Pribilof Islands Golden King Crab

– 2020 Tier 5 Assessment

2020 Crab SAFE Report Chapter

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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, 2015, and 2016) 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 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 or 2016, but 2 vessels fished in 2017 and 2019 and one vessel fished in 2018. Discarded (non-retained) catch has occurred in the directed golden king crab fishery, the eastern Bering Sea snow crab fishery, the Bering Sea grooved Tanner crab fishery, and in Bering Sea groundfish fisheries. Estimates of annual total fishery mortality during 2001–2019 due to crab fisheries range from 0 t to 73 t, with an average of 31 t. Estimates of annual fishery mortality during 1991/92–2019 due to groundfish fisheries range from <1 t to 9 t, with an average of 2 t (estimates of annually discarded catch during Bering Sea groundfish fisheries are reported for crab fishing years from 1991 to 2008, and by calendar years from 2009 to 2019). Total fishery mortality in groundfish fisheries during the 2019 crab fishing year was 3.91 t.

3. Stock biomass:

Stock biomass (all sizes, both sexes) of golden king crab have been estimated for the Pribilof Canyon area using the area-swept technique applied to data obtained from the biennial eastern Bering Sea upper continental slope trawl survey performed by NMFS-AFSC in 2002, 2004, 2008, 2010, 2012, and 2016 (Hoff and Britt 2003, 2005, 2009, 2011; Hoff 2013, 2016). See Appendix A1 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 2008–2016 biennial surveys (J. Hoff, NMFS-AFSC, Kodiak). Biomass estimates by sex and size class from the 2008, 2010, 2012, and 2016 surveys were presented in May 2017 (Pengilly and Daly 2017).

4. Recruitment:

Estimated from size-sex composition data from the eastern Bering Sea upper continental slope trawl survey, mature male biomass in the entire survey area increased slightly from 812 t (1,790,154 lb) in 2012 to 869 t (1,916,329 lb) in 2016, and from 256 t (564,383 lb) in 2012 to 463 t (1,021,602lb) in 2016 in the Pribilof canyon.

5. Management performance:

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 have been presented to, and considered by, the Crab Plan Team (Gaeuman 2013a, 2013b; Pengilly 2015, Pengilly and Daly 2017; Appendix B). Two vessels participated in the 2019 directed fishery and 3.91 t of fishery mortality occurred during groundfish fisheries in 2019 (mostly in Greenland Turbot and Rockfish fisheries). Overfishing did not occur in 2017, 2018, or 2019. The GHL for the 2017-2019 seasons was 59 t. The 2021, 2022, and 2023 OFL and ABC in the table below are the author's recommendations, which follow previous determinations.

Management Performance Table (values in t)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2016	N/A	N/A	59	0	0.24	91	68
2017	N/A	N/A	59	Conf.[c]	Conf.[c]	93	70
2018	N/A	N/A	59	Conf.[c]	Conf.[c]	93	70
2019	N/A	N/A	59	Conf.[c]	Conf.[c]	93	70
2020	N/A	N/A	59			93	70
2021	N/A	N/A				93	70
2022	N/A	N/A				93	70
2023	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 and bycatch mortality due to groundfish fisheries are included here, but not for 2017-2019 because the directed fishery is confidential.

c. Confidential under Sec. 16.05.815 (SOA statute).

Management Performance Table (values in millions of lb)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2016	N/A	N/A	130,000	0	<0.001	0.20	0.15
2017	N/A	N/A	130,000	Conf. [c]	Conf. [c]	0.20	0.15
2018	N/A	N/A	130,000	Conf. [c]	Conf. [c]	0.20	0.15
2019	N/A	N/A	130,000	Conf. [c]	Conf. [c]	0.20	0.15
2020	N/A	N/A	130,000			0.20	0.15
2021	N/A	N/A				0.20	0.15
2022	N/A	N/A				0.20	0.15
2023	N/A	N/A				0.20	0.15

a. Guideline harvest level.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab fisheries and bycatch mortality due to groundfish fisheries are included here, but not for 2017-2019 because the directed fishery is confidential
c. Confidential under Sec. 16.05.815 (SOA statute).

6. Basis for the OFL and ABC: The values for 2021-2023 are the author's recommendation.

Calendar Year	Tier	Years to define Average catch (OFL)	Natural Mortality[b]	Buffer
2016	5	1993–1998[a]	0.18 yr^{-1}	25%
2017	5	1993–1998[a]	0.18 yr^{-1}	25%
2018	5	1993–1998[a]	0.18 yr^{-1}	25%
2019	5	1993–1998[a]	0.18 yr^{-1}	25%
2020	5	1993–1998[a]	0.18 yr^{-1}	25%
2021	5	1993–1998[a]	0.18 yr^{-1}	25%
2022	5	1993–1998[a]	0.18 yr^{-1}	25%
2023	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 stocks.

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; 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 to account for bycatch mortality in the directed fishery,

non-directed crab fisheries, and groundfish fisheries, and to avoid exceeding the ABC. The GHL remained at 59 t (130,000 lb) from 2016 to 2020.

2. **Changes to the input data:**
   - Retained catch and discarded catch data have been updated with the results for the 2019 directed fishery, during which two vessels participated, but bycatch in other crab fisheries in 2019 was zero.
   - Discarded catch estimates from groundfish fisheries have been listed by calendar year from 2009 to 2019, including 3.91 t of bycatch mortality for 2019.

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 2013–2020 Tier 5 OFLs; computations applied directly to data and estimates expressed in metric units resulted in minor changes in results used in previous assessments due to rounding.

B. Responses to SSC and CPT Comments

Responses to the most recent two sets of SSC and CPT comments specific to the assessment:

- SSC, October 2019: "*The SSC encourages further efforts to move this analysis to Tier 4 and encourages the CPT to also consider VAST models in addition to RE modelling….. **The SSC strongly supports continued efforts to provide a fishery independent index of abundance for crab and groundfish species on the Bering Sea continental slope.** The SSC supports the development of a collaborative industry-based survey to provide data in the absence of the NMFS slope survey.*"
  - **Response:** We further explored RE modelling. An industry-cooperative survey is in development.
- CPT, September 2019:
  - *Continue the work using the random effects model by incorporating 2004 NMFS slope survey data point and possibly the 2002 data point in model runs. If needed, consider setting a lower bound on process error, although it was noted that this approach did not work for Pribilof Islands red king crab.*
    - **Response:** Included 2002 and 2004 estimates in Tier 4 scenario 2. Did not change process error lower bound, as model appeared to converge.
  - *Explore the feasibility of a simplified Gmacs model to assess the stock.*
    - **Response:** Work started; data is being compiled.
  - *Consider initiating an industry cooperative survey to assess abundance trends.*
    - **Response:** In the works.

- SSC, June 2017:

- *Following up on a SSC request, requests for waivers from harvesters were obtained. However, discussions are still in progress regarding processor waivers. The SSC hopes that these discussions will be fruitful.*
  - **Response:** Inquired. No progress in obtaining confidentiality waivers from processors.
- *The SSC would appreciate additional insights from the assessment author into the performance of the random effects model.*
  - **Response:** We further explored the random effects model performance and provide details in Appendix A.

- CPT, May 2017:
  - *Investigate whether size frequency data is available for the 2002 and 2004 surveys, so that biomass estimates for mature and legal males could be estimated and included in the model simulations.*
    - **Response:** Crab specimen data collection not part of 2002 survey protocol. Crab specimen data does exist for 2004 survey (in its original form) but we have not been able to acquire it. As a work around, we calculated the ratio of MMB:Total biomass for 2008-2016 surveys, and applied the average to total biomass to obtain MMB for 2002 and 2004.
  - *Investigate the sex ratios in 2008, 2012, 2012, and 2016 data. If the sex ratios are reasonably stable in each of those years, then mature and legal biomass estimates could be made in 2002 and 2004 using the sex ratios from the known survey years (i.e., use 2002 and 2004 raw survey data to get size compositions to extend time series backwards via scaling).*
    - **Response:** See previous comment.
  - *Put bounds on the process error and rerun the model.*
    - **Response:** After investigating the model performance in the .par file, it appears the model did converge (maximum gradient component is <0.0001).

C. Introduction

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

2. **Description of general distribution:**

General distribution of golden king crab:

> 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 (NMFS 2004).
>
> 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, and are frequently found on coral (NMFS 2004, pages 3–43).

The Pribilof District is part of king crab Registration Area Q (Figure 1). Leon et al. (2017) define those boundaries:

> The Bering Sea king crab Registration Area Q southern boundary is 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. The northern boundary is the latitude of Point Hope (68°21′N lat). The eastern boundary is a line from 54°36′N lat, 168°W long, to 58°39′N lat, 168°W long, to Cape Newenham (58°39′N lat). The western boundary is the United States-Russia Maritime Boundary Line of 1990 (Figure 2-4). Area Q is divided into 2 districts: the Pribilof District, which includes waters south of Cape Newenham; and the Northern District, which includes all waters north of Cape Newenham.

The NMFS-AFSC conducted an eastern Bering Sea continental slope trawl survey on a biennial schedule during 2002–2016 (the 2014 survey was cancelled). Results of this survey from 2002–2016 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, 2016; Hoff and Britt 2003, 2005, 2009, 2011; Pengilly 2015; Pengilly and Daly 2017). Of the six survey subareas (see Figure 1 in Hoff 2016), biomass and abundance of golden king crab were estimated through 2016 to be highest in the Pribilof Canyon area (survey subarea 2), and most of the commercial fishery catches for golden king crab have occurred there (Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006; Leon et al. 2017).

Results of the 2002–2016 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 (Hoff and Britt 2003, 2005, 2009, 2011; Haaga et al. 2009; Hoff 2013, 2016). 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 and Britt 2003, 2005, 2009, 2011; Gaeuman 2013b, 2014; Hoff 2013, 2016). 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, Pengilly and Daly 2017; Appendix A1), but the stock relationship between golden king crab within and 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 observations on embryo development in golden king crab, Otto and Cummiskey (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 two 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 lecithoatrophic 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 was reviewed by Webb (2014).

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

5. Brief summary of management history:

A complete summary of the management history through 2015 is provided in Leon et al. (2017).

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 have 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, 2015, and 2016, one vessel fished in each of 2010, 2012–2014, and 2018 and two vessels fished in 2011, 2017, and 2019.

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, 2010–2014, and 2017-2019 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).

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)). 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. Summary of new information:

1. Retained catch and estimated discarded catch during the 2019 directed, estimated discarded catch during other crab fisheries in 2019 (no catch), and the estimated discarded catch in groundfish fisheries during 2019 have been added.

2. Data presented as time series:

a. Total catch and b. Information on bycatch and discards:

- The 1981/82–1983/84, 1984–2019 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 1993–2019 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 within 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, 2010−2014, and 2017-2019. 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 from 1991/92–2008/09, and by calendar years from 2009–2019. The 1991/92–2019 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 2009–2019 are from the State statistical areas falling within the Pribilof District.
- 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 Appendix A for biomass estimates of mature male golden king crab using data from the 2002–2016 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 Appendix A for size data composition by sex of golden king crab during the 2002–2016 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 = 0.0014240 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 is classified as 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, 2013b; Hoff 2016). Data and analysed results pertaining to golden king crab from the 2002–2016 EBS upper continental slope surveys are provided in Appendices A and B but are not used in this Tier 5 assessment.

- 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, 2013b), Pengilly (2015), and Pengilly and Daly (2017) presented assessment-modelling approaches for this stock to the Crab Plan Team using data from the biennial NMFS EBS continental slope survey. However, this stock continued to be managed as a Tier 5 stock for 2018-2020, as had been recommended by NPFMC (2007) and by the CPT and SSC in 2008−2017.

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 2021-2023.

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, and 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 2014–2017 Tier 5 OFLs (i.e., the Alternative 1 that was presented in 2013). The 2021-2023 Tier 5 OFL recommended here uses the same approach as used for the 2013–2020 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.,

$$OFL_{2021\text{-}2023} = (1+R_{2001–2010})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93–98/99,}$$

where,

- $R_{2001–2010}$ is the average of the estimated annual ratio of 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).

There are no discarded catch data available for the non-directed fisheries during 1993, thus 1994–1998 is used to estimate average annual bycatch mortality in non-directed fisheries.

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_{2018} is,

$$OFL_{2021\text{-}2023} = (1+0.052)*78.80 \text{ t} + 6.09 \text{ t} + 3.79 \text{ t} = 93 \text{ t (204,527 lbs)}.$$

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

Model	Retained-vs. Total-catch	Time Period	Resulting OFL (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 2010–2020. The time period 1993–1998 provides the longest continuous time period through 2019 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. Basis for projecting MMB to the time of mating: Not applicable for Tier 5 stock.

c. ***Specification of F_{OFL}, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:*** See table below. Because less than three vessels participated in the 2017, 2018, and 2019 directed fisheries, catch numbers are not reported here under the confidentiality requirements of State of Alaska (SOA) statute Sec. 16.05.815. Although fishery mortality occurred during groundfish fisheries in 2017, 2018, and 2019, this and the fishery mortality in the directed fisheries did not exceed the corresponding OFL. As such, overfishing did not occur in 2017, 2018, and 2019. Values for the 2021-2023 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
2016	N/A	N/A	59	0	0.24	91	68
2017	N/A	N/A	59	Conf.	Conf.	93	70
2018	N/A	N/A	59	Conf. [c]	Conf. [c]	93	70
2019	N/A	N/A	59	Conf.	Conf.	93	70
2020	N/A	N/A	59			93	70
2021	N/A	N/A				93	70
2022	N/A	N/A				93	70
2023	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 and groundfish fisheries. Total reratined catch is not listed for 2017–2019 because the directed fishery is confidential under Sec. 16.05.815(SOA statute).
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.

Management Performance Table (values in millions of lb)

Calendar Year	MSST	Biomass (MMB)	GHL[a]	Retained Catch	Total Catch[b]	OFL	ABC
2016	N/A	N/A	130,000	0	<0.001	0.20	0.15
2017	N/A	N/A	130,000	Conf.	Conf.	0.20	0.15
2018	N/A	N/A	130,000	Conf.[c]	Conf.[c]	0.20	0.15
2019	N/A	N/A	130,000	Conf.	Conf.	0.20	0.15
2020	N/A	N/A	130,000				
2021	N/A	N/A					
2022	N/A	N/A					
2023	N/A	N/A					

a. Guideline harvest level, established in lb and converted to t.
b. Total retained catch plus estimated bycatch mortality of discarded catch during crab and groundfish fisheries. Total reratined catch is not listed for 2017–2019 because the directed fishery is confidential under Sec. 16.05.815(SOA statute).
c. Confidential under Sec. 16.05.815 (SOA statute). GHL not attained.

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 2021, 2022, 2023 (70 t); see G.4, below.

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

G. Calculation of ABC

1. PDF of OFL. A bootstrap estimate 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 2020 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 2008–2016 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, 2013b), Pengilly and Daly (2017), and Appendix A of this assessment. Cancellation of the survey that was scheduled for 2018 and 2020 raised uncertainties on the prospects for obtaining fishery-independent survey data on this stock in the future. However,

ADF&G is currently exploring the feasibility of initiating in industry-cooperative survey as a means to acquire biological data for future assessments.

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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	–	–
2016	0	59	0	0	0	–	–
2017	2	59	CF	CF	CF	CF	CF
2018	1	59	CF	CF	CF	CF	CF
2019	2	59	CF	CF	CF	CF	CF

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 2019: 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	–	–
2016	0	130,000	0	0	0	–	–
2017	2	130,000	CF	CF	CF	CF	CF
2018	1	130,000	CF	CF	CF	CF	CF
2019	2	130,000	CF	CF	CF	CF	CF

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, 1993–2019, 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
2016	no fishing	no fishing	0.00	no fishing	0.00
2017	confidential	confidential	0.00	confidential	confidential
2018	confidential	confidential	0.00	no fishing	confidential
2019	confidential	confidential	0.00	no fishing	confidential

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) 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. 1991/92–2008/09 is listed by crab fishery year, while 2009-2019 are listed by calendar year.

Crab fishing year (1991/92–2008/09) or Calendar year (2009-2019)	Bycatch in groundfish fisheries (no mortality rate applied)			Total Mortality
	Fixed	Trawl	Total	
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	2.67	2.55	5.22	3.38
2010	2.13	1.01	3.14	1.87
2011	0.85	1.33	2.18	1.49
2012	0.73	0.82	1.55	1.02
2013	0.50	2.49	2.99	2.24
2014	0.61	0.53	1.14	0.73
2015	0.81	1.89	2.70	1.92
2016	0.23	0.16	0.39	0.24
2017	0.15	1.34	1.49	1.15
2018	0.10	1.59	1.69	1.32
2019	0.05	4.86	4.91	3.91
Average	1.53	1.91	3.44	2.29

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	2.67	2.55
2010	2010/11	Confidential	**Confidential**	0.00	2.13	1.01
2011	2011/12	Confidential	Confidential	0.27	0.85	1.33
2012	2012/13	Confidential	Confidential	0.27	0.73	0.82
2013	2013/14	Confidential	Confidential	0.58	0.50	2.49
2014	2014/15	Confidential	Confidential	0.12	0.61	0.53
2015	2015/16	0.00	0.00	0.00	0.814	1.890
2016	2016/17	0.00	0.00	0.00	0.232	0.158
2017	2017/18	Confidential	Confidential	0.81	0.146	1.345
2018	2018/19	Confidential	Confidential	0.00	0.103	1.589
2019	2019/20	Confidential	Confidential	0.00	0.049	4.861

a. Year convention for retained weights in directed fishery, 1984-2019, estimates of discarded bycatch weights in directed, non-directed crab fisheries, and grounfish (2009-2019).

b. Year convention for retained weights in directed fishery, 1981/82-1983/84, and estimates of discarded bycatch rates in groundfish fisheries (1991/92-2008/09).

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 2021-2023 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 $BM_{GF,92/93\text{-}98/99}$.

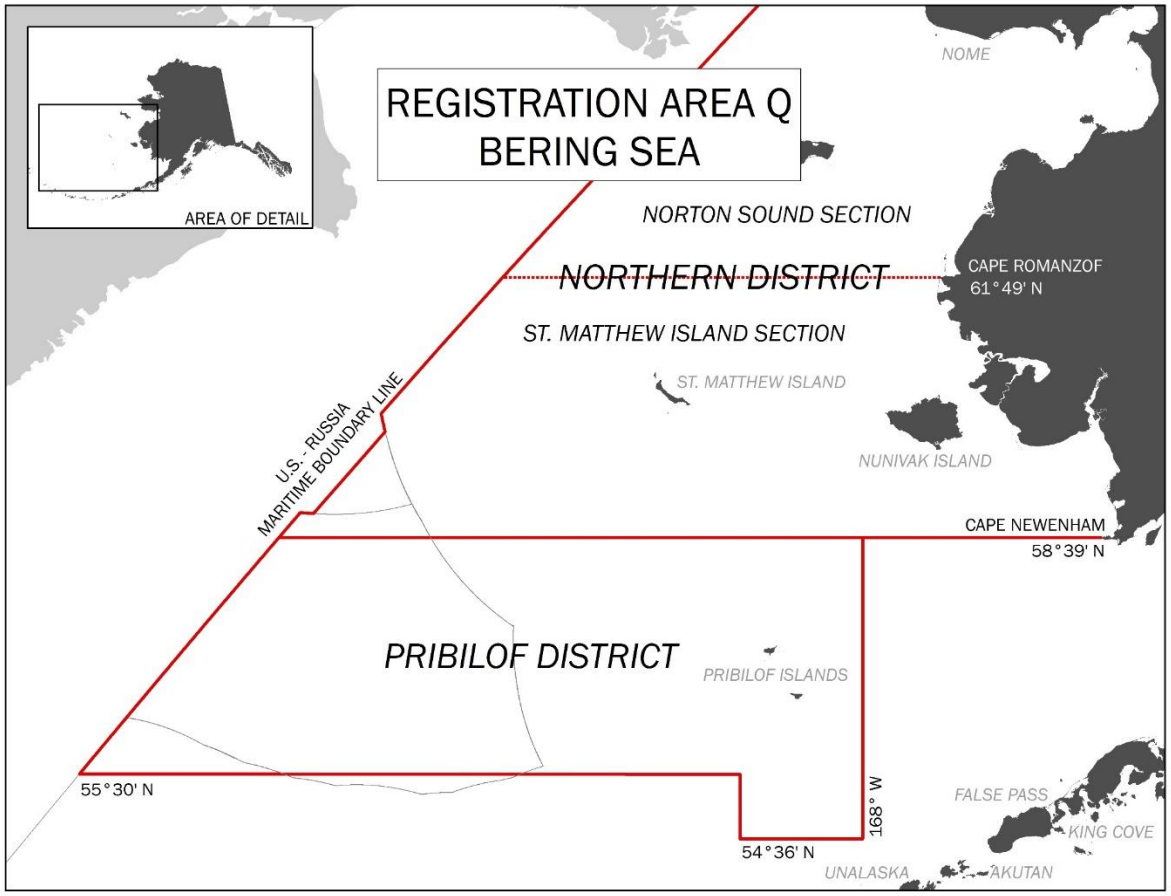

Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District.

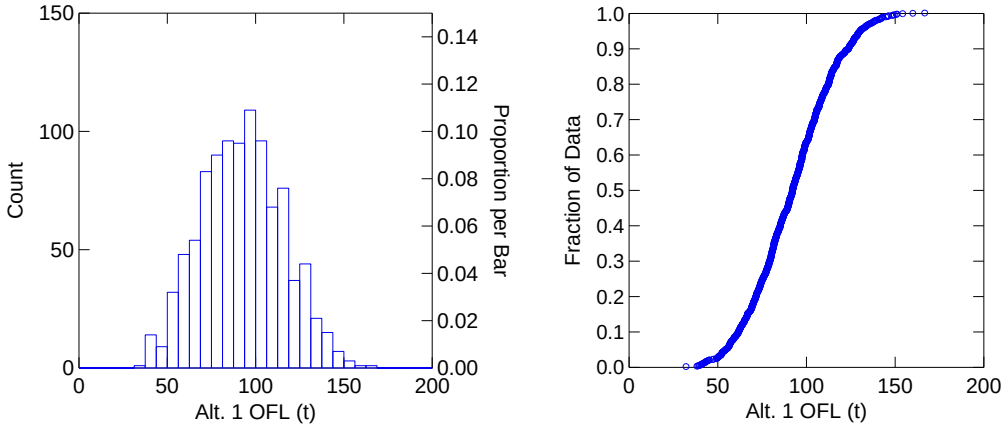

Figure 2. Bootstrapped estimates of the sampling distribution of the 2021-2023 Alternative 1 Tier 5 OFL (total catch, t) for the Pribilof Islands golden king crab stock; histogram on left, quantile plot on right.