Pribilof Islands Golden King Crab

– 2016 Tier 5 Assessment

2016 Crab SAFE Report Chapter (September 2016)

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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 domestic fishery developed in 1982/83, although some limited fishing occurred at least as early as 1981/82. Peak retained catch occurred in 1983/84 at 388 t (856,475 lb). The fishing season for this stock has been defined as a calendar year (as opposed to 1-July-to-30-June crab fishing year) after 1983/84. Since then, participation in the fishery has been sporadic and annually retained catch has been variable: from 0 t (0 lb) in the ten years that no vessels participated (1984, 1986, 1990–1992, 2006–2009, and 2015) to 155 t (341,908 lb) 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 91 t (200,000 lb). The GHL was reduced to 68 t (150,000 lb) for 2000–2014 and reduced to 59 t (130,000 lb) in 2015. No vessels participated in the directed fishery and no landings were made during 2006–2009. Catch data from 2003–2005 and 2010–2014 cannot be reported here under the confidentiality requirements of State of Alaska (SOA) statute Sec. 16.05.815. The 2003 and 2004 fisheries were closed by emergency order to manage the fishery retained catch towards the GHL; the 2005 and 2010–2014 fisheries were not closed by emergency order. No vessels participated in the directed fishery during 2015. Discarded (non-retained) catch has occurred in the directed golden king crab fishery and in the eastern Bering Sea snow crab fishery and in the Bering Sea grooved Tanner crab fishery. Estimates of annual total fishery mortality during 2001–2015 due to crab fisheries range from 0 t to 73 t, with an average of 29 t. There was no discarded catch during crab fisheries in 2015. Discarded catch also occurs in Bering Sea groundfish fisheries. Estimates of annual fishery mortality during 1991/92–2015/16 due to groundfish fisheries range from <1 t to 12 t, with an average of 3 t (estimates of annually discarded catch during Bering Sea groundfish fisheries are reported for crab fishing years, rather than for calendar years). Total fishery mortality in groundfish fisheries during the 2015/16 crab fishing year was 1.15 t.

3. **<u>Stock biomass</u>:**

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 from the erstwhile biennial eastern Bering Sea upper continental slope trawl survey performed by NMFS-AFSC in 2002 (Hoff and Britt 2003), 2004 (Hoff and Britt 2005), 2008 (Hoff and Britt 2009), 2010 (Hoff and Britt 2011), and 2012 (Hoff 2013). See Appendices A1–A3 for summaries of the slope survey as they pertain to data on and estimates of Pribilof Island golden king crab stock biomass. Complete data on size-sex composition of survey catch are available only from the 2008–2012 biennial surveys (C. Armistead, NMFS-AFSC, Kodiak). Biomass estimates by sex and size class from the 2008, 2010, and 2012 surveys were presented in a May 2013 (Gaeuman 2013b; Appendix 2) report to the Crab Plan Team and biomass estimates of mature males from the 2008–2012 biennial surveys were presented in a September 2013 (Gaeuman 2013a) report to the Crab Plan Team. Using the size-sex composition data from the 2012 NMFS-AFSC eastern Bering Sea upper continental slope survey, Gaeuman (2013b) estimated total biomass for 2012 to be 1,925 t for the entire survey area and 711 t in the Pribilof Canyon area; Gaeuman (2013a) estimated mature male biomass for 2012 to be 812 t for the entire survey area and 256 t in the Pribilof Canyon area. Pengilly (2015; Appendix A3) estimated total and mature male biomass in the Pribilof District to be 1,444 t and 429 t, respectively, from the 2012 slope survey data.

4. **<u>Recruitment</u>:**

Using the size-sex composition data from the eastern Bering Sea upper continental slope trawl survey (see above), Gaeuman (2013a) estimated mature male biomass in the entire survey area to have increased slightly from 767 t in 2010 to 812 t in 2012, but have decreased in the Pribilof canyon area between those two years 440 t to 256 t. Pengilly (2015; Appendix A3) estimated mature male biomass from the slope survey data to have declined in the Pribilof District from 638 t in 2008 to 565 t in 2010 and to 429 t in 2012.

5. **<u>Management performance</u>:**

No overfished determination (i.e., MSST) has been made for this stock, although approaches to using data from the biennial NMFS-AFSC eastern Bering Sea upper continental slope surveys has been presented to and considered by the Crab Plan Team (Gaeuman 2013a, 2013b, Pengilly 2015; see Appendices A2 and A3). No vessels participated in the 2015 directed fishery (i.e., retained catch= 0 t; 0 lb) and no bycatch was observed in crab fisheries in 2015; therefore total catch in 2015 was zero. Although 1.15 t of fishery mortality occurred during groundfish fisheries in 2015/16, bycatch due to groundfish fisheries is not included in the total catch here because available data are summarized by "crab fishery year" rather than calendar year. Overfishing did not occur in 2015. The GHL for the 2017 has yet to be established (W. Donaldson, ADF&G, Kodiak, *pers. comm.*, 5 April 2016). The 2017 OFL and ABC in the table below are the author's recommendations.

Management Performance Table (values in t)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	68	Conf. [c]	Conf. [c]	90.7	81.6
2014	N/A	N/A	68	Conf. [c]	Conf. [c]	90.7	81.6
2015	N/A	N/A	59	0	0	91	68
2016	N/A	N/A	59			91	68
2017	N/A	N/A				93	70

a. Guideline harvest level, established in lb and converted to t.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data are summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2015/16 groundfish fisheries are ≤12 t, with an average of 3 t.
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.

Management Performance Table (values in lb)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2014	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2015	N/A	N/A	130,000	0	0	0.20[d]	0.15[d]

a. Guideline harvest level.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data are summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2015/16 groundfish fisheries are ≤27,234 lb, with an average of 7,619 lb.

2016	N/A	N/A	130,000			0.20[d]	0.15[d]
2017	N/A	N/A				204,527	153,395

c. Guideline harvest level.
d. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data are summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2014/15 groundfish fisheries are ≤19,480 lb, with an average of 5,101 lb.
e. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.
f. Established in millions of lb to the nearest 0.01-million lb.

6. **Basis for the OFL and ABC:** The values for 2017 are the author's recommendation.

Calendar Year	**Tier**	**Years to define Average catch (OFL)**	**Natural Mortality[b]**	**Buffer**
2013	5	1993–1998[a]	0.18 yr^{-1}	10%
2014	5	1993–1998[a]	0.18 yr^{-1}	10%
2015	5	1993–1998[a]	0.18 yr^{-1}	25%
2016	5	1993–1998[a]	0.18 yr^{-1}	25%
2017	5	1993–1998[a]	0.18 yr^{-1}	25%

a. OFL was for total catch and was determined by the average of the annual retained catch for these years multiplied by 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.
b. 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 recommended Tier 5 OFL was estimated by bootstrapping. The standard deviation of the estimated sampling distribution of the recommended OFL (Alternative 1) is 23 t (CV = 0.25). See section G.1.

8. **Basis for the ABC recommendation:** A 25% buffer on the OFL, the default; i.e., ABC = (1-0.25)·OFL. This is a data-poor stock.

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:** Fishery continues to be managed under authority of an ADF&G commissioner's permit; guideline harvest level (GHL) was reduced from 68 t (150,000 lb) to 59 t (130,000 lb) in 2015 and remained at that level in 2016. The GHL for the 2017 has yet to be established.

2. **Changes to the input data:**
   - Retained catch and discarded catch data have been updated with the results for the 2015 directed fishery, during which no vessels participated, and bycatch in other crab fisheries in 2015, which was zero.
   - Discarded catch estimates from groundfish fisheries have been updated with estimates for the 2015/16 crab fishery season, which resulted in 1.15 t of bycatch mortality.

3. **Changes to the assessment methodology:** This assessment follows the methodology recommended by the CPT since May 2012 and the SSC since June 2012.

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 computation of OFL in this assessment follows the methodology recommended by the CPT in May 2012 and the SSC in June 2012 applied to the same data and estimates with the same assumptions that were used for estimating the 2013–2017 Tier 5 OFLs; computations applied directly to data and estimates expressed in metric units resulted in minor changes in results due to rounding used in previous assessments.

B. Responses to SSC and CPT Comments

- **Responses to the most recent two sets of SSC and CPT comments on assessments in general (and relevant to this assessment):**
  - CPT, May 2015: *None pertaining to a Tier 5 assessment.*
  - SSC, June 2015: "*The SSC appreciates the author's inclusion of standard and metric units in the text but requests consistency in which units are used (e.g., lbs., thousand lbs., or million lbs. and t, mt, or kg). The SSC also requests consistency in the units chosen for tables and figures, requests that the units cited in the table legends match the values in the tables, and suggests authors refer to the terms of reference for chapters.*"
    - Response: The CPT terms of reference (as updated during the January 2016 meeting) were referred to: "*To maintain consistency among SAFEs, the documents should report everything in the document in metric tons. The executive summary and the data used in the harvest strategy should be presented in both metric tons (abbreviated t) and pounds (lb).*" Everything weight-wise is reported here in metric tons. Weights are given in both t and lb for the following: weights in the text of the Management performance section of the Executive Summary;

weights in the Management Performance table; retained catch weights in the Executive Summary; GHLs/TACs throughout the document; retained catch weights when presented relative to GHLs/TACs throughout the document; retained catch weights in section C.4 ("Brief summary of management history); and the results of computation of the recommended 2017 OFL and ABC. Otherwise weights are presented only in t. For consistency in units, weights in the text and in reporting of recommended OFL and ABC are given in whole t for metric units and whole lb for U.S. customary units; in tables of data and estimates, however, some metric weights are given to several decimal places because some non-zero values round to 0 t. Reporting OFL and ABC for 2017 in t and lb may result in inconsistencies in the Management Performance tables and in the text when presenting previous OFLs and ABCs established using different conventions for units.

  - *"Provide single plot of all model data sources and years applicable – **Comment [4]: The Stockhausen tables**."* Done. See Table 4.
- CPT, September 2015 (via September 2014 SAFE Introduction chapter): *None pertaining to a Tier 5 assessment*.
- SSC, October 2015: *None.*

- **Responses to the most recent two sets of SSC and CPT comments specific to the assessment:**
  - CPT, May 2015:
    - "*The CPT recommends the author add a notation to tables specifying whether or not the GHL was reached.*"
      - Response: Done.
    - "*...the document should include a summary of available slope survey data.*"
      - Response: Done (see Appendices A1–A3).
  - SSC, June 2015:
    - "*...supports the CPT recommendation that the author add notation to tables specifying whether or not the GHL was reached.*"
      - Response: Done.
    - "*The SSC also requests that the author approach the harvester(s) regarding whether they would voluntarily allow confidential data to be presented in assessments.*"
      - In progress (M. Westphal, ADF&G, Dutch Harbor, *pers. comm.*, 29 August 2016)
    - "*The SSC supports the CPT recommendation that a preliminary Tier 4 assessment be brought to the September 2015 meeting, using existing slope data and applying a Kalman filter approach.*"
      - Done in September 2015 (see Appendix A3).
    - "*The SSC also asks that a Stock Structure Template be completed for PI GKC.*"
      - Done in September 2015 (see Appendix A3:C of Appendix A3).
    - "*...future versions of the document include a summary of available slope survey data with appropriate graphs and plots...*"
      - Done (see Appendices A1–A3).

- CPT, September 2015:
  - "*The CPT recommends the random effects model be re-evaluated after results from the 2016 slope survey are available.*"
    - Response: Okay. Any update on that?
- SSC, October 2015:
  - *"The SSC concurs with the CPT recommendation"* ["*that the random effects model be re-evaluated after results from the 2016 slope survey are available*"]
    - Response: Okay.

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). Fitch et al. (2014, page 8) 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.

NMFS-AFSC conducted an eastern Bering Sea continental slope trawl survey on a biennial schedule during 2002–2012, the survey scheduled for 2014 was cancelled, and the survey schedule resumed in 2016. Results of the 2002–2012 biennial eastern Bering Sea continental slope trawl surveys 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 (Gaeuman 2013a, 2013b; Haaga et al. 2009; Hoff 2013; Hoff and Britt 2003, 2005, 2009, 2011; Pengilly 2015). Of the six survey subareas (see Figure 1 in Hoff 2013), biomass and abundance of golden king crab were estimated through 2010 to be highest in the Pribilof Canyon area (survey subarea 2). Most of the commercial fishery catch for golden king crab is reported to occur in the Pribilof Canyon area (Fitch et al. 2014; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006). However, biomass was estimated to have decreased between 2010 and

2012 in the Pribilof Canyon area and to have increased between 2010 and 2012 in the survey subarea 1 (the southernmost of the survey subareas), so that biomass in 2012 was estimated to be highest in survey subarea 1. Results from the 2016 survey have yet to be reviewed.

Results of the 2002–2012 biennial NMFS-AFSC eastern Bering Sea continental slope trawl surveys showed that a majority of golden king crab on the eastern Bering Sea continental slope occurred in the 200–400 m and 400–600 m depth ranges (Haaga et al. 2009; Hoff 2013; Hoff and Britt 2003, 2005, 2009, 2011). Commercial fishing for golden king crab in the Bering Sea typically occurs at depths of 100–300 fathoms (183–549 m; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006; Gaeuman 2011, 2013c, 2014; Neufeld and Barnard 2003); average depth of pots fished in the 2002 Pribilof District golden king crab fishery (the most recently prosecuted fishery for which fishery observer data are not confidential) was 214 fathoms (391 m).

3. **Evidence of stock structure:**

Although highest densities of golden king crab are found in the deep canyons of the eastern Bering Sea continental slope, golden king crab occur sporadically on the surveyed slope at locations between those canyons in the eastern Bering Sea (Hoff 2013; Hoff and Britt 2003, 2005, 2009, 2011; Gaeuman 2013b, 2014). Stock structure within the Pribilof District has not been evaluated. Fishery and slope survey data suggest that areas at the northern and southern border of the Pribilof District are largely devoid of golden king crab (Pengilly 2015; Appendix A3), but the stock relationship of the golden king crab within the Pribilof District with the golden king crab outside of the Pribilof District has not been evaluated.

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).

Current knowledge of reproductive biology and maturity of male and female golden king crab is also reviewed by Webb (2014).

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. <u>Brief summary of management history</u>:
A complete summary of the management history through 2011 is provided in Fitch et al. (2014, pages 86–87).

The first domestic harvest of golden king crab in the Pribilof District was in 1981/82 when two vessels fished. Peak retained catch and participation occurred in 1983/84 at a retained catch of 388 t (856,475 lb) landed by 50 vessels (Tables 1a and 1b). Since 1984 the fishery has been managed with a calendar-year fishing season under authority of a commissioner's permit and landings and participation has been low and sporadic. Retained catch since 1984 has ranged from 0 t (0 lb) to 155 t (341,908 lb) and the number of vessels participating annually has ranged from 0 to 8. No vessels fished in 2006–2009 and 2015, 1 vessel fished in each of 2010 and 2012–2014, and 2 vessels fished in 2011.

The fishery is not rationalized and has been managed inseason to a guideline harvest level (GHL) since 1999. The GHL for 1999 was 91 t (200,000 lb), whereas the GHL for 2000–2014 was 68 t (150,000 lb). Following the reduction of ABC from 82 t for 2014 to 68 t for 2015, the GHL was reduced in 2015 to 59 t (130,000 lb).

Catch statistics for 2003–2005 and 2010–2014 are confidential under Sec. 16.05.815 of SOA statutes. It can be noted, however, that the 2003 and 2004 fisheries were closed by emergency order to manage the fishery retained catch towards the GHL, whereas the 2005 and 2010–2014 fisheries were not closed by emergency order. With regard to 2004, "Catch rates during the 2004 fishery were among the highest on record, and the fishery was the shortest ever at approximately three weeks in duration" (Bowers et al. 2005, pages 84–85).

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 take golden king crab in Registration Area Q (Bering Sea) may be longlined (5 AAC 34.925(f)). Pots used to fish for golden king crab in the Pribilof District 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 discarded catch during the 2015 directed fishery (no effort and no catch), estimated discarded catch during other crab fisheries in 2015 (no catch), and the estimated discarded catch in groundfish fisheries during the 2015/16 crab fishery year have been added.

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, 1984–2015 time series of retained catch (number and weight of crab, including deadloss), effort (vessels 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 Tables 1a and 1b.
- The 1993–2015 time series of weight of retained catch and estimated weight of discarded catch and estimated weight of fishery mortality of Pribilof golden king crab during the directed fishery and all other crab fisheries are given in Table 2. Discarded catch 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 when prosecuted. Because the Bering Sea snow crab fishery is largely prosecuted between January and May and the Bering Sea grooved Tanner crab fishery is prosecuted with a calendar year season, discarded catch in the crab fisheries can be estimated on a calendar year basis to align with the calendar-year season for Pribilof District golden king crab. Observer data on size distributions and estimated catch numbers of discarded catch were used to estimate the weight of discarded catch of golden king crab by applying a weight-at-length estimator (see below). Observers were first deployed to collect discarded catch 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 2010−2014. Following Siddeek et al. (2014), 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 (2013), 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 discarded catch data are grouped into crab fishery years, rather than into calendar years. The 1991/92–2015/16 time series of estimated annual weight of discarded catch and total fishery mortality of golden king crab 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 (2013), 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. Data from 1991/92–2008/09 are from federal reporting areas 513, 517, and 521, whereas the data from 2009/10–2015/16 are from the State statistical areas falling within the Pribilof District (see various attachments to 13 August 2015 email from R. Foy, NMFS-AFSC-Kodiak).
- Table 4 summarizes the available data on retained catch weight and the available estimates of discarded catch weight.

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, see Appendices A2-A3 for biomass estimates of mature male golden king crab using data from the 2002–2012 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey.

e. ***Survey catch at length:*** Survey catch at length data are not used in a Tier 5 assessment. However, see Appendices A1–A3 for size data composition by sex of golden king crab during the 2002–2012 Bering Sea upper continental slope trawl surveys.

f. ***Other data time series:*** None.

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 collected from golden king crab in the Pribilof District. 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 golden 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.

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 upper continental slope were performed in 2002, 2004, 2008, 2010, 2012, and 2016 (Hoff and Britt 2003, 2005, 2009, 2011; Haaga et al. 2009, Gaeuman 2013a, b). Data and analysed results pertaining to golden king crab from the 2008–2012 EBS upper continental slope surveys are provided in Appendices A1–A3, but are not used in this Tier 5 assessment. Data from the 2016 survey has yet to be reviewed.
- Data on the size and sex composition of retained catch and discarded catch of Pribilof District golden king crab during the directed fishery and other crab fisheries are available but are not presented in this Tier 5 assessment.

E. Analytic Approach

1. History of modeling approaches for this stock:
Gaeuman (2013a, b) and Pengilly (2015) presented assessment-modelling approaches for this stock to the Crab Plan Team using data from the biennial NMFS EBS continental slope survey Appendices A2 and A3). However, following the cancellation of the 2014 slope survey, this stock continued to be managed as a Tier 5 stock for 2016, as had been recommended by NPFMC (2007) and by the CPT and SSC in 2008−2015.

2. Model Description: *Subsections a–i are not applicable to a Tier 5 sock.*
Only an OFL and ABC is estimated For Tier 5 stocks, where "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 non-target 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 2017.

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 discarded catch 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 District 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 set 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 and the 2013 OFLs, 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.

Two alternative approaches for determination of the 2013 OFL were presented to the CPT and SSC in May–June 2013. Alternative 1 was the status quo approach (i.e., the approach used to establish the 2012 total-catch OFL). Alternative 2 was the same as Alternative 1 except that it used updated discarded catch data from crab fisheries in 2011. Alternative 2 was presented specifically 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. The CPT and the SSC both recommended Alternative 1, clarifying that Tier 5 OFLs for future years should be computed using only data collected through 2010. Following that recommendation from CPT and the SSC, only one alternative was presented for computing the 2014–2016 Tier 5 OFLs (i.e., the Alternative 1 that was presented in 2013). The 2017 Tier 5 OFL recommended here uses the same approach as used for the 2013–2016 Tier 5 OFLs.

3. Model Selection and Evaluation:

a. *Description of alternative model configurations*

The recommended OFL is set as a total-catch OFL using 1993–1998 to compute average annual retained catch, an estimate of the ratio of bycatch mortality to 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.,

$$OFL_{2017} = (1+R_{2001\text{–}2010})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93\text{–}98/99},$$

where,

- $R_{2001–2010}$ is the average of the estimated annual ratio of bycatch mortality to 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 bycatch mortality to retained catch 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 are no data on discarded catch for the directed fishery during 1993–1998, there are 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 are no discarded catch 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 $BM_{GF,93/94\text{-}98/99}$, the calculated value of OFL_{2017} is,

$$OFL_{2017} = (1+0.052)*78.80 \text{ t} + 6.09 \text{ t} + 3.79 \text{ t} = 93 \text{ t (204,527 lbs).}$$

b. ***<u>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</u>:*** See the table, below.

Model	Retained- vs. Total-catch	Time Period	Resulting OFL (t)
Recommended/status quo	Total-catch	1993–1998	93

This is recommended as being the best approach with the limited data available and follows the advice of the CPT and SSC to “freeze” the period for calculation of the OFL at the time period that was established for the 2012 OFL and uses the computations recommended by the CPT and SSC in 2013.

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

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 2012. Retained catch data come from fish tickets and annual retained catch is considered a known (not estimated) value. Estimates of discarded catch from crab fisheries data are generally considered credible (e.g., Byrne and Pengilly 1998, Gaeuman 2011, 2013c, 2014), 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 discarded catch times an assumed bycatch mortality rate. The assumed bycatch mortality rates (i.e., 0.2 for crab fisheries, 0.5 for fixed-gear groundfish fisheries, and 0.8 for trawl groundfish fisheries) 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 2–5.

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 discarded catch due to the directed fishery are available from the period used to compute the OFL. Estimation of the OFL rests on the assumption that data on the ratio of discarded catch to retained catch from post-2000 can be used to accurately estimate that ratio in 1993–1998.
- 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 are 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 same time period that was used to establish OFL for 2010–2016. The time period 1993–1998 provides the longest continuous time period through 2015 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 discarded catch contemporaneous with 1993-1998 to the extent possible are used to calculate the total-catch OFL.

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. <u>Basis for projecting MMB to the time of mating:</u> Not applicable for Tier 5 stock.

c. <u>Specification of F_{OFL}, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:</u> See table below. No vessels participated in the 2015 directed fishery and no bycatch was observed in crab fisheries in 2015; therefore total catch in 2015 was zero. Although 1.15 t of fishery mortality occurred during groundfish fisheries in 2015/16, bycatch due to groundfish fisheries is not included in the total catch here because available data are summarized by "crab fishery year" rather than calendar year. Overfishing did not occur in 2015. Values for the 2017 OFL and ABC are the author's recommendations.

Management Performance Table (values in t)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	68	Conf. [c]	Conf. [c]	90.7	81.6
2014	N/A	N/A	68	Conf. [c]	Conf. [c]	90.7	81.6
2015	N/A	N/A	59	0	0	91	68
2016	N/A	N/A	59			91	68
2017	N/A	N/A				93	70

a. Guideline harvest level, established in lb and converted to t.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data are summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2014/15 groundfish fisheries are ≤9 t, with an average of 2 t.
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.

Management Performance Table (values in lb)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2013	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2014	N/A	N/A	150,000	Conf.[c]	Conf.[c]	0.20[d]	0.18[d]
2015	N/A	N/A	130,000	0	0	0.20[d]	0.15[d]

a. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.
b. Established in millions of lb to the nearest 0.01-million lb.

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 (Table 5).
= 79 t.

Note that a retained catch of 79 t would exceed the author's recommended ABC for 2017 (70 t); see G.4, below.

5. <u>Recommended F_{OFL}, OFL total catch and the retained portion for the coming year</u>: 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. A bootstrap estimates of the sampling distribution (assuming no error in estimation of discarded catch) of the status quo Alternative 1 OFL is shown in Figure 2 (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_{2016}). The mean and CV computed from the 1,000 replicates are 92 t and 0.25, respectively. Note that generated sampling distribution and computed standard deviation are meaningful as measures in the uncertainty of the OFL only if assumptions on the choice of years used to compute the Tier 5 OFL are true (see Sections E.2 and E.4.f).

2. List of variables related to scientific uncertainty.

- Bycatch mortality rate in each fishery that discarded catch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch mortality 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 discarded catch and bycatch mortality for each fishery that discarded catch 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.”
- Stock size in 2017 is unknown.

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

5. **Author recommended ABC.** 25% buffer on OFL; i.e., ABC = (1-0.25)·(93 t) = 70 t (153,395 lb).

H. Rebuilding Analyses

Not applicable; this stock has not been declared overfished.

I. Data Gaps and Research Priorities

Data from the 2008–2012 biennial NMFS-AFSC eastern Bering Sea upper continental slope trawl surveys have been examined for their utility in determining overfishing levels and stock status by Gaeuman (2103a, b) and Pengilly (2015). Cancellation of the survey that was scheduled for 2014 raised uncertainties on the prospects for obtaining fishery-independent survey data on this stock in the future; however, the slope survey was conducted in summer 2016.

J. Literature Cited

Barnard, D. R., and R. Burt. 2004. Alaska Department of Fish and Game summary of the 2002 mandatory shellfish observer program database for the general and CDQ crab fisheries. Alaska Department of Fish and Game, Regional Information Report No. 4K04-27, Kodiak.

Barnard, D. R., and R. Burt. 2006. Alaska Department of Fish and Game summary of the 2005 mandatory shellfish observer program database for the non-rationalized crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 06-36, Anchorage.

Blau, S. F., and D. Pengilly. 1994. Findings from the 1991 Aleutian Islands golden king crab survey in the Dutch Harbor and Adak management areas including analysis of recovered tagged crabs. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-35, Kodiak.

Blau, S. F., L. J. Watson, and I. Vining. 1998. The 1997 Aleutian Islands golden king crab survey. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K98-30, Kodiak.

Bowers, F.B., B. Failor-Rounds, and M.E. Cavin. 2005. Annual management report for the commercial shellfish fisheries of the Bering Sea, 2004. Pages 71–186 *in* Bowers, F.R., K.L. Bush, M. Schwenzfeier, J. Barnhart, M. Bon, M.E. Cavin, S. Coleman, B. Failor-Rounds, K. Milani, and M. Salmon. 2005. Annual management report for the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfish Observer Program, 2004. Alaska Department of Fish and Game, Fishery Management Report No. 05-51, Anchorage.

Burt, R., and D. R. Barnard. 2005. Alaska Department of Fish and Game summary of the 2003 mandatory shellfish observer program database for the general and CDQ fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 05-05, Anchorage.

Burt, R., and D. R. Barnard. 2006. Alaska Department of Fish and Game summary of the 2004 mandatory shellfish observer program database for the general and CDQ fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 06-03, Anchorage.

Byrne, L. C., and D. Pengilly. 1998. Evaluation of CPUE estimates for the 1995 crab fisheries of the Bering Sea and Aleutian Islands based on observer data. Pages 61–74 *in*: Fishery stock assessment models, edited by F. Funk, T.J. Quinn II, J. Heifetz, J.N. Iannelli, J.E. Powers, J.F. Schweigert, P.J. Sullivan, and C.-I Zhang, Alaska Sea Grant College Program Report No. AK-SG-98-01, University of Alaska Fairbanks, 1998.

Fitch H., M. Good, C. Trebesch, E. Aus, J. Shaisnikoff, and K. Herring. 2014. Annual management report for the commercial shellfish fisheries of the Bering Sea, 2011/12. Pages 72–179 *in* Fitch, H., M. Schwenzfeier, B. Baechler, C. Trebesch, M. Salmon, M. Good, E. Aus, C. Cook, E. Evans, E. Henry, L. Wald, J. Shaishnikoff, and K. Herring. 2014. Annual management report for the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfish Observer Program, 2011/12. Alaska Department of Fish and Game, Fishery Management Report No. 14-54, Anchorage.

Foy, R. J., 2013. 2013 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Red King Crab Fisheries of the Bering Sea and Aleutian Islands Regions. *in*:

Stock Assessment and fishery Evaluation report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions: 2013 Crab SAFE. NPFMC, Anchorage, September 2013.

Gaeuman, W. B. 2010. Summary of the 2008/2009 Mandatory Crab Observer Program Database for the Bering Sea/Aleutian Islands commercial crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 10-01, Anchorage.

Gaeuman, W. B. 2011. Summary of the 2010/2011 Mandatory Crab Observer Program Database for the Bering Sea/Aleutian Islands commercial crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 11-73, Anchorage.

Gaeuman, W. B. 2013a. Alternative Pribilof Islands golden king crab stock assessment strategy. Report to the North Pacific Fishery Management Council Bering Sea-Aleutian Island Crab Plan Team, 17–20 September 2013 meeting, Seattle, WA.

Gaeuman, W. B. 2013b. Pribilof Islands golden king crab Tier 4 stock assessment considerations. Report to the North Pacific Fishery Management Council Bering Sea-Aleutian Island Crab Plan Team, 30 April – 3 May 2013 meeting, Anchorage, AK.

Gaeuman, W. B. 2013c. Summary of the 2011/2012 Mandatory Crab Observer Program Database for the Bering Sea/Aleutian Islands commercial crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 13-21, Anchorage.

Gaeuman, W. B. 2014. Summary of the 2013/14 Mandatory Crab Observer Program Database for the Bering Sea/Aleutian Islands commercial crab fisheries. Alaska Department of Fish and Game, Fishery Data Series No. 14-49, Anchorage.

Haaga, J. A., S. Van Sant, and G. R. Hoff. 2009. Crab abundance and depth distribution along the continental slope of the eastern Bering Sea. Poster presented at the 25th Lowell Wakefield Fisheries Symposium (Biology and Management of Exploited Crab Populations under Climate Change), Anchorage, AK, March 2009. Available online at: ftp://ftp.afsc.noaa.gov/posters/pJHaaga01_ebs-crab.pdf

Hiramoto, K. 1985. Overview of the golden king crab, *Lithodes aequispina*, fishery and its fishery biology in the Pacific waters of Central Japan. *in*: Proc. Intl. King Crab Symp., University of Alaska Sea Grant Rpt. 85-12, Fairbanks.

Hiramoto, K., and S. Sato. 1970. Biological and fisheries survey on an anomuran crab, *Lithodes aequispina* Benedict, off Boso Peninsula and Sagami Bay, central Japan. Jpn. J. Ecol. 20:165-170. In Japanese with English summary.

Hoff, G.R. 2013. Results of the 2012 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-258.

Hoff, G.R., and L. Britt. 2003. Results of the 2002 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-141.

Hoff, G.R., and L. Britt. 2005. Results of the 2004 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-156.

Hoff, G.R., and L. Britt. 2009. Results of the 2008 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-197.

Hoff, G.R., and L. Britt. 2011. Results of the 2010 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-224.

Jewett, S. C., Sloan, N. A., and Somerton, D. A. 1985. "Size at sexual maturity and fecundity of the fjord-dwelling golden king crab *Lithodes aequispina* Benedict from northern British Columbia." *Journal of Crustacean Biology*, 5: pp. 377-385.

McBride, J., D. Fraser, and J. Reeves. 1982. Information on the distribution and biology of the golden (brown) king crab in the Bering Sea and Aleutian Islands area. NOAA, NWAFC Proc. Rpt. 92-02.

National Marine Fisheries Service (NMFS). 2004. Bering Sea Aleutian Islands Crab Fisheries Final Environmental Impact Statement. DOC, NOAA, National Marine Fisheries Service, AK Region, P.O. Box 21668, Juneau, AK 99802-1668, August 2004.

Neufeld, G., and D. R. Barnard. 2003. Alaska Department of Fish and Game summary of the 2001 mandatory shellfish observer program database for the general and CDQ fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4K03-2, Kodiak.

North Pacific Fishery Management Council (NPFMC). 2007. Public Review Draft: Environmental Assessment for proposed Amendment 24 to the Fishery Management Plan for Bering Sea and Aleutian Islands King and Tanner Crabs to Revise Overfishing Definitions. 14 November 2007. North Pacific Fishery Management Council, Anchorage.

Nyblade, C.F. 1987. Phylum or subphylum Crustacea, class Malacostraca, order Decopoda, Anomura. *in*: M.F. Strathman (ed.), Reproduction and development of marine invertebrates on the northern Pacific Coast. Univ. Wash. Press, Seattle, pp.441-450.

Otto, R. S., and P. A. Cummiskey. 1985. Observations on the reproductive biology of golden king crab (*Lithodes aequispina*) in the Bering Sea and Aleutian Islands. Pages 123–136 *in* Proceedings of the International King Crab Symposium. University of Alaska Sea Grant Report No. 85-12, Fairbanks.

Paul, A. J., and J. M. Paul. 2000. Changes in chela heights and carapace lengths in male and female golden king crabs *Lithodes aequispinus* after molting in the laboratory. Alaska Fishery Research Bulletin 6: 70–77.

Paul, A. J., and J. M. Paul. 2001a. Growth of juvenile golden king crabs *Lithodes aequispinus* in the laboratory. Alaska Fishery Research Bulletin 8: 135–138.

Paul, A. J., and J. M. Paul. 2001b. The reproductive cycle of golden king crab *Lithodes aequispinus* (Anomura: Lithodidae). Journal of Shellfish Research 20:369–371.

Pengilly, D. 2015. Discussion paper for September 2015 Crab Plan Team meeting: Random effects approach to modelling NMFS EBS slope survey area-swept estimates for Pribilof Islands golden king crab. Report to the North Pacific Fishery Management Council Bering Sea-Aleutian Island Crab Plan Team, 14-17 September 2015 meeting, Seattle, WA.

Shirley, T. C., and S. Zhou . 1997. Lecithotrophic development of the golden king crab *Lithodes aequispinus* (Anomura: Lithodidae). Journal of Crustacean Biology 17:207–216.

Siddeek, M.S.M., J. Zheng, and D. Pengilly. 2014. Aleutian Islands golden king crab (*Lithodes aequispinus*) model-based stock assessment in spring 2015. http://www.npfmc.org/wp-content/PDFdocuments/membership/PlanTeam/Crab/May2015/AIGKC.pdf

Sloan, N.A. 1985. Life history characteristics of fjord-dwelling golden king crabs *Lithodes aequispina*. Mar. Ecol. Prog. Ser. 22:219-228.

Somerton, D.A., and R.S. Otto. 1986. Distribution and reproductive biology of the golden king crab, *Lithodes aequispina*, in the eastern Bering Sea. Fish. Bull. 84:571-584.

Watson, L. J., D. Pengilly, and S. F. Blau. 2002. Growth and molting probability of golden king crabs (*Lithodes aequispinus*) in the eastern Aleutian Islands, Alaska. Pages 169–187 *in* 2002. A. J. Paul, E. G. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Sainte-Marie, T. C. Shirley, and D. Woodby (eds.). Crabs in coldwater regions: Biology, Management, and Economics. University of Alaska Sea Grant, AK-SG-02-01, Fairbanks.

Webb. J. 2014. Reproductive ecology of commercially important Lithodid crabs. Pages 285–314 *in* B.G. Stevens (ed.): King Crabs of the World: Biology and Fisheries Management. CRC Press, Taylor & Francis Group, New York.

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Appendix A2: page 39. EBS slope survey data on Pribilof Islands golden king crab (from Gaeuman May 2013 report to Crab Plan Team: Pribilof Islands golden king crab Tier 4 Stock assessment considerations, April 2013).

Appendix A3: page 43. EBS slope survey data on Pribilof Islands golden king crab and draft Pribilof Island golden king crab stock structure template (from Pengilly September 2015 report to Crab Plan Team).

Table 1a. Commercial fishery history for the Pribilof District golden king crab fishery, 1981/82 through 2015: number of vessels, guideline harvest level (GHL; established in lb, **converted to t**), weight of retained catch (Harvest; **t**), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**kg**) of landed crab.

Fishing/Calendar Year	Vessels	GHL	Harvest[a]	Crab[a]	Pot lifts	CPUE	Average weight
1981/82	2	–	CF	CF	CF	CF	CF
1982/83	10	–	32	15,330	5,252	3	2.1
1983/84	50	–	388	253,162	26,035	10	1.5
1984	0	–	0	0	0	–	–
1985	1	–	CF	CF	CF	CF	CF
1986	0	–	0	0	0	–	–
1987	1	–	CF	CF	CF	CF	CF
1988 - 1989	2	–	CF	CF	CF	CF	CF
1990 - 1992	0	–	0	0	0	–	–
1993	5	–	31	17,643	15,395	1	1.7
1994	3	–	40	21,477	1,845	12	1.9
1995	7	–	155	82,489	9,551	9	1.9
1996	6	–	149	91,947	9,952	9	1.6
1997	7	–	81	43,305	4,673	9	1.9
1998	3	–	16	9,205	1,530	6	1.8
1999	3	91	80	44,098	2,995	15	1.8
2000	7	68	58	29,145	5,450	5	2.0
2001	6	68	66	33,723	4,262	8	2.0
2002	8	68	68	34,860	5,279	6	2.0
2003	3	68	**CF**	**CF**	**CF**	**CF**	**CF**
2004	5	68	**CF**	**CF**	**CF**	**CF**	**CF**
2005	4	68	CF	CF	CF	CF	CF
2006 - 2009	0	68	0	0	0	–	–
2010	1	68	CF	CF	CF	CF	CF
2011	2	68	CF	CF	CF	CF	CF
2012	1	68	CF	CF	CF	CF	CF
2013	1	68	CF	CF	CF	CF	CF
2014	1	68	CF	CF	CF	CF	CF
2015	0	59	0	0	0	–	–

Note: CF: confidential information due to less than three vessels or processors having participated in fishery;

CF: confidential information and fishery was closed by emergency order to manage the harvest to the preseason GHL.

[a] Deadloss included.

Table 1b. Commercial fishery history for the Pribilof District golden king crab fishery, 1981/82 through 2015: number of vessels, guideline harvest level (GHL; **lb**), weight of retained catch (Harvest; **lb**), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**lb**) of landed crab.

Fishing/Calendar Year	Vessels	GHL	Harvest[a]	Crab[a]	Pot lifts	CPUE	Average weight
1981/82	2	–	CF	CF	CF	CF	CF
1982/83	10	–	69,970	15,330	5,252	3	4.6
1983/84	50	–	856,475	253,162	26,035	10	3.4
1984	0	–	0	0	0	–	–
1985	1	–	CF	CF	CF	CF	CF
1986	0	–	0	0	0	–	–
1987	1	–	CF	CF	CF	CF	CF
1988 - 1989	2	–	CF	CF	CF	CF	CF
1990 - 1992	0	–	0	0	0	–	–
1993	5	–	67,458	17,643	15,395	1	3.8
1994	3	–	88,985	21,477	1,845	12	4.1
1995	7	–	341,908	82,489	9,551	9	4.1
1996	6	–	329,009	91,947	9,952	9	3.6
1997	7	–	179,249	43,305	4,673	9	4.1
1998	3	–	35,722	9,205	1,530	6	3.9
1999	3	200,000	177,108	44,098	2,995	15	4.0
2000	7	150,000	127,217	29,145	5,450	5	4.4
2001	6	150,000	145,876	33,723	4,262	8	4.3
2002	8	150,000	150,434	34,860	5,279	6	4.3
2003	3	150,000	**CF**	**CF**	**CF**	**CF**	**CF**
2004	5	150,000	**CF**	**CF**	**CF**	**CF**	**CF**
2005	4	150,000	CF	CF	CF	CF	CF
2006 - 2009	0	150,000	0	0	0	–	–
2010	1	150,000	CF	CF	CF	CF	CF
2011	2	150,000	CF	CF	CF	CF	CF
2012	1	150,000	CF	CF	CF	CF	CF
2013	1	150,000	CF	CF	CF	CF	CF
2014	1	150,000	CF	CF	CF	CF	CF
2015	0	130,000	0	0	0	–	–

Note: CF: confidential information due to less than three vessels or processors having participated in fishery.

CF: confidential information and fishery was closed by emergency order to manage the harvest to the preseason GHL.

[a] Deadloss included.

Table 2. Weight (**t**) of retained catch and estimated discarded catch of Pribilof golden king crab during crab fisheries, 1993–2015, with total fishery mortality (**t**) estimated by applying a bycatch mortality rate of 0.2 to the discarded catch in the directed fishery and a bycatch mortality rate of 0.5 to the discarded catch in the non-directed fisheries.

		Discarded (no mortality rate applied)			
Calendar Year	Retained	Pribilof Islands golden king crab	Bering Sea snow crab	Bering Sea grooved Tanner crab	Total Mortality
1993	30.60	no data	0.00	no data	—
1994	40.36	no data	3.80	1.15	—
1995	155.09	no data	0.63	15.65	—
1996	149.24	no data	0.24	2.34	—
1997	81.31	no data	4.05	no fishing	—
1998	16.20	no data	33.00	no fishing	—
1999	80.33	no data	0.00	confidential	—
2000	57.70	no data	0.00	confidential	—
2001	66.17	17.82	0.00	confidential	confidential
2002	68.24	19.00	1.06	no fishing	72.57
2003	confidential	confidential	0.15	confidential	72.20
2004	confidential	confidential	0.00	confidential	66.93
2005	confidential	confidential	0.00	confidential	29.85
2006	no fishing	no fishing	0.00	0.00	0.00
2007	no fishing	no fishing	0.00	0.00	0.00
2008	no fishing	no fishing	0.00	no fishing	0.00
2009	no fishing	no fishing	0.96	no fishing	0.48
2010	confidential	confidential	0.00	no fishing	confidential
2011	confidential	confidential	0.27	no fishing	confidential
2012	confidential	confidential	0.27	no fishing	confidential
2013	confidential	confidential	0.58	no fishing	confidential
2014	confidential	confidential	0.12	no fishing	confidential
2015	no fishing	no fishing	0.00	no fishing	0.00

Table 3. Estimated annual weight (**t**) of discarded catch of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl), 1991/92–2015/16, with total bycatch mortality (**t**) estimated by assuming bycatch mortality rate = 0.5 for fixed-gear fisheries and bycatch mortality rate = 0.8 for trawl fisheries.

	Discarded catch (no mortality rate applied)			Total
Crab fishing year	Fixed	Trawl	Total	Mortality
1991/92	0.05	6.11	6.16	4.91
1992/93	3.49	8.87	12.35	8.84
1993/94	0.51	9.64	10.14	7.96
1994/95	0.25	3.22	3.47	2.70
1995/96	0.41	1.90	2.31	1.72
1996/97	0.02	0.87	0.89	0.71
1997/98	1.34	0.49	1.83	1.06
1998/99	6.77	0.18	6.95	3.53
1999/00	4.79	0.65	5.43	2.91
2000/01	1.63	1.88	3.50	2.31
2001/02	1.50	0.36	1.85	1.03
2002/03	0.55	0.21	0.77	0.45
2003/04	0.23	0.18	0.41	0.26
2004/05	0.16	0.39	0.55	0.39
2005/06	0.09	0.06	0.15	0.09
2006/07	1.32	0.12	1.44	0.75
2007/08	8.47	0.16	8.63	4.36
2008/09	3.99	1.56	5.55	3.24
2009/10	2.40	1.17	3.57	2.14
2010/11	0.65	0.94	1.59	1.08
2011/12	0.73	1.13	1.87	1.27
2012/13	0.70	0.87	1.58	1.05
2013/14	0.46	2.73	3.19	2.42
2014/15	0.31	0.23	0.54	0.34
2015/16	0.66	1.02	1.68	1.15
Average	1.66	1.80	3.46	2.27

Table 4. Retained-catch weights (**t**) and estimates of discarded catch weights (**t**) of Pribilof Islands golden king crab available for a Tier 5 assessment; shaded, bold values are used in computation of the recommended (status quo Alternative 1) Tier 5 OFL.

		Retained catch weight	Discarded catch weight (estimated)			
		Fish tickets	Observer data: lengths, catch per sampled pot		Blend method; Catch Accounting System	
Calendar Year[a]	Crab Fishing Year[b]	Directed fishery	Directed fishery	Non-directed crab fisheries	Fixed gear, groundfish	Trawl gear, groundfish
	1981/82	Confidential				
	1982/83	31.74				
	1983/84	388.49				
1984	1984/85	0.00				
1985	1985/86	Confidential				
1986	1986/87	0.00				
1987	1987/88	Confidential				
1988	1988/89	Confidential				
1989	1989/90	Confidential				
1990	1990/91	0.00				
1991	1991/92	0.00			0.05	6.11
1992	1992/93	0.00			**3.49**	**8.87**
1993	1993/94	**30.60**			**0.51**	**9.64**
1994	1994/95	**40.36**		**4.95**	**0.25**	**3.22**
1995	1995/96	**155.09**		**16.28**	**0.41**	**1.90**
1996	1996/97	**149.24**		**2.58**	**0.02**	**0.87**
1997	1997/98	**81.31**		**4.05**	**1.34**	**0.49**
1998	1998/99	**16.20**		**33.00**	**6.77**	**0.18**
1999	1999/00	80.33		Confidential	4.79	0.65
2000	2000/01	57.70		Confidential	1.63	1.88
2001	2001/02	**66.17**	**17.20**	Confidential	1.50	0.36
2002	2002/03	**68.24**	**19.00**	1.06	0.55	0.21
2003	2003/04	**Confidential**	**Confidential**	Confidential	0.23	0.18
2004	2004/05	**Confidential**	**Confidential**	Confidential	0.16	0.39
2005	2005/06	**Confidential**	**Confidential**	Confidential	0.09	0.06
2006	2006/07	0.00	0.00	0.00	1.32	0.12
2007	2007/08	0.00	0.00	0.00	8.47	0.16
2008	2008/09	0.00	0.00	0.00	3.99	1.56
2009	2009/10	0.00	0.96	0.96	2.40	1.17
2010	2010/11	**Confidential**	**Confidential**	0.00	0.65	0.94
2011	2011/12	Confidential	Confidential	0.27	0.73	1.13
2012	2012/13	Confidential	Confidential	0.27	0.70	0.87
2013	2013/14	Confidential	Confidential	0.58	0.46	2.73
2014	2014/15	Confidential	Confidential	0.12	0.31	0.23
2015	2015/16	0.00	0.00	0.00	0.66	1.02

a. Year convention for retained weights in directed fishery, 1984-2015, and estimates of discarded bycatch weights in directed, non-directed crab fisheries.
b. Year convention for retained weights in directed fishery, 1981/82-1983/84, and estimates of discarded bycatch rates in groundfish fisheries.

Table 5. Data for calculation of $RET_{1993\text{-}1998}$ (**t**) and estimates used in calculation of $R_{2001\text{-}2010}$ (ratio, t:t), $BM_{NC,1994\text{-}1998}$ (**t**), and $BM_{GF,92/93\text{-}98/99}$ (**t**) for calculation of the recommended (status quo Alternative 1) Pribilof Islands golden king crab Tier 5 2017 OFL (**t**); 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 discarded catch 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 discarded catch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93\text{-}98/99}$ are from Table 3.

Calendar Year[a]	Crab Fishing Year[b]	$RET_{1993\text{-}1998}$	$R_{2001\text{-}2010}$	$BM_{NC,1994\text{-}1998}$	$BM_{GF,92/93\text{-}98/99}$
1993	1992/93	30.60			8.84
1994	1993/94	40.36		2.48	7.96
1995	1994/95	155.09		8.14	2.70
1996	1995/96	149.24		1.29	1.72
1997	1996/97	81.31		2.03	0.71
1998	1997/98	16.20		16.50	1.06
1999	1998/99				3.53
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	78.80	0.052	6.09	3.79
	S.E.M	24.84	0.004	2.87	1.25
	CV	0.32	0.07	0.47	0.33

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

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

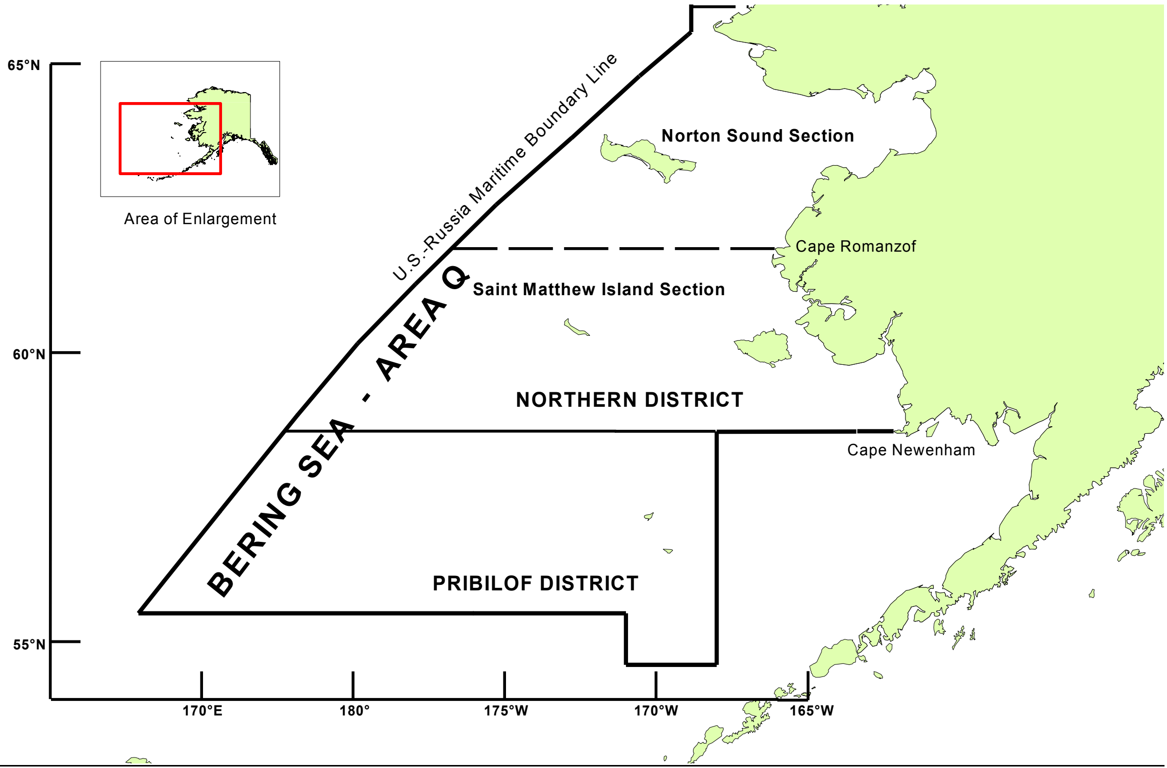

Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Fitch et al. 2014).

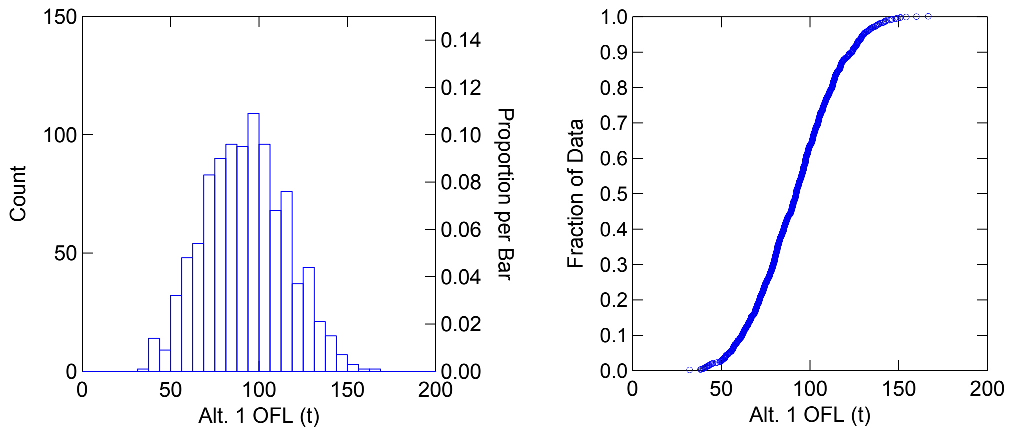

Figure 2. Bootstrapped estimates of the sampling distribution of the 2017 Alternative 1 Tier 5 OFL (total catch, t) for the Pribilof Islands golden king crab stock; histogram on left, quantile plot on right.

Appendix A1. EBS slope survey data on Pribilof Islands golden king crab (from Pengilly 2012, 2012 SAFE chapter).

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.

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.

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.

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.

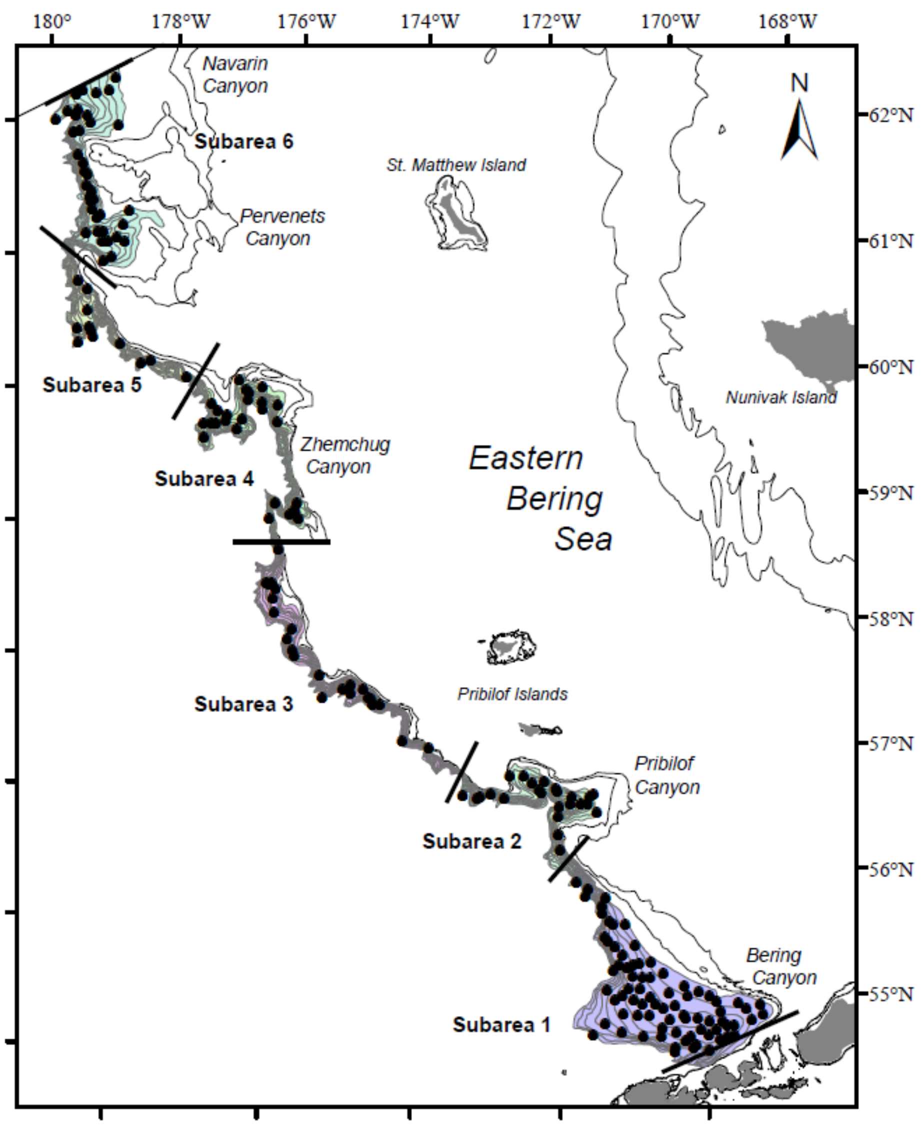

Figure 2. Map of standard survey area for NMFS-AFSC eastern Bering Sea upper continental slope trawl survey with survey subareas identified; black dots show locations of successful tows during the 2010 survey (from Figure 1 *in* Hoff and Britt 2011).

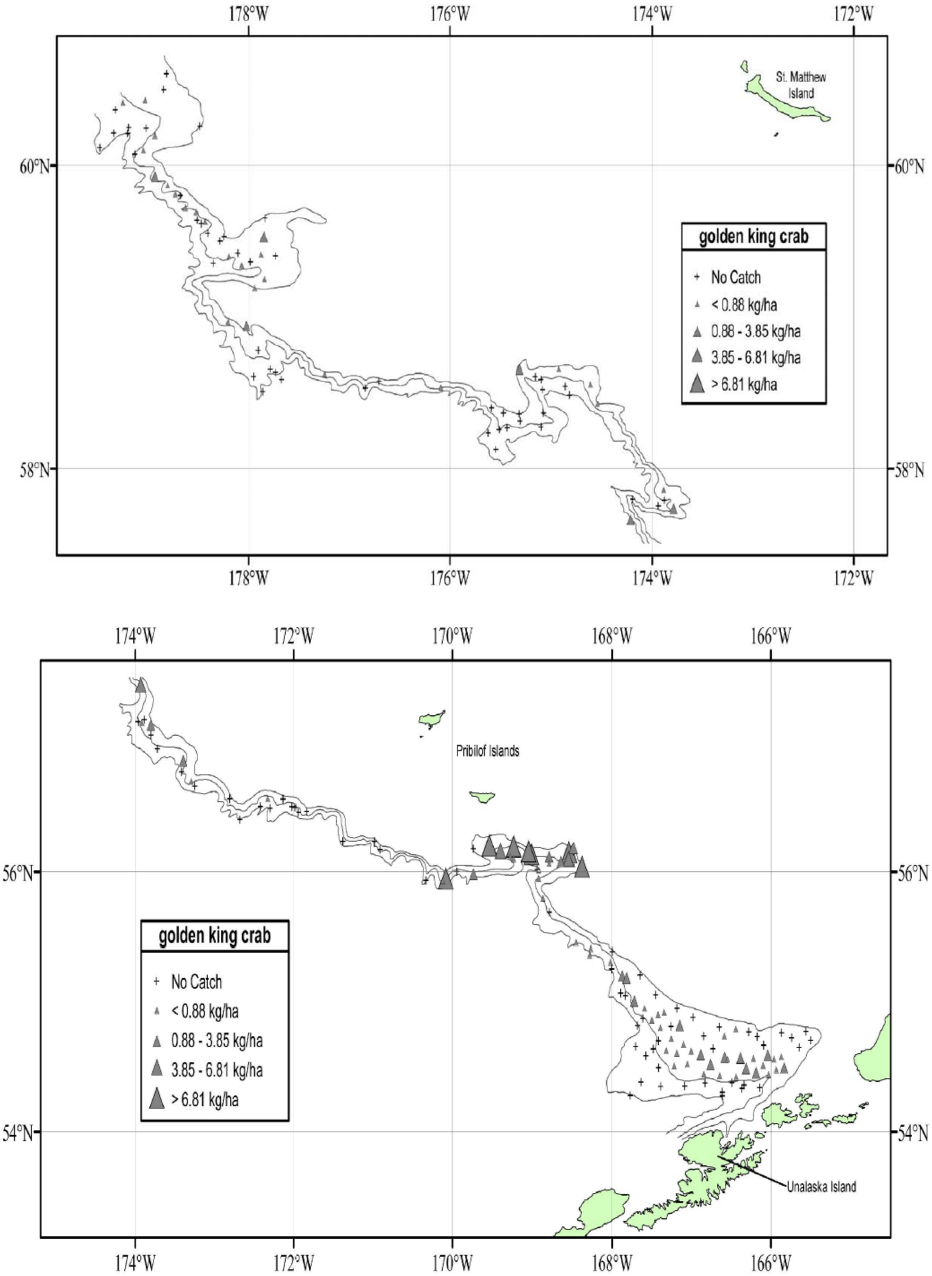

Figure 3. Distribution and relative abundance of golden king crab from the 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey. Relative abundance is categorized by no catch, sample CPUE less than the mean CPUE, between the mean CPUE and two standard deviations above the mean CPUE,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

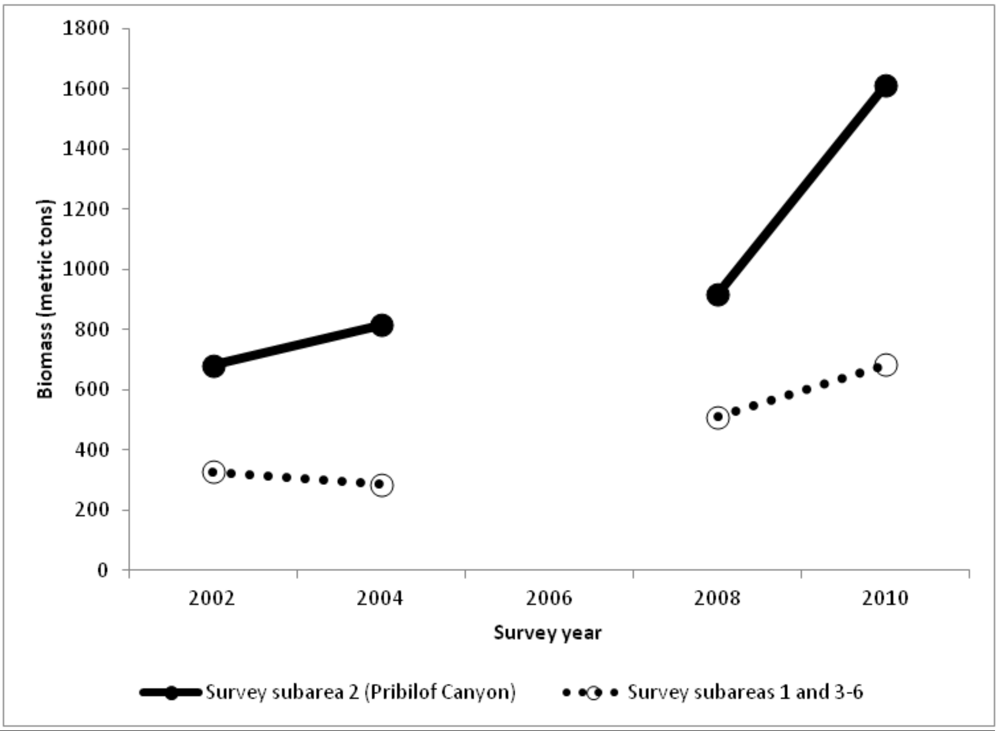

Figure 4. Biomass estimates (all sexes and sizes) for the Pribilof Canyon survey subarea and the aggregated remaining survey subareas (see Figure 2) from the biennial eastern Bering Sea upper continental slope surveys that were performed during 2002–2010.

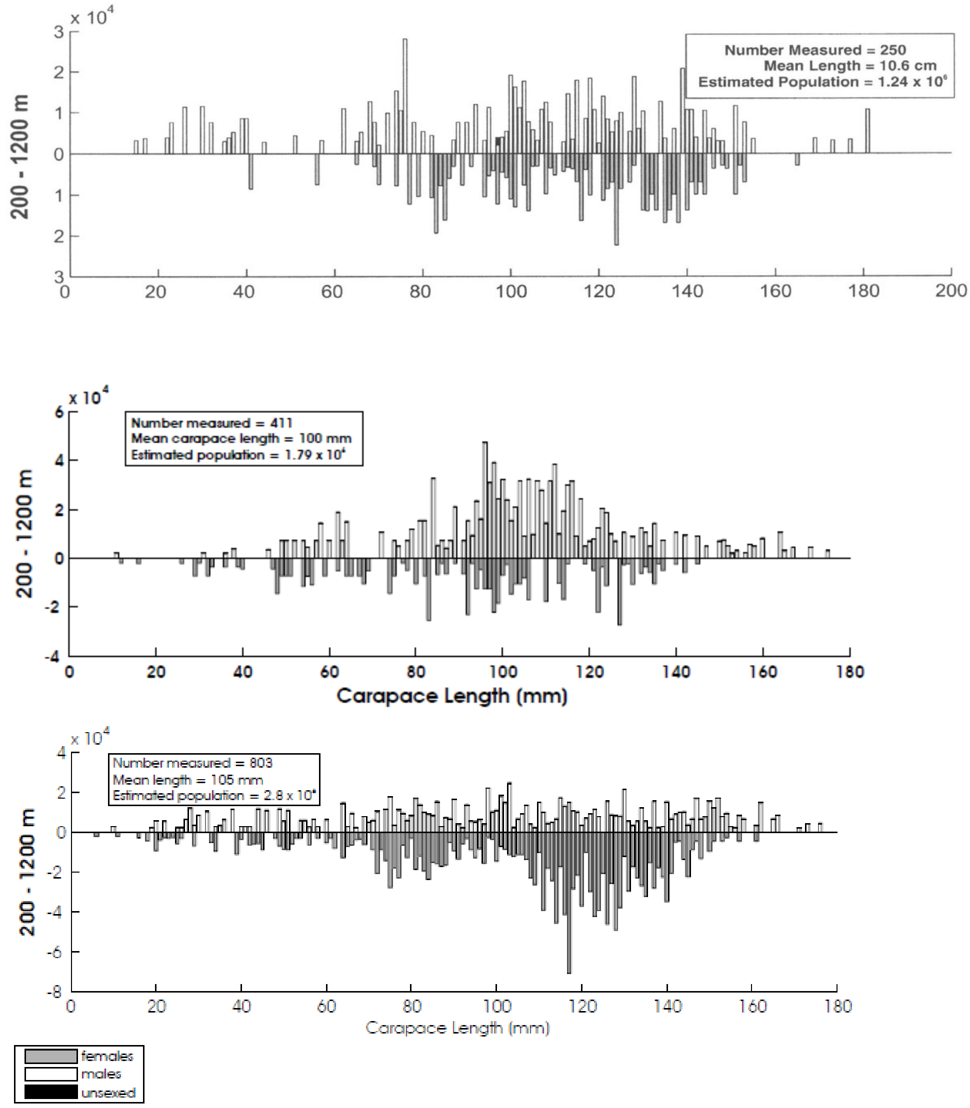

Figure 5. Size distribution of male and female golden king crab captured in all survey subareas and depths fished during the 2004, 2008, and 2010 (bottom panel; from Figure 83 *in* Hoff and Britt 2011) NMFS-ASFC eastern Bering Sea upper continental shelf trawl surveys (not available for the 2002 survey).

Appendix A2. EBS slope survey data on Pribilof Islands golden king crab (from Gaeuman May 2013 report to Crab Plan Team: Pribilof Islands golden king crab Tier 4 Stock assessment considerations, April 2013).

The EBS upper continental slope survey

Details on the EBS continental slope survey methods are provided in Hoff and Britt (2011). Standardized surveys have been conducted in 2002, 2004, 2008, 2010, and 2012; although intended to be biennial, no survey was performed in 2006. The survey occurs during June–July and the surveyed region consists of a swath of (trawlable[1]) ocean bottom at depths of 200–1,200 m extending northwest from near Dutch Harbor some 600 mi along the EBS continental slope (Figure 1). The survey area is divided into 6 geographic subareas running north-to-south in the survey area: Bering Canyon area, Pribilof Canyon area, the inter-canyon area between Pribilof Canyon and Zhemchug Canyon, the Zhemchug Canyon area, the inter-canyon area between Zhemchug and Pervenets Canyon, and the Pervenets and Navarin Canyons area. The subareas are partitioned into five 200-m depth zones, from 200 to 1,200 m. The survey samples approximately 200 locations by stratified simple random sampling from the 30 area-by-depth-zone strata. In 2010 sampling densities within strata ranged from one haul per 112.39 km^2 to one haul per 368.96 km^2 (survey tow sampling is denser at depths < 800 m), and the mean sampling density over the total surveyed area of 32,723 km^2 was one haul per 204.48 km^2. 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. The survey uses a Poly Nor' eastern high-opening bottom trawl equipped with mud-sweep roller gear; the mudsweep roller gear was constructed of 203 mm solid rubber disks strung over 16 mm high-tensile chain. The standard tow is 30 minutes at 2.5 knots.

Limited biennial data series. The set of available EBS slope-survey results useful for such an assessment consists only of those for 2008, 2010, and 2012, resulting in an extremely limited time series of abundance and biomass estimates by which to understand stock history and dynamics and to use in formulating credible management quantities. Length measurements on individual crab were not recorded during the first survey in 2002 (Claire Armistead, NMFS-AFSC Kodiak Laboratory, 18 March 2013 email) and incompletely so in 2004 (250 of 321 captured GKC in successful tows; Hoff and Britt 2005), precluding necessary Tier-4 sex-by-size-class estimates for those surveys, and no EBS slope survey was conducted in 2006. Moreover, how the mud-sweep roller gear used in the survey affects survey selectivity by size or sex is unknown, as is how such selectivity compares with that realized by the continental shelf survey gear, which does not use mud-sweep roller gear.

Determination of stock boundaries for assessment. The boundaries of the PIGKC fishery are defined by the boundaries of the Pribilof District of Registration Area Q and, within that area, the fishery has occurred mostly in the Pribilof Canyon area to the south of the Pribilof Islands (Figure 1). By contrast, the surveyed area extends north into the Northern District of Registration Area Q (north of 58° 39' N) and south into the Aleutian Islands Registration Area O (south of 54° 36' N). Though a large proportion of the GKC encountered in the slope survey are caught in the Pribilof Canyon area, some GKC crab are captured sporadically throughout the surveyed area (Hoff and Britt 2003, 2005, 2009, 2011), and a Northern District GKC fishery has been successfully prosecuted historically, mostly to the west of St. Matthew Island in the area of the northern-most extent of the slope survey, with a peak harvest of

[1] A site was considered trawlable "when the depth changed less than 50 m over the 2-nmi transect and there were no detectable obstacles in the trawl path." (Hoff and Britt 2011, p.4)

414,000 lb in 1987 (Fitch et al. 2012). All of this serves to underscore the fact that the PIGKC "stock" is, like some other fisheries stocks, an artificial construct, depending for its existence on the reification of administrative boundaries rather than on biological reality. It is thus inherently unclear how slope-survey results should be used for its assessment.

Biomass estimates and other results from the 2012, 2010, and 2008 surveys

Estimates of mature male biomass necessary for the sketched Tier-4 assessment, along with estimates of mature male abundance and legal male, total male and total female biomass and abundance, were calculated by the author from 2012, 2010 and 2008 NMFS-AFSC EBS slope-survey data supplied by the NMFS-AFSC Kodiak Laboratory. All estimates were calculated for both the full survey area (Table 3) and for the Pribilof Canyon subarea of the survey region (Table 4) assuming the survey's stratified simple-random-sample design (Hoff and Britt 2011). Survey-recorded CL measurements of individual crab (Figure 4) were used to delineate sex-by-size classes and to model individual crab weights in class biomass estimation. In a few instances (5 of 416 captured crab in 2008 and 1 of 427 in 2012) missing CL measurements were imputed by averaging over recorded CL measurements within the same haul and sex; sex had also to be imputed for the 1 unsized animal in the 2012 dataset. By contrast, Hoff and Britt (2011, 2009, 2005, 2003) report only total (all sizes and both sexes combined) GKC abundance and biomass estimates based on haul total-catch numbers and weights (G.R. Hoff, NMFS-AFSC Seattle, 13 Mar 2013 email) from the 2002, 2004, 2008 and 2010 slope surveys (Table 5). Some discrepancies between the comparable sets of estimates are evident. So far as the author is aware, 2012 slope-survey results have yet to be reported.

Table 3: EBS slope-survey estimates of golden king crab abundance and biomass for the full survey region.

year	Abundance (1000s) and CV							
	female		male		mature male		legal male	
2012	1,282	0.33	1,061	0.21	540	0.24	378	0.28
2010	1,743	0.26	1,083	0.14	508	0.16	348	0.17
2008	748	0.25	1,187	0.26	593	0.30	257	0.22
	Biomass (1000 lb) and CV							
	female		male		mature male		legal male	
2012	2,120	0.43	2,124	0.24	1,791	0.26	1,478	0.28
2010	2,812	0.33	2,042	0.15	1,692	0.17	1,384	0.18
2008	943	0.25	2,173	0.26	1,624	0.25	997	0.22

Table 4: EBS slope-survey estimates of golden king crab abundance and biomass for the Pribilof Canyon subarea.

year	Abundance (1000s) and CV							
	female		male		mature male		legal male	
2012	592	0.53	360	0.42	174	0.32	113	0.36
2010	1,295	0.34	633	0.20	288	0.24	185	0.25
2008	395	0.43	908	0.34	403	0.43	167	0.29
	Biomass (1000 lb) and CV							
	female		male		mature male		legal male	
2012	866	0.54	701	0.34	565	0.32	456	0.34
2010	2,219	0.41	1,200	0.22	970	0.24	770	0.25
2008	340	0.54	1,546	0.36	1,080	0.36	648	0.29

Table 5: Hoff and Britt (2011, 2009, 2005, 2003) reported EBS slope-survey estimates of total (all sizes and both sexes combined) golden king crab abundance and biomass.

	Full survey region		Pribilof Canyon subarea	
year	Abundance (1000s)	Biomass (1000 lb)	Abundance (1000s)	Biomass (1000 lb)
2012	NA[a]	NA[a]	NA[a]	NA[a]
2010	2,830	5,070	1,930	3,560
2008	1,860	3,150	1,300	2,030
2004	1,240	2,430	862	1,800
2002	1,800	2,230	1,300	1,500

[a] Not yet available.

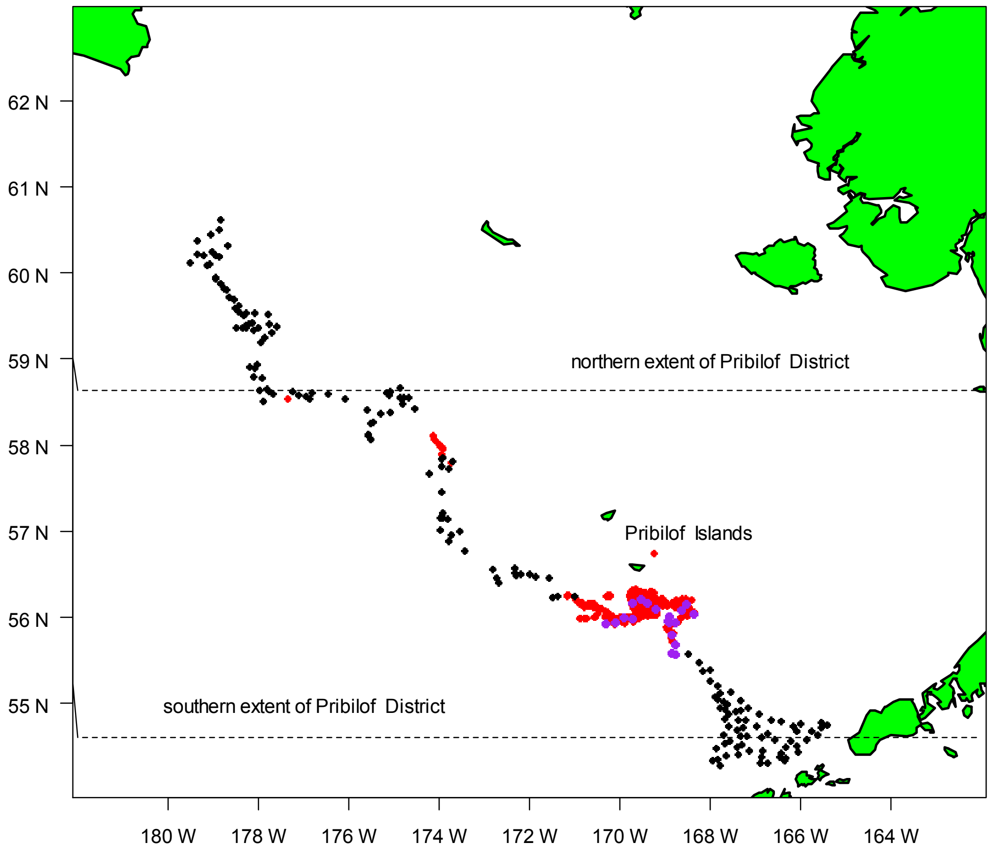

Figure 1. Locations of observer-sampled pots (red) from the 2001–2005 and 2010–2012 PIGKC fisheries and of the 189 tows of the 2012 EBS slope-survey (black/purple) used to construct abundance and biomass estimates. Locations of the 19 tows in the Pribilof Canyon subarea are colored purple.

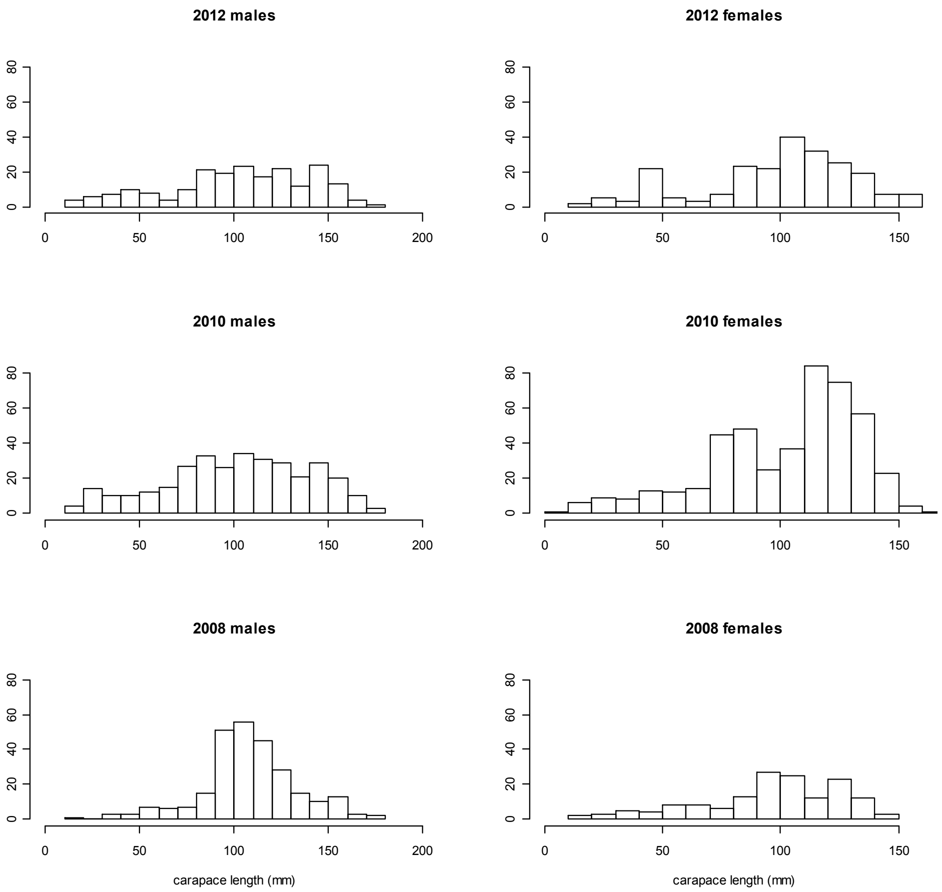

Figure 4: Size-frequency distributions of male (left panels) and female (right panels) GKC captured in the 2012 (189 tows; 427 crab), 2010 (200 tows; 790 crab) and 2008 (200 tows; 416 crab) EBS slope surveys.

Appendix A3. EBS slope survey data on Pribilof Islands golden king crab and draft Pribilof Island golden king crab stock structure template (from Pengilly September 2015 report to Crab Plan Team).

Discussion paper for September 2015 Crab Plan Team meeting:
Random effects approach to modeling NMFS EBS slope survey area-swept biomass estimates for Pribilof Islands golden king crab.

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Introduction.

The Pribilof Islands golden king crab stock has been defined by the geographic borders of the Pribilof District (Figure 1) and has been managed as a Tier 5 stock (i.e., no reliable estimates of biomass and only historical catch data available) for determination of federal overfishing limits and annual catch limits (Pengilly 2014). Since 2011, the Council's Crab Plan Team (CPT) and the Scientific and Statistical Committee (SSC) have expressed interest in utilizing data collected during NMFS eastern Bering Sea (EBS) upper continental slope surveys (Hoff 2013) to establish an annual overfishing limit (OFL) and acceptable biological catch (ABC) on the basis of biomass estimates as an alternative to the standard Tier 5 historical-catch approach (see: reports of the June 2011, June 2012, June 2013, and October 2013 SSC meetings; reports of the May 2013 and September 2013 CPT meetings). Reviews of the EBS slope survey relative to the data collected on golden king crab, summaries of those data, and area-swept biomass estimates (Pengilly 2012, Gaeuman 2013a, 2013b), a Tier 4 approach to establishing OFL and ABC (Gaeuman 2013b), and "modified Tier 5" approach to establishing OFL and ABC (Gaeuman 2013a) have been presented to the CPT and SSC. Cancellation of the EBS biennial slope survey scheduled for 2014 precluded application of Gaeuman's (2013a) approach to establishment of OFL and ABC (see: report of the May 2015 CPT meeting; report of the June 2015 SSC meeting).

In May 2105 the CPT recommended that, "*a preliminary Tier 4 assessment be brought to the September 2015 meeting using available slope survey data and applying a Kalman filter approach (e.g., the program developed by Jim Ianelli for groundfish stock assessments)*" (report of May 2015 CPT meeting). In June 2015, the SSC supported "*the CPT recommendation that a preliminary Tier 4 assessment be brought to the September 2015 meeting, using existing slope data and applying a Kalman filter approach*" (report of the June 2015 SSC meeting). The SSC also requested that the assessment include "*a discussion … of what stock delineation was chosen (what slope data were used) and the reason for that delineation,*" and that "*a Stock Structure Template be completed for PI GKC*" (report of the June 2015 SSC meeting).

This report provides: results of applying the program developed for groundfish stock assessments to the slope survey area-swept biomass estimates of golden king crab; a discussion of the stock delineation chosen (what slope data were used and why); and a Stock

Structure Template for Pribilof Islands golden king crab (Appendix C) that was prepared with the guidance of Spencer et al. (2010).

This report does not provide a Tier 4 assessment, however (i.e., no OFLs or ABCs are computed from the results of this exercise). Prior to computation of an OFL or ABC, the author would like to review the biomass estimates with the CPT so that the CPT can evaluate the results relative to the Tier 4 and Tier 5 criteria (i.e., Do the biomass estimates meet the "reliability" criterion for removing the stock from Tier 5? Do the results meet the Tier 4 criterion of having sufficient information for simulation modeling that captures the essential population dynamics of the stock?). Additionally, the term "Tier 4 assessment" in application to this stock since 2013 has lost its clarity, making it unclear if the requested assessment was to be made according to Tier 4 as defined in the FMP, according to the "modified Tier 5" approach of Gaeuman (2014a), or according to some modification to a Tier 4 assessment. Dependent on the evaluation of results and after clarification of the assessment approach, the computations of OFL and ABC can be performed with the results presented here.

The NMFS EBS slope survey.

Only data from NMFS EBS slope trawl surveys performed in 2002 and later are used here. Although 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), Hoff and Britt (2011) noted that, "Comparisons between the post-2000 surveys and those conducted from 1979–1991 remain confounded due to differences in sampling gear, survey design, sampling methodology, and species identification." Starting in 2002, the slope survey was nominally a biennial survey, but no survey was performed in 2006 and no survey has been performed since 2012. Details on the methods and survey gear used in the 2002, 2004, 2008, 2010, and 2012 NMFS EBS slope surveys are provided in Hoff and Britt (2003, 2005, 2009, 2011) and Hoff (2013), respectively. Those methods and the applicability of the slope survey data to golden king crab abundance and biomass estimation have also been summarized by Pengilly (2012) and Gaeuman (2013a,b).

Briefly, the survey samples from an area of 32,723 km^2 in the 200-1,200 m depth zone. The surveyed area is divided into six subareas (Figure 1). Each subarea is divided into strata defined by 200 m depth zones and tows are performed at randomly-selected locations within each stratum, with target sampling density within strata proportional to the area in each subarea and stratum. Number of stations towed per survey ranged from 156 in 2002 to 231 in 2004; mean sampling density within strata ranged from approximately one tow per 162 km^2 in 2004 to approximately one tow per 255 km^2 in 2002. With regard to survey catchability of golden king crab by size and sex, the survey uses a Poly Nor' eastern high-opening bottom trawl equipped with mud-sweeper roller gear and the opinion of ASFC scientists was conveyed to the CPT during the May meeting that, with respect to golden king crab, "… the catchability of the slope net is less than 1.0 and probably considerably lower than the shelf net due to the differences in the foot rope and surveyed habitat" (report of the May 2013 CPT meeting).

Methods.

Data available by survey. Data on golden king crab that are available from the 2002, 2004, 2006, 2008, 20010, and 2012 NMFS EBS slope surveys are summarized in Table 1.

Although the CPT and SSC both suggested that NMFS would "*provide the author with slope survey CPUE data based on State statistical areas or other stratification instead of the entire slope survey area because the entire survey extends beyond the Pribilof management area*" (reports of the May 2015 CPT meeting and June 2015 SSC meeting), the author did not find it necessary or useful for this exercise to receive the data stratified by State statistical area or by any other stratification besides that defined by the survey design.

Data summarization: area-swept biomass estimates. Area-swept estimates of total (male and female, all sizes) biomass and variances of estimates within strata within survey subarea for 2002, 2004, 2008, 2010, and 2012 were obtained directly from the tables presented in Hoff and Britt (2003, 2005, 2009, 2011) and Hoff (2013). For area-swept biomass estimation of mature males and legal males from the 2008, 2010, and 2012 survey data, 107 mm CL was used as a proxy for size at maturity (Somerton and Otto 1986) and 124 mm CL was used as a proxy for the 5.5 in carapace width (including spines) legal size (NPFMC 2007); weight of males was estimated from the CL measured during the survey by weight (g) = $(0.0002988)\text{x}(CL)^{3.135}$ (NPFMC 2007). An area-swept estimate of biomass and of the variance of the biomass estimate was computed for each stratum within a survey subarea and summed over strata within the subarea to obtain area-swept estimates of biomass within a subarea and of the variance of that biomass estimate; estimates of the biomass and of variances of estimates within subareas were summed over subareas to obtain estimates of biomass in aggregates of subareas and of the variances of those estimates.

Model estimates of biomass and projections to 2016.[2] The program "re.exe" was used to estimate biomass from the area-swept estimates in surveyed years and to project biomass estimates for unsurveyed years into 2016 via a state-space random walk plus noise model. The state-space random walk plus noise is formulated as a random effect model. The random effects model considers the process errors as "random effects" (i.e., drawn from an underlying distribution) and integrated out of the likelihood. The method was developed by the NPFMC groundfish plan team's survey averaging working group as a smoothing technique similar to the Kalman Filter, but which provides more flexibility with non-linear processes and non-normal error structures.

Stock delineation chosen (what slope data were used). The author followed the guidance provided by the SSC in June 2013 (report of the June 2013 SSC meeting):

> "*Because the stock structure is unknown, the SSC recommends that the authors examine maps of catch-per-unit-effort by survey year to identify natural breaks in the spatial distribution of golden king crab along the slope. If no obvious breaks exist, the SSC recommends that the authors bring forward biomass estimates for the Pribilof canyon region and for the slope as a whole. However, we note that the Pribilof Canyon stations do not encompass the historical catches, which occurred inside and to the north of Pribilof Canyon. Therefore, the authors should consider a biomass estimate for an area that encompasses the majority of historical catches*."

[2] The author acknowledges help from Martin Dorn, Jim Ianelli, and Paul Spencer, AFSC, in getting this paragraph completed.

Figures 2–6 show CPUE (kg/km^2) of golden king crab (males and females, all sizes) by tow and survey subarea during the 2002, 2004, 2008, 2010, and 2012 NMFS EBS slope surveys relative to the boundaries of the Pribilof District. Highest survey CPUE occurs at tows within survey subareas 2–4 (particularly in subarea 2; i.e., Pribilof Canyon). Tows performed in the portion of subarea 5 that lie within the Pribilof District have produced little or no catch of golden king crab, indicating a gap in golden king crab distribution between subarea 4 and the portion of the surveyed area north of the Pribilof District boundary (i.e., the portion of subarea 5 that is north of the Pribilof District boundary and all of subarea 6). Tows performed in subarea 1 that are within the Pribilof District have produced little or no catch of golden king crab, indicating a gap in distribution between Pribilof Canyon and the area east of the Pribilof District within subarea 1. It appears that the areas of subareas 1 and 5 that lie within the Pribilof District support limited densities of golden king crab. Subarea 3 appears to support only low-to-moderate densities of golden king crab relative to subarea 4 and – especially – subarea 2; tows with catch of golden king crab occurred sporadically within subarea 3, with highest densities occurring near the border of subarea 4 in 2010 and 2012 and near the border of subarea 2 in 2002.

Figure 7 shows the distribution of all 6,104 pot lifts sampled by observers with locations recorded during 1992–2014 Bering Sea golden king crab fisheries (including the Saint Matthew section of the Northern District, which is north of the Pribilof District) relative to the borders of the Pribilof District and of the survey subareas. Only one of those locations is within the portion of subarea 5 that is within the Pribilof District, none are within the portion of subarea 1 that is within the Pribilof District, and none are within subarea 3.

Figure 8 shows the 26 statistical areas with reported catch during the 1985–2014 Pribilof District golden king crab fisheries relative to the borders of the Pribilof District and of the survey subareas: one (accounting for 0.7% of the 1985–2014 total catch) lies largely in subarea 4, but extends into subarea 5; four (2.9% of the total catch) include portions of subarea 4; six (1.5% of total catch) include portions of subarea 3; one (8.9% of total catch) includes portions of subareas 3 and 2; four (83.9% of total catch) are in or extend into subarea 2; one (0.7% of total catch) includes portions of subareas 2 and 1; one (<0.1% of total catch) is largely within subarea 1; and eight (1.4% of total catch) are outside of the survey area (some of those may be errors in recording of statistical area).

This review of survey distribution and fishery catch and effort distribution shows that golden king crab in the Bering Sea and the fishery for golden king crab in the Bering Sea are concentrated in the Pribilof Canyon area (survey subarea 2). Nonetheless, golden king crab do occur more sporadically and at lower densities in survey subareas 3 and 4 and there has been some limited catch and effort during Pribilof District fisheries within survey subareas 3 and 4. Portions of survey subareas 1 and 5 that lie within the Pribilof District appear to be largely devoid of golden king crab, have produced little or no catch during the Pribilof District fishery, and have received little or no fishery effort. The golden king crab that occur in survey subarea 6 are exploited by the Saint Matthew section fishery when it is prosecuted. Accordingly, the following analyses to estimate trends in the Pribilof District stock were performed using survey data from only survey subareas 2, 3, and 4. Because of the high concentration of fishery effort and fishery catch in Pribilof Canyon and the high CPUE of golden king crab within Pribilof Canyon during the slope surveys, data summaries and analyses were also performed using data only from survey Subarea 2.

Results.
Size frequency distributions of golden king crab captured within subareas 2, 3, and 4 during the 2008, 2010, and 2012 NMFS EBS slope surveys are shown in Figures 9–12.

Area-swept biomass estimates by survey subarea, for the total surveyed area (pooled subareas 1–6), and for pooled subareas 2–4 for 2002, 2004, 2008, 2010, and 2012 are in Table 2.

Estimates and projections through 2016 of total, mature male, and legal male biomass in survey subareas 2-4 and survey subarea 2 from the state-space random walk plus noise model are plotted in Figures 13 and 14, respectively. More detailed results produced by re.exe are provided in Appendices A and B.

References.

Gaeuman, W. 2013a. Alternative Pribilof Islands golden king crab stock assessment strategy. Discussion paper presented to the NPFMC Crab Plan Team, September 2013.

Gaeuman, W. 2013b. Pribilof Islands golden king crab Tier 4 stock assessment considerations. Discussion paper presented to the NPFMC Crab Plan Team, May 2013.

Hoff, G.R., and L. Britt. 2003. Results of the 2002 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-141.

Hoff, G.R., and L. Britt. 2005. Results of the 2004 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-156.

Hoff, G.R., and L. Britt. 2009. Results of the 2008 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-197.

Hoff, G.R., and L. Britt. 2011. Results of the 2010 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-224.

Hoff, G.R. 2013. Results of the 2012 eastern Bering Sea upper continental slope survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-258.

North Pacific Fishery Management Council (NPFMC). 2007. Public Review Draft: Environmental assessment for proposed Amendment 24 to the Fishery Management Plan for Bering Sea and Aleutian Islands king and Tanner crabs to revise overfishing definitions. 14 November 2007. North Pacific Fishery Management Council, Anchorage.

Pengilly, D. 2012. Pribilof Islands golden king crab. [*in*]: Stock Assessment and fishery Evaluation report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions: 2012 Crab SAFE. NPFMC, Anchorage, September 2012.

Pengilly, D. 2014. Pribilof Islands golden king crab. [*in*]: Stock Assessment and fishery Evaluation report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions: 2014 Crab SAFE. NPFMC, Anchorage, September 2014.

Spencer, P., M. Canino, J. DiCosimo, M. Dorn, A.J. Gharret, D. Hanselman, K. Palof, and M. Sigler. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans. http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2012/Sept/stock_structure_report.pdf

Somerton, D.A., and R.S. Otto. 1986. Distribution and reproductive biology of the golden king crab, *Lithodes aequispina*, in the eastern Bring Sea. Fishery Bulletin, Vol. 84 (3): 571–584.

Table 1. Data on golden king crab recorded during the 2002, 2004, 2008, 2010, and 2012 NMFS EBS slope surveys.

Survey	Weight in tow	Count in tow	Sex/CL/shell con/fem repro	Individual weights
2002	YES	YES	NO	NO
2004	YES	YES	NO	NO
2008	YES	YES	YES	285 of 416 meas'd
2010	YES	YES	YES	NO
2012	YES	YES	YES[a]	495 of 899 meas'd

a. Golden king crab <100 mm CL were subsampled for data recording at one tow in subarea 4 during the 2012 survey.

Table 2. Area-swept biomass (t) estimates of total (sexes combined), mature-sized males, and legal male golden king crab computed from 2002, 2004, 2008, 2010, and 2012 NMFS eastern Bering Sea slope survey data, by survey subarea, and with coefficients of variation (CV = standard error of estimate divided by the estimate).

		Total (males and females)		Mature males (males ≥ 107 mm CL)		Legal males (males ≥ 124 mm CL)	
Survey Year	Subarea	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV
2002	1	131	0.39	–	–	–	–
2002	2	682	0.22	–	–	–	–
2002	3	81	0.40	–	–	–	–
2002	4	53	0.40	–	–	–	–
2002	5	19	0.86	–	–	–	–
2002	6	44	0.69	–	–	–	–
2002	1–6	1,010	0.16	–	–	–	–
2002	2–4	816	0.19	–	–	–	–
2004	1	65	0.22	–	–	–	–
2004	2	817	0.38	–	–	–	–
2004	3	51	0.41	–	–	–	–
2004	4	121	0.36	–	–	–	–
2004	5	20	0.73	–	–	–	–
2004	6	24	0.73	–	–	–	–
2004	1–6	1,098	0.29	–	–	–	–
2004	2–4	989	0.32	–	–	–	–
2008	1	146	0.40	47	0.35	11	0.70
2008	2	920	0.32	490	0.36	294	0.29
2008	3	91	0.44	64	0.44	28	0.54
2008	4	205	0.46	85	0.53	78	0.52
2008	5	2	1.00	22	1.00	22	1.00
2008	6	66	0.50	30	0.63	19	0.61
2008	1–6	1,431	0.22	737	0.25	452	0.22
2008	2–4	1,216	0.26	638	0.29	401	0.24
2010	1	363	0.20	168	0.20	145	0.23
2010	2	1,614	0.31	440	0.24	349	0.25
2010	3	89	0.63	79	0.72	71	0.75
2010	4	72	0.41	46	0.47	44	0.50
2010	5	37	0.45	10	0.76	7	1.00
2010	6	122	0.43	25	0.51	12	1.00
2010	1–6	2,298	0.22	768	0.17	628	0.18
2010	2–4	1,776	0.29	565	0.22	464	0.23
2012	1	421	0.37	328	0.45	280	0.50
2012	2	778	0.45	256	0.32	207	0.34
2012	3	172	0.75	146	0.83	131	0.81
2012	4	494	0.69	26	0.48	8	1.00
2012	5	12	0.43	6	0.74	4	1.00
2012	6	149	0.40	49	0.33	40	0.38
2012	1–6	2,025	0.26	812	0.26	670	0.28
2012	2–4	1,444	0.35	429	0.34	346	0.37

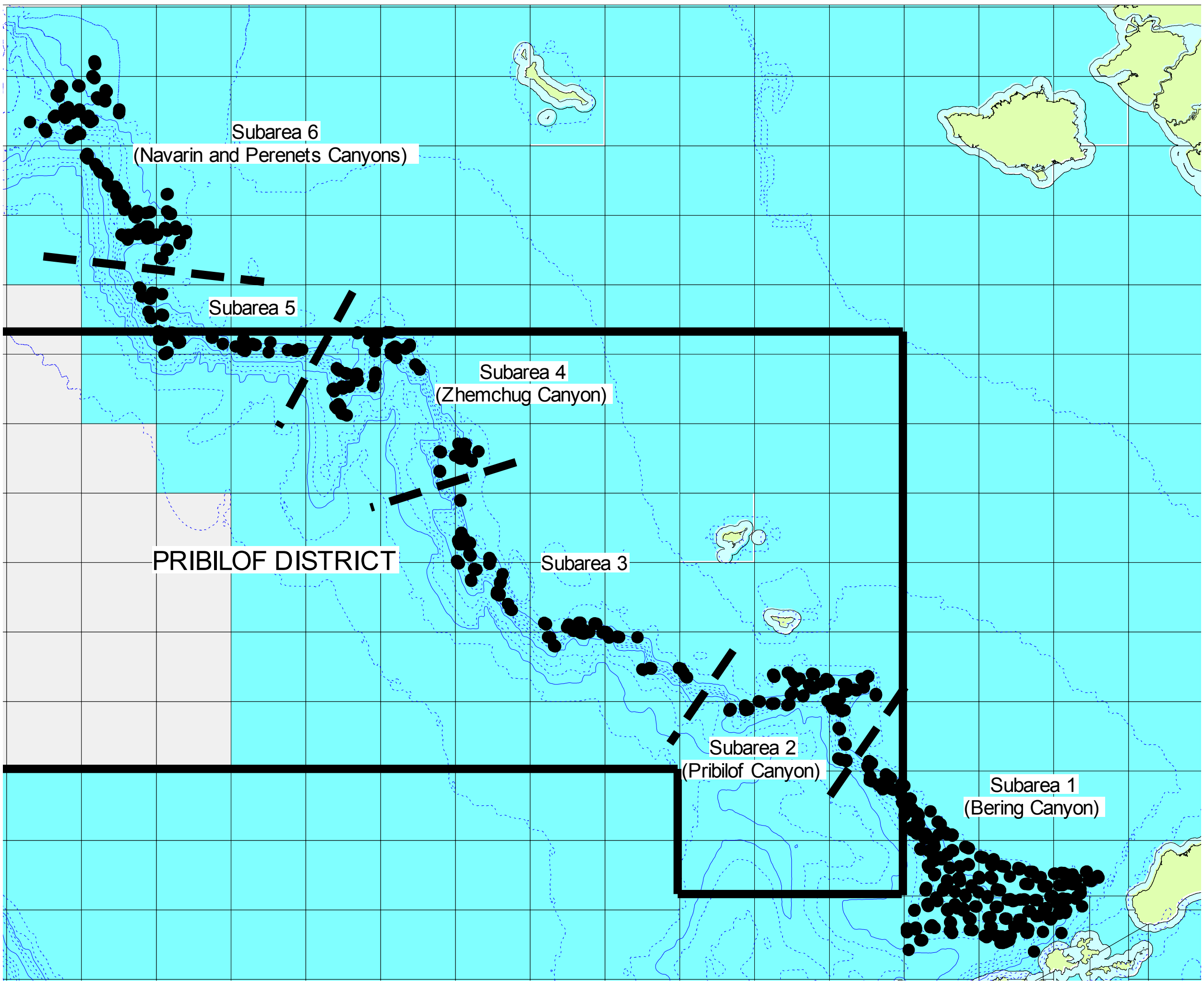


Figure 1. Pribilof District boundaries, slope survey subareas, and 2002–2012 slope survey tow locations; squares are 1° longitude x 30' latitude State statistical areas.

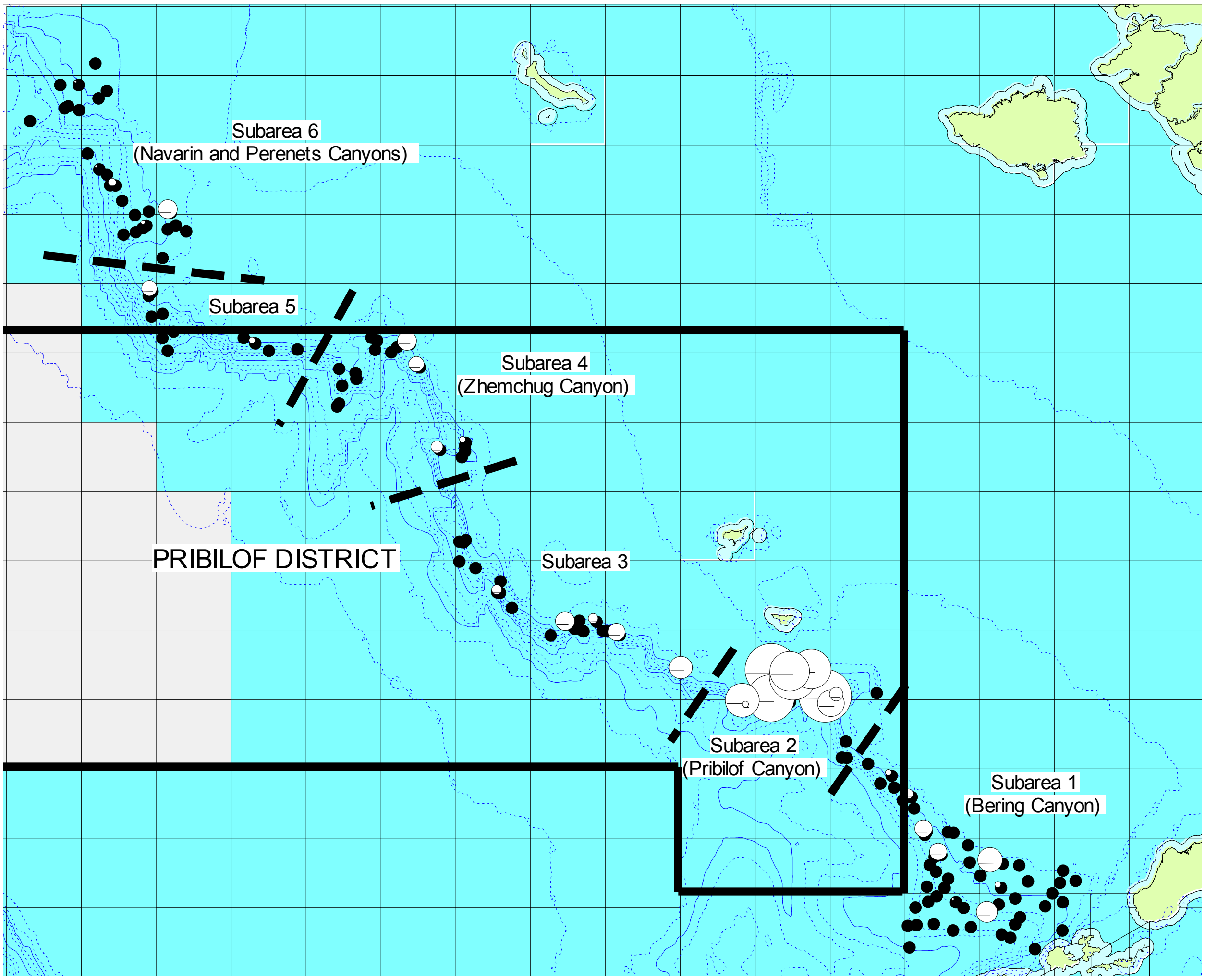


Figure 2. 2002 slope survey tow locations (black circles) and golden king crab CPUE (kg/sq-km; white circles; largest circle = 510 kg/sq-km); squares are 1° longitude x 30' latitude State statistical areas.

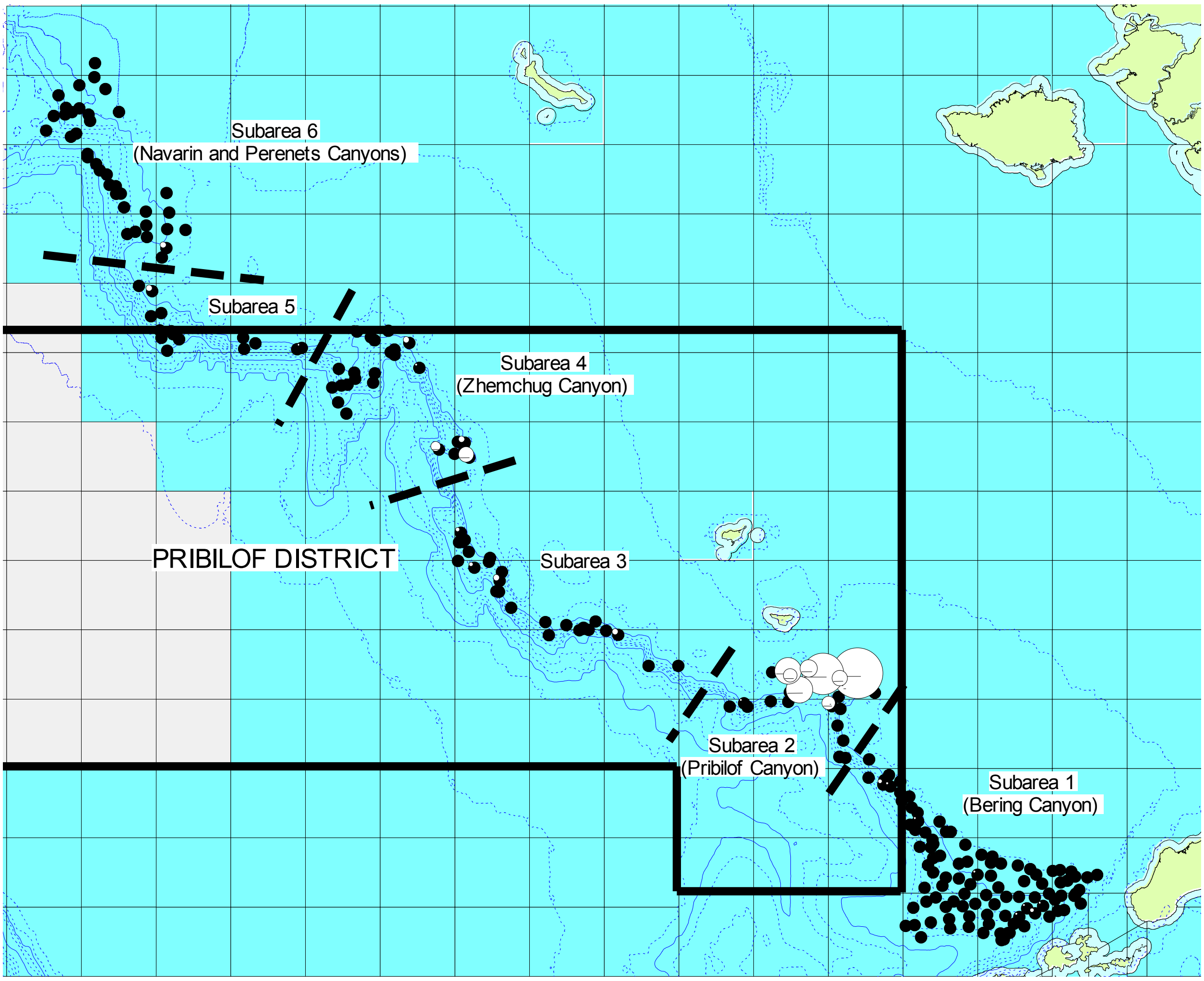


Figure 3. 2004 slope survey tow locations (black circles) and golden king crab CPUE (kg/sq-km; white circles; largest circle = 2,300 kg/sq-km); squares are 1° longitude x 30' latitude State statistical areas.

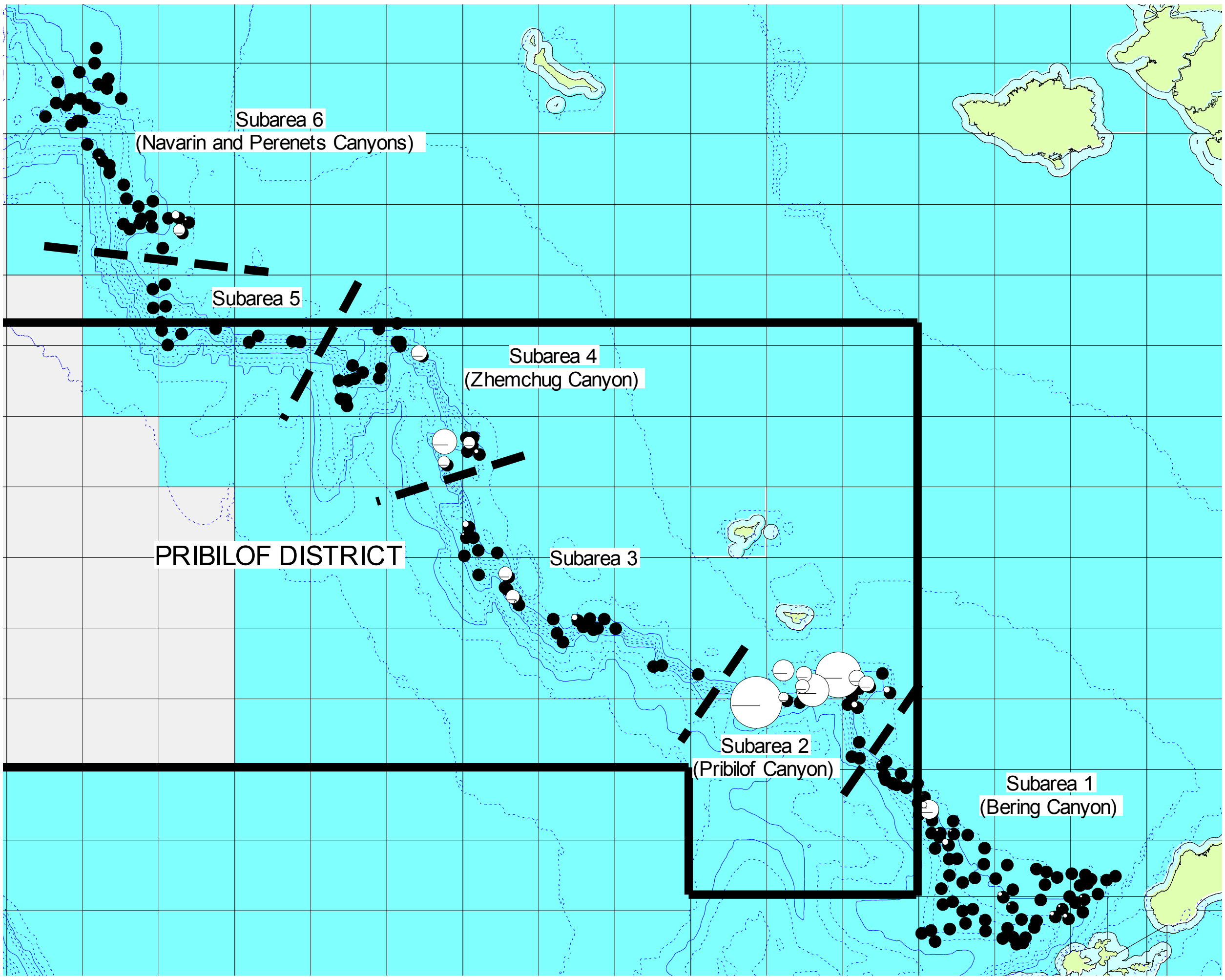


Figure 4. 2008 slope survey tow locations (black circles) and golden king crab CPUE (kg/sq-km; white circles; largest circle = 1,700 kg/sq-km); squares are 1° longitude x 30' latitude State statistical areas.

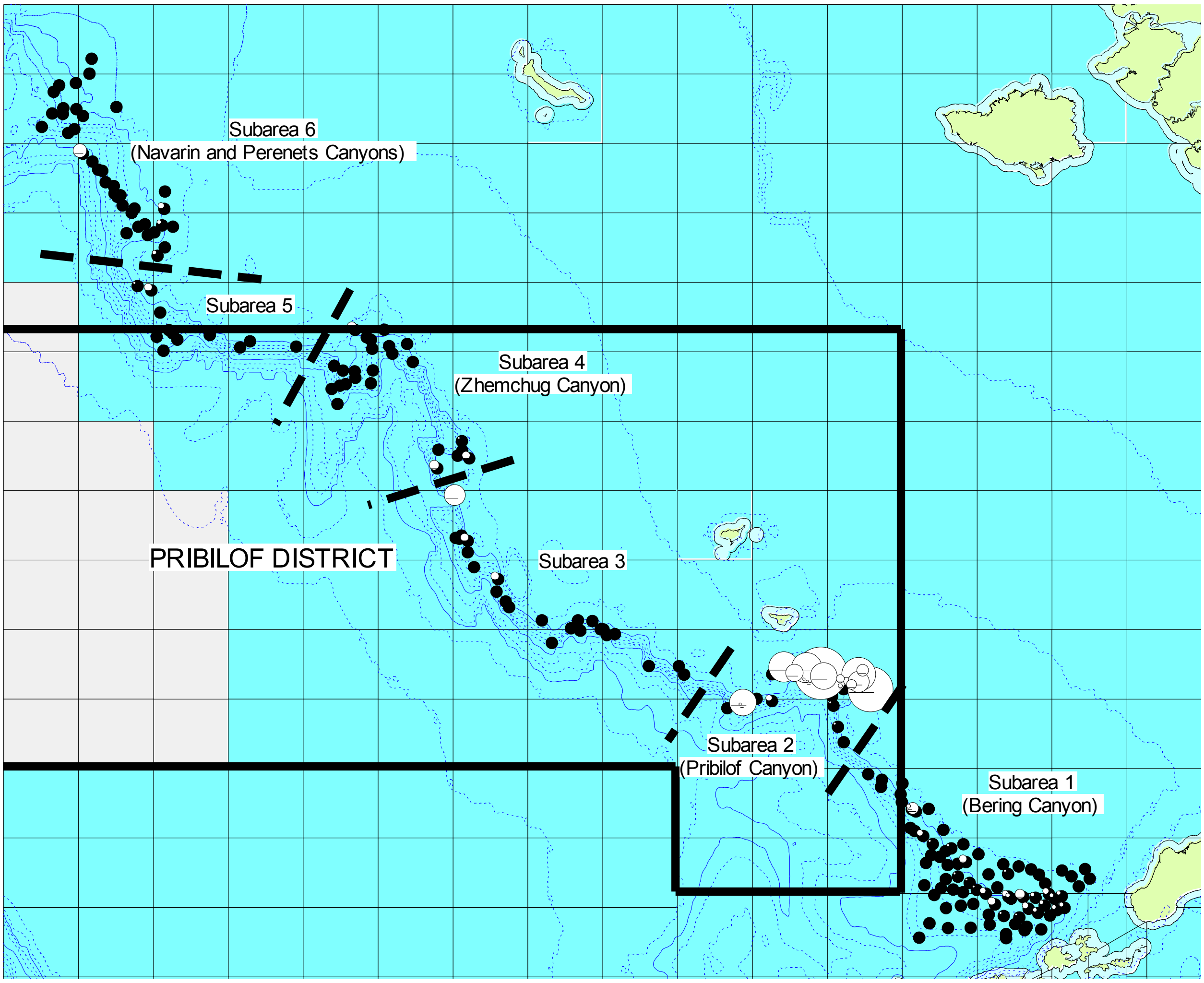


Figure 5. 2010 slope survey tow locations (black circles) and golden king crab CPUE (kg/sq-km; white circles; largest circle = 2,700 kg/sq-km); squares are 1° longitude x 30' latitude State statistical areas.

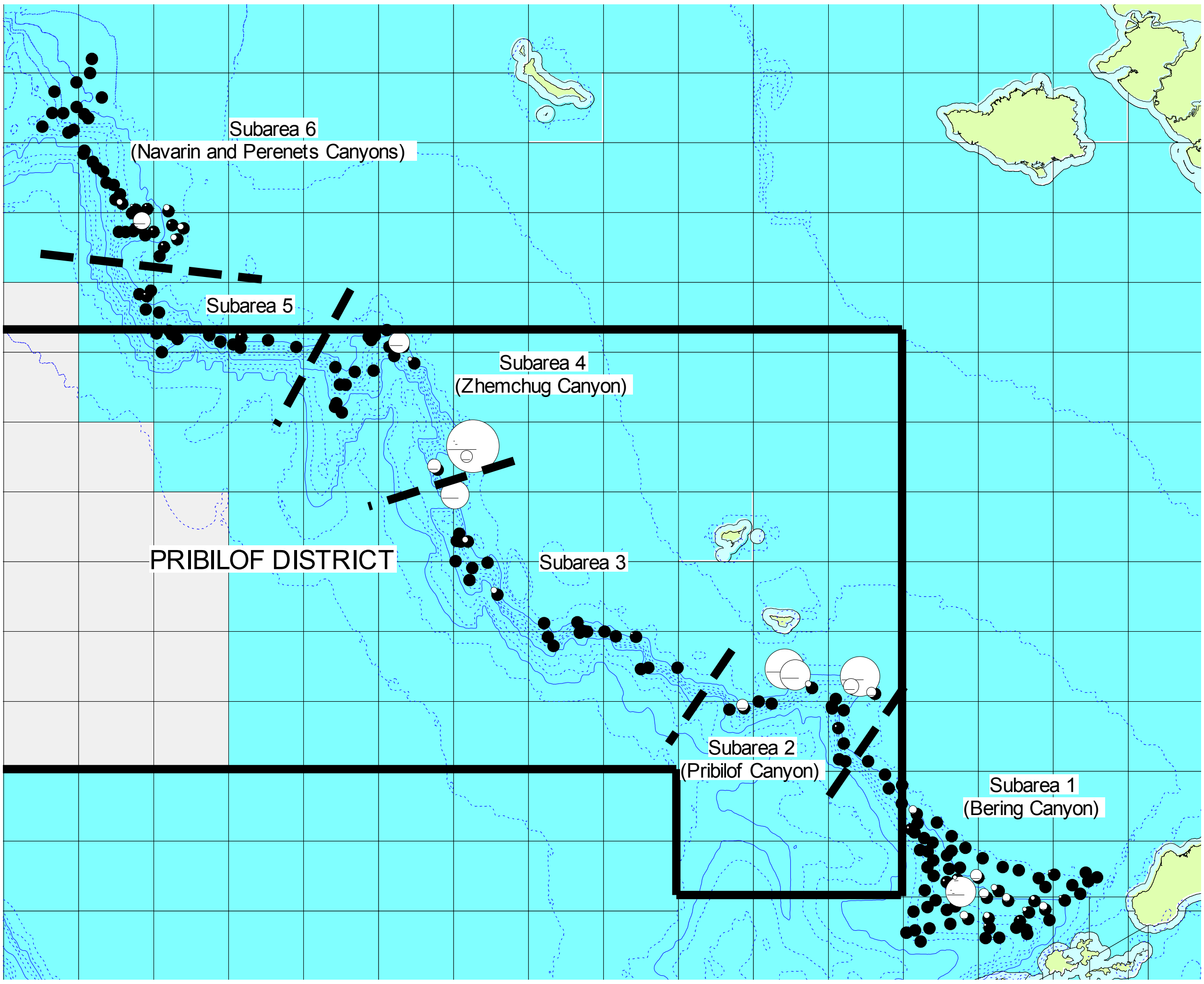


Figure 6. 2012 slope survey tow locations (black circles) and golden king crab CPUE (kg/sq-km; white circles; largest circle = 2,000 kg/sq-km); squares are 1° longitude x 30' latitude State statistical areas.

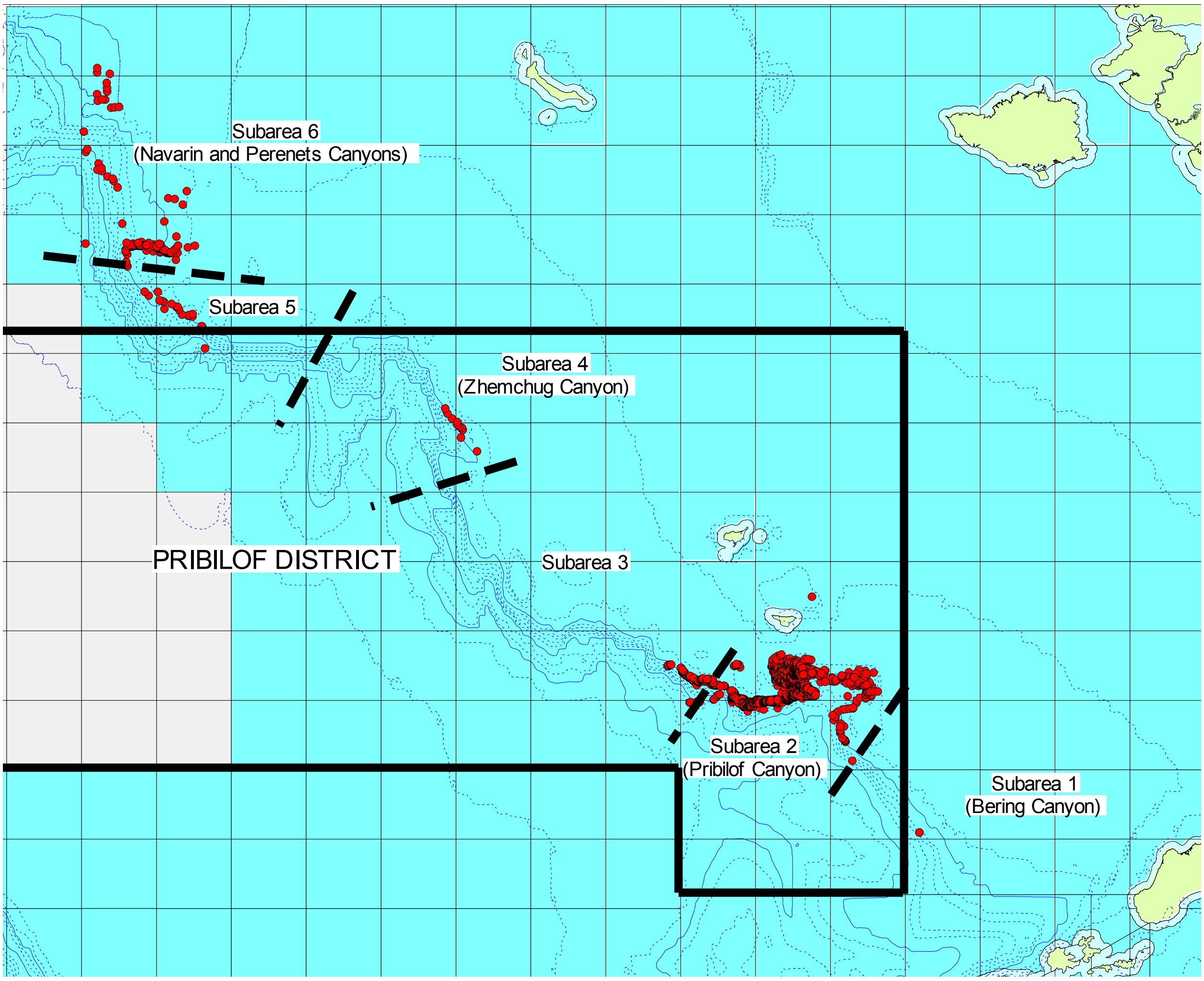


Figure 7. Locations of all pots sampled by observers during Bering Sea golden king crab fisheries (n = 6,104), 1992–2014; pots north of the Pribilof District northern boundary were fished during the Northern District – Saint Matthew Island Section fishery; squares are 1° longitude x 30' latitude State statistical areas.

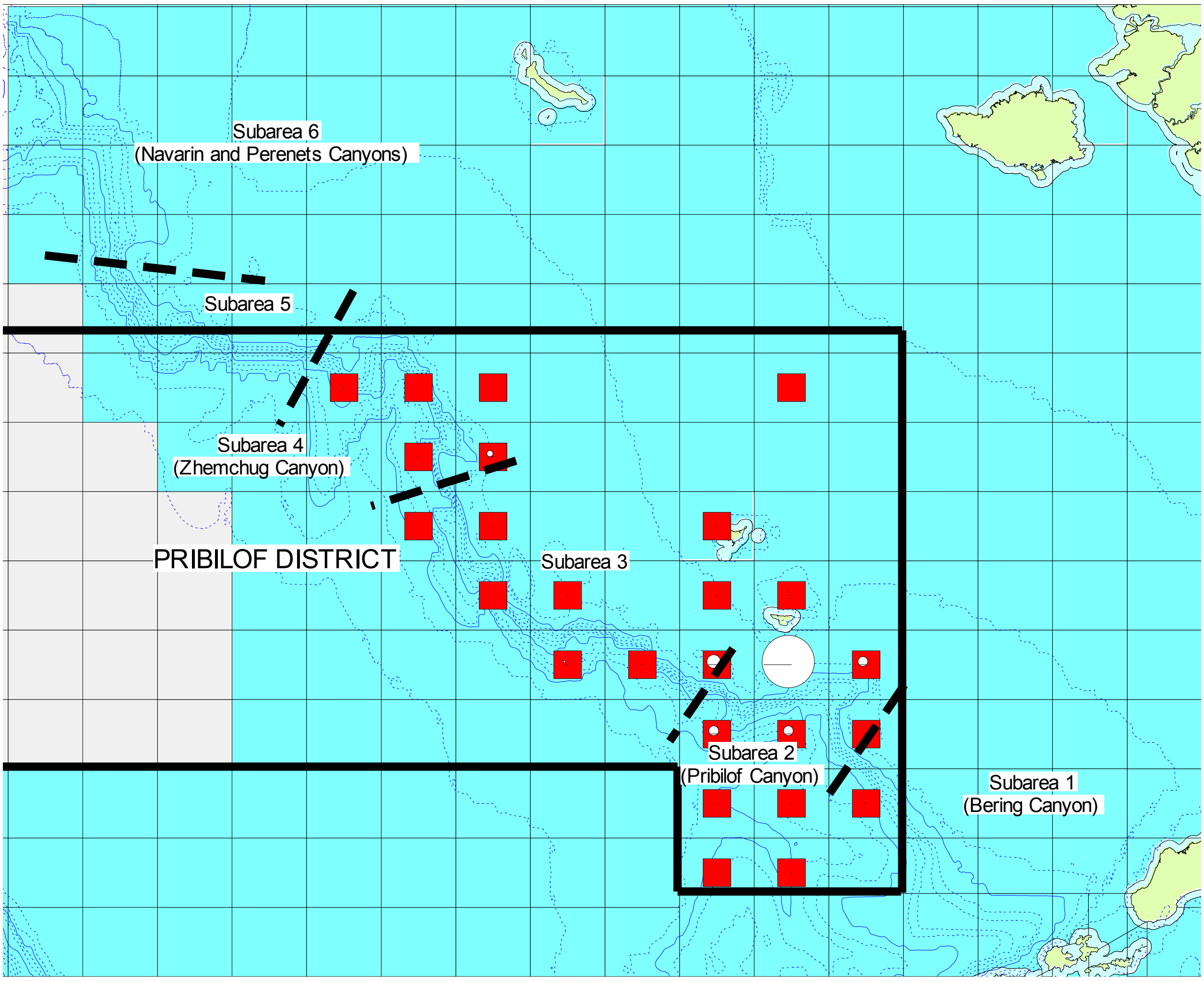


Figure 8. Statistical areas with reported catch during the 1985–2014 Pribilof District golden king crab fisheries: filled red squares denote statistical areas with reported catch; size of overlain white circles are proportional to the percentage of the total 1985–2014 catch reported from statistical area (biggest circle = 68% of total); squares are 1° longitude x 30' latitude State statistical areas.

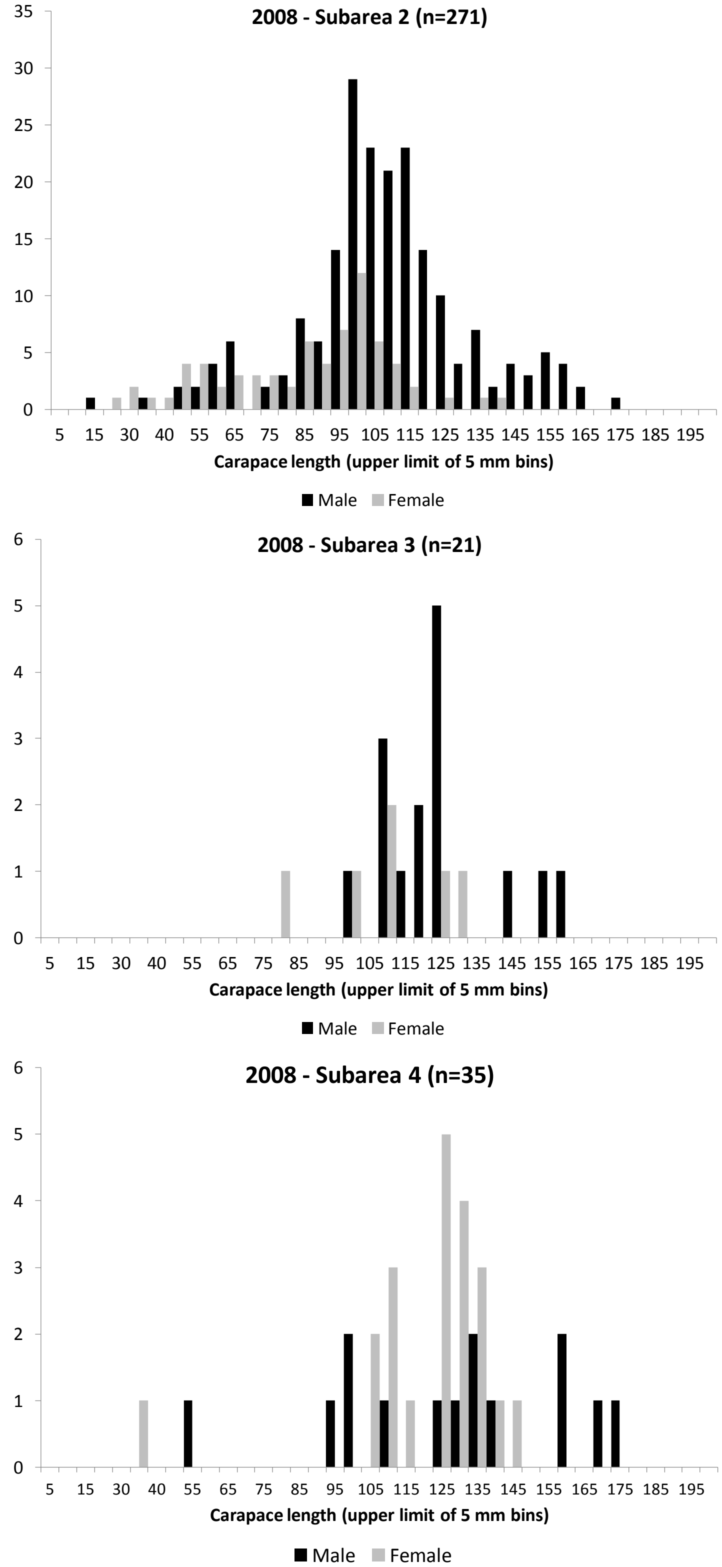


Figure 9. Size distribution of measured golden king crab during the 2008 NMFS EBS slope survey in survey Subareas 2, 3, and 4, by survey subarea.

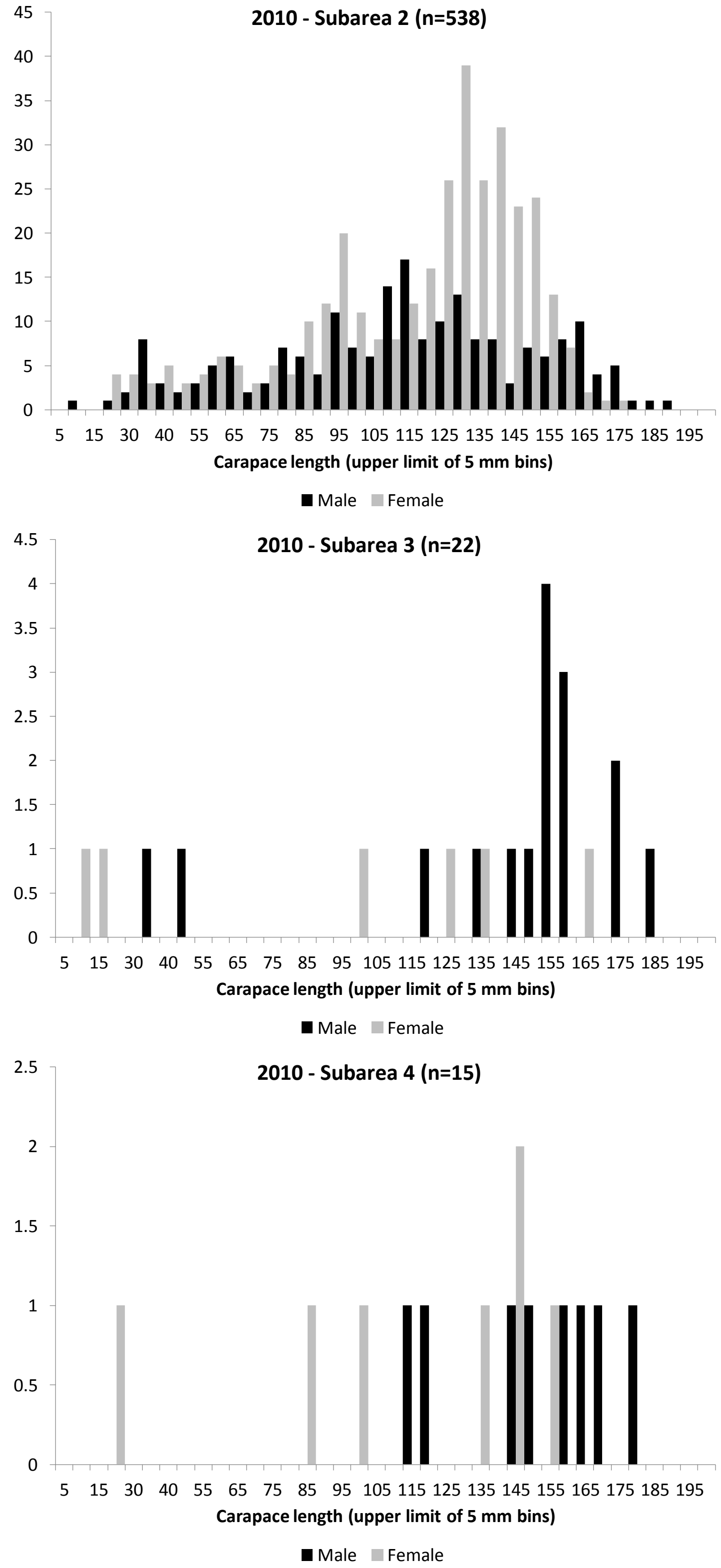
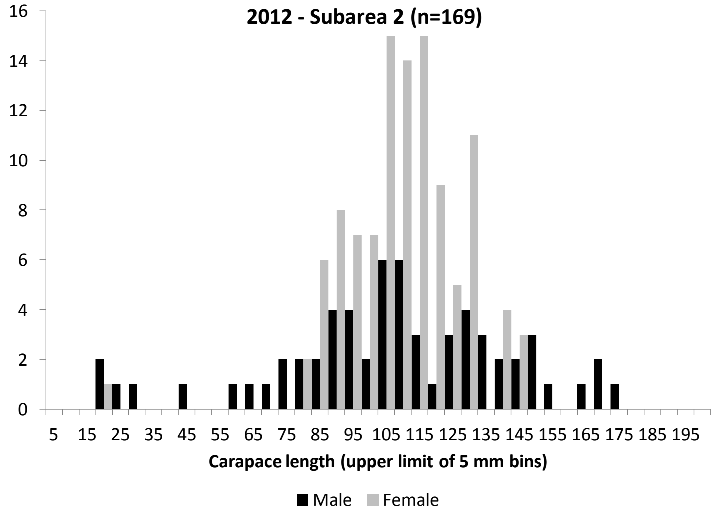
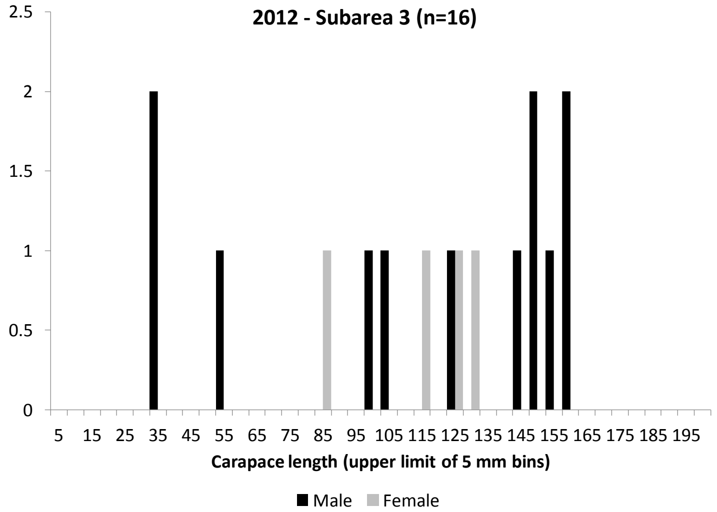


Figure 10. Size distribution of measured golden king crab during the 2010 NMFS EBS slope survey in survey Subareas 2, 3, and 4, by survey subarea.


2012 - Subarea 2 (n=169)
0
2
4
6
8
10
12
14
16
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Carapace length (upper limit of 5 mm bins)
Male Female


2012 - Subarea 3 (n=16)
0
0.5
1
1.5
2
2.5
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Carapace length (upper limit of 5 mm bins)
Male Female

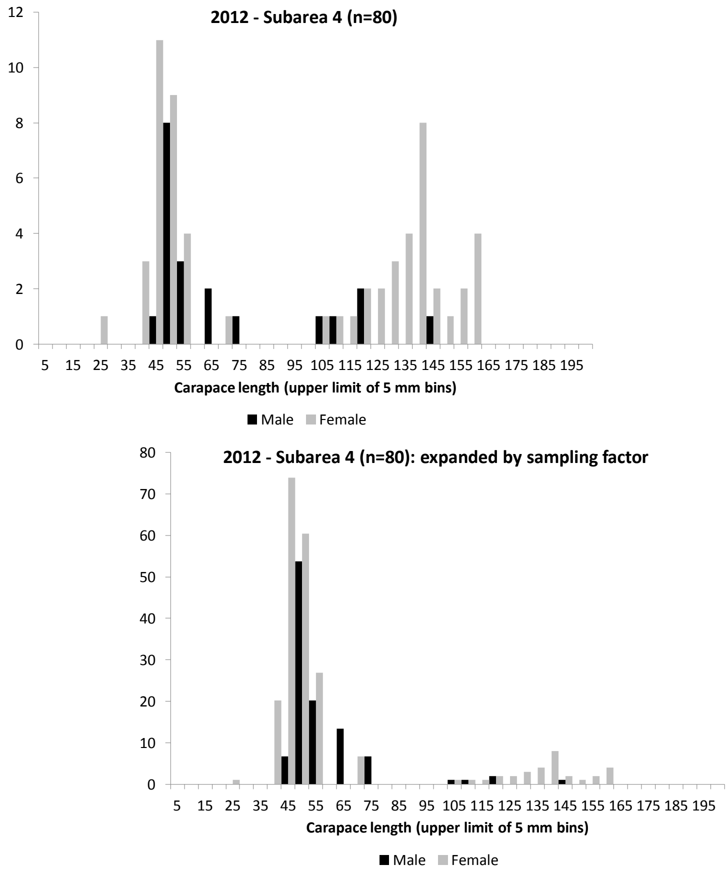


Figure 12. Size distribution of measured golden king crab during the 2012 NMFS EBS slope survey in survey Subareas 2, 3, and 4, by survey subarea.

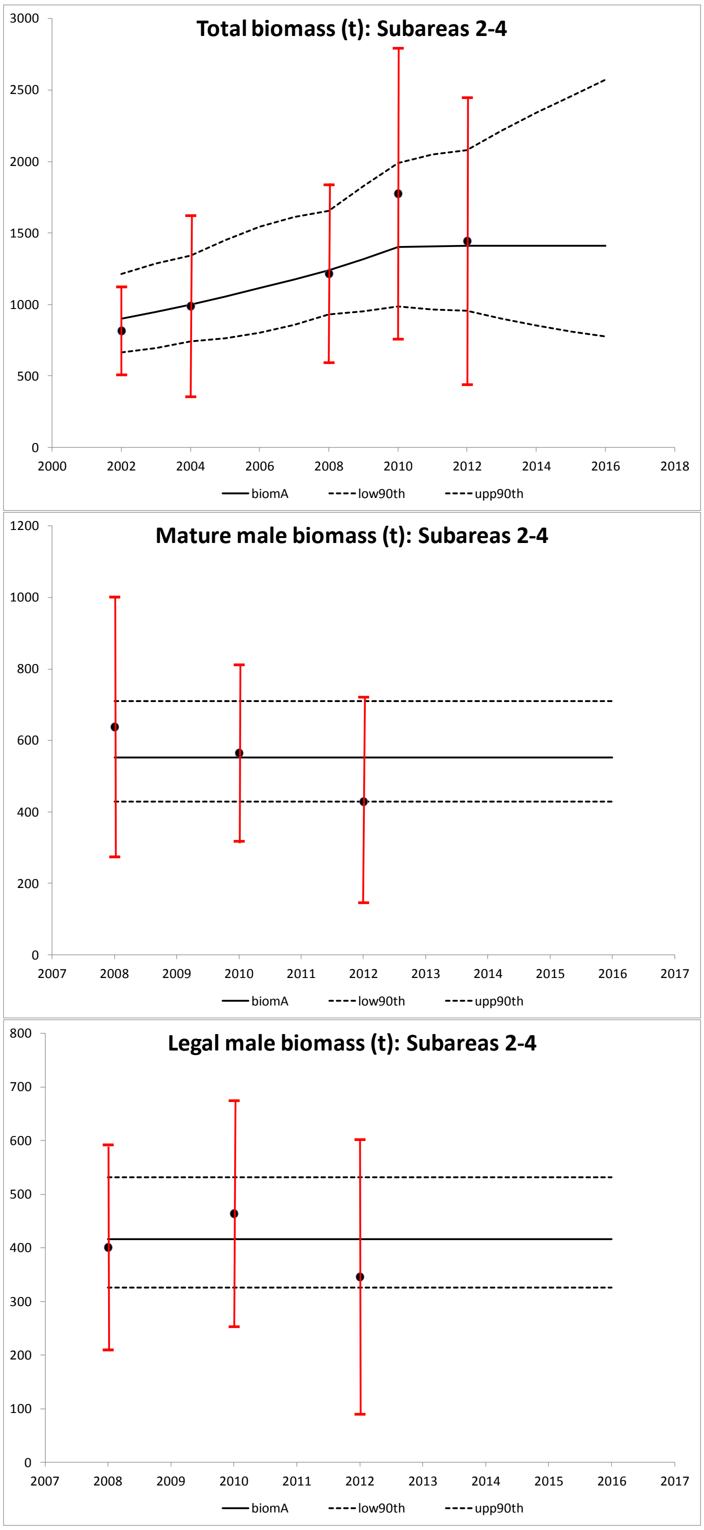


Figure 13. Plots of estimated and projected-into-2016 biomass of total, mature male, and legal male golden king crab in NMFS slope survey Subareas 2–4 with 90% confidence intervals and survey area-swept estimates; red bars are survey estimate plus/minus 2 standard errors.

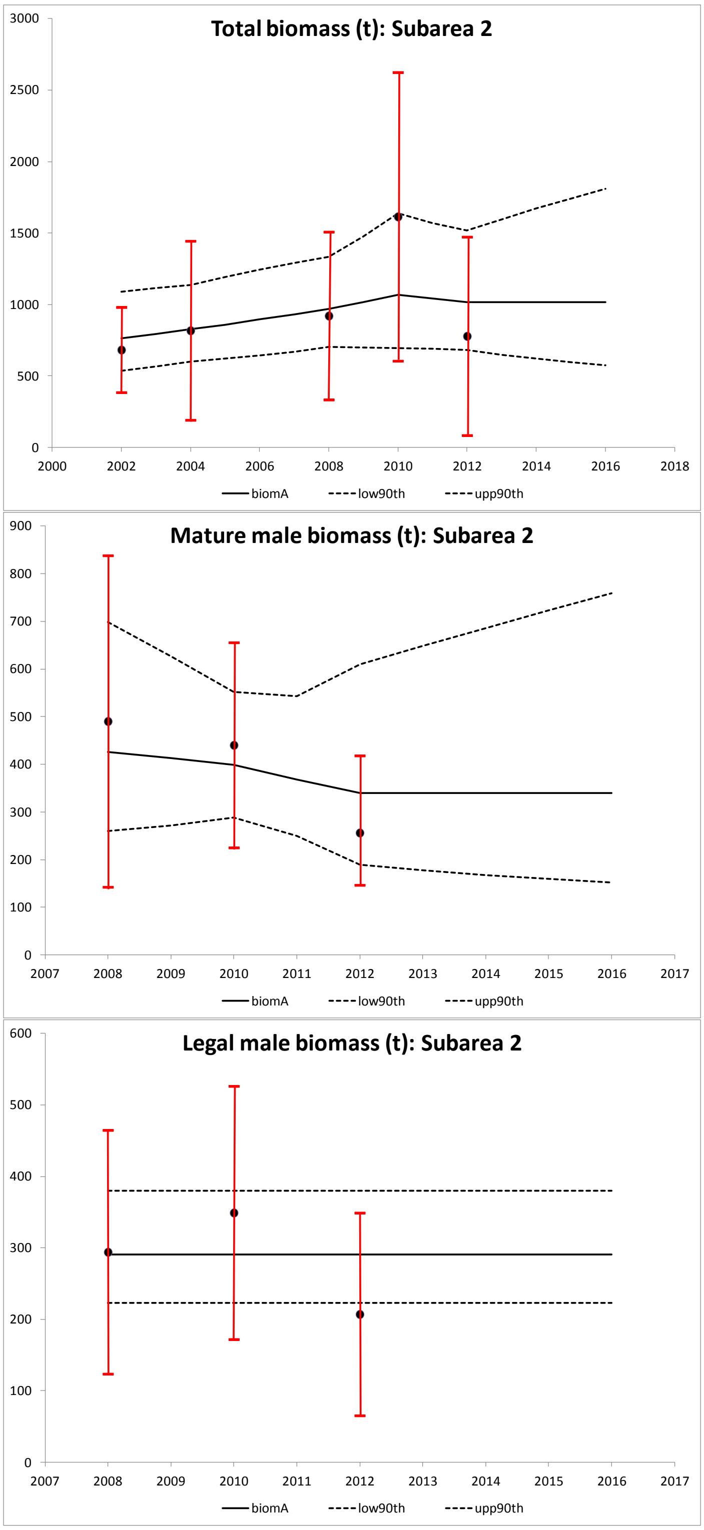


Figure 14. Plots of estimated and projected-into-2016 biomass of total, mature male, and legal male golden king crab in NMFS slope survey Subarea 2 with 90% confidence intervals and survey area-swept estimates; red bars are survey estimate plus/minus 2 standard errors.

Appendix A3:A1. Input file (re.dat) for total golden king crab biomass in NMFS EBS slope survey Subareas 2-4 and results file (rwout.rep) produced by re.exe.

Total biomass (t) estimates for subareas 2-4, 2002-2012 slope surveys

re.dat file					
2002	#Start year of model				
2016	#End year of model				
5	#number of survey estimates				
#Years of survey					
	2002	2004	2008	2010	2012
#Biomass estimates					
	816	989	1216	1776	1444
#Coefficients of variation for biomass estimates					
	0.19	0.32	0.26	0.29	0.35

rwout.rep file															
yrs_srv															
	2002	2004	2008	2010	2012										
srv_est															
	816	989	1216	1776	1444										
srv_sd															
	0.188318	0.312233	0.25576	0.284166	0.339939										
yrs															
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI															
	629.437	656.433	701.98	720.12	754.662	806.877	882.1	894.822	923.012	898.032	888.492	825.005	773.028	728.958	690.711
biomA															
	898.729	947.241	998.371	1054.23	1113.21	1175.49	1241.26	1318.69	1400.94	1406.26	1411.6	1411.6	1411.6	1411.6	1411.6
UCI															
	1283.23	1366.88	1419.91	1543.35	1642.11	1712.51	1746.66	1943.33	2126.34	2202.12	2242.7	2415.29	2577.69	2733.52	2884.89
low90th															
	666.517	696.286	742.863	765.61	803.314	857.176	931.878	952.361	987.031	965.15	957.12	899.382	851.578	810.642	774.792
upp90th															
	1211.84	1288.65	1341.76	1451.65	1542.66	1612.02	1653.36	1825.92	1988.42	2048.98	2081.89	2215.55	2339.92	2458.08	2571.82
biomsd															
	6.80098	6.85355	6.90613	6.96056	7.015	7.06944	7.12388	7.18439	7.2449	7.24869	7.25248	7.25248	7.25248	7.25248	7.25248
biomsd.sd															
	0.181712	0.187108	0.179704	0.194463	0.198334	0.191976	0.174274	0.19784	0.212886	0.228819	0.236202	0.274026	0.307228	0.337176	0.364673

Appendix A3:A2. Input file (re.dat) for mature male golden king crab biomass in NMFS EBS slope survey Subareas 2-4 and results file (rwout.rep) produced by re.exe.

Mature (>=107 mm CL) male biomass (t) estimates for subareas 2-4, 2008-2012 slope surveys

re.dat file			
2008	#Start year of model		
2016	#End year of model		
3	#number of survey estimates		
#Years of survey			
2008	2010	2012	
#Biomass estimates			
638	565	429	
#Coefficients of variation for biomass estimates			
0.29	0.22	0.34	

rwout.rep file									
yrs_srv									
	2008	2010	2012						
srv_est									
	638	565	429						
srv_sd									
	0.284166	0.217406	0.330745						
yrs									
	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI									
	408.72	408.738	408.744	408.724	408.686	408.673	408.661	408.649	408.636
biomA									
	551.765	551.76	551.755	551.749	551.743	551.743	551.743	551.743	551.743
UCI									
	744.872	744.828	744.803	744.824	744.878	744.9	744.923	744.945	744.967
low90th									
	428.915	428.93	428.936	428.917	428.882	428.871	428.861	428.85	428.839
upp90th									
	709.8	709.764	709.743	709.759	709.8	709.818	709.836	709.854	709.872
biomsd									
	6.31312	6.31311	6.3131	6.31309	6.31308	6.31308	6.31308	6.31308	6.31308
biomsd.sd									
	0.153107	0.153081	0.153069	0.153089	0.153131	0.153146	0.153162	0.153177	0.153193

Appendix A3:A3. Input file (re.dat) for legal male golden king crab biomass in NMFS EBS slope survey Subareas 2-4 and results file (rwout.rep) produced by re.exe.

Legal (>=124 mm CL) male biomass (t) estimates for subareas 2-4, 2008-2012 slope surveys

re.dat file		
2008	#Start year of model	
2016	#End year of model	
3	#number of survey estimates	
#Years of survey		
2008	2010	2012
#Biomass estimates		
401	464	346
#Coefficients of variation for biomass estimates		
0.24	0.23	0.37

rwout.rep file									
yrs_srv									
	2008	2010	2012						
srv_est									
	401	464	346						
srv_sd									
	0.236648	0.227042	0.358197						
yrs									
	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI									
	310.83	310.831	310.832	310.829	310.823	310.819	310.814	310.809	310.805
biomA									
	416.246	416.246	416.247	416.246	416.244	416.244	416.244	416.244	416.244
UCI									
	557.413	557.412	557.412	557.415	557.42	557.429	557.437	557.445	557.454
low90th									
	325.766	325.767	325.768	325.765	325.76	325.756	325.752	325.748	325.744
upp90th									
	531.856	531.855	531.855	531.857	531.862	531.868	531.875	531.882	531.888
biomsd									
	6.03128	6.03128	6.03128	6.03128	6.03127	6.03127	6.03127	6.03127	6.03127
biomsd.sd									
	0.148995	0.148994	0.148992	0.148997	0.149004	0.149011	0.149019	0.149027	0.149034

Appendix A3:B1. Input file (re.dat) for total golden king crab biomass in NMFS EBS slope survey Subarea 2 and results file (rwout.rep) produced by re.exe.

Total biomass (t) estimates for subarea 2, 2002-2012 slope surveys

re.dat file				
2002	#Start year of model			
2016	#End year of model			
5	#number of survey estimates			
#Years of survey				
2002	2004	2008	2010	2012
#Biomass estimates				
682	817	920	1614	778
#Coefficients of variation for biomass estimates				
0.22	0.38	0.32	0.31	0.45

rwout.rep file															
yrs_srv															
	2002	2004	2008	2010	2012										
srv_est															
	682	817	920	1614	778										
srv_sd															
	0.217406	0.367261	0.312233	0.302917	0.429421										
yrs															
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI															
	501.727	530.855	565.671	582.598	603.885	629.85	661.103	651.433	639.392	639.842	632.362	595.772	564.672	537.6	513.629
biomA															
	765.392	795.334	826.446	859.928	894.766	931.015	968.733	1016.4	1066.42	1042.21	1018.54	1018.54	1018.54	1018.54	1018.54
UCI															
	1167.62	1191.58	1207.44	1269.27	1325.76	1376.18	1419.51	1585.86	1778.65	1697.6	1640.55	1741.31	1837.22	1929.73	2019.79
low90th															
	536.964	566.491	601.209	620.218	643.275	670.677	702.97	699.711	694.179	692.03	682.709	649.397	620.824	595.745	573.37
upp90th															
	1091	1116.62	1136.07	1192.28	1244.58	1292.41	1334.97	1476.44	1638.28	1569.58	1519.57	1597.52	1671.04	1741.39	1809.35
biomsd															
	6.64039	6.67876	6.71714	6.75685	6.79656	6.83628	6.87599	6.92403	6.97206	6.9491	6.92613	6.92613	6.92613	6.92613	6.92613
biomsd.sd															
	0.215476	0.206262	0.19343	0.198649	0.200602	0.199385	0.194939	0.226966	0.260994	0.248915	0.243196	0.273606	0.300959	0.326026	0.349298

Appendix A3:B2. Input file (re.dat) for mature male golden king crab biomass in NMFS EBS slope survey Subarea 2 and results file (rwout.rep) produced by re.exe.

Mature (>=107 mm CL) male biomass (t) estimates for subarea 2, 2008-2012 slope surveys

re.dat file		
2008 #Start year of model		
2016 #End year of model		
3 #number of survey estimates		
#Years of survey		
2008	2010	2012
#Biomass estimates		
490	440	256
#Coefficients of variation for biomass estimates		
0.36	0.24	0.32

rwout.rep file									
yrs_srv									
	2008	2010	2012						
srv_est									
	490	440	256						
srv_sd									
	0.34909	0.236648	0.312233						
yrs									
	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI									
	236.563	250.548	271.48	231.49	168.758	156.739	146.522	137.661	129.86
biomA									
	426.017	412.406	399.23	367.956	339.133	339.133	339.133	339.133	339.133
UCI									
	767.196	678.825	587.094	584.872	681.513	733.775	784.941	835.466	885.654
low90th									
	260.02	271.441	288.838	249.389	188.79	177.438	167.678	159.125	151.522
upp90th									
	697.987	626.577	551.811	542.894	609.201	648.175	685.902	722.769	759.037
biomsd									
	6.05448	6.02201	5.98954	5.90796	5.82639	5.82639	5.82639	5.82639	5.82639
biomsd.sd									
	0.300135	0.254263	0.196759	0.236443	0.356084	0.393781	0.428172	0.459999	0.489763

Appendix A3:B3. Input file (re.dat) for legal male golden king crab biomass in NMFS EBS slope survey Subareas 2 and results file (rwout.rep) produced by re.exe.

Legal (>=124 mm CL) male biomass (t) estimates for subarea 2, 2008-2012 slope surveys

re.dat file		
2008	#Start year of model	
2016	#End year of model	
3	#number of survey estimates	
#Years of survey		
2008	2010	2012
#Biomass estimates		
294	349	207
#Coefficients of variation for biomass estimates		
0.29	0.25	0.34

rwout.rep file									
yrs_srv									
	2008	2010	2012						
srv_est									
	294	349	207						
srv_sd									
	0.284166	0.246221	0.330745						
yrs									
	2008	2009	2010	2011	2012	2013	2014	2015	2016
LCI									
	211.81	211.814	211.818	211.805	211.755	211.744	211.733	211.723	211.712
biomA									
	291.091	291.091	291.09	291.083	291.075	291.075	291.075	291.075	291.075
UCI									
	400.047	400.038	400.029	400.033	400.107	400.128	400.148	400.168	400.189
low90th									
	222.914	222.918	222.922	222.909	222.864	222.854	222.845	222.835	222.826
upp90th									
	380.119	380.112	380.105	380.106	380.163	380.18	380.196	380.212	380.228
biomsd									
	5.67364	5.67363	5.67363	5.67361	5.67358	5.67358	5.67358	5.67358	5.67358
biomsd.sd									
	0.162218	0.162207	0.162196	0.162214	0.162322	0.162348	0.162374	0.1624	0.162426

Appendix A3:C. Draft Pribilof Islands (Pribilof District) golden king crab stock structure template (adapted from Spencer et al. 2010). Page 1 of 2.

Factor and criterion	Justification
Harvest and trends	
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	F, F_{ABC}, and F_{OFL} are not estimated for Tier 5 stock. Total catch annual catch is confidential, but has been below the OFLs and ABCs established for season.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Fishery effort and catch is concentrated in Pribilof Canyon, a very small area of the Pribilof District, but also an area of concentrated golden king crab density (see EBS slope survey data).
Population trends (Different areas show different trend directions)	Uncertain. Standardized trawl surveys in the Pribilof District have only been performed in 2002, 2004, 2008, 2010, and 2012. Total biomass estimates generally increased from 2002 through 2012; mature-sized male biomass estimates decreased from 2008 through 2012, principally due to decrease between 2010 and 2012 within the Pribilof Canyon area.
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	Unknown, but likely >10 years.
Physical limitations (Clear physical inhibitors to movement)	Species occurs primarily in the 200-1000 m depth zone. No known physical barriers exist in the Pribilof District, although survey and fishery data suggest low densities in the 200-1000 m depth zone of the EBS slope between Pribilof Canyon and Zhemchug Canyon.
Growth differences (Significantly different LAA, WAA, or LW parameters)	No data for estimating size at age. Spatial differences in length-weight relationship within Pribilof District have not been investigated. Within the Bering Sea males at higher latitudes have been estimated to be heavier than equal-sized males at lower latitudes.
Age/size-structure (Significantly different size/age compositions)	Age structure data is lacking. Spatial trends within Pribilof District in size structure have not been investigated, but trend of latitudinal decrease in mean size may exist over the Bering Sea due to latitudinal decrease in size at maturity.
Spawning time differences (Significantly different mean time of spawning)	Species is known to exhibit an asynchronous reproductive cycle lacking distinct seasonal variation; mean spawning time within Pribilof District has not been estimated.

Appendix A3:C. Page 2 of 2.

Factor and criterion	Justification
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	No data for estimating maturity at age. Spatial differences in size at maturity within Pribilof District have not been investigated. Within Bering Sea, estimates of size at maturity decrease south-to-north.
Morphometrics (Field identifiable characters)	Spatial trends within Pribilof District in morphometrics have not been investigated. Latitudinal trends in male morphometrics (chela size at length) may exist over the Bering Sea that are related to latitudinal trends in size at maturity.
Meristics (Minimally overlapping differences in counts)	N/A.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Not likely: ovigerous females tend to occur in the shallower depth zones at sites throughout the Pribilof District within the species depth distribution.
Mark-recapture data (Tagging data may show limited movement)	Mark-recapture data not available.
Natural tags (Acquired tags may show movement smaller than management areas)	Unknown.
Genetics	
Isolation by distance (Significant regression)	Unknown.
Dispersal distance (<<Management areas)	Unknown.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Unknown.