# Stock Assessment and Fishery Evaluation Report
# for the
# **KING AND TANNER CRAB FISHERIES**
# of the
# Bering Sea and Aleutian Islands Regions

## 2012 Crab SAFE

Compiled by

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of the Bering Sea and Aleutian Islands

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# Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries Fisheries of the Bering Sea and Aleutian Islands Regions

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# Introduction

The annual stock assessment and fishery evaluation (SAFE) report is a requirement of the North Pacific Fishery Management Council's *Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs* (FMP), and is a federal requirement [50 CFR Section 602.12(e)]. The SAFE report summarizes the current biological and economic status of fisheries, total allowable catch (TAC) or Guideline Harvest Level (GHL), and analytical information used for management decisions. Additional information on Bering Sea/Aleutian Islands (BSAI) king and Tanner crab is available on the NMFS web page at http://www.fakr.noaa.gov and the Alaska Department of Fish and Game (ADF&G) Westward Region Shellfish web page at: http://www.cf.adfg.state.ak.us/region4/shellfsh/shelhom4.php.

This FMP applies to 10 crab stocks in the BSAI: 4 red king crab, *Paralithodes camtschaticus*, stocks (Bristol Bay, Pribilof Islands, Norton Sound, and Adak), 2 blue king crab, *Paralithodes platypus,* stocks (Pribilof District and St Matthew Island), 2 golden (or brown) king crab, *Lithodes aequispinus,* stocks (Aleutian Island and Pribilof Islands), Eastern Bering Sea (EBS) Southern Tanner crab, *Chionoecetes bairdi*, and EBS snow crab *Chionoecetes opilio*. All other BSAI crab stocks are exclusively managed by the State of Alaska.

The Crab Plan Team (CPT) annually assembles the SAFE report with contributions from ADF&G and the National Marine Fisheries Service (NMFS). This SAFE report is presented to the North Pacific Fishery Management Council (NPFMC) and is available to the public on the NPFMC web page at: http://fakr.noaa.gov/npfmc/membership/plan_teams/CRAB_team.htm. Under a process approved in 2008 for revised overfishing level (OFL) determinations, and new ACL requirements in 2011, the CPT reviews four assessments in May to provide recommendations on OFL, ABC, and stock status specifications for review by the Council's Science and Statistical Committee (SSC) in June. In September, the CPT reviews the remaining assessments and provides final OFL and ABC recommendations and stock status determinations. Additional information on the OFL and ABC determination process is contained in this report.

The CPT met from September 18-21, 2012 in Seattle, WA to review the final stock assessments as well as additional related issues, to provide the recommendations and status determinations contained in this SAFE report. This final 2012 Crab SAFE report contains all recommendations for all 10 stocks including those whose OFL and ABC were determined in June 2012. This SAFE report will be presented to the Council in October for their annual review of the status of BSAI Crab stocks. Members of the team who participated in this review include the following: Bob (Chair), Ginny Eckert (Vice-Chair), Wayne Donaldson, Bill Bechtol, Karla Bush, Heather Fitch, Brian Garber-Yonts, Jason Gasper, Steve Martell, Doug Pengilly, André Punt, Lou Rugolo, Shareef Siddeek, Diana Stram, and Jack Turnock.

## Stock Status Definitions

The FMP (incorporating all changes made following adoption of Amendment 24) contains the following stock status definitions:

<u>Acceptable biological catch</u> (ABC) is a level of annual catch of a stock that accounts for the scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty and is set to prevent, with a greater than 50 percent probability, the OFL from being exceeded. The ABC is set below the OFL.

ABC Control Rule is the specified approach in the five-tier system for setting the maximum permissible ABC for each stock as a function of the scientific uncertainty in the estimate of OFL and any other specified scientific uncertainty.

Annual catch limit (ACL) is the level of annual catch of a stock that serves as the basis for invoking accountability measures. For crab stocks, the ACL will be set at the ABC.

Total allowable catch (TAC) is the annual catch target for the directed fishery for a stock, set to prevent exceeding the ACL for that stock and in accordance with section 8.2.2 of the FMP.

Maximum sustainable yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY is estimated from the best information available.

$F_{MSY}$ control rule means a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY.

$B_{MSY}$ stock size is the biomass that results from fishing at constant $F_{MSY}$ and is the minimum standard for a rebuilding target when a rebuilding plan is required.

Maximum fishing mortality threshold (MFMT) is defined by the $F_{OFL}$ control rule, and is expressed as the fishing mortality rate.

Minimum stock size threshold (MSST) is one half the $B_{MSY}$ stock size.

Overfished is determined by comparing annual biomass estimates to the established MSST. For stocks where MSST (or proxies) are defined, if the biomass drops below the MSST (or proxy thereof) then the stock is considered to be overfished.

Overfishing is defined as any amount of catch in excess of the overfishing level (OFL). The OFL is calculated by applying the $F_{OFL}$ control rule annually estimated using the tier system in Chapter 6.0 to abundance estimates.

## Status Determination Criteria

The FMP defines the following status determination criteria and the process by which these are defined following adoption of amendment 24 and 38.

Status determination criteria for crab stocks are annually calculated using a five-tier system that accommodates varying levels of uncertainty of information. The five-tier system incorporates new scientific information and provides a mechanism to continually improve the status determination criteria as new information becomes available. Under the five-tier system, overfishing and overfished criteria and acceptable biological catch (ABC) levels are annually formulated. The annual catch limit (ACL) for each stock equals the ABC for that stock. Each crab stock is annually assessed to determine its status and whether (1) overfishing is occurring or the rate or level of fishing mortality for the stock is approaching overfishing, (2) the stock is overfished or the stock is approaching an overfished condition, and (3) the catch has exceeded the ACL.

For crab stocks, the overfishing level (OFL) equals maximum sustainable yield (MSY) and is derived through the annual assessment process, under the framework of the tier system. Overfishing is determined by comparing the OFL with the catch estimates for that crab fishing year. For the previous crab fishing year, NMFS will determine whether overfishing occurred by comparing the previous year's OFL with the catch from the previous crab fishing year. For the previous crab fishing year, NMFS will also determine whether the ACL was exceeded by comparing the ACL with the catch estimates for that crab fishing year. Catch includes all fishery removals, including retained catch and discard losses, for those stocks where non-target fishery removal data are available. Discard losses are determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks where only retained catch information is available, the OFL and ACL will be set for and compared to the retained catch.

Each year, NMFS will determine whether a stock is in an overfished condition by comparing annual biomass estimates to the established MSST, defined as ½ $B_{MSY}$. For stocks where MSST (or proxies) are defined, if the biomass drops below the MSST (or proxy thereof) then the stock is considered to be overfished. MSSTs or proxies are set for stocks in Tiers 1-4. For Tier 5 stocks, it is not possible to set an MSST because there are no reliable estimates of biomass.

If overfishing occurred or the stock is overfished, section 304(e)(3)(A) of the Magnuson-Stevens Act, as amended, requires the Council to immediately end overfishing and rebuild affected stocks.

The Magnuson-Stevens Act requires that FMPs include accountability measures to prevent ACLs from being exceeded and to correct overages of the ACL if they do occur. Accountability measures to prevent TACs and GHLs from being exceeded have been used under this FMP for the management of the BSAI crab fisheries and will continue to be used to prevent ACLs from being exceeded. These include: individual fishing quotas and the measures to ensure that individual fishing quotas are not exceeded, measures to minimize crab bycatch in directed crab fisheries, and monitoring and catch accounting measures. Accountability measures in the harvest specification process include downward adjustments to the ACL and TAC in the fishing year after an ACL has been exceeded.

Annually, the Council, SSC, and CPT will review (1) the stock assessment documents, (2) the OFLs and ABCs, and total allowable catches or guideline harvest levels, (3) NMFS's determination of whether overfishing occurred in the previous crab fishing year, (4) NMFS's determination of whether any stocks are overfished and (5) NMFS's determination of whether catch exceeded the ACL in the previous crab fishing year.

Optimum yield is defined in Chapter 4 of the FMP. Information pertaining to economic, social and ecological factors relevant to the determination of optimum yield is provided in several sections of the FMP, including sections 7.2 (Management Objectives), Chapter 11, Appendix D (Biological and Environmental Characteristics of the Resource), and Appendix H (Community Profiles).

For each crab fishery, the optimum yield range is 0 to < OFL catch. For crab stocks, the OFL is the annualized maximum sustainable yield (MSY) and is derived through the annual assessment process, under the framework of the tier system. Recognizing the relatively volatile reproductive potential of crab stocks, the cooperative management structure of the FMP, and the past practice of restricting or even prohibiting directed harvests of some stocks out of ecological considerations, this optimum yield range is intended to facilitate the achievement of the biological objectives and economic and social objectives of the FMP (see sections 7.2.1 and 7.2.2) under a variety of future biological and ecological conditions. It enables the State of Alaska to determine the appropriate TAC levels below the OFL to prevent overfishing or address other biological concerns that may affect the reproductive potential of a stock but that are not reflected in the OFL itself. Under FMP section 8.2.2, the State of Alaska establishes TACs at levels that maximize harvests, and associated economic and social benefits, when biological and ecological conditions warrant doing so.

Five-Tier System

The OFL and ABC for each stock are annually estimated for the upcoming crab fishing year using the five-tier system, detailed in Table 6-1 and 6-2. A stock is assigned to one of the five tiers based on the availability of information for that stock and model parameter choices are made. Tier assignments and model parameter choices are recommended through the CPT process to the SSC. The SSC recommends tier assignments, stock assessment and model structure, and parameter choices, including whether information is "reliable," for the assessment authors to use for calculating the proposed OFLs and ABCs based on the five-tier system.

For Tiers 1 through 4, once a stock is assigned to a tier, the determination of stock status level is based on recent survey data and assessment models, as available. The stock status level determines the equation used in calculating the $F_{OFL}$. Three levels of stock status are specified and denoted by “a,” “b,” and “c” (see Table 6-1). The $F_{MSY}$ control rule reduces the $F_{OFL}$ as biomass declines by stock status level. At stock status level “a,” current stock biomass exceeds the $B_{MSY}$. For stocks in status level “b,” current biomass is less than $B_{MSY}$ but greater than a level specified as the “critical biomass threshold” (β).

In stock status level “c,” the ratio of current biomass to $B_{MSY}$ (or a proxy for $B_{MSY}$) is below β. At stock status level “c,” directed fishing is prohibited and an $F_{OFL}$ at or below $F_{MSY}$ would be determined for all other sources of fishing mortality in the development of the rebuilding plan. The Council will develop a rebuilding plan once a stock level falls below the MSST.

For Tiers 1 through 3, the coefficient α is set at a default value of 0.1, and β set at a default value of 0.25, with the understanding that the SSC may recommend different values for a specific stock or stock complex as merited by the best available scientific information.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, γ, are used in the calculation of the $F_{OFL}$.

In Tier 5, the OFL is specified in terms of an average catch value over an historical time period, unless the SSC recommends an alternative value based on the best available scientific information.

The assessment author prepares the stock assessment and calculates the proposed OFLs by applying the $F_{OFL}$ and using the most recent abundance estimates. The assessment authors calculate the proposed ABCs by applying the ABC control rule to the proposed OFL.

Stock assessment documents shall:

- use risk-neutral assumptions;
- specify how the probability distribution of the OFL used in the ABC control rule is calculated for each stock; and
- specify the factors influencing scientific uncertainty that are accounted for in calculation of the probability distribution of the OFL.

The CPT annually reviews stock assessment documents, the most recent abundance estimates, the proposed OFLs and ABCs, and complies the SAFE Report. The CPT then makes recommendations to the SSC on the OFLs, ABCs, and any other issues related to the crab stocks.

The SSC annually reviews the SAFE Report, including the stock assessment documents, recommendations from the CPT, and the methods to address scientific uncertainty.

In reviewing the SAFE Report, the Crab Plan Team and the SSC shall evaluate and make recommendations, as necessary, on:

- the assumptions made for stock assessment models and estimation of OFLs;
- the specifications of the probability distribution of the OFL;
- the methods to appropriately quantify uncertainty in the ABC control rule; and
- the factors influencing scientific uncertainty that the State of Alaska has accounted for and will account for on an annual basis in TAC setting.

The SSC will then set the final OFLs and ABCs for the upcoming crab fishing year. The SSC may set an ABC lower than the result of the ABC control rule, but it must provide an explanation for setting the ABC less than the maximum ABC.

As an accountability measure, the total catch estimate used in the stock assessment will include any amount of harvest that may have exceeded the ACL in the previous fishing season. For stocks managed under Tiers 1 through 4, this would result in a lower maximum ABC in the subsequent year, all else being equal, because maximum ABC varies directly with biomass. For Tier 5 stocks, the information used to establish the ABC is insufficient to reliably estimate abundance or discern the existence or extent of biological consequences caused by an overage in the preceding year. Consequently, the subsequent year's maximum ABC will not automatically decrease. However, when the ACL for a Tier 5 stock has been exceeded, the SSC may decrease the ABC for the subsequent fishing season as an accountability measure.

Tiers 1 through 3

For Tiers 1 through 3, reliable estimates of B, $B_{MSY}$, and $F_{MSY}$, or their respective proxy values, are available. Tiers 1 and 2 are for stocks with a reliable estimate of the spawner/recruit relationship, thereby enabling the estimation of the limit reference points $B_{MSY}$ and $F_{MSY}$.

- Tier 1 is for stocks with assessment models in which the probability density function (pdf) of $F_{MSY}$ is estimated.
- Tier 2 is for stocks with assessment models in which a reliable point estimate, but not the pdf, of $F_{MSY}$ is made.
- Tier 3 is for stocks where reliable estimates of the spawner/recruit relationship are not available, but proxies for $F_{MSY}$ and $B_{MSY}$ can be estimated.

For Tier 3 stocks, maturity and other essential life-history information are available to estimate proxy limit reference points. For Tier 3, a designation of the form "$F_X$" refers to the fishing mortality rate associated with an equilibrium level of fertilized egg production (or its proxy such as mature male biomass at mating) per recruit equal to X% of the equilibrium level in the absence of any fishing.

The OFL and ABC calculation accounts for all losses to the stock not attributable to natural mortality. The OFL and ACL are total catch limits comprised of three catch components: (1) non-directed fishery discard losses; (2) directed fishery discard losses; and (3) directed fishery retained catch. To determine the discard losses, the handling mortality rate is multiplied by bycatch discards in each fishery. Overfishing would occur if, in any year, the sum of all three catch components exceeds the OFL.

Tier 4

Tier 4 is for stocks where essential life-history, recruitment information, and understanding are insufficient to achieve Tier 3. Therefore, it is not possible to estimate the spawner-recruit relationship. However, there is sufficient information for simulation modeling that captures the essential population dynamics of the stock as well as the performance of the fisheries. The simulation modeling approach employed in the derivation of the annual OFLs captures the historical performance of the fisheries as seen in observer data from the early 1990s to present and thus borrows information from other stocks as necessary to estimate biological parameters such as $\gamma$.

In Tier 4, a default value of natural mortality rate (M) or an M proxy, and a scalar, $\gamma$, are used in the calculation of the $F_{OFL}$. Explicit to Tier 4 are reliable estimates of current survey biomass and the instantaneous M. The proxy $B_{MSY}$ is the average biomass over a specified time period, with the understanding that the SSC may recommend a different value for a specific stock or stock complex as merited by the best available scientific information. A scalar, $\gamma$, is multiplied by M to estimate the $F_{OFL}$ for stocks at status levels **"**a**"** and **"**b,**"** and $\gamma$ is allowed to be less than or greater than unity. Use of the scalar $\gamma$ is intended to allow adjustments in the overfishing definitions to account for differences in biomass measures. A default value of $\gamma$ is set at 1.0, with the understanding that the SSC may recommend a different value for a specific stock or stock complex as merited by the best available scientific information.

If the information necessary to determine total catch OFLs and ACLs is available for a Tier 4 stock, then the OFL and ACL will be total catch limits comprised of three catch components: (1) non-directed fishery discard losses; (2) directed fishery discard losses; and (3) directed fishery retained catch. If the information necessary to determine total catch OFLs and ACLs is not available for a Tier 4 stock, then the OFL and ACL are determined for retained catch. In the future, as information improves, data would be available for some stocks to allow the formulation and use of selectivity curves for the discard fisheries (directed and non-directed losses) as well as the directed fishery (retained catch) in the models. The resulting OFL and ACL from this approach, therefore, would be the total catch OFL and ACL.

Tier 5

Tier 5 stocks have no reliable estimates of biomass and only historical catch data is available. For Tier 5 stocks, the OFL is set equal to the average catch from a time period determined to be representative of the production potential of the stock, unless the SSC recommends an alternative value based on the best available scientific information. The ABC control rule sets the maximum ABC at less than or equal to 90 percent of the OFL and the ACL equals the ABC.

For Tier 5 stocks where only retained catch information is available, the OFL and ACL will be set for the retained catch portion only, with the corresponding limits applying to the retained catch only. For Tier 5 stocks where information on bycatch mortality is available, the OFL and ACL calculations could include discard losses, at which point the OFL and ACL would be applied to the retained catch plus the discard losses from directed and non-directed fisheries.

**Figure 1. Overfishing control rule for Tiers 1 through 4. Directed fishing mortality is 0 below β.**

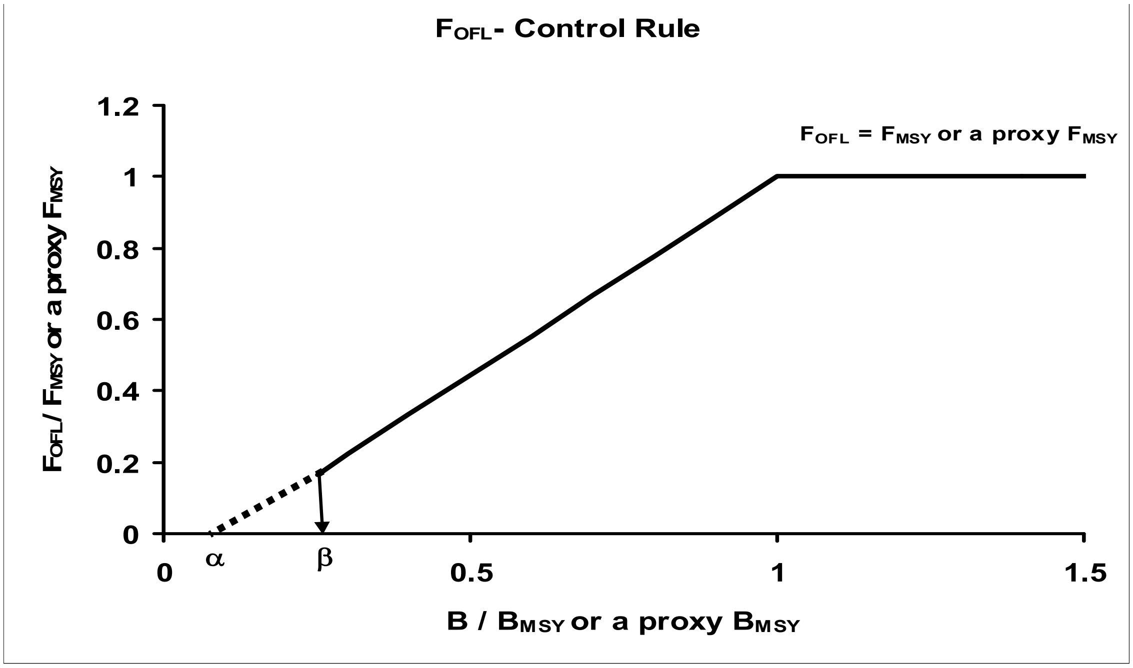

**Table 1 Five-Tier System for setting overfishing limits (OFLs) and Acceptable Biological Catches (ABCs) for crab stocks. The tiers are listed in descending order of information availability. Table 2 contains a guide for understanding the five-tier system.**

| Information available | Tier | Stock status level | $F_{OFL}$ | ABC control rule |
|---|---|---|---|---|
| $B$, $B_{MSY}$, $F_{MSY}$, and pdf of $F_{MSY}$ | **1** | a. $\frac{B}{B_{msy}} > 1$ | $F_{OFL} = \mu_A$ =arithmetic mean of the pdf | |
| | | b. $\beta < \frac{B}{B_{msy}} \le 1$ | $F_{OFL} = \mu_A \frac{B/B_{msy} - \alpha}{1-\alpha}$ | ABC≤(1-$b_y$) * OFL |
| | | c. $\frac{B}{B_{msy}} \le \beta$ | *Directed fishery F = 0* <br> $F_{OFL} \le F_{MSY}$ † | |
| $B$, $B_{MSY}$, $F_{MSY}$ | **2** | a. $\frac{B}{B_{msy}} > 1$ | $F_{OFL} = F_{msy}$ | |
| | | b. $\beta < \frac{B}{B_{msy}} \le 1$ | $F_{OFL} = F_{msy} \frac{B/B_{msy} - \alpha}{1-\alpha}$ | ABC≤(1-$b_y$) * OFL |
| | | c. $\frac{B}{B_{msy}} \le \beta$ | *Directed fishery F = 0* <br> $F_{OFL} \le F_{MSY}$ † | |
| $B$, $F_{35\%}{}^*$, $B_{35\%}{}^*$ | **3** | a. $\frac{B}{B_{35\%*}} > 1$ | $F_{OFL} = F_{35\%}{}^*$ | |
| | | b. $\beta < \frac{B}{B_{35\%}{}^*} \le 1$ | $F_{OFL} = F^*{}_{35\%} \frac{\frac{B}{B^*{}_{35\%}} - \alpha}{1-\alpha}$ | ABC≤(1-$b_y$) * OFL |
| | | c. $\frac{B}{B_{35\%}{}^*} \le \beta$ | *Directed fishery F = 0* <br> $F_{OFL} \le F_{MSY}$ † | |
| $B$, $M$, $B_{msy^{prox}}$ | **4** | a. $\frac{B}{B_{msy^{prox}}} > 1$ | $F_{OFL} = \gamma M$ | |
| | | b. $\beta < \frac{B}{B_{msy^{prox}}} \le 1$ | $F_{OFL} = \gamma M \frac{B/B_{msy^{prox}} - \alpha}{1-\alpha}$ | ABC≤(1-$b_y$) * OFL |
| | | c. $\frac{B}{B_{msy^{prox}}} \le \beta$ | *Directed fishery F = 0* <br> $F_{OFL} \le F_{MSY}$ † | |
| Stocks with no reliable estimates of biomass or M. | **5** | | OFL = average catch from a time period to be determined, unless the SSC recommends an alternative value based on the best available scientific information. | ABC≤0.90 * OFL |

*35% is the default value unless the SSC recommends a different value based on the best available scientific information.
† An $F_{OFL} \le F_{MSY}$ will be determined in the development of the rebuilding plan for an overfished stock.

**Table 2 A guide for understanding the five-tier system.**

- $F_{OFL}$ — the instantaneous fishing mortality (F) from the directed fishery that is used in the calculation of the overfishing limit (OFL). $F_{OFL}$ is determined as a function of:
    - $F_{MSY}$ — the instantaneous F that will produce MSY at the MSY-producing biomass
        - A proxy of $F_{MSY}$ may be used; e.g., $F_{x\%}$, the instantaneous F that results in x% of the equilibrium spawning per recruit relative to the unfished value
    - B — a measure of the productive capacity of the stock, such as spawning biomass or fertilized egg production.
        - A proxy of B may be used; e.g., mature male biomass
    - $B_{MSY}$ — the value of B at the MSY-producing level
        - A proxy of $B_{MSY}$ may be used; e.g., mature male biomass at the MSY-producing level
    - $\beta$ — a parameter with restriction that $0 \leq \beta < 1$.
    - $\alpha$ — a parameter with restriction that $0 \leq \alpha \leq \beta$.
- The maximum value of $F_{OFL}$ is $F_{MSY}$. $F_{OFL} = F_{MSY}$ when $B > B_{MSY}$.
- $F_{OFL}$ decreases linearly from $F_{MSY}$ to $F_{MSY} \cdot (\beta-\alpha)/(1-\alpha)$ as B decreases from $B_{MSY}$ to $\beta \cdot B_{MSY}$
- When $B \leq \beta \cdot B_{MSY}$, F = 0 for the directed fishery and $F_{OFL} \leq F_{MSY}$ for the non-directed fisheries, which will be determined in the development of the rebuilding plan.
- The parameter, $\beta$, determines the threshold level of B at or below which directed fishing is prohibited.
- The parameter, $\alpha$, determines the value of $F_{OFL}$ when B decreases to $\beta \cdot B_{MSY}$ and the rate at which $F_{OFL}$ decreases with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.
    - Larger values of $\alpha$ result in a smaller value of $F_{OFL}$ when B decreases to $\beta \cdot B_{MSY}$.
    - Larger values of $\alpha$ result in $F_{OFL}$ decreasing at a higher rate with decreasing values of B when $\beta \cdot B_{MSY} < B \leq B_{MSY}$.
- The parameter, $b_y$, is the value for the annual buffer calculated from a P* of 0.49 and a probability distribution for the OFL that accounts for scientific uncertainty in the estimate of OFL.
- P* is the probability that the estimate of ABC, which is calculated from the estimate of OFL, exceeds the “true” OFL (noted as OFL’) (P(ABC>OFL’).

# Crab Plan Team Recommendations

Table 3 lists the team’s recommendations for 2012/2013 on Tier assignments, model parameterizations, time periods for reference biomass estimation or appropriate catch averages, OFLs and ABCs. The team recommends three stocks be placed in Tier 3 (EBS snow crab, Bristol Bay red king crab and EBS Tanner crab), four stocks in Tier 4 (St. Matthew blue king crab, Pribilof Islands blue king crab, Pribilof Islands red king crab, and Norton Sound red king crab) and three stocks in Tier 5 (Aleutian Islands golden king crab, Pribilof Islands golden king crab, and Adak red king crab). Table 4 lists those stocks for which the team recommends an ABC less than the maximum permissible ABC for 2012/13. Stock status in relation to status determination criteria are evaluated in this September report (Table ).

The team has general recommendations for all assessments and specific comments related to individual assessments. All recommendations are for consideration for the 2013 assessment. The general comments are listed below while the comments related to individual assessments are contained within the summary of CPT deliberations and recommendations contained in the stock specific summary section. Additional details regarding recommendations are contained in the Crab Plan Team Report (September 2012 CPT Report).

## General recommendations for all assessments

1. The team recommends that all assessment authors document assumptions and simulate data under those assumptions to test the ability of the model to estimate key parameters in an unbiased manner. These simulations would be used to demonstrate precision and bias in estimated model parameters.
2. The CPT recommends the listing of sigmas instead of absolute weights as being more informative for factors such as $L_{50}$ and β. Also, the team recommends specifying weights for the penalties on $L_{50}$ and β from the standard errors from the analysis on which the estimates for these parameters were based.
3. The team requests all authors to consult the Guidelines for SAFE preparation and to follow the Terms of Reference as listed therein as applicable by individual assessment for both content and diagnostics.
4. The team requests that to the extent possible assessments include a listing of the tables and figures in the assessment (i.e., Table of Tables, Table of Figures).

By convention, the CPT used the following conversions to include tables in both lb and t in the status status summary sections:

- lb to t [/2.204624]
- t to lb [x 0.453592]

## Economic SAFE overview

The economic status chapter summarizes exvessel and first wholesale value, vessel crew and processing sectors employment and wages, and IFQ catch share performance for BSAI FMP crab stocks.

*Highlights in the 2012 economic status report*

- Approximately 100 catcher vessels and three catcher processors currently participate in FMP fisheries, delivering to twenty processing facilities.
- Vessel consolidation, following crab rationalization has largely stabilized over the last three years.
- During calendar year 2011
  - 70.2 million lb were landed in all FMP crab fisheries.
  - Bristol Bay red king crab exvessel and first wholesale prices reached historic high values.
  - Exvessel value for all FMP fisheries was $258 million, with a first wholesale value of $363 million.
  - There were an estimated 967 crew positions on 77 vessels.
  - Total labor payment was approximately $34.7 million to crew members and $16.1 million to vessel captains.
  - Processing labor was estimated at 681,000 hours, generating $8 million in income.
- Catch-share program economics are reported based on Office of Science and Technology (OST) protocols.
  - Catch-share utilization has reached 99.5 percent across all currently open rationalized fisheries.
  - The IFQ cost-recovery averaged 1.35 percent over the last three crab years.

# Stock Status Summaries

## 1 Eastern Bering Sea Snow crab

*Fishery information relative to OFL setting*

The total catch in the 2011/12 fishery was estimated at 44,600 t (including model estimated bycatch) and the retained catch in the directed fishery was 40,500 t. This is below the 2011/12 OFL of 73,500 t. Since 1992 when observers were placed on the boats, estimated discard mortality from the directed pot fishery has averaged 15.5% with an assumed discard mortality rate of 50%. Snow crab is also taken as bycatch in the trawl fishery and estimates of trawl bycatch in recent years are less than 1% of the total snow crab catch. Current estimates of stock status have been above $B_{35\%}$(154,669 t) for the past three years.

*Data and assessment methodology*

The stock assessment is based on a size- and sex-structured model in which crabs are categorized into immature, mature, new and old shell. The growth transition matrix is based on an exponential growth function with the transition probability based on a gamma distribution where the variance term for the growth increment is fixed. The model is fitted to abundance data from the NMFS trawl survey, total catch data from the directed fishery and the bycatch data from the trawl fishery, size frequency data by maturity status for the male crab pot fishery, female bycatch in the crab pot fishery, trawl fishery bycatch. The model is also fitted to the 2009 and 2010 Bering Sea Fisheries Research Foundation study area biomass estimates and length frequency data. There were no changes to the model for the 2012 assessment, with the exception of the addition of fishery and survey data.

An additional model scenario (Model 1) was presented that assumed a curvilinear relationship between pre-molt and post-molt size. The new growth model assumes that the molt increment decreases with increasing carapace width. Model 1 resulted in a decrease in the OFL from 73,500 t to 51,600 t. The CPT recommends the base model for setting the OFL.

*Stock biomass and recruitment trends*

Observed survey mature male biomass decreased from 167,400 t in 2011 to 120,800 t in 2012. Observed survey mature female biomass also decreased from 280,000 t in 2011 to 220,600 t in 2012. The trends in model predictions were consistent with trends in the recent survey data.

*Tier determination/Plan Team discussion and resulting OFL/ABC determination Status and catch specifications*

The CPT recommends that the EBS snow crab is a Tier 3 stock so the OFL will be determined by the $F_{35\%}$ control rule. The team recommends that the proxy for $B_{MSY}$ ($B_{35\%}$) be the mature male biomass at mating based on average recruitment over 1979 to present (154,669 t), and hence the minimum stock size threshold (MSST) is 77,300 t. The CPT recommends that the ABC be less than maximum permissible ABC and concurs with the authors recommendation to use a default 10% buffer for setting the ABC.

*Historical status and catch specifications for snow crab (kt).*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 74.1 | 109.3 [A] | 26.6 | 26.5 | 31.5 | 35.1 | |
| 2009/10 | 66.6 | 127.7 [B] | 21.8 | 21.8 | 23.9 | 33.1 | |
| 2010/11 | 73.7 | 196.6 [C] | 24.6 | 24.7 | 26.7 | 44.4 | |
| 2011/12 | 77.3 | 165.2 [D] | 40.3 | 40.5 | 44.7 | 73.5 | 66.2 |
| 2012/13 | | 146.3 [D] | | | | 67.8 | 61.0 |

*Historical status and catch specifications for snow crab (millions of lb).*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 163.4 | 241.0 [A] | 58.6 | 58.4 | 69.4 | 77.4 | |
| 2009/10 | 146.8 | 281.5 [B] | 48.1 | 48.1 | 52.7 | 73.0 | |
| 2010/11 | 162.5 | 433.4 [C] | 54.2 | 54.5 | 58.9 | 97.9 | |
| 2011/12 | 170.4 | 364.2 [D] | 88.8 | 89.3 | 98.5 | 162.0 | 145.8 |
| 2012/13 | | 322.6 [D] | | | | 149.5 | 134.5 |

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2012

*Additional Plan Team recommendations*

The CPT also recommends that further investigations using the empirical growth data from recent molt-increment studies continue and that this information be more formally integrated into the model.

# 2 Bristol Bay Red King Crab

*Fishery information relative to OFL setting.*

The commercial harvest of Bristol Bay red king crab dates to the 1930s, initially prosecuted mostly by foreign fleets but shifting to a largely domestic fishery in the early 1970s. Retained catch peaked in 1980 at 129.9 million lb (58.9 thousand t), but harvests dropped sharply in the early 1980s, and population abundance has remained at relatively low levels over the last two decades compared to those in the 1970s. The fishery is managed for a TAC coupled with restrictions for size (≥ 165.1mm (6.5 in) carapace width), sex (male only), and season (no fishing during mating/molting periods). Prior to 1990, the harvest rate was based on estimated population size and prerecruit and postrecruit abundances at survey time, and varied from 20% to 60% of legal males. In 1990, the harvest strategy became 20% of the mature male (≥120-mm CL) abundance, with a maximum of 60% on legal males, and a threshold abundance of 8.4 million mature females. The current stepped harvest strategy allows a maximum harvest rate of 15% of mature males, but also incorporates a maximum harvest rate of 50% of legal males, a threshold of 14.5 million lb (6.6 thousand t) of effective spawning biomass (ESB), and a minimum GHL of 4.0 million lb (8.8 thousand t) to prosecute a fishery. The TAC increased from 15.5 million lb (34.2 thousand t) for the 2006/07 season to 20.4 million lb (45.0 thousand t) for the 2007/08 and 2008/09 seasons, and then declined through the next two seasons to 14.9 million lb (32.8 thousand t) for 2010/2011. Catch of legal males per pot lift was relatively high in the 1970s and low in the 1980s to mid-1990s. Following implementation of the crab rationalization program in 2005, CPUE increased to31 crab/pot in 2006, but fell to 18 crab/pot by 2010/11. Annual non-retained catch of female and sublegal male RKC during the fishery averaged less than 3.9 million lb (8.6 thousand t) since data collection began in 1990. Estimated fishing mortality ranged from 0.3 to 0.4 $yr^{-1}$ following implementation of crab rationalization. Total catch (retained and bycatch mortality) increased from 17.0 million lb (7.7 thousand t) in 2010/11 to 23.4 million lb (10.6 thousand t) in 2008/09, but has decreased each season since then; total retained catch in 2011/12 was 7.95 million lb (3.61 thousand t).

*Data and assessment methodology*

The stock assessment model is based on a sex- and size-structured population dynamics model incorporating data from the NMFS eastern Bering Sea trawl survey, commercial catch, and at-sea observer data program. Annual stock abundance is estimated for male and female crabs ≥ 65-mm carapace length during 1968/69−2011/12 to the time of the 2012 survey and mature male biomass is projected for 15 February 2013. Catch data (retained catch numbers, retained catch weight, and pot lifts by statistical area and landing date from the fishery which targets males ≥ 165mm (6.5 in. carapace width) were obtained from ADF&G fish tickets and reports, red king crab and Tanner crab fisheries bycatch data from the ADF&G observer database, and groundfish trawl bycatch data from the NMFS trawl observer database. Catch and bycatch data were updated with data from the 2011/12 crab fishery year. The 2012 assessment was based on the base model (model 7ac from 2011 assessment). This model assumes three levels of molting probabilities, a constant natural mortality $M = 0.18 yr^{-1}$ (but with additional natural mortality for males and females during 1980−1984 and for females during the "split period" 1976−1979 and 1985−1993), incorporates the BSFRF data, estimates effective sample sizes, estimates proportions in initial years, and (with respect to the "Bristol Bay retow data") uses only the standard survey data for males and uses the retow data for females.

*Stock biomass and recruitment trends*

Model estimates of total survey biomass increased from 74.2 thousand t in 1968 to 280.4 thousand t in 1978, fell to 36.1 thousand t in 1985, generally increased to 88.5 thousand t in 2007, and declined to 71.5 thousand t in 2012. Estimated recruitment was high during the 1970s and early 1980s and has been generally low since 1985. Near term outlook for this stock is a continued declining trend. Recruitment has been very poor in the last 6 years. The 2011 survey produced a high catch of juvenile males and females <65 mm CL in one survey tow but that catch did not track into the 2012 survey.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The CPT supports the use of base model for the 2012 assessment for stock status determination.

The Plan Team recommends Bristol Bay red king crab as a Tier 3 stock. The team recommends that the proxy for $B_{MSY}$ ($B_{35\%}$) be the mature male biomass at mating, computed as the average recruitment from 1984 to the last year of the assessment (2012) multiplied by the mature male biomass-per-recruit corresponding to $F_{35\%}$ less the mature male catch under an $F_{35\%}$ harvest strategy. Estimated $B_{35\%}$ is 60.7 million lb (27.5 thousand t).

The team recommends that the total-catch OFL for 2012/13 be set according to the base model and the calculated OFL is 17.55 million lb (7.96 thousand t). The team recommends that the ABC for 2012/13 be set below the maximum ABC (17.50 million lb, or 7.94 thousand t). The team noted a downward trend in most-recent biomass estimates in the retrospective assessment analysis, giving rise to concerns that the 2012 MMB may be over-estimated. The team recommends that a 10% buffer from the OFL be used to set the ABC at 15.80 million lb (7.17 thousand t).

The stock is estimated to have been above MSST in 2011/12, hence the stock was not overfished in 2011/12 (Table, below). Overfishing did not occur in 2011/12. The stock at 2012/13 time of mating is projected to be 58.0 million lb (26.32 thousand t), which is above the MSST and 96% of the $B_{MSY}$ calculated from the 2012 assessment. Hence the stock is not projected to be in overfished condition in 2012/13.

*Status and catch specifications (millions of lb) for Bristol Bay red king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 34.2[A] | 87.8[A] | 20.37 | 20.32 | 23.43 | 24.20 | |
| 2009/10 | 31.3[B] | 89.0[B] | 16.00 | 16.03 | 18.32 | 22.56 | |
| 2010/11 | 30.0[C] | 72.0[C] | 14.84 | 14.91 | 17.00 | 23.52 | |
| 2011/12 | 30.4[D] | 68.1[D] | 7.83 | 7.95 | 9.01 | 19.39 | 17.46 |
| 2012/13 | | 58.0[D] | | | | 17.55 | 15.80 |

*Status and catch specifications (kt) for Bristol Bay red king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 15.56[A] | 39.83[A] | 9.24 | 9.22 | 10.48 | 10.98 | |
| 2009/10 | 14.22[B] | 40.37[B] | 7.26 | 7.27 | 8.31 | 10.23 | |
| 2010/11 | 13.63[C] | 32.64[C] | 6.73 | 6.76 | 7.71 | 10.66 | |
| 2011/12 | 13.77[D] | 30.88[D] | 3.55 | 3.61 | 4.09 | 8.80 | 7.92 |
| 2012/13 | | 26.32[D] | | | | 7.96 | 7.17 |

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2012

# 3 Eastern Bering Sea Tanner crab

*Fishery information relative to OFL setting.*

Eastern Bering Sea (EBS) Tanner crabs are caught as bycatch in the groundfish fisheries, scallop fisheries, in the directed Tanner crab fishery (principally as non-retained females and sublegal males), and in other crab fisheries (notably, eastern Bering Sea snow crab and to a lesser extent in the fishery for Bristol Bay red king crab). Two directed fisheries, one east and one west of 166˚ W longitude, harvest EBS Tanner crab. Under the Crab Rationalization Program, ADF&G sets separate TACs and NMFS issues separate individual fishing quota (IFQ) for these two fisheries. However, one OFL is set for EBS Tanner crab because there is no evidence that EBS Tanner crab is not one stock. Both fisheries were closed from 1997 to 2004 due to low abundance and the fisheries were closed again for the 2010/11 and 2011/12 crab fishery years. NMFS declared this stock overfished in 1999 and the Council developed a rebuilding plan. In 2005/06, abundance increased to a level to support a fishery in the area west of $166^0$ W. ADF&G opened both fisheries for the 2006/07 to 2008/09 crab fishing years and to the area east of 166˚ W longitude only in 2009/10. In 2007, NMFS determined the stock was rebuilt because spawning biomass was above $B_{\mathrm{MSY}}$ for two consecutive years. The mature male biomass was, however, estimated to be below the Minimum Stock Size Threshold ($0.5B_{\mathrm{MSY}}$) in February 2010 (the assumed time of mating) based on trends in mature male biomass from the survey, and NMFS declared the stock overfished in September 2010. New minimum size limits adopted by the Alaska Board of Fisheries were implemented for the 2011/12 fishing season.

*Data and assessment methodology*

A stock assessment model has been developed for EBS Tanner crab. This model was reviewed several times by the CPT and the SSC, and during the January 2011 and 2012 stock assessment workshops. The SSC accepted the model for use in specifications for 2012 and determined it as a Tier 3 stock. In addition, a model configuration was identified as a candidate base model. The model is structured by size, sex, shell condition, and maturity state. It uses available information on the magnitude and size-composition of the landings and discards by the directed fishery, and bycatch in the Bristol Bay red king crab, EBS snow crab, and groundfish fisheries. It also uses index and size-composition data from the NMFS trawl survey. The model includes prior distributions on parameters related to growth, natural mortality, catchability, and changes in recruitment and in the proportion maturing.

*Stock biomass and recruitment trends*

The MMB peaked in the mid-1970s and early 1990s; MMB at the time of mating was highest at the start of modeled period (February 1975; 317.2 thousand t), with secondary peaks in February 1990 (71.6 thousand t) and February 2010 (71.2 thousand t). MMB has subsequently declined. Recruitment is estimated to have peaked before 1974, the first year for which survey data are included in the assessment. Subsequent peaks in recruitment occurred during 1985/86 and 2009/10. The MMB in February 2012 is estimated to be 58.59 thousand t from the assessment compared to the 26.06 thousand t from the Tier 4 control rule. The primary reasons for increase in the estimate of biomass compared to the 2011 assessment are that: (a) the assessment allows for selectivity being a logistic function of size and estimates a survey catchability to be 0.72, and (b) because the catch for 2011/12 was less than the 2011/12 OFL. The MMB projected for February 2013 is 42.74 thousand t under the assumption that the total catch for 2012/13 equals the OFL. The 2012 survey estimated a high abundance of pre-recruit females.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The team recommends the OFL for this stock be based on the Tier 3 control rule. Application of the Tier 3 control rule requires a set of years for defining the mean recruitment corresponding to $B_{\mathrm{MSY}}$, $\overline{R}_{MSY}$. This mean recruitment should reflect the current environmental conditions. The CPT has previously requested that the analysts examine available data to assess whether a change in productivity has occurred. The analysts provided results for four alternative sets of years for defining $\overline{R}_{MSY}$. They noted that the recruitments which led to the large biomass in the early 1970s were substantially larger than the subsequent recruitment and that there was no evidence for a substantial change in the ratio of recruitment (at spawning) to the corresponding mature male biomass (e.g., R/MMB). Some members of the team were concerned about using the recruitment estimates for 1966-73 because there are no direct estimates of these recruitments. The CPT explored the relationship between log(R/MMB) and MMB and identified a change in this relationship in 1985 (1990 year of recruitment to the model). This analysis is appended to the Tanner crab assessment chapter. The team consequently recommended that $\bar{R}_{MSY}$ be set to the mean recruitment from 1990 onwards. The resulting estimate of $B_{\mathrm{MSY}}$ is 22.80 thousand t and hence MSST is 11.40 thousand t. This value for $B_{\mathrm{MSY}}$ is substantially lower than the $B_{\mathrm{MSYPROXY}}$ used for the 2011/12 assessment. Consequently, the current assessment implies that the stock was not overfished in 2010 and is well above $B_{\mathrm{MSY}}$ currently. The change in stock status is therefore not a consequence of the model or new data but rather an analysis (appended to the stock assessment chapter) of the model estimates of recruitment and MMB.

Based on the estimated biomass at 15 February 2013, the stock is at Tier 3 level a. The $F_{\mathrm{MSY}}$ proxy ($F_{35\%}$) is 0.61 $\mathrm{yr}^{-1}$, and the 2012/13 $F_{\mathrm{OFL}}$=0.61$\mathrm{yr}^{-1}$ under the Tier 3 OFL Control Rule, equating to a total male and female catch of 19.02 thousand t. The marked change in OFL arises because of (a) the change from a Tier 4 OFL calculation to a model-based assessment where catchability is estimated and (b) the stock is now estimated to be above $B_{\mathrm{MSY}}$. The absolute change in biomass due to the move to an assessment model is not unexpected.

Two methods have been applied to identify whether and when changes in productivity have occurred, based on the log recruits- per- MMB vs MMB. A weighted regression approach identified a shift in productivity in 1990 but the possibility this is due to depensation has yet to be explored quantitatively. The team recommends that the ABC reflect this uncertainty and proposes that the ABCs for 2012/13, 2013/14 and 2014/15 increase proportionally from the 2011/12 OFL of 2.75 thousand t to 19.02 thousand t in 2014/15 (or the estimated OFL for that year). A 3-year period was selected because fluctuations in abundance of EBS Tanner crab have occurred over 3-5 years, and 3 years should be sufficient for the additional analyses and for the model to stabilize. This leads to a recommended ABC for 2012/13 of 8.17 thousand t.

*Historical status and catch specifications (millions lb) for eastern Bering Sea Tanner crab*

| Year | MSST | Biomass (MMB) | TAC (east + west) | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 [b/] | 94.89[d/] | 118.23[d/A] | 4.30 | 1.94 | 4.96 | 15.52 | |
| 2009/10 | 92.37[d/] | 62.70[d/B] | 1.34[a/] | 1.32 | 3.73 | 5.00 | |
| 2010/11 | 91.87[d/] | 58.93[d/C] | 0.00 | 0.00 | 1.92 | 3.55 | |
| 2011/12 | 25.13 | 129.17[D] | 0.00 | 0.00 | 2.73 [e/] | 6.06 | 5.47 |
| 2012/13 | | 94.22 [c/D] | | | | 41.93 | 18.01 |

*(b) Historical status and catch specifications (thousand t) for eastern Bering Sea Tanner crab*

| Year | MSST | Biomass (MMB) | TAC (east + west) | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 [b/] | 43.04[d/] | 53.63[d/A] | 1.95 | 0.88 | 2.25 | 7.04 | |
| 2009/10 | 41.90[d/] | 28.44[d/B] | 0.61[a/] | 0.60 | 1.69 | 2.27 | |
| 2010/11 | 41.67[d/] | 26.73[d/C] | 0.00 | 0.00 | 0.87 | 1.45 | |
| 2011/12 | 11.40 | 58.59[D] | 0.00 | 0.00 | 1.24[e/] | 2.75 | 2.48 |
| 2012/13 | | 42.74[c/D] | | | | 19.02 | 8.17 |

a/ Only the area east of 166 deg. W opened in 2009/10;
b/ Biomass and threshold definitions based on survey estimates derived using 50ft net width area-swept calculations
c/ Projected 2012/13 MMB at time of mating after extraction of the estimated total catch OFL.
d/ Based on mature male biomass at the time of mating inferred from the NMFS survey under the assumption Q=1
e/ Observed total catch – the model over predicts bycatches in the snow crab and groundfish fisheries.
A – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2012

EBS Tanner crab MMB was above $B_{MSY}$ at the time of mating in mid-February 2012. Overfishing did not occur during the 2011/12 fishing year because total catch losses (1.24 thousand t) did not exceed the total catch OFL (2.75 thousand t).

*Additional Plan Team comments*
Given the marked change in $B_{MSY}$ (and hence MSST), the team strongly recommends that further analyses be conducted to examine whether productivity has indeed changed and to assess whether the lower recent productivity is perhaps due to depensation rather than a change in productivity.

# 4 Pribilof Islands red king crab

*Fishery information relative to OFL setting*

The ADF&G has not published harvest regulations for the Pribilof Islands red king crab fishery. The fishery began in 1973 as bycatch during the blue king crab fishery. The directed red king crab fishery opened with a specified GHL for the first time in September 1993. Beginning in 1995, combined Pribilof Islands red and blue king crab GHLs were established. Declines in crab abundance of both king crab stocks from 1996 to 1998 resulted in poor fishery performance during those seasons with annual harvest levels below the GHLs. The Pribilof red king crab fishery was closed from 1999 through 2011/12 due to uncertainty in estimated red king crab survey abundance and concerns for incidental catch and mortality of Pribilof blue king crab which was an overfished and severely depressed stock. Prior to the closure, the 1998/99 harvest was 246.9 t (0.544 million lb). The non-retained catches, with application of bycatch mortality rates, from pot and groundfish bycatch estimates of red king crab ranged from 2.8 t (0.001 million lb) to 192.1 t (0.424 million lb) during 1991/92 to 2011/12.

*Data and assessment methodology*

Although a catch survey analysis which incorporated data from the trawl survey, commercial catch, pot survey and at-sea observer data has been used for assessing the stock in the past, the 2012 assessment is based on trends in male mature biomass (MMB) at the time of mating inferred from NMFS bottom trawl survey from 1975-2012 and commercial catch and observer data from 1973/74 to 2011/12. The revised time-series of historical NMFS trawl survey abundance estimates were used in this assessment. The 2011/12 assessments of non-retained catch from all non-directed pot and groundfish fisheries were included in the SAFE report. Groundfish catches of red king crab are reported for all crab combined by federal reporting areas. Catches from observed fisheries were used to estimate total annual catch. An $F_{\text{OFL}}$ for 2012/13 was determined using a mean MMB at the time of mating, the default $\gamma$ value of 1.0 and an $M$ of 0.18yr$^{-1}$. As recommended by the CPT (September 2011) and SSC (October 2011), the annual index of MMB for this stock was derived as the 3-yr running average centered on the current year MMB and weighted by the inverse variance. The $B_{\text{MSY proxy}}$ was calculated using the unaveraged observed survey MMBs from 1991-2011. The resultant $F_{\text{OFL}}$ from the control rule was applied to the projected legal male biomass at the time of the fishery to determine the total male catch OFL.

*Stock biomass and recruitment trends*

The stock exhibited widely varying mature male and female abundances during 1975-2011. The average MMB estimated for 2012 was 4,175 t (9.20 million lb). Retained catches have not occurred since the 1998/99 season. Non-directed discard losses in the pot fisheries decreased in recent years, and there are no discard losses in the current year. Mature stock biomass declined in 2008/09 and 2009/10 followed by increases in MMB in 2010/11 and 2011/12. The estimated biomass of pre-recruit size crab remained relatively constant over the past decade although pre-recruit sized crab may not be well sampled by the NMFS survey. Bycatch losses resulting from the fixed gear groundfish fleet increased slightly from 2010/11 to 2011/12, while losses resulting from discards in the groundfish trawl fleet increased from 3,870 t (8.53 million lb) to 4,780 t (10.53 million lb) between 2010/11 to 2011/12. In 2012, estimates of legal male biomass and mature male biomass increased substantially relative to 2011, whereas mature female biomass decreased from 817 t to 663 t.

In 2011/12, 7.21 t of male and female blue king crab were caught in groundfish fisheries (fixed gear (1.24 t) and trawl gear (5.97 t)) which are 33% greater than was caught in 2010/11 groundfish fisheries. The catch was mostly in non-pelagic trawls (83%) followed by longline (12%), and pot (5%) fisheries. The targeted species in these fisheries were Pacific cod (17%), flathead sole (38%), pollock (4%), yellowfin sole (40%), and traces <1% found in the rock sole fisheries. Unlike previous years no bycatch was observed in Alaska plaice fisheries in 2011/12.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

Based on available data, the author recommended classification for this stock is Tier 4 for stock status level determination. For 2011/12 the $B_{\mathrm{MSY\ proxy}}$ =5,136 t of $\mathrm{MMB}_{\mathrm{mating}}$ derived as the mean of 1991/92 to 2011/12. MMB varied considerably during these periods likely leading to varying estimates of $B_{\mathrm{MSY}}$. Male mature biomass at the time of mating for 2012/13 was estimated at 3,302 t. The $B/\ B_{\mathrm{MSY\ Proxy}}$ =0.65 and $F_{\mathrm{OFL}}$=0.11. $B/\ B_{\mathrm{MSY\ Proxy}}$ is < 1, therefore the stock status level is *b*. For the 2012/2013 fishery, the total catch OFL was estimated at 569 t of crab. The projected exploitation rates based on full retained catches up to the OFL for LMB and $\mathrm{MMB}_{\mathrm{fishery}}$ are 0.11 and 0.12, respectively.

The author recommended an ABC less than the maximum permissible as calculated by the maxABC control rule. The CPT concurred with the author's recommendation to set the ABC below the maximum permissible, given the relative amount of information available for Pribilof Island red king crab. For 2012/13 using the recommended $B_{\mathrm{MSYprox}}$, the multiplier equivalent to a P* of 0.49 was 0.88. The maxABC was thus estimated to be 501 t. Incorporating additional uncertainty by applying a $\sigma_b$ of 0.45 resulted in a multiplier of 0.80 and a recommended ABC of 455 t (1.00 million lb).

*Historical status and catch specifications (million lb) of Pribilof Islands red king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 4.39 | 11.06$^{A}$ | 0 | 0 | 0.021 | 3.32 | |
| 2009/10 | 4.22 | 4.46$^{B}$ | 0 | 0 | 0.006 | 0.50 | |
| 2010/11 | 4.97 | 5.44$^{C}$ | 0 | 0 | 0.009 | 0.77 | |
| 2011/12 | 5.67 | 5.68$^{D*}$ | 0 | 0 | 0.011 | 0.87 | 0.68 |
| 2012/13 | | 7.28$^{E**}$ | | | | 1.25 | 1.00 |

*Historical status and catch specifications ( t) of Pribilof Islands red king crab*

| Year | MSST | Biomass ($\mathrm{MMB}_{\mathrm{mating}}$) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 1,990 | 5,020$^{A}$ | 0 | 0 | 10 | 151 | |
| 2009/10 | 1,914 | 2,175$^{B}$ | 0 | 0 | 2.7 | 227 | |
| 2010/11 | 2,255 | 2,754$^{C}$ | 0 | 0 | 4.2 | 349 | |
| 2011/12 | 2,571 | 2,775$^{D*}$ | 0 | 0 | 5.4 | 393 | 307 |
| 2012/13 | | 3,302$^{E**}$ | | | | 569 | 455 |

A – Based on survey data available to the Crab Plan Team in September 2008 and updated with 2008/2009 catches
B – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
C – Based on survey data available to the Crab Plan Team in September 20010 and updated with 2010/2011 catches
D – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/2012 catches
E - Based on survey data available to the Crab Plan Team in September 2012
*– 2011/12 estimates based on 3 year running average
** – 2012/13 estimates based on weighted 3 year running average

The stock was above MSST in 2011/2012 and is hence not overfished. Overfishing did not occur during the 2011/2012 fishing year.

# 5 Pribilof Islands blue king crab

*Fishery information relative to OFL setting.*

The Pribilof blue king crab fishery began in 1973, with peak landings of 11.0 million lb during the 1980/81 season. A steep decline in landings occurred after the 1980/81 season. Directed fishery harvest from 1984/85 until 1987/88 was annually less than 1.0 million lb with low CPUE. The fishery was closed from 1988 until 1995. The fishery reopened from 1995 to 1998. Fishery harvests during this period ranged from 1.3 to 2.5 million lb. The fishery closed again in 1999 due to declining stock abundance and has remained closed through the 2011/12 season. The stock was declared overfished in 2002.

*Data and assessment methodology*

NMFS conducts an annual trawl survey that is used to produce area-swept abundance estimates. The CPT has discussed the history of the fishery and the rapid decline in landings. It is clear that the stock has collapsed, although the annual area-swept abundance estimates are imprecise.

The survey biomass time series was re-calculated with a new area definition that includes an additional 20 nm strip east of the Pribilof District. MMB was estimated using a three-year running average centered on the current year weighted by the inverse variance of the area-swept estimate. Groundfish bycatch for 2011/12 was calculated with improved spatial resolution using a catch-in-areas database (CIADB) that uses the new stock boundary area which includes the 20nm strip to the east instead of only the area (NMFS reporting area 513) that was used in prior years.

*Stock biomass and recruitment trends*

The survey biomass time series was recalculated in 2011 to include actual measured net widths. Based on 2012 NMFS bottom-trawl survey, the estimated total mature-male biomass increased to 644 t from 461 t in 2011. The 2012/13 MMB at mating is projected to be 496 t (1.09 million lb) which is about 13% of $B_{MSYproxy}$. The Pribilof blue king crab stock biomass continues to be low. From recent surveys there is no indication of recruitment.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

This stock is recommended for placement into Tier 4. $B_{MSY}$ was estimated using the time period 1980/81 - 1984/85 plus 1990/1991-1997/1998. This range was chosen because it eliminates periods of extremely low abundance that may not be representative of the production potential of the stock. $B_{MSY}$ is estimated at 3,944 t (8.70 million pounds).

The retained catch OFL is 0 because the 2011/12 estimate of MMB is less than 25% $B_{MSY}$. Due to the Tier level and stock status an $F_{OFL}$ must be determined for the non-directed catch. Ideally this should be based on the rebuilding strategy. Due to inadequate progress towards rebuilding, a new rebuilding plan has been developed and is in final review with the Secretary of Commerce.

The OFL for 2012/13 was estimated at 1.16 t (0.003 million lb), the same as the 2011/12 OFL. The OFL is estimated from the average groundfish bycatch between 1999/00 and 2005/06.

The CPT concurred with the author’s recommendation to set ABC less than the maximum permissible by employing a 10% buffer consistent with a Tier 5 average catch calculation. The ABC was estimated at 1.04 t (0.002 million lb.).

*Historical status and catch specifications (t) of Pribilof Islands blue king crab in recent years.*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 2,105[A] | 110[A] | closed | 0 | 0.5 | 1.81 | |
| 2009/10 | 2,105[B] | 401[B] | closed | 0 | 0.5 | 1.81 | |
| 2010/11 | 2,105[C] | 286[C] | closed | 0 | 0.18 | 1.81 | |
| 2011/12 | 2,247[D] | 365[D]* | closed | 0 | 0.36 | 1.16 | 1.04 |
| 2012/13 | | 496[E]** | | | | 1.16 | 1.04 |

*Historical status and catch specifications (million lb) of Pribilof Islands blue king crab in recent years.*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 4.64 | 0.25 [A] | closed | 0 | 0.001 | 0.004 | |
| 2009/10 | 4.64 | 0.88 [B] | closed | 0 | 0.001 | 0.004 | |
| 2010/11 | 4.64 | 0.63 [C] | closed | 0 | 0.0004 | 0.004 | |
| 2011/12 | 4.95 | 0.80 [D] * | closed | 0 | 0.0008 | 0.003 | 0.002 |
| 2012/13 | | 1.09 [E] ** | | | | 0.003 | 0.002 |

A – Based on survey data available to the Crab Plan Team in September 2008 and updated with 2008/09 catches.
B – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/10 catches.
C – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/11 catches.
D – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/12 catches.
E – Based on survey data available to the Crab Plan Team in September 2012.
*- 3- year average survey biomass
**- weighted 3-year running average

The total catch for 2011/12 (0.36 t, 0.0008 million lb) was less than the 2011/12 OFL (1.16 t, 0.003 million lb) so overfishing did not occur during 2011/12. The 2012/13 projected MMB estimate of 496 t (1.09 million lb) is below the proxy for MSST (MMB/$B_{MSY}$ = 0.13) so the stock continues to be in an overfished condition and failed to rebuild within the maximum required rebuilding time.

*Additional Plan Team comments*

The Council in June 2012 approved a revised rebuilding plan in June 2012. The new rebuilding plan closes the Pribilof Island Habitat Conservation Zone to groundfish vessels fishing with pot gear year-round. This closure is anticipated to be implemented in late 2013. This area is already closed to trawling.

The State of Alaska closed additional statistical areas to crab fishing for the 2011/12 season based on all locations that the survey caught blue king crab.

# 6 Saint Matthew blue king crab

*Fishery information relative to OFL setting*

The fishery was prosecuted as a directed fishery from 1977 to 1998. The fishery developed when ten U.S. vessels harvested 1.202 million pounds during 1977/78. Harvests peaked in 1983/84 when 9.454-million pounds were landed by 164 vessels. Harvest were fairly stable from 1986/87 to 1990/91, averaging 1.252-million pounds annually, then increased to a mean catch of 3.297-million lb during the 1991/92 to 1998/99 seasons. The fishery was declared overfished and closed in 1999 when the stock size estimate was below the MSST. In November of 2000, Amendment 15 to the FMP was approved to implement a rebuilding plan for the St. Matthew Island blue king crab stock. The rebuilding plan included a harvest strategy established in regulation by the Alaska Board of Fisheries, an area closure to control bycatch, and gear modifications. In 2008/09 and 2009/10, the MMB was above $B_{MSY}$ for two years and the stock declared rebuilt in 2009.

The fishery re-opened in 2009/10 with a TAC of 1.167 million lb and 0.461 million lb of retained catch were harvested. The 2010/11 TAC was 1.600 million pounds and the fishery reported a retained catch of 1.264 million pounds The 2011/12 harvest of 1.88 million lb represented 74% of 2.54 million lb TAC; the 2011/12 CPUE of 9.0 crab/pot was down 11% from the 2010/11 CPUE. Bycatch of non-retained blue king crab has been observed in the Saint Matthew blue king crab fishery, the eastern Bering Sea snow crab fishery, and trawl and fixed-gear groundfish fisheries. Based on limited observer data, bycatch of sublegal male and female crabs in the directed blue king crab fishery off Saint Matthew Island was relatively high when the fishery was prosecuted in the 1990s, and total bycatch (in terms of number of crabs captured) was often twice as high or higher than total catch of legal crabs.

*Data and assessment methodology*

A three-stage catch-survey analysis (CSA) is used to assess the male crab ≥90 mm CL. The three size categories are: 90–104 mm CL; 105–119 mm CL; and ≥120 mm CL. Males ≥ 105 are used as a proxy to identify mature males, and males ≥ 120 are used as a proxy to identify legal males. The CSA incorporates the following data: (1) commercial catch data from 1978 to 2011/12; (2) annual trawl survey data from 1978 to 2012; (3) triennial pot survey data from 1995 to 2010; (4) bycatch data in the groundfish trawl and groundfish fixed-gear fisheries from 1991 to 2012; and (5) ADF&G crab-observer composition data for the years 1990/91–1998/99, 2009/10–2011/12. Trawl survey data are from summer trawl survey for stations within the St. Matthew Section. Trawl survey data provided estimates of density (number/$nm^2$) at each station for males in the three size categories.

Pot survey data are from the July–August 1995, 1998, 2001, 2004, 2007, and 2010 ADF&G triennial pot surveys for Saint Matthew Island blue king crab. The pot survey samples areas of high-relief habitat important to blue king crab, particularly females, that the NMFS trawl survey cannot sample. Data used are from only the 96 stations fished in common during each of the five surveys. The CPUE (catch per pot lift) indices from those 96 stations for the male categories listed above were used in the assessment.

NMFS observer data were used to estimate groundfish trawl and fixed-gear bycatch. Bycatch composition data were not available so total biomass caught as bycatch was estimated by summing blue king crab biomass from federal reporting areas 524 and 521 according to gear type.

*Stock biomass and recruitment trends*

The stock is estimated to have been above $B_{MSY}$ during 2008/09 through 2011/12 and is projected to be above $B_{MSY}$ in 2012/13. The MMB has fluctuated substantially over three periods, increasing during 1978 to 1981 of the first period from 7.6 to 17.6 million lb, followed by a steady decrease to 2.9 million lb in

1985. The second period had a steady increase from 1986 to 13.3 million lb in 1997 followed by a rapid decline to 2.8 million lb in 1999. The third period had a steady increase in all size classes from 2000 to 12.4 million lb in 2012/2013.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The CPT and SSC recommends that the stock be in Tier 4, with gamma ($\gamma$)=1 used for calculating $F_{OFL}$, and stock status level a. The CPT discussed 5 alternative model options and accepted the base model. The CPT modified its recommended time period for estimating $B_{\text{MSYproxy}}$ to be the full assessment time period of 1978 to 2011/12 because there is no additional information to suggest productivity changed over time. The $B_{\text{MSYproxy}}$ during this time period is 7.93 million lb. The OFL is a total male OFL, as recommended by the team. The maxABC is based on CV = 0.5 and P*=0.49, which is 2.24 million pounds. However, due to the nature of the scientific uncertainty in the OFL, the team recommended a 10% buffer for an ABC of 2.02 million lb (916 t) due to structural assumptions and observational uncertainties in this assessment.

*Historical status and catch specifications (millions lb.) of St. Matthew blue king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 4.0 | 10.74[A] | closed | closed | 0.20 | 1.63 [retained] | |
| 2009/10 | 3.4 | 12.76[B] | 1.17 | 0.46 | 0.53 | 1.72 | |
| 2010/11 | 3.4 | 14.77[C] | 1.60 | 1.26 | 1.41 | 2.29 | |
| 2011/12 | 4.0 | 11.09[D*] | 2.54 | 1.88 | 2.10 | 3.74 | 3.40 |
| 2012/13 | | 12.41[D] | | | | 2.24 | 2.02 |

*Historical status and catch specifications (kt) of St. Matthew blue king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 1.81 | 4.87[A] | closed | closed | 0.09 | 0.74 [retained] | |
| 2009/10 | 1.52 | 5.79[B] | 0.53 | 0.21 | 0.24 | 0.78 | |
| 2010/11 | 1.52 | 6.70[C] | 0.73 | 0.57 | 0.64 | 1.04 | |
| 2011/12 | 1.81 | 5.03[D*] | 1.15 | 0.85 | 0.95 | 1.70 | 1.50 |
| 2012/13 | | 5.63[D] | | | | 1.02 | 0.9 |

A – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2012
* Biomass estimate based upon survey biomass not model-based estimate

The total male catch for 2011/12 (2.1 million lb) was less than the 2011/12 OFL (3.74 million lb) so overfishing did not occur during 2011/12. Likewise, the 2011/12 MMB (11.09 million lb) is above the MSST (4.0 million lb) so the stock is not overfished.

*Additional Plan Team recommendations*

The team made additional recommendations for the stock assessment model for the 2012 assessment cycle. The CPT recommends a combination of models B1 and C for the next assessment cycle (varying Q and M simultaneously). These recommendations are contained in the September 2012 Crab Plan Team report.

# 7 Norton Sound Red King Crab

*Fishery information relative to OFL setting*

This stock supports three main fisheries: summer commercial, winter commercial, and winter subsistence. The summer commercial fishery, which accounts for the majority of the catch, reached a peak in the late 1970s at a little over 2.9 million pounds retained catch. Retained catches since 1982 have been below 0.5 million pounds, averaging 275,000 pounds, including several low years in the 1990s. Retained catches in the past four years have been about 400,000 pounds.

*Data and assessment methodology*

Four types of surveys have been conducted periodically during the last three decades: summer trawl, summer pot, winter pot, and preseason summer pot, but none of these surveys have been conducted every year. To improve abundance estimates, a length-based model of male crab abundance was previously developed that combines multiple sources of data. The 1976-2011 trawl survey data were revised and there were no new sources of data added to the assessment. A maximum likelihood approach was used to estimate abundance, recruitment, and selectivity and catchability of the commercial pot gear. The model has been updated with data from 2011/12 winter pot survey, 2011 summer commercial fishery, 2011 summer trawl survey, 2010/2011 winter commercial and subsistence finalized catch, and the 2011/2012 winter commercial and subsistence catch (based on available data). The current model assumes $M=0.18yr^{-1}$ for all length classes, except $M=0.68\ yr^{-1}$ for the largest (> 123 mm CL) length group.

The assessment author revised the model in order to identify a set of model specifications such that the extreme retrospective patterns seen in last year's assessment are no longer present.

*Stock biomass and recruitment trends*

Mature male biomass was estimated to be on an upward trend following a recent low in 1997 and an historic low in 1982 following a crash from the peak biomass in 1977. Estimated recruitment was weak during the late 1970s and high during the early 1980s with a slight downward trend from 1983 to 1993. Estimated recruitment has been highly variable but on an increasing trend in recent years.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The team recommended Tier 4 stock status for Norton Sound red king crab. The estimated abundance and biomass in 2012 are:

Legal males: 1.38 million crabs with a standard deviation of 0.13 million crabs.
Mature male biomass: 4.25 million lb with a standard deviation of 0.39 million lb.

Average of mature male biomasses during 1980-2012 was used as the $B_{MSY}$ proxy and the CPT chose gamma =1.0 to derive the $F_{MSY}$ proxy.
Estimated $B_{MSY}$ proxy, $F_{MSY}$ proxy and retained catch limit in 2012 are:

- $B_{MSY}$ proxy = 3.51 million lb,
- $F_{MSY}$ proxy = 0.18

The maximum permissible ABC would be 0.53 million lb. The CPT recommended an ABC less than the maximum permissible due to potential concerns with model specification, lack of bycatch data as well as issues noted with the M employed for the largest length group. The CPT recommended an ABC = 90% of the OFL (10% buffer) of 0.48 million pounds.

*Status and catch specifications (million lb)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 1.78[A] | 5.24 | 0.41 | 0.39 | 0.43 | 0.68[A] | |
| 2009/10 | 1.54[B] | 5.83 | 0.38 | 0.40 | 0.43 | 0.71[B] | |
| 2010/11 | 1.56[C] | 5.44 | 0.40 | 0.42 | 0.46 | 0.73[C] | |
| 2011/12 | 1.56[D] | 4.70 | 0.36 | 0.40 | 0.43 | 0.66[D] | 0.59 |
| 2012/13 | 1.76[E] | 4.59 | | | | 0.53[E] | 0.48 |

*Status and catch specifications (kt)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 0.81[A] | 2.38 | 0.19 | 0.18 | 0.21 | 0.31[A] | |
| 2009/10 | 0.70[B] | 2.64 | 0.17 | 0.18 | 0.22 | 0.32[B] | |
| 2010/11 | 0.71[C] | 2.47 | 0.18 | 0.19 | 0.22 | 0.33[C] | |
| 2011/12 | 0.71[D] | 2.13 | 0.16 | 0.18 | 0.20 | 0.30[D] | 0.27 |
| 2012/13 | 0.80[E] | 2.08 | | | | 0.24[E] | 0.22 |

[A]-Calculated from the assessment reviewed by the Crab Plan Team in May 2008
[B]-Calculated from the assessment reviewed by the Crab Plan Team in May 2009
[C]-Calculated from the assessment reviewed by the Crab Plan Team in May 2010
[D]-Calculated from the assessment reviewed by the Crab Plan Team in May 2011
[E]-Calculated from the assessment reviewed by the Crab Plan Team in May 2012

Total catch in 2011/12 did not exceed the OFL for this stock thus overfishing is not occurring. Stock biomass is above MSST; thus, the stock is not overfished.

*Additional Plan Team recommendations*

The CPT notes that this stock assessment should be reviewed in a modeling workshop in January 2013. The values for the biological parameters should be more clearly documented and discussed at the upcoming workshop. The team recommends considering starting the model in 1980.

# 8 Aleutian Islands golden king crab

*Fishery information relative to OFL setting*

The directed fishery has been prosecuted annually since the 1981/82 season. Retained catch peaked in 1986/87 at 14.7 million lb and averaged 11.9 million lb over the 1985/86-1989/90 seasons. Average harvests dropped sharply from 1989/90 to 1990/91 to a level of 6.9 million lb for the period 1990/91–1995/96. Management based on a formally established GHL began with the 1996/97 season. The 5.9 million lb GHL established for the 1996/97 season, which was based on the previous five-year average catch, was subsequently reduced to 5.7 million lb beginning in 1998/99. The GHL (or TAC, since 2005/06) remained at 5.7 million lb for 2007/08, but was increased to 6.0 million lb for the 2008/09-2011/12 seasons. Average retained catch for the period 1996/97–2007/08 was 5.6 million lb, and 5.8 million lb for the period 2008/09-2010/11. The Alaska Board of Fisheries increased the TAC for this stock to 6.3 million lb in March 2012. This fishery is rationalized under the Crab Rationalization Program. The 2011/12 season remains open until 15 May 2012.

Non-retained bycatch occurs mainly in the directed fishery, and to a minor extent in other crab fisheries. Bycatch also occurs in fixed-gear and trawl groundfish fisheries although that bycatch is low relative to the weight of bycatch in the directed fishery. Total annual non-retained catch of golden king crab during crab fisheries has decreased relative to the retained catch since the 1990s. It decreased from 13.8 million lb in 1990/91 (199% of the retained catch) to 9.1 million lb in 1996/97 (156% of the retained catch), and to 4.3 million lb in the 2004/05 season (78% of the retained catch). Bycatch has ranged from 2.5 million lb in 2005/06 (46% of the retained catch) to 3.0 million lb for 2007/08 (55% of the retained catch) during the six seasons prosecuted as rationalized fisheries (2005/06–2010/11). Bycatch mortality has correspondingly decreased since 1996/97 both in absolute weight and relative to the retained catch weight. Estimated total mortality (retained catch plus bycatch in crab and groundfish fisheries) ranged from 5.8-9.4 million lb over 1995/96–2010/11. Estimated total mortality in 2010/11 was 6.6 million lb.

*Data and assessment methodology*

Available data are from ADF&G fish tickets (retained catch numbers, retained catch weight, and pot lifts by ADF&G statistical area and landing date), size-frequencies from samples of landed crabs, at-sea observations from pot lifts sampled during the fishery (date, location, soak time, catch composition, size, sex, and reproductive condition of crabs, etc.), triennial pot surveys in the Yunaska-Amukta Island area of the Aleutian Islands approximately 171° W longitude, tag recoveries from crabs released during the triennial pot surveys, and bycatch from the groundfish fisheries. These data are available through the 2010/11 season and the 2006 triennial pot survey. Most of the available data were obtained from the fishery which targets legal-size (≥6-inch CW) males and trends in the data can be affected by changes in both fishery practices and the stock. The triennial survey is too limited in geographic scope and too infrequent to provide a reliable index of abundance for the Aleutian Islands area. A triennial survey was scheduled for 2009, but was cancelled. An assessment model is currently being developed for this stock.

*Stock biomass and recruitment trends*

Although a stock assessment is in development, it has not yet been accepted for use in management. There are consequently no estimates of stock biomass. Estimates of recruitment trends and current levels relative to virgin or historic levels are also not available.

*Summary of major changes*

In March 2012, the BOF approved a change that increased the TAC by 5% (from 6.0 to 6.3 million lb) for this fishery, apportioned to 3.3 million lb and 3.0 million lb respectively for the areas east and west of 174° W longitude. Fishery data have been updated with the results for 2010/11: retained catch for the directed fishery and bycatch estimates for the directed fishery, non-directed crab fisheries, and groundfish fisheries. This assessment follows the methodology recommended by the CPT in May 2011 and the SSC in June 2010 and 2011.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The CPT recommends that this stock be managed as a Tier 5 stock in 2011/12. $B_{MSY}$ and MSST are not estimated for this stock. Observer data on bycatch from the directed fishery and groundfish fisheries provides the estimate of total bycatch mortality. Bycatch data from the directed fishery for years after the 1990/91 season (excluding 1993/94 and 1994/95 seasons due to insufficient data) and from the groundfish fisheries since the 1993/94 season were used. There are no directed fishery observer data prior to the 1988/89 season and observer data are lacking or confidential for four seasons in at least one management area in the Aleutian Islands during 1988/89–1994/95.

This assessment provided two alternatives for calculating the 2012/13 total catch OFL. The assessment author recommended the use of Alternative-2 for establishing the 2012/13 OFL. Alternative-2 differs from Alternative-1 in the years used to estimate the mean annual rate of bycatch mortality to retained catch in the crab fisheries. Alternative-2 uses four years of data available over 1985/86–1995/96, whereas Alternative-1 uses seventeen years of data available over 1985/86-2008/09 recommended by the SSC as likely providing a more robust estimate than a shorter time period. For Alternative-1, this mean annual rate of bycatch mortality is 0.240, whereas that for Alternative-2 is 0.363. The main rationale for choosing Alternative 2 was that using the four years of data available over 1985/86–1995/96 to estimate the mean annual bycatch mortality rate was more appropriate than using the average retained catch over 1985/96-1995/96 as a measure of sustainable catch. The CPT concurred with the author's recommendation.
Alternative-2:

$$OFL_{Alt\text{-}1,\ 2012/13} = (1+R_{90/91\text{-}95/96}) \bullet RET_{85/86\text{-}95/96} + BM_{GF,93/94\text{-}08/09} = 12{,}537{,}757 \text{ lb}$$

where,

- $R_{90/91\text{-}95/96}$ is the average of the annual ratios of bycatch mortality due to crab fisheries to retained catch in pounds over the period of the subscripted years, excluding 1993/94–1994/95 due to data confidentiality and lack of data,
- $RET_{85/86\text{-}95/96}$ is the average annual retained catch in the directed crab fishery over 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.

The team concurred with the author's recommendation to set the ABC based on the maximum permissible from the ABC control rule which specifies an ABC based on a 10% buffer on the OFL. The recommended ABC is 11,283,981 lb under Alternative-2.

*Historical status and catch specifications (millions lb.) of Aleutian Islands golden king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | NA | NA | 5.99 | 5.68 | 6.31 | 9.18 [A] | |
| 2009/10 | NA | NA | 5.99 | 5.91 | 6.51 | 9.18 [A] | |
| 2010/11 | NA | NA | 5.99 | 5.97 | 6.56 | 11.06 | |
| 2011/12 | NA | NA | 5.99 | 5.96 | 6.51 | 11.40 | 10.26 |
| 2012/13 | NA | NA | | | | 12.54 | 11.28 |

A – retained catch

*Historical status and catch specifications (kt) of Aleutian Islands golden king crab*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | NA | NA | 2.72 | 2.58 | 2.86 | 4.16 [A] | |
| 2009/10 | NA | NA | 2.72 | 2.68 | 2.95 | 4.16 [A] | |
| 2010/11 | NA | NA | 2.72 | 2.71 | 2.98 | 5.02 | |
| 2011/12 | NA | NA | 2.72 | 2.71 | 2.95 | 5.17 | 4.66 |
| 2012/13 | NA | NA | | | | 5.69 | 5.17 |

A – retained catch

No overfished determination is possible for this stock given the lack of biomass information. Total catch in 2011/12 was below the OFL, thus overfishing did not occur. The final 2011/12 total catch relative to the 2011/12 OFL and ABC will be reviewed by the CPT in September 2012.

*Additional Plan Team recommendations*

The CPT has reviewed draft versions of a developing stock assessment model for this stock. The most recent version was reviewed at the 2012 Crab Modeling Workshop. The team reviewed progress on validating the data sources considered in the model along with a preliminary analysis of catch effort standardization at its May 2012 CPT meeting, and identified further analyses (see the May 2012 CPT report). The author is revising the model in accordance with review comments and recommendations of the Workshop and CPT meeting and will present an update on the model to the CPT in September 2012. This model is recommended for additional review at the 2013 Model Workshop.

# 9 Pribilof District Golden King Crab

*Fishery information relative to OFL setting*

The Pribilof District fishery for male golden king crab ≥ 5.5 in carapace width (≥ 124 mm carapace length) developed in the 1981/82 season. The directed fishery mainly occurs in Pribilof Canyon of the continental slope. Peak directed harvest is 856-thousand lb during the 1983/84 season. Historical fishery participation has been sporadic and retained catches variable. The current fishing season is based on a calendar year. Since 2000, the fishery was managed for a guideline harvest level (GHL) of 150-thousand lb. Non-retained bycatch occurs in the directed fishery, Bering Sea snow crab, Bering Sea groundfish, and historical grooved Tanner crab fisheries. Estimated total fishing mortality in crab fisheries averages 78-thousand lb (2001-2011). Crab mortality in groundfish fisheries (July 1–June 30, 1991/92–2010/11) averages 6-thousand lb. There was no participation in the directed fishery from 2006-2009; two vessels participated in 2011. Pribilof District golden king crab is not included in the Crab Rationalization Program.

*Data and assessment methodology*

Total golden king crab biomass has been estimated during the NMFS upper-continental-slope trawl surveys in 2002, 2004, 2008, and 2010. There is no assessment model for this stock. Fish ticket and observer data are available (including retained catch numbers, retained catch weight, and pot lifts by statistical area and landing date), size-frequency data from samples of landed crabs, and pot lifts sampled during the fishery (including date, location, soak time, catch composition, size, sex, and reproductive condition of crabs, etc.), and from the groundfish fisheries. Much of the directed fishery data are confidential due to low number of participants.

*Stock biomass and recruitment trends*

Estimates of stock biomass (all sizes, both sexes) were provided for the Pribilof Canyon. The 2008 Pribilof Canyon area-swept estimate of golden king crab biomass from the triennial slope survey was 2.03 million lb (CV=38%). This estimate is not being used for estimating stock biomass because it does not represent the whole distribution of the stock.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The Team recommends this stock be managed under Tier 5 in 2013.

The assessment author presented two alternatives for establishing the OFL. The Team concurs with the author's recommendation for an OFL based on Alternative 1 for 2013 of 0.2 million lb and the maximum permissible ABC of 0.18 million lb. The ABC was derived by applying the Tier 5 control rule a 10% buffer of the OFL, ABC = 0.9 * OFL. The OFL was derived based on the following data:

$OFL_{TOT,2013} = (1+R_{2001\text{-}2010}) * RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93\text{-}98/99}$

- $R_{2001–2010}$ is the average of the estimated average annual ratio of pounds of bycatch mortality to pounds of retained in the directed fishery during 2001–2010.
- $RET_{1993\text{-}1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998 (period of unconstrained catch).
- $BM_{NC,1994\text{-}1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998.
- $BM_{GF,1992/93–1998/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

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

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

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

*Status and catch specifications (millions lb)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009 | N/A | N/A | 0.15 | 0 | 0.001 | 0.17[A] | |
| 2010 | N/A | N/A | 0.15 | Conf. | Conf. | 0.17[A] | |
| 2011 | N/A | N/A | 0.15 | Conf. | Conf. | 0.18 | |
| 2012 | N/A | N/A | 0.15 | Conf. | Conf. | 0.20 | 0.18 |
| 2013 | N/A | N/A | | | | 0.20 | 0.18 |

A= Retained-catch OFL
Conf. = confidential

*Status and catch specifications (t)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009 | N/A | N/A | 68 | 0 | 0.5 | 77.1[A] | |
| 2010 | N/A | N/A | 68 | Conf. | Conf. | 77.1[A] | |
| 2011 | N/A | N/A | 68 | Conf. | Conf. | 81.6 | |
| 2012 | N/A | N/A | 68 | Conf. | Conf. | 90.7 | 81.6 |
| 2013 | N/A | N/A | | | | 90.7 | 81.6 |

A= Retained-catch OFL
Conf. = confidential

No overfished determination is possible for this stock given the lack of biomass information. Although catch information is confidential under Alaska statute (AS 16.05.815) the assessment author indicated that the total catch did not exceed the OFL of 0.20 million lb therefore overfishing did not occur. The 2012 fishery is ongoing until the GHL is achieved or until December 31.

## 10 Adak red king crab, Aleutian Islands

*Fishery information relative to OFL and ABC setting*

The domestic fishery has been prosecuted since 1960/61 and was opened every season through the 1995/96 season. Since 1995/96, the fishery was opened only in 1998/99, and from 2000/01-2003/04. Peak harvest occurred during the 1964/65 season with a retained catch of 21.19 million lb. During the early years of the fishery through the late 1970s, most or all of the retained catch was harvested in the area between 172° W longitude and 179° 15' W longitude. As the annual retained catch decreased into the mid-1970s and the early-1980s, a large portion of the retained catch came from the area west of 179° 15' W longitude.

Retained catch during the 10-year period, 1985/86 through 1994/95, averaged 0.94 million lb, but the retained catch during the 1995/96 season was low, only 0.04 million lb. There was an exploratory fishery with a low guideline harvest level (GHL) in 1998/99; three Commissioner's permit fisheries in limited areas during 2000/01 and 2002/03 to allow for ADF&G-Industry surveys, and two commercial fisheries with a GHL of 0.50 million lb. during the 2002/03 and 2003/04 seasons. Most of the catch since the 1990/91 season was harvested in the Petrel Bank area (between 179° W longitude and 179° E longitude) and the last two commercial fishery seasons (2002/03 and 2003/04) were opened only in the Petrel Bank area. Retained catches in those two seasons were 0.51 million lb (2002/03) and 0.48 million lb (2003/04). The fishery has been closed since the end of the 2003/04 season.

Non-retained catch of red king crabs occurs in both the directed red king crab fishery (when prosecuted), in the Aleutian Islands golden king crab fishery, and in groundfish fisheries. Estimated bycatch mortality during the 1995/96-2009/10 seasons averaged 0.003 million lb in crab fisheries and 0.022 million lb in groundfish fisheries. Estimated annual total fishing mortality (in terms of total crab removal) during 1995/96-2009/10 averaged 0.109 million lb. The average retained catch during that period was 0.084 million lb. This fishery is rationalized under the Crab Rationalization Program only for the area west of 179° W longitude.

*Data and assessment methodology*

The 1960/61-2007/08 time series of retained catch (number and pounds of crabs), effort (vessels, landings and pot lifts), average weight and average carapace length of landed crabs, and catch-per-unit effort (number of crabs per pot lift) are available. Bycatch from crab fisheries during 1995/96-2009/10 and from groundfish fisheries during 1993/94-2009/10 are available. There is no assessment model for this stock. The standardized surveys of the Petrel Bank area conducted by ADF&G in 2006 and 2009 and the ADF&G-Industry Petrel Bank surveys conducted in 2001 have been too limited in geographic scope and too infrequent for reliable estimation of abundance for the entire western Aleutian Islands area.

*Stock biomass and recruitment trends*

Estimates of stock biomass are not available for this stock. Estimates of recruitment trends and current levels relative to virgin or historic levels are not available. The fishery has been closed since the end of 2003/04 season due to apparent poor recruitment. An ADF&G-Industry survey was conducted as a commissioner's permit fishery in the Adak-Atka-Amlia Islands area in November 2002 and provided no evidence of recruitment sufficient to support a commercial fishery. A pot survey conducted by ADF&G in the Petrel Bank area in 2006 provided no evidence of strong recruitment. A 2009 survey conducted by ADF&G in the Petrel Bank area encountered a smaller, ageing population with the catch of legal male crab occurring in a more limited area and at lower densities than were found in the 2006 survey and provided no expectations for recruitment. A test fishery conducted by a commercial vessel during October-December 2009 in the area west of Petrel Bank yielded only one legal male red king crab.

*Tier determination/Plan Team discussion and resulting OFL and ABC determination*

The CPT recommends that this stock be managed under Tier 5 for the 2012/13 season. The CPT concurs with the assessment author's recommendation of an OFL based on the 1995/96–2007/08 average total catch following the recommendation of the SSC in June 2010 to freeze the time period for computing the OFL at 1995/96–2007/08. The CPT recommends an OFL for 2012/13 of 0.12 million lb..

The team recommends that the directed fishery remain closed given concerns of stock status. Groundfish bycatch in recent years has accounted for the majority of the catch of this stock. The maximum permissible ABC is 0.11 million lb based on the Tier 5 control rule of a 10% buffer on the OFL.

As in 2011, the CPT recommends an ABC of 0.074 million lb for 2012/13, which is below the maximum permissible ABC (maxABC = 0.11 million lb). This recommended ABC is based on the maximum annual groundfish and crab fishery bycatch during the period 1995/96–2009/10. Industry has expressed interest in a test fishery around the Adak area based on anecdotal information that there may be legal crab available in this stock. ADF&G has estimated a mortality of about 0.05 million lb to prosecute a test fishery. The CPT notes that the recommended ABC of 0.074 million lb for 2012/13 would allow for the proposed test fishery.

*Status and catch specifications (millions of lb) of Adak RKC.*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | NA | NA | Closed | 0 | 0.014 | 0.46[A] | |
| 2009/10 | NA | NA | Closed | 0 | 0.012 | 0.50[A] | |
| 2010/11 | NA | NA | Closed | 0 | 0.004 | 0.12 | |
| 2011/12 | NA | NA | Closed | 0 | 0.009 | 0.12 | 0.03 |
| 2012/13 | NA | NA | | | | 0.12 | 0.07 |

A-Retained catch OFL based on 1984/85-2007/08 mean retained catch

*Status and catch specifications (t) of Adak RKC.*

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | NA | NA | Closed | 0 | 6.35 | 208.7[A] | |
| 2009/10 | NA | NA | Closed | 0 | 5.44 | 226.8[A] | |
| 2010/11 | NA | NA | Closed | 0 | 1.81 | 54.43 | |
| 2011/12 | NA | NA | Closed | 0 | 0.02 | 54.43 | 12.0 |
| 2012/13 | NA | NA | | | | 54.43 | 33.57 |

A-Retained catch OFL based on 1984/85-2007/08 mean retained catch

No overfished determination is possible for this stock given the lack of biomass information. Total catch was 0.0045 million lb, below the OFL in 2010/11, therefore overfishing did not occur.

Table 3 Crab Plan Team recommendations for September 2012 (stocks 1-6). Note that recommendations for stocks 7-10 represent those final values recommended by the SSC in June 2012. Note diagonal fill indicates parameters are not applicable for that tier level. Values in metric tons (t).

| Chapter | Stock | Tier | Status (a,b,c) | $F_{OFL}$ | $B_{MSY}$ or $B_{MSYproxy}$ | Years[1] (biomass or catch) | 2012/13[2,3] MMB | 2012 MMB / $MMB_{MSY}$ | $\gamma$ | Mortality (M) | 2012/13 OFL | 2012/13 ABC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | EBS snow crab | 3 | b | 1.42 | 154.7 | 1979-current [recruitment] | 146.3 | 0.95 | | 0.23(females) 0.329 (imm) 0.273 (mat males) | 67.8 | 61.02 |
| 2 | BB red king crab | 3 | b | 0.31 | 27.5 | 1984-current [recruitment] | 26.32 | 0.96 | | 0.18default Estimated[4] | 7.96 | 7.17 |
| 3 | EBS Tanner crab | 3 | a | 0.61 | 22.80 | 1990-current [recruitment] | 42.74 | 1.87 | | 0.337 (females), 0.252 (mat male), 0.249 (imm males and females) | 19.02 | 8.17 |
| 4 | Pribilof Islands red king crab | 4 | b | 0.11 | 5.14 | 1991-current | 3.30 | 0.64 | 1.0 | 0.18 | 0.60 | 0.46 |
| 5 | Pribilof Islands blue king crab | 4 | c | 0 | 3.94 | 1980-1984 1990-1997 | 0.50 | 0.13 | 1.0 | 0.18 | 0.00116 | .00104 |
| 6 | St. Matthew Island blue king crab | 4 | a | 0.18 | 3.56 | 1978-current | 5.63 | 1.58 | 1.0 | 0.18 | 1.02 [total male catch] | 0.92 [total male catch] |
| 7 | Norton Sound red king crab | 4 | a | 0.18 | 3.51 | 1983-current [model estimate] | 4.25 | 1.21 | 1.0 | 0.18 0.68 (>123 mm) | 0.24 [total male] | 0.22 [total male] |
| 8 | AI golden king crab | 5 | | | | See intro chapter | | | | | 5.69 | 5.12 |
| 9 | Pribilof Island golden king crab | 5 | | | | See intro chapter | | | | | 0.09 | 0.08 |
| 10 | Adak red king crab | 5 | | | | 1995/96–2007/08 | | | | | 0.05 | 0.03 |

1 For Tiers 3 and 4 where $B_{MSY}$ or $B_{MSYproxy}$ is estimable, the years refer to the time period over which the estimate is made. For Tier 5 stocks it is the years upon which the catch average for OFL is obtained.
2 MMB as projected for 2/15/2013 at time of mating.
3 Model mature biomass on 7/1/2012
4 Additional mortality males: two periods-1980-1985; 1968-1979 and 1986-2008. Females three periods: 1980-1984; 1976-1979; 1985 to 1993 and 1968-1975; 1994-2008. See assessment for mortality rates associated with these time periods.

Table 4 Maximum permissible ABCs for 2012/13 and Crab Plan Team recommended ABCs for those stocks where the CPT recommendation is below the maximum permissible ABC as defined by Amendment 38 to the Crab FMP. Note that the rationale is provided in the individual introduction chapters for recommending an ABC less than the maximum permissible for these stocks. Values are in 1000 t. Note that recommendations for Norton Sound red king crab and Adak red king crab represent those final values recommended by the SSC in June 2012.

| Stock | Tier | 2012/13 *Max*ABC | 2012/13 ABC |
|---|---|---|---|
| EBS Snow Crab | 3b | 67.60 | 61.02 |
| BBRKC | 3b | 7.94 | 7.17 |
| Tanner Crab | 3a | 19.01 | 8.17 |
| PIRKC | 4b | 0.501 | 0.455 |
| PIBKC | 4c | 0.00116 | 0.00104 |
| SMBKC | 4a | 1.02 | 0.92 |
| Norton Sound RKC | 4a | 0.24 | 0.22 |
| Adak red king crab | 5 | 0.045 | 0.03 |

Table 5. Stock status in relation to status determination criteria 2011/12
(Note diagonal fill indicates parameters not applicable for that tier level)

| Chapter | Stock | Tier | MSST | $B_{MSY}$ or $B_{MSYproxy}$ | 2011/12[4] MMB | 2011/12 MMB / $MMB_{MSY}$ | 2011/12 OFL 1000 t | 2011/12 Total catch | Rebuilding Status |
|---|---|---|---|---|---|---|---|---|---|
| 1 | EBS snow crab | 3 | 77.3 | 154.67 | 165.2 | 1.07 | 73.5 | 44.7 | |
| 2 | BB red king crab | 3 | 13.77 | 27.54 | 30.88 | 1.12 | 8.80 | 4.09 | |
| 3 | EBS Tanner crab | 3 | 11.40 | 22.80 | 58.59 | 2.57 | 2.75 | 1.24 | |
| 4 | Pribilof Islands red king crab | 4 | 2.57 | 5.14 | 2.78 | 0.54 | 0.39 | 0.005 | |
| 5 | Pribilof Islands blue king crab | 4 | 2.25 | 4.49 | 0.37 | 0.08 | 0.0012 | 0.0004 | overfished |
| 6 | St. Matthew Island blue king crab | 4 | 1.81 | 3.62 | 5.03 | 1.39 | 1.70 [total male catch] | 0.95 [total male catch] | |
| 7 | Norton Sound red king crab | 4 | 0.71 | 1.42 | 2.13 | 1.50 | 0.3 | 0.20 | |
| 8 | AI golden king crab | 5 | | | | | 5.17 | 2.95 | |
| 9 | Pribilof Islands golden king crab | 5 | | | | | 0.09 | Conf. | |
| 10 | Adak red king crab | 5 | | | | | 0.05 | 0.02 | |

4 MMB as estimated during this assessment for 2011/12 as of 2/15/2012.

# Stock Assessment of eastern Bering Sea snow crab

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September 21, 2012



## EXECUTIVE SUMMARY

A size based model was developed for eastern Bering Sea snow crab (*Chionoecetes opilio*) to estimate population biomass and harvest levels. Model estimates of total mature biomass of snow crab increased from the early 1980's to a peak in 1990 of about 954,700 t. The total mature biomass includes all sizes of mature females and morphometrically mature males. The stock was declared overfished in 1999 due to the survey estimate of total mature biomass (149,900 t) being below the minimum stock size threshold (MSST = 208,710 t). A rebuilding plan was implemented in 2000. The currency for estimating $B_{MSY}$ changed during the 10 year rebuilding period from total mature survey biomass to model estimated mature male biomass at mating (MMB) as well as assessment model structure. Using the current definitions for estimating $B_{MSY}$, MMB at mating was above B35% in 2010/11 and the stock was declared rebuilt in 2011. The total mature observed survey biomass in 2011 was 447,400 t which was also above the Bmsy(418,150 t) in place under the rebuilding plan implemented in 2000. The increase in total mature biomass was mainly due to a large increase in female mature biomass in 2011.

Observed survey mature male biomass decreased from 167,400 t in 2011 to 120,800 t in 2012. Observed survey mature female biomass also decreased from 280,000 t in 2011 to 220,600 t in 2012. The 2012 estimate of males greater than 101 mm decreased to 87 million crab from 150.7 million in 2011, a decrease of 42%.

Base model estimates of mature male biomass at mating decreased from 198,800 t in 2010/11 to 165,200 t in 2011/12 (107% of B35% (154,669 t)).

Catch trends have followed survey abundance estimates of large males, as the survey estimates have been the basis for calculating the GHL (Guideline Harvest Level for retained catch). Retained catches increased from about 3,040 t at the beginning of the directed fishery in 1973 to a peak of 149,110 t in 1991, declined thereafter, then increased to another peak of 110,410 t in 1998. Retained catch in the 1999/2000 fishery was reduced to 15,200 t due to the low abundance estimated by the 1999 survey. A harvest strategy (Zheng et al. 2002) was developed using a simulation model previous to the development of the current stock assessment model, that has been used to set the GHL since the 2000/01 fishery. Retained catch in the 2011/12 fishery

increased to 40,500 t, an increase from the 2010/11 fishery retained catch of 24,670 t. The total catch in the 2011/12 fishery was estimated at 44,600 t below the OFL of 73,800 t.

Estimated discard mortality (mostly undersized males and old shell males) in the directed pot fishery has averaged about 15.5% (with assumed discard mortality of 50%) of the retained catch biomass since 1992 when observers were first placed on crab vessels. Discards prior to 1992 were estimated based on fishery selectivities estimated for the period with observer data and the full selection fishing mortality estimated using the retained catch and retained fishery selectivities.

The assessment model used for the September 2011 assessment was the model recommended by the CPT in May 2011 and the SSC in June 2011 ("Model 6"). The model structure of the Base model in the current assessment is the same as the recommended Model 6 of the September 2011 assessment. An alternative Model scenario is included in this assessment which estimates growth using parameters from a new growth per molt curve as priors estimated from the 2011 growth study (Somerton, pers. Comm.).

The OFL for 2012/13 for the Base model was 67,800 t, a declined from the 2011/12 OFL of 73,500 t mainly due to a decrease in biomass.

The MMB at mating projected for 2012/13 when fishing at the F35% control rule (OFL) was 94.6% of B35%. The ACL was estimated at 67,610 t using a p*=0.49. The total catch estimated at 90% of OFL (the ACL recommended by the SSC for 2011/12) was 60,849 t. The MMB projected for 2012/13 when fishing at 90% of the OFL catch was 98% of B35%. B35% for the Base model was estimated at 154,669 t and F35% 1.32.

The OFL for 2012/13 for Model 1 (new growth) was 51,600 t (90% of OFL 46,440 t). The MMB at mating projected for 2012/12 when fishing at the F35% control rule (OFL) was 86% of B35%. B35% for Model 1 was estimated at 138,960 t and F35% at 1.127.

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2007/08 | 72.1 | 98.9[A] | 28.6 | 28.6 | 35.0 | | |
| 2008/09 | 74.1 | 109.3[B] | 26.6 | 26.5 | 31.5 | 35.1 | |
| 2009/10 | 66.6 | 127.7[C] | 21.8 | 21.8 | 23.9 | 33.1 | |
| 2010/11 | 73.7 | 196.6[D] | 24.6 | 24.7 | 26.7 | 44.4 | |
| 2011/12 | 77.3[E] | 165.2[E] | 40.3 | 40.3 | 44.7 | 73.5 | 66.2 |
| 2012/13 | | 146.3 [F] | | | | 67.8 | 60.8 |

The stock was above MSST in 2011/12 and is hence not overfished. Overfishing did not occur during the 2011/12 fishing year.

Notes:
A – Calculated from the assessment reviewed by the Crab Plan Team in September 2008
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
E – Calculated from the assessment reviewed by the Crab Plan Team in September 2012
F- Projected MMB at mating fishing at the OFL in 2012/13

## Changes to the Model

There were no changes to the base model structure from the September 2011 Model 6 assessment.

## Changes to the Data

2012 Bering Sea survey biomass and length frequency data added to the model. 2011/12 directed fishery retained and discard catch and length frequencies. Groundfish discard length frequency from 2011/12 added and 2011/12 groundfish discard catch.

**CPT September 2011 Recommendations for next assessment**:
1) add parameter bounds to Table 13;
2) add a table of parameter correlations;
3) include a plot overlaying the MMB trajectories for each of the scenarios for easier comparison (similar to Figure 87 but with all the runs);
4) the model description for the likelihood functions for the experimental data is incomplete and needs to be elaborated;
5) fix caption (legend) for Figure 24;
6) develop a more formal and reasonable model selection criterion based on statistical descriptions of the model fit to the data rather than having a zero prior for all models that don't have an M = 0.23yr-1;
7) provide retrospective estimates of Q and *B*35%; and
8) conduct further work on estimating M and the associated confounding of M, and growth with Q.

## Authors response

3) included in document, 5) fixed caption, 6) only two model scenarios presented in this assessment, 7) B35% estimates are in table in the executive summary. Q estimates for 2011 and 2012 in text. A profile on Q is included. 1), 2) and 4) not completed due to time constraints.

## SSC recommendations

- Because of considerable uncertainty in natural mortality (M) and difficulties in estimating M internally in the assessment, the uncertainty in estimates of M should be fully characterized in the assessment by including standard errors or a full posterior distribution for M.
- Female mortality remains fixed at M=0.23 in the model although females are generally believed to have higher mortality rates than males. Therefore, the authors should explore estimating female mortality in the model (as in the new Tanner crab model) or provide a better rationale for the choice of female M.
- Further examination of the survey availability curves is warranted to assess the justification for using a smooth curve in the model. The SSC suggests the use of the DIC instead of the AIC for selecting among alternative models as it provides an objective method for determining the effective number of parameters.

• To compare model-estimated selectivity to the empirical (Somerton) estimates, the weighting scheme for the empirical estimates of selectivity should be reviewed and clarified. In particular, the SSC is uncertain about whether estimates of selectivity at a given location were weighted twice in the process of scaling selectivity estimates up to the "average" selectivity experienced by the snow crab population within the survey area (p. 13).

**Authors Response**

Estimation of the posterior distributions are not yet implemented in the snow crab model. No further exploration of availability curve shapes was explored. The CPT recommended use of the smooth functions as they provided the best fit to the data. The fourth bullet would need to be addressed by Somerton as it concerns his analysis of the data.

## INTRODUCTION

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. In the Bering Sea, snow crab are common at depths less than about 200 meters. The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population may extend into Russian waters to an unknown degree.

## FISHERY HISTORY

Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. Retained catch in the domestic fishery increased in the late 1980’s to a high of about 149,110 t in 1991, declined to 29,820 t in 1996, increased to 110,410 t in 1998 then declined to 15,200 t in the 1999/2000 fishery (Table 1, Figure 1). Due to low abundance and a reduced harvest rate, retained catches from 2000/01 to 2006/07 ranged from a low of about 10,860 t to 16,780 t. The total catch for the 2010/11 fishery was estimated at 26,600 t. Total catch increased in 2011/12 to 44,600 t, due to an increase in stock biomass and increase in the retained catch to 40,500 t.

Discard from the directed pot fishery was estimated from observer data since 1992 and ranged from 11% to 64% (average 33%) of the retained catch of male crab biomass (Table 1). Female discard catch is very low and not a significant source of mortality. In 1992 trawl discard mortality was about 1,950 t, increased to about 3,550 t in 1995, then declined and ranged between 900 t and 1,500t until 1999. Trawl bycatch in 2010/11 and 2011/12 was 190 t and 170 t respectively. Discard of snow crab in groundfish fisheries from highest to lowest is the yellowfin sole trawl fishery, flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery and the Pacific cod hook and line and pot fisheries.

Size frequency data and catch per pot have been collected by observers on snow crab fishery vessels since 1992. Observer coverage was 10% on catcher vessels larger than 125 ft (since 2001), and 100% coverage on catcher processors (since 1992).

The average size of retained crabs has remained fairly constant over time ranging between 105 mm and 118 mm, and most recently about 110 mm to 111 mm. The percent new shell animals in the catch has varied between 69% (2002 fishery) to 98% (1999), and was 87% for the 2005/6 fishery and 93% in the 2007/8 fishery. In the 2007/8 fishery 94% of the new shell males >101mm CW were retained, while 78% of the old shell males >101mm CW were retained. Only 3% of crab were retained between 78mm and 101 mm CW. The average weight of retained crab has varied between 0.5 kg (1983-1984) and 0.73 kg (1979), and 0.59 kg in the recent fisheries.

Several modifications to pot gear have been introduced to reduce bycatch mortality. In the 1978/79 season, pots used in the snow crab fishery first contained escape panels to prevent ghost fishing. Escape panels consisted of an opening with one-half the perimeter of the tunnel eye laced with untreated cotton twine. The size of the cotton laced panel to prevent ghost fishing was increased in 1991 to at least 18 inches in length. No escape mechanisms for undersized crab were required until the 1997 season when at least one-third of one vertical surface had to contain not less than 5 inches stretched mesh webbing or have no less than four circular rings of no less than 3 3/4 inches inside diameter. In the 2001 season the escapement for undersize crab was increased to at least eight escape rings of no less than 4 inches placed within one mesh measurement from the bottom of the pot, with four escape rings on each side of the two sides of a four-sided pot, or one-half of one side of the pot must have a side panel composed of not less than 5 1/4 inch stretched mesh webbing.

Harvest rates

The harvest rate used to set the GHL (Guideline Harvest Level of retained crab only) previous to 2000 was 58% of the number of male crab over 101 mm carapace width estimated from the survey. The minimum legal size limit for snow crab is 78 mm, however, the snow crab market generally accepts animals greater than 101 mm. In 2000, due to the decline in abundance and the declaration of the stock as overfished, the harvest rate for calculation of the GHL was reduced to 20% of male crab over 101 mm. After 2000, a rebuilding strategy was developed based on simulations by Zheng (2002).

The realized retained catch typically exceeded the GHL historically, resulting in exploitation rates for the retained catch (using survey numbers) ranging from about 60% to 100% for most years (Figure 2). The exploitation fraction is calculated using the abundance for male crab over 101 mm estimated from the survey data reduced by the natural mortality from the time of the survey until the fishery occurs, approximately 7 months later, since the late 1980's. The historical GHL calculation did not include the correction for time lapsed between the survey and the fishery. In 1986 and 1987 the exploitation rate exceeded 1.0 because some crabs are retained that are less than 102 mm, discard mortality of small crabs is also included, and survey catchability is estimated in the model at less than 1.0. The exploitation fraction was derived using the total catch divided by the mature male biomass estimated from the model, ranged from 10% to 60% (Figure 3). The exploitation fraction estimated by dividing the total catch by the model estimate of the crabs over 101 mm ranged from about 15% to 85% (Figure 3). The total exploitation rate on males > 101 mm was 50% to 85% for 1988 to 1994 and 50% to 60% for 1998 and 1999 (year when fishery occurred).

Prior to adoption of Amendment 24, $B_{MSY}$ (921.6 million lbs (418,150 t)) was defined as the average total mature biomass (males and females) estimated from the survey for the years 1983 to 1997 (NPFMC 1998). MSST was defined as 50% of the $B_{MSY}$ value (MSST=460 million lbs of total mature biomass (209,074 t)). The harvest strategy since 2000/1 used a retained crab harvest rate on the mature male biomass of 0.10 on levels of total mature biomass greater than ½ MSST (230 million lbs), increasing linearly to 0.225 when biomass is equal to or greater than $B_{MSY}$ (921.6 million lbs) (Zheng et al. 2002). The GHL was actually set as the number of retained crab allowed in the harvest, calculated by dividing the GHL in lbs by the average weight of a male crab > 101 mm. If the GHL in numbers was greater than 58% of the estimated number of new shell crabs greater than 101 mm plus 25% of the old shell crab greater than 101 mm, the GHL is capped at 58%. If natural mortality is 0.2, then this actually results in a realized exploitation rate cap for the retained catch of 66% at the time of the fishery, occurring approximately 7 months after the survey. The fishing mortality rate that results from this harvest strategy depends on the relationship between mature male size numbers and male numbers greater than 101 mm.

# DATA

## Data Sources

Catch data and size frequencies of retained crab from the directed snow crab pot fishery from 1978 to the 2011/12 season were used in this analysis. Observers were placed on directed crab fishery vessels starting in 1990. Size frequency data on the total catch (retained plus discarded) in the directed crab fishery were available from 1992 to 2009/10. Total discarded catch was estimated from observer data from 1992 to 2011/12 (Table 1). The discarded male catch was estimated for 1978 to 1991 in the model using the estimated fishery selectivities based on the observer data for the period 1992 to 2011/12. The discard catch estimate was multiplied by the assumed mortality of discards from the pot fishery. The mortality of discarded crab was assumed to be 50%. This estimate differs from the current rebuilding harvest strategy used since 2001, which assumes a discard mortality of 25% (Zheng, et al. 2002). The discard mortality assumptions will be discussed in a later section. The discards prior to 1992 may be underestimated due to the lack of escape mechanisms for undersized crab in the pots before 1997.

The following table contains the various data components used in the model,

| Data component | Years |
|---|---|
| | |
| Retained male crab pot fishery size frequency by shell condition | 1978/79-2011/12 |
| Discarded male and female crab pot fishery size frequency | 1992/3-2011/12 |
| Trawl fishery bycatch size frequencies by sex | 1991-2011/2012 |
| Survey size frequencies by sex and shell condition | 1978-2012 |
| Retained catch estimates | 1978/79-2011/12 |
| Discard catch estimates from snow crab pot fishery | 1992/93-2011/12 from observer data |

| | |
|---|---|
| Trawl bycatch estimates | 1973-2011/12 |
| Total survey biomass estimates and coefficients of variation | 1978-2012 |
| 2009 study area biomass estimates and coefficients of variation and length frequencies for BSFRF and NMFS tows | 2009 |
| 2010 study area biomass estimates and coefficients of variation and length frequencies for BSFRF and NMFS tows | 2010 |

## Survey Biomass

Abundance is estimated from the annual eastern Bering Sea (EBS) bottom trawl survey conducted by NMFS (see Rugolo et al. 2003 for design and methods). Since 1989, the survey has sampled stations farther north than previous years (61.2° N previous to 1989). In 1982 the survey net was changed resulting in a change in catchability. Juvenile crabs tend to occupy more inshore northern regions (up to about 63° N) and mature crabs deeper areas to the south of the juveniles (Zheng et al. 2001).

All survey data in this assessment use measured net widths instead of a fixed 50 ft net width used in the September 2009 snow crab assessment (variable net width data were shown for comparison in the September 2009 assessment). Snow crab assessments prior to and including September 2009 used survey biomass estimates for all crab based on an assumed 50 ft net width. In 2009, Chilton et al. (2009) provided new survey estimates based on measured net width. The average measured net width for all tows in the 2009 survey was 17.08 meters which is about 112% of 50ft (15.24 meters) (Chilton et al. 2009). The 2009 mature male survey biomass was 162,890 t using the fixed 50 ft net width and 141,300 t using the measured net width for each tow. The difference between the survey male mature biomass estimates calculated with the fixed 50 ft width and the measured net width is small in the early part of the time series, and then is an average ratio of 0.86 (range 0.81 to 0.90) from 1998 to 2009.

The total mature biomass (all sizes of morphometrically mature males and females) estimated from the survey declined to a low of 82,100 t in 1985, increased to a high of 809,600 t in 1991 (includes northern stations after 1989), then declined to 140,900 t in 1999, when the stock was declared overfished (Table 3 and Figure 4). The mature biomass increased in 2000 and 2001, mainly due to a few large catches of mature females. The survey estimate of total mature biomass increased from 245,000 t in 2009 to 302,400 t in 2010 and increased again to 447,400 t in 2011. Survey total mature biomass declined to 341,400 t in 2012.

Survey mature male biomass increased from 157,300 t in 2010 and 167,400 t in 2011, then declined to 120,800 t in 2012. The observed survey estimate of males greater than 101 mm increased from 137.6 million in 2010 and 150.7 million in 2011 then declined to 87.0 million in 2012 (Table 3). Survey mature female biomass increased from 145,100 t in 2010 and 280,000 t in 2011 then declined to 220,600 t in 2012.

The term mature for male snow crab in this assessment means morphometrically mature. Morphometric maturity for males refers to a marked change in chelae size (thereafter termed "large claw"), after which males are assumed to be effective at mating. Males are functionally mature at smaller sizes than when they become morphometrically mature, although the contribution of these “small-clawed” males to annual reproductive output is negligible. The minimum legal size limit for the snow crab fishery is 78 mm, however the size for males that are generally accepted by the fishery is >101mm. The historical quotas were based on the survey abundance of large males (>101mm).

Survey Size Composition

Carapace width is measured on snow crab and shell condition noted in the survey and the fishery. Snow crab cannot be aged at present (except by radiometric aging of the shell since last molt) however, shell condition has been used as a proxy for age. Based on protocols adopted in the NMFS EBS trawl survey, shell condition class and presumptive age are as follows: soft shell (SC1) (less than three months from molting), new shell (SC2) (three months to less than one year from molting), old shell (SC3) (two years to three years from molting), very old shell (SC4) (three years to four years form molting), and very very old shell (SC5) (four years or longer from molting). Radiometric aging of shells from terminal molt male crabs (after the last molt of their lifetime) elucidated the relationship between shell condition and presumptive age, which will be discussed in a later section (Nevissi et al 1995).

Survey abundance by size for males and females indicate a moderate level of recruitment moving through the stock and resulting in the recent increase in abundance. (Figures 6 - 8). In 2009 small crab (<50mm) increased in abundance relative to 2008. The 2010 length frequency data showed high abundance in the 40 to 50 mm range. The recruitment progressed into the mature female abundance in 2011 and also can be seen in male abundance in the 50-65mm range in 2011(Figure 8a). However, in 2012, the progress of the recruitment is not evident. High numbers of small crab in the late 1970’s survey data did not follow through the population to the mid-1980’s. The high numbers of small crab in the late 1980’s resulted in the high biomass levels of the early 1990’s and subsequent high catches. Moderate increase in numbers can also be seen in the mid 1990’s.

Spatial distribution of catch and survey abundance

The majority of the fishery catch occurs south of 58.5$^o$ N., even in years when ice cover did not restrict the fishery moving farther north. In past years, most of the fishery catch occurred in the southern portion of the snow crab range possibly due to ice cover and proximity to port and practical constraints of meeting delivery schedules. In 2004 78% of the catch was south of 58.5$^o$ N. (Figure 9). In 2003 and 2004 the ice edge was farther north than past years, allowing some fishing to occur as far north as 60-61$^o$ N. Catch in the 2006/07 fishery was similar to recent years (Figure 10) with most catch south of 58 $^o$ N. and west of the Pribilof Islands between about 171$^o$ W and 173$^o$ W. The pattern of catch was similar to previous years for the 2008/09 fishery however, about 3,580 t of retained catch was taken east and south of the Pribilof Islands at 168 to 167 $^o$ longitude and 55.5 to 56.6 $^o$ latitude which has not occurred in recent years (Figure 11). About 93% of the retained catch came from south of 58.5$^o$ N. The directed fishery catch in 2011/12 is shown in Figure 11b.

Survey data from 2010 estimated a larger abundance of small crab than in 2009 (male and female) mostly in the northern part of the survey area (Figures 12 through 18). Large males (>101mm) were distributed similar to 2009, however, farther south than in previous years (Figure 14). Mature females with less than or equal to half clutch of eggs were mostly in the northern part of the survey area above 58 $^{o}$ N (Figure 17).

Distribution of snow crab by haul for 2011 are shown in Figures 19 through 25.
Survey data from 2011 show more widespread distributions of male crab greater than 77mm and >101mm (Figures 19 and 21). Immature female snow crab distribution extends farther south than in 2010 (Figures 15 and 22). Distribution of snow crab in the survey for 2012 are shown in Figures 25b through 25h.

The difference between the summer survey distribution of large males and the fishery catch distribution indicates that survey catchability may be less than 1.0 and/or some movement occurs between the summer survey and the winter fishery. However, the exploitation rate on males south of 58.5$^{o}$ N latitude may exceed the target rate, possibly resulting in localized depletion of males from the southern part of their range. Snow crab larvae probably drift north and east after hatching in spring. Snow crab appear to move south and west as they age, however, no tagging studies have been conducted to fully characterize the ontogenetic or annual migration patterns of this stock. High exploitation rates in the southern area may have resulted in a northward shift in snow crab distribution. The last few years of survey data indicate a shift to the south in distribution of snow crab, which reverses the trends seen in early 2000's.

Ernst, et al. (2005) found the centroids of survey summer distributions have moved to the north over time (Figures 26 and 27). In the early 1980's the centroids of mature female distribution were near 58.5 $^{o}$ N, in the 1990's the centroids were about 59.5 $^{o}$ N. The centroids of old shell male distribution was south of 58 $^{o}$ N in the early 1980's, moved north in the late 1980's and early 1990's then shifted back to the south in the late 1990's. The distribution of males>101 mm was about at 58 $^{o}$ N in the early 1980's, then was farther north (58.5 to 59 $^{o}$ N) in the late 1980's and early 1990's, went back south in 1996 and 1997 then has moved north with the centroid of the distribution in 2001 just north of 59 $^{o}$ N.. The centroids of the catch are generally south of 58 $^{o}$ N, except in 1987. The centroids of catch also moved north in the late 1980's and most of the 1990's. The centroids of the catch were about at 56.5 $^{o}$ N in 1997 and 1998, then moved north to above 58.5 $^{o}$ in 2002.

### 2009 and 2010 Study Area Data Additional survey data

Bering Sea Fisheries Research Foundation (BSFRF) conducted a survey of 108 tows in 27 survey stations (10,827 sq nm, hereafter referred to as the "study area") in the Bering Sea in summer 2009(Figure 28, see Somerton et al 2010 for more details). The abundance estimated by the BSFRF survey in the study area was 66.9 million male crab >=100 mm compared to 36.7 million for the NMFS tows (Table 4). The NMFS abundance of females >=50mm (121.5 million) was greater than the BSFRF abundance estimate in the study area (113.6 million) (Table 4).

The abundance of male crab in the entire Bering Sea survey for 2009 was greatest in the 30 – 60mm size range (Figures 29 and 30). The abundance of crab in the 35 to 60mm size range for the BSFRF net in the study area was very low compared to the abundance of the same size range for the NMFS entire Bering Sea survey. The differences in abundance by size for the NMFS entire Bering Sea survey and the BSFRF study area are due to availability of crab in the study area as well as capture probability. While the abundance of larger male crab for the NMFS net in the study area is less than for the BSFRF, the abundance of females >45 mm is greater for the NMFS net than the BSFRF (Figure 29). This difference may be due to different towing locations for the two nets within the study area, or to higher catchability of females possibly due to aggregation behavior. The ratio of abundance of the NMFS net and BSFRF net in the study area are quite different for males and females (Figure 31). The ratio of abundance indicates a catchability for mature females (mainly 45 – 65 mm) that is greater than 1.0 for the NMFS net.

The largest tows for small (<78mm) male crab in the entire Bering Sea area were north of the study area near St. Matthew Island (Figure 12 and 20). Some higher tows for large males (>=100mm) and for mature females occurred in the study area as well as outside the study areas (Figures 5-18 and 22-24). These distributions indicate that availability of crab of different sizes and sex varies spatial throughout the Bering Sea. The numbers by length and mature biomass by sex for the BSFRF tows and the NMFS tows within the study area were added to the model as an additional survey.

The 2009 estimated snow crab abundance by length in the study area had very low numbers of both male and female crab in the 35 mm to 70 mm range than observed in the Bering sea wide survey(Figures 29 and 30). The ratio of abundance (NMFS/BSFRF) by length for 2009 was 0.2 at about 45 mm increasing gradually to 0.4 at 95mm then increasing steeply to 0.9 to 1.25 above 115 mm (Figure 31). The mean size of crab retained by the fishery is about 110 mm, with minimum size retained about 102mm. Ratios of abundance for female crab were above 1.0 from 45mm to 60mm then declined to 0.5 to 0.8 above 60mm to 80mm. There were very few female crab above 80mm in the population.

The 2010 study area covered a larger portion of the distribution of snow crab than the 2009 study area. The abundance by length for the 2010 study area is very different from the 2009 data, with higher abundance in 2010 of small crab (Figure 32). The expanded estimate (expanded to the study area) of male abundance from BSFRF data is higher than the Bering Sea wide abundance for length from 50mm to about 110mm. Female abundance shows a similar relationship (Figure 33). The ratio of male abundance by length (NMFS/BSFRF) in 2010 increased to 0.6 at 40mm then decreased to about 0.2 at 65-70mm then increased and ranged between 0.3 and 0.4 up to about 112mm (Figure 34). The ratios increased from 0.4 at 112 to about 0.7 at 122mm then to 1.55 at 132mm. The ratio of female abundance by length in 2010 was 0.6 at about 45mm and declined to 0.4 at about 67mm then declined below 0.1 above about 77mm.

Several processes influence net performance. Somerton et al. accounted for area swept, sediment type, depth and crab size. They did not correct for the probability of encountering crab. The 2010 study area data have a number of paired tows where BSFRF caught no crab (within a particular size bin) or where NMFS caught no crab. This creates problems with simply taking the ratio of catches since a number of ratios will be infinity (dividing by 0). This occurs because the paired tows although near in space were not fishing on the same density of crab. In addition, the BSFRF tow covered about 10% of the area of the NMFS tow, due to the narrower net width and the 5 minute tow duration compared to the 30 minute NMFS tow duration. In order to analyze this data, first the ratio of the NMFS density (numbers per $nm^2$) to the sum of the density of NMFS and BSFRF were calculated (Figure 35 males and Figure 38 females). These values range from 0 to 1.0. The simple mean of these values was estimated by length bin and then transformed to estimate mean catchability by length bin (Figure 39 males Figure 40 females). A value of 0.5 for the ratio of NMFS to sum of density is equivalent to a catchability of 1.0 and 0.33 is catchability of 0.5. The size of the catch for each observation is plotted in Figure 36 (same data as Figure 35).

The BSFRF study provides a rich data set to evaluate net performance. In this survey the sample is the paired tows and the goal would be to evaluate net performance over a wide range of densities, sediment types and depths. Somerton et al. (February 2011 Modeling Workshop) used catch to weight observations for estimation of the selectivity curve. This assumes that trawl performance is influenced by local density of crab (an untested assumption). No weighting of the observations assumes that there is no relationship between catch and the selectivity of crab. If selectivity changes depending on whether catches are high or low, then further study and analysis is needed. Further analysis needs to be done on whether data should be weighted in the initial estimation of the selectivity curve. The unweighted mean values by length bin are higher than the values estimated by Somerton et al.. Somerton weights again by survey abundance and adjusts for depth and sediment type in a separate step in the analysis to estimate a Bering Sea wide survey selectivity. Simulation studies are needed to determine the influence of weighting (whether bias is introduced) and whether the distributional assumptions and likelihood equations used in the analysis of the paired tow data are correct and unbiased.

The overall distribution of the ratio of NMFS density to the sum of the densities is skewed with about 140 - 0.0 values and 110 - 1.0 values (Figure 41). The percentage of observations where NMFS caught crab and no crab were caught by the BSFRF tow increases by size bin for male crab (Figures 41 through 46).

Catches of male crab decrease with size simply because they are lower in abundance in the population. At sizes of male crab greater than about 90 mm the fraction of observations where the ratio of NMFS density to the sum of densities was 1.0 and 1 crab was caught in the net was about 10% to 30%. In other, words the majority of the tows involved more than 1 crab caught.

The mean values of the ratio of NMFS density to the sum of densities for female crab transformed to catchability increase from less than 0.1 at 25mm to about 0.5 at 55mm then decrease slightly above 70mm (Figures 38 and 40).

## Weight - Size

The weight (kg) – size (mm) relationship was estimated from survey data, where weight = a* $size^b$. Juvenile female a= 0.00000253, b=2.56472. Mature female a=0.000675 b=2.943352, and males, a= 0.00000023, b=3.12948 (Figure 47).

## Maturity

Maturity for females was determined by visual examination during the survey and used to determine the fraction of females mature by size for each year. Female maturity was determined by the shape of the abdomen, by the presence of brooded eggs or egg remnants.

Morphometric maturity for males is determined by chela height measurements, which are available starting from the 1989 survey (Otto 1998). The number of males with chela height measurements has varied between about 3,000 and 7,000 per year. In this report a mature male refers to a morphometrically mature male.

One maturity curve for males was estimated using the average fraction mature based on chela height data and applied to all years of survey data to estimate mature survey numbers. The separation of mature and immature males by chela height at small widths may not be adequately refined given the current measurement to the nearest millimeter. Chela height measured to the nearest tenth of a millimeter (by Canadian researchers on North Atlantic snow crab) shows a clear break in chela height at small and large widths and shows fewer mature animals at small widths than the Bering Sea data measured to the nearest millimeter. Measurements taken in 2004-2005 on Bering Sea snow crab chela to the nearest tenth of a millimeter show a similar break in chela height to the Canadian data (Rugolo et al. 2005).

The probability of a new shell crab maturing was estimated in the model at a smooth function to move crab from immature to mature (Figure 48). The probability of maturing was estimated to match the observed fraction mature for all mature males and females observed in the survey data. The probability of maturing was fixed in the September 2009 assessment. The probability of maturing by size for female crab was about 50% at about 48 mm and increased to 100% at 60mm (Figure 49). The probability of maturing for male crab was about 15% to 20% at 60 mm to 90mm and increased sharply to 50% at about 98mm, and 100% at 108 mm.

## Natural Mortality

Natural mortality is an essential control variable in population dynamic modeling, and may have a large influence on derived optimal harvest rates. Natural mortality rates estimated in a population dynamics model may have high uncertainty and may be correlated with other parameters, and therefore are usually fixed. The ability to estimate natural mortality in a population dynamics model depends on how the true value varies over time as well as other factors (Fu and Quinn 2000, Schnute and Richards 1995).

Nevissi, et al. (1995) used radiometric techniques to estimate shell age from last molt (Table 7). The total sample size was 21 male crabs (a combination of Tanner and snow crab) from a collection of 105 male crabs from various hauls in the 1992 and 1993 NMFS Bering Sea survey. Fishing mortality rates before and during the time period when these crab were collected were relatively high, and therefore maximum age would represent Z (total mortality) rather than M. Representative samples for the 5 shell condition categories were collected that made up the 105 samples. The oldest looking crab within shell conditions 4 and 5 were selected from the total sample of SC4 and SC5 crabs to radiometrically age (Orensanz, pers comm.). Shell condition 5 crab (SC5 = very, very old shell) had a maximum age of 6.85 years (s.d. 0.58, 95% CI approximately 5.69 to 8.01 years). The average age of 6 crabs with SC4 (very old shell) and SC5, was 4.95 years. The range of ages was 2.70 to 6.85 years for those same crabs. Given the small sample size, this maximum age may not represent the 1.5% percentile of the population that is approximately equivalent to Hoenig's method (1983). Maximum life span defined for a virgin stock is reasonably expected to be longer than these observed maximum ages from exploited populations. Radiometric ages estimated by Nevissi, et al. (1995) may be underestimated by several years, due to the continued exchange of material in crab shells even after shells have hardened (Craig Kastelle, pers. comm., Alaska Fisheries Science Center, Seattle, WA).

Tag recovery evidence from eastern Canada reveal observed maximum ages in exploited populations of 17-19 years (Nevissi, et al. 1995, Sainte-Marie 2002). A maximum time at large of 11 years for tag returns of terminally molted mature male snow crab in the North Atlantic has been recorded since tagging started about 1993 (Fonseca, et al. 2008). Fonseca, et al. (2008) estimated a maximum age of 7.8 years post terminal molt using data on dactal wear.

We reasoned that in a virgin population of snow crab, longevity would be at least 20 years. Hence, we used 20 years as a proxy for longevity and assumed that this age would represent the upper 99$^{th}$ percentile of the distribution of ages in an unexploited population if observable. Under negative exponential depletion, the 99$^{th}$ percentile corresponding to age 20 of an unexploited population corresponds to a natural mortality rate of 0.23. Using Hoenig's (1983) method an M=0.23 corresponds to a maximum age of 18 years (Table 8). M=0.23 was used for all female crab in the model. Male natural mortality estimated in the model with a prior constraint of mean M=0.23 with a se = 0.054 estimated from using the 95% CI of +-1.7 years on maximum age estimates from dactal wear and tag return analysis in Fonseca, et al. (2008).

## Molting probability

Female and male snow crab have a terminal molt to maturity. Many papers have dealt with the question of terminal molt for Atlantic Ocean mature male snow crab (e.g., Dawe, et al. 1991). A laboratory study of morphometrically mature male Tanner crab, which were also believed to have a terminal molt, found all crabs molted after two years (Paul and Paul 1995). Bering Sea male snow crab appear to have a terminal molt based on data on hormone levels (Tamone et al. 2005) and findings from molt stage analysis via setagenesis. The models presented here assume a terminal molt for both males and females.

Male Tanner and snow crabs that do not molt (old shell) may be important in reproduction. Paul et al. (1995) found that old shell mature male Tanner crab out-competed new shell crab of the same size in breeding in a laboratory study. Recently molted males did not breed even with no competition and may not breed until after about 100 days from molting (Paul et al. 1995). Sainte-Marie et al. (2002) states that only old shell males take part in mating for North Atlantic snow crab. If molting precludes males from breeding for a three month period, then males that are new shell at the time of the survey (June to July), would have molted during the preceding spring (March to April), and would not have participated in mating. The fishery targets new shell males, resulting in those animals that molted to maturity and to a size acceptable to the fishery of being removed from the population before the chance to mate. Animals that molt to maturity at a size smaller than what is acceptable to the fishery may be subjected to fishery mortality from being caught and discarded before they have a chance to mate. However, new shell males will be a mixture of crab less than 1 year from terminal molt and 1+ years from terminal molt due to the inaccuracy of shell condition as a measure of shell age.

Crabs in their first few years of life may molt more than once per year, however, the smallest crabs included in the model are probably 3 or 4 years old and would be expected to molt annually. The growth transition matrix was applied to animals that grow, resulting in new shell animals. Those animals that don't grow become old shell animals. Animals that are classified as new shell in the survey are assumed to have molted during the last year. The assumption is that shell condition (new and old) is an accurate measure of whether animals have molted during the previous year. The relationship between shell condition and time from last molt needs to be investigated further. Additional radiometric aging for male and female snow crab shells is being investigated to improve the estimate of radiometric ages from Orensanz (unpub. data).

## Mating ratio and reproductive success

Full clutches of unfertilized eggs may be extruded and appear normal to visual examination, and may be retained for several weeks or months by snow crab. Resorbtion of eggs may occur if not all eggs are extruded resulting in less than a full clutch. Female snow crab at the time of the survey may have a full clutch of eggs that are unfertilized, resulting in overestimation of reproductive potential. Male snow crab are sperm conservers, using less than 4% of their sperm at each mating. Females also will mate with more than one male. The amount of stored sperm and clutch fullness varies with sex ratio (Sainte-Marie 2002). If mating with only one male is inadequate to fertilize a full clutch, then females will need to mate with more than one male, necessitating a sex ratio closer to 1:1 in the mature population, than if one male is assumed to be able to adequately fertilize multiple females.

The fraction barren females and clutch fullness observed in the survey increased in the early 1990's then decreased in the mid- 1990's then increased again in the late 1990's (Figures 49 and 50). The highest levels of barren females coincides with the peaks in catch and exploitation rates that occurred in 1992 and 1993 fishery seasons and the 1998 and 1999 fishery seasons. While the biomass of mature females was high in the early 1990's, the rate of production from the stock may have been reduced due to the spatial distribution of the catch relative and the resulting sex ratio in areas of highest reproductive potential. The percentage of barren females was low in 2006, increased in 2007, then declined in 2008 and 2009 to below 1 percent for new and old shell females and about 17% for very old females. Clutch fullness for new shell females declined slightly in 2009 relative to 2008, however, on average is about 70% compared to about 80% before 1997. Clutch fullness for old and very old shell females was high in 2006, declined in 2007, then was higher in 2009 (about 78% old shell and 60% very old).

The fraction of barren females in the 2003 and 2004 survey south of 58.5 $^{o}$ N latitude was generally higher than north of 58.5 $^{o}$ N latitude (Figures 51 and 52). In 2004 the fraction barren females south of 58.5 $^{o}$ N latitude was greater for all shell conditions. In 2003, the fraction barren was greater for new shell and very very old shell south of 58.5 $^{o}$ N latitude.

Laboratory analysis of female snow crab collected in waters colder than 1.5 $^{o}$ C from the Bering Sea have been determined to be biennial spawners in the Bering Sea. Future recruitment may be affected by the fraction of biennial spawning females in the population as well as the estimated fecundity of females, which may depend on water temperature.

An index of reproductive potential for crab stocks needs to be defined that includes spawning biomass, fecundity, fertilization rates and frequency of spawning. In most animals, spawning biomass is a sufficient index of reproductive potential because it addresses size related impacts on fecundity, and because the fertilization rates and frequency of spawning are relatively constant over time. This is not the case for snow crab.

The centroids of the cold pool (<2.0 $^{o}$ C) were estimated from the summer survey data for 1982 to 2006 (Figure 53). The centroid is the average latitude and average longitude. In the 1980's the cold pool was farther south(about 58 to 59 $^{o}$ N latitude) except for 1987 when the centroid shifted to north of 60 $^{o}$ N latitude. The cold pool moved north from about 58 $^{o}$ N latitude in 1999 to about 60.5 $^{o}$ N latitude in 2003. The cold pool was farthest south in 1989, 1999 and 1982 and farthest north in 1987, 1998, 2002 and 2003. In 2005 the cold pool was north, then in 2006 back to the south. The last three years (2007, 2008 and 2009) have all been cold years.

The clutch fullness and fraction of unmated females however, does not account for the fraction of females that may have unfertilized eggs. The fraction of barren females observed in the survey may not be an accurate measure of fertilization success because females may retain unfertilized eggs for months after extrusion. To examine this hypothesis, RACE personnel sampled mature females from the Bering Sea in winter and held them in tanks until their eggs hatched in March of the same year. All females then extruded a new clutch of eggs in the absence of males. All eggs were retained until the crabs were sacrificed near the end of August. Approximately 20% of the females had full clutches of unfertilized eggs. The unfertilized eggs could not be distinguished from fertilized eggs by visual inspection at the time they were sacrificed. Indices of fertilized females based on the visual inspection method of assessing clutch fullness and percent unmated females may overestimate fertilized females and not an accurate index of reproductive success.

McMullen and Yoshihara (1969) examined female red king crab around Kodiak Island in 1968 and found high percentages of females without eggs in areas of most intense fishing (up to 72%). Females that did not extrude eggs and mate were found to resorb their eggs in the ovaries over a period of several months. One trawl haul captured 651 post-molt females and nine male red king crab during the period April to May 1968. Seventy-six percent of the 651 females were not carrying eggs. Ten females were collected that were carrying eggs and had firm post-molt shells. The eggs were sampled 8 and 10 days after capture and were examined microscopically. All eggs examined were found to be infertile. This indicates that all ten females had extruded and held egg clutches without mating. Eggs of females sampled in October of 1968 appear to have been all fertile from a table of results in McMullen and Yoshihara(1969), however the results are not discussed in the text, so this is unclear. This may mean that extruded eggs that are unfertilized are lost between May and October.

# ANALYTIC APPROACH

## Model Structure

The model structure was developed following Fournier and Archibald's (1982) methods, with many similarities to Methot (1990). The model was implemented using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed for finding the objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

The model estimates the abundance by length bin and sex in the first year (1978) as parameters rather than estimating the recruitments previous to 1978. This results in 44 estimated parameters.

Recruitment is determined from the estimated mean recruitment, the yearly recruitment deviations and a gamma function that describes the proportion of recruits by length bin,

$$N_{t,1} = pr_l \, e^{R_0^l + \tau_t}$$

where,

$R_0^l$ Log Mean recruitment

$pr_l$ Proportion of recruits for each length bin

$\tau_t$ Recruitment deviations by year.

Recruitment is estimated equal for males and females in the model.

Crab were distributed into 5mm CW length bins based on a pre-molt to post-molt length transition matrix. For immature crab, the number of crabs in length bin *l* in year *t-1* that remain immature in year *t* is given by,

$$N_{t,l}^{s} = (1-\phi_l^s) \sum_{l=l_1}^{l'} \psi_{l',l}^{s} \, e^{-Z_{l'}^{s}} N_{t-1,l'}^{s}$$

| | |
|---|---|
| $\psi^{s}_{l',l}$ | growth transition matrix by sex, pre-molt and post-molt length bins which defined the fraction of crab of sex *s* and pre-molt length bin *l'*, that moved to length bin *l* after molting, |
| $N^{s}_{t,l}$ | abundance of immature crab in year *t*, sex *s* and length bin *l*, |
| $N^{s}_{t-1,l'}$ | abundance of immature crab in year *t-1*, sex s and length bin *l'*, |
| $Z^{s}_{l'}$ | total instantaneous mortality by sex *s* and length bin *l'*, |
| $\phi^{s}_{l}$ | fraction of immature crab that became mature for sex *s* and length bin *l*, |
| *l'* | pre-molt length bin, |
| *l* | post-molt length bin. |

Growth

Very little information exists on growth for Bering Sea snow crab. Tagging experiments were conducted on snow crab in 1980 with recoveries occurring in the Tanner crab (*Chionoecetes bairdi*) fishery in 1980 to 1982 (Mcbride 1982). All tagged crabs were males greater than 80mm CW and which were released in late May of 1980. Forty-nine tagged crabs were recovered in the Tanner crab fishery in the spring of 1981 of which only 5 had increased in carapace width. It is not known if the tags inhibited molting or resulted in mortality during molting, or the extent of tag retention. One crab was recovered after 15 days in the 1980 fishery, which apparently grew from 108 mm to 123 mm carapace width. One crab was recovered in 1982 after almost 2 years at sea that increased from 97 to 107 mm.

Growth data from 14 male crabs collected in March of 2003 that molted soon after being captured were used to estimate a linear function between premolt and postmolt width (Lou Rugolo unpublished data, Figure 54). The crabs were measured when shells were still soft because all died after molting, so measurements are probably underestimates of postmolt width (Rugolo, pers. com.). Growth appears to be greater than growth of some North Atlantic snow crab stocks (Sainte-Marie 1995). Growth from the 1980 tagging of snow crab was not used due to uncertainty about the effect of tagging on growth. No growth measurements exist for Bering Sea snow crab females. North Atlantic growth data indicate growth is slightly less for females than males.

Growth was modeled using a linear function to estimate the mean width after molting given the mean width before molting (Figure 55),

$$\text{Width}_{t+1} = a + b^{*}\ \text{width}_{t}$$

Where a = 6.773 , b = 1.16 , for males and a= 6.773 , b= 1.05 , for females.

The parameters a and b were estimated from the observed growth data for Bering Sea male snow crab. However, the intercept for both male and female crab was estimated as the average of the intercepts estimated for males from the Bering Sea data and the value assumed for females. Equal intercepts were used because growth of both sexes is probably equal at some small size.

The growth parameters are estimated in the model using the observed values as constraints, with standard errors estimated from Canadian growth data.

A new growth curve was estimated by Somerton (pers. Comm.) from snow crab males collected in 2011 combined with data from Rugolo(pers.Comm.) as a three parameter equation (Figure 55),

post-molt CW = -0.75 + 1.39 Premolt CW – 0.0015 * (Premolt CW)$^2$

Model 1 used the above growth curve with parameters as priors to estimate growth. Variance estimates were not available at the time of this assessment. A cv of 0.1 was assumed for each parameter in the likelihood equation.

Crab were assigned to 5mm width bins using a two-parameter gamma distribution with mean equal to the growth increment by sex and length bin and a beta parameter (which determines the variance),

$$\psi^{s}_{l',l} = \int_{l-2.5}^{l+2.5} gamma(l / \alpha_{s,l'}, \beta_s)$$

where,

$\alpha_{s,l'}$ expected growth interval for sex *s* and size *l'* divided by the shape parameter $\beta$,

$\psi^{s}_{l',l}$ growth transition matrix for sex, *s* and length bin *l'* (pre-molt size), and post-molt size *l*.

The Gamma distribution was,

$$gamma(l / \alpha_{s,l}, \beta_s) = \frac{l^{\alpha_{s,l}-1} e^{-\frac{l}{\beta_s}}}{\beta^{\alpha_{s,l}} \Gamma(\alpha_{s,l})}$$

where *l* is the length bin, $\beta$ for both males and females was set equal to 0.75, which was estimated from growth data on Bering Sea Tanner and King crab due to the small amount of growth data available for snow crab. The distribution was truncated at postmolt sizes greater 40mm above the premolt size due to problems in estimation of very small values in the growth transition matrix, and that crab would not be expected to have a larger molt increment than 40mm. There was no difference in the results of the model with the truncated growth matrix and without.

The probability of an immature crab becoming mature by size is applied to the post-molt size. Crab that mature and reach their terminal molt in year t then are mature new shell during their first year of maturity. The abundance of newly mature crab ($\Omega^{s}_{t,l}$) in year *t* is given by,

$$\Omega^{s}_{t,l} = \phi^{s}_{l} \sum_{L=l_1}^{l'} \psi^{s}_{l',l}\, e^{-Z^{s}_{l'}} N^{s}_{t-1,l'}$$

Crab that were mature SC2 in year *t-1* no longer molt and move to old shell mature crab (SC3+) in year *t* ($\Lambda^{s}_{t,l}$). Crab that are SC3+ in year *t-1* remained old shell mature for the rest of their lifespan. The total old shell mature abundance ($\Lambda^{s}_{t,l}$) in year *t* is the sum of old shell mature crab in year *t-1* plus previously new shell (SC2) mature crabs in year *t-1*,

$$\Lambda^{s}_{t,l} = e^{-Z^{s,old}_{l}} \Lambda^{s}_{t-1,l} + e^{-Z^{s,new}_{l}} \Omega^{s}_{t-1,l}$$

The fishery is prosecuted in early winter prior to growth in the spring. Crab that molted in year *t-1* remain as SC2 until after the spring molting season. Crab that molted to maturity in year *t-1* are SC2 through the fishery until the spring molting season after which they become old shell mature (SC3).

Mature male biomass (MMB) was calculated as the sum of all mature males at the time of mating multiplied by respective weight at length.

$$B_t = \sum_{L=1}^{lbins} (\Lambda^{males}_{tm,l} + \Omega^{males}_{tm,l})\, W^{males}_{l}$$

| | |
|---|---|
| *tm* | nominal time of mating after the fishery and before molting, |
| *lbins* | number of length bins in the model, |
| $\Lambda^{males}_{tm,l}$ | abundance of mature old shell males at time of mating in length bin *l*, |
| $\Omega^{males}_{tm,l}$ | abundance of mature new shell males at the time of mating in length bin *l*, |
| $W_1$ | mean weight of a male crab in length bin *l*. |

Catch of male snow crab was estimated as a pulse fishery 0.62 yr after the beginning of the assessment year (July 1),

$$catch = \sum_{l} (1 - e^{-(F * Sel_l + Ftrawl * TrawlSel_l)}) w_l N_l e^{-M * .62}$$

| | |
|---|---|
| F | Full selection fishing mortality determined from the control rule using biomass including implementation error |
| $Sel_{,l}$ | Fishery selectivity for length bin l for male crab |
| Ftrawl | Fishing mortality for trawl bycatch fixed at 0.01 (average F) |
| $TrawlSel_l$ | Trawl bycatch fishery selectivity by length bin l |
| $W_l$ | weight by length bin l |
| $N_l$ | Numbers by length for length bin l |
| M | Natural Mortality |

## Selectivity

The selectivity curve total catch, female discard and groundfish bycatch were estimated as two-parameter ascending logistic curves (Figure 56 and 67).

$$S_l = \frac{1}{1 + e^{-a(l-b)}}$$

The probability of retaining crabs by size with combined shell condition was estimated as an ascending logistic function. The selectivities for the retained catch were estimated by multiplying a two parameter logistic retention curve by the selectivities for the total catch.

$$S_{ret,l} = \frac{1}{1 + e^{-a(l-b)}} \frac{1}{1 + e^{-c_{ret}(l-d_{ret})}}$$

The selectivities for the survey were estimated with three-parameter (Q, L95% and L50%), ascending logistic functions (Survey selectivities in Figure 57).

$$\text{Selectivity}_l = \frac{Q}{1 + e^{\left\{\frac{-\ln(19)(l - l_{50\%})}{(l_{95\%} - l_{50\%})}\right\}}}$$

Separate survey selectivities were estimated for the period 1978 to 1981, 1982 to 1988, and 1989 to the present. Survey selectivities were estimated separately for males and females in the 1989 to present period. The maximum selectivity(Q) for each time period was estimated in the model for the Base Model. The separate selectivities were used due to the change in catchability in 1982 from the survey net change, and the addition of more survey stations to the north of the survey area after 1988. Survey selectivities have been estimated for Bering Sea snow crab from underbag trawl experiments (Somerton and Otto 1999). A bag underneath the regular trawl was used to catch animals that escaped under the footrope of the regular trawl, and was assumed to have selectivity equal to 1.0 for all sizes. The selectivity was estimated to be 50% at about 74 mm, 0.73 at 102 mm, and reached about 0.88 at the maximum size in the model of 135 mm.

## Likelihood Equations

Weighting values ($\lambda$) for each likelihood equation are shown in Table 11.

Catch biomass is assumed to have a normal distribution,

$$\lambda \sum_{t=1}^{T} \left[ C_{t, fishery, obs} - C_{t, fishery.pred} \right]^2$$

There are separate likelihood components for the retained and total catch.

The robust multinomial likelihood is used for length frequencies from the survey and the catch (retained and total) for the fraction of animals by sex in each 5mm length interval. The number of samples measured in each year is used to weight the likelihood. However, since thousands of crab are measured each year, the sample size was set at 200.

$$Length\,Likelihood = -\sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{t,l} \log(\hat{p}_{t,l} + o) - Offset$$

$$Offset = \sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{t,l} \log(p_{t,l})$$

Where, T is the number of years, $p_{t,l}$ is the proportion in length bin $l$, an $o$ is fixed at 0.001.

An additional length likelihood weight (2) is added to the first year survey length composition fit to facilitate the estimation of the initial abundance parameters. A smoothness constraint is also added to the numbers at length by sex in the first year,

$$\sum_{S=1}^{2} \sum_{l=1}^{L} (first\,differences(N_{1978,s,l}))^2$$

The survey biomass (including biomass in the 2009 and 2010 study areas) assumes a lognormal distribution with the inverse of the standard deviation of the log(biomass) in each year used as a weight,

The survey biomass assumes a lognormal distribution with the inverse of the standard deviation of the log(biomass) in each year used as a weight,

$$\lambda \sum_{t=1}^{ts} \left[ \frac{\log(SB_t) - \log(\hat{SB}_t)}{sqrt(2) * s.d.(\log(SB_t))} \right]^2$$

$$s.d.(\log(SB_t)) = sqrt(\log((cv(SB_t))^2 + 1))$$

Recruitment deviations likelihood equation is,

$$\lambda \sum_{s=1}^{2} \sum_{t=1}^{T} \tau_{s,t}^2$$

Smooth constraint on probability of maturing by sex and length

$$\sum_{S=1}^{2} \sum_{l=1}^{L} (\mathit{first\ differences}(\mathit{first\ differences}(PM_{s,l}))^2$$

Where $PM_{s,l}$ is a vector of parameters that define the probability of molting.

Fishery cpue in average number of crab per pot lift.

$$\sum_{t=1}^{tf} \left[ \frac{\log(CPUE_t) - \log(\hat{C}PUE_t)}{sqrt(2) * s.d.(\log(CPUE_t))} \right]^2$$

Penalties on Fishing mortalities.

Penalty on average F for males (low weight in later phases),

$$\lambda \sum_{t=1}^{T} (F_t - 1.15)^2$$

Fishing mortality deviations for males,

$$\lambda \sum_{s=1}^{2} \sum_{t=1}^{T} \varepsilon_{s,t}^2$$

Female bycatch fishing mortality penalty.

$$\lambda \sum_{t=1}^{T} (\varepsilon_{female,t})^2$$

Trawl bycatch fishing mortality penalty

$$\lambda \sum_{t=1}^{T} (\varepsilon_{trawl,t})^2$$

Male natural mortality, when estimated in the model uses a penalty which assumes a normal distribution. A 95% CI of +/- 1.7 yrs translates to a 95% CI in M of about +-0.025 using an exponential model, which is a CV= 0.054.

$$0.5(\frac{M-0.23}{0.0125})^2$$

No penalty was used when immature M was estimate.
Growth parameters were estimated in the model using a penalty which assumes a normal distribution,

$$0.5(\frac{a-6.773}{0.3})^2$$

Where a is the intercept parameter of the linear growth equation and is the same for males and females.

Likelihood equations for the slope parameters assumed sd=0.1 for both males (bm)and females (bf).

$$0.5(\frac{bm-1.16}{0.1})^2$$

$$0.5(\frac{bf-1.05}{0.1})^2$$

Likelihood equations for Model 1 with the new growth curve, where post-molt CW = a + b Premolt CW – c * (Premolt CW)$^2$ , assumed a cv=0.1 for each parameter.

$$0.5(\frac{a-(-0.75)}{0.075})^2$$

$$0.5(\frac{b-1.39}{0.139})^2$$

$$0.5\left(\frac{c-0.0015}{0.00015}\right)^2$$

There were a total of 329 parameters estimated in the Base model (Table 10) for the 35 years of data (1978-2012). The 99 fishing mortality parameters (one set for the male catch, one set for the female discard catch, and one set for the trawl fishery bycatch) estimated in the model were constrained so that the estimated catch fit the observed catch closely. There were 35 recruitment parameters estimated in the model, one for the mean recruitment, 34 for each year from 1979 to 2012 (male and female recruitment were fixed to be equal). There were 8 fishery selectivity parameters that did not change over time. Survey selectivity was estimated for three different periods resulting in 9 parameters for males and 9 parameters for females. There were 6 survey selectivity parameters estimated for the study area for BSFRF female logistic availability curves for 2009 and 2010. 22 parameters for each year (2009 and 2010) for male crab were estimated for the smooth availability curve for the BSFRF net. Two parameters for natural mortality and 3 growth parameters were also estimated in the Base model. Model 1 estimated 3 growth parameters for the male curve and 2 parameters for the female curve.

Molting probabilities for mature males and females were fixed at 0, i.e., growth ceases at maturity which is consistent with the terminal molt paradigm (Rugolo et al. 2005 and Tamone et al. 2005). Molting probabilities were fixed at 1.0 for immature females and males. The intercept and slope of the linear growth function of postmolt relative to premolt size were estimated in the model (3 parameters, Table 10). A gamma distribution was used in the growth transition matrix with the beta parameters fixed at 0.75 for male and females.

The model separates crabs into mature, immature, new shell and old shell, and male and female for the population dynamics. The model estimate of survey mature biomass is fit to the observed survey mature biomass time series by sex. The model fits the size frequencies of the survey by immature and mature separately for each sex. The probability of immature crab maturing was estimated in the model using 22 parameters for each sex with a second difference smooth constraint (44 total parameters). The model fits the size frequencies for the pot fishery catch by new and old shell and by sex.

Crabs 25 mm CW (carapace width) and larger were included in the model, divided into 22 size bins of 5 mm each, from 25-29 mm to a plus group at 130-135mm. In this report the term size as well as length will be considered synonymous with CW. Recruits were distributed in the first few size bins using a two parameter gamma distribution with the parameters estimated in the model. The alpha parameter of the distribution was fixed at 11.5 and the beta parameter was fixed at 4.0. Seventy parameters were estimated for the initial population size composition of new and old shell males and females in 1978. No spawner-recruit relationship was used in the population dynamics part of the model. Recruitments for each year were estimated in the model to fit the data.

The NMFS trawl survey occurs in summer each year, generally in June-July. In the model, the time of the survey is considered to be the start of the year (July), rather than January. The modern directed snow crab pot fishery has occurred generally in the winter months (January to February) over a short period of time. In contrast, in the early years the fishery occurred over a longer time period. The mean time of the fishery was estimated from the weighted distribution of catch by day for each year. The fishing mortality was applied all at once at the mean time for that year. Natural mortality is applied to the population from the time the survey occurs until the fishery occurs, then catch is removed. After the fishery occurs, growth and recruitment take place (in spring), with the remainder of the natural mortality through the end of the year as defined above.

## Discard mortality

Discard mortality was assumed to be 50% for this assessment. The fishery for snow crabs occurs in winter when low temperatures and wind may result in freezing of crabs on deck before they are returned to the sea. Short term mortality may occur due to exposure, which has been demonstrated in laboratory experiments by Zhou and Kruse (1998) and Shirley (1998), where 100% mortality occurred under temperature and wind conditions that may occur in the fishery. Even if damage did not result in short term mortality, immature crabs that are discarded may experience mortality during molting some time later in their life.

## Model Scenarios

The CPT and SSC in 2010 and 2011 recommended the use of the BSFRF 2009 and 2010 survey data as an additional survey in the assessment model to inform estimates of survey selectivity.

The current models and the September 2011 assessment estimated natural mortality for immature crab (male and female as 1 parameter), mature male crab and growth parameters for male and female crab. Survey selectivities for the BSFRF and NMFS data in the study area are also estimated separately for males and females.

Following the recommendation of the CPT and SSC in 2011, abundance estimates by length as well as survey biomass for the study area for the BSFRF tows as well as the NMFS tows were included in the September 2011 stock assessment model and the current assessment as an additional survey. Likelihood equations were added to the model for fits to the length frequency by sex for the BSFRF tows in the study area and the NMFS tows in the study area. A likelihood equation was also added for fit to the mature biomass by sex in the study area for the BSFRF tows and NMFS tows separately.

The formulation used in this assessment (and the September 2011 assessment) was recommended by the February 2011 Crab Modeling Workshop,

$$\widetilde{C}_l^s = N_l \, Q_{BSFRF}^s A_l S_l Q_{NMFS}^n$$

$\widetilde{C}_l^s =$ numbers by length for NMFS in study area

$A_l$ = 2 parameter logistic function of availability in the study area for the BSFRF net

$S_l$ = 2 parameter logistic function for the entire Bering Sea for the NMFS net

$Q^s_{BSFRF}$ = Q for study area (s) for the BSFRF net

$Q^n_{NMFS}$ = Q for the entire Berring Sea NMFS net

$N_l$ = population abundance by length

All Bering Sea male survey selectivity was estimated as a 3 parameter logistic function,

$$\text{Selectivity}_l = \frac{Q}{1+e^{\left\{\frac{-\ln(19)(l-l_{50\%})}{(l_{95\%}-l_{50\%})}\right\}}}$$

The BSFRF availability was estimated as a smooth function (23 parameters, 1 parameter for each length bin(22),

$$A_l = \exp(p_l); \qquad p_l \le 0.$$

A second difference constraint was added to the likelihood with a weight of 5.0,

$$5.0 \sum_{l=1}^{L} (\mathit{first\ differences}(\mathit{first\ differences}(p_l)))^2 \quad .$$

The maximum survey selectivity (Q) estimated for the entire Bering Sea area in Somerton et al. 2010 was estimated at 0.76 at 140 mm. The maximum size bin in the model is 130-135, which for the Somerton curve has a maximum selectivity of 0.75.

A second model scenario that incorporates the new growth data and growth curve estimated by Somerton is included as Model 1. Tis model estimates the three growth parameters for males with an assumed prior using a cv = 0.1 for each parameter. Variance estimates for the growth parameters are not available at this time.

## Projection Model Structure

Variability in recruitment, as well as implementation error, was simulated with temporal autocorrelation. Recruitment was generated from a Beverton-Holt stock-recruitment model,

$$R_t = \frac{0.8\,h\,R_0\,B_t}{0.2\;spr_{F=0}\;R_0(1-h)+(h-0.2)B_t}\;e^{\varepsilon_t-\sigma_R^2/2}$$

| | |
|---|---|
| $spr_{F=0}$ | mature male biomass per recruit fishing at F=0. $B_0 = spr_{F=0}\;R_0$, |
| $B_t$ | mature male biomass at time t, |
| $h$ | steepness of the stock-recruitment curve defined as the fraction of $R_0$ at 20% of $B_0$, |
| $R_0$ | recruitment when fishing at F=0, |
| $\sigma_R^2$ | variance for recruitment deviations, estimated at 0.74 from the assessment model. |

The temporal autocorrelation error ($\varepsilon_t$) was estimated as,

$$\varepsilon_t = \rho_R\varepsilon_{t-1} + \sqrt{1+\rho_R^2}\;\;\eta_t \qquad where\;\eta_t \sim N(0;\sigma_R^2) \tag{2}$$

| | |
|---|---|
| $\rho_R$ | temporal autocorrelation coefficient for recruitment, set at 0.6. |

Recruitment variability and autocorrelation were estimated using recruitment estimates from the stock assessment model. Steepness (h) and $R_0$ were estimated by setting Bmsy and Fmsy equal to B35% and F35% using a Beverton and Holt spawner recruit curve.

Implementation error was modeled as a lognormal autocorrelated error on the mature male biomass used to determine the fishing mortality rate in the harvest control rule,

$$B_t^{'} = B_t\,e^{\phi_t-\sigma_I^2/2}\;;\;\;\phi_t = \rho_I\phi_{t-1} + \sqrt{1+\rho_I^2}\;\;\varphi_t \qquad where\;\varphi_t \sim N(0;\sigma_I^2)$$

| | |
|---|---|
| $B_t^{'}$ | mature male biomass in year t with implementation error input to the harvest control rule, |
| $B_t$ | mature male biomass in year t, |
| $\rho_I$ | temporal autocorrelation for implementation error, set at 0.6 (estimated from the recruitment time series), |
| $\sigma_I$ | standard deviation of $\varphi$ which determines the magnitude of the implementation error. |

Implementation error was set at a fixed value (e.g., 0.2) plus the s.d. on log scale from the assessment model for mature male biomass. Implementation error in mature male biomass resulted in fishing mortality values applied to the population that were either higher or lower than the values without implementation error. The autocorrelation was assumed to be the same value as that estimated for recruitment. Implementation autocorrelation was used to more closely approximate the process of estimating a biomass time series from within a stock assessment model. The variability in biomass of the simulated population resulted from the variability in recruitment and variability in full selection F arising from implementation error on biomass. The population dynamics equations were identical to those presented for the assessment model in the model structure section of this assessment.

# RESULTS

The Base model estimated immature M at 0.329 and mature male M at 0.273. The September 2011 assessment (model 6) estimated immature M at 0.319 and mature male M at 0.299. Changes in model results are due to the additional survey and fishery data for 2011/12.

The total mature biomass increased from about 390,600 t in 1978 to the peak biomass of 954,700 t in 1990 for the Base model(Table 6). Table 6a contains model predicted survey biomass and numbers. Biomass declined after 1997 to about 351,100 t in 2003. Total mature biomass increased to 514,500 t in 2012 (Table 6 and Figure 4). The model results are informed by the population dynamics structure, including natural mortality, the growth and selectivity parameters and the fishery catches. The low observed survey abundance in the mid-1980's were followed by an abrupt increase in the survey abundance of crab in 1987, which followed through the population and resulted in the highest catches recorded in the early 1990's.

Average discard catch mortality for 1978 to 2008 was estimated to be about 16.7% of the retained catch (with 50% mortality applied), similar to the average observed discards from 1992 to 2008 (15.5%) (Tables 1 and 2, and Figure 58). Parameter estimates are listed in Table 10. Estimates of observed discard mortality ranged from 6% of the retained catch to 32% of the retained catch (assuming 50% discard mortality). Discard mortality has declined over the last three years from 12.9% in 2008/09 to 9.4% in 2009/10 and 4.2% in 2010/11.

The model fit to the total directed male catch, groundfish bycatch, male discard catch and female discard catch are shown in Figures 58, 59, 60, and 61 respectively.

Mature male and female biomass show similar trends (Table 3 and Table 6, Figures 62 and 64). Model estimates of mature male biomass increased from 169,200 t in 2003 to 279,600 t in 2009, and then declined to 268,300 t in 2012. Observed survey mature male biomass increased from 157,300 t in 2010 to 167,400 t in 2011, then declined to 120,800 t in 2012. Model estimates of mature female biomass have an increasing trend from 180,700 t in 2009 to 220,100 t in 2011 and 268,300 t in 2012. Mature female biomass observed from the survey increased from 145,100 t in 2010 to 280,000 t in 2011 then declined to 220,600 t in 2012.

Fishery selectivities and retention curves were estimated using ascending logistic curves (Figures 56 and 66). Selectivities for trawl bycatch were estimated as ascending logistic curves (Figure 67). Plots of model fits to the survey size frequency data are presented in Figures 68 and 70 by sex for shell conditions combined with residual plots in Figures 69 and 71. A summary of the fit across all years for male and female length frequency data indicates a very good fit overall (Figure 72). The model is not fit to crab by shell condition due to the inaccuracy of shell condition as a measure of shell age. Tagging results presented earlier indicate that the number of animals that are more than one year from molting may be underestimated by using shell condition as a proxy for shell age. However, an accurate measure of shell age is needed to improve the estimation of the composition of the catch that is extracted from the stock.

Differences between the observed and predicted survey length frequencies could be a result of spatial differences in growth due to temperature, or size at maturity. These would need to be investigated using a spatial model. Changing growth or maturity over time simply to fit the length frequency data was not recommended by the 2008 CIE reviewers. There also could be changes in survey catchability by area or between years that could contribute to any lack of fit to the observed survey length frequency data.

The September 2011 assessment survey Q for the 1989 to present period was estimated at 0.58 for male crab (Turnock and Rugolo 2011). The Base model estimate for survey Q was 0.59. The maximum survey selectivity estimated using the 2009 study area by Somerton (2010) was 0.76 at 140 mm for male crab (Figure 90The survey selectivity curves estimated for the base model are shown in Figure 57. Immature M was estimated at 0.329 (2011 assessment 0.319) and mature male M 0.273 (2011 assessment 0.299). Mature female M was fixed at 0.23. ). The survey Q for male crab, 1989 to present, depends on the estimation of natural mortality (Figure 107). Q declines from about 0.70 at M=0.23 to 0.58 at M=0.30.

The estimated number of males > 101mm generally follows the observed survey abundance estimates (Figure 73). Observed survey Males >101mm increased from 137.6 million crab in 2010 to 150.7 million crab in 2011, then declined to 87.0 million in 2012 (Table 3). Model estimates of large males show a decreasing trend from 262.2 million in 2009 to 203.3 million in 2012.

Several periods of above average recruitment were estimated by the model, in 1979 to 1983, 1987 and 2004 (fertilization year, Figure 74). Recruits are 25mm to about 40 mm and may be about 4 years from hatching, 5 years from fertilization (Figure 75, although age is approximated). Lower than average recruitments were estimated from 1988 to 1997, 2000 to 2003, 2006-2007. The 1998-1999 and 2004 and 2005 year classes appear to be near or above average recruitment and have resulted in an increase in biomass in recent years.
The size at 50% selected for the pot fishery for total catch (retained plus discarded) was 106.2 mm for males (shell condition combined, Figure 56). The size at 50% selected for the retained catch was about 106 mm. The fishery generally targets and retains new shell animals > 101mm with clean hard shells and all legs intact. The fits to the fishery size frequencies are in Figures 76 through 81. Fits to the trawl fishery bycatch size frequency data are in Figures 82 through 84.

Fishing mortality rates ranged from 0.14 to 2.65 (Figure 85 and Table 6). Fishing mortality rates ranged from 0.64 to 2.65, for the 1986/87 to 1998/99 fishery seasons. For the period after the snow crab stock was declared overfished (1999/2000 to 20010/11), full selection fishing mortality ranged from 0.22 to 0.54. Fishing mortality rate increased from 0.29 in 2010/11 to 0.64 in 2011/12 due to the increase in TAC.

Base Model estimates of mature male biomass at mating decreased from 198,800 t in 2010/11 to 165,200 t in 2011/12 (107% of B35% (154,669 t), Figure 87).

Likelihood values for the Base model and Model 1 with the new growth function are shown in Table 13. Model 1 has two more parameters than the Base model, however, the total likelihood increased to 3749.6 for Model 1 from 3588.3 for the Base model. Fits to length data, catch data and survey biomass were worse for Model 1 relative to the Base model. Survey selectivity curves estimated for the Base model are shown in Figures 90 to 97. Base Model fits to the length frequency in the 2009 and 2010 study areas are shown in Figure 98. Base Model fits to the mature biomass in the 2009 and 2010 study areas are shown in Figures 99 and 100.

The history of fishing mortality and MMB at mating with the F35% control rule for the Base model estimates the 2011/12 F to be below the overfishing level and MMB at mating just above B35%(Figure 101).

## Harvest Strategy and Projected Catch

### Rebuilding Harvest Strategy

The harvest strategy described here was developed as the rebuilding strategy adopted in December 2000 in Amendment 14 and first applied in the 2000/01 fishing season (NPFMC 2000). Harvest strategy simulations are reported by Zheng et al. (2002) based on a model with structure and parameter values different than the model presented here. The harvest strategy by Zheng et al. (2002) was developed for use with survey biomass estimates. Prior to the passage of Amendment 24, Bmsy was defined as the average total mature survey biomass for 1983 to 1997. MSST was defined as ½ Bmsy. The harvest strategy consists of a threshold for opening the fishery (104,508 t (230.4 million lbs) of total mature biomass (TMB), 0.25*Bmsy), a minimum GHL of 6,804 t (15 million lbs) for opening the fishery, and rules for computing the GHL.

This exploitation rate is based on total survey mature biomass (TMB) which decreases below maximum E when TMB < average 1983-97 TMB calculated from the survey.

$$E = \begin{cases} Bycatch\ only, Directed\ E = 0, & if\ \dfrac{TMB}{averageTMB} < 0.25 \\ \dfrac{0.225 * \left[\dfrac{TMB}{averageTMB} - \alpha\right]}{(1-\alpha)} & if\ 0.25 < \dfrac{TMB}{averageTMB} < 1 \\ 0.225 & if\ TMB \geq averageTMB \end{cases} \quad (13)$$

Where, $\alpha$ = -0.35 and averageTMB = 418,030 t (921.6 million lbs).

The maximum target for the retained catch is determined by using E as a multiplier on survey mature male biomass (MMB),

Retained Catch = E * MMB.

There is a 58% maximum harvest rate on exploited legal male abundance. Exploited legal male abundance is defined as the estimated abundance of all new shell males >=102 mm CW plus a percentage of the estimated abundance of old shell males >= 102 mm CW. The percentage to be used is determined using fishery selectivities for old shell males.

**Overfishing Control Rule**

Amendment 24 to the FMP introduced revised the definitions for overfishing. The information provided in this assessment is sufficient to estimate overfishing based on Tier 3b. The overfishing control rule for tier 3b is based on spawning biomass per recruit reference points (NPFMC 2007) (Figure 101).

$$F = \begin{cases} Bycatch\ only,\ Directed\ F = 0, & if\ \dfrac{B_t}{B_{REF}} \le \beta \\[2ex] \dfrac{F_{REF}\left[\dfrac{B_t}{B_{REF}} - \alpha\right]}{(1-\alpha)} & if\ \beta < \dfrac{B_t}{B_{REF}} < 1 \\[2ex] F_{REF} & if\ B_t \ge B_{REF} \end{cases} \qquad (12)$$

$B_t$ mature male biomass at time of mating in year t,

$B_{REF}$ mature male biomass at time of mating resulting from fishing at $F_{REF}$,

$F_{REF}$ $F_{MSY}$ or the fishing mortality that reduces mature male biomass at the time of mating-per-recruit to x% of its unfished level,

$\alpha$ fraction of $B_{REF}$ where the harvest control rule intersects the x-axis if extended below $\beta$, β fraction of $B_{REF}$ below which directed fishing mortality is 0.

B35% was estimated using average recruitment from1978 to 2012 and mature male biomass per recruit fishing at F35%.

The natural log of recruits/MMB at mating (5 yr lag for recruitment) indicates productivity of the Bering sea snow crab stock is currently not different from earlier levels (Figure 102).

Biomass and catch projections based on $F_{REF} = F_{35\%}$ and $B_{REF} = B_{35\%}$ were used to estimate the catch OFL and the ACL (Tables 9a and 9b). The OFL was estimated as the median of the distribution of OFLs from the stochastic projection model described earlier. The OFL for the Base model in 2012/13 was estimated at 67,800 t of total catch (48,100 t retained catch). The average catch from 1978/79 to 1998/99 was 70,348 t, and was 19,975 t during the rebuilding period 1999/2000 to 2010/11.

The ACL was estimated at 67,610 t, based on a probability of overfishing of 49% from the projection model with a cv= 0.08 on 2011/12 biomass estimated from the Hessian matrix by the ADMB software and the median of the projected distribution of catch fishing at F35% as the estimate of OFL (Table 9a). The SSC in 2011 recommended an ACL of 90% of the OFL (66,150 t) for the 2011/12 fishing season. 90% of the 2012/13 Base Model OFL is 60,849 t of total catch.

F35% in the September 2011 assessment was estimated at 1.42 and B35% at 147,500 t. F35% for the Base model was 1.32 and B35% 154,669 t.

The OFL for 2012/13 for Model 1 (new growth) was 51,600 t (90% of OFL 46,440 t) (Table 14). The MMB at mating projected for 2012/12 when fishing at the F35% control rule (OFL) was 86% of B35%. B35% was estimated at 138,960 t and F35% at 1.127. Growth estimates were lower for larger male crab than the curve estimated from the 2011 growth study (Figure 103). Fits to biomass data for Model 1 are shown in Figures 104 – 106.

The total catch, including all bycatch of both sexes, using the control rule is estimated by the following equation,

$$catch = \sum_{s} \sum_{l} (1 - e^{-(F*Sel_{s,l} + F_{trawl}*Sel_{Trawl,l})}) w_{s,l} N_{s,l}\ e^{-M_s*.62}$$

Where $N_{S,l}$ is the current year numbers at length(l) and sex at the time of the survey estimated from the population dynamics model, $M_s$ is natural mortality by sex, 0.625 is the time elapsed (in years) from when the survey occurs to the fishery, F is the value estimated from the harvest control rule using the current year mature male biomass projected forward to the time of mating time (Feb. 15), and $w_{s,l}$ is weight at length by sex. $Sel_{s,l}$ are the fishery selectivities by length and sex for the total catch (retained plus discard) estimated from the population dynamics model (Figure 56).

Projections were run for the Base model fishing at the F35% control rule and fishing at a catch of 90% of the OFL (the SSC recommended ACL method in 2011/12). Steepness of the Beverton and Holt spawner recruit curve used in projections was estimated at 0.759 and $R_0$ at 1.52 billion crab, by equating F35% with Fmsy and B35% with Bmsy

The rebuilding strategy implemented in 2000/01 was developed for use with observed survey data and includes reference points based on observed survey data, not based on the current assessment model.

Median MMB at mating was projected to decline in 2011/12 based on projections from the September 2011 assessment (Turnock and Rugolo 2011). Projections using the Base model estimate MMB at mating to decline to about 94% of B35% in 2012/12 fishing at the OFL and 98% of B35% fishing at 90% OFL (Tables 9a and 9b).

### Conservation concerns

- Estimation of natural mortality in the model at values higher than estimates based on current knowledge of snow crab age could be risk prone. Aging methods need to be developed to improve estimation of natural mortality.
- Exploitation rates in the southern portion of the range of snow crab may have been higher than target rates, possibly contributing to the shift in distribution to less productive waters in the north.

### Data Gaps and Research Needs

Research is needed to improve our knowledge of snow crab life history and population dynamics to reduce uncertainty in the estimation of current stock size, stock status and optimum harvest rates.

Tagging programs need to be initiated to estimate longevity and migrations. Studies and analyses are needed to estimate natural mortality.

A method of verifying shell age is needed for all crab species. A study was conducted using lipofuscin to age crabs, however verification of the method is needed. Radiometric aging of shells of mature crabs is costly and time consuming. Aging methods will provide information to assess the accuracy of assumed ages from assigned shell conditions (i.e. new, old, very old, etc), which have not been verified, except with the 21 radiometric ages reported here from Orensanz (unpub data).

Techniques for determining which males are effective at mating and how many females they can successfully mate with in a mating season are needed to estimate population dynamics and optimum harvest rates. At the present time it is assumed that when males reach morphometric maturity they stop growing and they are effective at mating. Field studies are needed to determine how morphometric maturity corresponds to male effectiveness in mating. In addition the uncertainty associated with the determination of morphometric maturity (the measurement of chelae height and the discriminate analysis to separate crabs into mature and immature) needs to be analyzed and incorporated into the determination of the maturity by length for male snow crab.

Female opilio in waters less than 1.5 $^{o}$ C and colder have been determined to be biennial spawners in the Bering Sea. Future recruitment may be affected by the fraction of biennial spawning females in the population as well as the estimated fecundity of females, which may depend on water temperature.

A female reproductive index needs to be developed that incorporates males, mating ratios, fecundity, sperm reserves, biennial spawning and spatial aspects.

Analysis needs to be conducted to determine a method of accounting for the spatial distribution of the catch and abundance in computing quotas.

A full management strategy evaluation of the snow crab model has been funded by NPRB for the period 2008-2011.

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Table 1. Catch (1,000 t) for the snow crab pot fishery and groundfish trawl bycatch. Retained catch for 1973 to 1981 contain Japanese directed fishing. Observed discarded catch is the total estimate of discards before applying mortality. Discards from 1992 to 2011/12 were estimated from observer data.

| Year fishery occurred | Retained catch (1000 t) | Observed Discard male catch (no mort. applied) (1000 t) | Observed Retained + discard male catch(no mort. Applied) (1000 t) | Year of trawl bycatch | Observed trawl bycatch(no mort. Applied) (1000 t) | GHL(retained catch only) (1000 t) | OFL (2008/9 first year of total catch OFL) (1000 t) |
|---|---|---|---|---|---|---|---|
| 1973/74 | 3.04 | | | 1973 | 13.63 | | |
| 1974/75 | 2.28 | | | 1974 | 18.87 | | |
| 1975/76 | 3.74 | | | 1975 | 7.30 | | |
| 1976/77 | 4.56 | | | 1976 | 3.16 | | |
| 1977/78 | 7.39 | | | 1977 | 2.14 | | |
| 1978/79 | 23.72 | | | 1978 | 2.46 | | |
| 1979/80 | 34.04 | | | 1979 | 1.98 | | |
| 1980/81 | 30.37 | | | 1980 | 1.44 | 17.9-41.3 | |
| 1981/82 | 13.32 | | | 1981 | 0.60 | 7.3-10.0 | |
| 1982/83 | 11.85 | | | 1982 | 0.24 | 7.17 | |
| 1983/84 | 12.17 | | | 1983 | 0.31 | 22.23 | |
| 1984/85 | 29.95 | | | 1984 | 0.33 | 44.46 | |
| 1985/86 | 44.46 | | | 1985 | 0.29 | 25.86 | |
| 1986/87 | 46.24 | | | 1986 | 1.23 | 25.59 | |
| 1987/88 | 61.41 | | | 1987 | 0.00 | 50.23 | |
| 1988/89 | 67.81 | | | 1988 | 0.44 | 59.89 | |
| 1989/90 | 73.42 | | | 1989 | 0.51 | 63.43 | |
| 1990/91 | 149.11 | | | 1990 | 0.39 | 142.92 | |
| 1991/92 | 143.06 | 43.65 | 186.71 | 1991 | 1.95 | 151.09 | |
| 1992/93 | 104.71 | 56.65 | 161.37 | 1992 | 1.84 | 94.01 | |
| 1993/94 | 67.96 | 17.66 | 85.62 | 1993 | 1.81 | 48.00 | |
| 1994/95 | 34.14 | 13.36 | 47.50 | 1994 | 3.55 | 25.27 | |
| 1995/96 | 29.82 | 19.10 | 48.92 | 1995 | 1.35 | 23.00 | |
| 1996/97 | 54.24 | 24.68 | 78.92 | 1996 | 0.93 | 53.09 | |
| 1997/98 | 110.41 | 19.05 | 129.46 | 1997 | 1.50 | 102.50 | |
| 1998/99 | 88.02 | 15.50 | 103.52 | 1998 | 1.02 | 84.48 | |
| 1999/00 | 15.20 | 1.72 | 16.92 | 1999 | 0.61 | 12.93 | |
| 2000/01 | 11.46 | 2.06 | 13.52 | 2000 | 0.53 | 12.39 | |
| 2001/02 | 14.85 | 6.27 | 21.12 | 2001 | 0.39 | 13.97 | |
| 2002/03 | 12.84 | 4.51 | 17.35 | 2002 | 0.23 | 11.62 | |
| 2003/04 | 10.86 | 1.90 | 12.77 | 2003 | 0.76 | 9.44 | |
| 2004/05 | 11.29 | 1.69 | 12.98 | 2004 | 0.96 | 9.48 | |
| 2005/06 | 16.78 | 4.52 | 21.30 | 2005 | 0.37 | 16.74 | |
| 2006/07 | 16.50 | 5.90 | 22.39 | 2006 | 0.84 | 16.42 | |
| 2007/08 | 28.60 | 8.42 | 37.02 | 2007 | 0.44 | 28.58 | |
| 2008/09 | 26.56 | 6.86 | 33.42 | 2008 | 0.30 | 26.59 | 35.07 |
| 2009/10 | 21.82 | 4.09 | 25.91 | 2009 | 0.68 | 21.80 | 33.10 |
| 2010/11 | 24.67 | 2.05 | 26.72 | 2010 | 0.19 | 24.62 | 44.40 |
| 2011/12 | 40.3 | 5.21 | 45.51 | 2011 | 0.17 | | 73.5 |

Table 2. Base model estimates of catch (1,000 t) for Bering Sea snow crab. Model estimates of pot fishery discards include 50% mortality and groundfish discard 80% mortality.

| Year | Model estimate of male retained (1000 t) | Model estimate of male discard(50% mort) (1000 t) | Model estimate Discard female catch (1000 t) | Model estimate groundfish bycatch(0.8 mort., 1000 t) | Model estimate total directed male catch (1000 t) | Model estimate total catch (1000 t) |
|---|---|---|---|---|---|---|
| 1978/79 | 23.8 | 1.8 | 0.1 | 3.8 | 25.6 | 29.4 |
| 1979/80 | 34.1 | 3.1 | 0.1 | 3 | 37.2 | 40.3 |
| 1980/81 | 30.5 | 7 | 0.1 | 2.1 | 37.4 | 39.7 |
| 1981/82 | 13.4 | 6.7 | 0.1 | 0.7 | 20.1 | 20.8 |
| 1982/83 | 11.9 | 3.3 | 0.1 | 0.2 | 15.2 | 15.5 |
| 1983/84 | 12.2 | 1.4 | 0.1 | 0.4 | 13.6 | 14.1 |
| 1984/85 | 30 | 2.5 | 0.1 | 0.4 | 32.5 | 33 |
| 1985/86 | 44.5 | 3.4 | 0.1 | 0.4 | 48 | 48.4 |
| 1986/87 | 46.3 | 4.5 | 0.1 | 1.8 | 50.8 | 52.7 |
| 1987/88 | 61.5 | 11 | 0.1 | 0.2 | 72.6 | 72.8 |
| 1988/89 | 67.9 | 16.4 | 0.1 | 0.6 | 84.3 | 85 |
| 1989/90 | 73.6 | 16.7 | 0.1 | 0.7 | 90.3 | 91.2 |
| 1990/91 | 149.4 | 29.8 | 0.2 | 0.6 | 179.2 | 179.9 |
| 1991/92 | 143.3 | 33.7 | 0.2 | 1.9 | 177 | 179 |
| 1992/93 | 105 | 28 | 0.3 | 1.7 | 133 | 135 |
| 1993/94 | 67.9 | 9.9 | 0.2 | 1.7 | 77.8 | 79.7 |
| 1994/95 | 34.3 | 6.4 | 0.2 | 3.5 | 40.7 | 44.3 |
| 1995/96 | 29.8 | 9.9 | 0.1 | 1.2 | 39.7 | 41 |
| 1996/97 | 54.7 | 10.6 | 0.2 | 0.8 | 65.3 | 66.3 |
| 1997/98 | 114.4 | 11.3 | 0.1 | 1.4 | 125.7 | 127.2 |
| 1998/99 | 88.3 | 7.9 | 0.1 | 0.9 | 96.2 | 97.2 |
| 1999/00 | 15.1 | 1.3 | 0 | 0.4 | 16.4 | 16.9 |
| 2000/01 | 11.5 | 1 | 0 | 0.3 | 12.5 | 12.9 |
| 2001/02 | 15 | 1.8 | 0 | 0.2 | 16.9 | 17.1 |
| 2002/03 | 13 | 1.9 | 0 | 0.2 | 14.9 | 15.1 |
| 2003/04 | 10.9 | 1.2 | 0 | 0.5 | 12 | 12.6 |
| 2004/05 | 11.3 | 0.9 | 0 | 0.8 | 12.2 | 13 |
| 2005/06 | 16.9 | 1.6 | 0 | 0.2 | 18.5 | 18.7 |
| 2006/07 | 16.6 | 2.3 | 0 | 0.6 | 19 | 19.6 |
| 2007/08 | 28.6 | 4.5 | 0.1 | 0.3 | 33.1 | 33.4 |
| 2008/09 | 26.6 | 3.1 | 0 | 0.2 | 29.8 | 30.1 |
| 2009/10 | 21.8 | 1.8 | 0 | 0.5 | 23.6 | 24.2 |
| 2010/11 | 24.6 | 1.8 | 0 | 0.2 | 26.4 | 26.6 |
| 2011/12 | 40.5 | 3.5 | 0.5 | 0.2 | 44 | 44.6 |

Table 3. Observed survey female, male and total spawning biomass(1000t) and numbers of males > 101mm (millions of crab).

| Year | Observed survey female mature biomass | CV female mature biomass | Observed survey male mature biomass | CV male mature biomass | Observed survey total mature biomass | Observed number of males > 101mm (millions) |
|---|---|---|---|---|---|---|
| 1978/79 | 153 | 0.2 | 193.1 | 0.12 | 346.2 | 163.4 |
| 1979/80 | 323.7 | 0.2 | 240.3 | 0.12 | 564.1 | 169.1 |
| 1980/81 | 364.9 | 0.2 | 193.8 | 0.12 | 558.7 | 133.9 |
| 1981/82 | 195.9 | 0.2 | 107.7 | 0.12 | 303.6 | 40.7 |
| 1982/83 | 213.3 | 0.2 | 173.1 | 0.12 | 386.4 | 60.9 |
| 1983/84 | 125.4 | 0.2 | 146 | 0.12 | 271.5 | 65.2 |
| 1984/85 | 70.4 | 0.4 | 161.2 | 0.24 | 231.5 | 139.9 |
| 1985/86 | 12.5 | 0.4 | 69.6 | 0.24 | 82.1 | 71.5 |
| 1986/87 | 47.7 | 0.4 | 87.3 | 0.24 | 135.1 | 77.1 |
| 1987/88 | 294.7 | 0.2 | 192.1 | 0.12 | 486.8 | 130.5 |
| 1988/89 | 276.9 | 0.125 | 251.6 | 0.12 | 528.5 | 170.2 |
| 1989/90 | 427.3 | 0.32 | 299.1 | 0.095 | 726.4 | 162.4 |
| 1990/91 | 312.1 | 0.185 | 442.4 | 0.105 | 754.5 | 389.6 |
| 1991/92 | 379.2 | 0.19 | 430.5 | 0.145 | 809.6 | 418.8 |
| 1992/93 | 242.4 | 0.2 | 238.5 | 0.12 | 480.9 | 232.5 |
| 1993/94 | 237.3 | 0.2 | 178.3 | 0.12 | 415.6 | 124.4 |
| 1994/95 | 216.8 | 0.16 | 163.6 | 0.15 | 380.4 | 71.2 |
| 1995/96 | 257 | 0.115 | 209.5 | 0.105 | 466.5 | 63 |
| 1996/97 | 161.7 | 0.145 | 281.7 | 0.09 | 443.4 | 154.8 |
| 1997/98 | 157.5 | 0.195 | 319.9 | 0.09 | 477.4 | 280.2 |
| 1998/99 | 124.3 | 0.255 | 201.1 | 0.12 | 325.4 | 208.4 |
| 1999/00 | 51.4 | 0.195 | 89.5 | 0.10 | 140.9 | 82.1 |
| 2000/01 | 152.4 | 0.435 | 88.9 | 0.14 | 241.3 | 65.7 |
| 2001/02 | 131.4 | 0.28 | 129.2 | 0.185 | 260.6 | 67.6 |
| 2002/03 | 50.5 | 0.295 | 90.2 | 0.195 | 140.8 | 63.1 |
| 2003/04 | 74.2 | 0.285 | 73 | 0.20 | 147.3 | 52.3 |
| 2004/05 | 84.5 | 0.28 | 75.8 | 0.16 | 160.3 | 56 |
| 2005/06 | 158.2 | 0.17 | 119.5 | 0.16 | 277.7 | 61.5 |
| 2006/07 | 109.6 | 0.17 | 134.5 | 0.18 | 244.2 | 118.7 |
| 2007/08 | 121.4 | 0.26 | 147.3 | 0.15 | 268.7 | 124.1 |
| 2008/09 | 86.4 | 0.22 | 121.6 | 0.10 | 208 | 97.7 |
| 2009/10 | 103.8 | 0.22 | 141.3 | 0.12 | 245 | 125.9 |
| 2010/11 | 145.1 | 0.156 | 157.3 | 0.142 | 302.4 | 137.6 |
| 2011/12 | 280.0 | 0.178 | 167.4 | 0.120 | 447.4 | 150.7 |
| 2012/13 | 220.6 | 0.198 | 120.8 | 0.143 | 341.4 | 87.0 |

Table 4. Abundance estimates of females and males by size groups for the BSFRF net in the 2009 and 2010 study areas, the NMFS net in the study area, and the NMFS survey of the entire Bering Sea. Mature abundance uses the maturity curve.

| | | Females | | | Males | |
|---|---|---|---|---|---|---|
| | >25mm | >50mm | mature | >25mm | mature | >100 |
| 2009 BSFRF Study | 585.3 | 113.6 | 129.4 | 422.9 | 200.9 | 66.9 |
| 2009 NMFS Study | 150.2 | 121.5 | 120.5 | 119.2 | 76.9 | 36.7 |
| 2009 NMFS Bering Sea | 1773.5 | 828.7 | 1,143.9 | 1,225.0 | 463.8 | 147.2 |
| 2010 BSFRF Study | 6372.1 | 2328.9 | 3459.4 | 3344.8 | 877.7 | 186.9 |
| 2010 NMFS Study | 2509.2 | 919.0 | 1102.6 | 1318.9 | 402.8 | 68.8 |

Table 5. Observed male and female mature biomass for the 2009 and 2010 study areas.

Mature Biomass (1000 t) 2009 and 2010 Study areas.

| | BSFRF | | NMFS | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| 2009 Obs | 12.2 | 68.4 | 11.9 | 32.3 |
| 2009 Pred | 12.6 | 54.4 | 10.3 | 41.0 |
| 2010 Obs | 279.0 | 193.3 | 91.5 | 77.7 |
| 2010 Pred | 203.9 | 176.3 | 163.3 | 132.7 |

Table 6. Base model estimates of population biomass (1000t), population numbers, male, female and total mature biomass(1000t) and number of males greater than 101 mm in millions. Recruits enter the population at the beginning of the survey year after molting occurs. * Numbers by length estimated in the first year, so recruitment estimates start in second year.

| Year | Biomass ( 1000t 25mm+) | numbers (million crabs 25mm+) | Female mature biomass( 1000t) | Male mature biomass(1 000t) | Total mature biomass (1000t) | Number of males >101mm (millions) | Recruit-ment (millions, 25 mm to 50 mm) | Male mature biomas s at mating time(Fe b of survey year+1) (1000t) | Full selec tion fishin g morta lity | Exp.rat e of total male catch on mature male biomas s |
|---|---|---|---|---|---|---|---|---|---|---|
| 1978/79 | 587.4 | 10566 | 180.3 | 210.3 | 390.6 | 173.1 | | 149.9 | 0.34 | 0.14 |
| 1979/80 | 637.7 | 10477.9 | 221.7 | 167.4 | 389.1 | 124.8 | 1372 | 102.6 | 0.82 | 0.26 |
| 1980/81 | 703.5 | 10219.8 | 311.5 | 127.5 | 439 | 66.3 | 1259.5 | 71.7 | 2.17 | 0.35 |
| 1981/82 | 743.5 | 9286.3 | 339.9 | 123.4 | 463.3 | 39.4 | 848 | 88.7 | 1.35 | 0.19 |
| 1982/83 | 764.5 | 7571.2 | 326.9 | 185.3 | 512.2 | 103.6 | 301.4 | 144.1 | 0.36 | 0.1 |
| 1983/84 | 797.1 | 8170.6 | 291.9 | 281.2 | 573.1 | 239.9 | 1213.6 | 224.5 | 0.14 | 0.06 |
| 1984/85 | 841.3 | 9997.2 | 271 | 328.5 | 599.5 | 309.8 | 1921.4 | 245.9 | 0.28 | 0.12 |
| 1985/86 | 902.9 | 12272 | 283.8 | 318.2 | 602 | 298.3 | 2423.6 | 222.1 | 0.45 | 0.18 |
| 1986/87 | 1071.9 | 17692.1 | 323.7 | 283.9 | 607.6 | 234.5 | 4319.9 | 189.8 | 0.64 | 0.21 |
| 1987/88 | 1157.5 | 14189.7 | 412.1 | 281.7 | 693.8 | 192.3 | 604.8 | 173 | 1.28 | 0.31 |
| 1988/89 | 1348.9 | 19157.1 | 439.9 | 317.1 | 756.9 | 198.1 | 4324.2 | 196.9 | 1.46 | 0.32 |
| 1989/90 | 1385.5 | 14373.9 | 485.7 | 386.4 | 872.1 | 255.5 | 148.1 | 250.6 | 1.11 | 0.28 |
| 1990/91 | 1351 | 11767.6 | 479.2 | 475.5 | 954.7 | 366.7 | 543.2 | 248 | 1.98 | 0.45 |
| 1991/92 | 1148.5 | 9788.9 | 422.8 | 427.9 | 850.7 | 306.1 | 572 | 209.6 | 2.65 | 0.49 |
| 1992/93 | 1170.9 | 19252.2 | 363.5 | 349.8 | 713.3 | 233.7 | 6050.4 | 185.1 | 2.38 | 0.45 |
| 1993/94 | 1161 | 16401.1 | 437.5 | 304.7 | 742.2 | 206.8 | 1215.4 | 185.1 | 1.37 | 0.3 |
| 1994/95 | 1175.5 | 13807.1 | 493.9 | 267.7 | 761.5 | 127.3 | 845.4 | 186.6 | 0.97 | 0.18 |
| 1995/96 | 1171.5 | 10770.7 | 471.5 | 302.7 | 774.2 | 131.9 | 207.4 | 223.3 | 0.78 | 0.16 |
| 1996/97 | 1125.9 | 8370.6 | 408 | 431.2 | 839.2 | 315.5 | 109.9 | 308.4 | 0.58 | 0.18 |
| 1997/98 | 985.3 | 6670.5 | 337 | 513.5 | 850.5 | 478.3 | 169 | 315.2 | 0.85 | 0.29 |
| 1998/99 | 762.5 | 6745.6 | 275.6 | 390.4 | 666 | 343 | 894.5 | 236 | 0.91 | 0.29 |
| 1999/00 | 605.8 | 6698.1 | 242.9 | 258.4 | 501.3 | 197.3 | 852.8 | 201.4 | 0.22 | 0.08 |
| 2000/01 | 545.6 | 5601.7 | 230.1 | 210 | 440.1 | 152.3 | 277.5 | 164.4 | 0.21 | 0.07 |
| 2001/02 | 500.1 | 4773.4 | 210.9 | 179.4 | 390.3 | 119.5 | 262.2 | 135 | 0.38 | 0.11 |
| 2002/03 | 477.3 | 4977.7 | 184.6 | 171.6 | 356.2 | 118.2 | 677.1 | 131 | 0.33 | 0.1 |
| 2003/04 | 500 | 6509.5 | 169.2 | 181.9 | 351.1 | 147 | 1381.3 | 141.8 | 0.21 | 0.08 |
| 2004/05 | 565.6 | 8475.4 | 179.9 | 183 | 362.9 | 155.2 | 1817.6 | 141.9 | 0.21 | 0.08 |
| 2005/06 | 612 | 7723.5 | 214 | 177.1 | 391.1 | 137.1 | 728.5 | 131.5 | 0.36 | 0.12 |
| 2006/07 | 648.8 | 7166.7 | 230 | 186.2 | 416.1 | 130.1 | 707.7 | 139.3 | 0.39 | 0.12 |

Table 6 Cont.. Base model estimates of population biomass (1000t), population numbers, male, female and total mature biomass(1000t) and number of males greater than 101 mm in millions. Recruits enter the population at the beginning of the survey year after molting occurs. * Numbers by length estimated in the first year, so recruitment estimates start in second year.

| Year | Biomass ( 1000t 25mm+) | numbers (million crabs 25mm+) | Female mature biomass( 1000t) | Male mature biomass(1 000t) | Total mature biomass (1000t) | Number of males >101mm (millions) | Recruit-ment (millions, 25 mm to 50 mm) | Male mature biomass at mating time(Feb of survey year+1) (1000t) | Full selection fishing mortality | Exp.rate of total male catch on mature male biomass |
|---|---|---|---|---|---|---|---|---|---|---|
| 2007/08 | 651.6 | 5700 | 224.7 | 226.2 | 450.8 | 171.4 | 168.6 | 161.3 | 0.54 | 0.17 |
| 2008/09 | 626.3 | 5369 | 201.8 | 265 | 466.8 | 229 | 544.2 | 196.2 | 0.35 | 0.13 |
| 2009/10 | 689.1 | 9831.6 | 180.7 | 279.6 | 460.3 | 262.2 | 2900.9 | 212.9 | 0.24 | 0.1 |
| 2010/11 | 749.8 | 10337.8 | 220.1 | 266.2 | 486.2 | 247.1 | 1552.9 | 198.8 | 0.29 | 0.12 |
| 2011/12 | 796.3 | 9532.3 | 268.3 | 246.3 | 514.5 | 203.3 | 948.8 | 165.2 | 0.64 | 0.21 |
| 2012/13 | 830.6 | 9401.0 | 281.6 | 233 | 514.7 | 152.4 | | | | |

Table 6a. Base model predicted survey values for female, male and total mature biomass and numbers of males > 101mm (millions of crab).

| | Predicted Female survey mature Biomass: | Predicted Male survey mature Biomass: | Predicted total survey mature Biomass: | model predicted males>101 (millions) |
|---|---|---|---|---|
| 1978 | 150.4 | 210.0 | 360.4 | 173.2 |
| 1979 | 179.7 | 166.2 | 345.9 | 125.0 |
| 1980 | 252.0 | 125.3 | 377.2 | 66.3 |
| 1981 | 278.0 | 120.6 | 398.5 | 39.4 |
| 1982 | 161.1 | 116.6 | 277.7 | 67.2 |
| 1983 | 144.3 | 179.0 | 323.3 | 155.7 |
| 1984 | 133.6 | 209.8 | 343.5 | 201.1 |
| 1985 | 139.2 | 202.8 | 342.0 | 193.6 |
| 1986 | 158.3 | 179.6 | 337.9 | 152.2 |
| 1987 | 200.8 | 176.5 | 377.2 | 124.8 |
| 1988 | 215.9 | 198.7 | 414.5 | 128.6 |
| 1989 | 271.9 | 227.2 | 499.1 | 151.1 |
| 1990 | 268.7 | 279.9 | 548.7 | 216.9 |
| 1991 | 237.3 | 252.0 | 489.3 | 181.0 |
| 1992 | 204.0 | 206.0 | 410.0 | 138.2 |
| 1993 | 244.6 | 179.0 | 423.6 | 122.3 |
| 1994 | 276.6 | 156.9 | 433.5 | 75.3 |
| 1995 | 264.5 | 177.8 | 442.3 | 78.0 |
| 1996 | 229.0 | 254.0 | 483.0 | 186.6 |
| 1997 | 189.3 | 302.9 | 492.2 | 282.9 |
| 1998 | 154.8 | 230.3 | 385.0 | 202.9 |
| 1999 | 136.3 | 152.2 | 288.5 | 116.7 |
| 2000 | 129.0 | 123.6 | 252.6 | 90.0 |
| 2001 | 118.3 | 105.6 | 223.9 | 70.7 |
| 2002 | 103.6 | 101.1 | 204.7 | 69.9 |
| 2003 | 94.9 | 107.2 | 202.1 | 86.9 |
| 2004 | 100.7 | 107.7 | 208.5 | 91.8 |
| 2005 | 119.8 | 104.1 | 223.9 | 81.1 |
| 2006 | 128.9 | 109.5 | 238.3 | 76.9 |
| 2007 | 126.0 | 133.2 | 259.1 | 101.3 |
| 2008 | 113.3 | 156.2 | 269.5 | 135.5 |
| 2009 | 101.4 | 164.9 | 266.3 | 155.1 |
| 2010 | 123.1 | 156.8 | 279.8 | 146.1 |
| 2011 | 150.1 | 144.9 | 295.0 | 120.2 |
| 2012 | 157.9 | 137.0 | 294.9 | 90.1 |

Table 7. Radiometric ages for male crabs for shell conditions 1 through 5. Data from Orensanz (unpub).

| | | | Radiometric age | | |
|---|---|---|---|---|---|
| Shell Condition | description | sample size | Mean | minimum | maximum |
| 1 | soft | 6 | 0.15 | 0.05 | 0.25 |
| 2 | new | 6 | 0.69 | 0.33 | 1.07 |
| 3 | old | 3 | 1.02 | 0.92 | 1.1 |
| 4 | very old | 3 | 5.31 | 4.43 | 6.6 |
| 5 | very very old | 3 | 4.59 | 2.7 | 6.85 |
| | | | | | |

Table 8. Natural mortality estimates for Hoenig (1983), the 5% rule and the 1% rule, given the oldest observed age.

| | Natural Mortality | | |
|---|---|---|---|
| oldest observed age | Hoenig (1983) empirical | 5% rule | 1% Rule |
| 10 | 0.42 | 0.3 | 0.46 |
| 15 | 0.28 | 0.2 | 0.30 |
| 17 | 0.25 | 0.18 | 0.27 |
| 20 | 0.21 | 0.15 | 0.23 |

Tables 9a-b. Projections using a multiplier on the F35% control rule for 2012/13 to 2020/21 fishery seasons. Median total catch ($ABC_{tot}$ 1000 t), median retained catch ($C_{dir}$ 1000 t), Percent mature male biomass at time of mating relative to B35. Values in parentheses are 90% CI. F is full selection fishing mortality. Base model $B_{35\%}$ = 154,669 t. $F_{35\%}$ = 1.32.

a) 100%OFL Base Model, 100% $F_{35\%}$ B35% = 154,669 t F35%=1.32

| Year | **$ABC_{tot}$ (1000t)** | **$C_{dir}$ (1000t)** | **Percent MMB/ $B_{35\%}$** | **Full Selection Fishing Mortality** |
|---|---|---|---|---|
| 2012/13 | 67.8(53.6,80.2) | 48.1(38.4,56.6) | 94.6(84.6,105.6) | 1.24 |
| 2013/14 | 83.8(56.4,105.2) | 59.5(41.3,72.6) | 107.9(93.2,123.8) | 1.29 |
| 2014/15 | 102.1(70.6,126.5) | 78.3(56.2,95.5) | 116.5(97.1,139.6) | 1.3 |
| 2015/16 | 89.5(59.8,114.2) | 66(46.5,82.9) | 114.6(91.4,147.2) | 1.27 |
| 2016/17 | 82.2(49.5,113.7) | 56.1(37.3,72.9) | 115.9(85.8,182) | 1.25 |
| 2017/18 | 89.5(47.1,183.1) | 62.4(35.6,124.8) | 126.3(81.9,240) | 1.26 |
| 2018/19 | 103.3(41.2,260) | 75(31,194.1) | 135.1(76.8,306.2) | 1.24 |
| 2019/20 | 105.3(35.8,272.5) | 77.9(26.2,210.8) | 136.6(71,317.8) | 1.25 |
| 2020/21 | 101.2(30.5,257.1) | 73.5(22.6,197.2) | 135.9(65.6,309.7) | 1.22 |
| 2021/22 | 97.1(25.4,254) | 70.4(19.2,189.1) | 137.2(62.4,309.1) | 1.2 |
| 2022/23 | 95.3(25.2,240.6) | 67.3(17.8,174.4) | 130(62.3,308.4) | 1.2 |

b) 90% Catch at FOFL Base Model, B35% = 154,669 t F35%=1.32

| Year | **$ABC_{tot}$ (1000t)** | **$C_{dir}$ (1000t)** | **Percent MMB/ $B_{35\%}$** | **Full Selection Fishing Mortality** |
|---|---|---|---|---|
| 2012/13 | 60.1(47.3,69.2) | 43.2(34.3,49.6) | 98(87.5,110.4) | 1.06 |
| 2013/14 | 74.8(51.9,94.7) | 54.5(38.6,67.4) | 114.2(98.8,131.8) | 1.06 |
| 2014/15 | 92.8(66.6,117) | 73.1(53.7,90.6) | 126.6(106.1,149.6) | 1.07 |
| 2015/16 | 83.7(58.1,108.1) | 64.4(46,81) | 124.6(100.2,158.2) | 1.05 |
| 2016/17 | 76.8(48.2,105.5) | 54.9(37.6,72.1) | 124.9(94,192.6) | 1.04 |
| 2017/18 | 82.9(46.1,165.1) | 59.9(35.7,117.2) | 135.6(88.9,255.3) | 1.04 |
| 2018/19 | 95.8(40,236.4) | 71.3(31.1,182.2) | 146.1(82.1,329.7) | 1.03 |
| 2019/20 | 98.2(34.5,253.2) | 74.7(26.5,202.3) | 148.4(76.5,346.4) | 1.03 |
| 2020/21 | 95(29.6,245.8) | 71(21.9,193.7) | 148.7(70.1,338.6) | 1.02 |
| 2021/22 | 92.4(24.9,238.9) | 68.5(19.3,186.7) | 150.7(67.2,339.3) | 1.01 |
| 2022/23 | 91.1(24.6,229.6) | 66.9(18,171.3) | 143.3(66.9,343.8) | 1.00 |

Table 10. Base Model Parameters values (excluding recruitments, probability of maturing and fishing mortality parameters).

| Parameter | Value | S.D. for estimated parameters | Estimated(Y/N) | Bounded (bounds) |
|---|---|---|---|---|
| Natural Mortality immature females and males | 0.329 | 0.020 | Y | |
| Natural Mortality mature females and males | 0.230 | | N | |
| | 0.273 | 0.008 | Y | |
| Female intercept (a) growth | 7.457 | 0.254 | set equal to male | |
| Male intercept(a) growth | 7.457 | 0.254 | Y | |
| Female slope(b) growth | 1.063 | 0.007 | Y | |
| Male slope (b) growth | 1.133 | 0.005 | Y | |
| Alpha for gamma distribution of recruits | 11.500 | | N | |
| Beta for gamma distribution of recruits | 4.000 | | N | |
| Beta for gamma distribution female growth | 0.750 | | N | |
| Beta for gamma distribution male growth | 0.750 | | N | |
| Fishery selectivity total males slope | 0.161 | 0.004 | Y | |
| Fishery selectivity total males length at 50% | 106.208 | 0.152 | Y | |
| Fishery selectivity retention curve males slope | 0.383 | 0.017 | Y | |
| Fishery selectivity retention curve males length at 50% | 97.120 | 0.148 | Y | |
| Pot Fishery discard selectivity female slope | 0.343 | 0.011 | Y | |
| Pot Fishery discard selectivity female length at 50% | | | Y | |
| Trawl Fishery selectivity slope | 0.097 | 0.003 | Y | |
| Trawl Fishery selectivity length at 50% | 95.712 | 1.547 | Y | |
| Survey Q 1978-1981 male | 1.000 | 0.000 | Y | |
| Survey 1978-1981 length at 95% of Q male | 61.963 | 2.941 | Y | |
| Survey 1978-1981 length at 50% of Q male | 42.730 | 1.504 | Y | |
| Survey Q 1978-1981 Female | 0.979 | 0.040 | Y | |
| Survey 1978-1981 length at 95% of Q female | 61.963 | 2.941 | Set equal to Male | |
| Survey 1978-1981 length at 50% of Q female | 42.730 | 1.504 | Set equal to Male | |
| Survey Q 1982-1988 male | 0.649 | 0.047 | Y | |
| Survey 1982-1988 length at 95% of Q male | 69.533 | 4.517 | Y | |
| Survey 1982-1988 length at 50% of Q male | 43.164 | 1.839 | Y | |
| Survey Q 1982-1988 female | 0.635 | 0.032 | Y | |
| Survey 1982-1988 length at 95% of Q female | 69.533 | 4.517 | Set equal to Male | |
| Survey 1982-1988 length at 50% of Q female | 43.164 | 1.839 | Set equal to Male | |

Table 10 cont. Base Model Parameters values for the base model (Model 1), excluding recruitments, probability of maturing and fishing mortality parameters.

| Parameter | Value | S.D. for estimated parameters | Estimated(Y/N) | Bounded (bounds) |
|---|---|---|---|---|
| Survey Q 1989-present male | 0.591 | 0.032 | Y | |
| Survey 1989-present, length at 95% of Q male | 53.929 | 2.820 | Y | |
| Survey 1989-present length at 50% of Q male | 36.693 | 1.037 | Y | |
| Female Survey Q 1989-present | 0.578 | 0.030 | Y | |
| Female Survey 1989-present, length at 95% of Q | 49.421 | 1.845 | Y | |
| Female Survey 1989-present length at 50% of Q | 35.521 | 0.769 | Y | |
| | | | | |
| Male BSFRF 2009 Study area Q (availability) | 0.309 | 0.076 | Y | |
| Male BSFRF 2009 Study area length at 95% of Q | | | Y | |
| Male BSFRF 2009 Study are length at 50% of Q | | | Y | |
| Female BSFRF 2009 Study area Q (availability) | 0.542 | 0.109 | Y | |
| Female BSFRF 2009 Study area length at 95% of Q | 61.369 | 2.548 | Y | |
| Female BSFRF 2009 Study are length at 50% of Q | 53.289 | 1.296 | Y | |
| | | | | |
| male BSFRF 2010 Study area Q (availability) | 0.977 | 15.629 | Y | |
| male BSFRF 2010 Study area length at 95% of Q | | | N | |
| male BSFRF 2010 Study are length at 50% of Q | | | N | |
| Female BSFRF 2010 Study area Q (availability) | 1.198 | 19.166 | Y | |
| Female BSFRF 2010 Study area length at 95% of Q | 25.025 | | N | |
| Female BSFRF 2010 Study are length at 50% of Q | 25.000 | | N | |
| | | | | |

Table 11. Weighting factors for likelihood equations.

| Likelihood component | Weighting factor |
|---|---|
| | |
| Retained catch | 10 |
| Retained catch length comp | 1 |
| Total catch | 10 |
| Total catch length comp | 1 |
| Female pot catch | 10 |
| Female pot fishery length comp | 0.2 |
| Trawl catch | 10 |
| Trawl catch length comp | 0.25 |
| Survey biomass | survey cv by year |
| Survey length comp | 1 |
| Recruitment deviations | 1 |
| Fishing mortality average | 1 |
| | |
| Fishing mortality deviations | 0.1 |
| Initial length comp smoothness | 1 |
| Fishery cpue | 0.14 (cv = 5.0) |

Table 12. Base Model estimated recruitments (male) and mature male biomass at mating with standard deviations. Recruits enter the population at the beginning of the survey year.

| Survey year | Recruit (male,millions) | S.D. | MMB at mating (1000 tons) | S.D. |
|---|---|---|---|---|
| 1978/79 | | | 149.91 | 10.77 |
| 1979/80 | 1,372.00 | 314.80 | 102.57 | 7.22 |
| 1980/81 | 1,259.50 | 292.64 | 71.71 | 5.36 |
| 1981/82 | 848.04 | 225.96 | 88.67 | 6.20 |
| 1982/83 | 301.44 | 133.06 | 144.13 | 10.28 |
| 1983/84 | 1,213.60 | 232.22 | 224.53 | 15.68 |
| 1984/85 | 1,921.40 | 337.68 | 245.93 | 18.06 |
| 1985/86 | 2,423.60 | 408.13 | 222.08 | 17.37 |
| 1986/87 | 4,319.90 | 520.08 | 189.77 | 14.92 |
| 1987/88 | 604.79 | 234.98 | 173.02 | 12.70 |
| 1988/89 | 4,324.20 | 425.85 | 196.89 | 12.93 |
| 1989/90 | 148.14 | 61.56 | 250.56 | 14.13 |
| 1990/91 | 543.19 | 90.46 | 247.98 | 13.01 |
| 1991/92 | 572.04 | 135.23 | 209.59 | 11.42 |
| 1992/93 | 6,050.40 | 634.67 | 185.08 | 10.78 |
| 1993/94 | 1,215.40 | 235.88 | 185.13 | 11.10 |
| 1994/95 | 845.40 | 138.86 | 186.61 | 12.05 |
| 1995/96 | 207.39 | 67.86 | 223.33 | 14.64 |
| 1996/97 | 109.90 | 39.88 | 308.41 | 18.83 |
| 1997/98 | 169.03 | 60.41 | 315.19 | 19.90 |
| 1998/99 | 894.46 | 148.49 | 236.04 | 17.54 |
| 1999/00 | 852.79 | 151.05 | 201.43 | 14.90 |
| 2000/01 | 277.54 | 78.39 | 164.43 | 12.56 |
| 2001/02 | 262.19 | 79.07 | 135.04 | 11.02 |
| 2002/03 | 677.05 | 132.16 | 131.02 | 10.53 |
| 2003/04 | 1,381.30 | 226.07 | 141.78 | 10.59 |
| 2004/05 | 1,817.60 | 267.19 | 141.91 | 10.23 |
| 2005/06 | 728.46 | 167.33 | 131.48 | 9.84 |
| 2006/07 | 707.72 | 142.77 | 139.33 | 10.38 |
| 2007/08 | 168.65 | 64.51 | 161.27 | 12.29 |
| 2008/09 | 544.24 | 128.07 | 196.18 | 14.58 |
| 2009/10 | 2,900.90 | 407.05 | 212.88 | 15.20 |
| 2010/11 | 1,552.90 | 299.13 | 198.79 | 14.73 |
| 2011/12 | 948.80 | 283.30 | 165.19 | 14.91 |
| 2012/13 | 1,165.90 | 343.07 | | |

Table 13. Likelihood values for base model and model 1 with new growth function.

| Likelihood Component | Base | 1 |
|---|---|---|
| | | |
| Recruitment | 33.19 | 35.28 |
| Initial numbers old shell males small length bins | 2.38 | 0.12 |
| ret fishery length | -1954.44 | -1917.58 |
| total fish length | 788.61 | 792.52 |
| female fish length | 175.98 | 175.04 |
| survey length | 3493.46 | 3510.07 |
| trawl length | 256.76 | 259.59 |
| 2009 BSFRF length | -79.33 | -67.03 |
| 2009 NMFS study area length | -70.34 | -11.69 |
| M prior | 6.13 | 9.06 |
| maturity smooth | 50.61 | 48.52 |
| growth a | 2.60 | 0.01 |
| growth b | 0.05 | 1.66 |
| 2009 BSFRF biomass | 0.14 | 0.88 |
| 2009 NMFS study area biomass | 0.06 | 0.68 |
| retained catch | 3.03 | 3.79 |
| discard catch | 119.83 | 144.41 |
| trawl catch | 9.78 | 8.73 |
| female discard catch | 65.10 | 67.55 |
| survey biomass | 165.24 | 188.97 |
| F penalty | 80.25 | 79.97 |
| 2010 BSFRF Biomass | 0.54 | 2.40 |
| 2010 NMFS Biomass | 2.30 | 2.82 |
| initial numbers fit | 515.55 | 518.88 |
| 2010 BSFRF length | -60.96 | -60.03 |
| 2010 NMFS length | -76.88 | -72.78 |
| male survey selectivity smooth constraint | 3.83 | 3.71 |
| init nos smooth constraint | 54.77 | 24.08 |
| | | |
| Total | 3588.26 | 3749.63 |
| | | |
| Q | 0.591 | 0.679 |
| no. parameters | 329 | 331 |
| immat M | 0.329 | 0.277 |
| M mature females | 0.23 | 0.23 |
| M mature males | 0.273 | 0.283 |

Table 14. Reference values for Base model and Model 1 with new growth function.

| | Base | Model 1 new growth |
|---|---|---|
| B35% | 154.669 | 138.96 |
| F35% | 1.319 | 1.127 |
| OFL 2012/13 | 67.8 | 51.6 |
| ACL (p*=.49) | 67.61 | 51.49 |
| ACL (90%OFL) | 60.8 | 46.44 |
| Percent MMB/B35% 2012/13 | 94.6 | 86.2 |

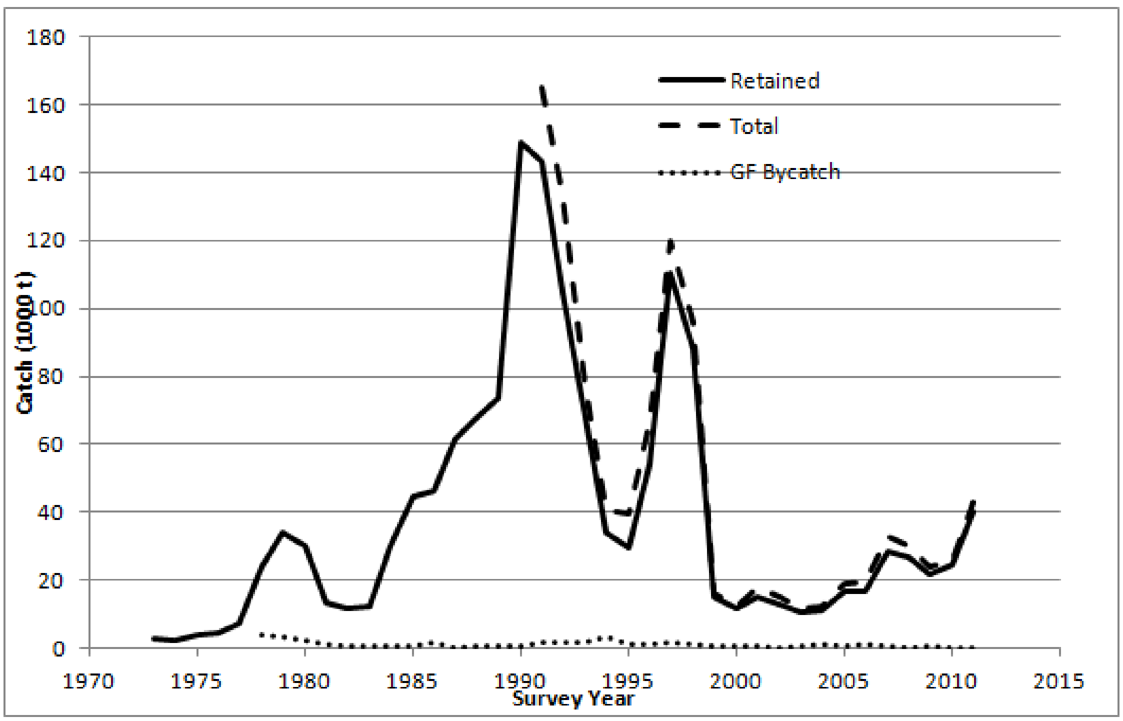

Figure 1. Catch (1000 t) from the directed snow crab pot fishery and groundfish trawl bycatch. Total catch is retained catch plus discarded catch after 50% discard mortality was applied. Trawl bycatch is male and female bycatch from groundfish trawl fisheries with 80% mortality applied.

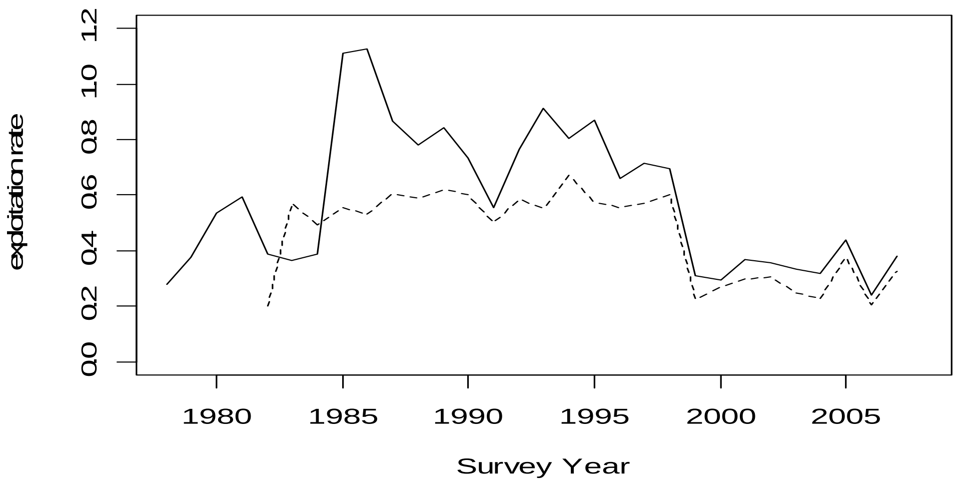


Figure 2. Exploitation rate estimated as the preseason GHL divided by the survey estimate of large male biomass (>101 mm) at the time the survey occurs (dotted line). The solid line is the retained catch divided by the survey estimate of large male biomass at the time the fishery occurs. Year is the survey year.

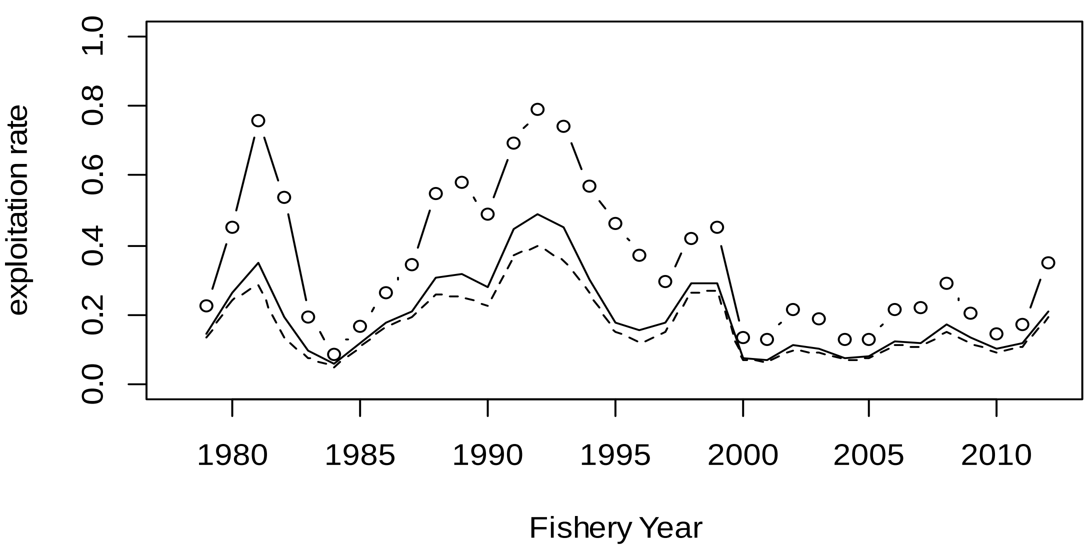


Figure 3. Base Model. Exploitation fraction estimated as the catch biomass (total or retained) divided by the mature male biomass from the model at the time of the fishery (solid line is total and dotted line is retianed). The exploitation rate for total catch divided by the male biomass

greater than 101 mm is the solid line with dots. Year is the year of the fishery.

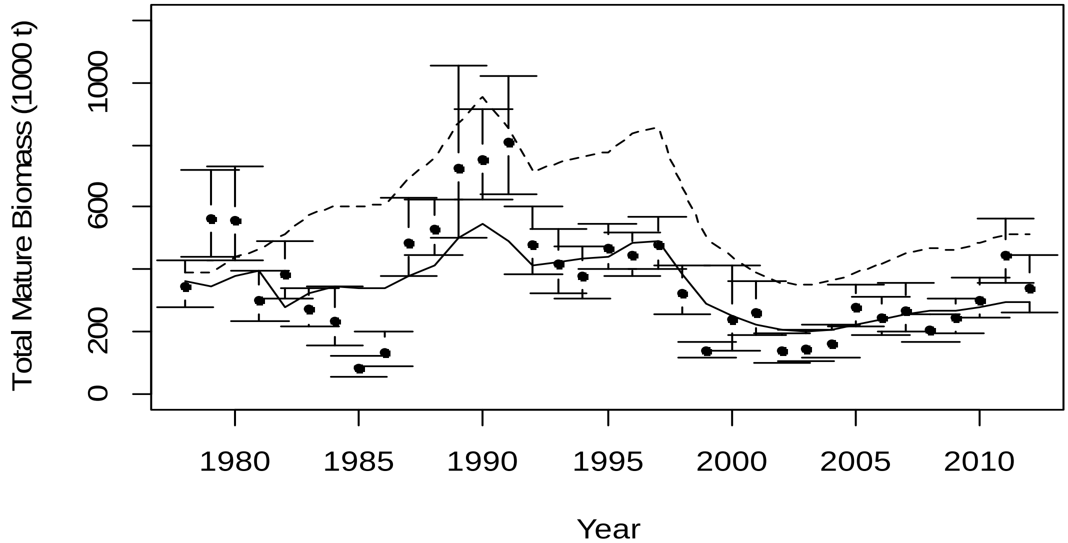


Figure 4. Population total mature biomass (millions of pounds, solid line), model estimate of survey mature biomass (dotted line) and observed survey mature biomass with approximate lognormal 95% confidence intervals.

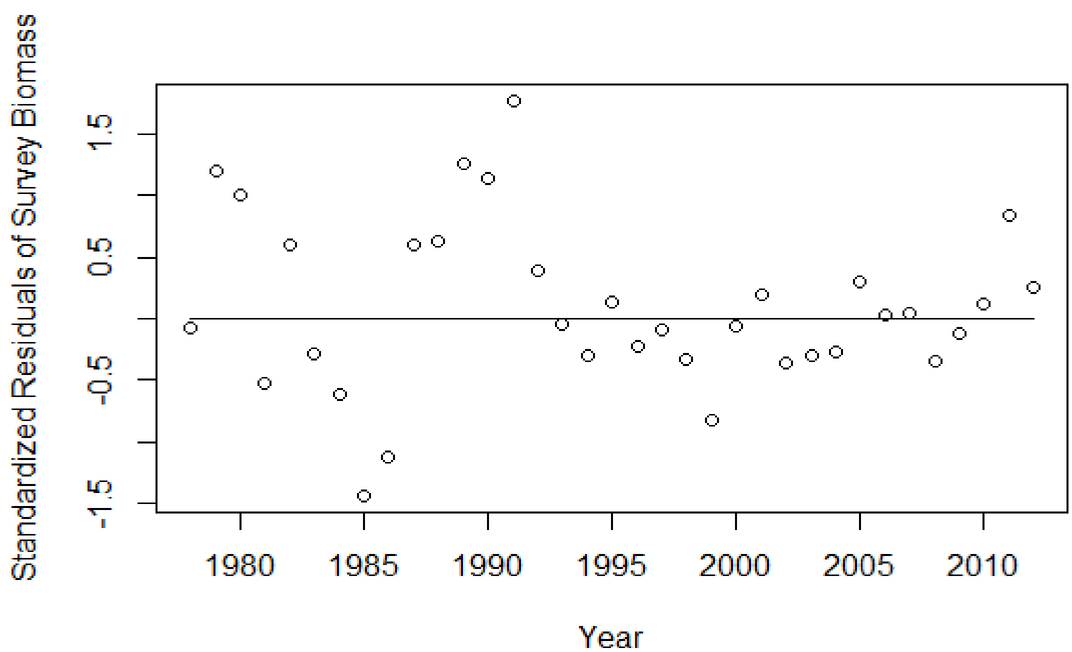


Figure 5. Standardized residuals for model fit to total mature biomass from Figure 4.

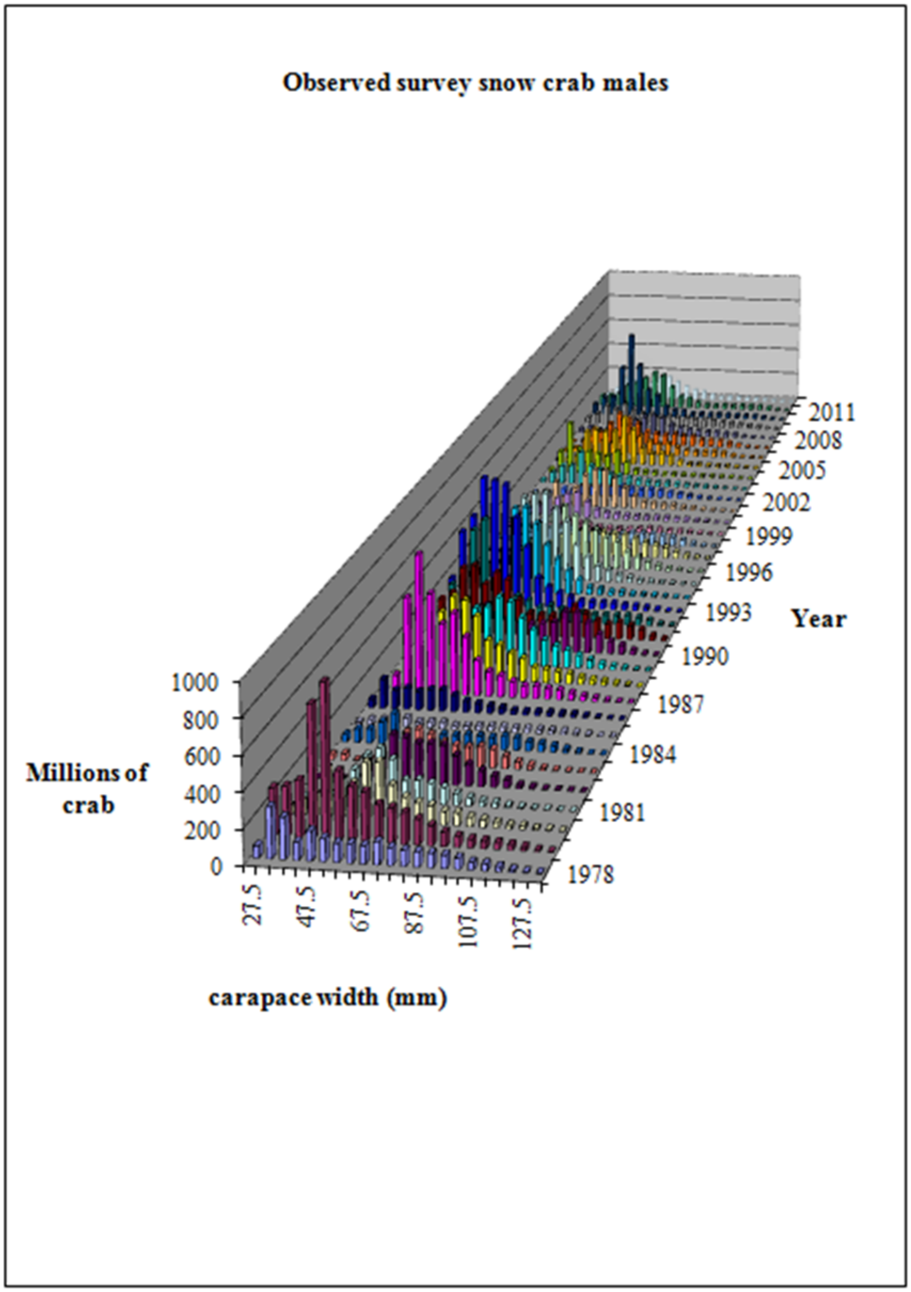


Figure 6. Observed survey numbers (millions of crab) by carapace width and year for male snow crab.

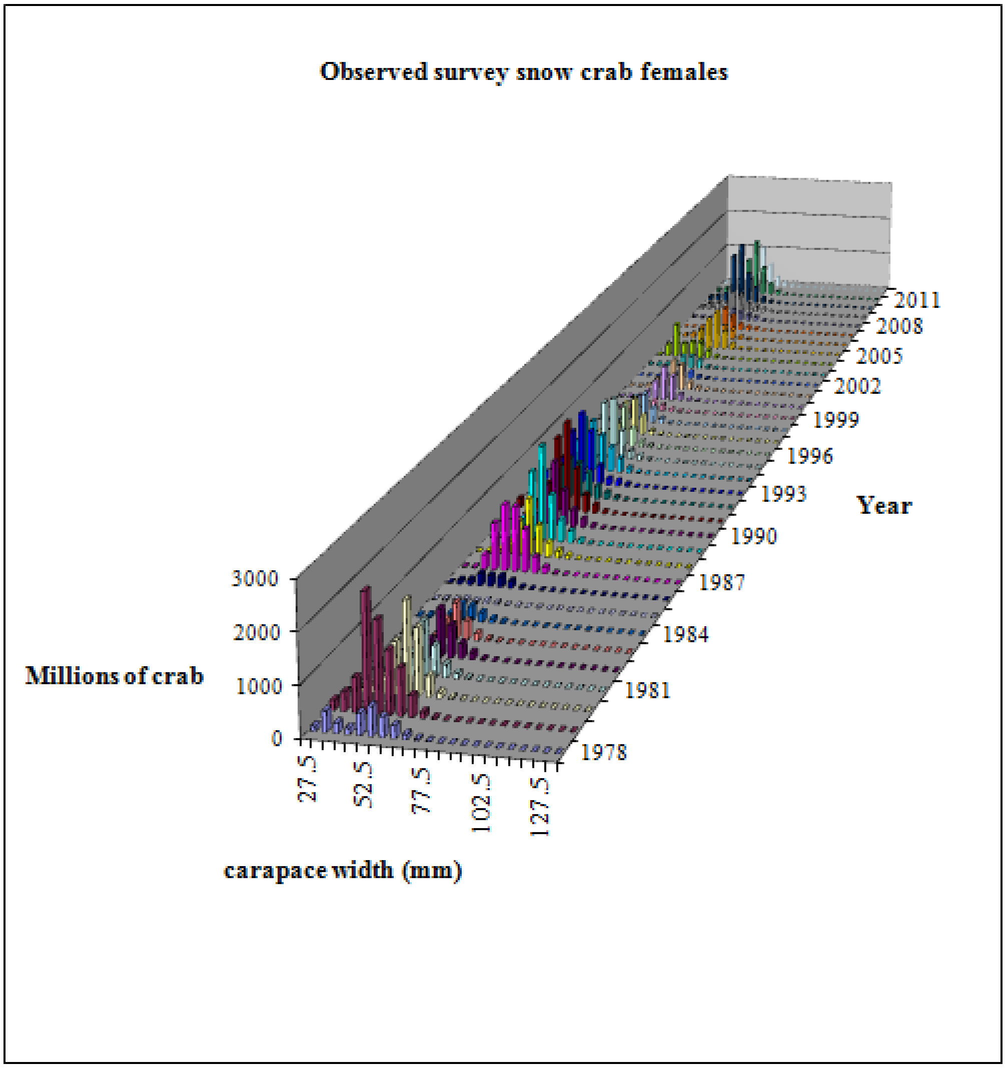


Figure 7. Observed survey numbers (millions of crab) by carapace width and year for female snow crab.

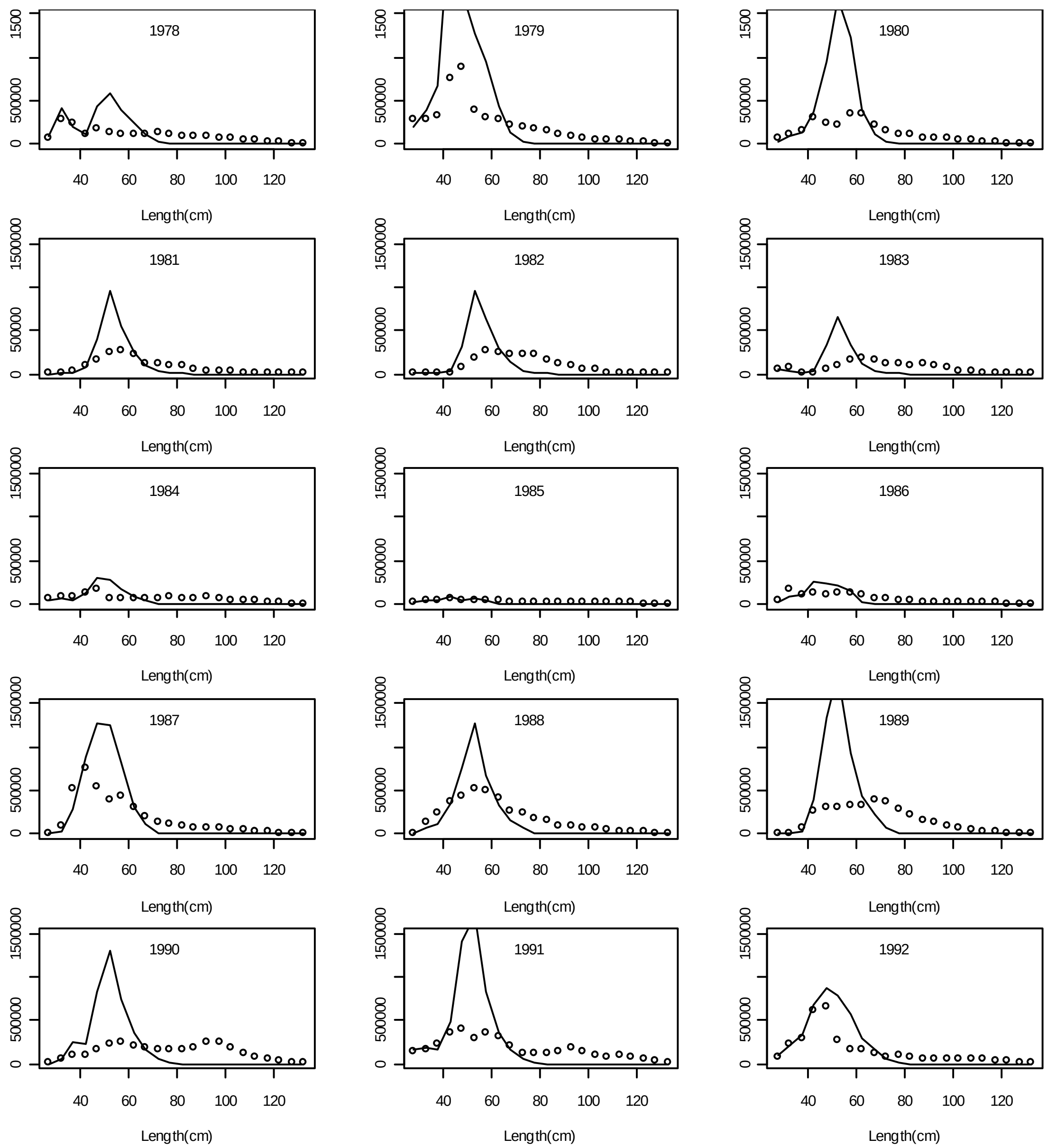


Figure 8. Observed survey numbers 1978 to 1992 by length, males circles, females solid line.

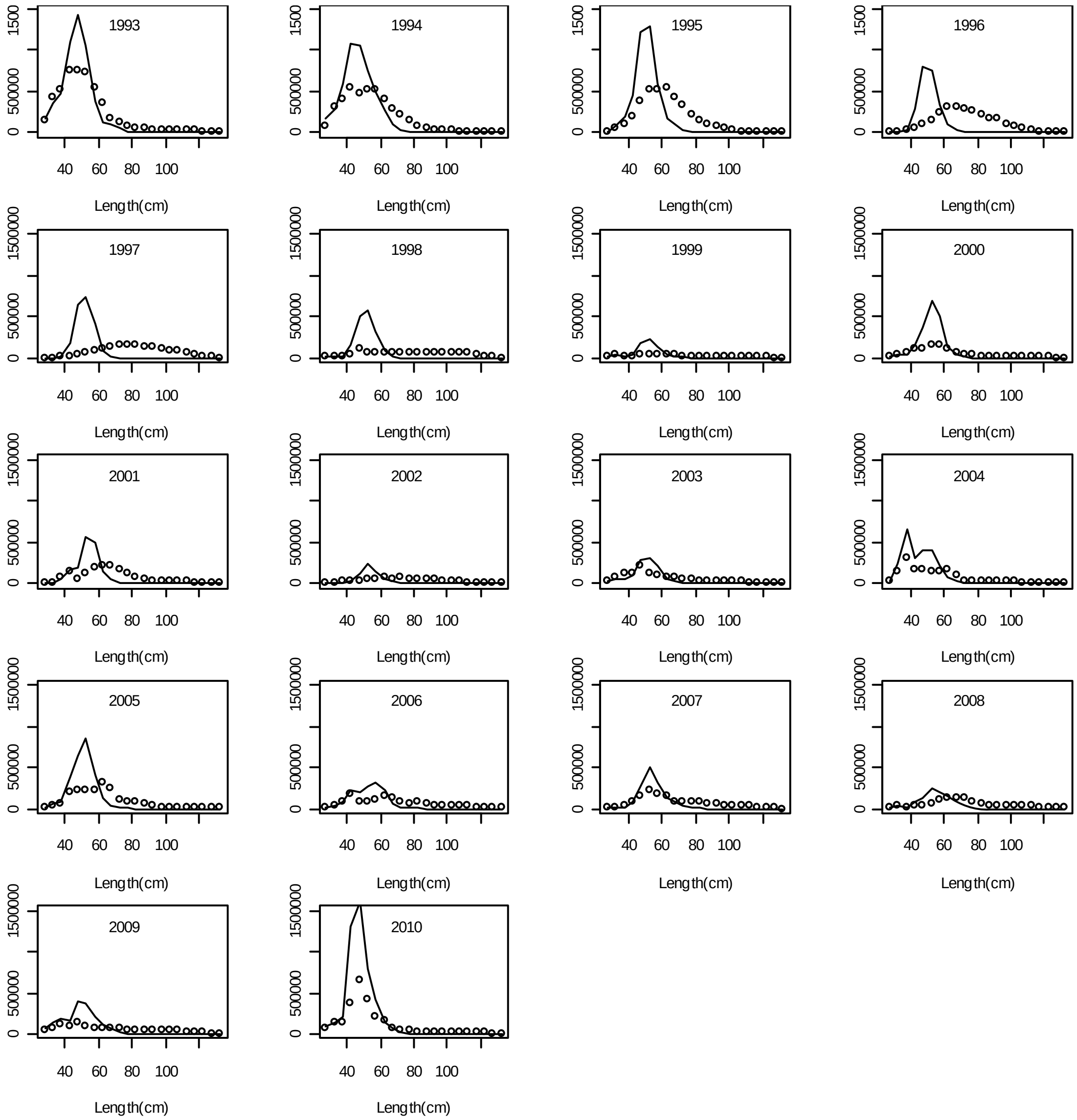


Figure 8 continued. Observed survey numbers 1993 to 2010 by length, males circles, females solid line.

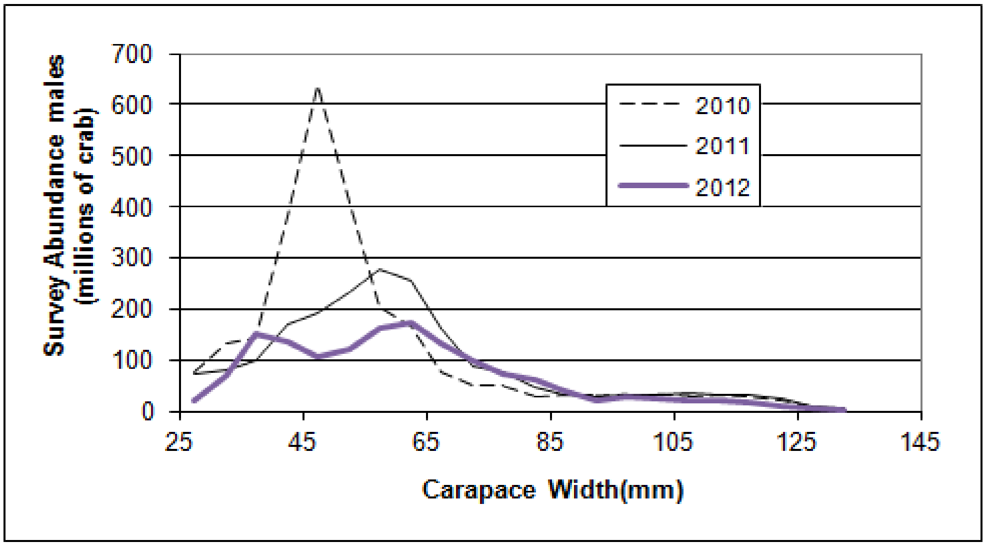


Figure 8a. Survey male abundance by length for 2010, 2011 and 2012.

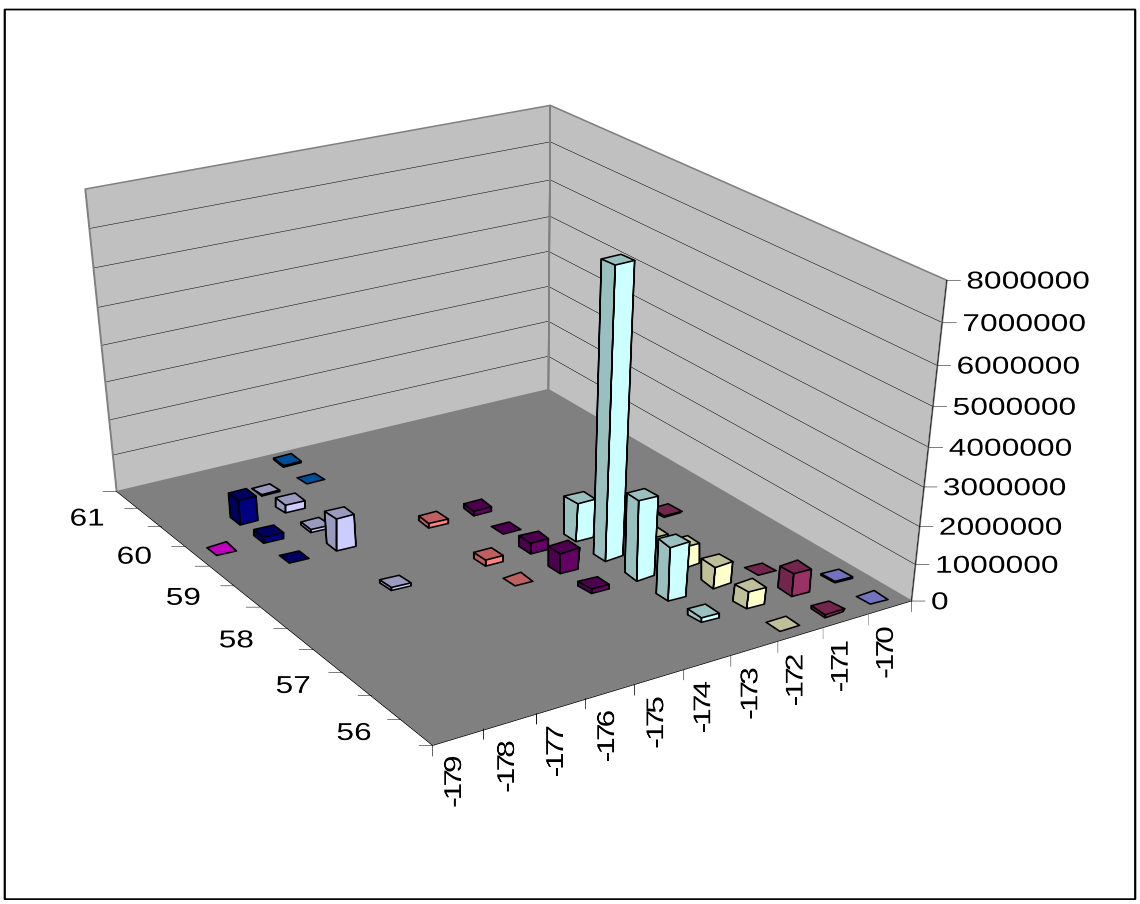


Figure 9. 2003/04 pot fishery retained catch in numbers by statistical area. Longitude in negative degrees. Areas are 1 degree longitude by 0.5 degree latitude.

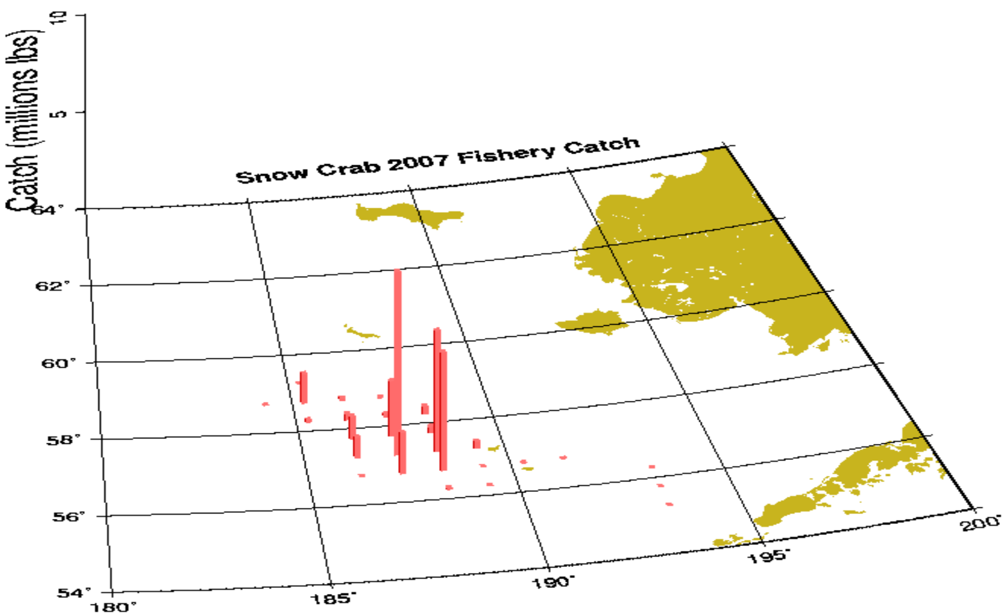


Figure 10. 2006/07 snow crab pot fishery retained catch(million lbs) by statistical area. Longitude increases from west to east (190 degrees = 170 degrees W longitude). Areas are 1 degree longitude by 0.5 degree latitude.

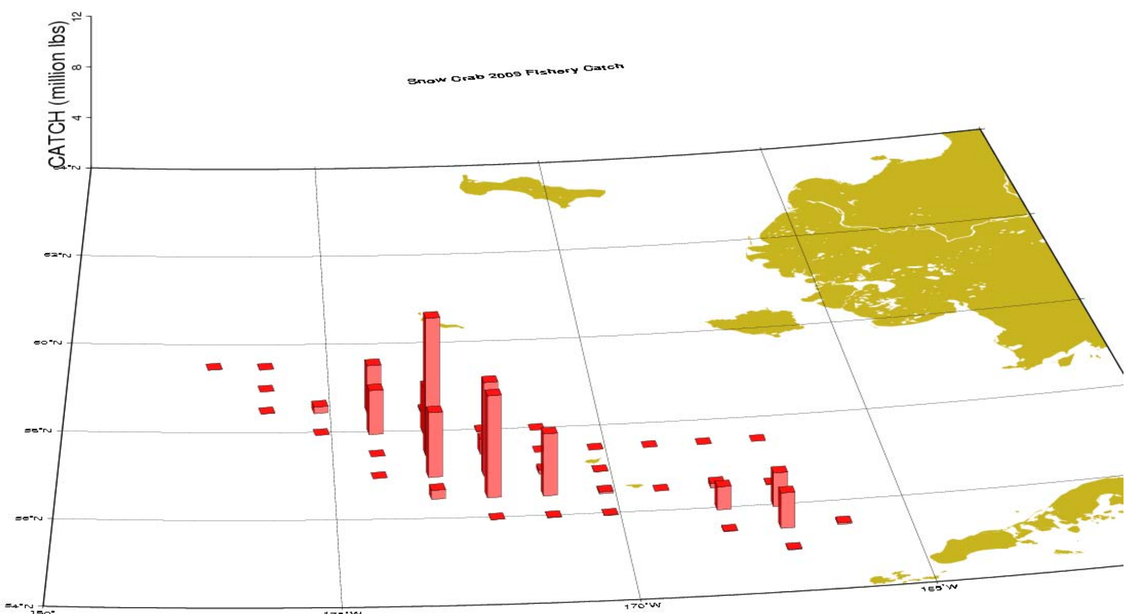


Figure 11. 2008/09 snow crab pot fishery retained catch(million lbs) by statistical area. Statistical areas are 1 degree longitude by 0.5 degree latitude.

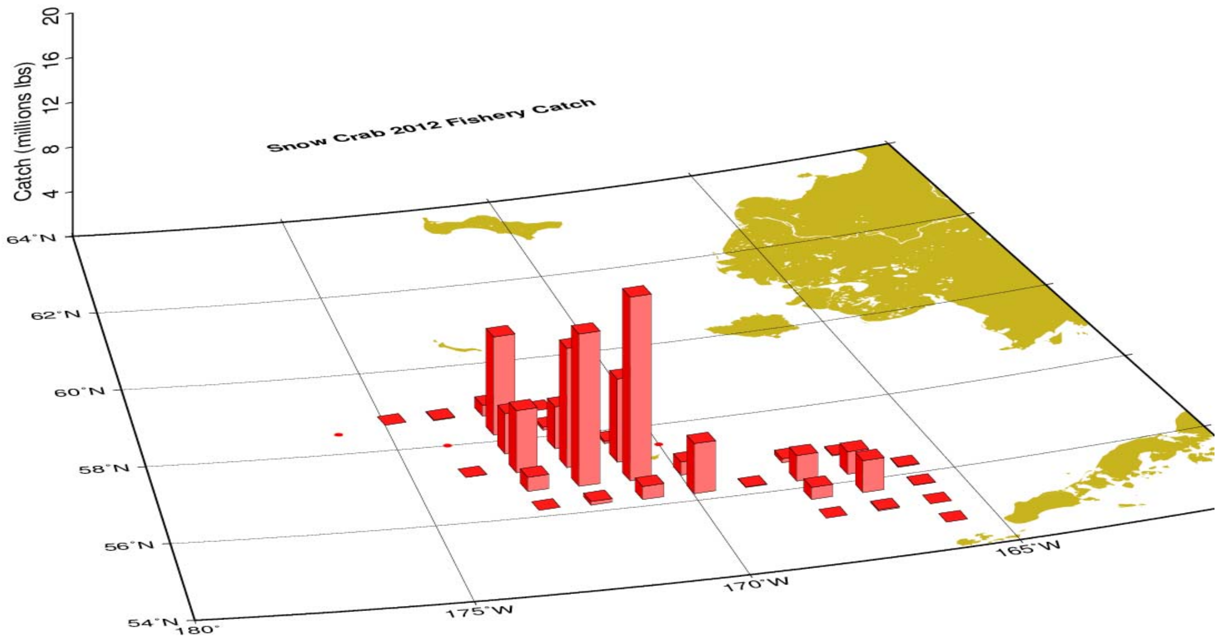


Figure 11b. 2011/12 snow crab pot fishery retained catch(million lbs) by statistical area. Statistical areas are 1 degree longitude by 0.5 degree latitude.

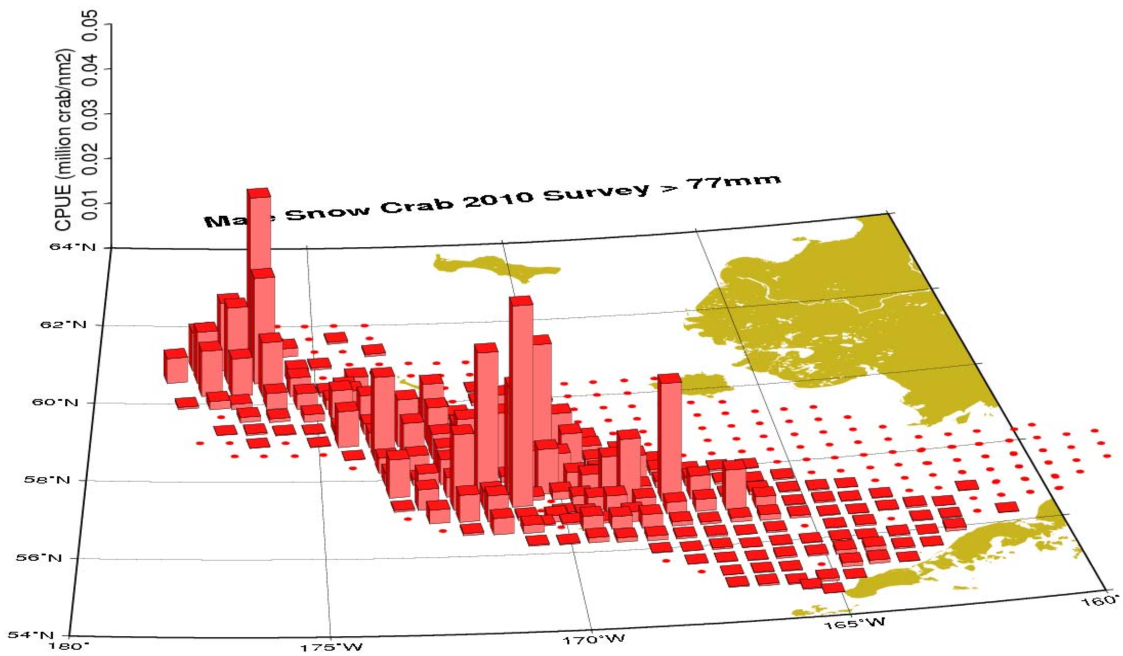


Figure 12. 2010 Survey CPUE (million crab per nm2) of males > 77 mm by tow. Filled circles are tows with 0 cpue.

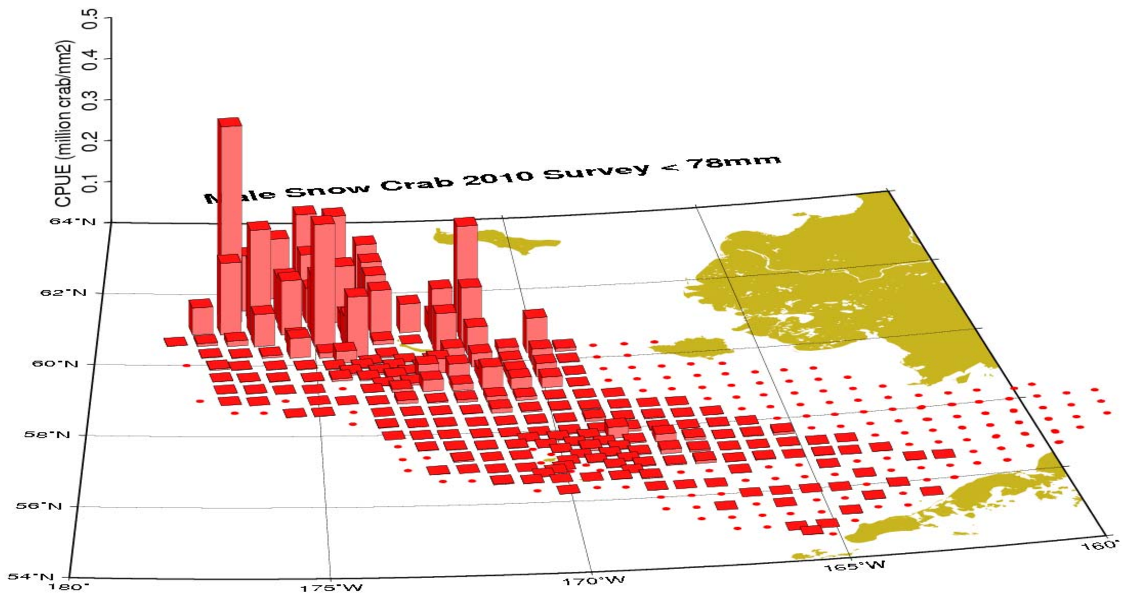


Figure 13. 2010 Survey CPUE (million crab per nm2) of males < 78 mm by tow. Filled circles are tows with 0 cpue.

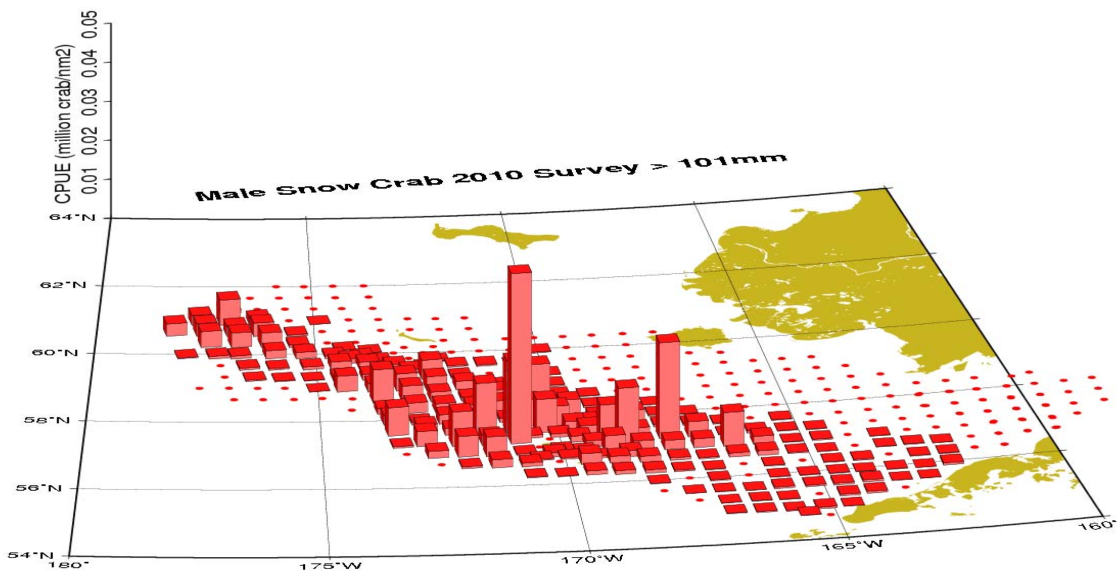


Figure 14. 2010 Survey CPUE (million crab per nm2) of males > 101 mm by tow. Filled circles are tows with 0 cpue.

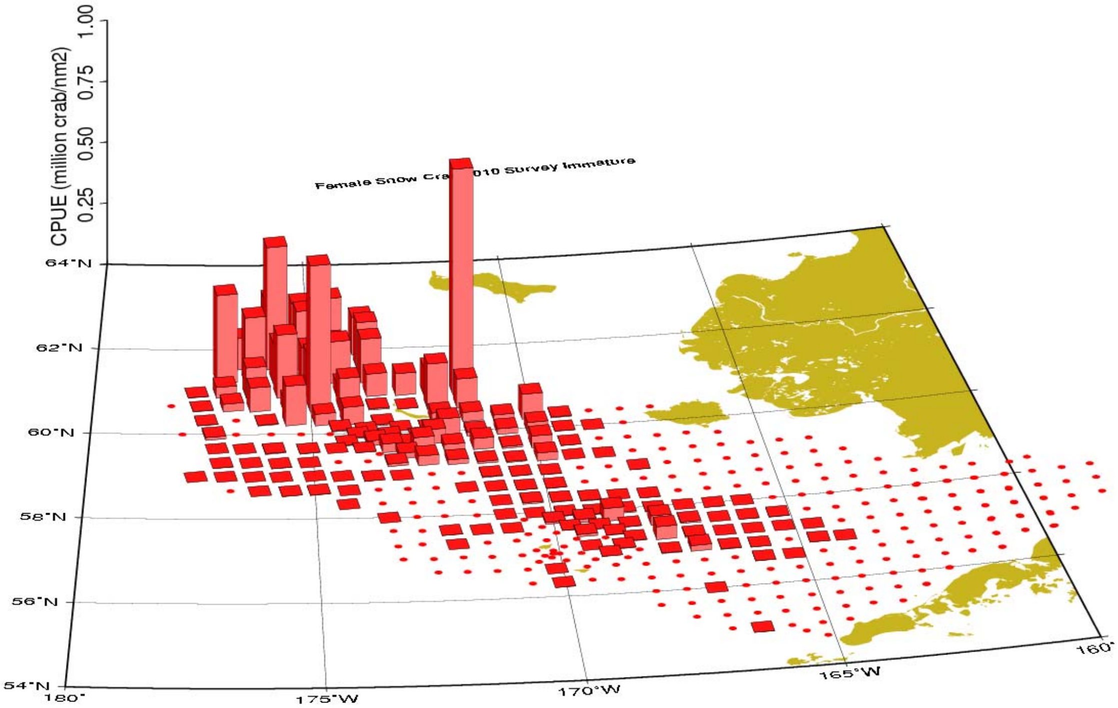


Figure 15. 2010 Survey CPUE (million crab per nm2) of immature females by tow. Filled circles are tows with 0 cpue.

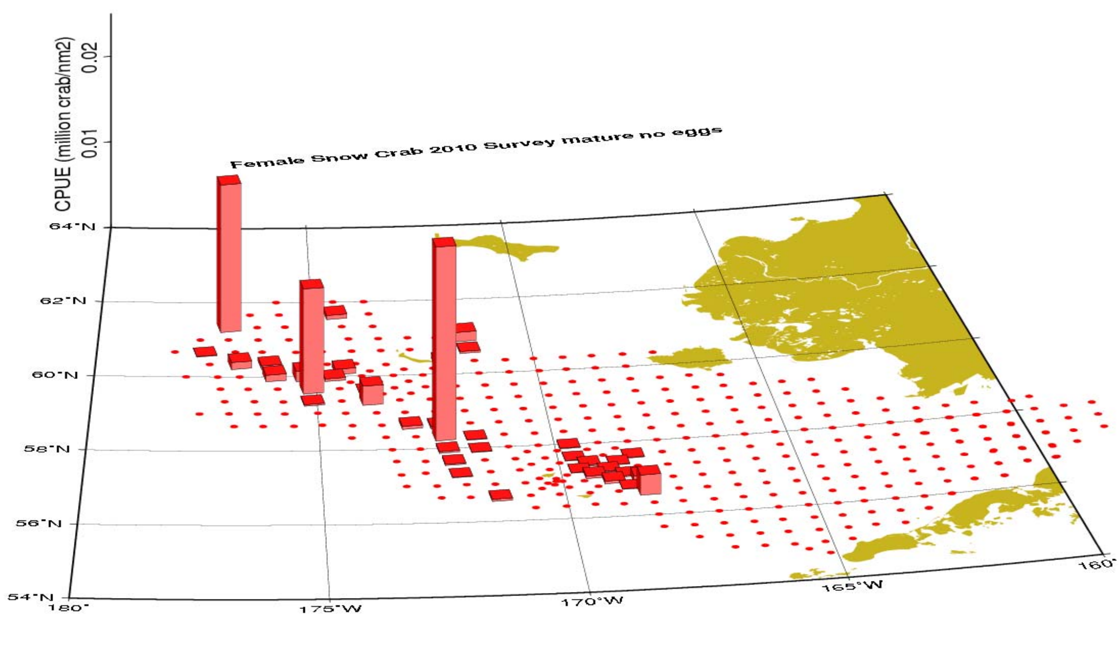


Figure 16. 2010 Survey CPUE (million crab per nm2) of mature females with no eggs by tow. Filled circles are tows with 0 cpue.

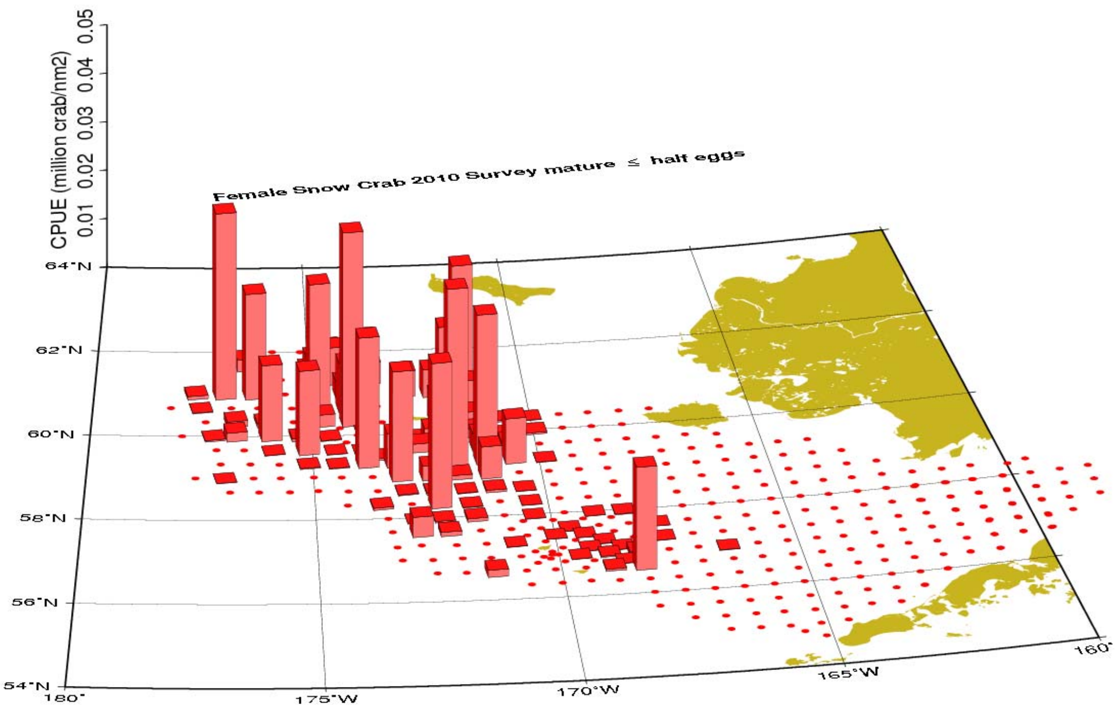


Figure 17. 2010 Survey CPUE (million crab per nm2) of mature females with <= half clutch of eggs by tow. Filled circles are tows with 0 cpue.

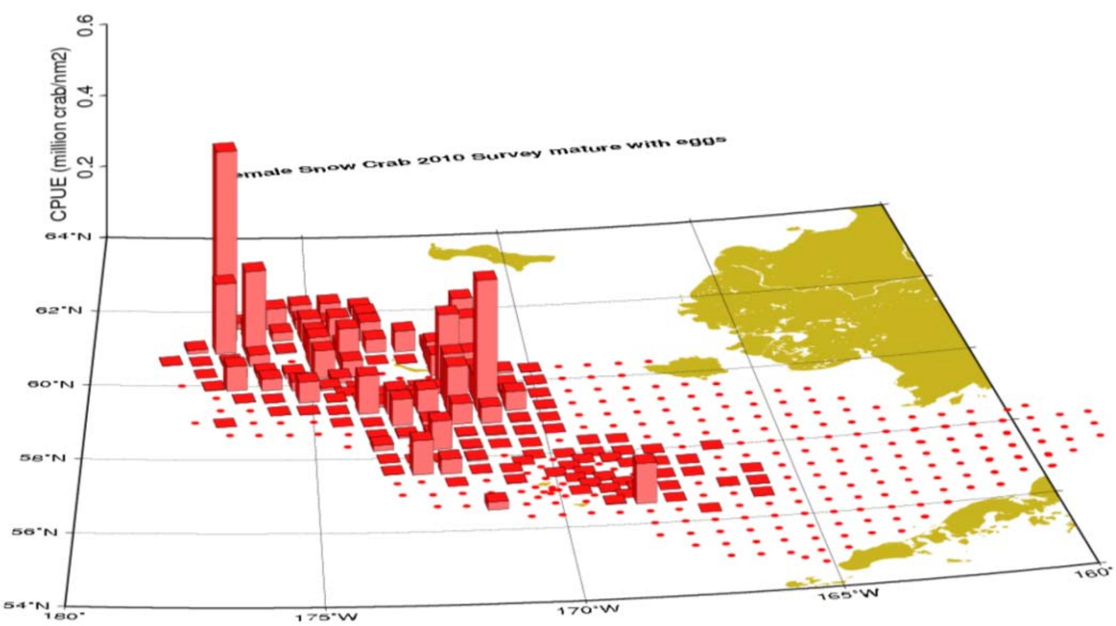


Figure 18. 2010 Survey CPUE (million crab per nm2) of mature females with eggs by tow. Filled circles are tows with 0 cpue.

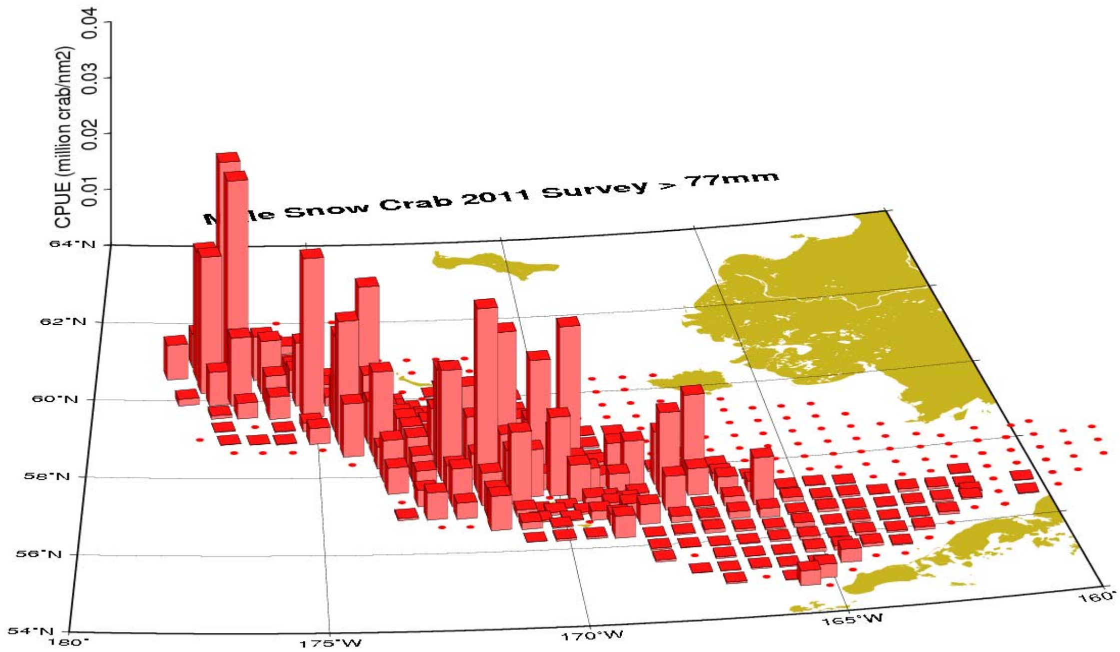


Figure 19. 2011 Survey CPUE (million crab per nm2) of males > 77 mm by tow. Filled circles are tows with 0 cpue

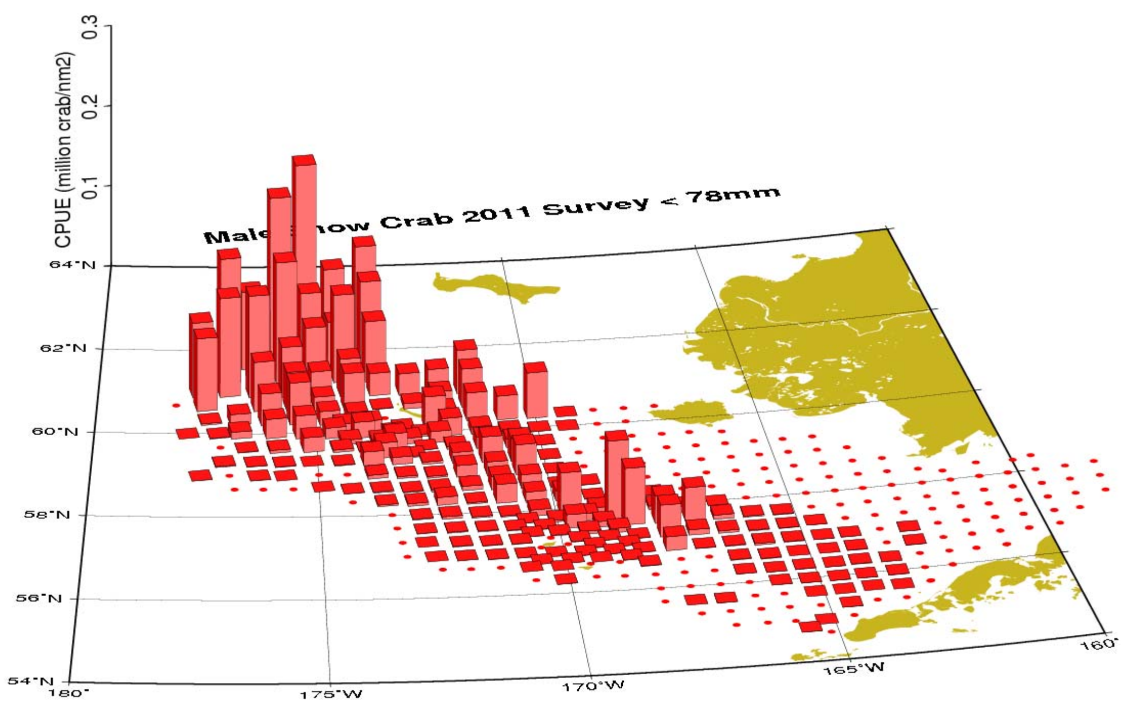


Figure 20. 2011 Survey CPUE (million crab per nm2) of males < 78 mm by tow. Filled circles are tows with 0 cpue

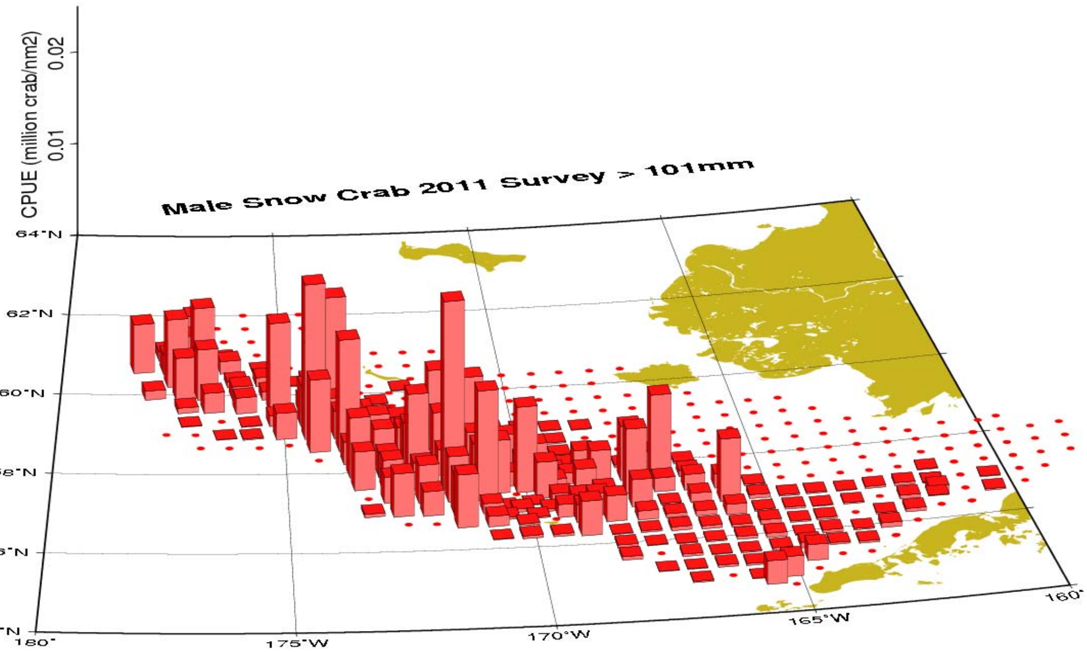


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Figure 21. 2011 Survey CPUE (million crab per nm2) of males > 101 mm by tow. Filled circles are tows with 0 cpue.

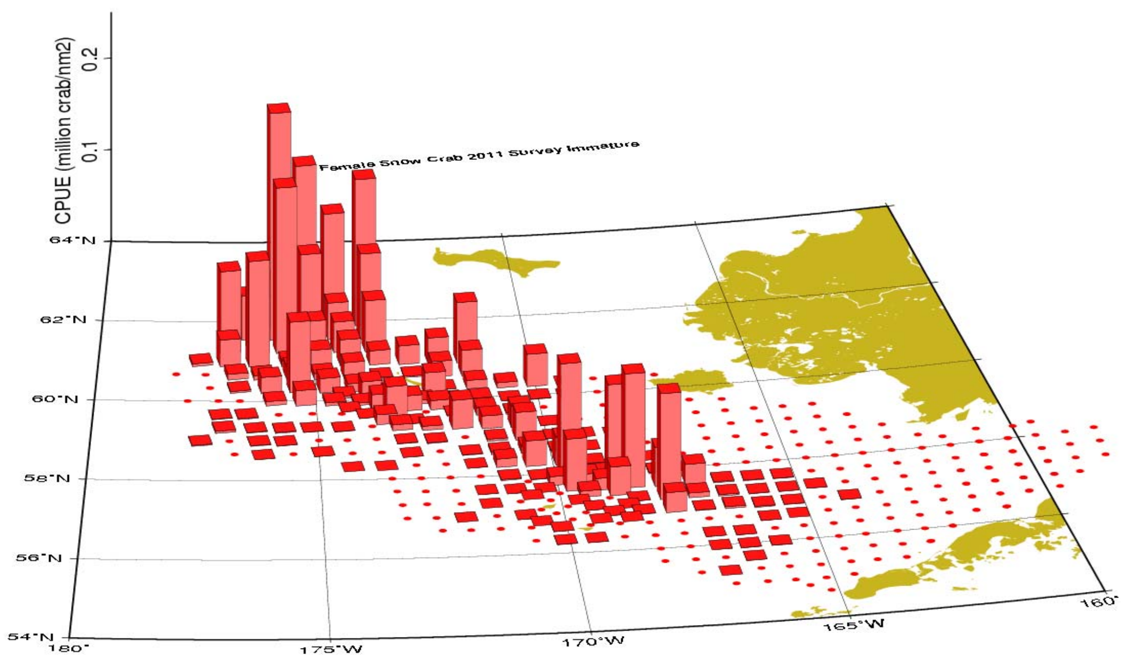


Figure 22. 2011 Survey CPUE (million crab per nm2) of immature females by tow. Filled circles are tows with 0 cpue.

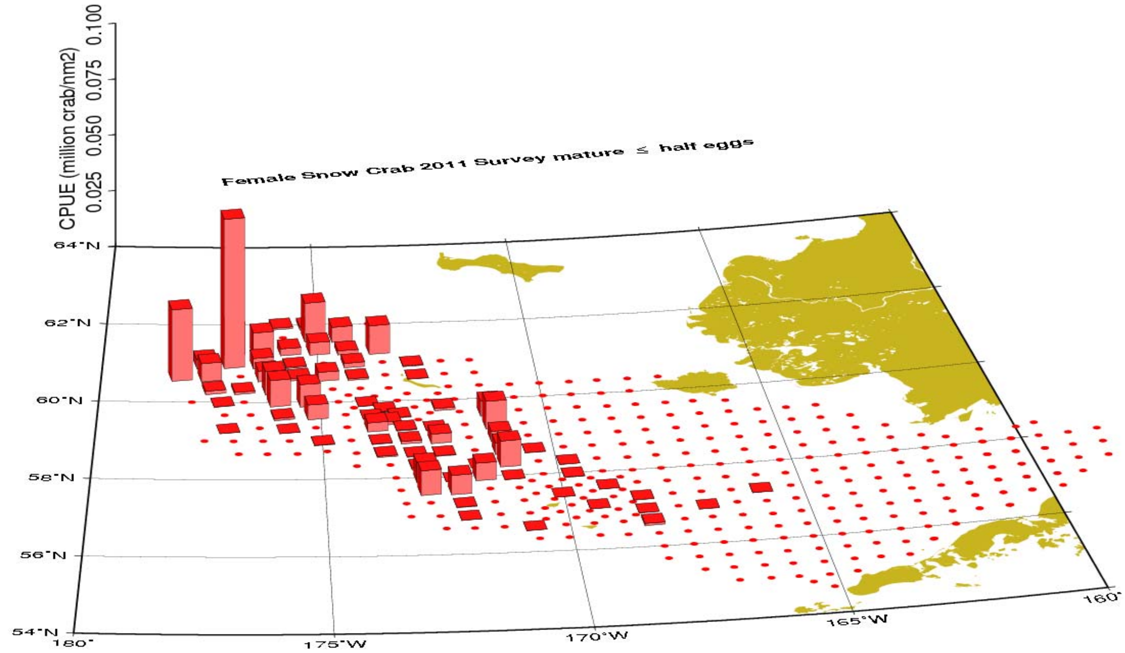


Figure 23. 2011 Survey CPUE (million crab per nm2) of mature females with <= half clutch of eggs by tow. Filled circles are tows with 0 cpue.

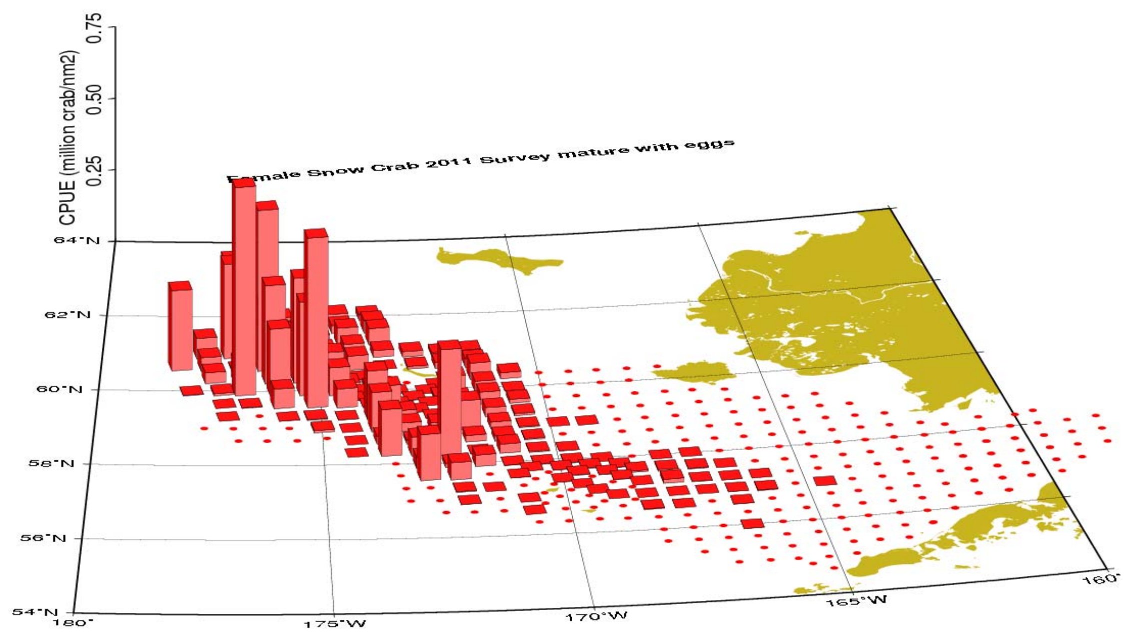


Figure 24. 2011 Survey CPUE (million crab per nm2) of mature females with eggs by tow. Filled circles are tows with 0 cpue.

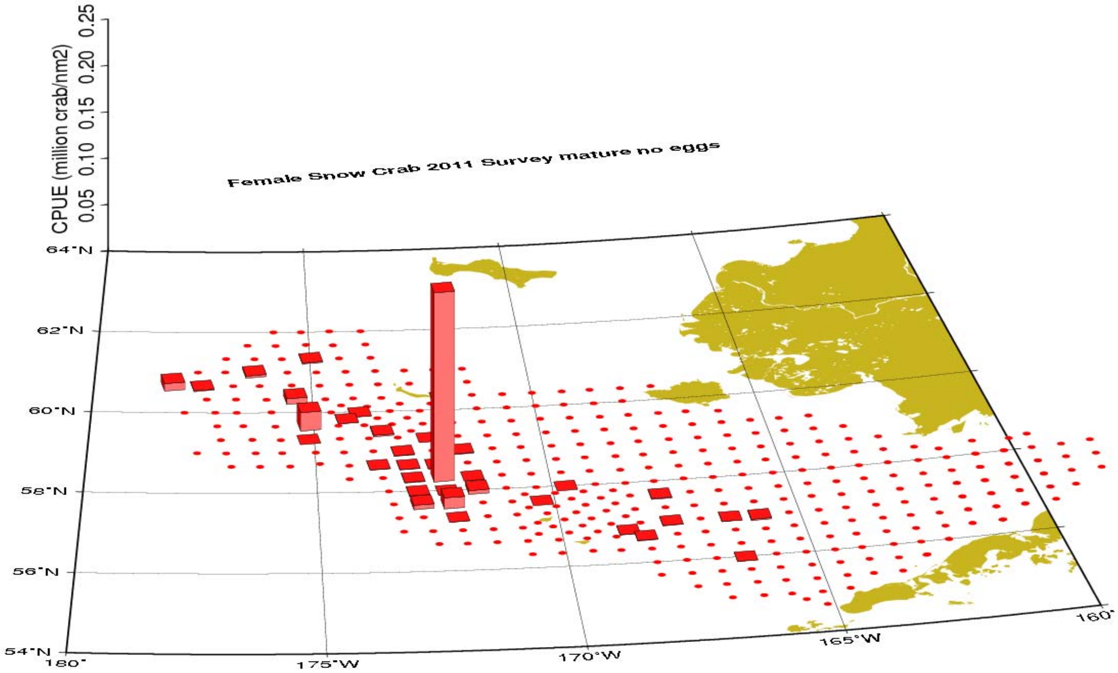


Figure 25. 2011 Survey CPUE (million crab per nm2) of mature females with no eggs by tow. Filled circles are tows with 0 cpue.

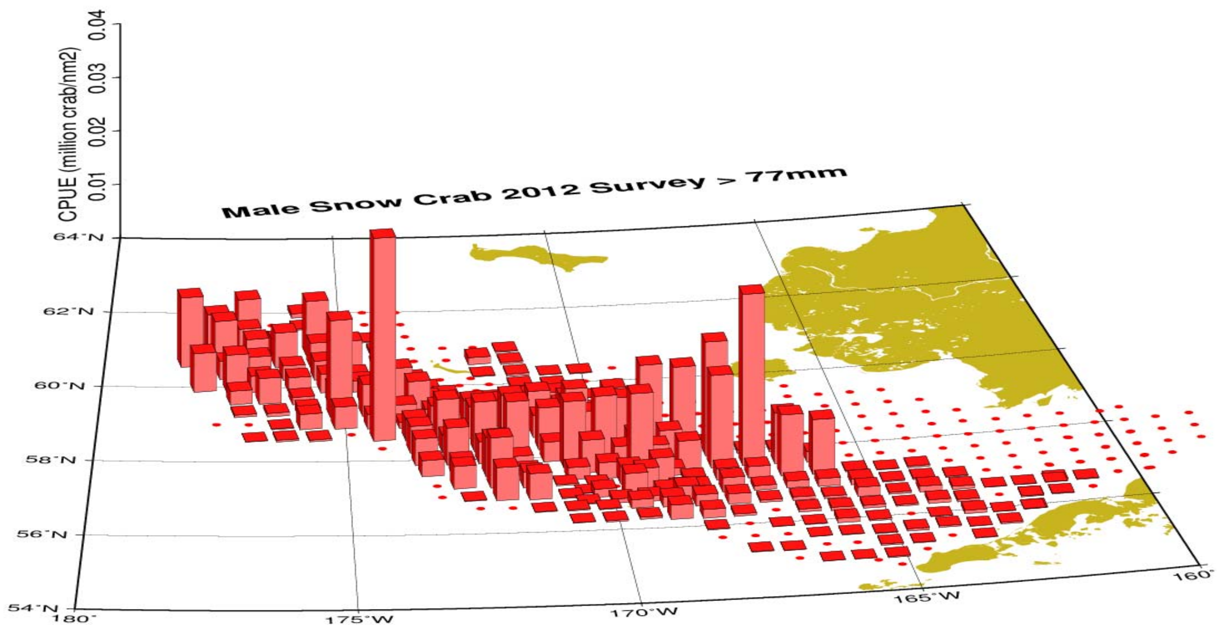


Figure 25b. 2012 Survey CPUE (million crab per nm2) of males > 77 mm by tow. Filled circles are tows with 0 cpue

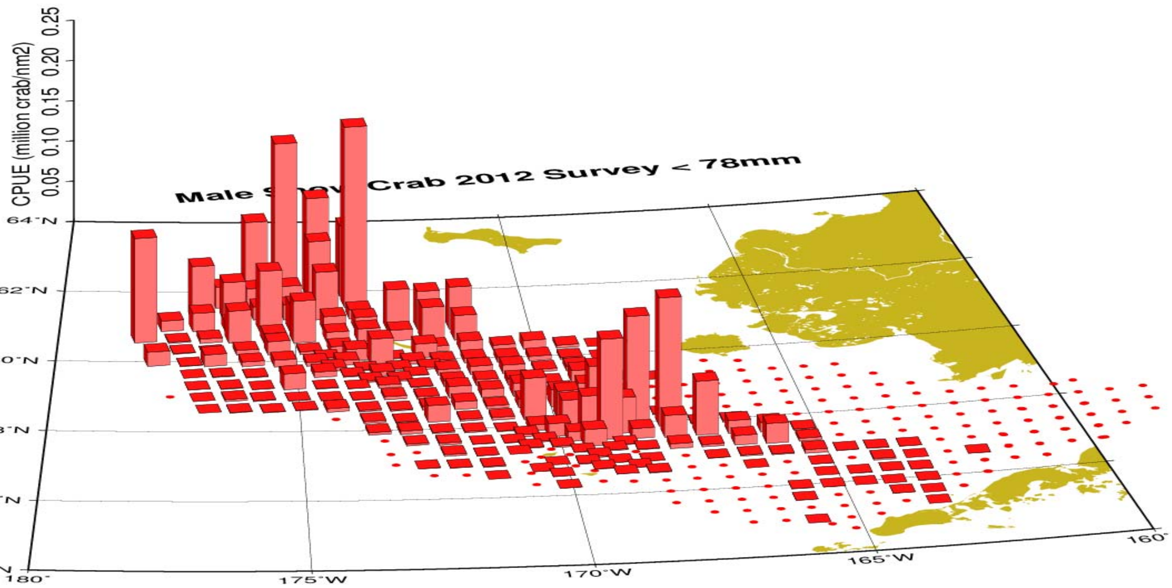


Figure 25c. 2012 Survey CPUE (million crab per nm2) of males < 78 mm by tow. Filled circles are tows with 0 cpue.

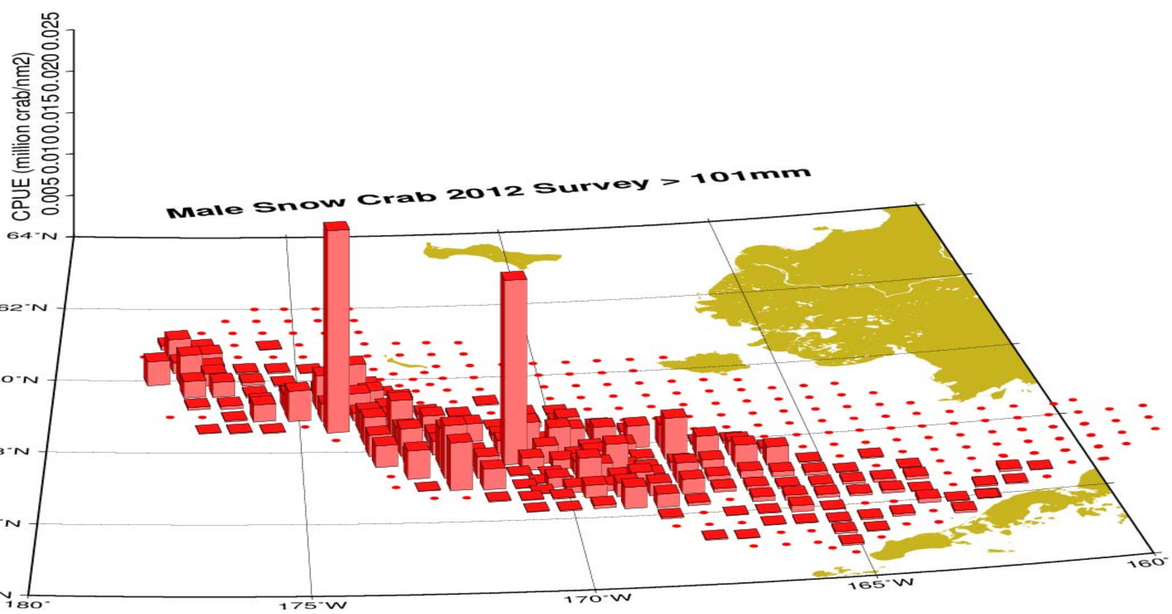


Figure 25d. 2012 Survey CPUE (million crab per nm2) of males > 101 mm by tow. Filled circles are tows with 0 cpue

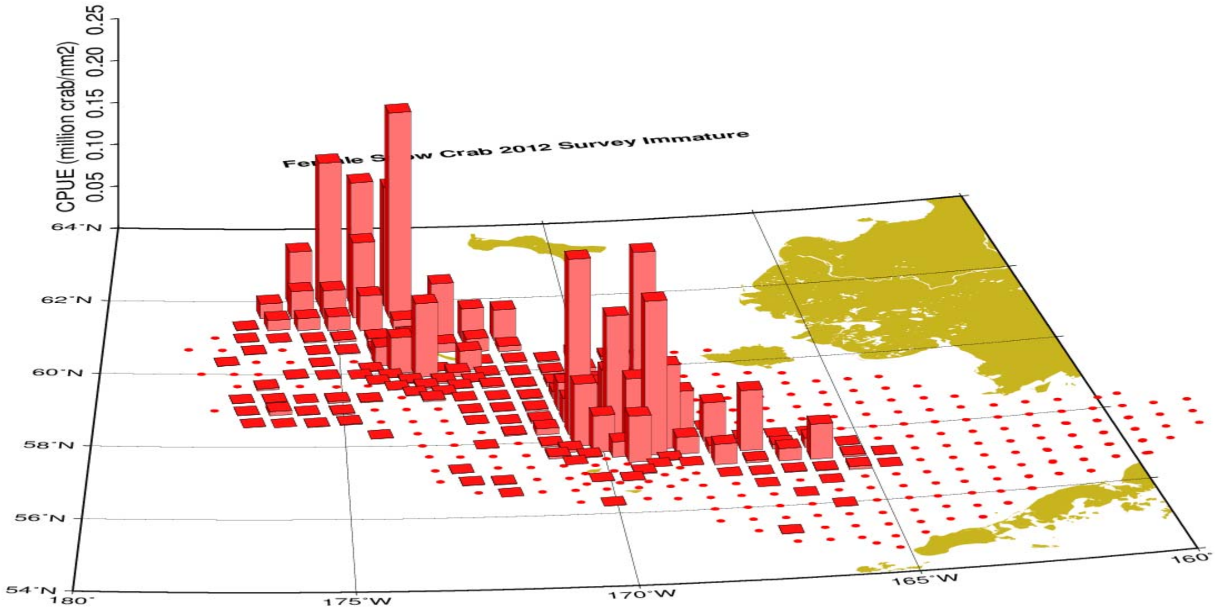


Figure 25e. 2012 Survey CPUE (million crab per nm2) of immature females by tow. Filled circles are tows with 0 cpue

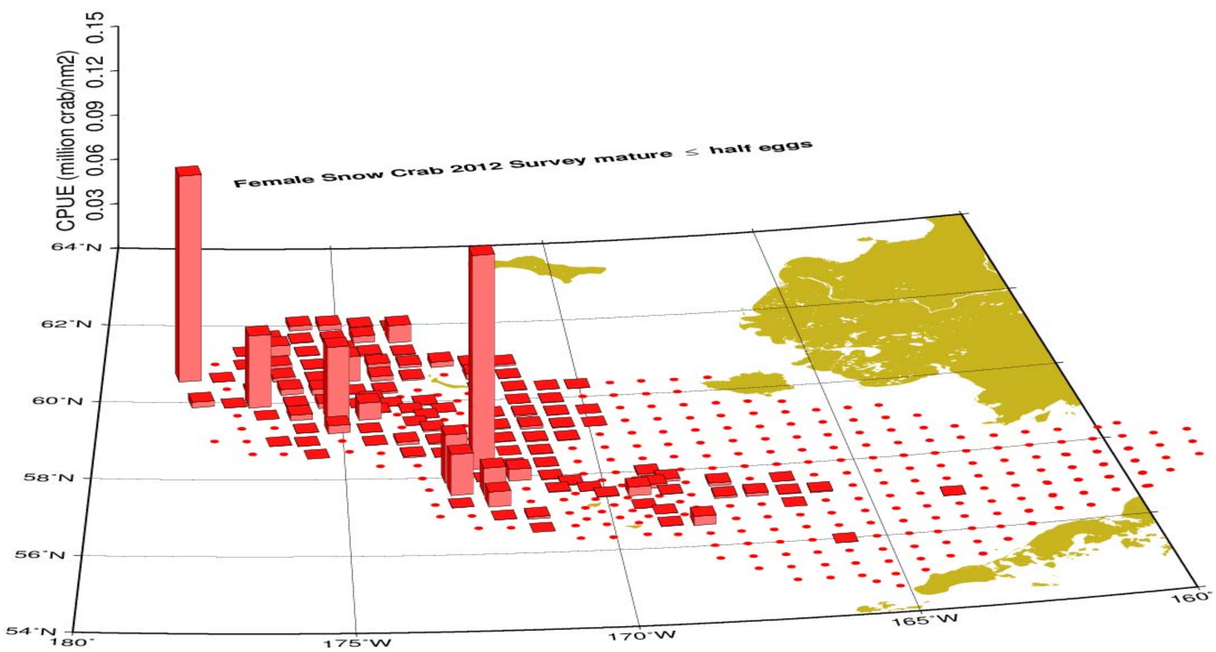


Figure 25f. 2012 Survey CPUE (million crab per nm2) of mature females with <= half clutch of eggs by tow. Filled circles are tows with 0 cpue.

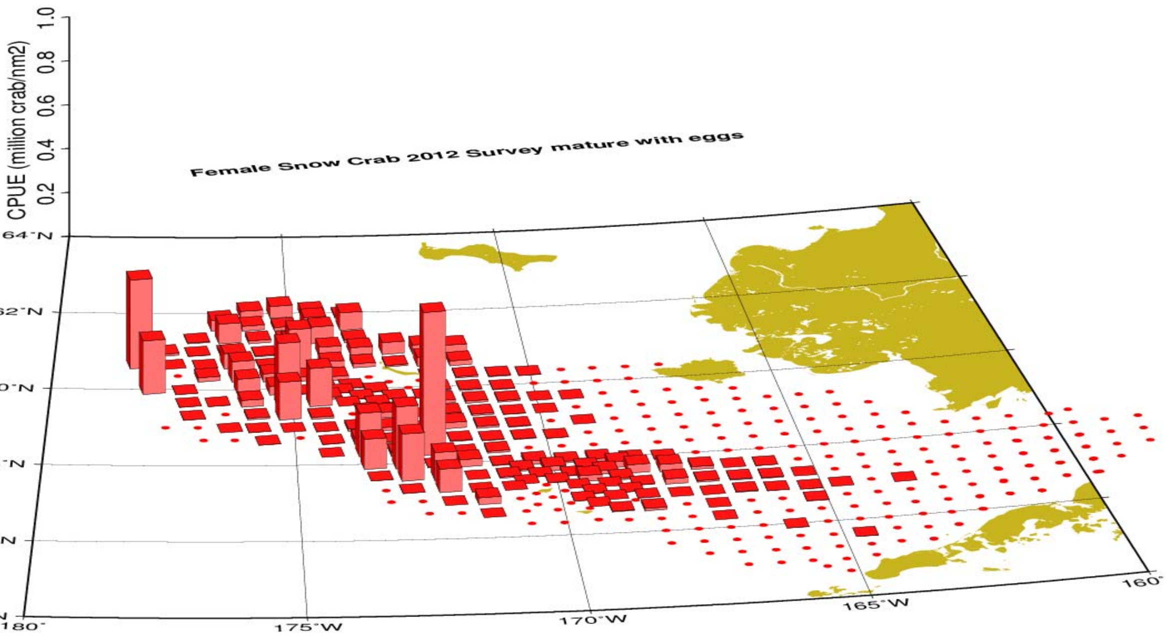


Figure 25g. 2012 Survey CPUE (million crab per nm2) of mature females with eggs by tow. Filled circles are tows with 0 cpue.

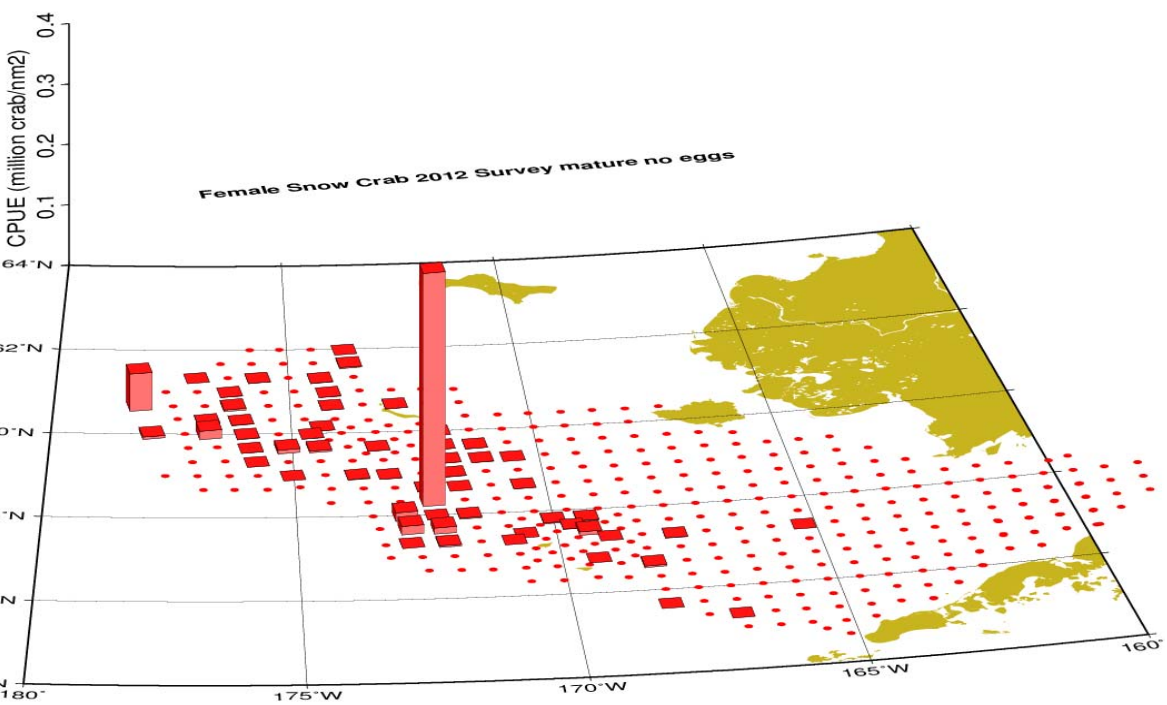


Figure 25h. 2012 Survey CPUE (million crab per nm2) of mature females with no eggs by tow. Filled circles are tows with 0 cpue.

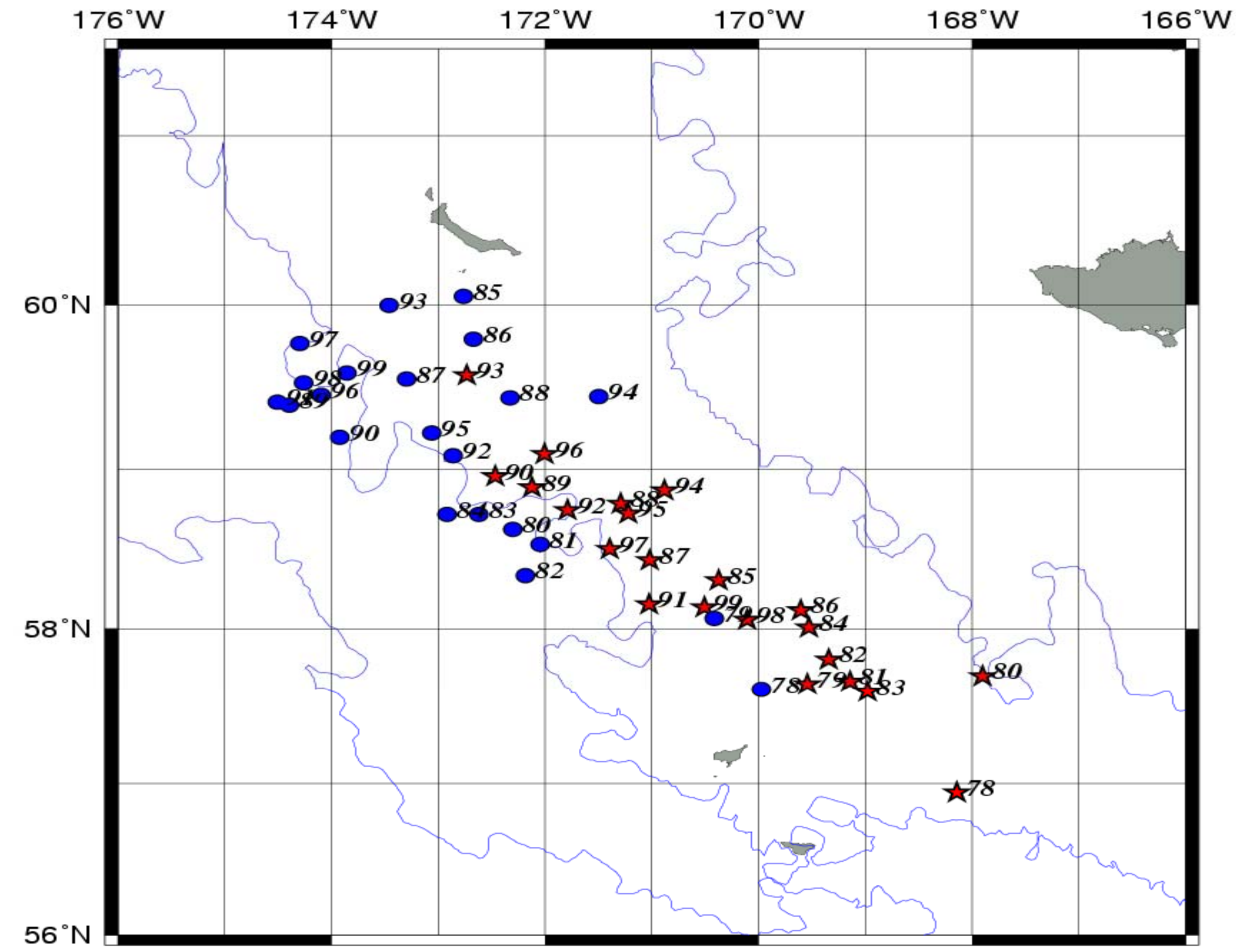


Figure 26. Centroids of abundance of mature female snow crabs (shell condition 2+) in blue circles and mature males (shell condition 3+) in red stars (Ernst, et al. 2005).

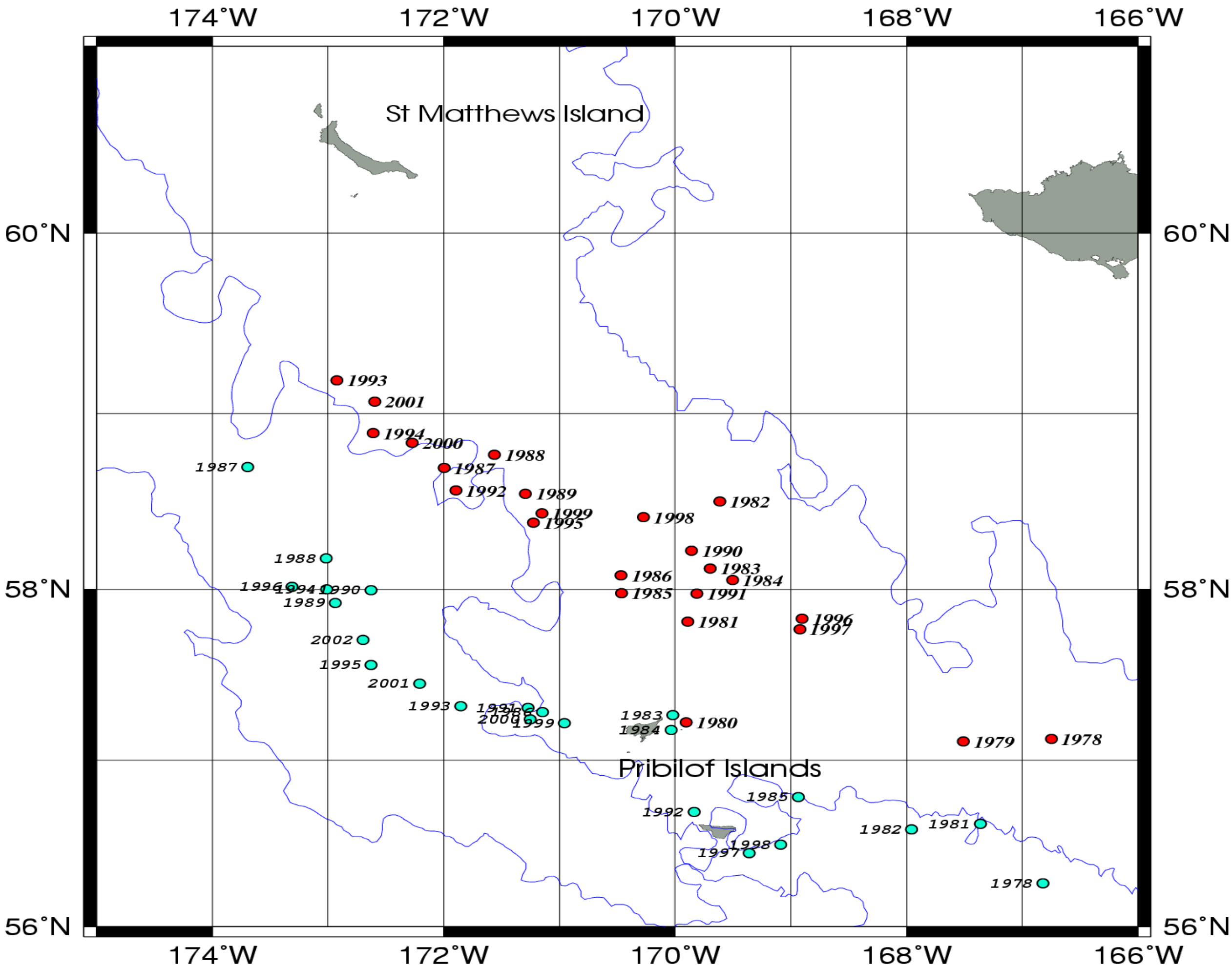


Figure 27. Centroids abundance (numbers) of snow crab males > 101 mm from the summer NMFS trawl survey (red) and from the winter fishery (blue-green) (Ernst, et al. 2005).

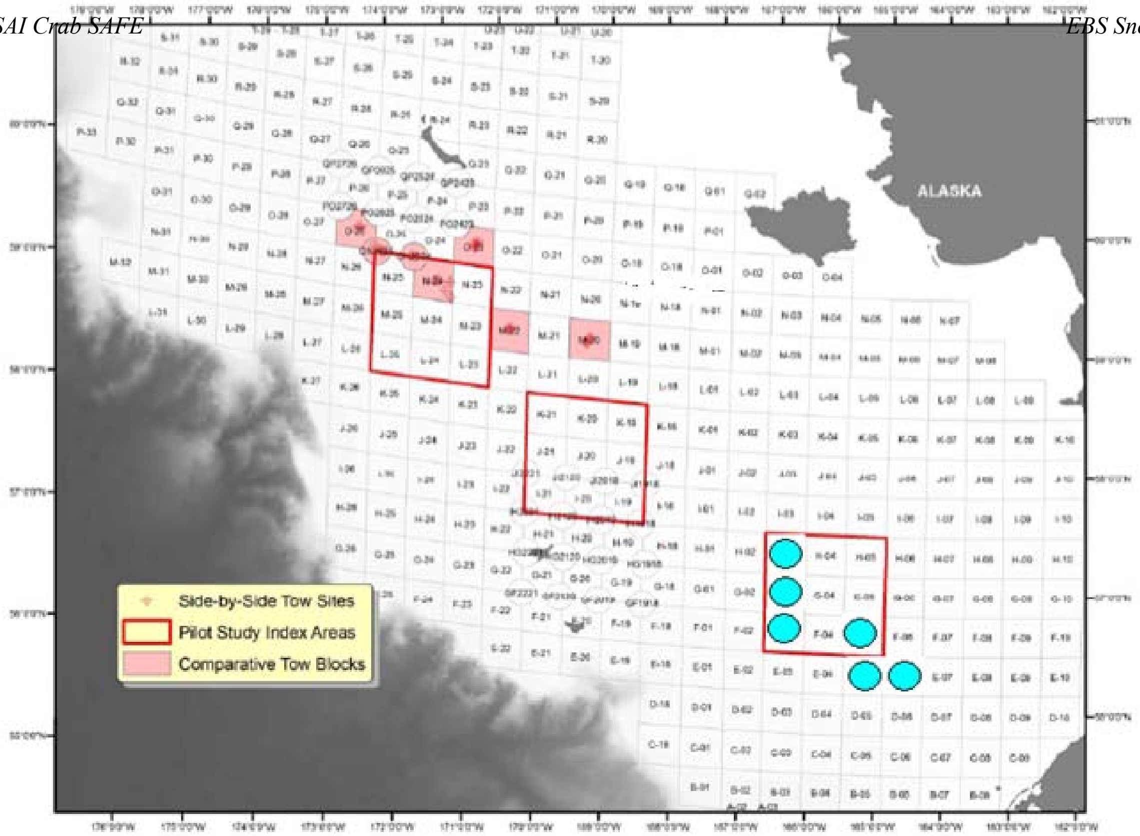


Figure 28. Location of the side-by-side trawling areas (shown with pink shading) and the 3 BSFRF survey areas encompassing the 27 NMFS survey blocks (shown with a red line). Location of the 1998 auxiliary bag experiment sampling areas are the blue circles.

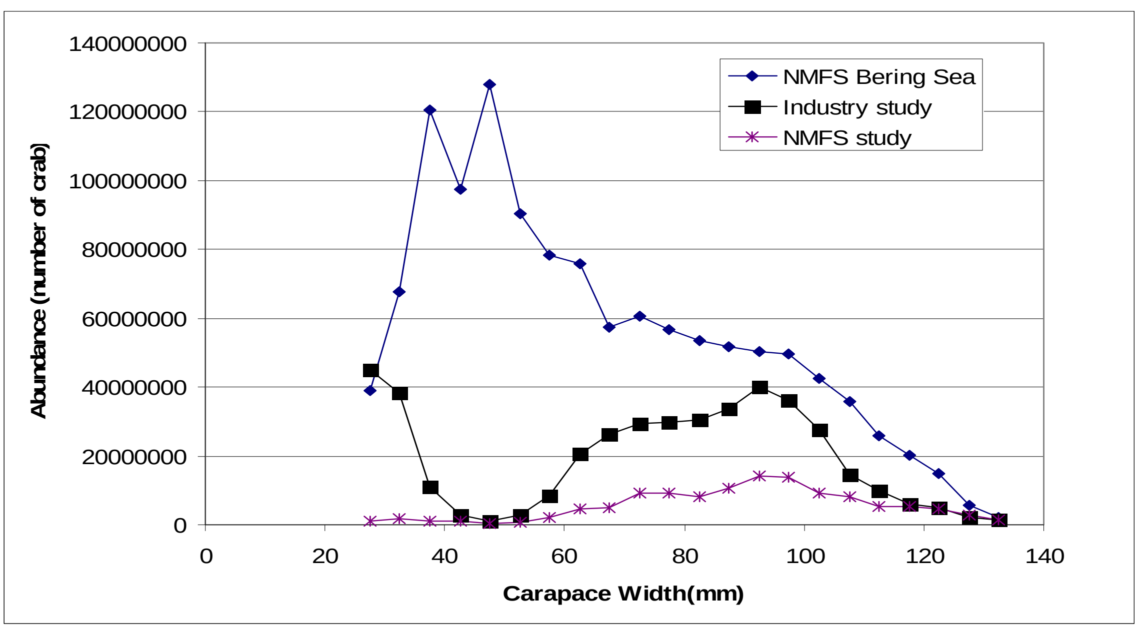


Figure 29. Abundance estimates of male snow crab by 5 mm carapace width(>=25mm) for the NMFS survey of the entire Bering Sea survey area (NMFS Bering Sea), the BSFRF net in the study area (108 tows) and the NMFS survey in the 2009 study area.

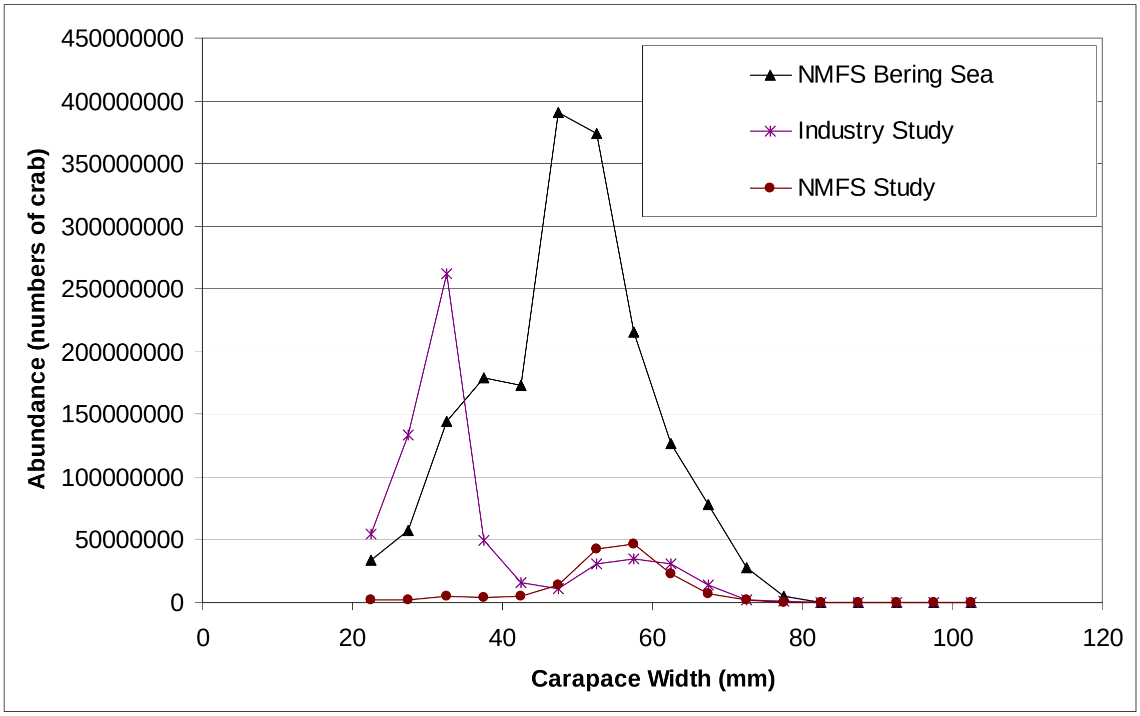


Figure 30. Abundance estimates of female snow crab by 5 mm carapace width for the NMFS survey of the entire Bering Sea survey area (NMFS Bering Sea), the BSFRF net in the study area (108 tows) and the NMFS survey in the 2009 study area.

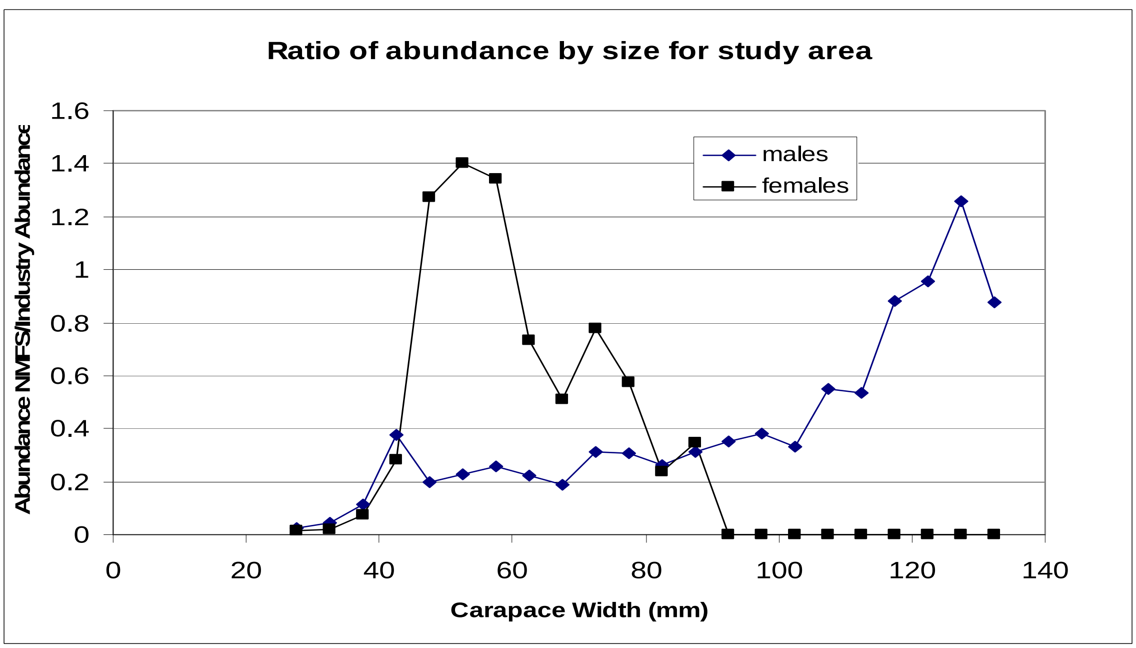


Figure 31. Ratio of abundance in the 2009 study area from the NMFS net to the BSFRF net for male and female crab.

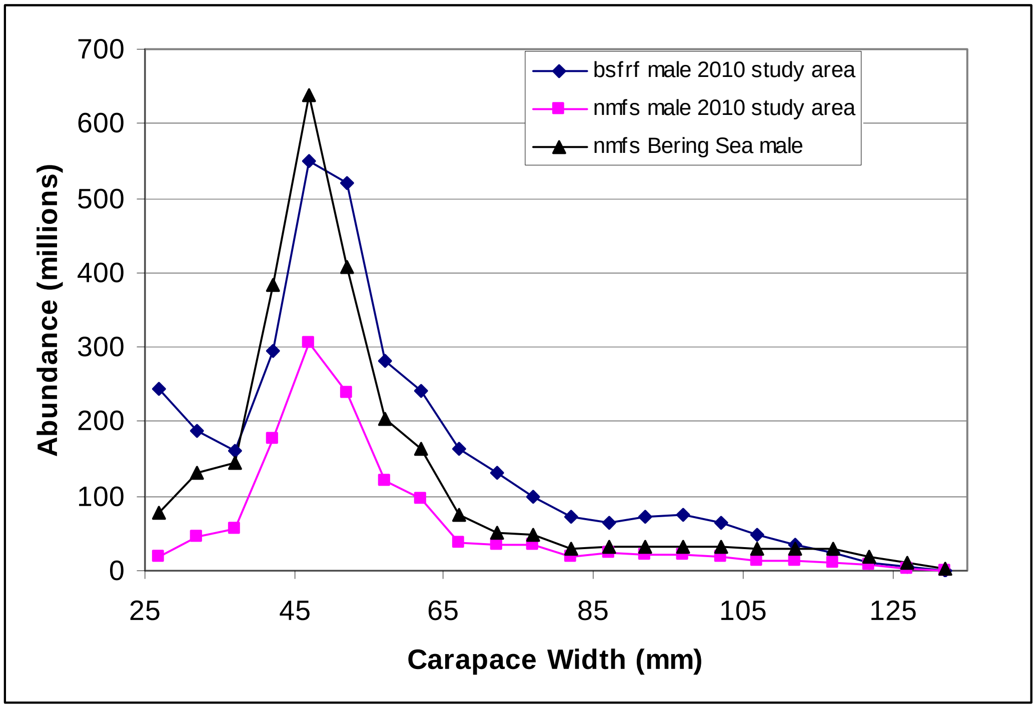


Figure 32. 2010 study area Male abundance.

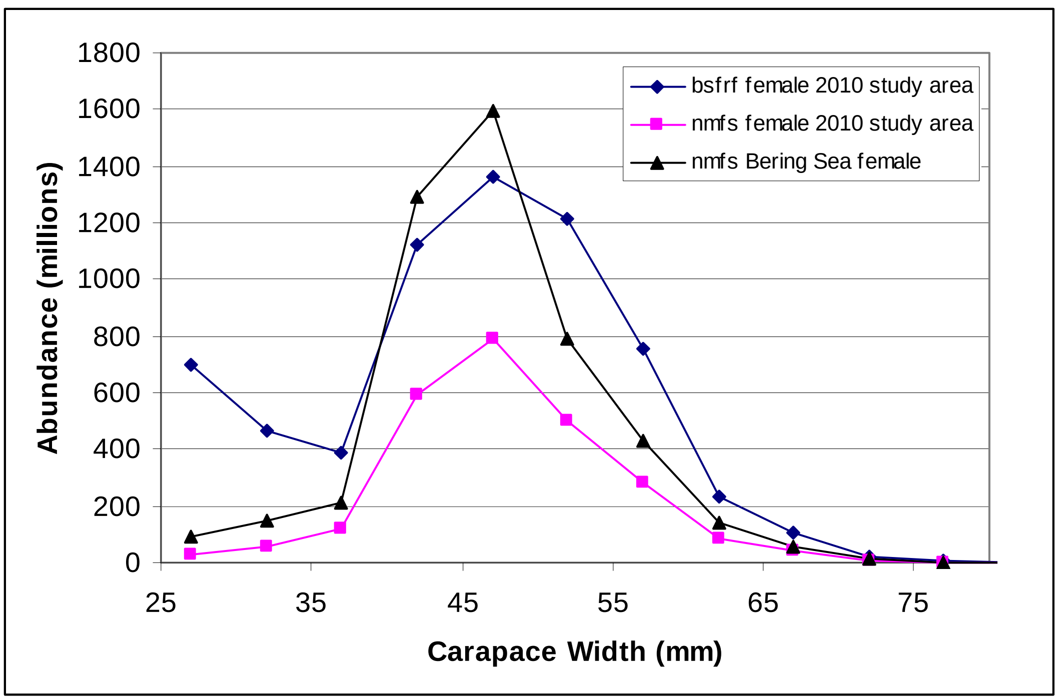


Figure 33. 2010 study area Female abundance.

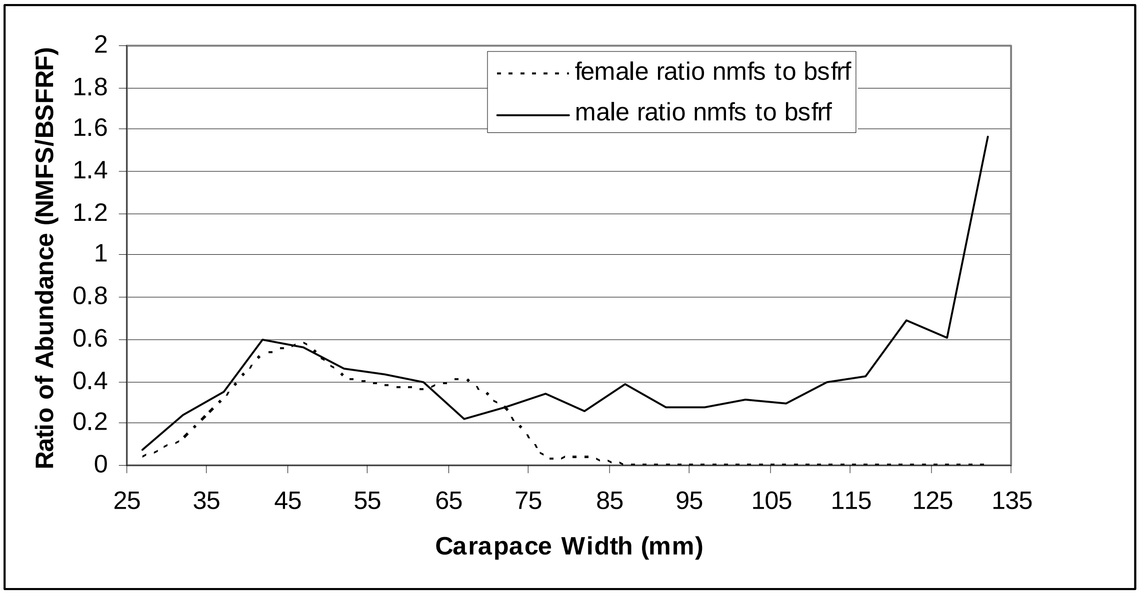


Figure 34. 2010 study area ratio of abundance

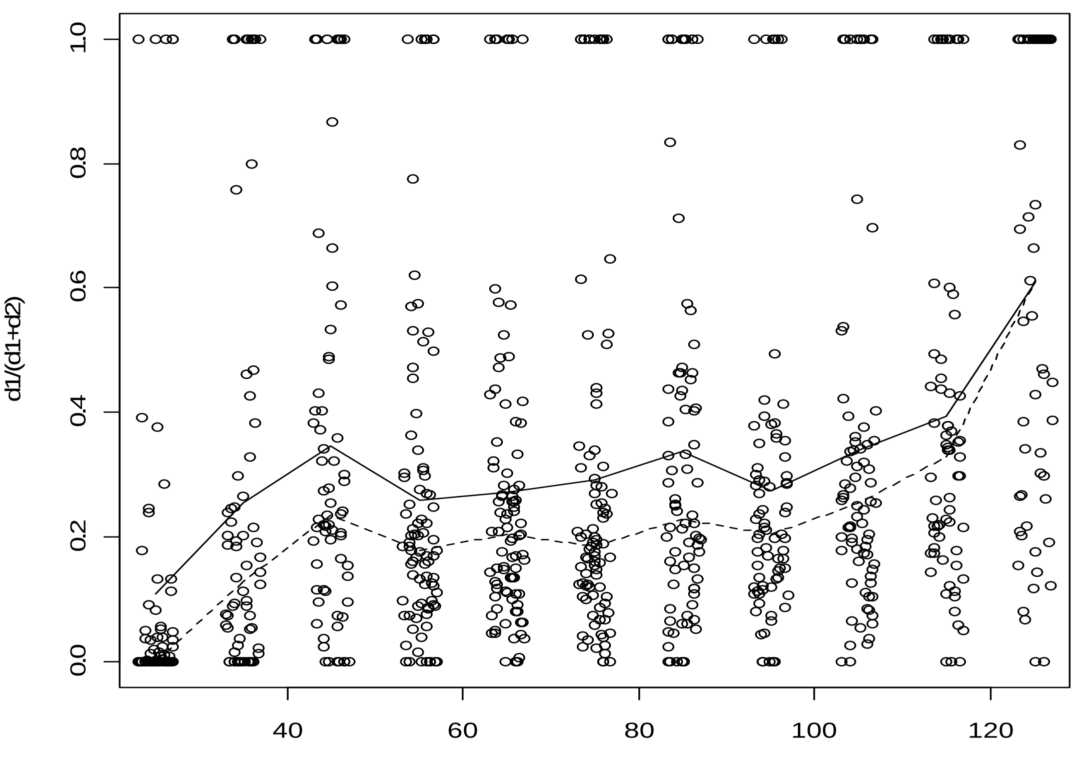


Figure 35. Male crab. Density (catch/nm2) of NMFS tow (d1) divided by sum of density (d2 is density of BSFRF tow). Solid line is unweighted mean, dotted line median of each length bin. A value of 0.5 is equal density (d1=d2). Length values are jittered to show multiple 1.0 and 0.0 data.

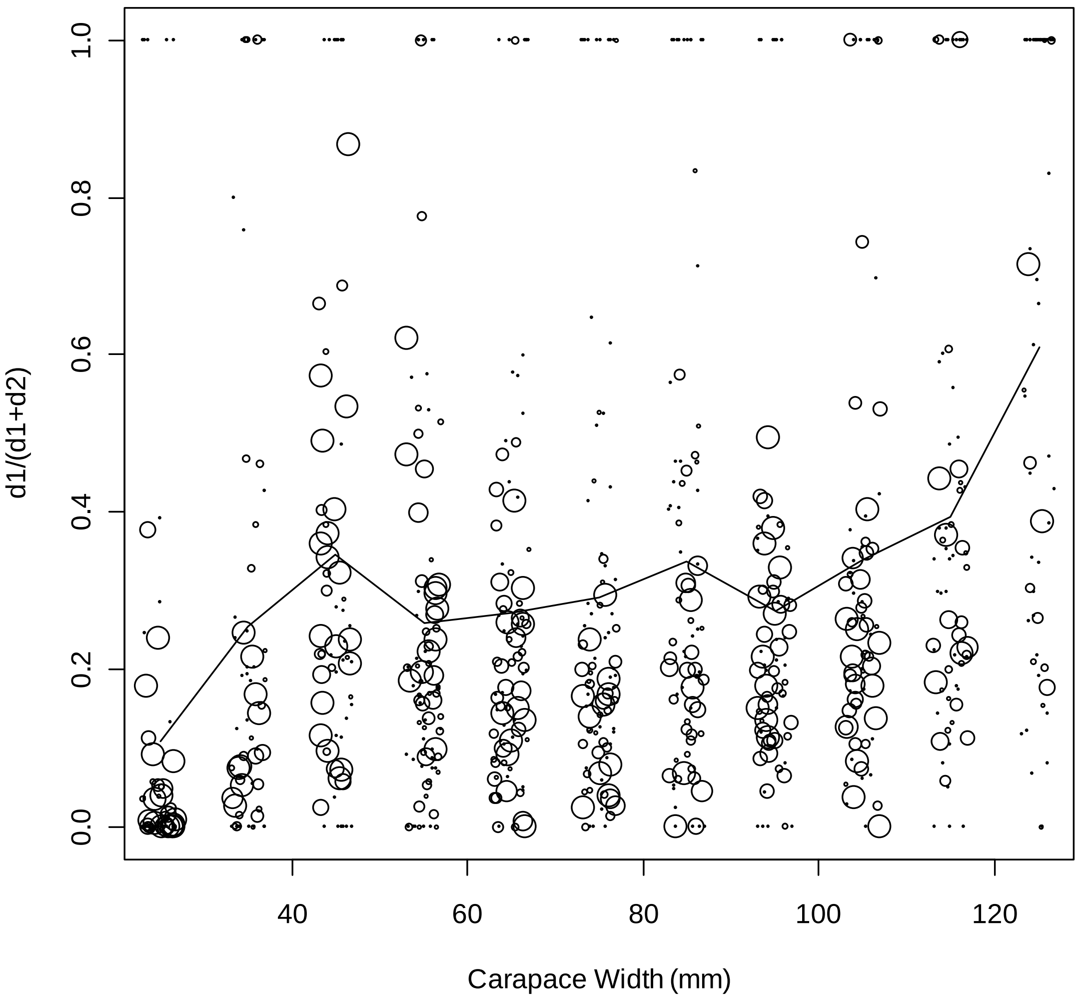


Figure 36. Density of NMFS tow (d1) divided by the sum of the density of the NMFS tow (d1) and the Industry tow (d2). The radius of the circle at each point is proportional to the sum of the catch in numbers where the Industry numbers are adjusted by the ratio of the NMFS area swept to the Industry area swept. The line is the unweighted mean values of d1/(d1+d2) in each size bin.

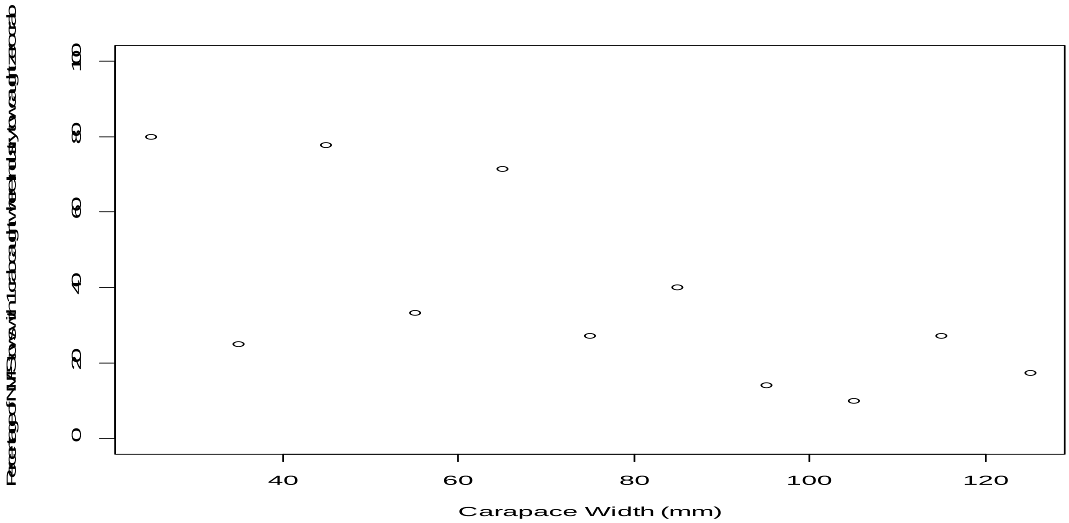


Figure 37. Percentage of paired tows where BSFRF caught no crab and NMFS caught only 1 crab.

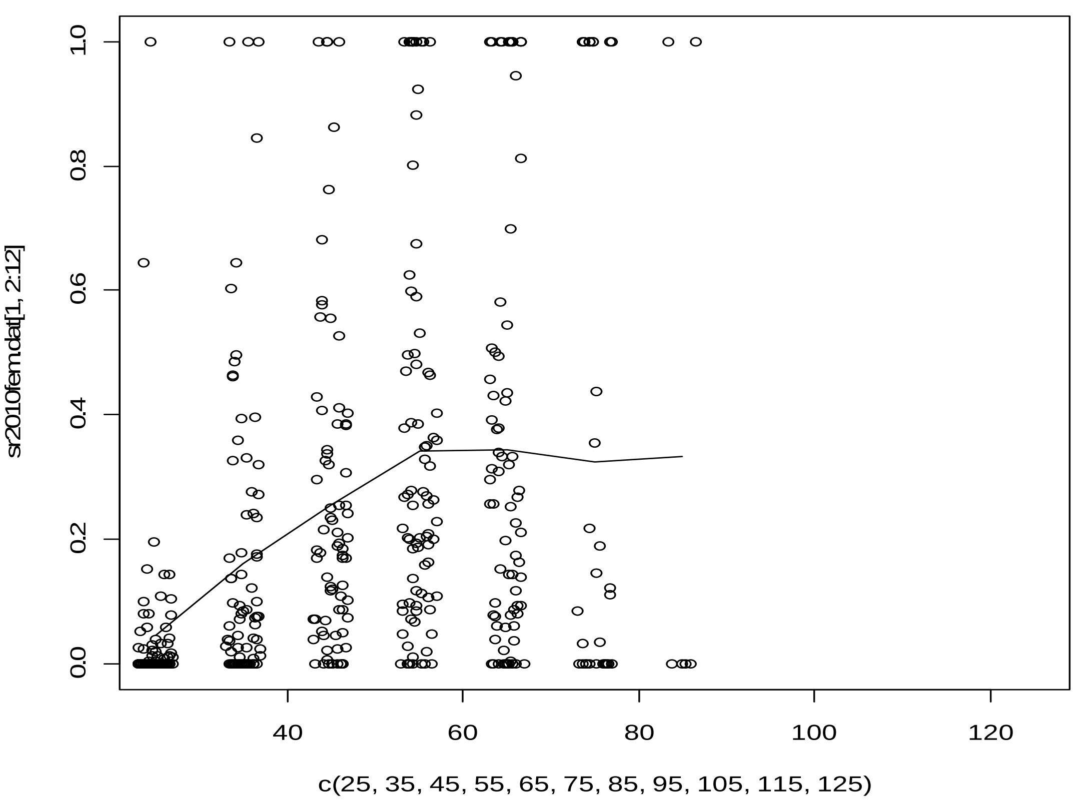


Figure 38. Female d1/(d1+d2) with mean. Density (catch/nm2) of NMFS tow (d1) divided by sum of density (d2 is density of BSFRF tow). Solid line is mean, dotted line median of each length bin. A value of 0.5 is equal density (d1=d2). Length values are jittered to show multiple 1.0 and 0.0 data.

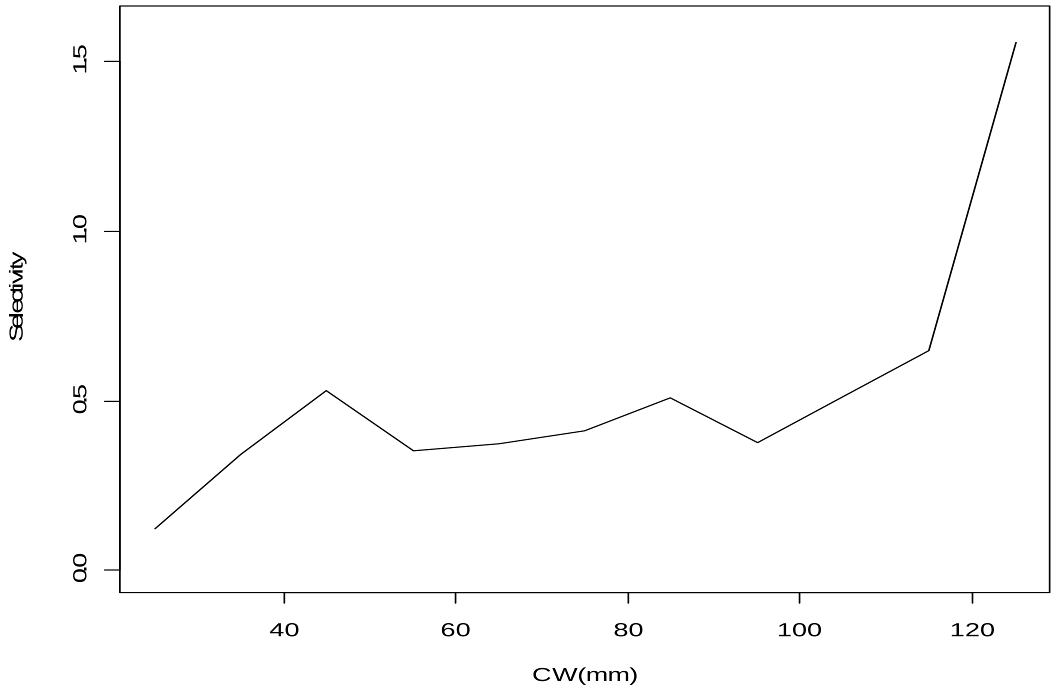


Figure 39. Mean from Figure 9 translated to selectivity (selectivity = p/(1-p), where p= d1/(d1+d2)).

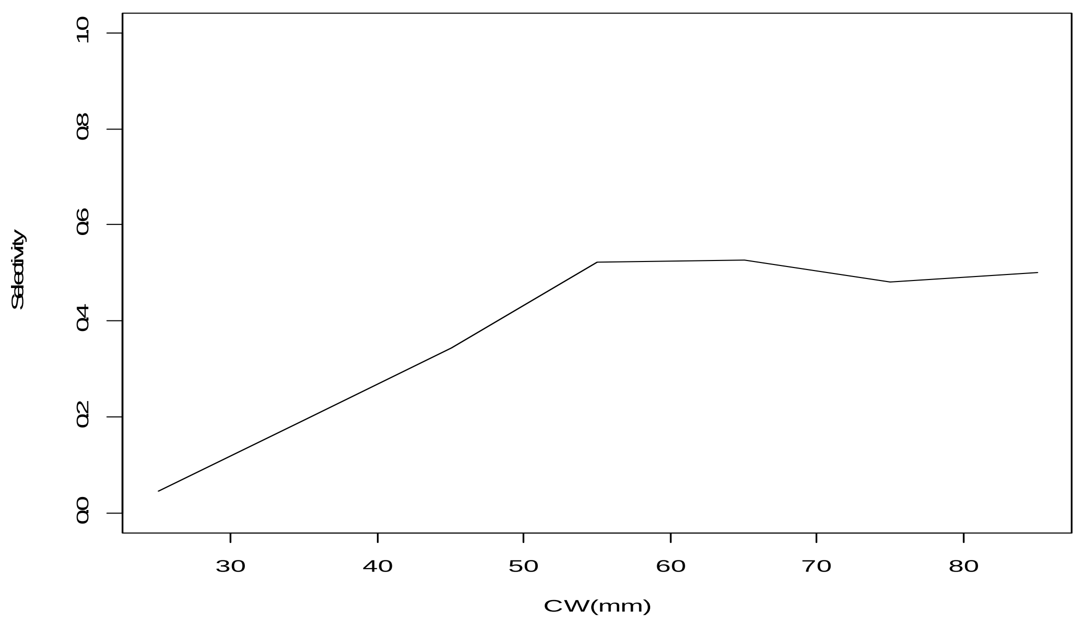


Figure 40. Mean from Figure 38, female crab translated to selectivity (selectivity = p/(1-p), where p= d1/(d1+d2))

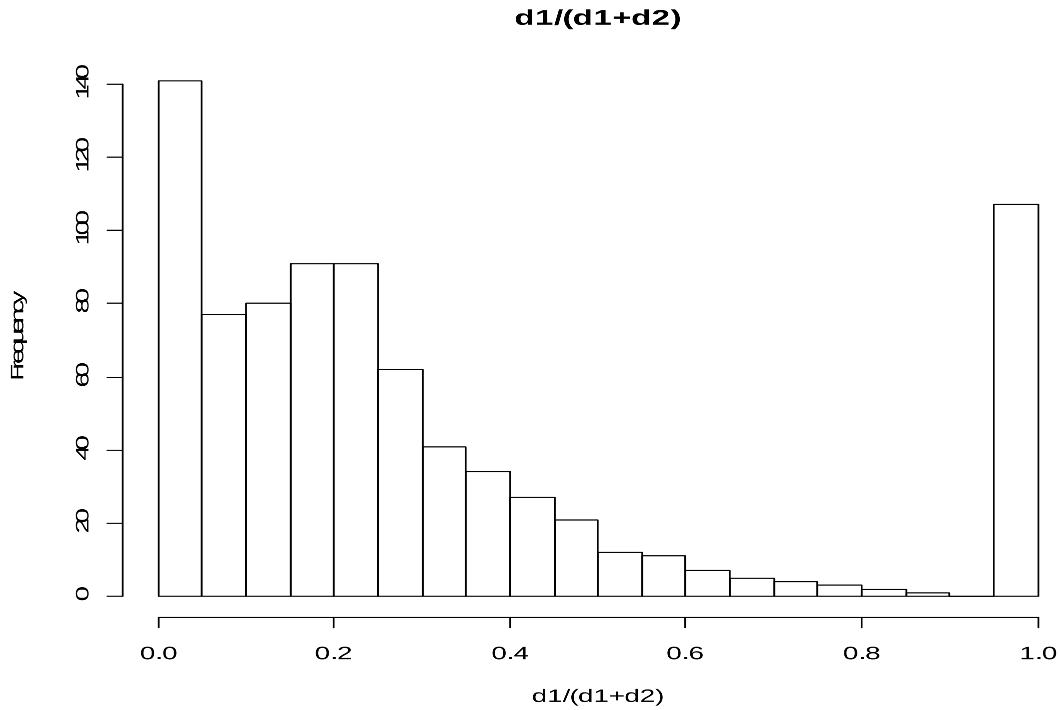


Figure 41. Histogram of d1/(d1+d2) over all sizes and tows. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

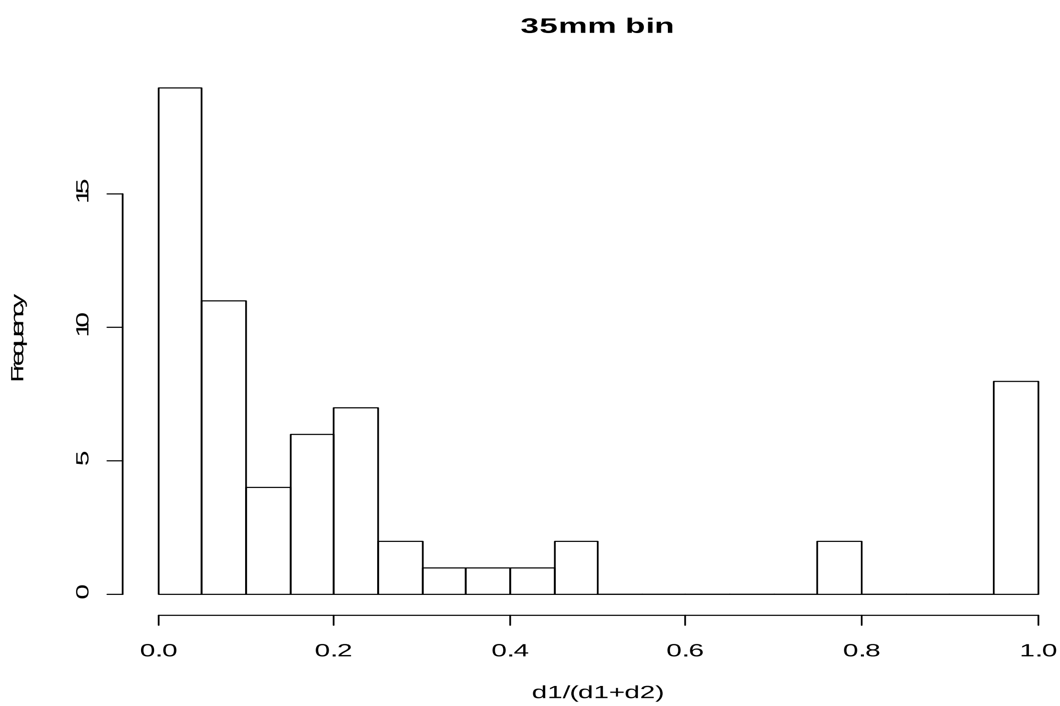


Figure 42. Histogram of d1/(d1+d2) for the 30 to 40 mm size bin. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

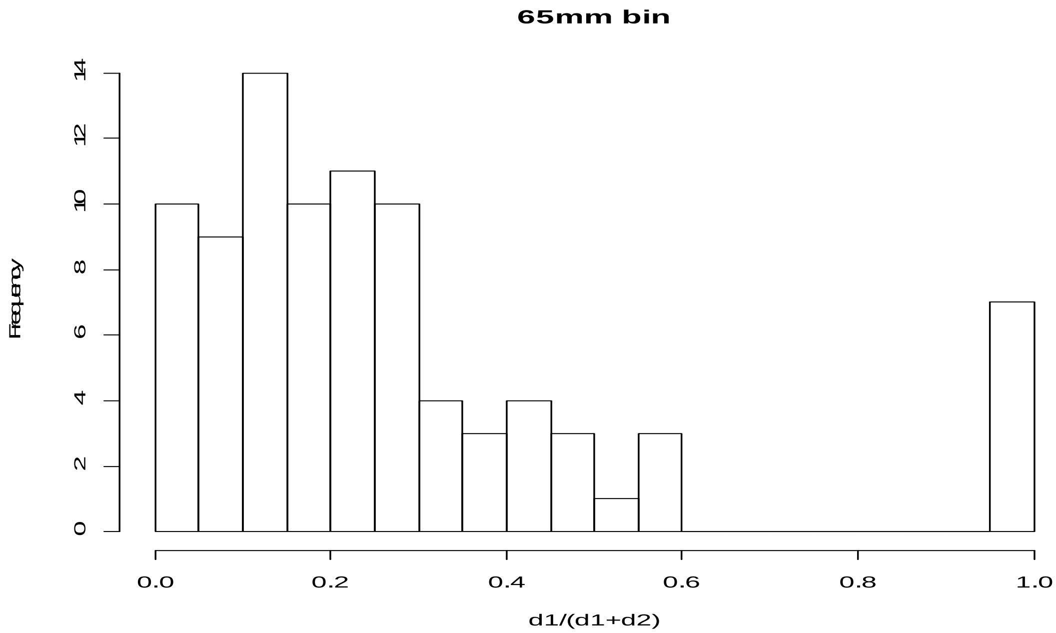


Figure 43. Histogram of d1/(d1+d2) for the 60 to 70 mm size bin. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

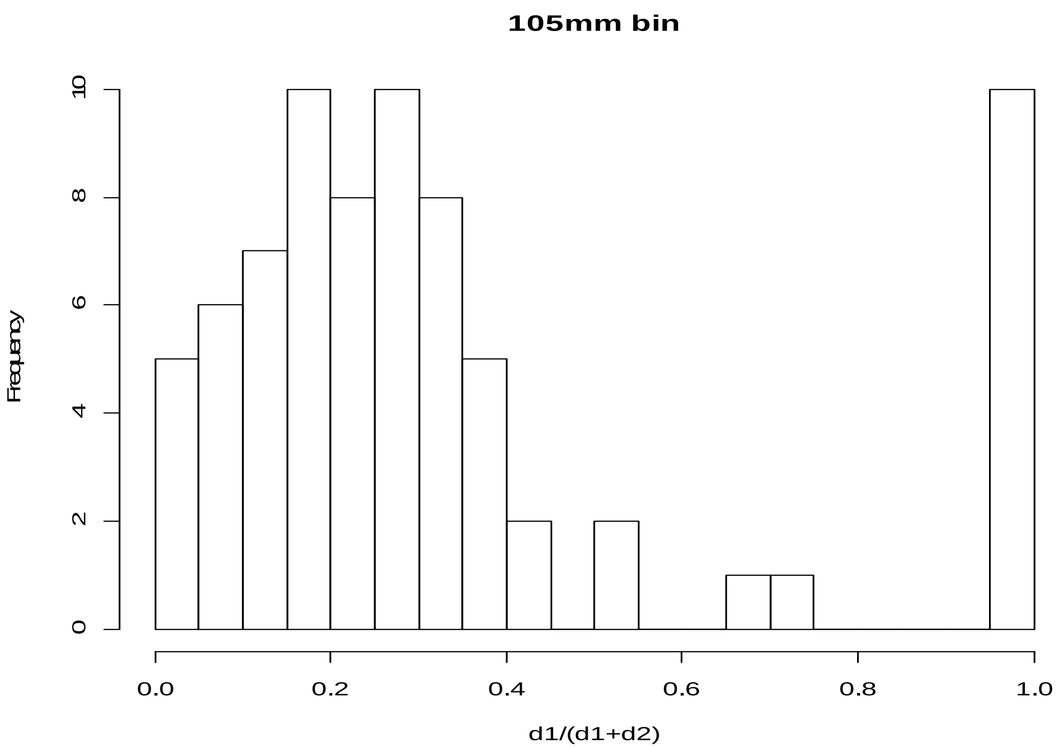


Figure 44. Histogram of d1/(d1+d2) for the 100 to 110 mm size bin. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

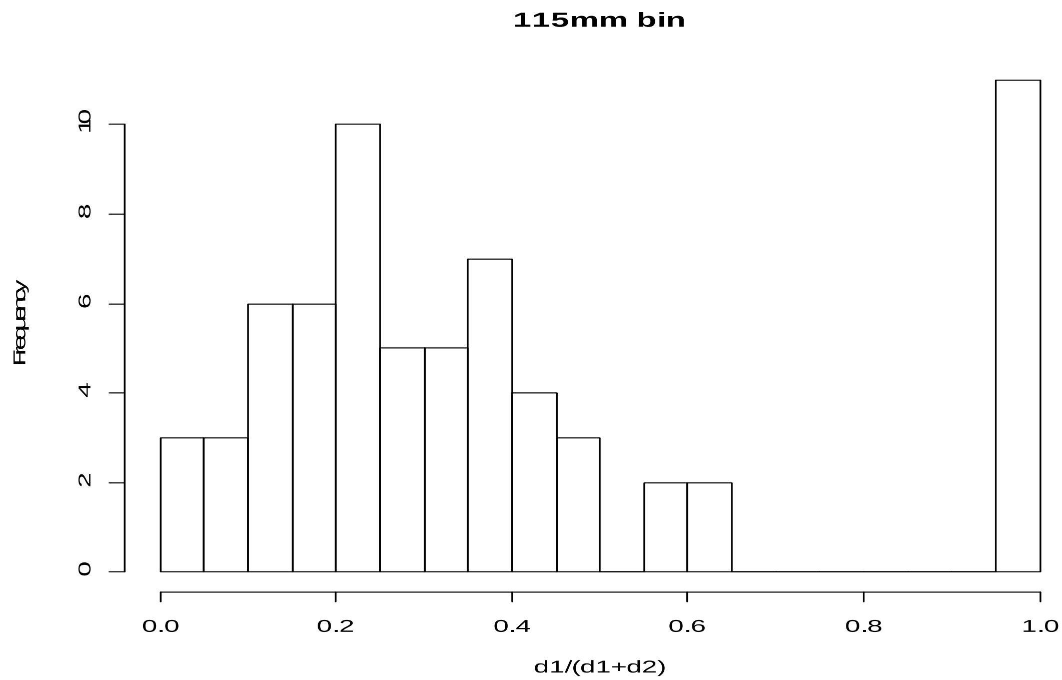


Figure 45. Histogram of d1/(d1+d2) for the 100 to 120 mm size bin. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

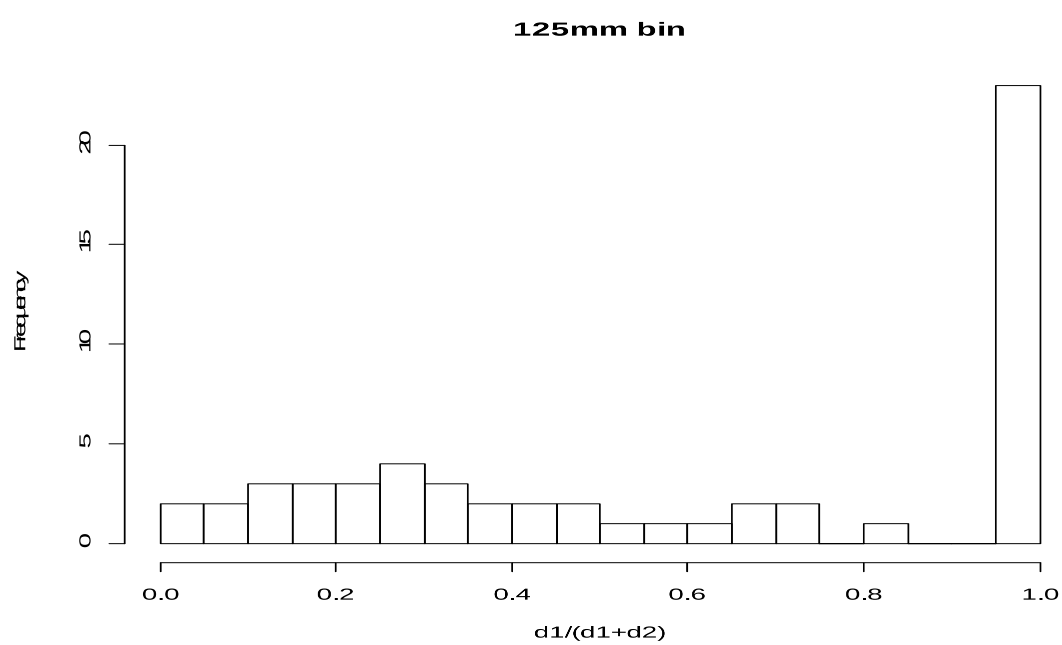


Figure 46. Histogram of d1/(d1+d2) for the 120+mm size bin. A value of 1.0 is a positive catch in the NMFS tow and a zero catch in the BSFRF tow. A value of 0.0 is a 0 catch in the NMFS tow and a positive catch in the BSRFR tow.

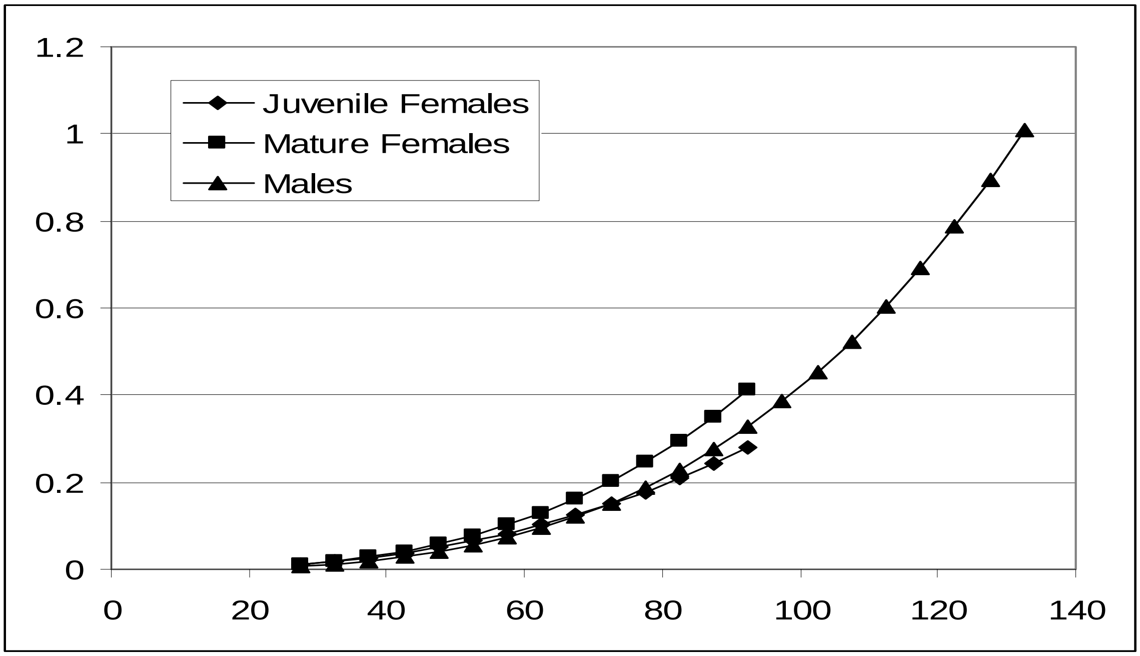


**Figure 47. Weight (kg) – size (mm) relationship for male, juvenile female and mature female snow crab.**

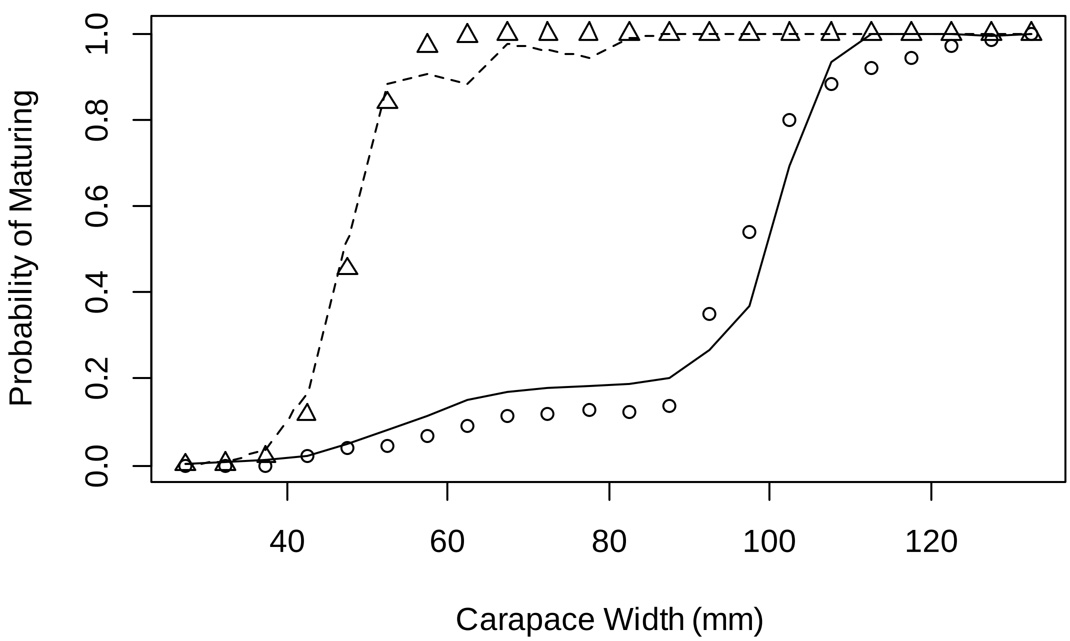


**Figure 48. Probability of maturing by size estimated in the model for male(solid line) and female (dashed line) snow crab (<u>not</u> the average fraction mature). Triangles are values for females used in the 2009 assessment. Circles are values for males used in the 2009 assessment.**

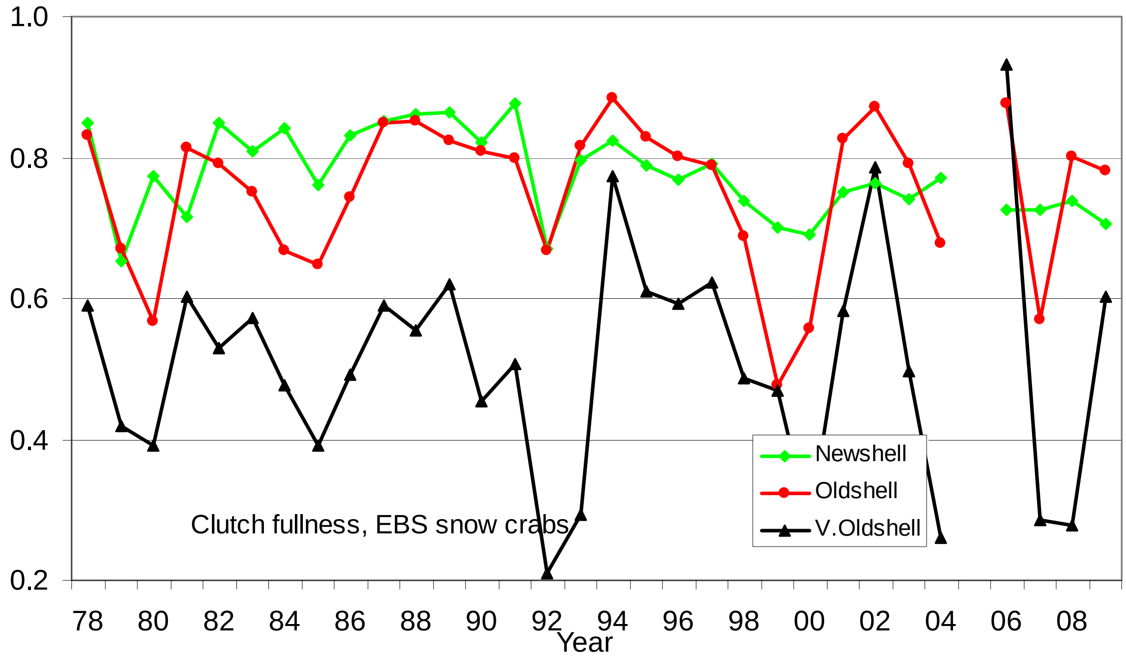


Figure 49. Clutch fullness for Bering Sea snow crab survey data by shell condition for 1978 to 2009.

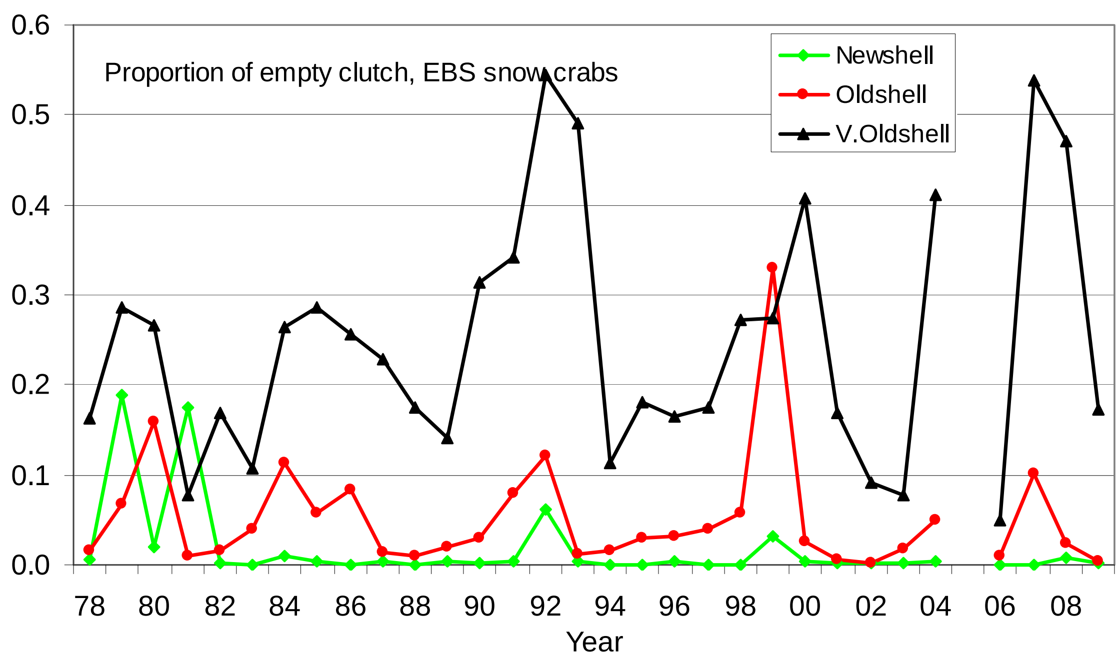


Figure 50. Proportion of barren females by shell condition from survey data 1978 to 2009.

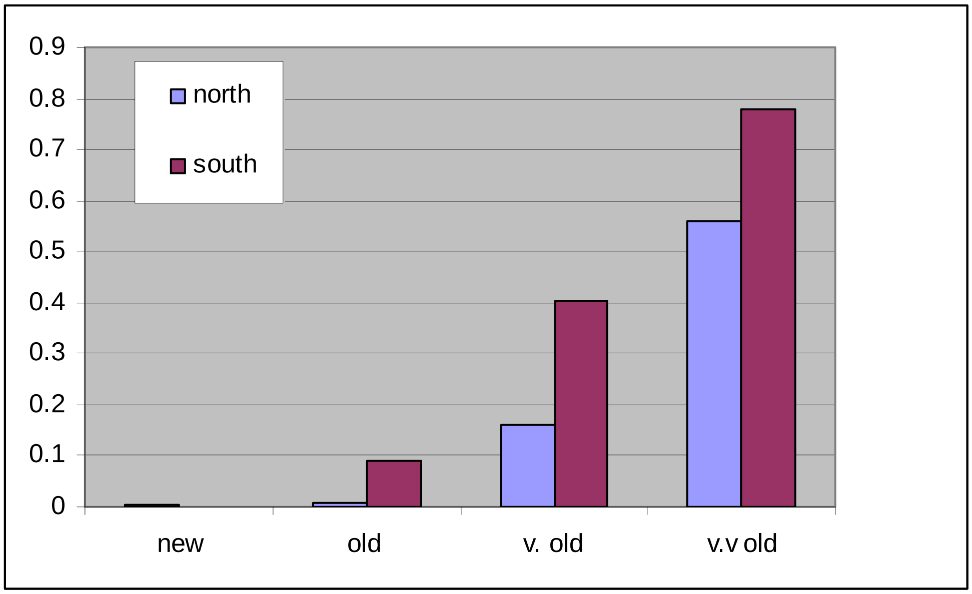


Figure 51. Fraction of barren females in the 2004 survey by shell condition and area north of 58.5 deg N and south of 58.5 deg N.

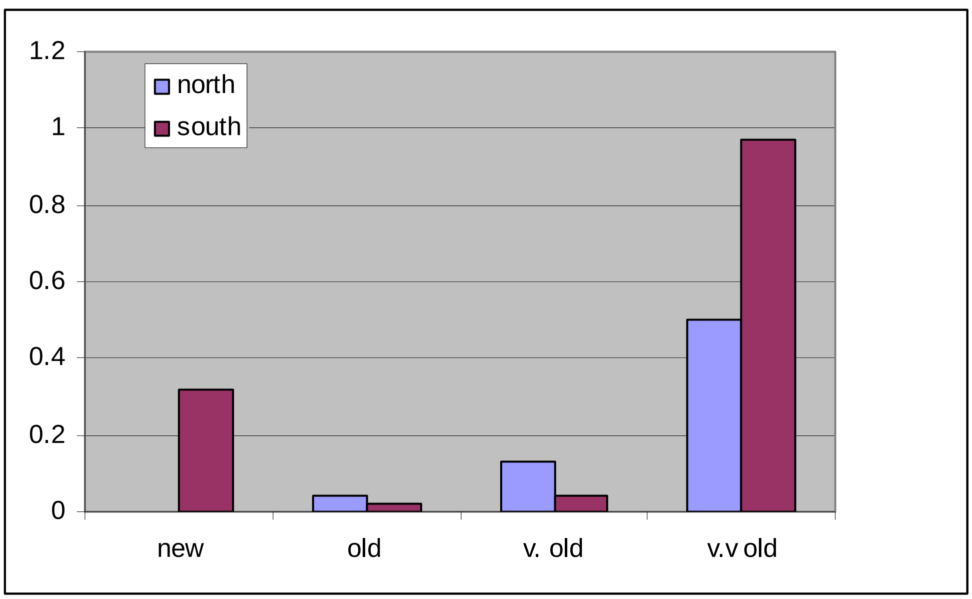


Figure 52. Fraction of barren females in the 2003 survey by shell condition and area north of 58.5 deg N and south of 58.5 deg N. The number of new shell mature females south of 58.5 deg N was very small in 2003.

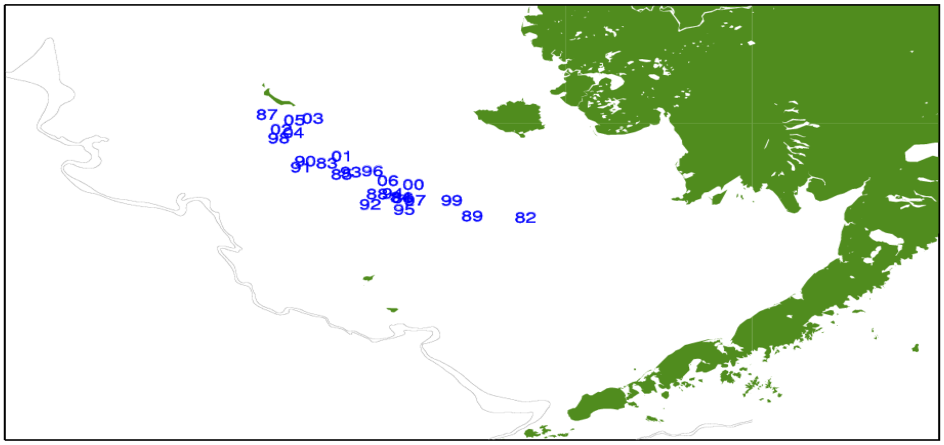


Figure 53. Centroids of cold pool (<2.0 deg C) from 1982 to 2006. Centroids are average latitude and longitude.

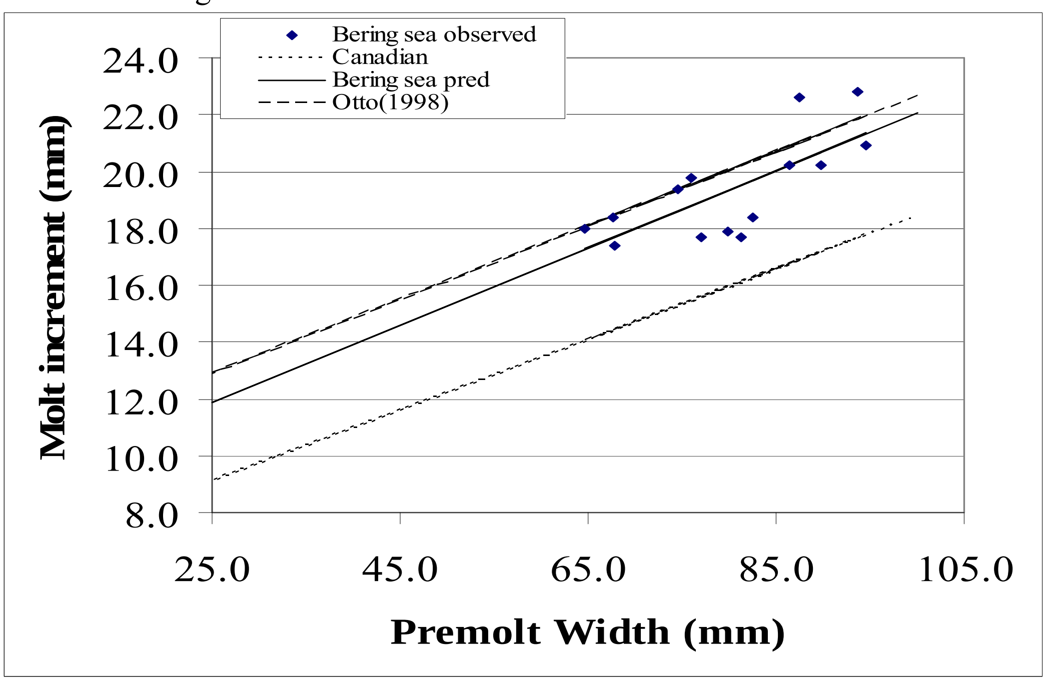


Figure 54. Growth increment as a function of premolt size for male snow crab. Points labeled Bering Sea observed are observed growth increments from Rugolo (unpub data). The line labeled Bering Sea pred is the predicted line from the Bering Sea observed growth, which is used as a prior for the growth parameters estimated in the model. The line labeled Canadian is estimated from Atlantic snow crab (Sainte-Marie data). The line labeled Otto(1998) was estimated from tagging data from Atlantic snow crab less than 67 mm, from a different area from Sainte-Marie data.

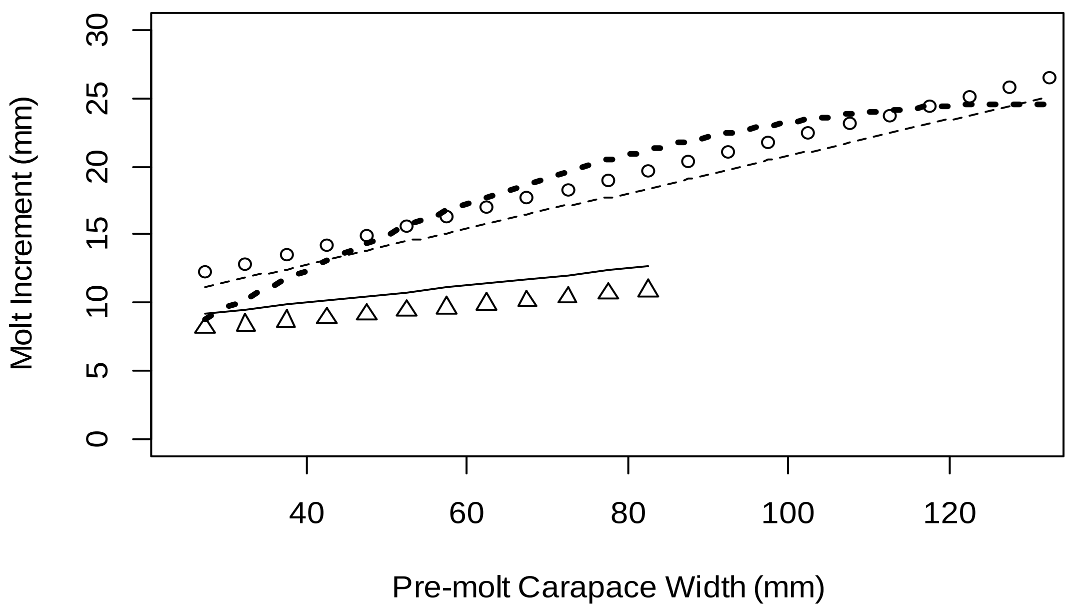


Figure 55. Growth(mm) for male(dotted line) and female snow crab (solid line) estimated from the base model. Circles are the observed growth curve. Heavy dotted line is the growth curve estimated by Somerton from the 2011 growth study (post-molt CW = -0.75 + 1.39 Premolt CW – 0.0015 * (Premolt CW)$^2$.

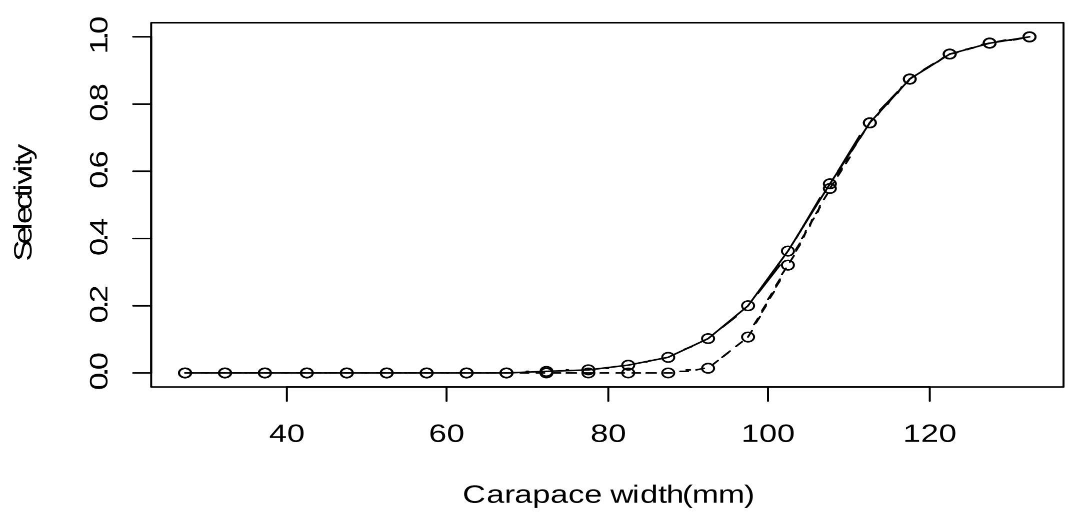


Figure 56. Base Model. Selectivity curve for total catch (discard plus retained, solid line) and retained catch (dotted line) for combined shell condition male snow crab.

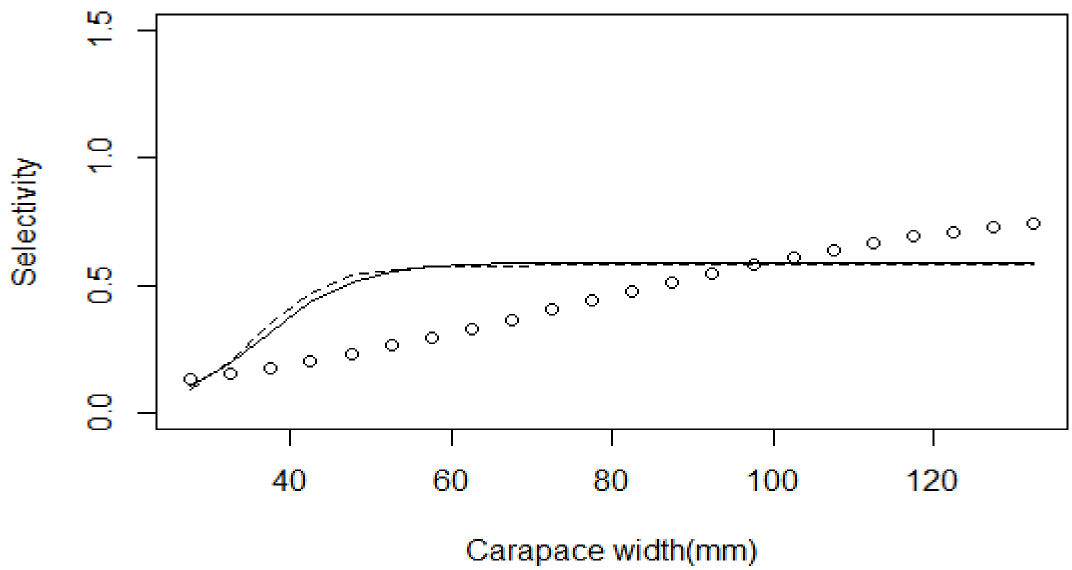


Figure 57. Base Model. Survey selectivity curves for female (dotted lines) and male snow crab (solid lines) estimated by the model for 1989 to present. Survey selectivities estimated by Somerton from 2009 study area data (2010) are the circles.

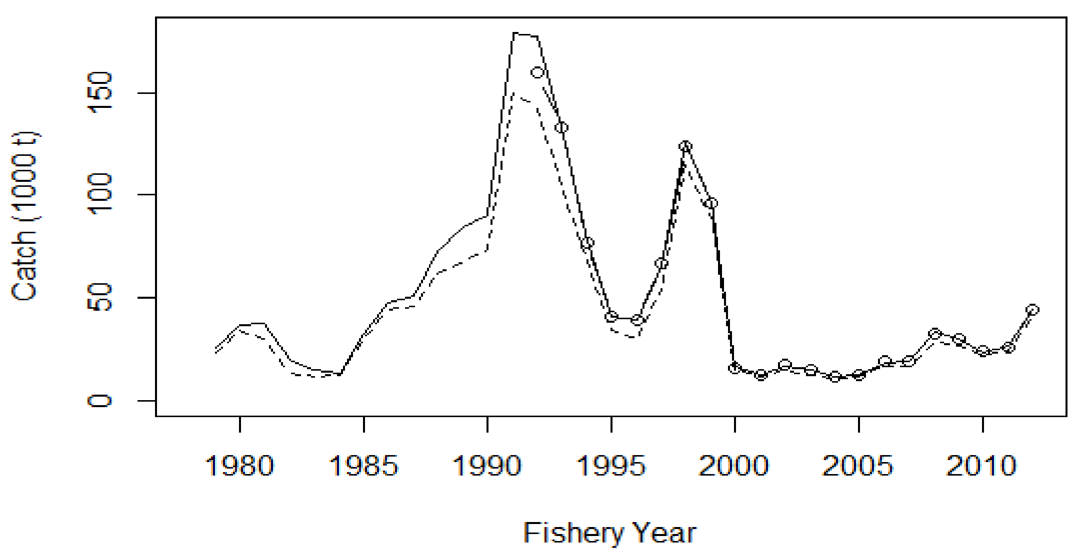


Figure 58. Base Model. Estimated total catch(discard + retained) (solid line), observed total catch (solid line with circles) (assuming 50% mortality of discarded crab) and observed retained catch (dotted line).

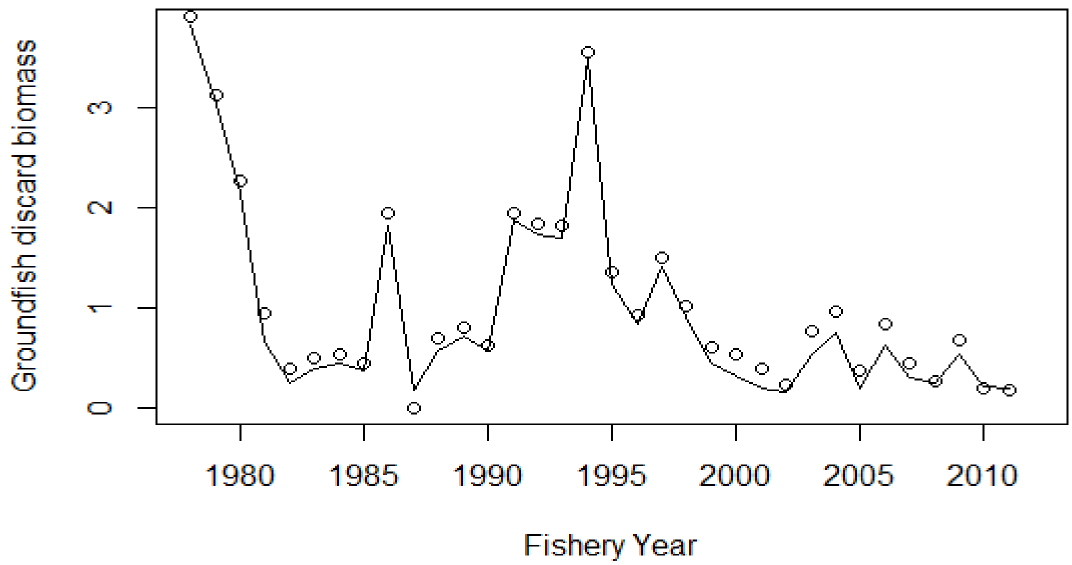


Figure 59. Base Model. Model fit to groundfish bycatch. Circles are observed catch, line is model estimate.

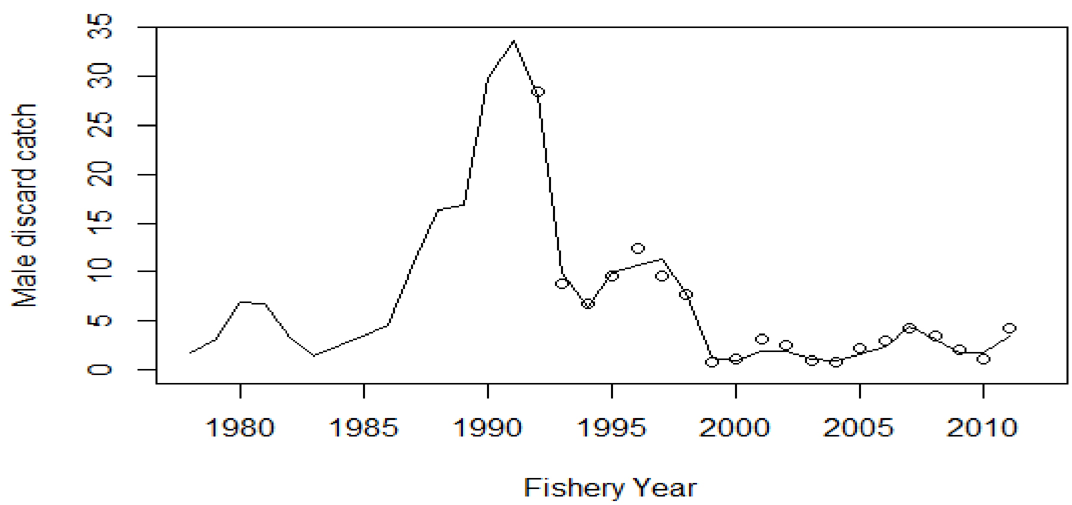


Figure 60. Base Model. Model fit to male directed discard catch for 1992/93 to 2010/11 and estimated male discard catch from 1978 to 1991.

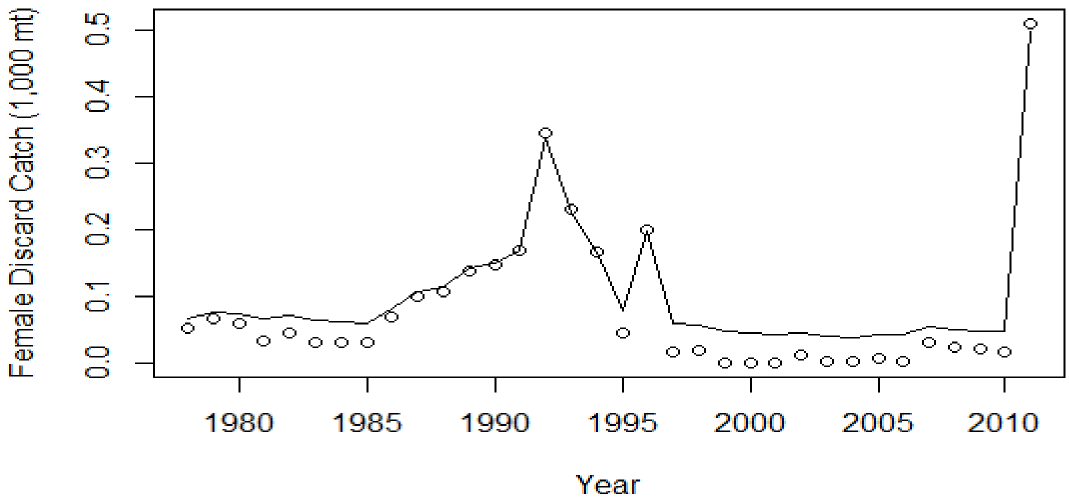


Figure 61. Base Model. Model fit to female discard bycatch in the directed fishery from 1992/93 to 2010/11 and model estimates of discard from 1978 to 1991.

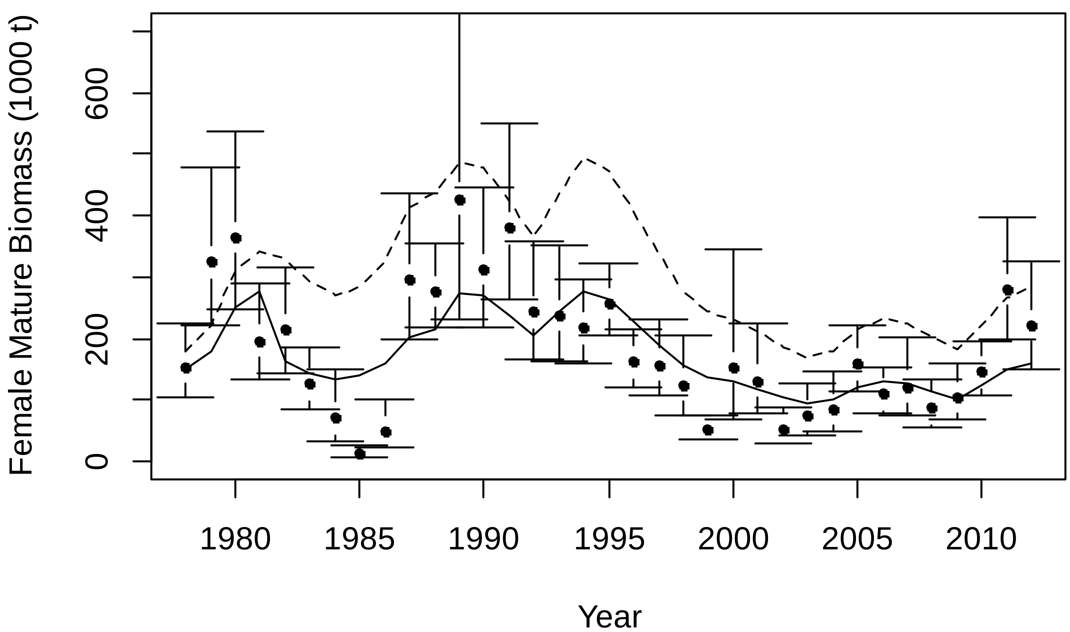


Figure 62. Base Model. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

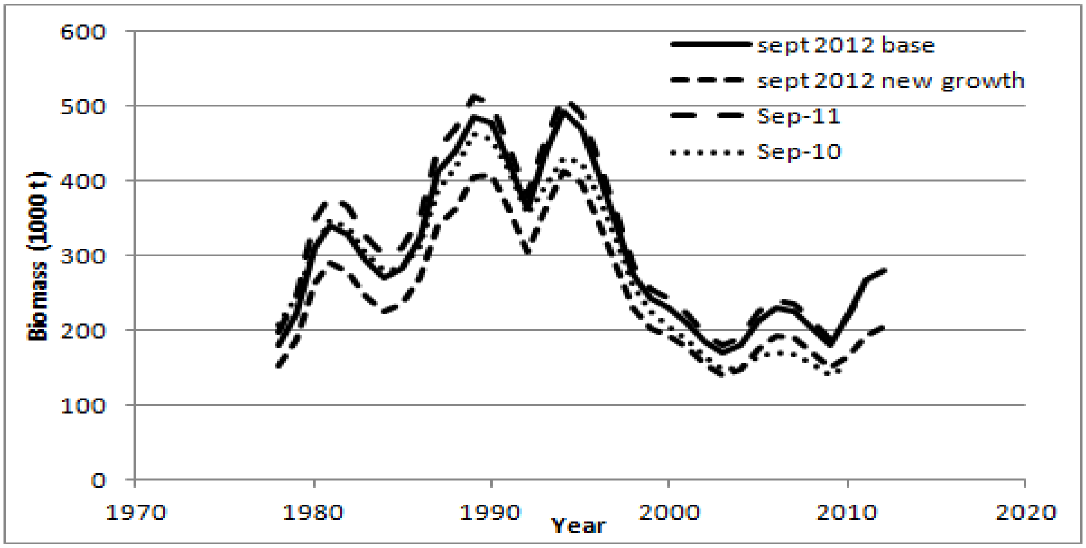


Figure 63. Population female mature biomass from the September 2010 and September 2011 assessments, Base Model and model with new growth function.

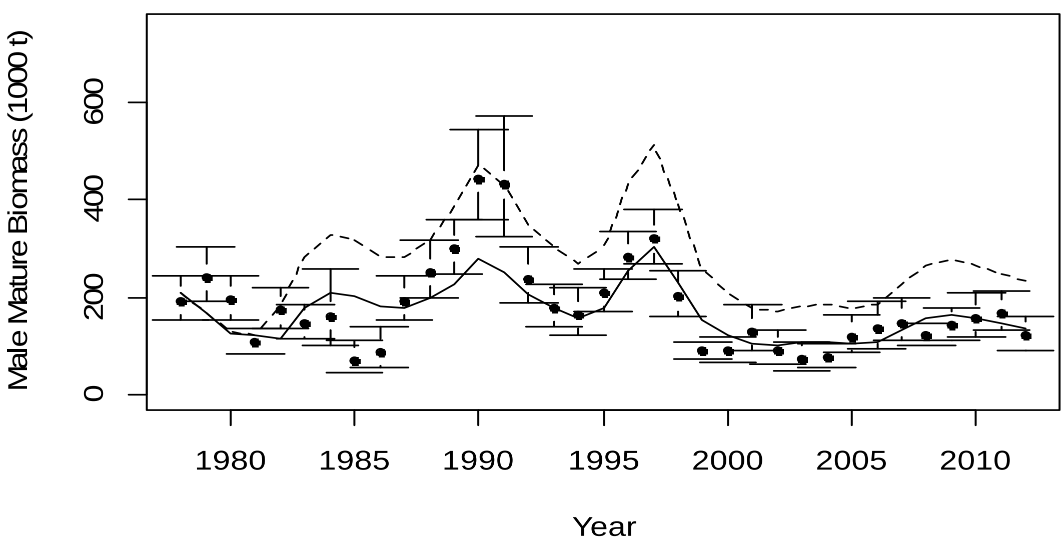


Figure 64. Base Model. Population male mature biomass (1000 t, dotted line), model estimate of survey male mature biomass (solid line) and observed survey male mature biomass with approximate lognormal 95% confidence intervals.

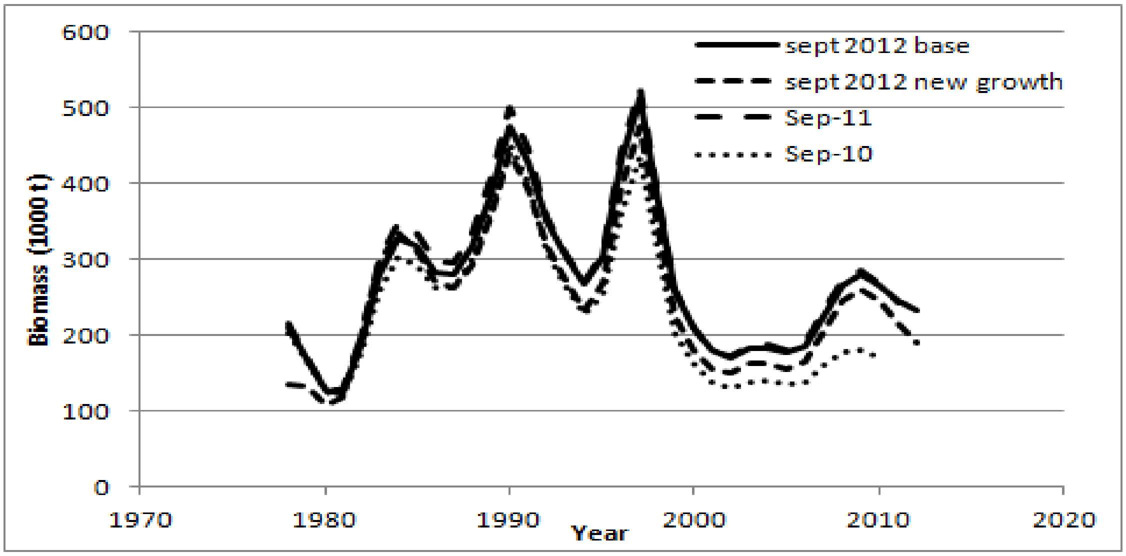


Figure 65. Population male mature from the September 2010 and September 2011 assessments, Base Model and model with new growth function.

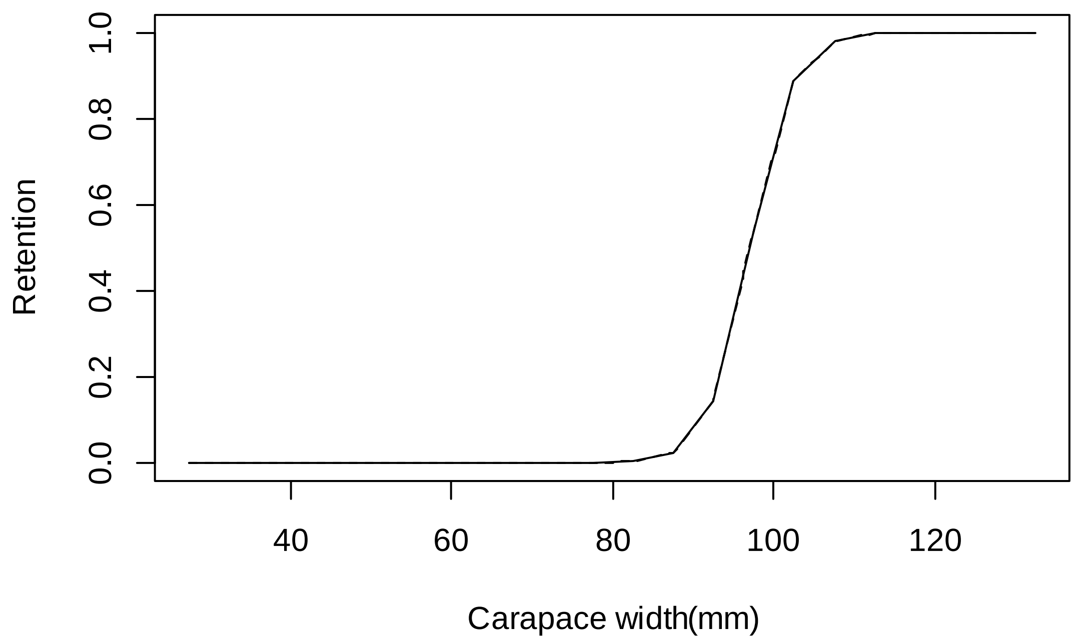


Figure 66. Base Model. Model estimated fraction of the total catch that is retained by size for male snow crab combined shell condition.

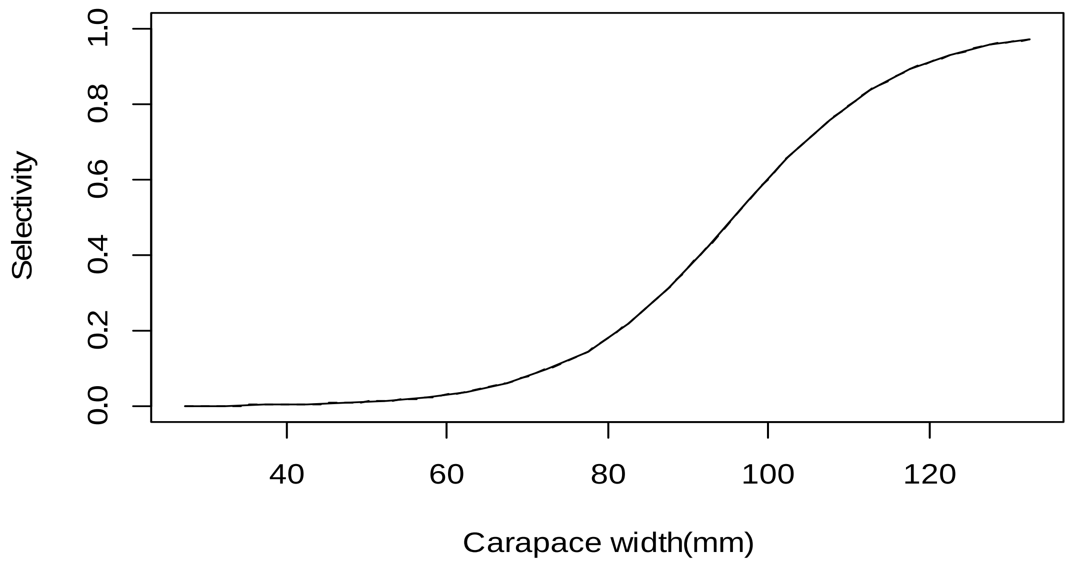


Figure 67. Base Model. Selectivity curve estimated by the model for bycatch in the groundfish trawl fishery for females and males.

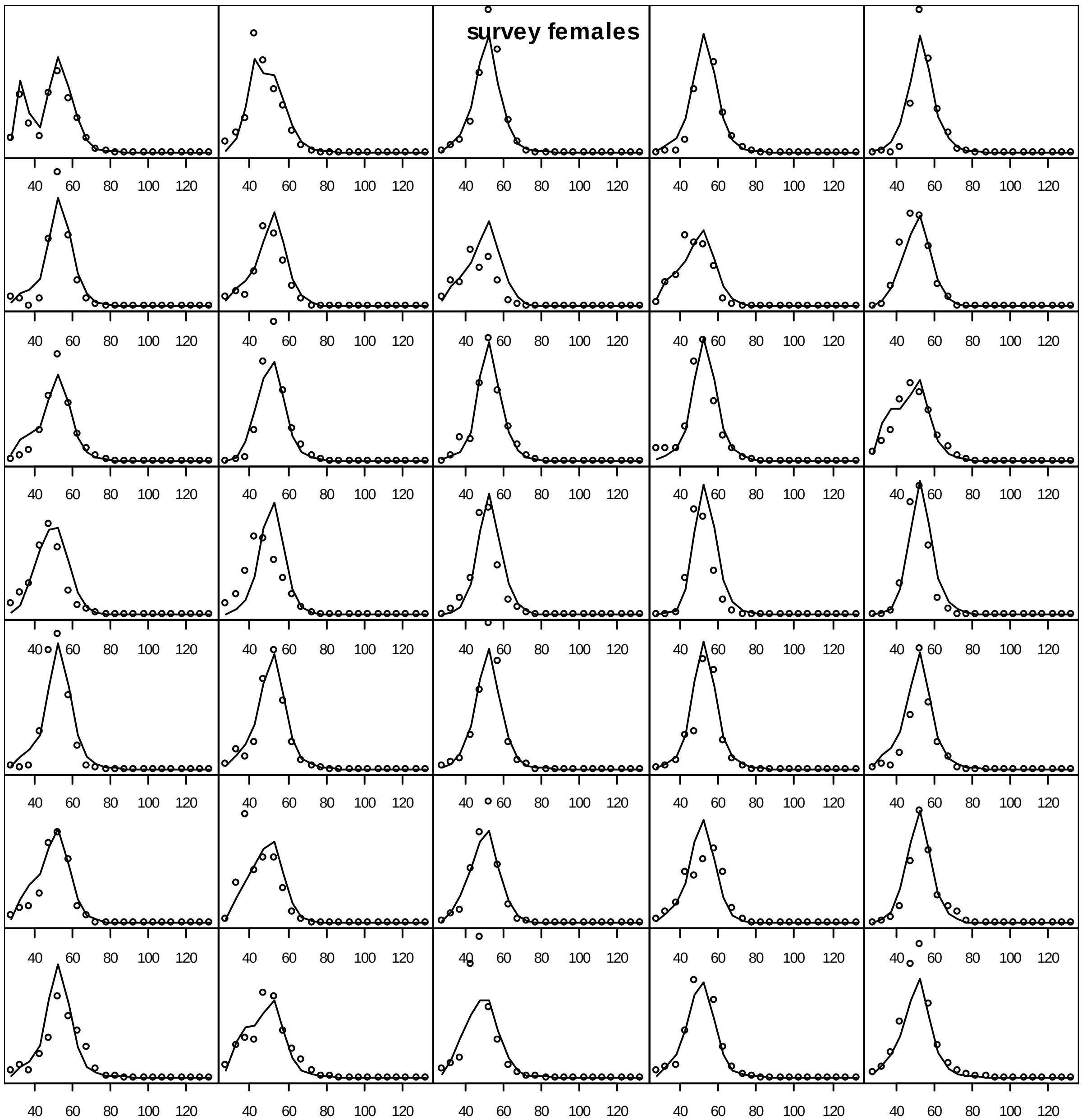


Figure 68. Base Model. Model fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

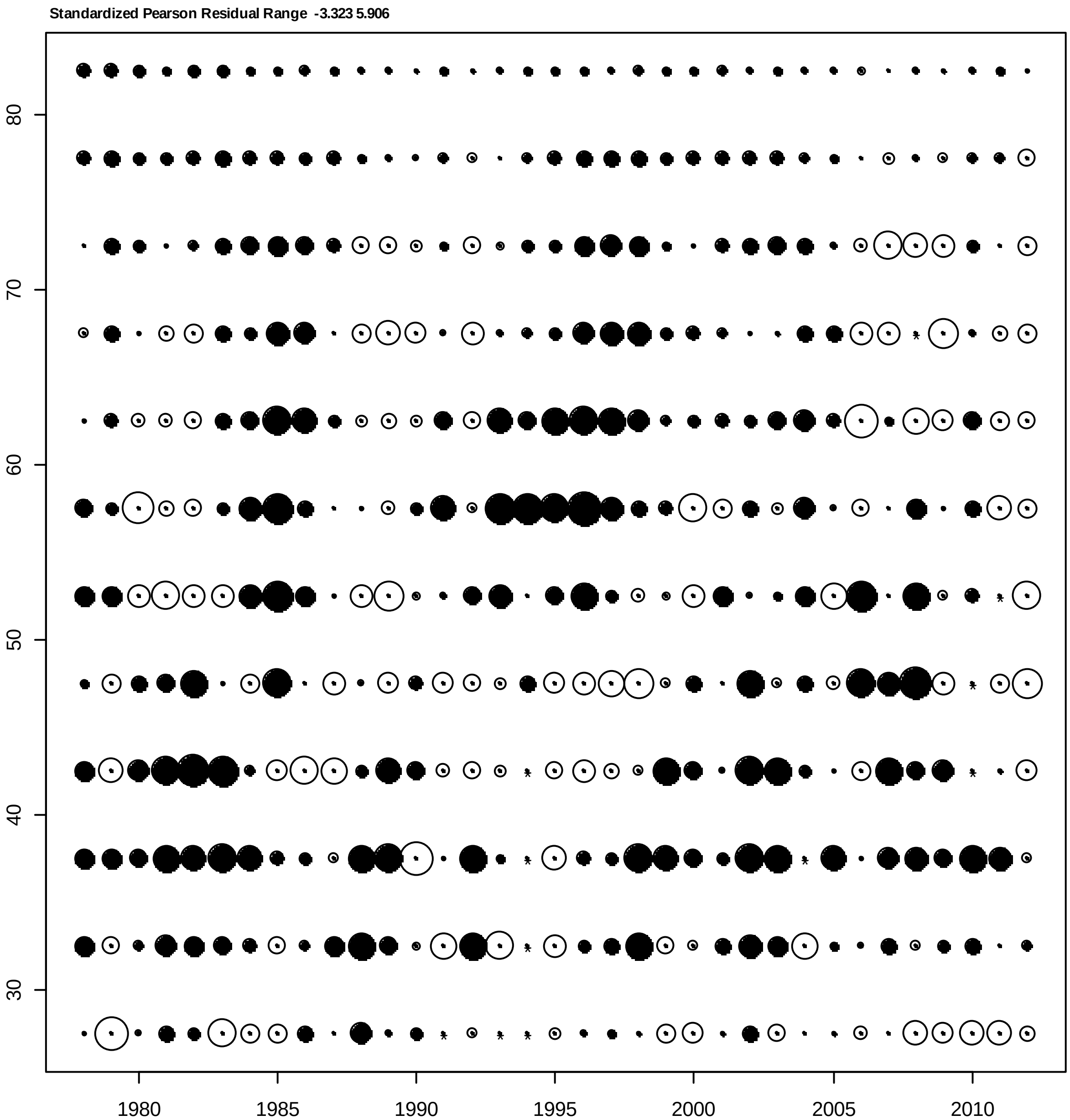


Figure 69. Base Model. Residuals of fit to survey female size frequency. Filled circles are negative residuals.

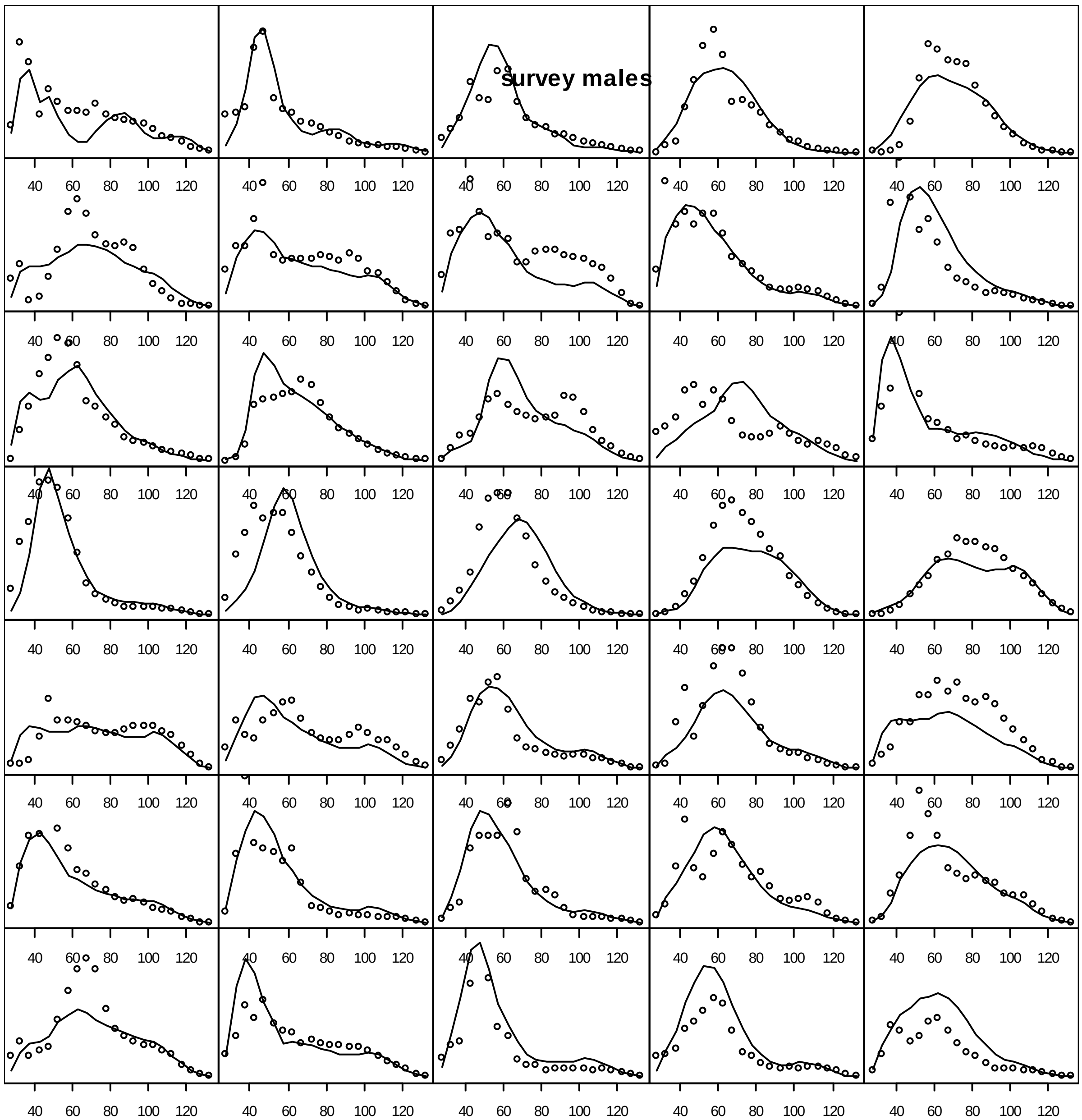


Figure 70. Base Model. Model fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

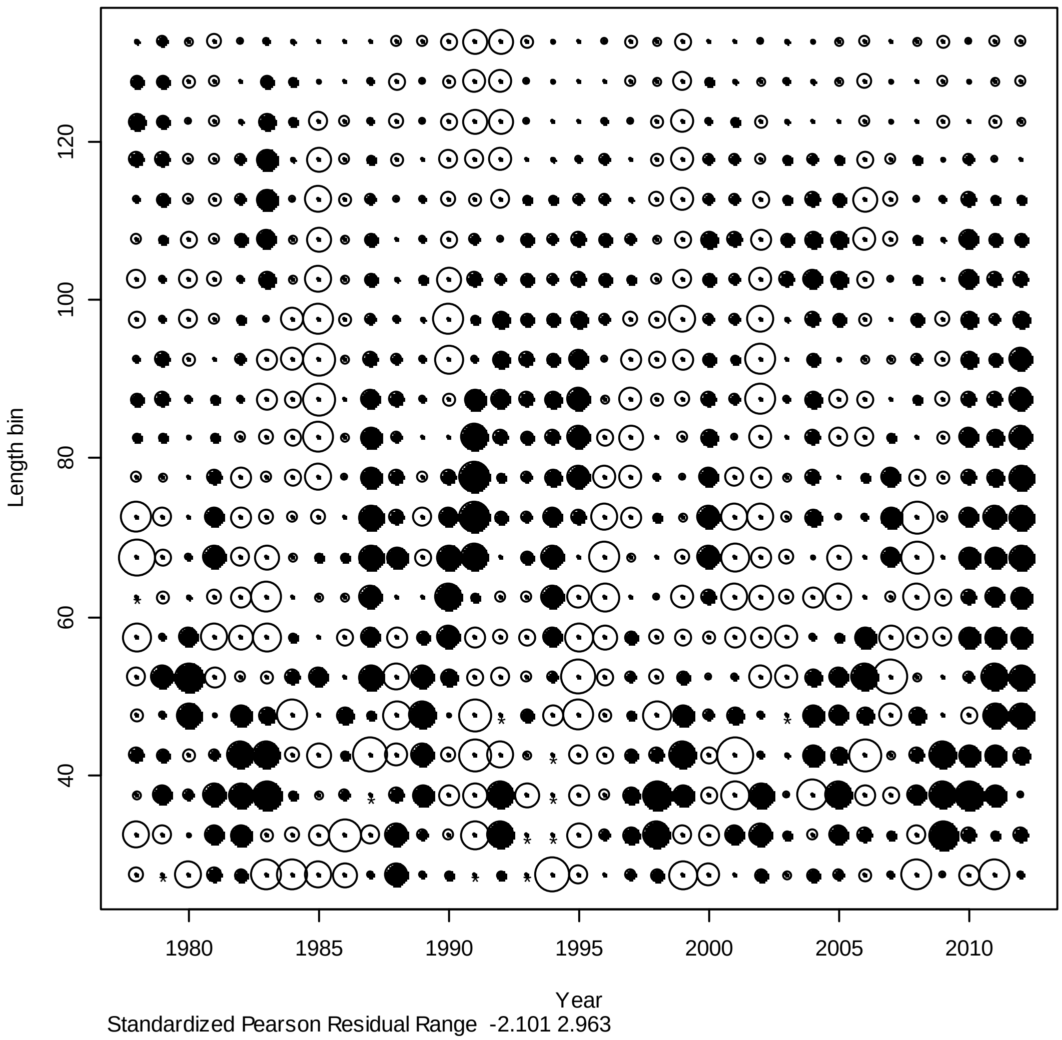


Figure 71. Base Model. Residuals for fit to survey male size frequency. . Filled circles are negative residuals (predicted higher than observed).

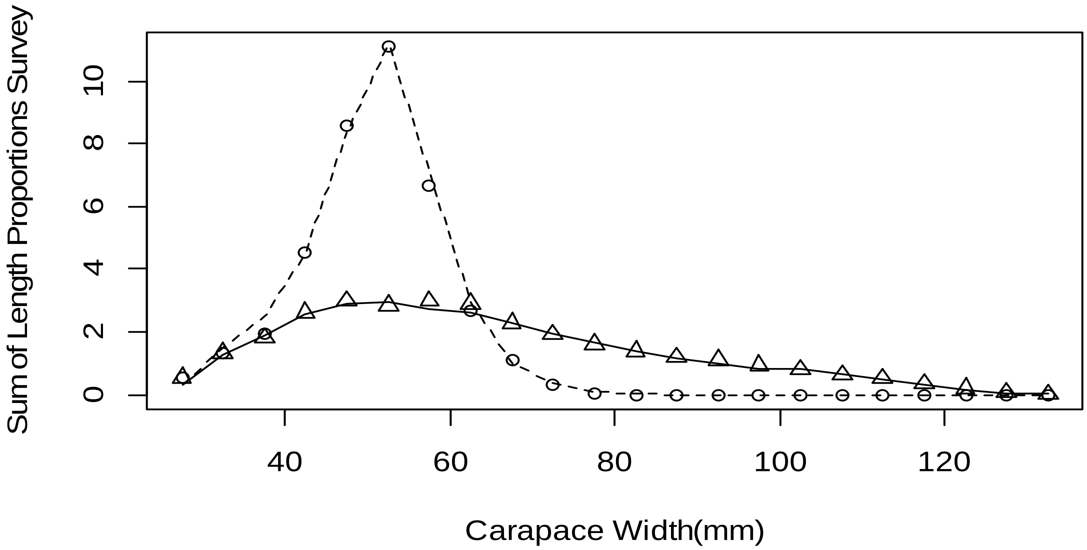


Figure 72. Base Model. Summary over years of fit to survey length frequency data by sex. Dotted line is fit for females, circles are observed. Solid line is fit for males, triangles are observed.

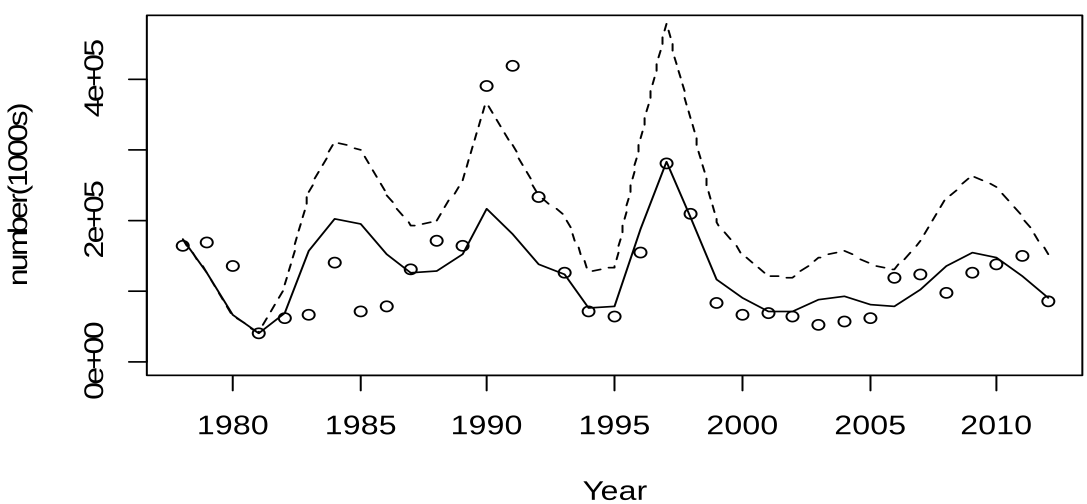


Figure 73. Base Model. Observed survey numbers of males >101mm (circles), model estimates of the population number of males >101mm(solid line) and model estimates of survey numbers of males >101 mm (dotted line).

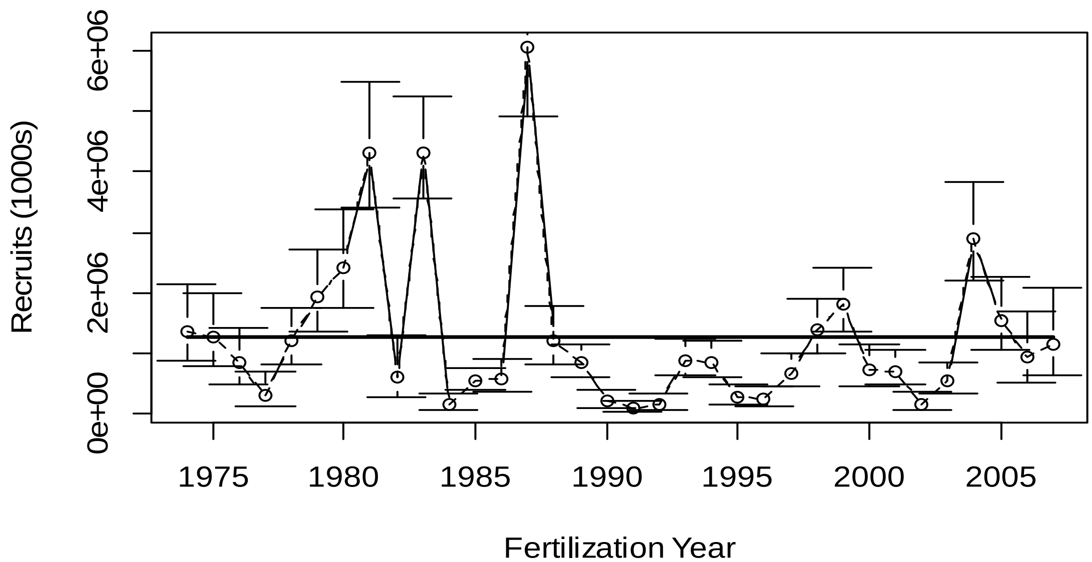


Figure 74. Base Model. Recruitment to the model for crab 25 mm to 50 mm. Total recruitment is 2 times recruitment in the plot. Male and female recruitment fixed to be equal. Solid horizontal line is average recruitment. Error bars are 95% C.I.

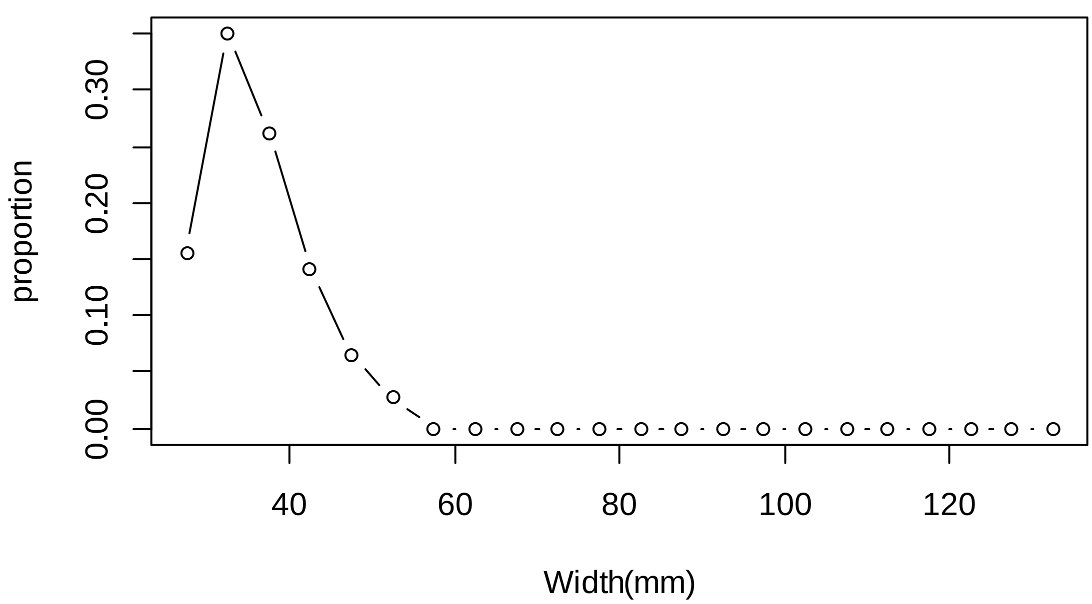


Figure 75. Base Model. Distribution of recruits to length bins estimated by the model.

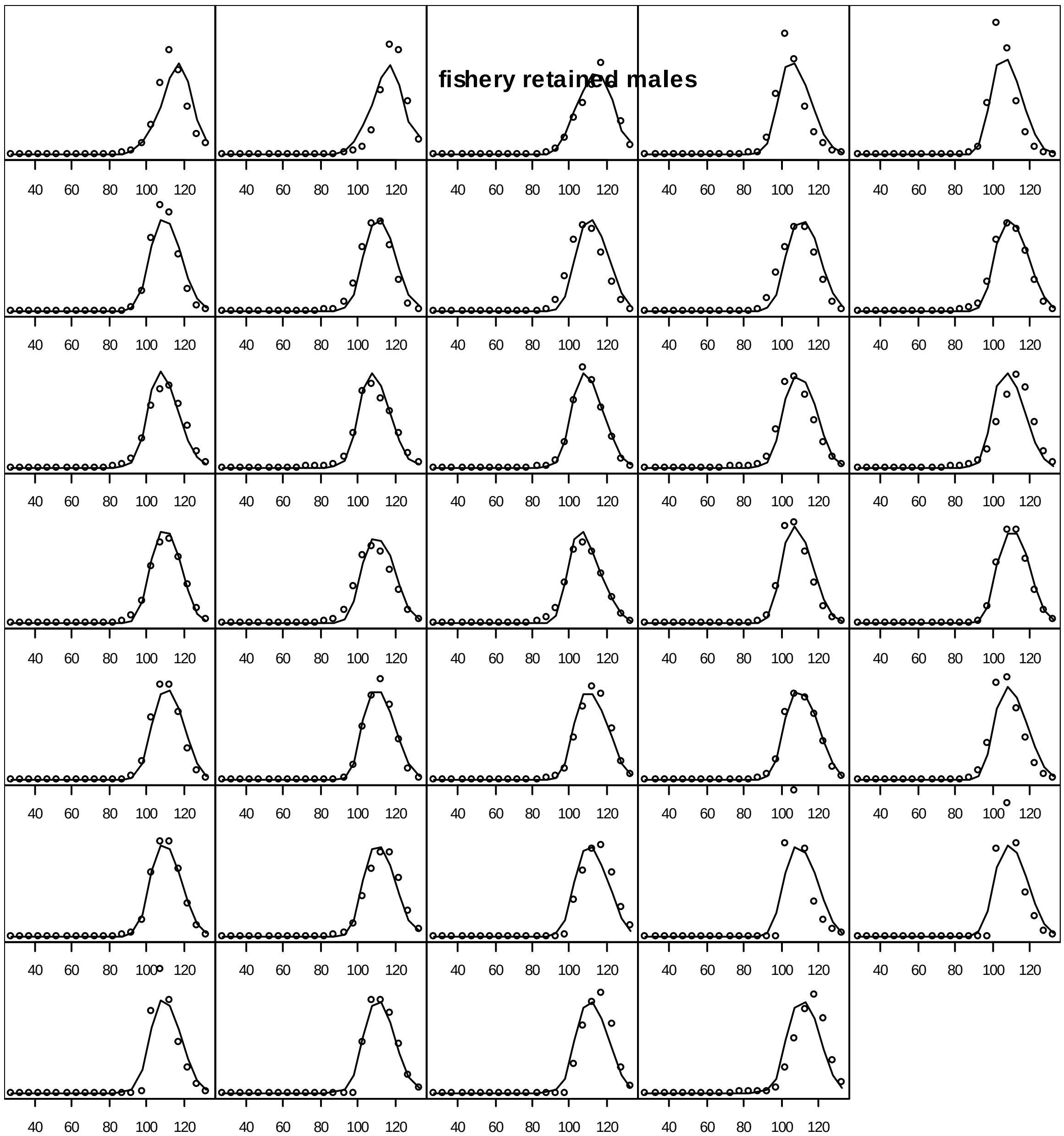


Figure 76. Base Model. Model fit to the retained male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data. Year is the survey year.

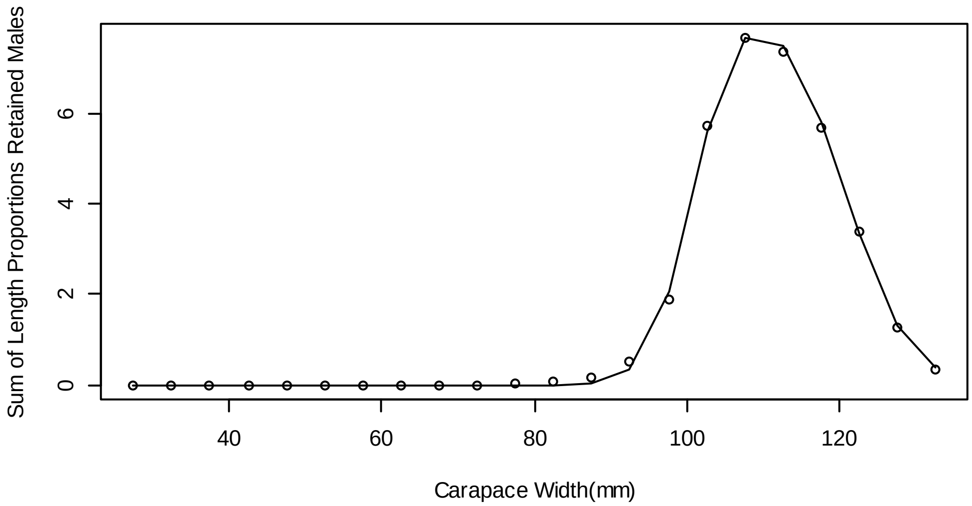


Figure 77. Base Model. Summary fit to retained male length.

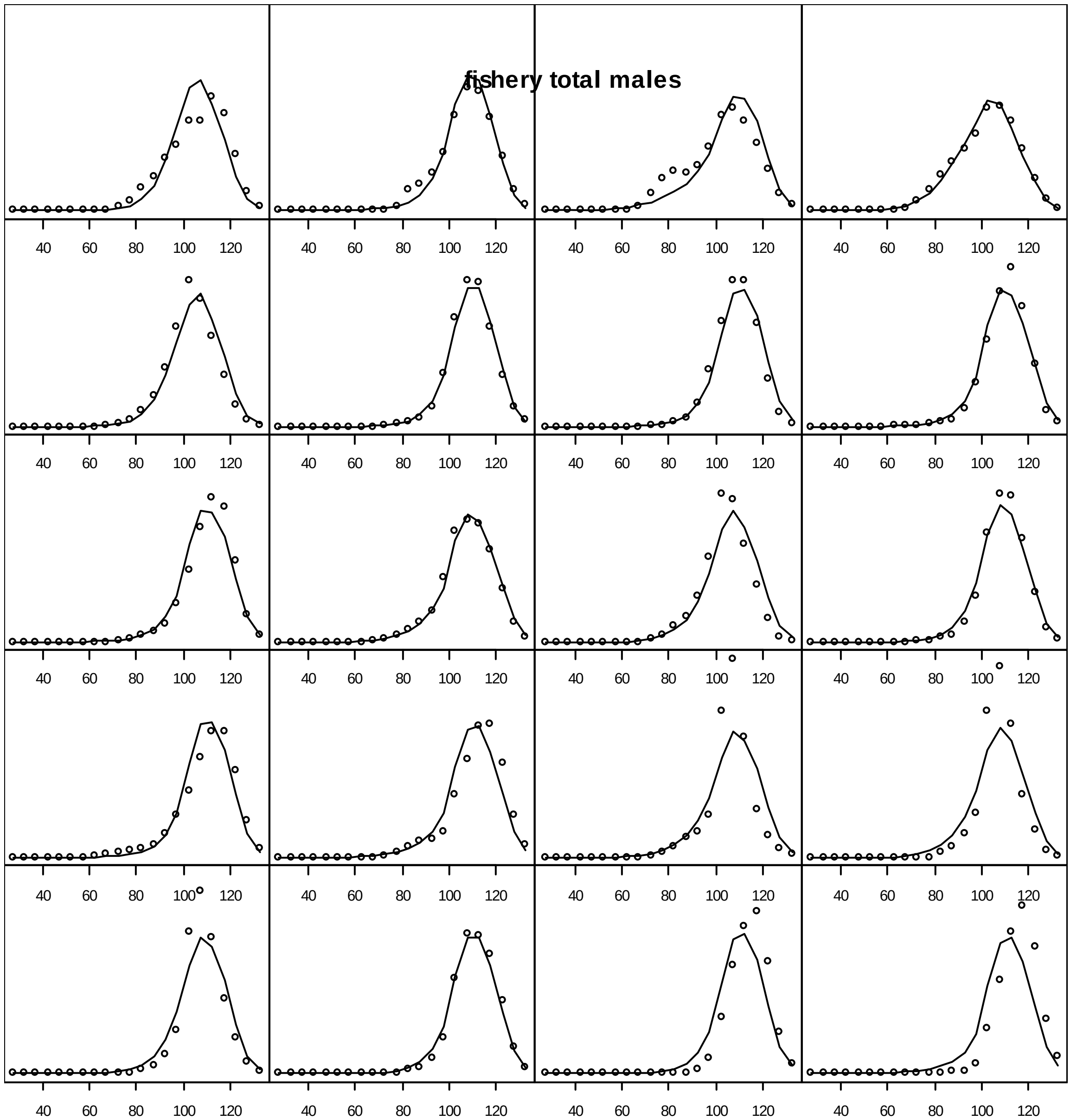


Figure 78. Base Model. Model fit to the total (discard plus retained) male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data. Year is the survey year.

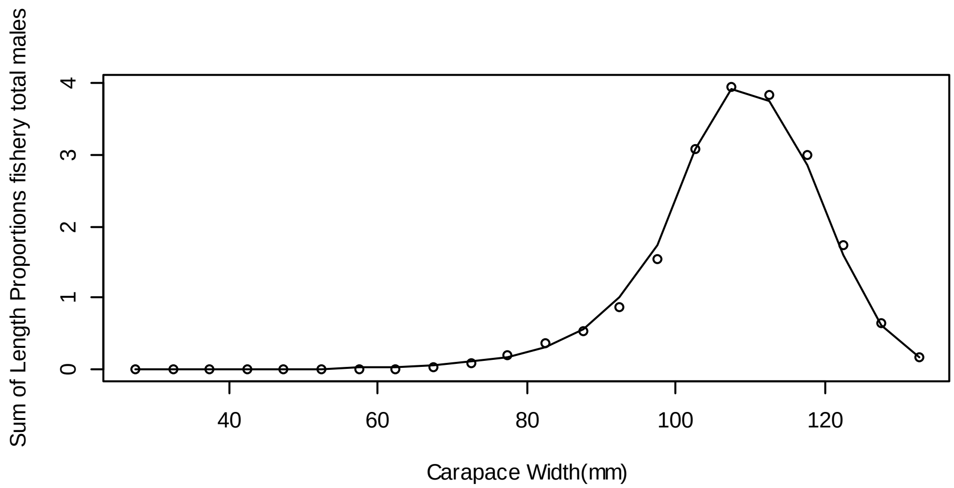


Figure 79. Base Model. Summary fit to total length frequency male catch.

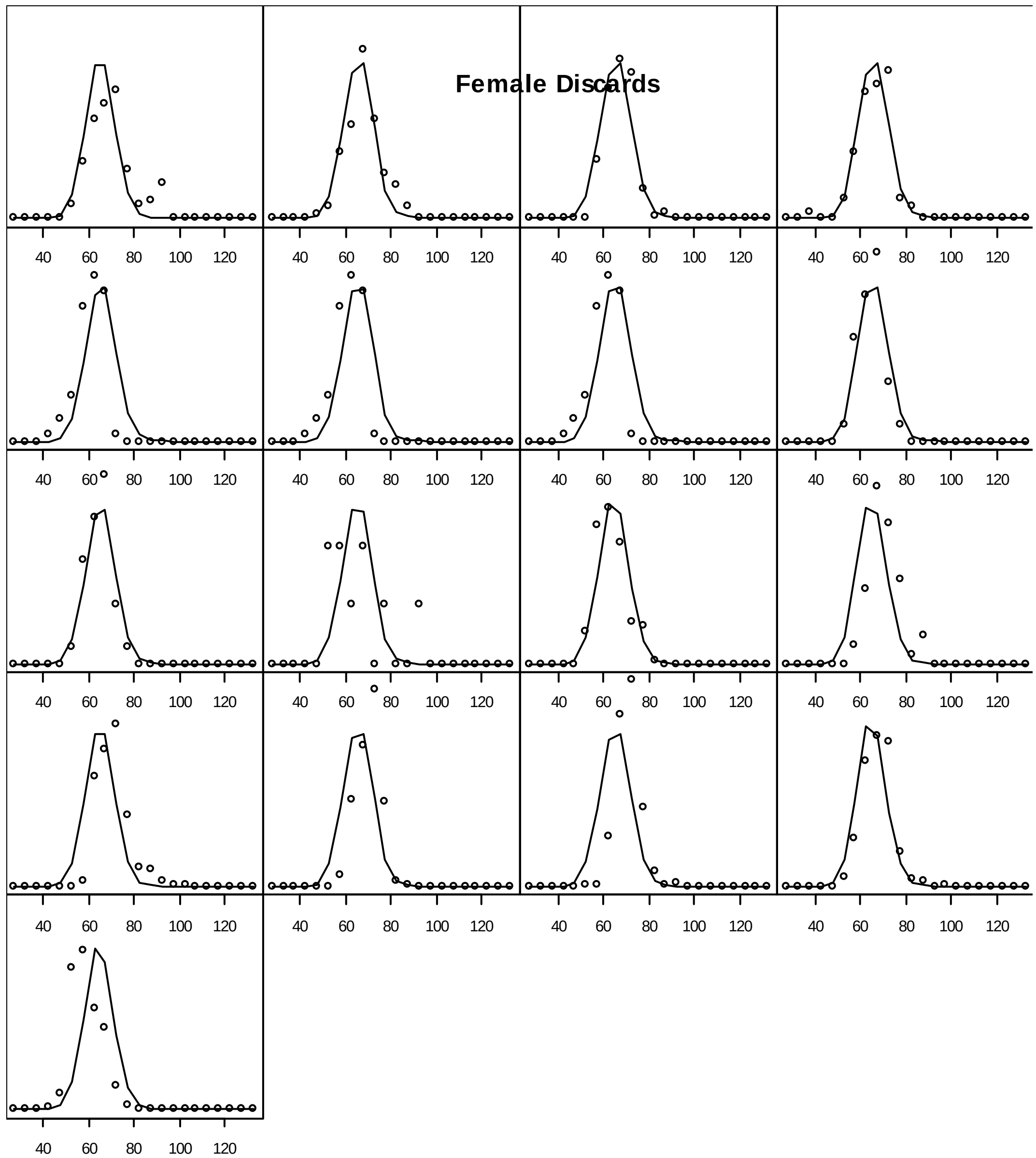


Figure 80. Base Model. Model fit to the discard female size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

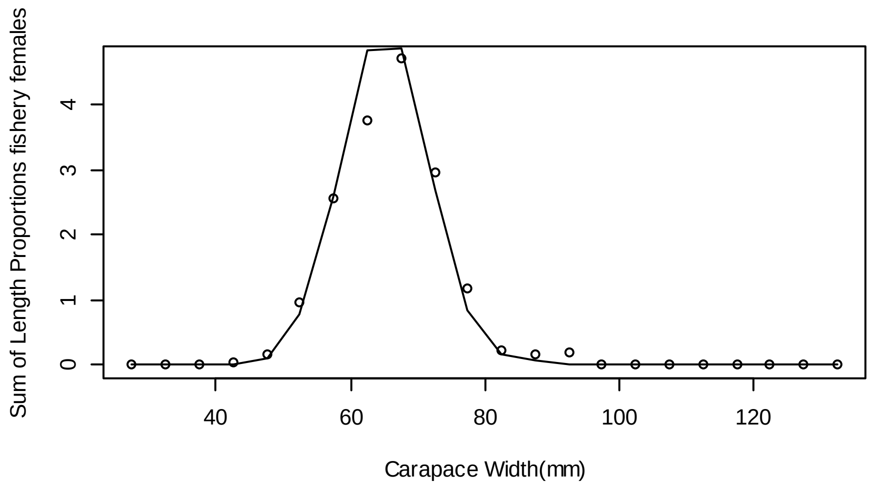


Figure 81. Base Model. Summary fit to directed fishery female discards.

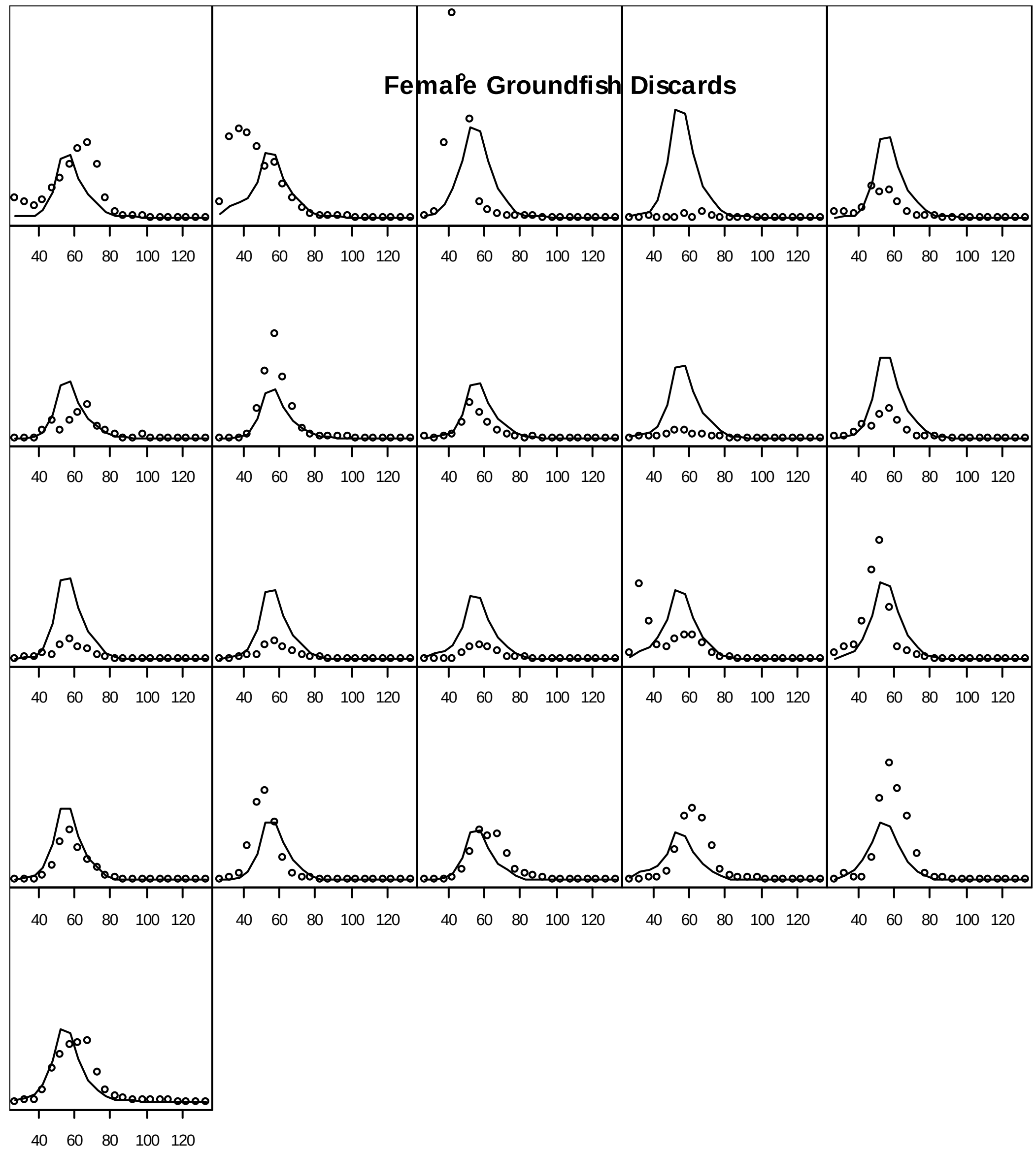


Figure 82. Base Model. Model fit to the groundfish trawl discard female size frequency data. Solid line is the model fit. Circles are observed data. Year is the survey year.

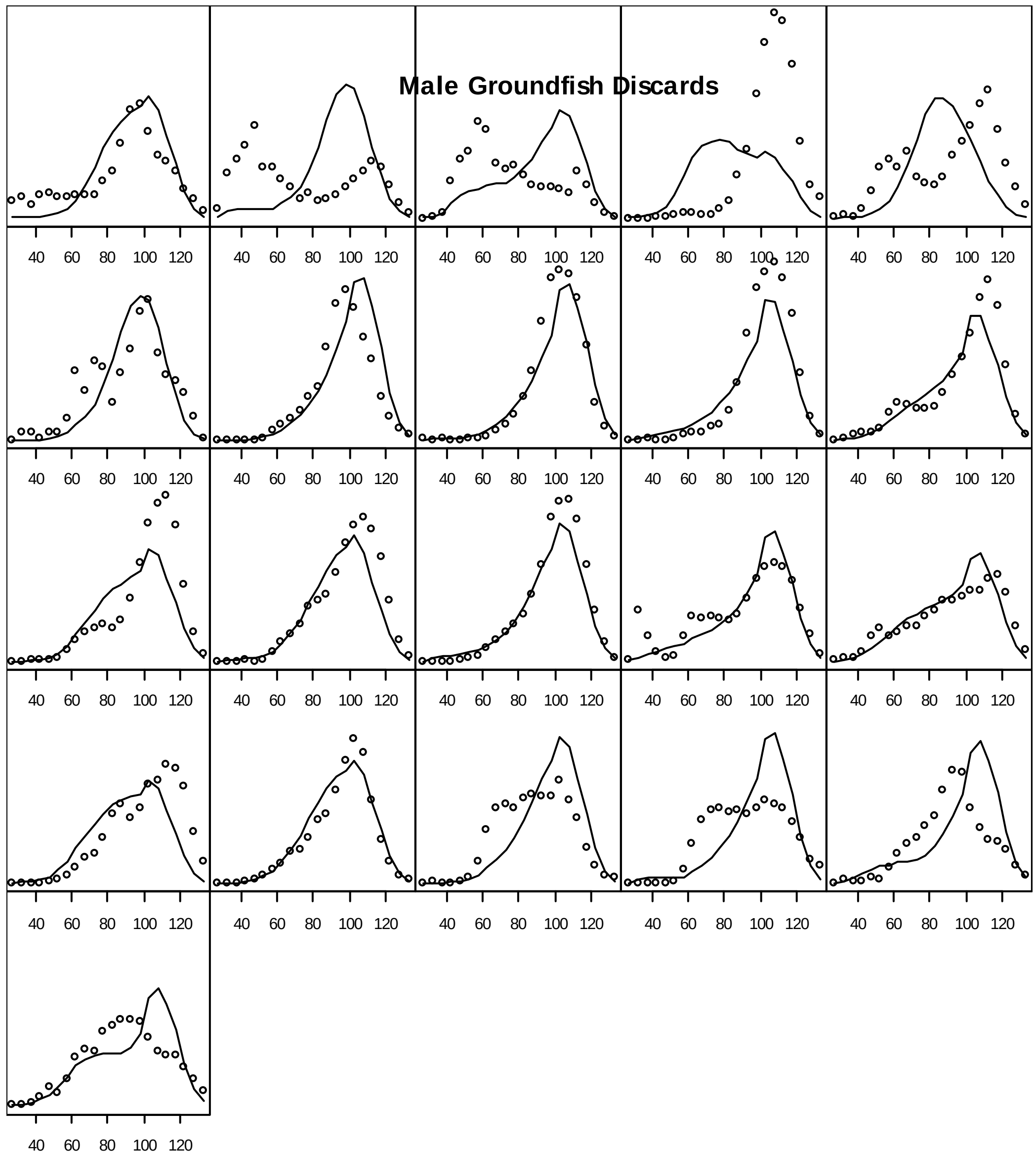


Figure 83. Base Model. Model fit to the groundfish trawl discard male size frequency data. Solid line is the model fit. Circles are observed data.

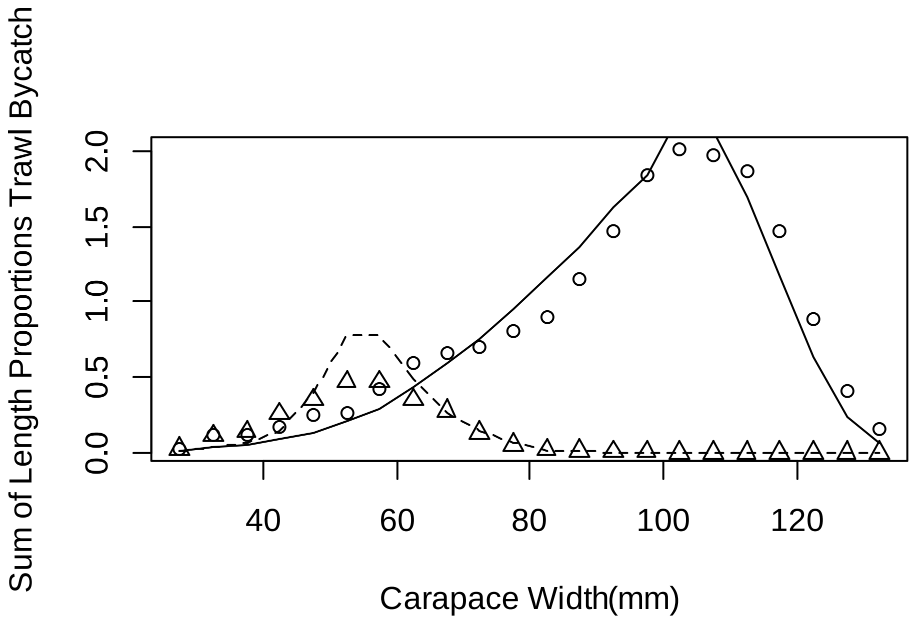


Figure 84. Base Model. Summary fit to groundfish length frequency.

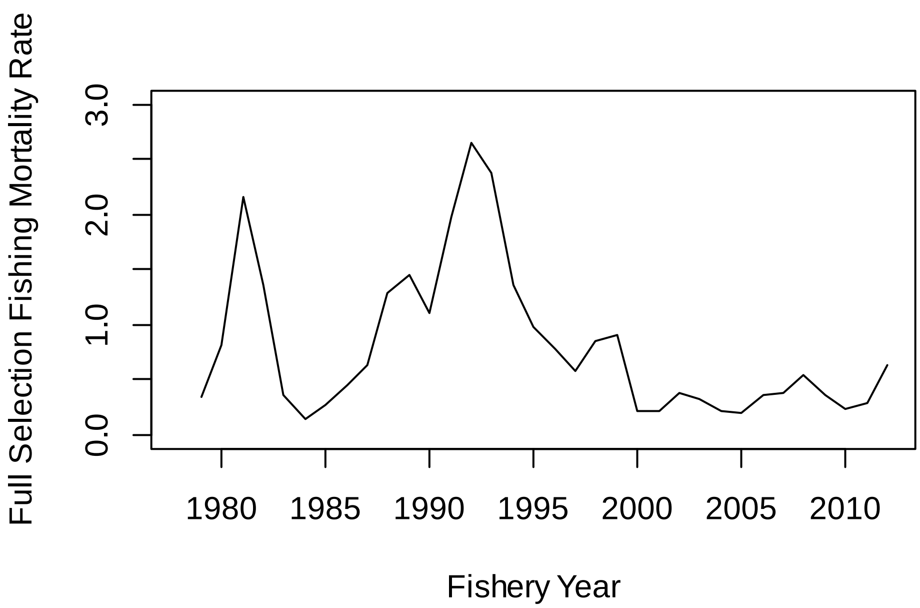


Figure 85. Base Model. Full selection fishing mortality estimated in the model from 1978/79 to 2011/12 fishery seasons.

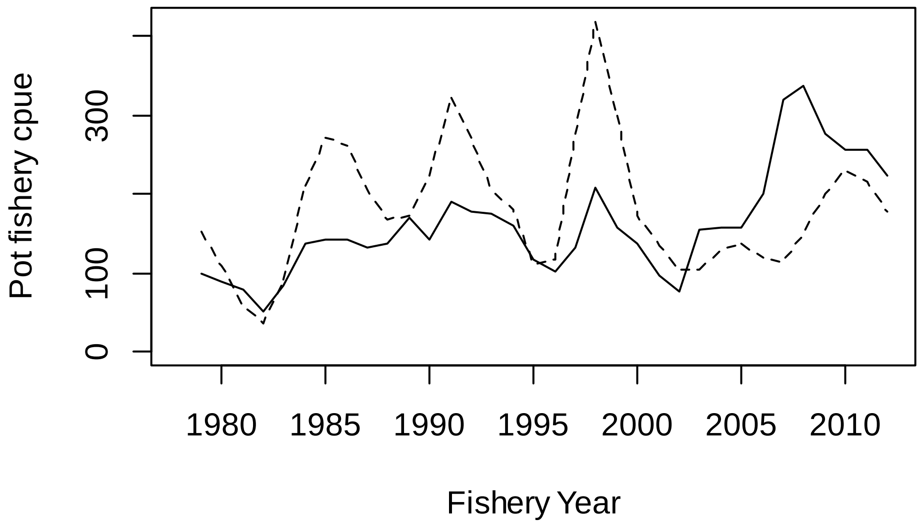


Figure 86. Base Model. Fit to pot fishery cpue for retained males (q is fixed in model). Solid line is observed fishery cpue, dotted line model fit.

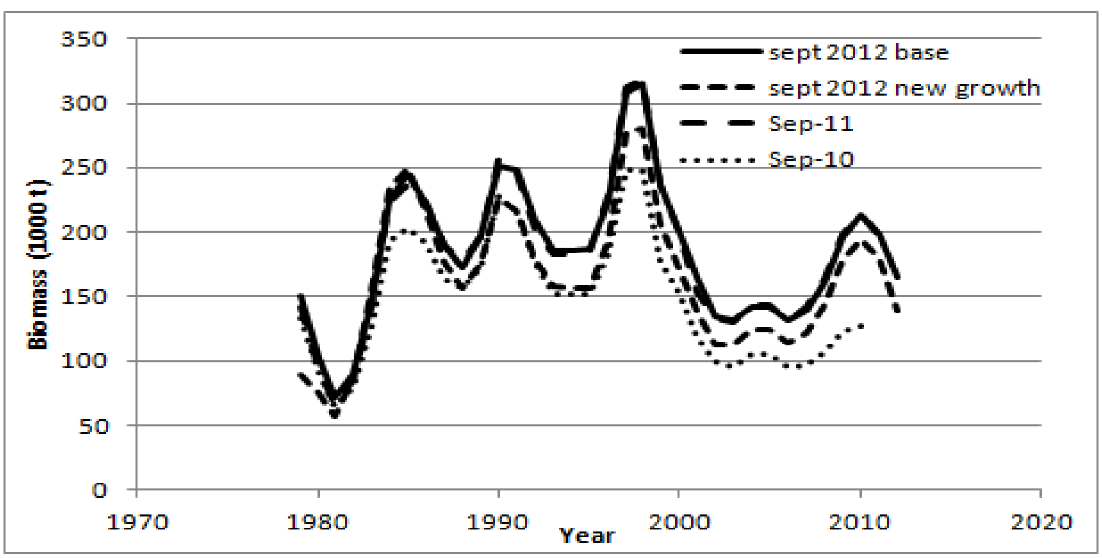


Figure 87. Mature male biomass at mating for the September 2010 model, Model 7 and Model 2.

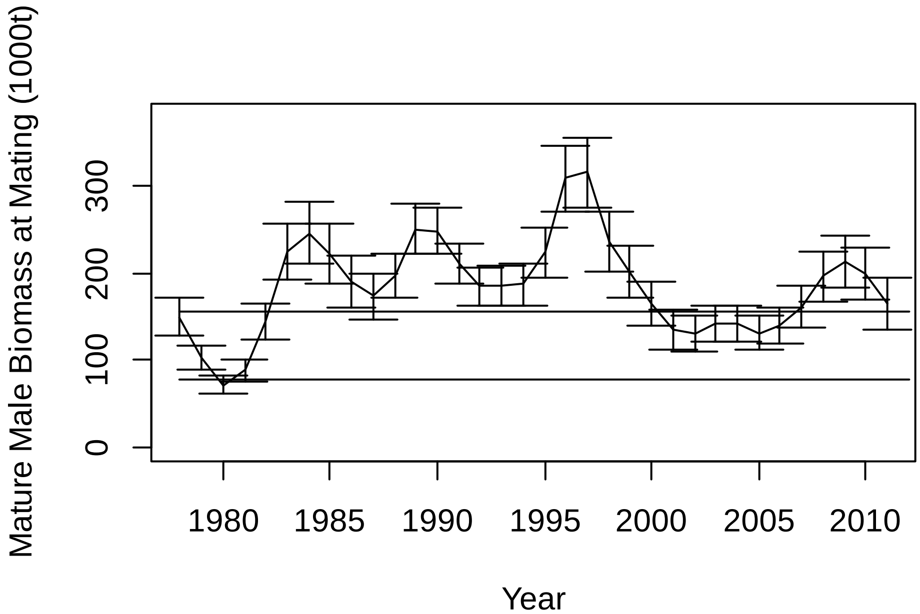


Figure 88. Base Model. Mature Male Biomass at mating with 95% confidence intervals. Top horizontal line is B35%, lower line is ½ B35%.

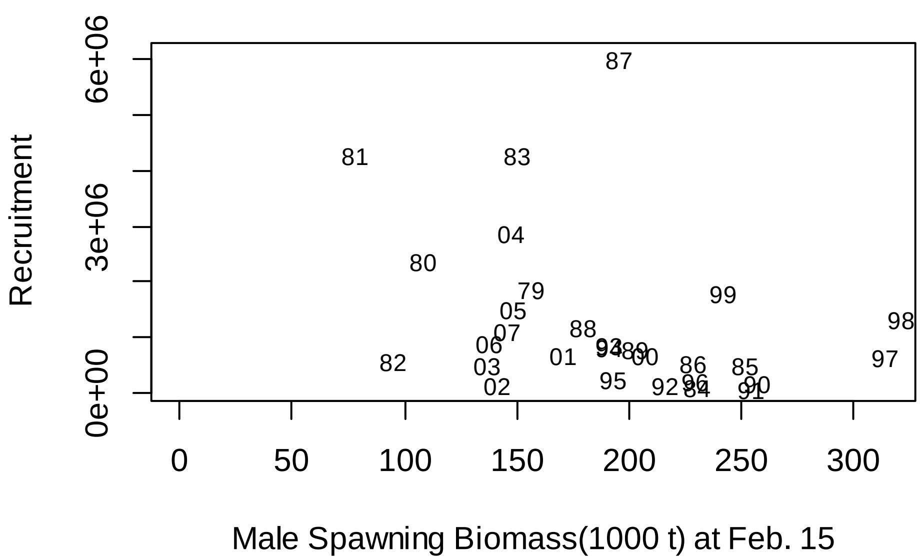


Figure 89. Base Model. Spawner recruit estimates using male mature biomass at time of mating (1000t). Numbers are fertilization year assuming a lag of 5 years. Recruitment is half total recruits in thousands of crab.

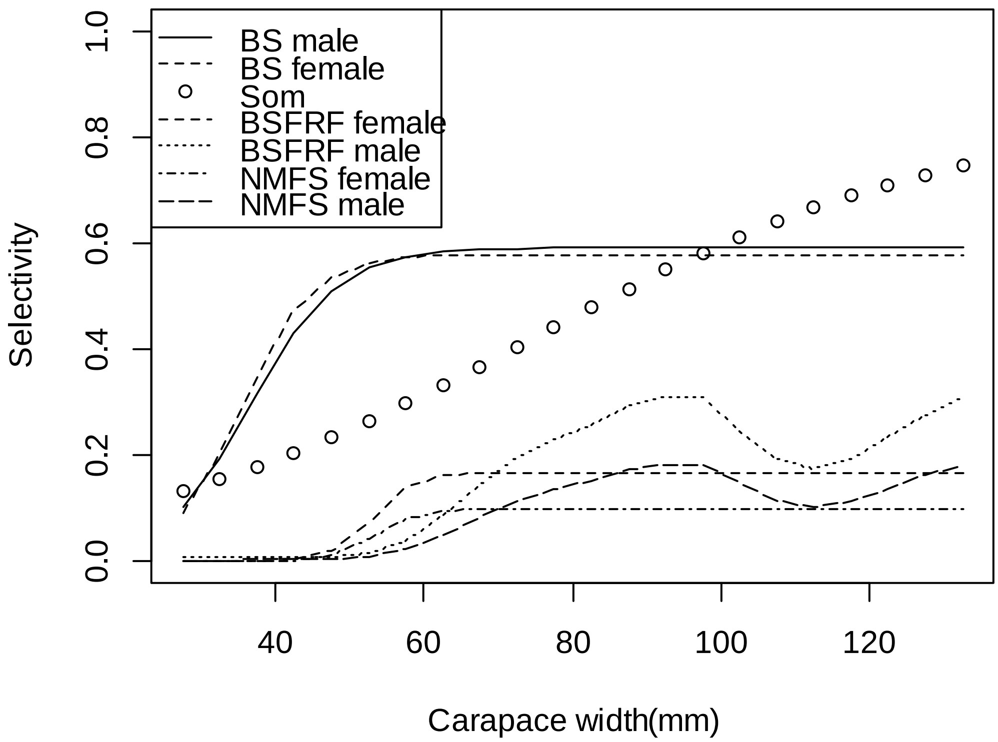


Figure 90. Base Model. Survey selectivity curves entire Bering Sea survey for female (upper dashed line) and male snow crab (solid lines) estimated by the model for 1989 to present. Survey selectivities estimated by Somerton(2010) from 2009 study area data are the circles. Lower lines are survey selectivities in the study area for BSFRF male and female crab and NMFS male and female crab.

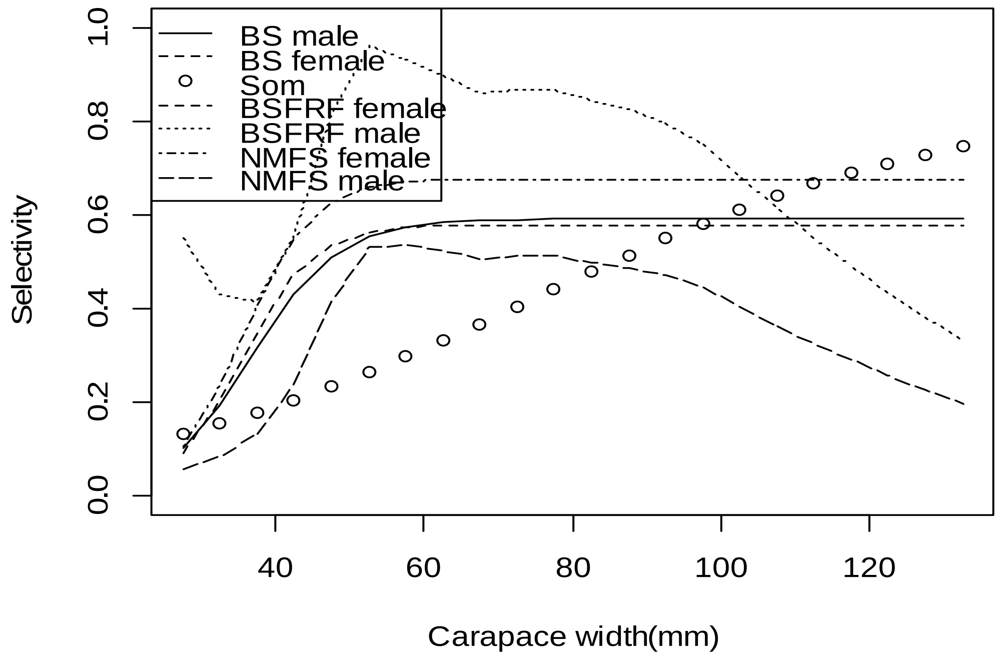


Figure 91. Base Model. 2010 study area survey selectivity curves (BSFRF and NMFS). BS are survey selectivity curves for the entire Bering Sea. Som is the selectivity curve estimated by Somerton from the 2009 study area data.

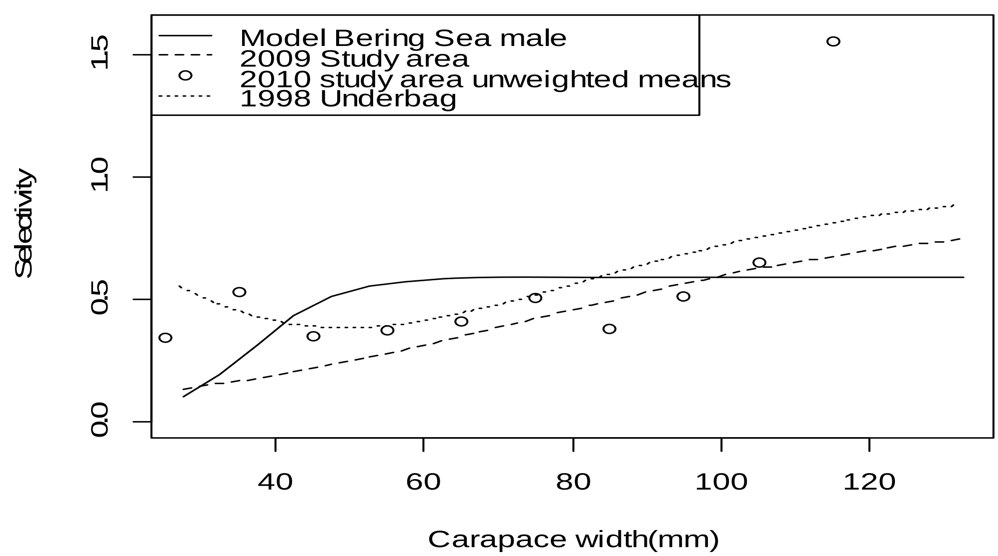


Figure 92. Base Model. Survey selectivity for male crab 1989- present (Model Bering Sea male), with selectivity curves estimated outside the model. 2009 study area is the curve estimated by Somerton from the 2009 study area data.

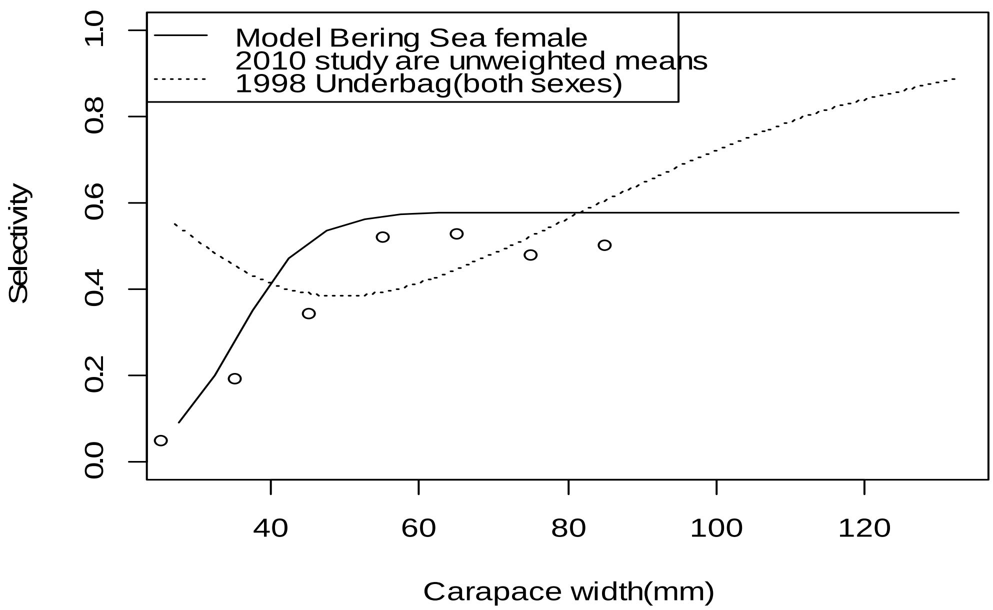


Figure 93. Base Model. Survey selectivity for female crab 1989- present (Model Bering Sea female).

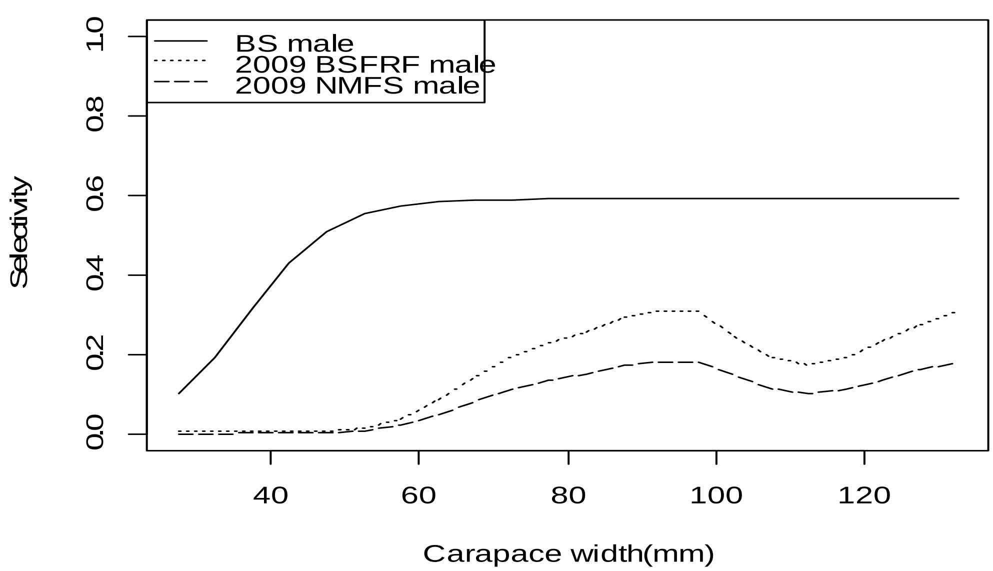


Figure 94. Base Model. Survey selectivity curves for male crab in the entire Bering sea 1989-present (BS male), 2009 study area BSFRF male and 2009 study area NMFS male.

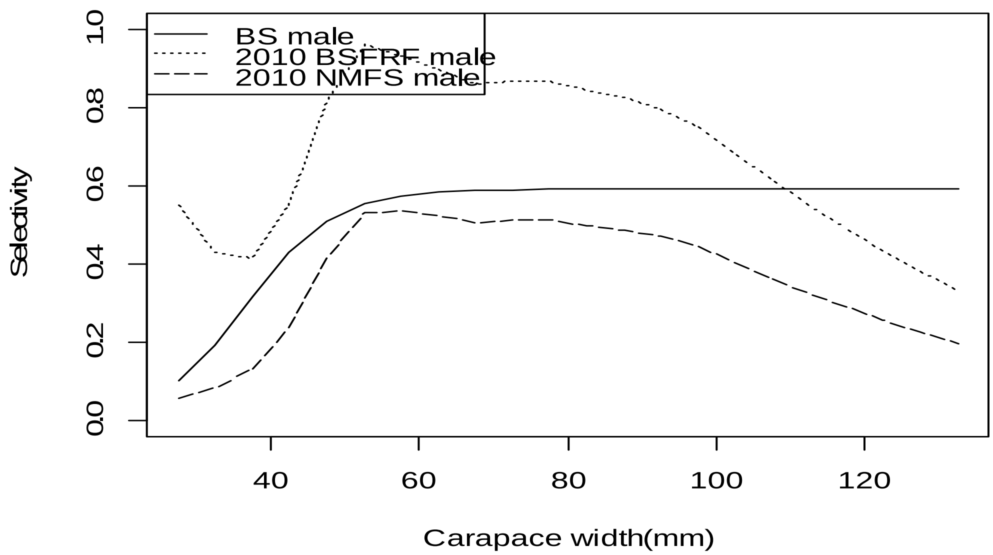


Figure 95. Base Model. Survey selectivity curves for male crab in the entire Bering sea 1989-present (BS male), 2010 study area BSFRF male and 2010 study area NMFS male.

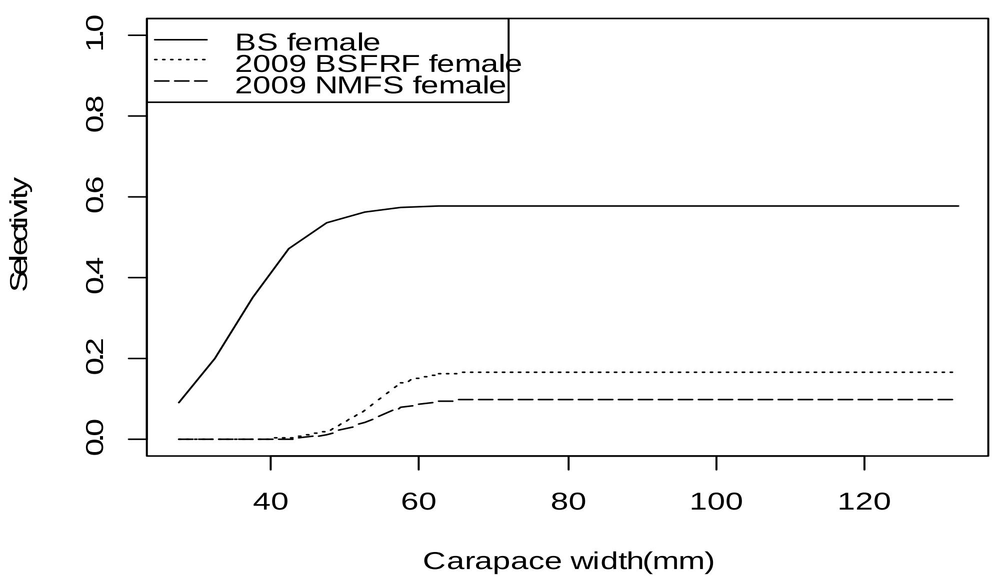


Figure 96. Base Model. Survey selectivity curves for female crab in the entire Bering sea 1989-present (BS female), 2009 study area BSFRF female and 2009 study area NMFS female.

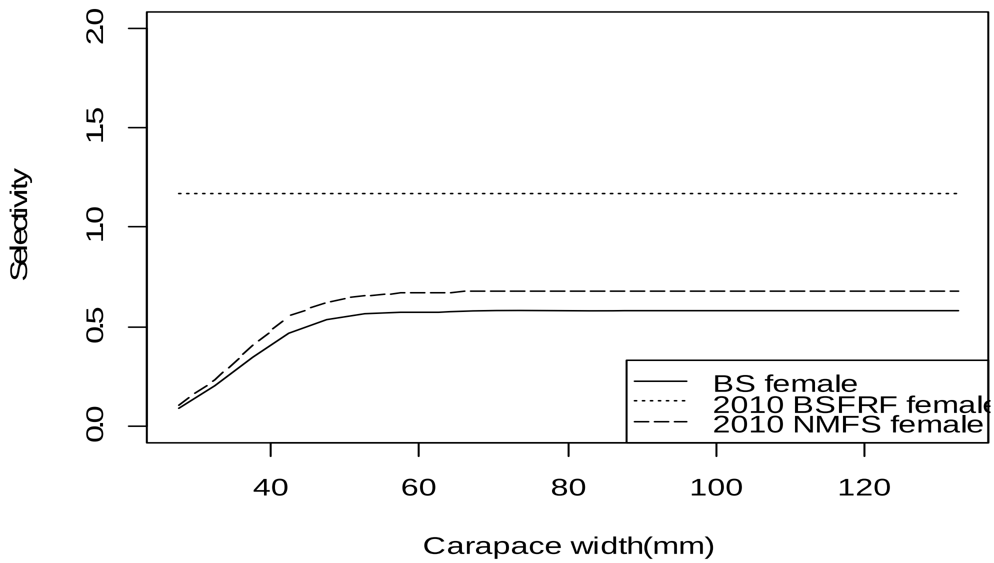


Figure 97. Base Model. Survey selectivity curves for female crab in the entire Bering sea 1989-present (BS female), 2010 study area BSFRF female and 2010 study area NMFS female.

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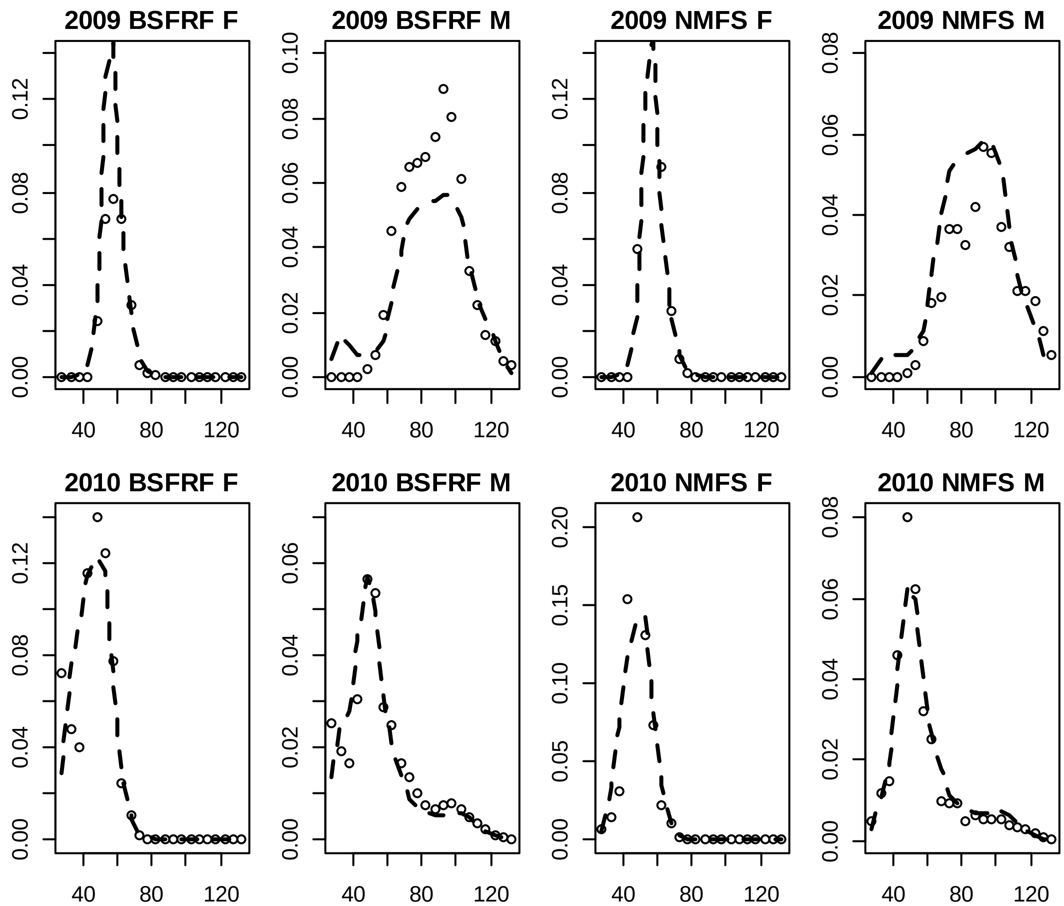


Figure 98. Base Model. Model fit to length frequency for BSFRF and NMFS females and males in the study area.

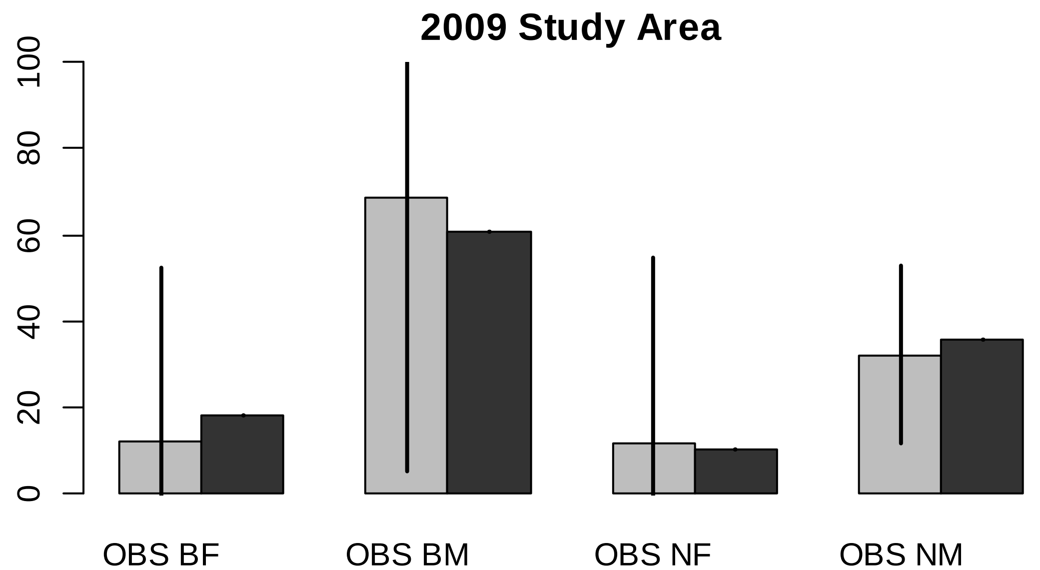


Figure 99. Base Model. Fits to 2009 study area mature biomass by sex for BSFRF and NMFS data.

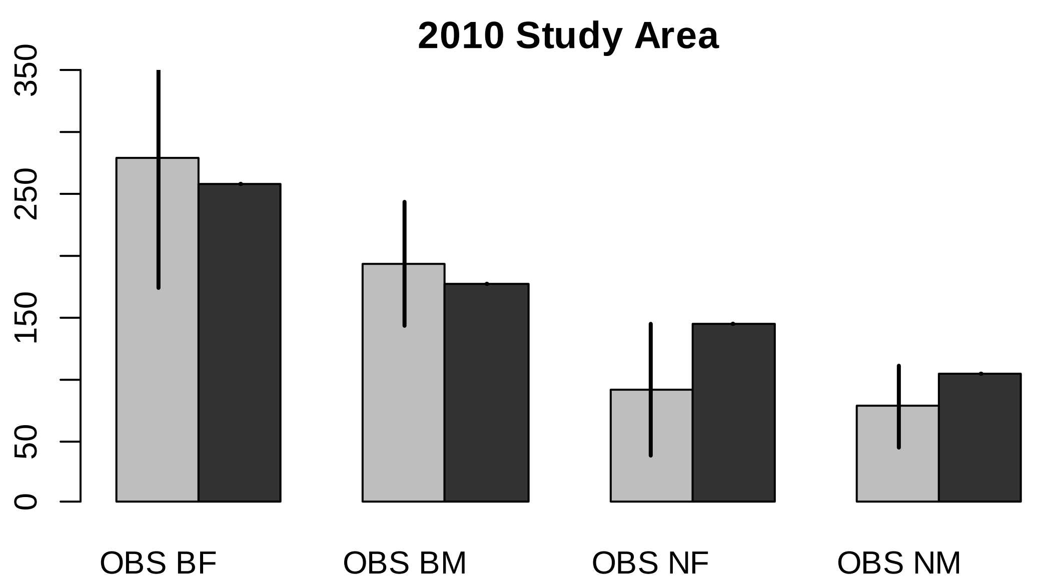


Figure 100. Base Model. Fits to 2010 study area mature biomass by sex for BSFRF and NMFS data.

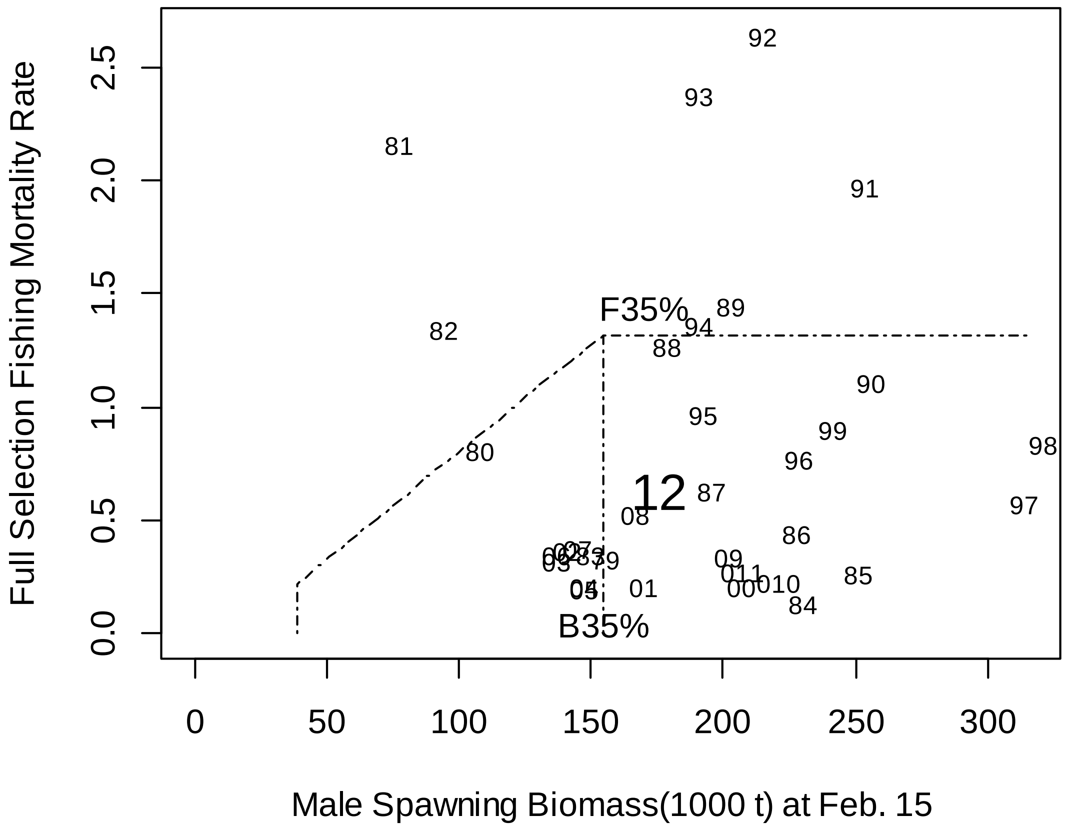


Figure 101. Base Model. Fishing mortality estimated from fishing years 1979 to 20011/12 (labeled 12 in the plot). The OFL control rule (F35%) is shown for comparison. The vertical line is B35%, estimated from the product of spawning biomass per recruit fishing at F35% and mean recruitment from the stock assessment model.

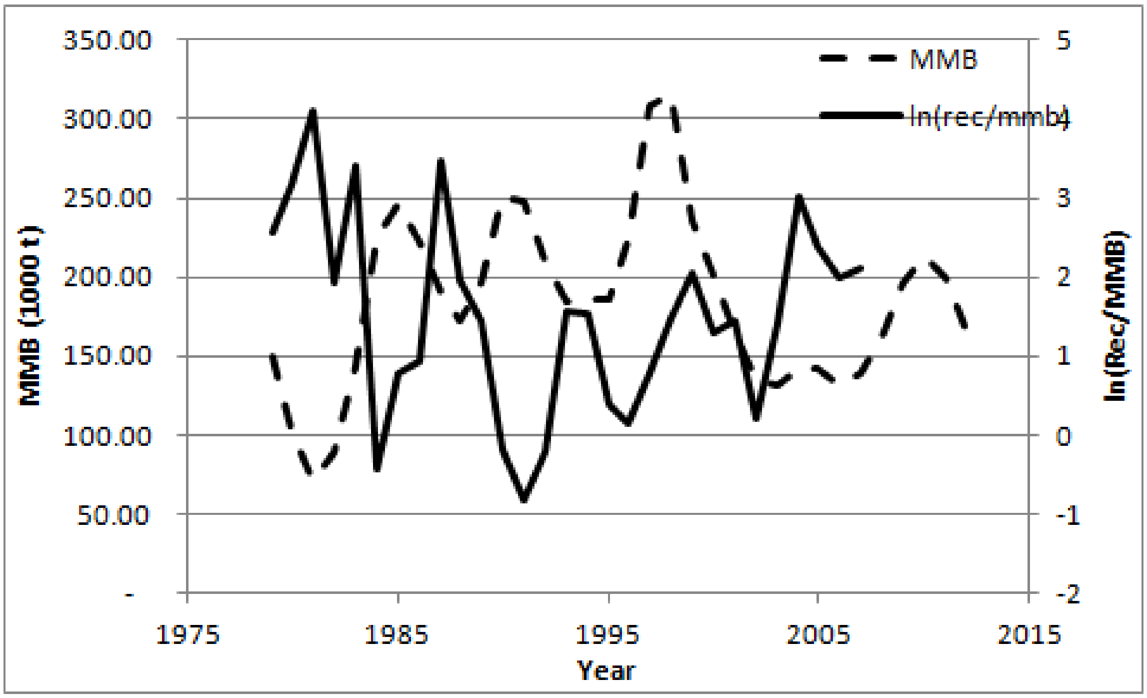


Figure 102. Log of recruits/MMB at mating with a 5 yr lag for recruitment and mature male biomass at mating.

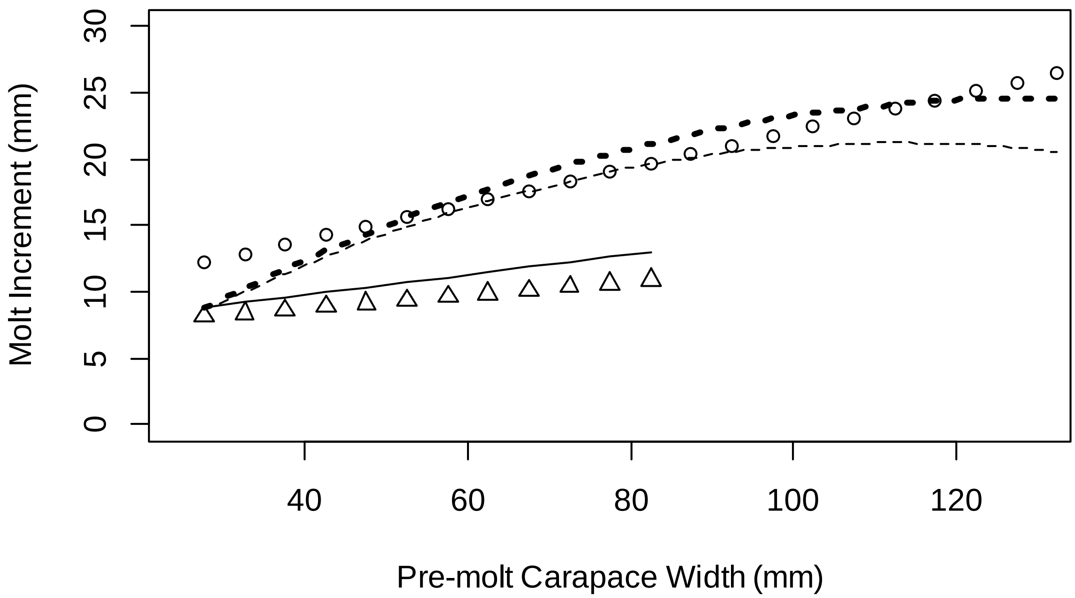


Figure 103. Model 1 with new growth function. Growth(mm) for male(dotted line) and female snow crab (solid line). Circles are the observed growth curve. Heavy dotted line is the growth curve estimated by Somerton from the 2011 growth study (post-molt CW = -0.75 + 1.39 Premolt CW – 0.0015 * (Premolt CW)$^2$. Estimated parameters model 1 are post-molt CW = -0.659 + 1.386 Premolt CW – 0.0017 *(Premolt CW)$^2$.

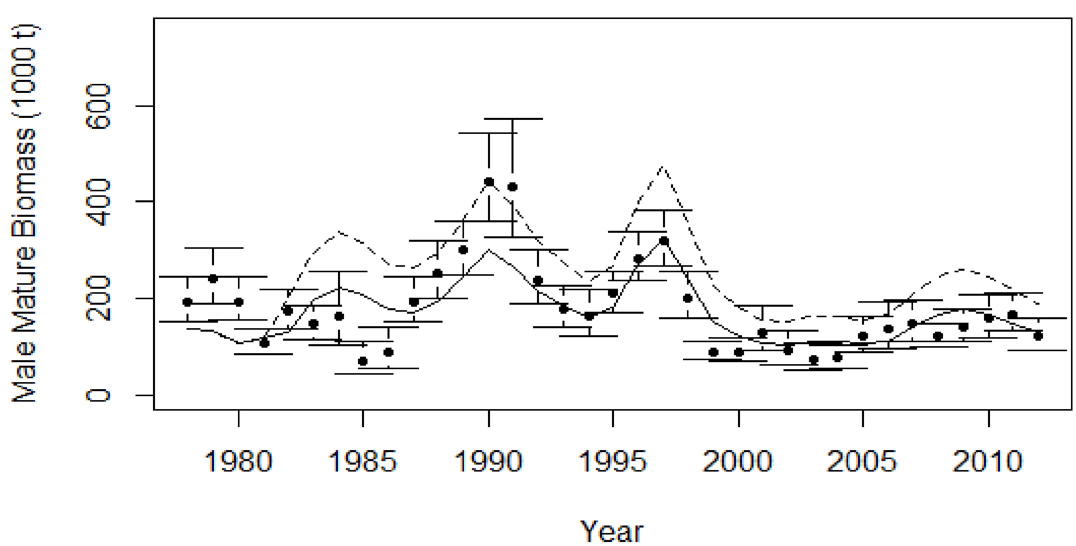

Figure 104. Model 1. Population male mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

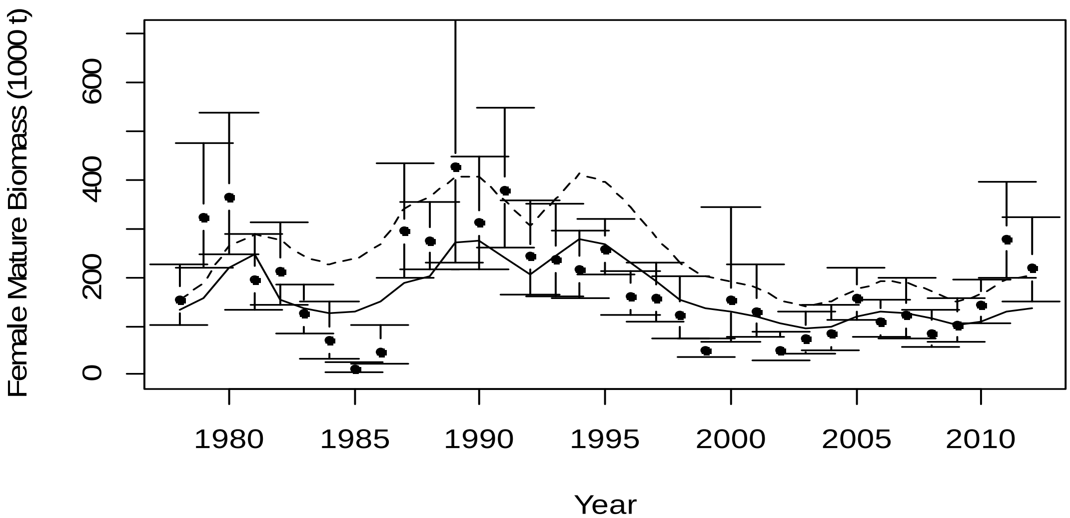


Figure 105. Model 1. Population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

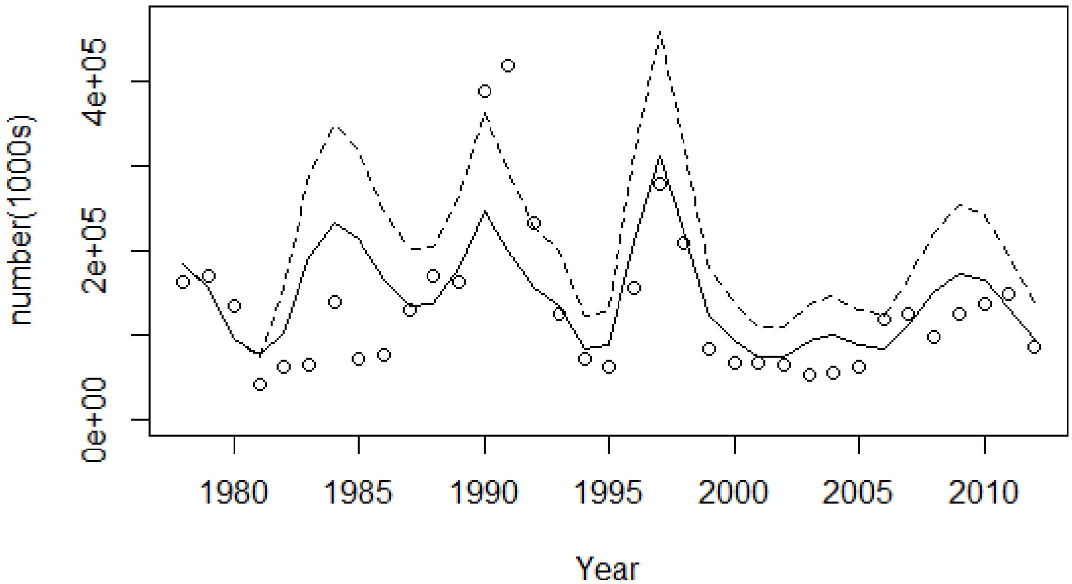


Figure 106. Model 1. Observed survey numbers of males >101mm (circles), model estimates of the population number of males >101mm(solid line) and model estimates of survey numbers of males >101 mm (dotted line).

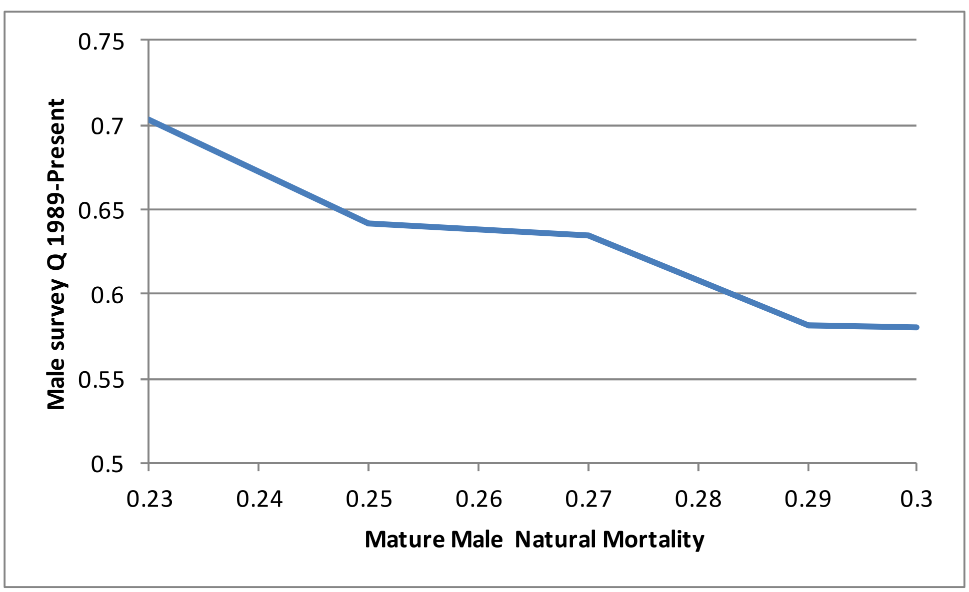


Figure 107. Male survey Q for 1989 to present at values of fixed mature male natural mortality for the Base Model.

# BRISTOL BAY RED KING CRAB STOCK ASSESSMENT IN FALL 2012

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## Executive Summary

1. Stock: red king crab (RKC), *Paralithodes camtschaticus*, in Bristol Bay, Alaska.
2. Catches: The domestic RKC fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lbs (58,943 t). The catch declined dramatically in the early 1980s and has stayed at low levels during the last two decades. Catches during recent years were among the high catches in last 15 years. The retained catch was about 7 million lbs (3,154 t) less in 2011/12 than in 2010/11. Bycatch from groundfish trawl fisheries were steady and small during the last 10 years.
3. Stock biomass: Estimated mature biomass increased dramatically in the mid 1970s and decreased precipitously in the early 1980s. Estimated mature crab abundance has increased during the last 25 years with mature females being 3.3 times more abundant in 2009 than in 1985 and mature males being 2.4 times more abundant in 2009 than in 1985. Estimated mature abundance has steadily declined since 2009.
4. Recruitment: Estimated recruitment was high during 1970s and early 1980s and has generally been low since 1985 (1979 year class). During 1984-2012, only estimated recruitment in 1984, 1995, 2002 and 2005 was above the historical average for 1969-2012. Estimated recruitment was extremely low during the last 6 years.
5. Management performance:

Status and catch specifications (1000 t):

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2006/07 | | | 7.04 | 7.14 | 7.81 | N/A | N/A |
| 2007/08 | | 37.69[A] | 9.24 | 9.30 | 10.54 | N/A | N/A |
| 2008/09 | 15.56[B] | 39.83[B] | 9.24 | 9.22 | 10.48 | 10.98 | N/A |
| 2009/10 | 14.22[C] | 40.37[C] | 7.26 | 7.27 | 8.31 | 10.23 | N/A |
| 2010/11 | 13.63[D] | 32.64[D] | 6.73 | 6.76 | 7.71 | 10.66 | N/A |
| 2011/12 | 13.77[E] | 30.88[E] | 3.55 | 3.61 | 4.09 | 8.80 | 7.92 |
| 2012/13 | | 26.32[E] | NA | NA | NA | 7.96 | 7.17 |

The stock was above MSST in 2011/12 and is hence not overfished. Overfishing did not occur.

Status and catch specifications (million lbs):

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2006/07 | | | 15.53 | 15.75 | 17.22 | N/A | N/A |
| 2007/08 | | 83.1[A] | 20.38 | 20.51 | 23.23 | N/A | N/A |
| 2008/09 | 34.2[B] | 87.8[B] | 20.37 | 20.32 | 23.43 | 24.20 | N/A |
| 2009/10 | 31.3[C] | 89.0[C] | 16.00 | 16.03 | 18.32 | 22.56 | N/A |
| 2010/11 | 30.0[D] | 72.0[D] | 14.84 | 14.91 | 17.00 | 23.52 | N/A |
| 2011/12 | 30.4[E] | 68.1[E] | 7.83 | 7.95 | 9.01 | 19.39 | 17.46 |
| 2012/13 | | 58.0[E] | NA | NA | NA | 17.55 | 15.80 |

Notes:
- A – Calculated from the assessment reviewed by the Crab Plan Team in September 2008
- B – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
- C – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
- D – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
- E – Calculated from the assessment reviewed by the Crab Plan Team in September 2012

6. Basis for the OFL: All table values are in 1000 t.

| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | Natural Mortality |
|---|---|---|---|---|---|---|---|
| 2008/09 | 3a | 34.1 | 43.4 | 1.27 | 0.33 | 1995–2008 | 0.18 |
| 2009/10 | 3a | 31.1 | 43.2 | 1.39 | 0.32 | 1995–2009 | 0.18 |
| 2010/11 | 3a | 28.4 | 37.7 | 1.33 | 0.32 | 1995-2010 | 0.18 |
| 2011/12 | 3a | 27.3 | 29.8 | 1.09 | 0.32 | 1984-2011 | 0.18 |
| 2012/13 | 3a | 27.5 | 26.3 | 0.96 | 0.31 | 1984-2012 | 0.18 |

Basis for the OFL: All table values are in million lbs.

| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | Natural Mortality |
|---|---|---|---|---|---|---|---|
| 2008/09 | 3a | 75.1 | 95.6 | 1.27 | 0.33 | 1995–2008 | 0.18 |
| 2009/10 | 3a | 68.5 | 95.2 | 1.39 | 0.32 | 1995–2009 | 0.18 |
| 2010/11 | 3a | 62.7 | 83.1 | 1.33 | 0.32 | 1995-2010 | 0.18 |
| 2011/12 | 3a | 60.1 | 65.6 | 1.09 | 0.32 | 1984-2011 | 0.18 |
| 2012/13 | 3a | 60.7 | 58.0 | 0.96 | 0.31 | 1984-2012 | 0.18 |

Average recruitments during three periods were used to estimate $B_{35\%}$: 1969-1983, 1969-present, and 1984-present. We recommend using the average recruitment during 1984-present, corresponding to the 1976/77 regime shift. Note that recruitment period 1984-present was used in 2011/12 to set the overfishing limits. There are several reasons for supporting our recommendation. First, estimated recruitment was lower after 1983 than before 1984, which corresponded to brood years 1978 and later, after the 1976/77 regime shift. Second, high recruitments during the late 1960s and 1970s generally occurred when the spawning stock was primarily located in the southern Bristol Bay, whereas the current spawning stock is mainly in the middle of Bristol Bay. The current flows favor larvae hatched in the southern Bristol Bay. Finally, stock productivity (recruitment/mature male biomass) was much higher before the 1976/1977 regime shift: the mean value was 4.054 during brood years 1968-1977 and 0.828 during 1978-2006. The two-tail t-tests with unequal variances show that ln(recruitment) and ln(recruitment/mature male biomass) between brood years 1968-1977 and 1978-2006 are strongly, statistically different with p values of 0.0000000007725 and 0.000708, respectively.

## *A. Summary of Major Changes*

**1. Change to management of the fishery:** None.

**2. Changes to the input data:**

a. Catch and bycatch were updated through August 2012 and the 2012 summer trawl survey data were added.

**3. Changes to the assessment methodology:**

Twelve model scenarios were evaluated in May 2011. In this report, only results for scenario 7ac are presented. The results for all other scenarios were presented in the SAFE report in May 2011. The 7ac scenario include: (1) basic M = 0.18, and additional mortalities as one level (1980-1984) for males and two levels (1980-1984 and 76-79 & 85-93) for females; (2) including BSFRF survey data in 2007 and 2008; (3) estimating NMFS survey catchability for 1970-72 and assuming it to be 0.896 for all other years; (4) three levels of molting probabilities for males; (5) estimating effective sample size from observed sample sizes; (6) standard survey data for males and retow data for females; and (7) estimating initial year length compositions.

**4. Changes to assessment results:**

Both male and female abundances from the 2012 summer trawl survey were lower than expected. Estimated mature male abundance in 2012 was about 10.2% lower than those in 2011.

Estimated crab abundance and biomass during recent five years were generally lower than those estimated in 2011.

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

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

None.

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

**Response to CPT Comments (from September 2011)**

*"… The CPT* ***recommends*** *that an analysis be prepared for May 2012that includes a constant-M model (i.e., no periods of increased natural mortality) so that the effect of the Scenario 7ac mortality estimates on the estimates of and trends in recruitment and R/MMB can be assessed; overall, it is* ***recommended*** *that a constant-M always be included as one of the scenarios in assessments for this stock so that the effects of, and need for, the variable-M models on the stock assessment can be assessed."*

Because no work is done for Bristol Bay red king crab in May 2012, the model comparison will be done in May 2013.

**Response to CPT Comments (from May 2011) (these responses were made in September 2011).**

"*More information should be provided why it is reasonable that assuming the bycatch rate in the 1980s equaled the two highest bycatch rates can address the question of whether high bycatch mortality in the 1980s caused the drop in abundance."*

Good information for estimating bycatch rates in the early 1980s is not available. From the responses to the CIE comments in the 2011 SAFE, the only observed data in the early 1980s from Griffin et al. (1983) did not show very high bycatch rates relative to the survey abundance. The two highest observed bycatch rates represent the high end of bycatch rates we have data on.

*"Page 175 – the text relative to the assumption being conservative should not be included in text; rather it should be made clear that this is the best estimate."*

Remove the wording of "conservative assumption"

*"Additional justification for differential mortality rates for males and females should be provided because, at present, the model fits the data, but the mechanisms for, for example, sex-specific natural mortality over different periods is unclear. "*

The following text was added to the report: These additional mortalities could be due to increase in natural mortality or unknown fishing mortality. Predation mortality could result in different natural mortalities for males and females because predation for mature crab is mainly on soft shell crab and mature females molt yearly.

*"The fraction of the female stock outside survey area in each year needs to be linked to something. It is possible that the differences in abundance between legs 3 and 1 relate to the proportion outside of the survey area. There are survey data indicating that the proportion of animals outside of survey area in a cold year. These data could be used as an index. The hot spot issue should be identified as research priority along with the need for tagging data."*

We also think this is an important issue because estimated recruitments for males and females are forced to be similar to each other each year. It is not easy to find a good index to link to. We will continue to examine this in the future.

*"How the BSFRF data are incorporated in the assessment should be re-evaluated in conjunction with scientists from BSFRF; specifically, the assessment currently ignores the length data from the BSFRF surveys as well as the female data. This could be a topic for a modeling workshop."*

We will look into this in the future.

*"The estimates of time-trajectories of mature biomass are computed from the output of the model because "maturity" is not explicitly represented in the model. The equation for the population dynamics should be modified to indicate that growth (for females) changes over time."*

Done. The description of the female model includes change of the growth matrix over time.

*"Indicate the MLE on the graph for OFL"*

Done.

*"The team recommends additional runs for the September assessment which combine model configurations 7 and 1a (the 'recommended' model). Model configurations 7 a,c should also be included in the September assessment."*

The "configurations 7 and 1a (the 'recommended' model)" conflicts with the CPT position that the standard survey data are used for male abundance estimates (see the CPT recommendation in September 2010 above). Scenario 7ac, the combination of scenarios 7, 1a and 1c, is used as the CPT recommended model for this report (based on my note from the May CPT meeting).

**Response to SSC Comments specific to this assessment (from Oct. 2011)**

*"The SSC notes that the authors' preferred model Model 7ac continues to apply higher M for the period 1980 through 1984 for males and 1980 through 1984, 1976 through 1979 and 1985 through 1993 for females. The SSC would like additional justification for these additional*

*natural mortality periods. The SSC requests that the author include two new options next year: (1) an option with no additional M periods and (2) an option without additional M periods and an additional survey selectivity period in the early 1980s. The author's justification for adding additional mortality based on increasing predation by Pacific cod is inconsistent with the Ecosystem Chapter that states that there is little evidence for predation on BBRKC by Pacific cod."*

Four potential factors for high mortality during the early 1980s are described in **Appendix A, Section e. Parameter estimation framework: (6) Potential Reasons for High Mortality during the Early 1980s.** The reason for lack of groundfish predation data is also described there. It is a sampling problem, rather than a lack of predation.

Because no work is done for Bristol Bay red king crab in May 2012, the model comparison will be done in May 2013.

*"The SSC also recommends that if the authors change their preferred model in the upcoming year they should bring forward the most recent SSC approved Model 7ac as well as the preferred model in the final SAFE. This will allow the SSC to compare the implications of adopting the proposed new model configuration. Proposed changes to the model should be brought forward for consideration during the May CPT meeting."*

Will do according to the request.

*"Bob Foy informed the SSC that the 2011 re-tow data revealed a marked decline in male survey catches. He speculated that this was due to dispersion of males during the summer. The CPT discussed this issue and concluded that the current practice of eliminating re-tow data for males should be continued to maintain the integrity of the time series. The SSC requests that the authors review the re-tow data for males to determine whether the decision to eliminate re-tow data for males is still the best use of the available data. Specifically the SSC is concerned that if the reduction in biomass was due to dispersion of males that the estimate based on more dispersed distributions may be the best estimate of biomass. Spatial patterns of male catches within the re-tow area may provide insights."*

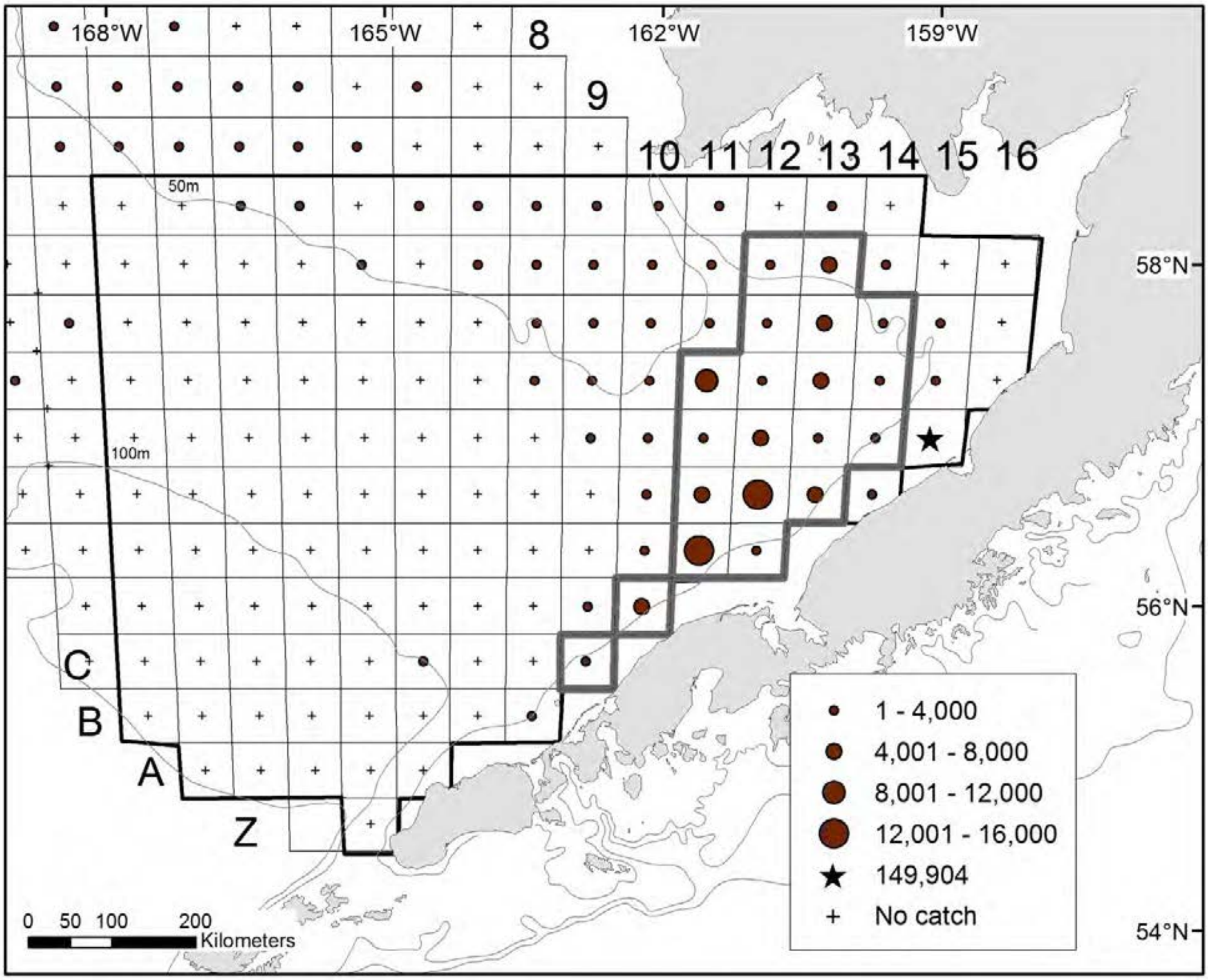
The spatial information (mature males in million) is summarized in the following table, and the map with stations is also shown below. In the following table, nearshore stations include B08, C08, C09, D09, D10, E11, E12, F12, F13, F14, G13, G14, H14, H15 and I14. Stations 14 or west include F14, G14, H14, H15 and I14. The distribution centers, which are abundance-weighted average of locations, indicate that mature males slightly move northward from the standard survey to the resurvey (7 out of 8 years). The mature male abundances are generally higher from the standard survey than the resurvey (7 out of 8 years). When the resurvey includes stations 14 or west, the difference of mature male abundances between the standard survey and resurvey are caused by the difference in the nearshore stations. This suggests that from the standard survey to resurvey, mature males in the nearshore stations generally move off the nearshore somewhat. Combination of including more nearshore stations and less offshore stations in 2010 and 2011 explains the marked decline of mature male catches.

We agree with SSC that "*the estimate based on more dispersed distributions may be the best estimate of biomass.*" However, when the dispersed distribution is outside of the resurvey stations, such dispersed distribution underestimates the male abundance. The issue is that the resurvey is designed for mature females and does not adequately cover the male distribution. Because of dispersion and inadequate coverage of the male distribution with the resurvey, we think that the standard survey provides better male abundance estimates.

---------------------------------------------------------------------------------------------------------------

| | 1999 | 2000 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|
| **Standard survey** | | | | | | | | |
| Total St. | 31 | 23 | 30 | 32 | 32 | 32 | 23 | 20 |
| St. 14 or west | 0 | 5 | 0 | 0 | 0 | 4 | 4 | 4 |
| Center Lat. | 56.5 | 56.615 | 57.181 | 57.030 | 56.732 | 56.855 | 56.758 | 56.903 |
| Center Long. | -162.321 | -161.479 | -161.909 | -161.897 | -161.708 | -161.210 | -161.375 | -160.983 |
| Total m.males | 13.097 | 8.839 | 8.987 | 10.238 | 11.161 | 7.955 | 11.897 | 6.389 |
| Nearshore m.males | 3.757 | 4.722 | 1.367 | 3.354 | 5.014 | 4.709 | 8.139 | 3.447 |
| | | | | | | | | |
| **Resurvey** | | | | | | | | |
| Center Lat. | 56.751 | 56.77 | 56.968 | 57.037 | 56.785 | 56.949 | 56.810 | 57.03 |
| Center Long. | -161.915 | -161.583 | -161.955 | -161.559 | -161.536 | -161.279 | -161.345 | -161.203 |
| Total m.males | 9.848 | 7.826 | 7.891 | 9.437 | 10.983 | 8.394 | 9.546 | 4.031 |
| Nearshore m.males | 3.444 | 2.321 | 1.994 | 2.454 | 5.303 | 3.217 | 5.585 | 0.882 |

Total density (number/nmi2) of red king crab (*Paralithodes camtschaticus*) at each station sampled in the 2011 Bristol Bay District. Data depicted by circles are equal interval densities, while stars are densities larger than the standard scale. Outlined area depicts the management district and the resurveyed stations outlined in grey within the management district. (source: NMFS crab survey report in 2011). The rows from the bottom to the top are Z, A, B, C, D, E, F, G, H, I, and J.

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*"Figures 4 and 5 should be pivoted to allow one to see modal progressions."*

Done.

**Response to SSC Comments specific to this assessment (from June 2011)**

*"The Plan Team made several suggestions to improve document clarity and recommended reevaluating the treatment of the BSFRF data by including length data and data for females. The Team also requested two additional scenarios: (1) a scenario combining (1a) with (7), and (2) a scenario combining (1c) with (7). The Team also developed 4 possible time periods for the baseline for calculating reference biomass. The SSC concurs with these recommendations."*

See the responses to the CPT comments in May 2011.

## *C. Introduction*

### 1. Species

Red king crab (RKC), *Paralithodes camtschaticus* in Bristol Bay, Alaska.

### 2. General distribution

Red king crab inhabit intertidal waters to depths >200 m of the North Pacific Ocean from British Columbia, Canada, to the Bering Sea, and south to Hokkaido, Japan. RKC are found in several areas of the Aleutian Islands and eastern Bering Sea.

### 3. Stock Structure

The State of Alaska divides the Aleutian Islands and eastern Bering Sea into three management registration areas to manage RKC fisheries: Aleutian Islands, Bristol Bay, and Bering Sea (Alaska Department of Fish and Game (ADF&G) 2005). The Aleutian Islands area covers two stocks, Adak and Dutch Harbor, and the Bering Sea area contains two other stocks, the Pribilof Islands and Norton Sound. The largest stock is found in the Bristol Bay area, which includes all waters north of the latitude of Cape Sarichef (54$^o$36’ N lat.), east of 168$^o$00’ W long., and south of the latitude of Cape Newenham (58$^o$39’ N lat.) (ADF&G 2005). Besides these five stocks, RKC stocks elsewhere in the Aleutian Islands and eastern Bering Sea are currently too small to support a commercial fishery. This report summarizes the stock assessment results for the Bristol Bay RKC stock.

### 4. Life History

Life history of RKC is complex. Fecundity is a function of female size, ranging from several tens of thousands to a few hundreds of thousands (Haynes 1968). The eggs are extruded by females and fertilized in the spring and are held by females for about 11 months (Powell and Nickerson 1965). Fertilized eggs are hatched in spring, most during the April to June period (Weber 1967). Primiparous females are bred a few weeks earlier in the season than multiparous females.

Larval duration and juvenile crab growth depend on temperature (Stevens 1990; Stevens and Swiney 2007). The RKC mature at 5–12 years old, depending on stock and temperature (Stevens 1990) and may live >20 years (Matsuura and Takeshita 1990), with males and females attaining a maximum size of 227 and 195 mm carapace length (CL), respectively (Powell and Nickerson 1965). For management purposes, females >89 mm CL and males > 119 mm CL are assumed to be mature for Bristol Bay RKC. Juvenile RKC molt multiple times per year until age 3 or 4; thereafter, molting continues annually in females for life and in males until maturity. After maturing, male molting frequency declines.

### 5. Fishery

The RKC stock in Bristol Bay, Alaska, supports one of the most valuable fisheries in the United States (Bowers et al. 2008). The Japanese fleet started the fishery in the early 1930s, stopped fishing from 1940 to 1952, and resumed the fishery from 1953 until 1974 (Bowers et al. 2008). The Russian fleet fished for RKC from 1959 through 1971. The Japanese fleet employed primarily tanglenets with a very small proportion of catch from trawls and pots. The Russian fleet used only tanglenets. United States trawlers started to fish for Bristol Bay RKC in 1947, and effort and catch declined in the 1950s (Bowers et al. 2008). The domestic RKC fishery began to expand in the late 1960s and peaked in 1980 with a catch of 129.95 million lbs (58,943 t), worth an estimated $115.3 million ex-vessel value (Bowers et al. 2008). The catch declined dramatically in the early 1980s and has stayed at low levels during the last two decades (Table 1). After the stock collapse in the early 1980s, the Bristol Bay RKC fishery took place during a short period in the fall (usually lasting about a week), with the catch quota based on the stock assessment conducted in the previous summer (Zheng and Kruse 2002). As a result of new regulations for crab rationalization, the fishery was open longer from October 15 to January 15, beginning with the 2005/2006 season. With the implementation of crab rationalization, historical guideline harvest levels (GHL) were changed to a total allowable catch (TAC). The GHL/TAC and actual catch are compared in Table 2. The implementation errors are quite high for some years, and total actual catch from 1980 to 2007 is about 6% less than the sum of GHL/TAC over that period (Table 2).

**6. Fisheries Management**

King and Tanner crab stocks in the Bering Sea and Aleutian Islands are managed by the State of Alaska through a federal king and Tanner crab fishery management plan (FMP). Under the FMP, management measures are divided into three categories: (1) fixed in the FMP, (2) frame worked in the FMP, and (3) discretion of the State of Alaska. The State of Alaska is responsible for developing harvest strategies to determine GHL/TAC under the framework in the FMP.

Harvest strategies for the Bristol Bay RKC fishery have changed over time. Two major management objectives for the fishery are to maintain a healthy stock that ensures reproductive viability and to provide for sustained levels of harvest over the long term (ADF&G 2005). In attempting to meet these objectives, the GHL/TAC is coupled with size-sex-season restrictions. Only males≥6.5-in carapace width (equivalent to 135-mm carapace length, CL) may be harvested and no fishing is allowed during molting and mating periods (ADF&G 2005). Specification of TAC is based on a harvest rate strategy. Before 1990, harvest rates on legal males were based on population size, abundance of prerecruits to the fishery, and postrecruit abundance, and rates varied from less than 20% to 60% (Schmidt and Pengilly 1990). In 1990, the harvest strategy was modified, and a 20% mature male harvest rate was applied to the abundance of mature-sized (≥120-mm CL) males with a maximum 60% harvest rate cap of legal (≥135-mm CL) males (Pengilly and Schmidt 1995). In addition, a minimum threshold of 8.4 million mature-sized females (≥90-mm CL) was added to existing management measures to avoid recruitment overfishing (Pengilly and Schmidt 1995). Based on a new assessment model and research findings (Zheng et al. 1995a, 1995b, 1997a, 1997b), the Alaska Board of Fisheries adopted a new harvest strategy in 1996. That strategy had two mature male harvest rates: 10% when effective spawning biomass (ESB) is between 14.5 and 55.0 million lbs and 15% when ESB is at or above 55.0 million lbs (Zheng el al. 1996). The maximum harvest rate cap of legal males was changed from 60% to 50%. An additional threshold of 14.5 million lbs of ESB was also added. In 1997, a minimum threshold of 4.0 million lbs was established as the minimum GHL for opening the fishery and maintaining fishery manageability when the stock abundance is low. In 2003, the Board modified the current harvest strategy by adding a mature harvest rate of 12.5% when the ESB is between 34.75 and 55.0 million lbs. The current harvest strategy is illustrated in Figure 1.

# *D. Data*

## 1. Summary of New Information

New data include commercial catch and bycatch in 2011/2012 and the 2012 summer trawl survey.

## 2. Catch Data

Data on landings of Bristol Bay RKC by length and year and catch per unit effort were obtained from annual reports of the International North Pacific Fisheries Commission from 1960 to 1973 (Hoopes et al. 1972; Jackson 1974; Phinney 1975) and from the ADF&G from 1974 to 2008 (Bowers et al. 2008). Bycatch data are available starting from 1990 and were obtained from the ADF&G observer database and reports (Bowers et al. 2008; Burt and Barnard 2006). Sample sizes for catch by length and shell condition are summarized in Table 2. Relatively large samples were taken from the retained catch each year. Sample sizes for trawl bycatch were the annual sums of length frequency samples in the National Marine Fisheries Service (NMFS) database.

### *(i). Catch Biomass*

Retained catch and estimated bycatch biomasses are summarized in Table 1. Retained catch and estimated bycatch from the directed fishery include both the general open access fishery (i.e., harvest not allocated to Community Development Quota [CDQ] groups) and the CDQ fishery. Starting in 1973, the fishery generally occurred during the late summer and fall. Before 1973, a small portion of retained catch in some years was caught from April to June. Because most crab bycatch from the groundfish trawl fisheries occurred during the spring, the years in Table 1 are one year less than those from the NMFS trawl bycatch database to approximate the annual bycatch for reporting years defined as June 1 to May 31; e.g., year 2002 in Table 1 corresponds to what is reported for year 2003 in the NMFS database. Catch biomass is shown in Figure 2. Bycatch data for the cost-recovery fishery before 2006 were not available.

### *(ii). Catch Size Composition*

Retained catch by length and shell condition and bycatch by length, shell condition, and sex were obtained for stock assessments. From 1960 to 1966, only retained catch length compositions from the Japanese fishery were available. Retained catches from the Russian and U.S. fisheries were assumed to have the same length compositions as the Japanese fishery during this period. From 1967 to 1969, the length compositions from the Russian fishery were assumed to be the same as those from the Japanese and U.S. fisheries. After 1969, foreign catch declined sharply and only length compositions from the U.S. fishery were used to distribute catch by length.

### *(iii). Catch per Unit Effort*

Catch per unit effort (CPUE) is defined as the number of retained crabs per tan (a unit fishing effort for tanglenets) for the Japanese and Russian fisheries and the number of retained crabs per potlift for the U.S. fishery (Table 3). Soak time, while an important factor influencing CPUE, is difficult to standardize. Furthermore, complete historical soak time data from the U.S. fishery are not available. Based on the approach of Balsiger (1974), all fishing effort from Japan, Russia, and

U.S. were standardized to the Japanese tanglenet from 1960 to 1971, and the CPUE was standardized as crabs per tan. The U.S. CPUE data have similar trends as survey legal abundance after 1971 (Figure 3). Due to the difficulty in estimating commercial fishing catchability and the ready availability of NMFS annual trawl survey data, commercial CPUE data were not used in the model.

**3. NMFS Survey Data**

The NMFS has performed annual trawl surveys of the eastern Bering Sea since 1968. Two vessels, each towing an eastern otter trawl with an 83 ft headrope and a 112 ft footrope, conduct this multispecies, crab-groundfish survey during the summer. Stations are sampled in the center of a systematic 20 X 20 nm grid overlaid in an area of ≈140,000 nm$^2$. Since 1972 the trawl survey has covered the full stock distribution except in nearshore waters. The survey in Bristol Bay occurs primarily during late May and June. Tow-by-tow trawl survey data for Bristol Bay RKC during 1975-2011 were provided by NMFS.

Abundance estimates by sex, carapace length, and shell condition were derived from survey data using an area-swept approach without post-stratification (Figures 4 and 5). If multiple tows were made for a single station in a given year, the average of the abundances from all tows was used as the estimate of abundance for that station. Until the late 1980s, NMFS used a post-stratification approach, but subsequently treated Bristol Bay as a single stratum. If more than one tow was conducted in a station because of high RKC abundance (i.e., the station is a "hot spot"), NMFS regards the station as a separate stratum. Due to poor documentation, it is difficult to duplicate past NMFS post-stratifications. A "hot spot" was not surveyed with multiple tows during the early years. Two such "hot spots" affected the survey abundance estimates greatly: station H13 in 1984 (mostly juvenile crabs 75-90 mm CL) and station F06 in 1991 (mostly newshell legal males). The tow at station F06 was discarded in the older NMFS abundance estimates (Stevens et al. 1991). In this study, all tow data were used. NMFS re-estimated historic areas-swept in 2008 and re-estimated area-swept abundance as well, using all tow data.

In addition to standard surveys, NMFS also conducted some surveys after the standard surveys to assess mature female abundance. Two surveys were conducted for Bristol Bay RKC in 1999, 2000, 2006-2011: the standard survey that was performed in late May and early June (about two weeks earlier than historic surveys) in 1999 and 2000 and the standard survey that was performed in early June in 2006-2010 and resurveys of 31 stations (1999), 23 stations (2000), 31 stations (2006, 1 bad tow and 30 valid tows), 32 stations (2007-2009), 23 tows (2010) and 20 stations (2011 and 2012) with high female density that was performed in late July, about six weeks after the standard survey. The resurveys were necessary because a high proportion of mature females had not yet molted or mated prior to the standard surveys (Figure 6). Differences in area-swept estimates of abundance between the standard surveys and resurveys of these same stations are attributed to survey measurement errors or to seasonal changes in distribution between survey and resurvey. More large females were observed in the resurveys than during the standard surveys in 1999 and 2000 because most mature females had not molted prior to the standard surveys. As in 2006, area-swept estimates of males >89 mm CL, mature males, and legal males within the 32 resurvey stations in 2007 were not significantly different between the standard survey and resurvey

(*P*=0.74, 0.74 and 0.95) based on paired *t*-tests of sample means. However, similar to 2006, area-swept estimates of mature females within the 32 resurvey stations in 2007 are significantly different between the standard survey and resurvey (*P*=0.03) based on the *t*-test. However, the re-tow stations were close to shore during 2010-2012, and mature and legal male abundance estimates were lower for the re-tow than the standard survey. Following the CPT recommendation, we used the standard survey data for male abundance estimates and only the resurvey data, plus the standard survey data outside the resurveyed stations, to assess female abundance during these resurvey years.

For 1968-1970 and 1972-1974, abundance estimates were obtained from NMFS directly because the original survey data by tow were not available. There were spring and fall surveys in 1968 and 1969. The average of estimated abundances from spring and fall surveys was used for those two years. Different catchabilities were assumed for survey data before 1973 because of an apparent change in survey catchability. A footrope chain was added to the trawl gear starting in 1973, and the crab abundances in all length classes during 1973-1979 were much greater than those estimated prior to 1973 (Reeves et al. 1977).

### 4. Bering Sea Fisheries Research Foundation Survey Data

The BSFRF conducted trawl surveys for Bristol Bay red king crab in 2007 and 2008 with a small-mesh trawl net and 5-minute tows. The surveys occurred at similar times with the NMFS standard surveys and covered about 97% of the Bristol Bay area. Few Bristol Bay red king crab were outside of the BSFRF survey area. Because of small mesh size, the BSFRF surveys wereee expected to catch nearly all red king crabs within the swept area. Crab abundances of different size groups were estimated by the Kriging method. Mature male abundances were estimated to be 22.331 and 19.747 million in 2007 and 2008 with a CV of 0.0634 and 0.0765.

## *E. Analytic Approach*

### 1. History of Modeling Approaches

To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, the ADF&G developed a length-based analysis (LBA) in 1994 that incorporates multiple years of data and multiple data sources in the estimation procedure (Zheng et al. 1995a). Annual abundance estimates of the Bristol Bay RKC stock from the LBA have been used to manage the directed crab fishery and to set crab bycatch limits in the groundfish fisheries since 1995 (Figure 1). An alternative LBA (research model) was developed in 2004 to include small size groups for federal overfishing limits. The crab abundance declined sharply during the early 1980s. The LBA estimated natural mortality for different periods of years, whereas the research model estimated additional mortality beyond a basic constant natural mortality during 1976-1993. In this report, we present only the research model that was fit to the data from 1968 to 2010.

### 2. Model Description

a. The original LBA model was described in detail by Zheng et al. (1995a, 1995b) and Zheng and Kruse (2002). The model combines multiple sources of survey, catch, and bycatch data using a maximum likelihood approach to estimate abundance, recruitment, and catchabilities, catches and bycatch of the commercial pot fisheries and groundfish trawl fisheries. A full model description is provided in Appendix A.

b-f. See appendix.

g. Critical assumptions of the model:

i. The base natural mortality is constant over shell condition and length and was estimated assuming a maximum age of 25 and applying the 1% rule (Zheng 2005).

ii. Survey and fisheries selectivities are a function of length and were constant over shell condition. Selectivities are a function of sex except for trawl bycatch selectivities, which are the same for both sexes. Four different survey selectivities were estimated: (1) 1968-69 (surveys at different times), (2) 1970-72 (surveys without a footrope chain), (3) 1973-1981, and (4) 1982-2012 (modifying approaches to surveys).

iii. Growth is a function of length and did not change over time for males. For females, three growth increments per molt as a function of length were estimated based on sizes at maturity (1968-1982, 1983-1993, and 1994-2012). Once mature, female red king crabs grow with a much smaller growth increment per molt.

iv. Molting probabilities are an inverse logistic function of length for males. Females molt annually.

v. Annual fishing seasons for the directed fishery are short.

vi. Survey catchability (*Q*) was estimated to be 0.896, based on a trawl experiment by Weinberg et al. (2004). *Q* was assumed to be constant over time except during 1970-1972. Q during 1970-1972 was estimated in the model.

vii. Males mature at sizes ≥120 mm CL. For convenience, female abundance was summarized at sizes ≥90 mm CL as an index of mature females.

viii. For summer trawl survey data, shell ages of newshell crabs were 12 months or less, and shell ages of oldshell and very oldshell crabs were more than 12 months.

ix. Measurement errors were assumed to be normally distributed for length compositions and were log-normally distributed for biomasses.

**3. Model Selection and Evaluation**

a. Alternative model configurations:

Eleven scenarios were compared for this report following September 2010 CPT request, the response to CIE review, and the response to the Stock Assessment Workshop recommendations.

Scenario 0: We called the base scenario as Scenario 0 and other scenarios as Scenarios 1-7. Scenario 0 is the original scenario 3 in the September 2010 SAFE report. The base scenario is: constant natural mortality (0.18), estimation of additional mortality for males during 1980-1984 (one parameter) and for females during 1976-1993 (one parameter for period 1980-1984 and another parameter for periods 1976-1979 and 1985-1993), and including the Bering Sea Fisheries Research Foundation (BSFRF) survey data. These additional mortalities could be due to increase in natural mortality or unknown fishing mortality. Predation mortality could result in different natural mortalities for males and females because predation for mature crab is mainly on soft shell crab and mature females molt yearly.

Scenario 1: The same as scenario 0 except for using observed proportions in the variance formula for size composition.

Scenario 1a: The same as scenario 1 except estimating initial abundance by length and sex. An additional 36 parameters from scenario 1 are estimated. An additional likelihood component is added from the length compositions in the first year:

$$f = \sum_{l,sex}(observed\ length\ proportions - estimated\ length\ proportions)^2$$

Scenario 1b: The same as scenario 1 except only the standard survey data are used for estimating survey male and female abundances.

Scenario 1c: The same as scenario 1 except only the standard survey data are used for estimating survey male abundance and re-tow data are used for female abundance (the CPT option).

Scenario 2: The same as scenario 1 except for survey catchability for females changes annually. Specifically, an annual variable within the range, 0.8 to 1.0, is estimated within the model and multiplied by the fixed survey catchability of 0.896 for females. A penalty term with a CV of 0.1 is used to estimate this variable. This scenario illustrates the effects of annual variation on population and parameter estimates. Due to lack of data, it is difficult to estimate annual catchability. An additional 43 parameters from scenario 1 are estimated.

Scenario 3: The same as scenario 1 except for three levels of molting probabilities for males over time. The years grouped into three groups are from the results from the ADF&G stock assessment model (Zheng et al. 1995). Group 1 consists of 1968-79; group 2 consists of 1980-84, 1992-94, 1997, 1999, 2001, 2007-2010; and group 3 consists of 1985-91, 1995-96, 1998, 2000, and 2002-2006. Four additional parameters from scenario 1 are estimated.

Scenario 4: The same as scenario 1 except for replacing additional mortality parameters with assumed predation mortality. Predation moralities are assumed to occur on newshell crab only with the same predation mortality rate for both males and females. One parameter is predation mortality during 1980-1984 and the second parameter is for predation mortality during 1976-1979 and 1985-1993. Data is lacking for estimating predation mortalities. These two predation mortality rates are estimated in the model as two parameters. One less parameter from scenario 1 is estimated.

Scenario 5: Combination of scenarios 1, 2 and 3. An additional 47 parameters from scenario 1 are estimated.

Scenario 6: The same as scenario 3 except for assuming high bycatch rates before 1990. The average of the highest two observed bycatch rates during 1990-2006 from the directed pot and the average of top 2 bycatch rates from the Tanner crab fishery during 1991-1994 are used to estimate bycatch before 1990. This scenario assumes bycatch mortality rates before 1990 are equal to the high ends of bycatch rates estimated from the available observer data after 1990. Four additional parameters from scenario 1 are estimated.

Scenario 7: The same as scenario 3 except for estimating effective sample size (ESS) using observed sample sizes. Four additional parameters from scenario 1 are estimated. Effective sample sizes are estimated through two steps:

(1) Initial effective sample sizes are estimated as

$$n_y = \sum_l \hat{P}_{y,l}(1-\hat{P}_{y,l}) / \sum_l (P_{y,l} - \hat{P}_{y,l})^2$$

where $\hat{P}_{y,l}$ and $P_{y,l}$ is estimated and observed size compositions in year $y$ and length group $l$, respectively.

(2) We assume $n_y$ has a Beverton-Holt relationship with observed sample sizes, $N_y$:

$$n_y = N_y / (\alpha + \beta N_y)$$

where $\alpha$ and $\beta$ are parameters. Different $\alpha$ and $\beta$ parameter values are estimated for survey males, survey females, retained catch, male directed pot bycatch and female directed pot bycatch. Due to unreliable observed sample sizes for trawl bycatch, effective sample sizes are not estimated. Effective sample sizes are also not estimated for Tanner crab bycatch due to short observed time series.

Following the recommendation of the CPT in May 2011, Scenario 7ac is developed for the stock assessment in this report. Scenario 7ac is a combination of scenarios 7, 1a and 1c, that is, scenario 7 plus standard survey data for males and retow data for females and estimating initial year length compositions.

Only the results for scenario 7ac are presented in this report. The results for all other scenarios were presented in the SAFE report in May 2011.

b. Progression of results: NA.

c. Evidence of search for balance between realistic and simpler models: NA.

d. Convergence status/criteria: ADMB default convergence criteria.

e. Sample sizes for length composition data. Estimated sample sizes and effective sample sizes are summarized in tables.

f. Credible parameter estimates: all estimated parameters seem to be credible.

g. Model selection criteria. The likelihood values were used to select among alternatives that could be legitimately compared by that criterion.

h. Residual analysis. Residual plots are illustrated in figures.

i. Model evaluation is provided under Results, below.

## 4. Results

a. Effective sample sizes and weighting factors.

i. For scenario 0-6, we assumed constant effective sample sizes for the length/sex composition data. Estimated effective sample sizes were computed as:

$$n_y = \sum_l \hat{P}_{y,l}(1-\hat{P}_{y,l}) / \sum_l (P_{y,l} - \hat{P}_{y,l})^2$$

where $\hat{P}_{y,l}$ and $P_{y,l}$ is estimated and observed size compositions in year $y$ and length group $l$, respectively. Estimated effective sample sizes vary greatly over time. For scenario 7ac, effective sample sizes are illustrated in Figure 7.

ii. Weights are assumed to be 500 for retained catch biomass, and 100 for all bycatch biomasses, 2 for recruitment variation, and 10 for recruitment sex ratio.

b. Tables of estimates.

i. Parameter estimates for scenario 7ac are summarized in Tables 4 and 5.

ii. Abundance and biomass time series are provided in Table 6 for scenario 7ac.

iii. Recruitment time series for scenario 7ac are provided in Table 6.

iv. Time series of catch/biomass are provided in Table 1.

Negative log-likelihood values and parameter estimates are summarized in Tables 4 and 5, respectively. Length-specific fishing mortality is equal to its selectivity times the full fishing mortality. Estimated full pot fishing mortalities for females and full fishing mortalities for trawl bycatch were very low due to low bycatch as well as handling mortality rates less than 1.0. Estimated recruits varied greatly from year to year (Table 6). Estimated low selectivities for male pot bycatch, relative to the retained catch, reflected the 20% handling mortality rate (Figure 8). Both selectivities were applied to the same level of full fishing mortality. Estimated selectivities for female pot bycatch were close to 1.0 for all mature females, and the estimated full fishing mortalities for female pot bycatch were lower than for male retained catch and bycatch (Table 5).

c. Graphs of estimates.

i. Selectivities and molting probabilities by length are provided in Figures 8 and 9 for scenario 7ac.

One of the most important results is estimated trawl survey selectivity/catchability (Figure 8). Survey selectivity affects not only the fitting of the data but also the absolute abundance estimates. Estimated survey selectivities in Figure 8 are generally smaller than the capture probabilities in Figure A1 because survey selectivities include capture probabilities and crab availability. NMFS survey catchability was estimated to be 0.896 from the trawl experiment and higher than that estimated from the BSFRF surveys (0.854). The reliability of estimated survey selectivities will greatly affect the application of the model to fisheries management. Under- or overestimates of survey selectivities will cause a systematic upward or downward bias of abundance estimates. Information about crab availability to the survey area at survey times will help estimate the survey selectivities.

For scenario 7ac, estimated molting probabilities during 1968-2012 (Figure 9) were generally lower than those estimated from the 1954-1961 and 1966-1969 tagging data (Balsiger 1974). Lower molting probabilities mean more oldshell crab, possibly due to changes in molting probabilities over time or shell aging errors. Overestimates or underestimates of oldshell crabs will result in lower or higher estimates of male molting probabilities.

ii. Estimated total survey biomass and mature male and female abundances are plotted in Figure 10.

Estimated survey biomass, mature male and female abundances are similar between the assessment made in 2011 and 2012 (Figure 10a).

The model did not fit the mature crab abundance directly and depicted the trends of the mature abundance well (Figure 10b). Estimated mature crab abundance increased dramatically in the mid 1970s then decreased precipitously in the early 1980s. Estimated mature crab abundance has increased during the last 27 years with mature females being 3.3 times more abundant in 2009 than in 1985 and mature males being 2.4 times more abundant in 2009 than in 1985 (Figure 10b). Mature abundances have declined since the late 2000s.

iii. Estimated recruitment time series are plotted in Figure 11 for scenario 7ac.

iv. Estimated harvest rates are plotted against mature male biomass in Figure 12 for scenario 7ac.

The average of estimated male recruits from 1984 to 2012 (Figure 11) and mature male biomass per recruit were used to estimate $B_{35\%}$. Alternative periods of 1969-present and 1969-1983 were compared in our report. The full fishing mortalities for the directed pot fishery at the time of fishing were plotted against mature male biomass on Feb. 15 (Figure 12). Before the current harvest strategy was adopted in 1996, many fishing mortalities were above $F_{35\%}$ (Figure 12). Under the current harvest strategy, estimated fishing mortalities were at or above the $F_{35\%}$ limits in 1998, 2005, 2007-2010 but below the $F_{35\%}$ limits in the other post-1995 years.

Estimated full pot fishing mortalities ranged from 0.00 to 1.39 during 1968-2011, with estimated values over 0.40 during 1968-1981, 1985-1987, and 2008 (Table 5, Figure 12). Estimated fishing mortalities for pot female bycatch and trawl bycatch were generally less than 0.06.

v. Estimated mature male biomass and recruitment are plotted to illustrate their relationships with scenario 7ac (Figure 13a). Annual stock productivities are illustrated in Figure 13b.

Stock productivity (recruitment/mature male biomass) was much higher before the 1976/1977 regime shift: the mean value was 4.054 during 1968-1977 and 0.828 during 1978-2012.

Egg clutch data collected during summer surveys may provide information about mature female reproductive conditions. Although egg clutch data are subject to rating errors as well as sampling errors, data trends over time may be useful. Proportions of empty clutches for newshell mature females >89 mm CL were high in some years before 1990, but have been low since 1990 (Figure 14). The highest proportion of empty clutches (0.2) was in 1986, and primarily involved soft shell females (shell condition 1). Clutch fullness fluctuated annually around average levels during two periods: before 1991 and after 1990 (Figure 14). The average clutch fullness was close for these two periods (Figure 14).

d. Graphic evaluation of the fit to the data.

i. Observed vs. estimated catches are plotted in Figure 15.

ii. Model fits to total survey biomass are shown in Figure 10 with a standardized residual plot in Figure 16.

iii. Model fits to catch and survey proportions by length are illustrated in Figures 17-24 and residual bubble plots are shown in Figures 25-27.

The model (scenario 7ac) fit the fishery biomass data well and the survey biomass reasonably well (Figures 10 and 15). Because the model estimates annual fishing mortality for pot male catch, pot female bycatch, and trawl bycatch, the deviations of observed and predicted (estimated) fishery biomass are mainly due to size composition differences.

The model also fit the length and shell composition data well (Figures 17-24). Model fit of length compositions in the trawl survey was better for newshell males and females than for oldshell males. The model predicted lower proportions of oldshell males in 1993, 1994, 2002, 2007 and 2008, and higher proportions of oldshell males in 1997, 2001, 2003, 2004, 2006 and 2010 than the area-swept estimates (Figure 18). In addition to size, molting probability may also be affected by age and environmental conditions. Tagging data show that molting probability changed over time (Balsiger 1974). Therefore, the relatively poor fit to oldshell males may be due to use of changes in molting probabilities as well as shell aging errors. It is surprising that the model fit the length proportions of the pot male bycatch well with two simple linear selectivity functions (Figure 21). We explored a logistic selectivity function, but due to the long left tail of the pot male bycatch selectivity, the logistic selectivity function did not fit the data well.

Modal progressions are tracked well in the trawl survey data, particularly beginning in the mid-1990s (Figures 17 and 19). Cohorts first seen in the trawl survey data in 1975, 1986, 1990, 1995, 1999, 2002 and 2005 can be tracked over time. Some cohorts can be tracked over time in the pot bycatch as well (Figure 21), but the bycatch data did not track the cohorts as well as the survey data. Groundfish trawl bycatch data provide little information to track modal progression (Figures 23 and 24).

Standardized residuals of total survey biomass and proportions of length and shell condition are plotted to examine their patterns. Residuals were calculated as observed minus predicted and standardized by the estimated standard deviation. Standardized residuals of total survey biomass did not show any consistent patterns (Figure 16). Standardized residuals of proportions of survey newshell males appear to be random over length and year (Figure 25). Standardized residuals of proportions of survey oldshell males were mostly positive or negative for some years (Figure 26). Changes in molting probability over time or shell aging errors would create such residual patterns. There is an interesting pattern for residuals of proportions of survey females. Residuals were generally negative for large-sized mature females during 1969-1987 (Figure 27). Changes in growth over time or increased mortality may cause this pattern. The inadequacy of the model can be corrected by adding parameters to address these factors. Further study for female growth and availability for survey gears due to different molting times may be needed.

e. Retrospective and historic analyses.

Two kinds of retrospective analyses were conducted for this report: (1) historical results and (2) the 2011/2012 model hindcast results. The historical results are the trajectories of biomass and abundance from previous assessments that capture both new data and changes in methodology over time. Treating the 2012 estimates as the baseline values, we can also evaluate how well the model had done in the past. The 2012 model results are based on sequentially excluding one-year of data to evaluate the current model performance with fewer data.

i. Retrospective analysis (retrospective bias in base model or models).

The performance of the 2011/2012 model includes sequentially excluding one-year of data. The model with scenario 7ac performed reasonably well during 2004-2011 with a lower terminal year estimate in 2004 and higher estimates during 2005-2010 (Figure 28).

Overall, both historical results and the 2011/2012 model results performed reasonably well. No great overestimates or underestimates occurred as was observed in Pacific halibut (*Hippoglossus stenolepis*) (Parma 1993) or some eastern Bering Sea groundfish stocks (Zheng and Kruse 2002; Ianelli et al. 2003). Since the most recent model was not used to set TAC or overfishing limits until 2009, historical implications for management from the stock assessment errors cannot be evaluated at the current time. However, management implications of the ADF&G stock assessment model were evaluated by Zheng and Kruse (2002).

ii. Historic analysis (plot of actual estimates from current and previous assessments).

The model first fit the data from 1985 to 2004 in the terminal year of 2004. Thus, six historical assessment results are available. The main differences of the 2004 model were weighting factors and effective sample sizes for the likelihood functions. In 2004, the weighting factors were 1000 for survey biomass, 2000 for retained catch biomass and 200 for bycatch biomasses. The effective sample sizes were set to be 200 for all proportion data but weighting factors of 5, 2, and 1 were also applied to retained catch proportions, survey proportions and bycatch proportions. Estimates of time series of abundance in 2004 were generally higher than those estimated after 2004 (Figure 29).

In 2005, to improve the fit for retained catch data, the weight for retained catch biomass was increased to 3000 and the weight for retained catch proportions was increased to 6. All other weights were not changed. In 2006, all weights were re-configured. No weights were used for proportion data, and instead, effective sample sizes were set to 500 for retained catch, 200 for survey data, and 100 for bycatch data. Weights for biomasses were changed to 800 for retained catch, 300 for survey and 50 for bycatch. The weights in 2007 were the same as 2006. Generally, estimates of time series of abundance in 2005 were slightly lower than in 2006 and 2007, and there were few differences between estimates in 2006 and 2007 (Figure 29).

In 2008, estimated coefficients of variation for survey biomass were used to compute likelihood values as suggested by the CPT in 2007. Thus, weights were re-configured to: 500 for retained catch biomass, 50 for survey biomass, and 20 for bycatch biomasses. Effective sample size was lowered to 400 for the retained catch data. These changes were necessary for the estimation to converge and for a relatively good balanced fit to both biomasses and proportion data. Also, sizes at 50% selectivities for all fisheries data were allowed to change annually, subject to a random walk pattern, for all assessments before 2008. The 2008 model does not allow annual changes in any fishery selectivities. Except for higher estimates of abundance during the late 1980s and early 1990s, estimates of time series of abundance in 2008 were generally close to those in 2006 and 2007 (Figure 29).

During 2009-2012, the model was extended to the data through 1968. No weight factors were used for the NMFS survey biomass during 2009-2012 assessments.

f. Uncertainty and sensitivity analyses

i. Estimated standard deviations of parameters are summarized in Table 5 for scenario 7ac. Estimated standard deviations of mature male biomass are listed in Table 6.

ii. Probabilities for mature male biomass in 2012 are illustrated in Figure 30 for scenario 7ac using the likelihood profile. The confidence intervals are quite narrow.

iii. Sensitivity analysis for handling mortality rate was reported in the SAFE report in May 2010. The baseline handling mortality rate for the directed pot fishery was set at 0.2. A 50% reduction and 100% increase resulted in 0.1 and 0.4 as alternatives. Overall, a higher handling mortality rate resulted in slightly higher estimates of mature abundance, and a lower rate resulted in a minor reduction of estimated mature abundance. Differences of estimated legal abundance and mature male biomass were small among these handling mortality rates.

iv. Sensitivity of weights. Sensitivity of weights was examined in the SAFE report in May 2010. Weights to biomasses (trawl survey biomass, retained catch biomass, and bycatch biomasses) were reduced to 50% or increased to 200% to examine their sensitivity to abundance estimates. Weights to the penalty terms (recruitment variation and sex ratio) were also reduced or increased. Overall, estimated biomasses were very close under different weights except during the mid-1970s. The variation of estimated biomasses in the mid-1970s was mainly caused by the changes in estimates of additional mortalities in the early 1980s.

g. Comparison of alternative model scenarios

These comparisons were reported in the SAFE report in May 2011 and based on the data up to 2010. Estimating length proportions in the initial year (scenario 1a) results in mainly a better fit of survey length compositions at an expense of 36 more parameters than scenario 1. Abundance and biomass estimates with scenario 1a are similar with scenario 1 that does not estimate initial length proportions. Using only standard survey data (scenario 1b) results in a poorer fit of survey length compositions and biomass than scenarios using both standard and re-tow data (scenarios 1, 1a, and 1c) and has the lowest likelihood value. Although the likelihood value is higher for using both standard survey and re-tow data for males (scenario 1) than using only standard survey for males (scenario 1c), estimated abundances and biomasses are almost identical. The higher likelihood value for scenario 1 over scenario 1c is due to trawl bycatch length compositions.

Scenario 7 statistically fits the data better than all other scenarios. The biggest improvements of scenario 7 over other scenarios are better fitting the survey length compositions and retained catch biomass. Mature male abundance estimate with scenario 7 in 2008 falls into the 95% confidence interval of BSFRF survey estimates. Scenario 4 with model estimated predation mortalities during late 1970s and 1980s does not fit the data as well as the other scenarios.

## *F. Calculation of the OFL and ABC*

1. Bristol Bay RKC is currently placed in Tier 3 (NPFMC 2007).
2. For Tier 3 stocks, estimated biological reference points include $B_{35\%}$ and $F_{35\%}$. Estimated model parameters were used to conduct mature male biomass-per-recruit analysis.
3. Specification of the OFL:

   The Tier 3 can be expressed by the following control rule:

   a) $\frac{B}{B^*} > 1$ $\qquad F_{OFL} = F^*$

   b) $\beta < \frac{B}{B^*} \le 1$ $\qquad F_{OFL} = F^*\left(\frac{B/B^* - \alpha}{1-\alpha}\right)$ (1)

c) $\frac{B}{B^*} \leq \beta$ directed fishery $F = 0$ and $F_{OFL} \leq F^*$

Where

$B$ = a measure of the productive capacity of the stock such as spawning biomass or fertilized egg production. A proxy of $B$, MMB estimated at the time of primiparous female mating (February 15) is used as a default in the development of the control rule.

$F^*$ = $F_{35\%}$, a proxy of $F_{MSY}$, which is a full selection instantaneous $F$ that will produce MSY at the MSY producing biomass,

$B^*$ = $B_{35\%}$, a proxy of $B_{MSY}$, which is the value of biomass at the MSY producing level,

$\beta$ = a parameter with restriction that $0 \leq \beta < 1$. A default value of 0.25 is used.

$\alpha$ = a parameter with restriction that $0 \leq \alpha \leq \beta$. A default value of 0.1 is used.

Because trawl bycatch fishing mortality was not related to pot fishing mortality, average trawl bycatch fishing mortality during 2000 to 2011 was used for the per recruit analysis as well as for projections in the next section. Pot female bycatch fishing mortality was set equal to pot male fishing mortality times 0.02, an intermediate level during 1990-2011. Some discards of legal males occurred since the IFQ fishery started in 2005, but the discard rates were much lower during 2007-2011 than in 2005 after the fishing industry minimized discards of legal males. Thus, the average of retained selectivities and discard male selectivities during 2009-2011 were used to represent current trends for per recruit analysis and projections. Average molting probabilities during 2001-2011 were used for per recruit analysis and projections.

Average recruitments during three periods were used to estimate $B_{35\%:}$ 1969-1983, 1969-2012, and 1984-2012 (Figure 11). Estimated $B_{35\%}$ is compared with historical mature male biomass in Figure 13a. We recommend using the average recruitment during 1984-present, corresponding to the 1976/77 regime shift. Note that recruitment period 1984-present was used in 2011 to set the overfishing limits. There are several reasons for supporting our recommendation. First, estimated recruitment was lower after 1983 than before 1984, which corresponded to brood years 1978 and later, after the 1976/77 regime shift. Second, high recruitments during the late 1960s and 1970s generally occurred when the spawning stock was primarily located in the southern Bristol Bay, whereas the current spawning stock is mainly in the middle of Bristol Bay. The current flows favor larvae hatched in the southern Bristol Bay (see the section on Ecosystem Considerations for SAFE reports in 2008 and 2009). Finally, stock productivity (recruitment/mature male biomass) was much higher before the 1976/1977 regime shift: the mean value was 4.054 during brood years 1968-1977 and 0.828 during 1978-2006 (Figure 13a-c). The two-tail t-tests with unequal variances show that ln(recruitment) and ln(recruitment/mature male biomass) between brood years 1968-1977 and 1978-2006 are strongly, statistically different with p values of 0.0000000007725 and 0.000708, respectively. There are several potential reasons for the recruitment and productivity differences between these two periods:

a. The 1976/77 regime shift created different environmental conditions before 1978 and after 1977. The PDO index matched crab recruitment strength very well (Figure

13d). The Aleutian Low index has the similar feature. Before 1978, the summer bottom temperatures in Bristol Bay were generally lower than those after 1977 (Figure 13d). Red king crab distributions changed greatly after the regime shift (Figure 13e). High recruitments during the late 1960s and 1970s (before brood year 1978) generally occurred when the spawning stock was primarily located in southern Bristol Bay while the current spawning stock is mainly in the middle of Bristol Bay. The current flows favor larvae hatched in southern Bristol Bay and these larvae settled within the juvenile nursery areas (Figure 13f). A proportion of the larvae hatched in central Bristol Bay may be carried away and settle outside of the juvenile nursery areas.

b. Predation on juvenile crabs may have increased after the 1976/77 regime shift. The biomass of the main crab predator, Pacific cod, increased greatly after the regime shift (Figure 13g). Yellowfin sole biomass also increased substantially during this period. The recruitment strength is statistically associated with the predator biomass (Figure 13h), but we lack stomach samples in shallow waters (juvenile habitat) to quantify the predation mortality.

c. Zheng and Kruse (2000) hypothesized that the strength of the Aleutian Low affects food availability for red king crab larvae. Strong Aleutian Lows may have effects on species composition of the spring bloom that are adverse for red king crab larvae. Diatoms such as *Thalassiosira* are important food for first-feeding red king crab larvae (Paul et al., 1989), and they predominate in the spring bloom in years of light winds when the water column is stable (Ziemann et al., 1991; Bienfang and Ziemann, 1995). Years of strong wind mixing associated with intensified Aleutian Lows may depress red king crab larval survival and subsequent recruitment. All strong year classes occurred before 1978 when the Aleutian Low was weak.

If we believe that the productivity differences and differences of other population characteristics before 1978 were caused by fishing, not by the regime shift, then we should use the recruitment from 1969-1983 (corresponding to brood years before 1978) as the baseline to estimate B35%.. If we believe that the regime shift during 1976/77 caused the productivity differences, then we should select the recruitments from period 1984-2012 as the baseline.

The control rule is used for stock status determination. If total catch exceeds OFL estimated at $B$, then "overfishing" occurs. If $B$ equals or declines below 0.5 $B_{MSY}$ (i.e., MSST), the stock is "overfished." If $B$ equals or declines below $\beta$*$B_{MSY}$ or $\beta$*a proxy $B_{MSY}$, then the stock productivity is severely depleted and the fishery is closed.

The likelihood profile is illustrated for the MMB in 2012 (Figure 30) and the normal approximation is used to estimate the 49 percentile for the OFL in 2012 (Figure 31). Based the SSC suggestion in 2011, ABC = 0.9*OFL is used to estimate ABC.

Status and catch specifications (1000 t):

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2006/07 | | | 7.04 | 7.14 | 7.81 | N/A | N/A |
| 2007/08 | | 37.69[A] | 9.24 | 9.30 | 10.54 | N/A | N/A |
| 2008/09 | 15.56[B] | 39.83[B] | 9.24 | 9.22 | 10.48 | 10.98 | N/A |
| 2009/10 | 14.22[C] | 40.37[C] | 7.26 | 7.27 | 8.31 | 10.23 | N/A |
| 2010/11 | 13.63[D] | 32.64[D] | 6.73 | 6.76 | 7.71 | 10.66 | N/A |
| 2011/12 | 13.77[E] | 30.88[E] | 3.55 | 3.61 | 4.09 | 8.80 | 7.92 |
| 2012/13 | | 26.32[E] | NA | NA | NA | 7.96 | 7.17 |

The stock was above MSST in 2010/11 and is hence not overfished. Overfishing did not occur.

Status and catch specifications (million lbs):

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2006/07 | | | 15.53 | 15.75 | 17.22 | N/A | N/A |
| 2007/08 | | 83.1[A] | 20.38 | 20.51 | 23.23 | N/A | N/A |
| 2008/09 | 34.2[B] | 87.8[B] | 20.37 | 20.32 | 23.43 | 24.20 | N/A |
| 2009/10 | 31.3[C] | 89.0[C] | 16.00 | 16.03 | 18.32 | 22.56 | N/A |
| 2010/11 | 30.0[D] | 72.0[D] | 14.84 | 14.91 | 17.00 | 23.52 | N/A |
| 2011/12 | 30.4[E] | 68.1[E] | 7.83 | 7.95 | 9.01 | 19.39 | 17.46 |
| 2012/13 | | 58.0[E] | NA | NA | NA | 17.55 | 15.80 |

Notes:
A – Calculated from the assessment reviewed by the Crab Plan Team in September 2008
B – Calculated from the assessment reviewed by the Crab Plan Team in September 2009
C – Calculated from the assessment reviewed by the Crab Plan Team in September 2010
D – Calculated from the assessment reviewed by the Crab Plan Team in September 2011
E – Calculated from the assessment reviewed by the Crab Plan Team in September 2012

4. Based on the $B_{35\%}$ estimated from the average male recruitment during 1984-2012, the biological reference points were estimated as follows:

Scenario 7ac

$B_{35\%}$ = 60.706 million lbs, or 27,535.7 t

$F_{35\%}$ = 0.31

$F_{40\%}$ = 0.25

Based on $B_{35\%}$ and $F_{35\%}$, the retained catch and total catch limits (OFL) for 2012 were estimated to be:

Scenario 7ac

Retained catch: 16.330 million lbs, or 7,407.0 t,

Total catch: 17.553 million lbs, or 7,962.1 t, MMB on 2/15/2013: 58.024 million lbs, or 26,319.1 t.

Total catch includes retained catch and all other bycatch.

4. Based on the 10% rule used last year, ABC = 0.9*OFL, or 15.798 million lbs, or 7,165.9 t. The P*=49% would result in ABC= 17.503 million lbs, or 7,939.0 t.

6. Alternative time periods of recruitment used to estimate $B_{35\%}$ for scenario 7ac:

| Periods | $B_{35\%}$ (t) | MMB in 2012 Value(t) | MMB in 2012 %$B_{35\%}$ | F | OFL (t) | Stock Status |
|---|---|---|---|---|---|---|
| 1969-1983 | 115,582.1 | 31,836.7 | 27.5% | 0.07 | 2,267.2 | Overfished |
| 1969-2012 | 58,249.6 | 29,785.4 | 51.1% | 0.14 | 4,145.6 | Close to overfished |
| 1984-2012 | 27,535.7 | 26,319.1 | 95.6% | 0.29 | 7,962.1 | No overfished |

## *G. Rebuilding Analyses*

NA.

## *H. Data Gaps and Research Priorities*

1. The following data gaps exist for this stock:

d. Information about changes in natural mortality in the early 1980s;
e. Un-observed trawl bycatch in the early 1980s;
f. Natural mortality;
g. Crab availability to the trawl surveys;
h. Juvenile crab abundance.

2. Research priorities:

a. Estimating natural mortality;
b. Estimating crab availability to the trawl surveys;
c. Surveying juvenile crab abundance in near shore;
d. Studying environmental factors that affect the survival rates from larvae to recruitment.

## *I. Projections and Future Outlook*

### 1. Projections

Future population projections primarily depend on future recruitment, but crab recruitment is difficult to predict. Therefore, annual recruitment for the projections was a random selection from estimated recruitments during 1984-2012. Besides recruitment, the other major uncertainty for the projections is estimated abundance in 2012. The 2012 abundance was randomly selected from the estimated normal distribution of the assessment model output for each replicate. Three scenarios of fishing mortality for the directed pot fishery were used in the projections:

(1) No directed fishery. This was used as a base projection.

(2) $F_{40\%}$. This fishing mortality creates a buffer between the limits and target levels.

(3) $F_{35\%}$. This is the maximum fishing mortality allowed under the current overfishing definitions.

Each scenario was replicated 1000 times and projections made over 10 years beginning in 2012 (Table 7).

As expected, projected mature male biomasses are much higher without the directed fishing mortality than under the other scenarios. At the end of 10 years, projected mature male biomass is above $B_{35\%}$ for all scenarios (Table 7; Figure 32). Projected retained catch for the $F_{35\%}$ scenario is higher than those for the $F_{40\%}$ scenario (Table 7, Figure 33). Due to the poor recruitment during recent years, the projected biomass and retained catch are expected to decline during the next few years.

**2. Near Future Outlook**

The near future outlook for the Bristol Bay RKC stock is a declining trend. The three recent above-average year classes (hatching years 1990, 1994, and 1997) had entered the legal population by 2006 (Figure 34). Most individuals from the 1997 year class will continue to gain weight to offset loss of the legal biomass to fishing and natural mortalities. The above-average year class (hatching year 2000) with lengths centered around 87.5 mm CL for both males and females in 2006 and with lengths centered around 112.5-117.5 mm CL for males and around 107.5 mm CL for females in 2008 has largely entered the mature male population in 2009 and the legal population by this year (Figure 34). No strong cohorts have been observed in the survey data after this cohort until last year (Figure 34). There was a huge tow of juvenile crab of size 45-55 mm in 2011. We are disappointed that no huge tows of juvenile crab were caught in the 2012 survey. Because this is one tow only, it is difficult to assume its strength until the next two or three years. Due to lack of recruitment, mature and legal crabs should continue to decline next year. Current crab abundance is still low relative to the late 1970s, and without favorable environmental conditions, recovery to the high levels of the late 1970s is unlikely.

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Table 1. Bristol Bay red king crab annual catch and bycatch mortality biomass (t) from June 1 to May 31. A handling mortality rate of 20% for pot and 80% for trawl was assumed to estimate bycatch mortality biomass. Bycatches from the cost-recovery fishery before 2006 are not included.

| Year | Retained Catch | | | | Pot Bycatch | | Trawl | Total |
|---|---|---|---|---|---|---|---|---|
| | U.S. | Cost-recovery | Foreign | Total | Males | Females | Bycatch | Catch |
| 1960 | 272.2 | | 12200.7 | 12472.9 | | | | 12472.9 |
| 1961 | 193.7 | | 20226.6 | 20420.3 | | | | 20420.3 |
| 1962 | 30.8 | | 24618.7 | 24649.6 | | | | 24649.6 |
| 1963 | 296.2 | | 24930.8 | 25227.0 | | | | 25227.0 |
| 1964 | 373.3 | | 26385.5 | 26758.8 | | | | 26758.8 |
| 1965 | 648.2 | | 18730.6 | 19378.8 | | | | 19690.4 |
| 1966 | 452.2 | | 19212.4 | 19664.6 | | | | 20290.0 |
| 1967 | 1407.0 | | 15257.0 | 16664.1 | | | | 17431.6 |
| 1968 | 3939.9 | | 12459.7 | 16399.6 | | | | 15659.4 |
| 1969 | 4718.7 | | 6524.0 | 11242.7 | | | | 11096.1 |
| 1970 | 3882.3 | | 5889.4 | 9771.7 | | | | 9305.8 |
| 1971 | 5872.2 | | 2782.3 | 8654.5 | | | | 9280.2 |
| 1972 | 9863.4 | | 2141.0 | 12004.3 | | | | 12381.4 |
| 1973 | 12207.8 | | 103.4 | 12311.2 | | | | 10962.0 |
| 1974 | 19171.7 | | 215.9 | 19387.6 | | | | 19387.6 |
| 1975 | 23281.2 | | 0.0 | 23281.2 | | | | 23281.2 |
| 1976 | 28993.6 | | 0.0 | 28993.6 | | | 646.9 | 29640.5 |
| 1977 | 31736.9 | | 0.0 | 31736.9 | | | 1217.9 | 32954.8 |
| 1978 | 39743.0 | | 0.0 | 39743.0 | | | 1250.5 | 40993.5 |
| 1979 | 48910.0 | | 0.0 | 48910.0 | | | 1262.4 | 50172.4 |
| 1980 | 58943.6 | | 0.0 | 58943.6 | | | 968.3 | 59911.9 |
| 1981 | 15236.8 | | 0.0 | 15236.8 | | | 203.0 | 15439.8 |
| 1982 | 1361.3 | | 0.0 | 1361.3 | | | 544.7 | 1906.1 |
| 1983 | 0.0 | | 0.0 | 0.0 | | | 401.5 | 401.5 |
| 1984 | 1897.1 | | 0.0 | 1897.1 | | | 1050.4 | 2947.5 |
| 1985 | 1893.8 | | 0.0 | 1893.8 | | | 375.9 | 2269.6 |
| 1986 | 5168.2 | | 0.0 | 5168.2 | | | 195.8 | 5363.9 |
| 1987 | 5574.2 | | 0.0 | 5574.2 | | | 140.9 | 5715.1 |
| 1988 | 3351.1 | | 0.0 | 3351.1 | | | 532.3 | 3883.4 |
| 1989 | 4656.0 | | 0.0 | 4656.0 | | | 169.4 | 4825.5 |
| 1990 | 9236.2 | 36.6 | 0.0 | 9272.8 | 516.5 | 523.4 | 227.2 | 10540.0 |
| 1991 | 7791.8 | 93.4 | 0.0 | 7885.1 | 399.7 | 64.2 | 261.2 | 9856.3 |
| 1992 | 3648.2 | 33.6 | 0.0 | 3681.8 | 540.4 | 353.6 | 258.9 | 5232.0 |
| 1993 | 6635.4 | 24.1 | 0.0 | 6659.6 | 747.8 | 514.1 | 379.0 | 8467.4 |
| 1994 | 0.0 | 42.3 | 0.0 | 42.3 | 0.0 | 0.0 | 81.9 | 124.2 |
| 1995 | 0.0 | 36.4 | 0.0 | 36.4 | 0.0 | 0.0 | 96.8 | 133.1 |
| 1996 | 3812.7 | 49.0 | 0.0 | 3861.7 | 161.3 | 0.9 | 107.9 | 4131.9 |
| 1997 | 3971.9 | 70.2 | 0.0 | 4042.1 | 239.7 | 15.5 | 76.1 | 4373.3 |
| 1998 | 6693.8 | 85.4 | 0.0 | 6779.2 | 940.7 | 701.9 | 161.1 | 8582.9 |
| 1999 | 5293.5 | 84.3 | 0.0 | 5377.9 | 308.1 | 6.7 | 184.9 | 5877.6 |
| 2000 | 3698.8 | 39.1 | 0.0 | 3737.9 | 353.5 | 35.2 | 104.5 | 4231.2 |
| 2001 | 3811.5 | 54.6 | 0.0 | 3866.2 | 409.3 | 140.0 | 149.9 | 4565.3 |
| 2002 | 4340.9 | 43.6 | 0.0 | 4384.5 | 433.8 | 6.1 | 111.1 | 4935.6 |
| 2003 | 7120.0 | 15.3 | 0.0 | 7135.3 | 882.3 | 321.4 | 135.0 | 8474.1 |
| 2004 | 6915.2 | 91.4 | 0.0 | 7006.7 | 338.3 | 153.3 | 125.4 | 7623.7 |
| 2005 | 8305.0 | 94.7 | 0.0 | 8399.7 | 1325.9 | 398.5 | 182.7 | 10306.8 |
| 2006 | 7005.3 | 137.9 | 0.0 | 7143.2 | 552.1 | 31.1 | 93.2 | 7819.6 |
| 2007 | 9237.9 | 66.1 | 0.0 | 9303.9 | 981.0 | 150.4 | 105.5 | 10540.9 |
| 2008 | 9216.1 | 0.0 | 0.0 | 9216.1 | 1142.1 | 119.8 | 151.4 | 10629.4 |
| 2009 | 7226.9 | 45.5 | 0.0 | 7272.5 | 870.7 | 67.5 | 104.2 | 8314.9 |
| 2010 | 6728.5 | 33.0 | 0.0 | 6761.5 | 781.9 | 97.1 | 73.9 | 7714.4 |
| 2011 | 3553.3 | 53.8 | 0.0 | 3607.1 | 387.2 | 19.4 | 72.3 | 4086.0 |

Table 2. Annual sample sizes (>64 mm CL) for catch by length and shell condition for retained catch and bycatch of Bristol Bay red king crab.

| | Trawl Survey | | Retained | Pot Bycatch | | Trawl Bycatch | |
|---|---|---|---|---|---|---|---|
| Year | Males | Females | Catch | Males | Females | Males | Females |
| 1968 | 3,684 | 2,165 | 18,044 | | | | |
| 1969 | 6,144 | 4,992 | 22,812 | | | | |
| 1970 | 1,546 | 1,216 | 3,394 | | | | |
| 1971 | | | 10,340 | | | | |
| 1972 | 1,106 | 767 | 15,046 | | | | |
| 1973 | 1,783 | 1,888 | 11,848 | | | | |
| 1974 | 2,505 | 1,800 | 27,067 | | | | |
| 1975 | 2,943 | 2,139 | 29,570 | | | | |
| 1976 | 4,724 | 2,956 | 26,450 | | | 2,327 | 676 |
| 1977 | 3,636 | 4,178 | 32,596 | | | 14,014 | 689 |
| 1978 | 4,132 | 3,948 | 27,529 | | | 8,983 | 1,456 |
| 1979 | 5,807 | 4,663 | 27,900 | | | 7,228 | 2,821 |
| 1980 | 2,412 | 1,387 | 34,747 | | | 47,463 | 39,689 |
| 1981 | 3,478 | 4,097 | 18,029 | | | 42,172 | 49,634 |
| 1982 | 2,063 | 2,051 | 11,466 | | | 84,240 | 47,229 |
| 1983 | 1,524 | 944 | 0 | | | 204,464 | 104,910 |
| 1984 | 2,679 | 1,942 | 4,404 | | | 357,981 | 147,134 |
| 1985 | 792 | 415 | 4,582 | | | 169,767 | 30,693 |
| 1986 | 1,962 | 367 | 5,773 | | | 62,023 | 20,800 |
| 1987 | 1,168 | 1,018 | 4,230 | | | 60,606 | 32,734 |
| 1988 | 1,834 | 546 | 9,833 | | | 102,037 | 57,564 |
| 1989 | 1,257 | 550 | 32,858 | | | 47,905 | 17,355 |
| 1990 | 858 | 603 | 7,218 | 873 | 699 | 5,876 | 2,665 |
| 1991 | 1,378 | 491 | 36,820 | 1,801 | 375 | 2,964 | 962 |
| 1992 | 513 | 360 | 23,552 | 3,248 | 2,389 | 1,157 | 2,678 |
| 1993 | 1,009 | 534 | 32,777 | 5,803 | 5,942 | | |
| 1994 | 443 | 266 | 0 | 0 | 0 | 4,953 | 3,341 |
| 1995 | 2,154 | 1,718 | 0 | 0 | 0 | 1,729 | 6,006 |
| 1996 | 835 | 816 | 8,896 | 230 | 11 | 24,583 | 9,373 |
| 1997 | 1,282 | 707 | 15,747 | 4,102 | 906 | 9,035 | 5,759 |
| 1998 | 1,097 | 1,150 | 16,131 | 11,079 | 9,130 | 25,051 | 9,594 |
| 1999 | 764 | 540 | 17,666 | 1,048 | 36 | 16,653 | 5,187 |
| 2000 | 731 | 1,225 | 14,091 | 8,970 | 1,486 | 36,972 | 10,673 |
| 2001 | 611 | 743 | 12,854 | 9,102 | 4,567 | 56,070 | 32,745 |
| 2002 | 1,032 | 896 | 15,932 | 9,943 | 302 | 27,705 | 25,425 |
| 2003 | 1,669 | 1,311 | 16,212 | 17,998 | 10,327 | 281 | 307 |
| 2004 | 2,871 | 1,599 | 20,038 | 8,258 | 4,112 | 137 | 120 |
| 2005 | 1,283 | 1,682 | 21,938 | 55,019 | 26,775 | 186 | 124 |
| 2006 | 1,171 | 2,672 | 18,027 | 32,252 | 3,980 | 217 | 168 |
| 2007 | 1,219 | 2,499 | 22,387 | 59,769 | 12,661 | 1,981 | 2,880 |
| 2008 | 1,221 | 3,352 | 14,567 | 49,315 | 8,488 | 1,013 | 673 |
| 2009 | 830 | 1,857 | 16,708 | 52,359 | 6,041 | 1,110 | 827 |
| 2010 | 705 | 1,633 | 20,137 | 36,654 | 6,868 | 898 | 863 |
| 2011 | 525 | 994 | 10,706 | 20,629 | 1,920 | 328 | 401 |
| 2012 | 580 | 707 | | | | | |

Table 3. Annual catch (million crabs) and catch per unit effort of the Bristol Bay red king crab fishery.

| | Japanese Tanglenet | | Russian Tanglenet | | U.S. Pot/trawl | | Standardized |
|---|---|---|---|---|---|---|---|
| Year | Catch | Crabs/tan | Catch | Crabs/tan | Catch | Crabs/potlift | Crabs/tan |
| 1960 | 1.949 | 15.2 | 1.995 | 10.4 | 0.088 | | 15.8 |
| 1961 | 3.031 | 11.8 | 3.441 | 8.9 | 0.062 | | 12.9 |
| 1962 | 4.951 | 11.3 | 3.019 | 7.2 | 0.010 | | 11.3 |
| 1963 | 5.476 | 8.5 | 3.019 | 5.6 | 0.101 | | 8.6 |
| 1964 | 5.895 | 9.2 | 2.800 | 4.6 | 0.123 | | 8.5 |
| 1965 | 4.216 | 9.3 | 2.226 | 3.6 | 0.223 | | 7.7 |
| 1966 | 4.206 | 9.4 | 2.560 | 4.1 | 0.140 | 52 | 8.1 |
| 1967 | 3.764 | 8.3 | 1.592 | 2.4 | 0.397 | 37 | 6.3 |
| 1968 | 3.853 | 7.5 | 0.549 | 2.3 | 1.278 | 27 | 7.8 |
| 1969 | 2.073 | 7.2 | 0.369 | 1.5 | 1.749 | 18 | 5.6 |
| 1970 | 2.080 | 7.3 | 0.320 | 1.4 | 1.683 | 17 | 5.6 |
| 1971 | 0.886 | 6.7 | 0.265 | 1.3 | 2.405 | 20 | 5.8 |
| 1972 | 0.874 | 6.7 | | | 3.994 | 19 | |
| 1973 | 0.228 | | | | 4.826 | 25 | |
| 1974 | 0.476 | | | | 7.710 | 36 | |
| 1975 | | | | | 8.745 | 43 | |
| 1976 | | | | | 10.603 | 33 | |
| 1977 | | | | | 11.733 | 26 | |
| 1978 | | | | | 14.746 | 36 | |
| 1979 | | | | | 16.809 | 53 | |
| 1980 | | | | | 20.845 | 37 | |
| 1981 | | | | | 5.308 | 10 | |
| 1982 | | | | | 0.541 | 4 | |
| 1983 | | | | | 0.000 | | |
| 1984 | | | | | 0.794 | 7 | |
| 1985 | | | | | 0.796 | 9 | |
| 1986 | | | | | 2.100 | 12 | |
| 1987 | | | | | 2.122 | 10 | |
| 1988 | | | | | 1.236 | 8 | |
| 1989 | | | | | 1.685 | 8 | |
| 1990 | | | | | 3.130 | 12 | |
| 1991 | | | | | 2.661 | 12 | |
| 1992 | | | | | 1.208 | 6 | |
| 1993 | | | | | 2.270 | 9 | |
| 1994 | | | | | 0.015 | | |
| 1995 | | | | | 0.014 | | |
| 1996 | | | | | 1.264 | 16 | |
| 1997 | | | | | 1.338 | 15 | |
| 1998 | | | | | 2.238 | 15 | |
| 1999 | | | | | 1.923 | 12 | |
| 2000 | | | | | 1.272 | 12 | |
| 2001 | | | | | 1.287 | 19 | |
| 2002 | | | | | 1.484 | 20 | |
| 2003 | | | | | 2.510 | 18 | |
| 2004 | | | | | 2.272 | 23 | |
| 2005 | | | | | 2.763 | 30 | |
| 2006 | | | | | 2.477 | 31 | |
| 2007 | | | | | 3.154 | 28 | |
| 2008 | | | | | 3.064 | 22 | |
| 2009 | | | | | 2.553 | 21 | |
| 2010 | | | | | 2.410 | 18 | |
| 2011 | | | | | 1.298 | 28 | |

Table 4. Summary of statistics for the model (Scenario 7ac).

**Parameter counts**

| | |
|---|---|
| Fixed growth parameters | 9 |
| Fixed recruitment parameters | 2 |
| Fixed length-weight relationship parameters | 6 |
| Fixed mortality parameters | 4 |
| Fixed survey catchability parameter | 1 |
| Fixed high grading parameters | 7 |
| Total number of fixed parameters | 29 |
| | |
| Free growth parameters | 8 |
| Initial abundance (1968) | 1 |
| Recruitment-distribution parameters | 2 |
| Mean recruitment parameters | 1 |
| Male recruitment deviations | 45 |
| Female recruitment deviations | 45 |
| Natural and fishing mortality parameters | 4 |
| Survey catchability parameters | 2 |
| Pot male fishing mortality deviations | 46 |
| Bycatch mortality from the Tanner crab fishery | 6 |
| Pot female bycatch fishing mortality deviations | 24 |
| Trawl bycatch fishing mortality deviations | 38 |
| Initial (1968) length composition deviations | 36 |
| Free selectivity parameters | 28 |
| Effective sample size parameters | 10 |
| | |
| Total number of free parameters | 296 |
| Total number of fixed and free parameters | 325 |

**Negative log likelihood components**

| | |
|---|---|
| Length compositions---retained catch | -1102.580 |
| Length compositions---pot male discard | -879.506 |
| Length compositions---pot female discard | -2144.030 |
| Length compositions---survey | -55189.700 |
| Length compositions---trawl discard | -1833.780 |
| Length compositions---Tanner crab discards | -272.217 |
| Pot discard male biomass | 206.027 |
| Retained catch biomass | 48.062 |
| Pot discard female biomass | 0.121 |
| Trawl discard | 0.833 |
| Survey biomass | 84.608 |
| Recruitment variation | 113.525 |
| Others | 20.536 |
| | |
| Total | -60948.100 |

Table 5. Summary of model parameter estimates (scenario 7ac) for Bristol Bay red king crab. Estimated values and standard deviations. All values are on a log scale. Male recruit is exp(mean+males), and female recruit is exp(mean+males+females).

| | Recruits | | | | F for Directed Pot Fishery | | | | F for Trawl | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Females | S. dev. | Males | S.dev. | Males | S.dev. | Females | S.dev. | Est. | S.dev. |
| Mean | 16.276 | 0.019 | 16.276 | 0.019 | -1.727 | 0.040 | 0.011 | 0.001 | -5.117 | 0.066 |
| 1968 | | | | | 1.837 | 0.070 | | | | |
| 1969 | -0.093 | 0.115 | 0.700 | 0.074 | 1.879 | 0.101 | | | | |
| 1970 | -0.056 | 0.108 | 0.978 | 0.078 | 1.588 | 0.114 | | | | |
| 1971 | -0.061 | 0.079 | 1.655 | 0.059 | 1.151 | 0.115 | | | | |
| 1972 | -0.321 | 0.176 | 0.697 | 0.093 | 1.226 | 0.112 | | | | |
| 1973 | -0.363 | 0.095 | 1.357 | 0.050 | 0.985 | 0.105 | | | | |
| 1974 | 0.046 | 0.080 | 1.517 | 0.049 | 1.156 | 0.091 | | | | |
| 1975 | 0.334 | 0.059 | 2.087 | 0.041 | 0.986 | 0.071 | | | | |
| 1976 | -0.464 | 0.195 | 0.899 | 0.084 | 1.060 | 0.065 | | | 0.261 | 0.106 |
| 1977 | 0.517 | 0.133 | 0.501 | 0.096 | 1.133 | 0.061 | | | 0.818 | 0.105 |
| 1978 | 0.359 | 0.107 | 0.812 | 0.078 | 1.263 | 0.055 | | | 0.750 | 0.104 |
| 1979 | 0.058 | 0.107 | 0.994 | 0.074 | 1.383 | 0.051 | | | 0.719 | 0.103 |
| 1980 | 0.034 | 0.100 | 1.236 | 0.076 | 2.056 | 0.046 | | | 0.674 | 0.104 |
| 1981 | 0.181 | 0.108 | 0.621 | 0.084 | 2.199 | 0.009 | | | 0.288 | 0.104 |
| 1982 | -0.149 | 0.047 | 2.083 | 0.041 | 0.396 | 0.047 | | | 2.063 | 0.106 |
| 1983 | -0.062 | 0.072 | 1.153 | 0.050 | -10.601 | 0.932 | | | 1.965 | 0.106 |
| 1984 | 0.309 | 0.061 | 1.005 | 0.043 | 0.902 | 0.061 | | | 2.972 | 0.105 |
| 1985 | 0.095 | 0.153 | -0.834 | 0.096 | 1.014 | 0.070 | | | 1.950 | 0.106 |
| 1986 | 0.379 | 0.054 | 0.423 | 0.041 | 1.298 | 0.064 | | | 0.825 | 0.105 |
| 1987 | -0.166 | 0.125 | -0.436 | 0.063 | 0.806 | 0.058 | | | 0.209 | 0.104 |
| 1988 | 0.219 | 0.155 | -1.156 | 0.094 | -0.143 | 0.053 | | | 1.310 | 0.102 |
| 1989 | 0.068 | 0.148 | -1.026 | 0.081 | -0.038 | 0.051 | | | -0.043 | 0.102 |
| 1990 | -0.029 | 0.065 | 0.041 | 0.042 | 0.570 | 0.048 | 2.016 | 0.106 | 0.160 | 0.102 |
| 1991 | -0.213 | 0.100 | -0.444 | 0.054 | 0.497 | 0.049 | -0.024 | 0.106 | 0.356 | 0.103 |
| 1992 | -0.470 | 0.349 | -2.146 | 0.164 | -0.043 | 0.049 | 2.280 | 0.105 | 0.432 | 0.103 |
| 1993 | -0.297 | 0.093 | -0.610 | 0.052 | 0.658 | 0.050 | 2.079 | 0.106 | 0.910 | 0.102 |
| 1994 | -0.229 | 0.333 | -2.277 | 0.174 | -4.386 | 0.052 | 1.568 | 0.132 | -0.456 | 0.103 |
| 1995 | 0.028 | 0.037 | 0.947 | 0.031 | -4.649 | 0.050 | 1.616 | 0.138 | -0.385 | 0.103 |
| 1996 | -0.427 | 0.224 | -0.999 | 0.114 | -0.181 | 0.048 | -3.647 | 0.158 | -0.437 | 0.103 |
| 1997 | -0.591 | 0.365 | -1.905 | 0.173 | -0.102 | 0.048 | -1.080 | 0.107 | -0.821 | 0.103 |
| 1998 | -0.246 | 0.111 | -0.488 | 0.061 | 0.655 | 0.048 | 1.990 | 0.104 | -0.057 | 0.102 |
| 1999 | 0.042 | 0.059 | 0.299 | 0.040 | 0.185 | 0.048 | -2.167 | 0.111 | 0.063 | 0.102 |
| 2000 | 0.114 | 0.129 | -0.748 | 0.081 | -0.098 | 0.048 | -0.335 | 0.106 | -0.496 | 0.102 |
| 2001 | 0.733 | 0.157 | -1.182 | 0.120 | -0.132 | 0.047 | 1.022 | 0.105 | -0.230 | 0.102 |
| 2002 | 0.175 | 0.053 | 0.803 | 0.037 | 0.033 | 0.048 | -2.332 | 0.112 | -0.515 | 0.102 |
| 2003 | -0.020 | 0.201 | -0.797 | 0.123 | 0.515 | 0.047 | 1.060 | 0.105 | -0.405 | 0.102 |
| 2004 | -0.013 | 0.143 | -0.253 | 0.085 | 0.343 | 0.048 | 0.342 | 0.105 | -0.699 | 0.102 |
| 2005 | 0.373 | 0.062 | 0.659 | 0.050 | 0.746 | 0.049 | 0.838 | 0.105 | -0.357 | 0.102 |
| 2006 | -0.688 | 0.156 | 0.090 | 0.068 | 0.432 | 0.050 | -1.510 | 0.106 | -0.818 | 0.103 |
| 2007 | -0.109 | 0.160 | -0.675 | 0.098 | 0.720 | 0.052 | -0.274 | 0.105 | -0.662 | 0.103 |
| 2008 | 0.161 | 0.164 | -1.070 | 0.108 | 0.901 | 0.055 | -0.651 | 0.106 | -0.319 | 0.103 |
| 2009 | 0.113 | 0.162 | -1.094 | 0.105 | 0.715 | 0.060 | -0.996 | 0.107 | -0.639 | 0.105 |
| 2010 | -0.145 | 0.134 | -0.611 | 0.083 | 0.646 | 0.065 | -0.505 | 0.109 | -0.966 | 0.107 |
| 2011 | 0.190 | 0.119 | -0.460 | 0.088 | -0.134 | 0.067 | -1.290 | 0.111 | -1.034 | 0.109 |
| 2012 | 1.162 | 0.163 | -0.927 | 0.146 | | | | | | |

Table 5 (continued). Summary of model parameter estimates for Bristol Bay red king crab. Estimated values and standard deviations. For initial year length composition deviations, the first 20 length groups are for males and the last 16 length groups are for females.

| | | | | | | Dev. From 1968 Obs. Length comp. | | |
|---|---|---|---|---|---|---|---|---|
| Parameter | Value | St.dev. | Parameter | Value | St.dev. | Length | Dev. | St.dev. |
| Mm80-84 | 0.495 | 0.015 | log_srv_L50, m, 70-72 | 4.598 | 0.043 | 68 | -0.007 | 0.003 |
| Mf80-84 | 0.798 | 0.019 | srv_slope, f, 70-72 | 0.128 | 0.012 | 73 | -0.005 | 0.003 |
| Mf76-79,85-93 | 0.065 | 0.006 | log_srv_L50, f, 70-72 | 4.373 | 0.017 | 78 | 0.000 | 0.003 |
| log_betal, females | 0.187 | 0.053 | log_srv_L50, m, 73-81 | 4.391 | 0.019 | 83 | 0.002 | 0.003 |
| log_betal, males | 0.478 | 0.080 | srv_slope, f, 73-81 | 0.069 | 0.004 | 88 | 0.004 | 0.004 |
| log_betar, females | -0.641 | 0.059 | log_srv_L50, f, 73-81 | 4.420 | 0.015 | 93 | 0.002 | 0.004 |
| log_betar, males | -0.575 | 0.043 | log_srv_L50, m, 82-11 | 4.500 | 0.010 | 98 | 0.003 | 0.004 |
| Q, females, 70-72 | 0.218 | 0.023 | srv_slope, f, 82-10 | 0.055 | 0.002 | 103 | 0.002 | 0.004 |
| Q, males, 70-72 | 0.513 | 0.078 | log_srv_L50, f, 82-11 | 4.529 | 0.012 | 108 | -0.003 | 0.004 |
| Q, 68-69, 73-11 | NA | NA | log_srv_L50, m, 68-69 | 4.516 | 0.022 | 113 | -0.003 | 0.004 |
| moltp_slope, 68-79 | 0.155 | 0.015 | srv_slope, f, 68-69 | 0.059 | 0.007 | 118 | 0.000 | 0.004 |
| moltp_slope, level 1 | 0.080 | 0.004 | log_srv_L50, f, 68-69 | 4.587 | 0.035 | 123 | -0.002 | 0.004 |
| moltp_slope, level 2 | 0.091 | 0.004 | TC_slope, females | 0.334 | 0.141 | 128 | -0.001 | 0.004 |
| log_moltp_L50, 68-79 | 4.978 | 0.008 | log_TC_L50, females | 4.552 | 0.017 | 133 | -0.003 | 0.004 |
| log_moltp_L50, level 1 | 4.872 | 0.004 | TC_slope, males | 0.232 | 0.101 | 138 | -0.004 | 0.003 |
| log_moltp_L50, level 2 | 4.951 | 0.003 | log_TC_L50, males | 4.579 | 0.023 | 143 | -0.001 | 0.003 |
| log_N68 | 18.795 | 0.038 | log_TC_F, males, 91 | -4.327 | 0.079 | 148 | 0.001 | 0.003 |
| log_avg_L50, 73-11 | 4.923 | 0.001 | log_TC_F, males, 92 | -5.457 | 0.080 | 153 | 0.003 | 0.003 |
| log_avg_L50, 68-72 | 4.865 | 0.006 | log_TC_F, males, 93 | -6.699 | 0.082 | 158 | 0.001 | 0.003 |
| ret_fish_slope, 73-11 | 0.502 | 0.023 | log_TC_F, females, 91 | -2.970 | 0.086 | 163 | 0.010 | 0.001 |
| ret_fish_slope, 68-72 | 0.429 | 0.107 | log_TC_F, females, 92 | -4.142 | 0.086 | 68 | -0.007 | 0.003 |
| pot disc.males, $\varphi$ | -0.259 | 0.010 | log_TC_F, females, 93 | -4.730 | 0.085 | 73 | -0.010 | 0.002 |
| pot disc.males, $\kappa$ | 0.003 | 0.000 | | | | 78 | -0.009 | 0.004 |
| pot disc.males, $\gamma$ | -0.013 | 0.000 | | | | 83 | -0.005 | 0.004 |
| sel_62.5mm, 68-72 | 1.415 | 0.000 | | | | 88 | -0.002 | 0.004 |
| post disc.fema., slope | 0.324 | 0.132 | | | | 93 | 0.002 | 0.005 |
| log_pot disc.fema., L50 | 4.408 | 0.008 | | | | 98 | -0.002 | 0.005 |
| trawl disc slope | 0.053 | 0.003 | | | | 103 | -0.004 | 0.005 |
| log_trawl disc L50 | 5.092 | 0.053 | | | | 108 | 0.000 | 0.005 |
| | | | | | | 113 | 0.001 | 0.005 |
| | | | | | | 118 | 0.003 | 0.005 |
| | | | | | | 123 | 0.004 | 0.006 |
| | | | | | | 128 | 0.004 | 0.006 |
| | | | | | | 133 | 0.006 | 0.007 |
| | | | | | | 138 | 0.009 | 0.006 |
| | | | | | | 143 | 0.010 | 0.001 |

Table 6. Annual abundance estimates (million crabs), mature male biomass (MMB, 1000 t), and total survey biomass estimates (1000 t) for red king crab in Bristol Bay estimated by length-based analysis (scenario 7ac) from 1968-2012. Mature male biomass for year *t* is on Feb. 15, year *t*+1. Size measurements are mm CL.

| | Males | | | | Females | Total | Total Survey Biomass | |
|---|---|---|---|---|---|---|---|---|
| Year (t) | Mature (>119mm) | Legal (>134mm) | MMB (>119mm) | MMB SD | Mature (>89mm) | Recruits | Model Est. (>64mm) | Area-swept (>64mm) |
| 1968 | 13.050 | 8.360 | 13.297 | 1.123 | 49.719 | | 74.174 | 80.070 |
| 1969 | 12.522 | 5.766 | 12.416 | 1.348 | 52.234 | 45.035 | 73.769 | 87.140 |
| 1970 | 16.086 | 6.400 | 18.001 | 2.105 | 56.026 | 60.556 | 35.673 | 43.040 |
| 1971 | 18.008 | 8.945 | 23.799 | 2.705 | 61.505 | 118.958 | 42.878 | |
| 1972 | 22.520 | 11.311 | 29.389 | 3.127 | 73.529 | 40.550 | 53.507 | 50.267 |
| 1973 | 29.132 | 13.918 | 40.730 | 3.713 | 88.980 | 77.141 | 163.538 | 159.504 |
| 1974 | 42.538 | 19.587 | 56.780 | 4.103 | 93.835 | 109.279 | 192.879 | 192.378 |
| 1975 | 47.599 | 26.866 | 67.404 | 4.166 | 100.620 | 226.042 | 231.186 | 207.459 |
| 1976 | 50.497 | 30.069 | 70.512 | 3.838 | 127.918 | 46.843 | 264.614 | 283.020 |
| 1977 | 57.784 | 31.244 | 78.180 | 3.389 | 154.685 | 51.731 | 279.781 | 362.280 |
| 1978 | 72.074 | 35.937 | 93.128 | 2.980 | 146.970 | 64.128 | 280.410 | 322.282 |
| 1979 | 71.159 | 43.016 | 87.703 | 2.659 | 131.693 | 65.199 | 265.318 | 243.490 |
| 1980 | 53.399 | 38.191 | 29.971 | 1.073 | 121.069 | 82.015 | 235.729 | 228.253 |
| 1981 | 17.383 | 9.084 | 10.098 | 0.436 | 53.078 | 47.916 | 97.982 | 111.748 |
| 1982 | 8.766 | 3.176 | 9.089 | 0.361 | 25.008 | 175.008 | 56.193 | 131.972 |
| 1983 | 7.494 | 2.921 | 8.933 | 0.328 | 17.054 | 71.935 | 48.551 | 47.189 |
| 1984 | 7.154 | 2.848 | 6.718 | 0.313 | 17.552 | 75.569 | 46.239 | 130.308 |
| 1985 | 8.418 | 2.330 | 11.084 | 0.466 | 14.558 | 10.673 | 36.082 | 33.005 |
| 1986 | 14.151 | 5.300 | 17.854 | 0.706 | 20.465 | 43.996 | 48.333 | 46.290 |
| 1987 | 17.557 | 8.031 | 25.105 | 0.869 | 24.719 | 13.990 | 55.282 | 66.139 |
| 1988 | 18.334 | 10.624 | 31.332 | 0.958 | 30.237 | 8.277 | 59.965 | 50.570 |
| 1989 | 20.309 | 12.549 | 35.872 | 1.003 | 28.365 | 8.684 | 63.807 | 58.735 |
| 1990 | 20.858 | 13.899 | 34.413 | 1.019 | 24.848 | 24.033 | 64.658 | 52.674 |
| 1991 | 17.331 | 12.842 | 29.785 | 0.995 | 23.005 | 13.575 | 59.401 | 82.835 |
| 1992 | 14.050 | 10.725 | 27.540 | 0.950 | 22.947 | 2.224 | 53.710 | 34.732 |
| 1993 | 13.943 | 9.193 | 23.075 | 0.871 | 20.467 | 11.083 | 50.227 | 47.159 |
| 1994 | 13.180 | 7.801 | 26.900 | 0.853 | 17.079 | 2.156 | 43.608 | 29.789 |
| 1995 | 13.532 | 9.025 | 28.584 | 0.811 | 16.493 | 61.217 | 48.915 | 35.927 |
| 1996 | 13.878 | 10.381 | 27.635 | 0.784 | 22.286 | 7.126 | 56.529 | 40.886 |
| 1997 | 13.168 | 9.742 | 26.304 | 0.761 | 32.230 | 2.707 | 60.859 | 78.993 |
| 1998 | 16.961 | 8.908 | 27.114 | 0.778 | 30.118 | 12.814 | 62.319 | 76.289 |
| 1999 | 19.043 | 10.698 | 32.621 | 0.870 | 26.452 | 32.261 | 62.633 | 59.684 |
| 2000 | 16.633 | 11.027 | 30.587 | 0.831 | 28.622 | 11.746 | 62.339 | 62.140 |
| 2001 | 15.738 | 11.400 | 30.340 | 0.824 | 32.579 | 11.061 | 65.217 | 47.621 |
| 2002 | 16.683 | 10.396 | 30.372 | 0.805 | 32.480 | 57.275 | 68.120 | 64.534 |
| 2003 | 17.545 | 11.431 | 29.754 | 0.823 | 38.476 | 10.450 | 73.092 | 87.428 |
| 2004 | 15.806 | 10.991 | 28.182 | 0.821 | 46.381 | 18.068 | 75.302 | 88.288 |
| 2005 | 18.741 | 10.571 | 29.477 | 0.881 | 44.799 | 55.492 | 80.940 | 96.177 |
| 2006 | 19.376 | 11.497 | 32.377 | 0.987 | 49.372 | 19.250 | 84.013 | 86.605 |
| 2007 | 18.840 | 12.355 | 30.097 | 1.067 | 56.939 | 11.311 | 88.529 | 94.460 |
| 2008 | 19.515 | 10.528 | 28.809 | 1.170 | 53.319 | 8.738 | 85.689 | 111.803 |
| 2009 | 20.092 | 10.190 | 30.468 | 1.381 | 48.194 | 8.312 | 80.614 | 80.545 |
| 2010 | 18.887 | 10.653 | 29.346 | 1.536 | 43.546 | 11.852 | 75.571 | 71.725 |
| 2011 | 16.635 | 11.552 | 30.875 | 1.706 | 39.763 | 16.322 | 72.276 | 58.064 |
| 2012 | 14.945 | 11.505 | 26.319 | 1.386 | 37.983 | 19.438 | 71.524 | 53.940 |

Table 7. Comparison of projected mature male biomass (1000 t) on Feb. 15, retained catch (1000 t), their 95% limits, and mean fishing mortality with no directed fishery, $F_{40\%}$, and $F_{35\%}$ harvest strategy with $F_{35\%}$ constraint during 2011-2020. Parameter estimates with scenario 0 are used for the projection.

| Year | MMB | 95% limits of MMB | | Catch | 95% limits of catch | |
|---|---|---|---|---|---|---|
| No directed fishery | | | | | | |
| 2012 | 33.443 | 30.292 | 36.408 | 0.000 | 0.000 | 0.000 |
| 2013 | 34.972 | 31.677 | 38.072 | 0.000 | 0.000 | 0.000 |
| 2014 | 36.986 | 33.501 | 40.264 | 0.000 | 0.000 | 0.000 |
| 2015 | 38.625 | 34.927 | 42.301 | 0.000 | 0.000 | 0.000 |
| 2016 | 41.473 | 35.692 | 51.626 | 0.000 | 0.000 | 0.000 |
| 2017 | 45.687 | 35.671 | 65.024 | 0.000 | 0.000 | 0.000 |
| 2018 | 50.107 | 35.664 | 75.884 | 0.000 | 0.000 | 0.000 |
| 2019 | 54.439 | 36.056 | 86.891 | 0.000 | 0.000 | 0.000 |
| 2020 | 58.450 | 36.716 | 94.026 | 0.000 | 0.000 | 0.000 |
| 2021 | 61.885 | 37.680 | 100.812 | 0.000 | 0.000 | 0.000 |
| $F_{40\%}$ | | | | | | |
| 2012 | 27.376 | 25.178 | 29.680 | 6.245 | 5.265 | 6.924 |
| 2013 | 24.629 | 22.913 | 26.358 | 4.940 | 4.215 | 5.729 |
| 2014 | 23.541 | 22.030 | 25.011 | 4.230 | 3.672 | 4.809 |
| 2015 | 22.859 | 21.362 | 24.432 | 3.881 | 3.393 | 4.403 |
| 2016 | 23.698 | 20.190 | 32.133 | 3.855 | 3.115 | 4.929 |
| 2017 | 25.820 | 18.936 | 41.093 | 4.136 | 2.751 | 6.260 |
| 2018 | 27.884 | 18.478 | 46.987 | 4.633 | 2.514 | 7.927 |
| 2019 | 29.634 | 17.990 | 51.762 | 5.133 | 2.444 | 9.198 |
| 2020 | 30.977 | 18.276 | 53.813 | 5.541 | 2.384 | 10.183 |
| 2021 | 31.810 | 18.425 | 55.980 | 5.836 | 2.465 | 10.563 |
| $F_{35\%}$ | | | | | | |
| 2012 | 26.314 | 24.319 | 28.286 | 7.334 | 6.146 | 8.356 |
| 2013 | 23.201 | 21.691 | 24.649 | 5.402 | 4.658 | 6.163 |
| 2014 | 21.980 | 20.655 | 23.222 | 4.495 | 3.939 | 5.044 |
| 2015 | 21.262 | 19.915 | 22.666 | 4.071 | 3.584 | 4.573 |
| 2016 | 22.031 | 18.725 | 29.977 | 4.077 | 3.259 | 5.500 |
| 2017 | 23.989 | 17.514 | 38.245 | 4.437 | 2.848 | 7.054 |
| 2018 | 25.808 | 17.089 | 43.963 | 5.015 | 2.608 | 8.879 |
| 2019 | 27.274 | 16.567 | 47.255 | 5.563 | 2.534 | 10.248 |
| 2020 | 28.350 | 16.984 | 48.921 | 5.976 | 2.487 | 11.186 |
| 2021 | 28.945 | 17.112 | 50.505 | 6.268 | 2.590 | 11.553 |

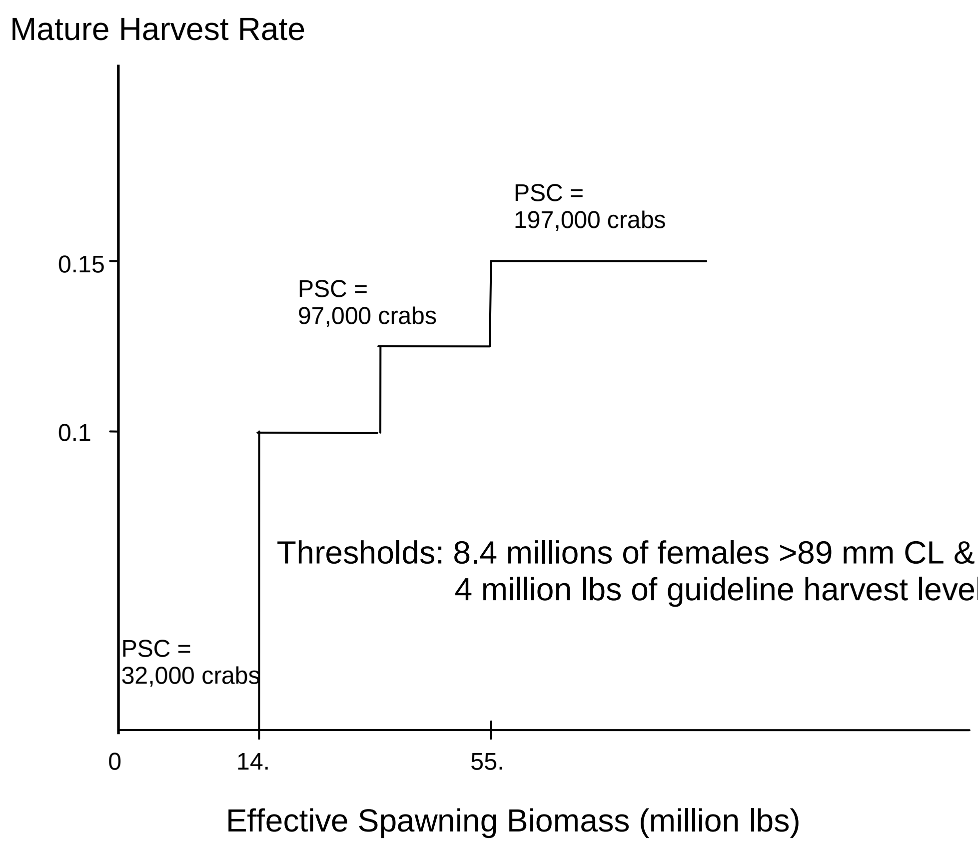



Figure 1. Current harvest rate strategy (line) for the Bristol Bay red king crab fishery and annual prohibited species catch (PSC) limits (numbers of crabs) of Bristol Bay red king crabs in the groundfish fisheries in zone 1 in the eastern Bering Sea. Harvest rates are based on current-year estimates of effective spawning biomass (ESB), whereas PSC limits apply to previous-year ESB.

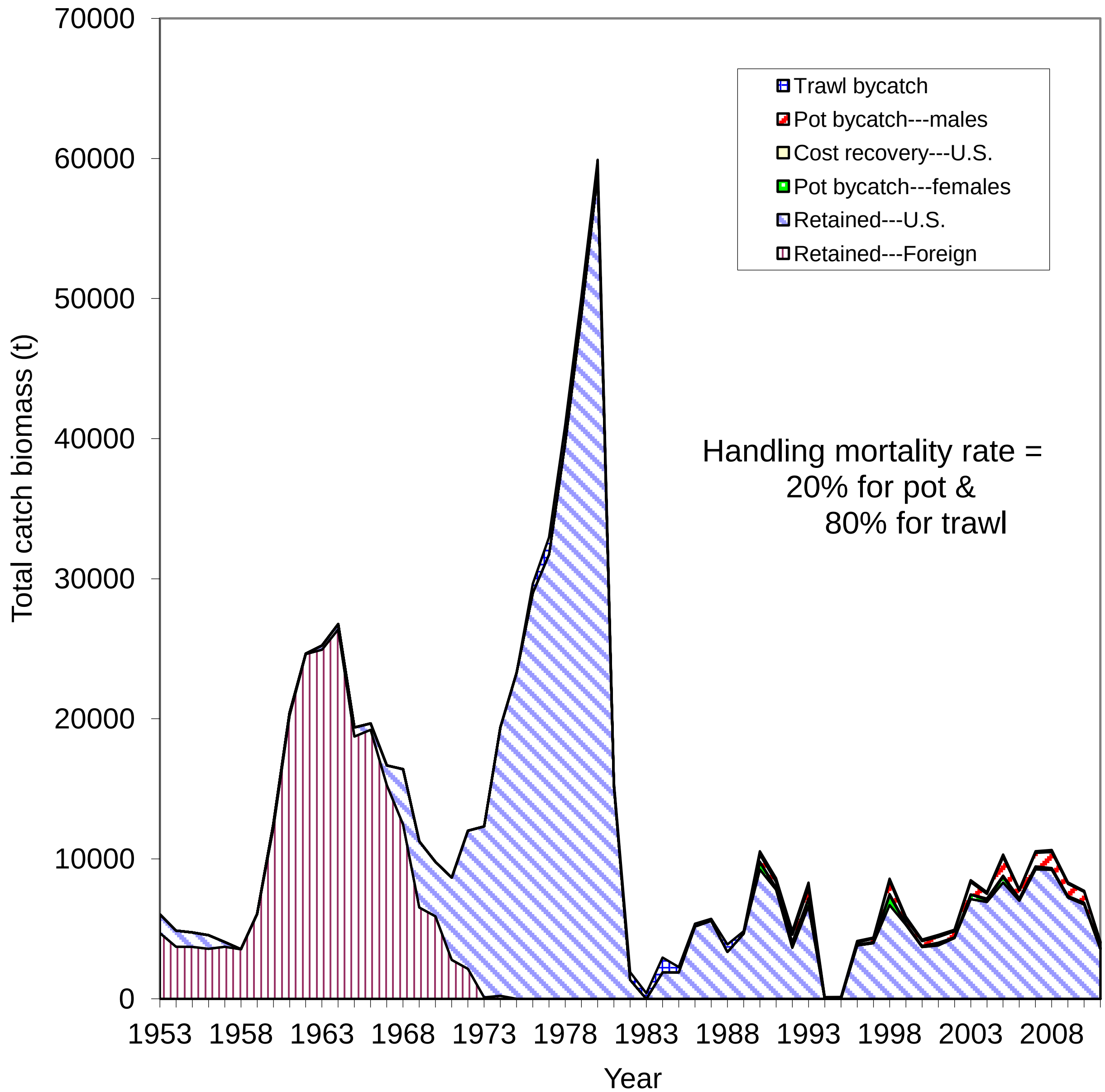



Figure 2. Retained catch biomass and bycatch mortality biomass (t) for Bristol Bay red king crab from 1960 to 2011. Handling mortality rates were assumed to be 0.2 for the directed pot fishery and 0.8 for the trawl fisheries.

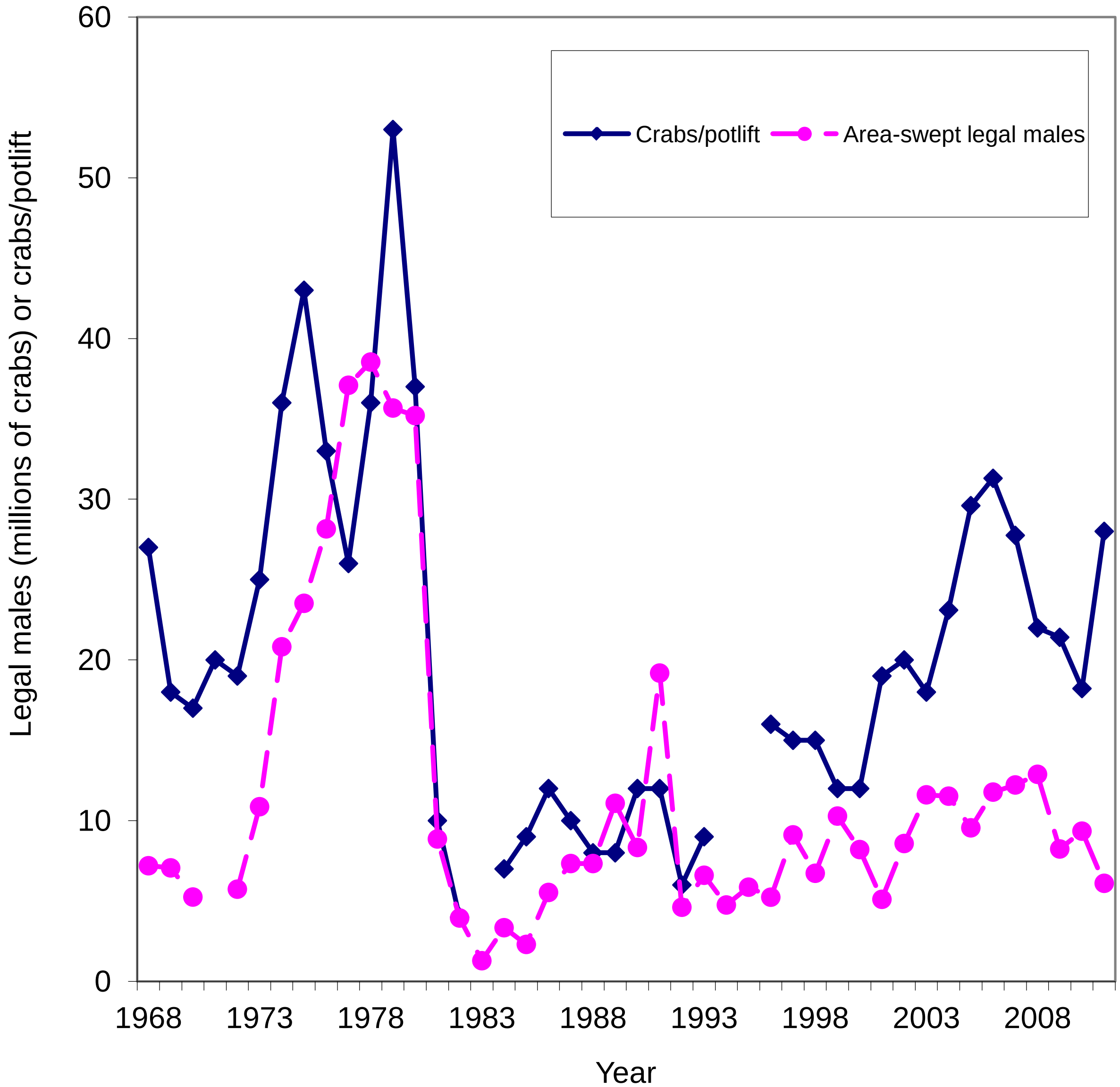



Figure 3. Comparison of survey legal male abundances and catches per unit effort for Bristol Bay red king crab from 1968 to 2011.

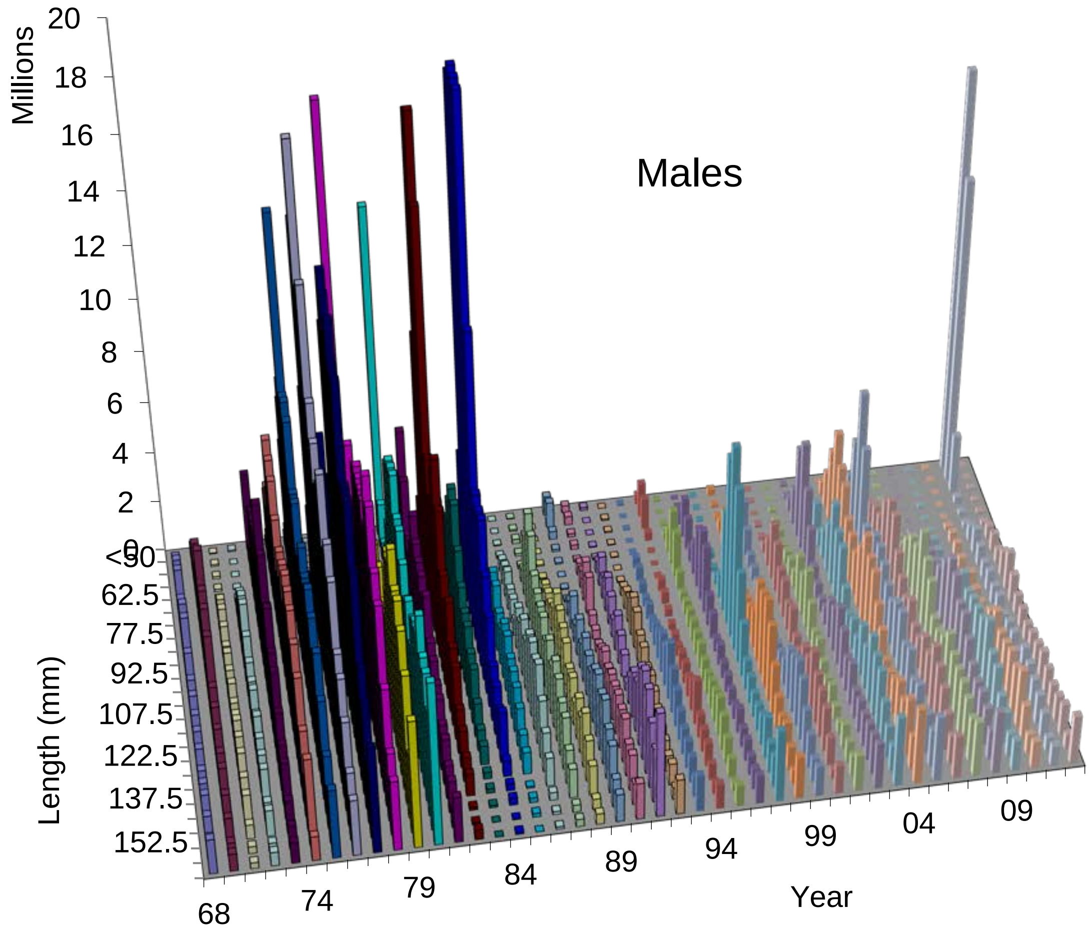



Figure 4. Survey abundances by length for male Bristol Bay red king crabs from 1968 to 2012.

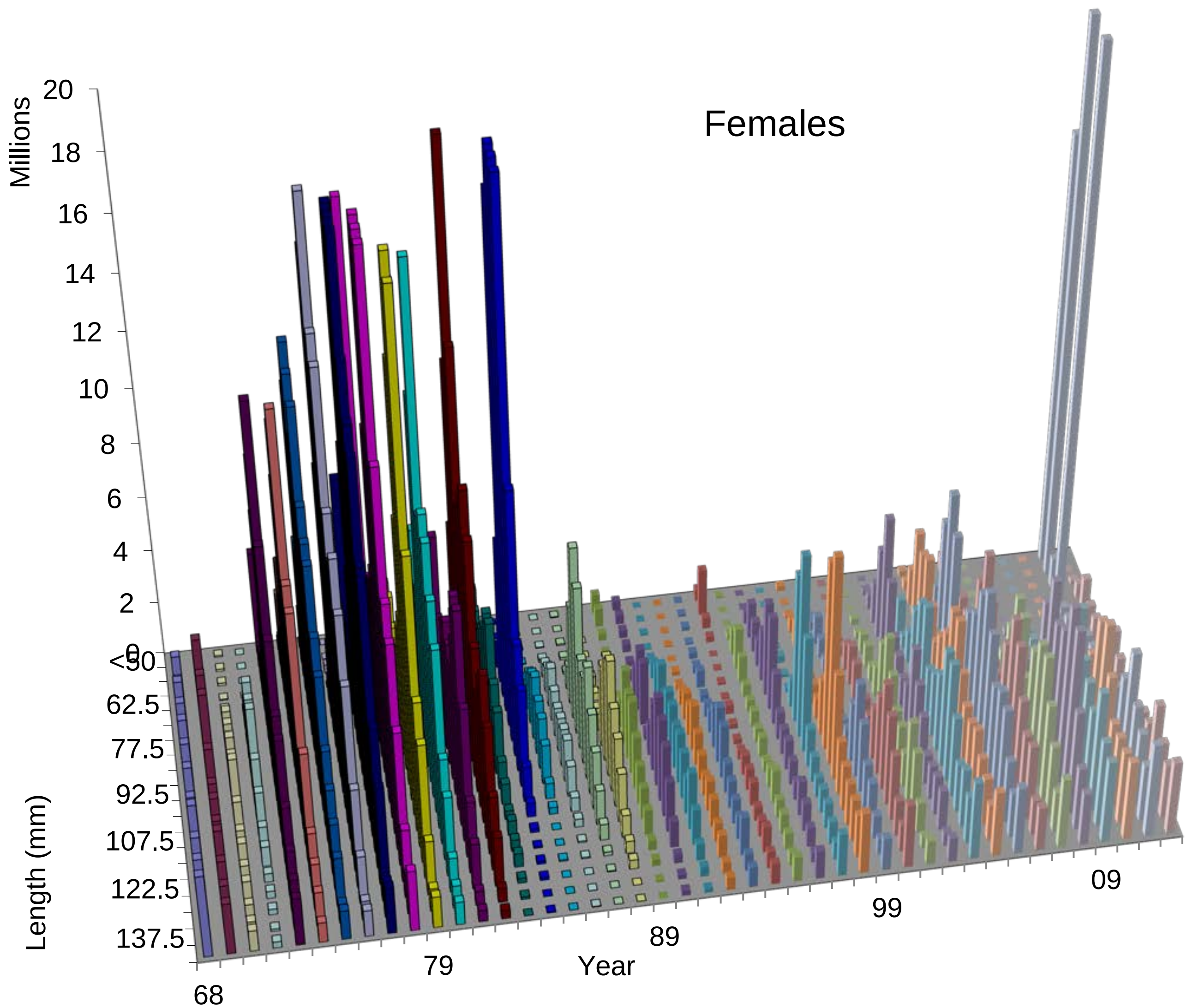



Figure 5. Survey abundances by length for female Bristol Bay red king crabs from 1968 to 2012.

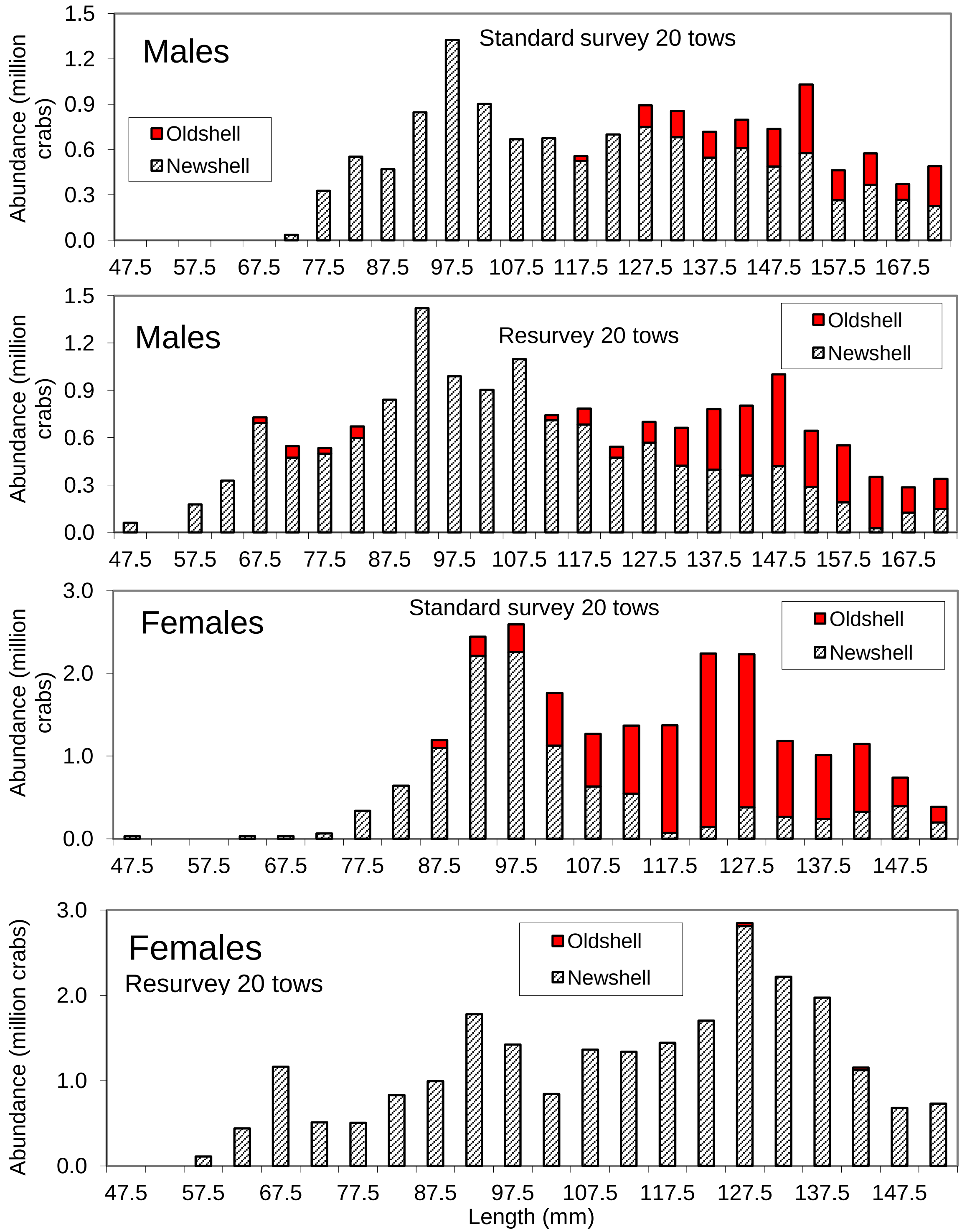



Figure 6. Comparison of area-swept estimates of abundance in 20 stations from the standard trawl survey and resurvey in 2012.

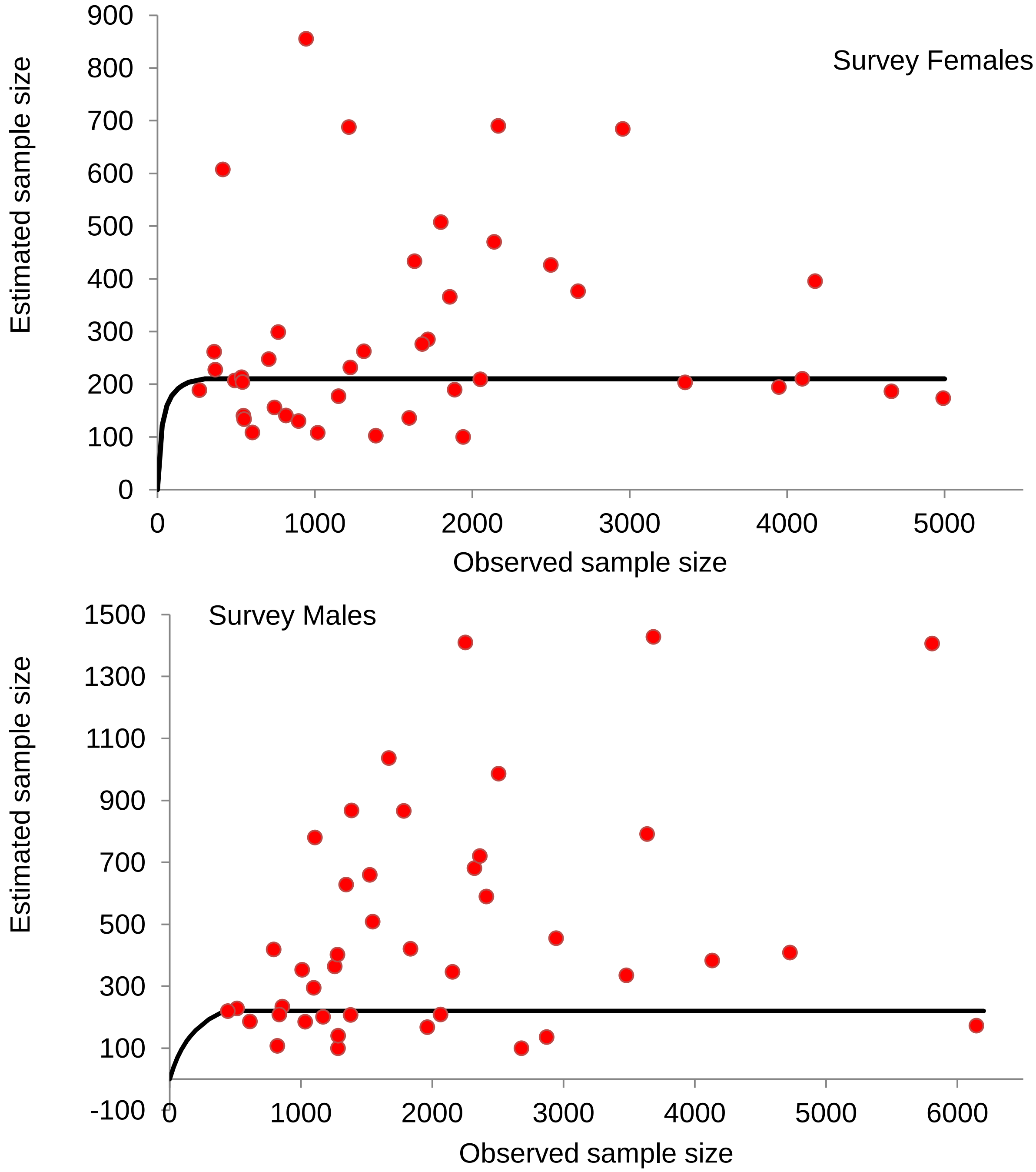



Figure 7a. Relationship between observed and estimated effective sample sizes for length/sex composition data with scenario 7ac: trawl survey data.

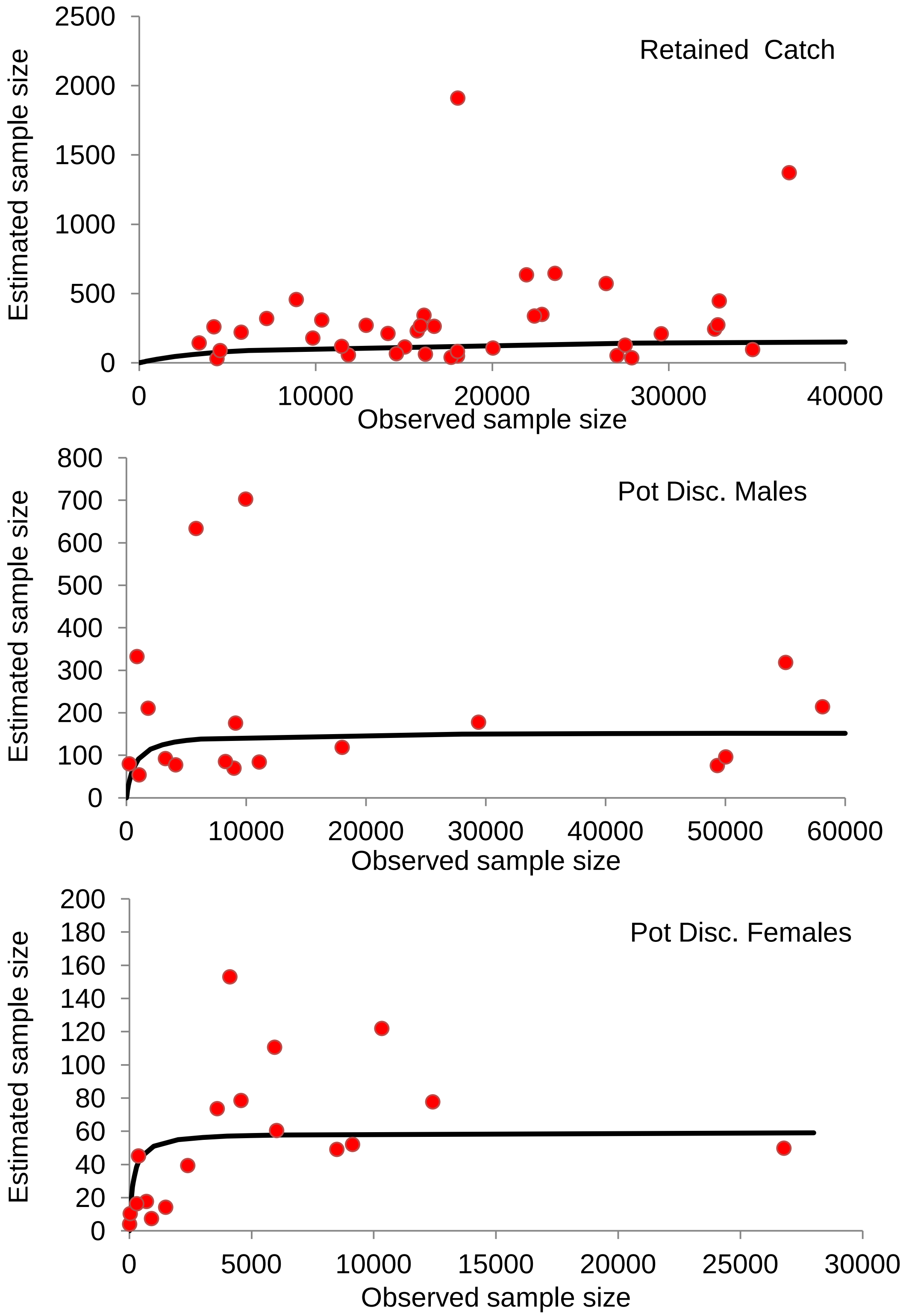



Figure 7b. Relationship between observed and estimated effective sample sizes for length/sex composition data with scenario 7ac: directed pot fishery data.

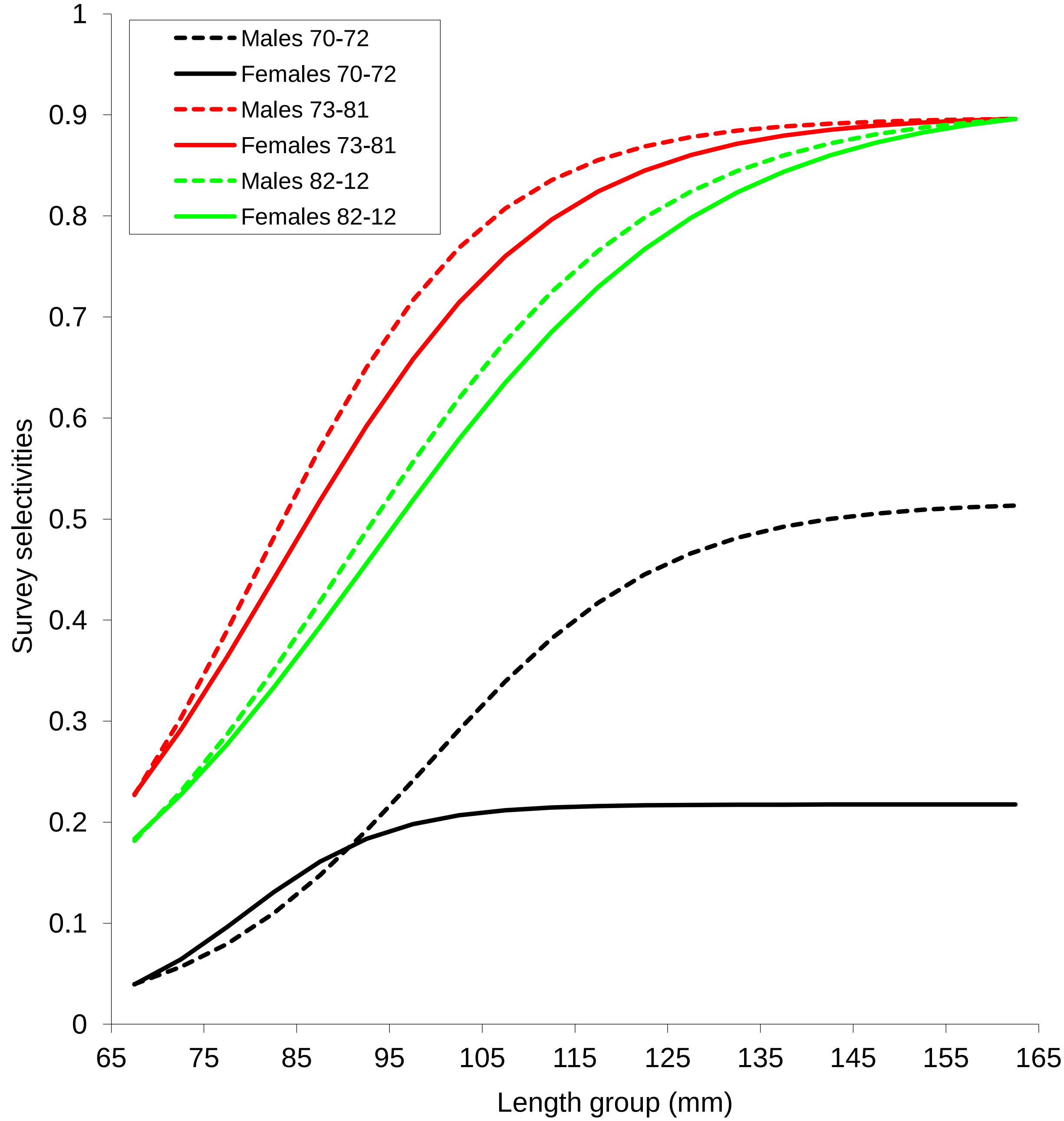
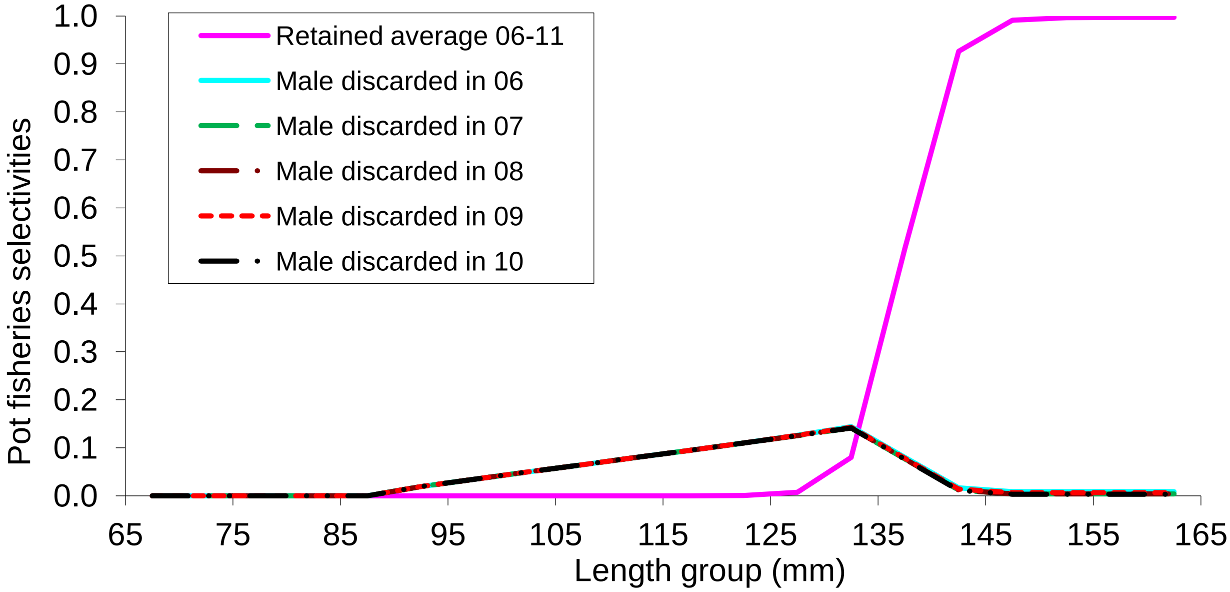



Figure 8a. Estimated trawl survey selectivities under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.



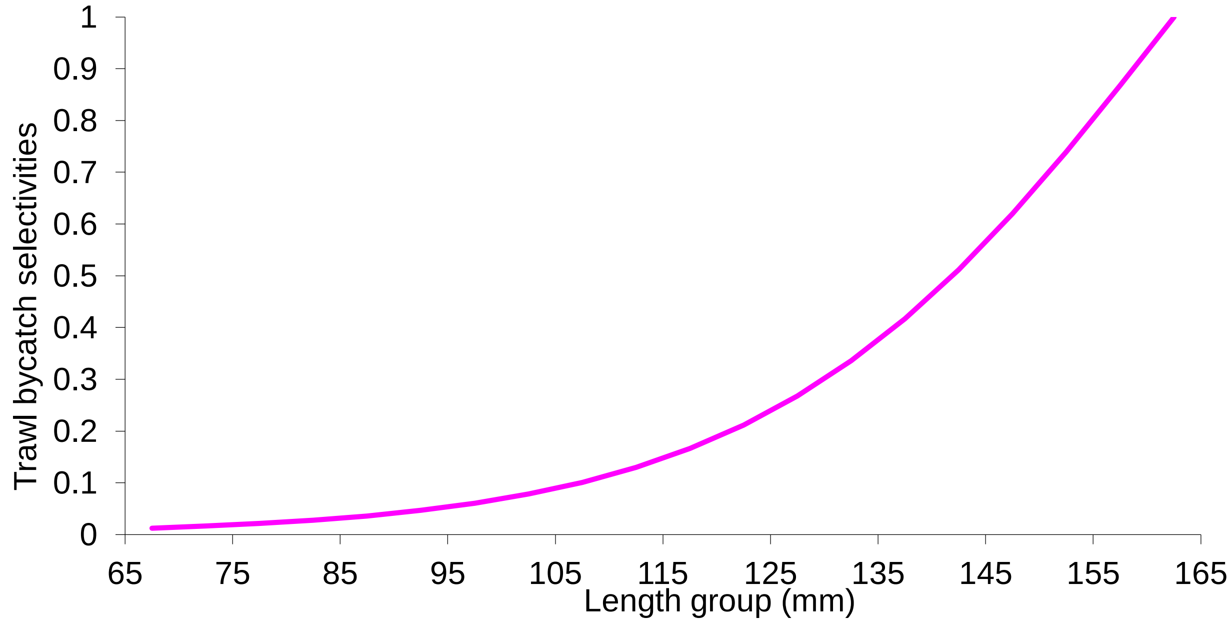




Figure 8b. Estimated pot fishery selectivities and groundfish trawl bycatch selectivities under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

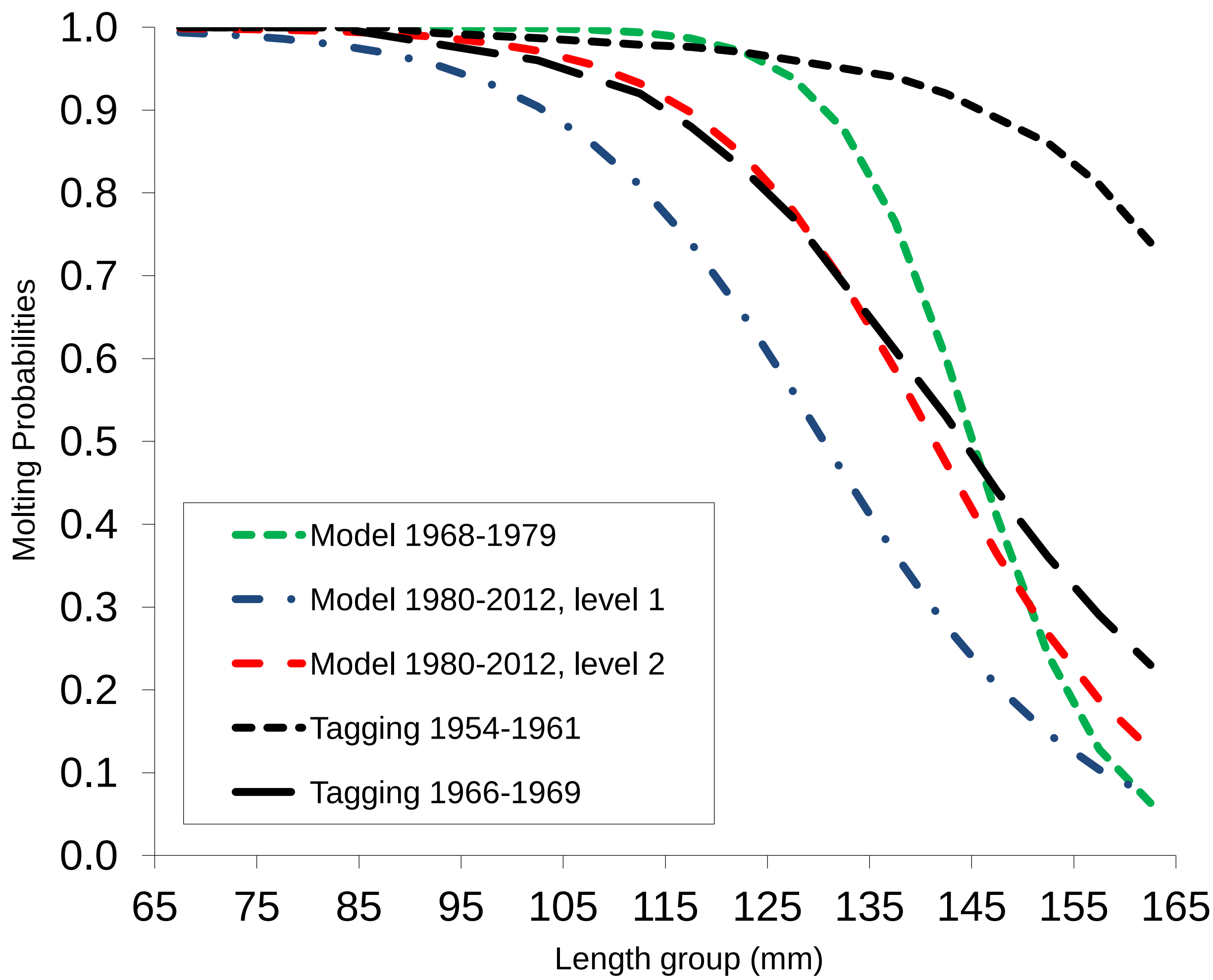



Figure 9. Comparison of estimated probabilities of molting of male red king crabs in Bristol Bay for different periods. Molting probabilities for periods 1954-1961 and 1966-1969 were estimated by Balsiger (1974) from tagging data. Molting probabilities for 1968-2012 were estimated with a length-based model with pot handling mortality rate to be 0.2 under scenario 7ac.

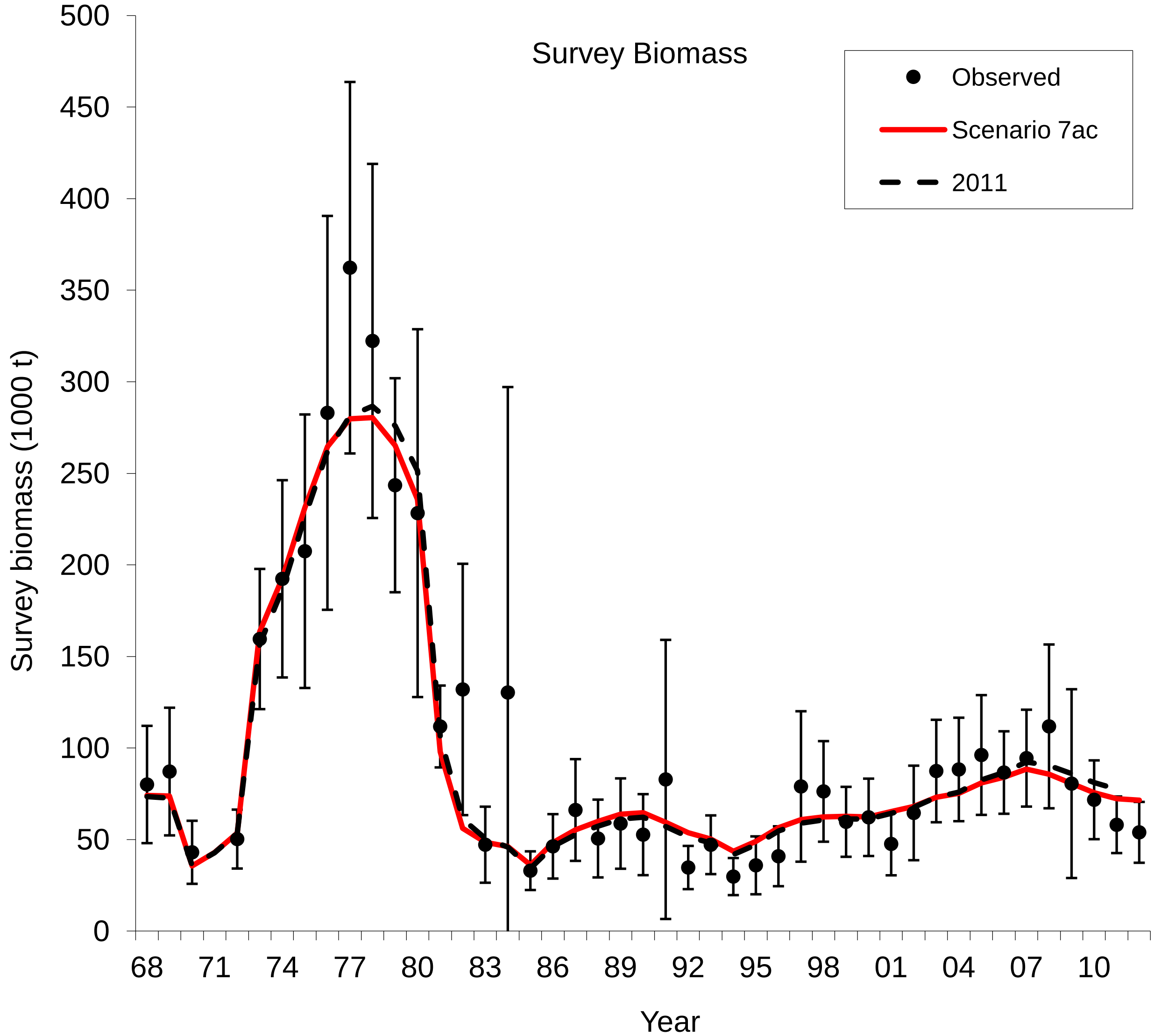



Figure 10a. Comparisons of area-swept estimates of total survey biomass and model prediction for model estimates in 2011 and 2012. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively. The error bars are plus and minus 2 standard deviations.

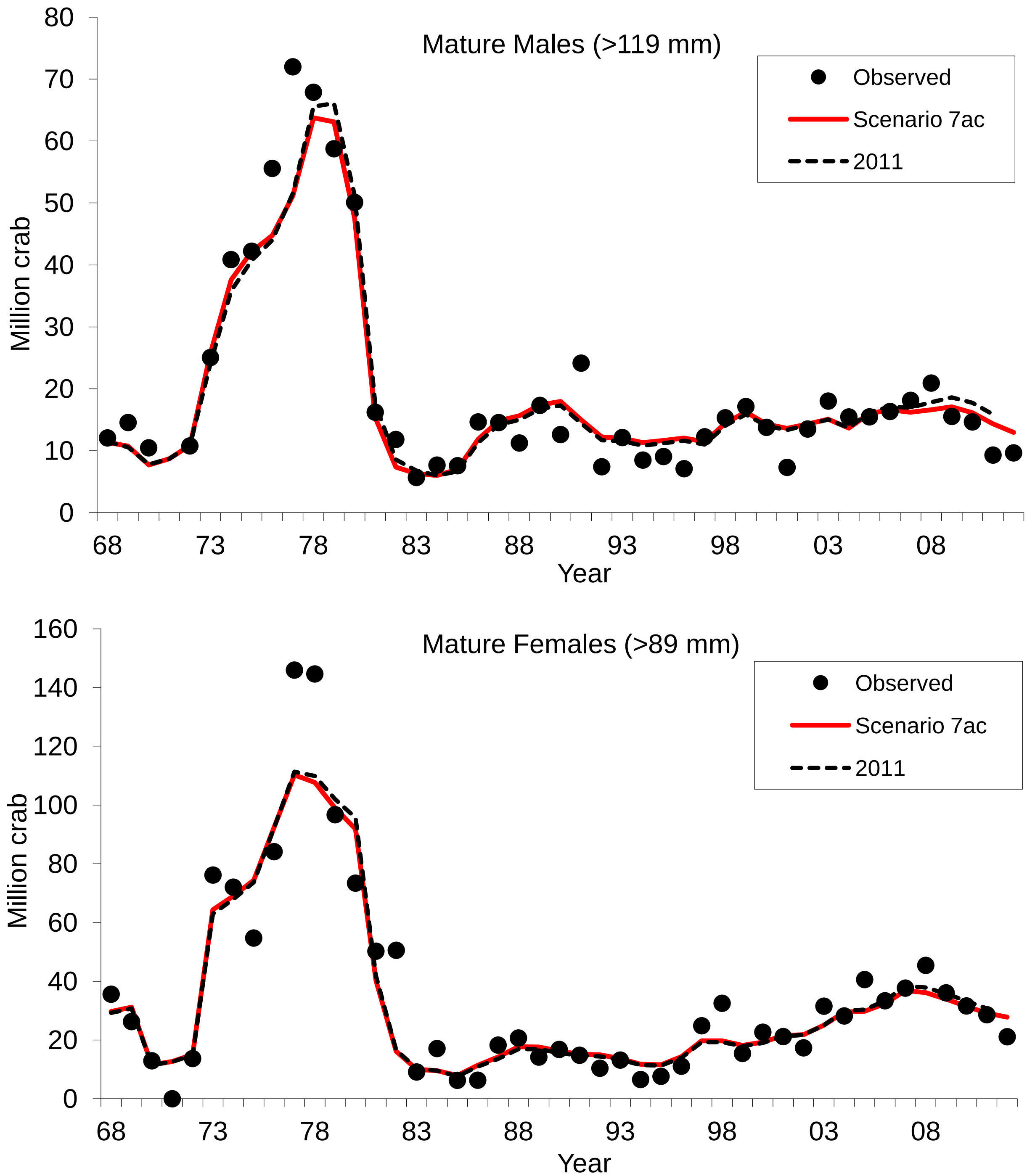



Figure 10b. Comparisons of area-swept estimates of mature male (>119 mm) and female (>89 mm) abundance and model prediction for model estimates in 2011 and 2012. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

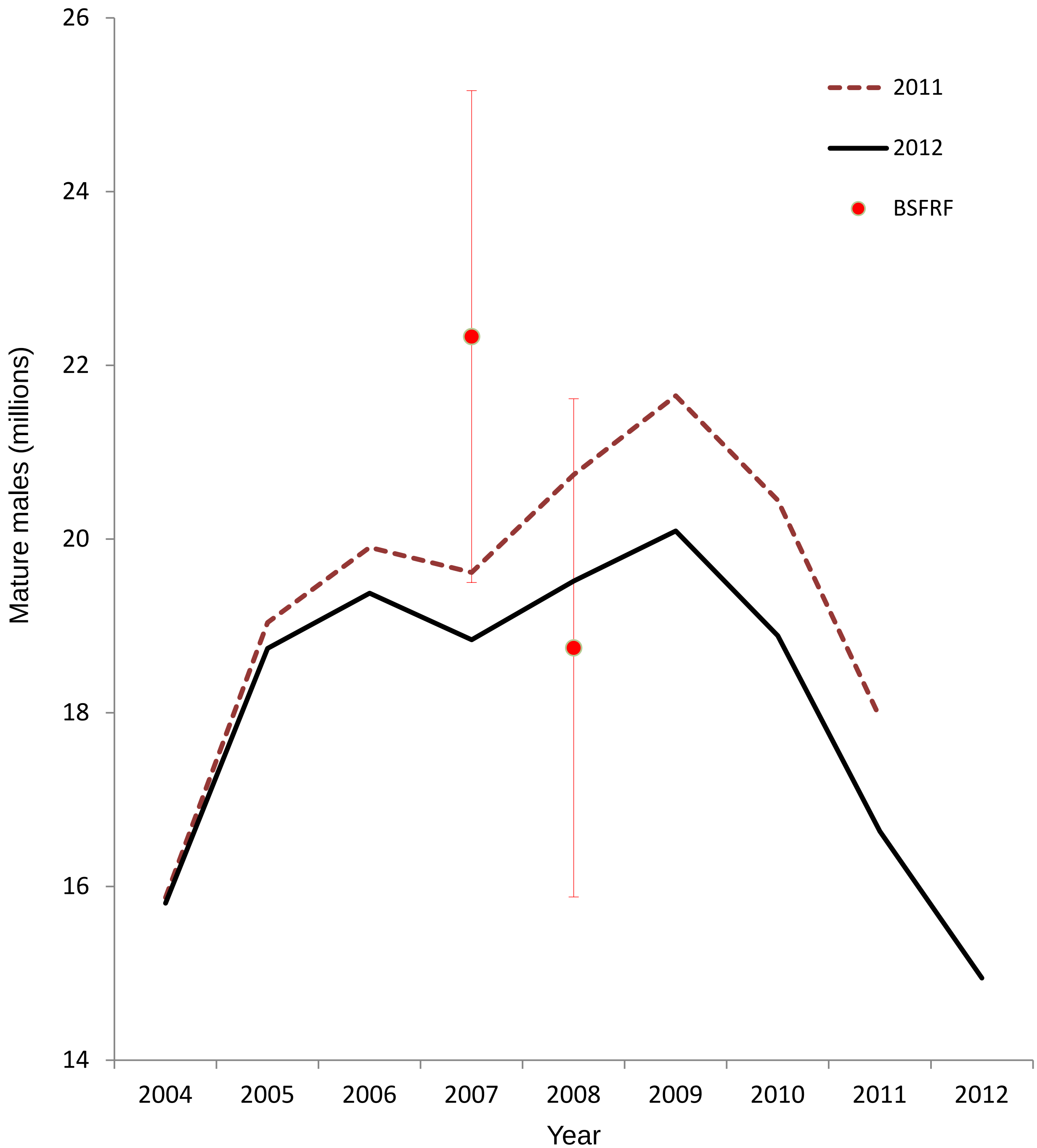



Figure 10c. Comparisons of total mature male abundance estimates by the BSFRF survey and the model for model estimates in 2011 and 2012. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively. The error bars are plus and minus 2 standard deviations.

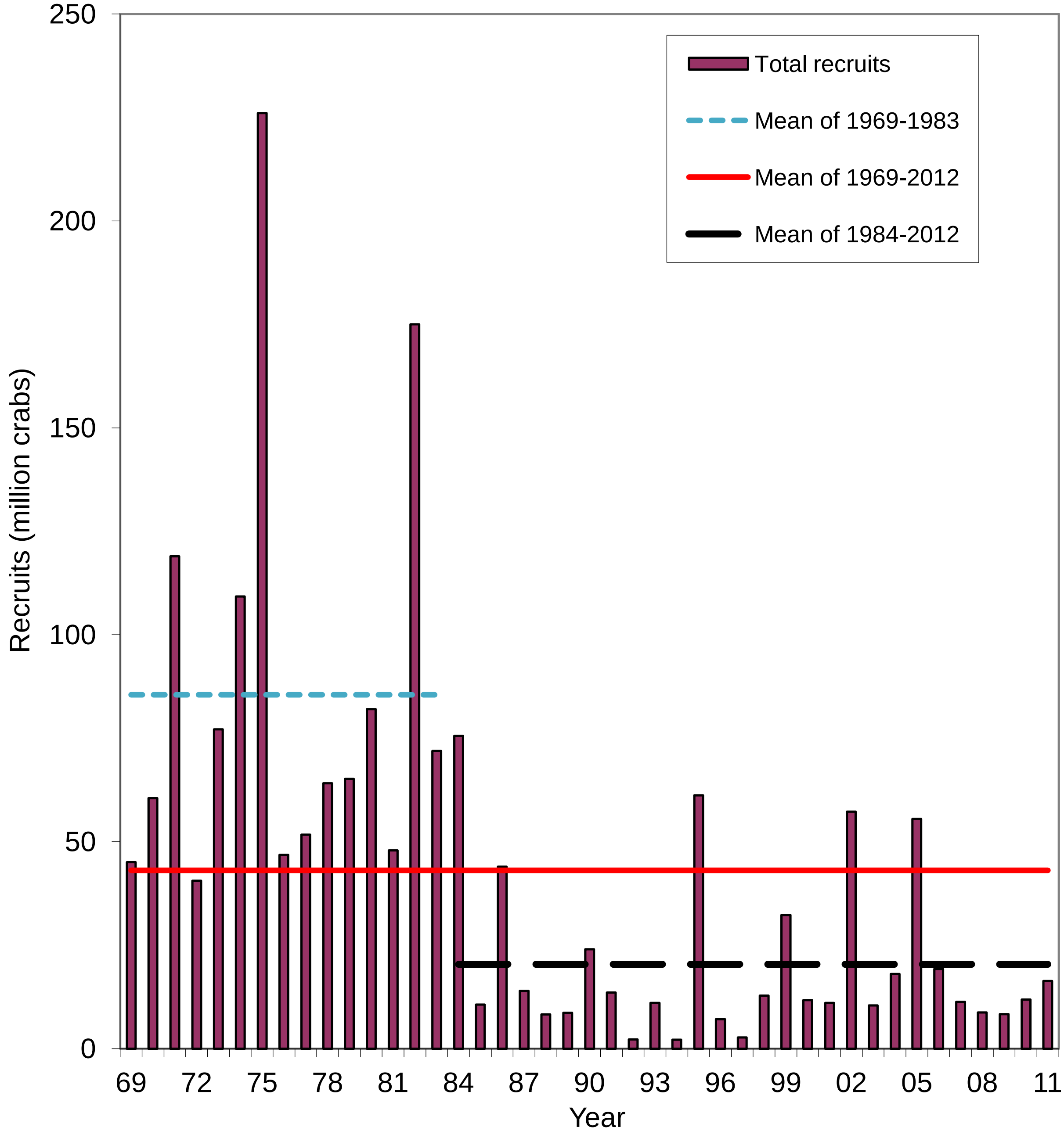



Figure 11. Estimated recruitment time series during 1969-2012 (occurred year) with scenario 7ac. Mean male recruits during 1984-2012 was used to estimate $B_{35\%}$.

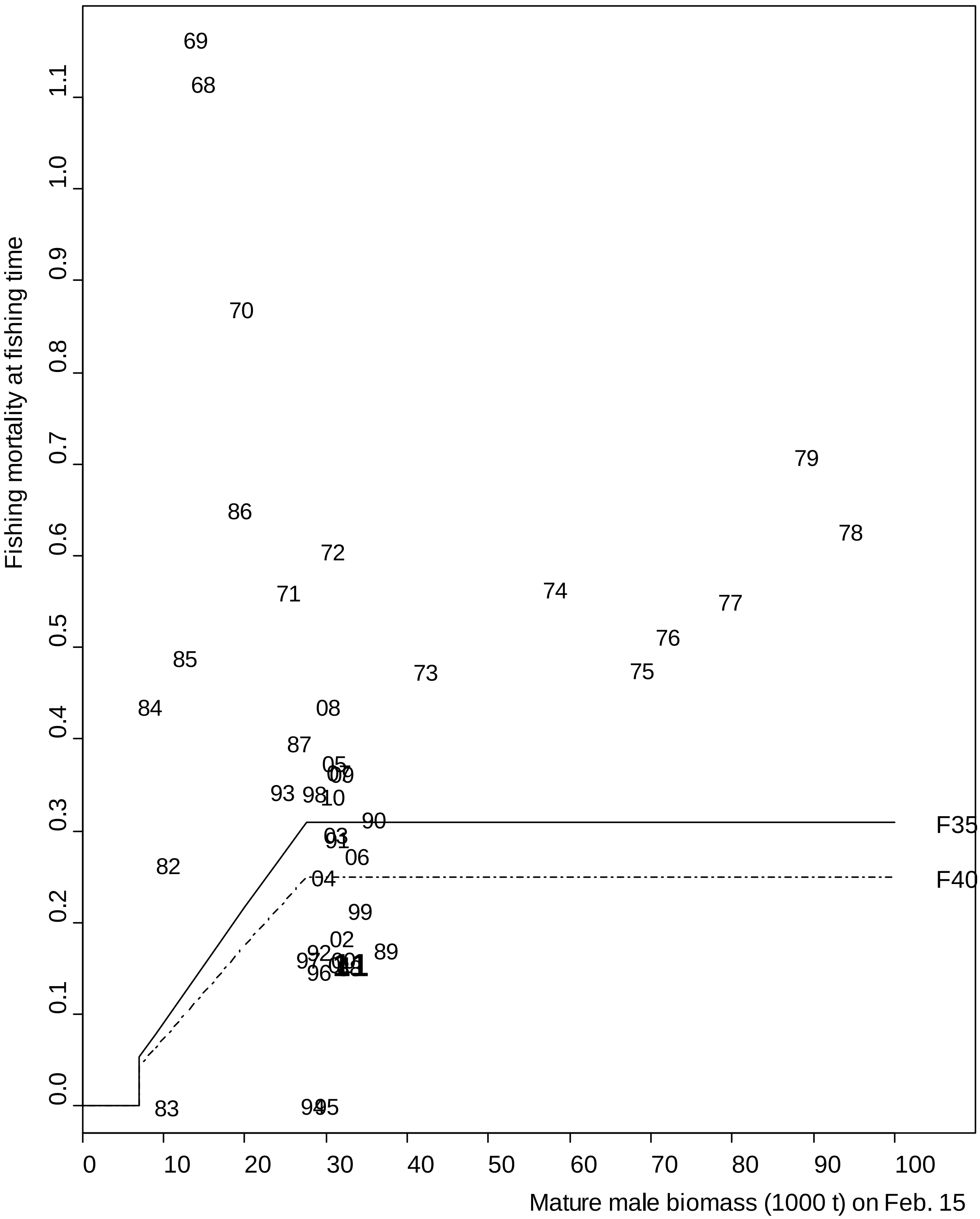



Figure 12. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass on Feb. 15 during 1968-2010 under scenario 7ac. Average of recruitment from 1984 to 2012 was used to estimate $B_{MSY}$. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

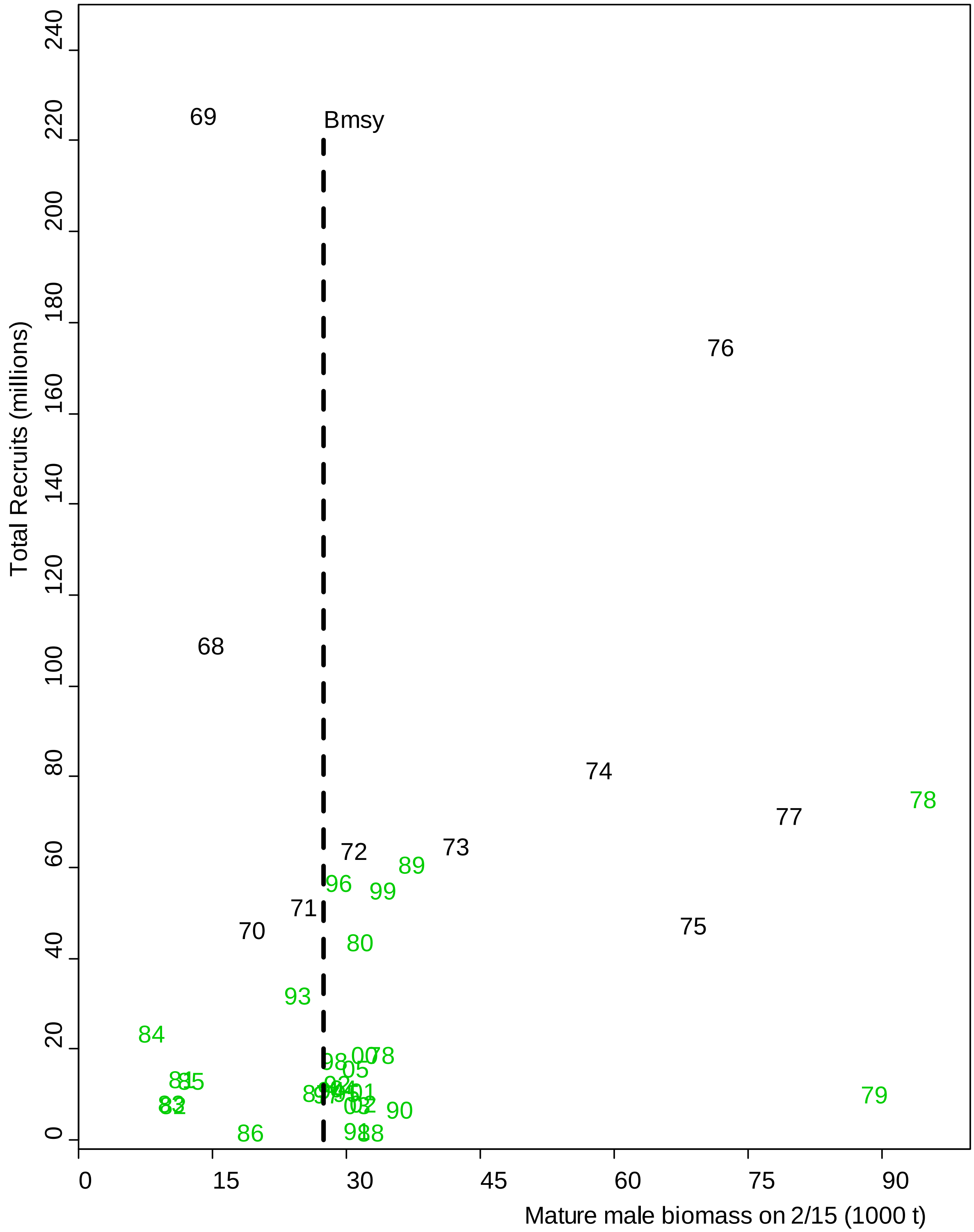



Figure 13a. Relationships between mature male biomass on Feb. 15 and total recruits at age 5 (i.e., 6-year time lag) for Bristol Bay red king crab with pot handling mortality rate to be 0.2 under scenario 7ac. Numerical labels are years of mating, and the vertical dotted line is the estimated $B_{35\%}$ based on the mean recruitment level during 1984 to 2012.

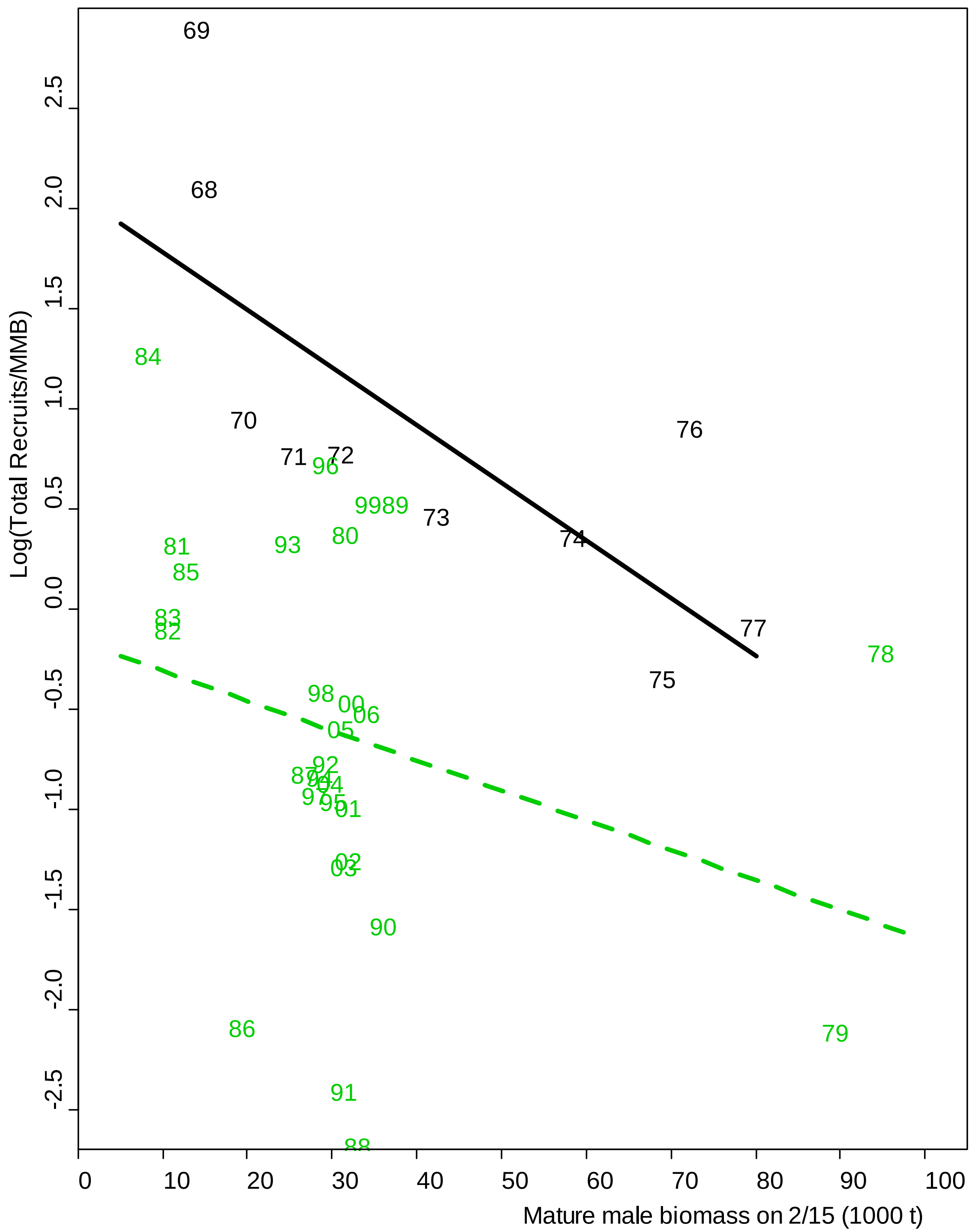



Figure 13b. Relationships between log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab with pot handling mortality rate to be 0.2 under scenario 7ac. Numerical labels are years of mating, the solid line is the regression line for data of 1968-1977, and the dotted line is the regression line for data of 1978-2006.

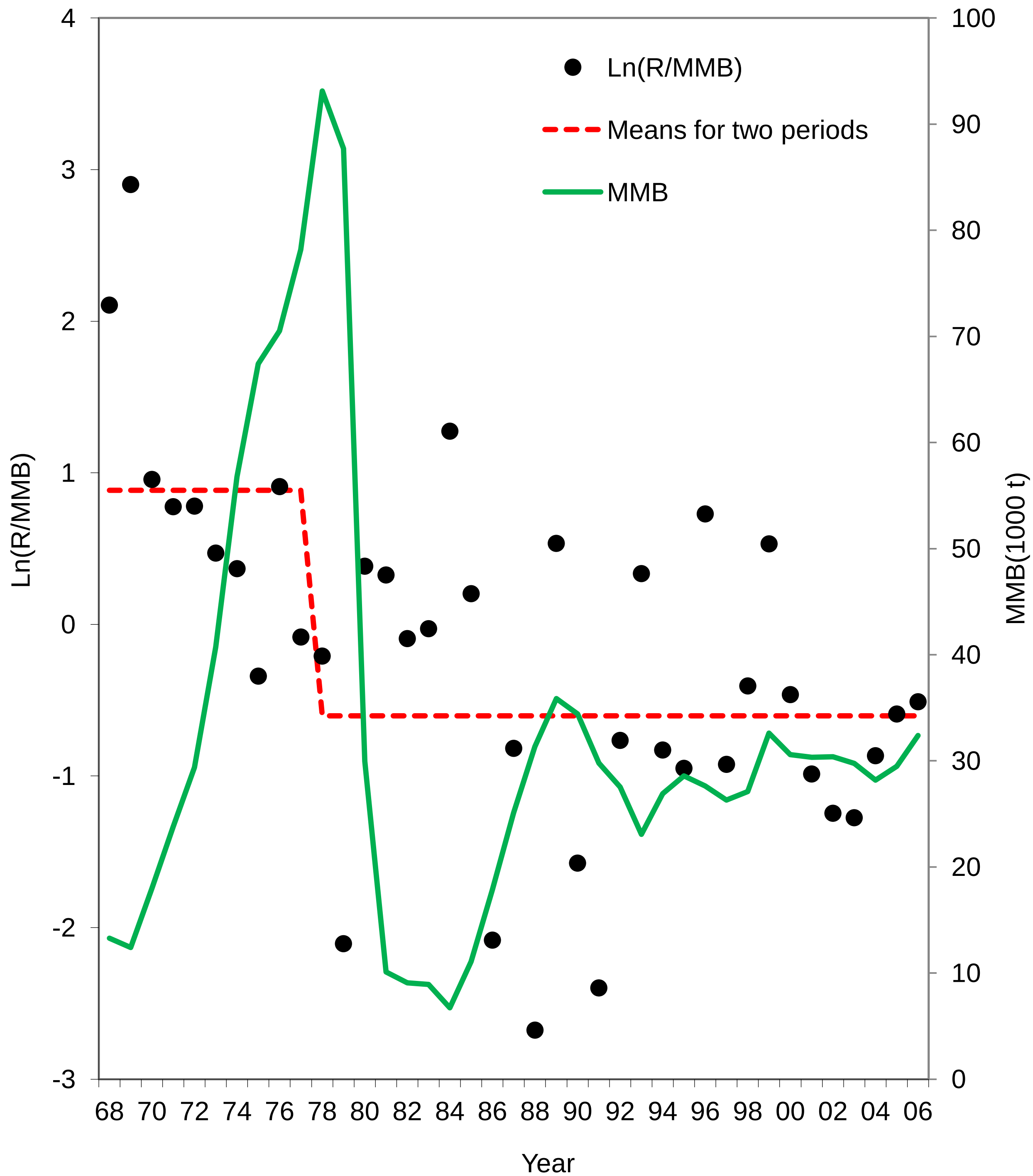



Figure 13c. Time series of log recruitment per mature male biomass and mature male biomass on Feb. 15 for Bristol Bay red king crab with pot handling mortality rate to be 0.2 under scenario 7ac. The dashed line is for the means of two periods: 1968-1977 and 1978-2006.

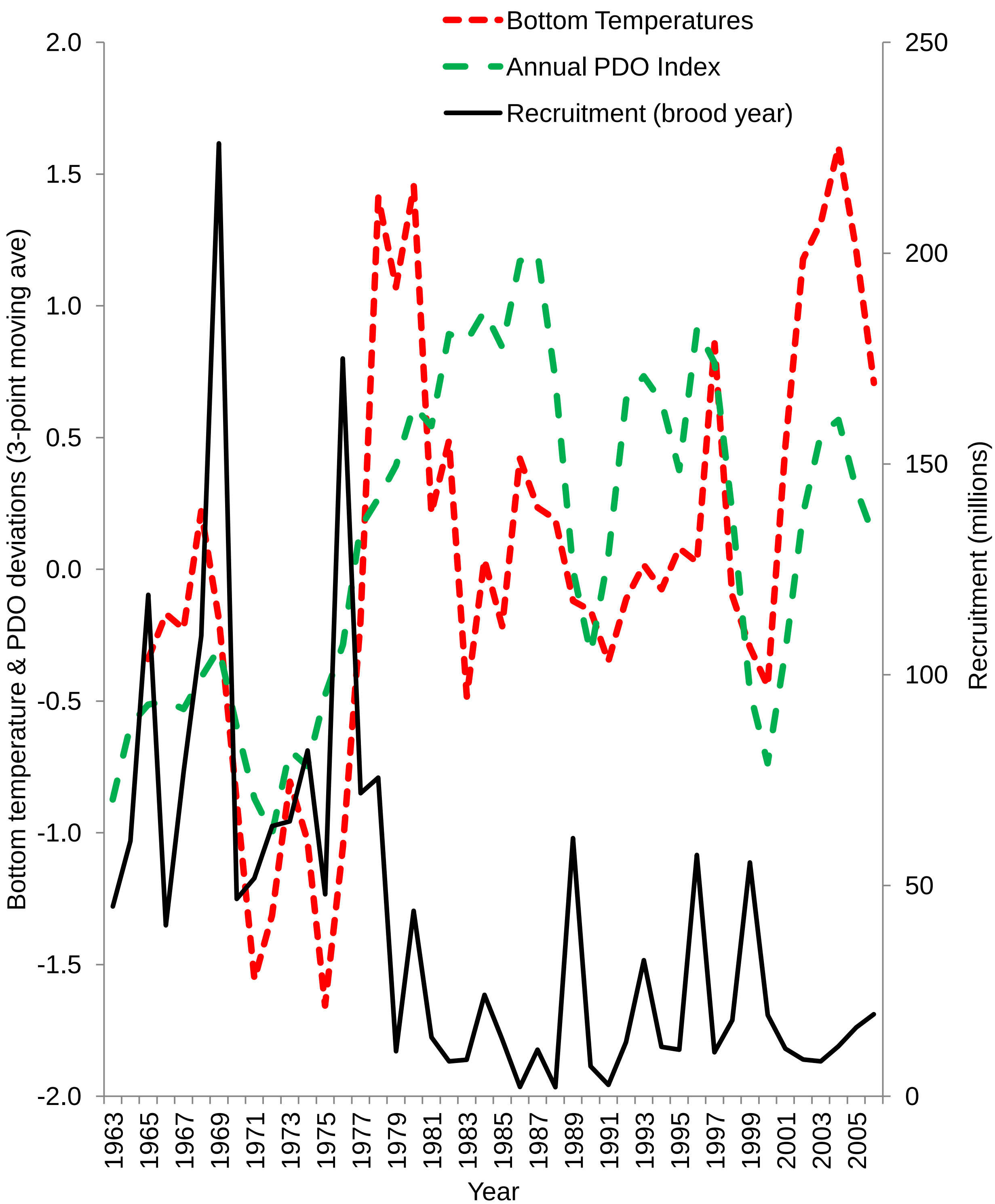



Figure 13d. Time series of recruitment in brood year, summer bottom temperatures in Bristol Bay and annual PDO index under scenario 7ac.

# Temperature Affects Crab Distribution

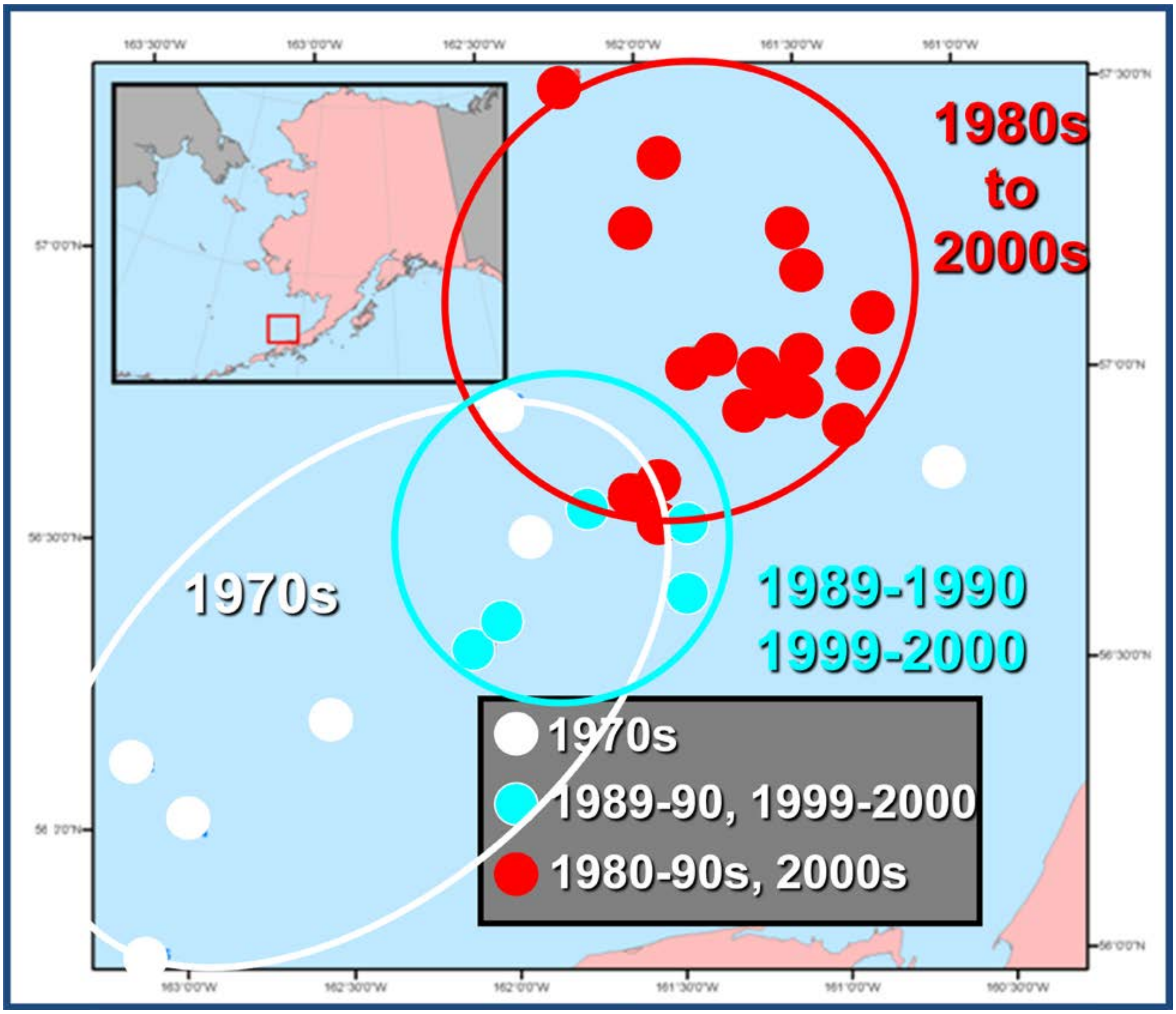



Figure 13e. Centers of Distribution of mature female red king crab in Bristol Bay (after Zheng & Kruse 2006). After the 1976/77 regime shift, the centers of distribution move from southern Bristol Bay to central Bristol Bay.

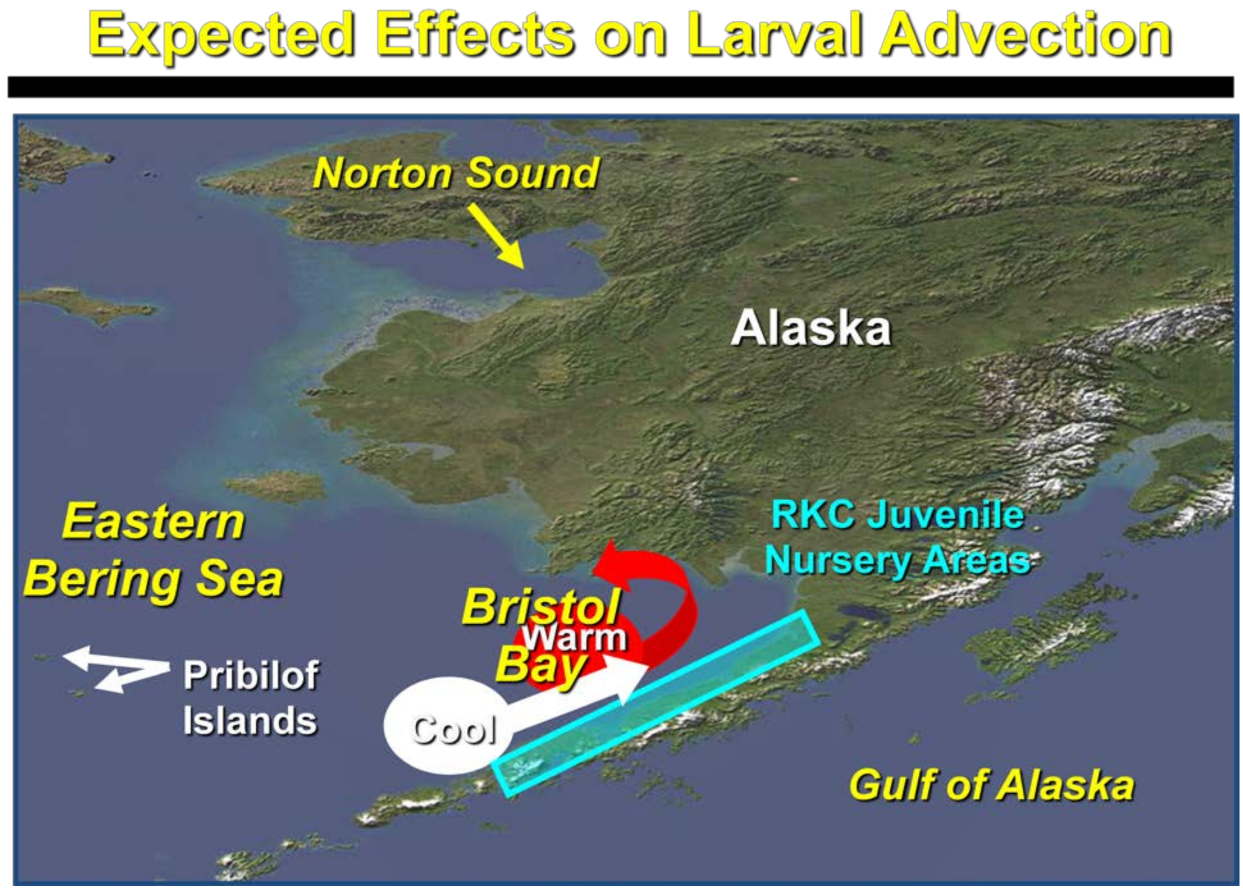



Figure 13f. During cool years, when crab hatching larvae in southern Bristol Bay, the larvae likely settle in the red king crab juvenile nursery areas. During warm years, when crab hatching larvae in central Bristol Bay, some larvae may settle in outside of the red king crab juvenile nursery areas.

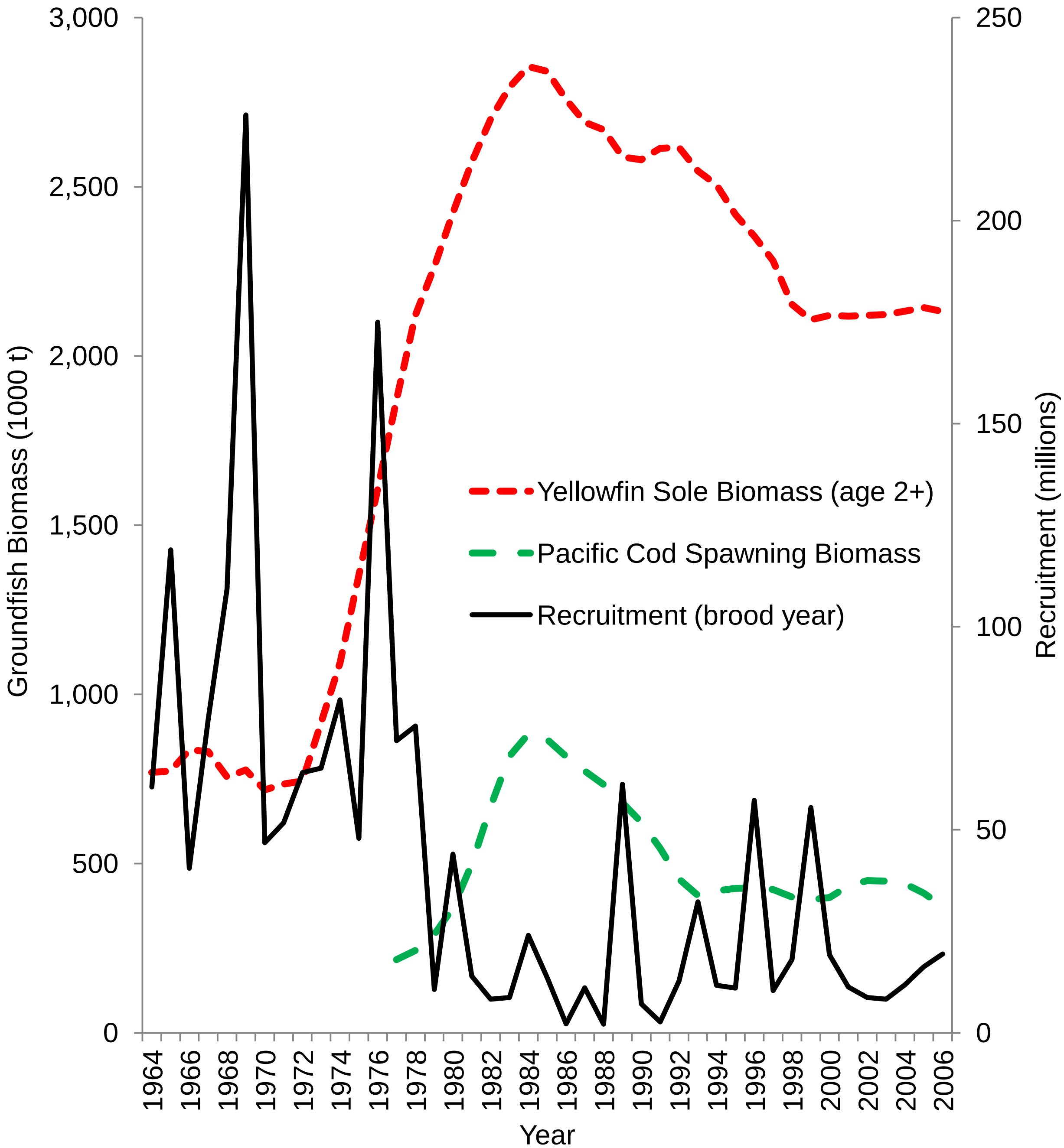



Figure 13g. Time series of recruitment in brood year, yellowfin sole biomass (age 2+) and Pacific cod spawning biomass under scenario 7ac. The groundfish biomass is from the Groundfish SAFE report. The Pacific cod biomass before 1977 was not available and should be less than the value in 1977.

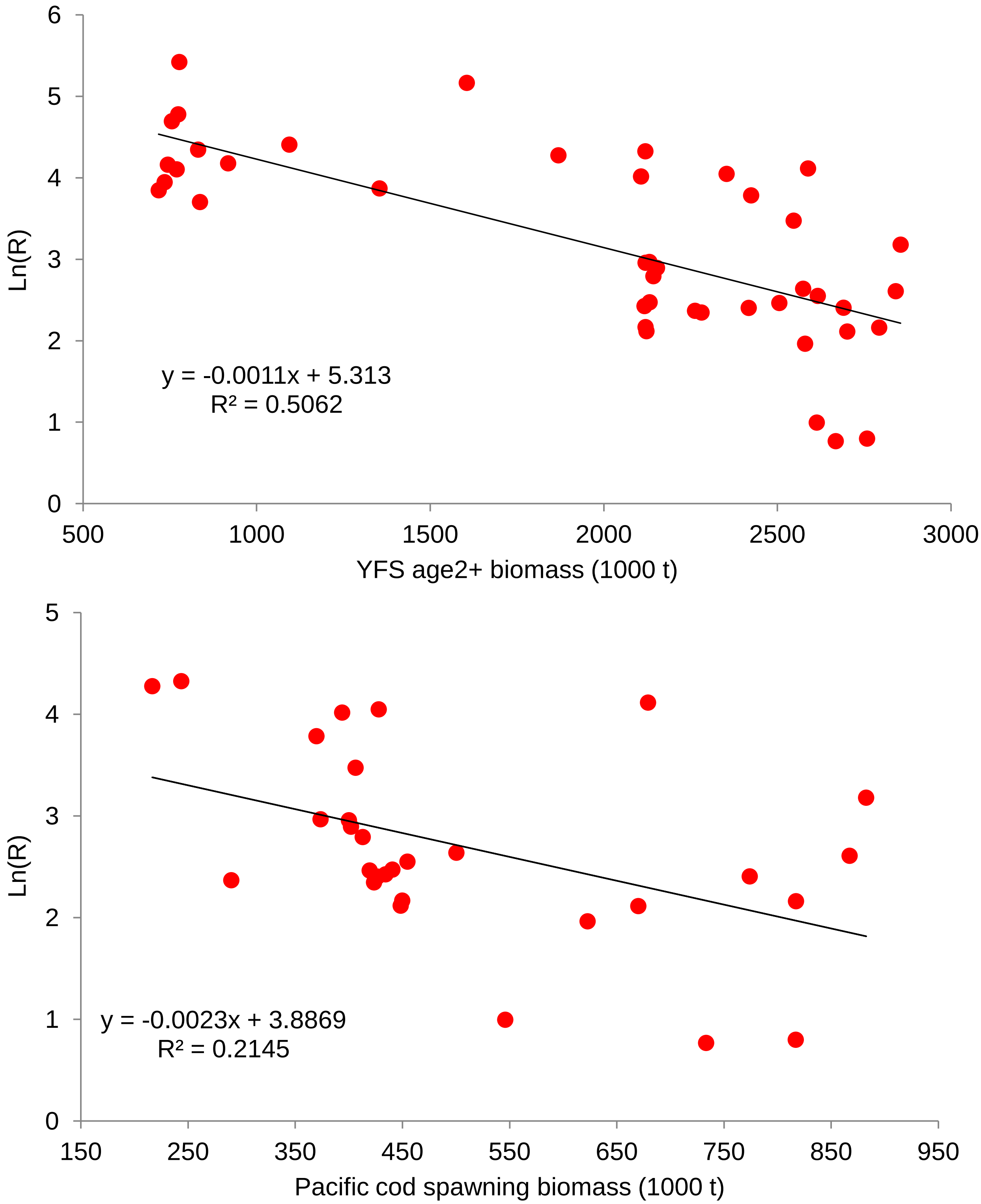



Figure 13h. Relationships between ln(recruitment) in brood year and yellowfin sole biomass (age 2+) and Pacific cod spawning biomass under scenario 7ac. The groundfish biomass is from the Groundfish SAFE report.

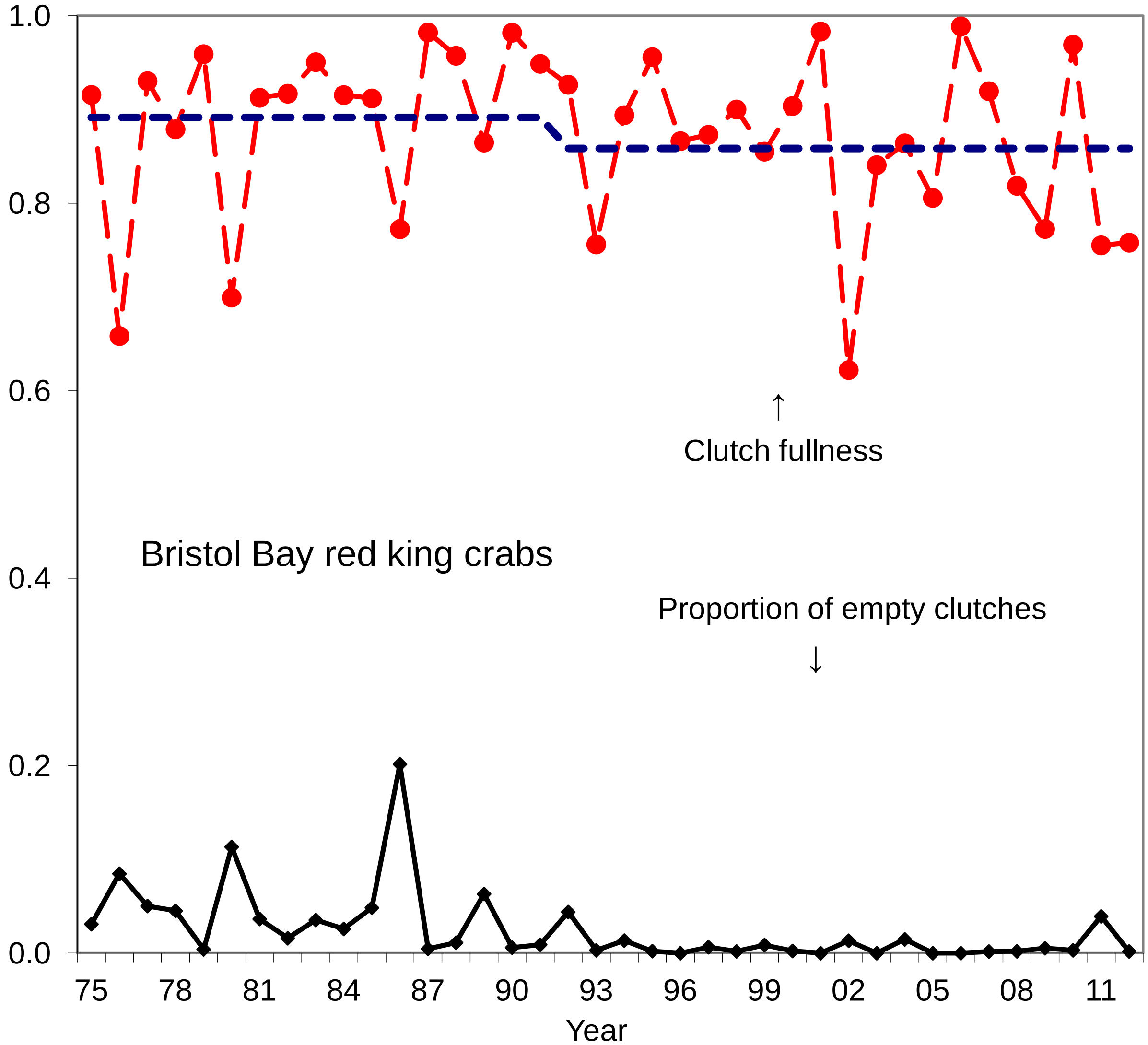



Figure 14. Average clutch fullness and proportion of empty clutches of newshell (shell conditions 1 and 2) mature female crabs >89 mm CL from 1975 to 2012 from survey data. Oldshell females were excluded.

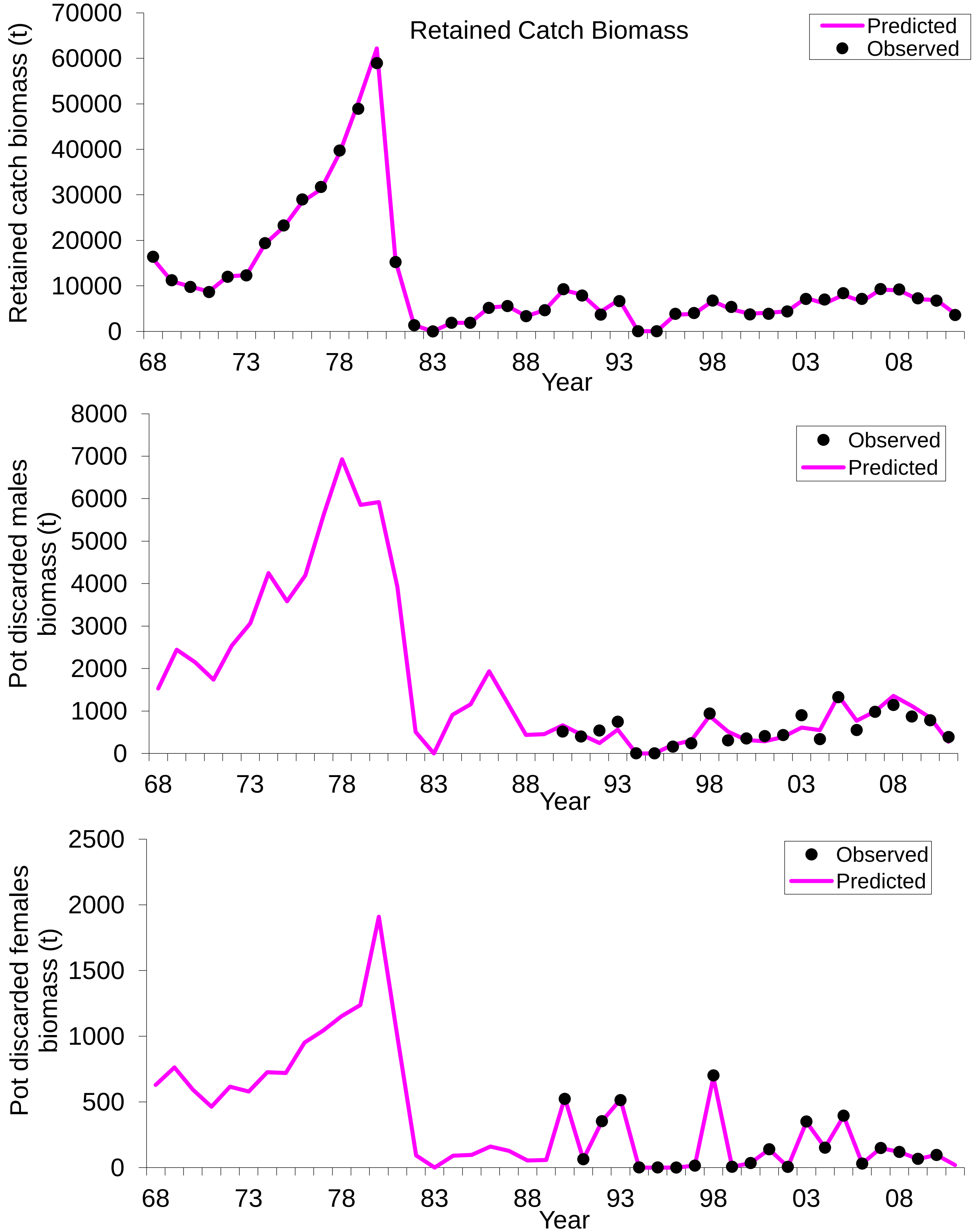
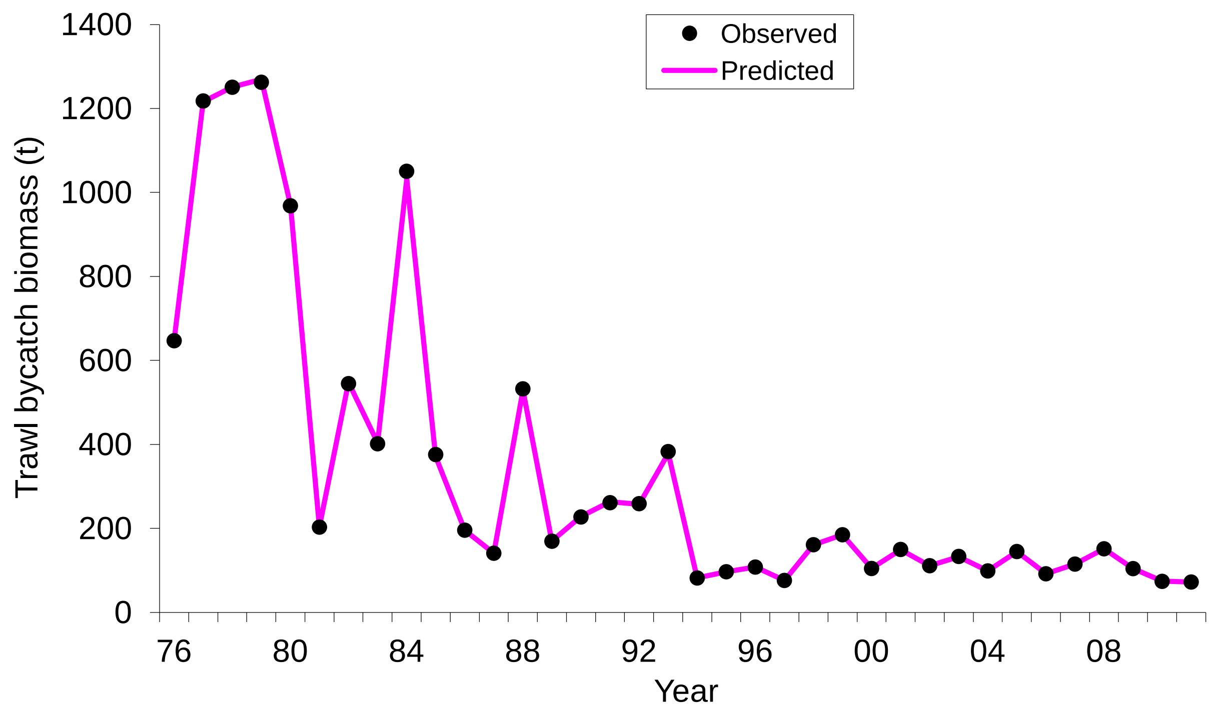



Figure 15a. Observed and predicted catch mortality biomass under scenario 7ac. Mortality biomass is equal to caught biomass times a handling mortality rate. Pot handling mortality rate is 0.2.



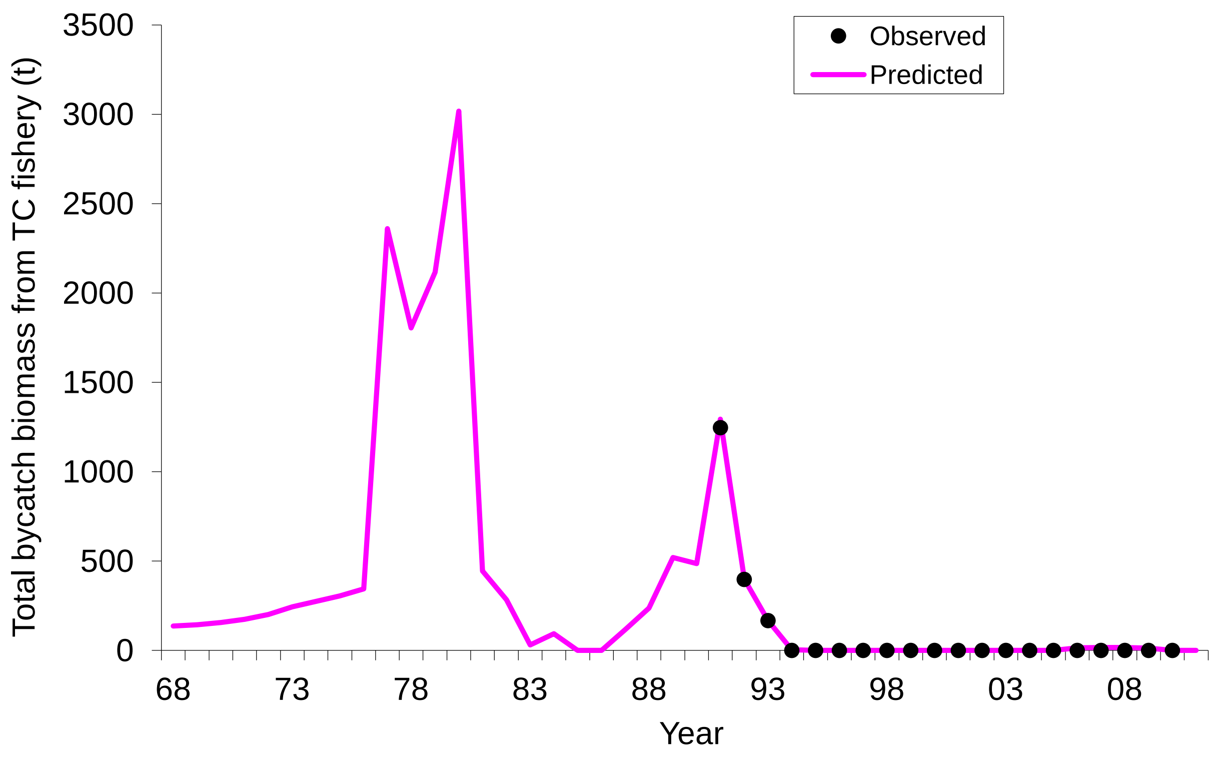




Figure 15b. Observed and predicted bycatch mortality biomass from trawl fisheries and Tanner crab fishery under scenario 7ac. Mortality biomass is equal to caught biomass times a handling mortality rate. Trawl handling mortality rate is 0.8, and Tanner crab pot handling mortality is 0.25. Trawl bycatch biomass was 0 before 1976.

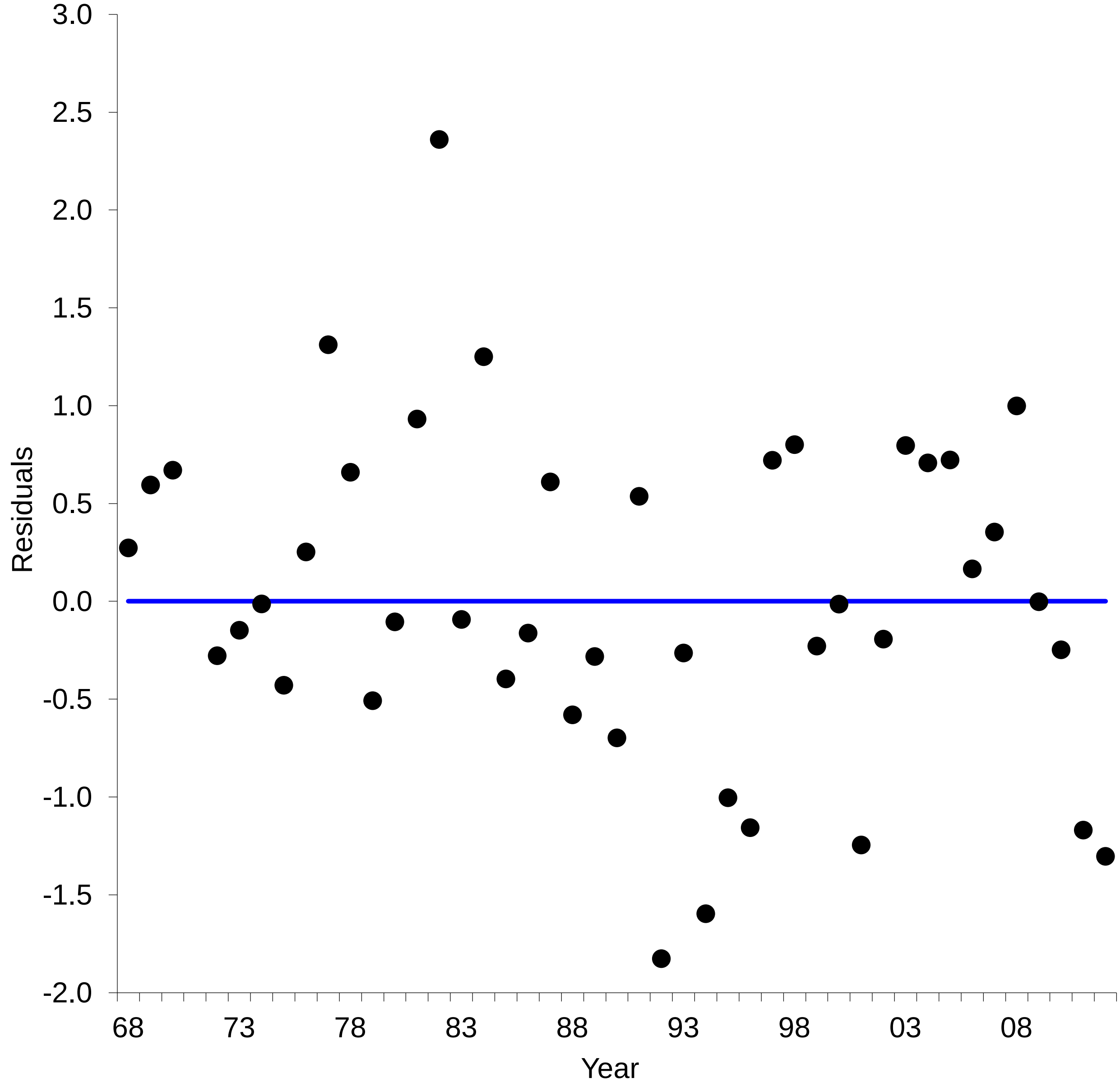



Figure 16. Standardized residuals of total survey biomass under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

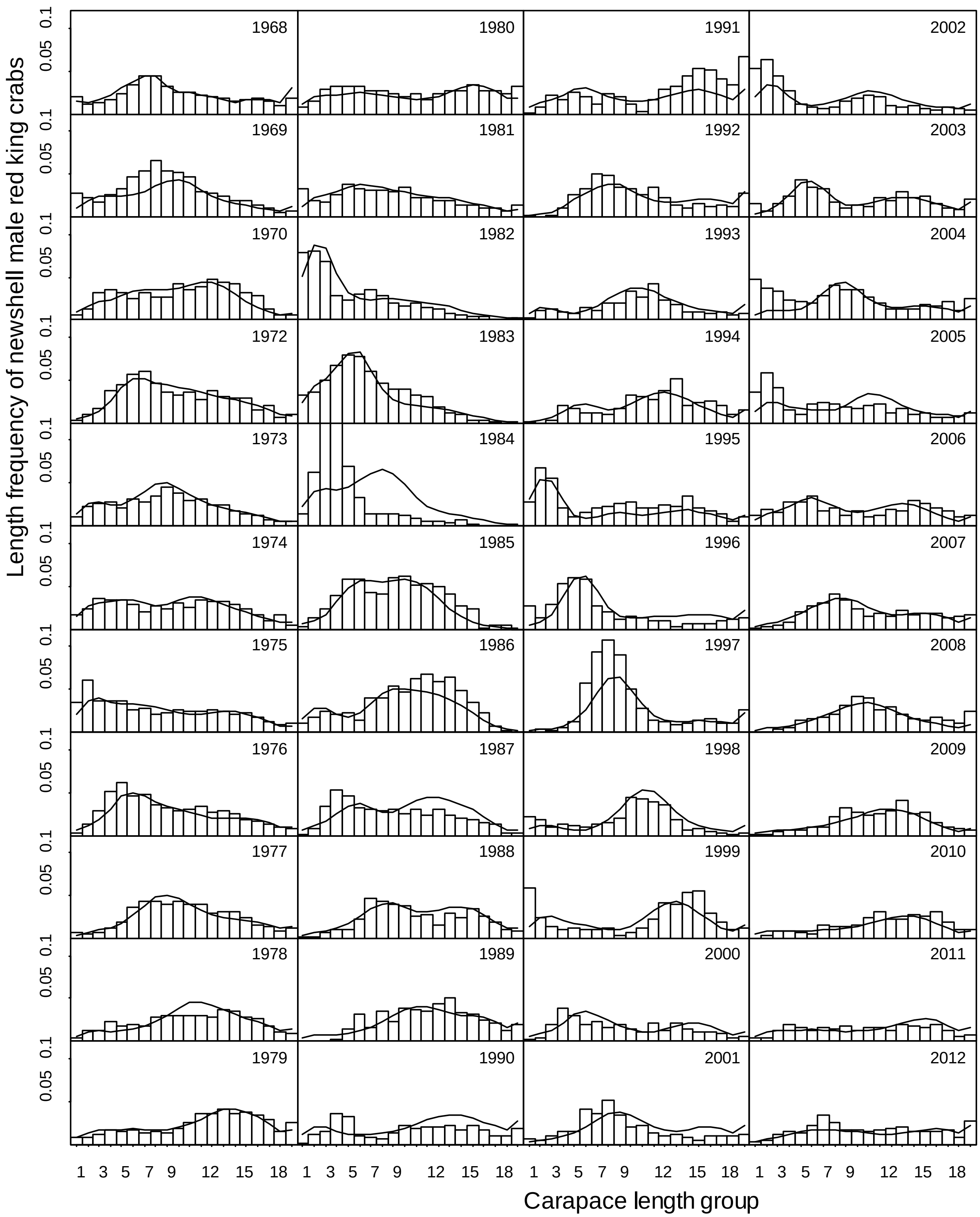



Figure 17. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay all-shell (before 1986) and newshell (1986-2012) male red king crabs by year under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, and the first length group is 67.5 mm.

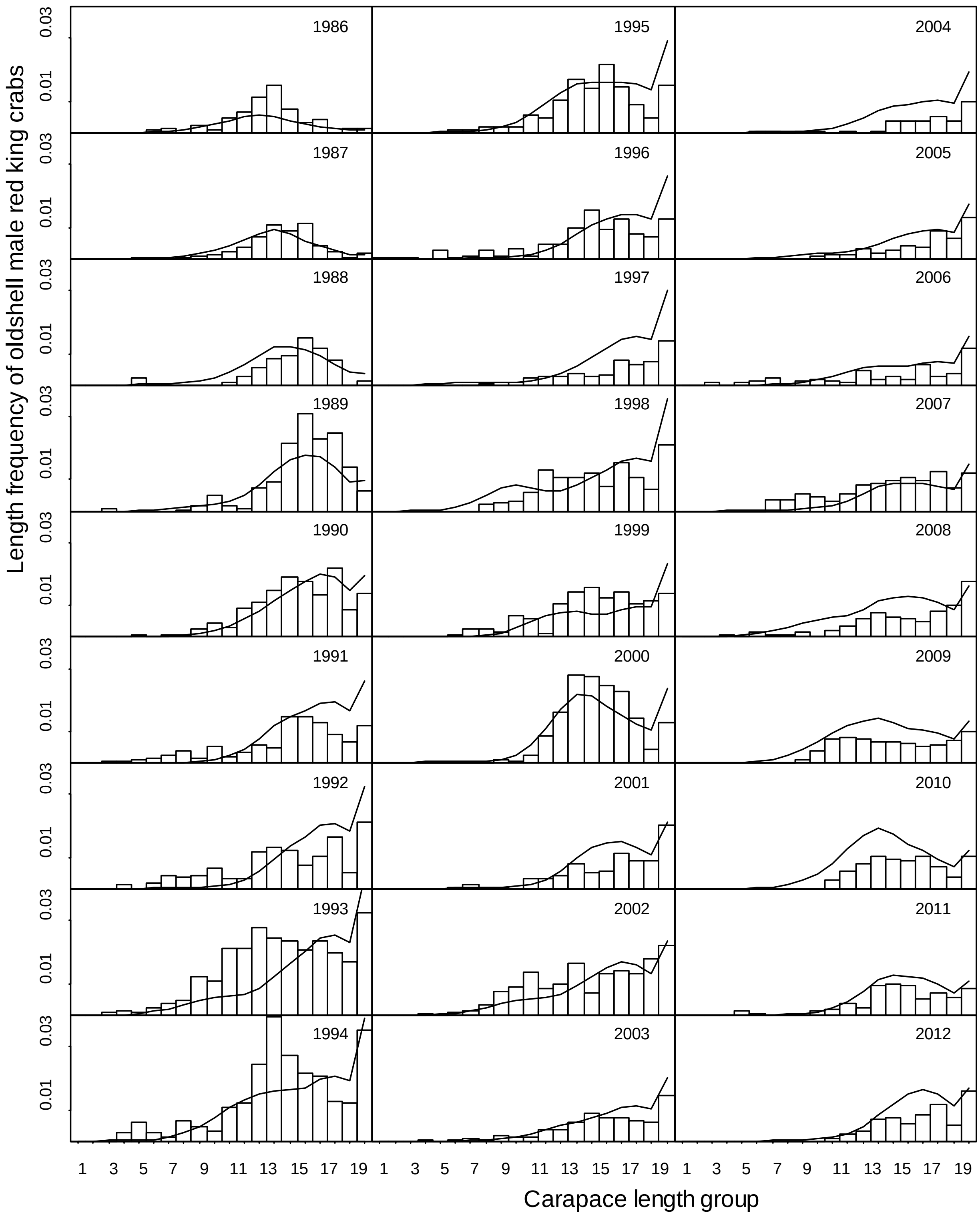



Figure 18. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay oldshell male red king crabs by year under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the first length group is 67.5 mm.

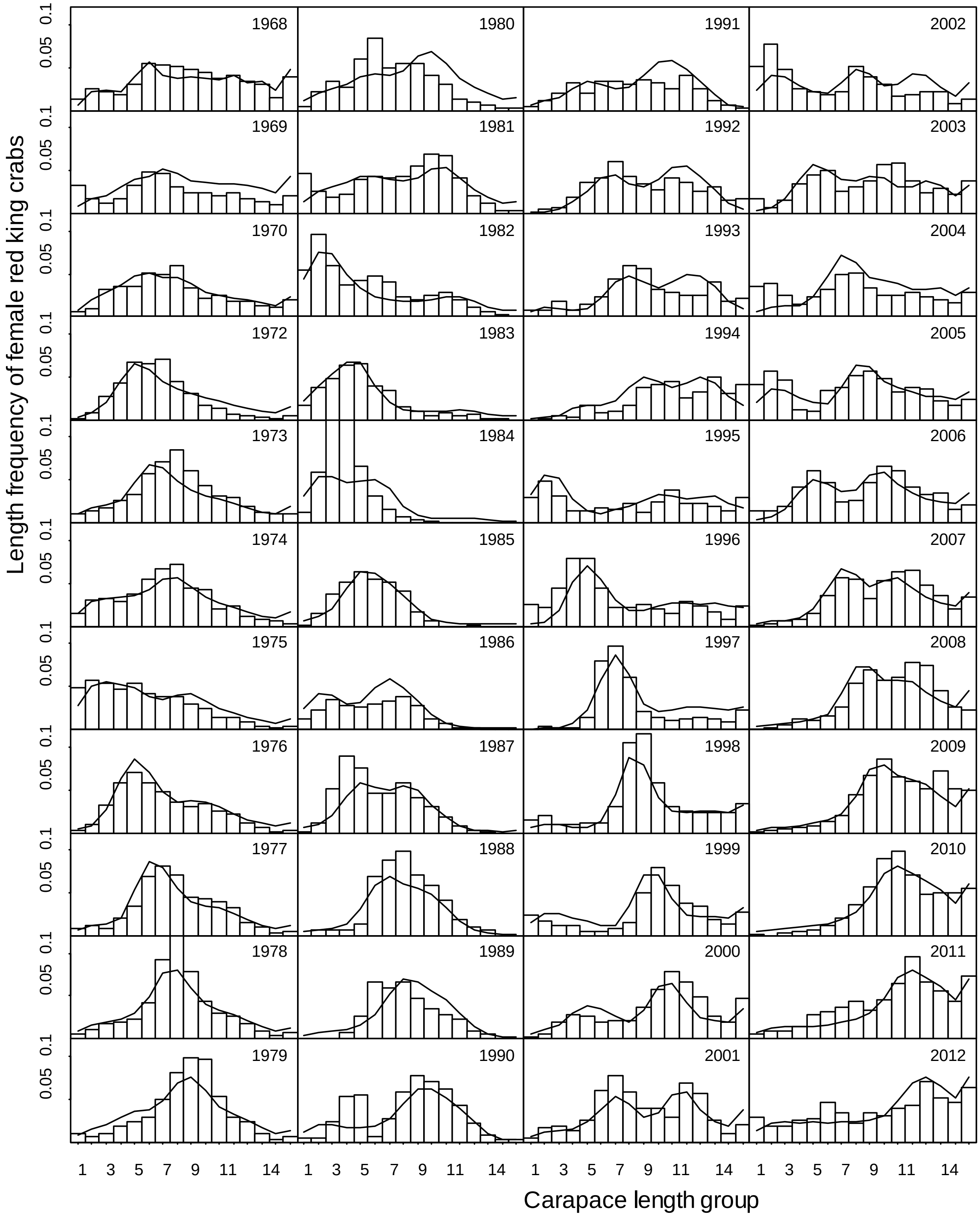



Figure 19. Comparison of area-swept and model estimated survey length frequencies of Bristol Bay female red king crabs by year under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the first length group is 67.5 mm.

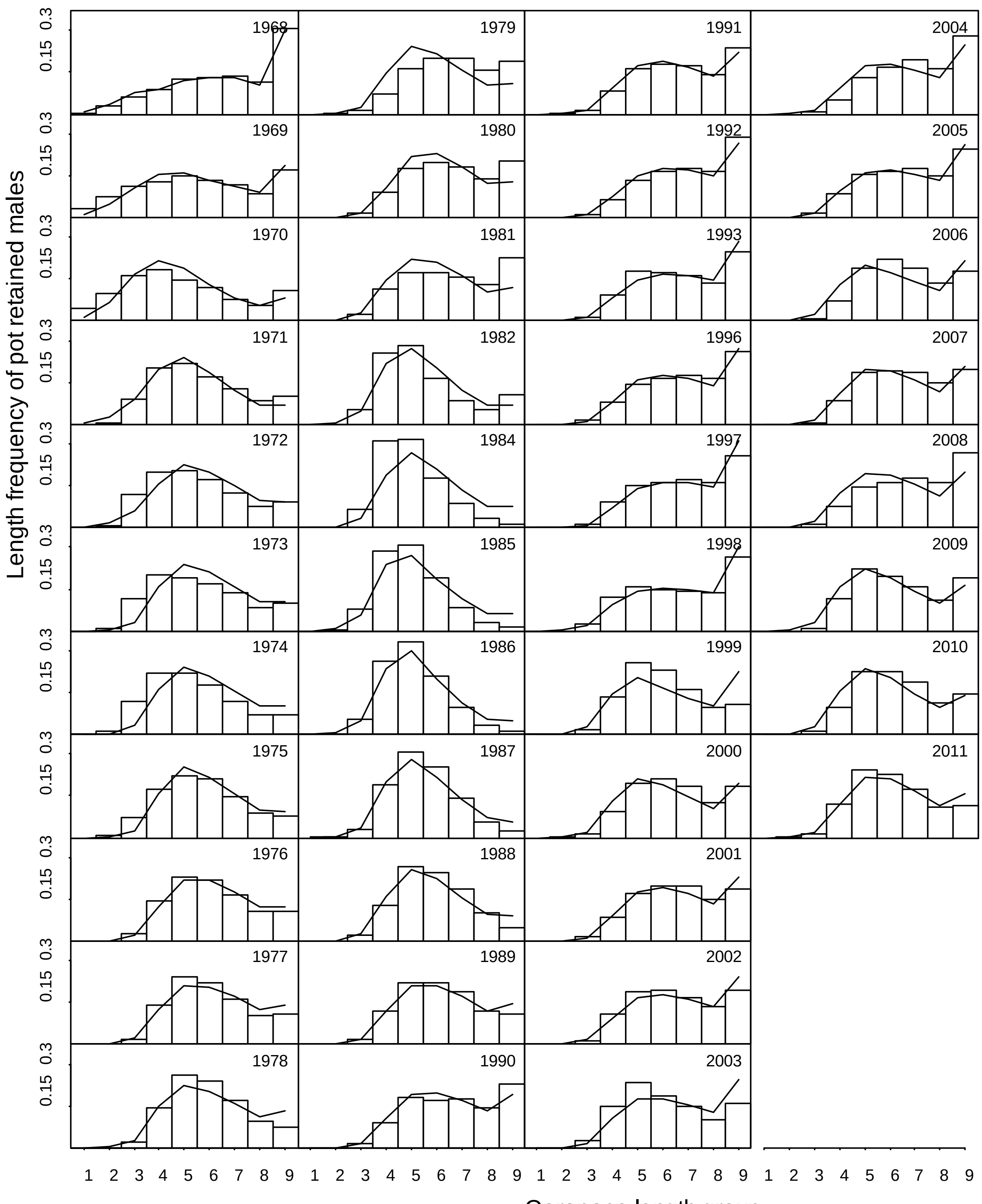



Figure 20. Comparison of observed and model estimated retained length frequencies of Bristol Bay male red king crabs by year in the directed pot fishery under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the first length group is 122.5 mm.

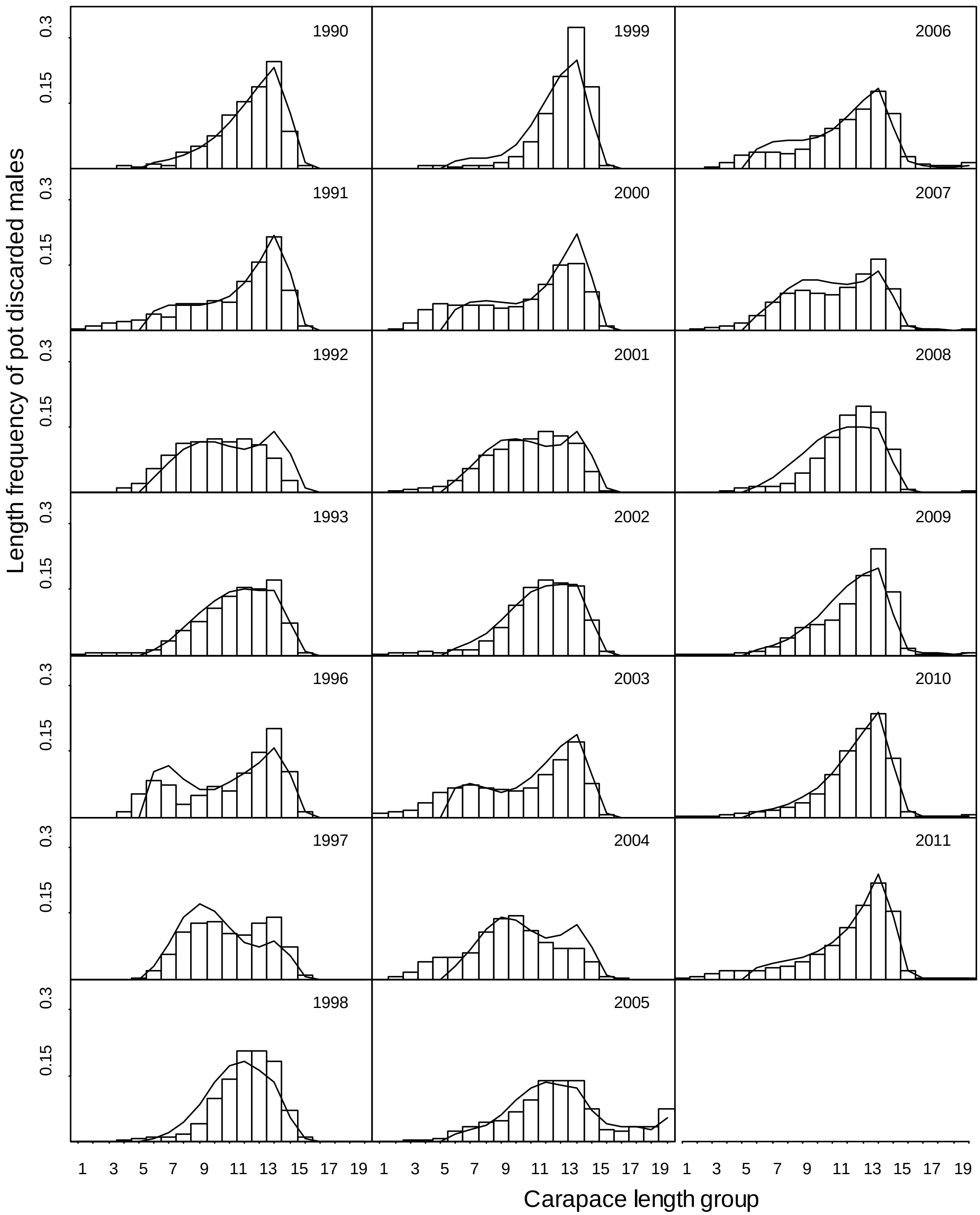



Figure 21. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crabs by year in the directed pot fishery under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the first length group is 67.5 mm.

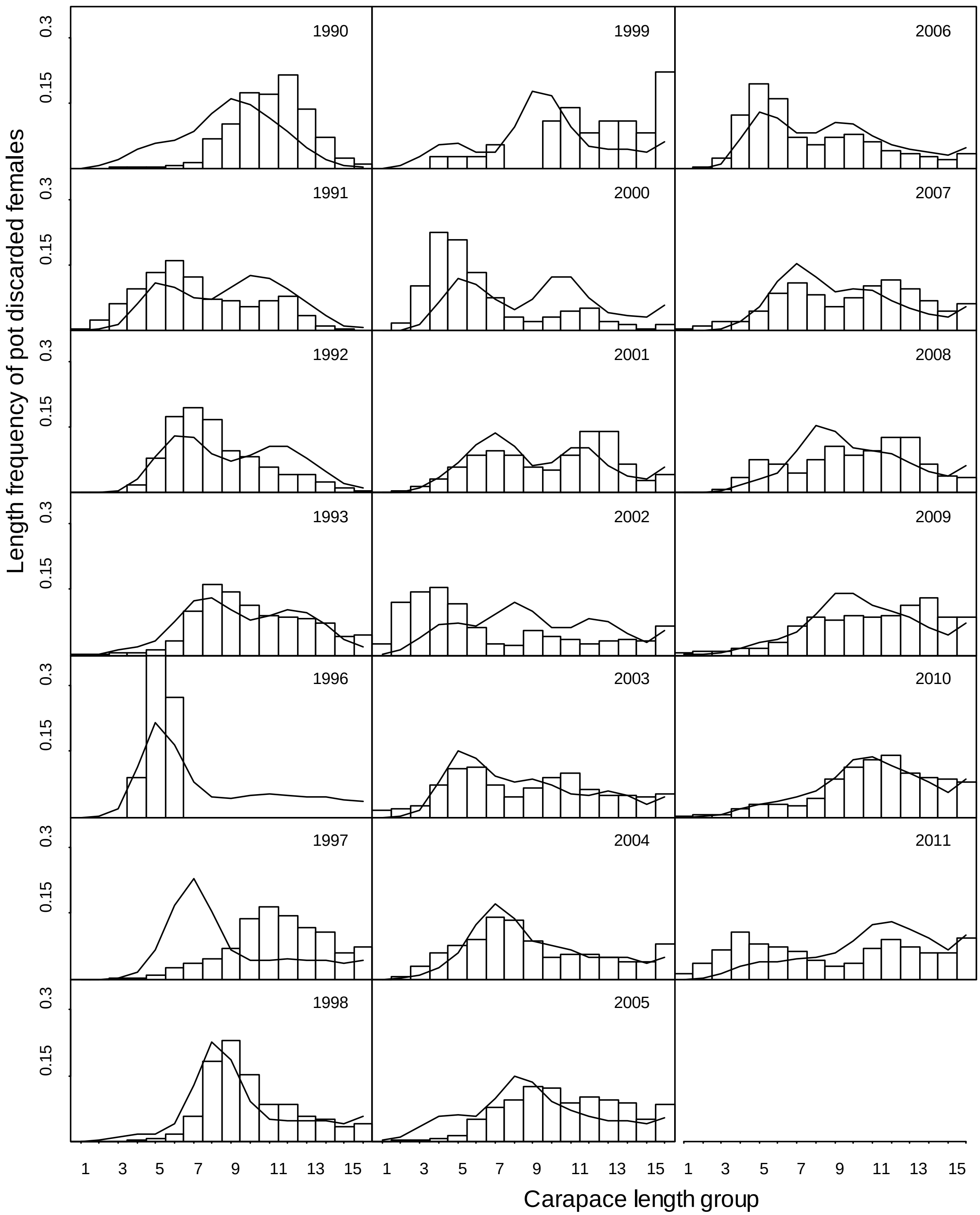



Figure 22. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crabs by year in the directed pot fishery under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the first length group is 67.5 mm.

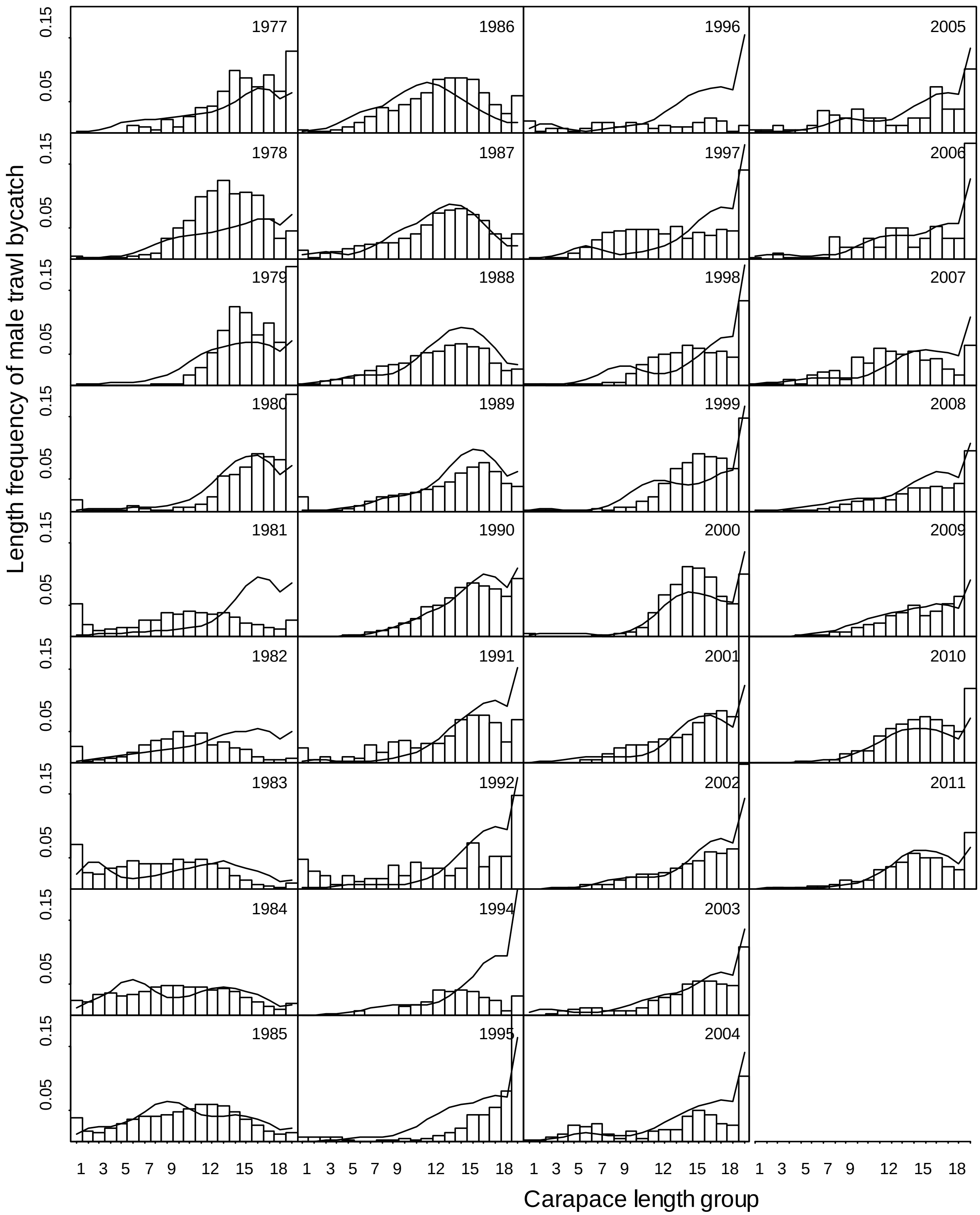



Figure 23. Comparison of observer and model estimated discarded length frequencies of Bristol Bay male red king crabs by year in the groundfish trawl fisheries under scenario 7ac. Pot handling mortality rate is 0.2, trawl bycatch mortality rate is 0.8, and the first length group is 67.5 mm.

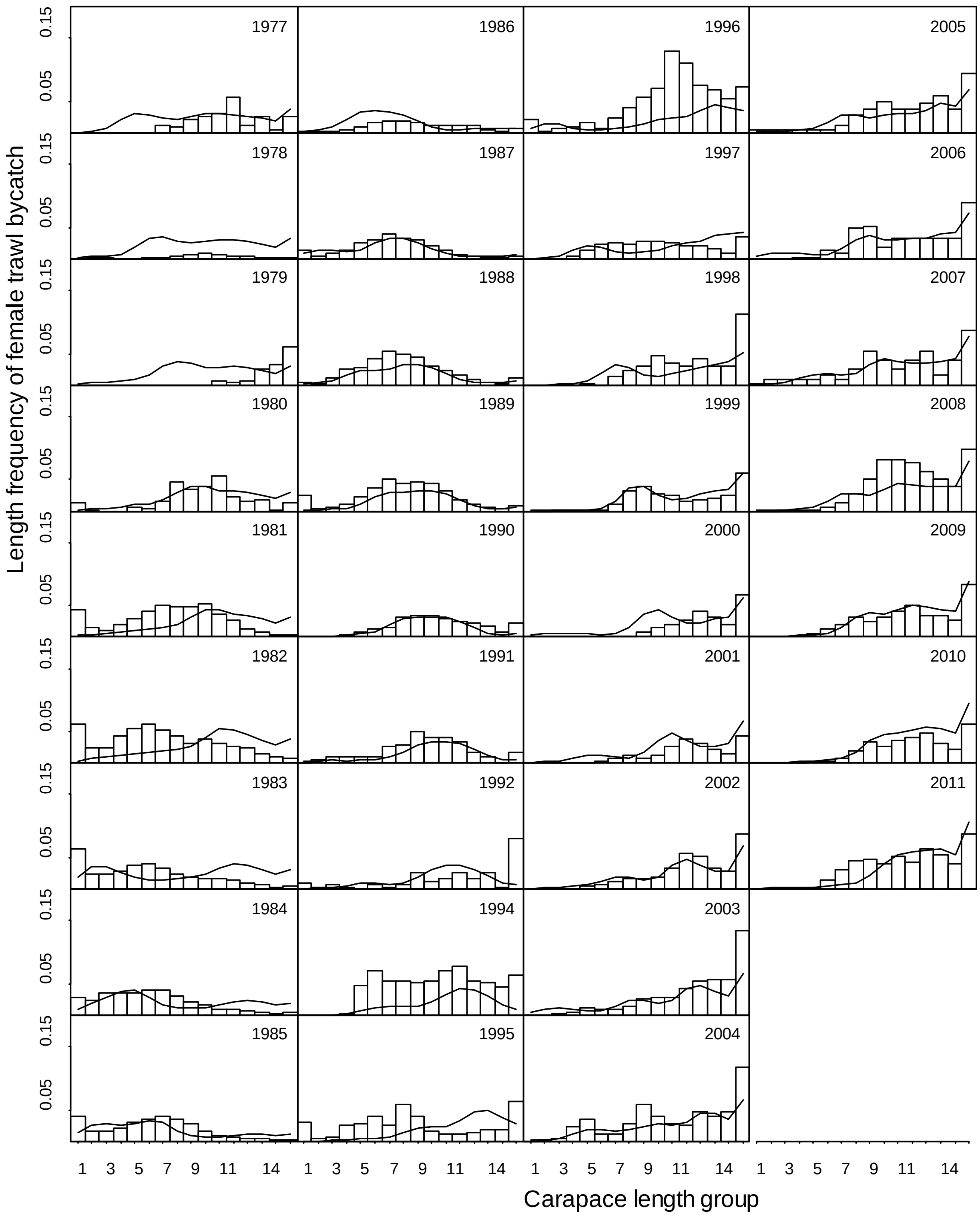



Figure 24. Comparison of observer and model estimated discarded length frequencies of Bristol Bay female red king crabs by year in the groundfish trawl fisheries under scenario 7ac. Pot handling mortality rate is 0.2, trawl bycatch mortality rate is 0.8, and the first length group is 67.5 mm.

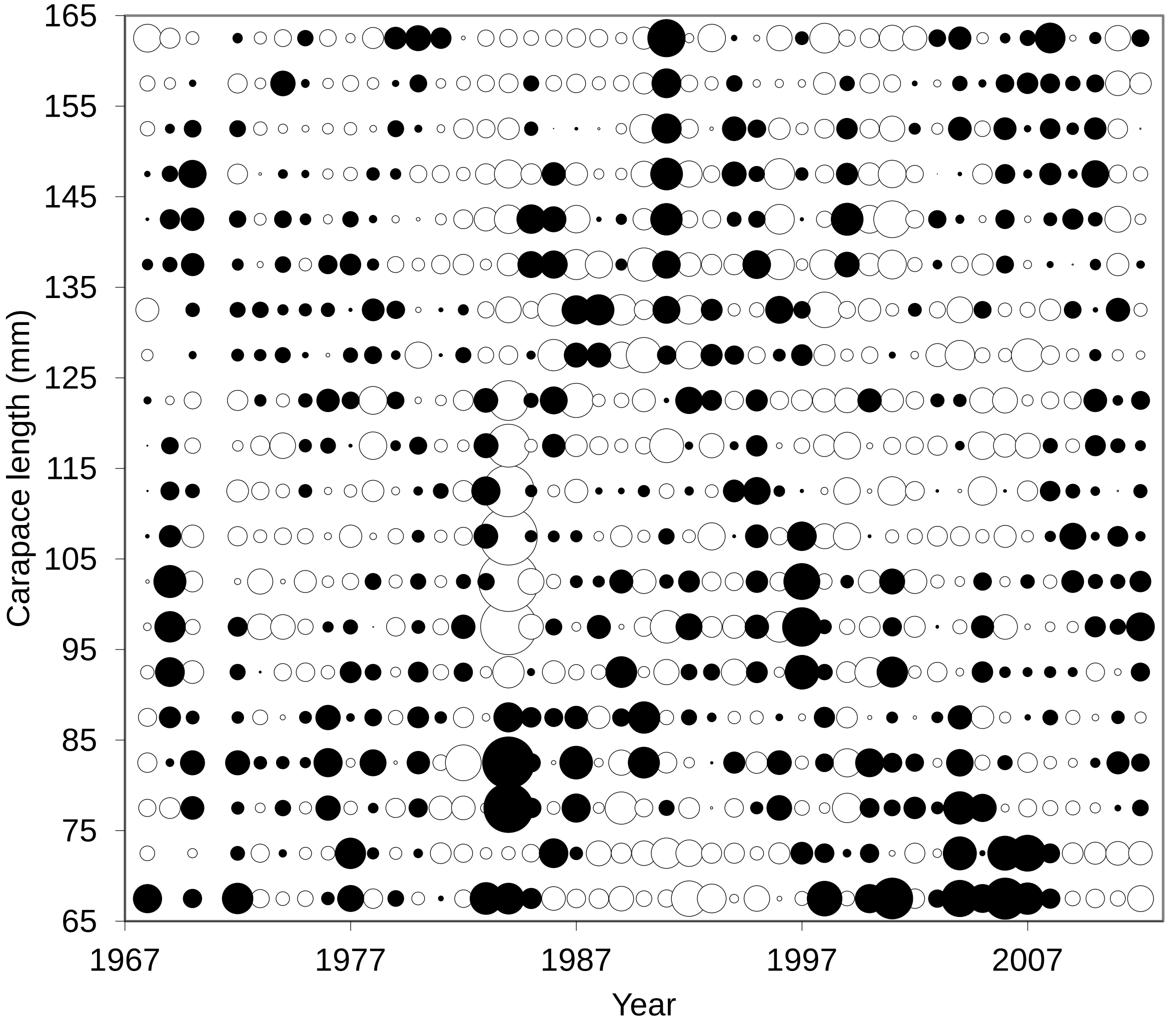



Figure 25. Standardized residuals of proportions of survey all-shell (1968-1985) and newshell (1986-2012) male red king crabs under scenario 7ac. Solid circles are positive residuals, and open circles are negative residuals. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

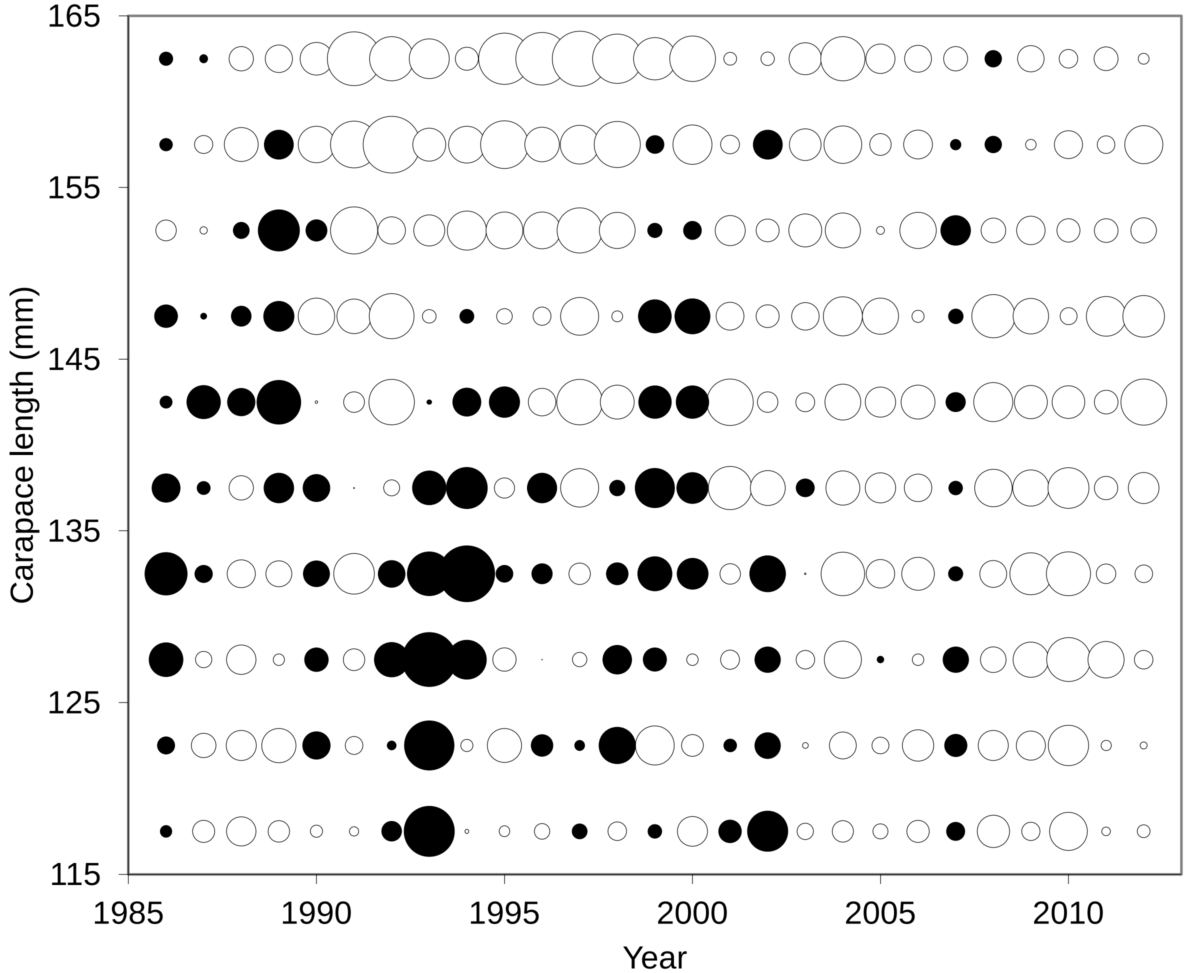



Figure 26. Standardized residuals of proportions of survey oldshell male red king crabs (1986-2012) under scenario 7ac. Solid circles are positive residuals, and open circles are negative residuals. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

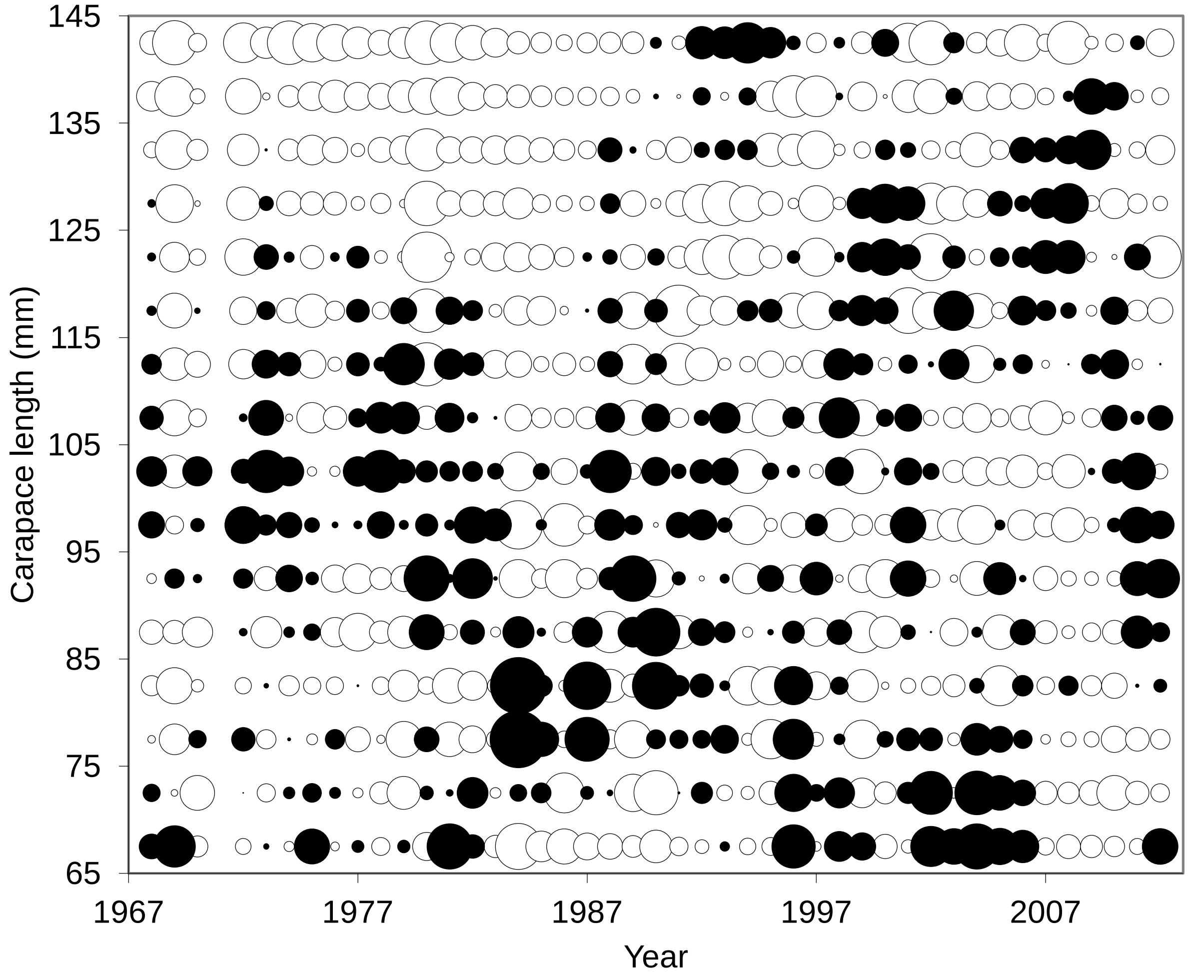
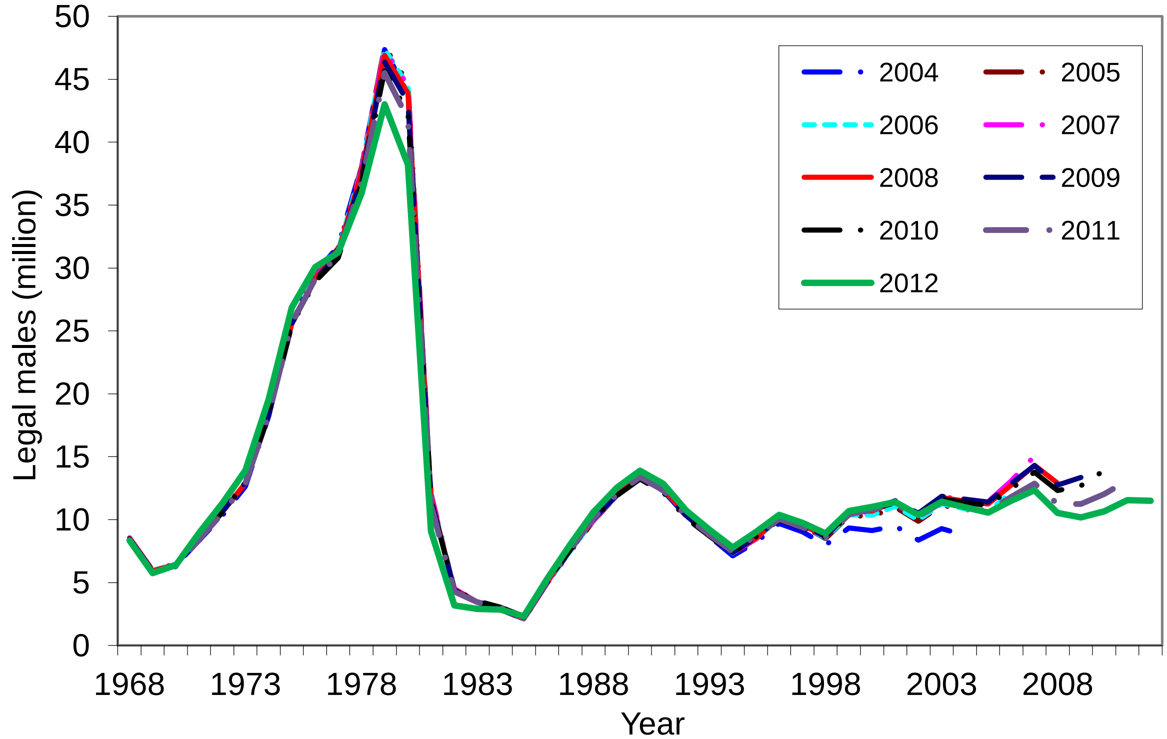



Figure 27. Standardized residuals of proportions of survey female red king crabs (1968-2012) under scenario 7ac. Solid circles are positive residuals, and open circles are negative residuals. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.



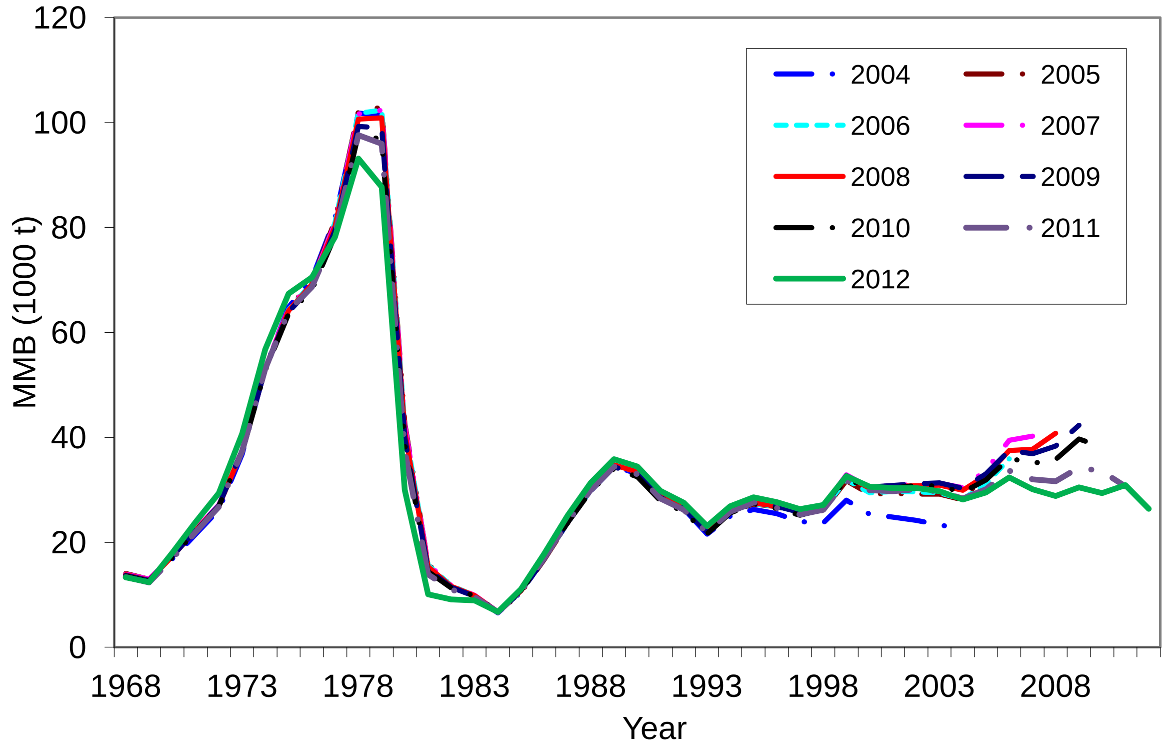
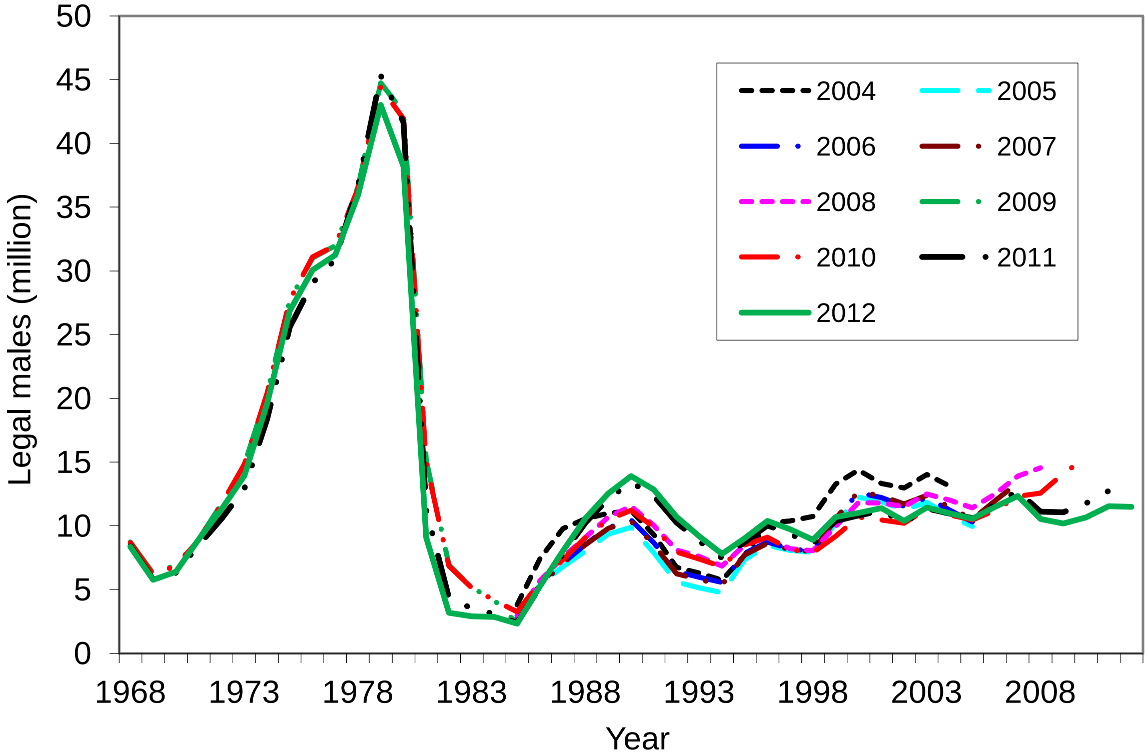




Figure 28. Comparison of estimates of legal male abundance (top) and mature male biomass (bottom) on Feb. 15 of Bristol Bay red king crab from 1968 to 2012 made with terminal years 2004-2012 with scenario 7ac. These are results of the 2012 model. Legend shows the year in which the assessment was conducted. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.



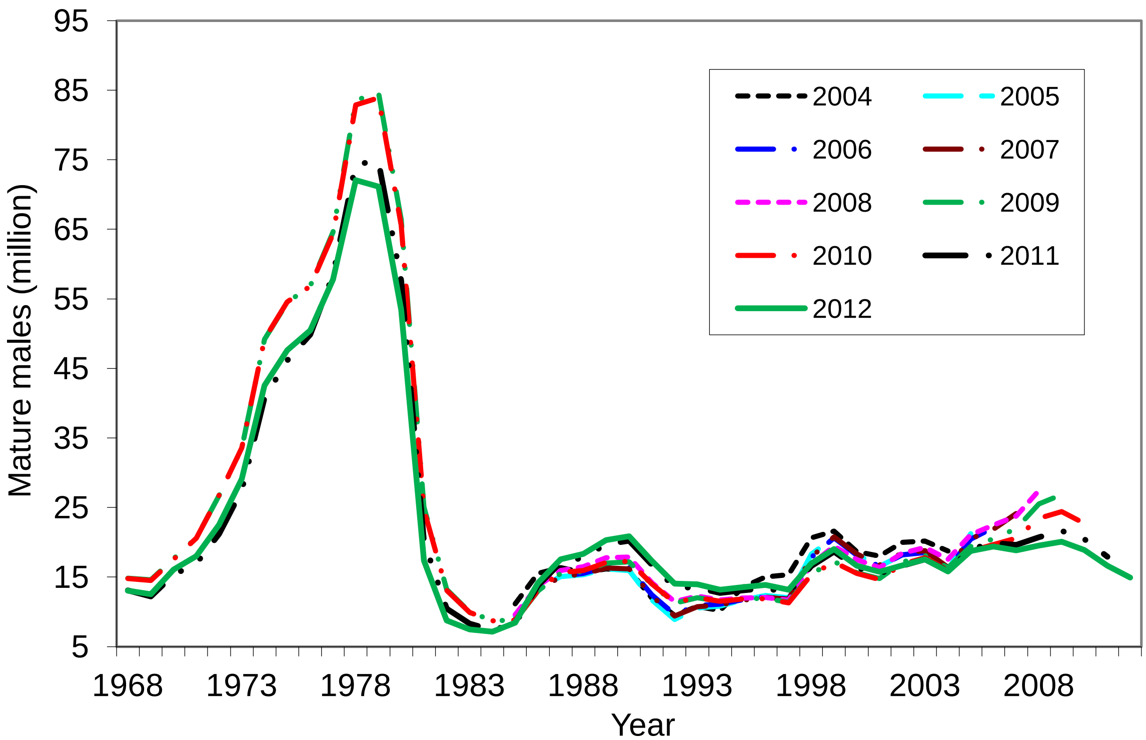




Figure 29. Comparison of estimates of legal male abundance (top) and mature males (bottom) of Bristol Bay red king crab from 1968 to 2012 made with terminal years 2004-2012. These are results of historical assessments. Legend shows the year in which the assessment was conducted. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

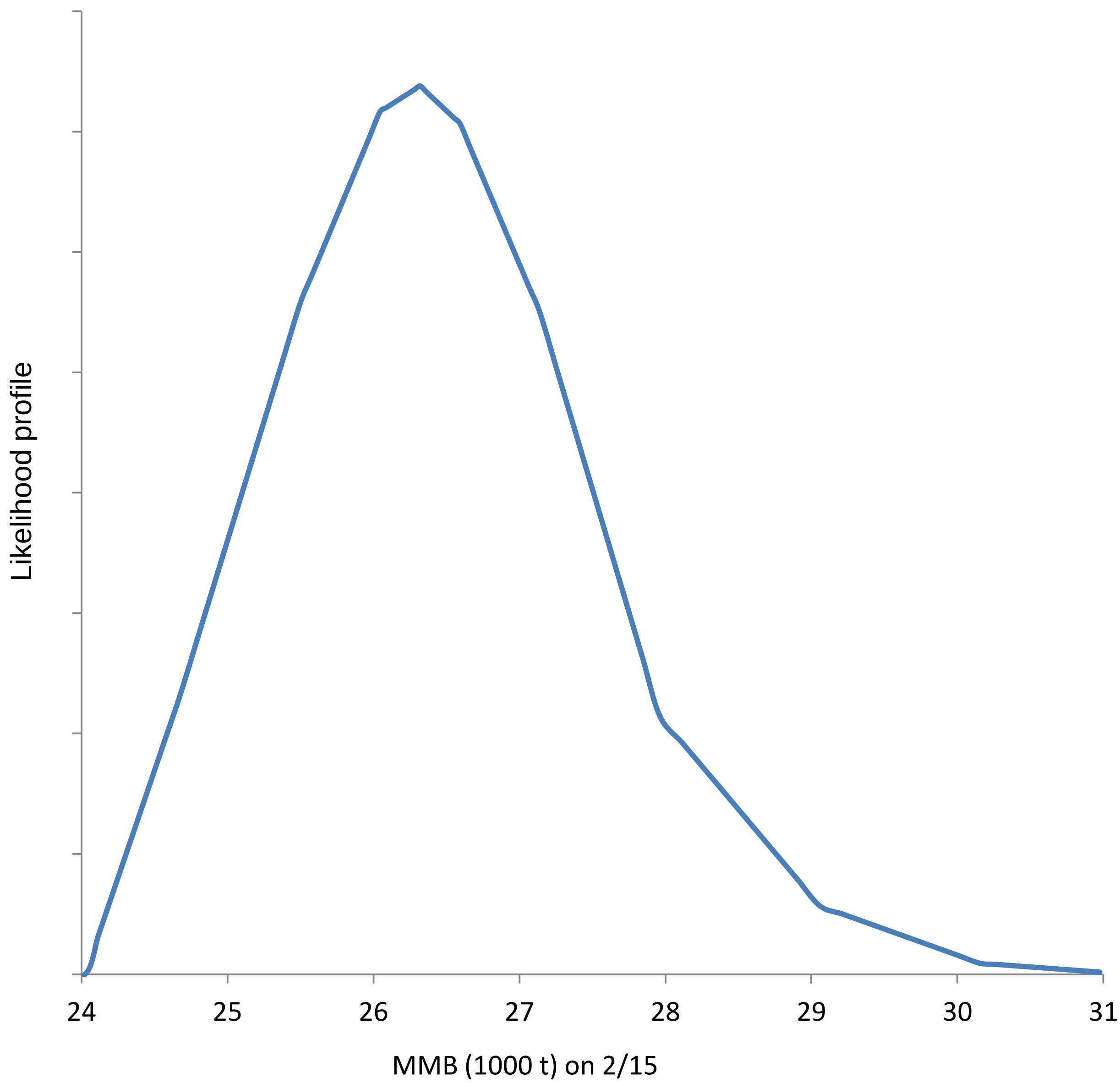



Figure 30. Likelihood profile of estimated mature male biomass on Feb. 15, 2013 with $F_{35\%}$ under scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

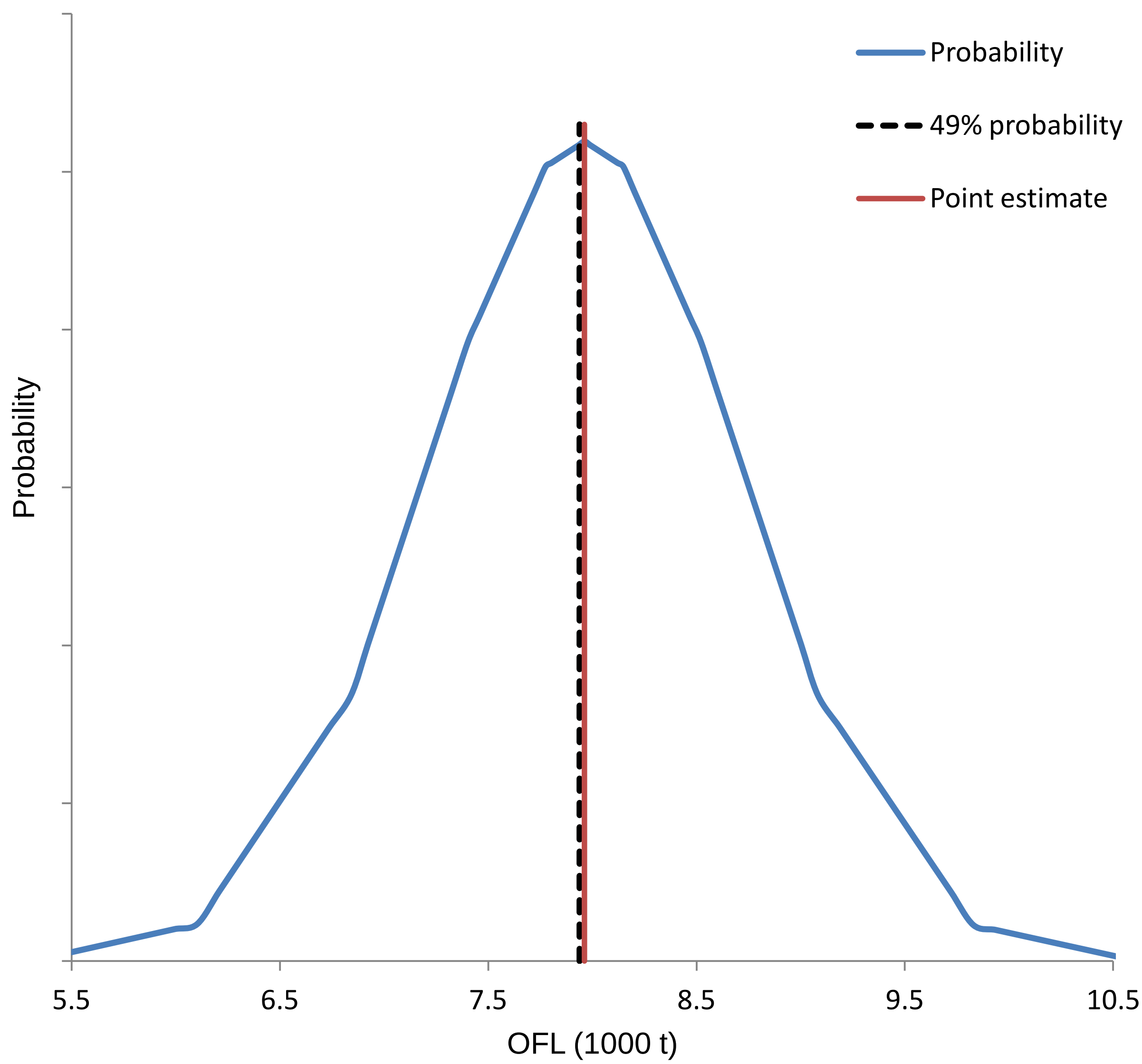



Figure 31. The 2012 OFL distributions with scenario 7ac based on normal approximation. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively.

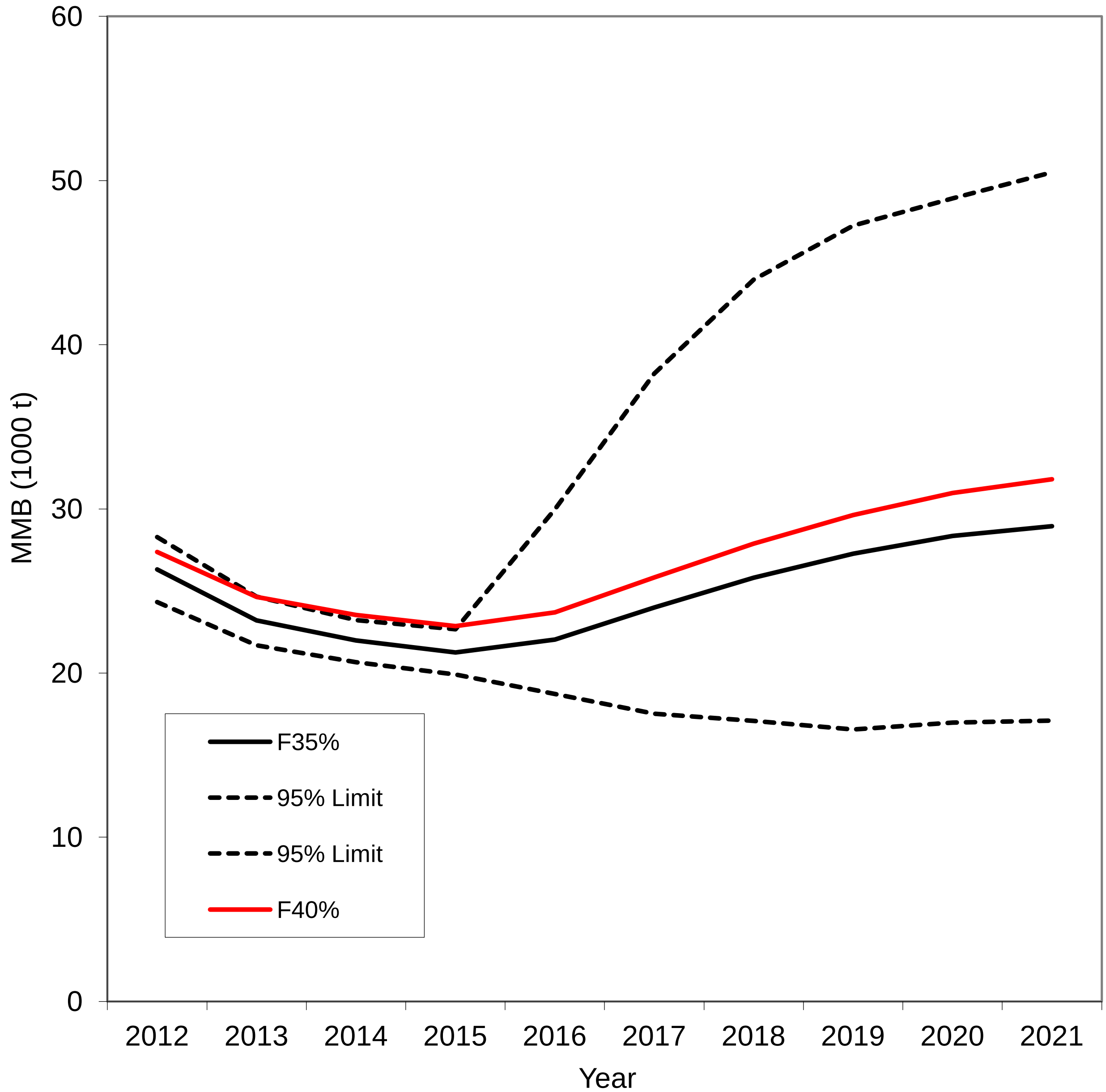



Figure 32. Projected mature male biomass on Feb. 15 with $F_{40\%}$ and $F_{35\%}$ harvest strategy during 2012-2121. Input parameter estimates are based on scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the confidence limits are for the $F_{35\%}$ harvest strategy.

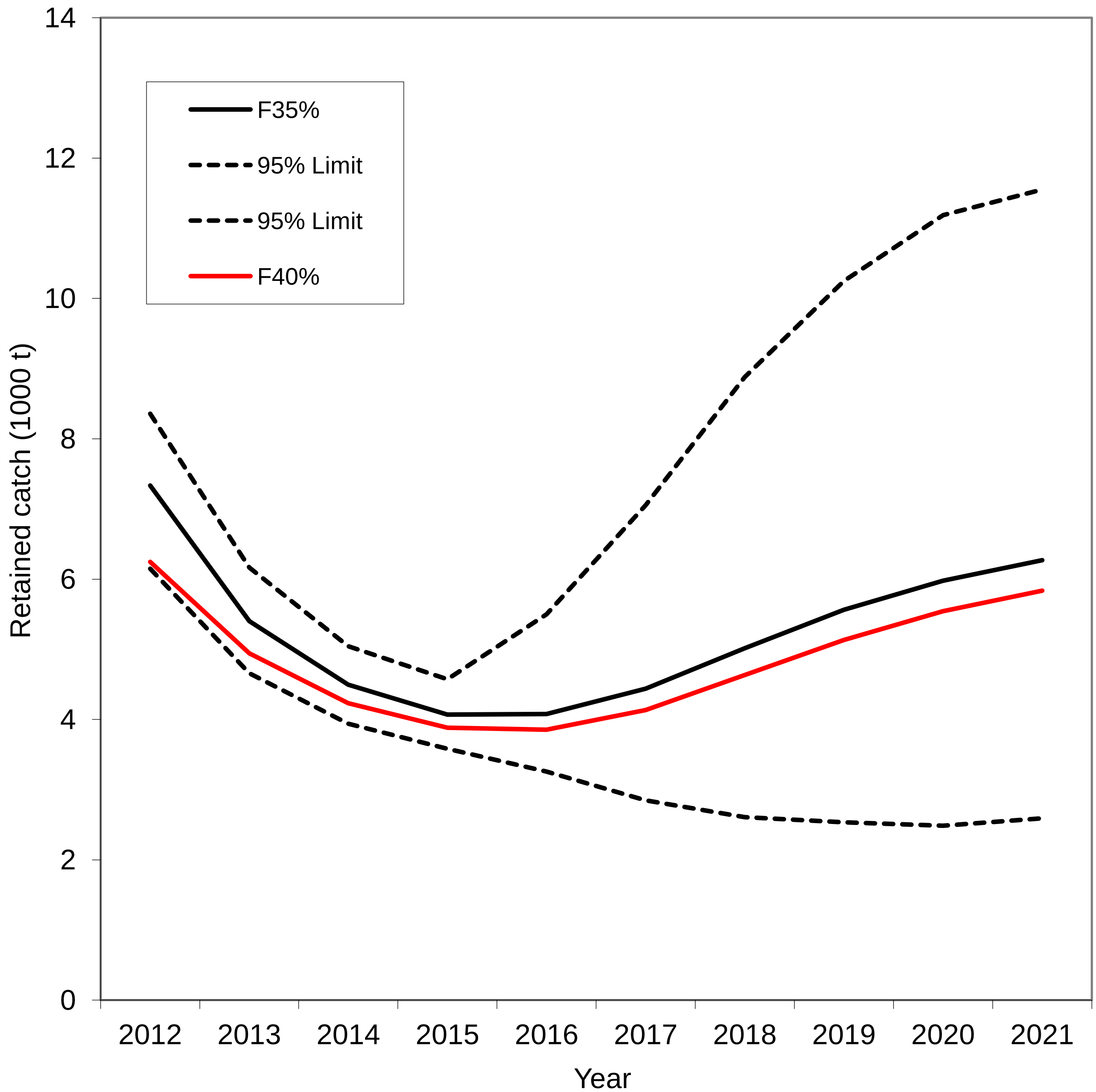



Figure 33. Projected retained catch biomass with $F_{40\%}$ and $F_{35\%}$ harvest strategy during 2012-2121. Input parameter estimates are based on scenario 7ac. Pot and trawl handling mortality rates were assumed to be 0.2 and 0.8, respectively, and the confidence limits are for the $F_{35\%}$ harvest strategy.

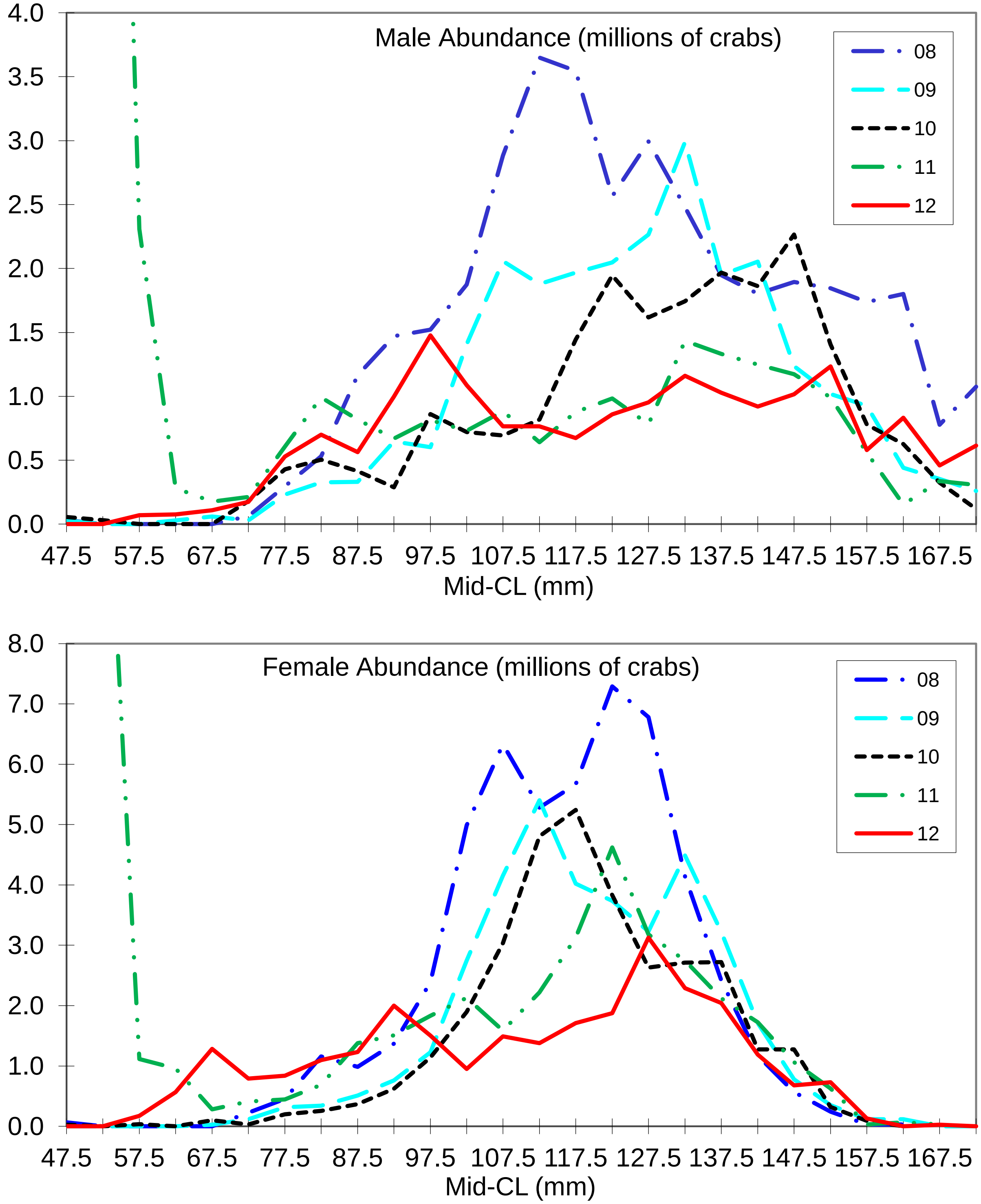



Figure 34. Length frequency distributions of male (top panel) and female (bottom panel) red king crabs in Bristol Bay from NMFS trawl surveys during 2007-2011. For purposes of these graphs, abundance estimates are based on area-swept methods.

# Appendix A. Description of the Bristol Bay Red King Crab Model

## a. Model Description

### *i. Population model*

The original LBA model was described in detail by Zheng et al. (1995a, 1995b) and Zheng and Kruse (2002). Male crab abundances by carapace length and shell condition in any one year are modeled to result from abundances in the previous year minus catch and handling and natural mortalities, plus recruitment, and additions to or losses from each length class due to growth:

$$N_{l+1,t+1} = \sum_{l'=1}^{l'=l+1} \{P_{l',l+1}[(N_{l',t} + O_{l',t})\,e^{-M_t} - (C_{l',t} + D_{l',t})\,e^{(y_t-1)M_t} - T_{l,t}e^{(j_t-1)M_t}]\,m_{l',t}\} + R_{l+1,t+1}\,,$$
$$O_{l+1,t+1} = [(N_{l+1,t} + O_{l+1,t})\,e^{-M_t} - (C_{l+1,t} + D_{l+1,t})\,e^{(y_t-1)M_t} - T_{l+1,t}e^{(j_t-1)M_t}](1 - m_{l+1,t}), \tag{1}$$

where

| | |
|---|---|
| $N_{l,t}$ | is newshell crab abundance in length class *l* and year *t*, |
| $O_{l,t}$ | is oldshell crab abundances in length class *l* and year *t*, |
| $M$ | is the instantaneous natural mortality, |
| $m_{l,t}$ | is the molting probability for length class *l* and year *t*, |
| $R_{l,t}$ | is recruitment into length class *l* in year *t*, |
| $y_t$ | is the lag in years between the assessment survey and the mid fishery time in year *t*, |
| $j_t$ | is the lag in years between the assessment survey and the mid Tanner crab fishery time in year *t*, |
| $P_{l',l}$ | is the proportion of molting crabs growing from length class *l'* to *l* after one molt, |
| $C_{l,t}$ | is the retained catch of length class *l* in year *t*, and |
| $D_{l,t}$ | is the discarded mortality catch of length class *l* in year *t*, including directed pot and trawl bycatch, |
| $T_{l,t}$ | is the discarded mortality catch of length class *l* in year *t* from the Tanner crab fishery. |

The minimum carapace length for males is set at 65 mm, and crab abundance is modeled with a length-class interval of 5 mm. The last length class includes all crabs ≥160-mm CL. There are 20 length classes/groups. $P_{l',l}$, $m_l$, $R_{l,t}$, $C_{l,t}$, and $D_{l,t}$ are computed as follows:

Mean growth increment per molt is assumed to be a linear function of pre-molt length:

$$G_l = a + b\,\iota, \tag{2}$$

where $a$ and $b$ are constants. Growth increment per molt is assumed to follow a gamma distribution:

$$g(x \mid \alpha_l, \beta) = x^{\alpha_l - 1} \; e^{-x/\beta} / [\beta^{\alpha_l} \; \Gamma(\alpha_l)]. \tag{3}$$

The expected proportion of molting individuals growing from length class $l_1$ to length class $l_2$ after one molt is equal to the sum of probabilities within length range [$\iota_1$, $\iota_2$) of the receiving length class $l_2$ at the beginning of the next year:

$$P_{l_1,l_2} = \int_{\iota_1 - \iota}^{\iota_2 - \iota} g(x \mid \alpha_l, \beta) dx, \tag{4}$$

where $\iota$ is the mid-length of length class $l_1$. For the last length class $L$, $P_{L,L} = 1$.

The molting probability for a given length class $l$ is modeled by an inverse logistic function:

$$m_{l,t} = 1 - \frac{1}{1 + e^{-\beta \; (l - L_{50})}}, \tag{5}$$

where

$\beta$, $L_{50}$ are parameters with three sets of values for three levels of molting probabilities, and $\iota$ is the mid-length of length class $l$.

Recruitment is defined as recruitment to the model and survey gear rather than recruitment to the fishery. Recruitment is separated into a time-dependent variable, $R_t$, and size-dependent variables, $U_l$, representing the proportion of recruits belonging to each length class. $R_t$ was assumed to consist of crabs at the recruiting age with different lengths and thus represents year class strength for year $t$. $R_{l,t}$ is computed as

$$R_{l,t} = R_t U_l, \tag{6}$$

where $U_l$ is described by a gamma distribution similar to equations (3) and (4) with a set of parameters $\alpha_r$ and $\beta_r$. Because of different growth rates, recruitment was estimated separately for males and females under a constraint of approximately equal sex ratios of recruitment over time.

Before 1990, no observed bycatch data were available in the directed pot fishery; the crabs that were discarded and died in those years were estimated as the product of handling mortality rate, legal harvest rates, and mean length-specific selectivities. It is difficult to estimate bycatch from the Tanner crab fishery before 1991. A reasonable index to estimate bycatch fishing mortalities is potlifts of the Tanner crab fishery within the distribution area of Bristol Bay red king crab. Thus, bycatch fishing mortalities from the Tanner crab fishery before 1991 were estimated to be proportional to the smoothing average of potlifts east of 163$^{o}$ W. The smoothing average is equal to ($P_{t-2}$+2$P_{t-1}$+3$P_t$)/6 for the potlift in year t. The smoothing process not only smoothes the annual number of potlifts, it also indexes the effects of lost pots during the previous years. For bycatch, all fishery catch and discard mortality bycatch are estimated as:

$$C_{l,t} \; or \; D_{l,t} = (N_{l,t} + O_{l,t}) \; e^{-y_t M_t} (1 - e^{-s_l F_t}) \tag{7}$$

where

$s_l$ is selectivity for retained, pot or trawl discarded mortality catch of length class *l*, and

$F_t$ is full fishing mortality of retained, pot or trawl discarded mortality catch in year *t*.

For discarded mortality bycatch from the Tanner crab fishery, $y_t$ is replaced by $j_t$ in the right side of equation (7).

The female crab model is the same as the male crab model except that the retained catch equals zero, molting probability equals 1.0 to reflect annual molting (Powell 1967), and growth matrix, *P*, changes over time due to change in size at maturity for females. The minimum carapace length for females is set at 65 mm, and the last length class includes all crabs ≥140-mm CL, resulting in length groups 1-16. Three sets of growth increments per molt are used for females due to changes in sizes at maturity over time (Figures A2 and A3).

### *ii. Fisheries Selectivities*

Retained selectivity, female pot bycatch selectivity, and both male and female trawl bycatch selectivity are estimated as a function of length:

$$s_l = \frac{1}{1+e^{-\beta\ (\iota - L_{50})}}, \qquad (8)$$

Different sets of parameters ($\beta$, $L_{50}$) are estimated for retained males, female pot bycatch, male and female trawl bycatch, and discarded males and females from the Tanner crab fishery. Because some catches were from the foreign fisheries during 1968-1972, a different set of parameters ($\beta$, $L_{50}$) are estimated for retained males for this period and a third parameter, sel_62.5mm, is used to explain the high proportion of catches in the last length group.

Male pot bycatch selectivity is modeled by two linear functions:

$$\begin{aligned} s_l &= \varphi + \kappa\, \iota, \quad if\ \ \iota < 135\,\text{mm CL}, \\ s_l &= s_{l-1} + 5\gamma, \quad if\ \ \iota > 134\,\text{mm CL} \end{aligned} \qquad (9)$$

Where

$\varphi$, $\kappa$, $\gamma$ are parameters.

During 2005-2008, a portion of legal males were also discarded in the pot fishery. The selectivity for this high grading was estimated to be the retained selectivity in each year times a high grading parameter, $hg_t$.

### *iii. Trawl Survey Selectivities/Catchability*

Trawl survey selectivities/catchability are estimated as

$$s_l = \frac{Q}{1 + e^{-\beta\ (l - L_{50})}}, \tag{10}$$

with different sets of parameters ($\beta$, $L_{50}$) estimated for males and females as well as four different periods (1968-69, 1970-72, 1973-81 and 1982-09). Survey selectivity for the first length group (67.5 mm) was assumed to be the same for both males and females, so only three parameters ($\beta$, $L_{50}$ for females and $L_{50}$ for males) were estimated in the model for each of the four periods. Parameter $Q$ was called the survey catchability that was estimated based on a trawl experiment by Weinberg et al. (2004, Figure A1). Q was assumed to be constant over time except during 1970-1972 when the survey catchability was small.

Assuming that the BSFRF survey caught all crabs within the area-swept, the ratio between NMFS abundance and BSFRF abundance is a capture probability for the NMFS survey net. The Delta method was used to estimate the variance for the capture probability. A maximum likelihood method was used to estimate parameters for a logistic function as an estimated capture probability curve (Figure A1). For a given size, the estimated capture probability is smaller based on the BSFRF survey than from the trawl experiment, but the $Q$ value is similar between the trawl experiment and the BSFRF surveys (Figure A1). Because many small-sized crabs are in the shallow water areas that are not accessible for the trawl survey, NMFS survey catchability/selectivity consists of capture probability and crab availability.

**b. Software Used**: AD Model Builder (Otter Research Ltd. 1994).

**c. Likelihood Components**

A maximum likelihood approach was used to estimate parameters. For length compositions ($p_{l,t,s,sh}$), the likelihood functions are :

$$Rf = \prod_{l=1}^{L}\prod_{t=1}^{T}\prod_{s=1}^{2}\prod_{sh=1}^{2}\frac{\left\{\exp\left[-\frac{(p_{l,t,s,sh}-\hat{p}_{l,t,s,sh})^2}{2\sigma^2}\right]+0.01\right\}}{\sqrt{2\pi\sigma^2}}, \tag{11}$$

$$\sigma^2 = \left[\hat{p}_{l,t,s,sh}(1-\hat{p}_{l,t,s,sh}) + 0.1/L\right]/n,$$

where

$L$ is the number of length groups,

$T$ is the number of years, and

$n$ is the effective sample size, which was estimated for trawl survey and pot retained catch and bycatch length composition data from the directed pot fishery, and was assumed to be 50 for groundfish trawl and Tanner crab fisheries bycatch length composition data.

The weighted negative log-likelihood functions are:

$$
\begin{aligned}
&\textit{Length compositions}: \quad -\sum \ln(Rf_i)\,, \\
&\textit{Biomasses other than survey}: \quad \lambda_j \sum \left[\ln(C_t / \hat{C}_t)^2\right], \\
&\textit{NMFS survey biomass}: \quad \sum \left[\ln(B_t / \hat{B}_t)^2 / (2\ln(CV_t^2 + 1))\right], \\
&\textit{BSFRF mature males}: \quad \sum [\ln(N_t / \hat{N}_t)^2 / (2\ln(CV_t^2 + 1))], \qquad (12) \\
&R \textit{ variation}: \quad \lambda_R \sum [\ln(R_t / \overline{R})^2]\,, \\
&R \textit{ sex ratio}: \quad \lambda_s [\ln(\overline{R}_M / \overline{R}_F)^2]\,,
\end{aligned}
$$

Where

$R_t$ is the recruitment in year $t$,

$\overline{R}$ is the mean recruitment,

$\overline{R}_M$ is the mean male recruitment,

$\overline{R}_F$ is the mean female recruitment.

Weights $\lambda_j$ are assumed to be 500 for retained catch biomass, and 100 for all bycatch biomasses, 2 for recruitment variation, and 10 for recruitment sex ratio. These $\lambda_j$ values represent prior assumptions about the accuracy of the observed catch biomass data and about the variances of these random variables.

**d. Population State in Year 1.**

To increase the efficiency of the parameter-estimation algorithm, we assumed that the smoothed relative frequencies of length and shell classes from survey year 1968 approximate the true relative frequencies within sexes. Thus, only total abundances of males and females for the first year were estimated; 3n unknown parameters for the abundances in the first year, where n is the number of length-classes, were reduced to one under this assumption.

**e. Parameter estimation framework:**

i. Parameters estimated independently

Basic natural mortality, length-weight relationships, and mean growth increments per molt were estimated independently outside of the model. Mean length of recruits to the model depends on growth and was assumed to be 72.5 for both males and females. High grading parameters $hg_t$ were estimated to be 0.2785 in 2005, 0.0440 in 2006, 0.0197 in 2007, and 0.0198 in 2008 based on the proportions of discarded legal males to total caught legal males. Handling mortality rates were set to 0.2 for the directed pot fishery, 0.25 for the Tanner crab fishery, and 0.8 for the trawl fisheries.

***(1). Natural Mortality***

Based on an assumed maximum age of 25 years and the 1% rule (Zheng 2005), basic $M$ was estimated to be 0.18 for both males and females. Natural mortality in a given year, $M_t$, equals to $M + Mm_t$ (for males) or $M + Mf_t$ (females). One value of $Mm_t$ during 1980-1985 was estimated and two values of $Mf_t$ during 1980-1984 and 1976-79, 1985-93 were estimated in the model.

### *(2). Length-weight Relationship*

Length-weight relationships for males and females were as follows:

Immature Females: $W = 0.010271\ L^{2.388}$,

Ovigerous Females: $W = 0.02286\ L^{2.234}$, (13)

Males: $W = 0.000361\ L^{3.16}$,

where

$W$ is weight in grams, and
$L$ is CL in mm.

### *(3). Growth Increment per Molt*

A variety of data are available to estimate male mean growth increment per molt for Bristol Bay RKC. Tagging studies were conducted during the 1950s, 1960s and 1990s, and mean growth increment per molt data from these tagging studies in the 1950s and 1960s were analyzed by Weber and Miyahara (1962) and Balsiger (1974). Modal analyses were conducted for the data during 1957-1961 and the 1990s (Weber 1967; Loher et al. 2001). Mean growth increment per molt may be a function of body size and shell condition and vary over time (Balsiger 1974; McCaughran and Powell 1977); however, for simplicity, mean growth increment per molt was assumed to be only a function of body size in the models. Tagging data were used to estimate mean growth increment per molt as a function of pre-molt length for males (Figure A2). The results from modal analyses of 1957-1961 and the 1990s were used to estimate mean growth increment per molt for immature females during 1968-1993 and 1994-2008, respectively, and the data presented in Gray (1963) were used to estimate those for mature females (Figure A2). To make a smooth transition of growth increment per molt from immature to mature females, weighted growth increment averages of 70% and 30% at 92.5 mm CL pre-molt length and 90% and 10% at 97.5 mm CL were used, respectively, for mature and immature females during 1983-1993. These percentages are roughly close to the composition of maturity. During 1968-1982, females matured at a smaller size, so the growth increment per molt as a function of length was shifted to smaller increments. Likewise, during 1994-2008, females matured at a slightly higher size, so the growth increment per molt was shifted to high increments for immature crabs (Figure A2). Once mature, the growth increment per molt for male crabs decreases slightly and annual molting probability decreases, whereas the growth increment for female crabs decreases dramatically but annual molting probability remains constant at 1.0 (Powell 1967).

### *(4). Sizes at Maturity for Females*

NMFS collected female reproductive condition data during the summer trawl surveys. Mature females are separated from immature females by a presence of egg clutches or egg cases. Proportions of mature females at 5-mm length intervals were summarized and a logistic curve was fitted to the data each year to estimate sizes at 50% maturity. Sizes at 50% maturity are illustrated in Figure A3 with mean values for three different periods (1975-82, 1983-93 and 1994-08).

***(5). Sizes at Maturity for Males***

Sizes at functional maturity for Bristol Bay male RKC have been assumed to be 120 mm CL (Schmidt and Pengilly 1990). This is based on mating pair data collected off Kodiak Island (Figure A4). Sizes at maturity for Bristol Bay female RKC are about 90 mm CL, about 15 mm CL less than Kodiak female RKC (Pengilly et al. 2002). The size ratio of mature males to females is 1.3333 at sizes at maturity for Bristol Bay RKC, and since mature males grow at much larger increments than mature females, the mean size ratio of mature males to females is most likely larger than this ratio. Size ratios of the large majority of Kodiak mating pairs were less than 1.3333, and in some bays, only a small proportion of mating pairs had size ratios above 1.3333 (Figure A4).

In the laboratory, male RKC as small as 80 mm CL from Kodiak and SE Alaska can successfully mate with females (Paul and Paul 1990). But few males less than 100 mm CL were observed to mate with females in the wild. Based on the size ratios of males to females in the Kodiak mating pair data, setting 120 mm CL as a minimum size of functional maturity for Bristol Bay male RKC is proper in terms of managing the fishery.

***(6) Potential Reasons for High Mortality during the Early 1980s***

Bristol Bay red king crab abundance had declined sharply during the early 1980s. Many factors have been speculated for this decline: (i) completely wiped out by fishing: directed pot fishery, other directed pot fishery (Tanner crab fishery), and bottom trawling; and (ii) high fishing and natural mortality. With the survey abundance, harvest rates in 1980 and 1981 were among the highest, thus the directed fishing definitely had a big impact on the stock decline, especially legal and mature males. However, for the sharp decline during 1980-1884 for males, 3 out of 5 years had low mature harvest rates. During 1981-1984 for females, 3 out of 4 years had low mature harvest rates. Also pot catchability for females and immature males are generally much lower than for legal males, so the directed pot fishing alone cannot explain the sharp decline for all segments of the stock during the early 1980s.

Red king crab bycatch in the eastern Bering Sea Tanner crab fishery is another potential factor. The main overlap between Tanner crab and Bristol Bay red king crab is east of $163^{o}$ W. No absolute red king crab bycatch estimates are available until 1991. So there are insufficient data to fully evaluate the impact. Retained catch and potlifts from the eastern Bering Sea Tanner crab fishery are illustrated in Figure A5. The observed red king crab bycatch in the Tanner crab fishery during 1991-1993 and total potlifts east of $163^{o}$ W during 1968 to 2005 were used to estimate the bycatch mortality in the current model. Because winter sea surface temperatures and air temperatures were warmer (which means a lower handling mortality rate) and there were fewer potlifts during the early 1980s than during the early 1990s, bycatch in the Tanner crab fishery is unlikely to have been a main factor for the sharp decline of Bristol Bay red king crab.

Several factors may have caused increases in natural mortality. Crab diseases in the early 1980s were documented by Sparks and Morado (1985), but inadequate data were collected to examine their effects on the stock. Stevens (1990) speculated that senescence may be a factor because many crabs in the early 1980s were very old due to low temperatures in the 1960s and early 1970s. The biomass of the main crab predator, Pacific cod, increased about 10 times during the late 1970s and early 1980s. Yellowfin sole biomass also increased substantially during this period. Predation is primarily on juvenile and molting/softshell crabs. But we lack stomach samples in shallow waters (juvenile habitat) and during the period when red king crabs molt. Also cannibalism occurs during molting periods for red king crabs. High crab abundance in the late 1970s and early 1980s may have increased the occurrence of cannibalism.

Overall, the likely causes for the sharp decline in the early 1980s are combinations of the above factors, such as pot fisheries on legal males, bycatch and predation on females and juvenile and sublegal males, senescence for older crabs, and disease for all crabs. In our model, we estimated one mortality parameter for males and another for females during 1980-1984. We also estimated a mortality parameter for females during 1976-1979 and 1985-1993. These three mortality parameters are additional to the basic natural mortality of 0.18, all directed fishing mortality and non-directed fishing mortality. These three mortality parameters could be attributed to natural mortality as well as undocumented non-directed fishing mortality. The model fit the data much better with these three parameters than without them.

ii. Parameters estimated conditionally

The following model parameters were estimated for male and female crabs: total recruits for each year (year class strength $R_t$ for $t$ = 1969 to 2009), total abundance in the first year (1968), growth parameter $\beta$ and recruitment parameter $\beta_r$ for males and females separately. Molting probability parameters $\beta$ and $L_{50}$ were also estimated for male crabs. Estimated parameters also include $\beta$ and $L_{50}$ for retained selectivity, $\beta$ and $L_{50}$ for pot-discarded female selectivity, $\beta$ and $L_{50}$ for pot-discarded male and female selectivities from the eastern Bering Sea Tanner crab fishery, $\beta$ and $L_{50}$ for groundfish trawl discarded selectivity, $\varphi$, $\kappa$ and $\gamma$ for pot-discarded male selectivity, and $\beta$ for trawl survey selectivity and $L_{50}$ for trawl survey male and females separately. NMFS survey catchabilities $Q$ for 1968-69 and 1973-2009 and $Q_m$ (for males) and $Q_f$ (for females) for 1970-72 were also estimated. Annual fishing mortalities were also estimated for the directed pot fishery for males (1968-2008), pot-discarded females from the directed fishery (1990-2008), pot-discarded males and females from the eastern Bering Sea Tanner crab fishery (1991-93), and groundfish trawl discarded males and females (1976-2008). Three additional mortality parameters for $Mm_t$ and $Mf_t$ were also estimated. The total number of parameters to be estimated was 223. Some estimated parameters were constrained in the model. For example, male and female recruitment estimates were forced to be close to each other for a given year.

**f. Definition of model outputs.**

i. Biomass: two population biomass measurements are used in this report: total survey biomass (crabs >64 mm CL) and mature male biomass (males >119 mm CL). Mating time is assumed to Feb. 15.

ii. Recruitment: new number of males in the $1^{st}$ seven length classes (65- 99 mm CL) and new number of females in the $1^{st}$ five length classes (65-89 mm CL).

iii. Fishing mortality: full-selected instantaneous fishing mortality rate at the time of fishery.

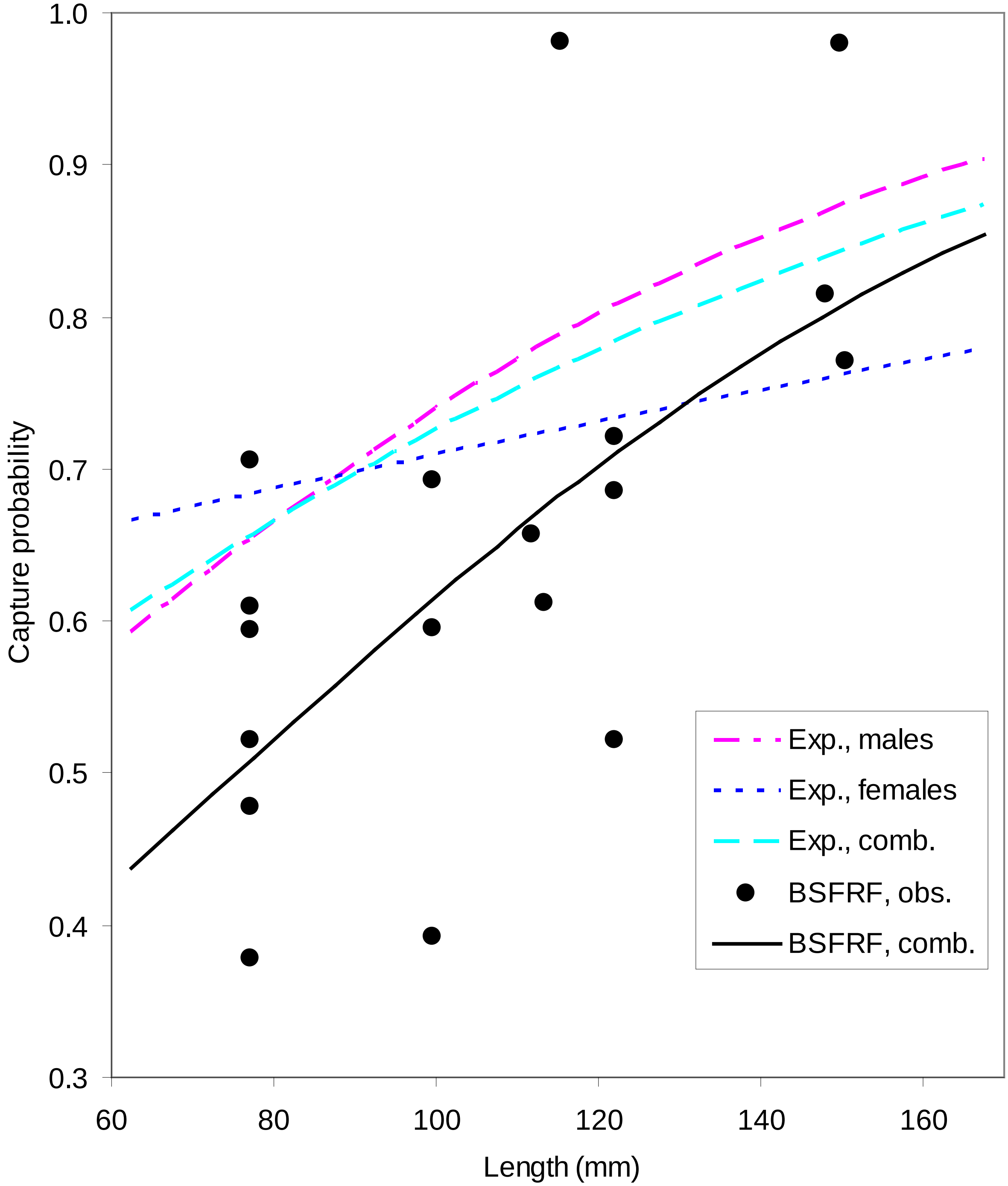
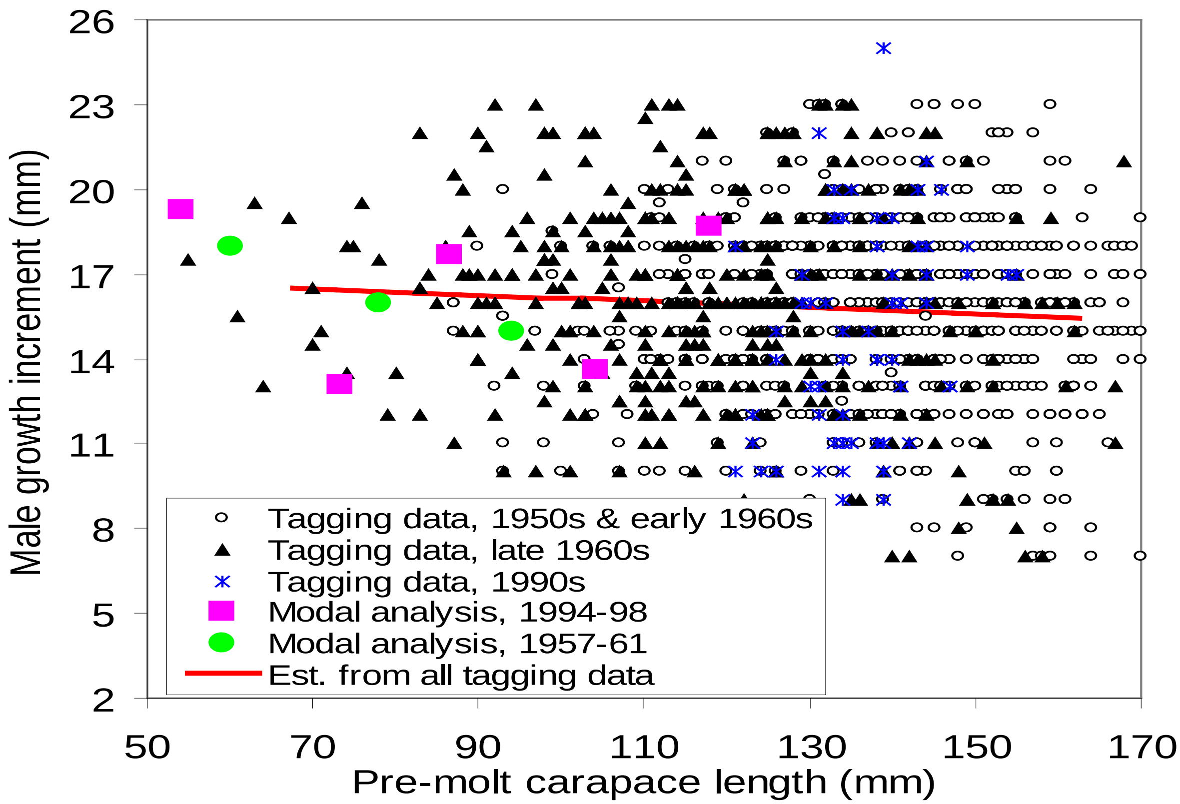



Figure A1. Estimated capture probabilities for NMFS Bristol Bay red king crab trawl surveys by Weinberg et al. (2004) and the Bering Sea Fisheries Research Foundation surveys.



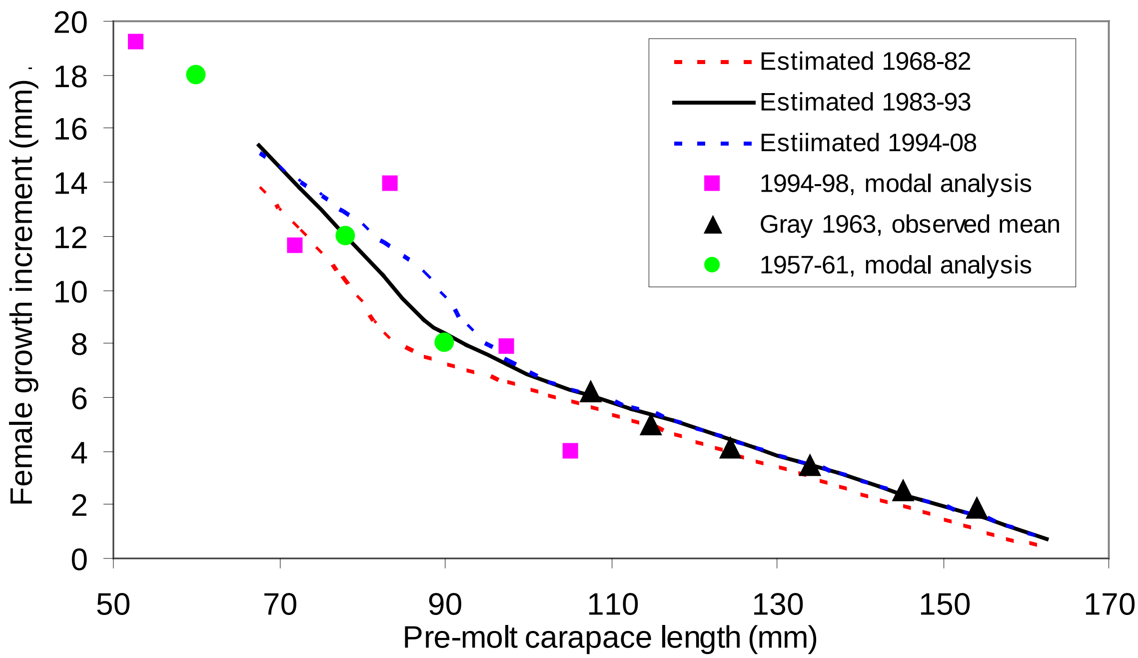




Figure A2. Mean growth increments per molt for Bristol Bay red king crab. Note: "tagging"---based on tagging data; "mode"---based on modal analysis.

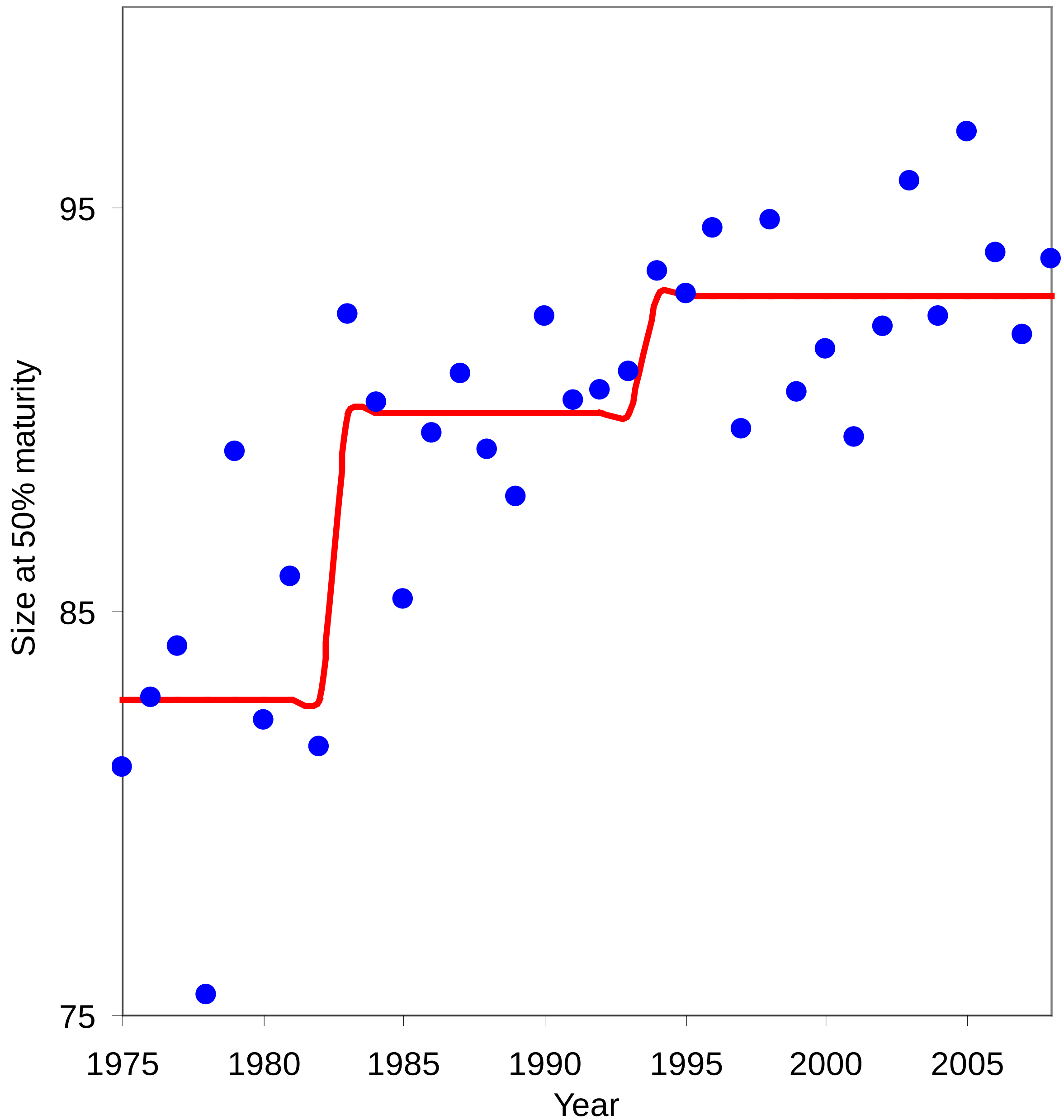



Figure A3. Estimated sizes at 50% maturity for Bristol Bay female red king crab from 1975 to 2008. Averages for three periods (1975-82, 1983-93, and 1994-08) are plotted with a line.

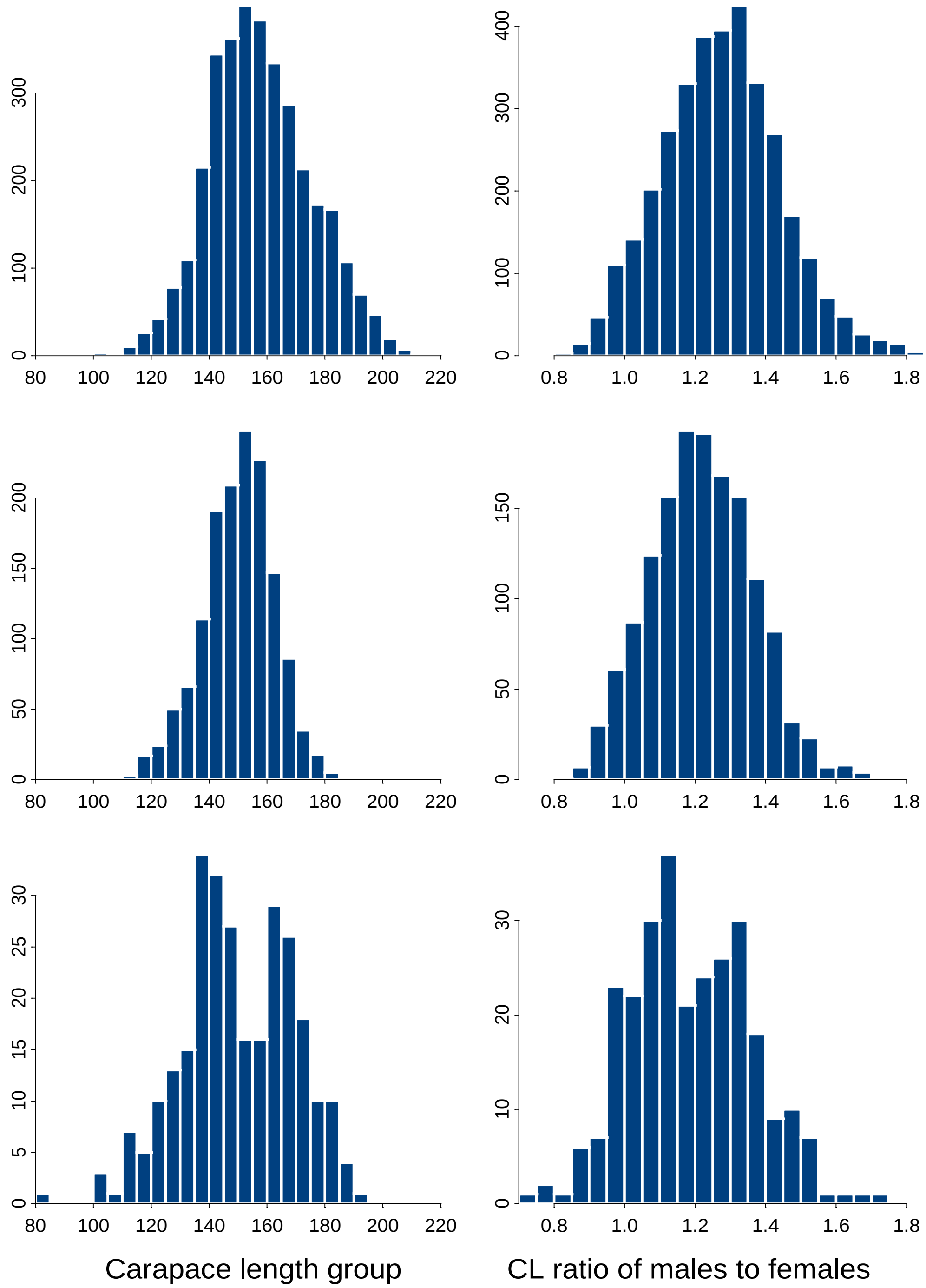
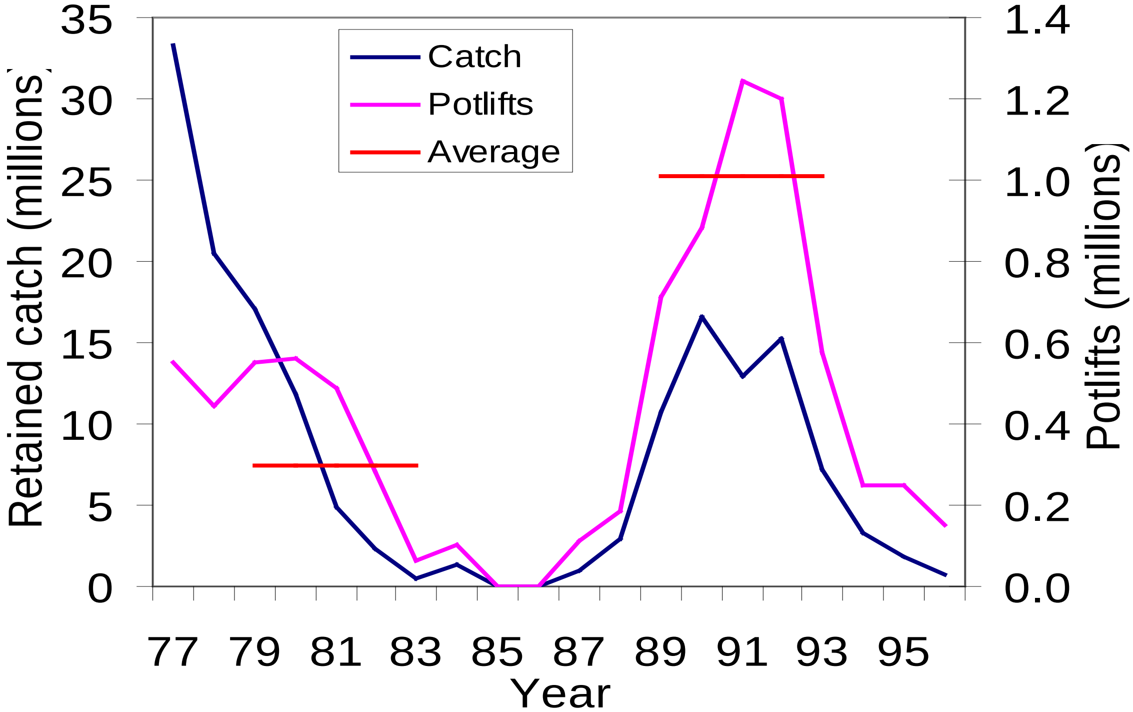



Figure A4. Histograms of carapace lengths (CL) and CL ratios of males to females for male shell ages ≤13 months of red king crab males in grasping pairs; Powell's Kodiak data. Upper plot: all locations and years pooled; middle plot: location 11; lower plot: locations 4 and 13. Sizes at maturity for Kodiak red king crab are about 15 mm larger than those for Bristol Bay red king crab. (Source: Doug Pengilly, ADF&G).



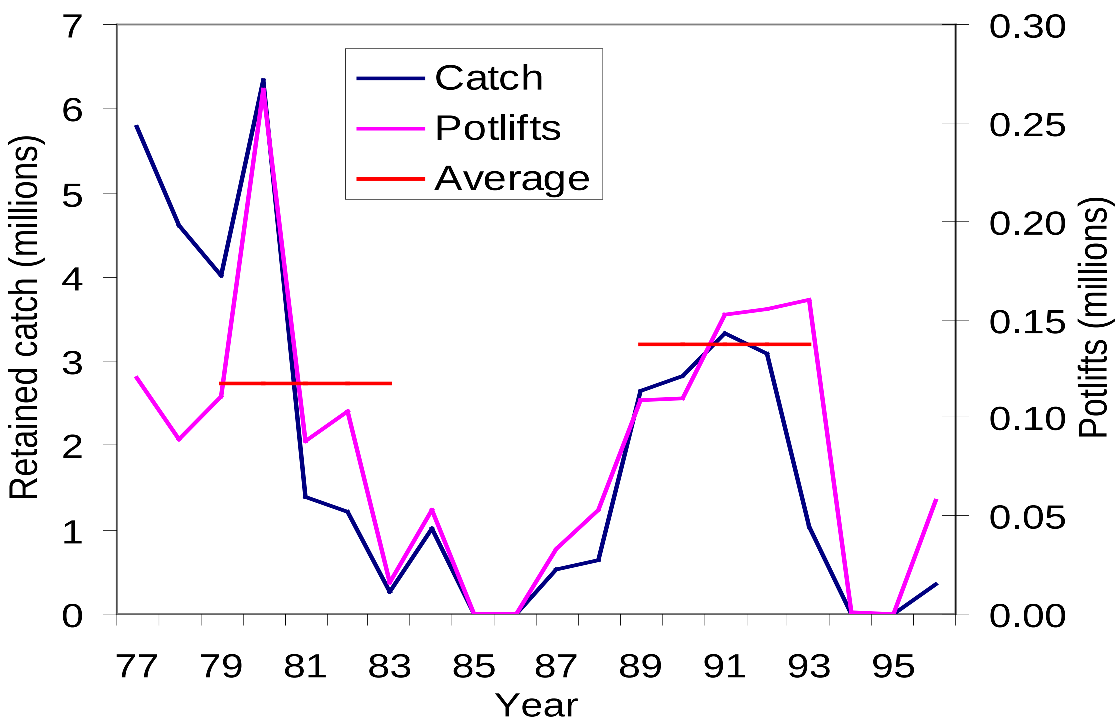
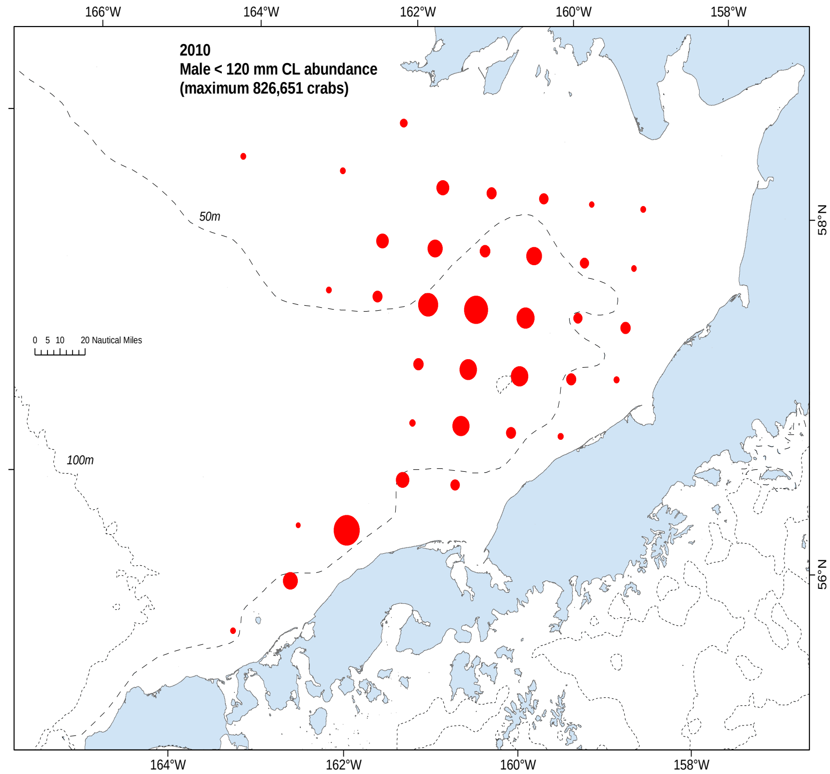
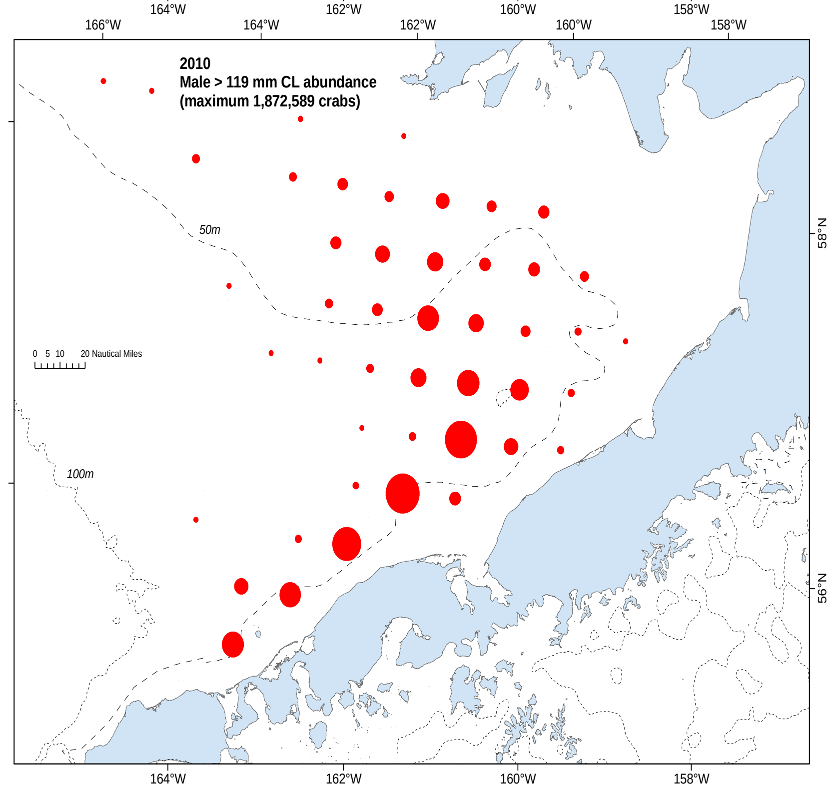




Figure A5. Retained catch and potlifts for total eastern Bering Sea Tanner crab fishery (upper plot) and the Tanner crab fishery east of 163° W (bottom).

**Appendix B. Spatial distributions of mature and juvenile male and female red king crabs in Bristol Bay from 2010-2012 summer standard trawl surveys.**

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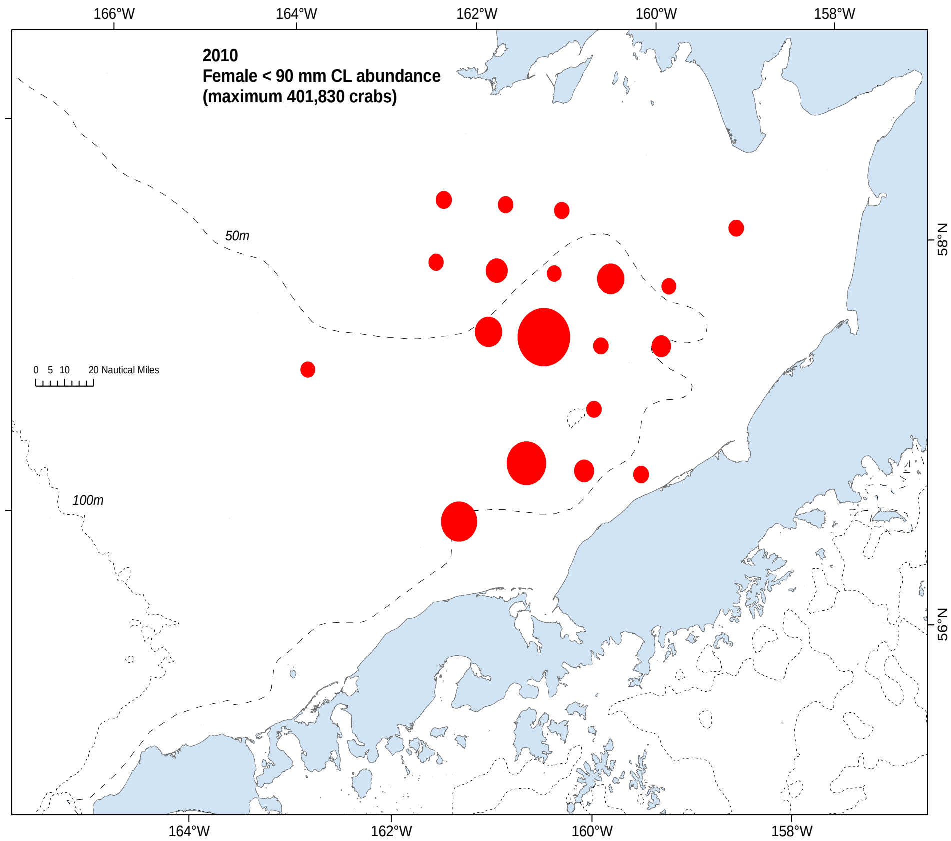
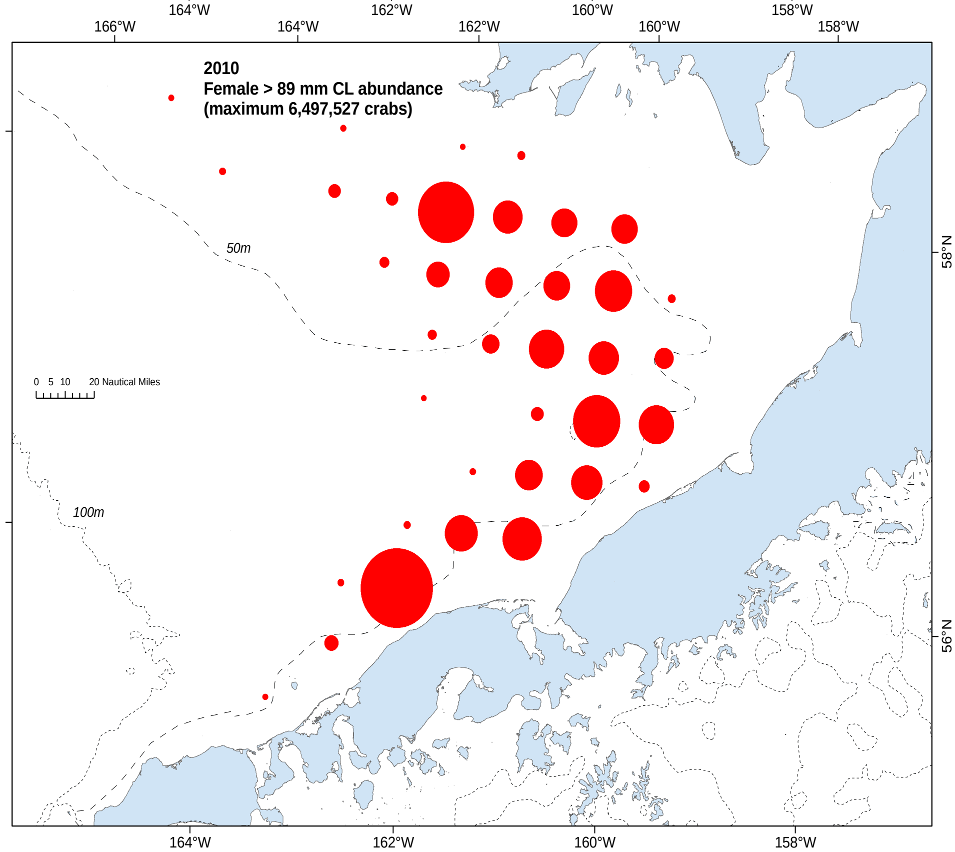
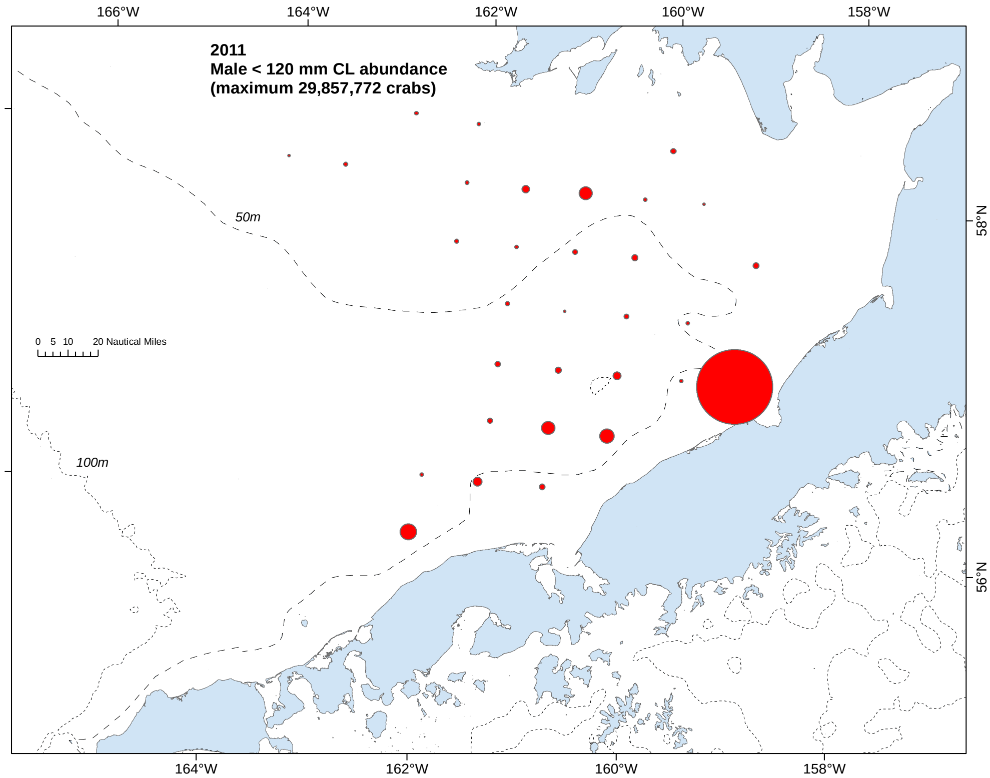
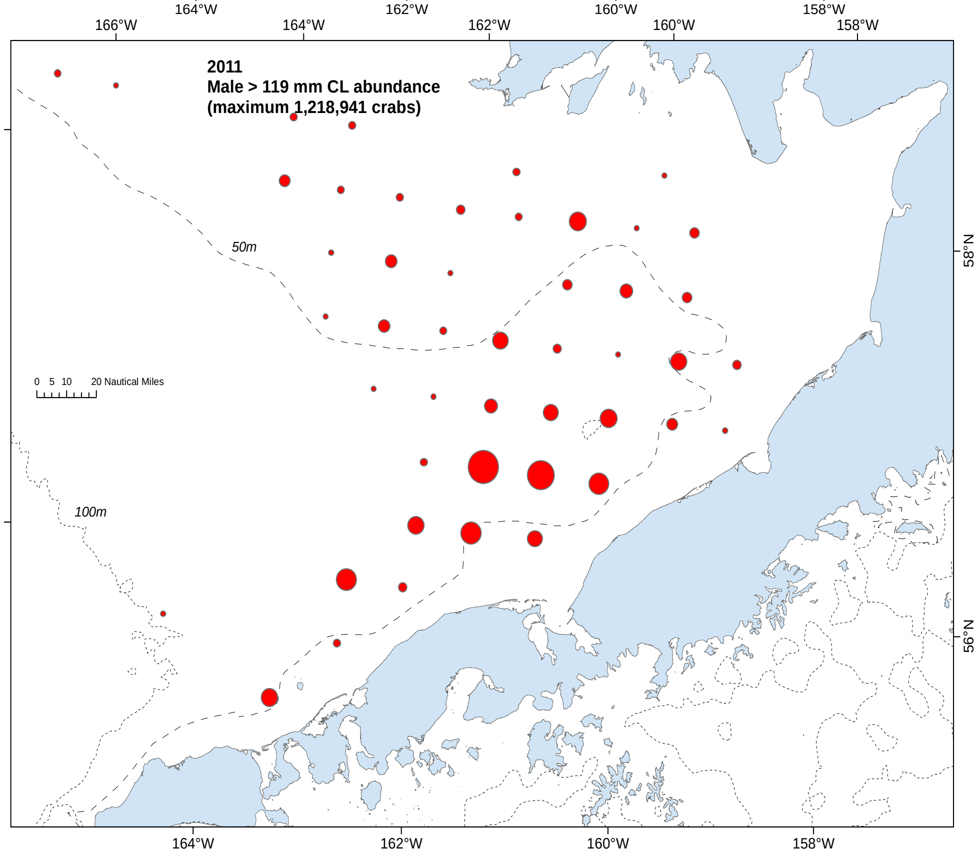

2010
Female < 90 mm CL abundance
(maximum 401,830 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles

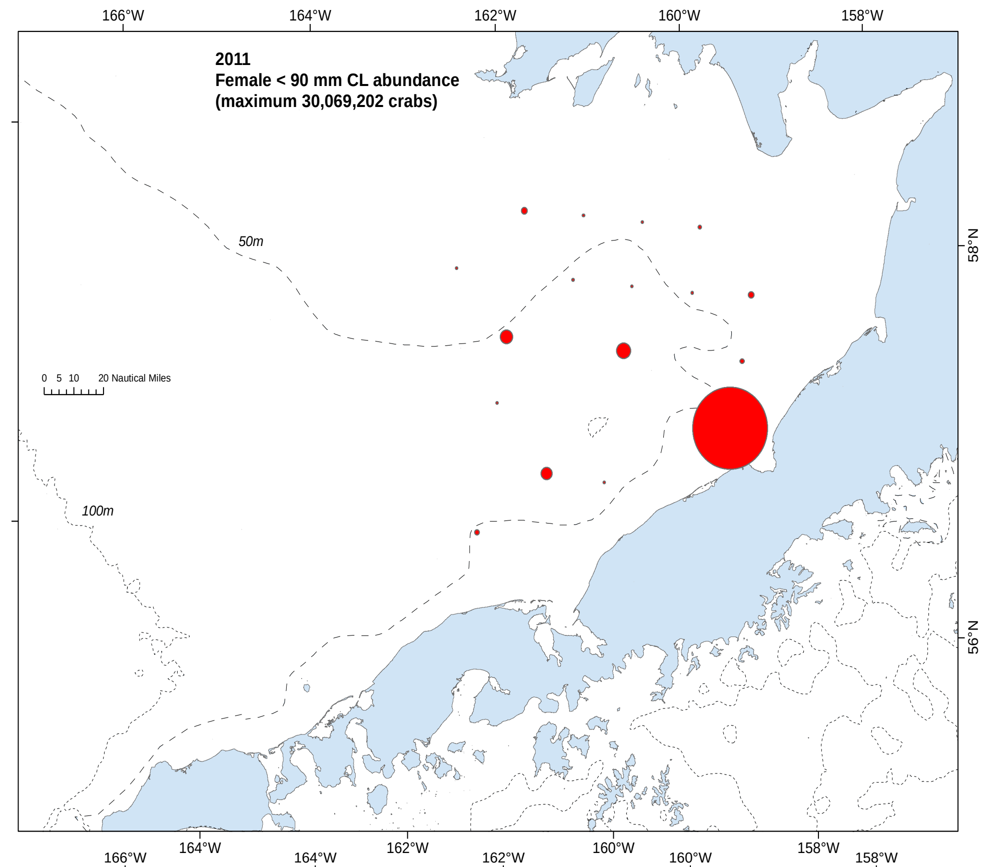

2010
Female > 89 mm CL abundance
(maximum 6,497,527 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles

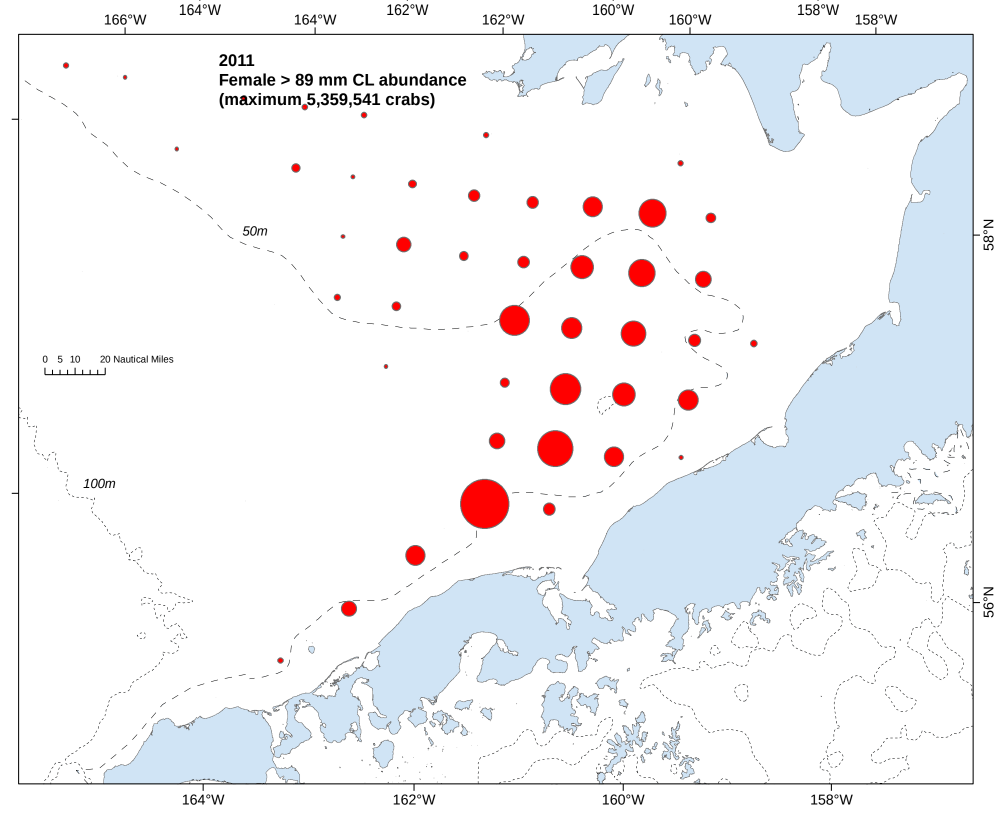
2


2011
Male < 120 mm CL abundance
(maximum 29,857,772 crabs)
50m
100m
0 5 10 20 Nautical Miles
166°W
164°W
162°W
160°W
158°W
58°N
56°N

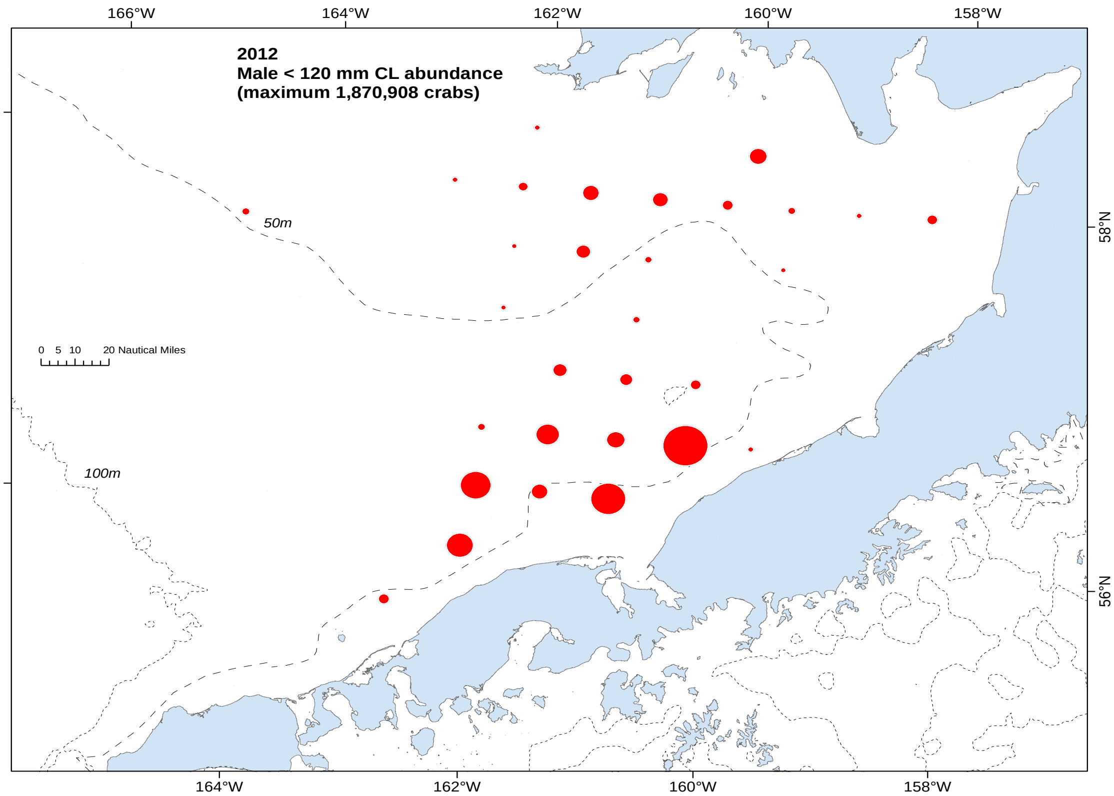

2011
Male > 119 mm CL abundance
(maximum 1,218,941 crabs)
50m
100m
0 5 10 20 Nautical Miles
166°W
164°W
162°W
160°W
158°W
58°N
56°N

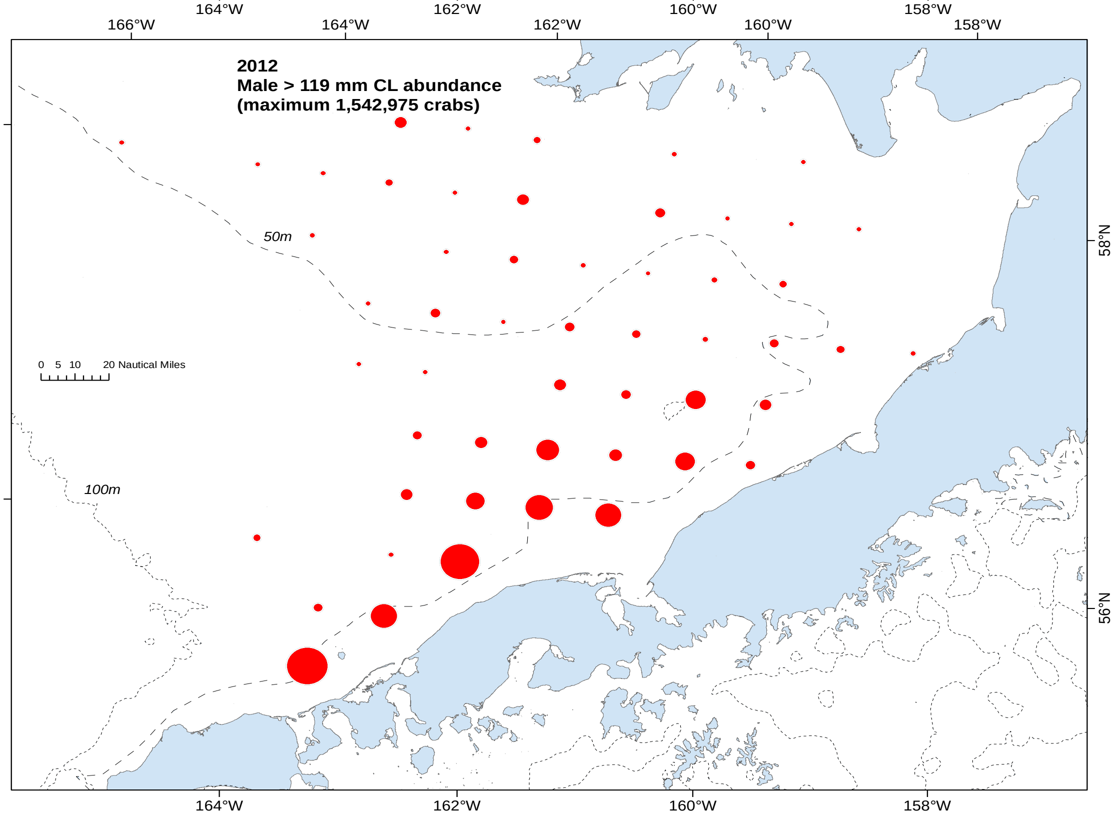
3


2011
Female < 90 mm CL abundance
(maximum 30,069,202 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles

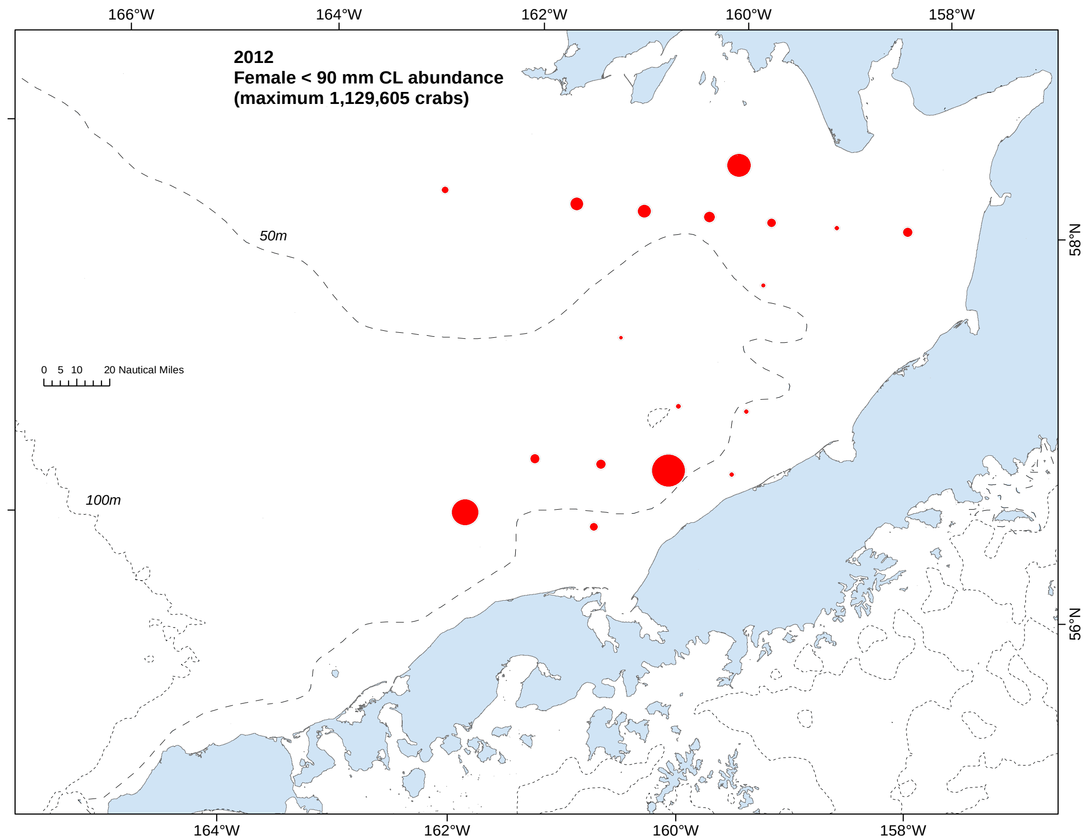

2011
Female > 89 mm CL abundance
(maximum 5,359,541 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles

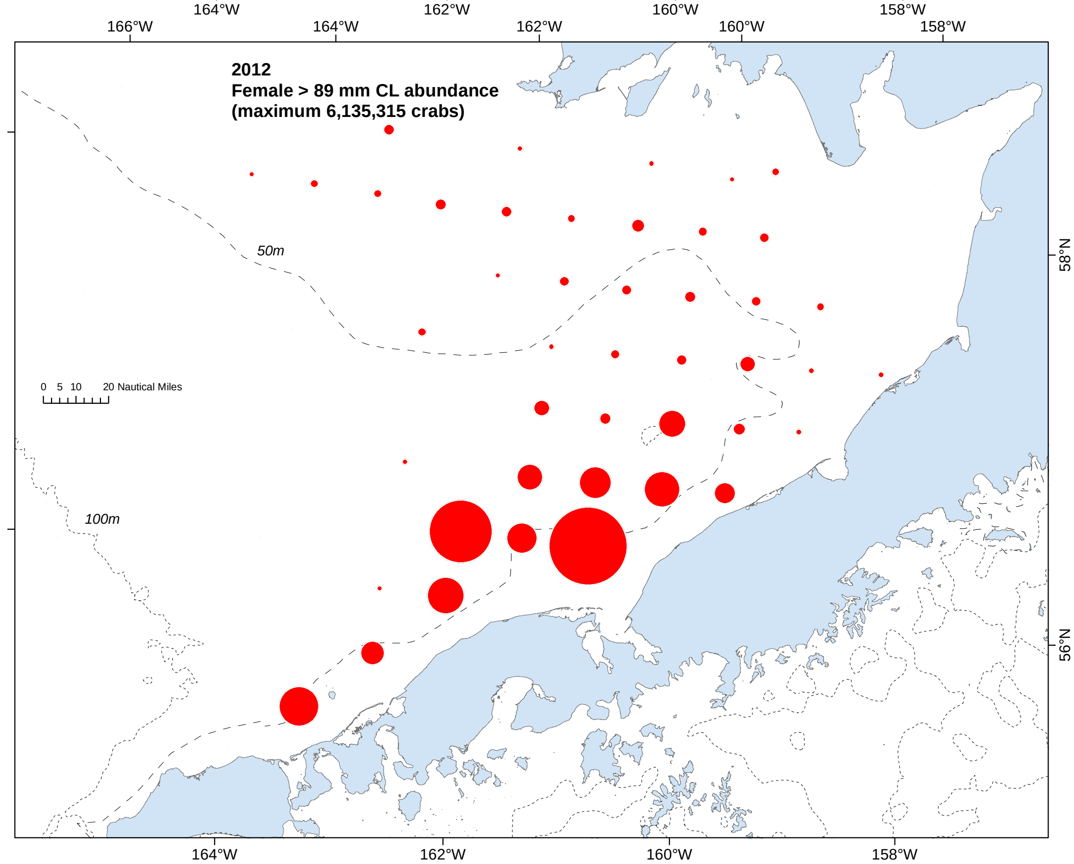
4


2012
Male < 120 mm CL abundance
(maximum 1,870,908 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles


2012
Male > 119 mm CL abundance
(maximum 1,542,975 crabs)
166°W
164°W
162°W
160°W
158°W
58°N
56°N
50m
100m
0 5 10 20 Nautical Miles

5


2012
Female < 90 mm CL abundance
(maximum 1,129,605 crabs)
50m
100m
0 5 10 20 Nautical Miles
166°W
164°W
162°W
160°W
158°W
58°N
56°N


2012
Female > 89 mm CL abundance
(maximum 6,135,315 crabs)
50m
100m
0 5 10 20 Nautical Miles
166°W
164°W
162°W
160°W
158°W
58°N
56°N

6

# 2012 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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21 September 2012



**Overview of Model Development**

The Tanner Crab Stock Assessment Model (TCSAM) was presented for review in February 2011 to the Crab Modeling Workshop (Martel and Stram 2011), to the SSC in March 2011, to the CPT in May 2011, and to the CPT and SSC in September 2011. The model was revised after May 2011 and the report to the CPT in September 2011 (Rugolo and Turnock 2011a) described the developments in the model per recommendations of the CPT, SSC and Crab Modeling Workshop through September 2011. In January 2012, the TCSAM was reviewed at a second Crab Modeling Workshop. Model revisions were made during the Workshop based on consensus recommendations. The model resulting from the Workshop was presented to the SSC in January 2012. Review findings and recommendations by the January 2012 Workshop and SSC, as well as the author's research plan guided changes to the model. A model incorporating all revisions recommended by the CPT, SSC and both Crab Modeling Workshops was presented to the SSC in March 2012.

In May 2012 and June 2012, respectively, the TCSAM was presented to the CPT and SSC to determine its suitability for stock assessment and the rebuilding analysis (Rugolo and Turnock 2012). The CPT agreed that the model could be accepted for management of the stock in the 2012/12 cycle, and that the stock should be promoted to Tier-3 status. The CPT also agreed that the TCSAM could be used as the basis for rebuilding analysis to underlie a rebuilding plan scheduled for developed in 2012. In June 2012, the SSC reviewed the model and accepted the recommendations of the plan team. The Council approved the SSC recommendations in June 2012. For 2011/12, the Tanner crab is assessed as a Tier-3 stock and the model will be used to estimate status determination criteria and overfishing levels.

**Review of Status of the Stock**

Tanner crab male mature biomass (MMB) in 2009/10 declined from previous years and fell below the minimum stock size threshold at survey time (MSST=0.5 $B_{MSY\ Proxy}$) (Rugolo and Turnock 2010). MMB at the time of the 2010 survey declined by 8.3% relative to 2009. Under the plan, MMB estimated at the time of mating accounts for losses due to natural morality from survey time to mating and losses due to directed and non-directed fishing. For the 2009/10 status determination, $B_{MSY\ Proxy}$=83.80 thousand metric tonnes (t) and the overfished status criterion, MSST, is 41.90 thousand t. After accounting for stock losses from M and the 2009/10 fisheries, the 2010 MMB at the time of mating was 28.44 thousand t. This represented a ratio of 0.34 relative to $B_{MSY\ Proxy}$ which was below the limit that defined an overfished stock. The 2009/10 Tanner crab stock was determined to be overfished by NOAA Fisheries based on the 2010 stock assessment (Rugolo and Turnock 2010).

For the 2010/11 stock status determination, losses from the time of the 2010 survey to mating in 2011, plus losses from non-directed fishing were considered. No directed fishing occurred in 2010/11 due to a closure. After accounting for losses from M and the 2010/11 non-directed pot and groundfish fisheries, the 2011 MMB at the time of mating was 26.73 thousand t (-6.4% relative to 2010). This represented a ratio of 0.32 relative to $B_{MSY\ Proxy}$ which remained below the limit (41.67 thousand t) that defines an overfished stock (Rugolo and Turnock 2011b). Thus, there was no change in the 2010/11 stock relative to the overfished determination made in 2010.

For the current 2011/12 stock status determination under Tier-4 management, losses from the time of the 2011 survey to mating in 2012, plus losses from non-directed fishing were considered. The directed fishery in 2011/12 was again closed to fishing. After accounting for losses from M and the 2011/12 non-directed pot and groundfish fisheries, the 2012 MMB at the time of mating is 34.67 thousand t (+29.7% relative to 2011). This represents a ratio of 0.42 relative to $B_{MSY\ Proxy}$ which remains below the limit of 41.67 thousand t that defines an overfished stock based on the Tier-4 assessment (Rugolo and Turnock 2011a). There was no change in the 2011/12 stock relative to the overfished determination made in 2010.

The status of the 2011/12 Tanner crab stock under Tier-3 management was assessed by the CPT (September 2012) relative to a selected $B_{35\%}$ proxy for $B_{MSY}$. The team decided that recruitment over 1990-2012 was representative of the production potential of this stock. This resulted in a $B_{35\%}$ of 22.80 thousand t. Using *Model (0)*, the estimate of 2011/12 MMB at mating is 58.59 thousand t which represents a ratio of 2.57 relative to $B_{35\%}$. Thus, the 2011/12 stock is currently at 257.02% of $B_{35\%}$. The team concluded that the stock was not overfished in 2011/12, and that the stock was never below MSST 2009/10 as was determined in the 2010 Tier-4 assessment (Rugolo and Turnock 2010).

For the 2012/13 fishery, the total catch OFL=19.02 thousand t, a 6.9-fold increase in the OFL relative to 2011/12. Fishing at the 2012/13 $F_{35\%}$=0.61, the 2012/13 MMB at mating is projected to be 42.74 thousand t, a decline of 25% relative to 2011/12 MMB at mating (58.59 thousand t). If this period of recruitment represents the current production potential of the stock, then by fishing under the $F_{35\%}$ control rule, we expect MMB at mating to equilibrate around 22.80 thousand t in the long-term.

In Appendix A, we present results of a rebuilding analysis using output from *Model (0)* and *Model (1)* as inputs to a stock projection model in order to evaluate the consequences of alternative harvest strategies on stock rebuilding and fishery performance. Appendix B presents the historical snow crab and Bristol Bay red king crab fisheries effort data.

**EXCUTIVE SUMMARY**

In 2012, Tanner crab MMB at the time of the survey was estimated at 45.8 thousand t representing a 9.7% increase relative to 2011. Mature male abundance rose 40.6% relative to 2011 and legal males were sparsely and patchily distributed throughout the survey range with regions of highest abundance in southwestern Bristol Bay and the Pribilof Islands (Figure 1). Legal male abundance decreased 48.2% to 7.1 million crabs between 2011 and 2012 Legal males were distributed 63.1% (4.5 million crabs) east and 36.9% (2.6 million crabs) west of $166^0$ W longitude compared to 37.1% (east) and 62.9% (west) in 2011 (Rugolo and Turnock 2011b). The 2012 abundance index for pre-recruit male crabs (110-137 mm cw) increased 4.6% relative to 2011, and that for small males (<110 mm cw) increased 19.2% relative to 2011 (Figure 2). Total male abundance increased 15.3% between 2011 and 2012. MMB in 2012 increased 9.7% relative to 2011. Compared to the 2011 survey, male recruit biomass (<110 mm cw) increased 89.7%, pre-recruit biomass (110-137 mm cw) decreased 0.6%, legal male biomass decreased 49.8% and total male biomass increased 26.2%. Total male abundance in 2012 was comprised of 60.6% immature, 30.8% new shell mature and 8.6% old shell mature males. Among all legal-sized males, 64.2% were old shell and 35.8% new shell.

Comparison of the male size frequency distributions between 2006 and 2012 revealed a decline in male abundance above 70 mm cw between 2006 and 2010, and relatively increasing percentage of old shell crabs in the mature male stock (Figures 3 a-g). The male size frequency distribution in 2011 (Figure 3 f) illustrates an apparent increase in pre-recruit abundance between 25-70 mm cw. The recruit mode (20-40mm cw) seen in 2009 (Figure 3 d) grew to 30-50 mm cw in 2010 (Figure 3 e) and to 55-65 mm cw in 2011 (Figure 3f). The increase in male abundance in 2011 is encouraging particularly for recruit-sized crab (<110 mm cw). The percentage of old and very old shell males in the 2012 mature stock declined relative to 2011. The size frequency distribution in 2012 (Figure 3 g) reveals a strong 55-65 mm mode of abundance which is consistent with that seen in 2011.

Large female (>=85 mm cw) Tanner crab increased 75.5% in abundance in 2012 relative to 2011 (Figure 2). Total female abundance in 2012 was comprised of 60.6% immature, 30.8% new shell mature and 8.6% old shell mature females. Among all female Tanner crab in 2012, 7.8% were collectively old shell and 92.2% new-hard shell. Small females (<85 mm cw) decreased by 10.7% relative to 2011. Total 2012 female abundance decreased 6.2%. Total survey abundance of males and females combined increased 6.2% over that in 2011 driven by the increase in small male and large female crabs. The distribution of ovigerous, barren and immature female Tanner crab is shown in Figure 4. The survey length frequency distributions of female Tanner crab from 2006-2012 reveals consistently declining abundance across the size modes and the general failure of modes of abundance to persist inter-annually (Figures 5 a-g). The prominent length mode between 65-75 mm cw seen in 2006 did not persist in expected levels of abundance in 2007 through 2010. The moderate mode of female abundance above 60 mm cw seen in 2009 (Figure 5 d), which was dominated by old and very old shell females, declined substantially in 2010 (Figure 5 e). A modest mode of new shell recruits seen in 2009 at 25-30 mm cw persists in 2010 at 35-50 mm cw. A relatively strong recruit mode (35-50 mm cw) is apparent in the 2010 survey data (Figure 5 e) which grew to 55-70 mm cw in 2011 (Figure 5 f). The female size frequency distribution in 2011 (Figure 11 f) reveals an apparent strong pre-recruit abundance mode between 30-50 mm cw. This mode did not persist into 2012 (Figure 5 g).

The 5 mm length frequency abundance observed in the survey for male and female crab from 1969/70 to 2011/12 is shown in Figures 6 and 7 respectively.

Status and catch specifications (1000 t) for EBS Tanner crab.

| Year | MSST | Biomass (MMB) | OFL | TAC [E+W] | Retained Catch | Total Catch |
|---|---|---|---|---|---|---|
| 2005/06[1/] | | 39.28 | | 0.73 | 0.43 | 1.61 |
| 2006/07[1/] | | 59.18 | | 1.35 | 0.96 | 3.15 |
| 2007/08[1/] | | 68.76 | | 2.55 | 0.96 | 3.63 |
| 2008/09[1/] | 43.04 | 53.63 | 7.04 | 1.95 | 0.88 | 2.25 |
| 2009/10 | 41.90 | 28.44 | 2.27 | 0.61 | 0.60 | 1.69 |
| 2010/11 | 41.67[2/] | 26.73 | 1.45 | 0 | 0 | 0.87 |
| 2011/12 | 11.40[3/] | 58.59[3/] | 2.75 | 0 | 0 | 1.24 |
| 2012/13 | | 42.74[4/] | 19.02[3/] | | | |

Notes:
1/ Biomass and threshold definitions based on survey estimates derived using fixed 50 ft net width area-swept calculations.
2/ Based on the mean 1974-1980 MMB at mating using revised survey biomass estimates in the Tier-4 survey-based assessment.
3/ Based on a Tier-3 assessment where the $B_{35\%}$ proxy for $B_{MSY}$=22.80 thousand t.
4/ Projected 2012/13 MMB at mating fishing at the $F_{35\%}$ control rule in 2012/13.

In 2011/12, under the Tier-4 assessment, MMB was below MSST at the time of the 2011 survey, the 2011/12 fishery, and at mating time in February 2012. Overfishing did not occur in 2011/12 as total catch (1.24 thousand t) did not exceed the total catch OFL (2.75 thousand t). The 2011/12 MMB at the time of mating represented a ratio of 0.42 relative to $B_{MSY\ Proxy}$. The 2011/12 Tanner crab stock is overfished based on the Tier-4 assessment.

In 2011/12 under Tier-3 management and decisions by the CPT (September 2012), MMB at mating in 2011/12 (58.59 thousand t) represents a ratio of 2.57 relative to $B_{35\%}$ (22.80 thousand t). Thus, the 2011/12 stock is currently at 257.02% of $B_{35\%}$. The team concluded that the stock was not overfished in 2011/12, and that the stock was never below MSST 2009/10 as determined in the 2010 Tier-4 assessment (Rugolo and Turnock 2010).

## A. SUMMARY OF MAJOR CHANGES

### 1. Management of Fishery:

No changes relative to the 2011 Tanner crab SAFE (Rugolo and Turnock 2011b).

### 2. Input Data:

No changes with the exception of the inclusion with the 2011/12 survey and fishery data.

### 3. Assessment Methodology:

This stock assessment and fishery evaluation report is based on a length-based stock assessment model. The model was approved by the Council in June 2012 for use in stock status determination, setting overfishing definitions, and rebuilding analysis. For the 2011/12 stock status determination and the 2012/13 OFL-setting, the Tanner crab stock is promoted to Tier-3 status.

## B. RESPONSES to SSC and CPT COMMENTS

During the development of the TCSAM, we implemented extensive revisions following review comments and recommendations of the CPT, SSC and two Crab Modeling Workshops. Two periods of model revisions are described: the first, from May to September 2011, and the second from September 2011 to May 2012. Rugolo and Turnock (2011a) reported on model developments in this first period per reviews of the Crab Modeling Workshop (Martel and Stram 2011), SSC in March 2011, CPT in May 2011, and CPT and SSC in September 2011. The TCSAM was reviewed at a second Crab Modeling Workshop in January 2012 and revisions made based on consensus recommendations. Rugolo and Turnock (2012) reported on model developments in the model during this second period per reviews of the January 2012 Workshop.

### 1. Responses to SSC and CPT Comments

**June 2011 SSC Meeting**

In their review of the 2011 draft crab SAFE report, the SSC made the following comments on eastern Bering Sea Tanner crab:

- *Authors Rugolo and Turnock developed a draft assessment in which they responded to changes suggested by the CPT and SSC in 2010, and to recommendations of the Crab Workshop (February 2011) and the SSC in April 2011. The CPT was encouraged by the changes and felt progress was being made, although the model is not yet ready for use in the stock assessment. The strategy is to continue improvements and evaluate it for assessment purposes in May 2012. Following a recommendation from the Crab Workshop, years 1969 through 1974 were not used for data quality reasons. The period 1974 through 1980 is now the period used for determining reference biomass; given the shortness of this period, the SSC recommends strongly that this time period be evaluated as intended by the authors.*
- *The main issues that have arisen in past (model) reviews were discussed:*
  - *Hybrids: concerned that misidentification of hybrids might have degraded data quality. However only 1 hybrid has been seen in the survey in the last 8 years of legal Tanner size. The authors did not think this is a significant issue in recent years.*
  - *Early bycatch data in groundfish fishery - specifically, why is bycatch estimated to be so high in 1973/74 and 1974/75. Concerns raised about misidentification of snow crabs. The authors are examining this issue.*
  - *Patterns in survey length frequency. (See model scenarios below)*
  - *Lack of fit to survey biomass between 1983 and 1987. (See model scenarios below)*
- *The following model scenarios were decided at the CPT meeting:*
  - *Estimate survey catchability, Q, to see if this improves survey biomass fit in mid 1980s.*
  - *Include the underbag data.*
  - *Estimate growth and natural mortality with priors (important since growth data is borrowed from Kodiak).*
  - *Try different selectivity periods based on fishery changes.*
  - *Try dynamic initial biomass estimation.*
- *The SSC agrees with this plan of action.*
- *The CPT would wants to use Tanner model for population projections despite its lack of approval for assessment. The SSC urges caution proceeding in this direction. It's more appropriate that a model is accepted for assessment and then used for the projection. The CPT requested the authors proceed with the rebuilding model for evaluation in September 2011 if it can produce plausible results. Rebuilding scenarios would include no catch, bycatch only, different percentages of $F_{35\%}$, and the SOA harvest strategy. Recruitment scenarios could include random, a spawner-recruit relationship (SRR) model, a SRR with autocorrelation, an SRR with periodic behavior, and others. The SSC will review these scenarios and the performance of the model in September, 2011.*

The TCSAM has been extensively revised since the May 2011 CPT meeting. We formulated several model configurations to show the effects of principal changes to the model, and recommend a model that attended to the recommendations of the Crab Workshop, the SSC and plan team. The model is significantly improved over earlier intermediate versions seen by the Crab Workshop and SSC in April 2011. The CPT and SSC will review the model in September 2011.

The potential degradation of the Tanner retained catch by misidentification of hybrid crab was addressed. The early bycatch data in the groundfish fishery was validated. The *Base Model* estimates survey selectivity in the period (1982-1987) to improve survey biomass fit in the mid-1980s. The model estimates growth, natural morality on immature and mature male and female crab, and includes different directed and non-directed fishery selectivity periods to improve model performance.

**May 2011 CPT Meeting**

In their review of the draft 2011 SAFE, the CPT made the following comments and recommendations. Only comments on the assessment model are included here:

- *On the stock assessment model, the team encourages development and an update on the model in September 2011 focusing on model fits and to move forward as quickly as possible. Suggestions on the model by the team:*
    - *free up Q to address the residual pattern*
    - *include underbag data as it pertains to this assessment*
    - *free up as many parameters (e.g., growth, M) as possible perhaps – e.g., growth data are not from the Bering Sea*
    - *examine length compositions and other data sources to evaluate model fit to the survey data, particularly in the early years.*
    - *consider a large number of selectivity time-blocks to see what the data want, then explore if reasons to justify choices of selectivity time-blocks*
    - *examine dynamic $B_0$, i.e. what would have happened has the fishery never occurred*
- *The team discussed how to develop and analyze rebuilding plan alternatives in absence of a model. Without an approved assessment model, it's not possible to estimate the required pieces of a rebuilding plan: minimum time to rebuild, target time to rebuild, and harvest rate that would achieve rebuilding in the target time period. Or to evaluate different rebuilding options. The team will develop rebuilding plan alternatives in September 2011 as the structure of the alternatives will be driven by whether the assessment model can be used. The model could be used for initial projection of the time frame to rebuild and which can be updated as the model improves. The team recommended going forward with projection model focusing on recruitment; it should be possible to use the model to develop a rebuilding plan if the model is sufficiently close to acceptance in September.*

The TCSAM has been extensively revised since the May 2011 CPT meeting and showed improved performance over earlier intermediate versions seen by the Crab Workshop, SSC in April 2011 and CPT in May 2011. The authors recommend a *Base Model* of demonstrating improved performance modeling stock and fishery dynamics and presented results of a stock projection model run using the *Base Model* configuration as a case example of its utility for rebuilding analysis.

In the *Base Model*, survey Q is freed in the three time periods and informed by the results of the underbag study. Male and female growth, and immature and mature male and female natural mortality are estimated. We examined the length compositions and all data to evaluate survey data fit, and modified the model accordingly. We implemented several selectivity time-blocks in the directed and non-directed fisheries to explore data fits and adopted time-blocks as required.

**May 2012 CPT and June 2012 SSC Meetings**

In their review of the TCSAM, the CPT and SSC made the following comments and recommendations for September 2012. Recommendations are grouped in two categorizes – those related to model output or presentation, and those related to model code revisions. The Council recommended a set of '*Longer-Term Tasks*' that the authors should consider as long-term research goals.

***1. Model Output or Presentation Issues:***

- *Update the weights in Table 8 (all LF weights = 1.0) and replace weights by CVs where possible.*
- *Plot input sample sizes for LF data vs. effective sample sizes inferred by the fit of the model.*
- *Indicate reference size for survey Q on plots of survey Q vs. length.*
- *Include a summary of the Somerton and Otto (1999) underbag experiment. Confirm the variance of survey Q matches that assumed in model.*
- *Add an appendix which details the effort series and their derivation.*
- *Add formulae used to calculate input sample sizes.*
- *Add equations on how full-selection F is calculated for years without catch using effort and a fishing mortality relationship.*
- *Update the plot of M vs. time for Bristol Bay red king crab.*
- *Check bubble plots are based on Pearson residuals and add key to indicate what largest circle means.*
- *Check that summary plots are sums over observed and predicted proportions.*
- *Add confidence intervals on the data to the summary plots for the compositional data.*
- *Label selectivity pattern plots better to indicate which curve applies to which year.*
- *Clearly indicate the current year on OFL Control Rule Figure 39.*
- *Add horizontal lines to effective sample size Figure 1 of the average input effective sample size by fleet.*
- *The model estimate of population biomass at the time of the survey should be a dotted line while the model estimate of survey biomass should be a solid line for Figures 17 & 18.*
- *Include a plot of the fits to survey biomass from reference model presented to September 2011 CPT meeting, the model at the end of the January 2012 workshop, and the May 2012 reference model.*
- *Since there are potentially a large number of runs, the document should contain results and diagnostics for reference model, as well as plots of recruitment and MMB time-series, and tables of likelihood components for the remaining runs. The full set of diagnostic plots should be made available electronically (e.g., using a "Dropbox")*

We've completed all output and presentation recommendations with the exception of #2 and #11. The effort time series data obtained from the SOA are provided in Appendix B. We recommend anyone interested in the details on how these data were gathered to contact the SOA. We've not yet added CIs to the summary plots of length compositions (#11) and will do so in the next release of the document.

***2. Model Code Revisions:***

- *Use ADMB derivative checker to check for impacts of non-differentiability of objective function implemented in the code.*
- *Explore sensitivity of dropping lower bound for input sample sizes (a lower bound of 4 was imposed for reference model).*
- *Explore sensitivity of allowing input sample sizes for survey LF to vary over time – if there's basis that some years better estimate of length composition than other years.*
- *Allow for a difference in selectivity by sex for groundfish fishery**;** resolves poor residual pattern.*
- *Allow M for immature as well as mature males to change during 1980-83.*
- *Include the following model runs for September 2012:*
    - *The current reference model (as modified by 3rd and 4th bullet).*
    - *Alternative specifications related to Ms (1-run as modified by 5th bullet).*

- *A likelihood profile for survey-q for males.*
- *Alternative specification related to dropping lower bound for input sample sizes.*
- *Runs identified in ToR (e.g., retrospective patterns & runs based on changing emphasis on different likelihood components).*

We've completed all model code revisions with the exception of the last sub-bullet to #6. We've not conducted retrospective analysis of the models presented here nor conducted runs based on changing emphasis on different likelihood components.

***3. Long-Term Research:***

- *Consider implementing changing penalty weight on F-deviations as function of estimation phase.*
- *Consider treating all of F-deviations (except for which catch is known to be zero) as parameters, and include the fishing mortality-effort relationship as a prior.*
- *Consider different input sample sizes for each category of survey compositional data (e.g., males, females, mature, immature).*
- *Consider fitting to total biomass (by sex?) and compositional data rather than mature biomass, and include the fit to the mature biomass by sex as a diagnostic.*
- *Do not fit to male compositional data by maturity state for the years for which chela height – maturity relationships are not available.*
- *Base the assessment on code which is fully documented and for which the objective function is differentiable.*

The Council recommended that the authors should consider these items as long-term research goals for the model. The objective function of the assessment model is fully differentiable (#6).

## C. INTRODUCTION

Tanner crab *Chionoecetes bairdi* is one of five species in the genus *Chionoecetes*. The common name for *C. bairdi* of "Tanner crab" (Williams et al. 1989) was recently modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" has also been used to refer to other members of the genus, or the genus as a whole. Hereafter, the common name "Tanner crab" will be used in reference to "southern Tanner crab".

Tanner crabs are found in continental shelf waters of the north Pacific. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974) and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a) where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east.

In the eastern Bering Sea (EBS), the Tanner crab distribution may be limited by water temperature (Somerton 1981a). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break, although sub-legal sized males (≤138 mm cw) and ovigerous and immature females of all sizes are distributed broadly from southern Bristol Bay northwest to St. Matthew Island (Rugolo and Turnock 2011a). The southern range of the cold water congener the snow crab, *C. opilio*, in the EBS is near the Pribilof Islands (Turnock and Rugolo 2011b). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 60°N, and in this area, the two species hybridize (Karinen and Hoopes 1971).

### 1. Stock Structure

Tanner crabs in the EBS are considered to be a separate stock distinct from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). The unit stock is that defined across the geographic range of the EBS continental shelf, and managed as a single unit (Figure 8). Somerton (1981a) suggests that clinal differences in some biological characteristics may exist across the range of the unit stock. These conclusions may be limited since terminal molt at maturity in this species was not recognized at the time of that analysis, nor was stock movement with ontogeny considered. Biological characteristics estimated based on comparisons of length frequency distributions across the range of the stock, or on modal length analysis over time may be confounded as a result.

Despite the custom of setting management controls for this stock east and west of 166° W longitude, the unit stock of Tanner crab in the EBS comprises crab throughout the geographic range of the NMFS bottom trawl survey. Evidence is lacking that the EBS shelf is member to two distinct, non-intermixing, non-interbreeding stocks that can be assessed and managed separately.
Given the distribution of the stock over its range and its availability to the fisheries, partitioning the total catch OFL may be possible to allow setting TACs or issuing of IFQs for the eastern and western area fisheries consistent with the total catch OFL.

## D. FISHERY HISTORY

### 1. Management Unit

Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the EBS is managed under a federal fisheries management plan (NPFMC 1998). The plan defers certain management controls for Tanner crab to the State of Alaska (SOA) with federal oversight (Bowers et al. 2008). The SOA manages Tanner crab based on registration areas divided into districts. Under the plan, the state can adjust or further subdivide districts as needed to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 1998).

The Bering Sea District of Tanner crab Registration Area J (Figure 8) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36’ N lat. and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173° W longitude. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W longitude and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008).

In March 2011, the Alaska Board of Fisheries approved a new minimum size limit strategy for Tanner crab effective for the 2011/12 fishery. The minimum legal size limit was 5.5” (138 mm cw) throughout the Eastern Subdistrict. The new regulations established different minimum size limits east and west of 166° West longitude. That for the fishery to the east will be 4.8” (122 mm cw), and that to the west will be 4.4” (112 mm cw). The industry may self-impose retention of crab above 5.5” (138 mm cw) and 5” (>127 mm cw) east and west of 166° West longitude, respectively.

The domestic Tanner crab pot fishery rapidly developed in the mid-1970s (Table 1, Figure 9). For stock biomass and fishery data tabled in this document, the convention is that ‘year’ refers to the survey year (t), and fishery data are those subsequent to the survey (t+1) through prior to year t+1 – e.g., 2008/09 is the 2008 summer survey and the winter 2009 fishery. Other notation is explicit. United States landings were first reported for Tanner crab in 1968 at 0.46 thousand t taken incidentally to the EBS red king crab fishery (Table 1). Tanner crab was targeted thereafter by the domestic fleet and landings rose sharply in the early-1970s, reaching a high of 30.21 thousand t in 1977 (Table 1, Figure 9). Landings fell sharply after the peak in 1977 through the early 1980s, and domestic fishing was closed in 1985 and 1986 due to depressed stock status. In 1987, the fishery reopened and landings rose again in the late-1980s to a second peak in 1990 at 18.19 thousand t, and then fell sharply through the mid-1990s. The domestic Tanner crab fishery closed between 1997 and 2004 as a result of conservation concerns regarding depressed stock status. The domestic Tanner crab fishery re-opened in 2005 and has averaged 0.77 thousand t retained catch between 2005-2009/10 (Table 1). Landings of Tanner crab in the Japanese pot and tangle net fisheries were reported between 1965-1978, peaking at 19.95 thousand t in 1969. The Russian tangle net fishery was prosecuted between 1965-1971 with peak landings in 1969 at 7.08 thousand t. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late-1970s (Table 1, Figure 9).

For the 2010/11 and 2011/12 seasons, the SOA closed directed commercial fishing for Tanner crab due to estimated female stock metrics threshold in the state strategy.

Discard and bycatch losses of Tanner crab originate from the directed pot fishery, non-directed snow crab and Bristol Bay red king crab pot fisheries, and the groundfish fisheries (Table 2). Discard mortalities were estimated using post-release handling mortality rates (HM) of 50% for pot fishery discards and 80% for groundfish fishery bycatch (NPFMC 2008). The pattern of total discard/bycatch losses is similar to that of the retained catch (Table 1). Losses were persistently high during the early-1970s; a subsequent peak mode of discard losses occurred in the early-1990s. In the early-1970s, the groundfish fisheries contributed significantly to total bycatch losses, although the combined crab pot fisheries are the principal source of contemporary non-retained losses to the stock. Tanner crab predicted retained plus discard catch in the directed fishery (Table 3, Figure 10) and bycatch losses of male and female crab in the non-directed fisheries (Table 4) reflect the performance patterns in the directed and non-directed fisheries. Total male catch rose sharply with fishery development in the early-1960s and reveals a bimodal distribution between 1965 and 1980 (Table 5, Figure 10). Total male catch rose sharply after the directed domestic fishery reopened in 1987 and reached a peak of 45.07 thousand t in 1990 (Table 5). Total male and female catch fell sharply thereafter with the collapse of the stock and the fishery closure in 1997.

After the Tanner crab stock declined to low levels by the early-1980s, retained catches were low and variable. Since the re-opening in 2005, retained catch has routinely been below the total catch OFL. A specialized directed Tanner crab fishery has not developed since 2005 due to low quota sizes, and the majority of catch is taken incidentally in the Bristol Bay red king crab fishery and the snow crab fishery that hold Tanner shares. After the development of the domestic fleet in late-1970s, the contribution to total catch from a specialized directed fleet versus incidental catch by the snow and red king crab fisheries is not well understood and, unlike the snow crab and Bristol Bay red king crab fisheries with defined fishing practices (e.g., seasons, areas and gear), the current directed Tanner crab fishery is much less defined.

## 2. Exploitation Rates

The historical patterns of fishery exploitation on legal male biomass and male mature biomass were derived. The exploitation rate on LMB was estimated as the predicted retained catch biomass divided by the estimated legal male biomass at the time of the fishery, while that on MMB as the predicted total catch biomass (retained plus discard) divided by the estimated male mature biomass at the time of the fishery. The patterns of exploitation rates on LMB and MMB are similar over the period of record, 1969-2011 (Figure 11). Exploitation rates were high in the late-1970s to early-1980s and fell with stock condition through the mid-1980s, followed by a second period of prominent rates during the early-1990s. The pattern of fishery exploitation of this stock coincides with the modes of high catches in the late-1970s and the early-1990s (Table 5, Figure 10). These high rates of exploitation on MMB and LMB exceed the mortality at M=0.23 for this stock; the EBS Tanner crab stock did not persist at sustainable levels subjected to these rates. Rugolo and Turnock (2011b) discuss the history of exploitation rates on the male Tanner crab stock based on observed survey data and conclude that these exceeded rates would be deemed biologically reasonable, and led to the erosion of stock biomass. Exploitation rates on mature and legal male biomass since the start of the rebuilding plan in 1998 have been low (Table 6).

## E. DATA

### 1. The Survey

The NMFS conducts an annual bottom trawl survey in the EBS to determine the distribution and abundance of commercially-important crab and groundfish fishery resources (Foy and Armistead 2012). The survey has been conducted since 1968 by the Resource Conservation and Engineering Division of the Alaska Fisheries Science Center. In 1975, it was expanded into Bristol Bay and the majority of the Bering Sea continental shelf. Since 1988, 376 standard stations have been included in the survey covering a 150,776 $nm^2$ area of the EBS with station depths ranging from 20 to 150 meters depth. The annual collection of data on the distribution and abundance of crab and groundfish resources provides fishery-independent estimates of population metrics and biological data used for the management of target fishery resources. Crustacean resources targeted by this survey are red king crab (*Paralithodes camtschaticus*), blue king crab (*P. platypus*), hair crab (*Erimacrus isenbeckii*), Tanner crab (*Chionoecetes bairdi*) and snow crab *(C. opilio*). The sampling methodology specifies the majority of tows made at the centers of squares defined by a 20 x 20 nmi (37 x 37 km) grid (Chilton et al. 2011). Near St. Matthew Island and the Pribilof Islands, additional tows are made at the corners of squares that define high density sampling strata for blue king crab and red king crab.

The 83-112 eastern otter trawl (83 ft/25.3 m headrope and 112 ft/34.1 m footrope) has been the standard gear since 1982. Each tow is approximately 0.5 h in duration towed at 3 knots conducted in accordance with established NMFS groundfish bottom trawl protocols (Stauffer 2004). Between 1968-1981, the 400 eastern otter trawl was the survey gear deployed and towed for approximately 1.0 h at 2.0 knots. Crabs are sorted by species and sex, and then a sample of the catch measured to the nearest millimeter to provide a size-frequency distribution. Derived population metrics are indices of relative abundance and biomass and do not necessarily represent absolute abundance or biomass. They are most precise for large crabs, and are least precise for small crabs due to gear selectivity, and for females of some stocks due to behavior. The observed male, female and total mature biomass, and observed abundance of legal male Tanner crab are shown in Table 7).

### 2. Data Sources

Estimates of Tanner crab stock biomass, population metrics and length frequencies from the trawl survey used in this assessment were based on area-swept calculations using measured net widths for 1974-2012. As recommended by the Crab Workshop (Martel and Stram 2011), 1969-1973 survey data are excluded from the analysis. The pre-1974 survey did not consistently sample Tanner habitat which resulted in variable and biased low biomass estimates and length frequency distributions. Each year from 1969-1973 represented a unique coverage ranging from 25% to 72% of the total Tanner distribution sampled since 1978 (Foy, pers. comm.). The male and female 5 mm length frequency abundance observed in the survey for 1969-2012 are shown in Figure 6 and Figure 7, respectively.

Size frequency data on retained Tanner crab in the directed fishery from 1981-1996 and 2005/06 to 2011/12 seasons were used in the analysis. Observers were placed on board directed crab vessels starting in 1990, and dockside sampling of the retained catch began in 1981. Length frequency data on the total catch and the retained catch in the directed fishery were available from 1991-2011/12 and 1981-2011/12 absent fishery closures. Retained catch data were available for 1974-2011/12. Total discard catch biomass was estimated from observer data from 1991 to 2011/12. The discard male catch was estimated from 1969-1990/91 in the model using the estimated fishery selectivity based on observer data from 1991-2011/12 and an applied post-release mortality rate of 50% for pot released crab. Male and female length frequency and catch biomass data in the snow crab fishery were available from 1989-2011/12.

Male and female length frequency and catch biomass data in the Bristol Bay red king crab fishery were available from 1989-1993 and 1996-2011/12. Trawl discard catch biomass estimates and the length frequency of discard crab included in the model were from 1973 to 2011/12.

The following table contains the various Tanner crab data components used in the model,

| Data Component | Years |
|---|---|
| Retained length frequency by shell condition of male crab in directed fishery | 1981-1996, 2005-2011/12 |
| Total catch length frequency of male and female crab in directed fishery | 1991/92-1996/97, 2005/06-2011/12 |
| Male and female length frequency and catch in snow crab fishery | 1989/90-2011/12 |
| Male and female length frequency and catch in red king crab fishery | 1989-1993, 1996-2011/12 |
| Retained catch in directed fishery | 1969-2011/12 |
| Trawl discard catch and length frequency | 1973-2011/12 |
| Survey length frequency by sex and shell condition | 1974-2012 |
| Survey biomass estimates and coefficients of variation | 1974-2012 |

## F. LIFE HISTORY

### 1. Reproduction

In most majid crabs, the molt to maturity is the final or terminal molt. For *C. bairdi*, it's now accepted that both males (Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo terminal molt at maturity. Females terminally molt from their last juvenile, or pubescent, instar usually while being grasped by a male (Donaldson and Adams 1989). Subsequent mating takes place annually in a hard shell state (Hilsinger 1976) and after extruding their clutch of eggs. While mating involving old-shell adult females has been documented (Donaldson and Hicks 1977), fertile egg clutches can be produced in the absence of males by using stored sperm from the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Two or more consecutive egg fertilization events can follow a single copulation using stored sperm to self-fertilize the new clutch (Paul 1982, Adams and Paul 1983), however, egg viability decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically. Physiological maturity refers to the presence or absence of spermataphores in the gonads whereas morphometric maturity refers to the presence or absence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). While many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow, there is now substantial evidence supporting a terminal molt for males (Otto 1998, Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never recruit to legal size (NPFMC 2007).

Although observations are lacking in the EBS, seasonal differences have been observed between mating periods for pubescent and multiparous females in the Gulf of Alaska and Prince William Sound. There, pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the EBS, egg condition for multiparous Tanner crabs assessed between April and July 1976 also suggested that hatching and extrusion of new clutches for this maturity status began in April and ended sometime in mid June (Somerton 1981a).

**2. Fecundity**

A variety of factors affect female fecundity including somatic size, maturity status (primiparous vs. multiparous), age post terminal molt, and egg loss (NMFS 2004a). Of these factors, somatic size is the most important, with estimates of 89 to 424 thousand eggs for females 75 to 124 mm cw respectively (Haynes et al. 1976). Maturity status is another important factor affecting fecundity with primiparous females being only ~70% as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt, and whether or not, a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., barren) suggesting that female crab reproductive output is a declining function of age (NMFS 2004a).

The fraction of barren mature females by shell condition (Figure 12) and the fraction of mature females with clutches one-half full or less by shell condition (Figure 13) are shown. After 1991, 20-40% of new shell females brooded clutches less than or equal to 50% full, and in 2009 this number was approximately 23%. We developed a Egg Production Index (EPI) by female shell condition that incorporates observed clutch size measurements taken on the survey and fecundity by carapace width for 1976-2009 (Figure 14). Figure 14 also presents estimates of male and female mature biomass relative to the shell condition class EPIs in these years. Although male and female mature biomass increased after 2005, egg production does not increase proportionally to mature biomass.

**3. Size at Maturity**

We estimated the maturity at length schedules for male and female Tanner crab from extant trawl survey data. For females, egg and maturity code information collected on the survey from 1976-2009 was analyzed to estimate the maturity curves for new shell females, and for the aggregate class of females all shell conditions combined (Figure 15). $SM_{50\%}$ for females all shell classes combined was estimated to be 68.8 mm cw, and that for new shell females was 74.6 mm cw. For males, data from the 2008 collection of morphometric measurements taken at 0.1 mm in 2008 on the NMFS survey served to derive the classification rules between immature and mature crab based on chela allometry using the mixture-of-two-regressions analysis. We estimated classification lines between chela height and carapace width defining morphometric maturity for the unit Tanner crab stock, and for the sub-stock components east and west of $166^0$ W longitude. These rules were then applied to historical survey data from 1990-2007 to apportion male crab to immature and mature population mature at length. We examined and found no significant differences between the classification lines of the sub-stock components (E and W of $166^0$ W longitude), or between the sub-stock components and that of the unit stock classification line. $SM_{50\%,}$ for males all shell condition classes combined was estimated to be 91.9 mm cw, and that for new shell males was 104.4 mm cw (Figure 16). By comparison, Zheng (1999) in development of the current SOA harvest strategy used knife-edge maturity at >79 mm cw for females and >112 mm cw for males.

The maturity curve for new shell females can be considered to represent the conditional probability of new shell immature females maturing given a representative sample of the length composition in the stock by shell condition class and no error in shell classification. For the *Model(0)* run presented here, the probability of maturing by size for males and females was estimated in the model with the constraint to be a smooth function (Figure 17). For comparison, the probability of new shell immature males maturing used by Zheng in the Amendment 24 analysis of overfishing definitions is shown in which $SM_{50\%}$=130.9 mm cw (NPFMC 2007) (Figure 17). We allow the assessment model to estimate a smooth function for both sexes that represents the probability that a new shell immature crab will molt to maturity which is distinguished from the average fraction of new shell mature crabs in the stock.

**4. Mortality**

Due to the lack of age information, Somerton (1981a) estimated mortality separately for individual EBS cohorts of juvenile (pre-recruit) and adult Tanner crab. Somerton postulated that because of net selectivity, age five crab (mean cw=95 mm) were the first cohort to be fully recruited to the gear; he estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using this analysis with two different data sets, Somerton estimated natural mortality rates of adult male crab from the fished stock to range from 0.20 to 0.28. When using CPUE data from the Japanese fishery, estimates of M ranged from 0.13 to 0.18. Somerton concluded that M estimates of 0.22 to 0.28 estimated from models that used both the survey and fishery data were the most representative.

We examined empirical evidence for reliable estimates of oldest observed age for male Tanner crab. Unlike its congener the snow crab, information on longevity of the Tanner crab is lacking. We reasoned that longevity in a virgin population of Tanner crab would be analogous to that of the snow crab (Turnock and Rugolo 2011) given the close analogues in population dynamic and life-history characteristics, where longevity would be at least 20 years. Employing 20 years as a proxy for longevity and assuming that this age represents the upper $98.5^{th}$ percentile of the distribution of ages in an unexploited population if observable, M is estimated to be 0.23 (Hoenig 1983). If 20 years is assumed to represent the 95% percentile of the distribution of ages in an unexploited stock, M is estimated to be 0.15. We adopted M=0.23 for both male and female Tanner crab in this analysis. This value corresponds with the range estimated by Somerton, and to the value used in the analysis to estimate new overfishing definitions which underlie Amendment 24 to the management plan (NPFMC 2007).

In the *Base Model (0)*, we allow the model to estimate M mature male crab, mature female crab, and for immature crab pooled by sex.

**5. Growth**

We derived growth relationships for male and female Tanner crab using data collected in the Gulf of Alaska near Kodiak (Munk pers. comm., Donaldson et al. 1981). Growth relationships were based on observed growth data for males to approximately 140 mm cw and for females to approximately 115 mm cw (Figure 10). Somerton (1981a) estimated growth for EBS Tanner crab based on modal size frequency analysis of Tanner crab in survey data assuming no terminal molt at maturity. This approach did not directly measure molt increments and Somerton's findings are constrained by not considering that the progression of modal lengths between years was biased since crab ceased growing after their maturity molt. We compared our growth per molt (gpm) relationships with those of Stone et al. (2003) for Tanner crab in southeast Alaska in terms of the overall pattern of gpm over the size range of crab. We found that the pattern of gpm for both males and females is characterized by a higher rate of growth to an intermediate size (90-100 mm cw) followed by a decrease in growth rate from that size thereafter (Figure 18). Such shaped growth curves are corroborated in work of Stone et al. (2003), Somerton (1981), Donaldson et al. (1981) and in the data of Munk. We modeled the relationship between pre-molt and post-molt size for males and females as a two parameter exponential function of the general form $y=ax^b$ where $y$=post-molt and $x$=pre-molt carapace width. The fitted growth relationship for males is $y=1.550x^{0.949}$, and that for females is $y=1.760x^{0.913}$.

**Weight at Length**

We derived weight at length relationships for male, immature female and mature female Tanner crab based on special collections of length and weight data on the summer trawl survey in 2006, 2007 and

2009 (Figure 19). The fitted weight (*kg*)-length (*mm cw*) relationship for males of shell condition classes 2 (SC2) through class 5 (SC5) inclusive is: $W=0.00016(cw)^{3.136}$. Those for immature (SC2) and mature (SC2-SC4) females are, respectively, $W=0.00064(cw)^{2.794}$ and $W=0.00034(cw)^{2.956}$.

## G. THE MODEL

We formulated a length-based assessment model for Tanner crab to characterize the performance of the stock and serve in estimating overfishing definitions. The model was initiated in 1950 to estimate recruitments to build the stock to fit initial observed biomass and length frequencies starting in 1974. Thirty-two 5mm length bins from 25-29 mm to a cumulative plus-group at 180-184 mm are modeled.

Fishery-independent estimates of biomass, population metrics and length frequency distributions used in the analysis were from NMFS trawl survey for 1974-2012. We estimated biological characteristics of male and female crab such as weight-length relationships, maturity schedules and growth functions from extant survey and experimental data, and from the literature to complete model parameterization. All component fishery-dependent data on Tanner crab were employed. Retained catch data in the domestic and foreign fisheries were available for 1965-2012. Retained male length-frequency by shell condition (1981-2012) and discard length frequency (1991-2012) for male and female crab in the directed fishery were incorporated. Sex-specific length frequencies of discarded crab in the snow crab and Bristol Bay red king pot fisheries (1989-2012), and from groundfish fisheries (1973-2012) were used to characterize non-directed stock losses and fishery performance.

Male and female survey selectivity were estimated for two time periods (1974-1981, 1982-2012) to address survey design and gear changes. Survey selectivity was estimated for each sex in both periods. In the most recent period, a prior on Q of 0.88 (cv-0.05) was used to inform male and female selectivity based on the net selectivity experiment of Somerton and Otto (1999). Fishery selectivity curves for the directed and all non-directed fleets were estimated for males and females over various periods. Post-release mortality for the pot discarded crab was set at 50%, and that for trawl discards set at 80%. Population dynamics in the model are separated by maturity status, shell condition class and sex. Estimated survey mature biomass is fit to observed mature biomass by sex, and survey length frequency is fit to immature and mature crab separately for each sex for the combined shell condition class. Model performance is evaluated by the fit to observed survey and fishery data.

The target biomass reference point of $B_{35\%}$ can be derived using model estimates of MMB over a reference time period (e.g., 1974-1980) representative of the proxy $B_{MSY}$, or as the product of mean recruitment (e.g., 1962-1974) which gave rise to the reference biomass and spawning biomass per recruit fishing at $F_{35\%}$. Mature male biomass at the nominal time of mating is the population metric used to gauge stock status relative to the limit reference point ($B_{MSY}$ or proxy $B_{MSY}$) and to derive the overfishing limit ($F_{OFL}$) from the control rule. The Tanner crab stock declined from high biomass levels early-1970s to low levels in the 1980s. The stock was under a rebuilding plan from 1999-2007 and the fishery closed in 1985-1986, 1997-2004, 2010 and 2011 due to conservation concerns. The stock was declared overfished in 2010. A rebuilding plan must be implemented in 2012 for the 2012/13 fishing season.

For the *Base Model (0)*, we estimated $B_{35\%}$=161.37 thousand t and $F_{35\%}$=0.612. The model estimate of 2010/11 MMB at mating (65.40 thousand t) represents $0.41B_{35\%}$. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $0.36B_{35\%}$.

## H. MODEL CONFIGURATION

We formulated a *Base Model (0)* that attends to recommendations of the CPT through May 2012 and SSC through June 2012. The base model represents the best available science in modeling the Tanner crab stock and fishery dynamics in the author's view. We formulated one alternative *Model (1)* to address discussion of the CPT (May 2012) to explore the sensitivity of allowing natural mortality to be estimated on immature male and female crab during 1980-84. *Model (2)* is presented for reference as it's the unmodified *Base Model (0)* that uses the earlier scaled sample size weights in the length-frequency multinomial likelihood with the minimum constraint n=4.

*Model (0)* is the model approved by the CPT (May 2012) and SSC (June 2012) for assessment and OFL-setting. For *Model (1),* the issue of whether M increased on immature crab during 1980-84 bears further examination. Table 14 presents the change in male and female biomass of Tanner crab observed in the bottom trawl survey in 1980-1985 for customary size groups. The change in biomass in the smallest groups (males≤109 mm cw, and females <85 mm cw) implies an increase in mortality of immature crabs although that's not demonstrated in these data. At 109 mm cw, males are approximately 70% mature, and at 85 mm cw females are approximately 98% mature. Thus, a relatively large percentage of mature individuals comprise these smallest size groups for both sexes.

Analysis is required to examine the status of immature biomass over 1980-85 which should address the issue of errors in shell aging and survey selectivity at small size. A consideration in interpreting *Model (1)* results is that since the model is fit to mature biomass, it can account for the decline in mature biomass by an increase in mortality on immature crab that recruit to the mature stock. Such an increase does not necessarily reflect a change in environmental processes that increase natural mortality on immature crabs.

The argument for including the 1980-84 mortality period in the assessment model was that, given their co-occurrence, the processes operating on Bristol Bay red king crab in these years also operate on Tanner crab. As shown (Section H. Results), estimating immature M in *Model (1)* affects the estimate of mature M on males in 1980-84 but not that on mature females relative to *Model (0)* (*see* Figure 22). Estimated mortality on mature males in *Model (0)* (0.72) correspond to that estimated on mature male red king crab (0.74) (*see* Figure 23), while M on mature male Tanner estimated in *Model (1)* (0.44) is lower. In terms of environmental processes, we lack understanding as to why M on mature male crab would decline between *Model (0)* and *Model (1)* in 1980-84 (0.74 to 0.44) but remain unchanged on mature females (0.25 to 26) other than *Model (1)* sufficiently accounts for the decline in mature male biomass by increasing immature M. This is contrary to the assumption that equivalent processes affect Bristol Bay red king crab and Tanner crab.

Results of *Model (1)* or derivative configurations to *Model (0)* bear further examination. One question is that if environmental processes modulating natural mortality are indiscriminate with respect to sex (e.g., predation, temperature effects, habitat change), it's unclear as to why *Model (0)* and *Model (1)* produce identical estimates of mature female M during 1980-84 and outside this period, while that for immature pooled sexes differs dramatically between *Model (0)* and *Model (1)* (*see* Figure 22).

The summary specification of the ***Base Model (0)*** is:

**i. Survey Selectivity:**
The 50%, Q and difference (95%-50%) parameters of the logistic function are estimated for both males and females in 2 periods, 1974-1981, 1982-2012.

**ii. Directed Fishery Selectivity:**
A retention function and total selectivity are estimated in 2 periods: retention function (1981-1990 and 1991-2010); total selectivity (1991-1996 and 2005-2010) with annual varying mean (50%) in periods 1991-1996 and 2005-2010/11.

**iii. Snow Crab Fishery Discard Selectivity:**
Selectivity is estimated in 3 periods, 1989-1996, 1997-2004 and 2005-2011/12. In each period, one selectivity curve for males and females.

**iv. Bristol Bay Red King Crab Fishery Discard Selectivity:**
Selectivity is estimated in 3 periods, 1989-1996, 1997-2004 and 2005-2011/12. In each period, one selectivity curve for males and females.

**v. Groundfish Fishery Discard Selectivity:**
Selectivity is estimated in 3 periods, 1973-1986, 1987-1996 and 1997-2012. In each period, one selectivity curve for males and females.

**vi. Growth:**
The *a* and *b* parameters of exponential growth for males and females are estimated, all years.

**vii. Natural Mortality:**
Immature M (pooled sexes), mature male M and mature female M are estimated, all years.

**viii. Recruitment Periods:**
Recruitment is estimated in 2 periods, 1950-1973 and 1974-2012 with a first-difference penalty in the early period.

**ix. Maturity:**
A maturity function that defines the probability of an immature crab molting to maturity for males and females is estimated, all years.

**x. Sample Size Weights on LFs:**
Annual sample sizes (n) for the directed retained fishery were estimated based a factor which scaled the overall mean to 200. All annual fleet samples sizes were scaled using this factor with the constraint not to exceed n=200. Ns for survey LFs=200 for male and female.

**xi. Additional Mortality Episode:**
Implemented for mature male and female crab during 1980-84 in a manner analogous to the 2011/12 Bristol Bay red king crab assessment (Zheng 2011).

**xii. Non-directed Pot Fishery Effort:**
Snow crab and Bristol Bay red king crab fishery pot lift data used to estimate Tanner crab discards pre-1992 prior to the availability of discard data.

**xiii. Penalty on Directed Fishing Mortality Deviations:** the F penalty is set to 1.0.

Specifications for the three model configurations in this analysis are:

Model 0: *Base Model*
Model 1: *Base Model* modified such that additional mortality is estimated for immature male and female crab (pooled) during 1980-84.
Model 2: *Base Model* unmodified but uses old scaled sample size weights on the length-frequency multinomial likelihood with the minimum constraint n=4.

| **Model:** | **Specification** |
|---|---|
| 0 | Base Model |
| 1 | Base Model *but* M estimated immature males and females in 1980-84. |
| 2 | Base Model *but* M uses sample size weights with minimum n=4. |

# I. MODEL APPROACH

***History of Approaches***

***Tier-4 Stock Designation***

Through the 2011/12 season, Tanner crab was managed as a Tier-4 stock using a survey-based assessment approach (Rugolo and Turnock 2011b). In 2010, MMB fell below the minimum stock size threshold at survey time (MSST=0.5 $B_{MSY\ Proxy}$) (Rugolo and Turnock 2010). The status determination criterion, $B_{MSY\ Proxy}$, was 83.80 thousand t and the overfished status criterion, MSST, 41.90 thousand t. After accounting for stock losses from M and those in the 2009/10 fisheries, the 2010 MMB at the time of mating was 28.44 thousand t and represented a ratio of 0.34 relative to $B_{MSY\ Proxy}$. The Tanner crab stock was determined to be overfished in 2019 by NOAA Fisheries and in need of a rebuilding plan.

For the 2010/11 status determination, the status criterion, $B_{MSY\ Proxy}$, was 83.33 thousand t and the overfished criterion, MSST, 41.67 thousand t (Rugolo and Turnock 2011 b). After accounting for stock losses due to M and the 2010/11 non-directed pot and groundfish fisheries, the 2011 MMB at the time of mating was 26.73 thousand t. This represented a ratio of 0.32 relative to $B_{MSY\ Proxy}$ which remained below the limit that defines an overfished stock. There was no change in the 2010/11 stock relative to the overfished determination made in 2010.

For the current 2011/12 stock status determination under Tier-4 management, after accounting for losses from M and the 2011/12 non-directed pot and groundfish fisheries, the 2012 MMB at the time of mating is 34.67 thousand t. This represents a ratio of 0.42 relative to $B_{MSY\ Proxy}$ which remains below the limit of 41.67 thousand t that defines an overfished stock based on the Tier-4 assessment (Rugolo and Turnock 2011b). There is no change in the 2011/12 stock relative to the overfished determination made in 2010.

In Tier-4, a default value of M and a Gamma ($\gamma$) are used in OFL setting. The proxy for $B_{MSY}$ is the level of equilibrium stock biomass yielding MSY to fisheries whose mean performance is at $F_{MSY.}$ For Tier-4 stocks, the $B_{MSY\ Proxy}$ is the average biomass over a specified period that satisfies the expectation of equilibrium biomass yielding MSY at $F_{MSY}$. It can be estimated as a percentage of pristine biomass ($B_0$) of an unfished or lightly exploited stock where data exist. The $F_{OFL}$ is calculated as the product of $\gamma$ and M, where M is the instantaneous rate of natural mortality. The Amendment 24 and its Environmental Assessment (NPFMC 2008) define a default value of gamma=1.0. Gamma can be less than or greater than 1.0 resulting in overfishing limits more or less biologically conservative than fishing at M. Since Tier-4 stocks are information-poor by definition, the EA states that $\gamma$ should not be a value that would provide less biological conservation and more risk-prone overfishing definitions without defensible evidence that the stock could support fishing at levels in excess of M. The resultant overfishing limit for Tier-4 stocks is the total catch OFL that includes expected retained plus discard and bycatch losses. For Tier-4 stocks, a minimum stock size threshold (MSST) is specified; if current MMB is below MSST, the stock is overfished.

For Tier-4 stocks, the $F_{OFL}$ is derived using and $F_{OFL}$ Control Rule (Figure 8) according to whether current mature stock biomass (B) belongs to status levels a, b or c in the algorithm below. The stock biomass level beta ($\beta$) represents a minimum threshold below which directed fishing mortality is set to zero. The $F_{OFL}$ Control Rule sets $\beta$=0.25. The parameter alpha moderates the slope of the non-constant portion of the control rule. For biomass levels where $\beta<B\leq B_{MSY}$, the $F_{OFL}$ is estimated as a function of the ratio $B/B_{MSY}$. The value of M is 0.23 for eastern Bering Sea Tanner crab. For Tier-4 stocks, a reference biomass value ($B_{MSY\ Proxy}$) must is specified consistent with the expectation of a measure of equilibrium stock biomass ($B_{MSY}$) capable of yielding MSY to the fisheries operating at $F_{MSY}$.

| Stock Status Level: | | $F_{OFL}$: |
|---|---|---|
| a. | $B/B_{MSY\ Proxy} > 1.0$ | $F_{OFL} = \gamma M$ |
| b. | $\beta < B/B_{MSY\ Proxy} \leq 1.0$ | $F_{OFL} = \gamma M\ [(B/B_{MSY\ Proxy} - \alpha)/(1 - \alpha)]$ |
| c. | $B/B_{MSY\ Proxy} \leq \beta$ | Directed Fishery F=0 |
| | | $F_{OFL} \leq F_{MSY}$ |

***Tier-3 Stock Designation***

This stock assessment and fishery evaluation report is based on a length-based stock assessment model (TCSAM). The model was approved by the Council in June 2012 for use in stock status determination, setting overfishing definitions, and rebuilding analysis. For the 2012/13 stock status determination and OFL-setting, the Tanner crab stock is promoted to Tier-3 status.

The status of the 2011/12 Tanner crab stock under Tier-3 management is yet to be determined. It is unclear how results of the model that will be implemented for the 2012/13 fisheries can be applied retroactively for the 2011/12 stock status determination since the 2011/12 benchmark reference points and overfishing definitions were based on the survey-based Tier-4 assessment. For the 2012/13 fisheries, a Tier-3 status determination will depend on the value of the $B_{35\%}$ proxy for $B_{MSY}$ adopted by the Council in October 2012.

In Tier-3, the $B_{MSY\ Proxy}$ is estimated using results of a spawning stock biomass-per-recruit (spr) analysis as the product of $SPR_{\%MSP}$ and mean recruitment over a selected period representative of $B_{\%MSP}$. The management target, %MSP, is a specified level of maximum spawning potential, $SPR_0$. Through simulation, $SPR_0$ is estimated fishing at F=0, then $F_{\%MSP}$ found as that level resulting in the specified proportion (%MSP) of $SPR_0$. In the analysis of Tier-3 for snow crab, *C. opilio,* and red king crab, *P. camtschaticus*, a $B_{MSY}$ proxy reference value ($B_{MSY\ Proxy}$) equal to 35% of the maximum spawning potential of the unfished stock was specified (Annon 2008, EA associated with Amendment 24). For Tier-3 stocks under the plan, the $B_{MSY\ Proxy}$ is $B_{35\%}$ and $F_{MSY\ Proxy}$ is $F_{35\%}$.

**Model Description**

In this analysis, we developed a length-, sex-, maturity- and shell condition-structured model to characterize stock performance and serve the basis of estimating overfishing definitions. The model structure was developed following the methods of Fournier and Archibald's (1982) with many similarities to Methot (1990). The model was implemented using automatic differentiation software developed as a set of libraries under C++ (ADModel Builder). ADModel Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. This software provides the derivative calculations needed to find the objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest.

The model estimates recruitments beginning in 1950 to build the stock to fit initial observed survey data biomass and length frequency estimates beginning in 1974. This results in 20 additional recruitment parameters. There are 32, 5mm length bins in the model starting from 25-29 mm up to a cumulative bin at 180-184 mm.

**1. Recruitment**

Recruitment is determined from the estimated mean recruitment, the yearly recruitment deviations and a gamma function that describes the proportion of recruits by length bin,

$$N_{t,1} = pr_l \, e^{R_0^l + \tau_t}$$

where,

$R_0^l$ Mean recruitment

$pr_l$ Proportion of recruits for each length bin

$\tau_t$ Recruitment deviations by year.

Recruitment numbers are estimated equal for males and females in the model.

Crab were distributed into 5mm CW length bins based on a pre-molt to post-molt length transition matrix. For immature crab, the number of crabs in length bin *l* in year *t-1* that remain immature in year *t* is given by,

$$N_{t,l}^{s} = (1 - \phi_l^{s}) \sum_{l=l_1}^{l'} \psi_{l',l}^{s} \, e^{-Z_{l'}^{s}} N_{t-1,l'}^{s}$$

| | |
|---|---|
| $\psi_{l',l}^{s}$ | growth transition matrix by sex, pre-molt and post-molt length bins which defined the fraction of crab of sex *s* and pre-molt length bin *l'*, that moved to length bin *l* after molting, |
| $N_{t,l}^{s}$ | abundance of immature crab in year *t*, sex *s* and length bin *l*, |
| $N_{t-1,l'}^{s}$ | abundance of immature crab in year *t-1*, sex s and length bin *l'*, |
| $Z_{l'}^{s}$ | total instantaneous mortality by sex *s* and length bin *l'*, |
| $\phi_l^{s}$ | fraction of immature crab that became mature for sex *s* and length bin *l*, |
| *l'* | pre-molt length bin, |
| *l* | post-molt length bin. |

**2. Growth**

Growth was modeled using a fixed non-linear exponential function to estimate the mean post-molt carapace width (*Y*) given the mean pre-molt carapace width (*X*),

$$Y_{t+1} = aX_t^b$$

Parameters values used in the model and whether parameters were estimated in the model, excluding recruitments and fishing mortality parameters are listed in Table 8.

Assignment to length bins was made using a two-parameter gamma distribution with mean equal to the growth increment by sex and length, over the 25-185 mm CW range, and a beta parameter which determines the variance,

$$\psi_{l',l}^{s} = \int_{l-2.5}^{l+2.5} gamma(l/\alpha_{s,l'}, \beta_s)$$

where,
$\alpha_{s,l'}$ expected growth interval for sex *s* and size *l'* divided by the shape parameter $\beta$,
$\psi^{s}_{l',l}$ growth transition matrix for sex, *s* and length bin *l'* (pre-molt size), and post-molt size *l*.

The Gamma distribution was,

$$gamma(l / \alpha_{s,l}, \beta_s) = \frac{l^{\alpha_{s,l}-1} e^{-\frac{l}{\beta_s}}}{\beta^{\alpha_{s,l}} \Gamma(\alpha_{s,l})}$$

where *l* is the length bin, $\beta$ was set equal to 0.75 for both males and females as estimated from growth data on EBS Tanner and king crab due to the scant amount of growth data available for snow crab.

### 3. Maturity

The probability of an immature crab becoming mature by size was applied to the post-molt size. Crab that matured and underwent their terminal molt in year *t* were mature new shell (SC2) by definition during their first year of maturity. The abundance of newly mature crab ($\Omega^{s}_{t,l}$) in year *t* is given by,

$$\Omega^{s}_{t,l} = \phi^{s}_{l} \sum_{L=l_1}^{l'} \psi^{s}_{l',l} \, e^{-Z^{s}_{l'}} N^{s}_{t-1,l'}$$

Crab that were mature SC2 in year *t-1* no longer molt and move to old shell mature crab (SC3+) in year *t* ($\Lambda^{s}_{t,l}$). Crab that are SC3+ in year *t-1* remained old shell mature for the rest of their lifespan. The total old shell mature abundance ($\Lambda^{s}_{t,l}$) in year *t* is the sum of old shell mature crab in year *t-1* plus previously new shell (SC2) mature crabs in year *t-1*,

$$\Lambda^{s}_{t,l} = e^{-Z^{s,old}_{l}} \Lambda^{s}_{t-1,l} + e^{-Z^{s,new}_{l}} \Omega^{s}_{t-1,l}$$

The fishery is prosecuted in early winter prior to growth in the spring. Crab that molted in year *t-1* remain as SC2 until after the spring molting season. Crab that molted to maturity in year *t-1* are SC2 through the fishery until the spring molting season after which they become old shell mature (SC3).

### 4. Male Mature Biomass

Mature male biomass (MMB) was calculated as the sum of all mature males at the time of mating multiplied by respective weight at length.

$$B_t = \sum_{L=1}^{lbins} (\Lambda^{males}_{tm,l} + \Omega^{males}_{tm,l}) W^{males}_{l}$$

| | |
|---|---|
| *tm* | nominal time of mating after the fishery and before molting, |
| *lbins* | number of length bins in the model, |
| $\Lambda^{males}_{tm,l}$ | abundance of mature old shell males at time of mating in length bin *l*, |
| $\Omega^{males}_{tm,l}$ | abundance of mature new shell males at the time of mating in length bin *l*, |
| $W_1$ | mean weight of a male crab in length bin *l*. |

## 5. Catch

Catch of male Tanner crab was taken as a pulse fishery on February 15 (0.62 y) after the beginning of the assessment year (July 1),

$$\hat{C}_t = \sum_l (1 - e^{-(F_{red} * Sel_l^{red} + F_{snow} * Sel_l^{snow} + F_{tanner} * Sel_l^{tanner} + F_{trawl} Sel_l^{trawl})}) w_l N_{t,l}^{males} e^{-M 0.62}$$

| | |
|---|---|
| $F_{tanner}$ | full selection fishing mortality ($y^{-1}$) determined from the control rule using biomass including assessment error, |
| $F_{trawl}$ | fishing mortality ($y^{-1}$) for trawl bycatch fixed at 0.01 (average *F*), |
| $F_{red}$ | fishing mortality ($y^{-1}$) for red king crab fishery trawl bycatch, |
| $Sel_l^{tanner}$ | directed fishery selectivity for shell condition and length bin *l* for male crab, |
| $Sel_l^{red}$ | red king bycatch fishery selectivity for shell condition and length bin *l* for male crab, |
| $Sel_l^{snow}$ | snow bycatch fishery selectivity for shell condition and length bin *l* for male crab, |
| $Sel_l^{trawl}$ | trawl bycatch fishery selectivity for shell condition and length bin *l* for male crab, |
| $w_l$ | mean weight of male crab in length bin *l*, |
| $N_{t,l}^{males}$ | numbers by length for shell condition class and length bin *l*, |
| *M* | instantaneous natural mortality rate. |

## 6. Selectivity

The selectivity curves for the total catch, the retention curve, catch in the red king crab fishery, female catch in the snow crab fishery, and catch in the groundfish fisheries, were estimated as two-parameter ascending logistic curves,

$$Sel_l = \frac{1}{1 + e^{(-a(l-b))}}$$

Where *a* is slope and *b* is length at 50% selectivity. Separate selectivity curves for males and females were estimated for the directed, snow and red king crab fisheries.

For male catch in the snow crab fishery, selectivity is modeled as dome shaped as a double logistic,

$$Sel_l^{snowmale} = \left[\frac{1}{1 + e^{(-a_1(l-b_1))}}\right]\left[\frac{1}{1 + e^{(a_2(l-b_2))}}\right]$$

The probability of retaining crabs by size in the directed fishery with combined shell condition was estimated as an ascending logistic function. The selectivity for the retained catch was estimated by multiplying a two parameter logistic retention curve (same logistic equation as the total selectivity) by the selectivity ties for the total catch,

$$S_{ret,l} = (selectivity\ total)(retention)$$

The selectivity for the survey was estimated with three-parameter, ascending logistic functions.

$$Sel_l = \frac{Q}{1+e^{\left\{\frac{-\ln(19)(l-l_{50\%})}{(l_{95\%}-l_{50\%})}\right\}}}$$

Survey selectivity was estimated for 2 periods, 1974-1981, 1982-2012 to address evolving survey design and gear changes. The spatial coverage of the survey was standardized in 1978 with the exception of the addition of some stations in the northwestern survey area, well outside the distribution of EBS Tanner crab. Years 1974-1981 were considered to have similar coverage of the Tanner crab distribution. In 1974-1981, the survey used a 400 eastern otter trawl which was changed to the current 83-112 otter trawl in 1982. Years prior to 1974 had unique coverage temporally and spatially relative to Tanner crab and not included in the analysis as recommended by the Crab Modeling Workshop (Martel and Stram 2011). All three parameters (50%, 95% and Q) of the logistic function for both males and females are estimated in the three periods. For males in period-3, we inform Q based on results of the Somerton and Otto (1999) underbag study (Q=0.88; sd=0.05).

**7. Likelihood Equations**

Weighting values ( $\lambda$ ) for each likelihood equation are shown in Table 9.

Catch biomass for the directed fishery, snow crab fishery, red king crab fishery and groundfish fishery is assumed to have a normal distribution,

$$\lambda \sum_{t=1}^{T}\left[(C_{t,fishery})-(\hat{C}_{t,fishery})\right]^2$$

There are separate likelihood components for the retained catch, discard in the directed fishery, discard in the snow crab fishery, discard in the red king crab fishery and groundfish bycatch.

The robust multinomial likelihood is used for length frequencies from the survey for the fraction of animals by sex in each 5mm length interval. The number of samples measured in each year is used to weight the likelihood. However, since thousands of crab are measured annually, the sample size was set at 200. Likelihood weights for the length frequencies of catch from the directed and non-directed fleets were scaled by a factor equal to the mean number of crab retained in the directed fishery over all years divided by 200. The scaled weight in any year for any fleet is the ratio of the number of crab measured to this factor with the constraint that the ratio is capped at 200. Let $\Lambda$ be the mean of the number of retained crab measured for all years, t. Let $\Phi$ be a constant equal to $\Lambda/200$. Then, the weighted sample size weight, $nsampwt_{jt}$, in any fleet j in year t is the number of measured crab fleet j in year t divided by the constant $\Phi$; thus, $nsampwt_{jt}=nsamp_{t,j}/\Phi$.

$$Length\,Likelihood = -\sum_{t=1}^{T}\sum_{l=1}^{L} nsampwt_t * p_{t,l}\log(\hat{p}_{t,l}+o)-Offset$$

$$Offset = \sum_{t=1}^{T} \sum_{l=1}^{L} nsamp_t * p_{t,l} \log(p_{t,l})$$

Where, T is the number of years, $p_{t,l}$ is the proportion in length bin *l*, an *o* is fixed at 0.001.

The survey biomass assumes a lognormal distribution with the inverse of the standard deviation of the log(biomass) in each year used as a weight,

$$\lambda \sum_{t=1}^{ts} \left[ \frac{\log(SB_t) - \log(\hat{SB}_t)}{sqrt(2) * s.d.(\log(SB_t))} \right]^2$$

$$s.d.(\log(SB_t)) = sqrt(\log((cv(SB_t))^2 + 1))$$

Recruitment deviations likelihood equation is (t is year),

$$\lambda \sum_{t=1}^{T} \tau_t^2$$

First difference constraint on early recruitments (years (t) from 1950 to 1973)

$$\sum_{t=1}^{T} (first\ differences(\tau_t))^2$$

Smooth constraint on probability of maturing by sex and length

$$\sum_{S=1}^{2} \sum_{l=1}^{L} (first\ differences(first\ differences(PM_{s,l}))^2$$

where, $PM_{s,l}$ is a vector of parameters that define the probability of molting.

Fishery CPUE in average number of crab per pot lift (currently not fit in the model),

$$\sum_{t=1}^{tf} \left[ \frac{\log(CPUE_t) - \log(\hat{C}PUE_t)}{sqrt(2) * s.d.(\log(CPUE_t))} \right]^2$$

Penalties on fishing mortality deviations,

$$\lambda \sum_{t=1}^{T} \varepsilon_t^2$$

Growth parameters likelihood,

$$0.5\left(\frac{\tau-\mu}{\sigma}\right)^2$$

M penalty, sd = 0.05,

$$0.5\left(\frac{M-0.23}{\sigma}\right)^2$$

Penalty on survey Q for 1982-present (2 period model), sd = 0.05, prior is from underbag experiment,

$$0.5\left(\frac{Q-0.88}{\sigma}\right)^2$$

Constraint on annual survey Q deviations (when estimated),

$$\lambda \sum_{t=1}^{T} \varepsilon_t^2$$

Snow crab and red king crab fisheries discard catch of Tanner crab for years when discard data are not available was estimated from the relationship between effort (total pot lifts) in the snow crab or red king crab fisheries and the bycatch of Tanner crab in those fisheries for years with observer data,

$$R = mean\left[\frac{F_{Tanner\,bycatch}}{Total\ Pot\ Lifts}\right]$$

Fishing mortality for Tanner crab bycatch for years when no observer data are available is estimated using R above with the effort in the snow crab or red king crab fisheries, $E_R$,

$F = R\,E_R$

A first difference penalty on annual deviations in the size at 50% selected for the total male catch in the directed Tanner fishery,

$$\sum_{t=1}^{T}(first\ differences(\tau_t))^2$$

In *Model (0)*, a total of 296 parameters for the 38 years of data (1974-2012) were estimated in the model (Table 8). The 97 fishing mortality parameters (one for the directed fishery deviations, 1970-2012, and one mean value), one set for the snow crab fishery, 1992-2012, one set for the red king crab fishery, 1992-2012, and one set for the trawl fishery bycatch, 1973-2012) estimated in the model were constrained so that the estimated catch fit the observed catch closely. There were 62 recruitment deviation parameters estimated in the model, 2 mean recruitments in 2 periods (male and female recruitment were fixed to be equal). There were 62 fishery selectivity parameters. Male and female survey selectivity was estimated for 3 periods resulting in 18 parameters estimated. A total of 64 parameters were estimated for the probability of maturing smooth constrained functions.

Molting probabilities for mature males and females were fixed at 0, i.e., growth ceases at maturity which is consistent with the terminal molt paradigm (Otto 1998, Tamone et al. 2005). Molting probabilities were fixed at 1.0 for immature females and males. The a and b parameters of the exponential model of post-molt size relative to pre-molt size describing growth of male and female were estimated in the model. A gamma distribution was used in the growth transition matrix with the beta parameters fixed at 0.75 for males and females. We modeled the variance of the distribution of post-molt size given pre-molt size bin using growth data on male and female GOA Tanner crab and found that a beta of 0.75 resulted in good approximation of the distribution of post-molt sizes over all size bins.

The model separates male and female crab into mature, immature, new shell and old shell for the population dynamics. The model estimate of survey mature biomass is fit to the observed survey mature biomass time series by sex. The model fits the size frequencies of the survey by immature and mature separately for each sex and shell condition combined. The model fits the size frequencies for the pot fishery catch by sex.

Crabs 25 mm cw and larger were included in the model, divided into 32 size bins of 5 mm each, from 25-29 mm to a plus group at 180-184 mm. In this report the term size as well as length will be considered synonymous with cw. Recruits were distributed in the first few size bins using a two parameter gamma distribution with the parameters estimated in the model. The alpha parameter of the distribution was fixed at 11.5 and the beta parameter fixed at 4.0. No spawner-recruit relationship was used in the population dynamics part of the model; annual recruitments were estimated in the model to fit the data.

The NMFS trawl survey occurs in summer each year, generally in June-August. In the model, the time of the survey (July) is considered to be the start of the year rather than January. The modern directed Tanner crab pot fishery has occurred generally in the winter months (January to February) over a contracted time period. In contrast, in the early years the fishery occurred over a more protracted period of time. Natural mortality is applied to the population from the time the survey occurs until the fishery occurs, then catch is extracted instantaneously. The fishing mortality was applied as a pulse fishery at the mean time for that year. After the fishery, growth and recruitment take place in spring, with the remainder of losses due to natural mortality through the end of the year.

## 8. Discard mortality

Pot fishery discard mortality was assumed to be 50% for this assessment. The fishery for snow crabs occurs in winter when low temperatures and wind may result in freezing of crabs on deck before they are returned to the sea. Short-term mortality may occur due to exposure, which has been demonstrated in laboratory experiments by Zhou and Kruse (1998) and Shirley (1998), where 100% mortality occurred under temperature and wind conditions that may occur in the fishery. Even if damage did not result in short term mortality, immature crabs that are discarded may experience mortality during molting some time later in their life.

**9. Estimation of F Using Non-Directed Pot Fishery Effort**

Fishing mortality from discards in the snow crab and Bristol Bay red king crab fisheries for years when no discard catch data are available (pre-1992) were estimated using the effort (pot lifts) data in the snow crab and Bristol Bay red king crab fisheries (Appendix B), and the relationship between the model estimates of discard Fs and effort for years with bycatch data.

If Ω is the mean ratio of discard F to effort for each fishery from 1992 to end year except years when the fishery was closed, then the component fishing mortality in each discard fishery in year t is estimated pre-1992 as the product of Ω and effort, $f_t$, in year t:

$$F_t = \Omega \cdot f_t$$

For the Bristol Bay red king crab fishery, the effort time series includes pot lifts from both the Japanese and the domestic US pot fisheries. Effort data through 1965 is only for the Japanese fleet, 1966 through 1972 is combined Japanese and domestic effort, and 1973 to 1991 is domestic pot effort only.

**10. Overfishing Control Rule**

Amendment 24 to the NPFMC fishery management plan (NPFMC 2007) introduced revised the definitions for overfishing for EBS crab stocks. The information provided in this assessment is sufficient to estimate overfishing limits for Tanner crab under Tier 3b. The OFL control rule for Tier 3b is based on spawning biomass-per-recruit reference points (NPFMC 2007).

$$F = \begin{cases} Bycatch\ only,\ Directed\ F = 0, & if\ \dfrac{B_t}{B_{REF}} \le \beta \\ \dfrac{F_{REF}\left[\dfrac{B_t}{B_{REF}} - \alpha\right]}{(1-\alpha)} & if\ \beta < \dfrac{B_t}{B_{REF}} < 1 \\ F_{REF} & if\ B_t \ge B_{REF} \end{cases} \qquad (12)$$

where,

| | |
|---|---|
| $B_t$ | mature male biomass at time of mating in year t |
| $B_{REF}$ | proxy for $B_{MSY}$ defined as mature male biomass at time of mating resulting from fishing at $F_{REF}$ (proxy $F_{MSY}$) |
| $F_{REF}$ | $F_{MSY}$ proxy defined as the fishing mortality that reduces mature male biomass at the time of mating-per-recruit to specified percent of its unfished level |
| α | fraction of $B_{REF}$ where the harvest control rule intersects the x-axis if extended below β |
| β | fraction of $B_{REF}$ below which directed fishing mortality is 0 |

The total catch, including all bycatch of both sexes from all fisheries, is estimated by the following equation,

$$catch = \sum_f \sum_s \sum_l \frac{F_{f,s,l}}{F_{tot,s,l}}(1-e^{-(F_{tot,s,l})})w_{s,l}N_{s,l}\, e^{-M*.62}$$

where, $N_{S,l}$ is the 2012 numbers in length bin *l* and sex *s* at the time of the survey estimated from the population dynamics model, $M_s$ is natural mortality by sex, 0.625 is the time elapsed (in years) from when the survey occurs to the fishery, $F_{tot}$ is the value estimated from the OFL control rule using the 2012 mature male biomass projected forward to the time of mating time (February 2013), $F_{f,s,l}$ is partial value for each directed and non-directed fishery component in length bin *l* by sex, and $w_{s,l}$ is the mean weight in length bin *l* by sex. Fishery selectivity by length for the total catch (retained plus discard) and retained catch estimated from the population dynamics model (Figures 16 and 17).

## 11. Projection Model Structure

Variability in recruitment, as well as assessment error, was simulated with temporal autocorrelation. Recruitment was generated from a Beverton-Holt stock-recruitment model,

$$R_t = \frac{0.8\, h\, R_0\, B_t}{0.2\; spr_{F=0}\; R_0(1-h)+(h-0.2)B_t}\; e^{\varepsilon_t - \sigma_R^2/2} \tag{1}$$

| | |
|---|---|
| $spr_{F=0}$ | mature male biomass per recruit fishing at $F$=0. $B_0 = spr_{F=0}\ R_0$ , |
| $B_t$ | mature male biomass at time *t*, |
| $h$ | steepness of the stock-recruitment curve defined as the fraction of $R_0$ at 20% of $B_0$, |
| $R_0$ | recruitment when fishing at $F$=0, |
| $\sigma_R$ | standard deviation for recruitment deviations, estimated at 0.86 from the assessment model. |

The temporal autocorrelation error ($\varepsilon_t$) was estimated as,

$$\varepsilon_t = \rho_R \varepsilon_{t-1} + \sqrt{1+\rho_R^2}\;\; \eta_t \qquad where\ \eta_t \sim N(0;\sigma_R^2) \tag{2}$$

$\rho_R$ temporal autocorrelation coefficient for recruitment, set at 0.6.

Recruitment variability and autocorrelation were estimated using recruitment estimates from the stock assessment model. $R_0$ and steepness were estimated such that $F_{35\%} = F_{MSY}$ and $B_{35\%} = B_{MSY}$ using a Beverton-Holt stock recruitment relationship.

Assessment error was modeled as a lognormal autocorrelated error on the mature male biomass used to determine the fishing mortality rate in the harvest control rule,

$$B_t^{'} = B_t\, e^{\phi_t - \sigma_I^2/2}\ ;\ \ \phi_t = \rho_I \phi_{t-1} + \sqrt{1+\rho_I^2}\;\; \varphi_t \qquad where\ \varphi_t \sim N(0;\sigma_I^2)$$

$B_t^{'}$ mature male biomass in year t with assessment error input to the harvest control rule,

| | |
|---|---|
| $B_t$ | mature male biomass in year t, |
| $\rho_I$ | temporal autocorrelation for assessment error, set at 0.6 (estimated from the recruitment time series), |
| $\sigma_I$ | standard deviation of $\varphi$, which determines the magnitude of the assessment error, set at the estimate of variance of ending biomass from the assessment model plus additional uncertainty. |

Assessment error in mature male biomass resulted in fishing mortality values applied to the population that was either higher or lower than the values without assessment error. The autocorrelation was assumed to be the same value as that estimated for recruitment. Assessment autocorrelation was used to more closely approximate the process of estimating a biomass time series from within a stock assessment model. The variability in biomass of the simulated population resulted from the variability in recruitment and variability in full selection *F* arising from implementation error on biomass. Uncertainty in initial numbers by length was added using a lognormal distribution with cv of ending biomass from the assessment model. The population dynamics equations were identical to those presented for the assessment model in the model structure section of this assessment.

## 12. State of Alaska Harvest Strategy Prior to 2011/12

The SOA harvest strategy (Zheng and Kruse 2000) in effect prior to the change in 2011/12 was: Let $MFB_t$ be the estimate of mature female biomass in the Eastern Subdistrict (i.e., the waters of the Bering Sea District east of 173$^0$ W longitude) at the time of the survey in year *t* defined as the estimated biomass of females > 79 mm carapace width (cw), $MFB_{t-1}$ be the estimate of mature female biomass in the Eastern Subdistrict at the time of the survey in the previous year (*t-1*), $MMMA_t$ be the molting mature male abundance in each area east and west of 166$^0$ W longitude within the Eastern Subdistrict at the time of the survey in year *t* defined as the estimated abundance of all new-shell males > 112-mm cw plus 15% of the estimated abundance of old-shell males > 112-mm cw, $ELMA_t$ be the exploitable legal male abundance in each area east and west of 166$^0$ W longitude within the Eastern Subdistrict at the time of the survey in year *t* defined as the estimated abundance of all new-shell legal males ≥ 138 mm cw plus 32% of the estimated abundance of old-shell legal males ≥ 138 mm cw, $W_t$ be the average weight of legal males in the Eastern Subdistrict east or west of 166$^0$ W longitude in year *t* estimated by applying a weight-length relationship to the survey size-frequency data for legal (≥ 138 mm cw) males, $HG_{COMP}$ be the total allowable catch computed for each area east and west of 166$^0$ W longitude in the Eastern Subdistrict, $HG_{CAP}$ be the capped total allowable catch derived for each area east and west of 166° W longitude in the Eastern Subdistrict. In applying the control rule, [i] a separate *HG* is determined as the minimum of the $HG_{COMP}$ and the $HG_{CAP}$ for each area east and west of 166$^0$ W longitude, and [ii] the *HG* of legal males in each area east or west of 166$^0$ W longitude in the Eastern Subdistrict is capped at 50% of the exploitable legal male abundance.

The control rule for the HG during year *t* in each area east and west of 166$^0$ W longitude in the Eastern Subdistrict is as follows: (mp=million pounds).

1. If $MFB_{t-1} < 21.0$ mp and $MFB_t < 21.0$ mp, then $HG_{COMP}=0$ and $HG_{CAP}=0$.
2. If $MFB_{t-1} < 21.0$ mp and 21.0 mp $\leq MFB_t < 45.0$ mp, then $HG_{COMP}=0.05 MMMA_t W_t$ and $HG_{CAP}=0.25 ELMA_t W_t$.
3. If $MFB_{t-1} < 21.0$ mp and $MFB_t \geq 45.0$ mp, then $HG_{COMP}=0.1 MMMA_t W_t$ and $HG_{CAP}=0.25 ELMA_t W_t$.
4. If $MFB_{t-1} \geq 21.0$ mp and $MFB_t < 21.0$ mp, then $HG_{COMP}=0$ and $HG_{CAP}=0$.
5. If $MFB_{t-1} \geq 21.0$ mp and 21.0 mp $\leq MFB_t < 45.0$ mp, then $HG_{COMP}=0.1 MMMA_t W_t$ and $HG_{CAP}=0.5 ELMA_t W_t$.
6. If $MFB_{t-1} < 21.0$ mp and $MFB_t \geq 45.0$ mp, then $HG_{COMP}=0.2 MMMA_t W_t$ and $HG_{CAP}=0.5 ELMA_t W_t$.

### 13. New Size Limits Strategy and Fishery Selectivity

In March 2011, the Alaska Board of Fisheries approved a new minimum size limit strategy for Tanner crab effective for the 2011/12 fishery. The previously minimum legal size limit was 5.5" (138 mm cw) throughout the Eastern Subdistrict. The new regulations established different minimum size limits east and west of 166° West longitude. That for the fishery to the east will be 4.8" (122 mm cw), and that to the west will be 4.4" (112 mm cw). The industry may self-impose retention of crab above 5.5" (138 mm cw) and 5" (127 mm cw) east and west of 166° West longitude, respectively. The operational framework of the these new regulations will be incorporated in stock projections.

The SOA closed the directed Tanner crab fishery in the 2010/11 and 2011/12 seasons. For stock projections, since fishery performance has not been observed under the new size limit regime, we would initially approximate east-west fishery selectivity and the catch splits in the projection model framework. As a first approximation, total selectivity is unchanged and applied to the east-west fisheries given that no gear changes accompanied the regulatory change in size limit. Retained selectivity for the eastern and western districts would be formulated based on the industry imposed size limits of 138 mm (east) and 127 mm (west). For the eastern fishery, retained selectivity would be unchanged. For the western fishery, the retained selectivity curve would be shifted 10 mm to the proposed 127 mm minimum size limit. The split in the catch east-west would be approximated by the 3-year average proportion of the abundance of crab observed in the 2010 to 2012 surveys east and west of $166^0$ W longitude.

## J. RESULTS

This analysis presents results of the *Base Model (0)* and two alternative models – *Model (1) and Model (2)*. Specification of the base model configuration is described in Section H (Model Configuration). Alternative *Model (1)* is the base model modified such that additional mortality is estimated for immature male and female crab (pooled) during the 1980-84 period. *Model (2)* is the base model, and results differ relative to the base model only by a change in the input data. Here, the scaled sample weights to the multinomial likelihood have a minimum constraint of n=4 for any fleet-year. The minimum constraint of n=4 was a decision in earlier model testing and the CPT (May 2012) requested it be removed. Model (2) results are presented only as a reference to what the CPT reviewed in May 2012.

| Model: | Specification |
|---|---|
| 0 | Base Model |
| 1 | Base Model *but* M estimated immature males and females in 1980-84. |
| 2 | Base Model *but* M uses sample size weights with minimum n=4. |

Table 1 provides the fishery history of observed retained catch in the domestic and foreign Tanner crab fisheries from 1965/66 to 2011/12. The total biomass of discard catch of Tanner crab in the domestic pot fisheries and groundfish fisheries for 1973/74 through 2011/12 is shown in Table 2. *Model (0)* estimates of predicted retained and discard catch of Tanner crab by sex in the directed fishery for 19674/75 through 2009/10 is shown in Table 3. Table 4 shows the discard catch in the non-directed pot and groundfish fisheries by sex estimated in the *Model (0)* for 19674/75 through 2011/12. The *Model (0)* predicted total (retained plus discard) Tanner crab catch biomass from the directed and all non-directed fisheries combined for years 19674/75 through 2011/12 is presented in Table 5. Table 6 presents the observed survey female, male and total spawning biomass, and observed abundance of legal male crab (≥ 138 mm cw) for 1974-2011. *Model (0)* estimates of population biomass and abundance, male, female and total mature biomass, abundance of legal males, recruitment to the population, male mature biomass at mating and full-selection fishing mortality rates are presented in Table 7. Table 8 provides the parameter values and whether the parameters were estimated in the model, excluding recruitments and fishing mortality parameters for *Model (0)*. The weighting factors for the likelihood equations used for all models is shown in Table 9. Table 10 shows the likelihood values by component for *Model (0)* through *Model (2)*. The values of natural morality (M) estimated or fixed for *Model (0)* through *Model (6)* are shown in Table 11. The total likelihood, maximum survey selectivity Q, and survey Q at a reference size for male (140 mm) and female (100 mm) crab are shown versus Q for the *Model (0)* in Table 12.

Figure 21 (a) and (b) show the sample sizes used in the multinomial likelihood in fitting the fishery length compositions by fleet and the resulting mean fleet samples sizes for comparison. The *Model (0)* and *Model (1)* estimates of natural morality for immature male and female (pooled) crab, and for mature males and females, and the estimated rate of additional mortality over 1980-84 are shown in Figure 22. The estimated rate of additional morality on mature male crab over 1980-84 is 3.2 times the baseline natural mortality of 0.23, equaling 0.74 (Table 11). By comparison, the values of fixed and estimated rates of natural mortality for male and female crab in the current Bristol Bay red king crab assessment (Zheng 2011) are shown in Figure 23. Over the period 1980-84, estimated M on male crab is 3.0M, where M represents the fixed life-history based value of 0.18, equaling 0.72.

Figure 24 presents a comparison of four reference model fits to the observed survey male mature biomass and the predicted population male mature biomass. This figure was requested by the CPT (May 2012), and the reference models are: #1=3-period model presented to CPT in September 2011, #2=2-perod model resulting from January 2012 Crab Workshop; #3=2-period model presented to CPT in May 2012; and #4=2-period model approved by the CPT in May 2012 with new data and sample weights. Figure 25 presents this same comparison of reference model fits but to mature female biomass.

***Model (0)*:**

Figure 10 presents predicted retained male catch and predicted retained plus discarded catches of male Tanner crab in the directed fishery, and total male catch in all fisheries combined. Predicted Mature male biomass declined sharply from its high in 1974 to the mid-1980s, increased modestly to a secondary mode in 1990, then declined thereafter through the early-2000s (Table 7, Figure 26). The model does not fit the increasing survey biomass trend in 2005-2008 but better fits the 2011-2012 observed biomass. The increasing trend in 2005-2008 was driven principally by hot-spot tows which inflated total biomass estimates (Rugolo and Turnock 2008). Exploitation rates on legal and mature male biomass demonstrated two peaks: the first in the late-1970s through early-1980s and the second in the mid-1990s (Figure 11).

Estimated total selectivity in the directed fishery for combined shell condition male Tanner crab in the directed fishery was estimated in three periods (1981-1990, 1991-1996 and 2005-2010). Figure 27 (a) shows the estimated total selectivity in 2008 as a reference for the shape of the function, where (b) shows the change in the mean (50%) of total selectivity over 1990-2010. The estimated fraction of total catch retained by size for male crab in the directed fishery for all shell condition classes combined estimated in three periods (1981-1990, 1991-1996 and 2005-2010). Figure 28 presents the retained selectivity curves for a year in each of these three periods. All three parameters (50%, 95% and Q) of the logistic function for male (Figure 29) and female (Figure 30) survey selectivity was estimated in two periods (1974-1981, 1982-2012). For males in period-2, we inform Q based on the 1999 Somerton and Otto underbag study (Q=0.88, sd=0.05). The profile of survey Q versus total likelihood, and survey selectivity at reference sizes (male=140 mm, female=100 mm) versus asymptotic Q are presented in Figures 31 (a) and (b).

Male and female Tanner crab fishery selectivity in the Bristol Bay red king crab fishery (Figure 32) and in the snow crab fishery (Figure 33) were estimate in three periods (1989-1996, 1997-2004 and 2005-2011). Selectivity of Tanner crab in the groundfish fisheries was estimated for three periods (1973-1986, 1987-1996 and 1997-2010) (Figure 34).

Model fits to mature female biomass is shown in Figure 35. Observed female mature biomass is relatively more variable than male mature biomass (Figure 26) and the model does not fit these female data as well in the early-1980s and early-1990s. Model fits to the survey length frequencies for males and females including observed survey biomass are shown in Figure 36 and Figure 38 respectively. Standardized Pearson residuals of model fits to the male survey length frequencies are shown in Figure 37, and those for mature females in Figure 39. A summary plot of the model fit to the survey length frequencies for males and females over all years is shown in Figure 40. Observed survey numbers of legal males (Table 6) and model estimates of the population of legal males (Table 7) are scaled by the model estimates survey Q.

The relationships of pre-molt length to post-molt length for male and female Tanner crab estimated in the model are shown in Figure 41. Figure 42 illustrates the estimated recruitment to model of crab 25 mm to 50 mm by fertilization year which are distributed by carapace width to the model as shown in Figure 43. Model fits to the retained male size frequency data in the 1981-2009/10 directed fishery, and the summary fit to the retained male size frequencies over all years are shown in Figure 44 and Figure 45 respectively. The model fits to the total male size frequency data for 1981-2009/10 in all fisheries combined, and the summary fit to the total male size frequencies over all years are shown in Figure 46 and Figure 47 respectively. Figure 48 presents the summary fit to the discard female size frequency data in the directed fishery. Figures 49 through 51 present the summary model fits to the size frequencies of male and female Tanner crab discards in the snow crab fishery, in the Bristol Bay red king crab fishery and in the EBS groundfish fisheries.

Full-selection fishing mortality rates varied from near zero to 2.2 (Figure 52, Table 7). Full-selection fishing mortality rates concur with a history of excessive exploitation, averaging 1.1 (1977/78-1981/82) peaking in 1979/80 at 2.2, and averaging 0.9 (1990/91-1993/94) peaking in 1992/93 at 1.2 coincident with peak extraction of catch and decline in stock biomass. Figure 53 shows realized instantaneous fishing morality rate versus male mature biomass at mating by fishing year where $F_{35\%}$=0.61 and $B_{35\%}$=161.37 thousand t. The pattern of recruitment to the model vs. male mature biomass is illustrated in Figure 54. Figure 55 presents the trajectory of estimated male mature biomass at the time of mating from 1974-2012. From the high biomass in 1974, MMB at mating has demonstrated a one-way trip of sharply declining biomass through 2000 and remaining at low levels thereafter. A modest mode of MMB was observed in the late-1980s to early-1990s, peaking in 1990 (Figure 55, Table 7), but this peak represented half of the male mature biomass estimated in 1974-1980. The observed male size frequencies from 1974-2012 (Figure 6) reveals a contraction of the distribution and a length shift to smaller sizes coincident with the decline; the modest increase in biomass associated with the 1990 mode is seen in the progression of lengths from 1987 through 1992. The 2012 observed length frequency reveals a relatively prominent mode of recruit-sized crab which is encouraging if it recruits to the mature stock. Inspection of the metrics of stock and fishery performance of Tanner crab over its history from indicate a severe stock decline.

The relative productivity of a stock is expressed as index based on the number of recruits per spawner – e.g., as the natural log of recruitment divided by spawning stock biomass. Figure 57 shows Tanner crab production index versus male mature biomass over 1968 to 2012. The stock production index versus the predicted exploitation rate on male mature biomass over 1968 to 2012 is shown in Figure 58.

***Alternative Models:***
For alternative *Model (1)*, we present nine figures representative of model performance. For females, these are the estimated population of mature female biomass with model fit to survey mature biomass, the model fit to the survey size frequency data, and the residual plot of model fit to the survey size frequency data. We repeat this set of three figures for males. Lastly, the summary plot of model fit to the survey male and female size frequency data, and the model estimates of male and female survey selectivity are given. The remaining plots for *Model (1)* are provided electronically in a Drop Box established by the CPT as a repository for model output. Similarly, the complete set of model plots for *Model (2)* are provided electronically.

***Model (1):***
Model fits to mature male biomass and to mature female biomass and the respective estimates of the population of mature biomass are shown in Figure 59 and Figure 62, respectively. Figure 60 and Figure 63 show the model fit to the survey size frequencies for males and females respectively, including the observed survey biomass data. Residuals of model fits to the male survey size frequency data are shown in Figure 61, and those for mature females in Figure 64. The summary plot of the model fit to the survey size frequencies for females and males over all years is shown in Figure 65. The model estimates of survey selectivity for male (Figure 66) and female (Figure 67) are shown for the two periods (1974-1981, 1982-2012) along with the survey selectivity estimated by Somerton and Otto (1999).

## K. Calculation of the 2012/13 OFL

**Average Recruitment Options**
We estimated the Total Catch OFL and associated catch components for the 2012/13 Tanner crab fishery for *Model (0)* and *Model (1)* at four levels of the $B_{35\%}$ proxy for $B_{MSY}$ resulting from four levels of mean recruitment. Here, year represents the recruitment year to the model. One additional $B_{35\%}$ proxy resulted from the CPT meeting in September 2012. The CPT decided to calculate the $B_{35\%}$ proxy using mean recruitment from 1990-2012 based on an analysis (A. Punt) of Tanner crab stock-recruitment data. The CPT also recommended *Model (0)* as the base model for this assessment.

1. ***R1 = 1966-1972 average recruitment.*** This represents the recruitment that 'gave rise to the biomass estimated in 1974-1980' – the reference biomass period used in the survey-based Tier-4 assessment. Requested by the Crab Modeling Workshop (Martel and Stram, 2011); SSC (March 2012) and CPT (June 2012).
2. ***R2 = 1966-1988 average recruitment.*** This alternative is a range of years that, although it includes recruitments that did not result from a stock at $B_{MSY}$ nor that subsequently yielded $B_{MSY}$, it captures the mode of secondary MMB in 1990 but not beyond mid-1990 when the stock was declared overfished. These years include wider variability in recruitment than R1. It accepts the fact that the stock declined to low levels in the mid-1980s, and the fishery closed (1986 and 1987) due to conservation concerns. In the author's opinion, 1988 is the last recruitment year to include as recruitments after 1988 are inconsistent with basic theory of a stock living at $B_{MSY}$, or a level of production that either maintained the stock at equilibrium $B_{MSY}$ or provided for its recovery to $B_{MSY}$ from overfished state.
3. ***R3 = 1982-2012 average recruitment.*** A 'bookend' range of recruitment requested by the Crab Modeling Workshop (Martel and Stram, 2011) and reaffirmed by the SSC (March 2012) and CPT (June 2012).
4. ***R4 = 1966-2012 average recruitment.*** A range of recruitment that include 'all years' requested by the SSC (March 2012).
5. ***R5 = 1990-2012 average recruitment.*** The mean recruitment recommended by the CPT at their September 2012 meeting.

Figure 56 shows the recruitments estimated by *Model (0)* and the mean recruitment period options R1 through R5. The authors recommend the use of average recruitment over 1966-1972 (R1). It's the recruitment that produced mature male biomass considered the benchmark reference point $B_{MSY}$. Average recruitment over 1966-1988 (R2) is an alternative that includes a longer range of recruitment that may not represent $B_{MSY}$. R2 is a level of mean recruitment that is seemingly inadequate to have led to recovery to $B_{MSY}$ following the stock decline in the 1970s. We don't consider average recruitment over 1982-2012 (R3) or 1966-2012 (R4) to represent the production of recruitment from a stock at $B_{MSY}$ given the overfished stock declarations and fishery closures during 1986-1987, 1997-2004 and again in 2011-2012 (Table 3, Figures 26 and 42). The CPT (September 2012) believes that R5 mean recruitment (1990-2012) represents the current production potential of the EBS Tanner crab stock. The authors do not agree with this conclusion.

**Changes in Stock Productivity**

The relative productivity of a stock is commonly expressed as index based on the number of recruits per spawner – e.g., as the natural log of recruitment divided by spawning stock biomass. Changes in this index over time may reflect a shift in the productivity of the stock which may be associated with a change in the environmental regime the stock inhabits. Directional trends or punctuated changes in the production index may be indicative of environmental shifts that would factor into decisions on the selection of years included in the estimation of proxy reference points. Figure 57 shows the Tanner crab production index versus male mature biomass over 1968 to 2012. The production index versus predicted exploitation rate on male mature biomass over 1968 to 2012 is shown in Figure 58. Although male mature biomass varied widely over the time period, the production index displays no directional trend or abrupt change in magnitude that would support splitting the time-series in order to calculation $B_{35\%}$.

The lack of change in the rate of production over time does not by default argue for the inclusion of all years in the average used to calculate the $B_{35\%}$ proxy. Total recruitment, the product of the recruitment rate and total spawning stock biomass, is also a governing factor. The expectation is that lower levels of stock biomass will produce lower recruitments even at the same productivity level. Following the stock decline in the mid-1970s, recruitment has been insufficient to maintain the stock, or to provide for its recovery. With the exception of the early time period, we have not observed recruitments from a stock living at the proxy $B_{MSY}$ level. Neither has total recruitment following the decline led to recovery to the proxy $B_{MSY}$.

The Tanner crab stock experienced a one-way trip from high biomass levels in the late-1960s and early-1970s to low levels in the 1980's to the present. The performance of stock and fishery reveal that the Tanner crab experienced a severe stock decline over the period of record. The stock was declared overfished in 2010 by the NOAA Fisheries and in need of a rebuilding plan (Rugolo and Turnock 2010). The historical bimodal distribution in male mature biomass (Figure 26) reflects that of the attendant directed fisheries (Figure 10) with peak modes in the early- and late-1970s and early-1990s, and depressed stock status subsequent to these modes. Full-selection fishing mortality rates estimated in the model concur with a history of excessive exploitation (Figure 52, Table 7). If the $F_{35\%}$ OFL control rule established by Amendment 24 had been in effect from 1974/75-2011/12, in approximately one-half of the 44 years, the realized F would have exceeded the overfishing limit (Figure 53). Fishing mortality rates on male Tanner crab have often exceeded the $F_{OFL}$, however, this did not constitute overfishing in the past because Amendment 24 was implemented in 2008.

Recruitment to the model at 25 mm to 50 mm fluctuated widely from 1950-2007 (fertilization year) displaying a prominent period of moderately high recruitment in the early-to-mid-1960s (Figure 42). These recruitments gave rise to the peak male mature biomass levels in the early-1970s. Recruitments to the stock following the decline in stock biomass from the 1970s have been low and insufficient to maintain the stock at levels observed pre-1980 or provide for stock growth.

The EBS Tanner crab stock was under a rebuilding plan for 1999-2009 and the directed fishery closed from 1997 to 2004 as a result of depressed stock status. The fishery was also closed in 1985 and 1986 due to conservation concerns, and the SOA again in 2010 and 2011 as stock biomass was the minimum threshold in the harvest strategy for opening. Under the former BSAI King and Tanner Crab fishery management plan (NPFMC 1998) and overfishing definitions, the Tanner crab stock was above the $B_{MSY}$ level indicative of a restored stock for the second consecutive year in 2007 and declared rebuilt. However, the increase in observed biomass in 2005-2008 was driven principally by hot-spot tows that inflated total biomass estimates (Rugolo and Turnock 2008). It was doubtful that MMB increased as suggested by estimated survey biomass. MMB declined in 2008-2010 from the apparent 2007 level and the stock was declared overfished in 2010 (Rugolo and Turnock 2010) and deemed in need of a rebuilding plan.

**Status of 2011/12 Stock and 2012/13 OFL**

**1. R1 Recruitment:**

***Model (0)***

$B_{35\%}$=161.37 thousand t and $F_{35\%}$=0.61. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $0.36B_{35\%}$. The total catch OFL is 9.29 thousand t, and the ACL=9.28 thousand t for a P*=0.49 and cv=0.077.

***Model (1)***

$B_{35\%}$=157.48 thousand t and $F_{35\%}$=0.59. The model estimate of 2011/12 MMB at mating (56.26 thousand t) represents $0.36B_{35\%}$. The total catch OFL is 9.14 thousand t, and the ACL=9.12 thousand t for a P*=0.49 and cv=0.077.

**2. R2 Recruitment:**

***Model (0)***

$B_{35\%}$=90.14 thousand t and $F_{35\%}$=0.61. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $0.65B_{35\%}$. The total catch OFL is 12.71 thousand t, and the ACL=12.39 thousand t for a P*=0.49 and cv=0.077.

***Model (1)***

$B_{35\%}$=97.57 thousand t and $F_{35\%}$=0.59. The model estimate of 2011/12 MMB at mating (56.26 thousand t) represents $0.58B_{35\%}$. The total catch OFL is 11.70 thousand t, and the ACL= 11.69 thousand t for a P*=0.49 and cv=0.077.

**3. R3 Recruitment:**

***Model (0)***

$B_{35\%}$= 33.45 thousand t and $F_{35\%}$=0.61. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $1.75B_{35\%}$. The total catch OFL is 19.00 thousand t, and the ACL= 18.99 thousand t for a P*=0.49 and cv=0.077.

***Model (1)***

$B_{35\%}$= 35.60 thousand t and $F_{35\%}$=0.59. The model estimate of 2011/12 MMB at mating (56.26 thousand t) represents $1.58B_{35\%}$. The total catch OFL is 18.40 thousand t, and the ACL= 18.39 thousand t for a P*=0.49 and cv=0.077.

**4. R4 Recruitment:**

***Model (0)***

$B_{35\%}$= 56.00 thousand t and $F_{35\%}$=0.61. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $1.05B_{35\%}$. The total catch OFL is 16.30 thousand t, and the ACL= 16.29 thousand t for a P*=0.49 and cv=0.077.

***Model (1)***
$B_{35\%}$= 59.55 thousand t and $F_{35\%}$=0.59. The model estimate of 2011/12 MMB at mating (56.26 thousand t) represents $0.95B_{35\%}$. The total catch OFL is 15.10 thousand t, and the ACL= 15.09 thousand t for a P*=0.49 and cv=0.077.

**4. R5 Recruitment:**
***Model (0)***
$B_{35\%}$= 22.80 thousand t and $F_{35\%}$=0.61. The model estimate of 2011/12 MMB at mating (58.59 thousand t) represents $2.57B_{35\%}$. The total catch OFL is 19.02 thousand t, and the ACL= 19.01 thousand t for a P*=0.49 and cv=0.077.
***Model (1)***
$B_{35\%}$= 22.59 thousand t and $F_{35\%}$=0.59. The model estimate of 2011/12 MMB at mating (56.26 thousand t) represents $2.49B_{35\%}$. The total catch OFL is 18.40 thousand t, and the ACL=18.30 thousand t for a P*=0.49 and cv=0.077.

The following table summarizes results for *Model (0)* and *Model (1)* with respect to estimated values of $B_{35\%}$, $F_{35\%}$, 2011/12 MMB at mating ($MMB_{11/12}$), and the percent $MMB_{11/12}$ is to the respective $B_{35\%}$ at the five mean recruitment scenarios. The bolded scenario is recommended by the CPT (September 2012).

Summary Table: Model vs Mean Recruitment Period ($B_{35\%}$ and MMB in 1000 t)

| Mean Recruitment | Model | $B_{35\%}$ | $F_{35\%}$ | $MMB_{11/12}$ | $\%MMB_{11/12}$ / B35% |
|---|---|---|---|---|---|
| R1 | Model (0) | 161.37 | 0.61 | 58.59 | 36.31 |
| | Model (1) | 157.48 | 0.59 | 56.26 | 35.73 |
| R2 | Model (0) | 90.14 | 0.61 | 58.59 | 65.00 |
| | Model (1) | 97.57 | 0.59 | 56.26 | 57.66 |
| R3 | Model (0) | 33.45 | 0.61 | 58.59 | 175.16 |
| | Model (1) | 35.60 | 0.59 | 56.26 | 158.03 |
| R4 | Model (0) | 56.00 | 0.61 | 58.59 | 104.63 |
| | Model (1) | 59.55 | 0.59 | 56.26 | 94.48 |
| **R5** | **Model (0)** | **22.80** | **0.61** | **58.59** | **257.02** |
| | Model (1) | 22.59 | 0.59 | 56.26 | 249.07 |

## L. CALCULATION OF THE 2012/13 ABC=ACL

Amendments 38 and 39 to the plan (NPFMC 2010) established methods for the Council to set Annual Catch Limits (ACLs). The Magnuson-Stevens Act requires that ACLs be established based upon an acceptable biological catch (ABC) control rule that accounts for scientific uncertainty in the OFL such that ACL=ABC and the total allowable catch (TAC) and guideline harvest levels (GHLs) be set below the ABC so as not to exceed the ACL. ABCs must be recommended annually by the Council's SSC.

Two methods for establishing the ABC control rule are: 1) a constant buffer where the ABC is set by applying a multiplier to the OFL to meet a specified buffer below the OFL; and 2) a variable buffer where the ABC is set based on a specified percentile (P*) of the distribution of the OFL that accounts for uncertainty in the OFL. P* is the probability that ABC would exceed the OFL and overfishing occur. In 2010, the NPFMC prescribed that ABCs for BSAI crab stocks be established at P*=0.49. Annual ACL=ABC levels are established such that the risk of ovefishing, P[ABC>OFL], is 49%.

Two sources of uncertainty are considered in setting the ABC: 1) $\sigma_w$, or within assessment uncertainty; and 2) $\sigma_b$ , additional uncertainty. The EA recommends that some level of additional uncertainty be used in computing ABCs for all stocks. Within assessment uncertainty, $\sigma_w$, in a Tier-3 stock is the coefficient of variation in the estimate of end year mature male biomass. Sources of additional uncertainty, $\sigma_b$ , are: pre-specified population dynamic parameters and life-history rates such as natural mortality, size-weight, maturity; the assumption that $F_{MSY}=F_{35\%}$ when applying the OFL control rule; estimates of the OFL; and the assumption that $B_{MSY}$ is represented by $B_{35\%}$ derived using average recruitment over a time period representative of a stock at $B_{MSY}$ via spawning stock biomass-per-recruit analysis.

The ABC=ACL for the 2012/13 fishery is estimated using the constant buffer approach. For the 2012/13 crab ABCs, the SSC utilized a buffer of 10% for all crab stocks.

**1. R1 Recruitment:**

***Model (0)***

OFL=9.29 thousand t, ACL=9.28 thousand t and ABC=8.36 thousand t.

***Model (1)***

OFL=9.14 thousand t, ACL=9.12 thousand t and ABC=8.20 thousand t.

**2. R2 Recruitment:**

***Model (0)***

OFL=12.71 thousand t, ACL=12.69 thousand t and ABC=11.44 thousand t.

***Model (1)***

OFL=11.70 thousand t, ACL=11.69 thousand t and ABC=10.53 thousand t.

**3. R3 Recruitment:**

***Model (0)***

OFL=19.00 thousand t, ACL=18.99 thousand t and ABC=17.10 thousand t.

***Model (1)***

OFL=18.40 thousand t, ACL=18.39 thousand t and ABC=16.56 thousand t.

**4. R4 Recruitment:**

***Model (0)***

OFL=16.30 thousand t, ACL=16.29 thousand t and ABC=14.67 thousand t.

***Model (1)***

OFL=15.10 thousand t, ACL=15.09 thousand t and ABC=13.59 thousand t.

**5. R5 Recruitment:**

***Model (0)***

OFL=19.02 thousand t, ACL=19.01 thousand t and ABC=17.12 thousand t.

***Model (1)***

OFL=18.40 thousand t, ACL=18.30 thousand t and ABC=16.56 thousand t.

The following table summarizes results for *Model (0)* and *Model (1)* with respect to estimated values of the 2012/13 OFL, ACL and ABC at the five mean recruitment scenarios. The bolded scenario is recommended by the CPT (September 2012).

| Summary Table: Model vs Mean Recruitment Period (2012/13 Catch Limits in 1000 t) | | | | |
|---|---|---|---|---|
| Mean Recruitment | Model | OFL | ACL | ABC |
| R1 | Model (0) | 9.29 | 9.28 | 8.36 |
| | Model (1) | 9.14 | 9.12 | 8.20 |
| R2 | Model (0) | 12.71 | 12.69 | 11.44 |
| | Model (1) | 11.70 | 11.69 | 10.53 |
| R3 | Model (0) | 19.00 | 18.99 | 17.10 |
| | Model (1) | 18.40 | 18.39 | 16.56 |
| R4 | Model (0) | 16.30 | 16.29 | 14.67 |
| | Model (1) | 15.10 | 15.09 | 13.59 |
| **R5** | **Model (0)** | **19.02** | **19.01** | **17.12** |
| | Model (1) | 18.40 | 18.30 | 16.56 |

## M. DATA GAPS and RESEARCH PRIORITIES

Long-term research associated with the length-based stock assessment model is required as itemized under Section B.2. Analysis to derive model inputs, parameters and schedules including growth, maturity, survey selectivity, and fishing power are require to improve model performance. Also required is the reformulation of length-weight relationships, molting probability schedules and growth transition matrices.

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Table 1. Eastern Bering Sea Tanner crab retained catch in the United States pot, the Japanese tangle net and pot, and the Russian tangle net fisheries, 1965/66-2011/12.

| Eastern Bering Sea *Chionoecetes bairdi* Retained Catch (1000T) | | | | |
|---|---|---|---|---|
| Year | US Pot | Japan | Russia | Total |
| 1965/66 | | 1.17 | 0.75 | 1.92 |
| 1966/67 | | 1.69 | 0.75 | 2.44 |
| 1967/68 | | 9.75 | 3.84 | 13.60 |
| 1968/69 | 0.46 | 13.59 | 3.96 | 18.00 |
| 1969/70 | 0.46 | 19.95 | 7.08 | 27.49 |
| 1970/71 | 0.08 | 18.93 | 6.49 | 25.49 |
| 1971/72 | 0.05 | 15.90 | 4.77 | 20.71 |
| 1972/73 | 0.10 | 16.80 | | 16.90 |
| 1973/74 | 2.29 | 10.74 | | 13.03 |
| 1974/75 | 3.30 | 12.06 | | 15.24 |
| 1975/76 | 10.12 | 7.54 | | 17.65 |
| 1976/77 | 23.36 | 6.66 | | 30.02 |
| 1977/78 | 30.21 | 5.32 | | 35.52 |
| 1978/79 | 19.28 | 1.81 | | 21.09 |
| 1979/80 | 16.60 | 2.40 | | 19.01 |
| 1980/81 | 13.47 | | | 13.43 |
| 1981/82 | 4.99 | | | 4.99 |
| 1982/83 | 2.39 | | | 2.39 |
| 1983/84 | 0.55 | | | 0.55 |
| 1984/85 | 1.43 | | | 1.43 |
| 1985/86 | 0 | | | 0 |
| 1986/87 | 0 | | | 0 |
| 1987/88 | 1.00 | | | 1.00 |
| 1988/89 | 3.15 | | | 3.18 |
| 1989/90 | 11.11 | | | 11.11 |
| 1990/91 | 18.19 | | | 18.19 |
| 1991/92 | 14.42 | | | 14.42 |
| 1992/93 | 15.92 | | | 15.92 |
| 1993/94 | 7.67 | | | 7.67 |
| 1994/95 | 3.54 | | | 3.54 |
| 1995/96 | 1.92 | | | 1.92 |
| 1996/97 | 0.82 | | | 0.82 |
| 1997/98 | 0 | | | 0 |
| 1998/99 | 0 | | | 0 |
| 1999/00 | 0 | | | 0 |
| 2000/01 | 0 | | | 0 |
| 2001/02 | 0 | | | 0 |
| 2002/03 | 0 | | | 0 |
| 2003/04 | 0 | | | 0 |
| 2004/05 | 0 | | | 0 |
| 2005/06 | 0.43 | | | 0.43 |
| 2006/07 | 0.96 | | | 0.96 |
| 2007/08 | 0.96 | | | 0.96 |
| 2008/09 | 0.88 | | | 0.88 |
| 2009/10 | 0.60 | | | 0.60 |
| 2010/11 | 0 | | | 0 |
| 2011/12 | 0 | | | 0 |

Table 2. Eastern Bering Sea Tanner crab discards (1000 t) in the domestic pot fisheries and groundfish fisheries, 1973/74-2011/12. No discard mortality applied.

| Discards (1000 t) of Tanner Crab by Fishery | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Tanner Crab | | Snow Crab | | Red King Crab | | Groundfish |
| Year | Male | Female | Male | Female | Male | Female | ♀+♂ |
| 1973/74 | | | | | | | 17.737 |
| 1974/75 | | | | | | | 24.450 |
| 1975/76 | | | | | | | 9.410 |
| 1976/77 | | | | | | | 4.700 |
| 1977/78 | | | | | | | 2.776 |
| 1978/79 | | | | | | | 1.868 |
| 1979/80 | | | | | | | 3.395 |
| 1980/81 | | | | | | | 2.114 |
| 1981/82 | | | | | | | 1.472 |
| 1982/83 | | | | | | | 0.449 |
| 1983/84 | | | | | | | 0.672 |
| 1984/85 | | | | | | | 0.646 |
| 1985/86 | | | | | | | 0.397 |
| 1986/87 | | | | | | | 0.650 |
| 1987/88 | | | | | | | 0.638 |
| 1988/89 | | | | | | | 0.464 |
| 1989/90 | | | | | | | 0.672 |
| 1990/91 | | | | | | | 0.945 |
| 1991/92 | | | | | | | 2.543 |
| 1992/93 | 10.986 | 1.787 | 25.759 | 1.787 | 1.188 | 0.029 | 2.760 |
| 1993/94 | 6.831 | 1.814 | 14.530 | 1.814 | 2.967 | 0.198 | 1.758 |
| 1994/95 | 3.130 | 1.270 | 7.124 | 1.271 | 0.000 | 0 | 2.096 |
| 1995/96 | 2.762 | 1.760 | 4.797 | 1.759 | 0.000 | 0 | 1.525 |
| 1996/97 | 0.236 | 0.091 | 0.833 | 0.229 | 0.027 | 0.004 | 1.594 |
| 1997/98 | 0 | 0 | 1.750 | 0.226 | 0.165 | 0.003 | 1.180 |
| 1998/99 | 0 | 0 | 1.989 | 0.175 | 0.119 | 0.003 | 0.935 |
| 1999/00 | 0 | 0 | 0.695 | 0.145 | 0.076 | 0.004 | 0.631 |
| 2000/01 | 0 | 0 | 0.146 | 0.022 | 0.067 | 0.002 | 0.742 |
| 2001/02 | 0 | 0 | 0.323 | 0.011 | 0.043 | 0.002 | 1.185 |
| 2002/03 | 0 | 0 | 0.557 | 0.037 | 0.062 | 0.003 | 0.719 |
| 2003/04 | 0 | 0 | 0.193 | 0.026 | 0.056 | 0.003 | 0.424 |
| 2004/05 | 0 | 0 | 0.078 | 0.014 | 0.048 | 0.003 | 0.675 |
| 2005/06 | 0.286 | 0.027 | 0.968 | 0.043 | 0.042 | 0.002 | 0.621 |
| 2006/07 | 1.243 | 0.322 | 1.462 | 0.169 | 0.026 | 0.003 | 0.717 |
| 2007/08 | 2.100 | 0.100 | 1.872 | 0.102 | 0.056 | 0.009 | 0.695 |
| 2008/09 | 0.431 | 0.014 | 1.119 | 0.050 | 0.270 | 0.004 | 0.533 |
| 2009/10 | 0.071 | 0.002 | 1.324 | 0.014 | 0.150 | 0.001 | 0.321 |
| 2010/11 | 0 | 0 | 1.344 | 0.016 | 0.033 | 0.001 | 0.217 |
| 2011/12 | 0 | 0 | 2.119 | 0.014 | 0.010 | 0.000 | 0.208 |

Table 3. *Base Model (0)* predicted retained and discard catch (1000 t) by sex in the directed Tanner crab pot fishery, 1973/74-2011/12.

| Directed Fishery Predicted Retained and Discard Catch Biomass (1000 t) | | | | |
|---|---|---|---|---|
| Year | Retained | Discard Catch | | Total |
| | Male Catch | Male | Female | Male Catch |
| 1973/74 | 13.02 | 6.07 | 0.52 | 19.10 |
| 1974/75 | 15.23 | 6.90 | 0.58 | 22.12 |
| 1975/76 | 17.65 | 8.00 | 0.67 | 25.65 |
| 1976/77 | 30.01 | 14.77 | 1.27 | 44.78 |
| 1977/78 | 35.52 | 20.78 | 1.99 | 56.30 |
| 1978/79 | 21.09 | 15.84 | 1.81 | 36.93 |
| 1979/80 | 18.97 | 23.93 | 3.44 | 42.89 |
| 1980/81 | 13.44 | 16.38 | 2.35 | 29.82 |
| 1981/82 | 5.03 | 3.09 | 0.48 | 8.13 |
| 1982/83 | 2.47 | 1.13 | 0.19 | 3.60 |
| 1983/84 | 0.79 | 0.28 | 0.06 | 1.07 |
| 1984/85 | 1.5 | 0.48 | 0.13 | 1.97 |
| 1985/86 | 0 | 0 | 0 | 0 |
| 1986/87 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1987/88 | 1.02 | 0.54 | 0.08 | 1.56 |
| 1988/89 | 3.10 | 1.59 | 0.20 | 4.70 |
| 1989/90 | 11.02 | 6.17 | 0.72 | 17.19 |
| 1990/91 | 18.09 | 10.25 | 1.26 | 28.34 |
| 1991/92 | 14.31 | 8.70 | 1.11 | 23.01 |
| 1992/93 | 15.32 | 6.42 | 1.56 | 21.74 |
| 1993/94 | 7.48 | 3.74 | 0.72 | 11.23 |
| 1994/95 | 3.46 | 1.76 | 0.30 | 5.22 |
| 1995/96 | 1.84 | 1.62 | 0.13 | 3.46 |
| 1996/97 | 0.8 | 0.36 | 0.06 | 1.16 |
| 1997/98 | 0 | 0 | 0 | 0 |
| 1998/99 | 0 | 0 | 0 | 0 |
| 1999/00 | 0 | 0 | 0 | 0 |
| 2000/01 | 0 | 0 | 0 | 0 |
| 2001/02 | 0 | 0 | 0 | 0 |
| 2002/03 | 0 | 0 | 0 | 0 |
| 2003/04 | 0 | 0 | 0 | 0 |
| 2004/05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2005/06 | 0.43 | 0.43 | 0.01 | 0.86 |
| 2006/07 | 0.93 | 0.81 | 0.03 | 1.74 |
| 2007/08 | 1.04 | 1.06 | 0.03 | 2.10 |
| 2008/09 | 0.92 | 0.34 | 0.03 | 1.26 |
| 2009/10 | 0.69 | 0.04 | 0.06 | 0.73 |
| 2010/11 | 0 | 0 | 0 | 0 |
| 2011/12 | 0 | 0 | 0 | 0 |

Table 4. *Base Model (0)* predicted discard catch (1000 t) by sex in the non-directed domestic pot and groundfish fisheries by sex, 1973/74-2011/12.

| Non-Directed Fishery Predicted Discard Catch Biomass (1000 t) | | | | | |
|---|---|---|---|---|---|
| Year | Snow Crab Fishery | | Red King Crab Fishery | | GF Fishery |
| | Male | Female | Male | Female | Male + Female |
| 1973/74 | 2.39 | 0.20 | 2.87 | 9.0E-05 | 14.19 |
| 1974/75 | 2.11 | 0.18 | 2.76 | 8.5E-05 | 19.56 |
| 1975/76 | 1.81 | 0.15 | 2.29 | 7.0E-05 | 7.53 |
| 1976/77 | 1.51 | 0.13 | 2.86 | 9.3E-05 | 3.76 |
| 1977/78 | 1.13 | 0.11 | 2.74 | 1.0E-04 | 2.23 |
| 1978/79 | 2.65 | 0.28 | 1.52 | 7.0E-05 | 1.52 |
| 1979/80 | 3.24 | 0.35 | 0.73 | 4.2E-05 | 2.71 |
| 1980/81 | 5.56 | 0.58 | 1.33 | 7.5E-05 | 1.70 |
| 1981/82 | 4.85 | 0.62 | 1.46 | 8.1E-05 | 1.21 |
| 1982/83 | 2.27 | 0.35 | 0.57 | 3.2E-05 | 0.49 |
| 1983/84 | 0.84 | 0.18 | 0.46 | 3.0E-05 | 0.59 |
| 1984/85 | 1.08 | 0.32 | 0 | 0 | 0.56 |
| 1985/86 | 1.28 | 0.42 | 0 | 0 | 0.40 |
| 1986/87 | 2.37 | 0.48 | 0.22 | 1.7E-05 | 0.54 |
| 1987/88 | 4.68 | 0.67 | 0.36 | 2.0E-05 | 0.55 |
| 1988/89 | 6.03 | 0.72 | 0.50 | 2.2E-05 | 0.47 |
| 1989/90 | 10.33 | 1.13 | 0.65 | 2.7E-05 | 0.61 |
| 1990/91 | 15.50 | 1.76 | 0.84 | 3.8E-05 | 0.79 |
| 1991/92 | 12.57 | 1.51 | 0.65 | 3.2E-05 | 2.03 |
| 1992/93 | 12.71 | 1.63 | 0.24 | 1.3E-05 | 2.22 |
| 1993/94 | 7.19 | 1.00 | 0.18 | 1.0E-05 | 1.45 |
| 1994/95 | 3.52 | 0.52 | 0 | 0 | 1.74 |
| 1995/96 | 2.44 | 0.37 | 0 | 0 | 1.32 |
| 1996/97 | 0.44 | 0.07 | 0.08 | 4.3E-06 | 1.43 |
| 1997/98 | 0.76 | 0.33 | 0.04 | 1.1E-05 | 1.02 |
| 1998/99 | 0.71 | 0.28 | 0.04 | 8.1E-06 | 0.70 |
| 1999/00 | 0.24 | 0.08 | 0.04 | 7.0E-06 | 0.47 |
| 2000/01 | 0.18 | 0.06 | 0.04 | 7.3E-06 | 0.58 |
| 2001/02 | 0.23 | 0.07 | 0.05 | 8.5E-06 | 0.94 |
| 2002/03 | 0.29 | 0.08 | 0.06 | 9.8E-06 | 0.58 |
| 2003/04 | 0.25 | 0.07 | 0.07 | 1.2E-05 | 0.41 |
| 2004/05 | 0.24 | 0.06 | 0.09 | 1.5E-05 | 0.57 |
| 2005/06 | 0.46 | 0.11 | 0.07 | 2.1E-07 | 0.54 |
| 2006/07 | 0.68 | 0.18 | 0.08 | 2.4E-07 | 0.63 |
| 2007/08 | 0.88 | 0.23 | 0.09 | 2.7E-07 | 0.63 |
| 2008/09 | 0.59 | 0.14 | 0.10 | 3.1E-07 | 0.53 |
| 2009/10 | 0.64 | 0.15 | 0.11 | 3.2E-07 | 0.39 |
| 2010/11 | 0.63 | 0.15 | 0.11 | 2.7E-07 | 0.33 |
| 2011/12 | 0.95 | 0.23 | 0.09 | 2.4E-07 | 0.32 |

Table 5. *Base Model (0)* predicted total (retained + discard) Tanner crab catch biomass (1000 t) in the directed and non-directed fisheries, 1973/74-2011/12. Post-release discard mortality rates applied (0.50=pot and 0.80=groundfish).

| Year | Total Catch Biomass (1000 t) | |
|---|---|---|
| | Male | Female |
| 1973/74 | 31.45 | 7.82 |
| 1974/75 | 36.78 | 10.53 |
| 1975/76 | 33.51 | 4.58 |
| 1976/77 | 51.03 | 3.28 |
| 1977/78 | 61.30 | 3.21 |
| 1978/79 | 41.85 | 2.84 |
| 1979/80 | 48.22 | 5.14 |
| 1980/81 | 37.56 | 3.79 |
| 1981/82 | 15.04 | 1.71 |
| 1982/83 | 6.68 | 0.78 |
| 1983/84 | 2.67 | 0.53 |
| 1984/85 | 3.33 | 0.73 |
| 1985/86 | 1.48 | 0.62 |
| 1986/87 | 2.85 | 0.75 |
| 1987/88 | 6.88 | 1.03 |
| 1988/89 | 11.46 | 1.16 |
| 1989/90 | 28.48 | 2.15 |
| 1990/91 | 45.07 | 3.43 |
| 1991/92 | 37.24 | 3.63 |
| 1992/93 | 35.80 | 4.30 |
| 1993/94 | 19.32 | 2.45 |
| 1994/95 | 9.62 | 1.69 |
| 1995/96 | 6.56 | 1.16 |
| 1996/97 | 2.40 | 0.84 |
| 1997/98 | 1.30 | 0.84 |
| 1998/99 | 1.10 | 0.63 |
| 1999/00 | 0.51 | 0.32 |
| 2000/01 | 0.51 | 0.35 |
| 2001/02 | 0.75 | 0.54 |
| 2002/03 | 0.64 | 0.37 |
| 2003/04 | 0.53 | 0.27 |
| 2004/05 | 0.61 | 0.35 |
| 2005/06 | 1.66 | 0.40 |
| 2006/07 | 2.81 | 0.52 |
| 2007/08 | 3.38 | 0.57 |
| 2008/09 | 2.22 | 0.44 |
| 2009/10 | 1.68 | 0.41 |
| 2010/11 | 0.90 | 0.31 |
| 2011/12 | 1.20 | 0.39 |

Table 6. Observed survey female, male and total spawning biomass (1000 t) and observed abundance of legal male crab ≥ 138mm (million crab), 1974-2012.

| Observed Survey Mature Male and Female Biomass and Legal Male Abundance | | | | |
|---|---|---|---|---|
| Year | Mature Biomass (1000 t) | | | Male ≥ 138 mm ($10^6$ crab) |
| | Male | Female | Total | |
| 1974 | 212.01 | 55.76 | 267.77 | 87.53 |
| 1975 | 265.07 | 38.76 | 303.83 | 151.45 |
| 1976 | 152.09 | 45.99 | 198.08 | 86.07 |
| 1977 | 130.41 | 47.59 | 177.99 | 68.49 |
| 1978 | 80.62 | 26.43 | 107.06 | 37.65 |
| 1979 | 47.82 | 20.43 | 68.25 | 21.33 |
| 1980 | 86.33 | 70.42 | 156.76 | 28.53 |
| 1981 | 50.67 | 45.24 | 95.91 | 10.14 |
| 1982 | 49.67 | 64.76 | 114.43 | 6.82 |
| 1983 | 29.04 | 20.72 | 49.76 | 4.70 |
| 1984 | 26.15 | 14.72 | 40.87 | 6.19 |
| 1985 | 11.71 | 5.68 | 17.39 | 3.54 |
| 1986 | 13.18 | 3.49 | 16.67 | 2.27 |
| 1987 | 24.18 | 5.27 | 29.46 | 5.73 |
| 1988 | 59.51 | 25.57 | 85.08 | 15.60 |
| 1989 | 101.48 | 25.47 | 126.96 | 32.73 |
| 1990 | 103.17 | 36.36 | 139.52 | 42.93 |
| 1991 | 110.82 | 45.56 | 156.37 | 33.89 |
| 1992 | 108.12 | 27.76 | 135.88 | 39.65 |
| 1993 | 62.12 | 11.91 | 74.03 | 18.22 |
| 1994 | 44.55 | 10.37 | 54.92 | 14.81 |
| 1995 | 33.86 | 13.44 | 47.30 | 9.45 |
| 1996 | 27.32 | 9.80 | 37.12 | 8.56 |
| 1997 | 11.07 | 3.53 | 14.60 | 3.24 |
| 1998 | 10.56 | 2.31 | 12.87 | 1.97 |
| 1999 | 12.40 | 3.81 | 16.21 | 2.07 |
| 2000 | 16.45 | 4.17 | 20.63 | 4.60 |
| 2001 | 18.20 | 4.61 | 22.81 | 5.97 |
| 2002 | 18.23 | 4.48 | 22.71 | 5.94 |
| 2003 | 23.71 | 8.35 | 32.06 | 6.31 |
| 2004 | 25.56 | 4.70 | 30.26 | 4.50 |
| 2005 | 43.99 | 11.62 | 55.61 | 10.41 |
| 2006 | 66.89 | 15.79 | 82.68 | 13.36 |
| 2007 | 72.63 | 13.33 | 85.97 | 10.90 |
| 2008 | 59.70 | 11.33 | 71.03 | 14.39 |
| 2009 | 37.60 | 8.22 | 45.82 | 6.91 |
| 2010 | 36.14 | 5.44 | 41.59 | 8.01 |
| 2011 | 46.30 | 8.67 | 54.97 | 13.68 |
| 2012 | 43.15 | 15.83 | 58.97 | 7.09 |

Table 7. *Base Model (0)* estimates of population biomass and abundance, male, female and total mature biomass, abundance of legal (≥ 138mm) males, recruitment to the population, male mature biomass at mating, and full-selection fishing mortality rate. (Biomass in 1000 t, abundance in $10^6$ crab).

| Year | Population ≥ 25mm | | Mature Biomass (1000 t) | | | Males ≥ 138 mm | R > 25-30mm | MMB @Mating | Full-Selection |
|---|---|---|---|---|---|---|---|---|---|
| | 1000 t | $10^6$ crab | Female | Male | Total | $10^6$ crab | $10^6$ crab | 1000 t | F |
| 1974/75 | 622.03 | 2396.92 | 116.72 | 417.70 | 534.41 | 161.67 | 170.91 | 317.24 | 0.19 |
| 1975/76 | 528.29 | 2070.50 | 98.93 | 362.18 | 461.11 | 140.35 | 392.90 | 275.01 | 0.22 |
| 1976/77 | 451.90 | 2302.84 | 83.68 | 308.44 | 392.12 | 116.99 | 272.24 | 212.46 | 0.45 |
| 1977/78 | 368.19 | 2237.05 | 68.95 | 237.37 | 306.32 | 83.73 | 251.58 | 141.90 | 0.85 |
| 1978/79 | 295.95 | 2138.16 | 58.75 | 160.42 | 219.17 | 45.67 | 67.39 | 96.08 | 0.98 |
| 1979/80 | 268.35 | 1713.19 | 57.40 | 126.13 | 183.53 | 27.78 | 13.53 | 62.39 | 2.20 |
| 1980/81 | 243.07 | 1247.01 | 57.41 | 114.56 | 171.98 | 23.73 | 53.48 | 47.16 | 1.53 |
| 1981/82 | 200.18 | 941.15 | 57.27 | 95.81 | 153.09 | 29.02 | 20.99 | 50.71 | 0.31 |
| 1982/83 | 163.65 | 687.83 | 52.68 | 86.12 | 138.80 | 33.00 | 204.83 | 49.86 | 0.12 |
| 1983/84 | 127.54 | 885.08 | 44.04 | 65.70 | 109.73 | 29.76 | 172.65 | 39.56 | 0.05 |
| 1984/85 | 100.76 | 993.78 | 35.75 | 40.94 | 76.68 | 19.29 | 361.45 | 23.53 | 0.11 |
| 1985/86 | 98.91 | 1466.08 | 30.45 | 26.41 | 56.86 | 11.30 | 287.01 | 21.52 | 0.01 |
| 1986/87 | 126.26 | 1696.07 | 29.32 | 33.59 | 62.92 | 12.59 | 277.72 | 26.91 | 0.02 |
| 1987/88 | 167.70 | 1851.78 | 33.62 | 53.16 | 86.78 | 17.92 | 200.09 | 40.52 | 0.10 |
| 1988/89 | 210.91 | 1807.34 | 41.23 | 80.57 | 121.79 | 28.08 | 111.48 | 59.82 | 0.18 |
| 1989/90 | 245.30 | 1586.51 | 49.17 | 112.42 | 161.59 | 39.49 | 47.42 | 71.57 | 0.49 |
| 1990/91 | 245.37 | 1256.65 | 52.68 | 125.88 | 178.56 | 45.05 | 23.79 | 67.73 | 0.80 |
| 1991/92 | 208.36 | 922.89 | 50.49 | 111.39 | 161.87 | 37.95 | 18.75 | 61.85 | 0.73 |
| 1992/93 | 166.30 | 664.09 | 43.97 | 95.04 | 139.00 | 32.65 | 15.50 | 48.34 | 1.17 |
| 1993/94 | 115.41 | 460.68 | 33.95 | 67.40 | 101.35 | 21.95 | 15.21 | 39.46 | 0.69 |
| 1994/95 | 81.48 | 337.18 | 25.27 | 48.37 | 73.64 | 15.91 | 21.55 | 32.00 | 0.39 |
| 1995/96 | 59.80 | 273.93 | 18.46 | 35.53 | 53.99 | 11.87 | 24.17 | 23.95 | 0.24 |
| 1996/97 | 44.77 | 238.63 | 13.56 | 25.70 | 39.26 | 8.82 | 62.21 | 19.50 | 0.18 |
| 1997/98 | 38.50 | 296.60 | 10.28 | 21.17 | 31.45 | 7.29 | 26.33 | 16.70 | 0.05 |
| 1998/99 | 35.58 | 273.75 | 8.09 | 18.56 | 26.66 | 6.62 | 81.78 | 14.75 | 0.04 |
| 1999/00 | 37.33 | 368.78 | 7.20 | 17.64 | 24.84 | 6.36 | 47.37 | 14.55 | 0.03 |
| 2000/01 | 42.53 | 376.72 | 7.65 | 19.60 | 27.25 | 6.93 | 148.01 | 16.22 | 0.03 |
| 2001/02 | 52.34 | 583.78 | 8.54 | 24.19 | 32.73 | 8.76 | 56.60 | 19.86 | 0.04 |
| 2002/03 | 61.57 | 560.65 | 9.73 | 28.70 | 38.43 | 10.91 | 100.79 | 23.88 | 0.02 |
| 2003/04 | 73.88 | 631.53 | 11.68 | 34.78 | 46.46 | 13.01 | 198.12 | 29.20 | 0.01 |
| 2004/05 | 91.01 | 881.36 | 14.49 | 43.45 | 57.94 | 16.40 | 57.63 | 36.50 | 0.02 |
| 2005/06 | 106.23 | 793.51 | 17.04 | 55.01 | 72.05 | 20.92 | 47.15 | 45.40 | 0.04 |
| 2006/07 | 117.40 | 701.68 | 19.10 | 63.40 | 82.50 | 25.61 | 36.38 | 51.43 | 0.06 |
| 2007/08 | 125.03 | 605.69 | 22.10 | 70.02 | 92.13 | 26.98 | 40.30 | 56.65 | 0.06 |
| 2008/09 | 128.24 | 536.41 | 23.40 | 81.58 | 104.98 | 32.04 | 194.21 | 67.49 | 0.05 |
| 2009/10 | 126.32 | 792.75 | 21.33 | 85.39 | 106.72 | 36.54 | 246.71 | 71.23 | 0.08 |
| 2010/11 | 123.43 | 1099.44 | 18.39 | 77.65 | 96.03 | 33.84 | 131.29 | 65.40 | 0.01 |
| 2011/12 | 127.23 | 1109.73 | 17.39 | 69.96 | 87.35 | 30.32 | 32.39 | 58.59 | 0.01 |
| 2012/13 | 139.88 | 918.99 | 20.79 | 68.98 | 89.76 | 27.71 | - | - | - |

Table 8. *Base Model (0)* parameter values and whether parameters were estimated in the model, excluding recruitments and fishing mortality parameters.

| Parameter | Value | S.Deviation | Estimated? |
|---|---|---|---|
| Natural Mortality - immature male and female | 0.249 | 0.01 | Y |
| Natural Mortality - mature male | 0.252 | 0.01 | Y |
| Natural Mortality - mature female | 0.337 | 0.01 | Y |
| Additional 1980-84 Mortality - mature male | 0.737 | 0.11 | Y |
| Additional 1980-84 Mortality - mature female | 0.280 | 0.04 | Y |
| Female (a) parameter of exponential growth | 1.98 | 0.05 | Y |
| Female (b) parameter of exponential growth | 0.89 | 0.01 | Y |
| Male (a) parameter of exponential growth | 1.56 | 0.02 | Y |
| Male (b) parameter of exponential growth | 0.97 | 0.01 | Y |
| Alpha for gamma distribution of recruits | 11.5 | | N |
| Beta for gamma distribution of recruits | 4.0 | | N |
| Beta for gamma distribution female growth | 0.75 | | N |
| Beta for gamma distribution male growth | 0.75 | | N |
| Fishery selectivity total male slope - 1991-1996 | 0.13 | 0.01 | Y |
| Fishery selectivity total male slope - 2005-2011 | 0.13 | 0.01 | Y |
| Fishery selectivity total male length at 50%, 1991 | 132.94 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 1992 | 139.78 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 1993 | 136.81 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 1994 | 135.02 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 1995 | 123.34 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 1996 | 134.72 | 0.32 | Y |
| Fishery selectivity total male length at 50%, 2005 | 118.26 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 2006 | 118.39 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 2007 | 116.14 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 2008 | 135.84 | 0.31 | Y |
| Fishery selectivity total male length at 50%, 2009 | 159.37 | 0.31 | Y |
| Fishery retention curve male slope, 1991-1996 | 0.74 | 0.14 | Y |
| Fishery retention curve male length at 50%, 1991-1996 | 137.95 | 0.40 | Y |
| Fishery retention curve male slope, 2005-2010 | 1.02 | 0.28 | Y |
| Fishery retention curve male length at 50%, 2005-2011 | 137.70 | 0.24 | Y |
| Directed Fishery discard selectivity female slope | 0.13 | 0.01 | Y |
| Directed Fishery discard selectivity female length at 50% | 115.93 | 2.86 | Y |
| Snow crab male selectivity slope ascending, 1989-1996 | 0.32 | 0.10 | Y |
| Snow crab male selectivity length at 50% ascending, 1989-1996 | 88.00 | 1.99 | Y |
| Snow crab male selectivity slope descending, 1989-1996 | 0.12 | 0.07 | Y |
| Snow crab male selectivity length at 50% descending, 1989-1996 | 135.79 | 6.31 | Y |
| Snow crab male selectivity slope ascending, 1997-2004 | 0.25 | 0.09 | Y |
| Snow crab male selectivity length at 50% ascending, 1997-2004 | 92.53 | 3.01 | Y |
| Snow crab male selectivity slope descending, 1997-2004 | 0.17 | 0.11 | Y |
| Snow crab male selectivity length at 50% descending, 1997-2004 | 141.72 | 5.41 | Y |
| Snow crab male selectivity slope ascending, 2005-2011 | 0.17 | 0.02 | Y |
| Snow crab male selectivity length at 50% ascending, 2005-2011 | 103.43 | 2.21 | Y |
| Snow crab male selectivity slope descending, 2005-2011 | 0.23 | 0.05 | Y |
| Snow crab male selectivity length at 50% descending, 2005-2011 | 137.39 | 1.63 | Y |

Table 8. (continued)

| Parameter | Value | S.Deviation | Estimated? |
|---|---|---|---|
| Snow crab fishery female selectivity slope, 1989-1996 | 0.05 | 0.00 | Y |
| Snow crab fishery female selectivity length at 50%, 1989-1996 | 118.81 | 5.84 | Y |
| Snow crab fishery female selectivity slope, 1997-2004 | 0.22 | 0.13 | Y |
| Snow crab fishery female selectivity length at 50%, 1997-2004 | 80.59 | 5.98 | Y |
| Snow crab fishery female selectivity slope, 2005-2011 | 0.14 | 0.05 | Y |
| Snow crab fishery female selectivity length at 50%, 2005-2011 | 87.45 | 7.84 | Y |
| Red king crab fishery male selectivity slope, 1989-1996 | 0.17 | 0.04 | Y |
| Red king crab fishery male selectivity length at 50%, 1989-1996 | 150.00 | 1.17 | Y |
| Red king crab fishery male selectivity slope, 1997-2004 | 0.14 | 0.07 | Y |
| Red king crab fishery male selectivity length at 50%, 1997-2004 | 150.00 | 2.95 | Y |
| Red king crab fishery male selectivity slope, 2005-2011 | 0.17 | 0.07 | Y |
| Red king crab fishery male selectivity length at 50%, 2005-2011 | 169.96 | 245.05 | Y |
| Red king crab fishery female selectivity slope, 1989-1996 | 0.18 | 0.07 | Y |
| Red king crab fishery female selectivity length at 50%, 1989-1996 | 115.64 | 5.36 | Y |
| Red king crab fishery female selectivity slope, 1997-2004 | 0.09 | 0.03 | Y |
| Red king crab fishery female selectivity length at 50%, 1997-2004 | 134.27 | 14.68 | Y |
| Red king crab fishery female selectivity slope, 2005-2011 | 0.07 | 0.01 | Y |
| Red king crab fishery female selectivity length at 50%, 2005-2011 | 150.00 | 0.00 | Y |
| Groundfish Fishery male selectivity slope, 1973-1986 | 0.14 | 0.03 | Y |
| Groundfish Fishery male selectivity length at 50%, 1973-1986 | 42.30 | 2.00 | Y |
| Groundfish Fishery male selectivity slope, 1987-1996 | 0.18 | 0.08 | Y |
| Groundfish Fishery male selectivity length at 50%, 1987-1996 | 40.00 | 0.00 | Y |
| Groundfish Fishery male selectivity slope, 1997-2011 | 0.10 | 0.01 | Y |
| Groundfish Fishery male selectivity length at 50%, 1997-2011 | 67.70 | 3.13 | Y |
| Groundfish Fishery female selectivity slope, 1973-1986 | 0.15 | 0.03 | Y |
| Groundfish Fishery female selectivity length at 50%, 1973-1986 | 47.02 | 1.96 | Y |
| Groundfish Fishery female selectivity slope, 1987-1996 | 0.15 | 0.12 | Y |
| Groundfish Fishery female selectivity length at 50%, 1987-1996 | 41.86 | 5.19 | Y |
| Groundfish Fishery female selectivity slope, 1997-2011 | 0.08 | 0.01 | Y |
| Groundfish Fishery female selectivity length at 50%, 1997-2011 | 81.21 | 4.74 | Y |
| Survey Q 1974-1981 – male | 0.53 | 0.04 | Y |
| Survey 1974-1981 difference in length (95%-50%) of Q – male | 21.51 | 3.53 | Y |
| Survey 1974-1981 length at 50% of Q – male | 45.36 | 1.92 | Y |
| Survey Q 1982-2012 – male | 0.72 | 0.04 | Y |
| Survey 1982-2012 difference in length (95%-50%) of Q – male | 61.79 | 9.31 | Y |
| Survey 1982-2012 length at 50% of Q – male | 30.14 | 3.56 | Y |
| Survey Q 1974-1981 – female | 0.71 | 0.20 | Y |
| Survey 1974-1981 difference in length (95%-50%) of Q – female | 55.07 | 19.84 | Y |
| Survey 1974-1981 length at 50% of Q – female | 60.63 | 13.91 | Y |
| Survey Q 1982-2012 – female | 0.56 | 0.04 | Y |
| Survey 1982-2012 difference in length (95%-50%) of Q – female | 100.00 | 0.00 | Y |
| Survey 1982-2012 length at 50% of Q – female | 7.90 | 14.03 | Y |
| Fishery cpue q | 0.00055 | | N |

Table 9. Weighting factors for likelihood equations for *Base Model (0),* and *Model (1)* through *Model (6)*. Sample sizes for all length components were set at 200.

| Likelihood Component | Weight |
|---|---|
| | |
| retained + discard male catch, male and female discards in snow and red king fisheries | 10.0 |
| directed fishery female discards | 10.0 |
| groundfish catch | 10.0 |
| total catch length composition | 1.0 |
| retained catch length composition | 1.0 |
| female directed fishery length composition | 1.0 |
| survey length composition | 1.0 |
| groundfish fishery length composition | 1.0 |
| snow and red king fishery length composition | 1.0 |
| survey biomass | 1.0 |
| recruitment deviations | 1.0 |
| directed fishing mortality deviations | 1.0 |
| snow fishing mortality deviations | 0.5 |
| red king crab fishing mortality deviations | 3.0 |
| trawl fishing mortality deviations | 0.5 |
| fishery cpue | 0 |
| natural mortality penalty standard deviation | 0.05 |
| growth penalty male a standard deviation | 0.025 |
| growth penalty male b standard deviation | 0.1 |
| growth penalty female a standard deviation | 0.1 |
| growth penalty female b standard deviation | 0.025 |
| penalty on first-difference early recruitment | 1.0 |
| penalty on second-difference maturity probability males | 0.5 |
| penalty on second-difference maturity probability females | 1.0 |
| penalty on survey Q annual deviations | 0.05 |
| survey Q standard deviation penalty | 10.0 |

Table 10. Likelihood values by component for the Tanner crab assessment model shown for *Base Model (0), Model (1)* and *Model (2)*.

| Likelihood Component | Likelihood Value | | |
|---|---|---|---|
| | *Model 0* | *Model 1* | *Model 2* |
| recruitment deviations | 1.9 | 1.7 | 1.9 |
| probability of maturity smooth constraint | 1.6 | 1.6 | 1.6 |
| Survey q penalty | 26.0 | 17.8 | 26.0 |
| F penalty | 65.2 | 65.3 | 65.4 |
| retained length | 39.4 | 38.4 | 39.7 |
| total directed length | 56.9 | 58.4 | 57.1 |
| female directed length | 9.1 | 9.7 | 9.7 |
| survey length | 829.4 | 827.3 | 830.0 |
| groundfish fishery length | 35.7 | 29.9 | 40.4 |
| snow fishery length | 44.6 | 45.8 | 51.0 |
| red king fishery length | 27.6 | 27.6 | 51.7 |
| survey biomass | 186.6 | 171.4 | 186.5 |
| fishery cpue | - | - | - |
| directed fishery male discard catch | 3.7 | 3.8 | 3.8 |
| directed fishery male retained catch | 5.4 | 5.3 | 5.4 |
| directed fishery female discard catch | 11.8 | 12.0 | 11.8 |
| groundfish fishery male + female catch | 1.9 | 2.0 | 1.9 |
| snow fishery male + female catch | 13.3 | 14.4 | 13.6 |
| red king fishery male + female catch | 18.7 | 19.2 | 18.7 |
| natural mortality penalty | 46.0 | 49.7 | 46.2 |
| | | | |
| Total Likelihood | 1426.0 | 1403.1 | 1463.7 |

Table 11. Natural mortality rates on immature male and female, mature female and mature male Tanner crab estimated in *Base Model (0)* and *Model (1)*.

| Category | *Base Model (0)* | | *Model (1)* | |
|---|---|---|---|---|
| | Pre-1984 + 1985-P | 1980-84 | Pre-1984 + 1985-P | 1980-84 |
| | | | | |
| Immature M-F | 0.249 | 0.249 | 0.246 | 0.689 |
| | | | | |
| Mature Male | 0.252 | 0.737 | 0.251 | 0.436 |
| | | | | |
| Mature Female | 0.337 | 0.280 | 0.342 | 0.258 |

Table 12. Total likelihood, maximum survey Q and survey Q at reference size for male (140 mm cw) and female (100 mm cw) Tanner crab versus Q for *Base Model (0)*.

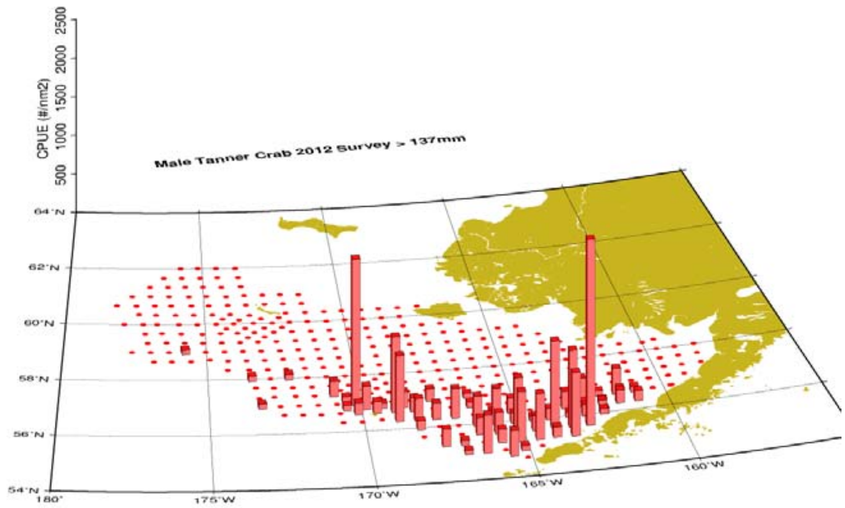
| Q | TL | Male | | Female | |
|---|---|---|---|---|---|
| | | maxQ | Q@140 mm | maxQ | Q@100 mm |
| | | | | | |
| 0.1 | 1740.6 | 0.10 | 0.10 | 0.193 | 0.139 |
| 0.2 | 1579.6 | 0.20 | 0.20 | 0.198 | 0.175 |
| 0.3 | 1515.0 | 0.30 | 0.30 | 0.263 | 0.246 |
| 0.4 | 1472.3 | 0.40 | 0.40 | 0.356 | 0.328 |
| 0.5 | 1446.5 | 0.50 | 0.50 | 0.434 | 0.398 |
| 0.6 | 1431.5 | 0.60 | 0.60 | 0.494 | 0.457 |
| 0.7 | 1426.1 | 0.70 | 0.70 | 0.546 | 0.511 |
| 0.8 | 1428.4 | 0.80 | 0.79 | 0.592 | 0.559 |
| 0.9 | 1437.3 | 0.90 | 0.89 | 0.631 | 0.600 |
| 1.0 | 1451.9 | 0.99 | 0.95 | 0.642 | 0.611 |

Table 13. Likelihood components at fixed values of survey Q for the *Base Model (0)*.

| Likelihood Component | Q | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 |
| recruitment deviations | 3.4 | 2.8 | 2.3 | 2.2 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 |
| probability of maturity smooth constraint | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Survey q penalty | 214.2 | 185.0 | 143.0 | 100.5 | 68.1 | 45.0 | 28.3 | 17.6 | 12.2 | 13.9 |
| F penalty | 92.6 | 74.3 | 73.3 | 69.1 | 66.9 | 65.4 | 65.2 | 65.2 | 65.1 | 64.8 |
| retained length | 41.9 | 41.4 | 42.4 | 41.6 | 40.2 | 39.4 | 39.4 | 39.4 | 39.4 | 39.4 |
| total directed length | 61.2 | 47.9 | 52.3 | 53.7 | 53.6 | 55.0 | 56.7 | 58.3 | 59.7 | 60.1 |
| female directed length | 7.9 | 8.4 | 8.7 | 8.8 | 8.9 | 9.0 | 9.1 | 9.2 | 9.3 | 9.4 |
| survey length | 825.0 | 792.8 | 778.1 | 792.4 | 808.6 | 819.4 | 827.9 | 836.1 | 844.8 | 853.6 |
| groundfish fishery length | 10.4 | 20.3 | 25.1 | 26.6 | 29.3 | 32.3 | 35.2 | 38.0 | 40.6 | 42.1 |
| snow fishery length | 42.1 | 43.0 | 44.6 | 44.3 | 44.2 | 44.2 | 44.5 | 45.0 | 45.5 | 45.9 |
| red king fishery length | 28.8 | 27.6 | 27.4 | 27.3 | 27.7 | 27.7 | 27.6 | 27.6 | 27.6 | 27.7 |
| survey biomass | 296.6 | 245.6 | 230.6 | 212.7 | 201.1 | 192.4 | 187.3 | 184.2 | 182.6 | 182.6 |
| fishery cpue | - | - | - | - | - | - | - | - | - | - |
| directed fishery male discard catch | 5.9 | 5.1 | 4.7 | 4.5 | 4.1 | 3.8 | 3.7 | 3.6 | 3.4 | 3.4 |
| directed fishery male retained catch | 10.7 | 7.3 | 6.1 | 6.2 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 |
| directed fishery female discard catch | 11.6 | 11.3 | 11.1 | 11.3 | 11.3 | 11.5 | 11.7 | 12.0 | 12.3 | 12.4 |
| groundfish fishery male + female catch | 1.7 | 1.5 | 1.6 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 |
| snow fishery male + female catch | 9.9 | 10.0 | 10.4 | 11.0 | 11.5 | 12.2 | 13.1 | 14.2 | 15.3 | 15.7 |
| red king fishery male + female catch | 20.3 | 11.7 | 12.8 | 14.9 | 16.2 | 17.5 | 18.5 | 19.3 | 20.0 | 20.4 |
| natural mortality penalty | 53.2 | 41.5 | 37.9 | 41.6 | 43.8 | 45.2 | 45.9 | 46.5 | 46.9 | 47.5 |
| | | | | | | | | | | |
| Total Likelihood | 1740.6 | 1579.6 | 1515.0 | 1472.3 | 1446.5 | 1431.5 | 1426.1 | 1428.4 | 1437.3 | 1451.9 |

Table14. Percent change in male and female biomass of Tanner crab estimated in the NMFS bottom trawl survey, 1980-1985, for customary survey size groupings.

| Percent Change in Tanner Crab Biomass, 1980-1985 | |
|---|---|
| Males: | % |
| Recruit (<=109 mm) | -93.7 |
| Pre-Recruit (110-137 mm) | -84.7 |
| Legal (>=138 mm) | -90.9 |
| Mature (All Sizes) | -88.5 |
| Females: | |
| Small (<85 mm) | -94.6 |
| Large (>=85 mm) | -85.3 |
| Mature (All Sizes) | -91.3 |



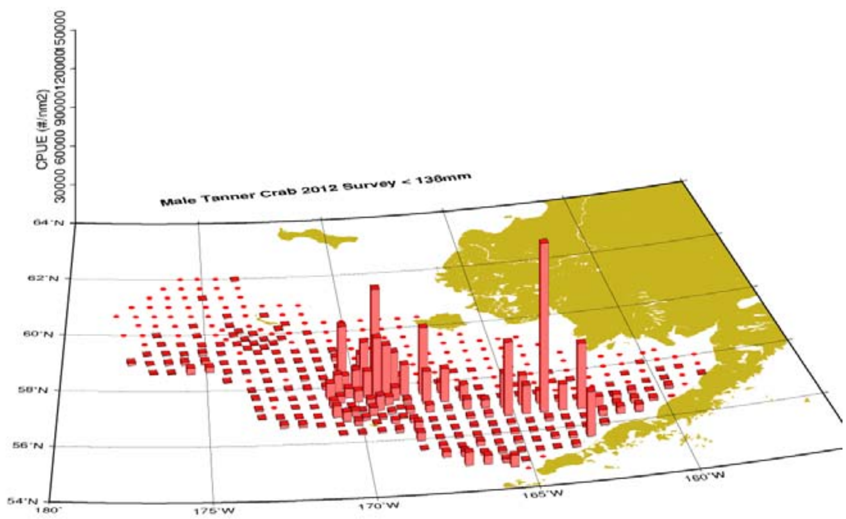




Figure 1. Distribution and abundance of legal (>= 138 mm cw) (top) and sublegal (< 138 mm cw) (bottom) male Tanner crab in the summer 2012 NMFS bottom trawl survey.

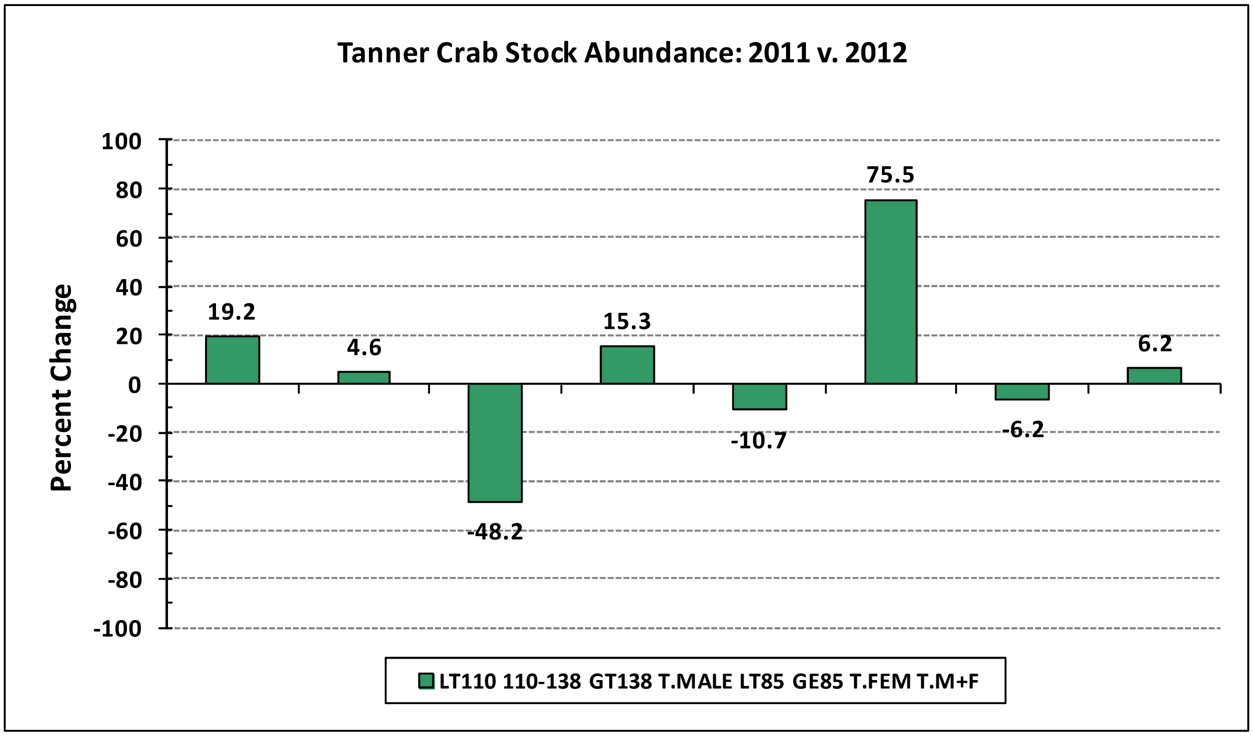
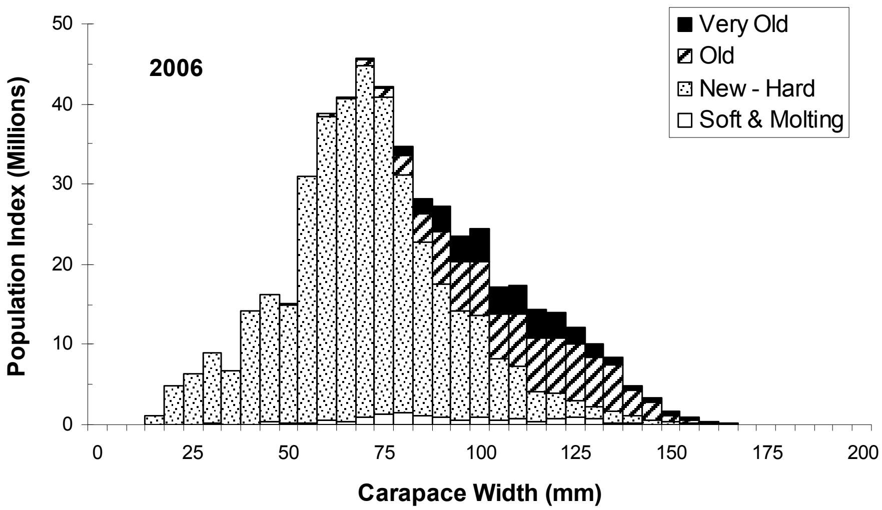



Figure 2. Percent change in Tanner crab stock abundance between the 2010 and 2011 summer trawl survey for males (< 110 mm cw, 110-137 mm cw, >= 138 mm cw and total males), females (<85 mm cw, >=85 mm cw and total females), and for total males + females combined.

(a)




(b)

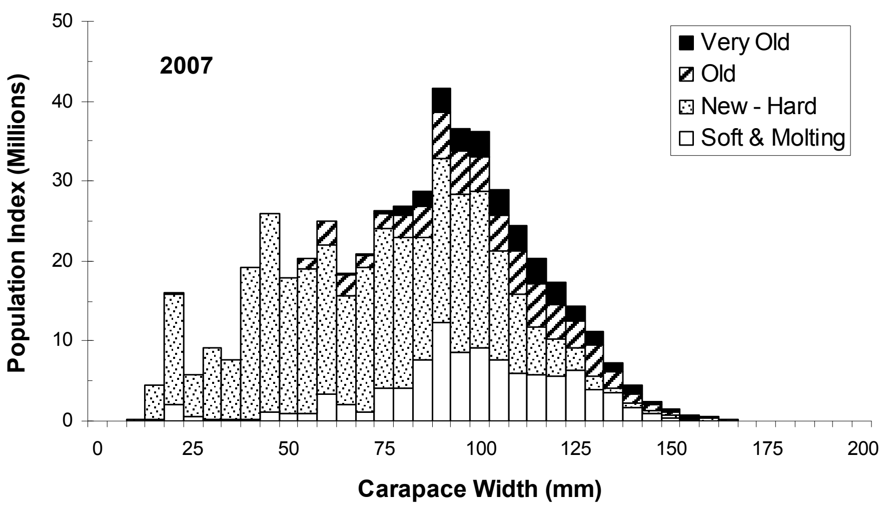
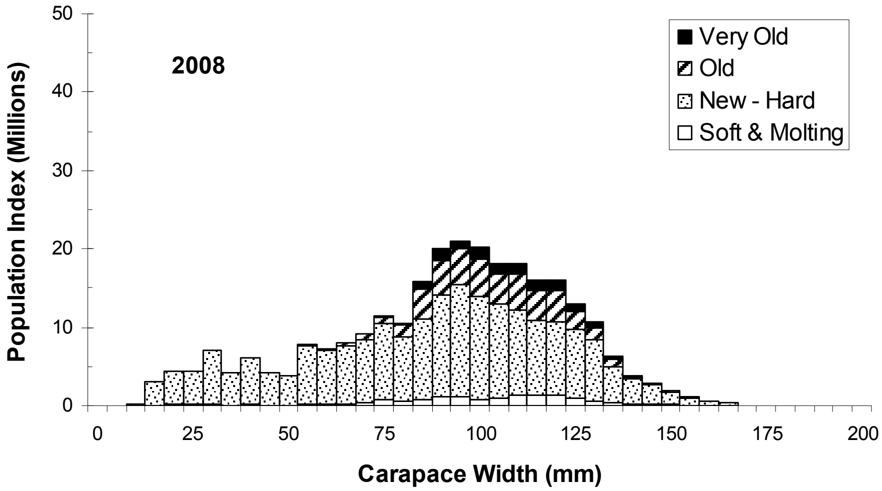



Figure 3 (a-b). Male Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2006/07 to 2007/08.

(c)




(d)

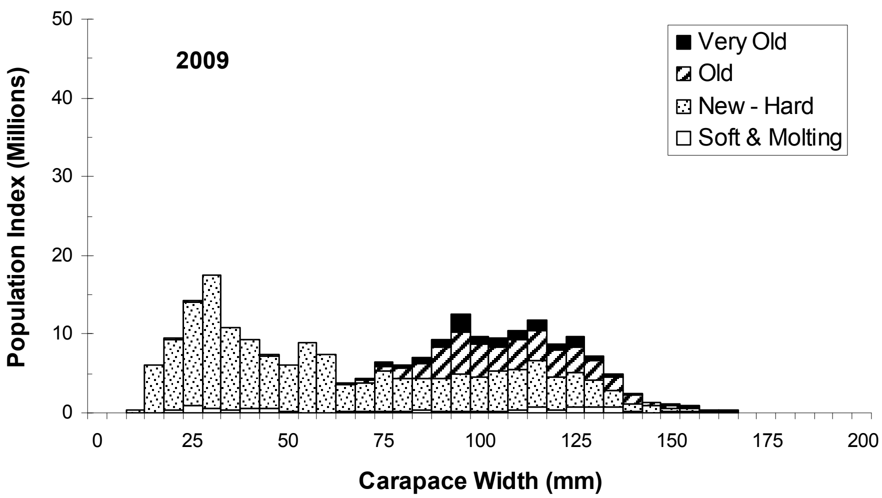
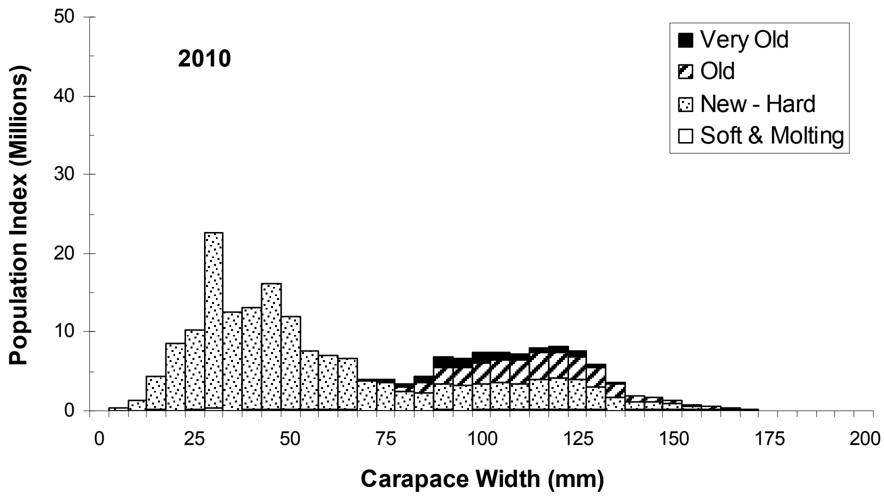



Figure 3 (c-d). Male Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2008/09 to 2009/10.

(e)




(f)

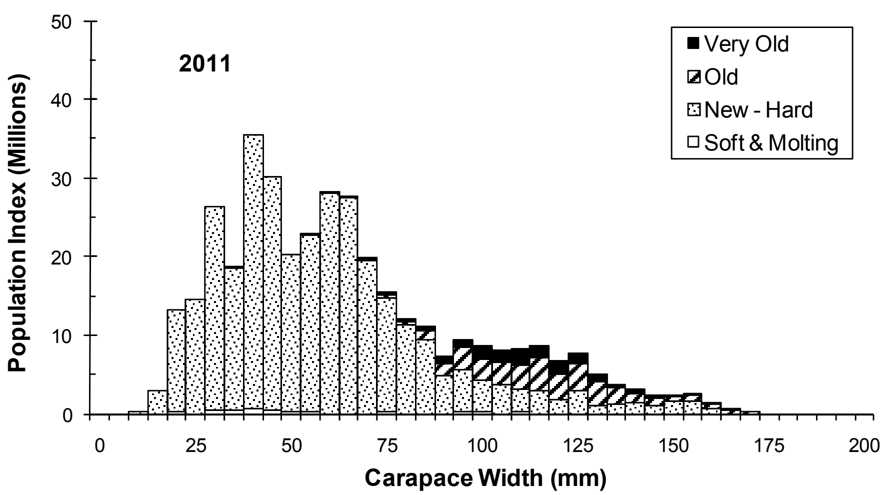



Figure 3 (e-f). Male Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2010/11 to 2011/12.

(g)

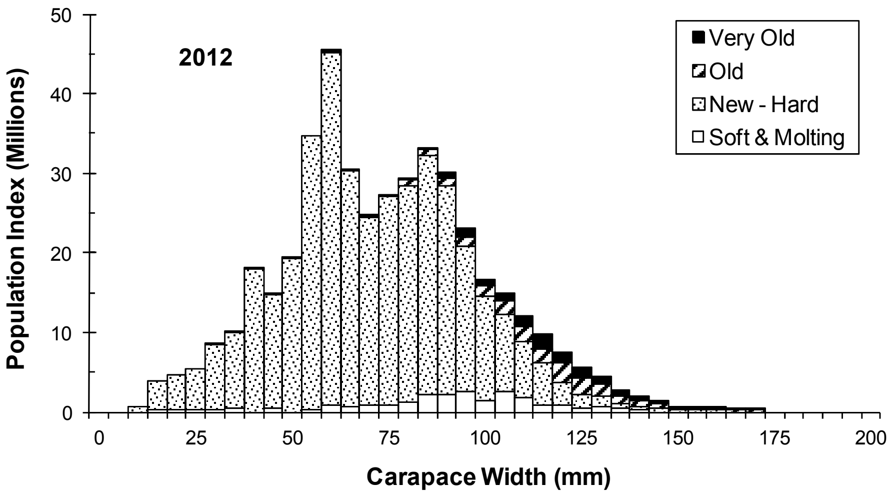



Figure 3 g. Male Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2012/13.

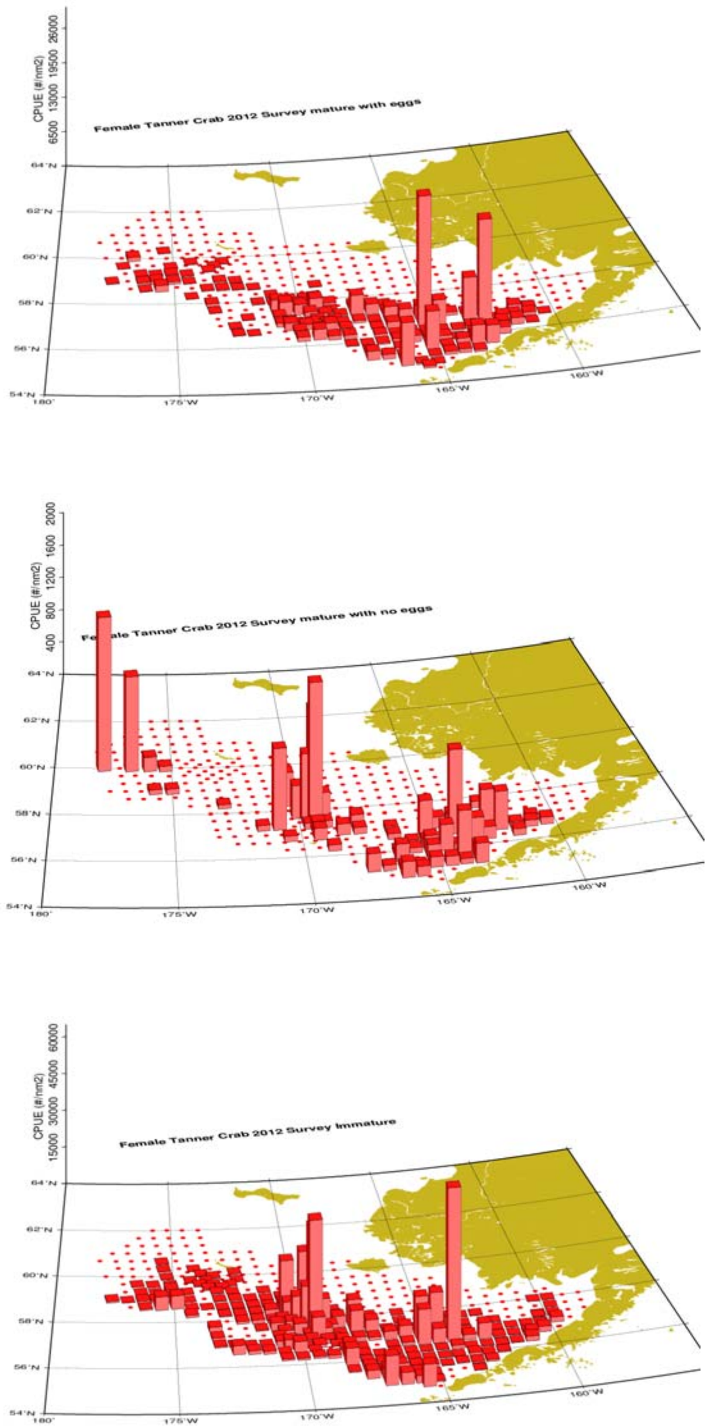
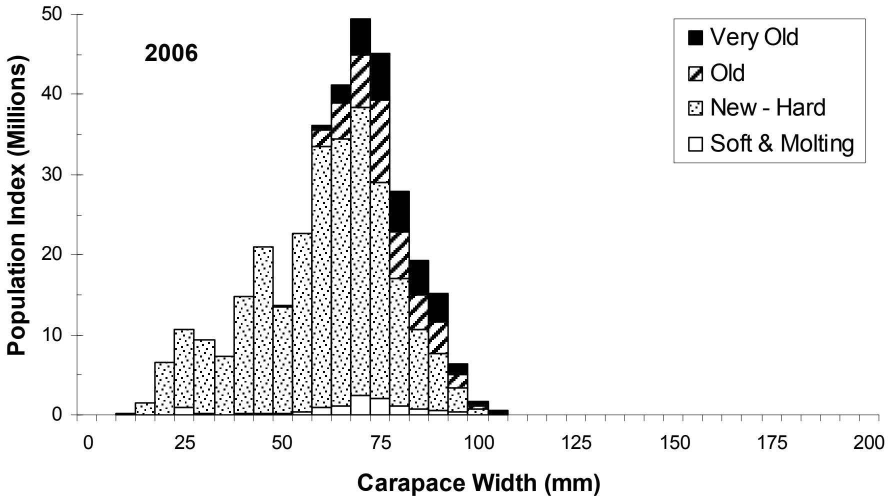



Figure 4. Distribution and abundance of ovigerous (top), barren mature (middle), and immature (bottom) female Tanner crab in the summer 2012 NMFS bottom trawl survey.

(a)




(b)

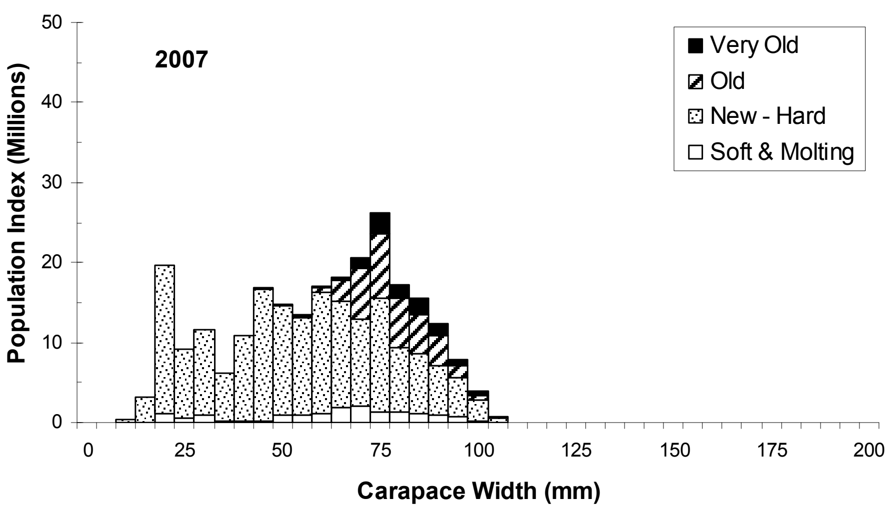
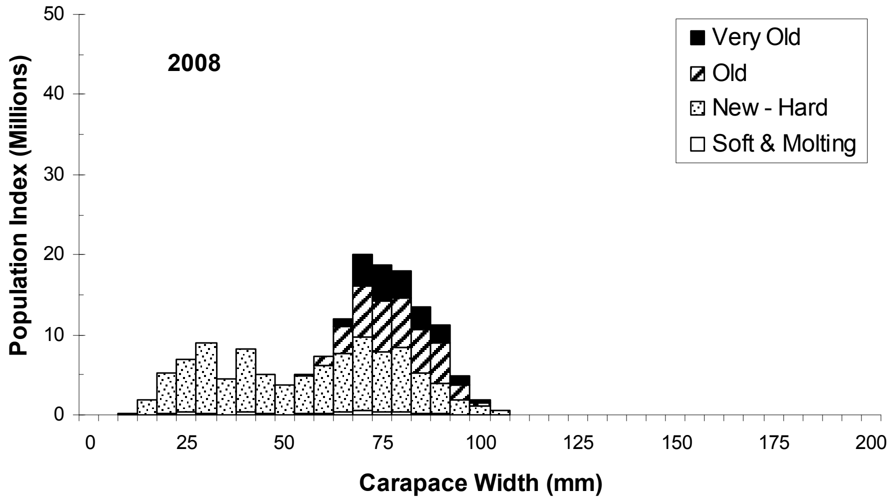



Figure 5 (a-b). Female Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2006/07 to 2007/08.

(c)




(d)

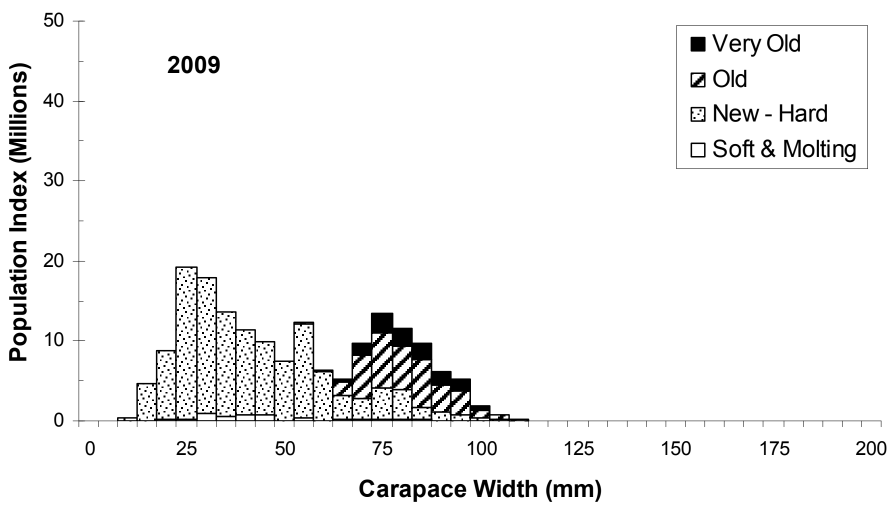
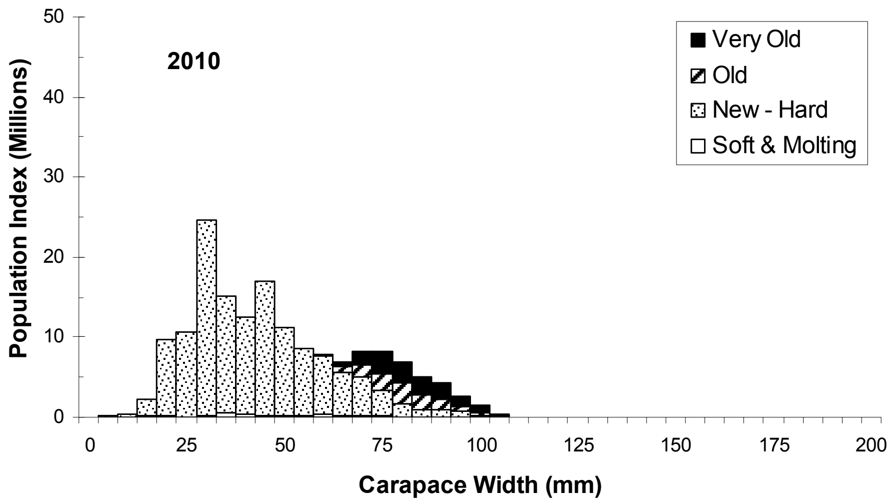



Figure 5 (c-d). Female Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2008/09 to 2009/10.

(e)




(f)

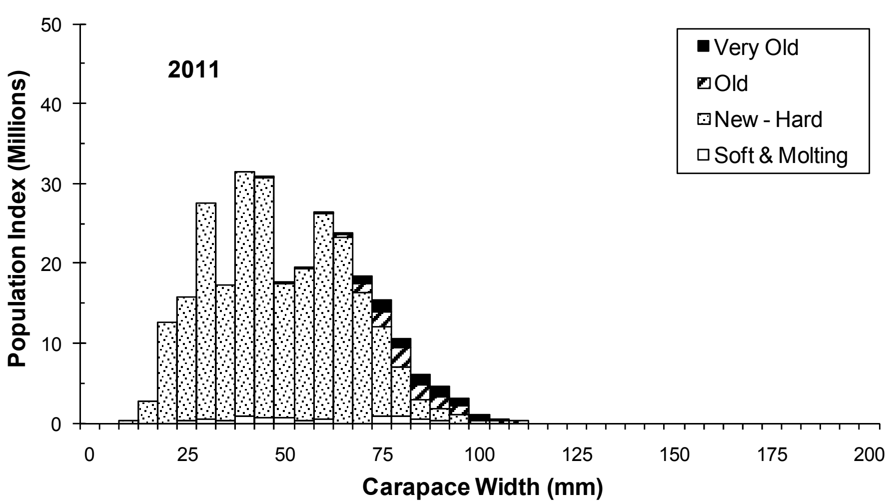



Figure 5 (e-f). Female Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2010/11 to 2011/12.

(g)

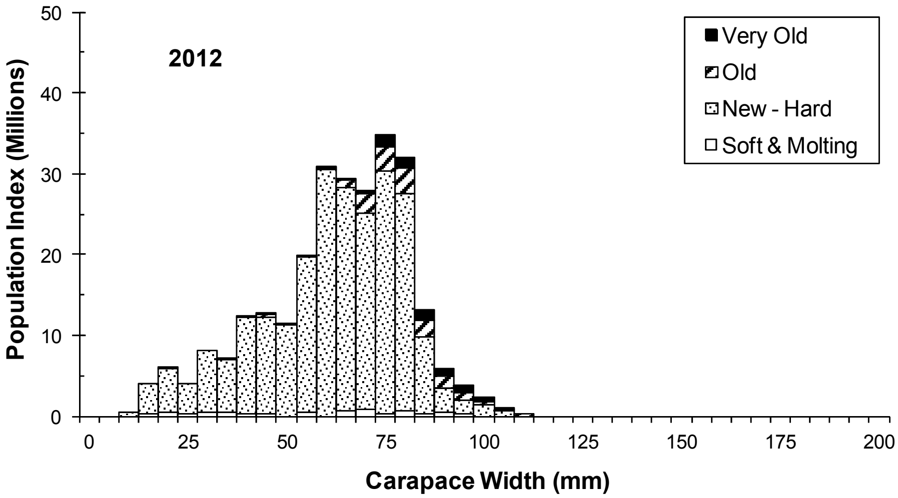



Figure 5 g. Female Tanner crab length frequency by shell class condition sampled by the EBS trawl survey, 2012/13.

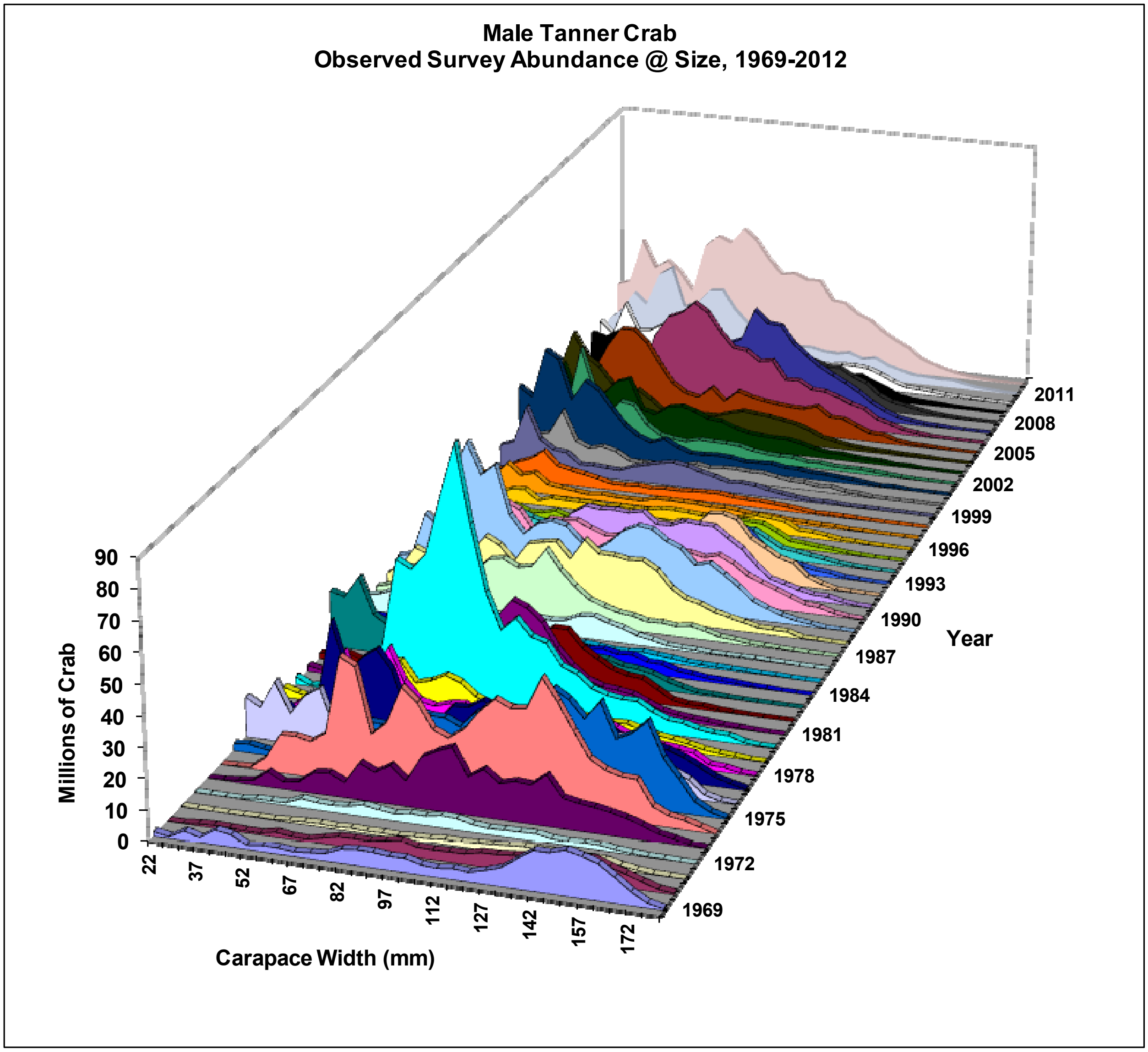



Figure 6. Observed male Tanner crab survey abundance (millions of crab) by carapace width for 1969/70 to 2011/12.

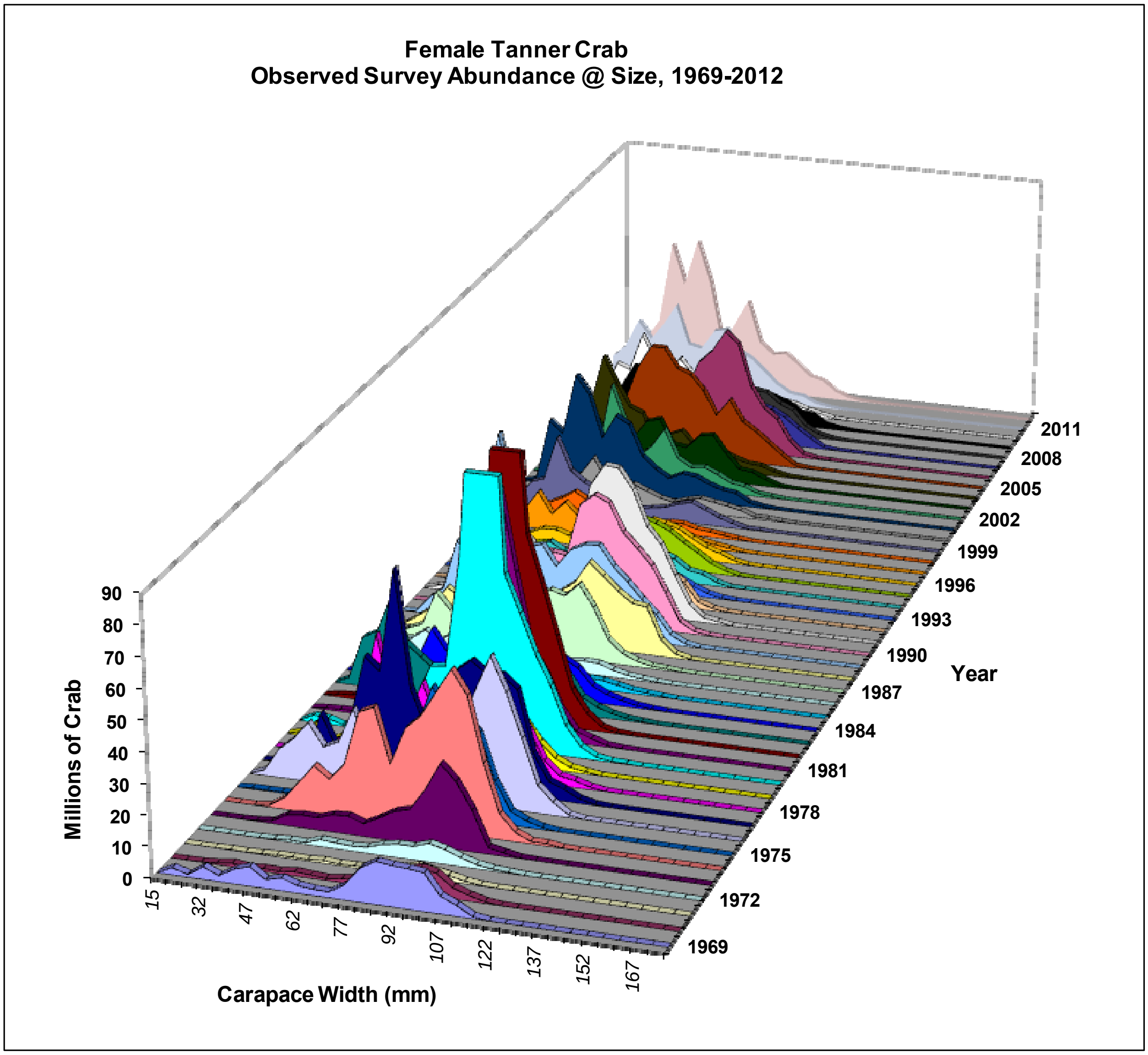



Figure 7. Observed female Tanner crab survey abundance (millions of crab) by carapace width for 1969/70 to 2011/12.

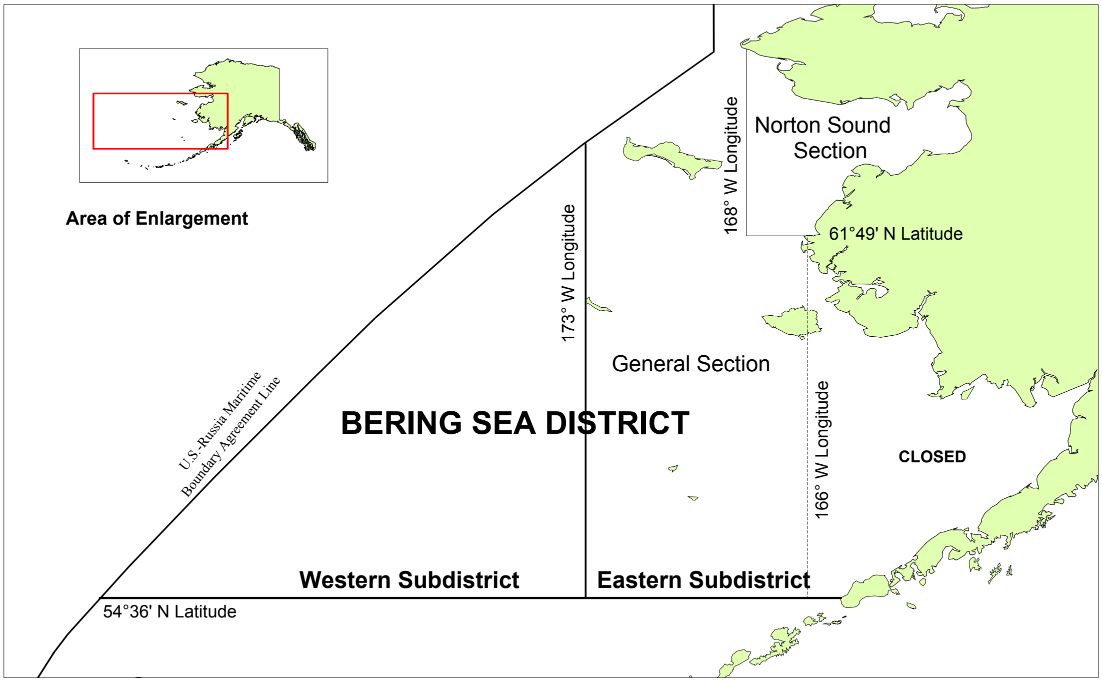



Figure 8. Eastern Bering Sea District of Tanner crab Registration Area J including subdistricts and sections (From Bowers et al. 2008).

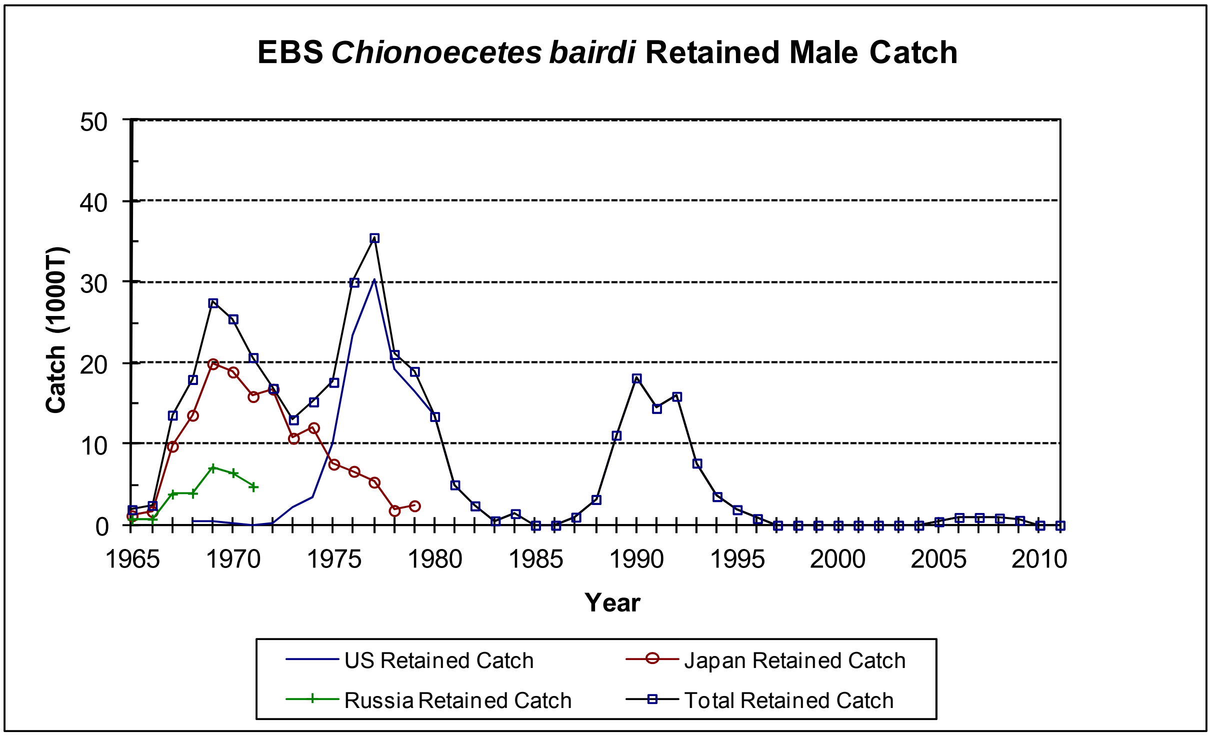



Figure 9. Eastern Bering Sea *C. bairdi* retained male catch in the directed United States, Russian and Japanese fisheries, 1965/66-2011/12.

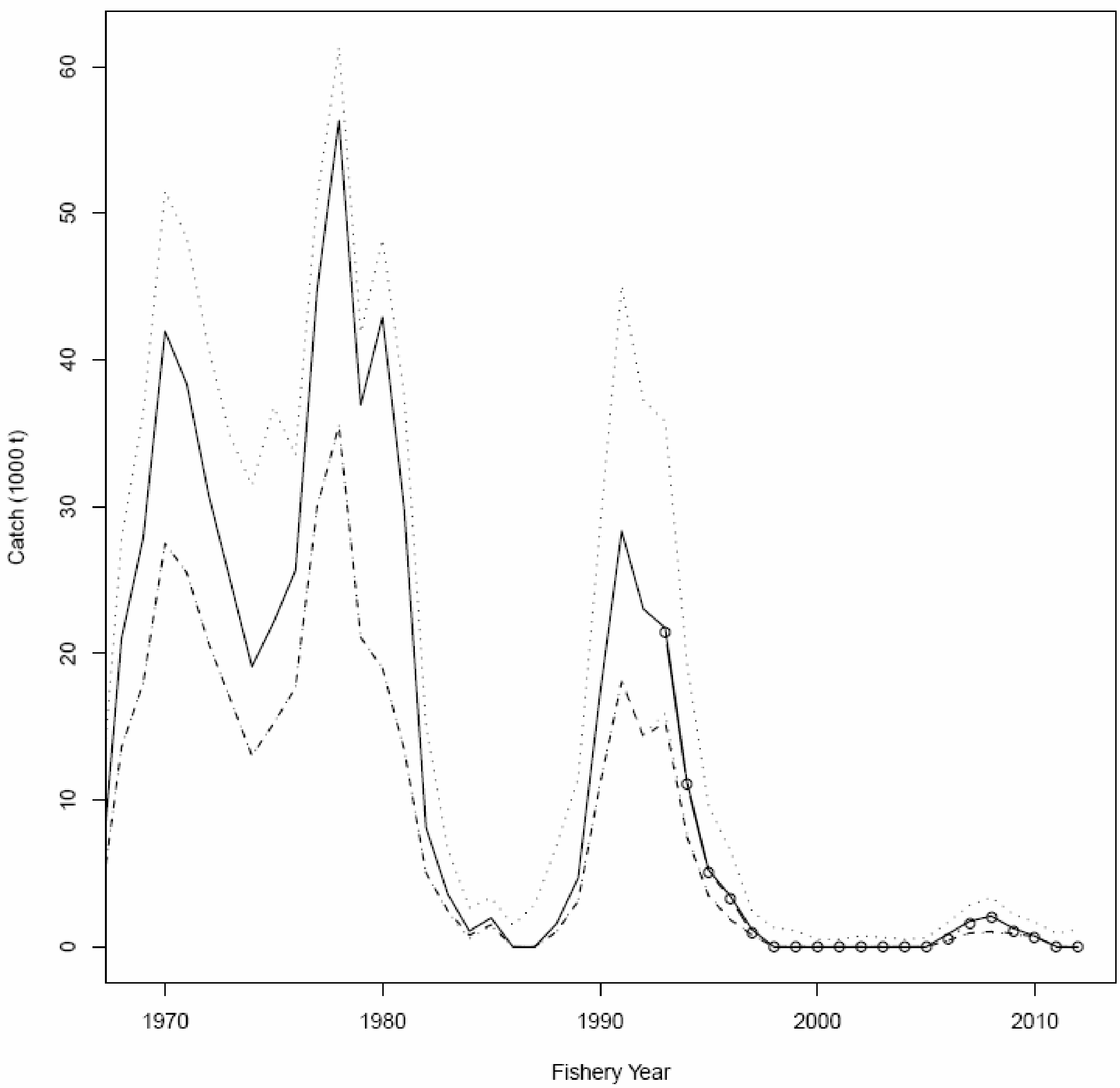



Figure 10. *Base Model (0)* predicted catch history of male Tanner crab catch by survey year. [solid line=predicted retained plus discard catch in the directed fishery; dashed line=predicted retained catch in the directed fishery; dotted line=predicted total male catch from all sources].

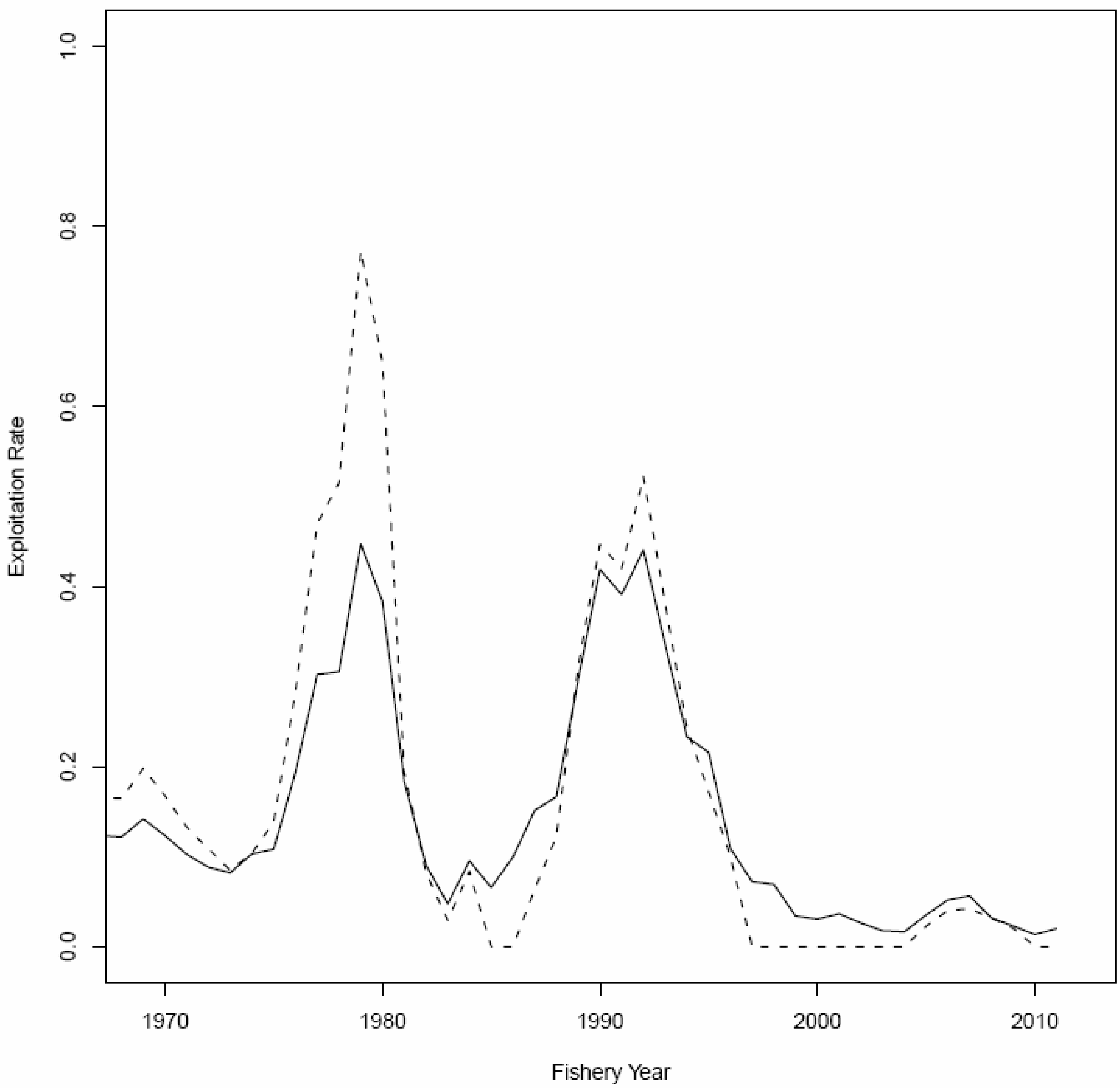



Figure 11.. *Base Model (0)* exploitation fraction estimated as the predicted catch biomass of legal males in all fisheries divided by the estimated legal male biomass at the time of the fishery (solid), and the predicted total catch (retained plus discard) divided by the estimated male mature biomass at the time of the fishery (dotted). Year is the year of the fishery.

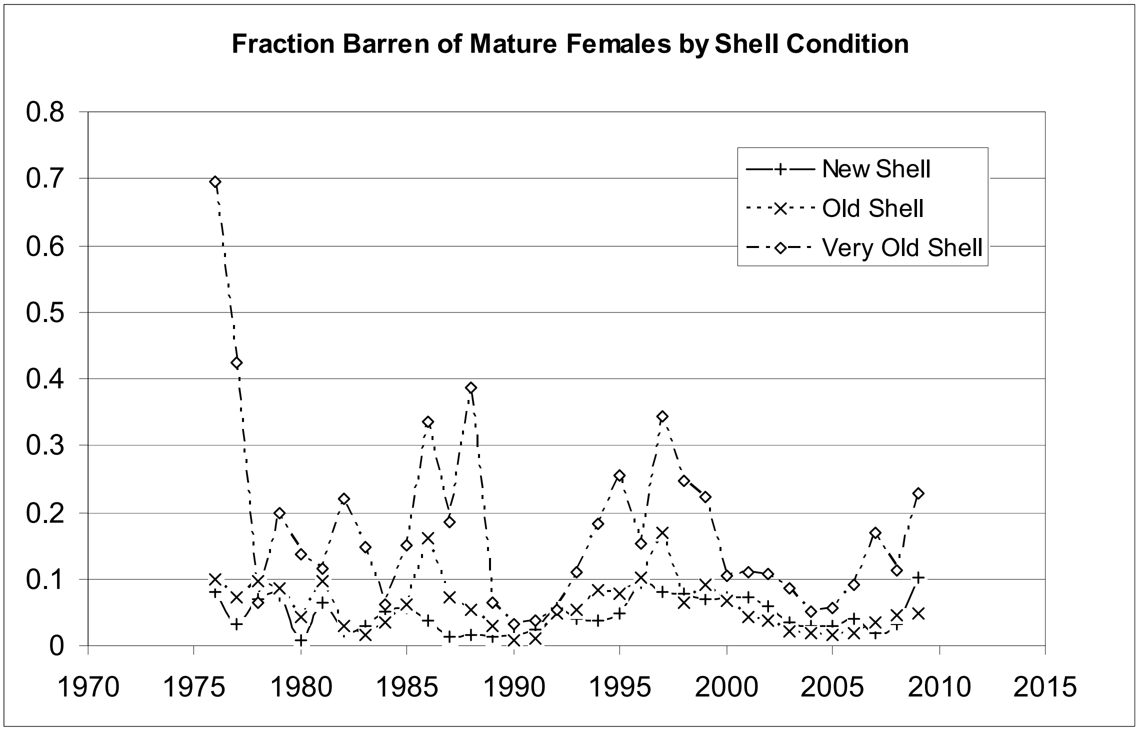



Figure 12. Proportion of female Tanner crab with barren clutches by shell condition from survey data for 1976/77 to 2009/10.

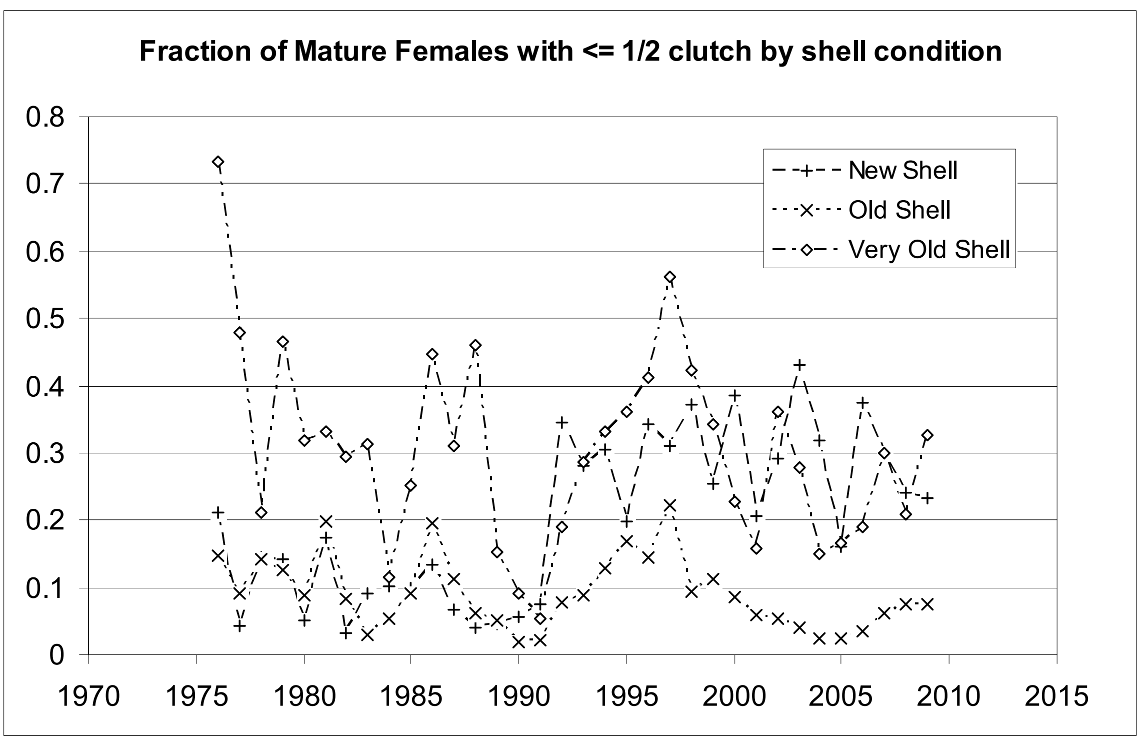



Figure 13. Proportion of female Tanner crab with less than or equal to one-half full clutch by shell condition from survey data 1976/77 to 2009/10.

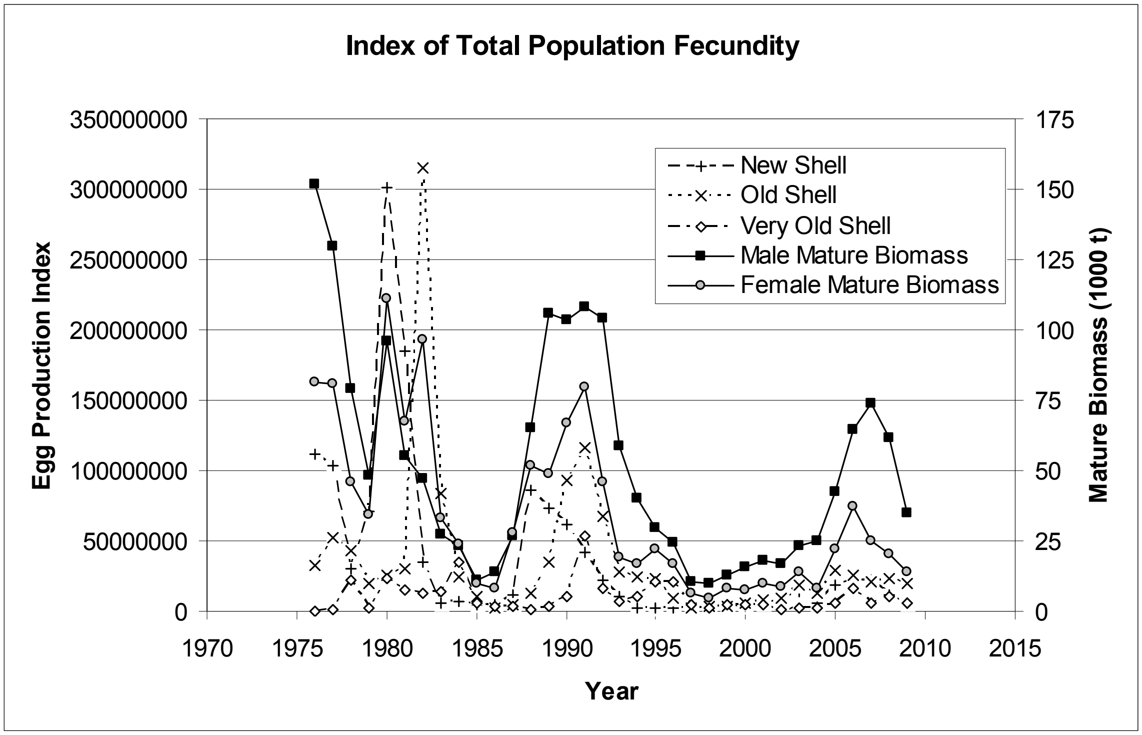



Figure 14. Tanner crab female egg production index (EPI) by shell condition, survey estimate of male mature biomass (1000 t), and survey estimate of female mature biomass (1000 t) from survey data for 1976/77 to 2009/10.

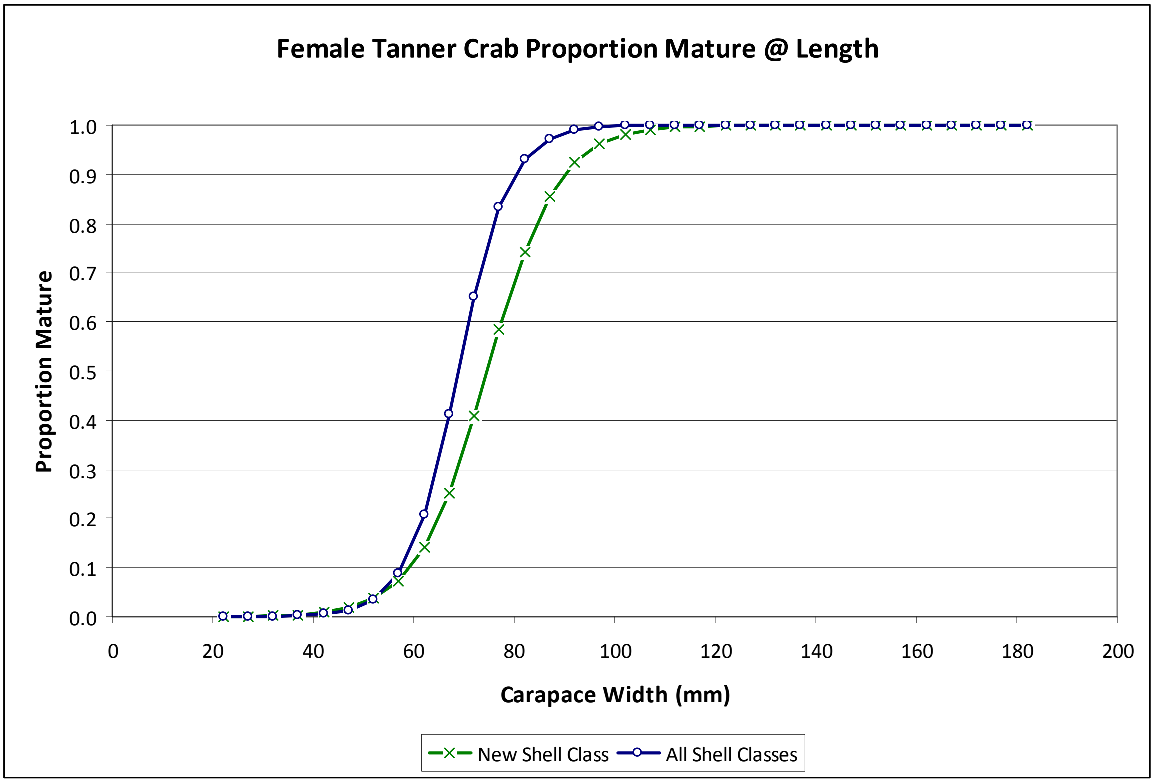



Figure 15. Fitted logistic functions of proportion mature in the stock for new shell and old shell female Tanner crab based on egg code classification of new and old shell crab in 1976-2009 survey data.

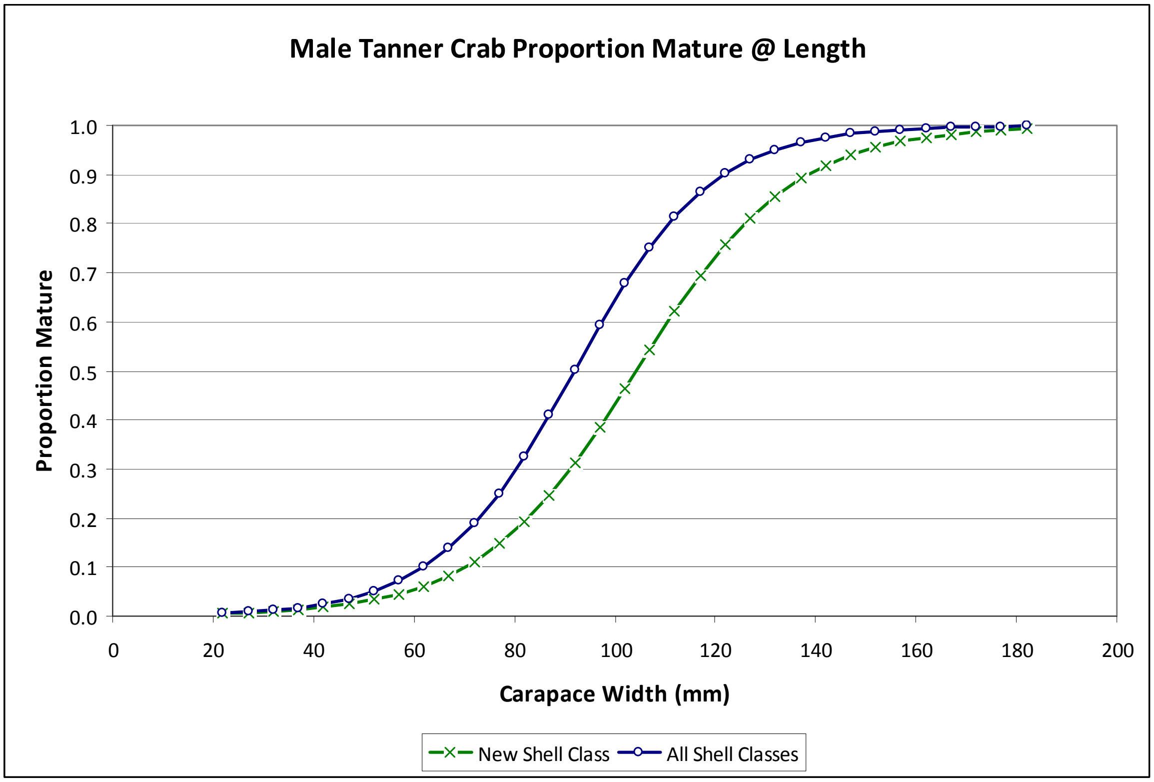



Figure 16. Fitted logistic functions of proportion mature in the stock for new shell and old shell male Tanner crab based on classification of new and old shell crab in 1990-2007 survey data.

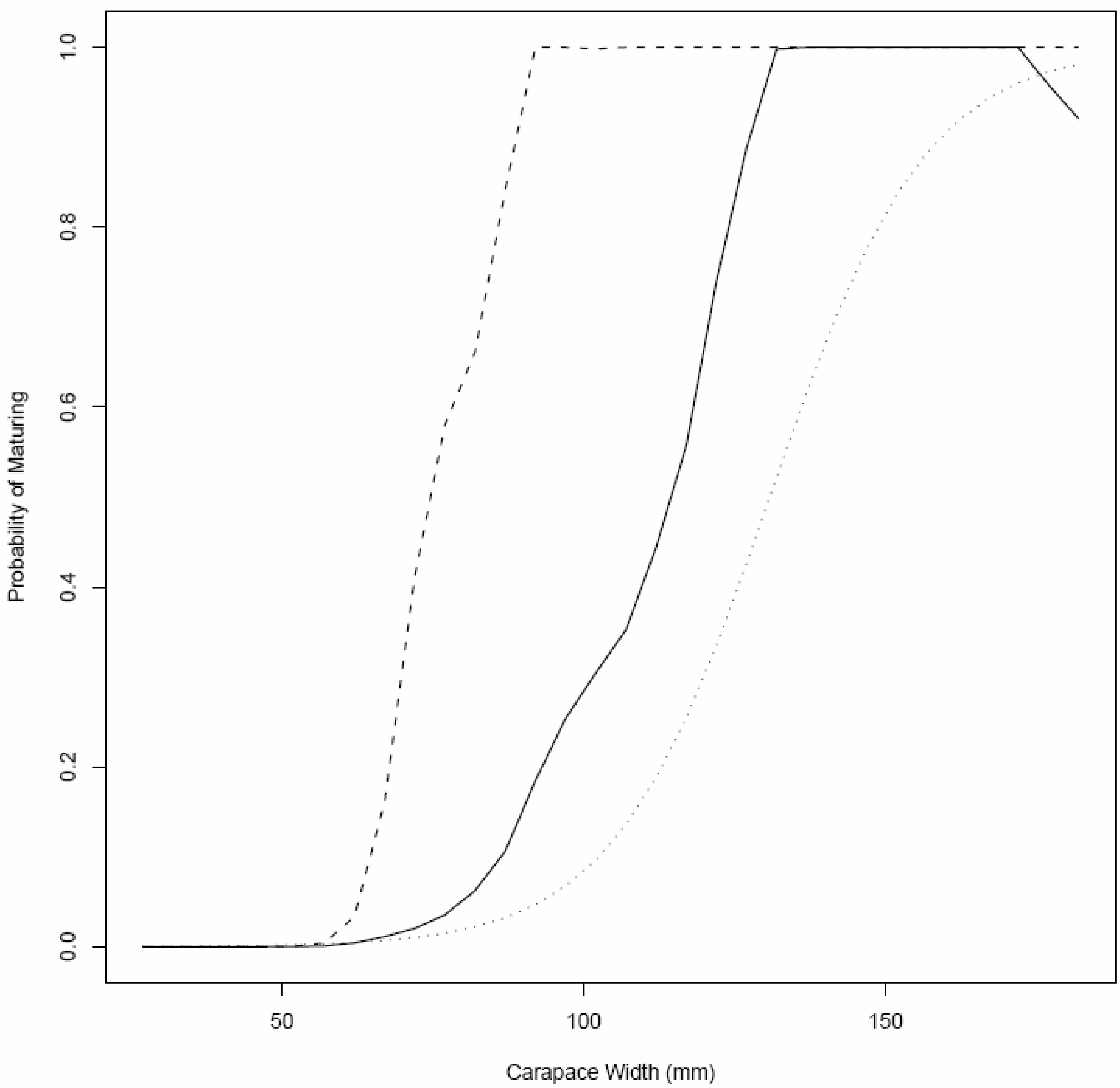
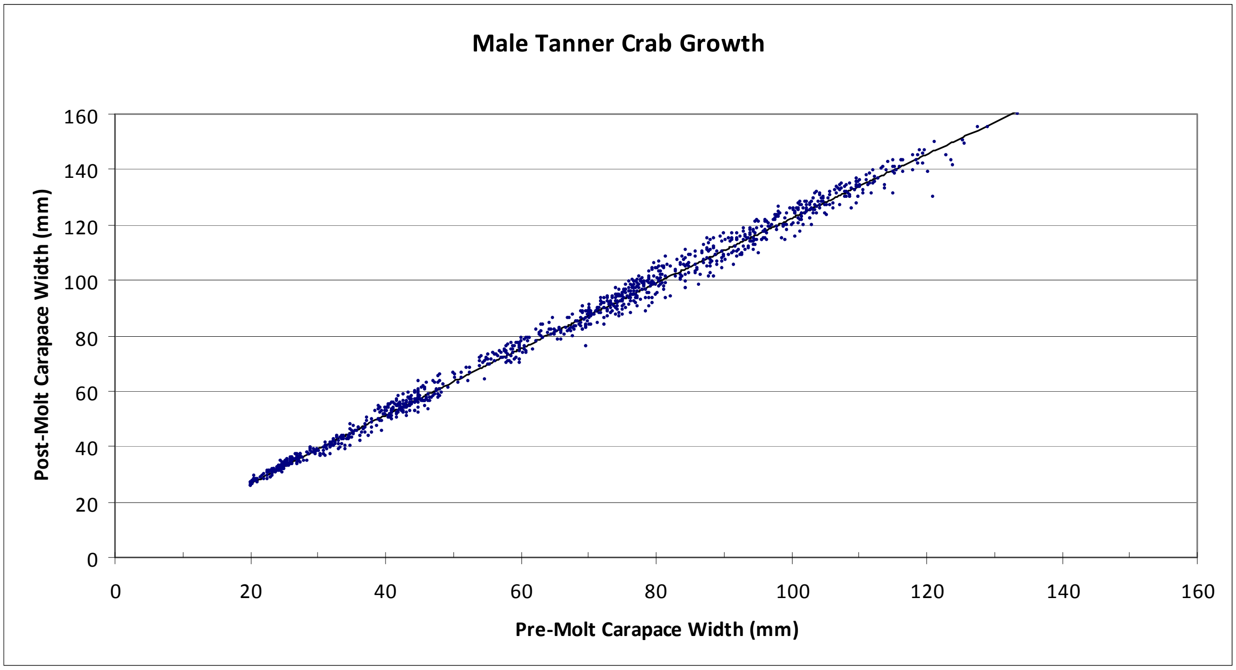



Figure 17. *Base Model (0)* estimate of probability of maturing by size for male (solid) and female (dashed) Tanner crab (not average fraction mature), and male probability of maturing by size used in Amendment #24 OFL analysis (dotted) (NPFMC 2007).

(a)




(b)

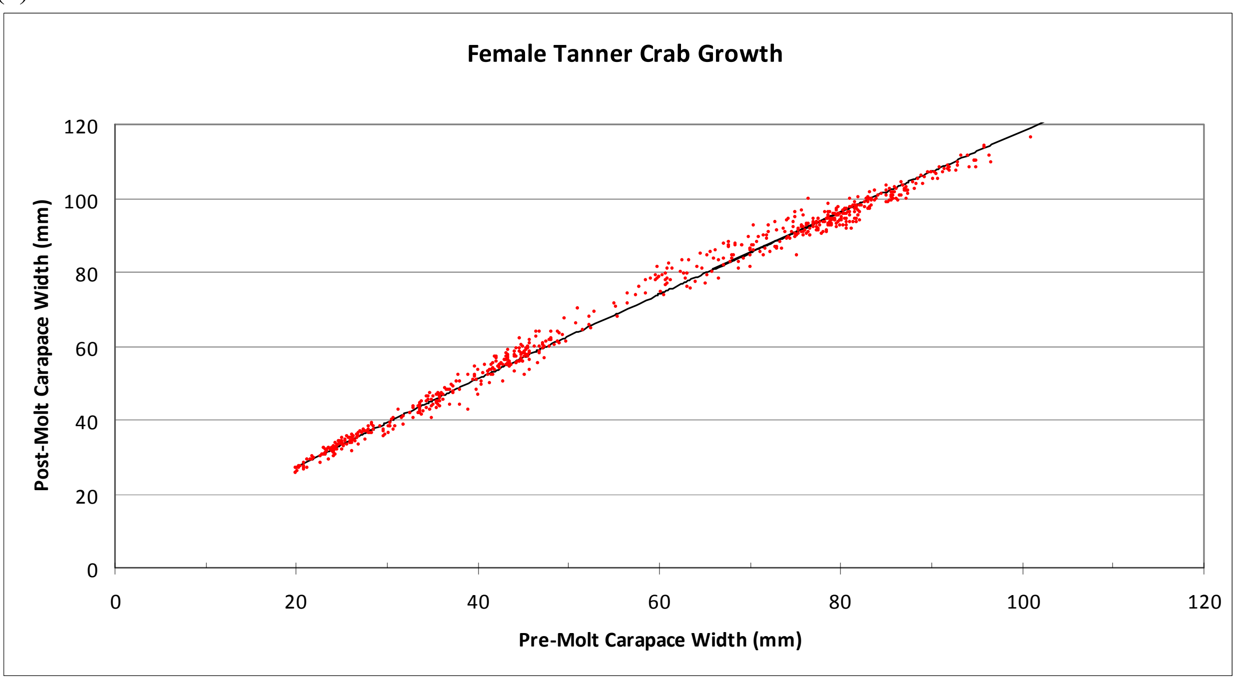



Figure 18. Growth of male (a) and female (b) Tanner crab as a function of premolt size. Estimated by Rugolo and Turnock 2010 based on data from GOA Tanner crab (Munk, unpublished data).

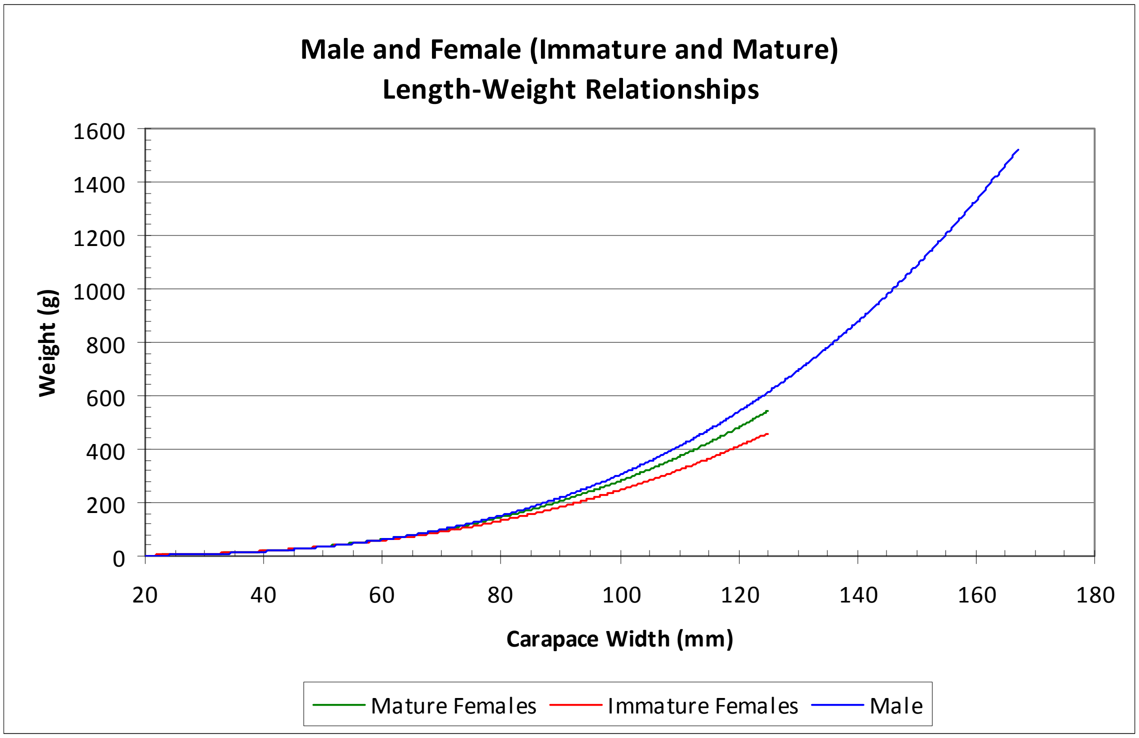



Figure 19. Weight (kg) – size (mm) relationship for male (top), mature female (middle) and immature female (bottom) Tanner crab.

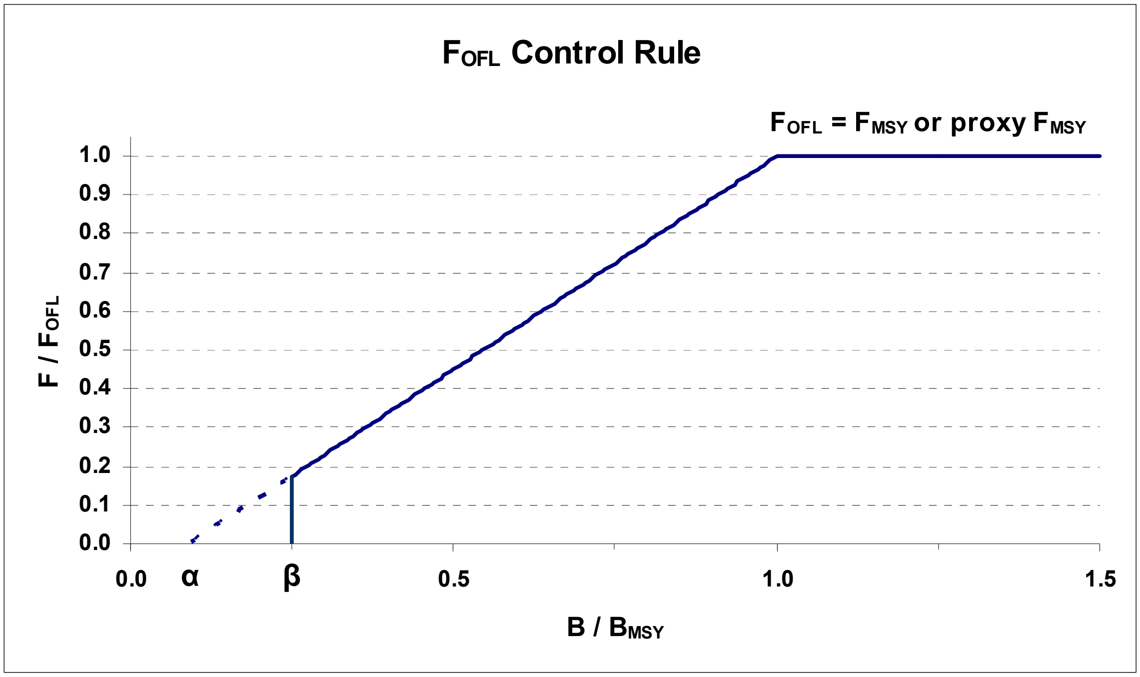
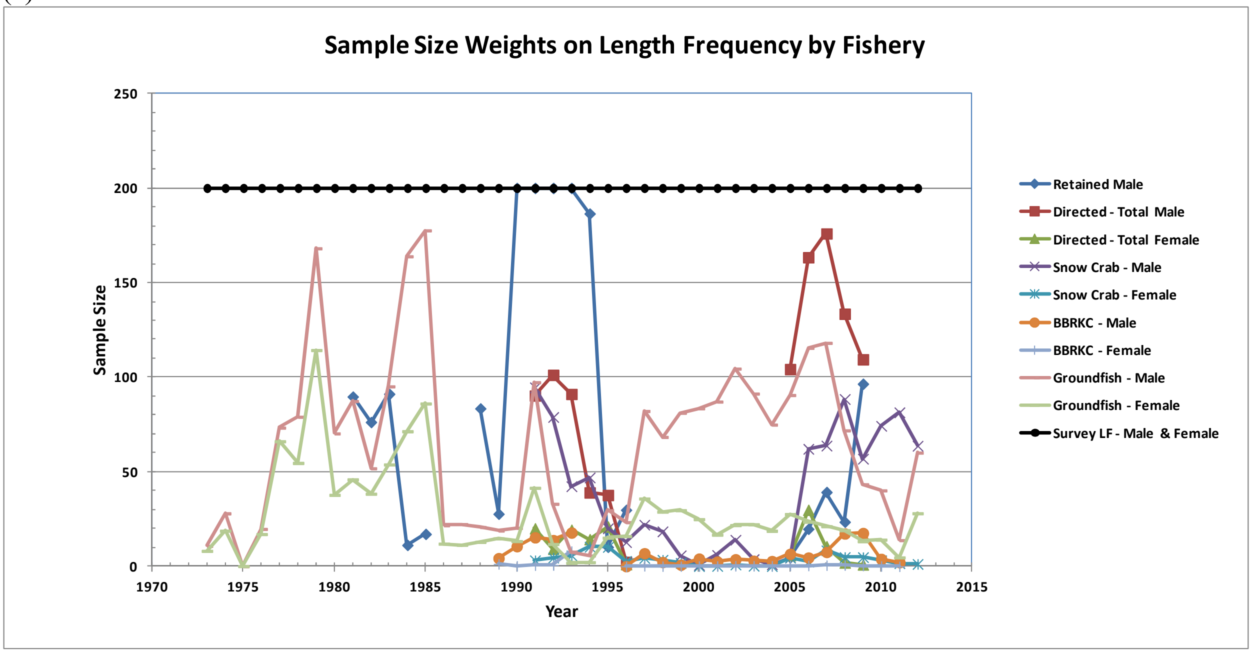



Figure 20. $F_{OFL}$ Control Rule for Tier-4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set 0 below β.

(a)




(b)

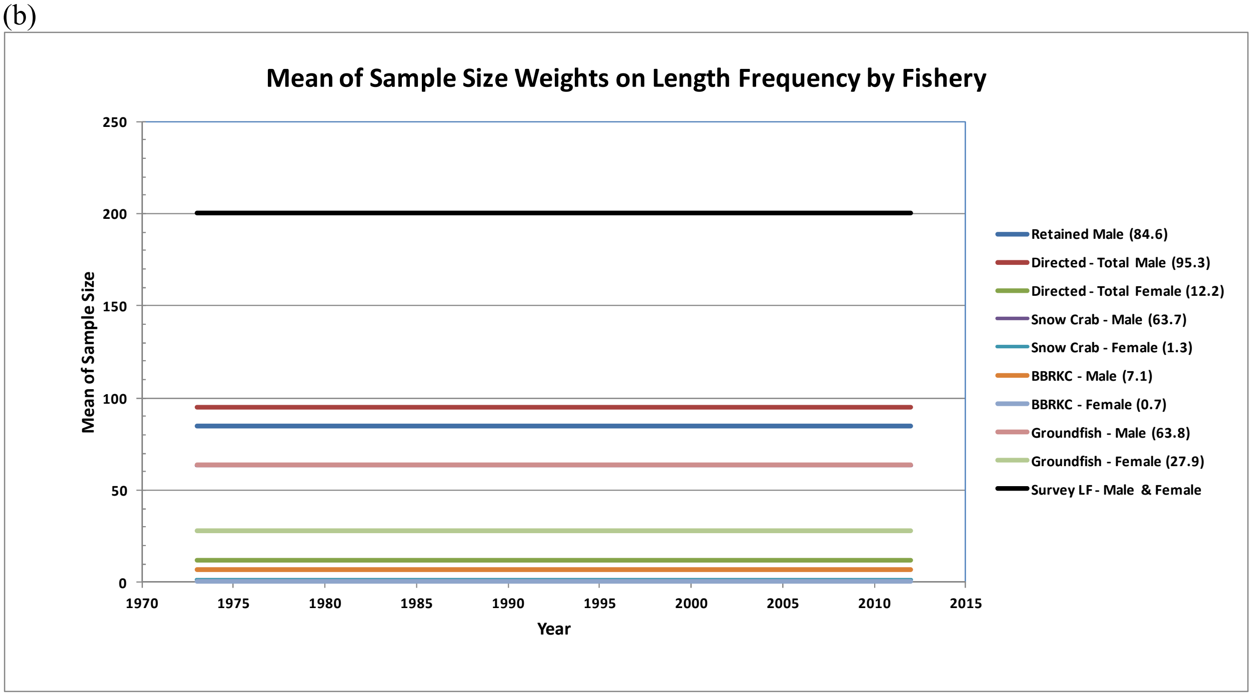
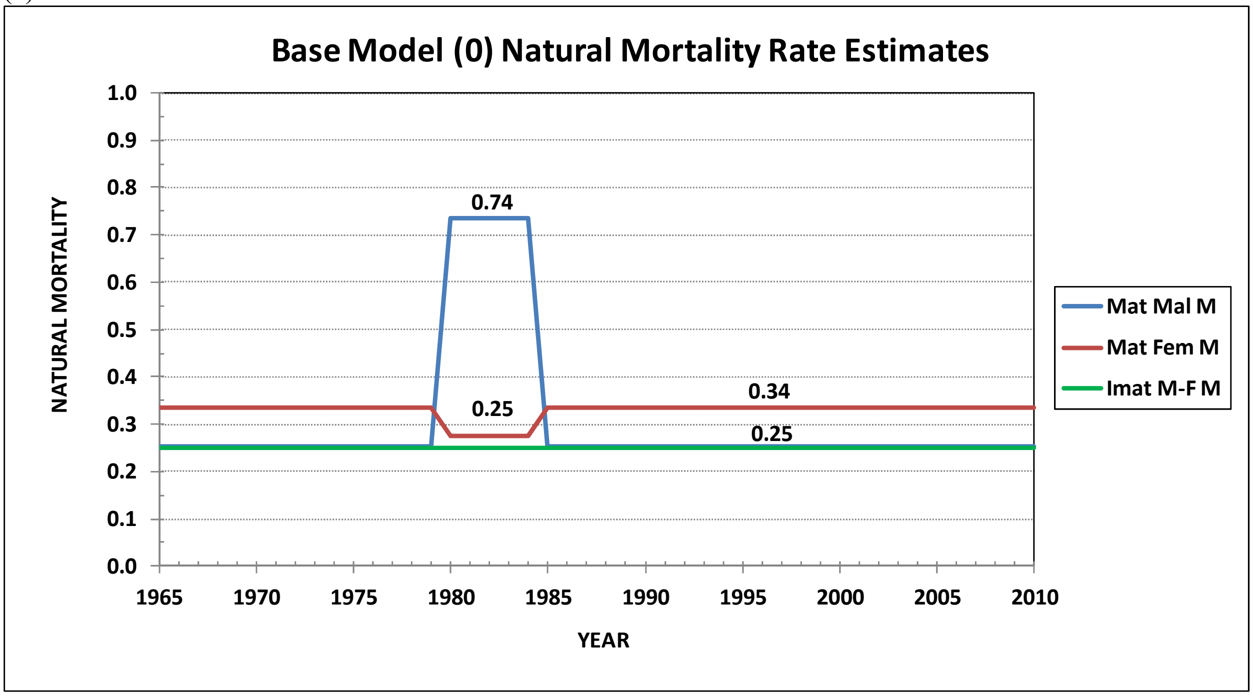



Figure 21. Sample sizes (a) used in the fitting of the fishery length compositions by fleet, and (b) meanof the fleet sample sizes for comparison.

(a)




(b)

i

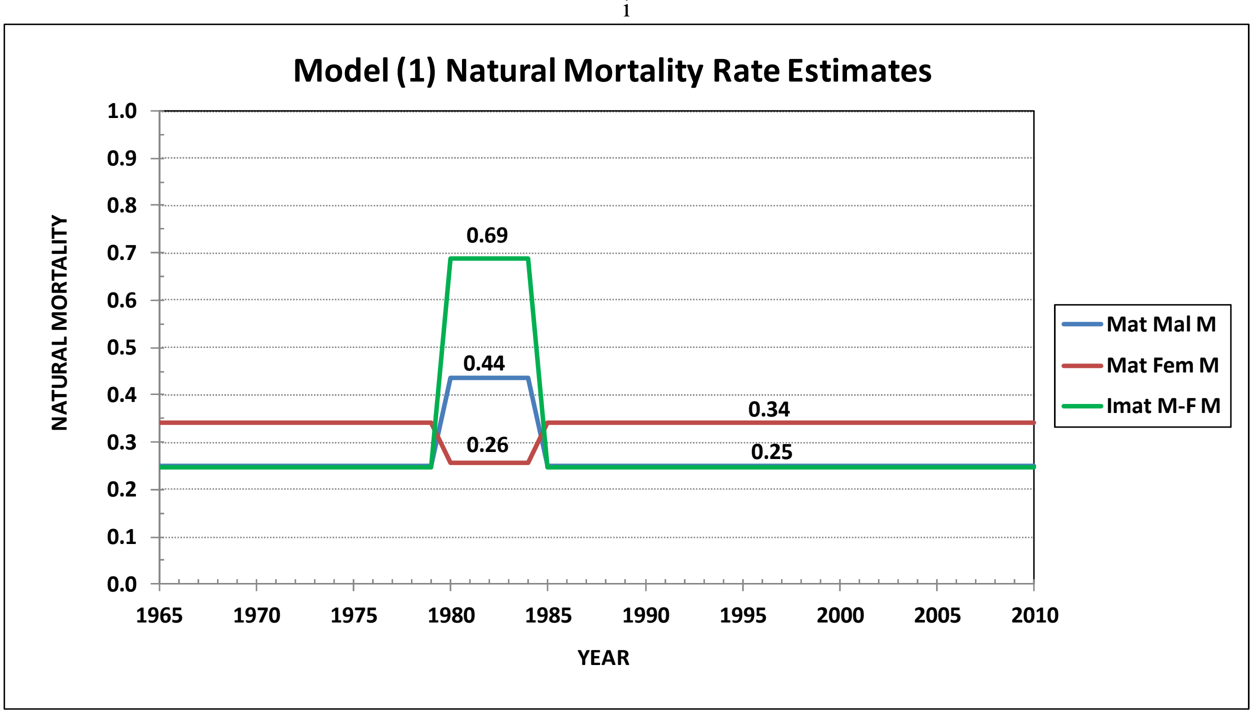



Figure 22. *Base Model(0)* (a) and *Model (1)* (b) estimates of the natural mortality rate for immature male and female, mature female and mature male Tanner crab, 1965-2012. In *Model (1)*, immature male-female M is estimated in 2-periods: 1980-84 and all other years combined.

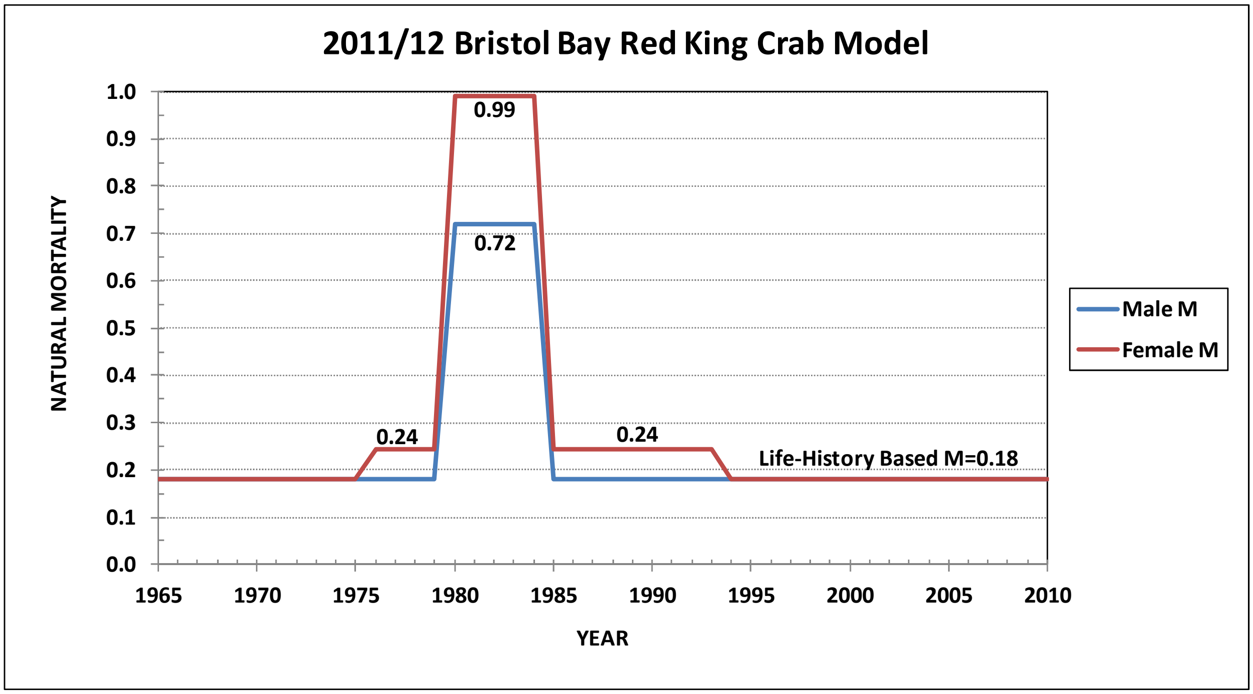



Figure 23. Model estimates of natural mortality rate for male (1980-1984) and female (1976-1993) Bristol Bay red king crab, and fixed M for remaining years in the 2011/12 stock assessment model (Zheng 2011).

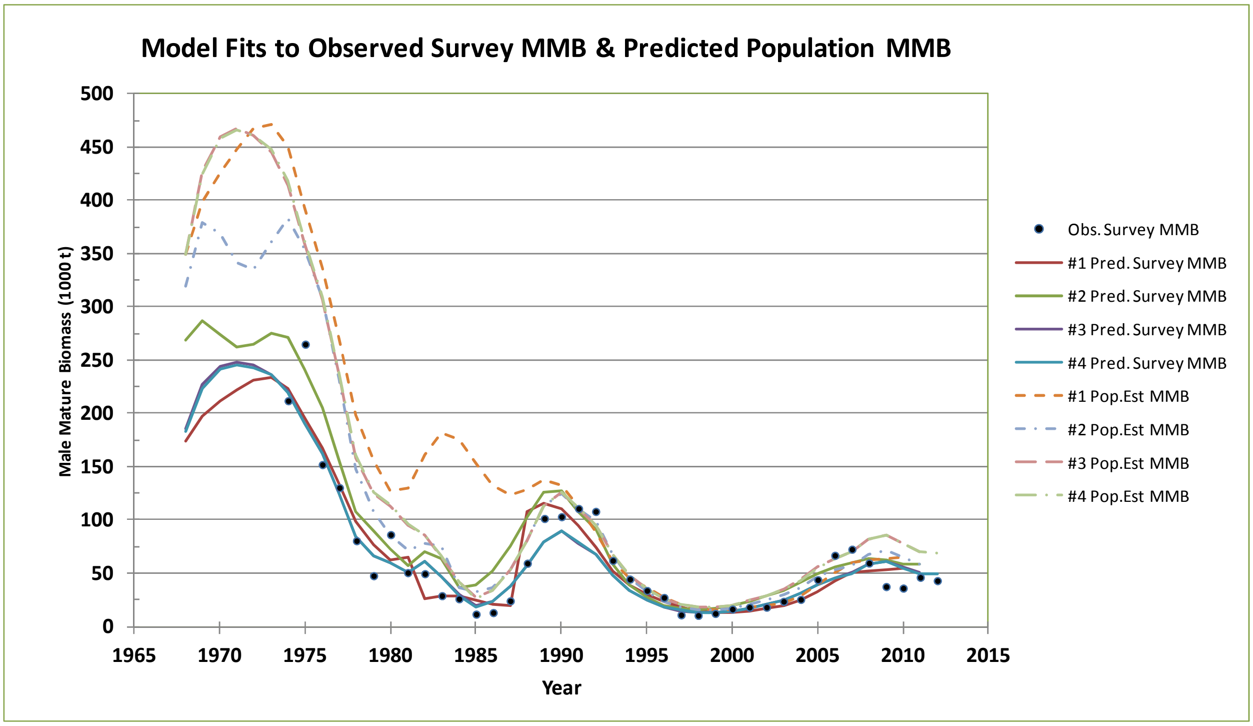



Figure 24. Comparison of past reference models performance in terms of fit (solid) to observed survey mature male biomass (points), and population mature male biomass (dotted line). Key: #1=3-period model presented to CPT (09/11); #2=2-perod model resulting from 01/2012 Crab Workshop; #3=2-period model presented to CPT (05/12); and #4=2-period model approved by the CPT (05/12) with new 2011/12 survey and fishery data and sample weights.

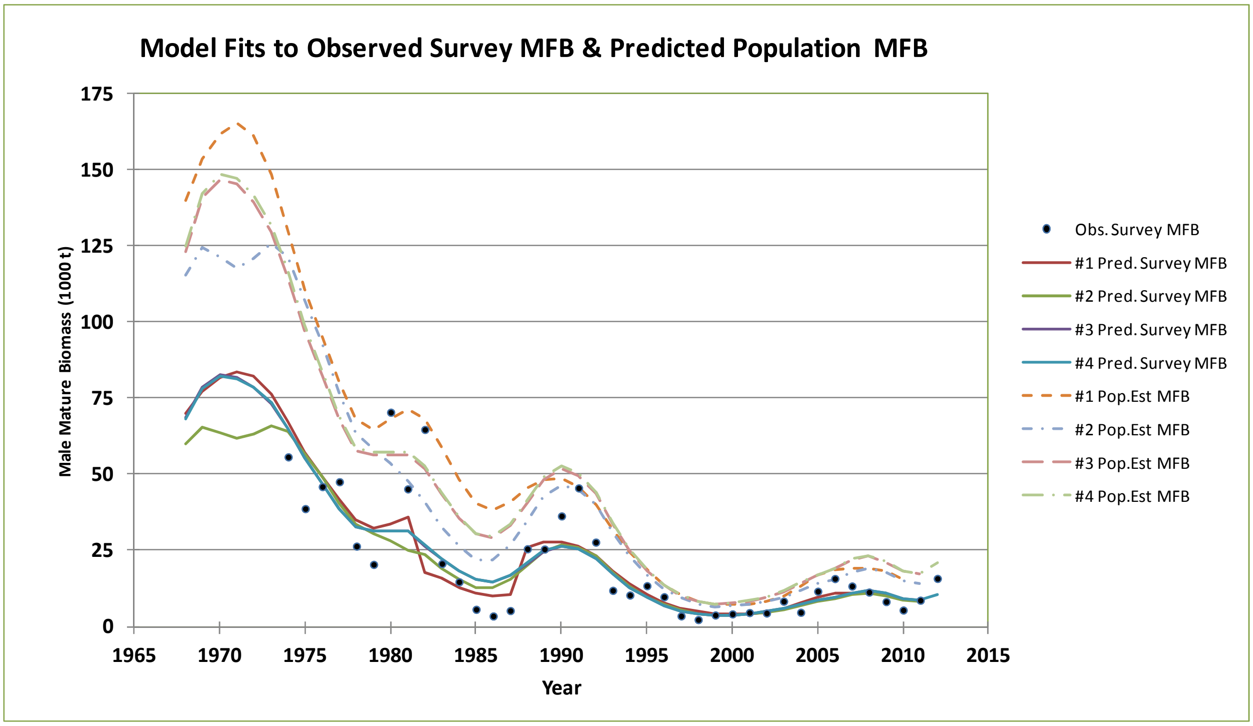



Figure 25. Comparison of past reference models performance in terms of fit (solid) to observed survey mature female biomass (points), and population mature female biomass (dotted line). Key: #1=3-period model presented to CPT (09/11); #2=2-perod model resulting from 01/2012 Crab Workshop; #3=2-period model presented to CPT (05/12); and #4=2-period model approved by the CPT (05/12) with new 2011/12 survey and fishery data and sample weights..

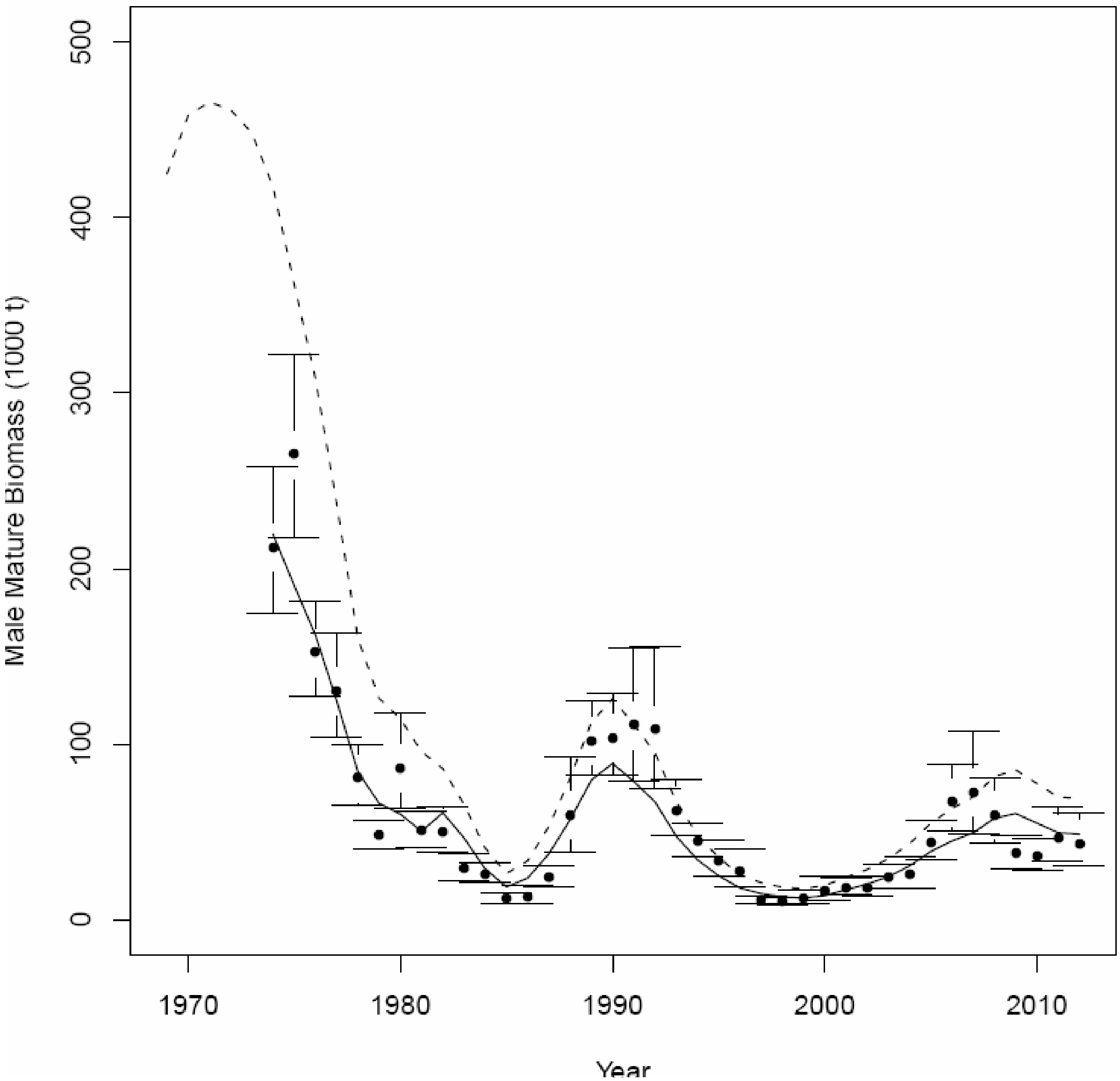
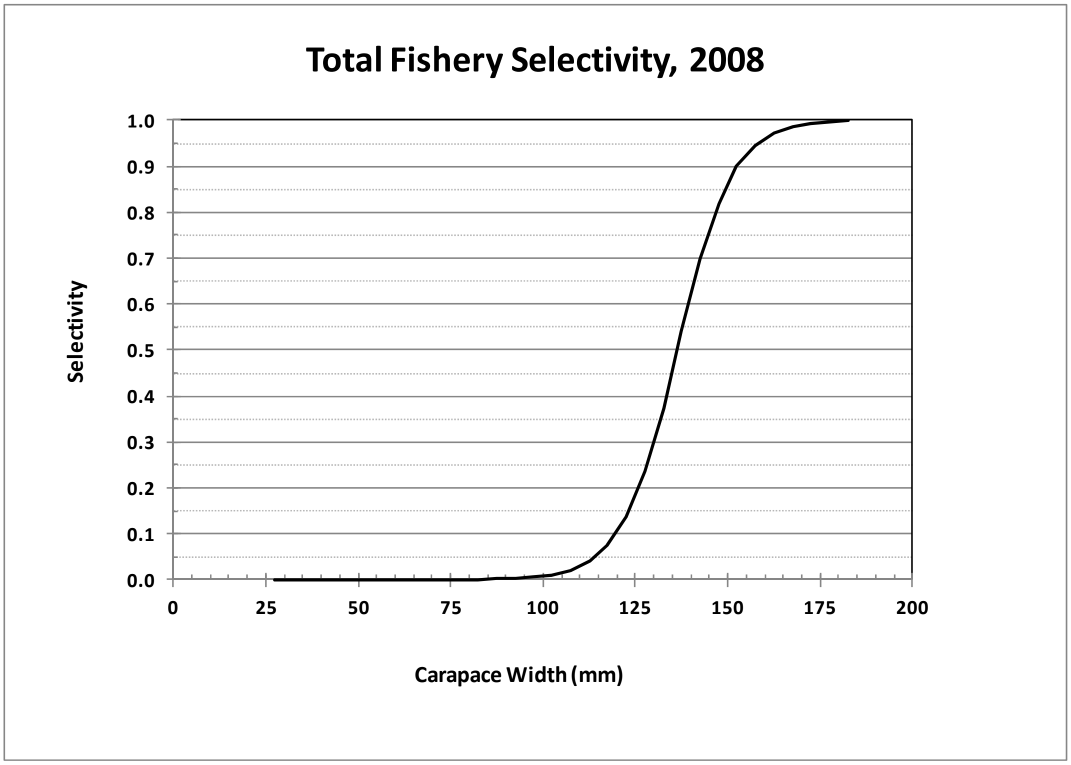



Figure 26. *Base Model (0)* population mature male biomass (1000 t, dotted line) at the time of the survey, model estimate of survey mature biomass (solid line) and observed survey mature male biomass with approximate lognormal 95% confidence intervals.

(a)




(b)

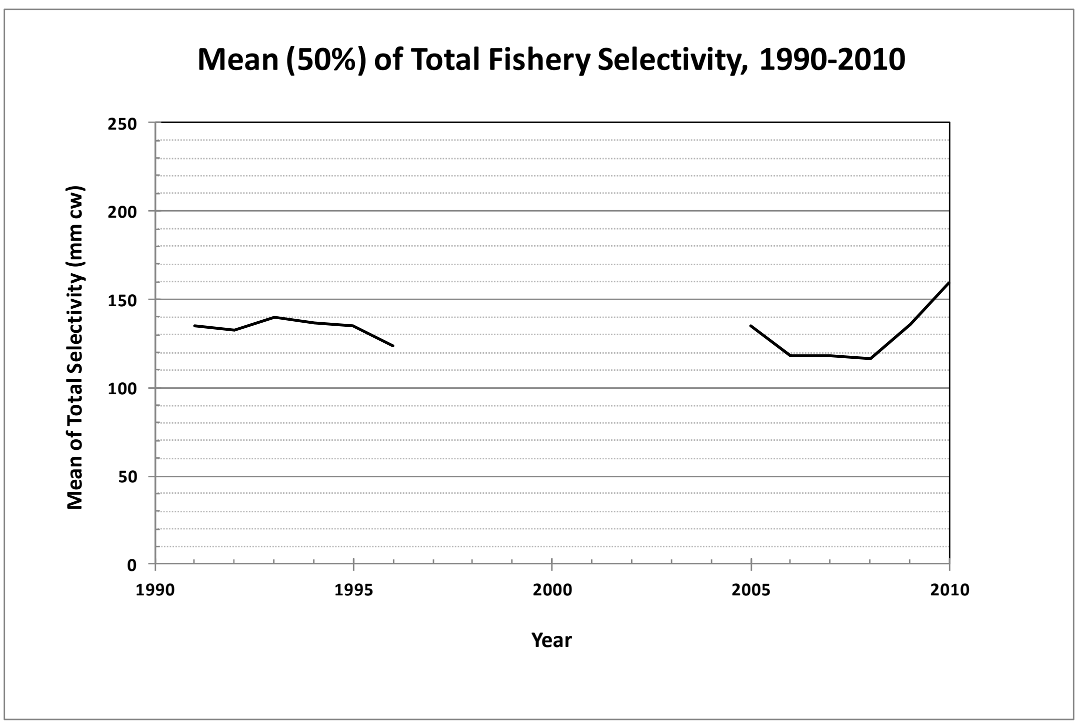



Figure 27. Estimated male total selectivity (a) in *Base Model (0)* in the 2008 (representative shape) and (b) change in the mean (50%) of total selectivity in the directed fishery for 1990-2010.

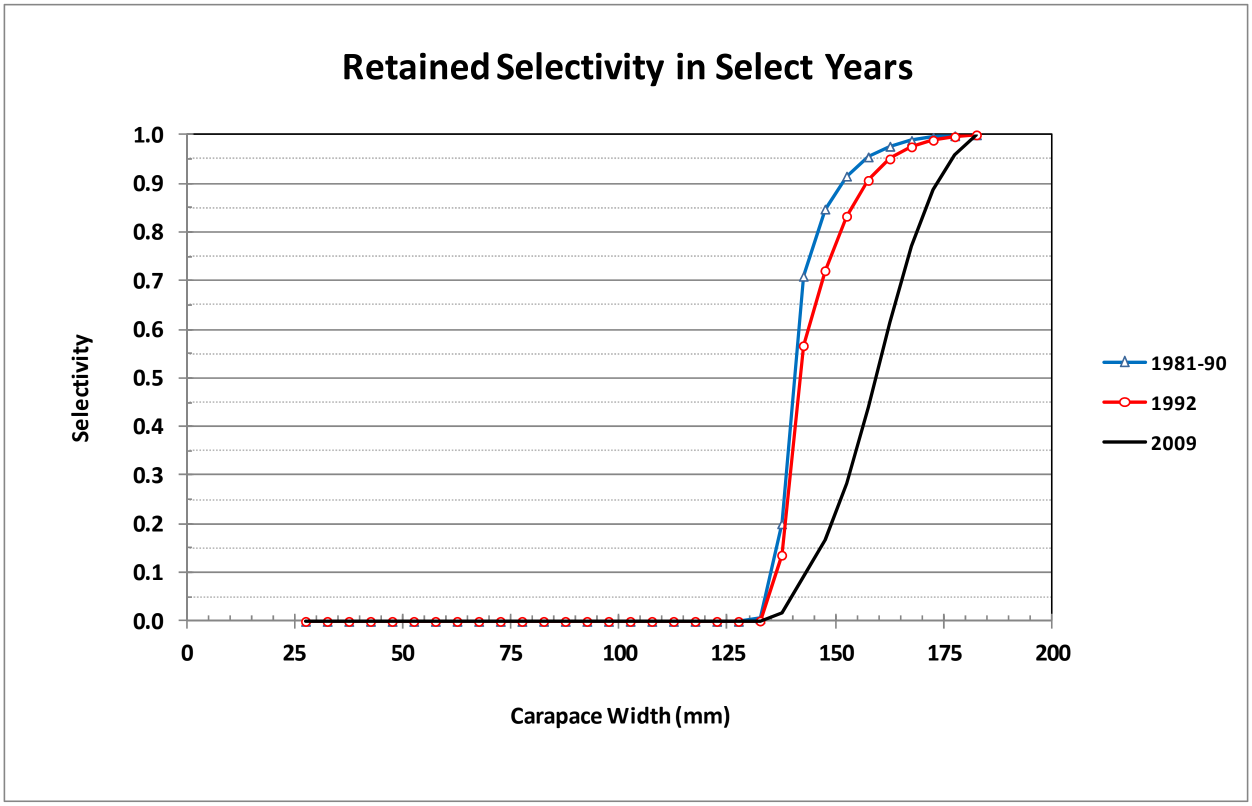



Figure 28. *Base Model (0)* fraction of total catch retained by size for male crab in the directed fishery, all shell conditions combined for 3 representative years-periods: mean of 1981-90, 1992 and 2009.

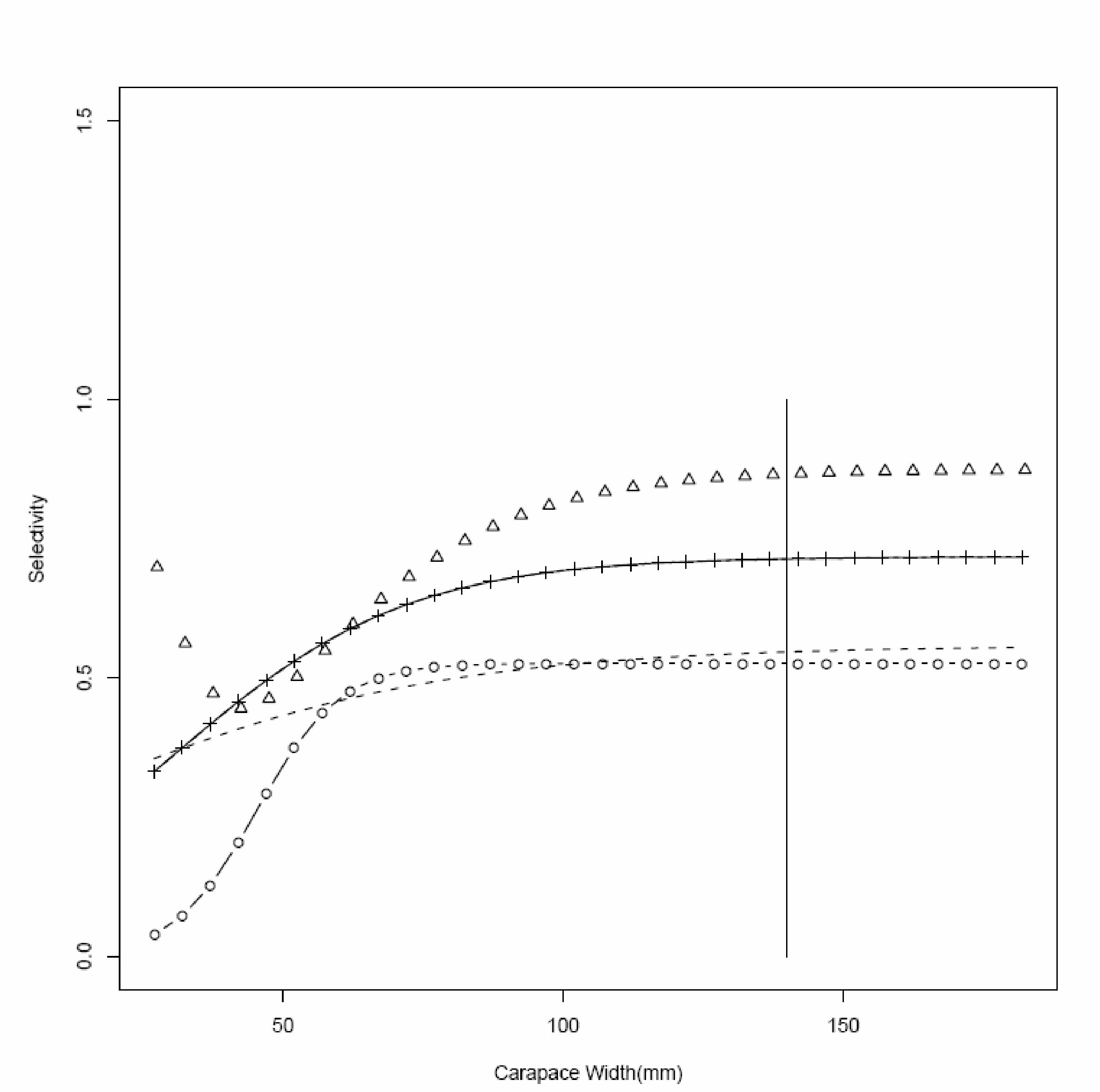



Figure 29. *Base Model(0)* survey selectivity curves for male Tanner crab estimated for 1974-1981 (dashed line with circles), 1982-2012 (solid line with pluses) with vertical reference line at 140 mm. Survey selectivity estimated by Somerton and Otto (1999) are triangle symbols, and female selectivity for 1982-2012 is dashed line for reference.

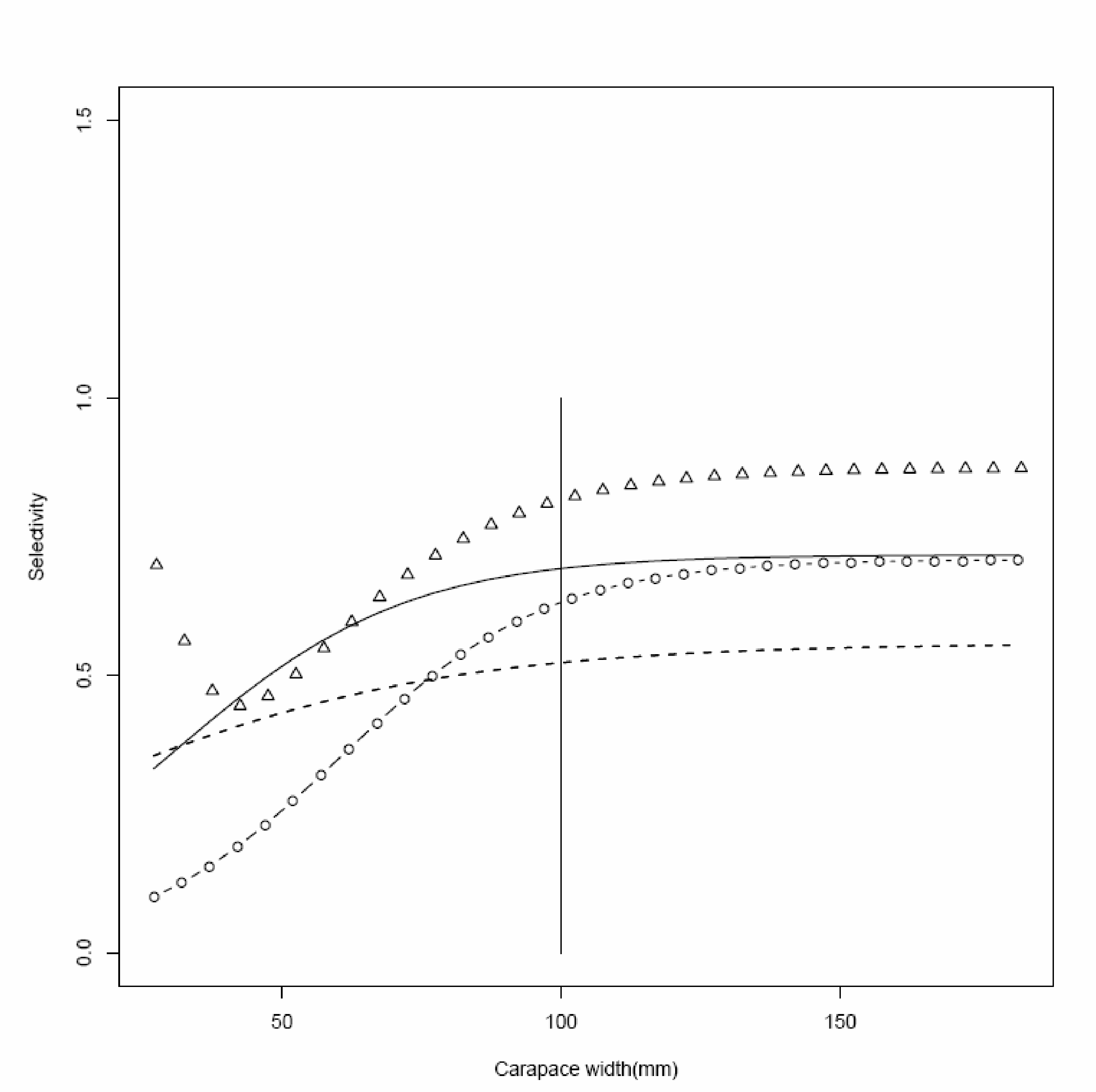
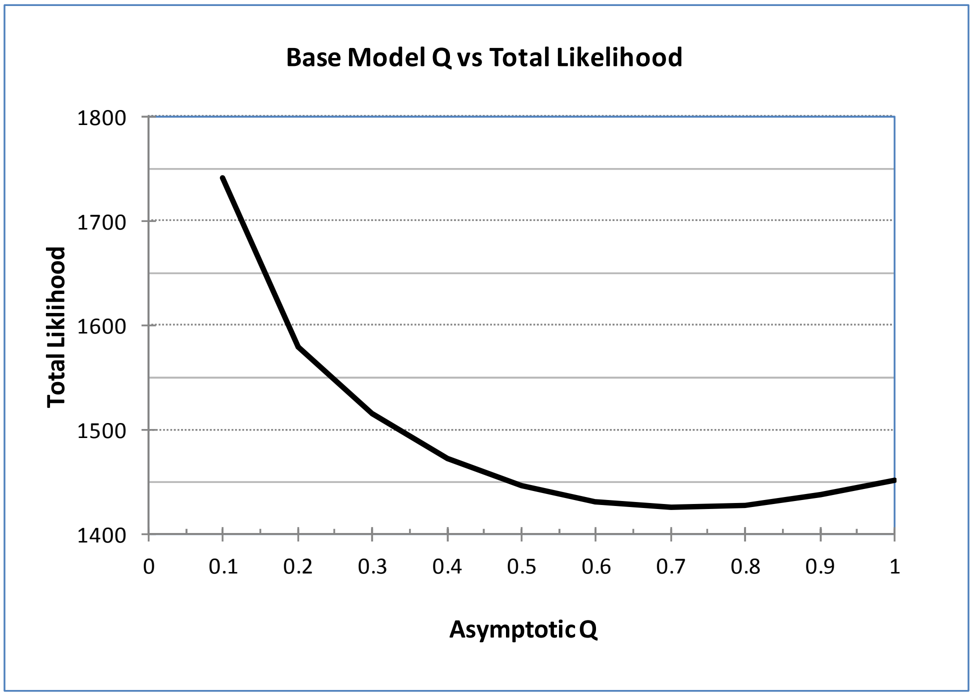



Figure 30. *Base Model (0)* survey selectivity curves for female Tanner crab estimated for 1974-1981 (dashed line with circles), 1982-2012 (dashed line) with vertical reference line at 100 mm. Survey selectivity estimated by Somerton and Otto (1999) are triangle symbols, and male selectivity for 1982-2012 is upper solid line for reference.

(a)




(b)

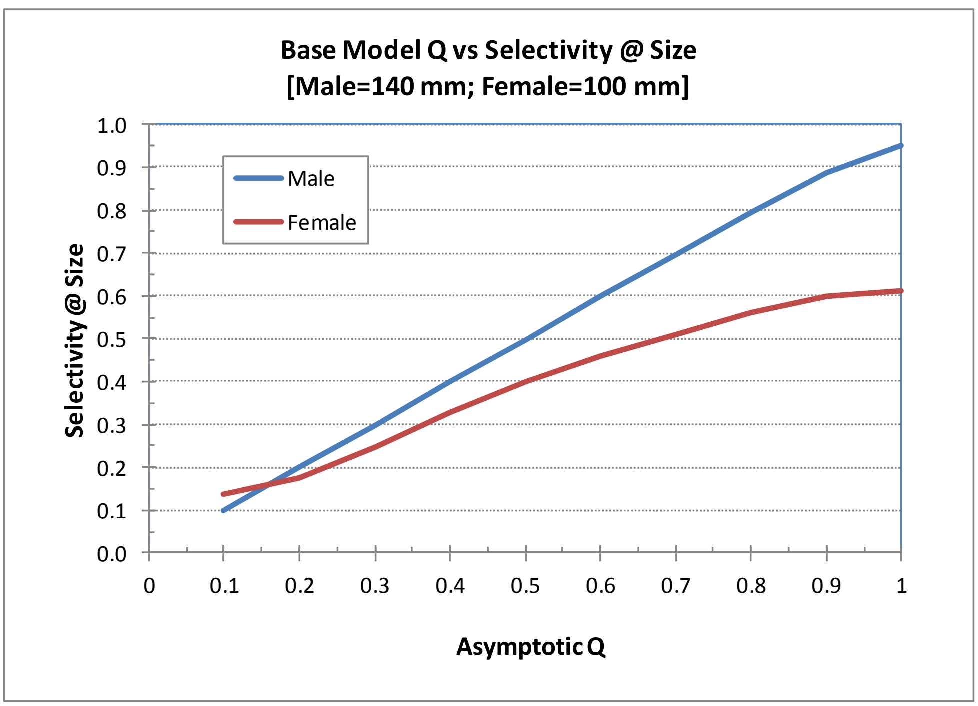



Figure 31. Survey Q profile versus total likelihood (a) and selectivity at reference size versus asymptotic Q (b) for the *Base Model (0)*.

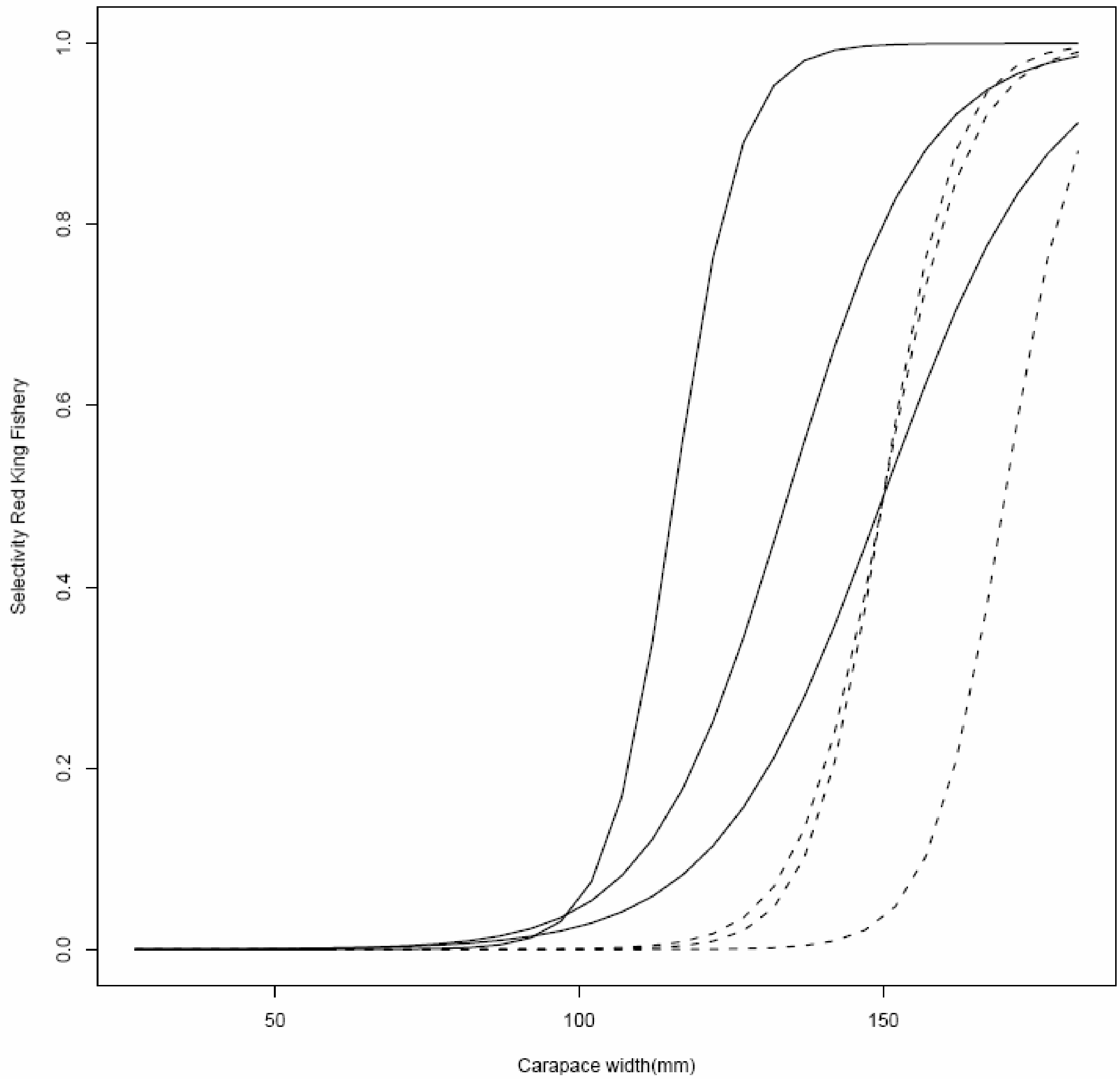



Figure 32. *Base Model (0)* selectivity curve estimated by the model for bycatch in the Bristol Bay red king crab fishery for females (dashed) and males (solid) for three periods: period-1 (1989-1996), period-2 (1997-2004) and period-3 (2005-P). The male and female curves for the three time periods are in chronological order from left to right – i.e., earliest to left, intermediate in center, and most recent to right.

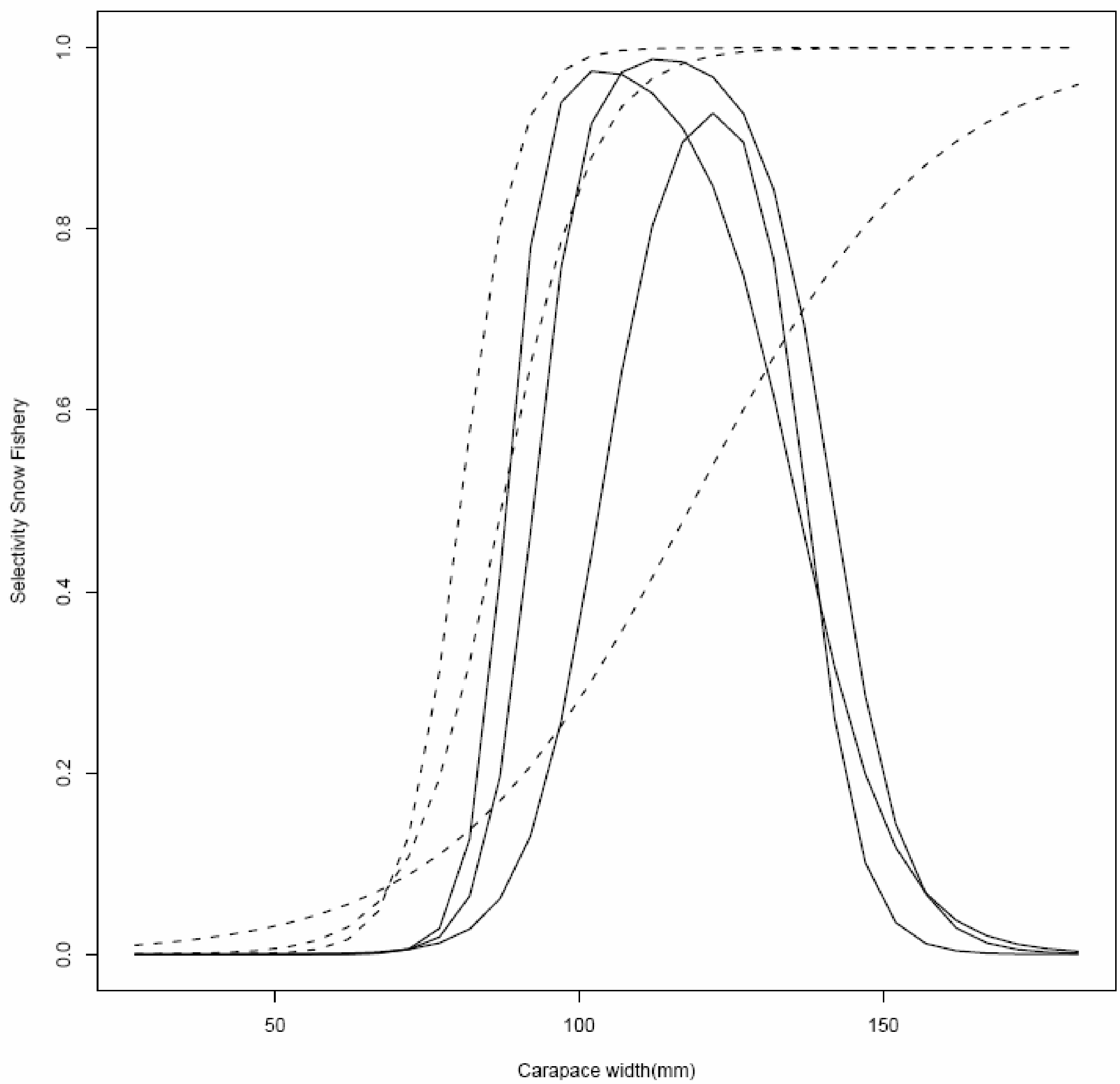



Figure 33. *Base Model (0)* selectivity curve estimated by the model for bycatch in the snow crab fishery for females (dashed) and males (solid) for three periods: period-1 (1989-1996), period-2 (1997-2004) and period-3 (2005-P). The curves for males: period-1 (left), period-2 (center) and period-3 (right). Curves for females: period-1 (right), period-2 (left) and period-3 (center).

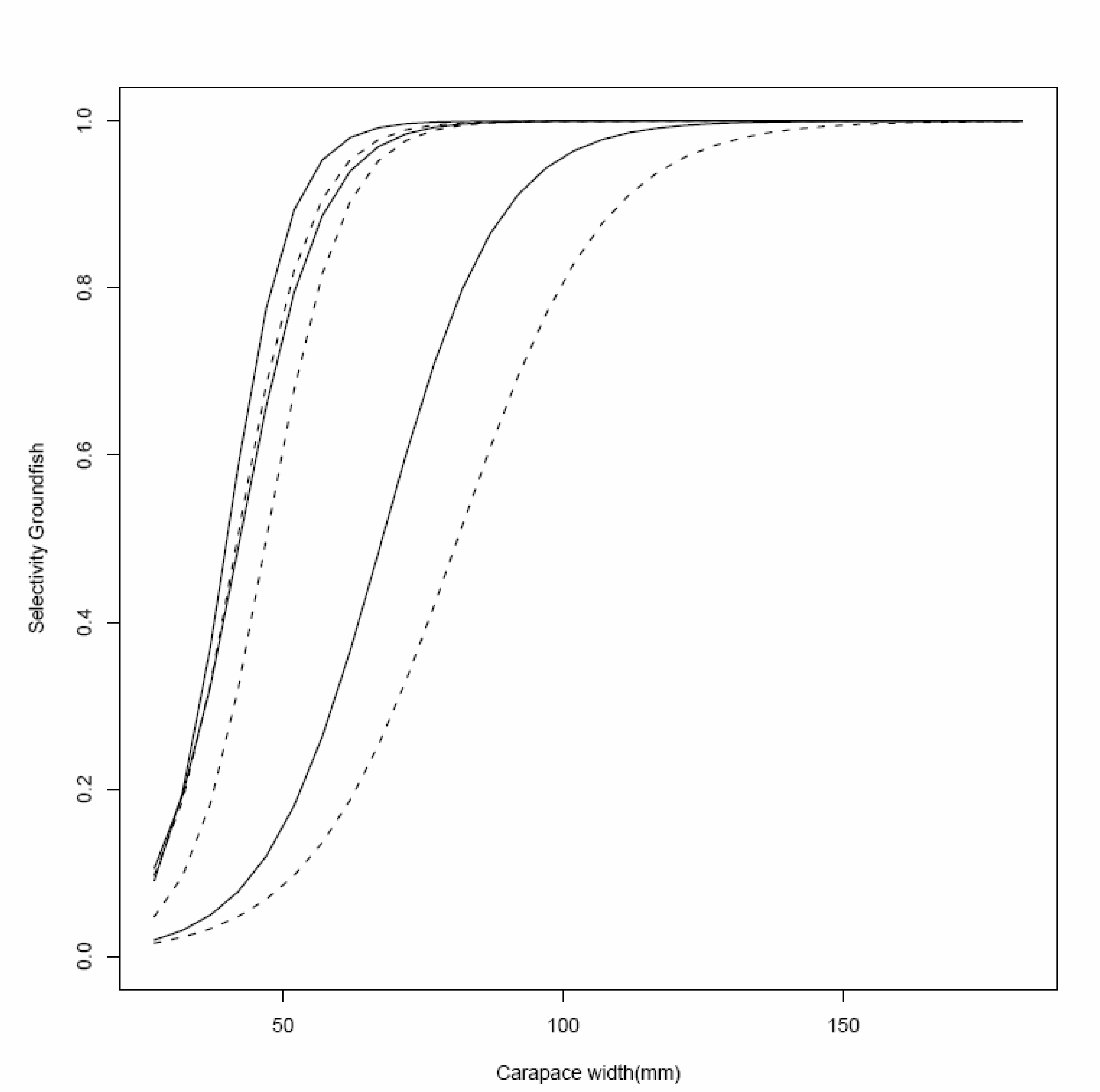



Figure 34. *Base Model (0)* selectivity curve estimated by the model for bycatch of males (dashed) and females (solid) in the groundfish fishery for three periods: period-1 (1973-1986), period-2 (1987-1996) and period-3 (1997-P). The curves for males: period-1 (left), period-2 (center) and period-3 (right). Curves for females: period-1 (left), period-2 (right) and period-3 (center).

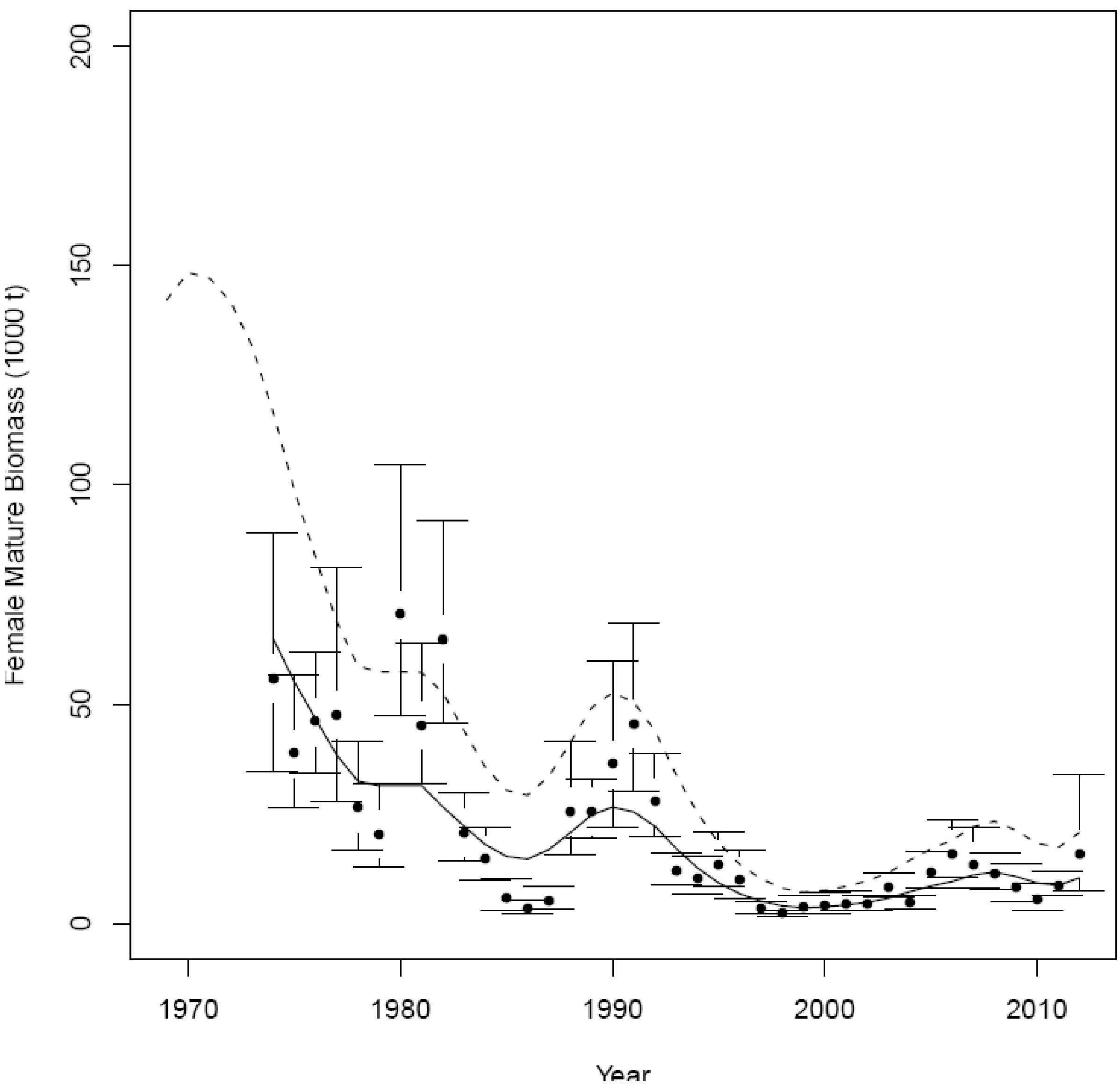



Figure 35. *Base Model (0)* population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

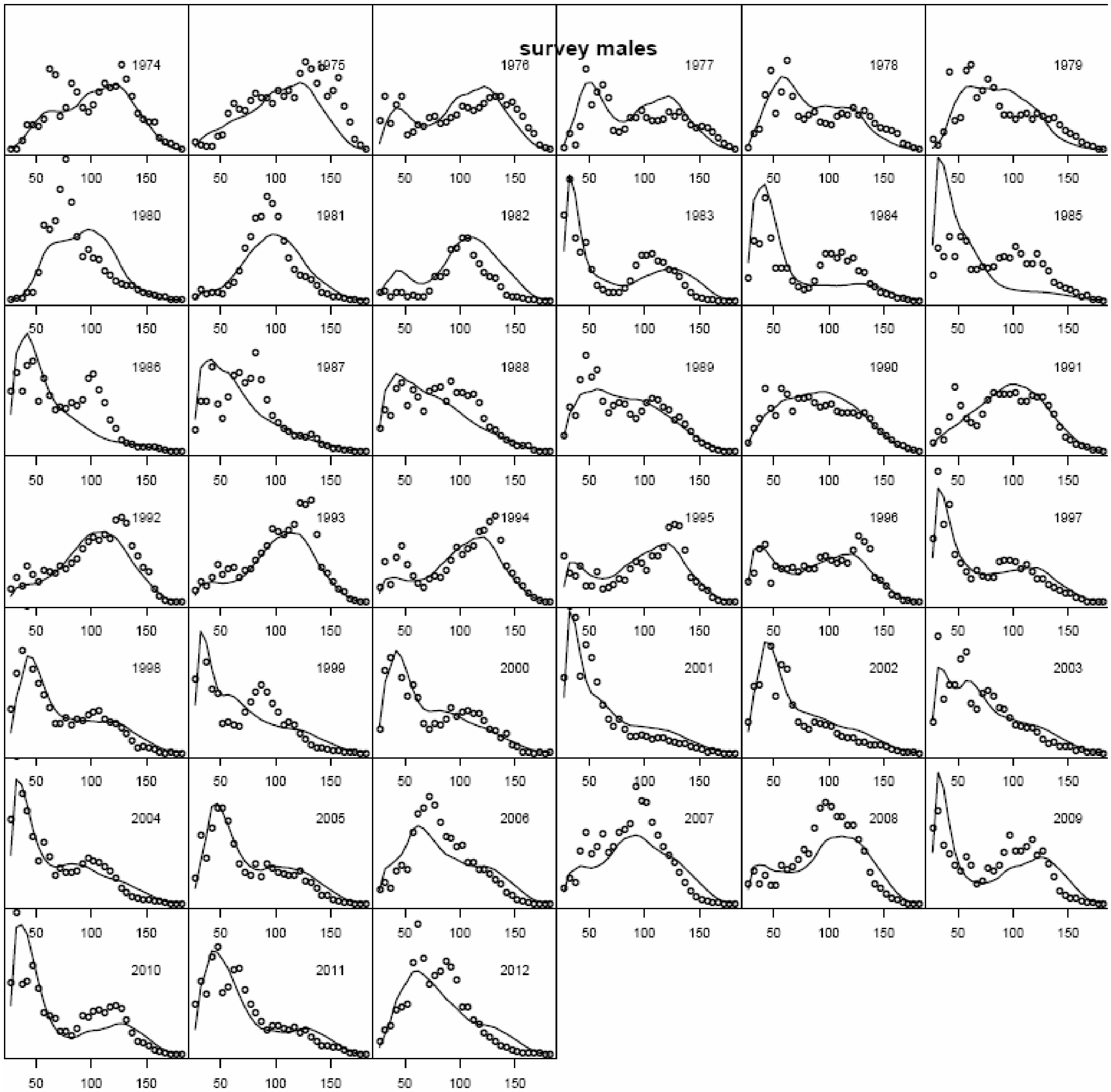



Figure 36. *Base Model (0)* fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

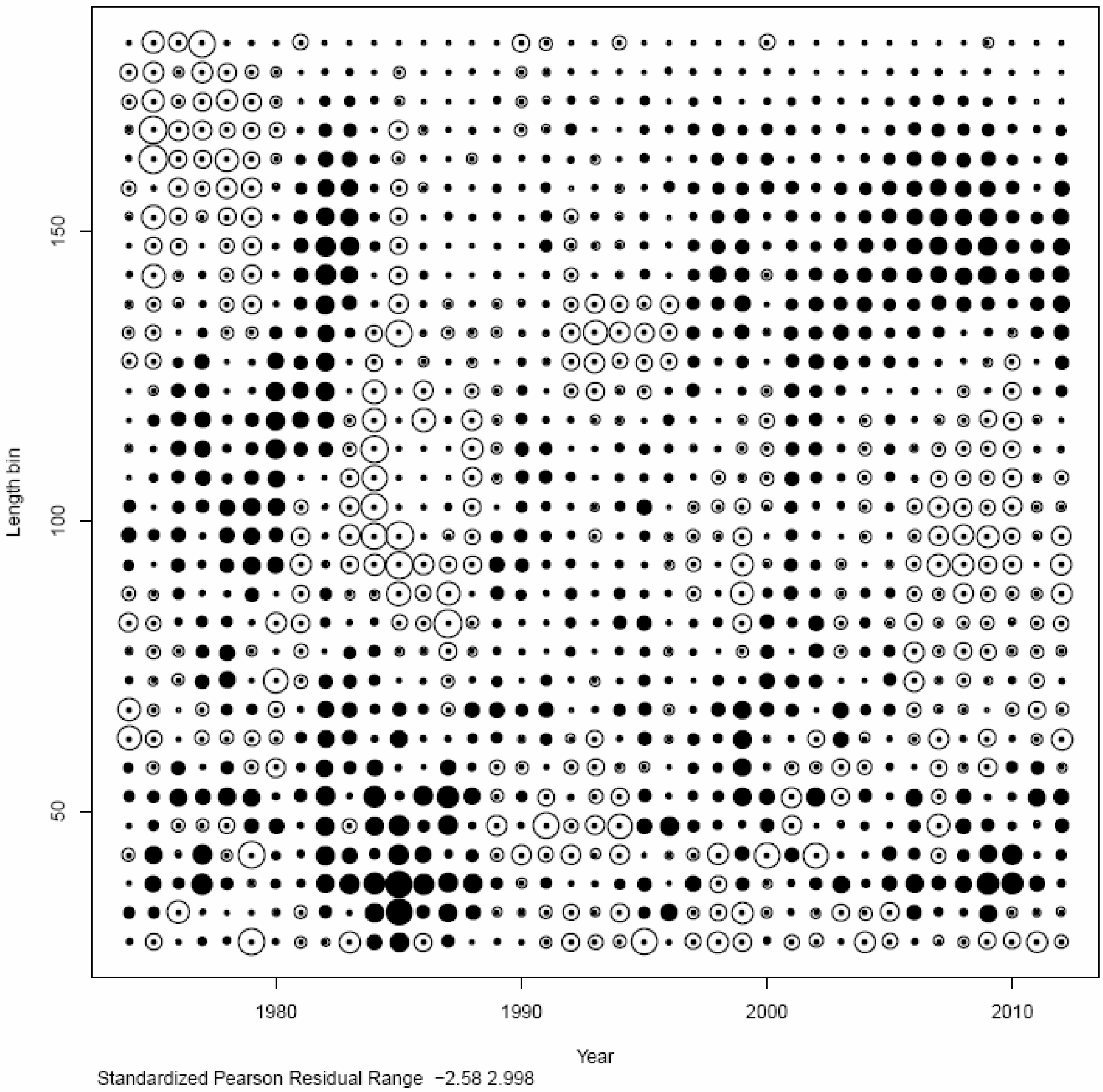



Figure 37. *Base Model (0)* standardized Pearson residuals of the model fit to the survey male size frequency data. Solid circles= overestimate and open circles=underestimate. Diameter of circle proportional to extent of lack of fit. Residual range shown at bottom.

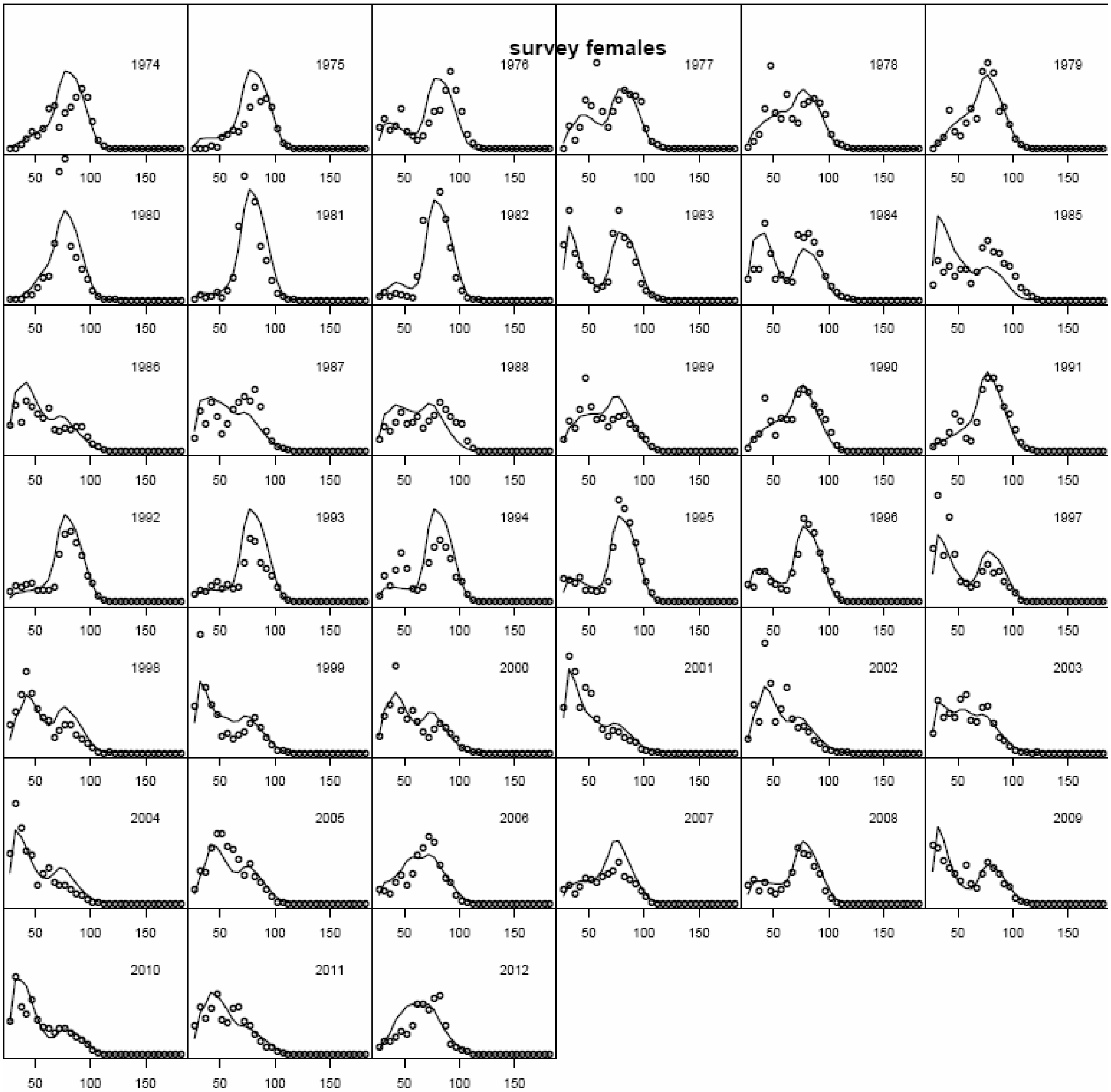



Figure 38. *Base Model (0)* fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

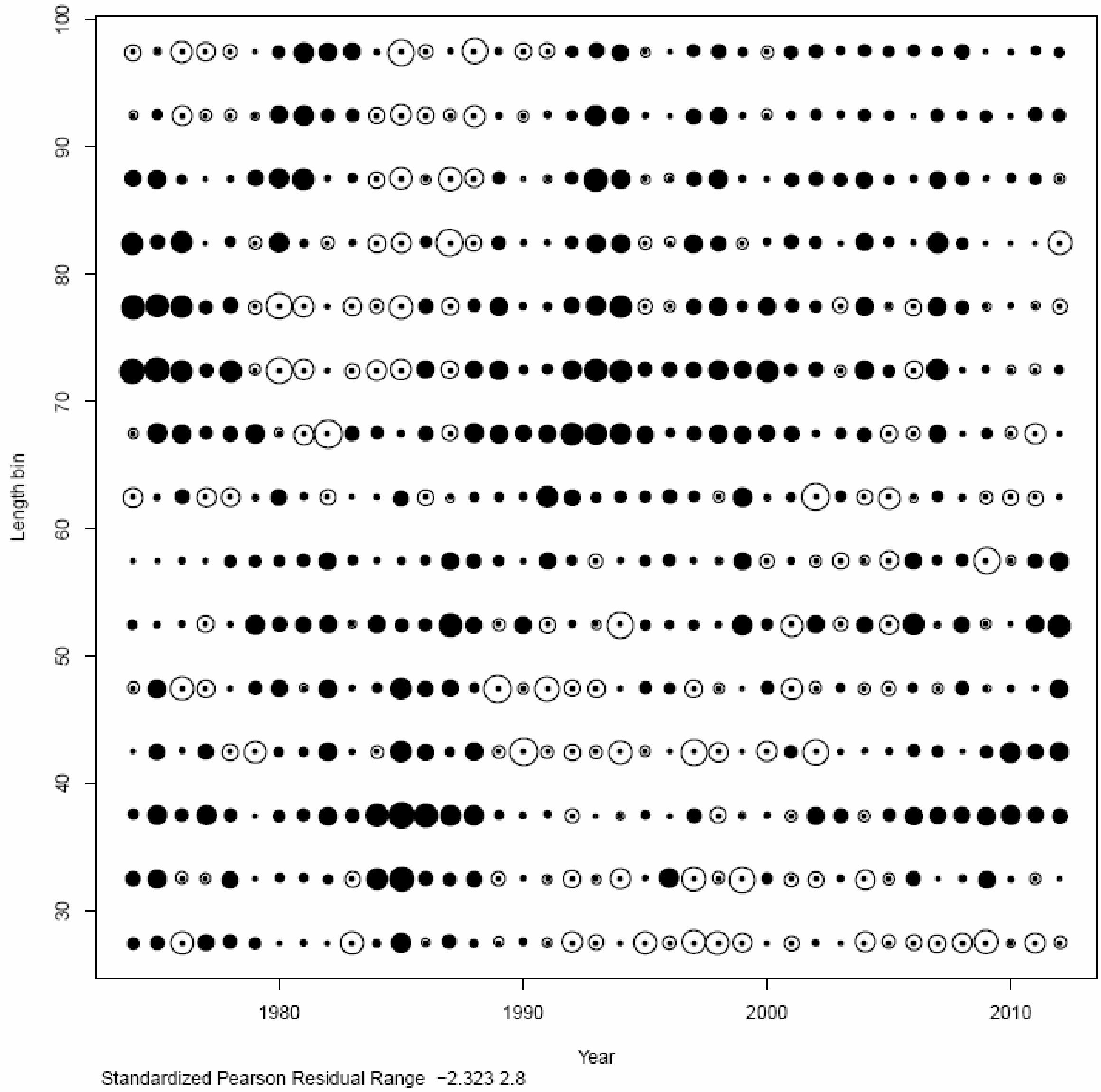



Figure 39. *Base Model (0)* standardized Pearson residuals of the model fit to the survey female size frequency data. Solid circles= overestimate and open circles=underestimate. Diameter of circle proportional to extent of lack of fit. Residual range shown at bottom.

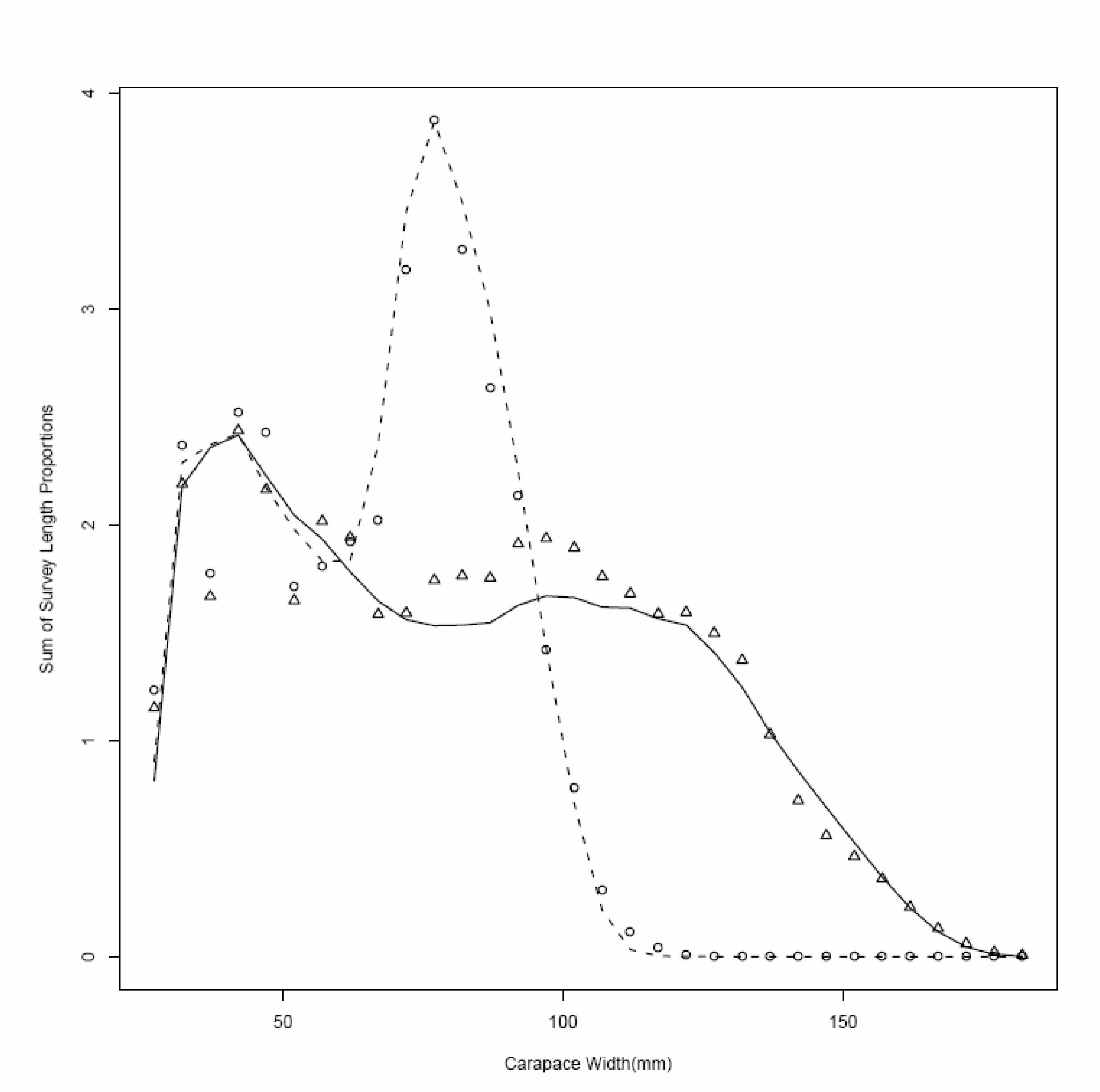



Figure 40. *Base Model (0)* summary fit to the survey male (solid line) and female (dotted line) size frequency data, all shell conditions combined. Symbols are observed data.

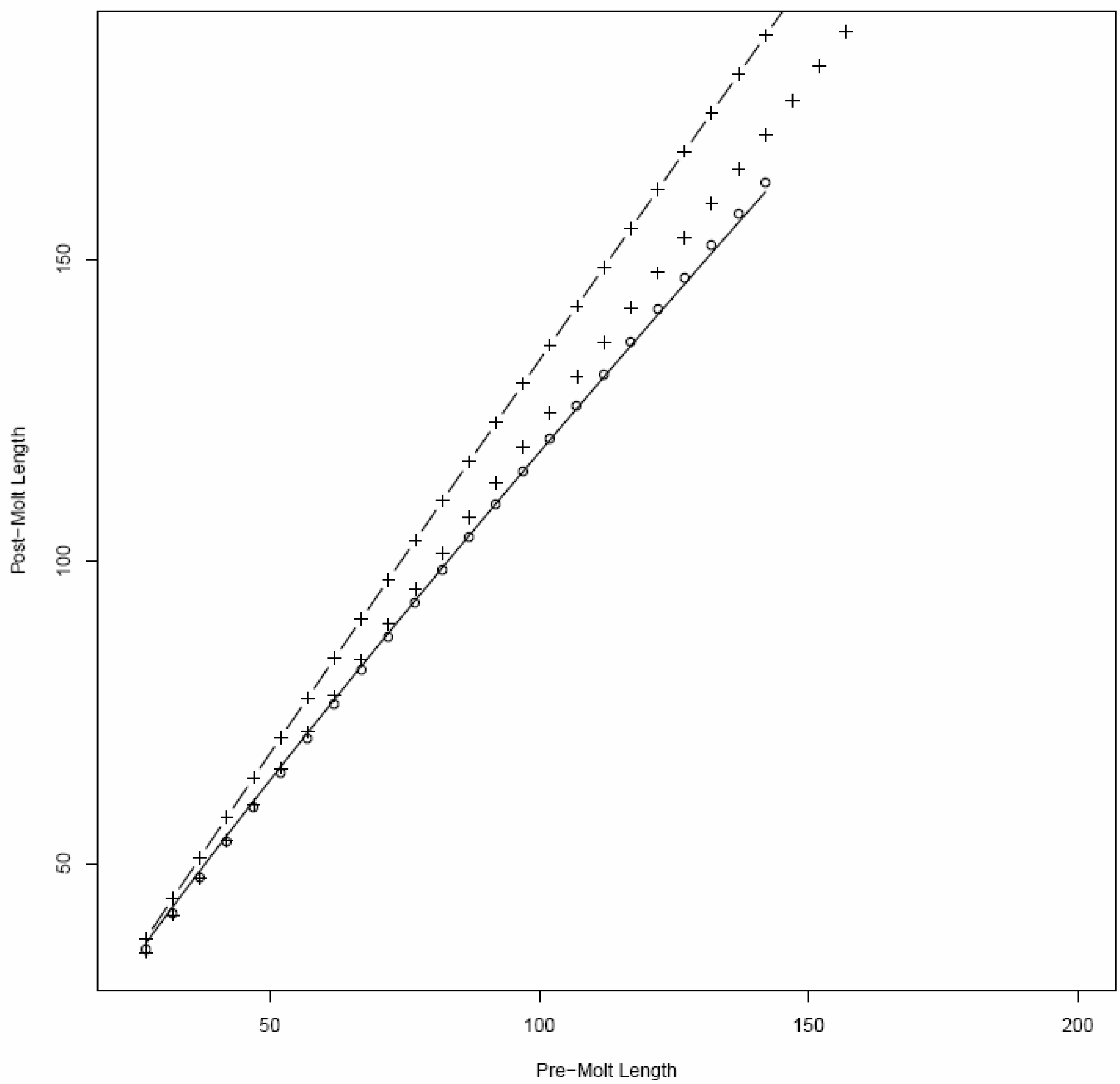



Figure 41. *Base Model (0)* estimated relationships of pre-molt length to post-molt length (mm cw) for male (dashed with pluses) and female (dashed with circles) eastern Bering Sea Tanner crab. The empirically-derived growth relationships for male (pluses) and female (circles) based on data collected near Kodiak Island in the Gulf of Alaska are shown for reference.

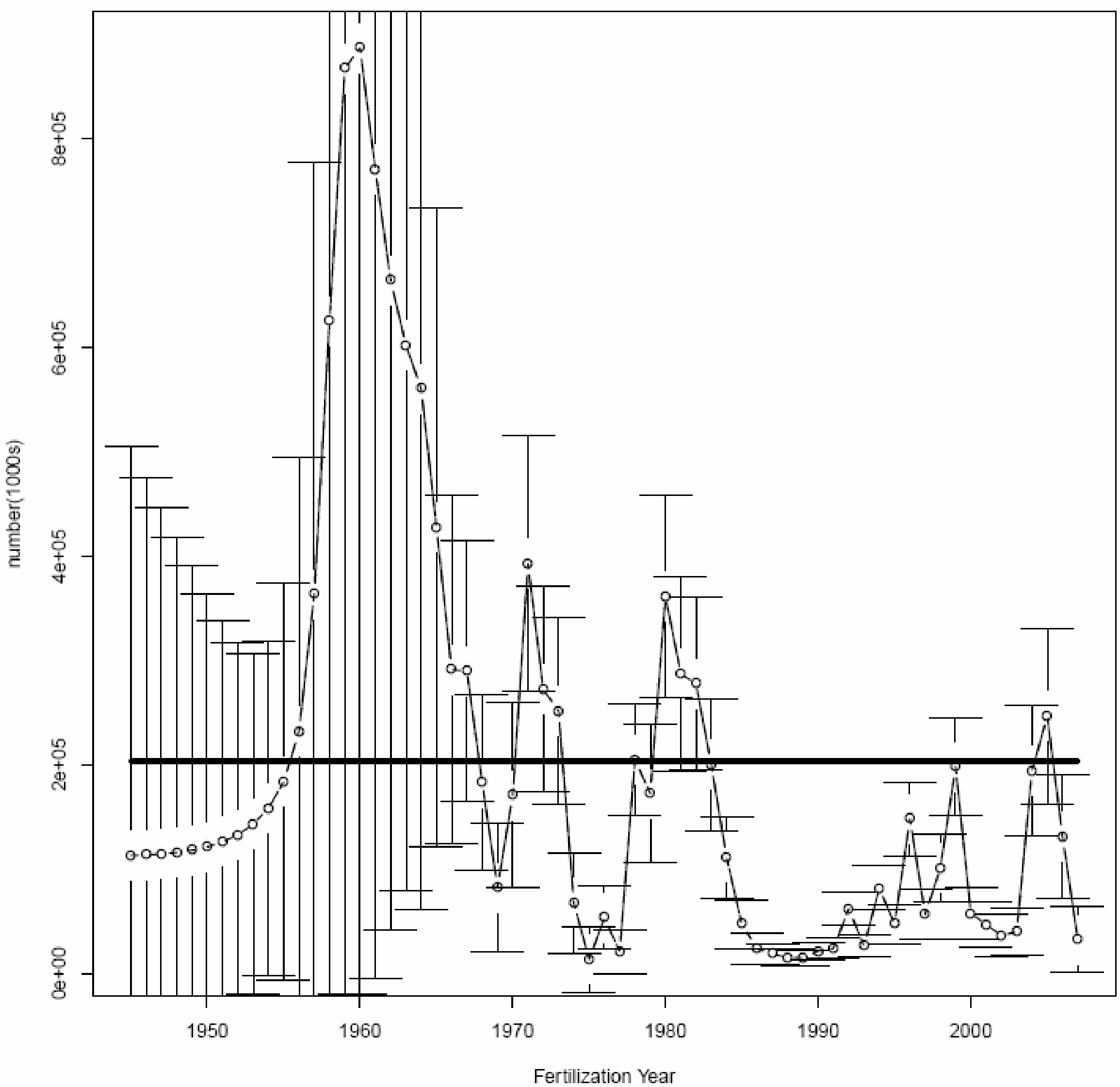



Figure 42. *Base Model (0)* recruitment to model of crab 25 mm to 50 mm by fertilization year. Total recruitment is 2 times recruitment in the plot given that male and female recruitment is set to be equal. Solid horizontal line is average recruitment.

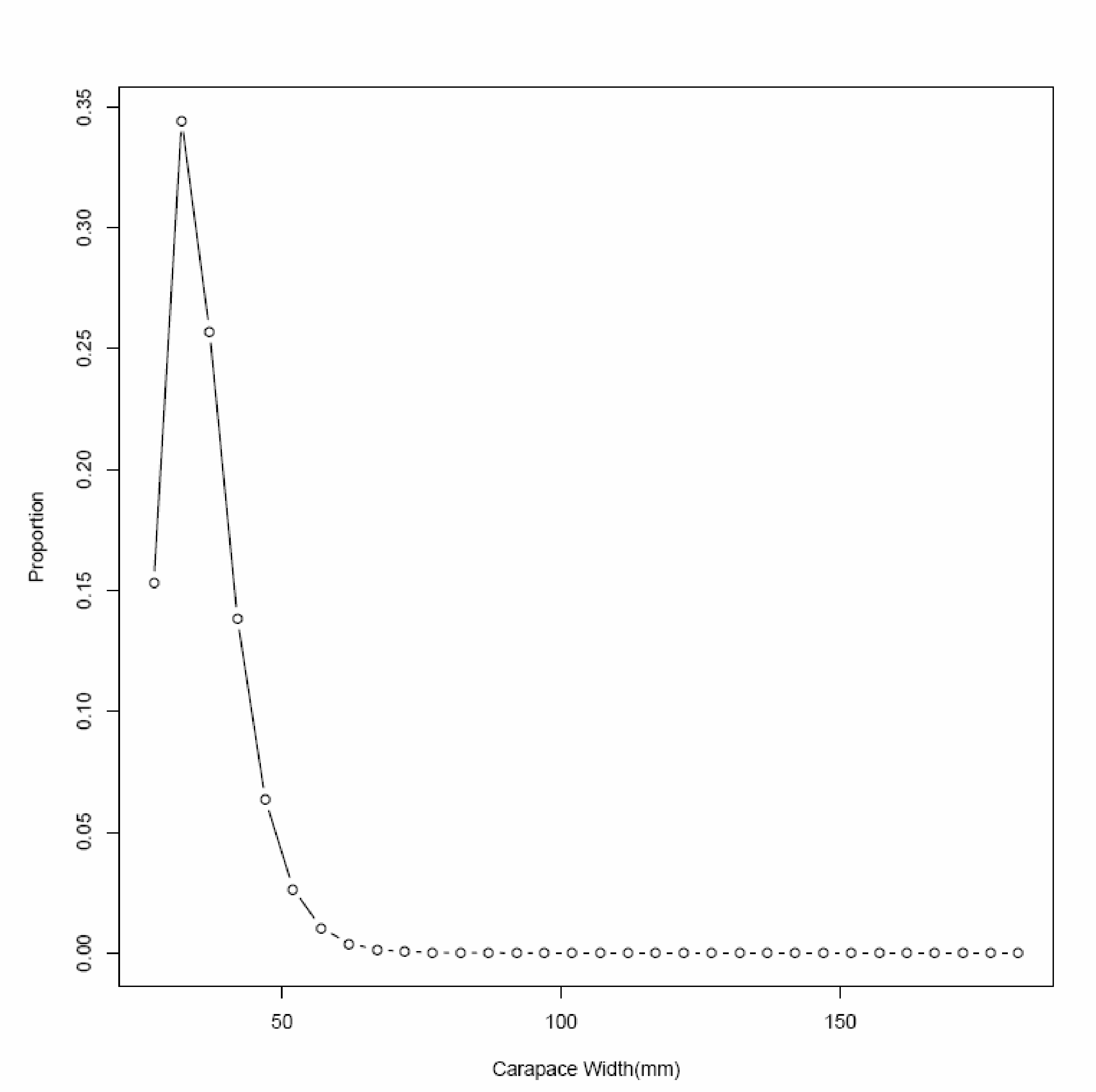



Figure 43. *Base Model (0)* distribution of recruits to length bins estimated by the model.

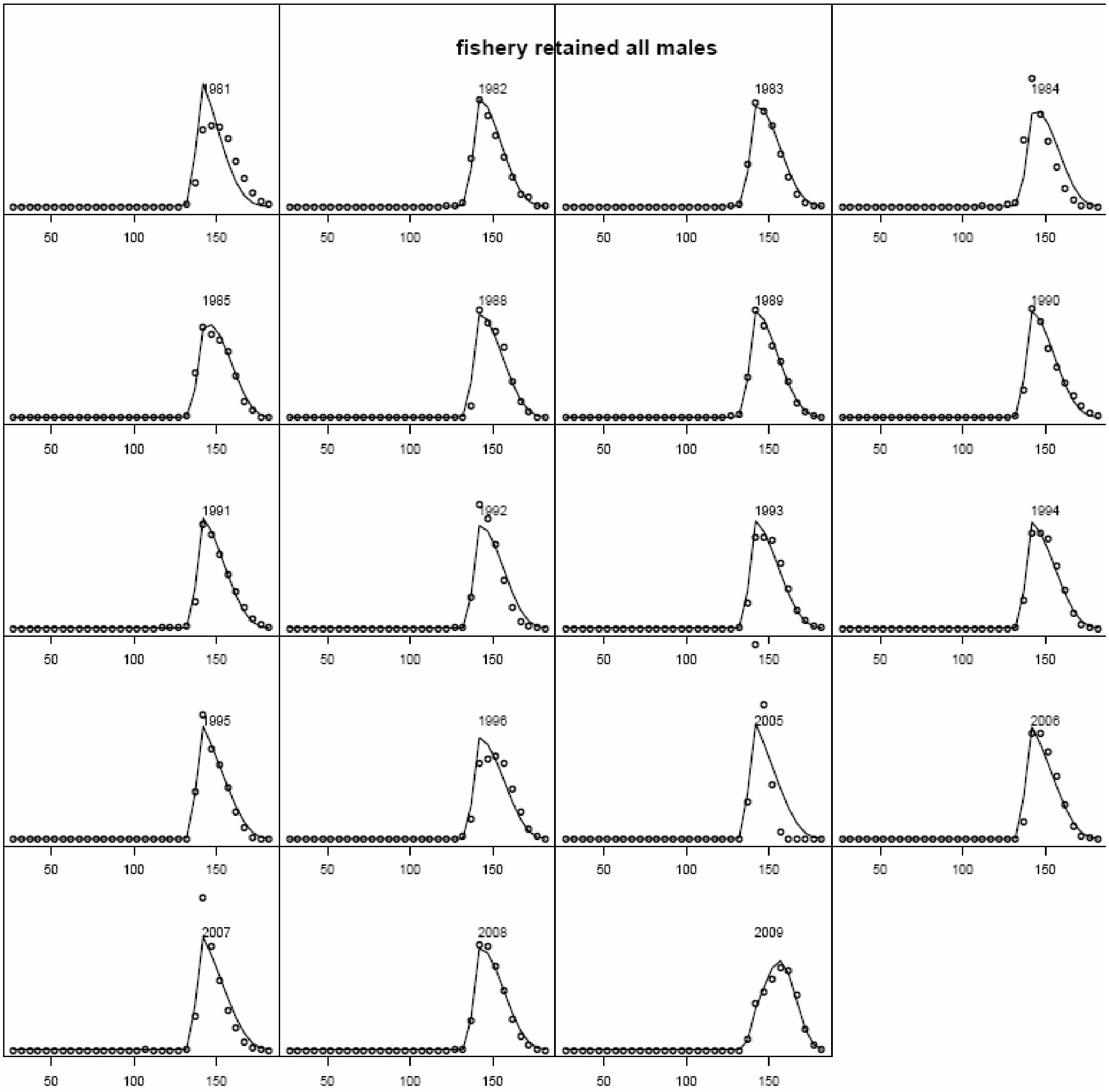



Figure 44. *Base Model (0)* fit to the retained male size frequency data in the directed fishery, shell condition combined. Circles are observed data.

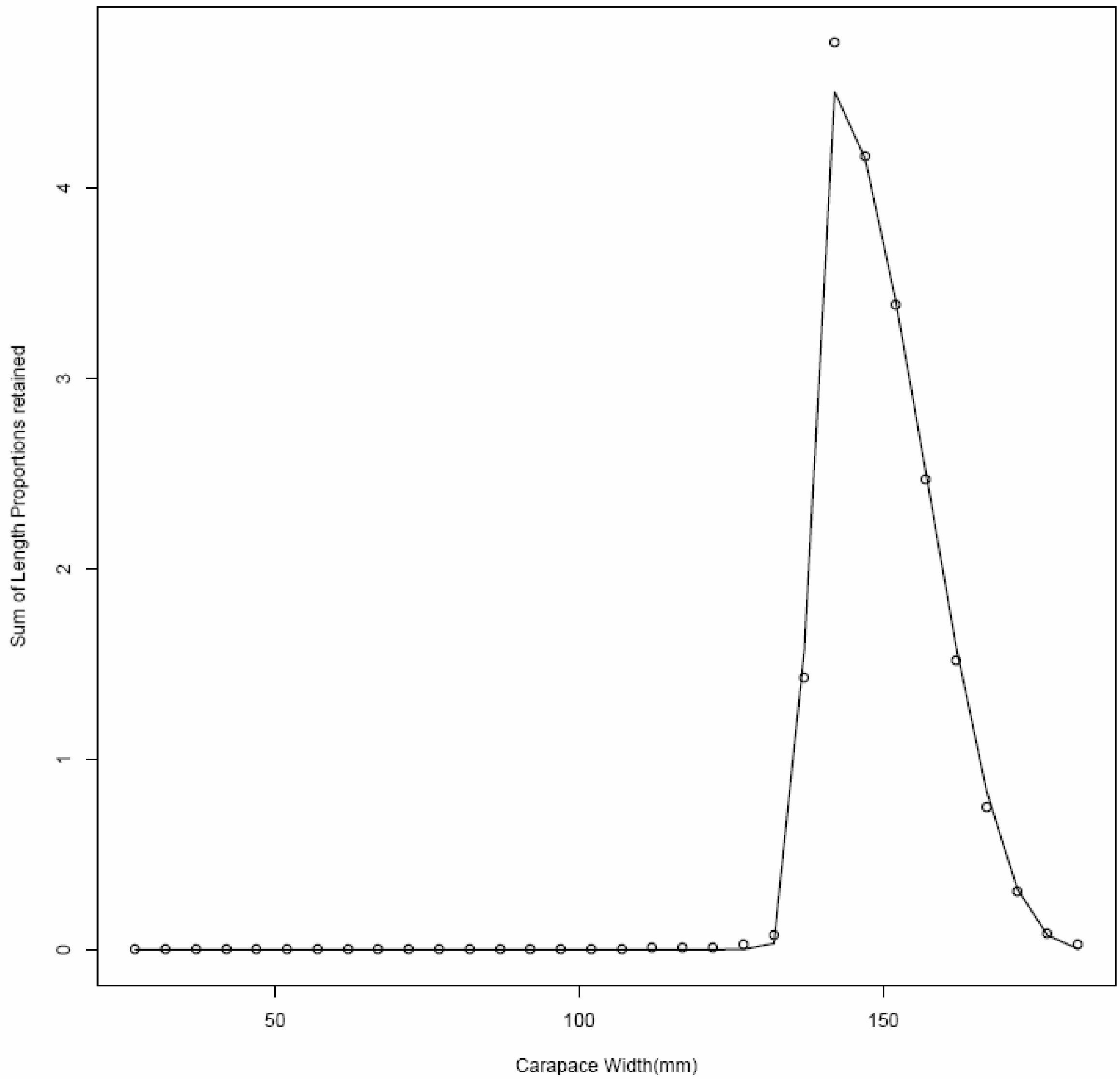



Figure 45. *Base Model (0)* summary fit to the retained male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data.

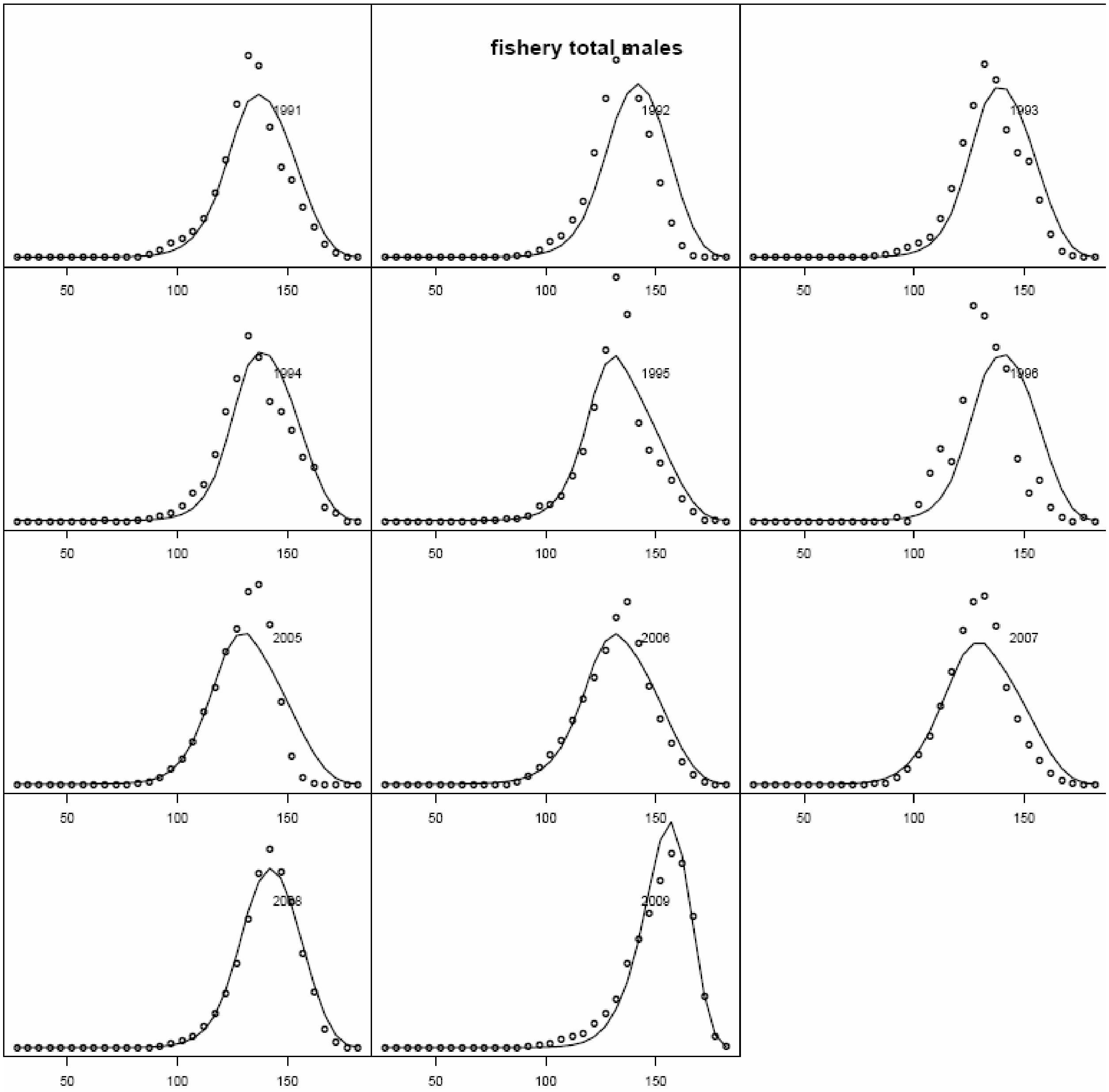



Figure 46. *Base Model (0)* fit to the total (discard plus retained) male size frequency data in the directed fishery, all shell condition combined. Circles are observed data.

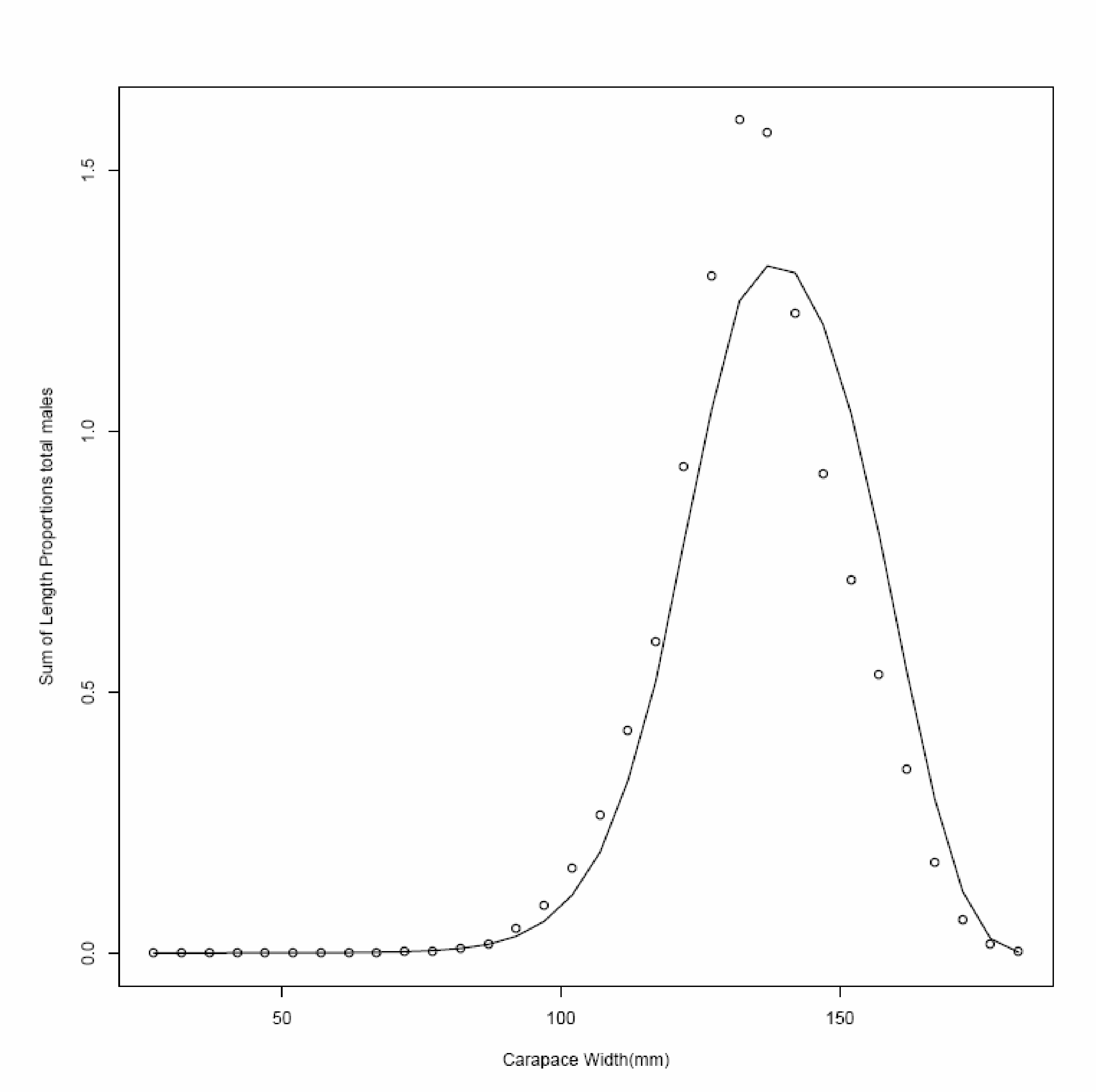



Figure 47. *Base Model (0)* summary fit to the total (discard plus retained) male size frequency data, shell condition combined. Solid line is the model fit. Circles are observed data.

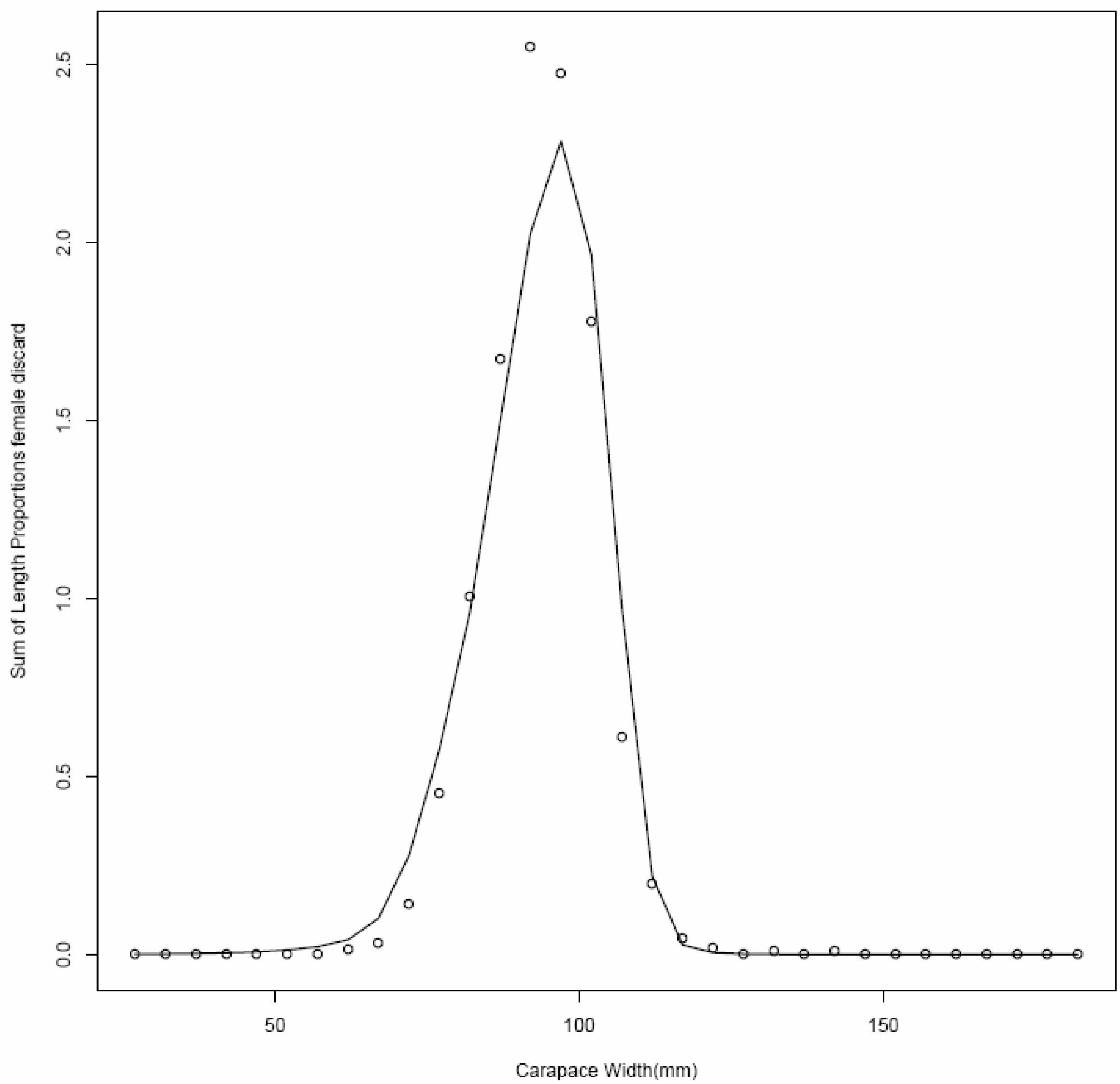



Figure 48. *Base Model (0)* summary fit to the discard female size frequency data in the directed fishery. Solid line is the model fit. Circles are observed data.

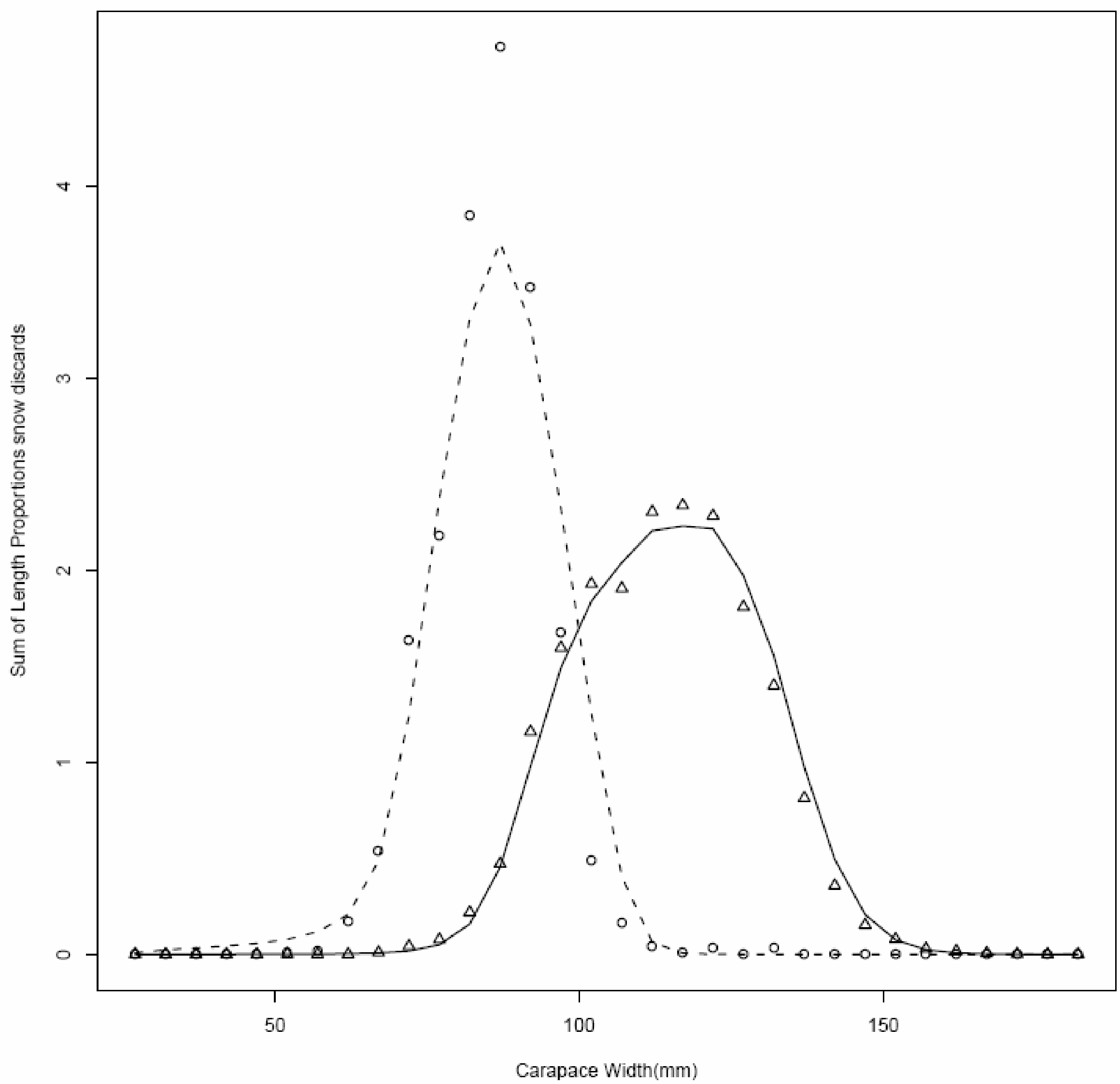



Figure 49. *Base Model (0)* summary fit to the discards in the snow crab fishery for males (solid line) and females (dotted line) size frequency data. Symbols are observed data.

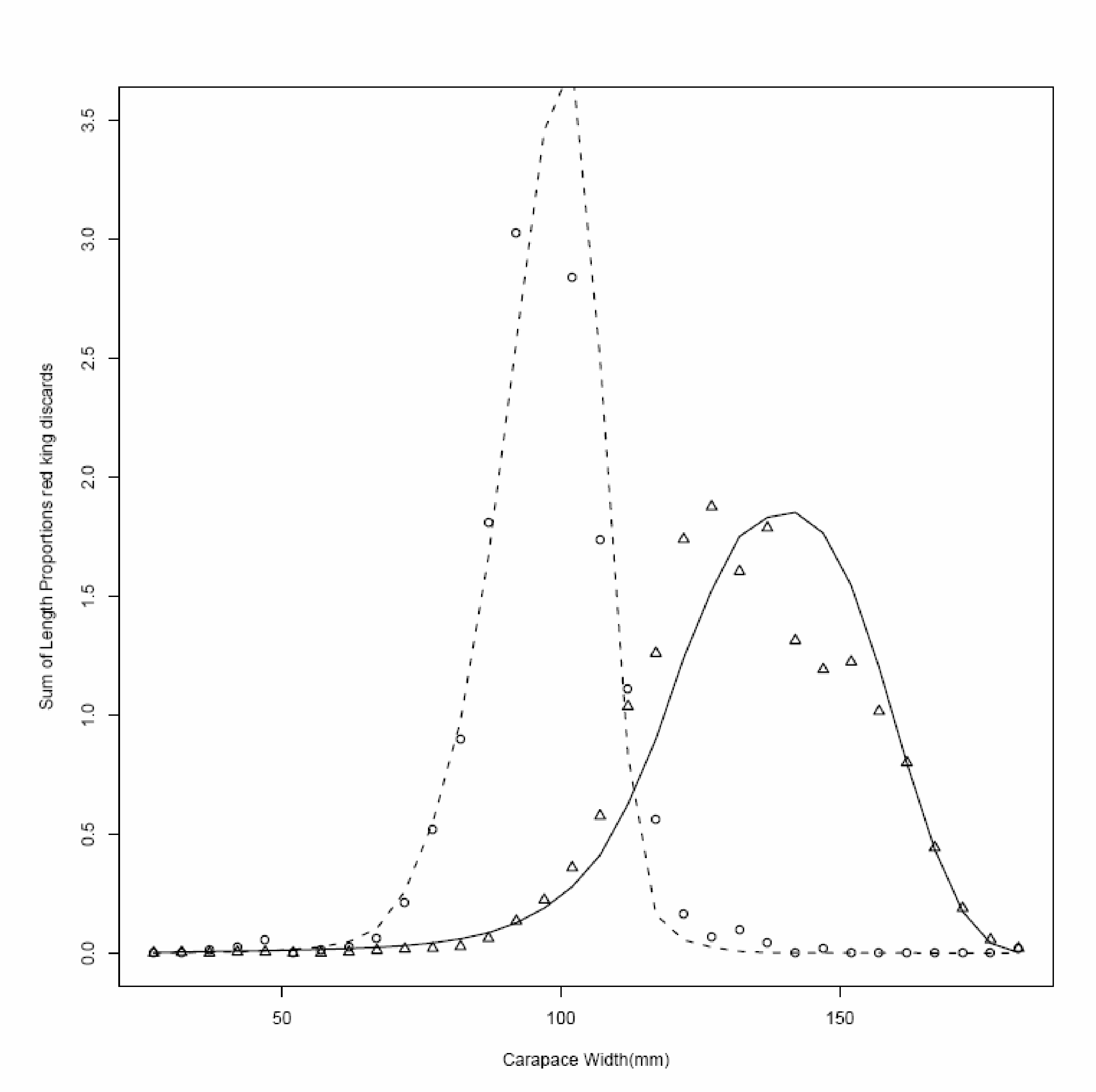



Figure 50. *Base Model (0)* summary fit to the discards in the Bristol Bay red king crab fishery for males (solid line) and females (dotted line) size frequency data. Symbols are observed data.

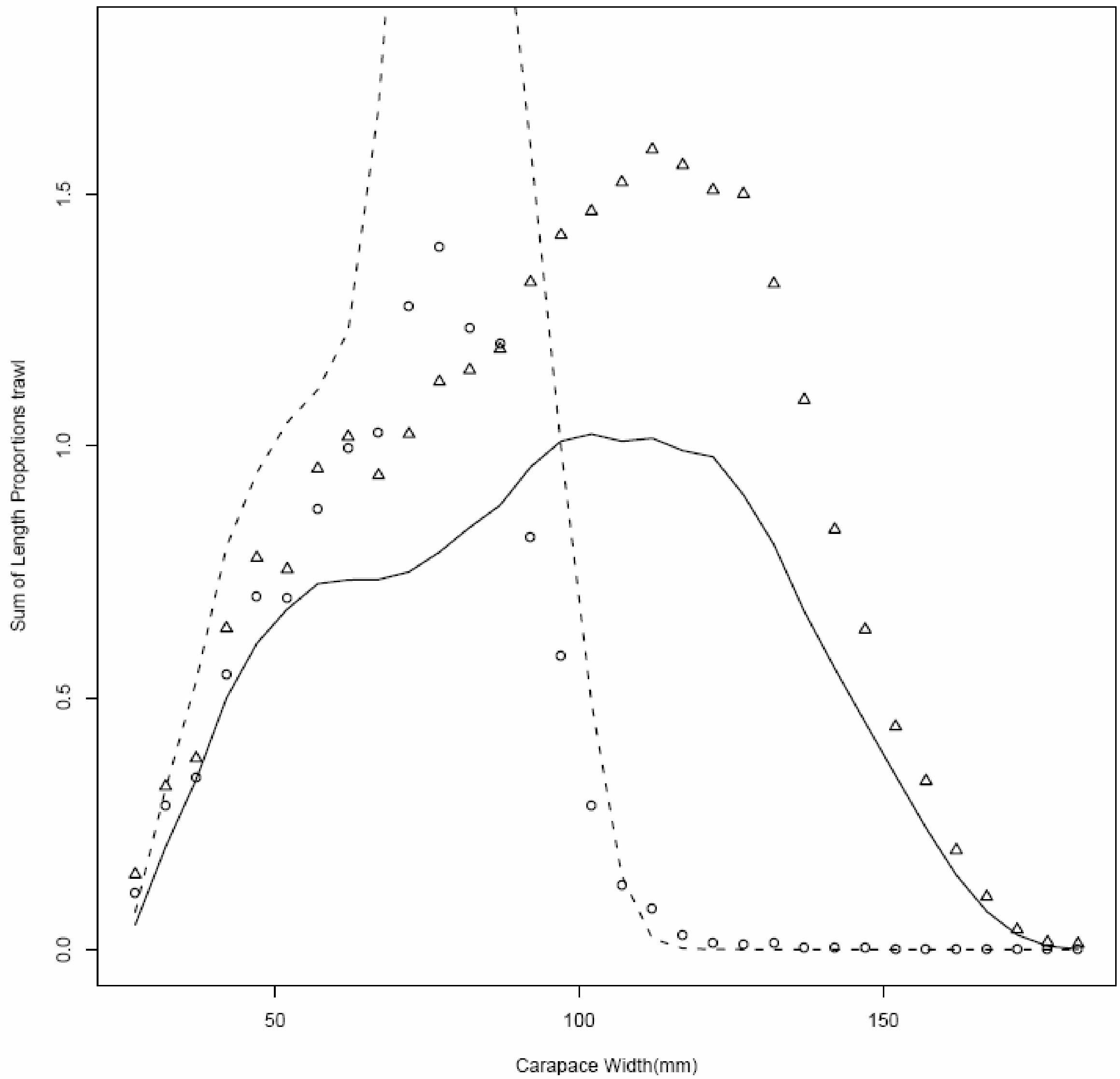



Figure 51. *Base Model (0)* summary fit to the discards in the eastern Bering Sea groundfish fisheries for males (solid line) and females (dotted line) size frequency data. Symbols are observed data.

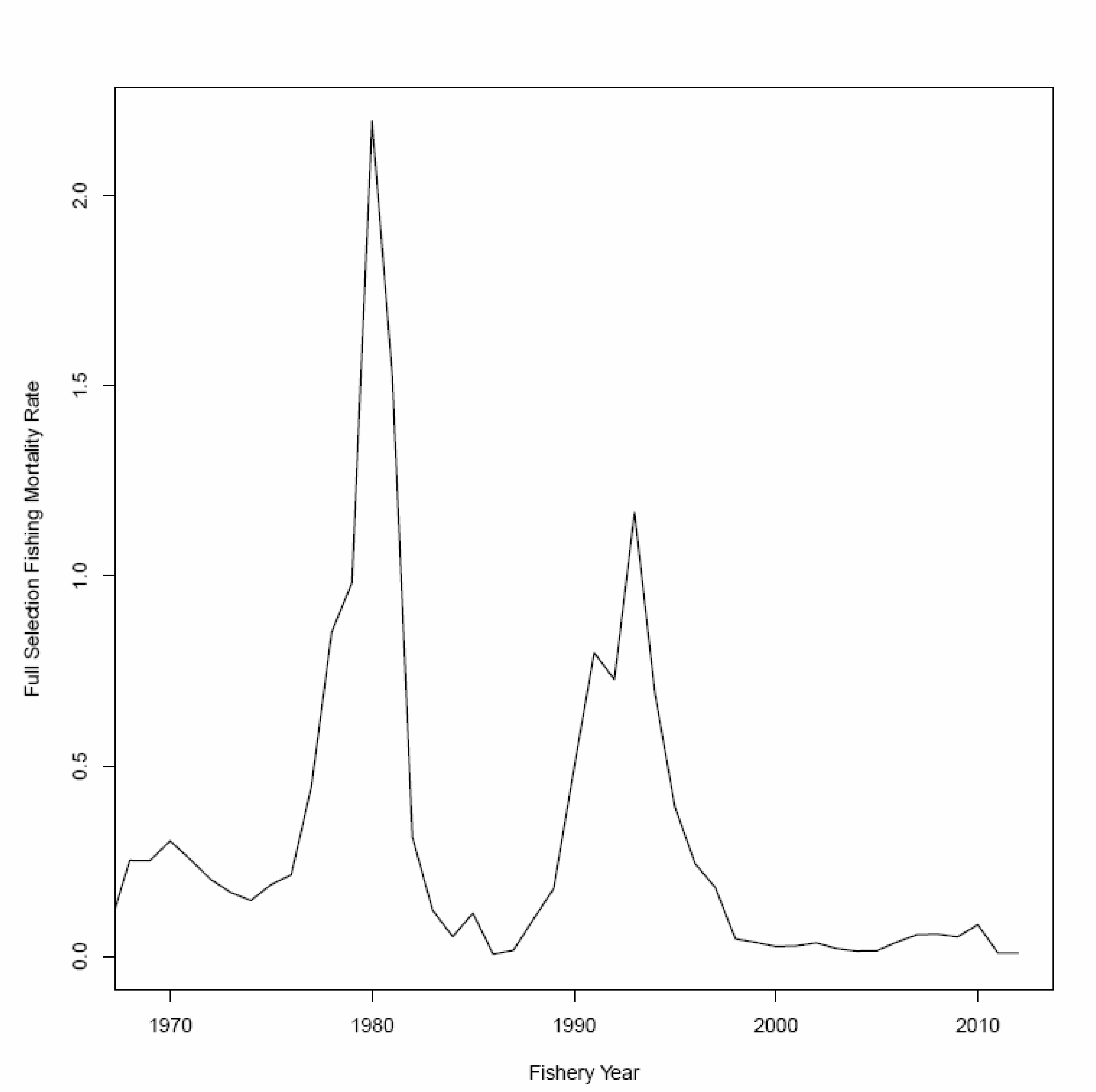



Figure 52. *Base Model (0)* full-selection total fishing mortality rates estimated in the model from 1970 to 2011 fishery seasons (1969 to 2010 survey years).

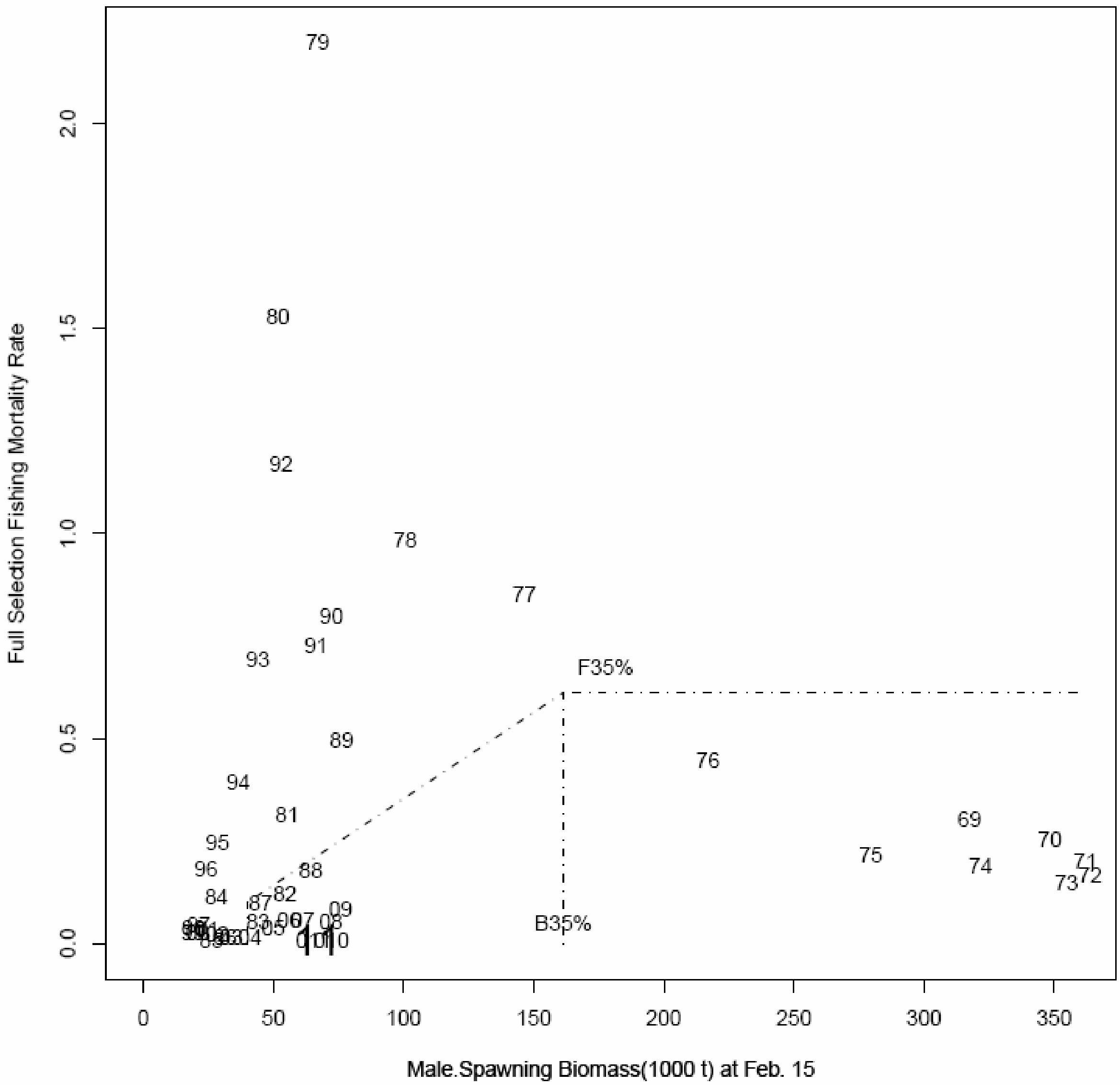



Figure 53. Full-selection fishing mortality versus male mature biomass at mating in fishing years 1967-2010/11. The *Base Model (0)* OFL control rule where $F_{35\%}$=0.612 and $B_{35\%}$=161.37 thousand t.

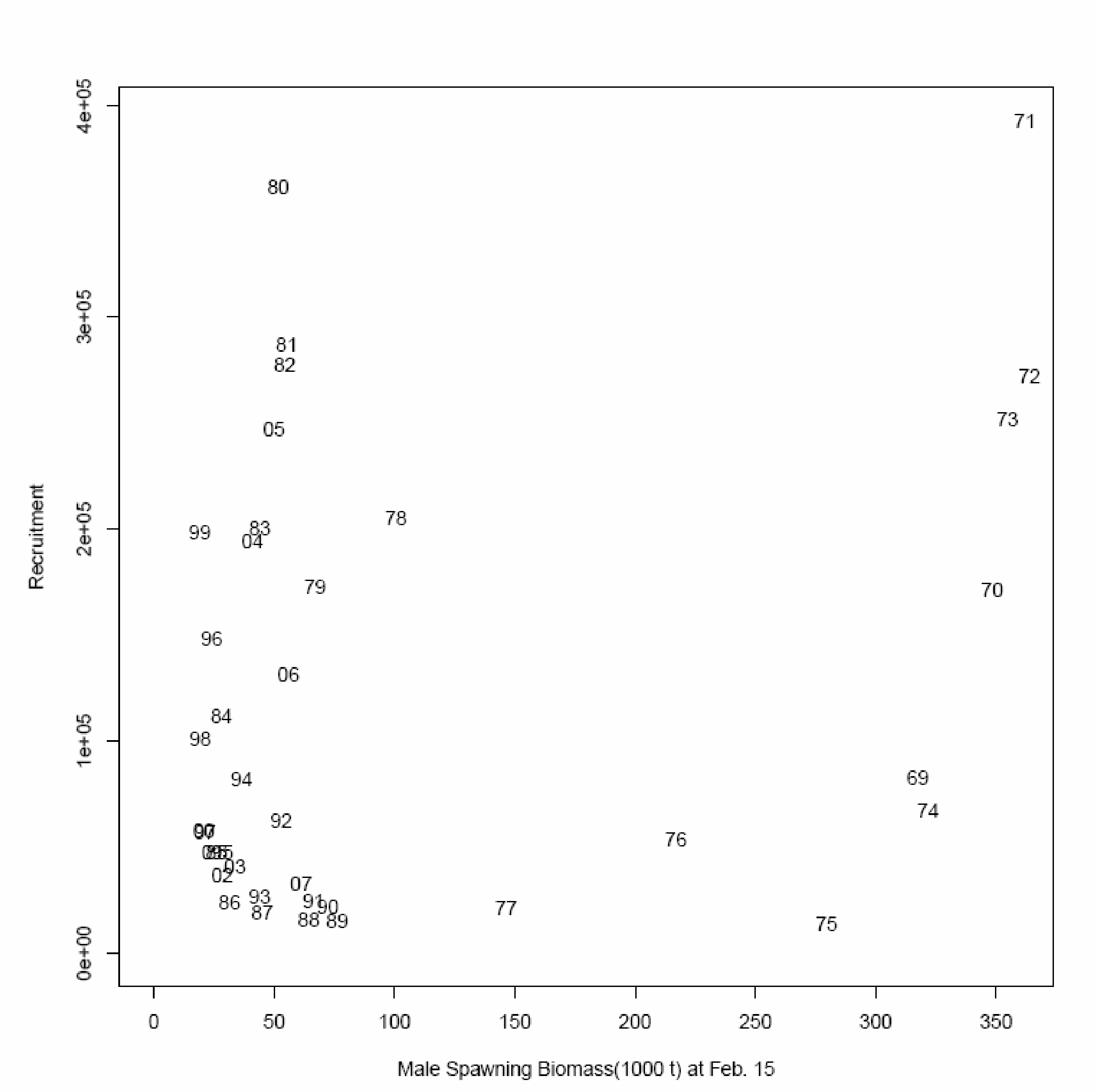



Figure 54. *Base Model (0)* recruitment (1000 crab) vs. male mature biomass at time of mating (1000 t). Two digit year numbers are fertilization year lagged 5 years. Recruitment is one-half of total recruits.

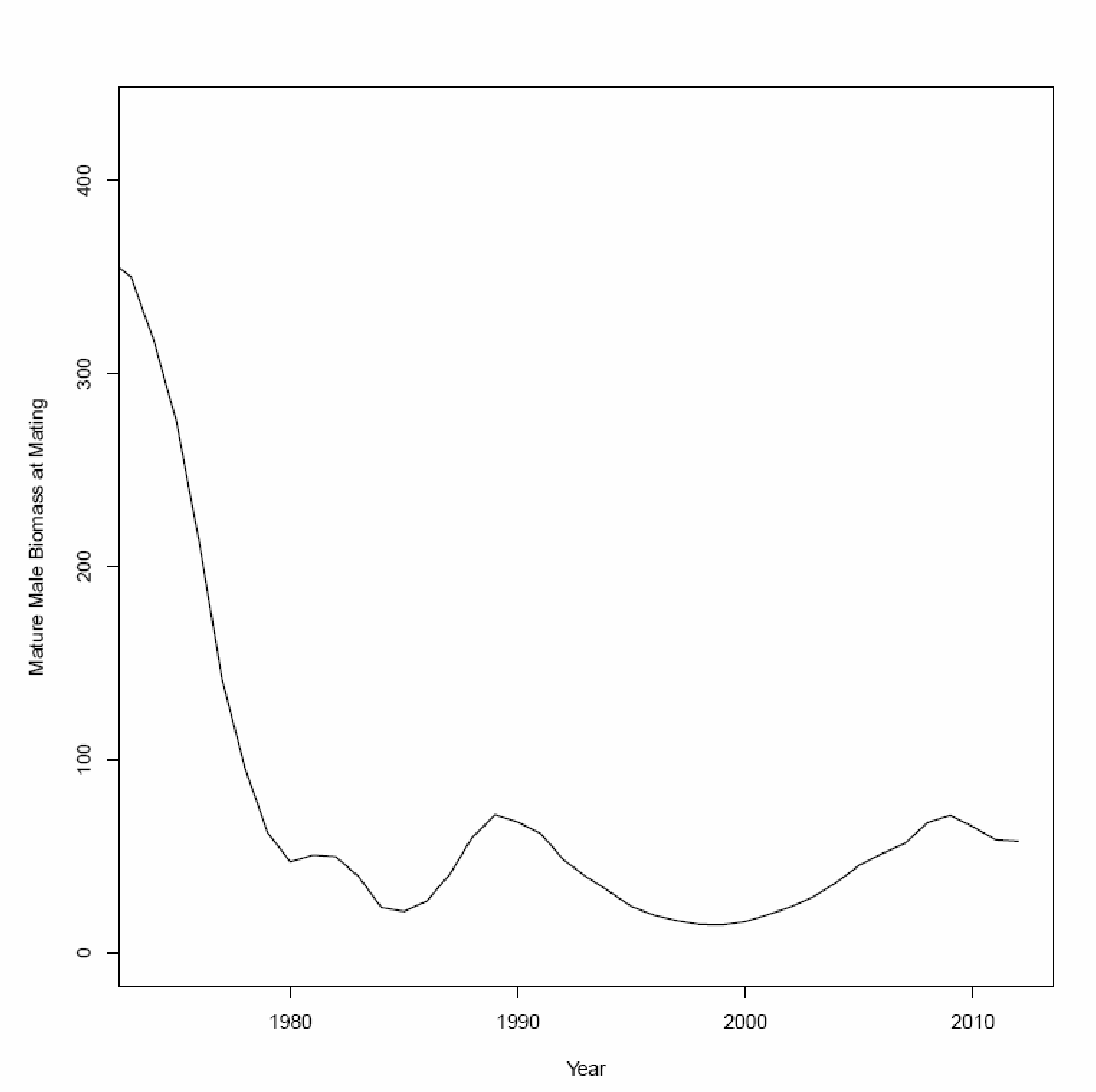



Figure 55. *Base Model (0)* time-trajectory of mature male biomass at the time of mating for EBS Tanner crab (1000 t) for years 1974-2012.

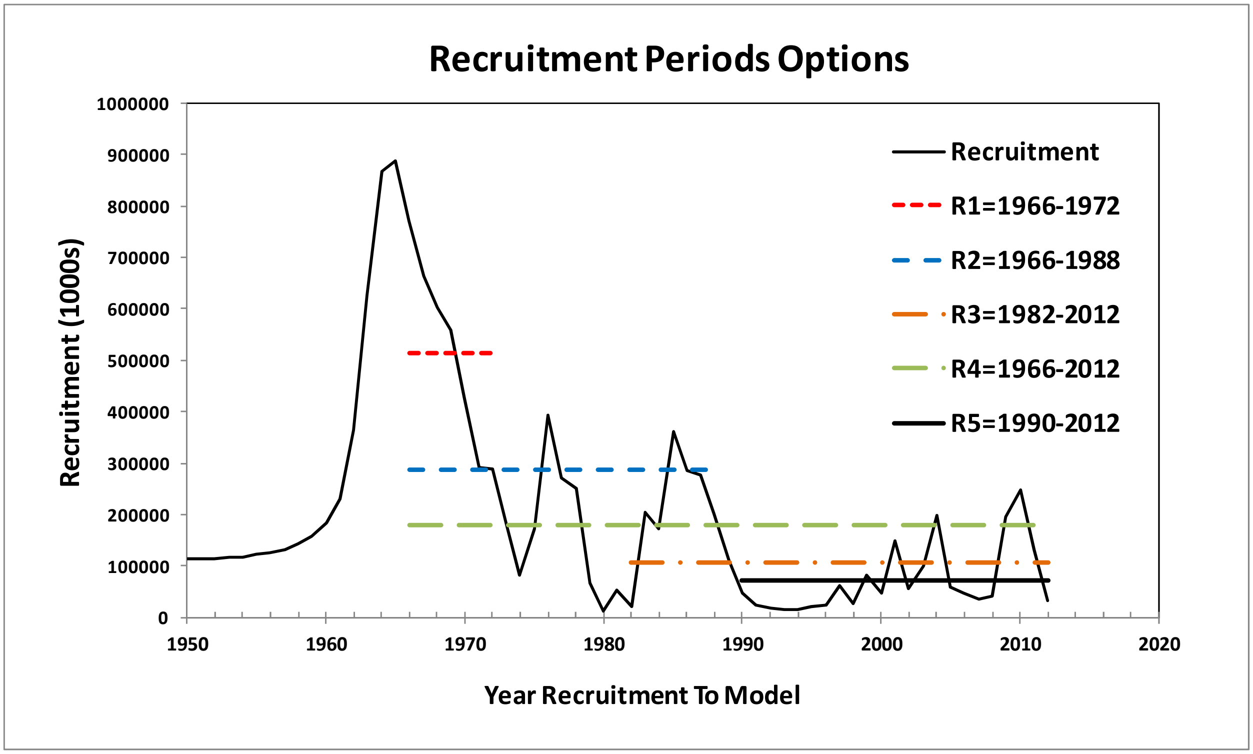



Figure 56. Estimated recruitments to *Base Model (0)* and mean recruitment periods R1 through R5.

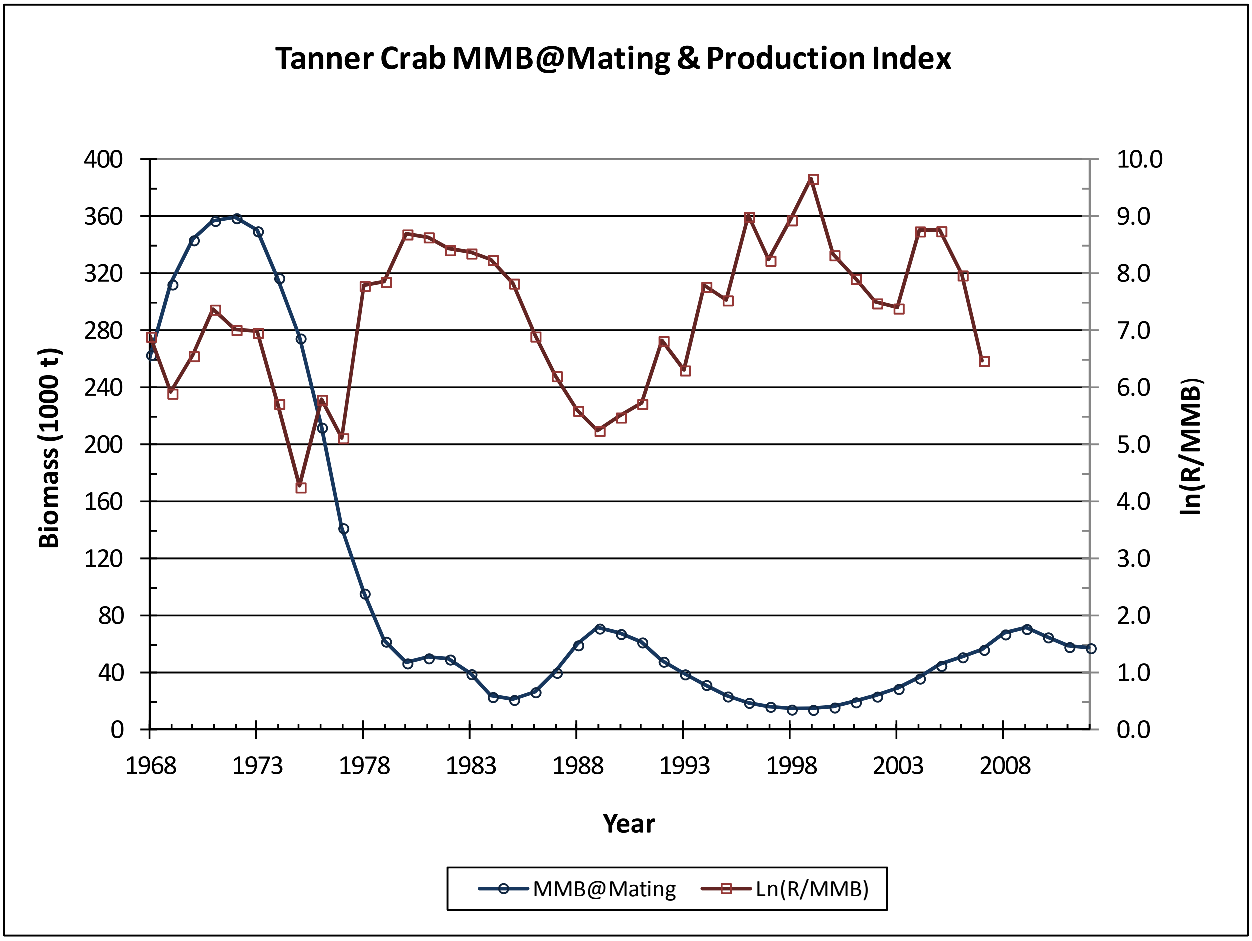



Figure 57. *Base Model (0)* estimate of male mature biomass at mating versus the stock production index, ln(R/MMB), for the Tanner crab stock, 1968-2012.

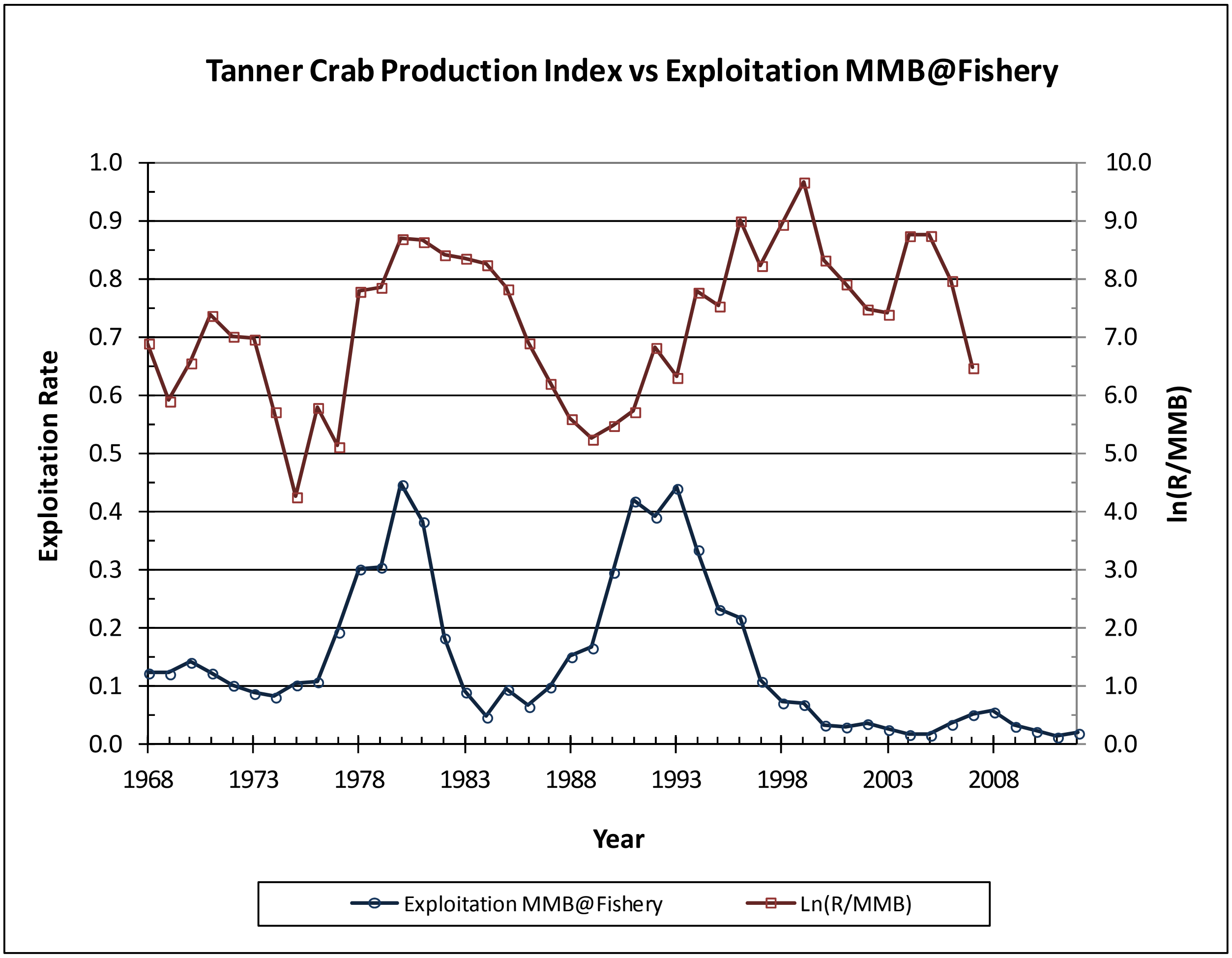



Figure 58. *Base Model (0)* exploitation rate history on Tanner crab male mature biomass at the time of the fishery versus the stock production index, ln(R/MMB), 1968-2012.

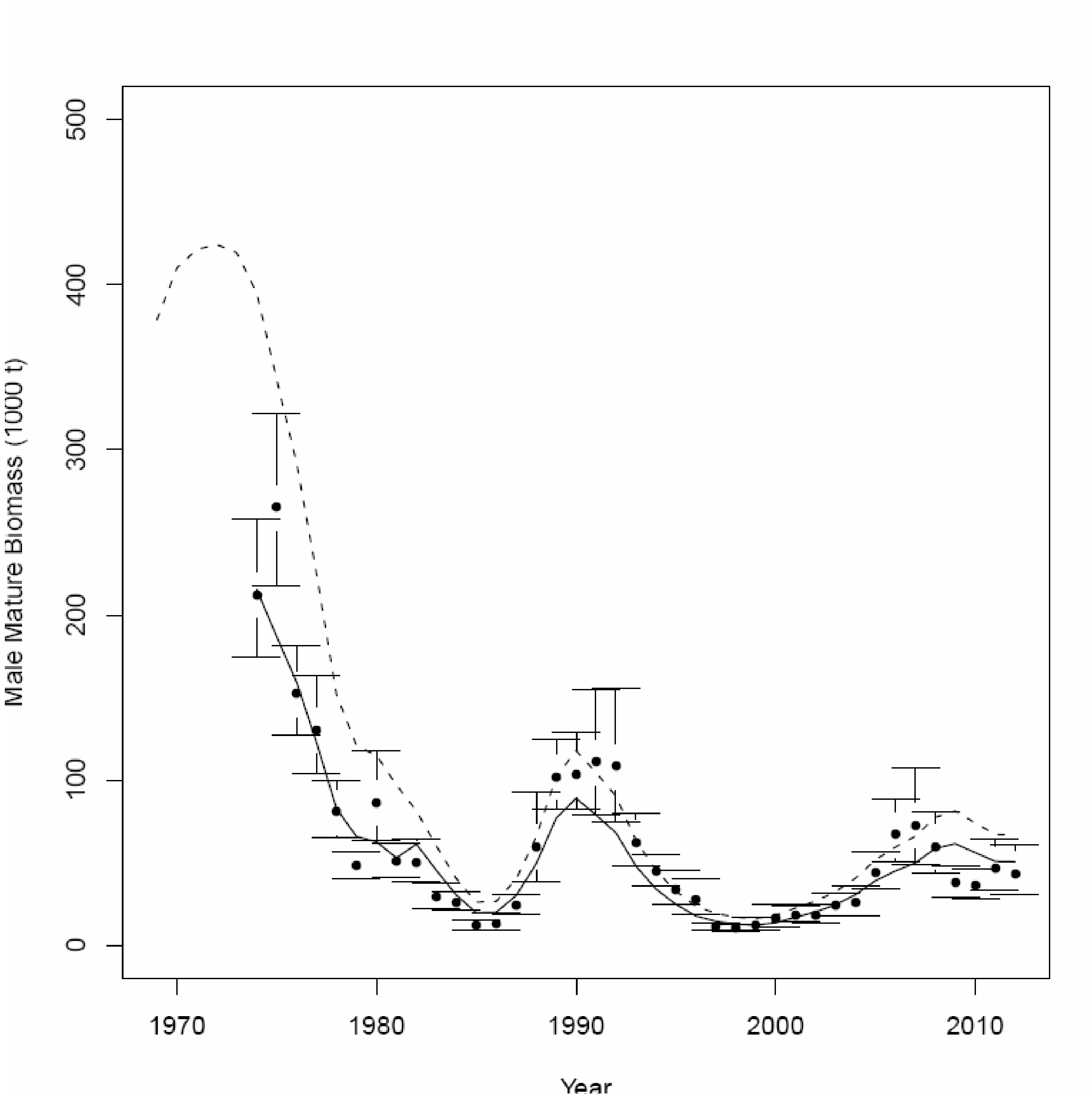



Figure 59. *Model (1)* population mature male biomass (1000 t, dotted line) at the time of the survey, model estimate of survey mature biomass (solid line) and observed survey mature male biomass with approximate lognormal 95% confidence intervals.

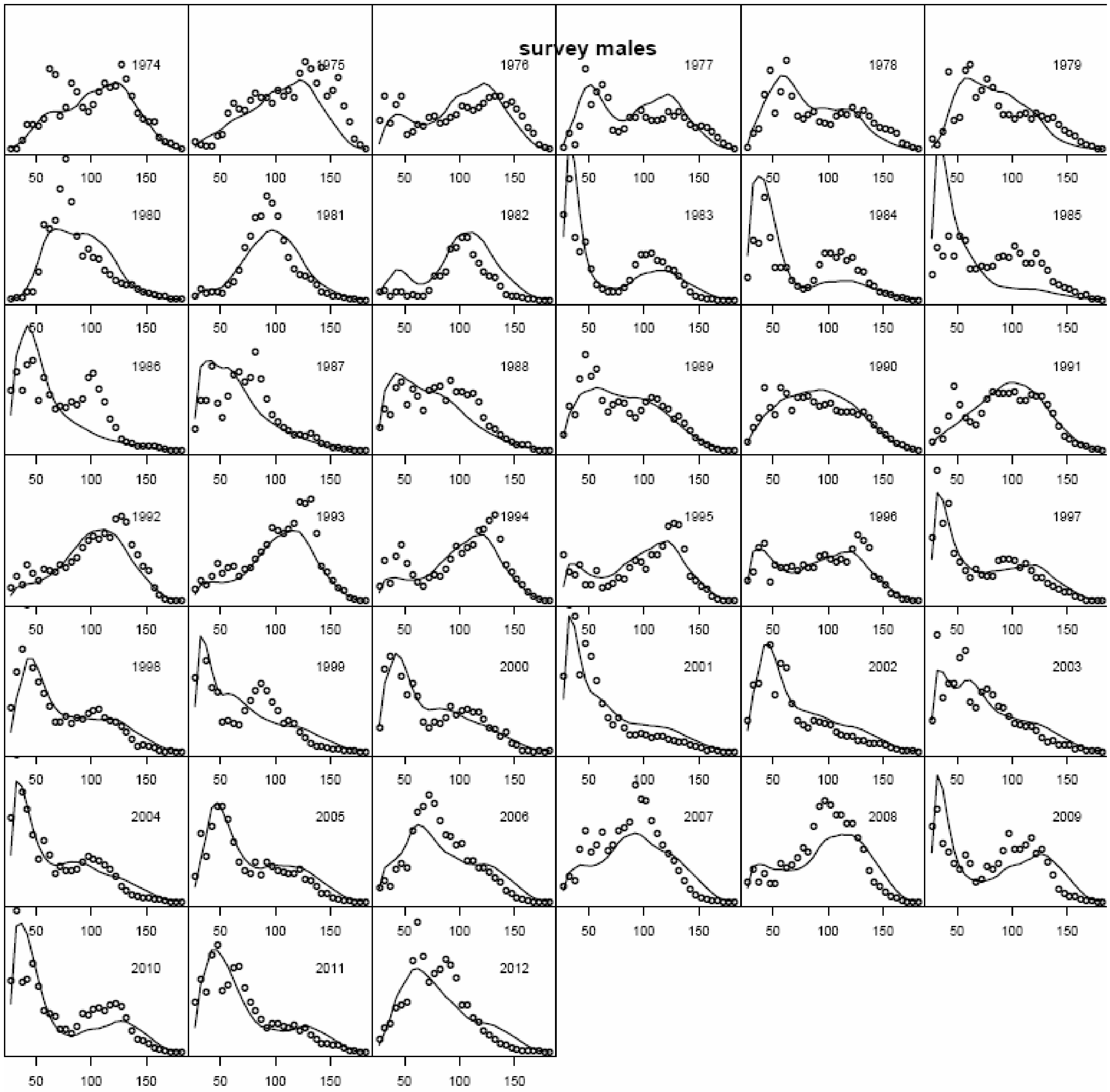



Figure 60. *Model (1)* fit to the survey male size frequency data. Circles are observed survey data. Solid line is the model fit.

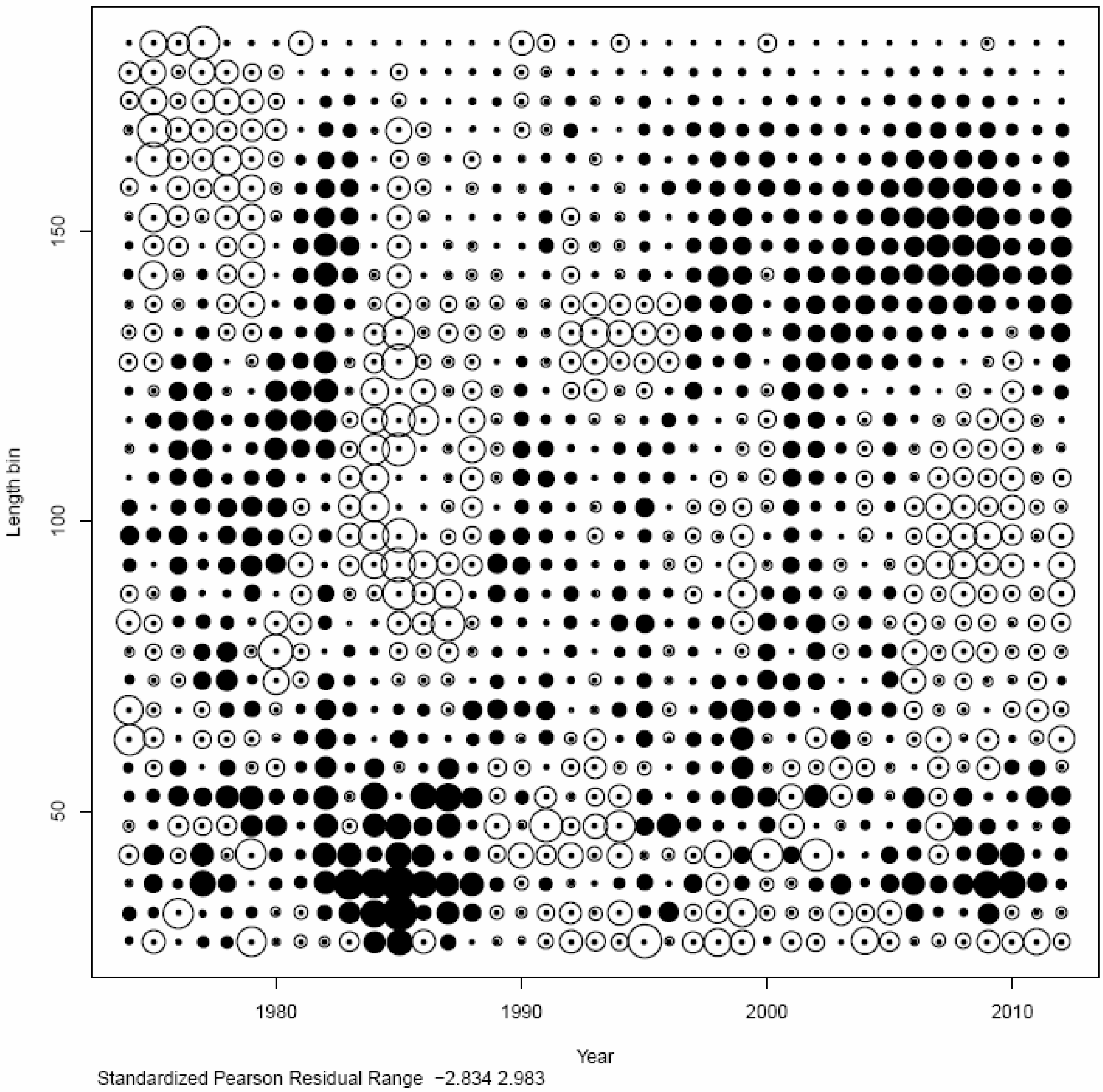



Figure 61. *Model (1)* standardized Pearson residuals of the model fit to the survey male size frequency data. Solid circles= overestimate and open circles=underestimate. Diameter of circle proportional to extent of lack of fit. Residual range shown at bottom.

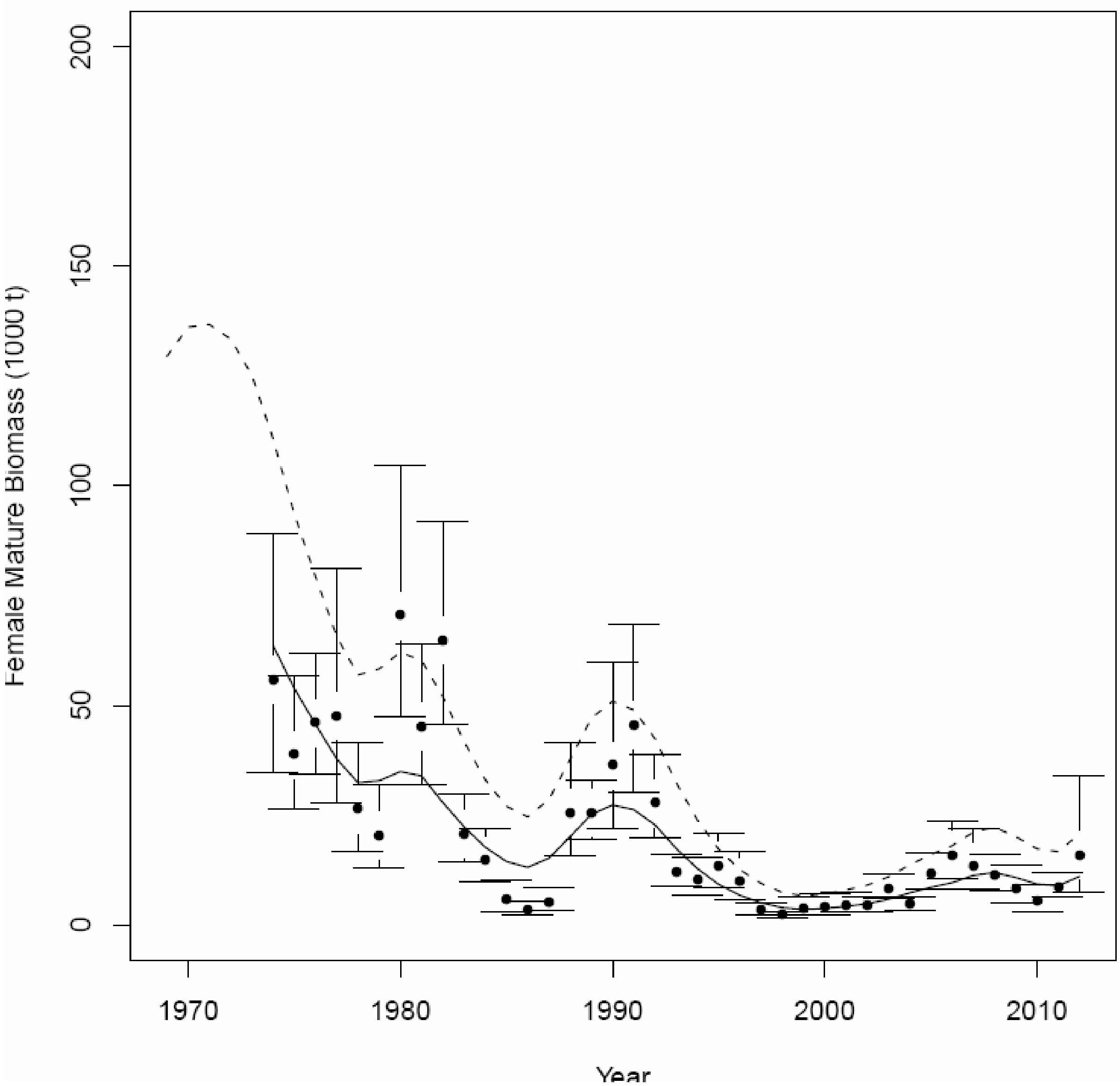



Figure 62. *Model (1)* population female mature biomass (1000 t, dotted line), model estimate of survey female mature biomass (solid line) and observed survey female mature biomass with approximate lognormal 95% confidence intervals.

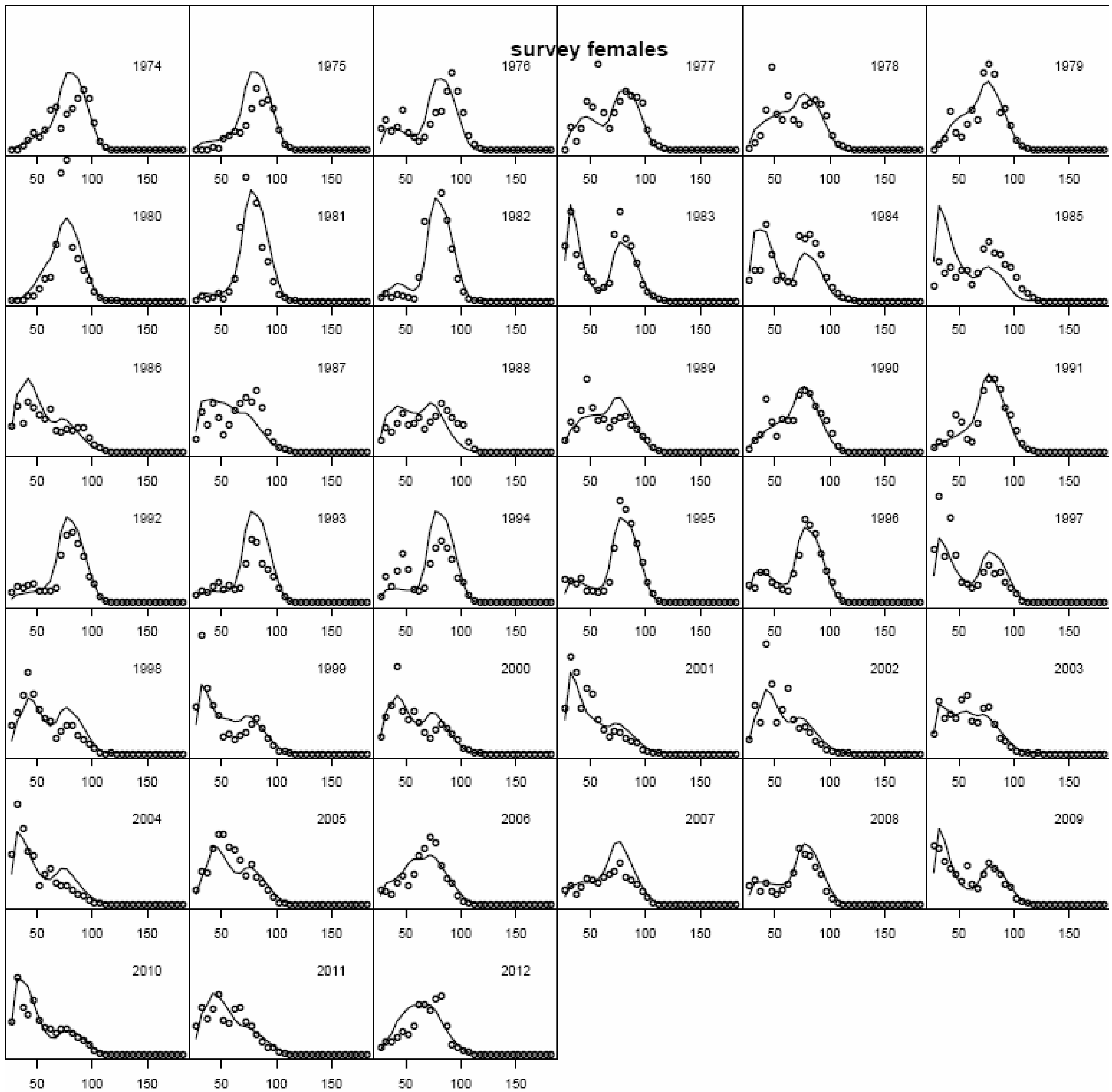



Figure 63. *Model (1)* fit to the survey female size frequency data. Circles are observed survey data. Solid line is the model fit.

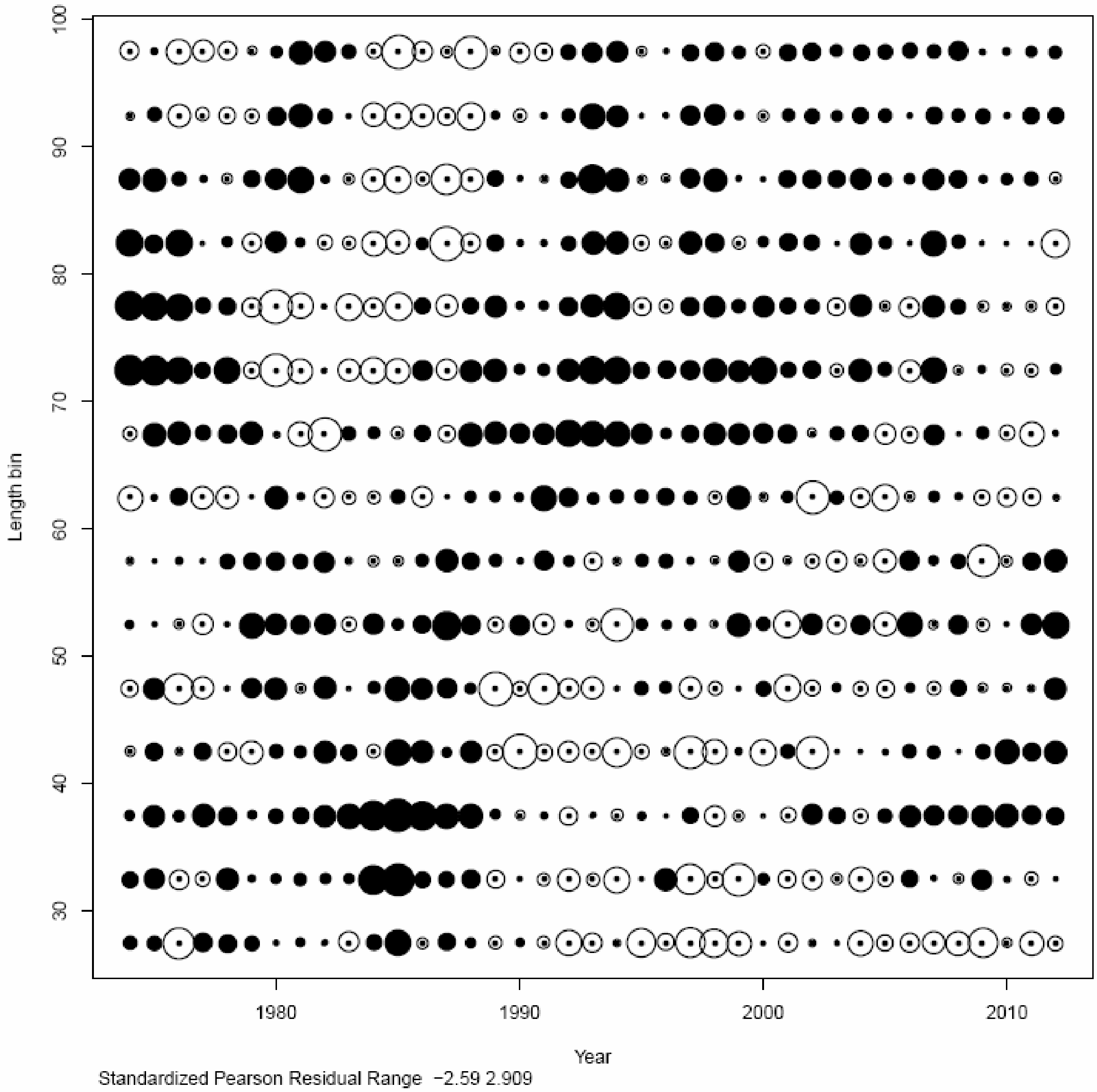



Figure 64. *Model (1)*standardized Pearson residuals of the model fit to the survey female size frequency data. Solid circles= overestimate and open circles=underestimate. Diameter of circle proportional to extent of lack of fit. Residual range shown at bottom.

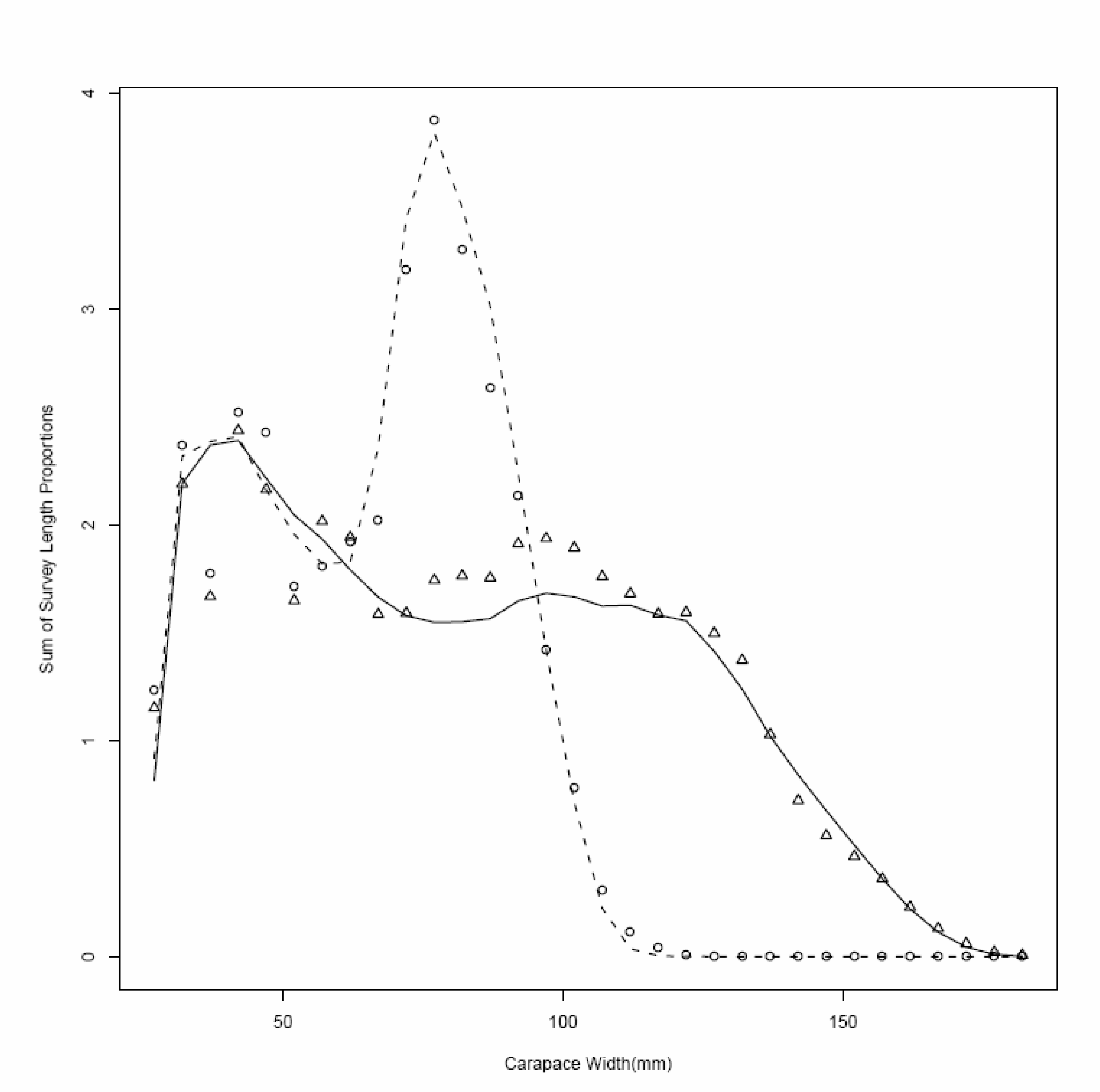



Figure 65. *Model (1)* summary fit to the survey male (solid line) and female (dotted line) size frequency data, all shell conditions combined. Symbols are observed data.

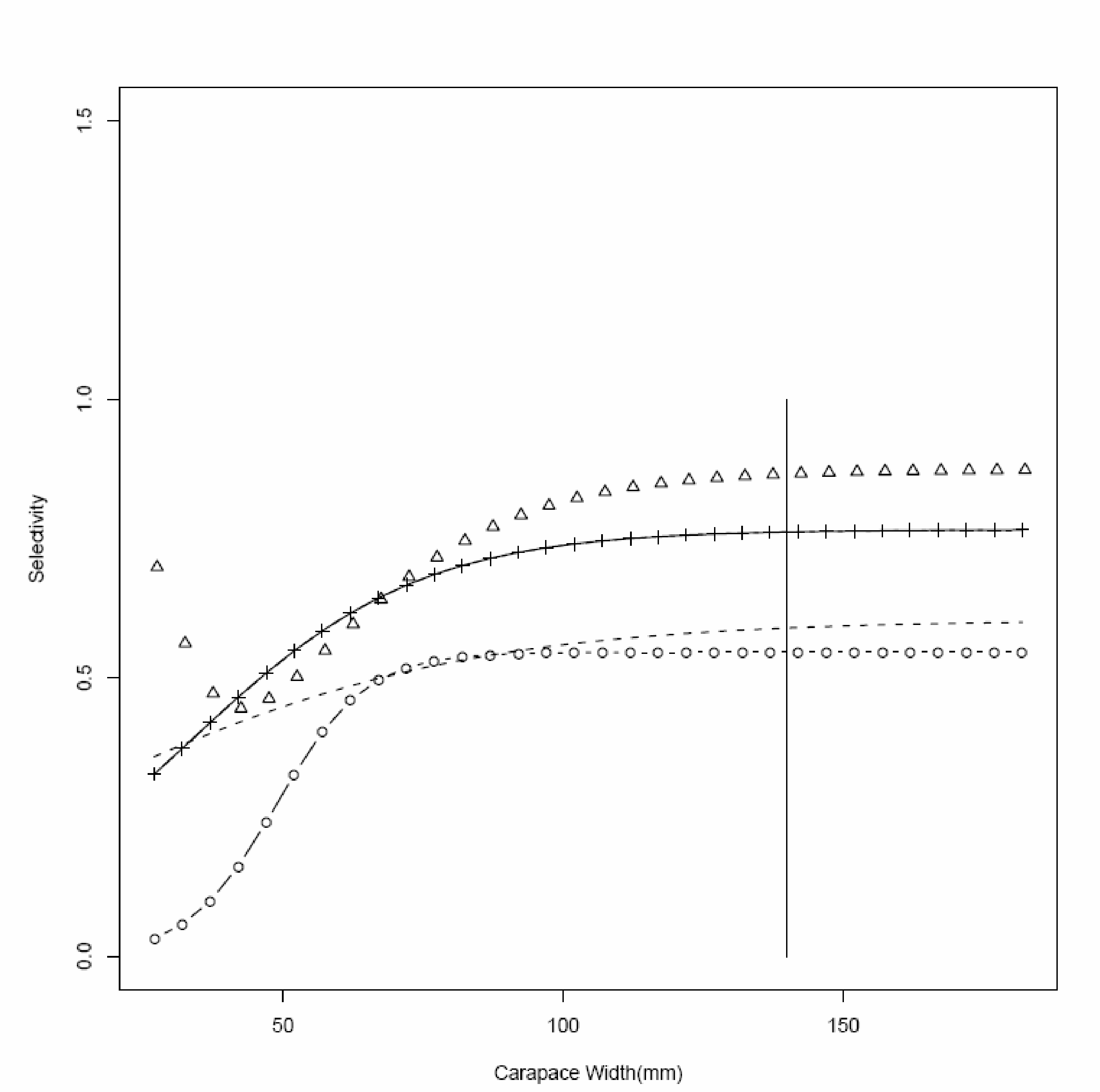



Figure 66. *Model (1)* survey selectivity curves for male Tanner crab estimated for 1974-1981 (dashed line with circles), 1982-2012 (solid line with pluses) with vertical reference line at 140 mm. Survey selectivity estimated by Somerton and Otto (1999) are triangle symbols, and female selectivity for 1982-2012 is dashed line for reference.

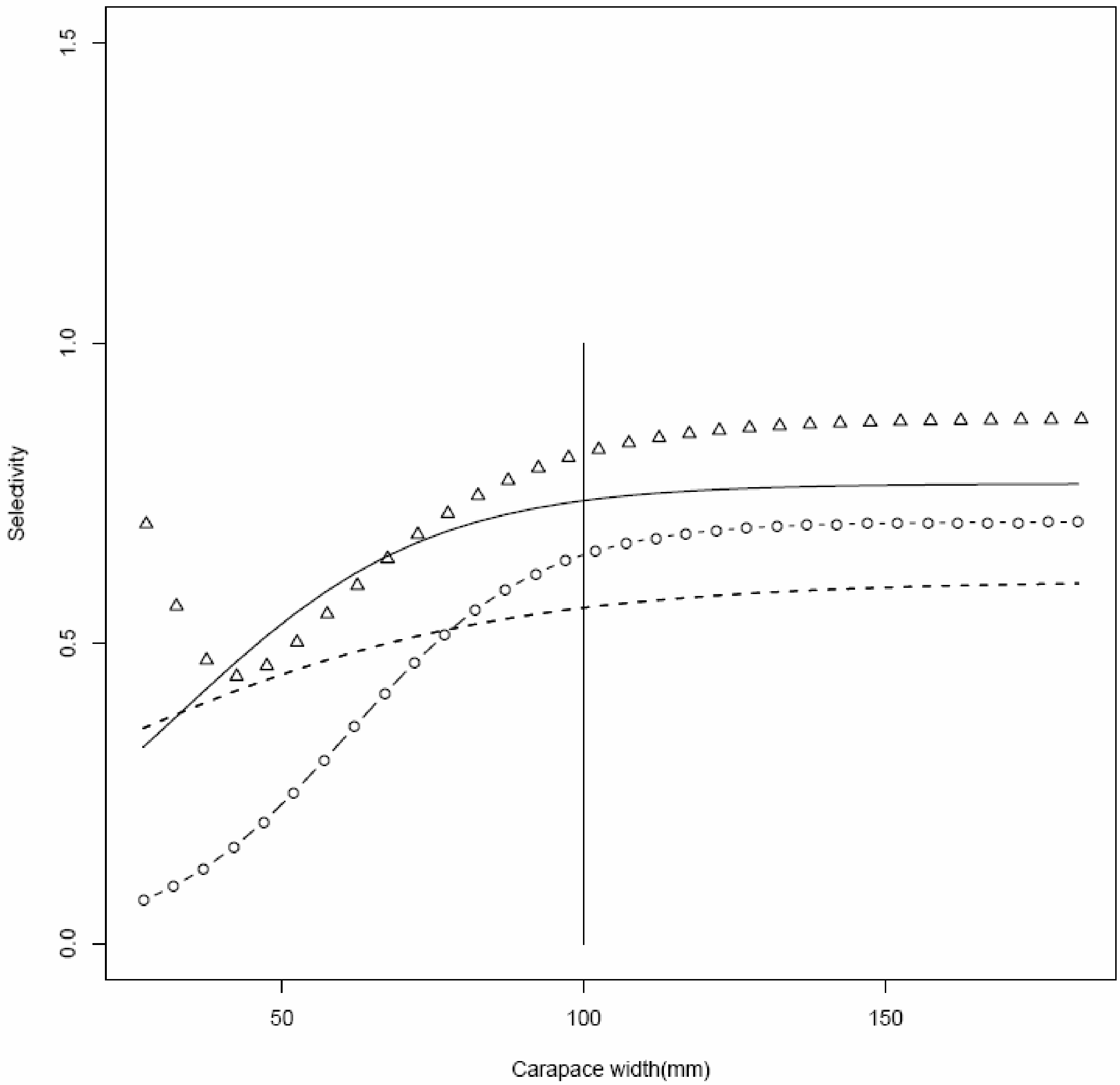



Figure 67. *Model (1)* survey selectivity curves for female Tanner crab estimated for 1974-1981 (dashed line with circles), 1982-2012 (dashed line) with vertical reference line at 100 mm. Survey selectivity estimated by Somerton and Otto (1999) are triangle symbols, and male selectivity for 1982-2012 is upper solid line for reference.

## Appendix A. Projections and Rebuilding Analysis

### Introduction

In this appendix, we report on results of a rebuilding analysis using output of the *Base Model (0)* and *Model (1)* in a projection modeling framework to perform stock simulations to evaluate the consequences of harvest strategies on stock rebuilding and fishery performance. The specification of the projection model is presented in section in I.11 (Projection Model Structure). The OFL in this analysis is based on the Tier-3 control rule where the proxy $F_{MSY}$ is taken to be $F_{35\%}$ and the proxy $B_{MSY}$ to be $B_{35\%}$ (NPFMC, 2008). The OFL is a total-catch OFL computed as the sum of catches from five sources: (i) retained legal males in directed fishery, (ii) discards in the directed fishery, (iii) bycatch in the snow crab fishery, (iv) bycatch in the Bristol Bay red king crab fishery, and (v) bycatch in the groundfish fisheries.

The following table presents the eight model-mean recruitment combinations potentially eligible for rebuilding analysis and the respective values of $B_{35\%}$, $F_{35\%,}$ 2011/12 MMB at the time of mating, and the percent the 2011/12 MMB at mating is of $B_{35\%}$. Recall, mean period recruitments are: R1=1966-1972; R2=1966-1988; R3=1982-2012; R4=1966-2012; and R5=1990-2012. The bolded scenario is recommended by the CPT (September 2012).

Summary Table: Model vs Mean Recruitment Period
($B_{35\%}$ and MMB in 1000 t)

| Mean Recruitment | Model | $B_{35\%}$ | $F_{35\%}$ | $MMB_{11/12}$ | $\%MMB_{11/12}$ / B35% |
|---|---|---|---|---|---|
| R1 | Model (0) | 161.37 | 0.61 | 58.59 | 36.31 |
| | Model (1) | 157.48 | 0.59 | 56.26 | 35.73 |
| R2 | Model (0) | 90.14 | 0.61 | 58.59 | 65.00 |
| | Model (1) | 97.57 | 0.59 | 56.26 | 57.66 |
| R3 | Model (0) | 33.45 | 0.61 | 58.59 | 175.16 |
| | Model (1) | 35.60 | 0.59 | 56.26 | 158.03 |
| R4 | Model (0) | 56.00 | 0.61 | 58.59 | 104.63 |
| | Model (1) | 59.55 | 0.59 | 56.26 | 94.48 |
| **R5** | **Model (0)** | **22.80** | **0.61** | **58.59** | **257.02** |
| | Model (1) | 22.59 | 0.59 | 56.26 | 249.07 |

For both *Model (0)* and *Model (1)*, simulations begin with the terminal year biomass form the respective assessment model. Simulations are performed under up to four scenarios: (1) fishing at the full $F_{OFL}$; (2) fishing at $F_{OFL}$=0 with only groundfish fishery discard mortality included; (3) fishing at $F_{OFL}$=0 with all non-directed fishery discard mortality included; and, if required, (4) fishing at a percentage full $F_{OFL}$ that achieves rebuilding within 10 years. The fourth scenario was not run if the stock was shown to rebuild within 10 years under either scenario (1), (2) or (3). Rebuilding simulations were not run for either *Model (0)* or *Model (1)* for cases where R3, R4 or R5 mean recruitment since the stock began the first year of simulation near or in excess of 100% of $B_{35\%}$.

The calculation of the total catch OFL is based on the assumption that $F_{\mathrm{OFL}}$ is the fishing mortality rate from the directed fishery for total males, plus the full-selection $F$ for males in the snow crab, Bristol Bay red king crab and groundfish fisheries. The future full-selection retained fishing mortality rate for males in the directed fishery is given by the directed fishery component of the $F_{\mathrm{OFL}}$ multiplied by the fishery selectivity for retained males estimated in the assessment model. The future fishing mortality rate on Tanner crab in the snow crab, Bristol Bay red king crab and groundfish trawl fisheries equals the average value over the last five years with their applied fishery selectivity curves estimated in the model. Thus, changes to $F_{\mathrm{OFL}}$ directly impact the predicted catches of retained males in the directed fishery as well as the predicted discard of males and females in the directed fishery, while the fishing mortality rates leading to bycatch in the snow, red king crab and groundfish fisheries are constant and independent of $F_{\mathrm{OFL.}}$

The new legal minimum size limit in effect for the 2012/13 fisheries is 122 mm to the east of $166^0$ W longitude and 112 mm for fisheries to the west. The previously minimum legal size limit was 5.5” (138 mm cw) throughout the Eastern Subdistrict. However, the industry may self-impose retention of crab above 5.5” (138 mm cw) and 5” (127 mm cw) east and west of 166° West longitude, respectively.

Since fishery performance has not been observed under the new size limit regime, we approximated east-west retained fishery selectivity and the catch splits in the modeling framework. Total selectivity is assumed to remain unchanged for both areas since no gear change accompanied the size limit change. Retained selectivity for the eastern and western districts was formulated based on the industry imposed size limits of 138 mm (east) and >127 mm (west). For the eastern fishery, retained selectivity is unchanged. For the western fishery, the retained selectivity curve formulated based on a minimum legal size limit of 138 mm was shifted 10 mm to the proposed 128 mm minimum size limit (Figure A-1). The split in the catch east-west was approximated by the 3-year average proportion of the abundance of crab observed in the 2010 to 2012 surveys east and west of $166^0$ W longitude. Figure A-2 presents the mean proportion of male abundance observed in the 2010-2012 NMFS bottom trawl survey east and west of $166^0$ W longitude.

**Results**

Projections using output from the *Model (0)* and *Model (1)* were run under a maximum of four harvest strategy scenarios: (1) fishing at the full $F_{OFL}$; (2) fishing at $F_{OFL}$=0 for the directed fishery but with only groundfish fishery discard mortality included; (3) fishing at $F_{OFL}$=0 for the directed fishery but with all non-directed fishery discard mortality included; (4) fishing at a percentage of the full $F_{OFL}$ that achieves rebuilding within 10 years. The starting year of estimated MMB at mating is 2012/13 (nominal 15 February) which, by procedure, is assessed in September 2013. Years to rebuilding, therefore, are gauged against the starting 2012/13 MMB at mating, and MMB at mating in any tabled year (t) is similarly assessed in the year t+1 September assessment cycle.

Projections using output from *Model (0)* and *Model (1)* were run at up to four harvest strategies against two benchmark $B_{35\%}$ reference points formulated using R1 and R2 mean recruitments. As noted, when either R3, R4 or R5 mean recruitment was used to estimate $B_{35\%}$, the terminal year MMB for either *Model (0)* or *Model (1)* was at or in excess of 100% $B_{35\%}$. Thus, stock rebuilding simulations were not run for *Model (0)* and *Model (1)* under R3, R4 and R5 mean recruitment. The various $B_{35\%}$ values estimated using mean recruitments to the model R1 through R5 are tabled above, as are the percentage of the 2011/12 MMB at mating relative to the respective $B_{35\%}$.

In September 2012, the Crab Plan Team decided that mean recruitment over 1990-2012 (R5) represented the current production potential of the EBS Tanner crab stock. The team also selected *Model (0)* as the base model for the 2011/12 assessment and 2012/13 OFL-setting. Rebuilding projections were not performed under CPT's preferred R5-*Model (0)* since 2011/12 MMB at mating (58.59 thousand t) represents 257.02% of the $B_{35\%}$ proxy of 22.80 thousand t.

Tables A-1 through A-4 present results of *Model (0)* for mean recruitment R1 fishing at four harvest strategies. Rebuilding is not achieved in 10 years fishing at the full $F_{OFL}$, $1.0F_{35\%}$ (Table A-1). Fishing at F=0 with only groundfish bycatch mortality (Table A-2), rebuilding is achieved in 2018/19 (6 y). Fishing at F=0 with bycatch mortality from all fisheries (Table A-3), rebuilding is achieved in 2021/22 (9 y). Fishing at a constant 33% of the $F_{OFL}$, $0.33F_{35\%}$ (Table A-4), rebuilding is achieved in 2022/23 (10 y).

For *Model (0)* using $B_{35\%}$ based on R2 mean recruitments, rebuilding is achieved in 2021/22 (9 y) fishing at the full $F_{OFL}$, $1.0F_{35\%}$ (Table A-5). Rebuilding is achieved in 2014/15 (2 y) fishing at F=0 with only groundfish bycatch mortality (Table A-6), and in 2017/18 (5 y) fishing at F=0 with bycatch mortality from all fisheries (Table A-7). Since rebuilding is achieved within 10 years fishing at the full $F_{OFL}$, $1.0F_{35\%}$ , no $\%F_{OFL}$ projections are required.

Tables A-8 through A-11 present results of *Model (1)* for mean recruitment R1 fishing at four harvest strategies. Rebuilding is not achieved in 10 years fishing at the full $F_{OFL}$, $1.0F_{35\%}$ (Table A-8). Fishing at F=0 with only groundfish bycatch mortality (Table A-9), rebuilding is achieved in 2018/19 (6 y). Fishing at F=0 with bycatch mortality from all fisheries (Table A-10), rebuilding is achieved in 2022/23 (9 y). Fishing at a constant 27% of the $F_{OFL}$, $0.27F_{35\%}$ (Table A-11), rebuilding is achieved in 2022/23 (10 y).

For *Model (1)* using $B_{35\%}$ based on R2 mean recruitments, rebuilding is achieved in 2022/23 (10 y) fishing at the full $F_{OFL}$, $1.0F_{35\%}$ (Table A-12). Rebuilding is achieved in 2015/16 (3 y) fishing at F=0 with only groundfish bycatch mortality (Table A-13), and in 2018/19 (6 y) fishing at F=0 with bycatch mortality from all fisheries (Table A-14). Since rebuilding is achieved within 10 years fishing at the full $F_{OFL}$, $1.0F_{35\%}$ , no $\%F_{OFL}$ projections are required.

For projections presented here, if actual total or retained fishery selectivity under the new SOA size limit strategy east or west of $166^0$ W longitude are different than those approximated in this analysis, $F_{35\%}$ and $B_{35\%}$ will be different and rebuilding trajectories will change. Estimated recruitment to the model have show an increasing trend, however, if recruitment is lower than expected, longer rebuilding times will result.

Table A-1. *Model (0)* fishing at $1.0F_{35\%}$ control rule. R1 $B_{35\%}$ = 161.37, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 9.3(8.2,10.4) | 2.7(2.2,3.2) | 32.2(29.7,34.5) | 0 | 0.14 | 1.9 | 1.4 | 1.6 | 1.3 |
| 2013/14 | 11.7(9.4,15.4) | 3.1(1.7,5.5) | 36.1(33,39) | 0 | 0.16 | 2.3 | 1.5 | 2.1 | 1.5 |
| 2014/15 | 15.4(11.8,20.9) | 5(2.5,8.8) | 42.9(38.4,46.9) | 0 | 0.21 | 3.7 | 2.5 | 3.3 | 2.5 |
| 2015/16 | 15.1(11.3,21.1) | 5.4(2.7,9.8) | 43.6(38.1,48.6) | 0 | 0.21 | 3.8 | 2.8 | 3.3 | 2.7 |
| 2016/17 | 13.7(9.4,22.2) | 4.5(2.2,8.7) | 40.7(33.8,51.7) | 0 | 0.19 | 3.3 | 2.3 | 2.8 | 2.2 |
| 2017/18 | 16.1(8.5,48.7) | 4.8(1.9,17.4) | 44(31.4,78.2) | 0.02 | 0.22 | 3.6 | 2.4 | 3.3 | 2.4 |
| 2018/19 | 23(8.9,79.9) | 8(2,33.8) | 53.8(31,116.5) | 0.08 | 0.28 | 6.0 | 4.0 | 5.6 | 4.1 |
| 2019/20 | 28.8(8.9,98.2) | 10.6(2.1,41.8) | 61.7(31.6,141.1) | 0.16 | 0.33 | 7.8 | 5.3 | 7.2 | 5.4 |
| 2020/21 | 31.1(8.7,100.8) | 12.6(2.1,46.4) | 65.1(31.4,147.4) | 0.22 | 0.35 | 9.3 | 6.3 | 8.4 | 6.4 |
| 2021/22 | 32(8.5,104.8) | 12.5(2.2,47.2) | 66.9(30.4,147.2) | 0.25 | 0.35 | 9.2 | 6.2 | 8.4 | 6.3 |
| 2022/23 | 34(8.7,106) | 13.3(2.2,44.1) | 67.6(30.5,154.5) | 0.29 | 0.36 | 9.8 | 6.6 | 8.9 | 6.8 |
| 2023/24 | 33.5(8.8,112.8) | 12.8(2,50.1) | 67.5(32,162.2) | 0.34 | 0.36 | 9.6 | 6.3 | 8.9 | 6.6 |

Table A-2. *Model (0)* fishing at F=0 with groundfish bycatch only. R1 $B_{35\%}$ = 161.37, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | East | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 0.1(0.1,0.1) | 0(0,0) | 36.6(33.5,39.5) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 0.2(0.2,0.3) | 0(0,0) | 45.7(42,49.4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 0.3(0.3,0.3) | 0(0,0) | 59.6(54.7,64.4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 0.2(0.2,0.4) | 0(0,0) | 66.8(61.4,72.9) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 0.3(0.1,0.8) | 0(0,0) | 70.6(61.1,97) | 0.04 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 0.5(0.2,1.6) | 0(0,0) | 91.1(61.6,190) | 0.39 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 0.7(0.2,2) | 0(0,0) | 125.6(67,314.9) | 0.69 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 0.7(0.2,2.1) | 0(0,0) | 158.5(72.7,408.5) | 0.81 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 0.6(0.2,1.9) | 0(0,0) | 177.6(76.7,475.6) | 0.86 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 0.6(0.2,2) | 0(0,0) | 195.1(78.1,495.1) | 0.89 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 0.6(0.2,2) | 0(0,0) | 215.5(82.7,543.8) | 0.92 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 0.6(0.2,2.4) | 0(0,0) | 227.6(87,606.6) | 0.94 | 0 | 0 | 0 | 0 | 0 |

Table A-3. *Model (0)* fishing at F=0 with bycatch from all fisheries. R1 $B_{35\%}$ = 161.37, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 5.5(5,5.9) | 0(0,0) | 34.3(31.5,37.1) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 7.2(6.6,7.8) | 0(0,0) | 40.5(37.1,43.7) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 8.5(7.8,9.1) | 0(0,0) | 50.7(46.5,54.7) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 8(7.3,8.9) | 0(0,0) | 54.3(49.9,58.8) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 7.7(6.3,12) | 0(0,0) | 52.4(46.9,64.7) | 0.002 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 9.6(5.9,21.4) | 0(0,0) | 57.2(42.7,102.1) | 0.06 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 12.1(6,31.1) | 0(0,0) | 70.1(41.9,158.8) | 0.23 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 14(6.1,37.7) | 0(0,0) | 86.3(42.8,208.9) | 0.38 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 15.1(5.9,39) | 0(0,0) | 94.8(42.8,245.9) | 0.48 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 16.4(6,41) | 0(0,0) | 105(41.9,254.2) | 0.56 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 17.3(6.2,45.4) | 0(0,0) | 114.6(44.4,283.1) | 0.63 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 18(6.8,51.4) | 0(0,0) | 121.2(46.7,312) | 0.68 | 0 | 0 | 0 | 0 | 0 |

Table A-4. *Model (0)* fishing at $0.33F_{35\%}$ control rule. R1 $B_{35\%}$ = 161.37, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 6.9(6.2,7.6) | 0.8(0.7,1) | 33.6(30.9,36.1) | 0 | 0.04 | 0.6 | 0.4 | 0.5 | 0.4 |
| 2013/14 | 9.1(7.9,10.7) | 1.1(0.5,2.1) | 38.9(35.7,41.9) | 0 | 0.05 | 0.8 | 0.6 | 0.7 | 0.5 |
| 2014/15 | 11.3(9.6,14.2) | 2(0.9,3.9) | 47.5(43.6,51.3) | 0 | 0.07 | 1.4 | 1.0 | 1.3 | 1.0 |
| 2015/16 | 11.3(9.2,14.6) | 2.3(1,4.7) | 49.9(45.5,54.1) | 0 | 0.08 | 1.6 | 1.2 | 1.4 | 1.1 |
| 2016/17 | 10.7(8,16.9) | 2.1(0.9,4.3) | 47.1(41.2,58.6) | 0.001 | 0.07 | 1.5 | 1.1 | 1.2 | 1 |
| 2017/18 | 12.9(7.4,34.8) | 2.3(0.8,8.5) | 51.4(37.6,90.9) | 0.04 | 0.08 | 1.7 | 1.2 | 1.5 | 1.1 |
| 2018/19 | 17.4(7.6,50.5) | 3.8(0.9,14.2) | 63(36.5,140.5) | 0.16 | 0.11 | 2.8 | 1.9 | 2.5 | 1.9 |
| 2019/20 | 21.5(7.7,62.9) | 5.3(1,19.2) | 74.3(37.5,179.7) | 0.29 | 0.13 | 3.9 | 2.7 | 3.4 | 2.6 |
| 2020/21 | 23.7(7.3,68.3) | 6.7(1,22.2) | 81(37.5,202) | 0.37 | 0.14 | 4.8 | 3.4 | 4.2 | 3.3 |
| 2021/22 | 25.9(7.5,70.9) | 7.2(1,24.3) | 85.6(36.8,207) | 0.44 | 0.14 | 5.2 | 3.7 | 4.5 | 3.5 |
| 2022/23 | 28.4(7.7,77.6) | 8.2(1,23.3) | 90.7(37.9,224.2) | 0.51 | 0.15 | 5.9 | 4.1 | 5.2 | 4.0 |
| 2023/24 | 28.9(8.1,82.5) | 8.6(1.1,26) | 93.1(39.2,241.8) | 0.56 | 0.15 | 6.2 | 4.4 | 5.4 | 4.3 |

Table A-5. *Model (0)* fishing at $1.0F_{35\%}$ control rule. R2 $B_{35\%}$ = 90.14, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 12.7(11.1,14.3) | 5.2(4.4,6.1) | 54(50.1,57.6) | 0 | 0.29 | 3.7 | 2.7 | 3.2 | 2.5 |
| 2013/14 | 14.8(11.5,20) | 5.2(3.1,8.5) | 58.5(52.6,63.6) | 0 | 0.31 | 3.9 | 2.6 | 3.7 | 2.7 |
| 2014/15 | 19.1(14.1,26.3) | 7.6(4.3,12.2) | 67.8(58.6,75.7) | 0 | 0.38 | 5.7 | 3.7 | 5.3 | 3.9 |
| 2015/16 | 18.1(13.4,25.5) | 7.8(4.5,12.7) | 67.4(56.1,77.5) | 0 | 0.36 | 5.6 | 3.9 | 5 | 3.9 |
| 2016/17 | 15.9(10.8,24.8) | 6.3(3.4,10.7) | 61.9(49.5,80.9) | 0.01 | 0.33 | 4.6 | 3.2 | 4.1 | 3.1 |
| 2017/18 | 18.5(9.5,47.9) | 6.5(2.8,17.1) | 67.6(47.2,120.3) | 0.12 | 0.37 | 5 | 3.2 | 4.7 | 3.4 |
| 2018/19 | 25.8(10.1,69.7) | 10.4(3.1,28.7) | 80.6(46.9,175.9) | 0.30 | 0.45 | 7.9 | 5.0 | 7.4 | 5.4 |
| 2019/20 | 30.2(10,82.3) | 12.5(3.2,35) | 89.2(47.2,211.2) | 0.43 | 0.49 | 9.4 | 6.2 | 8.9 | 6.5 |
| 2020/21 | 31.4(9.1,82) | 13.7(3,38.4) | 92(45.7,213.9) | 0.49 | 0.49 | 10.4 | 6.7 | 9.7 | 7.2 |
| 2021/22 | 30.8(8.7,82.8) | 12.9(2.8,37.8) | 92.3(43.6,209.5) | 0.54 | 0.48 | 9.7 | 6.3 | 9.1 | 6.7 |
| 2022/23 | 31.8(8.5,80.2) | 13.1(2.7,33.6) | 90.7(43.5,214) | 0.59 | 0.48 | 9.9 | 6.4 | 9.4 | 6.8 |
| 2023/24 | 29.4(8.2,82.9) | 12.3(2.4,37) | 88.9(43.8,215) | 0.62 | 0.47 | 9.3 | 6.0 | 8.7 | 6.4 |

Table A-6. *Model (0)* fishing at F=0 with groundfish bycatch only. R2 $B_{35\%}$ = 90.14, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | East | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 0.1(0.1,0.1) | 0(0,0) | 65.5(60.1,70.7) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 0.2(0.2,0.3) | 0(0,0) | 81.9(75.1,88.4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 0.3(0.3,0.3) | 0(0,0) | 106.7(97.8,115.2) | 0.91 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 0.2(0.2,0.3) | 0(0,0) | 119(109.4,129.2) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 0.3(0.1,0.6) | 0(0,0) | 122.2(108.4,154.6) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 0.4(0.2,1.1) | 0(0,0) | 146.6(107,263.9) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 0.5(0.2,1.4) | 0(0,0) | 188.5(111.8,409.1) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 0.5(0.2,1.4) | 0(0,0) | 224.8(117.1,517.7) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 0.5(0.1,1.3) | 0(0,0) | 245.7(119.8,576.5) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 0.5(0.1,1.3) | 0(0,0) | 264.6(119.3,604.3) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 0.4(0.1,1.3) | 0(0,0) | 286.3(123,637.7) | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 0.4(0.2,1.4) | 0(0,0) | 294(125.7,690) | 1.0 | 0 | 0 | 0 | 0 | 0 |

Table A-7. *Model (0)* fishing at F=0 with bycatch from all fisheries. R2 $B_{35\%}$ = 90.14, $F_{35\%}$=0.61. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB>B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 5.5(5,5.9) | 0(0,0) | 61.5(56.4,66.4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 7.2(6.6,7.8) | 0(0,0) | 72.5(66.5,78.3) | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 8.5(7.8,9.1) | 0(0,0) | 90.7(83.2,97.9) | 0.02 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 8(7.3,8.8) | 0(0,0) | 97.2(89.3,105) | 0.29 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 7.7(6.3,11.5) | 0(0,0) | 93.7(84.2,113.9) | 0.39 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 9.5(6,19.8) | 0(0,0) | 102(77,174.5) | 0.63 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 11.4(6.1,27.5) | 0(0,0) | 122.9(75.6,258.2) | 0.78 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 12.8(5.9,31.7) | 0(0,0) | 144.7(75.9,328.1) | 0.84 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 13.5(5.7,32.2) | 0(0,0) | 155.2(74.8,369.6) | 0.89 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 14.4(5.7,33.6) | 0(0,0) | 166.9(73,381.3) | 0.91 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 14.8(5.7,36.3) | 0(0,0) | 179.5(75.1,412.2) | 0.93 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 15.2(6.2,39.8) | 0(0,0) | 185.8(77.3,445.4) | 0.94 | 0 | 0 | 0 | 0 | 0 |

Table A-8. *Model (1)* fishing at $1.0F_{35\%}$ control rule. R1 $B_{35\%}$ = 157.48, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 9.1(8,10.2) | 2.5(2,3) | 32(29.6,34.3) | 0.00 | 0.13 | 1.8 | 1.3 | 1.5 | 1.2 |
| 2013/14 | 12(9.6,15.6) | 3.1(1.7,5.5) | 36.7(33.5,39.7) | 0.00 | 0.16 | 2.3 | 1.5 | 2.1 | 1.5 |
| 2014/15 | 16(12.2,21.6) | 5.2(2.6,9.1) | 44.3(39.7,48.5) | 0.00 | 0.21 | 3.8 | 2.6 | 3.4 | 2.6 |
| 2015/16 | 15.7(11.8,21.9) | 5.7(2.9,10.2) | 45.3(39.5,50.6) | 0.00 | 0.21 | 4.0 | 2.9 | 3.5 | 2.8 |
| 2016/17 | 14(9.8,21.6) | 4.7(2.3,8.7) | 41.9(34.9,51.9) | 0.00 | 0.19 | 3.3 | 2.4 | 2.9 | 2.3 |
| 2017/18 | 15.9(8.7,43.8) | 4.9(1.9,15.7) | 44.3(32.3,75) | 0.01 | 0.21 | 3.6 | 2.4 | 3.2 | 2.4 |
| 2018/19 | 21.8(8.9,72.5) | 7.6(2,30.5) | 53(31.8,108.7) | 0.07 | 0.26 | 5.6 | 3.8 | 5.1 | 3.8 |
| 2019/20 | 26.8(9.1,89) | 9.9(2.1,38) | 60(32.3,130.2) | 0.13 | 0.31 | 7.2 | 5.0 | 6.5 | 5.0 |
| 2020/21 | 29(8.7,89.8) | 11.5(2.2,41.9) | 63.8(31.9,134.6) | 0.19 | 0.33 | 8.5 | 5.8 | 7.6 | 5.8 |
| 2021/22 | 30.2(8.5,94.9) | 11.7(2.2,43.4) | 65.9(30.9,137.9) | 0.22 | 0.33 | 8.5 | 5.9 | 7.7 | 5.9 |
| 2022/23 | 32.7(8.9,97.7) | 12.7(2.3,40.6) | 67.1(31.5,144) | 0.26 | 0.34 | 9.3 | 6.3 | 8.3 | 6.3 |
| 2023/24 | 32.4(9.2,105.8) | 12.6(2.1,45.9) | 67.8(33.2,154.8) | 0.32 | 0.35 | 9.3 | 6.2 | 8.4 | 6.4 |

Table A-9. *Model (1)* fishing at F=0 with groundfish bycatch only. R1 $B_{35\%}$ = 157.48, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | East | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 0.1(0.1,0.2) | 0(0,0) | 36.4(31.7,41.1) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 0.3(0.2,0.3) | 0(0,0) | 46.5(40.5,52.6) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 0.3(0.3,0.3) | 0(0,0) | 61.8(53.7,69.7) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 0.3(0.2,0.4) | 0(0,0) | 69.7(60.8,78.8) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 0.3(0.2,0.8) | 0(0,0) | 73.1(62.1,96.6) | 0.04 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 0.5(0.2,1.5) | 0(0,0) | 91.4(62.9,177.8) | 0.38 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 0.7(0.2,1.9) | 0(0,0) | 122.1(67.6,284.6) | 0.68 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 0.7(0.2,1.9) | 0(0,0) | 152(73.2,368.6) | 0.79 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 0.6(0.2,1.8) | 0(0,0) | 170.4(76.4,429.6) | 0.86 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 0.6(0.2,1.9) | 0(0,0) | 187.1(77.9,449.1) | 0.90 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 0.7(0.2,2) | 0(0,0) | 208.3(82.4,499.3) | 0.92 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 0.7(0.2,2.3) | 0(0,0) | 222.4(87.9,561.6) | 0.95 | 0 | 0 | 0 | 0 | 0 |

Table A-10. *Model (1)* fishing at F=0 with bycatch from all fisheries. R1 $B_{35\%}$ = 157.48, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB >B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 5.5(4.8,6.2) | 0(0,0) | 34.2(29.7,38.6) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 7.5(6.5,8.4) | 0(0,0) | 41.1(35.8,46.5) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 8.8(7.7,9.9) | 0(0,0) | 52.4(45.6,59.2) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 8.3(7.3,9.5) | 0(0,0) | 56.5(49.3,63.8) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 7.9(6.4,11.8) | 0(0,0) | 54.6(46.9,66.1) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 9.6(6,20) | 0(0,0) | 58.1(43.9,97.5) | 0.04 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 11.8(6.2,28.2) | 0(0,0) | 69.7(42.8,145.8) | 0.21 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 13.4(6.1,34.6) | 0(0,0) | 83.9(43.7,190.4) | 0.36 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 14.6(6,35.3) | 0(0,0) | 92.4(43.6,226.8) | 0.45 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 15.9(6.1,38.1) | 0(0,0) | 102(43.2,235.2) | 0.54 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 17(6.4,42) | 0(0,0) | 112(45.3,263.4) | 0.61 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 17.9(7.1,48.9) | 0(0,0) | 119.8(47.9,290.3) | 0.67 | 0 | 0 | 0 | 0 | 0 |

Table A-11. *Model (1)* fishing at $0.27F_{35\%}$ control rule. R1 $B_{35\%}$ = 157.48, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 6.6(6,7.3) | 0.6(0.5,0.8) | 33.5(30.8,36.1) | 0.00 | 0.03 | 0.4 | 0.3 | 0.4 | 0.3 |
| 2013/14 | 9(7.9,10.4) | 0.9(0.4,1.7) | 39.8(36.6,42.9) | 0.00 | 0.04 | 0.6 | 0.4 | 0.6 | 0.4 |
| 2014/15 | 11.3(9.7,13.7) | 1.7(0.7,3.3) | 49.7(45.6,53.5) | 0.00 | 0.06 | 1.2 | 0.8 | 1.1 | 0.8 |
| 2015/16 | 11.2(9.3,14.2) | 2(0.9,4.1) | 52.6(48.3,57) | 0.00 | 0.06 | 1.4 | 1.1 | 1.2 | 1.0 |
| 2016/17 | 10.6(8,15.8) | 1.8(0.8,3.8) | 49.6(43.8,59.8) | 0.00 | 0.06 | 1.2 | 0.9 | 1.0 | 0.8 |
| 2017/18 | 12.2(7.4,30.1) | 1.9(0.7,6.6) | 52.7(39.8,88.2) | 0.03 | 0.06 | 1.4 | 1.0 | 1.2 | 0.9 |
| 2018/19 | 15.9(7.5,43) | 3(0.7,10.7) | 63.2(38.5,132.7) | 0.15 | 0.08 | 2.2 | 1.5 | 1.9 | 1.5 |
| 2019/20 | 19.4(7.5,53.1) | 4.2(0.8,14.5) | 74.2(39,168.3) | 0.28 | 0.10 | 3.0 | 2.1 | 2.6 | 2.0 |
| 2020/21 | 21.4(7.2,57.4) | 5.3(0.8,16.7) | 81.1(39.2,189.2) | 0.36 | 0.11 | 3.7 | 2.7 | 3.2 | 2.5 |
| 2021/22 | 23.6(7.4,60) | 5.8(0.8,18.3) | 86.3(38.5,199.7) | 0.43 | 0.11 | 4.1 | 3.0 | 3.5 | 2.8 |
| 2022/23 | 26.1(7.7,67.1) | 6.7(0.9,18) | 92.1(40,215.9) | 0.51 | 0.12 | 4.8 | 3.4 | 4.1 | 3.2 |
| 2023/24 | 26.9(8.3,73.6) | 7.2(0.9,20.3) | 96.3(41.6,237.4) | 0.57 | 0.12 | 5.2 | 3.7 | 4.5 | 3.5 |

Table A-12. *Model (1)* fishing at $1.0F_{35\%}$ control rule. R2 $B_{35\%}$ = 97.57, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | West | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 11.7(10.2,13.2) | 4.4(3.7,5.2) | 49.2(45.6,52.6) | 0.00 | 0.25 | 3.2 | 2.3 | 2.7 | 2.1 |
| 2013/14 | 14.4(11.3,19.3) | 4.8(2.9,8) | 54.8(49.5,59.5) | 0.00 | 0.27 | 3.6 | 2.4 | 3.3 | 2.4 |
| 2014/15 | 19.1(14.2,26.2) | 7.4(4.1,12.1) | 64.8(56.4,72.1) | 0.00 | 0.34 | 5.5 | 3.7 | 5.1 | 3.8 |
| 2015/16 | 18.3(13.6,25.5) | 7.8(4.5,12.8) | 65(54.6,74.4) | 0.00 | 0.33 | 5.6 | 3.9 | 4.9 | 3.9 |
| 2016/17 | 15.9(10.9,24.6) | 6.2(3.3,10.6) | 59.4(47.9,75.2) | 0.00 | 0.30 | 4.5 | 3.2 | 3.9 | 3.0 |
| 2017/18 | 18(9.5,46.4) | 6.3(2.8,16.9) | 63.4(45.1,107.4) | 0.07 | 0.33 | 4.7 | 3.1 | 4.4 | 3.2 |
| 2018/19 | 24.5(9.8,65.4) | 9.6(2.9,27.4) | 74.4(44.6,156) | 0.23 | 0.40 | 7.3 | 4.7 | 6.7 | 4.9 |
| 2019/20 | 28.5(9.9,77.4) | 11.6(3,33) | 81.9(44.7,181.4) | 0.36 | 0.44 | 8.7 | 5.7 | 8.0 | 5.9 |
| 2020/21 | 29.6(9.1,78.9) | 12.8(2.9,36.1) | 85.1(43.3,188.5) | 0.43 | 0.45 | 9.4 | 6.3 | 8.7 | 6.5 |
| 2021/22 | 29.6(8.7,80.1) | 12.3(2.7,36.4) | 86.2(41.4,187.5) | 0.47 | 0.44 | 9.2 | 6.1 | 8.4 | 6.3 |
| 2022/23 | 30.9(8.6,78.6) | 12.7(2.7,33.5) | 85.8(41.8,192.5) | 0.53 | 0.44 | 9.5 | 6.3 | 8.7 | 6.5 |
| 2023/24 | 29.6(8.5,82.5) | 12.3(2.4,37.7) | 85(42.4,198) | 0.58 | 0.44 | 9.1 | 6.0 | 8.5 | 6.3 |

Table A-13. *Model (1)* fishing at F=0 with groundfish bycatch only. R2 $B_{35\%}$ = 97.57, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | $\%MMB/B_{35\%}$ | $P[MMB > B_{35\%}]$ | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | East | | East | |
| | (1000 t) | | | | | Total | Retain | Total | Retain |
| 2012/13 | 0.1(0.1,0.2) | 0(0,0) | 58.7(53.9,63.4) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 0.3(0.2,0.3) | 0(0,0) | 75.1(68.9,81) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 0.3(0.3,0.3) | 0(0,0) | 99.6(91.3,107.5) | 0.47 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 0.3(0.2,0.4) | 0(0,0) | 111.9(102.9,121.2) | 0.98 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 0.3(0.2,0.6) | 0(0,0) | 115(102.2,144.1) | 0.99 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 0.4(0.2,1.1) | 0(0,0) | 137.1(100.8,243.2) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 0.5(0.2,1.4) | 0(0,0) | 174.8(105.1,373.6) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 0.5(0.2,1.4) | 0(0,0) | 208.4(109.6,465) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 0.5(0.2,1.3) | 0(0,0) | 228.2(112.6,522.6) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 0.5(0.2,1.4) | 0(0,0) | 246.4(111.9,549.9) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 0.5(0.2,1.4) | 0(0,0) | 267.8(116.2,592.7) | 1.00 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 0.5(0.2,1.6) | 0(0,0) | 278.4(120,656.3) | 1.00 | 0 | 0 | 0 | 0 | 0 |

Table A-14. *Model (1)* fishing at F=0 with bycatch from all fisheries. R2 $B_{35\%}$ = 97.57, $F_{35\%}$=0.59. Median total catch ($ABC_{TOT}$ 1000 t), median retained catch ($C_{DIR}$ 1000 t), percent mature male biomass at mating relative to $B_{35\%}$, probability of rebuilding in 1 year. Values in parentheses are 90% CI. F is the full selection fishing mortality.

| Year | $ABC_{TOT}$ | $C_{DIR}$ | %MMB/$B_{35\%}$ | P[MMB >$B_{35\%}$] | Full-Select F | Directed Fishery Catch (1000 t) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1000 t) | | | | | East | | West | |
| | | | | | | Total | Retain | Total | Retain |
| 2012/13 | 5.5(5.1,6) | 0(0,0) | 55.1(50.5,59.5) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2013/14 | 7.5(6.8,8.1) | 0(0,0) | 66.4(60.9,71.6) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2014/15 | 8.8(8.1,9.5) | 0(0,0) | 84.5(77.5,91.2) | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 2015/16 | 8.3(7.6,9.1) | 0(0,0) | 91.3(83.8,98.5) | 0.03 | 0 | 0 | 0 | 0 | 0 |
| 2016/17 | 7.9(6.5,11.6) | 0(0,0) | 87.8(78.9,104.8) | 0.11 | 0 | 0 | 0 | 0 | 0 |
| 2017/18 | 9.6(6.1,19.3) | 0(0,0) | 93.9(71.9,154.5) | 0.40 | 0 | 0 | 0 | 0 | 0 |
| 2018/19 | 11.4(6.2,26.4) | 0(0,0) | 110.7(70.1,225.3) | 0.62 | 0 | 0 | 0 | 0 | 0 |
| 2019/20 | 12.7(6,30.7) | 0(0,0) | 130.8(70.4,285.3) | 0.74 | 0 | 0 | 0 | 0 | 0 |
| 2020/21 | 13.5(5.8,31) | 0(0,0) | 140.5(69.2,325.9) | 0.79 | 0 | 0 | 0 | 0 | 0 |
| 2021/22 | 14.4(5.8,33.1) | 0(0,0) | 152(67.3,336.5) | 0.84 | 0 | 0 | 0 | 0 | 0 |
| 2022/23 | 14.9(6,35.4) | 0(0,0) | 162.9(69.6,367.4) | 0.87 | 0 | 0 | 0 | 0 | 0 |
| 2023/24 | 15.5(6.5,40.4) | 0(0,0) | 170.4(72.3,395.3) | 0.90 | 0 | 0 | 0 | 0 | 0 |

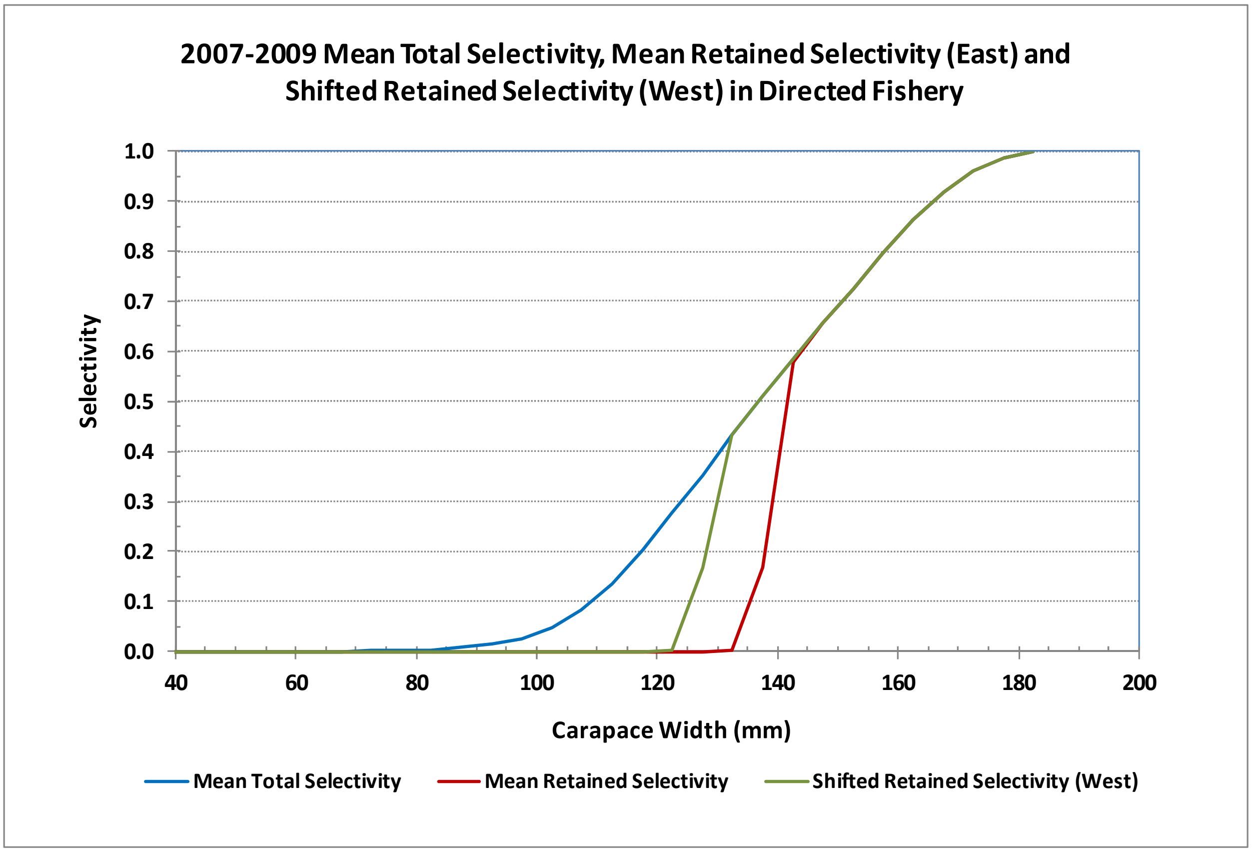



Figure A-1. Mean total and retained directed fishery selectivity curves, and the shifted (10 mm) retained selectivity curve for the area west of 166$^0$ W longitude for 2007 to 2009. Mean total selectivity used for both areas east and west of 1660 W longitude. The mean retained selectivity is used for the area east of 166$^0$ W longitude. East area industry imposed minimum size limit ≥138mm, west area industry imposed minimum size limit ≥128 mm.

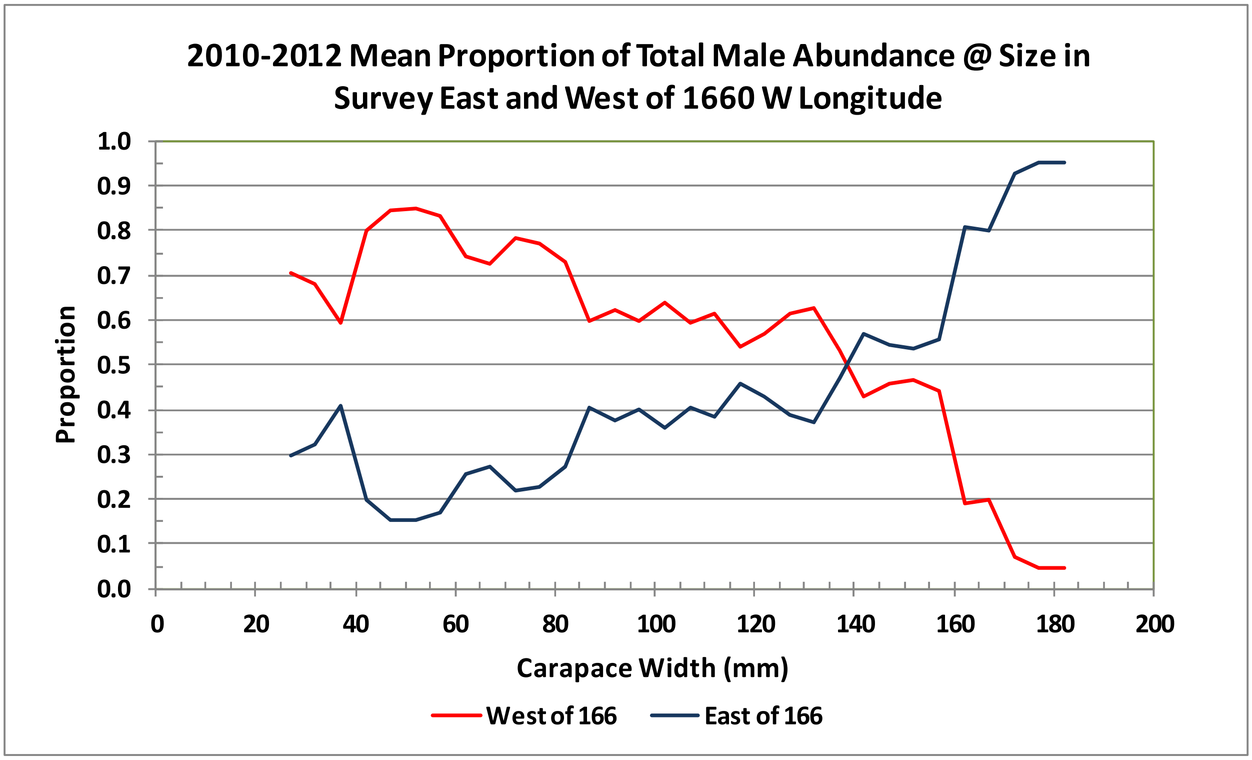



Figure A-2. Mean proportion of male abundance observed in the 2010 -2012 NMFS bottom trawl survey east and west of $166^0$ W longitude by carapace width (mm).

## Appendix B. Historical Snow Crab and Bristol Bay Red King Crab Fishery Effort Data

| Season | Total Pot Lifts x Fishery | |
|---|---|---|
| | Bristol Bay RKC | Snow Crab |
| 1966/67 | 2,720 | |
| 1967/68 | 10,621 | |
| 1968/69 | 47,496 | |
| 1969/70 | 98,426 | |
| 1970/71 | 96,658 | |
| 1971/72 | 118,522 | |
| 1972/73 | 205,045 | |
| 1973/74 | 194,095 | |
| 1974/75 | 212,915 | |
| 1975/76 | 205,096 | |
| 1976/77 | 321,010 | |
| 1977/78 | 451,273 | |
| 1978/79 | 406,165 | 190,746 |
| 1979/80 | 315,226 | 255,102 |
| 1980/81 | 567,292 | 435,742 |
| 1981/82 | 536,646 | 469,091 |
| 1982/83 | 140,492 | 287,127 |
| 1983/84 | 0 | 173,591 |
| 1984/85 | 107,406 | 370,082 |
| 1985/86 | 84,443 | 542,346 |
| 1986/87 | 175,753 | 616,113 |
| 1987/88 | 220,971 | 747,395 |
| 1988/89 | 146,179 | 665,242 |
| 1989/90 | 205,528 | 912,718 |
| 1990/91 | 262,761 | 1,394,897 |
| 1991/92 | 227,555 | 1,281,796 |
| 1992/93 | 206,815 | 972,118 |
| 1993/94 | 254,389 | 716,524 |
| 1994/95 | 697 | 507,603 |
| 1995/96 | 547 | 520,685 |
| 1996/97 | 77,081 | 754,140 |
| 1997/98 | 91,085 | 930,794 |
| 1998/99 | 145,689 | 945,533 |
| 1999/00 | 151,212 | 182,634 |
| 2000/01 | 104,056 | 191,200 |
| 2001/02 | 66,947 | 326,977 |
| 2002/03 | 72,514 | 153,862 |
| 2003/04 | 134,515 | 123,709 |
| 2004/05 | 97,621 | 75,095 |
| 2005/06 | 116,324 | 120,582 |
| 2006/07 | 72,807 | 89,419 |
| 2007/08 | 113,943 | 144,039 |
| 2008/09 | 140,055 | 163,536 |
| 2009/10 | 118,521 | 137,018 |
| 2010/11 | 132,183 | 147,244 |
| 2011/12 | 45,166 | 270,602 |

# A Regression Approach for Assessing if There is a Breakpoint in the Relationship between log(R/MMB) and MMB

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**Executive Summary**
The data on recruitment (*R*) and mature male biomass at the time of mating (*MMB*) for Eastern Bering Sea Tanner crab are analysed using linear models which account for measurement error and autocorrelation in process error to assess whether there is support in the data for a change over time in the relationship between $\log(R/MMB)$ and *MMB*. The data support a change in the relationship in 1985 (year of spawning; corresponding to 1990 in terms of recruitment to the assessment model).

**Background**
Application of the Tier 3 and 4 OFL control rules relies on being able to specify a set of years to define the recruitment corresponding to MSY (Tier 3) or the mature male biomass corresponding to MSY (Tier 4). Several considerations are taken into account by the CPT and SSC when selecting the set of years for a stock. One of these considerations is whether the years selected reflect current environmental conditions. The CPT has recommended that analyses be conducted to assess whether changes in productivity have occurred rather than using a set of years in which physical conditions (which may not have actually impacted productivity) changed. Several types of analyses have been undertaken to address this requirement, including examining the time-series of recruitment and recruits-per-spawner. An additional way to explore whether productivity has changed is to the examine whether there has been a change in the relationship between recruits-per-spawner and the mass of spawners, which allows the question of whether the recruits-per-spawner in the limit of zero population size has changed as well as whether the impact of density on pre-recruit survival has changed. This note explains how such an analysis has been conducted for EBS Tanner crab.

**Methods**
*Model structure*
Conceptually the relationship $\log(R/MMB) = \alpha + \beta MMB$ where *R* is recruitment, *MMB* is mature male biomass at mating time (nominally 15 February), α is slope of the relationship at the origin, and β is a measure of the extent of density dependence, is a representation of a Ricker stock-recruitment relationship. This analysis involved fitting models of the form $\log(R/MMB) = \alpha + \beta MMB$ where α and β change at some point in time (year *b*; i.e. the values for α and β are constant from 1961 to year *b*-1 and from *b* onwards), and to assess the evidence for a change, and if there is a change when it occurred. The fitting criteria cannot be simple linear regression because the estimates of $\log(R/MMB)$ arise from a stock assessment model so are measured with errors which are not temporally independent with homogeneous variance (in particular the variances are highest for the earliest years of the time-series for EBS Tanner crab)[1]. In addition, the analysis accounts for the possibility of temporal autocorrelation in process error.

[1] This analysis does not account for other [well known] problems with fitting stock-recruitment relationships such as the time-series bias and the fact that the independent variable is itself not measured without error.

Denoting $\log(R/MMB)$ as $y$ and $MMB$ as $x$ and accounting for the fact that $y$ is measured with error and that the errors about the relationship are themselves correlated, leads to the following negative log-likelihood function:

$$-\ell nL = 0.5\ell n\left|\mathbf{\Omega}\right| + 0.5\sum_i \sum_j (y_i - \hat{y}_i)[\mathbf{\Omega}^{-1}]_{i,j}(y_j - \hat{y}_j) \tag{1}$$

where $\hat{y}_i$ is the model-estimate for data point $i$:

$$\hat{y}_i = \begin{cases} \alpha_1 + \beta_1 x_i & \text{if } i < b \\ \alpha_2 + \beta_2 x_i & \text{otherwise} \end{cases} \tag{2}$$

$\mathbf{\Omega}$ accounts for observation and process error, i.e.:

$$\mathbf{\Omega} = \mathbf{V} + \mathbf{P} \tag{3}$$

**V** is the variance-covariance matrix for $y$ based on measurement error (i.e., from the stock assessment) and **P** is the process error matrix ($\sigma^2$ on the diagonal and $\sigma^2\rho^{|i-j|}$ on the off-diagonal entries). A similar approach was applied by Dichmont *et al*. (2003) to fit a stock-recruitment relationship to data for prawn species in Australia's northern prawn fishery.

All analyses were conducted using R.

*Data*

Estimates of $\log(R/MMB)$ and MMB from the EBS Tanner crab stock assessment (and the variance covariance matrix for $\log(R/MMB)$) for spawning years 1961-2007[2] were obtained from the stock assessment authors. Table 1 lists the data points. The variance-covariance matrix for the estimates of $\log(R/MMB)$ is available from the author.

*Analysis procedure*

Model 1 was fitted to the data for values for $b$ from 1965-2001, and $AIC_C$ (AIC corrected for small samples) applied to identify a best model. A model in which $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2$ was also fitted to assess the evidence in support of any model in which allowance is made for a change in productivity.

**Results**

Figure 1 shows the fits of model 1 for values for $b$ from 1961 to 2001. The solid dots denote the data for the years 1961 to $b$-1 while the open circles indicate the data for year $b$ onwards. Figure 2 shows the $AIC_C$ values as a function of $b$. The lowest values for $AIC_C$ occur for values of $b$ of 1973 and 1985 (corresponding to the years 1978 and 1990 in terms of the year of recruitment to the model). Of these two years, a change in 1985 has the lower $AIC_C$. Table 2 lists the estimates (and asymptotic standard errors) for the parameters of the model with a breakpoint in 1985.

$AIC_C$ supports the best change point models (the horizontal line in Figure 2 denotes the $AIC_C$ for the no change point model). Note that given the small number of data points (47) relative to the number of estimated parameters, the use of $AIC_C$ is critical here.

Figure 3 shows the fit of the no change point model, the model with a change point in 1985 (i.e. that with the most recent change point; also that with the lowest $AIC_C$), and the implied Ricker stock-recruitment relationship. Figure 3d illustrates the relationship between recruitment and MMB as a stacked plot. This plot shows several periods (in particular during

[2] Corresponding to the years 1966-2012 in terms of recruitment to the model given the assumption of a 5-year lag between spawning to entering the first size-class in the model).

the late 1980s and early 1990s) when MMB increased but recruitment did not, while the opposite effect is evident for the rest of the 1990s.

**Future work**

The analyses of this document implement some of the suggestions of the CPT and SSC regarding exploring the evidence for a change in productivity. Several avenues exist for future work. These include:

- Checking that models with more than two change points are not supported by the data.
- Testing the inference procedure using simulations.
- Exploring whether a change point model can be selected if the production function is not Ricker (e.g. Beverton-Holt or depensatory).
- Evaluate models in which only the slope of the relationship changes over time (the slopes even for the best model are not significantly different; Table 2). The estimates in Table 2 suggest that a model with $\alpha_1 = \alpha_2$ will be supported over a model with $\alpha_1 \neq \alpha_2$[3].

**Reference**

Dichmont, C.M., Punt, A.E., Deng, A., Dell, Q. and W. Venables. 2003. Application of a weekly delay-difference model to commercial catch and effort data for tiger prawns in Australia's Northern Prawn Fishery. *Fisheries Research* 65: 335-350.

**Acknowledgment**

Jack Turnock and Lou Rugulo are thanked for the providing the data and the specifications for the replacement line.

[3] Results for such a model are not presented here as they were not provided to the CPT.

Table 1. The data on which the analyses are based. Recruits are recruits to the stock assessment model and not to the population or the fishery.

| Year | MMB ('000t) | Recruits (in year y+5) | Log(R/MMB) | Year | MMB ('000t) | Recruits (in year y+5) | Log(R/MMB) |
|---|---|---|---|---|---|---|---|
| 1961 | 78.61 | 770284 | 9.1900 | 1985 | 21.52 | 47418 | 7.6977 |
| 1962 | 83.63 | 664408 | 8.9803 | 1986 | 26.91 | 23786 | 6.7844 |
| 1963 | 90.17 | 602120 | 8.8065 | 1987 | 40.52 | 18754 | 6.1373 |
| 1964 | 100.00 | 560416 | 8.6313 | 1988 | 59.82 | 15497 | 5.5570 |
| 1965 | 117.65 | 427603 | 8.1983 | 1989 | 71.57 | 15210 | 5.3590 |
| 1966 | 152.52 | 291329 | 7.5549 | 1990 | 67.73 | 21550 | 5.7626 |
| 1967 | 199.01 | 289581 | 7.2829 | 1991 | 61.85 | 24172 | 5.9682 |
| 1968 | 263.34 | 182979 | 6.5437 | 1992 | 48.34 | 62209 | 7.1600 |
| 1969 | 312.85 | 82263 | 5.5720 | 1993 | 39.46 | 26331 | 6.5032 |
| 1970 | 343.84 | 170911 | 6.2087 | 1994 | 32.00 | 81779 | 7.8460 |
| 1971 | 357.40 | 392900 | 7.0025 | 1995 | 23.95 | 47373 | 7.5897 |
| 1972 | 359.32 | 272235 | 6.6302 | 1996 | 19.50 | 148007 | 8.9349 |
| 1973 | 350.15 | 251577 | 6.5772 | 1997 | 16.70 | 56599 | 8.1286 |
| 1974 | 317.24 | 67387.5 | 5.3586 | 1998 | 14.75 | 100791 | 8.8299 |
| 1975 | 275.01 | 13530.8 | 3.8959 | 1999 | 14.55 | 198115 | 9.5191 |
| 1976 | 212.46 | 53484.4 | 5.5284 | 2000 | 16.22 | 57634 | 8.1755 |
| 1977 | 141.90 | 20990.1 | 4.9967 | 2001 | 19.86 | 47146 | 7.7722 |
| 1978 | 96.08 | 204827 | 7.6647 | 2002 | 23.88 | 36384 | 7.3289 |
| 1979 | 62.39 | 172653 | 7.9256 | 2003 | 29.20 | 40302 | 7.2299 |
| 1980 | 47.16 | 361450 | 8.9443 | 2004 | 36.50 | 194213 | 8.5793 |
| 1981 | 50.71 | 287010 | 8.6411 | 2005 | 45.40 | 246705 | 8.6005 |
| 1982 | 49.86 | 277721 | 8.6252 | 2006 | 51.43 | 131287 | 7.8449 |
| 1983 | 39.56 | 200085 | 8.5286 | 2007 | 56.65 | 32391 | 6.3487 |
| 1984 | 23.53 | 111485 | 8.4634 | | | | |

Table 2. Estimates (and asymptotic standard errors) for the parameters of the model with a breakpoint in 1985.

| Parameter | Estimate (SE) |
|---|---|
| $\alpha_1$ | 9.0445 (0.4960) |
| $\alpha_2$ | 9.0384 (0.6012) |
| $\beta_1$ | 0.00937 (0.00242) |
| $\beta_2$ | 0.04524 (0.01422) |
| $\ell n \sigma$ | -0.4122 (0.3203) |
| $\tan \rho$ | 1.3429 (0.5979) |

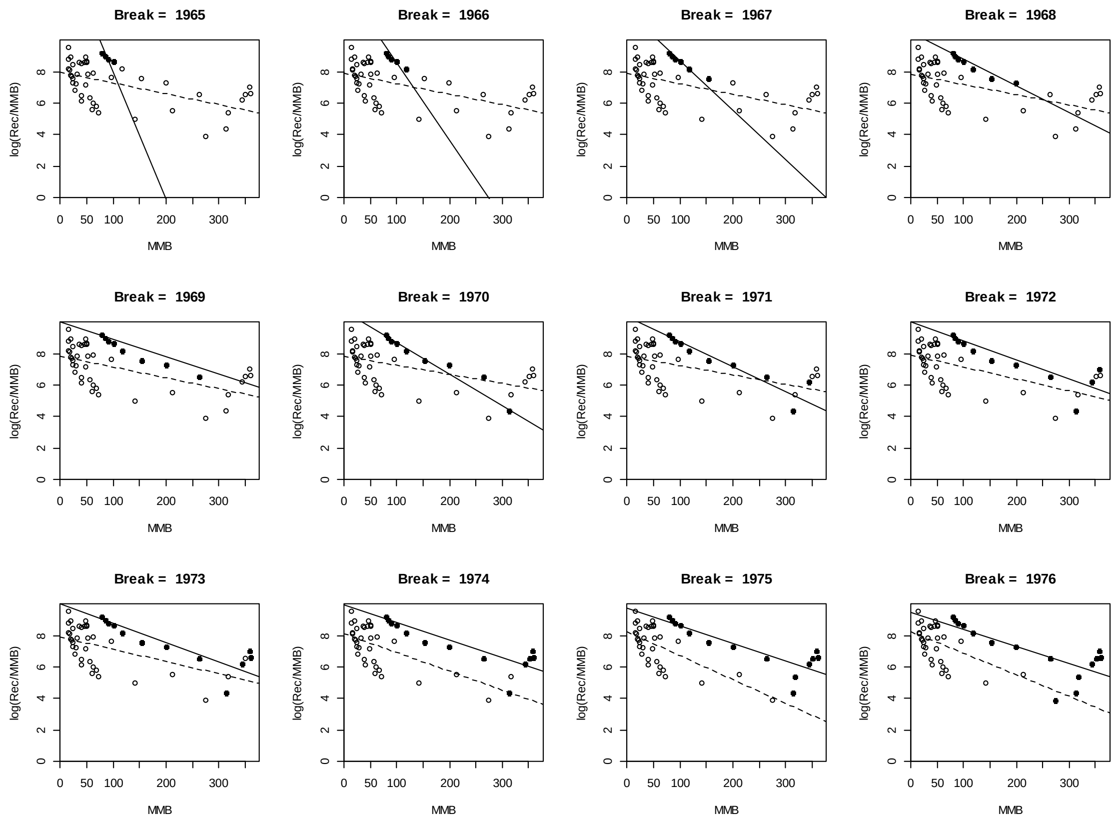


Figure 1. $\log(R / MMB)$ versus MMB for EBS Tanner crab. The solid dots indicate the data for the years prior to the breakpoint and the open circles the data for the years from the breakpoint onwards. The solid line is the fit to the solid dots and the dotted line that to the open circles.

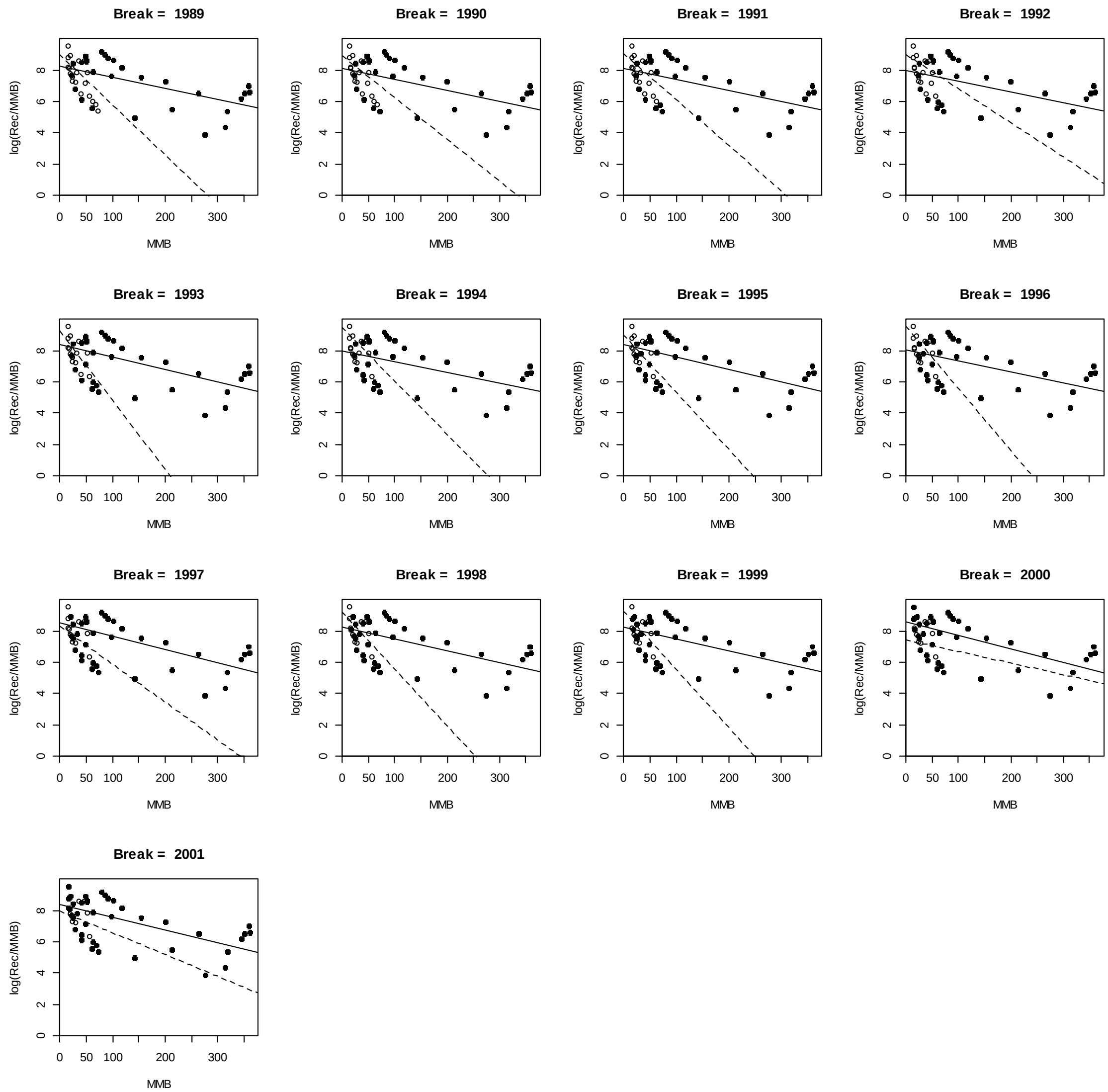


Figure 1 Continued

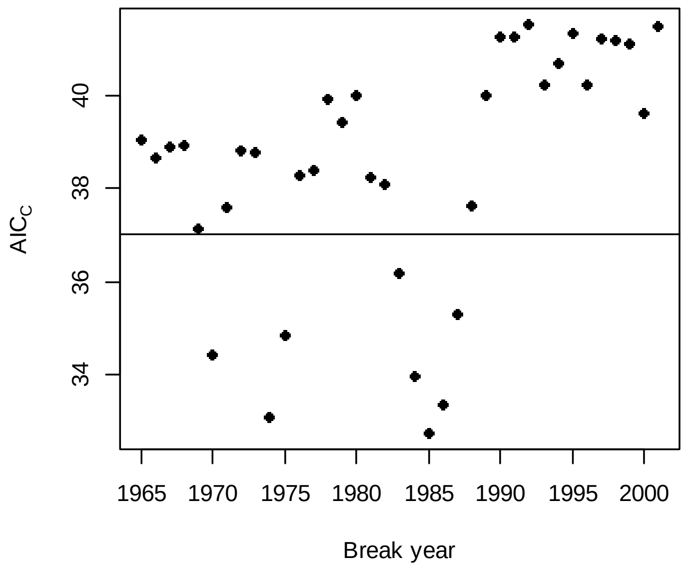


Figure 2. $AIC_C$ versus the year in which there is an assumed breakpoint in the $\log(R / MMB)$ versus MMB relationship. The horizontal line denotes the $AIC_C$ for the model with no breakpoints.

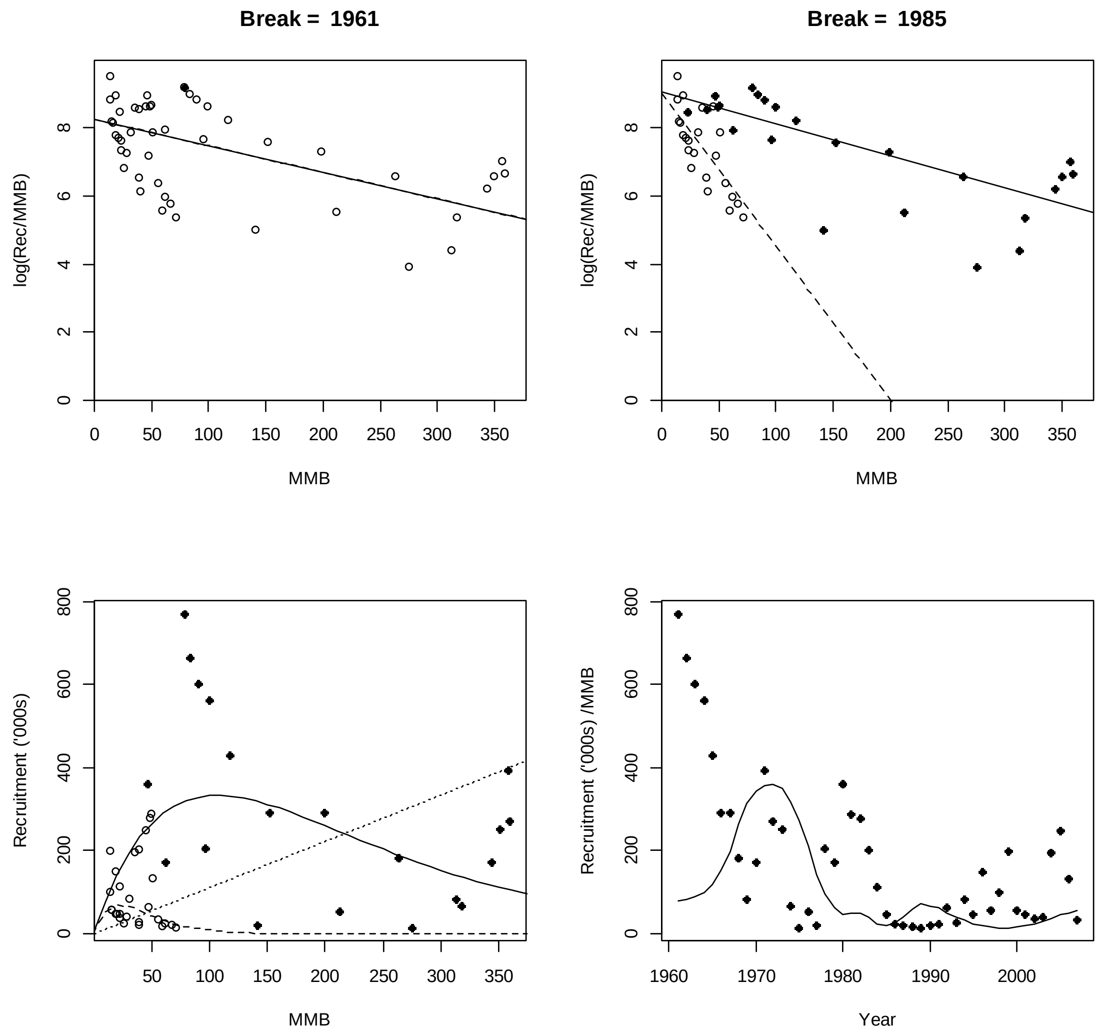


Figure 3. Fits of the models with no breakpoint and a breakpoint in 1985 (upper panels), and the fits of the breakpoint model in the form of a stock-recruitment relationship (lower left panel). The diagonal line in the lower left panel is the replacement line (i.e. the intersections between the stock-recruitment relationships and this line are the unfished equilibrium points). The lower right panel shows the model estimates of recruitment and MMB.

2012 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Red King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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**Executive Summary**

1. Stock: Pribilof Islands red king crab, *Paralithodes camtschaticus*
2. Catches: Retained catches have not occurred since 1998/1999. Bycatch and discards have been steady or decreased in recent years to current levels with no bycatch.
3. Stock biomass: Stock adult biomass in recent years decreased from 2007 to 2009 and increased in in 2010, 2011, and 2012.
4. Recruitment: Recruitment indices are not well understood for Pribilof red king crab. Pre-recruits may not be well assessed with the survey but increased between 2005 and 2007 and decreased each year since 2009.
5. Management performance:

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009/10 | 1,914 (4.22) | 2,175[A] (4.46) | 0 | 0 | 2.7 (0.006) | 227 (0.50) | |
| 2010/11 | 2,255 (4.97) | 2,754[B] (5.44) | 0 | 0 | 4.2 (0.009) | 349 (0.77) | |
| 2011/12 | 2,571 (5.67) | 2,775[C*] (5.68) | 0 | 0 | 5.4 (0.011) | 393 (0.87) | 307 (0.68) |
| 2012/13 | | 3,302[D**] (7.28) | | | | 569 (1.25) | 455 (1.00) |

All units are in t (million lbs) of crabs and the OFL is a total catch OFL for each year. The stock was above MSST in 2011/2012 and is hence not overfished. Overfishing did not occur during the 2011/2012 fishing year.

Notes:
A – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
B – Based on survey data available to the Crab Plan Team in September 20010 and updated with 2010/2011 catches
C – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/2012 catches
D – Based on survey data available to the Crab Plan Team in September 2012
* – 2011/12 estimates based on 3 year running average
** – 2012/13 estimates based on weighted 3 year running average

6. Basis for 2012/2013 OFL projection:

| Year | Tier | $B_{MSY}$ t ($10^6$ lbs) | Current $MMB_{mating}$ t ($10^6$ lbs) | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality $yr^{-1}$ | P* |
|---|---|---|---|---|---|---|---|---|
| 2012/13 | 4b | 5,136 (11.32) | 3,302 (7.33) | 0.64 | 1.0 | 1991/1992-2011/2012 | 0.18 | 0.49 |

7. The OFL distribution which quantifies uncertainty was constructed using bootstrapping methods approximating the lognormal distribution. Within assessment uncertainty was included based on the 2012 survey mature male biomass CV of 0.57.

8. The ABC recommendation incorporated a $\sigma_b$ of 0.4 to account for additional uncertainty, thus reducing the ABC from an $ABC_{max}$ of 501 t (1.10 million lbs) to 455 t (1.00 million lbs).

9. Rebuilding analyses results summary: not applicable.

**Summary of Major Changes:**

1. Management: There were no major changes to the 2011/2012 management of the fishery.
2. Input data: The crab fishery retained and discard catch time series were updated with 2011/2012 data.
3. Assessment methodology: MMB was estimated with an average centered on the current year and weighted by the inverse variance.
4. Assessment results: The projected MMB increased and the OFL increased in this assessment. Total catch mortality in 2011/2012 was 5.4 t.

**Responses to SSC and CPT Comments**

<u>SSC comments October 2011:</u>

General remarks pertinent to this assessment

*none*

Specific remarks pertinent to this assessment

*The fishery for red king crab in the Pribilof Islands district has been closed since 1999 due to concerns of low abundance, imprecision of biomass estimates, and pot bycatch of sympatric blue king crab, which are classified as overfished. Fishing mortality since the closure of the directed fishery has been limited to incidental catches in other crab fisheries and in groundfish fisheries. The SSC supports the CPT recommendation to continue using the same base years as used previously (1991 to the current year) for determination of BMSY for the Pribilof Islands red king crab stock. The SSC also supports a Tier 4b designation for this stock, noting that the estimate of mature male biomass (2.577 t) is below BMSY (5,143 t) and only slightly above MSST (2,572 t).*

*The SSC agrees with the CPT recommendation to include additional uncertainty (σb = 0.4) when calculating the ABC using the P* approach, which results in a multiplier of 0.78 times the estimated OFL (393 t). The resulting ABC is 307 t. The SSC's support for this approach is based in large part on the recognition that the brief history of exploitation of this stock makes it difficult to identify an appropriate period of time suitable for establishing BMSY, such that the true distribution of the OFL is poorly known. The SSC recognizes that the appropriate value for σb is uncertain, and we accept the plan teams' choice given their expertise and their prior discussions on this issue.*

*Estimates of mature male biomass (MMB) were calculated in the assessment as a three-year moving average using the target year's value averaged with the prior 2 years. The SSC agrees with the assessment author and the plan team that a more appropriate calculation would center the average on the target year and encourage consideration of other methods, including weighted averages, in subsequent assessments. The SSC continues to look forward to the implementation of a catch-survey analysis for this stock.*

Responses to SSC Comments: Methodology for an average biomass centered on the current year and additional weighting methods were considered. CSA model development is on hold.

<u>SSC comments June 2012:</u>

General remarks pertinent to this assessment *none*

Specific remarks pertinent to this assessment
*none*

CPT comments September 2011:
General remarks pertinent to this assessment
*none*

Specific remarks pertinent to this assessment
*The team recommended maintaining the status quo time period of 1991-2011 in the calculation of* $B_{MSYProxy}$. *It was suggested that the 3-yr average be used in estimating MMB at mating in any year t, but that the actual observed MMBs in each year over the reference period should be used to calculate the BMSY Proxy. The team recommended that the 3-yr average should be calculated based on the current year, the previous year and the following year, not the current year plus the preceding two years. These calculations will be corrected for the next assessment. The team also discussed alternative methods for deriving a 3-yr average index of MMB – e.g., an average weighted by the inverse of the coefficients of variation of each annual MMB, a lowess smoothed index, and a weighted index in which the weights reflected the relative importance of the years in the average.*

Responses to CPT Comments: A 3 year average centered on the current year and weighted by the inverse variance was used to calculate the MMB while unaveraged survey data was used to calculate $B_{\mathrm{MSY}}^{\mathrm{proxy}}$.

CPT comments May 2012:
General remarks pertinent to this assessment
*none*

Specific remarks pertinent to this assessment
*none*

**Introduction**

1. **Red king crabs, *Paralithodes camtschaticus*** (Tilesius, 1815)

2. **Distribution -** Red king crabs are anomurans in the family lithodidae and are distributed from the Bering Sea south to the Queen Charlotte Islands and to Japan in the western Pacific (Jensen 1995; Figure 1). Red king crabs have also been introduced and become established in the Barents Sea (Jørstad et al. 2002). The Pribilof Islands red king crab stock is located in the Pribilof District of the Bering Sea Management Area Q. The Pribilof District is defined as Bering Sea waters south of the latitude of Cape Newenham (58° 39’ N lat.), west of 168° W long., east of the United States – Russian convention line of 1867 as amended in 1991, north of 54° 36’ N lat. between 168° 00’ N and 171° 00’ W long and north of 55° 30’N lat. between 171° 00’ W. long and the U.S.-Russian boundary (Figure 2).

3. **Stock structure** – The information on stock structure of red king crabs in the North Pacific comes from two projects. One is based on 1,800 microsatellite DNA samples from red king crabs originating from the Sea of Okhotsk to Southeast Alaska (Seeb and Smith 2005). In the Bering Sea Aleutian Island region, samples from Bristol Bay, Port Moller, and the Pribilof Islands were divergent from the Aleutian Islands and Norton Sound. A more recent study describes the genetic

distinction of Southeast Alaska red king crab compared to Kodiak and the Bering Sea; the latter two being similar (Grant and Cheng 2012).

4. **Life History** - Red king crabs reproduce annually and mating occurs between hard-shelled males and soft-shelled females. Unlike brachyurans, red king crabs do not have spermathecae and cannot store sperm, therefore a female must mate every year to produce a fertilized clutch of eggs (Powell and Nickerson 1965). A pre-mating embrace is formed 3-7 days prior to female ecdysis, the female molts and copulation occurs within hours. During copulation, the male inverts the female so they are abdomen to abdomen and then the male extends his fifth pair of periopods to deposit sperm on the female's gonopores. After copulation, eggs are fertilized as they are extruded through the gonopores located at the ventral surface of the coxopides of the third periopods. The eggs form a spongelike mass, adhering to the setae on the pleopods where they are brooded until hatching (Powell and Nickerson 1965). Fecundity estimates are not available for Pribilof Islands red king crab, but range from 42,736 to 497,306 for Bristol Bay red king crab (Otto et al. 1990). The estimated size at 50 percent maturity of female Pribilof Islands red king crabs is approximately 102 mm carapace length (CL) which is larger than 89 mm CL reported for Bristol Bay and 71 mm CL for Norton Sound (Otto et al. 1990). Size at maturity has not been determined specifically for Pribilof Islands red king crab males, however, approximately 103 mm CL is reported for eastern Bering Sea male red king crabs (Somerton 1980). Early studies predicted that red king crab become mature at approximately age 5 (Powell 1967; Weber 1967); however, Stevens (1990) predicted mean age at recruitment in Bristol Bay to be 7 to 12 years, and Loher et al. (2001) predicted age to recruitment to be approximately 8 to 9 years after settlement. Based upon a long-term laboratory study, longevity of red king crab males is approximately 21 years and less for females (Matsuura and Takeshita 1990).

   Natural mortality of Bering Sea red king crab stocks is poorly known (Bell 2006) and estimates vary. Siddeek et al. (2002) reviewed natural mortality estimates from various sources. Natural mortality estimates based upon historical tag-recapture data range from 0.001 to 0.93 for crabs 80-169 mm CL with natural mortality increasing with size. Natural mortality estimates based on more recent tag-recovery data for Bristol Bay red king crab males range from 0.54 to 0.70, however, the authors noted that these estimates appear high considering the longevity of red king crab. Natural mortality estimates based on trawl survey data vary from 0.08 to 1.21 for the size range 85-169 mm CL, with higher mortality for crabs <125 mm CL. In an earlier analysis that utilized the same data sets, Zheng et al. (1995) concluded that natural mortality is dome shaped over length and varies over time. Natural mortality was set at 0.2 for Bering Sea king crab stocks (NPFMC 1998) and was changed to 0.18 with Amendment 24.

   The reproductive cycle of Pribilof Islands red king crabs has not been established, however, in Bristol Bay, timing of molting and mating of red king crabs is variable and occurs from the end of January through the end of June (Otto et al. 1990). Primiparous Bristol Bay red king crab females (brooding their first egg clutch) extrude eggs on average 2 months earlier in the reproductive season and brood eggs longer than multiparous (brooding their second or subsequent egg clutch) females (Stevens and Swiney 2007a, Otto et al. 1990) resulting in incubation periods that are approximately eleven to twelve months in duration (Stevens and Swiney 2007a, Shirley et al. 1990). Larval hatching among red king crabs is relatively synchronous among stocks and in Bristol Bay occurs March through June with peak hatching in May and June (Otto et al. 1990), however larvae of primiparous females hatch earlier than multiparous females (Stevens and Swiney 2007b, Shirley and Shirley 1989). As larvae, red king crabs exhibit four zoeal stages and a glaucothoe stage (Marukawa 1933).

Growth parameters have not been examined for Pribilof Islands red king crabs; however they have been studied for eastern Bering Sea red king crab. A review by the Center for Independent Experts (CIE) reported that growth parameters are poorly known for all red king crab stocks (Bell 2006). Growth increments of immature southeastern Bering Sea red king crabs are approximately: 23% at 10 mm CL, 27% at 50 mm CL, 20% at 80 mm CL and 16 mm for immature crabs over 69 mm CL (Weber 1967). Growth of males and females is similar up to approximately 85 mm CL, thereafter females grow more slowly than males (Weber 1967; Loher et al. 2001). In a laboratory study, growth of female red king crabs was reported to vary with age; during their pubertal molt (molt to maturity) females grew on average 18.2%, whereas primiparous females grew 6.3% and multiparous females grew 3.8% (Stevens and Swiney, 2007a). Similarly, based upon tag-recapture data from 1955-1965 researchers observed that adult female growth per molt decreases with increased size (Weber 1974). Adult male growth increment averages 17.5 mm irrespective of size (Weber 1974).

Molting frequency has been studied for Alaskan red king crabs, but Pribilof Islands specific studies have not been conducted. Powell (1967) reports that the time interval between molts increases from a minimum of approximately three weeks for young juveniles to a maximum of four years for adult males. Molt frequency for juvenile males and females is similar and once mature, females molt annually and males molt annually for a few years and then biennially, triennially and quadrennial (Powell 1967). The periodicity of mature male molting is not well understood and males may not molt synchronously like females who molt prior to mating (Stevens 1990).

5. **Management history** - Red king crab stocks in the Bering Sea and Aleutian Islands are managed by the Sate of Alaska through the federal Fishery Management Plan (FMP) for Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 1998). The Alaska Department of Fish and Game (ADF&G) has not published harvest regulations for the Pribilof district red king crab fishery. The king crab fishery in the Pribilof District began in 1973 with blue king crabs *Paralithodes platypus* being targeted (Figure 3). A red king crab fishery in the Pribilof District opened for the first time in September 1993. Beginning in 1995, combined red and blue king crab GHLs were established. Declines in red and blue king crab abundance from 1996 through 1998 resulted in poor fishery performance during those seasons with annual harvests below the fishery GHL. The North Pacific Fishery Management Council (NPFMC) established the Bering Sea Community Development Quota (CDQ) for Bering Sea fisheries including the Pribilof red and blue king crab fisheries which was implemented in 1998. From 1999 to 2011/2012 the Pribilof fishery was not open due to low blue king crab abundance, uncertainty with estimated red king crab abundance, and concerns for blue king crab bycatch associated with a directed red king crab fishery. Pribilof blue king crab was declared overfished in September of 2002 and is still considered overfished (see Bowers et al. 2011 for complete management history).

   Amendment 21a to the BSAI groundfish FMP established the Pribilof Islands Habitat Conservation Area (Figure 4) which prohibits the use of trawl gear in a specified area around the Pribilof Islands year round (NPFMC 1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from impacts from trawl gear.

   Pribilof red king crabs occur as bycatch in the eastern Bering Sea snow crab (*Chionocetes opilio*), eastern Bering Sea Tanner crab (*Chionocetes bairdi*), Bering Sea hair crab (*Erimacrus isenbeckii*), and Pribilof blue king crab fisheries. Many of these fisheries have been closed or recently re-opened so the opportunity to catch Pribilof red king crab is limited. Limited non-directed catch exists in crab fisheries and groundfish pot and hook and line fisheries.

**Data**

1. The standard survey time series data updated through 2012 and the standard groundfish discards time series data updated through 2012 were used in this assessment. The crab fishery retained and discard catch time series was updated with 2011/2012 data.

2. a. Total catch:

<u>Crab pot fisheries</u>

Retained pot fishery catches (live and deadloss landings data) are provided for 1993/1994 to 1998/1999 (Table 1 and 2), the seasons when red king crab were targeted in the Pribilof Islands District. In the 1995/1996 to 1998/1999 seasons red king crab and blue king crab were fished under the same Guideline Harvest Level (GHL). There was no GHL and therefore zero retained catch in the 2011/2012 fishing season.

b. Bycatch and discards:

<u>Crab pot fisheries</u>

Non-retained (directed and non-directed) pot fishery catches are provided for sub-legal males (≤138 mm CL), legal males (>138 mm CL), and females based on data collected by onboard observers. Catch weight was calculated by first determining the mean weight (g) for crabs in each of three categories: legal non-retained, sublegal, and female. Length to weight parameters were available for two time periods: 1973 to 2009 (males: A=0.000361, B=3.16; females: A=0.022863, B=2.23382) and 2010 to 2012 (males: A=0.000403, B=3.141; ovigerous females: A=0.003593, B=2.666; non-ovigerous females: A=0.000408, B=3.128). The average weight for each category was multiplied by the number of crabs at that CL, summed, and then divided by the total number of crabs (equation 2).

$$\text{Weight (g)} = A * CL(mm)^B \quad (1)$$

$$\text{Mean Weight (g)} = \sum(\text{weight at size} * \text{number at size}) / \sum(\text{crabs}) \quad (2)$$

Finally, weights were the product of average weight, CPUE, and total pot lifts in the fishery. To assess crab mortalities in these pot fisheries a 50% handling mortality rate is applied to these estimates.

Historical non-retained catch data are available from 1998/1999 to present from the snow crab, golden king crab (*Lithodes aequispina*), and Tanner crab fisheries (Table 3) although data may be incomplete for some of these fisheries. Prior to 1998 limited observer data exists for catcher-processor vessels only so non-retained catch before this date is not included here.

In 2011/2012, there were no Pribilof Islands red king crab incidentally caught in the crab fisheries (Table 3).

<u>Groundfish pot, trawl, and hook and line fisheries</u>

The 2011/2012 NOAA Fisheries Regional Office (J. Mondragon, NMFS, personal communication) assessments of non-retained catch from all groundfish fisheries are included in this SAFE report. Groundfish catches of crab are reported for all crab combined by federal reporting areas. Catches from observed fisheries were applied to non-observed fisheries to estimate a total catch. Catch counts were converted to biomass by applying the average weight measured from observed tows from July 2010 to June 2011. For Pribilof Islands red king crab, Areas 513 and 521 are included. It is noted that due to the extent of Area 513 into the Bristol Bay District, groundfish non-retained crab catches for Pribilof Islands red king crab may be overestimated. In 2012/2013 these data will be available in smaller units so that the management unit for each stock can be more appropriately represented. To estimate sex ratios for 2011/2012 catches, sex ratios by size and sex from the 2012 EBS bottom trawl survey were applied. To assess crab mortalities in these groundfish fisheries a 50% handling mortality rate was applied to pot and hook and line estimates and an 80% handling mortality rate was applied to trawl estimates.

Historical non-retained groundfish catch data are available from 1991/1992 to present (J. Mondragon, NMFS, personal communication) although sex ratios have not been discriminated by each year's survey proportions (Table 3).

In 2011/2012, 7.21 t of male and female red king crab were caught in fixed gear (1.24 t) and trawl gear (5.97 t) groundfish fisheries which is 33% greater than was caught in 2010/2011 pot, trawl, and hook and line groundfish fisheries. The catch was mostly in non-pelagic trawls (83%) followed by longline (12%), and pot (5%) fisheries. The targeted species in these fisheries were Pacific cod (17%), flathead sole (38%), pollock (4%), yellowfin sole (40%), and traces <1% found in the rock sole fisheries. Unlike previous years no bycatch was observed in Alaska plaice fisheries in 2011/2012.

c. Catch-at-length: NA

d. Survey biomass:
The 2012 NOAA Fisheries EBS bottom trawl survey results (Foy and Armistead in press) are included in this SAFE report (Figure 6). Abundance estimates of male and female crab are assessed for 5 mm length bins and for total abundances for each EBS stock (Figure 5). Weight (equation 1) and maturity (equation 3) schedules are applied to these abundances and summed to calculate mature male, female, and legal male biomass.

$$\text{Proportion mature male} = 1/(1 + (5.842 * 10^{14}) * e^{((CL(mm)+2.5) * -0.288)}$$
$$\text{Proportion mature female} = 1/(1 + (1.416 * 10^{13}) * e^{((CL(mm)+2.5) * -0.297)} \qquad (3)$$

Historical survey data are available from 1975 to the present (Tables 4 and 5, Figure 6). It should be noted that the survey data analyses were standardized in 1980.

In 2012, red king crab were caught at 12 of the 77 stations in the Pribilof District; 10 stations in the high-density sampling area and 2 stations in the standard-density sampling area (Foy and Armistead in press, Figure 7). The density of legal-sized males caught at a station ranged from 67 to 2,443 crab $nmi^{-2}$. Legal-sized male red king crab were caught at 9 of the 77 stations in the Pribilof District with a biomass estimate (± 95% CI) of 4,360 ± 4,846 t and an abundance estimate (± 95% CI) of 1.2 ± 1.3 million crab. Legal-size males represented 91% of the total male biomass but were below the average of 5,284 ± 5,905 t from the previous 20 years (Figure 8). The majority of the legal-sized males were distributed around and to the northeast of St. Paul Island.

Mature males were encountered at 9 of the 77 stations in the Pribilof District; 9 stations in the high-density sampling area, and zero stations in the standard-density sampling area. Two stations accounted for 81% of all mature red king crab caught. The biomass estimate of mature males was 4,477 ± 5,031 t and represented 93% of the total male biomass with the remaining 7% represented by 336 ± 636 t of immature male red king crab. Mature males were distributed around St. Paul Island in the nearshore shallow water stations and to the northeast of St. Paul Island (Figs. 20 and 21).

The 2012 size-frequency for red king crab males shows a similar number of oldshell and very oldshell legal-sized males compared to 2011. In 2012, 51% of the legal-sized males were new hardshell crabs and distributed northeast of St. Paul Island. Forty-one percent of the legal-sized males were in oldshell and very oldshell condition and primarily distributed southeast of St. Paul Island.

The 2012 biomass estimate of mature-sized red king crab females was 663 ± 710 t and abundance was 0.4 ± 0.5 million crab, representing 100% of the total female biomass collected during the survey. A majority of the mature females were carrying uneyed embryos with 43% of the mature females in new hardshell condition. The majority of mature females with uneyed embryos were in the 130 mm to 140 mm CL size class.

**Analytic Approach**

1. **History of modeling approaches**
   A catch survey analysis has been used for assessing the stock in the past although is currently not in development.

**Calculation of MMB**

Taking an average biomass across 3 years centered on the current year to calculate the MMB in the most recent year was considered to reduce the effect of high uncertainty in the survey based area swept estimates (Figure 9). In addition, this average was weighted by the inverse variance of the survey biomass estimate to account for changes in variability among years. A loess weighting function was also considered but did not fit the data trends adequately. An unweighted average was also considered but overfit the data in years with a large amount of variance (Figure 10). ***Therefore in this analysis the MMB was estimated by a three year moving average MMB weighted by the inverse variance.*** Figure 11 shows the three year running average of $MMB_{mating}$ with confidence intervals and CVs used for the analyses in this SAFE. The survey time series with three year moving weighted averages for each major size class for males and females is presented in Table 6.

**Calculation of the OFL**

1. Based on available data, the ***author recommended classification for this stock is Tier 4*** for stock status level determination defined by Amendment 24 to the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 2008).

2. In Tier 4, Maximum Sustainable Yield is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. In Tier 4, the fishing mortality that, if applied over the long-term, would result in MSY is approximated by $F_{MSY}{}^{proxy}$. The MSY stock size ($B_{MSY}$) is based on mature male biomass at mating ($MMB_{mating}$) which serves as an approximation for egg production. $MMB_{mating}$ is used as a basis for $B_{MSY}$ because of unknown sex ratios, a male only fishery, and the complicated female crab life history where molting and mating occur simultaneously. The $B_{MSY}{}^{proxy}$ represents the equilibrium stock biomass that provides maximum sustainable yield (MSY) to a fishery exploited at $F_{MSY}{}^{proxy}$. $B_{MSY}$ can be estimated as the average biomass over a specified period that satisfies these conditions (i.e., equilibrium biomass yielding MSY by an applied $F_{MSY}$). This is also considered a percentage of pristine biomass ($B_0$) of the unfished or lightly exploited stock. The current stock biomass reference point for status of stock determination is $MMB_{mating}$.

   The mature stock biomass ratio β where $B/B_{MSY}{}^{prox} = 0.25$ represents the critical biomass threshold below which directed fishing mortality is set to zero (Figure 12). The parameter α determines the slope of the non-constant portion of the control rule line and was set to 0.1. Values for α and β where based on sensitivity analysis effects on $B/B_{MSY}^{prox}$ (NPFMC 2008). The $F_{OFL}$ derivation where $B$ is greater than β includes the product of a scalar (**γ**) and $M$ (equations 5 and 6) where the default **γ** value is 1 and $M$ for Bering Sea red king crab is 0.18. The value of **γ** may alternatively be calculated as $F_{MSY}/M$ depending on the availability of data for the stock.

Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, the $F_{OFL}$ control rule resulting in a total catch greater than the OFL. For Tier 4 stocks, a minimum stock size threshold (MSST) is specified as 0.5 $B_{MSY}^{prox}$; if current MMB at the time of mating drops below MSST, the stock is considered to be overfished.

3. Calculation of $B_{MSY}^{prox}$:
   The time period for establishing $B_{MSYproxy}$ was assumed to be representative of the stock being fished at an average rate near $F_{MSY}$ fluctuating around $B_{MSY}$. The criteria to select the time period was based on 2011 CPT recommendations for this stock. For this assessment $B_{MSY}^{prox}$ was calculated as the average $MMB_{mating}$ from 1991 to current based on the observation that red king crab were relatively uncommon in the area prior to 1991 and the time series is not long enough to consider additional periods. Previously, an alternative time period was considered from 2000 to current because this time period represents the only period where the MMB oscillated relatively consistently over time without fishing pressure. However, not enough data exists to suggest a shift in productivity in the time series and there are only a few years with any exploitation. The recommendation for the entire time period was based on assessment of following established criteria:
   A. Production potential
      1) The stock does not appear to be below a threshold for responding to increased production given that increases in recruitment (120 – 134 mm males) lead to increases in adult biomass (Figure 13).
      2) An estimate of surplus production (ASP = $MMB_{t+1} - MMB_t$ + total $catch_t$) suggested that surplus existed prior to each increase in recruitment and mature male biomass in the mid 1990s, mid 2000s, and 2010s.
      3) A climate regime shift where temperature and current structure changes are likely to impact red king crab larval dispersal and subsequent juvenile crab distribution. Subsequent to the 1978 regime shift in the North Pacific, a small increase in production of red king crab occurred in the Pribilof Islands occurred but substantial increases did not occur until the mid 1990s. There are few empirical data to identify trends that may allude to a production shift. However, further analysis is warranted to determine if subsequent climate events in the Bering Sea led to increases in production observed by the spikes in recruits (male crab 120-134 mm) /spawner (MMB) observed in the early in later years (Figure 14).
   B. Exploitation rates fluctuated during the open fishery periods from 1993 to 1998 while total catch increased quickly in 1993 before declining rapidly until the fishery was closed in 1999 (Figure 15). The current $F_{MSY}^{proxy}$ assume $F=M$ is 0.18 so time periods with greater exploitation rates should not be considered to represent a period with an average rate of fishery removals. However, too few years with exploitation exist for there to be a trend here.
   C. No trend is apparent when comparing the ln (recruits/MMB) with exploitation on MMB.

4. OFL specification:
   a. In the Tier 4 OFL-setting approach, the "total catch OFL" and the "retained catch OFL" are calculated by applying the $F_{OFL}$ to all crab at the time of the fishery (total catch OFL) or to the mean retained catch determined for a specified period of time (retained catch OFL). The $F_{OFL}$ is derived using a Maximum Fishing Mortality Threshold (MFMT) or $F_{OFL}$ Control Rule (Figure

12) where Stock Status Level (level a, b or c; equations 4-6) is based on the relationship of current mature stock biomass ($B$) to $B_{\mathrm{MSY}}{}^{\mathrm{proxy}}$.

| Stock Status Level: | $F_{\mathrm{OFL}}$: | |
|---|---|---|
| a. $B/B_{\mathrm{MSY}}{}^{\mathrm{prox}} > 1.0$ | $F_{\mathrm{OFL}} = \gamma \cdot M$ | (4) |
| b. $\beta < B/B_{\mathrm{MSY}}{}^{\mathrm{prox}} \leq 1.0$ | $F_{\mathrm{OFL}} = \gamma \cdot M\ [(B/B_{\mathrm{MSY}}{}^{\mathrm{prox}} - \alpha)/(1 - \alpha)]$ | (5) |
| c. $B/B_{\mathrm{MSY}}{}^{\mathrm{prox}} \leq \beta$ | $F_{\mathrm{directed}} = 0;\ F_{\mathrm{OFL}} \leq F_{\mathrm{MSY}}$ | (6) |

b. The $\mathrm{MMB}_{\mathrm{Mating}}$ projection is based on application of $M$ from the 2012 NMFS trawl survey (July 15) to the period of a fishery (October 15) and to mating (February 15) and the removal of estimated retained, bycatch, and discarded catch mortality (equation 7). Catch mortalities are estimated from the proportion of catch mortalities in 2010/2011 to the 2011 survey biomass.

$$\mathrm{MMB}_{\mathrm{Survey}} \cdot e^{-\mathrm{PM(sm)}} - \text{(projected legal male catch OFL)-(projected non-retained catch)} \quad (7)$$

where, $\mathrm{MMB}_{\mathrm{Survey}}$ is the mature male biomass at the time of the survey, $e^{-\mathrm{PM(sm)}}$ is the survival rate from the survey to mating. PM(sm) is the partial M from the time of the survey to mating (8 months).

c. To project a total catch OFL for the upcoming crab fishing season, the $F_{\mathrm{OFL}}$ is estimated by an iterative solution that maximizes the projected $F_{\mathrm{OFL}}$ and projected catch based on the relationship of B to $B_{\mathrm{MSY}}{}^{\mathrm{prox}}$. B is approximated by MMB at mating (equation 7).

For a total catch OFL, the annual fishing mortality rate ($F_{\mathrm{OFL}}$) is applied to the total crab biomass at the fishery (equation 8).

$$\text{Projected Total Catch OFL} = [1 - e^{-\mathrm{Fofl}}] \cdot \text{Total Crab Biomass}_{\mathrm{Fishery}} \quad (8)$$

where $[1 - e^{-\mathrm{Fofl}}]$ is the annual fishing mortality rate.

Exploitation rates on legal male biomass ($\mu_{\mathrm{LMB}}$) and mature male biomass ($\mu_{\mathrm{MMB}}$) at the time of the fishery are calculated as:

$$\mu_{\mathrm{LMB}} = [\text{Total LMB retained and non-retained catch}] / \mathrm{LMB}_{\mathrm{Fishery}} \quad (9)$$

$$\mu_{\mathrm{MMB}} = [\text{Total MMB retained and non-retained catch}] / \mathrm{MMB}_{\mathrm{Fishery}} \quad (10)$$

5. Recommendations:
   For ***2011/2012 $B_{MSY}{}^{prox}$=5,136 t of $MMB_{mating}$ derived as the mean of 1991/1992 to 2011/2012***. The stock demonstrated highly variable levels of $\mathrm{MMB}_{\mathrm{mating}}$ during these periods likely leading to uncertain approximations of $B_{\mathrm{MSY}}$. Crabs were highly concentrated during the EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to a limited number of tows with crab catches.

***Male mature biomass at the time of mating for 2012/2013 was estimated at 3,302 t for $B_{MSY}^{prox}$. The $B/B_{MSY}^{prox}$ =0.64 and $F_{OFL}$=0.11.*** The biomass reference option $B/B_{\mathrm{MSY}}^{\mathrm{prox}}$ is < 1, therefore the ***stock status level is b*** (equation 5). For the 2012/2013 fishery, the ***total catch OFL was estimated at 569 t*** of crab and legal male catch OFL was estimated at 386 t of crab. The ***projected exploitation rates based on full retained catches up to the OFL for LMB and $MMB_{fishery}$ are both 0.11.***

Red king crabs in the Pribilof Islands have been historically harvested with blue king crabs and are currently the dominant of the two species in this area. There are concerns as to the low reliability of survey biomass estimates and the high levels of blue king crab incidental catch mortality that would occur in a directed Pribilof Islands red king crab fishery.

**Calculation of the ABC**

1. To calculate an Annual Catch Limit (ACL) to account for scientific uncertainty in the OFL, an acceptable biological catch (ABC) control rule was developed such that ACL=ABC. The ABC is set below the OFL by a proportion based a predetermined probability that the ABC would exceed the OFL (P*). Currently, P* is set at 0.49 and represents a proportion of the OFL distribution that accounts for within assessment uncertainty ($\sigma_w$) in the OFL to establish the maximum permissible ABC ($ABC_{max}$). Any additional uncertainty to account for uncertainty outside of the assessment methods ($\sigma_b$) will be considered as a recommended ABC below $ABC_{max}$. Additional uncertainty will be included in the application of the ABC by adding the uncertainty components as $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$ .

   Specification of the probability distribution of the OFL used in the ABC:
   A distribution for the OFL which quantifies uncertainty was constructed using bootstrapping methods approximating the lognormal distribution. This involves generating values for $M$ and annual $MMB_{mating}$ (e.g. by assuming that MMB is log-normally distributed and $M$ is normally distributed) and for each simulation calculating the OFL using the standard methods in sections 3 and 4 of the OFL Calculation section above. The OFL distribution for Pribilof Island red king crab is skewed to the right due to the patchy spatial distribution and small abundance which affects the variability of density estimates among trawl survey stations. This lognormal distribution suggests that use of the mean value (as opposed to the median) of the distribution would be appropriate as it changes with greater variability.

2. List of variables related to scientific uncertainty considered in the OFL probability distribution:
   Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands red king crab is high due to insufficient data and the small distribution of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass for the most recent year is 0.594 and has ranged between 0.357 and 0.786 since the 1995 peak in biomass.

3. List of additional uncertainties considered for alternative $\sigma_b$ applications to the ABC.
   Several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:
   - Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.
   - $F_{msy}$ is assumed to be equal to $\gamma M$ when applying the OFL control rule while $\gamma$ is assumed to be equal to 1 and $M$ is assumed to be known.
   - The coefficients of variation for the survey estimates of abundance for this stock are very high.

- $B_{msy}$ is assumed to be equivalent to average mature male biomass. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1981-1988 and 1993-1999. Therefore, considerable uncertainty exists with this estimate of $B_{msy}$.

Given the relative amount of information available for Pribilof Island's red king crab, ***the author recommended ABC includes an additional $\sigma_b$ of 0.4***.

4. Recommendations:
For 2012/2013 using the recommended $B_{MSY}^{prox}$, the multiplier equivalent to a P* of 0.49 was 0.88. The ***$ABC_{max}$ was thus estimated to be 501 t***. Incorporating additional uncertainty by applying a $\sigma_b$ of 0.4 resulted in a multiplier of 0.80 and a ***recommended ABC of 455 t***.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009/10 | 1,914 | 2,175[A] | 0 | 0 | 2.7 | 227 | |
| 2010/11 | 2,255 | 2,754[B] | 0 | 0 | 4.2 | 349 | |
| 2011/12 | 2,571 | 2,775[C*] | 0 | 0 | 5.4 | 393 | 307 |
| 2012/13 | | 3,302[D*] | | | | 569 | 455 |

All units are in t of crabs and the OFL is a total catch OFL for each year. The stock was above MSST in 2011/2012 and is hence not overfished. Overfishing did not occur during the 2011/2012 fishing year.
Notes:
A – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
B – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/2011 catches
C – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/2012 catches
D – Based on survey data available to the Crab Plan Team in September 2012
* – 2011/12 estimates based on 3 year running average
** – 2012/13 estimates based on weighted 3 year running average

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Table 1. Total retained catches from directed fisheries for Pribilof Islands District red king crab (Bowers et al. 2011; D. Pengilly, ADF&G, personal communications).

| Year | Catch (count) | Catch (t) | Avg CPUE (legal crab count $pot^{-1}$) |
|---|---|---|---|
| 1973/1974 | 0 | 0 | 0 |
| 1974/1975 | 0 | 0 | 0 |
| 1975/1976 | 0 | 0 | 0 |
| 1976/1977 | 0 | 0 | 0 |
| 1977/1978 | 0 | 0 | 0 |
| 1978/1979 | 0 | 0 | 0 |
| 1979/1980 | 0 | 0 | 0 |
| 1980/1981 | 0 | 0 | 0 |
| 1981/1982 | 0 | 0 | 0 |
| 1982/1983 | 0 | 0 | 0 |
| 1983/1984 | 0 | 0 | 0 |
| 1984/1985 | 0 | 0 | 0 |
| 1985/1986 | 0 | 0 | 0 |
| 1986/1987 | 0 | 0 | 0 |
| 1987/1988 | 0 | 0 | 0 |
| 1988/1989 | 0 | 0 | 0 |
| 1989/1990 | 0 | 0 | 0 |
| 1990/1991 | 0 | 0 | 0 |
| 1991/1992 | 0 | 0 | 0 |
| 1992/1993 | 0 | 0 | 0 |
| 1993/1994 | 380,286 | 1183.02 | 11 |
| 1994/1995 | 167,520 | 607.34 | 6 |
| 1995/1996 | 110,834 | 407.32 | 3 |
| 1996/1997 | 25,383 | 90.87 | <1 |
| 1997/1998 | 90,641 | 343.29 | 3 |
| 1998/1999 | 68,129 | 246.91 | 3 |
| 1999/2000 to 2010/2011 | 0 | 0 | 0 |

Table 2. Fishing effort during Pribilof Islands District commercial red king crab fisheries, 1993-2007/08 (Bowers et al. 2011).

| Season | Number of Vessels | Number of Landings | Number of Pots Registered | Number of Pots Pulled |
|---|---|---|---|---|
| 1993 | 112 | 135 | 4,860 | 35,942 |
| 1994 | 104 | 121 | 4,675 | 28,976 |
| 1995 | 117 | 151 | 5,400[a] | 34,885 |
| 1996 | 66 | 90 | 2,730[a] | 29,411 |
| 1997 | 53 | 110 | 2,230[a] | 28,458 |
| 1998 | 57 | 57 | 2,398[a] | 23,381 |
| 1999-2010/11 | Fishery Closed | | | |

Table 3. Non-retained total catch mortalities from directed and non-directed fisheries for Pribilof Islands District red king crab. Handling mortalities (pot and hook/line= 0.5, trawl = 0.8) were applied to the catches. (Bowers et al. 2011; D. Pengilly, ADF&G; J. Mondragon, NMFS).

| | Crab pot fisheries | | | Groundfish fisheries | |
|---|---|---|---|---|---|
| Year | Legal male (t) | Sublegal male (t) | Female (t) | All fixed (t) | All trawl (t) |
| 1991/1992 | 0.00 | 0.00 | 0.00 | 0.48 | 45.71 |
| 1992/1993 | 0.00 | 0.00 | 0.00 | 16.12 | 175.93 |
| 1993/1994 | 0.00 | 0.00 | 0.00 | 0.60 | 131.87 |
| 1994/1995 | 0.00 | 0.00 | 0.00 | 0.27 | 15.29 |
| 1995/1996 | 0.00 | 0.00 | 0.00 | 4.81 | 6.32 |
| 1996/1997 | 0.00 | 0.00 | 0.00 | 1.78 | 2.27 |
| 1997/1998 | 0.00 | 0.00 | 0.00 | 4.46 | 7.64 |
| 1998/1999 | 0.00 | 0.91 | 11.34 | 10.40 | 6.82 |
| 1999/2000 | 1.36 | 0.00 | 8.16 | 12.40 | 3.13 |
| 2000/2001 | 0.00 | 0.00 | 0.00 | 2.08 | 4.71 |
| 2001/2002 | 0.00 | 0.00 | 0.00 | 2.71 | 6.81 |
| 2002/2003 | 0.00 | 0.00 | 0.00 | 0.50 | 9.11 |
| 2003/2004 | 0.00 | 0.00 | 0.00 | 0.77 | 9.83 |
| 2004/2005 | 0.00 | 0.00 | 0.00 | 3.17 | 3.52 |
| 2005/2006 | 0.00 | 0.18 | 1.81 | 4.53 | 24.72 |
| 2006/2007 | 1.36 | 0.14 | 0.91 | 6.99 | 21.35 |
| 2007/2008 | 0.91 | 0.05 | 0.09 | 1.92 | 2.76 |
| 2008/2009 | 0.09 | 0.00 | 0.00 | 1.64 | 6.94 |
| 2009/2010 | 0.00 | 0.00 | 0.00 | 0.33 | 2.45 |
| 2010/2011 | 0.00 | 0.00 | 0.00 | 0.30 | 3.87 |
| 2011/2012 | 0.00 | 0.00 | 0.00 | 0.62 | 4.78 |

Table 4. Pribilof Islands District red king crab abundance, mature biomass, legal male biomass, and totals estimated based on the NMFS annual EBS bottom trawl survey with no running average.

| Year | Mature Male Abundance | Mature males @ survey t | Mature males @ mating t | Legal Males @ survey t | Total males @ survey t | Total females @ survey t |
|---|---|---|---|---|---|---|
| 1975/1976 | 0 | 0 | 0 | 0 | 0 | 10 |
| 1976/1977 | 50778 | 162 | 144 | 162 | 162 | 80 |
| 1977/1978 | 76159 | 116 | 103 | 0 | 253 | 120 |
| 1978/1979 | 367140 | 1228 | 686 | 1228 | 1228 | 42 |
| 1979/1980 | 279707 | 859 | 205 | 790 | 859 | 76 |
| 1980/1981 | 383898 | 1312 | 959 | 1312 | 1317 | 195 |
| 1981/1982 | 80928 | 299 | 246 | 299 | 299 | 97 |
| 1982/1983 | 331947 | 1440 | 1277 | 1440 | 1458 | 673 |
| 1983/1984 | 122661 | 518 | 460 | 486 | 544 | 216 |
| 1984/1985 | 64331 | 261 | 232 | 233 | 261 | 67 |
| 1985/1986 | 16823 | 60 | 54 | 60 | 60 | 0 |
| 1986/1987 | 38419 | 135 | 120 | 135 | 135 | 57 |
| 1987/1988 | 18611 | 53 | 47 | 53 | 53 | 25 |
| 1988/1989 | 66189 | 104 | 92 | 43 | 797 | 732 |
| 1989/1990 | 754994 | 1498 | 1328 | 854 | 2154 | 1846 |
| 1990/1991 | 617113 | 897 | 795 | 109 | 6815 | 1775 |
| 1991/1992 | 2435400 | 4335 | 3823 | 1295 | 4959 | 3860 |
| 1992/1993 | 1451102 | 3238 | 2780 | 2479 | 3505 | 2612 |
| 1993/1994 | 3532420 | 9687 | 7388 | 9017 | 9962 | 4837 |
| 1994/1995 | 3114248 | 9052 | 7436 | 7994 | 9600 | 3397 |
| 1995/1996 | 7098444 | 24282 | 21139 | 22428 | 24854 | 6199 |
| 1996/1997 | 555428 | 2323 | 1971 | 2292 | 2389 | 1456 |
| 1997/1998 | 1554857 | 6056 | 5035 | 5843 | 7528 | 1442 |
| 1998/1999 | 772660 | 2282 | 1778 | 1749 | 2688 | 1262 |
| 1999/2000 | 1939076 | 5422 | 4800 | 4394 | 8682 | 4762 |
| 2000/2001 | 1538502 | 4239 | 3757 | 3773 | 4393 | 734 |
| 2001/2002 | 3662559 | 8434 | 7476 | 5663 | 10714 | 4333 |
| 2002/2003 | 1891296 | 6916 | 6129 | 6894 | 6923 | 571 |
| 2003/2004 | 1470902 | 5280 | 4678 | 5184 | 5280 | 1644 |
| 2004/2005 | 811871 | 3563 | 3157 | 3563 | 3710 | 983 |
| 2005/2006 | 247739 | 1219 | 1067 | 1219 | 1272 | 2207 |
| 2006/2007 | 1370143 | 6762 | 5983 | 6484 | 6859 | 1406 |
| 2007/2008 | 1637966 | 7176 | 6362 | 6947 | 7378 | 2534 |
| 2008/2009 | 1305315 | 5375 | 4763 | 5022 | 5698 | 2099 |
| 2009/2010 | 887543 | 2454 | 2175 | 2088 | 2498 | 546 |
| 2010/2011 | 895960 | 3107 | 2754 | 2881 | 3137 | 468 |
| 2011/2012 | 1015866 | 3834 | 3398 | 3751 | 3878 | 817 |
| 2012/2013 | 1246228 | 4477 | | 4360 | 4813 | 663 |

Table 5. Pribilof Islands District red king crab abundance CV, legal male biomass CV, and total CVs estimated from the NMFS annual EBS bottom trawl survey data with no running average.

| Year | Mature Male Abundance CV | Mature males @ survey CV | Legal Males @ survey CV | Total males @ survey CV | Total females @ survey CV |
|---|---|---|---|---|---|
| 1975/1976 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 |
| 1976/1977 | 1.00 | 1.00 | 1.00 | 1.00 | 0.76 |
| 1977/1978 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 1978/1979 | 0.83 | 0.83 | 0.83 | 0.83 | 1.00 |
| 1979/1980 | 0.37 | 0.39 | 0.42 | 0.39 | 0.72 |
| 1980/1981 | 0.48 | 0.53 | 0.53 | 0.52 | 0.64 |
| 1981/1982 | 0.57 | 0.58 | 0.58 | 0.58 | 0.78 |
| 1982/1983 | 0.69 | 0.70 | 0.70 | 0.70 | 0.76 |
| 1983/1984 | 0.59 | 0.53 | 0.52 | 0.55 | 0.48 |
| 1984/1985 | 0.48 | 0.55 | 0.61 | 0.55 | 0.57 |
| 1985/1986 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 |
| 1986/1987 | 0.70 | 0.70 | 0.70 | 0.70 | 1.00 |
| 1987/1988 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1988/1989 | 1.00 | 1.00 | 1.00 | 0.56 | 0.65 |
| 1989/1990 | 0.93 | 0.91 | 0.85 | 0.77 | 0.69 |
| 1990/1991 | 0.93 | 0.93 | 1.00 | 0.88 | 0.69 |
| 1991/1992 | 0.79 | 0.80 | 0.81 | 0.80 | 0.60 |
| 1992/1993 | 0.64 | 0.60 | 0.54 | 0.61 | 0.91 |
| 1993/1994 | 0.92 | 0.92 | 0.92 | 0.92 | 0.72 |
| 1994/1995 | 0.76 | 0.74 | 0.72 | 0.74 | 0.76 |
| 1995/1996 | 0.42 | 0.43 | 0.44 | 0.43 | 0.51 |
| 1996/1997 | 0.37 | 0.37 | 0.37 | 0.37 | 0.74 |
| 1997/1998 | 0.57 | 0.62 | 0.64 | 0.54 | 0.57 |
| 1998/1999 | 0.38 | 0.36 | 0.38 | 0.37 | 0.76 |
| 1999/2000 | 0.58 | 0.67 | 0.70 | 0.58 | 0.86 |
| 2000/2001 | 0.39 | 0.37 | 0.37 | 0.38 | 0.63 |
| 2001/2002 | 0.85 | 0.79 | 0.70 | 0.83 | 0.99 |
| 2002/2003 | 0.67 | 0.69 | 0.69 | 0.69 | 0.51 |
| 2003/2004 | 0.68 | 0.66 | 0.65 | 0.66 | 0.91 |
| 2004/2005 | 0.60 | 0.59 | 0.59 | 0.60 | 0.53 |
| 2005/2006 | 0.59 | 0.59 | 0.59 | 0.57 | 0.78 |
| 2006/2007 | 0.38 | 0.36 | 0.36 | 0.36 | 0.61 |
| 2007/2008 | 0.42 | 0.39 | 0.39 | 0.40 | 0.52 |
| 2008/2009 | 0.46 | 0.51 | 0.52 | 0.50 | 0.70 |
| 2009/2010 | 0.69 | 0.64 | 0.62 | 0.64 | 0.55 |
| 2010/2011 | 0.38 | 0.38 | 0.36 | 0.38 | 0.41 |
| 2011/2012 | 0.63 | 0.65 | 0.65 | 0.64 | 0.73 |
| 2012/2013 | 0.59 | 0.57 | 0.57 | 0.59 | 0.55 |

Table 6. Three year running average weighted by inverse variance of Pribilof Islands District red king crab abundance, mature biomass, legal male biomass, and totals estimated based on the NMFS annual EBS bottom trawl survey.

| Year | Mature Male Abundance | Mature males @ survey t | Mature males @ mating t | Legal Males @ survey t | Total males @ survey t | Total females @ survey t |
|---|---|---|---|---|---|---|
| 1975/1976 | 0 | 0 | 0 | 0 | 0 | 12 |
| 1976/1977 | 58589 | 132 | 117 | 162 | 162 | 13 |
| 1977/1978 | 64340 | 141 | 125 | 215 | 201 | 59 |
| 1978/1979 | 157147 | 207 | 0 | 938 | 868 | 59 |
| 1979/1980 | 309001 | 969 | 303 | 1145 | 919 | 64 |
| 1980/1981 | 128009 | 461 | 204 | 982 | 549 | 96 |
| 1981/1982 | 107458 | 390 | 327 | 1144 | 395 | 132 |
| 1982/1983 | 99871 | 385 | 341 | 697 | 401 | 145 |
| 1983/1984 | 77502 | 334 | 296 | 346 | 341 | 87 |
| 1984/1985 | 31387 | 107 | 95 | 173 | 179 | 84 |
| 1985/1986 | 30083 | 102 | 90 | 139 | 135 | 64 |
| 1986/1987 | 21323 | 68 | 60 | 106 | 77 | 30 |
| 1987/1988 | 27127 | 77 | 69 | 114 | 615 | 32 |
| 1988/1989 | 22569 | 65 | 57 | 65 | 670 | 27 |
| 1989/1990 | 79304 | 124 | 110 | 340 | 1155 | 973 |
| 1990/1991 | 760737 | 1193 | 1058 | 837 | 6660 | 2074 |
| 1991/1992 | 944073 | 1408 | 1226 | 1096 | 6747 | 2304 |
| 1992/1993 | 1750550 | 3713 | 3200 | 2116 | 4249 | 3553 |
| 1993/1994 | 1793250 | 3931 | 2283 | 4221 | 3789 | 3353 |
| 1994/1995 | 4359155 | 12392 | 10398 | 18364 | 16380 | 4592 |
| 1995/1996 | 604933 | 2576 | 1887 | 9000 | 2552 | 2150 |
| 1996/1997 | 635407 | 2648 | 2259 | 7019 | 2633 | 1641 |
| 1997/1998 | 660434 | 2393 | 1786 | 3378 | 2620 | 1389 |
| 1998/1999 | 909389 | 2592 | 2053 | 3757 | 2870 | 1444 |
| 1999/2000 | 969553 | 2804 | 2478 | 2954 | 3083 | 873 |
| 2000/2001 | 1683865 | 4613 | 4088 | 4250 | 4876 | 824 |
| 2001/2002 | 1664114 | 4700 | 4164 | 4481 | 4608 | 630 |
| 2002/2003 | 1753904 | 6242 | 5532 | 5691 | 6967 | 628 |
| 2003/2004 | 1038025 | 4385 | 3884 | 4210 | 4378 | 698 |
| 2004/2005 | 317776 | 1601 | 1416 | 2498 | 1609 | 1143 |
| 2005/2006 | 368055 | 1846 | 1623 | 4542 | 2448 | 1167 |
| 2006/2007 | 382339 | 1974 | 1736 | 5300 | 2870 | 1816 |
| 2007/2008 | 1415033 | 6452 | 5720 | 6343 | 6784 | 1817 |
| 2008/2009 | 1249124 | 3939 | 3489 | 4827 | 4606 | 702 |
| 2009/2010 | 973476 | 3139 | 2782 | 3077 | 3204 | 510 |
| 2010/2011 | 915420 | 2990 | 2650 | 2841 | 3059 | 513 |
| 2011/2012 | 967819 | 3427 | 3037 | 3221 | 3288 | 534 |
| 2012/2013 | 1114792 | 4145 | | 4038 | 4381 | 705 |

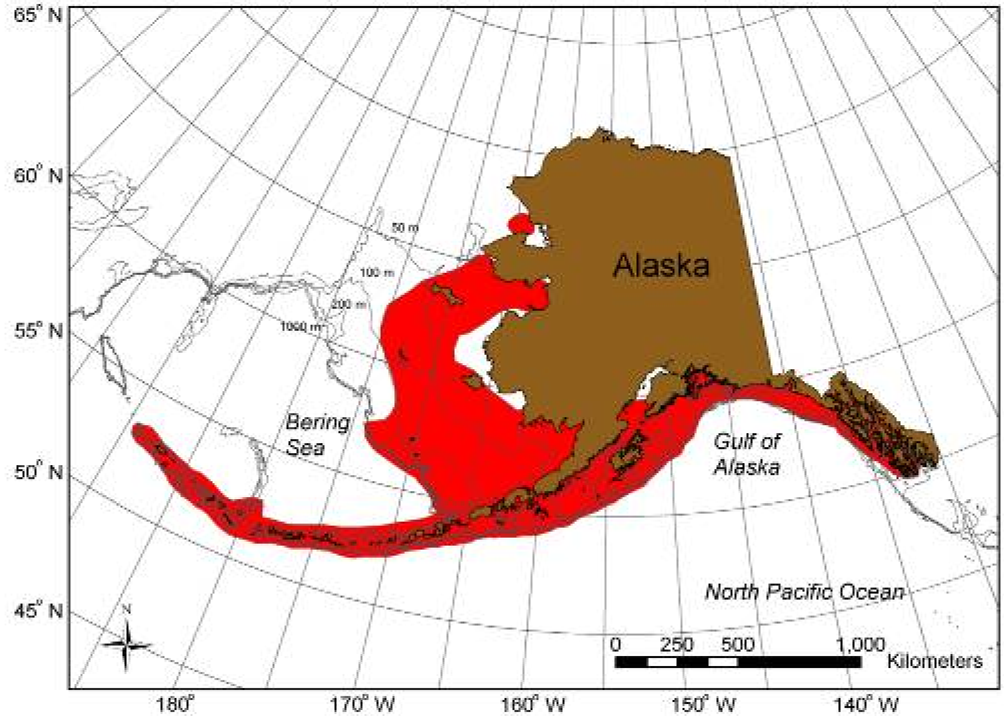


Figure 1. Red king crab distribution.

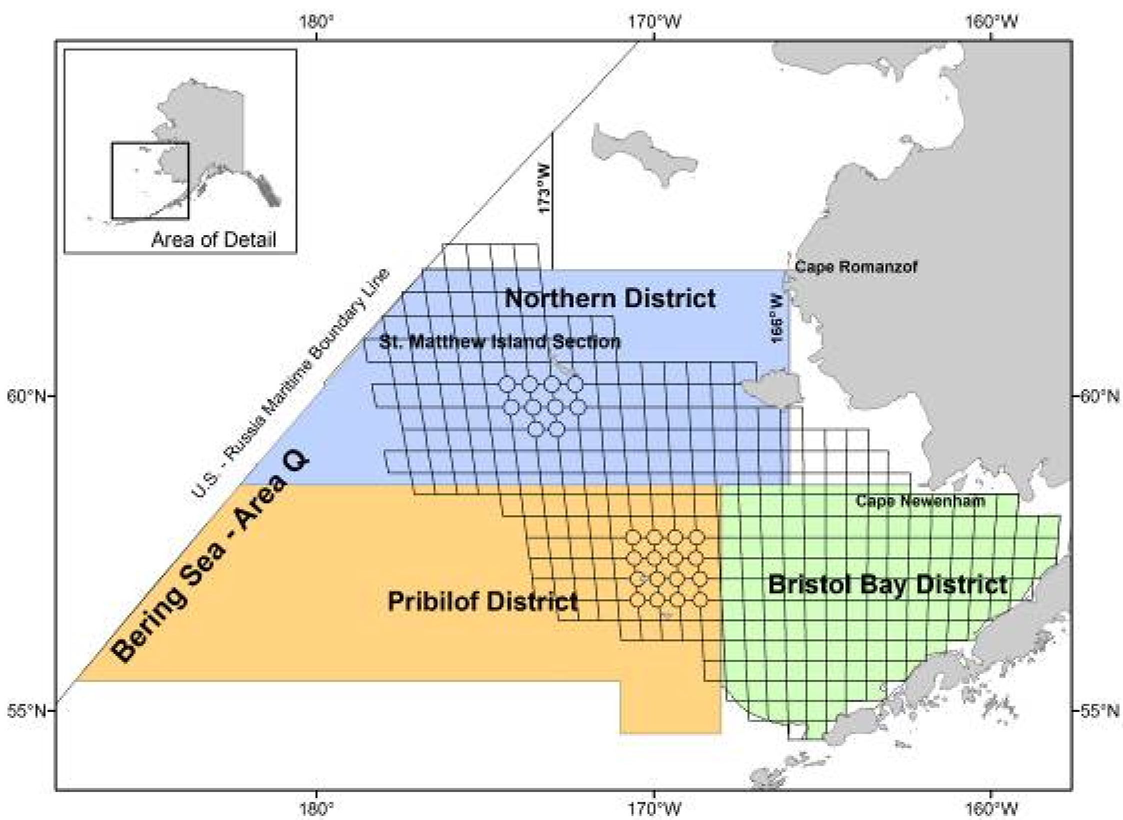


Figure 2. King crab Registration Area Q (Bering Sea) showing the Pribilof District.

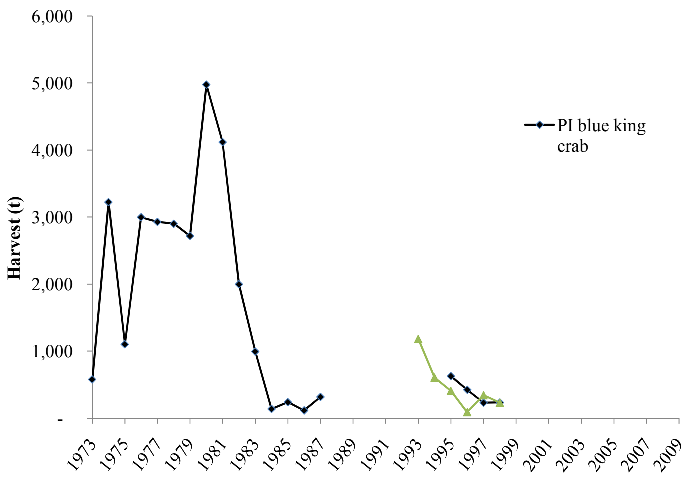


Figure 3. Historical harvests and GHLs for Pribilof Island blue and red king crab (Bowers et al. 2011).

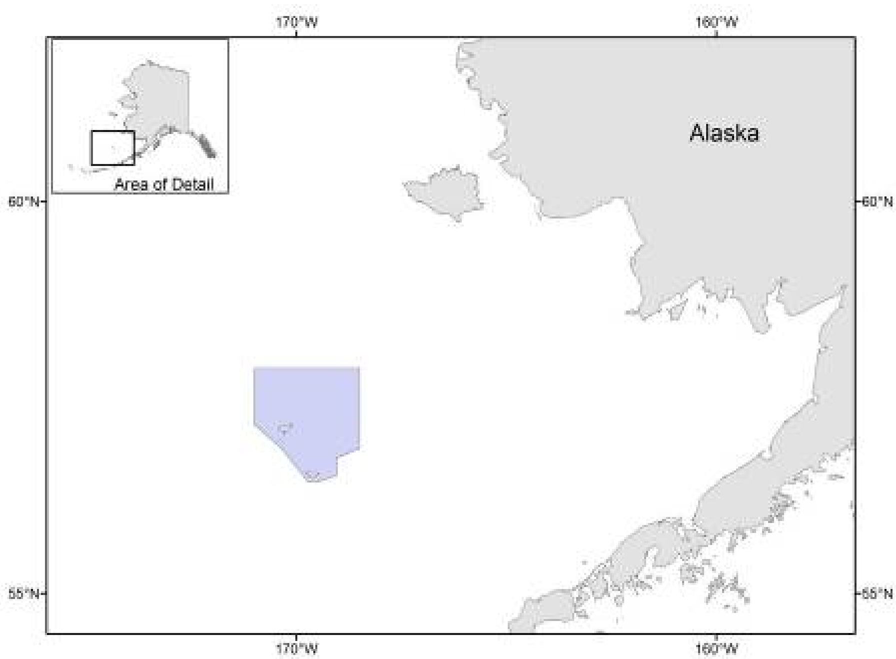


Figure 4. The shaded area shows the Pribilof Islands Habitat Conservation area.

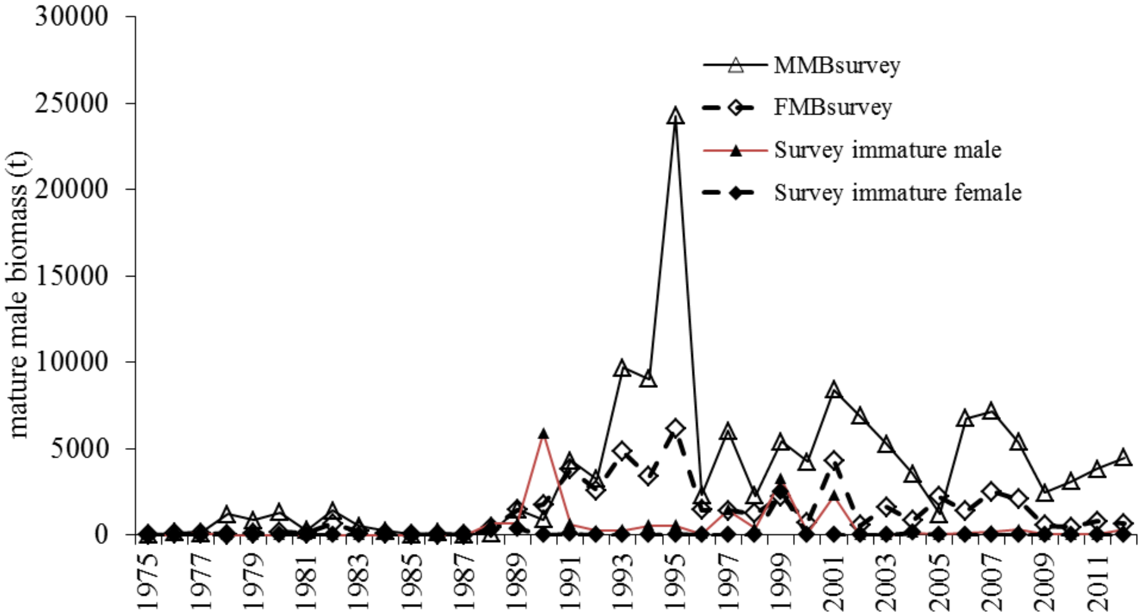


Figure 5. Time series of Pribilof Island blue king crab estimated from the NMFS annual EBS bottom trawl survey.

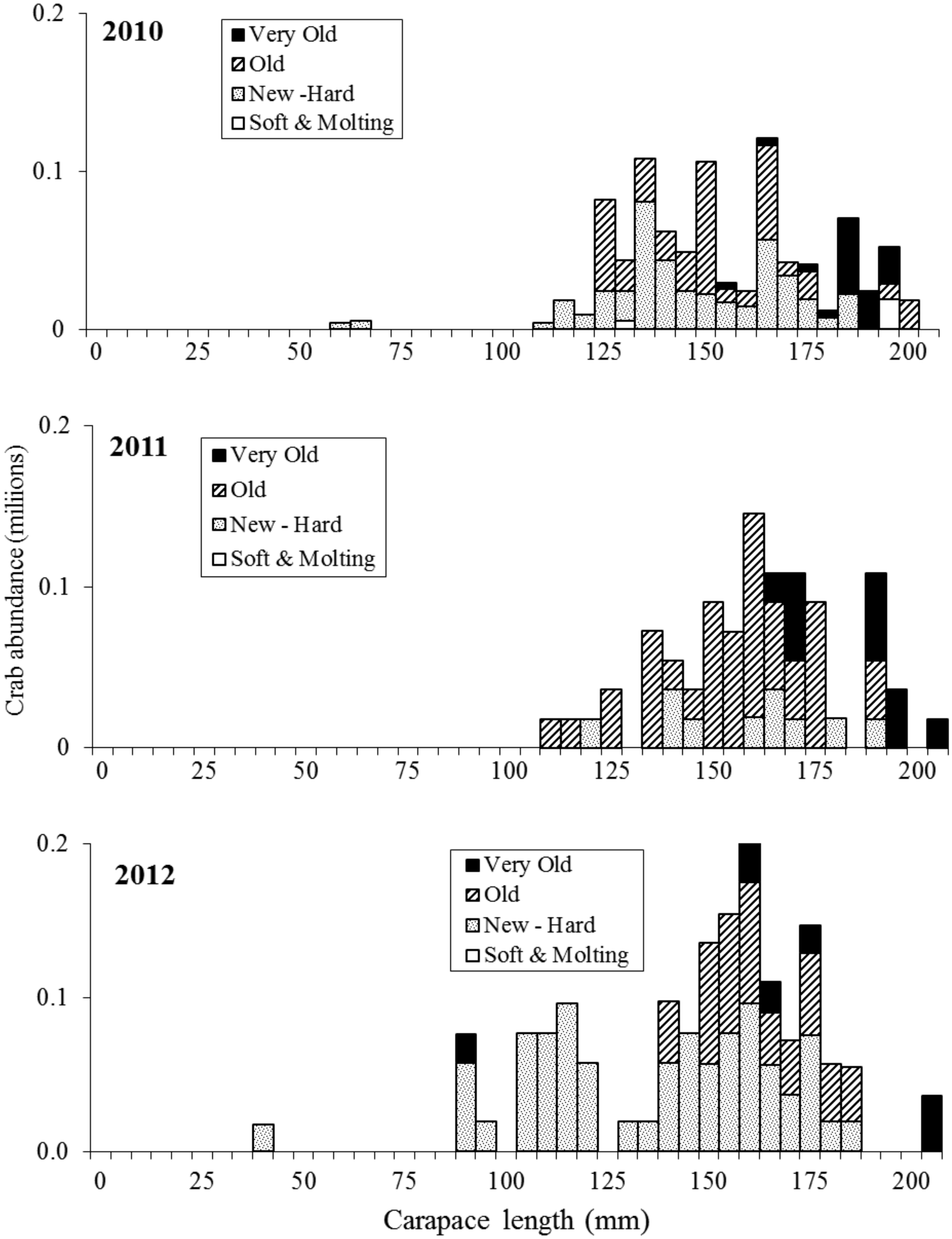


Figure 6. Distribution of Pribilof Island red king crab in 5 mm length bins by shell condition for the last 3 surveys.

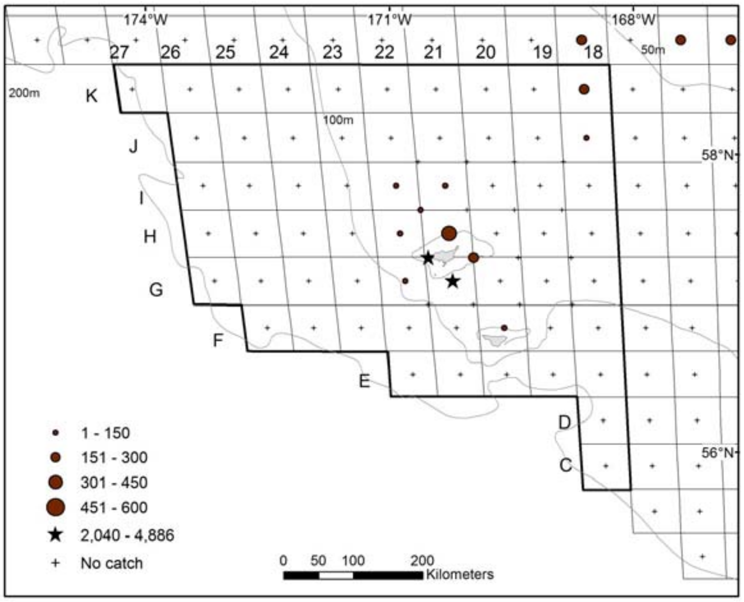


Figure 7. Total density (number $nm^{-2}$) of red king crab in the Pribilof District in the 2012 EBS bottom trawl survey.

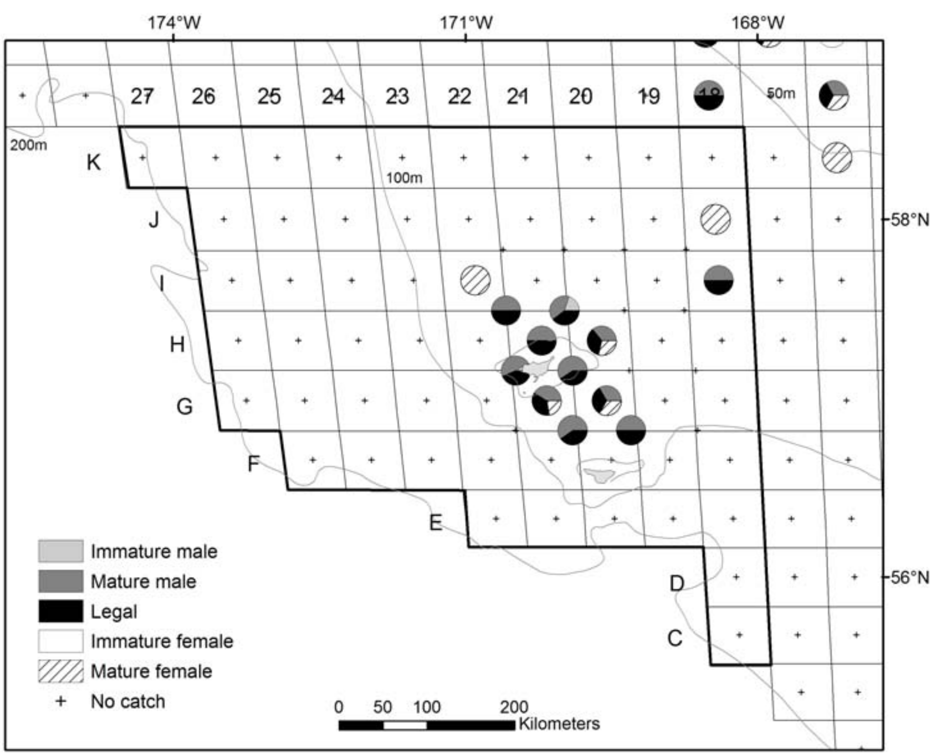


Figure 8. 2012 EBS bottom trawl survey size class distribution of red king crab in the Pribilof District.

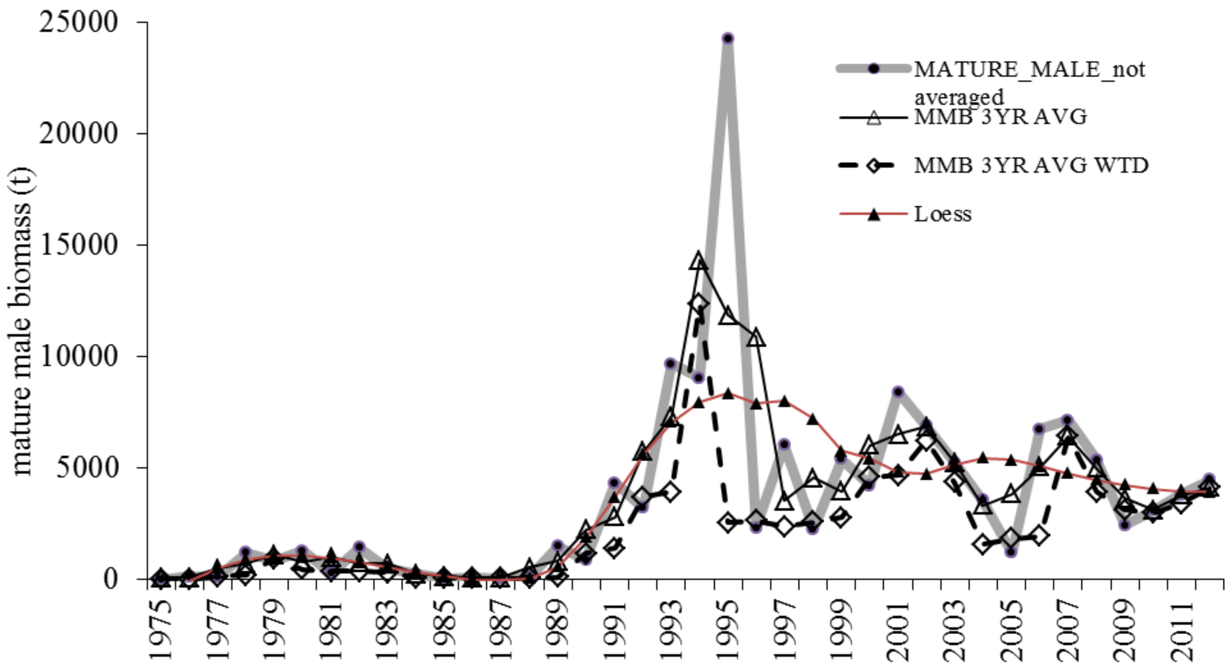


Figure 9. Alternative average biomass options including non-weighted average, average weighted by inverse variance, and loess for calculating MMB in the most recent year.

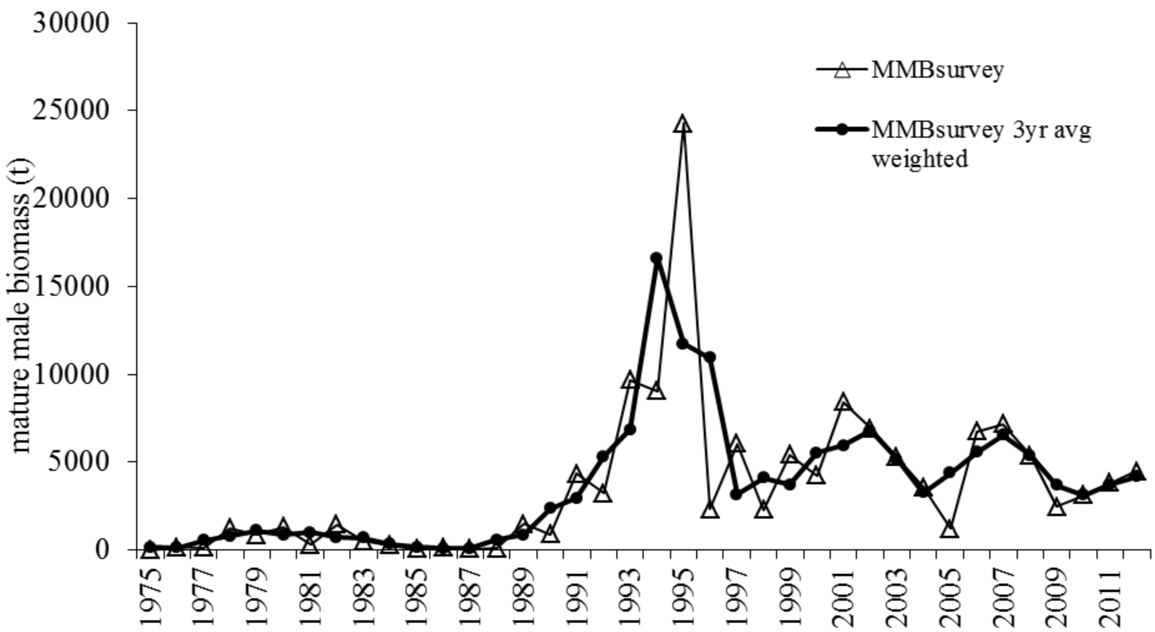


Figure 10. Time series comparison of MMB and the three year running average MMB at the time of the survey.

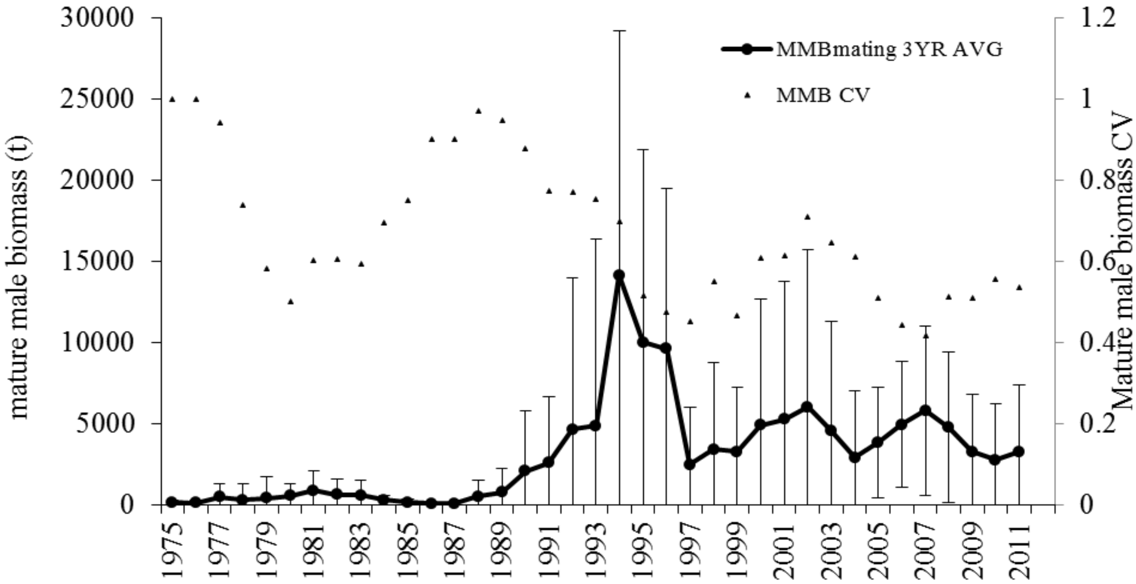


Figure 11. Time series of Pribilof Island red king crab 3 year weighted average mature male biomass (95% C.I.) and mature male biomass CV estimated from the NMFS annual EBS bottom trawl survey.

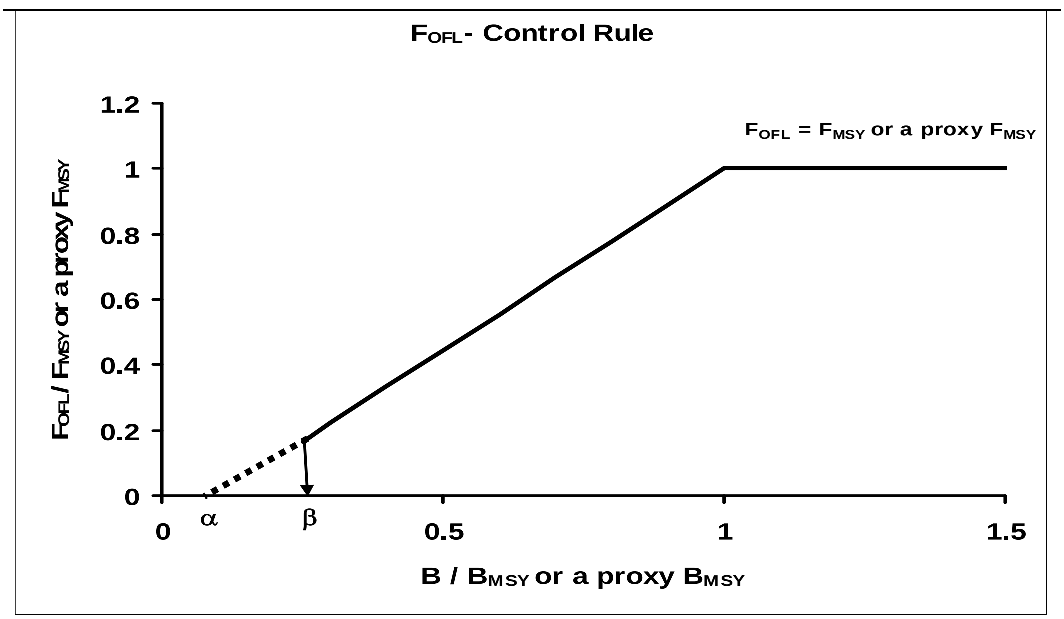


Figure 12. $F_{OFL}$ Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β.

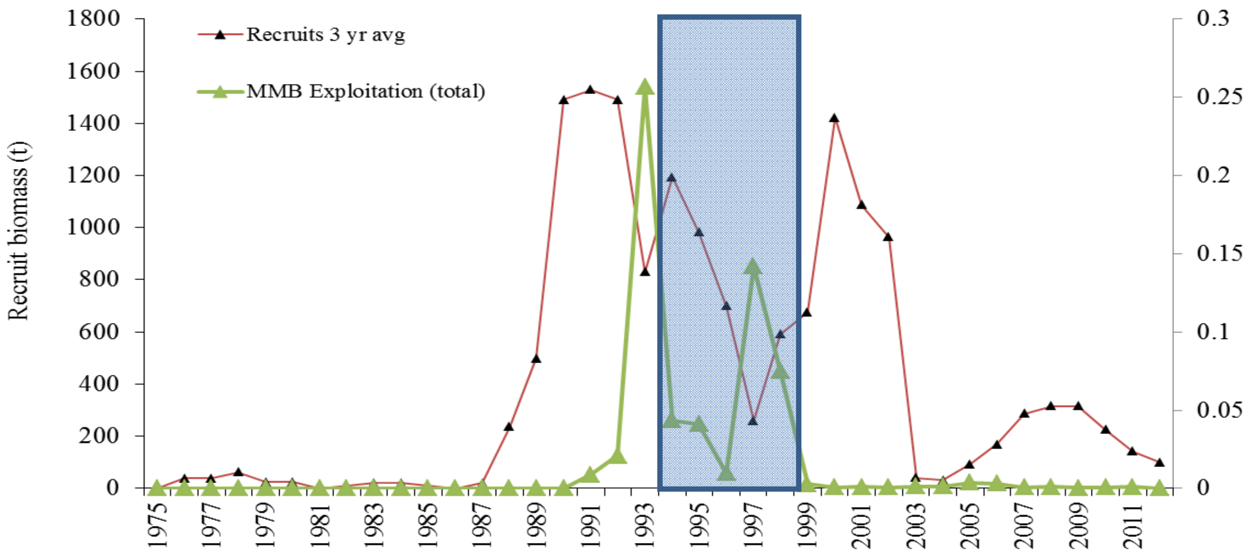


Figure 13. Time series of survey estimated recruit biomass (males 120-134 mm) and exploitation rate (based on total catch) of mature male biomass. The shaded region represents a period where commercial removals were occurring.

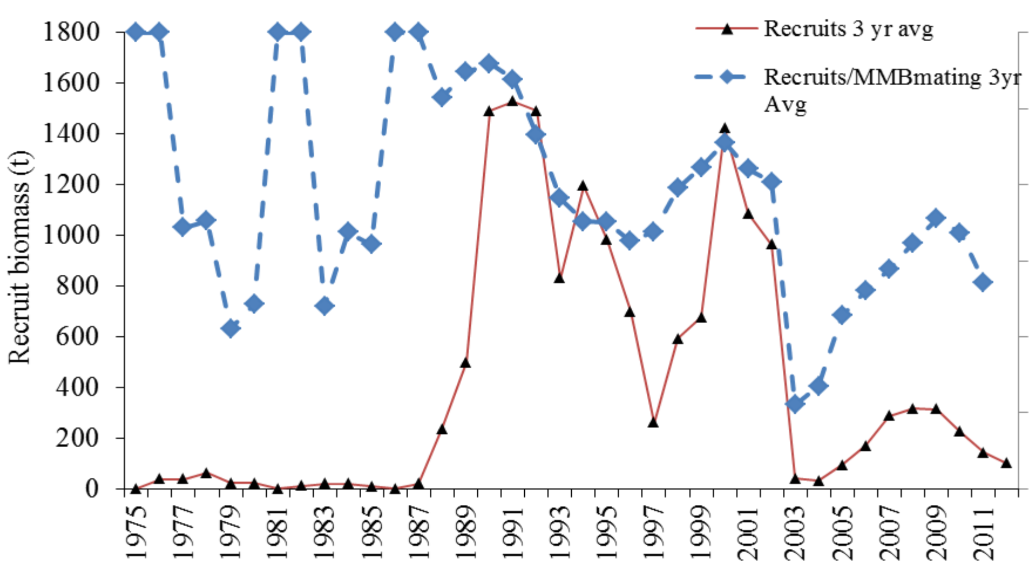


Figure 14. Time series of survey estimated recruit biomass (males 120-134 mm) and ln(Recruits/MMB). The shaded region represents a period where commercial removals were occurring.

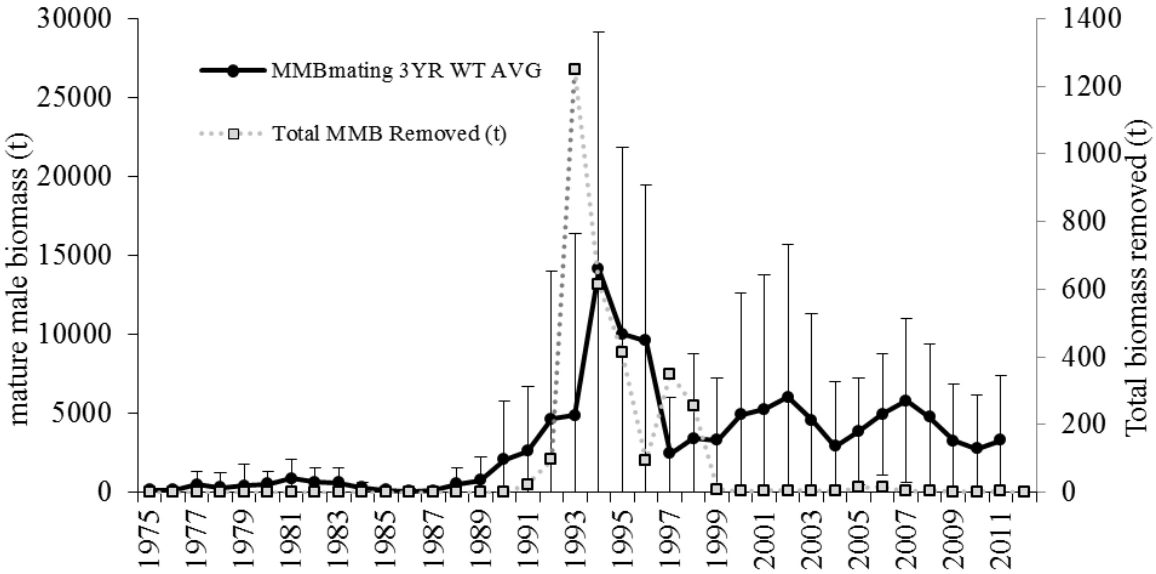


Figure 15. Time series of survey estimated Pribilof Island red king crab 3 year moving averaged mature male biomass at mating (95% C.I.) and total catch removals.

# 2012 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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**Executive Summary**

1. Stock: Pribilof Islands blue king crab, *Paralithodes platypus*
2. Catches: Retained catches have not occurred since 1998/1999. Bycatch and discards have been steady or decreased in recent years although a change in calculation methodology led to an increase in 2011/2012 to 0.36 t (0.0008 million lbs).
3. Stock biomass: Stock biomass in recent years decreased between the 1995 and 2008 surveys, and continues to fluctuate with an increase in all size classes in 2012 noting the lack of significance in any short term trends due to high uncertainty.
4. Recruitment: Recruitment indices are not well understood for Pribilof blue king crab. Pre-recruit have remained consistently low in the past 10 years although may not be well assessed with the survey.
5. Management performance:

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009/10 | 2,105 (4.64) | 401[A] (0.88) | 0 | 0 | 0.5 (0.001) | 1.81 (0.004) | |
| 2010/11 | 2,105 (4.64) | 286 [B] (0.63) | 0 | 0 | 0.18 (0.0004) | 1.81 (0.004) | |
| 2011/12 | 2,247 (4.95) | 365[C*] (0.80) | 0 | 0 | 0.36 (0.0008) | 1.16 (0.003) | 1.04 (0.002) |
| 2012/13 | | 496 [D**] (1.09) | | | | 1.16 (0.003) | 1.04 (0.002) |

All units are tons (million pounds) of crabs and the OFL is a total catch OFL for each year. The stock was below MSST in 2011/2012 and is hence overfished. Overfishing did not occur during the 2011/20122 fishing year.

Notes:
A – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
B – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/2011 catches
C – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/2012 catches
D – Based on survey data available to the Crab Plan Team in September 2012
* – 2011/12 estimates based on 3 year running average
** – 2012/13 estimates based on weighted 3 year running average

6. Basis for 2012/2013 OFL projection:

| Year | Tier | $B_{MSY}$ t ($10^6$ lbs) | Current $MMB_{mating}$ t ($10^6$ lbs) | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality $yr^{-1}$ | P* |
|---|---|---|---|---|---|---|---|---|
| 20012/13 | 4c | 3,944 (8.70) | 496 (1.09) | 0.13 | 1.0 | 1980/81-1984-85 & 1990/91-1978/79 | 0.18 | 10% buffer |

7. The OFL was set based on the existing control if the slope of the rule were to continue to 0 applied to the total catch. Previously a Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/2006 was done to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality.
8. The $ABC_{max}$ was calculated using a 10% buffer similar to that of the Tier 5 ABC control rule. The $ABC_{max}$ was thus estimated to be 1.04 t.
9. Rebuilding analyses results summary: The Pribilof Island blue king crab stock was declared overfished on September 23, 2002. The minimum required rebuilding time with 50% probability is 9 years (2011) and the maximum rebuilding time is 10 years (2012). As a result of not making adequate progress towards rebuilding a new rebuilding plan was initiated in 2009/2010. The new rebuilding plan is in final review with Secretary of Commerce and is expected to be complete in the fall 2012.

**Summary of Major Changes:**

1. Management: There were no major changes to the 2011/2012 management of the fishery.
2. Input data: The crab fishery retained and discard catch time series were updated with 2011/2012 data.
3. Assessment methodology: The survey biomass time series was calculated with a new area definition including an additional 20 nm strip towards the east. Bycatch in the groundfish fisheries was calculation using a catch in areas database to narrow catch data from the newly defined Pribilof District instead of just federal stat area 513. MMB was estimated with an average centered on the current year and weighted by the inverse variance.
4. Assessment results: The projected MMB increased in this assessment and remained below the MSST. Therefore, the OFL remained low with no directed fishery. Total catch mortality in 2011/2012 was 0.357 t.

**Responses to SSC and CPT Comments**

SSC comments October 2011:

General remarks pertinent to this assessment

*none*

Specific remarks pertinent to this assessment

*The SSC agrees with the CPT recommendation for management of Pribilof Islands blue king crab under Tier 4, where γ=1, M=0.18. Estimates of mature male biomass (MMB) were calculated in the assessment as a three-year moving average using the target year's value averaged with the prior 2 years. The SSC agrees with the assessment author and the plan team that a more appropriate calculation would center the average on the target year and encourage consideration of other methods, including weighted averages, in subsequent assessments.*

*The CPT also recommended that the time periods for determining average MMB as a proxy for $B_{MSY}$ be changed by adding in the earlier 1975/76 through 1979/80 time period to the time period used in the 14 September 2010 assessment (1980/81 through 1984/85 and 1990/91 through 1997/98; BMSY = 8,840 t). The CPT based their inclusion of these earlier data on a lack of evidence of a change in reproductive potential of the stock over these time periods. While the SSC understands the rationale for including the earlier time series into the BMSY proxy calculation, the addition of these data into the calculation more than doubles the estimate of BMSY (and MSST) over past assessments, with very little biological justification for adding these highly influential and uncertain data. The SSC recommends that the time periods from the September 2010 assessment be used to determine the average MMB as a proxy for BMSY (4,490 t).*

*The SSC agrees that this stock is in Tier 4c and accepts the CPT recommendations for OFL (116 t) and ABC (104 t) for 2011/12 based on the Tier 5-based method of averaging non-directed catch mortalities during 1999/00-2005/6 to determine the OFL and using a 10% buffer on OFL to determine the ABC. The SSC appreciates the recalculation of non-directed catches and mortalities in the SAFE chapter and continues to look forward to the implementation of a catch-survey analysis for this stock.*

Responses to SSC Comments: Methodology for an average biomass centered on the current year and additional weighting methods were considered. CSA model development is on hold.

SSC comments June 2012:

General remarks pertinent to this assessment

*none*

Specific remarks pertinent to this assessment

*As the NMFS trawl survey consistently finds blue king crabs in stations 20 nm east of the Pribilof District, the SSC recommends, as an interim measure, moving the effective stock boundary 20 nm to the east for management purposes.*

Responses to SSC Comments: Survey data and bycatch data are provided for the new area defines as the Pribilof District plus 20 nm strip to the east.

CPT comments September 2011:

Specific remarks pertinent to this assessment

*The CPT recommends examining different methods of estimating the average MMB using a weighted average of the last three years or a smoother that accounts for variances of the individual years. The team notes that the author calculated the average MMB using a running mean rather than a mean which is centered on the year for which an estimate is needed. This should be rectified for the May 2012 assessment but the results and conclusions of the current assessment are robust to changing how the average is computed.*

*The team concurred with the author's recommendation to set the ABC below the maximum permissible Tier 4 maxABC by using a 10% buffer from the OFL consistent with the Tier 5 calculation for this OFL for this stock based on its stock status.*

Responses to CPT Comments: A 3 year average centered on the current year and weighted by the inverse variance was used to calculate the MMB while unaveraged survey data was used to calculate $B_{MSY}^{proxy}$.

CPT comments May 2012:

Specific remarks pertinent to this assessment

*The CPT noted three potential options for areas used in OFL setting: 1) status quo; 2) move the boundary east 20 -40 nm based on survey blue king crab catches; and 3) include all of Bristol Bay. Although the CPT could not determine how far east to move the boundary, many team members felt confident using the eastern extent of survey catches of blue king crab rather than including all areas of groundfish bycatch.*

*It was discussed that in a tier 5 approach, as is currently employed for stocks at status C of tier 4, years with sustainable catches should be used to set the OFL. There is no recent catch level that could be deemed sustainable for Pribilof blue king crab, but rather* *to set using years in which average mortality would not impede rebuilding. A biomass-based OFL would be preferable.*

Responses to CPT Comments: Survey data and bycatch data are provided for the new area defines as the Pribilof District plus 20 nm strip to the east. A Tier 5 approach was considered for defining OFL.

**Introduction**

1. **Blue king crabs,** *Paralithodes platypus*

2. **Distribution** - Blue king crab are anomurans in the family Lithodidae which also includes the red king crab (*Paralithodes camtschaticus*) and golden or brown king crab (*Lithodes aequispinus*) in Alaska. Blue king crabs occur off Hokkaido in Japan, with disjunct populations occurring in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are known from the Diomede Islands, Point Hope, outer Kotzebue Sound, King Island, and the outer parts of Norton Sound. In the remainder of the Bering Sea, they are found in the waters off St. Matthew Island and the Pribilof Islands. In more southerly areas as far as southeastern Alaska in the Gulf of Alaska, blue king crabs are found in widely-separated populations that are frequently associated with fjord-like bays (Figure 1). This disjunct, insular distribution of blue king crab relative to the similar but more broadly distributed red king crab is likely the result of post-glacial period increases in water temperature that have limited the distribution of this cold-water adapted species (Somerton 1985). Factors that may be directly responsible for limiting the distribution include the physiological requirements for reproduction, competition with the more warm-water adapted red king crab, exclusion by warm-water predators, or habitat requirements for settlement of larvae (Somerton 1985; Armstrong et al 1985, 1987).

   During the years when the fishery was active (1973-1989, 1995-1999), the Pribilof Islands blue king crab were managed under the Bering Sea king crab Registration Area Q Pribilof District, which has as its southern boundary a line from 54° 36’ N lat., 168° W long., to 54° 36’ N lat., 171° W long., to 55° 30’ N lat., 171° W. long., to 55° 30’ N lat., 173° 30’ E long., as its northern boundary the latitude of Cape Newenham (58° 39’ N lat.), as its eastern boundary a line from 54° 36’ N lat., 168° W long., to 58° 39’ N lat., 168° W long., to Cape Newenham (58° 39’ N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991 (ADF&G 2008) (Figure 2). In the Pribilof District, blue king crab occupy the waters adjacent to and northeast of the Pribilof Islands (Armstrong et al. 1987).

3. **Stock structure** - Stock structure of blue king crabs in the North Pacific is largely unknown. To assess the potential relationship between blue king crab in the Pribilof Islands and St. Matthew, the author consulted the AFSC report entitled “Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans” by Spencer et al. (In Prep). Per this document, aspects of blue king crab harvest and abundance trends, phenotypic characteristics, behavior, movement, and genetics will be considered. Is was also, noted that ~200 samples were collected in 2009-2011 to support a genetic study on blue king crab population structure by a graduate student at the University of Alaska.

   To address the potential for species interactions between blue king crab and red king crab as a potential reason for PIBKC shifts in abundance and distribution, we compared the spatial extent of both speices in the Pribilof Islands from 1975 to 2009 (Figure 1). In the early 1980’s when red king crab first became abundant, blue king crab males and females dominated the 1 to 7 stations where the species co-occurred in the Pribilof Islands District (Figure 1A). Spatially, the stations with co-occurance were all dominated by blue king crab and broadly distributed around the

Pribilof Islands (Figure A). In the 1990's the red king crab population biomass increased substantially as the blue king crab population biomass decreased. During this time period, the number of stations with co-occurance remained around a max of 8 but they were equally dominated by both blue king crab ands red king crab sugggesting a direct overlap in distribution at the scale of a survey station (Figure 1A). Spatially during this time period, the red king crab dominated stations were dispersed around the Pribilof Islands (Figure B). Between 2001 and 2009 the blue king crab population has decreased dramatically while the red king crab have fluctuated (Figure 1B). Interstingly, the number of stations dominated by blue king crab is similar to those dominated by red king crab for both males and females suggesting continued competition for similar habitat (Figure 1A). Spatially the only stations dominated by blue king crab exist to the north and east of St. Paul Island (Figure C). It is noted that although the blue king crab protection measures also afford protection for the red king crab in this region, the red king crab stocks continue to fluctuate even considering the uncertainty in the survey.

4. **Life History** - Blue king crab are similar in size and appearance, except for color, to the more widespread red king crab, but are typically biennial spawners with lesser fecundity and somewhat larger sized (*ca.* 1.2 mm) eggs (Somerton and Macintosh 1983; 1985; Jensen et al. 1985; Jensen and Armstrong 1989; Selin and Fedotov 1996). Red king crab are annual spawners with relatively higher fecundity and smaller sized (*ca.* 1.0 mm) eggs. Blue king crab fecundity increases with size, from approximately 100,000 embryos for a 100-110 mm CL female to approximately 200,000 for a female >140-mm CL (Somerton and MacIntosh 1985). Blue king crab have a biennial ovarian cycle with embryos developing over a 12 or 13-month period depending on whether or not the female is primiparous or multiparous, respectively (Stevens 2006a). Armstrong et al. (1985, 1987), however, estimated the embryonic period for Pribilof blue king crab at 11-12 months, regardless of previous reproductive history and Somerton and MacIntosh (1985) placed development at 14-15 months. It may not be possible for large female blue king crabs to support the energy requirements for annual ovary development, growth, and egg extrusion due to limitations imposed by their habitat, such as poor quality or low abundance of food or reduced feeding activity due to cold water (Armstrong et al. 1987, Jensen and Armstrong 1989). Both the large size reached by Pribilof Islands blue king crab and the generally high productivity of the Pribilof area, however, argue against such environmental constraints. Development of the fertilized embryos occurs in the egg cases attached to the pleopods beneath the abdomen of the female crab and hatching occurs February through April (Stevens 2006b). After larvae are released, large female Pribilof blue king crab will molt, mate, and extrude their clutches the following year in late March through mid April (Armstrong et al. 1987).

   Female crabs require an average of 29 days to release larvae, and release an average of 110,033 larvae (Stevens 2006b). Larvae are pelagic and pass through four zoeal larval stages which last about 10 days each, with length of time being dependent on temperature; the colder the temperature the slower the development and vice versa (Stevens et al 2008). Stage I zoeae must find food within 60 hours as starvation reduces their ability to capture prey (Paul and Paul 1980) and successfully molt. Zoeae consume phytoplankton, the diatom *Thalassiosira* spp. in particular, and zooplankton. The fifth larval stage is the non-feeding (Stevens et al. 2008) and transitional glaucothoe stage in which the larvae take on the shape of a small crab but retain the ability to swim by using their extended abdomen as a tail. This is the stage at which the larvae searches for appropriate settling substrate, and once finding it, molts to the first juvenile stage and henceforth remains benthic. The larval stage is estimated to last for 2.5 to 4 months and larvae metamorphose and settle during July through early September (Armstrong et al. 1987, Stevens et al. 2008).

   Blue king crab molt frequently as juveniles, growing a few mm in size with each molt. Unlike red king crab juveniles, blue king crab juveniles are not known to form pods. Female king crabs typically reach sexual maturity at approximately five years of age while males may reach maturity one year later, at six years of age (NPFMC 2003). Female size at 50% maturity for Pribilof blue king crab is estimated at 96-mm carapace length (CL) and size at maturity for males, as estimated from size of chela relative to CL, is estimated at 108-mm CL (Somerton and MacIntosh 1983). Skip molting occurs with increasing probability for those males larger than 100 mm CL (NOAA 2005).

Longevity is unknown for the species, due to the absence of hard parts retained through molts with which to age crabs. Estimates of 20 to 30 years in age have been suggested (Blau 1997). Natural mortality for male Pribilof blue king crabs has been estimated at 0.34-0.94 with a mean of 0.79 (Otto and Cummiskey 1990) and a range of 0.16 to 0.35 for Pribilof and St. Matthew Island stocks combined (Zheng et al. 1997). An annual natural mortality of 0.2 for all king crab species was adopted in the federal crab fishery management plan for the BSAI areas (Siddeek et. al 2002).

5. **Management history -** The king crab fishery in the Pribilof District began in 1973 with a reported catch of 590 t by eight vessels (Figure 5). Landings increased during the 1970s and peaked at a harvest of 5,000 t in the 1980/81 season with an associated increase in effort to 110 vessels (ADF&G 2008). Following 1995, declines in the stock resulted in a closure from 1999 to present. The Pribilof blue king crab stock was declared overfished in September of 2002 and the Alaska Department of Fish and Game developed a rebuilding harvest strategy as part of the North Pacific Fishery Management Council's (NPFMC) comprehensive rebuilding plan for the stock. The fishery occurred September through January, but usually lasted less than 6 weeks (Otto and Cummiskey 1990, ADF&G 2008). The fishery was male only, and legal size was >16.5 cm carapace width (NOAA 1995). Guideline harvest level (GHL) was 10 percent of the abundance of mature male or 20 percent of the number of legal males (ADF&G 2006).

   Amendment 21a to the BSAI groundfish FMP established the Pribilof Islands Habitat Conservation Area (Figure 6) which prohibits the use of trawl gear in a specified area around the Pribilof Islands year round (NPFMC 1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from impacts from trawl gear.

   Blue king crab in the Pribilof District can occur as bycatch in the following crab fisheries: the eastern Bering Sea snow crab (*Chionoecetes opilio*), the eastern Bering Sea Tanner crab (*Chionoecetes bairdi*), the Bering Sea hair crab (*Erimacrus isenbeckii*), and the Pribilof red and blue king crab. In addition, blue king crab are bycatch in flatfish and Pacific cod fisheries.

**Data**

1. The standard survey time series data including an additional 20 nm strip on the eastern portion of the Pribilof District was updated through 2012 and the standard groundfish discards time series data through 2011 were used in this assessment. Groundfish discards for 2012 were estimated using the AKRO catch at areas database to apportion total observed blue king crab to groundfish fisheries actually fishing in the newly defined Pribilof District. As stated above, the new district definition includes the old are plus a 20 nm strip on the eastern portion. The crab fishery retained and discard catch time series was updated with 2011/2012 data.

2. a. Total catch:
   <u>Crab pot fisheries</u>
   Retained pot fishery catches (live and deadloss landings data) are provided for 1973/1974 to 2011/2012 (Table 1), including the 1973/1974 to 1987/1988 and 1995/1996 to 1998/1999 seasons

when blue king crab were targeted in the Pribilof Islands District. In the 1995/1996 to 1998/1999 seasons blue king crab and red king crab were fished under the same GHL. There was no total allowable catch (TAC) and therefore zero retained catch in the 2011/2012 fishing season

b. Bycatch and discards:
Crab pot fisheries
Non-retained (directed and non-directed) pot fishery catches are provided for sub-legal males (≤138 mm CL), legal males (>138 mm CL), and females based on data collected by onboard observers. Catch weight was calculated by first determining the mean weight (g) for crabs in each of three categories: legal non-retained, sublegal, and female. The average weight for each category was calculated from length frequency tables where the CL (mm) was converted to g using equation 1. Length to weight parameters were available for two time periods: 1973 to 2009 (males: A=0.000329, B=3.175; females: A=0.114389, B=1.9192) and 2010 to 2011 (males and females: A=0.000508, B=3.106). The average weight for each category was multiplied by the number of crabs at that CL, summed, and then divided by the total number of crabs (equation 2).

$$\text{Weight (g)} = A * CL(mm)^{B} \quad (1)$$

$$\text{Mean Weight (g)} = \sum(\text{weight at size} * \text{number at size}) / \sum(\text{crabs}) \quad (2)$$

Finally, weights were the product of average weight, CPUE, and total pot lifts in the fishery. To assess crab mortalities in these pot fisheries a 50% handling mortality rate is applied to these estimates.

Historical non-retained catch data are available from 1996/1997 to present from the snow crab general, snow crab CDQ, and Tanner crab fisheries (Table 2, Bowers et al. 2011) although data may be incomplete for some of these fisheries. Prior to 1998, limited observer data exists for catcher-processor vessels only so non-retained catch before this date is not included here.

In 2011/2012, there were no Pribilof blue king crab incidentally caught in crab fisheries (Table 2).

Groundfish pot, trawl, and hook and line fisheries
The 2011/2012 NMFS Alaska Region assessments of non-retained catch from all groundfish fisheries are included in this SAFE report (J. Mondragon, NMFS, personal communication). Groundfish catches of crab are typically reported for all males and females combined by federal reporting areas. For the Pribilof Islands stock 2010-2011 bycatch data only, data from observers and data on vessel movements acquired by satellite through the Vessel Monitoring System (VMS) were integrated by NMFS/Alaska Region. This VMS-Observer Enabled Catch-In-Areas database was used to assess the spatial resolution of the observed and unobserved groundfish fisheries in the newly defined Pribilof District. The VOE-CIA database integrates catch data from the Catch Accounting System (which has the spatial resolution of a NMFS Reporting Area) into a database that resolves the GIS data into polygons with areas of approximately seven kilometers. Catches from observed fisheries were applied to non-observed fisheries to estimate a total catch. Catch counts were converted to biomass by applying the average weight measured from observed tows from July 2010 to June 2011. For Pribilof Islands blue king crab in this document, data prior to 2011/2012 only includes catch data from Area 513. It is noted that in these earlier years groundfish non-retained crab catches for Pribilof Islands blue king crab may exist in Area 521 (and other areas) but the large number of St. Mathew Section Northern District blue crab in Area 521 would overestimate the blue king crab caught in groundfish fisheries. In 2011/2012 catch data are drawn from all federal stat areas that intersect the new Pribilof Islands District. To

estimate sex ratios for 2011/2012 groundfish catches, sex ratios by size and sex from the 2011EBS bottom trawl survey were applied. To assess crab mortalities in these groundfish fisheries a 50% handling mortality rate was applied to pot and hook and line estimates and an 80% handling mortality rate was applied to trawl estimates.

Historical non-retained groundfish catch data are available from 1991/1992 to present (J. Mondragon, NMFS, personal communication) although sex ratios have not been discriminated by each year's survey proportions (Table 2).

In 2011/2012, using the old method only focused on area 513, 0.1 t of male and female blue king crab were caught in fixed gear (0.04 t) and trawl (0.13 t) gear groundfish fisheries. The targeted species in these fisheries were rock sole (*Lepidopsetta bilineata*) (74%) and Pacific cod (*Gadus macrocephalus*) (26%) (Table 3). Notably absent in 2010/2011 were catches in the yellowfin sole (*Limanda aspera*) and flathead sole (*Hippoglossoides elassodon*) fisheries. The catch was in non-pelagic trawls (78%) and longline (22%) fisheries. There was no bycatch attributed to pot fisheries. (Table 4). Using the new VOE-CIA method bycatch , 0.39 t of male and female blue king crab were caught in fixed gear (0.35 t) and trawl (0.04 t) gear groundfish fisheries. Bycatch of blue king crab was attributed to fishing vessels in areas 513, 514, 517, 521, 523, and 524. The fisheries involved in the catch were hook and line (95%), non-pelagic trawls (2%), and pelagic trawls (3%). The discrepancy between the old and new methods highlights the problems using just area 513 to attribute blue king crab bycatch. The analyses in this document use only the new method for 2011/2012 catch data.

c. Catch-at-length: NA

d. Survey biomass:
The 2012 NMFS EBS bottom trawl survey results (Foy and Armistead in press) are included in this SAFE report for the new Pribilof Islands blue king crab stock area definition (Table 5, Figure 7) and the new stock area definition which adds 20 nm to the eastern edge of the previous boundary. This new area was defined as a result of the new rebuilding plan and the concern that crab outside of the Pribilof District were not being accounted for in the assessment. The addition of the 20 nm strip resulted in a small effect on the time series. Annual differences between the previous time series and the new time series ranged from 0 to 9% (Figure 8). Abundance estimates of male and female crab are assessed for 5 mm length bins with shell condition for total abundances for each EBS stock (Figure 9). Weight (equation 1) and maturity (equation 3) schedules are applied to these abundances and summed to calculate mature male, female, and legal male biomass.

Proportion mature male = $1/(1 + (3.726 * 10^{15}) * e^{((CL(mm)+2.5) * -0.332)}$
Proportion mature female = $1/(1 + (8.495 * 10^{13}) * e^{((CL(mm)+2.5) * -0.332)}$ (3)

Historical survey data are available from 1975 to the present (Table 5). It should be noted that the survey data analyses were standardized in 1980.

In 2012, blue king crab were caught at 6 of the 77 stations in the Pribilof District; 6 stations in the high-density sampling area and zero stations in the standard-density sampling area (Foy and Armistead in press, Figure 10). Legal-sized males were caught at one station northeast of St. Paul Island with a density of 73 to 442 crab nmi$^{-2}$ (Figure 11). The 2012 biomass estimate (± 95% CI) of legal-sized males was 459 ± 579 t and abundance was 0.16 ± 0.22 million crab, representing 57% of the total male abundance and well below the average of 1,545 ± 1,264 t for the previous 20 years (Figure 7).

Blue king crab mature males were caught at 4 of the 77 stations in the Pribilof District; 3 stations in the high-density sampling area and zero stations in the standard-density sampling area and 100% of the nine mature males caught were measured. One station accounted for 79% of the mature males in the survey. The mature male biomass estimate of 644 ± 928 t represents 80% of the total male abundance with 165 ± 323 t of immature male blue king crab estimated in the Pribilof District.

In 2012, crabs caught in the 85 to 125 mm range were not observed in the past few surveys (Figure 9). The 145 mm to 155 mm CL size class surveyed in 2010 was not observed as larger crabs in 2012. Eight legal-sized male blue king crab were captured on the 2012 survey in the Pribilof District; six new hardshell males and two oldshell male were caught east of St. Paul Island.

Five mature female blue king crab were caught at different stations in the Pribilof District high-density sampling area which extrapolated to a biomass estimate of 106 ± 91 t and an abundance estimate of 0.1 ± 0.1 million crab, and represents 46% of the total female biomass. Immature female blue king crab were caught at one station northeast of St. Paul Island in the Pribilof District high-density sampling area with a biomass estimate of 122 ± 240 t. Four of the five mature female blue king crab sampled in the Pribilof District were brooding uneyed embryos, while ten immature females were in new hardshell condition and one crab had empty egg cases with an old shell. The majority of mature females with embryos had 100% full clutches.

**Analytic Approach**

1. **History of modeling approaches**
   A catch survey analysis has been used for assessing the stock in the past and is in development.

**Calculation of MMB**

Taking an average biomass across 3 years centered on the current year to calculate the MMB in the most recent year was considered to reduce the effect of high uncertainty in the survey based area swept estimates (Figure 12). In addition, this average was weighted by the inverse variance of the survey biomass estimate to account for changes in variability among years. A loess weighting function was also considered but did not fit the data trends adequately (Figure 12). An unweighted average was also considered but overfit the data in years with a large amount of variance. ***Therefore in this analysis the MMB was estimated by a three year moving average MMB weighted by the inverse variance.*** Figure 13 shows the weighted three year running average of $MMB_{mating}$ with confidence intervals and CVs used for the analyses in this SAFE. The survey time series with weighted three year moving averages for each major size class for males and females is presented in Table 6.

**Calculation of the OFL**

1. Based on available data, the ***author recommended classification for this stock is Tier 4*** for stock status level determination defined by Amendment 24 to the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 2008).

2. In Tier 4, MSY is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. In Tier 4, the fishing mortality that, if applied over the long-term, would result in MSY is approximated by $F_{MSY}{}^{proxy}$. The MSY stock size ($B_{MSY}$) is based on mature male biomass at mating ($MMB_{mating}$) which serves as an approximation for egg production. $MMB_{mating}$ is used as a basis for $B_{MSY}$ because of the complicated female crab life history, unknown sex ratios, and male only fishery. The $B_{MSY}{}^{proxy}$

represents the equilibrium stock biomass that provides maximum sustainable yield (MSY) to a fishery exploited at $F_{MSY}^{proxy}$. $B_{MSY}$ can be estimated as the average biomass over a specified period that satisfies these conditions (i.e., equilibrium biomass yielding MSY by an applied $F_{MSY}$). This is also considered a percentage of pristine biomass ($B_0$) of the unfished or lightly exploited stock. The current stock biomass reference point for status of stock determination is $MMB_{mating}$.

The mature stock biomass ratio β where $B/B_{MSY}^{prox}$ = 0.25 represents the critical biomass threshold below which directed fishing mortality is set to zero (Figure 14). The parameter α determines the slope of the non-constant portion of the control rule line and was set to 0.1. Values for α and β where based on sensitivity analysis effects on $B/B_{MSY}^{prox}$ (NPFMC 2008). The $F_{OFL}$ derivation where $B$ is greater than β includes the product of a scalar (**γ**) and $M$ (equations 5 and 6) where the default **γ** value is 1 and M for Bering Sea blue king crab is 0.18. The value of **γ** may alternatively be calculated as $F_{MSY}$/M depending on the availability of data for the stock.

Overfishing is defined as any amount of fishing in excess of a maximum allowable rate, the $F_{OFL}$ control rule resulting in a total catch greater than the OFL. For Tier 4 stocks, a minimum stock size threshold (MSST) is specified as 0.5 $B_{MSY}^{prox}$; if current MMB at the time of mating drops below MSST, the stock is considered to be overfished.

3. Calculation of $B_{MSY}^{prox}$:
The time period for establishing $B_{MSYproxy}$ was assumed to be representative of the stock being fished at an average rate near $F_{MSY}$ fluctuating around $B_{MSY}$. The criteria to select the time period was based on 2011 CPT recommendations for estimating $B_{MSY}$. Previously, $B_{MSY}^{prox}$ for Pribilof Islands blue king crab was calculated as the average $MMB_{mating}$ from 1980 to 1984 and 1990 to 1997 to avoid time periods of low abundance possibly caused by high fishing pressure. In the previous assessment, an alternative time period from 1975 to 1979 was also considered because it represents the only period where a fishery was occurring where exploitation and MMB oscillated relatively consistently over time. During the remainder of the time series, the stock was either dropping under high exploitation or recovering during a no fishing period. This alternative time period was chosen by the CPT but the SSC recommended staying with the original time series. Considerations for choosing the time series included:

   A. Production potential
      1) Between 2006 and 2012 the stock does appears to be below a threshold for responding to increased production based on the lack of response of the adult stock biomass to slight fluctuations in recruitment (male crab 120-134 mm) (Figure 15).
      2) An estimate of surplus production (ASP = $MMB_{t+1}$ – $MMB_t$ + total $catch_t$) suggested that only meaningful surplus existed in the late 1970s and early 1980s while minor surplus production in the early 1990s may have led to the increases in biomass observed in the late 1990s.
      3) Although a climate regime shift where temperature and current structure changes are likely to impact blue king crab larval dispersal and subsequent juvenile crab distribution, no apparent trends in production before and after 1978 were observed. There are few empirical data to identify trends that may allude to a production shift. However, further analysis is warranted given the paucity of surplus production and recruitment subsequent to 1981 and the spikes in recruits (male crab 120-134 mm) /spawner (MMB) observed in the early 1990s and 2009 (Figure 16).
   B. Exploitation rates fluctuated during the open fishery periods from 1975 to 1987 and 1995

to 1998 (Figure 15) while total catch increased until 1980 before the fishery was closed in 1987 and increased again in 1995 before again closing in 1999 (Figure 17). The current $F_{\mathrm{MSY}}^{\mathrm{proxy}}$ assume $F$=$M$ is 0.18 so time periods with greater exploitation rates should not be considered to represent a period with an average rate of fishery removals.

C. Subsequent to increases in exploitation rates in the late 1980s and 1990s, the ln (recruits/MMB) dropped suggesting that exploitation rates at the levels of MMB present were not sustainable.

4. OFL specification:

a. In the Tier 4 OFL-setting approach, the "total catch OFL" and the "retained catch OFL" are calculated by applying the $F_{\mathrm{OFL}}$ to all crab at the time of the fishery (total catch OFL) or to the mean retained catch determined for a specified period of time (retained catch OFL). The $F_{\mathrm{OFL}}$ is derived using a Maximum Fishing Mortality Threshold (MFMT) or $F_{\mathrm{OFL}}$ Control Rule (Figure 14) where Stock Status Level (level a, b or c; equations 4-6) is based on the relationship of current mature stock biomass (B) to $B_{\mathrm{MSY}}^{\mathrm{proxy}}$.

| Stock Status Level: | $F_{\mathrm{OFL}}$: | |
|---|---|---|
| a. $B/B_{\mathrm{MSY}}^{\mathrm{prox}} > 1.0$ | $F_{\mathrm{OFL}} = \gamma \cdot M$ | (4) |
| b. $\beta < B/B_{\mathrm{MSY}}^{\mathrm{prox}} \leq 1.0$ | $F_{\mathrm{OFL}} = \gamma \cdot M\,[(B/B_{\mathrm{MSY}}^{\mathrm{prox}} - \alpha)/(1 - \alpha)]$ | (5) |
| c. $B/B_{\mathrm{MSY}}^{\mathrm{prox}} \leq \beta$ | $F_{\mathrm{directed}} = 0;\ F_{\mathrm{OFL}} \leq F_{\mathrm{MSY}}$ | (6) |

b. The $\mathrm{MMB}_{\mathrm{mating}}$ projection is based on application of $M$ from the 2012 NMFS trawl survey (July 15) to mating (February 15) and the removal of estimated retained, bycatch, and discarded catch mortality (equation 7). Catch mortalities are estimated from the proportion of catch mortalities in 2010/2011 to the 2011 survey biomass.

$$\mathrm{MMB}_{\mathrm{survey}} \cdot e^{-\mathrm{PM(sm)}} - (\text{projected legal male catch OFL})\text{-}(\text{projected non-retained catch}) \qquad (7)$$

where, $\mathrm{MMB}_{\mathrm{survey}}$ is the mature male biomass at the time of the survey, $e^{-\mathrm{PM(sm)}}$ is the survival rate from the survey to mating. PM(sm) is the partial $M$ from the time of the survey to mating (8 months).

c. To project a total catch OFL for the upcoming crab fishing season, the $F_{\mathrm{OFL}}$ is estimated by an iterative solution that maximizes the projected $F_{\mathrm{OFL}}$ and projected catch based on the relationship of B to $B_{\mathrm{MSY}}^{\mathrm{prox}}$. B is approximated by MMB at mating (equation 7).

For a total catch OFL, the annual fishing mortality rate ($F_{\mathrm{OFL}}$) is applied to the total crab biomass at the fishery (equation 8).

$$\text{Projected Total Catch OFL} = [1 - e^{-F\mathrm{ofl}}] \cdot \text{Total Crab Biomass}_{\mathrm{fishery}} \qquad (8)$$

where $[1 - e^{-F\mathrm{ofl}}]$ is the annual fishing mortality rate.

Exploitation rates on legal male biomass ($\mu_{\mathrm{LMB}}$) and mature male biomass ($\mu_{\mathrm{MMB}}$) at the time of the fishery are calculated as:

$$\mu_{\mathrm{LMB}} = [\text{Total LMB retained and non-retained catch}] / \mathrm{LMB}_{\mathrm{fishery}} \qquad (9)$$

$$\mu_{\mathrm{MMB}} = [\text{Total MMB retained and non-retained catch}] / \mathrm{MMB}_{\mathrm{fishery}} \qquad (10)$$

5. Specification of the retained catch portion of the total catch OFL:
   a. For a retained catch OFL, the annual fishing mortality rate ($F_{OFL}$) is applied to the legal crab biomass at the fishery (equation 11).

   $$\text{Projected Retained Catch OFL} = [1 - e^{-F_{ofl}}] \cdot \text{Legal Crab Biomass}_{\text{Fishery}} \quad (11)$$

   where $[1 - e^{-F_{ofl}}]$ is the annual fishing mortality rate.

6. Recommendations:
   For 2011/2012, ***$B_{MSY}^{prox}$ = 3,944 t of $MMB_{mating}$ derived as the mean MMB from 1980 to 1984 and 1990 to 1997***. The stock demonstrated highly variable levels of MMB during both of these periods likely leading to uncertain approximations of $B_{MSY}$. Crabs were highly concentrated during the EBS bottom trawl surveys and male biomass estimates were characterized by poor precision due to a limited number of tows with crab catches.

   ***$MMB_{mating}$ for 2012/2013 was estimated at 496 t for $B_{MSY}^{prox}$. The $B/B_{MSY}^{prox}$ ratio corresponding to the biomass reference is 0.13***. $B/B_{MSY}^{prox}$ is < β, therefore the ***stock status level is c, $F_{directed} = 0$, and $F_{OFL} \leq F_{MSY}$*** (as determined in the Pribilof Islands District blue king crab rebuilding plan). Total catch OFL calculations were explored in 2008 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality (NPFMC 2008). The preferred method was a total catch OFL equivalent to the average catch mortalities between 1999/2000 and 2005/2006. This period was after a targeted fishery and did not include the most recent changes to the groundfish fishery that led to increased blue king crab bycatch. ***The author recommended OFL for 2011/2012 based on an average catch mortality is 1.16 t***. An alternative to establish a biomass based OFL the existing control rule was applied to MMB and $B_{MSY}^{prox}$ to derive an $F_{OFL} \leq F_{MSY}$ which was then applied to the total blue king crab biomass. The alternative OFL for 2012/2013 is 2.71 t. The $F_{OFL}$ corresponding to the biomass reference and the control rule with this alternative scenario was 0.005.

**Calculation of the ABC**

1. To calculate an Annual Catch Limit (ACL) to account for scientific uncertainty in the OFL, an acceptable biological catch (ABC) control rule was developed such that ACL=ABC. For Tier 3 and 4 stocks, the ABC is set below the OFL by a proportion based a predetermined probability that the ABC would exceed the OFL (P*). Currently, P* is set at 0.49 and represents a proportion of the OFL distribution that accounts for within assessment uncertainty ($\sigma_w$) in the OFL to establish the maximum permissible ABC ($ABC_{max}$). Any additional uncertainty to account for uncertainty outside of the assessment methods ($\sigma_b$) will be considered as a recommended ABC below $ABC_{max}$. Additional uncertainty will be included in the application of the ABC by adding the uncertainty components as $\sigma_{\text{total}} = \sqrt{\sigma_b^2 + \sigma_w^2}$. For a Tier 5 stock a constant buffer of 10% is applied to the OFL.

   <u>Specification of the probability distribution of the OFL used in the ABC:</u>
   The OFL was set based on a Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/2006 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality.

   An alternative approach was considered with the OFL calculated based on the control rule for total crab biomass. A distribution for the OFL which quantifies uncertainty was constructed using bootstrapping methods approximating the lognormal distribution. This involves generating values for $M$ and annual $MMB_{mating}$ (e.g. by assuming that MMB is log-normally distributed and $M$ is normally distributed) and for each simulation calculating the OFL using the standard methods in sections 3 and 4 of the OFL Calculation section above. The OFL distribution for Pribilof Island red king crab is skewed to the right due to the patchy spatial distribution and small abundance which affects the variability of density estimates among trawl survey stations. This lognormal distribution suggests that use of the mean value (as opposed to the median) of the distribution would be appropriate as it changes with greater variability.

2. <u>List of variables related to scientific uncertainty considered in the OFL probability distribution:</u>
   Compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands blue king crab is very high due to insufficient data and the small distribution of the stock relative to the survey sampling density. The coefficient of variation for the estimate of mature male biomass from the surveys for the most recent year is 0.74 and has ranged between 0.17 and 0.80 in since the 1980 peak in biomass.

3. <u>List of additional uncertainties considered for alternative $\sigma_b$ applications to the ABC.</u>
   Several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:
   - Survey catchability and natural mortality uncertainties are not estimated but are rather pre-specified.
   - $F_{msy}$ is assumed to be equal to $\gamma M$ when applying the OFL control rule while $\gamma$ is assumed to be equal to 1 and $M$ is assumed to be known.
   - The coefficients of variation for the survey estimates of abundance for this stock are very high.
   - $B_{msy}$ is assumed to be equivalent to average mature male biomass. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1973-1987 and 1995-1998 so considerable uncertainty exists with this estimate of $B_{msy}$.

   *Given the relative amount of information available for Pribilof Island's blue king crab, the author recommended ABC would include an additional $\sigma_b$ of 0.4.*

4. Recommendations:
   For 2012/2013, $F_{directed} = 0$ and the total catch OFL based on catch biomass would maintain the conservation needs with this stock and acknowledge the existing non-directed catch mortality. In that case the ***$ABC_{max}$ based on a 10% buffer of the average catch between 1999/2000 and 2005/2006 would be 1.04 t.*** Considering the alternative using the OFL based on the control rule for total crab biomass, the multiplier equivalent to a P* of 0.49 was 0.37. The alternative $ABC_{max}$ was thus estimated to be 1.00 t. Incorporating additional uncertainty by applying a $\sigma_b$ of 0.4 resulted in a multiplier of 0.28 and an ABC of 0.75 t.

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2009/10 | 2,105 | 401[A] | 0 | 0 | 0.45 | 1.81 | |
| 2010/11 | 2,105 | 286[B] | 0 | 0 | 0.18 | 1.81 | |
| 2011/12 | 2,247 | 365[C] | 0 | 0 | 0.36 | 1.16 | 1.04 |
| 2012/13 | | 496[D] | | | | 1.16 | 1.04 |

All units are tons of crabs and the OFL is a total catch OFL for each year. The stock was below MSST in 2011/12 and is hence overfished. Overfishing did not occur during the 2011/12 fishing year.

Notes:

A – Based on survey data available to the Crab Plan Team in September 2009 and updated with 2009/2010 catches
B – Based on survey data available to the Crab Plan Team in September 2010 and updated with 2010/2011 catches
C – Based on survey data available to the Crab Plan Team in September 2011 and updated with 2011/2012 catches
D – Based on survey data available to the Crab Plan Team in September 2012

**Rebuilding Analyses**

Under the current rebuilding plan, this stock has to recover to the $B_{MSY}$ proxy in 2011/2012 and 2012/2013 to be defined as rebuilt. As the 2009/10 mature male biomass was smaller than $B_{MSY}$ and has not shown signs of recovery in an adequate timeframe, the stock was deemed likely fail to recover as planned. A new rebuilding plan was developed and is in final review with the Secretary of Commerce.

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Table 1. Total retained catches from directed fisheries for Pribilof Islands District blue king crab (Bowers et al. 2011; D. Pengilly, ADF&G, personal communications).

| Year | Catch (count) | Catch (t) | Avg CPUE (legal crab count/pot) |
|---|---|---|---|
| 1973/1974 | 174,420 | 579 | 26 |
| 1974/1975 | 908,072 | 3224 | 20 |
| 1975/1976 | 314,931 | 1104 | 19 |
| 1976/1977 | 855,505 | 2999 | 12 |
| 1977/1978 | 807,092 | 2929 | 8 |
| 1978/1979 | 797,364 | 2901 | 8 |
| 1979/1980 | 815,557 | 2719 | 10 |
| 1980/1981 | 1,497,101 | 4976 | 9 |
| 1981/1982 | 1,202,499 | 4119 | 7 |
| 1982/1983 | 587,908 | 1998 | 5 |
| 1983/1984 | 276,364 | 995 | 3 |
| 1984/1985 | 40,427 | 139 | 3 |
| 1985/1986 | 76,945 | 240 | 3 |
| 1986/1987 | 36,988 | 117 | 2 |
| 1987/1988 | 95,130 | 318 | 2 |
| 1988/1989 | 0 | 0 | 0 |
| 1989/1990 | 0 | 0 | 0 |
| 1990/1991 | 0 | 0 | 0 |
| 1991/1992 | 0 | 0 | 0 |
| 1992/1993 | 0 | 0 | 0 |
| 1993/1994 | 0 | 0 | 0 |
| 1994/1995 | 0 | 0 | 0 |
| 1995/1996 | 190,951 | 628 | 5 |
| 1996/1997 | 127,712 | 425 | 4 |
| 1997/1998 | 68,603 | 232 | 3 |
| 1998/1999 | 68,419 | 234 | 3 |
| 1999/2000 to 2011/2012 | 0 | 0 | 0 |

Table 2. Non-retained total catch mortalities from directed and non-directed fisheries for Pribilof Islands District blue king crab. Handling mortalities (pot and hook/line= 0.5, trawl = 0.8) were applied to the catches. Groundfish fishery data is not available prior to 1991/1992 and ADF&G catch data is not available prior to 1996/1997 (Bowers et al. 2011; D. Pengilly, ADF&G; J. Mondragon, NMFS). ***New calculation of bycatch using AKRO catch in areas database in areas 513, 514, 517, 521, 523, and 524 that overlap with the Pribilof Island District.**

| | Crab pot fisheries | | | Groundfish fisheries | |
|---|---|---|---|---|---|
| Year | Legal male non-retained (t) | Sublegal male (t) | Female (t) | All fixed (t) | All Trawl (t) |
| 1991/1992 | | | | 0.03 | 4.96 |
| 1992/1993 | | | | 0.44 | 48.63 |
| 1993/1994 | | | | 0.00 | 27.39 |
| 1994/1995 | | | | 0.02 | 5.48 |
| 1995/1996 | | | | 0.05 | 1.03 |
| 1996/1997 | 0.00 | 0.40 | 0.00 | 0.02 | 0.05 |
| 1997/1998 | 0.00 | 0.00 | 0.00 | 0.73 | 0.10 |
| 1998/1999 | 1.15 | 0.23 | 1.86 | 9.90 | 0.06 |
| 1999/2000 | 1.75 | 2.15 | 0.99 | 0.40 | 0.02 |
| 2000/2001 | 0.00 | 0.00 | 0.00 | 0.06 | 0.02 |
| 2001/2002 | 0.00 | 0.00 | 0.00 | 0.42 | 0.02 |
| 2002/2003 | 0.00 | 0.00 | 0.00 | 0.04 | 0.24 |
| 2003/2004 | 0.00 | 0.00 | 0.00 | 0.17 | 0.18 |
| 2004/2005 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 |
| 2005/2006 | 0.00 | 0.00 | 0.05 | 0.18 | 1.07 |
| 2006/2007 | 0.00 | 0.00 | 0.05 | 0.07 | 0.06 |
| 2007/2008 | 0.00 | 0.00 | 0.05 | 2.00 | 0.11 |
| 2008/2009 | 0.00 | 0.00 | 0.00 | 0.07 | 0.38 |
| 2009/2010 | 0.00 | 0.00 | 0.00 | 0.17 | 0.43 |
| 2010/2011 | 0.00 | 0.09 | 0.00 | 0.07 | 0.02 |
| 2011/2012 | 0.00 | 0.00 | 0.00 | 0.02 | 0.10 |
| ***2011/2012** | | | | **0.35** | **0.01** |

Table 3. Proportion of the Pribilof Islands blue king crab bycatch from area 513 among target species between 2003/2004 and 2011/2012 crab fishing seasons.

| Crab fishing season | Yellowfin sole % | Pacific cod % | Flathead sole % | Rocksole % | TOTAL (# crabs) |
|---|---|---|---|---|---|
| 2003/2004 | 47 | 22 | 31 | | 252 |
| 2004/2005 | | 100 | | | 259 |
| 2005/2006 | | 97 | 3 | | 757 |
| 2006/2007 | 54 | 20 | | 26 | 96 |
| 2007/2008 | 3 | 96 | 1 | | 2,950 |
| 2008/2009 | 77 | 23 | | | 295 |
| 2009/2010 | 51 | 39 | 10 | | 487 |
| 2010/2011 | | 86 | 14 | | 256 |
| 2011/2012 | | 26 | | 74 | 117 |

Table 4. Proportion of the Pribilof Islands blue king crab bycatch from area 513 among gear types between 2003/2004 and 2011/2012 crab fishing seasons. ***New calculation of bycatch using AKRO catch in areas database in areas 513, 514, 517, 521, 523, and 524 that overlap with the Pribilof Island District.**

| Crab fishing season | hook and line % | non-pelagic trawl % | pot % | Pelagic trawl % | TOTAL (# crabs) |
|---|---|---|---|---|---|
| 2003/04 | 21 | 79 | 0 | | 252 |
| 2004/05 | 99 | 1 | 0 | | 259 |
| 2005/06 | 18 | 3 | 79 | | 757 |
| 2006/07 | 20 | 20 | 0 | | 96 |
| 2007/08 | 1 | 3 | 95 | | 2,950 |
| 2008/09 | 23 | 77 | 0 | | 295 |
| 2009/10 | 21 | 61 | 18 | | 487 |
| 2010/11 | 4 | 14 | 83 | | 256 |
| 2011/12 | 22 | 78 | 0 | | 117 |
| **2011/12*** | **95** | **2** | **0** | **3** | **494** |

Table 5. Pribilof Islands District blue king crab abundance, mature biomass, legal male biomass, and totals estimated based on the NMFS annual EBS bottom trawl survey with no running average.

| Year | Mature Male Abundance | Mature males @ survey t | Mature males @ mating t | Legal Males @ survey t | Total males @ survey t | Total females @ survey t |
|---|---|---|---|---|---|---|
| 1975/1976 | 15019937 | 34051 | 29138 | 24267 | 41393 | 12166 |
| 1976/1977 | 3549948 | 9543 | 5575 | 8595 | 13304 | 5773 |
| 1977/1978 | 13043983 | 38756 | 31552 | 36706 | 42137 | 13572 |
| 1978/1979 | 6140638 | 15798 | 11217 | 12291 | 18315 | 6492 |
| 1979/1980 | 5275966 | 13261 | 9142 | 11198 | 14582 | 4138 |
| 1980/1981 | 5630220 | 14782 | 8318 | 12418 | 16376 | 63676 |
| 1981/1982 | 3897456 | 10675 | 5501 | 9617 | 12893 | 9923 |
| 1982/1983 | 2286666 | 6584 | 3915 | 6185 | 7633 | 9376 |
| 1983/1984 | 1822397 | 4867 | 3359 | 4069 | 5744 | 10248 |
| 1984/1985 | 609592 | 1615 | 1298 | 1342 | 1713 | 2580 |
| 1985/1986 | 428076 | 959 | 620 | 687 | 995 | 523 |
| 1986/1987 | 480198 | 1368 | 1101 | 1340 | 1372 | 2394 |
| 1987/1988 | 903180 | 2659 | 2051 | 2529 | 2833 | 913 |
| 1988/1989 | 237868 | 766 | 679 | 766 | 920 | 697 |
| 1989/1990 | 239948 | 752 | 667 | 752 | 1914 | 1746 |
| 1990/1991 | 1676791 | 3121 | 2768 | 1411 | 5196 | 3806 |
| 1991/1992 | 1980317 | 4203 | 3725 | 3025 | 5458 | 2779 |
| 1992/1993 | 1922884 | 3982 | 3508 | 2790 | 5636 | 2649 |
| 1993/1994 | 1844170 | 4072 | 3599 | 2841 | 5064 | 2092 |
| 1994/1995 | 1263447 | 3028 | 2683 | 2491 | 3578 | 4858 |
| 1995/1996 | 3111858 | 7696 | 6220 | 6307 | 8558 | 4843 |
| 1996/1997 | 1712015 | 4221 | 3334 | 3522 | 4864 | 5585 |
| 1997/1998 | 1201296 | 2940 | 2384 | 2515 | 3288 | 3028 |
| 1998/1999 | 938796 | 2453 | 1944 | 2191 | 3083 | 2182 |
| 1999/2000 | 588718 | 1476 | 1308 | 1201 | 1623 | 2868 |
| 2000/2001 | 725050 | 1902 | 1687 | 1588 | 2005 | 1462 |
| 2001/2002 | 522239 | 1454 | 1289 | 1329 | 1533 | 1817 |
| 2002/2003 | 225476 | 618 | 548 | 588 | 618 | 1401 |
| 2003/2004 | 228897 | 638 | 566 | 610 | 656 | 1307 |
| 2004/2005 | 47905 | 97 | 86 | 44 | 130 | 121 |
| 2005/2006 | 91932 | 313 | 277 | 313 | 610 | 847 |
| 2006/2007 | 50638 | 137 | 122 | 115 | 205 | 553 |
| 2007/2008 | 100295 | 254 | 224 | 170 | 417 | 257 |
| 2008/2009 | 18256 | 42 | 37 | 42 | 235 | 672 |
| 2009/2010 | 248626 | 452 | 401 | 170 | 684 | 625 |
| 2010/2011 | 138787 | 322 | 286 | 202 | 420 | 433 |
| 2011/2012 | 165525 | 461 | 409 | 399 | 461 | 37 |
| 2012/2013 | 272233 | 644 | | 459 | 809 | 229 |

Table 6. Three year weighted running average of Pribilof Islands District blue king crab abundance, mature biomass, and legal male biomass based on the NMFS annual EBS bottom trawl survey.

| Year | Mature Male Abundance | Mature males @ survey t | Mature males @ mating t | Legal Males @ survey t | Mature females @ survey t |
|---|---|---|---|---|---|
| 1975/1976 | 3985164 | 10839 | 8550 | 9871 | 3195 |
| 1976/1977 | 4186551 | 11299 | 7133 | 10251 | 3509 |
| 1977/1978 | 4220720 | 11035 | 6966 | 9584 | 3504 |
| 1978/1979 | 5552737 | 13878 | 9514 | 11531 | 3260 |
| 1979/1980 | 5486563 | 13968 | 9769 | 11703 | 3155 |
| 1980/1981 | 4293173 | 11673 | 5561 | 10341 | 3525 |
| 1981/1982 | 2836178 | 8334 | 3424 | 7720 | 8598 |
| 1982/1983 | 2262128 | 6220 | 3592 | 5233 | 8636 |
| 1983/1984 | 940946 | 2686 | 1424 | 2167 | 2805 |
| 1984/1985 | 590683 | 1401 | 1108 | 1014 | 636 |
| 1985/1986 | 494071 | 1223 | 854 | 912 | 647 |
| 1986/1987 | 475461 | 1133 | 892 | 853 | 590 |
| 1987/1988 | 369370 | 1165 | 727 | 1153 | 558 |
| 1988/1989 | 278353 | 901 | 799 | 902 | 589 |
| 1989/1990 | 260312 | 879 | 780 | 904 | 633 |
| 1990/1991 | 359228 | 1250 | 1109 | 1157 | 1057 |
| 1991/1992 | 1861142 | 3763 | 3335 | 1840 | 1909 |
| 1992/1993 | 1903111 | 4135 | 3644 | 2867 | 1733 |
| 1993/1994 | 1539687 | 3572 | 3155 | 2691 | 1767 |
| 1994/1995 | 1535984 | 3632 | 3219 | 2779 | 2267 |
| 1995/1996 | 1520530 | 3713 | 2688 | 3084 | 4694 |
| 1996/1997 | 1428055 | 3480 | 2677 | 2951 | 3565 |
| 1997/1998 | 1118738 | 2943 | 2386 | 2542 | 2283 |
| 1998/1999 | 812803 | 2166 | 1689 | 1764 | 2239 |
| 1999/2000 | 733933 | 1948 | 1726 | 1574 | 1737 |
| 2000/2001 | 635555 | 1696 | 1504 | 1371 | 1740 |
| 2001/2002 | 336836 | 954 | 846 | 905 | 1490 |
| 2002/2003 | 237187 | 658 | 583 | 628 | 1447 |
| 2003/2004 | 72140 | 138 | 122 | 71 | 127 |
| 2004/2005 | 67024 | 134 | 118 | 70 | 142 |
| 2005/2006 | 52721 | 119 | 105 | 68 | 147 |
| 2006/2007 | 60960 | 171 | 152 | 147 | 309 |
| 2007/2008 | 29890 | 67 | 59 | 67 | 316 |
| 2008/2009 | 23986 | 57 | 50 | 70 | 308 |
| 2009/2010 | 28621 | 69 | 61 | 80 | 419 |
| 2010/2011 | 154495 | 357 | 317 | 195 | 26 |
| 2011/2012 | 153347 | 364 | 322 | 238 | 40 |
| 2012/2013 | 194065 | 535 | | 434 | 37 |

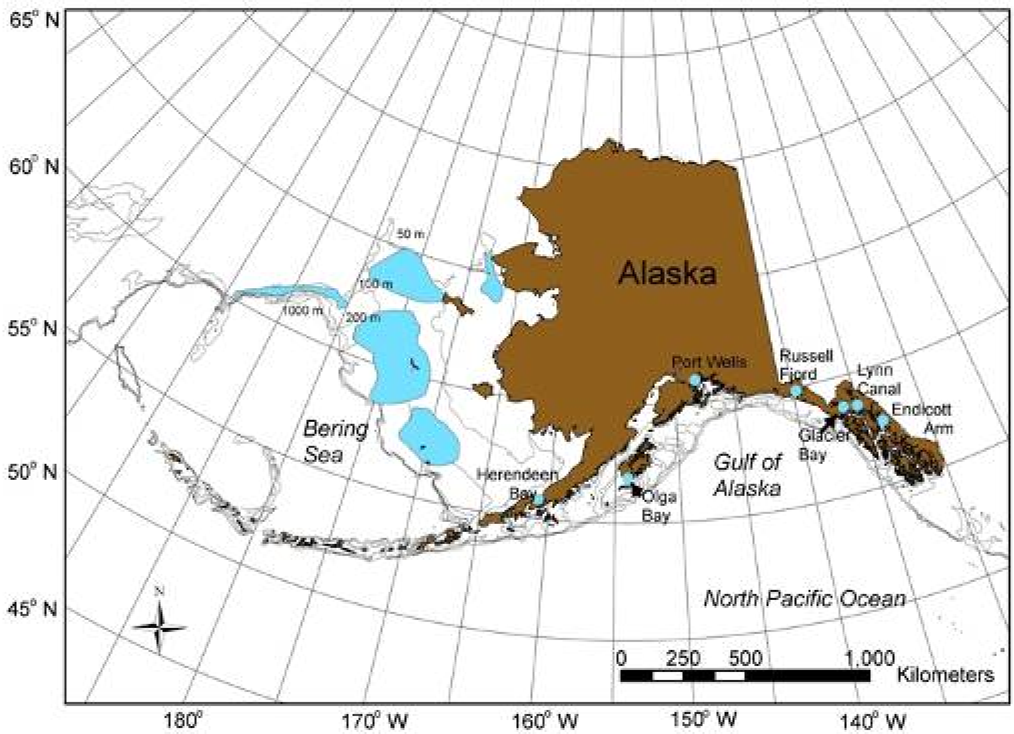


Figure 1. Distribution of blue king crab (*Paralithodes platypus*) in Alaskan waters.

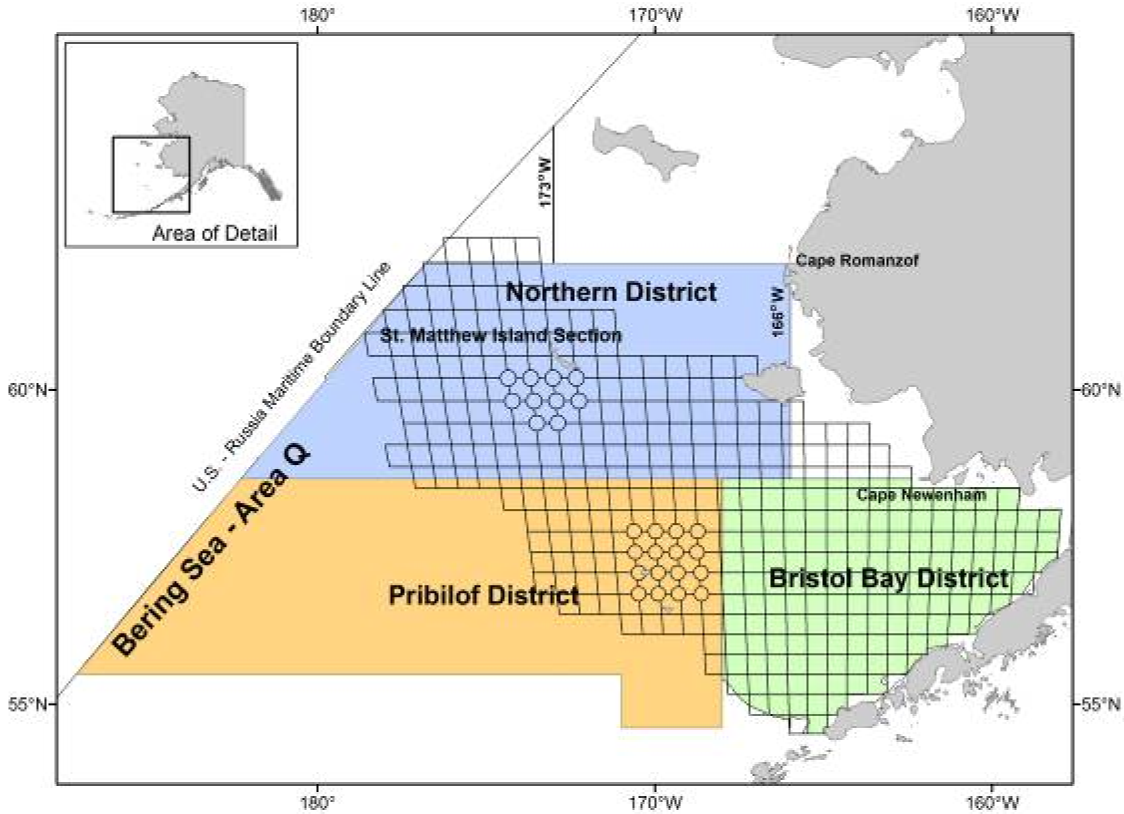


Figure 2. King crab Registration Area Q (Bering Sea) showing the Pribilof District. This figure does not show the additional 20 nm strip considered this year for biomass and catch data in the Pribilof District.

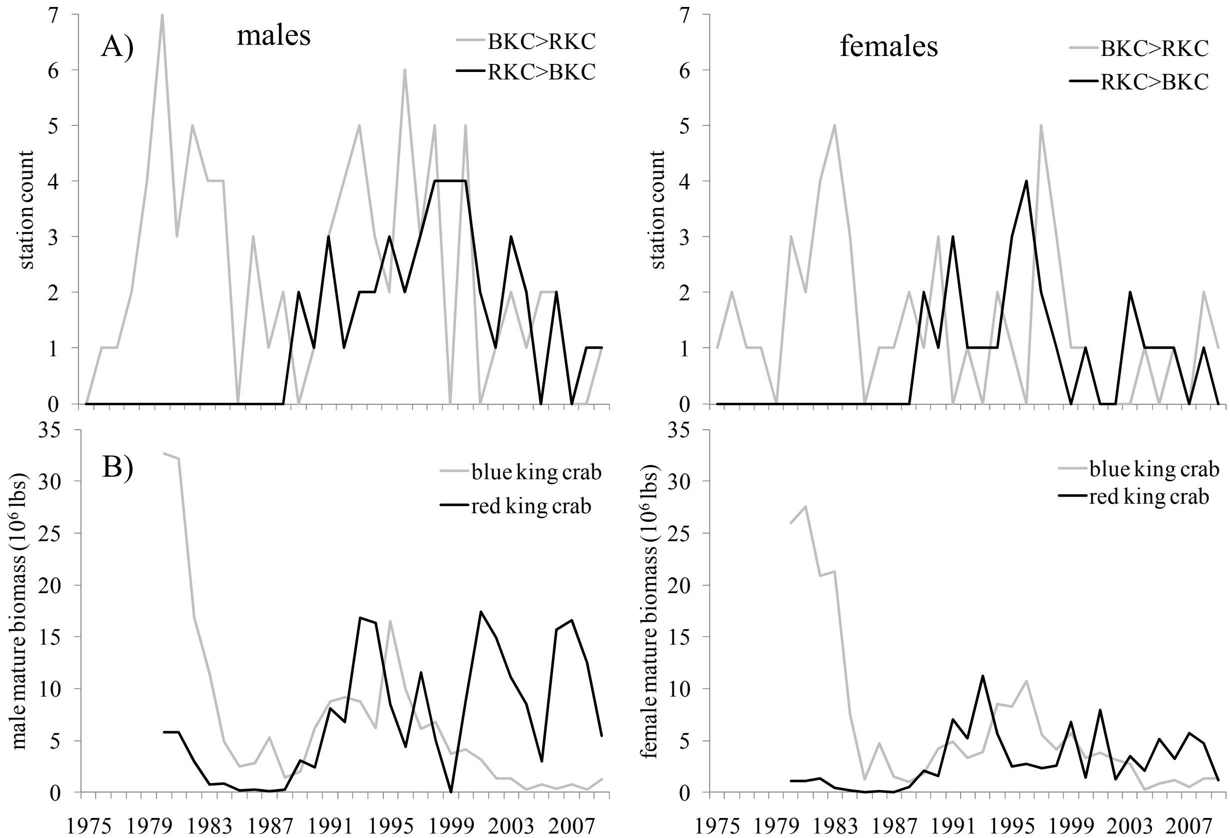


Figure 1. Time series of overlap between blue king crab and red king crab for males and females in the eastern Bering Sea showing A) the number of stations with blue king crab (BKC) or red king crab (RKC) as the dominant species and B) the mature biomass of both species.

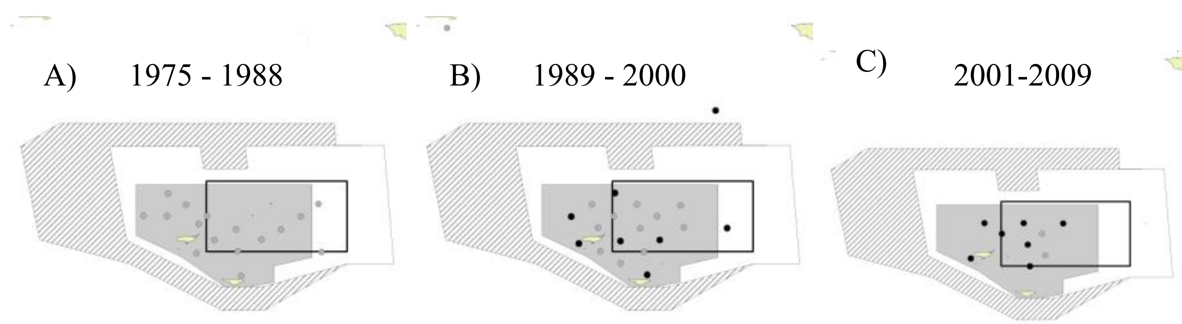


Figure 4. Spatial distribution of stations where there is overlap between blue king crab and red king crab males showing the dominant species (blue king crab=gray circles; red king crab=black circles) corresponding to time periods of major changes in biomass of both species.

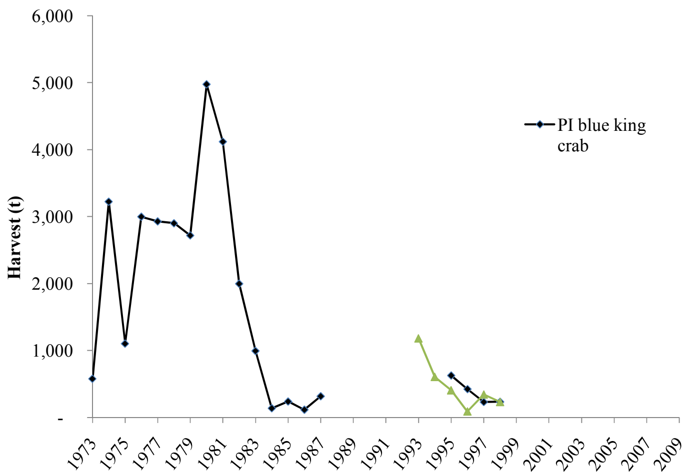


Figure 5. Historical harvests (t) and GHLs for Pribilof Island blue and red king crab (Bowers et al. 2011).

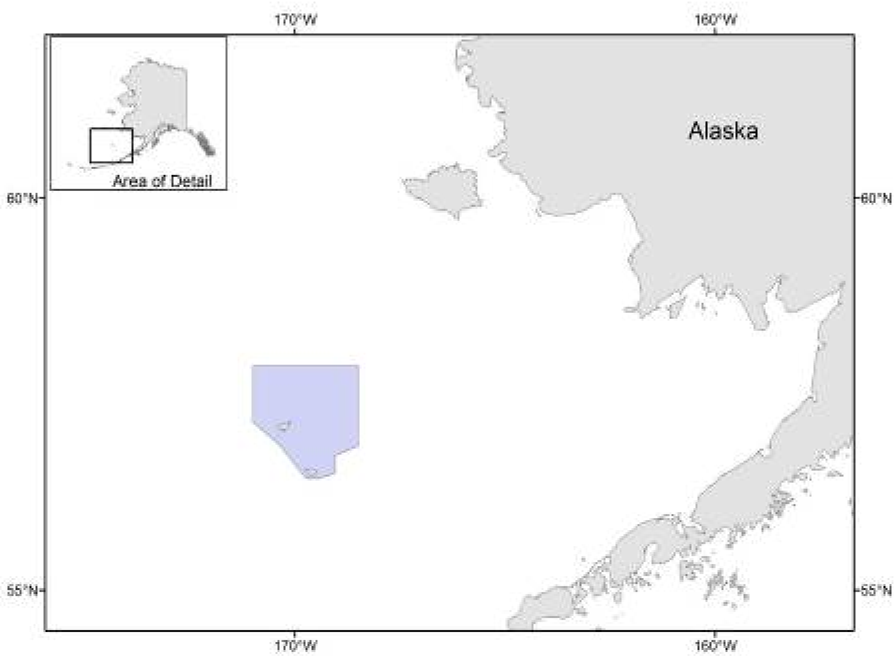


Figure 6. The shaded area shows the Pribilof Islands Habitat Conservation area. Trawl fishing is prohibited year-round in this zone.

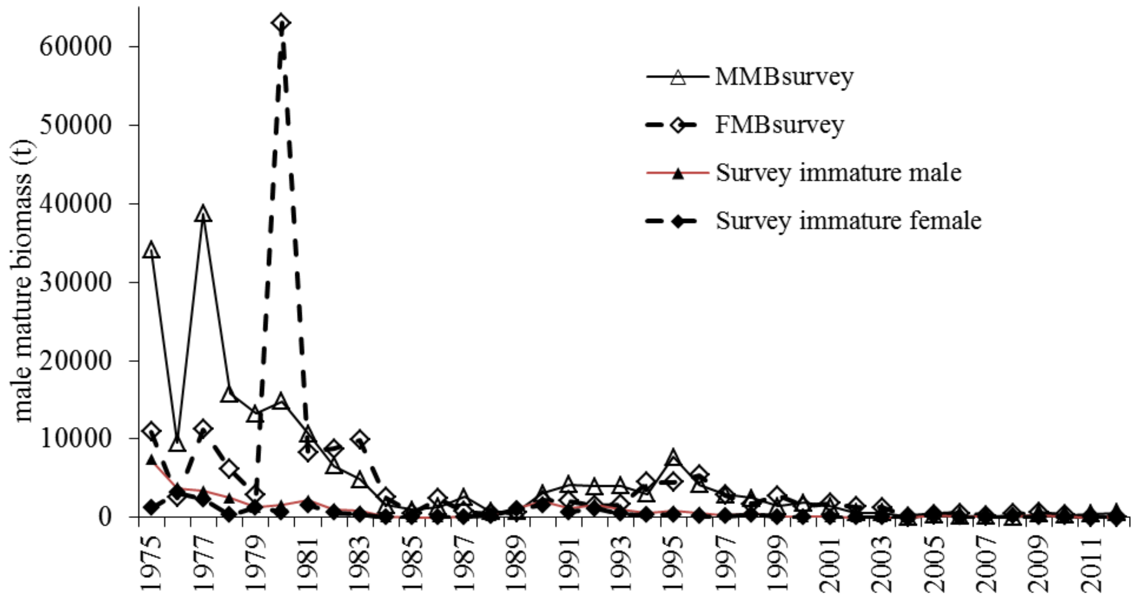


Figure 7. Time series of Pribilof Island blue king crab estimated from the NMFS annual EBS bottom trawl survey.

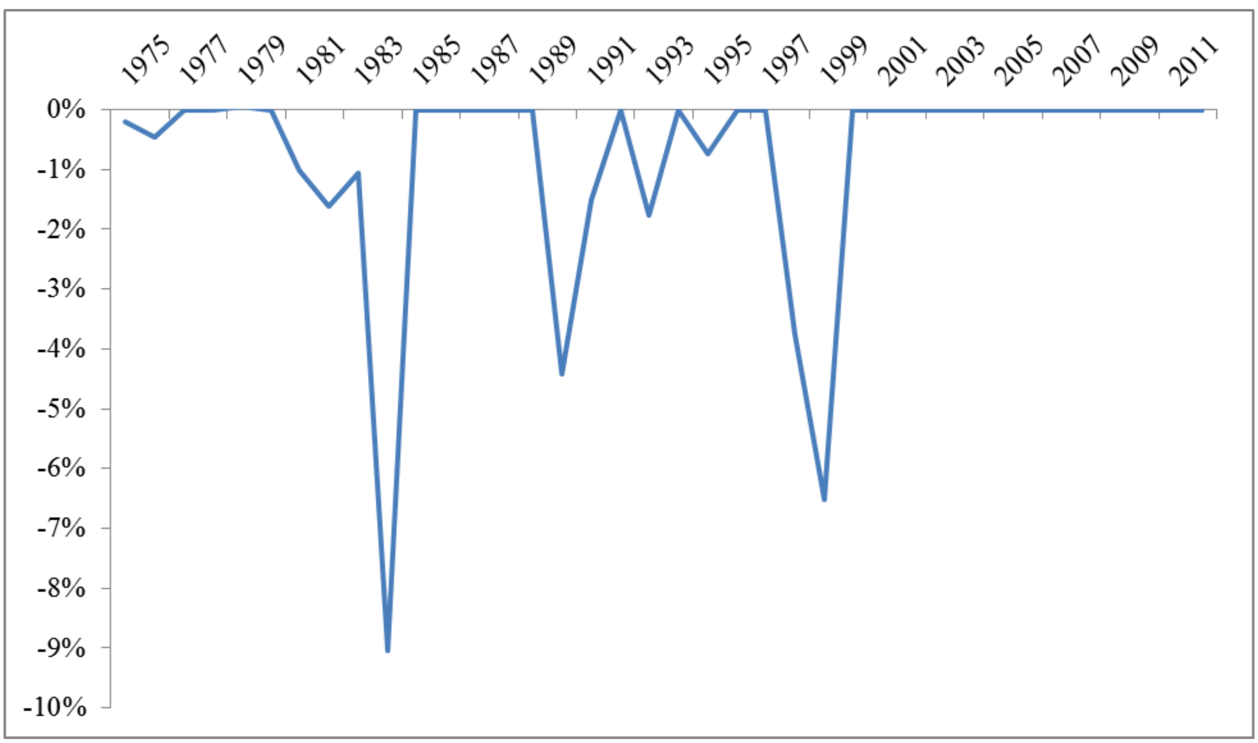


Figure 8. Percent change in MMB between the previous survey biomass estimate and the new estimate which includes an additional region 20 nm on the eastern edge of the Pribilof District.

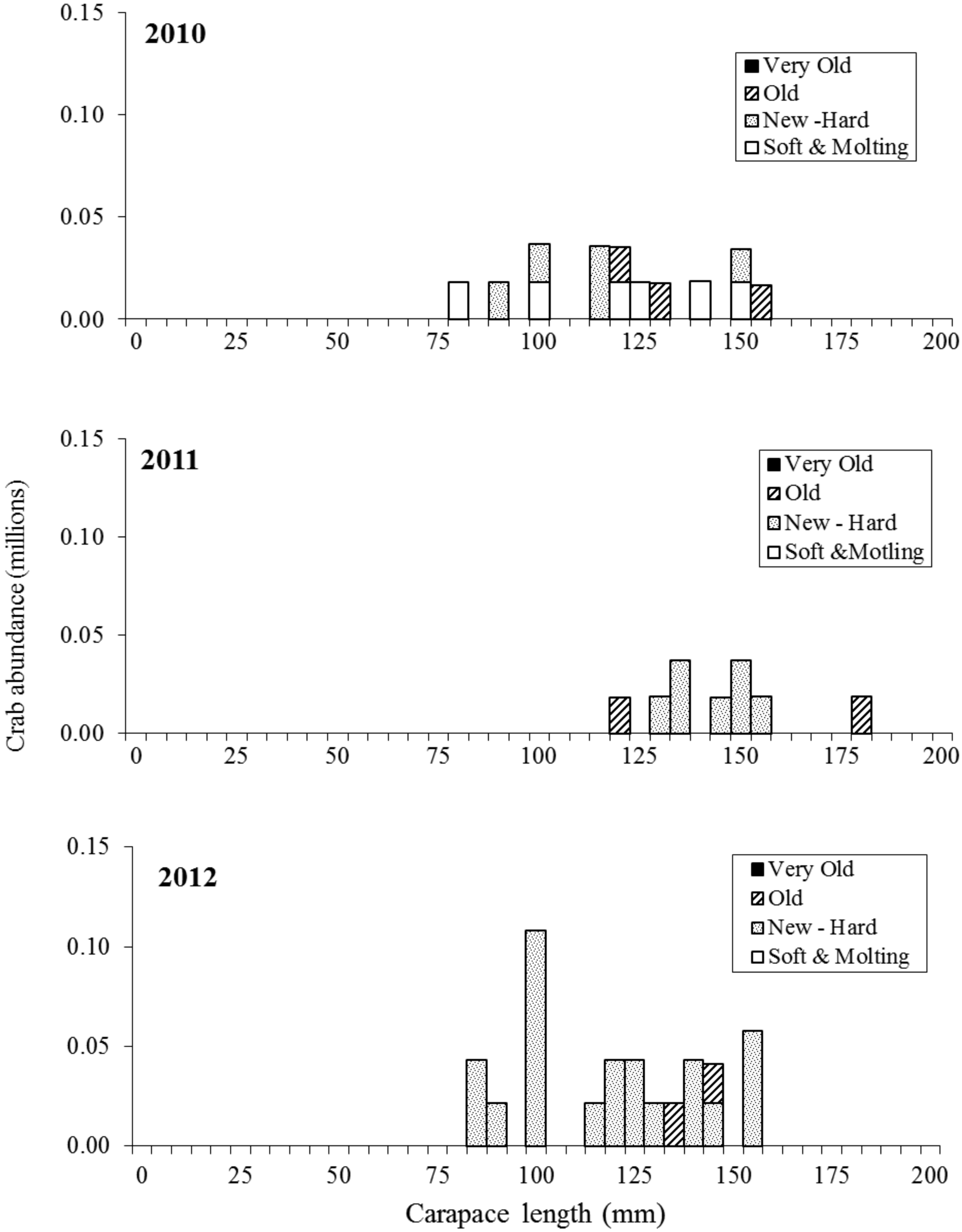


Figure 9. Distribution of Pribilof Island blue king crab in 5 mm length bins by shell condition for the last 3 surveys.

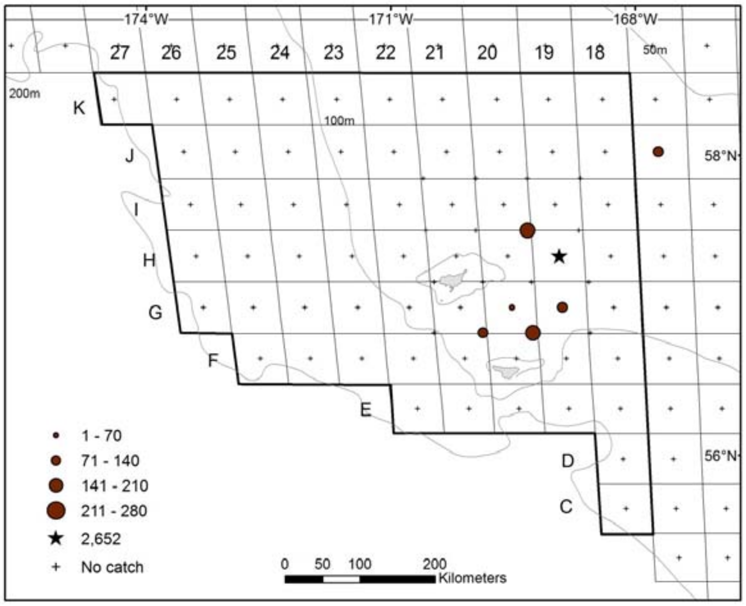


Figure 10. Total density (number/nm$^2$) of blue king crab in the Pribilof District in the 2012 EBS bottom trawl survey.

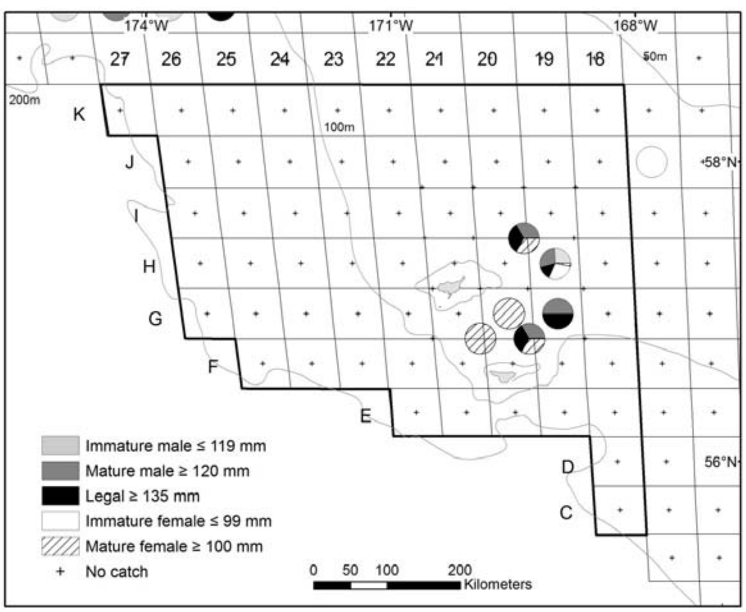


Figure 11. 2012 EBS bottom trawl survey size class distribution of blue king crab in the Pribilof District.

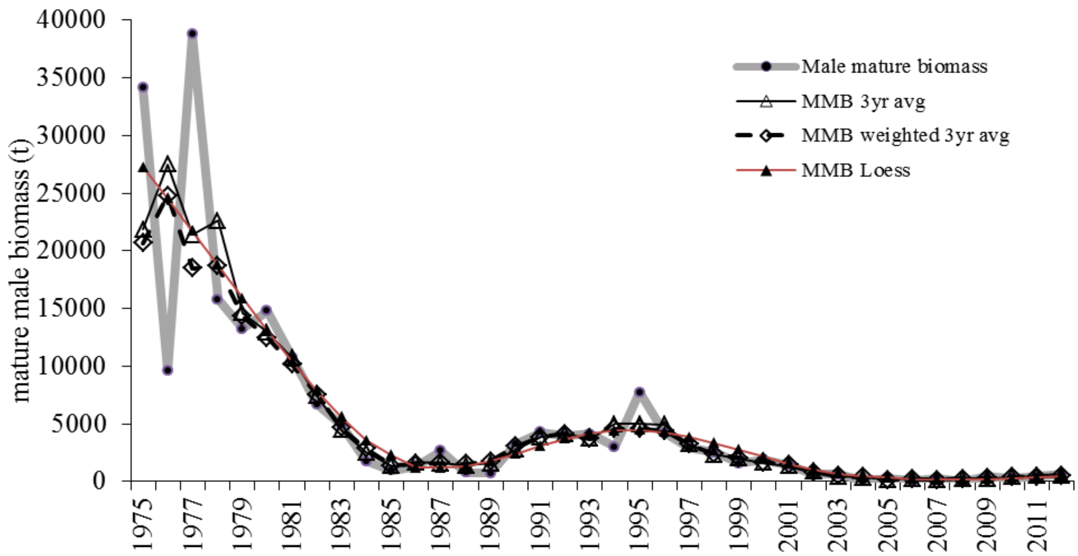


Figure 12. Time series comparison of MMB and the three year running average MMB at the time of the survey.

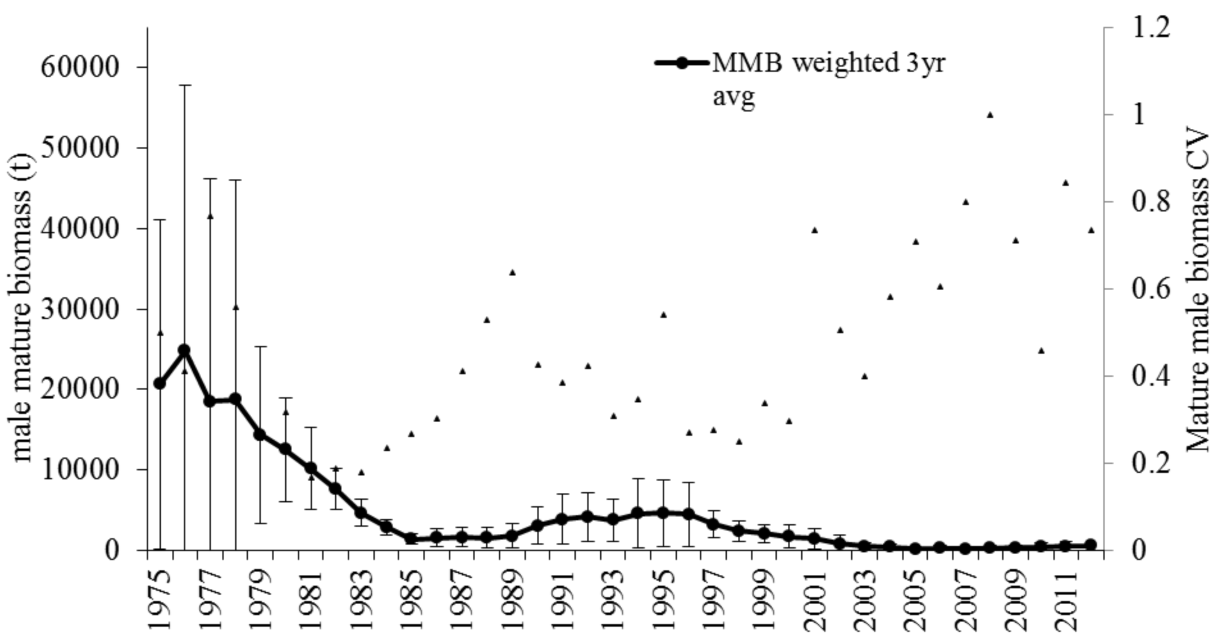


Figure 13. Time series of Pribilof Island blue king crab 3 year moving averaged mature male biomass (95% C.I.) and mature male biomass CV estimated from the NMFS annual EBS bottom trawl survey.

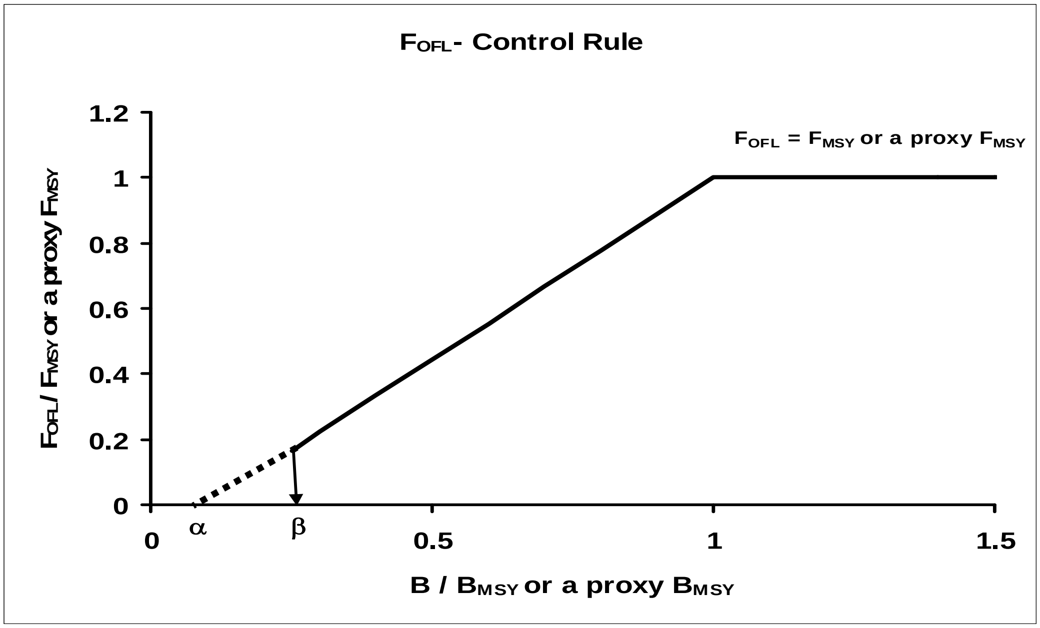


Figure 14. $F_{OFL}$ Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fishery management plan. Directed fishing mortality is set to 0 below β.

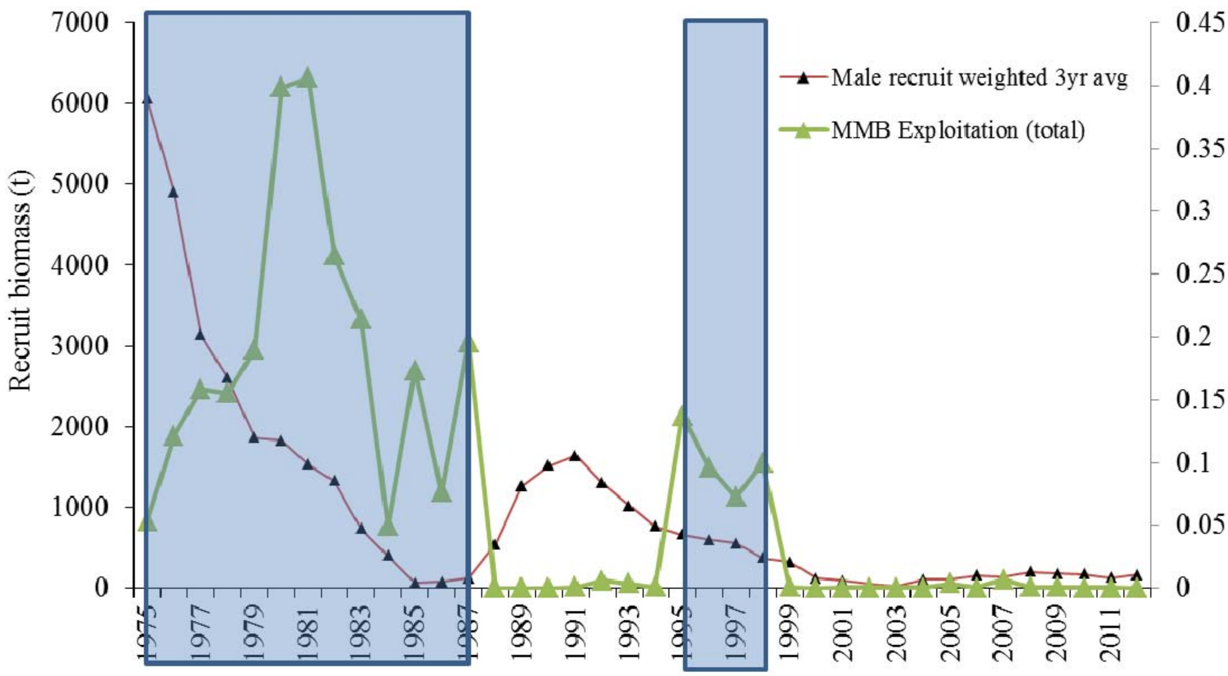


Figure 15. Time series of survey estimated recruit biomass (males 120-134 mm) and exploitation rate (based on total catch) of mature male biomass. The shaded region represents a period where commercial removals were occurring.

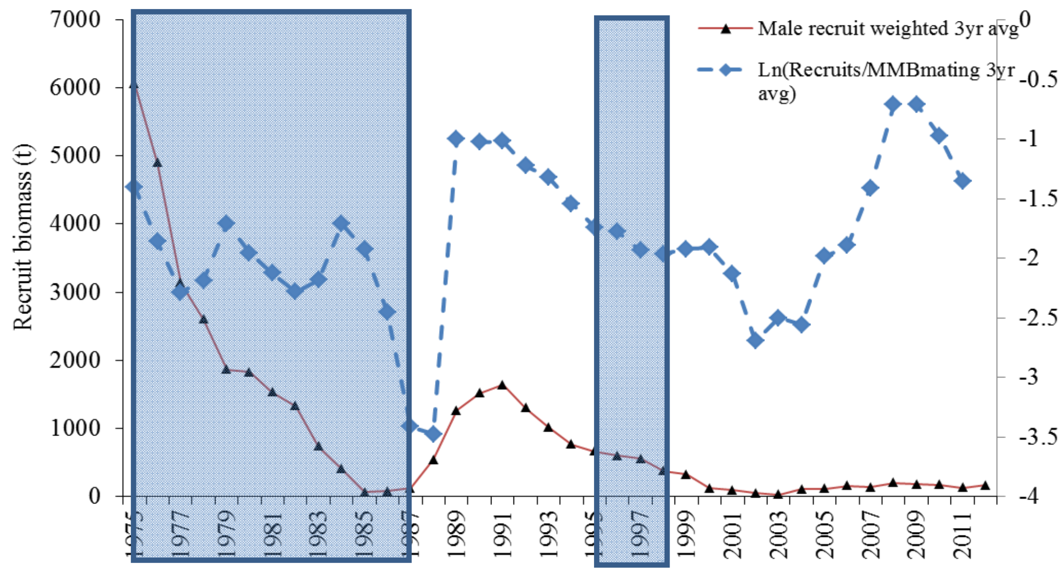


Figure 16. Time series of survey estimated recruit biomass (males 120-134 mm) and ln(Recruits/MMB). The shaded region represents a period where commercial removals were occurring.

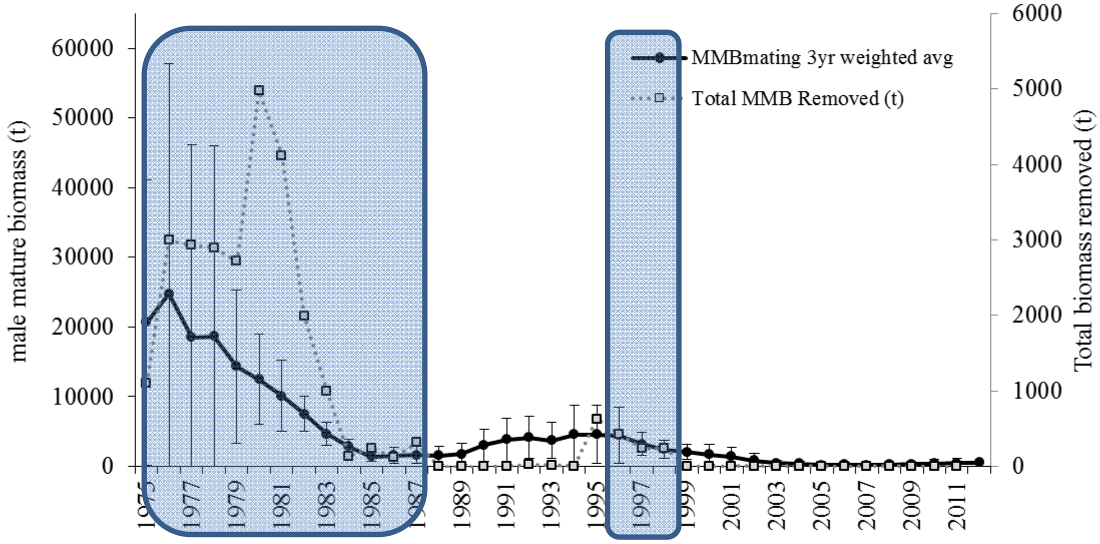


Figure 17. Time series of survey estimated Pribilof Island blue king crab 3 year moving averaged mature male biomass at mating (95% C.I.) and total catch removals.

# 2011 Saint Matthew Island Blue King Crab Stock Assessment

W. Gaeuman, ADF&G, Kodiak
Sept 2012

## Executive Summary

1. <u>Stock</u>: Blue king crab, *Paralithodes platypus,* Saint Matthew Island, Alaska.

2. <u>Catches</u>: Peak historical harvest was 9.454 million pounds (4,288 t) in 1983/84. The fishery was closed for 10 years after the stock was declared overfished in 1999. Fishing resumed in 2009/10 with a fishery-reported retained catch of 0.461 million pounds (209 t), less than half the 1.167 million pound (529.3 t) TAC. The TAC was increased to 1.600 million pounds (725.7 t) in 2010/11 and to 2.359 million pounds (1,151 t) in 2011/12, but reported catches again fell short at 1.264 million pounds (573.3 t; 79% of the TAC) and 1.881 million pounds (853.2 t; 80% of the TAC), respectively. Total male discard mortality in the 2011/12 directed fishery is estimated from ADF&G crab-observer data at 0.217 million pounds (98.3 t), assuming 20% handling mortality. Male bycatch mortality in the 2011/12 groundfish fisheries is estimated from NMFS observer data at 0.0009 million pounds (0.4 t).

3. <u>Stock biomass</u>: Following a period of low numbers in the wake of a hypothesized 1998/99 stock collapse (Zheng and Kruse 2002), trawl-survey indices of SMBKC stock abundance and biomass have generally increased in recent years, with 2011 estimated mature male biomass at 21.07 million pounds (9,557 t; CV 0.53), the second highest in the 35-year time series used in this assessment . Although the 2012 estimate of 12.46 million pounds (5,652 t; CV 0.33) represents a marked decrease from the 2011 estimate, it is still among the highest values since 1988 and well above the post-collapse low of 2.812 million pounds (1,275 t; CV 0.36) reported in 2005.

4. <u>Recruitment</u>: Because little information about the abundance of small crab is available for this stock, recruitment has been assessed in terms of the number of male crab entering the 90-104 mm CL size class in each year. The 2012 trawl-survey area-swept estimate of 0.705 million crab (CV 0.44) is less than half the previous year's estimate of 1.693 million and the lowest since 2005. This 2012 estimate is based on 29 captured animals from the 56 survey stations used to assess the SMBKC stock.

5. <u>Management performance</u>: Estimated 2011/12 total male catch is determined as the sum of fishery-reported retained catch, estimated male discard mortality in the directed fishery, and estimated male bycatch mortality in the groundfish fisheries. With the 2011/12 OFL at 3.74 million pounds (1,70 t) and estimated 2011/12 total male catch equal to 1.88 + 0.217 + 0.0009 = 2.10 million pounds (953 t), no declaration of overfishing is warranted. Recent assessments of stock biomass suggest it is well above the MSST and that the stock is neither overfished nor approaching an overfished condition. See table below. (Biomass measures in millions of pounds with metric ton equivalents in parentheses.)

| Year | MSST | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch | OFL[a] | ABC |
|---|---|---|---|---|---|---|---|
| 2009/10 | 3.4 (1,500) | 12.76 (5,790) | 1.167 (529.3) | 0.461 (209) | 0.530 (240) | 1.72 (780) | - |
| 2010/11 | 3.4 (1,500) | 14.77 (6,700) | 1.600 (725.7) | 1.264 (573) | 1.408 (639) | 2.29 (1,040) | - |
| 2011/12 | 3.4 (1,500) | 11.09[b] (5,030) | 2.539 (1,151) | 1.881 (853) | 2.10 (953) | 3.74 (1,700) | 3.40 (1,540) |
| 2012/13 | 4.0[c] (1,800) | 12.41[d] (5,629) | TBD | TBD | TBD | 2.24[e] (1,020) | 2.02[e, f] (916) |

[a] Total male catch OFL.
[b] Fall 2012 base-model estimate.
[c] Fall 2012 base-model estimate using the reference period 1978/79 – 2011/12.
[d] Fall 2012 base-model projection assuming OFL catch.
[e] From Fall 2012 base model.
[f] As described in §G with P* = 0.49 and additional 10% buffer.

6. Basis for the OFL: Estimated Feb 15 mature-male biomass ($MMB_{mating}$) is used as the measure of biomass for this Tier 4 stock, with males measuring 105 mm CL or more considered mature. Under the Fall 2011 survey-based methodology, the $B_{MSY}$ proxy was computed as average estimated 1989/99 – 2009/10 $MMB_{mating}$, determined to be 6.85 million pounds (3,110 t). The current default and author recommendation is to use the full assessment time frame, 1978 – 2011, as the reference period, giving 7.93 million pounds (3,600 t) under the base-model configuration. The $F_{MSY}$ proxy is taken equal to the assumed 0.18 $yr^{-1}$ instantaneous natural mortality. See table below. (Biomass measures in millions of pounds with metric ton equivalents in parentheses.)

| Year | Tier | $B_{MSY}$ | B ($MMB_{mating}$) | $B/B_{MSY}$ | $F_{OFL}$ | $\gamma$ | Basis for $B_{MSY}$ | Natural Mortality | $P^*$ |
|---|---|---|---|---|---|---|---|---|---|
| 2009/10 | 4a | 6.95 (3,150) | 12.76 (5,790) | 1.84 | 0.18$yr^{-1}$ | 1 | 1989/90 -2009/10 | 0.18$yr^{-1}$ | - |
| 2010/11 | 4a | 6.86 (3,110) | 15.29 (6,940) | 2.23 | 0.18$yr^{-1}$ | 1 | 1989/90 - 2009/10 | 0.18$yr^{-1}$ | - |
| 2011/12 | 4a | 6.85 (3,110) | 15.80 (7,167) | 2.31 | 0.18$yr^{-1}$ | 1 | 1989/90 - 2009/10 | 0.18$yr^{-1}$ | 0.49 |
| 2012/13 | 4a | 7.93 (3,560) | 12.41[a] (5,629) | 1.56 | 0.18$yr^{-1}$ | 1 | 1978/79 - 2011/12 | 0.18$yr^{-1}$ | 0.49 |

[a] Fall 2012 base-model projection assuming OFL catch.

7. Distribution of the OFL: It is recognized that the use of the assessment methodology to compute the OFL involves substantial inherent uncertainty by virtue of, among other things, its dependence on estimated quantities as key inputs. Accordingly, the calculated OFL may be viewed as a random variable with an associated probability distribution. Following recommendations developed during the Jan 2012 NPFMC crab modeling workshop, the model associated standard error of the logarithm of the estimated OFL is used to specify a probability distribution to quantify some of this uncertainty and to facilitate determination of the ABC. Details are provided in §G of this document.

8. Basis for the ABC: For determining an acceptable biological catch (ABC) and hence the annual catch limit (ACL), current instructions are to require that P[ABC > OFL] = P* with P* = 0.49. Implementation of this requirement to determine a maximum ABC relies on the assigned OFL probability distribution and is described in §G. To account for additional sources of uncertainty, and in keeping with past CPT and SSC guidance, the author recommends that the ABC be set at no more than 90% of the maximum value.

9. Summary of rebuilding analyses: The stock was declared rebuilt in 2009.

## A. Summary of Major Changes

### Changes in Management of The Fishery
There are no new changes in management of the fishery.

### Changes to The Input Data
All time series used in the assessment have been updated to include the most recent fishery and survey results.

### Changes in Assessment Methodology
The Fall 2011 assessment employed a survey-based approach. This assessment employs a 3-stage length-based assessment model first presented in May 2011 and accepted by the CPT in May 2012. The model was developed as an alternative to a similar 4-stage model used prior to 2011.

Consistent with the most recent recommendations, the full assessment time frame 1978 – 2011 is now used as the default for determining the $B_{MSY}$ proxy value, and the author has revised the approach used to specify a distribution for the OFL and set the ABC, as described in §G.

### Changes in Assessment Results
There are no noteworthy changes in assessment results at this time. Results are in line with those from recent years.

## B. Responses to SSC and CPT Comments

### CPT and SSC Comments on Assessments in General

- Sept 2011 CPT
  Comments: *The team discussed the necessity of including survey catch into assessments for total catch accounting purposes as needed under the revised MSA… Guidance will be sent out this winter in terms of the process for accounting for these catches in the next assessment cycle.*

  Response: The author believes the impact of survey catches presently is inconsequential for this stock but remains open to further guidance on the issue.

- Sept 2011 SSC
  Comments: No new recommendations.

- Jan 2012 NPFMC Crab Modeling Workshop
  The workshop included a day of discussion focusing on the choice of methodology for assigning a probability distribution to the OFL for use in determining the ABC.
  Comments:
  *Shorter term considerations*
  *1. Make clear distinctions between regulatory values (OFL and ABC), true but unknown values ( $\mu_{OFL}$ ), and estimators (e.g., $\hat{X}_{OFL}$)*
  *2. Calculate the pdf of the OFL using pragmatic approaches such as using point estimates of OFL and variances from the uncertainty estimates either from the Hessian or MCMC.*
  *3. Simulation approaches as outlined above for crab Tier 3 and 4 should be implemented in a standard software package with clear documentation Note that there is potential for lack of transparency because since the simulation procedure is complex it may detract from other fundamental issues related to the probability that $F_{msy}$ will be exceeded.*

  *Longer-term broader considerations for both groundfish and crab control rules*
  *4. Alternative candidate pdf estimators for OFL-ABC determinations might best be evaluated relative to $F_{msy}$ instead of relative to legally-defined OFL control rules (which have explicitly been designed to avoid exceeding $F_{msy}$, when biomass is estimated to be below $B_{msy}$)*
  *5. Evaluate/reconsider the utility of computing probabilities of proxies:*
  *a. Do they accurately reflect the uncertainty in actual Fmsy estimates?*
  *b. Should post-control rule computation of uncertainties (i.e., computing probabilities of exceeding control rule outputs rather than of Fmsy) be avoided?*
  *c. What is the latitude for legal definitions of OFL (via a pre-specified control rule) versus OFL= $f(F_{msy})$?*
  *6. Evaluate the consequences of applying control rules from lower tiers to higher-tier stocks to understand general consistency (in terms of risk aversion) and conditions where they vary*
  *7. For crab examine method applied in 2010 to compute OFL pdfs for Tier 4 to a range of stocks including uncertainty in $B_{msy}$ (proxy) and consider bootstrapping to generate*

*uncertainty similar to Tier 3 estimates (using MCMC). It may be difficult to predict how distributional assumptions will compare (e.g., log-normal vs normal since with larger variances more "samples" will be truncated/omitted).*
*8. Quantify the impact of each source of uncertainty for pdf estimates based on multiple sources of uncertainty (e.g. the Tier 4 OFL control rule). For example, for Tier 4 stocks, what is the contribution to the variance for the OFL from the assumed level of uncertainty associated with natural mortality compared to that related to stock size and the* $B_{msy}$ *(proxy)? This could be done by successively turning off each source of uncertainty to evaluate the relative impact on results. This has been done in the Crab ACL analysis in conjunction with* $\sigma_B$ *values.*
*9. Examine model-based uncertainty compared to survey-based values. Uncertainty may be underestimated for data-poor stocks for which the assessment pre-specifies many parameters. For Alaska crab and groundfish, survey CVs may provide a consistent treatment across tier levels commensurate with the reliability of stock size estimates as observed in surveys. In general, the stock size and associated reference points of a stock with a high survey CV is considered more uncertain and in need of a larger buffer, then a stock with a low survey CV. However, assuming the uncertainty of the estimate of OFL is primarily due to survey CVs assumes uncertainty in biological rates plays a minor role, and that both survey catchability and selectivity is reasonably high.*
*10. The size of the buffer between the OFL and the ABC for crab stock is small because of the specification P* = 0.49. Perhaps a comprehensive reconsideration of the Crab Tier system including both the OFL and ABC control rules should be pursued. There should be a "risk neutral" treatment of uncertainty and other measures inherent in current specifications process. For example, MMB as a measure of spawning biomass and treatment of 'total catch' when control rules currently applied to MMB (only) and females added in afterwards and* $B_{msy}$ *includes only males and yet the MSST should conceptually include females. CPT to discuss progress towards using an alternative (and more appropriate) measure of effective spawning biomass/reproductive potential for crab stocks in May.*
*11. Identifying additional uncertainty in OFL distribution*
*a.* $\sigma_B$
*b. asymmetry of the uncertainty (if assessment and OFL estimates are not "risk neutral")*
*c. The impact of pre-specifying rather than estimating parameters. For example, in stocks where fishery availability may change significantly from year to year due to spatial targeting of strong recruitments, more data would be needed to account for this process and model appropriately. In low data situations, the assessment would (typically) assume constant selectivity and hence likely overestimate the precision of abundance and mortalities.*

Response: The author has revised the approach used to determine the ABC consistent with his understanding of the guidance provided. Details are given in §G of this document.

- May 2012 CPT: No new directives.

- June 2012 SSC: No new directives.

## CPT and SSC Comments Specific to SMBKC Stock Assessment

- Sept 2011 CPT

  Comments: *The author clarified that the OFL in the assessment was calculated for mature males only. The team discussed calculating the OFL in this manner and how to reconcile this with evaluating whether overfishing occurred. The team requested that the author recalculate the OFL to apply to total males.*

  *The team discussed the years used to calculate BMSYproxy and the author recommended the period from 1989/90 to 2009/10. The team* ***recommends*** *that the assessment provide further justification for this choice of this period at the May 2012 meeting.*

  *St. Matthew model discussion: The team made* ***recommendations*** *to adopt a standardized weighting procedure based on CVs for indices and catch biomass, to provide several model configurations [along with an author-preferred model] for evaluation by the team, and to provide diagnostics to evaluate the choices. The issues of effective sample size and survey representation should be evaluated. The team noted that the report from the team's modeling workshop in 2009 (and annual SAFE guidelines) provide additional guidance for addressing these issues.*

  Response: Calculation of the OFL and determination of the $B_{MSY}$ proxy have been revised with adoption of the 3-stage model for the 2012 assessment. Details are given in §F of this document. Recommendations with respect to the model have likewise been addressed since Fall 2011.

- Sept 2011 SSC

  Comments: *The author continues to refine the stock assessment model following recommendations from the CPT, and the SSC looks forward to reviewing the model in 2012. The SSC found the material on the model to be nicely presented, but had some recommendations for the authors. The way effective sample size is determined differs from what others do, and some explanation would be helpful. Also, the assumption of high mortality in 1998/99, and a rationale for that assumption needs to be provided. Finally, a couple of alternative models would be useful for comparison, including one that does not rely on assumption of high mortality in 1998/99.*

  Response: The author has revised computation of effective sample sizes and has presented some alternative models. This work appears to justify the assumption of high 1998/99 mortality.

- Jan 2012 NPFMC Crab Modeling Workshop

  Comments: No new recommendations specific to this assessment.

- May 2012 CPT

  Comments:

  *1. Present alternative models for September which (a) represent different values to weight the trawl and pot surveys (including giving the pot survey more weight than the trawl survey), (b) assume the same selectivity for stages 2-3 in the trawl survey to*

*address concerns about the 1.24 value for the stage-3 trawl survey selectivity, and (c) assume that Q=1 applies to stage-2 rather than stage-3.*
*2. Avoid giving the pot or trawl surveys weights larger than 1.*
*3. Base the distribution for the OFL on its asymptotic sampling distribution (i.e., use the standard error for the logarithm of the OFL from the assessment).*
*4. Overlay model-predictions on Figure 1 showing the fits of the various alternative models to the trawl and pot survey data.*
*5. Include retrospective runs with plots of the mature male biomass.*
*6. Add a table of parameter correlations to aid in diagnosing potentially confounded parameters.*
*7. Add a plot with the number of stage-1 recruits (that could be used to determine $B_{35\%}$ by multiplying $SPR_{35\%}$ if the CPT decided that this stock should be placed in Tier 3).*
*8. Provide more information on the basis for the maturity assumption.*
*9. Calculate effective multinomial sample sizes for the compositional data: Neff = sum(p(1-p)/sum((o-p)^2 and plot the Neff versus the assumed sqrt transformed numbers with a 1:1 line on the graph. Consider using this to iteratively reweight sample sizes for a more parsimonious fit.*
*10. Plot standardized residuals and compute standard deviations of the mean absolute deviations (all should theoretically have an std=0.8 ~ sqrt(2/pi) ) if all the data are properly weighted.*

Response:
1.–7. The author has complied with all recommendations.
8. As noted in the body of this report, some justification for the 105 mm CL proxy for male maturity is provided in Pengilly and Schmidt (1995), who used it to develop the current regulatory SMBKC harvest strategy.
9. Estimated effective multinomial sample sizes were computed for composition data and plotted against year for the trawl-survey, but the requested plots were uninformative and so not included. Iterative reweighting was not attempted at this time, though the author would like to experiment with this technique in the future.
10. The author requests additional explanation.

- June 2012 SSC
  Comments:
  ***The CPT recommended using the three-stage CSA for the fall 2012 fishery and the SSC concurs with this recommendation.*** *The assessment author has clearly described the model structure, data, parameters, and fitting procedure, including provision of the AD Model Builder code. The model fits the survey data reasonably well and residual fits to the three stage proportions are generally well behaved. The CPT has provided some very helpful recommendations to the assessment author, and the SSC supports these recommendations. In addition, the SSC offers the following comments and recommendations:*

  *1. Clarify that "recruits" corresponding to stage 1 are recruits to the model, not recruits to the fishery (page 2).*

*2. In the section on model population dynamics, it is stated that the impact of groundfish fisheries on the stock are small. However, the survey-based methods document (Table 4) indicates that 300,000 lbs of blue king crab were caught in fixed gear in 2007/08, resulting in an estimated PSC mortality of 150,000 lbs. Please address this and explain whether the proposed approach adequately addresses such situations.*
*3. On the bottom of page 3, please provide a little more explanation about the abundance index proportionality constants (Qs) and trawl or pot survey abundance indices (As). Are the Qs calculated as the abundance index for any one year divided by the largest abundance index in the time series? Also, please explain the units for the As. For the trawl survey, are these total area-swept abundances or mean station densities? For the pot survey, do the As represent mean catch per pot?*
*4. On the top of page 4, the stage mean weights are subscripted by year, suggesting that they are estimated annually. However, Table 5 indicates that the means for stage 1 and 2 are fixed and only the stage-3 mean weights are estimated annually. True stage-1 and -2 mean weights would vary by year depending on variability in year-class size and growth rates, so it should be mentioned that fixing these to constants is a simplifying assumption. Are data insufficient to reliably estimate these annually?*
*5. The SSC appreciates the author's attempts to explore various weighting scenarios. As pots are designed to catch crab, one might expect to put a higher weight on the pot survey compared to the trawl survey. However, the trawl surveys are conducted annually and cover a wider area. Some additional explanation for the relative weights applied to pot and trawl surveys would be helpful.*
*6. In eq. (3), stage 3 selectivity is set to unity and the selectivities of the other two stages are estimated in the model. However, the model estimates the trawl selectivity of stage 2 crab to be 1.24 (Table 6). It does not seem plausible that smaller crab (stage 2) would have a higher selectivity than larger crab (stage 3). The Crab Plan Team provided advice on this issue, which the SSC supports.*
*7. The SSC appreciates the four alternative model scenarios that were considered. It would be more helpful if the alternative model fits were plotted with time series of survey estimates, as was done for the preferred model in Fig. 1. For viable alternatives, it would also be useful to plot residuals and other diagnostics, or using retrospective analysis to help confirm the model choice. The SSC is inclined to agree that it is best to estimate mortality for 1998/99, but remains interested in seeing a comparison of fits, as well as the diagnostics mentioned in the text.*
*8. The SSC requests the assessment author work toward future development of both Tier 3 and 4 reference points for this stock, including a description of the quality of data used for each and the author's recommendation for choice of tier level.*
*9. The SSC suggests estimating the natural mortalities corresponding to each size class. This can increase the understanding of the survival of this species directly and avoid confounding from movement and growth on the natural mortality estimate. With the three known size classes, the mathematical symbols are* $M_1$, $M_2$, *and* $M_3$ *and they are independent from time* $t$.
*10. The SSC suggests that the input data be corrected or adjusted for any bias due to the differences arising from data, index, or information collected at different time periods within a year.*

*11. The authors might consider using the "universally optimal" concept from statistical experimental design to determine the weighting of each component of the likelihood. Universally optimal means the variance covariance matrix of the model is close to a completely symmetric matrix.*
*12. The author might consider plotting the annual estimate of population size that is over the largest size class stated in the model.*

Response:
1. – 4.The author has attempted to address these points by way of additional explanation in Appendix A describing model details.
5. A range of alternative weighting schemes for the two survey indices is presented in this report. Determining an appropriate choice is difficult. A concern in this context is that the assessment data from the two surveys come from different areas and thus contribute potentially conflicting information about population status and trend. In each of the last three years, for example, a large number of all SMBKC crab captured in the trawl survey came from a single station north of St. Matthew Island (R29) that lies outside of the region used for the pot-survey assessment data.
6. This report includes the recommended strategies for dealing with the putative implausibility of the high model estimate of stage-2 trawl-survey selectivity.
7. The author has presented an expanded range of model scenarios together with additional results and diagnostics for comparison.
8. As this is the first use of the new model in the assessment process, the author has here completed only the Tier 4 approach to determining reference points. A Tier 3 analysis, which is more intimately linked to model structure and behavior, remains an option for future assessments once the author and CPT have become more familiar with model behavior.
9. Under all model configurations presented in this report, natural mortality (or its time geometric mean) is assumed equal to 0.18 $yr^{-1}$ across all stages and all years, except in 1998/99, for which year it is model estimated to account for an apparent anomalous decline in stock abundance. Given current model structure, however, a global value of natural mortality cannot be meaningfully estimated. Moreover, estimation of separate stage-specific natural mortalities would require extensive revision of the existing code, aside from any necessary structural changes. For these reasons, the author requests further explanation and guidance before attempting to implement this recommendation.
10. Though a potentially worthwhile undertaking, adjusting the various assessment inputs for possible discrepancies in timing represents a significant bookkeeping exercise that was infeasible preliminary to this assessment.
11. Determining an appropriate objective function weighting scheme is both fundamentally important and notoriously difficult, and the author welcomes further guidance on the issue. With regard to the intriguing concept of universal optimality, some additional explanation or relevant references would be helpful.
12. It is unclear to the author what quantity is being referred to with this recommendation inasmuch as the largest size class comprises **all** male crab measuring at least 120 mm CL. Some indication as to the motivation behind this recommendation might help clarify what is intended.

## C. Introduction

### Scientific Name

The blue king crab is a lithodid crab, *Paralithodes platypus* (Brant 1850).

### Distribution

Blue king crab are sporadically distributed throughout the North Pacific Ocean from Hokkaido, Japan, to southeastern Alaska (Figure 1). In the eastern Bering Sea small populations are distributed around St. Matthew Island, the Pribilof Islands, St. Lawrence Island, and Nunivak Island. Isolated populations also exist in some other cold water areas of the Gulf of Alaska (NPFMC 1998). The St. Matthew Island Section for blue king crab is within Area Q2 (Figure 2), which is the Northern District of the Bering Sea king crab registration area and includes the waters north of of Cape Newenham (58°39’ N. lat.) and south of Cape Romanzof (61°49’ N. lat.).

### Stock Structure

The Alaska Department of Fish and Game (ADF&G) Gene Conservation Laboratory division has detected regional population differences between blue king crab collected from St. Matthew Island and the Pribilof Islands (NOAA grant Bering Sea Crab Research II, NA16FN2621, 1997). NMFS tag-return data from studies on blue king crab in the Pribilof Islands and St. Matthew Island support the idea that legal-sized males do not migrate between the two areas (Otto and Cummiskey 1990). St. Matthew Island blue king crab tend to be smaller than their Pribilof conspecifics, and the two stocks are managed separately.

### Life History

Like the red king crab, *Paralithodes camtshaticus*, the blue king crab is considered a shallow water species by comparison with its lithodid cousin the golden or brown king crab, *Lithodes aequispinus,* and the scarlet king crab, *Lithodes couesi* (Donaldson and Byersdorfer 2005). Adult male blue king crab are found at an average depth of 70m (NPFMC 1998). Mature females have a biennial ovarian cycle and seasonally migrate inshore, where they molt and mate. Unlike red king crab, juvenile blue king crab do not form pods but instead rely on cryptic coloration for protection from predators and require suitable habitat such as cobble and shell hash. Size at 50% maturity has been estimated at 77 mm carapace length (CL) for SMBKC males and 81 mm CL for females. Otto and Cummiskey (1990) report an average growth increment of 14 mm CL for adult males.

### Management History

The SMBKC fishery developed subsequent to baseline ecological studies associated with oil exploration (Otto 1990). Ten U.S. vessels harvested 1.202 million pounds in 1977, and harvests peaked in 1983 when 164 vessels landed 9.454 million pounds (Table 1). The fishing seasons were generally short, often last only a few days. The fishery was declared overfished and closed in 1999 when the stock biomass estimate was below the minimum stock-size threshold (MSST) of 11.0 million pounds as defined by the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner crabs (NPFMC 1999). Zheng and Kruse (2002) hypothesized a high level of SMBKC natural mortality from 1998 to 1999 as an explanation for the low catch per unit effort (CPUE) in the 1998/99 commercial fishery and 1999 ADF&G pot survey, as well as the low numbers across all male crab size groups caught in the annual NMFS eastern Bering Sea trawl survey from 1999 to 2005 (Table 2). In Nov 2000, Amendment 15 to the FMP for Bering Sea/Aleutian Islands king and Tanner crabs was approved to implement a rebuilding plan for the SMBKC stock (NPFMC 2000). The rebuilding plan included a regulatory harvest strategy (5 AAC 34.917), area closures, and gear modifications. In addition, commercial crab fisheries near St. Matthew Island were scheduled in fall and early winter to reduce the potential for bycatch mortality of vulnerable molting and mating crab.

NMFS declared the stock rebuilt on Sept 21, 2009, and the fishery was reopened after a 10-year closure on Oct 15, 2009 with a TAC of 1.167 million pounds, closing again by regulation on Feb 1, 2010. Seven participating vessels landed a catch of 460,859 pounds with a reported effort of 10,697 pot lifts and an estimated CPUE of 9.9 retained crab per pot lift. The TAC was increased to 1.600 million pounds in 2010/11 and to 2.359 million pounds in 2011/12, with similarly low CPUEs and reported catches again falling short at 1.264 million pounds (79% of the TAC) and 1.881 million pounds (80% of the TAC), respectively.

Though historical observer data are limited, bycatch of female and sublegal male crab from the directed blue king crab fishery off St. Matthew Island was relatively high in past years, with estimated total bycatch in terms of number of crab captured sometimes twice or more as high as the catch of legal crab (Moore et al. 2000). Pot-lift sampling by ADF&G crab observers indicates similar bycatch rates of discarded male crab since the reopening of the fishery (Table 3), with total male discard mortality in the 2011/12 directed fishery estimated at about 10% (0.179 million pounds) of the reported retained catch weight, assuming 20% handling mortality. On the other hand, these same data suggest a significant reduction in the bycatch of females (Gaeuman 2011), which may be attributable to the later timing of the contemporary fishery (D. Pengilly, ADF&G, Kodiak, pers. comm.). Some bycatch of discarded blue king crab has also been historically observed in the eastern Bering Sea snow crab fishery, but ADF&G crab observers recorded just 3 blue king crab in a combined 6,023 sampled pot lifts during the 2009/10 - 2011/12 Bering Sea snow crab fisheries (ADF&G Crab Observer Database). The St. Matthew Island golden king crab fishery, the third commercial crab fishery to have taken place in the area, typically occurred in areas with depths exceeding blue king crab distribution. NMFS observer data suggest that variable but mostly limited SMBKC bycatch has also occurred in the eastern Bering Sea groundfish fisheries (Table 4).

## D. Data

### Summary of New Information

Data used in this assessment have been updated to include the most recent fishery and survey numbers.

### Major Data Sources

Major data sources used in this assessment are annual directed-fishery retained-catch statistics from fish tickets (1978/79-1998/99, 2009/10 - 2011/12; Table 1); the annual NMFS eastern Bering Sea trawl survey (1978-2012; Table 2); the triennial ADF&G SMBKC pot survey (every third year 1995-2010; Table 3); ADF&G crab-observer pot-lift sampling (1990/91-1998/99, 2009/10-2011/12; Table 4); and NMFS groundfish-observer bycatch biomass data (1992/93-2010/12; Table 5). Figure 3 maps stations from which SMBKC trawl-survey and pot-survey data were obtained. Further information concerning the NMFS trawl survey as it relates to commercial crab species is available in Chilton et al. (2011); see Gish et al. (2012) for a description of ADF&G SMBKC pot-survey methods. It is especially noteworthy that the two surveys cover different geographic regions and that each has in some years encountered proportionally large numbers of male blue king crab in areas where the other is not represented, e.g. Figure 4. Crab-observer sampling protocols are detailed in the crab-observer training manual (ADF&G 2011). Groundfish SMBKC bycatch data come from NMFS Bering Sea reporting areas 521 and 524 (Figure 5).

### Other Data Sources

Other relevant data sources, including assumed population and fishery parameters, are discussed in Appendix A, which gives a detailed description of the assessment model.

### Major Excluded Data Sources

Groundfish bycatch size-frequency data available for selected years, though used in the model-based assessment in place prior to 2011, play no direct role in this analysis. These data tend to be severely limited: for example, 2011/12 data are based on a total of 5 male blue king crab. The timing of these data, and presumably also of the groundfish bycatch biomass data, is also problematic, with 2 of the 5 2011/12 recorded crab captured in June 2011 prior to the nominal July 1 start of the crab year.

# E. Analytic Approach

### History of Modeling Approaches for this Stock

A four-stage catch-survey-analysis (CSA) assessment model was used before 2011 to estimate abundance and biomass and prescribe fishery quotas for the SMBKC stock (2010 SAFE; Zheng et al. 1997). The four-stage CSA is similar to a full length-based analysis, the major difference being coarser length groups, which are more suited to a small stock with consistently low survey catches. In this approach, the abundance of male crab with a CL of 90 mm or more is modeled in terms of four crab stages: stage 1 (90-104 mm CL); stage 2 (105-119 mm CL); stage 3 (newshell 120-133 mm CL); and stage 4 (oldshell $\geq$ 120 mm CL and newshell $\geq$ 134 mm CL). Motivation for these stage definitions comes from the fact that for management of the SMBKC stock, male crab measuring at least 105 mm CL are considered mature, whereas 120 mm CL is considered a proxy for the legal size of 5.5 in carapace width, including spines. Additional motivation for these stage definitions derives from an estimated average growth increment of about 14 mm per molt for SMBKC (Otto and Cummiskey 1990), with the slightly narrower stage-3 size range intended to buttress the model assumption that all stage-3 crab transition to stage 4 after one year (Z. Zheng, ADF&G, pers. comm.).

Concerns about the 2010 assessment model led to CPT and SSC recommendations that included development of an alternative model with provisional assessment based on survey biomass or some other index of abundance (NPFMC March 2011, CPT May 2011, SSC June 2011). The author proposed an alternative 3-stage model to the CPT in May 2011but was requested to proceed with a survey-based approach for the Fall 2011 assessment. In May 2012 the CPT approved for use a slightly revised and better documented version of the alternative model.

### Assessment Methodology

The current SMBKC stock assessment model is similar in complexity to that described by Collie et al. (2005) and a variant of the previous four-stage SMBKC CSA model (2010 SAFE). Like the earlier model, it considers only male crab at least 90 mm in CL, but it combines stages 3 and 4 of the earlier model resulting in just three stages (male size classes) determined by carapace length measurements of (1) 90-104 mm, (2) 105-119 mm, and (3) 120 mm+. This consolidation was heavily driven by concern about the accuracy and consistency of shell-condition information, which had been used in distinguishing stages 3 and 4 of the earlier model. A detailed description of the model and its implementation in the software AD Model Builder (ADMB Project 2009) is presented in technical Appendix A to this report. Basic model code was previously provided to the CPT in May 2012 and is available from the author upon request.

### Model Selection and Evaluation

Six alternative model configurations, denoted A1, A2, A3, B1, B2, and C, were examined along with the base-model configuration described in detail in Appendix A. Five of the six alternatives were designed to address specific CPT and SSC recommendations from Spring 2012. By comparison with the alternatives, the base-model configuration is characterized by 1) trawl and pot-survey abundance index component weights both equal to unity; 2) separate estimated parameters for stage-1 and stage-2 trawl-survey selectivity, with stage-3 selectivity equal to survey catchability assumed equal to unity; and 3) natural mortality model estimated in 1998/99 and otherwise fixed at 0.18 $yr^{-1}$. Model configurations A1, A2, and A3 reflect different weighting schemes for the trawl and pot-survey abundance index components, with the added difference that configuration A2 makes no use of the pot-survey data whatsoever: both pot-survey abundance index and pot-survey composition data components are assigned weights of zero. Model configurations B1 and B2 differ from the base model and from each other in how trawl-survey stage selectivities are parametrized. Configuration C modifies the base model to allow natural mortality M to vary by year according to $\log(M_t) = \log(0.18yr^{-1}) + \eta_t$, with the $\eta_t$ subject to a mild quadratic penalty $5.0\frac{\sum \eta_t^2}{2}$ and the requirement $\sum \eta_t = 0$. For better comparability with the other model configurations, however, model configuration C also uses a separate parameter to estimate1998/99 natural mortality. The following table summarizes all seven model configurations documented in this report.

| | abundance index component objective function weight | | trawl-survey selectivity parametrization | | | |
|---|---|---|---|---|---|---|
| model | trawl-survey | pot-survey | stage 1 | stage 2 | stage 3 | natural mortality[a] |
| base | 1.0 | 1.0 | s1 | s2 | Q = 1 | 0.18 $yr^{-1}$ |
| A1 | 1.0 | 0.5 | s1 | s2 | Q = 1 | 0.18 $yr^{-1}$ |
| A2 | 1.0 | 0[b] | s1 | s2 | Q = 1 | 0.18 $yr^{-1}$ |
| A3 | 0.5 | 1.0 | s1 | s2 | Q = 1 | 0.18 $yr^{-1}$ |
| B1 | 1.0 | 1.0 | s1 | s2 | s2 | 0.18 $yr^{-1}$ |
| B2 | 1.0 | 1.0 | s1 | Q = 1 | s2 | 0.18 $yr^{-1}$ |
| C | 1.0 | 1.0 | s1 | s2 | Q = 1 | random, with geometric mean 0.18 $yr^{-1}$ |

[a] In all models, a separate parameter is used to estimate M in 1998/99 .
[b] Model A2 excludes **all** pot-survey data, i.e. index and composition data component weights are both set to zero.

At the request of the CPT, management biomass quantities for model configuration C were computed using more stringent mortality deviation penalty weights of 12.5 and 50.0 in addition to the author-specified value of 5.0. These results are listed in Table 6. The higher weights correspond to CVs on natural mortality of roughly 29 and 14%, respectively, compared to a CV of $\sqrt{\exp\left(\frac{1}{5.0}\right) - 1} \approx 0.47$ for the author-specified weight.

Estimation of 1998/99 natural mortality proved a useful strategy with respect to the previous SMBKC stock assessment model (2010 SAFE) and was retained in all seven model configurations. Zheng and Kruse (2002) provided a biological motivation for this hypothesis. To test its efficacy, a variant of the base model was fit in which natural mortality was fixed at 0.18 $yr^{-1}$ in 1998/99, as well as in all other years. Estimation of the one additional parameter reduces the minimized value of the model objective function by 21 from 3,591 to 3,570, providing good justification at least in terms of conventional likelihood theory for continuing to prefer the more complex model and thus including the additional structure. The simpler model was not considered further.

Figures 6 – 17 and Table 6 facilitate basic comparison of the different model configurations examined for this assessment. Figures 6 and 7 show model fits to trawl and pot-survey abundance indices, and Figures 8 and 9 display model estimates of mature male biomass at time of mating. Note that each figure includes base-model results against which to compare results for alternative model configurations. Particularly striking in these figures are the high estimates of mature male biomass associated with model B2 over the entire assessment time frame. These high estimates result in a correspondingly high $B_{MSY}$ and are themselves primarily the result of a pathologically low estimate of trawl-survey stage-3 selectivity (Table 6). Table 6 makes clear that estimation of trawl-survey selectivity parameters is generally problematic; only configuration B1 leads to what might immediately be considered plausible values, though it is unclear that it should for that reason be preferred to some of the other model configurations.

As Figures 10 – 16 indicate, model fit to trawl-survey composition data is likewise problematic, particularly over the last part of the time series, possibly indicative of an important change in stock dynamics or distribution. Other than B2, which is suspect for other reasons, model configuration C (with penalty weight 5.0) is perhaps the most satisfactory in this regard, but the estimate of stage-2 selectivity in the trawl survey remains suspect, and estimates of key management quantities are notably low by comparison with those of the other model configurations (Table 6). Moreover, whereas letting natural mortality vary randomly by year may lead to a better fit to the data, it is arguably an ad hoc device that does not directly address what appear to be basic structural problems in the model. The pattern of deviations from the assumed geometric mean value 0.18 $yr^{-1}$, shown in Figure 17, is in any case remarkably uniform except for a few years in the latter part of the time series, again suggestive of some fundamental change. Figure 17 also displays model recruitment (stage-1abundance) under the different configurations. In spite of some stability in the overall pattern, there is appreciable variation in magnitude between the different model configurations, which could have important implications for a Tier-3 analysis.

In CPT discussion of model choice, model configurations B1 and C were each proposed as potential alternatives to the base model. It was noted that B1 led to more plausible estimates of trawl-survey selectivity, whereas C provided a better fit to the data, especially the trawl-survey composition data. The author provided additional displays and results for the two candidate model configurations (Appendix B), but no clear preference was articulated. Accordingly, the CPT opted to go with the base-model configuration for this assessment, inasmuch as it was the basis for CPT and SSC acceptance of the model in Spring 2012.

**Results**

Additional results are here presented for the base-model configuration, as the default choice for use in the Fall 2012 SMBKC stock assessment. Additional results for model configurations B1 and C, which were provided to the CPT during the Fall 2012 meeting, are included in Appendix B to this document.

Table 7 lists AD Model Builder estimates and standard errors of base-model estimated parameters, with main correlation structure shown in Table 8. The high estimate of trawl-survey stage-2 selectivity (1.37) is a concern and was previously identified by the CPT and SSC as a troubling feature of the model in their critique of the Spring 2012 implementation, which yielded an estimate of 1.24. Base-model fits to trawl and pot-survey abundance index data are displayed in Figure 6, as well as Figure 7, in comparison to other model configurations.

Figures 10, 18, and 19 display standardized residuals of base-model fits to trawl-survey, pot-survey, and pot-fishery composition data, respectively. Whereas actual sample sizes (number of measured crab) range between 38 and 385 for the trawl-survey (Table 2) and are generally much higher for both the pot-fishery (Table 3) and pot-survey (Table 4) data, model effective sample sizes are set at 100 for the pot-fishery and pot-survey and are typically equal to, and never exceed, 50 for the trawl-survey. (See Appendix A for further details.) Despite a great deal of experimentation in the choice of model effective samples sizes, a satisfactory fit to the trawl-survey composition data in particular proved elusive. Methods such as iterative reweighting using estimated effective sample size were not attempted; however, estimated effective samples sizes were computed and are plotted against survey year for the trawl-survey (Figure 20). A plot of these values against model effective sample size, all but four of which are equal to 50, is less than enlightening and was omitted. Estimated effective sample sizes ranged from 62.3 to 3,937.9 for the pot-survey composition data (6 years) and from 29.8 to 285.6 for the pot-fishery composition data (12 years).

Historical model recruitment under the base-model configuration is included in Figure 17, and Figure 21 depicts the time series of retained catch and model discard-mortality biomass. Full-selection fishing mortality in the directed fishery is plotted in Figure 22 against model mature male abundance at the time of the previous trawl survey. There is some indication during the middle period of the time series of a potentially stable fishery, after which elevated fishing mortalities may have contributed to an apparent stock collapse and a period of very low abundances that persisted even after the 1999 fishery closure.

A retrospective plot of base-model mature male biomass at time of mating (Figure 23) appears to show clear evidence of the influence of data from the triennial pot-survey. This effect is particularly noticeable for the high biomass estimates of the early 80s, with the different trajectories obviously arranged in four ordered bundles associated with the 2001, 2004, 2007, and 2010 pot-surveys. Interestingly, the ordering of the bundles and of the trajectories within them mostly reverses itself after the large overall decline from 1998 to 1999, so that trajectories with the latest terminal years and the most dependence on pot-survey data tend to be associated with the highest estimates of biomass before the decline but the lowest following it. During the period since its introduction into the analysis, the overall effect of the pot-survey data in the model is to moderate the influence of the comparatively large year-to-year changes in the trawl-survey measure of abundance.

## F. Calculation of The OFL

The overfishing level (OFL) is the fishery-related mortality biomass associated with fishing mortality $F_{OFL}$. The SMBKC stock is currently managed as Tier 4 (2011 SAFE), and only a Tier 4 analysis is presented here, with development of a Tier 3 approach deferred until the behavior of the new assessment model is better understood. Thus given stock estimates or suitable proxy values of $B_{MSY}$ and $F_{MSY}$, along with two additional parameters $\alpha$ and $\beta$, $F_{OFL}$ is determined by the control rule

$$a) \quad F_{OFL} = F_{MSY}\,, \; when \;\; B / B_{MSY} > 1;$$

$$b) \quad F_{OFL} = F_{MSY}\,(B / B_{MSY} - \alpha)/(1-\alpha), \; when \;\; \beta < B / B_{MSY} \le 1;$$

$$c) \quad F_{OFL} < F_{MSY} \;\; with \; directed \;\; fishery \; F = 0, \; when \;\; B / B_{MSY} \le \beta\,,$$

where $B$ is quantified as mature-male biomass at mating $MMB_{mating}$. Note that as $B$ is itself a function of the fishing mortality $F_{OFL}$, in case b) numerical approximation of $F_{OFL}$ is required. As implemented for this assessment, all calculations proceed according to the model equations given in Appendix A. In particular, the OFL catch is computed using equations [3], [4], and [5], with $F_{OFL}$ taken to be full-selection fishing mortality in the directed pot fishery and groundfish trawl and fixed-gear fishing mortalities set at their model geometric mean values over years for which there are data-based estimates of bycatch-mortality biomass. This approach is consistent with that used under the previous model-based SMBKC stock assessment methodology (e.g. 2010 SAFE).

The currently recommended Tier 4 convention is to use the full assessment period 1978 – 2011 to define a $B_{MSY}$ proxy in terms of average estimated $MMB_{mating}$ and to put $\gamma = 1.0$ with assumed stock natural mortality $M = 0.18$ $yr^{-1}$ in setting the $F_{MSY}$ proxy value $\gamma M$. The parameters $\alpha$ and $\beta$ are assigned their default values $\alpha = 0.10$ and $\beta = 0.25$. With these specifications and letting $F_{OFL}$ determine directed-fishery fishing mortality, under the base-model configuration the $B_{MSY}$ proxy is 7.93 million pounds, and case a) of the control rule obtains, resulting in a Tier 4a 2012/13 total male catch OFL of 2.24 million pounds with $F_{OFL} = F_{MSY} = 0.18$ $yr^{-1}$. The retained catch component of the OFL is 2.14 million pounds. Complete partitioning of the OFL under the base-model configuration is given in Table 9.

## G. Calculation of The ABC

For determining an acceptable biological catch (ABC), and hence the annual catch limit (ACL), current recommendations are to require that $P[ABC > OFL] = P^*$, with $P^*$ = 0.49. As implemented here, the maximum ABC is set equal to $\lambda \times ofl$, where *ofl* is the Tier 4 model-calculated overfishing level from the control rule and the multiplier $\lambda$ is determined by the probability statement $P[\lambda\widehat{OFL} > OFL]$ = $P^*$, under the assumptions that $OFL$ = *median*$(\widehat{OFL})$ and $\log\left(\widehat{OFL}\right) \sim N(\log(OFL)\,, \sigma)$, where σ is the ADMB-reported standard error of $\log(\widehat{OFL})$ from the model. With this set up, $P^* = P\left[\lambda\widehat{OFL} > OFL\right] = 1 - \Phi(-\frac{\log(\lambda)}{\sigma})$, so that $\log(\lambda) = -\sigma\Phi^{-1}(1 - P^*)$ and $\lambda = \exp(\sigma\Phi^{-1}(P^*))$.

For the base model, this procedure yields $\lambda = \exp\left(0.00359\Phi^{-1}(0.49)\right) \cong 1$ and a maximum ABC of $\lambda \times ofl$ = 1 × 2.24 = 2.24 million pounds. To account for additional sources of uncertainly and in keeping with past CPT and SSC guidance, the author recommends that the ABC be set at no more than 90% of the maximum value. In this instance, the use of an additional 10% buffer leads to a provisional author-recommended ABC of 2.02 million pounds.

## H. Rebuilding Analysis

This stock is not currently subject to a rebuilding plan.

## I. Data Gaps and Research Priorities

Currently, no recommendations regarding research priorities for this stock have been advanced.

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Table 1. The 1978/79 – 2011/12 directed St. Matthew Island blue king crab pot fishery. Source: Bowers et al. 2011; ADF&G Dutch Harbor staff, pers. comm.; ADF&G Crab Observer Database.

| | | | Harvest[b] | | | | | |
|---|---|---|---|---|---|---|---|---|
| season | dates | GHL/TAC[a] | crab | pounds | pot lifts | CPUE[c] | avg wt[d] | avg CL[e] |
| 1978/79 | 07/15-09/03 | | 436,126 | 1,984,251 | 43,754 | 10 | 4.5 | 132.2 |
| 1979/80 | 07/15-08/24 | | 52,966 | 210,819 | 9,877 | 5 | 4.0 | 128.8 |
| 1980/81 | 07/15-09/03 | | | **CONFIDENTIAL** | | | | |
| 1981/82 | 07/15-08/21 | | 1,045,619 | 4,627,761 | 58,550 | 18 | 4.4 | NA |
| 1982/83 | 08/01-08/16 | | 1,935,886 | 8,844,789 | 165,618 | 12 | 4.6 | 135.1 |
| 1983/84 | 08/20-09/06 | 8 | 1,931,990 | 9,454,323 | 133,944 | 14 | 4.9 | 137.2 |
| 1984/85 | 09/01-09/08 | 2.0-4.0 | 841,017 | 3,764,592 | 73,320 | 11 | 4.5 | 135.5 |
| 1985/86 | 09/01-09/06 | 0.9-1.9 | 436,021 | 2,175,087 | 46,988 | 9 | 5.0 | 139.0 |
| 1986/87 | 09/01-09/06 | 0.2-0.5 | 219,548 | 1,003,162 | 22,073 | 10 | 4.6 | 134.3 |
| 1987/88 | 09/01-09/05 | 0.6-1.3 | 227,447 | 1,039,779 | 28,230 | 8 | 4.6 | 134.1 |
| 1988/89 | 09/01-09/05 | 0.7-1.5 | 280,401 | 1,236,462 | 21,678 | 13 | 4.4 | 133.3 |
| 1989/90 | 09/01-09/04 | 1.7 | 247,641 | 1,166,258 | 30,803 | 8 | 4.7 | 134.6 |
| 1990/91 | 09/01-09/07 | 1.9 | 391,405 | 1,725,349 | 26,264 | 15 | 4.4 | 134.3 |
| 1991/92 | 09/16-09/20 | 3.2 | 726,519 | 3,372,066 | 37,104 | 20 | 4.6 | 134.1 |
| 1992/93 | 09/04-09/07 | 3.1 | 545,222 | 2,475,916 | 56,630 | 10 | 4.5 | 134.1 |
| 1993/94 | 09/15-09/21 | 4.4 | 630,353 | 3,003,089 | 58,647 | 11 | 4.8 | 135.4 |
| 1994/95 | 09/15-09/22 | 3.0 | 827,015 | 3,764,262 | 60,860 | 14 | 4.9 | 133.3 |
| 1995/96 | 09/15-09/20 | 2.4 | 666,905 | 3,166,093 | 48,560 | 14 | 4.7 | 135.0 |
| 1996/97 | 09/15-09/23 | 4.3 | 660,665 | 3,078,959 | 91,085 | 7 | 4.7 | 134.6 |
| 1997/98 | 09/15-09/22 | 5.0 | 939,822 | 4,649,660 | 81,117 | 12 | 4.9 | 139.5 |
| 1998/99 | 09/15-09/26 | 4.0 | 635,370 | 2,968,573 | 91,826 | 7 | 4.7 | 135.8 |
| 1999/00-2008/09 | | | | **FISHERY CLOSED** | | | | |
| 2009/10 | 10/15-02/01 | 1.17 | 103,376 | 460,859 | 10,697 | 10 | 4.5 | 134.9 |
| 2010/11 | 10/15-02/01 | 1.60 | 298,669 | 1,263,982 | 29,344 | 10 | 4.2 | 129.3 |
| 2011/12 | 10/15-02/01 | 2.54 | 437,862 | 1,881,322 | 48,554 | 9 | 4.3 | 130.0 |

[a] Guideline Harvest Level/Total Allowable Catch in millions of pounds.
[b] Includes deadloss.
[c] Harvest number/pot lifts.
[d] Harvest weight/harvest number, in pounds.
[e] Average CL of retained crab in millimeters, from dockside sampling of delivered crab.

Table 2. NMFS EBS trawl-survey area-swept estimates of male crab abundance ($10^6$ crab) and of mature male biomass ($10^6$ lb). Total number of captured male crab $\geq$ 90 mm CL is also given. Source: J.Zheng, ADF&G; R.Foy, NMFS.

| | abundance | | | | | biomass | | |
|---|---|---|---|---|---|---|---|---|
| year | stage 1 (90-104mm CL) | stage 2 (105-119mm CL) | stage 3 (120mm+ CL) | Total | CV | mature male (105mm+ CL) | cv | number of crab |
| 1978 | 2.384 | 2.268 | 1.764 | 6.416 | 0.46 | 11.876 | 0.39 | 163 |
| 1979 | 2.939 | 2.225 | 2.223 | 7.388 | 0.44 | 12.864 | 0.39 | 187 |
| 1980 | 2.539 | 2.456 | 2.867 | 7.861 | 0.57 | 16.724 | 0.47 | 188 |
| 1981 | 0.477 | 1.233 | 2.346 | 4.055 | 0.36 | 12.833 | 0.40 | 140 |
| 1982 | 1.713 | 2.495 | 5.987 | 10.194 | 0.38 | 30.748 | 0.32 | 269 |
| 1983 | 1.078 | 1.663 | 3.363 | 6.104 | 0.34 | 17.921 | 0.28 | 231 |
| 1984 | 0.410 | 0.499 | 1.478 | 2.387 | 0.24 | 7.684 | 0.19 | 104 |
| 1985 | 0.381 | 0.376 | 1.124 | 1.881 | 0.22 | 5.750 | 0.22 | 93 |
| 1986 | 0.206 | 0.457 | 0.377 | 1.039 | 0.44 | 2.578 | 0.39 | 46 |
| 1987 | 0.325 | 0.631 | 0.715 | 1.671 | 0.32 | 4.060 | 0.29 | 71 |
| 1988 | 0.410 | 0.816 | 0.957 | 2.183 | 0.30 | 5.693 | 0.24 | 81 |
| 1989 | 2.164 | 1.158 | 1.792 | 5.115 | 0.37 | 9.675 | 0.25 | 211 |
| 1990 | 1.053 | 1.031 | 2.338 | 4.422 | 0.32 | 11.955 | 0.26 | 170 |
| 1991 | 1.135 | 1.680 | 2.236 | 5.052 | 0.36 | 12.255 | 0.25 | 198 |
| 1992 | 1.074 | 1.382 | 2.291 | 4.746 | 0.33 | 12.649 | 0.20 | 220 |
| 1993 | 1.521 | 1.828 | 3.276 | 6.626 | 0.26 | 16.959 | 0.16 | 324 |
| 1994 | 0.883 | 1.298 | 2.257 | 4.438 | 0.18 | 11.696 | 0.18 | 211 |
| 1995 | 1.025 | 1.188 | 1.741 | 3.953 | 0.19 | 9.843 | 0.17 | 178 |
| 1996 | 1.238 | 1.891 | 3.064 | 6.193 | 0.25 | 17.112 | 0.24 | 285 |
| 1997 | 1.165 | 2.228 | 3.789 | 7.182 | 0.35 | 20.143 | 0.33 | 296 |
| 1998 | 0.660 | 1.661 | 2.849 | 5.170 | 0.34 | 15.054 | 0.36 | 243 |
| 1999 | 0.223 | 0.222 | 0.558 | 1.003 | 0.24 | 2.871 | 0.18 | 52 |
| 2000 | 0.282 | 0.285 | 0.740 | 1.307 | 0.30 | 3.795 | 0.31 | 61 |
| 2001 | 0.419 | 0.502 | 0.938 | 1.859 | 0.28 | 5.064 | 0.26 | 91 |
| 2002 | 0.111 | 0.230 | 0.640 | 0.981 | 0.30 | 3.311 | 0.32 | 38 |
| 2003 | 0.449 | 0.280 | 0.465 | 1.194 | 0.56 | 2.483 | 0.32 | 65 |
| 2004 | 0.247 | 0.184 | 0.562 | 0.993 | 0.45 | 2.705 | 0.29 | 48 |
| 2005 | 0.319 | 0.310 | 0.501 | 1.130 | 0.41 | 2.812 | 0.36 | 42 |
| 2006 | 0.917 | 0.642 | 1.240 | 2.798 | 0.36 | 6.494 | 0.36 | 126 |
| 2007 | 2.518 | 2.020 | 1.193 | 5.730 | 0.40 | 9.157 | 0.35 | 250 |
| 2008 | 1.352 | 0.801 | 1.457 | 3.609 | 0.36 | 7.354 | 0.29 | 167 |
| 2009 | 1.573 | 2.161 | 1.410 | 5.144 | 0.27 | 10.189 | 0.26 | 251 |
| 2010 | 3.927 | 3.253 | 2.458 | 9.638 | 0.58 | 17.948 | 0.37 | 385 |
| 2011 | 1.693 | 3.215 | 3.252 | 8.160 | 0.59 | 21.073 | 0.53 | 315 |
| 2012 | 0.705 | 1.967 | 1.808 | 4.483 | 0.36 | 12.461 | 0.33 | 193 |

Table 3. Observed proportion of crab by size class during ADF&G crab observer pot-lift sampling. Source: ADF&G Crab Observer Database.

| year | pot lifts (sampled/total) | number of crab (90 mm+ CL) | stage 1 (90-104 mm CL) | stage 2 (105-119 mm CL) | stage 3 (120 mm+ CL) |
|---|---|---|---|---|---|
| 1990/91 | 10/26,264 | 150 | 0.113 | 0.393 | 0.493 |
| 1991/92 | 125/37,104 | 3,393 | 0.133 | 0.177 | 0.690 |
| 1992/93 | 71/56,630 | 1,606 | 0.191 | 0.268 | 0.542 |
| 1993/94 | 84/58,647 | 2,241 | 0.281 | 0.210 | 0.510 |
| 1994/95 | 203/60,860 | 4,735 | 0.294 | 0.271 | 0.434 |
| 1995/96 | 47/48,560 | 663 | 0.148 | 0.212 | 0.640 |
| 1996/97 | 96/91,085 | 489 | 0.160 | 0.223 | 0.618 |
| 1997/98 | 133/81,117 | 3,195 | 0.182 | 0.205 | 0.613 |
| 1998/99 | 135/91,826 | 1,322 | 0.193 | 0.216 | 0.591 |
| 2009/10 | 989/10,484 | 19,802 | 0.141 | 0.324 | 0.535 |
| 2010/11 | 2,419/29,356 | 45,466 | 0.131 | 0.315 | 0.553 |
| 2011/12 | 3,359/48,554 | 58,666 | 0.131 | 0.305 | 0.564 |

Table 4. Size-class and total CPUE (90 mm+ CL) and estimated CV and total number of captured crab (90 mm+ CL) from the 96 common stations surveyed during the six triennial ADF&G SMBKC pot surveys. Source: D.Pengilly and R.Gish, ADF&G.

| year | stage 1 (90-104mm CL) | stage 2 (105-119mm CL) | stage 3 (120mm+ CL) | CPUE | CV | number of crab |
|---|---|---|---|---|---|---|
| 1995 | 1.919 | 3.198 | 6.922 | 12.042 | 0.13 | 4,624 |
| 1998 | 0.964 | 2.763 | 8.804 | 12.531 | 0.06 | 4,812 |
| 2001 | 1.266 | 1.737 | 5.487 | 8.477 | 0.08 | 3,255 |
| 2004 | 0.112 | 0.414 | 1.141 | 1.667 | 0.15 | 640 |
| 2007 | 1.086 | 2.721 | 4.836 | 8.643 | 0.09 | 3,319 |
| 2010 | 1.326 | 3.276 | 5.607 | 10.209 | 0.13 | 3,920 |

Table 5. Groundfish SMBKC male bycatch biomass ($10^3$ pounds) data. Source: R.Foy, NMFS.

| year | bycatch: trawl[a] | bycatch: fixed gear | total mortality[b] |
|---|---|---|---|
| 1991/92 | 7.8 | 0.1 | 6.3 |
| 1992/93 | 4.4 | 5.0 | 6.0 |
| 1993/94 | 3.4 | 0.0 | 2.7 |
| 1994/95 | 0.7 | 0.2 | 0.7 |
| 1995/96 | 1.4 | 0.3 | 1.3 |
| 1996/97 | 0.0 | 0.1 | 0.1 |
| 1997/98 | 0.0 | 0.4 | 0.2 |
| 1998/99 | 0.0 | 2.0 | 1.0 |
| 1999/00 | 0.0 | 3.0 | 1.5 |
| 2000/01 | 0.0 | 0.0 | 0.0 |
| 2001/02 | 0.0 | 1.9 | 1.0 |
| 2002/03 | 1.6 | 0.9 | 1.7 |
| 2003/04 | 2.2 | 2.5 | 3.0 |
| 2004/05 | 0.2 | 1.4 | 0.9 |
| 2005/06 | 0.0 | 1.3 | 0.7 |
| 2006/07 | 6.2 | 3.2 | 6.6 |
| 2007/08 | 0.1 | 153.7 | 76.9 |
| 2008/09 | 0.6 | 14.6 | 7.8 |
| 2009/10 | 1.7 | 18.3 | 10.5 |
| 2010/11 | 0.1 | 7.5 | 3.8 |
| 2011/12 | 0.0 | 1.8 | 0.9 |

[a] Trawl, pelagic trawl, and non-pelagic trawl gear types.
[b] Assuming handling mortalities of 0.8 for trawl and 0.5 for fixed gear.

Table 6. Base and alternative model estimates of trawl-survey selectivity parameters and of key management quantities. Numbers associated with model-configuration C are natural mortality deviation penalty weights.

| | trawl-survey selectivity estimates | | | management quantities (millions of pounds) | | |
|---|---|---|---|---|---|---|
| model | stage 1 | stage 2 | stage 3 | Bmsy[a] | OFL[b] | MMBmating[c] |
| base | 0.93 | 1.37 | Q = 1 | 7.93 | 2.24 | 12.41 |
| A1 | 0.90 | 1.34 | Q = 1 | 7.86 | 2.25 | 14.01 |
| A2 | 0.84 | 1.27 | Q = 1 | 7.90 | 3.36 | 18.60 |
| A3 | 1.01 | 1.48 | Q = 1 | 8.72 | 2.10 | 11.469 |
| B1 | 0.72 | 0.87 | 0.87 | 8.81 | 3.18 | 17.79 |
| B2 | 0.65 | Q = 1 | 0.49 | 14.57 | 3.25 | 17.87 |
| C (5.0) | 0.79 | 1.22 | Q = 1 | 6.82 | 1.72 | 9.82[d] |
| C (12.5) | 0.86 | 1.30 | Q = 1 | 7.23 | 2.02 | 11.33[d] |
| C (50.0) | 0.93 | 1.37 | Q = 1 | 7.75 | 2.13 | 11.82[d] |

[a] Average 1978-2011 model MMBmating.
[b] Tier 4 assuming Fmsy = 0.18 $yr^{-1}$.
[c] Model projected 2013 value assuming OFL catch.
[d] Assuming M = 0.18 $yr^{-1}$ in 2013.

Table 7. Base-model parameter estimates and standard errors. Ranges are given for log recruit and log fishing mortality deviations.

| parameter | estimate | standard error |
|---|---|---|
| 1998/99 natural mortality | 1.03 | 0.135 |
| pot-survey proportionality constant | 3.88 | 0.359 |
| trawl-survey stage-1 selectivity | 0.93 | 0.066 |
| trawl-survey stage-2 selectivity | 1.37 | 0.087 |
| pot-survey stage-1 selectivity | 0.36 | 0.059 |
| pot-survey stage-2 selectivity | 0.99 | 0.122 |
| pot-fishery stage-1 selectivity | 0.42 | 0.045 |
| pot-fishery stage-2 selectivity | 0.74 | 0.066 |
| log initial stage-1 abundance | 7.69 | 0.182 |
| log initial stage-2 abundance | 7.34 | 0.243 |
| log initial stage-3 abundance | 7.40 | 0.249 |
| mean log recruit abundance | 6.80 | 0.054 |
| mean log recruit abundance deviations (34) | [-1.69, 1.12] | [0.103, 0.369] |
| mean log directed fishing mortality | -1.42 | 0.068 |
| log directed fishing mortality deviations (24) | [-3.17, 1.39] | [0.089, 0.272] |
| mean log GF trawl fishing mortality | -10.92 | 0.237 |
| log GF trawl fishing mortality deviations (21) | [-1.61, 1.78] | [0.698, 0.734] |
| mean log GF fixed-gear fishing mortality | -9.58 | 0.228 |
| log GF fixed-gear fishing mortality deviations (21) | [-2.20, 2.44] | [0.689, 0.701] |

Table 8. Base-model ADMB parameter correlations. Does not include those for recruit and fishing mortality deviations.

| | parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1998/99 M | 1 | | | | | | | | | | | | | |
| 2 | PS Q | -0.26 | 1 | | | | | | | | | | | | |
| 3 | TS s1 selectivity | -0.34 | 0.22 | 1 | | | | | | | | | | | |
| 4 | TS s2 selectivity | -0.29 | 0.21 | 0.46 | 1 | | | | | | | | | | |
| 5 | PS s1 selectivity | -0.14 | -0.23 | 0.10 | 0.09 | 1 | | | | | | | | | |
| 6 | PS s2 selectivity | -0.14 | -0.36 | 0.09 | 0.08 | 0.22 | 1 | | | | | | | | |
| 7 | PF s1 selectivity | -0.15 | -0.06 | 0.10 | 0.12 | 0.15 | 0.16 | 1 | | | | | | | |
| 8 | PF s2 selectivity | -0.07 | -0.13 | 0.05 | 0.05 | 0.11 | 0.14 | 0.51 | 1 | | | | | | |
| 9 | log initial N1 | -0.05 | 0.02 | 0.09 | 0.10 | 0.02 | 0.02 | 0.05 | 0.05 | 1 | | | | | |
| 10 | log initial N2 | -0.05 | 0.03 | 0.17 | 0.04 | 0.02 | 0.02 | 0.04 | 0.04 | 0.09 | 1 | | | | |
| 11 | log initial N3 | -0.13 | 0.09 | 0.29 | 0.32 | 0.05 | 0.04 | 0.07 | 0.05 | 0.00 | -0.16 | 1 | | | |
| 12 | mean log PF F | 0.00 | 0.30 | -0.21 | -0.21 | -0.10 | -0.13 | -0.37 | -0.41 | -0.21 | -0.18 | -0.44 | 1 | | |
| 13 | mean log recruits | 0.46 | -0.68 | -0.43 | -0.38 | -0.11 | -0.06 | 0.01 | 0.13 | -0.12 | -0.12 | -0.22 | -0.24 | 1 | |
| 14 | mean log GFT F | -0.06 | 0.23 | 0.09 | 0.08 | 0.00 | -0.01 | -0.03 | -0.05 | 0.01 | 0.01 | 0.03 | 0.12 | -0.26 | 1 |
| 15 | mean log GFF F | -0.06 | 0.24 | 0.09 | 0.08 | 0.00 | -0.01 | -0.03 | -0.05 | 0.01 | 0.01 | 0.03 | 0.12 | -0.27 | 0.09 |

Table 9. Partitioning of the OFL. Catches are in millions of pounds, with metric ton equivalents in parentheses.

| | | | OFL | | | | |
|---|---|---|---|---|---|---|---|
| | | | directed fishery | | groundfish bycatch mortality | | |
| year | tier | $F_{OFL}$ ($yr^{-1}$) | retained | discard mortality | trawl | fixed gear | total male |
| 2009/10 | 4a | 0.18 | 1.53 (694) | NA | NA | NA | 1.72 (780) |
| 2010/11 | 4a | 0.18 | 1.90 (862) | 0.263 (119) | 0.003 (1) | 0.038 (17) | 2.29 (1,040) |
| 2011/12 | 4a | 0.18 | 3.36 (1,520) | 0.296 (134) | 0.001 (0.5) | 0.009 (4) | 3.74 (1,700) |
| 2012/13[a] | 4a | 0.18 | 2.14 (971) | 0.095 (43) | 0.0002 (0.1) | 0.0009 (0.4) | 2.24 (1,020) |

[a] From Fall 2012 base-model configuration.

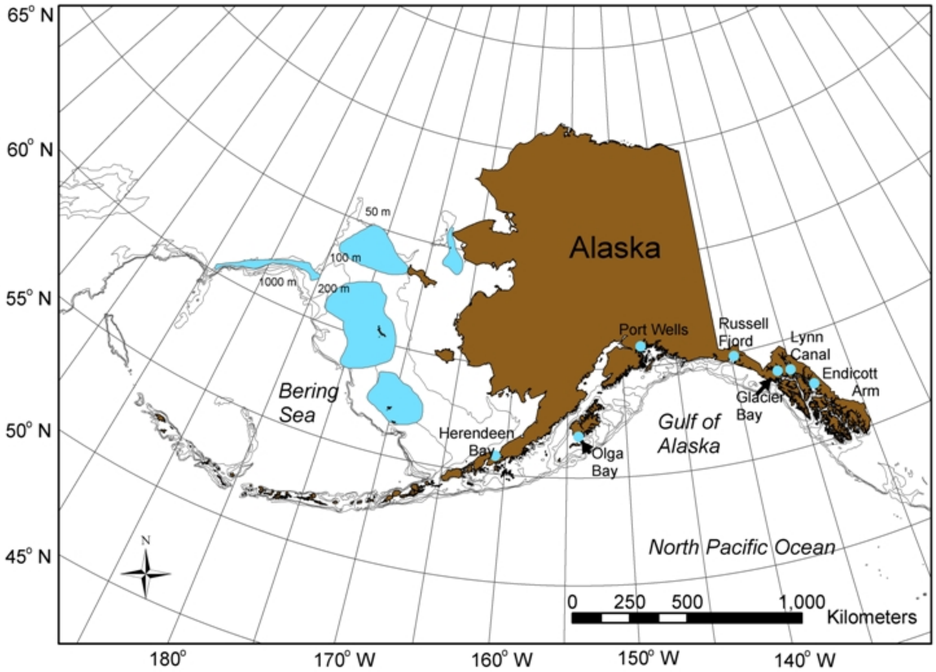


Figure 1. Distribution of blue king crab *Paralithodes platypus* in the Gulf of Alaska, Bering Sea, and Aleutian Islands waters. Shown in blue.

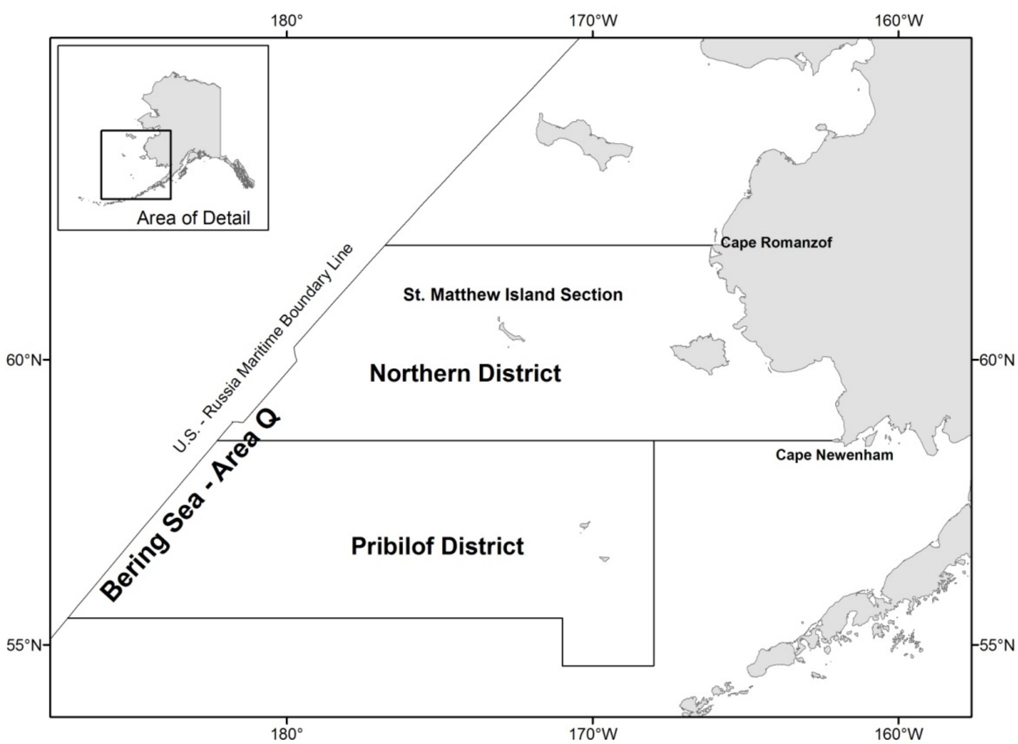


Figure 2. King crab Registration Area Q (Bering Sea).

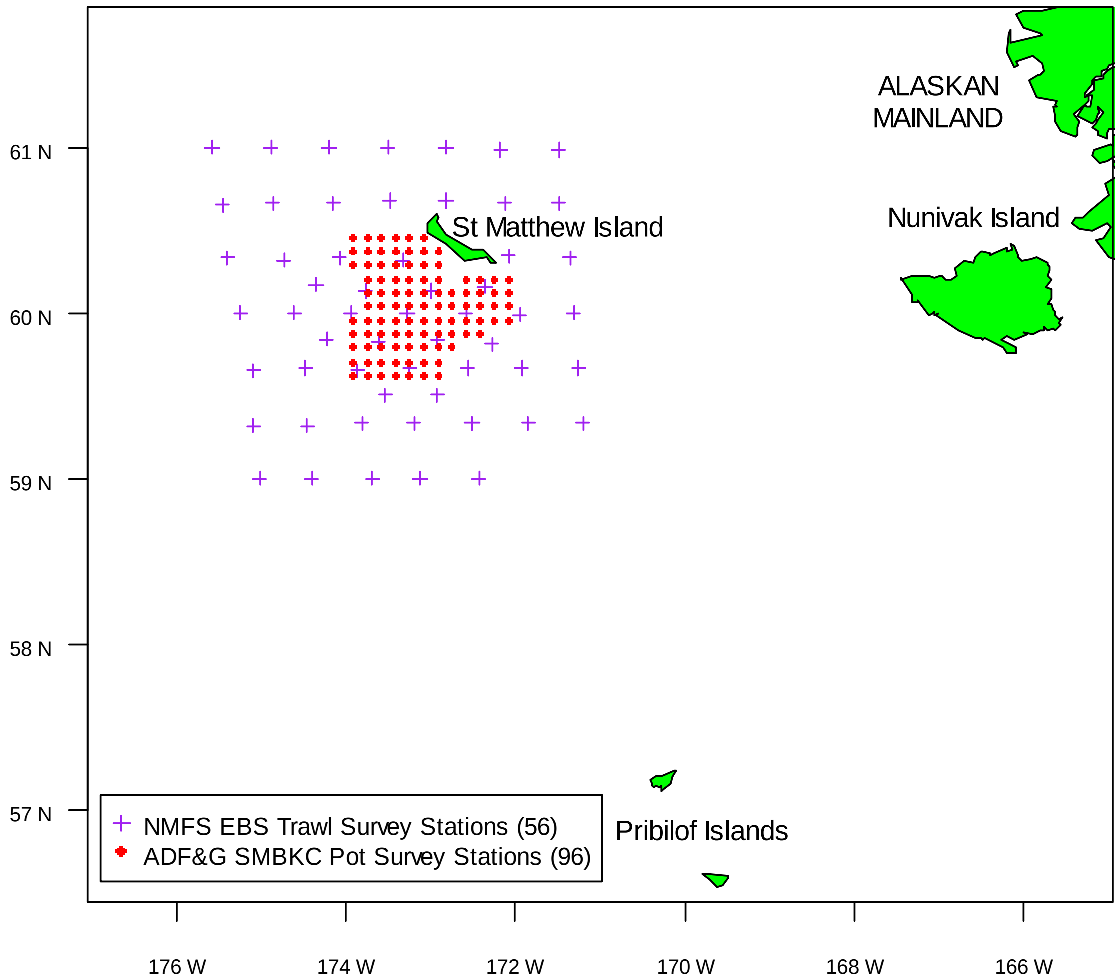


Figure 3: Trawl and pot-survey stations used in the SMBKC stock assessment.

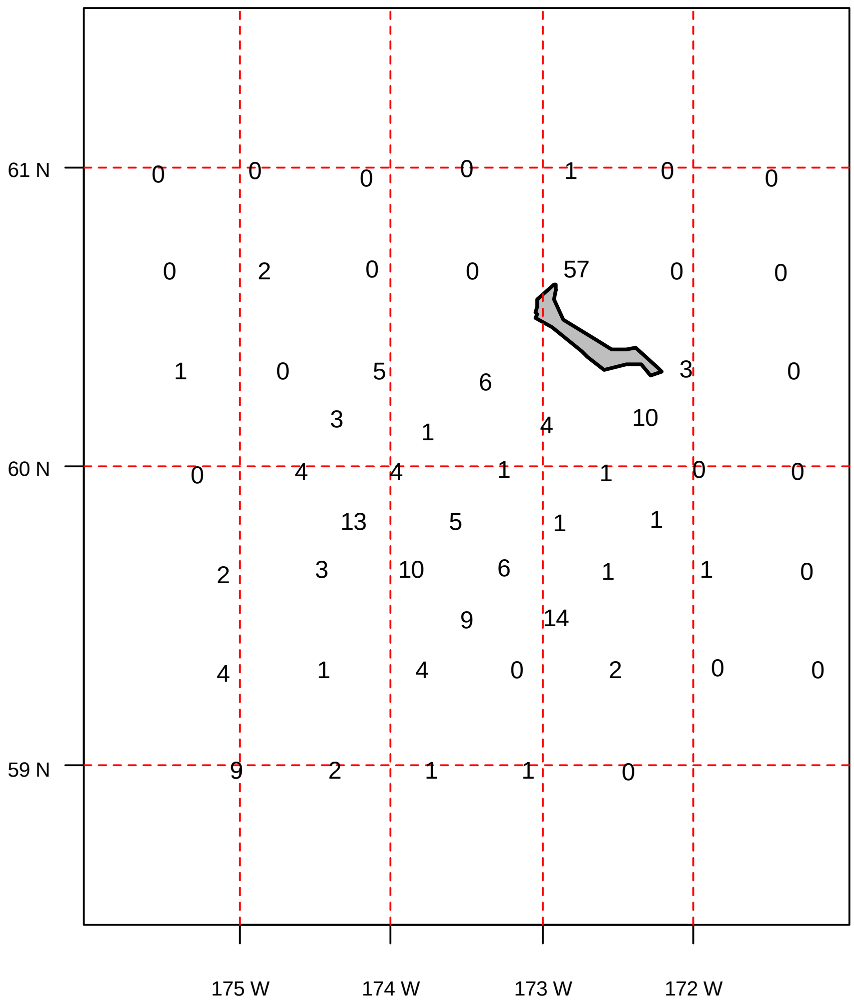


Figure 4. Catches of male blue king crab measuring at least 90 mm CL from the 2012 NMFS trawl-survey at the 56 stations used to assess the SMBKC stock. Note that the area north of St. Matthew Island is not represented in the ADF&G pot-survey data used in the assessment.

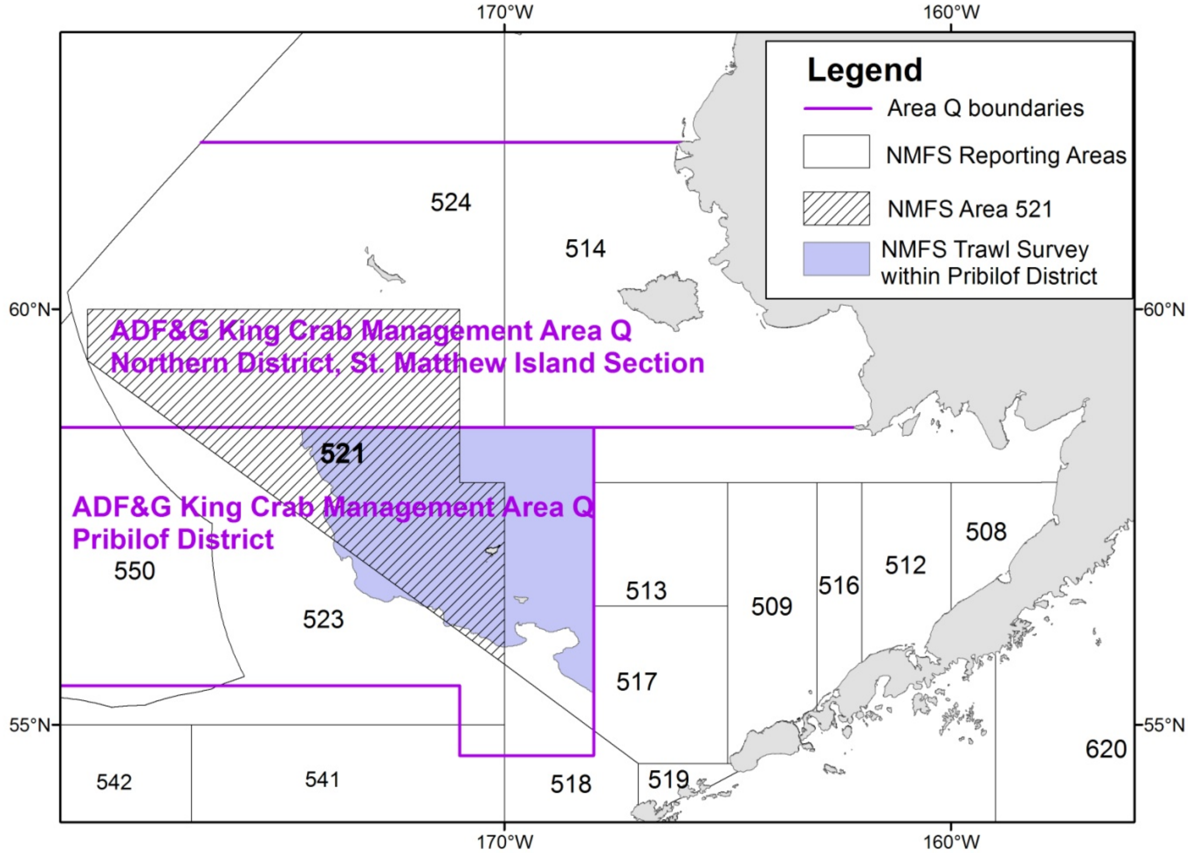


Figure 5. NFMS Bering Sea reporting areas. Estimates of SMBKC bycatch in the groundfish fisheries are based on NMFS observer data from reporting areas 524 and 521.

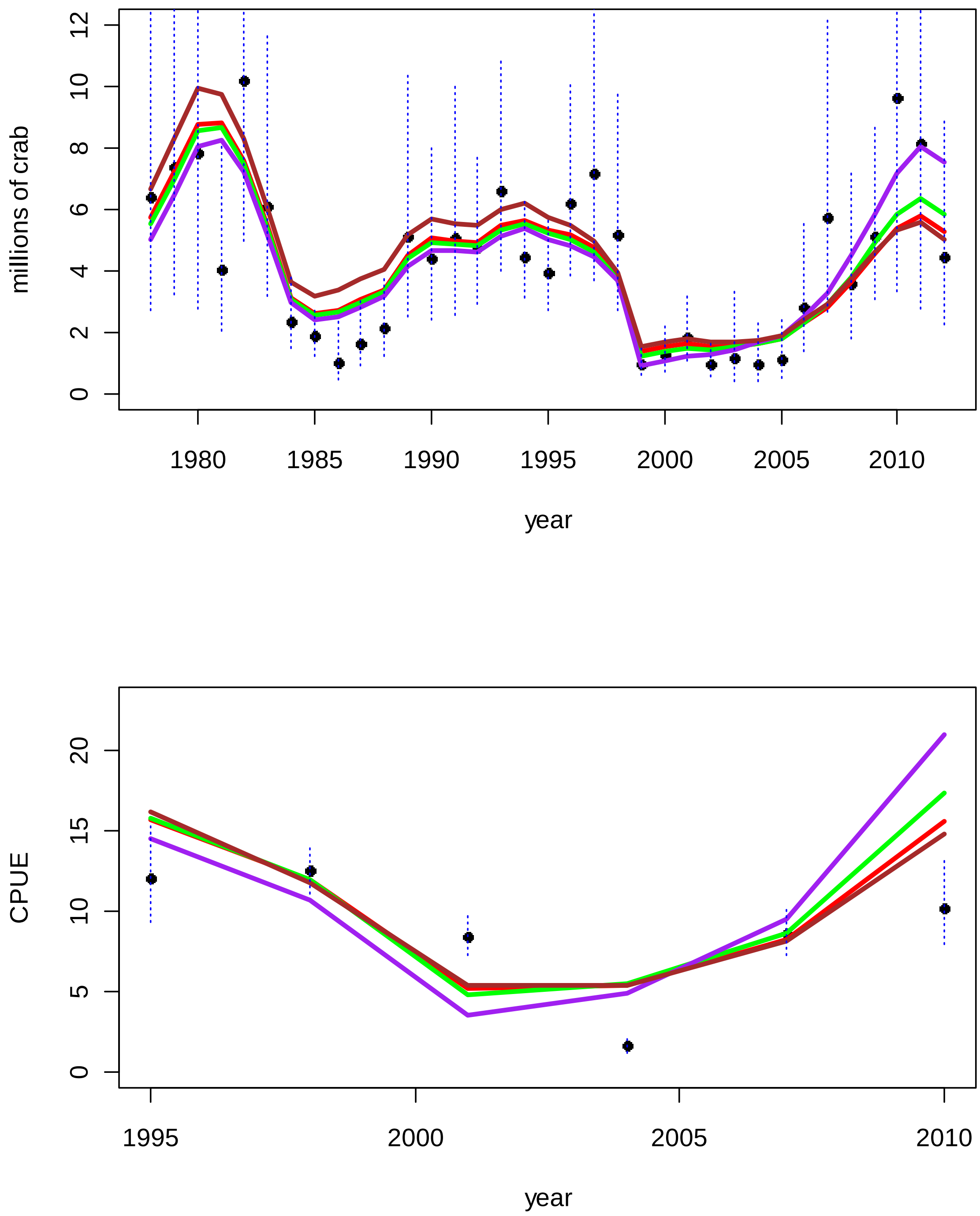


Figure 6. Model fits to trawl (top panel) and pot-survey abundance indices (points) for base model (red) and model configurations A1 (green), A2 (purple), and A3 (brown).

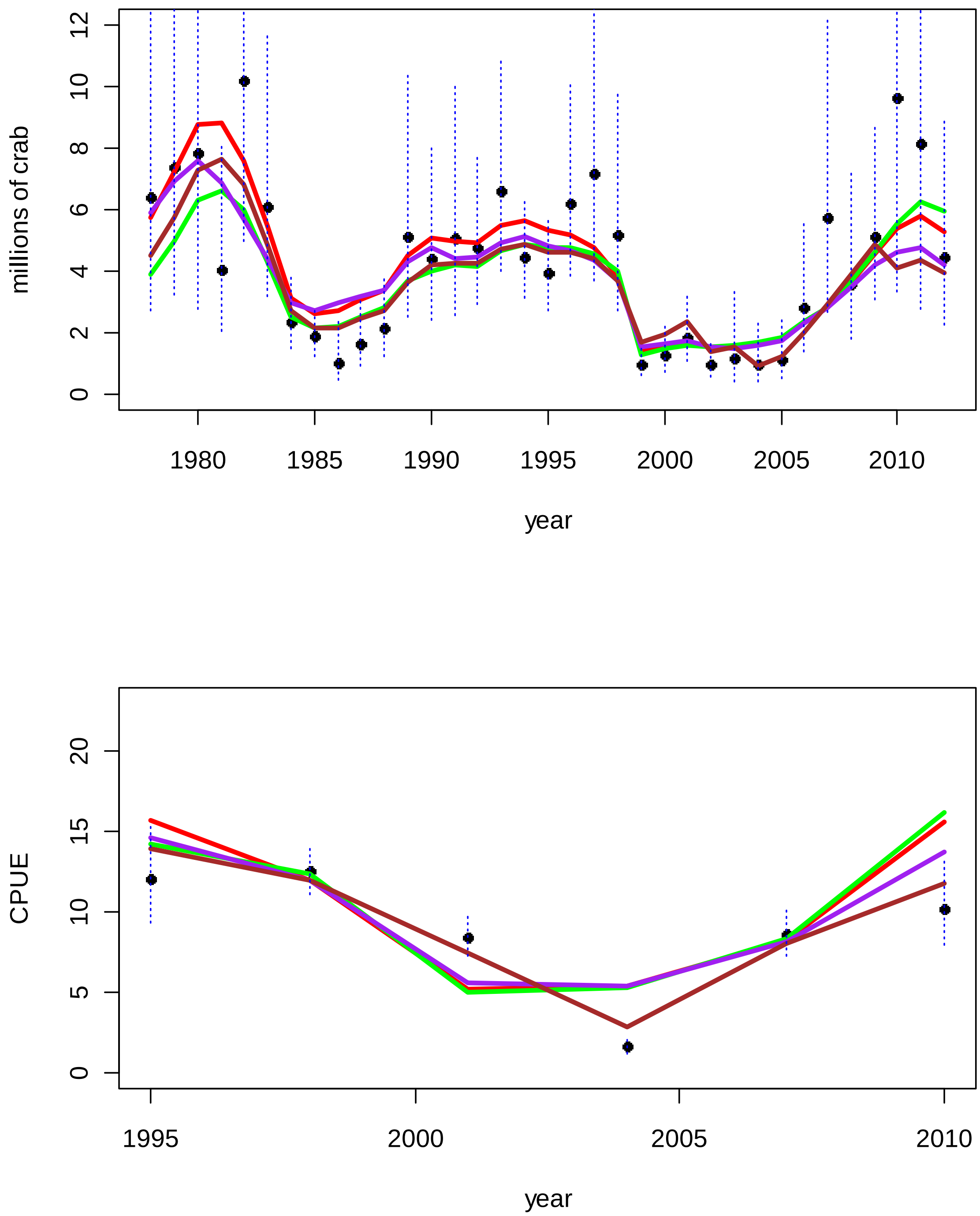


Figure 7. Model fits to trawl (top panel) and pot-survey abundance indices (points) for base model (red) and model configurations B1 (green), B2 (purple), and C (brown).

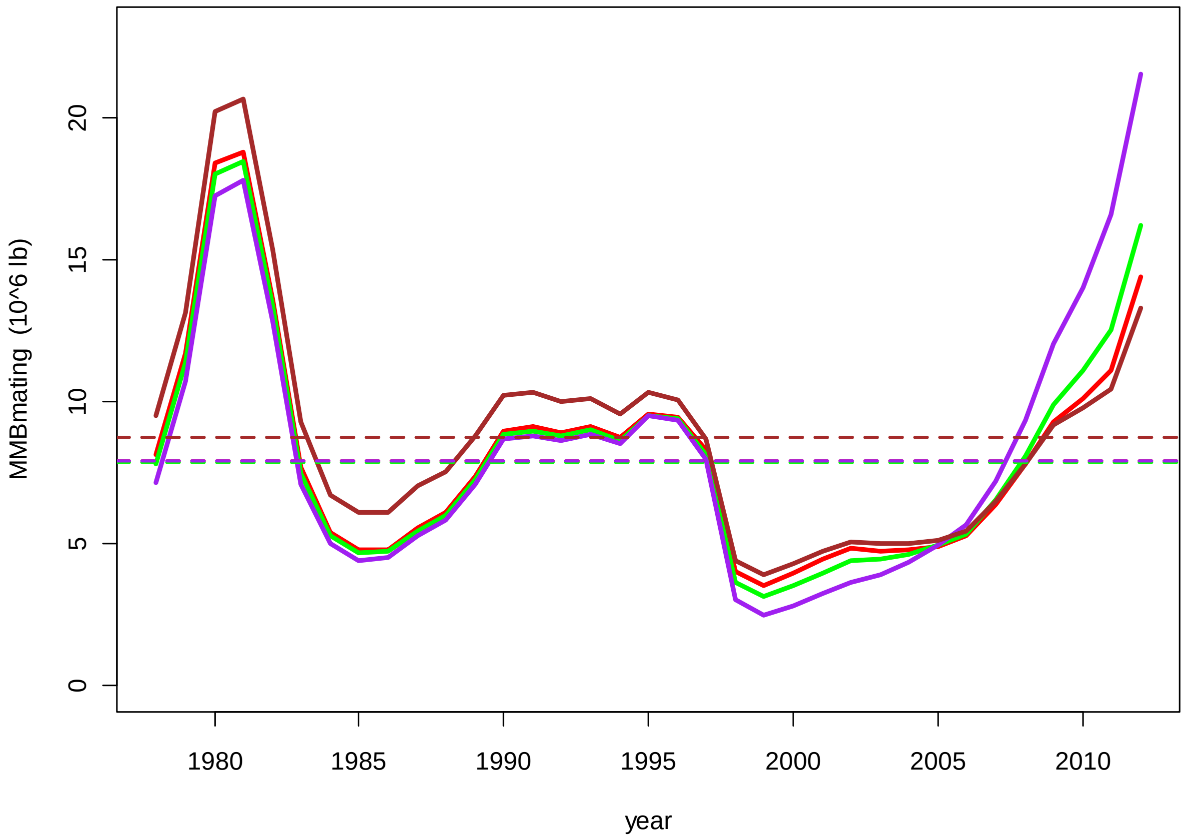


Figure 8. Model mature male biomass at time of mating for base model (red) and model configurations A1 (green), A2 (purple) and A3 (brown). Terminal 2012 estimate assumes no directed fishery. Dotted lines represent respective $B_{MSY}$ proxy values calculated as 1978-2011 average.

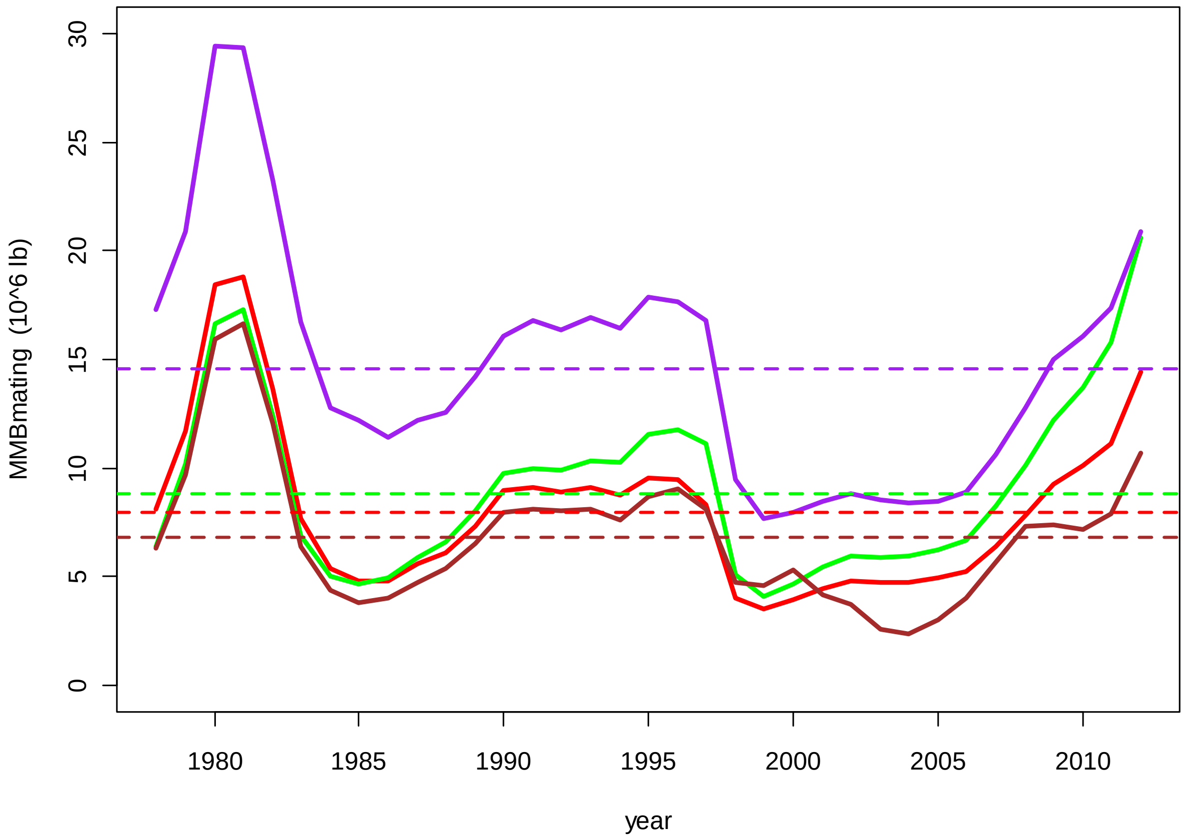


Figure 9. Model mature male biomass at time of mating for base model (red) and model configurations B1 (green), B2 (purple) and C (brown). Terminal 2012 estimate assumes no directed fishery. Dotted lines represent respective $B_{MSY}$ proxy values calculated as 1978-2011 average.

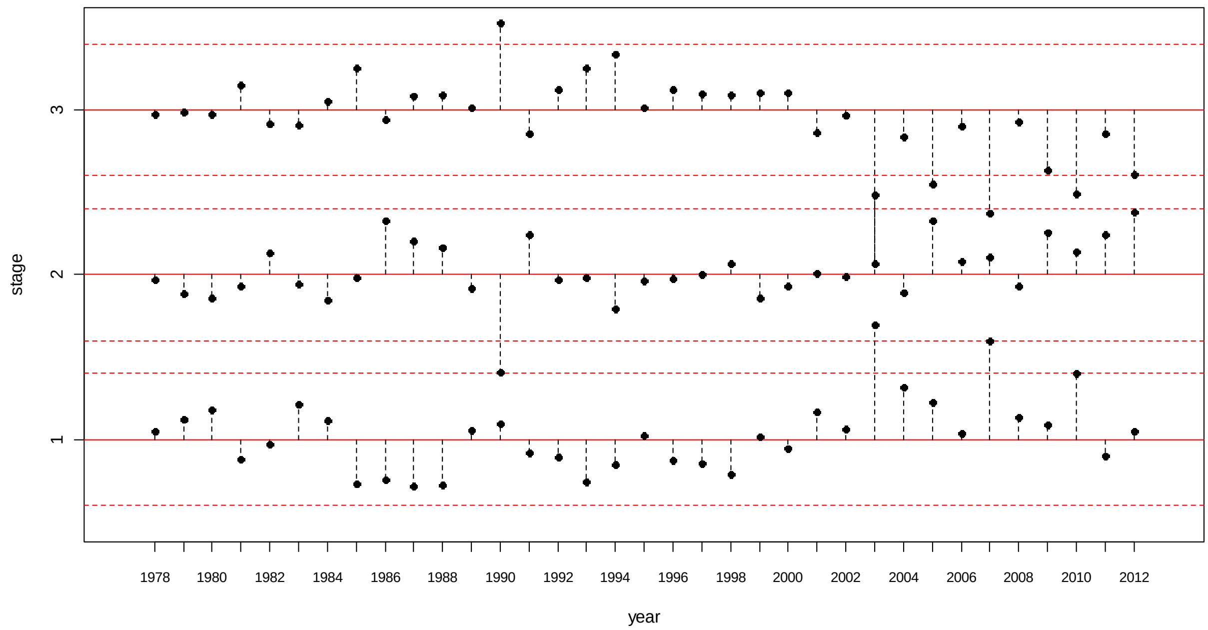


Figure 10. Base-model trawl-survey composition data standardized residuals.

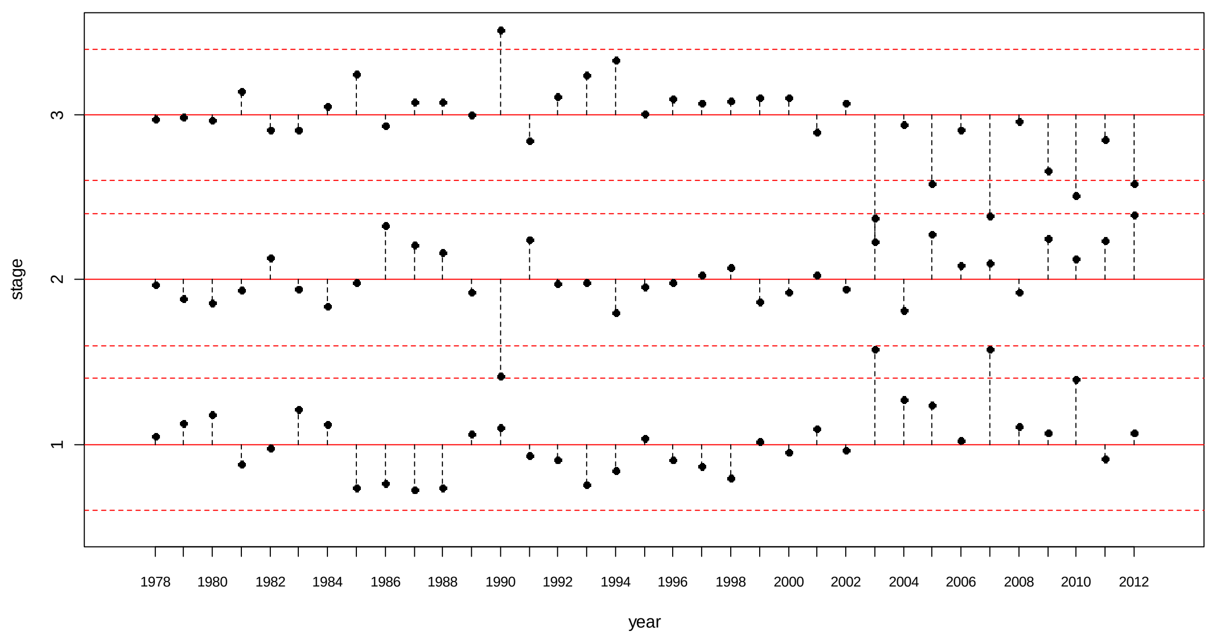


Figure 11. Model A1 trawl-survey composition data standardized residuals.

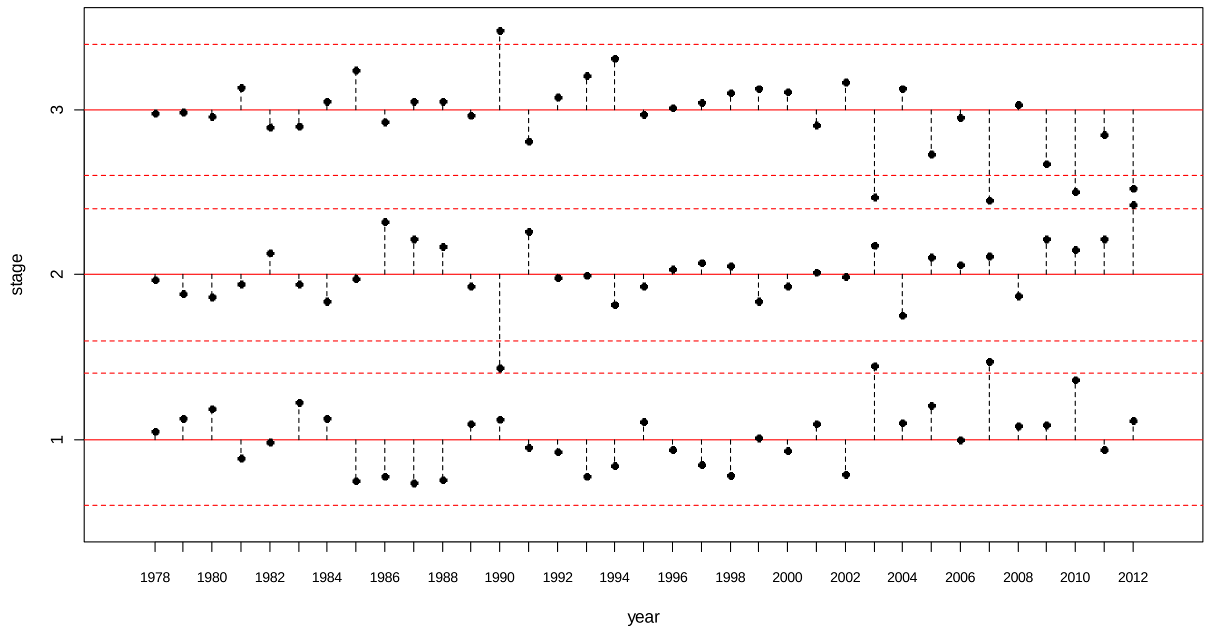


Figure 12. Model A2 trawl-survey composition data standardized residuals.

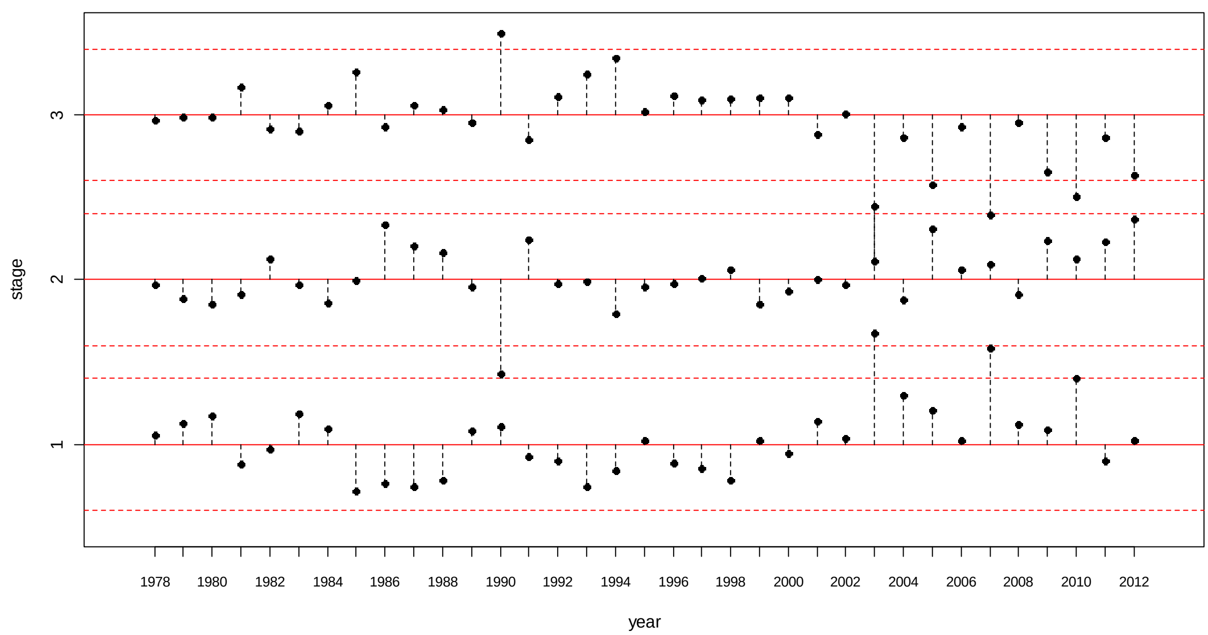


Figure 13. Model A3 trawl-survey composition data standardized residuals.

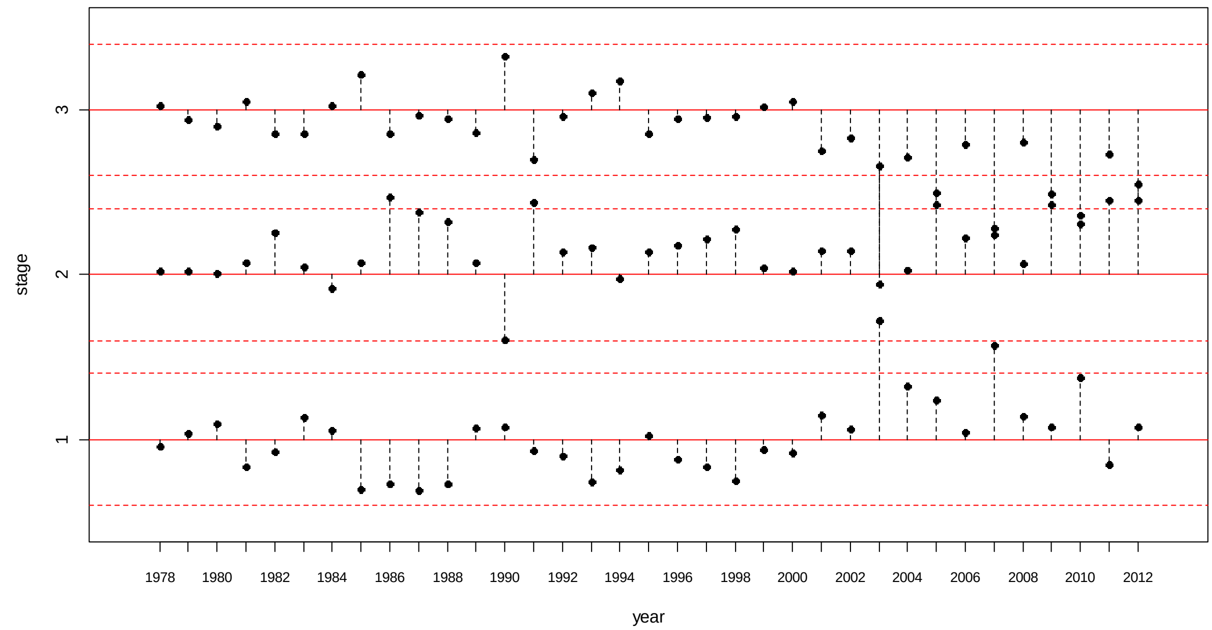


Figure 14. Model B1 trawl-survey composition data standardized residuals.

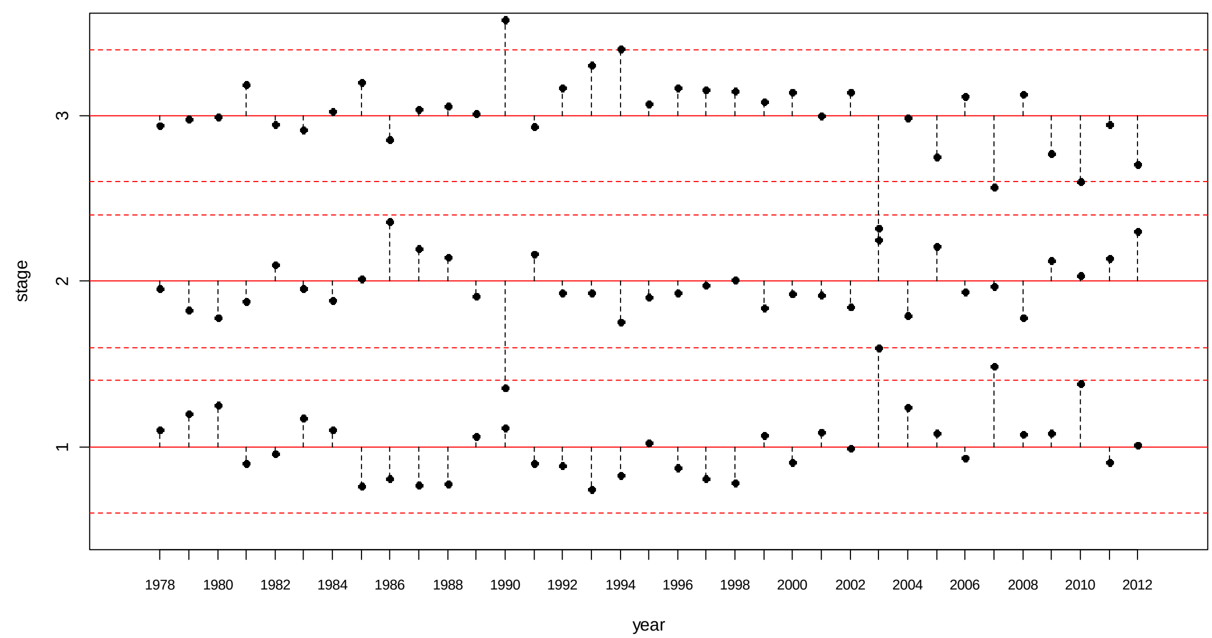


Figure 15. Model B2 trawl-survey composition data standardized residuals.

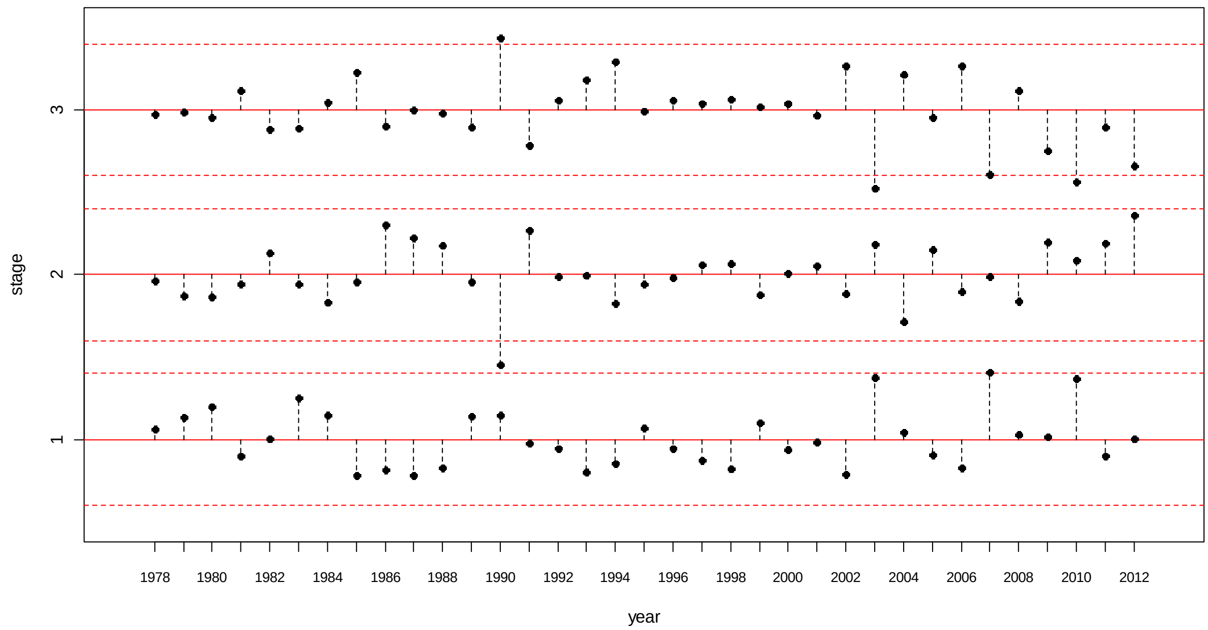


Figure 16. Model C trawl-survey composition data standardized residuals.

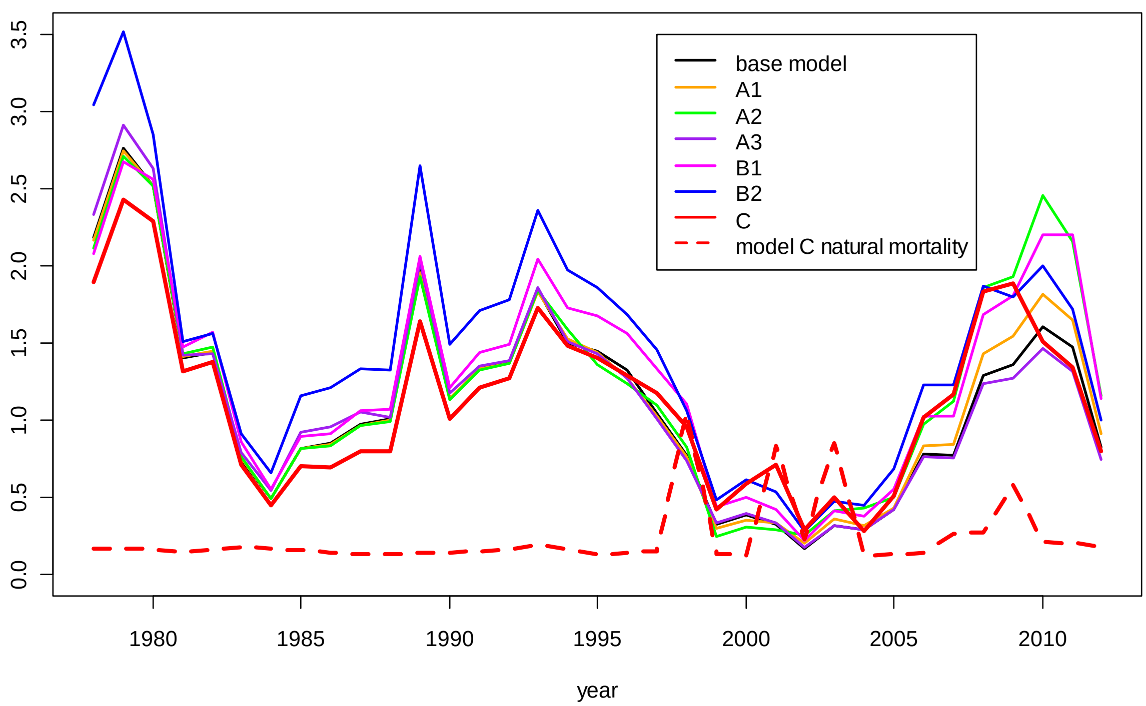


Figure 17. Model recruitment (stage-1 abundance; millions of crab) under the alternative model configurations. Random natural mortality under model configuration C is also shown.

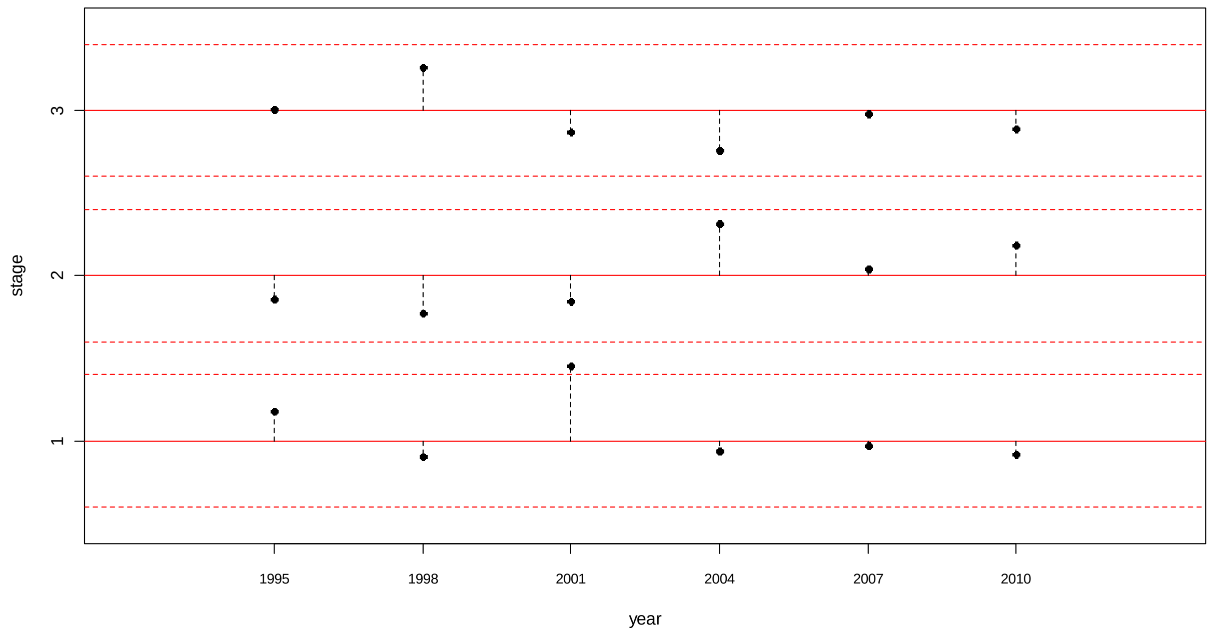


Figure 18. Base-model pot-survey composition data standardized residuals.

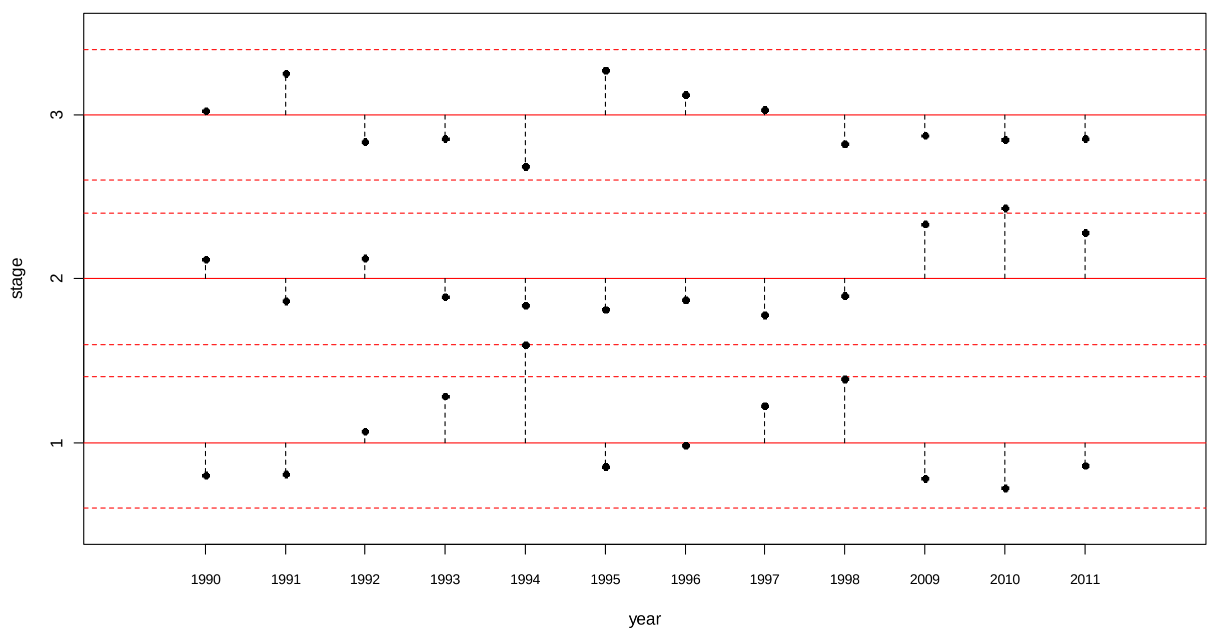


Figure 19. Base-model pot-fishery composition data standardized residuals.

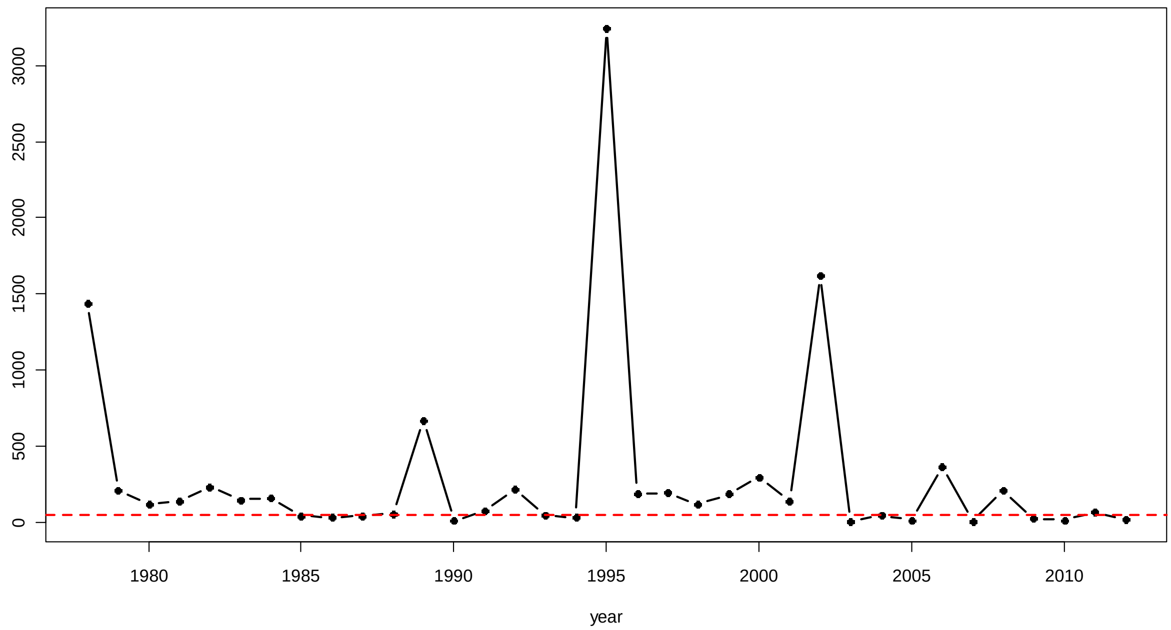


Figure 20. Estimated effective samples sizes for trawl-survey composition data. Model effective sample size is equal to the assumed maximum value 50 (dotted red line) in all but 4 years.

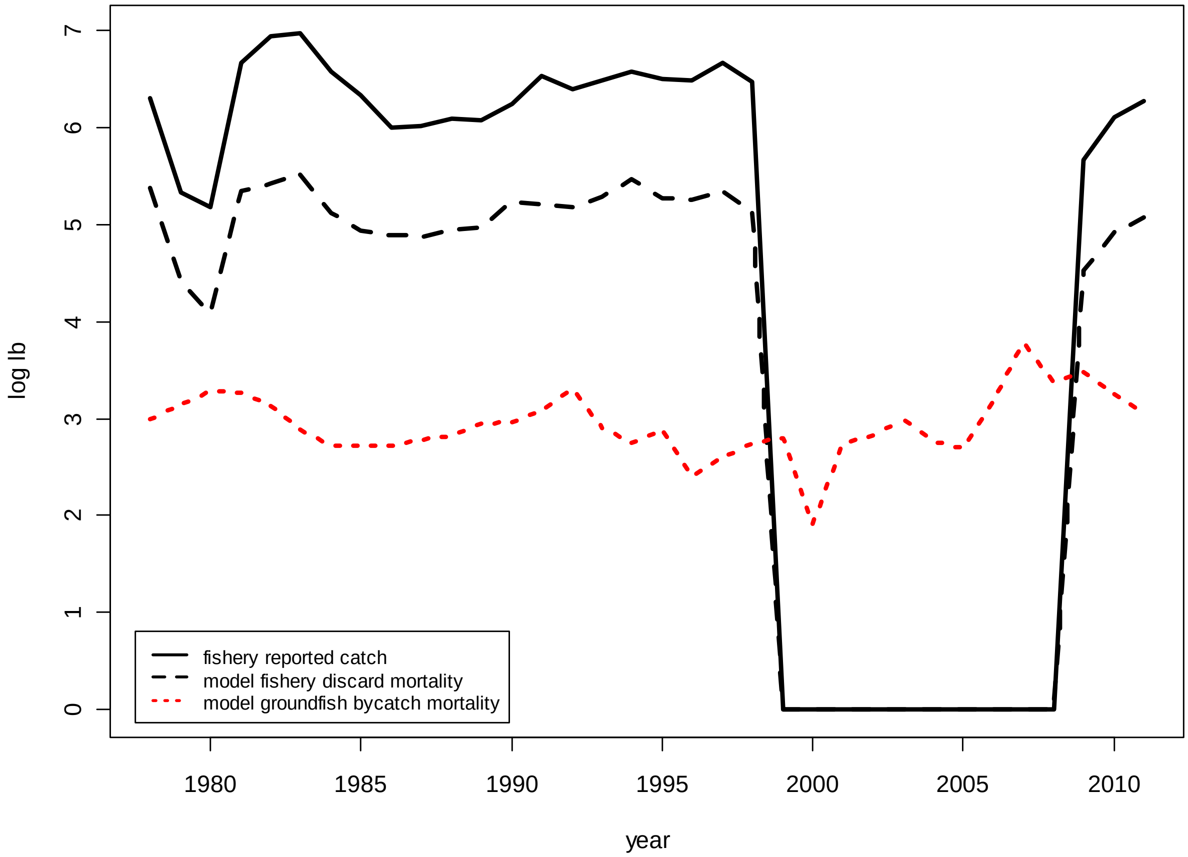


Figure 21. Components of SMBKC fishing mortality biomass for the years 1978/79 – 2011/12. Note logarithmic scale.

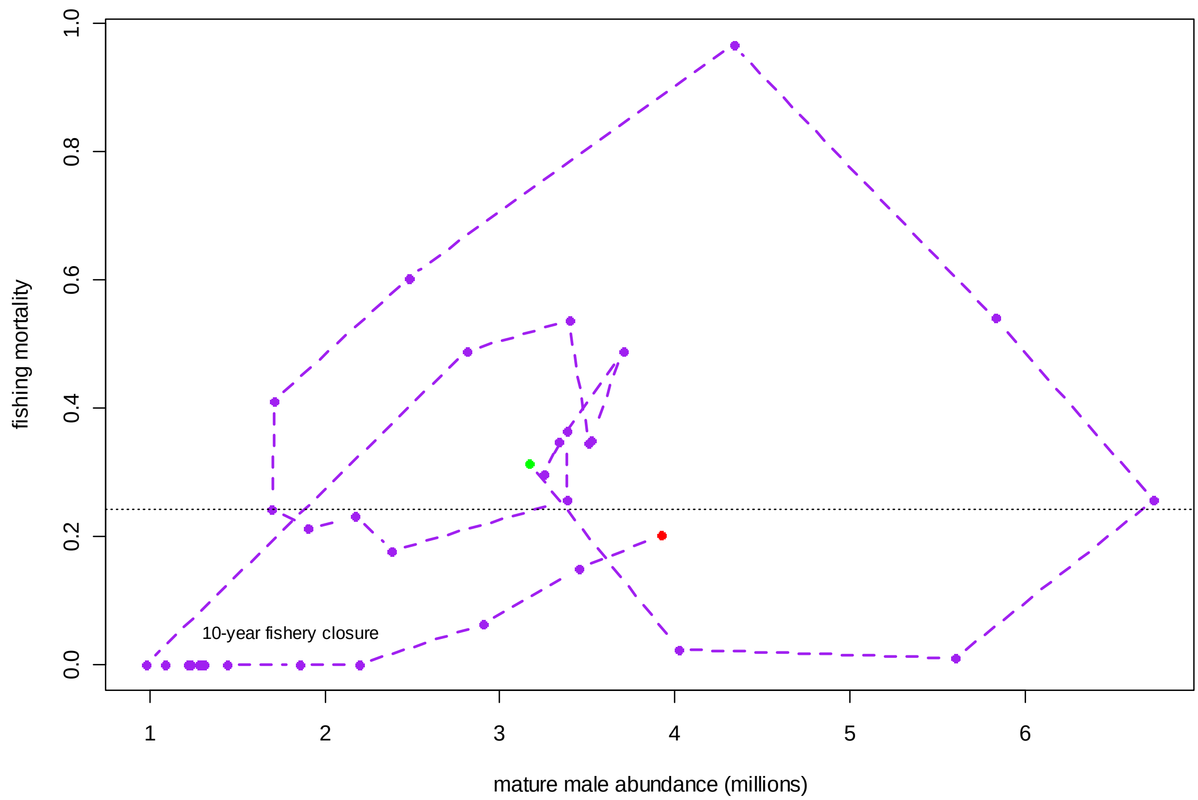


Figure 22. Base-model directed-fishery fishing mortality versus mature male abundance at the time of the previous trawl survey, for fishery years 1978/79 (green) to 2011/12 (red ). Dotted horizontal line indicates model estimated geometric mean fishing mortality over years with a fishery.

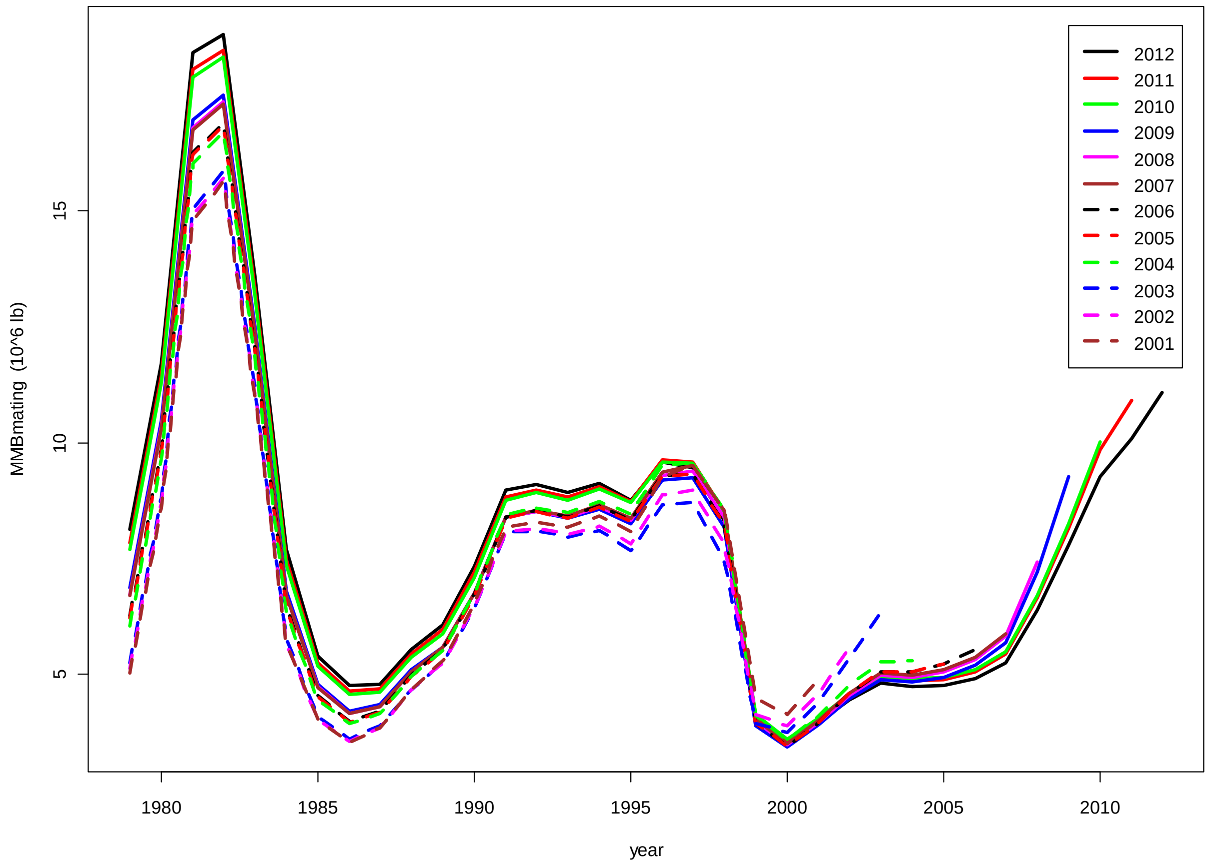


Figure 23. Retrospective plot of mature male biomass at time of mating for base-model configuration and terminal years 2001 – 2012. Estimates are for Feb 15 biomass in the indicated year based on all assessment data up to and including terminal year surveys.

# Appendix A: SMBKC Stock Assessment Model Description

## 1. Introduction

The model accounts only for male crab at least 90 mm in carapace length (CL). These are partitioned into three stages (male size classes) determined by CL measurements of (1) 90-104 mm, (2) 105-119 mm, and (3) 120 mm+. For management of the St. Matthew Island blue king crab (SMBKC) fishery, 120 mm CL is used as the proxy value for the legal measurement of 5.5 in carapace width (CW), whereas 105mm CL is the management proxy for mature-male size. Accordingly, within the model only stage-3 crab are retained in the directed fishery, and stage-2 and stage-3 crab together comprise the collection of mature males. Some justification for the 105 mm value is presented in Pengilly and Schmidt (1995), who used it in developing the current regulatory SMBKC harvest strategy. The term "recruit" here designates recruits to the model, i.e. annual new stage-1 crab, rather than recruits to the fishery. The following description of model structure reflects the base-model configuration. Differences characterizing alternative model scenarios considered in this document are described under **Model Selection and Evaluation** of §G.

### 2. Model Population Dynamics

Within the model framework, the beginning of the crab year is assumed contemporaneous with the NMFS trawl survey, nominally assigned a date of July 1. With boldface letters indicating vector quantities, let $\boldsymbol{N}_t = [\, N_{1,t}, N_{2,t}, N_{3,t}\,]^{\mathrm{T}}$ designate the vector of stage abundances at the start of year $t$. Then the basic population dynamics underlying model construction are described by the linear equation

$$\boldsymbol{N}_{t+1} = \boldsymbol{G}e^{-M_t}\boldsymbol{N}_t + \boldsymbol{N}^{new}{}_{t+1}, \qquad [1]$$

where the scalar factor $e^{-M_t}$ accounts for the effect of year-$t$ natural mortality $M_t$ and the hypothesized transition matrix $\boldsymbol{G}$ has the simple structure

$$\boldsymbol{G} = \begin{bmatrix} 1-\pi_{12} & \pi_{12} & 0 \\ 0 & 1-\pi_{23} & \pi_{23} \\ 0 & 0 & 1 \end{bmatrix}, \qquad [2]$$

with $\pi_{jk}$ equal to the proportion of stage-$j$ crab that molt and grow into stage $k$ from any one year to the next. The vector $\boldsymbol{N}^{new}{}_{t+1} = [\, N^{new}{}_{1,t+1},\, 0\,,0\,]^{\mathrm{T}}$ registers the number $N^{new}{}_{1,\,t+1}$ of new crab, or "recruits," entering the model at the start of year $t+1$, all of which are assumed to go into stage 1. Aside from natural mortality and molting and growth, only the directed fishery and some limited bycatch mortality in the groundfish fisheries are assumed to affect the stock. The directed fishery is modeled as a mid-season pulse occurring at time $\tau_t$ with full-selection fishing mortality $F_t^{df}$ relative to stage-3 crab. Year-$t$ directed-fishery removals from the stock are computed as

$$\boldsymbol{R}_t^{df} = \boldsymbol{H}^{df}\boldsymbol{S}^{df}(1-e^{-F_t^{df}})e^{-\tau_t M}\boldsymbol{N}_t, \qquad [3]$$

where the diagonal matrices $\boldsymbol{S}^{df} = \begin{bmatrix} s_1^{df} & 0 & 0 \\ 0 & s_2^{df} & 0 \\ 0 & 0 & 1 \end{bmatrix}$ and $\boldsymbol{H}^{df} = \begin{bmatrix} h^{df} & 0 & 0 \\ 0 & h^{df} & 0 \\ 0 & 0 & 1 \end{bmatrix}$ account for stage selectivities $s_1^{df}$ and $s_2^{df}$ and discard handling mortality $h^{df}$ in the directed fishery, both assumed constant over time. Yearly stage removals resulting from bycatch mortality in the groundfish trawl and fixed-gear fisheries are calculated as Feb 15 (0.63 yr) pulse effects in terms of the respective fishing mortalities $F_t^{gt}$ and $F_t^{gf}$ by

$$\boldsymbol{R}_t^{gt} = \frac{F_t^{gt}}{F_t^{gt}+F_t^{gf}} e^{-(0.63-\tau_t)M_t}(e^{-\tau_t M_t}\boldsymbol{N}_t - \boldsymbol{R}_t^{df})(1 - e^{-(F^{gt}+F^{gf})})h^{gt} \quad [4]$$

$$\boldsymbol{R}_t^{gf} = \frac{F_t^{gf}}{F_t^{gt}+F_t^{gf}} e^{-(0.63-\tau_t)M_t}(e^{-\tau_t M_t}\boldsymbol{N}_t - \boldsymbol{R}_t^{df})(1 - e^{-(F^{gt}+F^{gf})})h^{gf}. \quad [5]$$

These last two computations assume that the groundfish fisheries affect all stages proportionally, i.e. that all stage selectivities equal one, and that handling mortalities $h^{gt}$ and $h^{gf}$ are constant across both stages and years. The author believes that the available composition data from these fisheries are of such dubious quality as to preclude meaningful use in estimation. Moreover, evidently with the exception of 2007/08, which in the author's view is suspiciously anomalous, the impact of these fisheries on the stock has typically been small. These considerations suggest that more elaborate efforts to model that impact are unwarranted. Model population dynamics are thus completely determined by the equation

$$\boldsymbol{N}_{t+1} = \boldsymbol{G}e^{-0.37M_t}(e^{-(0.63-\tau_t)M_t}(e^{-\tau_t M_t}\boldsymbol{N}_t - \boldsymbol{R}_t^{df}) - (\boldsymbol{R}_t^{gt} + \boldsymbol{R}_t^{gf})) + \boldsymbol{N}^{new}{}_{t+1}, \quad [6]$$

for $t \geq 1$ and initial stage abundances $\boldsymbol{N}_1$.

Necessary biomass computations, such as required for management purposes or for integration of groundfish bycatch biomass data into the model, are based on application of the SMBKC length-to-weight relationship of Chilton and Foy (2010) to the stage-1 and stage-2 CL interval midpoints and use fishery reported average retained weights for stage-3 ("legal") crab. In years with no fishery, including the current assessment year, the time average value over years with a fishery is used. The author believes this approach to be an appropriate simplification given the data limitations associated with the stock.

## 3. Model Data

Data inputs used in model estimation are listed in Table 1. All quantities relate to male SMBKC ≥ 90mm CL.

Table 1. Data inputs used in model estimation.

| Data Quantity | Years | Source |
|---|---|---|
| Directed pot-fishery retained-catch number | 1978/79-1998/99<br>2009/10-2011/12 | Fish tickets<br>(fishery closed 1999/00-2008/09) |
| NMFS trawl-survey abundance index (area-swept estimate) and CV | 1978-2012 | NMFS EBS trawl survey |
| ADFG pot-survey abundance index (CPUE) and CV | Triennial 1995-2010 | ADF&G SMBKC pot survey |
| NMFS trawl-survey stage proportions and total number of measured crab | 1978-2011 | NMFS EBS trawl survey |
| ADFG pot-survey stage proportions and total number of measured crab | Triennial 1995-2010 | ADF&G SMBKC pot survey |
| Directed pot-fishery stage proportions and total number of measured crab | 1990/91-1998/99<br>2009/10-2011/12 | ADF&G crab observer program<br>(fishery closed 1999/00-2008/09) |
| Groundfish trawl bycatch biomass | 1992/93-2011/12 | NMFS groundfish observer program |
| Groundfish fixed-gear bycatch biomass | 1992/93-2011/12 | NMFS groundfish observer program |

Model-predicted retained-catch number $C_t$ is calculated assuming catch consists precisely of those stage-three crab captured in the directed fishery so that

$$C_t = e^{-\tau_t M_t} N_{3,t}(1 - e^{-F^{df}}), \quad [7]$$

which is just the third component of [3]. In fact, in the actual pot fishery a small number of captured stage-3 males are discarded, whereas some captured stage-2 males are legally retained, but data from onboard observers and dockside samplers suggest that [7] here provides a serviceable approximation (ADF&G Crab Observer Database). Model analogs of trawl and pot-survey abundance indices are given by

$$A_t^{ts} = Q^{ts}(s_1^{ts} N_{1,t} + s_2^{ts} N_{2,t} + N_{3,t}) \quad [8]$$

$$A_t^{ps} = Q^{ps}(s_1^{ps} N_{1,t} + s_2^{ps} N_{2,t} + N_{3,t}), \quad [9]$$

these being year-*t* trawl-survey area-swept abundance and year-*t* pot-survey CPUE, respectively, both with respect to 90 mm+ CL males. In these expressions, $Q^{ts}$ and $Q^{ps}$ denote model proportionality constants, assumed independent of year and with $Q^{ts} = 1.0$ under all scenarios considered for this assessment, and $s_j^{ts}$ and $s_j^{ps}$ denote corresponding stage-*j* survey selectivities, also assumed independent of year. Model trawl-survey, pot-survey, and directed-fishery stage proportions $\boldsymbol{P}_t^{ts}$, $\boldsymbol{P}_t^{ps}$, and $\boldsymbol{P}_t^{df}$ are then determined by

$$\boldsymbol{P}_t^{ts} = \frac{Q^{ts}}{A_t^{ts}} \begin{bmatrix} s_1^{ts} & 0 & 0 \\ 0 & s_2^{ts} & 0 \\ 0 & 0 & 1 \end{bmatrix} \boldsymbol{N}_t \quad [10]$$

$$\boldsymbol{P}_t^{ps} = \frac{Q^{ps}}{A_t^{ps}} \begin{bmatrix} s_1^{ps} & 0 & 0 \\ 0 & s_2^{ps} & 0 \\ 0 & 0 & 1 \end{bmatrix} \boldsymbol{N}_t \quad [11]$$

$$\boldsymbol{P}_t^{df} = \frac{1}{\langle (\boldsymbol{H}^{df})^{-1} \boldsymbol{R}_t^{df},\ \boldsymbol{1} \rangle} (\boldsymbol{H}^{df})^{-1} \boldsymbol{R}_t^{df}. \quad [12]$$

Letting $\boldsymbol{w}_t = [w_1, w_2, w_{3,t}]^T$ be an estimate of stage mean weights in year *t* as described above, model predicted groundfish bycatch mortality biomasses in the trawl and fixed-gear fisheries are given by

$$B_t^{gt} = \boldsymbol{w}_t{}^T \boldsymbol{R}_t^{gt} \text{ and } B_t^{gf} = \boldsymbol{w}_t{}^T \boldsymbol{R}_t^{gf}. \quad [13]$$

Recall that stage-1 and stage-2 mean weights do not depend on year, being based on the length-to-weight relationship of Chilton and Foy (2010), whereas stage-3 mean weight is set equal to year-*t* fishery reported average retained weight or its time average for years with no fishery.

## 4. Model Parameters

Base-model estimated parameters are listed in Table 2 and include an estimated parameter for natural mortality in 1998/99 on the assumption of an anomalous mortality event in that year, as hypothesized by Zheng and Kruse (2002), with natural mortality otherwise fixed at 0.18 $yr^{-1}$. In any year with no directed fishery, and hence zero retained catch, $F_t^{df}$ is set to zero rather than model estimated. Similarly, for years in which no groundfish bycatch data are available, $F_t^{gf}$ and

$F_t^{gt}$ are imputed to be the geometric means of the estimates from years for which there are data. Table 3 lists additional externally determined parameters used in model computations. Note, in particular, that under all model configurations examined for this assessement, stage 1 to 2 and stage 2 to 3 transition probabilities are assumed equal to 1.0, consistent with Otto and Commiskey (2009).

Both surveys are assigned a nominal date of July 1, the start of the crab year. The directed fishery is treated as a season midpoint pulse. Groundfish bycatch is likewise modeled as a pulse effect, occurring at the nominal time of mating, Feb 15, which is also the reference date for calculation of management biomass quantities.

Table 2. Base-model estimated parameters.

| Parameter | Number |
|---|---|
| Log initial stage abundances | 3 |
| 1998/99 natural mortality | 1 |
| Pot-survey “catchability” | 1 |
| Stage 1 and 2 Trawl-survey selectivities | 2 |
| Stage 1 and 2 Pot-survey selectivities | 2 |
| Stage 1 and 2 Directed-fishery selectivities | 2 |
| Mean log recruit abundance | 1 |
| Log recruit abundance deviations | 34[a] |
| Mean log directed-fishery mortality | 1 |
| Log directed-fishery mortality deviations | 24[a] |
| Mean log groundfish trawl fishery mortality | 1 |
| Log groundfish trawl fishery mortality deviations | 21[a] |
| Mean log groundfish fixed-gear fishery mortality | 1 |
| Log groundfish fixed-gear fishery mortality deviations | 21[a] |
| Total | 115 |

[a] Subject to zero-sum constraint.

Table 3. Base-model fixed parameters.

| Parameter | Value | Source/Rationale |
|---|---|---|
| Trawl-survey “catchability”, i.e. abundance-index proportionality constant | 1.0 | Conventional calibration strategy |
| Natural mortality (except 1998/99) | 0.18 $yr^{-1}$ | Zheng 2005 |
| Stage 1 and 2 transition probabilities | 1.0, 1.0 | Otto and Commiskey 2009 |
| Stage-1 and 2 mean weights | 1.65, 2.57 lb | Chilton and Foy (2010) length-weight equation applied to stage size-interval midpoints. |
| Stage-3 mean weight | depends on year | Fishery-reported average retained weight from fish tickets, or its average. |
| Directed-fishery handling mortality | 0.20 | 2010 Crab SAFE |
| Groundfish trawl handling mortality | 0.80 | 2010 Crab SAFE |
| Groundfish fixed-gear handling mortality | 0.50 | 2010 Crab SAFE |

## 5. Model Objective Function and Weighting Scheme

The objective function consists of a sum of eight “negative loglikelihood” terms characterizing the hypothesized error structure of the principal data inputs with respect to their true, i.e. model-predicted, values and four “penalty” terms associated with year-to-year variation in model recruit abundance and fishing mortality in the directed fishery and groundfish trawl and fixed-gear fisheries. See Table 4, where upper and lower case letters designate model-predicted and data-computed quantities, respectively, and boldface letters again indicate vector quantities. Sample sizes $n_t$ (observed number of male SMBKC $\geq$ 90mm CL) and estimated coefficients of variation $\widehat{cv}_t$ were used to develop appropriate variances for stage-proportion and abundance-index components. The weights $\lambda_j$ appearing in the objective function component expressions in Table 4 play the role of "tuning" parameters in the modeling procedure.

Table 4. Loglikelihood and penalty components of base-model objective function. The $\lambda_k$ are weights, described in text; the $neff_t$ are effective sample sizes, also described in text. All summations are with respect to years over each data series.

| Component | | Form |
|---|---|---|
| Legal retained-catch number | Lognormal | $-\lambda_1 0.5 \sum [\log(c_t + 0.001) - \log(C_t + 0.001)]^2$ |
| Trawl-survey abundance index | Lognormal | $-\lambda_2 0.5 \sum [\frac{\ln(a_t^{ts}) - \ln(A_t^{ts})}{\ln(1 + \widehat{cv_t^{ts}}^2)}]^2$ |
| Pot-survey abundance index | Lognormal | $-\lambda_3 0.5 \sum [\frac{\ln(a_t^{ps}) - \ln(A_t^{ps})}{\ln(1 + \widehat{cv_t^{ps}}^2)}]^2$ |
| Trawl-survey stage proportions | Multinomial | $\lambda_4 \sum neff_t^{ts} (\boldsymbol{p}_t^{ts})^T \ln(\boldsymbol{P}_t^{ts} + 0.01)$ |
| Pot-survey stage proportions | Multinomial | $\lambda_5 \sum neff_t^{ps} (\boldsymbol{p}_t^{ps})^T \ln(\boldsymbol{P}_t^{ps} + 0.01)$ |
| Directed-fishery stage proportions | Multinomial | $\lambda_6 \sum neff_t^{df} (\boldsymbol{p}_t^{df})^T \ln(\boldsymbol{P}_t^{df} + 0.01)$ |
| Groundfish trawl mortality biomass | Lognormal | $-\lambda_7 \sum [\ln(b_t^{gt}) - \ln(B_t^{gt})]^2$ |
| Groundfish fixed-gear mortality biomass | Lognormal | $-\lambda_8 \sum [\ln(b_t^{gf}) - \ln(B_t^{gf})]^2$ |
| $\ln(N_{1,t}^{new})$ deviations | Quadratic/Normal | $\lambda_9 0.5 \sum \Delta_t^2$, with $\sum \Delta_t = 0$ |
| $\ln(F_t^{df})$ deviations | Quadratic/Normal | $\lambda_{10} 0.5 \sum \Delta_t^2$, with $\sum \Delta_t = 0$ |
| $\ln(F_t^{gft})$ deviations | Quadratic/Normal | $\lambda_{11} 0.5 \sum \Delta_t^2$, with $\sum \Delta_t = 0$ |
| $\ln(F_t^{gff})$ deviations | Quadratic/Normal | $\lambda_{12} 0.5 \sum \Delta_t^2$, with $\sum \Delta_t = 0$ |

Determination of the weighting scheme involved a great deal of trial and error with respect to graphical and other diagnostic tools; however, the author's basic strategy was to begin with a baseline weighting scheme that was either unity or otherwise defensible in terms of plausible variances. The CPT noted in May 2012 that survey weights should generally not exceed unity, and the author has complied with that advice for this assessment.

Table 5 shows the weighting scheme used for the base-model scenario. The weight of 1,000 applied to the lognormal fishery catch-number component ($\lambda_1$) corresponds to a coefficient of variation of approximately 3% for the fishery estimate of catch number. The weights $\lambda_2$ and $\lambda_3$ on the lognormal trawl-survey and pot-survey abundance components are set at 1.0, allowing the yearly conventional survey-based CV estimates to govern the terms contributed by these two series. The default 1.0 weights on the lognormal groundfish bycatch mortality biomass components ($\lambda_7$ and $\lambda_8$) correspond to implied CVs of about 130%, which this author judges probably appropriate given the nature of the data. The weight of 1.25 applied to the quadratic/normal recruit-deviation penalty ($\lambda_9$) is approximately the inverse of the sample variance of trawl-survey time-series estimates of 90-104 mm male crab ("recruit") abundance. With $\lambda_4$, $\lambda_5$, *and* $\lambda_6$ equal to 1.0, the factors denoted by $neff_t$ appearing in the multinomial loglikelihood expressions of the objective function represent effective sample sizes describing observed survey and fishery stage-proportion error structure with respect to model predicted values. Each set is determined by a single set-specific parameter $N_{max}$ such that the effective sample size in any given year $neff_t$ is equal to the observed number of crab $n_t$ if $n_t < N_{max}$ and otherwise equal to $N_{max}$. For the base-model configuration, $N_{max}$ was assigned a value of 50 for trawl-survey composition data and 100 for both pot-survey and fishery observer composition data. Graphical displays of the standardized residuals, including normal Q-Q plots, provided some guidance in making this choice, although model fit to the composition data tends to be rather poor under all scenarios.

Table 5. Base-model objective-function weighting scheme.

| Objective-Function Component | Weight $\lambda_j$ |
|---|---|
| Legal retained-catch number | 1000 |
| Trawl-survey abundance index | 1.0 |
| Pot-survey abundance index | 1.0 |
| Trawl-survey stage proportions | 1.0 |
| Pot-survey stage proportions | 1.0 |
| Directed-fishery stage proportions | 1.0 |
| Groundfish trawl mortality biomass | 1.0 |
| Groundfish fixed-gear mortality biomass | 1.0 |
| Log model recruit-abundance deviations | 1.25 |
| Log directed fishing mortality deviations | 0.001 |
| Log groundfish trawl fishing mortality deviations | 1.0 |
| Log groundfish fixed-gear fishing mortality deviations | 1.0 |

## 6. Estimation

The model was implemented using the software AD Model Builder (ADMB Project 2009), with parameter estimation by automatic differentiation and minimization of the model objective function. Standard errors and estimated parameter correlations provided in this document are AD Model Builder reported values assuming maximum likelihood theory asymptotics.

# Appendix B: Additional Results for Model Configurations B1 and C

Table B1. Model configuration B1 parameter estimates and standard errors.

| parameter | estimate | standard error |
|---|---|---|
| 1998/99 natural mortality | 1.24 | 0.132 |
| pot-survey proportionality constant | 3.06 | 0.474 |
| trawl-survey stage-1 selectivity | 0.72 | 0.078 |
| trawl-survey stage-2,3 selectivity | 0.87 | 0.101 |
| pot-survey stage-1 selectivity | 0.35 | 0.057 |
| pot-survey stage-2 selectivity | 0.97 | 0.122 |
| pot-fishery stage-1 selectivity | 0.47 | 0.051 |
| pot-fishery stage-2 selectivity | 0.85 | 0.081 |
| log initial stage-1 abundance | 7.65 | 0.182 |
| log initial stage-2 abundance | 7.35 | 0.234 |
| log initial stage-3 abundance | 7.08 | 0.256 |
| mean log recruit abundance | 6.99 | 0.089 |
| mean log recruit abundance deviations (34) | [-1.62, 0.90] | [0.10, 0.37] |
| mean log directed fishing mortality | -1.47 | 0.127 |
| log directed fishing mortality deviations (24) | [-2.99, 1.57] | [0.09, 0.31] |
| mean log GF trawl fishing mortality | -11.14 | 0.263 |
| log GF trawl fishing mortality deviations (21) | [-1.67, 1.76] | [0.70, 0.74] |
| mean log GF fixed-gear fishing mortality | -9.80 | 0.256 |
| log GF fixed-gear fishing mortality deviations (21) | [-2.15, 2.41] | [0.69, 0.70] |

Table B2. Model configuration C parameter estimates and standard errors.

| parameter | estimate | standard error |
|---|---|---|
| 1998/99 natural mortality | 1.052 | 0.156 |
| log natural mortality deviations (33) | [-0.43, 1.55] | [0.379, 0.601] |
| pot-survey proportionality constant | 4.02 | 0.422 |
| trawl-survey stage-1 selectivity | 0.80 | 0.062 |
| trawl-survey stage-2 selectivity | 1.22 | 0.083 |
| pot-survey stage-1 selectivity | 0.26 | 0.043 |
| pot-survey stage-2 selectivity | 0.75 | 0.096 |
| pot-fishery stage-1 selectivity | 0.38 | 0.044 |
| pot-fishery stage-2 selectivity | 0.68 | 0.066 |
| log initial stage-1 abundance | 7.55 | 0.207 |
| log initial stage-2 abundance | 7.17 | 0.255 |
| log initial stage-3 abundance | 7.10 | 0.276 |
| mean log recruit abundance | 6.87 | 0.061 |
| mean log recruit abundance deviations (34) | [-1.25, 0.93] | [0.121, 0.400] |
| mean log directed fishing mortality | -1.25 | 0.078 |
| log directed fishing mortality deviations (24) | [-3.14, 1.43] | [0.107, 0.322] |
| mean log GF trawl fishing mortality | -10.81 | 0.238 |
| log GF trawl fishing mortality deviations (21) | [-1.59, 1.79] | [0.699, 0.739] |
| mean log GF fixed-gear fishing mortality | -9.47 | 0.229 |
| log GF fixed-gear fishing mortality deviations (21) | [-2.21, 2.38] | [0.689, 0.722] |

Table B3. Model configuration B1 main parameter correlation structure.

| | parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1998/99 M | 1 | | | | | | | | | | | | | |
| 2 | PS Q | -0.24 | 1 | | | | | | | | | | | | |
| 3 | TS s1 selectivity | -0.26 | 0.71 | 1 | | | | | | | | | | | |
| 4 | TS s2, 3 selectivity | -0.15 | 0.80 | 0.81 | 1 | | | | | | | | | | |
| 5 | PS s1 selectivity | -0.10 | -0.27 | -0.08 | -0.15 | 1 | | | | | | | | | |
| 6 | PS s2 selectivity | -0.07 | -0.39 | -0.14 | -0.21 | 0.23 | 1 | | | | | | | | |
| 7 | PF s1 selectivity | -0.07 | -0.31 | -0.26 | -0.37 | 0.17 | 0.20 | 1 | | | | | | | |
| 8 | PF s2 selectivity | 0.00 | -0.41 | -0.36 | -0.47 | 0.15 | 0.20 | 0.56 | 1 | | | | | | |
| 9 | log initial N1 | 0.01 | -0.14 | -0.12 | -0.18 | 0.04 | 0.05 | 0.11 | 0.13 | 1 | | | | | |
| 10 | log initial N2 | -0.02 | -0.14 | -0.06 | -0.20 | 0.05 | 0.06 | 0.11 | 0.13 | 0.10 | 1 | | | | |
| 11 | log initial N3 | -0.02 | -0.12 | -0.05 | -0.18 | 0.04 | 0.05 | 0.10 | 0.11 | 0.02 | -0.16 | 1 | | | |
| 12 | mean log PF F | -0.15 | 0.79 | 0.64 | 0.84 | -0.17 | -0.24 | -0.46 | -0.56 | -0.26 | -0.26 | -0.36 | 1 | | |
| 13 | mean log recruits | 0.34 | -0.89 | -0.77 | -0.82 | 0.08 | 0.16 | 0.30 | 0.43 | 0.10 | 0.10 | 0.08 | -0.80 | 1 | |
| 14 | mean log GFT F | -0.10 | 0.48 | 0.39 | 0.44 | -0.07 | -0.10 | -0.17 | -0.23 | -0.08 | -0.08 | -0.07 | 0.43 | -0.49 | 1 |
| 15 | mean log GFF F | -0.10 | 0.49 | 0.40 | 0.46 | -0.07 | -0.11 | -0.18 | -0.24 | -0.08 | -0.08 | -0.07 | 0.45 | -0.51 | 0.27 |

Table B4. Model configuration C main parameter correlation structure.

| | parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1998/99 M | 1 | | | | | | | | | | | | | |
| 2 | PS Q | -0.25 | 1 | | | | | | | | | | | | |
| 3 | TS s1 selectivity | -0.34 | 0.14 | 1 | | | | | | | | | | | |
| 4 | TS s2 selectivity | -0.29 | 0.14 | 0.55 | 1 | | | | | | | | | | |
| 5 | PS s1 selectivity | -0.14 | -0.24 | 0.21 | 0.18 | 1 | | | | | | | | | |
| 6 | PS s2 selectivity | -0.16 | -0.35 | 0.20 | 0.17 | 0.29 | 1 | | | | | | | | |
| 7 | PF s1 selectivity | -0.17 | -0.12 | 0.21 | 0.21 | 0.20 | 0.22 | 1 | | | | | | | |
| 8 | PF s2 selectivity | -0.10 | -0.18 | 0.15 | 0.13 | 0.16 | 0.20 | 0.58 | 1 | | | | | | |
| 9 | log initial N1 | -0.03 | 0.00 | 0.14 | 0.14 | 0.07 | 0.07 | 0.12 | 0.11 | 1 | | | | | |
| 10 | log initial N2 | -0.05 | 0.01 | 0.20 | 0.08 | 0.07 | 0.07 | 0.10 | 0.09 | 0.24 | 1 | | | | |
| 11 | log initial N3 | -0.12 | 0.04 | 0.32 | 0.34 | 0.11 | 0.11 | 0.14 | 0.12 | 0.19 | -0.01 | 1 | | | |
| 12 | mean log PF F | 0.02 | 0.35 | -0.28 | -0.27 | -0.19 | -0.22 | -0.44 | -0.48 | -0.23 | -0.21 | -0.44 | 1 | | |
| 13 | mean log recruits | 0.45 | -0.50 | -0.53 | -0.47 | -0.20 | -0.15 | -0.10 | 0.02 | -0.16 | -0.15 | -0.26 | -0.11 | 1 | |
| 14 | mean log GFT F | -0.06 | 0.22 | 0.08 | 0.08 | 0.00 | -0.02 | -0.03 | -0.06 | 0.00 | 0.01 | 0.03 | 0.13 | -0.25 | 1 |
| 15 | mean log GFF F | -0.06 | 0.23 | 0.08 | 0.08 | 0.00 | -0.02 | -0.04 | -0.06 | 0.00 | 0.01 | 0.03 | 0.13 | -0.26 | 0.10 |

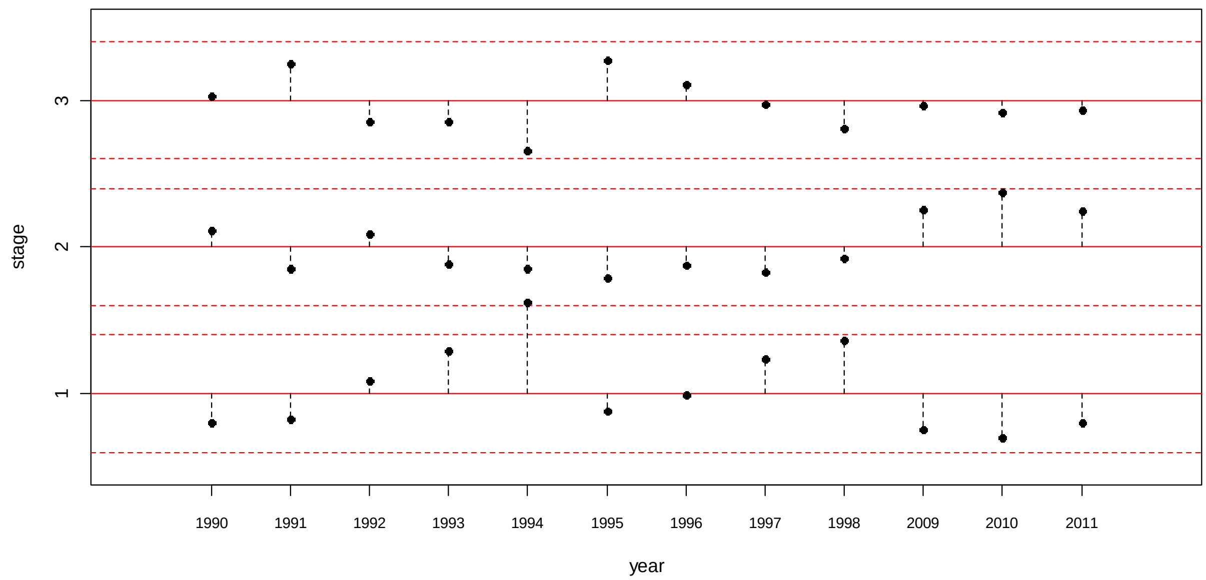


Figure B1. Model configuration B1 pot-fishery composition data standardized residuals.

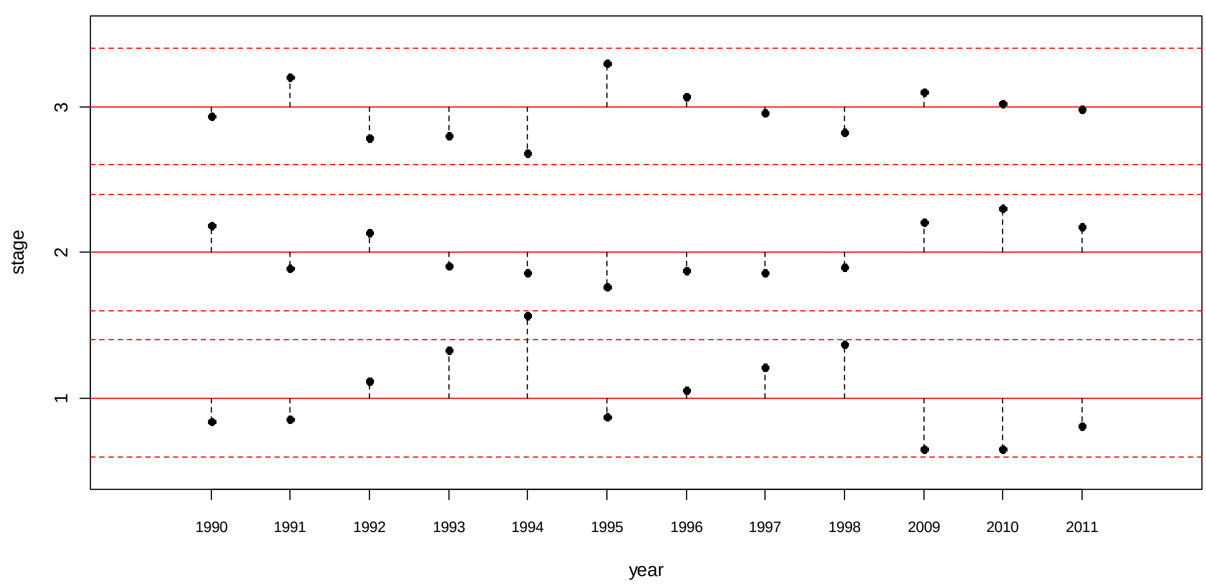


Figure B2. Model configuration C pot-fishery composition data standardized residuals.

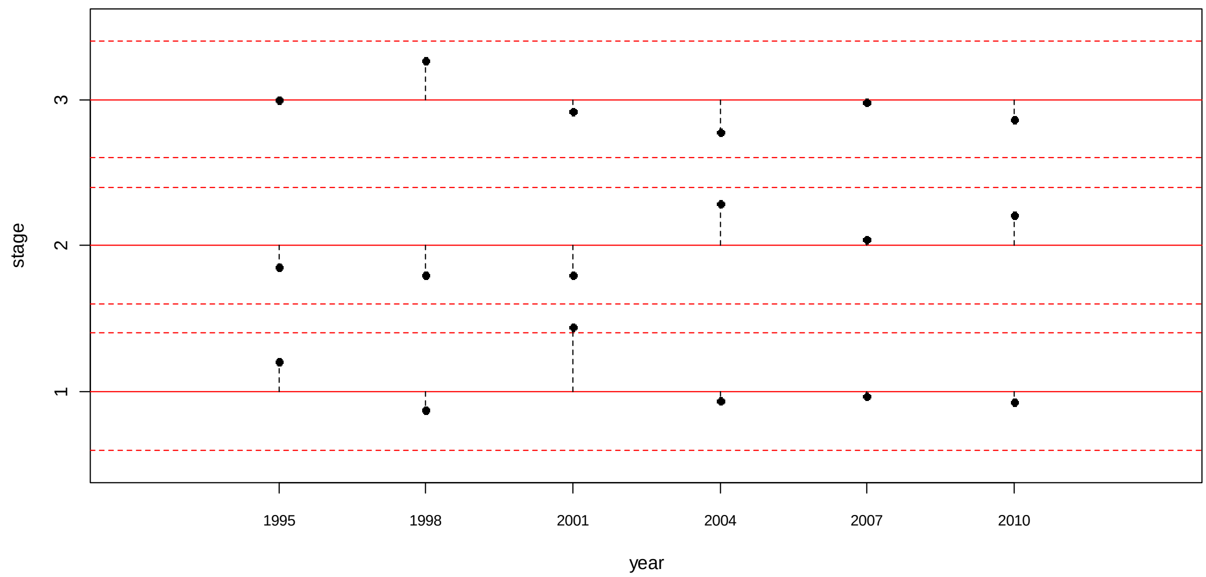


Figure B3. Model configuration B1 pot-survey composition data standardized residuals.

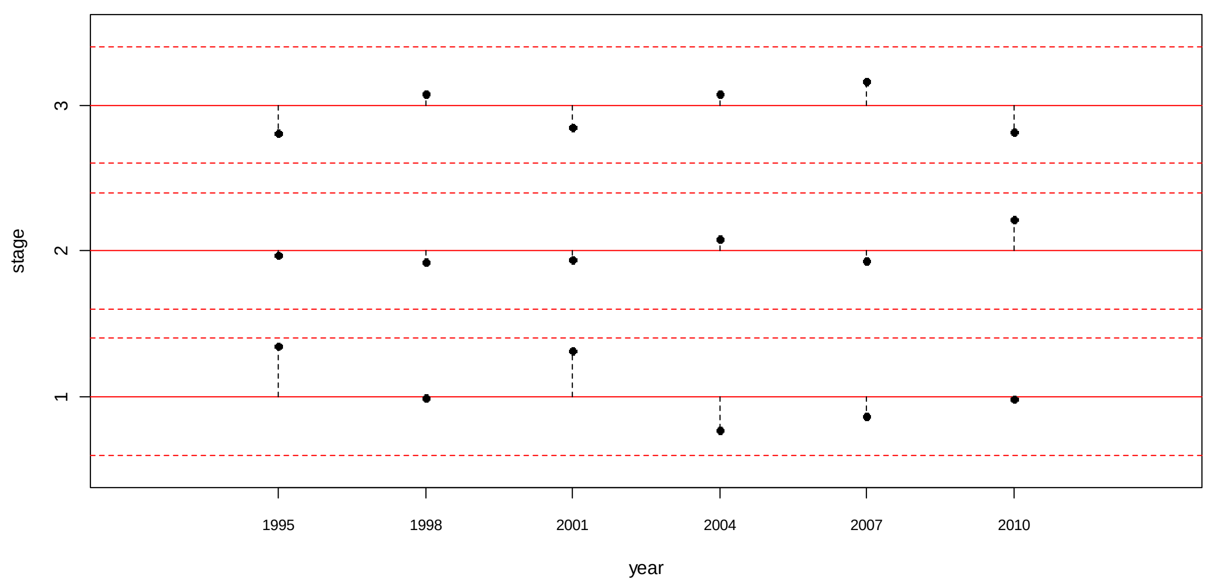


Figure B4. Model configuration C pot-survey composition data standardized residuals.

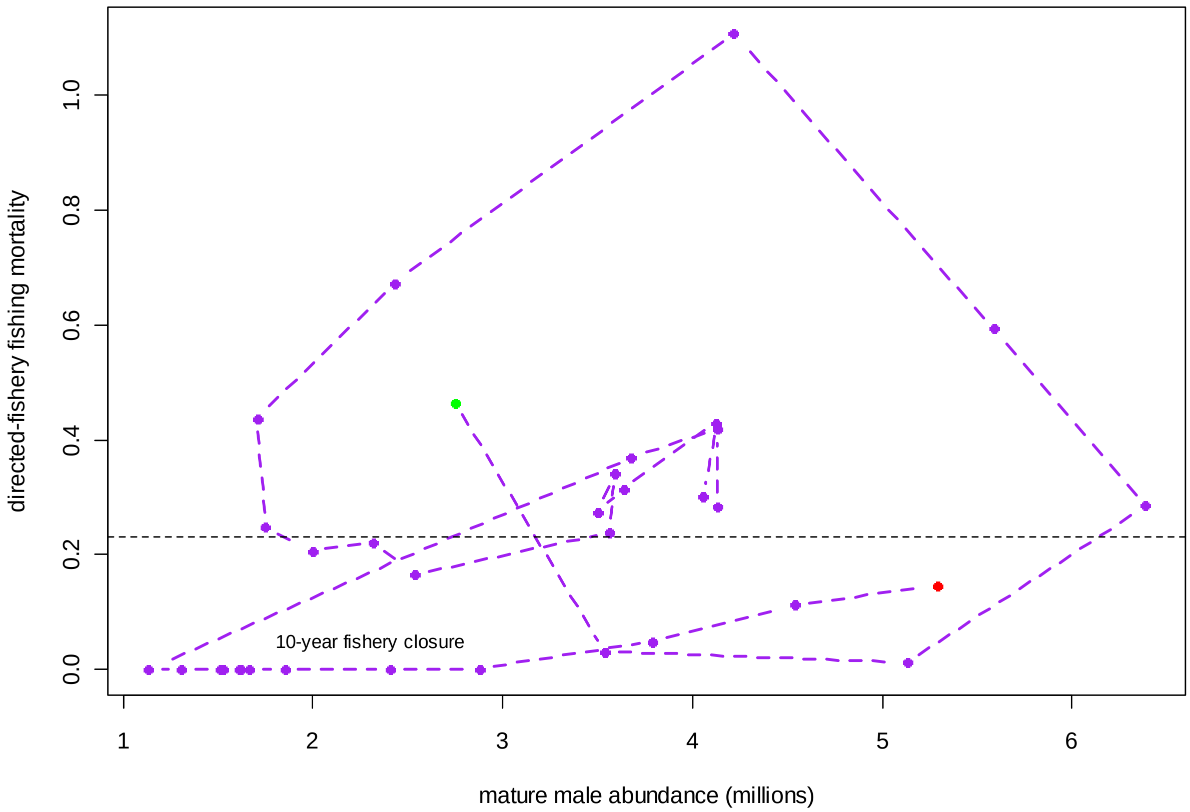


Figure B5. Model configuration B1 directed-fishery fishing mortality vs mature male abundance at the time of the preceding trawl-survey. Dashed horizontal line represents geometric mean fishing mortality over years with a directed pot fishery.

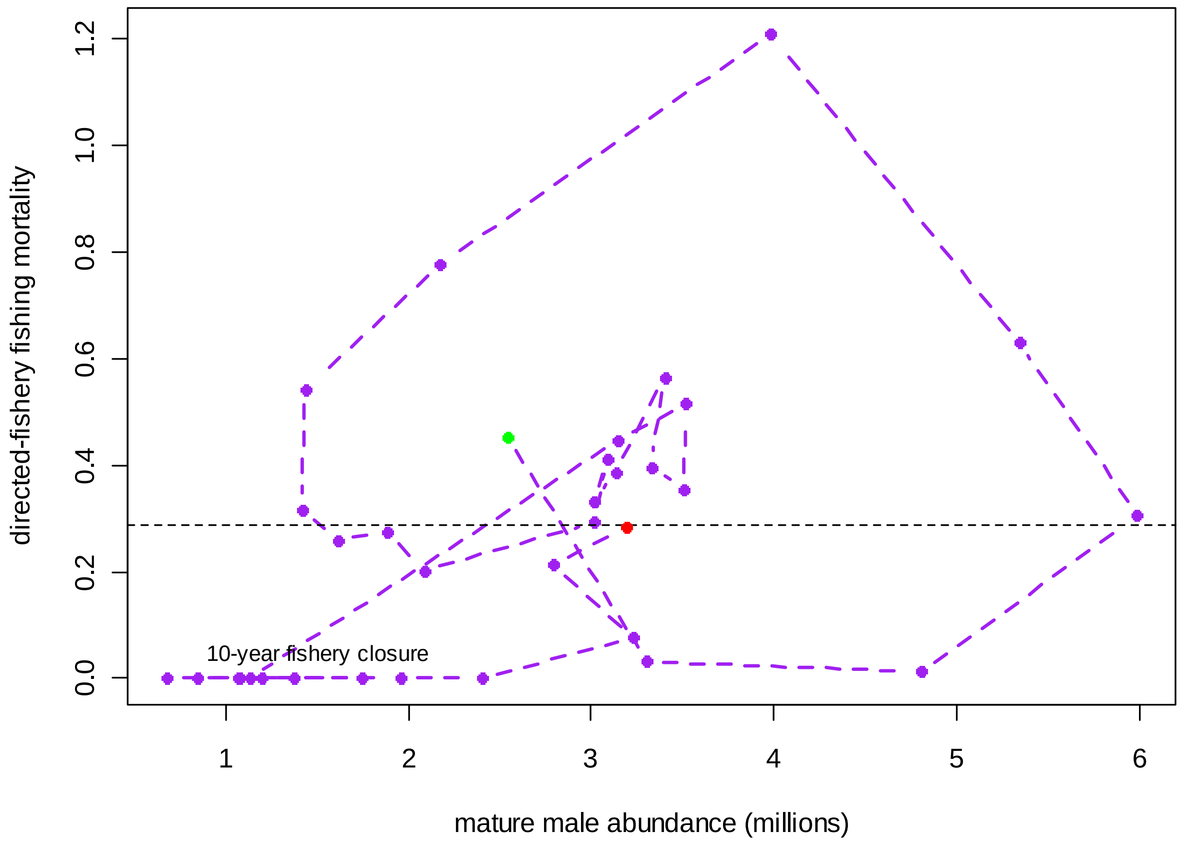


Figure B6. Model configuration C directed-fishery fishing mortality vs mature male abundance at the time of the preceding trawl-survey. Dashed horizontal line represents geometric mean fishing mortality over years with a directed pot fishery.

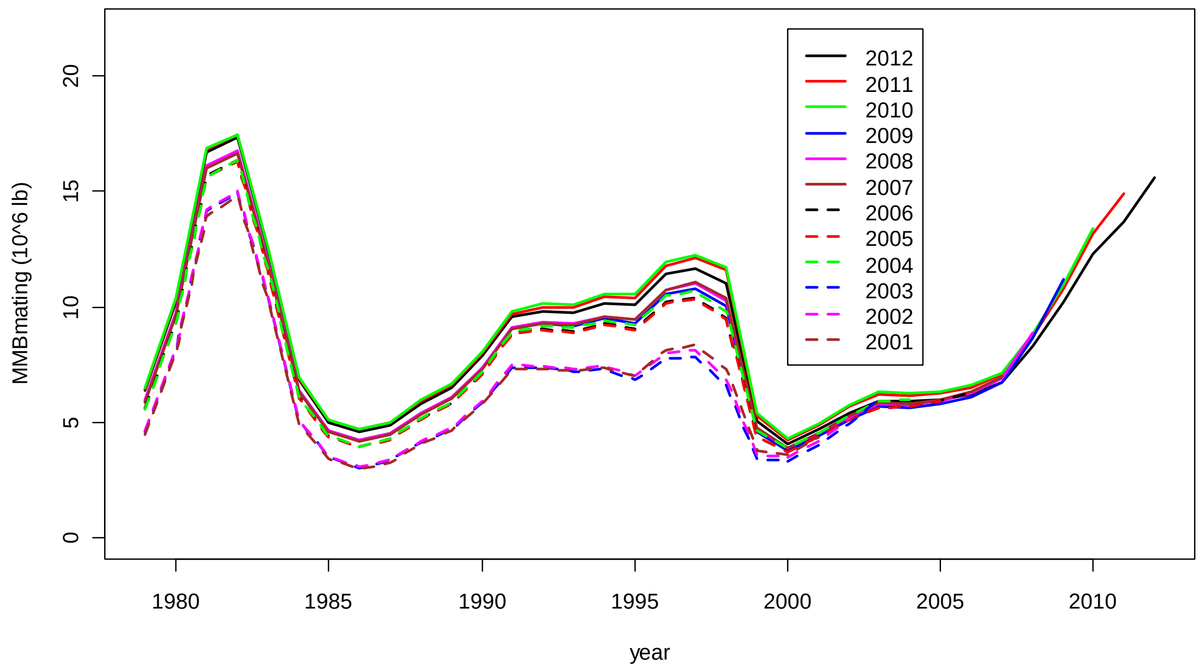


Figure B7. Model configuration B1 retrospective plot of mature male biomass at time of mating. Estimates are for Feb 15 biomass in the indicated year based on all assessment data up to and including terminal year surveys.

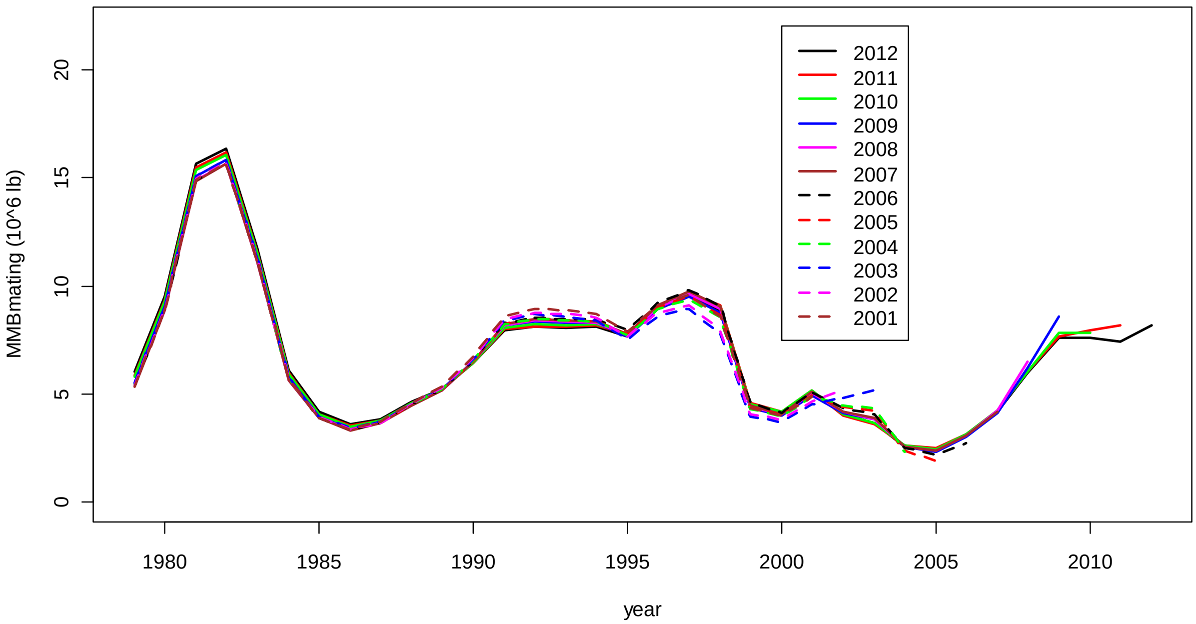


Figure 8. Model configuration C retrospective plot of mature male biomass at time of mating. Estimates are for Feb 15 biomass in the indicated year based on all assessment data up to and including terminal year surveys.

# Norton Sound Red King Crab Stock Assessment for the fishing year 2012/13

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## Executive Summary

1. Stock. Red king crab, *Paralithodes camtschaticus*, in Norton Sound, Alaska.

1. Catches. This stock supports three main fisheries: summer commercial, winter commercial, and winter subsistence fisheries. Of those, the summer commercial fishery accounts for more than 90% of total harvest. The summer commercial fishery retained catch reached a peak in the late 1970s at a little over 2.9 million pounds. Since 1982, retained catches have been below 0.5 million pounds, averaging 275,000 pounds, including several low years in the 1990s. Retained catches in the past two years have been about 400,000 pounds.

2. Stock Biomass. Mature male biomass (MMB) is estimated to be on an upward trend following a recent low in 1997, and an historic low in 1982 following a crash from the peak in 1977. Uncertainty in biomass is driven in part by infrequent trawl surveys (every 3 to 5 years) and limited area of the winter pot survey.

3. Recruitment. Model estimated recruitment was weak during the late 1970s and high during the early 1980s with a slight downward trend from 1983 to 1993. Estimated recruitment has been highly variable but on an increasing trend in recent years.

4. Management performance.

*Status and catch specifications (million lbs.)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 1.78[A] | 5.24 | 0.41 | 0.39 | 0.43 | 0.68[A] | |
| 2009/10 | 1.54[B] | 5.83 | 0.38 | 0.40 | 0.43 | 0.71[B] | |
| 2010/11 | 1.56[C] | 5.44 | 0.40 | 0.42 | 0.46 | 0.73[C] | |
| 2011/12 | 1.56[D] | 4.70 | 0.36 | 0.40 | 0.43 | 0.66[D] | 0.59 |
| 2012/13 | 1.78[E] | 4.59 | TBD | TBD | TBD | 0.53[E] | 0.48 |

*Status and catch specifications (1000t)*

| Year | MSST | Biomass (MMB) | GHL | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2008/09 | 0.81[A] | 2.38 | 0.19 | 0.18 | 0.21 | 0.31[A] | |
| 2009/10 | 0.70[B] | 2.64 | 0.17 | 0.18 | 0.22 | 0.32[B] | |
| 2010/11 | 0.71[C] | 2.47 | 0.18 | 0.19 | 0.22 | 0.33[C] | |
| 2011/12 | 0.71[D] | 2.13 | 0.16 | 0.18 | 0.20 | 0.30[D] | 0.27 |
| 2012/13 | 0.80[E] | 2.08 | TBD | TBD | TBD | 0.24[E] | 0.22 |

Notes:
MSST was calculated as $B_{MSY}/2$
A-Calculated from the assessment reviewed by the Crab Plan Team in May 2008
B-Calculated from the assessment reviewed by the Crab Plan Team in May 2009
C-Calculated from the assessment reviewed by the Crab Plan Team in May 2010
D-Calculated from the assessment reviewed by the Crab Plan Team in May 2011
E-Calculated from the assessment reviewed by the Crab Plan Team in May 2012

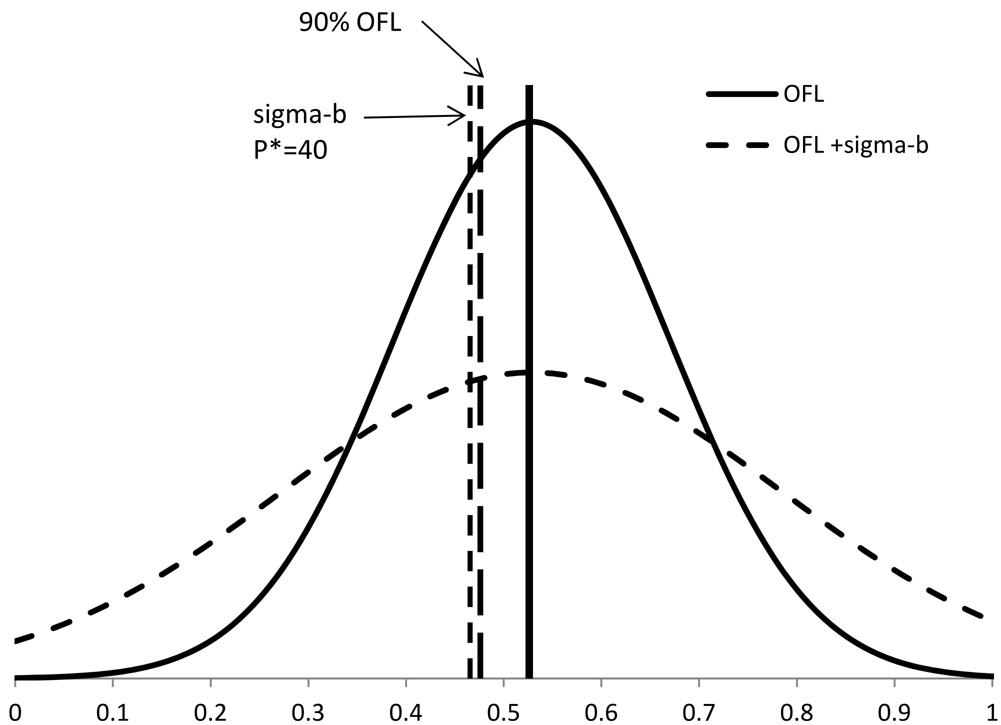
*Biomass in millions of pounds*

| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | Natural Mortality (M) | 1-Buffer | ABC |
|---|---|---|---|---|---|---|---|---|---|
| 2008/09 | 4a | 3.57 | 5.24 | 1.5 | 0.18 | 1983-2008 | 0.18 | | |
| 2009/10 | 4a | 3.07 | 5.83 | 1.9 | 0.18 | 1983-2009 | 0.18 | | |
| 2010/11 | 4a | 3.12 | 5.44 | 1.7 | 0.18 | 1983-2010 | 0.18 | | |
| 2011/12 | 4a | 2.97 | 4.70 | 1.6 | 0.18 | 1983-2011 | 0.18 | 0.9 | 0.59 |
| 2012/13 | 4a | 3.51 | 4.25 | 1.2 | 0.18 | 1980-2012 | 0.18 | 0.9 | 0.48 |

*Biomass in 1000t*

| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | Natural Mortality (M) | 1-Buffer | ABC |
|---|---|---|---|---|---|---|---|---|---|
| 2008/09 | 4a | 1.62 | 2.38 | 1.5 | 0.18 | 1983-2008 | 0.18 | | |
| 2009/10 | 4a | 1.39 | 2.64 | 1.9 | 0.18 | 1983-2009 | 0.18 | | |
| 2010/11 | 4a | 1.42 | 2.47 | 1.7 | 0.18 | 1983-2010 | 0.18 | | |
| 2011/12 | 4a | 1.35 | 2.18 | 1.6 | 0.18 | 1983-2011 | 0.18 | 0.9 | 0.27 |
| 2012/13 | 4a | 1.59 | 1.93 | 1.2 | 0.18 | 1980-2012 | 0.18 | 0.9 | 0.22 |

7. Probability Density Function of the OFL




8. The basis for the ABC recommendation

For Tier 4 stocks, the default maximum ABC is OFL P*=49. However, P*=49 is essentially identical to the OFL. Accounting for uncertainties in assessment and model results, the NPFMC chose to use 90% OFL (10% Buffer) for the Norton Sound red king crab stock in 2011, partially because of uncertainties in model prediction.

**For 2012 analyses, we chose 90% OFL (10% Buffer) which was 0.48 million lb** because of remained uncertainties in the model. We also examined P*=49, and P*=40 for both with and without sigma-b (0.4). **The 90% OFL was similar to P*=40 with sigma-b.**

9. A summary of the results of any rebuilding analyses.

N/A

## *A. Summary of Major Changes in 2012*

1. Changes to the management of the fishery**:**

In March 2012, the board of fish adopted a revised GHL: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.25 million lbs; (2) ≤ 7% of legal male abundance when the estimated legal biomass falls within the range 1.25-2.0 million lbs; (3) ≤ 13% of legal male abundance when the estimated legal biomass falls within the range 2.0-3.0 million lbs; and (3) ≤ 15% of legal male when estimated legal biomass >3.0 million lbs.

2. Changes to the input data
    a. Data update: the 2011/12 winter pot survey, 2011 summer commercial fishery, 2011 summer trawl survey, 2010/2011 winter commercial and subsistence catch finalized, and 2011/2012 winter commercial and subsistence catch (projected from available data up to date)
    b. Data revision: 1976-2011 trawl survey abundance were revised and source of the numbers were documented (Table 3)
    c. New Data: None

3. Changes to the assessment methodology: Following model modification were evaluated
    a. See Appendix A for model modification.

4. Changes to the assessment results.

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

CPT Review May 10-14, 2011

The team had the following comments:

1. *The OFL for Norton Sound red king crab should take account of all three fisheries and their selectivity patterns rather than assuming that the catch is taken entirely from the legal crab biomass.*

    **Author response:**

    Two OFLs are estimated: retained OFL and total male OFL. Retained OFL is derived from proxy Fmsy and legal male abundance. Total male OFL is the sum of retained OFL and estimated discarded catch based on the proxy Fmsy, bycatch selectivity from the summe fishery and sublegal male abundance. The retained catches from all three fisheries are combined when comparing the actual catch to the retained OFL. Since bycatch data are not collected from any of the three fisheries, no comparison can be made on the total male OFL. The estimated selectivity for the summer commercial fishery is 1 for legal males. We does not use the bycatch selectivities from the subsistence and winter fisheries to estimate bycatch OFL due to extremely small catch from them and no data to estimate bycatch selectivities.

2. *Table 10 should be clarified regarding the definitions of parameters and which are log-transformed and which are not (e.g. SST1 and SST2). These two parameters appear inestimable (very large standard errors); this needs to be addressed further.*

    **Author response:**
    Table 11 has parameter estimates that were revised to incorporate the CPT requests.

3. *The author indicated he used the MCMC to estimate the pdf for OFL. The mean of this OFL distribution is higher than the point estimate of the OFL from the assessment. The team expressed concern that the posterior was not smooth, which suggests some MCMC convergence issues. However the team noted this OFL is more conservative as it is based on the retained legal proportion.*

   **Author response:**
   OFL pdf was calculated based on CPT direction on Jan 10th 2012.

## SSC Review on June 6-8, 2011

*The SSC noted that the 2010 NMFS survey used a 20×20 nmi$^2$ grid rather than the 10×10 nmi$^2$ used in all other surveys. The SSC requests that the author examines the potential impact of this shift in grid size on the 2010 abundance estimate.*

**Author response:**
The model likelihood calculation includes CV of the survey estimates (see Appendix A), so that impacts of the survey shifts are already included.

*The SSC did not accept this ad-hoc adjustment for the retrospective pattern, because opinions differ within the scientific community on whether correcting for retrospective bias is appropriate and if a correction is applied, what methods should be used. Clearly there is a need to develop guidance on when and how assessment authors should account for retrospective bias in assessment models. Instead* ***the authors should look for the cause of the retrospective pattern, which may be due to time variation in certain population parameters (e.g., natural mortality, selectivity)***

**Author response:**
In this assessment, we examined effects of natural mortality (M), natural mortality of crab size 6 (ms6), weight of commercial efforts (lamc), and sample weight (maxss).

*The SSC recognizes that under the Council's recommended P* of 0.49 and no adjustment to max ABC for the term sigma-b for other sources of uncertainty, that the maximum permissible ABC (0.65 million lbs.) would be nearly identical to the OFL (0.66 million lbs.). We caution that this estimate does not reflect the scientific uncertainty in model parameterization evidenced by the strong retrospective pattern or the issues regarding natural mortality for large crabs.* ***This assessment is an example where the SSC would have preferred to incorporate a sigma-b adjustment to quantify additional uncertainty or apply a buffer between ABC and OFL. To avoid this situation in the future, the SSC requests that the authors include estimates of ABC under different levels of sigma-b or using buffers for data poor stocks (e.g.,10% as for Tier 5 under the Crab FMP or 25% under Tiers 5 and 6 for groundfish) to better justify the rational for selecting an ABC below the maximum.***

**Author response:**
In this report, we chose sigma-w = 0.2 (based on survey) and sigma-b = 0.4 (based on NPFMC/NMFS 2010) were selected. For evaluation of ABC, we presented: P*=49, P*= 40, 10% buffer, 25% buffer.

## C. Introduction

1. Species: red king crab (*Paralithodes camtschaticus*) in Norton Sound, Alaska.
2. General Distribution: Norton Sound red king crab is one of the northernmost red king crab populations that can support a commercial fishery (Powell et al. 1983). It is distributed throughout Norton Sound with a westward limit of 167-168$^{o}$ W. longitude with depths less than 30 m and summer bottom temperatures above 4$^{o}$C. The Norton Sound red king crab management area consists of two units: Norton Sound Section (Q3) and Kotzebue Section (Q4) (Menard et al. 2011). The Norton Sound Section (Q3) consists of all waters in Registration Area Q north of the latitude of Cape Romanzof, east of the International Dateline, and south of 66°N latitude (Figure 1). The Kotzebue Section (Q4) lies immediately north of the Norton Sound Section and includes Kotzebue Sound. Commercial fisheries have not occurred regularly in the Kotzebue Section. Our report deals with the Norton Sound Section of the Norton Sound red king crab management area.
3. Evidence of stock structure: Thus far, no studies have been made on possible stock separation within the putative stock known as Norton Sound red king crab.
4. Life history characteristics relevant to management: One of the unique life-history traits of Norton Sound red king crab is that they spend their entire lives in shallow water since Norton Sound is generally less than 40 m in depth. Distribution and migration patterns of Norton Sound red king crab have not been well studied. Based on the 1976-2006 trawl surveys, red king crab in Norton Sound are found in areas with a mean depth range of 19 ± 6 (SD) m and bottom temperatures of 7.4 ± 2.5 (SD) $^{o}$C during the summer. Norton Sound red king crab are consistently abundant offshore of Nome.

   Red king crab migrate between deeper offshore waters during molting/feeding and inshore shallow waters during the mating period. Timing of the inshore mating migration is unknown. They are assumed to mate during March-June. Offshore migration is considered to begin in May-July. Trawl surveys during 1976-2010 show that crab distribution is dynamic. Recent surveys show high abundance on the southeast side of the Sound, offshore of Stebbins and Saint Michael.
5. Brief management history: Norton Sound red king crab fisheries consist of commercial and subsistence fisheries. The commercial red king crab fishery started in 1977 and occurs in summer (June – August) and in winter (December – May) (Menard et al. 2008). The majority of red king crab are harvested by the summer commercial fisheries, whereas the majority of the winter harvest is in the subsistence fishery occurring near the coast (Table 2).

   <u>Summer Commercial Fishery</u>

   Summer commercial crab fishery started in 1977. A large-vessel summer commercial crab fishery existed in the Norton Sound Section from 1977 through 1990. No summer commercial fishery occurred in 1991 because there was no staff to manage the fishery. In March 1993, the Alaska Board of Fisheries (BOF) limited participation in the fishery to small boats. Then on June 27, 1994, a super-exclusive designation went into effect for the fishery. This designation stated that a vessel registered for the Norton Sound crab fishery may not be used to take king crabs in any other registration areas during that registration year. A vessel moratorium was put into place before the 1996 season. This was intended to precede a license limitation program. In 1998, Community Development Quota (CDQ) groups were allocated a portion of the summer harvest; however, no CDQ harvest occurred until the 2000 season. On January 1, 2000 the North Pacific License Limitation Program (LLP) went into effect for the Norton Sound crab fishery. The program dictates that a vessel which exceeds 32 feet in length overall must hold a valid crab license issued under the LLP by the National Marine Fisheries Service. Regulation changes and location of buyers resulted in harvest distribution moving eastward in Norton Sound in the mid-1990s. In the Norton Sound, a legal crab is defined as ≥ 4-3/4 inch carapace width (CW, Menard et al. 2011; equivalent to ≥ 124 mm carapace length [CL]). Since 2005, commercial buyers started accepting only legal crabs of ≥ 5 inch carapace.

Not all Norton Sound area is open for commercial fisheries. Since beginning of the commercial fisheries in 1977, inland waters near Nome area has been closed for summer commercial crab fishery, possibly to protect crab nursery grounds (Figure 2). Extent of closed water changed throughout history.

<u>CDQ Fishery</u>

The Norton Sound and Lower Yukon CDQ groups divide the CDQ allocation. Only fishers designated by the Norton Sound and Lower Yukon CDQ groups are allowed to participate in this portion of the king crab fishery. Fishers are required to have a CDQ fishing permit from the Commercial Fisheries Entry Commission (CFEC) and register their vessel with the Alaska Department of Fish and Game (ADF&G) before they make their first delivery. Fishers operate under authority of the CDQ group and each CDQ group decides how their crab quota is to be harvested. During the March 2002 BOF meeting, new regulations were adopted that affected the CDQ crab fishery and relaxed closed-water boundaries in eastern Norton Sound and waters west of Sledge Island. At its March 2008, the BOF changed the start date of the Norton Sound open-access portion of the fishery to be opened by emergency order and as early as June 15. **The CDQ fishery may open at any time (as soon as ice is out), by emergency order. It is possible that the fishery starts BEFORE determination of OFL and ABC.**

<u>Winter Commercial Fishery</u>

The Norton Sound winter commercial fishery is a small fishery using hand lines and pots through the nearshore ice. Approximately 10 permit holders participated in this fishery harvesting, on average 2,500 crabs during 1978-2009 (Menard 2011). The winter commercial fishery catch is influenced not only by crab abundance, but also by changes in near shore crab distribution, and ice conditions.

<u>Subsistence Fishery</u>

The Norton Sound subsistence crab fishery mainly occurs during winter using hand lines and pots through the nearshore ice. Average annual subsistence harvest was 5,300 crabs (1978-2007). Subsistence harvesters need to obtain a permit before fishing and record daily effort and catch. There is no size limit in the subsistence fishery. The subsistence fishery catch is influenced not only by crab abundance, but also by changes in distribution, changes in gear (e.g., more use of pots instead of hand lines since 1980s), and ice conditions (e.g., reduced catch due to unstable ice conditions: 1987-88, 1988-89, 1992-93, 2000-01, 2003-04, 2004-05, and 2006-07).

6. Brief description of the annual ADF&G harvest strategy

Since 1997 Norton Sound red king crab have been managed based on a guideline harvest limit (GHL). Detailed history of GHL determination methods are unknown. Since 1999, GHL is determined by a prediction model and the model estimated predicted biomass: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.5 million lbs; (2) ≤ 5% of legal male abundance when the estimated legal biomass falls within the range 1.5-2.5 million lbs; and (3) ≤ 10% of legal male when estimated legal biomass >2.5 million lbs.

In 2012 the Alaska Board of Fisheries adopted a revised GHL: (1) 0% harvest rate of legal crab when estimated legal biomass < 1.25 million lbs; (2) ≤ 7% of legal male abundance when the estimated legal biomass falls within the range 1.25-2.0 million lbs; (3) ≤ 13% of legal male abundance when the estimated legal biomass falls within the range 2.0-3.0 million lbs; and (3) ≤ 15% of legal male when estimated legal biomass >3.0 million lbs.

| Year | Notable historical management changes |
|---|---|
| 1976 | The abundance survey started |
| 1977 | Large vessel commercial fisheries began |
| 1991 | Fishery closed due to staff constraints |
| 1994 | Super exclusive designation into effect. The end of large vessel commercial fishery operation.<br>Participation limited to small boats.<br>The majority of commercial fishery subsequently shifted to east of 164$^{o}$W line. |
| 1998 | Community Development Quota (CDQ) allocation into effect |
| 1999 | Guideline Harvest Limit (GHL) into effect |
| 2000 | North Pacific License Limitation Program (LLP) into effect. |
| 2002 | Change in closed water boundaries (Figure 2) |
| 2005 | Commercially accepted legal crab size changed from ≥ 4-3/4 inch CW to ≥ 5 inch CW |
| 2006 | The Statistical area Q3 section expanded (Figure 1) |
| 2008 | Start date of the open access fishery changed from July1 to after June 15 by emergency order.<br>Pot configuration requirement: at least 4 escape rings (>4½ inch diameter) per pot located within one mesh of the bottom of the pot, or at least ½ of the vertical surface of a square pot or sloping side-wall surface of a conical or pyramid pot with mesh size > 6½ inches. |
| 2012 | Board of fisheries adopted a revised GHL |

7. Summary of the history of the $B_{\mathrm{MSY}}$.

Direct estimation of the $B_{\mathrm{MSY}}$ is not possible, hence, NSRKC is a tier4a crab stock. .

$B_{\mathrm{MSY}}$ is calculated as mean model estimated mature male biomass (MMB) from 1983 to present. Choice of this period was based on a belief that PDO shift occurred in 1976-77 could have changed the productivity.

## D. Data

1. Summary of new information:

    a. Trawl survey 2011 and historical abundance data were updated. Historical 1976-1991 survey conducted by NMFS trawl survey was updated (Table 3). Original source of the abundance estimates were included.

    b. Harvests of 2011 summer commercial fishery, and 2010/2011 winter commercial and subsistence fisheries, were updated. For winter 2011/12 harvest data, 2010/2011 winter harvest data were used.

2. Available survey, catch, and tagging data

| Data Set | Years | Data Types | Tables |
|---|---|---|---|
| Summer trawl survey | 76,79,82,85,88,91,96, 99, 02,06,08,10,11 | Abundance and proportion by length and shell condition | 3,5, Appendix E |
| Summer pot survey | 80-82,85 | Abundance and proportion by length and shell condition | 3,6 |
| Winter pot survey | 81-87, 89-91,93,95-00,02-12 | Proportion by length and shell condition | 7 |
| Summer preseason survey | 95 | Proportion by length and shell condition | Not used for model |
| Summer commercial fishery | 76-90,92-11 | Catch abundance, effort, and proportion by length and shell condition | 1,4 |
| Observer data | 87-90,92,94 | Proportion by length and shell condition (sub-legal only) | 8 |
| Winter commercial and subsistence fishery | 76-11 | The Number of crab harvested | 2 |
| Tagging data | 80-07 | Used to create a growth increment matrix | 10 |

a. Summer commercial fishery and winter commercial and subsistence catch, and effort (potlifts) (ADF&G 1976-2011) (Tables 1 and 2).

b. Discards of sublegal males (observer data) from the summer fishery (ADF&G 1987-90, 1992, 1994). The survey was opportunistic, so that the number of crab discarded was not recorded. Only catch-at-length and shell condition of sub-legal male were recorded (Table 8). In Norton Sound, no other crab, groundfish, or shellfish fisheries exist.

| | Fishery | Data availability |
|---|---|---|
| Directed pot fishery (males) | Summer commercial | None |
| Directed pot fishery (females) | Winter commercial/subsistence | None |
| Bycatch in other crab fisheries | Does not exist | NA |
| Bycatch in ground pot | Does not exist | NA |
| Bycatch in ground fish trawl | Does not exist | NA |
| Bycatch in the scallop fishery | Does not exist | NA |

c. Catch at length data for summer commercial fisheries (Table 4).

d. Survey abundance estimates:

Triennial trawl surveys were conducted by the NMFS (1976-1991, 2010) and by the ADF&G (1996-2011) (Table 3). The NMFS survey was conducted using the 83-112 Eastern Otter Trawl, whereas the ADF&G survey was conducted using the 400 Eastern Otter Trawl. In both surveys, survey design was based on 10×10nm square, except for the NMFS survey in 2010 where survey grid was 20×20nm.

Abundance of crabs were estimated by "area-swept" methods (Alverson and Pereyra 1969).

While the assessment model is based on crab population of ≥ 74mm CL, none of surveys have reported abundance of crab ≥ 74mm CL. NMFS survey reported crab abundance of ≥ 100mm CL, < 100mm CL, and all sizes, whereas ADF&G survey reported crab abundance of legal size (≥ 4 ¾ inch CW). Hence, abundance and CV of crab ≥ 74mm CL had to be re-estimated either directly from original survey data (when available and possible) or converted from numbers reported in each study (See Table 3 for details).

**Survey coverage differed among years (Appendix E); however, we did not correct/standardize estimated abundance based on survey coverage. It was assumed that there were no crab in unsurveyed area.**

Summer pot surveys were conducted in 1980-82, 85. Except for 1985, survey abundance CV was not reported.

e. Survey catch-at-length data available include: Summer commercial catch (1977-2011) (Table 4), triennial Trawl survey (Table 5) and winter pot survey (Table 7). Other miscellaneous data include: summer pot survey (1980-82, 85) (Table 6), summer commercial catch observer survey (1987-90, 92, 94) (Table 8), and summer preseason survey (1995) (Not included for the assessment model).

f. Other miscellaneous data: None.

3. Growth-per-molt (Table 9), estimated from tagging data (1991-2007).
4. Proportion of legal size crab, estimated from trawl survey data (Table 5).

## *E. Analytic Approach*

### 1. History of the modeling approach.

The Norton Sound red king crab stock was assessed using a length-based synthesis model (Zheng et al. 1998). The model was updated in 2009-2010 to provide information for the federal OFL. At the May 2010 CPT meeting, seven alternative models were presented: 1) based on 2009 model reviewed by Punt (University of Washington), 2) model 1 and including bycatch mortality, 3) model 2 with weight of fishing effort increased from 5 to 20; 4) model 3 with fishery selectivity for the last length group from 0.6 to being estimated from the model, 5) model 3 and reduce the maximum effective sample size for commercial catch and winter surveys from 200 to 100, 6) model 5 with M for the last length group increased from the default 0.18 to 0.288, and 7) model 6 with M increased to 0.34. The CPT and subsequent SSC recommended using the Model 6 for the 2010/11 iteration. During 2011 NPFMC meeting in June, SSC was concerned high hindcast prediction error and bias (i.e., model predicted crab abundance for assessment year tend to be *higher* than “actual/model reconstructed” abundance, which resulted in *higher* exploitation rate, than anticipated at the time of an assessment. The SSC, directed assessment authors to revise the model and reduce hindcast prediction error. In this 2012/13 iteration, we present several alternative model configurations.

## 2. Model Description

a. Description of overall modeling approach:

The model is a male-only size structured model that combines multiple sources of survey, catch, and mark-recovery data using a maximum likelihood approach to estimate abundance, recruitment, catchability of the commercial pot gear, and parameters for selectivity and molting probabilities (See Appendix A for full model description).

b-f. See Appendix A.

g. Critical assumptions of the model:

i. Male crab mature at CL length 94mm.

Bases for this assumption have not been located. No formal study has been conducted to test this assumption.

ii. Instantaneous natural mortality *M* is 18% for all length classes, except for the last length group (> 123mm) where M = 28.8% (18% × 1.6) (Zheng et al. 1998). M is constant over time.

This mortality is based on Bristol Bay red king crab, estimated with a maximum age 25 and the 1% rule (Zheng 2005), and was adopted for NSRKC by CPT. The assumption of the higher M for the last length group is based not on biological data, but rather a working hypothesis attempting to explain the lower than model predicted proportion of this group in summer commercial fisheries (Figures 10, 13). It is possible, that the last length group moved into areas inaccessible to commercial fisheries (CPT review 2010). However, this does not explain the low proportion observed in the summer trawl survey, when all of the Norton Sound Area was surveyed. In addition, lowering the catch selectivity did not result in lower log likelihood than increasing the mortality (CPT 2010).

iii. Trawl survey selectivity is sigmoid function: 1.0 for length classes 3-6, and a sigmoid function for length classes 1-2.

This assumption was not based on biological/mechanistic data and reasoning, but rather an attempt to improve model fit. Further, all models estimated selectivity of classes 1-2 to 1.0. Thus, essentially, trawl survey selectivity is 1.0 for classes 1- 6.

iv. Winter pot survey selectivity is a dome shaped function: 1.0 for length classes 3-5, a sigmoid function for length classes 1-2, and model estimate for the last length group.

This assumption is based on a belief (but no empirical data) that very large crab less representative in near shore area where the winter surveys occur. This assumption improves the model fit and reduces the bias in the bubble plot.

v. Summer commercial fisheries selectivity is a sigmoid function of length peaking at the length class 5 (104-113 mm). It has two curves: before 1993, and 1993-present, reflecting changes in fishing vessel composition and pot configuration.

vi. Winter commercial and subsistence fishery selectivity and length-shell conditions are the same as those of the winter pot survey.

Winter commercial king crab pots can be any dimension (5AAC 34.925(d)). No data exists about crab pot configuration of commercial or subsistence crab fishery gears. However, because commercial fishers are also subsistence fishers, it is reasonable to assume that the commercial fishers used crab pots that they also used for subsistence harvest, and hence both fisheries have the same selectivity.

vii. Growth increments are is a function of length and are constant over time.

viii. Molting probabilities are an inverse logistic function of length for males.

ix. A summer fishing season for the directed fishery is short.

x. Discards handling mortality is assumed to be 20%. No empirical estimate is available.

xi. Annual retained catch is measured without error.

xii. All legal size crabs (≥ 4-3/4 inch CW) are taken to the commercial dock.

xiii. Since 2005, all commercially acceptable size crabs ( ≥ 5 inch CW) are taken to the commercial dock.

xiv. All sublegal size crab or commercially unacceptable size crab (< 5 inch CW, since 2005) are discarded.

xv. Length compositions have a multinomial error structure, and abundance has a log-normal error structure.

h. Changes of assumptions since last assessment:

Following model modifications were made:

1. Likelihoods for summer pot survey in 2011 model had two components: legal and sublegal. This time, this size separation was eliminated. In observed data, only total crab abundance was estimated (Table 3), and abundance of legal and sub-legal crab was estimated by multiplying by the observed size proportion. Since likelihood of size proportion is already calculated, it is inappropriate to fit the same data twice.
2. In size class 4, proportion of legal crab was further adjusted for summer commercial fisheries since 2005 to reflect the fact that commercial buyers accept only >5 inch CW crab even though legal crab size is >4 3/4 inch CW. It is likely that commercial crab fishermen would discard legal crab of less than 5 inch CW at sea.

i. Code validation. Model code is available from the authors.

## 3. Model Selection and Evaluation

a. Description of alternative model configurations.

The following model modifications were evaluated. See Appendix B for the rationale for selecting candidate alternative models.

ms6: multipliers of M for length class 6 natural mortality, default value 1.6
lamc: weight for commercial catch effort, default value 20

maxss: maximum effective sample size, default value 200

Fourteen models are evaluated:

0. 2011 model (2010 model 6)
1. Baseline 2012 model:
2. Model 1 and change ms6 = 3.6
3. Model 1 and change lamc = 50
4. Model 1 and change lamc = 100
5. Model 1 and change maxss = 100
6. Model 1 and change maxss = 50
7. Model 1 and change maxss = 10
8. Model 1 and change M = 0.32
9. Model 1 and change ms6 = 1.0
10. Model 9 change M = 0.4
11. Model 3 & Model 6
12. Model 11 & Model 2
13. Model 4 & Model 6
14. Model 13 & Model 2

b. Evaluation of alternative models results

Per 2011 SSC's directive (see SCC comments in section B), we were tasked to reduce retrospective/hindcast prediction bias. Hence, for best model selection, both mean hindcast error and mean hindcast bias for 1997-2011 were calculated. For each model, reconstructed historical legal crab abundance of *i*-th year ($y_i$) was estimated using the most up-to-date data (i.e., 2011). Similarly, using the data up to (*i*-1)-th year (e.g., 1998), legal crab abundance of *i*-th year ($yp_i$) (e.g., 1999) was predicted.

From hindcast predicted and reconstructed legal crab abundance, hindcast error for each year was calculated as

$$E_i = (yp_i - y_i)/yp_i, \quad \text{mean hindcast error} \qquad (\Sigma E_i)/n$$

Mean hindcast bias (1-$\beta$) was calculated by regressing reconstructed legal crab abundance with hindcast predicted abundance as

$$y_i = \beta\, yp_i.$$

In these two measures, a better model should have lower mean hindcast error and mean bias (close to 0). Positive values indicate that predicted abundance tends to be higher than hindcast abundance.

| Alternative models | ms6[1] | lamc | maxss | M | Negative LL | Predicted Legal abundance | % abundance change | Mean hindcast Error | Mean hindcast bias |
|---|---|---|---|---|---|---|---|---|---|
| 0. 2011 model (2010 model 6) | 1.6 | 20 | 200 | 0.18 | 11016.9 | 1611.7 | | 0.612 | 0.318 |
| 1. 2012 Base model (see Sec 2.h) | | | | | 11026.3 | 1454.9 | -9.7% | 0.454 | 0.272 |
| 2. Moel 1 & ms6 = 3.6 | 3.6 | | | | 1097.20 | 1484.9 | -7.9% | 0.256 | 0.195 |
| 3. Model 1 & lamc = 50 | | 50 | | | 11181.7 | 1328.8 | -17.6% | 0.187 | 0.150 |
| 4. Model 1 & lamc = 100 | | 100 | | | 11420.6 | 1219.3 | -24.3% | 0.057 | 0.090 |
| 5. Model 1 & maxss = 100 | | | 100 | | 6939.7 | 1500.8 | -6.9% | 0.273 | 0.190 |
| 6. Model 1 & maxss = 50 | | | 50 | | 3687.5 | 1528.9 | -5.1% | 0.165 | 0.138 |
| 7. Model 1 & maxss = 10 | | | 10 | | 840.5 | 1549.1 | -3.9% | 0.083 | 0.071 |
| 8. Model 1 & M= 0.32 | | | | 0.32 | 10987.0 | 1421.6 | -11.8% | 0.041 | 0.077 |
| 9. Model 1 & ms6 = 1.0 | 1.0 | | | | 11052.5 | 1430.9 | -11.2% | 0.646 | 0.656 |
| 10. Model 9 & M = 0.4 | 1.0 | | | 0.4 | 10988.5 | 1388.4 | -13.9% | 0.058 | 0.076 |
| 11. Model 3 & Model 6 | | 50 | 50 | | 3829.1 | 1405.4 | -12.8% | 0.018 | 0.051 |
| 12. Model 11 & Model 2 | 3.6 | 50 | 50 | | 3804.0 | 1378.5 | -14.5% | -0.010 | 0.037 |
| 13. Model 4 & Model 6 | | 100 | 50 | | 4043.3 | 1285.8 | -20.2% | -0.103 | 0.047 |
| 14. Model 13 & Model 2 | 3.6 | 100 | 50 | | 3986.2 | 1244.6 | -22.8% | -0.055 | 0.021 |

1- values for ms6, lamc, maxss, and M in the table for models 2 through 20 indicate values that are different from values in model 0 and model 1.

c. Selection of best models:

Comparing the alternative model configurations with the baseline model, following trends were observed (Appendix C).

1) All alternative models decrease hindcast error and bias and predicted legal crab abundance of 2012 from those of the 2011 model.
2) Increase of M greatly lowered hindcast error and bias; however, it also increased estimates of initial abundance in 1976 (i.e., initial unexploited population abundance). Predicted legal abundance was slightly lower than the 2011 model.
3) Increase of ms6 moderately reduced the hindcast bias and errors moderately, and increased an estimate of initial abundance in 1976 (i.e., initial unexploited population abundance).
4) Increase of lamc greatly lowered hindcast bias and error, and lowered abundance estimates of 1992-2011 by 10-20% from the 2011 model.

5) Lowering of maxss greatly decreased hindcast error and bias; the abundance estimate was slightly lower than 2011 model.

For the selection of best models, we chose models4, 7,8,10, 11, 12, and 14 set criteria of mean hindcast error and bias less than 0.1.

Second, we eliminated the model 14 for instability of the model estimates (See Appendix C).
Among those, we chose models with smaller hindcast bias and error, which left models 11 and 12. Both models are similar

| Data Component | 2011 Model 0 | Baseline Model 1 | Model 4 | Model 7 | Model 8 | Model 10 | Model 11 | Model 12 |
|---|---|---|---|---|---|---|---|---|
| Trawl abundance | -25.13 | -26.86 | -29.8 | -16.9 | -29.9 | -30.1 | -21.8 | -28.1 |
| Pot abundance | -1.14 | -1.45 | -1.44 | -1.74 | -1.87 | -2.23 | -1.62 | -2.17 |
| Commercial effort | 2.40 | -5.44 | -4.61 | -4.37 | -5.05 | -5.09 | -4.52 | -3.93 |
| Trawl length comp | 2580.2 | 2580.5 | 2598.7 | 211.7 | 2580.5 | 2581.2 | 1025.7 | 1027.9 |
| Pot length comp | 1284.4 | 1284.1 | 1285.6 | 64.7 | 1276.0 | 1276.9 | 322.6 | 321.4 |
| Winter length comp | 2823.9 | 2825.3 | 2840.7 | 222.7 | 2819.9 | 2824.2 | 1061.2 | 1065.3 |
| Commercial length comp | 3655.6 | 3652.8 | 3655.1 | 196.5 | 3632.6 | 3632.6 | 979.1 | 972.6 |
| Recruitment deviation | -0.487 | -0.486 | -0.428 | -0.444 | -0.353 | -0.327 | -0.467 | -0.436 |
| Observer length comp | 546.1 | 545.9 | 547.6 | 38.5 | 545.0 | 544.9 | 190.8 | 189.5 |
| Total | 11015.7 | 11026.3 | 11420.6 | 840.5 | 10987.0 | 10994.2 | 3829.1 | 3804.0 |

Comparing the two models, the model 12 showed slightly better mean hindcast error and bias, and low total likelihood. **Hence, we chose the model 12 for calculation of the OFL and ABC.**

d. Parameter estimates:

e. Model selection criteria. The Likelihood values were used to evaluate model.

f. Residual analysis. Residual plots for length compositions are shown in Figures 5 and 6.

g. Model evaluation: See Appendix C

## 4. Results

1. Effective sample sizes and weighting factors.

Effective sample sizes were calculated as

$$n = \sum_l \hat{P}_{y,l}(1-\hat{P}_{y,l}) \Big/ \sum_l (P_{y,l} - \hat{P}_{y,l})^2$$

Where $P_{y,l}$ and $\hat{P}_{y,l}$ are observed and estimated length compositions in year *y* and length group *l*, respectively. Estimated effective sample sizes vary greatly overtime.

Following weights were used

| Data | Weighting Factor |
|---|---|
| Summer fishing effort | 50 |
| Recruitment | 0.01 |

Maximum sample size for length proportion:

| Survey data | Sample size |
|---|---|
| Summer commercial, winter pot, and summer observer | minimum of 0.1× actual sample size or 25 |
| Summer trawl and pot survey | minimum of 0.5× actual sample size or 50 |

Effective sample sizes for length compositions ( Tables 4,5,6,7, and 8).

2. Tables of estimates.

Model Parameter estimates (Table 11).

a. Most of parameters were estimated with CV of around 30%. Notable exception was recruitment parameter for 1978 and 1979 ($log\_R_{78}$ , $log\_R_{79}$), trawl selectivity parameter ($log\_\phi_{st}$ and $log\_\omega_{st}$), and winter pot survey selectivity ($log\_\omega_{sw}$). For 1978 and 1979, estimates were close to zero reflecting extremely low proportion of < 94mm crab observed in 1979 trawl survey (Table 5, Figure 3,4). The high CVs for those selectivity parameters are an artifact because the estimated selectivity was 1.0 for those cases. In asymptotic sigmoid function, multitudes of parameter combinations can result in 1.0, so that model was not able to converge into single parameter. The parameter $p_4$ hit the bound of 1.0. This shows that commercial buyer's preference of purchasing only ≥ 5 inch CW legal crab (as opposed to 4 ¾ inch CW legal crab), did not seem to change fishing behavior (i.e., discarding <5 inch CW legal crabs).

b. Abundance and biomass time series are provided in Table 12 and Figure 4.

c. Recruitment time series are in Table 12 and Figure 4. One noticeable observation was high recruitment estimate in 1976.

d. Time series of catch/biomass are in Table 13

e. Selectivities, molting probabilities, and proportions of legal crabs by length are provided in Table 9.

3. Graphs of estimates.

a. Estimated male abundances (recruits, legal, and total) are plotted in Figures 4 and 5.

b. Time series of catch and harvest rates are plotted in Figure 6.

c. Harvest rate are plotted against mature male biomass in Figure 7.

d. Estimated and observed catch effort was plotted in Figure 8.

e. Estimated and observed trawl survey abundance was plotted in Figure 9.

4. Evaluation of the fit to the data

a. Fits to observed and model predicted catches.
Not applicable. Catch is assumed to be measured without error. Instead, summer commercial fishery effort was modeled (Figure 8). Modeled efforts generally followed observed efforts. Notable exception was 1980.

b. Model fits to survey numbers (Figure 9).

The majority of model estimated abundances of total crabs were within the 95% confidence interval of the survey observed abundance, except for 1976 and 1979, where model estimates was higher than the observed abundance.

c. Model fits to catch and survey proportions by length (Figure 10-13).
Generally, the model fits to

A residual plot for the commercial catch showed that the model tended to overestimate catches of largest length class and thus underestimate crab sizes of (4 and 5). Residuals of winter pot survey showed the model tended to overestimate (negative residuals) the proportion of large length classes (>103 mm). However, during 1991-1995, the pattern was reversed.

Plots of summer trawl, pot, and observer data did not seem show noticeable patterns. Similar to the winter pot survey, the model tended to overestimate proportion of large length classes. This tendency was most prominent during the last 3 trawl surveys.

d. Marginal distribution for the fits to the composition data: Not provided

e. Plots of implied versus input effective sample sizes and time-series of implied effective sample sizes: See Tables 4-8.

g. Tables of RMSEs for the indices: Not provided

h. QQ plots and histograms of residuals: not provided.

5. Retrospective and historic analyses.

See Figure 14, Appendix C, model selection section

6. Uncertainty and sensitivity analyses.

See Appendix B.

## F. Calculation of the OFL

1. Specification of the Tier level and stock status.

The Norton Sound red king crab stock is currently placed in Tier 4 (NPFMC 2007). It is not possible to estimate the spawner-recruit relationship, but some abundance and harvest estimates are available to build a computer simulation model that capture the essential population dynamics. Whereas tier 4 stocks are assumed to have reliable estimates of current survey biomass and instantaneous M, the estimates for the Norton Sound red king crab stock uncertain. Survey biomass is based on triennial trawl surveys with CVs ranging 15-42% (Table 4). The natural mortality of 18% adopted by the CPT (2010) is based on Bristol Bay red king crab with the maximum age 25 and the 1% rule (Zheng 2005); however, no data are available to support the assumption of a maximum age 25 for the Norton Sound red king crab.

The OFL is estimated by the $F_{MSY}$ proxy, $B_{MSY}$ proxy, and estimated legal male abundance and biomass:

$$F_{OFL} = \gamma M, \quad when\, B / B_{MSY^{prox}} > 1, \tag{1}$$

$$F_{OFL} = \gamma M\,(B / B_{MSY^{prox}} - 0.1) / 0.9, \quad when \;\; 0.25 < B / B_{MSY^{prox}} \le 1, \tag{2}$$

$$F_{OFL} = bycatch\,mortality\,\&\,directed\ fishery\,F = 0, \quad when\, B / B_{MSY^{prox}} \le 0.25, \tag{3}$$

where $B$ is a mature male biomass (MMB), $B_{MSY}$ proxy is average mature male biomass over a specified time period. $M$ = 0.18 and $\gamma$ = 1.

For Norton Sound red king crab, MMB is defined as CL > 94 mm.

OFL was calculated for retained catch and total male catch. The retained OFL is based on legal crab biomass catchable to summer commercial pot fisheries (*Legal_B*):

$$Legal\_B = \sum_{l} (N_{s,l,} + O_{s,l,}) S_{s,l} L_l wm_l$$

$$OFL_{retained} = (1 - \exp(-F_{OFL})) Legal\_B$$

The total male OFL is

$$OFL_{totalmales} = OFL_{retained} + (1 - \exp(-F_{OFL})) \sum_{l} (N_{s,l,} + O_{s,l,}) S_{s,l} (1 - L_l) wm_l\, hm$$

where $N_{s,l}$ and $O_{s,l}$ are summer abundances of newshell and oldshell crabs in length class $l$ in the terminal year, $L_l$ is the proportion of legal males in length class $l$, $S_{s,l}$ is summer commercial catch selectivity, $wm_l$ is average weight in length class $l$ and $hm$ is handling mortality rate

For the selection of the $B_{MSY}$ proxy, default data used are survey MMB. However, for the Norton Sound red king crab stock, only available survey MMB data are triennial trawl surveys, 11 years of data during 37 years period. Instead, we used the ***model estimated*** MMB for calculation of $B_{MSY}$ proxy.

**For the Norton Sound red king crab stock, $B_{MSY}$ proxy is based on the period from of 1980 – 2012. This is based on the fact that fishery started 1977, and that uncertainties exist on recruit. Resulting $B_{MSY}$ proxy is 3.51 million lbs MMB and $B/B_{MSY}$ = 1.210 (Figure 4).**

Predicted legal male and mature male biomass in 2012 are:

Legal male biomass: 3.21 million lb with a standard deviation of 0.31 million lb.

Mature male biomass: 4.25 million lbs with a standard deviation of 0.39 million lb.

The average of model estimated mature male biomasses during 1983-2012 was used as the $B_{MSY}$ proxy.

Estimated $B_{MSY}$ proxy, $F_{OFL}$ and retained catch limit in 2012 are:

Model 12

$B_{MSY}$ proxy = 3.51 million lbs,

$F_{OFL}$ = 0.18,

Hence, the overfishing limits **for retained catch** in 2012 are $F_{OFL}$ = 0.18 ($\gamma$=1.0) **0.529 million lbs (3.21×(1-exp(-0.18)).**

## G. Calculation of the ABC

1. Specification of the probability distribution of the OFL.

Probability distribution of the OFL was determined based on the CPT recommendation in January 2012 as follows:

**Tier 4 crab stocks**
Calculation of a distribution for the OFL for Tier 4 stocks involves repeating four steps (detailed below). The aim is to have the median of the distribution for the OFL equal the point estimate (so that P*=0.5 implies that the ABC equals to the point estimate of the OFL). The proposed steps are: (a) Sample current MMB from a normal distribution with mean given by the point estimate of current MMB and CV equal to the sampling CV. (b)The $B_{MSY}$ proxy is the average MMB over a pre-specified set of years. Uncertainty in the $B_{MSY}$ proxy only accounts for uncertainty in MMB for the years for which it is assumed the stock was "at $B_{MSY}$" and not uncertainty in the years concerned. For each of the years used when defining the $B_{MSY}$ proxy, sample MMB from a distribution with mean given by its point estimate and CV equal to the sampling CV. The pseudo $B_{MSY}$ proxy is then the average of the samples values. (c)Sample $M$ from a normal distribution with mean equal to the assumed $M$ and CV equal to an assumed CV (e.g. 0.2). (d)Compute the OFL. Form a cumulative distribution for the OFL from the sampled values. Find the median of this distribution. Using normal quantiles to rescale the distribution so that the median equals the OFL (similar to a bias-corrected bootstrap).

For the Norton Sound red king crab, calculation of OFL is based on summer commercial retained legal male biomass that is more than 90% of harvests. Second largest harvest is winter subsistence harvest, which does not have harvest limit. Hence, retained OFL is used. Sampling

CV was assumed 0.2 that was average CV for trawl survey. For inclusion of uncertainties sigma-b, sigma-b = 0.4 was considered, which was recommended by the CPT (2010).

For calculation of the ABC, default percentile is P* = 49; however because P*=49 is nearly identical to OFL, we also calculated P* = 40. Additionally, in 2011 at the NPFMC meeting in June, the council adopted 10% buffer of OFL (i.e., ABC = 0.9×OFL), and also suggested to explore a 25% buffer.

Candidate ABC

| | Model 12 |
|---|---|
| OFL | 0.529 |
| ABC | |
| Buffer 10% | 0.476 |
| Buffer 25% | 0.397 |
| P*=49 | 0.526 |
| P*=40 | 0.491 |
| P*=49, sigma-b = 0.4 | 0.522 |
| P*=40, sigma-b = 0.4 | 0.464 |

The above shows that ABC P*=49 was identical to OFL, and ABC 10% buffer was similar to P*=40 with sigma-b. **Based on these and uncertainties, we recommend a 10% buffer with ABC = 0.476 million lbs.**

## *H. Rebuilding Analyses*

Not applicable

## *I. Data Gaps and Research Priorities*

The major data gaps of the Norton Sound red king crab are: spatially and temporarily consistent estimate of abundance, **length frequency of discards** from fisheries, and estimates of the instantaneous natural mortality. In addition, life-history of the Norton Sound red king crab stock is poorly understood. This includes **size at maturity**, **natural mortality rate**, timing and locations of reproduction, location of females during summer.

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Table 1. Historical summer commercial red king crab fishery economic performance, Norton Sound Section, eastern Bering Sea, 1977-2011.

| | Guideline Harvest Level | Commercial Harvest (lb) [a, b] | | | Total Number (incl. CDQ) | | | Total Pots | | Season Length | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | (lbs) [b] | Open Access | CDQ | Harvest | Vessels | Permits | Landings | Registered | Pulls | Days | Dates |
| 1977 | [c] | 0.52 | | 195,877 | 7 | 7 | 13 | | 5,457 | 60 | [c] |
| 1978 | 3.00 | 2.09 | | 660,829 | 8 | 8 | 54 | | 10,817 | 60 | 6/07-8/15 |
| 1979 | 3.00 | 2.93 | | 970,962 | 34 | 34 | 76 | | 34,773 | 16 | 7/15-7/31 |
| 1980 | 1.00 | 1.19 | | 329,778 | 9 | 9 | 50 | | 11,199 | 16 | 7/15-7/31 |
| 1981 | 2.50 | 1.38 | | 376,313 | 36 | 36 | 108 | | 33,745 | 38 | 7/15-8/22 |
| 1982 | 0.50 | 0.23 | | 63,949 | 11 | 11 | 33 | | 11,230 | 23 | 8/09-9/01 |
| 1983 | 0.30 | 0.37 | | 132,205 | 23 | 23 | 26 | 3,583 | 11,195 | 3.8 | 8/01-8/05 |
| 1984 | 0.40 | 0.39 | | 139,759 | 8 | 8 | 21 | 1,245 | 9,706 | 13.6 | 8/01-8/15 |
| 1985 | 0.45 | 0.43 | | 146,669 | 6 | 6 | 72 | 1,116 | 13,209 | 21.7 | 8/01-8/23 |
| 1986 | 0.42 | 0.48 | | 162,438 | 3 | 3 | | 578 | 4,284 | 13 | 8/01-8/25 |
| 1987 | 0.40 | 0.33 | | 103,338 | 9 | 9 | | 1,430 | 10,258 | 11 | 8/01-8/12 |
| 1988 | 0.20 | 0.24 | | 76,148 | 2 | 2 | | 360 | 2,350 | 9.9 | 8/01-8/11 |
| 1989 | 0.20 | 0.25 | | 79,116 | 10 | 10 | | 2,555 | 5,149 | 3 | 8/01-8/04 |
| 1990 | 0.20 | 0.19 | | 59,132 | 4 | 4 | | 1,388 | 3,172 | 4 | 8/01-8/05 |
| 1991 | 0.34 | | | 0 | No Summer Fishery | | | | | | |
| 1992 | 0.34 | 0.07 | | 24,902 | 27 | 27 | | 2,635 | 5,746 | 2 | 8/01-8/03 |
| 1993 | 0.34 | 0.33 | | 115,913 | 14 | 20 | 208 | 560 | 7,063 | 52 | 7/01-8/28 |
| 1994 | 0.34 | 0.32 | | 108,824 | 34 | 52 | 407 | 1,360 | 11,729 | 31 | 7/01-7/31 |
| 1995 | 0.34 | 0.32 | | 105,967 | 48 | 81 | 665 | 1,900 | 18,782 | 67 | 7/01-9/05 |
| 1996 | 0.34 | 0.22 | | 74,752 | 41 | 50 | 264 | 1,640 | 10,453 | 57 | 7/01-9/03 |
| 1997 | 0.08 | 0.09 | | 32,606 | 13 | 15 | 100 | 520 | 2,982 | 44 | 7/01-8/13 |
| 1998 | 0.08 | 0.03 | 0.00 | 10,661 | 8 | 11 | 50 | 360 | 1,639 | 65 | 7/01-9/03 |
| 1999 | 0.08 | 0.02 | 0.00 | 8,734 | 10 | 9 | 53 | 360 | 1,630 | 66 | 7/01-9/04 |
| 2000 | 0.33 | 0.29 | 0.01 | 111,728 | 15 | 22 | 201 | 560 | 6,345 | 91 | 7/01- 9/29 |
| 2001 | 0.30 | 0.28 | 0.00 | 98,321 | 30 | 37 | 319 | 1,200 | 11,918 | 97 | 7/01- 9/09 |
| 2002 | 0.24 | 0.24 | 0.01 | 86,666 | 32 | 49 | 201 | 1,120 | 6,491 | 77 | 6/15-9/03 |
| 2003 | 0.25 | 0.25 | 0.01 | 93,638 | 25 | 43 | 236 | 960 | 8,494 | 68 | 6/15-8/24 |
| 2004 | 0.35 | 0.31 | 0.03 | 120,289 | 26 | 39 | 227 | 1,120 | 8,066 | 51 | 6/15-8/08 |
| 2005 | 0.37 | 0.37 | 0.03 | 138,926 | 31 | 42 | 255 | 1,320 | 8,867 | 73 | 6/15-8/27 |
| 2006 | 0.45 | 0.42 | 0.03 | 150,358 | 28 | 40 | 249 | 1,120 | 8,867 | 68 | 6/15-8/22 |
| 2007 | 0.32 | 0.29 | 0.02 | 110,344 | 38 | 30 | 251 | 1,200 | 9,118 | 52 | 6/15-8/17 |
| 2008 | 0.41 | 0.36 | 0.03 | 143,337 | 23 | 30 | 248 | 920 | 8,721 | 73 | 6/23-9/03 |
| 2009 | 0.38 | 0.37 | 0.03 | 143,485 | 22 | 27 | 359 | 920 | 11,934 | 98 | 6/15-9/20 |
| 2010 | 0.40 | 0.39 | 0.03 | 149,822 | 23 | 32 | 286 | 1,040 | 9,698 | 58 | 6/28-8/24 |
| 2011 | 0.36 | 0.37 | 0.03 | 141,626 | 24 | 25 | 173 | 1,040 | 6,808 | 33 | 6/28-7/30 |

[a] Deadloss included in total. [b] Millions of pounds. [c] Information not available.

Table 2. Historical winter commercial and subsistence red king crab fishery economic performance, Norton Sound Section, eastern Bering Sea, 1977-2011.

| Commercial | | | Subsistence | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Permits | | | Total Crab | | |
| Year[a] | # of Fishers | # of Crab Harvested | Winter[b] | Issued | Returned | Fished | Caught[c] | Retained[d] | Average Permit Fished |
| 1978 | 37 | 9,625 | 1977/78 | 290 | 206 | 149 | [e] | 12,506 | 84 |
| 1979 | 1[f] | 221[f] | 1978/79 | 48 | 43 | 38 | [e] | 224 | 6 |
| 1980 | 1[f] | 22[f] | 1979/80 | 22 | 14 | 9 | [e] | 213 | 24 |
| 1981 | 0 | 0 | 1980/81 | 51 | 39 | 23 | [e] | 360 | 16 |
| 1982 | 1[f] | 17[f] | 1981/82 | 101 | 76 | 54 | [e] | 1,288 | 24 |
| 1983 | 5 | 549 | 1982/83 | 172 | 106 | 85 | [e] | 10,432 | 123 |
| 1984 | 8 | 856 | 1983/84 | 222 | 183 | 143 | 15,923 | 11,220 | 78 |
| 1985 | 9 | 1,168 | 1984/85 | 203 | 166 | 132 | 10,757 | 8,377 | 63 |
| 1985/86 | 5 | 2,168 | 1985/86 | 136 | 133 | 107 | 10,751 | 7,052 | 66 |
| 1986/87 | 7 | 1,040 | 1986/87 | 138 | 134 | 98 | 7,406 | 5,772 | 59 |
| 1987/88 | 10 | 425 | 1987/88 | 71 | 58 | 40 | 3,573 | 2,724 | 68 |
| 1988/89 | 5 | 403 | 1988/89 | 139 | 115 | 94 | 7,945 | 6,126 | 65 |
| 1989/90 | 13 | 3,626 | 1989/90 | 136 | 118 | 107 | 16,635 | 12,152 | 114 |
| 1990/91 | 11 | 3,800 | 1990/91 | 119 | 104 | 79 | 9,295 | 7,366 | 93 |
| 1991/92 | 13 | 7,478 | 1991/92 | 158 | 105 | 105 | 15,051 | 11,736 | 112 |
| 1992/93 | 8 | 1,788 | 1992/93 | 88 | 79 | 37 | 1,193 | 1,097 | 30 |
| 1993/94 | 25 | 5,753 | 1993/94 | 118 | 95 | 71 | 4,894 | 4,113 | 58 |
| 1994/95 | 42 | 7,538 | 1994/95 | 166 | 131 | 97 | 7,777 | 5,426 | 56 |
| 1995/96 | 9 | 1,778 | 1995/96 | 84 | 44 | 35 | 2,936 | 1,679 | 48 |
| 1996/97 | 2[f] | 83[f] | 1996/97 | 38 | 22 | 13 | 1,617 | 745 | 57 |
| 1997/98 | 5 | 984 | 1997/98 | 94 | 73 | 64 | 20,327 | 8,622 | 135 |
| 1998/99 | 5 | 2,714 | 1998/99 | 95 | 80 | 71 | 10,651 | 7,533 | 106 |
| 1999/2000 | 10 | 3,045 | 1999/2000 | 98 | 64 | 52 | 9,816 | 5,723 | 107 |
| 2000/01 | 3 | 1,098 | 2000/01 | 50 | 27 | 12 | 366 | 256 | 21 |
| 2001/02 | 11 | 2,591 | 2001/02 | 114 | 61 | 45 | 5,119 | 2,177 | 48 |
| 2002/03 | 13 | 6,853 | 2002/03 | 107 | 70 | 61 | 9,052 | 4,140 | 68 |
| 2003/04[g] | 2 | 522 | 2003/04[g] | 96 | 77 | 41 | 1,775 | 1,181 | 29 |
| 2004/05 | 4 | 2,091 | 2004/05 | 170 | 98 | 58 | 6,484 | 3,973 | 112 |
| 2005/06 | 1[f] | 75[f] | 2005/06 | 98 | 97 | 67 | 2,083 | 1,239 | 18 |
| 2006/07 | 8 | 3,313 | 2006/07 | 129 | 127 | 116 | 21,444 | 10,690 | 92 |
| 2007/08 | 9 | 5,796 | 2007/08 | 139 | 137 | 108 | 18,621 | 9,485 | 88 |
| 2008/09 | 7 | 4,951 | 2008/09 | 105 | 105 | 70 | 6,971 | 4,752 | 68 |
| 2009/10 | 10 | 4,834 | 2009/10 | 125 | 123 | 85 | 9004 | 7,044 | 83 |
| 2010/11 | 9 | 3365 | 2010/11 | 148 | 148 | 95 | 9183 | 6640 | 70 |
| 2011/12 | | | 2011/12 | | | | | | |

a Prior to 1985 the winter commercial fishery occurred from January 1 - April 30. As of March 1985, fishing may occur from November 15 - May 15.
b The winter subsistence fishery occurs during months of two calendar years (as early as December, through May).
c The number of crab actually caught; some may have been returned.
d The number of crab Retained is the number of crab caught and kept.
e Information not available.
f Confidential under AS 16.05.815.
g Confidentiality was waived by the fishers.
h Prior to 2005, permits were only given out of the Nome ADF&G office. Starting with the 2004-5 season, permits were given out in Elim, Golovin, Shaktoolik, and White Mountain.
i Preliminary

Table 3. Summary of triennial trawl survey Norton Sound male red king crab abundance estimates. Trawl survey abundance estimate is based on 10×10 nmil$^2$ grid, except for 2010 (20×20 nmil$^2$).

| | | | | Survey coverage | | | Abundance (1,000s) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Dates | Survey Agency | Survey method | surveyed stations | Stations w/ NSRKC | n mile$^2$ covered | Reported | ≥74 mm Males | CV |
| 1976 | 9/02 - 9/05 | NMFS | Trawl | 103 | 62 | 10260 | 3119.800[a] | 4219.294[k] | 0.163 |
| 1979 | 7/26 - 8/05 | NMFS | Trawl | 85 | 22 | 8421 | 762.000[b] | 901.000[l] | 0.233 |
| 1980 | 7/04 - 7/14 | ADFG | Pots | | | | 1900.000[c] | 2092.303[m] | N/A[s] |
| 1981 | 6/28 - 7/14 | ADFG | Pots | | | | 1285.195[d] | 2153.407[n] | N/A[s] |
| 1982 | 7/06 - 7/20 | ADFG | Pots | | | | 353.273[e] | 1140.582[o] | N/A[s] |
| 1982 | 9/05 - 9/11 | NMFS | Trawl | 58 | 37 | 5721 | 970.646[f] | 2323.379[p] | 0.256 |
| 1985 | 7/01 - 7/14 | ADFG | Pots | | | | 907.579[g] | 2320.381[q] | 0.083[s] |
| 1985 | 9/16 -10/01 | NMFS | Trawl | 78 | 49 | 7688 | 2111.000[h] | 3195.535[r] | 0.263 |
| 1988 | 8/16 - 8/30 | NMFS | Trawl | 78 | 41 | 7721 | 1607.000[i] | 3035.621[r] | 0.298 |
| 1991 | 8/22 - 8/30 | NMFS | Trawl | 52 | 38 | 5183 | 1771.000[j] | 3092.794[r] | 0.350 |
| 1996 | 8/07 - 8/18 | ADFG | Trawl | 50 | 30 | 4938 | | 1264.691[r] | 0.317 |
| 1999 | 7/28 - 8/07 | ADFG | Trawl | 53 | 31 | 5221 | | 2276.095[r] | 0.194 |
| 2002 | 7/27 - 8/06 | ADFG | Trawl | 57 | 37 | 5621 | | 1747.581[r] | 0.125 |
| 2006 | 7/25 - 8/08 | ADFG | Trawl | 101 | 45 | 10008 | | 2549.726[r] | 0.288 |
| 2008 | 7/24 - 8/11 | ADFG | Trawl | 74 | 44 | 7330 | | 2707.083[r] | 0.164 |
| 2010[t] | 7/27 - 8/09 | NMFS | Trawl | 35 | 15 | 13749 | | 2041.021[r] | 0.455 |
| 2011 | 7/18 - 8/15 | ADFG | Trawl | 65 | 34 | 6447 | | 2701.708[r] | 0.133 |

[a,b]: Male ≥ 100mm CL (Wolotira et al 1977,Sample and Wolotira 1985)
[c,d,e]: Legal Male ≥ 4.75 in CW (original source unknown, in Table 2 Schwarz 1984)
[f]: Original source unknown, in Table 2 Schwarz 1984
[g]: Legal Male ≥ 4.75 in CW (Brannian 1987)
[h,i,j]: Male ≥ 90mm CL (Stevens and MacIntosh 1986, Stevens 1989, Stevens 1992)
[k]: 3119.8+1171.2(reported estimate ≤99mm)×0.939 (proportion of 74-99mm): original data insufficient to re-estimate
[l]: 762+178.7(reported estimate ≤99mm)×0.778 (proportion of 74-99 mm): original data insufficient to re-estimate
[m]: 1900×1.101(proportion of ≥74 mm/≥100 mm): original data insufficient to re-estimate
[n]: 1285.195×1.676 (proportion of ≥74 mm/≥100 mm): original data insufficient to re-estimate
[o]: 353.273×3.229 (proportion of ≥74 mm/≥100 mm): original data insufficient to re-estimate
[p]: Archival data file (Claire Armistead, NMFs personal comm.): (re-estimated from the raw l data = 3605.42)
[q]: 907.579+1600.668(reported sublegal estimate)×0.883 (proportion of ≥74 mm): raw data insufficient to re-estimate
[r]: re-estimated from the raw data (confirmed reported numbers from the raw data)
[s]: In the model, cv
[t]: 20×20 n mile$^2$ grid survey

Table 4. Summer commercial catch size/shell composition. Sizes in this and Tables 5-10 and 12 are mm carapace length. Legal size (4.75 inch carapace width is approximately equal to 124 mm carapace length.

| | | | | New Shell | | | | | | Old Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Sample | Modeled N | Effect N | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 1977 | 1549 | 25 | 14 | 0 | 0 | 0.0032 | 0.4196 | 0.3422 | 0.122 | 0 | 0 | 0 | 0.0626 | 0.04 | 0.0103 |
| 1978 | 389 | 25 | 159 | 0 | 0 | 0.0103 | 0.1851 | 0.473 | 0.3059 | 0 | 0 | 0 | 0.0051 | 0.0103 | 0.0103 |
| 1979 | 1660 | 25 | 91 | 0 | 0 | 0.0253 | 0.2325 | 0.3831 | 0.3217 | 0 | 0 | 0 | 0.0253 | 0.0006 | 0.0114 |
| 1980 | 1068 | 25 | 27 | 0 | 0 | 0.0037 | 0.0983 | 0.3062 | 0.5543 | 0 | 0 | 0 | 0.0028 | 0.0112 | 0.0234 |
| 1981 | 1748 | 25 | 10 | 0 | 0 | 0.0039 | 0.0734 | 0.1541 | 0.509 | 0 | 0 | 0 | 0.0045 | 0.0504 | 0.2046 |
| 1982 | 1093 | 25 | 18 | 0 | 0 | 0.0421 | 0.1921 | 0.1647 | 0.505 | 0 | 0 | 0.0037 | 0.0128 | 0.022 | 0.0576 |
| 1983 | 802 | 25 | 47 | 0 | 0 | 0.0387 | 0.4127 | 0.3579 | 0.0973 | 0 | 0 | 0.0037 | 0.0362 | 0.01 | 0.0436 |
| 1984 | 963 | 25 | 26 | 0 | 0 | 0.0966 | 0.4195 | 0.2804 | 0.0717 | 0 | 0 | 0.0104 | 0.0654 | 0.0488 | 0.0073 |
| 1985 | 2691 | 25 | 129 | 0 | 0.0004 | 0.0643 | 0.3122 | 0.3716 | 0.1747 | 0 | 0 | 0.0026 | 0.0334 | 0.0312 | 0.0097 |
| 1986 | 1138 | 25 | 103 | 0 | 0 | 0.029 | 0.3559 | 0.3937 | 0.1353 | 0 | 0 | 0.0018 | 0.0202 | 0.0378 | 0.0264 |
| 1987 | 1542 | 25 | 18 | 0 | 0 | 0.0166 | 0.1788 | 0.2912 | 0.3798 | 0 | 0 | 0.0025 | 0.0267 | 0.065 | 0.0393 |
| 1988 | 1522 | 25 | 8384 | 0.0007 | 0 | 0.0237 | 0.2004 | 0.3003 | 0.2181 | 0 | 0 | 0.0059 | 0.0644 | 0.0972 | 0.0894 |
| 1989 | 2595 | 25 | 172 | 0 | 0 | 0.0127 | 0.1643 | 0.3185 | 0.2148 | 0 | 0 | 0.0042 | 0.0555 | 0.1215 | 0.1084 |
| 1990 | 1289 | 25 | 224 | 0 | 0 | 0.0147 | 0.1435 | 0.3468 | 0.3251 | 0 | 0 | 0.0008 | 0.0372 | 0.0737 | 0.0582 |
| 1991 | | | | | | | | | | | | | | | |
| 1992 | 2566 | 25 | 28 | 0 | 0 | 0.0172 | 0.201 | 0.2662 | 0.2244 | 0 | 0 | 0.0027 | 0.0792 | 0.1292 | 0.08 |
| 1993 | 1813 | 25 | 21 | 0 | 0 | 0.0142 | 0.2312 | 0.3939 | 0.263 | 0 | 0 | 0.0004 | 0.0173 | 0.0437 | 0.0362 |
| 1994 | 404 | 25 | 50 | 0 | 0 | 0.0248 | 0.0941 | 0.0817 | 0.0891 | 0 | 0 | 0.0248 | 0.1881 | 0.25 | 0.2475 |
| 1995 | 1174 | 25 | 45 | 0 | 0 | 0.0392 | 0.2615 | 0.2853 | 0.207 | 0 | 0 | 0.0077 | 0.0486 | 0.0741 | 0.0767 |
| 1996 | 787 | 25 | 234 | 0 | 0 | 0.0318 | 0.2236 | 0.2389 | 0.141 | 0 | 0 | 0.014 | 0.1194 | 0.136 | 0.0953 |
| 1997 | 1198 | 25 | 24 | 0 | 0 | 0.0292 | 0.3656 | 0.3414 | 0.1244 | 0 | 0 | 0.0033 | 0.0559 | 0.0417 | 0.0384 |
| 1998 | 1055 | 25 | 94 | 0 | 0 | 0.0284 | 0.2332 | 0.2427 | 0.1071 | 0 | 0 | 0.0218 | 0.1118 | 0.1431 | 0.1118 |
| 1999 | 561 | 25 | 13 | 0 | 0 | 0.0026 | 0.2434 | 0.2698 | 0.3836 | 0 | 0 | 0 | 0 | 0.0423 | 0.0582 |
| 2000 | 17213 | 25 | 85 | 0 | 0 | 0.0194 | 0.2991 | 0.3917 | 0.1249 | 0 | 0 | 0.0028 | 0.0531 | 0.0654 | 0.0436 |
| 2001 | 20030 | 25 | 733 | 0 | 0 | 0.0243 | 0.2232 | 0.3691 | 0.2781 | 0 | 0 | 0.0008 | 0.0241 | 0.0497 | 0.0304 |
| 2002 | 5198 | 25 | 126 | 0 | 0 | 0.0442 | 0.2341 | 0.2814 | 0.3253 | 0 | 0 | 0.0046 | 0.0282 | 0.0419 | 0.0402 |
| 2003 | 5220 | 25 | 372 | 0 | 0 | 0.0232 | 0.368 | 0.3197 | 0.1523 | 0 | 0 | 0.0011 | 0.0218 | 0.0465 | 0.0674 |
| 2004 | 9605 | 25 | 81 | 0 | 0 | 0.0087 | 0.3811 | 0.388 | 0.1395 | 0 | 0 | 0.0004 | 0.0255 | 0.0347 | 0.0221 |
| 2005 | 5360 | 25 | 50 | 0 | 0 | 0.0022 | 0.2539 | 0.4709 | 0.1823 | 0 | 0 | 0 | 0.0205 | 0.0451 | 0.025 |
| 2006 | 6707 | 25 | 126 | 0 | 0 | 0.0021 | 0.1822 | 0.3484 | 0.199 | 0 | 0 | 0.0003 | 0.0498 | 0.1375 | 0.0807 |
| 2007 | 6125 | 25 | 37 | 0 | 0 | 0.0111 | 0.3574 | 0.3407 | 0.1714 | 0 | 0 | 0.0008 | 0.0247 | 0.0573 | 0.0366 |
| 2008 | 5766 | 25 | 21 | 0 | 0 | 0.0047 | 0.3512 | 0.3476 | 0.0668 | 0 | 0 | 0.0014 | 0.0895 | 0.0928 | 0.0461 |
| 2009 | 6026 | 25 | 39 | 0 | 0 | 0.0105 | 0.3445 | 0.3294 | 0.1339 | 0 | 0 | 0.0012 | 0.0768 | 0.0795 | 0.0242 |
| 2010 | 5902 | 25 | 44 | 0 | 0 | 0.0053 | 0.3855 | 0.3617 | 0.1095 | 0 | 0 | 0.0019 | 0.0546 | 0.0546 | 0.0271 |
| 2011 | 2552 | 25 | 64 | 0 | 0 | 0 | 0.0043 | 0.317 | 0.3969 | 0 | 0 | 0.002 | 0.0611 | 0.0588 | 0.0212 |

Table 5. Summer Trawl Survey size/shell composition

| | | | | New Shell | | | | | | Old Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Sample | Modeled N | Effect N | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 1976 | 1311 | | | 0.0214 | 0.1053 | 0.1915 | 0.3455 | 0.1831 | 0.0290 | 0.0046 | 0.0114 | 0.0252 | 0.032 | 0.0366 | 0.0145 |
| 1979 | 133 | 50 | 25 | 0.0151 | 0.0075 | 0.0301 | 0.0752 | 0.0827 | 0.0602 | 0 | 0.0075 | 0.0301 | 0.1203 | 0.3835 | 0.188 |
| 1982 | 256 | 50 | 22 | 0.0898 | 0.2031 | 0.2891 | 0.2109 | 0.0352 | 0.0078 | 0 | 0.0156 | 0.0195 | 0.043 | 0.0234 | 0.0625 |
| 1985 | 311 | 50 | 111 | 0.1190 | 0.2122 | 0.1865 | 0.1768 | 0.0643 | 0.0193 | 0 | 0 | 0.0193 | 0.0514 | 0.0868 | 0.0643 |
| 1988 | 306 | 50 | 20 | 0.2255 | 0.1405 | 0.1536 | 0.1275 | 0.0686 | 0.0392 | 0 | 0.0065 | 0.0131 | 0.0392 | 0.0882 | 0.098 |
| 1991 | 250 | 50 | 33 | 0.0967 | 0.0223 | 0.0372 | 0.0743 | 0.0409 | 0.0223 | 0.0706 | 0.0297 | 0.0967 | 0.197 | 0.1747 | 0.1375 |
| 1996 | 196 | 50 | 28 | 0.2959 | 0.1786 | 0.1224 | 0.0816 | 0.0051 | 0.0153 | 0.0051 | 0.0357 | 0.0459 | 0.0612 | 0.0612 | 0.0918 |
| 1999 | 274 | 50 | 43 | 0.0109 | 0.1058 | 0.2993 | 0.2701 | 0.1314 | 0.0401 | 0 | 0.0036 | 0.0292 | 0.0511 | 0.0401 | 0.0182 |
| 2002 | 230 | 50 | 87 | 0.1261 | 0.1435 | 0.1565 | 0.0304 | 0.0348 | 0.0348 | 0.0304 | 0.0739 | 0.1087 | 0.0957 | 0.0913 | 0.0739 |
| 2006 | 208 | 50 | 48 | 0.3235 | 0.2614 | 0.1405 | 0.0752 | 0.0458 | 0.0294 | 0 | 0 | 0.0196 | 0.0458 | 0.0458 | 0.0131 |
| 2008 | 242 | 50 | 41 | 0.1743 | 0.2407 | 0.1286 | 0.112 | 0.0332 | 0.029 | 0.0083 | 0.0498 | 0.0705 | 0.0954 | 0.0125 | 0.0456 |
| 2010 | 68 | 34 | 177 | 0.1202 | 0.1366 | 0.2077 | 0.1257 | 0.1093 | 0.0437 | 0.0109 | 0.0328 | 0.082 | 0.071 | 0.0383 | 0.0219 |
| 2011 | 320 | 50 | 163 | 0.1282 | 0.0989 | 0.1282 | 0.2051 | 0.1612 | 0.0476 | 0.0037 | 0.0147 | 0.0256 | 0.0989 | 0.0513 | 0.0366 |

Table 6. Summer Pot Survey size/shell composition

| | | | | New Shell | | | | | | Old Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Sample | Modeled N | Effect N | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 1980 | 3619 | 50 | 25 | 0.0288 | 0.0241 | 0.0444 | 0.0956 | 0.2286 | 0.4575 | 0 | 0 | 0.0003 | 0.0072 | 0.0506 | 0.0627 |
| 1981 | 4588 | 50 | 58 | 0.2095 | 0.1899 | 0.0699 | 0.0642 | 0.0845 | 0.2398 | 0 | 0 | 0.0010 | 0.0048 | 0.0339 | 0.1024 |
| 1982 | 6354 | 50 | 275 | 0.1678 | 0.2220 | 0.2717 | 0.1190 | 0.0411 | 0.1129 | 0 | 0 | 0.0025 | 0.0145 | 0.0157 | 0.0328 |
| 1985 | 9900 | 50 | 83 | 0.1471 | 0.2088 | 0.2467 | 0.1385 | 0.1356 | 0.0644 | 0 | 0 | 0.0063 | 0.0283 | 0.0202 | 0.0040 |

Table 7. Winter pot survey size/shell composition

| | | | | New Shell | | | | | | Old Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Sample | Modeled N | Effect N | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 1981/82 | 243 | 24 | 109 | 0.1481 | 0.3374 | 0.3169 | 0.1029 | 0.0288 | 0.0247 | 0 | 0 | 0.0041 | 0.0082 | 0.0082 | 0.0206 |
| 1982/83 | 2520 | 25 | 77 | 0.0855 | 0.2824 | 0.2854 | 0.2155 | 0.0706 | 0.0085 | 0 | 0 | 0.004 | 0.0194 | 0.0097 | 0.0189 |
| 1983/84 | 1655 | 25 | 213 | 0.1638 | 0.2626 | 0.2291 | 0.1502 | 0.0601 | 0.0057 | 0 | 0 | 0.0178 | 0.065 | 0.0329 | 0.0127 |
| 1984/85 | 773 | 25 | 45 | 0.0932 | 0.2589 | 0.3618 | 0.1586 | 0.057 | 0.0097 | 0 | 0 | 0.0065 | 0.0291 | 0.0239 | 0.0013 |
| 1985/86 | 568 | 25 | 59 | 0.1276 | 0.1831 | 0.2553 | 0.2025 | 0.0863 | 0.0132 | 0 | 0 | 0.015 | 0.0607 | 0.044 | 0.0123 |
| 1986/87 | 144 | 14 | 35 | 0.0556 | 0.1597 | 0.1944 | 0.0694 | 0.0417 | 0 | 0 | 0 | 0.0417 | 0.2986 | 0.1111 | 0.0278 |
| 1987/88 | | | | | | | | | | | | | | | |
| 1988/89 | 492 | 25 | 81 | 0.1341 | 0.1514 | 0.1352 | 0.1941 | 0.1758 | 0.0346 | 0 | 0 | 0.002 | 0.0528 | 0.0854 | 0.0346 |
| 1989/90 | 2072 | 25 | 25 | 0.0495 | 0.2075 | 0.2616 | 0.1795 | 0.1221 | 0.0726 | 0 | 0 | 0.001 | 0.0263 | 0.056 | 0.0239 |
| 1990/91 | 1281 | 25 | 31 | 0.0125 | 0.0921 | 0.2857 | 0.2678 | 0.096 | 0.0109 | 0 | 0 | 0.0039 | 0.0265 | 0.1163 | 0.0882 |
| 1992/93 | 181 | 18 | 17 | 0.0055 | 0.0331 | 0.0552 | 0.1271 | 0.116 | 0.0276 | 0 | 0 | 0.0166 | 0.1934 | 0.2707 | 0.1547 |
| 1993/94 | | | | | | | | | | | | | | | |
| 1994/95 | 850 | 25 | 10 | 0.0588 | 0.08 | 0.0988 | 0.2576 | 0.2341 | 0.0847 | 0 | 0 | 0.0035 | 0.0329 | 0.0718 | 0.0776 |
| 1995/96 | 776 | 25 | 147 | 0.1214 | 0.1835 | 0.1733 | 0.1022 | 0.0599 | 0.0265 | 0 | 0 | 0.0181 | 0.1214 | 0.1242 | 0.0695 |
| 1996/97 | 1582 | 25 | 32 | 0.2297 | 0.2351 | 0.1189 | 0.1568 | 0.1216 | 0.0676 | 0 | 0 | 0 | 0.0189 | 0.027 | 0.0243 |
| 1997/98 | 399 | 25 | 15 | 0.1395 | 0.4136 | 0.2653 | 0.0544 | 0.0236 | 0.0034 | 0 | 0 | 0.0238 | 0.0317 | 0.017 | 0.0272 |
| 1998/99 | 882 | 25 | 27 | 0.0192 | 0.1168 | 0.3566 | 0.3605 | 0.0838 | 0.0154 | 0 | 0 | 0.01 | 0.0223 | 0.0069 | 0.0085 |
| 1999/00 | 1308 | 25 | 339 | 0.0885 | 0.1062 | 0.1646 | 0.3345 | 0.1788 | 0.0372 | 0 | 0 | 0.0018 | 0.0513 | 0.023 | 0.0142 |
| 2000/01 | | | | | | | | | | | | | | | |
| 2001/02 | 832 | 25 | 19 | 0.3136 | 0.2763 | 0.1761 | 0.0681 | 0.0668 | 0.0501 | 0 | 0 | 0.0077 | 0.0051 | 0.0154 | 0.0064 |
| 2002/03 | 826 | 25 | 85 | 0.0994 | 0.2236 | 0.2994 | 0.1801 | 0.0559 | 0.0261 | 0 | 0 | 0.0224 | 0.0273 | 0.0261 | 0.0273 |
| 2003/04 | 286 | 25 | 73 | 0.0175 | 0.1643 | 0.2622 | 0.3462 | 0.1119 | 0.0105 | 0 | 0 | 0.0175 | 0.021 | 0.014 | 0.0245 |
| 2004/05 | 406 | 16 | 135 | 0.0741 | 0.1407 | 0.1827 | 0.2173 | 0.1852 | 0.0765 | 0 | 0 | 0.0025 | 0.0395 | 0.0593 | 0.0173 |
| 2005/06 | 512 | 25 | 64 | 0.1406 | 0.2266 | 0.209 | 0.1563 | 0.0547 | 0.0215 | 0 | 0 | 0.0176 | 0.043 | 0.0742 | 0.0352 |
| 2006/07 | 160 | 16 | 37 | 0.1486 | 0.2095 | 0.3784 | 0.1419 | 0.0473 | 0 | 0 | 0 | 0.0068 | 0.0203 | 0.0405 | 0 |
| 2007/08 | 3482 | 25 | 50 | 0.1898 | 0.3219 | 0.1703 | 0.1479 | 0.0672 | 0.0083 | 0 | 0 | 0.0359 | 0.0339 | 0.0155 | 0.0092 |
| 2008/09 | 526 | 25 | 27 | 0.0706 | 0.1336 | 0.3511 | 0.2023 | 0.084 | 0.0134 | 0 | 0 | 0.0019 | 0.0382 | 0.0992 | 0.0057 |
| 2009/10 | 581 | 25 | 118 | 0.047 | 0.1357 | 0.2157 | 0.2452 | 0.113 | 0.0191 | 0 | 0 | 0.0591 | 0.1009 | 0.0539 | 0.0104 |
| 2010/11 | 597 | 24 | 155 | 0.0786 | 0.1368 | 0.2103 | 0.1744 | 0.1333 | 0.0513 | 0 | 0.0120 | 0.0325 | 0.1128 | 0.0462 | 0.0120 |
| 2011/12 | 676 | 25 | 89 | 0.1155 | 0.2340 | 0.1945 | 0.1246 | 0.1292 | 0.0456 | 0.0030 | 0.0030 | 0.0912 | 0.0532 | 0.0532 | 0.0350 |

Table 8. Summer commercial1987-1994 observer survey (Sub legal crab only)

| | | | | New Shell | | | | | Old Shell | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Sample | Modeled N | Effect N | 84-93 | 94-103 | 104-113 | 114-123 | 124+ | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 1987 | 1076 | 25 | 43 | 0.2026 | 0.3625 | 0.3522 | 0.0344 | 0 | 0 | 0 | 0 | 0.0437 | 0.0046 | 0 |
| 1988 | 712 | 25 | 16 | 0.052 | 0.184 | 0.4831 | 0.139 | 0 | 0 | 0 | 0 | 0.0969 | 0.0449 | 0 |
| 1989 | 911 | 25 | 83 | 0.2492 | 0.3392 | 0.2371 | 0.0274 | 0 | 0 | 0 | 0 | 0.1196 | 0.0274 | 0 |
| 1990 | 459 | 25 | 47 | 0.2702 | 0.3203 | 0.3028 | 0.0414 | 0 | 0 | 0 | 0 | 0.0588 | 0.0065 | 0 |
| 1992 | 515 | 25 | 430 | 0.2175 | 0.3592 | 0.332 | 0.0369 | 0 | 0 | 0 | 0 | 0.0447 | 0.0097 | 0 |
| 1994 | 726 | 25 | 81 | 0.1556 | 0.303 | 0.1736 | 0.0262 | 0 | 0 | 0 | 0 | 0.2824 | 0.0592 | 0 |

Table 9. Growth matrix (proportion of crabs molting from a given pre-molt carapace length range into post-molt length ranges) for Norton Sound male red king crab. Length is measured as mm CL. Results are derived from mark-recapture and winter tagging data from 1980 to 2007.

| Pre-molt | | Post-molt Length Class | | | | | |
|---|---|---|---|---|---|---|---|
| Length Class | Mean weight (lb) | 74-83 | 84-93 | 94-103 | 104-113 | 114-123 | 124+ |
| 74-83 | 0.854 | 0 | 0.33 | 0.67 | 0 | 0 | 0 |
| 84-93 | 1.210 | 0 | 0 | 0.56 | 0.44 | 0 | 0 |
| 94-103 | 1.652 | 0 | 0 | 0 | 0.76 | 0.24 | 0 |
| 104-113 | 2.187 | 0 | 0 | 0 | 0.18 | 0.61 | 0.21 |
| 114-123 | 2.825 | 0 | 0 | 0 | 0 | 0.33 | 0.67 |
| 124+ | 3.697 | 0 | 0 | 0 | 0 | 0 | 1.00 |

Table 10. Estimated selectivities, molting probabilities, and proportions of legal crabs by length (mm CL) class for Norton Sound male red king crab.

| | | Selectivity | | | | | |
|---|---|---|---|---|---|---|---|
| Length Class | Proportion of Legal | Summer Trawl | Summer Pot | Winter Pot | Summer Fishery 77-92 | Summer Fishery 93-11 | Molting Probability |
| 74 - 83 | 0.00 | 1.00 | 0.57 | 0.57 | 0.19 | 0.01 | 1.00 |
| 84 - 93 | 0.00 | 1.00 | 0.86 | 1.00 | 0.31 | 0.05 | 0.92 |
| 94 - 103 | 0.26 | 1.00* | 1.00* | 1.00* | 0.47 | 0.22 | 0.85 |
| 104 - 113 | 0.97 | 1.00* | 1.00* | 1.00* | 0.70 | 0.63 | 0.78 |
| 114 - 123 | 0.99 | 1.00* | 1.00* | 1.00* | 1.00* | 1.00* | 0.71 |
| 124+ | 1.00 | 1.00* | 1.00* | 0.32 | 1.00 | 1.00 | 0.65 |

*: Assumed to be 1.0

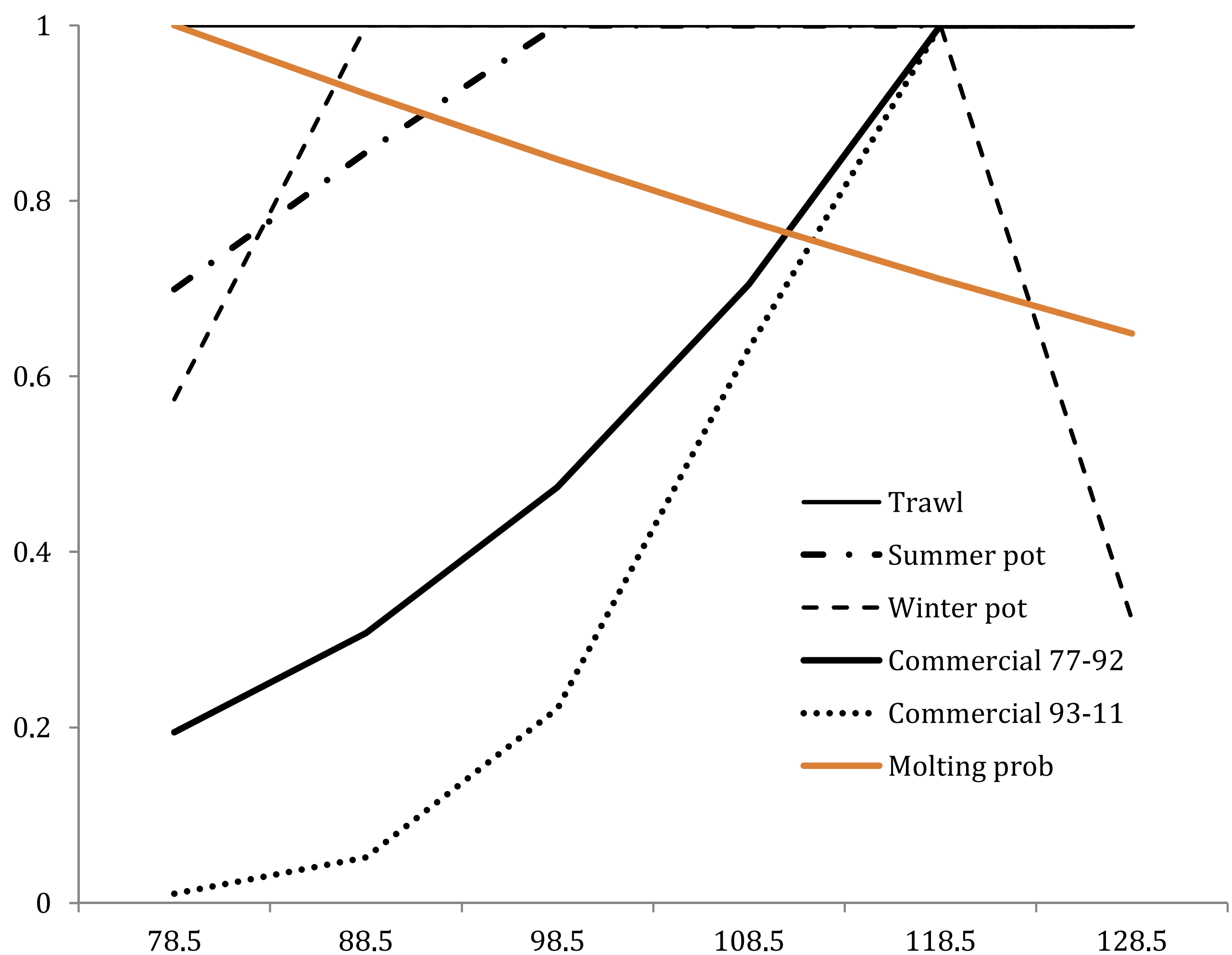


Table 11. Summary of parameter estimates for a length-based stock synthesis population model of Norton Sound red king crab.

Model 12

| Parameter | Value | Std | Parameter | Value | Std |
|---|---|---|---|---|---|
| log_$N_{76}$ | 8.93 | 0.08 | log_$R_{09}$ | 0.92 | 0.31 |
| log_mean | 5.98 | 0.23 | log_$R_{10}$ | 0.26 | 0.38 |
| log_$R_{77}$ | 1.48 | 0.32 | log_$R_{11}$ | 0.46 | 0.34 |
| log_$R_{78}$ | -3.89 | 3.10 | | | |
| log_$R_{79}$ | -2.43 | 1.07 | r1 | 0.61 | 0.03 |
| log_$R_{80}$ | -0.89 | 0.47 | log_$q_1$ | -11.34 | 0.08 |
| log_$R_{81}$ | 1.23 | 0.26 | log_$q_2$ | -10.86 | 0.09 |
| log_$R_{82}$ | 0.70 | 0.30 | | | |
| log_$R_{83}$ | 0.96 | 0.33 | log_$\phi_1$ | -2.99 | 0.41 |
| log_$R_{84}$ | 1.44 | 0.27 | log_$\omega_1$ | 4.87 | 0.35 |
| log_$R_{85}$ | 0.79 | 0.31 | log_$\phi_2$ | -1.82 | 0.17 |
| log_$R_{86}$ | 0.67 | 0.34 | log_$\omega_2$ | 4.68 | 0.02 |
| log_$R_{87}$ | 0.33 | 0.33 | | | |
| log_$R_{88}$ | -0.11 | 0.32 | | | |
| log_$R_{89}$ | -0.01 | 0.30 | $p_4$ | 1.00 | 0.00 |
| log_$R_{90}$ | -0.19 | 0.32 | log_$\alpha$ | -4.47 | 0.15 |
| log_$R_{91}$ | -0.59 | 0.39 | log_$\beta$ | 0.55 | 0.62 |
| log_$R_{92}$ | -0.21 | 0.38 | log_$\phi_{st}$ | -1.34 | 291.72 |
| log_$R_{93}$ | -1.46 | 0.81 | log_$\omega_{st}$ | 1.67 | 1312.50 |
| log_$R_{94}$ | 0.22 | 0.29 | log_$\phi_{sp}$ | -2.42 | 1.60 |
| log_$R_{95}$ | -0.82 | 0.45 | log_$\omega_{sp}$ | 4.24 | 0.28 |
| log_$R_{96}$ | -0.36 | 0.30 | log_$\phi_{sw}$ | 0.64 | 263.97 |
| log_$R_{97}$ | -0.23 | 0.33 | log_$\omega_{sw}$ | 4.36 | 0.54 |
| log_$R_{98}$ | 0.93 | 0.25 | $Sw_6$ | 0.32 | 0.06 |
| log_$R_{99}$ | -2.23 | 0.97 | | | |
| log_$R_{00}$ | -0.25 | 0.42 | | | |
| log_$R_{01}$ | 0.61 | 0.31 | | | |
| log_$R_{02}$ | 0.63 | 0.29 | | | |
| log_$R_{03}$ | 0.62 | 0.33 | | | |
| log_$R_{04}$ | -0.64 | 0.71 | | | |
| log_$R_{05}$ | 0.09 | 0.35 | | | |
| log_$R_{06}$ | 0.84 | 0.27 | | | |
| log_$R_{07}$ | 0.16 | 0.37 | | | |
| log_$R_{08}$ | 0.99 | 0.27 | | | |

Table 12. Annual abundance estimates (million crabs) and mature male biomass (MMB, million lbs) for Norton Sound red king crab estimated by length-based analysis from 1976-2011.

**Model 12**

| | Abundance | | | Legal (≥ 104 mm) | | | | MMB | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Recruits | Total (≥ 74 mm) | Matures (≥ 94 mm) | Abundance | S.D | Biomass | S.D | Biomass | S.D. |
| 1976 | 1.74 | 7.47 | 6.51 | 5.20 | 0.42 | 12.70 | 1.02 | 14.91 | 1.19 |
| 1977 | 0.01 | 7.57 | 5.85 | 5.30 | 0.42 | 14.42 | 1.10 | 15.39 | 1.19 |
| 1978 | 0.03 | 5.63 | 5.31 | 4.57 | 0.29 | 13.10 | 0.88 | 14.37 | 0.80 |
| 1979 | 0.16 | 3.67 | 3.62 | 3.39 | 0.17 | 9.99 | 0.55 | 10.40 | 0.55 |
| 1980 | 1.35 | 2.05 | 1.89 | 1.83 | 0.12 | 5.62 | 0.37 | 5.73 | 0.37 |
| 1981 | 0.80 | 2.43 | 1.15 | 1.08 | 0.08 | 3.42 | 0.25 | 3.54 | 0.26 |
| 1982 | 1.03 | 2.30 | 1.32 | 0.84 | 0.07 | 2.24 | 0.20 | 3.04 | 0.26 |
| 1983 | 1.67 | 2.71 | 1.60 | 1.18 | 0.10 | 2.95 | 0.24 | 3.67 | 0.31 |
| 1984 | 0.87 | 3.60 | 1.86 | 1.39 | 0.12 | 3.52 | 0.29 | 4.32 | 0.37 |
| 1985 | 0.77 | 3.58 | 2.46 | 1.74 | 0.14 | 4.40 | 0.36 | 5.59 | 0.44 |
| 1986 | 0.55 | 3.43 | 2.54 | 2.03 | 0.16 | 5.26 | 0.42 | 6.13 | 0.49 |
| 1987 | 0.35 | 3.07 | 2.41 | 2.00 | 0.16 | 5.40 | 0.43 | 6.09 | 0.48 |
| 1988 | 0.39 | 2.60 | 2.17 | 1.86 | 0.15 | 5.19 | 0.41 | 5.72 | 0.44 |
| 1989 | 0.33 | 2.25 | 1.82 | 1.61 | 0.12 | 4.63 | 0.36 | 4.99 | 0.38 |
| 1990 | 0.22 | 1.90 | 1.52 | 1.33 | 0.10 | 3.88 | 0.30 | 4.21 | 0.32 |
| 1991 | 0.32 | 1.55 | 1.28 | 1.11 | 0.09 | 3.25 | 0.25 | 3.54 | 0.27 |
| 1992 | 0.09 | 1.41 | 1.07 | 0.95 | 0.07 | 2.79 | 0.21 | 3.00 | 0.22 |
| 1993 | 0.49 | 1.10 | 0.96 | 0.81 | 0.06 | 2.37 | 0.16 | 2.61 | 0.18 |
| 1994 | 0.17 | 1.17 | 0.69 | 0.62 | 0.05 | 1.79 | 0.14 | 1.92 | 0.15 |
| 1995 | 0.28 | 0.96 | 0.71 | 0.52 | 0.04 | 1.44 | 0.12 | 1.75 | 0.14 |
| 1996 | 0.31 | 0.92 | 0.62 | 0.51 | 0.04 | 1.34 | 0.11 | 1.54 | 0.13 |
| 1997 | 1.00 | 0.95 | 0.61 | 0.48 | 0.04 | 1.28 | 0.11 | 1.50 | 0.13 |
| 1998 | 0.04 | 1.64 | 0.65 | 0.51 | 0.05 | 1.36 | 0.12 | 1.60 | 0.15 |
| 1999 | 0.31 | 1.34 | 1.12 | 0.73 | 0.06 | 1.83 | 0.15 | 2.48 | 0.19 |
| 2000 | 0.73 | 1.33 | 1.03 | 0.89 | 0.07 | 2.34 | 0.18 | 2.57 | 0.20 |
| 2001 | 0.75 | 1.63 | 0.89 | 0.76 | 0.06 | 2.09 | 0.17 | 2.32 | 0.19 |
| 2002 | 0.73 | 1.89 | 1.06 | 0.77 | 0.06 | 2.04 | 0.17 | 2.54 | 0.21 |
| 2003 | 0.21 | 2.10 | 1.28 | 0.93 | 0.07 | 2.38 | 0.19 | 2.97 | 0.23 |
| 2004 | 0.43 | 1.80 | 1.46 | 1.11 | 0.08 | 2.84 | 0.21 | 3.44 | 0.26 |
| 2005 | 0.92 | 1.71 | 1.27 | 1.09 | 0.09 | 2.92 | 0.23 | 3.23 | 0.25 |
| 2006 | 0.46 | 2.07 | 1.14 | 0.94 | 0.08 | 2.61 | 0.21 | 2.94 | 0.24 |
| 2007 | 1.07 | 1.93 | 1.33 | 0.96 | 0.08 | 2.52 | 0.21 | 3.14 | 0.25 |
| 2008 | 0.99 | 2.41 | 1.33 | 1.05 | 0.09 | 2.75 | 0.23 | 3.21 | 0.26 |
| 2009 | 0.52 | 2.72 | 1.60 | 1.16 | 0.09 | 2.98 | 0.24 | 3.73 | 0.29 |
| 2010 | 0.63 | 2.52 | 1.86 | 1.38 | 0.11 | 3.52 | 0.27 | 4.32 | 0.33 |
| 2011 | 0.73 | 2.45 | 1.77 | 1.45 | 0.12 | 3.82 | 0.32 | 4.36 | 0.37 |
| 2012 | | 2.48 | 1.68 | 1.38 | 0.13 | 3.74 | 0.35 | 4.25 | 0.39 |

Table 13. Summary of catch and bycatch (million lbs) for Norton Sound red king crab. The bycatch (discards) is estimated from the model. Summer commercial catches are from ADF&G fish ticket database during 1985-2009 and from Menard et al. (2011) during 1977 to 1984. Winter commercial and subsistence catches are from ADF&G permit reporting and average weight of 2.5 lbs for the winter commercial catch and 2.0 lbs for the subsistence catch were assumed to estimate total weight.

Model 12

| *Year* | *Summer* | *Winter* | *Subsistence* | *Bycatch/ discards* | *Total* | *Catch/MMB* |
|---|---|---|---|---|---|---|
| 1977 | 0.52 | 0.024 | 0.025 | 0.005 | 0.57 | 0.04 |
| 1978 | 2.09 | 0.001 | 0.000 | 0.010 | 2.10 | 0.15 |
| 1979 | 2.93 | 0.000 | 0.000 | 0.009 | 2.94 | 0.28 |
| 1980 | 1.19 | 0.000 | 0.001 | 0.004 | 1.19 | 0.21 |
| 1981 | 1.38 | 0.000 | 0.003 | 0.029 | 1.41 | 0.40 |
| 1982 | 0.23 | 0.001 | 0.021 | 0.010 | 0.26 | 0.09 |
| 1983 | 0.37 | 0.002 | 0.022 | 0.016 | 0.41 | 0.11 |
| 1984 | 0.39 | 0.003 | 0.017 | 0.017 | 0.43 | 0.10 |
| 1985 | 0.43 | 0.005 | 0.014 | 0.015 | 0.46 | 0.08 |
| 1986 | 0.48 | 0.003 | 0.012 | 0.011 | 0.51 | 0.08 |
| 1987 | 0.33 | 0.001 | 0.005 | 0.005 | 0.34 | 0.06 |
| 1988 | 0.24 | 0.001 | 0.012 | 0.003 | 0.26 | 0.04 |
| 1989 | 0.25 | 0.009 | 0.024 | 0.003 | 0.29 | 0.06 |
| 1990 | 0.19 | 0.010 | 0.015 | 0.002 | 0.22 | 0.05 |
| 1991 | 0 | 0.019 | 0.023 | 0.000 | 0.04 | 0.01 |
| 1992 | 0.07 | 0.004 | 0.002 | 0.001 | 0.08 | 0.03 |
| 1993 | 0.33 | 0.014 | 0.008 | 0.002 | 0.35 | 0.14 |
| 1994 | 0.32 | 0.019 | 0.011 | 0.002 | 0.35 | 0.18 |
| 1995 | 0.32 | 0.004 | 0.003 | 0.003 | 0.33 | 0.19 |
| 1996 | 0.22 | 0.000 | 0.001 | 0.002 | 0.22 | 0.14 |
| 1997 | 0.09 | 0.002 | 0.017 | 0.001 | 0.11 | 0.07 |
| 1998 | 0.03 | 0.007 | 0.015 | 0.000 | 0.05 | 0.03 |
| 1999 | 0.02 | 0.008 | 0.011 | 0.000 | 0.04 | 0.02 |
| 2000 | 0.3 | 0.003 | 0.001 | 0.002 | 0.31 | 0.12 |
| 2001 | 0.28 | 0.006 | 0.004 | 0.002 | 0.29 | 0.13 |
| 2002 | 0.25 | 0.017 | 0.008 | 0.003 | 0.28 | 0.11 |
| 2003 | 0.26 | 0.001 | 0.002 | 0.003 | 0.27 | 0.09 |
| 2004 | 0.34 | 0.005 | 0.008 | 0.004 | 0.36 | 0.10 |
| 2005 | 0.4 | 0.000 | 0.002 | 0.003 | 0.41 | 0.13 |
| 2006 | 0.45 | 0.008 | 0.021 | 0.004 | 0.48 | 0.16 |
| 2007 | 0.31 | 0.014 | 0.019 | 0.004 | 0.35 | 0.11 |
| 2008 | 0.39 | 0.012 | 0.010 | 0.005 | 0.42 | 0.13 |
| 2009 | 0.4 | 0.012 | 0.014 | 0.005 | 0.43 | 0.12 |
| 2010 | 0.42 | 0.008 | 0.013 | 0.005 | 0.45 | 0.10 |
| 2011 | 0.4 | 0.011 | 0.018 | 0.003 | 0.43 | 0.10 |

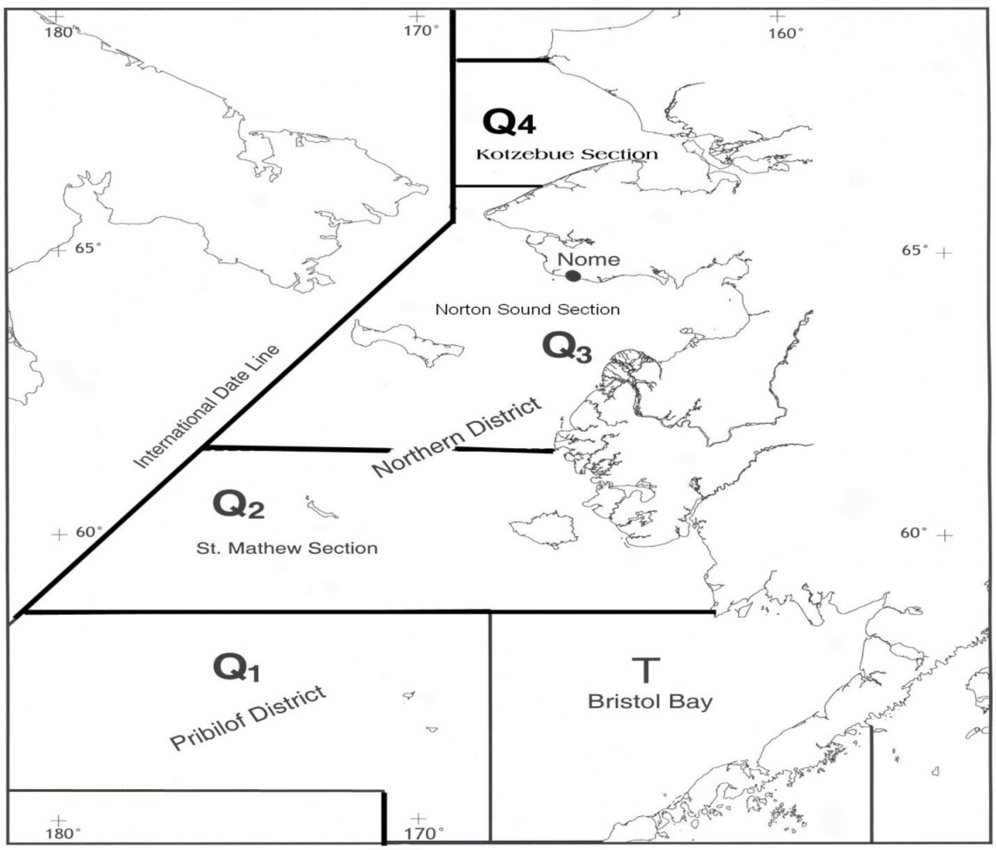



Figure 1. King crab fishing districts and sections of Statistical Area Q.

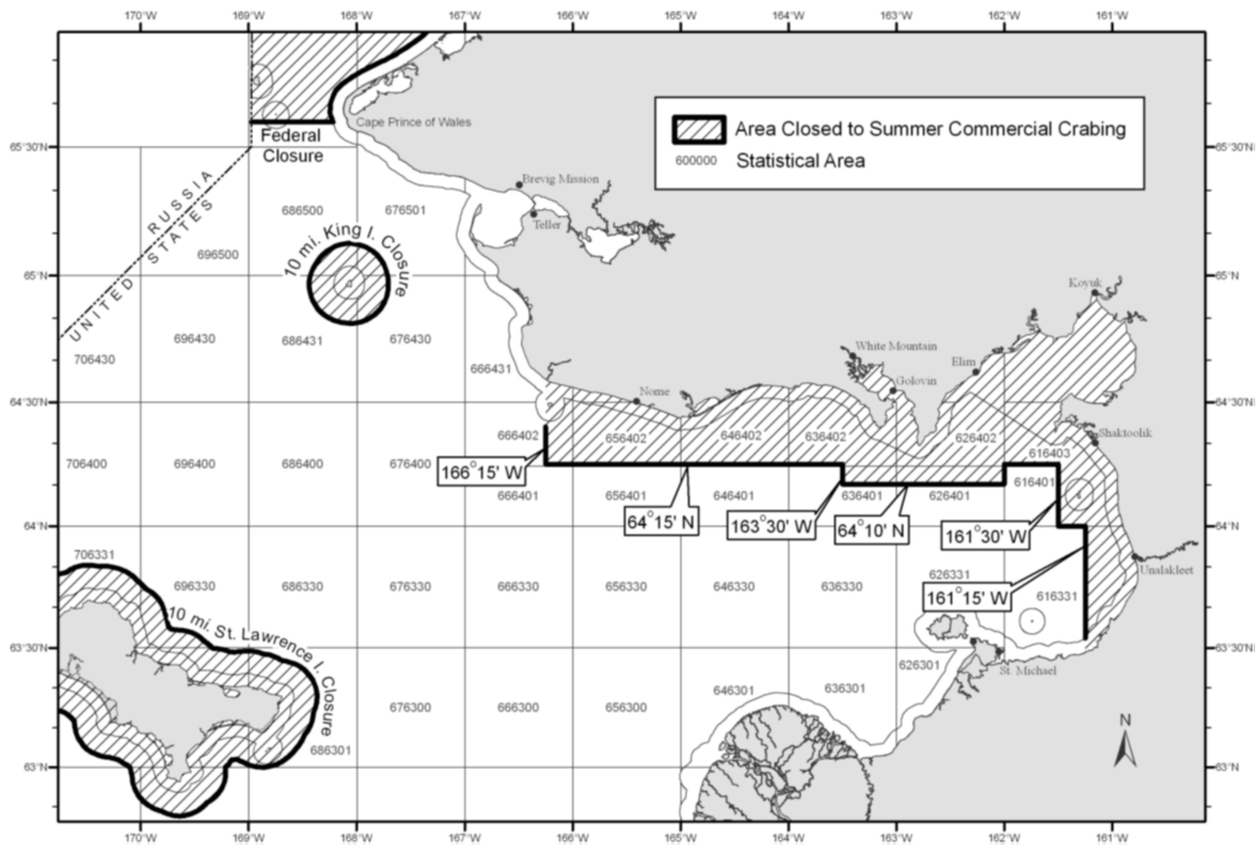



Figure 2. Closed water regulations in effect for the Norton Sound commercial crab fishery.

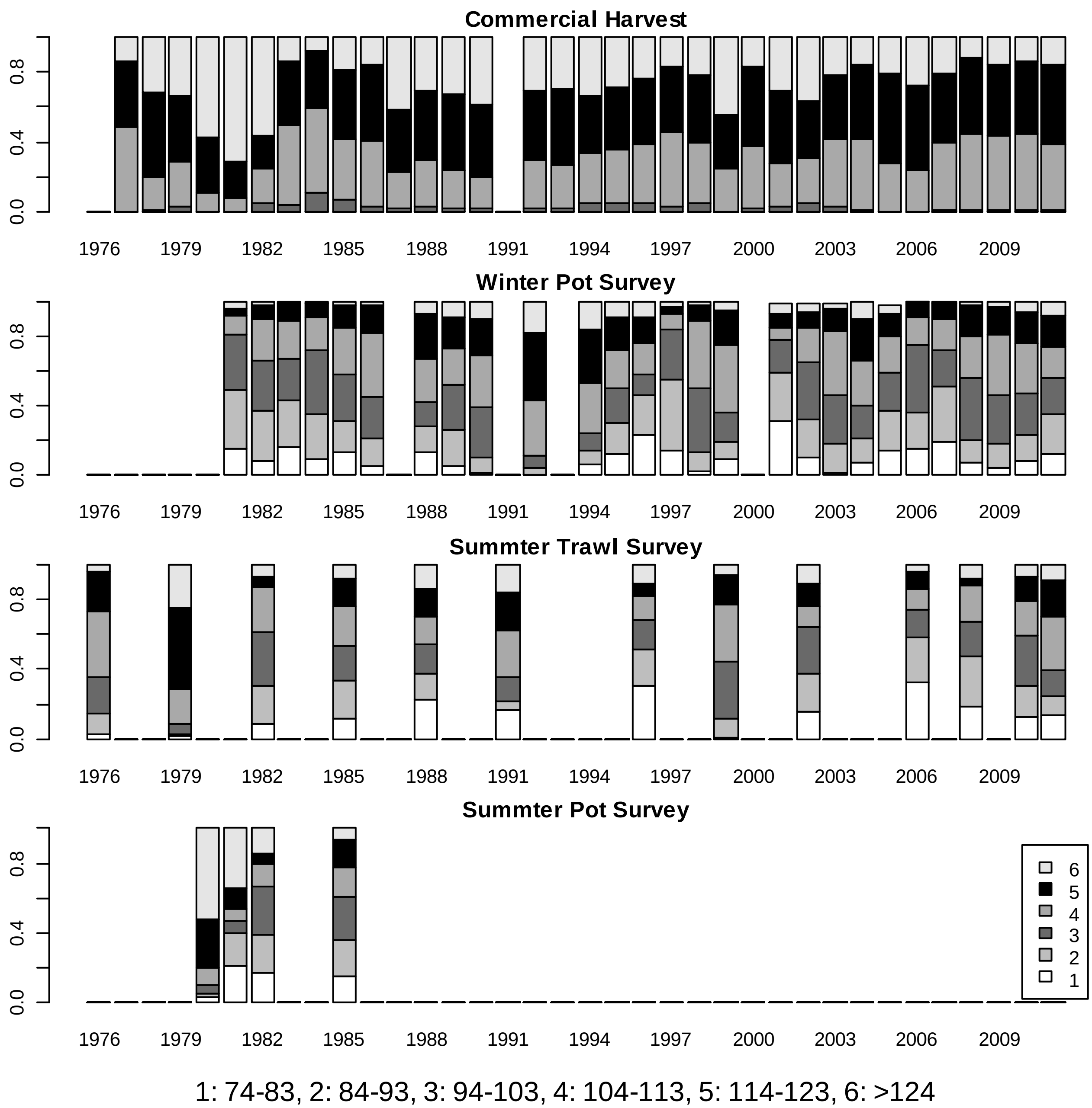



Figure 3. Observed length compositions 1976-2012.

Model 12

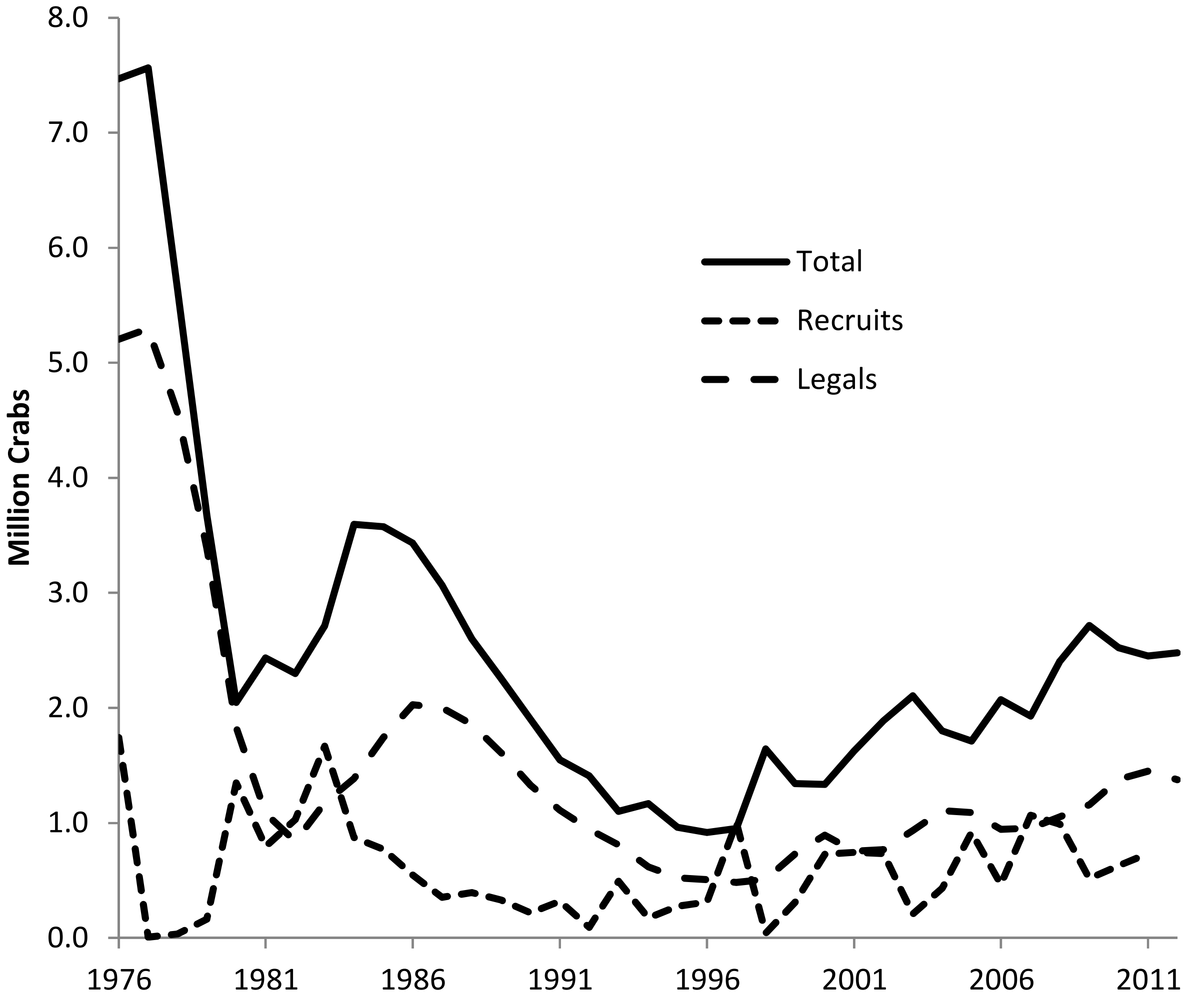



Figure 4. Estimated abundance of total (crabs ≥ 74 mm CL), legal male, and recruits from 1976-2012.

Model 12

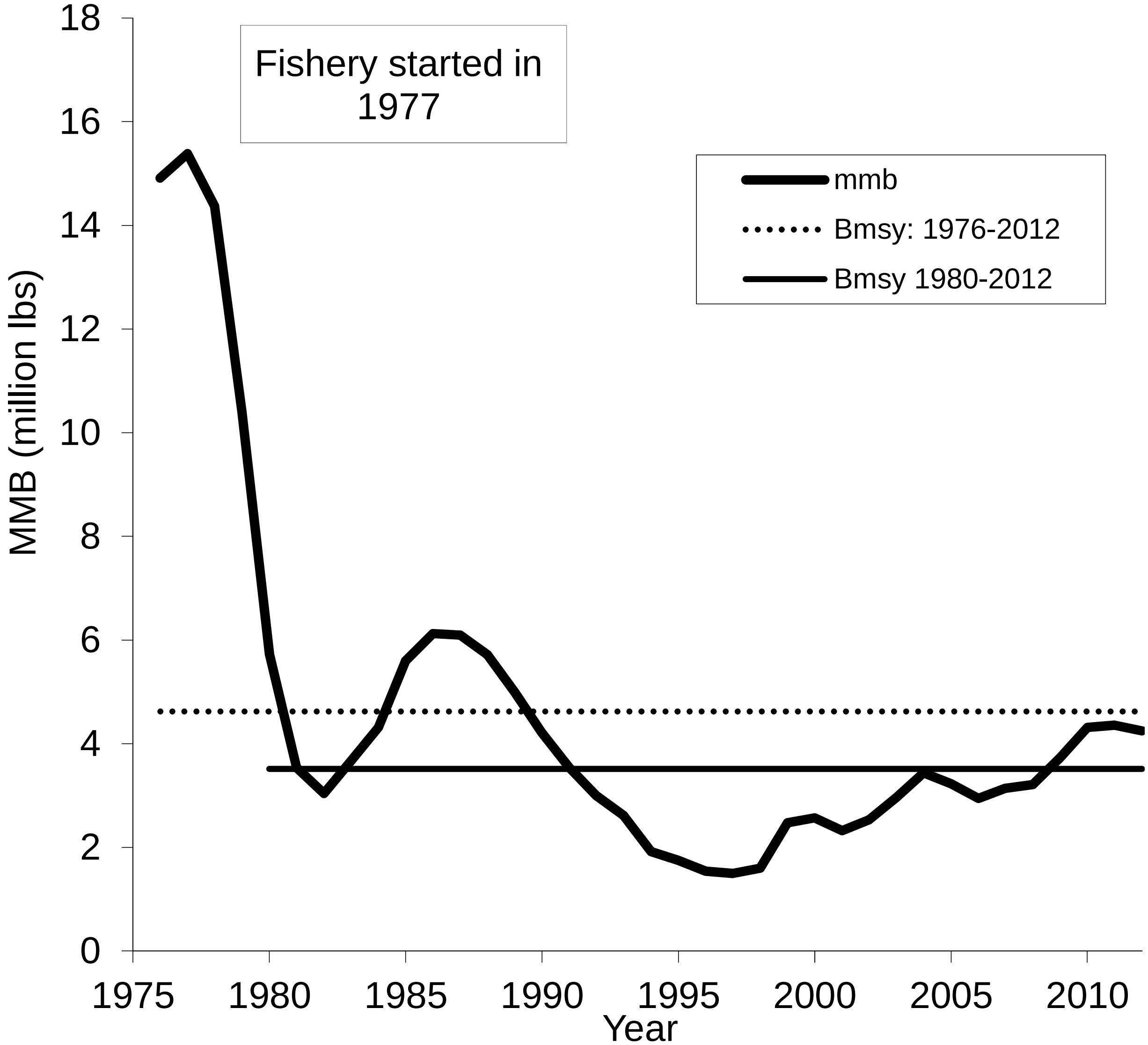



Figure 5. Estimated mature male biomass from 1976-2011.

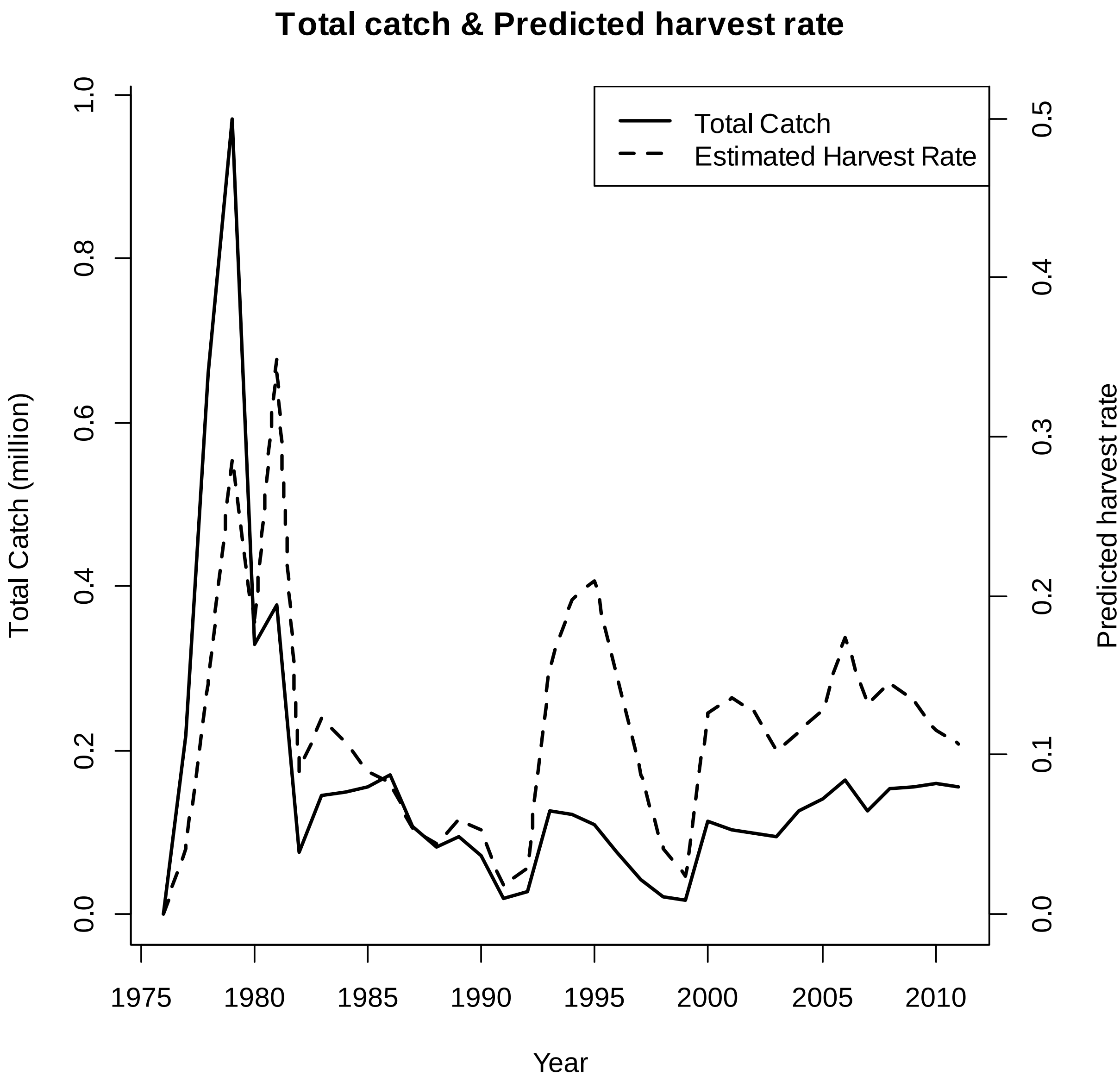



Figure 6. Total catch and predicted harvest rate time series. Note that harvest rate during the 2000-2011peiriods exceeded 0.1 (10%) despite that the GHL was set to maximum 10%. This is largely due to higher model predicted biomass estimate at the time of assessment.

Model 12

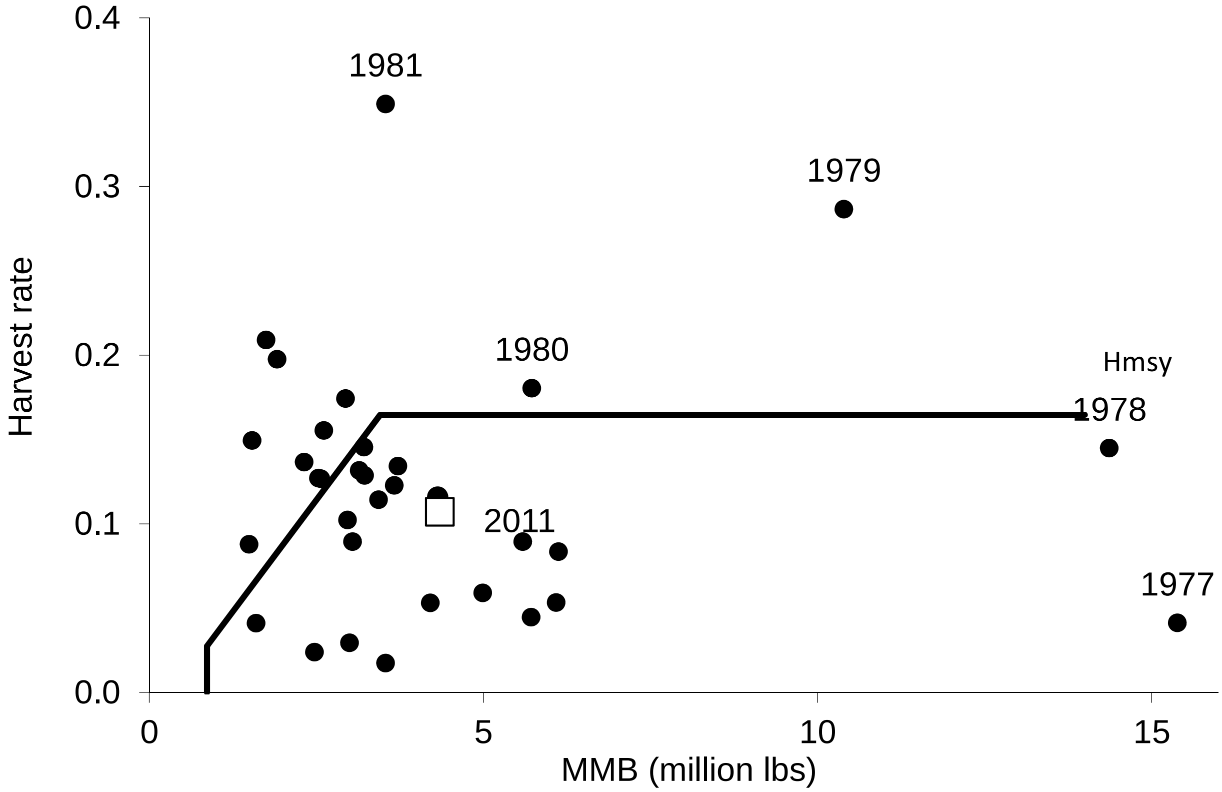



Figure 7. Relationship between harvest rates and mature male biomass (lower plot) of Norton Sound red king crab from June 1, 1976 to May 31, 2011. *Hmsy* is a proxy MSY harvest rate corresponding to *Fmsy* with $\gamma$=1.0 and *M*=0.18. White box is 2011.

Model 12

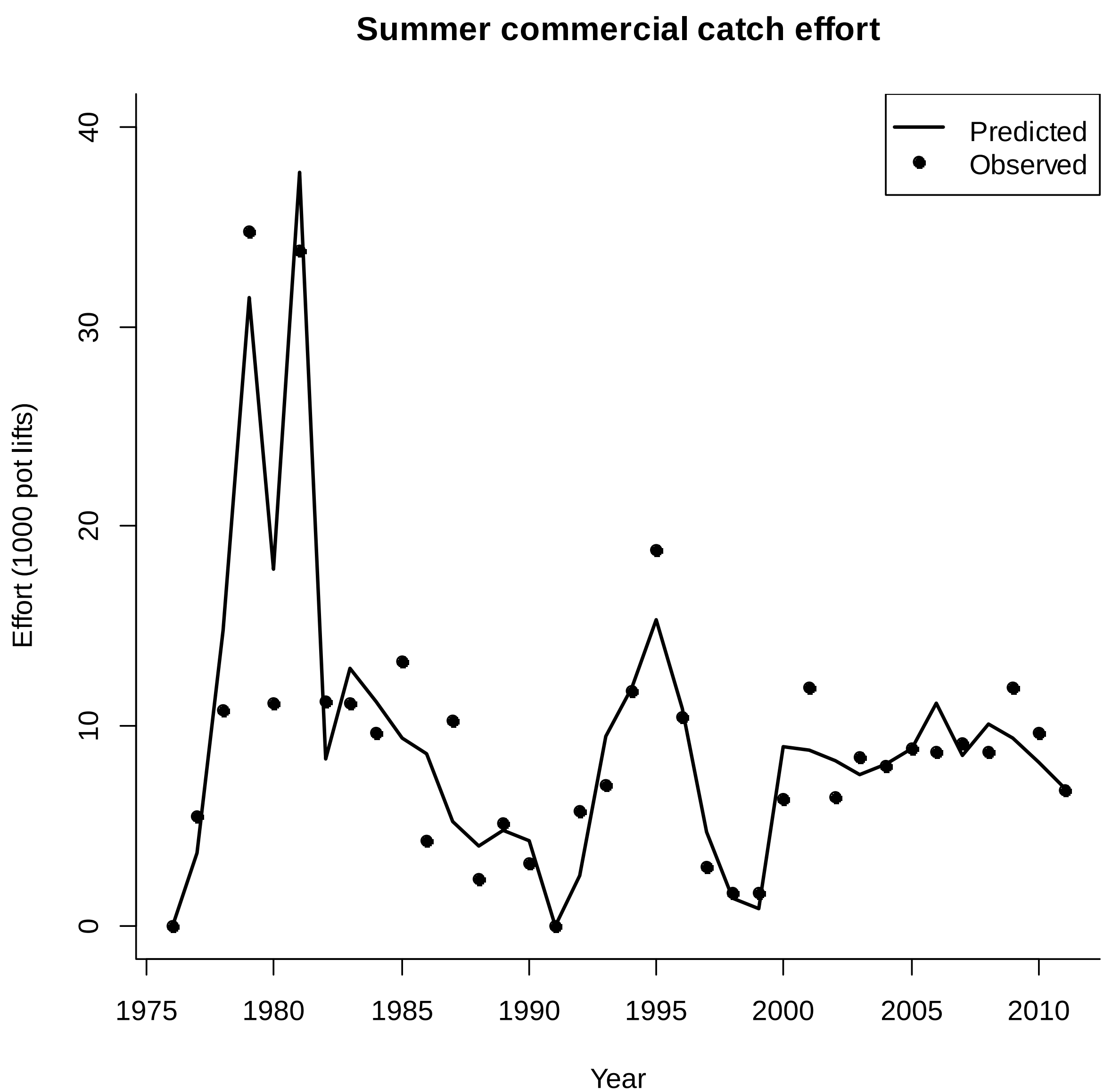



Figure 8. Comparison of observed and estimated summer fishing efforts during 1977-2011.

Model 12

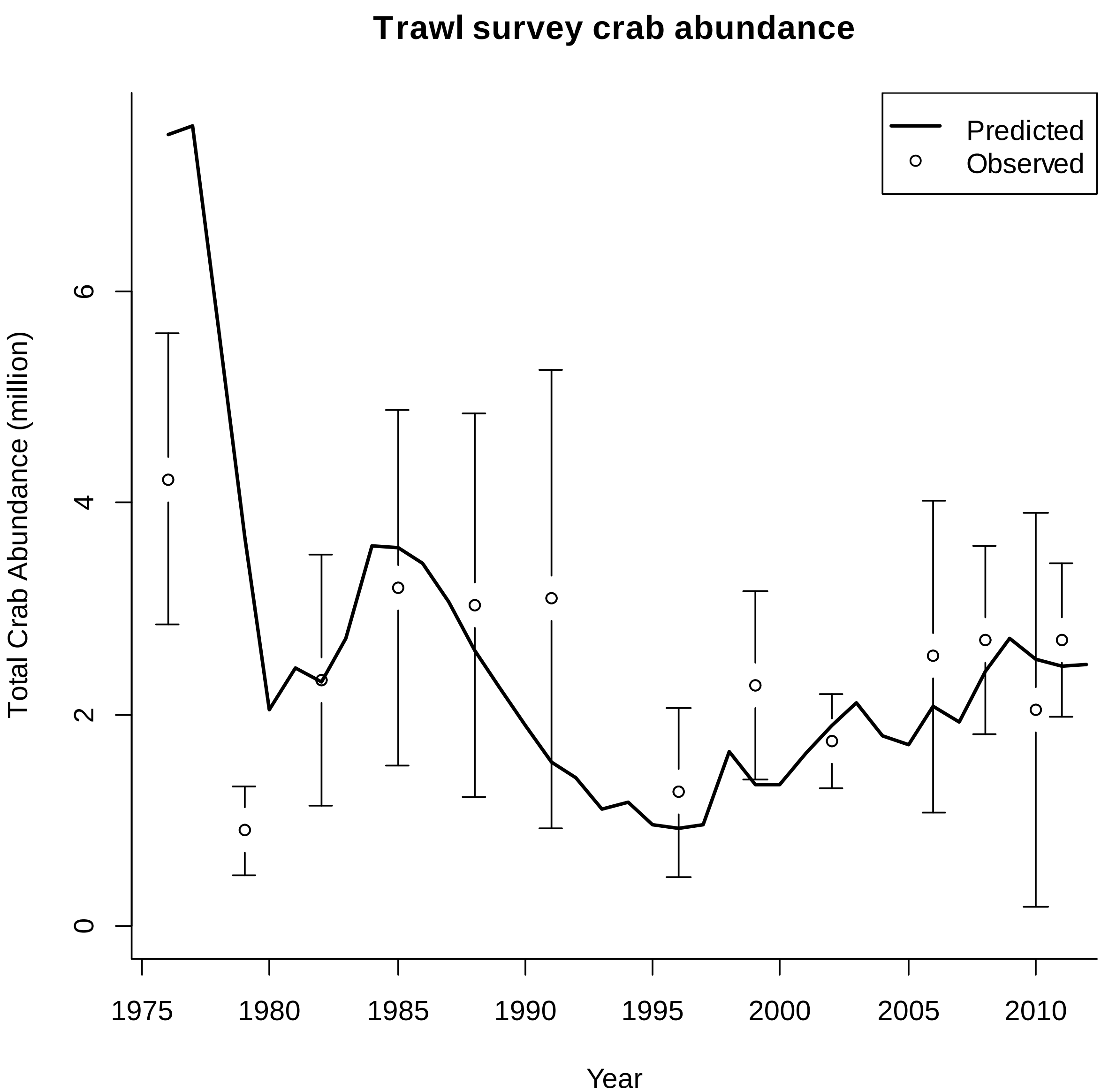



Figure 9. Observed (with 95% C.I. ) and estimated Norton Sound red king crab abundances by summer trawl survey.

Model 12

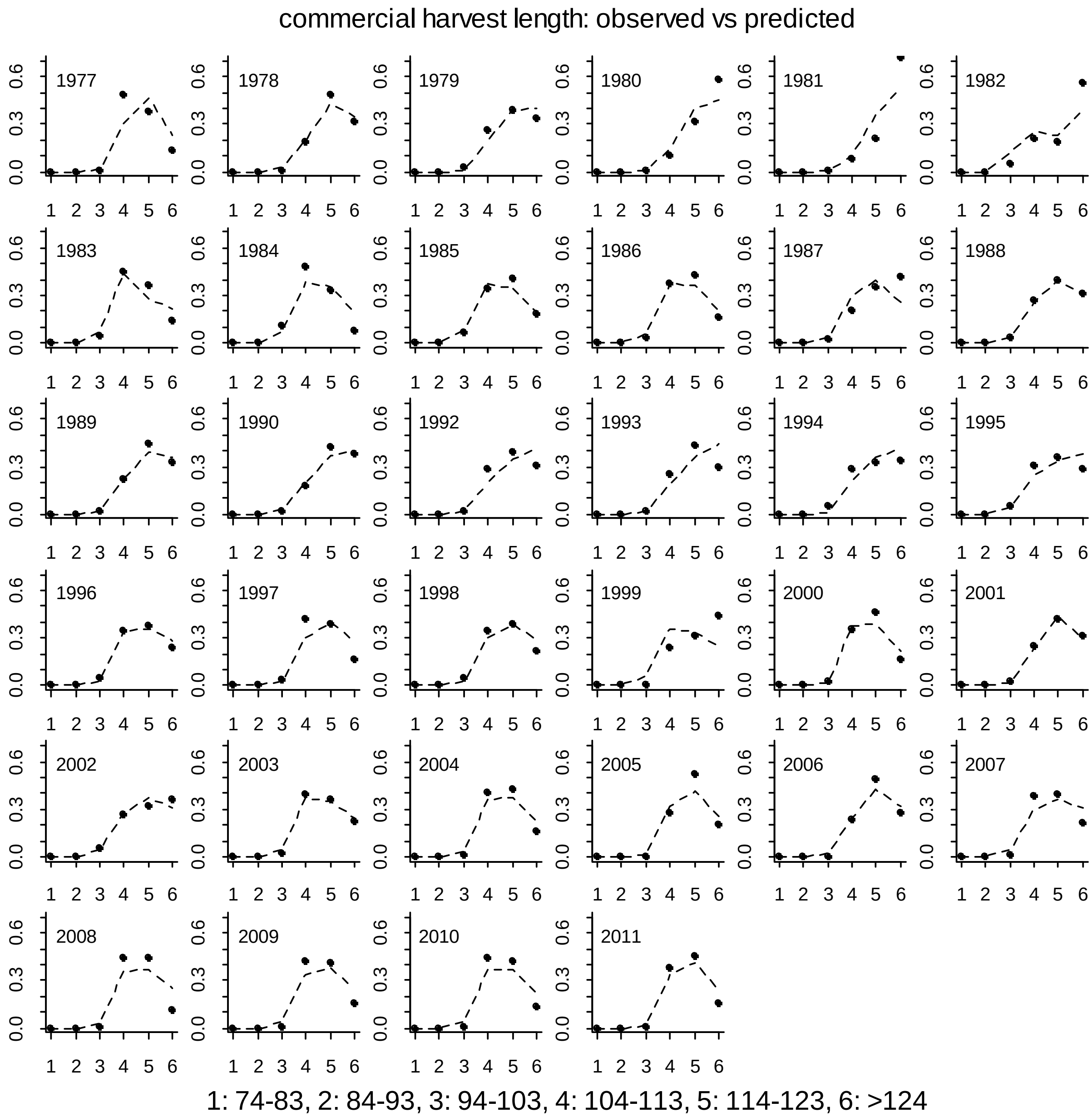
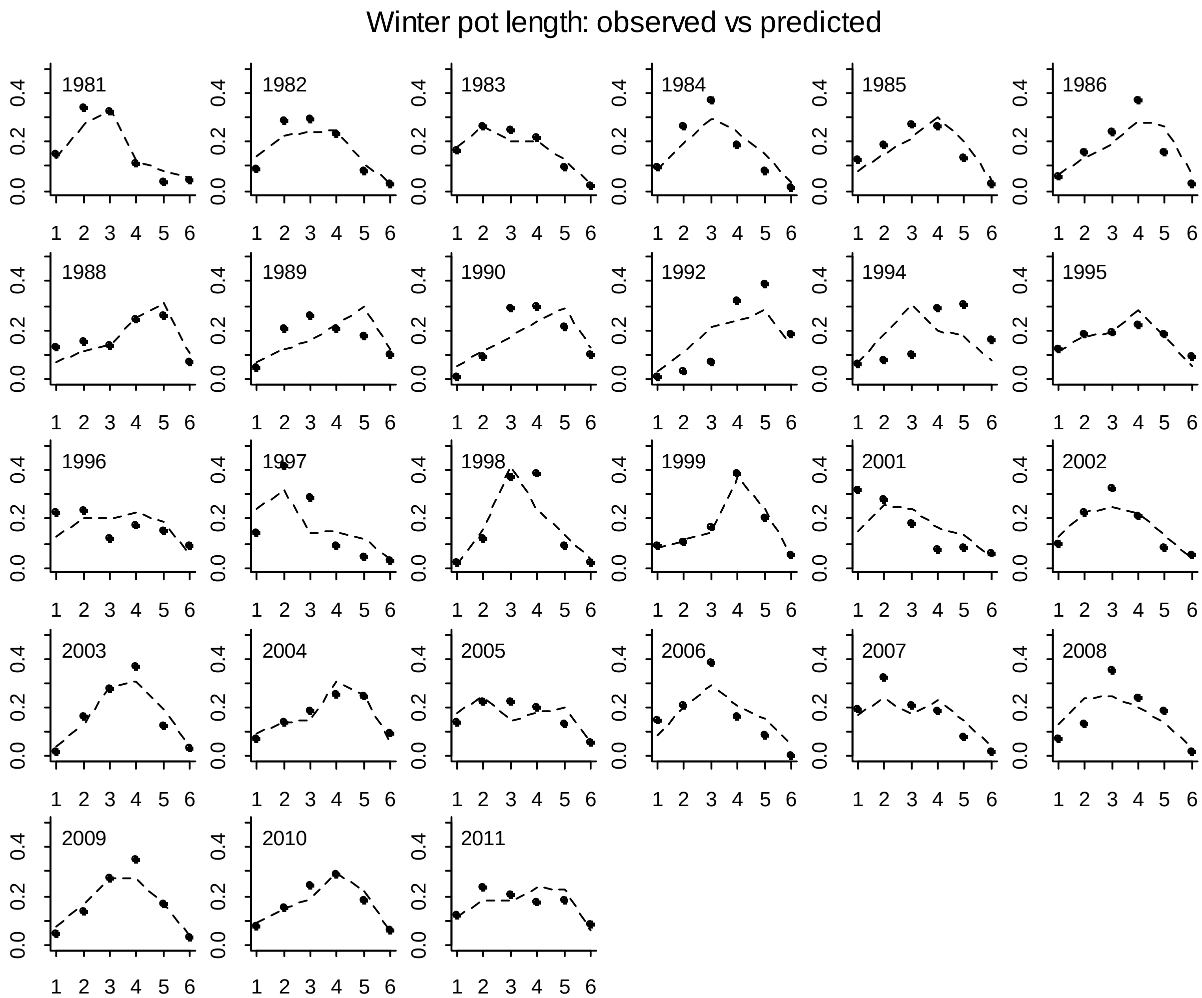



Figure 10. Observed and predicted length composition for summer commercial pot fishery.

Model 12




1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 11. Observed and predicted length composition for winter pot survey.

Model 12

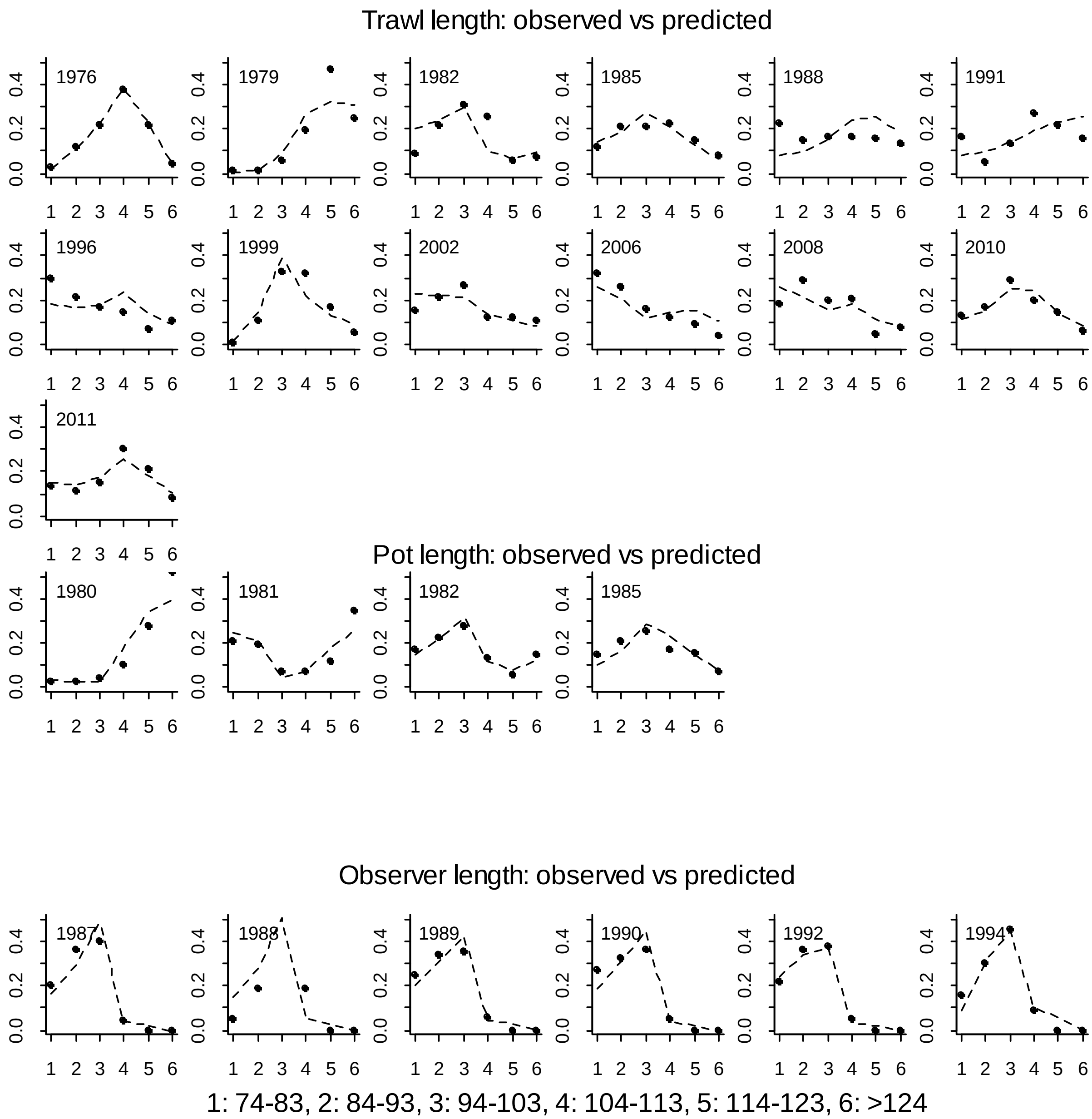



Figure 12. Observed and predicted length composition for summer trawl survey, summer pot, and summer observer surveys.

Model 12

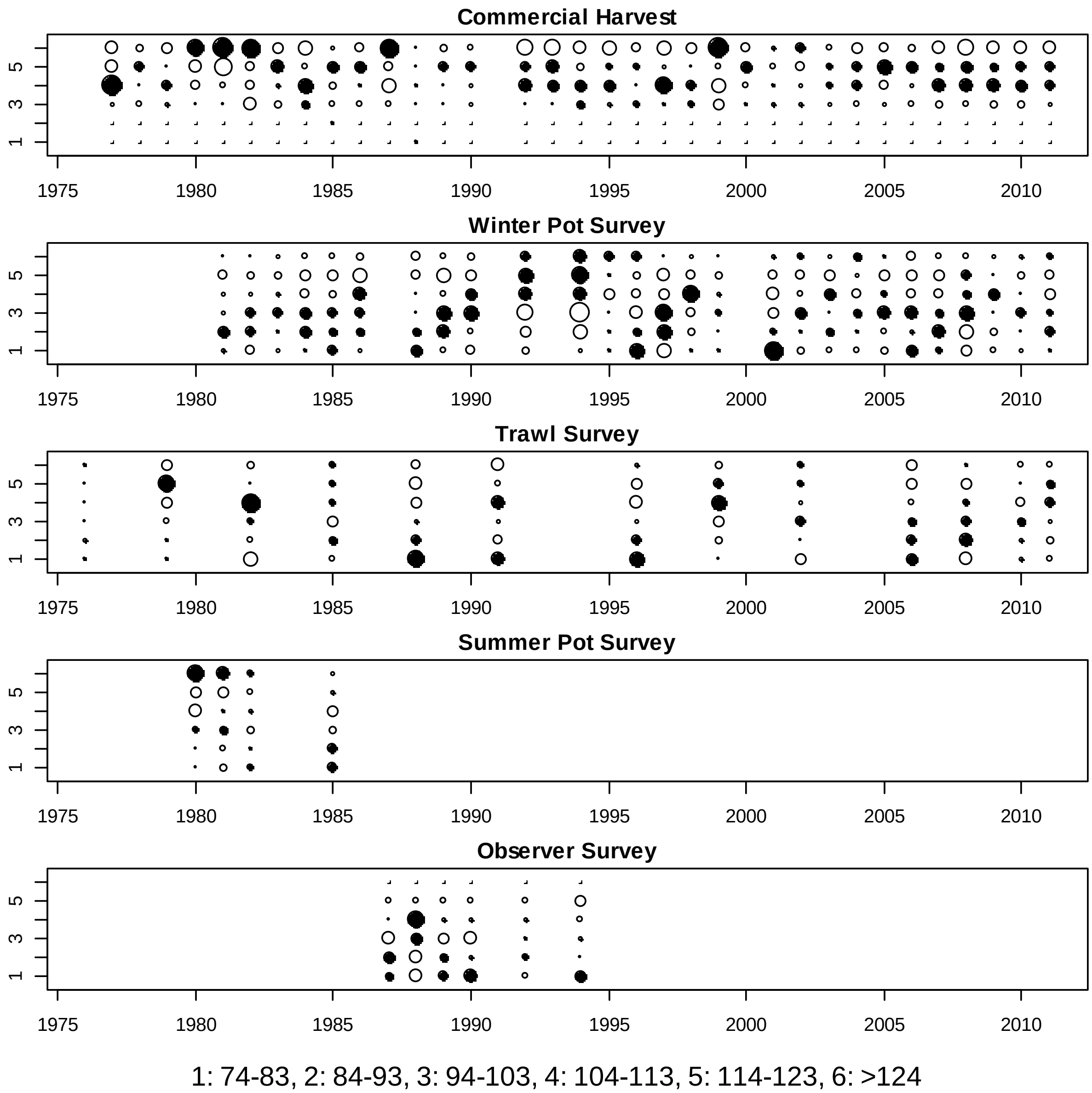



Figure 13. Bubble residual plots of catch length (mm) compositions by year for summer commercial catch, summer trawl, summer pot, and winter pot survey for Norton Sound red king crab. Solid circles are positive residuals (i.e., modeled proportion is lower than observed proportion), and open circles are negative residuals (i.e., modeled proportion is higher than observed proportion). Larger circle indicates larger residuals.

Model 12

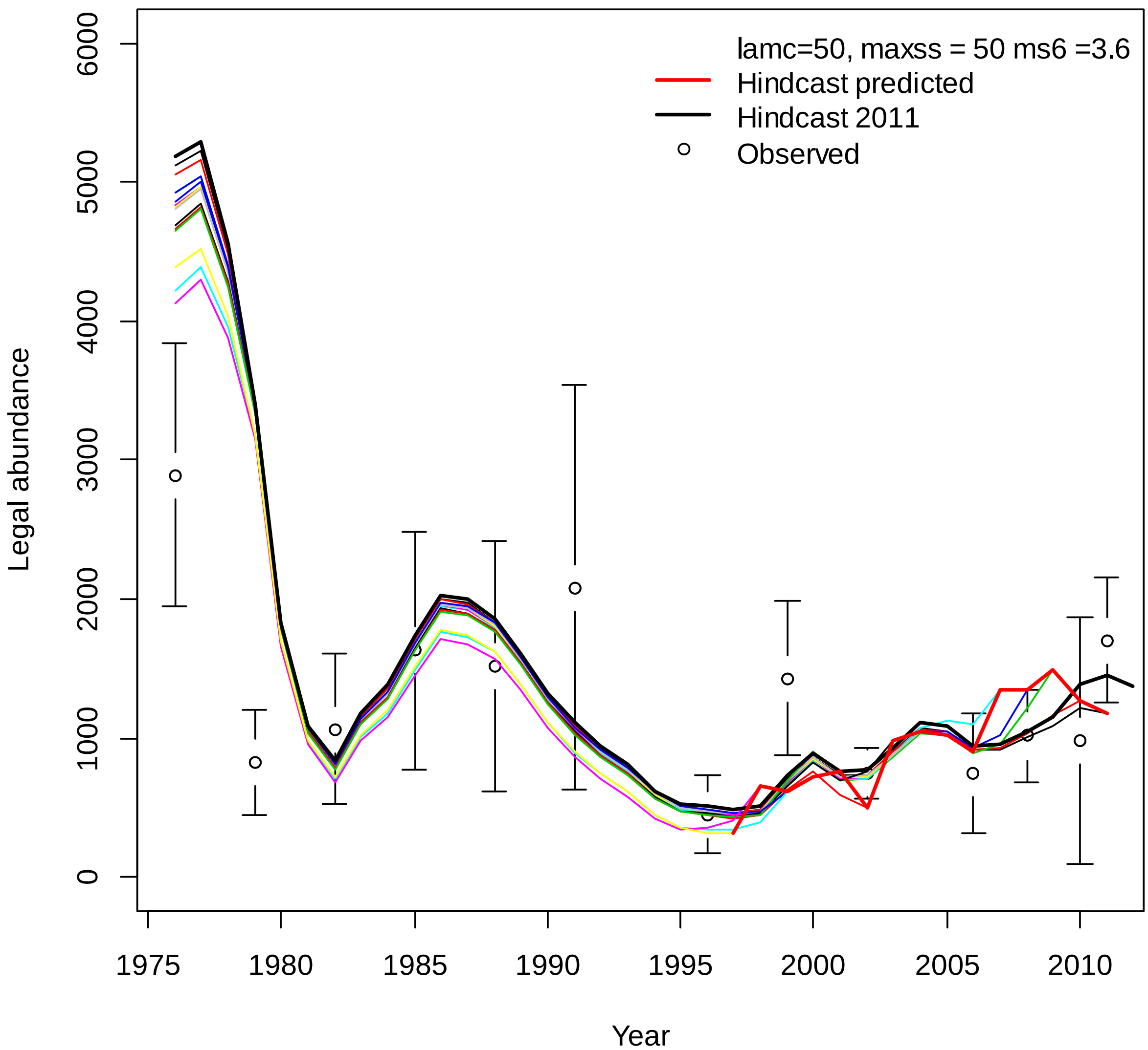



Figure 14. Hindcast model predicted (Red) and retrospect (Black) estimates of legal male abundance of Norton Sound red king crab from 1976 to 2011. Extremely different trajectories for some years are caused by failure of the model converging. When the model estimates and predictions are stable, all lines should be close to each other.

# Appendix A. Description of the Norton Sound Red King Crab Model

## a. Model description.

The model is an extension of the length-based model developed by Zheng et al. (1998) for Norton Sound red king crab. The model has 6 length classes with model parameters estimated by the maximum likelihood method. The model estimates abundances of crabs with CL ≥74 mm and with 10-mm length intervals because few crabs with CL <74 mm were caught during surveys or fisheries and there were relatively small sample sizes for trawl and winter pot surveys. The model was made for newshell and oldshell male crabs separately, but assumed they have the same molting probability and natural mortality.

*Summer crab abundance on July 1st*

Summer crab abundance of the t-th year of the length new and old shell of *l*-th length class before the summer commercial fishery, is the survivors of winter crab from fishery and natural mortality

$$\begin{aligned} \hat{N}_{s,l,t} &= (N_{w,l,t-1} - C_{w,t}\,\hat{P}_{w,n,l,t-1} - C_{p,t-1}\,\hat{P}_{p,n,l,t-1})\,e^{-0.417M_l} \\ O_{s,l,t} &= (O_{w,l,t-1} - C_{w,t}\,\hat{P}_{w,o,l,t-1} - C_{p,t-1}\,\hat{P}_{p,o,l,t-1})\,e^{-0.417M_l} \end{aligned} \qquad (1)$$

where

$N_{s,l,t}$ , $O_{s,l,t}$ : summer abundances of newshell and oldshell crabs in length class $l$ in year $t$
$N_{w,l,t}$, $O_{w,l,t}$ :winter abundances of newshell and oldshell crabs in length class $l$ in year $t$
$C_{w,t}$, $C_{p,t}$ : total winter and subsistence catches in year $t$,
$P_{w,n,l,t}$, $P_{p,n,l,t}$ : Length proportion of winter and subsistence catches for newshell crabs for length class $l$ in year $t$
$P_{w,o,l,t}$, $P_{p,o,l,t}$ : length compositions of winter and subsistence catches for oldshell crabs in length class $l$ in year $t$
$M_l$ : instantaneous natural mortality in length class $l$, constant for all sizes and shell conditions except for the last length class, in which $M$ is 60% higher than the other classes.
0.417 : proportion of the year from Feb. 1 to July 1 is 5 months, or 0.417

*Winter crab abundance on February 1st*

Abundance of newshell crab of the *t*-th year and *l*-th length class ($N_{w,l,t}$ ), is opulation that molted to become *l*-th length class minus *l*-th length class harvested by summer commercial fishery and discards)

the combined result of growth, molting probability, summer commercial harvests, mortality, and recruitment from the summer population:

$$N_{w,l,t} = \sum_{l'=1}^{l'=l} [\, G_{l',l}((N_{s,l',t} + O_{s,l',t})e^{-y_c M_l} - C_{s,t}(\hat{P}_{s,n,l',t} + \hat{P}_{s,o,l',t}) - D_{l',t})\, m_{l'}\, e^{-(0.583-y_c)M_l}\,] + R_{l,t} \qquad (2)$$

Winter abundance of oldshell crabs $O_{s,l,t}$ is the non-molting portion of survivors of crabs from summer:

$$O_{w,l,t} = [\,(N_{s,l,t} + O_{s,l,t})e^{-y_c M_l} - C_{s,t}(\hat{P}_{s,n,l,t} + \hat{P}_{s,o,l,t}) - D_{l,t}\,]\,(1 - m_l)\,e^{-(0.583-y_c)M_l} \qquad (3)$$

where

$G_{l',l}$ : a growth matrix representing the expected proportion of crabs molting from length class $l'$ to length class $l$,
$C_{s,t}$ : total summer catch in year $t$,
$P_{s,n,l,t}$ , $P_{s,o,l,t}$ : Compositions of summer catch for newshell and oldshell crabs in length class $l$ in year $t$,
$D_{l,t}$ : discards of length class $l$ in year $t$,
$m_l$ : molting probability in length class $l$,
$y_c$ : the time in year from July 1 to the mid-point of the summer fishery
0.583: Proportion of the year from July 1 to Feb. 1 is 7 months, or 0.583 year
$R_{l,t}$: recruitment into length class $l$ in year $t$.

*Molting Probability*

Molting probability for length class $l$, $m_l$, was calculated using a reverse logistic function fitted as a function of length and time (Balsiger's 1974)

$$m_l = 1 - \frac{1}{1+e^{-\alpha(i-\beta)}} \tag{4}$$

where
$\alpha$ and $\beta$ are parameters, and $i$ is the mid-length of length class $l$.
$m_l$ was re-scaled such that $m_1 = 1$.

*Discards*

In summer commercial fisheries, sublegal males (<4.75 inch CW or <5.0 inch CW since 2005) are not retained, but are sorted and discarded. Those discarded crabs are subject to handling mortality. Due to lack of data, we assumed discards mortality to be 0.2.

Discards of length class $l$ in year $t$ from the commercial pot fishery were estimated as:

$$D_{l,t} = (N_{s,l,t} + O_{s,l,t})\, S_{s,l}\,(1-L_l)\, hm\, [C_{s,t} / \sum_l (N_{s,l,t} + O_{s,l,t})\, L_l] \tag{5}$$

where

$hm$: handling mortality rate assumed to be 0.2

$L_l$ : the proportion of legal males in length class $l$.
Reflecting the change of commercial acceptable crab size since 2005, proportion of legal males in the length class 4, was calculated as $p_4L_4$. Where $p_4$ is the proportion of commercially acceptable crab among legal crab of the length class 4. $p_4$ was estimated from the model.

$S_{s,l}$ : Selectivity of the summer commercial fishery.

*Selectivities*

Selectivity of length class $l$ for summer commercial fishery ( $S_{s,l}$ ), summer trawl survey ( $S_{st,l}$ ), summer pot survey ($S_{p,l}$), winter pot survey ($S_{w,l}$), were calculated using a logistic function with parameters $\phi$ and $\omega$, where $i$ is the mid-length of the length class $l$.

$$S_l = \frac{1}{1+e^{-\phi(i-\omega)}} \quad (6)$$

For summer commercial fisheries, $S_{s,l}$ was re-scaled such that $S_{s,5} = 1$ and $S_{s,6} \leq 1$. Three sets of parameters ($\phi_1$, $\omega_1$), ($\phi_2$, $\omega_2$), ($\phi_3$, $\omega_3$) were estimated for selectivities: 1) before 1993, and 2) 1933 to 2011 reflecting changes in fisheries, and crab pot configurations.

For winter pot survey and harvest selectivity ($S_{w,l}$), $S_{w,1}$ and $S_{w,2}$ were estimated using the equation (6), $S_{w,3}$ - $S_{w,5}$ were assumed to be 1, and $S_{w,6}$ was directly estimated from the model.

For summer pot survey selectivity ($S_{sp,l}$), $S_{sp,1}$ and $S_{sp,2}$ were estimated using the equation (6), and $S_{sp,3\text{-}6}$ were assumed to be 1.

For summer trawl survey selectivity ($S_{st,l}$), $S_{st,1}$ and $S_{st,2}$ were estimated using the equation (6), and $S_{st,3\text{-}6}$ were assumed to be 1,

*Estimation of Recruitment*

We modeled recruitment of year $t$, $R_t$, as a stochastic process around the mean, $R_0$:

$$R_t = R_0 e^{\tau_t}, \tau_t \sim N(0, \sigma_R^2) \quad (7)$$

$R_t$ was assumed to come from only length classes 1 ($R_{1,t}$) and 2 ($R_{2,t}$), and was calculated as

$$R_{1,t} = r R_t$$
$$R_{2,t} = (1-r) R_t \quad (8)$$

where $r$ is a parameter with a value less than or equal to 1. $R_{l,t} = 0$ when $l \geq 3$.

Estimates of survey abundances

*Summer trawl survey abundance*

Abundance of $t$-th year trawl survey was estimated by subtracting population of July 1st abundance minus summer commercial fisheries harvested by before trawl survey, multiplied by selectivity of trawl.

$$\hat{B}_{st,t} = \sum_l [(N_{s,l,t} + O_{s,l,t}) e^{-y_c M_l} - C_{s,t}(\hat{P}_{s,n,l',t} + \hat{P}_{s,o,l',t}) P_{c,t}] e^{-(y_{st}-y_c)M_l} S_{st,l} \quad (9)$$

Where
$y_{st}$ : the time in year from July 1 to the mid-point of the summer trawl survey.
($y_{st} > y_c$: Trawl survey starts after opening of commercial fisheries)
$P_{c,t}$ : proportion of summer commercial crab harvested by trawl survey before the survey.

*Summer pot survey abundance*

Abundance of $t$-th year pot survey was estimated as

$$\hat{B}_{p,t} = \sum_{l}[(N_{s,l,t} + O_{s,l,t})\, e^{-y_p M_l}]S_{p,l} \tag{10}$$

Where
$y_p$ : the time in year from July 1 to the mid-point of the summer trawl survey.

Estimates of length composition

*Winter commercial catch*

Length compositions of winter commercial catch ($P_{w,n,l,t}$, $P_{w,o,l,t}$) for length $l$ in year $t$ were estimated from the winter population, winter pot selectivity, and proportion of legal crabs for each length class as:

$$\begin{aligned} \hat{P}_{w,n,l,t} &= N_{w,l,t} S_{w,l} L_l / \sum_{l=3}[(N_{w,l,t} + O_{w,l,t})S_{w,l} L_l] \\ \hat{P}_{w,o,l,t} &= O_{w,l,t} S_{w,l} L_l / \sum_{l=3}[(N_{w,l,t} + O_{w,l,t})S_{w,l} L_l] \end{aligned} \tag{11}$$

Where $S_{wo}$, is an extra selectivity multiplier for old shell crabs.

*Winter subsistence catch*

Subsistence fishery does not have a size limit; however, crabs of size smaller than length class 3 are generally not retained. Hence, we assumed proportion of length composition $l$ = 1 and 2 as 0, and estimated length compositions ($l \geq 3$) as follows

$$\begin{aligned} \hat{P}_{p,n,l,t} &= N_{w,l,t} S_{w,l} / \sum_{l=3}[(N_{w,l,t} + O_{w,l,t})S_{w,l}] \\ \hat{P}_{p,o,l,t} &= O_{w,l,t} S_{w,l} / \sum_{l=3}[(N_{w,l,t} + O_{w,l,t})S_{w,l}] \end{aligned} \tag{12}$$

*Winter pot survey*

The above equations were also used to calculate length compositions of winter pot survey for newshell and oldshell crabs, $P_{sw,n,l,t}$ and $P_{sw,o,l,t}$ ($l \geq 1$).

$$\begin{aligned} \hat{P}_{sw,n,l,t} &= N_{w,l,t} S_{w,l} / \sum_{l}[(N_{w,l,t} + O_{w,l,t})S_{w,l}] \\ \hat{P}_{sw,o,l,t} &= O_{w,l,t} S_{w,l} / \sum_{l}[(N_{w,l,t} + O_{w,l,t})S_{w,l}] \end{aligned} \tag{13}$$

*Summer commercial catch*

Length compositions of the summer commercial catch for new and old shell crabs $P_{s,n,l,t}$ and $P_{s,o,l,t}$, were calculated based on summer population, selectivity, and legal abundance;

$$\hat{P}_{s,n,l,t} = N_{s,l,t} S_{s,l} L_l / A_t$$
$$\hat{P}_{s,o,l,t} = O_{s,l,t} S_{s,l} L_l / A_t \tag{14}$$

Where $A_t$ is exploitable legal abundance in year $t$, estimated as

$$A_t = \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{s,l} L_l] \tag{15}$$

*Observer discards*

Length/shell compositions of Observer discards in 87-90, 92, 94 were estimated as

$$\hat{P}_{b,n,l,t} = N_{s,l,t} S_{s,l}(1-L_l) / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{s,l}(1-L_l)]$$
$$\hat{P}_{b,o,l,t} = O_{s,l,t} S_{s,l}(1-L_l) / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{s,l}(1-L_l)] \tag{16}$$

*Summer pre-season survey (1976)*

The same selectivity for the summer commercial fishery was applied to the summer pre-season survey, resulting in estimated length compositions for both newshell and oldshell crabs as:

$$\hat{P}_{sf,n,l,t} = N_{s,l,t} S_{s,l} / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{s,l}]$$
$$\hat{P}_{sf,o,l,t} = O_{s,l,t} S_{s,l} / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{s,l}] \tag{17}$$

*Summer pot survey (1980-82, 85)*

The length/shell condition compositions of summer pot survey were estimated as

$$\hat{P}_{sp,n,l,t} = N_{s,l,t} S_{sp,l} / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{sp,l}]$$
$$\hat{P}_{sp,o,l,t} = O_{s,l,t} S_{sp,l} / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{sp,l}] \tag{18}$$

*Summer trawl survey*

Some trawl surveys occurred during the molting period, and thus we combined the length compositions of newshell and oldshell crabs as one single shell condition, $P_{st,l,t}$, and were estimated as

$$\hat{P}_{st,,l,t} = N_{s,l,t} S_{st,l} / \sum_l [(N_{s,l,t} + O_{s,l,t}) S_{st,l}] \tag{19}$$

Estimation of summer commercial fishing effort

Summer commercial fishing effort ($f_t$), the number of pot-lifts, was calculated as total summer catch, $C_t$, divided by the product of catchability coefficient $q$ and mean exploitable abundance:

$$\hat{f}_t = C_t / [q_i(A_t - 0.5C_t)] \tag{20}$$

Because fishing fleet and pot limit configuration changed in 1993 and 2008, $q_1$ is for fishing efforts before 1993, $q_2$ is from 1994 to present.

**b. Software used**: AD Model Builder (Otter Research Ltd. 1994).

**c. Likelihood components.**

Under assumptions that measurement errors of annual total survey abundances and summer commercial fishing efforts follow lognormal distributions and each type of length composition has a multinomial error structure (Fournier and Archibald 1982; Methot 1989), the log-likelihood function is:

$$\sum_{i=1}^{i=5}\sum_{t=1}^{t=n_i}\{K_{i,t}\sum_{l=1}^{l=6}[P_{i,l,t}\, ln(\hat{P}_{i,l,t}+\kappa)]\} - \sum_{t=1}^{t=n_i}[ln(\hat{B}_{i,t}+\kappa) - ln(B_{i,t}+\kappa)]^2/(2*ln(CV_{i,t}^2+1))$$
$$-W_f\sum_{t=1}[ln(\hat{f}_t+\kappa) - ln(f_t+\kappa)]^2 - W_R\sum_{t=1}\tau_t^2 \tag{21}$$

1where

$i$: length/shell compositions of :

1 triennial summer trawl survey
2 summer pot survey (1980-82, 85)
3 annual winter pot survey
4 summer commercial fishery
5 observer bycatch during the summer fishery

$n_i$: the number of years in which data set $i$ is available
$K_{i,t}$: the effective sample size of length/shell compositions for data set $i$ in year $t$
$P_{i,l,t}$ : observed and estimated length compositions for data set $i$, length class $l$, and year $t$

In this, while observation and estimation were made for oldshell and newshell separately, both were combined for likelihood calculations.

$\kappa$ : a constant equal to 0.001
$CV$ : coefficient of variation for the survey abundance. CV for summer pot survey was assumed 0.34
$B_{i,k,t}$: observed and estimated annual total abundances for data set $i$ and year $t$
$W_f$ : the weighting factor of the summer fishing effort
$f_t$ : observed and estimated summer fishing efforts
$W_R$ : the weighting factor of recruitment.

It is generally believed that total annual commercial crab catches in Alaska are fairly accurately reported. Thus, no measurement error was imposed on total annual catch. Variances for total survey abundances and summer fishing effort were not estimated; rather, we used weighting factors to reflect these variances.

**d. Population state in year 1.**

Length and shell compositions from the first year (1976) summer trawl survey data approximated the true relative compositions.

**e. Parameter estimation framework:**

i. Parameters Estimated Independently

The following parameters were estimated independently: natural mortality ($M$ =0.18), proportions of legal males by length group, and the growth matrix.

Natural mortality was based on an assumed maximum age, $t_{max}$, and the 1% rule (Zheng 2005):

$$M = -\ln(p) / t_{\max} , \qquad (19)$$

where $p$ is the proportion of animals that reach the maximum age and is assumed to be 0.01 for the 1% rule (Shepherd and Breen 1992, Clarke et al. 2003). The maximum age of 25, which was used to estimate $M$ for U.S. federal overfishing limits for red king crab stocks (NPFMC 2007) results in an estimated $M$ of 0.18. Among the 199 recovered crabs from the tagging returns during 1991-2007 in Norton Sound, the longest time at liberty was 6 years and 4 months from a crab tagged at 85 mm CL. The crab was below the mature size and was likely less than 6 years old when tagged. Therefore, the maximum age from tagging data is about 12, which does not support the maximum age of 25 chosen by the CPT.

Proportions of legal males (CW > 4.75 inches) by length group were estimated from the ADF&G trawl data 1996-2011 (Table 8).

Mean growth increment per molt, standard deviation for each pre-molt length class, and the growth matrix (Table 8), were estimated from tagging surveys conducted in summer 1981-1985, and winter 1981-present. In summer 1981-1985 study legal and sublegal males captured by the survey pots were tagged, and in the1981-present winter survey, sublegal males were tagged. All tagged crabs were recaptured by summer and winter commercial/subsistence fisheries.

ii. Parameters Estimated Conditionally

Estimated parameters are listed in Table 5. Selectivity and molting probabilities based on these estimated parameters are summarized in Table 4 (also in the primary document).

A likelihood approach was used to estimate parameters, which include fishing catchability, parameters for selectivities of survey and fishing gears and for molting probabilities, recruits each year (except the first and the last years), and total abundance in the first year (Table 5).

Crabs usually aggregate, and this increases the uncertainty in survey estimates of abundance. To reduce the effect of aggregation, annual total sample sizes for summer trawl and pot survey data sets were reduced to 50% and all other sample sizes were reduced to 10%. Also, annual effective sample sizes were capped at 200 for summer trawl and pot surveys and 100 for the other data to avoid overweighting the data with a large sample size (Fournier and Archibald 1982). Weighting factors represent prior assumptions about the accuracy or the variances of the observed data or random variables. $W_f$ was set to be 20, and $W_R$ was set to be 0.01. According to the fishery manager, the estimate of fishing effort in 1992 was not as reliable as in the other years (C. Lean, ADF&G, personal communication). Thus, we weighted the effort in 1992 half as much as in the other years. $W_f$ and maximum effective sample size was investigated.

To reduce the number of parameters, we assumed that length and shell compositions from the first year (1976) summer trawl survey data approximated the true relative compositions. Abundances by length and shell condition in all other years were computed recursively from abundances by length and shell condition in the first year and by annual recruitment, catch, and model parameters. Initial parameter estimates were an educated guess based on observation and current knowledge.

**f. Definition of model outputs.**

i. Mature Male Biomass (MMB): defined as those 94 mm carapace length and above (size classes 3 to 6). The mean weights for size classes 1-6 are 0.854, 1.210, 1.652, 2.187, 2.825 and 3.697 lbs.

ii. Projected Legal Male Biomass for OFL calculation: defined as the number of crab on July 1st 2012 of size class greater than 94mm ($N_{sl}$+$O_{sl}$), multiplied by commercial pot selectivity($S_{sl}$), proportion of legal crab ($L_l$), and mean weight lb ($w_{ml}$)

$$Legal\_B = \sum_l (N_{s,l,} + O_{s,l,}) S_{s,l} L_l wm_l$$

iii. Recruitment: the number of males in the 1st two length classes.

iv. Fishing mortality: applied as an annual exploitation rate to the legal segment of the stock per equations 2 and 3 (above), including bycatch mortality according to equation 4 (above).

# Appendix B: Sensitivity Analyses of Model Assumptions.

The model has several assumptions:

1. M for the length class 6 is 1.6 (ms6 = 1.6) times higher
2. Weight for commercial catch efforts (lamc) is 20.
3. The maximum sample size for length classes (maxss) is 200
4. Instantaneous natural mortality *M* is 0.18 for all length class, except for the last length group (> 123mm). M is constant over time.

The assumption of 1 was not fully based on biological facts, but are efforts to improve model fits. The parameter values were selected without detailed diagnoses. Hence, we chose those for further analyses.

The assumptions 2 and 3: Selections of weights are to some extent arbitrary, based on authors' beliefs on which datasets are more reliable than others. In this round, we chose to examine commercial catch efforts (lamc) and the maximum sample size for length classes (maxss). In the Norton Sound red king crab assessment, abundance survey is conducted triennially, so that model projection is heavily relied upon commercial catch and length size compositions. Reliability of those data are unknown.

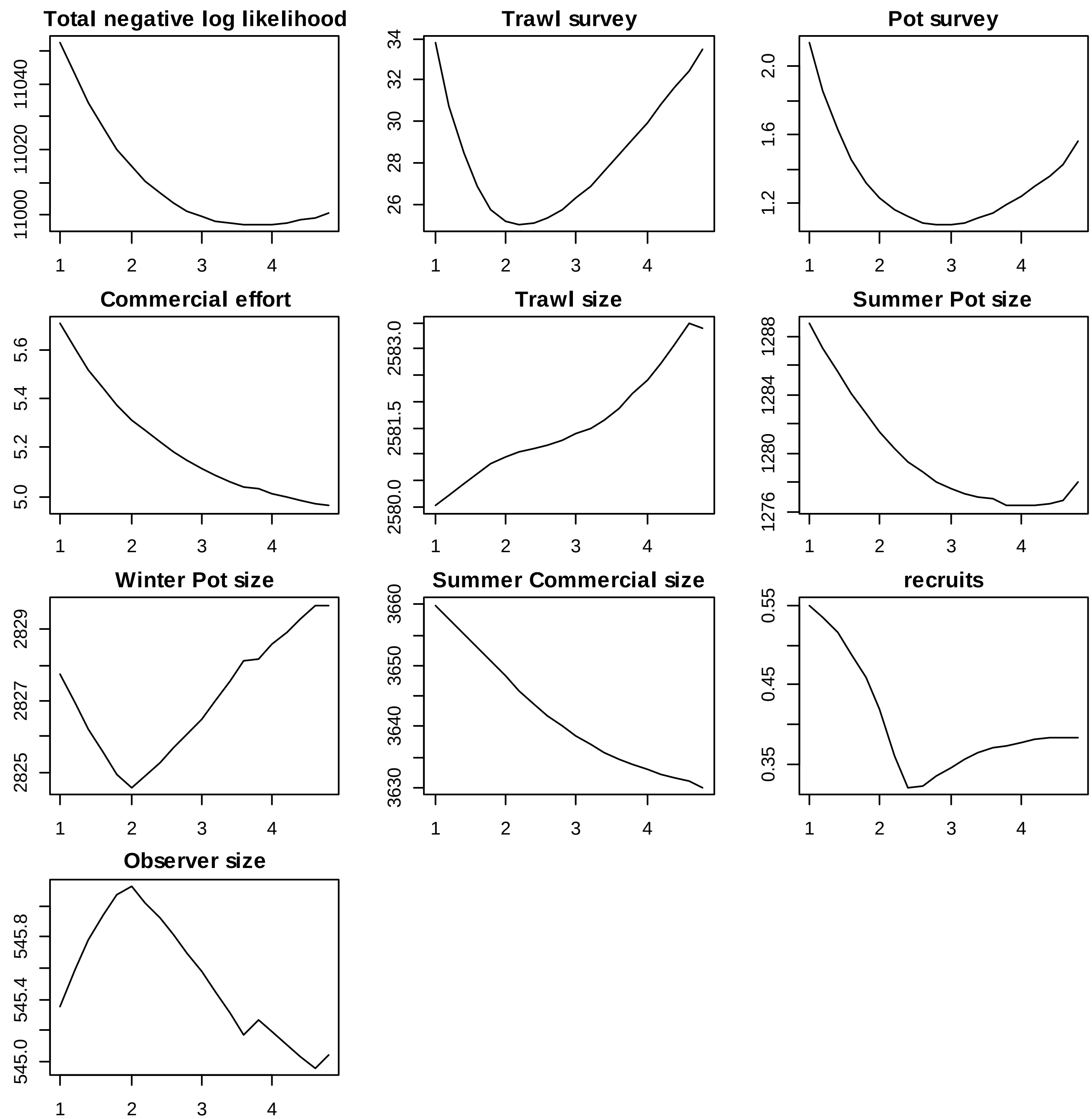
The assumption 4 is default value adopted by the CPT; however, no data exist on appropriateness of this value for NSRKC. Adoption of M=0.18 also lead to an inclusion of the assumptions of 1 (higher mortality for the length class 6). Hence, we evaluated appropriateness of the M=0.18 assumption in two ways: 1) change M with assumptions 1 (i.e., ms6 =1.6), and 2) change M without assumptions 1 and 2 (i.e., ms6 =1).

In this section, we conducted sensitivity analyses of the above factors. We examined change of total and individual likelihood component associated with changing of values of the assumed parameters.

**Note:**
In conducting this analyses, likelihood of some components became extremely high or extremely low. This is primarily caused by model failing to converge and can be fixed by changing initial value, parameter search bounds. However, because this analysis was more focused on searching more likely parameter values for choice of alternative model configurations, no attempts were made to correct this convergence issue.

### B1. Sensitivity analyses on ms6

The ms6 parameters was included to explain the low proportion the last length class. The ms6 assumes high mortality of the length class, whereas slt6 assumes that they are not observed from trawl survey. By setting slt6 = 1.0, we re-evaluated possible range of ms6. At the reasonable range of 1.0 to 5.0 (M6 = 0.18 – 0.8), total negative likelihood became stable at ms6 = 3.6-4.0. Likelihood of trawl and pot survey, winter pot size, and recruits seemed to reach minimum at 2.0-2.2 range. From this, ms6 = 3.6 was selected for further analyses.



### B3. Changing commercial catch effort: lamc

Currently, the default commercial catch effort is 20. We examined sensitivities of the weight by changing weight from 10 to 200. As expected, likelihood of commercial catch effort kept dropping. While likelihoods are minimalized at weight 20-30 for trawl and pot survey, likelihood of recruits was minimized at weight120. From this, we chose lamc =50 and100 for further diagnoses.

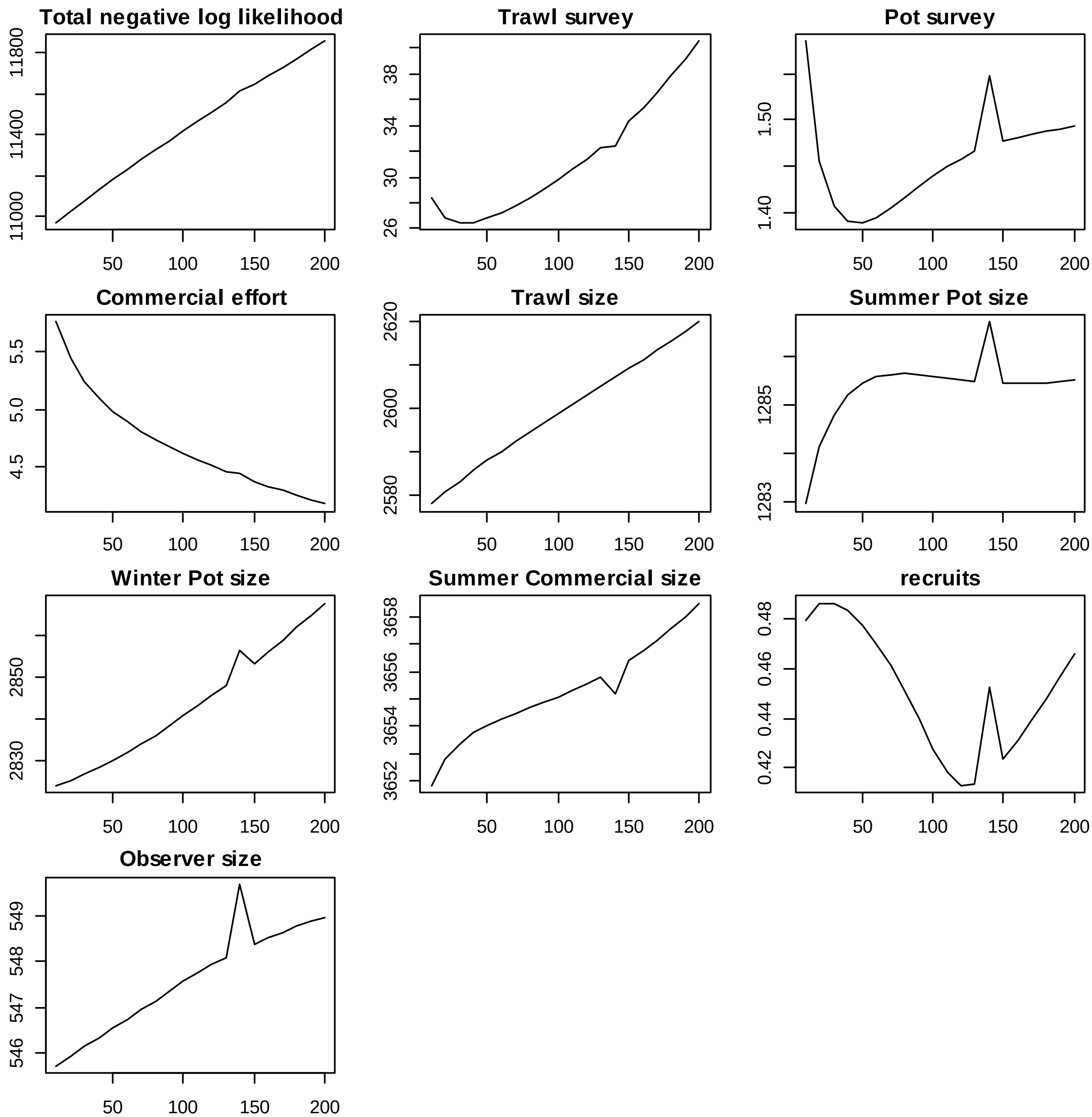



Figure B3: commercial trawl weight sensitivity changed from 10 to 200 (x-axis) and corresponding likelihood components.

## B4. Changing size sample weight: maxss

Currently, the default maximum sample size was set 200. We examined effects of sample size on total likelihood. The results suggests that lowering maxss would improve the model fit. The model failed to converge well on maxss = 60, As such, we examined maxss = 100, maxss =50, and maxss = 10.

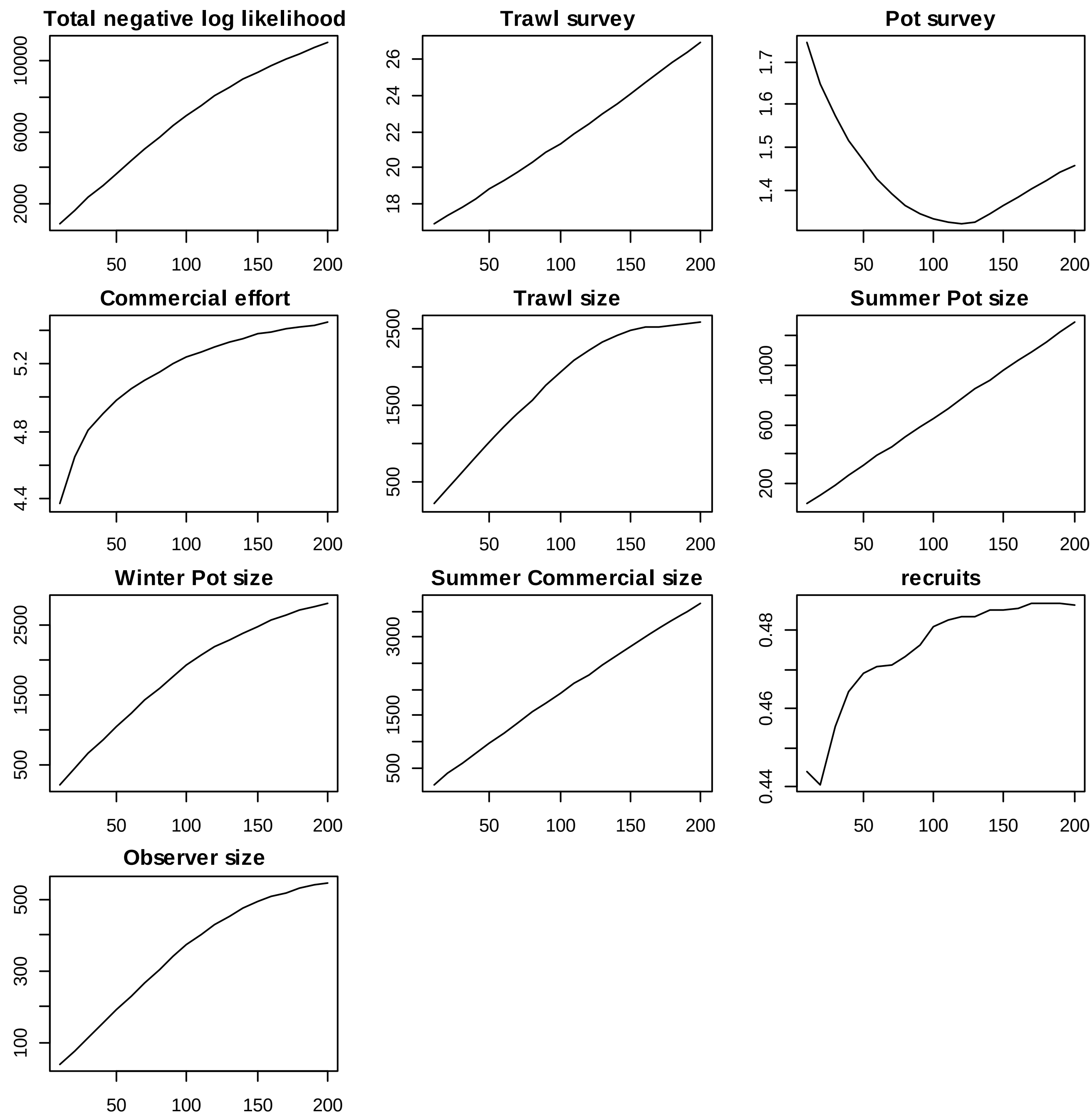



Figure B4: weight sensitivity changed from 10 to 200 (x-axis) and corresponding likelihood components.

## B5. Sensitivity analyses of M with ms6 = 1.6

In the reasonable range of M 0.1 – 0.6, total likelihood was minimized at M = 0.32, compared to the baseline M = 0.18. For individual likelihood component, trawl survey, pot survey, and recruits likelihoods were minimized at M=0.2-0.26. On the other hand, summer pot, winter pot, and summer commercial size likelihoods were minimized at M=0.3-0.4 range. From this, M = 0.32 was selected for further analyses.

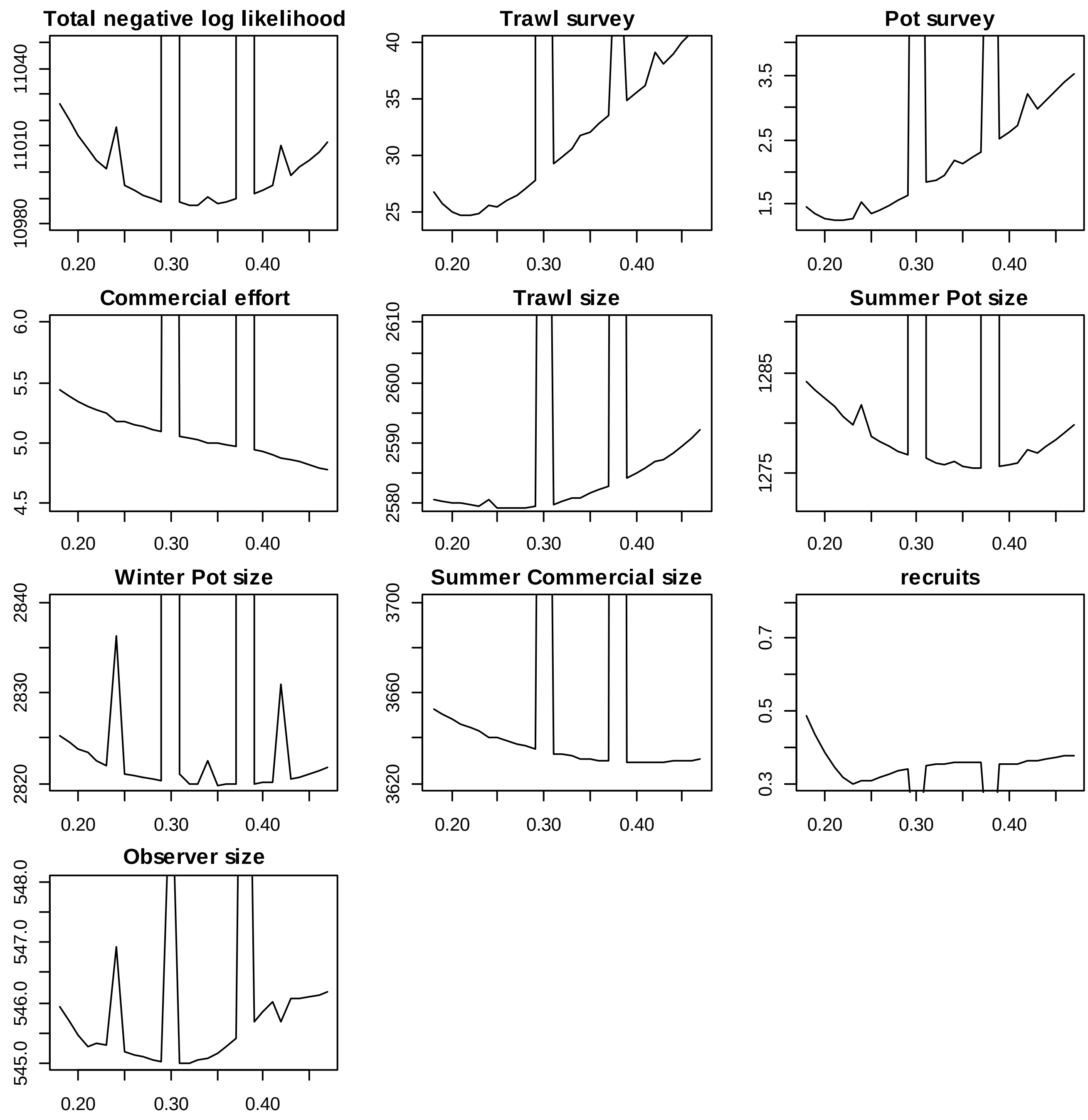



Figure B5. Likelihood profile for M changing from 0.03 to 0.6

**B6. Sensitivity analysis for M, ms6 =1**

The assumptions of high mortality and low trawl selectivity of the length class 6 (ms6, slt6) was intended to improve the model fit under the assumption of M= 0.18. In this sensitivity analysis, we set ms6 and slt6 to 1.0, and examined the effects of changing M. In the reasonable range of M 0.1 – 0.5, total likelihood was minimized at M = 0.4. For individual likelihood component, trawl survey, pot survey, and recruits likelihoods were minimized at M=0.2-0.26. We chose M=0.4 for further analyses.

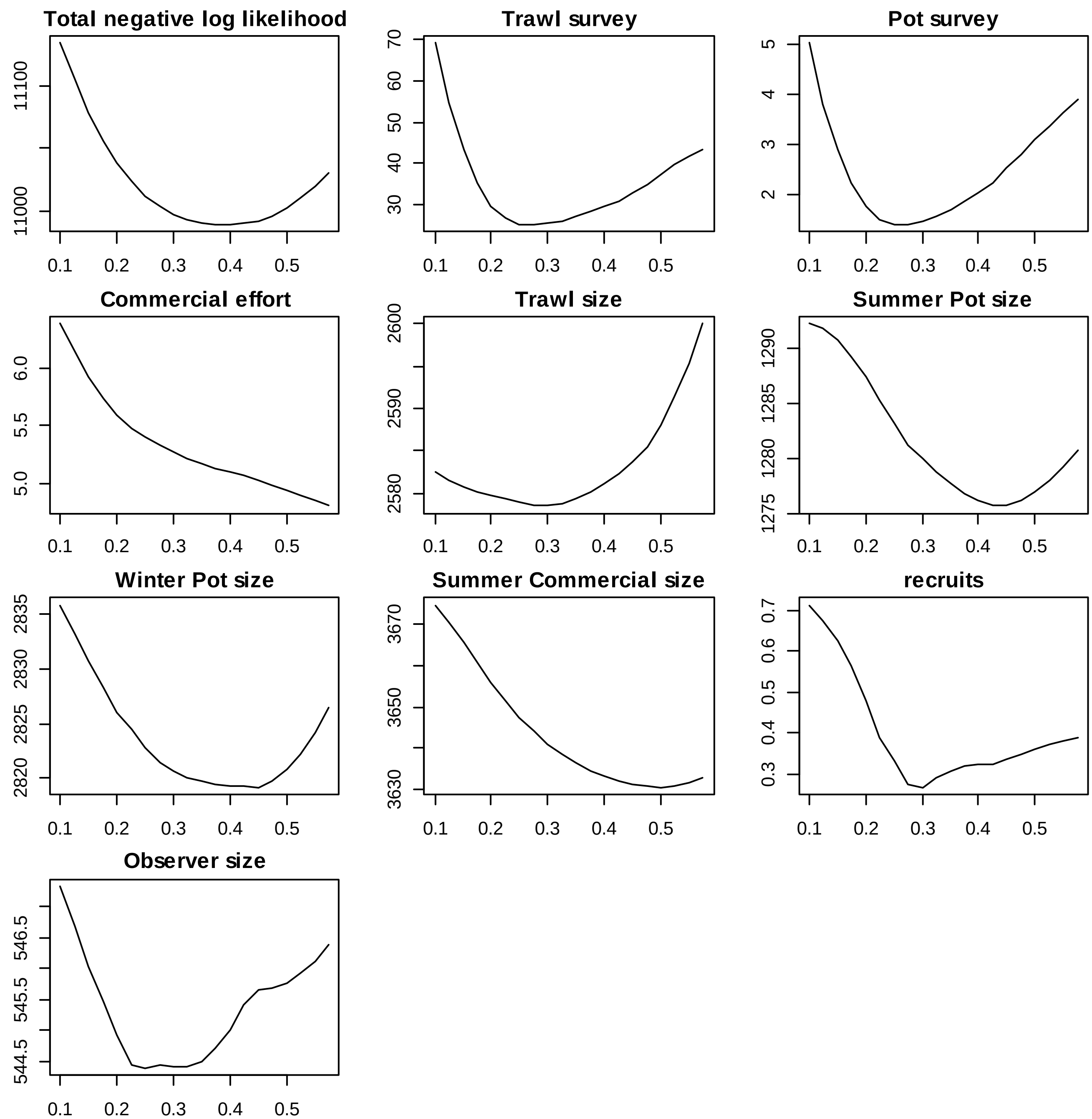


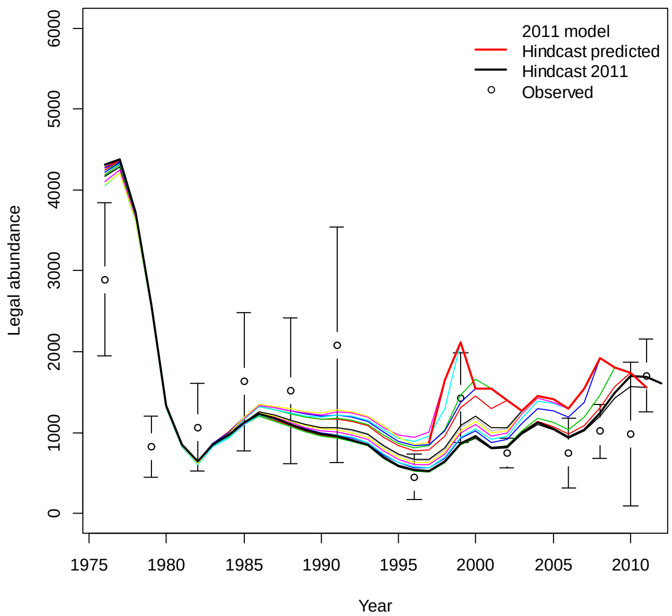

Figure B6: weight sensitivity M changed 0.1 to 0.5 (x-axis) and corresponding likelihood components, slt6 = ms6 = 1.

Appendix C: Retrospective analyses various model configurations.

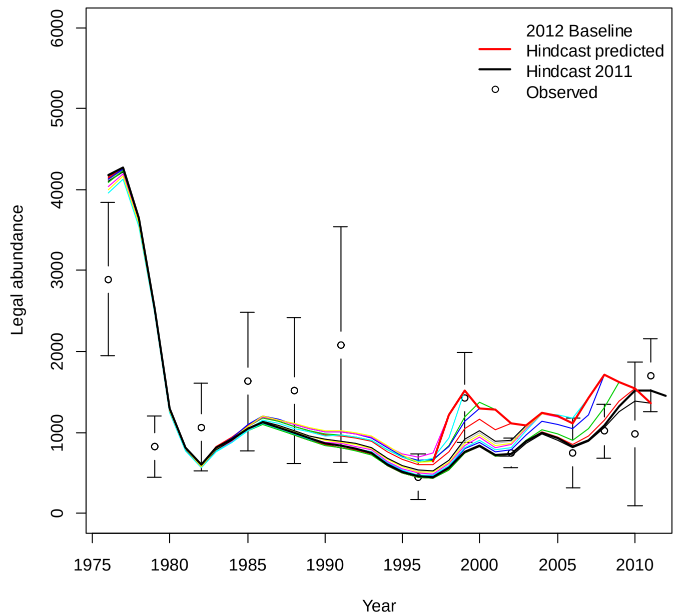
See Model selection and evaluation section for details of alternative models.

**Note:**

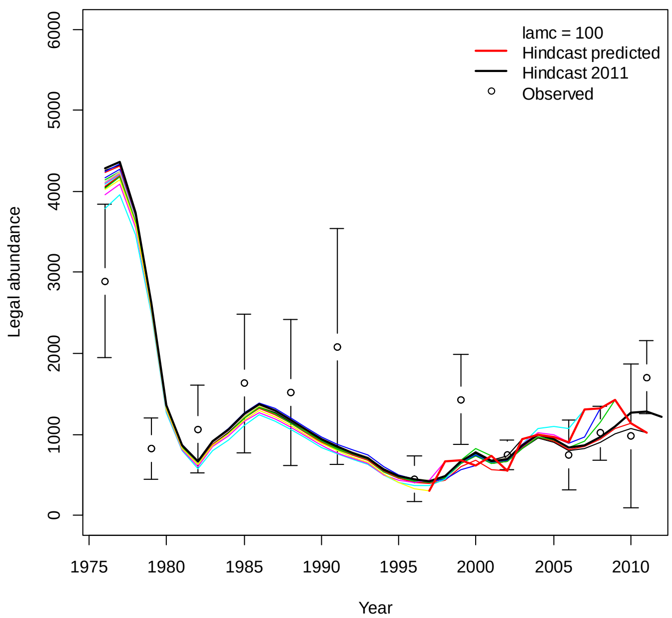
In conducting this analyses, trajectory of some years became extremely different from other years. This is primarily caused by model failing to converge and can be fixed by changing initial value, parameter search bounds. However, because this analysis was more focused on searching more likely parameter values for choice of alternative model configurations, no attempts were made to correct this convergence issue.



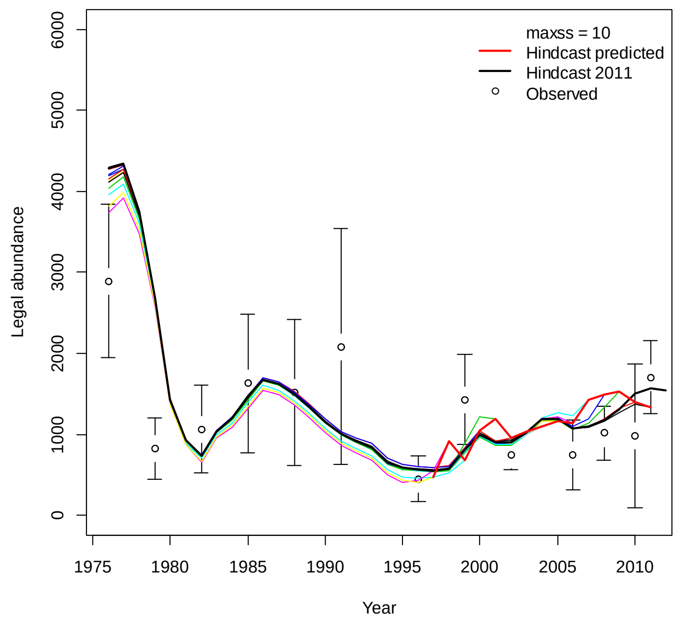

Model 0: 2011 Model



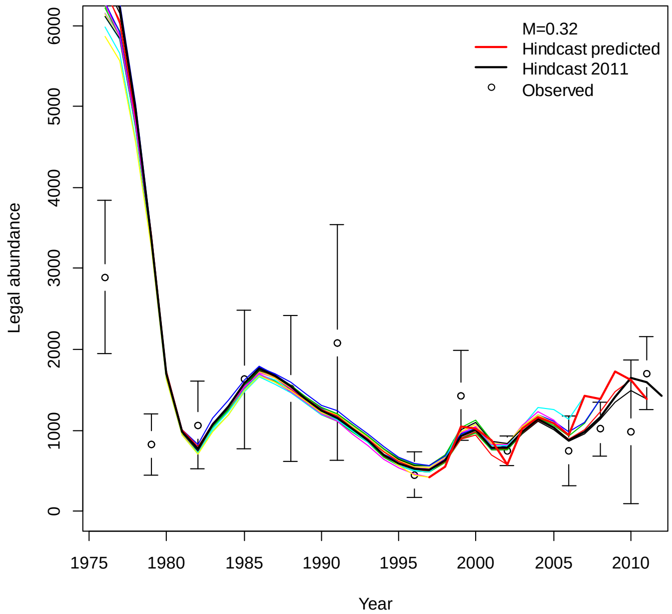

Model 1: 2012 Baseline Model



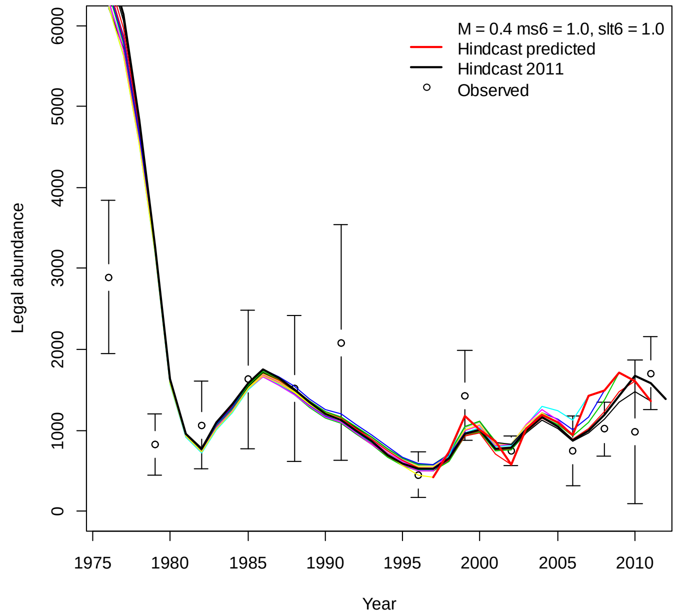

Model 4: Model 1+ lamc = 100



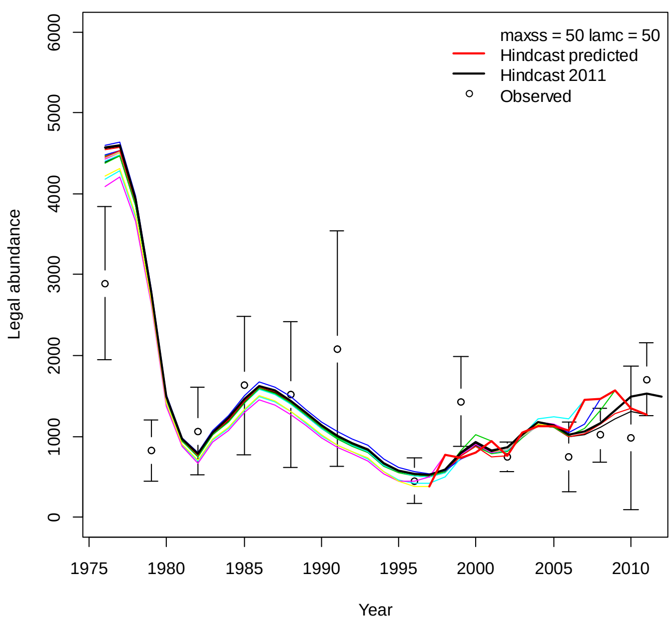

Model 7: Model 1+ maxss = 10



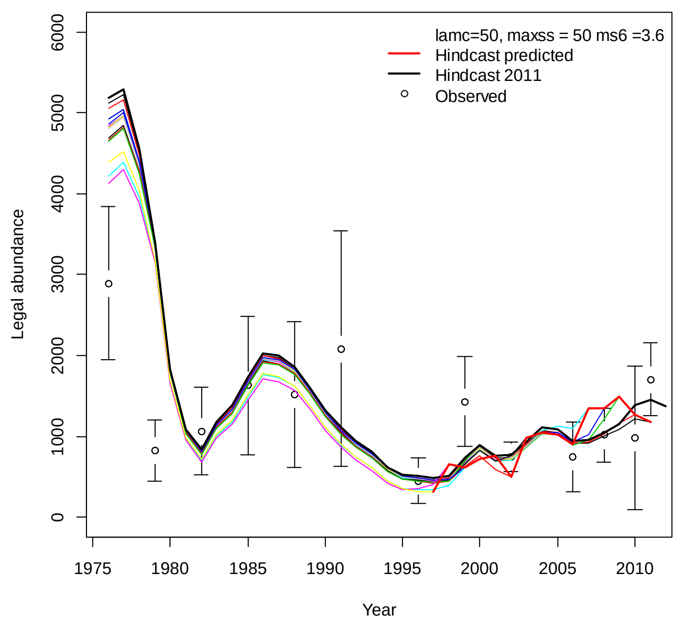

Model 8: Model 1+ M = 0.32



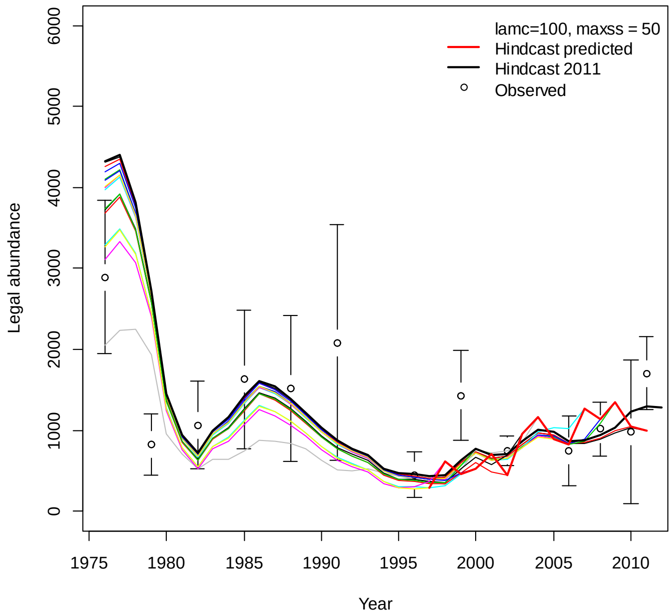

Model 10: Model 1 + M=0.4, ms6 = 1.0, slt6 = 1.0



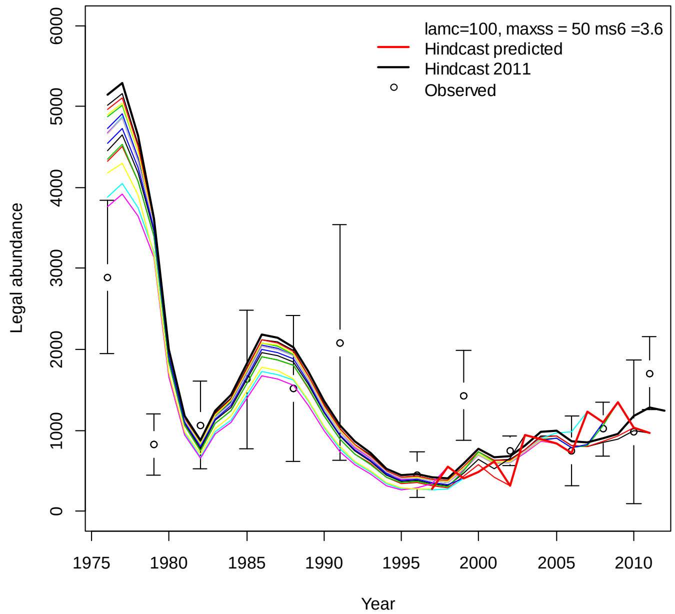

Model 11: Model 3 & Model 6



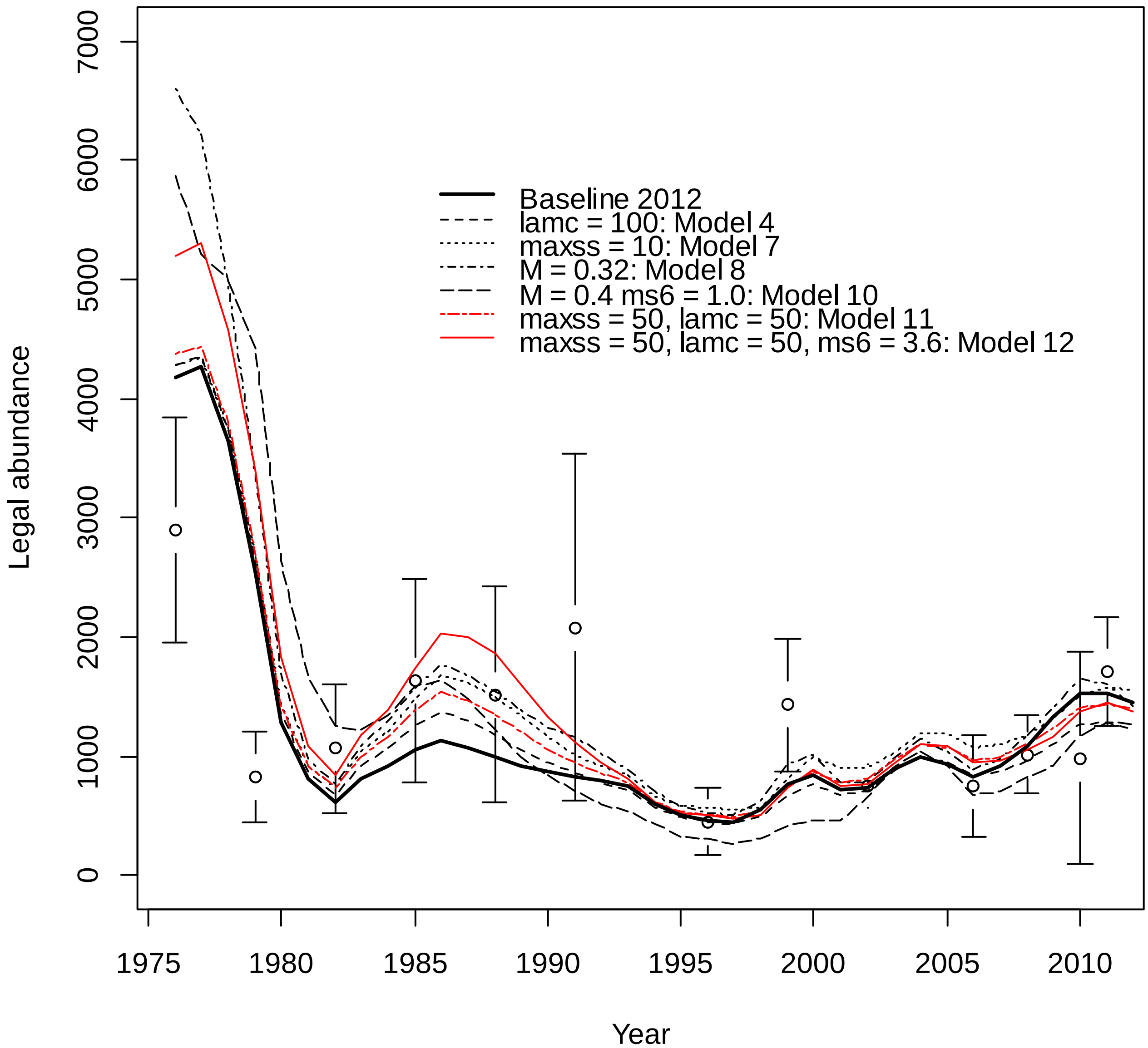

Model 12: Model 11 + Model 2




Model 13: Model 4 & Model 6




Model 14: Model 13 + Model 2

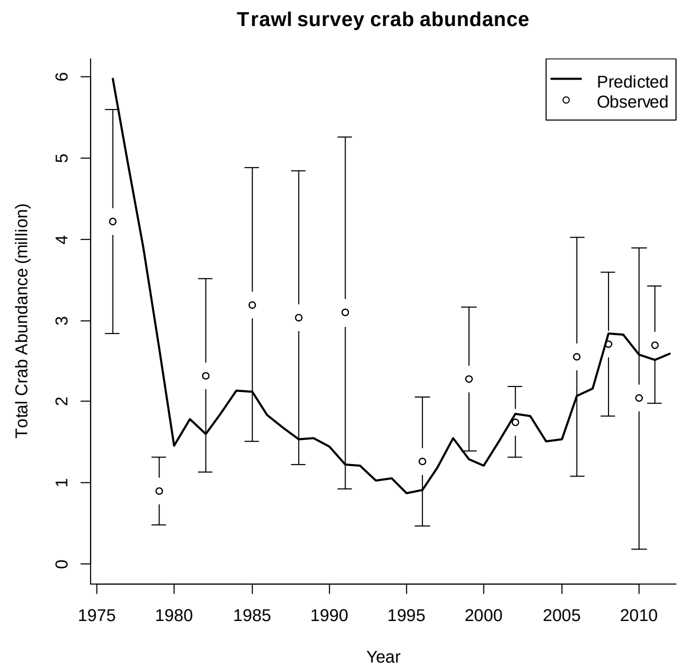


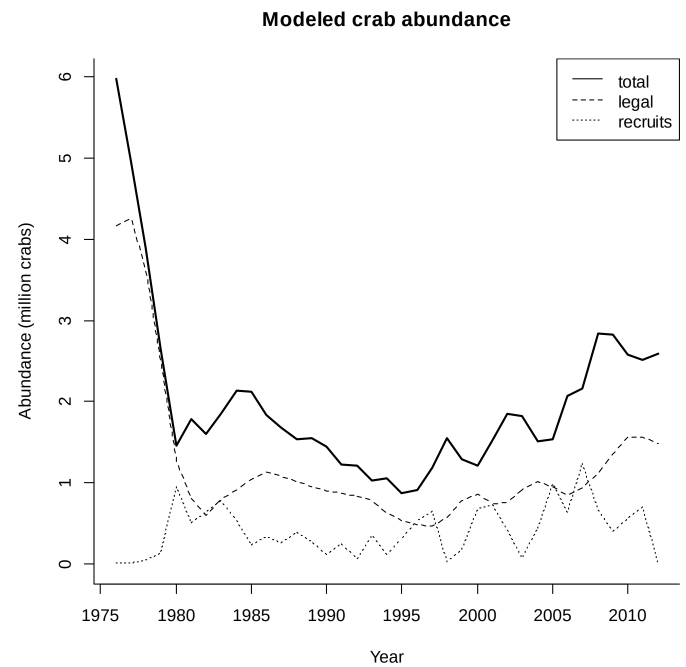

Comparison of various candidate model estimates of legal male crab abundance.

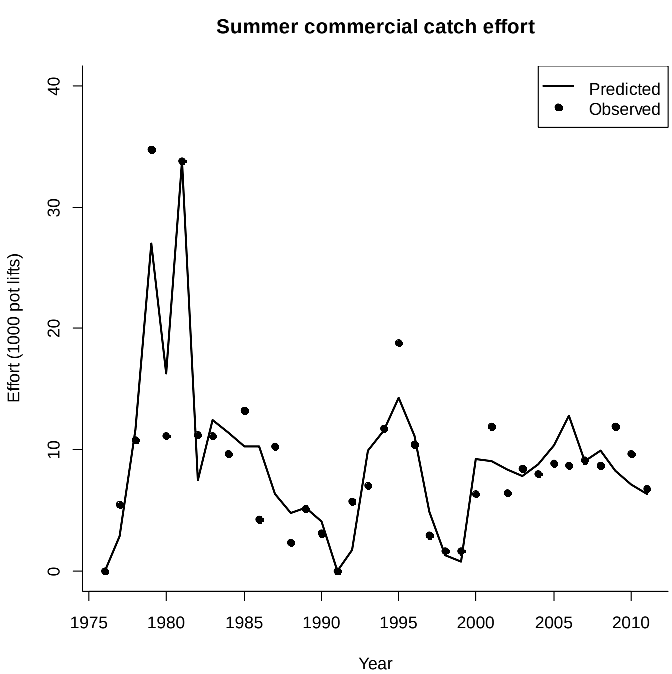
# Appendix D

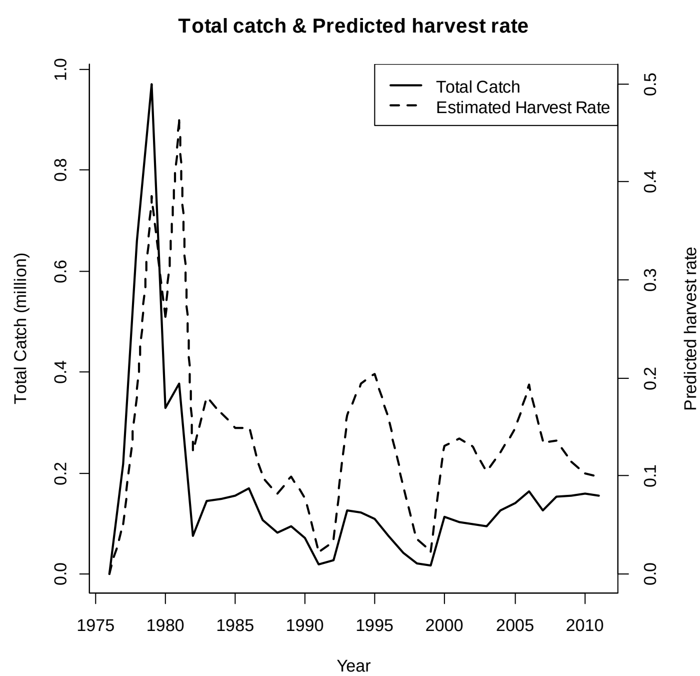
## Estimates of crab abundance, residual analyses for selected candidate models

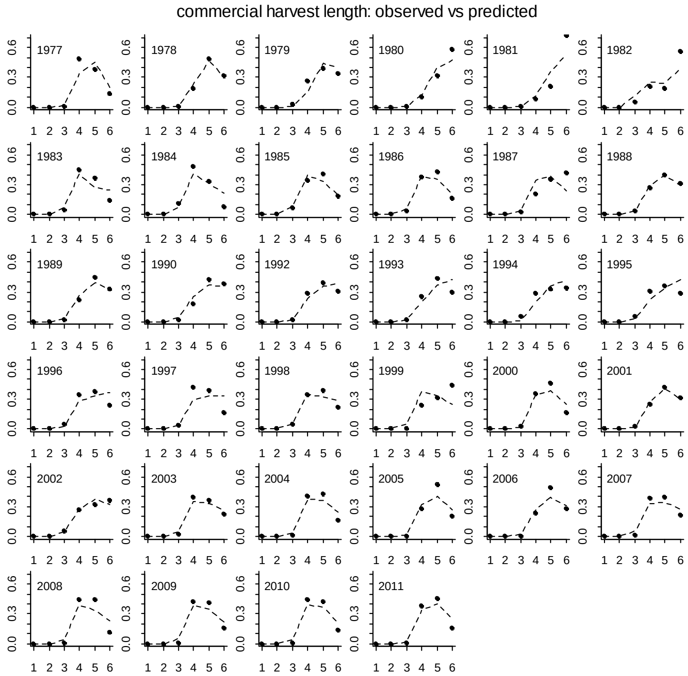
## Model 0: 2011 model



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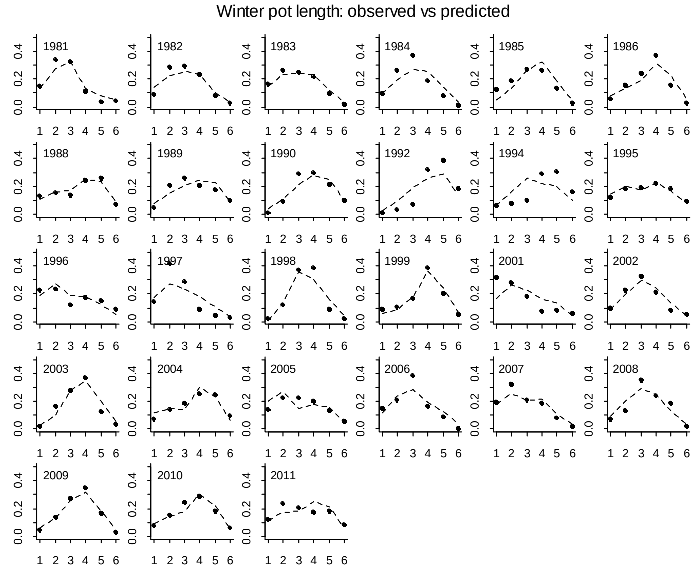


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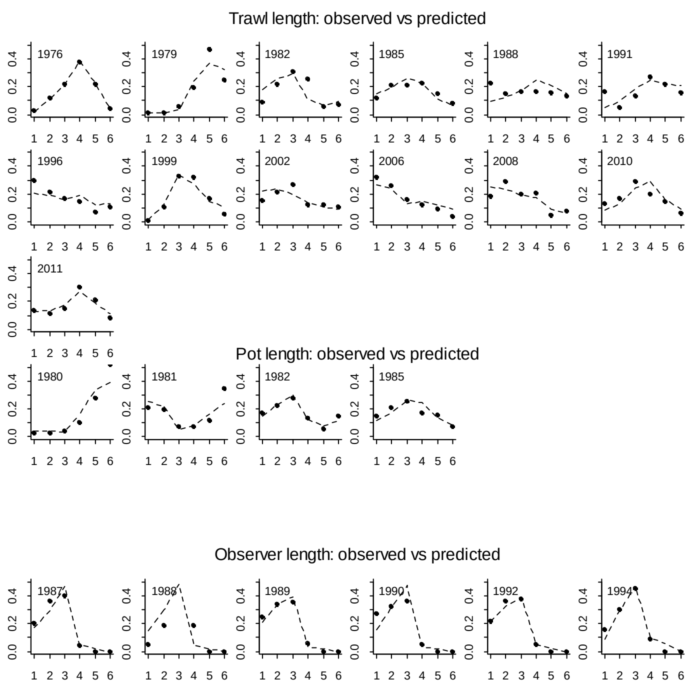


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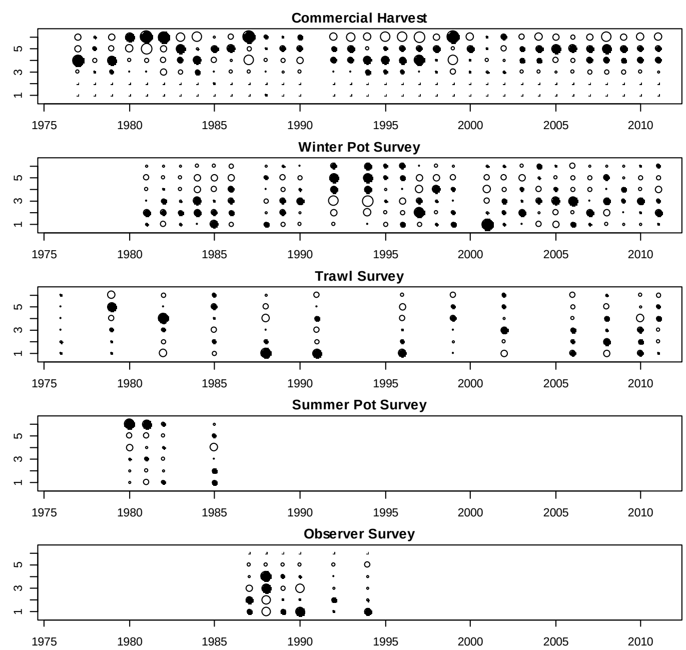
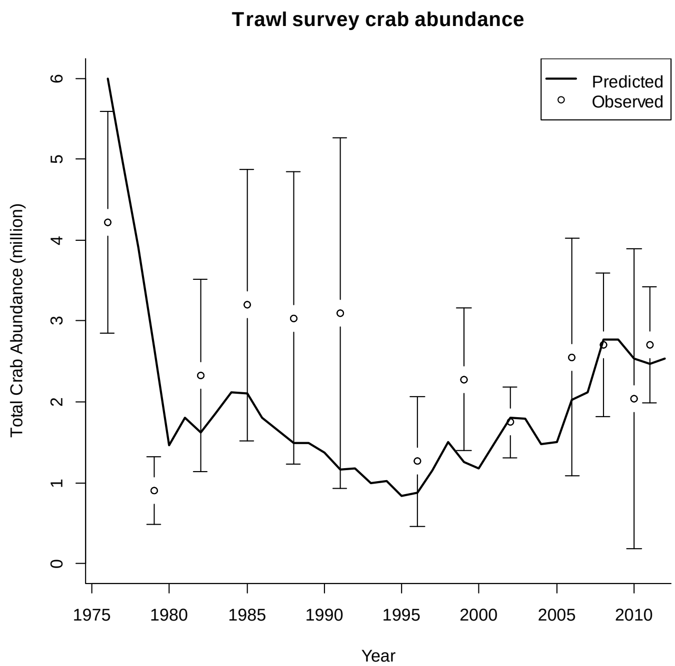
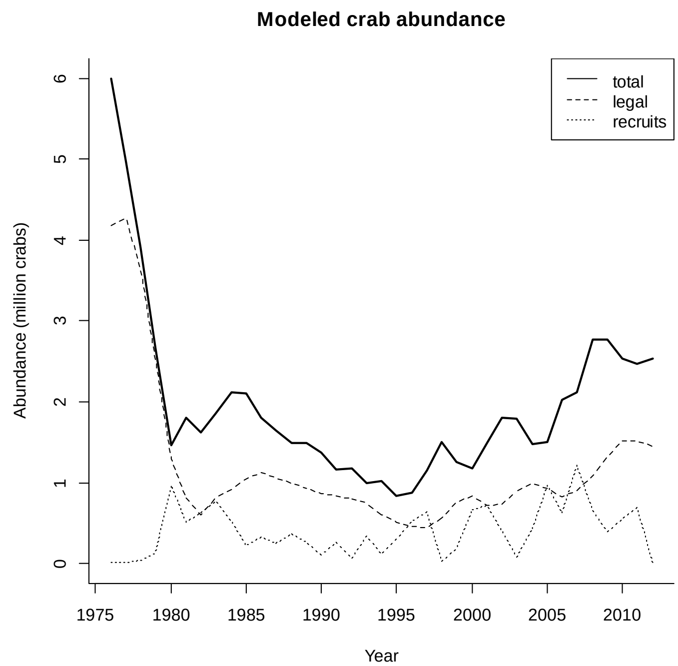
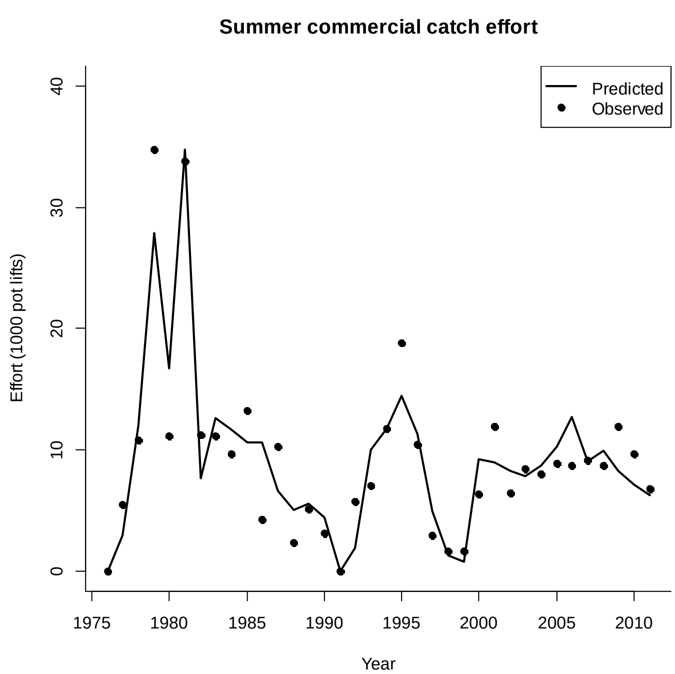


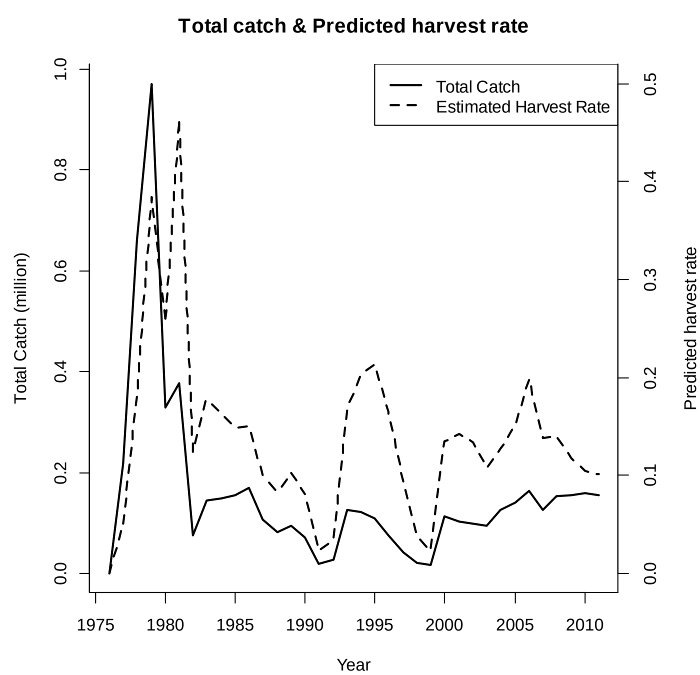

1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Model 1: 2012 Baseline model

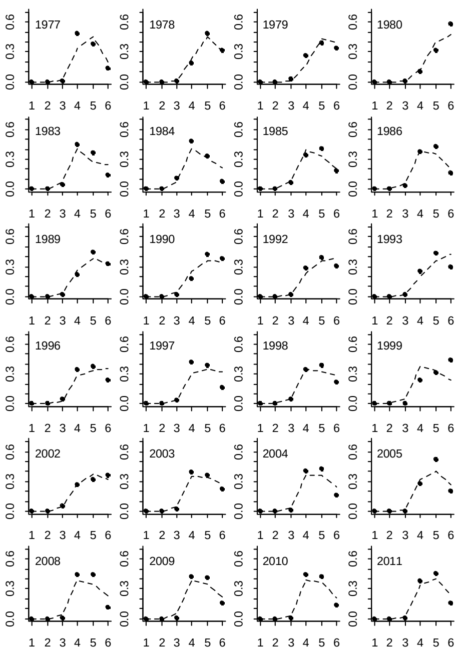


commercial harvest length: observed vs predicted



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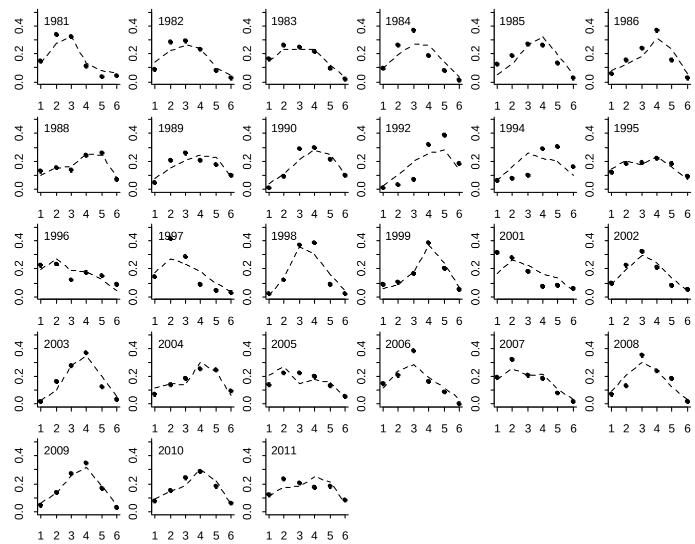
Winter pot length: observed vs predicted



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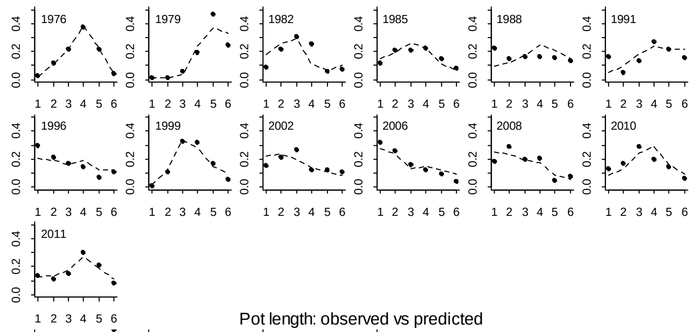
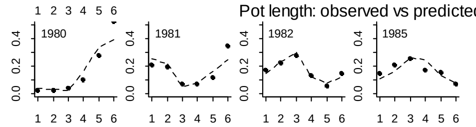
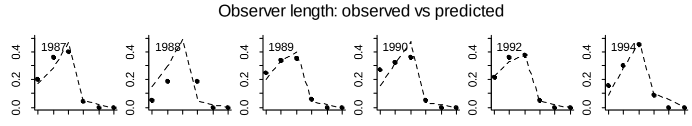
Trawl length: observed vs predicted



Pot length: observed vs predicted



Observer length: observed vs predicted



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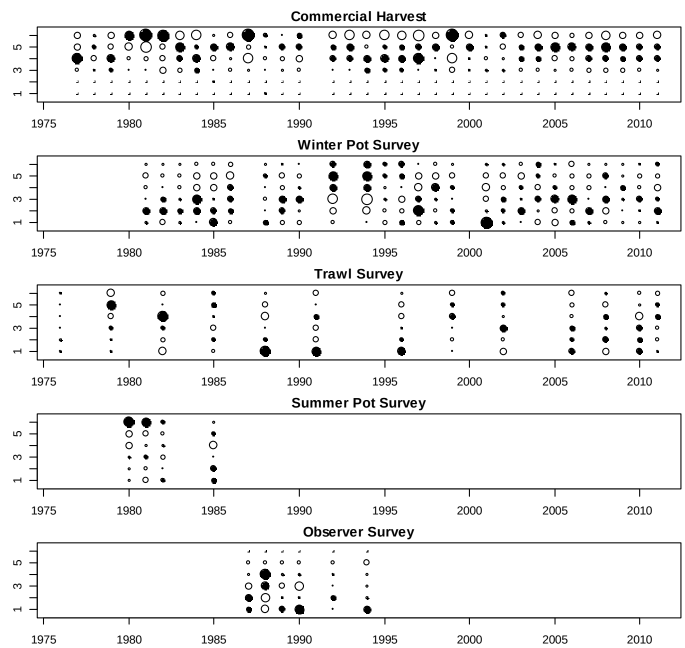


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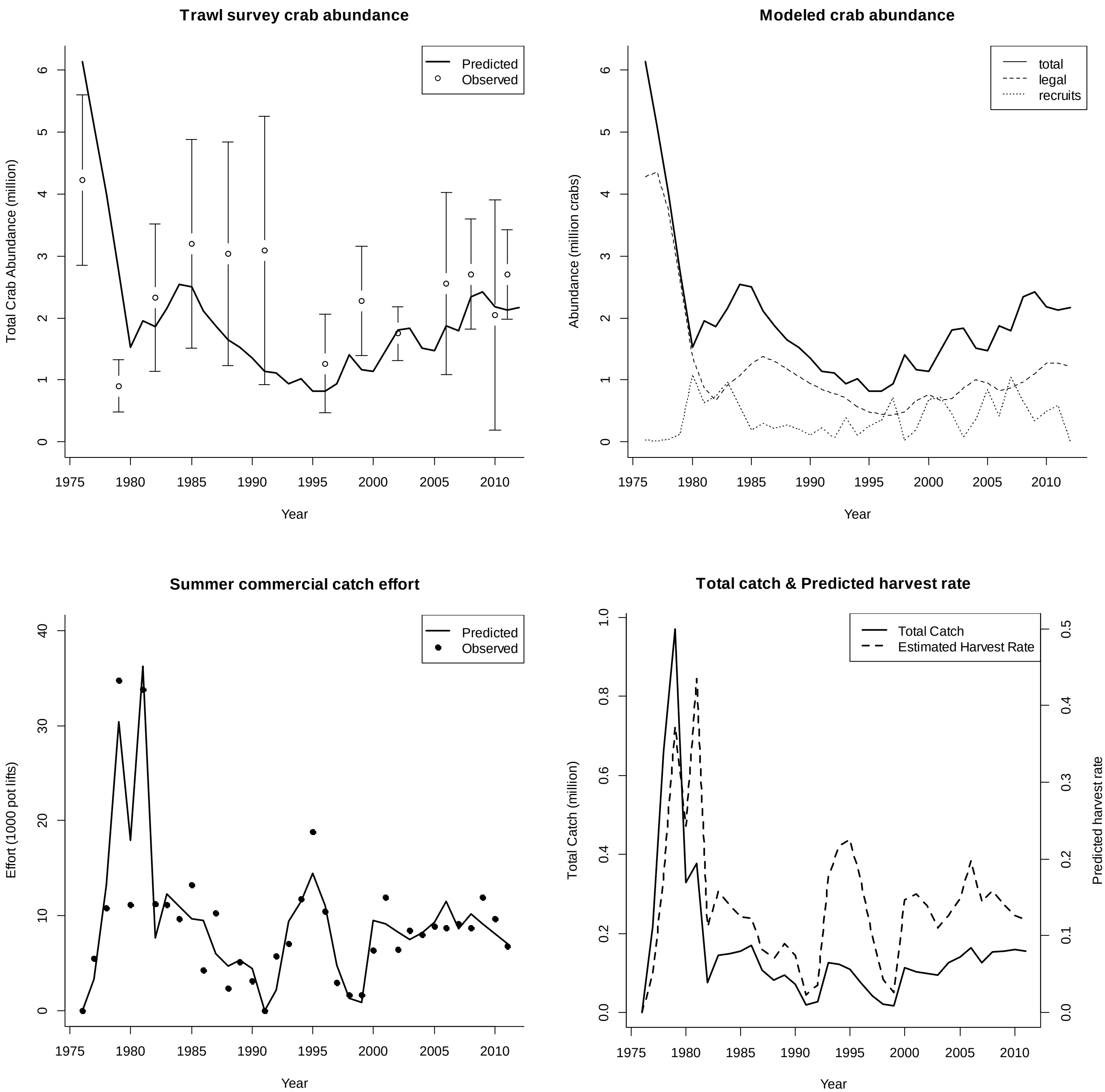
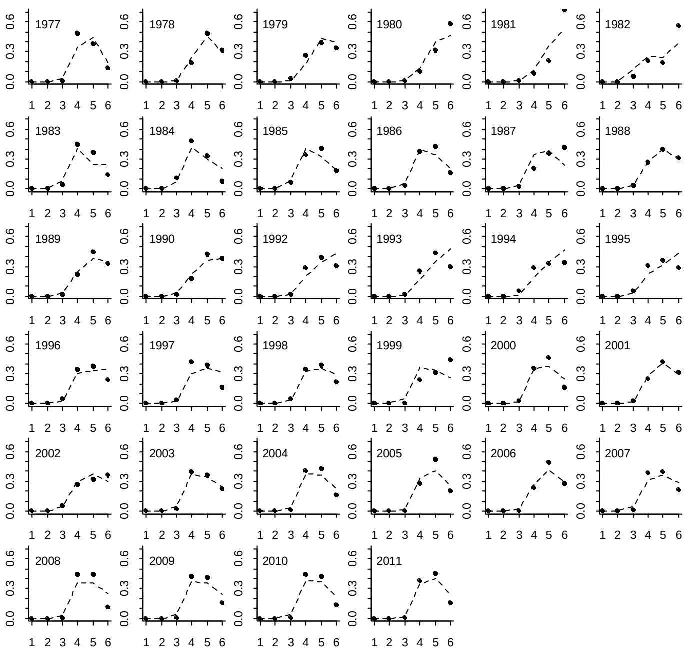
Model 4: Model 1 + lamc = 100



commercial harvest length: observed vs predicted



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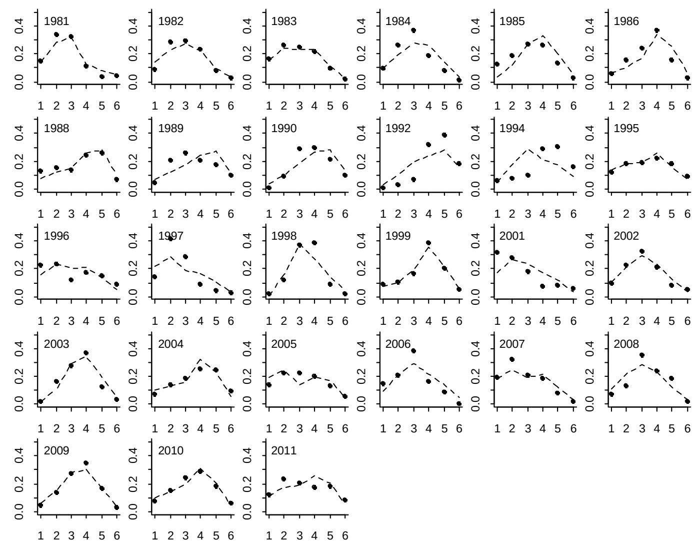
Winter pot length: observed vs predicted



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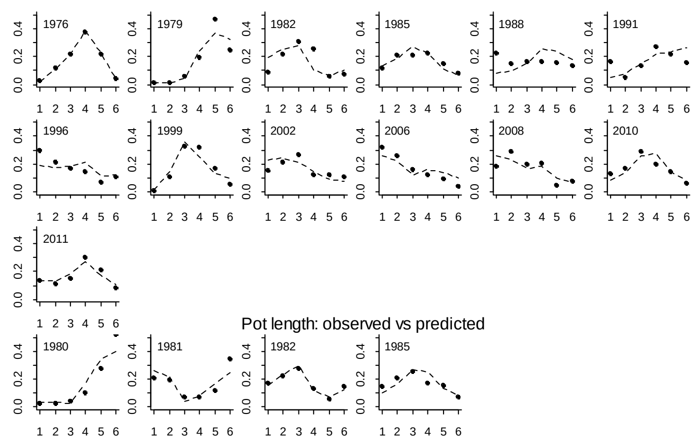
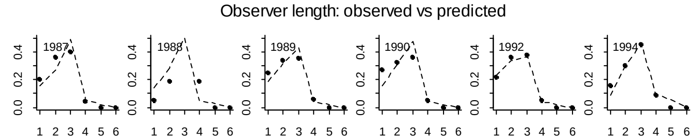
Trawl length: observed vs predicted




Observer length: observed vs predicted



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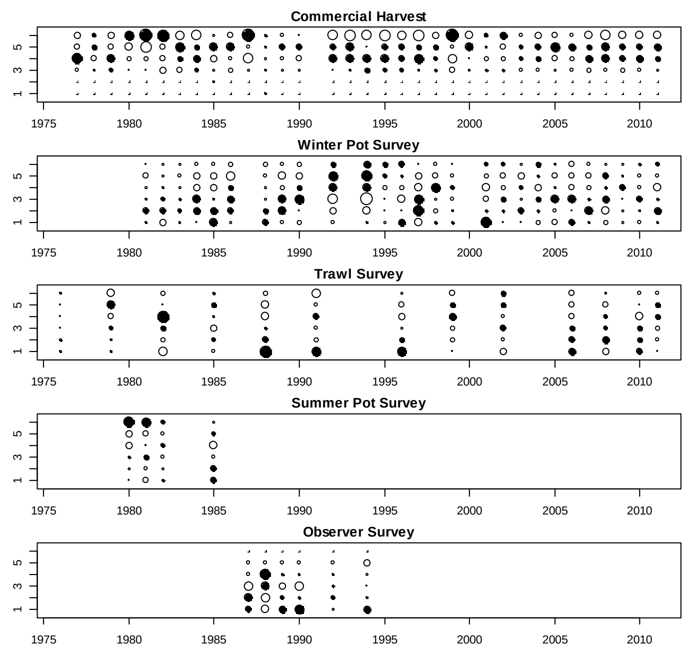


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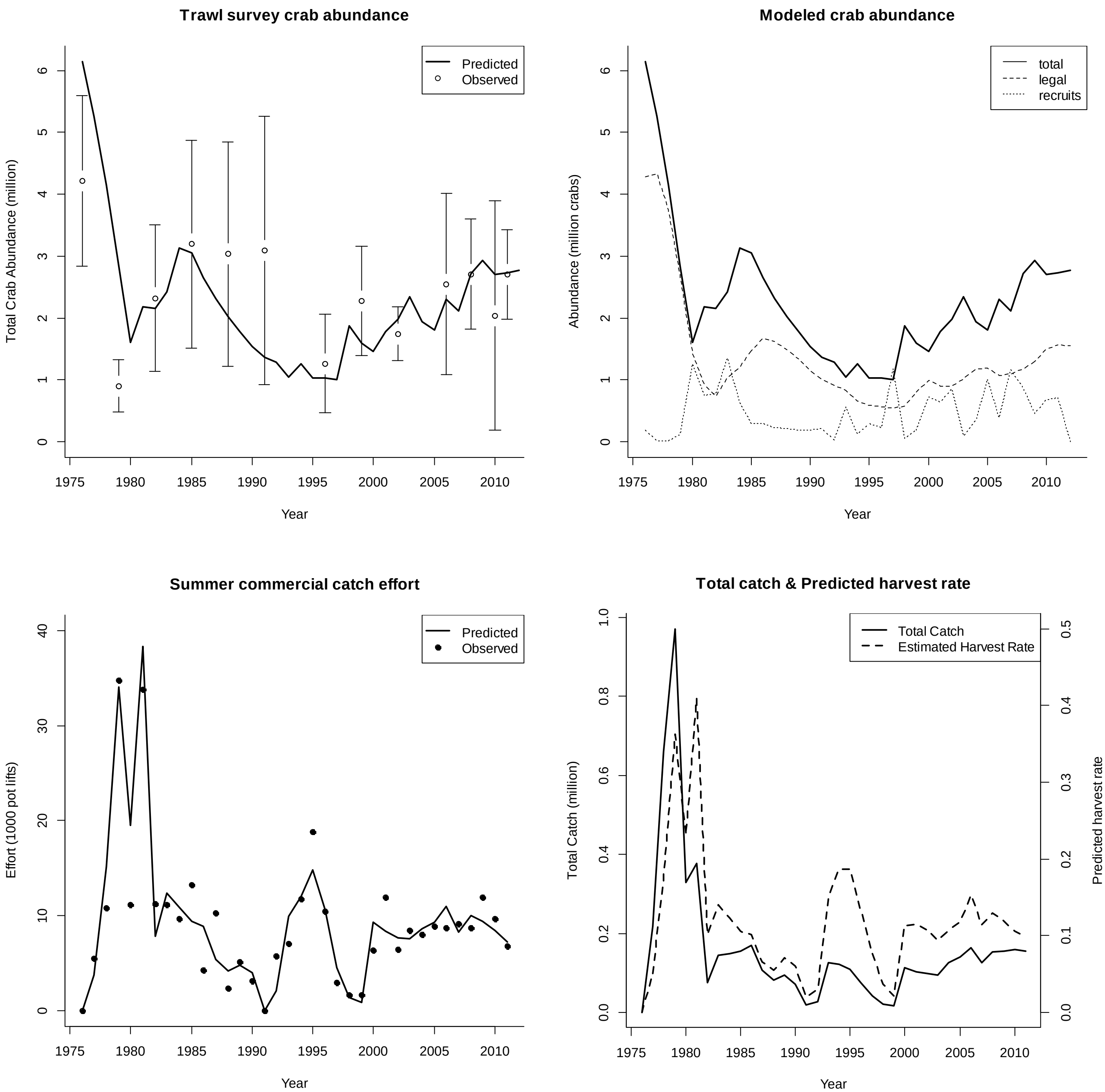
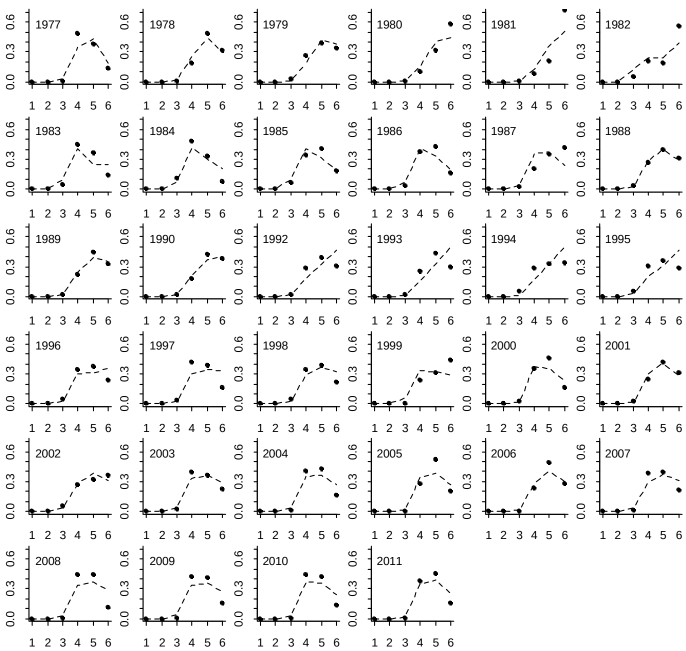
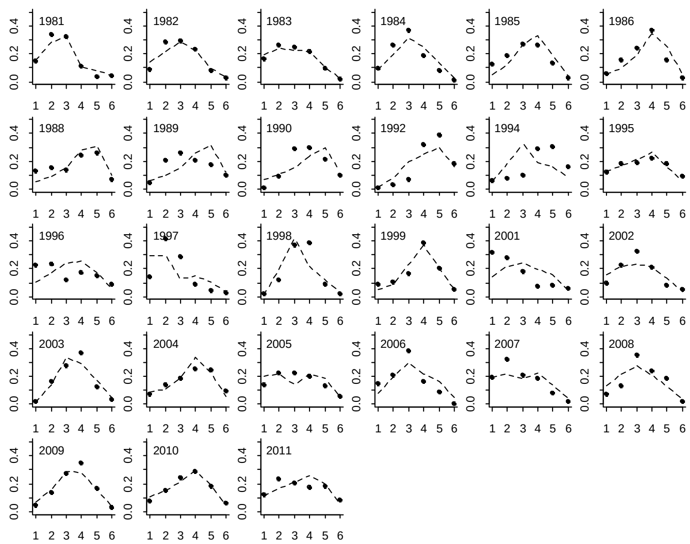
Model 7: Model 1+ Maxss = 10



commercial harvest length: observed vs predicted



Winter pot length: observed vs predicted



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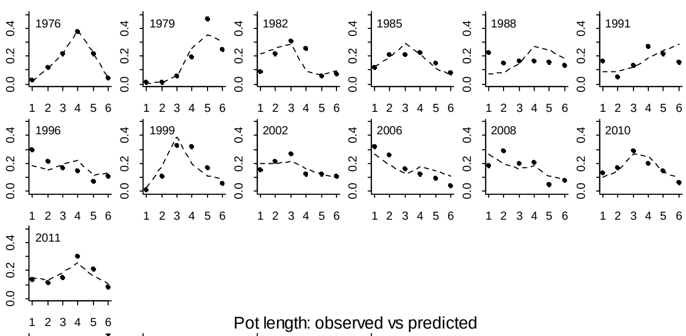
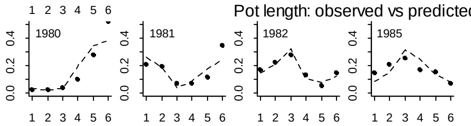
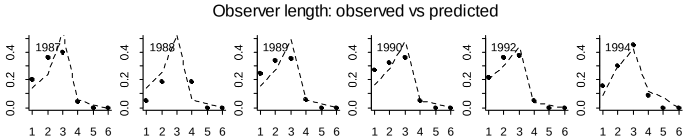
Trawl length: observed vs predicted

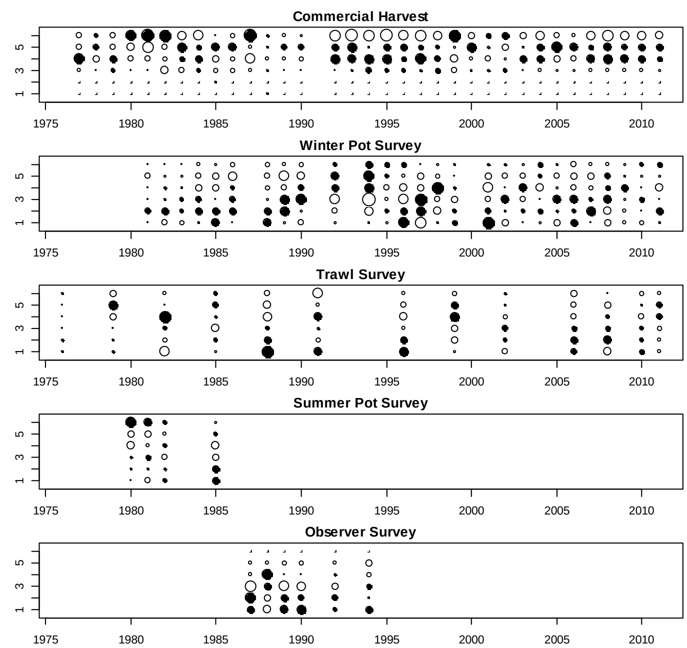


Pot length: observed vs predicted



Observer length: observed vs predicted



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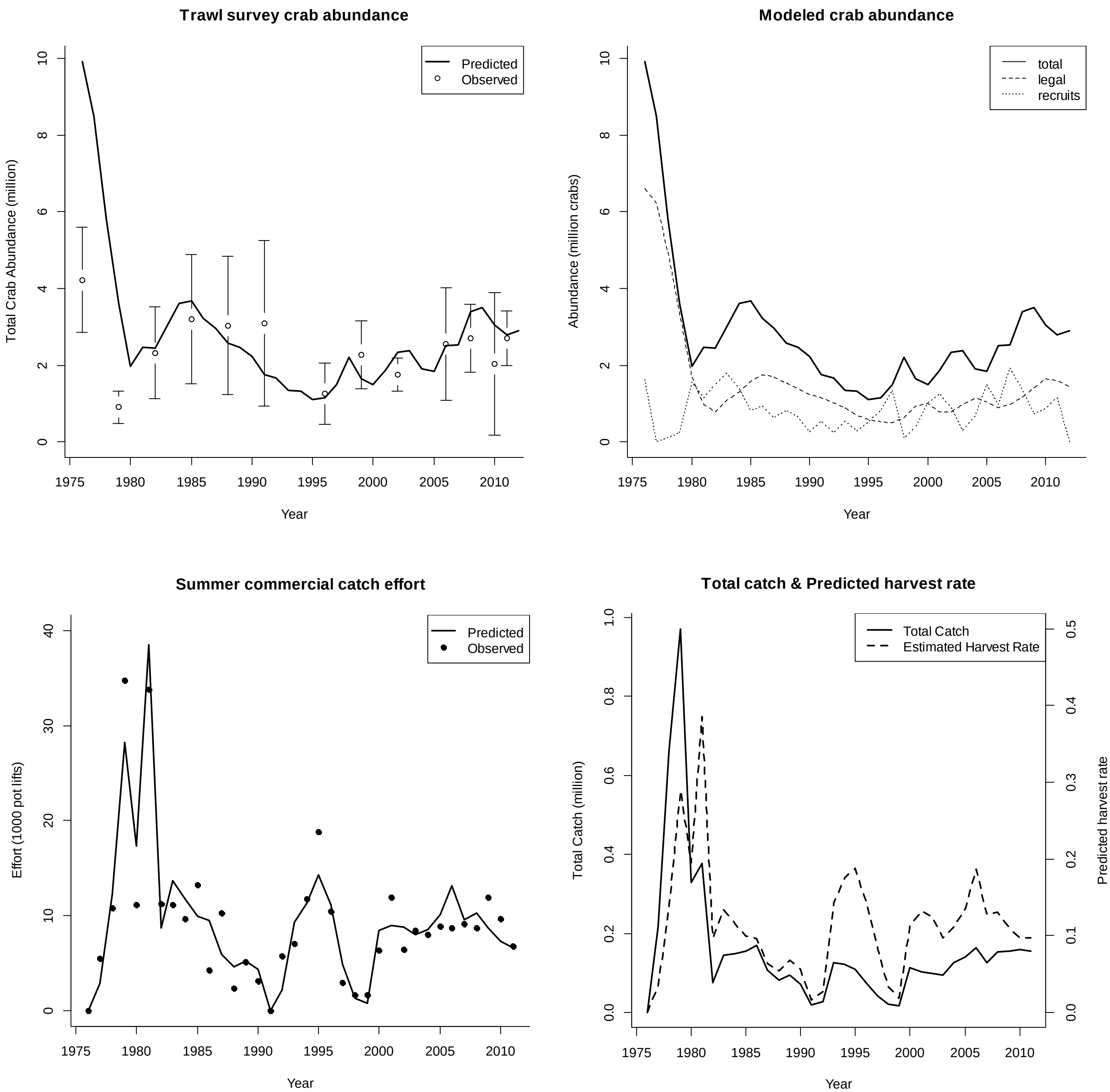
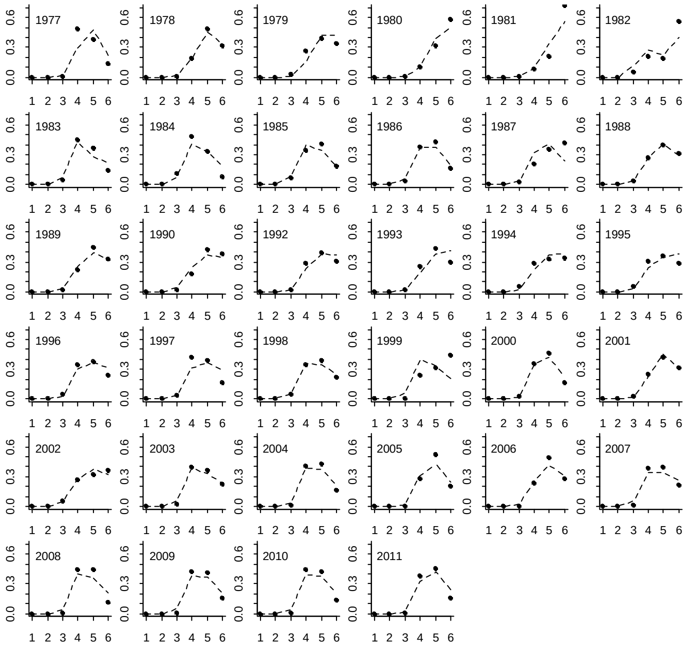
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Model 8: Model 1+M=0.32



commercial harvest length: observed vs predicted



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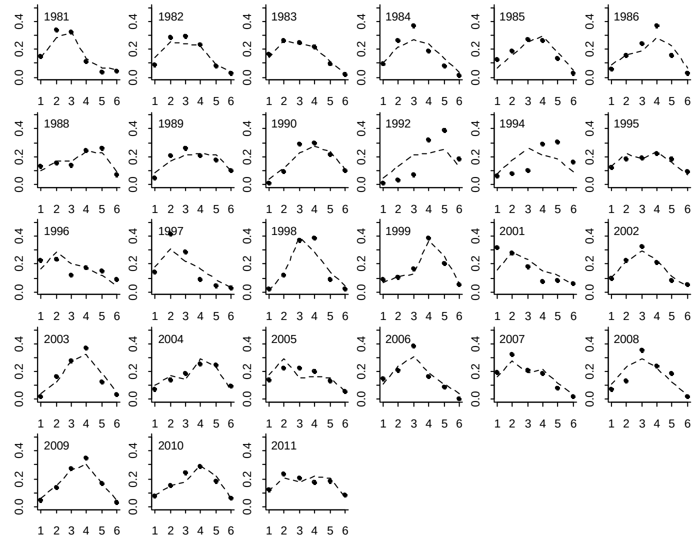
Winter pot length: observed vs predicted



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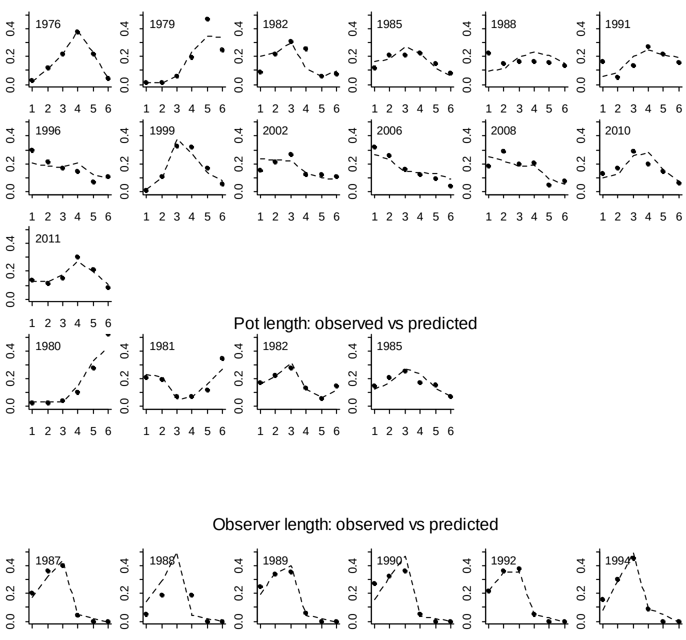
Trawl length: observed vs predicted

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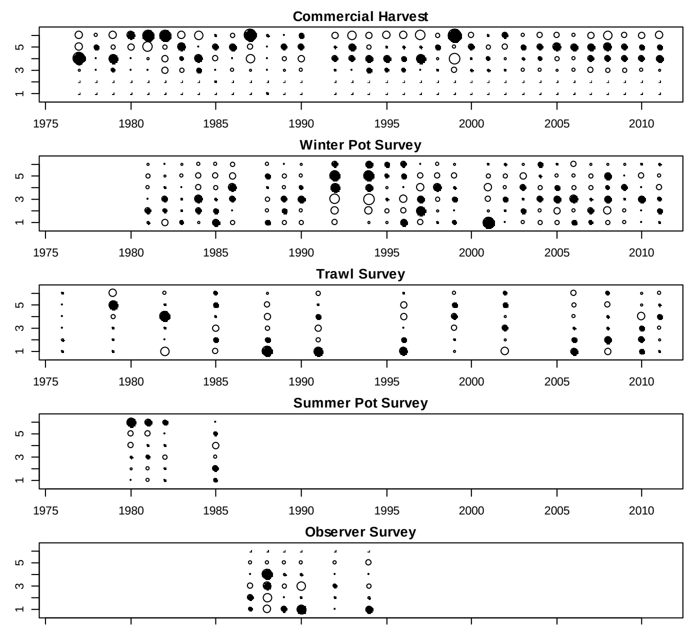


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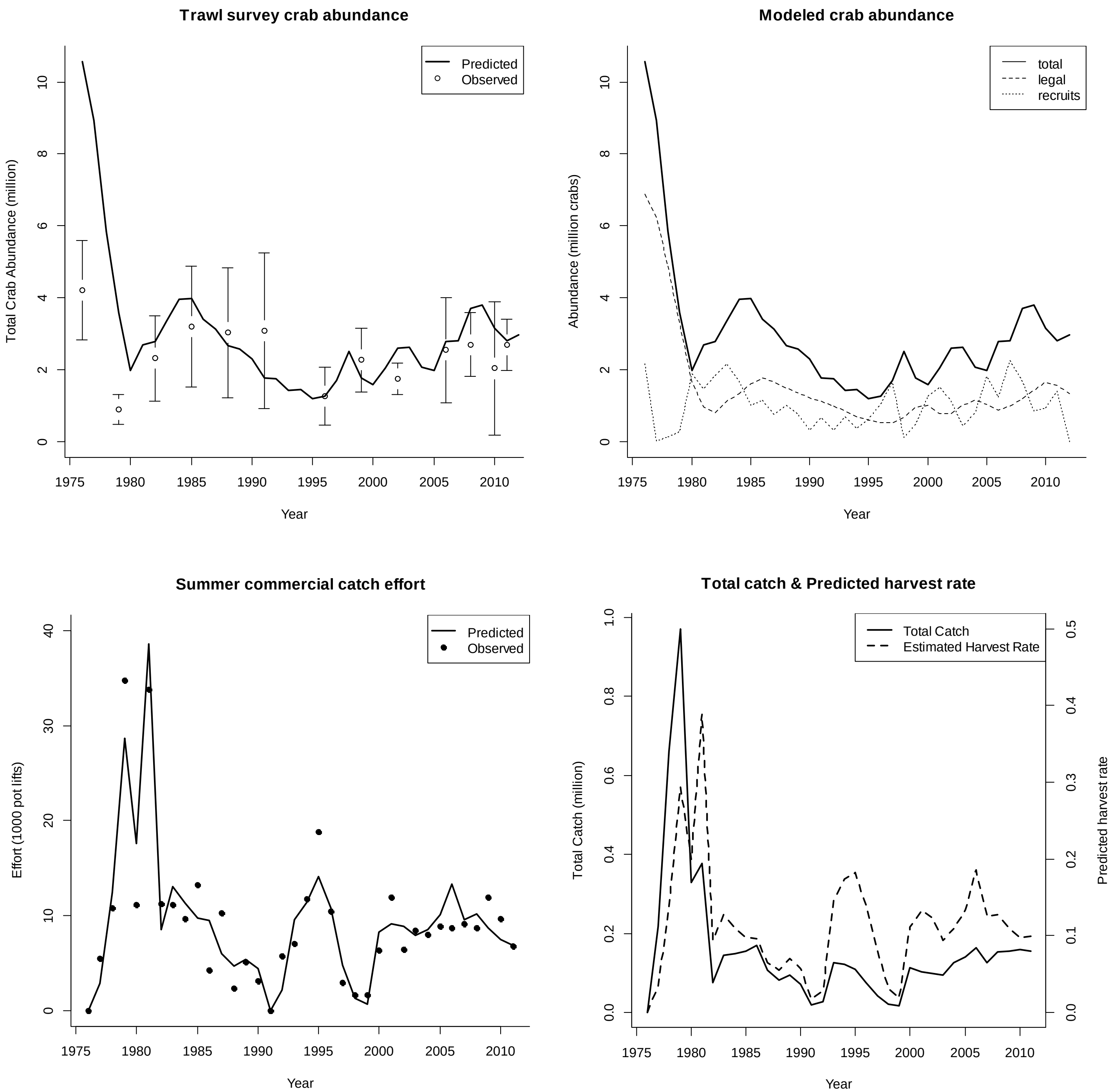
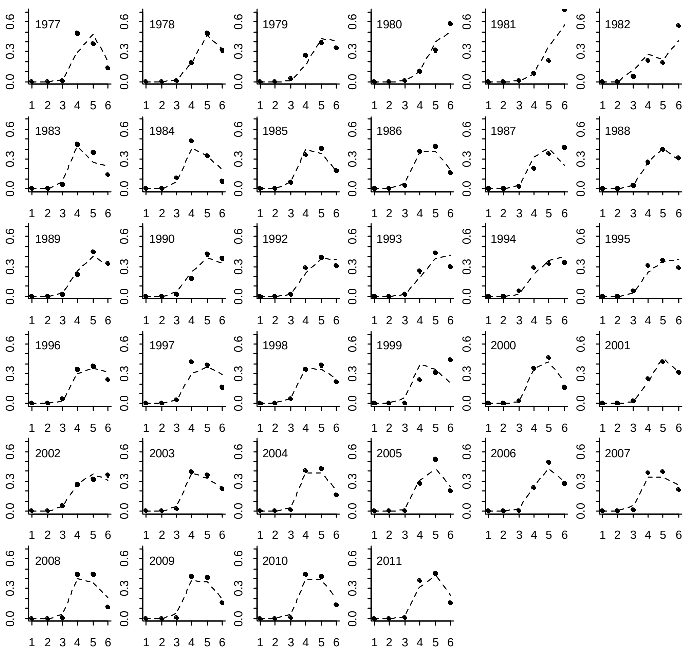
Alternative model 10: Model 9 (ms6 =1.0) + M=0.4

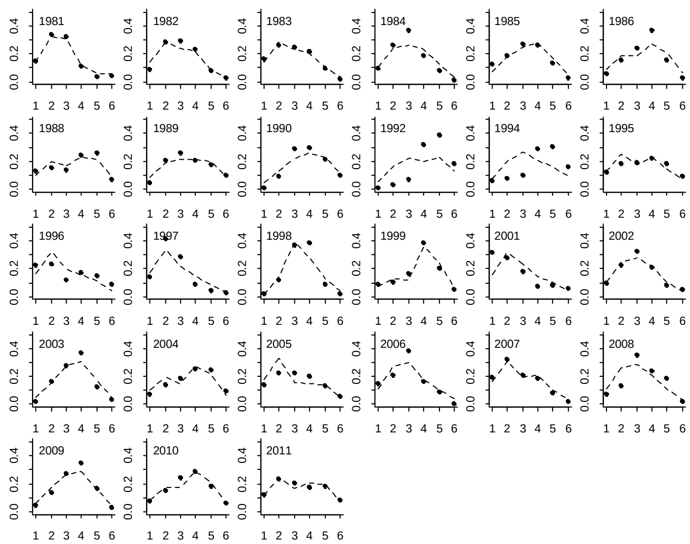


commercial harvest length: observed vs predicted



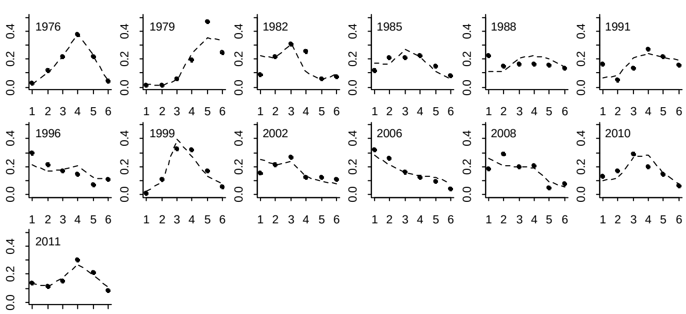
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Winter pot length: observed vs predicted

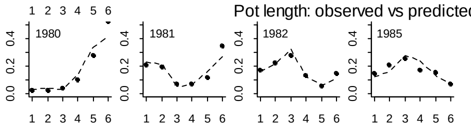


1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

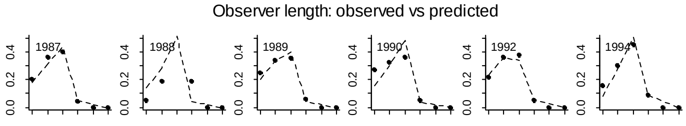
Trawl length: observed vs predicted



Pot length: observed vs predicted



Observer length: observed vs predicted



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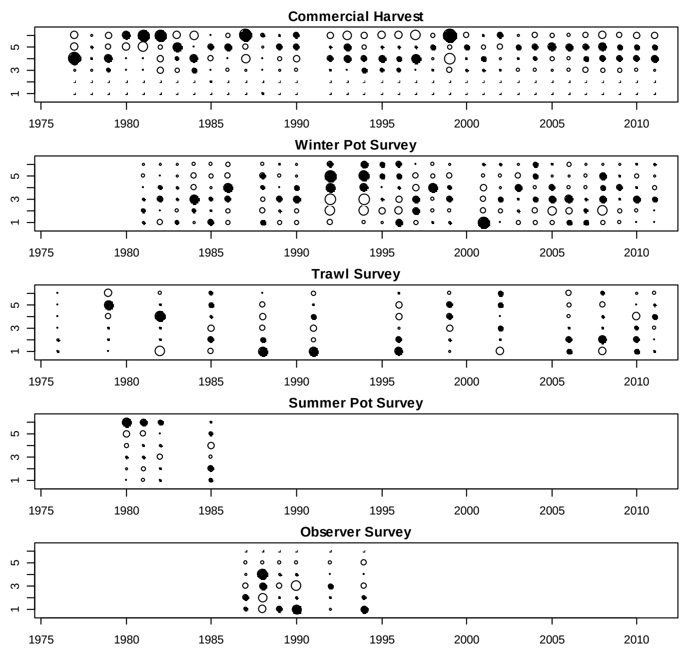
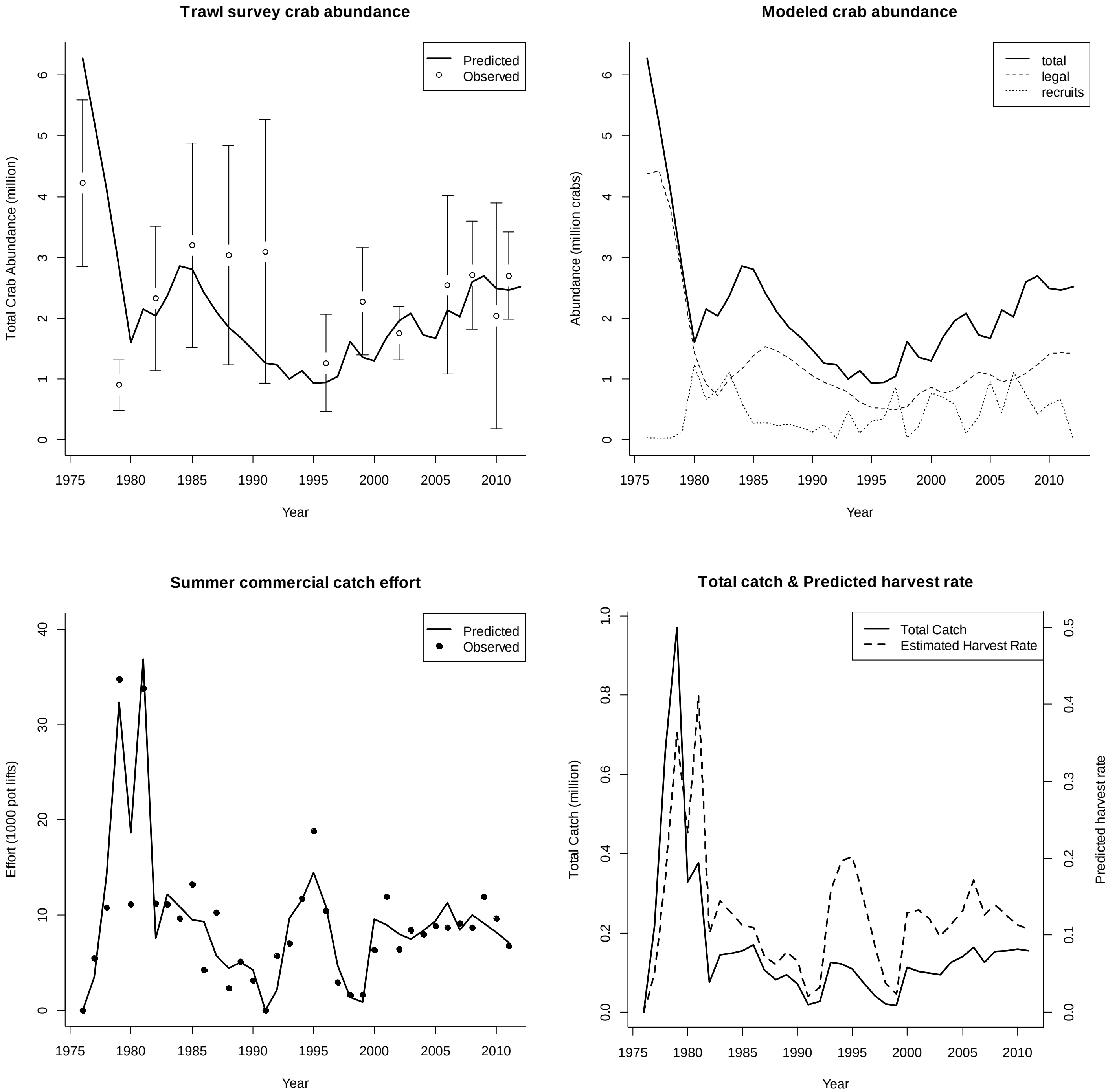
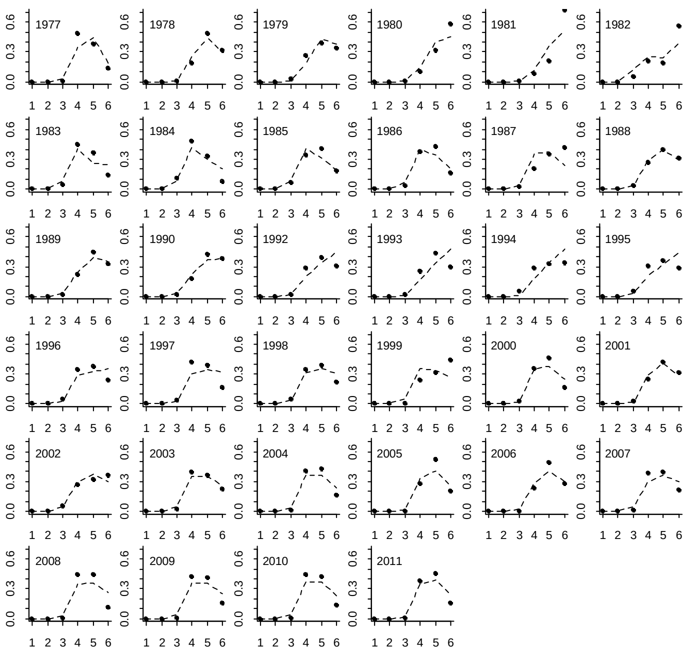



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Model 11: Model 3 + Model 6: Maxss = 50 lamc = 50



commercial harvest length: observed vs predicted



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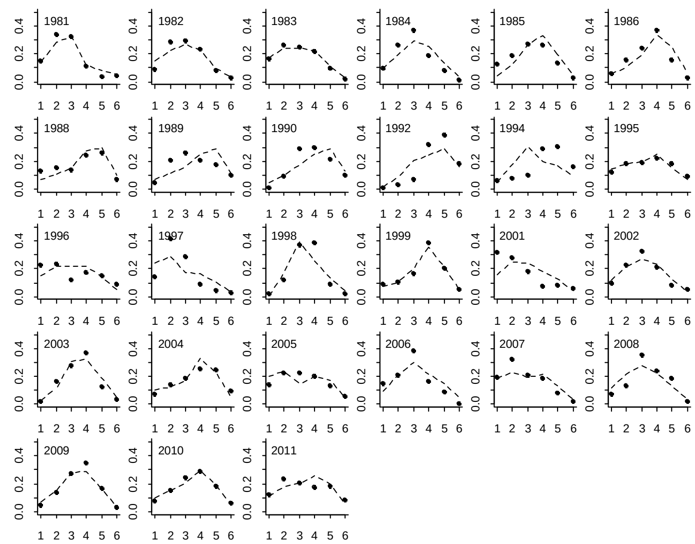
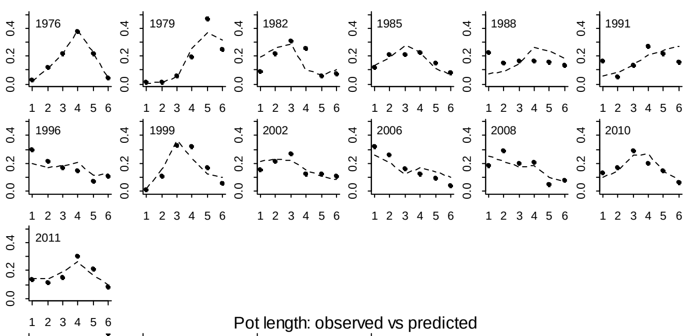
Winter pot length: observed vs predicted

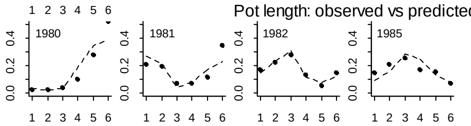


1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

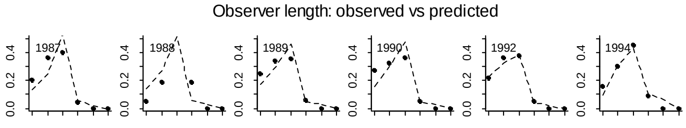
Trawl length: observed vs predicted



Pot length: observed vs predicted



Observer length: observed vs predicted



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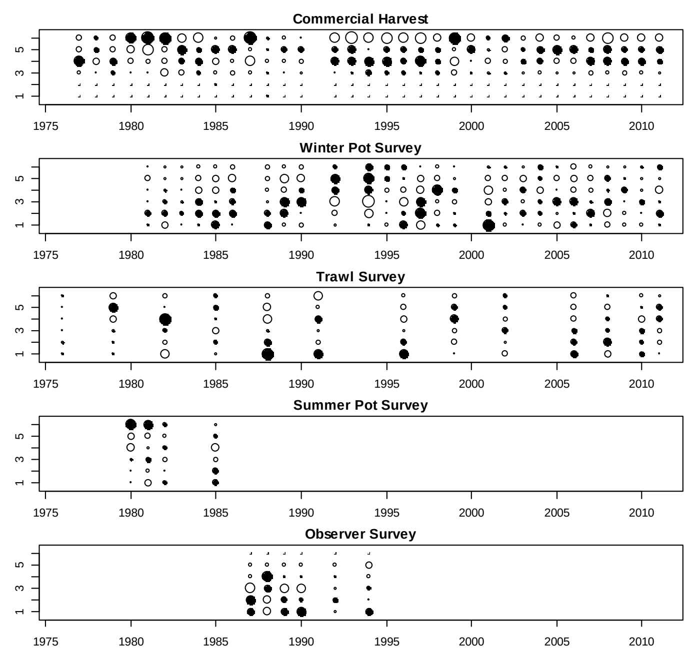
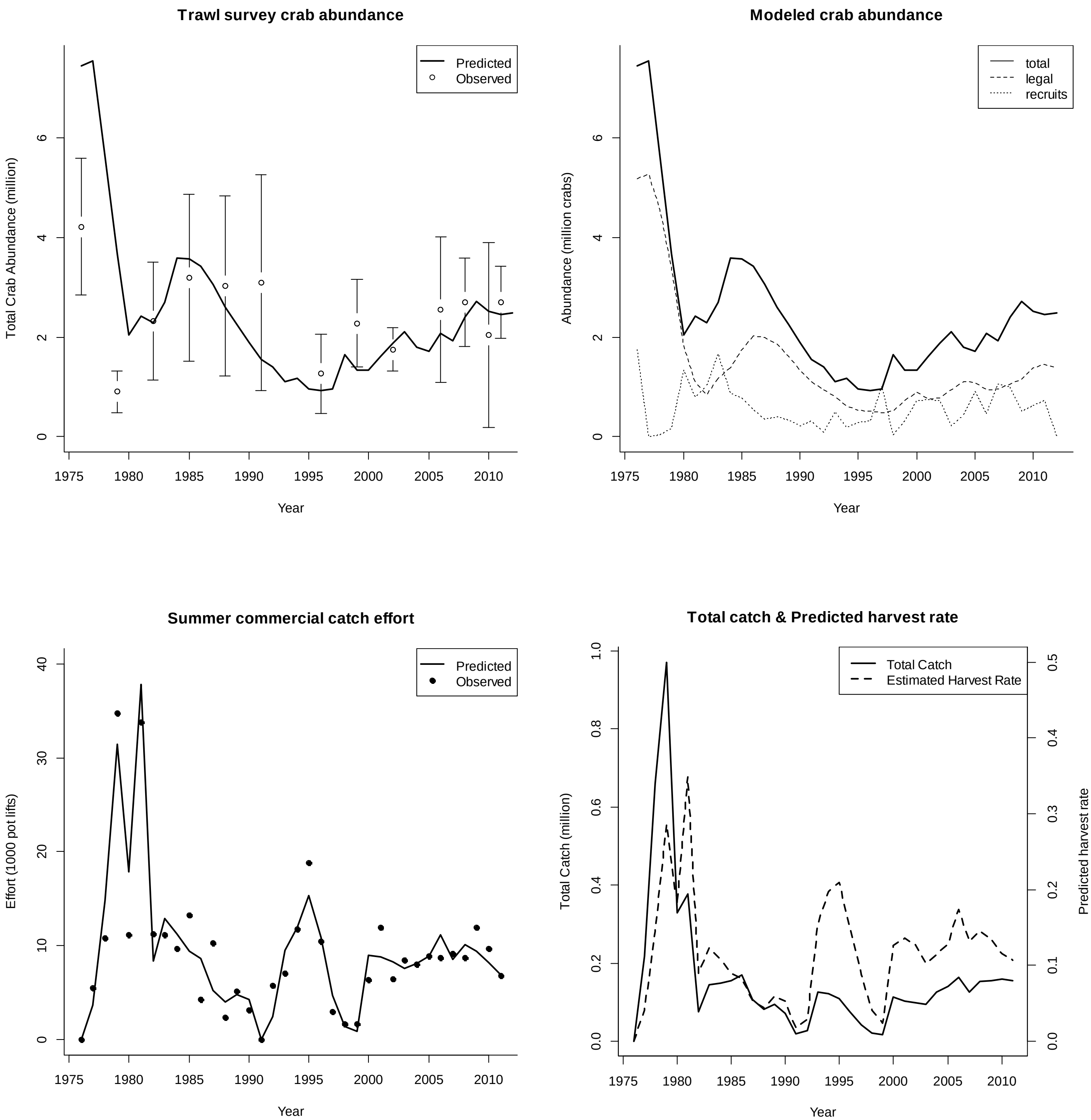
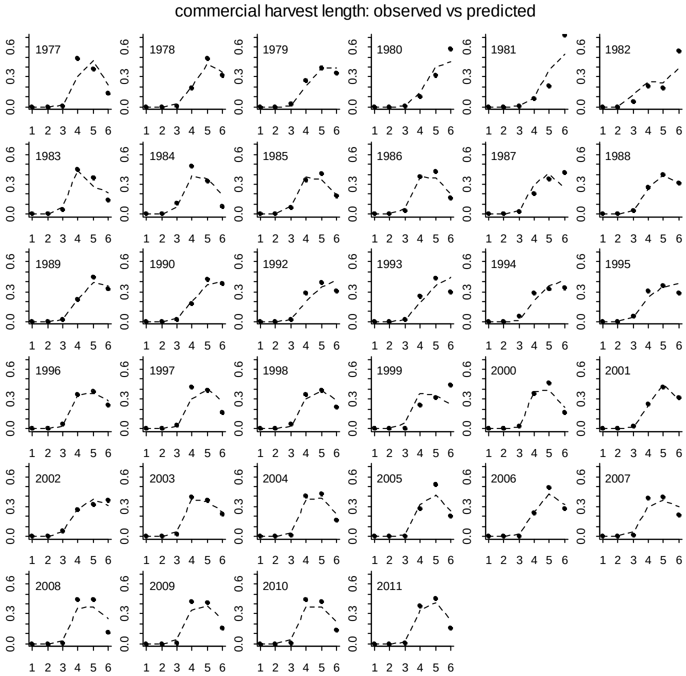



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Model 12: Model 11 + Model 2: Maxss = 50 lamc = 50 ms6 = 3.6



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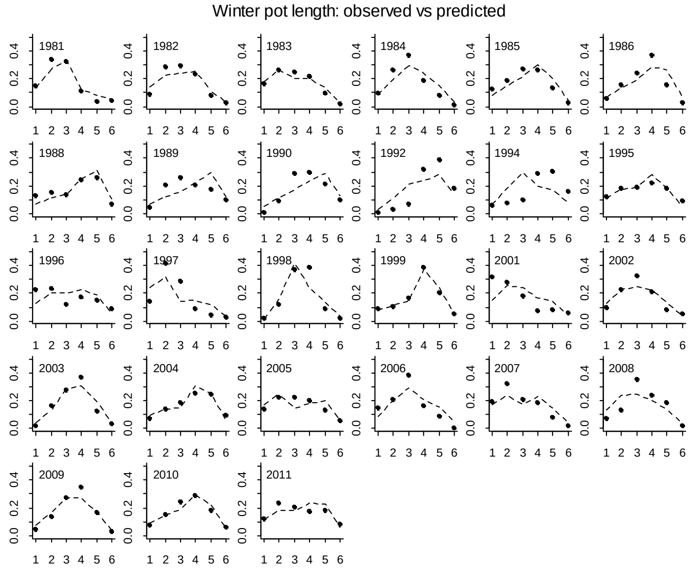
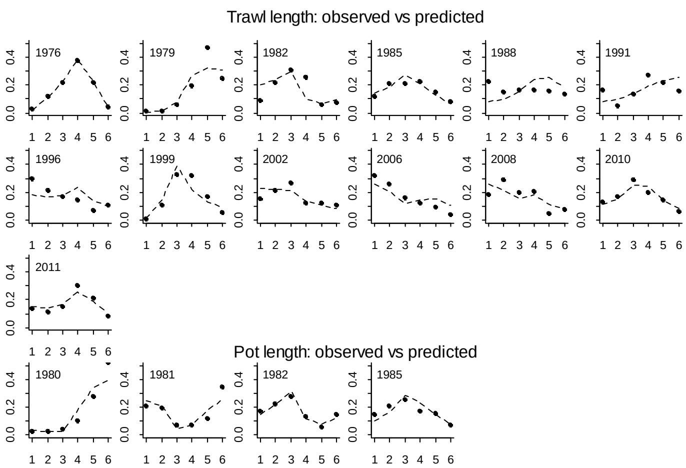
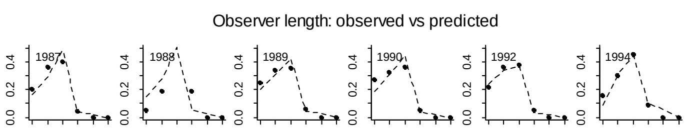
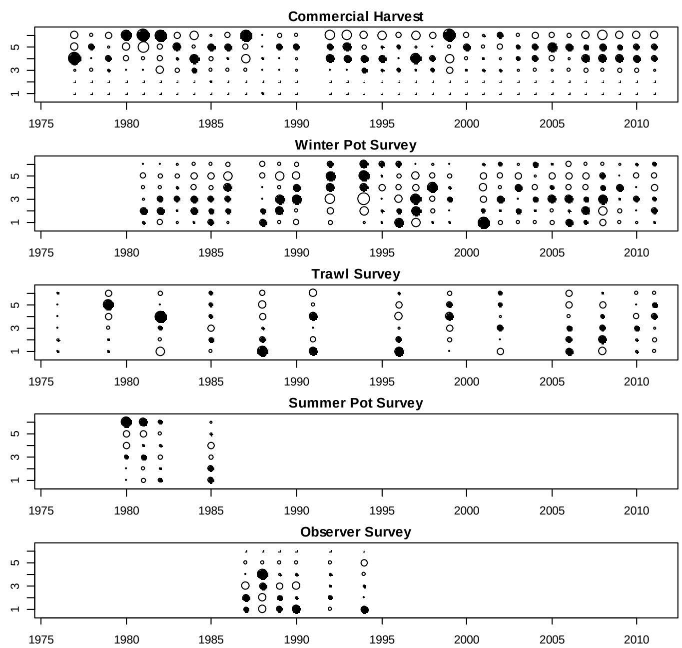



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124




1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

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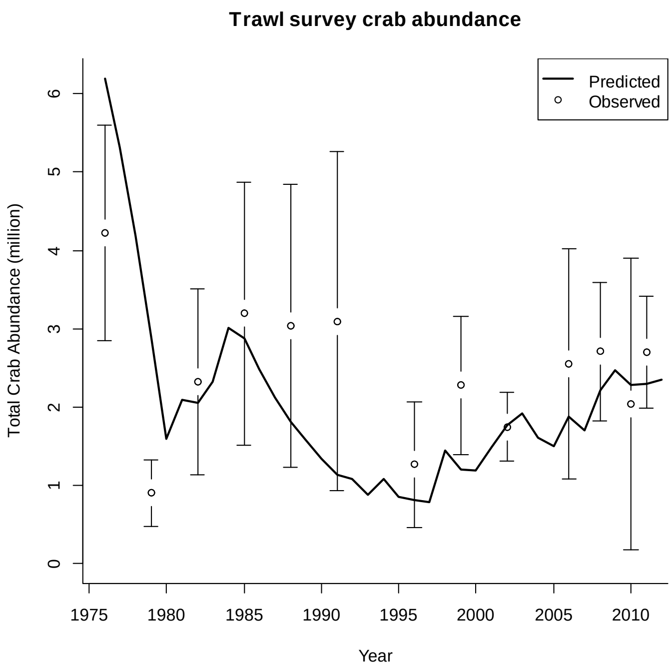
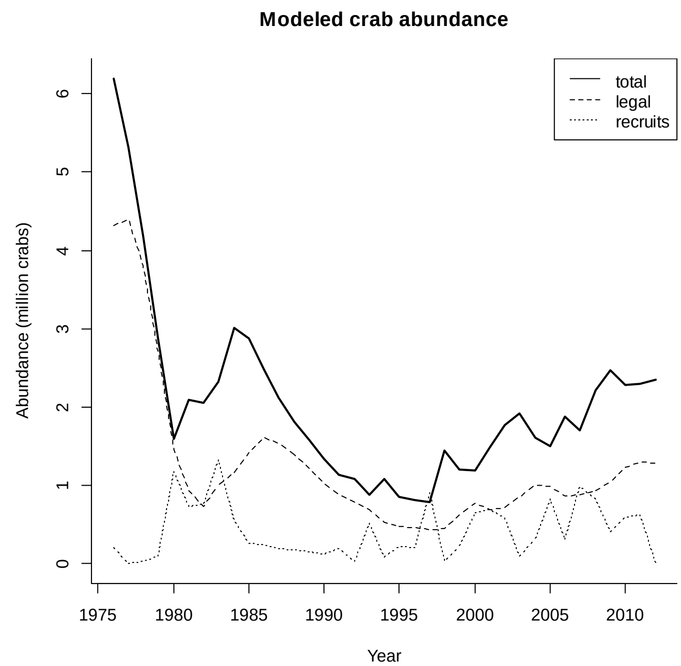
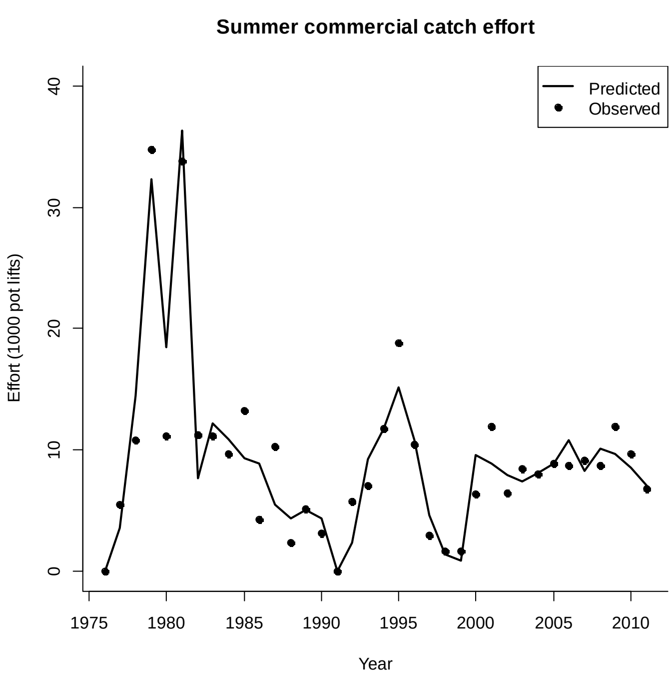
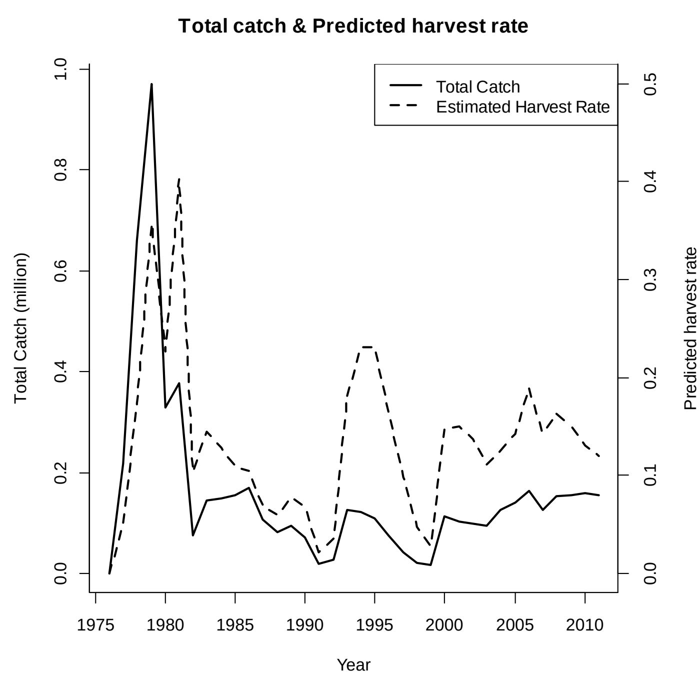
Alternative model 13: Model 4 (lamc=100) + Model 6 (maxss=50)

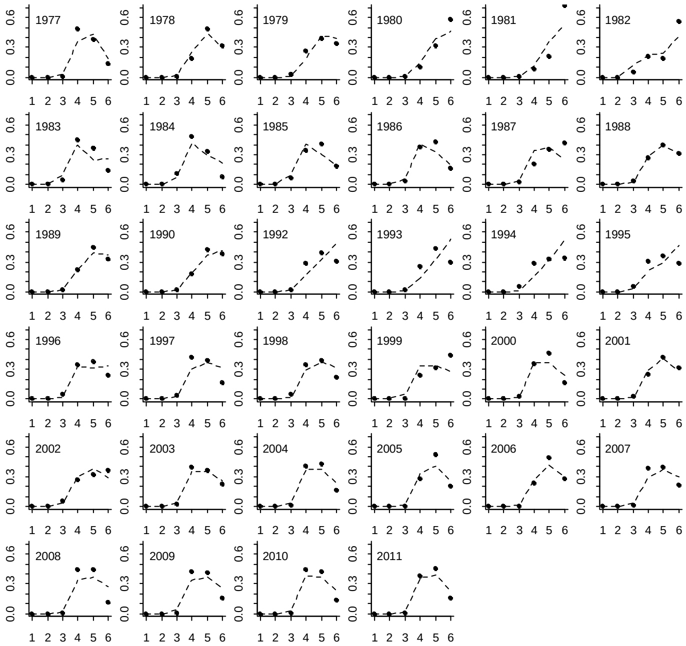


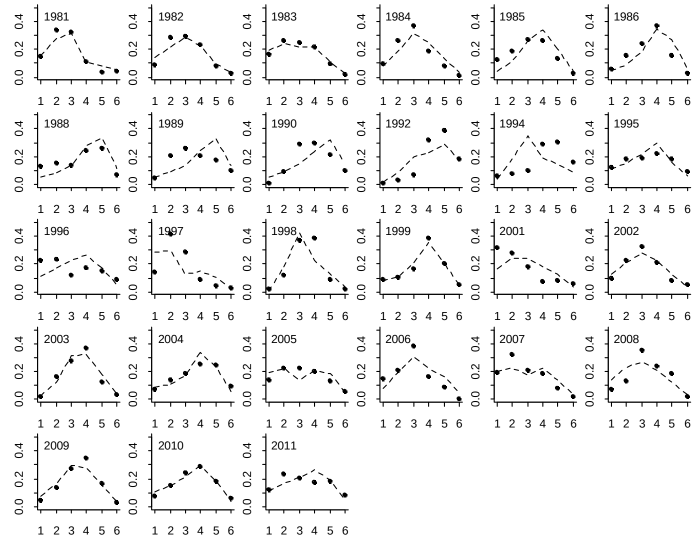



commercial harvest length: observed vs predicted



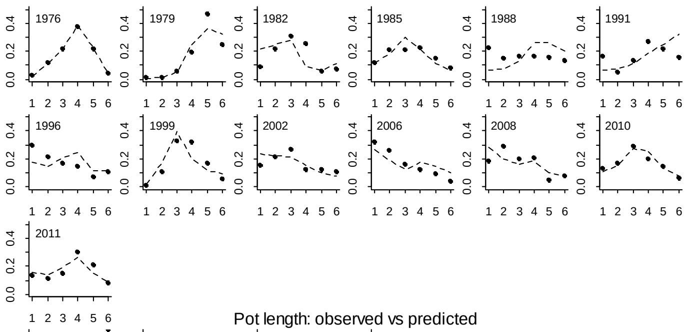
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Winter pot length: observed vs predicted

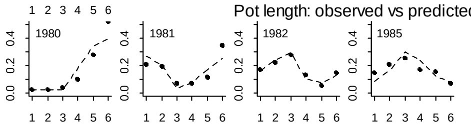


1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

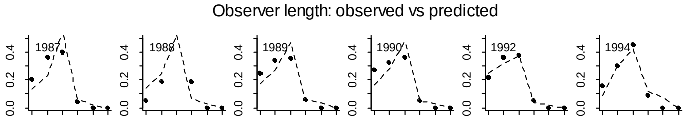
Trawl length: observed vs predicted



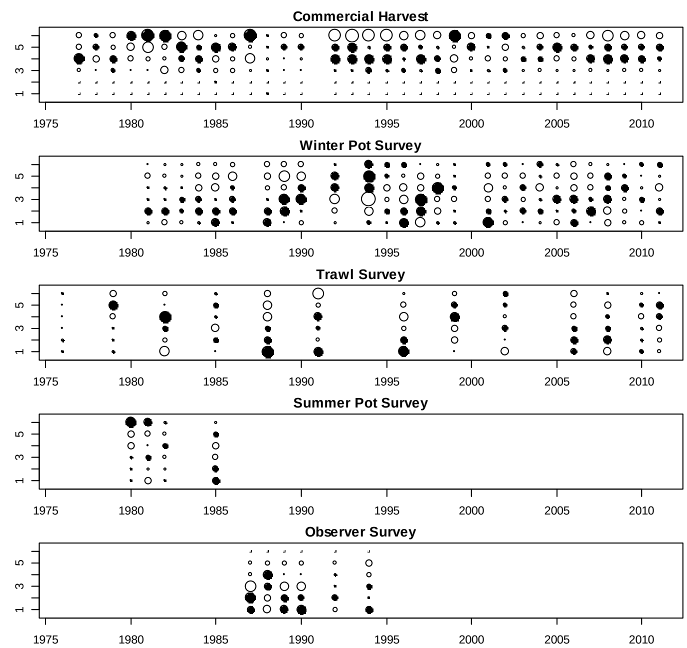
Pot length: observed vs predicted



Observer length: observed vs predicted



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

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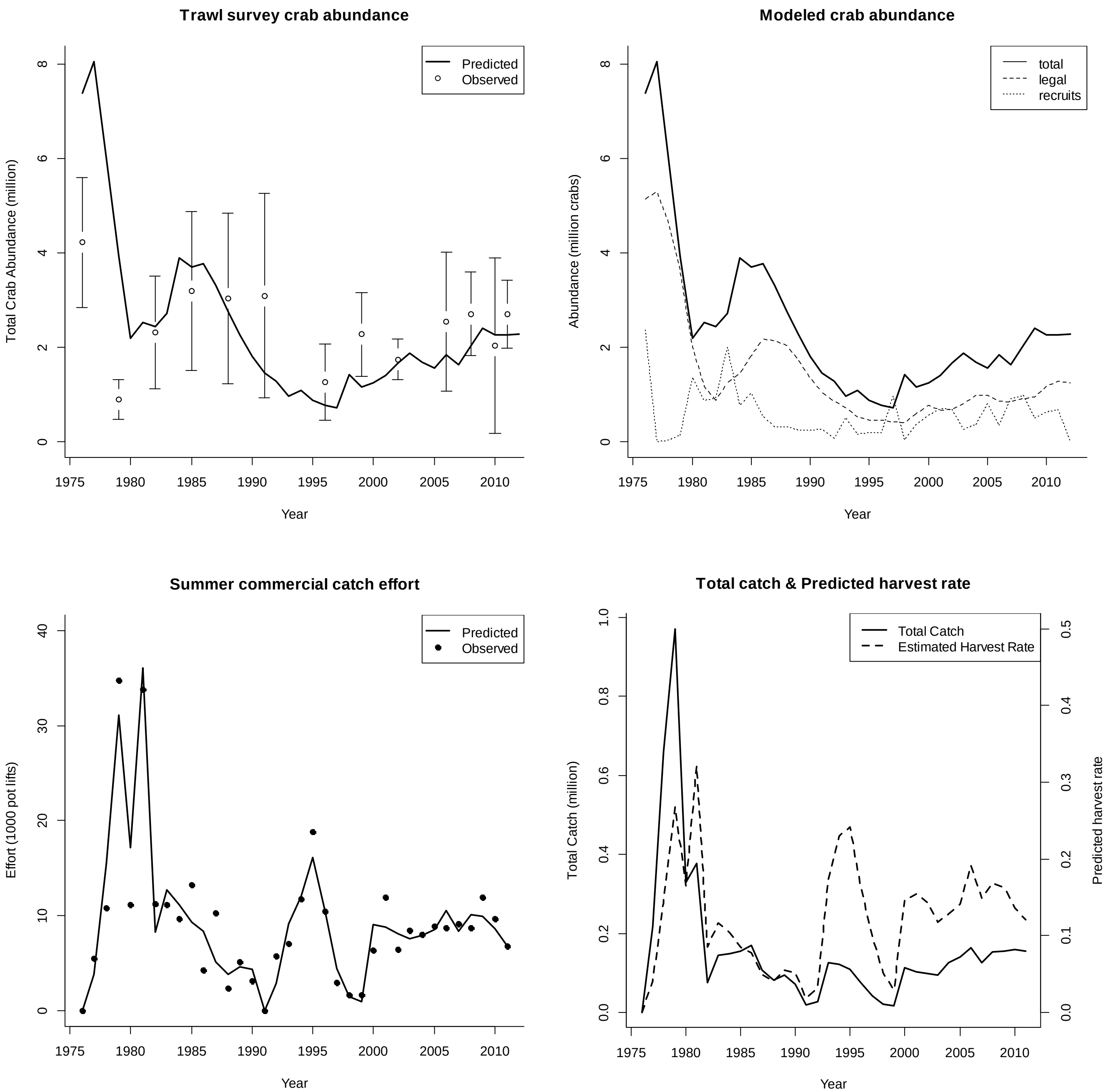
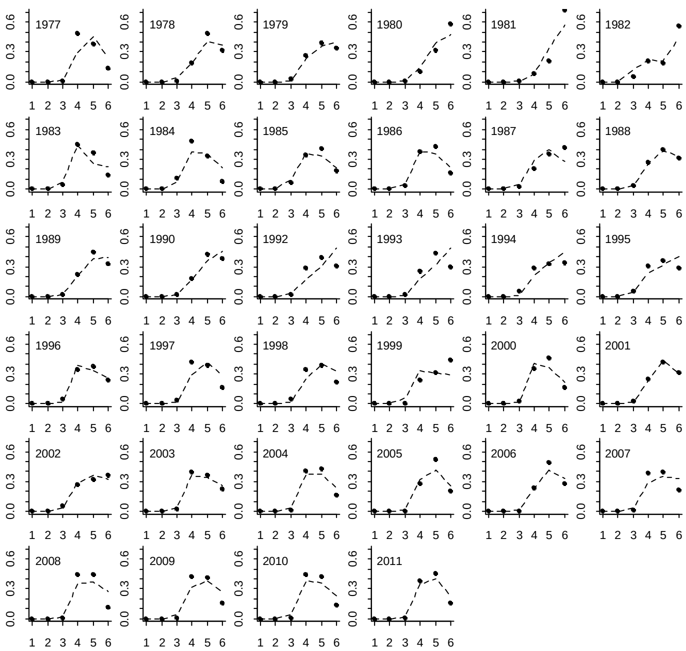
Alternative model 14: Model 4 (lamc=100) + Model 6 (maxss=50) + Model 2 (ms6 = 3.6)

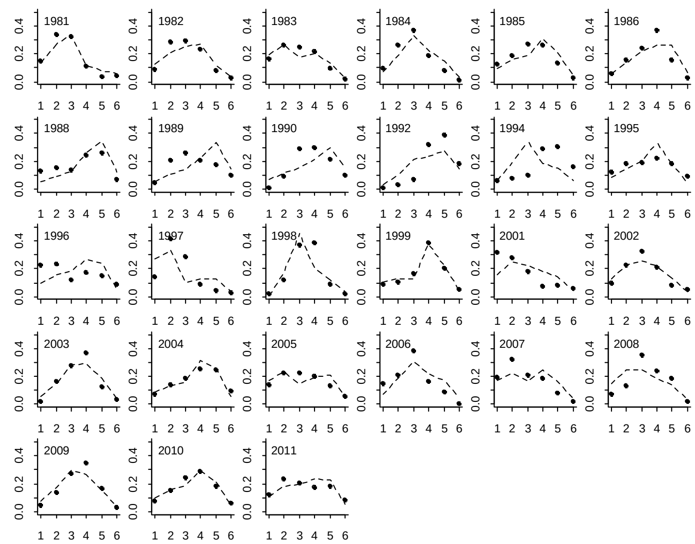


commercial harvest length: observed vs predicted



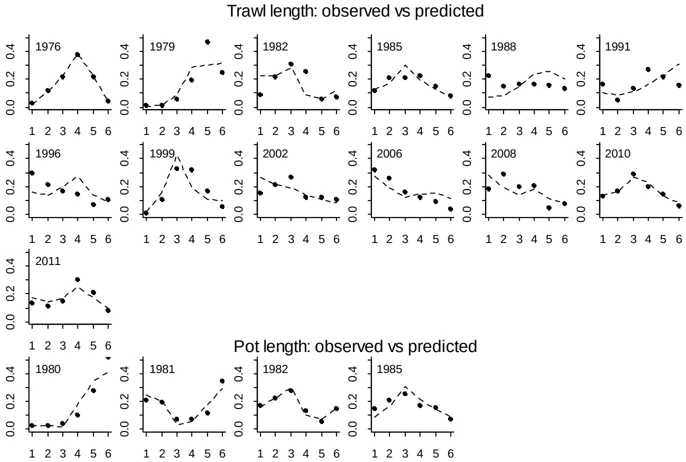
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Winter pot length: observed vs predicted

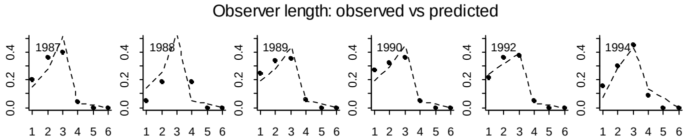


1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

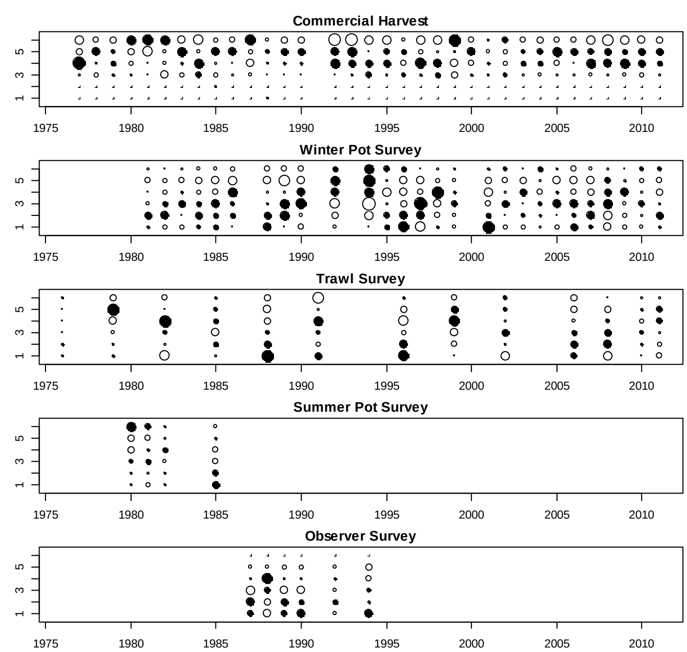
Trawl length: observed vs predicted



Observer length: observed vs predicted



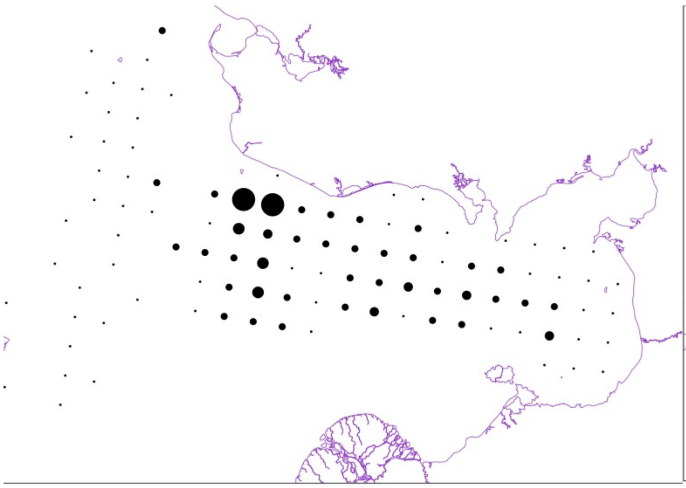
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

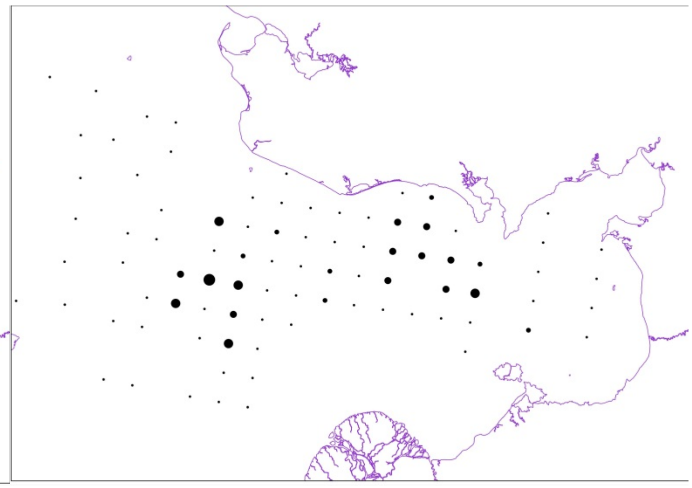



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

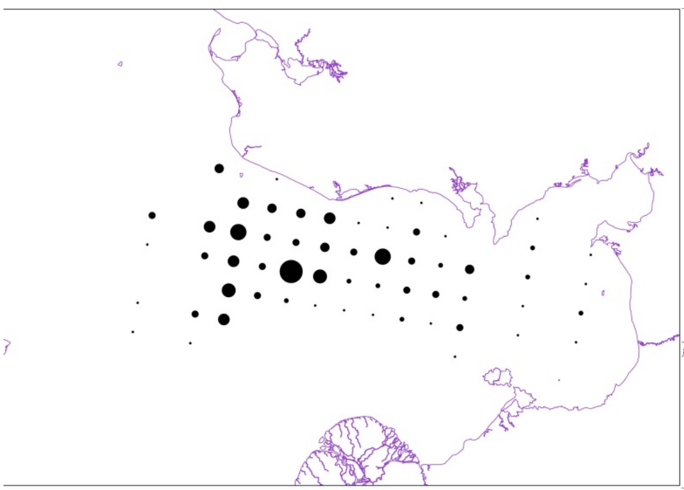
Appendix E: Trawl Survey Location and CPUE. Larger circle indicate higher CPUE. The smallest dots indicate 0 CPUE.

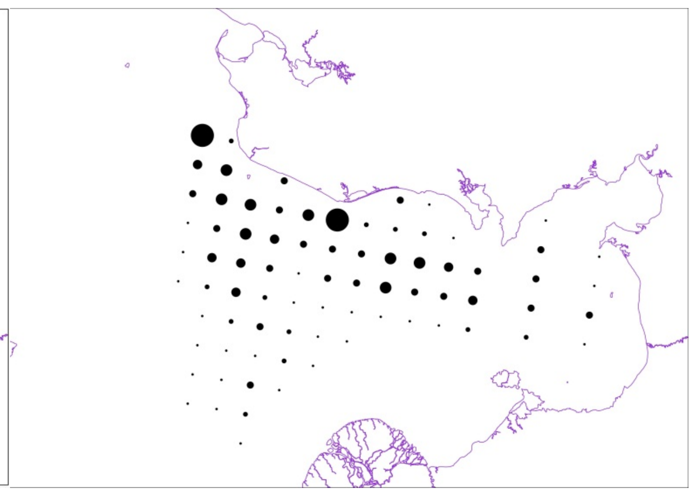
1976 1979



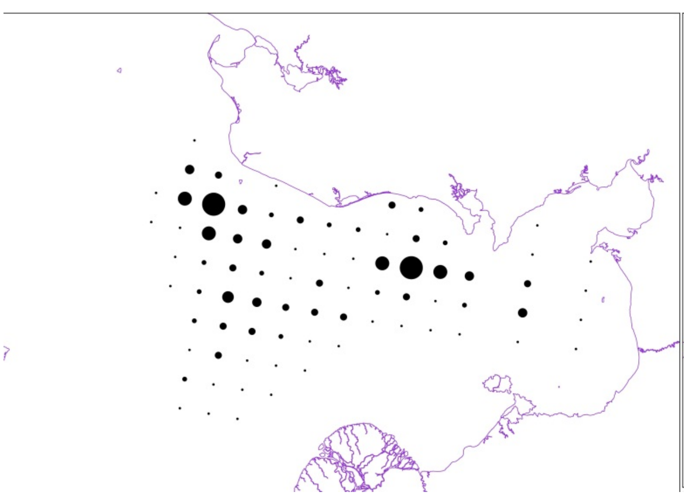


1982 1985

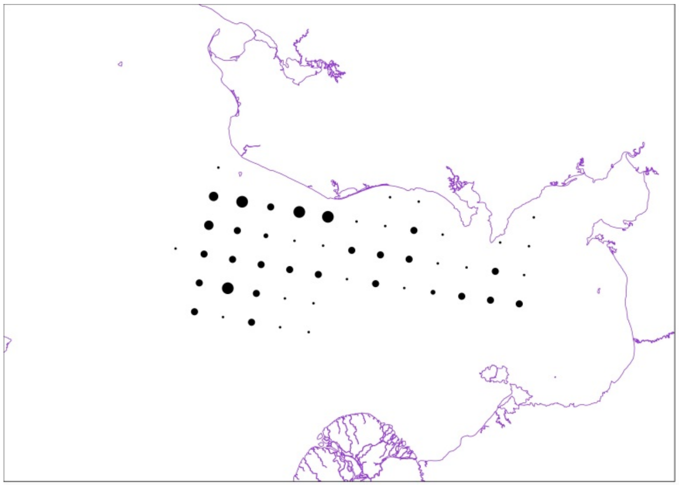


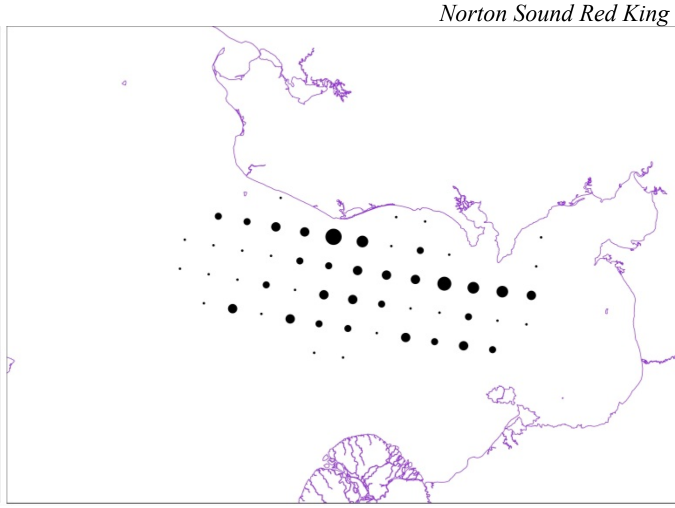


1988 1991



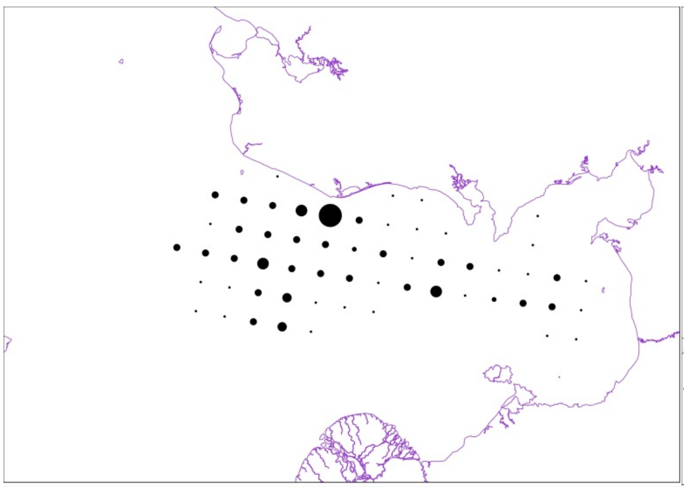
1996 1999

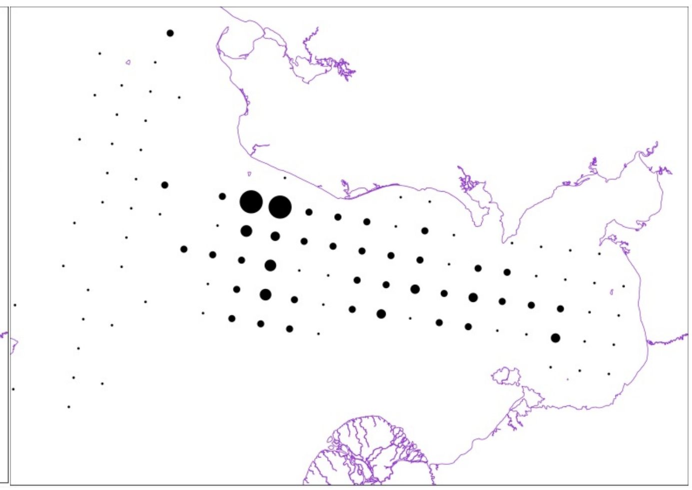




2002

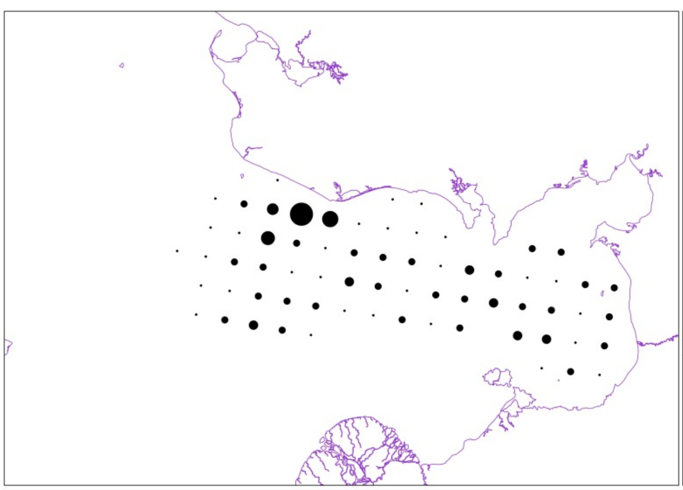
2006

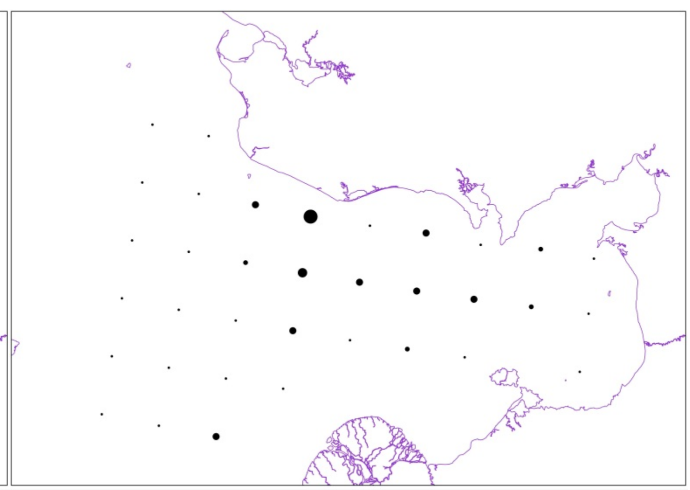




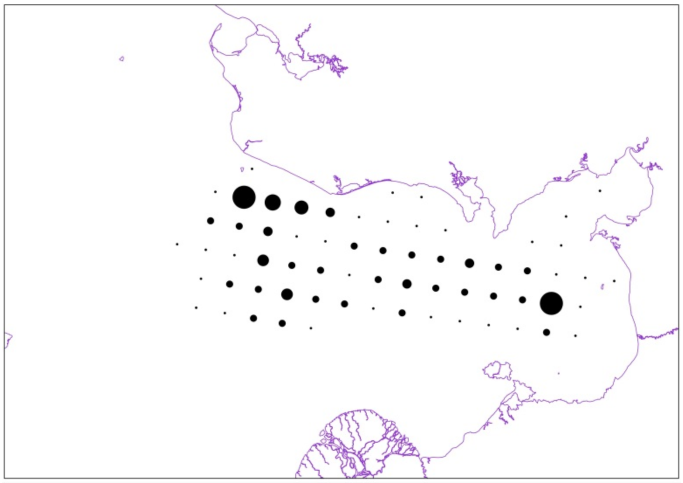
2008

2010





2011



Appendix F

Comparison of full vs. without the latest winter pot survey data.

Norton Sound red king crab summer CDQ commercial fishery can start as soon as ice is out of Norton Sound (April – May) before NPFMC's determination of OFL and ABC (June). Hence, we recommend that the Norton Sound Crab assessment and finalization of OFL and ABC be done at April NPFMC meeting. Moving the date, would result in the loss of the winter pot survey length frequency data. Here we compared results of projected MMB, Bmsy, OFL, and ABC of the Model 12 between full and without winter data (Reduced).

| | Full | Reduced |
|---|---|---|
| Projected MMB 2012 | 4.251 | 4.259 |
| Projected Legal Biomass 2012 | 3.213 | 3.237 |
| Bmsy | 3.515 | 3.522 |
| B/Bmsy | 1.209 | 1.209 |
| OFL | 0.529 | 0.533 |
| ABC | | |
| Buffer 10% | 0.476 | 0.480 |
| P*=49 | 0.526 | 0.530 |
| P*=40 | 0.491 | 0.497 |
| P*=49, sigma-b = 0.4 | 0.522 | 0.527 |
| P*=40, sigma-b = 0.4 | 0.464 | 0.467 |

This suggests that moving the Norton Sound Crab would have little impacts on determination of OFL and ABC.

# Aleutian Islands Golden King Crab

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

Douglas Pengilly, ADF&G, Kodiak

### Executive Summary

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

2. **Catches:**

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

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

**3. Stock biomass:**

Estimates of stock biomass are not available for this Tier 5 assessment.

**4. Recruitment:**

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

**5. Management performance:**

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

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

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

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

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

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

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

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

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

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

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

## *A. Summary of Major Changes*

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

   (a) Until the Aleutian Islands golden king crab stock assessment model and a state regulatory harvest strategy are established, the harvest levels for the Registration Area O golden king crab fishery are as follows:

   (1) east of 174° W long.: 3.31 million pounds; and
   (2) west of 174° W long.: 2.98 million pounds;

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

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

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

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

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

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

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

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

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

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

  *where:*

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

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

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

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

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

## C. Introduction

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

2. **Description of general distribution:**

General distribution of golden king crab is summarized by NMFS (2004):

> Golden king crab, also called brown king crab, range from Japan to British Columbia. In the BSAI, golden king crab are found at depths from 200 m to 1,000 m, generally in high-relief habitat such as inter-island passes (page 3-34).
>
> Golden, or brown, king crab occur from the Japan Sea to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett et al. 1985). They are typically found on the continental slope at depths of 300-1,000 m on extremely rough bottom. They are frequently found on coral bottom (page 3-43).

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

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

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

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

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

**<u>Evidence of stock structure</u>:** Given the expansiveness of the Aleutian Islands Area and the existence of deep (>1,000 m) canyons between some islands, at least some weak structuring of the stock within the area would be expected. Data for making inferences on stock structure of golden king crab within the Aleutian Islands is largely limited to the geographic location of commercial fishery catch and effort. Effort and catch by statistical area since 1982 and locations of over 70,000 fished pots that were sampled by observers since 1996 seasons indicate that habitat for legal-sized males may be continuous throughout the waters adjacent to the Aleutian Islands. However, regions within the area in which available habitat is attenuated are suggested by regions of low fishery effort and catch (Figures 3 and 4); for example the southern side of islands between 174° W longitude and 177° W longitude (i.e., from Atka I. west to Adak I.) as compared to the area surrounding islands between 170°W longitude and 173° W longitude (i.e., between the Islands of the Four Mountains and Seguam Pass). Additionally, there is a gap of catch and effort in statistical areas between Petrel Bank/Petrel Spur and Bowers Bank, both of which areas have reported effort and catch. Recoveries during commercial fisheries of golden king crab tagged during ADF&G surveys (Blau and Pengilly 1994, Blau et al. 1998, Watson and Gish 2002, Watson 2004, 2007) provided no evidence of substantial movements by crab in the size classes that were tagged (males and females ≥90-mm CL). Maximum straight-line distance between release and recovery location of 90 golden king crab released prior to the 1991/92 season and recovered through the 1992/93 season was 33.1 nm (61.2 km; Blau and Pengilly 1994). Of the 4,053 recoveries reported through 14 March 2008 of the golden king crab tagged and released between 170.5° W longitude and 171.5° W longitude during the 1997, 2000, 2003, and 2006 triennial ADF&G Aleutian Island golden king pot surveys, none were recovered west of 174° W longitude and only four were recovered west of 172° W longitude (L. J. Watson, Fishery Biologist, ADF&G, Kodiak, retired; personnel communication).

**3. <u>Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology)</u>:**

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. <u>Brief summary of management history</u>:**

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

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

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

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

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

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

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

Golden king crab may be commercially fished only with king crab pots (as defined in **5 AAC 34.050**). Pots used to fish for golden king crab in the Aleutian Islands Area may be operated only from a shellfish longline and, since 1996, must have at least four escape rings of five and one-half inches minimum inside diameter installed on the vertical plane or at least one-third of one vertical surface of the pot composed of not less than nine-inch stretched mesh webbing to permit escapement of undersized golden king crab (**5 AAC 34.625 (b)**). Prior to the regulation requiring an escape mechanism on pots, some participants in the Aleutian Islands golden king crab fishery voluntarily sewed escape rings (typically 139-mm or 5.5") into their gear or, more rarely, included panels with escape mesh (Beers 1992). With regard to the gear used by fishers since the establishment of **5 AAC 34.625 (b)** in 1996, Linda Kozak, a representative of the industry, reported in a 19 September 2008 email to the Crab Plan Team that, "… the golden king crab fleet has modified their gear to allow for small crab sorting," and provided a written statement from Lance Nylander, of Dungeness Gear Works in Seattle, who "believes he makes all the gear for the golden king crab harvesting fleet," saying that, "Since 1999, DGW has installed 9" escape web on the door of over 95% of Golden Crab pot orders we manufactured." In March 2011 (effective for the 2011/12 season) the BOF amended **5 AAC 34.625 (b)** to relax the "biotwine" specification for pots used in the Aleutian Islands golden king crab fishery relative to the requirement in **5 AAC 39.145** (Escape Mechanism for Shellfish and Bottomfish Pots) that "(1) a sidewall ... of all shellfish and bottomfish pots must contain an opening equal to or exceeding 18 inches in length... The opening must be laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 30 thread." **5 AAC 34.625 (b)(1)** allows the opening described in **5 AAC 39.145 (1)** to be "laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 60 [rather than 30] thread."

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

Current regulations stipulate that onboard observers are required during the harvest of 50% of the total golden king crab weight harvested by each catcher vessel and 100% of the fishing activity of each catcher-processor during each of the three trimesters as outlined in **5 AAC 39.645 (d)(4)(A)**.

### *D. Data*

**1. Summary of new information:**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## *E. Analytic Approach*

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

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

It has been recommended by NPFMC (2007b) and by the CPT and SSC in 2009 that the Aleutian Islands golden king crab stock be managed as a Tier 5 stock until the assessment model (Siddeek et al. 2011) is accepted for use. For Tier 5 stocks only an OFL is estimated, because it is not possible to estimate MSST without an estimate of biomass, and "the OFL represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock" (NPFMC 2007b). Additionally, NPFMC (2007b) states that for estimating the OFL of Tier 5 stocks, "The time period selected for computing the average catch, hence the OFL, should be based on the best scientific information available and provide the required risk aversion for stock conservation and utilization goals." Although NPFMC (2007b) defined the OFL in terms of the retained catch, total-catch OFLs may be considered for Tier 5 stocks for which nontarget fishery removal data are available (Federal Register/Vol. 73, No. 116, 33926). The CPT (in May 2010) and the SSC (in June 2010) endorsed the use of a total-catch OFL to establish the 2010/11 OFL for this stock. This assessment recommends – and only considers – use of a total-catch OFL for 2012/13.

Additionally, NPFMC (2007b) states that for estimating the OFL of Tier 5 stocks, "The time period selected for computing the average catch, hence the OFL, should be based on the best scientific information available and provide the required risk aversion for stock conservation and utilization goals." Prior to 2008, two time periods considered for computing the average retained catch for Aleutian Islands golden king crab: 1985–2005 (NPFMC 2007a) and 1985–1999 (NPFMC 2007b). NPFMC (2007b) suggested using the average retained catch over the years 1985 to 1999 as the estimated OFL for Aleutian Islands golden king crab. Years post-

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

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

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

where

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

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

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

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

where,

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

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

## 3. <u>Model Selection and Evaluation</u>:

### a. ***<u>Description of alternative model configurations</u>***

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

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

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

where,

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

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

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

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

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

where,

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

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

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

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

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

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

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

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

f. ***Do parameter estimates for all models make sense, are they credible?:***
The time period used for determining the OFL was established by the SSC in June 2010. However, temporal trends exist in the retained catch (Figure 6) and in the ratio of the estimated bycatch mortality in crab fisheries to the retained catch (Figure 7) during that period. An interesting relationship exists between the ratio of the estimated bycatch mortality in crab fisheries to the retained catch and the retained weight for the season (Figure 8), but that trend is difficult to separate from the temporal trend. Estimates of total retained catch (pounds) during a season are from fish tickets landings recorded at landings and are assumed here to be correct. Estimates of bycatch from crab fisheries data are generally considered credible (e.g., Byrne and Pengilly 1998, Gaeuman 2011). Estimates of bycatch mortality are estimates of bycatch times an assumed bycatch mortality rate. Bycatch mortality rates have not been estimated from data.

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

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

i. ***Evaluation of the model, if only one model is presented; or evaluation of alternative models and selection of final model, if more than one model is presented:*** The two alternatives differ only in the time period that is used to estimate the average annual ratio of pounds of bycatch mortality due to crab fisheries to pounds of retained crab in the directed fishery. Both alternatives follow the June 2010 SSC recommendations to freeze the time period to stabilize the control role by using only 1985/86–1995/96 to estimate the average annual retained catch component of the OFL and to not include bycatch data after 2008/09. Alternative 1 (status quo) follows the June 2010 argument of the SSC that the approach that "includes the most data... may be the most robust" [*ordering of the two quoted phrases (separated by ellipses) switched by the author for clarity of exposition!*] by using the time period 1990/91–2008/09 to estimate the average annual ratio of pounds of bycatch mortality due to crab fisheries to pounds of retained crab in the directed fishery during 1985/86–1995/96. Alternative 2 uses the time period 1990/91–1995/96 to estimate that average annual ratio for the period 1985/86–1995/96. The author recommends the Alternative 2 approach because the bycatch data from 1990/91–1995/96 can be considered more representative of the conditions that existed during 1985/86–1995/96: they are from within the period 1985/86–1995/96; regulations stipulating escape mechanisms in pots became effective after 1995/96 (see section **C.5-Brief summary of management history**); and there is a clear decreasing trend in the estimated ratio of pounds of bycatch mortality due to crab fisheries to pounds of retained crab in the directed fishery since 1996/97 (Figure 7). Someone other than the author will need to come up with the argument supporting the approach of Alternative 1 (i.e., for including the data on bycatch due to crab fisheries from 1996/97–2008/09 to estimate the bycatch rate during the 1985/86–1995/96 crab fisheries).

**4. Results (best model(s)):**

***a. List of effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties:*** Not applicable.

***b. Tables of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible; include estimates from previous SAFEs for retrospective comparisons):*** See Tables 5–7.

***c. Graphs of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible):*** Information requested for this subsection is not applicable to a Tier 5 stock.

***d. Evaluation of the fit to the data:*** Not applicable for Tier 5 stock.

***e. Retrospective and historic analyses (retrospective analyses involve taking the "best" model and truncating the time-series of data on which the assessment is based; a historic analysis involves plotting the results from previous assessments):*** Not applicable for Tier 5 stock.

***f. Uncertainty and sensitivity analyses (this section should highlight unresolved problems and major uncertainties, along with any special issues that complicate scientific assessment, including questions about the best model, etc.):*** For a Tier 5 assessment, the major uncertainties are:

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

2009 recommended that the years 1990/91–1995/96 be used to compute the retained-catch OFL (resulting in a retained-catch OFL of 6.93-million pounds). In both 2008 and 2009, the SSC overrode the CPT's recommendation and recommended that the years 1985/86–1995/96 to compute the retained-catch OFL at 9.18-million pounds. The SSC recommended that the time period for computing the retained-catch portion of the OFL "be frozen" at 1985/86–1995/96 "to stabilize the control rule."
  - The Tier 5 OFL is also sensitive to the choice of years used to estimate the average annual ratio of pounds of bycatch mortality to pounds of retained crabs in the crab fisheries. The SSC recommended that the time period for computing the bycatch-mortality portion of the OFL be frozen to end at 2008/09. The estimates of annual bycatch biomass (not discounted for bycatch mortality) to retained catch are generally highest during 1990/91–1995/96 and show a decreasing trend during 1996/97–2008/09: that ratio during 1990/91–1995/96 ranges from 1.5:1 to 2.1:1, during 1996/97–2004/05 ranges from 0.8:1 to 1.7:1, and during 2005/06–2008/09 ranges from 0.5:1 to 0.6:1 (see Table 2; see also Figure 7 for the trend in ratios after a default bycatch mortality rate is applied to the bycatch biomass estiamates). Hence including the later years to compute the average annual ratio decreases the OFL estimate, whereas restricting the period to 1990/91–1995/96 increases the OFL estimate.
  - The Tier 5 OFL has only a slight sensitivity to the choice of years used to compute the bycatch due to groundfish fisheries. This assessment only considers the period 1993/94–2008/09 for bycatch in the groundfish fisheries. Estimates of annual bycatch mortality due to groundfish fisheries during 1993/94–2008/09 range from <0.01-million pounds to 0.130-million pounds. Because the estimates of bycatch biomass due to groundfish fisheries is small relative to the biomass of retained catch (≥4.82-million pounds annually during 1985/86–2010/11), the effect of choice of years here is negligibly small.
- The assumed bycatch mortality rates used in estimation of total fishery mortality. Bycatch mortality is unknown and no data that could be used to estimate the bycatch mortality of this stock is known to the author. Hence only the values that are assumed for other BSAI king crab stock assessments are considered in this assessment. Due to the difference in scale between the estimated bycatch in crab fisheries and the groundfish fisheries (see bullet above), the estimated OFL is most sensitive to the assumed bycatch mortality in crab fisheries and less sensitive to the assumed bycatch in groundfish fisheries. Given a fixed period of years to compute the average of annual bycatch biomass estimates for the crab fisheries, the estimated OFL increases (decreases) linearly with increases (decreases) in the bycatch mortality rate assumed for the crab fisheries: double the assumed bycatch mortality rate from 0.2 to 0.4, and the OFL estimate increases by a factor of 1.4/1.2 = 1.17; half the assumed bycatch mortality rate from 0.2 to 0.1, and the OFL estimate decreases by a factor of 1.1/1.2 = 0.92.

## *F. Calculation of the OFL*

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

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

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

**2. List of parameter and stock size estimates (or best available proxies thereof) required by limit and target control rules specified in the fishery management plan:** Not applicable for Tier 5 stock.

**3. Specification of the OFL:**

***a. Provide the equations (from Amendment 24) on which the OFL is to be based:***

From **Federal Register** / Vol. 73, No. 116, page 33926, "For stocks in Tier 5, the overfishing level is specified in terms of an average catch value over an historical time period, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information." Additionally, "For stocks where nontarget fishery removal data are available, catch includes all fishery removals, including retained catch and discard losses. Discard losses will be determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks where only retained catch information is available, the overfishing level is set for and compared to the retained catch" (FR/Vol. 73, No. 116, 33926). That compares with the specification of NPFMC (2007b) that the OFL "represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock."

***b. Basis for projecting MMB to the time of mating:*** Not applicable for Tier 5 stock.

***c. Specification of $F_{OFL}$, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:*** See table below. 2012/13 OFL and ABC are author's recommendations. 2012/13 TAC has not yet been determined; the value given in the table is the default TAC according to current SOA regulations

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

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

**4. Specification of the retained-catch portion of the total-catch OFL:**

***a.*** **Equation for recommended retained-portion of total-catch OFL.**

Retained-catch portion = average retained catch during 1985/86–1995/96
= 9,178,438 pounds (9.18-million pounds).

5. **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 9 (1,000 samples drawn with replacement independently from each of the three columns of values in Table 5 to calculate $R_{90/91\text{-}08/09}$, $RET_{85/86\text{-}95/96}$, $BM_{GF,93/94\text{-}08/09}$ and $OFL_{Alt\text{-}1,2010/11}$ and 1,000 samples drawn with replacement independently from each of the three columns of values in Table 6 to calculate $R_{90/91\text{-}95/96}$, $RET_{85/86\text{-}95/96}$, $BM_{GF,93/94\text{-}08/09}$ and $OFL_{Alt\text{-}2,2010/11}$). Table 7 provides statistics on the generated distributions.

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

- The time period to compute the average catch relative to assumption that it represents "a time period determined to be representative of the production potential of the stock."
- Bycatch mortality rate in each fishery that bycatch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch rate will increase the total-catch OFL (and hence the ABC), but has no effect on the retained-catch portion of the OFL or the retained-catch portion of the ABC.
- Estimated bycatch and bycatch mortality for each fishery that bycatch occurred in during 1985/86–1995/96.
- See **E.4.*f*** for details.

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

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

## *H.* Rebuilding Analyses

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

## *I.* Data Gaps and Research Priorities

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

## J. Literature Cited


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**Table of tables**.

**<u>Table of figures</u>.**

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

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

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

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

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

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

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

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

| Season | Retained Catch | Bycatch Mortality by Fishery Type | | Total estimated fishery mortality |
|---|---|---|---|---|
| | | 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 |
| 2010/11 | 5,968,849 | 545,264 | 43,569 | 6,557,682 |

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

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

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

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

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

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

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

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

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

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

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

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

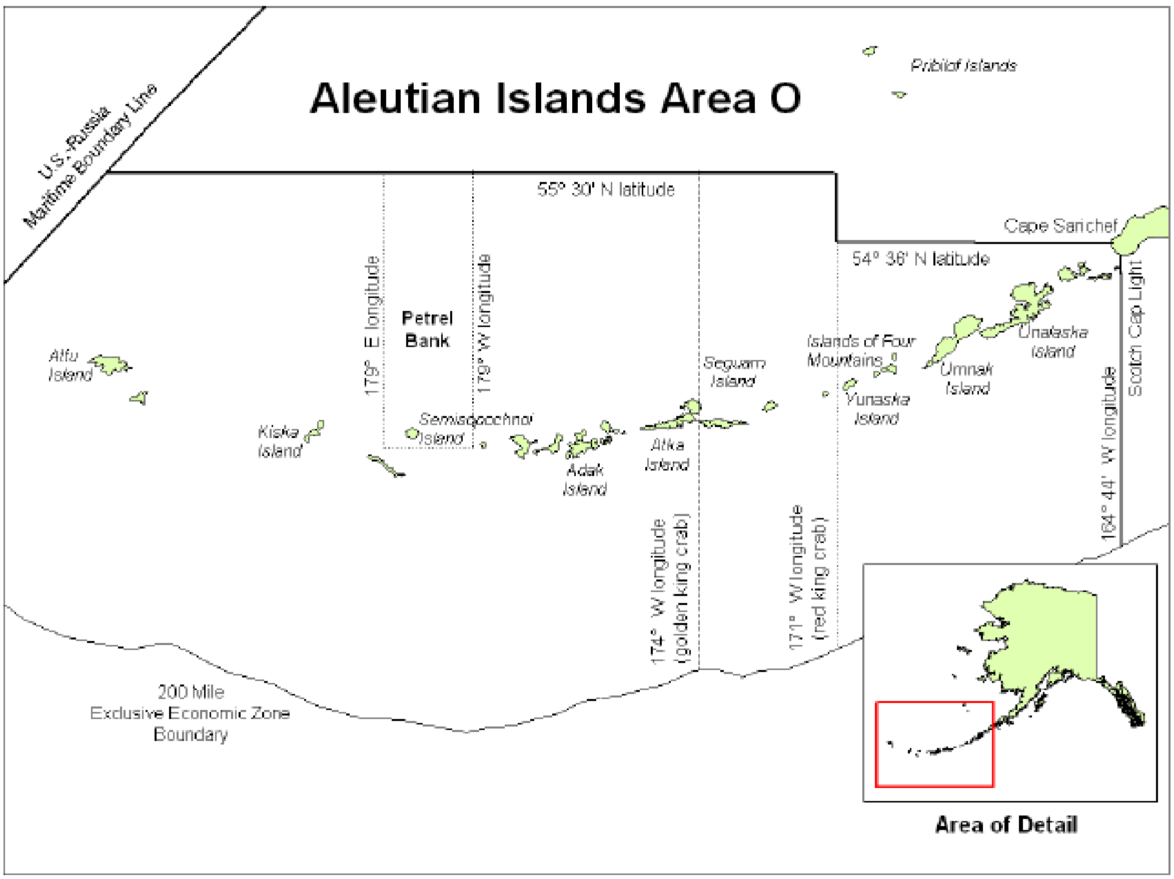


Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Bowers et al. 2011).

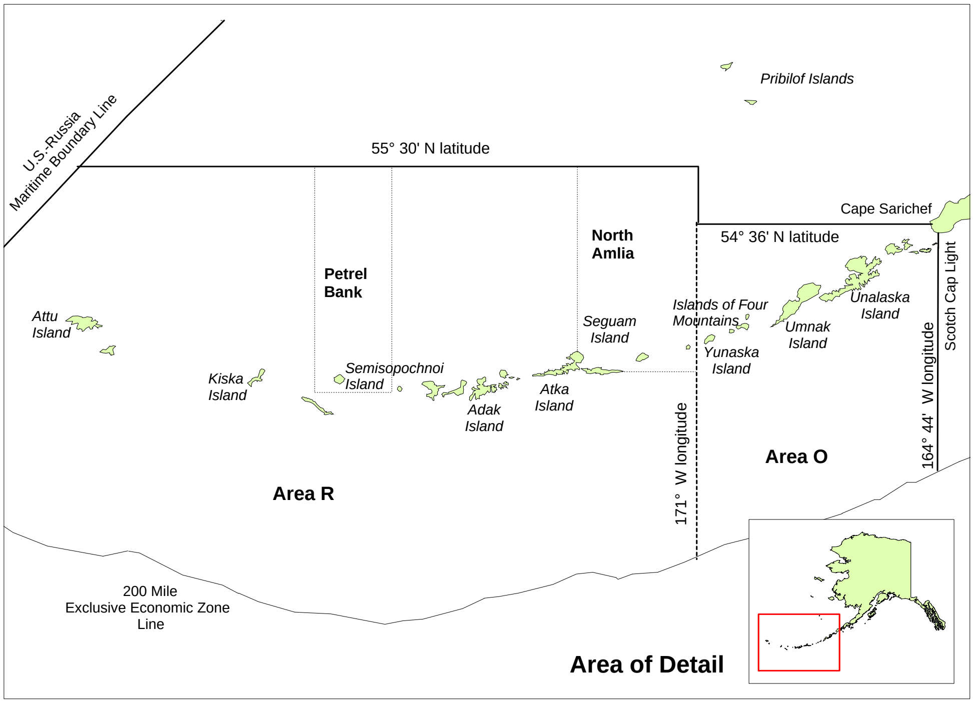


Figure 2. Adak (Area R) and Dutch Harbor (Area O) king crab Registration Areas and Districts, 1984/85 – 1995/96 seasons (Bowers et al. 2011).

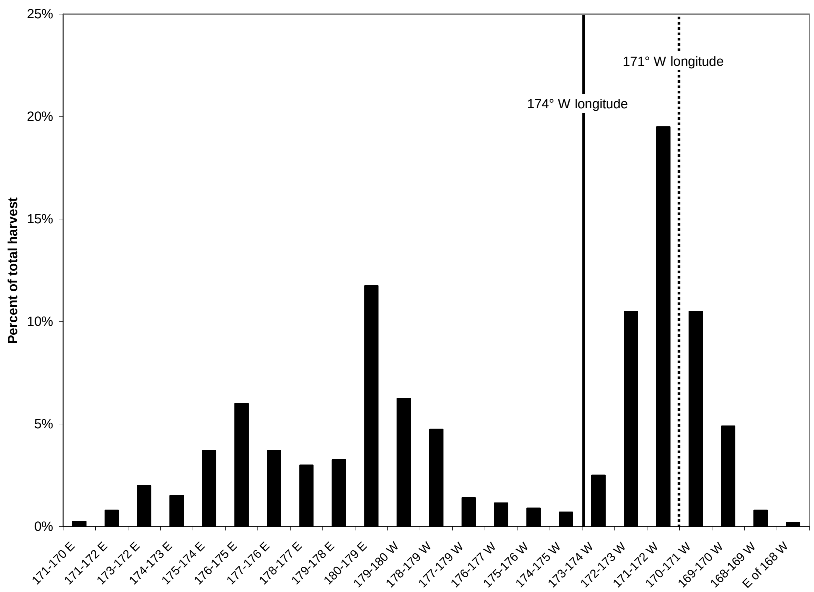


Figure 3. Percent of total 1982–1996 golden king crab harvest by one-degree longitude intervals in the Aleutian Islands, with dotted line denoting the border at 171° W longitude that was used until the end of the 1995/96 season to divide fishery management between the Dutch Harbor Area (east of 171°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

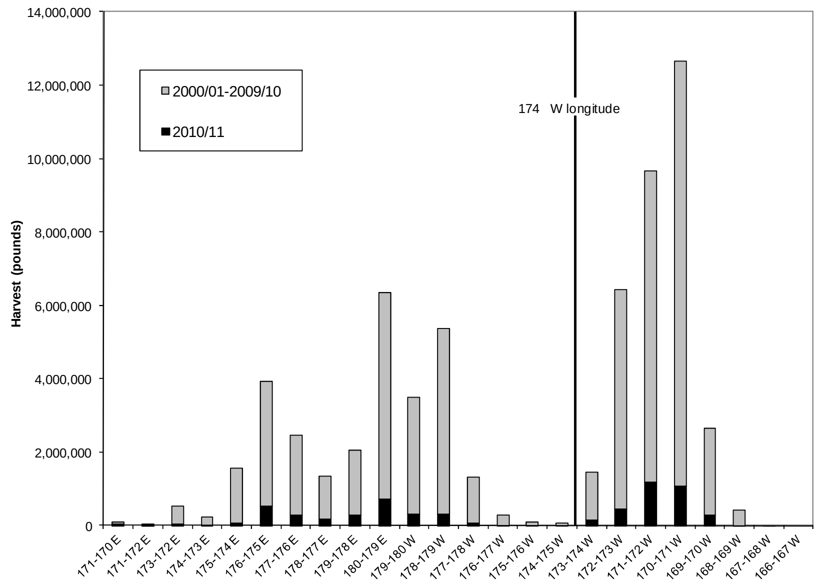


Figure 4. Harvest (pounds) of golden king crab by one-degree longitude intervals in the Aleutian Islands during the 2000/01 through 2010/11 commercial fishery seasons; solid line denotes the border at 174° W longitude that has been used since the 1996/97 season to manage Aleutian Island golden king crab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

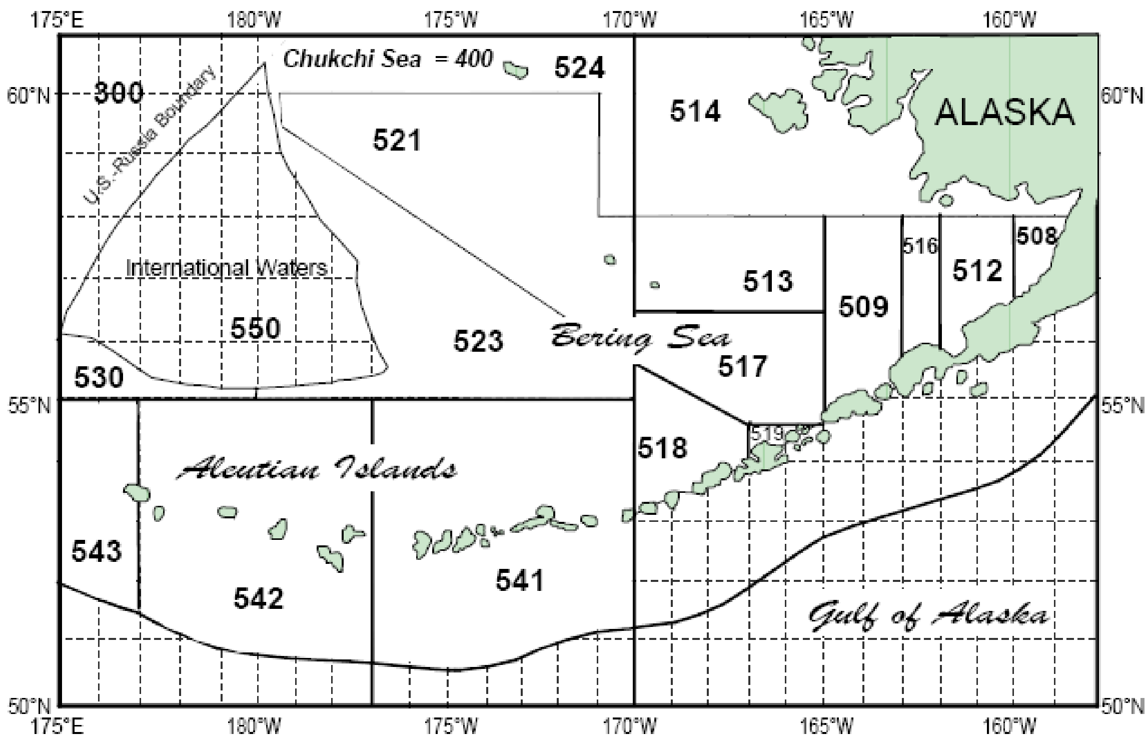


Figure 5. Map of federal groundfish fishery reporting areas for the Bering Sea and Aleutian Islands showing reporting areas 541, 542, and 543 that are used to obtain data on bycatch of Aleutian Islands golden king crab during groundfish fisheries (from http://www.fakr.noaa.gov/rr/figures/fig1.pdf).

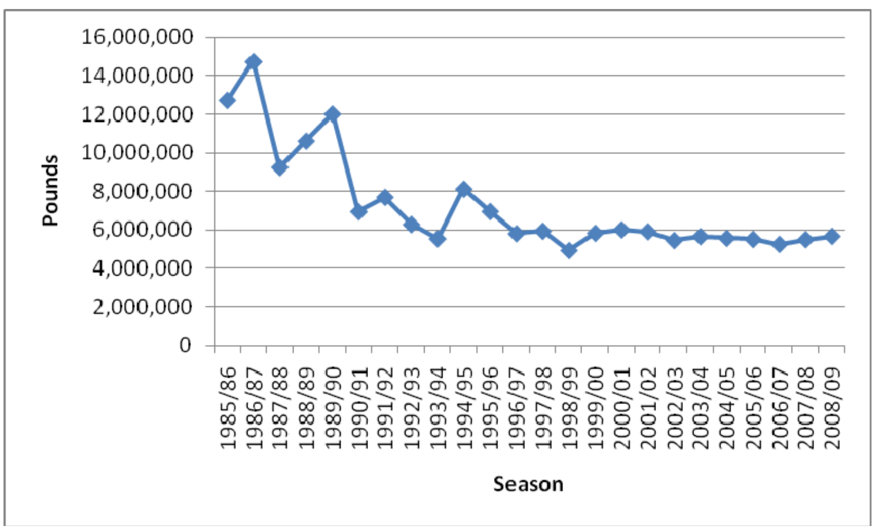


Figure 6. Retained catch (pounds) in the Aleutian Islands golden king crab fishery, 1985/86–2008/09.

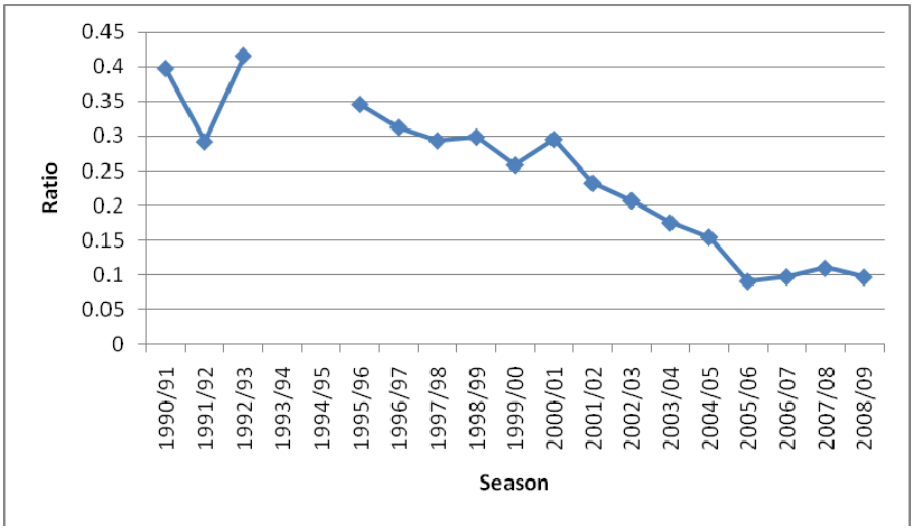


Figure 7. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Islands golden king crab, 1990/91–2008/09 (ratios for 1993/94–1994/95 not available due to data confidentialities and insufficiencies).

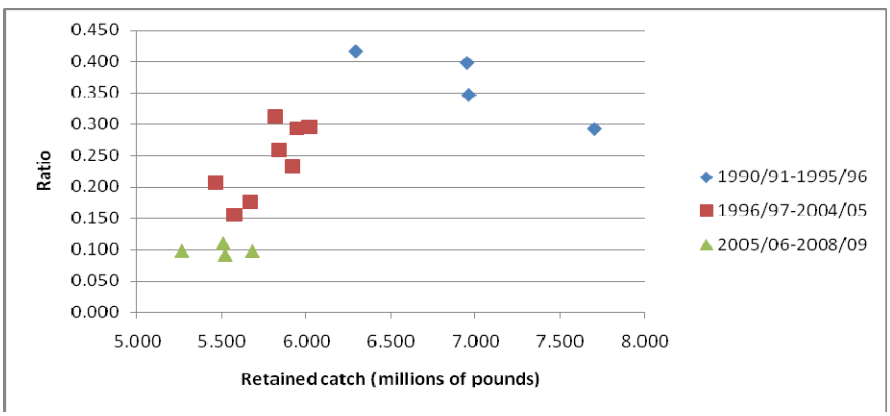


Figure 8. Ratio of estimated weight of bycatch mortality in directed and non-directed crab fisheries to weight of retained catch for Aleutian Islands golden king crab plotted against weight of retained catch, 1990/91–2008/09 (ratios for 1993/94–1994/95 not available due to data confidentialities and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

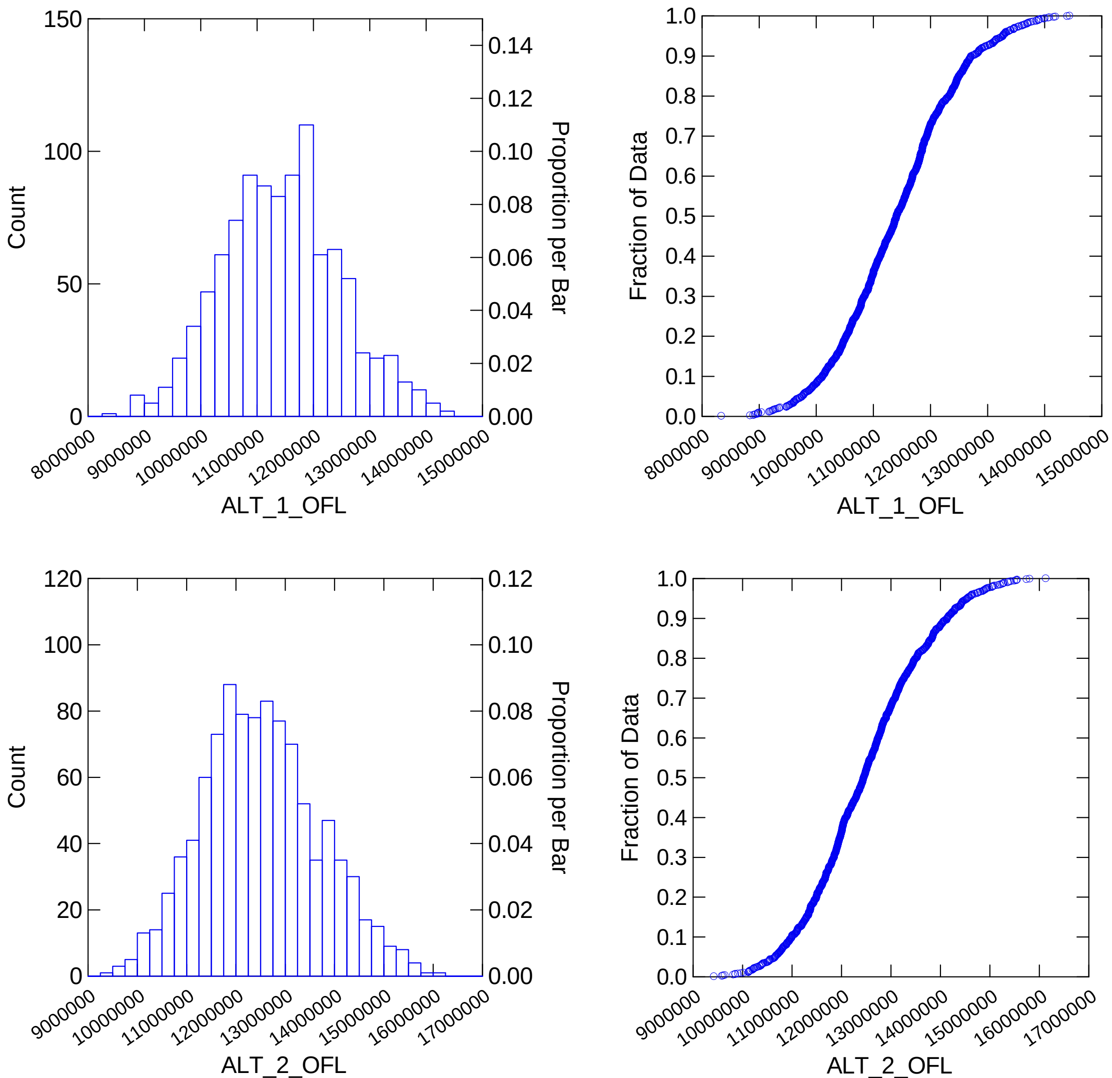


Figure 9. Bootstrapped estimates of the sampling distribution of the Alternative 1 (above) and Alternative 2 (below) 2012/2013 Tier 5 OFLs (pounds of total-catch) for the Aleutian Islands golden king crab stock; histograms in left column, quantile plots in right column.

# Pribilof Islands Golden King Crab

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

Douglas Pengilly, ADF&G, Kodiak

## Executive Summary

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

2. **Catches:**

Commercial fishing for golden king crab in the Pribilof District has been concentrated in the Pribilof Canyon. The fishing season for this stock has been defined as a calendar year (as opposed to a "crab fishery year") following the close of the 1983/84 season. The domestic fishery developed in the 1982/83 season, although some limited fishing occurred at least as early as 1981/82. Peak harvest occurred in the 1983/84 season with a retained catch of 0.856-million pounds (388 t) by 50 vessels. Since then, participation in the fishery has been sporadic and annually retained catch has been variable, from 0 pounds in the nine years that no vessels participated (1984, 1986, 1990–1992, 2006–2009) up to a maximum of 0.342-million pounds (155 t) in 1995, when seven vessels made landings. The fishery is not rationalized. There is no state harvest strategy in regulation. A guideline harvest level (GHL) was first established for the fishery in 1999 at 0.200-million pounds (91 t) and has been managed towards a GHL of 0.150-million pounds (68 t) since 2000. No vessels participated in the directed fishery and no landings were made during 2006–2009. One vessel landed catch in 2010 and two vessels landed catch in 2011; directed fishery catch cannot be reported in those two years under the confidentiality requirements of Sec. 16.05.815 (SOA statute). Non-retained bycatch occurs in the directed golden king crab fishery, the eastern Bering Sea snow crab fishery, the Bering Sea grooved Tanner crab fishery, and Bering Sea groundfish fisheries. Estimated annual weight of non-retained bycatch in directed and non-directed crab fisheries during calendar years 2001–2011 ranges from 0 pounds to 0.049-million pounds (22 t). Estimates of annual total fishery mortality during calendar years 2001–2011 due to crab fisheries range from 0 to 0.160-million pounds (73 t), with an average of 0.078-million pounds (35 t). Estimates of annually discarded bycatch during Bering Sea groundfish fisheries are reported for crab fishery years. Those estimates range from <0.001-million (<1 t) to 0.027-million pounds (12 t) annually during the 1991/92–2010/11 crab fishery years. Estimates of annual fishery mortality during 1991/92–2010/11 due to groundfish fisheries range from <0.001-million pounds (<1 t) to 0.019-million pounds (9 t), with an average of 0.006-million pounds (3 t).

3. **Stock biomass:**

Stock biomass (all sizes, both sexes) of golden king crab have been estimated for the Pribilof Canyon area using the area-swept technique applied to data obtained during eastern Bering Sea upper continental slope trawl surveys performed by NMFS-AFSC in 2002, 2004, 2008, and 2010 (Hoff and Britt 2003, 2005, 2009, 2011). The biomass estimate for the Pribilof Canyon area in 2010 was 3.560-million pounds (1,615 t). The biomass estimate for the entire eastern Bering Sea slope survey area in 2010 was 5.071-million pounds (2,300 t).

## 4. Recruitment:

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

## 5. Management performance:

No overfished determination (i.e., MSST) is possible for this stock given the limited information and analysis on stock biomass; there are presently no estimates of mature male biomass or mature female biomass for this stock. Overfishing did not occur during 2011 (the golden king crab season in the Pribilof District is based on a calendar year); the estimated total catch did not exceed the OFL of 0.18-million pounds (82 t). Retained catch and total-catch mortality in 2011 are confidential under the requirements of Sec. 16.05.815 (SOA statute). No ABC was established for the 2011 season. The 2012 season is currently ongoing. Values given in the tables below for the 2013 OFL and ABC are the author's recommendations.

| Year[a] | MSST | Biomass (MMB) | GHL[b] | Retained Catch[c] | Total Catch[c,d] | OFL[c,e] | ABC[c,e] |
|---|---|---|---|---|---|---|---|
| 2009 | N/A | N/A | 0.150 | 0 | 0.001 | 0.17 R | N/A |
| 2010 | N/A | N/A | 0.150 | Conf.[f] | Conf.[f] | 0.17 R | N/A |
| 2011 | N/A | N/A | 0.150 | Conf.[f] | Conf.[f] | 0.18 T | N/A |
| 2012 | N/A | N/A | 0.150 | TBD | TBD | 0.20 T | 0.18 T |
| 2013 | N/A | N/A | TBD | TBD | TBD | [0.20 T] | [0.18 T] |

a. Season is based on a calendar year.
b. Guideline harvest level expressed in millions of pounds.
c. Millions of pounds.
d. Total retained catch plus estimated bycatch mortality during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
e. Noted as "R" for retained-catch-only OFL and "T" for total-catch OFL and ABC.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season.

| Year[a] | MSST | Biomass (MMB) | GHL[b] | Retained Catch[c] | Total Catch[c,d] | OFL[c,e] | ABC[c,e] |
|---|---|---|---|---|---|---|---|
| 2009 | N/A | N/A | 68 | 0 | 0.5 | 77 R | N/A |
| 2010 | N/A | N/A | 68 | Conf. [f] | Conf. [f] | 77 R | N/A |
| 2011 | N/A | N/A | 68 | Conf. [f] | Conf. [f] | 82 T | N/A |
| 2012 | N/A | N/A | 68 | TBD | TBD | 91 T | 82 T |
| 2013 | N/A | N/A | TBD | TBD | TBD | [91 T] | [82 T] |

a. Season is based on a calendar year.
b. Guideline harvest level expressed in t.
c. Metric tons.
d. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by “crab fishery year” rather than calendar year; estimates of annual bycatch mortality during 1991/92–2010/11 groundfish fisheries are ≤9 t, with an average of 3 t.
e. Noted as “R” for retained-catch-only OFL and “T” for total-catch OFL and ABC.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season.

6. **Basis for the OFL and ABC:** The values for 2013 are the author’s recommendation.

| Year[a] | Tier | Years to define Average catch (OFL) | Natural Mortality | Buffer |
|---|---|---|---|---|
| 2009 | 5 | 1993-1999[b] | 0.18[e] | N/A |
| 2010 | 5 | 1993–1998[b] | 0.18[e] | N/A |
| 2011 | 5 | 1993–1998[c] | 0.18[e] | N/A |
| 2012 | 5 | 1993–1998[d] | 0.18[e] | 10% |
| 2013 | 5 | [1993–1998[d]] | [0.18[e]] | [10%] |

a. Season is based on a calendar year.
b. OFL was for retained catch and was determined by the average of the retained catch for these years.
c. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.05 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
d. OFL was for total catch and was determined by the average of the annual retained catch for these years times a factor of 1.052 to account for the estimated bycatch mortality occurring in the directed fishery plus an estimate of the average annual bycatch mortality due to non-directed crab fisheries and groundfish fisheries for the period.
e. Assumed value for FMP king crab in NPFMC (2007); does not enter into OFL estimation for Tier 5 stock.

7. **PDF of the OFL:** Sampling distribution of the two alternative Tier 5 OFLs was estimated by bootstrapping. The standard deviation of the estimated sampling distribution of the recommended OFL (Alternative 1) is 0.510-million pounds (CV = 0.25). See section G.1.

8. **Basis for the ABC recommendation:** A 10% buffer on the OFL, the default; i.e., ABC = (1-0.1)·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. Fishery continues to be managed under authority of an ADF&G commissioner's permit and with a guideline harvest level (GHL) of 0.150-million pounds. As of this writing, one vessel has registered for the 2012 season, but has not yet begun fishing (H. Fitch, ADF&G, 23 April 2012 email).

2. **Changes to the input data:**
   - Retained catch and bycatch data has been updated with the results for the 2011 directed fishery, during which only two vessels participated in the fishery, rendering the catch data confidential under the requirements of Sec. 16.05.815 (SOA statute).
   - Information on bycatch during other crab fisheries during 1993 (0 bycatch in the snow crab fishery and no data for the grooved Tanner crab fishery) was added.
   - Bycatch estimates have been updated using the data collected from groundfish fisheries during 2010/11.

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

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

     $$OFL_{tot,2011} = 1.05 * OFL_{ret,1993\text{-}1998} + 0.006\text{-million pounds.}$$

     $OFL_{ret,1993\text{-}1998}$ is the average annual retained catch in the directed fishery during 1993–1998. The factor of 1.05 was used to account for the crab bycatch mortality in the directed crab fishery and 0.006-million pounds was used to account for the "background level" of bycatch mortality occurring in the groundfish and non-directed crab fisheries, estimated by the average annual bycatch mortality using data available; 2001–2005 for crab fisheries and 1991/92–2008/09 for groundfish fisheries.
   - The OFL for 2012 was a total-catch OFL of 0.20-million pounds and was estimated using 1993–1998 to compute average annual retained catch, an estimate of pounds of bycatch mortality per pound of retained catch during the directed fishery, an estimate of the average annual bycatch mortality due to non-directed crab fisheries during 1994–1998 and an estimate of average annual bycatch mortality due to groundfish fisheries during 1992/93–1998/99; i.e.,

$OFL_{TOT(1),2012} = (1+R_{2001–2010})*RET_{1993-1998} + BM_{NC,1994-1998} + BM_{GF,1992/93–1998/99}$,

where,

- $R_{2001–2010}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained in the directed fishery during 2001–2010
- $RET_{1993-1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998
- $BM_{NC,1994-1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
- $BM_{GF,1992/93–1998/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

- The recommended OFL for 2013 is a total-catch OFL of 0.20-million pounds, estimated by the calculations given for the 2012 OFL.

## B. Responses to SSC and CPT Comments

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

2. **Responses to the most recent two sets of SSC and CPT comments specific to the assessment:**
   - CPT, May 2011: *"The team concurred with the author's recommendation for the OFL based on Alternative 1. This freezes the time frame to that used previously and provides the retained catch data now available corresponding roughly with that time frame and total fishery mortality estimates over that time frame." "The team concurred with the author's recommendation for an ABC = maximum permissible ABC."*
     - Response: The Alternative 1 OFL and ABC presented here for 2013 are the same as the Alternative 1 OFL and ABC for 2012 that were presented to the CPT in May 2011.

- SSC, June 2011: The SSC recommended: 1) *"… calculating OFL using the average annual ratio of bycatch mortality to retained catch between 2001 and 2010, average annual retained catch from 1993 through 1998, average annual bycatch mortality in non-directed crab fisheries during 1994-1998, and the average annual rate of bycatch mortality in groundfish fisheries over 1992/93-1998/99"*; and 2) *"using the 10% buffer for tier-5 stocks"* to calculate the ABC. The SSC also encouraged the author to explore the eastern Bering Sea upper continental slope survey data *"for their utility to provide estimates of biomass for the Pribilof District"*, giving consideration to *"the distribution of the survey with respect to stock distribution, as well as estimation of survey catchability by size and sex."* The SSC looked forward to the results of that examination.
  - Response: The Alternative 1 OFL and ABC presented here for 2013 are the same as recommended for 2012 by the SSC in June 2011. The assessment presents results for golden king crab (as summarized in the survey report) from the 2010 slope survey and compares with results with the previous surveys in 2000, 2002, and 2008. Distribution of the survey with respect to stock distribution is commented on. No estimates of survey catchability by sex and size are presented here, but some comments are made given what information is presented in the survey reports. See **D.4**.

- CPT, September 2011: None.

- SSC, October 2011: None.

## C. Introduction

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

2. **Description of general distribution:** General distribution of golden king crab is summarized by NMFS (2004):

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

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

The Pribilof District is part of king crab Registration Area Q (Figure 1). Bowers et al. (2011, pages 87–88) define those boundaries:

> The Bering Sea king crab Registration Area Q has as its southern boundary a line from 54° 36' N lat., 168° W long., to 54° 36' N lat., 171° W long., to 55° 30' N lat., 171° W. long., to 55° 30' N lat., 173° 30' E long., as its northern boundary the latitude of Point Hope (68° 21' N lat.), as its eastern boundary a line from 54° 36' N

> lat., 168° W long., to 58° 39' N lat., 168° W long., to Cape Newenham (58° 39' N lat.), and as its western boundary the United States-Russia Maritime Boundary Line of 1991. Area Q is divided into the Pribilof District, which includes waters south of Cape Newenham, and the Northern District, which incorporates all waters north of Cape Newenham.

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

Results of the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea continental slope trawl surveys presented by Haaga et al. (2009) and Hoff and Britt (2003, 2005, 2009, and 2011) show that majority of golden king crab on the eastern Bering Sea continental slope occurred in the 200–400 m and 400–600 m depth ranges (see section D.2.d). Commercial fishing for golden king crab in the Bering Sea typically occurs at depths of 100–300 fathoms (183–549 m; Neufeld and Barnard 2003; Barnard and Burt 2004, 2006; Burt and Barnard 2005, 2006; Gaeuman 2011); average depth of pots fished in the Pribilof golden king crab fishery during the 2002 fishery (the most recently prosecuted fishery for which fishery observer data are not confidential) was 214 fathoms (391 m).

3. **Evidence of stock structure:** I am aware of no data for evaluating stock structure within this stock.

4. **Description of life history characteristics relevant to stock assessments (e.g., special features of reproductive biology):** The following review of molt timing and reproductive cycle of golden king crab is adapted from Watson et al. (2002):

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

suggested a reproductive cycle >1 year with a protracted barren phase for female golden king crab. Data from tagging studies on female golden king crab in the Aleutian Islands are generally consistent with a molt period for mature females of 2 years or less and that females carry embryos for less than two years with a prolonged period in which they remain in barren condition (Watson et al 2002). From laboratory studies of golden king crab collected from Prince William Sound, Paul and Paul (2001b) estimated a 20-month reproductive cycle with a 12-month clutch brooding period.

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

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

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

5. **Brief summary of management history:** A complete summary of the management history through 2009 is provided in Bowers et al. (2011, pages 92–94).

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

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

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

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

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

## *D. Data*

**1. <u>Summary of new information</u>:**

1. Retained catch and estimated bycatch during the 2011 directed fishery (both of which are confidential), estimated bycatch in non-directed crab fisheries during 2011, and estimated bycatch in groundfish fisheries during the 2010/11 crab fishery year have been added. Available information on bycatch data from the non-directed crab fisheries in 1993 was added, which turned out to be not much information; there were no observers during the 1993 Bering Sea grooved Tanner crab fishery. Published results of 2010 Bering Sea upper continental slope survey are provided and compared with those of the 2002, 2004, and 2008 surveys.

**2. <u>Data presented as time series</u>:**

***a. <u>Total catch</u> and b. <u>Information on bycatch and discards</u>:***

- The 1981/82–1983/84, 1984–2011 time series of retained catch (number and pounds of crab harvested, including deadloss), effort (vessels, landings, and pot lifts), average weight of landed crab, average carapace length of landed crab, and CPUE (number of landed crab captured per pot lift) are presented in Table 1.
- The 1993–2011 time series of weight of retained catch, estimated bycatch and estimated weight of fishery mortality of Pribilof golden king crab during commercial crab fisheries are given in Table 2. Bycatch of Pribilof golden king crab occurs mainly in the directed golden king crab fishery, when prosecuted, and to a lesser extent in the Bering Sea snow crab fishery and the Bering Sea grooved Tanner crab fishery. Because the Bering Sea snow crab fishery is prosecuted mainly or entirely between January and May and the Bering Sea grooved Tanner crab fishery is prosecuted with a calendar-year season, bycatch for the crab fisheries can be estimated on a calendar-year basis to align with the season for Pribilof District golden king crab. Observer data on size distributions and estimated catch numbers of non-retained catch were used to estimate the weight of non-retained catch of golden king crab by applying a weight-at-length estimator (see below). Observers were first deployed to collect bycatch data during the Pribilof District golden

king crab fishery in 2001 and during the Bering Sea grooved Tanner crab fishery in 1994. Retained catch or observer data are confidential for at least one of the crab fisheries in 1999–2001, 2003–2005, and 2010−2011. Following Siddeek et al. (2011), the bycatch mortality rate of golden king crab captured and discarded during Aleutian Islands golden king crab fishery was assumed to be 0.2. Following Foy (2011a, b), bycatch mortality rate of king crab during the snow crab fishery was assumed to be 0.5. The bycatch mortality rate during the grooved Tanner crab fishery was also assumed to be 0.5.

- The groundfish fishery data were grouped into crab fishery years, rather than into calendar years. The 1991/92–2010/11 time series of estimated annual weight of bycatch and total fishery mortality of golden king crab in reporting areas 513, 517, and 521 during federal groundfish fisheries by gear type (combining pot and hook-and-line gear as a single "fixed gear" category and combining non-pelagic and pelagic trawl gear as a single "trawl" category) is provided in Table 3. Following Foy (2011a, b), 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:*** Survey biomass estimates are not used in a Tier 5 assessment. However, biomass estimates of golden king crab (all sizes and sexes) by area and depth zone from the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey are presented in Table 4. The survey area is depicted in Figure 2 and catch distribution and density of golden king crab during the 2010 survey is shown in Figure 3. Trends in survey biomass, with the Pribilof Canyon area shown separately, are presented graphically in Figure 4.

e. ***Survey catch at length:*** Survey catch at length data are not used in a Tier 5 assessment. However, size composition by sex of the estimated golden king crab population from the 2004, 2008, and 2010 eastern Bering Sea upper continental slope trawl survey is presented in Figure 5.

*f.* ***Other data time series:*** See section **D.4** on other time-series data that is 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):***

The author is not aware of data on growth per molt of Pribilof golden king crab. Growth per molt of juvenile golden king crab, 2–35-mm CL, collected from Prince William Sound have been observed in a laboratory setting and equations describing the increase in CL and intermolt period were estimated from those observations (Paul and Paul 2001a); those results are not provided here. Growth per molt has also been estimated from golden king crab with CL ≥ 90 mm that were tagged in the Aleutian Islands and recovered during subsequent commercial fisheries (Watson et al. 2002); those results are not presented here because growth-per-molt information does not enter into a Tier 5 assessment.

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

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

Parameters (A and B) used for estimating weight (g) from carapace length (CL, mm) of male and female red king crab according to the equation, Weight = $A*CL^B$ (from Table 3-5, NPFMC 2007) are: A = 0.0002988 and B = 3.135 for males and A = 0.001424 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 (2007) is M=0.18. Note, however, natural mortality was not used for OFL estimation because this stock belongs to Tier 5.

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

Standardized bottom trawl surveys to assess the groundfish and invertebrate resources of the eastern Bering Sea (EBS) upper continental slope have been performed in 2002, 2004, 2008, 2010 (Hoff and Britt 2003, 2005, 2009, 2011; Haaga et al. 2009). The raw data from those surveys have not been accessed for this assessment; only summary of results and stock biomass estimates that have been reported by Hoff and Britt (2003, 2005, 2009, 2011) and reported by Haaga et al. (2009) are presented in this assessment. Access to the raw data from those standardized surveys could allow for "area-swept" estimation of abundance and biomass of golden king crab in the Pribilof District by relevant size, sex, and reproductive-status classes (e.g., mature male biomass, mature female biomass, legal-sized male biomass, etc.). Additionally, a pilot slope survey was also performed in 2000 and triennial surveys using a variety of nets, methods, vessels, and sampling locations were performed during 1979–1991 (Hoff and Britt 2011); no data from those surveys were accessed for, and no results from those surveys were reported on, in this assessment because, according to Hoff and Britt (2011), "Comparisons between the post-2000 surveys and those conducted from 1979–1991 remains confounded due to differences in sampling gear, survey design, sampling methodology, and species identification."

The CPT encouraged that data from the EBS slope survey be included to the extent possible to consider whether that information may be sufficient to move this assessment up to Tier 4 in future years (2009 Crab SAFE, Executive Summary). Although published and unpublished summaries of the EBS slope survey data have been included in recent SAFEs, the author has not acquired the raw survey data, as would be necessary for considering if that data is sufficient for a Tier 4 assessment. With regard to the 2011 SSC's encouragement to explore the eastern Bering Sea upper continental slope survey data "for their utility to provide estimates of biomass for the Pribilof District" and to give consideration to "the distribution of the survey with respect to stock distribution, as well as estimation of survey catchability by size and sex," the author reports the following, generalizing from the 2010 survey report (Hoff and Britt 2011).

The survey samples approximately 200 randomly-chosen locations (stratified by 200 m depth zones) from the areas of 200–1,200 m depth. In 2010, the mean sampling density over the total surveyed area of 32,723 $km^2$ was one haul per 204.48 $km^2$; survey tow sampling is denser at depths < 800 m. That sampling density compares to one haul per 400 $nmi^2$ (1,372 $km^2$) for the standard stations in the eastern Bering Sea continental shelf survey. Hence the survey design provides a high sampling density within the depth range that golden king crab typically occur and at which the commercial fishery is typically prosecuted. Moreover, the survey area contains all areas at depths of 200–1,200 m within the borders of the Pribilof District and the survey area, extending beyond the north and south borders of the district.

With regard to the survey catchability by size and sex, the survey uses a Poly Nor'eastern high-opening bottom trawl equipped with mud-sweeper roller gear (see Hoff and Britt 2011 for details). The author has no idea how such gear affects survey catchability by size or sex, or how such would compare with that realized by the continental shelf survey, which does not use mud-sweeper roller gear. The author is not aware of any studies that provide data to estimate catchability by size and sex for this survey. Under the survey protocols, sites are considered towable when depth change less than 50 m over a 2-nmi transect and there are no detectable obstacles in the trawl path; that restriction on trawl locations may or may not affect catchability for all sizes and both sexes, depending on habitat preferences. The author notes that a cursory examination of the size/sex frequency distribution of golden king crab captured during the last three biennial surveys (Figure 5), shows that golden king crab <20 mm CL are captured by the survey gear, but that highest frequencies tend to occur at sizes >100 mm CL, consistent with reduced catchability at smaller sizes. Size and sex frequencies of captured golden king crab appear to track poorly across the last three biennial surveys (Figure 4). For example, the catch in 2008 was dominated by males of roughly 90–120 mm CL and the size frequency distribution of females in 2008 was relatively flat, whereas the catch in 2010 was dominated by females of roughly 110–140 mm CL and the size frequency distribution of males in 2010 was relatively flat.

## *E. Analytic Approach*

1. **History of modeling approaches for this stock:** This is a Tier 5 stock; there is no assessment model and no history of assessment modelling approaches for this stock.

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

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

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

With regard to choosing from alternative time periods for computing average annual catch to compute the OFL, NPFMC (2007) suggested using the average retained catch over the years 1993 to 1999 as the estimated OFL for Pribilof Islands golden king crab. Years post-1984 were chosen based on an assumed 8-year lag between hatching and growth to legal size after the 1976/77 "regime shift". With regard to excluding data from years 1985 to 1992 and years after 1999, NPFMC (2007) states, "The excluded years are from 1985 to 1992 and from 2000 to 2005 for Pribilof Islands golden king crab when the fishing effort was less than 10% of the average or the GHL was set below the previous average catch." In 2008 the CPT and SSC endorsed the approach of estimating OFL as the average retained catch during 1993–1999 for setting a retained-catch OFL for 2009. However, in May 2009 the CPT setting a retained-catch OFL for 2010, but using the average retained catch during 1993–1998; 1999 was excluded because it was the first year that a preseason GHL was established for the fishery. In May 2010, the CPT established a total-catch OFL computed as a function of the average retained catch during 1993–1998, a ratio-based estimate of the bycatch mortality during the directed fishery of that period, and an estimate of the "background" bycatch mortality due to other fisheries. Other time periods, extending into years post-1999, had been considered for computing the average retained catch in the establishment of the 2009, 2010, 2011 OFLs, but those time periods were rejected by the CPT and the SSC. Hence the period for calculating the retained-catch portion of the Tier 5 total-catch OFL for this stock has been firmly established by the CPT and SSC at 1993–1998 (the CPT said "this freezes the time frame..."). For the 2012 OFL, the CPT and SSC recommended the period 2001–2010 for calculating the ratio-based estimate of the bycatch mortality during the 1993–1998 directed fishery, the period 1994–1998 for calculating the estimated bycatch mortality due to non-directed crab fisheries during 1993–1998, and the period 1992/93–1998/99 for calculating the estimated bycatch mortality due to groundfish fisheries during 1993–1998.

Because no new information has become available since the May 2011 CPT meeting (aside from the confidential catch data from the 2011 Pribilof District golden king crab fishery season, the non-directed crab fishery bycatch estimates for 2011, and the groundfish bycatch estimates for 2009/10 and because both the CPT and the SSC have settled on a time period of 1993–1998 for computing the average retained catch in the calculations of the 2010 –2012 OFLs, the author sees no reason to consider any other time periods besides 1993–1998 for computing the average retained catch in the calculation of the 2013 OFL; those who <u>do</u> see a reason should consult the minutes on this subject from the May 2009 and 2010 CPT meetings. Likewise, in their recommendations for the 2012 OFL, the CPT and SSC have established the periods for estimating bycatch mortality during 1993–1998 due to groundfish fisheries (1992/93–1998/99) and non-directed crab fisheries (1994–1998; insufficient data was collected from other crab fisheries to estimate bycatch mortality in 1993; see Table 1).

With regard to the alternative approaches for estimating the non-retained component of the total catch mortality, an obvious issue is that there are no data on bycatch in the directed fishery during 1993–1998, so choices must be made on how to best estimate the bycatch mortality during that period.

## 3. Model Selection and Evaluation:

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

Two alternatives are presented. Alternative 1 is the status quo approach (i.e., the approach used to establish the 2012 total-catch OFL) and the author's recommended alternative. Alternative 2 is the same as Alternative 1 except that it uses updated bycatch data from crab fisheries in 2011; it is presented to allow the CPT and the SSC to clarify whether the 2013 and subsequent OFLs should be computed using data collected after 2010, or if the time periods for data used to calculate the 2013 and subsequent OFLs should be "frozen" at the years used to calculate the 2012 OFL.

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

$$OFL_{1,\,2013} = (1+R_{2001\text{–}2010})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93\text{–}98/99},$$

where,

- $R_{2001\text{–}2010}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained catch in the directed fishery during 2001–2010
- $RET_{1993\text{-}1998}$ is the average annual retained catch in the directed crab fishery during 1993–1998
- $BM_{NC,1994\text{-}1998}$ is the estimated average annual bycatch mortality in non-directed crab fisheries during 1994–1998
- $BM_{GF,92/93\text{–}98/99}$ is the estimated average annual bycatch mortality in groundfish fisheries during 1992/93–1998/99.

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

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

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

Statistics on the data and estimates used to calculate $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$ are provided in Table 5; the column means in Table 5 are the calculated values of $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$. Using the calculated values of $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,93/94\text{-}98/99}$, $OFL_{1,\ 2013}$ is,

$$OFL_{1,2013} = (1+0.052)*173{,}722 + 13{,}418 + 8{,}353 = 204{,}611 \text{ lbs (0.20-million lbs).}$$

<u>Alternative 2</u>. Alternative 2 follows the approach as Alternative 1, but uses the updated data on bycatch from the 2011 directed fishery to estimate the ratio of bycatch mortality to retained catch during the 1993–1998 directed fishery; i.e.,

$$OFL_{2,\ 2013} = (1+R_{2001\text{–}2011})*RET_{1993\text{-}1998} + BM_{NC,1994\text{-}1998} + BM_{GF,92/93\text{–}98/99,}$$

where,

- $R_{2001\text{–}2011}$ is the average of the estimated annual ratio of pounds of bycatch mortality to pounds of retained catch in the directed fishery during 2001–2011
- $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{–}98/99}$ are as defined for Alternative 1, above.

Statistics on the data and estimates used to calculate, $RET_{1993\text{-}1998}$, $R_{2001\text{-}2011}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{–}98/99}$ are provided in Table 6. Using those calculated values, $OFL_{2,\ 2013}$ is calculated as,

$$OFL_{\ 2,2013} = (1+0.053)*173{,}722 + 13{,}418 + 8{,}353 = 204{,}700 \text{ lbs (0.20-million lbs).}$$

b. ***<u>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</u>:*** See the table, below.

| Model | Retained- vs. Total-catch | Time Period | Resulting OFL (millions of pounds) |
|---|---|---|---|
| Alt. 1 – recommended/status quo | Total-catch | 1993–1998 | 0.20 |
| Alt. 2 | Total-catch | 1993–1998 | 0.20 |

Alternative 1 is recommended and is the status quo; it is recommended as being the best approach with the limited data available. The choice between Alternative 1 and Alternative 2 makes no difference in the 2013 OFL – both round to 0.20 million pounds. The choice here is to decide whether the periods used to calculate the OFL should be "frozen" at the periods chosen to calculate the 2012 OFL or if the period used to estimate the ratio of bycatch mortality to retained catch should be updated each year with the most recent fishery.

c. ***<u>Evidence of search for balance between realistic (but possibly over-parameterized) and simpler (but not realistic) models</u>:***

Both alternatives have the same number of parameters. Both can be seen as equally realistic.

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

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 6-8.

*c.* ***Graphs of estimates (all quantities should be accompanied by confidence intervals or other statistical measures of uncertainty, unless infeasible):*** Information requested for this subsection is not applicable to a Tier 5 stock.

*d.* ***Evaluation of the fit to the data:*** Not applicable for Tier 5 stock.

*e.* ***Retrospective and historic analyses (retrospective analyses involve taking the "best" model and truncating the time-series of data on which the assessment is based; a historic analysis involves plotting the results from previous assessments):*** Not applicable for Tier 5 stock.

*f.* ***Uncertainty and sensitivity analyses (this section should highlight unresolved problems and major uncertainties, along with any special issues that complicate scientific***

***assessment, including questions about the best model, etc.):*** For this assessment, the major uncertainties are:

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

## F. Calculation of the OFL

1. **Specification of the Tier level and stock status level for computing the OFL:**
    - Recommended as Tier 5, total-catch OFL estimated by estimated average total catch over a specified period.
    - Recommended time period for computing retained-catch OFL: 1993–1998.
        - This is the time period used to establish OFL for the 2010–2012 seasons. The time period 1993–1998 provides the longest continuous time period through 2011 during which vessels participated in the fishery, retained-catch data can be retrieved that are not confidential, and the retained catch was not constrained by a GHL. Data on bycatch mortality contemporaneous with 1993-1998 to the extent possible is used to calculate the total-catch OFL in the recommended Alternative 1.

2. **List of parameter and stock size estimates (or best available proxies thereof) required by limit and target control rules specified in the fishery management plan:** Not applicable for Tier 5 stock.

3. **Specification of the total-catch OFL:**

***a. Provide the equations (from Amendment 24) on which the OFL is to be based:***

From **Federal Register** / Vol. 73, No. 116, page 33926, "For stocks in Tier 5, the overfishing level is specified in terms of an average catch value over an historical time period, unless the Scientific and Statistical Committee recommends an alternative value based on the best available scientific information." Additionally, "For stocks where nontarget fishery removal data are available, catch includes all fishery removals, including retained catch and discard losses. Discard losses will be determined by multiplying the appropriate handling mortality rate by observer estimates of bycatch discards. For stocks where only retained catch information is available, the overfishing level is set for and compared to the retained catch" (FR/Vol. 73, No. 116, 33926). That compares with the specification of NPFMC (2007) that the OFL "represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock."

***b. Basis for projecting MMB to the time of mating:*** Not applicable for Tier 5 stock.

***c. Specification of $F_{OFL}$, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:*** See table below. Although the retained and total catch for 2011 cannot be presented here due to the confidentiality of data, the author can report that total catch in 2011 did not exceed the 2011 OFL. Values for the 2013 OFL and ABC are the author's recommendations.

| Year[a] | MSST | Biomass (MMB) | GHL[b] | Retained Catch[c] | Total Catch[c,d] | OFL[c,e] | ABC[c,e] |
|---|---|---|---|---|---|---|---|
| 2009 | N/A | N/A | 0.150 | 0 | 0.001 | 0.17 R | N/A |
| 2010 | N/A | N/A | 0.150 | Conf.[f] | Conf.[f] | 0.17 R | N/A |
| 2011 | N/A | N/A | 0.150 | Conf.[f] | Conf.[f] | 0.18 T | N/A |
| 2012 | N/A | N/A | 0.150 | TBD | TBD | 0.20 T | 0.18 T |
| 2013 | N/A | N/A | TBD | TBD | TBD | [0.20 T] | [0.18 T] |

a. Season is based on a calendar year.
b. Guideline harvest level expressed in millions of pounds. The Pribilof District golden king crab fishery is not rationalized and a TAC is not established for the fishery.
c. Millions of pounds.
d. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries only. Bycatch mortality due to groundfish fisheries is not included here because available data is summarized by "crab fishery year" rather than calendar year; estimates of annual bycatch mortality during 1991/92–2009/10 groundfish fisheries are ≤0.019-million pounds, with an average of 0.006-million pounds.
e. Noted as "R" for retained-catch-only OFL and "T" for total-catch OFL.
f. Catch statistics are confidential under Sec. 16.05.815 (SOA statute): one vessel participated in the 2010 season and two vessels participated in the 2011 season..

**4. Specification of the retained-catch portion of the total-catch OFL:**

***a.* Equation for recommended retained-portion of total-catch OFL.**

Retained-catch portion = average retained catch during 1993–1998
= 173,722 pounds (0.17-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 Alternatives 1 and 2 OFLs are shown in Figure 6 (1,000 samples drawn with replacement independently from each of the four columns of values in Table 5 to calculate $R_{2001\text{-}2010}$, $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, $BM_{GF,92/93\text{-}98/99}$ and $OFL_{1,2013}$; and 1,000 samples drawn with replacement independently from each of the four columns of values in Table 6 to calculate $R_{2001\text{-}2011}$, $RET_{1993\text{-}1998}$, $BM_{NC,1994\text{-}1998}$, $BM_{GF,92/93\text{-}98/99}$ and $OFL_{2,2013}$). 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 OFL (and hence the ABC), but has no effect on the retained-catch portion of the OFL or the retained-catch portion of the ABC.
- Estimated bycatch and bycatch mortality for each fishery that bycatch occurred in during 1993–1998.
- The time period to compute the average catch under the assumption of representing "a time period determined to be representative of the production potential of the stock."

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

**4. Author recommended ABC.** (1-0.1)·(204,612 pounds) = 0.18-million pounds.

## H. Rebuilding Analyses

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

## I. Data Gaps and Research Priorities

Data from the 2002, 2004, 2008, and 2010 NMFS-AFSC eastern Bering Sea upper continental shelf trawl surveys have not been examined for their utility in providing reliable estimates of biomass and abundance of golden king crab by size, sex, and reproductive status within the Pribilof District. Survey catchability of golden king crab by sex and size is not estimated.

## J. Literature Cited

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**Table of Tables.**

**Table of Figures.**

Table 1. Harvest history for the Pribilof District golden king crab fishery from the 1981/82 season through 2011 (from 2011 SAFE, updated with 2011 data provided by P. Converse, ADF&G, Kodiak via 17 April 2012 email).

| | Number of | | | | | | Average | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | Vessels | Landings | Crabs[a] | Pots lifted | GHL[b] | Harvest[a,c] | Weight[c] | CPUE[d] | Length[e] | Deadloss[c] |
| 1981/82 | 2 | CF | CF | CF | - | CF | CF | CF | CF | CF |
| 1982/83 | 10 | 19 | 15,330 | 5,252 | - | 69,970 | 4.6 | 3 | 151 | 570 |
| 1983/84 | 50 | 115 | 253,162 | 26,035 | - | 856,475 | 3.4 | 10 | 127 | 20,041 |
| 1984 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 1985 | 1 | CF | CF | CF | - | CF | CF | CF | CF | CF |
| 1986 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 1987 | 1 | CF | CF | CF | - | CF | CF | CF | CF | CF |
| 1988 | 2 | CF | CF | CF | - | CF | CF | CF | CF | CF |
| 1989 | 2 | CF | CF | CF | - | CF | CF | CF | CF | CF |
| 1990 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 |
| 1993 | 5 | 15 | 17,643 | 15,395 | - | 67,458 | 3.8 | 1 | NA | 0 |
| 1994 | 3 | 5 | 21,477 | 1,845 | - | 88,985 | 4.1 | 12 | NA | 730 |
| 1995 | 7 | 22 | 82,489 | 9,551 | - | 341,908 | 4.1 | 9 | NA | 716 |
| 1996 | 6 | 32 | 91,947 | 9,952 | - | 329,009 | 3.6 | 9 | NA | 3,570 |
| 1997 | 7 | 23 | 43,305 | 4,673 | - | 179,249 | 4.1 | 9 | NA | 5,554 |
| 1998 | 3 | 9 | 9,205 | 1,530 | - | 35,722 | 3.9 | 6 | NA | 474 |
| 1999 | 3 | 9 | 44,098 | 2,995 | 200,000 | 177,108 | 4.0 | 15 | NA | 319 |
| 2000 | 7 | 19 | 29,145 | 5,450 | 150,000 | 127,217 | 4.4 | 5 | NA | 4,599 |
| 2001 | 6 | 14 | 33,723 | 4,262 | 150,000 | 145,876 | 4.3 | 8 | 143 | 8,227 |
| 2002 | 8 | 20 | 34,860 | 5,279 | 150,000 | 150,434 | 4.3 | 6 | 144 | 8,984 |
| 2003 | 3 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2004 | 5 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2005 | 4 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2006-2009 | 0 | 0 | 0 | 0 | 150,000 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 1 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |
| 2011 | 2 | CF | CF | CF | 150,000 | CF | CF | CF | CF | CF |

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

[a] Deadloss included.

[b] Guideline harvest level in pounds.

[c] In pounds.

[d] Number of legal crab per pot lift.

[e] Carapace length in millimeters.

Table 2. Weight (in pounds) of retained catch, estimated non-retained bycatch, and estimated total fishery mortality of Pribilof golden king crab during crab fisheries, 1993–2011 (assumes a bycatch mortality rate of 0.2 for the directed fishery and a bycatch mortality rate of 0.5 for non-directed fisheries; from 2011 Crab SAFE, with update for 2011 and bycatch data for 1993 added).

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

a. Value is likely an over-estimate. Only 5 golden king crab (1 sublegal male and 4 legal males) were counted in 1,657 pot lifts sampled out of the 163,536 pot lifts performed during the 2008/09 Bering Sea snow crab fishery, but none of those were measured to provide an estimate of weight. An average weight of 4.3 pounds per crab was used to estimate the total bycatch weight; 4.3 pounds is average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.

b. Value is likely an over-estimate. Only 2 golden king crab (1 sublegal male and 1 legal male) were counted in 2,142 pot lifts sampled out of the 147,244 pot lifts performed during the 2010/11 Bering Sea snow crab fishery (Gaeuman 2011), but none of those were measured to provide an estimate of weight. Bycatch weight was estimated by 4.3x(2x147,244)/2,142; the assumed average weight per crab (4.3 pounds) is the average weight of landed golden king crab during the 2002 Pribilof District golden king crab fishery.

Table 3. Estimated annual weight (pounds) of discarded bycatch and total bycatch mortality (pounds) of Pribilof golden king crab (all sizes, males and females) during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 513, 517, and 521, 1991/92–2010/11 (assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries; updated from 2011 SAFE with 2010/11 data provided by R. Foy AFSC, Kodiak Laboratory via 9 August 2011 email).

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

Table 4. Biomass estimates (metric tons) of golden king crab (all sizes, both sexes) from results of the 2002, 2004, 2008, 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey, by survey subarea and depth zone (from Haaga et al. 2009, Hoff and Britt 2003, 2005, 2009, 2011, and J. Haaga, NMFS-AFSC, Kodiak, 26 August 2009).

| Year | Depth (m) | Subarea 1 Bering Canyon[a] | **Subarea 2 Pribilof Canyon[b]** | **Subarea 3[b]** | **Subarea 4 Zhemchug Canyon[b]** | Subarea 5[a] | Subarea 6 Pervenets/Navarin Canyons[c] |
|---|---|---|---|---|---|---|---|
| 2002 | 200-400 | 53 | **289** | **49** | **52** | 16 | 29 |
| | 400-600 | 78 | **253** | **32** | **1** | 3 | 14 |
| | 600-800 | 0 | **121** | **1** | **0** | 0 | 0 |
| | 800-1000 | 1 | **0** | **0** | **0** | 0 | 0 |
| | 1000-1200 | 0 | **19** | **-** | **0** | 0 | 0 |
| | Total | 131 | **682** | **81** | **53** | 19 | 44 |
| 2004 | 200-400 | 4 | **526** | **25** | **121** | 13 | 2 |
| | 400-600 | 45 | **220** | **13** | **0** | 13 | 22 |
| | 600-800 | 14 | **67** | **10** | **0** | 0 | 0 |
| | 800-1000 | 1 | **4** | **3** | **0** | 0 | 0 |
| | 1000-1200 | 0 | **0** | **0** | **0** | 0 | 0 |
| | Total | 65 | **817** | **51** | **121** | 25 | 24 |
| 2008 | 200-400 | 67 | **258** | **65** | **173** | 0 | 38 |
| | 400-600 | 78 | **584** | **19** | **0** | 2 | 29 |
| | 600-800 | 2 | **76** | **8** | **32** | 0 | 0 |
| | 800-1000 | 0 | **0** | **0** | **0** | 0 | 0 |
| | 1000-1200 | 0 | **2** | **0** | **0** | 0 | 0 |
| | Total | 146 | **919** | **91** | **206** | 2 | 66 |
| 2010 | 200-400 | 116 | **1050** | **85** | **72** | 34 | 53 |
| | 400-600 | 246 | **432** | **4** | **0** | 3 | 64 |
| | 600-800 | 0.4 | **104** | **0.1** | **0** | 0 | 6 |
| | 800-1000 | 1 | **12** | **0** | **0** | 0 | 0 |
| | 1000-1200 | 0 | **17** | **0** | **0** | 0 | 0 |
| | Total | 363 | **1615** | **89** | **72** | 37 | 123 |

a. Partially in Pribilof District.
b. Entirely in Pribilof District.
c. Not in Pribilof District.

Table 5. Data for calculation of $RET_{1993\text{-}1998}$ and estimates used in calculation of $R_{2001\text{-}2010}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{-}98/99}$ for calculation of the Alternative 1 Pribilof Islands golden king crab Tier 5 2013 total-catch OFL; values under $RET_{1993\text{-}1998}$ are from Table 1, values under $R_{2001\text{-}2010}$ were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under $BM_{NC,1994\text{-}1998}$ were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93\text{-}98/99}$ are from Table 3.

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

a. Season convention corresponding with values under $RET_{1993\text{-}1998}$, $R_{2001\text{-}2010}$, and $BM_{NC,1994\text{-}1998}$.
b. Season convention corresponding with values under $BM_{GF,92/93\text{-}98/99}$.

Table 6. Data for calculation of $RET_{1993\text{-}1998}$ and estimates used in calculation of $R_{2001\text{-}2011}$, $BM_{NC,1994\text{-}1998}$, and $BM_{GF,92/93\text{-}98/99}$ for calculation of the Alternative 2 Pribilof Islands golden king crab Tier 5 2013 total-catch OFL; values under $RET_{1993\text{-}1998}$ are from Table 1, values under $R_{2001\text{-}2011}$ were computed from the retained catch data and the directed fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.2), values under $BM_{NC,1994\text{-}1998}$ were computed from the non-directed crab fishery bycatch estimates in Table 2 (assumed bycatch mortality rate = 0.5) and values under $BM_{GF,92/93\text{-}98/99}$ are from Table 3.

| Season[a] | Season[b] | $RET_{1993\text{-}1998}$ | $R_{2001\text{-}2011}$ | $BM_{NC,1994\text{-}1998}$ | $BM_{GF,92/93\text{-}98/99}$ |
|---|---|---|---|---|---|
| 1993 | 1992/93 | 67,458 | | | 19,480 |
| 1994 | 1993/94 | 88,985 | | 5,459 | 17,556 |
| 1995 | 1994/95 | 341,908 | | 17,941 | 5,962 |
| 1996 | 1995/96 | 329,009 | | 2,839 | 3,797 |
| 1997 | 1996/97 | 179,249 | | 4,469 | 1,561 |
| 1998 | 1997/98 | 35,722 | | 36,380 | 2,335 |
| 1999 | 1998/99 | | | | 7,781 |
| 2000 | 1999/00 | | | | |
| 2001 | 2000/01 | | 0.054 | | |
| 2002 | 2001/02 | | 0.056 | | |
| 2003 | 2002/03 | | conf. | | |
| 2004 | 2003/04 | | conf. | | |
| 2005 | 2004/05 | | conf. | | |
| 2006 | 2005/06 | | | | |
| 2007 | 2006/07 | | | | |
| 2008 | 2007/08 | | | | |
| 2009 | 2008/09 | | | | |
| 2010 | 2009/10 | | conf. | | |
| 2011 | 2010/11 | | conf. | | |
| | N | 6 | 7 | 5 | 7 |
| | Mean | 173,722 | 0.053 | 13,418 | 8,353 |
| | S.E.M | 54,756 | 0.003 | 6,337 | 2,750 |
| | CV | 0.32 | 0.06 | 0.47 | 0.33 |

a. Season convention corresponding with values under $RET_{1993\text{-}1998}$, $R_{2001\text{-}2011}$, and $BM_{NC,1994\text{-}1998}$.

b. Season convention corresponding with values under $BM_{GF,92/93\text{-}98/99}$.

Table 7. Statistics for 1,000 bootstrap 2013 OFLs for Pribilof Islands golden king crab stock calculated according to Alternatives 1 and 2, with the computed OFLs for comparison.

| | Alternative 1 | Alternative 2 |
|---|---|---|
| Computed OFL | 204,611 | 204,700 |
| Mean of 1,000 bootstrapped OFLs | 203,870 | 201,399 |
| Std. dev. of 1,000 bootstrapped OFLs | 51,030 | 52,988 |
| CV = (std. dev.)/(Mean) | 0.25 | 0.26 |

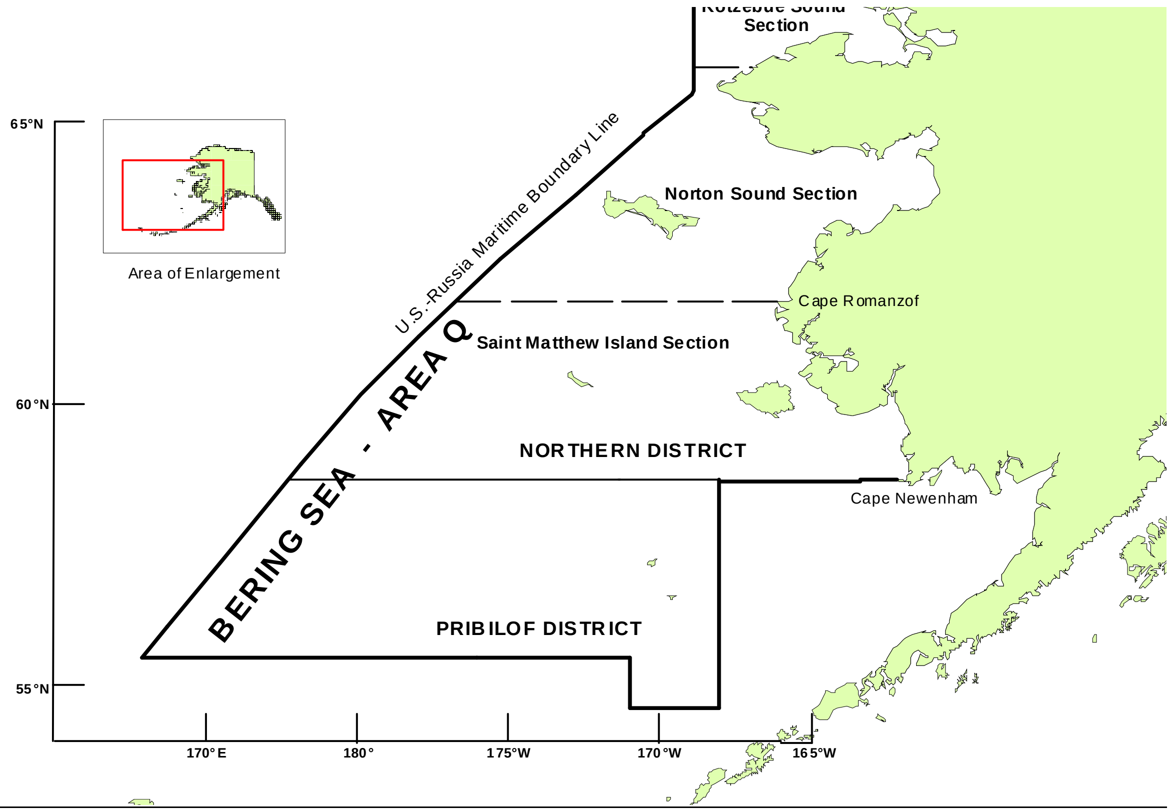


Figure 1. King crab Registration Area Q (Bering Sea), showing borders of the Pribilof District (from Figure 2-4 *in* Bowers et al. 2011).

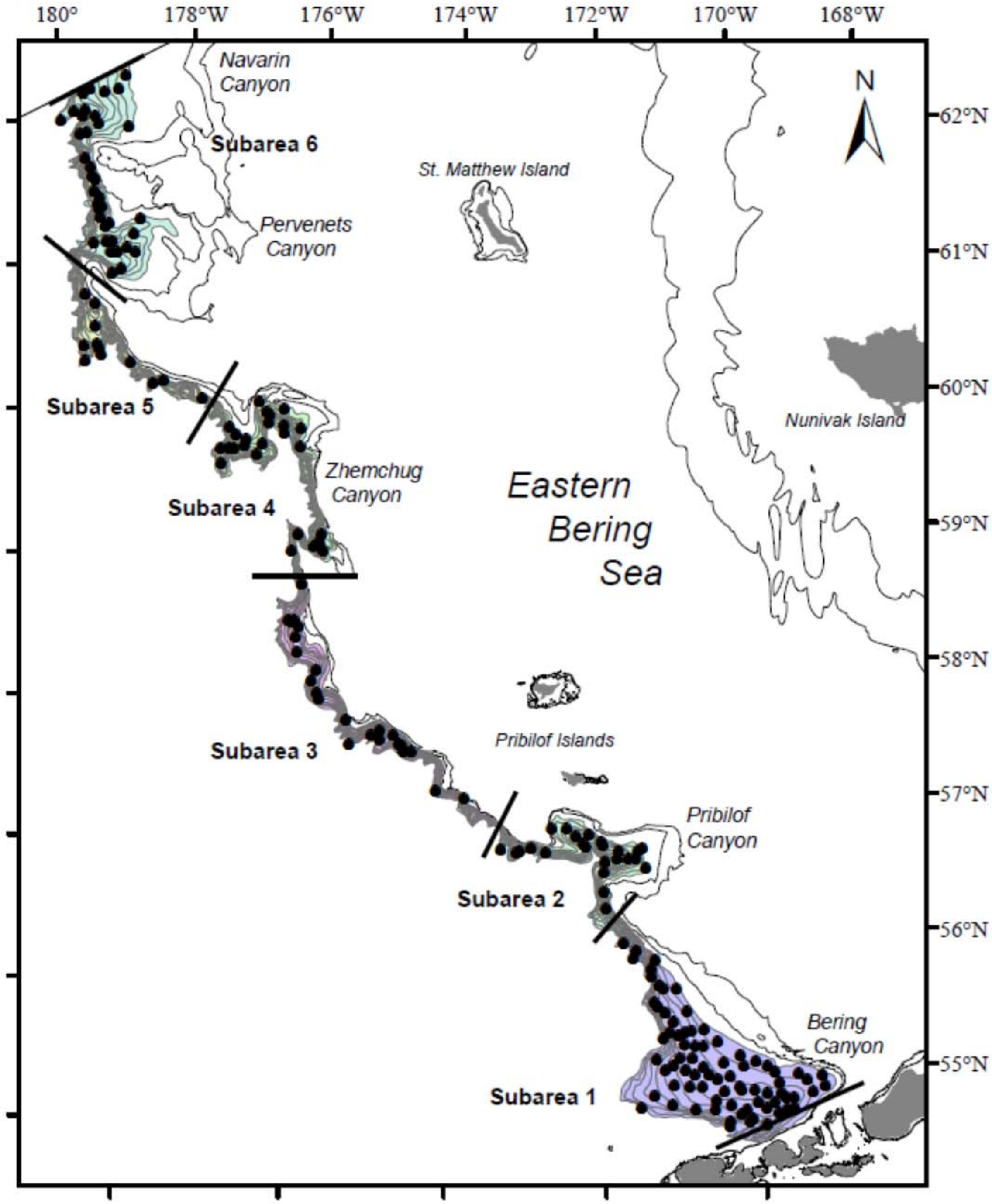


Figure 2. Map of standard survey area for NMFS-AFSC eastern Bering Sea upper continental slope trawl survey with survey subareas identified; black dots show locations of successful tows during the 2010 survey (from Figure 1 *in* Hoff and Britt 2011).

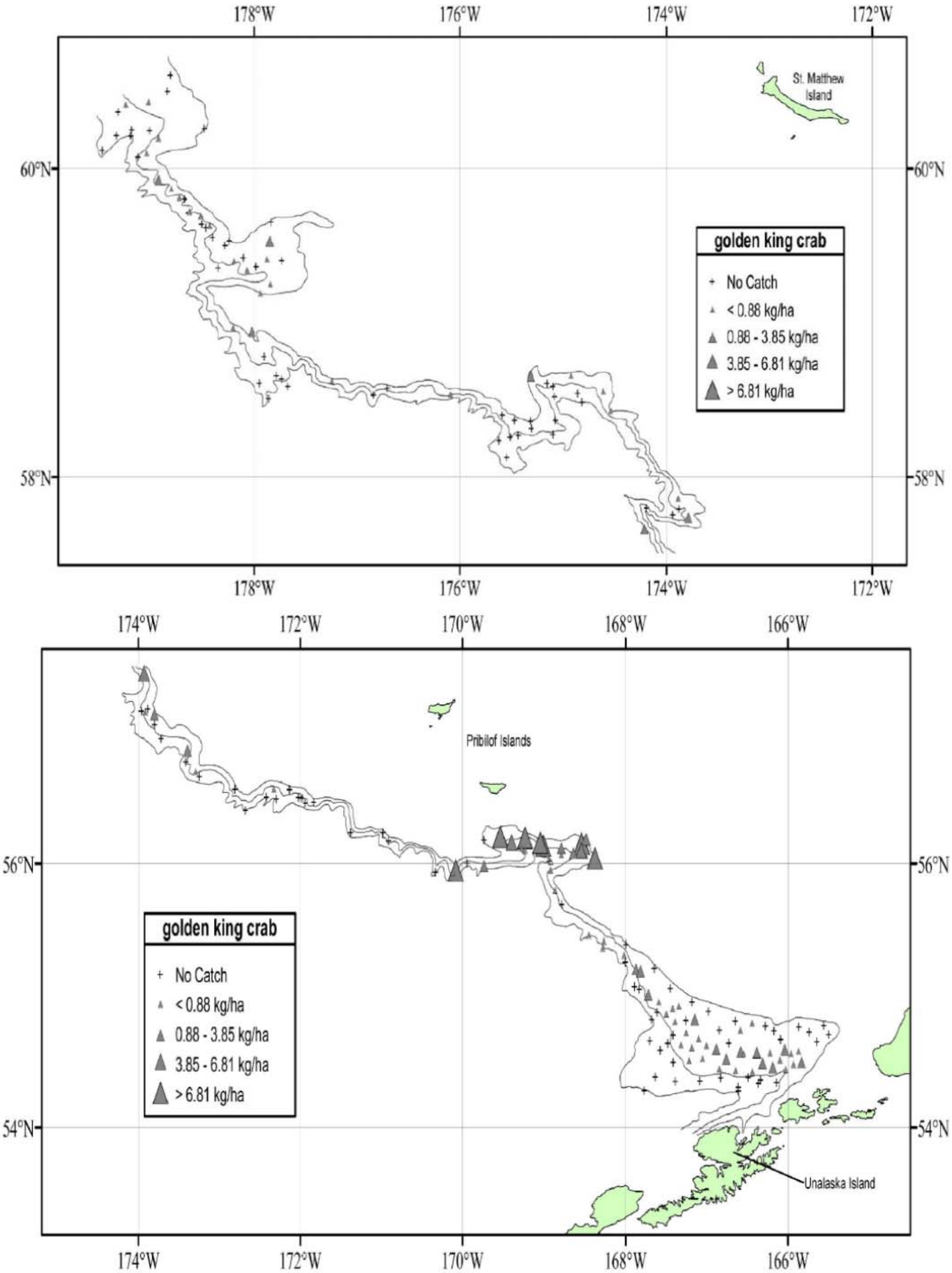


Figure 3. Distribution and relative abundance of golden king crab from the 2010 NMFS-AFSC eastern Bering Sea upper continental slope trawl survey. Relative abundance is categorized by no catch, sample CPUE less than the mean CPUE, between the mean CPUE and two standard deviations above the mean CPUE, between two and four standard deviations above the mean CPUE, and greater than four standard deviations above the mean CPUE (from Figure 82 *in* Hoff and Britt 2011).

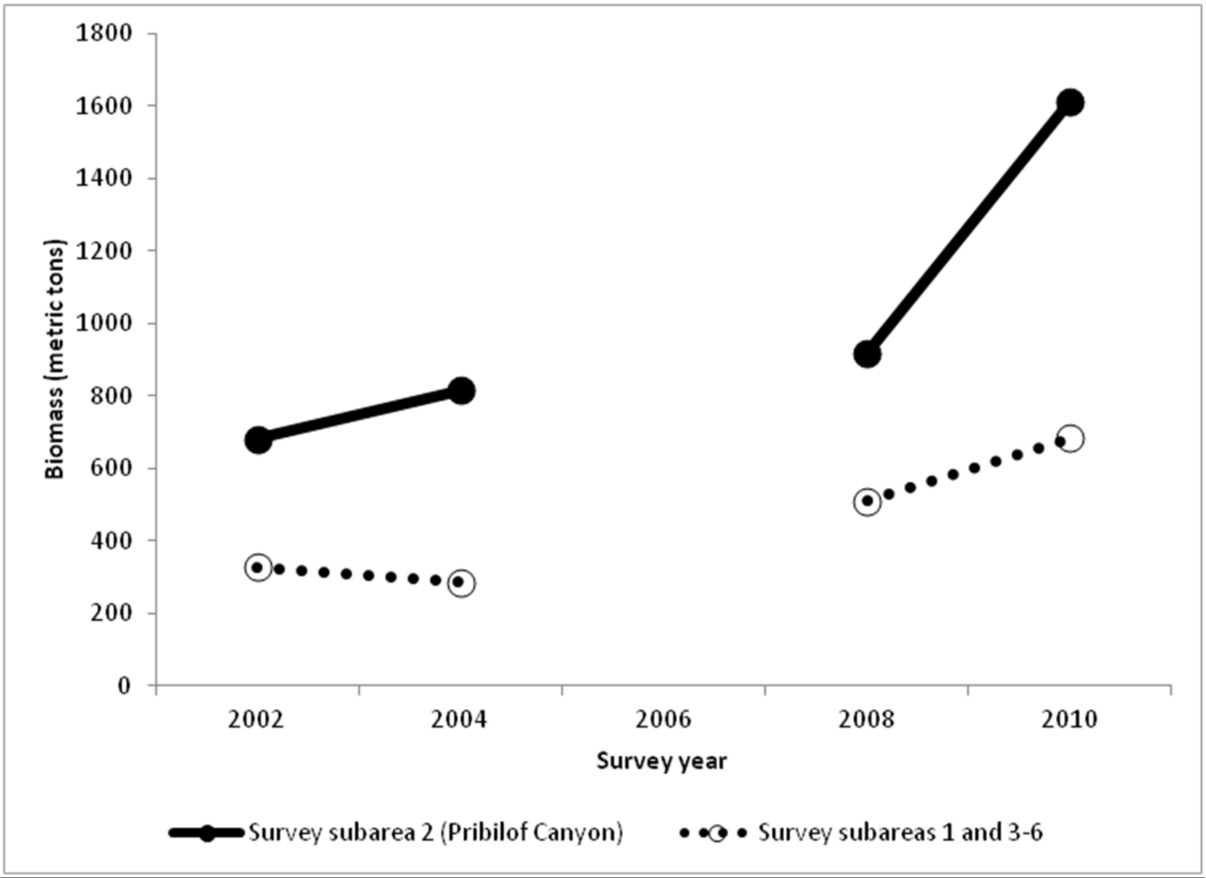


Figure 4. Biomass estimates (all sexes and sizes) for the Pribilof Canyon survey subarea and the aggregated remaining survey subareas (see Figure 2) from the biennial eastern Bering Sea upper continental slope surveys that were performed during 2002–2010.

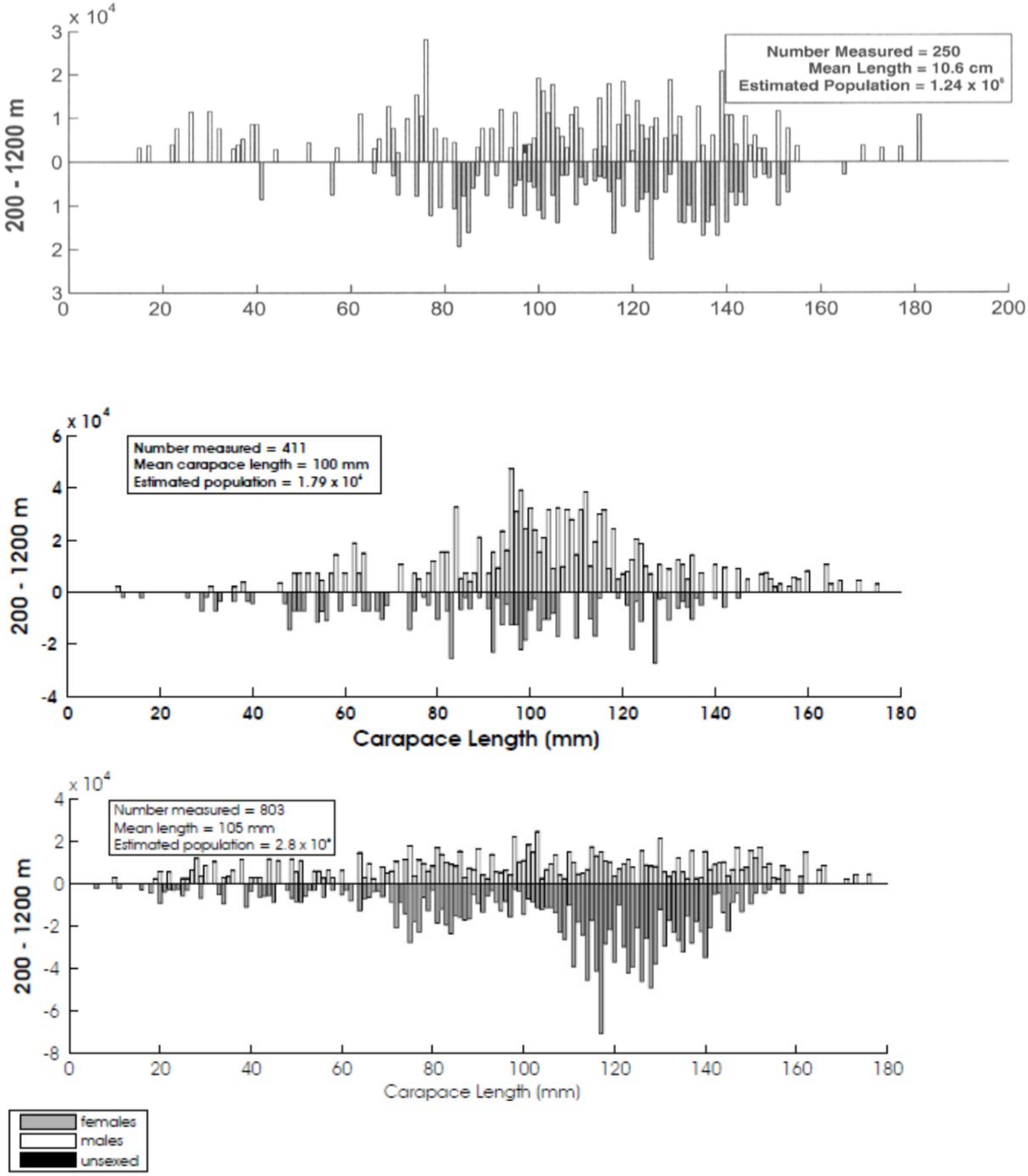


Figure 5. Size distribution of male and female golden king crab captured in all survey subareas and depths fished during the 2004, 2008, and 2010 (bottom panel; from Figure 83 *in* Hoff and Britt 2011) NMFS-ASFC eastern Bering Sea upper continental shelf trawl surveys (not available for the 2002 survey).

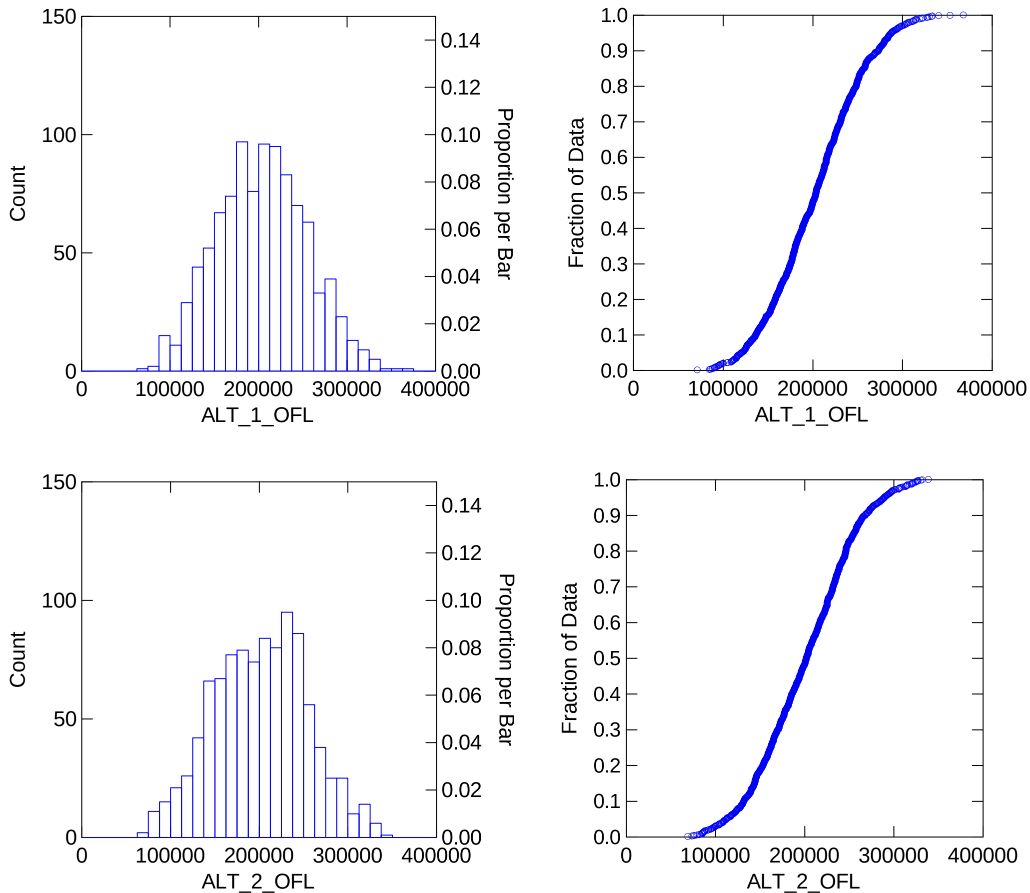


Figure 6. Bootstrapped estimates of the sampling distribution of the Alternative 1 (above), Alternative 2 (bottom) 2013 Tier 5 OFLs (pounds of total catch) for the Pribilof Islands golden king crab stock; histograms in left column, quantile plots in right column.

# Adak Red King Crab

# May 2012 Crab SAFE Report Chapter (10 May 2012)

Douglas Pengilly, ADF&G, Kodiak

## Executive Summary

1. **Stock:** Adak/Western Aleutian Islands (the Aleutian Islands, west of 171° W longitude) golden king crab *Paralithodes camtschaticus*

**2. Catches:**

The domestic fishery has been prosecuted since 1960/61 and was opened every season through the 1995/96 season. Peak harvest occurred during the 1964/65 season with a retained catch of 21.193-million pounds (9,613 t). During the early years of the fishery through the late 1970s, most or all of the retained catch was harvested in the area between 172° W longitude and 179°15' W longitude. As the annual retained catch decreased into the mid-1970s and the early-1980s, the area west of 179°15' W longitude began to account for a larger portion of the retained catch. Retained catch during the 10-year period 1985/86–1994/95 averaged 0.943-million pounds (428 t), but the retained catch during the 1995/96 season was only 0.039-million pounds (18 t). During the 1995/96 through 2011/12 seasons, the fishery was opened only occasionally. There was an exploratory fishery with a low guideline harvest level (GHL) in 1998/99, three commissioner's permit fisheries in limited areas during 2000/01–2002/03 to allow for ADF&G-Industry surveys, and two commercial fisheries with a GHL of 0.500-million pounds (227 t) during the 2002/03 and 2003/04 seasons. Most of the catch since the 1990/91 season was harvested in the Petrel Bank area (between 179° W longitude and 179° E longitude) and the last two commercial seasons (the 2002/03 and 2003/04 seasons) were opened only in the Petrel Bank area. Retained catch in the last two commercial fishery seasons was 0.506-million pounds (230 t) in 2002/03 and 0.479-milliion pounds (217 t) in 2003/04. The fishery has been closed through the 2011/12 season since the end of the 2003/04 season. Non-retained catch of red king crab occurs in the directed red king crab fishery (when prosecuted), in the Aleutian Islands golden king crab fishery, and in the groundfish fisheries. Estimated annual weight of bycatch mortality during the 1995/96–2009/10 seasons averaged 0.003-million pounds (1 t) in crab fisheries and 0.022-million pounds (10 t) during groundfish fisheries. Estimated weight of annual total fishery mortality during 1995/96–2009/10 averaged 0.109-million pounds (49 t); the average annual retained catch during that period was 0.084-million pounds (38 t). Estimated total fishery mortality for 2010/11 was 0.004-million pounds (2 t).

**3. Stock biomass:**

Estimates of past or present stock biomass are not available. There is no assessment model developed for this stock and standardized stock surveys have been too limited in geographic scope and too infrequent to provide a reliable index of abundance for the entire red king crab population in the Aleutian Islands west of 171° W longitude.

**4. Recruitment:**

Estimates of recruitment trends and current levels relative to virgin or historic levels are not available. The fishery has been closed since the end of the 2003/04 season due to apparent poor recruitment. A pot survey conducted by ADF&G in the Petrel Bank area (roughly, 179° W longitude to 179° E longitude) in November 2006 provided no evidence of strong recruitment (Gish 2007). The overall survey CPUEs (catch per pot lift) of red king crab in the standard, systematic survey (170 stations with 4 pots per station resulting in 680 pot lifts) of the Petrel Bank area were 1.2 legal males, 0.2 sublegal males, and 0.2 females; 98% of all red king crab were captured at 30 stations within an area of approximately 185 $nmi^2$ (633 $km^2$). Additionally, concurrent with the November 2006 ADF&G survey, 165 pots were fished in "string" arrays, similar to the setting of pots during commercial fishing, between standard survey stations in areas with high CPUE during the standard survey and at locations where strings were fished during the November 2001 ADF&G-Industry survey (see Bowers et al. 2002). The CPUE of red king crab in those "niche fishing" pots in 2006 was 15.6 legal males, 4.1 sublegal males, and 3.1 females. Ninety-two pots fished in four strings during the November 2006 ADF&G survey at the locations where four strings were fished during the November 2001 ADF&G-Industry yielded CPUEs of 9.8 legal males, 2.5 sublegal males, and 2.1 females; during the November 2001 ADF&G-Industry survey the CPUEs for the 121 pots fished at those locations were 85.5 legal males, 5.5 sublegal males, and 9.7 females. Red king crab captured during the November 2009 pot survey conducted by ADF&G were predominately larger, matured-sized crab and the size distribution of captured males provided no expectations for near-term recruitment of legal males (Gish 2010). Only 117 4-pot stations (468 pot lifts) could be fished in the November 2009 ADF&G survey. The overall CPUEs of red king crab during the November 2009 ADF&G survey was 1.5 legal males, <0.1 sublegal males, and 0.1 females. Limited (18 pot lifts) exploratory catch-and-release fishing for red king crab was also conducted by a commercial fishing vessel during mid-October to mid-December 2009 under provisions of a commissioner's permit at depths ≤ 100 fathoms (183 m) using red king crab pot gear (i.e., fished as single-pots, not long-lined) with escape webbing closed to help retain sublegal and female crab in four areas west of Petrel Bank between 178°00' E longitude and 175°30' E longitude; that limited effort yielded a catch of one legal-sized male red king crab (J. Alas, ADF&G, 7 May 2010 ADF&G Memorandum).

Another ADF&G-Industry survey was conducted as a commissioner's permit fishery in the Adak-Atka-Amlia Islands area in November 2002 (Granath 2003). Although the survey design called for a possible 2,900 pot lifts to be performed, survey participants only completed 1,085 pot lifts before withdrawing from participation. Four legal male red king crabs were captured: three legal males and one sublegal male red king crab were captured around Adak Island; no red king crabs were captured in areas on the north side of Atka Island, but an estimated 520 sublegal males and females were captured in one pot on the north side of Atka Island; one legal male and no sublegal or female red king crabs were captured on the north side of Amlia Island; and no red king crabs were captured on the south side of Atka and Amlia Islands. By comparison, ADF&G conducted a pot survey in the Atka-Amlia Islands area in 1977 and captured 4,035 male and 1,088 female red king crabs in 360 pot lifts (ADF&G 1978), although from those results it was reported that "King crab stocks at Adak still seem to be depressed" (ADF&G 1978, page 167).

**5. <u>Management performance</u>:**

No overfished determination (i.e., MSST) is possible for this stock given the lack of biomass information. Overfishing did not occur during the 2010/11 fishing year; the 2011/12 fishing year is ongoing. No ABC was established for any season prior to the 2011/12 season; the ABC established for the ongoing 2011/12 season was 0.03 million pounds (12 t). OFL and ABC values for 2012/13 in the table below are the author's recommendations.

| Year | MSST | Biomass (MMB) | TAC | Retained Catch[a] | Total Catch[a,b] | OFL[a,c] | ABC[a,c] |
|---|---|---|---|---|---|---|---|
| 2008/09 | N/A | N/A | Closed | 0 | 0.014 | 0.46 R | N/A |
| 2009/10 | N/A | N/A | Closed | 0 | 0.012 | 0.50 R | N/A |
| 2010/11 | N/A | N/A | Closed | 0 | 0.004 | 0.12 T | N/A |
| 2011/12 | N/A | N/A | Closed | 0 | TBD | 0.12 T | 0.03 T |
| 2012/13 | N/A | N/A | TBD | TBD | TBD | [0.12 T] | [0.03 T] |

a. Millions of pounds.
b. Includes bycatch mortality of discarded bycatch.
c. Noted as "R" for retained-catch OFL and "T" for total-catch OFL.

| Year | MSST | Biomass (MMB) | TAC | Retained Catch[a] | Total Catch[a,b] | OFL[a,c] | ABC[a,c] |
|---|---|---|---|---|---|---|---|
| 2008/09 | N/A | N/A | Closed | 0 | <1 | 209 R | N/A |
| 2009/10 | N/A | N/A | Closed | 0 | <1 | 227 R | N/A |
| 2010/11 | N/A | N/A | Closed | 0 | 2 | 56 T | N/A |
| 2011/12 | N/A | N/A | Closed | 0 | TBD | 56 T | 12 T |
| 2012/13 | N/A | N/A | TBD | TBD | TBD | [56 T] | [12 T] |

a. Metric tons.
b. Includes bycatch mortality of discarded bycatch.
c. Noted as "R" for retained-catch OFL and "T" for total-catch OFL.

6. **<u>Basis for the OFL and ABC</u>:** See table, below; values for 2012/13 are the author's recommendations

| Year | Tier | Years to define Average catch (OFL) | Natural Mortality | Buffer |
|---|---|---|---|---|
| 2009/10 | 5 | 1985/86-2007/08[a] | 0.18[b] | N/A |
| 2010/11 | 5 | 1995/96-2007/08[c] | 0.18[b] | N/A |
| 2011/12 | 5 | 1995/96-2007/08[c] | 0.18[b] | 75% |
| 2012/13 | 5 | [1995/96-2007/08[c]] | [0.18[b]] | [75%] |

a. OFL was for retained catch and was determined by the average of the retained catch for these years.
b. Assumed value for FMP king crab in NPFMC (2007); does not enter into OFL estimation for Tier 5 stock.
c. OFL was for total catch and was determined by the average of the total catch for these years

7. **<u>PDF of the OFL:</u>** Sampling distribution of the recommended Tier 5 OFL was estimated by bootstrapping; see section G.1. Estimated CV (sample standard error of mean divided by sample mean) of the annual total catch estimates for 1995/96–2007/08 is 0.43.

8. **<u>Basis for the ABC recommendation:</u>** The recommended ABC is the status quo; i.e., the ABC recommended by the CPT and SSC for 2011/12.

.

9. **<u>A summary of the results of any rebuilding analyses</u>:** Not applicable; stock is not under a rebuilding plan.

## *A. Summary of Major Changes*

1. **<u>Changes to the management of the fishery</u>:** None. (But Industry has expressed in an exploratory fishery in the area east of 179° W longitude).

2. **<u>Changes to the input data</u>:**
   - Data on non-retained bycatch and estimates of bycatch mortality in crab and groundfish fisheries during 2010/11 have been added to judge if overfishing occurred in 2010/11, but is not put into the calculation of the recommended 2012/13 total-catch OFL.

3. **<u>Changes to the assessment methodology</u>:** None.

4. **<u>Changes to the assessment results, including projected biomass, TAC/GHL, total catch (including discard mortality in all fisheries and retained catch), and OFL</u>:** None.

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

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

<u>SSC, October 2011</u>: None.

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

<u>CPT, May 2011 (May 2011 CPT minutes)</u>:

1. *"The team struggled to establish an adequate means to recommend an ABC to appropriately reflect the uncertainty surrounding and conservation concerns regarding this stock."*

<u>Response</u>: In this regard, the author has empathy for the team.

2. *"The time frame for establishing the OFL leads to a biased estimate of catch and using the maximum permissible ABC control rule would not be appropriate reflection of the bias imparted by the average catch calculation. To account for this bias a lower percentage of OFL is recommended." "…the team recommended an ABC based upon the maximum incidental catch (pot and groundfish fishery) over the time frame used to calculate the OFL."*

   Response: The time period for calculating the OFL was established **and fixed** by the SSC in June 2010. The author recommends the status quo (2011/12) ABC, as recommended by the SSC in June 2011 and which is well below the maximum permissible ABC and less than half of what the CPT recommended in May 2011.

3. *"Further recommendations for the next assessment include evaluation of the bycatch for each of stat regions 541-543, as well as in total historically and to compile historical fishery information pre-1980."*

   Response: Estimated bycatch by groundfish fisheries for each of the stat regions 541–543 during 1993/94–2010/11 is provided in Table 4. Aside from the information provided in Table 1, the author has not compiled historical fishery information pre-1980. The author agrees that compilation of historic fishery data would be valuable, but does not know where the historical fishery information pre-1980 could be found and has noted that, if found, it would be difficult to compile (see Section **I**. **Data Gaps and Research Priorities**). That compilation of information would be a good project for someone to do. Nonetheless, the author does not see the utility of that information from 30+ years ago in helping the CPT with its struggle *"to establish an adequate means to recommend an ABC to appropriately reflect the uncertainty surrounding and conservation concerns regarding this stock."*

SSC, June 2011:

*1)" Review of the time series of bycatch shows an allowance based on the mean bycatch for the period 1995/96-2007/08 should be sufficient"[to establish the 2011/12 ABC for this stock].*

Response: The author recommends the same ABC for 2012/13.

CPT, September 2011: [*None.*]

SSC, October 2011: [*None.*]

## C. Introduction

1. **Scientific name:** *Paralithodes camtschaticus*, Tilesius, 1815

**2. Description of general distribution:**

The general distribution of red king crab is summarized by NMFS (2004):

> "Red king crab are widely distributed throughout the BSAI, GOA, Sea of Okhotsk, and along the Kamchatka shelf up to depths of 250 m. Red king crab are found from eastern Korea around the Pacific rim to northern British Columbia and as far north as Point Barrow (page 3-27).
>
> Most red and blue king crab fisheries occur at depths from 50-200 m, but red king crab fisheries in the Aleutian Islands sometimes extend to 300 m (page 3-41).

> Red king crab is native to waters of 300 m or less extending from eastern Korea, the northern coast of the Japan Sea, Hokkaido, the Sea of Okhotsk, through the eastern Kamchatkan Peninsula, the Aleutian Islands, the Bering Sea, the GOA, and the Pacific Coast of North America as far south as Alice Arm in British Columbia. They are not found north of the Kamchatkan Peninsula on the Asian Pacific Coast. In North America red king crab range includes commercial fisheries in Norton Sound and sparse populations extending through the Bering Straits as far east as Barrow on the northern coast of Alaska. Red king crab have been acclimated to Atlantic Ocean waters in Russia and northern Norway. In the Bering Sea, red king crab are found near the Pribilof Islands and east through Bristol Bay; but north of Bristol Bay (58 degrees 39 minutes) they are associated with the mainland of Alaska and do not extend to offshore islands such as St. Matthew or St. Laurence Islands (pages 3-41–42)."

Commercial fishing for Adak red king crab during the last two prosecuted seasons (2002/03 and 2003/04) was opened only in the Petrel Bank area and effort during those two seasons typically occurred at depths of 60–90 fathoms (110–165 m); average depth of pots fished in the Aleutian Islands area during the 2002/03 season was 68 fathoms (124 m; Barnard and Burt 2004) and during the 2003/04 season was 82 fathoms (151 m; Burt and Barnard 2005). In the 580 pot lifts sampled by observers during the 1996/97–2006/07 Aleutian Islands golden king crab fishery that contained one or more red king crab, depth was recorded for 578 pots. Of those, the deepest recorded depth was 266 fathoms (486 m) and 90% of pot lifts had recorded depths of 100–200 fathoms (183–366 m); no red king crab were present in any of the 6,465 pot lifts sampled during the 1996/97–2006/07 Aleutian Islands golden king crab fishery with depths >266 fathoms (486 m; ADF&G observer database, Dutch Harbor, April 2008).

Although the Adak Registration Area is no longer defined in State regulation, in this chapter we will refer to the area west of 171° W longitude within the Aleutian Islands king crab Registration Area O as the "Adak Area". The Aleutian Islands king crab Registration Area O is described by Bowers et al (2011, page 8) as follows (see also Figure 1):

> "The Aleutian Islands king crab Registration Area O has as its eastern boundary the longitude of Scotch Cap Light (164° 44' W longitude), its northern boundary a line from Cape Sarichef (54° 36' N latitude) to 171° W longitude, north to 55° 30' N latitude, 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 [Figure 1]. 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)."

From the 1984/85 season until the March 1996 Alaska Board of Fisheries meeting, the Aleutian Islands king crab Registration Area O as currently defined had been subdivided at 171° W longitude into the historic Adak Registration Area R and the Dutch Harbor Registration Area O. The geographic boundaries of the Adak red king crab stock are defined here by the boundaries of the historic Adak Registration Area R; i.e., the current Aleutian Islands king crab Registration Area O, west of 171° W longitude.

**3. <u>Evidence of stock structure</u>:**

Seeb and Smith (2005) analyzed microsatellite DNA variability in nearly 1,800 individual red king crab originating from the Sea of Okhotsk to Southeast Alaska, including a sample 75 specimens collected during 2002 from the vicinity of Adak Island in the Aleutian Islands (51° 51' N latitude, 176° 39' W longitude), to evaluate the degree to which the established geographic boundaries between stocks in the BSAI reflect genetic stock divisions. Seeb and Smith (2005) concluded that, "There is significant divergence of the Aleutian Islands population (Adak sample) and the Norton Sound population from the southeastern Bering Sea population (Bristol Bay, Port Moller, and Pribilof Islands samples)."

We know of no analyses of genetic relationships among red king crab from different locations within the Adak Area. However, given the expansiveness of the Adak Area and the canyons between some islands that are deep (>1,000 m) relative to the depth zone restrictions of red king crab (see above), at least some weak structuring within the Adak red king crab stock would be expected. McMullen and Yoshihara (1971) reported the following on male red king crab that were tagged in February 1970 on the Bering Sea and Pacific Ocean sides of Atka Island and recovered in the subsequent fishery season:

> "Fishermen landing tagged crabs were questioned carefully concerning the location of recapture. In no instance did crabs migrate through ocean passes between the Pacific Ocean and Bering Sea."

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

Red king crab eggs are fertilized externally and the clutch of fertilized eggs (embryos) are carried under the female's abdominal flap until hatching. Male king crab fertilize eggs by passing spermatophores from the fifth periopods to the gonopores and coxae of the female's third periopods; the eggs are fertilized during ovulation and attach to the female's pleopodal setae (Nyblade 1987, McMullen 1967). Females are generally mated within hours after molting (Powell and Nickerson 1965), but may mate up to 13 days after molting (McMullen 1969). Males must wait at least 10 days after completing a molt before mating (Powell et al. 1973), but, unlike females, do not need to molt prior to mating (Powell and Nickerson 1965).

Wallace et al. (1949, page 23) described the "egg laying frequency" of red king crab:

> "Egg laying normally takes place once a year and only rarely are mature females found to have missed an egg laying cycle. The eggs are laid in the spring immediately following shedding [i.e., molting] and mating and are incubated for a period of nearly a year. Hatching of the eggs does not occur until the following spring just prior to moulting [i.e., molting] season."

McMullen and Yoshihara (1971) reported that from 804 female red king crab (79–109-mm CL) collected during the 1969/70 commercial fishery in the western Aleutians, "Female king crab in the western Aleutians appeared to begin mating at 83 millimeters carapace length and virtually all females appeared to be mature at 102 millimeters length." Blau (1990) estimated size at maturity for Adak Area red king crab females as the estimated CL at which 50% of females are mature (SM50; as evidenced by presence of clutches of eggs or empty) according to a logistic regression: 89-mm CL (SD = 2.6 mm). Size at maturity has not been estimated for Adak Area male red king crab. However, because the estimated SM50 for Adak Area red king crab females is the same as that estimated for Bristol Bay red king crab females (Otto et al. 1990), the estimated maturity schedule used for Bristol Bay red king crab males (see SAFE chapter on Bristol Bay red king crab) could be applied to males in the Adak stock as a proxy.

Little data is available on the molting and mating period for red king crab specifically in the Adak Area. Among the red king crab captured by ADF&G staff for tagging on the south side of Amlia Island (173° W longitude to 174° W longitude) in the first half of April 1971, males and females were molting, females were hatching embryos, and mating was occurring (McMullen and Yoshihara 1971). The spring mating period for red king crab is known to last for several months, however. For example, although mating activity in the Kodiak area apparently peaks in April, mating pairs in the Kodiak area have been documented from January through May (Powell et al. 2002). Due to the season timing for the commercial fishery, little data on reproductive condition of Adak red king crab females have been collected by at-sea fishery observers that can be used for evaluating the mating period. For example, of the 3,211 mature females that were examined during the 2002/03 and 2003/04 red king crab seasons in the Petrel Bank area, both of which seasons were restricted to late October, only 10 were scored as "hatching."

Data on mating pairs of red king crab collected from the Kodiak area during March–May of 1968 and 1969 showed that size of the females in the pairs increased from March to May, indicating that females tend to release their larvae and mate later in the mating season with increasing age (Powell et al. 2002). Size of the males in those mating pairs did not increase with later sampling periods, but did show a decreasing trend in estimated time since last molt. In all the data on mating pairs collected from the Kodiak area during 1960–1984, the proportion of males that were estimated to have not recently molted prior to mating decreased monthly over the mating period (Powell et al. 2002). Those data suggest that males that do not molt early in the mating period have an advantage in mating early in the mating period, when smaller, younger mature females and the primiparous females tend to ovulate, and that males that do molt early in the mating period participate in the later mating period, when the larger, older females tend to be mated.

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

A complete summary of the management history through 2009/10 is provided in Bowers et al. (2011, pages 8–12). The domestic fishery for red king crab in the Adak Area began with the 1960/61 season. Retained catch of red king crab in the Aleutians west of 172º W longitude averaged 11.595-million pounds during the 1960/61–1975/76 seasons, with a peak harvest of 21.193-million pounds in the 1964/65 season (Table 1, Figure 2). Guideline harvest levels (GHL; sometimes expressed as ranges, with an upper and lower GHL) for the fishery have been established for most seasons since the 1970s. The fishery was closed for the 1976/77 season in the area west of 172º W longitude, but reopened for the 1977/78–1995/96 seasons. Average retained catch during the 1977/78–1995/96 seasons (for the area west of 172º W longitude prior to the 1984/85 season and for the area west of 171º W longitude since the 1984/85 season) was 1.044-million pounds; the peak harvest during that period was 1.982-million pounds for the 1983/84 season. During the mid-to-late 1980s, significant portions of the catch during the Adak red king crab fishery occurred west of 179º E longitude or east of 179º W longitude, whereas most of the retained catch was harvested from the Petrel Bank area (179° W longitude to 179° W longitude) during the 1990/91–1994/95 seasons (Figure 3). The Adak red king crab fishery was closed for the 1996/97 season following the diminishing harvests of the preceding two seasons that did not reach the lower GHL. Due to concerns about low stock levels and poor recruitment, the fishery has been opened only intermittently since 1996/97. The fishery was closed for the 1996/97–1997/98 seasons, closed in the Petrel Bank area for the 1998/99 season, closed for the 1999/2000 season, restricted to the Petrel Bank area for the 2000/01–2003/04 seasons (except for an ADF&G-Industry survey in the Adak, Atka, and Amlia Islands area conducted as a commissioner's permit fishery), and closed for the 2004/05–2011/12 seasons. Management history since the 1996/97 closure is summarized in the table below. The peak harvest since the 1996/97 season was 0.506-million pounds, which occurred in the 2002/03 season.

| **Season** | **Change in management measure** |
|---|---|
| 1996/97–1997/98 | • Fishery closed |
| 1998/99 | • GHL of 15,000 pounds (for exploratory fishing) with fishery closed in the Petrel Bank area (i.e., between 179° W longitude and 179° E longitude) |
| 1999/00 | • Fishery closed |
| 2000/01 | • Fishery closed<br>• Catch retained during ADF&G-Industry survey of Petrel Bank area conducted as commissioner's permit fishery, Jan–Feb 2001 |
| 2001/02 | • Fishery closed<br>• Catch retained ADF&G-Industry survey of Petrel Bank area conducted as commissioner's permit fishery, November 2001 |
| 2002/03 | • Fishery opened with GHL of 500,000 pounds restricted to Petrel Bank area<br>• ADF&G-Industry survey of the Adak, Atka, and Amlia Islands area conducted as a commissioner's permit fishery (4 legal males captured in 1,085 pot lifts) |
| 2003/04 | • Fishery opened with GHL of 500,000 pounds restricted to Petrel Bank area |
| 2004/05–2011/12 | • Fishery closed |

A summary of relevant fishery regulations and management actions pertaining to the Adak red king crab fishery is provided below.

Only males of a minimum legal size may be retained by the commercial red king crab fishery in the Adak Area. By State of Alaska regulation (**5 AAC 34.620 (a)**), the minimum legal size limit is 6.5-inches (165 mm) carapace width (CW), including spines. A carapace length (CL) ≥138 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007). Except for the years 1968–1970, the minimum size has been 6.5-inches CW since 1950; in 1968 there was a "first-season" minimum size of 6.5-inches CW and a "second-season" minimum size of 7.0-inches and in 1969–1970 the minimum size was 7.0-inches CW (Donaldson and Donaldson 1992).

Red king crab may be commercially fished only with king crab pots (as defined in **5 AAC 34.050**). Pots used to fish for red king crab in the Adak Area must, since 1996, have 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 red king crab and may not be longlined (**5 AAC 34.625 (e)**). The sidewall of the pot "…must contain an opening equal to or exceeding 18 inches in length... The opening must be laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 30 thread." (**5 AAC 39.145(1)**).

By State of Alaska regulation (**5 AAC 34.610 (a)**) the Adak red king crab commercial fishing season is from October 15 to February 15, unless closed by emergency order.

The Adak Area red king crab fishery west of 179° W longitude has been managed since the 2005/06 season under the Crab Rationalization program (50 CFR Parts 679 and 6805). The Adak Area red king crab fishery in the area east of 179° W longitude was not included in the Crab Rationalization program (Bowers et al. 2011). Fishing for red king crab in the area between 172° W longitude and 179° W longitude in the Aleutian Islands is limited to vessels 90 feet or less in overall length (**5 AAC 34.610 (d)**). Additionally, there is a pot limit of 250 pots per vessel for vessels fishing for red king crab in the Petrel Bank area (**5 AAC 34.625 (d)**).

The Adak red king crab fishery was closed for the 1996/97–1997/98 seasons. The following area closures and harvest restrictions have been applied to the red king crab fishery, when opened, in the Adak Area since the 1998/99 season:

- The 1998/99 season for red king crab in the Adak Area was open east of 179° W longitude with a guideline harvest level (GHL) of 0.005-million pounds and west of 179° E longitude with a GHL of 0.010-million pounds, but was closed between 179° W longitude and 179° E longitude.
- ADF&G-Industry pot surveys for red king crab were conducted in January—February 2001 (the 2000/01 season) and November 2001 (the 2001/02 season) under the restrictions of a commissioner's permit fishery in the Petrel Bank area (north of 51° 45' N latitude and between 179° W longitude and 179° E longitude; Bowers et al. 2002, Bowers et al. 2011). The Adak Area was closed to commercial red king crab fishing outside of the designated survey area.
- The 2002/03 season opened in those waters of king crab Registration Area O between 179° W longitude and 179° E longitude and north of 51° 45' N latitude (the Petrel Bank area; Bowers et al. 2011) with a GHL of 0.500-million pounds. Additionally, an ADF&G-Industry pot survey for red king crab was conducted in November 2002 under the restrictions of a commissioner's permit fishery in the vicinity of Adak, Atka, and Amlia Islands to assess the Adak red king crab stock in the area between 172° W longitude and 179° W longitude (Granath 2003). The remaining area outside of the Petrel Bank area and the designated survey area in the Adak Area was closed to commercial red king crab fishing during the 2002/03 season.
- The 2003/04 season opened in those waters of king crab Registration Area O between 179° W longitude and 179° E longitude and north of 51° 45' N latitude (the so-called "Petrel Bank area"; Bowers et al. 2011). The remaining area in the

Adak Area was closed to commercial red king crab fishing during the 2003/04 season.

## *D. Data*

1. **Summary of new information:**
   - Retained catch data from the closed 2011/12 directed fishery season has been added; the retained catch was 0 pounds.
   - Data on non-retained bycatch in crab and groundfish fisheries has been updated with data from the 2010/11 Aleutian Islands golden king crab fishery and the 2010/11 groundfish fisheries in reporting areas 541, 542, and 543 (Figure 4).

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

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

- The 1960/61–2011/12 time series of retained catch (number and pounds of crab harvested, including deadloss), effort (vessels, landings, and pot lifts), average weight of landed crab, average carapace length of landed crab, and CPUE (number of landed crab captured per pot lift) is presented in Table 1.
- The 1960/61–20011/12 time series of retained catch (pounds of landed crab) is presented graphically in Figure 2.
- The 1995/96–2010/11 times series of weight of retained legal males and estimated weight of non-retained legal male, non-retained sublegal male, and non-retained female red king crab in the Adak Area during commercial crab fisheries is given in Table 2. 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). Estimates of bycatch prior to the 1995/96 season are not given due to non-existence of data or to limitations on bycatch sampling during the crab fisheries. Prior to 1988/89 there was no fishery observer program for Aleutian Islands crab fisheries and during the 1988/89–1994/95 seasons observers were required only on vessels processing king crab at sea, including catcher-processor vessels. Observer data from the Aleutian Islands prior to 1990/91 is considered unreliable and the observer data from the directed Adak red king crab fishery in the 1990/91 and 1992/93–1994/95 seasons and golden king crab fishery in the 1993/94 and 1994/95 seasons are confidential due to the limited number of observed vessels. During the 1995/96–2004/05 seasons, observers were required on all vessels fishing for king crab in the Aleutian Islands area at all times that a vessel was fishing. With the advent of the Crab Rationalization program in the 2005/06 season, all vessels fishing for golden king crab in the Aleutian Islands area are now required to carry an observer for a period during which 50% of the vessel's harvest was obtained during each trimester of the fishery; observers continue to be required at all times a vessel is fishing in the red king crab fishery west of 179° W longitude. All king crab that were captured as bycatch during the Aleutian Islands golden king crab fishery west of 174° W longitude by a vessel while an observer was on board during the 2001/02–2002/03 and 2004/05–2010/11 seasons were counted and recorded for capture location and biological data.
- The 1993/94–2010/11 time series of estimated weight of bycatch and estimated bycatch mortality of red king crab in the Adak Area (reporting areas 541, 542, and 543; i.e., Aleutian Islands west of 170° W longitude; Figure 4) during federal groundfish fisheries

by gear type (fixed or trawl) is provided in Table 3. Estimated weight of bycatch during the 1993/94–2010/11 groundfish fisheries by reporting area (541, 542, or 543) is provided in Table 4. Bycatch estimates for 1992/93 are available, but appear to be suspect because they are extremely low. Following Foy (2011 a, b), the bycatch mortality rate 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.

- The 1995/96–2008/09 time series of estimated weight of total fishery mortality of red king crab in the Adak Area, partitioned into retained catch, bycatch mortality during crab fisheries, and bycatch mortality during federal groundfish fisheries, is provided in Table 5. Following Siddeek et al. (2011), the bycatch mortality rate of king crab captured and discarded during Aleutian Islands king crab fisheries was assumed to be 0.2; bycatch mortality in crab fisheries was estimated for Table 5 by applying that assumed bycatch mortality rate to the estimates of non-retained catch given in Tables 2. The estimates of bycatch mortality in groundfish fisheries given in Table 5 are from Table 3.

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

***d. Survey biomass estimates:*** Not available; there is no program for regular performance of standardized surveys sampling from the entirety of the stock range.

***e. Survey catch at length:*** Not used in a Tier 5 assessment; none are presented here.

***f. Other data time series:***

Data on CPUE (number of retained crab per pot lift) during the red king crab in the Adak Area are available for the 1972/73–2010/11 seasons (see Table 1).

**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 was estimated for Adak Area male red king crab by Vining et al. (2002) based on information received from recoveries during commercial fisheries of tagged red king crab released in the Adak Island to Amlia Island area during the 1970s (see Table 5 in Pengilly 2009). Vining et al. (2002) used a logit estimator to estimate the probability as a function of carapace length (CL, mm) at release that a male Adak Area red king tagged and released in new-shell condition would molt within 8–14 months after release (see Tables 6 and 7 in Pengilly 2009).

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

Parameters (A and B) used for estimating weight (g) from carapace length (CL, mm) of male and female red king crab according to the equation, Weight = $A*CL^B$ (from Table 3-5, NPFMC 2007) are: A = 0.000361 and B = 3.16 for males and A = 0.022863 and B = 2.23382 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:*** Natural mortality rate has not been estimated specifically for red king crab in the Adak Area. NPFMC (2007) assumed a natural mortality rate of M =0.18 for king crab species.

4. **Information on any data sources that were available, but were excluded from the assessment:**
   - Distribution of effort and catch during the 2006 ADF&G Petrel Bank red king crab pot survey (Gish 2007) and the 2009 ADF&G Petrel Bank red king crab pot survey (Gish 2010).
   - Sex-size distribution of catch and distribution of effort and catch during the January/February 2001 and November 2001 ADF&G-Industry red king crab survey of the Petrel Bank area (Bowers et al. 2002) and ADF&G-Industry red king crab pot survey conducted as a commissioner's permit fishery in November 2002 in the Adak Island and Atka-Amlia Islands areas (Granath 2003).
   - Observer data on size distribution and geographic distribution of bycatch of red king crab in the Adak red king crab fishery and the Adak/Aleutian Islands golden king crab fishery, 1988/89–2009/10 (ADF&G observer database).
   - Summary of data collected by ADF&G Adak red king crab fishery observers or surveys during 1969–1987 (Blau 1993).
   - Retained catch-at-length data for the red king crab fishery in the Adak Area for the 1984/85–1995/96, 1999/00, 2000/01–2001/02, and 2002/03–2003/04 seasons (data from the 1999/2000 season and the 2000/01–2001/02 seasons collected made during either restricted exploratory fishing or during ADFG-Industry surveys).

## *E. Analytic Approach*

1. **History of modeling approaches for this stock:** This is a Tier 5 stock; there is no assessment model and no history of assessment modelling approaches for this stock.

2. **Model Description:** There is no regular survey of this stock. No assessment model for the Adak Area red king crab stock exists and none is in development. The SSC in June 2010 recommended that: the Adak Area red king crab stock be managed as a Tier 5 stock; the OFL be specified as a total-catch OFL; the total-catch OFL be established as the estimated average annual weight of the retained catch and bycatch mortality in crab and groundfish fisheries over the period 1995/96–2007/08; and the period used for computing the Tier 5 total-catch OFL be fixed at 1995/96–2007/08.

   Given the strong recommendations from the SSC in June 2010, Tier 5 total-catch OFLs would change only if retained catch data and bycatch estimates for the period 1995/96–2007/08 or assumed values of bycatch mortality rates used in the 2010 SAFE were revised. Given that no need has been shown to revise either retained catch data and bycatch estimates for the period 1995/96–2007/08 or assumed values of bycatch mortality rates used in the 2010 SAFE, the recommended approach for establishing the 2012/13 OFL is the approach identified by the SSC in June 2010 and no alternative approaches are suggested by the author. Hence the recommended total-catch OFL for 2012/13 is

$$OFL_{2012/13} = RET_{95/96\text{-}07/08} + BM_{CF,\ 95/96\text{-}07/08} + BM_{GF,\ 95/96\text{-}07/08},$$

   where,

- $RET_{95/96\text{-}07/08}$ is the average annual retained catch in the directed crab fishery during 1995/96–2007/08
- $BM_{CF,\ 95/96\text{-}07/08}$ is the estimated average annual bycatch mortality in the directed and non-directed crab fisheries during 1995/96–2007/08, and
- $BM_{GF,\ 95/96\text{-}07/08}$ is the estimated average annual bycatch mortality in the groundfish fisheries during 1995/96–2007/08.

Given the June 2010 SSC recommendations, items ***E.2 a–i*** are not applicable.

3. **Model Selection and Evaluation:** Not applicable; see section ***E.2***.

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 Table 4.

*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.
  - In this regard, the CPT (May 2011 minutes) noted that the OFL (0.12 million pounds) that was established for this stock by the SSC in June 2010 "could be considered biased high because of years of high exploitation" and questioned "whether the time frame used to compute the OFL is meaningful as an estimate of the productivity potential of this stock." Additionally, the CPT registered its concern with a fishery mortality equivalent to 90% of that OFL: "Discussion further noted to what extent removing 110,000 lbs in perpetuity is reasonable rate of sustainable catch for this stock given its current size."
- The bycatch mortality rates used in estimation of total catch. Being as most (78%) of the estimated total mortality during 1995/96–2007/08 is due to the retained catch component,

the total catch estimate is not severely sensitive to the assumed bycatch mortality rates. Doubling the assumed bycatch mortality during crab fisheries from 0.2 to 0.4 would increase the OFL by a factor of 1.02; halving that assumed rate from 0.2 to 0.1 would decrease the OFL by a factor of 0.99. Increasing the assumed bycatch mortality rate for all groundfish fisheries (regardless of gear type) to 1.0, would increase the OFL by a factor of 1.07.

### *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 specified as the estimated average annual total-catch during the period 1995/96–2007/08; i.e.,

$$OFL_{2012/13} = RET_{95/96\text{-}07/08} + BM_{CF,\ 95/96\text{-}07/08} + BM_{GF,\ 95/96\text{-}07/08},$$

where,

- $RET_{95/96\text{-}07/08}$ is the average annual retained catch in the directed crab fishery during 1995/96–2007/08
- $BM_{CF,\ 95/96\text{-}07/08}$ is the estimated average annual bycatch mortality in the directed and non-directed crab fisheries during 1995/96–2007/08, and
- $BM_{GF,\ 95/96\text{-}07/08}$ is the estimated average annual bycatch mortality in the groundfish fisheries during 1995/96–2007/08.

Statistics on the data and estimates used to calculate $RET_{95/96\text{-}07/08}$, $BM_{CF,\ 95/96\text{-}07/08}$, and $BM_{GF,95/96\text{-}07/08}$ are provided in the "Mean, 1995/96–2007/08" row of Table 5. Using the calculated values of $RET_{95/96\text{-}07/08}$, $BM_{CF,\ 95/96\text{-}07/08}$, and $BM_{GF,95/96\text{-}07/08}$, $OFL_{2012/13}$ is,

$$OFL_{2012/13} = 96{,}932 + 3{,}000 + 23{,}935 = 123{,}867 \text{ lbs (0.12-million lbs)}.$$

**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 for Tier 5 stock.

**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 (2007) that the OFL "represent[s] the average retained catch from a time period determined to be representative of the production potential of the stock."

***b.*** ***Basis for projecting MMB to the time of mating:*** Not applicable for Tier 5 stock.

***c.*** ***Specification of $F_{OFL}$, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:***

See table, below; OFL and ABC values for 2012/13 are the author's recommendations.

| Year | MSST | Biomass (MMB) | TAC | Retained Catch[a] | Total Catch[a,b] | OFL[a,c] | ABC[a,c] |
|---|---|---|---|---|---|---|---|
| 2008/09 | N/A | N/A | Closed | 0 | 0.014 | 0.46 R | N/A |
| 2009/10 | N/A | N/A | Closed | 0 | 0.012 | 0.50 R | N/A |
| 2010/11 | N/A | N/A | Closed | 0 | 0.004 | 0.12 T | N/A |
| 2011/12 | N/A | N/A | Closed | 0 | TBD | 0.12 T | 0.03 T |
| 2012/13 | N/A | N/A | TBD | TBD | TBD | [0.12 T] | [0.03 T] |

a. Millions of pounds.
b. Includes bycatch mortality of discarded bycatch.
c. Noted as "R" for retained-catch OFL and "T" for total-catch OFL.

**4. Specification of the recommended retained-catch portion of the total-catch OFL:**

***a.*** Equation for recommended retained portion of the total-catch OFL,
Retained-catch portion = average retained catch during 1995/96–2007/08
= 96,932 pounds (0.10-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.** A bootstrap estimate of the sampling distribution (assuming no error in estimation of bycatch) of the OFL is shown in Figure 5 (the sample means of 1,000 samples drawn with replacement from the 1995/96–2007/08 estimates of total fishery mortality in Table 5). The mean and CV computed from the 1,000 replicates are essentially the same as for the mean and CV of the 1995/96–2007/08 total catch estimates given in Table 5.

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

- Bycatch mortality rate in each fishery that bycatch occurs. Note that for Tier 5 stocks, an increase in an assumed bycatch rate will increase the OFL (and hence the ABC), but has no effect on the retained-catch portion of the OFL or the retained-catch portion of the ABC.
- Estimated bycatch mortality for each fishery that bycatch occurred in during 1995/96–2007/08.
- 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 addititional uncertainties for alternative sigma-b.** Not applicable to this Tier 5 assessment.

**4. Author recommended ABC.** 0.03 million pounds = the SSC's June 2011 estimate of the average bycatch mortality due to groundfish and the non-directed crab fisheries during 1995/96–2007/08.

## H. Rebuilding Analyses

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

## I. Data Gaps and Research Priorities

This fishery has a long history, with the domestic fishery dating back to 1960/61. However, much of the data on this stock prior to the early-mid 1980s is difficult to retrieve for analysis. Fishery data summarized to the level of statistical area are presently not available prior to 1980/81. Changes in definitions of fishery statistical areas between 1984/85 and 1985/86 also make it difficult to assess geographic trends in effort and catch over much of the fishery's history. An effort to compile all fishery data and other written documentation on the stock and fishery and to enter all existing fishery, observer, survey, and tagging data into a database that allows for analysis of all data from the stock through the history of the fishery would be very valuable.

The SSC in October 2008 and June 2011 noted the need for systematic surveys to obtain the data to estimate the biomass of this stock. Surveys on this stock have, however, been few and the geographic scope of the surveyed area is limited. Aside from the pot surveys performed in the Adak-Atka area during the mid-1970s (ADF&G 1978, Blau 1993), the only standardized surveys for red king crab performed by ADF&G were performed in November 2006 and November 2009 and those were limited to the Petrel Bank area (Gish 2007, 2010). ADF&G-Industry surveys, conducted as limited fisheries that allowed retention of captured legal males under provisions of a commissioner's permit, have been performed in limited areas of the Adak Area: during January–February 2001 and November 2001 in the Petrel Bank area (Bowers et al. 2002) and during November 2002 in the Adak-Atka-Amlia area (Granath 2003). A very limited (18 pot lifts) Industry exploratory survey without any retention of crab was performed during mid-October to mid-December 2009 between 178°00' E longitude and 175°30' E longitude, but only produced a catch of one red king crab (J. Alas, ADF&G, 7 May 2010 ADF&G Memorandum).

Trawl surveys are preferable relative to pot surveys for providing density estimates, but crab pots may be the only practical gear for sampling king crab in the Aleutians. Standardized pot surveys are a prohibitively expensive approach to surveying the entire Adak Area. Surveys or exploratory fishing performed by Industry in cooperation with ADF&G, with or without allowing retention of captured legal males, reduce the costs to agencies. Agency-Industry cooperation can provide a means to obtain some information on distribution and density during periods of fishery closures. However, there can be difficulties in assuring standardization of procedures during ADF&G-Industry surveys (Bowers et al. 2002). Moreover, costs of performing a survey have resulted in incompletion of ADF&G-Industry surveys (Granath 2003). Hence surveys performed by Industry in cooperation with ADF&G cannot be expected to provide sampling over the entire Adak Area during periods of limited stock distribution and overall low density, as apparently currently exists.

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**Table of tables.**

**Table of Figures.**

Table 1. Aleutian Islands, Area O, red king crab commercial fishery data, 1960/61–2011/12, partitioned into the Adak area (west of 172º W longitude prior to 1984/85 and west of 171º W longitude since 1984/85) and the Dutch Harbor area (from Bowers et al. 2011, updated for the 2010/11–2011/12 seasons).

| | | Number of | | | | | Average | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | Locale | Vessels[a] | Landings | Crabs[b] | Pots Lifted | Harvest[b,c] | Weight[c] | CPUE[d] | Length[e] | Deadloss[c] |
| 1960/61 | East of 172° W | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | West of 172° W | 4 | 41 | NA | NA | 2,074,000 | NA | NA | NA | NA |
| | **TOTAL** | | | | | | | | | |
| 1961/62 | East of 172° W | 4 | 69 | NA | NA | 533,000 | NA | NA | NA | NA |
| | West of 172° W | 8 | 218 | NA | NA | 6,114,000 | NA | NA | NA | NA |
| | **TOTAL** | | **287** | | | **6,647,000** | | | | |
| 1962/63 | East of 172° W | 6 | 102 | NA | NA | 1,536,000 | NA | NA | NA | NA |
| | West of 172° W | 9 | 248 | NA | NA | 8,006,000 | NA | NA | NA | NA |
| | **TOTAL** | | **350** | | | **9,542,000** | | | | |
| 1963/64 | East of 172° W | 4 | 242 | NA | NA | 3,893,000 | NA | NA | NA | NA |
| | West of 172° W | 11 | 527 | NA | NA | 17,904,000 | NA | NA | NA | NA |
| | **TOTAL** | | **769** | | | **21,797,000** | | | | |
| 1964/65 | East of 172° W | 12 | 336 | NA | NA | 13,761,000 | NA | NA | NA | NA |
| | West of 172° W | 18 | 442 | NA | NA | 21,193,000 | NA | NA | NA | NA |
| | **TOTAL** | | **778** | | | **34,954,000** | | | | |
| 1965/66 | East of 172° W | 21 | 555 | NA | NA | 19,196,000 | NA | NA | NA | NA |
| | West of 172° W | 10 | 431 | NA | NA | 12,915,000 | NA | NA | NA | NA |
| | **TOTAL** | | **986** | | | **32,111,000** | | | | |
| 1966/67 | East of 172° W | 27 | 893 | NA | NA | 32,852,000 | NA | NA | NA | NA |
| | West of 172° W | 10 | 90 | NA | NA | 5,883,000 | NA | NA | NA | NA |
| | **TOTAL** | | **983** | | | **38,735,000** | | | | |
| 1967/68 | East of 172° W | 34 | 747 | NA | NA | 22,709,000 | NA | NA | NA | NA |
| | West of 172° W | 22 | 505 | NA | NA | 14,131,000 | NA | NA | NA | NA |
| | **TOTAL** | | **1,252** | | | **36,840,000** | | | | |
| 1968/69 | East of 172° W | NA | NA | NA | NA | 11,300,000 | NA | NA | NA | NA |
| | West of 172° W | 30 | NA | NA | NA | 16,100,000 | NA | NA | NA | NA |
| | **TOTAL** | | | | | **27,400,000** | | | | |
| 1969/70 | East of 172° W | 41 | 375 | NA | 72,683 | 8,950,000 | NA | NA | NA | NA |
| | West of 172° W | 33 | 435 | NA | 115,929 | 18,016,000 | 6.5 | NA | NA | NA |
| | **TOTAL** | | **810** | | **188,612** | **26,966,000** | | | | |
| 1970/71 | East of 172° W | 32 | 268 | NA | 56,198 | 9,652,000 | NA | NA | NA | NA |
| | West of 172° W | 35 | 378 | NA | 124,235 | 16,057,000 | NA | NA | NA | NA |
| | **TOTAL** | | **646** | | **180,433** | **25,709,000** | | | | |
| 1971/72 | East of 172° W | 32 | 210 | 1,447,692 | 31,531 | 9,391,615 | 7 | 46 | NA | NA |
| | West of 172° W | 40 | 166 | NA | 46,011 | 15,475,940 | NA | NA | NA | NA |
| | **TOTAL** | | **376** | | **77,542** | **24,867,555** | | | | |
| 1972/73 | East of 172° W | 51 | 291 | 1,500,904 | 34,037 | 10,450,380 | 7 | 44 | | |
| | West of 172° W | 43 | 313 | 3,461,025 | 81,133 | 18,724,140 | 5.4 | 43 | NA | NA |
| | **TOTAL** | | **604** | **4,961,929** | **115,170** | **29,174,520** | **5.9** | **43** | | |
| 1973/74 | East of 172° W | 56 | 290 | 1,780,673 | 41,840 | 12,722,660 | 7.1 | 43 | NA | NA |
| | West of 172° W | 41 | 239 | 1,844,974 | 70,059 | 9,741,464 | 5.3 | 26 | 148.6 | NA |
| | **TOTAL** | | **529** | **3,625,647** | **111,899** | **22,464,124** | **6.2** | **32** | | |

(Continued)

Table 1. page 2 of 3.

| Season | Locale | Number of | | | | | Average | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Vessels[a] | Landings | Crabs[b] | Pots Lifted | Harvest[b,c] | Weight[c] | CPUE[d] | Length[e] | Deadloss[c] |
| 1974/75 | East of 172° W | 87 | 372 | 1,812,647 | 71,821 | 13,991,190 | 7.7 | 25 | | |
| | West of 172° W | 36 | 97 | 532,298 | 32,620 | 2,774,963 | 5.2 | 16 | 148.6 | NA |
| | **TOTAL** | | **469** | **2,344,945** | **104,441** | **16,766,153** | **7.1** | **22** | | |
| 1975/76 | East of 172° W | 79 | 369 | 2,147,350 | 86,874 | 15,906,660 | 7.4 | 25 | | |
| | West of 172° W | 20 | 25 | 79,977 | 8,331 | 411,583 | 5.2 | 10 | 147.2 | NA |
| | **TOTAL** | | **394** | **2,227,327** | **95,205** | **16,318,243** | **7.3** | **23** | | |
| 1976/77 | East of 172° W | 72 | 226 | 1,273,298 | 65,796 | 9,367,965 [f] | 7.4 | 19 | | |
| | East of 172° W | 38 | 61 | 86,619 | 17,298 | 830,458 [g] | 9.6 | 5 | NA | NA |
| | West of 172° W | FISHERY CLOSED | | | | | | | | |
| | **TOTAL** | | **287** | **1,359,917** | **83,094** | **10,198,423** | **7.5** | **16** | | |
| 1977/78 | East of 172° W | 33 | 227 | 539,656 | 46,617 | 3,658,860 [f] | 6.8 | 12 | | |
| | East of 172° W | 6 | 7 | 3,096 | 812 | 25,557 [h] | 8.3 | 4 | NA | NA |
| | West of 172° W | 12 | 18 | 160,343 | 7,269 | 905,527 | 5.7 | 22 | 152.2 | NA |
| | **TOTAL** | | **252** | **703,095** | **54,698** | **4,589,944** | **6.5** | **13** | | |
| 1978/79 | East of 172° W | 60 | 300 | 1,233,758 | 51,783 | 6,824,793 | 5.5 | 24 | NA | NA |
| | West of 172° W | 13 | 27 | 149,491 | 13,948 | 807,195 | 5.4 | 11 | NA | 1,170 |
| | **TOTAL** | | **327** | **1,383,249** | **65,731** | **7,631,988** | **5.5** | **21** | | |
| 1979/80 | East of 172° W | 104 | 542 | 2,551,116 | 120,554 | 15,010,840 | 5.9 | 21 | NA | NA |
| | West of 172° W | 18 | 23 | 82,250 | 9,757 | 467,229 | 5.7 | 8 | 152 | 24,850 |
| | **TOTAL** | | **565** | **2,633,366** | **130,311** | **15,478,069** | **5.9** | **20** | | |
| 1980/81 | East of 172° W | 114 | 830 | 2,772,287 | 231,607 | 17,660,620 [f] | 6.4 | 12 | NA | NA |
| | East of 172° W | 54 | 120 | 182,349 | 30,000 | 1,392,923 [h] | 7.6 | 6 | | |
| | West of 172° W | 17 | 52 | 254,390 | 20,914 | 1,419,513 | 5.6 | 12 | 149 | 54,360 |
| | **TOTAL** | | **1,002** | **3,209,026** | **282,521** | **20,473,056** | **6.4** | **11** | | |
| 1981/82 | East of 172° W | 92 | 683 | 741,966 | 220,087 | 5,155,345 | 6.9 | 3 | NA | NA |
| | West of 172° W | 46 | 106 | 291,311 | 40,697 | 1,648,926 | 5.7 | 7 | 148.3 | 8,759 |
| | **TOTAL** | | **789** | **1,033,277** | **260,784** | **6,804,271** | **6.6** | **4** | | |
| 1982/83 | East of 172° W | 81 | 278 | 64,380 | 72,924 | 431,179 | 6.7 | 1 | | |
| | West of 172° W | 72 | 191 | 284,787 | 66,893 | 1,701,818 | 6.0 | 4 | 150.8 | 7,855 |
| | **TOTAL** | | **469** | **349,167** | **139,817** | **2,132,997** | **6.1** | **3** | | |
| 1983/84 | East of 172° W | FISHERY CLOSED | | | | | | | | |
| | West of 172° W | 106 | 248 | 298,958 | 60,840 | 1,981,579 | 6.6 | 5 | 157.3 | 3,833 |
| 1984/85 | East of 171° W | FISHERY CLOSED | | | | | | | | |
| | West of 171° W | 64 | 106 | 196,276 | 48,642 | 1,296,385 | 6.6 | 4 | 155.1 | 0 |
| 1985/86 | East of 171° W | | | | FISHERY CLOSED | | | | | |
| | West of 171° W | 35 | 82 | 156,097 | 29,095 | 868,828 | 5.6 | 5 | 152.2 | 0 |
| 1986/87 | East of 171° W | FISHERY CLOSED | | | | | | | | |
| | West of 171° W | 33 | 69 | 126,204 | 29,189 | 712,543 | 5.7 | 4 | NA | 800 |
| 1987/88 | East of 171° W | FISHERY CLOSED | | | | | | | | |
| | West of 171° W | 71 | 103 | 211,692 | 43,433 | 1,213,892 | 5.7 | 5 | 148.5 | 6,900 |

(Continued)

Table 1. page 3 of 3.

| Season | Locale | Number of Vessels[a] | Landings | Crabs[b] | Pots Lifted | | Harvest[b,c] | Average Weight[c] | CPUE[d] | Length[e] | Deadloss[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1988/89 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 73 | 156 | 266,053 | 64,334 | | 1,567,314 | 5.9 | 4 | 153.1 | 557 |
| 1989/90 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 56 | 123 | 193,177 | 54,213 | | 1,105,971 | 5.7 | 4 | 151.5 | 759 |
| 1990/91 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 7 | 34 | 146,903 | 10,674 | | 828,105 | 5.6 | 14 | 148.1 | 0 |
| 1991/92 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 10 | 35 | 165,356 | 16,636 | | 951,278 | 5.8 | 10 | 149.8 | 0 |
| 1992/93 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 12 | 30 | 218,049 | 16,129 | | 1,286,424 | 6.0 | 14 | 151.5 | 5,000 |
| 1993/94 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 12 | 21 | 119,330 | 13,575 | | 698,077 | 5.9 | 9 | 154.6 | 7,402 |
| 1994/95 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 20 | 31 | 30,337 | 18,146 | | 196,967 | 6.5 | 2 | 157.5 | 1,430 |
| 1995/96 | East of 171° W | F I S H E R Y C L O S E D | | | | | | | | | |
| | West of 171° W | 4 | 12 | 6,880 | 1,986 | | 38,941 | 5.7 | 3 | 153.6 | 235 |
| 1996/97 | | F I S H E R Y C L O S E D | | | | | | | | | |
| 1997/98 | | F I S H E R Y C L O S E D | | | | | | | | | |
| 1998/99 | West of 174° W | 1 | CF | CF | CF | 0.015 | CF | CF | CF | CF | CF |
| 1999/2000 | | FC | FC | FC | FC | FC | FC | FC | FC | FC | FC |
| 2000/01[k] | Petrel Bank[l] | 1 | 3 | 11,299 | 496 | FC | 76,562 | 6.8 | 23 | 161.0 | 0 |
| 2001/02[m] | Petrel Bank[l] | 4 | 5 | 22,080 | 564 | FC | 153,961 | 7.0 | 39 | 159.5 | 82 |
| 2002/03 | Petrel Bank[l] | 33 | 35 | 68,300 | 3,786 | 0.5 | 505,642 | 7.4 | 18 | 162.4 | 1,311 |
| 2003/04 | Petrel Bank[l] | 30 | 31 | 59,828 | 5,774 | 0.5 | 479,113 | 8.0 | 10 | 167.9 | 2,617 |
| 2004/05 - 2009/10 | | FC | FC | FC | FC | FC | FC | FC | FC | FC | FC |
| 2010/11–2011/12 | | FC | FC | FC | FC | FC | FC | FC | FC | FC | FC |

*Note:* NA = Not available.

[a] Many vessels fished both east and west of 171° W long., thus total number of vessels reflects registrations for entire Aleutian Islands.

[b] Deadloss included.

[c] In pounds.

[d] Number of legal crab per pot lift.

[e] Carapace length in millimeters.

[f] Split season based on 6.5 inch minimum legal size.

[g] Split season based on 8 inch minimum legal size.

[h] Split season based on 7.5 inch minimum legal size.

[i] January/February 2001 Petrel Bank survey (fish ticket harvest code 15).

[j] Those waters of king crab Registration Area O between 179° E long., 179° W long., and north of 51° 45' N lat.

[k] November 2001 Petrel Bank survey (fish ticket harvest code 15).

[m] November Petrel Bank survey (fish ticket harvest code 15, exploratory shellfish harvest).

Table 2. Weight (in pounds) of retained legal males and estimated weight of non-retained legal male, non-retained sublegal male, and non-retained female red king crab in the Adak Area during commercial crab fisheries by season for the 1995/96–2010/11 seasons (from 2011 SAFE).

| | Adak red king crab fishery | | | | AI golden king crab fishery | | | |
|---|---|---|---|---|---|---|---|---|
| | Retained | Non-retained | | | | | | Total |
| Season | legal male | Legal male | Sublegal male | Female | Legal male | Sublegal male | Female | non-retained |
| 1995/96 | 38,941 | 0 | 20,669 | 27,624 | 0 | 2,047 | 314 | 50,654 |
| 1996/97 | 0 | 0 | 0 | 0 | 3,292 | 2,024 | 666 | 5,982 |
| 1997/98 | 0 | 0 | 0 | 0 | 178 | 579 | 179 | 936 |
| 1998/99[a] | 5,900 | - | - | - | 747 | 138 | 186 | - |
| 1999/00 | 0 | 0 | 0 | 0 | 161 | 756 | 93 | 1,010 |
| 2000/01 | 76,562 | 0 | 771 | 374 | 365 | 274 | 35 | 1,819 |
| 2001/02 | 153,961 | 174 | 6,574 | 8,369 | 19,995 | 0 | 364 | 35,476 |
| 2002/03 | 505,642 | 1,658 | 6,027 | 17,432 | 21,738 | 355 | 512 | 47,722 |
| 2003/04 | 479,113 | 631 | 6,597 | 7,962 | 9,425 | 6,352 | 6,686 | 37,653 |
| 2004/05 | 0 | 0 | 0 | 0 | 2,143 | 210 | 0 | 2,353 |
| 2005/06 | 0 | 0 | 0 | 0 | 189 | 0 | 49 | 239 |
| 2006/07 | 0 | 0 | 0 | 0 | 323 | 117 | 50 | 491 |
| 2007/08 | 0 | 0 | 0 | 0 | 615 | 1,819 | 561 | 2,995 |
| 2008/09 | 0 | 0 | 0 | 0 | 220 | 20 | 97 | 337 |
| 2009/10 | 0 | 0 | 0 | 0 | 574 | 249 | 43 | 866 |
| 2010/11 | 0 | 0 | 0 | 0 | 4,312 | 167 | 82 | 4,561 |
| Average, through 2010/11 | 78,757 | 164 | 2,709 | 4,117 | 4,117 | 944 | 620 | 12,873 |

[a.] Data on non-retained bycatch of red king crab during the red king crab fishery not available (see Moore et al. 2000).

Table 3. Estimated annual weight (pounds) of discarded bycatch of red king crab (all sizes, males and females) and bycatch mortality during federal groundfish fisheries by gear type (fixed or trawl) in reporting areas 541, 542, and 543 (Aleutian Islands west of 170° W longitude), 1993/94–2010/11 (assumes bycatch mortality rate of 0.5 for fixed-gear fisheries and 0.8 for trawl fisheries; from 2011 SAFE).

| | Bycatch | | Bycatch Mortality | | |
|---|---|---|---|---|---|
| Season | Fixed Gear | Trawl Gear | Fixed Gear | Trawl Gear | Total |
| 1993/94 | 1,312 | 88,384 | 656 | 70,707 | 71,363 |
| 1994/95 | 2,993 | 22,792 | 1,497 | 18,234 | 19,730 |
| 1995/96 | 5,804 | 15,289 | 2,902 | 12,231 | 15,133 |
| 1996/97 | 2,874 | 44,662 | 1,437 | 35,730 | 37,167 |
| 1997/98 | 3,819 | 11,717 | 1,910 | 9,374 | 11,283 |
| 1998/99 | 10,143 | 45,532 | 5,072 | 36,426 | 41,497 |
| 1999/00 | 37,765 | 27,973 | 18,883 | 22,378 | 41,261 |
| 2000/01 | 2,697 | 13,879 | 1,349 | 11,103 | 12,452 |
| 2001/02 | 5,340 | 59,552 | 2,670 | 47,642 | 50,312 |
| 2002/03 | 11,295 | 73,027 | 5,648 | 58,422 | 64,069 |
| 2003/04 | 3,577 | 9,151 | 1,789 | 7,321 | 9,109 |
| 2004/05 | 791 | 12,930 | 396 | 10,344 | 10,740 |
| 2005/06 | 3,546 | 2,359 | 1,773 | 1,887 | 3,660 |
| 2006/07 | 6,781 | 617 | 3,391 | 494 | 3,884 |
| 2007/08 | 16,971 | 2,630 | 8,486 | 2,104 | 10,590 |
| 2008/09 | 10,778 | 10,290 | 5,389 | 8,232 | 13,621 |
| 2009/10 | 315 | 14,104 | 158 | 11,283 | 11,441 |
| 2010/11 | 92 | 4,381 | 46 | 3,504 | 3,551 |
| Average, through 2010/11 | 7,050 | 25,515 | 3,525 | 20,412 | 23,937 |

Table 4. Estimated pounds of bycatch (not discounted by an assumed bycatch mortality) during federal groundfish fisheries (all gear types combined) by NMFS Reporting Area, 1993/94–2010/11.

| | Reporting Area | | | |
|---|---|---|---|---|
| Season | 541 | 542 | 543 | Total |
| 1993/94 | 83,752 | 5,862 | 82 | 89,696 |
| 1994/95 | 23,637 | 1,922 | 226 | 25,785 |
| 1995/96 | 13,122 | 4,056 | 3,916 | 21,094 |
| 1996/97 | 4,294 | 6,810 | 36,433 | 47,537 |
| 1997/98 | 2,218 | 8,739 | 4,579 | 15,536 |
| 1998/99 | 14,892 | 15,798 | 24,986 | 55,676 |
| 1999/00 | 36,027 | 17,755 | 11,955 | 65,738 |
| 2000/01 | 3,899 | 8,056 | 4,621 | 16,577 |
| 2001/02 | 7,661 | 52,986 | 4,244 | 64,891 |
| 2002/03 | 24,250 | 46,980 | 13,092 | 84,323 |
| 2003/04 | 4,915 | 7,778 | 36 | 12,728 |
| 2004/05 | 1,164 | 12,523 | 34 | 13,721 |
| 2005/06 | 3,540 | 87 | 2,278 | 5,905 |
| 2006/07 | 6,545 | 853 | 0 | 7,398 |
| 2007/08 | 11,295 | 6,708 | 1,598 | 19,601 |
| 2008/09 | 2,522 | 16,635 | 1,911 | 21,068 |
| 2009/10 | 3,686 | 8,278 | 2,455 | 14,419 |
| 2010/11 | 468 | 4,004 | 1 | 4,473 |
| Average | 13,772 | 12,546 | 6,247 | 32,565 |

Table 5. Estimates of total fishery mortality (pounds) for red king crab in the Adak Area, 1995/96–2010/11, partitioned into retained catch, bycatch mortality during crab fisheries, and bycatch mortality during federal groundfish fisheries (from Table 2 with assumed bycatch mortality rate of 0.2 applied to total non-retained bycatch and Table 3).

| | | Bycatch mortality | | |
|---|---|---|---|---|
| Season | Retained Catch | Crab Fisheries | Groundfish Fisheries | Total |
| 1995/96 | 38,941 | 10,131 | 15,133 | 64,205 |
| 1996/97 | 0 | 1,196 | 37,167 | 38,363 |
| 1997/98 | 0 | 187 | 11,283 | 11,470 |
| 1998/99[a] | 5,900 | 1,535 | 41,497 | 48,931 |
| 1999/00 | 0 | 202 | 41,261 | 41,463 |
| 2000/01 | 76,562 | 364 | 12,452 | 89,378 |
| 2001/02 | 153,961 | 7,095 | 50,312 | 211,368 |
| 2002/03 | 505,642 | 9,544 | 64,069 | 579,256 |
| 2003/04 | 479,113 | 7,531 | 9,109 | 495,753 |
| 2004/05 | 0 | 471 | 10,740 | 11,210 |
| 2005/06 | 0 | 48 | 3,660 | 3,708 |
| 2006/07 | 0 | 98 | 3,884 | 3,982 |
| 2007/08 | 0 | 599 | 10,590 | 11,189 |
| 2008/09 | 0 | 67 | 13,621 | 13,688 |
| 2009/10 | 0 | 173 | 11,441 | 11,614 |
| 2010/11 | 0 | 912 | 3,551 | 4,463 |
| Mean, 1995/96–2007/08 | 96,932 | 3,000 | 23,935 | 123,867 |
| CV of mean | 52% | 37% | 23% | 43% |
| Mean, 1995/96–2010/11 | 78,757 | 2,510 | 21,236 | 102,503 |
| CV of mean | 53% | 37% | 22% | 43% |

*a.* No bycatch data was available from the 1998/99 directed fishery for red king crab (see Table 2); bycatch mortality due to the 1998/99 crab fisheries was estimated by multiplying the retained catch for the 1998/99 directed red king crab fishery by the ratio of the 1995/96 bycatch mortality in crab fisheries to the 1995/96 retained catch.

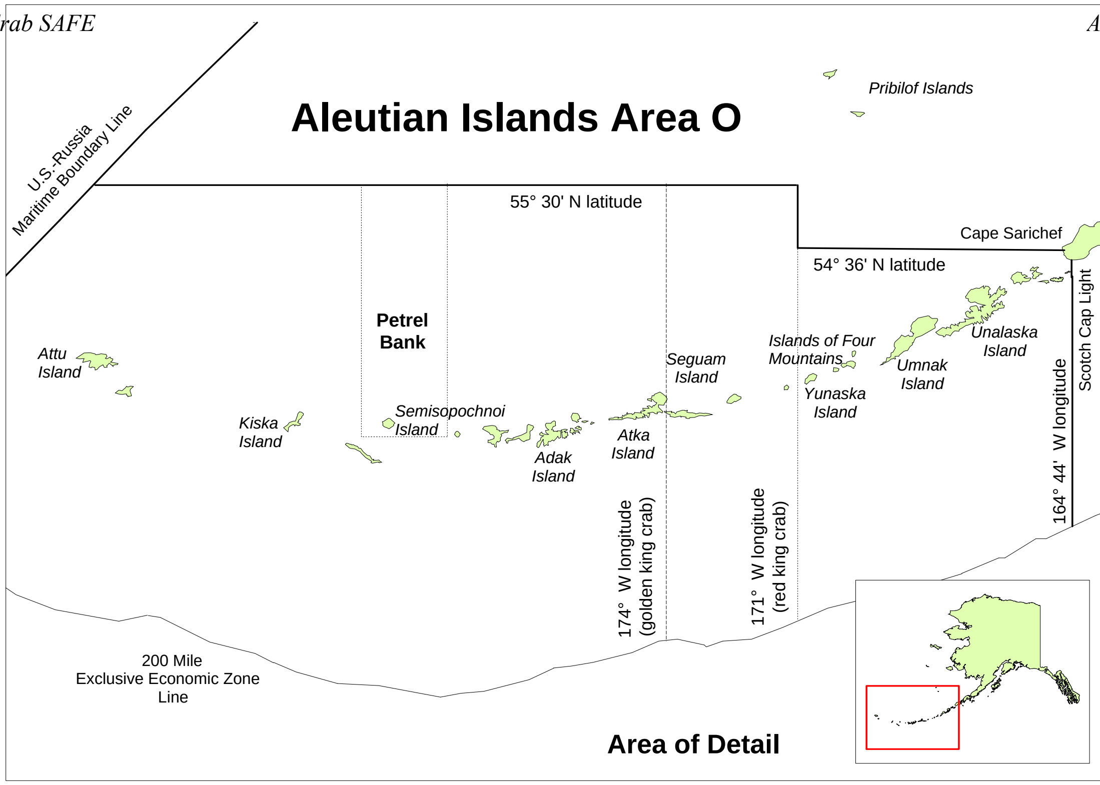


Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Bowers et al 2011).

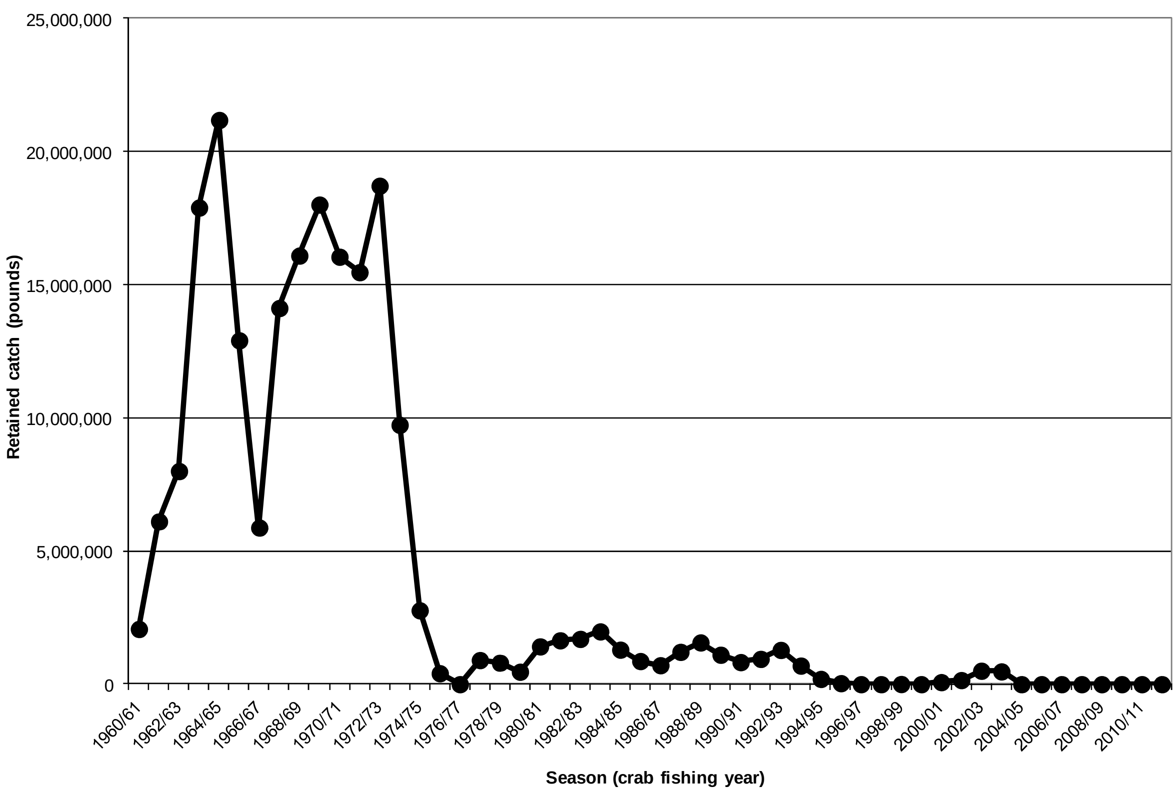


Figure 2. Retained catch in the Adak red king crab fishery, 1960/61–2011/12 (catch is for the area west of 172º W longitude during 1960/61–1983/84 and for the area west of 171º W longitude during 1984/85–2011/12; see Table 1).

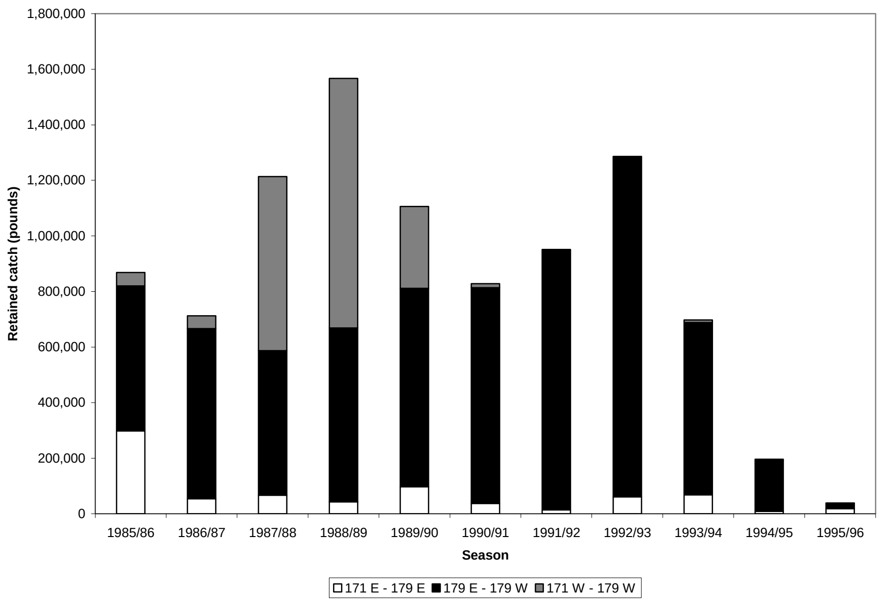


Figure 3. Retained catch (pounds) in the Adak red king crab fishery for the 1985/86–1995/96 seasons, partitioned into three longitudinal zones (171º W longitude to 179º W longitude, 179º W longitude to 179º E longitude, and 179º E longitude to 171º E longitude; from ADF&G fish ticket summary provided by F. Bowers, ADF&G, March 2008).

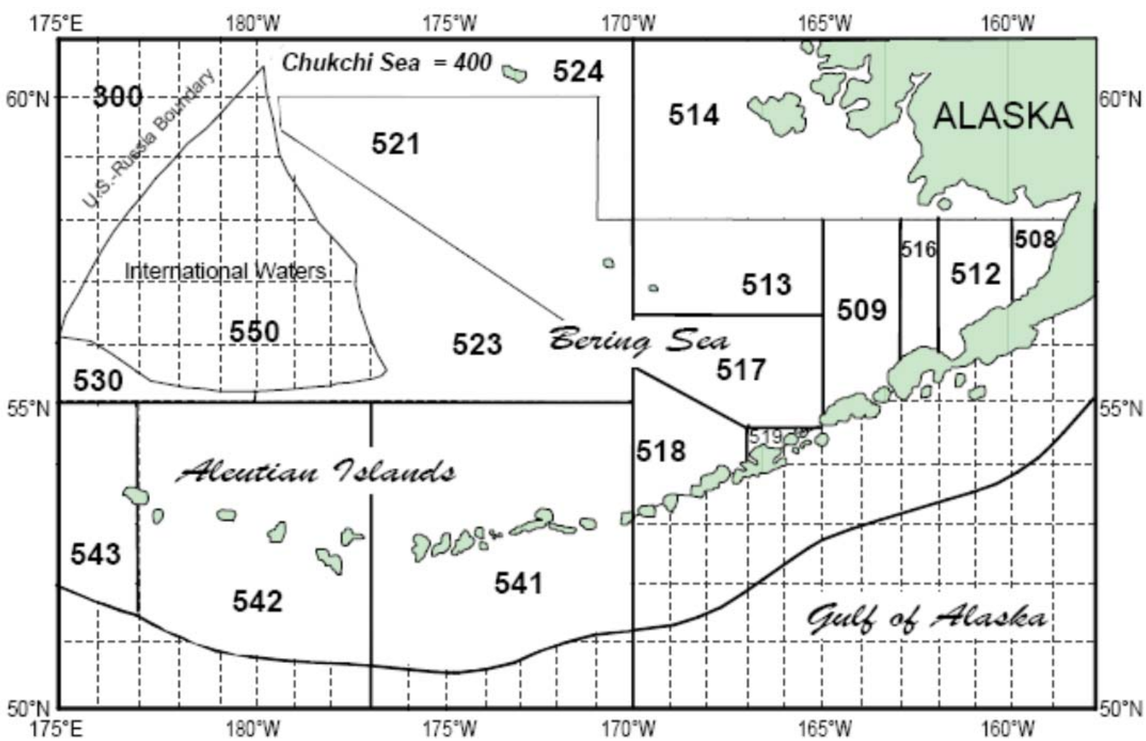


Figure 4. Map of federal groundfish fishery reporting areas for the Bering Sea and Aleutian Islands showing reporting areas 541, 542, and 543 that are used to obtain data on bycatch of Adak red king crab during groundfish fisheries (from http://www.fakr.noaa.gov/rr/figures/fig1.pdf).

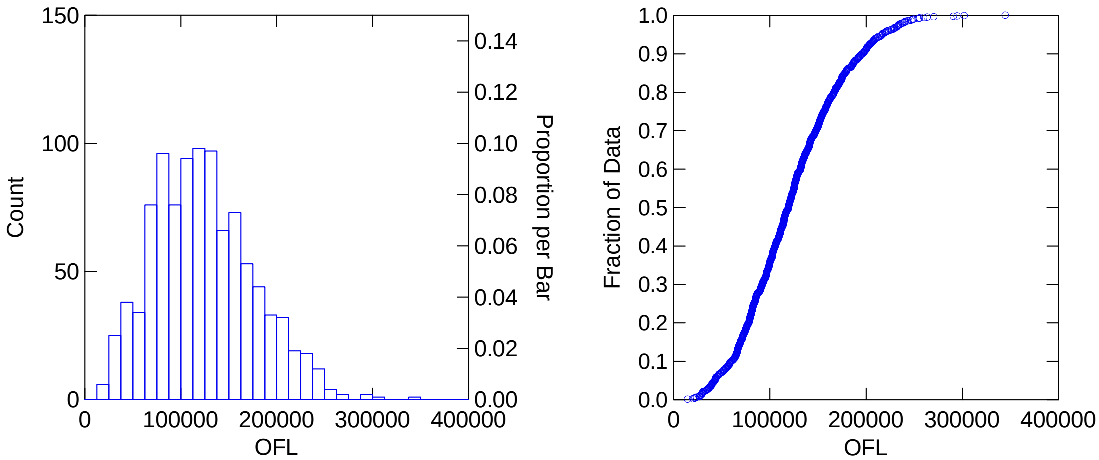


Figure 5. Bootstrapped estimate of the sampling distribution of the recommended 2012/2013 Tier 5 OFL (pounds of total catch) for the Adak red king crab stock; histogram in left column, quantile plot in right column (from 2011 SAFE).

# STOCK ASSESSMENT AND FISHERY EVALUATION REPORT FOR KING AND TANNER CRAB FISHERIES OF THE BERING SEA AND ALEUTIAN ISLANDS REGIONS

DRAFT 2012 ECONOMIC STATUS REPORT

Prepared by Brian Garber-Yonts & Jean Lee
September 2012

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## Request for comments

While the statistics in this report are intended to characterize the economic status of BSAI crab fisheries, the authors welcome any comments from industry members, fishery managers, researchers, and other BSAI crab fishery stakeholders on the validity and utility of the statistics presented. As this report is anticipated to evolve into a suite of annually-reported statistics, accompanied by one-time analyses with more immediate relevance to current fishery conditions, it is hoped that users will take an active role in this report's development by identifying data or estimates that can be improved; by providing the information and methods necessary to improve estimates for both past and future years; by suggesting other means of summarizing or presenting available data; and by suggesting additional measures of economic performance that should be included for regular or one-time reporting. Those interested in providing comments on this report are encouraged to do so through the user feedback survey available online at:

http://www.afsc.noaa.gov/REFM/Socioeconomics/Contact/SAFE_crab_survey.php

This report, along with electronic files of selected tabular data, is available online at:
http://www.afsc.noaa.gov/REFM/Socioeconomics/BSAI_crab_econ_safe.php

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# Abstract

This report presents information on economic activity in commercial crab fisheries currently managed under the Federal Fishery Management Plan (FMP) for Bering Sea and Aleutian and Islands King and Tanner Crab (BSAI crab), with attention to the subset of fisheries included in the Crab Rationalization (CR) Program. Statistics on harvesting and processing activity; effort; revenue; labor employment and compensation; operational costs; and quota ownership, usage and disposition among participants in the fisheries are provided. Additionally, this report provides a summary of BSAI crab-related research being undertaken by the Economic and Social Sciences Research Program (ESSRP) at the Alaska Fisheries Science Center (AFSC).

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# Abbreviations

## Crab fisheries

| | |
|---|---|
| AIG | Aleutian Islands golden king crab (East and West fisheries combined) |
| BBR | Bristol Bay red king crab |
| BSS | Bering Sea snow crab |
| BST | Bering Sea Tanner crab (East and West fisheries combined) |
| BTE | Bering Sea Tanner crab, East |
| BTW | Bering Sea Tanner crab, West |
| EAG | Aleutian Islands golden king crab, East |
| NSR | Norton Sound red king crab |
| PIG | Pribilof Islands golden king crab |
| PIK | Pribilof Islands red and blue king crab |
| SMB | St. Matthew Island blue king crab |
| WAG | Aleutian Islands golden king crab, West |
| WAI | Western Aleutian Islands (Adak) red king crab |

## Other

| | |
|---|---|
| ACA | Adak Community Allocation |
| ADF&G | Alaska Department of Fish & Game |
| AFSC | NMFS Alaska Fishery Science Center |
| AKR | NMFS Alaska Region Office |
| BSAI | Bering Sea and Aleutian Islands |
| CDQ | Community Development Quota |
| CFEC | Alaska Commercial Fisheries Entry Commission |
| COAR | Commercial Operators Annual Report |
| CP | Catcher processor (industry sector) |
| CPC | Catcher processor crew (quota share type) |
| CPO | Catcher processor owner (quota share type) |
| CPUE | Catch per unit effort |
| CR | Crab rationalization |
| CV | Catcher vessel (industry sector) |
| CVC | Catcher vessel crew share (quota share type) |
| CVCP | Catcher vessel + catcher processor; denotes crab industry sectors with harvesting activity components |
| CVOA | Catcher vessel owner ‘A’ share (quota share type) |
| CVOB | Catcher vessel owner ‘B’ share (quota share type) |
| EDR | Economic Data Report |
| ESSRP | Economics and Social Sciences Research Program |
| FMP | Fishery Management Plan |
| GHL | Guideline harvest limit |
| IFQ | Individual Fishing Quota |
| IPQ | Individual Processing Quota |
| LLP | License Limitation Program |
| MSA | Magnuson-Stevens Fishery Conservation and Management Act |
| NMFS | NOAA Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |

| | |
|---|---|
| NPFMC | North Pacific Fisheries Management Council |
| PQS | Processor quota share |
| PSMFC | Pacific States Marine Fisheries Commission |
| QS | Quota share |
| RAM | NMFS Alaska Region Restricted Access Management |
| RCR | Registered Crab Receiver |
| RPUE | Revenue per unit effort |
| SAFE | Stock Assessment and Fishery Evaluation |
| SFCP | Shoreside and floating processor + catcher processor; denotes crab industry sectors with processing activity component |
| SFP | Shoreside and floating processor (industry sector) |
| TAC | Total allowable catch |

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# BSAI Crab Fisheries Economic Status Report

## 1 Introduction

This report provides statistics on economic activity in commercial crab fisheries managed under the North Pacific Fishery Management Council's *Federal Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs* (BSAI crab FMP), with substantial additional detail available for active fisheries managed under the Crab Rationalization Program. The report is produced as part of the annual *Stock Assessment and Fishery Evaluation for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions* (SAFE), provided as a reference source for information on status and trends in social and economic dimensions of fisheries managed under the FMP, to support evaluation of management and regulatory decision making. The report consolidates relevant information published in annual management reports by Alaska Department of Fish and Game and NOAA Fisheries Alaska Region, supplemented with additional analysis and information derived from primary data collected annually by the State of Alaska's Commercial Fisheries Entry Commission, NOAA Fisheries Alaska Fisheries Science Center and, and Pacific States Marine Fisheries Commission.

Section 2 of this report depicts available information on economic status and trends in commercial BSAI crab fisheries are in a variety of dimensions. These are broadly encompassed under the following categories: economic output; income and employment; operating and production costs; use and distribution of ownership in quota share allocations and other fishery capital assets; fishing and processing capacity and effort, and international trade in crab commodities. Within each of these categories, current economic status is depicted in terms of the most recent data available. In most cases this is the prior calendar year or crab fishery year. Data are summarized as aggregate totals and/or averages calculated over relevant economic units, primarily at the level of harvest and processing sectors within individual crab fisheries, with additional levels of stratification as appropriate, and/or aggregated over all crab fisheries. The presentation is largely limited to these descriptive statistics, with measures of variability and/or uncertainty for selected variables where supported by available data. Statistical tests to assess significant differences in measured values of the descriptive statistics are not employed in the presentation, however, further analytical and statistical treatment of these and other data in applied social and economic research regarding aspects of fishery management are ongoing, and research under the sponsorship of AFSC is documented in an appendix to the report.

As many of the key data sources are reported on an annual basis, current status and trends are framed in the context of inter-annual variation, with a focus on the most recent five to seven years of the crab fishery, although longer time series are presented where available and longer historical perspectives noted where relevant, particularly with regard to pre- and post-rationalization comparisons. The current report summarizes information available to-date, largely comprising data reported through calendar year 2012 for the 2011 calendar year and 2011/2012 crab season.

Section 3 of the report as provides results of a selected set of economic performance metrics calculated for IFQ crab fisheries as part of a national-level effort by NOAA Fisheries, Office of Science and Technology (OST) to coordinate monitoring and reporting of economic performance of catch share programs across all regions and rationalized (catch share) fisheries (citation to be added). Values calculated for IFQ crab fisheries are reported using OST protocols for catch share performance metrics depicting status and trends in program fisheries with respect to catch and landings, effort, economic value, and cost recovery. As discussed further below, coordinated monitoring and reporting of performance metrics under OST protocols is a recent effort under active development. Much of this information overlaps the analysis reported in Section 2, and is included for the purpose of drawing attention to efforts by OST Division of Economics and Social Analysis to define a uniform set of metrics for monitoring the economic and social effects of fishery catch share programs of over time, and to the values reported for CR program fisheries in the context of coordinated performance monitoring and reporting across catch share programs nationally. As an added benefit, Section 3 metrics are reported on the basis of crab fishery year, in contrast to Section 2 calendar year reporting.

## Fishery overview

Ten crab stocks are currently managed under the North Pacific Fishery Management Council's Fishery Management Plan (FMP) for Bering Sea/ Aleutian Islands: four red king crab (*Paralithodes camtschaticus*) stocks: Bristol Bay, Pribilof Islands, Norton Sound and Adak; two blue king crab (*Paralithodes platypus)* stocks: Pribilof District and St. Matthew Island; two golden (or brown) king crab (*Lithodes aequispinus)* stocks: Aleutian Island and Pribilof Islands; Bering Sea Tanner crab (*Chionoecetes bairdi)*, and Bering Sea snow crab (*Chionoecetes opilio)*. All other crab stocks in the BSAI are exclusively managed by the State of Alaska. In the context of this report the terms "BSAI crab" and "FMP crab" will be used to denote only those commercial crab fisheries associated with the 10 crab stocks currently managed under the BSAI crab FMP.

Management of Aleutian Island golden king crab and Bering Sea Tanner crab distinguishes separate fisheries for eastern and western components of the stocks as described in the FMP, and jointly manages Pribilof Island red and blue king crab stocks as a single fishery. Of the eleven distinct fisheries managed under the FMP, seven are currently open to targeted fishing, with Eastern and Western Bering Sea Tanner, Pribilof Islands red- and blue king, and Western Aleutian red king crab stocks currently designated overfished and closed to targeted fishing, as detailed in the annual stock assessments for these stocks and ADF&G management reports. After being opened to targeted fishing in 2005/06 through 2008/09 and 2009/10, respectively, the Western and Eastern Bering Sea Tanner crab fisheries were designated overfished and closed to targeted fishing. A rebuilding plan for the stock is currently under development, as detailed in the SAFE summary chapter and assessment. After closure for ten years while under a rebuilding plan beginning in 1999, the Saint Matthew Island blue king crab stock was declared rebuilt in 2009 and the fishery has been open since 2009/10.

The seven fisheries open during the most recent three crab fishing years have been collectively prosecuted by an active fleet of approximately 100 catcher vessels and three catcher processors, and landed and processed at approximately 20 processing facilities throughout the region.

BSAI Crab Rationalization Program

Key details regarding the structure of the CR programs as referenced in this report are outlined below. Readers are referred to the annual Crab Rationalization Reports and the CR Program webpage maintained by AKR for detailed information regarding the regulatory structure and management of the CRP as overseen by the Council and administered by NOAA Fisheries. The CR Report provides details regarding all recent management changes, emergency rules issued, and other significant events in p[rogram administration during the previous fishery year, as well as an appendix providing a comprehensive overview of all elements of the CR Program as initially implemented and all subsequent revisions and FMP amendments. Several elements of annual CRP administration of importance to economic status of the fisheries are provided in the annual CR Report, including QS/PQS permanent transfer and IFQ/IPQ annual allocation transfer activity, harvest cooperative formation and IFQ assignment by fishery, initiation and outcomes of arbitration proceedings between harvesters and processors, safety and regulatory compliance by program participants, loan issuance under the Fisheries Finance Program, and CRP cost recovery fee assessment and collection. Website address URL's and links to other useful references regarding the CR Program are provided below.

In March 2005, NOAA Fisheries issued a final rule to implement the Crab Rationalization (CR) Program as Amendments 18 and 19 to the BSAI Crab FMP. The CR Program went into effect with the 2005/2006 crab season that began in August 2005, which affects the following fisheries: Bristol Bay red king crab (BBR), Bering Sea snow crab (BSS), Eastern Bering Sea Tanner crab (BTE), Western Bering Sea Tanner crab (BTW), Pribilof blue and red king crab (PIK), St. Matthew Island blue king crab (SMB), Western Aleutian Islands golden king crab (WAG), Eastern Aleutian Islands golden king crab (EAG), and Western Aleutian Islands (Adak) red king crab (WAI). Two fisheries managed under the BSAI crab FMP, Norton Sound red king crab and Pribilof Islands golden king crab, are excluded from the CR Program.

The CR Program allocates BSAI crab resources to qualifying harvesters, vessel crew members, processors, and Western Alaska coastal communities. Under terms of FMP Amendments 18 and 19 and subsequent amendments, harvest and processing privileges in the CRP fisheries are granted as long-term percentage shares, designated as harvest quota share (QS) and processor quota share (PQS). Subject to annual application requirements, annual allocations proportional to QS and PQS percentages are issued to participating share holders as Individual Fishing Quota (IFQ) and Individual Processing Quota (IPQ) permits, granting pound-denominated quantities of catch and processing shares of the annual Total Allowable Catch (TAC). The harvest component of the CR fisheries is divided between the QS/IFQ component, representing 90 percent of the annual TAC, and the remaining ten percent allocated as Community Development Quota (CDQ) or, for Western Aleutian Islands golden king crab fishery, Adak Community Allocation (ACA) quota. Under the three-pie allocation system that is unique to the CRP, a portion of the harvest shares issued as IFQ are subject to a share matching requirement, wherein subject IFQ must be sold to qualified crab buyers holding shares of IPQ, with additional delivery requirements designating a portion of share-matched IFQ for delivery to specified regions within the BSAI. Specifically, IFQ allocations issued to catcher vessel owners (CVO-IFQ) are issued as 90 percent Class A IFQ, subject to regional delivery requirements and share-matching, and the remaining 10% designated Class B IFQ exempt from share matching and regional delivery requirements.

All other QS/IFQ pools, including those issued to catcher processor owners, catcher processor crew members, and catcher vessel crew members, as well as CDQ and ACA allocations, are exempt from regional delivery and share matching requirements.

This report uses the term "CR program fisheries" to denote those fisheries included in the CR program, inclusive of all QS/PQS, CDQ, and ACA allocations; and the term "IFQ fisheries" to denote specifically the QS/IFQ and PQS/IPQ allocation fisheries within the program.

Additional information on BSAI crab fisheries is available from the Alaska Department of Fish & Game (ADF&G); NOAA Fisheries (NMFS), Alaska Region (AKR); and the North Pacific Fishery Management Council (NPFMC). Readers seeking more extensive discussion of fishery history and management may find the following resources particularly useful:

- NOAA Fisheries Alaska Region
    - BSAI Crab Fisheries: http://www.fakr.noaa.gov/sustainablefisheries/crab/
    - BSAI Crab Rationalization (includes history of relevant amendments to the FMP): http://www.fakr.noaa.gov/sustainablefisheries/crab/crfaq.htm#CRreports
- NPFMC
    - BSAI Crab FMP: http://www.fakr.noaa.gov/npfmc/fishery-management-plans/crab.html
    - Bering Sea and Aleutian Islands Crab Rationalization Program: http://www.fakr.noaa.gov/npfmc/catch-shares-allocation/bsai-crab-rationalization-program.html
- ADF&G Shellfish Management
    - Westward Region, Bering Sea & Aleutian Islands Area Shellfish: http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareaaleutianislands.shellfish
    - Arctic-Yukon-Kuskokwim Region, Norton Sound and Kotzebue Shellfish (for information on the Norton Sound red king crab fishery): http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareanortonsound.shellfish

## Data sources

This document is the primary channel for publication of aggregate data from the BSAI Crab Economic Data Report (EDR) program administered by NMFS Alaska Science Fisheries Science Center (AFSC), Economics and Social Science Research Program (ESSRP). The EDR program is a mandatory census involving reporting of detailed operational and financial information by owners and leaseholders of vessels and processing plants participating in CR program fisheries. Broadly speaking, the objectives of this reporting requirement are to monitor the economic performance of the rationalization program in terms of changes in the efficiency and profitability of the fisheries, and economic stability for harvesters, processors, and coastal communities, as a result of the rationalization of the fisheries and in response to ongoing management decision-making. The EDR reporting requirement was implemented in 2005, with baseline data submission required retroactively for 1998, 2001, and 2004, and subsequently, on an annual basis, for calendar year crab fishing and processing activities for 2005 to present.

The current Economic Status Report focuses on reporting summary statistics for reported values across EDR data elements identified as sufficiently accurate for public reporting. Several key elements in the EDR data collection currently limited by data quality have been withheld from the current report and have not been used in analysis of the CR program (AFSC, 2011. These include quantity and cost of fuel used in the fishery, prices and costs for leasing of Individual Fishing Quota (IFQ), and spending for factor inputs by individual location. Given the importance of these elements in examining changes in profitability and distribution of income generated by and within the fishery, these data quality issues limit the analysis of several key performance metrics for the fishery. Ongoing research and analysis will provide additional interpretation and syntheses of EDR data in future reports, and it is expected that these data will be used in a broad array of focused analyses for decision support and research purposes. Future improvements in the data collection are expected to improve the ability of these data to support computation of broader array of performance metrics.

Varying degrees of coverage error apply to EDR data collected retroactively in 2005 for calendar years 1998, 2001, and 2004, as well as for certain processing-sector reporting elements in all years of the data collection. The historic (pre-2005) reporting requirement was tied to issuance of fishing and processing quota in the rationalized fishery; and as such, the historic data may exclude operations that participated in the crab fisheries in 1998, 2001, and/or 2004 but did not anticipate receiving quota in the rationalized fishery. Additionally, because purchasers of CR crab that do not process any crab in their own facility are exempt from EDR reporting requirements, the data collection does not represent a full census of activity, revenue, and costs in the processing sector. Statistics on EDR coverage of harvesting and processing sector activity in comparison to other administrative data collections are presented in the Appendix.

A number of other sources in addition to the EDR database have been utilized to compile the statistics presented in this report. ADF&G fish tickets document commercial harvest from Alaska commercial fishery resources, including all BSAI crab fisheries. Since implementation of the crab rationalization program in 2005/06, NMFS Alaska Region, Restricted Access Management (RAM) division has maintained accounting on landings, quota usage, and quota disposition in the IFQ crab fisheries. The ADF&G Commercial Operator's Annual Report (COAR) provides data on statewide crab production differentiated by crab species, product, and process type; and is additionally used by the Alaska Commercial Fisheries Entry Commission (CFEC) to estimate crab ex-vessel pricing. Regular reporting on BSAI crab fisheries cited in this document include the *Bering Sea and Aleutian Islands Crab Rationalization Program Report,* published annually by NMFS Alaska Region, RAM Division; and area management reports published by ADF&G.[1] The Program Report provides information on the annual management of the CR program fisheries, and particularly the IFQ fishery component of the program. ADF&G fishery management reports provide information on fishery history, management, and stock status, in addition to detailed information on fishing activity occurring in the most recent fishing

[1] With the exception of Norton Sound red king crab, all fisheries included in the BSAI crab FMP are managed as part of the ADF&G Westward Region, Bering Sea/Aleutian Islands Management Area, with annual reporting on these fisheries available in the *Annual Management Report for the Commercial and Subsistence Shellfish Fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfish Observer Program* (http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareaaleutianislands.shellfish#/management*)*. Norton Sound red king crab is managed as part of the Norton Sound and Kotzebue Management Area within the Artic-Yukon-Kuskokwim Region; reporting is provided in *Annual Management Report Norton Sound, Port Clarence, and Kotzebue* (http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareanortonsound.shellfish)/

season. Citations for these and other sources used in compiling this report are provided in figure and table footnotes and in the References section.

## Data conventions

Under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (P.L. 109-479), fishery information required to be submitted under Fishery Management Plans, including landings data, is confidential. NOAA Administrative Order (NAO) 216-100 is the principal guidance for NOAA Fisheries employees on protocols for handling confidential data. To assure confidentiality, data must be structured or aggregated so that the identity of the submitter cannot be determined from the present release of the data or in combination with other releases. "Submitter" is applied in context for the specific data presented. Data provided by the State of Alaska are treated consistent with the Memorandum of Understanding between NMFS and the State of Alaska regarding data sharing. Due to the sensitive nature of financial information reported in this document, confidentiality protocols have been interpreted conservatively and may result in greater suppression of statistical information representing contributions from low numbers of reporting units.

Data cited in this report have been aggregated across time, fishery management units, and reporting entities so as to satisfy confidentiality requirements while maximizing the comparability of statistics both within and among tables and figures. Some notable restrictions on comparability still exist, however. In particular, the calendar-year basis by which most statistics in this report are presented is incongruent with the July-to-June management season of crab rationalization fisheries. Declining participation in fisheries post-rationalization has necessitated increased aggregation in order to preserve the confidentiality of reported data. Notably, EDR data for the Eastern and Western Aleutian Islands golden king crab fisheries are reported together in aggregate, even though the fisheries are typically prosecuted by distinct fleets and managed as distinct fisheries. Users should also note the discontinuity in presentation of EDR statistics by industry sector between 2009 and earlier years: due to low participation in the catcher processor sector, EDR data starting in 2009 are presented with aggregations over the catcher processor and catcher vessel sectors for statistics related to harvest activity; and over the catcher processor, shoreside processor, and floating processor sectors for statistics related to processing activity. Users should also note that EDR data is generally not finalized until the beginning of the second calendar year following a reporting year. As of the date of this report, 2011 statistics derived from the EDR, including ex-vessel and first wholesale prices and revenue, should be considered preliminary and subject to change.

Except where otherwise noted, monetary values in tables and figures are adjusted to 2011 values using the Producer Price Index for unprocessed and packaged fish2. Index values from 1991 to 2011 are provided in Table 52 of the Appendix.

Users of this report are strongly encouraged to consult table and figure footnotes, which provide citations of data sources, interpretive guidance, and discussion of data limitations and qualifications in addition to those already cited in this section or in discussion text accompanying

[2] Bureau of Labor Statistics. *Producer Price Index-Commodities, Series WPU0223 (Unprocessed and packaged fish).*Retrieved July 2012 from http://www.bls.gov/ppi/

figures and tables. Full footnotes are provided with the tabular data only in order to conserve space, although each figure is accompanied by cross-references to the relevant tabular data. Users should also note the abbreviations and conventions used in tabular and graphical presentations of data in this report:

| | |
|---|---|
| -- | Confidential value not reported |
| n/a | Not applicable |
| n/d | No data available (data not collected, no observations in reported data, or available data is insufficient for public reporting) |
| 2005 or 05 | Calendar year; or fishing season that occurred wholly within calendar year |
| 2005/06 or 05/06 | Fishing season for CR program fishery |
| lbs | Pounds |
| mt, or *t* | Metric tons |
| obs / observations | Number of observations with value > 0 for measure of interest |
| sd | Standard deviation |
| $ | US dollars |

# 2 Economic Status and Trends in BSAI Crab Fisheries

## Economic Output

Total Allowable Catch levels for FMP crab fisheries[3] since 2005/06 are illustrated in Figure 1. With the exception of closures in the Tanner crab fisheries and significant volatility in TAC's issued in Bristol Bay red king (BBR) and Bering Sea snow (BSS) crab, most fisheries have been stable or modestly increasing over the recent years. The BSS allowable catch has varied substantially over the 2005/06 to 2012 period, with interannual changes as great as 72 percent, and increasing by nearly 64 percent to a recent a recent peak of 88.9 million pounds declared for the 2011/12 crab season. BBR TAC's have varied within a narrower range, proportionately, but declined in 2011/12 by the greatest margin since rationalization, reduced by 42 percent from the previous year to 7.83 million pounds.

Total catch and production volume produced in the harvest and processing sectors for all FMP crab fisheries under annual TAC levels and the associated gross revenue value of production in the respective sectors are shown in Figure 2. Corresponding average ex-vessel and first wholesale prices in are shown in Figure 3[4], noting that information on processing sector revenue and prices is limited in the smaller fisheries due the number of entities participating and associated confidentiality limitations on reporting.

During the 2011 calendar year and across all fisheries managed under the FMP, total volume of landings was 70.2 million pounds (31.8 thousand *t*), slightly lower overall than the total volume produced during the 2010 calendar year. A substantial reduction in the 2011/12 season allowable catch and landed volume of Bristol Bay red king crab from 14.7 to 7.8 million pounds was largely offset in overall landed volume for FMP stocks by a 12 percent increase in catch and production in the Bering Sea snow crab fishery under the 2010/11 catch limits.

Increases in ex-vessel and first wholesale prices observed in 2010 continued the trend for a second year, with Bristol Bay red king crab finished production receiving a weighted average $18.89 per pound at first wholesale and $10.41 per pound ex-vessel in 2011 (weighted by volume over all product forms and landings, respectively). Both wholesale and ex-vessel prices for BBR production during 2011 represented historic highs, exceeding the previous high point for first wholesale price of $16.93 per pound in 1999 by nearly 12 percent, 38 percent higher than the 2010 average, and 76 percent over the previous five-year (2006-2010) average. Similarly, the average ex-vessel price for BBR exceeded the 1999 peak of $9.44 per pound by greater than 10 percent, and reaching 34 and 82 percent above the previous 1- and 5-year averages, respectively.

In addition to increased Bering Sea snow crab catch and production volume in calendar year 2011, wholesale prices for finished snow crab production rose substantially for a second year in a row, to a weighted average $5.50 per pound, 59 percent above the level for 2010 and 39

[3] Guideline Harvest Levels, in the case of Norton Sound red king (NSR) and Pribilof Island golden king crab (PIG) fisheries.
[4] All prices shown are inflation-adjusted to 2011 dollars.

percent over the five-year average. Correspondingly, ex-vessel prices increased to $2.55 per pound on average, 88 percent above 2010 and 53 percent over the five-year average. Preliminary data for IFQ component of the 2011/12 BSS fishery (which closed as recently as June 15), indicate ex-vessel prices decreasing on average to $1.89 per pound. Note that preliminary data are unlikely to include the full extent of post-season adjustments to ex-vessel sales values, which may ultimately result in significant upward revision of this value. Even with limited post-season adjustments, total ex-vessel revenue from IFQ landings in the most recent BSS fishery appear likely to exceed $150 million.

Increased prices in all other BSAI crab fisheries open during 2011, although somewhat smaller in effect than the price gains in the two largest fisheries, resulted in substantial net increases in overall gross revenues in FMP crab fisheries in 2011 relative to the prior calendar year. Ex-vessel revenue value in aggregate was approximately $258 million, exceeding the 2010 level by 22 percent and the previous five-year average by 14 percent. Total finished pounds reported by processors in 2011 across all FMP crab species and product forms was approximately 48 million pounds (21.9 thousand *t*), with an estimated first wholesale value of $363 million (F.O.B Alaska), a year-on-year increase of over 21 percent and 28 percent above the five-year average.

These results are further stratified in Table 5 throughTable 7, reporting ex-vessel revenues by vessel-owner State of residence, vessel length-class, and by harvest quota share type. As illustrated in Figure 4, prices for ex-vessel IFQ landings sold using Class A IFQ have generally been somewhat lower than those produced from ex-vessel sales using harvest quota not encumbered by the share matching requirement associated with processor quota, including B Class and Crew share IFQ. The price differential is observable intermittently in annual mean ex-vessel values and was absent from the average ex-vessel prices observed in 2009 and 2010. The price differential is consistent directionally in BBR and BSS fisheries. BST and AIG fisheries indicate a less consistent directional pattern (reporting is limited to 2006 and 2007 results for AIG due to confidentiality limitations), which may be associated with limitations in both fisheries that resulted in significant portions of the allocated quota going unused. Error bars display variation over distinct vessels within one standard deviation of the annual mean price.

Table 8 displays the distribution of deadloss landings by fishery and use of harvest quota type for CR program participating catcher vessels. Deadloss quantities are generally quite small, but are reported for nearly all participating vessels. In both BSS and BBR fisheries over the 2006-2011 period, Class B and CDQ landings account proportionally for between 14 percent and 27 percent of total CV deadloss landings, with crew share quota accounting for proportions of deadloss landings varying between 0.3 percent to 3.9 percent over the same period. No distinct pattern with respect to type of quota used on deadloss landings is discernible, and no results are available indicating relative compensation of quota share holders for harvest quota used for deadloss landings.

Table 10 andTable 11 provide extended time series and additional detail on the volume, revenue and both weighted average and mean first wholesale prices for finished production from CR fisheries (Table 10), and pooled over all state and federal crab fisheries in Alaska by crab species (Table 11). Table 12 provides additional detail regarding the distribution of statewide processed crab production volume, revenue value, and average prices by general product form, including whole crab, crab sections, and other for 2007 to 2011. Although reporting is limited by confidentiality data cannot be shown for all years, species, and product forms, it is clear that across all species, frozen crab sections predominate as the primary product form, with the notable exception of golden king crab, for which a greater proportion of product sales are in the form of whole crab than is the case with other crab species, comprising nearly 18 percent of total sales volume and revenue in 2008, and likely greater proportions in more recent years.

## Income and Employment

Consolidation in the crab harvest sector following rationalization in 2005/06 resulted in both a substantial reduction in the number of active vessels and lengthening of the seasons over which the fisheries are prosecuted. Correspondingly, the number of crew positions was reduced and working conditions changed, resulting in longer periods of active work in the fisheries for remaining crab crews. Vessel consolidation has largely stabilized over the last three years of the program to a total of 74 catcher vessels and three catcher-processors prosecuting the IFQ and CDQ crab fisheries during 2009 through 2011. A summary of selected indicators from the most recent employment data available for Crab Rationalization (CR) program fisheries is illustrated in **Error! Reference source not found.** and enumerated in Table 13 andTable 14. Based on the average (mean) number of crew onboard as (reported in eLandings catch accounting records), there were an estimated 967 crew positions across all 77 vessels in CR fisheries in 2011. Counting crew share contracts for each fishery separately from crew positions, there were approximately 1,020 share contracts issued to participating crew members, with the larger number of share contracts relative to positions likely reflecting a combination of variation in a given vessel's reported crew size on different landings and turnover in crew during the course of a fishery. Crew employment over the last five years of the program has fluctuated somewhat, but remained largely stable, with the total number of crew positions over all CR fluctuating between 1072 in 2009 and 918 in 2010. Across all vessels participating in the rationalized fisheries in 2011, 605 different crew member licenses and permits were reported as participating fishing crew, including deckhands, vessel captains, and other positions requiring commercial fishing crew licenses from Alaska Department of Fish and Game (ADF&G; see Table 15 in the full report for details on crew license data and results).

Total revenue-share payments to crab vessel crew members as a group totaled approximately $34.7 million in 2011, and $16.1 million to vessel captains. For both groups, incomes rose in 2011, reflecting the overall increase in ex-vessel revenue described above. However, crew and captain revenue-share earnings increased by 31 and 27 percent over 2010 levels, somewhat greater proportionally than the corresponding increase in aggregate ex-vessel revenue. Although total earnings declined for crews in the Bristol Bay red king fishery, a shorter season associated with the reduced allowable catch, combined with the record high ex-vessel price, resulted in a substantial increase in average daily earnings (42- and 66 percent above levels for 2010 and the 2006-2010 average, respectively) as depicted in Figure 5 (third panel). In addition to revenue-share payments, income is derived by some crew and many captains from royalties for harvesting quota shares held by either the captain or crew. While this may become an increasingly important source of income as opportunities for investment in QS ownership are advanced, there is no evidence to-date that the proportion of CR fishery quota share pools held by crab crew members has changed in recent years, following some limited consolidation that occurred during the initial years of the program (described in greater detail within the report; also see the Bering Sea and Aleutian Islands Crab Rationalization Program Report (NMFS AKR, 2012, forthcoming) for information on quota allocation and transfer activity, and other current CR program administration details).

Table 19 andTable 20 present data on crab processing labor employment associated with the IFQ and CDQ fisheries. It is estimated that nearly 681 thousand hours of processing labor was expended on crab production in 2011, generating slightly more than $8 million in labor income. Most processing facilities that receive crab landings do not exclusively process crab, however, and it is likely that processing labor hours and wages reported and attributed to specific crab fisheries are influenced by production activity and working conditions in other fisheries. The high degree of variance in the measure of crab processing labor hours likely reflects variation in processors' ability to track labor input by species for reporting compliance. The trend in processing labor input as reported in the BSAI Crab Economic Data Report (EDR) indicates general consistency with catch and production volume fluctuations. However, total labor hours declined across all CR fisheries, and by approximately 14% from 2010 overall, despite aggregate production volume remaining approximately constant from 2010 to 2011.

## Operating, Production, and Capital Costs

In addition to labor input and costs for the harvest and processing sectors, operating and production cost information is collected from participating vessels and processors in the CR program fisheries. Table 21 through Table 25 present total and average values for selected production cost elements, where data quality permits dissemination. Although fuel comprises a primary operating cost for vessels, data quality concerns regarding accuracy of reported fuel quantity and cost data prevents dissemination of the summarized data, as noted above. Table 26 presents results from a monthly survey of marine fuel prices in Adak, Dutch Harbor, Kodiak, and Seattle, showing that fuel prices were substantially higher in all four locations during 2011 than in the previous five years, with the exception of the period of elevated prices during late 2008.

## Quota Share and Distribution of Ownership

Figure 7 andFigure 8 illustrate 2010 and 2011 changes in the distribution of holdings in CR program QS and PQS relative to initial issuance in 2005, with values reported separately for QS held by crew and vessel owners reported, and PQS holdings by initial issuees and new entrants. Across all fisheries for both QS and PQS holdings, no net change in distribution occurred between 2010 and 2011. Share holding distribution has changed most significantly in BBR and BSS fisheries, in which the total number of unique share holders has consolidated from an initial pool of 424 (BBR) and 388 (BSS) to the current pool of 315 and 289 individuals, respectively. Additional details on crab QS and PQS share holding and concentration is provided in Table 27 through Table 32 of the report.

## Fishing and Processing Capacity and Effort

Changes in CR program fishery participation since pre-rationalization seasons 1998-2004 up to the current period is depicted in Figure 9, as indicated by counts of vessels and unique CFEC permits in the harvest sector, and unique crab buyers in the processing sector. The rapid of consolidation of vessel effort following rationalization is clearly depicted in fleet composition, particularly in BBR and BSS fisheries. Both BSS and BBR fisheries have seen relative stability harvest and processing sector participation in recent years over significant changes in TAC levels, although it is unclear to what degree the current configuration of vessel and processing capacity represents a stable economic equilibrium.

## International Trade in Crab Commodities

This section will be updated in the final draft of this report.

## Catch-share Program Economic Performance Metrics

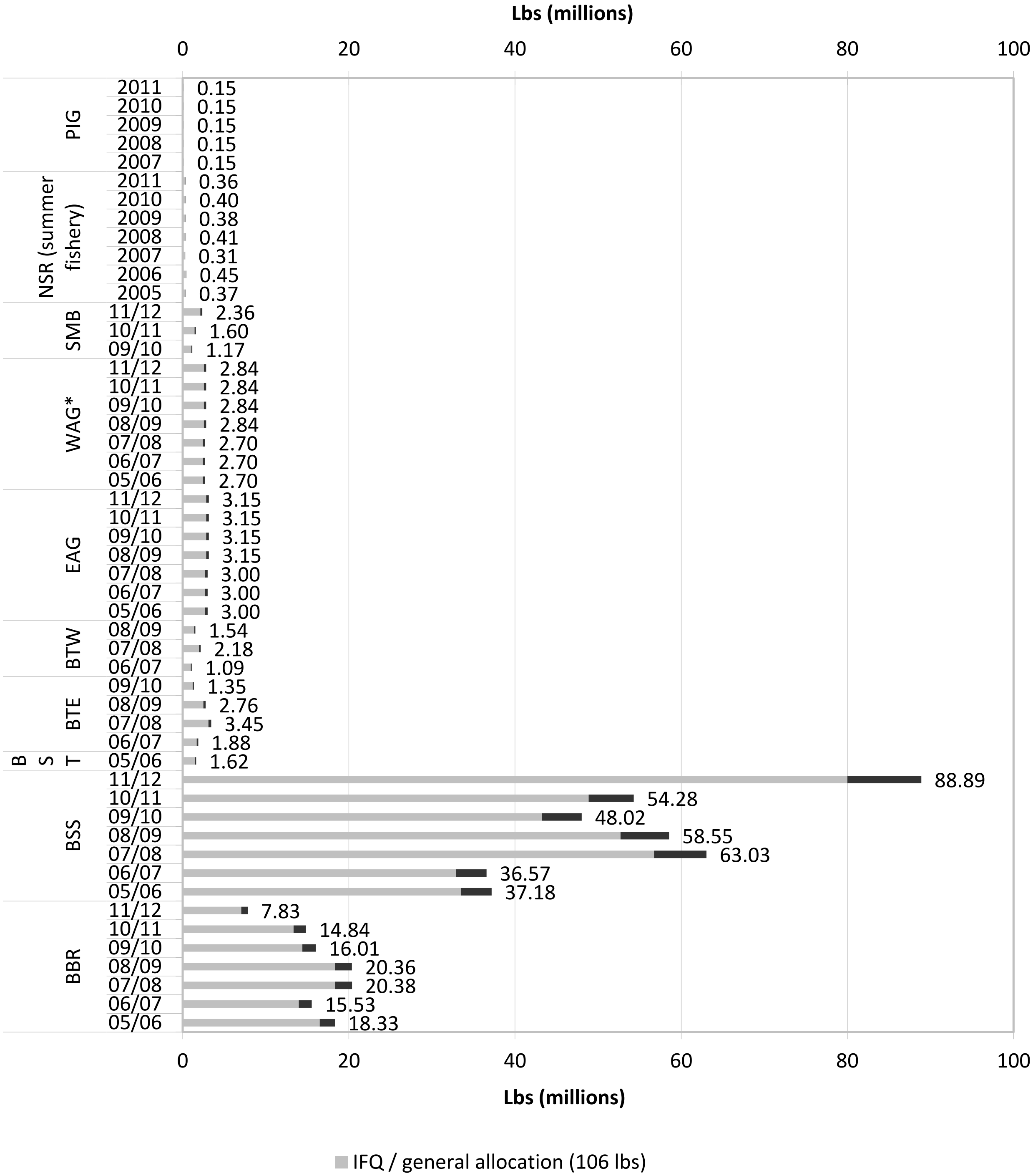
Tables 4-4h present results for a selected set of economic performance metrics depicting status and trends in the BSAI Crab Rationalization program with respect to catch and landings, effort, economic value, and cost recovery. As part of a national-level effort by NOAA Fisheries, Office of Science and Technology (OST) to coordinate monitoring and reporting of economic performance of catch share programs across all regions,[5] Table 4 has been prepared following protocols outlined by OST and presents results summarized over all IFQ crab fisheries. To avoid confusion in comparing this information to other tabular data presented in Tables 1-3 and in the rest of this report, it is important to note that the performance metrics presented in Tables 4-4h are reported in terms of crab season years (including a pre-rationalization baseline of values averaged over 1998/99, 2001/02, and 2004/5 seasons), and the reported values for these metrics do not include production or activity associated with the Community Development Program quota (CDQ) or Adak Community Allocation (ACA) components of the rationalized crab fisheries. Tables 4a-4h provide results using the OST framework for individual crab fisheries through the 2011/12 crab season; values for 2011/12 are preliminary pending finalization of validation procedures for the most recent round of reporting of associated data sources.

Both IFQ allocations and commercial landings increased overall for 2011/2012, to 94.56 and 93.35 million pounds, respectively, reflecting the increase in Bering Sea snow crab allowable catch to approximately 80 million pounds (64 percent greater than the previous season). This was concurrent with the sharp decrease in 2011/2012 Bristol Bay red king crab allowable catch, as noted above. Deadloss across all IFQ fisheries has fluctuated between 0.46 and 0.7 million pounds during the period since rationalization, from an average of 1.08 million pounds during the baseline period. Deadloss increased somewhat during the most recent 2011/2012 snow crab fishery, which was extended an additional two weeks beyond the usual season end date to June 15 due to an extended period of sea ice coverage and the resulting delay of the fishery.

[5] Table 4 represents preliminary results for the second iteration of annual reporting to OST, being implemented in collaboration with Alaska Region and with the assistance of the Alaska Fisheries Information Network (AKFIN). Reporting conventions are consistent with protocols defined by OST, and are subject to modification.

# Figures

Figure 1: BSAI crab fishery TACs/GHLs and management program allocations

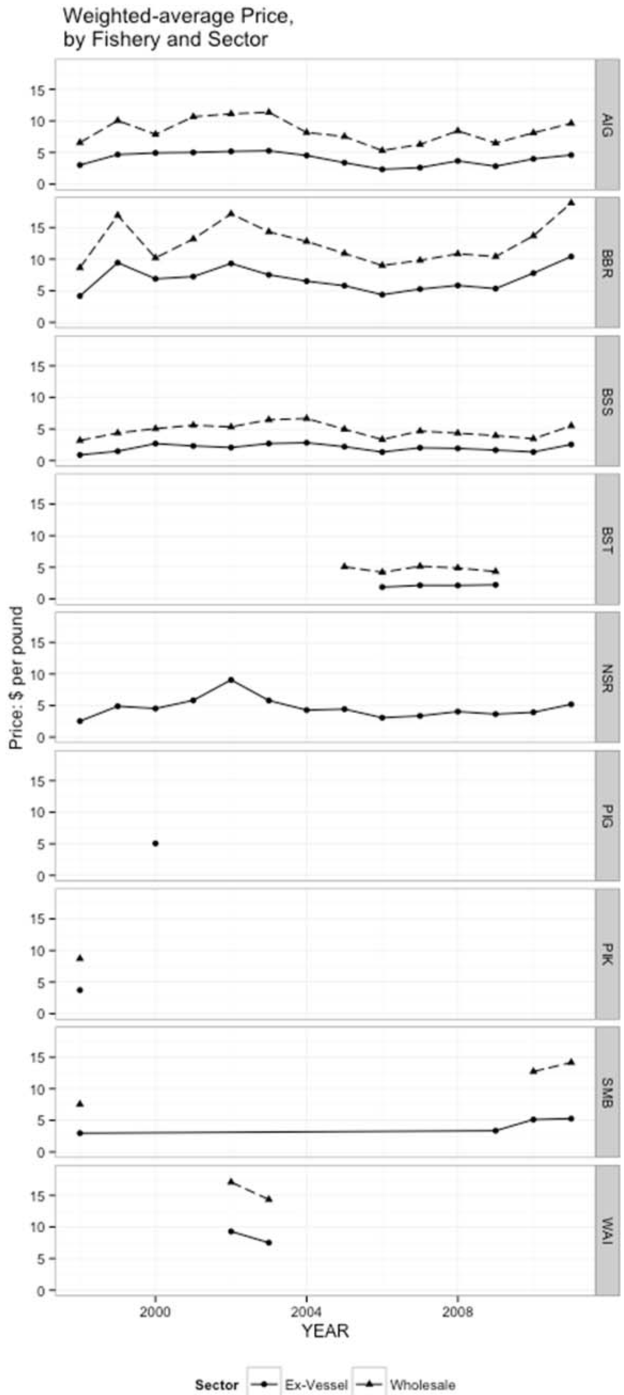



*Source: ADF&G.*
Tabular data available in Table 1.

Figure 2: Ex-vessel and first wholesale gross revenue and production volume, by calendar year, selected fisheries (2011 base year)

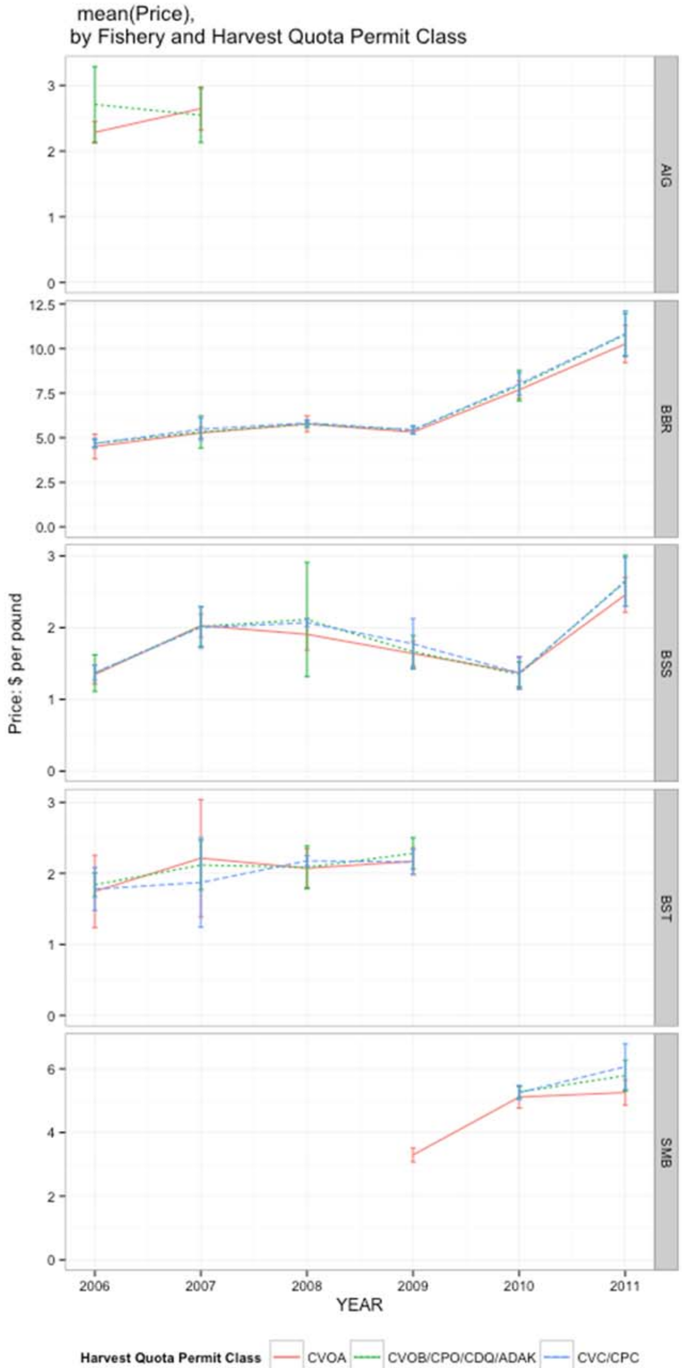
*Source: ADF&G fish tickets, eLandings, CFEC pricing based on COAR buying reports.*
Data shown by calendar year. Includes commercial harvest from general, IFQ, and CDQ management programs and commercial pounds harvested by catcher processors. Source data available in Table 4.

Figure 3: Ex-vessel and first wholesale prices, selected fisheries (2011 base year)



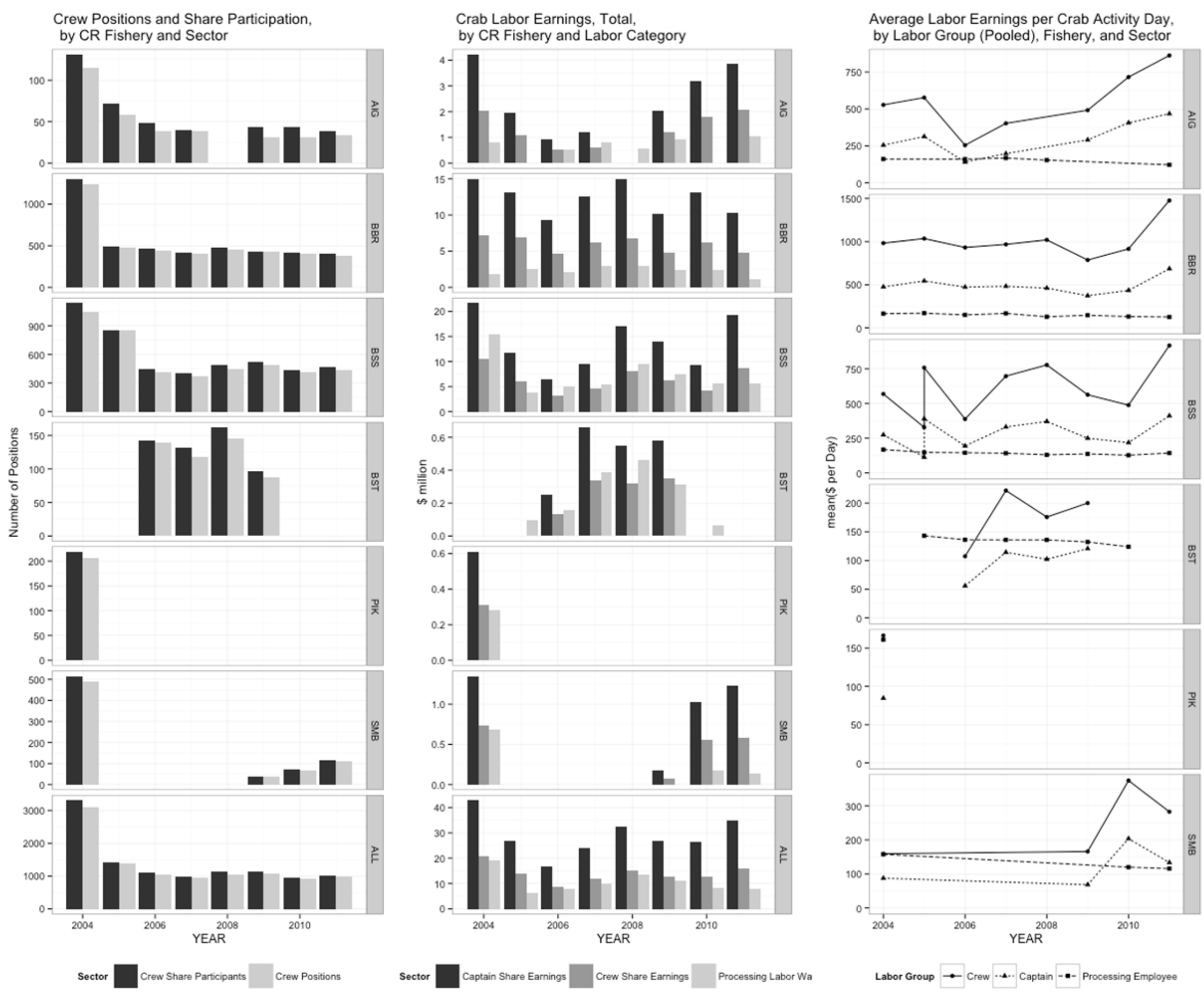

*Source: ADF&G fish tickets via eLandings, CFEC pricing based on ADF&G Commercial Operators Annual Report, NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Error bars show one standard deviation from mean. Tabular data available in Table 8: CR program fisheries sold lbs, ex-vessel value, and price by year (2011 base year) and Table 10.

Figure 4: Ex-vessel catcher vessel price by quota type, selected fisheries (2011 base year)




*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. CVC/CPC=catcher vessel and catcher processor C share quota, CVOA=catcher vessel owner A share quota, CVOB=catcher vessel owner B share quota, CPO=catcher processor owner quota. 2005 ex-vessel revenue data was reported over all quota types. 2005 BSS data includes revenue earned prior to and after rationalization. Error bars show one standard deviation from mean. Selected data for AIG and BST suppressed for confidentiality. Tabular data available in Table 7.

Figure 5: Harvest crew labor employment and compensation, selected fisheries (2011 base year)



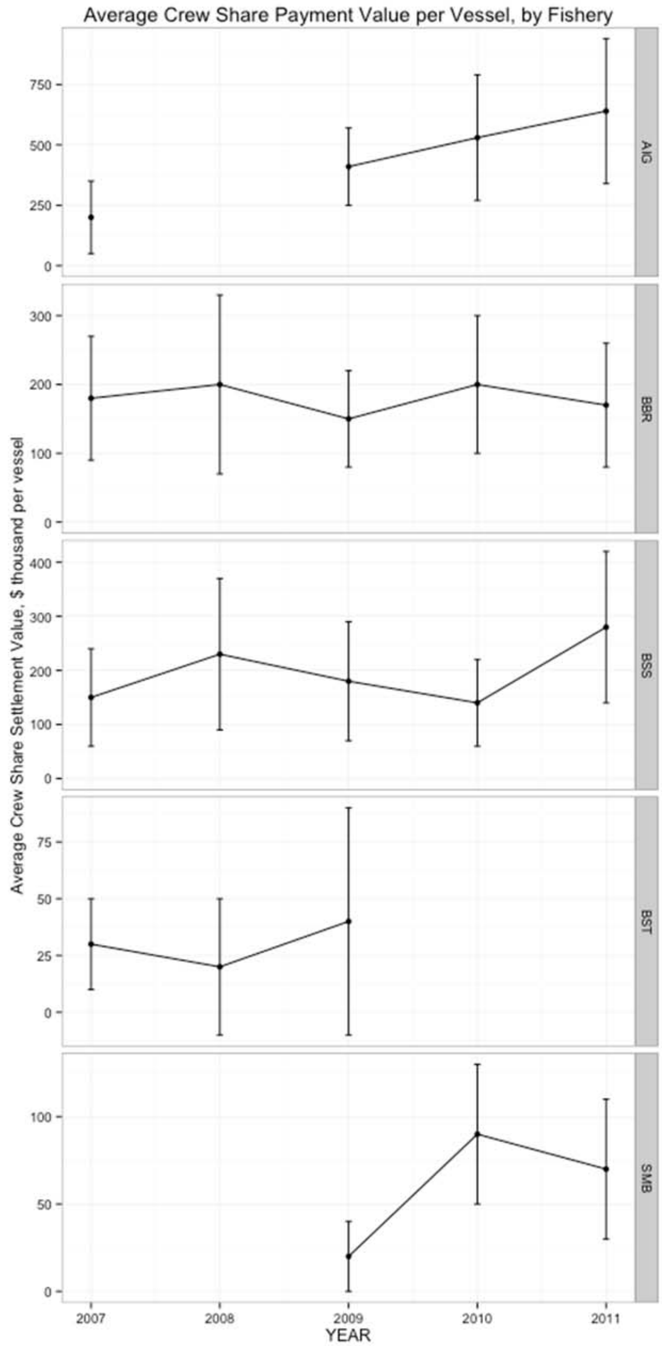

*Source: NMFS AFSC BSAI Crab Economic Data.*

Data shown by calendar year. Data for WAI fisheries are not shown. 2008 data for AIG and 1998-2005 data for BST are suppressed for confidentiality. Tabular data available in Table 13, Table 14, and Table 19.

(a)1998-2008 shows CV positions and participants only; 2009 shows data aggregated over CV and CP sectors 2005 and later crew positions data from ADF&G fish tickets. BSS crew positions was not collected in 2005.

(b) 1998-2008 data show total and mean CV and SFP payments only; 2009 data show total and mean crew payments over CV and CP sectors combined and processing employee payments over CP and SFP combined.

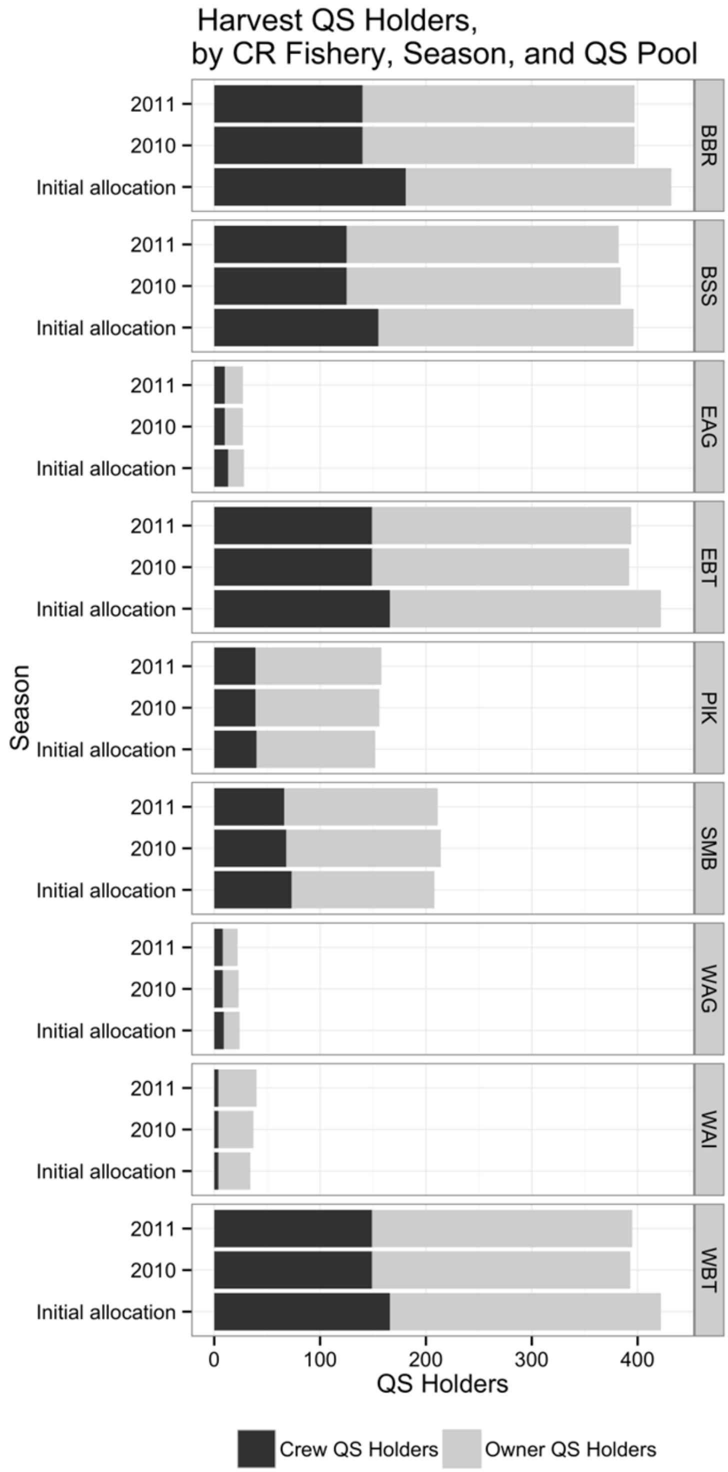
## Figure 6: Mean harvest crew labor payments, selected fisheries (2011 base year)




*Source: NMFS AFSC BSAI Crab Economic Data.*

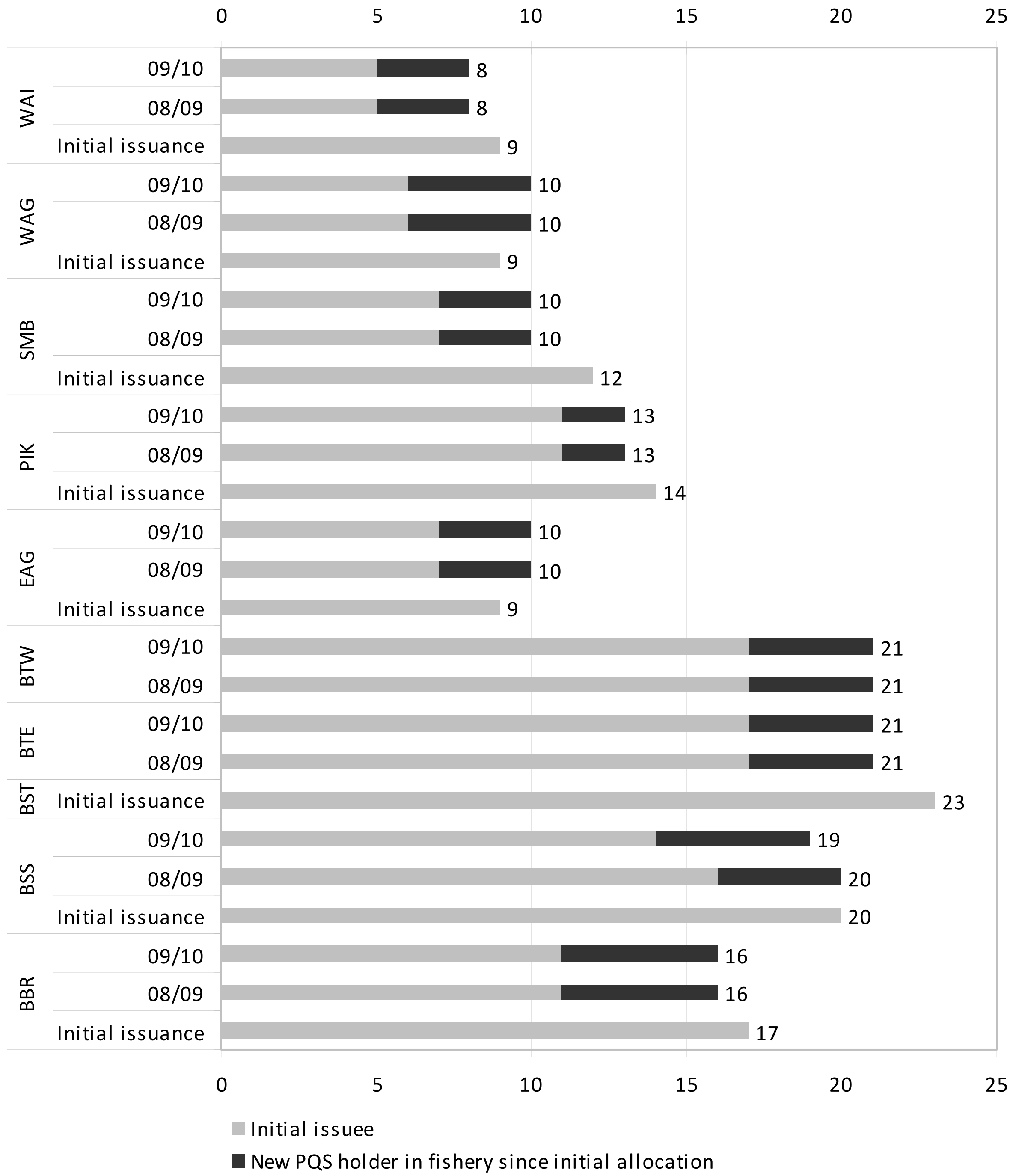
Data shown by calendar year. Mean pay in dollars shown for CV sector only for 1998-2008 and for CV and CP sectors combined for 2009. Mean crab-equivalent crew pay shown for CV sector only for all years. Crab equivalent pay is given in pounds and is calculated by dividing vessel crew share payment by ex-vessel price per pound (ex-vessel revenue/landed pounds). Error bars show one standard deviation from mean. These statistics do not include captain's share payments. Selected data for AIG and BST fisheries suppressed for confidentiality. Tabular data available in Table 13.

Figure 7: CR-program fisheries quota share holders



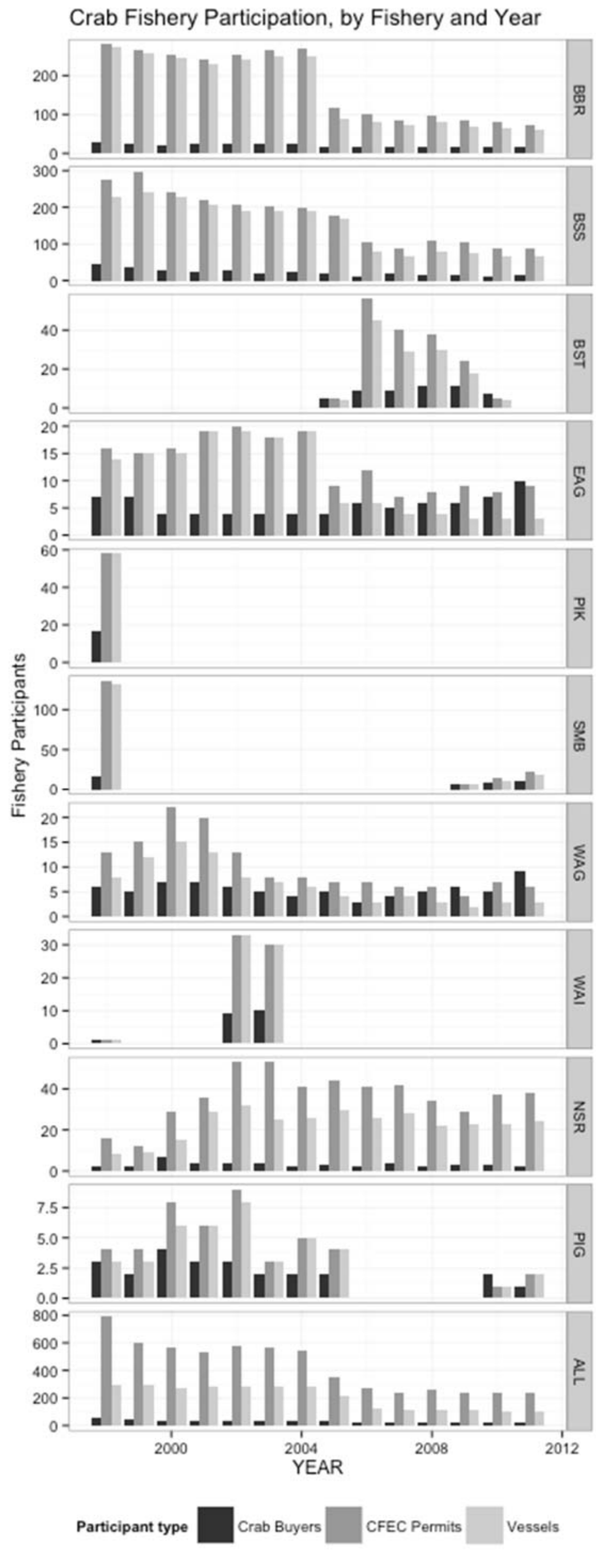

*Source: NMFS RAM Division, quota share holders files.*Tabular data available upon request.

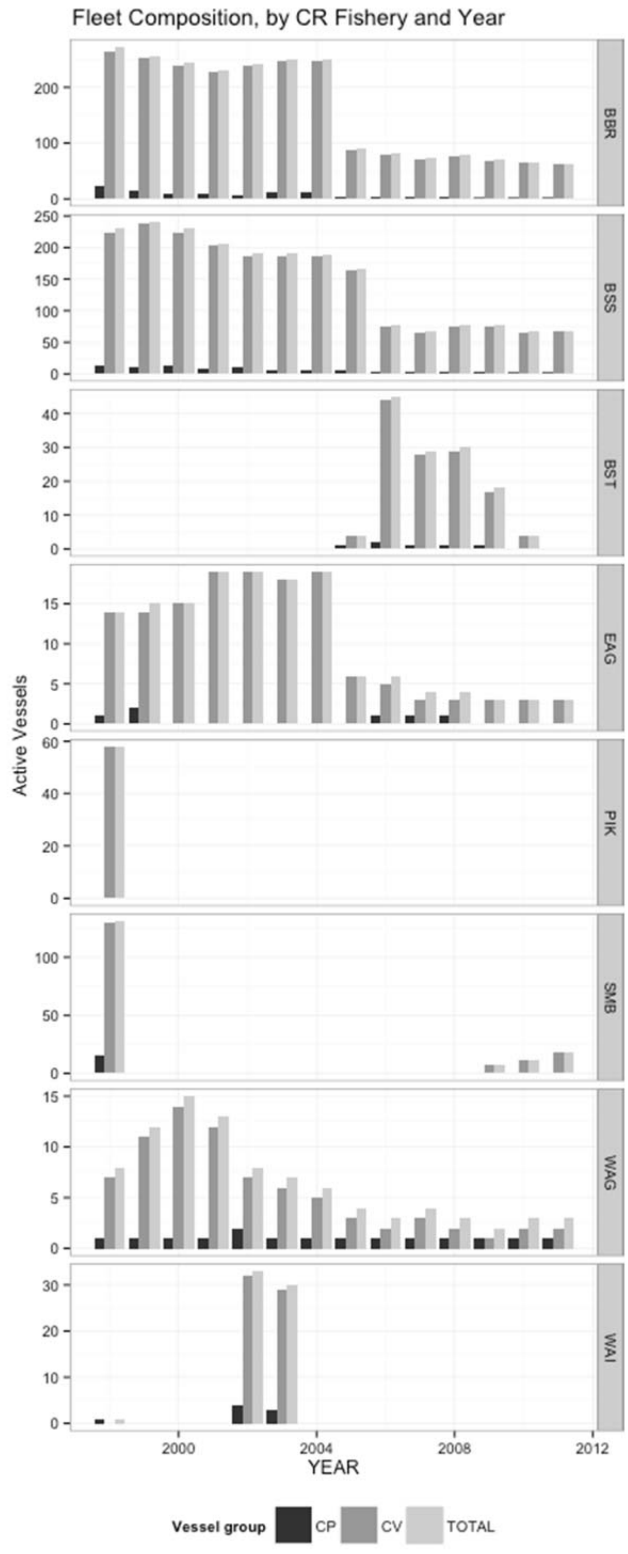
Figure 8: CR program fisheries processing quota share holders




*Source: NMFS RAM Division,* processor quota share holder files.Tabular data available upon request.
*p*

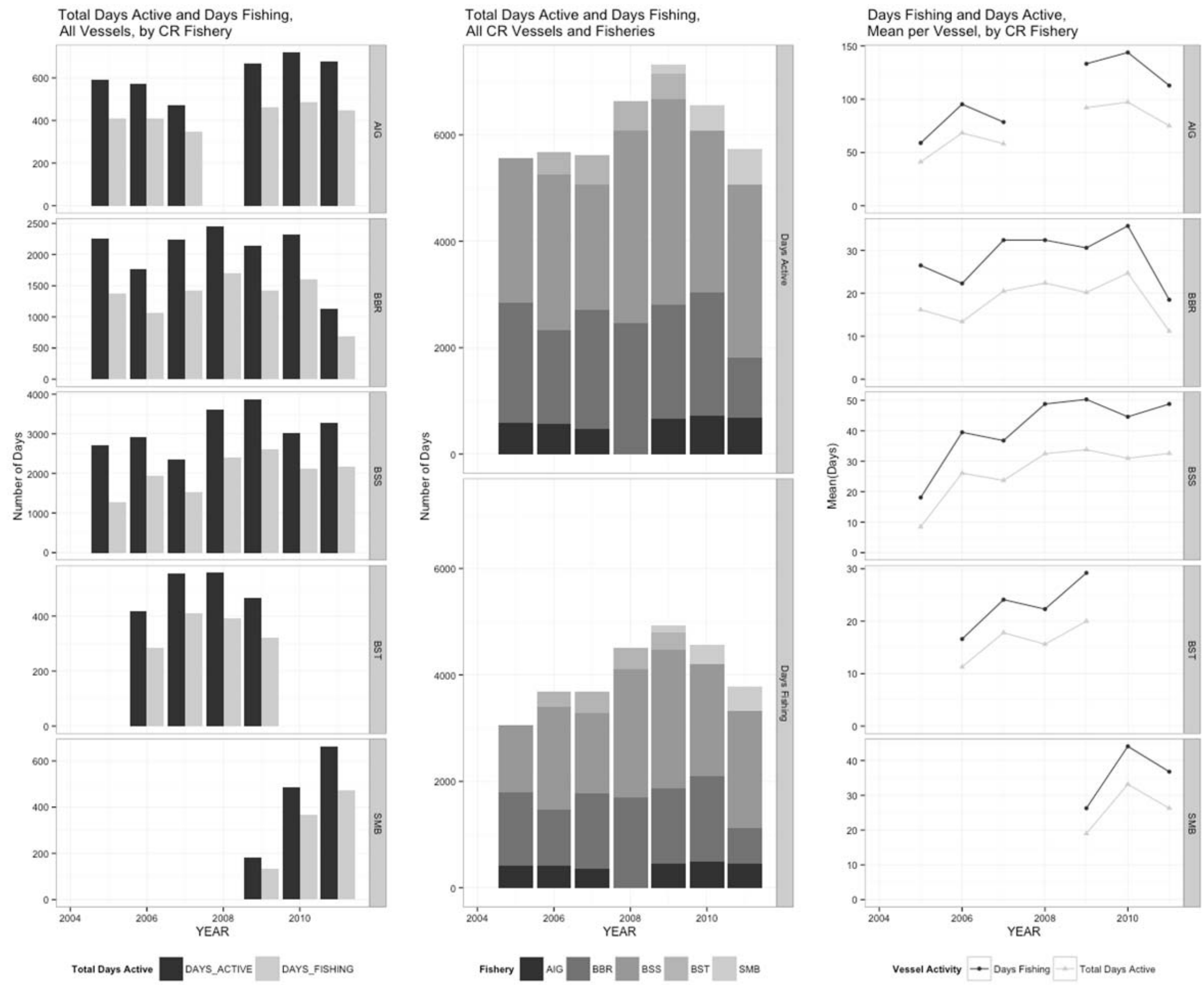
Figure 9: BSAI Crab Fishery Participation and Fleet Composition, 2007-2011



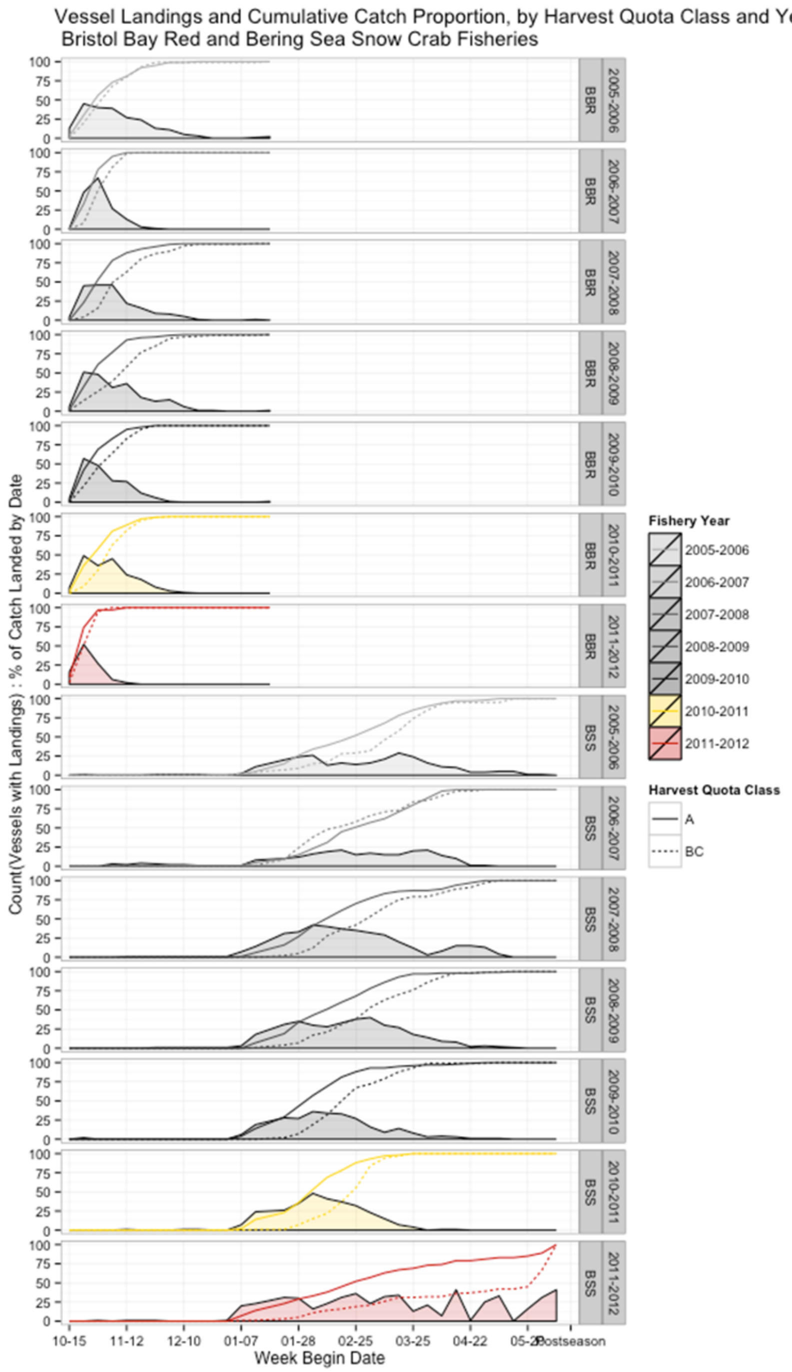

*Source: ADF&G fish tickets, eLandings.*
Fishery closure years not shown. Tabular data available in Table 2.

## Figure 10: Harvest vessel activity days, selected fisheries




*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Data for PIK, SMB, and WAI fisheries not shown; selected years for AIG and BST suppressed for confidentiality. 1998-2008 shows CV activity only; 2009 shows activity aggregated over CV and CP sectors. Total days active calculated using days at sea reported in the 1998-2004 EDR and the sum of days fishing and days travelling and offloading in 2005 and later data. Mean days are calculated over vessels participating in the fishery rather than all vessels in the BSAI crab fleet. Note that the 1998-2004 and 2005 and later figures for both total and mean days active are not directly comparable, as the pre-2005 data do not include days spent queuing and offloading at processors. BST fishery was closed in 2001; reported days active in this fishery may reflect reporting error or days attributed to incidental catch of BST in another target fishery. Tabular data available in Table 18.

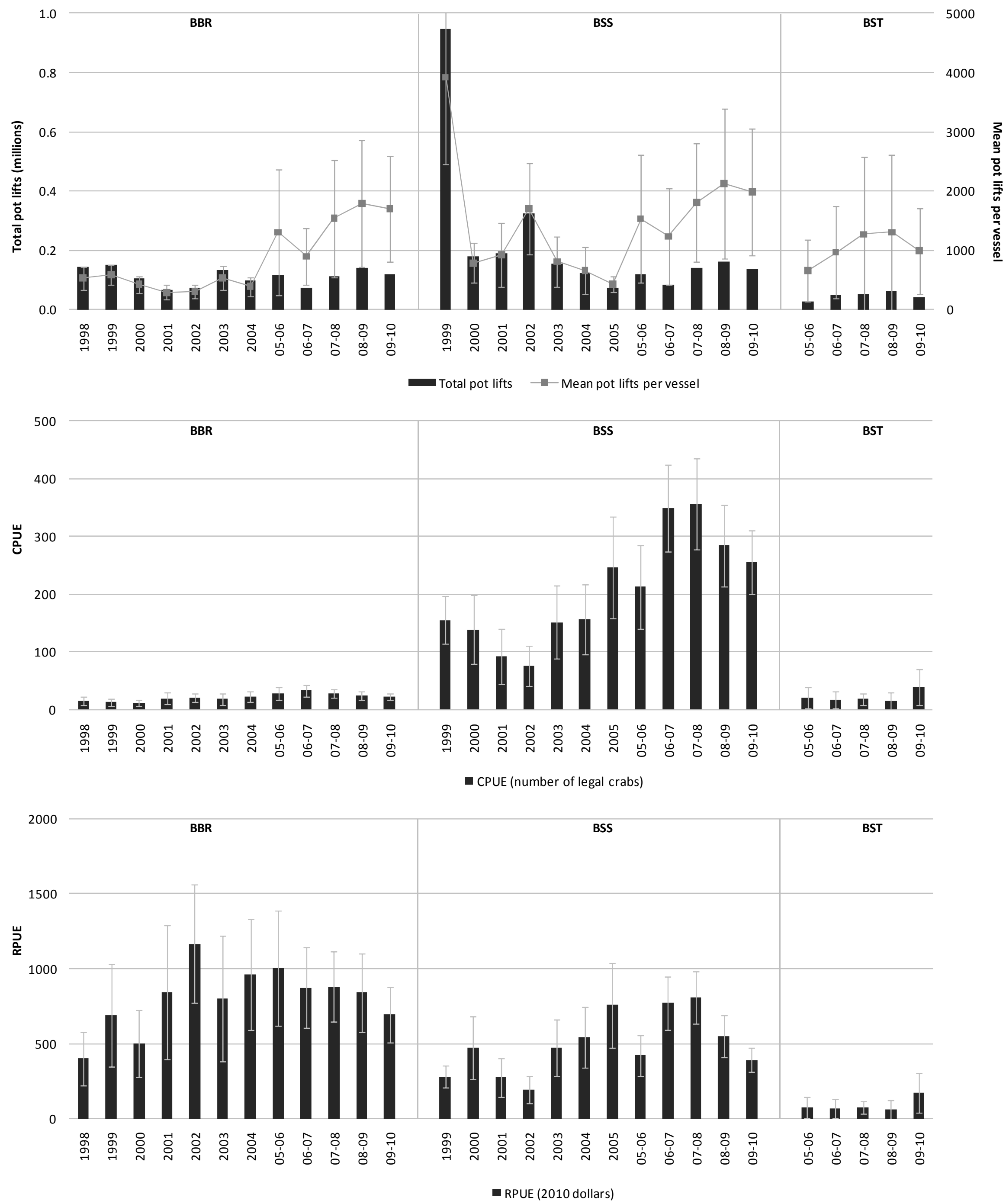
Figure 11: Crab fishery commercial landings and cumulative catch, by quota share class and week of season: Bristol Bay red king and Bering Sea snow crab




*Source: ADF&G fish tickets via eLandings. NMFS RAM Division, IFQ accounting database.*

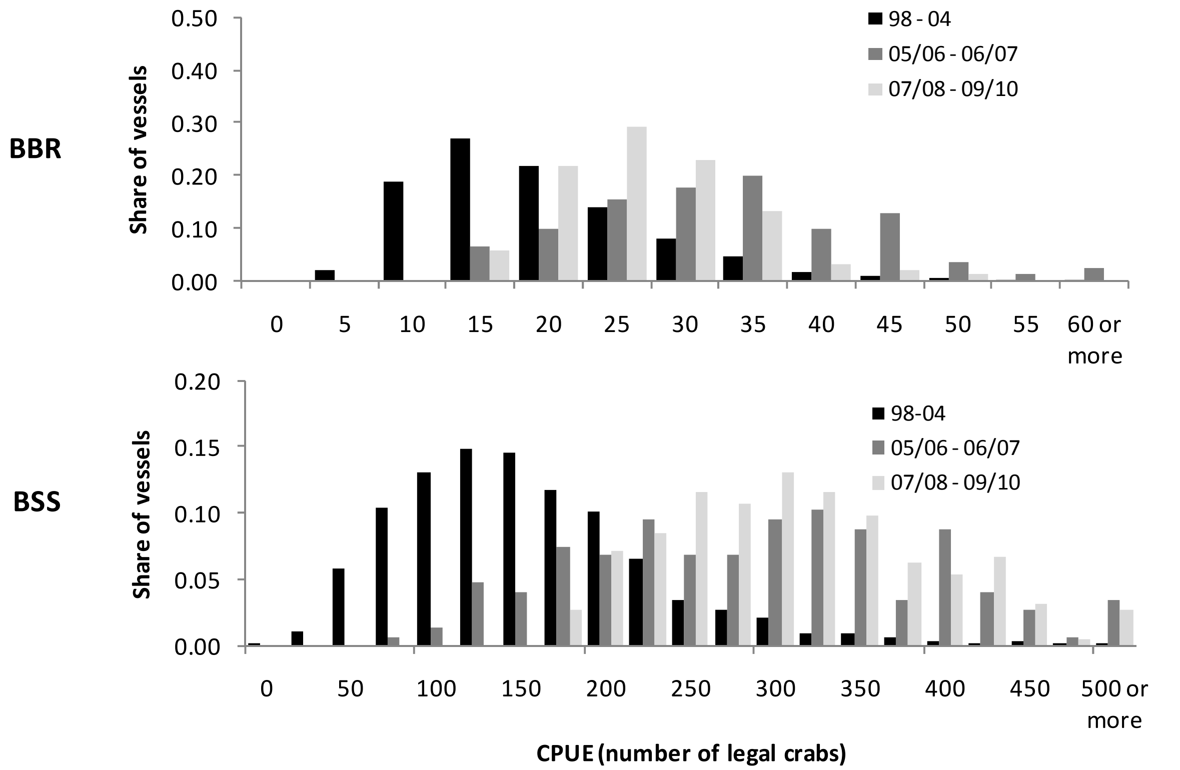
"Share of landings – all" = share of landings in IFQ and CDQ programs by catcher vessels and catcher processors. "Share of landings – CVOA" = share of landings on catcher vessel owner, A type quota permits."Share of landings - CVOB/CVC" = share of landings on catcher vessel owner, B type permits or catcher vessel crew permits.BSS seasons open October 15 and close May 31 of the next calendar year. Tabular data available in Table 42 and Table 43.

Figure 12: Pot lifts, mean CPUE, and mean RPUE by season, selected crab fisheries



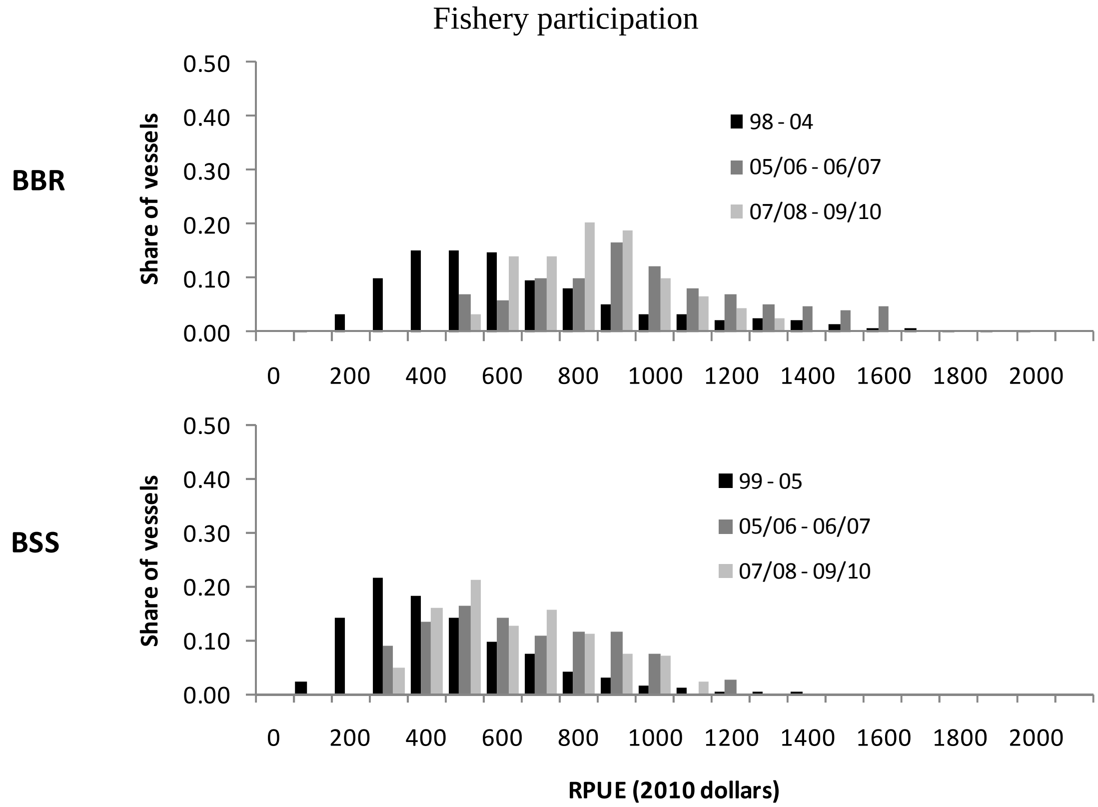

*Source: ADF&G fish tickets (August 2005 and later data via eLandings).*
Error bars show one standard deviation from mean. CPUE = number of legal crab per potlift. RPUE = ex-vessel value of commercially sold crab per potlift, adjusted to 2010 dollars. Tabular data available in Table 38.

Figure 13: CPUE vessel distribution by season, selected crab fisheries




*Source: ADF&G fish tickets (August 2005 and later data via eLandings).*
Data shown by season, grouped into three periods. "98-04" series for BSS fishery denote fisheries that took place January 1999 through January 2005. CPUE = number of legal crab per potlift. Some smaller percentages in distribution are suppressed for confidentiality. Tabular data available upon request.

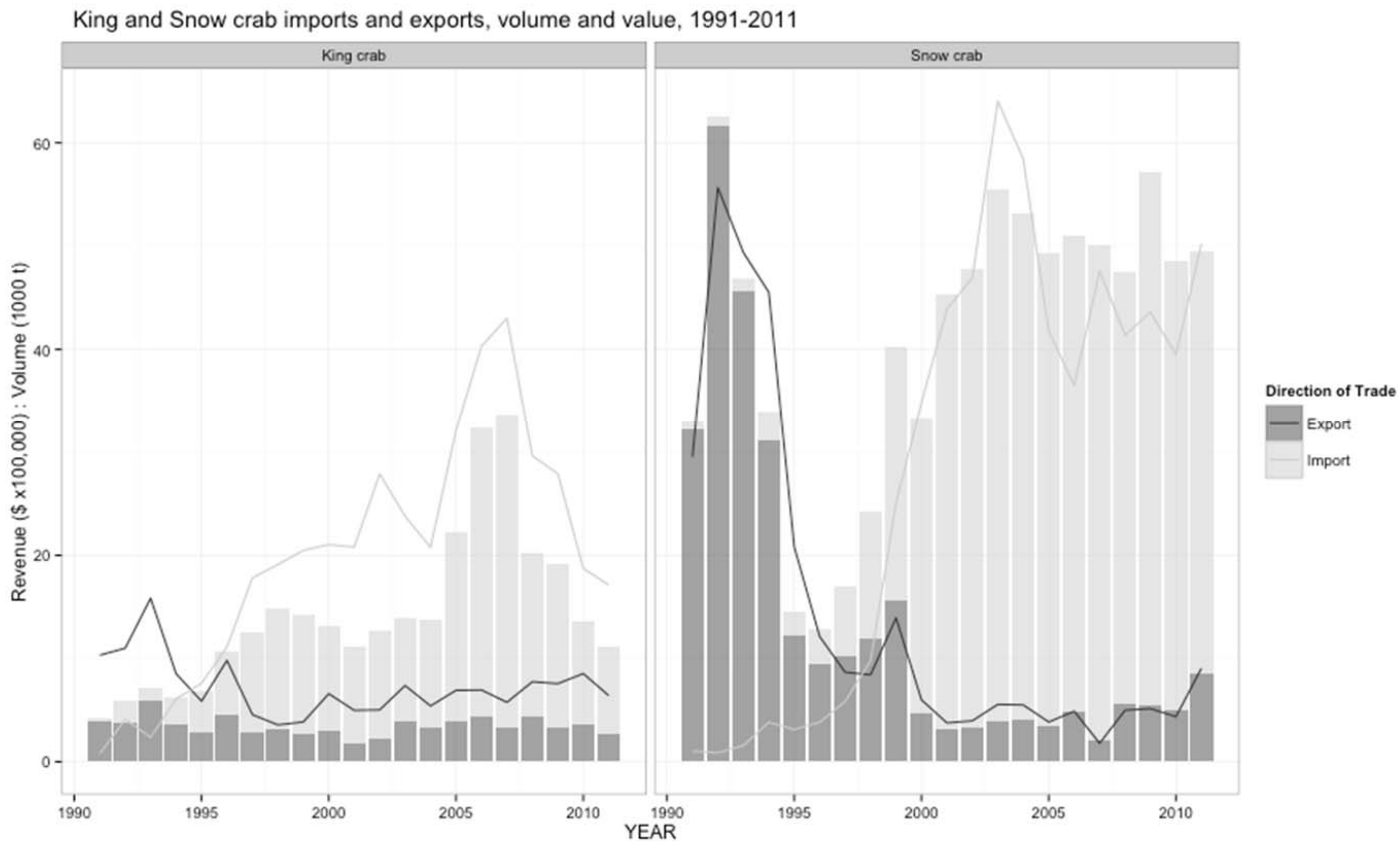
Figure 14: RPUE vessel distribution by season, selected crab fisheries




*Source: ADF&G fish tickets (August 2005 and later data via eLandings).*

Data shown by season, grouped into three periods. "98-04" series for BSS fishery denote fisheries that took place January 1999 through January 2005. RPUE = ex-vessel value of commercially sold crab per potlift, adjusted to 2010 dollars. Some smaller percentages in distribution are suppressed for confidentiality. Tabular data available upon request.

Figure 15: King and snow crab exports and imports by calendar year (2011 base year)




*Source: U.S. Foreign Census Bureau Foreign Trade Division, via NMFS Fisheries Statistics Division, U.S. Foreign Trade Database.* Data available at http://www.st.nmfs.noaa.gov/st1/trade/. Tabular data available in Table 45.

Imports and exports shown for TSUSA product codes 306144010 (frozen king crab) and 306144020 (frozen snow crab).

# Tables

Table 1: BSAI crab fishery TACs/GHLs, management program allocations, and usage

| Fishery | Year | IFQ / general allocation ($10^6$ lbs) | CDQ/Adak allocation ($10^6$ lbs) | TAC/GHL ($10^6$ lbs) | % IFQ/general allocation landed | % CDQ allocation landed |
|---|---|---|---|---|---|---|
| BBR | 05/06 | 16.50 | 1.83 | 18.33 | 100% | 100% |
| | 06/07 | 13.97 | 1.55 | 15.53 | 99% | 100% |
| | 07/08 | 18.34 | 2.04 | 20.38 | 100% | 100% |
| | 08/09 | 18.33 | 2.04 | 20.36 | 100% | 100% |
| | 09/10 | 14.41 | 1.60 | 16.01 | 100% | 100% |
| | 10/11 | 13.36 | 1.48 | 14.84 | 100% | 100% |
| | 11/12 | 7.05 | 0.78 | 7.83 | 100% | 100% |
| BSS | 05/06 | 33.47 | 3.72 | 37.18 | 99% | 100% |
| | 06/07 | 32.91 | 3.66 | 36.57 | 99% | 100% |
| | 07/08 | 56.73 | 6.30 | 63.03 | 100% | 100% |
| | 08/09 | 52.70 | 5.86 | 58.55 | 100% | 100% |
| | 09/10 | 43.22 | 4.80 | 48.02 | 100% | 100% |
| | 10/11 | 48.85 | 5.43 | 54.28 | 100% | 100% |
| | 11/12 | 80.00 | 8.89 | 88.89 | 100% | 100% |
| BST | 05/06 | 1.46 | 0.16 | 1.62 | 54% | 100% |
| BTE | 06/07 | 1.69 | 0.19 | 1.88 | 75% | 72% |
| | 07/08 | 3.10 | 0.34 | 3.45 | 46% | 42% |
| | 08/09 | 2.49 | 0.28 | 2.76 | 62% | 100% |
| | 09/10 | 1.22 | 0.14 | 1.35 | 98% | 100% |
| BTW | 06/07 | 0.98 | 0.11 | 1.09 | 64% | 79% |
| | 07/08 | 1.96 | 0.22 | 2.18 | 24% | 26% |
| | 08/09 | 1.38 | 0.15 | 1.54 | 8% | <1% |
| EAG | 05/06 | 2.70 | 0.30 | 3.00 | 95% | -- |
| | 06/07 | 2.70 | 0.30 | 3.00 | 100% | -- |
| | 07/08 | 2.70 | 0.30 | 3.00 | 100% | 100% |
| | 08/09 | 2.84 | 0.32 | 3.15 | 100% | 100% |
| | 09/10 | 2.84 | 0.32 | 3.15 | -- | -- |
| | 10/11 | 2.84 | 0.32 | 3.15 | -- | -- |
| | 11/12 | 2.84 | 0.32 | 3.15 | -- | 100% |
| WAG* | 05/06 | 2.43 | 0.27 | 2.70 | 98% | -- |
| | 06/07 | 2.43 | 0.27 | 2.70 | 82% | -- |
| | 07/08 | 2.43 | 0.27 | 2.70 | 92% | -- |
| | 08/09 | 2.55 | 0.28 | 2.84 | 88% | -- |
| | 09/10 | 2.55 | 0.28 | 2.84 | -- | -- |
| | 10/11 | 2.55 | 0.28 | 2.84 | -- | -- |
| | 11/12 | 2.55 | 0.28 | 2.84 | -- | -- |

Table continues on next page.

Table 1 cont.

| Fishery | Year | IFQ / general allocation ($10^6$ lbs) | CDQ/Adak allocation ($10^6$ lbs) | TAC/GHL ($10^6$ lbs) | % IFQ/general allocation landed | % CDQ allocation landed |
|---|---|---|---|---|---|---|
| SMB | 09/10 | 1.05 | 0.12 | 1.17 | 44% | 0% |
| | 10/11 | 1.44 | 0.16 | 1.60 | 77% | 98% |
| | 11/12 | 2.12 | 0.24 | 2.36 | 80% | 77% |
| NSR (summer fishery) | 2005 | 0.34 | 0.03 | 0.37 | 108% | 100% |
| | 2006 | 0.42 | 0.03 | 0.45 | 100% | 96% |
| | 2007 | 0.29 | 0.02 | 0.31 | 99% | 100% |
| | 2008 | 0.38 | 0.03 | 0.41 | 96% | 100% |
| | 2009 | 0.35 | 0.03 | 0.38 | 107% | 100% |
| | 2010 | 0.37 | 0.03 | 0.40 | 106% | 98% |
| | 2011 | 0.33 | 0.03 | 0.36 | 113% | -- |
| PIG | 2007 | 0.15 | n/a | 0.15 | 0% | n/a |
| | 2008 | 0.15 | n/a | 0.15 | 0% | n/a |
| | 2009 | 0.15 | n/a | 0.15 | 0% | n/a |
| | 2010 | 0.15 | n/a | 0.15 | -- | n/a |
| | 2011 | 0.15 | n/a | 0.15 | -- | n/a |

*Source: TAC and allocation amounts for all fisheries and usage for Norton Sound red king crab, Pribilof Islands golden king crab and CDQ/ACA fisheries from ADF&G. IFQ usage from NMFS RAM Division*. Adak Community Allocation (ACA) applies to Western Aleutian Islands golden king crab fishery only. General allocations and GHL apply to non-rationalized stocks (NSR and PIG). Figures for PIK fishery (closed since 1999) and WAI fishery (closed since 2004/2005) are not shown. NSR winter commercial fishery is not shown, as this is not managed with a GHL or TAC.

## Table 2: BSAI crab fishery participation by calendar year

| | | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BBR | CFEC permits fished | 280 | 266 | 255 | 240 | 253 | 264 | 268 | 115 | 100 | 85 | 97 | 86 | 79 | 71 |
| | Vessels | 273 | 256 | 244 | 230 | 241 | 250 | 251 | 89 | 81 | 73 | 79 | 70 | 65 | 62 |
| | Fish buyers/processors | 28 | 24 | 22 | 23 | 24 | 26 | 25 | 16 | 15 | 18 | 17 | 16 | 17 | 18 |
| BSS | CFEC permits fished | 276 | 297 | 243 | 219 | 205 | 202 | 200 | 178 | 106 | 89 | 108 | 103 | 87 | 88 |
| | Vessels | 230 | 241 | 230 | 207 | 191 | 190 | 189 | 167 | 78 | 68 | 78 | 77 | 68 | 68 |
| | Fish buyers/processors | 44 | 37 | 28 | 23 | 26 | 21 | 23 | 20 | 13 | 18 | 17 | 17 | 13 | 16 |
| BST | CFEC permits fished | | | | | | | | 5 | 56 | 40 | 38 | 24 | 5 | |
| | Vessels | | | | | | | | 4 | 45 | 29 | 30 | 18 | 4 | |
| | Fish buyers/processors | | | | | | | | 5 | 9 | 9 | 11 | 11 | 7 | |
| EAG | CFEC permits fished | 16 | 15 | 16 | 19 | 20 | 18 | 19 | 9 | 12 | 7 | 8 | 9 | 8 | 9 |
| | Vessels | 14 | 15 | 15 | 19 | 19 | 18 | 19 | 6 | 6 | 4 | 4 | 3 | 3 | 3 |
| | Fish buyers/processors | 7 | 7 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 5 | 6 | 6 | 7 | 10 |
| NSR [a] | CFEC permits fished | 16 | 12 | 29 | 36 | 53 | 53 | 41 | 44 | 41 | 42 | 34 | 29 | 37 | 38 |
| | Vessels | 8 | 9 | 15 | 29 | 32 | 25 | 26 | 30 | 26 | 28 | 22 | 23 | 23 | 24 |
| | Fish buyers/processors[b] | 2 | 2 | 7 | 4 | 4 | 4 | 2 | 3 | 2 | 4 | 2 | 3 | 3 | 2 |
| PIG | CFEC permits fished | 4 | 4 | 8 | 6 | 9 | 3 | 5 | 4 | | | | | 1 | 2 |
| | Vessels | 3 | 3 | 6 | 6 | 8 | 3 | 5 | 4 | | | | | 1 | 2 |
| | Fish buyers/processors | 3 | 2 | 4 | 3 | 3 | 2 | 2 | 2 | | | | | 2 | 1 |
| PIK | CFEC permits fished | 58 | | | | | | | | | | | | | |
| | Vessels | 58 | | | | | | | | | | | | | |
| | Fish buyers/processors | 17 | | | | | | | | | | | | | |
| SMB | CFEC permits fished | 136 | | | | | | | | | | | 7 | 14 | 23 |
| | Vessels | 131 | | | | | | | | | | | 7 | 11 | 18 |
| | Fish buyers/processors | 16 | | | | | | | | | | | 6 | 9 | 11 |
| WAG | CFEC permits fished | 13 | 15 | 22 | 20 | 13 | 8 | 8 | 7 | 7 | 6 | 6 | 4 | 7 | 6 |
| | Vessels | 8 | 12 | 15 | 13 | 8 | 7 | 6 | 4 | 3 | 4 | 3 | 2 | 3 | 3 |
| | Fish buyers/processors | 6 | 5 | 7 | 7 | 6 | 5 | 4 | 5 | 3 | 4 | 5 | 6 | 5 | 9 |
| WAI [c] | CFEC permits fished | 1 | 0 | | | 33 | 30 | 0 | | | | | | | |
| | Vessels | 1 | 0 | | | 33 | 30 | 0 | | | | | | | |
| | Fish buyers/processors | 1 | 0 | | | 9 | 10 | 0 | | | | | | | |
| All BSAI crab fisheries | CFEC permits fished | 790 | 605 | 561 | 529 | 575 | 570 | 538 | 355 | 272 | 232 | 261 | 242 | 232 | 235 |
| | Vessels | 294 | 292 | 277 | 280 | 280 | 278 | 281 | 212 | 128 | 114 | 116 | 112 | 102 | 102 |
| | Fish buyers/processors | 54 | 43 | 39 | 36 | 37 | 37 | 34 | 30 | 20 | 27 | 23 | 26 | 24 | 27 |

*Source*: *ADF&G fish tickets, eLandings.* Data shown by calendar year. Shaded cells indicate fishery closure years. [a] Data for Norton Sound red king crab are aggregated over the summer and winter commercial fisheries. As no vessels are used in the winter commercial fishery, the number of CFEC permits fished is a better measure of participation and effort for the combined fisheries. [b] Count of fish buyers/processors for Norton Sound red king crab excludes catcher seller operations. [c] Excludes participation in 2000/2001 and 2001/2002 Western Aleutian Islands red king crab Petrel Bank test fishery.

Table 3: CR program fisheries fleet composition by season

| Fishery | Season | Total vessels | Catcher vessels | Catcher processors |
|---|---|---|---|---|
| BBR | 1998 | 273 | 262 | 11 |
| | 1999 | 256 | 248 | 8 |
| | 2000 | 244 | 238 | 8 |
| | 2001 | 230 | 224 | 8 |
| | 2002 | 241 | 234 | 9 |
| | 2003 | 250 | 242 | 8 |
| | 2004 | 251 | 243 | 8 |
| | 2005-2006 | 89 | 86 | 4 |
| | 2006-2007 | 81 | 79 | 3 |
| | 2007-2008 | 74 | 72 | 3 |
| | 2008-2009 | 78 | 76 | 3 |
| | 2009-2010 | 70 | 69 | 2 |
| | 2010-2011 | 65 | 64 | 2 |
| | 2011-2012[a] | 62 | 61 | 2 |
| BSS | 1998 | 230 | 219 | 12 |
| | 1999 | 241 | 232 | 10 |
| | 2000 | 230 | 221 | 9 |
| | 2001 | 207 | 201 | 8 |
| | 2002 | 191 | 183 | 9 |
| | 2003 | 190 | 185 | 5 |
| | 2004 | 189 | 183 | 6 |
| | 2005 | 167 | 161 | 6 |
| | 2005-2006 | 78 | 74 | 4 |
| | 2006-2007 | 69 | 65 | 4 |
| | 2007-2008 | 78 | 74 | 4 |
| | 2008-2009 | 77 | 73 | 4 |
| | 2009-2010 | 68 | 66 | 2 |
| | 2010-2011 | 68 | 67 | 2 |
| | 2011-2012[a] | 71 | 69 | 2 |
| BST | 2005-2006 | 33 | 31 | 2 |
| | 2006-2007 | 39 | 37 | 2 |
| | 2007-2008 | 27 | 26 | 1 |
| | 2008-2009 | 20 | 19 | 1 |
| | 2009-2010 | 13 | 12 | 1 |

Table continues on next page.

Table 3 cont.

| Fishery | Season | Total vessels | Catcher vessels | Catcher processors |
|---|---|---|---|---|
| EAG | 1998 | 14 | 13 | 1 |
| | 1999 | 15 | 14 | 1 |
| | 2000 | 15 | 15 | 0 |
| | 2001 | 19 | 19 | 0 |
| | 2002 | 19 | 19 | 0 |
| | 2003 | 18 | 18 | 0 |
| | 2004 | 19 | 19 | 0 |
| | 2005-2006 | 7 | 6 | 1 |
| | 2006-2007 | 6 | 5 | 1 |
| | 2007-2008 | 4 | 3 | 1 |
| | 2008-2009 | 3 | 3 | 0 |
| | 2009-2010 | 3 | 3 | 0 |
| | 2010-2011 | 3 | 3 | 0 |
| | 2011-2012[a] | 3 | 3 | 0 |
| WAG | 1998-1999 | 3 | 2 | 1 |
| | 1999-2000 | 15 | 14 | 1 |
| | 2000-2001 | 12 | 11 | 1 |
| | 2001-2002 | 9 | 8 | 1 |
| | 2002-2003 | 6 | 5 | 1 |
| | 2003-2004 | 6 | 5 | 1 |
| | 2004-2005 | 6 | 5 | 1 |
| | 2005-2006 | 3 | 2 | 1 |
| | 2006-2007 | 4 | 3 | 1 |
| | 2007-2008 | 3 | 2 | 1 |
| | 2008-2009 | 3 | 2 | 1 |
| | 2009-2010 | 3 | 2 | 1 |
| | 2010-2011 | 3 | 2 | 1 |
| | 2011-2012[a] | 3 | 2 | 1 |
| SMB | 1998 | 131 | 129 | 2 |
| | 2009-2010 | 7 | 7 | 0 |
| | 2010-2011 | 11 | 11 | 0 |
| | 2011-2012[a] | 18 | 18 | 0 |
| PIK | 1998 | 58 | 58 | 0 |
| WAI [b] | 1998-1999 | 1 | 0 | 1 |
| | 2002-2003 | 33 | 31 | 2 |
| | 2003-2004 | 30 | 28 | 2 |

*Source: ADF&G fish tickets, eLandings.*

[a] Figures for 2011-2012season represent IFQ fishery participation only.

[b] Excludes participation in 2000/2001 and 2001/2002 Western Aleutian Islands red king crab Petrel Bank test fishery.

Table 4: BSAI crab fisheries sold lbs, ex-vessel value, and price by year (2011 base year)

| Fishery | Year | Sold weight ($10^6$ lbs) | Ex-vessel value ($\$10^6$) [c] | Weighted price/lb [c] | Ave price/lb (sd) [c] |
|---|---|---|---|---|---|
| AIG | 1998 | 5.44 | $16.38 | $3.01 | $3.05 (0.21) |
| | 1999 | 5.10 | $23.84 | $4.67 | n/a (n/a) |
| | 2000 | 5.95 | $29.33 | $4.93 | n/a (n/a) |
| | 2001 | 6.38 | $31.97 | $5.01 | $5.07 (0.56) |
| | 2002 | 5.54 | $28.62 | $5.17 | n/a (n/a) |
| | 2003 | 5.82 | $30.64 | $5.27 | n/a (n/a) |
| | 2004 | 6.02 | $27.26 | $4.53 | $4.52 (0.11) |
| | 2005 | 4.44 | $14.98 | $3.38 | $3.34 (0.29) |
| | 2006 | 5.24 | $12.21 | $2.33 | $2.49 (0.40) |
| | 2007 | 5.44 | $14.14 | $2.60 | $2.63 (0.35) |
| | 2008 | 5.73 | $21.03 | $3.67 | -- (--) |
| | 2009 | 5.51 | $15.57 | $2.82 | -- (--) |
| | 2010 | 6.09 | $24.32 | $3.99 | -- (--) |
| | 2011 | 6.00 | $27.59 | $4.60 | -- (--) |
| BBR [a] | 1998 | -- | -- | $4.17 | $4.20 (0.77) |
| | 1999 | -- | -- | $9.44 | n/a (n/a) |
| | 2000 | -- | -- | $6.89 | n/a (n/a) |
| | 2001 | -- | -- | $7.24 | $7.24 (0.60) |
| | 2002 | -- | -- | $9.32 | n/a (n/a) |
| | 2003 | -- | -- | $7.52 | n/a (n/a) |
| | 2004 | 15.02 | $97.87 | $6.52 | $6.55 (0.32) |
| | 2005 | 18.14 | $105.23 | $5.80 | $5.76 (0.17) |
| | 2006 | 15.55 | $67.99 | $4.37 | $4.61 (0.48) |
| | 2007 | 20.17 | $106.15 | $5.26 | $5.34 (0.63) |
| | 2008 | 20.13 | $117.58 | $5.84 | $5.79 (0.32) |
| | 2009 | 15.78 | $84.28 | $5.34 | $5.38 (0.19) |
| | 2010 | 14.73 | $114.72 | $7.79 | $7.84 (0.67) |
| | 2011 | 7.79 | $81.04 | $10.41 | $10.57 (1.18) |
| BSS [a] | 1998 | 249.05 | $221.06 | $0.89 | $0.89 (0.06) |
| | 1999 | 192.37 | $284.89 | $1.48 | n/a (n/a) |
| | 2000 | -- | -- | $2.69 | n/a (n/a) |
| | 2001 | -- | -- | $2.32 | $2.33 (0.14) |
| | 2002 | 31.94 | $66.24 | $2.07 | n/a (n/a) |
| | 2003 | 27.51 | $74.35 | $2.70 | n/a (n/a) |
| | 2004 | 23.69 | $67.00 | $2.83 | $2.84 (0.11) |
| | 2005 | 24.86 | $54.69 | $2.20 | $2.32 (0.23) |
| | 2006 | 38.02 | $51.34 | $1.35 | $1.36 (0.18) |
| | 2007 | 34.76 | $70.57 | $2.03 | $2.02 (0.24) |
| | 2008 | 62.23 | $119.85 | $1.93 | $2.02 (0.50) |
| | 2009 | 57.69 | $95.90 | $1.66 | $1.68 (0.25) |
| | 2010 | 47.84 | $64.91 | $1.36 | $1.36 (0.20) |
| | 2011 | 54.05 | $137.71 | $2.55 | $2.57 (0.32) |

Table continues on next page.

Table 4 cont.

| Fishery | Year | Sold weight ($10^6$ lbs) | Ex-vessel value (\$$10^6$) [c] | Weighted price/lb [c] | Ave price/lb (sd) [c] |
|---|---|---|---|---|---|
| BST | 2005 | 0.26 | -- | -- | -- (--) |
| | 2006 | 0.99 | $1.85 | $1.86 | $1.77 (0.42) |
| | 2007 | 2.25 | $4.81 | $2.14 | $2.12 (0.69) |
| | 2008 | 2.33 | $4.94 | $2.12 | $2.09 (0.26) |
| | 2009 | 2.14 | $4.75 | $2.22 | $2.20 (0.20) |
| | 2010 | 0.37 | -- | -- | -- (--) |
| NSR[d] | 1998 | 0.03 | $0.07 | $2.53 | n/a (n/a) |
| | 1999 | 0.03 | $0.15 | $4.89 | n/a (n/a) |
| | 2000 | 0.32 | $1.45 | $4.52 | n/a (n/a) |
| | 2001 | 0.28 | $1.62 | $5.82 | n/a (n/a) |
| | 2002 | 0.26 | $2.35 | $9.06 | n/a (n/a) |
| | 2003 | 0.28 | $1.63 | $5.79 | n/a (n/a) |
| | 2004 | 0.33 | $1.43 | $4.28 | n/a (n/a) |
| | 2005 | 0.40 | $1.76 | $4.43 | n/a (n/a) |
| | 2006 | 0.44 | $1.36 | $3.07 | n/a (n/a) |
| | 2007 | 0.32 | $1.06 | $3.36 | n/a (n/a) |
| | 2008 | 0.40 | $1.61 | $4.04 | n/a (n/a) |
| | 2009 | 0.40 | $1.44 | $3.64 | n/a (n/a) |
| | 2010 | 0.42 | $1.66 | $3.93 | n/a (n/a) |
| | 2011 | 0.40 | $2.09 | $5.19 | n/a (n/a) |
| PIG | 1998 | -- | -- | -- | n/a (n/a) |
| | 1999 | -- | -- | -- | n/a (n/a) |
| | 2000 | 0.12 | $0.62 | $5.06 | n/a (n/a) |
| | 2001 | -- | -- | -- | n/a (n/a) |
| | 2002 | -- | -- | -- | n/a (n/a) |
| | 2003 | -- | -- | -- | n/a (n/a) |
| | 2004 | -- | -- | -- | n/a (n/a) |
| | 2005 | -- | -- | -- | n/a (n/a) |
| | 2010 | -- | -- | -- | n/a (n/a) |
| | 2011 | -- | -- | -- | n/a (n/a) |
| PIK | 1998 | 1.03 | $3.82 | $3.72 | $3.79 (0.60) |
| SMB | 1998 | 2.95 | $8.72 | $2.96 | $2.99 (0.23) |
| | 2009 | 0.45 | $1.51 | $3.35 | $3.40 (0.29) |
| | 2010 | 1.25 | $6.42 | $5.12 | $5.20 (0.27) |
| | 2011 | 1.85 | $9.73 | $5.26 | $5.62 (0.60) |
| WAI [b] | 1998 | -- | -- | -- | -- |
| | 2002 | 0.50 | $4.66 | $9.29 | n/a (n/a) |
| | 2003 | 0.48 | $3.57 | $7.51 | n/a (n/a) |

*Source: ADF&G fish tickets, eLandings, CFEC pricing, ADF&G Commercial Operator's Annual Report, NMFS AFSC BSAI Crab Economic Data Report (EDR) database.* Data shown by calendar year. Landed volume reflects sold commercial pounds across all management programs (LLP/open access, IFQ, CDQ, ACA). Includes catch and estimated value of catch by catcher processors and catcher sellers. [a] Landings and ex-vessel revenue suppressed in years where CDQ fishery landings are confidential. [b] Excludes landings in Petrel Bank test fishery in 2001. [c] Pricing sourced from EDR catcher vessel gross earnings reports where available (1998, 2001, 2004, and 2005-2011 for CR fisheries) and secondarily from CFEC gross earnings estimates (all years for non-CR fisheries; 1999-2000, 2002-2003 for CR fisheries). Average price per pound, available only in EDR-reporting years, represents per-vessel average. [d] Data for Norton Sound red king crab are aggregated over the summer and winter commercial fisheries.

Table 5: CR program fisheries ex-vessel price and share of fishery-year landings by owner or leaseholder state (2011 base year) - catcher vessels

| Fishery | Year [a] | State | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| AIG | 98/01/04 | AK | 3 (2) | n/d | n/d | -- | 4 | -- (--) |
| | | WA | 43 (18) | n/d | n/d | $4.25 | 57 | $4.34 (0.94) |
| | | Other | 6 (2) | n/d | n/d | -- | 8 | -- (--) |
| | 2005 | WA | 8 | -- | -- | -- | 9 | $3.30 (0.26) |
| | | Other | 2 | -- | -- | -- | 2 | -- (--) |
| | 2006 | WA | 5 | -- | -- | -- | 15 | $2.42 (0.20) |
| | | Other | 1 | -- | -- | -- | 2 | -- (--) |
| | 2007 | AK | 1 | -- | -- | -- | 3 | -- (--) |
| | | WA | 4 | -- | -- | -- | 9 | -- (--) |
| | | Other | 1 | -- | -- | -- | 3 | -- (--) |
| | 2008 | AK | 1 | -- | -- | -- | 5 | -- (--) |
| | | WA | 2 | -- | -- | -- | 6 | -- (--) |
| | | Other | 1 | -- | -- | -- | 3 | -- (--) |
| | 2009 | AK | 1 | -- | -- | -- | 3 | -- (--) |
| | | WA | 2 | -- | -- | -- | 6 | -- (--) |
| | | Other | 1 | -- | -- | -- | 3 | -- (--) |
| | 2010 | AK | 1 | -- | -- | -- | 6 | -- (--) |
| | | WA | 2 | -- | -- | -- | 6 | -- (--) |
| | | Other | 1 | -- | -- | -- | 3 | -- (--) |
| | 2011 | AK | 1 | -- | -- | -- | 6 | -- (--) |
| | | WA | 2 | -- | -- | -- | 6 | -- (--) |
| | | Other | 1 | -- | -- | -- | 3 | -- (--) |
| BBR | 98/01/04 | AK | 122 (49) | n/d | n/d | $5.93 | 122 | $5.97 (1.42) |
| | | WA | 429 (174) | n/d | n/d | $5.84 | 429 | $6.00 (1.42) |
| | | Other | 82 (33) | n/d | n/d | $5.72 | 82 | $6.06 (1.36) |
| | 2005 | AK | 19 | 16% | 16% | $5.76 | 19 | $5.72 (0.21) |
| | | WA | 53 | 69% | 70% | $5.81 | 53 | $5.78 (0.15) |
| | | Other | 13 | 14% | 14% | $5.80 | 13 | $5.75 (0.21) |
| | 2006 | AK | 24 | 27% | 24% | $3.84 | 49 | $4.54 (0.64) |
| | | WA | 48 | 63% | 66% | $4.57 | 122 | $4.65 (0.44) |
| | | Other | 8 | 10% | 10% | $4.59 | 20 | $4.59 (0.20) |
| | 2007 | AK | 17 | 22% | 23% | $5.29 | 34 | $5.36 (1.16) |
| | | WA | 44 | 67% | 68% | $5.26 | 106 | $5.33 (0.40) |
| | | Other | 9 | 10% | 10% | $5.09 | 19 | $5.31 (0.24) |
| | 2008 | AK | 17 | 20% | 20% | $6.01 | 37 | $5.88 (0.58) |
| | | WA | 51 | 71% | 71% | $5.80 | 115 | $5.76 (0.20) |
| | | Other | 8 | 9% | 9% | $5.83 | 15 | $5.77 (0.13) |
| | 2009 | AK | 19 | 28% | 28% | $5.30 | 45 | $5.35 (0.15) |
| | | WA | 40 | 62% | 62% | $5.36 | 94 | $5.40 (0.16) |
| | | Other | 9 | 10% | 10% | $5.29 | 19 | $5.38 (0.35) |
| | 2010 | AK | 12 | 25% | 24% | $7.66 | 31 | $7.71 (0.74) |
| | | WA | 38 | 62% | 63% | $7.88 | 89 | $7.97 (0.62) |
| | | Other | 13 | 14% | 13% | $7.57 | 28 | $7.59 (0.67) |
| | 2011 | AK | 12 | 23% | 22% | $9.89 | 29 | $10.30 (1.14) |
| | | WA | 36 | 60% | 61% | $10.64 | 82 | $10.71 (1.17) |
| | | Other | 11 | 17% | 17% | $10.28 | 25 | $10.44 (1.22) |

Table continues on next page.

Table 5 cont.

| Fishery | Year [a] | State | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| BSS | 98/01/04 | AK | 100 (41) | n/d | n/d | $1.18 | 100 | $2.00 (0.86) |
| | | WA | 354 (143) | n/d | n/d | $1.19 | 354 | $2.03 (0.83) |
| | | Other | 70 (30) | n/d | n/d | $1.19 | 70 | $1.99 (0.83) |
| | 2005 | AK | 29 | 16% | 17% | $2.34 | 29 | $2.34 (0.04) |
| | | WA | 103 | 73% | 71% | $2.15 | 103 | $2.31 (0.27) |
| | | Other | 18 | 11% | 12% | $2.36 | 18 | $2.36 (0.10) |
| | 2006 | AK | 17 | 20% | 20% | $1.32 | 42 | $1.34 (0.08) |
| | | WA | 48 | 67% | 67% | $1.35 | 122 | $1.36 (0.20) |
| | | Other | 9 | 13% | 13% | $1.38 | 24 | $1.37 (0.16) |
| | 2007 | AK | 14 | 23% | 23% | $2.01 | 32 | $2.03 (0.22) |
| | | WA | 43 | 66% | 66% | $2.04 | 105 | $2.03 (0.26) |
| | | Other | 7 | 11% | 11% | $2.01 | 19 | $1.95 (0.15) |
| | 2008 | AK | 15 | 22% | 21% | $1.87 | 34 | $1.91 (0.30) |
| | | WA | 50 | 66% | 69% | $1.99 | 123 | $2.07 (0.54) |
| | | Other | 9 | 12% | 11% | $1.68 | 20 | $1.88 (0.46) |
| | 2009 | AK | 19 | 32% | 33% | $1.69 | 47 | $1.73 (0.36) |
| | | WA | 45 | 59% | 59% | $1.66 | 105 | $1.66 (0.18) |
| | | Other | 9 | 9% | 9% | $1.61 | 20 | $1.64 (0.23) |
| | 2010 | AK | 14 | 23% | 23% | $1.36 | 34 | $1.37 (0.08) |
| | | WA | 40 | 65% | 65% | $1.36 | 96 | $1.37 (0.25) |
| | | Other | 12 | 11% | 11% | $1.33 | 27 | $1.34 (0.11) |
| | 2011 | AK | 15 | 24% | 24% | $2.56 | 35 | $2.62 (0.12) |
| | | WA | 40 | 62% | 63% | $2.56 | 95 | $2.55 (0.39) |
| | | Other | 11 | 14% | 13% | $2.51 | 27 | $2.60 (0.22) |
| BST | 2005 | AK | 1 | -- | -- | -- | 1 | -- (--) |
| | | WA | 3 | -- | -- | -- | 3 | -- (--) |
| | 2006 | AK | 6 | -- | -- | $1.91 | 10 | $1.75 (0.31) |
| | | WA | 30 | 81% | 81% | $1.86 | 47 | $1.81 (0.45) |
| | | Other | 5 | -- | -- | -- | 6 | -- |
| | 2007 | AK | 7 | 26% | 25% | $2.06 | 13 | $2.05 (0.29) |
| | | WA | 17 | 55% | 57% | $2.25 | 31 | $2.15 (0.83) |
| | | Other | 3 | -- | -- | -- | 4 | -- (--) |
| | 2008 | AK | 6 | 5% | 4% | $1.87 | 6 | $1.74 (0.49) |
| | | WA | 19 | 61% | 61% | $2.11 | 31 | $2.13 (0.17) |
| | | Other | 4 | -- | -- | -- | 6 | -- (--) |
| | 2009 | AK | 5 | -- | -- | $2.24 | 11 | $2.22 (0.12) |
| | | WA | 10 | 43% | 41% | $2.13 | 18 | $2.17 (0.21) |
| | | Other | 2 | -- | -- | -- | 4 | -- (--) |
| | 2010 | AK | 1 | -- | -- | -- | 3 | -- (--) |
| | | WA | 1 | -- | -- | -- | 2 | -- (--) |
| | | Other | 2 | -- | -- | -- | 3 | -- (--) |
| PIK | 1998 | AK | 12 | n/d | n/d | $3.78 | 12 | $3.98 (0.83) |
| | | WA | 28 | n/d | n/d | $4.04 | 28 | $3.87 (0.76) |
| | | Other | 5 | n/d | n/d | $3.60 | 5 | $3.62 (0.07) |

Table continues on next page.

Table 5 cont.

| Fishery | Year [a] | State | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| SMB | 1998 | AK | 20 | n/d | n/d | $2.92 | 20 | $2.93 (0.09) |
| | | WA | 61 | n/d | n/d | $2.97 | 61 | $3.02 (0.27) |
| | | Other | 14 | n/d | n/d | $2.93 | 14 | $2.94 (0.11) |
| | 2009 | AK | 1 | -- | -- | -- | 1 | -- (--) |
| | | WA | 5 | -- | -- | $3.41 | 7 | $3.46 (0.31) |
| | | Other | 1 | -- | -- | -- | 1 | -- (--) |
| | 2010 | AK | 3 | -- | -- | -- | 8 | -- (--) |
| | | WA | 5 | 47% | 49% | $5.31 | 11 | $5.31 (0.07) |
| | | Other | 2 | -- | -- | -- | 4 | -- (--) |
| | 2011 | AK | 6 | -- | -- | $5.53 | 13 | $5.75 (0.63) |
| | | WA | 9 | 50% | 50% | $5.27 | 20 | $5.62 (0.54) |
| | | Other | 3 | -- | -- | -- | 9 | -- (--) |
| WAI [b] | 2001 | WA | 2 | n/d | n/d | -- | 2 | -- (--) |
| | | Other | 1 | n/d | n/d | -- | 1 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year for EDR reporting years (1998, 2001, 2004, 2005-present). Provisional prices by year, fishery and, when applicable, quota type are used to correct for missing revenue or pounds data in some observations. 1998, 2001, and 2004 data are not shown as coverage in EDR data collection for these years was not 100% of vessels.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years; 'vessels' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years).

[b] Landings in 2001 Petrel Bank test fishery. 1998 fishery data unavailable.

Table 6: CR program fisheries ex-vessel price and share of fishery-year landings by vessel length (2011 base year) – catcher vessels

| Fishery | Year [a] | Vessel length | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| AIG | 98/01/04 | 85'-99' | 12 (5) | n/d | n/d | $4.05 | 16 | $4.16 (0.87) |
| | | 100'-124' | 16 (7) | n/d | n/d | $4.51 | 20 | $4.63 (1.03) |
| | | >=125' | 24 (10) | n/d | n/d | $4.26 | 33 | $4.23 (0.82) |
| | 2005 | 85'-99' | 1 | -- | -- | -- | 1 | -- (--) |
| | | 100'-124' | 3 | -- | -- | -- | 3 | -- (--) |
| | | >=125' | 6 | 57% | 57% | $3.38 | 7 | $3.40 (0.32) |
| | 2006 | 100'-124' | 2 | -- | -- | -- | 6 | -- (--) |
| | | >=125' | 4 | -- | -- | -- | 11 | -- (--) |
| | 2007 | 100'-124' | 4 | -- | -- | -- | 11 | -- (--) |
| | | >=125' | 2 | -- | -- | -- | 4 | -- (--) |
| | 2008 | 100'-124' | 3 | -- | -- | -- | 11 | -- (--) |
| | | >=125' | 1 | -- | -- | -- | 3 | -- (--) |
| | 2009 | 100'-124' | 3 | -- | -- | -- | 9 | -- (--) |
| | | >=125' | 1 | -- | -- | -- | 3 | -- (--) |
| | 2010 | 100'-124' | 3 | -- | -- | -- | 12 | -- (--) |
| | | >=125' | 1 | -- | -- | -- | 3 | -- (--) |
| | 2011 | 100'-124' | 3 | -- | -- | -- | 12 | -- (--) |
| | | >=125' | 1 | -- | -- | -- | 3 | -- (--) |
| BBR | 98/01/04 | Under 85' | 44(23) | n/d | n/d | $5.73 | 44 | $5.94 (1.36) |
| | | 85'-99' | 129(59) | n/d | n/d | $5.92 | 129 | $6.00 (1.43) |
| | | 100'-124' | 298(118) | n/d | n/d | $5.81 | 298 | $6.03 (1.39) |
| | | >=125' | 162(69) | n/d | n/d | $5.85 | 162 | $5.97 (1.44) |
| | 2005 | Under 85' | 3 | -- | -- | -- | 3 | -- (--) |
| | | 85'-99' | 12 | -- | -- | $5.79 | 12 | $5.73 (0.18) |
| | | 100'-124' | 46 | 44% | 44% | $5.79 | 46 | $5.76 (0.20) |
| | | >=125' | 24 | 42% | 42% | $5.82 | 24 | $5.79 (0.11) |
| | 2006 | Under 85' | 3 | -- | -- | -- | 6 | -- (--) |
| | | 85'-99' | 12 | -- | -- | $4.63 | 25 | $4.74 (0.19) |
| | | 100'-124' | 44 | 49% | 46% | $4.08 | 107 | $4.56 (0.61) |
| | | >=125' | 21 | 40% | 42% | $4.66 | 53 | $4.67 (0.20) |
| | 2007 | Under 85' | 1 | -- | -- | -- | 2 | -- (--) |
| | | 85'-99' | 9 | -- | -- | $5.19 | 20 | $5.07 (1.14) |
| | | 100'-124' | 40 | 49% | 49% | $5.24 | 90 | $5.36 (0.50) |
| | | >=125' | 20 | 39% | 39% | $5.27 | 47 | $5.40 (0.56) |
| | 2008 | Under 85' | 2 | -- | -- | -- | 4 | -- (--) |
| | | 85'-99' | 10 | 9% | 10% | $6.20 | 21 | $5.69 (0.29) |
| | | 100'-124' | 43 | 50% | 50% | $5.84 | 96 | $5.82 (0.39) |
| | | >=125' | 21 | 37% | 37% | $5.76 | 46 | $5.76 (0.13) |
| | 2009 | Under 85' | 3 | -- | -- | -- | 5 | -- (--) |
| | | 85'-99' | 9 | -- | -- | $5.31 | 20 | $5.32 (0.21) |
| | | 100'-124' | 35 | 46% | 46% | $5.35 | 86 | $5.41 (0.18) |
| | | >=125' | 21 | 39% | 39% | $5.35 | 47 | $5.38 (0.18) |
| | 2010 | Under 85' | 1 | -- | -- | -- | 3 | -- (--) |
| | | 85'-99' | 8 | -- | -- | $7.56 | 17 | $7.76 (0.58) |
| | | 100'-124' | 33 | 45% | 45% | $7.75 | 79 | $7.79 (0.79) |
| | | >=125' | 21 | 44% | 44% | $7.87 | 49 | $7.96 (0.48) |

Table continues on next page.

Table 6 cont.

| Fishery | Year [a] | Vessel length | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| BBR | 2011 | Under 85' | 1 | -- | -- | -- | 2 | -- (--) |
| | | 85'-99' | 8 | -- | -- | $9.29 | 22 | $9.85 (1.33) |
| | | 100'-124' | 29 | 39% | 39% | $10.53 | 68 | $10.58 (1.28) |
| | | >=125' | 21 | 48% | 49% | $10.55 | 44 | $10.90 (0.75) |
| BSS | 98/01/04 | Under 85' | 25 (14) | n/d | n/d | $1.15 | 25 | $2.05 (0.86) |
| | | 85'-99' | 103 (51) | n/d | n/d | $1.11 | 103 | $1.92 (0.86) |
| | | 100'-124' | 245 (98) | n/d | n/d | $1.20 | 245 | $2.03 (0.82) |
| | | >=125' | 151 (63) | n/d | n/d | $1.21 | 151 | $2.06 (0.85) |
| | 2005 | Under 85' | 5 | 2% | 2% | $2.33 | 5 | $2.33 (0.00) |
| | | 85'-99' | 25 | 20% | 15% | $1.70 | 25 | $2.25 (0.43) |
| | | 100'-124' | 77 | 48% | 51% | $2.33 | 77 | $2.34 (0.20) |
| | | >=125' | 43 | 30% | 32% | $2.32 | 43 | $2.32 (0.06) |
| | 2006 | Under 85' | 2 | -- | -- | -- | 6 | -- (--) |
| | | 85'-99' | 8 | -- | -- | $1.31 | 19 | $1.34 (0.43) |
| | | 100'-124' | 39 | 41% | 41% | $1.36 | 100 | $1.37 (0.11) |
| | | >=125' | 25 | 49% | 49% | $1.34 | 63 | $1.35 (0.15) |
| | 2007 | Under 85' | 2 | -- | -- | -- | 5 | -- (--) |
| | | 85'-99' | 7 | -- | -- | $1.97 | 16 | $1.91 (0.18) |
| | | 100'-124' | 35 | 44% | 43% | $2.01 | 82 | $2.01 (0.24) |
| | | >=125' | 20 | 45% | 46% | $2.06 | 53 | $2.06 (0.26) |
| | 2008 | Under 85' | 1 | -- | -- | -- | 3 | -- (--) |
| | | 85'-99' | 9 | -- | -- | $1.91 | 20 | $2.28 (1.35) |
| | | 100'-124' | 43 | 51% | 51% | $1.95 | 107 | $1.99 (0.19) |
| | | >=125' | 21 | 39% | 38% | $1.90 | 47 | $1.97 (0.28) |
| | 2009 | Under 85' | 2 | -- | -- | -- | 5 | -- (--) |
| | | 85'-99' | 8 | -- | -- | $1.61 | 19 | $1.66 (0.08) |
| | | 100'-124' | 40 | 46% | 45% | $1.64 | 95 | $1.66 (0.20) |
| | | >=125' | 23 | 43% | 44% | $1.70 | 53 | $1.72 (0.35) |
| | 2010 | Under 85' | 2 | -- | -- | -- | 6 | -- (--) |
| | | 85'-99' | 9 | -- | -- | $1.34 | 21 | $1.38 (0.08) |
| | | 100'-124' | 33 | 43% | 44% | $1.36 | 77 | $1.37 (0.27) |
| | | >=125' | 22 | 47% | 47% | $1.35 | 53 | $1.35 (0.12) |
| | 2011 | Under 85' | 1 | -- | -- | -- | 2 | -- (--) |
| | | 85'-99' | 9 | -- | -- | $3.09 | 23 | $2.63 (0.17) |
| | | 100'-124' | 33 | 44% | 43% | $2.50 | 77 | $2.56 (0.39) |
| | | >=125' | 23 | 46% | 45% | $2.50 | 55 | $2.57 (0.28) |

Table continues on next page.

Table 6 cont.

| Fishery | Year [a] | Vessel length | Vessels [a] | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| BST | 2005 | 85'-99' | 1 | -- | -- | -- | 1 | -- (--) |
| | | 100'-124' | 1 | -- | -- | -- | 1 | -- (--) |
| | | >=125’ | 2 | -- | -- | -- | 2 | -- (--) |
| | 2006 | Under 85' | 2 | -- | -- | -- | 4 | -- (--) |
| | | 85'-99' | 5 | -- | -- | -- | 7 | $1.72 (0.27) |
| | | 100'-124' | 22 | 70% | 69% | $1.85 | 33 | $1.73 (0.27) |
| | | >=125’ | 12 | 16% | 16% | $1.87 | 19 | $1.71 (0.31) |
| | 2007 | Under 85' | 2 | -- | -- | -- | 3 | -- (--) |
| | | 85'-99' | 2 | -- | -- | -- | 6 | -- (--) |
| | | 100'-124' | 16 | 52% | 49% | $2.02 | 25 | $2.04 (0.33) |
| | | >=125’ | 7 | -- | -- | $2.19 | 14 | $1.98 (0.52) |
| | 2008 | Under 85' | 3 | -- | -- | -- | 4 | -- (--) |
| | | 85'-99' | 4 | -- | -- | -- | 6 | -- (--) |
| | | 100'-124' | 17 | 60% | 60% | $2.12 | 23 | $2.07 (0.24) |
| | | >=125’ | 5 | 13% | 13% | $2.07 | 10 | $2.16 (0.20) |
| | 2009 | Under 85' | 2 | -- | -- | -- | 5 | -- (--) |
| | | 85'-99' | 1 | -- | -- | -- | 1 | -- (--) |
| | | 100'-124' | 11 | 77% | 80% | $2.28 | 21 | $2.26 (0.20) |
| | | >=125’ | 3 | -- | -- | -- | 6 | -- (--) |
| | 2010 | Under 85' | 1 | -- | -- | -- | 3 | -- (--) |
| | | 100'-124' | 3 | -- | -- | -- | 5 | -- (--) |
| PIK | 1998 | Under 85' | 9 | n/d | n/d | $4.07 | 9 | $4.23 (1.08) |
| | | 85'-99' | 12 | n/d | n/d | $3.80 | 12 | $3.76 (0.34) |
| | | 100'-124' | 17 | n/d | n/d | $3.72 | 17 | $3.71 (0.45) |
| | | >=125’ | 7 | n/d | n/d | $4.33 | 7 | $4.01 (1.15) |
| SMB | 1998 | Under 85' | 2 | n/d | n/d | -- | 2 | -- (--) |
| | | 85'-99' | 16 | n/d | n/d | $2.98 | 17 | $3.00 (0.30) |
| | | 100'-124' | 48 | n/d | n/d | $2.93 | 48 | $2.98 (0.24) |
| | | >=125’ | 28 | n/d | n/d | $2.99 | 28 | $3.01 (0.17) |
| | 2009 | 100'-124' | 5 | 90% | 90% | $3.36 | 7 | $3.44 (0.25) |
| | | >=125’ | 2 | -- | -- | -- | 2 | -- (--) |
| | 2010 | 100'-124' | 8 | 89% | 88% | $5.09 | 19 | $5.17 (0.29) |
| | | >=125’ | 2 | -- | -- | -- | 4 | -- (--) |
| | 2011 | Under 85' | 1 | -- | -- | -- | 1 | -- (--) |
| | | 85'-99' | 1 | -- | -- | -- | 1 | -- (--) |
| | | 100'-124' | 9 | 71% | 69% | $5.15 | 23 | $5.48 (0.66) |
| | | >=125’ | 7 | 24% | 26% | $5.57 | 17 | $5.84 (0.47) |
| WAI | 2001 | 100'-124' | 1 | n/d | n/d | -- | 1 | -- (--) |
| | | >=125' | 2 | n/d | n/d | -- | 2 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year for EDR reporting years (1998, 2001, 2004, 2005-present). Provisional prices by year, fishery and, when applicable, quota type are used to correct for missing revenue or pounds data in some observations. 1998, 2001, and 2004 data are not shown as coverage in EDR data collection for these years was not 100% of vessels.

[a] For ‘98/01/04’, data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years; ‘vessels’ for 98/01/04 shows count of vessel-years (count of unique vessels over all three years).

[b] Landings in 2001 Petrel Bank test fishery. 1998 fishery data unavailable.

Table 7: CR program fisheries ex-vessel price and share of fishery-year landings by quota type (2011 base year) – catcher vessels

| Fishery | Year | Quota type | Vessels | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| AIG | 1998 | N/A | 13 | | | $3.01 | 19 | $3.05 (0.21) |
| | 2001 | N/A | 19 | | | $5.01 | 27 | $5.07 (0.56) |
| | 2004 | N/A | 20 | | | $4.53 | 23 | $4.52 (0.11) |
| | 2005 | ALL | 10 | | | $3.38 | 11 | $3.34 (0.29) |
| | 2006 | ALL | 6 | | | $2.33 | 17 | $2.49 (0.40) |
| | | CVOA | 6 | 75% | 72% | $2.22 | 7 | $2.29 (0.16) |
| | | CVOB/CPO/CDQ/ADAK | 5 | -- | -- | -- | 6 | $2.71 (0.58) |
| | | CVC/CPC | 3 | -- | -- | -- | 4 | -- (--) |
| | 2007 | ALL | 6 | | | $2.60 | 15 | $2.63 (0.35) |
| | | CVOA | 5 | -- | -- | -- | 6 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 6 | 17% | 16% | $2.51 | 6 | $2.55 (0.41) |
| | | CVC/CPC | 3 | -- | -- | -- | 3 | -- (--) |
| | 2008 | ALL | 4 | | | -- | 14 | -- (--) |
| | | CVOA | 4 | -- | -- | -- | 5 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 4 | -- | -- | -- | 4 | -- (--) |
| | | CVC/CPC | 4 | -- | -- | -- | 5 | -- (--) |
| | 2009 | ALL | 4 | | | -- | 12 | -- (--) |
| | | CVOA | 4 | -- | -- | -- | 4 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 4 | -- | -- | -- | 4 | -- (--) |
| | | CVC/CPC | 4 | -- | -- | -- | 4 | -- (--) |
| | 2010 | ALL | 4 | | | -- | 15 | -- (--) |
| | | CVOA | 4 | -- | -- | -- | 5 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 4 | -- | -- | -- | 5 | -- (--) |
| | | CVC/CPC | 4 | -- | -- | -- | 5 | -- (--) |
| | 2011 | ALL | 4 | | | -- | 15 | -- (--) |
| | | CVOA | 4 | -- | -- | -- | 5 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 4 | -- | -- | -- | 5 | -- (--) |
| | | CVC/CPC | 4 | -- | -- | -- | 5 | -- (--) |
| BBR | 1998 | N/A | 206 | | | $4.17 | 206 | $4.20 (0.77) |
| | 2001 | N/A | 197 | | | $7.24 | 197 | $7.24 (0.60) |
| | 2004 | N/A | 230 | | | $6.52 | 230 | $6.55 (0.32) |
| | 2005 | ALL | 85 | | | $5.80 | 85 | $5.76 (0.17) |
| | 2006 | ALL | 80 | | | $4.37 | 191 | $4.61 (0.48) |
| | | CVOA | 77 | 78% | 77% | $4.29 | 77 | $4.51 (0.69) |
| | | CVOB/CPO/CDQ/ADAK | 65 | 18% | 20% | $4.69 | 65 | $4.69 (0.21) |
| | | CVC/CPC | 49 | 3% | 4% | $4.59 | 49 | $4.68 (0.25) |
| | 2007 | ALL | 70 | | | $5.26 | 159 | $5.34 (0.63) |
| | | CVOA | 69 | 78% | 78% | $5.25 | 69 | $5.28 (0.30) |
| | | CVOB/CPO/CDQ/ADAK | 53 | 19% | 19% | $5.25 | 52 | $5.32 (0.90) |
| | | CVC/CPC | 41 | 3% | 3% | $5.14 | 38 | $5.48 (0.63) |
| | 2008 | ALL | 76 | | | $5.84 | 167 | $5.79 (0.32) |
| | | CVOA | 73 | 76% | 76% | $5.86 | 73 | $5.78 (0.44) |
| | | CVOB/CPO/CDQ/ADAK | 56 | 22% | 22% | $5.79 | 56 | $5.77 (0.20) |
| | | CVC/CPC | 38 | 2% | 2% | $5.83 | 38 | $5.83 (0.17) |
| | 2009 | ALL | 68 | | | $5.34 | 158 | $5.38 (0.19) |
| | | CVOA | 68 | 77% | 77% | $5.32 | 68 | $5.31 (0.11) |
| | | CVOB/CPO/CDQ/ADAK | 53 | 20% | 20% | $5.40 | 53 | $5.42 (0.22) |
| | | CVC/CPC | 39 | 3% | 3% | $5.40 | 37 | $5.44 (0.23) |

Table continues on next page.

Table 7 cont.

| Fishery | Year | Quota type | Vessels | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| BBR | 2010 | ALL | 63 | | | $7.79 | 148 | $7.84 (0.67) |
| | | CVOA | 63 | 76% | 76% | $7.71 | 63 | $7.69 (0.50) |
| | | CVOB/CPO/CDQ/ADAK | 52 | 20% | 21% | $8.09 | 52 | $7.92 (0.85) |
| | | CVC/CPC | 33 | 4% | 4% | $7.68 | 33 | $8.02 (0.61) |
| | 2011 | ALL | 59 | | | $10.41 | 136 | $10.57 (1.18) |
| | | CVOA | 58 | 79% | 77% | $10.25 | 58 | $10.27 (1.06) |
| | | CVOB/CPO/CDQ/ADAK | 48 | 19% | 20% | $11.08 | 48 | $10.79 (1.18) |
| | | CVC/CPC | 34 | 2% | 2% | $10.18 | 30 | $10.83 (1.28) |
| BSS | 1998 | N/A | 176 | | | $0.89 | 176 | $0.89 (0.06) |
| | 2001 | N/A | 173 | | | $2.32 | 173 | $2.33 (0.14) |
| | 2004 | N/A | 175 | | | $2.83 | 175 | $2.84 (0.11) |
| | 2005 | N/A | 150 | | | $2.20 | 150 | $2.32 (0.23) |
| | 2006 | ALL | 74 | | | $1.35 | 188 | $1.36 (0.18) |
| | | CVOA | 73 | 80% | 79% | $1.35 | 73 | $1.35 (0.13) |
| | | CVOB/CPO/CDQ/ADAK | 63 | 18% | 18% | $1.36 | 63 | $1.37 (0.25) |
| | | CVC/CPC | 52 | 3% | 3% | $1.39 | 52 | $1.37 (0.10) |
| | 2007 | ALL | 64 | | | $2.03 | 156 | $2.02 (0.24) |
| | | CVOA | 62 | 80% | 80% | $2.02 | 62 | $2.03 (0.16) |
| | | CVOB/CPO/CDQ/ADAK | 53 | 17% | 18% | $2.07 | 53 | $2.02 (0.28) |
| | | CVC/CPC | 41 | 3% | 3% | $1.97 | 41 | $2.00 (0.29) |
| | 2008 | ALL | 74 | | | $1.93 | 177 | $2.02 (0.50) |
| | | CVOA | 73 | 75% | 75% | $1.93 | 73 | $1.91 (0.22) |
| | | CVOB/CPO/CDQ/ADAK | 62 | 22% | 22% | $1.88 | 62 | $2.11 (0.80) |
| | | CVC/CPC | 42 | 3% | 3% | $2.09 | 42 | $2.07 (0.05) |
| | 2009 | ALL | 73 | | | $1.66 | 172 | $1.68 (0.25) |
| | | CVOA | 73 | 78% | 78% | $1.66 | 73 | $1.64 (0.17) |
| | | CVOB/CPO/CDQ/ADAK | 59 | 19% | 19% | $1.66 | 59 | $1.66 (0.22) |
| | | CVC/CPC | 40 | 2% | 3% | $1.81 | 40 | $1.77 (0.35) |
| | 2010 | ALL | 66 | | | $1.36 | 157 | $1.36 (0.20) |
| | | CVOA | 66 | 73% | 73% | $1.36 | 66 | $1.37 (0.21) |
| | | CVOB/CPO/CDQ/ADAK | 53 | 24% | 24% | $1.36 | 53 | $1.35 (0.17) |
| | | CVC/CPC | 38 | 3% | 3% | $1.26 | 38 | $1.37 (0.23) |
| | 2011 | ALL | 66 | | | $2.55 | 157 | $2.57 (0.32) |
| | | CVOA | 63 | 75% | 74% | $2.53 | 63 | $2.46 (0.24) |
| | | CVOB/CPO/CDQ/ADAK | 60 | 23% | 23% | $2.63 | 59 | $2.65 (0.35) |
| | | CVC/CPC | 37 | 2% | 2% | $2.58 | 35 | $2.64 (0.34) |

Table continues on next page.

Table 7 cont.

| Fishery | Year | Quota type | Vessels | Share of catcher vessel ex-vessel volume | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| BST | 2005 | ALL | 4 | | | -- | 4 | -- (--) |
| | 2006 | ALL | 41 | | | $1.86 | 63 | $1.77 (0.42) |
| | | CVOA | 39 | 75% | 74% | $1.84 | 38 | $1.75 (0.51) |
| | | CVOB/CPO/CDQ/ADAK | 14 | 23% | 24% | $1.95 | 14 | $1.84 (0.17) |
| | | CVC/CPC | 12 | 2% | 2% | $1.75 | 11 | $1.78 (0.30) |
| | 2007 | ALL | 27 | | | $2.14 | 48 | $2.12 (0.69) |
| | | CVOA | 28 | 87% | 87% | $2.14 | 26 | $2.21 (0.82) |
| | | CVOB/CPO/CDQ/ADAK | 14 | 12% | 12% | $2.16 | 13 | $2.12 (0.35) |
| | | CVC/CPC | 9 | 1% | 1% | $2.01 | 9 | $1.87 (0.63) |
| | 2008 | ALL | 29 | | | $2.12 | 43 | $2.09 (0.26) |
| | | CVOA | 26 | 73% | 72% | $2.09 | 26 | $2.07 (0.27) |
| | | CVOB/CPO/CDQ/ADAK | 12 | 26% | 27% | $2.19 | 12 | $2.08 (0.30) |
| | | CVC/CPC | 5 | 2% | 2% | $2.18 | 5 | $2.18 (0.07) |
| | 2009 | ALL | 17 | | | $2.22 | 33 | $2.20 (0.20) |
| | | CVOA | 17 | 75% | 74% | $2.20 | 16 | $2.17 (0.19) |
| | | CVOB/CPO/CDQ/ADAK | 9 | 22% | 23% | $2.31 | 9 | $2.28 (0.22) |
| | | CVC/CPC | 9 | 3% | 3% | $2.12 | 8 | $2.16 (0.17) |
| | 2010 | ALL | 4 | | | -- | 8 | -- (--) |
| | | CVOA | 4 | -- | -- | -- | 4 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 2 | -- | -- | -- | 2 | -- (--) |
| | | CVC/CPC | 2 | -- | -- | -- | 2 | -- (--) |
| SMB | 1998 | N/A | 95 | | | $2.96 | 95 | $2.99 (0.23) |
| | 2009 | ALL | 7 | | | $3.35 | 9 | $3.40 (0.29) |
| | | CVOA | 7 | -- | -- | -- | 7 | -- (--) |
| | | CVOB/CPO/CDQ/ADAK | 1 | -- | -- | -- | 1 | -- (--) |
| | | CVC/CPC | 1 | -- | -- | -- | 1 | -- (--) |
| | 2010 | ALL | 10 | | | $5.12 | 23 | $5.20 (0.27) |
| | | CVOA | 10 | 79% | 78% | $5.08 | 10 | $5.11 (0.35) |
| | | CVOB/CPO/CDQ/ADAK | 8 | 19% | 20% | $5.28 | 8 | $5.27 (0.17) |
| | | CVC/CPC | 5 | 2% | 2% | $5.16 | 5 | $5.25 (0.22) |
| | 2011 | ALL | 18 | | | $5.26 | 42 | $5.62 (0.60) |
| | | CVOA | 18 | 79% | 78% | $5.14 | 18 | $5.26 (0.39) |
| | | CVOB/CPO/CDQ/ADAK | 15 | 17% | 19% | $5.74 | 15 | $5.78 (0.48) |
| | | CVC/CPC | 9 | 4% | 4% | $5.52 | 9 | $6.07 (0.72) |
| PIK | 1998 | N/A | 43 | | | $3.72 | 43 | $3.79 (0.60) |
| WAI [a] | 2001 | N/A | 3 | | | -- | 3 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.*
Data shown by calendar year for EDR reporting years (1998, 2001, 2004, 2005-present). Provisional prices by year, fishery, and quota type are used to correct for missing revenue or pounds data in some observations. Quota types are as follows: CVC/CPC=catcher vessel and catcher processor C share quota, CVOA=catcher vessel owner A share quota, CVOB=catcher vessel owner B share quota, CPO=catcher processor owner quota.
[a] Landings in 2001 Petrel Bank test fishery. 1998 fishery data unavailable.

Table 8: CR program fisheries deadloss by quota type – catcher vessels

| Fishery | Year | Quota type | Vessels (vessels with deadloss) | Deadloss ($10^3$ lbs) | % of fishery-year sold lbs | Mean deadloss ($10^3$ lbs) |
|---|---|---|---|---|---|---|
| AIG | 2005 | ALL | 10 (10) | 40.51 | 1.06% | 4.05 |
| | 2006 | CVOA | 6 (6) | 52.74 | 1.21% | 8.79 |
| | | CVOB/CPO/CDQ/ADAK | 5 (3) | -- | -- | -- |
| | | CVC/CPC | 3 (3) | -- | -- | -- |
| | 2007 | CVOA | 5 (5) | 30.94 | 0.78% | 6.19 |
| | | CVOB/CPO/CDQ/ADAK | 6 (5) | 4.98 | 0.13% | 1.00 |
| | | CVC/CPC | 3 (1) | -- | -- | -- |
| | 2008 | CVOA | 4 (4) | -- | -- | -- |
| | | CVOB/CPO/CDQ/ADAK | 4 (3) | -- | -- | -- |
| | | CVC/CPC | 4 (2) | -- | -- | -- |
| | 2009 | CVOA | 4 (4) | -- | -- | -- |
| | | CVOB/CPO/CDQ/ADAK | 4 (3) | -- | -- | -- |
| | | CVC/CPC | 4 (2) | -- | -- | -- |
| | 2010 | CVOA | 4 (4) | -- | -- | -- |
| | | CVOB/CPO/CDQ/ADAK | 4 (3) | -- | -- | -- |
| | | CVC/CPC | 4 (2) | -- | -- | -- |
| | 2011 | CVOA | 4 (4) | -- | -- | -- |
| | | CVOB/CPO/CDQ/ADAK | 4 (3) | -- | -- | -- |
| | | CVC/CPC | 4 (2) | -- | -- | -- |
| BBR | 2005 | ALL | 85 (83) | 85.74 | 0.52% | 1.03 |
| | 2006 | CVOA | 77 (75) | 87.96 | 0.56% | 1.17 |
| | | CVOB/CPO/CDQ/ADAK | 65 (31) | 27.87 | 0.18% | 0.90 |
| | | CVC/CPC | 49 (15) | 3.35 | 0.02% | 0.22 |
| | 2007 | CVOA | 69 (69) | 114.36 | 0.61% | 1.66 |
| | | CVOB/CPO/CDQ/ADAK | 53 (36) | 20.76 | 0.11% | 0.58 |
| | | CVC/CPC | 41 (17) | 5.49 | 0.03% | 0.32 |
| | 2008 | CVOA | 73 (71) | 135.81 | 0.73% | 1.91 |
| | | CVOB/CPO/CDQ/ADAK | 56 (43) | 31.53 | 0.17% | 0.73 |
| | | CVC/CPC | 38 (20) | 1.25 | 0.01% | 0.06 |
| | 2009 | CVOA | 68 (66) | 100.96 | 0.67% | 1.53 |
| | | CVOB/CPO/CDQ/ADAK | 53 (37) | 22.66 | 0.15% | 0.61 |
| | | CVC/CPC | 39 (20) | 2.99 | 0.02% | 0.15 |
| | 2010 | CVOA | 63 (63) | 98.58 | 0.69% | 1.56 |
| | | CVOB/CPO/CDQ/ADAK | 52 (32) | 17.72 | 0.12% | 0.55 |
| | | CVC/CPC | 33 (13) | 2.57 | 0.02% | 0.20 |
| | 2011 | CVOA | 58 (57) | 29.63 | 0.39% | 0.52 |
| | | CVOB/CPO/CDQ/ADAK | 48 (20) | 6.67 | 0.09% | 0.33 |
| | | CVC/CPC | 34 (6) | 0.12 | 0.00% | 0.02 |

Table continues on next page.

Table 8 cont.

| Fishery | Year | Quota type | Vessels (vessels with deadloss) | Deadloss ($10^3$ lbs) | % of fishery-year sold lbs | Mean deadloss ($10^3$ lbs) |
|---|---|---|---|---|---|---|
| BSS | 2005 | ALL | 150 (138) | 196.46 | 0.83% | 1.42 |
| | 2006 | CVOA | 73 (72) | 282.94 | 0.85% | 3.93 |
| | | CVOB/CPO/CDQ/ADAK | 63 (37) | 60.79 | 0.18% | 1.64 |
| | | CVC/CPC | 52 (18) | 9.05 | 0.03% | 0.50 |
| | 2007 | CVOA | 62 (61) | 260.57 | 0.83% | 4.27 |
| | | CVOB/CPO/CDQ/ADAK | 53 (35) | 65.26 | 0.21% | 1.86 |
| | | CVC/CPC | 41 (15) | 8.66 | 0.03% | 0.58 |
| | 2008 | CVOA | 73 (71) | 411.77 | 0.72% | 5.80 |
| | | CVOB/CPO/CDQ/ADAK | 62 (49) | 96.71 | 0.17% | 1.97 |
| | | CVC/CPC | 42 (29) | 12.70 | 0.02% | 0.44 |
| | 2009 | CVOA | 73 (73) | 338.71 | 0.65% | 4.64 |
| | | CVOB/CPO/CDQ/ADAK | 59 (55) | 95.38 | 0.18% | 1.73 |
| | | CVC/CPC | 40 (24) | 6.21 | 0.01% | 0.26 |
| | 2010 | CVOA | 66 (66) | 245.05 | 0.54% | 3.71 |
| | | CVOB/CPO/CDQ/ADAK | 53 (41) | 91.18 | 0.20% | 2.22 |
| | | CVC/CPC | 38 (17) | 6.00 | 0.01% | 0.35 |
| | 2011 | CVOA | 63 (63) | 255.29 | 0.51% | 4.05 |
| | | CVOB/CPO/CDQ/ADAK | 60 (33) | 76.47 | 0.15% | 2.32 |
| | | CVC/CPC | 37 (16) | 3.59 | 0.01% | 0.22 |
| BST | 2005 | ALL | 4 (4) | -- | -- | -- |
| | 2006 | CVOA | 39 (27) | 2.76 | 0.30% | 0.10 |
| | | CVOB/CPO/CDQ/ADAK | 14 (8) | 1.06 | 0.11% | 0.13 |
| | | CVC/CPC | 12 (2) | -- | -- | -- |
| | 2007 | CVOA | 28 (25) | 26.16 | 1.25% | 1.05 |
| | | CVOB/CPO/CDQ/ADAK | 14 (7) | 1.24 | 0.06% | 0.18 |
| | | CVC/CPC | 9 (2) | -- | -- | -- |
| | 2008 | CVOA | 26 (22) | 14.67 | 0.68% | 0.67 |
| | | CVOB/CPO/CDQ/ADAK | 12 (11) | 4.53 | 0.21% | 0.41 |
| | | CVC/CPC | 5 (4) | -- | -- | -- |
| | 2009 | CVOA | 17 (16) | 10.31 | 0.50% | 0.64 |
| | | CVOB/CPO/CDQ/ADAK | 9 (6) | 2.18 | 0.11% | 0.36 |
| | | CVC/CPC | 9 (4) | -- | -- | -- |
| | 2010 | CVOA | 4 (4) | -- | -- | -- |
| | | CVOB/CPO/CDQ/ADAK | 2 (2) | -- | -- | -- |
| | | CVC/CPC | 2 (0) | -- | -- | -- |
| | 2011 | CVOA | 1 (1) | -- | -- | -- |
| SMB | 2009 | CVOA | 7 (7) | 10.17 | 2.26% | 1.45 |
| | | CVOB/CPO/CDQ/ADAK | 1 (1) | -- | -- | -- |
| | | CVC/CPC | 1 (1) | -- | -- | -- |
| | 2010 | CVOA | 10 (10) | 9.06 | 0.73% | 0.91 |

| | | | | | |
|---|---|---|---|---|---|
| | CVOB/CPO/CDQ/ADAK | 8 (2) | -- | -- | -- |
| | CVC/CPC | 5 (1) | -- | -- | -- |
| 2011 | CVOA | 18 (18) | 23.70 | 1.27% | 1.32 |
| | CVOB/CPO/CDQ/ADAK | 15 (7) | 1.64 | 0.09% | 0.23 |

*Source: NMFS AFSC BSAI Crab Economic Data.*

Data shown by calendar year. Quota types are as follows: CVC/CPC=catcher vessel and catcher processor C share quota, CVOA=catcher vessel owner A share quota, CVOB=catcher vessel owner B share quota, CPO=catcher processor owner quota.

Table 9: CR program fisheries ex-vessel price and share of fishery-year landings by cooperative membership status (2011 base year) – catcher vessels

| | | Cooperative members | | | | | Non-cooperative members | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | Vessels | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) | Vessels | Share of catcher vessel ex-vessel revenue | Weighted value/lb | Price observations | Mean price/lb (sd) |
| AIG | 2005 | 10 | 100.00% | $3.20 | 11 | $3.17 (0.28) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2006 | 6 | 100.00% | $2.21 | 17 | $2.36 (0.38) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2007 | 6 | 100.00% | $2.46 | 15 | $2.49 (0.33) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2008 | 4 | 100.00% | -- | 14 | -- (--) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2009 | 3 | -- | -- | 9 | -- (--) | 1 | -- | -- | 3 | -- (--) |
| BBR | 2005 | 73 | 89.04% | $5.49 | 73 | $5.46 (0.17) | 12 | 10.96% | $5.51 | 12 | $5.48 (0.08) |
| | 2006 | 76 | -- | $4.14 | 185 | $4.38 (0.46) | 4 | -- | -- | 6 | -- (--) |
| | 2007 | 68 | -- | $4.97 | 156 | $5.06 (0.60) | 2 | -- | -- | 3 | -- (--) |
| | 2008 | 71 | 95.67% | $5.54 | 155 | $5.49 (0.32) | 5 | 4.33% | $5.42 | 12 | $5.41 (0.08) |
| | 2009 | 64 | -- | $5.06 | 148 | $5.10 (0.18) | 4 | -- | -- | 10 | -- (--) |
| BSS | 2005 | 126 | 85.76% | $2.07 | 126 | $2.20 (0.23) | 24 | 14.24% | $2.16 | 24 | $2.17 (0.10) |
| | 2006 | 72 | -- | $1.28 | 182 | $1.29 (0.17) | 2 | -- | -- | 6 | -- (--) |
| | 2007 | 63 | -- | $1.92 | 155 | $1.91 (0.23) | 1 | -- | -- | 1 | -- (--) |
| | 2008 | 70 | -- | $1.82 | 166 | $1.91 (0.49) | 4 | -- | -- | 11 | -- (--) |
| | 2009 | 68 | 94.90% | $1.57 | 157 | $1.59 (0.24) | 5 | 5.10% | $1.58 | 15 | $1.61 (0.05) |
| BST | 2005 | 4 | 100.00% | -- | 4 | -- (--) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2006 | 40 | -- | $1.76 | 60 | $1.67 (0.41) | 1 | -- | -- | 3 | -- (--) |
| | 2007 | 30 | 100.00% | $2.03 | 48 | $2.01 (0.65) | 0 | 0.00% | n/a | 0 | n/a (n/a) |
| | 2008 | 27 | -- | $1.99 | 40 | $1.97 (0.25) | 2 | -- | -- | 3 | -- (--) |
| | 2009 | 16 | -- | $2.11 | 30 | $2.09 (0.19) | 2 | -- | -- | 3 | -- (--) |
| SMB | 2009 | 7 | 100.00% | $3.17 | 9 | $3.22 (0.27) | 0 | 0.00% | n/a | n/a | n/a (n/a) |

*Source: NMFS AFSC BSAI Crab Economic Data.*

Data shown by calendar year. Provisional prices by year, fishery and, when applicable, quota type are used to correct for missing revenue or pounds data in some observations.

Table 10: CR program fisheries estimated finished production, first wholesale value, and price by fishery (2011 base year)

| Fishery | Year | Processing operations | Finished weight ($10^6$ lbs)[a] | First wholesale value ($10^6$)[b] | Weighted price/lb [b] | Mean price/lb (sd) [b] |
|---|---|---|---|---|---|---|
| AIG | 1998 | 7 | 3.65 | $23.96 | $6.56 | $6.66 (0.45) |
| | 1999 | 8 | 3.42 | $34.42 | $10.05 | $8.91 (2.57) |
| | 2000 | 7 | 3.99 | $31.44 | $7.87 | $8.68 (3.68) |
| | 2001 | 5 | 4.28 | $45.65 | $10.66 | $10.57 (0.28) |
| | 2002 | 5 | 3.72 | $41.34 | $11.12 | $9.30 (4.10) |
| | 2003 | 6 | 3.91 | $44.40 | $11.36 | $12.18 (3.12) |
| | 2004 | 5 | 4.04 | $32.97 | $8.16 | $9.00 (1.41) |
| | 2005 | 6 | 2.98 | $22.45 | $7.53 | $6.46 (2.04) |
| | 2006 | 7 | 3.13 | $16.58 | $5.30 | $4.87 (1.15) |
| | 2007 | 6 | 3.42 | $21.47 | $6.28 | $5.80 (0.89) |
| | 2008 | 7 | 3.41 | $28.72 | $8.42 | $7.96 (0.89) |
| | 2009 | 5 | 3.3 | $21.40 | $6.49 | $7.14 (2.57) |
| | 2010 | 4 | 3.17 | $25.68 | $8.11 | $8.04 (1.31) |
| | 2011 | 9 | 3.64 | $35.01 | $9.61 | $9.97 (2.59) |
| BBR | 1998 | 21 | 9.95 | $86.00 | $8.64 | $8.25 (1.71) |
| | 1999 | 20 | 7.82 | $132.40 | $16.93 | $16.55 (3.81) |
| | 2000 | 20 | 5.48 | $55.83 | $10.20 | $11.81 (3.63) |
| | 2001 | 20 | 5.63 | $74.28 | $13.20 | $12.39 (4.06) |
| | 2002 | 20 | 6.43 | $110.40 | $17.17 | $15.32 (6.53) |
| | 2003 | 25 | 10.44 | $149.61 | $14.33 | $12.78 (4.38) |
| | 2004 | 23 | 10.19 | $130.37 | $12.80 | $12.06 (2.71) |
| | 2005 | 16 | 12.3 | $134.21 | $10.91 | $10.06 (4.06) |
| | 2006 | 14 | 9.17 | $82.51 | $9.00 | $8.84 (2.64) |
| | 2007 | 14 | 13.09 | $128.42 | $9.81 | $9.17 (2.71) |
| | 2008 | 14 | 13.31 | $144.40 | $10.85 | $10.48 (2.48) |
| | 2009 | 13 | 10.4 | $108.31 | $10.41 | $9.65 (2.44) |
| | 2010 | 14 | 10.03 | $137.34 | $13.69 | $12.84 (3.39) |
| | 2011 | 17 | 5.27 | $99.47 | $18.89 | $16.71 (5.13) |
| BSS | 1998 | 32 | 177.43 | $563.45 | $3.18 | $2.86 (0.83) |
| | 1999 | 30 | 137.05 | $596.86 | $4.36 | $3.59 (1.35) |
| | 2000 | 22 | 23.33 | $118.11 | $5.06 | $5.15 (2.02) |
| | 2001 | 19 | 17.65 | $98.86 | $5.60 | $5.15 (1.43) |
| | 2002 | 21 | 22.75 | $121.26 | $5.33 | $4.85 (1.38) |
| | 2003 | 19 | 19.6 | $126.63 | $6.46 | $6.53 (2.89) |
| | 2004 | 21 | 16.88 | $112.36 | $6.66 | $6.19 (1.49) |
| | 2005 | 20 | 17.71 | $87.87 | $4.96 | $4.57 (1.05) |
| | 2006 | 14 | 24.92 | $83.22 | $3.34 | $3.52 (1.77) |
| | 2007 | 14 | 22.66 | $105.83 | $4.67 | $4.78 (1.76) |
| | 2008 | 16 | 41.02 | $178.12 | $4.34 | $4.25 (1.17) |
| | 2009 | 14 | 35.97 | $142.09 | $3.95 | $4.26 (3.85) |
| | 2010 | 11 | 31.41 | $108.75 | $3.46 | $3.52 (0.83) |
| | 2011 | 16 | 37.5 | $206.41 | $5.50 | $5.38 (0.79) |

Table continues on next page.

Table 10 cont.

| Fishery | Year | Processing operations | Finished weight ($10^6$ lbs)[a] | First wholesale value ($10^6$)[b] | Weighted price/lb [b] | Mean price/lb (sd) [b] |
|---|---|---|---|---|---|---|
| BST | 2005 | 4 | 0.18 | $0.91 | $5.08 | $4.04 (1.70) |
| | 2006 | 10 | 0.72 | $3.02 | $4.20 | $3.88 (0.86) |
| | 2007 | 8 | 1.46 | $7.52 | $5.16 | $5.53 (3.17) |
| | 2008 | 9 | 1.34 | $6.54 | $4.89 | $4.86 (0.52) |
| | 2009 | 8 | 1.39 | $5.99 | $4.32 | $4.66 (1.00) |
| | 2010 | 3 | -- | -- | -- | -- (--) |
| PIK | 1998 | 11 | 0.67 | $5.80 | $8.71 | $8.44 (1.18) |
| SMB | 1998 | 13 | 1.77 | $13.29 | $7.53 | $7.58 (0.32) |
| | 2009 | 2 | -- | -- | -- | -- (--) |
| | 2010 | 6 | 0.91 | $11.63 | $12.72 | $11.16 (3.38) |
| | 2011 | 7 | 1.33 | $18.84 | $14.15 | $13.29 (3.77) |
| WAI[c] | 1998 | 1 | -- | -- | -- | -- (--) |
| | 2002 | 9 | 0.34 | $5.90 | $17.09 | $15.36 (7.72) |
| | 2003 | 9 | 0.33 | $4.68 | $14.34 | $13.59 (4.90) |

*Source: ADF&G fish tickets, eLandings, ADF&G Commercial Operators Annual Report, NMFS AFSC BSAI Crab Economic Data.*
Data shown by calendar year.

**[a]** For 1998-2005, wholesale production volume is estimated by multiplying the volume of ex-vessel commercial landings reported in fish tickets to the 1998-2005 mean product recovery rate calculated from COAR production and buying reports for processors reporting landings >=1000 lbs in the relevant BSAI crab fishery. Production volume for 2006 and later years sourced from EDR.

**[b]** For 1998-2005, wholesale value is estimated from COAR data by multiplying yearly estimate of wholesale production volume with the weighted first wholesale value per lb, by species, from COAR production reports for processors reporting processing in the given fishery and year. Wholesale value and prices for 2006 and later years are estimated by applying prices derived from EDR crab sales data to yearly estimates of wholesale production volume. Note that crab sales reported in the EDR may reflect sales from prior-year inventory.

[c] Excludes estimates of production from landings made in the 2000/2001 and 2001/2002 Western Aleutian Islands red king crab Petrel Bank test fishery.

Table 11: Statewide crab production, first wholesale value and pricing for selected species (2011 base year)

| Species | Year | Processors[a] | Finished weight ($10^6$ lbs) | First wholesale value ($10^6$) | Weighted price/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|
| crab, red king | 1998 | 29 | 9.23 | $79.76 | $8.64 | 43 | $8.46 (2.10) |
| | 1999 | 31 | 7.05 | $119.26 | $16.92 | 51 | $15.54 (4.22) |
| | 2000 | 22 | 6.58 | $67.07 | $10.20 | 32 | $12.18 (3.81) |
| | 2001 | 30 | 6.35 | $83.84 | $13.21 | 52 | $12.27 (4.25) |
| | 2002 | 32 | 6.93 | $117.38 | $16.94 | 67 | $15.24 (6.05) |
| | 2003 | 38 | 10.5 | $149.74 | $14.26 | 91 | $12.92 (4.60) |
| | 2004 | 26 | 9.73 | $124.90 | $12.84 | 62 | $11.89 (2.87) |
| | 2005 | 23 | 12.5 | $135.69 | $10.85 | 64 | $10.56 (4.28) |
| | 2006 | 16 | 10.4 | $93.65 | $9.00 | 49 | $8.10 (3.31) |
| | 2007 | 19 | 13.32 | $134.44 | $10.09 | 52 | $8.78 (2.71) |
| | 2008 | 17 | 13.18 | $144.03 | $10.93 | 48 | $9.60 (2.78) |
| | 2009 | 18 | 10.96 | $108.25 | $9.88 | 58 | $8.71 (3.01) |
| | 2010 | 18 | 9.45 | $132.95 | $14.06 | 53 | $12.28 (3.84) |
| | 2011 | 25 | 6.03 | $106.24 | $17.62 | 64 | $16.59 (6.16) |
| crab, blue king | 1998 | 19 | 2.08 | $15.67 | $7.53 | 22 | $7.52 (0.99) |
| | 1999 | 4 | 0.01 | $0.08 | $13.56 | 4 | $10.94 (--) |
| | 2000 | 2 | -- | -- | -- | -- | -- (--) |
| | 2001 | 1 | -- | -- | -- | -- | -- (--) |
| | 2002 | 1 | -- | -- | -- | -- | -- (--) |
| | 2003 | 1 | -- | -- | -- | -- | -- (--) |
| | 2005 | 1 | -- | -- | -- | -- | -- (--) |
| | 2009 | 4 | 0.19 | $1.42 | $7.44 | 7 | $6.65 (--) |
| | 2010 | 7 | 0.67 | $8.24 | $12.37 | 11 | $10.93 (3.13) |
| | 2011 | 12 | 1.25 | $17.02 | $13.67 | 18 | $12.70 (4.89) |
| crab, golden (brown) king | 1998 | 13 | 2.92 | $19.53 | $6.69 | 17 | $8.60 (2.20) |
| | 1999 | 16 | 3.44 | $34.21 | $9.94 | 26 | $9.32 (3.86) |
| | 2000 | 16 | 4.92 | $40.63 | $8.26 | 27 | $9.82 (3.41) |
| | 2001 | 16 | 4.3 | $44.54 | $10.36 | 26 | $9.69 (3.59) |
| | 2002 | 16 | 3.82 | $42.41 | $11.12 | 28 | $12.34 (4.80) |
| | 2003 | 16 | 3.93 | $45.02 | $11.47 | 32 | $12.27 (4.14) |
| | 2004 | 13 | 4.65 | $38.98 | $8.38 | 27 | $10.24 (3.66) |
| | 2005 | 13 | 2.85 | $21.97 | $7.70 | 28 | $8.77 (4.25) |
| | 2006 | 14 | 3.65 | $20.49 | $5.62 | 27 | $7.45 (3.96) |
| | 2007 | 11 | 3.75 | $25.06 | $6.68 | 22 | $7.89 (3.35) |
| | 2008 | 13 | 3.89 | $30.10 | $7.73 | 22 | $8.22 (2.84) |
| | 2009 | 15 | 4.09 | $25.56 | $6.25 | 31 | $7.45 (3.56) |
| | 2010 | 17 | 5.13 | $41.16 | $8.03 | 31 | $8.33 (2.85) |
| | 2011 | 20 | 4.16 | $45.69 | $10.98 | 32 | $11.16 (4.20) |

Table continues on next page.

Table 11 cont.

| Species | Year | Processors [a] | Finished weight ($10^6$ lbs) | First wholesale value ($10^6$) | Weighted price/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|
| crab, Tanner, bairdi | 1998 | 16 | 1.65 | $11.56 | $7.00 | 27 | $6.77 (3.49) |
| | 1999 | 11 | 1.48 | $8.78 | $5.95 | 19 | $6.49 (2.87) |
| | 2000 | 10 | 1 | $8.44 | $8.41 | 15 | $7.60 (1.85) |
| | 2001 | 17 | 1.27 | $9.58 | $7.57 | 24 | $6.95 (1.70) |
| | 2002 | 12 | 0.74 | $5.82 | $7.85 | 21 | $6.68 (2.20) |
| | 2003 | 13 | 0.81 | $7.27 | $9.03 | 23 | $7.88 (2.96) |
| | 2004 | 12 | 0.94 | $8.63 | $9.19 | 18 | $8.77 (1.76) |
| | 2005 | 19 | 2.22 | $12.30 | $5.54 | 32 | $6.42 (3.50) |
| | 2006 | 21 | 2.94 | $13.95 | $4.74 | 41 | $4.52 (1.45) |
| | 2007 | 18 | 2.49 | $13.03 | $5.23 | 30 | $5.94 (3.52) |
| | 2008 | 22 | 2.44 | $12.98 | $5.33 | 40 | $5.23 (1.88) |
| | 2009 | 17 | 2.25 | $9.91 | $4.41 | 34 | $4.87 (2.12) |
| | 2010 | 17 | 1.9 | $7.73 | $4.06 | 28 | $4.36 (1.07) |
| | 2011 | 15 | 3.88 | $25.54 | $6.58 | 32 | $6.77 (1.53) |
| crab, Tanner, snow (opilio) | 1998 | 34 | 157.2 | $499.69 | $3.18 | 59 | $2.92 (0.90) |
| | 1999 | 31 | 116.91 | $509.31 | $4.36 | 54 | $3.61 (1.35) |
| | 2000 | 23 | 22.78 | $115.44 | $5.07 | 37 | $5.19 (2.00) |
| | 2001 | 20 | 15.15 | $84.75 | $5.60 | 31 | $5.01 (1.68) |
| | 2002 | 25 | 20.84 | $110.39 | $5.30 | 36 | $4.75 (1.41) |
| | 2003 | 19 | 17.38 | $112.31 | $6.46 | 32 | $6.53 (2.89) |
| | 2004 | 22 | 15.3 | $101.89 | $6.66 | 30 | $6.23 (1.44) |
| | 2005 | 20 | 16.29 | $80.80 | $4.96 | 28 | $4.57 (1.05) |
| | 2006 | 13 | 27.89 | $97.33 | $3.49 | 29 | $3.45 (0.91) |
| | 2007 | 16 | 20.38 | $94.64 | $4.64 | 32 | $4.72 (1.12) |
| | 2008 | 16 | 31.35 | $142.66 | $4.55 | 32 | $4.33 (1.01) |
| | 2009 | 16 | 35.89 | $140.63 | $3.92 | 23 | $3.79 (0.51) |
| | 2010 | 12 | 29.91 | $103.14 | $3.45 | 22 | $3.43 (1.07) |
| | 2011 | 16 | 35.58 | $190.24 | $5.35 | 27 | $5.09 (1.31) |

*Source: ADF&G Commercial Operators Annual Report.* Data shown by calendar year. Includes processing of crab taken from stocks/fisheries other than those managed under the BSAI crab FMP.

[a] Entities reporting crab production in the Commercial Operators Annual Report, including purchasers of crab that had all crab custom processed for them by other processors. Processor counts in Tables 10 and 11 are not comparable to processor counts in other tables, which show the number of operations engaging in crab processing activity.

## Table 12: Statewide crab production by product for selected species (2011 base year)

| Species | Year | Product | Processors[a] | Finished weight ($10^6$ lbs) | First wholesale value ($10^6$) | Weighted price/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| King, red | 2007 | Whole crab | 10 | $0.36 | $3.07 | $8.52 | 15 | $8.71 (2.05) |
| | | Sections | 19 | $12.86 | $131.04 | $10.19 | 29 | $10.26 (0.95) |
| | | Other | 8 | $0.10 | $0.34 | $3.53 | 8 | $3.59 (1.28) |
| | 2008 | Whole crab | 8 | $0.44 | $4.90 | $11.06 | 13 | $9.62 (2.46) |
| | | Sections | 17 | $12.58 | $138.40 | $11.00 | 28 | $10.88 (1.26) |
| | | Other | 7 | $0.16 | $0.73 | $4.64 | 7 | $4.44 (1.52) |
| | 2009 | Whole crab | 11 | $0.51 | $1.60 | $3.14 | 16 | $8.43 (2.58) |
| | | Sections | 17 | $10.34 | $106.19 | $10.27 | 33 | $10.07 (2.15) |
| | | Other | 8 | $0.12 | $0.46 | $4.00 | 9 | $4.22 (1.79) |
| | 2010 | Whole crab | 11 | $0.22 | $2.83 | $12.89 | 16 | $12.15 (3.24) |
| | | Sections | 17 | $9.10 | $129.52 | $14.24 | 28 | $14.40 (1.52) |
| | | Other | 8 | $0.14 | $0.60 | $4.35 | 9 | $5.91 (2.64) |
| | 2011 | Whole crab | 15 | $0.23 | $3.80 | $16.85 | 18 | $15.25 (4.07) |
| | | Sections | 23 | $5.72 | $101.97 | $17.82 | 34 | $19.21 (3.16) |
| | | Other | 11 | $0.08 | $0.47 | $5.91 | 12 | $11.18 (10.29) |
| King, blue | 2009 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 4 | -- | -- | -- | 5 | $7.76 (--) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2010 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 7 | -- | -- | -- | 9 | $11.96 (2.38) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2011 | Whole crab | 2 | -- | -- | -- | -- | -- (--) |
| | | Sections | 12 | -- | -- | -- | 14 | $13.53 (5.11) |
| | | Other | 2 | -- | -- | -- | -- | -- (--) |
| King, golden | 2007 | Whole crab | 6 | $0.46 | $3.46 | $7.56 | 7 | $7.58 (1.21) |
| | | Sections | 7 | $2.96 | $19.44 | $6.57 | 10 | $7.44 (2.46) |
| | | Other | 4 | $0.34 | $2.17 | $6.41 | 5 | $9.22 (--) |
| | 2008 | Whole crab | 8 | $0.51 | $3.80 | $7.41 | 8 | $7.02 (1.23) |
| | | Sections | 8 | $2.96 | $23.15 | $7.82 | 9 | $8.84 (1.97) |
| | | Other | 4 | $0.42 | $3.14 | $7.53 | 5 | $9.03 (--) |
| | 2009 | Whole crab | 8 | -- | -- | -- | 10 | $6.34 (1.64) |
| | | Sections | 10 | $3.31 | $20.34 | $6.15 | 15 | $7.78 (3.03) |
| | | Other | 3 | -- | -- | -- | -- | -- (--) |
| | 2010 | Whole crab | 12 | $1.08 | $6.65 | $6.14 | 12 | $7.02 (1.44) |
| | | Sections | 11 | -- | -- | -- | 14 | $9.53 (1.34) |
| | | Other | 3 | -- | -- | -- | -- | -- (--) |
| | 2011 | Whole crab | 10 | -- | -- | -- | 11 | $9.71 (1.14) |
| | | Sections | 14 | $3.40 | $38.12 | $11.22 | 17 | $11.93 (4.26) |
| | | Other | 3 | -- | -- | -- | -- | -- (--) |

Table continues on next page.

Table 12 cont.

| Species | Year | Product | Processors[a] | Finished weight (106 lbs) | First wholesale value (106) | Weighted price/lb | Price observations | Mean price/lb (sd) |
|---|---|---|---|---|---|---|---|---|
| Tanner, bairdi | 2007 | Whole crab | 4 | -- | -- | -- | 6 | $7.27 (--) |
| | | Sections | 18 | $2.46 | $12.90 | $5.25 | 23 | $5.68 (1.06) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2008 | Whole crab | 4 | $0.00 | $0.01 | $3.64 | 5 | $3.05 (--) |
| | | Sections | 22 | $2.39 | $12.80 | $5.36 | 31 | $5.52 (1.25) |
| | | Other | 4 | $0.04 | $0.17 | $3.92 | 4 | $5.76 (--) |
| | 2009 | Whole crab | 3 | -- | -- | -- | -- | -- (--) |
| | | Sections | 16 | $2.20 | $9.81 | $4.46 | 27 | $4.92 (1.39) |
| | | Other | 4 | -- | -- | -- | 4 | $6.09 (--) |
| | 2010 | Whole crab | 6 | -- | -- | -- | 6 | $3.49 (1.37) |
| | | Sections | 16 | $1.45 | $6.38 | $4.40 | 21 | $4.65 (0.85) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2011 | Whole crab | 5 | $0.30 | $2.28 | $7.58 | 5 | $5.51 (2.00) |
| | | Sections | 14 | $3.49 | $22.70 | $6.51 | 23 | $6.88 (1.12) |
| | | Other | 4 | $0.10 | $0.56 | $5.88 | 4 | $7.69 (--) |
| Tanner, opilio (snow) | 2007 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 16 | -- | -- | -- | 26 | $4.76 (0.23) |
| | | Other | 2 | -- | -- | -- | -- | -- (--) |
| | 2008 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 16 | $29.60 | $135.09 | $4.56 | 27 | $4.64 (0.30) |
| | | Other | 3 | -- | -- | -- | -- | -- (--) |
| | 2009 | Sections | 16 | -- | -- | -- | 21 | $3.94 (0.20) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2010 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 12 | -- | -- | -- | 20 | $3.52 (1.07) |
| | | Other | 1 | -- | -- | -- | -- | -- (--) |
| | 2011 | Whole crab | 1 | -- | -- | -- | -- | -- (--) |
| | | Sections | 16 | -- | -- | -- | 24 | $5.06 (1.36) |

Source: ADF&G Commercial Operators Annual Report. Data shown by calendar year.

[a] Entities reporting crab production in the Commercial Operators Annual Report, including purchasers of crab that had all crab custom processed for them by other processors. Processor counts in Tables 15 and 16 are not comparable to processor counts in other tables, which show the number of operations engaging in crab processing activity.

Table 13: CR program fisheries crew and captain share payments and crab-equivalent crew pay (2011 base year)

| | | | Crew share payment ($$10^6$) [b] | | | Crew payment, crab equivalent ($10^3$ lbs) [c] | | | Captain share payment ($$10^6$) [b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year [a] | Vessels reporting pay [a] | Total pay [a] | Mean pay per vessel (sd) | Vessels reporting pay [a] | Total pay [a] | Mean pay per vessel (sd) | Vessels reporting pay [a] | Total pay [a] | Mean pay per vessel (sd) |
| AIG | CP | 98/01/04 | 4 (2) | -- | -- (--) | n/d | n/d | n/d | 4 (2) | -- | -- (--) |
| | | 2005 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | | 2006 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | CV | 98/01/04 | 50 (21) | $4.22 | $0.19 (0.21) | 50 (21) | 1002.58 | 60.15 (55.09) | 48 (20) | $2.04 | $0.10 (0.1) |
| | | 2005 | 10 | $1.97 | $0.18 (0.14) | 10 | 583.75 | 58.38 (48.02) | 10 | $1.07 | $0.10 (0.08) |
| | | 2006 | 6 | $0.92 | $0.13 (0.09) | 6 | 386.17 | 64.36 (37.65) | 6 | $0.51 | $0.07 (0.04) |
| | | 2007 | 6 | $1.20 | $0.20 (0.15) | 6 | 466.01 | 77.67 (--) | 6 | $0.59 | $0.10 (--) |
| | | 2008 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- | -- (--) |
| | | 2009 | | | | 4 | -- | -- (--) | | | |
| | | 2010 | | | | 4 | -- | -- (--) | | | |
| | | 2011 | | | | 4 | -- | -- (--) | | | |
| | CVCP | 2009 | 5 | $2.03 | $0.41 (0.16) | | | | 5 | $1.20 | $0.24 (--) |
| | | 2010 | 5 | $3.19 | $0.53 (0.26) | | | | 5 | $1.81 | $0.30 (--) |
| | | 2011 | 5 | $3.85 | $0.64 (0.3) | | | | 5 | $2.09 | $0.35 (--) |
| BBR | CP | 98/01/04 | 20 (9) | $0.76 | $0.11 (0.07) | n/d | n/d | n/d | 20 (9) | $0.24 | $0.04 (0.02) |
| | | 2005 | 3 | -- | -- (--) | n/d | n/d | n/d | 3 | -- | -- (--) |
| | | 2006 | 3 | -- | -- (--) | n/d | n/d | n/d | 3 | -- | -- (--) |
| | | 2007 | 3 | -- | -- (--) | n/d | n/d | n/d | 3 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) | n/d | n/d | n/d | 3 | -- | -- (--) |
| | CV | 98/01/04 | 626 (249) | $15.00 | $0.07 (0.04) | 618 (249) | 2551.38 | 12.39 (7.72) | 610 (244) | $7.25 | $0.04 (0.02) |
| | | 2005 | 84 | $13.08 | $0.16 (0.09) | 84 | 2261.7 | 26.93 (15.86) | 84 | $6.87 | $0.08 (0.05) |
| | | 2006 | 79 | $9.26 | $0.12 (0.06) | 79 | 2236 | 28.30 (23.54) | 77 | $4.70 | $0.06 (0.03) |
| | | 2007 | 70 | $12.58 | $0.18 (0.09) | 70 | 2391.78 | 34.17 (17.03) | 70 | $6.27 | $0.09 (0.04) |
| | | 2008 | 76 | $14.92 | $0.20 (0.13) | 76 | 2568.73 | 33.80 (23.39) | 75 | $6.74 | $0.09 (0.04) |
| | | 2009 | | | | 68 | 1848.53 | 27.18 (12.71) | | | |
| | | 2010 | | | | 63 | 1627.72 | 25.84 (12.04) | | | |
| | | 2011 | | | | 59 | 945.62 | 16.03 (8.91) | | | |
| | CVCP | 2009 | 70 | $10.19 | $0.15 (0.07) | | | | 69 | $4.83 | $0.07 (0.03) |
| | | 2010 | 65 | $13.08 | $0.20 (0.1) | | | | 63 | $6.21 | $0.10 (0.04) |
| | | 2011 | 62 | $10.34 | $0.17 (0.09) | | | | 61 | $4.80 | $0.08 (0.03) |

Table continues on next page.

Table 13 cont.

| | | | Crew share payment ($\$10^6$)[b] | | | Crew payment, crab equivalent ($10^3$ lbs)[c] | | | Captain share payment ($\$10^6$)[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) |
| BSS | CP | 98/01/04 | 18 (8) | $1.86 | $0.31 (0.24) | n/d | n/d | n/d | 18 (8) | $0.60 | $0.10 (0.07) |
| | | 2005 | 6 | $0.61 | $0.10 (0.05) | n/d | n/d | n/d | 6 | $0.21 | $0.04 (0.01) |
| | | 2006 | 4 | -- | -- (--) | n/d | n/d | n/d | 4 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) | n/d | n/d | n/d | 4 | -- | -- (--) |
| | | 2008 | 4 | -- | -- (--) | n/d | n/d | n/d | 4 | -- | -- (--) |
| | CV | 98/01/04 | 517 (210) | $21.65 | $0.13 (0.11) | 510 (210) | 18059.94 | 106.23 (133.2) | 504 (204) | $10.44 | $0.06 (0.05) |
| | | 2005 | 150 | $11.72 | $0.08 (0.03) | 150 | 5335.74 | 35.57 (28.95) | 148 | $6.03 | $0.04 (0.02) |
| | | 2006 | 74 | $6.42 | $0.09 (0.05) | 74 | 4787.81 | 64.70 (40.7) | 73 | $3.21 | $0.04 (0.02) |
| | | 2007 | 65 | $9.52 | $0.15 (0.09) | 64 | 4701.2 | 73.46 (44.72) | 64 | $4.52 | $0.07 (0.04) |
| | | 2008 | 74 | $16.95 | $0.23 (0.14) | 74 | 8833.86 | 119.38 (70.51) | 74 | $8.07 | $0.11 (0.05) |
| | | 2009 | | | | 73 | 7695.39 | 105.42 (58.73) | | | |
| | | 2010 | | | | 65 | 6557.45 | 100.88 (61.15) | | | |
| | | 2011 | | | | 66 | 7340.85 | 111.23 (57.37) | | | |
| | CVCP | 2009 | 77 | $13.91 | $0.18 (0.11) | | | | 76 | $6.16 | $0.08 (0.04) |
| | | 2010 | 67 | $9.24 | $0.14 (0.08) | | | | 66 | $4.13 | $0.06 (0.03) |
| | | 2011 | 68 | $19.29 | $0.28 (0.14) | | | | 67 | $8.64 | $0.13 (0.06) |
| BST | CP | 2006 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | n/d | n/d | n/d | 1 | -- | -- (--) |
| | CV | 2005 | 4 | -- | -- (--) | 4 | -- | -- (--) | 3 | -- | -- (--) |
| | | 2006 | 25 | $0.25 | $0.01 (0.02) | 25 | 135.42 | 5.42 (8.22) | 25 | $0.13 | $0.01 (0.01) |
| | | 2007 | 21 | $0.66 | $0.03 (0.02) | 21 | 308.06 | 14.67 (11.99) | 20 | $0.34 | $0.02 (0.01) |
| | | 2008 | 26 | $0.55 | $0.02 (0.03) | 26 | 259.61 | 9.99 (14.26) | 25 | $0.32 | $0.01 (0.02) |
| | | 2009 | | | | 13 | 256.98 | 19.77 (21.29) | | | |
| | | 2010 | | | | 4 | -- | -- (--) | | | |
| | CVCP | 2009 | 14 | $0.58 | $0.04 (0.05) | | | | 14 | $0.35 | $0.03 (0.04) |
| | | 2010 | 4 | -- | -- (--) | | | | 4 | -- | -- (--) |

Table continues on next page.

Table 13 cont.

| | | | Crew share payment ($\$10^6$)[b] | | | Crew payment, crab equivalent ($10^3$ lbs)[c] | | | Captain share payment ($\$10^6$)[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) | Vessels reporting pay[a] | Total pay[a] | Mean pay per vessel (sd) |
| PIK | CV | 1998 | 42 | $0.61 | $0.01 (0.01) | 42 | 163.87 | 3.90 (2.82) | 41 | $0.31 | $0.01 (0.01) |
| SMB | CP | 1998 | 2 | -- | -- (--) | n/d | n/d | n/d | 2 | -- | -- (--) |
| | CV | 1998 | 92 | $1.35 | $0.01 (0.01) | 88 | 429.84 | 4.88 (3.57) | 91 | $0.74 | $0.01 (0.01) |
| | | 2009 | 7 | $0.17 | $0.02 (0.02) | 7 | 49.67 | 7.10 (5.05) | 7 | $0.07 | $0.01 (0) |
| | | 2010 | 12 | $1.03 | $0.09 (0.04) | 10 | 163.26 | 16.33 (7.59) | 12 | $0.56 | $0.05 (0.02) |
| | | 2011 | 17 | $1.23 | $0.07 (0.04) | 17 | 232.83 | 13.70 (7.84) | 17 | $0.58 | $0.03 (0.02) |
| WAI[d] | CP | 98/01 | 2 (1) | -- | -- (--) | n/d | n/d | n/d | 2 (1) | -- | -- (--) |
| | CV | 2001 | 3 (3) | -- | -- (--) | 3 (3) | -- | -- (--) | 3 (3) | -- | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Starting in 2009, data are summarized over all harvesting sectors (CVCP) to preserve confidentiality. No catcher processor operations reported fishing activity in the SMB fishery from 2009 to 2011.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels reporting pay' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years). 'Total pay' for 98/01/04 shows total annual payments averaged across years with participating/reporting vessels.
[b] Crew and captain payments reflect amounts paid for harvesting labor. Where applicable, these figures include post-season adjustments, bonuses, and deductions made to labor payments for shared expenses such as fuel, bait, and food and provisions. Payments to harvest crew and captains for IFQ are excluded. Starting in 2009, data are summarized over all harvesting sectors (CVCP) to preserve confidentiality. No catcher processor operations reported fishing activity in the SMB fishery from 2009 to 2011.
[c] Crab-equivalent crew pay, given in pounds, is calculated for catcher vessels by dividing vessel crew share payment by ex-vessel price per pound (ex-vessel revenue/landed pounds). Crab-equivalent crew pay statistics are unavailable for the catcher processor sector, which does not report ex-vessel landings or revenue in EDR reporting.
[d] 2001 Western Aleutian red king crab fishery was closed; 2001 data reflect activity in Petrel Bank test fishery.

## Table 14: CR program fisheries harvest crew participants and positions

| | | | | Crew participants[b] | | Crew positions[c] | |
|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels[a] | Total[a] | Mean participants per vessel (sd) | Total[a] | Mean positions per vessel (sd) |
| AIG[d] | CP | 98/01/04 | 4 (2) | -- | -- (--) | n/d | n/d |
| | | 2005 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 52 (22) | 131 | 7.56 (2.09) | 115 | 6.65 (0.99) |
| | | 2005 | 10 | 72 | 7.2 (2.58) | 58 | 5.8 (1.14) |
| | | 2006 | 6 | 48 | 7.92 (2.58) | 38 | 6.33 (0.52) |
| | | 2007 | 6 | 40 | 6.67 (--) | 38 | 6.33 (--) |
| | | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| | CVCP | 2009 | 5 | 43 | 8.6 (--) | 31 | 6.2 (--) |
| | | 2010 | 5 | 43 | 8.5 (--) | 31 | 6.2 (--) |
| | | 2011 | 5 | 38 | 7.6 (--) | 33 | 6.6 (--) |
| BBR | CP | 98/01/04 | 20 (9) | 70 | 10.49 (2.11) | n/d | n/d |
| | | 2005 | 3 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 3 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 3 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 633 (250) | 1304 | 6.18 (1.16) | 1233 | 5.85 (0.92) |
| | | 2005 | 84 | 493 | 5.87 (1.04) | 472 | 5.61 (0.82) |
| | | 2006 | 79 | 465 | 5.89 (1.06) | 445 | 5.63 (0.83) |
| | | 2007 | 70 | 419 | 5.99 (0.86) | 407 | 5.81 (0.79) |
| | | 2008 | 76 | 473 | 6.22 (1.11) | 452 | 5.95 (0.91) |
| | CVCP | 2009 | 70 | 435 | 6.21 (1.01) | 424 | 6.06 (0.98) |
| | | 2010 | 65 | 413 | 6.35 (1.2) | 401 | 6.16 (1.19) |
| | | 2011 | 62 | 401 | 6.47 (1.24) | 385 | 6.21 (1.13) |
| BSS | CP | 98/01/04 | 18 (8) | 78 | 12.93 (5.31) | n/d | n/d |
| | | 2005 | 6 | 59 | 9.83 (1.47) | n/d | n/d |
| | | 2006 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 524 (210) | 1139 | 6.52 (1.45) | 1049 | 6.01 (0.89) |
| | | 2005 | 150 | 857 | 5.71 (0.73) | n/d | n/d |
| | | 2006 | 74 | 448 | 6.05 (1.19) | 418 | 5.65 (0.78) |
| | | 2007 | 65 | 400 | 6.15 (1.08) | 377 | 5.79 (0.79) |
| | | 2008 | 74 | 489 | 6.61 (1.41) | 447 | 6.03 (0.79) |
| | CVCP | 2009 | 77 | 522 | 6.78 (1.82) | 491 | 6.38 (1.67) |
| | | 2010 | 67 | 436 | 6.51 (1.27) | 418 | 6.24 (1.12) |
| | | 2011 | 68 | 463 | 6.81 (1.7) | 437 | 6.43 (1.63) |
| BST | CP | 2006 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | -- | -- (--) |
| | CV | 2005 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 25 | 143 | 5.72 (1.02) | 140 | 5.6 (1) |
| | | 2007 | 22 | 131 | 5.95 (0.84) | 118 | 5.36 (0.66) |
| | | 2008 | 26 | 162 | 6.23 (1.31) | 146 | 5.62 (0.75) |
| | CVCP | 2009 | 14 | 96 | 6.86 (2.54) | 87 | 6.21 (1.48) |
| | | 2010 | 4 | -- | -- (--) | -- | -- (--) |

Table continues on next page.

Table 14 cont.

| Fishery | Sector | Year [a] | Vessels [a] | Crew participants [b] Total [a] | Crew participants [b] Mean participants per vessel (sd) | Crew positions [c] Total [a] | Crew positions [c] Mean positions per vessel (sd) |
|---|---|---|---|---|---|---|---|
| PIK | CV | 1998 | 43 | 219 | 5.09 (0.87) | 207 | 4.81 (0.88) |
| SMB | CP | 1998 | 2 | -- | -- (--) | n/d | n/d |
| | CV | 1998 | 9 | 516 | 5.49 (0.84) | 489 | 5.2 (0.8) |
| | | 2009 | 7 | 40 | 5.71 (0.76) | 39 | 5.57 (0.79) |
| | | 2010 | 12 | 71 | 5.92 (0.9) | 68 | 5.67 (0.65) |
| | | 2011 | 17 | 118 | 6.94 (1.39) | 112 | 6.56 (1.12) |
| WAI [e] | CP | 98/01 | 2 (1) | -- | -- (--) | n/d | n/d |
| | CV | 2001 | 3 (3) | -- | -- (--) | -- | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data. 2005 and later crew positions information from ADF&G fish tickets.* Data shown by calendar year. Starting in 2009, data are summarized over all harvesting sectors (CVCP) to preserve confidentiality. No catcher processor operations reported fishing activity in the SMB fishery from 2009 to 2011.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years). Totals for 98/01/04 shows total annual participants or positions averaged across years with participating/reporting vessels.
[b] Total crew share participants for each submission calculated using the number of paid harvest crew members reported in the EDR in addition to the captain. A change in the definition of harvest crew from number of crew earning shares to paid crew members may introduce systematic undercounting of paid crew in 1998-2004 data where some crew did not receive shares.
[c] Crew positions/mean crew size statistics include skipper. For 1998-2004 catcher vessels, these figures use reporting of mean crew size in EDR; note that these data were not collected for CPs in 1998-2004. For 2005 and later data, total and mean crew positions are calculated using the crew size reporting implemented with eLandings. Crew positions data for 2005 BSS fishery are unavailable due to prosecution of this year's fishery prior to implementation of crew size reporting in eLandings. For CP observations, EDR reporting for the mean number of crab processing positions may be used to adjust eLandings crew size reporting in order to estimate the number of harvest-only crew positions.
[d] Data on EAG and WAG fisheries are reported by submitters separately in the EDR but are summarized together here as the Aleutian Islands golden king crab (AIG) fishery to preserve confidentiality. Where operations reported harvest crew labor in both the eastern and western fisheries, mean figures over the two fisheries for crew share participants and crew positions were used in place of cumulative figures under the assumption that the same individuals are employed in both fisheries.
[e] 2001 Western Aleutian red king crab fishery was closed; 2001 data reflect activity in Petrel Bank test fishery.

Table 15: CR program fisheries participating licensed crew members and gear operators by Alaska residence

| Year | Crew license holders: Alaska non-resident | Alaska resident | Unknown | Total crew license holders | Gear operators: Alaska non-resident | Alaska resident | Total gear operators | Total crew and gear operators |
|---|---|---|---|---|---|---|---|---|
| 1998 | n/d | n/d | n/d | n/d | 243 | 106 | 349 | n/d |
| 1999 | n/d | n/d | n/d | n/d | 246 | 105 | 351 | n/d |
| 2000 | n/d | n/d | n/d | n/d | 208 | 90 | 298 | n/d |
| 2001 | n/d | n/d | n/d | n/d | 210 | 78 | 288 | n/d |
| 2002 | n/d | n/d | n/d | n/d | 204 | 77 | 281 | n/d |
| 2003 | n/d | n/d | n/d | n/d | 199 | 82 | 281 | n/d |
| 2004 | n/d | n/d | n/d | n/d | 197 | 81 | 278 | n/d |
| 2005 | n/d | n/d | n/d | n/d | 137 | 56 | 193 | n/d |
| 2006 | 347 | 192 | 2 | 541 | 93 | 39 | 132 | 673 |
| 2007 | 342 | 188 | 0 | 530 | 73 | 27 | 100 | 630 |
| 2008 | 424 | 209 | 2 | 635 | 90 | 29 | 119 | 754 |
| 2009 | 385 | 183 | 0 | 568 | 82 | 28 | 110 | 678 |
| 2010 | 332 | 159 | 5 | 496 | 69 | 30 | 99 | 595 |
| 2011 | 335 | 177 | 0 | 512 | 67 | 26 | 93 | 605 |

*Source: NMFS AFSC BSAI Crab Economic Data, ADF&G commercial crewmember license files, ADF&G fish tickets, eLandings.* Data shown by calendar year. Excludes gear operator permit holders and catcher processor crewmembers working solely on the processing line. Commercial crewmember license is required of any individual participating directly or indirectly in taking of raw fishery products on a commercial vessel, including cooks, engineers, and individuals handling fishing gear or involved in maintenance or operation of the vessel.

Table 16: CR program fisheries active gear operators by state of residence

| | | Non-Alaska residents | | Alaska residents | |
|---|---|---|---|---|---|
| Fishery | Year | Permit holders | Share of fishery ex-vessel value | Permit holders | Share of fishery ex-vessel value |
| AIG | 1998 | 24 | -- | 2 | -- |
| | 1999 | 21 | -- | 5 | -- |
| | 2000 | 23 | -- | 3 | -- |
| | 2001 | 24 | 97% | 4 | 3% |
| | 2002 | 25 | -- | 3 | -- |
| | 2003 | 19 | -- | 3 | -- |
| | 2004 | 21 | -- | 3 | -- |
| | 2005 | 10 | 100% | 0 | 0% |
| | 2006 | 9 | -- | 1 | -- |
| | 2007 | 5 | -- | 1 | -- |
| | 2008 | 6 | -- | 1 | -- |
| | 2009 | 7 | 100% | 0 | 0% |
| | 2010 | 8 | -- | 1 | -- |
| | 2011 | 5 | -- | 2 | -- |
| BBR | 1998 | 186 | 76% | 87 | 24% |
| | 1999 | 185 | 74% | 72 | 26% |
| | 2000 | 174 | 73% | 70 | 27% |
| | 2001 | 164 | 77% | 66 | 23% |
| | 2002 | 176 | 73% | 67 | 27% |
| | 2003 | 180 | 79% | 73 | 21% |
| | 2004 | 183 | 78% | 73 | 22% |
| | 2005 | 69 | 78% | 33 | 22% |
| | 2006 | 59 | 76% | 28 | 24% |
| | 2007 | 55 | 78% | 19 | 22% |
| | 2008 | 64 | 79% | 21 | 21% |
| | 2009 | 54 | 78% | 21 | 22% |
| | 2010 | 50 | 77% | 20 | 23% |
| | 2011 | 44 | 78% | 18 | 22% |
| BSS | 1998 | 183 | 77% | 72 | 23% |
| | 1999 | 194 | 75% | 81 | 25% |
| | 2000 | 156 | 72% | 74 | 28% |
| | 2001 | 154 | 81% | 54 | 19% |
| | 2002 | 138 | 77% | 56 | 23% |
| | 2003 | 136 | 76% | 56 | 24% |
| | 2004 | 137 | 78% | 53 | 22% |
| | 2005 | 126 | 78% | 45 | 22% |
| | 2006 | 74 | 84% | 18 | 16% |
| | 2007 | 58 | 76% | 19 | 24% |
| | 2008 | 72 | 82% | 21 | 18% |
| | 2009 | 69 | 83% | 19 | 17% |
| | 2010 | 55 | 78% | 21 | 22% |
| | 2011 | 55 | 80% | 19 | 20% |

Table continues on next page.

Table 16 cont.

| Fishery | Year | Non-Alaska residents Permit holders | Non-Alaska residents Share of fishery ex-vessel value | Alaska residents Permit holders | Alaska residents Share of fishery ex-vessel value |
|---|---|---|---|---|---|
| BST | 2005 | 4 | 100% | 0 | 0% |
| | 2006 | 38 | 89% | 10 | 11% |
| | 2007 | 25 | 79% | 9 | 21% |
| | 2008 | 28 | 83% | 6 | 17% |
| | 2009 | 17 | -- | 3 | -- |
| | 2010 | 2 | -- | 2 | -- |
| PIK | 1998 | 23 | 43% | 34 | 57% |
| SMB | 1998 | 97 | 75% | 34 | 25% |
| | 2009 | 5 | -- | 2 | -- |
| | 2010 | 7 | 67% | 4 | 33% |
| | 2011 | 14 | 76% | 4 | 24% |
| WAI[a] | 1998 | 1 | 100% | 0 | 0% |
| | 2002 | 26 | 82% | 7 | 18% |
| | 2003 | 26 | 88% | 8 | 24% |

*Source: ADF&G fish tickets, eLandings, CFEC pricing, CFEC gear operator permit data.* Data shown by calendar year.
[a] 2001 Petrel Bank test fishery excluded.

## Table 17: CR program fisheries harvest revenue share

| Sector | Fishery | Year[a] | Share | Vessels[a] | Mean share (sd) |
|---|---|---|---|---|---|
| CP | ALL | 98/01/04 | Owner | 25 (10) | 0.67 (0.04) |
| | | | Labor total | 25 (10) | 0.34 (0.03) |
| | | | Captain/crew | 25 (10) | 0.29 (0.06) |
| | | | Processing employee | 25 (10) | 0.05 (0.05) |
| | AIG | 2005 | Owner | 1 | -- (--) |
| | | | Labor total | 1 | -- (--) |
| | | | Captain | 1 | -- (--) |
| | | | Crew | 1 | -- (--) |
| | | | Processing employee | 1 | -- (--) |
| | BBR | 2005 | Owner | 3 | -- (--) |
| | | | Labor total | 3 | -- (--) |
| | | | Captain | 3 | -- (--) |
| | | | Crew | 3 | -- (--) |
| | | | Processing employee | 3 | -- (--) |
| | BSS | 2005 | Owner | 5 | 0.59 (0.16) |
| | | | Labor total | 5 | 0.33 (0.02) |
| | | | Captain | 5 | 0.07 (0.03) |
| | | | Crew | 5 | 0.2 (0.05) |
| | | | Processing employee | 5 | 0.06 (0.05) |
| CV | ALL | 98/01/04 | Owner | 660 (257) | 0.6 (0.05) |
| | | | Captain/crew | 660 (257) | 0.4 (0.05) |
| | AIG | 2005 | Owner | 10 | 0.65 (0.06) |
| | | | Labor total | 10 | 0.35 (0.06) |
| | | | Captain | 10 | 0.12 (0.02) |
| | | | Crew | 10 | 0.23 (0.05) |
| | | 2006 | Owner | 6 | 0.62 (0.05) |
| | | | Labor total | 6 | 0.39 (0.05) |
| | | | Captain | 6 | 0.13 (0.02) |
| | | | Crew | 6 | 0.26 (0.06) |
| | | 2007 | Owner | 6 | 0.59 (0.04) |
| | | | Labor total | 6 | 0.41 (0.04) |
| | | | Captain | 6 | 0.13 (0.01) |
| | | | Crew | 6 | 0.28 (0.04) |
| | | 2008 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |
| | | 2009 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |
| | | 2010 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |
| | | 2011 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |

Table continues on next page.

Table 17 cont.

| Sector | Fishery | Year[a] | Share | Vessels[a] | Mean share (sd) |
|---|---|---|---|---|---|
| CV | BBR | 2005 | Owner | 82 | 0.61 (0.06) |
| | | | Labor total | 82 | 0.39 (0.06) |
| | | | Captain | 82 | 0.13 (0.04) |
| | | | Crew | 82 | 0.25 (0.05) |
| | | 2006 | Owner | 78 | 0.61 (0.05) |
| | | | Labor total | 78 | 0.39 (0.05) |
| | | | Captain | 78 | 0.13 (0.04) |
| | | | Crew | 78 | 0.26 (0.04) |
| | | 2007 | Owner | 69 | 0.6 (0.06) |
| | | | Labor total | 69 | 0.39 (0.05) |
| | | | Captain | 69 | 0.13 (0.03) |
| | | | Crew | 69 | 0.26 (0.04) |
| | | 2008 | Owner | 75 | 0.6 (0.07) |
| | | | Labor total | 75 | 0.4 (0.05) |
| | | | Captain | 75 | 0.13 (0.04) |
| | | | Crew | 75 | 0.26 (0.04) |
| | | 2009 | Owner | 67 | 0.61 (0.05) |
| | | | Labor total | 67 | 0.39 (0.04) |
| | | | Captain | 67 | 0.13 (0.03) |
| | | | Crew | 67 | 0.26 (0.05) |
| | | 2010 | Owner | 62 | 0.6 (0.05) |
| | | | Labor total | 62 | 0.4 (0.04) |
| | | | Captain | 62 | 0.13 (0.03) |
| | | | Crew | 62 | 0.27 (0.04) |
| | | 2011 | Owner | 59 | 0.59 (0.06) |
| | | | Labor total | 59 | 0.41 (0.06) |
| | | | Captain | 59 | 0.13 (0.04) |
| | | | Crew | 59 | 0.28 (0.05) |
| | BSS | 2005 | Owner | 150 | 0.6 (0.05) |
| | | | Labor total | 150 | 0.4 (0.04) |
| | | | Captain | 150 | 0.14 (0.04) |
| | | | Crew | 150 | 0.26 (0.04) |
| | | 2006 | Owner | 73 | 0.61 (0.04) |
| | | | Labor total | 73 | 0.39 (0.04) |
| | | | Captain | 73 | 0.13 (0.03) |
| | | | Crew | 73 | 0.26 (0.04) |
| | | 2007 | Owner | 63 | 0.61 (0.04) |
| | | | Labor total | 63 | 0.39 (0.04) |
| | | | Captain | 63 | 0.13 (0.03) |
| | | | Crew | 63 | 0.26 (0.03) |
| | | 2008 | Owner | 73 | 0.6 (0.07) |
| | | | Labor total | 73 | 0.39 (0.04) |
| | | | Captain | 73 | 0.13 (0.03) |
| | | | Crew | 73 | 0.26 (0.04) |
| | | 2009 | Owner | 74 | 0.61 (0.04) |
| | | | Labor total | 74 | 0.39 (0.04) |
| | | | Captain | 74 | 0.13 (0.03) |
| | | | Crew | 74 | 0.26 (0.04) |
| | | 2010 | Owner | 65 | 0.59 (0.09) |
| | | | Labor total | 65 | 0.41 (0.08) |
| | | | Captain | 65 | 0.13 (0.03) |
| | | | Crew | 65 | 0.28 (0.07) |

Table continues on next page.

Table 17 cont.

| Sector | Fishery | Year[a] | Share | Vessels[a] | Mean share (sd) |
|---|---|---|---|---|---|
| CV | BSS | 2011 | Owner | 64 | 0.6 (0.04) |
| | | | Labor total | 64 | 0.4 (0.04) |
| | | | Captain | 64 | 0.13 (0.02) |
| | | | Crew | 64 | 0.28 (0.04) |
| | BST | 2005 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |
| | | 2006 | Owner | 31 | 0.61 (0.04) |
| | | | Labor total | 31 | 0.39 (0.04) |
| | | | Captain | 31 | 0.13 (0.03) |
| | | | Crew | 31 | 0.26 (0.04) |
| | | 2007 | Owner | 24 | 0.59 (0.08) |
| | | | Labor total | 24 | 0.41 (0.07) |
| | | | Captain | 24 | 0.12 (0.04) |
| | | | Crew | 24 | 0.29 (0.07) |
| | | 2008 | Owner | 25 | 0.59 (0.09) |
| | | | Labor total | 25 | 0.41 (0.08) |
| | | | Captain | 25 | 0.13 (0.03) |
| | | | Crew | 25 | 0.28 (0.07) |
| | | 2009 | Owner | 15 | 0.61 (0.03) |
| | | | Labor total | 15 | 0.39 (0.03) |
| | | | Captain | 15 | 0.12 (0.02) |
| | | | Crew | 15 | 0.26 (0.03) |
| | | 2010 | Owner | 4 | -- (--) |
| | | | Labor total | 4 | -- (--) |
| | | | Captain | 4 | -- (--) |
| | | | Crew | 4 | -- (--) |
| | SMB | 2009 | Owner | 7 | 0.59 (0.02) |
| | | | Labor total | 7 | 0.41 (0.02) |
| | | | Captain | 7 | 0.14 (0.02) |
| | | | Crew | 7 | 0.27 (0.02) |
| | | 2010 | Owner | 11 | 0.56 (0.12) |
| | | | Labor total | 11 | 0.44 (0.12) |
| | | | Captain | 11 | 0.15 (0.03) |
| | | | Crew | 11 | 0.3 (0.09) |
| | | 2011 | Owner | 18 | 0.59 (0.03) |
| | | | Labor total | 18 | 0.41 (0.03) |
| | | | Captain | 18 | 0.12 (0.02) |
| | | | Crew | 18 | 0.29 (0.03) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. For 1998-2004, harvest revenue share data was reported over all fisheries, and figures for crew share include captains' harvest revenue share. Reporting of harvest revenue shares was discontinued with the 2006 EDR for the catcher processor sector. Mean labor share for the catcher vessel sector represents the sum of the mean captain and crew share. For the catcher processor sector, mean labor share includes the percentage of net share paid to processing workers.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years).

Table 18: CR program fisheries harvest days

| | | | | Days active[b] | | Days fishing[c] | |
|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels[a] | Total days[a] | Mean days (sd) | Total days | Mean days (sd) |
| AIG | CP | 98/01/04 | 4 (2) | -- | -- (--) | n/d | n/d |
| | | 2005 | 2 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 52 (22) | 1203 | 69.4 (60) | n/d | n/d |
| | | 2005 | 10 | 589 | 58.9 (36) | 411 | 41.1 (24.3) |
| | | 2006 | 6 | 571 | 95.2 (47.3) | 410 | 68.3 (35.9) |
| | | 2007 | 6 | 471 | 78.5 (--) | 349 | 58.2 (--) |
| | | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| | CVCP | 2009 | 6 | 666 | 133.2 (87.9) | 460 | 92 (65.9) |
| | | 2010 | 5 | 719 | 143.8 (--) | 486 | 97.2 (--) |
| | | 2011 | 6 | 677 | 112.8 (62.2) | 450 | 75 (35.6) |
| BBR | CP | 98/01/04 | 20 (9) | 59 | 8.8 (6) | n/d | n/d |
| | | 2005 | 5 | 162 | 32.4 (--) | 98 | 24.5 (--) |
| | | 2006 | 3 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 3 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 631 (250) | 2611 | 12.5 (8.8) | n/d | n/d (n/d) |
| | | 2005 | 85 | 2253 | 26.5 (13.9) | 1374 | 16.2 (10.5) |
| | | 2006 | 79 | 1766 | 22.3 (10) | 1062 | 13.4 (6.5) |
| | | 2007 | 70 | 2238 | 32.4 (12.8) | 1416 | 20.5 (9.6) |
| | | 2008 | 76 | 2459 | 32.4 (13.4) | 1702 | 22.4 (10.5) |
| | CVCP | 2009 | 70 | 2139 | 30.6 (13) | 1415 | 20.2 (9.1) |
| | | 2010 | 65 | 2321 | 35.7 (14.1) | 1604 | 24.7 (11.4) |
| | | 2011 | 61 | 1128 | 18.5 (8.7) | 681 | 11.2 (5.4) |
| BSS | CP | 98/01/04 | 18 (8) | 239 | 39.8 (21.1) | n/d | n/d |
| | | 2005 | 6 | 189 | 31.5 (19.1) | 80 | 13.3 (10.9) |
| | | 2006 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| | CV | 98/01/04 | 522 (210) | 6331 | 36.7 (26.3) | n/d | n/d |
| | | 2005 | 150 | 2710 | 18.1 (8) | 1275 | 8.5 (5.2) |
| | | 2006 | 74 | 2927 | 39.5 (20.6) | 1930 | 26.1 (14.7) |
| | | 2007 | 64 | 2357 | 36.8 (16.3) | 1517 | 23.7 (12.2) |
| | | 2008 | 74 | 3611 | 48.8 (20.9) | 2409 | 32.5 (15.5) |
| | CVCP | 2009 | 77 | 3869 | 50.3 (21) | 2600 | 33.8 (15.1) |
| | | 2010 | 68 | 3032 | 44.6 (20.4) | 2110 | 31 (17.5) |
| | | 2011 | 67 | 3266 | 48.8 (20.8) | 2185 | 32.6 (16.6) |

Table continues on next page.

Table 18 cont.

| Fishery | Sector | Year[a] | Vessels[a] | Days active[b] Total days[a] | Days active[b] Mean days (sd) | Days fishing[c] Total days | Days fishing[c] Mean days (sd) |
|---|---|---|---|---|---|---|---|
| BST | CP | 2005 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) | -- | -- (--) |
| | CV | 2005 | 4 | -- | -- (--) | -- | -- (--) |
| | | 2006 | 25 | 416 | 16.6 (14.9) | 283 | 11.3 (9.8) |
| | | 2007 | 24 | 555 | 24.1 (11) | 410 | 17.8 (8.6) |
| | | 2008 | 26 | 557 | 22.3 (18.5) | 391 | 15.6 (12.8) |
| | CVCP | 2009 | 17 | 467 | 29.2 (23) | 321 | 20 (15.1) |
| | | 2010 | 4 | -- | -- (--) | -- | -- (--) |
| PIK | CV | 1998 | 43 | 762 | 17.7 (13.8) | n/d | n/d |
| SMB | CP | 1998 | 2 | -- | -- (--) | n/d | n/d |
| | CV | 1998 | 93 | 1630 | 17.5 (5.8) | n/d | n/d |
| | | 2009 | 7 | 184 | 26.3 (18.4) | 133 | 19 (13.5) |
| | | 2010 | 11 | 485 | 44.1 (27.3) | 365 | 33.2 (22.6) |
| | | 2011 | 18 | 663 | 36.8 (14.1) | 473 | 26.3 (10.3) |
| WAI [d] | CP | 98/01 | 2 (1) | -- | -- (--) | n/d | n/d |
| | CV | 2001 | 3 (3) | -- | -- (--) | n/d | n/d |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Starting in 2009, data are summarized over all harvesting sectors (CVCP) to preserve confidentiality. No catcher processor operations reported fishing activity in the SMB fishery from 2009 to 2011.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years). 'Total days' for 98/01/04 shows total annual days active or fishing averaged across years with participating/reporting vessels.
[b] Days active by fishery is calculated using reported days at sea in the 1998-2004 EDR data and, for 2005 and later, the sum of days fishing and days travelling and offloading. Note that the 1998-2004 and 2005 and later figures for both total and mean days active are not directly comparable, as the pre-2005 data do not include days spent queuing and offloading at processors.
[c] Days fishing not reported in 1998-2004 EDR.
[d] 2001 data reflect activity in Petrel Bank test fishery.

## Table 19: CR program fisheries processing labor payments (2011 base year)

| | | | | Labor payments ($10³)[b] | | Pay per worker [b, c] | | Pay per hour (shoreside and floating processors) [b, c, d] | | Pay per lb [b, c] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Processors[a] | Total[a] | Mean per plant (sd) | Obs | Mean (sd) | Obs | Mean (sd) | Obs | Mean(sd) |
| AIG[e] | CP | 98/01/04 | 4 (2) | -- | -- (--) | 4 | -- (--) | n/d | n/d | 4 | -- (--) |
| | | 2005 | 2 | -- | -- (--) | 2 | -- (--) | n/d | n/d | 2 | -- (--) |
| | | 2006 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | SF | 98/01/04 | 13 (7) | $806.20 | $186.10 (148.6) | 12 | $2.30 (2) | 12 | $13.42 (2.42) | 13 | $0.31 (0.12) |
| | | 2005 | 4 | -- | -- (--) | 4 | -- (--) | 4 | -- (--) | 4 | -- (--) |
| | | 2006 | 6 | $539.50 | $89.90 (119.2) | 6 | $1.60 (2) | 6 | $13.37 (5.17) | 6 | $0.17 (0.07) |
| | | 2007 | 5 | $813.30 | $162.70 (--) | 5 | $2.90 (--) | 5 | $13.99 (--) | 5 | $0.32 (--) |
| | | 2008 | 6 | $585.10 | $97.50 (71.4) | 4 | -- (--) | 5 | $12.81 (--) | 6 | $0.22 (0.07) |
| | SFCP | 2009 | 5 | $939.60 | $187.90 (--) | 5 | $1.80 (--) | 4 | -- (--) | 4 | -- (--) |
| | | 2010 | 4 | -- | -- (--) | 4 | -- (--) | 3 | -- (--) | 3 | -- (--) |
| | | 2011 | 6 | $1,023.90 | $170.70 (245.1) | 6 | $1.10 (1.9) | 5 | $10.19 (--) | 6 | $0.29 (0.32) |
| BBR | CP | 98/01/04 | 18 (10) | $315.70 | $52.60 (31.9) | 18 | $5.30 (5.3) | n/d | n/d | 18 | $0.59 (0.26) |
| | | 2005 | 4 | -- | -- (--) | 4 | -- (--) | n/d | n/d | 4 | -- (--) |
| | | 2006 | 3 | -- | -- (--) | 3 | -- (--) | n/d | n/d | 3 | -- (--) |
| | | 2007 | 3 | -- | -- (--) | 3 | -- (--) | n/d | n/d | 3 | -- (--) |
| | | 2008 | 3 | -- | -- (--) | 3 | -- (--) | n/d | n/d | 3 | -- (--) |
| | SF | 98/01/04 | 40 (20) | $1,855.70 | $139.20 (108.3) | 40 | $1.40 (0.8) | 40 | $13.77 (2.53) | 40 | $0.28 (0.11) |
| | | 2005 | 11 | $2,519.30 | $229.00 (193.1) | 11 | $1.90 (1.2) | 11 | $14.22 (3.71) | 11 | $0.33 (0.17) |
| | | 2006 | 11 | $2,180.90 | $198.30 (173.4) | 11 | $2.20 (2.2) | 11 | $12.54 (1.76) | 11 | $0.29 (0.13) |
| | | 2007 | 11 | $3,028.90 | $275.40 (215.5) | 11 | $2.70 (1.8) | 11 | $13.98 (6.57) | 11 | $0.29 (0.14) |
| | | 2008 | 11 | $2,966.00 | $269.60 (233.4) | 9 | $3.20 (3.4) | 10 | $10.76 (3.56) | 11 | $0.26 (0.14) |
| | SFCP | 2009 | 12 | $2,409.20 | $200.80 (176.8) | 12 | $3.20 (3.2) | 10 | $12.20 (2.49) | 12 | $0.26 (0.1) |
| | | 2010 | 13 | $2,403.60 | $184.90 (140.3) | 13 | $3.30 (3.7) | 11 | $10.95 (2.1) | 13 | $0.20 (0.04) |
| | | 2011 | 13 | $1,168.60 | $89.90 (60.6) | 13 | $1.90 (2.5) | 11 | $10.54 (1.96) | 13 | $0.37 (0.3) |

Table continues on next page.

Table 19 cont.

| | | | | Labor payments ($\$10^3$)[b] | | Pay per worker [b, c] | | Pay per hour (shoreside and floating processors) [b, c, d] | | Pay per lb [b, c] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Processors[a] | Total[a] | Mean per plant (sd) | Obs | Mean (sd) | Obs | Mean (sd) | Obs | Mean(sd) |
| BSS | CP | 98/01/04 | 17 (8) | $826.40 | $155.00 (107.8) | 16 | $10.40 (6.8) | n/d | n/d | 16 | $0.34 (0.1) |
| | | 2005 | 6 | $308.10 | $51.30 (32.9) | 6 | $5.30 (3.4) | n/d | n/d | 6 | $0.33 (0.17) |
| | | 2006 | 4 | -- | -- (--) | 4 | -- (--) | n/d | n/d | 4 | -- (--) |
| | | 2007 | 4 | -- | -- (--) | 4 | -- (--) | n/d | n/d | 4 | -- (--) |
| | | 2008 | 4 | -- | -- (--) | 4 | -- (--) | n/d | n/d | 4 | -- (--) |
| | SF | 98/01/04 | 50 (24) | $15,354.90 | $921.30 (944.3) | 50 | $5.50 (5.2) | 50 | $14.01 (2.22) | 50 | $0.30 (0.1) |
| | | 2005 | 13 | $3,710.00 | $285.40 (204.4) | 13 | $2.00 (1.4) | 13 | $12.30 (0.58) | 13 | $0.25 (0.1) |
| | | 2006 | 10 | $5,014.10 | $501.40 (367.8) | 10 | $4.10 (3.3) | 10 | $12.09 (1.69) | 10 | $0.27 (0.1) |
| | | 2007 | 10 | $5,458.60 | $545.90 (377.8) | 10 | $3.20 (1.7) | 10 | $11.80 (1.31) | 10 | $0.41 (0.37) |
| | | 2008 | 12 | $9,435.50 | $786.30 (837) | 10 | $4.90 (4.9) | 11 | $10.83 (3.63) | 12 | $0.24 (0.08) |
| | SFCP | 2009 | 14 | $7,405.70 | $529.00 (526.8) | 14 | $7.60 (5.3) | 10 | $11.39 (1.01) | 14 | $0.25 (0.08) |
| | | 2010 | 11 | $5,642.60 | $513.00 (346.9) | 11 | $9.60 (13) | 9 | $10.59 (1.69) | 11 | $0.25 (0.12) |
| | | 2011 | 13 | $5,672.00 | $436.30 (336) | 13 | $6.00 (6.5) | 11 | $11.90 (3.56) | 13 | $0.26 (0.16) |
| BST | CP | 2006 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | SF | 2005 | 7 | $97.50 | $13.90 (17.3) | 7 | $0.20 (0.2) | 7 | $11.92 (0.89) | 7 | $0.27 (0.16) |
| | | 2006 | 8 | $157.00 | $19.60 (18) | 8 | $0.70 (1.6) | 8 | $11.34 (0.69) | 8 | $0.24 (0.07) |
| | | 2007 | 7 | $386.40 | $55.20 (35.3) | 7 | $1.30 (1.4) | 7 | $11.32 (1.03) | 7 | $0.23 (0.05) |
| | | 2008 | 8 | $464.10 | $58.00 (39.7) | 6 | $1.40 (2.3) | 7 | $11.32 (1) | 8 | $0.33 (0.17) |
| | SFCP | 2009 | 8 | $314.10 | $39.30 (24.7) | 8 | $0.60 (0.8) | 7 | $11.02 (0.96) | 8 | $0.24 (0.05) |
| | | 2010 | 5 | $64.10 | $12.80 (--) | 5 | $1.50 (--) | 5 | $10.33 (--) | 3 | -- (--) |
| PIK | SF | 1998 | 13 | $281.10 | $21.60 (19.9) | 13 | $1.20 (1.5) | 13 | $13.42 (3.4) | 13 | $0.32 (0.1) |
| SMB | CP | 1998 | 1 | -- | -- (--) | 1 | -- (--) | n/d | n/d | 1 | -- (--) |
| | SF | 1998 | 10 | $688.40 | $68.80 (87.9) | 10 | $0.80 (0.6) | 10 | $13.13 (3.96) | 10 | $0.36 (0.18) |
| | | 2009 | 2 | -- | -- (--) | 2 | -- (--) | 2 | -- (--) | 2 | -- (--) |
| | | 2010 | 5 | -- | -- (--) | 5 | -- (--) | 5 | -- (--) | 5 | -- (--) |
| | | 2011 | 5 | -- | -- (--) | 5 | -- (--) | 5 | -- (--) | 5 | -- (--) |
| WAI | CP | 98/01/04 | 2 (1) | -- | -- (--) | 2 | -- (--) | n/d | n/d | 2 | -- (--) |
| | SF | 98/01/04 | 1 (1) | -- | -- (--) | 1 | -- (--) | 1 | -- (--) | 1 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.*

Data shown by calendar year. Starting in 2009, data are summarized over all processing sectors (SFCP) to preserve confidentiality. No catcher processor operations reported processing activity in the SMB fishery from 2009 to 2011.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Processors' for 98/01/04 shows count of processor-years (count of unique processors over all three years). Total labor payments shown for 98/01/04 represent total annual payments averaged across years with participating/reporting

processors.

[b] Processing labor payments exclude payments to salaried workers employed by processors. Where applicable, these figures include bonuses and deductions to labor payments for shared expenses such as food and provisions. Benefits and indirect expenses paid on behalf of processing workers are excluded.

[c] Number of observations for pro-rata statistics (pay per plant, worker, and finished pounds) may differ from the number of observations for total labor payments due to missing observations for the denominator variable (i.e., mean number of processing positions, processing labor hours, and finished production pounds) in the fishery-year of interest. Outlier observations are excluded in the calculation of mean and standard deviation values for pro-rata statistics (pay per worker, pay per hour, and pay per pound).

[d] Mean pay per hour values are representative of the shoreside and floating processor sectors only.

[e] Data for EAG and WAG fisheries are summarized together as the 'AIG' fishery. Where a submitter reported separate labor payments and processing positions in the two fisheries, the maximum reported number of processing positions, rather than the sum of processing positions over the two fisheries, is used to calculate pay per worker statistics. All other variables used in pro-rata statistics for the AIG fisheries are treated cumulatively.

## Table 20: CR program fisheries processing employment

| | | | | Processing positions[b] | | Labor hours ($10^3$)[c] | | | Processing labor hours per job | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Processors[a] | Total[a] | Mean per plant (sd) | Obs | Total[a] | Mean per plant (sd) | Obs | Mean (sd) |
| AIG[d] | CP | 98/01/04 | 4 (2) | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2005 | 2 | -- | -- (--) | 2 | -- | -- (--) | 2 | -- (--) |
| | | 2006 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | SF | 98/01/04 | 13 (7) | 376 | 94 (73) | 12 | 54 | 13 (9) | 12 | 279 (312) |
| | | 2005 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2006 | 6 | 289 | 48 (44) | 6 | 47 | 8 (12) | 6 | 129 (205) |
| | | 2007 | 5 | 404 | 81 (--) | 5 | 72 | 14 (--) | 5 | 219 (--) |
| | | 2008 | 6 | 296 | 59 (--) | 6 | 38 | 6 (6) | 5 | 171 (--) |
| | SFCP | 2009 | 5 | 383 | 77 (--) | 5 | 48 | 10 (--) | 5 | 327 (--) |
| | | 2010 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2011 | 6 | 678 | 113 (96) | 6 | 45 | 7 (9) | 6 | 237 (346) |
| BBR | CP | 98/01/04 | 18 (10) | 69 | 12 (6) | 17 | 6 | 1 (1) | 17 | 85 (54) |
| | | 2005 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2006 | 3 | -- | -- (--) | 3 | -- | -- (--) | 3 | -- (--) |
| | | 2007 | 3 | -- | -- (--) | 3 | -- | -- (--) | 3 | -- (--) |
| | | 2008 | 3 | -- | -- (--) | 3 | -- | -- (--) | 3 | -- (--) |
| | SF | 98/01/04 | 40 (20) | 1400 | 105 (85) | 40 | 142 | 11 (8) | 40 | 106 (72) |
| | | 2005 | 11 | 1024 | 93 (75) | 11 | 202 | 18 (17) | 11 | 181 (151) |
| | | 2006 | 11 | 1027 | 93 (66) | 11 | 180 | 16 (15) | 11 | 178 (206) |
| | | 2007 | 11 | 965 | 88 (39) | 11 | 261 | 24 (20) | 11 | 301 (309) |
| | | 2008 | 11 | 873 | 87 (53) | 11 | 245 | 22 (21) | 10 | 311 (291) |
| | SFCP | 2009 | 12 | 1132 | 94 (72) | 12 | 205 | 17 (17) | 12 | 223 (220) |
| | | 2010 | 13 | 1106 | 85 (65) | 13 | 222 | 17 (15) | 13 | 239 (182) |
| | | 2011 | 13 | 1192 | 92 (72) | 13 | 104 | 8 (7) | 13 | 105 (89) |
| BSS | CP | 98/01/04 | 17 (8) | 82 | 15 (5) | 15 | 30 | 6 (4) | 15 | 403 (227) |
| | | 2005 | 6 | 62 | 10 (4) | 6 | 12 | 2 (1) | 6 | 200 (125) |
| | | 2006 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2007 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | | 2008 | 4 | -- | -- (--) | 4 | -- | -- (--) | 4 | -- (--) |
| | SF | 98/01/04 | 50 (24) | 2481 | 149 (112) | 50 | 1134 | 68 (74) | 50 | 505 (598) |
| | | 2005 | 13 | 1487 | 114 (67) | 13 | 302 | 23 (17) | 13 | 220 (174) |
| | | 2006 | 10 | 1061 | 106 (76) | 10 | 445 | 45 (35) | 10 | 484 (492) |
| | | 2007 | 10 | 1140 | 114 (56) | 10 | 442 | 44 (38) | 10 | 418 (449) |
| | | 2008 | 12 | 1170 | 106 (61) | 12 | 712 | 59 (77) | 11 | 603 (611) |
| | SFCP | 2009 | 14 | 1302 | 93 (76) | 14 | 633 | 45 (49) | 14 | 498 (316) |
| | | 2010 | 11 | 1189 | 108 (82) | 11 | 548 | 50 (39) | 11 | 889 (1492) |
| | | 2011 | 13 | 1521 | 117 (76) | 13 | 516 | 40 (39) | 13 | 408 (329) |
| BST | CP | 2006 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |
| | SF | 2005 | 7 | 401 | 57 (42) | 7 | 8 | 1 (2) | 7 | 13 (14) |
| | | 2006 | 8 | 668 | 84 (43) | 8 | 14 | 2 (2) | 8 | 70 (158) |
| | | 2007 | 7 | 445 | 64 (28) | 7 | 35 | 5 (3) | 7 | 118 (122) |
| | | 2008 | 8 | 647 | 92 (72) | 8 | 27 | 3 (3) | 7 | 135 (219) |
| | SFCP | 2009 | 8 | 807 | 101 (75) | 8 | 31 | 4 (2) | 8 | 75 (86) |
| | | 2010 | 5 | 477 | 95 (--) | 5 | 6 | 1 (--) | 5 | 145 (--) |
| PIK | SF | 1998 | 13 | 669 | 51 (61) | 13 | 25 | 2 (2) | 13 | 71 (68) |
| SMB | CP | 1998 | 1 | -- | -- (--) | 0 | -- | -- (--) | 0 | -- (--) |
| | SF | 1998 | 10 | 820 | 82 (65) | 10 | 55 | 6 (7) | 10 | 65 (44) |
| | | 2009 | 2 | -- | -- (--) | 2 | -- | -- (--) | 2 | -- (--) |
| | | 2010 | 5 | -- | -- (--) | 5 | -- | -- (--) | 5 | -- (--) |
| | | 2011 | 5 | -- | -- (--) | 5 | -- | -- (--) | 5 | -- (--) |
| WAI | CP | 98/01/04 | 2 (1) | -- | -- (--) | 2 | -- | -- (--) | 2 | -- (--) |
| | SF | 98/01/04 | 1 (1) | -- | -- (--) | 1 | -- | -- (--) | 1 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Starting in 2009, data are summarized over all processing sectors (SFCP) to preserve confidentiality. No catcher processor operations reported processing activity in the SMB fishery from 2009 to 2011.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Processors' for 98/01/04 shows count of processor-years (count of unique processors over all three years). Total processing positions and labor hours shown for 98/01/04 represent total annual positions or labor hours averaged across years with participating/reporting processors.

[b] Total processing positions statistics excludes salaried workers employed in the processing sectors.

[c] Processing labor hours for the catcher processor sector are estimated by multiplying processing positions, number of days processing, and an assumed shift length of 12 hours per day.

[d] Data for EAG and WAG fisheries are summarized together as the 'AIG' fishery. Where a submitter reported processing employment in both EAG and WAG fisheries, the maximum reported number of processing positions, rather than the sum of processing positions, is used to calculate total and mean processing positions.

Table 21: CR program fisheries processing salary costs (2011 base year)

| | | | Salary costs ($10^3)[b] | | | | Salaried employees | | |
|---|---|---|---|---|---|---|---|---|---|
| Sector | Year[a] | Processors[a] | Salary cost obs | Total[a] | Mean cost per plant (sd) | Mean cost per employee (sd) | Processors | Total[a] | Mean per plant (sd) |
| CP | 98/01/04 | 17 (9) | 17 | $387.50 | $68.40 (56.4) | $37.40 (44.3) | 17 | 17 | 3 (3) |
| | 2005 | 8 | 7 | $1,120.70 | $160.10 (215) | $43.90 (72.6) | 7 | 44 | 6 (8) |
| | 2006 | 4 | 4 | -- | -- (--) | -- (--) | 3 | -- | -- (--) |
| | 2007 | 4 | 4 | -- | -- (--) | -- (--) | 4 | -- | -- (--) |
| | 2008 | 4 | 4 | -- | -- (--) | -- (--) | 4 | -- | -- (--) |
| | 2009 | 5 | 3 | -- | -- (--) | -- (--) | 3 | -- | -- (--) |
| | 2010 | 3 | 2 | -- | -- (--) | -- (--) | 2 | -- | -- (--) |
| | 2011 | 3 | 3 | -- | -- (--) | -- (--) | 3 | -- | -- (--) |
| SF | 98/01/04 | 65 (32) | 65 | $9,248.80 | $426.90 (548) | $15.70 (18.2) | 64 | 1096 | 51 (100) |
| | 2005 | 17 | 17 | $11,073.80 | $651.40 (1283.3) | $4.90 (4) | 17 | 1592 | 94 (157) |
| | 2006 | 13 | 13 | $13,473.00 | $1036.40 (1883.3) | $13.50 (19.2) | 13 | 2031 | 156 (282) |
| | 2007 | 14 | 14 | $5,851.90 | $418.00 (577.4) | $12.60 (10.3) | 14 | 691 | 49 (73) |
| | 2008 | 13 | 13 | $11,729.20 | $902.20 (1148.6) | $15.40 (11.3) | 13 | 1056 | 81 (131) |
| | 2009 | 17 | 11 | $8,179.00 | $743.50 (916.2) | $13.90 (14) | 12 | 900 | 75 (94) |
| | 2010 | 17 | 12 | $6,133.60 | $511.10 (789.7) | $7.30 (6.1) | 12 | 786 | 66 (96) |
| | 2011 | 17 | 13 | $6,675.40 | $513.50 (636.7) | $8.60 (9.2) | 13 | 1148 | 88 (116) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Processors' for 98/01/04 shows count of processor-years (count of unique processors over all three years). Totals for 98/01/04 represent total annual salary costs or salaried employees averaged across years with participating/reporting processors.
[b] Where a submitter provided salary data applicable to more than just crab processing activity, reported salary costs are prorated using the ratio of crab-specific processing days to total processing days in all fisheries. Where this ratio is unavailable, the ratio of crab processing revenue to total processing revenue in all fisheries; or of finished crab pounds to total finished pounds in all fisheries may be used. Data for number of salaried employees are not pro-rated.

## Table 22: CR program fisheries capital costs and selected operating costs (2011 base year)

| Cost | Sector[a] | Year[a] | Vessels/plants[a] | Total cost[a] ($$10^3$) | Mean cost (sd) ($$10^3$) |
|---|---|---|---|---|---|
| Capital investments[b] | CV | 98/01/04 | 348 (186) | $16,590 | $143 (399) |
| | | 2005 | 93 | $2,909 | $31 (62) |
| | | 2006 | 54 | $2,480 | $46 (99) |
| | | 2007 | 38 | $3,846 | $101 (311) |
| | | 2008 | 57 | $4,220 | $74 (94) |
| | | 2009 | 56 | $6,640 | $119 (200) |
| | | 2010 | 42 | $2,275 | $54 (81) |
| | | 2011 | 39 | $3,476 | $89 (90) |
| | CP | 98/01/04 | 16 (10) | $1,850 | $347 (1060) |
| | | 2005 | 5 | $746 | $149 (--) |
| | | 2006 | 2 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 2 | -- | -- (--) |
| | | 2009 | 3 | -- | -- (--) |
| | | 2010 | 1 | -- | -- (--) |
| | | 2011 | 1 | -- | -- (--) |
| | SFP | 98/01/04 | 40 (21) | $6,710 | $503 (1277) |
| | | 2005 | 12 | -- | -- (--) |
| | | 2006 | 12 | $11,637 | $970 (1689) |
| | | 2007 | 14 | $19,175 | $1370 (2387) |
| | | 2008 | 12 | $8,552 | $713 (1463) |
| | | 2009 | 11 | -- | -- (--) |
| | | 2010 | 12 | $6,767 | $564 (1167) |
| | | 2011 | 12 | $7,419 | $618 (1006) |
| Repair/maintenance[b] | CV | 98/01/04 | 645 (252) | $17,424 | $81 (100) |
| | | 2005 | 160 | $5,776 | $36 (43) |
| | | 2006 | 95 | $5,214 | $55 (67) |
| | | 2007 | 80 | $5,292 | $66 (71) |
| | | 2008 | 89 | $7,493 | $84 (82) |
| | | 2009 | 84 | $7,427 | $88 (111) |
| | | 2010 | 76 | $5,354 | $71 (74) |
| | | 2011 | 73 | $6,190 | $85 (82) |
| | CP | 98/01/04 | 25 (10) | $1,791 | $215 (158) |
| | | 2005 | 8 | $2,528 | $316 (276) |
| | | 2006 | 5 | $1,719 | $344 (--) |
| | | 2007 | 5 | $1,597 | $319 (--) |
| | | 2008 | 5 | $1,996 | $399 (--) |
| | | 2009 | 5 | $841 | $168 (--) |
| | | 2010 | 3 | -- | -- (--) |
| | | 2011 | 3 | -- | -- (--) |
| | SFP | 98/01/04 | 62 (29) | $5,506 | $266 (361) |
| | | 2005 | 17 | $4,382 | $258 (477) |
| | | 2006 | 13 | $5,095 | $392 (744) |
| | | 2007 | 14 | $7,383 | $527 (873) |
| | | 2008 | 13 | $7,714 | $593 (888) |
| | | 2009 | 11 | $5,940 | $540 (627) |
| | | 2010 | 12 | $3,304 | $275 (228) |
| | | 2011 | 13 | $3,080 | $237 (244) |

Table continues on next page.

Table 22 cont.

| Cost | Sector[a] | Year[a] | Vessels/plants[a] | Total cost[a] ($$10^3$) | Mean cost (sd) ($$10^3$) |
|---|---|---|---|---|---|
| Fisheries tax | CV | 98/01/04 | 628 (252) | $3,621 | $17 (15) |
| | | 2005 | 162 | $6,171 | $38 (49) |
| | | 2006 | 90 | $6,712 | $75 (62) |
| | | 2007 | 81 | $10,840 | $134 (111) |
| | | 2008 | 91 | $15,475 | $170 (137) |
| | | 2009 | 83 | $10,947 | $132 (89) |
| | | 2010 | 76 | $11,782 | $155 (106) |
| | | 2011 | 71 | $16,542 | $233 (165) |
| | CP | 98/01/04 | 22 (10) | $489 | $67 (60) |
| | | 2005 | 6 | $582 | $97 (74) |
| | | 2006 | 5 | $766 | $153 (--) |
| | | 2007 | 5 | $1,257 | $251 (--) |
| | | 2008 | 5 | $1,727 | $346 (--) |
| | | 2009 | 5 | $1,490 | $298 (--) |
| | | 2010 | 3 | -- | -- (--) |
| | | 2011 | 3 | -- | -- (--) |
| | SFP | 98/01/04 | 64 (31) | $8,325 | $390 (429) |
| | | 2005 | 18 | $8,342 | $463 (568) |
| | | 2006 | 11 | $6,975 | $634 (613) |
| | | 2007 | 15 | $8,049 | $537 (548) |
| | | 2008 | 12 | $9,560 | $797 (669) |
| | | 2009 | 11 | $6,782 | $617 (475) |
| | | 2010 | 13 | $8,101 | $623 (624) |
| | | 2011 | 16 | $10,172 | $636 (654) |
| Food and provisions | CV | 98/01/04 | 622 (249) | $2,649 | $13 (13) |
| | | 2005 | 149 | $1,425 | $10 (11) |
| | | 2006 | 66 | $688 | $10 (11) |
| | | 2007 | 57 | $664 | $12 (9) |
| | | 2008 | 65 | $1,349 | $21 (38) |
| | | 2009 | 56 | $812 | $15 (11) |
| | | 2010 | 47 | $1,011 | $22 (36) |
| | | 2011 | 50 | $744 | $15 (12) |
| | CP | 98/01/04 | 25 (10) | $364 | $44 (22) |
| | | 2005 | 7 | $198 | $28 (16) |
| | | 2006 | 4 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 4 | -- | -- (--) |
| | | 2009 | 4 | -- | -- (--) |
| | | 2010 | 2 | -- | -- (--) |
| | | 2011 | 2 | -- | -- (--) |
| | SFP | 98/01/04 | 49 (24) | $2,920 | $179 (179) |
| | | 2005 | 13 | $1,010 | $78 (56) |
| | | 2006 | 10 | $1,072 | $107 (96) |
| | | 2007 | 12 | $1,199 | $100 (76) |
| | | 2008 | 9 | $1,366 | $152 (155) |
| | | 2009 | 7 | $848 | $121 (73) |
| | | 2010 | 11 | $1,632 | $148 (183) |
| | | 2011 | 11 | $1,497 | $136 (127) |

Table continues on next page.

Table 22 cont.

| Cost | Sector[a] | Year[a] | Vessels/plants[a] | Total cost[a] ($10^3) | Mean cost (sd) ($10^3) |
|---|---|---|---|---|---|
| Crab freight[c] | CV | 98/01/04 | 6 (4) | -- | -- (--) |
| | | 2005 | 3 | -- | -- (--) |
| | | 2006 | 5 | $33 | $7 (--) |
| | | 2007 | 2 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) |
| | | 2009 | 2 | -- | -- (--) |
| | | 2010 | 1 | -- | -- (--) |
| | | 2011 | 2 | -- | -- (--) |
| | CP | 98/01/04 | 20 (10) | $675 | $101 (91) |
| | | 2005 | 5 | $270 | $54 (--) |
| | | 2006 | 4 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 5 | $1,543 | $309 (--) |
| | | 2009 | 5 | $844 | $169 (--) |
| | | 2010 | 3 | -- | -- (--) |
| | | 2011 | 3 | -- | -- (--) |
| | SFP | 98/01/04 | 48 (23) | $13,947 | $872 (1133) |
| | | 2005 | 14 | $5,520 | $394 (372) |
| | | 2006 | 10 | $7,780 | $778 (941) |
| | | 2007 | 11 | $4,854 | $441 (545) |
| | | 2008 | 9 | $6,231 | $692 (812) |
| | | 2009 | 8 | $6,813 | $852 (1062) |
| | | 2010 | 12 | $7,047 | $587 (858) |
| | | 2011 | 16 | $7,195 | $450 (594) |
| Fishing gear | CV | 98/01/04 | 482 (211) | $2,911 | $18 (25) |
| | | 2005 | 80 | $1,077 | $14 (19) |
| | | 2006 | 61 | $1,035 | $17 (23) |
| | | 2007 | 52 | $862 | $17 (16) |
| | | 2008 | 56 | $1,465 | $26 (26) |
| | CP | 98/01/04 | 23 (10) | $242 | $32 (31) |
| | | 2005 | 6 | -- | -- (--) |
| | | 2006 | 4 | -- | -- (--) |
| | | 2007 | 3 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) |
| | CV/CP | 2009 | 56 | $1,330 | $24 (25) |
| | | 2010 | 44 | $944 | $22 (20) |
| | | 2011 | 50 | $1,544 | $31 (36) |
| Gear storage | CV | 98/01/04 | 539 (223) | $1,745 | $10 (11) |
| | | 2005 | 119 | $1,130 | $10 (10) |
| | | 2006 | 68 | $615 | $9 (7) |
| | | 2007 | 61 | $668 | $11 (8) |
| | | 2008 | 68 | $1,061 | $16 (20) |
| | CP | 98/01/04 | 22 (10) | $144 | $20 (15) |
| | | 2005 | 5 | $281 | $56 (--) |
| | | 2006 | 5 | $285 | $57 (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) |
| | CV/CP | 2009 | 64 | $867 | $14 (10) |
| | | 2010 | 52 | $694 | $13 (10) |
| | | 2011 | 51 | $629 | $12 (10) |

Table continues on next page.

Table 22 cont.

| Cost | Sector[a] | Year[a] | Vessels/plants[a] | Total cost[a] ($10^3) | Mean cost (sd) ($10^3) |
|---|---|---|---|---|---|
| Cooperative fees[d] | CV | 2005 | 82 | $329 | $4 (5) |
| | | 2006 | 67 | $532 | $8 (14) |
| | | 2007 | 51 | $937 | $18 (41) |
| | | 2008 | 46 | $650 | $14 (41) |
| | CP | 2005 | 3 | -- | -- (--) |
| | | 2006 | 2 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) |
| | | 2008 | 2 | -- | -- (--) |
| | CV/CP | 2009 | 49 | $627 | $13 (34) |
| | | 2010 | 43 | $485 | $11 (18) |
| | | 2011 | 40 | $1,226 | $31 (63) |
| Supply freight[e] | CV | 98/01/04 | 265 (140) | $236 | $3 (4) |
| | CP | 98/01/04 | 20 (9) | $61 | $9 (12) |
| | SFP | 98/01/04 | 40 (21) | $1,320 | $99 (168) |
| | | 2005 | 11 | $616 | $56 (72) |
| | | 2006 | 9 | $909 | $101 (108) |
| | | 2007 | 11 | $1,110 | $101 (127) |
| | | 2008 | 11 | $806 | $73 (95) |
| | | 2009 | 8 | $617 | $77 (104) |
| | | 2010 | 9 | $680 | $76 (90) |
| | | 2011 | 10 | $933 | $93 (129) |
| Processing and packaging | CP | 98/01/04 | 25 (10) | $423 | $51 (49) |
| | | 2005 | 7 | $301 | $43 (38) |
| | | 2006 | 5 | $545 | $109 (--) |
| | | 2007 | 5 | $442 | $88 (--) |
| | | 2008 | 5 | $698 | $140 (--) |
| | SFP | 98/01/04 | 64 (32) | $6,230 | $292 (333) |
| | | 2005 | 16 | $2,141 | $134 (128) |
| | | 2006 | 11 | $2,117 | $192 (167) |
| | | 2007 | 14 | $3,220 | $230 (163) |
| | | 2008 | 13 | $3,234 | $249 (219) |
| | SFCP | 2009 | 15 | $2,786 | $186 (189) |
| | | 2010 | 17 | $2,384 | $140 (156) |
| | | 2011 | 14 | $2,176 | $156 (131) |
| Repackaging | CP | 98/01/04 | 2 (2) | -- | -- (--) |
| | | 2005 | 1 | -- | -- (--) |
| | | 2006 | 2 | -- | -- (--) |
| | | 2007 | 2 | -- | -- (--) |
| | | 2008 | 2 | -- | -- (--) |
| | SFP | 98/01/04 | 11 (6) | $1,009 | $275 (355) |
| | | 2005 | 2 | -- | -- (--) |
| | | 2006 | 2 | -- | -- (--) |
| | | 2007 | 2 | -- | -- (--) |
| | | 2008 | 2 | -- | -- (--) |
| | SFCP | 2009 | 5 | $231 | $46 (--) |
| | | 2010 | 4 | -- | -- (--) |
| | | 2011 | 3 | -- | -- (--) |

Table continues on next page.

Table 22 cont.

| Cost | Sector[a] | Year[a] | Vessels/plants[a] | Total cost[a] ($$10^3$) | Mean cost (sd) ($$10^3$) |
|---|---|---|---|---|---|
| Product storage | CP | 98/01/04 | 13 (6) | $75 | $17 (29) |
| | | 2005 | 5 | $74 | $15 (--) |
| | | 2006 | 3 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) |
| | SFP | 98/01/04 | 29 (13) | $1,936 | $200 (476) |
| | | 2005 | 9 | $1,231 | $137 (113) |
| | | 2006 | 7 | $1,322 | $189 (116) |
| | | 2007 | 6 | $618 | $103 (97) |
| | | 2008 | 7 | $986 | $141 (114) |
| | SFCP | 2009 | 10 | $1,613 | $161 (156) |
| | | 2010 | 13 | $975 | $75 (98) |
| | | 2011 | 13 | $866 | $67 (73) |

*Source: NMFS AFSC BSAI Crab Economic Data.*
Data shown by calendar year. Starting in 2009, selected data are reported over all harvesting sectors (CVCP) or all processing sectors (SFCP) to preserve confidentiality.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels/plants' for 98/01/04 shows count of vessel-years or processor-years (count of unique vessels or processors over all three years). Total costs for 98/01/04 represent total annual costs averaged across years with participating/reporting vessels or processors.
[b] Where a submitter reported capital investment or repair and maintenance costs inclusive of activity outside the crab fishery, reported costs are prorated using the ratio of the submitter's crab processing or harvesting days to total processing or harvesting days. Where this ratio is unavailable, one of the following ratios of crab to all-fisheries activity is used: finished processed pounds (processing sectors), harvested pounds (catcher vessel sector), processing revenue (processing sectors), ex-vessel harvest revenue (catcher vessel sector), and labor costs (all sectors).
[c] Crab freight statistics do not include crab shipping costs for crab buyers who had all of their crab custom-processed for them.
[d] Reporting of crab cooperative fees for catcher processor and catcher vessels began with the 2005 EDR.
[e] Reporting of this supply freight costs was discontinued for catcher processors in the 2005 EDR, as this is a minimal cost element in the sector.

Table 23: CR program fisheries bait costs (2011 base year)

| | | | Bait pounds | | | | Bait costs | | Bait price | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels[a] | Total weight[a], $10^3$ lbs | Mean weight, $10^3$ lbs (sd) | Vessels[a] | Total bait costs[a], $\$10^3$ | Mean bait costs, $\$10^3$ (sd) | Weighted price/lb | Price lbs | Mean price/lb (sd) |
| AIG | CP | 98/01/04 | 4 (2) | -- | -- (--) | 4 (2) | -- | -- (--) | -- | 4 | -- (--) |
| | | 2005 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 3 | -- (--) |
| | | 2006 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 5 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 3 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 6 | -- (--) |
| | CV | 98/01/04 | 50 (21) | 1825 | 109 (128) | 50 (21) | $1,141 | $68 (83) | $0.63 | 61 | $0.61 (0.14) |
| | | 2005 | 9 | 863 | 96 (79) | 9 | $490 | $54 (42) | $0.57 | 22 | $0.58 (0.09) |
| | | 2006 | 6 | 778 | 130 (53) | 6 | $412 | $69 (30) | $0.53 | 17 | $0.52 (0.07) |
| | | 2007 | 6 | 741 | 124 (--) | 6 | $308 | $51 (--) | $0.42 | 13 | $0.45 (--) |
| | | 2008 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 11 | -- (--) |
| | CVCP | 2009 | 7 | 1137 | 162 (138) | 7 | $659 | $94 (87) | $0.58 | 16 | $0.59 (0.1) |
| | | 2010 | 6 | 1259 | 210 (133) | 6 | $679 | $113 (84) | $0.54 | 15 | $0.56 (0.11) |
| | | 2011 | 5 | 1172 | 234 (--) | 5 | $703 | $141 (--) | $0.60 | 12 | $0.51 (--) |
| BBR | CP | 98/01/04 | 15 (8) | 90 | 18 (16) | 15 (8) | $50 | $10 (8) | $0.55 | 15 | $0.58 (0.15) |
| | | 2005 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 9 | -- (--) |
| | | 2006 | 3 | -- | -- (--) | 3 | -- | -- (--) | -- | 8 | -- (--) |
| | | 2007 | 2 | -- | -- (--) | 2 | -- | -- (--) | -- | 3 | -- (--) |
| | | 2008 | 3 | -- | -- (--) | 3 | -- | -- (--) | -- | 6 | -- (--) |
| | CV | 98/01/04 | 547 (227) | 1742 | 10 (6) | 546 (227) | $1,194 | $7 (4) | $0.69 | 535 | $0.69 (0.13) |
| | | 2005 | 82 | 1380 | 17 (12) | 84 | $904 | $11 (9) | $0.65 | 176 | $0.60 (0.12) |
| | | 2006 | 74 | 1162 | 16 (12) | 74 | $657 | $9 (6) | $0.57 | 141 | $0.59 (0.08) |
| | | 2007 | 70 | 1488 | 21 (14) | 70 | $881 | $13 (8) | $0.59 | 147 | $0.57 (0.13) |
| | | 2008 | 76 | 1683 | 22 (15) | 76 | $1,102 | $14 (11) | $0.65 | 149 | $0.65 (0.15) |
| | CVCP | 2009 | 68 | 1666 | 24 (15) | 68 | $1,053 | $15 (9) | $0.63 | 156 | $0.63 (0.13) |
| | | 2010 | 61 | 1625 | 27 (16) | 61 | $991 | $16 (9) | $0.61 | 135 | $0.61 (0.13) |
| | | 2011 | 62 | 972 | 16 (13) | 61 | $635 | $10 (9) | $0.65 | 120 | $0.65 (0.17) |

Table continues on next page.

Table 23 cont.

| | | | Bait pounds | | | Bait costs | | | Bait price | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Sector | Year[a] | Vessels[a] | Total weight[a], $10^3$ lbs | Mean weight, $10^3$ lbs (sd) | Vessels[a] | Total bait costs[a], $\$10^3$ | Mean bait costs, $\$10^3$ (sd) | Weighted price/lb | Price lbs | Mean price/lb (sd) |
| BSS | CP | 98/01/04 | 13 (7) | 147 | 34 (29) | 13 (7) | $88 | $20 (19) | $0.60 | 13 | $0.59 (0.09) |
| | | 2005 | 5 | 102 | 20 (--) | 5 | $55 | $11 (--) | $0.54 | 13 | $0.57 (--) |
| | | 2006 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 11 | -- (--) |
| | | 2007 | 3 | -- | -- (--) | 3 | -- | -- (--) | -- | 5 | -- (--) |
| | | 2008 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 8 | -- (--) |
| | CV | 98/01/04 | 448 (190) | 3270 | 22 (20) | 448 (190) | $2,321 | $16 (14) | $0.71 | 443 | $0.72 (0.18) |
| | | 2005 | 148 | 1758 | 12 (7) | 150 | $1,107 | $7 (4) | $0.63 | 334 | $0.63 (0.16) |
| | | 2006 | 74 | 1041 | 14 (9) | 75 | $616 | $8 (5) | $0.59 | 140 | $0.60 (0.15) |
| | | 2007 | 64 | 869 | 14 (10) | 64 | $495 | $8 (5) | $0.57 | 107 | $0.59 (0.09) |
| | | 2008 | 72 | 1288 | 18 (14) | 72 | $756 | $10 (8) | $0.59 | 131 | $0.60 (0.24) |
| | CVCP | 2009 | 75 | 1616 | 22 (18) | 75 | $1,007 | $13 (9) | $0.62 | 145 | $0.64 (0.16) |
| | | 2010 | 67 | 1374 | 21 (14) | 67 | $832 | $12 (9) | $0.61 | 134 | $0.61 (0.09) |
| | | 2011 | 67 | 1504 | 22 (14) | 67 | $865 | $13 (8) | $0.57 | 143 | $0.59 (0.18) |
| BST | CP | 2006 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 2 | -- (--) |
| | | 2007 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 2 | -- (--) |
| | | 2008 | 1 | -- | -- (--) | 1 | -- | -- (--) | -- | 3 | -- (--) |
| | CV | 2005 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 7 | -- (--) |
| | | 2006 | 15 | 41 | 3 (3) | 15 | $26 | $2 (2) | $0.63 | 19 | $0.57 (0.07) |
| | | 2007 | 16 | 191 | 12 (9) | 16 | $90 | $6 (4) | $0.47 | 24 | $0.54 (0.1) |
| | | 2008 | 21 | 230 | 11 (12) | 21 | $134 | $6 (7) | $0.58 | 35 | $0.59 (0.07) |
| | CVCP | 2009 | 12 | 204 | 17 (16) | 12 | $137 | $11 (11) | $0.67 | 25 | $0.65 (0.13) |
| | | 2010 | 4 | -- | -- (--) | 4 | -- | -- (--) | -- | 9 | -- (--) |
| PIK | CV | 1998 | 35 | 249 | 7 (4) | 35 | $186 | $5 (3) | $0.75 | 34 | $0.75 (0.12) |
| SMB | CV | 1998 | 72 | 668 | 9 (3) | 72 | $481 | $7 (2) | $0.72 | 71 | $0.73 (0.12) |
| | | 2009 | 7 | 96 | 14 (12) | 7 | $66 | $9 (8) | $0.68 | 14 | $0.60 (0.1) |
| | | 2010 | 13 | 329 | 25 (19) | 13 | $198 | $15 (11) | $0.60 | 23 | $0.58 (0.23) |
| | | 2011 | 18 | 448 | 25 (19) | 18 | $289 | $16 (12) | $0.64 | 32 | $0.65 (0.17) |
| WAI | CP | 98/01/04 | 2 (1) | -- | -- (--) | 2 (1) | -- | -- (--) | -- | 2 | -- (--) |
| | CV | 98/01/04 | 3 (3) | -- | -- (--) | 3 (3) | -- | -- (--) | -- | 3 | -- (--) |

*Source: NMFS AFSC BSAI Crab Economic Data.*

Data shown by calendar year. Starting in 2009, data are reported over all harvesting sectors (CVCP) to preserve confidentiality. No catcher processor operations reported fishing activity in the SMB fishery from 2009 to 2011.

Changes in the reporting of bait quantity and costs in the EDR limit the comparability of bait statistics over multiple years. Beginning in 2006, EDR submitters were directed to report only pounds and costs of bait purchased during the reporting year; treatment of bait caught by the vessel or purchased in the prior year was not specified in EDR reporting instructions for 2005 and earlier years. Additionally, bait quantity reporting is differentiated by species and fishery in all years of EDR data collection, whereas bait costs are reported only by fishery for the years 1998-2004 and by fishery and species together for 2005 and later years. Methods for generating price per pound statistics differ across reporting years. For 1998-2004 statistics, reported bait quantities are aggregated by submitter and fishery to match reported bait costs. 2005 and later bait price statistics reflect the exclusion of quantity-cost observations that indicate zero or no reported costs, as well as of observations where the quantity of bait is less than 100 pounds.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Vessels' for 98/01/04 shows count of vessel-years (count of unique vessels over all three years). Totals for 98/01/04 represent total annual bait pounds purchased or bait costs averaged across years with participating/reporting vessels.

Table 24: CR program fisheries observer costs (2011 base year)

| Fishery | Sector | Year[a] | Vessels[a] | Total cost[a], $\$10^3$ | Mean cost per vessel, $\$10^3$ (sd) |
|---|---|---|---|---|---|
| AIG | CP | 98/01/04 | 4 (2) | -- | -- (--) |
| | | 2005 | 1 | -- | -- (--) |
| | | 2006 | 1 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) |
| | CV | 98/01/04 | 49 (20) | $623.9 | $28.8 (24) |
| | | 2005 | 10 | $189.2 | $17.2 (7) |
| | | 2006 | 6 | $180.6 | $25.8 (17.8) |
| | | 2007 | 6 | $118.9 | $19.8 (--) |
| | | 2008 | 4 | -- | -- (--) |
| | CVCP | 2009 | 5 | $196.3 | $39.3 (--) |
| | | 2010 | 5 | $179.9 | $30.0 (--) |
| | | 2011 | 5 | $168.9 | $28.1 (--) |
| BBR | CP | 98/01/04 | 17 (9) | $56.6 | $10.0 (4.9) |
| | | 2005 | 5 | $109.5 | $21.9 (--) |
| | | 2006 | 3 | -- | -- (--) |
| | | 2007 | 3 | -- | -- (--) |
| | | 2008 | 3 | -- | -- (--) |
| | CV | 98/01/04 | 37 (23) | $37.2 | $3.0 (3.3) |
| | | 2005 | 1 | -- | -- (--) |
| | | 2008 | 2 | -- | -- (--) |
| | CVCP | 2009 | 2 | -- | -- (--) |
| | | 2010 | 2 | -- | -- (--) |
| | | 2011 | 5 | $31.9 | $6.4 (--) |
| BSS | CP | 98/01/04 | 15 (8) | $107.4 | $21.5 (10.6) |
| | | 2005 | 6 | $63.4 | $10.6 (5.8) |
| | | 2006 | 4 | -- | -- (--) |
| | | 2007 | 4 | -- | -- (--) |
| | | 2008 | 4 | -- | -- (--) |
| | CV | 98/01/04 | 24 (17) | $113.3 | $14.2 (6.3) |
| | | 2005 | 6 | $47.8 | $8.0 (4.1) |
| | CVCP | 2009 | 4 | -- | -- (--) |
| | | 2010 | 2 | -- | -- (--) |
| | | 2011 | 6 | $70.3 | $11.7 (12.4) |
| BST | CP | 2006 | 1 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) |
| | | 2008 | 1 | -- | -- (--) |
| | CV | 2005 | 1 | -- | -- (--) |
| | | 2007 | 1 | -- | -- (--) |
| | CVCP | 2009 | 1 | -- | -- (--) |
| SMB | CP | 1998 | 2 | -- | -- (--) |
| | CV | 1998 | 3 | -- | -- (--) |
| | | 2009 | 4 | -- | -- (--) |
| | | 2010 | 6 | $123.9 | $20.7 (3.2) |
| | | 2011 | 13 | $204.7 | $15.7 (8.5) |
| WAI | CP | 98/01/04 | 2 (1) | -- | -- (--) |
| | CV | 98/01/04 | 2 (2) | -- | -- (--) |

Source: NMFS AFSC BSAI Crab Economic Data.

Table 25: CR program fisheries broker costs (2011 base year)

| Sector | Year | Processors[a] | Total cost[a], \$10³ | Mean cost, \$10³ (sd) | Weighted cost/sold lb | Mean cost/sold lb |
|---|---|---|---|---|---|---|
| CP | 98/01/04 | 14 (7) | \$238 | \$51 (52) | \$0.12 | \$0.17 (0.11) |
| | 2005 | 3 | -- | -- (--) | -- | -- (--) |
| | 2006 | 4 | -- | -- (--) | -- | -- (--) |
| | 2007 | 2 | -- | -- (--) | -- | -- (--) |
| | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| SFP | 98/01/04 | 31 (14) | \$2,904 | \$281 (374) | \$0.07 | \$0.08 (0.08) |
| | 2005 | 9 | \$856 | \$95 (99) | \$0.05 | \$0.07 (0.07) |
| | 2006 | 8 | \$1,823 | \$228 (212) | \$0.05 | \$0.06 (0.06) |
| | 2007 | 5 | -- | -- (--) | -- | -- (--) |
| | 2008 | 4 | -- | -- (--) | -- | -- (--) |
| SFCP | 2009 | 8 | \$1,237 | \$155 (165) | \$0.05 | \$0.07 (0.05) |
| | 2010 | 7 | \$1,084 | \$155 (192) | \$0.05 | \$0.05 (0.07) |
| | 2011 | 10 | \$1,400 | \$140 (174) | \$0.06 | \$0.12 (0.13) |

*Source: NMFS AFSC BSAI Crab Economic Data.* Data shown by calendar year. Starting in 2009, data are reported over all processing sectors (SFCP) to preserve confidentiality.

[a] For '98/01/04', data shown represent aggregates over the 1998, 2001, and 2004 calendar reporting years. 'Processors for 98/01/04 shows count of processor-years (count of unique processors over all three years). Totals for 98/01/04 represent total annual broker costs averaged across years with participating/reporting processors.

Table 26: Average monthly fuel prices for selected ports (nominal value)

| Year | Port | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | Dutch Harbor | n/d | $0.87 | $0.83 | $0.97 | $0.94 | $0.95 | $1.05 | $1.09 | $1.10 | $1.08 | $1.07 | $1.07 |
| | Kodiak | n/d | $0.78 | $0.78 | $0.93 | $0.99 | $0.99 | $1.06 | $1.07 | $1.08 | $1.08 | $1.10 | $1.10 |
| | Seattle | $0.53 | $0.58 | $0.53 | $0.84 | $0.64 | $0.77 | $0.89 | $0.78 | $0.90 | $0.86 | $0.82 | $0.85 |
| 2000 | Dutch Harbor | $1.09 | $1.19 | $1.44 | $1.44 | $1.29 | n/d | $1.31 | $1.33 | $1.40 | $1.54 | $1.59 | $1.59 |
| | Kodiak | $1.10 | $1.20 | $1.40 | $1.40 | $1.36 | $1.32 | $1.36 | $1.36 | $1.43 | $1.51 | $1.60 | $1.60 |
| | Seattle | $0.95 | $0.98 | $1.08 | $1.08 | $0.95 | $0.95 | $1.09 | $0.99 | $1.38 | $1.39 | $1.32 | $1.42 |
| 2001 | Adak | n/d | n/d | $1.54 | $1.44 | $1.44 | $1.39 | $1.44 | $1.32 | $1.32 | $1.39 | n/d | $1.27 |
| | Dutch Harbor | $1.59 | $1.50 | $1.50 | $1.41 | $1.39 | $1.39 | $1.39 | $1.31 | $1.37 | $1.38 | $1.31 | $1.23 |
| | Kodiak | $1.60 | $1.54 | $1.46 | $1.37 | $1.36 | $1.37 | $1.37 | $1.34 | $1.37 | $1.30 | $1.26 | $1.13 |
| | Seattle | $1.31 | $1.10 | $1.04 | $1.08 | $1.09 | $1.05 | $0.97 | $0.93 | $1.13 | $0.86 | $0.85 | $0.67 |
| 2002 | Adak | $1.27 | $1.27 | $1.27 | $1.27 | $1.36 | n/d | n/d | $1.27 | $1.35 | $1.45 | n/d | n/d |
| | Dutch Harbor | $1.16 | $0.99 | $0.98 | $1.09 | $1.14 | $1.14 | $1.14 | $1.14 | $1.19 | $1.24 | $1.27 | $1.29 |
| | Kodiak | $1.11 | $1.04 | $1.04 | $1.06 | $1.10 | $1.10 | $1.27 | $1.09 | $1.15 | $1.18 | $1.18 | $1.18 |
| | Seattle | $0.76 | $0.69 | $0.85 | $0.94 | $0.99 | $0.99 | $1.00 | $0.98 | $1.13 | $1.01 | $1.11 | $0.99 |
| 2003 | Adak | $1.45 | $1.45 | n/d | $1.67 | $1.60 | $1.60 | $1.55 | $1.55 | $1.55 | $1.55 | $1.55 | $1.55 |
| | Dutch Harbor | $1.29 | $1.35 | $1.46 | $1.55 | $1.47 | $1.45 | $1.45 | $1.45 | $1.50 | $1.50 | $1.50 | $1.50 |
| | Kodiak | $1.19 | $1.23 | $1.38 | $1.51 | $1.41 | $1.37 | $1.37 | $1.37 | $1.35 | $1.49 | $1.35 | $1.35 |
| | Seattle | $1.14 | $1.16 | $1.68 | $1.38 | $1.18 | $1.15 | $1.25 | $1.24 | $1.23 | $1.17 | $1.19 | $1.21 |
| 2004 | Adak | $1.60 | $1.60 | $1.60 | n/d | $1.75 | $1.95 | $1.95 | $1.95 | n/d | $2.05 | $2.10 | $2.10 |
| | Dutch Harbor | $1.50 | $1.50 | $1.64 | $1.60 | $1.65 | $1.78 | $1.78 | $1.84 | $1.85 | $1.94 | $2.00 | $2.00 |
| | Kodiak | $1.35 | $1.38 | $1.48 | $1.50 | $1.63 | $1.76 | $1.79 | $1.78 | $1.79 | $1.84 | $1.97 | $1.98 |
| | Seattle | $1.28 | $1.41 | $1.48 | $1.52 | $1.76 | $1.70 | $1.66 | $1.68 | $1.69 | $1.98 | $2.00 | $1.68 |
| 2005 | Adak | $2.10 | $2.10 | $2.15 | $2.21 | n/d | $2.65 | $2.30 | $2.35 | $2.51 | $2.65 | $2.65 | $2.65 |
| | Dutch Harbor | $2.00 | $2.00 | $2.08 | $2.15 | $2.20 | $2.20 | $2.20 | $2.30 | $2.51 | $2.53 | $2.59 | $2.57 |
| | Kodiak | $1.92 | $1.92 | $1.97 | $2.11 | $2.23 | $2.23 | $2.23 | $2.23 | $2.48 | $2.68 | $2.64 | $2.60 |
| | Seattle | $1.66 | $1.83 | $2.23 | $2.28 | $2.24 | $2.08 | $2.22 | $2.37 | $2.87 | $2.82 | $2.53 | $2.22 |
| 2006 | Adak | n/d | $2.56 | $2.56 | n/d | $3.40 | $2.82 | $2.82 | $2.82 | $2.99 | $2.99 | $2.94 | $2.94 |
| | Dutch Harbor | $2.47 | $2.46 | $2.46 | $2.46 | $2.64 | $2.71 | $2.70 | $2.77 | $2.85 | $2.71 | $2.58 | $2.56 |
| | Kodiak | $2.49 | $2.50 | $2.49 | $2.52 | $2.69 | $2.69 | $2.69 | $2.75 | $2.89 | $2.75 | $2.54 | $2.60 |
| | Seattle | $2.32 | $2.19 | $2.52 | $2.43 | $2.82 | $2.90 | $2.78 | $2.96 | $3.02 | $2.45 | $2.47 | $2.70 |

Table continues on next page.

Table 26 cont.

| Year | Port | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | Adak | $2.99 | $2.99 | $2.76 | $2.66 | $2.86 | $2.86 | $2.86 | $2.86 | $2.86 | $2.93 | $2.99 | $3.20 |
| | Dutch Harbor | $2.56 | $2.52 | $2.48 | $2.50 | $2.63 | $2.72 | $2.72 | $2.73 | $2.81 | $2.82 | $2.99 | $3.18 |
| | Kodiak | $2.54 | $2.52 | $2.49 | $2.49 | $2.59 | $2.69 | $2.69 | $2.69 | $2.84 | $2.80 | $2.94 | $3.01 |
| | Seattle | $2.66 | $2.60 | $2.48 | $2.71 | $2.78 | $2.78 | $2.84 | $2.89 | $2.77 | $2.98 | $3.41 | $3.23 |
| 2008 | Adak | $3.20 | $3.20 | $3.27 | $3.60 | $3.97 | $4.15 | $4.50 | $4.65 | $4.65 | $4.65 | $4.65 | $4.65 |
| | Dutch Harbor | $2.99 | $3.00 | $3.21 | $3.73 | $3.96 | $4.33 | $4.47 | $4.61 | $4.46 | $4.30 | $3.94 | $3.85 |
| | Kodiak | $3.02 | $3.06 | $3.17 | $3.79 | $3.87 | $4.25 | $4.39 | $4.64 | $4.49 | $4.24 | $3.98 | $3.29 |
| | Seattle | $3.33 | $3.18 | $3.53 | $3.76 | $4.12 | $4.44 | $4.42 | $4.31 | $4.07 | $3.14 | $2.94 | $2.43 |
| 2009 | Adak | $4.65 | $3.34 | $3.24 | $3.14 | $3.14 | $2.89 | $2.89 | $2.89 | n/d | $2.99 | $2.99 | $2.99 |
| | Dutch Harbor | $3.06 | $2.71 | $2.56 | $2.56 | $2.56 | $2.56 | $2.78 | $2.75 | $2.78 | $2.90 | $2.90 | $2.95 |
| | Kodiak | $2.89 | $2.74 | $2.59 | $2.49 | $2.49 | $2.59 | $2.69 | $2.69 | $2.73 | $2.89 | $2.77 | $2.79 |
| | Seattle | $2.29 | $2.16 | $2.01 | $2.09 | $2.27 | $2.40 | $2.40 | $2.44 | $2.71 | $2.59 | $2.70 | $2.70 |
| 2010 | Adak | $2.99 | $2.99 | n/d | $2.99 | $3.12 | $3.12 | $3.12 | $3.12 | $3.19 | $3.19 | $3.34 | $3.34 |
| | Dutch Harbor | $2.90 | $2.95 | $2.90 | $2.97 | $3.05 | $3.03 | $3.12 | $3.05 | $3.05 | $3.05 | $3.20 | $3.20 |
| | Kodiak | $2.79 | $2.95 | $2.89 | $2.99 | $3.14 | $3.09 | $3.00 | $2.99 | $2.99 | $3.02 | $3.15 | $3.14 |
| | Seattle | $2.82 | $2.68 | $2.75 | $2.95 | $3.15 | $2.91 | $2.77 | $2.89 | $2.99 | $2.90 | $3.12 | $3.07 |
| 2010 | Adak | $2.99 | $2.99 | NA | $2.99 | $3.12 | $3.12 | $3.12 | $3.12 | $3.19 | $3.19 | $3.34 | $3.34 |
| | Dutch Harbor | $2.90 | $2.95 | $2.90 | $2.97 | $3.05 | $3.03 | $3.12 | $3.05 | $3.05 | $3.05 | $3.20 | $3.20 |
| | Kodiak | $2.79 | $2.95 | $2.89 | $2.99 | $3.14 | $3.09 | $3.00 | $2.99 | $2.99 | $3.02 | $3.15 | $3.14 |
| | Seattle | $2.82 | $2.68 | $2.75 | $2.95 | $3.15 | $2.91 | $2.77 | $2.89 | $2.99 | $2.90 | $3.12 | $3.07 |
| 2011 | Adak | $3.34 | $3.51 | $3.69 | $3.99 | $4.29 | $4.14 | NA | $4.19 | $4.09 | $4.09 | $4.21 | $4.39 |
| | Dutch Harbor | $3.20 | $3.30 | $3.40 | $3.75 | $3.83 | $3.85 | $3.85 | $3.85 | $3.85 | $3.85 | $3.85 | $3.85 |
| | Kodiak | $3.14 | $3.24 | $3.28 | $3.75 | $3.83 | $3.91 | $3.87 | $3.88 | $3.82 | $3.88 | $3.86 | $3.88 |
| | Seattle | $3.16 | $3.33 | $3.75 | $3.95 | $4.04 | $3.94 | $3.65 | $3.75 | $3.96 | $3.66 | $3.75 | $3.68 |

*Source: Pacific States Marine Fisheries Commission. EFIN monthly marine fuel price data.* Data available at http://www.psmfc.org/efin/data/fuel.html#FUEL_AK.

Table 27: IFQ fisheries owner- and crew- type quota share holdings

| | | Owner QS | | | | Crew QS | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fishery | Season | QS holders | Mean holding in fishery-owner pool (sd) | Median holding | Max holding | QS holders | Mean holding in fishery-crew pool (sd) | Median holding | Max holding |
| BBR | Initial allocation | 252 | 0.40% (0.30) | 0.36% | 2.24% | 181 | 0.55% (0.21) | 0.52% | 1.23% |
| | 2010/2011 | 257 | 0.39% (0.44) | 0.29% | 4.93% | 140 | 0.71% (0.46) | 0.55% | 2.00% |
| | 2011/2012 | 257 | 0.39% (0.44) | 0.29% | 4.96% | 140 | 0.71% (0.47) | 0.55% | 2.00% |
| BSS | Initial allocation | 241 | 0.41% (0.32) | 0.39% | 2.35% | 155 | 0.65% (0.25) | 0.64% | 1.59% |
| | 2010/2011 | 259 | 0.39% (0.47) | 0.29% | 4.90% | 125 | 0.80% (0.46) | 0.69% | 1.99% |
| | 2011/2012 | 257 | 0.39% (0.48) | 0.30% | 4.94% | 125 | 0.80% (0.46) | 0.69% | 1.99% |
| EAG | Initial allocation | 15 | 6.67% (5.18) | 5.90% | 20.11% | 13 | 7.69% (3.28) | 8.20% | 12.79% |
| | 2010/2011 | 17 | 5.88% (5.14) | 4.45% | 20.00% | 10 | 10.00% (6.88) | 8.55% | 20.14% |
| | 2011/2012 | 17 | 5.88% (5.14) | 4.45% | 20.00% | 10 | 10.00% (6.88) | 8.55% | 20.14% |
| WAG | Initial allocation | 15 | 6.67% (12.38) | 1.78% | 45.73% | 9 | 11.11% (12.84) | 6.17% | 41.74% |
| | 2010/2011 | 15 | 6.67% (12.50) | 1.78% | 45.73% | 8 | 12.50% (13.37) | 7.45% | 41.74% |
| | 2011/2012 | 14 | 7.14% (12.96) | 1.69% | 45.73% | 8 | 12.50% (13.37) | 7.45% | 41.74% |
| EBT | Initial allocation | 256 | 0.39% (0.39) | 0.30% | 3.87% | 166 | 0.60% (0.34) | 0.56% | 1.99% |
| | 2010/2011 | 243 | 0.41% (0.49) | 0.28% | 4.92% | 149 | 0.67% (0.43) | 0.58% | 1.99% |
| | 2011/2012 | 245 | 0.41% (0.49) | 0.28% | 4.93% | 149 | 0.67% (0.43) | 0.58% | 1.99% |
| WBT | Initial allocation | 256 | 0.39% (0.39) | 0.30% | 3.87% | 166 | 0.60% (0.34) | 0.56% | 1.99% |
| | 2010/2011 | 244 | 0.41% (0.49) | 0.28% | 4.93% | 149 | 0.67% (0.43) | 0.58% | 1.99% |
| | 2011/2012 | 246 | 0.41% (0.49) | 0.27% | 4.94% | 149 | 0.67% (0.43) | 0.58% | 1.99% |
| SMB | Initial allocation | 137 | 0.73% (0.61) | 0.62% | 4.43% | 73 | 1.37% (0.44) | 1.35% | 3.10% |
| | 2010/2011 | 146 | 0.68% (0.63) | 0.53% | 4.81% | 68 | 1.47% (0.54) | 1.41% | 3.29% |
| | 2011/2012 | 145 | 0.69% (0.64) | 0.55% | 4.85% | 67 | 1.49% (0.57) | 1.42% | 3.29% |
| PIK | Initial allocation | 112 | 0.89% (0.85) | 0.53% | 3.41% | 40 | 2.50% (1.05) | 2.47% | 4.81% |
| | 2010/2011 | 117 | 0.85% (0.96) | 0.50% | 6.95% | 39 | 2.56% (1.17) | 2.60% | 4.81% |
| | 2011/2012 | 119 | 0.84% (0.93) | 0.50% | 6.96% | 39 | 2.56% (1.17) | 2.60% | 4.81% |
| WAI | Initial allocation | 30 | 3.33% (8.46) | 0.65% | 45.16% | 4 | 25.00% (17.29) | 20.84% | 49.46% |
| | 2010/2011 | 33 | 3.03% (8.11) | 0.62% | 45.16% | 4 | 25.00% (17.29) | 20.84% | 49.46% |
| | 2011/2012 | 36 | 2.78% (7.72) | 0.62% | 45.16% | 4 | 25.00% (17.29) | 20.84% | 49.46% |

*Source: NMFS RAM Division, Quota share holders files*
2010/2011 and 2011/2012 holdings as of season end.

Table 28: IFQ fisheries owner and crew quota share holdings by fishery and sector

| | | | Owner QS | | | | Crew QS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Quota type | Year | QS holders | Mean holding in fishery-owner-QS type pool (sd) | Median holding | Max holding | QS holders | Mean holding in fishery-crew-QS type pool (sd) | Median holding | Max holding |
| BBR | CV | Initial allocation | 242 | 0.41% (0.30) | 0.37% | 2.17% | 178 | 0.56% (0.22) | 0.52% | 1.17% |
| | | 2010/2011 | 250 | 0.40% (0.44) | 0.31% | 4.83% | 137 | 0.73% (0.47) | 0.56% | 2.07% |
| | | 2011/2012 | 250 | 0.40% (0.44) | 0.31% | 4.86% | 137 | 0.73% (0.48) | 0.56% | 2.07% |
| | CP | Initial allocation | 13 | 7.69% (5.52) | 8.40% | 21.62% | 8 | 12.50% (12.15) | 11.16% | 35.13% |
| | | 2010/2011 | 11 | 9.09% (6.67) | 7.03% | 21.62% | 9 | 11.11% (11.89) | 10.01% | 35.13% |
| | | 2011/2012 | 11 | 9.09% (6.67) | 7.03% | 21.62% | 9 | 11.11% (11.89) | 10.01% | 35.13% |
| BSS | CV | Initial allocation | 231 | 0.43% (0.32) | 0.41% | 2.58% | 152 | 0.66% (0.24) | 0.66% | 1.39% |
| | | 2010/2011 | 246 | 0.41% (0.44) | 0.32% | 4.34% | 123 | 0.81% (0.48) | 0.72% | 2.11% |
| | | 2011/2012 | 243 | 0.41% (0.44) | 0.33% | 4.37% | 123 | 0.81% (0.48) | 0.72% | 2.11% |
| | CP | Initial allocation | 14 | 7.14% (3.66) | 7.78% | 13.53% | 8 | 12.50% (7.31) | 11.79% | 27.11% |
| | | 2010/2011 | 19 | 5.26% (5.77) | 3.50% | 24.29% | 7 | 14.29% (9.52) | 11.33% | 33.82% |
| | | 2011/2012 | 22 | 4.55% (5.65) | 2.31% | 24.29% | 7 | 14.29% (9.52) | 11.33% | 33.82% |
| EAG | CV | Initial allocation | 13 | 7.69% (5.49) | 6.90% | 21.12% | 13 | 7.69% (3.28) | 8.20% | 12.79% |
| | | 2010/2011 | 15 | 6.67% (5.55) | 5.25% | 21.02% | 10 | 10.00% (6.88) | 8.55% | 20.14% |
| | | 2011/2012 | 15 | 6.67% (5.55) | 5.25% | 21.02% | 10 | 10.00% (6.88) | 8.55% | 20.14% |
| | CP | Initial allocation | 2 | 50.00% (48.92) | 50.00% | 84.59% | 0 | n/a | n/a | n/a |
| | | 2010/2011 | 2 | 50.00% (48.92) | 50.00% | 84.59% | 0 | n/a | n/a | n/a |
| | | 2011/2012 | 2 | 50.00% (48.92) | 50.00% | 84.59% | 0 | n/a | n/a | n/a |
| WAG | CV | Initial allocation | 13 | 7.69% (11.98) | 3.31% | 45.51% | 8 | 12.50% (10.75) | 9.67% | 37.75% |
| | | 2010/2011 | 12 | 8.33% (12.82) | 3.34% | 45.51% | 7 | 14.29% (11.66) | 10.96% | 37.75% |
| | | 2011/2012 | 11 | 9.09% (13.72) | 3.31% | 45.51% | 7 | 14.29% (11.66) | 10.96% | 37.75% |
| | CP | Initial allocation | 2 | 50.00% (69.21) | 50.00% | 98.94% | 2 | 50.00% (68.14) | 50.00% | 98.19% |
| | | 2010/2011 | 3 | 33.33% (56.81) | 1.06% | 98.93% | 2 | 50.00% (68.14) | 50.00% | 98.19% |
| | | 2011/2012 | 3 | 33.33% (56.81) | 1.06% | 98.93% | 2 | 50.00% (68.14) | 50.00% | 98.19% |

Table continues on next page.

Table 28 cont.

| | | | Owner QS | | | | Crew QS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fishery | Quota type | Year | QS holders | Mean holding in fishery-owner-QS type pool (sd) | Median holding | Max holding | QS holders | Mean holding in fishery-crew-QS type pool (sd) | Median holding | Max holding |
| EBT | CV | Initial allocation | 246 | 0.41% (0.38) | 0.32% | 2.94% | 160 | 0.63% (0.38) | 0.58% | 2.08% |
| | | 2010/2011 | 235 | 0.43% (0.47) | 0.29% | 4.50% | 143 | 0.70% (0.48) | 0.61% | 2.17% |
| | | 2011/2012 | 237 | 0.42% (0.47) | 0.29% | 4.51% | 143 | 0.70% (0.48) | 0.61% | 2.17% |
| | CP | Initial allocation | 13 | 7.69% (5.11) | 6.97% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| | | 2010/2011 | 13 | 7.69% (5.21) | 6.39% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| | | 2011/2012 | 13 | 7.69% (5.21) | 6.39% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| WBT | CV | Initial allocation | 246 | 0.41% (0.38) | 0.32% | 2.94% | 160 | 0.63% (0.38) | 0.58% | 2.08% |
| | | 2010/2011 | 236 | 0.42% (0.47) | 0.29% | 4.52% | 143 | 0.70% (0.48) | 0.61% | 2.17% |
| | | 2011/2012 | 238 | 0.42% (0.47) | 0.29% | 4.53% | 143 | 0.70% (0.48) | 0.61% | 2.17% |
| | CP | Initial allocation | 13 | 7.69% (5.11) | 6.97% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| | | 2010/2011 | 13 | 7.69% (5.21) | 6.39% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| | | 2011/2012 | 13 | 7.69% (5.21) | 6.39% | 16.79% | 15 | 6.67% (4.74) | 5.37% | 18.32% |
| SMB | CV | Initial allocation | 133 | 0.75% (0.62) | 0.65% | 4.52% | 73 | 1.37% (0.44) | 1.35% | 3.10% |
| | | 2010/2011 | 142 | 0.70% (0.65) | 0.55% | 4.90% | 68 | 1.47% (0.54) | 1.41% | 3.29% |
| | | 2011/2012 | 141 | 0.71% (0.66) | 0.56% | 4.95% | 67 | 1.49% (0.57) | 1.42% | 3.29% |
| | CP | Initial allocation | 5 | 20.00% (13.24) | 15.46% | 43.40% | 0 | n/a | n/a | n/a |
| | | 2010/2011 | 5 | 20.00% (13.24) | 15.46% | 43.40% | 0 | n/a | n/a | n/a |
| | | 2011/2012 | 5 | 20.00% (13.24) | 15.46% | 43.40% | 0 | n/a | n/a | n/a |
| PIK | CV | Initial allocation | 111 | 0.90% (0.86) | 0.55% | 3.42% | 40 | 2.50% (1.05) | 2.47% | 4.81% |
| | | 2010/2011 | 116 | 0.86% (0.97) | 0.50% | 6.98% | 39 | 2.56% (1.17) | 2.60% | 4.81% |
| | | 2011/2012 | 118 | 0.85% (0.94) | 0.50% | 6.99% | 39 | 2.56% (1.17) | 2.60% | 4.81% |
| | CP | Initial allocation | 1 | 100.00% (0.00) | 100.00% | 100.00% | 0 | n/a | n/a | n/a |
| | | 2010/2011 | 1 | 100.00% (0.00) | 100.00% | 100.00% | 0 | n/a | n/a | n/a |
| | | 2011/2012 | 1 | 100.00% (0.00) | 100.00% | 100.00% | 0 | n/a | n/a | n/a |
| WAI | CV | Initial allocation | 29 | 3.45% (5.32) | 1.01% | 22.09% | 4 | 25.00% (22.34) | 16.53% | 57.26% |
| | | 2010/2011 | 32 | 3.13% (5.16) | 0.88% | 22.09% | 4 | 25.00% (22.34) | 16.53% | 57.26% |
| | | 2011/2012 | 35 | 2.86% (4.61) | 1.01% | 18.78% | 4 | 25.00% (22.34) | 16.53% | 57.26% |
| | CP | Initial allocation | 2 | 50.00% (66.26) | 50.00% | 96.86% | 1 | 100.00% (0.00) | 100.00% | 100.00% |
| | | 2010/2011 | 2 | 50.00% (66.26) | 50.00% | 96.86% | 1 | 100.00% (0.00) | 100.00% | 100.00% |
| | | 2011/2012 | 2 | 50.00% (66.26) | 50.00% | 96.86% | 1 | 100.00% (0.00) | 100.00% | 100.00% |

*Source: NMFS RAM Division, Quota share holders files*
2010/2011 and 2011/2012 holdings as of season end.

Table 29: IFQ fisheries crew –type quota share holdings by active gear operators

| Quota type | | Season | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2005/2006 | 2006/2007 | 2007/2008 | 2008/2009 | 2009/2010 | 2010/2011 | 2011/2012 |
| CVC | Total QS holders at season end | 218 | 208 | 205 | 200 | 201 | 198 | 197 |
| | QS holders active as gear operators during season | 94 | 81 | 83 | 80 | 72 | 70 | 71 |
| | % QS holders active as gear operators during season | 43% | 39% | 40% | 40% | 36% | 35% | 36% |
| | % season-end quota pool held by active gear operators | 53% | 51% | 51% | 49% | 49% | 47% | 45% |
| CPC | Total QS holders at season end | 24 | 24 | 24 | 24 | 25 | 27 | 28 |
| | QS holders active as gear operators during season | 13 | 10 | 12 | 13 | 9 | 12 | 12 |
| | % QS holders active as gear operators during season | 54% | 42% | 50% | 54% | 36% | 44% | 43% |
| | % season-end quota pool held by active gear operators | 69% | 69% | 60% | 60% | 43% | 51% | 51% |
| CVC+CPC | Total QS holders at season end | 224 | 214 | 211 | 206 | 207 | 204 | 203 |
| | QS holders active as gear operators during season | 95 | 82 | 84 | 82 | 72 | 71 | 72 |
| | % QS holders active as gear operators during season | 42% | 38% | 40% | 40% | 35% | 35% | 35% |
| | % season-end quota pool held by active gear operators | 54% | 52% | 51% | 50% | 49% | 48% | 46% |

*Source: NMFS RAM Division, Quota share holders files and IFQ accounting data; ADF&G fish tickets via eLandings.* Active gear operators are those who made landings of any CR-program crab (including landings on IFQ, CDQ, and ACA permits), irrespective of fishery, during the given season. Data show gear operators active during the season and holding crew-type quota share (CVC, CPC) at season end.

Table 30: IFQ fisheries processor quota share holdings by fishery

| Fishery | Year | PQS holders | Mean holding of fishery PQS pool (sd) | Median holding | Max holding |
|---|---|---|---|---|---|
| BBR | Initial allocation | 17 | 5.88% (7.07) | 1.64% | 22.98% |
| | 2011/2012 | 16 | 6.25% (6.50) | 4.39% | 22.98% |
| | 2010/2011 | 16 | 6.25% (6.50) | 4.39% | 22.98% |
| BSS | Initial allocation | 20 | 5.00% (6.73) | 2.08% | 25.18% |
| | 2010/2011 | 19 | 5.26% (6.81) | 3.42% | 25.18% |
| | 2011/2012 | 19 | 5.26% (6.81) | 3.42% | 25.18% |
| EAG | Initial allocation | 9 | 11.11% (15.37) | 3.55% | 45.36% |
| | 2011/2012 | 10 | 10.00% (13.84) | 5.24% | 45.36% |
| | 2010/2011 | 10 | 10.00% (13.84) | 5.24% | 45.36% |
| WAG | Initial allocation | 9 | 11.11% (21.23) | 1.03% | 62.98% |
| | 2011/2012 | 10 | 10.00% (12.04) | 3.41% | 29.98% |
| | 2010/2011 | 10 | 10.00% (12.04) | 3.41% | 29.98% |
| EBT | Initial allocation | 23 | 4.35% (6.51) | 0.83% | 24.26% |
| | 2010/2011 | 21 | 4.76% (6.51) | 1.85% | 24.26% |
| | 2011/2012 | 21 | 4.76% (6.51) | 1.85% | 24.26% |
| WBT | Initial allocation | 23 | 4.35% (6.51) | 0.83% | 24.26% |
| | 2011/2012 | 21 | 4.76% (6.51) | 1.85% | 24.26% |
| | 2010/2011 | 21 | 4.76% (6.51) | 1.85% | 24.26% |
| SMB | Initial allocation | 12 | 8.33% (10.56) | 5.06% | 32.67% |
| | 2010/2011 | 10 | 10.00% (10.87) | 6.87% | 32.67% |
| | 2011/2012 | 10 | 10.00% (10.87) | 6.87% | 32.67% |
| PIK | Initial allocation | 14 | 7.14% (8.09) | 3.17% | 24.49% |
| | 2011/2012 | 13 | 7.69% (8.19) | 3.87% | 24.49% |
| | 2010/2011 | 13 | 7.69% (8.19) | 3.87% | 24.49% |
| WAI | Initial allocation | 9 | 11.11% (21.23) | 1.03% | 62.98% |
| | 2011/2012 | 8 | 12.50% (14.67) | 4.03% | 32.99% |
| | 2010/2011 | 8 | 12.50% (14.67) | 4.03% | 32.99% |

*Source: NMFS RAM Division, Processor quota share holders files*
2010/2011 and 2011/2012 holdings as of season end.

Table 31: IFQ fisheries CDQ/ACA group direct holdings of quota share and processor quota share

| | | CP QS | | CV QS | | All QS | | PQS | |
|---|---|---|---|---|---|---|---|---|---|
| Fishery | Year | CDQ groups | Share of fishery CP QS held | CDQ groups | Share of fishery CV QS held | CDQ groups | Share of fishery QS held | CDQ groups | Share of fishery PQS held |
| BBR | Initial allocation | 1 | 4.29% | 3 | 1.99% | 4 | 2.09% | 0 | 0.00% |
| | 2010/2011 | 3 | 21.55% | 5 | 11.06% | 5 | 11.53% | 2 | 3.92% |
| | 2011/2012 | 3 | 21.55% | 5 | 11.12% | 5 | 11.59% | 2 | 3.92% |
| BSS | Initial allocation | 1 | 3.86% | 3 | 2.13% | 4 | 2.29% | 0 | 0.00% |
| | 2010/2011 | 3 | 27.38% | 5 | 11.21% | 5 | 12.67% | 3 | 11.51% |
| | 2011/2012 | 3 | 27.38% | 6 | 11.51% | 6 | 12.95% | 3 | 11.51% |
| EAG | Initial allocation | 0 | 0.00% | 1 | 6.00% | 1 | 5.72% | 0 | 0.00% |
| | 2010/2011 | 0 | 0.00% | 3 | 29.17% | 3 | 27.80% | 2 | 8.16% |
| | 2011/2012 | 0 | 0.00% | 3 | 29.17% | 3 | 27.80% | 2 | 8.16% |
| WAG | Initial allocation | 0 | 0.00% | 1 | 2.35% | 1 | 1.27% | 0 | 0.00% |
| | 2010/2011 | 0 | 0.00% | 3 | 23.81% | 3 | 12.83% | 1 | 29.98% |
| | 2011/2012 | 0 | 0.00% | 3 | 27.83% | 3 | 15.00% | 1 | 29.98% |
| EBT | Initial allocation | 1 | 3.39% | 3 | 2.04% | 4 | 2.13% | 0 | 0.00% |
| | 2010/2011 | 3 | 26.52% | 5 | 9.82% | 5 | 10.95% | 2 | 7.74% |
| | 2011/2012 | 3 | 26.52% | 6 | 9.93% | 6 | 11.06% | 2 | 7.74% |
| WBT | Initial allocation | 1 | 3.39% | 3 | 2.04% | 4 | 2.13% | 0 | 0.00% |
| | 2010/2011 | 3 | 26.52% | 5 | 9.83% | 5 | 10.96% | 2 | 7.74% |
| | 2011/2012 | 3 | 26.52% | 6 | 9.95% | 6 | 11.07% | 2 | 7.74% |
| SMB | Initial allocation | 0 | 0.00% | 3 | 2.46% | 3 | 2.41% | 0 | 0.00% |
| | 2010/2011 | 0 | 0.00% | 4 | 8.50% | 4 | 8.33% | 2 | 5.90% |
| | 2011/2012 | 0 | 0.00% | 4 | 8.58% | 4 | 8.41% | 2 | 5.90% |
| PIK | Initial allocation | 0 | 0.00% | 2 | 2.52% | 2 | 2.51% | 0 | 0.00% |
| | 2010/2011 | 0 | 0.00% | 5 | 12.16% | 5 | 12.10% | 1 | 2.46% |
| | 2011/2012 | 0 | 0.00% | 5 | 12.18% | 5 | 12.12% | 1 | 2.46% |
| WAI | Initial allocation | 0 | 0.00% | 1 | 0.16% | 1 | 0.10% | 0 | 0.00% |
| | 2010/2011 | 0 | 0.00% | 4 | 3.81% | 4 | 2.35% | 0 | 0.00% |
| | 2011/2012 | 0 | 0.00% | 4 | 3.81% | 4 | 2.35% | 0 | 0.00% |

*Source: NMFS RAM Division, Processor quota share holders files and Quota share holders files*

2010/2011 and 2011/2012 holdings as of season end. Includes QS and PQS held by wholly-owned direct subsidiaries of CDQ groups.

## Table 32: IFQ fisheries initial QS/PQs issuees with holdings at season end

| Fishery | Sector | Initial issuance | 09/10 | 10/11 | *Net change from initial issuance* | *Net change from 09/10-10/11* |
|---|---|---|---|---|---|---|
| BBR | CPC | 8 | 7 | 7 | *-1* | *0* |
| | CPO | 13 | 9 | 9 | *-4* | *0* |
| | CVC | 178 | 122 | 120 | *-58* | *-2* |
| | CVO | 241 | 197 | 196 | *-45* | *-1* |
| | *Unique harvesting QS holders* | 424 | 319 | 315 | *-109* | *-4* |
| | Processing | 17 | 11 | 11 | *-6* | *0* |
| BSS | CPC | 8 | 7 | 7 | *-1* | *0* |
| | CPO | 14 | 11 | 12 | *-2* | *1* |
| | CVC | 152 | 108 | 106 | *-46* | *-2* |
| | CVO | 231 | 190 | 188 | *-43* | *-2* |
| | *Unique harvesting QS holders* | 388 | 296 | 289 | *-99* | *-7* |
| | Processing | 20 | 14 | 14 | *-6* | *0* |
| BST | CPC | 15 | n/a | n/a | *n/a* | *n/a* |
| | CPO | 14 | n/a | n/a | *n/a* | *n/a* |
| | CVC | 170 | n/a | n/a | *n/a* | *n/a* |
| | CVO | 248 | n/a | n/a | *n/a* | *n/a* |
| | *Unique harvesting QS holders* | 425 | n/a | n/a | *n/a* | *n/a* |
| | Processing | 23 | n/a | n/a | *n/a* | *n/a* |
| BTE | CPC | n/a | 15 | 15 | *0* | *0* |
| | CPO | n/a | 10 | 10 | *-4* | *0* |
| | CVC | n/a | 129 | 127 | *-43* | *-2* |
| | CVO | n/a | 196 | 191 | *-57* | *-5* |
| | *Unique harvesting QS holders* | n/a | 327 | 320 | *-105* | *-7* |
| | Processing | n/a | 17 | 17 | *-6* | *0* |
| BTW | CPC | n/a | 15 | 15 | *0* | *0* |
| | CPO | n/a | 10 | 10 | *-4* | *0* |
| | CVC | n/a | 129 | 127 | *-43* | *-2* |
| | CVO | n/a | 197 | 192 | *-56* | *-5* |
| | *Unique harvesting QS holders* | n/a | 328 | 321 | *-104* | *-7* |
| | Processing | n/a | 17 | 17 | *-6* | *0* |
| EAG | CPO | 2 | 1 | 1 | *-1* | *0* |
| | CVC | 13 | 10 | 9 | *-4* | *-1* |
| | CVO | 13 | 12 | 12 | *-1* | *0* |
| | *Unique harvesting QS holders* | 28 | 23 | 22 | *-6* | *-1* |
| | Processing | 9 | 7 | 7 | *-2* | *0* |
| PIK | CPO | 1 | 1 | 1 | *0* | *0* |
| | CVC | 40 | 39 | 39 | *-1* | *0* |
| | CVO | 111 | 101 | 98 | *-13* | *-3* |
| | Unique harvesting QS holders | 147 | 135 | 132 | *-15* | *-3* |
| | *Processing* | 14 | 11 | 11 | *-3* | *0* |
| SMB | CPO | 5 | 5 | 5 | *0* | *0* |
| | CVC | 72 | 62 | 61 | *-11* | *-1* |
| | CVO | 131 | 110 | 107 | *-24* | *-3* |
| | Unique harvesting QS holders | 207 | 174 | 170 | *-37* | *-4* |
| | Processing | 12 | 7 | 7 | *-5* | *0* |
| WAG | *CPC* | 2 | 1 | 1 | *-1* | *0* |
| | CPO | 2 | 1 | 1 | *-1* | *0* |
| | CVC | 8 | 6 | 6 | *-2* | *0* |
| | CVO | 13 | 10 | 10 | *-3* | *0* |
| | Unique harvesting QS holders | 24 | 18 | 18 | *-6* | *0* |
| | *Processing* | 9 | 6 | 6 | *-3* | *0* |
| WAI | CPC | 1 | 1 | 1 | *0* | *0* |
| | CPO | 2 | 2 | 2 | *0* | *0* |
| | CVC | 4 | 4 | 4 | *0* | *0* |
| | CVO | 29 | 28 | 28 | *-1* | *0* |
| | *Unique harvesting QS holders* | 34 | 33 | 33 | *-1* | *0* |
| | Processing | 9 | 5 | 5 | *-4* | *0* |
| Unique QS/PQS holders across all fisheries | | 510 | 422 | 413 | *-97* | *-9* |

*Source: NMFS RAM Division. Bering Sea and Aleutian Islands Crab Rationalization Program Report, 2010/2011.* Initial issuees were issued BST quota; eastern and western BST quota (BTE, BTW) was issued in subsequent seasons. For BTE and BTW, net change from initial issuance shows the difference between initial quota holders in BTE or BTW in 2009/2010 and initial quota holders in BST at initial issuance.

Table 33: IFQ fisheries quota share transfers and quota leases across all fisheries

| Sector | Transfer type | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| Harvest | Cooperative lease | 144 | 269 | 302 | 301 | 226 | 268 | 180 |
| | Noncooperative lease | 113 | 39 | 16 | 0 | 0 | 0 | 4 |
| | QS | 199 | 329 | 292 | 209 | 222 | 192 | 126 |
| Processing | PQS lease | 40 | 39 | 32 | 45 | 31 | 25 | 28 |
| | PQS | 7 | 7 | 12 | 42 | 4 | 0 | 0 |

*Source: NMFS RAM Division. Bering Sea and Aleutian Islands Crab Rationalization Program Report, 2011/2012.* Data preliminary as of September 2012.

Table 34: IFQ fisheries estimated weighted mean price per crab quota unit for QS and PQS transfers (nominal value)

| | | CVC QS | | CVO QS | | PQS | |
|---|---|---|---|---|---|---|---|
| Fishery | Year | Transfers of CVC QS | Weighted average price per QS unit | Transfers of CVO QS | Weighted average price per QS unit | Transfers of PQS | Weighted average price per QS unit |
| BBR | 2005/2006 | 21 | $0.72 | 14 | $0.56 | 0 | N/A |
| | 2006/2007 | 24 | $0.68 | 27 | $1.20 | 0 | N/A |
| | 2007/2008 | 10 | $0.65 | 21 | $1.17 | 0 | N/A |
| | 2008/2009 | 9 | $0.80 | 25 | $1.16 | 4 | $0.12 |
| | 2009/2010 | 9 | $0.75 | 12 | $0.90 | 0 | N/A |
| | 2010/2011 | 5 | $0.62 | 33 | $0.62 | 0 | N/A |
| | 2011/2012 | 0 | N/A | 3 | $0.82 | 0 | N/A |
| BSS | 2005/2006 | 25 | $0.24 | 22 | $0.39 | 0 | N/A |
| | 2006/2007 | 35 | $0.19 | 36 | $0.26 | 0 | N/A |
| | 2007/2008 | 12 | $0.26 | 26 | $0.47 | 0 | N/A |
| | 2008/2009 | 10 | $0.42 | 15 | $0.53 | 0 | N/A |
| | 2009/2010 | 15 | $0.28 | 14 | $0.34 | 0 | N/A |
| | 2010/2011 | 11 | $0.35 | 56 | $0.44 | 0 | N/A |
| | 2011/2012 | 0 | N/A | 21 | $0.64 | 0 | N/A |
| BST | 2005/2006 | 14 | $0.19 | 10 | $0.29 | 0 | N/A |
| | 2006/2007 | 3 | $0.11 | 0 | N/A | 0 | N/A |
| EAG | 2008/2009 | 4 | $2.62 | 0 | N/A | 0 | N/A |
| EBT | 2006/2007 | 17 | $0.05 | 17 | $0.07 | 0 | N/A |
| | 2007/2008 | 5 | $0.07 | 9 | $0.26 | 0 | N/A |
| | 2008/2009 | 4 | $0.10 | 14 | $0.14 | 5 | $0.01 |
| | 2009/2010 | 0 | N/A | 5 | $0.06 | 0 | N/A |
| | 2010/2011 | 3 | $0.02 | 0 | N/A | 0 | N/A |
| SMB | 2006/2007 | 4 | $0.17 | 0 | N/A | 0 | N/A |
| | 2007/2008 | 0 | N/A | 10 | $0.35 | 0 | N/A |
| WAG | 2008/2009 | 0 | N/A | 0 | N/A | 8 | $0.07 |
| WBT | 2006/2007 | 16 | $0.03 | 22 | $0.08 | 0 | N/A |
| | 2007/2008 | 5 | $0.04 | 8 | $0.08 | 0 | N/A |
| | 2008/2009 | 4 | $0.07 | 14 | $0.10 | 5 | $0.01 |
| | 2009/2010 | 0 | N/A | 5 | $0.03 | 0 | N/A |
| | 2010/2011 | 3 | $0.02 | 0 | N/A | 0 | N/A |

*Source: NMFS RAM Division. Bering Sea and Aleutian Islands Crab Rationalization Program Report, 2011/2012.* Data preliminary as of September 2012.

Table 35: IFQ fisheries new holders of QS and PQS relative to initial allocation and 2010/2011 season end

| | | Owner QS | | | | Crew QS | | | | PQS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | New holder of owner QS in fishery | | New holder of owner QS, all fisheries | | New holder of crew QS in fishery | | New holder of crew QS, all fisheries | | New holder of PQS in fishery | | New holder of PQS in all fisheries | |
| Fishery | Relative to | Entrants | Share of fishery owner QS pool acquired | Entrants | Share of fishery owner QS pool acquired | Entrants | Share of fishery crew QS pool acquired | Entrants | Share of fishery crew QS pool acquired | Entrants | Share of fishery PQS pool acquired | Entrants | Share of fishery PQS pool acquired |
| BBR | Initial allocation | 67 | 22% | 55 | 19% | 21 | 18% | 13 | 12% | 6 | 23% | 5 | 22% |
| | 2010 season end | 6 | 2% | 4 | 1% | 2 | 2% | 1 | 2% | 0 | 0% | 0 | 0% |
| BSS | Initial allocation | 74 | 21% | 63 | 18% | 19 | 14% | 13 | 10% | 6 | 20% | 5 | 20% |
| | 2010 season end | 10 | 1% | 10 | 1% | 1 | 1% | 1 | 1% | 0 | 0% | 0 | 0% |
| EAG | Initial allocation | 7 | 42% | 4 | 39% | 4 | 23% | 1 | 13% | 4 | 20% | 3 | 20% |
| | 2010 season end | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| WAG | Initial allocation | 4 | 15% | 4 | 15% | 2 | 18% | 1 | 12% | 4 | 53% | 3 | 53% |
| | 2010 season end | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| EBT | Initial allocation | 44 | 17% | 44 | 17% | 11 | 6% | 10 | 6% | 5 | 11% | 4 | 11% |
| | 2010 season end | 7 | 1% | 4 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| WBT | Initial allocation | 44 | 17% | 44 | 17% | 11 | 6% | 10 | 6% | 5 | 11% | 4 | 11% |
| | 2010 season end | 7 | 1% | 4 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| SMB | Initial allocation | 40 | 22% | 30 | 15% | 12 | 20% | 5 | 10% | 4 | 14% | 3 | 6% |
| | 2010 season end | 4 | 1% | 2 | 1% | 1 | 3% | 1 | 3% | 0 | 0% | 0 | 0% |
| PIK | Initial allocation | 29 | 27% | 19 | 21% | 3 | 10% | 0 | 0% | 2 | 16% | 1 | 2% |
| | 2010 season end | 4 | 5% | 2 | 1% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| WAI | Initial allocation | 12 | 18% | 7 | 5% | 0 | 0% | 0 | 0% | 3 | 62% | 2 | 35% |
| | 2010 season end | 4 | 14% | 2 | 2% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |

*Source: NMFS RAM Division, Processor quota share holders files and Quota share holders files*
Quota holdings as of 2011/2012 season end.

## Table 36: IFQ fisheries landings by season

| Fishery | Season | IFQ permit holders | RCR permit holders | Landings | IFQ lbs ($10^6$) | Sold lbs ($10^6$) | Personal use lbs ($10^3$) | Deadloss lbs ($10^3$) |
|---|---|---|---|---|---|---|---|---|
| BBR | 2005/2006 | 83 | 13 | 255 | 16.5 | 16.4 | 18.4 | 77.5 |
| | 2006/2007 | 36 | 13 | 183 | 13.9 | 13.8 | 10.3 | 98.7 |
| | 2007/2008 | 27 | 17 | 246 | 18.3 | 18.2 | 33.8 | 132 |
| | 2008/2009 | 25 | 16 | 252 | 18.3 | 18.1 | 21 | 160.8 |
| | 2009/2010 | 13 | 14 | 212 | 14.4 | 14.2 | 20.8 | 111.5 |
| | 2010/2011 | 10 | 14 | 223 | 13.3 | 13.2 | 25.9 | 99.5 |
| | 2011/2012 | 10 | 15 | 254 | 7.1 | 7 | 15.1 | 30.2 |
| BSS | 2005/2006 | 70 | 13 | 301 | 33.3 | 32.9 | 0.7 | 322.6 |
| | 2006/2007 | 30 | 16 | 272 | 32.7 | 32.3 | 0.3 | 378.8 |
| | 2007/2008 | 25 | 17 | 459 | 56.7 | 56.2 | 6.5 | 500.1 |
| | 2008/2009 | 24 | 15 | 428 | 52.7 | 52.3 | 0.6 | 403.3 |
| | 2009/2010 | 12 | 11 | 321 | 43.2 | 42.7 | 1.8 | 500 |
| | 2010/2011 | 10 | 14 | 466 | 48.8 | 48.5 | 3.3 | 314 |
| | 2011/2012 | 11 | 14 | 798 | 79.9 | 79.4 | 5.4 | 582.4 |
| BST | 2005/2006 | 34 | 9 | 73 | 0.8 | 0.8 | 2.9 | 14.6 |
| EBT | 2006/2007 | 21 | 10 | 57 | 1.3 | 1.3 | 0.7 | 8.4 |
| | 2007/2008 | 10 | 8 | 58 | 1.4 | 1.4 | 0.1 | 15.6 |
| | 2008/2009 | 10 | 10 | 60 | 1.6 | 1.5 | 0.8 | 11.9 |
| | 2009/2010 | 8 | 12 | 45 | 1.2 | 1.2 | 3.5 | 7.1 |
| WBT | 2006/2007 | 14 | 10 | 60 | 0.6 | 0.6 | 0 | 18.5 |
| | 2007/2008 | 8 | 8 | 44 | 0.5 | 0.5 | 1.1 | 4.1 |
| | 2008/2009 | 10 | 7 | 50 | 0.1 | 0.1 | 0.1 | 2.6 |
| | 2009/2010 | 4 | 1 | 22 | -- | -- | -- | -- |
| EAG | 2005/2006 | 6 | 5 | 32 | 2.6 | 2.5 | 0.1 | 23.8 |
| | 2006/2007 | 4 | 6 | 32 | 2.7 | 2.7 | 0 | 31.3 |
| | 2007/2008 | 4 | 4 | 36 | 2.7 | 2.7 | 0 | 21 |
| | 2008/2009 | 3 | 5 | 29 | 2.8 | 2.8 | 0 | 24.1 |
| | 2009/2010 | 2 | 6 | 32 | -- | -- | -- | -- |
| | 2010/2011 | 2 | 7 | 30 | -- | -- | -- | -- |
| | 2011/2012 | 2 | 9 | 45 | -- | -- | -- | -- |
| WAG | 2005/2006 | 3 | 5 | 42 | 2.4 | 2.4 | 3.5 | 26.3 |
| | 2006/2007 | 3 | 5 | 31 | 2 | 2 | 0 | 19.8 |
| | 2007/2008 | 3 | 4 | 34 | 2.2 | 2.2 | 0 | 23.2 |
| | 2008/2009 | 3 | 7 | 37 | 2.3 | 2.2 | 0.2 | 22.8 |
| | 2009/2010 | 2 | 5 | 38 | -- | -- | -- | -- |
| | 2010/2011 | 2 | 7 | 37 | -- | -- | -- | -- |
| | 2011/2012 | 2 | 7 | 43 | -- | -- | -- | -- |
| SMB | 2009/2010 | 1 | 6 | 30 | -- | -- | -- | -- |
| | 2010/2011 | 2 | 8 | 63 | -- | -- | -- | -- |
| | 2011/2012 | 6 | 10 | 107 | 1.7 | 1.7 | 2.9 | 25.6 |

*Source: NMFS RAM Division IFQ accounting database.*

Excludes harvest from CDQ programs. A landing is an offload by a vessel to a registered crab receiver, and includes at sea landings on catcher processors and stationary floating processors. A fishing cooperative and its members are counted as a single IFQ permit holder.

## Table 37: CR program fisheries fleet harvest statistics by calendar year

| Fishery | Year | Vessels | Sold weight, $10^6$ lbs | Mean vessel harvest: Sold weight, $10^3$ lbs (sd) | Mean vessel harvest: as percent of fishery-year commercial lbs (sd) | Median vessel harvest: Sold weight, $10^3$ lbs | Median vessel harvest: as percent of fishery-year commercial lbs | Gini ratio |
|---|---|---|---|---|---|---|---|---|
| AIG | 1998 | 16 | 5.44 | 340 (272) | 6.25% (5.01) | 302.09 | 5.55% | 0.42 |
| | 1999 | 16 | 5.1 | 319 (267) | 6.25% (5.23) | 249.34 | 4.89% | 0.42 |
| | 2000 | 17 | 5.95 | 350 (303) | 5.88% (5.09) | 228.92 | 3.85% | 0.45 |
| | 2001 | 21 | 6.38 | 304 (275) | 4.76% (4.31) | 209.56 | 3.28% | 0.47 |
| | 2002 | 22 | 5.54 | 252 (238) | 4.55% (4.30) | 167.04 | 3.02% | 0.46 |
| | 2003 | 21 | 5.82 | 277 (274) | 4.76% (4.71) | 189.45 | 3.26% | 0.45 |
| | 2004 | 22 | 6.02 | 274 (298) | 4.55% (4.94) | 168.79 | 2.80% | 0.49 |
| | 2005 | 9 | 4.44 | 493 (257) | 11.11% (5.79) | 595.27 | 13.42% | 0.31 |
| | 2006 | 7 | 5.24 | 749 (429) | 14.29% (8.18) | 623.29 | 11.89% | 0.34 |
| | 2007 | 6 | 5.44 | 907 (515) | 16.67% (9.46) | 755.96 | 13.90% | 0.34 |
| | 2008 | 5 | 5.73 | 1145 (371) | 20.00% (6.48) | 1246.72 | 21.77% | 0.18 |
| | 2009 | 5 | 5.51 | 1102 (365) | 20.00% (6.62) | 1109.87 | 20.13% | 0.19 |
| | 2010 | 5 | 6.09 | 1218 (421) | 20.00% (6.91) | 1410.32 | 23.15% | 0.2 |
| | 2011 | 5 | 6 | 1199 (424) | 20.00% (7.07) | 1324.31 | 22.09% | 0.21 |
| BBR | 1998 | 273 | 14.67 | 54 (30) | 0.37% (0.20) | 49.36 | 0.34% | 0.3 |
| | 1999 | 256 | 11.53 | 45 (28) | 0.39% (0.24) | 37.92 | 0.33% | 0.29 |
| | 2000 | 244 | 8.07 | 33 (20) | 0.41% (0.24) | 28.46 | 0.35% | 0.31 |
| | 2001 | 230 | 8.3 | 36 (24) | 0.43% (0.29) | 29.26 | 0.35% | 0.34 |
| | 2002 | 241 | 9.48 | 39 (21) | 0.41% (0.22) | 36.09 | 0.38% | 0.24 |
| | 2003 | 250 | 15.39 | 62 (43) | 0.40% (0.28) | 48.19 | 0.31% | 0.35 |
| | 2004 | 251 | 15.02 | 60 (34) | 0.40% (0.23) | 53.79 | 0.36% | 0.28 |
| | 2005 | 89 | 18.14 | 204 (143) | 1.12% (0.79) | 177.99 | 0.98% | 0.37 |
| | 2006 | 81 | 15.55 | 192 (124) | 1.23% (0.80) | 169.27 | 1.09% | 0.35 |
| | 2007 | 73 | 20.17 | 276 (173) | 1.37% (0.86) | 259.63 | 1.29% | 0.32 |
| | 2008 | 79 | 20.13 | 255 (142) | 1.27% (0.70) | 240.73 | 1.20% | 0.31 |
| | 2009 | 70 | 15.78 | 225 (104) | 1.43% (0.66) | 209.29 | 1.33% | 0.26 |
| | 2010 | 65 | 14.73 | 227 (117) | 1.54% (0.80) | 214.69 | 1.46% | 0.28 |
| | 2011 | 62 | 7.79 | 126 (74) | 1.61% (0.95) | 109.07 | 1.40% | 0.3 |
| BSS | 1998 | 230 | 249.05 | 1083 (446) | 0.43% (0.18) | 1050.76 | 0.42% | 0.23 |
| | 1999 | 241 | 192.37 | 798 (356) | 0.41% (0.18) | 813.75 | 0.42% | 0.25 |
| | 2000 | 230 | 32.75 | 142 (74) | 0.43% (0.23) | 133.18 | 0.41% | 0.28 |
| | 2001 | 207 | 24.78 | 120 (102) | 0.48% (0.41) | 88.71 | 0.36% | 0.4 |
| | 2002 | 191 | 31.94 | 167 (98) | 0.52% (0.31) | 149.81 | 0.47% | 0.31 |
| | 2003 | 190 | 27.51 | 145 (79) | 0.53% (0.29) | 127.15 | 0.46% | 0.27 |
| | 2004 | 189 | 23.69 | 125 (64) | 0.53% (0.27) | 113.04 | 0.48% | 0.26 |
| | 2005 | 167 | 24.86 | 149 (71) | 0.60% (0.28) | 131.14 | 0.53% | 0.24 |
| | 2006 | 78 | 38.02 | 487 (365) | 1.28% (0.96) | 402.31 | 1.06% | 0.37 |
| | 2007 | 68 | 34.76 | 511 (334) | 1.47% (0.96) | 447.33 | 1.29% | 0.34 |
| | 2008 | 78 | 62.23 | 798 (466) | 1.28% (0.75) | 702.73 | 1.13% | 0.31 |
| | 2009 | 77 | 57.69 | 749 (448) | 1.30% (0.78) | 599.96 | 1.04% | 0.32 |
| | 2010 | 68 | 47.84 | 704 (436) | 1.47% (0.91) | 642.93 | 1.34% | 0.32 |
| | 2011 | 68 | 54.05 | 795 (437) | 1.47% (0.81) | 693.58 | 1.28% | 0.3 |
| BST | 2005 | 4 | 0.26 | 64 (41) | 25.00% (15.93) | -- | -- | 0.37 |
| | 2006 | 45 | 0.99 | 22 (36) | 2.22% (3.64) | 5.94 | 0.60% | 0.72 |
| | 2007 | 29 | 2.25 | 77 (74) | 3.45% (3.31) | 56.02 | 2.49% | 0.52 |
| | 2008 | 30 | 2.33 | 78 (127) | 3.33% (5.42) | 45.52 | 1.95% | 0.65 |
| | 2009 | 18 | 2.14 | 119 (163) | 5.56% (7.62) | 91.97 | 4.30% | 0.63 |
| | 2010 | 4 | 0.37 | 94 (37) | 25.00% (9.87) | -- | -- | 0.25 |

Table continues on next page.

Table 37 cont.

| Fishery | Year | Vessels | Sold weight, $10^6$ lbs | Mean vessel harvest: Sold weight, $10^3$ lbs (sd) | Mean vessel harvest: as percent of fishery-year commercial lbs (sd) | Median vessel harvest: Sold weight, $10^3$ lbs | Median vessel harvest: as percent of fishery-year commercial lbs | Gini ratio |
|---|---|---|---|---|---|---|---|---|
| SMB | 1998 | 131 | 2.95 | 23 (10) | 0.76% (0.33) | 20.54 | 0.70% | 0.34 |
| | 2009 | 7 | 0.45 | 64 (47) | 14.29% (10.45) | 33.85 | 7.52% | 0.22 |
| | 2010 | 11 | 1.25 | 114 (66) | 9.09% (5.27) | 117.3 | 9.36% | 0.42 |
| | 2011 | 18 | 1.85 | 103 (58) | 5.56% (3.15) | 80.15 | 4.33% | 0.34 |
| PIK | 1998 | 58 | 1.03 | 18 (11) | 1.72% (1.04) | 15.61 | 1.52% | 0.32 |
| WAI | 1998 | 1 | -- | -- (--) | -- | -- | -- | -- |
| | 2002 | 33 | 0.5 | 15 (8) | 3.03% (1.56) | 14.29 | 2.83% | 0.3 |
| | 2003 | 30 | 0.48 | 16 (10) | 3.33% (2.04) | 13.18 | 2.77% | 0.31 |

*Source: ADF&G fish tickets, eLandings*

Data shown by calendar year. Includes harvest from CDQ and IFQ fisheries and pre-rationalization general access fisheries, as well as landings and harvest made on catcher processors.

Table 38: CR program fisheries effort (pot lifts, CPUE, and RPUE) by season (2011 base year)

| | | | Pot lifts | | CPUE (# legal crab) | | RPUE ($) | |
|---|---|---|---|---|---|---|---|---|
| | Season | Vessels | Total, $10^3$ | Mean per vessel, $10^3$ (sd) | Weighted mean | Mean CPUE per vessel (sd) | Weighted mean | Mean RPUE per vessel (sd) |
| BBR | 1998 | 273 | 144.6 | 0.5 (0.2) | 15.2 | 15.3 (6.8) | $419 | $423 (186) |
| | 1999 | 257 | 150 | 0.6 (0.2) | 12.5 | 12.6 (6.1) | $726 | $728 (360) |
| | 2000 | 244 | 103.4 | 0.4 (0.1) | 12 | 11.9 (5.2) | $538 | $531 (233) |
| | 2001 | 230 | 66.2 | 0.3 (0.1) | 19.2 | 19.1 (10) | $897 | $895 (476) |
| | 2002 | 241 | 72.2 | 0.3 (0.1) | 20.4 | 20.6 (7.1) | $1,223 | $1235 (420) |
| | 2003 | 250 | 134.1 | 0.5 (0.2) | 18.4 | 18.2 (9.5) | $862 | $847 (441) |
| | 2004 | 251 | 96.3 | 0.4 (0.1) | 22.9 | 22.9 (9) | $1,023 | $1020 (390) |
| | 2005-2006 | 89 | 114.6 | 1.3 (1) | 23.7 | 28 (10.5) | $906 | $1064 (402) |
| | 2006-2007 | 81 | 71.7 | 0.9 (0.5) | 34 | 33.3 (9.9) | $954 | $934 (286) |
| | 2007-2008 | 74 | 113.1 | 1.5 (0.9) | 27.5 | 27.9 (7.2) | $918 | $931 (244) |
| | 2008-2009 | 78 | 139.7 | 1.8 (1.1) | 21.7 | 23.7 (7.1) | $814 | $888 (276) |
| | 2009-2010 | 70 | 118.4 | 1.7 (0.8) | 21.2 | 22.3 (5.9) | $701 | $734 (194) |
| | 2010-2011 | 65 | 131.4 | 2 (1) | 18.1 | 18.6 (5.1) | $871 | $896 (251) |
| BSS | 1999 | 241 | 945.1 | 3.9 (1.5) | 158.3 | 155.4 (42) | $301 | $297 (75) |
| | 2000 | 230 | 180.9 | 0.8 (0.3) | 136.4 | 138.8 (59.8) | $487 | $499 (222) |
| | 2001 | 207 | 191 | 0.9 (0.5) | 95.6 | 91.6 (48) | $303 | $290 (139) |
| | 2002 | 191 | 325.6 | 1.7 (0.8) | 75.6 | 76.2 (35.2) | $203 | $205 (95) |
| | 2003 | 190 | 153.7 | 0.8 (0.4) | 146.9 | 151.6 (62.9) | $484 | $501 (198) |
| | 2004 | 189 | 123.4 | 0.7 (0.4) | 149.6 | 156 (60.3) | $549 | $573 (215) |
| | 2005 | 168 | 72.9 | 0.4 (0.1) | 242.8 | 246.2 (87.9) | $786 | $798 (300) |
| | 2005-2006 | 78 | 119.5 | 1.5 (1.1) | 203.4 | 212.5 (71.8) | $430 | $447 (144) |
| | 2006-2007 | 69 | 85.3 | 1.2 (0.8) | 343 | 349.1 (74.7) | $788 | $814 (188) |
| | 2007-2008 | 78 | 141.2 | 1.8 (1) | 353.2 | 356.3 (78.8) | $848 | $855 (186) |
| | 2008-2009 | 77 | 163.3 | 2.1 (1.3) | 279.1 | 284.7 (70.5) | $569 | $580 (148) |
| | 2009-2010 | 69 | 136.8 | 2 (1.1) | 255 | 255.8 (55.6) | $479 | $481 (99) |
| | 2010-2011 | 68 | 147.2 | 2.2 (1.1) | 254.9 | 255.3 (51.4) | $781 | $782 (158) |
| BST | 2005-2006 | 42 | 27.8 | 0.7 (0.5) | 15.7 | 20.6 (18.8) | $61 | $79 (73) |
| | 2006-2007 | 52 | 49.6 | 1 (0.8) | 18.4 | 16.9 (15.3) | $80 | $74 (67) |
| | 2007-2008 | 40 | 52 | 1.3 (1.3) | 17.7 | 18.6 (10.1) | $77 | $80 (44) |
| | 2008-2009 | 49 | 61.9 | 1.3 (1.3) | 13.3 | 14.8 (15.7) | $57 | $63 (68) |
| | 2009-2010 | 41 | 40.5 | 1 (0.7) | 11.8 | 38.8 (30.9) | $60 | $194 (154) |
| EAG | 1998 | 14 | 83.4 | 6 (2.3) | 8.7 | 8.1 (4.3) | $113 | $107 (53) |
| | 1999 | 15 | 79 | 5.3 (2.2) | 8.8 | 9 (4.6) | $177 | $182 (95) |
| | 2000 | 15 | 71.5 | 4.8 (1.5) | 9.7 | 9.7 (4.4) | $218 | $217 (104) |
| | 2001 | 19 | 62.6 | 3.3 (1.1) | 11.5 | 11.2 (5.6) | $243 | $239 (114) |
| | 2002 | 19 | 52 | 2.7 (0.7) | 12.1 | 12.2 (4.9) | $278 | $277 (109) |
| | 2003 | 18 | 58.9 | 3.3 (0.7) | 10.6 | 10.6 (2.9) | $260 | $256 (71) |
| | 2004 | 19 | 34.8 | 1.8 (0.4) | 18 | 18.6 (7.1) | $363 | $374 (133) |
| | 2005-2006 | 7 | 24.6 | 3.5 (1.9) | 25.2 | 25.3 (7.9) | $400 | $380 (143) |
| | 2006-2007 | 6 | 26.2 | 4.4 (3.5) | 24.5 | 23.7 (5.4) | $262 | $236 (61) |
| | 2007-2008 | 4 | 22.7 | 5.7 (--) | 27.8 | 29.1 (--) | $347 | $321 (--) |
| | 2008-2009 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2009-2010 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2010-2011 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |

Table continues on next page.

Table 38 cont.

| | Season | Vessels | Pot lifts | | CPUE (# legal crab) | | RPUE ($) | |
|---|---|---|---|---|---|---|---|---|
| | | | Total, $10^3$ | Mean per vessel, $10^3$ (sd) | Weighted mean | Mean CPUE per vessel (sd) | Weighted mean | Mean RPUE per vessel (sd) |
| WAG | 1998-1999 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 1999-2000 | 15 | 108.7 | 7.2 (8) | 6.1 | 4.1 (2.7) | $119 | $82 (51) |
| | 2000-2001 | 12 | 99.5 | 8.3 (6.9) | 6.8 | 4.7 (3.3) | $134 | $95 (62) |
| | 2001-2002 | 9 | 105.5 | 11.7 (9.4) | 6.4 | 5.8 (1.7) | $126 | $116 (30) |
| | 2002-2003 | 6 | 79 | 13.2 (10.5) | 8.3 | 6.4 (3.4) | $170 | $132 (65) |
| | 2003-2004 | 6 | 66.2 | 11 (7.8) | 10 | 8.5 (3.3) | $201 | $173 (65) |
| | 2004-2005 | 6 | 56.8 | 9.5 (7.1) | 11.9 | 9.3 (4.4) | $204 | $161 (74) |
| | 2005-2006 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2006-2007 | 4 | 26.7 | 6.7 (--) | 19.4 | 18.3 (--) | $155 | $152 (--) |
| | 2007-2008 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2008-2009 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2009-2010 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2010-2011 | 3 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| SMB | 1998 | 132 | 91.7 | 0.7 (0.3) | 6.9 | 7.1 (2) | $97 | $99 (27) |
| | 2009-2010 | 7 | 10.6 | 1.5 (1) | 9.6 | 9.3 (1.4) | $107 | $103 (16) |
| | 2010-2011 | 11 | 29.3 | 2.7 (1.2) | 10.1 | 9.7 (2) | $224 | $215 (43) |
| PIK | 1998 | 58 | 46 | 0.8 (0.3) | 3 | 3 (1.7) | $80 | $82 (46) |
| WAI | 1998-1999 | 1 | -- | -- (--) | -- | -- (--) | -- | -- (--) |
| | 2002-2003 | 33 | 3.8 | 0.1 (0) | 17.9 | 18.7 (12.7) | $1,233 | $1291 (877) |
| | 2003-2004 | 30 | 5.8 | 0.2 (0.1) | 10.3 | 10.2 (5.4) | $621 | $612 (329) |

*Source: ADF&G fish tickets (August 2005 and later data via eLandings).* CPUE = number of legal crab per potlift. RPUE = ex-vessel value of commercially sold crab per potlift, adjusted to 2011 dollars. Includes catcher processor harvest and effort.

Table 39: CR program fisheries opening and closing dates, season length, and days fished by season

| Fishery | Season | Season dates | Season length, days | Earliest landing | Latest landing | Days fished | Percent of season fished |
|---|---|---|---|---|---|---|---|
| BBR | 1998 | Nov 1 - Nov 6 | 6 | | | | |
| | 1999 | Oct 15 - Oct 20 | 6 | | | | |
| | 2000 | Oct 16 - Oct 20 | 5 | | | | |
| | 2001 | Oct 15 - Oct 18 | 4 | | | | |
| | 2002 | Oct 15 - Oct 18 | 4 | | | | |
| | 2003 | Oct 15 - Oct 20 | 6 | | | | |
| | 2004 | Oct 15 - Oct 18 | 4 | | | | |
| | 2005/2006 | Oct 15 - Jan 15 | 93 | 20-Oct | 16-Jan | 89 | 96% |
| | 2006/2007 | Oct 15 - Jan 15 | 93 | 19-Oct | 28-Nov | 41 | 44% |
| | 2007/2008 | Oct 15 - Jan 15 | 93 | 18-Oct | 15-Jan | 90 | 97% |
| | 2008/2009 | Oct 15 - Jan 15 | 93 | 18-Oct | 17-Jan | 92 | 99% |
| | 2009/2010 | Oct 15 - Jan 15 | 93 | 17-Oct | 16-Jan | 92 | 99% |
| | 2010/2011 | Oct 15 - Jan 15 | 93 | 16-Oct | 11-Dec | 57 | 61% |
| | 2011/2012 | Oct 15 - Jan 15 | 93 | 17-Oct | 18-Nov | 33 | 35% |
| BSS | 1998 | Jan 15 - Mar 20 | 65 | | | | |
| | 1999 | Jan 15 - Mar 22 | 67 | | | | |
| | 2000 | Apr 1 - Apr 8 | 8 | | | | |
| | 2001 | Jan 15 - Feb 14 | 31 | | | | |
| | 2002 | Jan 15 - Feb 8 | 25 | | | | |
| | 2003 | Jan 15 - Jan 25 | 11 | | | | |
| | 2004 | Jan 15 - Jan 23 | 9 | | | | |
| | 2005 | Jan 15 - Jan 20 | 6 | | | | |
| | 2005/2006 | Oct 15 - May 31 | 229 | 27-Oct | 27-May | 213 | 93% |
| | 2006/2007 | Oct 15 - May 31 | 229 | 7-Nov | 5-May | 180 | 79% |
| | 2007/2008 | Oct 15 - May 31 | 230 | 18-Nov | 10-May | 175 | 76% |
| | 2008/2009 | Oct 15 - May 31 | 229 | 30-Nov | 16-May | 168 | 73% |
| | 2009/2010 | Oct 15 - May 31 | 229 | 11-Jan | 6-May | 116 | 51% |
| | 2010/2011 | Oct 15 - May 31 | 229 | 18-Nov | 9-Apr | 143 | 62% |
| | 2011/2012 | Oct 15 - Jun 15[a] | 245 | 2-Nov | 19-Jun | 231 | 94% |
| BST | 2005/2006 | Oct 15 - Mar 31 | 168 | 27-Oct | 2-Apr | 158 | 94% |
| | 2006/2007 | Oct 15 - Mar 31 | 168 | 23-Oct | 6-Apr | 166 | 99% |
| | 2007/2008 | Oct 15 - Mar 31 | 169 | 20-Oct | 2-Apr | 166 | 98% |
| | 2008/2009 | Oct 15 - Mar 31 | 168 | 19-Oct | 25-Mar | 158 | 94% |
| | 2009/2010 | Oct 15 - Mar 31 | 168 | 17-Oct | 1-Mar | 136 | 81% |
| EAG | 1998 | Sep 1 - Nov 7 | 68 | | | | |
| | 1999 | Sep 1 - Oct 25 | 55 | | | | |
| | 2000 | Aug 15 - Sep 24 | 41 | | | | |
| | 2001 | Aug 15 - Sep 10 | 27 | | | | |
| | 2002 | Aug 15 - Sep 7 | 24 | | | | |
| | 2003 | Aug 15 - Sep 8 | 25 | | | | |
| | 2004 | Aug 15 - Aug 29 | 15 | | | | |
| | 2005/2006 | Aug 15 - May 15 | 274 | 30-Aug | 28-Mar | 211 | 77% |
| | 2006/2007 | Aug 15 - May 15 | 274 | 31-Aug | 13-Jan | 136 | 50% |
| | 2007/2008 | Aug 15 - May 15 | 275 | 30-Aug | 9-Feb | 164 | 60% |
| | 2008/2009 | Aug 15 - May 15 | 274 | 7-Sep | 22-Dec | 107 | 39% |
| | 2009/2010 | Aug 15 - May 15 | 274 | 31-Aug | 10-Jan | 133 | 49% |
| | 2010/2011 | Aug 15 - May 15 | 274 | 22-Aug | 16-Dec | 117 | 43% |
| | 2011/2012 | Aug 15 - May 15 | 275 | 26-Aug | 24-Nov | 91 | 33% |

Table continues on next page.

Table 39 cont.

| Fishery | Season | Season dates | Season length, days | Earliest landing | Latest landing | Days fished | Percent of season fished |
|---|---|---|---|---|---|---|---|
| WAG | 1998/1999 | Sep 1 - Aug 31 | 365 | | | | |
| | 1999/2000 | Sep 1 - Aug 14 | 349 | | | | |
| | 2000/2001 | Aug 15 - May 28 | 287 | | | | |
| | 2001/2002 | Aug 15 - Mar 30 | 228 | | | | |
| | 2002/2003 | Aug 15 - Mar 8 | 206 | | | | |
| | 2003/2004 | Aug 15 - Feb 6 | 176 | | | | |
| | 2004/2005 | Aug 15 - Jan 3 | 142 | | | | |
| | 2005/2006 | Aug 15 - May 15 | 274 | 6-Sep | 25-Mar | 201 | 73% |
| | 2006/2007 | Aug 15 - May 15 | 274 | 10-Sep | 12-May | 245 | 89% |
| | 2007/2008 | Aug 15 - May 15 | 275 | 14-Sep | 21-May | 251 | 91% |
| | 2008/2009 | Aug 15 - May 15 | 274 | 13-Sep | 12-May | 242 | 88% |
| | 2009/2010 | Aug 15 - May 15 | 274 | 5-Sep | 18-May | 256 | 93% |
| | 2010/2011 | Aug 15 - May 15 | 274 | 11-Sep | 18-Mar | 189 | 69% |
| | 2011/2012 | Aug 15 - May 15 | 275 | 6-Sep | 10-Apr | 218 | 79% |
| SMB | 1998 | Sep 15 - Sep 26 | 12 | | | | |
| | 2009/2010 | Oct 15 - Feb 1 | 110 | 23-Oct | 7-Dec | 46 | 42% |
| | 2010/2011 | Oct 15 - Feb 1 | 110 | 23-Oct | 11-Dec | 50 | 45% |
| | 2011/2012 | Oct 15 - Feb 1 | 110 | 21-Oct | 15-Dec | 56 | 51% |
| PIK | 1998 | Sep 15 - Sep 28 | 14 | | | | |
| WAI | 1998/1999 | Nov 1 - Jul 31 | 273 | | | | |
| | 2002/2003 | Oct 25 - Oct 27 | 3 | | | | |
| | 2003/2004 | Oct 25 - Oct 29 | 5 | | | | |

*Source: Season dates and season length from ADF&G. Earliest and latest landing dates in 2005/206 and later seasons from NMFS RAM Division IFQ accounting database and ADF&G fish tickets via eLandings. Data for 2004/2005 and earlier seasons from ADF&G Annual Management Report for the Commercial and Subsistence Shellfish Fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfish Observer Program, 2010/11. .*Some 2007/2008 fisheries extended by a day due to the leap year. Days fished is calculated as the difference between latest and earliest landing dates, inclusive. Percent of season fished is calculated as days fished divided by season length. In some fisheries, deliveries made were after the season closing date. Includes landings made on catcher processors.

[a] 2011/2012 Bering Sea Snow crab fishery season extended past regular season closing date (May 31) due to sea ice coverage.

## Table 40: CR program fisheries days between first and last delivery by season

| Fishery | Season | Vessels with one delivery | Vessels with multiple deliveries: Vessels | Mean days between first and last delivery (sd) | Median days | Minimum days | Maximum days |
|---|---|---|---|---|---|---|---|
| BBR | 2005-2006 | 20 | 69 | 20 (15) | 17 | 1 | 70 |
| | 2006-2007 | 22 | 59 | 10 (6) | 9 | 2 | 26 |
| | 2007-2008 | 6 | 68 | 18 (12) | 15 | 1 | 51 |
| | 2008-2009 | 9 | 69 | 22 (14) | 16 | 4 | 57 |
| | 2009-2010 | 7 | 63 | 18 (12) | 18 | 4 | 67 |
| | 2010-2011 | 4 | 61 | 21 (10) | 19 | 5 | 51 |
| BSS | 2005-2006 | 3 | 75 | 32 (30) | 20 | 1 | 148 |
| | 2006-2007 | 9 | 60 | 33 (26) | 26 | 5 | 156 |
| | 2007-2008 | 0 | 78 | 41 (25) | 36 | 7 | 116 |
| | 2008-2009 | 0 | 77 | 38 (22) | 38 | 5 | 117 |
| | 2009-2010 | 1 | 67 | 31 (20) | 27 | 9 | 107 |
| | 2010-2011 | 1 | 67 | 34 (19) | 29 | 7 | 102 |
| BST | 2005-2006 | 15 | 18 | 30 (34) | 19 | 1 | 148 |
| | 2006-2007 | 14 | 25 | 49 (48) | 30 | 1 | 145 |
| | 2007-2008 | 4 | 23 | 73 (56) | 86 | 4 | 161 |
| | 2008-2009 | 6 | 14 | 56 (50) | 40 | 3 | 146 |
| | 2009-2010 | 5 | 8 | 24 (34) | 15 | 2 | 105 |
| EAG | 2005-2006 | 0 | 7 | 72 (66) | 47 | 23 | 182 |
| | 2006-2007 | 0 | 6 | 41 (25) | 37 | 17 | 86 |
| | 2007-2008 | 0 | 4 | 78 (30) | 77 | 47 | 112 |
| | 2008-2009 | 0 | 3 | 70 (37) | 75 | 31 | 105 |
| | 2009-2010 | 0 | 3 | 85 (50) | 91 | 33 | 132 |
| | 2010-2011 | 0 | 3 | 77 (39) | 76 | 38 | 116 |
| SMB | 2009-2010 | 3 | 4 | 24 (16) | 24 | 5 | 45 |
| | 2010-2011 | 0 | 11 | 25 (17) | 24 | 6 | 47 |
| WAG | 2005-2006 | 0 | 3 | 177 (3) | 176 | 175 | 181 |
| | 2006-2007 | 0 | 4 | 123 (95) | 114 | 22 | 241 |
| | 2007-2008 | 0 | 3 | 143 (112) | 153 | 26 | 250 |
| | 2008-2009 | 1 | 2 | 196 (60) | 196 | 153 | 238 |
| | 2009-2010 | 0 | 3 | 129 (107) | 136 | 18 | 232 |
| | 2010-2011 | 0 | 3 | 121 (72) | 134 | 44 | 186 |

*Source: NMFS RAM Division IFQ accounting database and eLandings.* A delivery is counted as each unique day that a vessel landed fish and may include landings to multiple processors. A single fishing trip may result in multiple deliveries if fish was landed on multiple days. Includes landings on catcher processors.

Table 41: CR program fisheries delivery and trip statistics by season

| | Season | Vessels | Deliveries Total | Mean deliveries per vessel (sd) | Mean landings per delivery, $10^3$ lbs (sd) | Trips Total | Mean trips per vessel (sd) | Mean landings per trip, $10^3$ lbs (sd) |
|---|---|---|---|---|---|---|---|---|
| BBR | 1998 | 273 | 292 | 1.1 (0.3) | 50.3 (27.3) | n/d | n/d | n/d |
| | 1999 | 256 | 273 | 1.1 (0.3) | 42.2 (22.8) | n/d | n/d | n/d |
| | 2000 | 244 | 263 | 1.1 (0.4) | 30.7 (16.2) | n/d | n/d | n/d |
| | 2001 | 230 | 249 | 1.1 (0.4) | 33.3 (20.1) | n/d | n/d | n/d |
| | 2002 | 241 | 258 | 1.1 (0.4) | 36.7 (14.6) | n/d | n/d | n/d |
| | 2003 | 250 | 274 | 1.1 (0.4) | 56.2 (35.5) | n/d | n/d | n/d |
| | 2004 | 251 | 278 | 1.1 (0.4) | 54 (25.1) | n/d | n/d | n/d |
| | 2005-2006 | 89 | 261 | 2.9 (1.7) | 69.8 (47.8) | n/d | n/d | n/d |
| | 2006-2007 | 81 | 187 | 2.3 (1.1) | 82.8 (61.6) | 156 | 1.9 (0.9) | 100.1 (72.8) |
| | 2007-2008 | 74 | 247 | 3.3 (1.6) | 81.7 (53.7) | 207 | 2.8 (1.4) | 98.4 (55.7) |
| | 2008-2009 | 78 | 263 | 3.4 (1.8) | 76.5 (48.1) | 237 | 3 (1.5) | 85.8 (51.3) |
| | 2009-2010 | 70 | 211 | 3 (1.2) | 74.8 (48.4) | 197 | 2.8 (1.1) | 80.9 (50.1) |
| | 2010-2011 | 65 | 213 | 3.3 (1.3) | 69 (42.7) | 198 | 3 (1.1) | 74.9 (50.1) |
| BSS | 1999 | 241 | 1719 | 7.1 (2.7) | 111.9 (71.8) | n/d | n/d | n/d |
| | 2000 | 230 | 312 | 1.4 (0.7) | 105 (53.8) | n/d | n/d | n/d |
| | 2001 | 207 | 316 | 1.5 (1) | 78.4 (56.3) | n/d | n/d | n/d |
| | 2002 | 191 | 430 | 2.3 (1.1) | 74.3 (57.5) | n/d | n/d | n/d |
| | 2003 | 190 | 261 | 1.4 (1) | 105.4 (55.9) | n/d | n/d | n/d |
| | 2004 | 189 | 243 | 1.3 (0.8) | 97.5 (53.9) | n/d | n/d | n/d |
| | 2005 | 167 | 211 | 1.3 (0.7) | 116.1 (52.3) | n/d | n/d | n/d |
| | 2005-2006 | 78 | 316 | 4.1 (2.9) | 115.9 (75.7) | n/d | n/d | n/d |
| | 2006-2007 | 69 | 273 | 4 (2.5) | 131.5 (83.1) | 215 | 3.1 (2) | 169.1 (104.1) |
| | 2007-2008 | 78 | 466 | 6 (2.9) | 134.1 (81.2) | 413 | 5.3 (2.5) | 151.9 (85.9) |
| | 2008-2009 | 77 | 437 | 5.7 (2.7) | 132.9 (77.9) | 373 | 4.8 (2.2) | 157 (90.5) |
| | 2009-2010 | 68 | 308 | 4.5 (1.9) | 154.1 (85.4) | 283 | 4.2 (1.6) | 168.5 (91.5) |
| | 2010-2011 | 68 | 343 | 5 (2.2) | 157.2 (83.9) | 311 | 4.6 (2.1) | 174.5 (91.8) |
| BST | 2005-2006 | 33 | 64 | 1.9 (1.1) | 14.6 (22.9) | n/d | n/d | n/d |
| | 2006-2007 | 39 | 88 | 2.3 (1.3) | 23.8 (28.2) | 81 | 2.1 (1.2) | 18.5 (28.3) |
| | 2007-2008 | 27 | 95 | 3.5 (2.4) | 21.9 (25.3) | 93 | 3.4 (2.4) | 17.9 (25.3) |
| | 2008-2009 | 20 | 67 | 3.4 (3) | 28.7 (35.8) | 59 | 3 (2.3) | 15.4 (34.4) |
| | 2009-2010 | 13 | 32 | 2.5 (1.6) | 41 (43) | 28 | 2.2 (1.2) | 15.1 (35.9) |
| EAG | 1998 | 14 | 53 | 3.8 (1.4) | 59.7 (36) | n/d | n/d | n/d |
| | 1999 | 15 | 59 | 3.9 (1.2) | 50.8 (32.5) | n/d | n/d | n/d |
| | 2000 | 15 | 50 | 3.3 (0.8) | 61.5 (33) | n/d | n/d | n/d |
| | 2001 | 19 | 45 | 2.4 (0.6) | 69.5 (44.3) | n/d | n/d | n/d |
| | 2002 | 19 | 43 | 2.3 (0.5) | 64.3 (38.1) | n/d | n/d | n/d |
| | 2003 | 18 | 37 | 2.1 (0.2) | 78.4 (38) | n/d | n/d | n/d |
| | 2004 | 19 | 32 | 1.7 (0.5) | 88.8 (54.7) | n/d | n/d | n/d |
| | 2005-2006 | 7 | 34 | 4.9 (2.1) | 83.5 (47.3) | n/d | n/d | n/d |
| | 2006-2007 | 6 | 28 | 4.7 (4.2) | 105.6 (59.5) | 22 | 3.7 (2) | 136 (82.5) |
| | 2007-2008 | 4 | 35 | 8.8 (--) | 84.8 (57.7) | 28 | 7 (--) | 106.8 (62.3) |
| | 2008-2009 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| | 2009-2010 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| | 2010-2011 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |

Table continues on next page.

Table 41 cont.

| | Season | Vessels | Deliveries: Total | Mean deliveries per vessel (sd) | Mean landings per delivery, $10^3$ lbs (sd) | Trips: Total | Mean trips per vessel (sd) | Mean landings per trip, $10^3$ lbs (sd) |
|---|---|---|---|---|---|---|---|---|
| WAG | 1998-1999 | 3 | -- | -- (--) | -- (--) | n/d | n/d | n/d |
| | 1999-2000 | 15 | 113 | 7.5 (10.4) | 24.1 (15.3) | n/d | n/d | n/d |
| | 2000-2001 | 12 | 97 | 8.1 (9.4) | 28.6 (17.4) | n/d | n/d | n/d |
| | 2001-2002 | 9 | 90 | 10 (8.2) | 29.9 (16.2) | n/d | n/d | n/d |
| | 2002-2003 | 6 | 72 | 12 (9.2) | 36.2 (20.7) | n/d | n/d | n/d |
| | 2003-2004 | 6 | 60 | 10 (6.8) | 44 (29.5) | n/d | n/d | n/d |
| | 2004-2005 | 6 | 51 | 8.5 (5.9) | 51.8 (36.2) | n/d | n/d | n/d |
| | 2005-2006 | 3 | -- | -- (--) | -- (--) | n/d | n/d | n/d |
| | 2006-2007 | 4 | 33 | 8.3 (--) | 67.6 (29.6) | 29 | 7.3 (--) | 77.7 (32) |
| | 2007-2008 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| | 2008-2009 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| | 2009-2010 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| | 2010-2011 | 3 | -- | -- (--) | -- (--) | -- | -- (--) | -- (--) |
| SMB | 1998 | 131 | 259 | 2 (0.5) | 11.4 (7.1) | n/d | n/d | n/d |
| | 2009-2010 | 7 | 16 | 2.3 (1.5) | 28.1 (16.5) | 15 | 2.1 (1.5) | 30.7 (22.3) |
| | 2010-2011 | 11 | 40 | 3.6 (1.5) | 31.3 (17.8) | 38 | 3.5 (1.4) | 33.3 (17.7) |
| PIK | 1998 | 58 | 91 | 1.6 (0.7) | 11.3 (8.7) | n/d | n/d | n/d |
| WAI | 1998-1999 | 1 | -- | -- (--) | -- (--) | n/d | n/d | n/d |
| | 2002-2003 | 33 | 35 | 1.1 (0.2) | 14.4 (8.3) | n/d | n/d | n/d |
| | 2003-2004 | 30 | 30 | 1 (0) | 15.8 (9.7) | n/d | n/d | n/d |

*Source: NMFS RAM Division IFQ accounting database and ADF&G fish tickets via eLandings.* A delivery is counted as each unique day that a vessel landed fish and may include landings to multiple processors. A single fishing trip may result in multiple deliveries if fish was landed on multiple days. Includes landings on catcher processors. Trip accounting data unavailable prior to 2006/2007 season.

## Table 42: BBR fishery harvest by week of season

| | 2007/2008 | | 2008/2009 | | 2009/2010 | | 2010/2011 | | 2011/2012[a] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) |
| 1: 15-Oct | 4 | 0.01 (0.00, 0.00) | 6 | 0.01 (0.02, 0.01) | 5 | 0.01 (0.01, 0.00) | 7 | 0.02 (0.02, 0.00) | 16 | 0.08 (0.09, 0.02) |
| 2: 22-Oct | 45 | 0.23 (0.23, 0.04) | 51 | 0.28 (0.32, 0.14) | 57 | 0.42 (0.42, 0.21) | 49 | 0.34 (0.36, 0.09) | 52 | 0.71 (0.74, 0.51) |
| 3: 29-Oct | 46 | 0.50 (0.53, 0.16) | 48 | 0.53 (0.61, 0.26) | 48 | 0.68 (0.69, 0.46) | 36 | 0.54 (0.58, 0.30) | 27 | 0.97 (0.97, 0.95) |
| 4: 5-Nov | 46 | 0.74 (0.78, 0.49) | 31 | 0.69 (0.77, 0.39) | 28 | 0.81 (0.83, 0.64) | 45 | 0.78 (0.81, 0.63) | 6 | 0.98 (0.97, 1.00) |
| 5: 12-Nov | 22 | 0.84 (0.88, 0.63) | 36 | 0.85 (0.93, 0.58) | 27 | 0.93 (0.95, 0.83) | 24 | 0.87 (0.89, 0.82) | 2 | 1.00 (1.00, 1.00) |
| 6: 19-Nov | 16 | 0.91 (0.93, 0.80) | 18 | 0.91 (0.96, 0.77) | 12 | 0.98 (0.98, 0.95) | 18 | 0.95 (0.97, 0.95) | 0 | 1.00 (1.00, 1.00) |
| 7: 26-Nov | 9 | 0.94 (0.96, 0.87) | 13 | 0.94 (0.97, 0.85) | 6 | 1.00 (1.00, 1.00) | 8 | 0.99 (0.99, 0.99) | 0 | 1.00 (1.00, 1.00) |
| 8: 3-Dec | 8 | 0.98 (0.99, 0.90) | 15 | 0.99 (0.99, 0.95) | 1 | 1.00 (1.00, 1.00) | 3 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 9: 10-Dec | 5 | 1.00 (1.00, 0.97) | 6 | 1.00 (1.00, 0.97) | 0 | 1.00 (1.00, 1.00) | 1 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 10: 17-Dec | 1 | 1.00 (1.00, 0.99) | 1 | 1.00 (1.00, 0.98) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 11: 24-Dec | 0 | 1.00 (1.00, 0.99) | 1 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 12: 31-Dec | 0 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 13: 7-Jan | 0 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| 14: 14-Jan | 1 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |
| Postseason: 16-Jan | 0 | 1.00 (1.00, 1.00) | 1 | 1.00 (1.00, 1.00) | 1 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) |

*Source:ADF&G fish tickets and NMFS RAM IFQ accounting database via eLandings.*

BBR fishery season open by regulation from October 15 to January 15. Running share of sold lbs landed shows running share of a) combined IFQ and CDQ sold pounds, including catcher processor landings ("All"); b) sold pounds landed on catcher vessel owner A-type IFQ permits (CVOA); and c) sold pounds landed on catcher vessel owner B-type IFQ permits or catcher vessel crew type IFQ permits (CVOB + CVC). CVOA IFQ permits are subject to matching to processing quota, whereas CVC and CVOB may be landed at any processor.

[a] "All" landings category in 2011/2012 season reflects the running total percentage of combined IFQ catcher vessel quota pounds (CVOA, CVOB, and CVC-type quota) landed; landings of CDQ and catcher processor quota are excluded.

## Table 43: BSS fishery harvest by week of season

| | 2007/2008 | | 2008/2009 | | 2009/2010 | | 2010/2011 | | 2011/2012[a] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) | Vessels | Running share of sold lbs landed: All (CVOA, CVOB+CVC) |
| 1: 15-Oct | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) |
| 2: 22-Oct | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 2 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) |
| 3: 29-Oct | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) |
| 4: 5-Nov | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) |
| 5: 12-Nov | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) |
| 6: 19-Nov | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) |
| 7: 26-Nov | 1 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.01 (0.00, 0.00) |
| 8: 3-Dec | 1 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.01 (0.00, 0.00) |
| 9: 10-Dec | 1 | 0.01 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.01 (0.00, 0.00) |
| 10: 17-Dec | 1 | 0.01 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.00 (0.00, 0.00) | 0 | 0.01 (0.00, 0.00) |
| 11: 24-Dec | 1 | 0.01 (0.00, 0.00) | 1 | 0.01 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.01 (0.00, 0.00) |
| 12: 31-Dec | 1 | 0.01 (0.00, 0.00) | 1 | 0.01 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 0 | 0.00 (0.00, 0.00) | 1 | 0.01 (0.00, 0.00) |
| 13: 7-Jan | 7 | 0.03 (0.01, 0.00) | 3 | 0.01 (0.00, 0.00) | 6 | 0.03 (0.04, 0.00) | 7 | 0.01 (0.01, 0.00) | 20 | 0.06 (0.07, 0.01) |
| 14: 14-Jan | 14 | 0.07 (0.06, 0.00) | 18 | 0.06 (0.07, 0.01) | 19 | 0.10 (0.14, 0.00) | 7 | 0.03 (0.03, 0.00) | 23 | 0.13 (0.14, 0.01) |
| 15: 21-Jan | 31 | 0.16 (0.16, 0.02) | 31 | 0.17 (0.19, 0.04) | 28 | 0.22 (0.29, 0.02) | 68 | 0.54 (0.54, 0.50) | 31 | 0.20 (0.23, 0.03) |
| 16: 28-Jan | 33 | 0.25 (0.27, 0.05) | 35 | 0.28 (0.34, 0.07) | 27 | 0.33 (0.43, 0.07) | 29 | 0.59 (0.60, 0.50) | 30 | 0.25 (0.29, 0.05) |
| 17: 4-Feb | 42 | 0.36 (0.41, 0.12) | 30 | 0.36 (0.43, 0.17) | 36 | 0.48 (0.57, 0.19) | 37 | 0.66 (0.68, 0.55) | 16 | 0.30 (0.33, 0.11) |
| 18: 11-Feb | 40 | 0.47 (0.51, 0.28) | 28 | 0.44 (0.51, 0.21) | 34 | 0.59 (0.69, 0.32) | 46 | 0.75 (0.77, 0.58) | 23 | 0.35 (0.38, 0.14) |
| 19: 18-Feb | 37 | 0.56 (0.61, 0.36) | 33 | 0.54 (0.60, 0.31) | 33 | 0.72 (0.81, 0.50) | 39 | 0.82 (0.84, 0.62) | 31 | 0.41 (0.45, 0.16) |
| 20: 25-Feb | 35 | 0.66 (0.70, 0.42) | 38 | 0.64 (0.68, 0.38) | 27 | 0.81 (0.88, 0.67) | 35 | 0.88 (0.90, 0.71) | 36 | 0.48 (0.52, 0.19) |
| 21: 4-Mar | 32 | 0.73 (0.77, 0.53) | 40 | 0.74 (0.78, 0.53) | 16 | 0.86 (0.93, 0.72) | 30 | 0.93 (0.95, 0.80) | 23 | 0.52 (0.57, 0.21) |
| 22: 11-Mar | 29 | 0.79 (0.83, 0.65) | 30 | 0.83 (0.86, 0.63) | 9 | 0.89 (0.93, 0.79) | 21 | 0.96 (0.97, 0.94) | 32 | 0.58 (0.63, 0.26) |
| 23: 18-Mar | 20 | 0.84 (0.86, 0.75) | 27 | 0.90 (0.93, 0.70) | 14 | 0.93 (0.95, 0.88) | 13 | 0.98 (0.99, 0.97) | 34 | 0.62 (0.67, 0.31) |
| 24: 25-Mar | 12 | 0.85 (0.87, 0.79) | 18 | 0.93 (0.97, 0.76) | 8 | 0.96 (0.96, 0.93) | 5 | 0.99 (0.99, 0.99) | 13 | 0.64 (0.69, 0.31) |
| 25: 1-Apr | 3 | 0.86 (0.87, 0.79) | 14 | 0.95 (0.97, 0.86) | 3 | 0.97 (0.97, 0.99) | 3 | 1.00 (1.00, 1.00) | 21 | 0.68 (0.73, 0.32) |
| 26: 8-Apr | 8 | 0.88 (0.89, 0.84) | 9 | 0.97 (0.98, 0.93) | 4 | 0.98 (0.97, 0.99) | 1 | 1.00 (1.00, 1.00) | 7 | 0.69 (0.74, 0.32) |
| 27: 15-Apr | 15 | 0.92 (0.94, 0.89) | 8 | 0.98 (0.98, 0.98) | 3 | 0.99 (0.98, 0.99) | 0 | 1.00 (1.00, 1.00) | 41 | 0.74 (0.79, 0.36) |
| 28: 22-Apr | 15 | 0.96 (0.97, 0.91) | 2 | 0.98 (0.98, 0.98) | 1 | 0.99 (0.99, 0.99) | 1 | 1.00 (1.00, 1.00) | 1 | 0.74 (0.79, 0.37) |
| 29: 29-Apr | 13 | 0.99 (1.00, 0.97) | 3 | 0.99 (0.99, 0.99) | 1 | 1.00 (1.00, 0.99) | 0 | 1.00 (1.00, 1.00) | 25 | 0.76 (0.81, 0.39) |
| 30: 6-May | 4 | 1.00 (1.00, 1.00) | 2 | 0.99 (0.99, 1.00) | 1 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 33 | 0.78 (0.83, 0.42) |
| 31: 13-May | 0 | 1.00 (1.00, 1.00) | 1 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 0.78 (0.83, 0.42) |
| 32: 20-May | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 16 | 0.81 (0.85, 0.45) |
| 33: 27-May | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 31 | 0.87 (0.89, 0.67) |
| Postseason: 1-Jun | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 0 | 1.00 (1.00, 1.00) | 41 | 1.00 (1.00, 1.00) |

*Source:ADF&G fish tickets and NMFS RAM IFQ accounting database via eLandings.*

BSS fishery open by regulation from October 15 to May 31. Running share of sold lbs landed shows running share of a) combined IFQ and CDQ sold pounds, including catcher processor landings (“All”); b) sold pounds landed on catcher vessel owner A-type IFQ permits (CVOA); and c) sold pounds landed on catcher vessel owner B-type IFQ permits or catcher vessel crew type IFQ permits (CVOB + CVC). CVOA IFQ permits are subject to matching to processing quota, whereas CVC and CVOB may be landed at any processor.

[a] 2011/2012 season extended to June 15th due to sea ice coverage persisting into mid-May. “All” landings category in 2011/2012 season reflects the running total percentage of combined IFQ catcher vessel quota pounds (CVOA, CVOB, and CVC-type quota) landed; landings of CDQ and catcher processor quota are excluded.

## Table 44: CR program fisheries purchasing statistics

| Fishery | Year | Buyers | Purchased lbs ($10^6$) | Mean purchase per buyer: Lbs, $10^6$ (sd) | Mean purchase per buyer: as percent of fishery year commercial lbs (sd) | Median purchase per buyer: Lbs, $10^6$ | Median purchase per buyer: as percent of fishery year commercial lbs | Gini ratio |
|---|---|---|---|---|---|---|---|---|
| AIG | 1998 | 9 | 5.44 | 0.60 (0.71) | 11.1% (13.0) | 0.24 | 4.4% | 0.65 |
| | 1999 | 8 | 5.1 | 0.64 (0.67) | 12.5% (13.1) | 0.29 | 5.7% | 0.60 |
| | 2000 | 7 | 5.95 | 0.85 (0.58) | 14.3% (9.8) | 0.66 | 11.1% | 0.41 |
| | 2001 | 7 | 6.38 | 0.91 (0.95) | 14.3% (14.9) | 0.36 | 5.7% | 0.59 |
| | 2002 | 6 | 5.54 | 0.92 (0.76) | 16.7% (13.8) | 0.83 | 15.1% | 0.50 |
| | 2003 | 6 | 5.82 | 0.97 (0.71) | 16.7% (12.3) | 1.08 | 18.6% | 0.45 |
| | 2004 | 5 | 6.02 | 1.20 (0.77) | 20.0% (12.8) | 1.35 | 22.5% | 0.40 |
| | 2005 | 6 | 4.44 | 0.74 (0.63) | 16.7% (14.2) | 0.48 | 10.8% | 0.49 |
| | 2006 | 6 | 5.24 | 0.87 (0.80) | 16.7% (15.3) | 0.71 | 13.5% | 0.56 |
| | 2007 | 6 | 5.44 | 0.91 (0.72) | 16.7% (13.2) | 0.79 | 14.5% | 0.49 |
| | 2008 | 7 | 5.73 | 0.82 (0.47) | 14.3% (8.2) | 1.04 | 18.1% | 0.34 |
| | 2009 | 9 | 5.51 | 0.61 (0.63) | 11.1% (11.4) | 0.30 | 5.4% | 0.58 |
| | 2010 | 9 | 6.09 | 0.68 (0.48) | 11.1% (7.9) | 0.49 | 8.0% | 0.42 |
| | 2011 | 14 | 6 | 0.43 (0.43) | 7.1% (7.1) | 0.28 | 4.7% | 0.52 |
| BBR | 1998 | 28 | 14.67 | 0.52 (0.62) | 3.6% (4.2) | 0.26 | 1.8% | 0.61 |
| | 1999 | 24 | 11.53 | 0.48 (0.57) | 4.2% (5.0) | 0.21 | 1.9% | 0.61 |
| | 2000 | 24 | 8.07 | 0.34 (0.43) | 4.2% (5.3) | 0.11 | 1.4% | 0.65 |
| | 2001 | 25 | 8.3 | 0.33 (0.42) | 4.0% (5.1) | 0.10 | 1.2% | 0.66 |
| | 2002 | 26 | 9.48 | 0.36 (0.46) | 3.8% (4.8) | 0.13 | 1.4% | 0.64 |
| | 2003 | 26 | 15.39 | 0.59 (0.68) | 3.8% (4.4) | 0.29 | 1.9% | 0.58 |
| | 2004 | 25 | 15.02 | 0.60 (0.71) | 4.0% (4.7) | 0.23 | 1.5% | 0.61 |
| | 2005 | 16 | 18.14 | 1.13 (1.28) | 6.3% (7.0) | 0.50 | 2.8% | 0.61 |
| | 2006 | 15 | 15.55 | 1.04 (1.16) | 6.7% (7.5) | 0.54 | 3.5% | 0.61 |
| | 2007 | 18 | 20.17 | 1.12 (1.28) | 5.6% (6.4) | 0.52 | 2.6% | 0.60 |
| | 2008 | 17 | 20.13 | 1.18 (1.20) | 5.9% (6.0) | 0.61 | 3.0% | 0.54 |
| | 2009 | 16 | 15.78 | 0.99 (1.03) | 6.3% (6.5) | 0.48 | 3.1% | 0.55 |
| | 2010 | 17 | 14.73 | 0.87 (0.93) | 5.9% (6.3) | 0.39 | 2.7% | 0.58 |
| | 2011 | 18 | 7.79 | 0.43 (0.49) | 5.6% (6.3) | 0.20 | 2.5% | 0.58 |
| BSS | 1998 | 44 | 249.05 | 5.66 (6.22) | 2.3% (2.5) | 1.73 | 0.7% | 0.59 |
| | 1999 | 37 | 192.37 | 5.20 (5.55) | 2.7% (2.9) | 3.79 | 2.0% | 0.55 |
| | 2000 | 28 | 32.75 | 1.17 (1.07) | 3.6% (3.3) | 0.86 | 2.6% | 0.52 |
| | 2001 | 24 | 24.78 | 1.03 (0.98) | 4.2% (4.0) | 0.63 | 2.5% | 0.51 |
| | 2002 | 27 | 31.94 | 1.18 (1.46) | 3.7% (4.6) | 0.35 | 1.1% | 0.63 |
| | 2003 | 21 | 27.51 | 1.31 (1.12) | 4.8% (4.1) | 0.97 | 3.5% | 0.48 |
| | 2004 | 23 | 23.69 | 1.03 (0.98) | 4.3% (4.1) | 0.61 | 2.6% | 0.53 |
| | 2005 | 20 | 24.86 | 1.24 (1.18) | 5.0% (4.8) | 0.86 | 3.5% | 0.53 |
| | 2006 | 13 | 38.02 | 2.92 (2.32) | 7.7% (6.1) | 2.27 | 6.0% | 0.47 |
| | 2007 | 18 | 34.76 | 1.93 (1.71) | 5.6% (4.9) | 1.74 | 5.0% | 0.49 |
| | 2008 | 17 | 62.23 | 3.66 (3.14) | 5.9% (5.0) | 2.96 | 4.8% | 0.49 |
| | 2009 | 17 | 57.69 | 3.39 (3.02) | 5.9% (5.2) | 2.64 | 4.6% | 0.49 |
| | 2010 | 13 | 47.84 | 3.68 (2.62) | 7.7% (5.5) | 3.30 | 6.9% | 0.42 |
| | 2011 | 16 | 54.05 | 3.38 (2.91) | 6.3% (5.4) | 2.21 | 4.1% | 0.49 |
| BST | 2005 | 5 | 0.26 | 0.05 (0.07) | 20.0% (27.8) | -- | -- | 0.78 |
| | 2006 | 9 | 0.99 | 0.11 (0.12) | 11.1% (12.3) | 0.07 | 7.4% | 0.61 |
| | 2007 | 9 | 2.25 | 0.25 (0.17) | 11.1% (7.7) | 0.21 | 9.4% | 0.41 |
| | 2008 | 11 | 2.33 | 0.21 (0.20) | 9.1% (8.6) | 0.16 | 6.9% | 0.51 |
| | 2009 | 11 | 2.14 | 0.19 (0.16) | 9.1% (7.4) | 0.16 | 7.5% | 0.45 |
| | 2010 | 7 | 0.37 | 0.05 (0.04) | 14.3% (11.7) | -- | -- | 0.43 |

Table continues on next page.

Table 44 cont.

| Fishery | Year | Buyers | Purchased lbs ($10^6$) | Mean purchase per buyer: Lbs, $10^6$ (sd) | Mean purchase per buyer: as percent of fishery year commercial lbs (sd) | Median purchase per buyer: Lbs, $10^6$ | Median purchase per buyer: as percent of fishery year commercial lbs | Gini ratio |
|---|---|---|---|---|---|---|---|---|
| PIK | 1998 | 17 | 1.03 | 0.06 (0.06) | 5.9% (6.3) | 0.03 | 2.8% | 0.57 |
| SMB | 1998 | 16 | 2.95 | 0.18 (0.25) | 6.3% (8.4) | 0.09 | 3.1% | 0.66 |
| | 2009 | 6 | 0.45 | 0.08 (0.06) | 16.7% (12.6) | 0.06 | 12.2% | 0.45 |
| | 2010 | 9 | 1.25 | 0.14 (0.16) | 11.1% (12.6) | 0.07 | 5.7% | 0.59 |
| | 2011 | 11 | 1.85 | 0.17 (0.21) | 9.1% (11.5) | 0.08 | 4.1% | 0.61 |
| WAI | 1998 | 1 | -- | -- (--) | -- | -- | -- | -- |
| | 2002 | 9 | 0.5 | 0.06 (0.05) | 11.1% (9.2) | 0.04 | 8.2% | 0.42 |
| | 2003 | 10 | 0.48 | 0.05 (0.04) | 10.0% (9.3) | 0.04 | 8.2% | 0.53 |

*Source: ADF&G fish tickets and eLandings.*

Data shown by calendar year. Includes harvest from CDQ and IFQ fisheries and pre-rationalization general access fisheries.
Landings/harvest made by and self-processed by catcher processors are treated as purchases, with catcher processors treated
Buyers include catcher processors landing and processing their own crab.

Table 45: Snow and red king crab exports and imports (2011 base year)

| | King crab | | | | Snow crab | | | |
|---|---|---|---|---|---|---|---|---|
| | Exports | | Imports | | Exports | | Imports | |
| Year | Metric tons ($10^3$) | Value (\$$10^6$) | Metric tons ($10^3$) | Value (\$$10^6$) | Metric tons ($10^3$) | Value (\$$10^6$) | Metric tons ($10^3$) | Value (\$$10^6$) |
| 1991 | 3.85 | $103.24 | 0.30 | $7.68 | 32.20 | $295.26 | 0.74 | $10.22 |
| 1992 | 3.70 | $109.98 | 2.19 | $40.91 | 61.61 | $556.64 | 0.88 | $8.66 |
| 1993 | 5.96 | $158.40 | 1.12 | $23.69 | 45.56 | $493.88 | 1.33 | $15.72 |
| 1994 | 3.62 | $85.31 | 2.60 | $60.80 | 31.12 | $455.34 | 2.86 | $38.25 |
| 1995 | 2.85 | $58.68 | 4.01 | $76.06 | 12.26 | $208.30 | 2.26 | $31.23 |
| 1996 | 4.46 | $98.13 | 6.27 | $111.25 | 9.53 | $121.25 | 3.38 | $38.34 |
| 1997 | 2.80 | $45.60 | 9.77 | $178.07 | 10.17 | $86.70 | 6.90 | $58.28 |
| 1998 | 3.10 | $35.74 | 11.82 | $191.11 | 11.99 | $84.17 | 12.26 | $98.04 |
| 1999 | 2.73 | $38.53 | 11.49 | $204.84 | 15.62 | $139.38 | 24.68 | $250.54 |
| 2000 | 3.05 | $65.87 | 10.05 | $210.42 | 4.75 | $59.97 | 28.61 | $348.40 |
| 2001 | 1.83 | $49.79 | 9.29 | $208.09 | 3.09 | $37.62 | 42.18 | $439.19 |
| 2002 | 2.28 | $50.22 | 10.42 | $278.88 | 3.36 | $39.69 | 44.41 | $469.32 |
| 2003 | 3.94 | $73.80 | 9.96 | $237.86 | 3.92 | $55.53 | 51.60 | $640.46 |
| 2004 | 3.25 | $54.03 | 10.55 | $207.79 | 4.09 | $54.98 | 49.10 | $584.37 |
| 2005 | 3.90 | $69.22 | 18.39 | $321.32 | 3.42 | $38.50 | 45.97 | $417.62 |
| 2006 | 4.32 | $69.52 | 28.07 | $403.10 | 4.79 | $48.88 | 46.28 | $365.40 |
| 2007 | 3.31 | $57.55 | 30.35 | $430.22 | 2.12 | $17.88 | 47.98 | $475.81 |
| 2008 | 4.33 | $77.52 | 15.92 | $296.52 | 5.55 | $49.91 | 42.00 | $413.78 |
| 2009 | 3.36 | $75.67 | 15.83 | $279.14 | 5.48 | $51.40 | 51.65 | $436.01 |
| 2010 | 3.61 | $85.41 | 10.04 | $187.36 | 4.96 | $43.65 | 43.58 | $394.68 |
| 2011 | 2.70 | $64.13 | 8.51 | $171.40 | 8.48 | $90.58 | 41.06 | $502.34 |

*Source: U.S. Foreign Census Bureau Foreign Trade Division, via NMFS Fisheries Statistics Division, U.S. Foreign Trade Database.* Data available at http://www.st.nmfs.noaa.gov/st1/trade/.

Imports and exports shown for product codes 306144010 (frozen king crab) and 306144020 (frozen snow crab) from the Tariff Schedule for the United States, Annotated (TSUSA).

## Table 46: IFQ fisheries catch share performance metrics

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 97.74 | 56.55 | 54.69 | 85.25 | 80.28 | 65.28 | 69.03 | 94.56 |
| Commercial landings ($10^6$ lbs) | 96.94 | 54.99 | 52.62 | 81.17 | 77.08 | 63.81 | 68.05 | 93.35 |
| Landed deadloss ($10^6$ lbs) | 1.08 | 0.46 | 0.56 | 0.70 | 0.63 | 0.70 | 0.53 | 0.69 |
| Percent TAC/GHL utilized[c] | 104.5% | 98.1% | 97.3% | 96.1% | 96.8% | 98.9% | 99.4% | 99.5% |
| Decreased deadloss from last season[d] | n/a | YES | NO | NO | YES | NO | YES | NO |
| TAC or GHL exceeded[e] | YES | NO | NO | NO | NO | NO | NO | NO |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 491 | 491 | 509 | 494 | 503 | 505 | 513 | 522 |
| Active vessels[g] | 262 | 101 | 91 | 87 | 88 | 78 | 78 | 78 |
| Season length (days)[l] | | | | | | | | |
| Bristol Bay red | 4.67 | 93 | 93 | 93 | 93 | 93 | 93 | 93 |
| Bering Sea snow | 32.67 | 229 | 229 | 230 | 229 | 229 | 229 | 245 |
| Eastern Aleutian golden king | 36.67 | 274 | 274 | 275 | 274 | 274 | 274 | 275 |
| Western Aleutian golden king | 245 | 274 | 274 | 275 | 274 | 274 | 274 | 275 |
| Bering Sea Tanner, East[n] | F/C | F/C | 168 | 169 | 168 | 168 | F/C | F/C |
| Bering Sea Tanner, West[n] | F/C | 168 | 168 | 169 | 168 | F/C | F/C | F/C |
| St. Matthew blue king[m] | 12 | F/C | F/C | F/C | F/C | 110 | 110 | 110 |
| Pribilof Islands red and blue king[m] | 14 | F/C | F/C | F/C | F/C | F/C | F/C | F/C |
| Western Aleutian red king[m] | 273 | F/C | F/C | F/C | F/C | F/C | F/C | F/C |
| Trips[h] | n/d | 595 | 426 | 640 | 623 | 516 | 552 | 754 |
| **Revenues (USD $\$10^6$)**[i] | | | | | | | | |
| Total revenue on IFQ trips | n/d | $173.82 | $153.63 | $239.85 | $225.89 | $163.55 | $267.79 | n/d |
| IFQ landings | $224.62 | $156.54 | $143.36 | $228.38 | $215.34 | $154.91 | $255.78 | $258.12 |
| Non-IFQ landings on IFQ trips[j] | n/d | $17.28 | $10.27 | $11.47 | $10.55 | $8.64 | $12.01 | n/d |
| IFQ revenue / active vessel | $0.84 | $1.55 | $1.58 | $2.63 | $2.45 | $1.99 | $3.28 | $3.31 |
| IFQ revenue / trip | n/d | $0.26 | $0.34 | $0.36 | $0.35 | $0.30 | $0.46 | $0.34 |
| **Price**[i]: Weighted price/lb, IFQ crab | $3.05 | $2.85 | $2.72 | $2.81 | $2.79 | $2.43 | $3.76 | $2.77 |
| **Cost recovery**[i]: Fees collected ($\$10^6$)[k] | n/a | $4.85 | $4.47 | $6.93 | $2.06 | $0.00 | $7.05 | $3.35 |

*Source: NMFS AKR RAM, ADF&G fish tickets, CFEC ex-vessel pricing, NMFS AFSC BSAI Crab Economic Data, ADF&G Westward Region Shellfish Management Report 2010/2011.* **2011/2012 data and 2010/2011 revenue and prices are preliminary as of September 2012.**

[a] Baseline seasons are 1998/1999, 2001/2002, and 2004/2005. Except where otherwise noted, baseline values reflect the per-season mean for activity in the open access/LLP fisheries (excludes fishing activity on CDQ permits).
[b] July 1 through June 30 crab fishing season.
[c] GHL applies to baseline years; TAC applies to 2005/2006 and later seasons. Baseline percentage greater than 100% indicates GHL exceeded
[d] Weight of retained catch discarded at landing as deadloss and, following crab rationalization, debited against IFQ; at-sea discard, including low-grade catch of target crab species, bycatch of female and sublegal males of targeted crab stocks, and/or bycatch of other fish and shellfish species, is not counted against IFQ.
[e] For baseline, indicates if GHL was exceeded in any fishery in any one season.
[f] Count of unique holders of harvest QS in one or more IFQ crab fisheries at the beginning of each fishing year. Baseline value represents the number of entities receiving initial quota share and is equal to the count for the first catch share program year.
[g] Count of crab catcher vessels and catcher/processor vessels with any commercial landings (sold crab) of IFQ crab or, during baseline years, open access/LLP fishery crab.
[h] Count of unique vessel trips resulting in one or more landings of IFQ crab. Trip identification unavailable for baseline years.
[i] All prices and revenues adjusted to 2011 dollars.
[j] Estimated ex-vessel value of commercial landings of non-IFQ crab landed jointly with IFQ or, during baseline years, open access crab. This primarily represents BSAI crab landed on CDQ and ACA permits. Trip identification unavailable for baseline years. Data not yet available for 2011/2012 season. To avoid double counting of non-IFQ revenue in reporting by individual crab fishery, non-IFQ revenue is assigned to a single target crab fishery per trip, determined as the fishery accounting for the greatest volume of sold crab by weight at the landing.
[k] Estimated cost recovery fee value attributable to IFQ landings in all crab CSP fisheries. Cost recovery fees are collected jointly for crab IFQ as well as CDQ and ACA community-based allocation programs; values reported are the amount apportionable to the IFQ program as estimated from pro-ration of cost recovery fees by relative volume of landings in respective management programs. Note that year-to-year variance in fees collected is due to regulatory formula for pre-season determination of fee percentage to assess on ex-vessel revenues based on ex-vessel value and program management costs for the prior fishery year. The formula results in realized surpluses in years where fees paid by program participants are in excess of fee amount billed. In 2009, no cost recovery fees were billed due to fee percent set to 0 for the year; in 2008 fee

collection was lower than billed amount due to bankruptcy of a processing sector entity.

[l] "F/C" indicates fishery closure.

[m] St. Matthew blue king, Pribilof red and blue king, and Western Aleutian red king crab fisheries were open only during the 1998/1998 season in the baseline period.

[n] Bering Sea Tanner crab fishery closed in all baseline seasons. Eastern and Western areas were managed as a single fishery in 2005/2006 and as separate fisheries in subsequent seasons. The Eastern area was closed by ADF&G in the 2005/2006 season as an inseason management measure.

## Table 46a- IFQ crab fisheries performance metrics, Bristol Bay red king crab

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 12.23 | 16.50 | 13.97 | 18.33 | 18.33 | 14.41 | 13.36 | 7.05 |
| Commercial landings ($10^6$ lbs) | 11.91 | 16.39 | 13.78 | 18.16 | 18.11 | 14.22 | 13.22 | 7.00 |
| Landed deadloss ($10^6$ lbs) | 0.09 | 0.08 | 0.10 | 0.13 | 0.16 | 0.11 | 0.10 | 0.03 |
| Percent TAC/GHL utilized[c] | 102.3% | 99.9% | 99.4% | 100.0% | 99.8% | 99.6% | 100.0% | 100.0% |
| Decreased deadloss from last season[d] | n/a | YES | NO | NO | NO | YES | YES | YES |
| TAC or GHL exceeded[e] | YES | NO | NO | NO | NO | NO | NO | NO |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 426 | 426 | 411 | 391 | 389 | 382 | 386 | 385 |
| Active vessels[g] | 251 | 89 | 81 | 74 | 77 | 70 | 65 | 62 |
| Season length (days)[l] | 4.67 | 93 | 93 | 93 | 93 | 93 | 93 | 93 |
| Trips[h] | n/d | 236 | 153 | 192 | 207 | 182 | 188 | 112 |
| **Revenues (USD $10^6$)**[i] | | | | | | | | |
| Total revenue on IFQ trips | n/d | $104.89 | $69.13 | $103.51 | $110.25 | $81.18 | $109.18 | n/d |
| IFQ landings | $68.65 | $94.39 | $63.57 | $96.95 | $104.79 | $76.59 | $103.74 | $74.06 |
| Non-IFQ landings on IFQ trips[j] | n/d | $10.50 | $5.56 | $6.56 | $5.46 | $4.59 | $5.44 | n/d |
| IFQ revenue / active vessel | $0.27 | $1.06 | $0.78 | $1.31 | $1.36 | $1.09 | $1.60 | $1.19 |
| IFQ revenue / trip | n/d | $0.40 | $0.42 | $0.50 | $0.51 | $0.42 | $0.55 | $0.66 |
| **Price**[i]: Weighted price/lb, IFQ crab | $5.99 | $5.76 | $4.61 | $5.34 | $5.79 | $5.39 | $7.84 | $10.57 |

See Table 46 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.**

## Table 46b - IFQ crab fisheries performance metrics, Bering Sea snow crab

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 78.03 | 33.47 | 32.91 | 56.73 | 52.70 | 43.22 | 48.85 | 80.00 |
| Commercial landings ($10^6$ lbs) | 78.37 | 32.93 | 32.32 | 56.23 | 52.29 | 42.71 | 48.46 | 79.36 |
| Landed deadloss ($10^6$ lbs) | 0.88 | 0.32 | 0.38 | 0.50 | 0.40 | 0.50 | 0.31 | 0.58 |
| Percent TAC/GHL utilized[c] | 108.0% | 99.4% | 99.4% | 100.0% | 100.0% | 100.0% | 99.8% | 99.9% |
| Decreased deadloss from last season[d] | n/a | YES | NO | NO | YES | NO | YES | NO |
| TAC or GHL exceeded[e] | YES | NO | NO | NO | NO | NO | NO | NO |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 389 | 389 | 375 | 356 | 362 | 361 | 361 | 369 |
| Active vessels[g] | 200 | 78 | 70 | 78 | 77 | 68 | 69 | 71 |
| Season length (days)[l] | 32.67 | 229 | 229 | 230 | 229 | 229 | 229 | 245 |
| Trips[h] | n/d | 282 | 192 | 350 | 333 | 250 | 280 | 540 |
| **Revenues (USD $10^6$)**[i] | | | | | | | | |
| Total revenue on IFQ trips | n/d | $50.10 | $67.97 | $116.96 | $91.06 | $60.80 | $128.76 | n/d |
| IFQ landings | $128.26 | $45.14 | $64.24 | $113.41 | $87.94 | $58.21 | $124.19 | $149.97 |
| Non-IFQ landings on IFQ trips[j] | n/d | $4.96 | $3.73 | $3.55 | $3.12 | $2.59 | $4.57 | n/d |
| IFQ revenue / active vessel | $0.59 | $0.58 | $0.92 | $1.45 | $1.14 | $0.86 | $1.80 | $2.11 |
| IFQ revenue / trip | n/d | $0.16 | $0.33 | $0.32 | $0.26 | $0.23 | $0.44 | $0.28 |
| **Price**[i]: Weighted price/lb, IFQ crab | $1.96 | $1.37 | $1.99 | $2.02 | $1.68 | $1.36 | $2.56 | $1.89 |

See Table 46 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.**

## Table 46c - IFQ crab fisheries performance metrics, Bering Sea Tanner crab – East and West

### Bering Sea Tanner crab – East

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | F/C | F/C | 1.69 | 3.10 | 2.49 | 1.22 | F/C | F/C |
| Commercial landings ($10^6$ lbs) | | | 1.26 | 1.42 | 1.54 | 1.18 | | |
| Landed deadloss ($10^6$ lbs) | | | 0.01 | 0.02 | 0.01 | 0.01 | | |
| Percent TAC/GHL utilized[c] | | | 75.1% | 46.4% | 62.5% | 97.9% | | |
| Decreased deadloss from last season[d] | | | n/a | NO | YES | YES | | |
| TAC or GHL exceeded[e] | | | NO | NO | NO | NO | | |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 426 | 426 | 412 | 389 | 388 | 376 | 383 | 380 |
| Active vessels[g] | | | 35 | 20 | 17 | 13 | | |
| Season length (days)[l] | | | 168 | 169 | 168 | 168 | | |
| Trips[h] | | | 48 | 55 | 45 | 26 | | |
| **Revenues (USD $\$10^6$)[i]** | | | | | | | | |
| Total revenue on IFQ trips | | | -- | -- | -- | $2.76 | | |
| IFQ landings | | | $2.62 | $2.98 | $3.32 | $2.47 | | |
| Non-IFQ landings on IFQ trips[j] | | | -- | -- | -- | $0.29 | | |
| IFQ revenue / active vessel | | | $0.07 | $0.15 | $0.20 | $0.19 | | |
| IFQ revenue / trip | | | $0.05 | $0.05 | $0.07 | $0.09 | | |
| **Price**[i]: Weighted price/lb, IFQ crab | | | $2.09 | $2.10 | $2.15 | $2.09 | | |

### Bering Sea Tanner crab – West

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | F/C | 1.46 | 0.98 | 1.96 | 1.38 | F/C | F/C | F/C |
| Commercial landings ($10^6$ lbs) | | 0.77 | 0.62 | 0.46 | 0.11 | | | |
| Landed deadloss ($10^6$ lbs) | | 0.01 | 0.02 | 0.00 | 0.00 | | | |
| Percent TAC/GHL utilized[c] | | 54.3% | 64.4% | 23.9% | 7.8% | | | |
| Decreased deadloss from last season[d] | | n/a | NO | YES | YES | | | |
| TAC or GHL exceeded[e] | | NO | NO | NO | NO | | | |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 426 | 426 | 412 | 389 | 389 | 377 | 384 | 381 |
| Active vessels[g] | | 33 | 20 | 18 | 9 | | | |
| Season length (days)[l] | | 168 | 168 | 169 | 168 | | | |
| Trips[h] | | 60 | 32 | 28 | 13 | | | |
| **Revenues (USD $\$10^6$)[i]** | | | | | | | | |
| Total revenue on IFQ trips | | -- | -- | $0.97 | $0.23 | | | |
| IFQ landings | | $1.40 | $1.27 | $0.97 | $0.23 | | | |
| Non-IFQ landings on IFQ trips[j] | | -- | -- | $0.00 | $0.00 | | | |
| IFQ revenue / active vessel | | $0.04 | $0.06 | $0.05 | $0.03 | | | |
| IFQ revenue / trip | | $0.02 | $0.04 | $0.03 | $0.02 | | | |
| **Price**[i]: Weighted price/lb, IFQ crab | | $1.81 | $2.07 | $2.09 | $2.20 | | | |

See Table 4 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.**

Bering Sea Tanner crab managed as a single fishery in 2005/2006 and as Eastern and Western fisheries in subsequent seasons. Eastern area closed as an inseason management measure in 2005/2006. Count of quota holding entities in the baseline, 2005/2006 and 2006/2007 seasons represent holders of Bering Sea Tanner quota; subsequent seasons show count of holders of Eastern or Western quota.

Effort and revenue metrics are inclusive of vessels with any landings of sold crab from the fishery. Given that a large proportion of Bering Sea Tanner crab is landed as bycatch in other fisheries, metrics on participating vessels, trips, and IFQ revenue per trip shown here are not representative of effort and revenue on vessels and trips actually targeting this fishery.

## Table 46e - IFQ crab fisheries performance metrics, Eastern Aleutian golden king crab

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 3.00 | 2.70 | 2.70 | 2.70 | 2.84 | 2.84 | 2.84 | 2.84 |
| Commercial landings ($10^6$ lbs) | 3.05 | 2.55 | 2.66 | 2.67 | 2.81 | -- | -- | -- |
| Landed deadloss ($10^6$ lbs) | 0.06 | 0.02 | 0.03 | 0.02 | 0.02 | -- | -- | -- |
| Percent TAC/GHL utilized[c] | 103.5% | 95.2% | 99.7% | 99.6% | 99.8% | -- | -- | -- |
| Decreased deadloss from last season[d] | n/a | YES | NO | YES | NO | NO | NO | YES |
| TAC or GHL exceeded[e] | YES | NO | NO | NO | NO | NO | NO | NO |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 28 | 28 | 27 | 26 | 26 | 24 | 28 | 27 |
| Active vessels[g] | 17 | 7 | 6 | 4 | 3 | 3 | 3 | 3 |
| Season length (days)[l] | 36.67 | 274 | 274 | 275 | 274 | 274 | 274 | 275 |
| Trips[h] | n/d | 32 | 23 | 27 | 21 | 22 | 21 | 20 |
| **Revenues (USD $10^6$)[i]** | | | | | | | | |
| Total revenue on IFQ trips | n/d | -- | -- | -- | -- | -- | -- | -- |
| IFQ landings | $12.79 | $8.49 | $6.62 | $7.04 | $11.19 | -- | -- | -- |
| Non-IFQ landings on IFQ trips[j] | n/d | -- | -- | -- | -- | -- | -- | n/d |
| IFQ revenue / active vessel | $0.73 | $1.21 | $1.10 | $1.76 | $3.73 | -- | -- | -- |
| IFQ revenue / trip | n/d | $0.27 | $0.29 | $0.26 | $0.53 | -- | -- | -- |
| **Price**[i]: Weighted price/lb, IFQ crab | $4.21 | $3.34 | $2.49 | $2.64 | $3.99 | -- | -- | -- |

See Table 4 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.**

## Table 46f - IFQ crab fisheries performance metrics, Western Aleutian golden king crab

| | Baseline[a, m] | 05/06 | 06/07 | 07/08 | 08/09 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|---|---|---|
| **Catch and Landings** | | | | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 2.70 | 2.43 | 2.43 | 2.43 | 2.55 | 2.55 | 2.55 | 2.55 |
| Commercial landings ($10^6$ lbs) | 2.67 | 2.35 | 1.98 | 2.23 | 2.23 | -- | -- | -- |
| Landed deadloss ($10^6$ lbs) | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | -- | -- | -- |
| Percent TAC/GHL utilized[c] | 100.5% | 98.1% | 82.4% | 92.5% | 88.3% | -- | -- | -- |
| Decreased deadloss from last season[d] | n/a | YES | YES | NO | YES | NO | YES | NO |
| TAC or GHL exceeded[e] | YES | NO | NO | NO | NO | NO | NO | NO |
| **Effort** | | | | | | | | |
| Entities holding harvest quota share[f] | 24 | 24 | 24 | 25 | 24 | 23 | 23 | 23 |
| Active vessels[g] | 6 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Season length (days)[l] | 245 | 274 | 274 | 275 | 274 | 274 | 274 | 275 |
| Trips[h] | n/d | 41 | 27 | 28 | 30 | 29 | 28 | 27 |
| **Revenues (USD $10^6$)[i]** | | | | | | | | |
| Total revenue on IFQ trips | n/d | -- | -- | -- | -- | -- | -- | -- |
| IFQ landings | $12.77 | $7.12 | $5.04 | $7.02 | $7.86 | -- | -- | -- |
| Non-IFQ landings on IFQ trips[j] | n/d | -- | -- | -- | -- | -- | -- | n/d |
| IFQ revenue / active vessel | $1.75 | $2.37 | $1.68 | $2.34 | $2.62 | -- | -- | -- |
| IFQ revenue / trip | n/d | $0.17 | $0.19 | $0.25 | $0.26 | -- | -- | -- |
| **Price**[i]: Weighted price/lb, IFQ crab | $4.78 | $3.02 | $2.54 | $3.16 | $3.53 | -- | -- | -- |

See Table 4 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.** To preserve confidentiality of 1998/1999 data, baseline values for selected landings metrics (commercial landings, landed deadloss, and utilization) and all revenue and price metrics represent the average over the 2001/2002 and 2004/2005 seasons only.

## Table 46g - IFQ crab fisheries catch share performance metrics, St. Matthew blue king crab

| | Baseline[a, m] | 2005 - 2008 | 09/10 | 10/11 | 11/12 |
|---|---|---|---|---|---|
| **Catch and Landings** | | | | | |
| IFQ quota allocated ($10^6$ lbs) | 4.00 | F/C | 1.05 | 1.44 | 2.12 |
| Commercial landings ($10^6$ lbs) | 2.85 | | -- | -- | 1.67 |
| Landed deadloss ($10^6$ lbs) | 0.02 | | -- | -- | 0.03 |
| Percent TAC/GHL utilized[c] | 71.7% | | -- | -- | 80.0% |
| Decreased deadloss from last season[d] | n/a | | n/a | YES | NO |
| TAC or GHL exceeded[e] | NO | | NO | NO | NO |
| **Effort** | | | | | |
| Entities holding harvest quota share[f] | 210 | | 207 | 213 | 212 |
| Active vessels [g] | 132 | | 7 | 11 | 18 |
| Season length (days)[l] | 12 | | 110 | 110 | 110 |
| Trips [h] | n/d | | 0 | 0 | 0 |
| **Revenues (USD $10^6$)**[i] | | | | | |
| Total revenue on IFQ trips | n/d | | -- | -- | n/d |
| IFQ landings | $8.52 | | -- | -- | $9.38 |
| Non-IFQ landings on IFQ trips [j] | n/d | | -- | -- | n/d |
| IFQ revenue / active vessel | $0.07 | | -- | -- | $0.52 |
| IFQ revenue / trip | n/d | | -- | -- | $0.17 |
| **Price** [i]: Weighted price/lb, IFQ crab | $2.99 | | -- | -- | $5.62 |

See Table 46 for data sources and footnotes. **2011/2012 season data and 2010/2011 revenue and prices are preliminary as of September 2012.** St. Matthew blue king crab fishery open only during the 1998/1998 season in the baseline period. Fishery closed from 2005/2006 to 2008/2009 seasons.

## Table 46h - IFQ crab fisheries catch share performance metrics, Pribilof Islands red and blue king crab, Western Aleutian red king crab

| | Pribilof Islands red and blue king crab | | Western Aleutian red king crab | |
|---|---|---|---|---|
| | Baseline[a, m] | 2005 - 2012 | Baseline[a, m] | 2005 - 2012 |
| **Catch and Landings** | | | | |
| IFQ quota allocated ($10^6$ lbs) | 1.30 | FC | 0.02 | FC |
| Commercial landings ($10^6$ lbs) | 1.00 | | -- | |
| Landed deadloss ($10^6$ lbs) | 0.03 | | -- | |
| Percent TAC/GHL utilized[c] | 79.0% | | -- | |
| Decreased deadloss from last season[d] | n/a | | n/a | |
| TAC or GHL exceeded[e] | NO | | NO | |
| **Effort** | | | | |
| Entities holding harvest quota share[f] | 148 | | 34 | |
| Active vessels [g] | 57 | | 1 | |
| Season length (days)[l] | 14 | | 273 | |
| Trips [h] | n/d | | n/d | |
| **Revenues (USD $10^6$)**[i] | | | | |
| Total revenue on IFQ trips | n/d | | n/d | |
| IFQ landings | $3.77 | | n/d | |
| Non-IFQ landings on IFQ trips [j] | n/d | | n/d | |
| IFQ revenue / active vessel | $0.07 | | n/d | |
| IFQ revenue / trip | n/d | | n/d | |
| **Price** [i]: Weighted price/lb, IFQ crab | $3.79 | | n/d | |

See Table 46 for data sources and footnotes. Both fisheries open only during the 1998/1998 season in the baseline period.

# Appendix

Table 47: Harvesting and processing participants submitting EDRs

| | Harvest operations | | Processing operations | | | Hired processing only | |
|---|---|---|---|---|---|---|---|
| Year | Catcher vessel | Catcher processor | Shoreside processor | Floating processor | Catcher processor | Shoreside processor | Floating processor |
| 1998 | 8 | 218 | 13 | 12 | 8 | 0 | 0 |
| 2001 | 7 | 219 | 16 | 5 | 7 | 1 | 1 |
| 2004 | 10 | 237 | 14 | 5 | 10 | 0 | 1 |
| 2005 | 8 | 166 | 13 | 4 | 8 | 1 | 0 |
| 2006 | 5 | 97 | 11 | 2 | 5 | 0 | 1 |
| 2007 | 5 | 82 | 11 | 3 | 5 | 1 | 0 |
| 2008 | 5 | 91 | 11 | 2 | 5 | 3 | 0 |
| 2009 | 5 | 84 | 12 | 2 | 5 | 3 | 0 |
| 2010 | 3 | 76 | 12 | 3 | 3 | 2 | 1 |
| 2011 | 3 | 74 | 16 | 2 | 3 | 1 | 0 |

*Source: NOAA Fisheries, Alaska Fisheries Science Center. BSAI Crab Economic Data*

For harvesters, participation in the rationalized crab fisheries is determined from harvest activity, landing revenues, and labor in crab fisheries, as reported in the EDR. For processors, participation is determined from processing activity, raw pounds input to production, and finished production in crab fisheries, as reported in the EDR. “Hired processing only” refers to processing operations that had all of their purchased BSAI crab custom-processed by another processor and that submitted voluntary EDRs.

Table 48: Harvesting and processing participants submitting EDRs, by sector and fishery

| | | Harvest operations | | | Processing operations | | | |
|---|---|---|---|---|---|---|---|---|
| Fishery | Year | Catcher vessel | Catcher processor | Total harvesting operations | Shoreside processor | Floating processor | Catcher processor | Total processing operations |
| AIG | 1998 | 2 | 13 | 15 | 4 | 0 | 2 | 6 |
| | 2001 | 1 | 19 | 20 | 5 | 0 | 1 | 6 |
| | 2004 | 1 | 20 | 21 | 4 | 0 | 1 | 5 |
| | 2005 | 2 | 10 | 12 | 4 | 0 | 2 | 6 |
| | 2006 | 1 | 6 | 7 | 6 | 0 | 1 | 7 |
| | 2007 | 1 | 6 | 7 | 5 | 0 | 1 | 6 |
| | 2008 | 1 | 4 | 5 | 6 | 0 | 1 | 7 |
| | 2009 | 1 | 4 | 5 | 5 | 0 | 1 | 6 |
| | 2010 | 1 | 4 | 5 | 5 | 0 | 1 | 6 |
| | 2011 | 1 | 5 | 6 | 7 | 1 | 1 | 9 |
| BBR | 1998 | 7 | 206 | 213 | 9 | 3 | 7 | 19 |
| | 2001 | 5 | 199 | 204 | 11 | 2 | 5 | 18 |
| | 2004 | 8 | 230 | 238 | 13 | 2 | 8 | 23 |
| | 2005 | 5 | 86 | 91 | 10 | 1 | 6 | 17 |
| | 2006 | 3 | 80 | 83 | 10 | 1 | 3 | 14 |
| | 2007 | 3 | 70 | 73 | 10 | 1 | 3 | 14 |
| | 2008 | 3 | 76 | 79 | 10 | 1 | 3 | 14 |
| | 2009 | 2 | 68 | 70 | 10 | 1 | 2 | 13 |
| | 2010 | 2 | 63 | 65 | 11 | 2 | 2 | 15 |
| | 2011 | 2 | 60 | 62 | 14 | 1 | 2 | 17 |
| BSS | 1998 | 6 | 177 | 183 | 10 | 12 | 6 | 28 |
| | 2001 | 6 | 174 | 180 | 9 | 5 | 6 | 20 |
| | 2004 | 6 | 175 | 181 | 10 | 5 | 6 | 21 |
| | 2005 | 6 | 150 | 156 | 9 | 4 | 6 | 19 |
| | 2006 | 4 | 74 | 78 | 8 | 2 | 4 | 14 |
| | 2007 | 4 | 65 | 69 | 8 | 2 | 4 | 14 |
| | 2008 | 4 | 74 | 78 | 10 | 2 | 4 | 16 |
| | 2009 | 4 | 73 | 77 | 8 | 2 | 4 | 14 |
| | 2010 | 2 | 66 | 68 | 7 | 2 | 2 | 11 |
| | 2011 | 2 | 66 | 68 | 12 | 2 | 2 | 16 |
| BST | 1998 | 0 | 2 | 2 | 1 | 0 | 0 | 1 |
| | 2001 | 0 | 4 | 4 | 3 | 1 | 0 | 4 |
| | 2004 | 0 | 1 | 1 | 3 | 0 | 0 | 3 |
| | 2005 | 1 | 4 | 5 | 7 | 0 | 1 | 8 |
| | 2006 | 1 | 42 | 43 | 6 | 2 | 2 | 10 |
| | 2007 | 1 | 28 | 29 | 6 | 1 | 1 | 8 |
| | 2008 | 1 | 29 | 30 | 7 | 1 | 1 | 9 |
| | 2009 | 1 | 17 | 18 | 5 | 2 | 1 | 8 |
| | 2010 | 0 | 4 | 4 | 3 | 1 | 0 | 4 |
| | 2011 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| PIK | 1998 | 0 | 43 | 43 | 11 | 2 | 0 | 13 |
| | 2001 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| | 2004 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| SMB | 1998 | 2 | 95 | 97 | 7 | 4 | 2 | 13 |
| | 2009 | 0 | 7 | 7 | 2 | 0 | 0 | 2 |
| | 2010 | 0 | 12 | 12 | 5 | 1 | 0 | 6 |
| | 2011 | 0 | 18 | 18 | 8 | 0 | 0 | 8 |
| WAI | 1998 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| | 2001 | 1 | 3 | 4 | 1 | 0 | 1 | 2 |
| | 2004 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

*Source: NOAA Fisheries, Alaska Fisheries Science Center. BSAI Crab Economic Data*

For harvesters, participation in a rationalized crab fishery is determined from harvest activity, landing revenues, and labor in the fishery, as reported in the EDR. For processors, participation is determined from processing activity, raw pounds input to production, and finished production in the crab fishery, as reported in the EDR. Note that the figures for processing operations exclude voluntary EDR submissions from crab buyers who had all of their purchased BSAI crab custom processed by another processor. Years not shown for PIK, SMB, and WAI fisheries indicate no harvest or processing participants due to fishery closure.

Table 49: EDR vessel coverage

| Year | Vessels in EDR & ADF&G fish tickets/eLandings | Vessels in ADF&G fish tickets/eLandings | EDR vessel coverage |
|---|---|---|---|
| 1998 | 231 | 286 | 80.8% |
| 2001 | 220 | 253 | 87.0% |
| 2004 | 245 | 256 | 95.7% |
| 2005 | 171 | 182 | 94.0% |
| 2006 | 102 | 102 | 100.0% |
| 2007 | 86 | 86 | 100.0% |
| 2008 | 94 | 94 | 100.0% |
| 2009 | 88 | 89 | 98.9% |
| 2009 | 89 | 89 | 100.0% |
| 2010 | 79 | 79 | 100.0% |
| 2011 | 77 | 77 | 100.0% |

*Source: NMFS AFSC BSAI Crab Economic Data.* EDR vessels are catcher vessel operations that reported sold crab in the year of interest and catcher processors that reported processing or purchasing crab in the year of interest, per EDR data. Vessels in ADF&G fish tickets/eLandings are vessels that had commercial crab landings in the year of interest, per fish ticket or eLandings data.

## Table 50: EDR vessel coverage by fishery

| Fishery | Year | Vessels in EDR + FT | Vessels in EDR only | Vessels in fish tickets only | Estimated landings from EDR as % of FT landings |
|---|---|---|---|---|---|
| AIG | 1998 | 14 | 1 | 2 | 99% |
| | 2001 | 19 | 1 | 2 | 96% |
| | 2004 | 21 | 0 | 1 | 95-98% |
| | 2005 | 9 | 3 | 0 | 110-115% |
| | 2006 | 7 | 0 | 0 | 102% |
| | 2007 | 7 | 0 | 0 | 96% |
| | 2008 | 5 | 0 | 0 | 94% |
| | 2009 | 5 | 0 | 0 | 113% |
| | 2010 | 5 | 2 | 0 | 90% |
| | 2011 | 5 | 2 | 0 | 102% |
| BBR | 1998 | 206 | 1 | 67 | 80% |
| | 2001 | 202 | 0 | 28 | 89% |
| | 2004 | 237 | 0 | 14 | 98% |
| | 2005 | 89 | 2 | 0 | 99% |
| | 2006 | 81 | 2 | 0 | 100-105% |
| | 2007 | 73 | 1 | 0 | 98% |
| | 2008 | 79 | 1 | 0 | 97% |
| | 2009 | 70 | 0 | 0 | 99% |
| | 2010 | 65 | 1 | 0 | 100% |
| | 2011 | 61 | 1 | 1 | 100% |
| BSS | 1998 | 177 | 0 | 54 | 78% |
| | 2001 | 178 | 0 | 30 | 87% |
| | 2004 | 179 | 0 | 10 | 97% |
| | 2005 | 155 | 1 | 12 | 100% |
| | 2006 | 78 | 0 | 0 | 101% |
| | 2007 | 67 | 1 | 0 | 99% |
| | 2008 | 78 | 0 | 0 | 100% |
| | 2009 | 76 | 1 | 1 | 97% |
| | 2010 | 68 | 1 | 0 | 0.99 |
| | 2011 | 68 | 1 | 0 | 0.97 |
| BST | 2001 | 0 | 4 | 2 | 533% |
| | 2004 | 0 | 1 | 0 | 0% |
| | 2005 | 4 | 1 | 0 | 100-105% |
| | 2006 | 42 | 1 | 3 | 103% |
| | 2007 | 27 | 1 | 2 | 100% |
| | 2008 | 28 | 2 | 2 | 98% |
| | 2009 | 16 | 2 | 2 | 97% |
| PIK | 1998 | 42 | 1 | 16 | 73% |
| | 2001 | 0 | 1 | 0 | -- |
| | 2004 | 0 | 1 | 0 | -- |
| SMB | 1998 | 92 | 0 | 39 | 76% |
| | 2009 | 7 | 0 | 0 | 100% |
| | 2010 | 10 | 3 | 1 | 99% |
| | 2011 | 18 | 3 | 0 | 101% |
| WAI | 1998 | 1 | 1 | 0 | 1207% |
| | 2001 | 4 | 0 | 0 | 100% |
| | 2004 | 0 | 1 | 0 | -- |

*Source: NMFS AFSC BSAI Crab Economic Data, ADF&G fish tickets, eLandings.* EDR vessels are catcher vessel operations that reported sold crab in the fishery and year of interest and catcher processors that reported processing or purchasing crab in the fishery and year of interest, per EDR data. Vessels in ADF&G fish tickets/eLandings are vessels that had commercial crab landings in the year of interest, per fish ticket or eLandings data.

## Table 51: Operations reporting crab purchasing in EDR and fish tickets, by fishery

| Fishery | Year | Operations in EDR + FT | Operations in EDR only | Operations in FT only | EDR lbs as % of FT lbs |
|---|---|---|---|---|---|
| AIG | 1998 | 4 | 2 | 3 | 91% |
| | 2001 | 5 | 1 | 1 | 89% |
| | 2004 | 4 | 1 | 0 | 60% |
| | 2005 | 6 | 1 | 1 | 101% |
| | 2006 | 7 | 1 | 2 | 92% |
| | 2007 | 7 | 0 | 0 | 114% |
| | 2008 | 7 | 1 | 1 | 89% |
| | 2009 | 5 | 0 | 6 | 104% |
| | 2010 | 12 | 3 | 4 | 119% |
| | 2011 | 12 | 2 | 4 | 100% |
| BBR | 1998 | 14 | 6 | 4 | 90% |
| | 2001 | 10 | 8 | 5 | 99% |
| | 2004 | 14 | 9 | 1 | 97% |
| | 2005 | 14 | 4 | 2 | 101% |
| | 2006 | 13 | 2 | 3 | 91% |
| | 2007 | 12 | 4 | 5 | 96% |
| | 2008 | 14 | 4 | 1 | 100% |
| | 2009 | 10 | 3 | 6 | 100% |
| | 2010 | 12 | 3 | 4 | 119% |
| | 2011 | 12 | 2 | 4 | 100% |
| BSS | 1998 | 22 | 6 | 7 | 90% |
| | 2001 | 15 | 6 | 3 | 96% |
| | 2004 | 17 | 5 | 2 | 98% |
| | 2005 | 15 | 4 | 1 | 97% |
| | 2006 | 14 | 0 | 1 | 100% |
| | 2007 | 14 | 2 | 4 | 109% |
| | 2008 | 13 | 4 | 3 | 103% |
| | 2009 | 9 | 5 | 5 | 94% |
| | 2010 | 9 | 5 | 2 | 97% |
| | 2011 | 11 | 3 | 3 | 92% |
| BST | 1998 | 0 | 1 | 0 | n/a |
| | 2001 | 0 | 5 | 0 | n/a |
| | 2004 | 0 | 3 | 0 | n/a |
| | 2005 | 4 | 4 | 0 | 209% |
| | 2006 | 10 | 0 | 1 | 110% |
| | 2007 | 9 | 0 | 1 | 100% |
| | 2008 | 9 | 2 | 3 | 85% |
| | 2009 | 6 | 3 | 5 | 94% |
| | 2010 | 5 | 2 | 2 | 64% |
| PIK | 1998 | 12 | 2 | 4 | 94% |
| SMB | 1998 | 12 | 2 | 2 | 95% |
| | 2009 | 4 | 1 | 2 | 100% |
| | 2010 | 7 | 2 | 3 | 108% |
| | 2011 | 8 | 1 | 4 | 69% |
| WAI | 1998 | 0 | 1 | 0 | 100% |
| | 2001 | 1 | 1 | 0 | 48% |

*Source: NMFS AFSC BSAI Crab Economic Data. Fish ticket data from ADF&G.*

EDR operations are shoreside and floating processors that reported purchasing and catcher processors that reported processing or purchasing crab in the fishery and year of interest, per EDR data. Fish ticket operations are operations that made purchases in the fishery and year of interest or, starting in 2005, received crab landings as a custom processor, per fish ticket data,. Operations from the two data sources were matched on the basis of ADF&G processor code. Percent coverage in pounds compares the volume of raw crab input to production, as reported in the EDR, to the volume of crab purchased, as reported in ADF&G fish tickets.

Table 52: Producer price index – unprocessed and packaged fish

| Year | Index | 2011 Adjustment Factor |
|---|---|---|
| 1991 | 149.5 | 1.92 |
| 1992 | 156.1 | 1.84 |
| 1993 | 156.5 | 1.84 |
| 1994 | 161.4 | 1.78 |
| 1995 | 170.8 | 1.68 |
| 1996 | 165.9 | 1.73 |
| 1997 | 178.1 | 1.61 |
| 1998 | 183.2 | 1.57 |
| 1999 | 190.9 | 1.51 |
| 2000 | 198.1 | 1.45 |
| 2001 | 190.8 | 1.51 |
| 2002 | 191.2 | 1.50 |
| 2003 | 195.3 | 1.47 |
| 2004 | 206.3 | 1.39 |
| 2005 | 222.6 | 1.29 |
| 2006 | 237.4 | 1.21 |
| 2007 | 242.8 | 1.18 |
| 2008 | 255.4 | 1.13 |
| 2009 | 250.9 | 1.15 |
| 2010 | 272.4 | 1.06 |
| 2011 | 287.6 | 1.00 |

*Source: Bureau of Labor Statistics. Producer Price Index-Commodities, Series WPU0223 (Unprocessed and packaged fish).Retrieved July 2012 from http://www.bls.gov/ppi/*

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# Ongoing Research

**Bioeconomic Models of North Pacific Crab Stocks to Analyze Effects of Market Variability and Climate-Oceanographic Change**

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Maximum sustainable yield (MSY) is the default reference point in U.S. fisheries management. However the Magnuson-Stevens Act defines optimum yield in National Standard 1 as the amount of fish that provides the greatest overall benefit to the nation, which could deviate from MSY because of economic (or other) factors. While it has long been recognized that MSY is not in general an economic optimum, estimates of maximum economic yield (MEY) are not typically reported in fishery management plans, presumably because of data limitations on economic costs related to fishing. Furthermore, uncertainty is a fundamental feature of the environment in which fishermen and processors make decisions. Coupled bioeconomic models are being developed to analyze effects of market variability and changes in climate-ocean conditions on North Pacific crab stocks. The first bioeconomic model that was developed consisted of a population dynamics model for the Eastern Bering Sea snow crab stock (BSS) coupled to an economic dynamics model which was calibrated to revenue and cost data from the BSAI Crab EDR database. The second bioeconomic model is similar to the first, but applied to the Bristol Bay red king crab stock (BBR). To evaluate impacts of ocean acidification on the BBR stock, this second model was extended with an explicit stage structured pre-recruitment component that was calibrated to results of exposure experiments conducted at the AFSC Kodiak lab. The third model coupled the BBR and BSS bioeconomic models to estimate joint maximum economic yield. A new project for 2012-13 at the University of Washington's Joint Institute for the Study of the Atmosphere will develop a bioeconomic model for the Bering Sea tanner crab (BST) stock, including a pre-recruitment component. The BST bioeconomic model will be coupled with BBR and BSS bioeconomic models, and used to forecast effects of ocean acidification. The development of a bioeconomic model for Aleutian Islands golden king crab is planned for future research.

**Center for Independent Experts Review: Bering Sea and Aleutian Islands Crab Economic Data Report Program**

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During the past year ESSRP partnered with the Center for Independent Experts (CIE) to undertake a peer review of methodological practices employed in the development and administration of the Bering Sea and Aleutian Islands (BSAI) Crab Economic Data Report (EDR) program. The crab EDR program has been managed by ESSRP under the direction of the North Pacific Fishery Management Council (Council) and in accordance with 50 CFR 680.6 since the transition to the rationalized management regime in 2005. The program is currently under revision by the North Pacific Fishery Management Council for to address changing analytical objectives, data quality limitations, and excessive submitter burden. Final action by the

Council to identify mandatory economic reporting requirements occurred in December 2011, with regulatory changes and implementation procedures to be developed during the coming year. To support implementation of the Council's final action concerning the BSAI crab EDR program using best scientific and methodological practices, AFSC has sought guidance from independent experts in the fields of applied economic analysis of fishery resource management, design and testing of economic surveys of business establishments, and methods for data quality assessment and data quality control.
The CIE steering committee appointed the following individuals to provide independent peer reviews:

- Dr. Susan Hanna, Professor Emeritus of Marine Economics, Oregon State University
- Dr. Danna L. Moore, Associate Director, Social & Economic Sciences Research Center, Washington State University
- Dr. Richard Wang , Director, MIT Information Quality Program, Massachusetts Institute of Technology

The panel convened a public meeting at AFSC on August 23-24, 2011. The meeting was chaired by Dr. Chris Anderson of University of Rhode Island, and included the participation of crab industry representatives and other members of the public. ESSRP staff and contractors presented documentation of methods and practices employed to date in the implementation of the data collection, validation, and dissemination, and panel members engaged both agency staff and industry participants in active discussion throughout the course of the meeting. The completed peer review reports were received on October 3, and the meeting chair's report is currently being finalized.# General findings of the panel noted the advances made in implementation and validation of economic data collection in commercial fisheries by the program in collaboration with industry participants, despite significant limitations associated with survey design, recordkeeping practices, and constraints on more timely modification of survey instruments in response to data quality limitations and changing conditions in the fishery. Panel recommendations include methodological improvements in survey design and development and application of data quality standards. Recommended process improvements included improved collaboration between industry and agency personnel, and appointment of a standing technical body similar to the Council's Plan Development Teams to be tasked with coordinating and advising in the development and implementation of best practices for economic data collection and analyses.

**Production Efficiency and Exit in Catch Share Fisheries**

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Economic theory predicts that the least efficient vessels are more likely to exit a fishery following the transition from an open-access fishery to an individual transferable quota (ITQ) management regime. Tools are needed to help analysts predict the likely degree and distribution of consolidation prior to implementing ITQ programs. Previous research analyzing efficiency in ITQ fisheries has either relied upon data before and after the program was implemented and/or used a two-step procedure to model vessel efficiency, wherein the decision to be active following the transition is assumed to be independent from one's prior production practices.  This research utilizes a one-stage estimation procedure to determine the degree to which one's technical inefficiency preceding an ITQ regime influences the likelihood of them exiting after the transition, which can be used for ex-ante predictions regarding the changes in composition after a transition to ITQs.  Using pre-ITQ data on fishermen participating in the North Pacific crab fisheries, our results indicate that a vessel's measure of technical inefficiency is a significant and positive factor in explaining whether it exits the fishery following the implementation of ITQs.  This paper is forthcoming in *Land Economics.*

**Updating the North Pacific Fishing Community Profiles**

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A NOAA Technical Memorandum finalized in October 2011 documents the process we are undertaking to update the *Community Profiles for North Pacific Fisheries – Alaska*. In addition, the communities to be included in the updated document were reevaluated to ensure that communities with significant reliance on commercial, recreational and subsistence fishing are included. This resulted in a total of 195 communities that will be profiled, including the 136 communities that were profiled in the 2005 *Community Profiles for North Pacific Fisheries – Alaska* (Community Profiles; Sepez et al 2005) and an additional 60 communities that were not previously included. ESSRP staff spent the majority of 2011 developing a template for the new community profiles, researching and compiling data sources needed for the profile update, and working with the Alaska Fisheries Information Network to compile all of the data for the profiles into a database for use during the profile update process. The new template adds a significant amount of new information to help provide a better understanding of each community's reliance on fishing.  The community profiles comprise additional information including, but not limited to, annual population fluctuation, fisheries-related infrastructure, community finances, natural resources, educational opportunities, fisheries revenue, shore-based processing plant narratives, landings and permits by species, and subsistence and recreational fishing participation, as well as information collected from communities in the Alaska Community Survey, which was implemented during summer 2011.

A team of research assistants was assembled in November 2011 to start the process of revising the profiles. Throughout 2012, this team has been systematically revising all of the existing community profiles and drafting new profiles for the additional 60 communities. Each of the 195 communities has been sent a copy of their updated profile and is being encouraged to provide comments. All comments received will be incorporated into the profiles to the extent feasible. A final version of each community profile is expected to be completed by early October 2012. In October and November 2012, regional profiles will be drafted that summarize overall involvement in fishing by communities in each of the major regions of Alaska.

Final versions of the regional profiles and community profiles will be made available on the AFSC website. ESSRP staff have been working with AFSC GIS specialists to develop an interactive website where the user can view high level commercial, recreational and subsistence data through a webmapping tool. The user will also be able to download non-confidential data per community and each community’s profile. The webmapping tool is expected to launch in fall 2012 and can be reached via the existing community profiles website: http://www.afsc.noaa.gov/REFM/Socioeconomics/Projects/CPU.php.

## Surveying the Importance of Fishing to Alaskan Communities

Amber Himes-Cornell

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In FY11, ESSRP social scientists developed, tested, and finalized survey materials and completed the OMB approval process for the Alaska Community Survey. As a part of the survey development process, ESSRP social scientists compiled data sets to run a data envelopment analysis model to select fishing communities most engaged in or dependent on North Pacific fisheries to receive the survey. Data collection with the survey instrument was also completed by ESSRP social scientists and an initial analysis of the data was performed. The Alaska Community Survey was implemented during summer 2011. Surveys were sent out to community leaders in 181 fishing communities. Surveys for 111 communities were returned, representing a response rate of 61.3%. The information collected in the survey included time series data, information on community revenues based in the fisheries economy, population fluctuations, fisheries infrastructure available in the community, support sector business operations in the community, community participation in fisheries management, and effects of fisheries management decisions on the community. The data received from the surveys has been incorporated into the updated *Community Profiles for North Pacific Fisheries – Alaska* (NOAA Tech Memo NMFS-AFSC-160; currently being revised) and to provide summary statistics on fishing communities throughout different regions of Alaska. The survey will be repeated in late 2012 in order to provide a second year of data and to give communities that did not submit the survey in 2011 another opportunity to provide data.

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### Developing Comparable Socio-economic Indices of Fishing Community Vulnerability and Resilience for the Contiguous U.S. and Alaska

Amber Himes-Cornell and Stephen Kasperski*
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Fishing communities exist within a larger coastal economy. Therefore, the ability to understand the context of vulnerability to social factors is critical to understanding how regulatory change will be absorbed into these multifaceted communities. Creating social indicators of vulnerability for fishing communities provides a pragmatic approach toward standardization of data and analysis for assessment of some of the long term effects of management actions. Historically, the ability to conduct such analysis has been due to the lack of quantitative social data. Over the past two years, social scientists working in NOAA's Alaska, Northeast (NE) and Southeast (SE) regions have been engaged in the development of indices for evaluating aspects of fishing community vulnerability and resilience to be used in the assessment of the social impacts of proposed fishery management plans and actions (Colburn and Jepson, 2012). In addition, a social scientist at the Northwest Fisheries Science Center is in the early stages of developing similar indicators for the west coast and is expected to have them completed by the time the results are needed for the proposed project. The Northeast Fisheries Science Center (NEFSC) and Southeast Regional Office (SERO) have developed a set of social indices using secondary data for nearly 3,000 coastal communities in the Eastern U.S. and Gulf Coast (Jepson and Colburn, *In prep*).

The Alaska Fisheries Science Center (AFSC) has developed similar indices for over 500 communities in Alaska. We compiled socio-economic and fisheries data from a number of sources to conduct an analysis using the same methodology used by the NEFSC and SERO. To the extent feasible, the same sources of data are being used in order to allow comparability between regions. However, initial comparisons indicate that resource, structural and infrastructural differences between the NE and SE and Alaska will require modifications of each of the indices to make them strictly comparable. The data are being analyzed using principal components analysis which allow us to separate out the most important socio-economic and fisheries related factors associated with community vulnerability and resilience in Alaska in a statistically meaningful way.

These social indices are intended to improve the analytical rigor of fisheries Social Impact Assessments, through analysis of adherence to National Standard 8 of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act and Executive Order 12898 on Environmental Justice in components of Environmental Impact Statements. Given the often short time frame in which such analyses are often conducted, an advantage to the approach taken by the Principal Investigators to date is that the majority of the data used to construct these indices are readily accessible secondary data and can be compiled quickly to create measures of social vulnerability and to update community profiles.

The next step in this research project is to incorporate stakeholder feedback to adapt the current methodology so that a new set of indices can be created that will enable comparisons across these regions and eventually, nationwide. This will allow cross regional analysis of fishing community vulnerability and resilience and testing of the validity of the results through in-community education and outreach. Modifications to the methodology will be made based on community feedback.

Groundtruthing the results will facilitate the use of these tools by the AFSC, NOAA's Alaska Regional Office and the North Pacific Fishery Management Council staff to analyze the comparative vulnerability of fishing communities across Alaska to proposed fisheries management regulations, in accordance with NS8. This research will provide policymakers with an objective and data driven approach to support effective management of North Pacific fisheries.

References

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### Using Indicators to Assess the Vulnerability and Resiliency of Alaskan Communities to Climate Change

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Communities in Alaska are experiencing impacts of unexpected climate-related changes and unprecedented environmental conditions on the harvests of marine and terrestrial resources. Residents of rural Alaska are already reporting heretofore unseen changes in the geographic distribution and abundance of fish and marine mammals, increases in the frequency and ferocity of storm surges in the Bering Sea, changes in the distribution and thickness of sea ice, and increases in river and coastal erosion. When combined with ongoing social and economic change, climate, weather, and changes in the biophysical system interact in a complex web of feedbacks and interactions that make life in rural Alaska extremely challenging.

We develop a framework of indicators to assess three basic forms of community vulnerability to climate change: exposure to the bio-physical effects of climate change, dependence on resources that will be affected by climate change, and a community's adaptive capacity to offset negative impacts of climate change.We conduct a principal components analysis on each of the three forms of vulnerability, and then combine all three forms of vulnerability together to determine each community's overall vulnerability to climate change. The principal components analysis, which is a variable reduction strategy, allows us to separate the most important factors determining the vulnerability of each community to each type of risk factor in a robust, consistent, and statistically meaningful way. For the 392 communities in Alaska with data, the 105 variables included in the principal components analysis break down into 21 different principal components which explain a total of 78.4% of the variation across all variables. The components with the most explanatory power include poverty and demographics, subsistence halibut and commercial participation, latitude of catch, sportfishing, and employment diversification.

The framework developed here can also be applied more generally through indicators that assess community vulnerability and resiliency to sea level rise, drought, storm intensity, and other likely impacts of climate change. These indicators can help inform how best to allocate resources for climate change adaptation.

## Coupling Bioeconomic Model and Regional Computable General Equilibrium (CGE) Model for Alaska Crab Fisheries

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A comprehensive two-stock bioeconomic model for Bristol Bay red king crab (BBR) and Eastern Bering Sea Snow Crab (BSS) was developed with support from NOAA Fisheries Office of Science and Technology, and NOAA's Office of Oceanic and Atmospheric Research. Increases in atmospheric $CO_2$ concentrations, caused primarily by fossil fuel emissions and deforestation, has led to corresponding increases in oceanic $CO_2$ concentrations, and hence, changes in carbonate chemistry of the oceans and decreases in ocean pH. As $CO_2$ levels continue to rise over the coming decades, the pH in the ocean will fall even further. This trend could have substantial physiological effects on marine organisms, affecting growth, survival, reproduction, and behavior.  Calcifying organisms may be particularly affected because the reduction in pH makes it more difficult to excrete and sustain a calcified shell or exoskeleton.

Most of the management strategies developed for fish and invertebrate species in the U.S. and elsewhere are predicated on the assumption that the productivity of the resources remains constant over long time periods. This assumption is likely to be violated by the impact of ocean acidification. However, the impact of such violation is poorly understood generally, and for North Pacific crab fisheries in particular. The ideal tool to explore the biological and economic impacts of ocean acidification is a bio-economic modeling framework which a) integrates predictions regarding trends over time in ocean pH; b) separates life-history stages for growth and mortality of juveniles and adults; and c) includes fishery impacts by analyzing catch and effort in both biological and economic terms. In this model, a size-structured population dynamics model component for larger animals is coupled to a stage-structured model component for smaller animals that have not been recruited into the fishery (i.e., “pre-recruits”). Including an explicit pre-recruit component is unusual in population dynamics models, and it is used in the new king crab bio-economic model to represent the impacts of ocean acidification on pre-recruit life-history stages. These impacts are the subject of ongoing laboratory experiments with juvenile crabs, and data from these experiments will be used to parameterize the pre-recruit component of the new bio-economic model.

Once development of the crab bioeconomic model is completed, as a next step, the model will be coupled with a regional CGE model in order to calculate the impacts of the ocean acidification on the economy of the region depending on the fisheries. Recently, a state-level CGE has been developed and some hypothetical scenarios for change in the total allowable catches (TACs) of the two species, which is driven by ocean acidification, have been simulated to calculate the economic impacts on industry output, value added, and household income for the state of Alaska.

### Evaluating Statistical Estimation Strategies for BSAI Crab Rationalization Economic Data Reports

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In 2005 the Bering Sea and Aleutian Islands (BSAI) crab fisheries managed under authority of NOAA Fisheries underwent a drastic change in management regime when the Crab Rationalization Program (CRP) was implemented. As designed by the North Pacific Fishery Management Council, the CRP allocated catch-share quota privileges to both harvesters and processors with the objectives of addressing excess harvesting and processing capacity and improving the performance of the crab fisheries with respect to low economic returns and economic instability for harvesters, processors, and communities. In anticipation of potential changes in the magnitude and distribution of benefits, employment, and other social and economic effects of the CRP, the Council tasked the Alaska Fisheries Science Center (AFSC) with leading the development and implementation of a mandatory reporting requirement to collect annual cost, earnings, and employment data from crab fishery participants. Economic Data Report (EDR) data are intended to support computation of a number of economic performance metrics to evaluate the effects of rationalization on fishery participants and dependent communities, and to provide data and analysis in support of future management changes.

EDR data are a rich source of information for analyzing economic performance of BSAI crab fisheries. As a whole, EDRs include a panel data set of production factor inputs and costs (e.g., fuel, bait), and output and revenue (e.g., landed catch, finished products), and supplement extensive administrative records capturing operational aspects of fishery participants’ production. Despite providing a detailed census of all fishery participants’ costs and earnings, the full potential of these data has not been realized because of data quality concerns arising from non-sampling sources of survey error and a lack of statistical methods for addressing these concerns. While incomplete, empirical information regarding incidence and structure of measurement error in the panel is provided by annual records-check validation audits performed on a random sample of observations. Both the costs and earnings data panel as well as the qualitative and quantitative data quality information regarding the panel are unique among commercial fisheries economic monitoring efforts. In order to make the best use of these data, address existing concerns about data quality, and establish a statistical framework to support future monitoring and analysis, AFSCs economic research program is seeking technical guidance on how to systematically treat observed and unobserved measurement error and obtain consistent estimates of economic performance measures from EDR and other ancillary data sources. We are also interested in examining the extent to which the addition of EDR cost data improves model performance beyond simpler specifications based upon revenue and effort data.

The study will first examine and review the data and assess alternative model frameworks applicable to the EDR data, including the Errors in Variables (EIV) framework and others (e.g., Bound et al. 2001, Fuller 1987 , Griliches and Hausman 1986, Hsiao 1986, Solon 1985, Tong 2002). Based upon the assessment, analysts will determine a preferred model approach to develop further. The principal focus will be on estimating vessel productions function and various efficiency metrics, with specification to be determined. Using the model chosen, the study will estimate the relationship between a performance variable and data (including both production input quantity/price and output/revenue data as well as measurement error data), and assess changes in model performance using out-of-sample predictions on catch as well as standard model selection and ranking criteria. This latter step will give insight into the extent to which the use of data that are known to contain noise or reporting errors can still be useful in improving model performance and predictive ability.