Aleutian Islands Golden King Crab – 2016 Tier 5 Assessment

2016 Crab SAFE Report Chapter (May 2016 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 1981/82 and has been opened every year since then. Retained catch peaked in 1986/87 at 6,696 t (14,762,494 lb), but the retained catch dropped sharply from 1989/90 to 1990/91 and average annual retained catch for 1990/91–1995/96 was 3,145 t (6,933,822 lb). A guideline harvest level (GHL) was introduced into management for the first time in 1996/97. A GHL of 2,676 t (5,900,000 lb) was established in 1996/97 and subsequently reduced to 2,585 t (5,700,000 lb) beginning in 1998/99. The GHL (or, since 2005/06, the total allowable catch, or TAC) remained at 2,585 t (5,700,000 lb) through 2007/08, but was increased to 2,715 t (5,985,000 lb) for 2008/09–2011/12 and increased to 2,853 t (6,290,000 lb) for 2012/13–2015/16. In addition to the retained catch that is allotted as TAC, there was retained catch in a cost-recovery fishery towards a $300,000 goal in 2013/14–2014/15 and towards a $500,000 goal in 2015/16. Retained catch in 2014/15 was 2,771 t (6,108,674 lb). Catch per pot lift (CPUE) of retained legal males decreased from the 1980s into the mid-1990s, but increased steadily after 1994/95 and increased markedly at the initiation of the Crab Rationalization program in 2005/06. The fishery has been managed separately east and west of 174° W longitude since 1996/97 and, although CPUE for the two areas showed similar trends through 2010/11, during 2011/12–2014/14 CPUE trends have diverged (increasing east of 174° W longitude and decreasing west of 174° W longitude). Discarded (non-retained) catch occurs mainly during the directed fishery. Although low levels of discarded catch 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. Estimates of the bycatch mortality during crab fisheries decreased during 1995/96–2005/06, both in absolute value and relative to the retained catch weight, and stabilized during 2005/06–2014/15. Estimated bycatch mortality during crab fisheries in 2014/15 was 303 t. Discarded catch also occurs during fixed-gear and trawl groundfish fisheries, but is small relative to that during the directed fishery and the groundfish fisheries are a minor contributor to total fishery mortality; estimated bycatch mortality during groundfish fisheries in 2014/15 was 5 t. Estimated total fishery mortality during 1995/96–2014/15 has ranged from 2,638 t in 2006/07 to 4,252 t in 1995/96; estimated total fishery mortality in 2014/15 was 3,079 t. The 2015/16 fishery closes by regulation on 30 April 2016; complete fishery data from 2015/16 are not yet available at this time.

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:
Overfishing did not occur in 2014/15 because the 2014/15 estimated total catch (3,079 t; 6,788,025 lb) did not exceed the Tier 5 OFL established for 2014/15 (5.69-thousand t; 12.54-million lb). The 2014/15 estimated total catch did not exceed the ABC established for 2014/15 (4.26-thousand t; 9.40-million lb). The TACs for 2013/15–2014/15 do not include landings towards a cost-recovery fishing goal of $300,000; the catch reported for 2013/14–2014/15 includes the catch towards the cost-recovery fishery. Fishery catch data for estimating total catch in 2015/16 are not yet available. The 2016/17 TAC has not yet been established. The OFL and ABC values for 2016/17 are the author's status quo, Alternative 1 recommended values.

Management Performance Table (values in t)

Fishing Year	MSST	Biomass (MMB)	TAC[a]	Retained Catch	Total Catch	OFL	ABC
2012/13	N/A	N/A	2,853	2,843	3,115	5.69[c]	5.12[c]
2013/14	N/A	N/A	2,853	2,894[b]	3,192	5.69[c]	5.12[c]
2014/15	N/A	N/A	2,853	2,771[b]	3,079	5.69[c]	4.26[c]
2015/16	N/A	N/A	2,853			5.69[c]	4.26[c]
2016/17	N/A	N/A				5,689	4,267

a. Total allowable catch, established in lb and converted to t.
b. Includes retained catch towards cost-recovery fisheries.
c. Established in thousands of t.

Management Performance Table (values in lb)

Fishing Year	MSST	Biomass (MMB)	TAC[a]	Retained Catch	Total Catch	OFL	ABC
2012/13	N/A	N/A	6,290,000	6,267,759	6,867,391	12.54[c]	11.28[c]
2013/14	N/A	N/A	6,290,000	6,379,553[b]	7,037,147	12.54[c]	11.28[c]
2014/15	N/A	N/A	6,290,000	6,108,674[b]	6,788,025	12.53[c]	9.40[c]
2015/16	N/A	N/A	6,290,000			12.53[c]	9.40[c]
2016/17	N/A	N/A				12,542,830	9,407,122

a. Total allowable catch.
b. Includes retained catch towards cost-recovery fisheries.
c. Established in millions of lb.

Basis for the OFL and ABC: See table below; 2016/17 values are the author's recommended values.

Year	Tier	Years to define Average catch (OFL)	Natural Mortality[a]	Buffer
2012/13	5	1985/86–1995/96[b]	0.18	10%
2013/14	5	1985/86–1995/96[b]	0.18	10%
2014/15	5	1985/86–1995/96[b]	0.18	25%
2015/16	5	1985/86–1995/96[b]	0.18	25%
2016/17	5	1985/86–1995/96[b]	0.18	25%

a. Assumed value for FMP king crab in NPFMC (2007b); does not enter into OFL estimation for Tier 5 stock.
b. OFL was for total catch as 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 recommended (status quo Alternative 1) Tier 5 OFL was estimated by bootstrapping (see section G.1). The standard deviation of the estimated sampling distribution of the recommended OFL is 537 t (CV = 0.09). Note that generated sampling distribution and computed standard deviation are meaningful as measures in the uncertainty of the OFL only if assumptions on the choice of years used to compute the Tier 5 OFL are true (see Sections E.2 and E.4.f).

7. **Basis for the ABC recommendation:** A 25% buffer on the OFL; i.e., ABC = (1.0-0.25)·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 2014 the BOF changed the 9-month season opening date from 15 August to 1 August; that change became effective in 2015/16.
- In 2014 the State of Alaska (SOA) legislature increased the allocation that ADF&G may receive annually from the harvest and sale of Aleutian Islands golden king crab from $300,000 for funding of observer coverage in the fishery to $500,000, with the additional $200,000 for funding red king crab surveys and research in the Aleutian Islands. Harvest towards the increased cost-recovery goal was initiated in 2015/16. Retained catch from that cost-recovery fishing is not counted towards attainment of the annually-established TAC.

2. Changes to the input data:

- Commercial fishery data (weight of retained catch, number of retained crab, and number of pot lifts) that have been used in previous assessments were updated with values from the most recent ADF&G Area Management Report (Baechler and Cook 2014) and more recent fish ticket data. Fishery data has been updated with the catches during 2014/15: retained catch for the directed fishery and discarded catch estimates for the directed fishery, non-directed crab fisheries, and groundfish fisheries. Data from 2014/15 does not enter as input into computation of the recommended 2016/17 OFL. Complete fishery data from 2015/16 are not presently available.

3. **Changes to the assessment methodology:** None: the computation of OFL in this assessment follows the methodology recommended by the CPT in May 2012 and the SSC in June 2012.

4. **Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL:** None: the computation of OFL in this assessment follows the methodology recommended by the CPT in May 2012 and the SSC in June 2012 applied to the same data and estimates with the same assumptions that were used for estimating the 2012/13–2015/16 OFLs.

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 2015: *None pertaining to a Tier 5 assessment*.
    - SSC, June 2015: "*The SSC appreciates the author's inclusion of standard and metric units in the text but requests consistency in which units are used (e.g., lbs., thousand lbs., or million lbs. and t, mt, or kg). The SSC also requests consistency in the units chosen for tables and figures, requests that the units cited in the table legends match the values in the tables, and suggests authors refer to the terms of reference for chapters.*"
        - Response: The CPT terms of reference (as updated during the January 2016 meeting) were referred to:
        - "*To maintain consistency among SAFEs, the documents should report everything in the document in metric tons. The executive summary and the data used in the harvest strategy should be presented in both metric tons (abbreviated t) and pounds (lb).*" Everything weight-wise is reported here in metric tons. Weights are given in both t and lb for the following: weights in the text of the Management performance section of the Executive Summary; weights in the Management Performance table; retained catch weights in the Executive Summary; GHLs/TACs throughout the document; retained catch weights when presented relative to GHLs/TACs throughout the document; retained catch weights in section C.4 ("Brief summary of management history); and the results of computation of the recommended 2016/17 OFL and ABC. Otherwise weights are presented only in t. For consistency in units, weights in the text and in reporting of recommended OFL and ABC are given in whole t for metric units and whole lb for U.S. customary units; in tables of data and estimates, however, some metric weights in are given to several decimal places because some non-zero values round to 0 t. Reporting OFL and ABC for 2016/17 in t and lb may result in inconsistencies in the Management Performance tables and in the text when presenting previous OFLs and ABCs established using different conventions for units.
        - "*Provide single plot of all model data sources and years applicable – **Comment [4]: The Stockhausen tables.**"* Done. See Table 5.
    - CPT, September 2015 (via September 2015 SAFE Introduction chapter): *None pertaining to a Tier 5 assessment*.
    - SSC, October 2015: *None pertaining to a Tier 5 assessment*.

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

- CPT, May 2015 (May 2015 CPT minutes):
  - *"The CPT recommended that the author plot CPUE over time by area rather than by both areas combined so that these trends can be tracked in the Tier 5 assessment."*
    - Response: Done. See Table 1c and Figure 6.
- SSC, June 2015 (June 2015 SSC minutes):
  - *"The SSC also endorses this recommendation" (i.e, of the CPT recommendation of, "splitting the CPUE trend data into areas east and west of 174 degrees west, so that trends in CPUE can be tracked in the Tier 5 assessment.")*
    - Response: Done. See Table 1c and Figure 6.
- CPT, September 2015 (via Sept 2014 SAFE): *None.*
- SSC, October 2015: *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 [Bering Sea and Aleutian Islands], golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island passes.
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> 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.

The Aleutian Islands king crab stock boundary is defined by the boundaries of the Aleutian Islands king crab Registration Area O (Figure 1). In this chapter, "Aleutian Islands Area" means the area described by the current definition of Aleutian Islands king crab Registration Area O. Baechler and Cook (2014, page 7) define the boundaries of Aleutian Islands king crab Registration Area O:

> 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 1984/85–1995/96, 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; Baechler and Cook 2014). In March 1996 the Alaska Board of Fisheries (BOF) replaced the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and directed the Alaska Department of Fish and Game (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, coherent with the longitudinal pattern in fishery production prior to 1996/97 (Figure 3). The longitudinal pattern in fishery production relative to 174° W longitude since 1996/97 is similar to that observed prior to the change in management area definition, although there have been some changes in the longitudinal pattern in fishery production within the areas east and west of 174° W longitude (Figure 4).

Commercial fishing for golden king crab in the Aleutian Islands Area typically occurs at depths of 100–275 fathoms (183–503 m). Pots sampled by at-sea fishery observers in 2013/14 were fished at an average depth of 176 fathoms (322 m; N=499) in the area east of 174° W longitude and 158 fathoms (289 m; N=1,223) for the area west of 174° W longitude (Gaeuman 2014).

3. **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 are largely limited to the geographic distribution of commercial fishery catch and effort. Catch data by statistical area from fish tickets and catch data by location from pots sampled by observers suggest that habitat for legal-sized males may be continuous throughout the waters adjacent to the islands in the Aleutian chain. However, regions of low fishery catch suggest that availability of suitable habitat, in which golden king crab are present at only low densities, may vary longitudinally. Catch has been low in the fishery in the area between 174° W longitude and 176° W longitude (the Adak Island area, Figures 3 and 4) in comparison to adjacent areas, a pattern that is consistent with low CPUE for golden king crab between 174° W longitude and 176° W longitude (Figure 5) during the 2002, 2004, 2006, 2010, and 2012 NMFS Aleutian Islands bottom trawl surveys (von Szalay et al. 2011). In addition to longitudinal variation in density, there is also a gap in fishery catch and effort between the Petrel Bank-Petrel Spur area and the Bowers Bank area; both of those areas, which are separated by Bowers Canyon, 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 carapace length [CL]). Maximum straight-line distance between release and recovery location of 90 golden king crab released prior to the 1991/92 fishery and recovered through the 1992/93 fishery was 61.2 km (Blau and Pengilly 1994). Of the 4,567 recoveries reported through 12 April 2016 for the male and female golden king crab tagged and released between 170.5° W longitude and 171.5° W longitude during the 1991, 1997, 2000, 2003, and 2006 ADF&G Aleutian Island golden king pot surveys, none of the 3,807 with recovery locations specified by latitude and longitude were recovered west of 173° W longitude and only fifteen were recovered west of 172° W longitude (V. Vanek, ADF&G, Kodiak, pers. comm.). Similarly, of 139 recoveries in which only the statistical area of recovery was reported, none

were recovered in statistical areas west of 173° W longitude and only one was in a statistical area west of 172° W longitude.

4. Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology):

The following review of molt timing and reproductive cycle of golden king crab is adapted from Watson et al. (2002):

> Unlike red king crab, golden king crab may have an asynchronous molting cycle (McBride et al. 1982; Otto and Cummiskey 1985; Sloan 1985; Blau and Pengilly 1994). In a sample of male golden king crab 95–155-mm CL and female golden king crab 104–157-mm CL collected from Prince William Sound and held in seawater tanks, Paul and Paul (2000) observed molting in every month of the year, although the highest frequency of molting occurred during May–October. Watson et al. (2002) estimated that only 50% of 139-mm CL male golden king crab in the eastern Aleutian Islands molt annually and that the intermolt period for males ≥150-mm CL averages >1 year.
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> Female lithodids molt before copulation and egg extrusion (Nyblade 1987). From their observations on embryo development in golden king crab, Otto and Cummiskey (1985) suggested that time between successive ovipositions was roughly twice that of embryo development and that spawning and molting of mature females occurs approximately every two years. Sloan (1985) also suggested a reproductive cycle >1 year with a protracted barren phase for female golden king crab. Data from tagging studies on female golden king crab in the Aleutian Islands are generally consistent with a molt period for mature females of 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). Current knowledge of reproductive biology and maturity of male and female golden king crab is also reviewed by Webb (2014).

Note that asynchronous, aseasonal molting and the prolonged intermolt period (>1 year) of mature female and the larger male golden king crab likely makes precise scoring of shell condition very difficult. That difficulty obscures potential relationships between shell

condition and time-elapsed since molting and pose problems for inclusion of shell condition data into assessment models.

5. Brief summary of management history:

A complete summary of the management history through 2011/12 is provided in Baechler and Cook (2014, pages 13–19). 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 retained catch occurred in 1986/87 at 6,696 t (14,762,494 lb; Tables 1a and 1b). From 1981/82 to 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 divided 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 3,816 t (8,412,587 lb).

The Aleutian Islands golden king crab fishery was restructured beginning in 1996/97 to replace the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and golden king crab in the areas east and west of 174° W longitude were managed separately as two stocks. Table 1c and Figure 6 summarize trends in retained catch and CPUE (retained crab per pot lift) for the areas east and west of 174° W longitude. The fisheries in 1996/97–1997/98 were managed under a 2,676 t (5,900,000 lb) guideline harvest level (GHL; Tables 1a and 1b), with 1,452 t (3,200,000 lb) apportioned to the area east of 174° W longitude and 1,225 t (2,700,000 lb) apportioned to the area west of 174° W longitude. During 1998/99–2004/05 the fisheries were managed under a 2,585 t (5,700,000 lb) GHL, with 1,361 t (3,000,000 lb) apportioned to the area east of 174° W longitude and 1,225 t (2,700,000 lb) apportioned to the area west of 174° W longitude. During 2005/06–2007/08 the fisheries were managed under a 2,585 t (5,700,000 lb) total allowable catch (TAC), with a TAC of 1,361 t (3,000,000 lb) for the area east of 174° W longitude and a TAC of 1,225 t (2,700,000 lb) for the area west of 174° W longitude. By state regulation (**5 AAC 34.612**), TAC for the Aleutian Islands golden king crab fishery during 2008/09–2011/12 was 2,715 t (5,985,000 lb), with a TAC of 1,429 t (3,150,000 lb) for the area east of 174° W longitude and a TAC of 1,286 t (2,835,000 lb) for the area west of 174° W longitude. In March 2012 the BOF changed **5 AAC 34.612** so that the TAC beginning in 2012/13 would be 2,853 t (6,290,000 lb), with a TAC of 1,501 t (3,310,000 lb) for the area east of 174° W longitude and a TAC of 1,352 t (2,980,000 lb) 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 the specified level if conservation concerns arise. During 1996/97–2014/15 the annual retained catch during commercial fishing (including cost-recovery fishing that occurred during 2013/14–2014/15) has averaged 2% below the annual GHL/TACs. During 1996/97–2014/15, the retained catch has been as much as 13% below (1998/99) and as much as 6% above (2000/01) the GHL/TAC. The retained catch in 2014/15 was 3% below the TAC. Fishery CPUE (retained crab per pot lift) declined from 12 in 1985/86 to 5 in 1994/95, increased from 5 to 14 during 1995/96–2004/06, and increased to 23 in 2005/06 (Tables 1a and 1b, Figure 6). During 2006/07–2014/15 fishery CPUE has ranged from 22 to 29. Trends in fishery CPUE within the areas east of 174° W longitude and west of 174° longitude generally paralleled each other during 1985/86–2010/11, but diverged during 2011/12–2014/15 (an increasing trend in the area east of 174° W longitude and a decreasing trend in the area west of 174° W longitude; Table 1c, Figure 6).

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

Beginning in 2005/06 the Aleutian Islands golden king crab fishery has been 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; Hartill 2012). 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 managed by ADF&G and prosecuted concurrently with the IFQ fishery.

Only males of a minimum size may be retained by the commercial golden king crab fishery in the Aleutian Islands Area. By SOA 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) ≥136 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 (165 mm) CW for the entire Aleutian Islands Area 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 (defined in **5 AAC 34.050**). Pots used to fish for golden king crab in the Aleutian Islands Area must be operated 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 inches) into their gear or, more rarely, included panels with escape mesh (Beers 1992). With regard to the gear used 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[-inch] escape web on the door of over 95% of Golden Crab pot orders we manufactured." A study to estimate the contact-selection curve for male golden king crab that was conducted aboard one vessel commercial fishing for golden king crab during the 2012/13 season showed that gear and fishing practices used by that vessel was highly effective in reducing bycatch of sublegal-sized males and females (Vanek et al. 2013). In March 2011 (effective for 2011/12), 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** 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." Regulation **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."

Regulation (**5 AAC 34.610 (b)**) sets the commercial fishing season for golden king crab in the Aleutian Islands Area as 1 August through 30 April. That regulatory fishing season became effective in 2015/16 (the commercial fishing season was set in regulation as 15 August through 15 May during 2005/06–2014/15).

Current regulations (**5 AAC 39.645 (d)(4)(A)**) stipulate that onboard observers are required on catcher vessels during the time that at least 50% of the retained catch is captured in each of the three trimesters of the 9-month fishing season. Onboard observers are required on catcher-processors at all times during the fishing season.

6. Brief description of the annual ADF&G harvest strategy:
The annual TAC is set by state regulation, **5 AAC 34.612 (Harvest Levels for Golden King Crab in Registration Area O),** as approved by the BOF in March 2012:

> (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.

In addition to the retained catch that is limited by the TAC established by ADF&G under **5 AAC 34.612**, ADF&G also has authority to annually receive receipts of $500,000 through cost-recovery fishing on Aleutian Islands golden king crab. The retained catch from that cost-recovery fishing is not counted against attainment of the annually-established TAC.

7. **Summary of the history of B_{MSY}:** Not applicable for this Tier 5 stock.

D. Data

1. Summary of new information:

- Commercial fishery data (weight of retained catch, number of harvested crab, and number of pot lifts) that have been used in previous assessments were updated with values from the most recent ADF&G Area Management Report (Baechler and Cook 2014) and more recent fish ticket data.
- Fishery data on retained catch and discarded catch during crab fisheries in 2014/15 have been added.
- Data on discarded catch during groundfish fisheries in reporting areas 541, 542, and 543 (Figure 7) have been updated with data grouped by "fixed" (hook-and-line and pot) and "trawl" (non-pelagic trawl) in 2014/15 have been added.
- Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) in 2014/15 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 weight, catch numbers, pot lifts, CPUE, and average weight of retained catch for 1981/82–2014/15 (Tables 1a–1c).
- Statistics from all available data on discarded catch 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 1995/96–2014/15 (Table 2). Some observer data exists for the 1988/89–1989/90 seasons, but those data are not considered reliable. Although discarded catch can occur in the red king crab, scarlet king crab, grooved Tanner crab, and triangle Tanner crab fisheries of the Aleutian Islands, those discards account for ≤2% of the estimated total discarded catch weight in the crab fisheries when those fisheries were prosecuted. 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 discarded catch during the 1993/94 and 1994/95 directed fishery seasons are confidential. Observer data on size distributions and estimated catch numbers of discarded catch were used to estimate the weight of discarded catch of red king crab by applying a weight-at-length estimator (see below); data on the size distribution of discarded legal males was not recorded prior to 1998/99 and weights of retained legal males are used to estimate the weights of discarded legal males during the unobserved years.
- Data on discarded catch of golden king crab obtained by at-sea observers during groundfish fisheries in reporting areas 541, 542, and 543 (Figure 7) for 1993/94–2014/15 are presented (estimates for 1991/92–1992/93 are also presented, but they seem suspect; Table 3).
- Estimates of bycatch mortality in 1990/91–1992/93 and 1995/96–2014/15 directed and non-directed crab fisheries and 1993/94–2014/15 groundfish fisheries are presented in Table 4. Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) in 1995/96–2014/15 are presented (Table 4). Following Siddeek et al. (2014), 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 (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.
- Table 5 summarizes the available data on retained catch weight and the available estimates of discarded catch weight.

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

d. Survey biomass estimates: 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):***

Not used in a Tier 5 assessment. Growth per molt and probability of molt estimates are not used in a Tier 5 assessment. However, growth per molt and probability of molt have been estimated for Aleutian Islands golden king crab by Watson et al. (2002) using data from male and female golden king crab that were tagged and released during July–August 1997 in the area east of 174° W longitude and recovered during the 1997/98–2000/01 commercial fisheries (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 golden king crab according to the equation, Weight = $A*CL^B$ (from Table 3-5 in NPFMC 2007b) are: A = 0.0002988 and B = 3.135 for males and A = 0.001424 and B = 2.781 for females.

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

Not used in a Tier 5 assessment. The default natural mortality rate assumed for king crab species by NPFMC (2007b) is M=0.18.

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 assessment.

2. Model Description: *Subsections a–i are not applicable to a Tier 5 assessment.*
It was recommended by NPFMC (2007b) that the Aleutian Islands golden king crab stock be managed as a Tier 5 stock until an assessment model is accepted for use in management. In 2015 the SSC recommended that this stock continue to be managed under Tier 5 in 2015/16 (June 2015 SSC minutes). Separate from this Tier 5 assessment, an Aleutian Islands golden king crab assessment model will be reviewed for use in Tier 4 management of this stock by the Crab Plan Team in May 2016.

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 and subsequent OFLs for this stock. This assessment recommends – and only considers – use of a total-catch Tier 5 OFL for 2016/17.

For estimating the OFL of Tier 5 stocks, NPFMC (2007b) states, "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 were considered for computing the average retained catch for Aleutian Islands golden king crab: 1985–2005 (NPFMC 2007a) and 1985–1999 (NPFMC 2007b). The average retained catch over the years 1985 to 1999 was recommended by NPFMC (2007b) for 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). Pengilly (2008) discussed nine periods, with durations as long as 26 years (1981/82–2006/07) to as short as six years (1990/91–1995/96), for computing average annual retained catch and estimating 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 (Tables 1a and 1b, footnotes d–f). The Crab Plan Team in 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-1990s, the 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 as a compromise between the desire for the longest period possible under the current size limit for averaging catch and the desire for a period reflecting long-term production potential of the stock (the years excluded from the period, 1985/86–1986/87, were the years with the highest retained catch in the history of the fishery and there were trends of declining catch, declining CPUE, and declining average weight of landed crab that occurred from 1985/86 into the mid-1990s). Of those, the CPT 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):

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

where

- $R_{96/97\text{-}08/09}$ is the average of the estimated annual ratios of bycatch mortality due to crab fisheries to retained catch in the directed fishery during 1996/97–2008/09,
- $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery during 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 during 1996/97–2008/09.

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

Data on discarded catch during crab fisheries prior to 1996/97 were 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 bycatch mortality due to crab fisheries to retained catch in the directed fishery during 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 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 during 1993/94–2008/09).

Trends in the estimated annual ratios of bycatch mortality due to crab fisheries to retained catch in the directed fishery during 1990/91–2008/09 were presented to the CPT in May 2012 and SSC in June 2012. The SSC found that the estimated annual ratios of bycatch mortality due to crab fisheries to retained catch in the directed fishery prior to 1996/97 were a better reflection of bycatch mortality during 1985/86–1995/96 than the estimates from 1996/97–2008/09. Accordingly, the SSC (June 2012 SSC minutes) recommended that the OFL for the 2012/13 season be computed according to the "Alternative 1" approach as:

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

where,

- $R_{90/91\text{-}95/96}$ is the average of the estimated annual ratios of bycatch mortality due to crab fisheries to retained catch in the directed fishery during 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 $OFL_{2010/11}$ and $OFL_{2011/12}$, above (i.e., the average annual retained catch in the directed crab fishery during 1985/86–1995/96), and
- $BM_{GF,93/94\text{-}08/09}$ is the same as defined for $OFL_{2010/11}$ and $OFL_{2011/12}$, above (i.e., the average of the annual estimates of bycatch mortality due to groundfish fisheries over the period 1993/94–2008/09).

The OFLs for 2013/14–2015/16 and the recommended OFL for 2016/17 were computed following the status quo, Alternative 1 approach as for $OFL_{2012/13}$, above.

3. Model Selection and Evaluation:

a. *Description of alternative model configurations*

The SSC has recommended that the "time period be frozen to stabilize the control rule" in determination of a Tier 5 OFL (see section 2, above). With regard to the Tier 5 OFL for the Aleutian Islands golden king crab stock, the SSC has recommended that computation of the OFL computation should use: 1) the period 1985/86–1995/96 to compute the average retained catch (June 2008, and 2009 SSC minutes); 2) the "time period [to compute the Tier 5 OFL] be frozen to stabilize the control rule" at 1985/86–2008/09 (June 2010 SSC minutes); and 3) that discarded catch data from crab fisheries from the period prior to 1996/97 be used to compute the Tier 5 OFL (June 2012 SSC minutes). Given those recommendations from the SSC and the lack of any additional fishery data from the period 1985/86–2008/09 that were not already available and presented during 2012–2015, only one alternative is presented, the author's recommended Alternative 1, which is the status quo (i.e., the same as the Tier 5 OFL for 2012/13–2015/16 that was established in 2012):

$$OFL_{2016/17} = (1+R_{90/91\text{-}95/96}) \bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09},$$

where,

- $R_{90/91\text{-}95/96}$ is the average of the estimated annual ratios of bycatch mortality due to crab fisheries to 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 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.

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:*** None; see section A.4.

c. ***Evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models:*** None; see section A.4.

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 1985/86–2008/09 time period and the time periods for fishery mortality subcomponents within 1985/86–2008/09 used for determining the OFL were established by the SSC during 2008–2012. The values for retained catch and estimated bycatch mortality used in the OFL computation are in Table 6. Temporal trends during 1985/86–2014/15 in retained catch and in the available estimates of bycatch mortality due to crab fisheries and groundfish fisheries are shown in Figure 8. Trends in the ratio of the estimated bycatch mortality due to crab fisheries to the retained catch are shown in Figures 9 and 10 for the years that data and estimates are available during 1985/86–2014/15. Retained catch data come from fish tickets and annual retained catch is considered a known (not estimated) value. Estimates of discarded catch from crab fishery observer data are generally considered credible (e.g., Byrne and Pengilly 1998; Gaeuman 2014). Estimates of bycatch mortality were derived as estimates of discarded catch weight times an assumed bycatch mortality rate. The assumed bycatch mortality rates (i.e., 0.2 for crab fisheries, 0.5 for fixed-gear groundfish fisheries, and 0.8 for trawl groundfish fisheries) have not been estimated from data.

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

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

i. ***Evaluation of the model, if only one model is presented; or evaluation of alternative models and selection of final model, if more than one model is presented:*** The model for computing the single, status quo Alternative 1 recommended OFL follows the 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 (June 2008 and June 2009 SSC minutes), to not include discarded catch data after 2008/09 (June 2010 SSC minutes), and to use only the bycatch mortality estimates from the crab fisheries that are available from 1990/91–1995/96 (June 2012 SSC minutes). The author and the SSC (June 2012 SSC minutes) agree that the discarded catch data from crab fisheries during 1990/91–1995/96 are the most representative data available of the

conditions that existed during 1985/86–1995/96: those years fall 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 bycatch mortality due to crab fisheries to retained catch weight in the directed fishery since 1996/97 (Figures 9 and 10).

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 to a Tier 5 assessment.

b. Tables of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible; include estimates from previous SAFEs for retrospective comparisons): See Tables 6–7.

c. Graphs of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible): Not applicable to a Tier 5 assessment.

d. Evaluation of the fit to the data: Not applicable to a Tier 5 assessment.

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 to a Tier 5 assessment.

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 19 of Pengilly (2008) addressed the justifications for alternative choices of time periods that could be used to compute the retained-catch OFL. Interested readers are directed to that document. Briefly, however, the average retained-catch for the nine alternative time periods presented by Pengilly (2008) range from 2,555 t for 1996/97–2006/07 to 4,166 t for 1985/86–1995/96. The CPT in 2008 and 2009 recommended that the average retained catch during 1990/91–1995/96 (3,145 t) be used to compute the retained-catch OFL. In both 2008 and 2009, the SSC overrode the CPT's recommendation and selected the years 1985/86–1995/96 to compute the retained-catch OFL. The SSC recommended in 2009 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 bycatch mortality in the crab fisheries to retained catch. The SSC has recommended that the time period for computing the bycatch-mortality portion of the OFL be restricted to pre-2008/09. Within the

pre-2008/09 period, estimates of annual bycatch mortality in crab fisheries to retained catch are generally highest during 1990/91–1995/96 and show a decreasing trend during 1996/97–2008/09: the ratios are 0.3–0.4 during 1990/91–1995/96, 0.2–0.3 during 1996/97–2004/05, and 0.1 during 2005/06–2014/15 (Figures 9 and 10). 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 mortality due to groundfish fisheries. This assessment only considers the period 1993/94–2008/09 for discarded catch in the groundfish fisheries. Estimates of annual bycatch mortality due to groundfish fisheries during 1993/94–2008/09 range from <1 t to 59 t. Because the estimate of weight of discarded catch due to groundfish fisheries is small relative to the weight of retained catch (≥2,242 t annually since 1985/86), the effect of choice of years here is negligibly small.

- The bycatch mortality rates used in estimation of total fishery mortality are assumed values. Bycatch mortality is unknown and no data that could be used to estimate the bycatch mortality of this stock is known to the author. After discussion on information presented on the apparent "hardiness" of golden king relative to red king crab at the May 2013 meeting, the CPT concluded that the handling mortality rate used in golden king crab assessments should remain at the status quo, 0.2, until data for estimating handling mortality are presented (May 2013 CPT minutes). 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 discarded catch in crab fisheries and the groundfish fisheries (see bullet above), the estimated OFL is most sensitive to the assumed bycatch mortality rate in crab fisheries and less sensitive to the assumed bycatch mortality rate in groundfish fisheries. Given a fixed period of years to compute the average of annual discarded catch estimates for the crab fisheries, the estimated OFL is inversely related to the bycatch mortality rate assumed for the crab fisheries. If the assumed bycatch mortality rate is doubled from 0.2 to 0.4, the OFL estimate increases by a factor of 1.17 (1.4/1.2); if halved from 0.2 to 0.1, the assumed bycatch mortality rate, and the OFL estimate decreases by a factor of 0.92 (1.1/1.2).
- There has been no program to survey this stock in its entirety and a program to survey a portion of this stock on a triennial basis ended after 2006 due to the costs of survey implementation. The CPT in September 2013 strongly recommended that, *"A survey is needed to provide a better index of abundance and information on recruitment for stock assessment"* and encouraged ADF&G, NMFS, and industry to discuss how to make such a survey happen. Such discussions occurred at meetings amongst ADF&G, NMFS, and the Aleutian King Crab Research Foundation (AKCRF) in January and March 2014 and follow-up meetings between ADF&G and AKCRF to develop plans for a survey designed to be implemented with cooperating commercial fishing vessels (see May 2014 CPT minutes for more details on the survey design that was developed). See the May 2015 and September 2015 CPT minutes for updates from AKCRF and ADF&G on survey development, activities, and plans for the future.

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 mortality 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.
- Recommended OFL for 2016/17 is estimated by,

$$OFL_{2016/17} = (1+R_{90/91\text{-}95/96})\bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09},$$

where,

- $R_{90/91\text{-}95/96}$ is the average of the estimated annual ratios of bycatch mortality due to crab fisheries to 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 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, $RET_{(85/86\text{-}95/96}$, $R_{90/91\text{-}95/96}$, and $BM_{GF,93/94\text{-}08/09}$ are provided in Table 6; the column averages 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 $BM_{GF,93/94\text{-}08/09}$, $OFL_{2015/16}$ is computed as,

$$OFL_{2016/17} = (1+0.363)\bullet(4{,}166 \text{ t}) + 10.6 \text{ t} = 5{,}689 \text{ t } (12{,}542{,}830 \text{ lb}).$$

2. <u>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</u>:
Not applicable to Tier 5 assessment.

3. <u>Specification of the OFL</u>:

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

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

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 Management Performance tables, below. The OFL and ABC values for 2016/17 in the table below are the recommended values. The 2016/17 TAC has not yet been established. Complete catch data for 2015/16 are not presently available. The TACs for 2013/14–2015/16 in the table below do not include landings towards a cost-recovery fishery goal, but the catches towards cost-recovery fishing in 2013/14–2014/15 are included in the retained and total catch.

Management Performance Table (values in t)

Fishing Year	MSST	Biomass (MMB)	TAC[a]	Retained Catch	Total Catch	OFL	ABC
2012/13	N/A	N/A	2,853	2,843	3,115	5.69[c]	5.12[c]
2013/14	N/A	N/A	2,853	2,894[b]	3,192	5.69[c]	5.12[c]
2014/15	N/A	N/A	2,853	2,771[b]	3,079	5.69[c]	4.26[c]
2015/16	N/A	N/A	2,853			5.69[c]	4.26[c]
2016/17	N/A	N/A				5,689	4,267

a. Total allowable catch, established in lb and converted to t.
b. Includes retained catch towards cost-recovery fisheries.
c. Established in thousands of t.

Management Performance Table (values in lb)

Fishing Year	MSST	Biomass (MMB)	TAC[a]	Retained Catch	Total Catch	OFL	ABC
2012/13	N/A	N/A	6,290,000	6,267,759	6,867,391	12.54[c]	11.28[c]
2013/14	N/A	N/A	6,290,000	6,379,553[b]	7,037,147	12.54[c]	11.28[c]
2014/15	N/A	N/A	6,290,000	6,108,674[b]	6,788,025	12.53[c]	9.40[c]
2015/16	N/A	N/A	6,290,000			12.53[c]	9.40[c]
2016/17	N/A	N/A				12,542,830	9,407,122

a. Total allowable catch.
b. Includes retained catch towards cost-recovery fisheries.
c. Established in millions of lb.

4. Specification of the retained-catch portion of the total-catch OFL:
a. Equation for recommended retained-portion of total-catch OFL:

Retained-catch portion = average retained catch during 1985/86–1995/96
= 4,166 t (9,185,232 lb).

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

G. Calculation of ABC

1. PDF of OFL. Bootstrap estimate of the sampling distribution (assuming no error in estimation of discarded catch) of the recommended OFL is shown in Figure 11 (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 $OFL_{Alt\text{-}2,2010/11}$). The mean and CV computed from the 1,000 replicates are 5,675 t and 0.09, respectively. Note that generated sampling distribution and computed standard deviation are meaningful as measures

in the uncertainty of the OFL only if assumptions on the choice of years used to compute the Tier 5 OFL are true (see Sections E.2 and E.4.f).

2. List of variables related to scientific uncertainty.

- The time period to compute the average catch relative to the assumption that this represents "a time period determined to be representative of the production potential of the stock."
- Bycatch mortality rate in each fishery that discarded catch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch mortality rate will increase the 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 discarded catch and bycatch mortality for each fishery that bycatch occurred in during 1985/86–1995/96.
- See **E.4.*f*** for details.

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

5. Author recommended ABC.

$$(1.0\text{-}0.25)\cdot 5{,}689 \text{ t} = 4{,}267 \text{ t } (9{,}407{,}122 \text{ lb}).$$

The recommended ABC for 2016/17 was computed according to the status quo buffer of 0.25 recommended by the Crab Plan Team and SSC for 2014/15 – 2015/16. The 2014 SAFE, May 2014 CPT minutes, and June 2014 SSC minutes provide the reasoning for use of a buffer of 0.25, rather than a buffer of 0.1 as was used to compute the ABCs for 2011/12 – 2013/14.

H. Rebuilding Analyses

Not applicable; this stock has not been declared overfished.

I. Data Gaps and Research Priorities

Currently, there are no biomass estimates for this stock. A Tier 4 assessment based on fishery data has been in development to provide such estimates and will be reviewed again at the May 2016 CPT meeting. The CPT in September 2013 identified the need for development of a survey to provide fishery-independent data for estimation of stock abundance and recruitment. See the May 2015 and September 2015 CPT minutes for information on a cooperative effort by the Aleutian King Crab Research Foundation and ADF&G to implement such a survey.

Bycatch mortality rate in directed fishery is unknown.

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Table 1a. Commercial fishery history for the Aleutian Islands golden king crab fishery 1981/82–2014/15: number of vessels, guideline harvest level (GHL; established in lb, **converted to t**) for 1981/82–2004/05, total allowable catch (TAC; established in lb, **converted to t**) for 2005/06–2014/15, weight of retained catch (Harvest; **t**), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**kg**) of landed crab.

Crab fishing year	Vessels	GHL/TAC	Harvest[a]	Crab[a]	Pot lifts	CPUE[b]	Average weight[c]
1981/82	14−20	-	599	240,458	27,533	9	2.5[d]
1982/83	99−148	-	4,169	1,737,109	179,472	10	2.4[d]
1983/84	157−204	-	4,508	1,773,262	256,393	7	2.5[d]
1984/85	38−51	-	2,132	971,274	88,821	11	2.2[e]
1985/86	53	-	5,787	2,816,313	236,601	12	2.1[f]
1986/87	64	-	6,696	3,345,680	433,870	8	2.0[f]
1987/88	66	-	4,202	2,177,229	307,130	7	1.9[f]
1988/89	76	-	4,820	2,488,433	321,927	8	1.9[f]
1989/90	68	-	5,453	2,902,913	357,803	8	1.9[f]
1990/91	24	-	3,161	1,707,618	215,840	8	1.9[f]
1991/92	20	-	3,494	1,847,398	234,857	8	1.9[f]
1992/93	22	-	2,854	1,528,328	203,221	8	1.9[f]
1993/94	21	-	2,518	1,397,530	234,654	6	1.8[f]
1994/95	35	-	3,687	1,924,271	386,593	5	1.9[f]
1995/96	28	-	3,157	1,582,333	293,021	5	2.0[f]
1996/97	18	2,676	2,638	1,334,877	212,727	6	2.0[f]
1997/98	15	2,676	2,697	1,350,160	193,214	7	2.0[f]
1998/99	16	2,585	2,242	1,150,029	119,353	10	1.9[f]
1999/00	17	2,585	2,648	1,385,890	186,169	7	1.9[f]
2000/01	17	2,585	2,730	1,410,315	172,790	8	1.9[f]
2001/02	21	2,585	2,685	1,416,768	168,151	8	1.9[f]
2002/03	22	2,585	2,478	1,308,709	131,021	10	1.9[f]
2003/04	21	2,585	2,570	1,319,707	125,119	11	1.9[f]
2004/05	22	2,585	2,529	1,323,001	91,694	14	1.9[f]
2005/06	8	2,585	2,504	1,263,339	54,685	23	2.0[f]
2006/07	7	2,585	2,380	1,174,288	52,885	22	2.0[f]
2007/08	5	2,585	2,498	1,233,848	52,609	23	2.0[f]
2008/09	5	2,715	2,576	1,254,608	50,666	25	2.1[f]
2009/10	5	2,715	2,682	1,308,218	52,787	25	2.0[f]
2010/11	5	2,715	2,707	1,297,229	55,795	23	2.1[f]
2011/12	5	2,715	2,705	1,284,946	44,241	29	2.1[f]
2012/13	6	2,853	2,843	1,360,582	53,543	25	2.1[f]
2013/14[g]	5	2,853	2,894	1,407,103	63,223	22	2.1[f]
2014/15[g]	5	2,853	2,771	1,354,376	58,550	23	2.0[f]

a. Includes deadloss.
b. Catch (number of crab) per pot lift.
c. Average weight 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.
g. Catch and effort data includes cost-recovery fishery.

Table 1b. Commercial fishery history for the Aleutian Islands golden king crab fishery 1981/82–2014/15: number of vessels, guideline harvest level (GHL; **lb**) for 1981/82–2004/05, total allowable catch (TAC; **lb**) for 2005/06–2014/15, weight of retained catch (Harvest; **lb**), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**lb**) of landed crab.

Crab fishing year	Vessels	GHL/TAC	Harvest[a]	Crab[a]	Pot lifts	CPUE[b]	Average weight[c]
1981/82	14–20	-	1,319,761	240,458	27,533	9	5.5[d]
1982/83	99–148	-	9,191,245	1,737,109	179,472	10	5.3[d]
1983/84	157–204	-	9,939,002	1,773,262	256,393	7	5.6[d]
1984/85	38–51	-	4,701,237	971,274	88,821	11	4.8[e]
1985/86	53	-	12,758,637	2,816,313	236,601	12	4.5[f]
1986/87	64	-	14,762,494	3,345,680	433,870	8	4.4[f]
1987/88	66	-	9,264,395	2,177,229	307,130	7	4.3[f]
1988/89	76	-	10,627,042	2,488,433	321,927	8	4.3[f]
1989/90	68	-	12,022,052	2,902,913	357,803	8	4.1[f]
1990/91	24	-	6,969,535	1,707,618	215,840	8	4.1[f]
1991/92	20	-	7,702,141	1,847,398	234,857	8	4.2[f]
1992/93	22	-	6,291,197	1,528,328	203,221	8	4.1[f]
1993/94	21	-	5,551,143	1,397,530	234,654	6	4.0[f]
1994/95	35	-	8,128,511	1,924,271	386,593	5	4.2[f]
1995/96	28	-	6,960,406	1,582,333	293,021	5	4.4[f]
1996/97	18	5,900,000	5,815,772	1,334,877	212,727	6	4.4[f]
1997/98	15	5,900,000	5,945,683	1,350,160	193,214	7	4.4[f]
1998/99	16	5,700,000	4,941,893	1,150,029	119,353	10	4.3[f]
1999/00	17	5,700,000	5,838,788	1,385,890	186,169	7	4.2[f]
2000/01	17	5,700,000	6,018,761	1,410,315	172,790	8	4.3[f]
2001/02	21	5,700,000	5,918,706	1,416,768	168,151	8	4.2[f]
2002/03	22	5,700,000	5,462,455	1,308,709	131,021	10	4.2[f]
2003/04	21	5,700,000	5,665,828	1,319,707	125,119	11	4.3[f]
2004/05	22	5,700,000	5,575,051	1,323,001	91,694	14	4.2[f]
2005/06	8	5,700,000	5,520,318	1,263,339	54,685	23	4.4[f]
2006/07	7	5,700,000	5,245,926	1,174,288	52,885	22	4.5[f]
2007/08	5	5,700,000	5,508,100	1,233,848	52,609	23	4.5[f]
2008/09	5	5,985,000	5,680,084	1,254,608	50,666	25	4.5[f]
2009/10	5	5,985,000	5,912,287	1,308,218	52,787	25	4.5[f]
2010/11	5	5,985,000	5,968,849	1,297,229	55,795	23	4.6[f]
2011/12	5	5,985,000	5,964,416	1,284,946	44,241	29	4.6[f]
2012/13	6	6,290,000	6,267,759	1,360,582	53,543	25	4.6[f]
2013/14[g]	5	6,290,000	6,379,553	1,407,103	63,223	22	4.5[f]
2014/15[g]	5	6,290,000	6,108,674	1,354,376	58,550	23	4.5[f]

a. Includes deadloss.
b. Catch (number of crab) per pot lift.
c. Average weight 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.
g. Catch and effort data includes cost-recovery fishery.

Table 1c. Commercial fishery history for the Aleutian Islands golden king crab fishery, 1985/86–2014/15, separately for the areas east and west of 174° W longitude: weight of retained catch (Harvest; **t**), number of retained crab, pot lifts, fishery catch per unit effort (CPUE; retained crab per pot lift), and average weight (**kg**) of landed crab.

	East of 174° W longitude					West of 174° W longitude				
Crab fishing year	Harvest	Crab	Pot lifts	CPUE	Avg weight	Harvest	Crab	Pot lifts	CPUE	Avg weight
1985/86	2,966	1,405,602	118,038	12	2.1	2,821	1,410,711	118,563	12	2.0
1986/87	2,697	1,312,085	156,090	8	2.1	3,999	2,033,595	277,780	7	2.0
1987/88	2,014	1,032,077	146,901	7	2.0	2,189	1,145,152	160,229	7	1.9
1988/89	2,335	1,169,427	155,518	8	2.0	2,485	1,319,006	166,409	8	1.9
1989/90	2,483	1,317,833	155,262	8	1.9	2,971	1,585,080	202,541	8	1.9
1990/91	1,795	950,008	107,307	9	1.9	1,366	757,610	108,533	7	1.8
1991/92	2,065	1,093,983	133,428	8	1.9	1,428	753,415	101,429	7	1.9
1992/93	2,089	1,118,955	133,778	8	1.9	764	409,373	69,443	6	1.9
1993/94	1,510	832,194	106,890	8	1.8	1,008	565,336	127,764	4	1.8
1994/95	2,155	1,128,013	191,455	6	1.9	1,532	796,258	195,138	4	1.9
1995/96	2,099	1,046,780	177,773	6	2.0	1,058	535,553	115,248	5	2.0
1996/97	1,493	731,909	113,460	6	2.0	1,145	602,968	99,267	6	1.9
1997/98	1,588	780,610	106,403	7	2.0	1,109	569,550	86,811	7	1.9
1998/99	1,473	740,011	83,378	9	2.0	768	410,018	35,975	11	1.9
1999/00	1,392	709,332	79,129	9	2.0	1,256	676,558	107,040	6	1.9
2000/01	1,422	704,702	71,551	10	2.0	1,308	705,613	101,239	7	1.9
2001/02	1,442	730,030	62,639	12	2.0	1,243	686,738	105,512	7	1.8
2002/03	1,280	643,886	52,042	12	2.0	1,198	664,823	78,979	8	1.8
2003/04	1,350	643,074	58,883	11	2.1	1,220	676,633	66,236	10	1.8
2004/05	1,309	637,536	34,848	18	2.1	1,219	685,465	56,846	12	1.8
2005/06	1,300	623,971	24,569	25	2.1	1,204	639,368	30,116	21	1.9
2006/07	1,357	650,587	26,195	25	2.1	1,022	523,701	26,690	20	2.0
2007/08	1,356	633,253	22,653	28	2.1	1,142	600,595	29,956	20	1.9
2008/09	1,426	666,947	24,466	27	2.1	1,150	587,661	26,200	22	2.0
2009/10	1,429	679,886	26,298	26	2.1	1,253	628,332	26,489	24	2.0
2010/11	1,428	670,983	25,851	26	2.1	1,279	626,246	29,944	21	2.0
2011/12	1,429	668,828	17,915	37	2.1	1,276	616,118	26,326	23	2.1
2012/13	1,504	687,666	20,827	33	2.2	1,339	672,916	32,716	21	2.0
2013/14	1,546	720,220	21,388	34	2.1	1,347	686,883	41,835	16	2.0
2014/15	1,554	719,064	17,002	42	2.2	1,217	635,312	41,548	15	1.9

Table 2. Retained catch (**t**) of Aleutian Islands golden king crab, with the estimated discarded catch (**t**; not discounted for an assumed bycatch mortality rate) and components of discarded catch during commercial crab fisheries, 1990/91–2014/15; observer data on discarded catch for 1993/94 and 1994/95 are confidential and considered to have poor reliability.

			Components of discarded catch:		
Crab fishing year	Retained	Discarded	Legal males	Sublegal males	Females
1990/91	3,161	6,270	5	2,906	3,359
1991/92	3,494	5,106	97	2,510	2,499
1992/93	2,854	5,934	28	2,665	3,241
1993/94	2,518	—	—	—	—
1994/95	3,687	—	—	—	—
1995/96	3,157	5,466	29	2,746	2,691
1996/97	2,638	4,128	11	1,915	2,202
1997/98	2,697	3,961	18	1,905	2,038
1998/99	2,242	3,351	19	1,952	1,381
1999/00	2,648	3,426	29	1,783	1,613
2000/01	2,730	4,038	16	2,169	1,852
2001/02	2,685	3,124	12	1,718	1,395
2002/03	2,478	2,572	19	1,412	1,141
2003/04	2,570	2,256	18	1,208	1,030
2004/05	2,529	1,960	34	1,139	786
2005/06	2,504	1,145	64	671	411
2006/07	2,380	1,167	54	573	540
2007/08	2,498	1,377	58	683	636
2008/09	2,576	1,254	79	619	555
2009/10	2,682	1,264	74	619	572
2010/11	2,707	1,236	101	567	569
2011/12	2,705	1,152	122	536	494
2012/13	2,843	1,315	155	560	600
2013/14	2,894	1,436	167	675	593
2014/15	2,771	1,514	218	623	673

Table 3. Estimated annual weight (**t**) of discarded catch of golden king crab (all sizes, males and females) and bycatch mortality (**t**) during federal groundfish fisheries in federal reporting areas 541, 542, and 543 (see Figure 7) by gear type (fixed or trawl), 1991/92–2014/15; assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries.

	Discarded Catch		Bycatch Mortality		
Crab fishing year	Fixed Gear	Trawl Gear	Fixed Gear	Trawl Gear	Total
1991/92	0.000	0.000	0.000	0.000	0.000
1992/93	0.002	0.001	0.001	0.001	0.002
1993/94	1.796	3.703	0.898	2.962	3.861
1994/95	0.611	1.213	0.305	0.970	1.276
1995/96	0.166	2.343	0.083	1.874	1.958
1996/97	0.012	6.288	0.006	5.030	5.036
1997/98	0.244	0.486	0.122	0.389	0.511
1998/99	1.769	0.626	0.885	0.501	1.386
1999/00	4.795	0.645	2.398	0.516	2.914
2000/01	3.250	0.303	1.625	0.243	1.868
2001/02	0.629	0.189	0.315	0.152	0.466
2002/03	34.451	0.395	17.226	0.316	17.542
2003/04	39.093	0.679	19.547	0.543	20.090
2004/05	1.111	1.112	0.556	0.890	1.446
2005/06	0.565	1.883	0.283	1.506	1.789
2006/07	32.797	1.396	16.399	1.117	17.515
2007/08	115.315	1.652	57.658	1.321	58.978
2008/09	49.298	10.302	24.649	8.242	32.890
2009/10	20.061	8.192	10.030	6.554	16.584
2010/11	14.268	15.785	7.134	12.628	19.763
2011/12	16.436	9.089	8.218	7.271	15.489
2012/13	0.540	11.155	0.270	8.924	9.194
2013/14	1.579	12.420	0.789	9.936	10.725
2014/15	0.137	6.055	0.069	4.844	4.913

Table 4. Estimated annual weight (**t**) of total fishery mortality to Aleutian Islands golden king crab, 1990/91–2014/15, partitioned by source of mortality: retained catch, estimated bycatch mortality during crab fisheries, and estimated bycatch mortality during groundfish fisheries; from Tables 2 and 3 with assumed bycatch mortality rate of 0.2 applied to the discarded catch estimates in Table 2.

		Bycatch Mortality by Fishery Type		Total Fishery
Crab fishing year	Retained Catch	Crab	Groundfish	Mortality
1990/91	3,161	1,254	—	—
1991/92	3,494	1,021	—	—
1992/93	2,854	1,187	—	—
1993/94	2,518	—	3.9	—
1994/95	3,687	—	1.3	—
1995/96	3,157	1,093	2.0	4,252
1996/97	2,638	823	5.0	3,466
1997/98	2,697	789	0.5	3,486
1998/99	2,242	670	1.4	2,913
1999/00	2,648	685	2.9	3,337
2000/01	2,730	807	1.9	3,539
2001/02	2,685	625	0.5	3,310
2002/03	2,478	514	17.5	3,010
2003/04	2,570	451	20.1	3,041
2004/05	2,529	392	1.4	2,922
2005/06	2,504	229	1.8	2,735
2006/07	2,380	234	17.5	2,638
2007/08	2,498	275	59.0	2,833
2008/09	2,576	251	32.9	2,860
2009/10	2,682	253	16.6	2,951
2010/11	2,707	247	19.8	2,975
2011/12	2,705	230	15.5	2,951
2012/13	2,843	263	9.2	3,115
2013/14	2,894	287	10.7	3,192
2014/15	2,771	303	4.9	3,079

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

	Retained catch weight	Discarded catch weight (estimated)		
	Fish tickets	Observer data: lengths, catch per sampled pot	Blend method; Catch Accounting System	
Crab Fishing Year	Directed fishery	Crab fisheries	Fixed gear, groundfish	Trawl gear, groundfish
1981/82	599	—	—	—
1982/83	4,169	—	—	—
1983/84	4,508	—	—	—
1984/85	2,132	—	—	—
1985/86	**5,787**	—	—	—
1986/87	**6,696**	—	—	—
1987/88	**4,202**	—	—	—
1988/89	**4,820**	—	—	—
1989/90	**5,453**	—	—	—
1990/91	**3,161**	**6,270**	—	—
1991/92	**3,494**	**5,106**	0.000	0.000
1992/93	**2,854**	**5,934**	0.002	0.001
1993/94	**2,518**	Confidential	**1.796**	**3.703**
1994/95	**3,687**	Confidential	**0.611**	**1.213**
1995/96	**3,157**	**5,466**	**0.166**	**2.343**
1996/97	2,638	5,466	**0.012**	**6.288**
1997/98	2,697	4,128	**0.244**	**0.486**
1998/99	2,242	3,961	**1.769**	**0.626**
1999/00	2,648	3,351	**4.795**	**0.645**
2000/01	2,730	3,426	**3.250**	**0.303**
2001/02	2,685	4,038	**0.629**	**0.189**
2002/03	2,478	3,124	**34.451**	**0.395**
2003/04	2,570	2,572	**39.093**	**0.679**
2004/05	2,529	2,256	**1.111**	**1.112**
2005/06	2,504	1,960	**0.565**	**1.883**
2006/07	2,380	1,145	**32.797**	**1.396**
2007/08	2,498	1,167	**115.315**	**1.652**
2008/09	2,576	1,377	**49.298**	**10.302**
2009/10	2,682	1,254	20.061	8.192
2010/11	2,707	1,264	14.268	15.785
2011/12	2,705	1,236	16.436	9.089
2012/13	2,843	1,152	0.540	11.155
2013/14	2,894	1,315	1.579	12.420
2014/15	2,771	1,436	0.137	6.055

Table 6. Data for calculation of $RET_{85/86\text{-}95/96}$ (**t**) and estimates used in calculation of $R_{90/91\text{-}95/96}$ (ratio, t:t) and $BM_{GF,93/94\text{-}08/09}$ (**t**) for calculation of the recommended (status quo Alternative 1) Aleutian Islands golden king crab Tier 5 2016/17 OFL (**t**); 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.

Crab fishing year	$RET_{85/86\text{-}95/96}$	$R_{90/91\text{-}95/96}$	$BM_{GF,93/94\text{-}08/09}$
1985/86	5,787		
1986/87	6,696		
1987/88	4,202		
1988/89	4,820		
1989/90	5,453		
1990/91	3,161	0.398	
1991/92	3,494	0.292	
1992/93	2,854	0.416	
1993/94	2,518	—	3.9
1994/95	3,687	—	1.3
1995/96	3,157	0.346	2.0
1996/97			5.0
1997/98			0.5
1998/99			1.4
1999/00			2.9
2000/01			1.9
2001/02			0.5
2002/03			17.5
2003/04			20.1
2004/05			1.4
2005/06			1.8
2006/07			17.5
2007/08			59.0
2008/09			32.9
N	11	4	16
Average	4,166	0.363	10.6
S.E.M.	407	0.028	4.0
CV	0.10	0.08	0.38

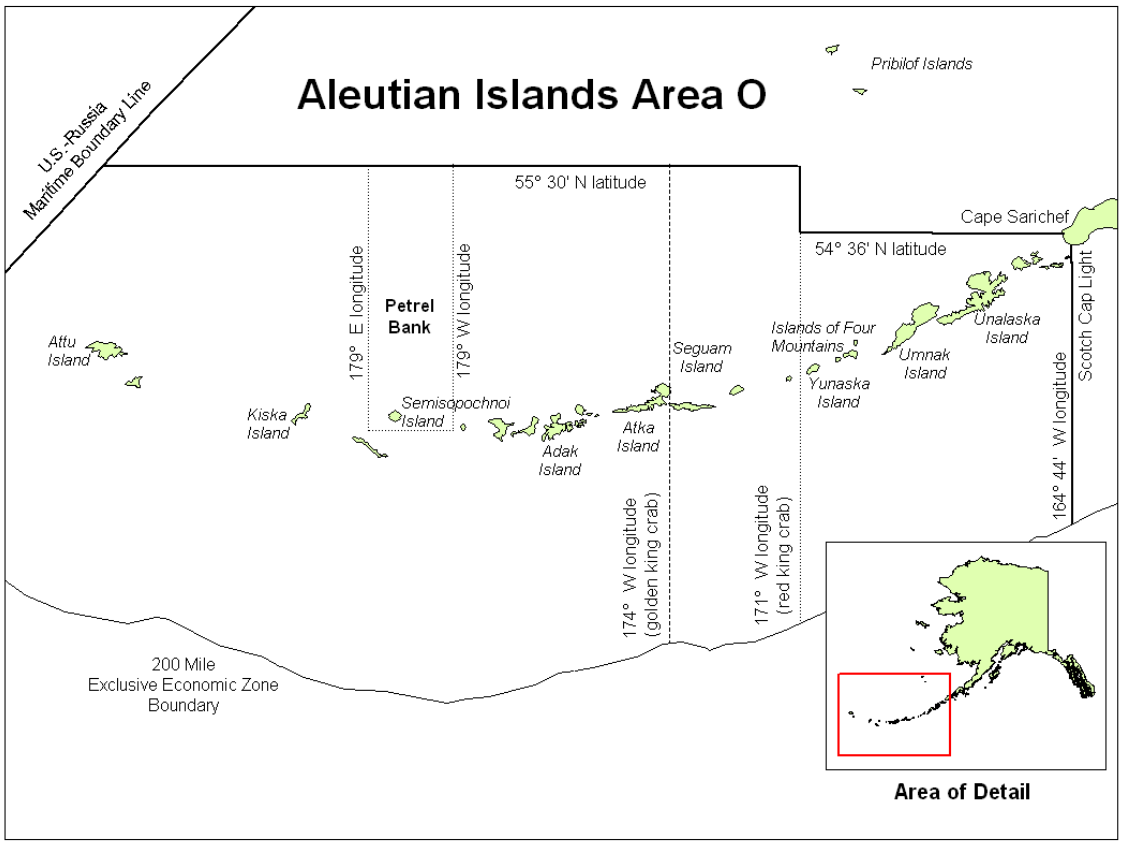

Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Baechler and Cook 2014).

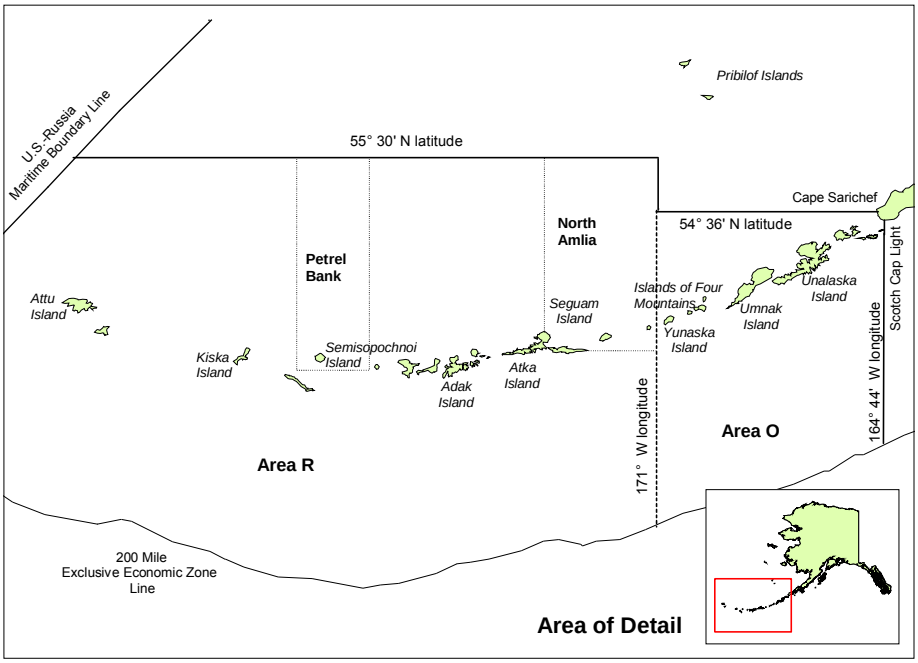

Figure 2. Adak (Area R) and Dutch Harbor (Area O) king crab Registration Areas and Districts, 1984/85–1995/96 seasons (from Baechler 2012).

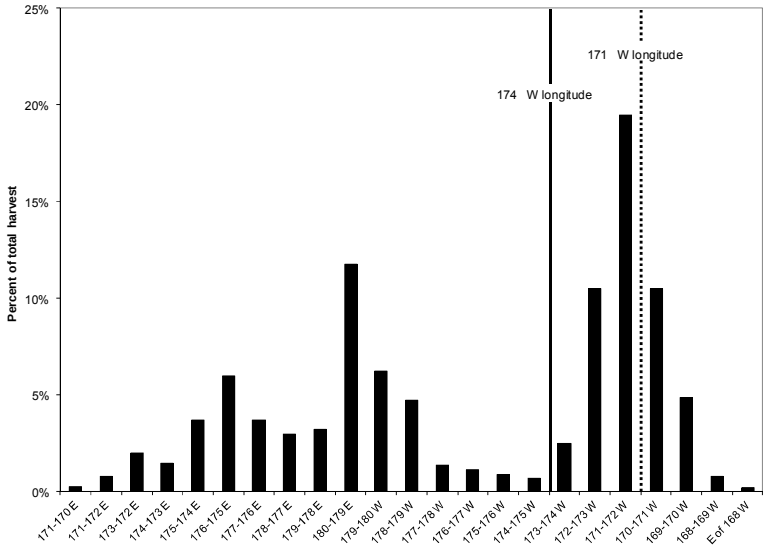

Figure 3. Percent of total 1981/82–1995/96 golden king crab retained catch weight (harvest) from one-degree longitude intervals in the Aleutian Islands, with dotted line denoting the border at 171° W longitude used during the 1984/85–1995/96 seasons to divide fishery management between the Dutch Harbor 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 used since the 1996/97 season to manage crab east and west of 174° W longitude (adapted from Figure 4-2 *in* Morrison et al. 1998).

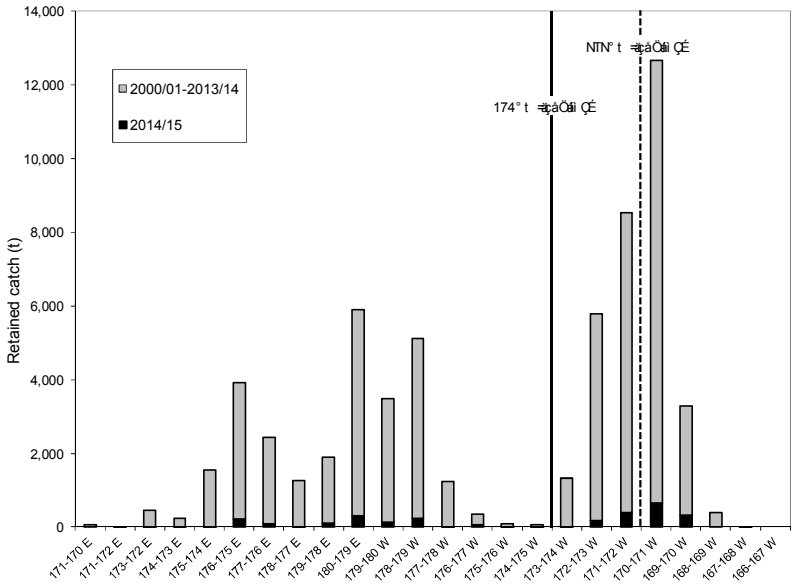

Figure 4. Retained catch (**t**) of golden king crab within one-degree longitude intervals in the Aleutian Islands during the 2000/01 through 2014/15 commercial fishery seasons; solid line denotes the border at 174° W longitude that has been used since the 1996/97 season to manage Aleutian Island golden king crab as separate stocks east and west of 174° W longitude and dashed line denotes the border at 171° W longitude used during the 1984/85–1995/96 seasons to divide fishery management between the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude).

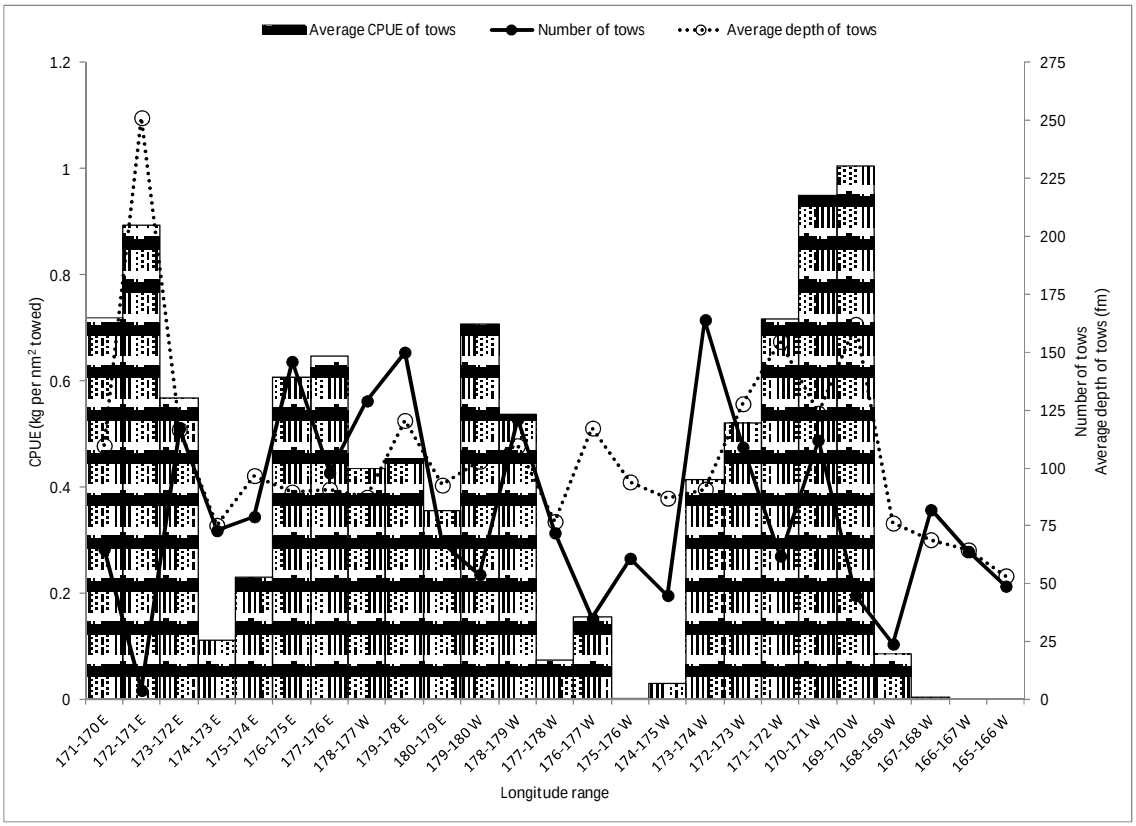

Figure 5. Average golden king crab CPUE (**kg**/nm^2) for tows, number of tows, and average depth of tows from one-degree longitude intervals during the 2002, 2004, 2006, 2010, and 2012 NMFS Aleutian Islands bottom trawl surveys; preliminary summary of data obtained on 1 April 2013 from http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm.

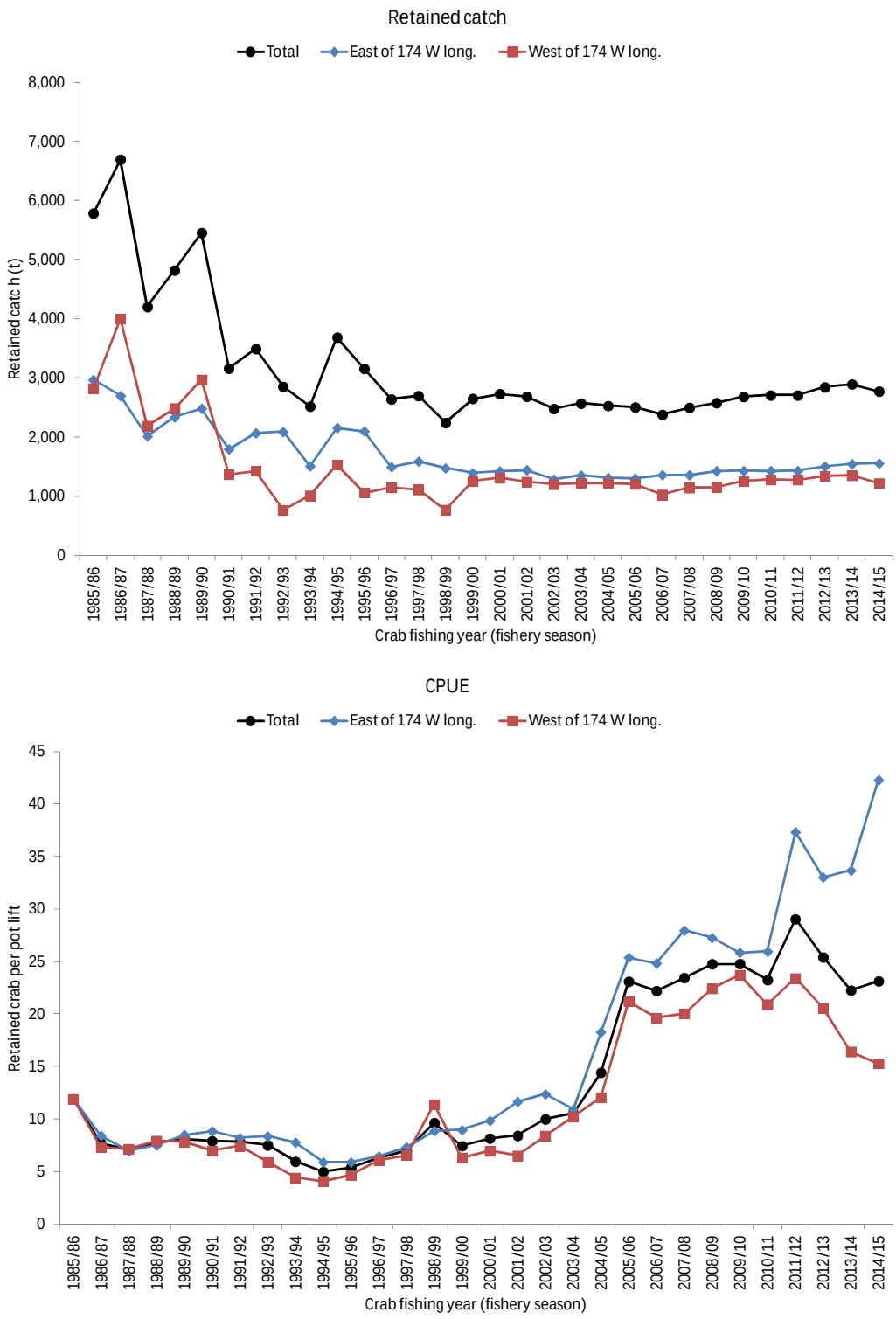

Figure 6. Retained catch (**t**; top) and catch per unit effort (CPUE; bottom) in the Aleutian Islands golden king crab fishery, 1985/86–2014/15: in the total area (east and west of 174° W longitude), in the area east of 174° W longitude, and in the area west of 174° W longitude.

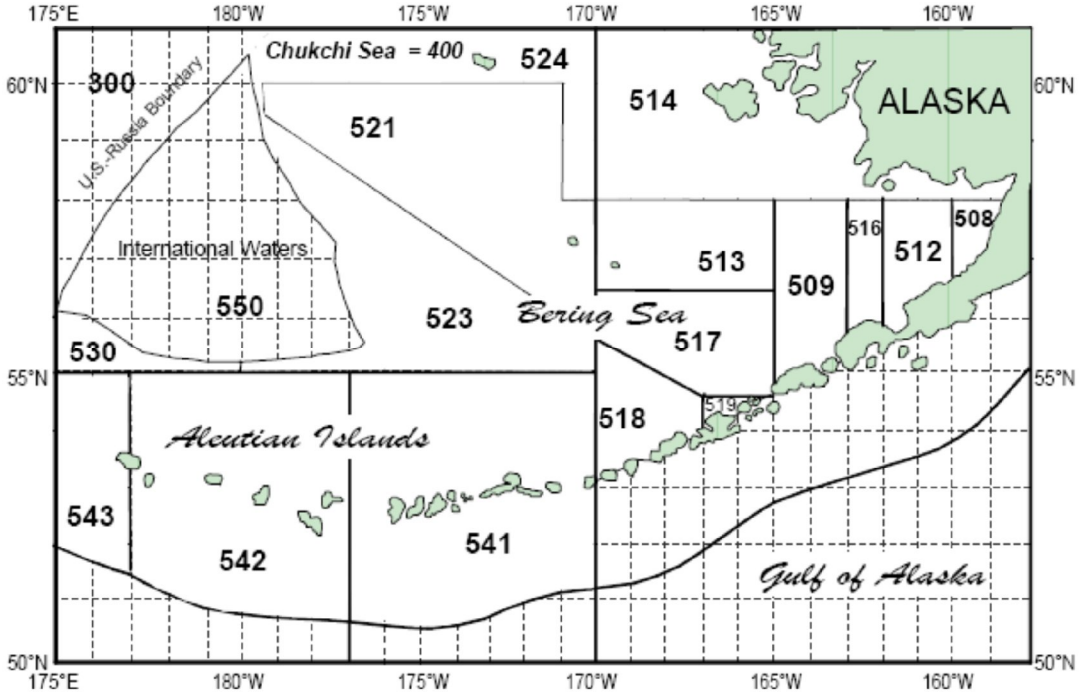

Figure 7. Map of federal groundfish fishery reporting areas for the Bering Sea and Aleutian Islands showing reporting areas 541, 542, and 543 that are used to summarize groundfish fisheries discarded catch data for Aleutian Islands golden king crab (from http://www.alaskafisheries.noaa.gov/rr/figures/fig1.pdf).

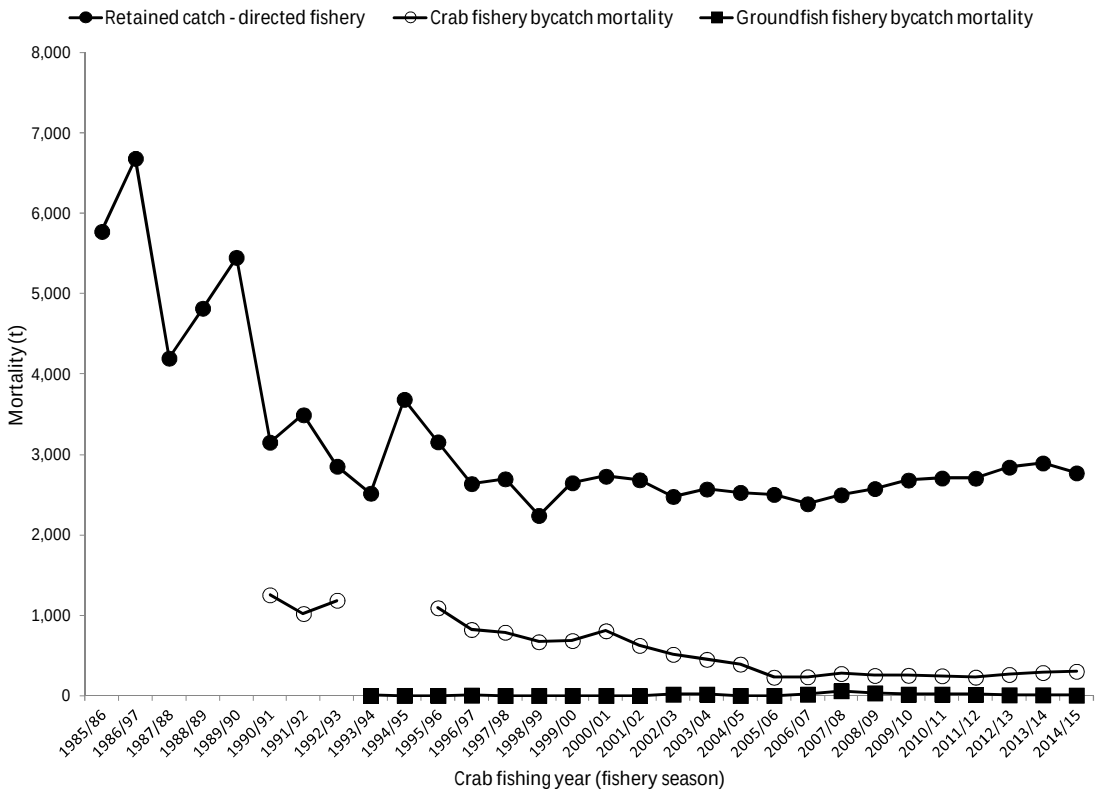

Figure 8. Retained catch (**t**) during the directed fishery, estimated bycatch mortality (**t**) during all crab fisheries, and estimated bycatch mortality (**t**) during all groundfish fisheries of Aleutian Islands golden king crab, 1985/86–2014/15 (from Table 4).

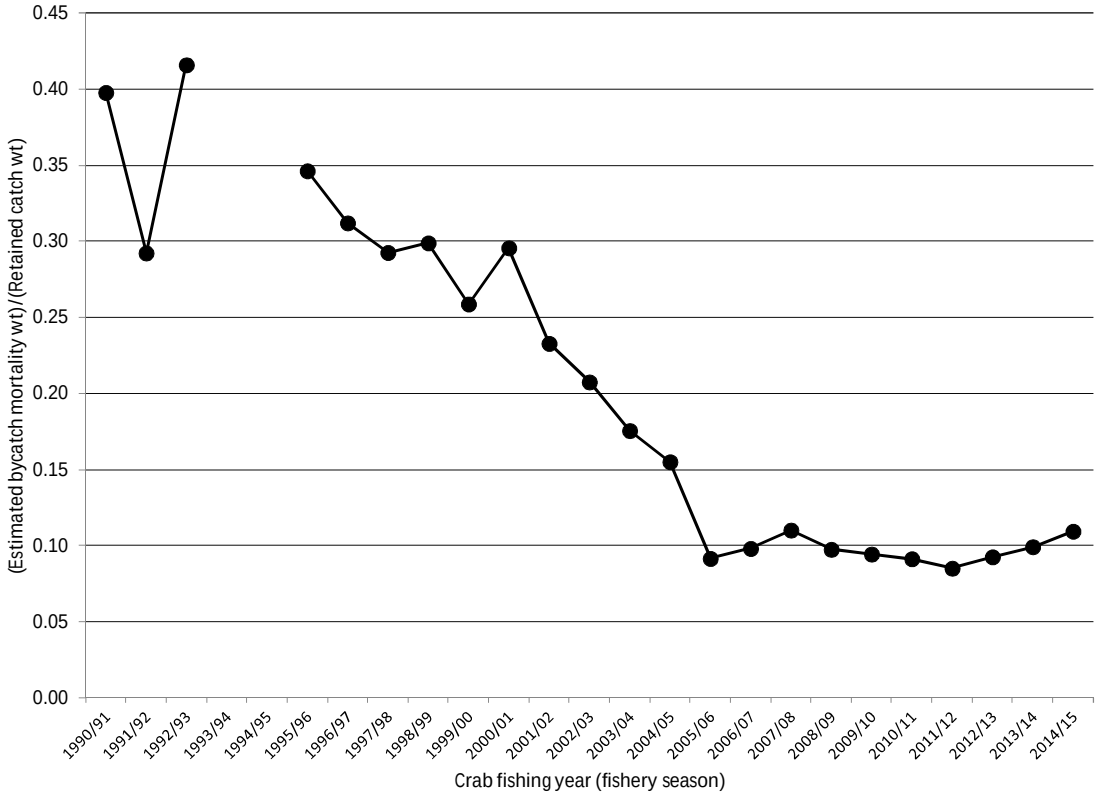

Figure 9. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch in the directed fishery for Aleutian Islands golden king crab, 1990/91–2014/15 (ratios for 1993/94–1994/95 are not available due to data confidentialities and insufficiencies).

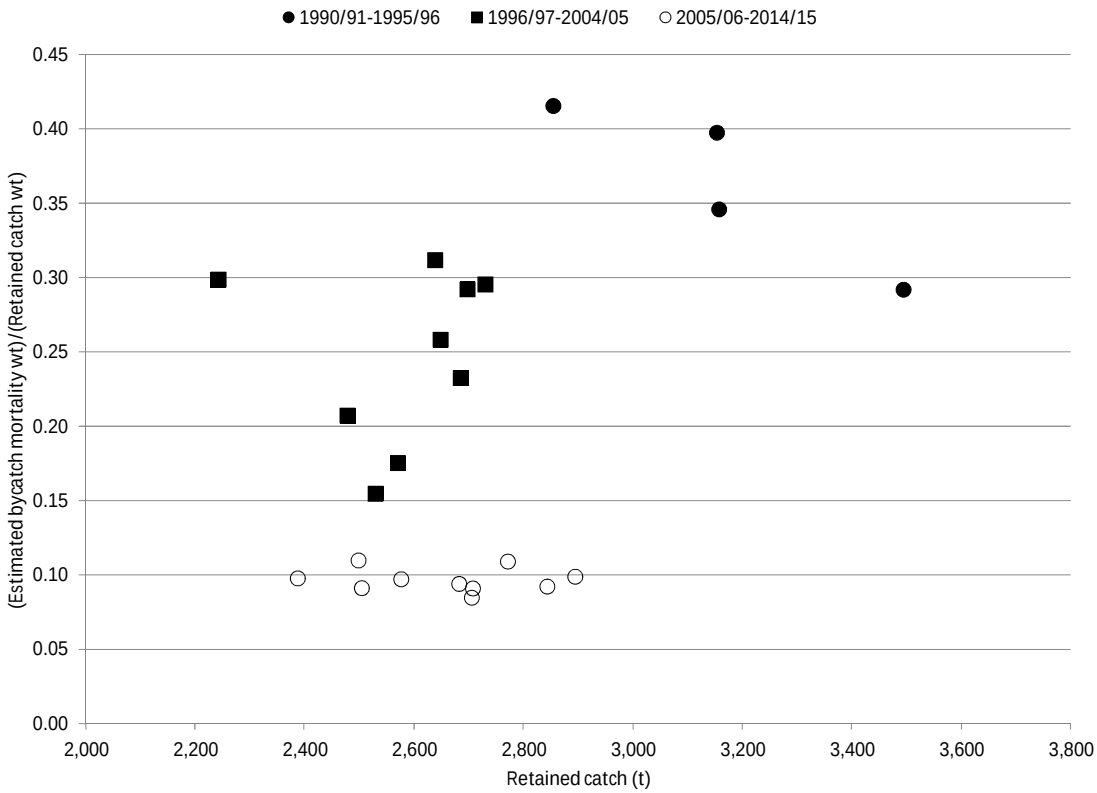

Figure 10. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch in the directed fishery for Aleutian Islands golden king crab plotted against weight (**t**) of retained catch, 1990/91–2014/15 (ratios for 1993/94–1994/95 are not available due to data confidentialities and insufficiencies).

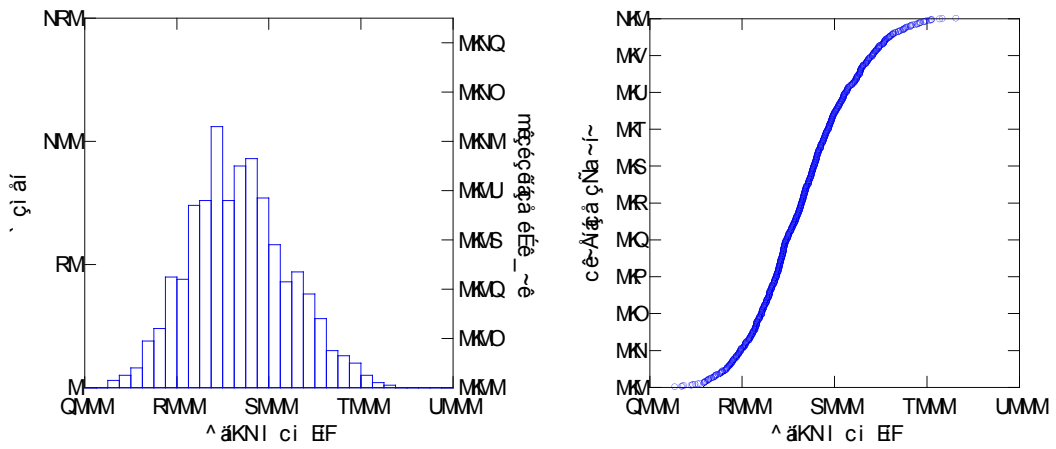

Figure 11. Bootstrapped estimates of the sampling distribution of the status quo, Alternative 1 recommended 2016/2017 Tier 5 OFL (total-catch, **t**) for the Aleutian Islands golden king crab stock; histograms in left column, cumulative distribution in right column.