012 email).

	Number of						Average			
Season	Vessels	Landings	Crabs[a]	Pots lifted	GHL[b]	Harvest[a,c]	Weight[c]	CPUE[d]	Length[e]	Deadloss[c]
1981/82	2	CF	CF	CF	-	CF	CF	CF	CF	CF
1982/83	10	19	15,330	5,252	-	69,970	4.6	3	151	570
1983/84	50	115	253,162	26,035	-	856,475	3.4	10	127	20,041
1984	0	0	0	0	-	0	0	0	0	0
1985	1	CF	CF	CF	-	CF	CF	CF	CF	CF
1986	0	0	0	0	-	0	0	0	0	0
1987	1	CF	CF	CF	-	CF	CF	CF	CF	CF
1988	2	CF	CF	CF	-	CF	CF	CF	CF	CF
1989	2	CF	CF	CF	-	CF	CF	CF	CF	CF
1990	0	0	0	0	-	0	0	0	0	0
1991	0	0	0	0	-	0	0	0	0	0
1992	0	0	0	0	-	0	0	0	0	0
1993	5	15	17,643	15,395	-	67,458	3.8	1	NA	0
1994	3	5	21,477	1,845	-	88,985	4.1	12	NA	730
1995	7	22	82,489	9,551	-	341,908	4.1	9	NA	716
1996	6	32	91,947	9,952	-	329,009	3.6	9	NA	3,570
1997	7	23	43,305	4,673	-	179,249	4.1	9	NA	5,554
1998	3	9	9,205	1,530	-	35,722	3.9	6	NA	474
1999	3	9	44,098	2,995	200,000	177,108	4.0	15	NA	319
2000	7	19	29,145	5,450	150,000	127,217	4.4	5	NA	4,599
2001	6	14	33,723	4,262	150,000	145,876	4.3	8	143	8,227
2002	8	20	34,860	5,279	150,000	150,434	4.3	6	144	8,984
2003	3	CF	CF	CF	150,000	CF	CF	CF	CF	CF
2004	5	CF	CF	CF	150,000	CF	CF	CF	CF	CF
2005	4	CF	CF	CF	150,000	CF	CF	CF	CF	CF
2006-2009	0	0	0	0	150,000	0	0	0	0	0
2010	1	CF	CF	CF	150,000	CF	CF	CF	CF	CF
2011	2	CF	CF	CF	150,000	CF	CF	CF	CF	CF

Note: CF = confidential, less than three vessels or processors participated in fishery

[a] Deadloss included.

[b] Guideline harvest level in pounds.

[c] In pounds.

[d] Number of legal crab per pot lift.

[e] Carapace length in millimeters.

Table 2. Weight (in pounds) of retained catch, estimated non-retained bycatch, and estimated total fishery mortality of Pribilof golden king crab during crab fisheries, 1993–2011 (assumes a bycatch mortality rate of 0.2 for the directed fishery and a bycatch mortality rate of 0.5 for non-directed fisheries; from 2011 Crab SAFE, with update for 2011 and bycatch data for 1993 added).

		Bycatch			
Year	Retained Catch	Pribilof Islands golden king crab	Bering Sea snow crab	Bering Sea grooved Tanner crab	Total Fishery Mortality
1993	67,458	no data	0	no data.	—
1994	88,985	no data	8,387	2,531	—
1995	341,908	no data	1,391	34,492	—
1996	329,009	no data	526	5,151	—
1997	179,249	no data	8,937	no fishing	—
1998	35,722	no data	72,760	no fishing	—
1999	177,108	no data	0	confidential	—
2000	127,217	no data	0	confidential	—
2001	145,876	39,278	0	confidential	confidential
2002	150,434	41,894	2,335	no fishing	159,980
2003	confidential	confidential	329	confidential	159,184
2004	confidential	confidential	0	confidential	147,552
2005	confidential	confidential	0	confidential	65,817
2006	no fishing	no fishing	0	0	0
2007	no fishing	no fishing	0	0	0
2008	no fishing	no fishing	0	no fishing	0
2009	no fishing	no fishing	2,122[a]	no fishing	1,061[a]
2010	confidential	confidential	0	no fishing	confidential
2011	confidential	confidential	591[b]	no fishing	confidential

a. Value is likely an over-estimate. Only 5 golden king crab (1 sublegal male and 4 legal males) were counted in 1,657 pot lifts sampled out of the 163,536 pot lifts performed during the 2008/09 Bering Sea snow crab fishery, but none of those were measured to provide an estimate of weight. An average weight of 4.3 pounds per crab was used to estimate the total bycatch weight; 4.3 pounds is average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.

b. Value is likely an over-estimate. Only 2 golden king crab (1 sublegal male and 1 legal male) were counted in 2,142 pot lifts sampled out of the 147,244 pot lifts performed during the 2010/11 Bering Sea snow crab fishery (Gaeuman 2011), but none of those were measured to provide an estimate of weight. Bycatch weight was estimated by 4.3x(2x147,244)/2,142; the assumed average weight per crab (4.3 pounds) is the average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.

Table 3. Estimated annual weight (pounds) of discarded bycatch and total bycatch mortality (pounds) of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 513, 517, and 521, 1991/92–2010/11 (assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries; updated from 2011 SAFE with 2010/11 data provided by R. Foy AFSC, Kodiak Laboratory via 9 August 2011 email).

Season	Fixed	Trawl	Total Bycatch	Total Bycatch Mortality
1991/92	110	13,464	13,574	10,826
1992/93	7,690	19,544	27,234	19,480
1993/94	1,116	21,248	22,364	17,556
1994/95	558	7,103	7,661	5,962
1995/96	895	4,187	5,082	3,797
1996/97	53	1,918	1,971	1,561
1997/98	2,952	1,074	4,026	2,335
1998/99	14,930	395	15,324	7,781
1999/00	10,556	1,426	11,982	6,419
2000/01	3,589	4,134	7,723	5,101
2001/02	3,300	783	4,083	2,276
2002/03	1,219	472	1,691	987
2003/04	503	401	904	572
2004/05	342	860	1,202	859
2005/06	198	126	324	200
2006/07	2,915	254	3,168	1,660
2007/08	18,678	351	19,028	9,619
2008/09	8,799	3,433	12,231	7,145
2009/10	7,228	13,464	13,574	10,826
2010/11	1,966	1,213	3,179	1,953

Table 4. Biomass estimates (metric tons) of golden king crab (all sizes, both sexes) from results of the 2002, 2004, 2008, 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey, by survey subarea and depth zone (from Haaga et al. 2009, Hoff and Britt 2003, 2005, 2009, 2011, and J. Haaga, NMFS-AFSC, Kodiak, 26 August 2009).

Year	Depth (m)	Subarea 1 Bering Canyon[a]	**Subarea 2 Pribilof Canyon[b]**	**Subarea 3[b]**	**Subarea 4 Zhemchug Canyon[b]**	Subarea 5[a]	Subarea 6 Pervenets/Navarin Canyons[c]
2002	200-400	53	**289**	**49**	**52**	16	29
	400-600	78	**253**	**32**	**1**	3	14
	600-800	0	**121**	**1**	**0**	0	0
	800-1000	1	**0**	**0**	**0**	0	0
	1000-1200	0	**19**	**-**	**0**	0	0
	Total	131	**682**	**81**	**53**	19	44
2004	200-400	4	**526**	**25**	**121**	13	2
	400-600	45	**220**	**13**	**0**	13	22
	600-800	14	**67**	**10**	**0**	0	0
	800-1000	1	**4**	**3**	**0**	0	0
	1000-1200	0	**0**	**0**	**0**	0	0
	Total	65	**817**	**51**	**121**	25	24
2008	200-400	67	**258**	**65**	**173**	0	38
	400-600	78	**584**	**19**	**0**	2	29
	600-800	2	**76**	**8**	**32**	0	0
	800-1000	0	**0**	**0**	**0**	0	0
	1000-1200	0	**2**	**0**	**0**	0	0
	Total	146	**919**	**91**	**206**	2	66
2010	200-400	116	**1050**	**85**	**72**	34	53
	400-600	246	**432**	**4**	**0**	3	64
	600-800	0.4	**104**	**0.1**	**0**	0	6
	800-1000	1	**12**	**0**	**0**	0	0
	1000-1200	0	**17**	**0**	**0**	0	0
	Total	363	**1615**	**89**	**72**	37	123

a. Partially in Pribilof District.
b. Entirely in Pribilof District.
c. Not in Pribilof District.

Table 5. Data for calculation of $RET_{1993\text{-}1998}$ and estimates used in calculation of $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{-}98/99}$ for calculation of the Alternative 1 Pribilof Islands golden king crab Tier 5 2013 total-catch OFL; values under $RET_{1993\text{-}1998}$ are from Table 1, values under $R_{2001\text{-}2010}$ were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under $BM_{NC,1994\text{-}1998}$ were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93\text{-}98/99}$ are from Table 3.

Season[a]	Season[b]	$RET_{1993\text{-}1998}$	$R_{2001\text{-}2010}$	$BM_{NC,1994\text{-}1998}$	$BM_{GF,92/93\text{-}98/99}$
1993	1992/93	67,458			19,480
1994	1993/94	88,985		5,459	17,556
1995	1994/95	341,908		17,941	5,962
1996	1995/96	329,009		2,839	3,797
1997	1996/97	179,249		4,469	1,561
1998	1997/98	35,722		36,380	2,335
1999	1998/99				7,781
2000	1999/00				
2001	2000/01		0.054		
2002	2001/02		0.056		
2003	2002/03		conf.		
2004	2003/04		conf.		
2005	2004/05		conf.		
2006	2005/06				
2007	2006/07				
2008	2007/08				
2009	2008/09				
2010	2009/10		conf.		
	N	6	6	5	7
	Mean	173,722	0.052	13,418	8,353
	S.E.M	54,756	0.004	6,337	2,750
	CV	0.32	0.07	0.47	0.33

a. Season convention corresponding with values under $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, and $BM_{NC,1994\text{-}1998}$.

b. Season convention corresponding with values under $BM_{GF,92/93\text{-}98/99}$.

Table 6. Data for calculation of $RET_{1993\text{-}1998}$ and estimates used in calculation of $R_{2001\text{-}2011}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{-}98/99}$ for calculation of the Alternative 2 Pribilof Islands golden king crab Tier 5 2013 total-catch OFL; values under $RET_{1993\text{-}1998}$ are from Table 1, values under $R_{2001\text{-}2011}$ were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under $BM_{NC,1994\text{-}1998}$ were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93\text{-}98/99}$ are from Table 3.

Season[a]	Season[b]	$RET_{1993\text{-}1998}$	$R_{2001\text{-}2011}$	$BM_{NC,1994\text{-}1998}$	$BM_{GF,92/93\text{-}98/99}$
1993	1992/93	67,458			19,480
1994	1993/94	88,985		5,459	17,556
1995	1994/95	341,908		17,941	5,962
1996	1995/96	329,009		2,839	3,797
1997	1996/97	179,249		4,469	1,561
1998	1997/98	35,722		36,380	2,335
1999	1998/99				7,781
2000	1999/00				
2001	2000/01		0.054		
2002	2001/02		0.056		
2003	2002/03		conf.		
2004	2003/04		conf.		
2005	2004/05		conf.		
2006	2005/06				
2007	2006/07				
2008	2007/08				
2009	2008/09				
2010	2009/10		conf.		
2011	2010/11		conf.		
	N	6	7	5	7
	Mean	173,722	0.053	13,418	8,353
	S.E.M	54,756	0.003	6,337	2,750
	CV	0.32	0.06	0.47	0.33

a. Season convention corresponding with values under $RET_{1993\text{-}1998}$, $R_{2001\text{-}2011}$, and $BM_{NC,1994\text{-}1998}$.

b. Season convention corresponding with values under $BM_{GF,92/93\text{-}98/99}$.

Table 7. Statistics for 1,000 bootstrap 2013 OFLs for Pribilof Islands golden king crab stock calculated according to Alternatives 1 and 2, with the computed OFLs for comparison.

	Alternative 1	Alternative 2
Computed OFL	204,611	204,700
Mean of 1,000 bootstrapped OFLs	203,870	201,399
Std. dev. of 1,000 bootstrapped OFLs	51,030	52,988
CV = (std. dev.)/(Mean)	0.25	0.26

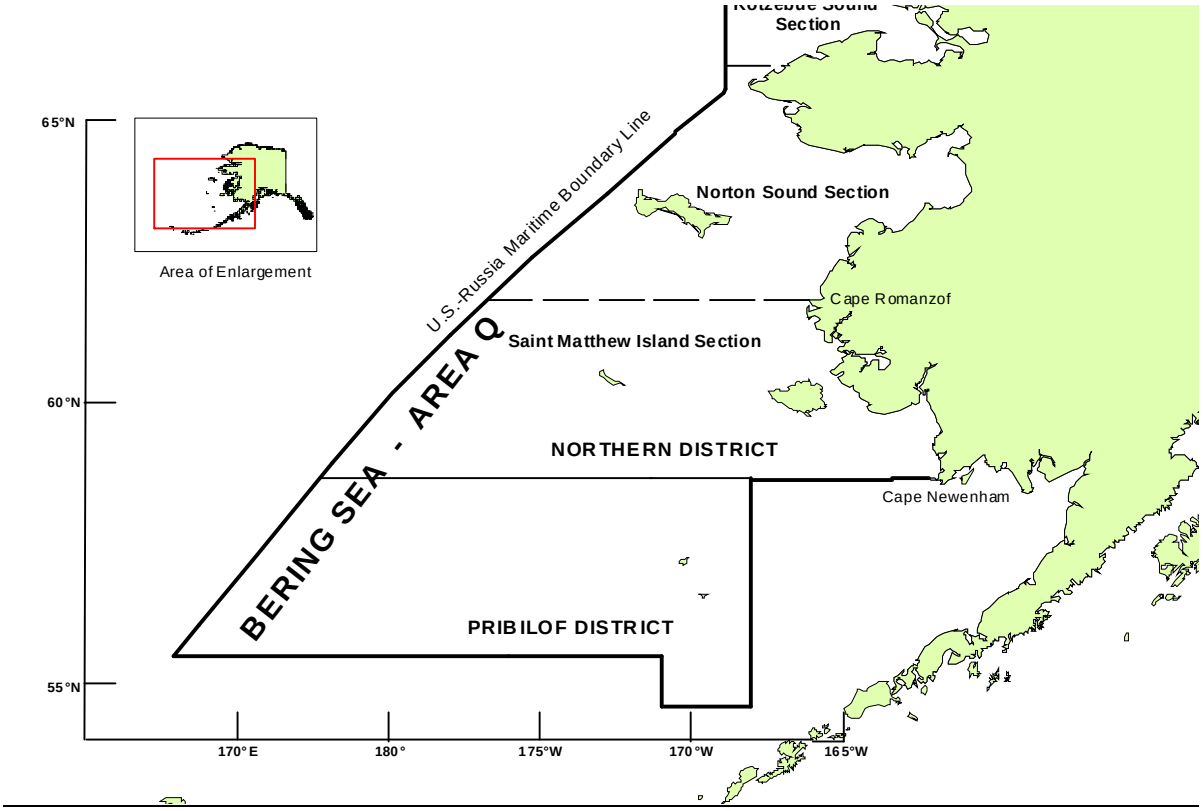

Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Bowers et al. 2011).

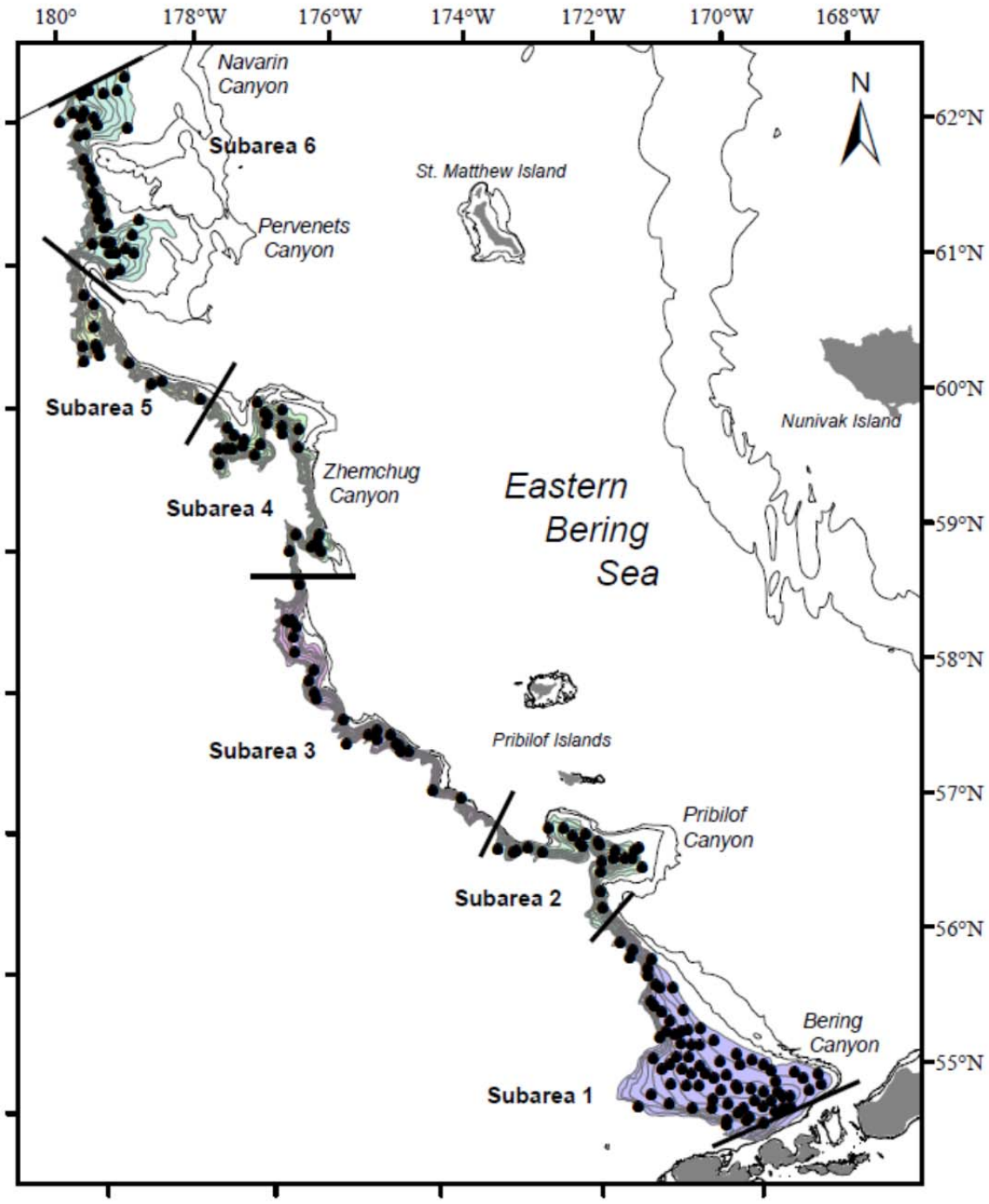

Figure 2. Map of standard survey area for NMFS-AFSC eastern Bering Sea upper continental slope trawl survey with survey subareas identified; black dots show locations of successful tows during the 2010 survey (from Figure 1 *in* Hoff and Britt 2011).

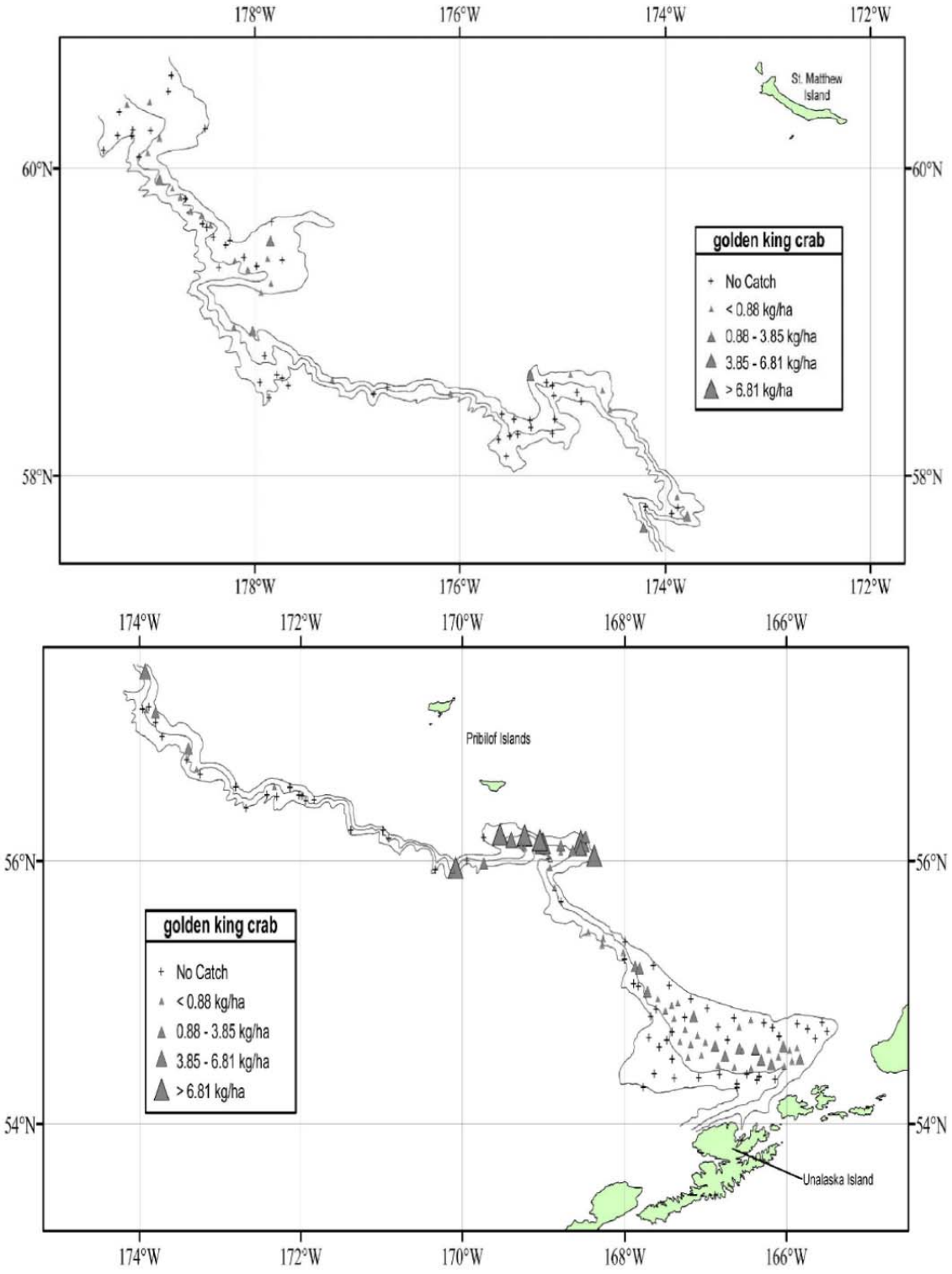

Figure 3. Distribution and relative abundance of golden king crab from the 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey. Relative abundance is categorized by no catch, sample CPUE less than the mean CPUE, between the mean CPUE and two standard deviations above the mean CPUE, between two and four standard deviations above the mean CPUE, and greater than four standard deviations above the mean CPUE (from Figure 82 *in* Hoff and Britt 2011).

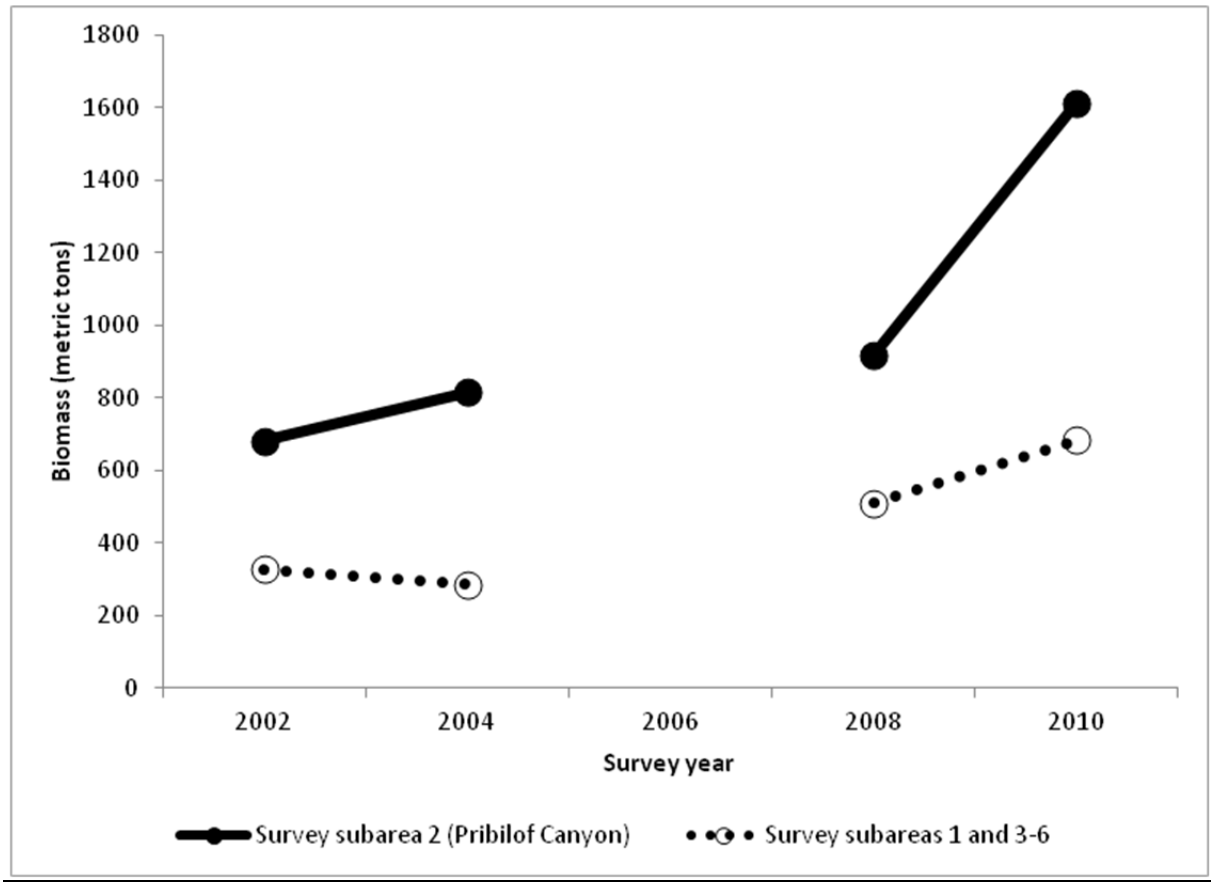

Figure 4. Biomass estimates (all sexes and sizes) for the Pribilof Canyon survey subarea and the aggregated remaining survey subareas (see Figure 2) from the biennial eastern Bering Sea upper continental slope surveys that were performed during 2002–2010.

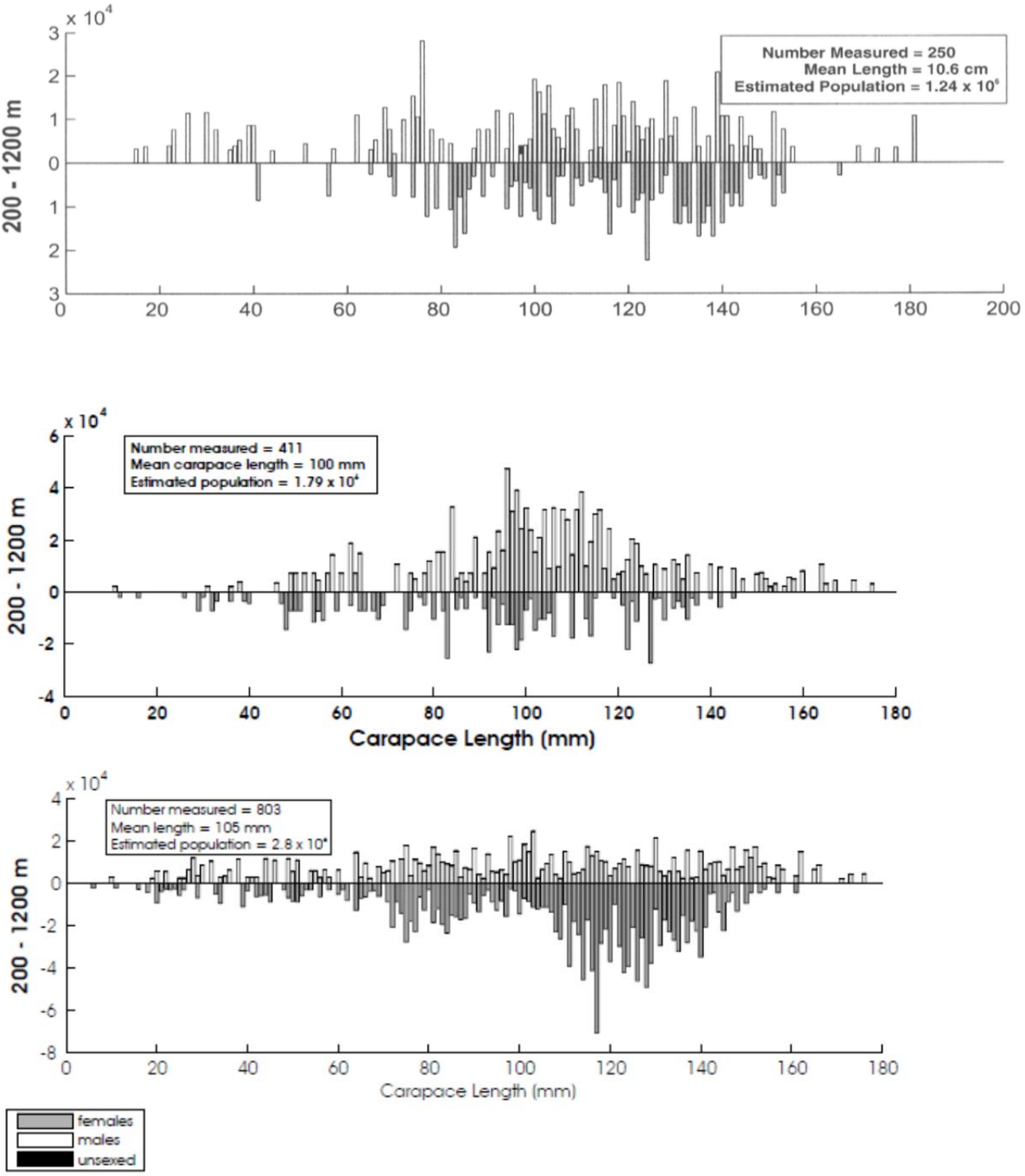

Figure 5. Size distribution of male and female golden king crab captured in all survey subareas and depths fished during the 2004, 2008, and 2010 (bottom panel; from Figure 83 *in* Hoff and Britt 2011) NMFS-ASFC eastern Bering Sea upper continental shelf trawl surveys (not available for the 2002 survey).

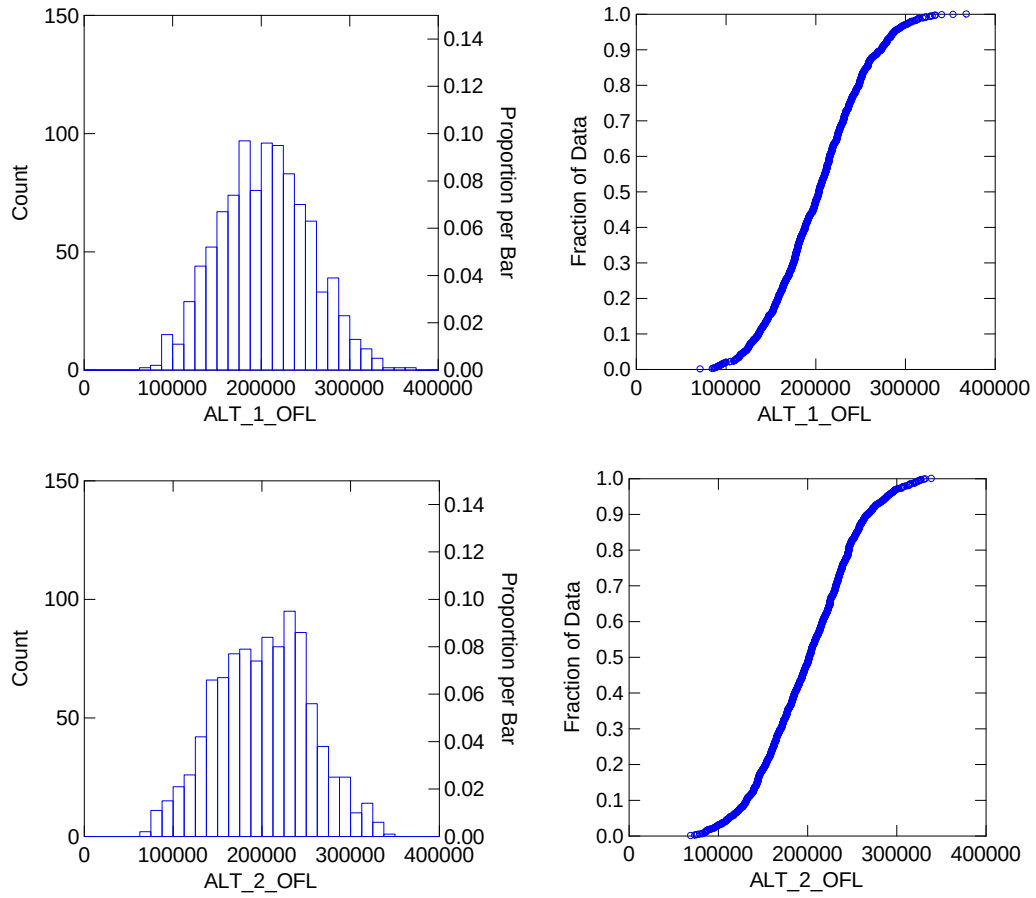

Figure 6. Bootstrapped estimates of the sampling distribution of the Alternative 1 (above), Alternative 2 (bottom) 2013 Tier 5 OFLs (pounds of total catch) for the Pribilof Islands golden king crab stock; histograms in left column, quantile plots in right column.