Pribilof Islands Golden King Crab – 2013 Tier 5 Assessment

May 2013 Crab SAFE Report Chapter (15 April 2013 Draft)

Douglas Pengilly, ADF&G, Kodiak

## Executive Summary

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

Commercial fishing for golden king crab in the Pribilof District has been concentrated in the Pribilof Canyon. The fishing season for this stock has been defined as a calendar year (as opposed to a “crab fishery year”) following the close of the 1983/84 season. The domestic fishery developed in the 1982/83 season, although some limited fishing occurred at least as early as 1981/82. Peak harvest occurred in the 1983/84 season with a retained catch of 0.856-million pounds (388 t) by 50 vessels. Since then, participation in the fishery has been sporadic and annually retained catch has been variable, from 0 pounds in the nine years that no vessels participated (1984, 1986, 1990–1992, 2006–2009) up to a maximum of 0.342-million pounds (155 t) in 1995, when seven vessels made landings. The fishery is not rationalized. There is no state harvest strategy in regulation. A guideline harvest level (GHL) was first established for the fishery in 1999 at 0.200-million pounds (91 t) and has been managed towards a GHL of 0.150-million pounds (68 t) since 2000. No vessels participated in the directed fishery and no landings were made during 2006–2009. One vessel landed catch in 2010, two vessels landed catch in 2011, and one vessel landed catch in 2012; directed fishery catch cannot be reported for those three years under the confidentiality requirements of State of Alaska (SOA) statute Sec. 16.05.815. Non-retained bycatch occurs in the directed golden king crab fishery, the eastern Bering Sea snow crab fishery, the Bering Sea grooved Tanner crab fishery, and Bering Sea groundfish fisheries. Estimated annual weight of non-retained bycatch in directed and non-directed crab fisheries during calendar years 2001–2012 ranges from 0 pounds to 0.049-million pounds (22 t). Estimates of annual total fishery mortality during calendar years 2001–2012 due to crab fisheries range from 0 to 0.160-million pounds (73 t), with an average of 0.076-million pounds (34 t). Estimates of annually discarded bycatch during Bering Sea groundfish fisheries are reported for crab fishery years. Those estimates range from <0.001-million (<1 t) to 0.027-million pounds (12 t) annually during the 1991/92–2011/12 crab fishery years. Estimates of annual fishery mortality during 1991/92–2011/12 due to groundfish fisheries range from <0.001-million pounds (<1 t) to 0.019-million pounds (9 t), with an average of 0.006-million pounds (3 t).

1. **Stock biomass:**

Stock biomass (all sizes, both sexes) of golden king crab have been estimated for the Pribilof Canyon area using the area-swept technique applied to data obtained during eastern Bering Sea upper continental slope trawl surveys performed by NMFS-AFSC in 2002 (Hoff and Britt 2003), 2004 (Hoff and Britt 2005), 2008 (Hoff and Britt 2009), and 2010 (Hoff and Britt 2011). Data is available from the 2012 upper continental slope survey (C. Armistead, NMFS-AFSC, Kodiak). Complete data on size-sex composition of survey catch is available only from the 2008, 2010, and 2012 surveys (C. Armistead, NMFS-AFSC, Kodiak). Biomass estimates by sex and size class from the 2008, 2010, and 2012 surveys are presented in a separate May 2013 report to the Crab Plan Team (Gaeuman 2013).

1. **Recruitment:**

From data collected during the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental slope surveys biomass of golden king crab (all sizes and both sexes) are estimated to have increased in the surveyed area of eastern Bering Sea. Biomass in the Pribilof Canyon area was estimated to have increased from 1.504-million pounds (682 t) in 2002 to 3.560-million pounds (1,615 t) in 2010; biomass for the entire slope survey area was estimated to have increased from 2.227-million pounds (1,010 t) in 2002 to 5.071-million pounds (2,300 t) in 2010. Using data from the 2012 NMFS-AFSC eastern Bering Sea upper continental slope survey, Gaeuman (2013) estimated total biomass for 2012 in the Pribilof Canyon area to be 1.567-million pounds (711 t) and 4.244-million pounds (1,925 t) for the entire survey area.

1. **Management performance:**

No overfished determination (i.e., MSST) has been made for this stock, but see Gaeuman (2013) for estimates of mature male biomass for this stock from the 2008, 2010, and 2012 eastern Bering Sea upper continental slope trawl survey data. Overfishing did not occur during 2012 (the golden king crab season in the Pribilof District is based on a calendar year); the estimated total catch did not exceed the OFL of 0.20-million pounds (91 t). Total catch did not exceed the total-catch ABC of 0.18-million pounds (82 t) that was established for the 2012 season. Retained catch and total-catch mortality in 2012 are confidential under the requirements of Sec. 16.05.815 (SOA statute). The 2013 season is currently ongoing; 2014 season hasn’t started yet. The 2014 OFL and ABC are the author’s recommendations.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Yeara** | **MSST** | **Biomass (MMB)** | **GHLb** | **Retained Catchc** | **Total Catchc,d** | **OFLc,e** | **ABCc,e** |
| 2010 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.17 R | N/A |
| 2011 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.18 T | N/A |
| 2012 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.20 T | 0.18 T |
| 2013 | N/A | N/A | 0.150 |  |  | 0.20 T | 0.18 T |
| 2014 | N/A | N/A |  |  |  | 0.20 T | 0.18 T |

1. Season is based on a calendar year.
2. Guideline harvest level expressed in millions of pounds.
3. Millions of pounds.
4. Total retained catch plus estimated bycatch mortality during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by “crab fishery year” rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
5. Noted as “R” for retained-catch-only OFL and “T” for total-catch OFL and ABC.
6. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): ≤2 vessels participated in each season.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Yeara** | **MSST** | **Biomass**  **(MMB)** | **GHLb** | **Retained**  **Catchc** | **Total**  **Catchc,d** | **OFLc,e** | **ABCc,e** |
| 2010 | N/A | N/A | 68 | Conf. f | Conf. f | 77 R | N/A |
| 2011 | N/A | N/A | 68 | Conf. f | Conf. f | 82 T | N/A |
| 2012 | N/A | N/A | 68 | Conf. f | Conf. f | 91 T | 82 T |
| 2013 | N/A | N/A | 68 |  |  | 91 T | 82 T |
| 2014 | N/A | N/A |  |  |  | 91 T | 82 T |

1. Season is based on a calendar year.
2. Guideline harvest level expressed in t.
3. Metric tons.
4. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by “crab fishery year” rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤9 t, with an average of 3 t.
5. Noted as “R” for retained-catch-only OFL and “T” for total-catch OFL and ABC.
6. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): ≤2 vessels participated in each season.
7. **Basis for the OFL and ABC:** The values for 2014 are the author’s recommendation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Yeara** | **Tier** | **Years to define**  **Average catch (OFL)** | **Natural**  **Mortalitye** | **Buffer** |
| 2010 | 5 | 1993–1998b | 0.18 yr-1 | N/A |
| 2011 | 5 | 1993–1998c | 0.18 yr-1 | N/A |
| 2012 | 5 | 1993–1998d | 0.18 yr-1 | 10% |
| 2013 | 5 | 1993–1998d | 0.18 yr-1 | 10% |
| 2014 | 5 | 1993–1998d | 0.18 yr-1 | 10% |

1. Season is based on a calendar year.
2. OFL was for retained catch and was determined by the average of the retained catch for these years.
3. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.05 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
4. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.052 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
5. Assumed value for FMP king crab in NPFMC (2007); does not enter into OFL estimation for Tier 5 stock.
6. **PDF of the OFL:** Sampling distribution of the two alternative Tier 5 OFLs was estimated by bootstrapping. The standard deviation of the estimated sampling distribution of the recommended OFL (Alternative 1) is 0.510-million pounds (CV = 0.25). See section G.1.
7. **Basis for the ABC recommendation:** A 10% buffer on the OFL, the default; i.e.,

ABC = (1-0.1)·OFL.

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

### A. Summary of Major Changes

1. **Changes to the management of the fishery:** None. Fishery continues to be managed under authority of an ADF&G commissioner’s permit and with a guideline harvest level (GHL) of 0.150-million pounds (68 t). As of this writing, one vessel has registered for the 2013 season, but has not yet begun fishing (W. Donaldson, ADF&G, 28 March 2013 *pers. comm*).
2. **Changes to the input data:**

* Retained catch and bycatch data has been updated with the results for the 2012 directed fishery, during which only one vessel participated in the fishery, rendering the catch data confidential under the requirements of Sec. 16.05.815 (SOA statute).
* Bycatch estimates from other non-directed crab fisheries have been updated with data from 2012.
* Bycatch estimates have been updated using the data collected from groundfish fisheries during 2011/12.

1. **Changes to the assessment methodology:** None. This assessment follows the methodology recommended by the CPT in May 2012 and the SSC in June 2012.
2. **Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL:**

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

OFLtot,2011= 1.05\*OFLret,1993-1998 + 0.006-million pounds.

OFLret,1993-1998 is the average annual retained catch in the directed fishery during 1993–1998. The factor of 1.05 was used to account for the crab bycatch mortality in the directed crab fishery and 0.006-million pounds was used to account for the “background level” of bycatch mortality occurring in the groundfish and non-directed crab fisheries, estimated by the average annual bycatch mortality using data available; 2001–2005 for crab fisheries and 1991/92–2008/09 for groundfish fisheries.

* The OFLs for 2012 and 2013 were each a total-catch OFL of 0.20-million pounds and were estimated using 1993–1998 to compute average annual retained catch, an estimate of pounds of bycatch mortality per pound of retained catch during the directed fishery, an estimate of the average annual bycatch mortality due to non-directed crab fisheries during 1994–1998 and an estimate of average annual bycatch mortality due to groundfish fisheries during 1992/93–1998/99; i.e.,

OFLTOT(1),2013= (1+R2001–2010)\*RET1993-1998 + BMNC,1994-1998 + BMGF,1992/93–1998/99,

where,

* R2001–2010 is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained in the directed fishery during 2001–2010
* RET1993-1998 is the average annual retained catch in the directed crab fishery during 1993–1998
* BMNC,1994-1998 is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
* BMGF,1992/93–1998/99 is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.
* The recommended Tier 5 OFL for 2014 is a total-catch OFL of 0.20-million pounds, estimated by the calculations given for the 2013 OFL.

### B. Responses to SSC and CPT Comments

1. **Responses to the most recent two sets of SSC and CPT comments on assessments in general (and relevant to this assessment):**

* CPT, May 2012: None.
* SSC, June 2012: None.
* CPT, September 2012 (via Sept 2012 SAFE):
  + - * *“The team recommends that all assessment authors document assumptions and simulate data under those assumptions to test the ability of the model to estimate key parameters in an unbiased manner. These simulations would be used to demonstrate precision and bias in estimated model parameters.”*
        + Response: Not applicable for Tier 5 assessment.
    - *“The CPT recommends the listing of sigmas instead of absolute weights as being more informative for factors such as L50 and β. Also, the team recommends specifying weights for the penalties on L50 and from the standard errors from the analysis on which the estimates for these parameters were based.”*
      * Response: Not applicable for Tier 5 assessment.
      * *“The team requests all authors to consult the Guidelines for SAFE preparation and to follow the Terms of Reference as listed therein as applicable by individual assessment for both content and diagnostics.”*
      * Response: Guidelines for SAFE preparation as supplied in 26 July 2012 email from the CPT chair were consulted and followed.
      * *“The team requests that to the extent possible assessments include a listing of the tables and figures in the assessment (i.e., Table of Tables, Table of Figures).”*
      * Response: Listing of tables and figures is included.
* SSC, October 2012: *None*.

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

* CPT, May 2012: *None.*
* SSC, June 2012:
  + *“Following the advice of the assessment author and CPT, the SSC recommends a total catch OFL of 0.09 kt (91 t) and ABC (using the 10% buffer for tier-5 stocks) of 0.08 kt (82 t) for 2012/13, based on Alternative 1 in the assessment, which uses bycatch data for the directed fishery through 2010 only.”*
  + Response: The SSC meant “2013” and not “2012/13.” This assessment presents the same Alternative 1 OFL with a 10% buffer for determination of the ABC for consideration of a Tier 5 OFL and ABC for 2014.
  + *“For the next assessment cycle, the SSC requests that the slope survey data be used to bring forward Tier 4 calculations because estimates from the slope survey appear reasonable, cover the known depth range of golden king crab, and size composition data are available to calculate biomass of legal-sized males.”*
  + Response:A report on the issues for consideration of a Tier 4 assessment using the slope survey data has been prepared by Gaeuman (2013) for consideration at the May 2013 CPT meeting.
  + *“The SSC also notes that the assessment uses calendar year for all calculations except for PSC in the groundfish fisheries, which are estimated based on “crab fishing years”. For consistency, the SSC suggests that calendar year be used throughout.”*
  + Response: The author has noted this situation in the past assessments, but has not directly asked NMFS-AFSC for the bycatch data to be summarized by calendar year. The author suggests that the CPT explore the feasibility of NMFS-AFSC providing the data on bycatch of this stock for the most recent calendar year by 1 April. If that is feasible, the CPT should request that for the next NMFS-AFSC provide the data from the previous calendar year to the assessment author by 1 April 2014 and subsequent years. If the author receives the bycatch data summary for the previous calendar year by 1 April, all fishery data will be summarized by calendar year in the 2014 and subsequent assessment reports.
* CPT, September 2012 (via Sept 2012 SAFE): *“The team concurs with the author’s recommendation for an OFL based on Alternative 1 for 2013 of 0.2 million lb and the maximum permissible ABC of 0.18 million lb. The ABC was derived by applying the Tier 5 control rule a 10% buffer of the OFL, ABC = 0.9\*OFL.”*
  + Response: This assessment presents the same Alternative 1 OFL with a 10% buffer for determination of the ABC for consideration of a Tier 5 OFL and ABC for 2014.
* SSC, October 2012: *None*.

## C. Introduction

1. **Scientific name:** *Lithodes aequispinus* J. E. Benedict, 1895
2. **Description of general distribution:** General distribution of golden king crab is summarized by NMFS (2004):

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

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

The Pribilof District is part of king crab Registration Area Q (Figure 1). Fitch et al. (2012, page 85) define those boundaries:

The Bering Sea king crab Registration Area Q has as its southern boundary a line from 54° 36’ N lat., 168° W long., to 54° 36’ N lat., 171° W long., to 55° 30’ N lat., 171° W. long., to 55° 30’ N lat., 173° 30’ E long., as its northern boundary the latitude of Point Hope (68° 21’ N lat.), as its eastern boundary a line from 54° 36’ N lat., 168° W long., to 58° 39’ N lat., 168° W long., to Cape Newenham (58° 39’ N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991. Area Q is divided into the Pribilof District, which includes waters south of Cape Newenham, and the Northern District, which incorporates all waters north of Cape Newenham.

Results of the 2002, 2004, 2008, 2010, and 2012 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009), Hoff and Britt (2003, 2005, 2009, 2011), and Gaeuman (2013) show that the biomass, number, and density (in number per area and in weight per area) of golden king crab on the eastern Bering Sea continental slope are higher in the southern areas than in the northern areas. Highest densities, biomass, and abundance of golden king crab in the Bering Sea occur in the Pribilof Canyon, as does most of the commercial catch of golden king crab (Fitch et al. 2012; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006).

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

1. **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 2013). Stock structure within the Pribilof District and the stock relationship of the golden king crab within the Pribilof District with the golden king crab outside of the Pribilof District have not been evaluated.
2. **Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology):** The following review of molt timing and reproductive cycle of golden king crab is adapted from Watson et al. (2002):

Unlike red king crab, golden king crab may have an asynchronous molting cycle (McBride et al. 1982, Otto and Cummiskey 1985, Sloan 1985, Blau and Pengilly 1994). In a sample of male golden king crab 95–155-mm CL and female golden king crab 104–157-mm CL collected from Prince William Sound and held in seawater tanks, Paul and Paul (2000) observed molting in every month of the year, although the highest frequency of molting occurred during May–October. Watson et al. (2002) estimated that only 50% of 139-mm CL male golden king crab in the eastern Aleutian Islands molt annually and that the intermolt period for males ≥150-mm CL averages >1 year.

Female lithodids molt before copulation and egg extrusion (Nyblade 1987). From their observations on embryo development in golden king crab, Otto and Cummiskey’s (1985) suggested that time between successive ovipositions was roughly twice that of embryo development and that spawning and molting of mature females occurs approximately every two years. Sloan (1985) also suggested a reproductive cycle >1 year with a protracted barren phase for female golden king crab. Data from tagging studies on female golden king crab in the Aleutian Islands are generally consistent with a molt period for mature females of 2 years or less and that females carry embryos for less than two years with a prolonged period in which they remain in barren condition (Watson et al 2002). From laboratory studies of golden king crab collected from Prince William Sound, Paul and Paul (2001b) estimated a 20-month reproductive cycle with a 12-month clutch brooding period.

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

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

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

1. **Brief summary of management history:** A complete summary of the management history through 2010 is provided in Fitch et al. (2012, pages 89–91).

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

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

Only males of a minimum legal size may be retained. By State of Alaska regulation (**5 AAC 34.920 (a)**), the minimum legal size limit for Pribilof District golden king crab is 5.5-inches (140 mm) carapace width (CW), including spines. A carapace length (CL) ≥124 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007).

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

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

### D. Data

1. **Summary of new information:**
2. Retained catch and estimated bycatch during the 2012 directed fishery (both of which are confidential), estimated bycatch in non-directed crab fisheries during 2012, and estimated bycatch in groundfish fisheries during the 2010/11 crab fishery year have been added. Results for golden king crab from the 2012 eastern Bering Sea upper continental slope survey are presented in Gaeuman (2013).
3. **Data presented as time series:**
4. ***Total catch and b. Information on bycatch and discards:***

* The 1981/82–1983/84, 1984–2012 time series of retained catch (number and pounds of crab harvested, including deadloss), effort (vessels, landings, and pot lifts), average weight of landed crab, average carapace length of landed crab, and CPUE (number of landed crab captured per pot lift) are presented in Table 1.
  + The 1993–2012 time series of weight of retained catch, estimated bycatch and estimated weight of fishery mortality of Pribilof golden king crab during commercial crab fisheries are given in Table 2. Bycatch of Pribilof golden king crab occurs mainly in the directed golden king crab fishery, when prosecuted, and to a lesser extent in the Bering Sea snow crab fishery and the Bering Sea grooved Tanner crab fishery. Because the Bering Sea snow crab fishery is prosecuted mainly or entirely between January and May and the Bering Sea grooved Tanner crab fishery is prosecuted with a calendar-year season, bycatch for the crab fisheries can be estimated on a calendar-year basis to align with the season for Pribilof District golden king crab. Observer data on size distributions and estimated catch numbers of non-retained catch were used to estimate the weight of non-retained catch of golden king crab by applying a weight-at-length estimator (see below). Observers were first deployed to collect bycatch data during the Pribilof District golden king crab fishery in 2001 and during the Bering Sea grooved Tanner crab fishery in 1994. Retained catch or observer data are confidential for at least one of the crab fisheries in 1999–2001, 2003–2005, and 2010−2012. Following Siddeek et al. (2011), the bycatch mortality rate of golden king crab captured and discarded during Aleutian Islands golden king crab fishery was assumed to be 0.2. Following Foy (2012a, 2012b), bycatch mortality rate of king crab during the snow crab fishery was assumed to be 0.5. The bycatch mortality rate during the grooved Tanner crab fishery was also assumed to be 0.5.
  + The groundfish fishery data were grouped into crab fishery years, rather than into calendar years. The 1991/92–2011/12 time series of estimated annual weight of bycatch and total fishery mortality of golden king crab in reporting areas 513, 517, and 521 during federal groundfish fisheries by gear type (combining pot and hook-and-line gear as a single “fixed gear” category and combining non-pelagic and pelagic trawl gear as a single “trawl” category) is provided in Table 3. Following Foy (2012a, 2012b), 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.

1. ***Catch-at-length:*** Not used in a Tier 5 assessment; none are presented.
2. ***Survey biomass estimates:*** Survey biomass estimates are not used in a Tier 5 assessment. However, see Gaeuman (2013) for biomass estimates of golden king crab using data from NMFS-AFSC eastern Bering Sea upper continental slope trawl survey.
3. ***Survey catch at length:*** Survey catch at length data are not used in a Tier 5 assessment. However, see Gaeuman (2013) for size data composition by sex of golden king crab during Bering Sea upper continental slope trawl surveys.
4. ***Other data time series:*** None.
5. **Data which may be aggregated over time:**
   1. ***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).

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

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

1. ***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.

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

* Standardized bottom trawl surveys to assess the groundfish and invertebrate resources of the eastern Bering Sea (EBS) upper continental slope were performed in 2002, 2004, 2008, 2010, and 2012 (Hoff and Britt 2003, 2005, 2009, 2011; Haaga et al. 2009, Gaeuman 2013). Data from the EBS upper continental slope surveys are not presented in this tier 5 assessment but are presented in Gaeuman (2013).
* Data on the size and sex composition of retained catch and bycatch 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:** This is a Tier 5 stock; there is no assessment model and no history of assessment modelling approaches for this stock.

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

No assessment model for the Pribilof Islands golden king crab stock exists and none is in development (Note, however, that the utility for stock assessment of data from the biennial NMFS EBS continental slope survey is considered by Gaeuman, 2013). Accordingly, it has been recommended by NPFMC (2007) and by the CPT and SSC in 2008−2011 that the Pribilof Islands golden king crab stock be managed as a Tier 5 stock. For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST without an estimate of biomass, and “the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock” (NPFMC 2007). Although NPFMC (2007) defined the OFL in terms of the retained catch, total-catch OFLs may be considered for Tier 5 stocks for which nontarget fishery removal data are available (Federal Register/Vol. 73, No. 116, 33926). The CPT (in May 2010) and the SSC (in June 2010) endorsed the use of a total-catch OFL to establish the OFL for this stock. This assessment recommends – and only considers – use of a total-catch OFL for 2014.

Additionally, NPFMC (2007) states that for estimating the OFL of Tier 5 stocks, “The time period selected for computing the average catch, hence the OFL, should be based on the best scientific information available and provide the required risk aversion for stock conservation and utilization goals.” Given that a total-catch OFL is to be used, alternative configurations for the Tier 5 model are limited to: 1) alternative time periods for computing the average total-catch mortality; and 2) alternative approaches for estimating the non-retained component of the total catch mortality during that period.

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

## Model Selection and Evaluation:

* 1. ***Description of alternative model configurations***

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

OFL1, 2014 = (1+R2001–2010)\*RET1993-1998 + BMNC,1994-1998 + BMGF,92/93–98/99,

where,

* R2001–2010 is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained catch in the directed fishery during 2001–2010
* RET1993-1998 is the average annual retained catch in the directed crab fishery during 1993–1998
* BMNC,1994-1998 is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
* BMGF,92/93–98/99 is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

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

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

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

Statistics on the data and estimates used to calculate RET1993-1998, R2001-2010, BMNC,1994-1998,and BMGF,93/94-98/99 are provided in Table 4; the column means in Table 4 are the calculated values of RET1993-1998, R2001-2010, BMNC,1994-1998,and BMGF,93/94-98/99. Using the calculated values of RET1993-1998, R2001-2010, BMNC,1994-1998,and BMGF,93/94-98/99, OFL1, 2014 is,

OFL1,2014= (1+0.052)\*173,722 + 13,418 + 8,353 = 204,611 lbs (0.20-million lbs).

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

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

Alternative 1 is recommended and is the status quo; it 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 to calculation of the OFL at that established for the 2012 OFL.

* 1. ***Evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models:*** See Section E, above.
  2. ***Convergence status and convergence criteria for the base-case model (or proposed base-case model):*** Not applicable.
  3. ***Table (or plot) of the sample sizes assumed for the compositional data:*** Not applicable.
  4. ***Do parameter estimates for all models make sense, are they credible?:***

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

* 1. ***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.
  2. ***Residual analysis (e.g. residual plots, time series plots of observed and predicted values or other approach):*** Not applicable.
  3. ***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.

## Results (best model(s)):

1. ***List of effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties:*** Not applicable.
2. ***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.
3. ***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.
4. ***Evaluation of the fit to the data:*** Not applicable for Tier 5 stock.
5. ***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.
6. ***Uncertainty and sensitivity analyses (this section should highlight unresolved problems and major uncertainties, along with any special issues that complicate scientific assessment, including questions about the best model, etc.):*** For this assessment, the major uncertainties are:

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

## *F. Calculation of the OFL*

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

* Recommended as Tier 5, total-catch OFL estimated by estimated average total catch over a specified period.
* Recommended time period for computing retained-catch OFL: 1993–1998.
  + This is the time period used to establish OFL for the 2010–2013 seasons. The time period 1993–1998 provides the longest continuous time period through 2012 during which vessels participated in the fishery, retained-catch data can be retrieved that are not confidential, and the retained catch was not constrained by a GHL. Data on bycatch mortality contemporaneous with 1993-1998 to the extent possible are used to calculate the total-catch OFL in the recommended Alternative 1.

1. **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.
2. **Specification of the total-catch OFL:**
   1. ***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.”

* 1. ***Basis for projecting MMB to the time of mating******:*** Not applicable for Tier 5 stock.
  2. ***Specification of FOFL, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:*** See table below. Although the retained and total catch for 2012 cannot be presented here due to the confidentiality of data, the author can report that total catch in 2012 did not exceed the 2012 OFL. Values for the 2014 OFL and ABC are the author’s recommendations.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Yeara** | **MSST** | **Biomass (MMB)** | **GHLb** | **Retained Catchc** | **Total Catchc,d** | **OFLc,e** | **ABCc,e** |
| 2010 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.17 R | N/A |
| 2011 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.18 T | N/A |
| 2012 | N/A | N/A | 0.150 | Conf.f | Conf.f | 0.20 T | 0.18 T |
| 2013 | N/A | N/A | 0.150 |  |  | 0.20 T | 0.18 T |
| 2014 | N/A | N/A |  |  |  | 0.20 T | 0.18 T |

1. Season is based on a calendar year.
2. Guideline harvest level expressed in millions of pounds.
3. Millions of pounds.
4. Total retained catch plus estimated bycatch mortality during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by “crab fishery year” rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
5. Noted as “R” for retained-catch-only OFL and “T” for total-catch OFL and ABC.
6. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): ≤2 vessels participated in each season.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Yeara** | **MSST** | **Biomass**  **(MMB)** | **GHLb** | **Retained**  **Catchc** | **Total**  **Catchc,d** | **OFLc,e** | **ABCc,e** |
| 2010 | N/A | N/A | 68 | Conf. f | Conf. f | 77 R | N/A |
| 2011 | N/A | N/A | 68 | Conf. f | Conf. f | 82 T | N/A |
| 2012 | N/A | N/A | 68 | Conf. f | Conf. f | 91 T | 82 T |
| 2013 | N/A | N/A | 68 |  |  | 91 T | 82 T |
| 2014 | N/A | N/A |  |  |  | 91 T | 82 T |

1. Season is based on a calendar year.
2. Guideline harvest level expressed in t.
3. Metric tons.
4. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by “crab fishery year” rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤9 t, with an average of 3 t.
5. Noted as “R” for retained-catch-only OFL and “T” for total-catch OFL and ABC.
6. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): ≤2 vessels participated in each season.
7. **Specification of the retained-catch portion of the total-catch OFL:**
   1. **Equation for recommended retained-portion of total-catch OFL.**

Retained-catch portion = average retained catch during 1993–1998

= 173,722 pounds (0.17-million pounds; 79 t).

1. **Recommended FOFL, OFL total catch and the retained portion for the coming year:**

See sections ***F.3*** and ***F.4***, above; no FOFL 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 bycatch) 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 4 to calculate R2001-2010, RET1993-1998, BMNC,1994-1998, BMGF,92/93-98/99  and OFL1,2014). Table 5 provides statistics on the generated distributions.

**2. List of variables related to scientific uncertainty.**

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

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

**4. Author recommended ABC.** 10% buffer on OFL; i.e., ABC = (1-0.1)·(204,612 pounds) = 0.18-million pounds (82 t).

## *H. Rebuilding Analyses*

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

### I. Data Gaps and Research Priorities

Data from the 2002, 2004, 2008, 2010, and 2012 NMFS-AFSC eastern Bering Sea upper continental shelf trawl surveys are examined for their utility in determining overfishing levels and stock status by Gaeuman (2103).

## *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.

## 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. Deiman, J. Shaisnikoff, and K. Herring. 2012. Annual management report for the commercial shellfish fisheries of the Bering Sea, 2010/11. Pages 75–176 *in* Fitch, H., M. Schwenzfeier, B. Baechler, T. Hartill, M. Salmon, M. Deiman, E. Evans, E. Henry, L. Wald, J. Shaishnikoff, K. Herring, and K. Herring. 2012. Annual management report for the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea and the Westward Region’s Shellfish Observer Program, 2010/11. Alaska Department of Fish and Game, Fishery Management Report No. 12-22, Anchorage.

Foy, R. J., 2012a. 2012 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue 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: 2012 Crab SAFE. NPFMC, Anchorage, September 2012.

Foy, R. J., 2012b. 2012 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: 2012 Crab SAFE. NPFMC, Anchorage, September 2012.

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. 2013. 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. *In press*. 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-XX, 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., 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.

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

Siddeek, M.S.M., D. Pengilly, and J. Zheng. 2011. Aleutian Islands golden king crab (*Lithodes aequispinus*) model based stock assessment. <http://www.fakr.noaa.gov/npfmc/PDFdocuments/membership/PlanTeam/Crab/GKCModelBasedAssessWorkShopJan2012.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.

**Table of Tables.**

**Table 1: page 22.** Harvest history for the Pribilof District golden king crab fishery from the 1981/82 season through 2012 (from 2012 SAFE, updated with 2012 data provided by J. Shaisnikoff, ADF&G, Kodiak via 28 March 2013 email).

**Table 2: page 23.** Weight (in pounds) of retained catch and estimated non-retained bycatch of Pribilof golden king crab during crab fisheries, 1993–2012, with total fishery mortality estimated by assuming a bycatch mortality rate of 0.2 for the directed fishery and a bycatch mortality rate of 0.5 for non-directed fisheries (from 2012 Crab SAFE, with update for 2012 catch and bycatch data).

**Table 3: page 24.** Estimated annual weight (pounds) of discarded bycatch of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 513, 517, and 521, 1991/92–2010/12, with total bycatch mortality (pounds) estimated by assuming bycatch mortality rate = 0.5 for fixed-gear fisheries and bycatch mortality rate = 0.8 for trawl fisheries (updated from 2012 SAFE with 2011/12 data provided by R. Foy AFSC, Kodiak Laboratory via 15 August 2012 email).

**Table 4: page 25.** Data for calculation of RET1993-1998 and estimates used in calculation of R2001-2010, BMNC,1994-1998, and BMGF,92/93-98/99 for calculation of the Alternative 1 Pribilof Islands golden king crab Tier 5 2013 total-catch OFL; values under RET1993-1998 are from Table 1, values under R2001-2010 were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under BMNC,1994-1998 were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under BMGF,92/93-98/99 are from Table 3.

**Table 5: page 26.** Statistics for 1,000 bootstrap 2014 OFL for Pribilof Islands golden king crab stock calculated according to Alternatives 1 with the computed OFL for comparison.

**Table of Figures.**

**Figure 1: page 27.** King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Fitch et al. 2012).

**Figure 2: page 28.** Bootstrapped estimates of the sampling distribution of the Alternative 1 2014 Tier 5 OFLs (pounds of total catch) for the Pribilof Islands golden king crab stock; histograms in left column, quantile plots in right column.

Table 1. Harvest history for the Pribilof District golden king crab fishery from the 1981/82 season through 2012 (from 2012 SAFE, updated with 2012 data provided by J. Shaisnikoff, ADF&G, Kodiak via 28 March 2013 email).



|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2010 | 1 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2011 | 2 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2012 | 1 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |

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

a Deadloss included.

b Guideline harvest level in pounds.

c In pounds.

d Number of legal crab per pot lift.

e Carapace length in millimeters.

Table 2. Weight (in pounds) of retained catch and estimated non-retained bycatch of Pribilof golden king crab during crab fisheries, 1993–2012, with total fishery mortality estimated by assuming a bycatch mortality rate of 0.2 for the directed fishery and a bycatch mortality rate of 0.5 for non-directed fisheries (from 2012 Crab SAFE, with update for 2012 catch and bycatch data).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Bycatch | | |  |
|  |  | Pribilof Islands |  | Bering Sea | Total |
| Year | Retained  Catch | golden  king crab | Bering Sea snow crab | grooved  Tanner crab | Fishery  Mortality |
| 1993 | 67,458 | no data | 0 | no data | — |
| 1994 | 88,985 | no data | 8,387 | 2,531 | — |
| 1995 | 341,908 | no data | 1,391 | 34,492 | — |
| 1996 | 329,009 | no data | 526 | 5,151 | — |
| 1997 | 179,249 | no data | 8,937 | no fishing | — |
| 1998 | 35,722 | no data | 72,760 | no fishing | — |
| 1999 | 177,108 | no data | 0 | confidential | — |
| 2000 | 127,217 | no data | 0 | confidential | — |
| 2001 | 145,876 | 39,278 | 0 | confidential | confidential |
| 2002 | 150,434 | 41,894 | 2,335 | no fishing | 159,980 |
| 2003 | confidential | confidential | 329 | confidential | 159,184 |
| 2004 | confidential | confidential | 0 | confidential | 147,552 |
| 2005 | confidential | confidential | 0 | confidential | 65,817 |
| 2006 | no fishing | no fishing | 0 | 0 | 0 |
| 2007 | no fishing | no fishing | 0 | 0 | 0 |
| 2008 | no fishing | no fishing | 0 | no fishing | 0 |
| 2009 | no fishing | no fishing | 2,122a | no fishing | 1,061a |
| 2010 | confidential | confidential | 0 | no fishing | confidential |
| 2011 | confidential | confidential | 591b | no fishing | confidential |
| 2012 | confidential | confidential | 598c | no fishing | confidential |

1. Only 5 golden king crab (1 sublegal male and 4 legal males) were counted in 1,657 pot lifts sampled out of the 163,536 pot lifts performed during the 2008/09 Bering Sea snow crab fishery (including waters north of the Pribilof District; Gaeuman 2010), but none of those were measured to provide an estimate of weight. Bycatch weight was estimated by (4.3)x(5)x(163,536)/(1,657); the assumed average weight per crab (4.3 pounds) is the average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.
2. Only 2 golden king crab (1 sublegal male and 1 legal male) were counted in 2,142 pot lifts sampled out of the 147,244 pot lifts performed during the 2010/11 Bering Sea snow crab fishery (including waters north of the Pribilof District; Gaeuman 2011), but none of those were measured to provide an estimate of weight. Bycatch weight was estimated by 4.3x(2x147,244)/2,142; the assumed average weight per crab (4.3 pounds) is the average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.
3. A single 156 mm CL legal male golden king crab occurred in the 2,235 pot lifts sampled out of the 270,602 pot lifts performed during the 2011/12 Bering Sea snow crab fishery ((including waters north of the Pribilof District; Gaeuman *in press*). Total bycatch weight was estimated by (4.9)x(270,602)/(2,235), where 4.9 is the average weight (pounds) of a 156 mm CL male golden king crab estimated by the weight-at-length estimator (Section D.3.b).

Table 3. Estimated annual weight (pounds) of discarded bycatch of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 513, 517, and 521, 1991/92–2010/12, with total bycatch mortality (pounds) estimated by assuming bycatch mortality rate = 0.5 for fixed-gear fisheries and bycatch mortality rate = 0.8 for trawl fisheries (updated from 2012 SAFE with 2011/12 data provided by R. Foy AFSC, Kodiak Laboratory via 15 August 2012 email).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Season | Fixed | Trawl | Total Bycatch | Total Bycatch Mortality |
| 1991/92 | 110 | 13,464 | 13,574 | 10,826 |
| 1992/93 | 7,690 | 19,544 | 27,234 | 19,480 |
| 1993/94 | 1,116 | 21,248 | 22,364 | 17,556 |
| 1994/95 | 558 | 7,103 | 7,661 | 5,962 |
| 1995/96 | 895 | 4,187 | 5,082 | 3,797 |
| 1996/97 | 53 | 1,918 | 1,971 | 1,561 |
| 1997/98 | 2,952 | 1,074 | 4,026 | 2,335 |
| 1998/99 | 14,930 | 395 | 15,324 | 7,781 |
| 1999/00 | 10,556 | 1,426 | 11,982 | 6,419 |
| 2000/01 | 3,589 | 4,134 | 7,723 | 5,101 |
| 2001/02 | 3,300 | 783 | 4,083 | 2,276 |
| 2002/03 | 1,219 | 472 | 1,691 | 987 |
| 2003/04 | 503 | 401 | 904 | 572 |
| 2004/05 | 342 | 860 | 1,202 | 859 |
| 2005/06 | 198 | 126 | 324 | 200 |
| 2006/07 | 2,915 | 254 | 3,168 | 1,660 |
| 2007/08 | 18,678 | 351 | 19,028 | 9,619 |
| 2008/09 | 8,799 | 3,433 | 12,231 | 7,145 |
| 2009/10 | 7,228 | 13,464 | 13,574 | 10,826 |
| 2010/11 | 1,966 | 1,213 | 3,179 | 1,953 |
| 2011/12 | 3,489 | 5,664 | 9,153 | 6,276 |
| Average | 4,337 | 4,834 | 8,832 | 5,866 |

Table 4. Data for calculation of RET1993-1998 and estimates used in calculation of R2001-2010, BMNC,1994-1998, and BMGF,92/93-98/99 for calculation of the Alternative 1 Pribilof Islands golden king crab Tier 5 2014 total-catch OFL; values under RET1993-1998 are from Table 1, values under R2001-2010 were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under BMNC,1994-1998 were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under BMGF,92/93-98/99 are from Table 3; from 2012 SAFE.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Seasona | Seasonb | RET1993-1998 | R2001-2010 | BMNC,1994-1998 | BMGF,92/93-98/99 |
| 1993 | 1992/93 | 67,458 |  |  | 19,480 |
| 1994 | 1993/94 | 88,985 |  | 5,459 | 17,556 |
| 1995 | 1994/95 | 341,908 |  | 17,941 | 5,962 |
| 1996 | 1995/96 | 329,009 |  | 2,839 | 3,797 |
| 1997 | 1996/97 | 179,249 |  | 4,469 | 1,561 |
| 1998 | 1997/98 | 35,722 |  | 36,380 | 2,335 |
| 1999 | 1998/99 |  |  |  | 7,781 |
| 2000 | 1999/00 |  |  |  |  |
| 2001 | 2000/01 |  | 0.054 |  |  |
| 2002 | 2001/02 |  | 0.056 |  |  |
| 2003 | 2002/03 |  | conf. |  |  |
| 2004 | 2003/04 |  | conf. |  |  |
| 2005 | 2004/05 |  | conf. |  |  |
| 2006 | 2005/06 |  |  |  |  |
| 2007 | 2006/07 |  |  |  |  |
| 2008 | 2007/08 |  |  |  |  |
| 2009 | 2008/09 |  |  |  |  |
| 2010 | 2009/10 |  | conf. |  |  |
|  | N | 6 | 6 | 5 | 7 |
|  | Mean | 173,722 | 0.052 | 13,418 | 8,353 |
|  | S.E.M | 54,756 | 0.004 | 6,337 | 2,750 |
|  | CV | 0.32 | 0.07 | 0.47 | 0.33 |

* 1. Season convention corresponding with values under RET1993-1998, R2001-2010, and BMNC,1994-1998.
  2. Season convention corresponding with values under BMGF,92/93-98/99.

Table 5. Statistics for 1,000 bootstrap 2014 OFL for Pribilof Islands golden king crab stock calculated according to Alternatives 1 with the computed OFL for comparison.

|  |  |
| --- | --- |
|  | Alternative 1 OFL |
| Computed OFL | 204,611 |
| Mean of 1,000 bootstrapped OFLs | 203,870 |
| Std. dev. of 1,000 bootstrapped OFLs | 51,030 |
| CV = (std. dev.)/(Mean) | 0.25 |



Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Fitch et al. 2012).

 

Figure 2. Bootstrapped estimates of the sampling distribution of the Alternative 1 2014 Tier 5 OFLs (pounds of total catch) for the Pribilof Islands golden king crab stock; histograms in left column, quantile plots in right column.