

Aleutian Islands Golden King Crab

May 2011 Crab SAFE Report Chapter

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Executive Summary

1. **Stock:** Golden king crab *Lithodes aequispinus*/Aleutian Islands

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 2008/09–2010/11 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 2008/09–2009/10 was 5.796-million pounds (2,629 t). 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, markedly so during the 2005/06 season with the advent of the Crab Rationalization program. Non-retained bycatch occurs mainly during the directed fishery. Although some 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 and estimated total bycatch in groundfish fisheries during 2009/10 was lower at 0.062-million pounds (28 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 five seasons 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 1995/96–2009/10, the period for which such estimates can be made.

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 2009/10; the retained catch was less than the retained-catch OFL established for 2009/10 (see tables below). No ABC was established prior to the 2011/12 season.

See tables below; retained catch for 2010/11 is preliminary, the OFL and ABC values for 2011/12 are the author's Tier 5 recommendations, and the 2011/12 TAC is according to current SOA regulations.

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	5.70	5.51	6.25	N/A	N/A
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	TBD	11.06, T	N/A
2011/12	N/A	N/A	5.99	TBD	TBD	11.40, T	10.26, 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	TBD	5,017, T	N/A
2011/12	N/A	N/A	2,715	TBD	TBD	5,173, T	4,655, 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.

6. **Basis for the OFL and ABC:** See table, below; 2011/12 values are the author's recommendations.

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%

- 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.

7. **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 recommended OFL (Alternative 1) is 1.04-million pounds (CV = 0.09). See section G.1.
8. **Basis for the ABC recommendation:** A 10% buffer on the OFL; i.e., $ABC = (1-0.1) \cdot OFL$.
9. **A summary of the results of any rebuilding analyses:** Not applicable; stock is not under a rebuilding plan.

A. Summary of Major Changes

1. **Changes to the management of the fishery:** None.
2. **Changes to the input data:**
- Fishery data has been updated with the results for 2009/10: retained catch for the directed fishery and bycatch estimates for the directed fishery, non-directed crab fisheries, and groundfish fisheries. Preliminary statistics for the 2010/11 season are included. Bycatch data from the 1990/91–1992/93 and 1995/96 crab fisheries (1993/94 and 1994/95 not included due to insufficient data) and from the 1993/94–1995/96 groundfish fisheries have been added to the assessment.
3. **Changes to the assessment methodology:** None. This assessment follows the methodology recommended by the CPT in May 2010 and the SSC in June 2010, but incorporates additional historical data that was not available for review in 2010.
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 recommended OFL for 2011/12 is a total-catch OFL of 11.40-million pounds. The author follows the June 2010 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 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.

B. Responses to SSC and CPT Comments

1. Responses to the most recent two sets of SSC and CPT comments on assessments in general:

- CPT, May 2010:
 1. *“Some assessments provided results in metric tons. The CPT recommendation to use metric tons refers only to the ACL analysis and traditional assessment currencies (lbs) should continue to be used in stock assessments.”*
 - Response: That was done.
 2. *“The team requested that all assessments explain how the groundfish bycatch data are used in the assessment and that all assessment chapters should be consistent in distinguishing and separately presenting groundfish bycatch from fixed gear fisheries and trawl gear fisheries.”*
 - Response: Explanations were made and statistics from fixed gear and trawl gear fisheries are distinguished and presented separately.
- SSC, June 2010: *“In order to have greater consistency between assessments, the SSC recommends that catch statistics reported in the executive summary section contain both metric tons and pounds (millions).”*
 - Response: That was done.
- CPT, September 2010: [None.]
- SSC, October 2010: [None.]

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

- CPT, May 2010: *“The CPT recommended that a total-catch OFL be established for the 2010/11 Aleutian Islands golden king crab season.” [Plus extended verbiage and presentation of tables and graphs pertaining to alternative approaches that were not used to compute the 2010/11 OFL. The May 2010 CPT minutes do not provide the recommendation for the 2010/11 total OFL that appears in the Executive Summary of the 2010 SAFE. The reader is directed to the June 2010 SSC minutes and the Executive Summary of the 2010 SAFE for information on this matter.]*
 - Response: The author recommends a total-catch OFL for 2011/2012. See also the SSC June 2010 comments and response.
- SSC, June 2010: [Verbiage on rejecting the alternatives for accounting for bycatch mortality in the 2010/11 total-catch OFL considered by the CPT in May 2010] *“In the end, the SSC resolved that basing this bycatch mortality on the full time period (1996/1997–2008/2009) may be most robust, as it includes the most data. Thus the SSC recommends its own alternative [for the 2010/11 total-catch OFL]:*

$$OFL_{TOT(4)} = (1 + RATE_{96/97-08/09}) \cdot OFL_{RET(85/86-95/96)} + MGF_{96/97-08/09} = 11.0 \text{ million lbs.},$$

where

$RATE_{96/97-08/09}$ = mean annual rate = (bycatch mortality in crab fisheries)/(retained catch) over the period 1996/97-2008/09,

$OFL_{RET(85/86-95/96)}$ = mean annual retained catch over the period 1985/86-1995/96, and

$MGF_{96/97-08/09}$ = mean of annual bycatch mortality in groundfish fisheries over the period 1996/97-2008/09.

The SSC recommends that this time period be frozen to stabilize the control rule.”

- **Response:** The author follows this recommended approach. In computing the recommended total-catch OFL for 2011/12, the time period for retained catch data is “frozen” at 1985/86–1995/96 and the last year of bycatch data included is “frozen” at 2008/09. Following the “more data = more robust” rule of thumb for estimating the bycatch mortality component of the total-catch, available data on bycatch in the crab and groundfish fisheries prior to 1996/97 are also included in the computation of the OFL.
- CPT, September 2009: None – this stock was not reviewed at the September 2010 CPT meeting.
- SSC, October 2010: None – this stock was not reviewed at the June 2010 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 2009/10 season the pots sampled by at-sea observers were fished at an average depth of 183 fathoms (335 m; N=411) in the area east of 174° W longitude and 174 fathoms (318 m; N=893) for the area east 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 crab 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 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 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 1996/97–2009/10 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 2009/10 season was <1% below the 5.985-million pound TAC.

A summary of relevant 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 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) \geq 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."

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 2009/10 crab fisheries (retained catch during 2010/11 is reported but is considered preliminary). Data on bycatch during the 1990/91–1992/93 and 1995/96 directed and non-directed 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 1991/92–1995/96 and 2009/10 (however, the 1991/92–1992/93 appears suspect and is not included in the analysis).
- Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) during 1995/96 and 2009/10 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 (2010/11 statistics considered preliminary) 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 1995/96–2009/10 (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 $\leq 2\%$ of the estimated total weight in the crab fisheries annually. Only one vessel was observed during the directed fishery only in the area west of 171° W longitude in each of the 1993/94 and 1994/95 seasons, disallowing for estimation of bycatch during the directed fishery for those two seasons east of 171° W longitude and for the Aleutian Islands as a whole. Data on bycatch of non-retained legal males appears to be less reliable in the seasons prior to 1998/99 than in later seasons; however, bycatch of non-retained legal males accounts for only $\leq 2\%$ of the estimated total weight in the crab fisheries annually in seasons prior to 2005/06. 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 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 1993/94–2009/10 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 1995/96–2009/10 directed and non-directed crab fisheries and 1993/94–2009/10 groundfish fisheries are presented in Table 4. Estimates of total fishery mortality (retained catch plus estimated bycatch mortality during crab and groundfish fisheries) during 1995/96–2009/10 are presented (Table 4). Following Siddeek et al. (2010), 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 (2010a, 2010b), 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:

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

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:

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

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, $\text{Weight} = A \cdot \text{CL}^B$ (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 $170^\circ 21'$ and $171^\circ 33'$ 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. 2010).

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 (e.g., Siddeek et al. 2010) 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 2011/12.

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 GHF established for the entire Aleutian Islands Area prior to the 1996/97 season (see above) and the GHF 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 GHF 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 estimate 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). Of those, the Crab Plan Team at the May 2008 recommended using the period 1990/91–1995/96 for computing the 2008/09 OFL to address 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 the full period 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. 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):

$$\text{“OFL}_{\text{TOT}(4)} = (1 + \text{RATE}_{96/97-08/09}) \cdot \text{OFL}_{\text{RET}(85/86-95/96)} + \text{MGF}_{96/97-08/09} = 11.0 \text{ million lbs.,}$$

where

$RATE_{96/97-08/09}$ = mean annual rate = (bycatch mortality in crab fisheries)/(retained catch) over the period 1996/97-2008/09,

$OFL_{RET(85/86-95/96)}$ = mean annual retained catch over the period 1985/86-1995/96, and

$MGF_{96/97-08/09}$ = mean of annual bycatch mortality in 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.”

Given the most recent recommendations from the SSC (June 2010) the author considers all debate and questions concerning alternative time periods to computing a Tier 5, total-catch OFL for this stock to be closed and will follow the June 2010 recommendation of the SSC unless instructed to do 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 preceding 2008/09 will be used in calculation of the 2011/2012 total-catch OFL. Data and estimates that are used in calculation of alternative total-catch OFLs for 2011/12 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 1 is the author’s recommended alternative.

Alternative 1 (author’s recommendation). The recommended OFL is set as a total-catch OFL following the June 2010 recommendation of the SSC, but uses additional historical data on bycatch that was not available for review in 2010:

$$OFL_{TOT(1), 2010/11} = (1+R_{90/91-08/09}) \cdot RET_{85/86-95/96} + BM_{GF,93/94-08/09},$$

where,

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

Statistics on the data and estimates used to calculate, $RET_{(85/86-95/96)}$, $R_{90/91-08/09}$, and $BM_{GF,93/94-08/09}$ are provided in Table 5; the column means in Table 5 are the calculated values of $RET_{(85/86-95/96)}$, $R_{90/91-08/09}$, and $BM_{GF,93/94-08/09}$. Using those calculated values of $RET_{(85/86-95/96)}$, $R_{90/91-08/09}$, and $BM_{GF,93/94-08/09}$, $OFL_{TOT(1), 2010/11}$ is,

$$OFL_{TOT(1), 2010/11} = (1+0.240) \cdot (9,178,438) + 23,359 = 11,404,670 \text{ lbs (11.40-million lbs).}$$

Alternative 2 (status quo). This alternative is the same total-catch OFL that was recommended by the SSC in June 2010 and which was established as the OFL for 2010/11:

$$OFL_{TOT(2), 2010/11} = (1+R_{96/97-08/09}) \cdot RET_{85/86-95/96} + BM_{GF,96/97-08/09},$$

where,

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

Statistics on the data and estimates used to calculate, $RET_{(85/86-95/96)}$, $R_{96/97-08/09}$, and $BM_{GF,96/97-08/09}$ are provided in Table 6; the column means in Table 6 are the calculated values of $RET_{(85/86-95/96)}$, $R_{96/97-08/09}$, and $BM_{GF,96/97-08/09}$. Using those calculated values of $RET_{(85/86-95/96)}$, $R_{96/97-08/09}$, and $BM_{GF,96/97-08/09}$, $OFL_{TOT(2), 2010/11}$ is,

$$OFL_{TOT(2), 2010/11} = (1+0.202) \cdot (9,178,438) + 27,546 = 11,061,356 \text{ lbs (11.06-million lbs).}$$

- 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. 2 – status quo	Total-catch	1985/86–1995/96	11.06
Alt. 1 - recommended	Total-catch	1985/86–1995/96	11.40

Given the June 2010 recommendation to freeze the time periods to stabilize the control role and the June 2010 argument of the SSC that the approach that “includes the most data... may be the most robust” [*with ordering of the two quoted phrases (separated by ellipses) switched by the author for clarity of exposition!*], the author recommends Alternative 1.

- 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), in the ratio of the estimated bycatch mortality in crab fisheries to the retained catch (Figure 7), the estimated bycatch mortality in groundfish fisheries (Figure 8), during that period. Additionally, 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 9). 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 2010). 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:** See section E.3.c, above.
4. **Results (best model(s)):**
- a. **List of effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties:** Not applicable.
- b. **Tables of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible; include estimates from previous SAFEs for retrospective comparisons):** See Tables 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 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. See Figures 6–9.
 - The bycatch mortality rates used in estimation of total catch.

See also Tables 5–7 and Figure 10.

F. Calculation of the OFL

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

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

- Recommended time period for computing retained-catch portion of the OFL: 1985/86–1995/96.
 - The recommended time period follows the recommendation of the SSC in June 2010. Moreover, the SSC in June 2009 also noted that, “the management system was relatively constant from 1985 onward” [until 1996/97]. The SSC in June 2010 recommended that data from 1996/97–2008/09 be used to estimate the bycatch mortality component of the total-catch OFL and to “freeze” time periods henceforth. This assessment uses estimates of bycatch mortality during the 1990/91–1992/93 and 1995/96–2008/09 crab fisheries and during the 1993/94–2008/09 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. 2011/12 values are author’s recommendations.

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	5.70	5.51	6.25	N/A	N/A
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	TBD	11.06, T	N/A
2011/12	N/A	N/A	5.99	TBD	TBD	11.40, T	10.26, 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. Recommended F_{OFL} , OFL total catch and the retained portion for the coming year:

See sections *F.3* and *F.4*, above; no F_{OFL} is recommended for a Tier 5 stock.

G. Calculation of ABC

1. PDF of OFL. 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 10 (1,000 samples drawn with replacement independently from each of the three columns of values in Table 5 to calculate $R_{90/91-08/09}$, $RET_{85/86-95/96}$, $BM_{GF,93/94-08/09}$ and $OFL_{TOT(1),2010/11}$ and 1,000 samples drawn with replacement independently from each of the three columns of values in Table 6 to calculate $R_{96/97-08/09}$, $RET_{85/86-95/96}$, $BM_{GF,96/97-08/09}$ and $OFL_{TOT(2),2010/11}$). Table 7 provides statistics on the generated distributions.

2. List of variables related to scientific uncertainty.

- Bycatch mortality rate in each fishery that bycatch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch rate will increase the 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.
- 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.”

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

4. Author recommended ABC. $(1-0.1) \cdot 11,404,670$ pounds = 10.26-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 2010) to estimate spawning biomass or a proxy will identify data gaps and research priorities.

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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 Bowers et al. 2011, updated with 2009/10 and 2010/11 data from H. Fitch, ADF&G, 8 April 2011 email; data for 2010/11 should be considered preliminary).

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	1,297,231	55,786	23.3	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. Estimated weight (pounds) of the catch of retained legal males, non-retained legal male, non-retained sublegal male, non-retained female, and total non-retained Aleutian Islands golden king crab during directed and non-directed commercial crab fisheries by season for the 1990/91–2010/11 seasons (from 2010 SAFE, updated with: 2009/10 retained catch data and preliminary 2010/11 retained catch data from H. Fitch, ADF&G, 8 April 2011 email; 2009/10 bycatch estimates from Gaeuman 2011 and data from the ADF&G Crab Observer Database, 25 April 2011; 1990/91–1995/96 bycatch estimates from the ADF&G Crab Observer Database, 25 April 2011).

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

Table 3. Estimated annual weight (pounds) of discarded bycatch and total fishery mortality of golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 541, 542, and 543, 1991/92–2009/10 (assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries); *estimates for 1991/92 and 1992/93 appear suspect and are not included in assessment analysis* (1991/92–2008/09 data provided by R. Foy, AFSC, Kodiak Laboratory, 7 August 2009 email; 2009/10 data provided by R. Foy, AFSC, Kodiak Laboratory, 13 August 2010 email).

Year	Fixed	Trawl	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

Table 4. Estimated annual weight (pounds) of total fishery mortality to Aleutian Islands golden king crab, 1990/91–2009/10, partitioned by source of mortality: retained catch, bycatch mortality during crab fisheries, and bycatch mortality during groundfish fisheries; see Table 2 (assumes bycatch mortality rate of 0.2 for crab fisheries) and Table 3.

Season	Retained Catch	Bycatch Mortality by Fishery Type		Total
		Crab	Groundfish	
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

Table 5. Data for calculation of $RET_{85/86-95/96}$ and estimates used in calculation of $R_{90/91-08/09}$ and $BM_{GF,93/94-08/09}$ for calculation of the recommended Alternative 1 Aleutian Islands golden king crab Tier 5 2011/12 total-catch OFL; values under $RET_{85/86-95/96}$ under from Table 1, values under $R_{90/91-08/09}$ were computed from the retained catch data and the crab bycatch mortality estimates in Table 4, and values under $BM_{GF,93/94-08/09}$ are from Table 4.

Season	$RET_{85/86-95/96}$	$R_{90/91-08/09}$	$BM_{GF,93/94-08/09}$
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

Table 6. Data for calculation of $RET_{85/86-95/96}$ and estimates used in calculation of $R_{96/97-08/09}$ and $BM_{GF,96/97-08/09}$ for calculation of the Alternative 2 Aleutian Islands golden king crab Tier 5 2011/12 total-catch OFL; values under $RET_{85/86-95/96}$ are from Table 1, values under $R_{96/97-08/09}$ were computed from the retained catch data and the crab bycatch mortality estimates in Table 4, and values under $BM_{GF,96/97-08/09}$ are from Table 4.

Season	$RET_{85/86-95/96}$	$R_{96/97-08/09}$	$BM_{GF,96/97-08/09}$
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		
1991/92	7,702,141		
1992/93	6,291,197		
1993/94	5,551,143		
1994/95	8,128,511		
1995/96	6,960,406		
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	13	13
Mean	9,178,438	0.202	27,546
S.E.M.	896,511	0.024	10,582
CV	0.10	0.12	0.38

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	11,061,356
Mean of 1,000 bootstrapped OFLs	11,433,908	11,072,214
Std. dev. of 1,000 bootstrapped OFLs	1,040,981	1,012,992
CV = (std. dev.)/(Mean)	0.09	0.09

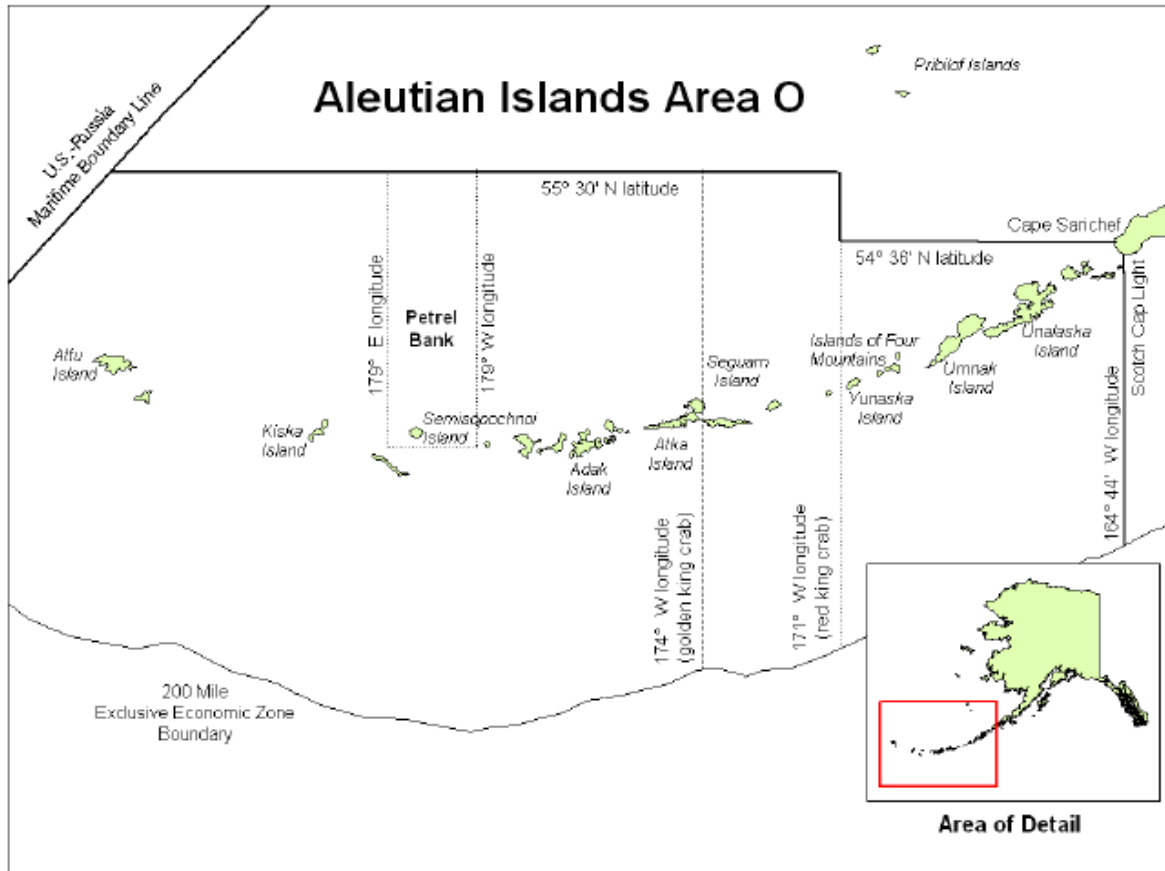


Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Bowers et al. 2011).

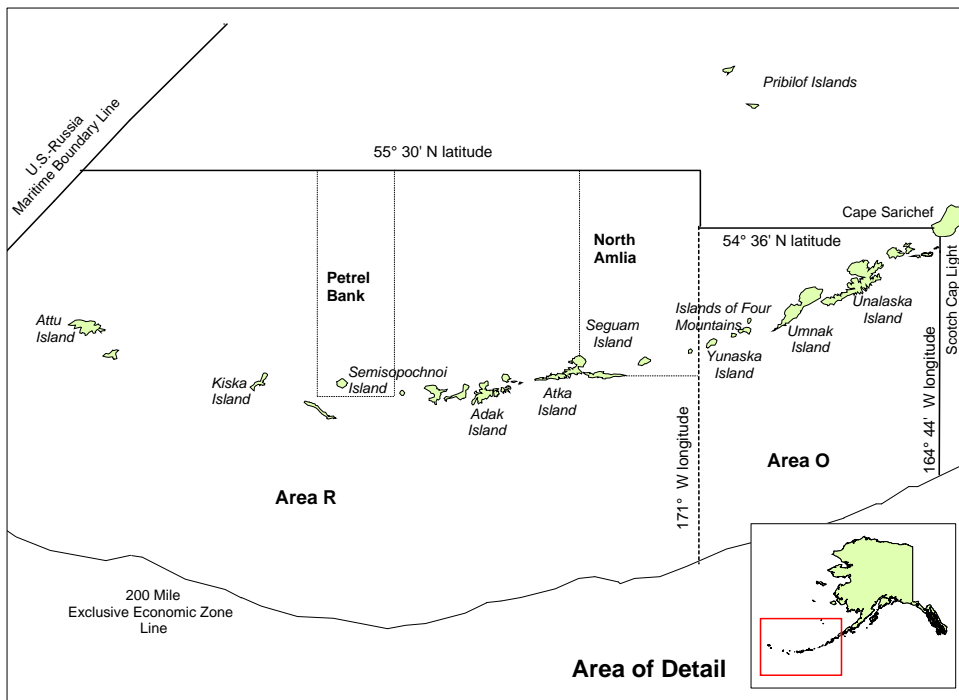


Figure 2. Adak (Area R) and Dutch Harbor (Area O) king crab Registration Areas and Districts, 1984/85 – 1995/96 seasons (Bowers et al. 2011).

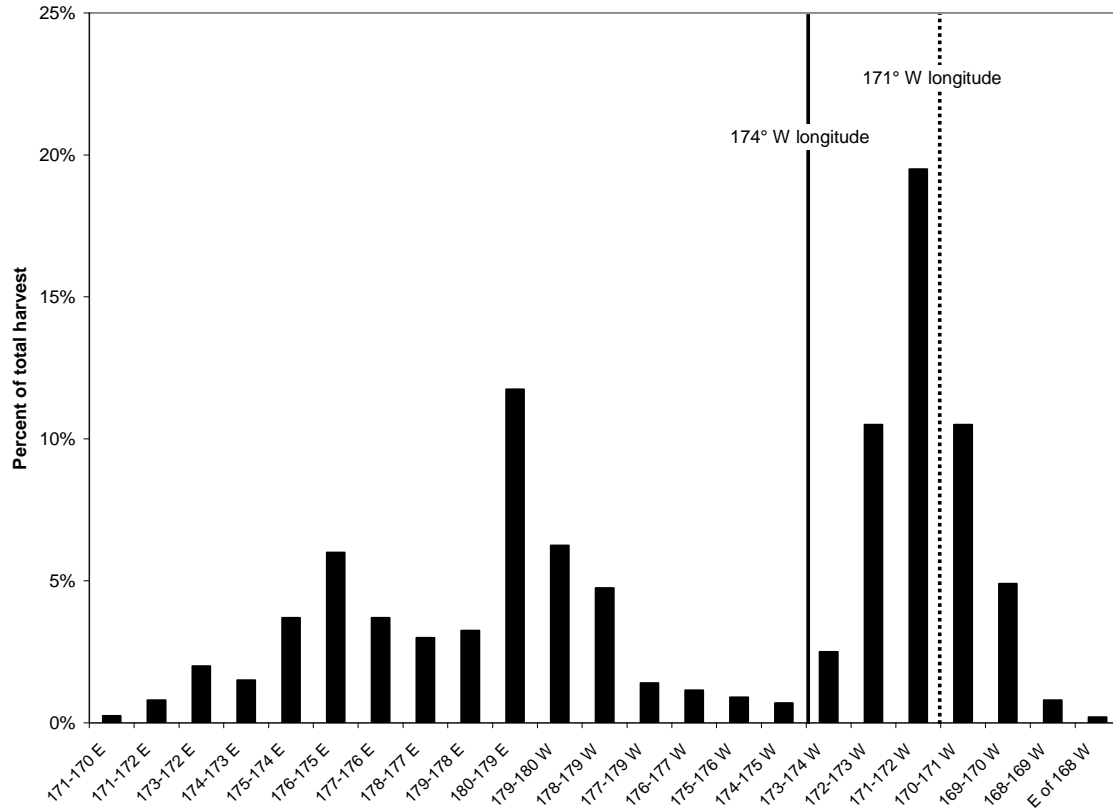


Figure 3. Percent of total 1982–1996 golden king crab harvest by one-degree longitude intervals in the Aleutian Islands, with dotted line denoting the border at 171° W longitude that was used until the end of the 1995/96 season to divide fishery management between the Dutch Harbor Area (east of 171° 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).

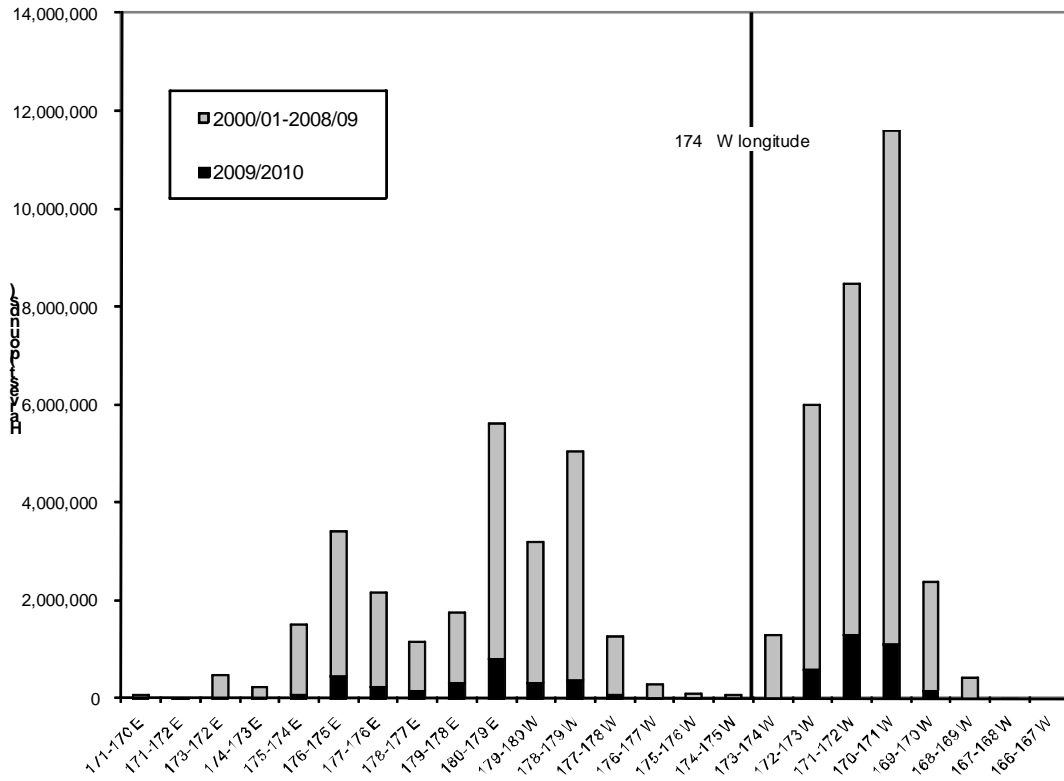


Figure 4. Harvest (pounds) of golden king crab by one-degree longitude intervals in the Aleutian Islands during the 2000/01 through 2009/10 commercial fishery seasons, with the harvest for the 2009/10 season distinguished from the total harvest for the 2000/01–2008/09 seasons; solid line denotes the 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 (2000/01–2008/09 data from Pengilly 2010; 2009/10 data from H. Fitch, ADF&G, 8 April 2011 email).

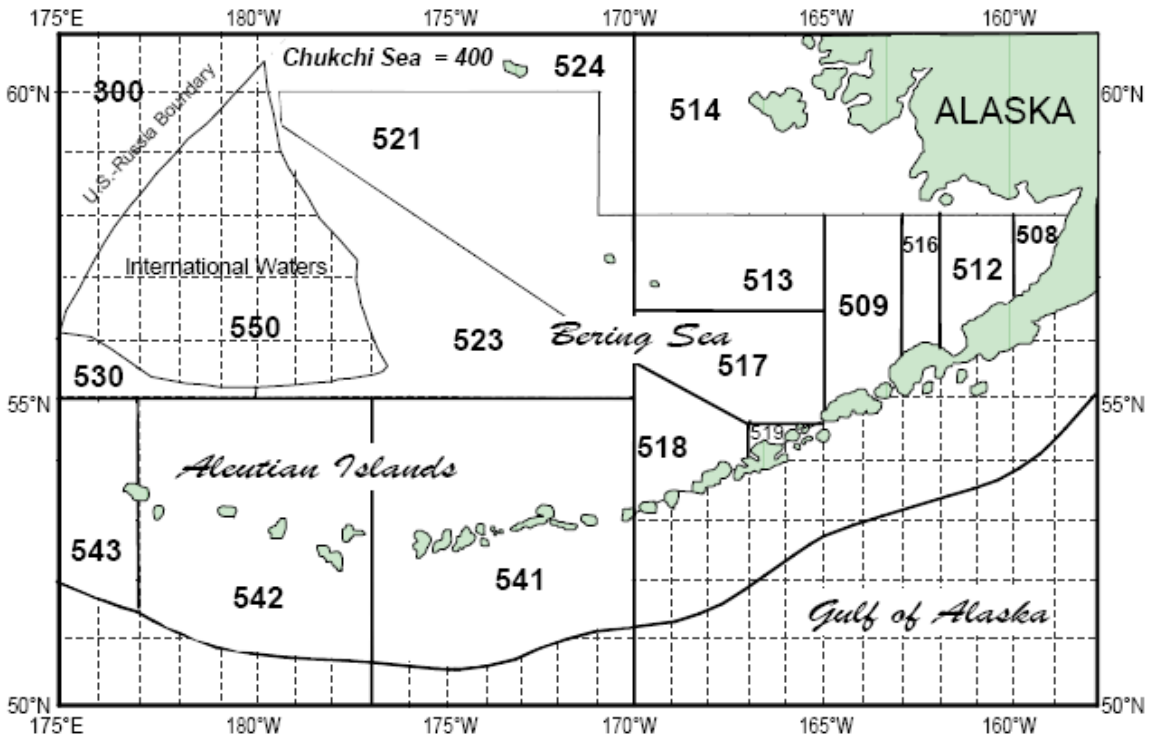


Figure 5. Map of federal groundfish fishery reporting areas for the Bering Sea and Aleutian Islands showing reporting areas 541, 542, and 543 that are used to obtain data on bycatch of Aleutian Islands golden king crab during groundfish fisheries (from <http://www.fakr.noaa.gov/rr/figures/fig1.pdf>).

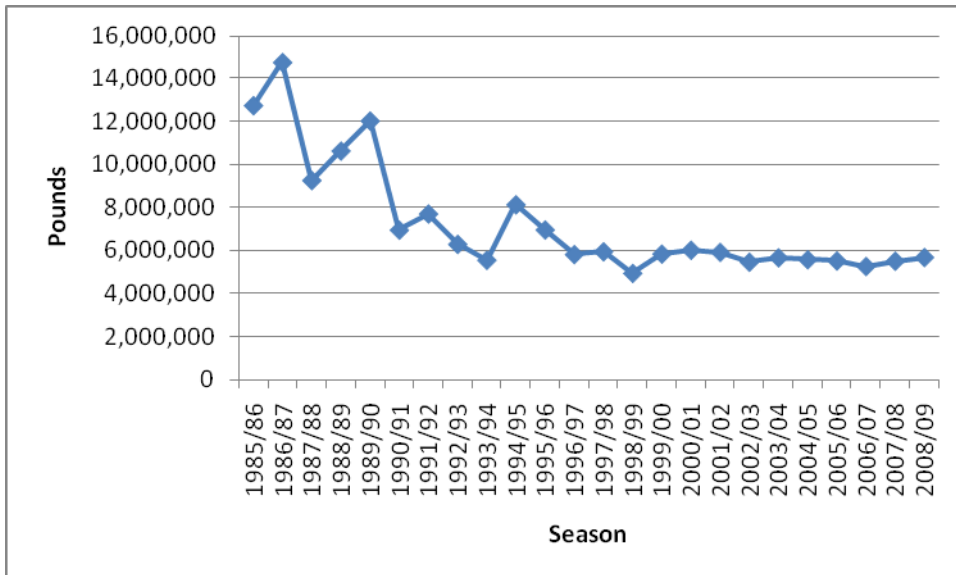


Figure 6. Retained catch (pounds) in the Aleutian Islands golden king crab fishery, 1985/86–2008/09.

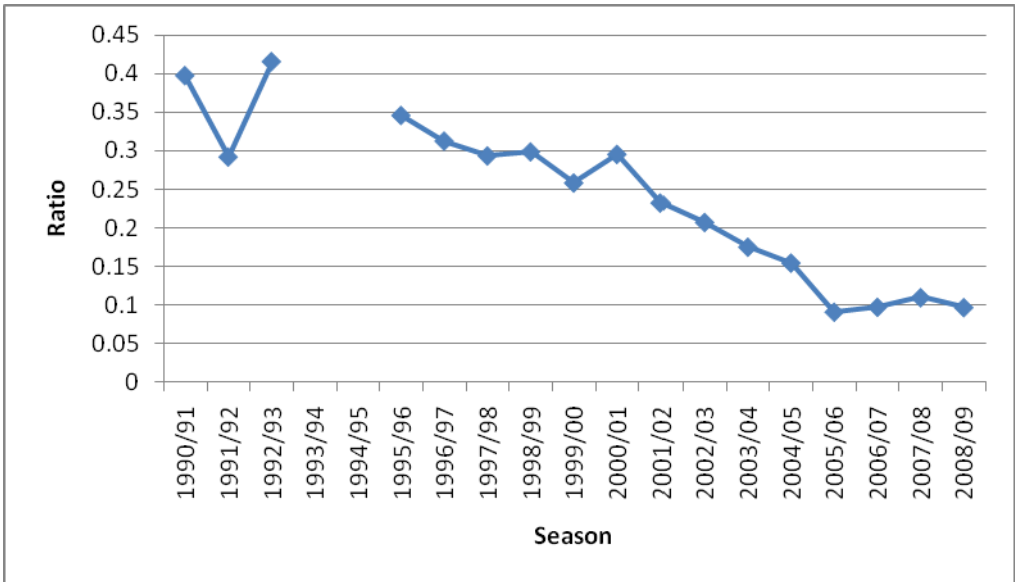


Figure 7. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Island golden king crab, 1990/91–2008/09.

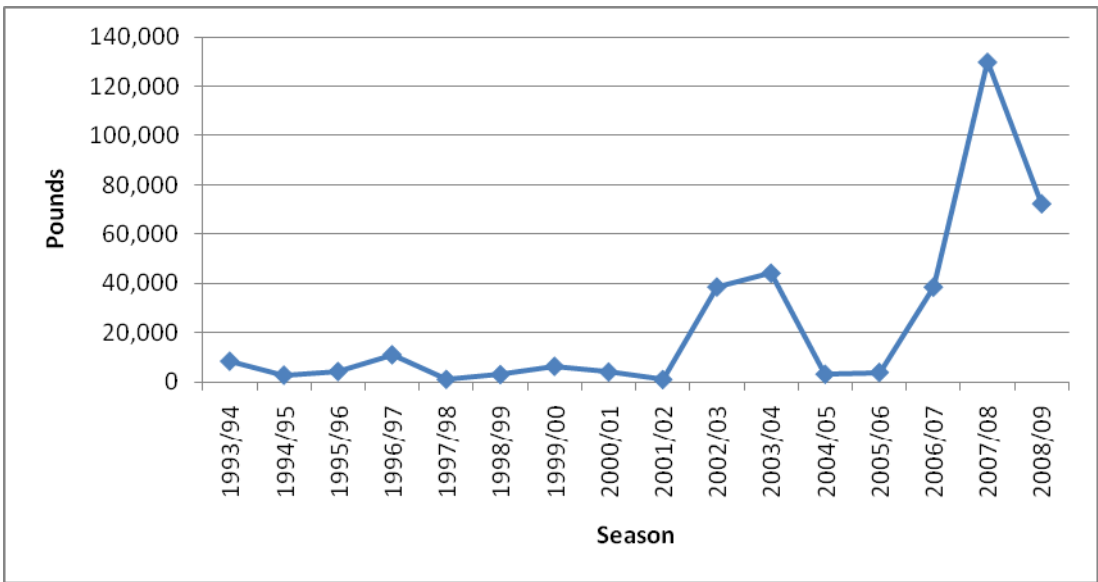


Figure 8. Estimated weight (pounds) of bycatch mortality of Aleutian Islands golden king crab due to groundfish fisheries, 1993/94–2008/09.

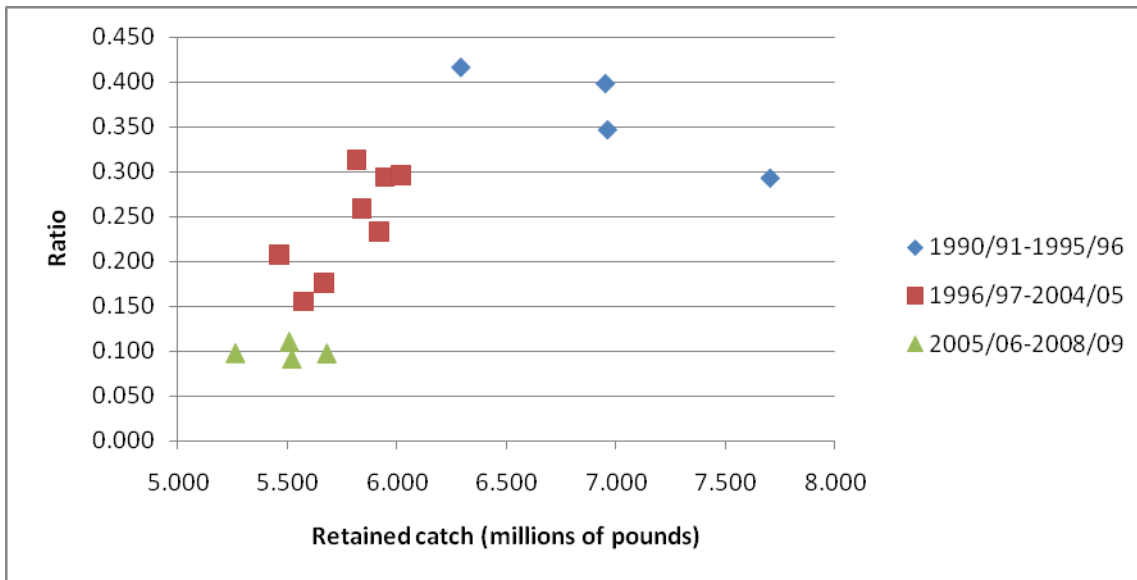


Figure 9. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Island golden king crab plotted against weight of retained catch, 1990/91–2008/09 (ratios for 1992/93–1993/94 not available).

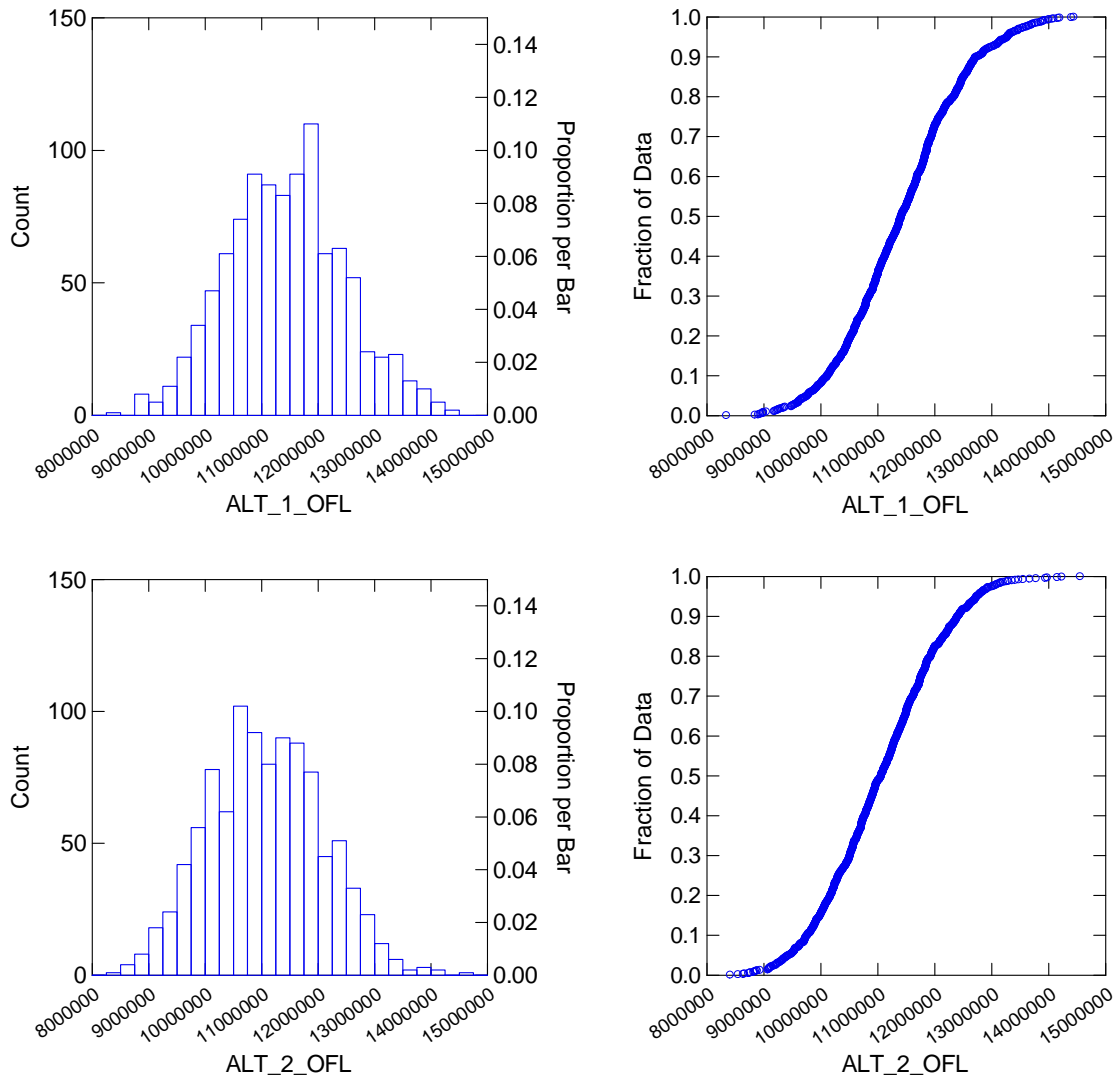


Figure 10. Bootstrapped estimates of the sampling distribution of the Alternative 1 (above) and Alternative 2 (below) 2011/2012 Tier 5 OFLs (pounds of total-catch) for the Aleutian Islands golden king crab stock; histograms in left column, quantile plots in right column.