# Aleutian Islands Golden King Crab

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

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## Executive Summary

1. **Stock:** Aleutian Islands golden king crab *Lithodes aequispinus*

**2. Catches:**

The fishery has been prosecuted as a directed fishery since the 1981/82 season and has been open every season since then. Retained catch peaked during the 1985/86–1989/90 seasons (average annual retained catch = 11.876-million pounds, 5,387 t), but the retained catch dropped sharply from the 1989/90 to 1990/91 season and average annual retained catch for the period 1990/91–1995/96 was 6.931-million pounds (3,144 t). Management towards a formally established guideline harvest level (GHL) was introduced for the first time in the 1996/97 season. A GHL of 5.900-million pounds (2,676 t) was established for the 1996/97 season, which was subsequently reduced to 5.700-million pounds (2,585 t) beginning with the 1998/99 season. The GHL (or, since the 2005/06 season, the total allowable catch, or TAC) remained at 5.700-million pounds (2,585 t) through the 2007/08 season, but was increased to 5.985-million pounds (2,715 t) for 2008/09–2011/12 seasons. Average annual retained catch for the period 1996/97–2007/08 was 5.623-million pounds (2,550 t). Average annual retained catch in 2008/09–2010/11 was 5.854-million pounds (2,655 t). The 2011/12 season remains open until 15 May 2012. Catch per pot lift of retained legal males decreased from the 1980s into the mid-1990's, but increased steadily following the 1994/95 season and increased markedly at the initiation of the Crab Rationalization program in the 2005/06 season. Non-retained bycatch occurs mainly during the directed fishery. Although minor levels of bycatch can occur during other crab fisheries, there have been no such fisheries prosecuted since 2004/05, except as surveys for red king crab conducted by industry under a commissioner's permit to conduct test fisheries. Bycatch also occurs during fixed-gear and trawl groundfish fisheries. Although bycatch during groundfish fisheries exceeded 0.100-million pounds (45 t) for the first time during 2007/08 and 2008/09, that bycatch was less than 10% of the weight of bycatch during the directed fishery for those seasons. Estimated total bycatch in groundfish fisheries during 2009/10–2010/11 was $\leq$ 0.066-million pounds (30 t). Annual non-retained catch of golden king crab during crab fisheries has decreased relative to the retained catch and in absolute numbers and weight since the 1990's. Annual estimated weight of discarded bycatch during crab fisheries decreased from 13.824-million pounds (6,270 t) in 1990/91 (representing 199% of the retained catch during that season), to 9.100-million pounds (4,128 t) in 1996/97 (representing 156% of the retained catch for that season), and to 4.321-million pounds (1,960 t) in the 2004/05 season (representing 78% of the retained catch for that season). During the six seasons (2005/06–2010/11) prosecuted as rationalized fisheries, estimated weight of discarded bycatch has ranged from 2.524-million pounds (1,145 t) for the 2005/06 season (representing 46% of the retained catch for that season) to 3.035-million pounds (1,376 t) for the 2007/08 season (representing 55% of the retained catch for that season). Estimates of the annual weight of bycatch mortality have correspondingly decreased since 1996/97, both in absolute value and relative to the retained catch weight. Estimated total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) has ranged from 5.816-million pounds (2,638 t) to 9.375-million pounds (4,252 t) during

1995/96–2010/11, the period for which such estimates can be made; estimated total fishery mortality for 2010/11 was 6.558-million pounds (2,975 t).

**3. Stock biomass:**
Estimates of stock biomass are not available for this Tier 5 assessment.

**4. Recruitment:**
Estimates of recruitment trends and current levels relative to virgin or historic levels are not available for this Tier 5 assessment.

**5. Management performance:**
No overfished determination (i.e., MSST) is possible for this Tier 5 stock. Overfishing did not occur during 2010/11, the most-recently completed season (i.e., the estimated total catch was less than 11.06-million pounds, the total-catch OFL established for 2010/11). No ABC was established prior to the 2011/12 season. The 2011/12 season remains open until 15 May 2012; the 2011/12 catch relative to the 2011/12 OFL and ABC will be reviewed by the plan team in September 2012. See tables below; the OFL and ABC values for 2012/13 are the Alternative 2 (recommended) values. The 2012/13 TAC has not yet been established; the value given in the table is the default TAC according to current SOA regulations.

| Year | MSST | Biomass (MMB) | TAC[a] | Retained Catch[a] | Total Catch[a,b] | OFL[a, c] | ABC[a, c] |
|---|---|---|---|---|---|---|---|
| 2008/09 | N/A | N/A | 5.99 | 5.68 | 6.31 | 9.18, R | N/A |
| 2009/10 | N/A | N/A | 5.99 | 5.91 | 6.51 | 9.18, R | N/A |
| 2010/11 | N/A | N/A | 5.99 | 5.97 | 6.56 | 11.06, T | N/A |
| 2011/12 | N/A | N/A | 5.99 | TBD | TBD | 11.40, T | 10.26, T |
| 2012/13 | N/A | N/A | [6.29] | TBD | TBD | [12.54, T] | [11.28, T] |

a. Millions of pounds.
b. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
c. Noted as "R" for retained-catch only and as "T" for total-catch.

| Year | MSST | Biomass (MMB) | TAC[a] | Retained Catch[a] | Total Catch[a,b] | OFL[a, c] | ABC[a, c] |
|---|---|---|---|---|---|---|---|
| 2007/08 | N/A | N/A | 2,585 | 2,498 | 2,833 | N/A | N/A |
| 2008/09 | N/A | N/A | 2,715 | 2,576 | 2,860 | 4,163, R | N/A |
| 2009/10 | N/A | N/A | 2,715 | 2,682 | 2,591 | 4,163, R | N/A |
| 2010/11 | N/A | N/A | 2,715 | 2,707 | 2,975 | 5,017, T | N/A |
| 2011/12 | N/A | N/A | 2,715 | TBD | TBD | 5,173, T | 4,655, T |
| 2012/13 | N/A | N/A | [2,851] | TBD | TBD | [5,687, T] | [5,118 T] |

a. Metric tons.
b. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
c. Noted as "R" for retained-catch only and as "T" for total-catch.

**Basis for the OFL and ABC:** See table, below; 2012/13 values are the Alternative 1 (status quo) values.

| Year | Tier | Years to define Average catch (OFL) | Natural Mortality[a] | Buffer |
|---|---|---|---|---|
| 2008/09 | 5 | 1985/86–1995/96[b] | 0.18 | N/A |
| 2009/10 | 5 | 1985/86–1995/96[b] | 0.18 | N/A |
| 2010/11 | 5 | 1985/86–1995/96[c] | 0.18 | N/A |
| 2011/12 | 5 | 1985/86–1995/96[c] | 0.18 | 10% |
| 2012/13 | [5] | [1985/86–1995/96[c]] | [0.18] | [10%] |

a. Assumed value for FMP king crab in NPFMC (2007b); does not enter into OFL estimation for Tier 5 stock.
b. OFL was for retained catch only and was determined by the average of the retained catch for these years.
c. OFL was for total catch and was computed as the average of the retained catch for these years times an estimated average annual value of (bycatch mortality in crab fisheries)/(retained catch) plus an estimated average annual bycatch mortality in groundfish fisheries.

6. **PDF of the OFL:** Sampling distribution of the alternative Tier 5 OFLs was estimated by bootstrapping. The standard deviation of the estimated sampling distribution of the Alternative 1 (status quo) OFL (Alternative 1) is 1.04-million pounds (CV = 0.09) and of the Alternative 2 (recommended) OFL is 1.18-million pounds (CV = 0.09). See section G.1.

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

8. **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:** In March 2012 the Alaska Board of Fisheries (BOF) approved a change in **5 AAC 34.612 (Harvest Levels for Golden King Crab in Registration Area O)** that increases the TAC for the Aleutian Islands golden king crab fishery by 5% (from 3.15 million pounds to 3.31 million pounds for the area east of 174° W longitude and from 2.835 million pounds to 2.98 million pounds for the area west of 174° W longitude) until a stock assessment model and state regulatory harvest strategy are established. In addition, the BOF added language to the existing regulation that allows ADF&G to reduce the TAC from the specified levels for stock conservation purposes. **5 AAC 34.612 (Harvest Levels for Golden King Crab in Registration Area O)** as approved by the BOF in March 2012 is as follows:

> (a) Until the Aleutian Islands golden king crab stock assessment model and a state regulatory harvest strategy are established, the harvest levels for the Registration Area O golden king crab fishery are as follows:
>
> (1) east of 174° W long.: 3.31 million pounds; and
> (2) west of 174° W long.: 2.98 million pounds;

(b) The department may reduce the harvest levels based on the best scientific information available and considering the reliability of estimates and performance measures, sources of uncertainty as necessary to avoid overfishing, and any other factors necessary to be consistent with sustained yield principles.

2. **Changes to the input data:**
   - Fishery data has been updated with the results for 2010/11: retained catch for the directed fishery and bycatch estimates for the directed fishery, non-directed crab fisheries, and groundfish fisheries

3. **Changes to the assessment methodology:** None. This assessment follows the methodology recommended by the CPT in May 2011 and the SSC in June 2010 and 2011.

4. **Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL:**
   - The OFL established for each of 2008/09 and 2009/10 was 9.18-million pounds of retained catch and was estimated by the average annual retained catch (not including deadloss) for the period 1985/86–1995/96.
   - The OFL for 2010/11 was established as a total-catch OFL of 11.06-million pounds and, following the recommendation of the SSC in June 2010, was computed as the average of the annual retained catch during 1985/86–1995/96 times the estimated average annual value of (bycatch mortality in crab fisheries)/(retained catch) during 1996/97–2008/09 plus the estimated average annual bycatch mortality in groundfish fisheries during 1996/97–2008/09.
   - The OFL for 2011/12 was established as a total-catch OFL of 11.40-million pounds, with ABC = 10.26 million pounds (the "maxABC"). Methods and results followed the June 2010 CPT, May 2011 CPT and June 2011 SSC recommendations by using 1985/86–1995/96 data for retained catch, incorporating as much data on bycatch as is available, and "freezing" the final year of bycatch data included in the assessment at 2008/09. The recommended total catch OFL was computed as the average of the annual retained catch during 1985/86–1995/96 times the estimated average annual value of (bycatch mortality in crab fisheries)/(retained catch) during 1990/91–2008/09 (excluding 1993/94–1994/95, due to lack of sufficient data) plus the estimated average annual bycatch mortality in groundfish fisheries during 1993/94–2008/09. That OFL and ABC reappear in this assessment as "Alternative 1 (status quo)."
   - The recommended ("Alternative 2") OFL and ABC for 2012/13 is a total-catch OFL of 12.54-million pounds, with ABC = 11.28 million pounds (the "maxABC" with a 10% buffer below the OFL). The methods to compute the OFL are the same as for Alternative 1, except that a different time period is used to estimate the average annual value of (bycatch mortality in crab fisheries)/(retained catch) in the directed fishery (1990/91–1995/96 as opposed to 1990/91–2008/09).

### *B. Responses to SSC and CPT Comments*

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

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

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

- CPT, May 2011 (May 2011 CPT minutes): *"Two alternative OFLs were considered by the team, one employing a mechanism which uses the actual bycatch data from a specified time frame, and another which uses bycatch according to the "SSC formula" from the previous years.* [See the June 2011 SSC comments, below, for a brief explanation of the "SSC formula".] *The team concurred with the author's recommended approach for setting the OFL based on the actual data (noting these data were not available last year)."*
    - Response: Both the "Alternative 1" and "Alternative 2" OFLs for 2012/13 were based on the "actual data" approach that was favored by the CPT in May 2011.
- CPT, May 2011 (May 2011 CPT minutes and 2011 SAFE): *"The team concurred with the author that the ABC should be set to the maxABC." "The team concurred with the author's recommendation to set the ABC based on the maximum permissible from the ABC control rule which specifies an ABC based on a 10% buffer on the OFL."*
    - Response: The ABC for 2012/13 is the maxABC and 10% buffer on the OFL for both Alternatives presented.
- CPT, May 2011 (from 2011 SAFE): *"The CPT recommends that this stock be managed as a Tier 5 stock in 2011/12. ... the CPT concurred with the author's recommended approach for establishing the OFL. This method is as follows:*

    *$OFLTOT = (1+RATE90/91\text{-}08/09) \bullet OFLRET(85/86\text{-}95/96) + BM_{GF}\ 93/94\text{-}08/09 = 11.40$ million lb*

    *where:*

    *RATE90/91-08/09 = mean annual rate = (bycatch mortality in crab fisheries)/(retained catch) over the period 1990/91-2008/09.*

    *OFLRET85/86-95/96 = mean annual retained catch over the period 1985/86-1995/96, and*

    *$BM_{GF}$93/94-08/09 = mean of annual bycatch mortality in groundfish fisheries over the period 1993/94-2008/09."*

- Response: The author follows that recommendation in computing the Alternative 1 (status quo) 2012/13 OFL; the recommended Alternative 2 OFL uses the period 1990/91–1995/96 to estimate the mean annual rate of (bycatch mortality in crab fisheries)/(retained catch).

- SSC, June 2011: *"In 2010, the SSC recommended an approach to estimated OFL based on the average annual ratio of bycatch mortality to retained catch during 1990/91–2008/09 (excluding 1993/94–1994/95 owing to insufficient data) average annual retained catch over 1985/86–1995/96, and average annual rate of bycatch mortality in groundfish fisheries over 1993/94–2008/09. For the current stock assessment, the assessment author recommends using this same approach, but using updated data, including data on historical bycatch that were not available for last year's assessment. The ABC is calculated using a 10% buffer on OFL. Based on this approach, the SSC recommends following the advice of the assessment author and Crab Plan Team to manage this fishery with a total catch OFL of 11.40 million pounds and ABC of 10.26 million pounds for 2011/12."*
    - Response: In providing Alternative 1 (status quo) the author followed the SSC's June 2011 recommendation to follow the author's May 2011 recommendation.
- CPT, September 2011: None – the OFL and ABC for this stock were not reviewed at the September 2011 CPT meeting.
- SSC, October 2011: None – the OFL and ABC for this stock were not reviewed at the October 2011 SSC meeting.

## 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 (page 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 (page 3-43).

The Aleutian Islands king crab stock boundary is defined by the boundaries of the Aleutian Islands king crab Registration Area O (Figure 1). Bowers et al. (2011, page 8) define those boundaries:

> The Aleutian Islands king crab Registration Area O has as its eastern boundary the longitude of Scotch Cap Light (164° 44' W long.), its northern boundary a line from Cape Sarichef (54° 36' N latitude) to 171° W long., north to 55° 30' N lat., and as its western boundary the Maritime Boundary Agreement Line as that line

is described in the text of and depicted in the annex to the Maritime Boundary Agreement between the United States and the Union of Soviet Socialist Republics signed in Washington, June 1, 1990. Area O encompasses both the waters of the Territorial Sea (0–3 nautical miles) and waters of the Exclusive Economic Zone (3–200 nautical miles).

During the 1984/85–1995/96 seasons, the Aleutian Islands king crab populations had been managed using the Adak and Dutch Harbor Registration Areas, which were divided at 171° W longitude (Figure 2), but from the 1996/97 season to present the fishery has been managed using a division at 174° W longitude (Figure 1; Bowers et al. 2011). At its March 1996 meeting, the Alaska Board of Fisheries (BOF) replaced the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and directed ADF&G to manage the golden king crab fishery in the areas east and west of 174° W longitude as two distinct stocks. That re-designation of management areas was intended to more accurately reflect golden king crab stock distribution, as is shown by the longitudinal pattern in fishery production prior to the 1996/97 season (Figure 3). The longitudinal pattern in fishery production during recent fisheries since that change in management is shown in Figure 4. In this chapter we use "Aleutian Islands Area" to mean the area described by the current definition of Aleutian Islands king crab Registration Area O.

Commercial fishing for golden king crab in the Aleutian Islands Area typically occurs at depths of 100–275 fathoms (183–503 m). During the 2010/11 season the pots sampled by at-sea observers were fished at an average depth of 175 fathoms (320 m; N=436) in the area east of 174° W longitude and 175 fathoms (320 m; N=867) for the area west of 174° W longitude (Gaeuman 2011).

**Evidence of stock structure:** Given the expansiveness of the Aleutian Islands Area and the existence of deep (>1,000 m) canyons between some islands, at least some weak structuring of the stock within the area would be expected. Data for making inferences on stock structure of golden king crab within the Aleutian Islands is largely limited to the geographic location of commercial fishery catch and effort. Effort and catch by statistical area since 1982 and locations of over 70,000 fished pots that were sampled by observers since 1996 seasons indicate that habitat for legal-sized males may be continuous throughout the waters adjacent to the Aleutian Islands. However, regions within the area in which available habitat is attenuated are suggested by regions of low fishery effort and catch (Figures 3 and 4); for example the southern side of islands between 174° W longitude and 177° W longitude (i.e., from Atka I. west to Adak I.) as compared to the area surrounding islands between 170°W longitude and 173° W longitude (i.e., between the Islands of the Four Mountains and Seguam Pass). Additionally, there is a gap of catch and effort in statistical areas between Petrel Bank/Petrel Spur and Bowers Bank, both of which areas have reported effort and catch. Recoveries during commercial fisheries of golden king crab tagged during ADF&G surveys (Blau and Pengilly 1994, Blau et al. 1998, Watson and Gish 2002, Watson 2004, 2007) provided no evidence of substantial movements by crab in the size classes that were tagged (males and females ≥90-mm CL). Maximum straight-line distance between release and recovery location of 90 golden king crab released prior to the 1991/92 season and recovered through the 1992/93 season was 33.1 nm (61.2 km; Blau and Pengilly 1994). Of the 4,053 recoveries reported through 14 March 2008 of the golden king crab tagged and released between 170.5° W longitude and 171.5° W longitude during the 1997, 2000, 2003,

and 2006 triennial ADF&G Aleutian Island golden king pot surveys, none were recovered west of 174° W longitude and only four were recovered west of 172° W longitude (L. J. Watson, Fishery Biologist, ADF&G, Kodiak, retired; personnel communication).

**3. 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 (2001) estimated a 20-month reproductive cycle with a 12-month clutch brooding period.
>
> Numerous observations on clutch and embryo condition of mature female golden king crab captured during surveys have been consistent with asynchronous, aseasonal reproduction (Otto and Cummiskey 1985, Hiramoto 1985, Sloan 1985, Somerton and Otto 1986, Blau and Pengilly 1994, Blau et al. 1998, Watson et al. 2002). Based on data from Japan (Hiramoto and Sato 1970), McBride et al. (1982) suggested that spawning of golden king crab in the Bering Sea and Aleutian Islands occurs predominately during the summer and fall.

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

Note that asynchronous, aseasonal molting and the prolonged intermolt period (>1 year) of mature female and the larger male golden king crab likely makes scoring shell conditions very

difficult and especially difficult to relate to "time post-molt," posing problems for inclusion of shell condition data into assessment models.

**5. Brief summary of management history:**

A complete summary of the management history through the 2009/10 season is provided in Bowers et al. (2011, pages 14–19). The first commercial landing of golden king crab in the Aleutian Islands was in 1975/76, but directed fishing did not occur until 1981/82. Peak harvest occurred during 1986/87 when 14.739-million pounds were harvested. Between 1981/82 and 1995/96 the fishery was managed as two separate fisheries in two separate registration areas, the Adak and Dutch Harbor areas, with the two areas divided at 172° W longitude through 1983/84 and at 171° W longitude after 1983/84. Prior to the 1996/97 season no formal preseason harvest target or limit was established for the fishery and average annual retained catch during 1981/82 – 1995/96 was 8.456-million pounds.

The Aleutian Islands golden king crab fishery was restructured beginning with the 1996/97 season to replace the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and the golden king crab in the areas east and west of 174° W longitude were managed separately as two stocks. The 1996/97–1997/98 seasons were managed under a 5.900-million pound guideline harvest level (GHL), with 3.200-million pounds apportioned to the area east of 174° W longitude and 2.700-million pounds apportioned to the area west of 174° W longitude. The 1998/99–2004/05 seasons were managed under a 5.700-million pound GHL, with 3.000-million pounds apportioned to the area east of 174° W longitude and 2.700-million pounds apportioned to the area west of 174° W longitude. The 2005/06–2007/08 seasons were managed under a 5.700-million pound total allowable catch (TAC), with 3.000-million pounds apportioned to the area east of 174° W longitude and 2.700-million pounds apportioned to the area west of 174° W longitude. By state regulation (**5 AAC 34.612**), the TAC for retained catch for the Aleutian Islands golden king crab fishery beginning with the 2008/09 season has been 5.985-million pounds (apportioned as 3.150-million pounds for the area east of 174° W longitude and 2.835-million pounds for the area west of 174° W longitude). Over the period 1996/97–2010/11 the total of the annual retained catch has been 2% below the total of the annual GHL/TACs. By season, retained catch has been as much as 13% below the GHL/TAC (the 1998/99 season) and as much as 6% above the GHL/TAC (the 2000/01 season). The retained catch for the 2010/11 season was <1% below the 5.985-million pound TAC.

In March 2012 the BOF changed **5 AAC 34.612** so that the TAC beginning with the 2012/13 season will be 6.29 million pounds (apportioned as 3.31 million pounds for the area east of 174° W longitude and 2.98 million pounds for the area west of 174° W longitude. Additionally, the BOF added a provision to **5 AAC 34.612** that allows ADF&G to lower the TAC below that specified if conservation concerns arise.

A summary of other relevant SOA fishery regulations and management actions pertaining to the Aleutian Islands golden king crab fishery is provided below.

The 2005/06 season was the first Aleutian Islands golden king crab fishery to be prosecuted under the Crab Rationalization Program. Accompanying the implementation of the Crab Rationalization program was implementation of a community development quota (CDQ) fishery for golden king crab in the eastern Aleutians (i.e., east of 174° W longitude) and the Adak

Community Allocation (ACA) fishery for golden king crab in the western Aleutians (i.e., west of 174° W longitude; Milani 2008). The CDQ fishery in the eastern Aleutians is allocated 10% of the golden king crab TAC for the area east of 174° W longitude and the ACA fishery in the western Aleutians is allocated 10% of the golden king crab TAC for the area west of 174° W longitude. The CDQ fishery and the ACA fishery are prosecuted concurrently with the IFQ fishery and managed by ADF&G.

Only males of a minimum legal size may be retained by the commercial golden king crab fishery in the Aleutian Islands Area. By State of Alaska regulation (**5 AAC 34.620 (b)**), the minimum legal size limit is 6.0-inches (152 mm) carapace width (CW), including spines. A carapace length (CL) ≥135 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007b). Note that size limit for golden king crab has been 6-inches CW for the entire Aleutian Islands Area only since the 1985/86 season. Prior to the 1985/86 season the legal size limit was 6.5-inches for at least one of the now-defunct Adak or Dutch Harbor Registration Areas.

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 Aleutian Islands Area may be operated only from a shellfish longline and, since 1996, must have at least four escape rings of five and one-half inches minimum 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 34.625 (b)**). Prior to the regulation requiring an escape mechanism on pots, some participants in the Aleutian Islands golden king crab fishery voluntarily sewed escape rings (typically 139-mm or 5.5") into their gear or, more rarely, included panels with escape mesh (Beers 1992). With regard to the gear used by fishers since the establishment of **5 AAC 34.625 (b)** in 1996, Linda Kozak, a representative of the industry, reported in a 19 September 2008 email to the Crab Plan Team that, "… the golden king crab fleet has modified their gear to allow for small crab sorting," and provided a written statement from Lance Nylander, of Dungeness Gear Works in Seattle, who "believes he makes all the gear for the golden king crab harvesting fleet," saying that, "Since 1999, DGW has installed 9" escape web on the door of over 95% of Golden Crab pot orders we manufactured." In March 2011 (effective for the 2011/12 season) the BOF amended **5 AAC 34.625 (b)** to relax the "biotwine" specification for pots used in the Aleutian Islands golden king crab fishery relative to the requirement in **5 AAC 39.145** (Escape Mechanism for Shellfish and Bottomfish Pots) that "(1) a sidewall ... of all shellfish and bottomfish pots 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 34.625 (b)(1)** allows the opening described in **5 AAC 39.145 (1)** to be "laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 60 [rather than 30] thread."

By State of Alaska regulation (**5 AAC 34.610 (b)**), the commercial fishing season for golden king crab in the Aleutian Islands Area is August 15 through May 15.

Current regulations stipulate that onboard observers are required during the harvest of 50% of the total golden king crab weight harvested by each catcher vessel and 100% of the fishing

activity of each catcher-processor during each of the three trimesters as outlined in **5 AAC 39.645 (d)(4)(A)**.

### *D. Data*

**1. Summary of new information:**

- Fishery data on retained catch and non-retained bycatch during 2010/11 crab fisheries have been added.
- Data on bycatch during groundfish fisheries in reporting areas 541, 542, and 543 have been updated with data grouped by "fixed" (hook-and-line and pot) and "trawl" (non-pelagic trawl) for 2010/11 have been added.
- Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) during 2010/11 have been added.

**2. Data presented as time series:**

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

- Fish ticket data on retained catch numbers, retained catch weight, pot lifts, CPUE, and average weight of retained catch for the 1981/82–2010/11 seasons are presented (Table 1).
- Statistics from all available data on bycatch of Aleutian Islands golden king crab obtained from pot lifts sampled by at-sea observers during the directed and non-directed crab fisheries are presented for 1990/91–1992/93 and 1995/96–2010/11 (Table 2). Some observer data exists for the 1988/89–1989/90 seasons, but that data is not considered reliable. Although bycatch can occur in the red king crab, scarlet king crab, grooved Tanner crab, and triangle Tanner crab fisheries of the Aleutian Islands, such bycatch accounts for ≤2% of the estimated total weight in the crab fisheries annually. Only one vessel was observed during the directed fishery throughout the 1993/94 season and only two vessels were observed throughout the 1994/95 season (an additional catcher vessel carried an observer for one trip during the 1993/94 season and an additional three catcher vessels carried an observer for one trip during the 1994/95 season, but observed effort was small relative to the total season effort for those vessels and the author does not consider the data from those vessels reliable). Hence data on bycatch during the 1993/94 and 1994/95 directed fishery seasons are confidential and not presented here. Observer data on size distributions and estimated catch numbers of non-retained catch were used to estimate the weight of non-retained catch of red king crab by applying a weight-at-length estimator (see below); data on the size distribution of non-retained legal males was not recorded prior to 1998/99 and weights of retained legal males are used to estimate the weights of non-retained legal males during those years. Data on bycatch of golden king crab obtained by at-sea observers during groundfish fisheries in reporting areas 541, 542, and 543 (Figure 5) for crab fishery years 1993/94–2010/11 are presented (estimates for 1991/92–1992/93 are also presented, but they appear to be suspect; Table 3).
- Estimates of bycatch mortality during 1990/91–1992/93 and 1995/96–2010/11 directed and non-directed crab fisheries and 1993/94–2010/11 groundfish fisheries are presented in Table 4. Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) during 1995/96–2010/11 are presented (Table 4). Following Siddeek et al. (2011), the bycatch mortality rate of king crab captured and discarded during Aleutian Islands king crab fisheries was assumed to be 0.2;

that value was also applied as the bycatch mortality during other crab fisheries. Following Foy (2011a, 2011b), the bycatch mortality of king crab captured by fixed gear during groundfish fisheries was assumed to be 0.5 and of king crab captured by trawls during groundfish fisheries was assumed to be 0.8.

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

***d.*** ***Survey biomass estimates:*** Not used in a Tier 5 assessment; none are presented.

***e.*** ***Survey catch at length:*** Not used in a Tier 5 assessment; none are presented (see section D.4).

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

**3. Data which may be aggregated over time:**

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

Growth per molt and probability of molt estimates are not used in a Tier 5 assessment. However, growth per molt and probability of molt has been estimated for Aleutian Islands golden king crab by Watson et al. (2002) based on information received from recoveries during the 1997/98 – 2000/01 commercial fisheries in the area east of 174° W longitude of male and female golden king crab tagged and released during July–August 1997 in the area east of 174° W longitude (see Tables 24–28 *in* Pengilly 2009).

Watson et al. (2002) used logistic regression to estimate the probability as a function of carapace length (CL, mm) at release that a male tagged and released in new-shell condition would molt within 12–15 months after release:

$$P(\text{molt}) = \exp(17.930 - 0.129*CL)/[1 + \exp(17.930 - 0.129*CL)].$$

Based on the above logistic regression Watson et al. (2002) estimated that the size at which 50% of new-shell males would be expected to molt within 12–15 months is 139-mm CL (S.E. = 0.81-mm CL).

Watson et al. (2002) used logistic regression to estimate the probability as a function of carapace length (CL, mm) at release that a male tagged and released as a sublegal ≥ 90-mm CL in new-shell condition would molt to legal size within 12–15 months after release:

$$P(\text{molt to legal size}) = 1 - \exp(15.541 - 0.127*CL)/[1 + \exp(15.541 - 0.127*CL)].$$

Based on the above logistic regression Watson et al. (2002) estimated that the size at which 50% of sublegal ≥90-mm CL, new-shell males would be expected to molt to legal size within 12–15 months is 123-mm CL (S.E. = 1.54-mm CL).

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

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

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

***c. Natural mortality rate:***

The default natural mortality rate assumed for king crab species by NPFMC (2007b) is M=0.18. Note, however, that this natural mortality assumption was not used in this Tier 5 stock assessment.

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

Data from triennial ADF&G pot surveys for Aleutian Islands golden king crab in a limited area east of 174° W longitude (between 170° 21' and 171° 33' W longitude) that were performed during 1997 (Blau et al. 1998), 2000 (Watson and Gish 2002), 2003 (Watson 2004), and 2006 (Watson 2007) are available, but were not used in this Tier 5 assessment.

## *E. Analytic Approach*

**1. History of modeling approaches for this stock:** This is a Tier 5 stock. There is an assessment model in development for this stock (Siddeek et al. 2011).

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

It has been recommended by NPFMC (2007b) and by the CPT and SSC in 2009 that the Aleutian Islands golden king crab stock be managed as a Tier 5 stock until the assessment model (Siddeek et al. 2011) is accepted for use. 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 2007b). Additionally, NPFMC (2007b) 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." Although NPFMC (2007b) 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 2010/11 OFL for this stock. This assessment recommends – and only considers – use of a total-catch OFL for 2012/13.

Additionally, NPFMC (2007b) 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." Prior to 2008, two time periods considered for computing the average retained catch for Aleutian Islands golden king crab: 1985–2005 (NPFMC 2007a) and 1985–1999 (NPFMC 2007b). NPFMC (2007b) suggested using the average retained catch over the years 1985 to 1999 as the estimated OFL for Aleutian Islands golden king crab. Years post-

1984 were chosen based on an assumed 8-year lag between hatching during the 1976/77 "regime shift" and growth to legal size. With regard to excluding data from years after 1999, NPFMC (2007b) states, "Years from 2000 to 2005 were excluded for Aleutian Islands golden king crab when the TAC was set below the previous average catch." Note, however, that there was no TAC or GHL established for the entire Aleutian Islands Area prior to the 1996/97 season (see above) and the GHL for the Aleutian Islands Area was reduced from 5.9-million pounds for the 1996/97 and 1997/98 seasons to 5.7-million pounds for the 1998/1999 season; the GHL or TAC has remained at 5.7-million pounds for all subsequent seasons until it was increased to 5.985-million pounds for the 2008/09 season. Pengilly (2008) discussed nine periods, spanning periods as long as 26 seasons (1981/82–2006/07) to as short as 6 seasons (1990/91–1995/96), for computing average annual retained catch to estimated the OFL for the 2008/09 season. Only periods beginning no earlier than 1985/86 were recommended for consideration, however, due to the size limit change that occurred prior to the 1985/86 season (Table 1, footnotes d–f). The Crab Plan Team at the May 2008 recommended using the period 1990/91–1995/96 for computing the 2008/09 OFL. The CPT recommended the period 1990/91–1995/96 due to concerns raised by a decline in retained catch and CPUE that occurred from 1985/86 into the mid-1990's, the first five seasons of unconstrained catch under the current size limit. The SSC recommended using the period 1985/86 – 1995/96 for computing the 2008/09 OFL, however, because the period 1985/86 – 1995/96 is the longest possible period of unconstrained catch under the current size limit ("Earlier years were not recommended for inclusion because of a difference in the size limit regulations prior to 1985/86." Minutes of the NPFMC SSC meeting, 2–4 June 2008)**.** Pengilly (2009) discussed only three time periods to consider for setting the 2009/10 OFL: 1985/86–1995/96 (the period recommended by the SSC for the 2008/09 OFL); 1990/91–1995/96; (the period recommended by the CPT for the 2008/09 OFL); and 1987/88–1995/96. The period 1987/88–1995/96 was offered for consideration on the basis of having the longest period of unconstrained catch under the current size limit, while excluding the two seasons with the highest retained catch in the history of the fishery (the 1985/86–1986/87 seasons). Trends of declining catch, declining CPUE, and declining average weight of landed crab that occurred from 1985/86 into the mid-1990's could be interpreted as resulting from fishery that relied increasingly on annual recruitment to legal size as it fished on a declining stock of legal-size males. Hence the catches during the full period of unconstrained catch under the current size limit, 1985/86–1995/96, could be viewed as unsustainable. Removal of the two highest-catch seasons, 1985/86–1986/87, at the beginning of that time period was offered as a compromise between the desire for the longest period possible for averaging catch and the desire for a period reflecting long-term production potential of the stock. Of those, the Crab Plan Team at the May 2009 again recommended using the period 1990/91–1995/96 for computing the 2009/10 OFL, whereas the SSC again recommended 1985/86–1995/96, noting that "the management system was relatively constant from 1985 onward" and that a "longer time period likely provides a more robust estimate than a shorter time period." (Minutes of the NPFMC SSC meeting, 1–3 June 2009).

Three alternatives were considered for setting a total-catch OFL for 2010/11 (see the Executive Summary of the May Draft of the 2010 Crab SAFE), none of which could be chosen with consensus by the CPT in May 2010 and all of which were rejected by the SSC in June 2010. In June 2010 the SSC recommended an approach to computing a total-catch OFL for this stock for 2010/11 as follows (Minutes of the NPFMC SSC meeting, 7–9 June 2010):

$$OFL_{2010/11} = (1+R_{96/97\text{-}08/09})\bullet RET_{85/86\text{-}95/96} + BM_{GF,96/97\text{-}08/09} = 11.0 \text{ million lbs.},$$

where

- $R_{96/97\text{-}08/09}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1996/97-2008/09,
- $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96, and
- $BM_{GF,\ 96/97\text{-}08/09}$ is the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1996/97-2008/09.

Additionally, the SSC in June 2010 recommended that "...this time period be frozen to stabilize the control rule."

Data on bycatch during crab fisheries prior to 1996/97 was presented to the CPT in May 2011 and the CPT recommended the following OFL for the 2011/12 season, which was also recommended by the SSC in June 2011:

$$OFL_{2011/12} = (1+R_{90/91\text{-}08/09})\bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09},$$

where,

- $R_{90/91\text{-}08/09}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1990/91-2008/09 (excluding 1993/94–1994/95, due to data confidentialities and insufficiencies)
- $RET_{85/86\text{-}95/96}$ is the same as defined for $OFL_{2010/11}$, above (i.e., the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96), and
- $BM_{GF,93/94\text{-}08/09}$ is the same as defined for $OFL_{2010/11}$, above (i.e., the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94-2008/09).

Given the recommendation from the SSC (June 2010) that the "time period be frozen to stabilize the control rule" and the OFL recommend by the SSC in June 2011, the author considers all debate and questions concerning alternative time periods for computing a Tier 5, total-catch OFL for this stock to be closed unless instructed otherwise. In particular, only the retained catch data for the period 1985/86–1995/96 and only the available estimates on bycatch mortality for seasons up to 2008/09 will be used in calculation of the alternative 2012/2013 total-catch OFLs presented here. Data and estimates that are used in calculation of alternative total-catch OLFs for 2012/13 and that are available for the period 1985/86–2008/09 are plotted in Figures 6–9.

## 3. Model Selection and Evaluation:

### a. *Description of alternative model configurations*

Two alternatives are presented. Alternative 2 is the author's recommended alternative.

Alternative 1 (status quo). The OFL is set as a total-catch OFL following the June 2011 recommendation of the SSC:

$$OFL_{Alt\text{-}1,\ 2012/13} = (1+R_{90/91\text{-}08/09})\bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09},$$

where,

- $R_{90/91\text{-}08/09}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1990/91-2008/09 (excluding 1993/94–1994/95, due to data confidentialities and insufficiencies)
- $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96, and
- $BM_{GF,93/94\text{-}08/09}$ is the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94-2008/09.

Statistics on the data and estimates used to calculate, $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}08/09}$, and $BM_{GF,93/94\text{-}08/09}$ are provided in Table 5; the column means in Table 5 are the calculated values of $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}08/09}$, and $BM_{GF,93/94\text{-}08/09}$. Using those calculated values of $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}08/09}$, and $BM_{GF,93/94\text{-}08/09}$, $OFL_{Alt\text{-}1,\ 2012/13}$ is,

$$OFL_{Alt\text{-}1,\ 2012/13} = (1+0.240)\bullet(9{,}178{,}438) + 23{,}359 = 11{,}404{,}670 \text{ lbs (11.40-million lbs).}$$

Alternative 2 (recommended). This alternative is the same as Alternative 1 except that it uses an estimated ratio of bycatch mortality due to crab fisheries to retained catch that the author believes is more appropriate for application to the retained catch during 1985/86–1995/96:

$$OFL_{Alt\text{-}2,\ 2012/13} = (1+R_{90/91\text{-}95/96})\bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09},$$

where,

- $R_{90/91\text{-}95/96}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1990/91–1995/96 (excluding 1993/94–1994/95, due to data confidentialities and insufficiencies),
- $RET_{85/86\text{-}95/96}$ is the same as defined for Alternative 1, above (i.e., the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96), and
- $BM_{GF,93/94\text{-}08/09}$ is the same as defined for Alternative 1, above (i.e., the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94-2008/09).

Statistics on the data and estimates used to calculate, $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}95/96}$, and $BM_{GF,93/94\text{-}08/09}$ are provided in Table 6; the column means in Table 6 are the calculated values of $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}95/96}$, and $BM_{GF,93/94\text{-}08/09}$. Using those calculated values of $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}95/96}$, and $BM_{GF,93/94\text{-}08/09}$, $OFL_{Alt\text{-}2,\ 2012/13}$ is,

$$OFL_{Alt\text{-}2,\ 2012/13} = (1+0.363)\bullet(9{,}178{,}438) + 23{,}359 = 12{,}537{,}757 \text{ lbs (12.54-million lbs)}$$

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

| Model | Retained- vs. Total-catch | Time Period | Resulting OFL (millions of pounds) |
|---|---|---|---|
| Alt. 1 – status quo | Total-catch | 1985/86–1995/96 | 11.40 |
| Alt. 2 - recommended | Total-catch | 1985/86–1995/96 | 12.54 |

c. ***Evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models:*** N/A – both alternatives have the same number of parameters; see the 2008–2010 Crab SAFEs for discussion on realism.

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

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

f. ***Do parameter estimates for all models make sense, are they credible?:***
The time period used for determining the OFL was established by the SSC in June 2010. However, temporal trends exist in the retained catch (Figure 6) and in the ratio of the estimated bycatch mortality in crab fisheries to the retained catch (Figure 7) during that period. An interesting relationship exists between the ratio of the estimated bycatch mortality in crab fisheries to the retained catch and the retained weight for the season (Figure 8), but that trend is difficult to separate from the temporal trend. Estimates of total retained catch (pounds) during a season are from fish tickets landings recorded at 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). Estimates of bycatch mortality are estimates of bycatch times an assumed bycatch mortality rate. Bycatch mortality rates have not been estimated from data.

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

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

i. ***Evaluation of the model, if only one model is presented; or evaluation of alternative models and selection of final model, if more than one model is presented:*** The two alternatives differ only in the time period that is used to estimate the average annual ratio of pounds of bycatch mortality due to crab fisheries to pounds of retained crab in the directed fishery. Both alternatives follow the June 2010 SSC recommendations to freeze the time period to stabilize the control role by using only 1985/86–1995/96 to estimate the average annual retained catch component of the OFL and to not include bycatch data after 2008/09. Alternative 1 (status quo) follows the June 2010 argument of the SSC that the approach that "includes the most data... may be the most robust" [*ordering of the two quoted phrases (separated by ellipses) switched by the author for clarity of exposition!*] by using the time period 1990/91–2008/09 to estimate the average annual ratio of pounds of bycatch mortality

due to crab fisheries to pounds of retained crab in the directed fishery during 1985/86–1995/96. Alternative 2 uses the time period 1990/91–1995/96 to estimate that average annual ratio for the period 1985/86–1995/96. The author recommends the Alternative 2 approach because the bycatch data from 1990/91–1995/96 can be considered more representative of the conditions that existed during 1985/86–1995/96: they are from within the period 1985/86–1995/96; regulations stipulating escape mechanisms in pots became effective after 1995/96 (see section **C.5-Brief summary of management history**); and there is a clear decreasing trend in the estimated ratio of pounds of bycatch mortality due to crab fisheries to pounds of retained crab in the directed fishery since 1996/97 (Figure 7). Someone other than the author will need to come up with the argument supporting the approach of Alternative 1 (i.e., for including the data on bycatch due to crab fisheries from 1996/97–2008/09 to estimate the bycatch rate during the 1985/86–1995/96 crab fisheries).

**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 5–7.

***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 a Tier 5 assessment, the major uncertainties are:

- Whether the chosen 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.
    - The Tier 5 OFL for this stock is highly sensitive to the choice of years used to compute the average annual catch. The table on page 393 of the 2008 SAFE pretty much covered all the bases on alternative choices for time periods that could be used to compute the retained-catch portion of the OFL. Interested readers are directed to that document, although we can note here that the average retained-catch of the OFL for the nine alternative time periods presented ranged from 5.63 million pounds (for 1996/97–2006/07) up to 9.18 million pounds (for 1985/86–1995/96, the time period frozen by the SSC). The CPT in 2008 and

2009 recommended that the years 1990/91–1995/96 be used to compute the retained-catch OFL (resulting in a retained-catch OFL of 6.93-million pounds). In both 2008 and 2009, the SSC overrode the CPT's recommendation and recommended that the years 1985/86–1995/96 to compute the retained-catch OFL at 9.18-million pounds. The SSC recommended that the time period for computing the retained-catch portion of the OFL "be frozen" at 1985/86–1995/96 "to stabilize the control rule."

  - The Tier 5 OFL is also sensitive to the choice of years used to estimate the average annual ratio of pounds of bycatch mortality to pounds of retained crabs in the crab fisheries. The SSC recommended that the time period for computing the bycatch-mortality portion of the OFL be frozen to end at 2008/09. The estimates of annual bycatch biomass (not discounted for bycatch mortality) to retained catch are generally highest during 1990/91–1995/96 and show a decreasing trend during 1996/97–2008/09: that ratio during 1990/91–1995/96 ranges from 1.5:1 to 2.1:1, during 1996/97–2004/05 ranges from 0.8:1 to 1.7:1, and during 2005/06–2008/09 ranges from 0.5:1 to 0.6:1 (see Table 2; see also Figure 7 for the trend in ratios after a default bycatch mortality rate is applied to the bycatch biomass estiamates). Hence including the later years to compute the average annual ratio decreases the OFL estimate, whereas restricting the period to 1990/91–1995/96 increases the OFL estimate.
  - The Tier 5 OFL has only a slight sensitivity to the choice of years used to compute the bycatch due to groundfish fisheries. This assessment only considers the period 1993/94–2008/09 for bycatch in the groundfish fisheries. Estimates of annual bycatch mortality due to groundfish fisheries during 1993/94–2008/09 range from <0.01-million pounds to 0.130-million pounds. Because the estimates of bycatch biomass due to groundfish fisheries is small relative to the biomass of retained catch (≥4.82-million pounds annually during 1985/86–2010/11), the effect of choice of years here is negligibly small.

- The assumed bycatch mortality rates used in estimation of total fishery mortality. 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. Due to the difference in scale between the estimated bycatch in crab fisheries and the groundfish fisheries (see bullet above), the estimated OFL is most sensitive to the assumed bycatch mortality in crab fisheries and less sensitive to the assumed bycatch in groundfish fisheries. Given a fixed period of years to compute the average of annual bycatch biomass estimates for the crab fisheries, the estimated OFL increases (decreases) linearly with increases (decreases) in the bycatch mortality rate assumed for the crab fisheries: double the assumed bycatch mortality rate from 0.2 to 0.4, and the OFL estimate increases by a factor of 1.4/1.2 = 1.17; half the assumed bycatch mortality rate from 0.2 to 0.1, and the OFL estimate decreases by a factor of 1.1/1.2 = 0.92.

## *F. Calculation of the OFL*

**1. <u>Specification of the Tier level and stock status level for computing the OFL:</u>**

- Recommended as Tier 5, total-catch OFL computed as the estimated average annual total catch over a specified period.

- Recommended time period for computing retained-catch portion of the OFL: 1985/86–1995/96.
- Recommended time period for computing bycatch mortality due to crab fisheries: 1990/91–1995/96.
- Recommended time period for computing bycatch due to groundfish fisheries: 1993/94–2008/09.
- Recommended bycatch mortality rates: 0.2 for crab fisheries; 0.5 for fixed-gear groundfish fisheries; 0.8 for trawl groundfish fisheries.

**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 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 (2007b) 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. 2012/13 OFL and ABC are author's recommendations. 2012/13 TAC has not yet been determined; the value given in the table is the default TAC according to current SOA regulations

| Year | MSST | Biomass (MMB) | TAC[a] | Retained Catch[a] | Total Catch[a,b] | OFL[a, c] | ABC[a, c] |
|---|---|---|---|---|---|---|---|
| 2008/09 | N/A | N/A | 5.99 | 5.68 | 6.31 | 9.18, R | N/A |
| 2009/10 | N/A | N/A | 5.99 | 5.91 | 6.51 | 9.18, R | N/A |
| 2010/11 | N/A | N/A | 5.99 | 5.97 | 6.56 | 11.06, T | N/A |
| 2011/12 | N/A | N/A | 5.99 | TBD | TBD | 11.40, T | 10.26, T |
| 2012/13 | N/A | N/A | [6.29] | TBD | TBD | [12.54 T] | [11.28 T] |

a. Millions of pounds.
b. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
c. Noted as "R" for retained-catch only and as "T" for total-catch.

**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 1985/86–1995/96
= 9,178,438 pounds (9.18-million pounds).

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

### *G. Calculation of ABC*

**1. PDF of OFL.** Bootstrap estimates of the sampling distributions (assuming no error in estimation of bycatch) of the Alternative 1 and Alternative 2 OFLs are shown in Figure 9 (1,000 samples drawn with replacement independently from each of the three columns of values in Table 5 to calculate $R_{90/91\text{-}08/09}$, $RET_{85/86\text{-}95/96}$, $BM_{GF,93/94\text{-}08/09}$ and $OFL_{Alt\text{-}1,2010/11}$ and 1,000 samples drawn with replacement independently from each of the three columns of values in Table 6 to calculate $R_{90/91\text{-}95/96}$, $RET_{85/86\text{-}95/96}$, $BM_{GF,93/94\text{-}08/09}$ and $OFL_{Alt\text{-}2,2010/11}$). Table 7 provides statistics on the generated distributions.

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

- The time period to compute the average catch relative to assumption that it represents "a time period determined to be representative of the production potential of the stock."
- 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 total-catch 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 1985/86–1995/96.
- See **E.4.*f*** for details.

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

**4. Author recommended ABC.** (1-0.1)·12,537,757 pounds = 12.54-million pounds.

### *H.* Rebuilding Analyses

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

### *I.* Data Gaps and Research Priorities

Currently, there are no biomass estimates for this stock. The process of development and annual use of an assessment model (e.g., Siddeek et al 2011) to estimate spawning biomass or a proxy will identify data gaps and research priorities. Triennial pot survey for portion of stock was not performed in 2009 and will not be performed in 2012. Bycatch mortality rate in directed fishery is unknown.

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**Table of tables**.

**Table of figures.**

Table 1. Harvest history for the Aleutian Islands golden king crab fishery (GHL/TAC, pounds and number of retained crabs, pot lifts, fishery catch per unit effort, and average weight of landed crab) by fishery season from the 1981/82 season through the 2010/11 season (includes the CDA and ACA fisheries for the 2005/06–2010/11 seasons; from 2011 SAFE).

| Season | GHL/TAC Millions of Pounds | Harvest Pounds[a] | Harvest Number[a] | Pot lifts | CPUE[b] | Average Weight[c] |
|---|---|---|---|---|---|---|
| 1981/82 | - | 1,319,666 | 242,407 | 28,263 | 8.4 | 5.4[d] |
| 1982/83 | - | 9,236,942 | 1,746,206 | 179,888 | 9.4 | 5.3[d] |
| 1983/84 | - | 10,495,045 | 1,964,772 | 267,519 | 7.2 | 5.3[d] |
| 1984/85 | - | 4,819,347 | 995,453 | 90,066 | 10.7 | 4.8[e] |
| 1985/86 | - | 12,734,212 | 2,811,195 | 236,281 | 11.9 | 4.5[f] |
| 1986/87 | - | 14,738,744 | 3,340,627 | 433,020 | 7.7 | 4.4[f] |
| 1987/88 | - | 9,257,005 | 2,174,576 | 306,730 | 7.1 | 4.2[f] |
| 1988/89 | - | 10,627,042 | 2,488,433 | 321,927 | 7.6 | 4.3[f] |
| 1989/90 | - | 12,022,052 | 2,902,913 | 357,803 | 8.0 | 4.1[f] |
| 1990/91 | - | 6,950,362 | 1,703,251 | 214,814 | 7.7 | 4.1[f] |
| 1991/92 | - | 7,702,141 | 1,847,398 | 234,857 | 7.7 | 4.2[f] |
| 1992/93 | - | 6,291,197 | 1,528,328 | 203,221 | 7.4 | 4.1[f] |
| 1993/94 | - | 5,551,143 | 1,397,530 | 234,654 | 5.8 | 4.0[f] |
| 1994/95 | - | 8,128,511 | 1,924,271 | 386,593 | 4.8 | 4.2[f] |
| 1995/96 | - | 6,960,406 | 1,582,333 | 293,021 | 5.2 | 4.4[f] |
| 1996/97 | 5.900 | 5,815,772 | 1,334,877 | 212,727 | 6.0 | 4.4[f] |
| 1997/98 | 5.900 | 5,945,683 | 1,350,160 | 193,214 | 6.8 | 4.4[f] |
| 1998/99 | 5.700 | 4,941,893 | 1,150,029 | 119,353 | 9.4 | 4.3[f] |
| 1999/00 | 5.700 | 5,838,788 | 1,385,890 | 186,169 | 7.2 | 4.2[f] |
| 2000/01 | 5.700 | 6,018,761 | 1,410,315 | 172,790 | 8.0 | 4.3[f] |
| 2001/02 | 5.700 | 5,918,706 | 1,416,768 | 168,151 | 8.3 | 4.2[f] |
| 2002/03 | 5.700 | 5,462,455 | 1,308,709 | 131,021 | 9.8 | 4.2[f] |
| 2003/04 | 5.700 | 5,665,828 | 1,319,707 | 125,119 | 10.3 | 4.3[f] |
| 2004/05 | 5.700 | 5,575,051 | 1,323,001 | 91,694 | 14.2 | 4.2[f] |
| 2005/06 | 5.700 | 5,520,318 | 1,263,339 | 54,685 | 22.9 | 4.4[f] |
| 2006/07 | 5.700 | 5,262,342 | 1,178,321 | 53,065 | 22.0 | 4.5[f] |
| 2007/08 | 5.700 | 5,508,100 | 1,233,848 | 52,609 | 23.5 | 4.5[f] |
| 2008/09 | 5.985 | 5,680,084 | 1,254,607 | 50,666 | 24.8 | 4.5[f] |
| 2009/10 | 5.985 | 5,912,287 | 1,308,218 | 52,787 | 24.8 | 4.5[f] |
| 2010/11 | 5.985 | 5,968,849 | 1,297,229 | 55,795 | 23.2 | 4.6[f] |

a. Includes deadloss.
b. Catch (number of crab) per pot lift.
c. Average weight (pounds) of landed crab, including deadloss.
d. Managed with 6.5" CW minimum size limit.
e. Managed with 6.5" CW minimum size limit west of 171° W longitude and 6.0" minimum size limit east of 171° W longitude.
f. Managed with 6.0" minimum size limit.

Table 2. Pounds of retained catch of Aleutian Islands golden king crab, with the estimated non-retained catch (not discounted for an assumed bycatch mortality rate) and components of non-retained catch (non-retained legal males, non-retained sublegal males, non-retained females), by season for the 1990/91–2010/11 seasons (from 2011 SAFE).

| | Retained | Non-retained | Components of non-retained catch: | | |
|---|---|---|---|---|---|
| Season | Catch | Catch | Legal males | Sublegal males | Females |
| 1990/91 | 6,950,362 | 13,823,802 | 12,017 | 6,406,866 | 7,404,919 |
| 1991/92 | 7,702,141 | 11,256,802 | 213,613 | 5,532,854 | 5,510,334 |
| 1992/93 | 6,291,197 | 13,082,222 | 62,275 | 5,874,729 | 7,145,218 |
| 1993/94 | 5,551,143 | — | — | — | — |
| 1994/95 | 8,128,511 | — | — | — | — |
| 1995/96 | 6,960,406 | 12,049,551 | 63,679 | 6,054,126 | 5,931,746 |
| 1996/97 | 5,815,772 | 9,100,304 | 24,756 | 4,221,753 | 4,853,795 |
| 1997/98 | 5,945,683 | 8,732,597 | 39,929 | 4,198,607 | 4,494,061 |
| 1998/99 | 4,941,893 | 7,388,274 | 41,325 | 4,303,406 | 3,043,543 |
| 1999/00 | 5,838,788 | 7,551,570 | 63,877 | 3,930,277 | 3,557,417 |
| 2000/01 | 6,018,761 | 8,901,534 | 35,432 | 4,782,427 | 4,083,675 |
| 2001/02 | 5,918,706 | 6,888,462 | 26,541 | 3,787,239 | 3,074,681 |
| 2002/03 | 5,462,455 | 5,671,318 | 41,621 | 3,113,341 | 2,516,355 |
| 2003/04 | 5,665,828 | 4,973,484 | 38,870 | 2,663,899 | 2,270,716 |
| 2004/05 | 5,575,051 | 4,321,014 | 76,100 | 2,511,523 | 1,733,391 |
| 2005/06 | 5,520,318 | 2,523,737 | 140,493 | 1,478,601 | 904,642 |
| 2006/07 | 5,262,342 | 2,573,040 | 119,590 | 1,263,303 | 1,190,147 |
| 2007/08 | 5,508,100 | 3,034,632 | 127,560 | 1,504,738 | 1,402,333 |
| 2008/09 | 5,680,084 | 2,763,673 | 174,866 | 1,365,338 | 1,223,469 |
| 2009/10 | 5,912,287 | 2,787,186 | 164,133 | 1,363,549 | 1,259,504 |
| 2010/11 | 5,968,849 | 2,726,322 | 222,573 | 1,248,680 | 1,255,068 |

Table 3. Estimated annual weight (pounds) of discarded bycatch (all sizes, males and females; not discounted by assumed bycatch mortality) by gear type (fixed or trawl and total) and total fishery mortality (assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries) of golden king crab during federal groundfish fisheries in reporting areas 541, 542, and 543, 1991/92–2009/10 (from 2011 SAFE).

| Year | Fixed-Gear Bycatch | Trawl Bycatch | Total Bycatch | Total Bycatch Mortality |
|---|---|---|---|---|
| 1991/92 | 0 | 0 | 0 | 0 |
| 1992/93 | 5 | 3 | 7 | 4 |
| 1993/94 | 3,960 | 8,164 | 12,124 | 8,511 |
| 1994/95 | 1,346 | 2,674 | 4,020 | 2,812 |
| 1995/96 | 367 | 5,165 | 5,532 | 4,315 |
| 1996/97 | 26 | 13,862 | 13,887 | 11,102 |
| 1997/98 | 539 | 1,071 | 1,610 | 1,126 |
| 1998/99 | 3,901 | 1,381 | 5,282 | 3,055 |
| 1999/00 | 10,572 | 1,422 | 11,995 | 6,424 |
| 2000/01 | 7,166 | 669 | 7,836 | 4,119 |
| 2001/02 | 1,387 | 417 | 1,804 | 1,027 |
| 2002/03 | 75,952 | 871 | 76,823 | 38,673 |
| 2003/04 | 86,186 | 1,498 | 87,684 | 44,291 |
| 2004/05 | 2,450 | 2,452 | 4,903 | 3,187 |
| 2005/06 | 1,246 | 4,151 | 5,397 | 3,944 |
| 2006/07 | 72,306 | 3,077 | 75,382 | 38,614 |
| 2007/08 | 254,225 | 3,641 | 257,867 | 130,026 |
| 2008/09 | 108,683 | 22,712 | 131,395 | 72,511 |
| 2009/10 | 44,226 | 18,061 | 62,287 | 36,562 |
| 2010/11 | 31,456 | 34,801 | 66,257 | 43,569 |

Table 4. Estimated annual weight (pounds) of total fishery mortality to Aleutian Islands golden king crab, 1990/91–2010/11, partitioned by source of mortality: retained catch, bycatch mortality during crab fisheries, and bycatch mortality during groundfish fisheries (from 2011 SAFE); see Table 2 (assumes bycatch mortality rate of 0.2 for crab fisheries) and Table 3.

| | | Bycatch Mortality by Fishery Type | | Total estimated |
|---|---|---|---|---|
| Season | Retained Catch | Crab | Groundfish | fishery mortality |
| 1990/91 | 6,950,362 | 2,764,760 | — | — |
| 1991/92 | 7,702,141 | 2,251,360 | — | — |
| 1992/93 | 6,291,197 | 2,616,444 | — | — |
| 1993/94 | 5,551,143 | — | 8,511 | — |
| 1994/95 | 8,128,511 | — | 2,812 | — |
| 1995/96 | 6,960,406 | 2,409,910 | 4,315 | 9,374,631 |
| 1996/97 | 5,815,772 | 1,815,110 | 11,102 | 7,641,984 |
| 1997/98 | 5,945,683 | 1,738,534 | 1,126 | 7,685,343 |
| 1998/99 | 4,941,893 | 1,477,655 | 3,055 | 6,422,603 |
| 1999/00 | 5,838,788 | 1,510,314 | 6,424 | 7,355,526 |
| 2000/01 | 6,018,761 | 1,780,307 | 4,119 | 7,803,187 |
| 2001/02 | 5,918,706 | 1,377,692 | 1,027 | 7,297,425 |
| 2002/03 | 5,462,455 | 1,134,264 | 38,673 | 6,635,392 |
| 2003/04 | 5,665,828 | 994,697 | 44,291 | 6,704,816 |
| 2004/05 | 5,575,051 | 864,203 | 3,187 | 6,442,441 |
| 2005/06 | 5,520,318 | 504,747 | 3,944 | 6,029,009 |
| 2006/07 | 5,262,342 | 514,608 | 38,614 | 5,815,564 |
| 2007/08 | 5,508,100 | 606,926 | 130,026 | 6,245,052 |
| 2008/09 | 5,680,084 | 552,735 | 72,511 | 6,305,330 |
| 2009/10 | 5,912,287 | 557,437 | 36,562 | 6,506,286 |
| 2010/11 | 5,968,849 | 545,264 | 43,569 | 6,557,682 |

Table 5. Data for calculation of $RET_{85/86\text{-}95/96}$[a] and estimates used in calculation of $R_{90/91\text{-}08/09}$[b] and $BM_{GF,93/94\text{-}08/09}$[c] for calculation of the Alternative 1 (status quo) Aleutian Islands golden king crab Tier 5 2012/13 OFL; values under $RET_{85/86\text{-}95/96}$ from Table 1, values under $R_{90/91\text{-}08/09}$ were computed from the retained catch data and the crab bycatch mortality estimates in Table 4, and values under $BM_{GF,93/94\text{-}08/09}$ are from Table 4.

| Season | $RET_{85/86\text{-}95/96}$ | $R_{90/91\text{-}08/09}$ | $BM_{GF,93/94\text{-}08/09}$ |
|---|---|---|---|
| 1985/86 | 12,734,212 | | |
| 1986/87 | 14,738,744 | | |
| 1987/88 | 9,257,005 | | |
| 1988/89 | 10,627,042 | | |
| 1989/90 | 12,022,052 | | |
| 1990/91 | 6,950,362 | 0.398 | |
| 1991/92 | 7,702,141 | 0.292 | |
| 1992/93 | 6,291,197 | 0.416 | |
| 1993/94 | 5,551,143 | — | 8,511 |
| 1994/95 | 8,128,511 | — | 2,812 |
| 1995/96 | 6,960,406 | 0.346 | 4,315 |
| 1996/97 | | 0.313 | 11,102 |
| 1997/98 | | 0.294 | 1,126 |
| 1998/99 | | 0.299 | 3,055 |
| 1999/00 | | 0.259 | 6,424 |
| 2000/01 | | 0.296 | 4,119 |
| 2001/02 | | 0.233 | 1,027 |
| 2002/03 | | 0.208 | 38,673 |
| 2003/04 | | 0.176 | 44,291 |
| 2004/05 | | 0.155 | 3,187 |
| 2005/06 | | 0.091 | 3,944 |
| 2006/07 | | 0.098 | 38,614 |
| 2007/08 | | 0.110 | 130,026 |
| 2008/09 | | 0.097 | 72,511 |
| N | 11 | 17 | 16 |
| Mean | 9,178,438 | 0.240 | 23,359 |
| S.E.M. | 896,511 | 0.026 | 8,827 |
| CV | 0.10 | 0.11 | 0.38 |

a. $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96

b. $R_{90/91\text{-}08/09}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1990/91-2008/09 (excluding 1993/94–1994/95, due to data confidentialities and insufficiencies).

c. $BM_{GF,93/94\text{-}08/09}$ is the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94-2008/09.

Table 6. Data for calculation of $RET_{85/86\text{-}95/96}$[a] and estimates used in calculation of $R_{90/91\text{-}95/96}$[b] and $BM_{GF,93/94\text{-}08/09}$[c] for calculation of the Alternative 2 (author-recommended) Aleutian Islands golden king crab Tier 5 2012/13 OFL; values under $RET_{85/86\text{-}95/96}$ are from Table 1, values under $R_{90/91\text{-}95/96}$ were computed from the retained catch data and the crab bycatch mortality estimates in Table 4, and values under $BM_{GF,93/94\text{-}08/09}$ are from Table 4.

| Season | $RET_{85/86\text{-}95/96}$ | $R_{90/91\text{-}95/96}$ | $BM_{GF,93/94\text{-}08/09}$ |
|---|---|---|---|
| 1985/86 | 12,734,212 | | |
| 1986/87 | 14,738,744 | | |
| 1987/88 | 9,257,005 | | |
| 1988/89 | 10,627,042 | | |
| 1989/90 | 12,022,052 | | |
| 1990/91 | 6,950,362 | 0.398 | |
| 1991/92 | 7,702,141 | 0.292 | |
| 1992/93 | 6,291,197 | 0.416 | |
| 1993/94 | 5,551,143 | — | 8,511 |
| 1994/95 | 8,128,511 | — | 2,812 |
| 1995/96 | 6,960,406 | 0.346 | 4,315 |
| 1996/97 | | | 11,102 |
| 1997/98 | | | 1,126 |
| 1998/99 | | | 3,055 |
| 1999/00 | | | 6,424 |
| 2000/01 | | | 4,119 |
| 2001/02 | | | 1,027 |
| 2002/03 | | | 38,673 |
| 2003/04 | | | 44,291 |
| 2004/05 | | | 3,187 |
| 2005/06 | | | 3,944 |
| 2006/07 | | | 38,614 |
| 2007/08 | | | 130,026 |
| 2008/09 | | | 72,511 |
| N | 11 | 4 | 16 |
| Mean | 9,178,438 | 0.363 | 23,359 |
| S.E.M. | 896,511 | 0.028 | 8,827 |
| CV | 0.10 | 0.08 | 0.38 |

a. $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery during the period 1985/86-1995/96

b. $R_{90/91\text{-}95/96}$ is the average of the estimated annual ratios of pounds of bycatch mortality due to crab fisheries to pounds of retained catch in the directed fishery during the period 1990/91-1995/96 (excluding 1993/94–1994/95, due to data confidentialities and insufficiencies).

c. $BM_{GF,93/94\text{-}08/09}$ is the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94-2008/09.

Table 7. Statistics for 1,000 bootstrap OFLs calculated according to Alternatives 1 and 2, with the computed OFLs for comparison.

| | Alternative 1 | Alternative 2 |
|---|---|---|
| Computed OFL | 11,404,670 | 12,537,757 |
| Mean of 1,000 bootstrapped OFLs | 11,433,908 | 12,510,742 |
| Std. dev. of 1,000 bootstrapped OFLs | 1,040,981 | 1,184,511 |
| CV = (std. dev.)/(Mean) | 0.09 | 0.09 |

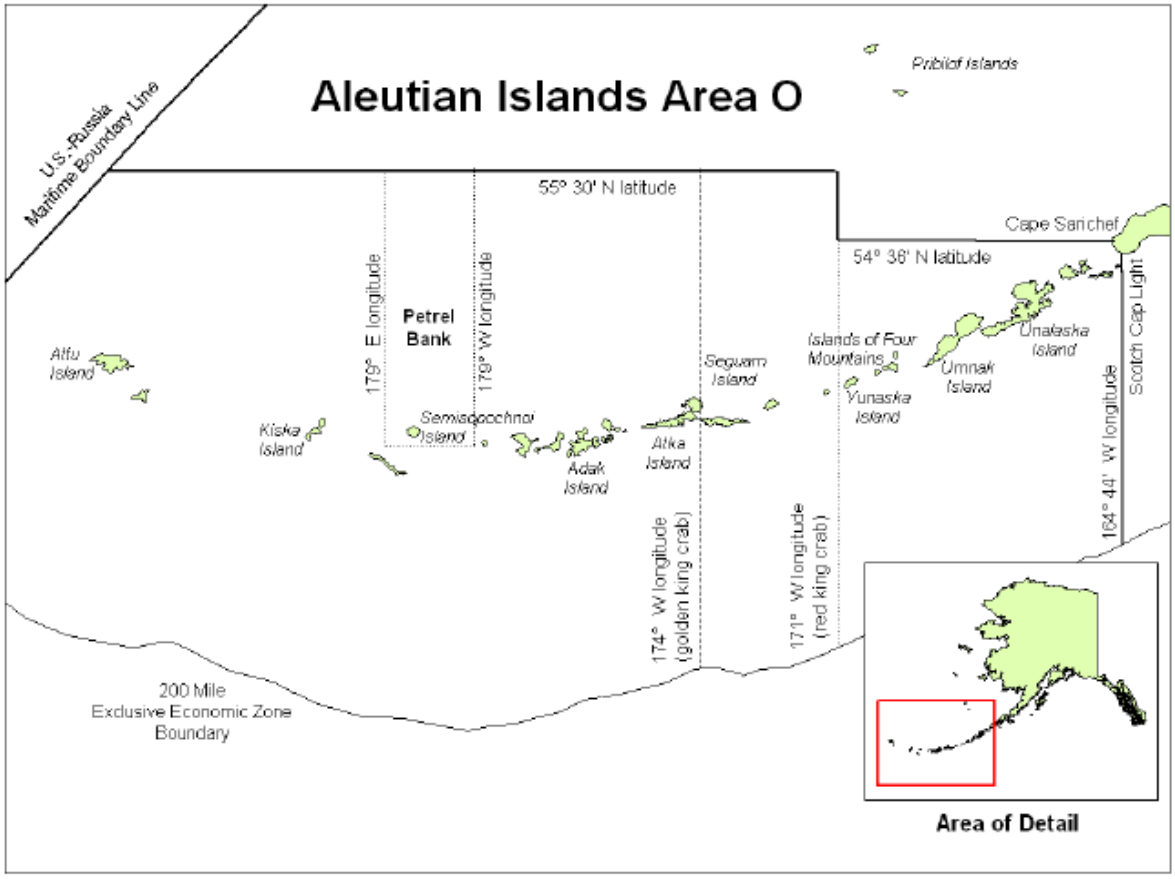

Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Bowers et al. 2011).

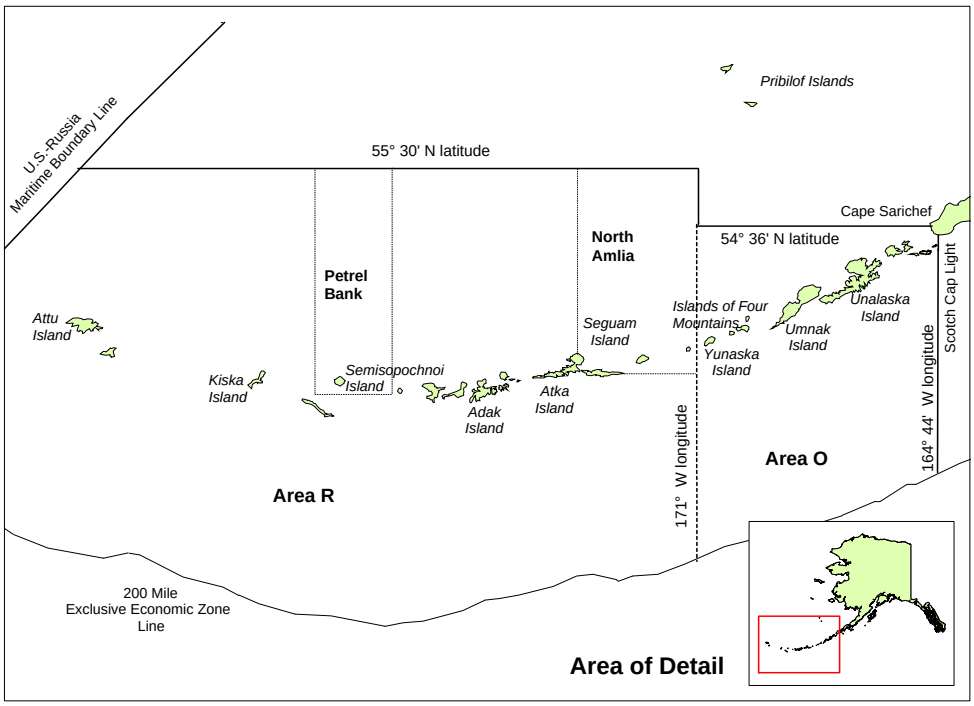


Figure 2. Adak (Area R) and Dutch Harbor (Area O) king crab Registration Areas and Districts, 1984/85 – 1995/96 seasons (Bowers et al. 2011).

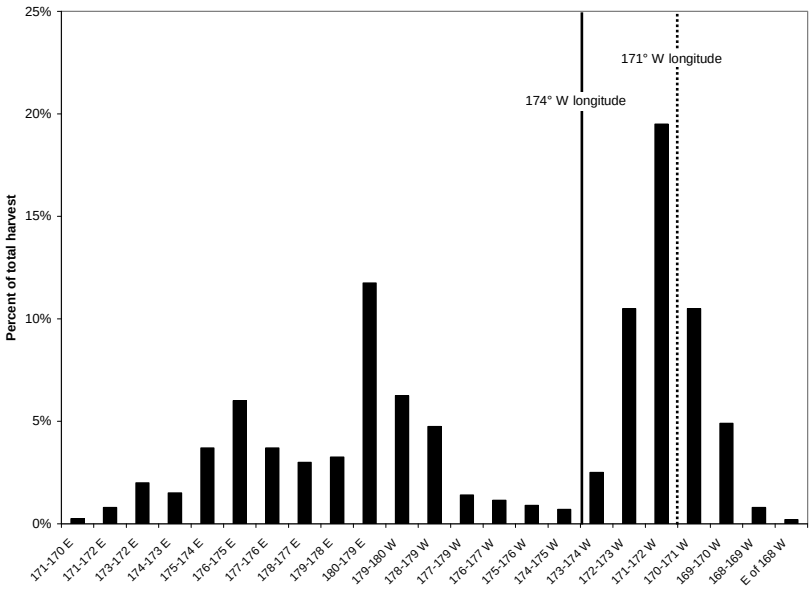


Figure 3. Percent of total 1982–1996 golden king crab harvest by one-degree longitude intervals in the Aleutian Islands, with dotted line denoting the border at 171° W longitude that was used until the end of the 1995/96 season to divide fishery management between the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude) and solid line denoting the border at 174° W longitude that has been used since the 1996/97 to manage Aleutian Island golden king crab as separate stocks east and west of 174° W longitude (from Figure 4-2 *in* Morrison et al. 1998).

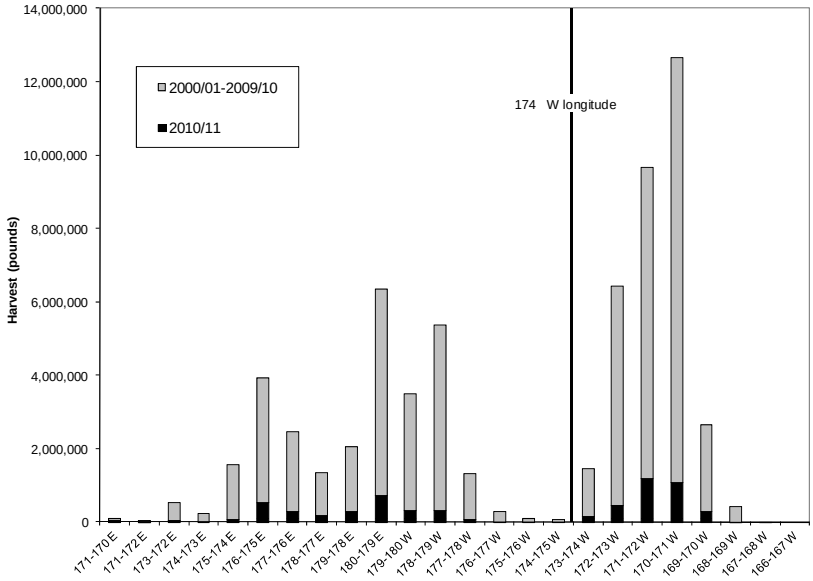


Figure 4. Harvest (pounds) of golden king crab by one-degree longitude intervals in the Aleutian Islands during the 2000/01 through 2010/11 commercial fishery seasons; solid line denotes the border at 174° W longitude that has been used since the 1996/97 season to manage Aleutian Island golden king crab as separate stocks east and west of 174° W longitude (from 2011 SAFE, updated with final 2010/11 data from H. Fitch, ADF&G, 15 August 2011 email).

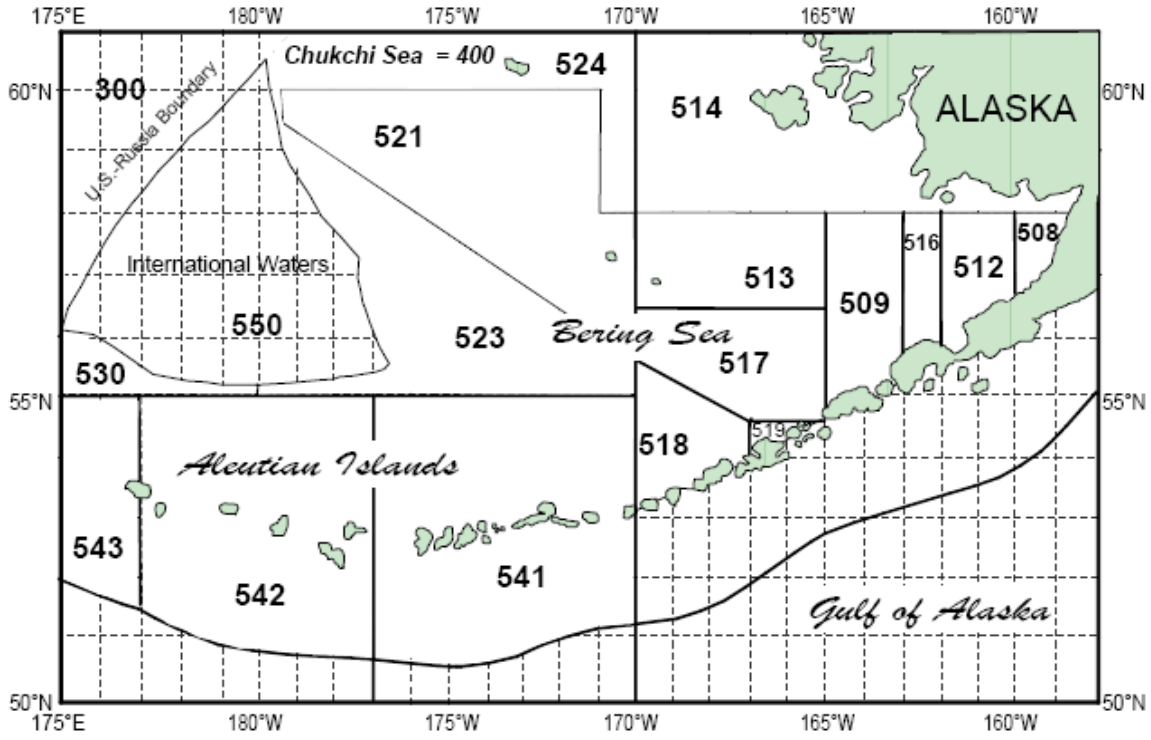


Figure 5. Map of federal groundfish fishery reporting areas for the Bering Sea and Aleutian Islands showing reporting areas 541, 542, and 543 that are used to obtain data on bycatch of Aleutian Islands golden king crab during groundfish fisheries (from http://www.fakr.noaa.gov/rr/figures/fig1.pdf).

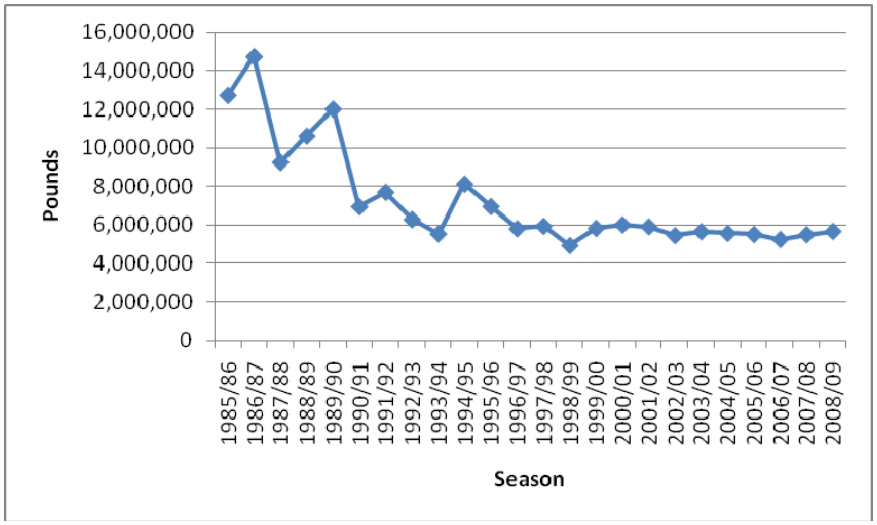


Figure 6. Retained catch (pounds) in the Aleutian Islands golden king crab fishery, 1985/86–2008/09.

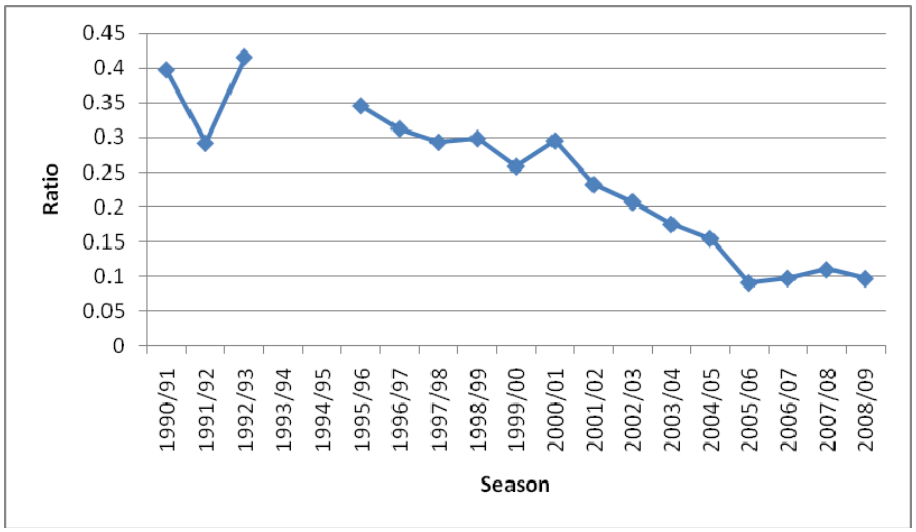


Figure 7. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Islands golden king crab, 1990/91–2008/09 (ratios for 1993/94–1994/95 not available due to data confidentialities and insufficiencies).

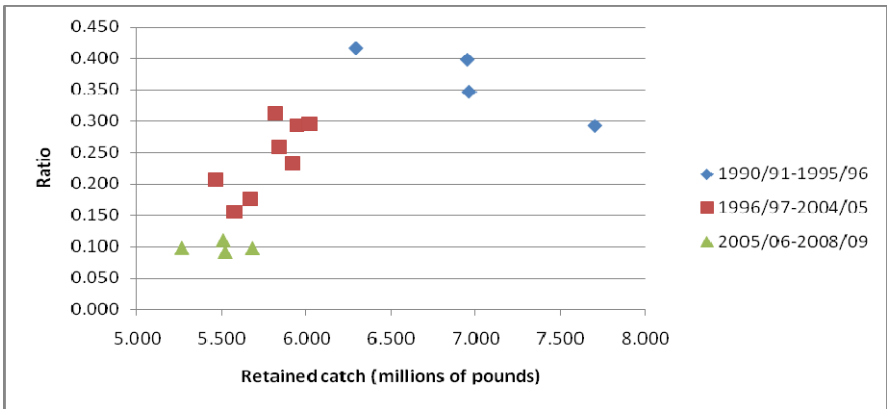


Figure 8. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Islands golden king crab plotted against weight of retained catch, 1990/91–2008/09 (ratios for 1993/94–1994/95 not available due to data confidentialities and insufficiencies).

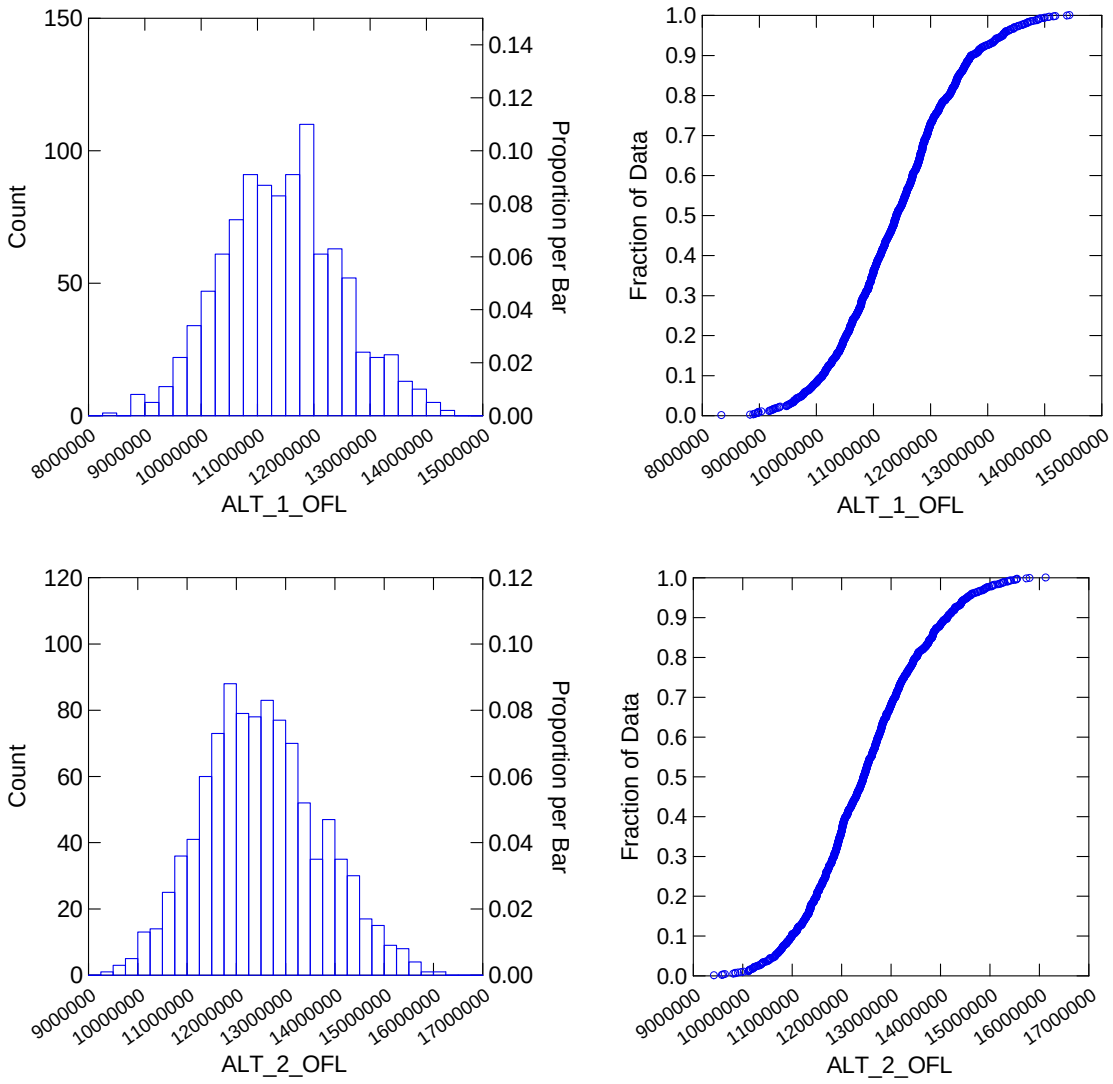


Figure 9. Bootstrapped estimates of the sampling distribution of the Alternative 1 (above) and Alternative 2 (below) 2012/2013 Tier 5 OFLs (pounds of total-catch) for the Aleutian Islands golden king crab stock; histograms in left column, quantile plots in right column.