2015 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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Executive Summary

1. Stock: species/area.
Southern Tanner crab (*Chionoecetes bairdi*) in the eastern Bering Sea (EBS).

2. Catches: trends and current levels.
Legal-sized male Tanner crab are caught and retained in the directed (male-only) Tanner crab fishery in the EBS. The directed fishery was opened in 2013/14 for the first time since 2009/10 because the stock was not overfished in 2012/13 (Stockhausen et al., 2013) and stock metrics met the State of Alaska (SOA) criteria for opening the fishery in 2013/14. TAC was set at 1,645,000 lbs (746.2 t) for the area west of 166^{o} W and at 1,463,000 lbs (663.6 t) for the area east of 166^{o} W in the SOA's Eastern Subdistrict of the Bering Sea District Tanner crab Registration Area J. The fisheries opened on October 15 and closed on March 31. On closing, 79.6% (593.6 t) of the TAC was taken in the western area while 98.6% (654.3 t) was taken in the eastern area. Prior to the closures, the retained catch averaged 770 t per year between 2005/06-2009/10.

Following the last year's assessment (Stockhausen, 2014), TAC was set at 6,625,000 lbs (2,328.7 t) for the area west of 166^{o} W and at 8,480,000 lbs (3,829.3 t) for the area east of 166^{o} W. On closing, 77.5% (2,328.7 t) of the TAC was taken in the western area while 99.6% (3,829.3 t) were taken in the eastern area.

Non-retained females and sub-legal males are caught in the directed fishery as bycatch and discarded. Total bycatch (not discounted for assumed handling mortality) in the directed fishery was 2,553 t. Tanner crab are also caught as bycatch in the snow crab and Bristol Bay red king crab fisheries, in the groundfish fisheries and, to a minor extent, in the scallop fishery. Over the last five years, the snow crab fishery has been the major source of Tanner crab bycatch among these fisheries, averaging 1,197 t for the 5-year period 2010/11-2014/15. Bycatch in the snow crab fishery in 2014/15 was 5,433 t. The groundfish fisheries have been the next major source of Tanner crab bycatch over the same five year time period, averaging 272 t. Bycatch in the groundfish fisheries in 2014/15 was 423 t. The Bristol Bay red king crab fishery has typically been the smallest source of Tanner crab bycatch among these fisheries, averaging 51 t over the 5-year time period, although 297 t caught and discarded in 2014/15.

In order to account for mortality of discarded crab, handling mortality rates are assumed to be 32.1% for Tanner crab discarded in the crab fisheries and 80% for Tanner crab discarded in the groundfish fisheries to account for differences in gear and handling procedures used in the various fisheries.

3. Stock biomass: trends and current levels relative to virgin or historic levels
For EBS Tanner crab, spawning stock biomass is expressed as mature male biomass (MMB) at the time of mating (mid February). From the author's preferred model (Model A), estimated MMB for 2014/15

was 71.6 thousand t (Table 19, Fig. 60). This was larger than that for 2013/14 (60.6 thousand t). The 2014 model estimate for 2013/14 MMB was 72.7 thousand t. MMB had undergone a slight downward trend since its most recent peak in 2008/09, but 2014/15 represents a return to values slightly higher than that peak. It remains above the very low levels seen in the mid-1990s to early 2000s (1990 to 2005 average: 29.3 thousand t). However, it is considerably below model-estimated historic levels in the early 1970s when MMB peaked at 328.2 thousand t (1972/73).

4. Recruitment: trends and current levels relative to virgin or historic levels.
From the author's preferred model (Model A, Dataset D), the estimated total recruitment in 2015/16 (number of crab entering the population on July 1) is 80.71 million crab (Table 18, Fig. 62. Recruitment is estimated to have declined from a peak last year of 124.0 million.

5. Management performance

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

Year	**MSST**	**Biomass (MMB)**	**TAC (East + West)**	**Retained Catch**	**Total Catch Mortality**	**OFL**	**ABC**
2011/12	25.13	129.17 [A]	0.00	0.00	2.73	6.06	5.47
2012/13	36.97	130.84 [A]	0.00	0.00	1.57	41.93	18.01
2013/14	37.43	160.28 [A]	3.11	2.78	6.14	55.89	39.29
2014/15	29.53 [C]	157.78 [A]	15.10	13.58	20.19	69.40	55.51
2015/16		116.39 [B]				61.14 [C]	48.92 [C]

(b) Historical status and catch specifications (thousands t) for eastern Bering Sea Tanner crab.

Year	**MSST**	**Biomass (MMB)**	**TAC (East + West)**	**Retained Catch**	**Total Catch Mortality**	**OFL**	**ABC**
2011/12	11.40	58.59 [A]	0.00	0.00	1.24	2.75	2.48
2012/13	16.77	59.35 [A]	0.00	0.00	0.71	19.02	8.17
2013/14	16.98	72.70 [A]	1.41	1.26	2.78	25.35	17.82
2014/15	13.40 [C]	71.57 [A]	6.85	6.16	9.16	31.48	25.18
2015/16		52.80 [B]				27.73 [C]	22.19 [C]

A—Estimated biomass at the time of mating for the year concerned. Note this represents a revised estimate, based on the subsequent assessment, from the projection the previous year.
B—Projected biomass from the current stock assessment. This value will be updated next year.
C—Based on the author's preferred model (Model A).

6. Basis for the OFL

Basis for the OFL (thousands t).

Year	Tier[A]	B_{MSY}[A]	Current MMB[A]	B/B_{MSY} (MMB)[A]	F_{OFL}[A]	Years to define B_{MSY}[A]	Natural Mortality[A,B]
2012/13	3a	33.45	58.59	1.75	0.61 yr^{-1}	1982-2012	0.23 yr^{-1}
2013/14	3a	33.54	59.35	1.77	0.73 yr^{-1}	1982-2013	0.23 yr^{-1}
2014/15	3a	29.82	63.80	2.14	0.61 yr^{-1}	1982-2014	0.23 yr^{-1}
2015/16	3a	26.79	52.80	1.97	0.64 yr^{-1}	1982-2015	0.23 yr^{-1}

A—Calculated from the assessment reviewed by the Crab Plan Team in 20XX of 20XX/YY or based on the author's preferred model for 2015/16.
B—Nominal rate of natural mortality. Actual rates used in the assessment are estimated and may be different.

Current male spawning stock biomass (MMB), as projected for 2015/16, is estimated at 52.80 thousand t. B_{MSY} for this stock is calculated to be 26.79 thousand t, so MSST is 13.40 thousand t. Because current MMB > MSST, **the stock is not overfished**. Total catch mortality (retained + discard mortality in all fisheries, using a discard mortality rate of 32.1% for pot gear and 0.8 for trawl gear) in 2014/15 was 9.16 thousand t, which was less than the OFL for 2014/15 (25.18 thousand t); consequently **overfishing did not occur**. The OFL for 2015/16 based on the author's preferred model (Model A) is 27.73 thousand t. The ABC_{max} for 2015/16, based on the p^* ABC, is 27.70 thousand t. In 2014, the SSC adopted a 20% buffer to calculate ABC for Tanner crab to incorporate concerns regarding model uncertainty for this stock. Based on this buffer, the ABC would be 22.19 thousand t.

7. Rebuilding analyses summary.
The EBS Tanner crab stock was found to be above MSST (and B_{MSY}) in the 2012 assessment (Rugolo and Turnock, 2012b) and was subsequently declared rebuilt. Consequently no rebuilding analyses were conducted.

A. Summary of Major Changes

1. Changes (if any) to the management of the fishery.
The Science and Statistical Committee (SSC) of the North Pacific Fisheries Management Council (NPFMC) moved the Tanner crab stock from Tier 4 to Tier 3 for status determination and OFL setting in October 2012 based on a newly-accepted assessment model (Rugolo and Turnock, 2012a). Status determination and OFL setting for Tier 4 stocks generally depend on current survey biomass and a proxy for B_{MSY} based on survey biomass averaged over a specified time period. In Tier 3, status determination and OFL setting depend on a model-estimated value for current MMB at mating time as well as proxies for F_{MSY} and B_{MSY} based on spawning biomass-per-recruit calculations and average recruitment to the population over a specified time period. The change from Tier 4 to Tier 3 resulted in a large reduction in the B_{MSY} used for status determination from 83.33 thousand t in 2011 to 33.45 thousand t in 2012. Concurrently, the estimated assessment-year MMB increased from 26.73 thousand t in 2011 to 58.59 thousand t in 2012. As a consequence, the status of Tanner crab changed from being an overfished stock following the 2011 assessment to one that was not-overfished following the 2012 assessment. The stock was subsequently declared rebuilt and an OFL of 19.02 thousand t was set for 2012/13. Although the stock was declared rebuilt as a result of the 2012 assessment, the directed fishery for Tanner crab remained closed by the SOA on the basis of its algorithms for setting harvest levels.

In the September 2013 assessment (Stockhausen et al., 2013), the Tanner crab stock was again found to be not overfished. For the 2013/14 fishing season, the SOA opened the fisheries for Tanner crab and set Total Allowable Catch limits in the two areas in which Tanner crab is commercially fished in the eastern Bering Sea (east and west of 166° W in the Eastern Subdistrict of the Bering Sea District Tanner crab Registration Area J, Fig. 1). TAC was set at 1,645,000 lbs (746.2 t) for the area west of 166° W and at 1,463,000 lbs (663.6 t) for the area east of 166° W. The fisheries opened on October 15 and closed on March 31. On closing, 79.6% (593.6 t) of the TAC was taken in the western area while 98.6% (654.3 t) was taken in the eastern area. Prior to the closures, the retained catch averaged 770 t per year between 2005/06-2009/10.

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At the March, 2015 SOA Board of Fish meeting, the Board adopted a revised harvest strategy for Tanner crab in the Bering Sea District[1], wherein the TAC for the area east of 166° W longitude would be based on a minimum preferred harvest size of 127 mm CW (5.0 inches), including the lateral spines. Formerly, this calculation was based on a minimum preferred size of 140 mm CW (5.5 inches). The TAC in the area west of 166° W longitude continues to be based on a minimum preferred harvest size of 127 mm CW (including lateral spines).

2. Changes to the input data

During the two past years, and involving considerable effort, the set of stations and hauls constituting the "standard" dataset for calculating crab-related trends in abundance, biomass and size compositions from the annual NMFS EBS bottom trawl survey was redefined for each crab stock to improve sampling design and consistency across the 40-plus year dataset (Daly et al., in prep.). The "old" dataset included stations with multiple hauls associated with special projects and "re-tows", as well as somewhat inconsistent strata definitions across the time series. The new dataset consists of a single haul per station and strata definitions that are temporally consistent. In conjunction with this effort, the weight-at-size regressions used to convert crab abundance to biomass were also revised (Daly et al., in prep.).

New survey size compositions have been calculated from the 1975-2015 annual survey results and incorporated into this assessment. In addition, the weight-at-size regressions used in past assessments have been updated to reflect the standardized trawl survey regressions. For comparison purposes, survey time series based on the "old" survey dataset have been updated with the results of the 2015 bottom trawl survey, and model results showing a progression from the old time series to the new time series have been compared.

Much of the crab fishery data from 1990-2013/14 was re-calculated last year (Stockhausen, 2014) by D. Pengilly and H. Fitch (ADF&G), including: 1) retained size frequencies; 2) effort (number of potlifts); and 3) bycatch numbers, biomass and size frequencies from fish ticket and dockside and at-sea observer sampling. These data were not re-calculated this year, except to update the 2013/14 data. Estimates of total retained biomass and abundance, as well as retained size frequencies by shell condition, in the 2014/15 directed fishery were provided by Mr. Pengilly based on fish ticket data and dockside observer sampling. Mr. Pengilly also provided estimates of Tanner crab bycatch (sex-specific numbers, biomass and size compositions) in the 2014/15 directed Tanner crab, snow crab, and Bristol Bay red king crab fisheries.

[1] https://aws.state.ak.us/OnlinePublicNotices/Notices/Attachment.aspx?id=100244

Much of the data concerning Tanner crab bycatch in the groundfish fisheries (biomass, size compositions) was recalculated last year and incorporated into the 2014 assessment (Stockhausen, 2014). This year, these data were updated for 2013/14 and newly-extracted for 2014/15 from the groundfish observer and AKFIN databases.

The following table summarizes data sources that have been updated for this assessment:

Updated data sources.

Data source	Data types	Time frame	Notes	Agency
NMFS EBS Bottom Trawl Survey	abundance, biomass, size compositions	2015	new	NMFS
NMFS EBS Bottom Trawl Survey	abundance, biomass, size compositions	1975-2015	new standardization	NMFS
Directed fishery	retained catch (numbers, biomass)	2013/14, 2014/15	updated, new	ADFG
	retained catch size compositions	2013/14, 2014/15	updated, new	ADFG
	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	total catch, discards size compositions	2013/14, 2014/15	updated, new	ADFG
Snow Crab Fishery	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	size compositions	2013/14, 2014/15	updated, new	ADFG
Bristol Bay Red King Crab Fishery	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	size compositions	2013/14, 2014/15	updated, new	ADFG
Groundfish Fisheries	total catch, discards (biomass)	2013/14, 2014/15	updated, new	NMFS
	size compositions	2013/14, 2014/15	updated, new	NMFS

3. Changes to the assessment methodology.

The computer code for a new assessment model has substantially been completed but was not used for this assessment. It will be reviewed by the CPT in May, 2016. The current assessment remains essentially unchanged from last year (see Stockhausen, 2014, Appendix 3 for a detailed description of the current model). Options to use an alternative fishing mortality model (Gmacs), to impose a lognormal error structure when fitting to fishery catch data, and to require logistic selectivity curves to reach 1 in the largest model size bin were implemented in the current assessment code and tested. However, the author's preferred model for status determination and OFL setting is the same as the model adopted last year by the CPT (Model Alt4b).

4. Changes to the assessment results

Results from the author's preferred model this year (Model A, Dataset D) are reasonably similar to those from the previous assessment, considering the large number of changes in the (primarily survey-related) data. Average recruitment (1982-present) was estimated at 187.90 million in last year's models, whereas it was estimated at 179.37 million in the author's preferred model this year. F_{MSY} was estimated at 0.61 yr^{-1} last year and 0.64 yr^{-1} this year. B_{MSY} was estimated at 29.82 thousand t last year and 26.79 thousand t this year.

B. Responses to SSC and CPT Comments

1. Responses to the most recent two sets of SSC and CPT comments on assessments in general. [Note: for continuity with the previous assessment, the following includes comments prior to the most recent two sets of comments.]

June 2015 SSC Meeting
Comment: "The SSC would like to reiterate a request to stock assessment author's for consistency in units used in the assessment. The SSC appreciates the author's inclusion of standard and metric units in the text but requests consistency in which units are used (e.g., lbs., thousands of lbs., …). The SSC also requests consistency in the units chosen for tables and figures, requests that units cited in the table match the values in the tables, and suggests authors refer to the terms of reference for chapters."
Response: Data sources vary widely as to units used, as do figures for which historical comparisons with previous assessments may be of interest. It would be convenient to standardize completely to metric units, but this is not necessarily responsive to public accessibility. When units vary, it is generally because one choice affords a reasonable scale and another does not (, e.g. 1 kg vs 0.001 t). However, the author has made an effort to accommodate this request in most instances, although some inconsistencies probably still exist.

May 2015 Crab Plan Team Meeting
No general comments.

January 2015 Crab Modeling Workshop
Comment: The team requested author's use the new NMFS EBS bottom trawl survey dataset in future assessments, but provide comparison runs with the old survey dataset for comparison.
Response: This has been addressed in this assessment.

October 2014 SSC Meeting
No general comments.

September 2014 Crab Plan Team Meeting
No general comments.

June 2014 SSC Meeting
No general comments.

January 2014 Crab Modeling Workshop
Comment: The CPT requested "all assessment authors should provide model scenarios which mimic the September 2013 assessments by replacing the bycatch data in the crab fisheries with updated data from Bill Gaeuman using the 'simple averaging' method and by replacing the NMFS survey data with recalculated series based on updated methodologies so the CPT can evaluate the implications of these changes to the data."
Response: This was addressed for the crab bycatch data provided by W. Gaeuman at the May, 2014 CPT Meeting (see http://www.npfmc.org/wp-content/PDFdocuments/membership/PlanTeam/Crab/CrabSafe14/tanner_rev.docx). The revised NMFS time series data (abundance, biomass and size frequencies) is incorporated into this assessment.

Comment: "The CPT recommends that assessment authors investigate the effects of the new [NMFS trawl survey] time series on size frequencies."
Response: Results (e.g., abundance and biomass estimates, size frequencies) for the revised NMFS trawl survey data have been incorporated into this assessment and compared with results using the old survey data.

2. Responses to the most recent two sets of SSC and CPT comments specific to the assessment. [Note: for continuity with the previous assessment, the following includes comments prior to the most recent two sets of comments.]

June 2015 SSC Meeting

No specific comments.

May 2015 CPT Meeting

Comment: "The CPT agrees that the September 2015 assessment should use the updated retained size frequencies and be based on an assessment that ignores the survey data from 1974."
Response: This has been done.

Comment: "The assessment author should report results in September 2015 using the new and original trawl survey data to allow the impact of updating these data to be quantified."
Response: This has been done.

Comment: "Future exploration…should consider the impact of handling mortality on the estimate of natural mortality and how the model behaves if Q for the most recent years is assumed known rather than being estimated."
Response: Model runs have been completed to address this issue, but time was not sufficient to complete the analysis.

Comment: "The CPT would like to see the results of analyses based on this (new) model at its September 2015 meeting".
Response: The new model is currently undergoing testing. Time constraints precluded presenting interim results at this point to the CPT. These will be presented at the Modeling Workshop (if there is one), or at the May 2016 CPT meeting.

Comment: "The CPT reiterates its suggestions from the September 2014 meeting, in particular that the sensitivity of the results to the prior on Q should be explored."
Response: Model runs have been completed to address this issue, but there was not sufficient time to complete the analysis.

Comment: The CPT recommends that model results for the four model configurations be provided to the September 2015 meeting: 1) the 2014 model with 2015 data added (Model 1), 2) Model 1, with revised trawl survey time series (Model 2), 3) Model 2, with survey selectivity constrained to 1 for at least one size class (Model 3), and 4) Model 3, with a lognormal likelihood for the fishery catch data.
Response: Results from these configurations are provided in the assessment.

Comment: "The CPT recommends that the change (in minimum preferred size in the area east of 166^{o}W for TAC setting) be addressed for OFL calculation by setting the retention curves for the areas east and west of 166oW with the approach currently used to compute selectivity for the area west of 166^{o}W."
Response: This has been addressed in the assessment.

October 2014 SSC Meeting

Comment: "The SSC encourages authors to explore alternative models such as time-varying growth to help address retrospective bias and patterns in other residuals."
Response: This can be addressed in the future with the new model code (currently being tested), but not with the current model.

Comment: "The SSC also encourages authors to explore model alternatives without time-varying selectivity for the groundfish fishery."
Response: This can be addressed in the future with the new model code (currently being tested), but not with the current model.

Comment: "The SSC also encourages…use of MSE to explore the effect of alternative harvest rates on stock status and yield under various sources of uncertainty."
Response: A good suggestion but a major undertaking. This represents an opportunity for a PhD student or post-doctoral researcher.

Comment: "The SSC encourages efforts to obtain better and more representative growth data."
Response: Growth increment data on ~60 individuals was collected in the EBS this spring by NMFS and ADF&G researchers. The author looks forward to incorporating the results of this study into the assessment context.

September 2014 CPT Meeting

Comment: "Explain/justify the three periods used for groundfish bycatch."
Response: The 1973-1987 time period represents the time of foreign and joint-venture fishing, the 1988-1996 represents the beginning of the domestic-only groundfish fisheries, and the start of the 1997-present time period (1997-2003/4) is when the directed Tanner crab fishery was closed. It seems reasonable to assume that changes in fleet composition associated with the transition to a domestic-only fleet would involve changes to selectivity. It also seems reasonable to assume that closure of the Tanner crab fishery and concern over prohibited species catches (i.e., crab) would alter fishing behavior, thus affecting selectivity. These periods are hard-wired in the current code and cannot be changed without a lot of difficulty. However, it will be possible to investigate this issue more fully when the new model code completes testing.

Comment: "Examine of clarify why the different H scenarios do not result in greater differences in total mortality for the directed fishery."
Response: This issue was addressed at the May 2015 CPT meeting.

Comment: "Examine issues related to misfits of the size composition residuals for retained males and total males in the directed fishery. Consider exploring alternative growth components, specification of sample sizes, or a combination of fishing selectivity and handling mortality is causing mis-fits."
Response: Not yet addressed.

June 2014 SSC Meeting

Comment: "Examine retrospective patterns of models being brought forward."
Response: I tried to address this issue for this assessment. Unfortunately, the current model code is not set up to make retrospective model runs in a time-effective manner. This is addressed in the new model code currently being tested.

May 2014 Crab Plan Team Meeting

Comment: "Compare actual discarded catch with model-estimated discarded catch (separately for directed fishery bycatch, snow crab bycatch, red king crab bycatch, and groundfish bycatch)."
Response: Plots and tables making these comparisons are provided in the assessment.

3. Older comments that were addressed this year or remain to be addressed:

Comment: "The SSC recommends conducting a management strategy evaluation (MSE) to determining [sic] the long-term consequences of alternative harvest rates on stock status and yield under various sources of uncertainty."
Response: It will not be feasible to address this request at least until the new model code is completed.

Comment: "The SSC continues to encourage alternative model specifications to address these patterns" [i.e., retrospective patterns in model-estimated biomass], which "inclusion of a time-varying growth function may address…"
Response: The option for time-varying growth (constant over blocks of time) has been implemented in the new model code that is currently under testing.

Comment: "The SSC…encourages a thorough review and re-compilation of all data sources."
Response: The review has been initiated and is ongoing. W. Gaeuman (ADFG) has re-extracted size composition data from the ADFG crab fisheries databases for (dockside) retained catch in the directed Tanner crab fishery and total and discarded catch in the directed, snow crab, and BBRKC fisheries. I have re-extracted size frequencies for Tanner bycatch in the groundfish fisheries from the NMFS groundfish observer database which I have adjusted to the crab fishery year (July 1-June 30) from the groundfish fishery year (Jan. 1-Dec.31). Effort in the directed Tanner crab, snow crab and BBRKC fisheries has been painstakingly re-evaluated by D. Pengilly (ADFG), resulting in substantially revised estimates for effort in the Tanner crab fishery primarily during the early 1990s. R. Foy (NMFS) is also revising data from the NMFS trawl survey; changes, however, will not be reviewed until the 2015 Crab Modeling Workshop.

Comment: "The CPT recommended that a sensitivity analysis on handling mortality be done in the Tanner crab assessment…"
Response: A sensitivity analysis addressing this issue was presented to the CPT at its May 2015 meeting.

Comment: "Collection of growth data specific to the Tanner crab stock in the EBS should be given a high research priority."
Response: Individuals were collected by NMFS, ADF&G, and BSFRF in May 2015 to address this issue. The author looks forward to incorporating the results of this study into the assessment..

Comment: "Evaluate the feasibility of estimating F_{MSY} (and B_{MSY}) for the stock using the estimates of recruitment and MMB during the post-1982 period, and compare to the $F_{35\%}$ MSY proxy."
Response: Not yet addressed.

Comment: "If time permits, apply the groundfish plan team's stock structure template to Tanner crab to synthesize the available information on stock structure."
Response: Not yet addressed.

Comment: The CPT "recommends that crab authors apply the [groundfish stock structure template] criteria for considering spatial issues in stocks."
Response: Not yet addressed.

Comment: The CPT "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."
Response: Not yet addressed. Simulation testing will be possible with the new model now being tested (an R package has been developed already to facilitate this using independent code).

Comment: The CPT encourages authors to "…develop approaches for accounting for this source of process error" (i.e., fitting to length-composition data accounts for sampling error but not within-year variability in selectivity).
Response: The size at 50% selected is allowed to vary annually (1992+) for males in the directed fishery, but the size at 50% retained is not. Given the recent change in minimum preferred size used to calculate TAC in the area east of 166°W, it may be a good idea to allow this to vary annually, as well. Allowing annually-varying selectivity in the discard fisheries may be problematic in terms estimability. However, these sorts of issues can be addressed with the new code currently undergoing testing.

Comment: "Plot the input effective sample sizes for the compositional data versus the effective sample sizes inferred by the fit of the model…"
Response: Not yet addressed.

Comment: "Allow M for immature as well as mature males to change during 1980-83 (the data on changes in abundance do not suggest that only mature males declined substantially) and test whether it is necessary to allow female M to change over time."
Response: Not yet addressed.

Comment: "Consider treating all of the F-deviations (except for which catch is known to be zero) as parameters, and include the fishing mortality-effort relationship as a prior—this will allow the uncertainty associated with this relationship to be reflected in the measures of uncertainty."
Response: Not yet addressed.

Comment: "Consider fitting to total biomass (by sex?) and to the compositional data rather than to mature biomass (include the fit to mature biomass by sex as a diagnostic)."
Response: Not yet addressed.

Comment: "Do not fit to male compositional data by maturity state for the years for which chela height-maturity relationships are not available."
Response: Not yet addressed.

Comment: "There is still a residual pattern in the fit to the size-composition data for the survey. This could be due to time-varying growth, which should be examined as an alternative model."
Response: Not yet addressed. Time-varying growth (using time blocks) is an option in the new model code now being tested.

Comment: "A major concern for the CPT was the inability of the model to match the magnitude of discards in the EBS snow crab and Bristol Bay red king crab fisheries…The CPT requested the analysts conduct further analyses in which mimicking the observer data was given higher weight."
Response: The model appears to fit male discard mortality in the snow crab fishery fairly well. Discard mortality for females in the snow crab fishery and both sexes in the BBRKC fishery are very small. I tried using a lognormal error structure this year to fit these data, but results were not satisfactory with the cv's that were assumed. This is an area for continued development.

C. Introduction

1. Scientific name.

*Chionocoetes bairdi.*Tanner crab is one of five species in the genus *Chionoecetes* (Rathbun, 1924). The common name "Tanner crab" for *C. bairdi* (Williams et al. 1989) was recently modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" had 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".

2. Description of general distribution

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). The unit stock is that defined across the geographic range of the EBS continental shelf, and managed as a single unit (Fig. 1). *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, 2011). 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).

3. Evidence of 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). Somerton (1981b) 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.

Although the State of Alaska's (SOA) harvest strategy and management controls for this stock are different east and west of 166^{o}W, the unit stock of Tanner crab in the EBS appears to encompass both regions and comprises crab throughout the geographic range of the NMFS bottom trawl survey. Evidence is lacking that the EBS shelf is home to two distinct, non-intermixing, non-interbreeding stocks that should be assessed and managed separately.

4. Life history characteristics

a. Molting and Shell Condition

Tanner crabs, like all crustaceans, normally exhibit a hard exoskeleton of chitin and calcium carbonate. This hard exoskeleton requires individuals to grow through a process referred to as molting, in which the individual sheds its current hard shell, revealing a new, larger exoskeleton that is initially soft but which rapidly hardens over several days. Newly-molted crab in this "soft shell" phase can be vulnerable to predators because they are generally torpid and have few defenses if discovered. Subsequent to hardening, an individual's shell provides a settlement substrate for a variety of epifaunal "fouling" organisms such as barnacles and bryozoans. The degree of hard-shell fouling was once thought to correspond closely to post-molt age and led to a classification of Tanner crab by shell condition (SC) in survey and fishery data similar to that described in the following table (NMFS/AFSC/RACE, unpublished):

Shell Condition Class	Description
0	pre-molt and molting crab
1	carapace soft and pliable
2	carapace firm to hard, clean
3	carapace hard; topside usually yellowish brown; thoracic sternum and underside of legs yellow with numerous scratches; pterygostomial and bronchial spines worn and polished; dactyli on meri and metabranchial region rounded; epifauna (barnacles and leech cases) usually present but not always.
4	carapace hard, topside yellowish-brown to dark brown; thoracic sternum and undersides of legs data yellow with many scratches and dark stains; pterygostomial and branchial spines rounded with tips sometimes worn off; dactyli very worn, sometimes flattened on tips; spines on meri and metabranchial region worn smooth, sometimes completely gone; epifauna most always present (large barnacles and bryozoans).
5	conditions described in Shell Condition 4 above much advanced; large epifauna almost completely covers crab; carapace is worn through in metabranchial regions, pterygostomial branchial spines, or on meri; dactyli flattened, sometimes worn through, mouth parts and eyes sometimes nearly immobilized by barnacles.

Although these shell classifications continue to be applied to crab in the field, it has been shown that there is little real correspondence between post-molt age and shell classifications SC 3 through 5, other than that they indicate that the individual has probably not molted within the previous year (Nevisi et al, 1996). In this assessment, crab classified into SCs 3-5 have been aggregated as “old-shell” crab, indicating that these are crab likely to have not molted within the previous year. In a similar fashion, crab classified in SCs 0-2 have been combined as “new shell” crab, indicating that these are crab have certainly (SCs 0 and 1), or are likely to have (SC 2), molted within the previous year.

b. Growth

Growth in immature Tanner crab larger than 25 mm CW proceeds by a series of annual molts, up to a final (terminal) molt to maturity (Tamone et al., 2007). Growth relationships specific to Tanner crab in the EBS are unknown, although data was collected this May on individual molt increments. Rugolo and Turnock (2012a) derived the growth relationships for male and female Tanner crab used in this and previous assessments from data on observed growth in males to approximately 140 mm carapace width (CW) and in females to approximately 115 mm CW that were collected near Kodiak Island in the Gulf of Alaska (Munk, pers. comm.; Donaldson et al. 1981). The relationship between pre-molt and post-molt size for males and females was modeled as two parameter exponential functions of the general form $y = ax^b$, where y is post-molt size (CW) and x is pre-molt size. The resulting parameters are:

sex	parameter	
	a	b
male	1.55	0.949
female	1.76	0.913

Rugolo and Turnock (2010) compared the resulting 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 and found that the pattern of gpm for both males and females was 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. Similarly-shaped growth curves were found by Somerton (1981a) and Donaldson et al. (1981), as well.

Previous work by 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. Somerton’s approach did not directly measure molt increments and his findings are constrained by not considering that the progression of modal lengths between years was biased because crab ceased growing after their terminal molt to maturity.

c. Weight at Size

Previously, trawl survey biomass calculations were made for surveys conducted before 2010 and for those conducted after 2009 using different weight-at-size parameter values in power-law models of the form $w = a \cdot z^b$ (Daly et al., 2014; table below). Rugolo and Turnock (2012a) derived a separate set of weight-at-size parameters for male, immature female, and mature female Tanner crab in the EBS based on special collections of size and weight data during the summer bottom trawl surveys in 2006, 2007 and 2009. Power-law models of the form $w = a \cdot z^b$, where w is weight in grams and z is size in mm CW, were fit to the survey data. These relationships were used in the 2012, 2013 and 2014 assessments to convert individual size to biomass in the assessment model in a consistent fashion across all years. The various parameter values are presented in the following table:

		Category					
		assessment model (2012-2014)		trawl survey (pre-2010)		trawl survey (2010-present)	
sex	maturity	a	b	a	b	a	b
males	all	0.00016	3.136	0.00019	3.09894	0.00027	3.022134
females	all	--	--	0.00182	2.70462	--	--
	immature	0.00064	2.794	--	--	562	2.816928
	mature	0.00034	2.956	--	--	0.000441	2.898686

The relationships used for the 2012-2014 assessments and the post-2009 surveys differ slightly at the largest crab sizes, but both give substantially larger weights-at-size than the pre-2010 relationships (Table 1, Fig. 2). This year, in conjunction with the NMFS trawl survey standardization, the pre-2010 weight-at-size regressions were dropped and the post-2009 weight-at-size relationships were adopted as standard and are used for the entire survey time series (Daly et al., in prep.). To be consistent with the survey data, I propose to adopt the now-standard survey parameters for use in this and subsequent assessments. Model runs using both the Rugolo and Turnock (2012a) parameters and the new standard survey parameters are compared below.

d. Maturity and Reproduction

It is now generally accepted that both Tanner crab males (Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo a terminal molt to maturity, as in most majid crabs. Females usually undergo their terminal molt from their last juvenile, or pubescent, instar 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 the female's 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 sperm stored in 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), although 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 achieve 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 state began in April and ended sometime in mid-June (Somerton 1981a).

e. Fecundity

A variety of factors affect female fecundity, including somatic size, maturity status (primiparous vs. multiparous), age post terminal molt, and egg loss (NMFS 2004). 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., are barren) suggesting that female crab reproductive output is a concave function of age (NMFS 2004).

f. Size at Maturity

Rugolo and Turnock (2012b) estimated size at 50% mature for females (all shell classes combined) from data collected in the NMFS bottom trawl survey at 68.8 mm CW, and 74.6 mm CW for new shell females. For males, Rugolo and Turnock (2012a) estimated classification lines using mixture-of-two-regressions analysis to define morphometric maturity for the unit Tanner crab stock, and for the sub-stock components east and west of 166^{o}W, based on chela height and carapace width data collected during the 2008 NMFS bottom trawl survey. These rules were then applied to historical survey data from 1990-2007 to apportion male crab as immature or mature based on size (Rugolo and Turnock, 2012b). Rugolo and Turnock (2012a) found no significant differences between the classification lines of the sub-stock components (i.e., east and west of 166^{o}W), or between the sub-stock components and that of the unit stock classification line. Size at 50% mature for males (all shell condition classes combined) was estimated at 91.9 mm CW, and at 104.4 mm CW for new shell males. By comparison, Zheng and Kruse (1999) used knife-edge maturity at >79 mm CW for females and >112 mm CW for males in development of the current SOA harvest strategy.

g. Mortality

Due to the lack of age information for crab, Somerton (1981a) estimated mortality separately for individual EBS cohorts of immature and adult Tanner crab. Somerton postulated that age five crab (mean CW = 95 mm) were the first cohort to be fully recruited to the NMFS trawl survey sampling gear and 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 estimates of M from 0.22 to 0.28 obtained from models that used both the survey and fishery data were the most representative.

Rugolo and Turnock (2011a) 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. They reasoned that longevity in a virgin population of Tanner crab would be analogous to that of the snow crab, where longevity would be at least 20 years, given the close analogues in population dynamic and life-history characteristics (Turnock and Rugolo 2011a). Employing 20 years as a proxy for longevity and assuming that this age represented the upper 98.5th percentile of the distribution of ages in an unexploited population, M was estimated to be 0.23 based on Hoenig's (1983) method. If 20 years was assumed to represent the 95% percentile of the distribution of ages in the unexploited stock, the estimate for M was 0.15. Rugolo and Turnock (2011a) adopted M=0.23 for both male and female Tanner because the value corresponded with the range estimated by Somerton (1981a), as well as the value used in the analysis to estimate new overfishing definitions underlying Amendment 24 to the Crab Fishery Management Plan (NPFMC 2007).

5. Brief summary of management history.

A complete summary of the management history is provided in the ADF&G Area Management Report appended to the annual SAFE. 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 Fishery Management Plan (FMP; NPFMC 1998). The plan defers certain management controls for Tanner crab to the State of Alaska, with federal oversight (Bowers et al. 2008). The State of Alaska manages Tanner crab based on registration areas divided into districts. Under the FMP, the state can adjust 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 (Fig. 1) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36'N 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. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168°W and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008). In this report, I use the terms "east region" and "west region" as shorthand to refer to the regions demarcated by 166°W.

In March 2011, the Alaska Board of Fisheries BOF) approved a new minimum size limit harvest strategy for Tanner crab effective for the 2011/12 fishery. Prior to this change, the minimum legal size limit was 5.5" (138 mm CW) throughout the Bering Sea District. The new regulations established different minimum size limits east and west of 166° W. The minimum size limit for the fishery to the east of 166°W is now 4.8" (122 mm CW) and that to the west is 4.4" (112 mm CW), where the size measurement includes the lateral spines. For economic reasons, fishers may adopt larger minimum sizes for retention of crab in both areas, and the SOA's harvest strategy and total allowable catch (TAC) calculations are based on assumed minimum preferred sizes that are larger than the legal minimums. In 2011, these minimum preferred sizes were set at 5.5" (140 mm CW) in the east and 5" (127 mm CW) in the west, including the lateral spines. In 2015, following a petition by the crab industry, the BOF revised the minimum preferred size for TAC calculations in the area east of 166° W longitude to 5" (127 mm CW), the same as that in the western area. The new size will be used in setting the TAC for the 2015/16 fishery season.

In previous assessments, the term "legal males" was used to refer to male crab ≥ 138 mm CW (not including the lateral spines), although this was not strictly correct as it referred to the industry's "preferred" crab size in the east region, as well as to the minimum size in the east used in the SOA's harvest strategy for TAC setting. Because the previous fishery season was conducted under the 2011 harvest strategy (and minimum preferred sizes), I continue to use the term "legal males" to refer to crab ≥ 138 mm CW in this assessment.

Landings of Tanner crab in the Japanese pot and tangle net fisheries were reported in the period 1965-1978, peaking at 19.95 thousand t in 1969. The Russian tangle net fishery was prosecuted during 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 2; Fig.s 3 and 4). Foreign fishing for Tanner crab ended in 1980.

The domestic Tanner crab pot fishery developed rapidly in the mid-1970s (Tables 2 and 3; Fig.s 3 and 4). Domestic US landings were first reported for Tanner crab in 1968 at 0.46 thousand t taken incidentally to the EBS red king crab fishery (Table 2). 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 1977/78 (Tables 2 and 3; Fig. 3). Landings fell sharply after the peak in 1977/78 through the early 1980s, and domestic fishing was closed in 1985/86 and 1986/87 due to depressed stock status. In 1987/88, the fishery reopened and landings rose again in the late-1980s to a second peak in 1990/91 at 18.19 thousand t, and then fell sharply through the mid-1990s. The domestic Tanner crab fishery was closed between 1996/97 and 2004/05 as a result of conservation concerns regarding depressed stock status. It re-opened in 2005/06 and averaged 0.77 thousand t retained catch between 2005/06-2009/10 (Tables 2 and 3). For the 2010/11-2012/13 seasons, the State of Alaska closed directed commercial fishing for Tanner crab due to estimated female stock metrics being below thresholds adopted in the state harvest strategy. However, these thresholds were met in fall 2013 and the directed fishery was opened in 2013/14. TAC was set at 1,645,000 lbs (746.2 t) for the area west of 166^o W and at 1,463,000 lbs (663.6 t) for the area east of 166^o W in the State of Alaska's Eastern Subdistrict of Tanner crab Registration Area J. The fisheries opened on October 15 and closed on March 31. On closing, 79.6% (593.6 t) of the TAC had been taken in the western area while 98.6% (654.3 t) had been taken in the eastern area. Prior to the closures, the retained catch averaged 770 t per year between 2005/06-2009/10. Following the last year's assessment (Stockhausen, 2014), TAC was set at 6,625,000 lbs (2,328.7 t) for the area west of 166^o W and at 8,480,000 lbs (3,829.3 t) for the area east of 166^o W. On closing, 77.5% (2,328.7 t) of the TAC was taken in the western area while 99.6% (3,829.3 t) were taken in the eastern area.

Bycatch and discard 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 4, Fig. 5). Bycatch estimates are converted to discard mortality using assumed handling mortality rates of 32.1% for bycatch in the crab fisheries and 80% for bycatch in the groundfish fisheries. Bycatch was 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. From 1992/93 (when reliable crab fishery bycatch estimates are first available) to 2004/05, the groundfish fisheries accounted for the largest proportion of discard mortality. Since 2005/06, however, the crab fisheries have accounted for the largest proportion.

D. Data

1. Summary of new information

During the two past years, and involving considerable effort, the set of stations and hauls constituting the "standard" dataset for calculating crab-related trends in abundance, biomass and size compositions from the annual NMFS EBS bottom trawl survey was redefined for each crab stock to improve sampling design and consistency across the 40-plus year dataset (Daly et al., in prep.). The "old" dataset included stations with multiple hauls associated with special projects and "re-tows", as well as somewhat inconsistent strata definitions across the time series. The new dataset consists of a single haul per station and strata definitions are temporally consistent. In conjunction with this effort, the size-weight regressions used to convert crab abundance to biomass were also revised (Table 1, Fig. 1).

Two sets of size compositions were employed in this assessment. The first dataset consisted of the "old" survey size compositions used in the 2014 assessment, which were updated with size compositions from the 2015 bottom trawl survey. The second dataset consisted of survey size compositions from 1975 to 2015 based on the "new" standardized survey dataset.

Much of the crab fishery data from 1990-2013/14 was re-calculated last year (Stockhausen, 2014) by D. Pengilly and H. Fitch (ADF&G), including: 1) retained size frequencies; 2) effort (number of potlifts); and 3) bycatch numbers, biomass and size frequencies from fish ticket and dockside and at-sea observer sampling. These data were not re-calculated this year, except to update the 2013/14 data. Estimates of total retained biomass and abundance, as well as retained size frequencies by shell condition, in the 2014/15 directed fishery were provided by Mr. Pengilly based on fish ticket data and dockside observer sampling. Mr. Pengilly also provided estimates of Tanner crab bycatch (sex-specific numbers, biomass and size compositions) in the 2014/15 directed Tanner crab, snow crab, and Bristol Bay red king crab fisheries.

Much of the data concerning Tanner crab bycatch in the groundfish fisheries (biomass, size compositions) was recalculated last year (to standardize to the crab fishery year, rather than the groundfish fishery year, and to utilize new estimates by ADF&G statistical areas) and incorporated into the 2014 assessment (Stockhausen, 2014). This year, these data were updated for 2013/14 and newly-extracted for 2014/15 from the groundfish observer and AKFIN databases.

Updated data sources.

Data source	Data types	Time frame	Notes	Agency
NMFS EBS Bottom Trawl Survey	abundance, biomass, size compositions	2015	new	NMFS
NMFS EBS Bottom Trawl Survey	abundance, biomass, size compositions	1975-2015	new standardization	NMFS
Directed fishery	retained catch (numbers, biomass)	2013/14, 2014/15	updated, new	ADFG
	retained catch size compositions	2013/14, 2014/15	updated, new	ADFG
	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	total catch, discards size compositions	2013/14, 2014/15	updated, new	ADFG
Snow Crab Fishery	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	size compositions	2013/14, 2014/15	updated, new	ADFG
Bristol Bay Red King Crab Fishery	effort	2013/14, 2014/15	updated, new	ADFG
	total catch, discards (biomass)	2013/14, 2014/15	updated, new	ADFG
	size compositions	2013/14, 2014/15	updated, new	ADFG
Groundfish Fisheries	total catch, discards (biomass)	2013/14, 2014/15	updated, new	NMFS
	size compositions	2013/14, 2014/15	updated, new	NMFS

2. Data presented as time series

For the stock biomass and fishery data presented in this document, the convention is that 'year' refers to the year in which the NMFS bottom trawl survey was conducted (nominally July 1, yyyy), and fishery data are those subsequent to the survey (July 1, yyyy to June 30, yyyy+1)--e.g., 2008/09 indicates the 2008 bottom trawl survey and the winter 2008/09 fishery.

a. Total catch

Retained catch (1000's t) in the directed fisheries for Tanner crab conducted by the foreign fisheries (Japan and Russia) and the domestic fleet, starting in 1965/66, is presented in Table 2 (and Fig.s 3 and 4) by fishery year. More detailed information on retained catch in the directed domestic pot fishery is provided in Table 3, which lists total annual catches in numbers of crab and biomass (in lbs), as well as the SOA's Guideline Harvest Level (GHL) or Total Allowable Catch (TAC) , number of vessels participating in the directed fishery, and the fishery season. Information from the Community Development Quota (CDQ) is included in the totals starting in 2005/06.

b. Information on bycatch and discards

Annual bycatch and discards (1000's t) of Tanner crab by sex are provided in Table 4 (and Fig.s 5 and 6) from crab observer sampling, starting in 1992/93 for the directed Tanner crab fishery, the snow crab fishery, and the BBRKC fishery. Annual discards for the groundfish fisheries are also provided starting in 1973/74, but sex is undifferentiated.

c. Catch-at-size for fisheries, bycatch, and discards

Retained (male) catch at size in the directed Tanner crab fishery from landings data is presented in Fig. 7 by fishery region for the most recent fishery periods from 2006/07-2014/15. Size compositions of total catch (retained + discards) from at-sea crab fishery observer sampling in the directed fishery are presented by shell condition and fishery region in Fig. 8 for male crab and in Fig. 9 for female crab. Size compositions for Tanner crab bycatch in the snow crab fishery from at-sea crab fishery observer sampling are presented by shell condition in Fig. 10 for males and in Fig. 11 for females. Fig.s 12 and 13 present similar information for the BBRKC fishery. Fig.s 14 and 15 present relative catch size composition information from groundfish observer sampling in the groundfish fisheries for undifferentiated males and females, respectively, from 1973/74 to the present. Raw sample sizes (number of individuals measured) for the various fisheries are presented in Tables 5-9.

d. Survey biomass estimates

Survey biomass estimates are not direct inputs to the stock assessment model. Instead, survey size compositions and sex-specific weight-at-size regressions from Rugolo and Turnock (2012a) are used to calculate the corresponding sex-specific mature survey biomass on an annual basis. This approach has been used since the 2012 assessment (Rugolo and Turnock, 2012a). These biomass estimates, while similar in scale, do not correspond exactly to corresponding time series published in recent survey technical memoranda for several reasons. First, the minimum size of crab included in the assessment model is 25 mm CW, while the "tech memo" time series include all crab. Second, the assessment model applies a single sex- and maturity state-specific weight-at-size regression to the entire size composition time series when calculating survey biomass components, whereas, prior to the survey standardization this year, the tech memos applied different regressions to pre-2010 and post-2009 survey data. Third, maturity state for females in the assessment has been based on morphological characters observed during the survey (clutch size), while prior to 2015 a size cut-point was used to classify females as mature or immature in the tech memos. Fourth, maturity state for males in the assessment has been based on a maturity ogive developed by Rugolo and Turnock (2010), while another size cut-point was used to classify male maturity for the tech memos.

Comparisons among survey biomass time series derived from the three "flavors" of the NMFS trawl survey considered in this assessment are shown in Fig. 16. The three flavors are: 1) Dataset A: size compositions from the "old" survey dataset, with the Rugolo and Turnock (2012a) weight-at-size regressions; 2) Dataset C: size compositions from the "new" survey dataset, with the Rugolo and Turnock (2012a) weight-at-size regressions; and 3) Dataset D: Dataset C but using the "new" standardized weight-at-size regressions. The largest differences, as judged by differences in survey biomass estimates, occur early in the time series (i.e., before 1985). The change in weight-at-size regressions (from Dataset C to D) has very little impact on the time series.

Estimates for mature male biomass, mature female biomass, and total biomass in the survey based on the size compositions from the new standardized survey dataset (stations/hauls and weight-at-size regressions) used in the assessment model increased from 2013 to 2014 by 21% for mature biomass, decreased 17% for mature females, and increased by 13% for all crab (> 25 mm CW) but decreased from 2014 to 2015 by 24% in all three categories (Fig. 17).

e. Survey catch-at-length

Plots of survey size compositions, expanded to total abundance, are presented for male and female crab in Fig.s 18 and 19, respectively, by shell condition and fishery region. Sample sizes for these size compositions are presented in Table 11.

f. Other time series data.

Spatial patterns of abundance in the 2012-2015 NMFS bottom trawl surveys are plotted in Fig.s 20-24 for immature males, mature males, "preferred" males, immature females, and mature females, respectively. A table of annual effort (number of potlifts) is provided for the snow crab and BBRKC fisheries (Table 12).

3. Data which may be aggregated over time:

a. Growth-per-molt

Sex-specific growth curves derived by Rugolo and Turnock (2010) are presented in Fig. 25. These curves provide the basis for priors on sex-specific growth estimated within the assessment model.

b. Weight-at size

Weight-at-size relationships used in the assessment model for males, immature females, and mature females are presented in Table 1 and depicted in Fig.2.

c. Size distribution at recruitment

The assumed size distribution for recruits to the population in the assessment model is presented in Fig. 26.

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

The 1974 NMFS trawl survey was dropped entirely from the new standardized survey dataset due to inconsistencies in spatial coverage with the standardized dataset.

E. Analytic Approach

1. History of modeling approaches for this stock

Prior to the 2012 stock assessment, Tanner crab was managed as a Tier-4 stock using a survey-based assessment approach (Rugolo and Turnock 2011b). The Tier 3 Tanner Crab Stock Assessment Model (TCSAM) was developed by Rugolo and Turnock and 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. Recommendations from the January 2012 Workshop and the SSC, as well as Rugolo's and Turnock's research plans, guided changes to the model. A model incorporating all revisions recommended by the CPT, the 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 2012b). The CPT agreed that the model could be accepted for management of the stock in the 2011/12 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 analyses to underlie a rebuilding plan developed in 2012. In June 2012, the SSC reviewed the model and accepted the recommendations of the CPT. The Council subsequently approved the SSC recommendations in June 2012. For 2011/12, the Tanner crab was assessed as a Tier-3 stock and the model was used for the first time to estimate status determination criteria and overfishing levels.

In December 2012, a new analyst (Stockhausen) was assigned as principal author for the Tanner crab assessment. Modifications have been made to the TCSAM computer code to improve code readability, computational speed, model output, and user friendliness without altering its underlying dynamics and overall framework. A detailed description of the 2013 model (TCSAM2013) is presented in Appendix 3 of the 2014 SAFE chapter (Stockhausen, 2014). Following the 2014 assessment, the model code was put under version control using "git" software and is publicly available for download from the GitHub website[2].

2. Model Description

a. Overall modeling approach

TCSAM is a stage/size-based population dynamics model that incorporates sex (male, female), shell condition (new shell, old shell), and maturity (immature, mature) as different categories into which the overall stock is divided on a size-specific basis. For details of the model, the reader is referred to Appendix 3 and Rugolo and Turnock (2012b).

In brief, crab enter the modeled population as recruits following the size distribution in Fig. 26. An equal (50:50) sex ratio is assumed at recruitment, and all recruits begin as immature, new shell crab. Within a model year, new shell, immature recruits are added to the population numbers-at-sex/shell condition/maturity state/size remaining on July 1 from the previous year. These are then projected forward to Feb. 15 ($\delta t = 0.625$ yr) and reduced for the interim effects of natural mortality. Subsequently, the various fisheries that either target Tanner crab or catch them as bycatch are prosecuted as pulse fisheries (i.e., instantaneously). Catch by sex/shell condition/maturity state/size in the directed Tanner crab, snow crab, BBRKC, and groundfish fisheries is calculated based on fishery-specific stage/size-based selectivity curves and fully-selected fishing mortalities and removed from the population. The numbers of surviving immature, new shell crab that will molt to maturity are then calculated based on sex/size-specific probabilities of maturing, and growth (via molt) is calculated for all surviving new shell crab. Crab that were new shell, mature crab become old shell, mature crab (i.e., they don't molt) and old shell crab remain old shell. Population numbers are then adjusted for the effects of maturation, growth, and change in shell condition. Finally, population numbers are reduced for the effects of natural mortality operating from Feb. 15 to July 1 ($\delta t = 0.375$ yr) to calculate the population numbers (prior to recruitment) on July 1.

Model parameters are estimated using a maximum likelihood approach, with Bayesian-like priors on some parameters and penalties for smoothness and regularity on others. Data components entering the likelihood include fits to survey biomass, survey size compositions, retained catch, retained catch size compositions, discard mortality in the bycatch fisheries, and discard size compositions in the bycatch fisheries (Stockhausen, 2014).

b. Changes since the previous assessment.

Although the fishing mortality equations implemented in the current Tanner crab model (TCSAM2013) represent a workable description of the fishing mortality process, the interpretation of the retention function in TCSAM2013 is not a simple reflection of the on-deck sorting process (see Appendix A). The fishing mortality model formulated in Gmacs, on the other hand, allows a simple and intuitive description of the on-deck process of retention and discarding whereas the standard model in TCSAM does not (Appendix A). Last year, an alternative version of the Tanner crab model implementing the Gmacs equations (TCSAM-FRev) was developed by modifying a copy of the TCSAM2013 code in Spring 2014, with results from initial model runs presented to the CPT in May. However, satisfactory runs with this model were not achieved in time for the September CPT meeting due to a presumed bug in the model code. This year, the Gmacs equations have been successfully integrated into the TCSAM2013 model code as an option that can be selected in the model control file. Several alternative models presented here use the Gmacs fishery model option.

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[2] https://github.com/wStockhausen/wtsTCSAM2013.git

Two other options that have now been implemented in the model and are incorporated in some of the alternative models used in this assessment are: 1) using lognormal likelihoods, as opposed to normal likelihoods, for fitting bulk fishery catch time series, and 2) forcing logistic selectivity functions to 1 in the largest model size bin.

i. Methods used to validate the code used to implement the model

The model code has been previously reviewed by members of the CPT and the assessment author.

3. Model Selection and Evaluation

a. Description of alternative model configurations

Six data configurations were considered in this assessment. These are briefly outlined in the following table:

Dataset Name	Base Dataset	Modifications
base (2014 assesssment)	--	--
2014 Corrected	2014 assessment	corrects 2013/14 retained catch, size frequencies
A	2014 corrected	updates 2013/14 fisheries data, adds 2014/15 data; adds 2015 survey data
B	A	replaces old trawl survey data with new time series
C	B	updates 2009/10-present bycatch size compositions in the groundfish fisheries
D	C	uses the standardized trawl survey LW regressions

The dataset used in the 2014 assessment is the base dataset for this assessment. Dataset D represents the complete 2015 assessment dataset against which all the alternative model configurations have been run. The base assessment model (the 2014 assessment model, also referred to as Model A below) has been run for each incremental change in the data from the base dataset to Dataset D to identify the sources of important data-related (as opposed to model-related) changes to the assessment results.

Soon after the September, 2014 CPT meeting, W. Gaeuman (ADF&G) discovered that the 2013/14 retained size compositions he had provided for the assessment were incorrect. The “2014 corrected” dataset replaces the bogus size compositions with the correct ones (Fig. 27) and corrects an additional problem with the 2013/14 retained catch in which the values for biomass and abundance were switched in the input files to the assessment model (Fig. 28).

Dataset A updates the 2013/14 fisheries data for interim changes since the 2014 assessment and adds abundance, biomass and size composition data from the 2014/15 fishery season for the directed and bycatch crab fisheries, as well as for the groundfish fisheries. Size composition data from the 2015 NMFS EBS bottom trawl survey was also added to the “old” trawl survey dataset. Input sample sizes were also recalculated for all size composition data, based on the approach described in Appendix 5 of the 2014 assessment (Stockhausen, 2014).

Dataset B replaces the “old” trawl dataset (1974-2015) with size compositions from the newly-defined standard trawl survey dataset (1975-2015). Dataset C replaces the relative bycatch size compositions from the 2009/10-2014/15 groundfish fisheries with estimates of total crab bycatch by size based on an algorithm that apportions AKRO estimates of total gear-specific bycatch available from AKFIN to size bins using relative gear-specific size compositions from groundfish observer sampling. Previous estimates of relative bycatch by size were based on the assumption of simple random sampling across all gear types.

Finally, Dataset D replaces the Rugolo and Turnock (2012a) weight-at-size regressions used in model runs with all previous datasets with the newly-defined, standard survey regressions (i.e., the regressions formerly used with the 2010-present surveys) when calculating biomass-related quantities from numbers-at-size.

Ten models (including the model configuration from the 2014 assessment) were evaluated against the five datasets just described and compared with to the 2014 assessment results. The CPT-preferred model configuration from the 2014 assessment, model Alt4b, was used as the base model (also referred to here as Model A) against which to judge the alternative models. In the interest of time, Model A was the only model run using all five datasets; the alternative models were all run using Dataset D (the final dataset). The principal interest in examining model results from the intermediate datasets was to more easily disentangle assessment results due to changes in the data from changes in the model. Running a single model against each dataset should suffice in this regard.

The ten models and the datasets they were run against are summarized in the following table:

Alternative Model	Base Model	ModelConfiguration			Datasets
		Fishing Mortality Model	Fishery Catch Likelihoods	Asymptotic Selectivity Forced?	
A	--	TCSAM2013	normal	no	2014 corrected, A, B, C, D
B	A	TCSAM2013	lognormal	no	D
C	A	Gmacs	normal	no	D
D	C	Gmacs	lognormal	no	D
E	A	TCSAM2013	normal	yes	D
F	B	TCSAM2013	lognormal	yes	D
G	C	Gmacs	normal	yes	D
H	D	Gmacs	lognormal	yes	D

The ten models differ as to whether the TCSAM2013 or Gmacs fishing mortality model was used, whether the fishery catch likelihoods reflected normal or lognormal error distribution assumptions, and whether or not logistic selectivity functions were normalized to 1 in the largest size bin ("Asymptotic Selectivity Forced?"). The nine alternative models were constructed by changing one of the features of a "base model" to obtain the alternative so that incremental effects in model configuration could be examined; the base models are listed in the second column of the table above (Model A does not really have a base model, it is the 2014 assessment model, Alt4b, updated to 2015).

In implementing the lognormal fishery catch likelihoods, it was necessary to specify relative error sizes for each data source. The same set of values were used for all models that included lognormal fishery catch likelihoods, and are documented in the following table:

Fishery	Data Source	Likelihood Component	Assumed CV
Directed fishery	fish tickets	retained catch	5%
	at-sea observers	total catch/discards	20%
snow crab	at-sea observers	total catch/discards	20%
BBRKC	at-sea observers	total catch/discards	20%
groundfish	at-sea observers	total catch/discards	20%

The values chosen were subjective, based on the author's experience with such data. It seems likely the chosen values can be refined in future work.

b. Progression of results from the previous assessment to the preferred base model

Basic results for Model A (the 2014 assessment model) run against the progression of incremental datasets from the 2014 assessment to Dataset D (the final 2015 dataset) are listed in the following table:

Model	Dataset	Description	Converged?	Positive-definite Hessian	Mean Recruitment (millions)		MMB (1000's t)			Objective Function Value
					1982+	2000+	1982+	3-year mean	Final Year	
A (2014)	2014	2014 assessment	Yes	Yes	187.9	186.8	40.5	62.9	72.7	1,701.2
A	2014 Corrected	2014 data with corrected retained catch and size compositions	Yes	Yes	187.1	186.3	39.1	65.1	72.1	1,722.9
A	A	2014 + 2014, 2015 Updates	Yes	Yes	178.6	166.7	40.5	62.2	72.6	1,847.8
A	B	A + Revised Trawl Survey Time Series	Yes	Yes	174.2	160.1	37.3	59.3	70.4	2,053.3
A	C	B + Revised Fishery Data	Yes	Yes	173.5	161.3	36.7	58.8	70.8	2,036.0
A	D	C + standard LW regressions	Yes	Yes	179.4	164.9	36.5	59.6	71.6	2,049.1

For each run, the model converged successfully, the hessian was invertible, and standard deviation estimates based on the "delta method" were obtained for all parameters and other selected quantities (e.g., recruitment time series). Resulting time series for recruitment and MMB-at-mating are listed in Tables 13 and 14 and compared visually in Fig.s 29 and 30. Correcting the 2013/14 retained catch abundance, biomass and size compositions had almost no effect on estimates of recruitment and only small effects on MMB (less than 5% change in mean values). Updating the 2013/14 fishery data for interim changes, adding the 2014/15 fishery data, and adding the 2014/15 trawl survey results to obtain Dataset A led to small declines (5-10%) in estimated mean recruitment and recent MMB. However, it had a substantial negative effect (-35%) on estimated recruitment in 2014/15, although large changes in terminal year estimates of recruitment are not surprising given the uncertainty in these estimates. Replacing the "old" trawl survey time series with the new version to obtain Dataset B had little effect on terminal year estimates of recruitment or MMB, but resulted in declines to estimated mean recruitment and MMB of 5-10% due to changes in estimates earlier in the time series. The incremental changes involved from Dataset A to Dataset D had little impact on estimates of mean recruitment and MMB. The most variability in recent recruitment occurred between 2003/04 and 2012/13, although the temporal patterns are similar. Because different datasets are involved in each of these model runs, it is not appropriate to compare the model results directly using their objective function values as relative measures of model fit.

Parameter estimates and associated uncertainties for each model run are listed in Table 15.

Basic results for the progression of alternative models from A to H are summarized in the following table:

Model	Dataset	Fishing Mortality Model	Fishery Catch Likelihoods	Asymptotic Selectivity Forced?	Converged?	Positive-definite Hessian?	Mean Recruitment (millions)		MMB (1000's t)			Objective Function Value	Delta OFV
							1982+	2000+	1982+	3-year mean	2014/15		
A (2014)	2014	TCSAM2013	normal	No	Yes	Yes	187.9	186.8	40.5	62.9	63.8	--	--
A	D	TCSAM2013	normal	No	Yes	Yes	179.4	164.9	36.5	59.6	71.6	2,049.1	0.0
B	D	TCSAM2013	lognormal	No	Yes	Yes	133.2	110.8	23.1	37.2	42.4	3,761.6	0.0
C	D	Gmacs	normal	No	Yes	Yes	180.9	168.1	36.4	58.2	70.6	2,112.5	63.4
D	D	Gmacs	lognormal	No	Yes	Yes	154.0	135.9	29.2	48.1	56.6	3,912.4	150.7
E	D	TCSAM2013	normal	Yes	No	No	151.0	133.1	28.3	46.7	55.3	2,052.8	3.7
F	D	TCSAM2013	lognormal	Yes	No	No	147.6	126.6	25.6	41.0	47.2	3,768.7	7.0
G	D	Gmacs	normal	Yes	No	No	151.6	133.1	28.4	46.3	55.3	2,116.2	67.1
H	D	Gmacs	lognormal	Yes	No	No	149.9	130.6	27.3	45.3	53.0	3,929.5	167.8

In the above table, "Delta OFV" is the difference between the objective function values for the alternative model and its base comparable model (comparable models are highlighted similarly). Positive values for OFV indicate that the alternative model fits the data more poorly than the base comparable model. For the model configurations considered above, models that don't share the same fishery catch likelihood functions are not comparable. Consequently, Model A was used as the base comparable model for alternative models C, E and G while Model B was used as the base comparable model for models D, F, and H. Overall, Models A and B had the smallest objective functions (fit the data better) compared to the comparable alternative models. In addition, none of the models that forced asymptotic selectivity (E-H) converged successfully. This is probably a result of structural constraints in the model: one possible candidate for a structural constraint is that fully-selected bycatch mortality rates in the groundfish fisheries are not explicitly sex-specific in the model. When asymptotic selectivity is not forced, effective sex-specific rates are possible if one of the associated sex-specific selectivity functions asymptotes at a value less than one. In the models runs where asymptotic selectivity was not forced, Models A-D, the selectivity curve estimated for female bycatch in the groundfish fisheries during the 1977-1996 time period asymptotes to much less than one in all models (Fig. 31).

The remaining models that incorporated lognormal fishery catch likelihoods (B, D) were eliminated as candidates for the preferred model because they tended to substantially mis-fit the discard mortality time series (Fig. 32)—overestimating total male mortality in the directed fishery, underestimating discard mortality in the groundfish fishery, and both under- and over-estimating male discard mortality in the snow crab fishery. The models that incorporated normal fishery catch likelihoods (A, C) fit the observed values quite well. This indicates that perhaps the relative error levels specified for the lognormal likelihoods overestimating the size of these errors, essentially not penalizing Models B and D enough for mis-fitting the fishery bycatch data. Better fitting models may be achieved by exploring alternative values for the specified cv's. As a consequence, however, Models B and D were eliminated from further consideration as preferred model candidates for this assessment, leaving only Models A and C.

Parameter values for Models A and C (as well as B and D) obtained using Dataset D are listed in Table 16.

Results for Models A and C are compared with those from the 2014 assessment for sex-specific mature survey biomass in Table 17 and Fig.s 33 and 34. All three models exhibit similar temporal patterns. Estimates are nearly identical for Models A and C after 1980 for both males and females. Estimates after 2005 are slightly less than those obtained last year.

Results for Models A and C are compared with those from the 2014 assessment for estimated trends in recruitment in Table 18 and Fig. 35. The temporal patterns are similar for all three models. Time series from Models A and C are almost identical after 1975 (when trawl survey data starts to inform the models). Since 2000, Models A and C estimates tend to be slightly lower than those from the 2014 assessment, and are substantially lower for last year (2013/14), although the associated uncertainty for 2013/14 in the assessment model (not shown) is large.

Time series estimates of MMB-at-mating for Models A and C are also almost identical after 1975. The temporal patterns are very similar to those from the 2014 asessment, as well, but Models A and C yield lower estimates of recent (since 2005) MMB-at-mating.

c. Evidence of search for balance between realistic (but possibly overparameterized) and simpler (but not realistic) models.

All models considered were parameterized in similar fashion, so no simpler or more realistic models were considered.

d. Convergence status and convergence criteria

Convergence in all models was assessed by running each model iteratively from a set of initial parameter configurations. Following an initial run, the final parameter estimates from the run were used as initial parameter estimates in a following run and this sequence was repeated six times. The model with the smallest objective function value was selected as the "converged" model, if it was possible to invert the associated hessian and obtain standard deviation estimates for parameter values. As noted previously, none of the four models (E-H) that forced asymptotic selectivity converged successfully. All other model runs converged, had invertible hessians, and standard deviation estimates based on the "delta method" were obtained for all parameter values.

e. Sample sizes assumed for the compositional data

Sample sizes assumed for compositional data used in Dataset D (the final dataset) are listed in Tables 4-8 for fishery-related size compositions. Sample sizes for all survey size compositions were set to 200, which was also the maximum allowed for the fishery-related sample sizes. Otherwise, input sample sizes were scaled as in the 2014 assessment (see Stockhausen, 2014 Appendix 5)

$$SS_y^{inp} = \min\left(200, \frac{SS_y}{(\overline{SS}/200)}\right)$$

where $\overline{SS}$ was the mean sample size for all males from dockside sampling in the directed fishery. Input sample sizes for all the size compositions that comprise Dataset D are compared in Fig. 37.

f. Parameter sensibility

For Models A-D, evaluated using Dataset D, most model parameter estimates obtained from the alternative models appear to be reasonable, or at least consistent with the 2014 assessment (Table 16). One notable exception is "af1", the ln-scale intercept for the mean female growth increment. This parameter reaches its upper bound (0.7) in every model, including the 2014 assessment. Anothe notable exception is "log_sel50_dev_3" (index 6), the ln-scale deviation from mean size at 50%-selected for males in the directed fishery for 1996, which hit the lower bounds put on the parameter (-0.5) in the 2014 assessment and remains small (-0.43) in Model A (Dataset D). This results in an unreasonably small estimates (~75 mm CW) for size at 50%-selected in 1996 in the directed fishery. The small input sample sizes associated with total catch size frequencies in the directed fishery for 1996 (< 3) seems to be the main factor allowing this parameter to go so small, but it is not clear what conflict in the data is pushing it that way.

g. Criteria used to evaluate the model or to choose among alternative models

Criteria used to evaluate the alternative models included: 1) data reliability, 2) goodness of fit and likelihood criteria, 3) parameter sensibility, and 4) biological realism.

h. Residual analysis

Residuals for the author's preferred model are discussed below under the Results section.

i. Evaluation of the model(s)

As discussed previously, Models E-H were eliminated from further consideration based on their non-convergence. Model B and D were eliminated because they tended to substantially mis-fit the discard mortality time series (Fig. 32)—overestimating total male mortality in the directed fishery, underestimating discard mortality in the groundfish fishery, and both under- and over-estimating male discard mortality in the snow crab fishery.

For the most part, Models A and C gave very similar results for estimated time series. Overall, however, Model A fit the data, with smaller penalties, much better than Model C did, as judged by comparing the total objective functions for the two models (Table 23). Model A had an objective function that was lower than Model C by more than 60 units, indicating a much better fit. Examination of the individual components to the objective function (Table 23, Fig.s 38 and 39) indicates that Model A fit the size compositions for retained males and total male catch in the directed fishery substantially better than Model C, size compositions for mature females in the trawl survey somewhat better (6 units), and biomass for mature males in the survey marginally better (4 units). Comparing Pearson's residuals from the fits to total male catch and retained catch for Models A and C indicate the generally the same patterns, although what appear to be rather small differences can be identified (primarily the patterns for 2005/06-200/10).

Model C, on the other hand, fit the data somewhat better (6-12 units) than Model A for size compositions for bycatch in the groundfish fisheries and for mature males in the survey, as well as for catch biomass of retained males and total males in the directed fishery.

However, given that Model A appears to fit the data substantially better than Model C, while both models give substantially similar results for population trends, I selected Model A as my "preferred" model for the 2015 assessment. This model is essentially identical to the 2014 assessment model selected by the CPT last year.

4. Results (best model(s))

Model A was selected as the author's preferred model for the 2015/16 assessment.

a. List of effective sample sizes, the weighting factors applied when fitting the indices, and the weighting factors applied to any penalties.

Input sample sizes for the various fishery-related size compositions are given in Tables 5-9 and Fig. 37. Input sample sizes for all survey-related size compositions were set to 200. Weighting factors for likelihood components and penalties are listed in Table 23, as are the associated objective function values from the converged model.

b. Tables of estimates:

i. All parameters

Parameter estimates and associated standard errors, based on inversion of the converged model's Hessian, are listed in Table 16 (non-"devs" parameters) and in Table 24 ("devs" parameters).

ii. Abundance and biomass time series, including spawning biomass and MMB.

Estimates of mature survey biomass are listed in Table 17 and presented graphically in Fig. 58. Estimates MMB are listed in Table 19 and presented graphically in Fig. 60. Estimates of mature female biomass at the time of mating (MFB) are presented graphically in Fig. 61. Numbers at size for males and females are given by year in 5 mm CW size bins in Tables 21 and 22, respectively.

iii. Recruitment time series

The estimated recruitment time series from the 2014 assessment and Model A are compared in Table 18 and Fig. 62.

iv. Time series of catch divided by biomass.

A comparison of catch divided by biomass (i.e., exploitation rate) from the 2014 assessment and Model A (Dataset D) is presented as a graph in Fig. 42.

c. Graphs of estimates

i. Fishery and survey selectivities, molting probabilities, and other schedules depending on parameter estimates.

Model-estimated growth curves from last year's model and the author's preferred model (Model A) are compared with empirical curves developed from growth data on Tanner crab in the GOA near Kodiak Island in Fig. 43. The model-estimated female growth is almost identical to that from Kodiak, while the model-estimated male growth curve suggests that molt increments are larger in the EBS than in the GOA. Model-estimated sex-specific probabilities at size of immature crab molting to maturity are compared in Fig. 44. The curve for males suggests an unlikely decline at the largest sizes, but it is not constrained to increase. In addition, size bins for which the curve is 1 (or 0) have corresponding parameter estimates that are on the upper (lower) boundary of the range of allowable values. This does not seem to affect model convergence or its ability to estimate standard deviations, which would ordinarily be a concern under such circumstances.

Estimates of natural mortality by sex and maturity state are shown in Fig. 45. Mortality rates are assumed equal by sex for immature crab, but are allowed to differ by sex for mature crab. Mortality rates for mature crab are estimated by sex across two time periods: 1949-1979+1985-2013 and 1980-1984. The latter period has been identified as a period of high natural mortality in the BBRKC stock (Zheng et al., 2012) and was identified as a separate period for Tanner crab in the 2012 assessment. The following table summarizes the estimated rates by stock component:

Stock component	Normal period		High Mortality	
	2014 assessment	Model A	2014 Assessment	Model A
immature crab	0.24	0.24	0.24	0.24
mature females	0.33	0.35	0.37	0.52
mature males	0.26	0.26	0.66	0.92

While the rates are almost identical in the “normal” period, Model A’s estimates for mature males and females are substantially larger than those from the 2014 assessment. Examining the dataset progression results, this jump occurs with the replacement of the old trawl survey dataset with the new one to obtain Dataset B.

Estimated total mortality selectivity curves for males in the directed fishery are very similar between Model A and the 2014 assessment model (Fig. 46). Small (< 5 mm CW) differences in size-at-50% selected occurred for 1994 and 1996. Retained mortality selectivity curves are also similar, although Model A indicates retention at slightly smaller sizes than the 2014 assessment did (Fig. 47). This is due to the difference in the estimated retention functions for the two models after 1990: the curve estimated by Model A indicates a slightly less steep rise in retention probability with size, as compared with the 2014 assessment estimate. The estimated selectivity curves for females in the model are also quite similar (Fig. 49).

Estimated bycatch selectivity curves for males and females are shown in Fig. 50 for the snow crab fishery, in Fig. 51 for the BBRKC fishery, and in Fig. 52 for the groundfish fisheries. Separate curves are estimated for 3 different time periods for each fishery, corresponding to changes in available data and fishery activity. For the snow crab fishery, separate sex-specific curves are estimated for 1989/90-1996/97, 1997/98-2004/05, and 2005/06-present. The time periods are the same for the BBRKC fishery. The directed Tanner crab fishery was closed during 1997/98-2004/05, which may have encouraged changes in how the snow crab and BBRKC fisheries were prosecuted—with associated changes in bycatch selectivity on Tanner crab. For the groundfish fisheries, the three time periods corresponding to the selectivity curves are 1973-1987, 1988-1996, and 1997-present. These correspond to changes in the groundfish fleets and Tanner crab fishery, with the curtailment of foreign and joint-venture fishing by 1988, the expansion of domestic fisheries from 1988 to 1996, and the closure of the tanner crab fishery in 1996/97.

The estimated selectivity curves for the snow crab fishery from Model A are similar to those from the 2014 assessment for both sexes (Fig. 50). The estimated selectivity curves for the BBRKC fishery are also quite similar, except for female bycatch selectivity before 1996, in which case Model A estimated a much smaller size-at-50% selection, compared with the 2014 assessment (Fig. 51). The pre-1996 curve estimated by Model A is, however, similar to that from the 2013 assessment—indicating, to some extent, the sensitivity of these underlying parameter estimates, in general. This may reflect differences in sex/size-specific bycatch fishing mortality in the BBRKC fishery such that the largest females and similarly-sized males are not subject to the same fishing mortality, as is assumed in the model by applying a fully-selected fishing mortality equally to selectivity curves for both sexes. If such were the case, the model might achieve a "better" fit to data by adjusting either the slope or location parameter (size at 50% selected) such that selectivity on females was less than 1 across the range of sizes found in the data. A possible solution to this confounding would be to fix sex-specific sizes for "fully-selected" animals in each fishery within observed size ranges and then estimate female-specific offsets to male "fully-selected" fishing mortality.

A similar phenomenon may be occurring in the groundfish selectivity curves for both Model A and the 2014 assessment model (Fig. 52), but with effects seen on the slope of the curves for females rather on size at 50% selected. For both models, the slopes of the female selectivity curves during 1977-1996 period are such that the curves never reach 1 (fully-selected) within the model's size range (the largest size bin corresponds to 182.5 mm CW). This did not occur in the 2013 Model, but the difference was traced, at least in part, to the extra emphasis placed on fitting female bycatch size compositions as a result of correcting input sample sizes between male and female groundfish bycatch size compositions (the true male sample sizes were always several times larger than the corresponding female ones).

Estimated survey selectivity curves (multiplied by sex-specific survey catchability) for males and females in three time periods (1974-1981, 1982-1987, and 1988-present) are shown in Fig.53, together with the selectivity curves inferred from Somerton's "underbag" experiments (Somerton and Otto, 1999). The curves are quite similar to those obtained in the 2014 assessment, except that the curve for females pre-1982 exhibits a smaller value for female catchability in the survey than was found in the 2014 assessment. This is a result of using the new survey dataset.

iii. Estimated full selection F over time

Estimated time series of fully-selected F on males in the directed fishery and as bycatch in the snow crab, BBRKC and groundfish fisheries are compared in Fig.s 54-57 between Model A and the 2014 assessment. Estimated trends are similar for the models across all four fisheries. In the directed fishery, fully-selected F peaked in 1980 at values larger than 2 in both models, then rapidly declined and was at low levels in the mid-1980s. It peaked again in 1993 and subsequently declined to low levels (when the fishery was open; Fig. 54). Exploitation rates (catch/biomass) in the directed fishery for total catch and large males > 138 mm CW followed similar trends (Fig. 42), with exploitation rates reaching almost 80% on large males in 1981 and 50 % in 1993.

ii. Estimated male, female, mature male, total and effective mature biomass time series

Time series of observed biomass of mature crab in the NMFS bottom trawl surveys are compared by sex with model-predicted values for Model A (Dataset D) and the 2014 assessment in Fig. 58. Both the model and the assessment under-predict mature female survey biomass in the early 1980s and again in the early 1990s. They also under-predict mature male survey biomass in the early 1990s as well as in the mid-2000s. The scale of the standardized log-scale residuals (Fig. 59) indicates a mediocre fit, as in the 2014 assessment,between the model and the data (the standard deviation of the residuals is ~2, whereas ~1 would indicate a good fit).

The time series of model-predicted MMB (i.e., mature male biomass at the time of mating) from the 2014 assessment and Model A is compared in Fig. 60, while mature female biomass (MFB) at the time of mating is shown in Fig. 61. For both models, MMB and MFB decline from peaks in the mid-1970s to low levels in the early-1980s. This period is followed by buildups to much lower peaks in 1989, followed by steady declines to minima in 1999. After 1999, both MMB and MFB have been on fairly steady increasing trends.

iv. Estimated fishing mortality versus estimated spawning stock biomass

See Section F (Calculation of the OFL).

v. Fit of a stock-recruitment relationship, if feasible.
Not available.

e. Evaluation of the fit to the data:

i. Graphs of the fits to observed and model-predicted catches
Graphs of model fits to retained catch, total male (retained + discard) mortality, and female discard mortality in the directed fishery are provided in Fig. 63. The fits are quite good for males, but less so for females. Model fits to discard mortality in the snow crab fishery in Fig. 64. As with the directed fishery, fits are better for males and less so for females. Model fits to discard mortality in the BBRKC fishery are shown in Fig. 65. These fits are quite poor for both sexes. Part of the problem is that the effective variance for fishery catch data is 1,000 t, but the observed discard mortalities, particularly for the BBRKC fishery, are much smaller than this level—consequently the model has no "motivation", as it were, to fit them more closely. Model fits to discard mortality in the groundfish fisheries are shown in Fig. 66, and are quite good.

ii. Graphs of model fits to survey numbers
Model predictions for total numbers of large males (≥ 138 mm CW), all females, and all males in the survey are compared with observations from the survey in Fig. 66. The model over-predicts numbers of large crab in recent years, but under-predicts the decline in survey numbers of both males and females in the mid-1980s and anticipates the subsequent increase in survey numbers to 1990. In the more recent past (since 2000), the model tends to underestimate the numbers of both sexes in the survey. These results suggest that growth in the model may be too rapid.

Model predictions for the number of mature males and females in the survey are compared with observed numbers in Fig. 67 for Model A. The fits seem to be better than those in Fig. 66.

iii. Graphs of model fits to catch proportions by length
Model-predicted proportions at size for retained males in the directed Tanner crab fishery are presented in Fig. 68 from the 2014 assessment and Model A. Both models appear to fit the observed proportions quite similarly. The peak in the predicted size compositions tends to be quite sharp in the 2014 assessment, but more rounded in Model A. Model A over-predicts the proportion of retained small crabs in 1996, but the input sample size for this year is very small and thus the mis-fit is not heavily penalized.

Model-predicted patterns from the 2014 assessment and Model A for the proportion caught-at-size in the directed fishery for all males are shown in Fig. 70. General residual patterns again indicate, more strongly than with the retained catch, that the fishery catches a larger proportion of smaller crab than predicted by the model (except in 1996) and catches fewer large crab than predicted by the model. Conceivably, among other potential explanations, this pattern may indicate that an asymptotic selectivity curve is inappropriate for the selection process or that the model overestimates growth into the largest size classes for males. 1996 is the exception to this, and exhibits an extremely poor fit to the data. However, as previously noted, the relative weight (input sample size) put on fitting this weight in the likelihood is quite small. It is notable that the fit to the 1996 size composition for females taken in the directed fishery (Fig. 71) is much better. The general pattern of residuals for females is similar to the general pattern for males. It should be noted, however, that the scale of the residuals for males is larger than that for females.

iv. Graphs of model fits to survey proportions by length
Model fits from the 2014 assessment and Model A (Dataset D) to observed proportions at size in the annual NMFS trawl survey are shown for males in Fig. 72. The similarity in results between the two models is fairly remarkable, and indicates that relative size compositions were not substantially different between the old and new trawl survey datasets. As with the 2014 assessment model, Model A appears to be suitably sensitive to relatively large cohorts recruiting to the model size range (e.g., 1997-2002), but

appear to be less able to track strong cohorts through time (the mode in the model proportions at ~100 mm CW in 1982 disappears after two years, but appears to last until at least 1985 in the observed proportions. After 1982, the model tends to under-predict size proportions for males in the 70-120 mm range and over-predict the proportion of large (> 120 mm CW) males after 2000. Model fits to proportions at size in the survey for females are shown in Fig. 73. The model tends to over-predict proportions-at-size in the 65-85 mm CW range. The patterns of residuals for males and females evident in the bubble plots for Model A are almost identical to those obtained from the 2014 assessment.

v. Marginal distributions for the fits to the compositional data.

Marginal fits of the Model A-predicted proportion of crab by size in the directed fishery catch show the model slightly over-predicts proportions for retained males at sizes smaller than the peak and under-predicts proportions at sizes larger than the peak (Fig. 74, upper graph). In contrast, the model under-predicts proportions near the peak and somewhat smaller for all males caught (retained and discarded), but over-estimates the proportions for crab larger than the peak (Fig. 74, middle graph). A similar pattern is evident for the model-predicted marginal proportion at size for female bycatch in the directed fishery (Fig. 74, lower graph).

The observed and predicted (Model A) marginal proportions for males taken as bycatch in the snow crab fishery are in good agreement at all sizes, while the model tends to underestimate the proportion of females taken as bycatch near the peak proportions (~80-90 mm CW) and over-estimate the proportions at larger sizes (Fig. 75, upper row).

The opposite pattern is true of the proportion-at-size of females taken as bycatch in the BBRKC fishery, where intermediate-size females are over-represented in the model predictions and under-represented at larger sizes (Fig. 75, middle row). The pattern of model-predicted marginal proportions-at-size for males taken as bycatch in the BBRKC fishery is similar to that found for the snow crab fishery, but shifted to larger sizes by ~20 mm CW. Unfortunately, it presents a poorer fit to the observations, overestimating proportions at larger sizes and underestimating them at smaller sizes, than in the snow crab fishery. The patterns of marginal predicted proportions at size for males and females taken in the groundfish fishery (Fig. 75, bottom row) obtained by Model A are again quite similar to those obtained in the 2014 assessment. Male proportions are over-estimated across the size range while female proportions are under-predicted. Somewhat oddly, the model predicts a plateau at smaller female sizes and suggests a bimodal distribution not seen in the data.

Marginal fits of Model A-predicted proportion-at-sizes in the survey are presented in Fig. 76. The model's marginal survey proportions fit the data quite well, and in quite similar fashion to the 2014 assessment.

Overall, the patterns for all of the marginal distributions are quite similar to those obtained in the 2014 assessment.

vi. Plots of implied versus input effective sample sizes and time-series of implied effective sample sizes.

Not available.

vii. Tables of the RMSEs for the indices (and a comparison with the assumed values for the coefficients of variation assumed for the indices).

Not available.

viii. Quantile-quantile (q-q) plots and histograms of residuals (to the indices and compositional data) to justify the choices of sampling distributions for the data.

Not available.

f. 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).

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

As currently coded, it is not possible to perform retrospective analyses with the TCSAM in the compressed time span allowed for this assessment. This deficiency has been addressed in the new code undergoing testing.

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

Many of the plots contained in this assessment feature comparisons between results from the 2014 assessment model and the author's preferred model for this assessment. Most of them indicate little difference between the two models, particularly for more recent periods (e.g., since 1990).

g. Uncertainty and sensitivity analyses

Not available.

F. Calculation of the OFL and ABC

1. Status determination and OFL calculation

EBS Tanner crab was elevated to Tier 3 status following acceptance of the TCSAM by the CPT and SSC in 2012. Based upon results from the model, the stock was subsequently declared rebuilt and not overfished. Consequently, EBS Tanner crab is assessed as a Tier 3 stock for status determination and OFL setting.

The (total catch) OFL for 2014/15 was 31.48 thousand t while the total catch mortality for 2014/15 was 9.16 thousand t, based on applying discard mortality rates of 0.321 for pot fisheries and 0.8 for the groundfish fisheries to the reported catch by fleet for 2014/15 (Tables 1 and 3). Therefore overfishing did not occur.

Amendment 24 to the NPFMC fishery management plan (NPFMC 2007) 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 3. The OFL control rule for Tier 3 is (Fig. 77):

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* $F_{OFL} \le F_{MSY}{}^{\dagger}$	

and is based on an estimate of "current" spawning biomass at mating (B above, taken as MMB at mating in the assessment year) and spawning biomass per recruit (SBPR)-based proxies for F_{MSY} and B_{MSY}. In the above equations, α=0.1 and β=0.25. For Tanner crab, the proxy for F_{MSY} is $F_{35\%}$, the fishing mortality that reduces the SBPR to 35% of its value for an unfished stock. Thus, if $\phi(F)$ is the SBPR at fishing mortality F, then $F_{35\%}$ is the value of fishing mortality that yields $\phi(F) = 0.35 \cdot \phi(0)$. The Tier 3 proxy for B_{MSY} is $B_{35\%}$, the equilibrium biomass achieved when fishing at $F_{35\%}$, where $B_{35\%}$ is simply 35% of the unfished stock biomass. Given an estimate of average recruitment, $\bar{R}$, then $B_{35\%} = 0.35 \cdot \bar{R} \cdot \phi(0)$.

Thus Tier 3 status determination and OFL setting for 2015/16 require estimates of B = $MMB_{2015/16}$ (the projected MMB at mating time for the coming year), $F_{35\%}$, spawning biomass per recruit in an unfished stock ($\phi(0)$), and $\bar{R}$. Current stock status is determined by the ratio $B/B_{35\%}$ for Tier 3 stocks. If the ratio is greater than 1, then the stock falls into Tier 3a and $F_{OFL} = F_{35\%}$. If the ratio is less than one but greater than β, then the stock falls into Tier 3b and F_{OFL} is reduced from $F_{35\%}$ following the descending limb of the control rule (Fig. 73). If the ratio is less than β, then the stock falls into Tier 3c and directed fishing must cease. In addition, if B is less than ½ $B_{35\%}$ (the minimum stock size threshold, MSST), the stock must be declared overfished and a rebuilding plan subsequently developed.

In 2015, the SOA's Board of Fish, under petition from the commercial Tanner crab fishing industry, changed the minimum preferred size for crab in the area east of 166°W longitude in calculations used for setting TACs from 138 mm CW (not including lateral spines) to 125 mm CW. The minimum preferred size in the area west of 166°W remained the same (125 mm CW). It would be desirable, if possible, to incorporate this change in harvest strategy in the projections made to determine F_{OFL} and calculate OFL.

In order to incorporate the spatial division of the directed fishery into two management areas into the projection model, previous assessments approached the problem using the following assumptions:

1. The whole-stock total (retained + discard) fishing mortality selectivity function, as estimated by the assessment model (an average over the last 4 years of fishing), applied equally to both areas.
2. The whole-stock retained mortality selectivity function, as estimated in the assessment model (an average over the last 4 years of fishing), applied to the area east of 166°W.
3. The whole-stock retained mortality selectivity function, as estimated in the assessment model, applied to the area west of 166°W, but was shifted 10 mm (two size bins) toward smaller sizes to incorporate the difference in preferred sizes between the two areas.
4. The effective whole stock retained mortality selectivity function was a weighted version of the functions in 2 and 3, with the size-specific weighting equal to the fraction of total survey abundance derived from each area.

This approach, referred to here as the 2014 projection approach, appeared to work satisfactorily. The selectivity functions used in the 2014 approach to calculate the OFL for Model A (Dataset D) are shown in Fig. 78.

Because of the changes noted previously to the preferred minimum size used for TAC setting in the area east of 166°W, two new approaches were considered in this assessment, as well the 2014 approach. The first one ("new (1)") applied the same rationale to step 2 above as was used in step 3 to assign a new retained mortality curve to the eastern area, but used a more flexible calculated version of the retention function that rises to 1 at the new minimum preferred size to left-shift the retained mortality selectivity function estimated in the assessment model. To be consistent, this was also done for the west area (rather than left-shifting by two size bins). For the 2015/16 preferred minimum sizes (which are the same in both areas), this approach assumes the whole stock retained mortality selectivity function for 2015/16 will simply be a left-shifted version of the average over the last four fishing years. However, total (retained + discard) directed fishing mortality selectivity would be the same as average over the last four fishing years. This approach, like the 2014 approach, attempts to capture changes in size-specific retention while size-specific total selectivity remains unchanged. The curves used to calculate OFL for Model A using the new (1) approach are shown in Fig. 79.

The second new approach ("new (2)") assumed that both the total directed fishing mortality selectivity and the retained mortality selectivity would be left-shifted versions of their equivalent assessment model averages. This approach attempts to capture changes in size-specific total selectivity as well as changes in size-specific retention. The curves used to calculate OFL for Model A using the new (2) approach are shown in Fig. 80.

Fully-selected fishing mortality and selectivity curves in the bycatch fisheries were set using the same approach as in previous assessments (Rugolo and Turnock, 2012b; Stockhausen 2014). The curves used for Model A are shown in Fig. 81.

The alternative models presented in the snow crab assessment this year resulted in substantially different snow crab F_{OFL}'s. Because the snow crab F_{OFL} is incorporated into the Tanner crab projection model, I considered two snow crab F_{OFL} scenarios (based on Turnock's preferred and 2014 models) for each of the three approaches outlined above for handling potential changes to the size-specific patterns of retained (and total) fishing mortality in the directed fishery. For Turnock's "preferred" snow crab model, I used his snow crab F_{OFL}=0.89 and recent 5-year average of fully-selected F's (1.54) to scale the recent 5-year average fully-selected Tanner crab discard mortality rate estimated in the assessment model to that used in the projection (0.012). For Turnock's 2014 model, F_{OFL} was 1.01, the 5-year average snow crab F was 1.02, and the fully-selected Tanner crab discard mortality rate used in the projection model was 0.021.

OFL results from the projection model using the snow crab F_{OFL} (0.89 yr^{-1}) from Turnock's preferred model and the 2014 projection approach are presented in Table 27 for illustrative purposes only to show the effects of the progression of datasets from the 2014 assessment to the final 2015 dataset (Dataset D). Correcting the 2013/14 directed fishery data had surprisingly little impact on the OFL and related quantities. The largest changes occurred with the addition of the 2015 data (Dataset A), when estimated average recruitment dropped 5 %, B_{MSY} dropped 7%, and the OFL dropped 10%. Replacing the "old" trawl survey dataset (A) with the "new" dataset (B) led to fairly small (< 5%) changes in these quantities, as did changing to the standardized trawl survey weight-at-size regressions (C->D).

OFL results from the 6 projection model scenarios for the author's preferred model, Model A, using the final 2015 dataset (Dataset D), are compared in Table 28 with results from the 2014 assessment and from running the projection model on results from Model C (for illustrative purposes). The author's preferred approach is highlighted in yellow: use results from Model A (Dataset D) as the preferred model, use the snow crab F_{OFL} from Turnock's preferred model, and use the 2014 projection approach (used in previous assessments). The choice of snow crab F_{OFL} has little impact on the resulting OFL values. Somewhat surprisingly, the 2014 and "new (1)" projection approaches yield identical results. In retrospect, this should have been anticipated because the OFL, as calculated, is a total catch mortality OFL—not a retained catch OFL—and thus depends only on the *total* fishing mortality selectivity in the directed fishery, and not the retained mortality selectivity, as currently formulated in the projection model. As discussed in Appendix B, the OFL is independent of the retained mortality selectivity (as currently formulated in the projection model). A different OFL is obtained if the "new (2)" projection model approach is used, but this scenario assumes an overall relative increase in directed fishing mortality on smaller crab (left-shifted total fishing mortality selectivity)—essentially a change in fishing patterns—while the change in the TAC setting which motivated this new approach is based on a change in retention, not fishing, patterns.

The estimate of *B* from Model A (Dataset D, preferred snow crab model F_{OFL}, 2014 projection approach), the author's preferred model and OFL calculation, is 52.80 thousand t (Table 28). Male spawning biomass per recruit in an unfished stock was calculated using the TCSAM population dynamics equations (Stockhausen, 2014) with total recruitment set to 1 and fishing mortality from all sources (directed fishery and all bycatch fisheries) set to 0, resulting in $\phi(0)$ = 0.427 kg/recruit. $F_{35\%}$ was calculated for this scenario as 0.64 yr^{-1}, which is somewhat larger than that calculated last year (0.61 yr^{-1}) but smaller than that calculated for 2013 (0.73 yr^{-1}; Stockhausen, 2014).

The determination of $B_{MSY}=B_{35\%}$ for Tanner crab depends on the selection of an appropriate time period over which to calculate average recruitment ($\bar{R}$). After much discussion in 2012 and 2013, the SSC endorsed an averaging period of 1982+. Starting the average recruitment period in 1982 is consistent with a 5-6 year recruitment lag from 1976/77, when a well-known climate regime shift occurred in the EBS (Rodionov and Overland, 2005) that may have affected stock productivity. The value of $\bar{R}$ for this period from the author's preferred model is 179.37 million. The estimates of average recruitment are reasonably similar between the 2014 assessment model and the author's preferred model (Table 27). The value of $B_{MSY}=B_{35\%}$ for $\bar{R}$ is 26.79 thousand t. Thus, the stock is "not overfished" because $B/B_{35\%} > 0.5$ (i.e., B > MSST).

Once F_{OFL} is determined using the control rule (Fig. 77), the (total catch) OFL can be calculated based on projecting the population forward one year assuming that $F = F_{OFL}$. In the absence of uncertainty, the OFL would then be the predicted total catch taken when fishing at $F = F_{OFL}$. When uncertainty (e.g. assessment uncertainty, variability in future recruitment) is taken into account, the OFL is taken as the median total catch when fishing at $F = F_{OFL}$.

The total catch (biomass), including all bycatch of both sexes from all fisheries, was estimated using

$$C = \sum_f \sum_x \sum_z \frac{F_{f,x,z}}{F_{.,x,z}} \cdot (1 - e^{-F_{.,x,z}}) \cdot w_{x,z} \cdot [e^{-M_x \cdot \delta t} \cdot N_{x,z}]$$

where C is total catch (biomass), $F_{f,x,z}$ is the fishing mortality in fishery f on crab in size bin z by sex (x), $F_{.,x,z} = \sum_f F_{f,x,z}$ is the total fishing mortality by sex on crab in size bin z, $w_{x,z}$ is the mean weight of crab in size bin z by sex, M_x is the sex-specific rate of natural mortality, δt is the time from July 1 to the time of the fishery (0.625 yr), and $N_{x,z}$ is the numbers by sex in size bin z on July 1, 2015 as estimated by the assessment model.

Assessment uncertainty was included in the calculation of OFL using the same approach as that used for the 2014 assessment (Stockhausen, 2014). Basically, initial numbers at size on July 1, 2015 were randomized based on an assumed lognormal assessment error distribution and the cv of estimated MMB for 2014/15 from the assessment model, the control rule was applied to obtain F_{OFL}, and the population projected forward to next year assuming that fishing occurred consistent with F_{OFL}. This was repeated 10,000 times to generate a distribution of total catch OFLs. **The value of OFL for 2014/15 from the author's preferred model (Model A) is 27.73 thousand t** (Table 28, Fig. 78)**.**

Model A is the author's preferred model for calculating the B_{MSY} proxy as $B_{35\%}$, so MSST = 0.5 B_{MSY} = 13.40 thousand t. Because current B = 52.80 thousand t > MSST, **the stock is not overfished**. The population state (directed F vs. MMB) is plotted for each year from 1965-2014 in Fig. 79 against the Tier 3 harvest control rule.

2. ABC calculation

Amendments 38 and 39 to the Fishery Management 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 (following Method 2). Thus, annual ACL=ABC levels should be established such that the risk of ovefishing, P[ABC>OFL], is 49%. For 2014/15, however, the SSC adopted a buffer of 20% on OFL for the Tanner crab stock for calculating ABC. Here, ABCs are provided based on both methods.

ABCs based on the P*=0.49 approach were calculated from quantiles of the associated OFL distributions such that probability that the selected ABC was greater than the true OFL was 0.49. The resulting ABC for each scenario was almost identical to the associated OFL (Table 27). ABCs were also calculated using the SSC's 20% OFL buffer (Table 27).

For the author's preferred model and projection (Model A, Turnock's preferred snow crab model F_{OFL}, 2014 projection approach), the P* ABC_{max} is 27.70 thousand t while the 20% Buffer ABC_{max} is 22.19 thousand t. The author remains concerned that the projection model, based on $F_{35\%}$ as a proxy for F_{MSY}, is overly optimistic regarding the actual productivity of the stock. Fishery-related mortality similar to these ABC levels has occurred only in the latter half of the 1970s and in 1992/93, coincident with collapses in stock biomass to low levels. This suggests that $F_{35\%}$ may not be a realistic proxy for F_{MSY} and/or that MMB may not be a good proxy for reproductive success, as are currently assumed for this stock. Given this uncertainty concerning the stock, **the author recommends using the 20% buffer adopted by the SSC last yearfor this stock to calculate ABC. Consequently, the author's recommended ABC is 22.19 thousand t**.

G. Rebuilding Analyses
Tanner crab is not currently under a rebuilding plan. Consequently no rebuilding analyses were conducted.

H. Data Gaps and Research Priorities
Some information on growth-per-molt has finally been collected in the EBS on Tanner crab (molt increments observed on ~60 individuals collected in May, 2015; R. Foy, AFSC, pers. comm.). Data on temperature-dependent effects on molting frequency would be helpful to assess potential impacts of the EBS cold pool on the stock. In addition, it would be extremely worthwhile to develop a "better" index of reproductive potential than MMB and to revisit the issue of MSY proxies for this stock.

The characterization of fisheries in the assessment model needs to be carefully reconsidered. How, and whether or not, the East 166°W and West 166°W directed fisheries should be explicitly represented in the assessment model should be addressed. In addition, how, and whether or not, bycatch in the groundfish fisheries should be split into pot- and trawl-related components should be addressed.

It is clear that a new projection model based on the Gmacs fishing mortality model needs to be developed

Effort needs to continue on developing the TCSAM model code, particularly so that model output can accommodate the wide range of diagnostic and evaluation protocols requested of SAFE documents (e.g., retrospective analyses, simulation testing). In a similar vein, the model code needs to be revised so the model is more configurable using control files, rather than requiring the code itself to be altered to run different configurations, than it currently is. These issues have been addressed in the new code currently undergoing testing.

I. Ecosystem Considerations
Mature male biomass is currently used as the "currency" of Tanner crab spawning biomass for assessment purposes. However, its relationship to stock-level rates of egg production, perhaps an ideal measure of stock-level reproductive capacity, is unclear. Thus, use of MMB to reflect Tanner crab reproductive

potential may be misleading as to stock health. Nor is it likely that mature female biomass has a clear relationship to annual egg production. For Tanner crab, the fraction of barren mature females by shell condition appears to vary on a decadal time scale (Rugolo and Turnock, 2012), suggesting a potential climatic driver.

1. Ecosystem Effects on Stock

Time series trends in prey availability or abundance are generally unknown for Tanner crab because typical survey gear is not quantitative for Tanner crab prey. On the other hand, Pacific cod (*Gadus macrocephalus*) is thought to account for a substantial fraction of annual mortality on Tanner crab (Aydin et al., 2007). Total P. cod biomass is estimated to have been slowly declining from 1990 to 2008, during the time frame of a collapse in the Tanner crab stock, but has been increasing rather rapidly since 2008 (Thompson and Lauth, 2012). This suggests that the rates of "natural mortality" used in the stock assessment for the period post-1980 may be underestimates (and increasingly biased low if the trend in P. cod abundance continues). This trend is definitely one of potential concern.

2. Effects of Tanner crab fishery on ecosystem

Potential effects of the Tanner crab fishery on the ecosystem are considered in the following table:

Effects of Tanner crab fishery on ecosystem

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	salmon are unlikely to be trapped inside a pot when it is pulled, although halibut can be	unlikely to have substantial effects at the stock level	minimal to none
Forage (including herring, Atka mackerel, cod and pollock)	Forage fish are unlikely to be trapped inside a pot when it is pulled	unlikely to have substantial effects	minimal to none
HAPC biota	crab pots have a very small footprint on the bottom	unlikely to be having substantial effects post-rationalization	minimal to none
Marine mammals and birds	crab pots are unlikely to attract birds given the depths at which they are fished	unlikely to have substantial effects	minimal to none
Sensitive non-target species	Non-targets are unlikely to be trapped in crab pot gear in substantial numbers	unlikely to have substantial effects	minimal to none
Fishery concentration in space and time	substantially reduced in time following rationalization of the fishery	unlikely to be having substantial effects	probably of little concern
Fishery effects on amount of large size target fish	Fishery selectively removes large males	May impact stock reproductive potential as large males can mate with a wider range of females	possible concern
Fishery contribution to discards and offal production	discarded crab suffer some mortality	May impact female spawning biomass and numbers recruiting to the fishery	possible concern
Fishery effects on age-at-maturity and fecundity	none	unknown	possible concern

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Table captions

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Tables

Table 1. Weight-at-size relationships for Tanner crab used to convert size to weight in the current assessment, NMFS EBS bottom trawl survey time series (post-2009 and pre-2010), and in previous assessments. Weights are in kilograms, size in mm CW.

Size	2015 Assessment/New Survey Time Series			Old Survey Time Series (pre-2010)			2014 Assessment		
	Females		Males	Females		Males	Females		Males
	immature	mature		immature	mature		immature	mature	
27.5	0.006	0.006	0.006	0.001	0.001	0.005	0.006	0.006	0.005
32.5	0.010	0.010	0.010	0.002	0.002	0.009	0.010	0.010	0.009
37.5	0.015	0.016	0.015	0.003	0.003	0.014	0.015	0.015	0.013
42.5	0.021	0.022	0.022	0.004	0.004	0.020	0.022	0.022	0.020
47.5	0.029	0.031	0.031	0.006	0.006	0.029	0.030	0.030	0.029
52.5	0.038	0.042	0.042	0.008	0.008	0.040	0.040	0.041	0.039
57.5	0.050	0.054	0.055	0.010	0.010	0.053	0.051	0.053	0.052
62.5	0.063	0.069	0.071	0.013	0.013	0.068	0.065	0.068	0.068
67.5	0.078	0.087	0.089	0.016	0.016	0.087	0.081	0.086	0.087
72.5	0.096	0.107	0.111	0.019	0.019	0.108	0.099	0.106	0.109
77.5	0.116	0.130	0.136	0.023	0.023	0.133	0.119	0.130	0.134
82.5	0.138	0.156	0.164	0.027	0.027	0.162	0.142	0.156	0.164
87.5	0.163	0.185	0.196	0.032	0.032	0.195	0.167	0.186	0.197
92.5	0.191	0.217	0.233	0.037	0.037	0.232	0.196	0.220	0.235
97.5	0.222	0.253	0.273	0.043	0.043	0.273	0.227	0.257	0.277
102.5	0.256	0.293	0.318	0.049	0.049	0.319	0.261	0.298	0.324
107.5	0.293	0.337	0.367	0.056	0.056	0.370	0.298	0.343	0.377
112.5	0.333	0.384	0.421	0.063	0.063	0.426	0.339	0.393	0.435
117.5	0.377	0.436	0.481	0.071	0.071	0.488	0.383	0.447	0.499
122.5	0.424	0.492	0.546	0.080	0.080	0.555	0.430	0.506	0.569
127.5	0.474	0.553	0.616	0.089	0.089	0.629	0.481	0.570	0.645
132.5	0.529	0.619	0.692	0.099	0.099	0.709	0.536	0.639	0.728
137.5	0.587	0.689	0.774	0.109	0.109	0.795	0.595	0.713	0.818
142.5	0.650	0.764	0.863	0.121	0.121	0.889	0.658	0.792	0.916
147.5	0.716	0.845	0.958	0.132	0.132	0.989	0.724	0.878	1.021
152.5	0.787	0.931	1.060	0.145	0.145	1.097	0.795	0.969	1.134
157.5	0.862	1.023	1.169	0.158	0.158	1.213	0.870	1.066	1.255
162.5	0.942	1.120	1.285	0.172	0.172	1.337	0.950	1.170	1.384
167.5	1.026	1.223	1.409	0.187	0.187	1.469	1.034	1.280	1.523
172.5	1.115	1.332	1.540	0.202	0.202	1.609	1.123	1.396	1.670
177.5	1.208	1.448	1.679	0.219	0.219	1.759	1.217	1.520	1.827
182.5	1.307	1.569	1.827	0.236	0.236	1.917	1.315	1.650	1.994

Table 2. Retained catch (males) in directed Tanner crab fisheries.

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	0.00			0.00
1986/87	0.00			0.00
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	0.00			0.00
1998/99	0.00			0.00
1999/00	0.00			0.00
2000/01	0.00			0.00
2001/02	0.00			0.00
2002/03	0.00			0.00
2003/04	0.00			0.00
2004/05	0.00			0.00
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	0.00			0.00
2011/12	0.00			0.00
2012/13	0.00			0.00
2013/14	1.25			1.25
2014/15	6.16			6.16

Table 3. Retained catch (males) in the US domestic pot fishery. Information from the Communnity Development Quota (CDQ) fisheries is included in the table for fishery years 2005/06 to the present. Number of crabs caught and harvest includes deadloss. The “Fishery Year” YYYY/YY+1 runs from July 1, YYYY to June 30, YYYY+1. The ADF&G year (in parentheses, if different from the “Fishery Year”) indicates the year ADF&G assigned to the fishery season in compiled reports.

year (ADF&G year)	Total Crab (no.)	Total Harvest (lbs)	GHL/TAC (millions lbs)	Vessels (no.)	Season
1968/69 (1969)	353,300	1,008,900			
1969/70 (1970)	482,300	1,014,700			
1970/71 (1971)	61,300	166,100			
1971/72 (1972)	42,061	107,761			
1972/73 (1973)	93,595	231,668			
1973/74 (1974)	2,531,825	5,044,197			
1974/75	2,773,770	7,028,378		28	
1975/76	8,956,036	22,358,107		66	
1976/77	20,251,508	51,455,221		83	
1977/78	26,350,688	66,648,954		120	
1978/79	16,726,518	42,547,174		144	
1979/80	14,685,611	36,614,315	28-36	152	11/01-05/11
1980/81 (1981)	11,845,958	29,630,492	28-36	165	01/15-04/15
1981/82 (1982)	4,830,980	11,008,779	12-16	125	02/15-06/15
1982/83 (1983)	2,286,756	5,273,881	5.6	108	02/15-06/15
1983/84 (1984)	516,877	1,208,223	7.1	41	02/15-06/15
1984/85 (1985)	1,272,501	3,036,935	3	44	01/15-06/15
1985/86 (1986)	closed	closed	closed	closed	closed
1986/87 (1987)	closed	closed	closed	closed	closed
1987/88 (1988)	957,318	2,294,997	5.6	98	01/15-04/20
1988/89 (1989)	2,894,480	6,982,865	13.5	109	01/15-05/07
1989/90 (1990)	9,800,763	22,417,047	29.5	179	01/15-04/24
1990/91	16,608,625	40,081,555	42.8	255	11/20-03/25
1991/92	12,924,102	31,794,382	32.8	285	11/15-03/31
1992/93	15,265,865	35,130,831	39.2	294	11/15-03/31
1993/94	7,235,898	16,892,320	9.1	296	11/01-11/10, 11/20-01/01
1994/95 (1994)	3,351,639	7,766,886	7.5	183	11/01-11/21
1995/96 (1995)	1,877,303	4,233,061	5.5	196	11/01-11/16
1996/97 (1996)	734,296	1,806,077	6.2	196	11/01-11/05, 11/15-11/27
1997/98-2004/05	closed	closed	closed	closed	closed
2005/06	443,978	952,887	1.7	49	10/15-03/31
2006/07	927,086	2,122,589	3.0	64	10/15-03/31
2007/08	927,164	2,106,655	5.7	50	10/15-03/31
2008/09	830,363	1,939,571	4.3	53	10/15-03/31
2009/10	485,676	1,327,952	1.3	45	10/15-03/31
2010/11	closed	closed	closed	closed	closed
2011/12	closed	closed	closed	closed	closed
2012/13	closed	closed	closed	closed	closed
2013/14	1,426,670	2,751,124	3.108	32	10/15-03/31
2014/15	7,442,931	13,576,105	15.105	100	10/15-03/31

Table 4. Total bycatch (1000's t) of Tanner crab in various fisheries. Total discard mortality was calculated assuming mortality rates of 0.321 in the crab fisheries and 0.80 in the groundfish fisheries.

	Discards (1,000's t) of Tanner Crab by Fishery							Total Discard
	Tanner Crab		Snow Crab		Red King Crab		Groundfish	Mortality
Year	Male	Female	Male	Female	Male	Female	All	(1,000's t)
1973/74							17.735	14.188
1974/75							24.449	19.559
1975/76							9.408	7.526
1976/77							4.699	3.759
1977/78							2.776	2.221
1978/79							1.869	1.495
1979/80							3.397	2.718
1980/81							2.114	1.691
1981/82							1.474	1.179
1982/83							0.449	0.359
1983/84							0.671	0.537
1984/85							0.644	0.515
1985/86							0.399	0.319
1986/87							0.649	0.519
1987/88							0.640	0.512
1988/89							0.463	0.370
1989/90							0.671	0.537
1990/91							0.943	0.755
1991/92							2.545	2.036
1992/93	6.175	1.005	25.759	1.787	1.188	0.029	2.758	13.744
1993/94	3.870	1.028	14.530	1.814	2.967	0.198	1.760	9.243
1994/95	3.130	1.270	7.124	1.271	0.000	0.000	2.096	5.784
1995/96	2.762	1.760	4.797	1.759	0.000	0.000	1.524	4.776
1996/97	0.116	0.045	0.833	0.229	0.027	0.004	1.597	1.680
1997/98	0.000	0.000	1.750	0.226	0.165	0.003	1.179	1.632
1998/99	0.000	0.000	1.989	0.175	0.119	0.003	0.934	1.481
1999/00	0.000	0.000	0.695	0.145	0.076	0.004	0.630	0.800
2000/01	0.000	0.000	0.146	0.022	0.067	0.002	0.739	0.667
2001/02	0.000	0.000	0.323	0.011	0.043	0.002	1.184	1.069
2002/03	0.000	0.000	0.557	0.037	0.062	0.003	0.721	0.788
2003/04	0.000	0.000	0.193	0.026	0.056	0.003	0.422	0.427
2004/05	0.000	0.000	0.078	0.014	0.048	0.003	0.676	0.587
2005/06	0.462	0.044	0.968	0.043	0.042	0.002	0.621	0.998
2006/07	1.370	0.355	1.462	0.169	0.026	0.003	0.717	1.660
2007/08	2.041	0.097	1.872	0.102	0.056	0.009	0.694	1.896
2008/09	0.431	0.014	1.119	0.050	0.269	0.004	0.531	1.030
2009/10	0.071	0.002	1.324	0.014	0.150	0.001	0.374	0.801
2010/11	0.000	0.000	1.344	0.016	0.033	0.001	0.231	0.632
2011/12	0.000	0.000	2.119	0.014	0.017	0.000	0.203	0.852
2012/13	0.000	0.000	1.187	0.009	0.042	0.001	0.153	0.520
2013/14	0.387	0.023	1.832	0.015	0.113	0.001	0.348	1.040
2014/15	2.515	0.039	5.383	0.050	0.296	0.001	0.423	2.998

Table 5. Sample sizes from the recalculated fishery data for retained catch-at-size in the directed fishery. N = number of individuals. N` = scaled sample size used in assessment.

year	new + old shell	
	N	N'
1980/81	13,310	97.8
1981/82	11,311	83.1
1982/83	13,519	99.3
1983/84	1,675	12.3
1984/85	2,542	18.7
1988/89	12,380	91.0
1989/90	4,123	30.3
1990/91	120,676	200.0
1991/92	126,299	200.0
1992/93	125,193	200.0
1993/94	71,622	200.0
1994/95	27,658	200.0
1995/96	1,525	11.2
1996/97	4,430	32.6
2005/06	705	5.2
2006/07	2,940	21.6
2007/08	6,935	51.0
2008/09	3,490	25.6
2009/10	2,417	17.8
2013/14	4,760	35.0
2014/15	14,055	103.3

Table 6. Sample sizes from the recalculated fishery data for total catch-at-size in the directed fishery, from crab observer sampling. N = number of individuals. N` = scaled sample size used in assessment.

	N		N'	
year	males	females	males	females
1991/92	31,252	5,605	200.0	40.2
1992/93	54,836	8,755	200.0	62.8
1993/94	40,388	10,471	200.0	75.1
1994/95	5,792	2,132	42.6	15.3
1995/96	5,589	3,119	41.1	22.4
1996/97	352	168	2.6	1.2
2005/06	19,715	1,107	144.9	7.9
2006/07	24,226	4,432	178.0	31.8
2007/08	61,546	3,318	200.0	23.8
2008/09	29,166	646	200.0	4.6
2009/10	17,289	147	127.0	1.1
2013/14	17,287	710	127.0	5.2
2014/15	85,114	1,191	200.0	8.8

Table 7. Sample sizes from the recalculated fishery data for total bycatch-at-size in the snow crab fishery, from crab observer sampling. N = number of individuals. N` = scaled sample size used in assessment.

year	N		N'	
	males	females	males	females
1992/93	6,280	859	46.1	6.3
1993/94	6,969	1,542	51.2	11.3
1994/95	2,982	1,523	21.9	11.2
1995/96	1,898	428	13.9	3.1
1996/97	3,265	662	24.0	4.9
1997/98	3,970	657	29.2	4.8
1998/99	1,911	324	14.0	2.4
1999/00	976	82	7.2	0.6
2000/01	1,237	74	9.1	0.5
2001/02	3,113	160	22.9	1.2
2002/03	982	118	7.2	0.9
2003/04	688	152	5.1	1.1
2004/05	848	707	6.2	5.2
2005/06	9,792	368	72.0	2.7
2006/07	10,391	1,256	76.4	9.2
2007/08	13,797	728	101.4	5.3
2008/09	8,455	722	62.1	5.3
2009/10	11,057	474	81.2	3.5
2010/11	12,073	250	88.7	1.8
2011/12	9,453	189	69.5	1.4
2012/13	7,336	190	53.9	1.4
2013/14	12,932	356	95.0	2.6
2014/15	24,877	804	182.8	5.9

Table 8. Sample sizes from the recalculated fishery data for total bycatch-at-size in the BBRKC fishery, from crab observer sampling. N = number of individuals. N` = scaled sample size used in assessment.

year	N		N'	
	males	females	males	females
1992/93	2,056	105	15.1	0.8
1993/94	7,359	1,196	54.1	8.8
1996/97	114	5	0.8	0.0
1997/98	1,030	41	7.6	0.3
1998/99	457	20	3.4	0.1
1999/00	207	14	1.5	0.1
2000/01	845	44	6.2	0.3
2001/02	456	39	3.4	0.3
2002/03	750	50	5.5	0.4
2003/04	555	46	4.1	0.3
2004/05	487	44	3.6	0.3
2005/06	983	70	7.2	0.5
2006/07	798	76	5.9	0.6
2007/08	1,399	91	10.3	0.7
2008/09	3,797	121	27.9	0.9
2009/10	3,395	72	24.9	0.5
2010/11	595	30	4.4	0.2
2011/12	344	4	2.5	0.0
2012/13	618	48	4.5	0.4
2013/14	2,110	60	15.5	0.4
2014/15	3,110	32	22.9	0.2

Table 9. Sample sizes from the recalculated fishery data for total catch-at-size in the groundfish fisheries, from groundfish observer sampling. N = number of individuals. N` = scaled sample size used in the assessment.

year	N		N'	
	males	females	males	females
1973/74	3,155	2,277	23.2	16.7
1974/75	2,492	1,600	18.3	11.8
1975/76	1,251	839	9.2	6.2
1976/77	6,950	6,683	51.1	49.1
1977/78	10,685	8,386	78.5	61.6
1978/79	18,596	13,665	136.6	100.4
1979/80	19,060	11,349	140.1	83.4
1980/81	12,806	5,917	94.1	43.5
1981/82	6,098	4,065	44.8	29.9
1982/83	13,439	8,006	98.8	58.8
1983/84	18,363	8,305	134.9	61.0
1984/85	27,403	13,771	200.0	101.2
1985/86	23,128	12,728	170.0	93.5
1986/87	14,860	7,626	109.2	56.0
1987/88	23,508	15,857	172.7	116.5
1988/89	10,586	7,126	77.8	52.4
1989/90	59,943	41,234	200.0	200.0
1990/91	23,545	11,212	173.0	82.4
1991/92	6,817	3,479	50.1	25.6
1992/93	3,128	1,175	23.0	8.6
1993/94	1,217	358	8.9	2.6
1994/95	3,628	1,820	26.7	13.4
1995/96	3,904	2,669	28.7	19.6
1996/97	8,306	3,400	61.0	25.0
1997/98	9,949	3,900	73.1	28.7
1998/99	12,105	4,440	89.0	32.6
1999/00	11,053	4,522	81.2	33.2
2000/01	12,895	3,087	94.8	22.7
2001/02	15,788	3,083	116.0	22.7
2002/03	15,401	3,249	113.2	23.9
2003/04	9,572	2,733	70.3	20.1
2004/05	13,844	4,460	101.7	32.8
2005/06	17,785	3,709	130.7	27.3
2006/07	15,903	3,047	116.9	22.4
2007/08	16,031	3,788	117.8	27.8
2008/09	25,976	4,164	190.9	30.6
2009/10	18,760	2,588	137.9	19.0
2010/11	15,135	2,211	111.2	16.2
2011/12	16,168	4,255	118.8	31.3
2012/13	13,050	3,089	95.9	22.7
2013/14	28,862	6,081	200.0	44.7
2014/15	38,807	4,099	200.0	30.1

Table 10. Trends in mature and total Tanner crab biomass (1000's t) in the NMFS summer bottom trawl survey as derived from survey size compositions and weight-at-size regressions.

year	Rugolo and Turnock weight-at-size regressions						new regressions		
	old survey time series			new survey time series			new survey time series		
	mature males	mature females	all crab >= 25 mm CW	mature males	mature females	all crab >= 25 mm CW	mature males	mature females	all crab >= 25 mm CW
1974	212.01	55.76	267.77	--	--	--	--	--	--
1975	265.07	38.76	303.83	260.83	32.05	292.88	245.98	31.71	277.68
1976	152.09	45.99	198.08	133.45	31.78	165.23	126.18	31.44	157.61
1977	130.41	47.59	177.99	117.09	39.15	156.25	110.59	38.76	149.35
1978	80.62	26.43	107.06	81.93	26.42	108.35	77.60	26.18	103.78
1979	47.82	20.43	68.25	33.74	19.72	53.46	32.21	19.65	51.86
1980	86.33	70.42	156.76	89.87	64.40	154.27	86.15	64.16	150.31
1981	50.67	45.24	95.91	51.31	43.16	94.47	49.36	43.06	92.41
1982	49.67	64.76	114.43	50.83	64.55	115.38	48.97	64.43	113.40
1983	29.04	20.72	49.76	29.59	20.72	50.31	28.46	20.61	49.07
1984	26.15	14.72	40.87	25.18	15.12	40.30	24.17	15.01	39.18
1985	11.71	5.68	17.39	11.88	5.68	17.57	11.36	5.63	16.99
1986	13.18	3.49	16.67	13.28	3.49	16.77	12.81	3.45	16.26
1987	24.18	5.27	29.46	25.02	5.24	30.26	24.08	5.19	29.27
1988	59.51	25.57	85.08	62.95	25.75	88.69	60.43	25.47	85.90
1989	101.48	25.47	126.96	96.20	19.68	115.89	91.93	19.50	111.44
1990	103.17	36.36	139.52	101.11	38.14	139.25	96.29	37.84	134.13
1991	110.82	45.56	156.37	114.87	45.36	160.23	109.71	45.03	154.75
1992	108.12	27.76	135.88	108.35	26.66	135.02	103.22	26.47	129.69
1993	62.12	11.91	74.03	63.07	11.82	74.89	60.14	11.74	71.88
1994	44.55	10.37	54.92	44.23	10.09	54.32	42.13	10.01	52.14
1995	33.86	13.44	47.30	32.61	12.80	45.41	31.10	12.72	43.82
1996	27.32	9.80	37.12	27.53	9.87	37.40	26.26	9.80	36.05
1997	11.07	3.53	14.60	11.16	3.54	14.70	10.69	3.51	14.21
1998	10.56	2.31	12.87	10.70	2.33	13.03	10.29	2.31	12.60
1999	12.40	3.81	16.21	12.88	3.90	16.79	12.45	3.88	16.33
2000	16.45	4.17	20.63	16.83	4.22	21.04	16.15	4.18	20.33
2001	18.20	4.61	22.81	18.62	4.63	23.25	17.85	4.61	22.46
2002	18.23	4.48	22.71	18.56	4.51	23.08	17.80	4.50	22.30
2003	23.71	8.35	32.06	24.26	8.46	32.72	23.32	8.44	31.76
2004	25.56	4.70	30.26	27.33	4.92	32.25	26.35	4.90	31.25
2005	43.99	11.62	55.61	44.94	11.66	56.60	43.14	11.62	54.76
2006	66.89	15.79	82.68	66.61	15.10	81.71	64.20	15.04	79.24
2007	72.63	13.33	85.97	68.85	13.61	82.45	66.44	13.53	79.97
2008	59.70	11.33	71.03	65.39	11.79	77.18	62.71	11.73	74.44
2009	37.60	8.22	45.82	37.84	8.61	46.45	36.32	8.56	44.87
2010	36.14	5.44	41.59	39.32	5.56	44.88	37.61	5.52	43.13
2011	46.30	8.67	54.97	43.38	5.53	48.91	41.49	5.49	46.98
2012	43.15	15.83	58.97	42.61	12.56	55.17	41.18	12.50	53.68
2013	69.81	19.10	88.91	68.15	18.08	86.24	65.66	17.98	83.64
2014	87.15	15.82	102.97	82.75	15.04	97.79	79.47	14.95	94.42
2015	62.88	11.34	74.22	62.88	11.34	74.22	60.18	11.29	71.47

Table 11. Sample sizes for NMFS survey size composition data (new survey dataset). In the assessment model, an effective sample size of 200 is used for all survey-related compositional data.

		females						males					
		immature		mature				immature		mature			
		new shell		new shell		old shell		new shell		new shell		old shell	
year	number of hauls	number of nonzero hauls	number of crab	number of nonzero hauls	number of crab	number of nonzero hauls	number of crab	number of nonzero hauls	number of crab	number of nonzero hauls	number of crab	number of nonzero hauls	number of crab
1975	136	73	1,040	7	91	1,861	39	127	2,895	127	3,993	80	399
1976	214	87	1,095	2	91	1,304	39	130	2,023	130	2,469	47	242
1977	155	66	765	11	76	1,183	60	114	1,778	114	1,971	79	485
1978	230	87	1,932	17	82	638	65	147	2,957	147	1,570	104	700
1979	307	71	725	8	62	735	42	138	1,805	138	808	68	306
1980	320	101	1,476	15	95	1,471	49	164	4,602	164	2,359	71	569
1981	305	71	579	0	79	1,319	94	158	3,809	158	2,293	116	886
1982	342	85	814	9	72	457	103	181	1,751	181	1,371	147	2,082
1983	353	102	2,108	5	56	201	102	166	2,484	166	983	132	1,181
1984	355	135	1,867	12	53	284	94	171	1,965	171	490	126	1,399
1985	353	140	846	1	52	228	65	179	1,060	179	381	86	459
1986	353	162	1,581	7	64	191	68	213	2,141	213	528	115	468
1987	355	189	4,230	0	105	445	73	226	4,659	226	1,306	103	498
1988	370	206	3,733	2	149	1,753	100	252	5,627	252	2,210	101	475
1989	373	204	3,264	7	144	1,241	108	237	4,977	237	3,201	135	1,067
1990	370	197	3,105	9	155	1,502	126	247	5,107	247	3,149	151	1,342
1991	371	159	2,227	32	138	1,283	141	227	4,361	227	2,692	181	2,893
1992	355	107	1,494	0	119	820	123	215	2,958	215	2,047	177	1,924
1993	374	99	865	4	96	545	122	207	2,051	207	1,677	180	1,865
1994	374	97	909	12	52	148	104	175	1,281	175	724	174	1,827
1995	375	113	830	4	35	140	107	153	958	153	220	137	1,611
1996	374	114	869	14	57	109	98	148	1,069	148	222	134	1,414
1997	375	116	1,325	4	62	168	83	161	1,336	161	289	125	582
1998	374	146	1,704	6	53	160	73	176	2,032	176	396	128	624
1999	372	137	2,608	20	52	255	85	170	2,816	170	550	124	567
2000	371	142	2,249	0	61	242	55	188	2,836	188	628	133	653
2001	374	164	3,675	3	83	364	72	211	4,036	211	629	145	817
2002	374	154	3,583	2	81	350	70	186	3,912	186	458	154	1,089
2003	375	153	2,830	4	111	923	83	203	4,754	203	900	153	1,349
2004	374	173	3,563	359	90	427	80	236	4,568	236	1,027	179	1,873
2005	372	201	3,349	3	103	634	74	254	4,496	254	1,280	185	1,753
2006	375	210	4,355	9	143	1,332	125	254	6,224	254	1,757	211	4,054
2007	375	185	2,420	10	138	1,311	136	261	4,697	261	1,982	201	2,907
2008	374	153	1,747	0	104	580	120	240	3,127	240	2,116	196	2,146
2009	375	171	2,408	0	75	363	115	216	2,879	216	1,144	187	1,954
2010	375	186	3,171	9	67	245	104	223	3,654	223	1,268	166	1,702
2011	375	193	5,044	0	90	471	102	210	6,095	210	1,115	167	1,941
2012	375	195	3,577	34	100	942	97	215	5,526	215	1,564	139	1,296
2013	375	163	2,900	17	116	1,417	101	207	5,592	207	2,675	137	1,344
2014	375	165	2,207	4	98	482	121	222	4,746	222	3,286	167	2,829
2015	375	118	1,455	0	60	445	94	225	2,737	225	1,859	200	2,817

Table 12. Effort data (1000's potlifts) in the snow crab and BBRKC fisheries (recalculated for 1990/91-2012/13).

Year	Effort (1000's Potlifts) BBRKC Fishery	Effort (1000's Potlifts) Snow Crab Fishery
1951/52		
1952/53		
1953/54	30.083	--
1954/55	17.122	--
1955/56	28.045	--
1956/57	41.629	--
1957/58	23.659	--
1958/59	27.932	--
1959/60	22.187	--
1960/61	26.347	--
1961/62	72.646	--
1962/63	123.643	--
1963/64	181.799	--
1964/65	180.809	--
1965/66	127.973	--
1966/67	129.306	--
1967/68	135.283	--
1968/69	184.666	--
1969/70	175.374	--
1970/71	168.059	--
1971/72	126.305	--
1972/73	208.469	--
1973/74	194.095	--
1974/75	212.915	--
1975/76	205.096	--
1976/77	321.01	--
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	1382.908
1991/92	227.555	1278.502
1992/93	206.815	969.209
1993/94	254.389	716.524
1994/95	0.697	507.603
1995/96	0.547	520.685
1996/97	77.081	754.14
1997/98	91.085	930.794
1998/99	145.689	945.533
1999/00	151.212	182.634
2000/01	104.056	191.2
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	116.32	117.375
2006/07	72.404	86.288
2007/08	113.948	140.857
2008/09	139.937	163.537
2009/10	118.521	136.477
2010/11	131.627	147.244
2011/12	45.166	270.602
2012/13	38.159	225.489
2013/14	45.927	225.245
2014/15	57.725	279.183

Table 13. Comparison of estimated recruitment running Model A against the incremental datasets.

Year	2014 Model	2014 Corrected	Dataset A	Dataset B	Dataset C	Dataset D
1949	62.19	61.05	63.73	59.37	58.01	59.68
1950	62.36	61.21	63.90	59.51	58.14	59.82
1951	62.75	61.59	64.30	59.86	58.47	60.16
1952	63.46	62.29	65.04	60.48	59.08	60.79
1953	64.64	63.45	66.26	61.52	60.08	61.83
1954	66.49	65.27	68.17	63.16	61.66	63.47
1955	69.36	68.09	71.16	65.71	64.13	66.02
1956	73.83	72.48	75.81	69.69	67.99	70.00
1957	80.96	79.49	83.27	76.05	74.16	76.35
1958	92.87	91.19	95.77	86.67	84.46	86.92
1959	114.43	112.35	118.54	105.80	103.03	105.92
1960	159.18	156.29	166.34	145.17	141.29	144.85
1961	273.92	268.95	290.11	245.53	238.65	243.60
1962	602.93	592.53	643.90	540.86	522.17	534.88
1963	1301.35	1282.31	1367.15	1246.18	1177.91	1244.51
1964	1807.55	1785.75	1855.97	1905.82	1758.59	1930.88
1965	1699.85	1683.44	1724.66	1888.01	1727.67	1929.26
1966	1397.57	1388.04	1421.00	1513.87	1395.88	1545.71
1967	1207.68	1204.26	1239.37	1195.77	1124.29	1214.54
1968	1161.20	1163.42	1204.89	1005.14	973.73	1015.76
1969	1196.51	1202.37	1245.47	916.42	916.66	926.12
1970	997.80	1000.34	997.65	860.08	867.67	879.66
1971	650.12	649.80	650.87	709.63	683.72	737.39
1972	542.54	542.41	551.12	549.30	518.16	572.56
1973	440.81	440.77	450.08	449.22	427.07	458.56
1974	122.18	122.66	120.89	256.98	214.99	299.76
1975	420.21	420.89	442.99	356.01	401.13	376.50
1976	919.41	918.43	964.46	1113.94	1027.08	1113.94
1977	560.43	560.16	585.74	811.16	766.13	829.22
1978	477.41	475.85	490.67	371.54	367.22	381.13
1979	118.24	117.92	121.25	125.03	125.25	126.07
1980	45.37	45.16	49.96	58.01	59.10	57.85
1981	106.97	106.34	113.65	76.50	77.57	76.54
1982	52.60	52.43	54.49	38.40	38.43	39.31
1983	372.92	370.84	383.73	273.26	270.66	275.66
1984	304.66	303.05	312.26	265.05	262.29	266.63
1985	578.41	576.00	582.02	659.23	628.88	673.12
1986	483.57	480.96	478.81	500.80	500.12	517.95
1987	438.11	433.89	435.98	471.18	457.75	485.61
1988	388.44	386.81	377.08	420.08	419.32	444.02
1989	172.35	171.12	169.50	161.23	161.85	168.66
1990	77.75	77.69	76.80	66.95	67.96	70.95
1991	36.43	36.34	36.38	38.64	38.43	40.76
1992	31.78	31.60	31.71	29.30	30.34	30.74
1993	26.66	26.55	27.51	26.69	27.31	27.74
1994	30.64	30.46	31.57	30.25	30.69	31.32
1995	45.05	44.79	46.46	40.39	40.96	41.62
1996	43.96	43.70	44.94	44.97	45.52	46.14
1997	119.75	119.06	121.14	111.04	111.96	113.81
1998	47.11	46.85	47.16	44.78	45.10	46.05
1999	147.24	146.35	148.34	138.34	138.42	140.55
2000	89.04	88.55	89.66	83.83	83.77	84.99
2001	276.17	274.46	274.67	276.13	274.91	279.15
2002	113.87	113.40	108.32	107.14	105.32	108.80
2003	202.76	201.16	197.12	185.89	182.91	185.04
2004	371.35	369.91	349.73	311.80	299.83	306.44
2005	114.16	113.89	103.71	91.58	84.98	87.26
2006	94.61	94.32	83.66	70.50	69.68	70.87
2007	66.43	66.18	58.48	48.45	51.64	52.92
2008	76.31	75.79	68.49	59.40	60.29	61.00
2009	410.40	412.22	327.13	321.53	351.07	354.63
2010	432.10	430.10	430.01	401.36	413.38	422.94
2011	216.25	216.46	231.79	246.97	241.95	251.06
2012	43.73	43.70	45.49	49.34	50.03	52.20
2013	117.42	117.27	111.17	111.88	112.77	115.80
2014	177.80	177.38	115.47	118.85	120.54	124.00
2015	--	--	72.28	76.84	78.41	80.71

Table 14. Comparison of estimated MMB-at-mating running Model A against the incremental datasets.

Year	2014 Model	2014 Corrected	Dataset A	Dataset B	Dataset C	Dataset D
1949	0.00	0.00	0.00	0.00	0.00	0.00
1950	0.01	0.01	0.01	0.01	0.01	0.01
1951	0.15	0.15	0.15	0.17	0.17	0.17
1952	1.24	1.22	1.20	1.35	1.31	1.36
1953	4.59	4.52	4.51	4.80	4.65	4.75
1954	8.82	8.68	8.84	8.85	8.60	8.66
1955	12.13	11.93	12.27	11.95	11.63	11.63
1956	14.61	14.36	14.84	14.26	13.88	13.84
1957	16.52	16.24	16.81	16.02	15.60	15.53
1958	18.08	17.77	18.42	17.45	17.00	16.92
1959	19.47	19.14	19.86	18.73	18.25	18.15
1960	20.90	20.55	21.32	20.05	19.52	19.43
1961	22.62	22.24	23.08	21.64	21.06	20.97
1962	25.03	24.61	25.55	23.89	23.23	23.15
1963	29.04	28.56	29.68	27.65	26.87	26.80
1964	37.09	36.49	38.00	35.30	34.24	34.23
1965	53.86	52.96	55.37	51.51	49.83	49.92
1966	94.82	93.32	97.44	92.81	88.80	90.17
1967	151.98	149.55	156.25	154.84	147.84	150.63
1968	225.91	222.45	231.87	239.64	226.89	233.51
1969	273.73	269.62	281.19	299.22	281.90	291.37
1970	296.50	292.39	305.04	326.08	306.72	317.01
1971	305.11	301.59	314.51	327.34	308.69	317.54
1972	310.35	307.80	320.52	315.46	299.84	305.40
1973	312.91	311.40	323.29	297.50	285.57	287.57
1974	292.48	291.68	301.81	266.17	258.10	257.21
1975	257.84	257.36	265.49	233.94	228.33	226.40
1976	195.34	195.04	201.66	177.87	176.23	171.84
1977	123.03	122.82	128.46	110.89	114.09	106.15
1978	79.23	79.04	83.87	73.34	78.05	70.30
1979	49.25	49.00	52.89	50.31	56.79	48.18
1980	34.48	34.22	35.77	32.26	39.85	31.15
1981	44.63	44.37	45.59	41.71	45.67	40.66
1982	48.67	48.45	49.16	38.55	38.91	37.88
1983	40.27	40.09	40.40	25.66	25.04	25.33
1984	24.89	24.76	24.67	12.89	12.46	12.79
1985	23.81	23.70	23.76	13.84	13.50	13.61
1986	29.58	29.45	29.60	19.42	18.95	19.12
1987	43.03	42.85	42.77	31.63	30.83	31.17
1988	59.68	59.41	59.43	49.10	48.03	48.32
1989	65.66	65.32	64.96	61.17	61.16	60.28
1990	56.02	55.56	54.87	56.12	59.21	55.10
1991	51.12	51.10	52.53	56.07	57.72	55.11
1992	43.53	43.39	44.52	48.99	49.28	48.23
1993	38.06	37.86	38.85	41.59	41.47	40.85
1994	30.58	30.40	31.41	32.11	31.84	31.48
1995	22.73	22.59	23.43	23.30	22.93	22.85
1996	17.84	17.72	18.34	17.96	17.71	17.66
1997	14.95	14.84	15.35	14.89	14.77	14.71
1998	13.43	13.33	13.76	13.31	13.24	13.22
1999	13.68	13.59	13.94	13.46	13.36	13.39
2000	15.52	15.43	15.68	15.24	15.09	15.17
2001	19.06	18.95	19.08	18.53	18.31	18.42
2002	22.71	22.59	22.68	21.71	21.42	21.49
2003	27.68	27.55	27.43	26.54	26.06	26.20
2004	34.61	34.45	34.14	33.44	32.74	32.90
2005	43.61	43.41	42.64	42.74	41.65	41.89
2006	49.90	49.65	48.60	48.09	46.67	46.77
2007	56.30	56.04	53.98	53.10	51.06	51.35
2008	67.30	67.03	63.62	61.05	58.10	58.42
2009	70.20	69.91	66.09	60.72	57.36	57.44
2010	64.36	64.11	60.09	53.92	50.77	50.95
2011	57.83	57.63	53.22	47.29	44.76	45.10
2012	58.23	58.12	52.00	47.56	45.93	46.55
2013	72.70	72.13	62.13	59.97	59.69	60.59
2014	--	--	72.58	70.43	70.82	71.57

Table 15. Parameter estimates (no devs vectors) from running Model A against the incremental datasets. flag = 1 indicates the estimate reached the upper parameter bound, flag=-1 indicates the estimate reached the lower bound.

Parameter	Limits		2014 Model			2014 Corrected			Dataset A			Dataset B			Dataset C			Dataset D		
	min	max	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag
af1	0.4	0.7	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1
am1	0.3	0.6	0.43	0.022	0	0.43	0.022	0	0.42	0.022	0	0.41	0.022	0	0.42	0.022	0	0.41	0.022	0
bf1	0.6	1.2	0.88	0.001	0	0.88	0.001	0	0.88	0.001	0	0.88	0.001	0	0.88	0.001	0	0.88	0.001	0
bm1	0.7	1.2	0.97	0.005	0	0.97	0.005	0	0.97	0.005	0	0.98	0.005	0	0.98	0.005	0	0.98	0.005	0
fish_disc_sel50_f	80	150	120.47	3.280	0	120.09	3.241	0	119.13	3.122	0	117.22	2.815	0	117.25	2.735	0	117.47	2.802	0
fish_disc_sel50_tf1	40	125.01	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1
fish_disc_sel50_tf2	40	250.01	175.95	52.035	0	175.95	52.120	0	183.95	57.827	0	164.03	37.477	0	159.71	35.035	0	159.21	34.425	0
fish_disc_sel50_tf3	40	150.01	148.32	11.394	0	148.33	11.391	0	147.08	10.750	0	145.48	10.234	0	145.27	10.122	0	143.99	9.954	0
fish_disc_sel50_tm1	40	120.01	53.76	1.972	0	53.75	1.973	0	54.09	1.984	0	57.27	2.047	0	56.69	1.972	0	57.07	2.034	0
fish_disc_sel50_tm2	40	120.01	64.66	8.958	0	64.56	8.938	0	65.33	9.007	0	72.86	9.891	0	72.30	9.834	0	72.61	9.681	0
fish_disc_sel50_tm3	40	120.01	94.02	2.322	0	94.04	2.323	0	88.43	2.162	0	87.69	2.119	0	84.50	2.127	0	83.19	2.113	0
fish_disc_slope_f	0.1	0.4	0.14	0.009	0	0.14	0.009	0	0.14	0.009	0	0.14	0.008	0	0.14	0.008	0	0.14	0.008	0
fish_disc_slope_tf1	0.01	0.5	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0
fish_disc_slope_tf2	0.005	0.5	0.01	0.005	0	0.01	0.005	0	0.01	0.005	0	0.02	0.005	0	0.02	0.005	0	0.02	0.005	0
fish_disc_slope_tf3	0.01	0.5	0.05	0.008	0	0.05	0.008	0	0.05	0.008	0	0.05	0.008	0	0.05	0.007	0	0.05	0.007	0
fish_disc_slope_tm1	0.01	0.5	0.11	0.013	0	0.11	0.013	0	0.11	0.012	0	0.11	0.011	0	0.11	0.011	0	0.11	0.011	0
fish_disc_slope_tm2	0.01	0.5	0.05	0.012	0	0.05	0.012	0	0.05	0.012	0	0.04	0.009	0	0.04	0.009	0	0.04	0.009	0
fish_disc_slope_tm3	0.01	0.5	0.07	0.004	0	0.07	0.004	0	0.08	0.004	0	0.08	0.004	0	0.08	0.004	0	0.08	0.004	0
fish_fit_sel50_mn1	85	160	138.23	0.394	0	138.22	0.394	0	138.21	0.394	0	137.82	0.364	0	137.32	0.370	0	137.67	0.355	0
fish_fit_sel50_mn2	85	160	136.86	0.303	0	136.28	0.384	0	133.16	0.484	0	133.19	0.485	0	133.09	0.495	0	133.08	0.488	0
fish_fit_slope_mn1	0.25	1.001	0.73	0.131	0	0.73	0.132	0	0.72	0.130	0	0.78	0.139	0	0.78	0.141	0	0.79	0.140	0
fish_fit_slope_mn2	0.25	2.001	0.84	0.118	0	0.64	0.077	0	0.37	0.029	0	0.37	0.029	0	0.36	0.029	0	0.37	0.030	0
fish_slope_1	0.05	0.75	0.12	0.007	0	0.12	0.007	0	0.12	0.006	0	0.11	0.007	0	0.11	0.007	0	0.11	0.007	0
fish_slope_yr_3	0.1	0.4	0.14	0.009	0	0.14	0.009	0	0.15	0.008	0	0.14	0.008	0	0.14	0.008	0	0.14	0.009	0
log_avg_sel50_3	4	5	4.83	0.009	0	4.83	0.009	0	4.83	0.008	0	4.83	0.023	0	4.87	0.010	0	4.83	0.023	0
log_sel50_dev_3[01]	-0.5	0.5	0.05	0.018	0	0.05	0.018	0	0.08	0.019	0	0.08	0.033	0	0.04	0.020	0	0.08	0.033	0
log_sel50_dev_3[02]	-0.5	0.5	0.15	0.015	0	0.14	0.015	0	0.14	0.016	0	0.13	0.029	0	0.09	0.016	0	0.13	0.029	0
log_sel50_dev_3[03]	-0.5	0.5	0.10	0.016	0	0.10	0.016	0	0.11	0.017	0	0.10	0.031	0	0.06	0.017	0	0.10	0.030	0
log_sel50_dev_3[04]	-0.5	0.5	0.10	0.021	0	0.11	0.021	0	0.15	0.020	0	0.14	0.035	0	0.09	0.021	0	0.14	0.034	0
log_sel50_dev_3[05]	-0.5	0.5	0.00	0.030	0	0.00	0.030	0	-0.01	0.033	0	-0.01	0.047	0	-0.07	0.037	0	-0.01	0.046	0
log_sel50_dev_3[06]	-0.5	0.5	-0.50	0.018	0	-0.50	0.018	0	-0.50	0.017	0	-0.44	0.297	0	0.04	0.070	0	-0.43	0.287	0
log_sel50_dev_3[07]	-0.5	0.5	-0.05	0.020	0	-0.05	0.020	0	-0.05	0.019	0	-0.05	0.030	0	-0.09	0.020	0	-0.06	0.029	0
log_sel50_dev_3[08]	-0.5	0.5	-0.05	0.020	0	-0.05	0.020	0	-0.06	0.020	0	-0.06	0.030	0	-0.10	0.020	0	-0.06	0.030	0
log_sel50_dev_3[09]	-0.5	0.5	-0.08	0.018	0	-0.08	0.018	0	-0.09	0.018	0	-0.09	0.029	0	-0.13	0.019	0	-0.09	0.028	0
log_sel50_dev_3[10]	-0.5	0.5	0.06	0.017	0	0.06	0.017	0	0.06	0.016	0	0.05	0.028	0	0.01	0.017	0	0.05	0.027	0
log_sel50_dev_3[11]	-0.5	0.5	0.23	0.021	0	0.23	0.020	0	0.23	0.019	0	0.22	0.030	0	0.18	0.020	0	0.22	0.029	0
log_sel50_dev_3[12]	-0.5	0.5	0.00	0.020	0	-0.01	0.019	0	-0.02	0.018	0	-0.02	0.029	0	-0.05	0.019	0	-0.02	0.028	0
log_sel50_dev_3[13]	-0.5	0.5	0.00	0.000	0	0.00	0.000	0	-0.04	0.015	0	-0.04	0.027	0	-0.08	0.016	0	-0.04	0.026	0
mat_big[01]	0.1	10	1.12	0.098	0	1.13	0.099	0	1.15	0.100	0	1.50	0.092	0	1.48	0.091	0	1.49	0.092	0
mat_big[02]	0.1	10	2.59	0.343	0	2.59	0.343	0	2.70	0.355	0	3.59	0.328	0	3.65	0.318	0	3.50	0.320	0
Mmult_imat	0.2	2	1.07	0.051	0	1.07	0.051	0	1.05	0.051	0	1.06	0.050	0	1.06	0.050	0	1.06	0.050	0
Mmultf	0.1	1.9	1.44	0.037	0	1.44	0.037	0	1.44	0.037	0	1.50	0.035	0	1.49	0.035	0	1.51	0.035	0
Mmultm	0.1	1.9	1.11	0.043	0	1.11	0.043	0	1.13	0.042	0	1.15	0.041	0	1.18	0.039	0	1.15	0.041	0
pAvgLnF_GTF	--	--	-4.21	0.075	0	-4.21	0.075	0	-4.26	0.075	0	-4.16	0.073	0	-4.16	0.072	0	-4.16	0.073	0
pAvgLnF_SCF	--	--	-3.80	0.132	0	-3.79	0.132	0	-3.74	0.125	0	-3.71	0.122	0	-3.68	0.120	0	-3.71	0.122	0
pAvgLnF_TCF	--	--	-1.62	0.087	0	-1.60	0.087	0	-1.59	0.086	0	-1.53	0.097	0	-1.39	0.102	0	-1.50	0.097	0
pMnLnRec	--	--	11.17	0.071	0	11.17	0.071	0	11.14	0.071	0	11.11	0.062	0	11.10	0.062	0	11.14	0.062	0
pMnLnRecEarly	--	--	11.84	0.511	0	11.83	0.511	0	11.87	0.508	0	11.79	0.517	0	11.75	0.516	0	11.80	0.518	0
rkfish_disc_sel50_f1	50	150	150.00	1.140	1	150.00	1.142	1	150.00	1.107	1	98.76	13.988	0	150.00	1.312	1	98.35	13.410	0
rkfish_disc_sel50_f2	50	150	103.08	45.740	0	103.05	45.507	0	103.83	49.048	0	103.12	43.952	0	102.70	42.903	0	103.26	44.773	0
rkfish_disc_sel50_f3	50	170	157.07	354.400	0	157.17	358.280	0	157.21	342.020	0	157.33	344.470	0	157.06	339.080	0	157.07	337.590	0
rkfish_disc_sel50_m1	95	150	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1
rkfish_disc_sel50_m2	95	150	132.31	11.907	0	132.32	11.957	0	134.03	12.734	0	133.39	12.443	0	134.39	12.724	0	133.22	12.448	0
rkfish_disc_sel50_m3	95	150	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1	150.00	0.001	1
rkfish_disc_slope_f1	0.05	0.5	0.17	0.040	0	0.17	0.040	0	0.17	0.040	0	0.24	0.131	0	0.17	0.039	0	0.24	0.132	0
rkfish_disc_slope_f2	0.05	0.5	0.18	0.173	0	0.18	0.173	0	0.18	0.171	0	0.18	0.170	0	0.18	0.172	0	0.18	0.170	0
rkfish_disc_slope_f3	0.05	0.5	0.18	0.056	0	0.18	0.056	0	0.19	0.054	0	0.18	0.054	0	0.18	0.054	0	0.18	0.054	0
rkfish_disc_slope_m1	0.01	0.5	0.11	0.011	0	0.11	0.011	0	0.11	0.011	0	0.10	0.010	0	0.10	0.010	0	0.10	0.010	0
rkfish_disc_slope_m2	0.01	0.5	0.09	0.027	0	0.09	0.027	0	0.09	0.026	0	0.09	0.026	0	0.09	0.026	0	0.09	0.027	0
rkfish_disc_slope_m3	0.01	0.5	0.08	0.007	0	0.08	0.007	0	0.08	0.007	0	0.08	0.007	0	0.08	0.007	0	0.08	0.007	0
selSCF_lnZ50_md_1	2	4.5	3.97	0.053	0	3.97	0.047	0	3.96	0.042	0	3.97	0.041	0	3.97	0.040	0	3.97	0.041	0
selSCF_lnZ50_md_2	2	4.5	3.82	0.132	0	3.82	0.132	0	3.80	0.136	0	3.81	0.133	0	3.79	0.141	0	3.80	0.136	0
selSCF_lnZ50_md_3	2	4.5	3.48	0.115	0	3.48	0.116	0	3.49	0.093	0	3.53	0.083	0	3.51	0.085	0	3.53	0.082	0
selSCF_Z50_ma_1	40	140	87.47	1.762	0	87.48	1.749	0	87.70	1.655	0	86.93	1.664	0	86.83	1.622	0	86.80	1.652	0
selSCF_Z50_ma_2	40	140	93.81	3.066	0	93.82	3.064	0	94.03	3.114	0	93.89	3.070	0	94.30	3.165	0	93.91	3.100	0
selSCF_Z50_ma_3	40	140	105.24	2.009	0	105.25	2.014	0	104.42	1.673	0	103.77	1.576	0	104.13	1.577	0	103.63	1.550	0
snowfish_disc_sel50_f_1	50	150	111.33	4.707	0	111.19	4.658	0	111.57	4.669	0	109.83	4.614	0	109.53	4.613	0	110.42	4.551	0
snowfish_disc_sel50_f_2	50	120	76.46	5.024	0	76.47	5.027	0	76.63	5.018	0	76.21	4.898	0	76.04	4.885	0	76.19	4.879	0
snowfish_disc_sel50_f_3	50	120	85.24	6.346	0	85.21	6.332	0	90.83	8.217	0	88.13	6.876	0	88.90	7.141	0	88.70	7.051	0
snowfish_disc_slope_f_1	0.05	0.5	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1
snowfish_disc_slope_f_2	0.05	0.5	0.25	0.129	0	0.25	0.129	0	0.24	0.125	0	0.25	0.130	0	0.26	0.132	0	0.25	0.130	0
snowfish_disc_slope_f_3	0.05	0.5	0.16	0.053	0	0.16	0.053	0	0.13	0.039	0	0.14	0.042	0	0.13	0.041	0	0.13	0.041	0
snowfish_disc_slope_m_1	0.1	0.5	0.36	0.126	0	0.36	0.126	0	0.36	0.120	0	0.39	0.142	0	0.41	0.147	0	0.40	0.147	0
snowfish_disc_slope_m_2	0.1	0.5	0.23	0.075	0	0.23	0.075	0	0.23	0.073	0	0.23	0.074	0	0.23	0.071	0	0.23	0.074	0
snowfish_disc_slope_m_3	0.1	0.5	0.17	0.017	0	0.17	0.017	0	0.17	0.017	0	0.18	0.018	0	0.18	0.017	0	0.18	0.018	0
snowfish_disc_slope_m2_1	0.1	0.5	0.37	0.249	0	0.44	0.310	0	0.50	0.001	1	0.50	0.005	1	0.50	0.002	1	0.50	0.004	1
snowfish_disc_slope_m2_2	0.1	0.5	0.18	0.092	0	0.18	0.093	0	0.18	0.089	0	0.18	0.090	0	0.18	0.090	0	0.18	0.089	0
snowfish_disc_slope_m2_3	0.1	0.5	0.17	0.030	0	0.17	0.030	0	0.18	0.027	0	0.18	0.028	0	0.18	0.028	0	0.18	0.028	0
srv2_q	0.5	1.001	0.56	0.033	0	0.56	0.033	0	0.54	0.033	0	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1
srv2_qFem	0.5	1.001	0.61	0.217	0	0.61	0.219	0	0.63	0.290	0	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1
srv2_sel50	0	90	46.88	2.015	0	46.87	2.016	0	47.12	2.033	0	48.88	1.883	0	48.40	1.812	0	49.01	1.905	0
srv2_sel50_f	-200	100.01	57.57	18.304	0	57.60	18.446	0	61.09	24.340	0	52.97	2.842	0	51.50	2.582	0	53.63	2.859	0
srv2_seldiff	0	100	23.03	3.734	0	23.03	3.737	0	23.31	3.778	0	21.30	3.230	0	20.78	3.118	0	21.57	3.309	0
srv2_seldiff_f	0	100	55.99	29.637	0	56.11	29.843	0	61.38	35.001	0	39.03	6.596	0	35.19	5.844	0	40.82	6.712	0
srv3_q	0.2	2	0.75	0.036	0	0.76	0.036	0	0.75	0.036	0	0.80	0.035	0	0.81	0.034	0	0.78	0.035	0
srv3_qFem	0.2	1	0.56	0.039	0	0.56	0.039	0	0.55	0.038	0	0.60	0.035	0	0.61	0.034	0	0.59	0.035	0
srv3_sel50	0	69	28.43	3.289	0	28.43	3.286	0	27.79	3.451	0	32.48	2.838	0	33.01	2.851	0	32.49	2.815	0
srv3_sel50_f	-50	69	-4.11	15.461	0	-4.05	15.415	0	-9.94	17.318	0	5.57	11.464	0	6.15	11.325	0	7.10	11.252	0
srv3_seldiff	0	100	57.17	8.050	0	57.12	8.036	0	59.21	8.362	0	55.92	6.787	0	57.05	6.858	0	55.62	6.771	0
srv3_seldiff_f	0	100	100.00	0.001	1	100.00	0.001	1	100.00	0.001	1	100.00	0.001	1	100.00	0.001	1	100.00	0.001	1

Table 16. Parameter estimates (no devs vectors) from running Models A-D against Dataset D. flag = 1 indicates the estimate reached the upper parameter bound, flag=-1 indicates the estimate reached the lower bound.

Parameter	Limits		2014 Model			Model A			Model B			Model C			Model D		
	min	max	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag	estimate	std. dev	flag
af1	0.4	0.7	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1	0.70	0.000	1
am1	0.3	0.6	0.43	0.022	0	0.41	0.022	0	0.44	0.022	0	0.42	0.022	0	0.46	0.022	0
bf1	0.6	1.2	0.88	0.001	0	0.88	0.001	0	0.89	0.001	0	0.88	0.001	0	0.89	0.001	0
bm1	0.7	1.2	0.97	0.005	0	0.98	0.005	0	0.97	0.005	0	0.97	0.005	0	0.97	0.005	0
fish_disc_sel50_f	80	150	120.47	3.280	0	117.47	2.802	0	119.99	1.387	0	104.81	2.335	0	114.23	1.302	0
fish_disc_sel50_tf1	40	125.01	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1	125.01	0.000	1
fish_disc_sel50_tf2	40	250.01	175.95	52.035	0	159.21	34.425	0	162.02	27.621	0	156.12	33.065	0	154.44	26.954	0
fish_disc_sel50_tf3	40	150.01	148.32	11.394	0	143.99	9.954	0	146.05	10.410	0	145.22	10.095	0	143.84	10.000	0
fish_disc_sel50_tm1	40	120.01	53.76	1.972	0	57.07	2.034	0	55.57	2.008	0	57.28	2.039	0	55.51	1.995	0
fish_disc_sel50_tm2	40	120.01	64.66	8.958	0	72.61	9.681	0	104.77	16.358	0	71.85	9.813	0	93.06	14.778	0
fish_disc_sel50_tm3	40	120.01	94.02	2.322	0	83.19	2.113	0	84.59	2.255	0	84.36	2.165	0	83.08	2.206	0
fish_disc_slope_f	0.1	0.4	0.14	0.009	0	0.14	0.008	0	0.17	0.008	0	0.16	0.011	0	0.17	0.009	0
fish_disc_slope_tf1	0.01	0.5	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0	0.03	0.002	0
fish_disc_slope_tf2	0.005	0.5	0.01	0.005	0	0.02	0.005	0	0.02	0.005	0	0.02	0.005	0	0.02	0.005	0
fish_disc_slope_tf3	0.01	0.5	0.05	0.008	0	0.05	0.007	0	0.05	0.007	0	0.05	0.007	0	0.05	0.007	0
fish_disc_slope_tm1	0.01	0.5	0.11	0.013	0	0.11	0.011	0	0.11	0.012	0	0.11	0.011	0	0.11	0.012	0
fish_disc_slope_tm2	0.01	0.5	0.05	0.012	0	0.04	0.009	0	0.03	0.005	0	0.04	0.009	0	0.03	0.006	0
fish_disc_slope_tm3	0.01	0.5	0.07	0.004	0	0.08	0.004	0	0.07	0.004	0	0.08	0.004	0	0.08	0.005	0
fish_fit_sel50_mn1	85	160	138.23	0.394	0	137.67	0.355	0	137.20	0.353	0	138.18	0.416	0	138.79	0.483	0
fish_fit_sel50_mn2	85	160	136.86	0.303	0	133.08	0.488	0	138.67	0.412	0	135.82	0.554	0	144.19	0.985	0
fish_fit_slope_mn1	0.25	1.001	0.73	0.131	0	0.79	0.140	0	0.77	0.142	0	0.70	0.123	0	0.66	0.115	0
fish_fit_slope_mn2	0.25	2.001	0.84	0.118	0	0.37	0.030	0	0.33	0.022	0	0.29	0.023	0	0.26	0.022	0
fish_slope_1	0.05	0.75	0.12	0.007	0	0.11	0.007	0	0.19	0.010	0	0.10	0.009	0	0.24	0.020	0
fish_slope_yr_3	0.1	0.4	0.14	0.009	0	0.14	0.009	0	0.16	0.010	0	0.18	0.015	0	0.20	0.016	0
log_avg_sel50_3	4	5	4.83	0.009	0	4.83	0.023	0	4.86	0.006	0	4.75	0.010	0	4.78	0.007	0
log_sel50_dev_3[01]	-0.5	0.5	0.05	0.018	0	0.08	0.033	0	0.01	0.014	0	0.09	0.026	0	0.00	0.015	0
log_sel50_dev_3[02]	-0.5	0.5	0.15	0.015	0	0.13	0.029	0	-0.01	0.014	0	0.14	0.019	0	-0.02	0.017	0
log_sel50_dev_3[03]	-0.5	0.5	0.10	0.016	0	0.10	0.030	0	0.00	0.013	0	0.10	0.022	0	0.00	0.015	0
log_sel50_dev_3[04]	-0.5	0.5	0.10	0.021	0	0.14	0.034	0	0.13	0.014	0	0.18	0.030	0	0.13	0.015	0
log_sel50_dev_3[05]	-0.5	0.5	0.00	0.030	0	-0.01	0.046	0	0.10	0.013	0	-0.06	0.061	0	0.11	0.014	0
log_sel50_dev_3[06]	-0.5	0.5	-0.50	0.018	0	-0.43	0.287	0	0.06	0.026	0	-0.50	0.017	0	0.02	0.044	0
log_sel50_dev_3[07]	-0.5	0.5	-0.05	0.020	0	-0.06	0.029	0	-0.08	0.019	0	-0.06	0.023	0	-0.08	0.020	0
log_sel50_dev_3[08]	-0.5	0.5	-0.05	0.020	0	-0.06	0.030	0	-0.07	0.018	0	-0.07	0.022	0	-0.09	0.020	0
log_sel50_dev_3[09]	-0.5	0.5	-0.08	0.018	0	-0.09	0.028	0	-0.11	0.016	0	-0.09	0.020	0	-0.11	0.018	0
log_sel50_dev_3[10]	-0.5	0.5	0.06	0.017	0	0.05	0.027	0	0.01	0.015	0	0.03	0.021	0	0.01	0.017	0
log_sel50_dev_3[11]	-0.5	0.5	0.23	0.021	0	0.22	0.029	0	0.11	0.014	0	0.26	0.020	0	0.13	0.019	0
log_sel50_dev_3[12]	-0.5	0.5	0.00	0.020	0	-0.02	0.028	0	-0.04	0.016	0	-0.01	0.021	0	-0.03	0.018	0
log_sel50_dev_3[13]	-0.5	0.5	0.00	0.000	0	-0.04	0.026	0	-0.10	0.015	0	-0.04	0.018	0	-0.08	0.016	0
mat_big[01]	0.1	10	1.12	0.098	0	1.49	0.092	0	1.65	0.089	0	1.51	0.092	0	1.57	0.089	0
mat_big[02]	0.1	10	2.59	0.343	0	3.50	0.320	0	4.00	0.323	0	3.55	0.308	0	3.92	0.325	0
Mmult_imat	0.2	2	1.07	0.051	0	1.06	0.050	0	1.05	0.049	0	1.06	0.050	0	1.06	0.049	0
Mmultf	0.1	1.9	1.44	0.037	0	1.51	0.035	0	1.59	0.036	0	1.50	0.035	0	1.60	0.036	0
Mmultm	0.1	1.9	1.11	0.043	0	1.15	0.041	0	1.29	0.039	0	1.19	0.039	0	1.24	0.039	0
pAvgLnF_GTF	--	--	-4.21	0.075	0	-4.16	0.073	0	-6.30	0.199	0	-3.93	0.073	0	-6.24	0.186	0
pAvgLnF_SCF	--	--	-3.80	0.132	0	-3.71	0.122	0	-3.57	0.072	0	-2.59	0.122	0	-2.65	0.075	0
pAvgLnF_TCF	--	--	-1.62	0.087	0	-1.50	0.097	0	-0.53	0.077	0	-1.36	0.086	0	-0.60	0.077	0
pMnLnRec	--	--	11.17	0.071	0	11.14	0.062	0	10.84	0.055	0	11.16	0.062	0	10.99	0.058	0
pMnLnRecEarly	--	--	11.84	0.511	0	11.80	0.518	0	11.11	0.536	0	11.70	0.520	0	11.12	0.527	0
rkfish_disc_sel50_f1	50	150	150.00	1.140	1	98.35	13.410	0	102.49	0.616	0	150.00	3.936	1	99.05	0.671	0
rkfish_disc_sel50_f2	50	150	103.08	45.740	0	103.26	44.773	0	127.47	17.467	0	150.00	8.893	1	109.64	9.618	0
rkfish_disc_sel50_f3	50	170	157.07	354.400	0	157.07	337.590	0	124.98	8.415	0	158.55	398.060	0	118.93	7.198	0
rkfish_disc_sel50_m1	95	150	150.00	0.001	1	150.00	0.001	1	139.02	1.340	0	150.00	0.001	1	132.27	1.197	0
rkfish_disc_sel50_m2	95	150	132.31	11.907	0	133.22	12.448	0	139.67	2.636	0	136.32	13.067	0	107.30	3.386	0
rkfish_disc_sel50_m3	95	150	150.00	0.001	1	150.00	0.001	1	150.00	0.000	1	150.00	0.001	1	146.00	1.936	0
rkfish_disc_slope_f1	0.05	0.5	0.17	0.040	0	0.24	0.132	0	0.50	0.000	1	0.16	0.037	0	0.50	0.000	1
rkfish_disc_slope_f2	0.05	0.5	0.18	0.173	0	0.18	0.170	0	0.08	0.038	0	0.15	0.066	0	0.10	0.049	0
rkfish_disc_slope_f3	0.05	0.5	0.18	0.056	0	0.18	0.054	0	0.14	0.043	0	0.18	0.052	0	0.14	0.042	0
rkfish_disc_slope_m1	0.01	0.5	0.11	0.011	0	0.10	0.010	0	0.36	0.043	0	0.11	0.011	0	0.50	0.001	1
rkfish_disc_slope_m2	0.01	0.5	0.09	0.027	0	0.09	0.027	0	0.08	0.013	0	0.09	0.024	0	0.21	0.103	0
rkfish_disc_slope_m3	0.01	0.5	0.08	0.007	0	0.08	0.007	0	0.11	0.007	0	0.08	0.007	0	0.09	0.008	0
selSCF_lnZ50_md_1	2	4.5	3.97	0.053	0	3.97	0.041	0	3.97	0.067	0	3.98	0.039	0	3.98	0.061	0
selSCF_lnZ50_md_2	2	4.5	3.82	0.132	0	3.80	0.136	0	3.84	0.128	0	3.81	0.149	0	3.84	0.129	0
selSCF_lnZ50_md_3	2	4.5	3.48	0.115	0	3.53	0.082	0	3.60	0.067	0	3.54	0.084	0	3.60	0.069	0
selSCF_Z50_ma_1	40	140	87.47	1.762	0	86.80	1.652	0	88.13	2.716	0	86.90	1.595	0	87.44	2.468	0
selSCF_Z50_ma_2	40	140	93.81	3.066	0	93.91	3.100	0	94.35	3.309	0	93.76	3.134	0	94.12	3.298	0
selSCF_Z50_ma_3	40	140	105.24	2.009	0	103.63	1.550	0	103.13	1.409	0	103.69	1.564	0	102.33	1.426	0
snowfish_disc_sel50_f_1	50	150	111.33	4.707	0	110.42	4.551	0	93.49	5.584	0	109.37	4.615	0	96.19	8.365	0
snowfish_disc_sel50_f_2	50	120	76.46	5.024	0	76.19	4.879	0	99.77	4.255	0	76.16	4.878	0	99.13	4.130	0
snowfish_disc_sel50_f_3	50	120	85.24	6.346	0	88.70	7.051	0	120.00	0.000	1	88.18	6.780	0	120.00	0.000	1
snowfish_disc_slope_f_1	0.05	0.5	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1	0.05	0.000	-1	0.05	0.026	0
snowfish_disc_slope_f_2	0.05	0.5	0.25	0.129	0	0.25	0.130	0	0.10	0.025	0	0.25	0.130	0	0.10	0.025	0
snowfish_disc_slope_f_3	0.05	0.5	0.16	0.053	0	0.13	0.041	0	0.11	0.004	0	0.14	0.042	0	0.10	0.004	0
snowfish_disc_slope_m_1	0.1	0.5	0.36	0.126	0	0.40	0.147	0	0.31	0.142	0	0.41	0.145	0	0.34	0.154	0
snowfish_disc_slope_m_2	0.1	0.5	0.23	0.075	0	0.23	0.074	0	0.21	0.070	0	0.23	0.075	0	0.22	0.073	0
snowfish_disc_slope_m_3	0.1	0.5	0.17	0.017	0	0.18	0.018	0	0.18	0.018	0	0.18	0.018	0	0.19	0.019	0
snowfish_disc_slope_m2_1	0.1	0.5	0.37	0.249	0	0.50	0.004	1	0.45	0.315	0	0.50	0.001	1	0.43	0.291	0
snowfish_disc_slope_m2_2	0.1	0.5	0.18	0.092	0	0.18	0.089	0	0.21	0.110	0	0.16	0.085	0	0.20	0.106	0
snowfish_disc_slope_m2_3	0.1	0.5	0.17	0.030	0	0.18	0.028	0	0.19	0.030	0	0.18	0.028	0	0.18	0.028	0
srv2_q	0.5	1.001	0.56	0.033	0	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1
srv2_qFem	0.5	1.001	0.61	0.217	0	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1	0.50	0.000	-1
srv2_sel50	0	90	46.88	2.015	0	49.01	1.905	0	47.11	1.709	0	49.56	1.912	0	47.60	1.718	0
srv2_sel50_f	-200	100.01	57.57	18.304	0	53.63	2.859	0	48.97	2.427	0	53.87	2.616	0	49.44	2.321	0
srv2_seldiff	0	100	23.03	3.734	0	21.57	3.309	0	19.58	2.972	0	21.92	3.327	0	19.88	2.983	0
srv2_seldiff_f	0	100	55.99	29.637	0	40.82	6.712	0	30.23	5.662	0	39.17	5.760	0	29.60	5.097	0
srv3_q	0.2	2	0.75	0.036	0	0.78	0.035	0	1.12	0.031	0	0.79	0.034	0	0.94	0.031	0
srv3_qFem	0.2	1	0.56	0.039	0	0.59	0.035	0	0.82	0.035	0	0.59	0.035	0	0.73	0.035	0
srv3_sel50	0	69	28.43	3.289	0	32.49	2.815	0	32.34	2.522	0	32.97	2.845	0	31.91	2.607	0
srv3_sel50_f	-50	69	-4.11	15.461	0	7.10	11.252	0	-1.81	10.991	0	6.55	11.348	0	6.18	10.105	0
srv3_seldiff	0	100	57.17	8.050	0	55.62	6.771	0	52.91	6.014	0	56.90	6.958	0	53.44	6.488	0
srv3_seldiff_f	0	100	100.00	0.001	1	100.00	0.001	1	100.00	0.002	1	100.00	0.001	1	100.00	0.001	1

Table 17. Comparison of fits to mature survey biomass (1000's t) by sex from the 2014 assessment and Models A and C using Dataset D. Columns are arranged to allow easy comparison of model predictions.

	Mature Males							Mature Females						
	2014 Assessment			Model A	Model C	Dataset D		2014 Assessment			Model A	Model C	Dataset D	
	observed		predicted	predicted	predicted	observed		observed		predicted	predicted	predicted	observed	
year	cv	value				cv	value	cv	value				cv	value
1949	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1950	--	--	0.0	0.0	0.0	--	--	--	--	0.0	0.0	0.0	--	--
1951	--	--	0.1	0.1	0.1	--	--	--	--	0.2	0.1	0.1	--	--
1952	--	--	0.8	0.8	0.8	--	--	--	--	0.6	0.6	0.5	--	--
1953	--	--	3.2	2.9	2.6	--	--	--	--	1.4	1.3	1.2	--	--
1954	--	--	6.1	5.4	4.8	--	--	--	--	2.0	1.8	1.7	--	--
1955	--	--	8.4	7.2	6.5	--	--	--	--	2.5	2.3	2.1	--	--
1956	--	--	10.2	8.6	7.7	--	--	--	--	2.9	2.6	2.3	--	--
1957	--	--	11.5	9.7	8.6	--	--	--	--	3.2	2.8	2.6	--	--
1958	--	--	12.6	10.6	9.4	--	--	--	--	3.4	3.0	2.7	--	--
1959	--	--	13.6	11.3	10.1	--	--	--	--	3.7	3.2	2.9	--	--
1960	--	--	14.6	12.1	10.8	--	--	--	--	4.0	3.4	3.1	--	--
1961	--	--	15.7	13.1	11.6	--	--	--	--	4.4	3.7	3.4	--	--
1962	--	--	17.4	14.4	12.8	--	--	--	--	5.0	4.3	3.9	--	--
1963	--	--	20.2	16.7	14.8	--	--	--	--	6.2	5.3	4.8	--	--
1964	--	--	25.8	21.3	18.9	--	--	--	--	8.9	7.6	6.9	--	--
1965	--	--	38.7	32.3	28.6	--	--	--	--	15.1	13.3	12.0	--	--
1966	--	--	67.1	57.3	50.7	--	--	--	--	27.2	24.7	22.2	--	--
1967	--	--	119.9	106.2	93.0	--	--	--	--	43.8	41.4	36.7	--	--
1968	--	--	174.7	160.6	139.4	--	--	--	--	59.1	57.3	50.3	--	--
1969	--	--	217.3	204.6	175.9	--	--	--	--	68.3	66.6	58.3	--	--
1970	--	--	229.7	217.5	186.5	--	--	--	--	71.5	68.5	60.3	--	--
1971	--	--	229.8	212.8	184.1	--	--	--	--	71.6	65.9	59.0	--	--
1972	--	--	228.9	201.7	178.6	--	--	--	--	70.7	61.6	56.9	--	--
1973	--	--	228.8	189.9	174.1	--	--	--	--	68.2	57.2	54.6	--	--
1974	0.10	212.0	220.6	176.6	166.9	--	--	0.24	55.8	62.8	52.3	51.0	--	--
1975	0.10	265.1	194.0	155.1	148.9	0.14	246.0	0.20	38.8	55.0	46.4	45.6	0.15	31.7
1976	0.09	152.1	165.1	133.7	129.2	0.12	126.2	0.15	46.0	47.1	40.4	39.7	0.09	31.4
1977	0.12	130.4	124.9	102.2	100.7	0.09	110.6	0.28	47.6	39.4	34.5	34.3	0.12	38.8
1978	0.11	80.6	80.8	68.3	71.1	0.09	77.6	0.23	26.4	34.0	30.9	31.3	0.20	26.2
1979	0.09	47.8	65.5	59.0	63.1	0.07	32.2	0.23	20.4	33.6	32.2	32.9	0.19	19.7
1980	0.16	86.3	61.7	61.5	63.2	0.10	86.2	0.20	70.4	34.3	34.2	34.6	0.14	64.2
1981	0.10	50.7	48.2	46.4	46.9	0.09	49.4	0.18	45.2	31.3	28.2	28.3	0.15	43.1
1982	0.13	49.7	61.2	58.9	60.0	0.11	49.0	0.18	64.8	28.1	25.2	25.1	0.28	64.4
1983	0.13	29.0	47.9	37.3	37.5	0.08	28.5	0.19	20.7	21.7	17.2	17.2	0.23	20.6
1984	0.11	26.2	31.7	21.5	21.3	0.11	24.2	0.21	14.7	16.4	11.6	11.6	0.20	15.0
1985	0.13	11.7	21.7	13.0	12.9	0.06	11.4	0.32	5.7	13.3	8.5	8.5	0.15	5.6
1986	0.19	13.2	27.2	18.3	18.3	0.10	12.8	0.21	3.5	13.3	9.3	9.3	0.12	3.5
1987	0.13	24.2	41.4	31.6	31.4	0.07	24.1	0.25	5.3	15.5	12.3	12.2	0.17	5.2
1988	0.23	59.5	59.6	51.1	50.8	0.11	60.4	0.25	25.6	18.8	17.2	17.1	0.12	25.5
1989	0.11	101.5	78.9	77.0	76.5	0.08	91.9	0.13	25.5	22.2	22.2	22.1	0.12	19.5
1990	0.11	103.2	83.8	85.7	86.9	0.09	96.3	0.26	36.4	23.8	24.8	24.6	0.14	37.8
1991	0.17	110.8	70.4	74.5	77.9	0.09	109.7	0.21	45.6	23.3	24.6	24.4	0.12	45.0
1992	0.19	108.1	61.6	68.4	70.5	0.11	103.2	0.17	27.8	20.8	21.8	21.6	0.17	26.5
1993	0.13	62.1	46.1	50.4	51.5	0.10	60.1	0.15	11.9	16.5	16.9	16.8	0.11	11.7
1994	0.11	44.6	33.9	36.0	36.5	0.09	42.1	0.21	10.4	12.5	12.6	12.5	0.20	10.0
1995	0.15	33.9	24.8	25.9	26.1	0.11	31.1	0.23	13.4	9.4	9.2	9.2	0.17	12.7
1996	0.20	27.3	17.9	18.6	18.6	0.18	26.3	0.28	9.8	7.0	6.9	6.8	0.24	9.8
1997	0.11	11.1	14.3	14.6	14.6	0.10	10.7	0.18	3.5	5.5	5.3	5.3	0.17	3.5
1998	0.10	10.6	12.6	12.9	12.8	0.11	10.3	0.16	2.3	4.5	4.3	4.3	0.13	2.3
1999	0.16	12.4	12.4	12.6	12.5	0.10	12.5	0.28	3.8	4.0	3.9	4.0	0.13	3.9
2000	0.20	16.5	14.1	14.3	14.2	0.10	16.1	0.29	4.2	4.2	4.2	4.2	0.14	4.2
2001	0.13	18.2	17.5	17.6	17.5	0.08	17.9	0.24	4.6	4.6	4.5	4.6	0.14	4.6
2002	0.15	18.2	20.5	20.2	20.0	0.09	17.8	0.18	4.5	5.1	5.1	5.1	0.16	4.5
2003	0.15	23.7	24.7	24.4	24.1	0.09	23.3	0.17	8.3	6.0	6.0	6.0	0.14	8.4
2004	0.18	25.6	30.9	30.6	30.2	0.09	26.3	0.15	4.7	7.4	7.5	7.5	0.12	4.9
2005	0.13	44.0	39.6	39.6	39.2	0.07	43.1	0.18	11.6	8.7	8.8	8.9	0.13	11.6
2006	0.14	66.9	45.9	44.9	44.5	0.10	64.2	0.21	15.8	9.9	9.7	9.8	0.14	15.0
2007	0.20	72.6	51.7	49.3	49.2	0.10	66.4	0.26	13.3	11.5	10.8	11.1	0.13	13.5
2008	0.16	59.7	60.9	55.3	55.2	0.10	62.7	0.18	11.3	12.1	11.0	11.2	0.12	11.7
2009	0.13	37.6	63.0	53.9	53.5	0.09	36.3	0.26	8.2	11.1	9.6	9.8	0.17	8.6
2010	0.13	36.1	57.2	47.2	46.6	0.09	37.6	0.28	5.4	9.6	8.1	8.3	0.12	5.5
2011	0.17	46.3	51.5	41.9	41.1	0.08	41.5	0.16	8.7	9.1	7.8	7.8	0.12	5.5
2012	0.18	43.1	51.5	42.9	42.0	0.09	41.2	0.41	15.8	11.0	9.8	9.8	0.12	12.5
2013	0.15	69.8	65.3	57.4	56.5	0.10	65.7	0.14	19.1	14.2	13.2	13.4	0.10	18.0
2014	0.11	87.1	81.9	73.8	73.5	0.07	79.5	0.19	15.8	15.6	15.0	15.3	0.14	14.9
2015	--	--	--	72.6	72.7	0.07	60.2	--	--	--	13.8	14.1	0.14	11.3

Table 18. Comparison of time series of estimated recruitment (millions) from the 2014 assessment and Models A and C using Dataset D.

Year	2014 Assessment	Model A	Model C
1949	62.19	59.68	53.52
1950	62.36	59.82	53.64
1951	62.75	60.16	53.94
1952	63.46	60.79	54.48
1953	64.64	61.83	55.38
1954	66.49	63.47	56.80
1955	69.36	66.02	59.03
1956	73.83	70.00	62.50
1957	80.96	76.35	68.07
1958	92.87	86.92	77.35
1959	114.43	105.92	94.08
1960	159.18	144.85	128.44
1961	273.92	243.60	215.88
1962	602.93	534.88	474.18
1963	1301.35	1244.51	1096.58
1964	1807.55	1930.88	1663.33
1965	1699.85	1929.26	1637.96
1966	1397.57	1545.71	1327.10
1967	1207.68	1214.54	1087.11
1968	1161.20	1015.76	973.66
1969	1196.51	926.12	957.08
1970	997.80	879.66	938.57
1971	650.12	737.39	733.05
1972	542.54	572.56	551.92
1973	440.81	458.56	418.16
1974	122.18	299.76	338.07
1975	420.21	376.50	463.86
1976	919.41	1113.94	1105.19
1977	560.43	829.22	883.98
1978	477.41	381.13	389.15
1979	118.24	126.07	134.09
1980	45.37	57.85	61.75
1981	106.97	76.54	78.68
1982	52.60	39.31	40.05
1983	372.92	275.66	275.79
1984	304.66	266.63	264.38
1985	578.41	673.12	664.52
1986	483.57	517.95	516.81
1987	438.11	485.61	484.66
1988	388.44	444.02	449.62
1989	172.35	168.66	168.88
1990	77.75	70.95	71.85
1991	36.43	40.76	41.98
1992	31.78	30.74	31.26
1993	26.66	27.74	28.35
1994	30.64	31.32	31.73
1995	45.05	41.62	42.35
1996	43.96	46.14	47.06
1997	119.75	113.81	115.20
1998	47.11	46.05	46.50
1999	147.24	140.55	141.20
2000	89.04	84.99	84.26
2001	276.17	279.15	281.85
2002	113.87	108.80	110.45
2003	202.76	185.04	194.42
2004	371.35	306.44	311.08
2005	114.16	87.26	87.88
2006	94.61	70.87	72.23
2007	66.43	52.92	53.34
2008	76.31	61.00	61.30
2009	410.40	354.63	345.36
2010	432.10	422.94	449.87
2011	216.25	251.06	256.42
2012	43.73	52.20	53.57
2013	117.42	115.80	118.34
2014	177.80	124.00	126.93
2015	--	80.71	82.65

Table 19. Estimated mature male biomass (1000's t) at mating from the 2014 assessment and Models A and C using Dataset D.

Year	2014 Assessment	Model A	Model C
1949	0.00	0.00	0.00
1950	0.01	0.01	0.01
1951	0.15	0.17	0.16
1952	1.24	1.36	1.24
1953	4.59	4.75	4.29
1954	8.82	8.66	7.78
1955	12.13	11.63	10.44
1956	14.61	13.84	12.41
1957	16.52	15.53	13.93
1958	18.08	16.92	15.16
1959	19.47	18.15	16.26
1960	20.90	19.43	17.39
1961	22.62	20.97	18.75
1962	25.03	23.15	20.67
1963	29.04	26.80	23.91
1964	37.09	34.23	30.51
1965	53.86	49.92	44.47
1966	94.82	90.17	80.01
1967	151.98	150.63	133.47
1968	225.91	233.51	204.04
1969	273.73	291.37	251.39
1970	296.50	317.01	272.07
1971	305.11	317.54	274.85
1972	310.35	305.40	271.02
1973	312.91	287.57	264.12
1974	292.48	257.21	244.46
1975	257.84	226.40	220.10
1976	195.34	171.84	171.37
1977	123.03	106.15	110.22
1978	79.23	70.30	75.10
1979	49.25	48.18	52.89
1980	34.48	31.15	33.63
1981	44.63	40.66	41.51
1982	48.67	37.88	37.86
1983	40.27	25.33	24.74
1984	24.89	12.79	12.46
1985	23.81	13.61	13.37
1986	29.58	19.12	18.87
1987	43.03	31.17	30.92
1988	59.68	48.32	48.30
1989	65.66	60.28	62.22
1990	56.02	55.10	59.73
1991	51.12	55.11	58.15
1992	43.53	48.23	49.76
1993	38.06	40.85	41.51
1994	30.58	31.48	31.66
1995	22.73	22.85	22.83
1996	17.84	17.66	17.54
1997	14.95	14.71	14.53
1998	13.43	13.22	12.98
1999	13.68	13.39	13.13
2000	15.52	15.17	14.91
2001	19.06	18.42	18.11
2002	22.71	21.49	21.09
2003	27.68	26.20	25.67
2004	34.61	32.90	32.21
2005	43.61	41.89	41.04
2006	49.90	46.77	45.91
2007	56.30	51.35	50.78
2008	67.30	58.42	57.76
2009	70.20	57.44	56.37
2010	64.36	50.95	49.71
2011	57.83	45.10	43.77
2012	58.23	46.55	45.07
2013	72.70	60.59	58.97
2014	--	71.57	70.63

Table 20. Estimated numbers of male crab ≥ 138 mm CW (millions) in the survey from the 2014 assessment and Models A and C using Dataset D.

Year	2014 Assessment	Model A	Model C
1949	0.00	0.00	0.00
1950	0.00	0.00	0.00
1951	0.00	0.00	0.00
1952	0.09	0.10	0.09
1953	0.80	0.82	0.70
1954	2.11	1.97	1.70
1955	3.17	2.85	2.46
1956	3.95	3.50	3.01
1957	4.53	3.98	3.42
1958	4.99	4.36	3.75
1959	5.38	4.69	4.02
1960	5.76	5.00	4.28
1961	6.19	5.36	4.58
1962	6.75	5.83	4.98
1963	7.61	6.56	5.59
1964	9.17	7.89	6.72
1965	12.59	10.86	9.23
1966	20.36	17.76	14.98
1967	38.29	34.60	29.05
1968	59.50	56.14	46.20
1969	79.41	77.56	62.66
1970	85.74	85.21	67.44
1971	85.99	84.39	66.37
1972	85.55	80.13	63.97
1973	86.45	75.34	62.36
1974	176.77	70.60	61.01
1975	230.46	215.27	208.15
1976	153.64	126.34	120.37
1977	115.31	100.09	95.21
1978	64.92	60.10	56.98
1979	37.92	26.64	25.26
1980	44.32	44.07	42.94
1981	25.48	27.54	26.65
1982	31.45	34.71	34.20
1983	26.61	23.76	23.23
1984	21.17	16.43	16.02
1985	12.89	9.53	9.25
1986	12.78	9.45	9.14
1987	21.11	17.72	17.24
1988	38.16	34.47	33.66
1989	62.99	61.02	59.65
1990	75.34	73.17	71.71
1991	60.52	63.37	62.33
1992	63.39	66.97	65.80
1993	35.16	38.27	37.15
1994	26.87	28.48	27.47
1995	18.11	18.64	17.78
1996	15.11	15.73	15.00
1997	8.33	8.68	8.02
1998	6.55	6.90	6.38
1999	6.48	6.83	6.39
2000	9.67	10.00	9.61
2001	12.35	12.80	12.41
2002	13.91	14.16	13.76
2003	15.93	16.24	15.78
2004	16.46	16.96	16.39
2005	26.34	27.10	26.39
2006	32.94	32.78	31.93
2007	31.90	31.77	30.89
2008	37.30	38.65	37.69
2009	35.05	32.40	31.37
2010	34.32	32.49	31.45
2011	38.03	33.17	32.19
2012	28.65	24.72	23.73
2013	34.57	31.58	30.30
2014	52.28	48.90	47.50
2015	--	48.67	47.19

Table 21. Observed retained catch (1000's t) in the directed fishery and predicted catch from the 2014 assessment and Models A and C using Dataset D..

	2014 Assessment		Model A	Model C	Dataset D
year	observed	predicted	predicted	predicted	observed
1949	--	0.0	0.0	0.0	--
1950	--	0.0	0.0	0.0	--
1951	--	0.0	0.0	0.0	--
1952	--	0.0	0.0	0.0	--
1953	--	0.1	0.1	0.0	--
1954	--	0.1	0.1	0.1	--
1955	--	0.2	0.2	0.2	--
1956	--	0.3	0.2	0.2	--
1957	--	0.3	0.3	0.2	--
1958	--	0.3	0.3	0.3	--
1959	--	0.4	0.3	0.3	--
1960	--	0.4	0.4	0.3	--
1961	--	0.4	0.4	0.3	--
1962	--	0.5	0.4	0.4	--
1963	--	0.5	0.5	0.4	--
1964	--	0.6	0.6	0.5	--
1965	1.92	2.0	2.0	2.0	1.9
1966	2.45	2.5	2.5	2.5	2.4
1967	13.60	13.6	13.6	13.6	13.6
1968	18.00	18.0	18.0	18.0	18.0
1969	27.49	27.5	27.5	27.5	27.5
1970	25.49	25.5	25.5	25.5	25.5
1971	20.71	20.7	20.7	20.7	20.7
1972	16.91	16.9	16.9	16.9	16.9
1973	13.03	13.0	13.0	13.0	13.0
1974	15.24	15.2	15.2	15.2	15.2
1975	17.65	17.7	17.6	17.6	17.7
1976	30.02	30.0	30.0	30.0	30.0
1977	35.53	35.5	35.5	35.5	35.5
1978	21.09	21.1	21.1	21.1	21.1
1979	19.01	18.9	18.8	18.8	19.0
1980	13.43	13.5	13.4	13.4	13.4
1981	4.99	5.1	5.1	5.1	5.0
1982	2.39	2.5	2.5	2.5	2.4
1983	0.55	0.8	0.7	0.7	0.5
1984	1.43	1.5	1.5	1.5	1.4
1985	--	--	--	--	--
1986	--	--	--	--	--
1987	1.00	1.0	0.9	0.9	1.0
1988	3.18	3.1	3.0	3.1	3.2
1989	11.11	11.0	11.0	11.0	11.1
1990	18.19	18.1	18.0	18.0	18.2
1991	14.43	14.3	14.3	14.3	14.4
1992	15.92	14.5	14.8	14.9	15.9
1993	7.67	6.8	7.2	7.2	7.7
1994	3.54	3.4	3.7	3.8	3.5
1995	1.92	1.7	1.9	2.0	1.9
1996	0.82	0.4	0.5	0.7	0.8
1997	--	--	--	--	--
1998	--	--	--	--	--
1999	--	--	--	--	--
2000	--	--	--	--	--
2001	--	--	--	--	--
2002	--	--	--	--	--
2003	--	--	--	--	--
2004	--	--	--	--	--
2005	0.43	0.5	0.5	0.6	0.4
2006	0.96	0.9	1.0	1.1	1.0
2007	0.96	0.9	1.0	1.2	1.0
2008	0.88	0.9	1.0	1.0	0.9
2009	0.60	0.7	0.7	0.8	0.6
2010	--	--	--	--	--
2011	--	--	--	--	--
2012	--	--	--	--	--
2013	0.66	0.6	1.1	1.2	1.2
2014	--	--	5.0	5.5	6.2

Table 22. Total male mortality (retained+discards) in the directed fishery (1000's t) from the 2014 assessment and Models A and C using Dataset D.

	2014 Assessment		Model A	Model C	Dataset D
year	observed	predicted	predicted	predicted	observed
1949	--	0.0	0.0	0.0	--
1950	--	0.0	0.0	0.0	--
1951	--	0.0	0.0	0.0	--
1952	--	0.0	0.0	0.0	--
1953	--	0.1	0.1	0.1	--
1954	--	0.3	0.2	0.2	--
1955	--	0.4	0.3	0.2	--
1956	--	0.5	0.4	0.3	--
1957	--	0.5	0.5	0.3	--
1958	--	0.6	0.5	0.4	--
1959	--	0.6	0.5	0.4	--
1960	--	0.7	0.6	0.4	--
1961	--	0.7	0.6	0.5	--
1962	--	0.8	0.7	0.5	--
1963	--	0.9	0.8	0.6	--
1964	--	1.1	1.0	0.7	--
1965	--	3.8	3.6	3.0	--
1966	--	5.1	4.8	3.9	--
1967	--	27.9	26.6	21.7	--
1968	--	35.1	33.5	27.6	--
1969	--	50.7	48.3	40.4	--
1970	--	45.7	43.3	36.8	--
1971	--	36.7	34.6	29.6	--
1972	--	29.8	28.0	24.1	--
1973	--	22.8	21.5	18.5	--
1974	--	26.1	25.1	21.5	--
1975	--	29.9	29.2	24.9	--
1976	--	51.9	50.9	43.8	--
1977	--	65.0	65.5	59.1	--
1978	--	42.5	44.7	44.6	--
1979	--	52.0	54.3	57.3	--
1980	--	41.3	42.0	40.1	--
1981	--	10.7	9.9	8.2	--
1982	--	4.4	3.9	3.3	--
1983	--	1.2	1.1	0.9	--
1984	--	2.3	2.3	1.9	--
1985	--	--	--	--	--
1986	--	--	--	--	--
1987	--	1.8	1.7	1.4	--
1988	--	5.5	5.5	4.5	--
1989	--	20.4	20.2	16.7	--
1990	--	33.7	32.7	27.8	--
1991	--	23.0	19.5	18.9	--
1992	17.90	18.9	18.7	18.6	17.9
1993	8.91	9.5	9.3	9.2	8.9
1994	4.54	4.7	4.5	4.4	4.5
1995	2.81	3.0	3.0	2.9	2.8
1996	0.86	1.3	1.3	1.2	0.9
1997	--	--	--	--	--
1998	--	--	--	--	--
1999	--	--	--	--	--
2000	--	--	--	--	--
2001	--	--	--	--	--
2002	--	--	--	--	--
2003	--	--	--	--	--
2004	--	--	--	--	--
2005	0.58	0.9	0.8	0.8	0.6
2006	1.40	1.6	1.6	1.5	1.4
2007	1.61	1.8	1.8	1.7	1.6
2008	1.02	1.2	1.2	1.2	1.0
2009	0.63	0.7	0.8	0.8	0.6
2010	--	--	--	--	--
2011	--	--	--	--	--
2012	--	--	--	--	--
2013	0.83	1.1	1.6	1.6	1.4
2014	--	--	7.8	7.5	7.0

Table 23. Comparison of the final objective function components for the alternative models A and C, which can be compared directly. Component differences greater or less than 4 units are highlighted. Negative differences (red highlighting) indicate better fits with Model A. Positive differences (blue highlighting) indicate better fits with Model C.

Type	weight	sigma	Model A	Model C	A - C	Component Description
Total	--	--	2,049.07	2,112.49	-63.42	total
Penalties	1	1.000	2.30	2.29	0.01	recruitment penalty
	0	--	0.00	0.00	0.00	sex ratio penalty
	1	1.000	0.64	0.67	-0.03	immatures natural mortality penalty
	1	1.000	4.21	6.98	-2.77	mature male natural mortality penalty
	1	1.000	51.27	50.01	1.26	mature female natural mortality penalty
	1	1.000	1.97	1.77	0.20	survey q penalty
	1	1.000	16.35	17.01	-0.66	female survey q penalty
	1	1.000	0.90	0.90	0.00	prior on female growth parameter a
	1	1.000	0.68	0.66	0.01	prior on female growth parameter b
	1	1.000	0.57	0.21	0.36	prior on male growth parameter a
	1	1.000	0.04	0.03	0.01	prior on male growth parameter b
	1	1.000	1.41	1.40	0.01	smoothing penalty on female maturity curve
	0.5	1.414	0.16	0.16	0.00	smoothing penalty on male maturity curve
	0	--	0.00	0.00	0.00	1st difference penalty on changes in male size at 50% selectivity in directed fishery
	1	1.000	49.39	48.50	0.88	penalty on F-devs in directed fishery
	0.5	1.414	7.70	7.52	0.18	penalty on F-devs in snow crab fishery
	0	--	0.00	0.00	0.00	penalty on F-devs in BBRKC fishery
	0.5	1.414	11.69	11.67	0.03	penalty on F-devs in groundfish fishery
Size Compositions	1	1.000	194.52	222.35	-27.83	likelihood for directed fishery: retained males
	1	1.000	115.60	180.05	-64.45	likelihood for directed fishery: total males
	1	1.000	14.32	11.06	3.26	likelihood for directed fishery: discarded females
	1	1.000	49.26	50.82	-1.56	likelihood for snow crab fishery: discarded males
	1	1.000	13.95	14.09	-0.15	likelihood for snow crab fishery: discarded females
	1	1.000	24.21	24.21	0.00	likelihood for BBRKC fishery: discarded males
	1	1.000	2.68	1.94	0.74	likelihood for BBRKC fishery: discarded females
	1	1.000	135.17	128.78	6.39	likelihood for groundfish fishery
	1	1.000	280.47	278.58	1.89	likelihood for survey: immature males
	1	1.000	272.48	260.23	12.26	likelihood for survey: mature males
	1	1.000	307.31	307.19	0.12	likelihood for survey: immature females
	1	1.000	99.13	105.26	-6.13	likelihood for survey: mature females
Biomass	1	1.000	311.35	315.61	-4.26	likelihood for survey: mature survey biomass
	10	0.316	31.87	19.61	12.25	likelihood for directed fishery: male retained catch biomass
	10	0.316	18.21	11.98	6.23	likelihood for directed fishery: male total catch biomass
	10	0.316	6.64	7.62	-0.98	likelihood for directed fishery: female catch biomass
	10	0.316	10.52	10.48	0.04	likelihood for snow crab fishery: total catch biomass
	10	0.316	9.59	10.29	-0.69	likelihood for BBRKC fishery: total catch biomass
	10	0.316	2.52	2.55	-0.03	likelihood for groundfish fishery: total catch biomass
Penalties	0	--	0.00	0.00	0.00	penalty on sel50 devs for TCF

Table 24. Parameter estimates for devs vectors from Model A (Dataset D), the author’s preferred model. Estimates for other parameters may be found in Table 15.

devs vector	year	estimate	std. dev.
historic recruitment devs (1949-1973)	1949	-1.496	1.627
	1950	-1.494	1.484
	1951	-1.488	1.346
	1952	-1.478	1.216
	1953	-1.461	1.095
	1954	-1.435	0.987
	1955	-1.395	0.894
	1956	-1.337	0.820
	1957	-1.250	0.767
	1958	-1.120	0.734
	1959	-0.923	0.717
	1960	-0.610	0.715
	1961	-0.090	0.725
	1962	0.697	0.729
	1963	1.541	0.720
	1964	1.980	0.702
	1965	1.980	0.700
	1966	1.758	0.703
	1967	1.517	0.698
	1968	1.338	0.689
	1969	1.246	0.685
	1970	1.194	0.669
	1971	1.018	0.609
	1972	0.765	0.575
	1973	0.543	0.584
recruitment deviations (1974+)	1974	0.781	0.415
	1975	1.009	0.323
	1976	2.094	0.126
	1977	1.799	0.138
	1978	1.022	0.186
	1979	-0.085	0.338
	1980	-0.864	0.461
	1981	-0.584	0.255
	1982	-1.250	0.385
	1983	0.698	0.104
	1984	0.664	0.160
	1985	1.590	0.107
	1986	1.328	0.134
	1987	1.264	0.133
	1988	1.174	0.120
	1989	0.206	0.172
	1990	-0.660	0.254
	1991	-1.214	0.291
	1992	-1.496	0.273
	1993	-1.599	0.250
	1994	-1.477	0.218
	1995	-1.193	0.182
	1996	-1.090	0.188
	1997	-0.187	0.098
	1998	-1.092	0.182
	1999	0.024	0.099
	2000	-0.479	0.174
	2001	0.710	0.088
	2002	-0.232	0.186
	2003	0.299	0.129
	2004	0.803	0.086
	2005	-0.453	0.197
	2006	-0.661	0.214
	2007	-0.953	0.261
	2008	-0.811	0.251
	2009	0.949	0.100
	2010	1.126	0.096
	2011	0.604	0.135
	2012	-0.966	0.369
	2013	-0.170	0.198
	2014	-0.101	0.204
	2015	-0.531	0.301

devs vector	year	estimate	std. dev.
directed fishery total mortality devs	1965	-0.518	0.498
	1966	-0.773	0.388
	1967	0.359	0.352
	1968	0.121	0.334
	1969	0.221	0.323
	1970	0.022	0.315
	1971	-0.200	0.294
	1972	-0.366	0.251
	1973	-0.570	0.187
	1974	-0.324	0.124
	1975	-0.041	0.095
	1976	0.761	0.092
	1977	1.491	0.104
	1978	1.688	0.133
	1979	2.387	0.166
	1980	2.443	0.216
	1981	0.596	0.156
	1982	-0.350	0.129
	1983	-1.277	0.265
	1984	0.097	0.176
	1987	-0.867	0.231
	1988	-0.113	0.112
	1989	0.880	0.087
	1990	1.372	0.091
	1991	1.289	0.136
	1992	1.668	0.140
	1993	0.961	0.134
	1994	0.762	0.176
	1995	-0.070	0.159
	1996	-1.228	0.198
	2005	-2.148	0.216
	2006	-1.652	0.149
	2007	-1.690	0.139
	2008	-1.753	0.167
	2009	-1.049	0.277
	2013	-1.686	0.147
	2014	-0.442	0.097
snow crab fishery discard mortality devs	1992	1.850	0.120
	1993	1.627	0.127
	1994	1.273	0.150
	1995	1.276	0.175
	1996	0.197	0.471
	1997	0.734	0.368
	1998	0.494	0.487
	1999	-0.382	0.684
	2000	-0.622	0.659
	2001	-0.580	0.630
	2002	-0.568	0.600
	2003	-0.812	0.584
	2004	-1.146	0.565
	2005	-0.649	0.503
	2006	-0.340	0.414
	2007	-0.206	0.342
	2008	-0.610	0.418
	2009	-0.486	0.421
	2010	-0.420	0.447
	2011	0.013	0.365
	2012	-0.578	0.470
	2013	-0.479	0.347
	2014	0.414	0.178

devs vector	year	estimate	std. dev.
groundfish fiesheries discard mortality devs	1973	0.845	0.115
	1974	1.273	0.086
	1975	0.461	0.082
	1976	-0.028	0.094
	1977	-0.249	0.121
	1978	-0.420	0.158
	1979	0.218	0.112
	1980	0.046	0.149
	1981	-0.071	0.191
	1982	-0.726	0.406
	1983	-0.150	0.389
	1984	0.252	0.414
	1985	-0.285	0.524
	1986	-0.368	0.409
	1987	-0.650	0.411
	1988	-1.116	0.420
	1989	-1.033	0.351
	1990	-0.716	0.290
	1991	0.392	0.146
	1992	0.686	0.135
	1993	0.556	0.175
	1994	1.068	0.154
	1995	1.115	0.188
	1996	1.473	0.180
	1997	1.374	0.234
	1998	1.066	0.332
	1999	0.531	0.498
	2000	0.658	0.390
	2001	1.003	0.244
	2002	0.367	0.367
	2003	-0.217	0.472
	2004	-0.125	0.370
	2005	-0.353	0.372
	2006	-0.289	0.326
	2007	-0.367	0.319
	2008	-0.584	0.358
	2009	-0.769	0.421
	2010	-0.881	0.480
	2011	-0.880	0.495
	2012	-1.057	0.494
	2013	-1.017	0.420
	2014	-1.030	0.391

Table 25. Estimated population size (thousands) for females on July 1 of year. from the author’s preferred model, Model A.

Size bin

27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	102.5	107.5	112.5	117.5	122.5	127.5	132.5	137.5	142.5	147.5	152.5	157.5	162.5	167.5	172.5	177.5	182.5
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.58E+03	1.09E+04	1.07E+04	1.01E+04	7.50E+03	4.66E+03	2.56E+03	1.28E+03	6.01E+02	2.67E+02	1.13E+02	4.65E+01	1.85E+01	7.14E+00	2.70E+00	9.96E-01	3.61E-01	1.28E-01	4.49E-02	1.54E-02	5.22E-03	1.74E-03	5.76E-04	1.88E-04	6.07E-05	1.94E-05	6.18E-06	1.95E-06	6.10E-07	1.90E-07	5.99E-08	2.33E-08
4.61E+03	1.09E+04	1.07E+04	1.05E+04	9.04E+03	7.76E+03	6.39E+03	4.73E+03	3.18E+03	1.95E+03	1.07E+03	5.15E+02	2.13E+02	7.70E+01	2.66E+01	8.44E+00	2.08E+00	4.12E-01	9.26E-02	2.71E-02	8.72E-03	2.88E-03	9.46E-04	3.09E-04	9.96E-05	3.19E-05	1.01E-05	3.19E-06	1.00E-06	3.11E-07	9.82E-08	3.82E-08
4.66E+03	1.10E+04	1.08E+04	1.06E+04	9.12E+03	7.96E+03	7.02E+03	6.19E+03	5.64E+03	5.00E+03	3.76E+03	2.37E+03	1.24E+03	5.45E+02	2.23E+02	7.68E+01	1.79E+01	2.60E+00	3.03E-01	4.92E-02	1.20E-02	3.67E-03	1.19E-03	3.88E-04	1.25E-04	4.00E-05	1.27E-05	4.01E-06	1.25E-06	3.90E-07	1.23E-07	4.79E-08
4.74E+03	1.12E+04	1.10E+04	1.07E+04	9.22E+03	8.03E+03	7.09E+03	6.36E+03	6.32E+03	6.65E+03	5.92E+03	4.48E+03	2.93E+03	1.63E+03	8.31E+02	3.40E+02	8.78E+01	1.30E+01	1.38E+00	1.58E-01	2.17E-02	4.58E-03	1.37E-03	4.41E-04	1.42E-04	4.55E-05	1.44E-05	4.55E-06	1.42E-06	4.43E-07	1.40E-07	5.43E-08
4.86E+03	1.15E+04	1.13E+04	1.09E+04	9.38E+03	8.15E+03	7.19E+03	6.48E+03	6.72E+03	7.67E+03	7.27E+03	5.82E+03	4.21E+03	2.61E+03	1.49E+03	6.75E+02	1.89E+02	2.97E+01	3.50E+00	4.32E-01	4.66E-02	6.23E-03	1.54E-03	4.84E-04	1.56E-04	4.98E-05	1.58E-05	4.98E-06	1.56E-06	4.85E-07	1.53E-07	5.95E-08
5.06E+03	1.20E+04	1.17E+04	1.13E+04	9.65E+03	8.35E+03	7.34E+03	6.64E+03	7.06E+03	8.44E+03	8.24E+03	6.78E+03	5.12E+03	3.32E+03	1.97E+03	9.26E+02	2.67E+02	4.28E+01	5.38E+00	7.04E-01	7.19E-02	7.84E-03	1.69E-03	5.18E-04	1.66E-04	5.32E-05	1.69E-05	5.32E-06	1.66E-06	5.17E-07	1.63E-07	6.34E-08
5.36E+03	1.27E+04	1.23E+04	1.18E+04	1.01E+04	8.66E+03	7.58E+03	6.85E+03	7.38E+03	9.05E+03	8.99E+03	7.49E+03	5.78E+03	3.84E+03	2.31E+03	1.10E+03	3.21E+02	5.20E+01	6.70E+00	8.95E-01	8.98E-02	9.01E-03	1.81E-03	5.49E-04	1.76E-04	5.62E-05	1.78E-05	5.62E-06	1.76E-06	5.47E-07	1.72E-07	6.70E-08
5.85E+03	1.38E+04	1.33E+04	1.27E+04	1.07E+04	9.14E+03	7.94E+03	7.15E+03	7.74E+03	9.61E+03	9.62E+03	8.07E+03	6.30E+03	4.23E+03	2.57E+03	1.23E+03	3.61E+02	5.86E+01	7.63E+00	1.03E+00	1.02E-01	9.93E-03	1.93E-03	5.81E-04	1.86E-04	5.95E-05	1.89E-05	5.95E-06	1.86E-06	5.79E-07	1.83E-07	7.09E-08
6.66E+03	1.57E+04	1.50E+04	1.41E+04	1.17E+04	9.90E+03	8.52E+03	7.60E+03	8.20E+03	1.02E+04	1.02E+04	8.60E+03	6.75E+03	4.55E+03	2.78E+03	1.34E+03	3.92E+02	6.36E+01	8.32E+00	1.13E+00	1.12E-01	1.07E-02	2.07E-03	6.22E-04	1.99E-04	6.37E-05	2.02E-05	6.37E-06	1.99E-06	6.20E-07	1.95E-07	7.59E-08
8.12E+03	1.91E+04	1.80E+04	1.65E+04	1.35E+04	1.12E+04	9.47E+03	8.33E+03	8.85E+03	1.09E+04	1.09E+04	9.16E+03	7.19E+03	4.84E+03	2.96E+03	1.42E+03	4.18E+02	6.79E+01	8.90E+00	1.21E+00	1.20E-01	1.17E-02	2.27E-03	6.83E-04	2.19E-04	7.00E-05	2.22E-05	7.00E-06	2.19E-06	6.80E-07	2.15E-07	8.34E-08
1.11E+04	2.60E+04	2.40E+04	2.11E+04	1.68E+04	1.35E+04	1.11E+04	9.56E+03	9.89E+03	1.19E+04	1.18E+04	9.85E+03	7.69E+03	5.17E+03	3.15E+03	1.52E+03	4.44E+02	7.21E+01	9.46E+00	1.28E+00	1.29E-01	1.29E-02	2.58E-03	7.84E-04	2.51E-04	8.03E-05	2.55E-05	8.03E-06	2.51E-06	7.81E-07	2.46E-07	9.57E-08
1.87E+04	4.33E+04	3.86E+04	3.20E+04	2.41E+04	1.83E+04	1.44E+04	1.19E+04	1.17E+04	1.36E+04	1.32E+04	1.08E+04	8.38E+03	5.60E+03	3.40E+03	1.63E+03	4.76E+02	7.71E+01	1.01E+01	1.38E+00	1.41E-01	1.50E-02	3.18E-03	9.74E-04	3.13E-04	1.00E-04	3.17E-05	1.00E-05	3.13E-06	9.72E-07	3.07E-07	1.19E-07
4.10E+04	9.45E+04	8.10E+04	6.22E+04	4.36E+04	3.07E+04	2.24E+04	1.71E+04	1.55E+04	1.66E+04	1.55E+04	1.25E+04	9.48E+03	6.24E+03	3.75E+03	1.79E+03	5.20E+02	8.43E+01	1.10E+01	1.51E+00	1.62E-01	1.96E-02	4.55E-03	1.42E-03	4.56E-04	1.46E-04	4.62E-05	1.46E-05	4.56E-06	1.42E-06	4.47E-07	1.74E-07
9.54E+04	2.19E+05	1.87E+05	1.41E+05	9.60E+04	6.42E+04	4.37E+04	3.09E+04	2.49E+04	2.37E+04	2.06E+04	1.59E+04	1.15E+04	7.38E+03	4.36E+03	2.05E+03	5.94E+02	9.61E+01	1.26E+01	1.77E+00	2.09E-01	3.17E-02	8.33E-03	2.64E-03	8.50E-04	2.72E-04	8.64E-05	2.72E-05	8.51E-06	2.65E-06	8.36E-07	3.24E-07
1.48E+05	3.44E+05	3.11E+05	2.61E+05	1.92E+05	1.35E+05	9.37E+04	6.54E+04	4.93E+04	4.17E+04	3.32E+04	2.39E+04	1.62E+04	9.84E+03	5.60E+03	2.57E+03	7.36E+02	1.19E+02	1.57E+01	2.29E+00	3.17E-01	6.11E-02	1.77E-02	5.68E-03	1.83E-03	5.86E-04	1.86E-04	5.87E-05	1.84E-05	5.71E-06	1.80E-06	7.00E-07
1.48E+05	3.51E+05	3.45E+05	3.34E+05	2.74E+05	2.16E+05	1.68E+05	1.27E+05	9.98E+04	8.32E+04	6.39E+04	4.39E+04	2.78E+04	1.59E+04	8.57E+03	3.80E+03	1.06E+03	1.70E+02	2.20E+01	3.22E+00	4.81E-01	1.02E-01	3.04E-02	9.81E-03	3.16E-03	1.01E-03	3.22E-04	1.01E-04	3.17E-05	9.87E-06	3.12E-06	1.21E-06
1.18E+05	2.85E+05	2.96E+05	3.11E+05	2.80E+05	2.49E+05	2.17E+05	1.84E+05	1.62E+05	1.49E+05	1.20E+05	8.47E+04	5.35E+04	2.98E+04	1.57E+04	6.77E+03	1.85E+03	2.88E+02	3.51E+01	4.76E+00	6.51E-01	1.27E-01	3.68E-02	1.17E-02	3.76E-03	1.20E-03	3.78E-04	1.19E-04	3.72E-05	1.16E-05	3.65E-06	1.42E-06
9.31E+04	2.24E+05	2.34E+05	2.50E+05	2.33E+05	2.21E+05	2.08E+05	1.94E+05	1.97E+05	2.08E+05	1.85E+05	1.39E+05	9.34E+04	5.44E+04	2.95E+04	1.29E+04	3.52E+03	5.46E+02	6.43E+01	8.10E+00	9.37E-01	1.45E-01	3.82E-02	1.20E-02	3.84E-03	1.22E-03	3.86E-04	1.21E-04	3.79E-05	1.18E-05	3.72E-06	1.45E-06
7.78E+04	1.87E+05	1.92E+05	2.01E+05	1.86E+05	1.77E+05	1.70E+05	1.68E+05	1.90E+05	2.31E+05	2.24E+05	1.82E+05	1.32E+05	8.23E+04	4.69E+04	2.12E+04	5.90E+03	9.15E+02	1.08E+02	1.33E+01	1.33E+00	1.46E-01	3.12E-02	9.38E-03	2.95E-03	9.27E-04	2.91E-04	9.11E-05	2.84E-05	8.81E-06	2.78E-06	1.08E-06
7.10E+04	1.69E+05	1.70E+05	1.73E+05	1.56E+05	1.45E+05	1.38E+05	1.37E+05	1.66E+05	2.23E+05	2.31E+05	1.97E+05	1.53E+05	1.01E+05	6.05E+04	2.83E+04	8.08E+03	1.27E+03	1.56E+02	1.97E+01	1.87E+00	1.63E-01	2.78E-02	7.95E-03	2.48E-03	7.76E-04	2.43E-04	7.59E-05	2.36E-05	7.33E-06	2.31E-06	8.97E-07
6.74E+04	1.60E+05	1.60E+05	1.59E+05	1.41E+05	1.28E+05	1.18E+05	1.15E+05	1.45E+05	2.06E+05	2.20E+05	1.93E+05	1.56E+05	1.07E+05	6.59E+04	3.16E+04	9.12E+03	1.44E+03	1.82E+02	2.36E+01	2.19E+00	1.71E-01	2.48E-02	6.79E-03	2.10E-03	6.54E-04	2.04E-04	6.38E-05	1.98E-05	6.15E-06	1.94E-06	7.51E-07
5.65E+04	1.35E+05	1.39E+05	1.44E+05	1.30E+05	1.17E+05	1.08E+05	1.04E+05	1.30E+05	1.88E+05	2.04E+05	1.80E+05	1.49E+05	1.04E+05	6.50E+04	3.15E+04	9.14E+03	1.45E+03	1.86E+02	2.45E+01	2.27E+00	1.70E-01	2.34E-02	6.28E-03	1.94E-03	6.06E-04	1.89E-04	5.90E-05	1.84E-05	5.69E-06	1.79E-06	6.96E-07
4.39E+04	1.06E+05	1.11E+05	1.19E+05	1.10E+05	1.03E+05	9.73E+04	9.52E+04	1.20E+05	1.74E+05	1.89E+05	1.67E+05	1.39E+05	9.77E+04	6.12E+04	2.97E+04	8.64E+03	1.37E+03	1.77E+02	2.35E+01	2.16E+00	1.60E-01	2.16E-02	5.80E-03	1.80E-03	5.62E-04	1.76E-04	5.49E-05	1.71E-05	5.30E-06	1.67E-06	6.48E-07
3.51E+04	8.44E+04	8.79E+04	9.34E+04	8.73E+04	8.37E+04	8.09E+04	8.20E+04	1.08E+05	1.60E+05	1.75E+05	1.55E+05	1.29E+05	9.08E+04	5.69E+04	2.76E+04	8.02E+03	1.27E+03	1.64E+02	2.17E+01	1.99E+00	1.46E-01	1.92E-02	5.15E-03	1.60E-03	5.01E-04	1.57E-04	4.90E-05	1.53E-05	4.74E-06	1.49E-06	5.79E-07
2.30E+04	5.60E+04	6.17E+04	6.99E+04	6.73E+04	6.53E+04	6.36E+04	6.60E+04	9.13E+04	1.42E+05	1.57E+05	1.41E+05	1.18E+05	8.36E+04	5.24E+04	2.55E+04	7.40E+03	1.17E+03	1.52E+02	2.00E+01	1.83E+00	1.31E-01	1.69E-02	4.49E-03	1.39E-03	4.38E-04	1.37E-04	4.30E-05	1.34E-05	4.15E-06	1.31E-06	5.08E-07
2.89E+04	6.77E+04	6.36E+04	5.87E+04	5.18E+04	4.96E+04	4.89E+04	5.18E+04	7.48E+04	1.21E+05	1.36E+05	1.23E+05	1.05E+05	7.48E+04	4.72E+04	2.29E+04	6.66E+03	1.05E+03	1.36E+02	1.79E+01	1.62E+00	1.12E-01	1.34E-02	3.47E-03	1.07E-03	3.37E-04	1.06E-04	3.30E-05	1.03E-05	3.18E-06	1.00E-06	3.88E-07
8.54E+04	1.95E+05	1.62E+05	1.16E+05	7.85E+04	5.59E+04	4.43E+04	4.23E+04	6.10E+04	1.01E+05	1.16E+05	1.06E+05	9.14E+04	6.56E+04	4.15E+04	2.02E+04	5.86E+03	9.21E+02	1.18E+02	1.56E+01	1.40E+00	9.72E-02	1.18E-02	3.05E-03	9.44E-04	2.96E-04	9.25E-05	2.89E-05	8.98E-06	2.78E-06	8.76E-07	3.39E-07
6.35E+04	1.53E+05	1.62E+05	1.71E+05	1.41E+05	1.04E+05	7.39E+04	5.62E+04	6.11E+04	8.93E+04	9.93E+04	9.00E+04	7.78E+04	5.60E+04	3.53E+04	1.70E+04	4.83E+03	7.37E+02	9.21E+01	1.19E+01	1.09E+00	9.08E-02	1.48E-02	4.10E-03	1.24E-03	3.82E-04	1.18E-04	3.65E-05	1.13E-05	3.50E-06	1.10E-06	4.27E-07
2.92E+04	7.36E+04	9.10E+04	1.16E+05	1.18E+05	1.18E+05	1.09E+05	9.36E+04	8.93E+04	1.02E+05	1.00E+05	8.40E+04	6.86E+04	4.77E+04	2.91E+04	1.35E+04	3.64E+03	5.18E+02	6.01E+01	7.31E+00	6.61E-01	5.84E-02	9.93E-03	2.63E-03	7.57E-04	2.23E-04	6.67E-05	2.03E-05	6.23E-06	1.92E-06	6.01E-07	2.33E-07
9.66E+03	2.53E+04	3.57E+04	5.19E+04	6.12E+04	7.23E+04	7.99E+04	8.54E+04	1.01E+05	1.25E+05	1.21E+05	9.76E+04	7.30E+04	4.69E+04	2.69E+04	1.17E+04	2.97E+03	3.97E+02	4.24E+01	4.81E+00	4.16E-01	3.31E-02	4.87E-03	1.20E-03	3.29E-04	9.37E-05	2.75E-05	8.24E-06	2.51E-06	7.69E-07	2.41E-07	9.31E-08
4.43E+03	1.12E+04	1.39E+04	1.89E+04	2.36E+04	3.09E+04	3.85E+04	4.88E+04	7.44E+04	1.13E+05	1.22E+05	1.05E+05	8.14E+04	5.22E+04	2.92E+04	1.22E+04	2.93E+03	3.81E+02	3.81E+01	4.02E+00	3.27E-01	1.91E-02	1.32E-03	2.02E-04	4.64E-05	1.18E-05	3.24E-06	9.32E-07	2.78E-07	8.41E-08	2.62E-08	1.01E-08
5.87E+03	1.37E+04	1.28E+04	1.18E+04	1.12E+04	1.23E+04	1.50E+04	2.13E+04	4.10E+04	7.50E+04	8.83E+04	8.13E+04	6.75E+04	4.57E+04	2.67E+04	1.15E+04	2.91E+03	4.06E+02	4.54E+01	5.40E+00	4.61E-01	2.48E-02	1.06E-03	7.70E-05	1.36E-05	3.19E-06	8.29E-07	2.31E-07	6.77E-08	2.03E-08	6.26E-09	2.35E-09
3.01E+03	7.50E+03	8.90E+03	1.07E+04	9.95E+03	8.84E+03	8.36E+03	1.04E+04	2.21E+04	4.59E+04	5.72E+04	5.51E+04	4.89E+04	3.53E+04	2.19E+04	1.02E+04	2.79E+03	4.21E+02	5.37E+01	7.16E+00	6.36E-01	3.53E-02	1.82E-03	2.39E-04	6.39E-05	1.91E-05	5.84E-06	1.80E-06	5.55E-07	1.71E-07	5.39E-08	2.09E-08
2.11E+04	4.79E+04	3.75E+04	2.35E+04	1.44E+04	1.03E+04	8.59E+03	8.62E+03	1.49E+04	2.96E+04	3.67E+04	3.55E+04	3.25E+04	2.43E+04	1.57E+04	7.56E+03	2.15E+03	3.37E+02	4.62E+01	6.51E+00	5.87E-01	3.28E-02	1.77E-03	2.53E-04	7.11E-05	2.19E-05	6.78E-06	2.11E-06	6.54E-07	2.03E-07	6.37E-08	2.45E-08
2.04E+04	4.86E+04	4.80E+04	4.62E+04	3.54E+04	2.37E+04	1.52E+04	1.10E+04	1.31E+04	2.16E+04	2.54E+04	2.40E+04	2.17E+04	1.62E+04	1.05E+04	5.12E+03	1.48E+03	2.36E+02	3.35E+01	4.86E+00	4.58E-01	3.19E-02	3.82E-03	1.01E-03	3.17E-04	1.01E-04	3.20E-05	1.01E-05	3.14E-06	9.78E-07	3.09E-07	1.20E-07
5.16E+04	1.18E+05	1.00E+05	7.49E+04	5.34E+04	4.06E+04	3.17E+04	2.40E+04	2.03E+04	2.17E+04	2.12E+04	1.83E+04	1.55E+04	1.12E+04	7.14E+03	3.45E+03	9.81E+02	1.53E+02	2.12E+01	3.00E+00	2.89E-01	2.49E-02	4.25E-03	1.22E-03	3.82E-04	1.20E-04	3.77E-05	1.18E-05	3.67E-06	1.14E-06	3.59E-07	1.39E-07
3.97E+04	9.56E+04	1.00E+05	1.05E+05	8.65E+04	6.50E+04	4.79E+04	3.67E+04	3.24E+04	3.28E+04	2.92E+04	2.26E+04	1.66E+04	1.09E+04	6.51E+03	3.06E+03	8.65E+02	1.36E+02	1.87E+01	2.69E+00	2.97E-01	3.87E-02	9.47E-03	2.97E-03	9.54E-04	3.05E-04	9.67E-05	3.04E-05	9.51E-06	2.96E-06	9.33E-07	3.62E-07
3.72E+04	8.86E+04	8.86E+04	8.94E+04	8.12E+04	7.55E+04	6.79E+04	5.72E+04	5.01E+04	4.79E+04	4.12E+04	3.13E+04	2.22E+04	1.38E+04	7.87E+03	3.55E+03	9.84E+02	1.53E+02	1.96E+01	2.69E+00	3.05E-01	4.40E-02	1.14E-02	3.60E-03	1.16E-03	3.71E-04	1.18E-04	3.71E-05	1.16E-05	3.60E-06	1.14E-06	4.41E-07
3.40E+04	8.11E+04	8.16E+04	8.23E+04	7.30E+04	6.59E+04	6.07E+04	5.74E+04	6.06E+04	6.65E+04	6.02E+04	4.59E+04	3.17E+04	1.91E+04	1.07E+04	4.81E+03	1.34E+03	2.08E+02	2.57E+01	3.34E+00	3.61E-01	4.72E-02	1.15E-02	3.60E-03	1.15E-03	3.67E-04	1.16E-04	3.65E-05	1.14E-05	3.53E-06	1.11E-06	4.32E-07
1.29E+04	3.33E+04	4.41E+04	5.89E+04	5.95E+04	5.75E+04	5.42E+04	5.15E+04	5.73E+04	7.03E+04	6.94E+04	5.71E+04	4.24E+04	2.68E+04	1.54E+04	6.96E+03	1.93E+03	3.00E+02	3.60E+01	4.50E+00	4.50E-01	4.93E-02	1.06E-02	3.21E-03	1.02E-03	3.22E-04	1.01E-04	3.17E-05	9.88E-06	3.06E-06	9.65E-07	3.75E-07
5.44E+03	1.38E+04	1.78E+04	2.44E+04	2.95E+04	3.61E+04	4.03E+04	4.29E+04	5.26E+04	6.97E+04	7.13E+04	6.03E+04	4.68E+04	3.09E+04	1.84E+04	8.58E+03	2.42E+03	3.73E+02	4.48E+01	5.55E+00	5.07E-01	4.00E-02	5.97E-03	1.63E-03	5.02E-04	1.56E-04	4.86E-05	1.51E-05	4.69E-06	1.45E-06	4.56E-07	1.77E-07
3.12E+03	7.70E+03	8.86E+03	1.09E+04	1.24E+04	1.50E+04	1.84E+04	2.41E+04	3.86E+04	6.10E+04	6.69E+04	5.86E+04	4.70E+04	3.16E+04	1.90E+04	8.79E+03	2.43E+03	3.63E+02	4.31E+01	5.30E+00	4.60E-01	2.87E-02	2.62E-03	5.74E-04	1.68E-04	5.07E-05	1.55E-05	4.78E-06	1.47E-06	4.54E-07	1.43E-07	5.52E-08
2.36E+03	5.68E+03	6.02E+03	6.61E+03	6.64E+03	7.16E+03	8.19E+03	1.12E+04	2.29E+04	4.43E+04	5.30E+04	4.93E+04	4.20E+04	2.94E+04	1.80E+04	8.38E+03	2.29E+03	3.38E+02	3.98E+01	4.88E+00	4.14E-01	2.34E-02	1.50E-03	2.53E-04	6.96E-05	2.06E-05	6.22E-06	1.90E-06	5.82E-07	1.79E-07	5.59E-08	2.16E-08
2.13E+03	5.07E+03	5.11E+03	5.22E+03	4.80E+03	4.65E+03	4.80E+03	6.38E+03	1.46E+04	3.11E+04	3.84E+04	3.64E+04	3.23E+04	2.33E+04	1.45E+04	6.71E+03	1.79E+03	2.53E+02	2.95E+01	3.63E+00	3.05E-01	1.65E-02	8.49E-04	1.07E-04	2.67E-05	7.55E-06	2.22E-06	6.64E-07	2.01E-07	6.15E-08	1.92E-08	7.38E-09
2.40E+03	5.66E+03	5.42E+03	5.11E+03	4.38E+03	3.90E+03	3.71E+03	4.58E+03	1.04E+04	2.26E+04	2.80E+04	2.65E+04	2.39E+04	1.74E+04	1.08E+04	5.01E+03	1.33E+03	1.86E+02	2.23E+01	2.84E+00	2.41E-01	1.31E-02	7.28E-04	1.05E-04	2.79E-05	8.14E-06	2.43E-06	7.38E-07	2.26E-07	6.92E-08	2.16E-08	8.34E-09
3.19E+03	7.47E+03	6.92E+03	6.16E+03	4.96E+03	4.08E+03	3.56E+03	3.93E+03	8.05E+03	1.69E+04	2.07E+04	1.95E+04	1.75E+04	1.27E+04	7.86E+03	3.60E+03	9.35E+02	1.28E+02	1.52E+01	1.91E+00	1.61E-01	9.10E-03	6.39E-04	1.20E-04	3.39E-05	1.01E-05	3.07E-06	9.40E-07	2.89E-07	8.88E-08	2.78E-08	1.07E-08
3.54E+03	8.34E+03	8.01E+03	7.51E+03	6.15E+03	4.97E+03	4.14E+03	4.03E+03	6.80E+03	1.31E+04	1.57E+04	1.46E+04	1.30E+04	9.36E+03	5.75E+03	2.62E+03	6.79E+02	9.28E+01	1.10E+01	1.39E+00	1.18E-01	7.43E-03	7.49E-04	1.79E-04	5.39E-05	1.66E-05	5.13E-06	1.59E-06	4.91E-07	1.52E-07	4.77E-08	1.84E-08
8.72E+03	2.00E+04	1.69E+04	1.27E+04	8.97E+03	6.69E+03	5.32E+03	4.75E+03	6.51E+03	1.10E+04	1.26E+04	1.15E+04	1.00E+04	7.15E+03	4.37E+03	2.00E+03	5.22E+02	7.26E+01	8.76E+00	1.12E+00	9.85E-02	7.05E-03	9.47E-04	2.56E-04	7.98E-05	2.51E-05	7.86E-06	2.46E-06	7.63E-07	2.36E-07	7.44E-08	2.88E-08
3.53E+03	9.02E+03	1.16E+04	1.48E+04	1.33E+04	1.05E+04	7.94E+03	6.38E+03	7.15E+03	1.03E+04	1.10E+04	9.60E+03	8.04E+03	5.62E+03	3.41E+03	1.56E+03	4.14E+02	5.91E+01	7.28E+00	9.53E-01	9.09E-02	8.71E-03	1.72E-03	5.18E-04	1.66E-04	5.29E-05	1.67E-05	5.26E-06	1.64E-06	5.09E-07	1.60E-07	6.20E-08
1.08E+04	2.46E+04	2.04E+04	1.50E+04	1.17E+04	1.09E+04	1.03E+04	9.25E+03	9.42E+03	1.13E+04	1.10E+04	9.08E+03	7.21E+03	4.88E+03	2.93E+03	1.34E+03	3.61E+02	5.31E+01	6.58E+00	8.61E-01	8.33E-02	8.13E-03	1.62E-03	4.92E-04	1.58E-04	5.03E-05	1.59E-05	5.00E-06	1.56E-06	4.83E-07	1.52E-07	5.87E-08
6.51E+03	1.60E+04	1.80E+04	2.02E+04	1.71E+04	1.29E+04	9.91E+03	8.69E+03	9.97E+03	1.28E+04	1.26E+04	1.02E+04	7.70E+03	5.00E+03	2.92E+03	1.33E+03	3.64E+02	5.50E+01	6.87E+00	9.09E-01	9.39E-02	1.10E-02	2.53E-03	7.90E-04	2.55E-04	8.18E-05	2.60E-05	8.19E-06	2.56E-06	7.95E-07	2.50E-07	9.71E-08
2.14E+04	4.89E+04	4.02E+04	2.87E+04	2.05E+04	1.66E+04	1.42E+04	1.19E+04	1.15E+04	1.33E+04	1.30E+04	1.08E+04	8.44E+03	5.60E+03	3.32E+03	1.53E+03	4.27E+02	6.58E+01	8.15E+00	1.06E+00	1.08E-01	1.20E-02	2.66E-03	8.25E-04	2.66E-04	8.53E-05	2.71E-05	8.54E-06	2.67E-06	8.28E-07	2.61E-07	1.01E-07
8.34E+03	2.14E+04	2.80E+04	3.59E+04	3.19E+04	2.44E+04	1.80E+04	1.44E+04	1.43E+04	1.64E+04	1.55E+04	1.23E+04	9.24E+03	6.03E+03	3.60E+03	1.70E+03	4.86E+02	7.74E+01	1.00E+01	1.36E+00	1.48E-01	1.91E-02	4.63E-03	1.46E-03	4.73E-04	1.52E-04	4.83E-05	1.52E-05	4.75E-06	1.48E-06	4.65E-07	1.80E-07
1.42E+04	3.29E+04	2.94E+04	2.54E+04	2.32E+04	2.42E+04	2.40E+04	2.13E+04	1.97E+04	2.04E+04	1.85E+04	1.47E+04	1.10E+04	7.10E+03	4.19E+03	1.96E+03	5.60E+02	8.93E+01	1.15E+01	1.55E+00	1.63E-01	1.91E-02	4.36E-03	1.36E-03	4.40E-04	1.41E-04	4.49E-05	1.42E-05	4.42E-06	1.37E-06	4.33E-07	1.68E-07
2.35E+04	5.46E+04	4.87E+04	4.04E+04	3.00E+04	2.25E+04	1.85E+04	1.78E+04	2.10E+04	2.56E+04	2.44E+04	1.92E+04	1.38E+04	8.69E+03	5.06E+03	2.36E+03	6.79E+02	1.09E+02	1.40E+01	1.88E+00	1.96E-01	2.23E-02	4.98E-03	1.55E-03	5.02E-04	1.61E-04	5.14E-05	1.62E-05	5.07E-06	1.58E-06	4.97E-07	1.93E-07
6.69E+03	1.80E+04	2.66E+04	3.78E+04	3.63E+04	3.10E+04	2.51E+04	2.05E+04	2.03E+04	2.48E+04	2.51E+04	2.14E+04	1.67E+04	1.10E+04	6.55E+03	3.07E+03	8.79E+02	1.41E+02	1.78E+01	2.37E+00	2.48E-01	2.90E-02	6.63E-03	2.08E-03	6.73E-04	2.16E-04	6.90E-05	2.18E-05	6.82E-06	2.12E-06	6.69E-07	2.60E-07
5.43E+03	1.30E+04	1.36E+04	1.55E+04	1.83E+04	2.30E+04	2.54E+04	2.48E+04	2.59E+04	2.97E+04	2.82E+04	2.29E+04	1.76E+04	1.18E+04	7.26E+03	3.52E+03	1.04E+03	1.69E+02	2.20E+01	2.96E+00	2.95E-01	2.85E-02	5.57E-03	1.69E-03	5.46E-04	1.75E-04	5.58E-05	1.76E-05	5.50E-06	1.71E-06	5.40E-07	2.10E-07
4.06E+03	9.79E+03	1.04E+04	1.13E+04	1.07E+04	1.07E+04	1.18E+04	1.48E+04	2.19E+04	3.11E+04	3.21E+04	2.68E+04	2.04E+04	1.34E+04	7.99E+03	3.81E+03	1.11E+03	1.80E+02	2.36E+01	3.18E+00	3.08E-01	2.66E-02	4.57E-03	1.35E-03	4.34E-04	1.39E-04	4.42E-05	1.39E-05	4.35E-06	1.35E-06	4.26E-07	1.66E-07
4.67E+03	1.10E+04	1.05E+04	9.95E+03	8.75E+03	8.17E+03	7.91E+03	8.57E+03	1.36E+04	2.36E+04	2.74E+04	2.52E+04	2.11E+04	1.46E+04	9.05E+03	4.36E+03	1.27E+03	2.06E+02	2.64E+01	3.48E+00	3.26E-01	2.54E-02	3.76E-03	1.07E-03	3.42E-04	1.09E-04	3.47E-05	1.09E-05	3.41E-06	1.06E-06	3.34E-07	1.30E-07
2.72E+04	6.17E+04	4.87E+04	3.10E+04	1.84E+04	1.16E+04	8.38E+03	7.54E+03	1.10E+04	1.89E+04	2.20E+04	2.04E+04	1.79E+04	1.31E+04	8.52E+03	4.28E+03	1.29E+03	2.13E+02	2.84E+01	3.86E+00	3.62E-01	2.62E-02	3.40E-03	9.27E-04	2.95E-04	9.43E-05	2.99E-05	9.39E-06	2.93E-06	9.10E-07	2.87E-07	1.11E-07
3.24E+04	7.62E+04	7.21E+04	6.51E+04	4.84E+04	3.19E+04	2.01E+04	1.33E+04	1.25E+04	1.72E+04	1.88E+04	1.71E+04	1.49E+04	1.09E+04	7.12E+03	3.60E+03	1.09E+03	1.81E+02	2.50E+01	3.54E+00	3.51E-01	3.19E-02	5.77E-03	1.71E-03	5.49E-04	1.75E-04	5.55E-05	1.75E-05	5.46E-06	1.70E-06	5.35E-07	2.08E-07
1.92E+04	4.73E+04	5.36E+04	6.18E+04	5.68E+04	4.94E+04	4.08E+04	3.14E+04	2.54E+04	2.41E+04	2.13E+04	1.70E+04	1.36E+04	9.49E+03	6.04E+03	3.02E+03	9.13E+02	1.52E+02	2.13E+01	3.08E+00	3.28E-01	3.72E-02	8.27E-03	2.57E-03	8.29E-04	2.66E-04	8.46E-05	2.67E-05	8.35E-06	2.60E-06	8.20E-07	3.19E-07
4.00E+03	1.14E+04	1.95E+04	3.13E+04	3.61E+04	3.99E+04	4.06E+04	3.87E+04	3.83E+04	3.92E+04	3.39E+04	2.51E+04	1.72E+04	1.06E+04	6.14E+03	2.90E+03	8.47E+02	1.39E+02	1.88E+01	2.67E+00	2.89E-01	3.51E-02	8.21E-03	2.57E-03	8.33E-04	2.67E-04	8.51E-05	2.68E-05	8.40E-06	2.61E-06	8.25E-07	3.21E-07
8.87E+03	2.04E+04	1.76E+04	1.48E+04	1.51E+04	1.91E+04	2.32E+04	2.72E+04	3.48E+04	4.43E+04	4.35E+04	3.50E+04	2.51E+04	1.55E+04	8.76E+03	3.97E+03	1.12E+03	1.77E+02	2.20E+01	2.85E+00	2.86E-01	3.02E-02	6.38E-03	1.97E-03	6.35E-04	2.04E-04	6.48E-05	2.04E-05	6.38E-06	1.99E-06	6.26E-07	2.43E-07
9.50E+03	2.25E+04	2.18E+04	2.05E+04	1.62E+04	1.26E+04	1.11E+04	1.31E+04	2.20E+04	3.63E+04	4.08E+04	3.64E+04	2.90E+04	1.94E+04	1.17E+04	5.52E+03	1.59E+03	2.54E+02	3.14E+01	4.00E+00	3.80E-01	3.29E-02	5.71E-03	1.69E-03	5.43E-04	1.74E-04	5.53E-05	1.74E-05	5.44E-06	1.69E-06	5.34E-07	2.07E-07
6.18E+03	1.51E+04	1.66E+04	1.87E+04	1.72E+04	1.53E+04	1.32E+04	1.20E+04	1.61E+04	2.73E+04	3.20E+04	2.99E+04	2.60E+04	1.87E+04	1.19E+04	5.88E+03	1.74E+03	2.83E+02	3.66E+01	4.85E+00	4.53E-01	3.45E-02	4.91E-03	1.37E-03	4.37E-04	1.39E-04	4.42E-05	1.39E-05	4.33E-06	1.35E-06	4.24E-07	1.65E-07

Table 26. Estimated population size (thousands) for males on July 1 of year. from the author's preferred mode, Model A.

year	Size bin 27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	102.5	107.5	112.5	117.5	122.5	127.5	132.5	137.5	142.5	147.5	152.5	157.5	162.5	167.5	172.5	177.5	182.5
1949	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1950	4.58E+03	1.07E+04	1.02E+04	9.11E+03	7.01E+03	4.92E+03	3.05E+03	1.74E+03	9.51E+02	4.99E+02	2.53E+02	1.25E+02	6.05E+01	2.88E+01	1.35E+01	6.23E+00	2.85E+00	1.29E+00	5.77E-01	2.56E-01	1.13E-01	4.95E-02	2.16E-02	9.34E-03	4.01E-03	1.70E-03	7.12E-04	2.92E-04	1.17E-04	4.58E-05	1.81E-05	9.06E-06
1951	4.61E+03	1.07E+04	1.03E+04	9.30E+03	7.76E+03	6.55E+03	5.67E+03	4.66E+03	3.67E+03	2.78E+03	1.99E+03	1.35E+03	8.83E+02	5.64E+02	3.51E+02	2.13E+02	1.27E+02	7.39E+01	4.21E+01	2.34E+01	1.27E+01	6.75E+00	3.58E+00	1.89E+00	9.78E-01	4.79E-01	2.16E-01	8.59E-02	2.83E-02	6.84E-03	9.99E-04	1.58E-05
1952	4.66E+03	1.08E+04	1.04E+04	9.38E+03	7.82E+03	6.61E+03	5.81E+03	5.01E+03	4.33E+03	3.83E+03	3.42E+03	2.99E+03	2.55E+03	2.13E+03	1.73E+03	1.36E+03	1.02E+03	7.51E+02	5.35E+02	3.68E+02	2.45E+02	1.60E+02	1.04E+02	6.68E+01	4.15E+01	2.42E+01	1.29E+01	6.01E+00	2.31E+00	6.53E-01	1.09E-01	3.74E-05
1953	4.74E+03	1.10E+04	1.05E+04	9.50E+03	7.91E+03	6.68E+03	5.87E+03	5.07E+03	4.40E+03	3.92E+03	3.57E+03	3.25E+03	2.98E+03	2.77E+03	2.57E+03	2.32E+03	2.05E+03	1.82E+03	1.57E+03	1.32E+03	1.05E+03	8.20E+02	6.29E+02	4.77E+02	3.46E+02	2.34E+02	1.43E+02	7.65E+01	3.37E+01	1.10E+01	2.10E+00	1.92E-03
1954	4.86E+03	1.13E+04	1.08E+04	9.70E+03	8.06E+03	6.80E+03	5.96E+03	5.15E+03	4.47E+03	4.00E+03	3.67E+03	3.38E+03	3.16E+03	3.04E+03	2.92E+03	2.73E+03	2.50E+03	2.37E+03	2.24E+03	2.07E+03	1.81E+03	1.52E+03	1.26E+03	1.04E+03	8.26E+02	6.12E+02	4.12E+02	2.42E+02	1.18E+02	4.27E+01	9.06E+00	3.71E-02
1955	5.06E+03	1.18E+04	1.12E+04	1.00E+04	8.29E+03	6.98E+03	6.10E+03	5.26E+03	4.57E+03	4.10E+03	3.77E+03	3.50E+03	3.31E+03	3.26E+03	3.19E+03	3.03E+03	2.82E+03	2.77E+03	2.71E+03	2.61E+03	2.36E+03	2.04E+03	1.73E+03	1.46E+03	1.19E+03	9.06E+02	6.26E+02	3.78E+02	1.90E+02	7.11E+01	1.55E+01	1.60E-01
1956	5.36E+03	1.25E+04	1.18E+04	1.05E+04	8.66E+03	7.25E+03	6.32E+03	5.44E+03	4.71E+03	4.23E+03	3.90E+03	3.63E+03	3.46E+03	3.45E+03	3.42E+03	3.28E+03	3.08E+03	3.07E+03	3.07E+03	3.02E+03	2.77E+03	2.42E+03	2.07E+03	1.77E+03	1.46E+03	1.12E+03	7.82E+02	4.77E+02	2.41E+02	9.16E+01	2.02E+01	2.76E-01
1957	5.85E+03	1.36E+04	1.28E+04	1.13E+04	9.23E+03	7.68E+03	6.66E+03	5.70E+03	4.93E+03	4.41E+03	4.06E+03	3.78E+03	3.62E+03	3.63E+03	3.63E+03	3.50E+03	3.30E+03	3.33E+03	3.37E+03	3.35E+03	3.09E+03	2.72E+03	2.33E+03	2.01E+03	1.66E+03	1.28E+03	8.97E+02	5.50E+02	2.80E+02	1.07E+02	2.36E+01	3.60E-01
1958	6.66E+03	1.55E+04	1.44E+04	1.26E+04	1.02E+04	8.37E+03	7.18E+03	6.11E+03	5.25E+03	4.67E+03	4.29E+03	3.99E+03	3.82E+03	3.84E+03	3.85E+03	3.72E+03	3.51E+03	3.56E+03	3.62E+03	3.62E+03	3.35E+03	2.95E+03	2.54E+03	2.19E+03	1.82E+03	1.40E+03	9.86E+02	6.06E+02	3.09E+02	1.18E+02	2.62E+01	4.21E-01
1959	8.12E+03	1.88E+04	1.73E+04	1.48E+04	1.17E+04	9.53E+03	8.06E+03	6.77E+03	5.76E+03	5.09E+03	4.64E+03	4.29E+03	4.09E+03	4.10E+03	4.11E+03	3.97E+03	3.74E+03	3.80E+03	3.87E+03	3.87E+03	3.59E+03	3.17E+03	2.72E+03	2.35E+03	1.95E+03	1.51E+03	1.06E+03	6.52E+02	3.33E+02	1.27E+02	2.83E+01	4.68E-01
1960	1.11E+04	2.56E+04	2.31E+04	1.91E+04	1.47E+04	1.16E+04	9.61E+03	7.92E+03	6.64E+03	5.79E+03	5.21E+03	4.77E+03	4.50E+03	4.48E+03	4.46E+03	4.29E+03	4.03E+03	4.08E+03	4.15E+03	4.15E+03	3.84E+03	3.38E+03	2.90E+03	2.51E+03	2.08E+03	1.61E+03	1.13E+03	6.96E+02	3.55E+02	1.36E+02	3.02E+01	5.06E-01
1961	1.87E+04	4.29E+04	3.75E+04	2.92E+04	2.14E+04	1.62E+04	1.28E+04	1.02E+04	8.29E+03	7.05E+03	6.21E+03	5.58E+03	5.18E+03	5.07E+03	4.99E+03	4.76E+03	4.44E+03	4.46E+03	4.51E+03	4.49E+03	4.15E+03	3.64E+03	3.12E+03	2.69E+03	2.23E+03	1.72E+03	1.21E+03	7.43E+02	3.79E+02	1.45E+02	3.22E+01	5.40E-01
1962	4.10E+04	9.37E+04	7.91E+04	5.77E+04	3.96E+04	2.79E+04	2.06E+04	1.54E+04	1.20E+04	9.77E+03	8.28E+03	7.19E+03	6.47E+03	6.16E+03	5.92E+03	5.55E+03	5.11E+03	5.07E+03	5.06E+03	4.99E+03	4.58E+03	4.00E+03	3.42E+03	2.94E+03	2.43E+03	1.87E+03	1.31E+03	8.04E+02	4.10E+02	1.57E+02	3.47E+01	5.76E-01
1963	9.54E+04	2.18E+05	1.83E+05	1.31E+05	8.83E+04	6.02E+04	4.20E+04	2.98E+04	2.19E+04	1.68E+04	1.34E+04	1.10E+04	9.41E+03	8.51E+03	7.84E+03	7.13E+03	6.41E+03	6.18E+03	6.03E+03	5.84E+03	5.29E+03	4.58E+03	3.89E+03	3.32E+03	2.73E+03	2.10E+03	1.47E+03	8.95E+02	4.55E+02	1.73E+02	3.83E+01	6.20E-01
1964	1.48E+05	3.40E+05	3.01E+05	2.39E+05	1.74E+05	1.26E+05	9.11E+04	6.52E+04	4.75E+04	3.57E+04	2.74E+04	2.14E+04	1.73E+04	1.46E+04	1.27E+04	1.10E+04	9.46E+03	8.69E+03	8.12E+03	7.58E+03	6.71E+03	5.71E+03	4.78E+03	4.04E+03	3.29E+03	2.50E+03	1.73E+03	1.05E+03	5.31E+02	2.01E+02	4.43E+01	6.85E-01
1965	1.48E+05	3.44E+05	3.30E+05	2.98E+05	2.42E+05	1.93E+05	1.54E+05	1.20E+05	9.36E+04	7.36E+04	5.81E+04	4.59E+04	3.67E+04	3.03E+04	2.53E+04	2.11E+04	1.75E+04	1.52E+04	1.35E+04	1.19E+04	1.01E+04	8.39E+03	6.86E+03	5.67E+03	4.53E+03	3.39E+03	2.31E+03	1.39E+03	6.91E+02	2.58E+02	5.64E+01	7.92E-01
1966	1.18E+05	2.78E+05	2.81E+05	2.73E+05	2.38E+05	2.07E+05	1.84E+05	1.57E+05	1.32E+05	1.13E+05	9.58E+04	8.09E+04	6.84E+04	5.88E+04	5.05E+04	4.27E+04	3.56E+04	3.05E+04	2.63E+04	2.25E+04	1.85E+04	1.49E+04	1.19E+04	9.53E+03	7.42E+03	5.42E+03	3.61E+03	2.12E+03	1.03E+03	3.78E+02	8.08E+01	9.25E-01
1967	9.31E+04	2.19E+05	2.22E+05	2.18E+05	1.95E+05	1.76E+05	1.66E+05	1.50E+05	1.34E+05	1.22E+05	1.13E+05	1.03E+05	9.32E+04	8.59E+04	7.84E+04	6.98E+04	6.09E+04	5.45E+04	4.85E+04	4.25E+04	3.55E+04	2.89E+04	2.32E+04	1.87E+04	1.45E+04	1.06E+04	7.00E+03	4.07E+03	1.97E+03	7.13E+02	1.51E+02	1.36E+00
1968	7.78E+04	1.83E+05	1.82E+05	1.76E+05	1.55E+05	1.40E+05	1.33E+05	1.22E+05	1.13E+05	1.06E+05	1.03E+05	9.86E+04	9.50E+04	9.36E+04	9.11E+04	8.57E+04	7.85E+04	7.44E+04	6.95E+04	6.33E+04	5.42E+04	4.48E+04	3.66E+04	2.99E+04	2.36E+04	1.74E+04	1.16E+04	6.80E+03	3.30E+03	1.20E+03	2.53E+02	2.05E+00
1969	7.10E+04	1.66E+05	1.62E+05	1.52E+05	1.31E+05	1.16E+05	1.08E+05	9.90E+04	9.09E+04	8.65E+04	8.48E+04	8.34E+04	8.33E+04	8.64E+04	8.83E+04	8.63E+04	8.18E+04	8.15E+04	8.01E+04	7.63E+04	6.77E+04	5.74E+04	4.79E+04	4.02E+04	3.25E+04	2.45E+04	1.68E+04	1.00E+04	4.97E+03	1.84E+03	3.96E+02	3.66E+00
1970	6.74E+04	1.57E+05	1.53E+05	1.41E+05	1.20E+05	1.04E+05	9.48E+04	8.51E+04	7.71E+04	7.27E+04	7.10E+04	7.02E+04	7.13E+04	7.62E+04	8.00E+04	7.97E+04	7.67E+04	7.88E+04	7.98E+04	7.83E+04	7.06E+04	6.06E+04	5.10E+04	4.33E+04	3.55E+04	2.72E+04	1.89E+04	1.15E+04	5.78E+03	2.17E+03	4.74E+02	5.59E+00
1971	5.65E+04	1.33E+05	1.32E+05	1.27E+05	1.10E+05	9.65E+04	8.76E+04	7.81E+04	7.00E+04	6.53E+04	6.31E+04	6.22E+04	6.33E+04	6.83E+04	7.24E+04	7.27E+04	7.02E+04	7.32E+04	7.55E+04	7.51E+04	6.82E+04	5.88E+04	4.97E+04	4.25E+04	3.51E+04	2.71E+04	1.90E+04	1.16E+04	5.92E+03	2.25E+03	4.96E+02	7.06E+00
1972	4.39E+04	1.03E+05	1.05E+05	1.03E+05	9.22E+04	8.31E+04	7.80E+04	7.11E+04	6.45E+04	6.05E+04	5.86E+04	5.76E+04	5.85E+04	6.32E+04	6.71E+04	6.73E+04	6.50E+04	6.81E+04	7.05E+04	7.06E+04	6.43E+04	5.55E+04	4.69E+04	4.02E+04	3.32E+04	2.57E+04	1.81E+04	1.12E+04	5.70E+03	2.18E+03	4.83E+02	7.74E+00
1973	3.51E+04	8.26E+04	8.33E+04	8.14E+04	7.27E+04	6.63E+04	6.35E+04	5.91E+04	5.48E+04	5.27E+04	5.22E+04	5.24E+04	5.39E+04	5.88E+04	6.28E+04	6.31E+04	6.09E+04	6.39E+04	6.63E+04	6.64E+04	6.05E+04	5.22E+04	4.41E+04	3.78E+04	3.12E+04	2.42E+04	1.70E+04	1.05E+04	5.37E+03	2.06E+03	4.57E+02	7.75E+00
1974	2.30E+04	5.45E+04	5.81E+04	6.04E+04	5.58E+04	5.17E+04	4.98E+04	4.66E+04	4.35E+04	4.24E+04	4.28E+04	4.38E+04	4.61E+04	5.13E+04	5.57E+04	5.67E+04	5.52E+04	5.85E+04	6.11E+04	6.16E+04	5.63E+04	4.87E+04	4.12E+04	3.54E+04	2.93E+04	2.27E+04	1.60E+04	9.85E+03	5.04E+03	1.93E+03	4.30E+02	7.44E+00
1975	2.89E+04	6.67E+04	6.12E+04	5.22E+04	4.32E+04	3.85E+04	3.74E+04	3.56E+04	3.38E+04	3.33E+04	3.39E+04	3.50E+04	3.74E+04	4.24E+04	4.68E+04	4.80E+04	4.71E+04	5.05E+04	5.32E+04	5.39E+04	4.94E+04	4.27E+04	3.62E+04	3.11E+04	2.58E+04	2.00E+04	1.41E+04	8.69E+03	4.45E+03	1.71E+03	3.80E+02	6.62E+00
1976	8.54E+04	1.94E+05	1.59E+05	1.09E+05	7.14E+04	4.93E+04	3.77E+04	3.08E+04	2.70E+04	2.59E+04	2.66E+04	2.81E+04	3.06E+04	3.55E+04	3.97E+04	4.11E+04	4.05E+04	4.36E+04	4.61E+04	4.67E+04	4.26E+04	3.66E+04	3.09E+04	2.65E+04	2.19E+04	1.70E+04	1.20E+04	7.40E+03	3.80E+03	1.46E+03	3.25E+02	5.74E+00
1977	6.35E+04	1.50E+05	1.54E+05	1.51E+05	1.26E+05	9.86E+04	7.31E+04	5.32E+04	3.98E+04	3.18E+04	2.76E+04	2.59E+04	2.65E+04	3.00E+04	3.33E+04	3.43E+04	3.37E+04	3.62E+04	3.77E+04	3.73E+04	3.29E+04	2.74E+04	2.25E+04	1.89E+04	1.55E+04	1.18E+04	8.30E+03	5.09E+03	2.59E+03	9.90E+02	2.19E+02	3.77E+00
1978	2.92E+04	7.09E+04	8.43E+04	9.84E+04	9.68E+04	9.30E+04	9.02E+04	8.09E+04	6.94E+04	5.86E+04	4.90E+04	4.14E+04	3.66E+04	3.53E+04	3.48E+04	3.30E+04	3.03E+04	3.02E+04	2.92E+04	2.65E+04	2.15E+04	1.66E+04	1.29E+04	1.04E+04	8.25E+03	6.19E+03	4.25E+03	2.56E+03	1.28E+03	4.77E+02	1.03E+02	1.51E+00
1979	9.66E+03	2.41E+04	3.25E+04	4.27E+04	4.69E+04	5.12E+04	5.71E+04	5.83E+04	5.73E+04	5.67E+04	5.63E+04	5.46E+04	5.24E+04	5.10E+04	4.87E+04	4.41E+04	3.83E+04	3.44E+04	2.98E+04	2.43E+04	1.81E+04	1.32E+04	9.72E+03	7.46E+03	5.64E+03	4.04E+03	2.65E+03	1.52E+03	7.28E+02	2.60E+02	5.40E+01	5.76E-01
1980	4.43E+03	1.08E+04	1.28E+04	1.55E+04	1.74E+04	2.04E+04	2.49E+04	2.79E+04	3.01E+04	3.31E+04	3.67E+04	3.95E+04	4.20E+04	4.53E+04	4.70E+04	4.54E+04	4.14E+04	3.78E+04	3.25E+04	2.60E+04	1.97E+04	1.49E+04	1.14E+04	8.73E+03	6.37E+03	4.27E+03	2.55E+03	1.31E+03	5.45E+02	1.64E+02	2.87E+01	8.78E-02
1981	5.87E+03	1.35E+04	1.23E+04	1.05E+04	8.97E+03	8.69E+03	9.55E+03	1.05E+04	1.17E+04	1.35E+04	1.59E+04	1.81E+04	2.04E+04	2.31E+04	2.51E+04	2.55E+04	2.44E+04	2.33E+04	2.10E+04	1.80E+04	1.51E+04	1.26E+04	1.07E+04	8.96E+03	7.06E+03	5.06E+03	3.20E+03	1.71E+03	7.37E+02	2.27E+02	4.00E+01	3.77E-02
1982	3.01E+03	7.25E+03	8.31E+03	9.25E+03	8.53E+03	7.48E+03	6.61E+03	5.94E+03	5.61E+03	5.80E+03	6.43E+03	7.27E+03	8.36E+03	9.94E+03	1.14E+04	1.22E+04	1.23E+04	1.28E+04	1.28E+04	1.24E+04	1.15E+04	1.04E+04	9.41E+03	8.50E+03	7.28E+03	5.73E+03	4.04E+03	2.47E+03	1.24E+03	4.62E+02	1.01E+02	4.87E-01
1983	2.11E+04	4.77E+04	3.71E+04	2.26E+04	1.31E+04	8.50E+03	6.76E+03	5.78E+03	5.10E+03	4.67E+03	4.41E+03	4.31E+03	4.42E+03	4.88E+03	5.41E+03	5.71E+03	5.80E+03	6.27E+03	6.67E+03	6.95E+03	6.79E+03	6.43E+03	6.00E+03	5.62E+03	4.99E+03	4.08E+03	2.99E+03	1.91E+03	1.00E+03	3.94E+02	9.03E+01	1.62E+00
1984	2.04E+04	4.77E+04	4.60E+04	4.15E+04	3.26E+04	2.37E+04	1.59E+04	1.04E+04	7.09E+03	5.28E+03	4.41E+03	3.96E+03	3.73E+03	3.73E+03	3.78E+03	3.71E+03	3.57E+03	3.67E+03	3.80E+03	3.93E+03	3.84E+03	3.63E+03	3.39E+03	3.18E+03	2.84E+03	2.35E+03	1.75E+03	1.13E+03	6.07E+02	2.44E+02	5.68E+01	1.62E+00
1985	5.16E+04	1.18E+05	9.79E+04	6.95E+04	4.76E+04	3.49E+04	2.79E+04	2.22E+04	1.75E+04	1.36E+04	1.03E+04	7.65E+03	5.78E+03	4.60E+03	3.88E+03	3.38E+03	3.01E+03	2.87E+03	2.77E+03	2.67E+03	2.46E+03	2.21E+03	1.97E+03	1.78E+03	1.54E+03	1.24E+03	9.00E+02	5.72E+02	3.02E+02	1.19E+02	2.75E+01	8.63E-01
1986	3.97E+04	9.34E+04	9.52E+04	9.26E+04	7.74E+04	6.08E+04	4.58E+04	3.40E+04	2.59E+04	2.07E+04	1.74E+04	1.48E+04	1.26E+04	1.09E+04	9.25E+03	7.72E+03	6.32E+03	5.34E+03	4.59E+03	4.02E+03	3.44E+03	2.92E+03	2.50E+03	2.21E+03	1.87E+03	1.47E+03	1.06E+03	6.64E+02	3.46E+02	1.36E+02	3.09E+01	8.51E-01
1987	3.72E+04	8.69E+04	8.45E+04	7.86E+04	6.81E+04	6.07E+04	5.64E+04	4.96E+04	4.21E+04	3.53E+04	2.90E+04	2.37E+04	1.96E+04	1.68E+04	1.46E+04	1.28E+04	1.11E+04	9.92E+03	8.81E+03	7.74E+03	6.54E+03	5.41E+03	4.46E+03	3.76E+03	3.02E+03	2.26E+03	1.53E+03	9.17E+02	4.57E+02	1.71E+02	3.76E+01	8.32E-01
1988	3.40E+04	7.95E+04	7.78E+04	7.25E+04	6.21E+04	5.39E+04	4.87E+04	4.34E+04	3.91E+04	3.64E+04	3.45E+04	3.22E+04	2.95E+04	2.71E+04	2.45E+04	2.15E+04	1.85E+04	1.62E+04	1.43E+04	1.24E+04	1.05E+04	8.63E+03	7.13E+03	6.03E+03	4.87E+03	3.64E+03	2.48E+03	1.48E+03	7.30E+02	2.71E+02	5.87E+01	8.17E-01
1989	1.29E+04	3.18E+04	4.06E+04	5.00E+04	4.94E+04	4.65E+04	4.38E+04	3.95E+04	3.55E+04	3.27E+04	3.08E+04	2.92E+04	2.80E+04	2.76E+04	2.72E+04	2.59E+04	2.41E+04	2.29E+04	2.14E+04	1.93E+04	1.66E+04	1.38E+04	1.14E+04	9.55E+03	7.61E+03	5.62E+03	3.76E+03	2.20E+03	1.07E+03	3.91E+02	8.34E+01	1.02E+00
1990	5.44E+03	1.33E+04	1.63E+04	2.02E+04	2.22E+04	2.50E+04	2.88E+04	2.97E+04	2.91E+04	2.84E+04	2.79E+04	2.72E+04	2.64E+04	2.65E+04	2.65E+04	2.55E+04	2.39E+04	2.33E+04	2.23E+04	2.06E+04	1.79E+04	1.50E+04	1.25E+04	1.08E+04	8.77E+03	6.58E+03	4.47E+03	2.65E+03	1.29E+03	4.71E+02	9.99E+01	9.68E-01
1991	3.12E+03	7.47E+03	8.27E+03	9.19E+03	9.48E+03	1.03E+04	1.20E+04	1.33E+04	1.46E+04	1.64E+04	1.87E+04	2.03E+04	2.15E+04	2.28E+04	2.38E+04	2.35E+04	2.22E+04	2.17E+04	2.05E+04	1.84E+04	1.54E+04	1.25E+04	1.03E+04	8.84E+03	7.16E+03	5.34E+03	3.61E+03	2.12E+03	1.03E+03	3.71E+02	7.81E+01	7.93E-01
1992	2.36E+03	5.55E+03	5.69E+03	5.71E+03	5.36E+03	5.32E+03	5.76E+03	6.18E+03	6.66E+03	7.63E+03	9.06E+03	1.06E+04	1.22E+04	1.43E+04	1.64E+04	1.74E+04	1.74E+04	1.82E+04	1.80E+04	1.69E+04	1.44E+04	1.18E+04	9.71E+03	8.33E+03	6.71E+03	4.99E+03	3.37E+03	1.99E+03	9.72E+02	3.54E+02	7.50E+01	6.50E-01
1993	2.13E+03	4.97E+03	4.87E+03	4.59E+03	4.03E+03	3.71E+03	3.72E+03	3.79E+03	3.90E+03	4.37E+03	5.18E+03	6.17E+03	7.07E+03	8.46E+03	9.98E+03	1.08E+04	1.10E+04	1.21E+04	1.26E+04	1.23E+04	1.07E+04	8.78E+03	7.14E+03	6.11E+03	4.84E+03	3.55E+03	2.40E+03	1.43E+03	7.14E+02	2.66E+02	5.79E+01	4.28E-01
1994	2.40E+03	5.57E+03	5.21E+03	4.56E+03	3.76E+03	3.25E+03	3.06E+03	2.96E+03	2.92E+03	3.16E+03	3.68E+03	4.32E+03	4.82E+03	5.67E+03	6.70E+03	7.26E+03	7.37E+03	8.21E+03	8.71E+03	8.63E+03	7.52E+03	6.10E+03	4.93E+03	4.29E+03	3.42E+03	2.52E+03	1.73E+03	1.05E+03	5.33E+02	2.04E+02	4.53E+01	6.00E-01
1995	3.19E+03	7.36E+03	6.68E+03	5.55E+03	4.34E+03	3.52E+03	3.08E+03	2.78E+03	2.59E+03	2.67E+03	2.98E+03	3.39E+03	3.66E+03	4.19E+03	4.88E+03	5.25E+03	5.30E+03	5.91E+03	6.30E+03	6.27E+03	5.46E+03	4.40E+03	3.53E+03	3.06E+03	2.39E+03	1.73E+03	1.16E+03	7.00E+02	3.55E+02	1.36E+02	3.05E+01	5.15E-01
1996	3.54E+03	8.21E+03	7.69E+03	6.72E+03	5.40E+03	4.37E+03	3.68E+03	3.14E+03	2.76E+03	2.65E+03	2.75E+03	2.96E+03	3.04E+03	3.32E+03	3.75E+03	3.95E+03	3.92E+03	4.28E+03	4.48E+03	4.38E+03	3.76E+03	3.02E+03	2.45E+03	2.19E+03	1.76E+03	1.28E+03	8.73E+02	5.28E+02	2.69E+02	1.03E+02	2.31E+01	4.54E-01
1997	8.72E+03	1.99E+04	1.66E+04	1.18E+04	8.04E+03	5.83E+03	4.64E+03	3.83E+03	3.27E+03	2.98E+03	2.89E+03	2.89E+03	2.81E+03	2.91E+03	3.13E+03	3.19E+03	3.10E+03	3.31E+03	3.44E+03	3.36E+03	2.93E+03	2.39E+03	1.97E+03	1.77E+03	1.44E+03	1.07E+03	7.30E+02	4.44E+02	2.26E+02	8.71E+01	1.95E+01	3.90E-01
1998	3.53E+03	8.65E+03	1.08E+04	1.28E+04	1.18E+04	9.77E+03	7.63E+03	5.82E+03	4.55E+03	3.81E+03	3.43E+03	3.22E+03	3.03E+03	3.01E+03	3.07E+03	3.01E+03	2.85E+03	2.96E+03	3.00E+03	2.92E+03	2.56E+03	2.12E+03	1.76E+03	1.58E+03	1.29E+03	9.68E+02	6.67E+02	4.06E+02	2.07E+02	7.96E+01	1.78E+01	3.53E-01
1999	1.08E+04	2.45E+04	2.00E+04	1.39E+04	9.81E+03	8.19E+03	8.00E+03	7.49E+03	6.72E+03	5.93E+03	5.18E+03	4.53E+03	3.97E+03	3.66E+03	3.48E+03	3.25E+03	2.98E+03	2.98E+03	2.96E+03	2.85E+03	2.51E+03	2.11E+03	1.77E+03	1.56E+03	1.28E+03	9.67E+02	6.68E+02	4.07E+02	2.07E+02	7.90E+01	1.76E+01	3.28E-01
2000	6.51E+03	1.55E+04	1.69E+04	1.77E+04	1.53E+04	1.22E+04	9.21E+03	7.02E+03	5.75E+03	5.25E+03	5.19E+03	5.16E+03	5.01E+03	4.90E+03	4.72E+03	4.36E+03	3.91E+03	3.73E+03	3.55E+03	3.32E+03	2.90E+03	2.43E+03	2.02E+03	1.75E+03	1.43E+03	1.08E+03	7.45E+02	4.52E+02	2.29E+02	8.71E+01	1.93E+01	3.30E-01
2001	2.14E+04	4.86E+04	3.95E+04	2.68E+04	1.79E+04	1.35E+04	1.17E+04	1.01E+04	8.65E+03	7.35E+03	6.23E+03	5.37E+03	4.80E+03	4.64E+03	4.60E+03	4.47E+03	4.26E+03	4.30E+03	4.29E+03	4.14E+03	3.70E+03	3.16E+03	2.65E+03	2.27E+03	1.84E+03	1.38E+03	9.49E+02	5.71E+02	2.86E+02	1.07E+02	2.35E+01	3.60E-01
2002	8.34E+03	2.05E+04	2.58E+04	3.10E+04	2.84E+04	2.31E+04	1.75E+04	1.29E+04	9.95E+03	8.34E+03	7.55E+03	7.00E+03	6.54E+03	6.26E+03	5.93E+03	5.43E+03	4.87E+03	4.69E+03	4.59E+03	4.46E+03	4.05E+03	3.52E+03	3.01E+03	2.61E+03	2.17E+03	1.67E+03	1.17E+03	7.18E+02	3.66E+02	1.40E+02	3.09E+01	4.34E-01
2003	1.42E+04	3.26E+04	2.84E+04	2.26E+04	1.86E+04	1.76E+04	1.85E+04	1.76E+04	1.57E+04	1.36E+04	1.14E+04	9.50E+03	8.13E+03	7.41E+03	6.95E+03	6.45E+03	5.94E+03	5.85E+03	5.76E+03	5.57E+03	5.04E+03	4.36E+03	3.70E+03	3.15E+03	2.58E+03	1.97E+03	1.37E+03	8.30E+02	4.20E+02	1.60E+02	3.53E+01	5.81E-01
2004	2.35E+04	5.39E+04	4.73E+04	3.69E+04	2.70E+04	2.00E+04	1.55E+04	1.27E+04	1.13E+04	1.11E+04	1.14E+04	1.14E+04	1.12E+04	1.09E+04	1.03E+04	9.35E+03	8.27E+03	7.73E+03	7.33E+03	6.94E+03	6.21E+03	5.36E+03	4.54E+03	3.88E+03	3.19E+03	2.45E+03	1.72E+03	1.05E+03	5.34E+02	2.03E+02	4.50E+01	6.71E-01
2005	6.69E+03	1.70E+04	2.42E+04	3.21E+04	3.13E+04	2.75E+04	2.30E+04	1.84E+04	1.48E+04	1.22E+04	1.05E+04	9.38E+03	8.95E+03	9.23E+03	9.57E+03	9.57E+03	9.30E+03	9.49E+03	9.53E+03	9.30E+03	8.45E+03	7.33E+03	6.21E+03	5.24E+03	4.26E+03	3.23E+03	2.23E+03	1.35E+03	6.77E+02	2.55E+02	5.59E+01	8.53E-01
2006	5.43E+03	1.28E+04	1.29E+04	1.30E+04	1.35E+04	1.54E+04	1.83E+04	1.88E+04	1.78E+04	1.63E+04	1.48E+04	1.32E+04	1.19E+04	1.13E+04	1.08E+04	1.01E+04	9.26E+03	9.30E+03	9.50E+03	9.60E+03	9.01E+03	8.04E+03	7.00E+03	6.09E+03	5.09E+03	3.97E+03	2.80E+03	1.73E+03	8.81E+02	3.37E+02	7.47E+01	1.04E+00
2007	4.06E+03	9.56E+03	9.82E+03	9.81E+03	8.85E+03	8.16E+03	8.07E+03	8.27E+03	8.84E+03	9.97E+03	1.13E+04	1.22E+04	1.28E+04	1.33E+04	1.34E+04	1.28E+04	1.18E+04	1.15E+04	1.13E+04	1.10E+04	1.01E+04	8.82E+03	7.56E+03	6.49E+03	5.37E+03	4.15E+03	2.92E+03	1.80E+03	9.19E+02	3.53E+02	7.86E+01	1.36E+00
2008	4.67E+03	1.08E+04	1.01E+04	8.83E+03	7.36E+03	6.49E+03	6.18E+03	5.83E+03	5.53E+03	5.54E+03	5.85E+03	6.42E+03	7.35E+03	8.88E+03	1.02E+04	1.08E+04	1.09E+04	1.17E+04	1.22E+04	1.23E+04	1.15E+04	1.02E+04	8.84E+03	7.60E+03	6.28E+03	4.83E+03	3.38E+03	2.06E+03	1.05E+03	3.98E+02	8.79E+01	1.44E+00
2009	2.72E+04	6.15E+04	4.82E+04	2.98E+04	1.72E+04	1.04E+04	7.24E+03	5.61E+03	4.78E+03	4.54E+03	4.65E+03	4.95E+03	5.53E+03	6.65E+03	7.62E+03	8.02E+03	8.08E+03	9.06E+03	1.01E+04	1.09E+04	1.07E+04	9.81E+03	8.70E+03	7.70E+03	6.53E+03	5.16E+03	3.69E+03	2.30E+03	1.18E+03	4.57E+02	1.02E+02	1.61E+00
2010	3.24E+04	7.51E+04	6.94E+04	5.90E+04	4.46E+04	3.19E+04	2.14E+04	1.40E+04	9.45E+03	6.86E+03	5.54E+03	5.00E+03	5.07E+03	5.81E+03	6.53E+03	6.81E+03	6.80E+03	7.64E+03	8.58E+03	9.39E+03	9.27E+03	8.58E+03	7.64E+03	6.78E+03	5.76E+03	4.54E+03	3.24E+03	2.02E+03	1.04E+03	4.07E+02	9.18E+01	1.81E+00
2011	1.92E+04	4.59E+04	5.03E+04	5.36E+04	4.86E+04	4.23E+04	3.66E+04	3.00E+04	2.39E+04	1.88E+04	1.45E+04	1.12E+04	9.12E+03	8.18E+03	7.69E+03	7.16E+03	6.63E+03	7.03E+03	7.64E+03	8.23E+03	8.08E+03	7.47E+03	6.66E+03	5.92E+03	5.04E+03	3.98E+03	2.85E+03	1.78E+03	9.22E+02	3.60E+02	8.12E+01	1.76E+00
2012	4.00E+03	1.06E+04	1.74E+04	2.57E+04	2.84E+04	2.98E+04	3.12E+04	2.99E+04	2.74E+04	2.51E+04	2.28E+04	2.03E+04	1.81E+04	1.63E+04	1.46E+04	1.27E+04	1.08E+04	9.95E+03	9.43E+03	9.10E+03	8.34E+03	7.36E+03	6.37E+03	5.54E+03	4.64E+03	3.62E+03	2.57E+03	1.59E+03	8.21E+02	3.19E+02	7.17E+01	1.56E+00
2013	8.87E+03	2.03E+04	1.71E+04	1.30E+04	1.13E+04	1.22E+04	1.50E+04	1.66E+04	1.75E+04	1.84E+04	1.92E+04	1.95E+04	1.94E+04	1.95E+04	1.91E+04	1.80E+04	1.64E+04	1.55E+04	1.47E+04	1.37E+04	1.21E+04	1.04E+04	8.67E+03	7.26E+03	5.85E+03	4.41E+03	3.02E+03	1.82E+03	9.10E+02	3.43E+02	7.53E+01	1.38E+00
2014	9.50E+03	2.21E+04	2.09E+04	1.84E+04	1.45E+04	1.13E+04	8.93E+03	7.76E+03	7.60E+03	8.46E+03	9.95E+03	1.14E+04	1.30E+04	1.50E+04	1.64E+04	1.68E+04	1.65E+04	1.70E+04	1.73E+04	1.71E+04	1.57E+04	1.37E+04	1.17E+04	9.96E+03	8.14E+03	6.20E+03	4.28E+03	2.58E+03	1.29E+03	4.85E+02	1.06E+02	1.39E+00
2015	6.18E+03	1.47E+04	1.57E+04	1.62E+04	1.46E+04	1.29E+04	1.15E+04	9.91E+03	8.43E+03	7.43E+03	6.92E+03	6.95E+03	7.71E+03	9.47E+03	1.11E+04	1.20E+04	1.22E+04	1.35E+04	1.47E+04	1.54E+04	1.47E+04	1.32E+04	1.16E+04	1.02E+04	8.56E+03	6.68E+03	4.71E+03	2.89E+03	1.47E+03	5.60E+02	1.24E+02	1.75E+00

Table 27. OFL and ABC values for the progression of datasets from the 2014 assessment dataset to the final 2015 dataset, Dataset D. These values are presented only to illustrate the effect of incremental changes in the data used for the assessment on the OFL and ABC.

Model	Dataset	Snow Crab Model	Projection Approach	Average Recruitment	B	Fmsy	Bmsy	B/Bmsy	OFL	ABC P-star	ABC (20% buffer)
2014 Model	Base	--	2014	187.90	63.80	0.61	29.82	2.14	31.48	31.43	25.18
2014 Model	2014 Corrected	--	2014	187.07	63.56	0.60	29.75	2.14	31.25	31.20	25.00
Model A	Dataset A	Preferred	2014	178.62	55.16	0.61	27.70	1.99	28.15	28.11	22.52
Model A	Dataset B	Preferred	2014	174.18	52.57	0.63	27.06	1.94	27.54	27.50	22.03
Model A	Dataset C	Preferred	2014	173.45	51.41	0.72	26.01	1.98	28.66	28.62	22.93
Model A	Dataset D	Preferred	2014	179.37	52.80	0.64	26.79	1.97	27.73	27.70	22.19

Table 28. OFLs and ABCs from the 2014 assessment (model Alt4b) and based on 2015 candidate models A and C run against Dataset D, using several approaches to compute the OFL. The author's preferred version is highlighted in yellow: his preferred model is Model A, his preferred approach to calculating the OFL for 2015/16 is based on Turnock's preferred snow crab model (see the snow crab SAFE chapter) and the 2014 projection approach.

Model	Snow Crab Model	Projection Approach	Average Recruitment	B	Fmsy	Bmsy	B/Bmsy	OFL	ABC P-star	ABC (20% buffer)
2014 Model	--	2014	187.90	63.80	0.61	29.82	2.14	31.48	31.43	25.18
Model A	Preferred	2014	179.37	52.80	0.64	26.79	1.97	27.73	27.70	22.19
Model A	Preferred	new (1)	179.37	52.80	0.64	26.79	1.97	27.73	27.70	22.19
Model A	Preferred	new (2)	179.37	55.91	0.44	26.79	2.09	24.78	24.75	19.82
Model A	2014	2014	179.37	53.02	0.62	26.79	1.98	27.60	27.56	22.08
Model A	2014	new (1)	179.37	53.02	0.62	26.79	1.98	27.60	27.56	22.08
Model A	2014	new (2)	179.37	56.02	0.43	26.79	2.09	24.76	24.72	19.80
Model C	Preferred	2014	180.95	54.53	0.44	25.62	2.13	26.27	26.24	21.02
Model C	2014	2014	180.95	54.88	0.41	25.62	2.14	26.15	26.12	20.92

Figures

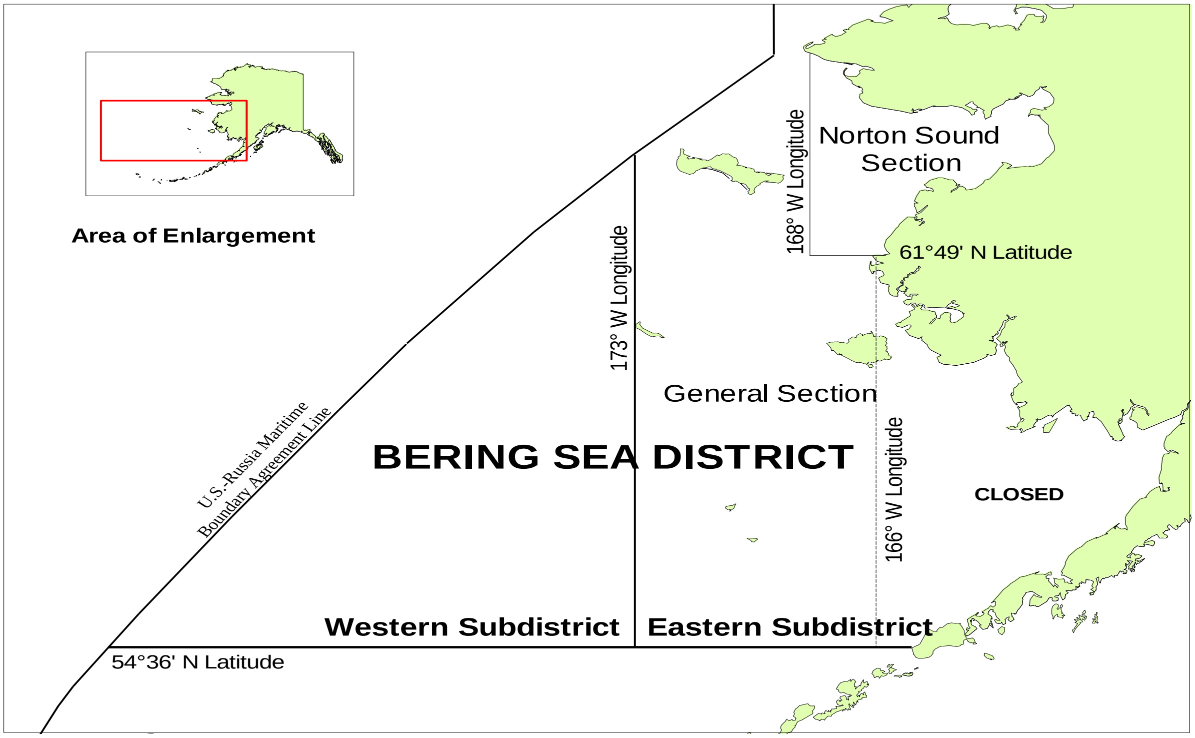


Figure 1. Eastern Bering Sea District of Tanner crab Registration Area J including sub-districts and sections (from Bowers et al. 2008).

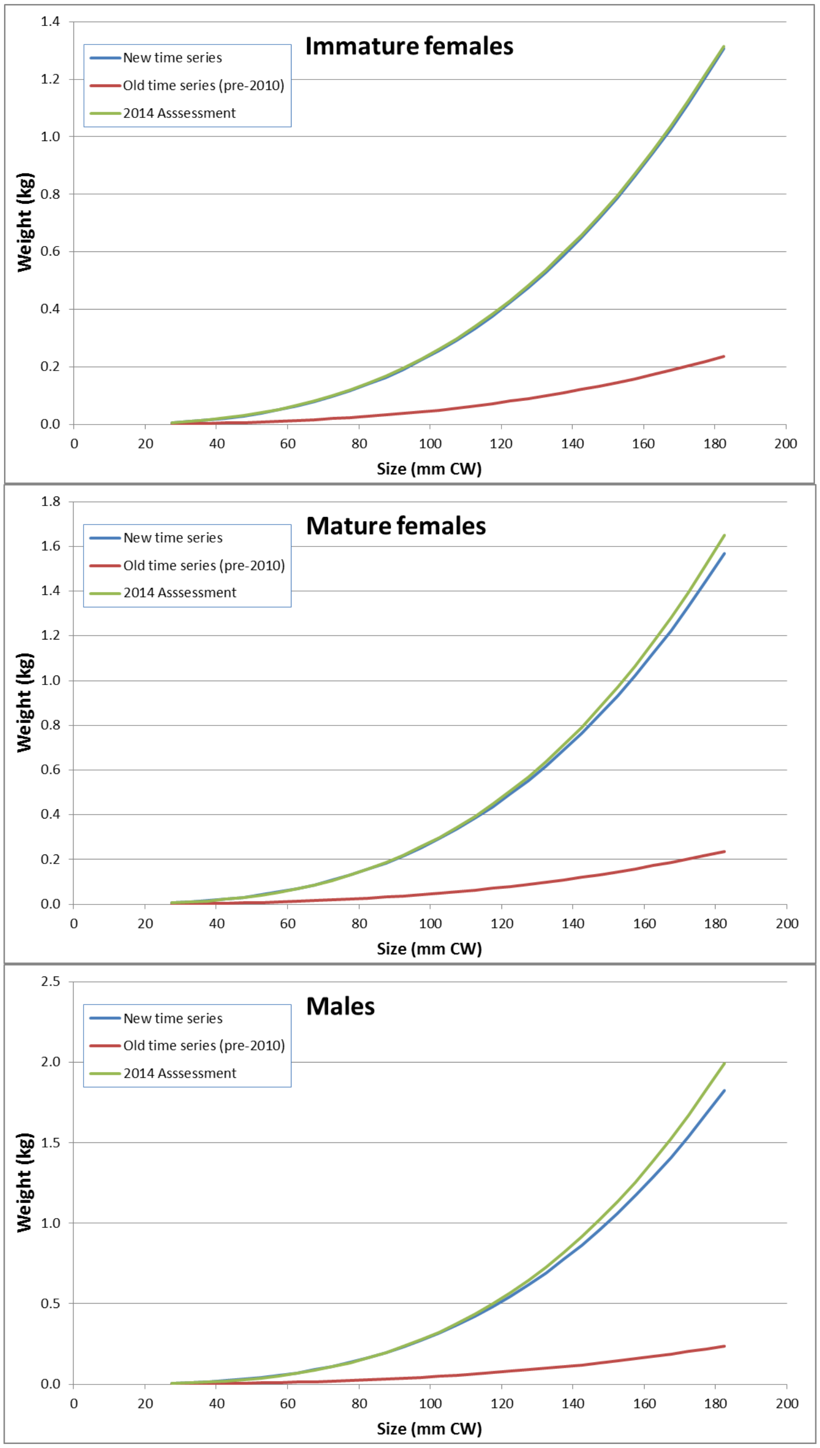


Figure 2. Comparison of weight-at-size relationships for Tanner crab used for the new survey time series (and this assessment; in blue), the old survey time series (in red), and previous assessments (in green).

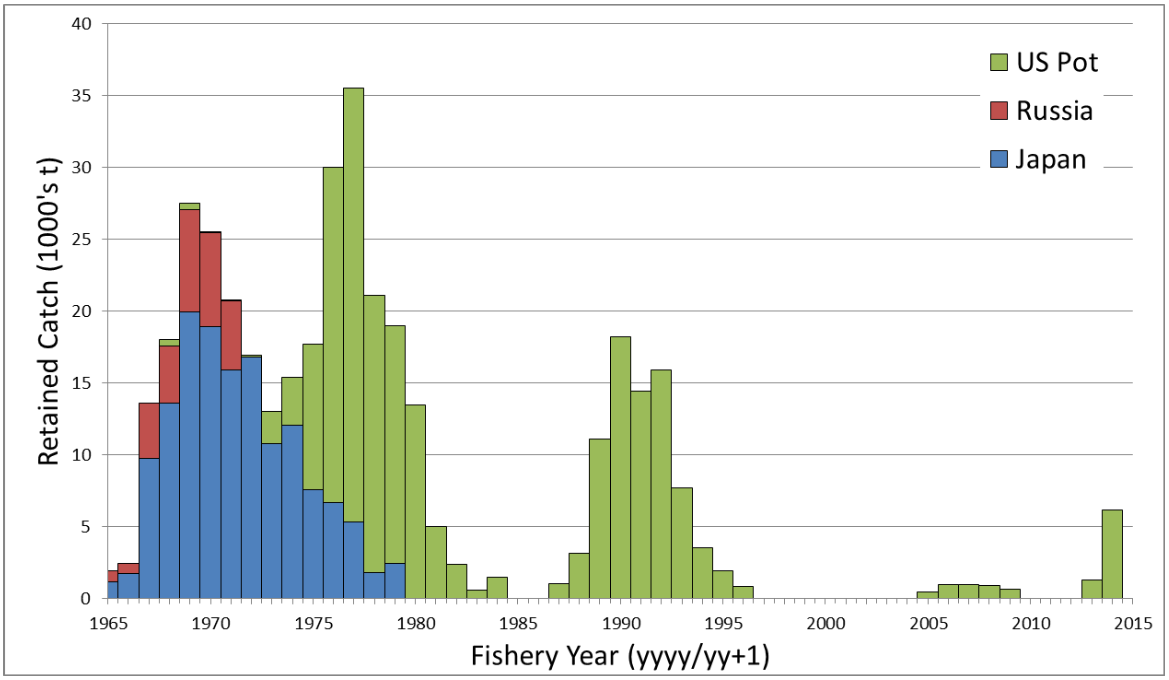


Figure 3. Retained catch (males, 1000’s t) in the directed fisheries (US pot fishery [green bars], Russian tangle net fishery [red bars], and Japanese tangle net fisheries [blue bars]) for Tanner crab since 1965/66.

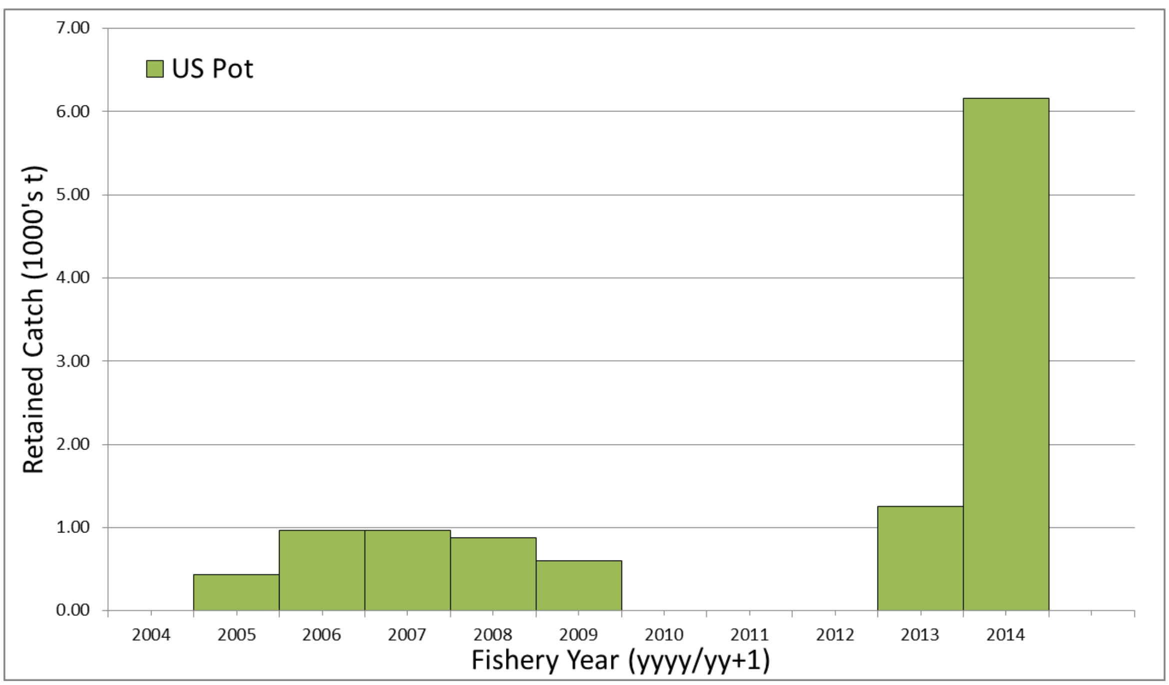


Figure 4. Retained catch (males, 1000’s t) in directed fishery for Tanner crab since 2001/02. The directed fishery was closed from 1996/97 to 2004/05 and from 2010/11 to 2012/13.

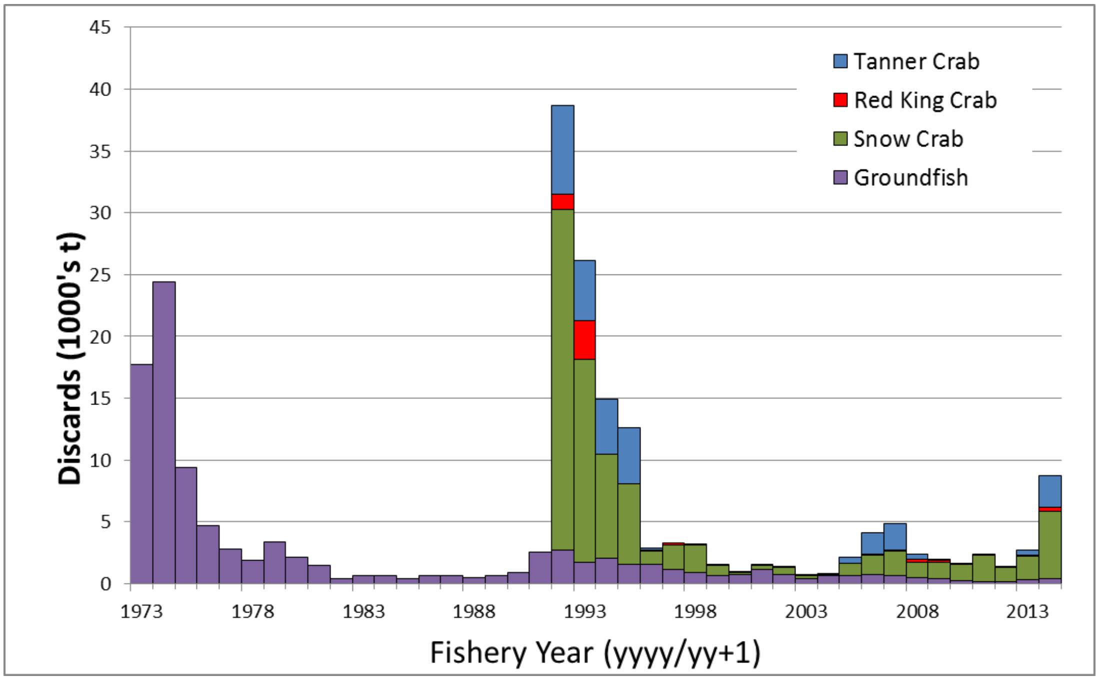


Figure 5. Tanner crab discards (males and females, 1000’s t) in the directed Tanner crab, snow crab, Bristol Bay red king crab, and groundfish fisheries. Discard reporting began in 1973 for the groundfish fisheries and in 1992 for the crab fisheries.

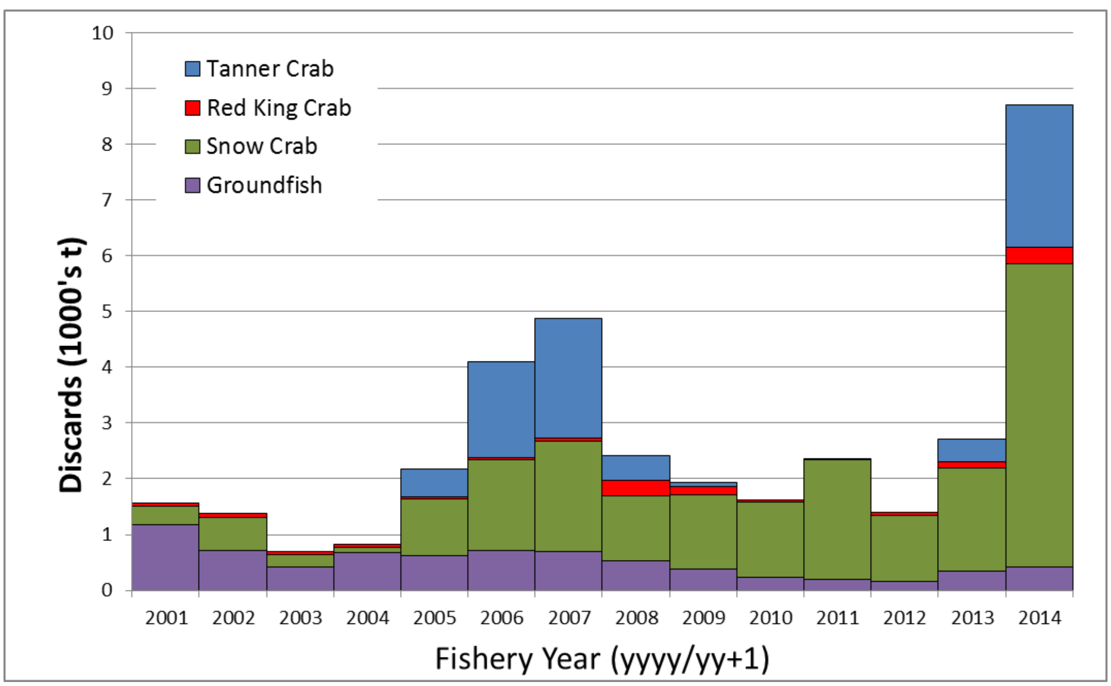


Figure 6.Tanner crab discards (males and females, 1000’s t) in the directed Tanner crab, snow crab, Bristol Bay red king crab, and groundfish fisheries since 2001.

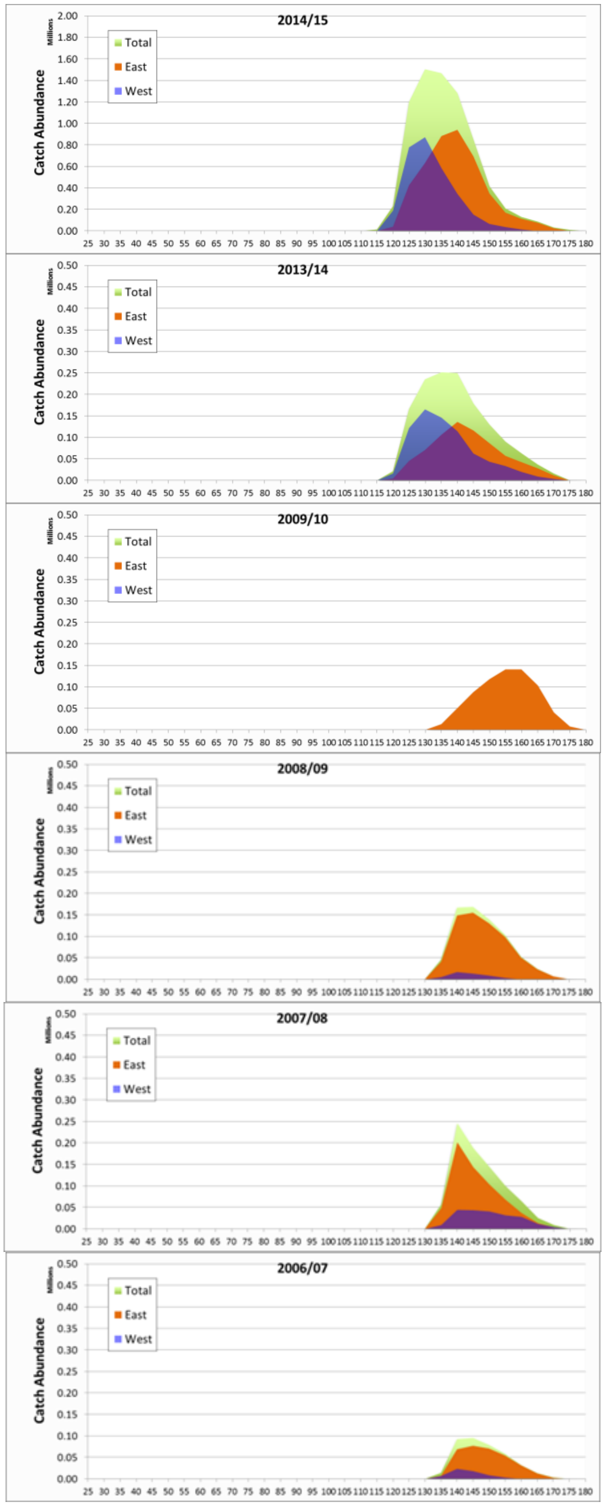


Figure 7. Size compositions, by 5 mm CW bins and expanded to total retained catch, for retained (male) crab in the directed Tanner crab pot fisheries since 2006/07, from dockside crab fishery observer sampling. Fishing occurred only east of 166°W in 2009/10. The entire fishery was closed in 2010/11-2012/13.

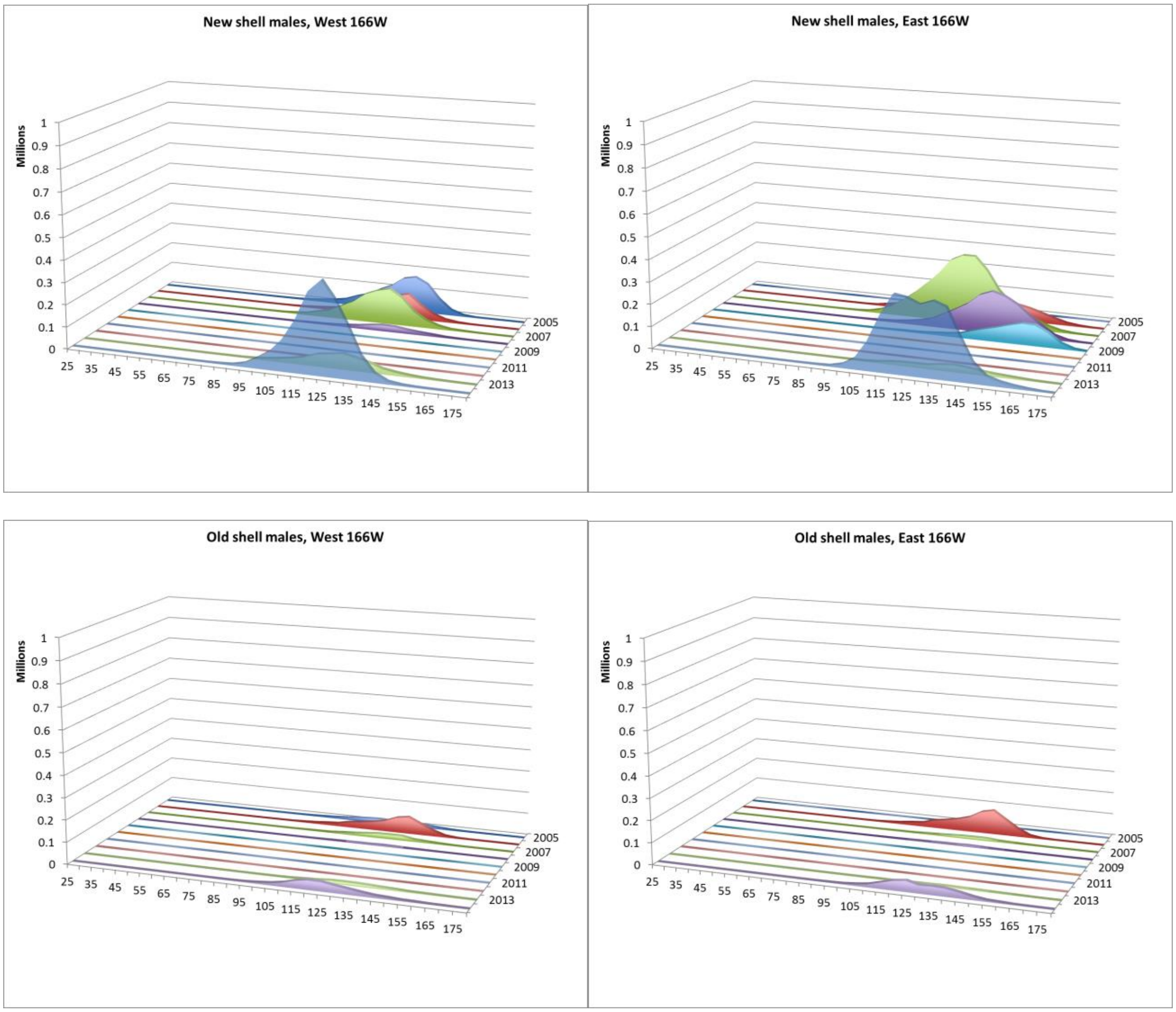


Figure 8. Male Tanner crab catch size compositions, expanded to total catch, by 5 mm CW bins in the directed Tanner crab pot fishery since 2005/06, from at-sea crab fishery observer sampling.

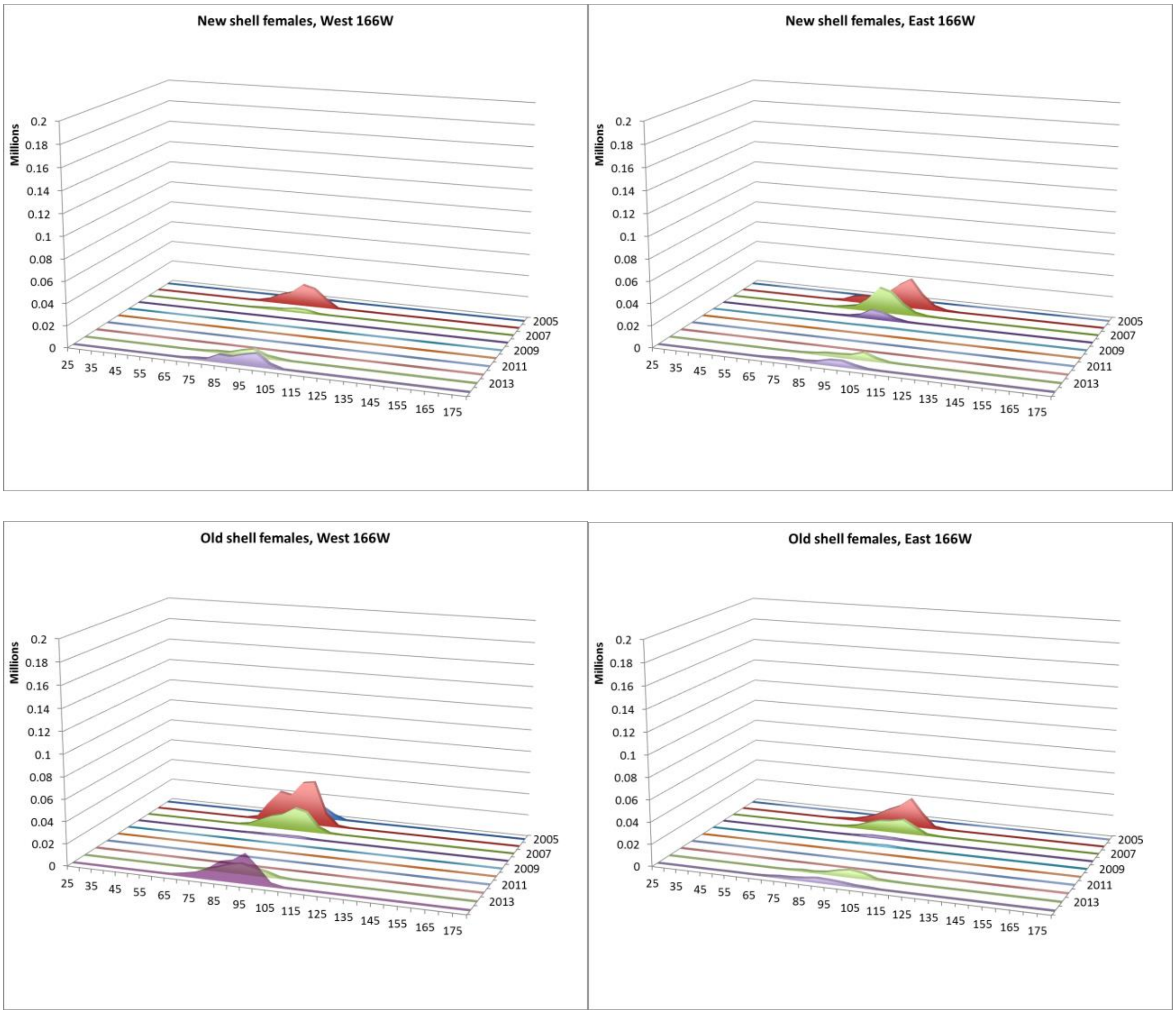


Figure 9. Female Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the directed Tanner crab pot fishery since 2005/06, from at-sea crab fishery observer sampling.

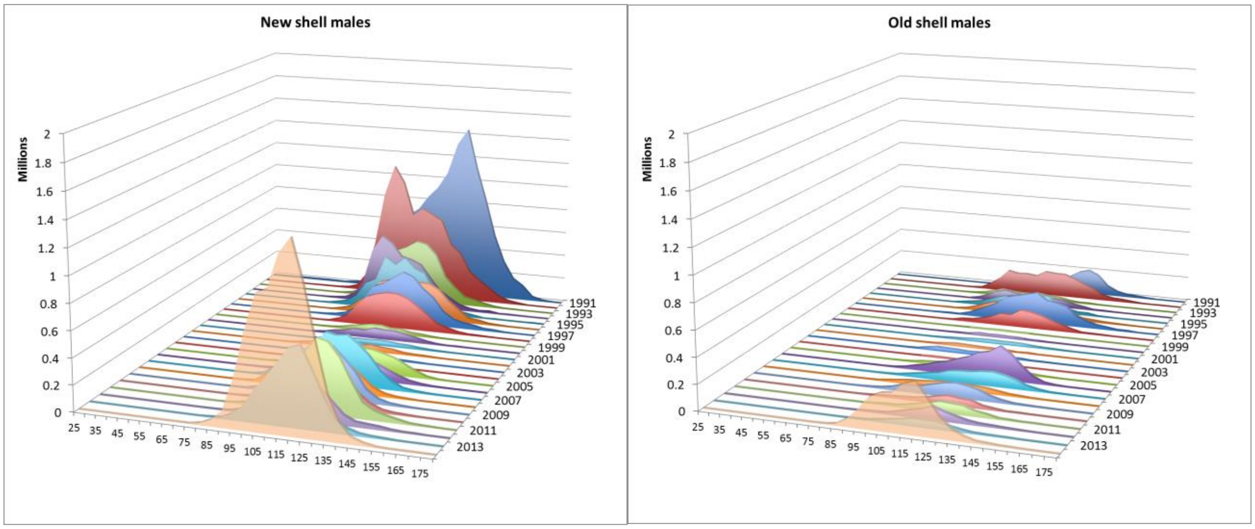


Figure 10. Male Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the snow crab pot fishery, from at-sea crab fishery observer sampling.

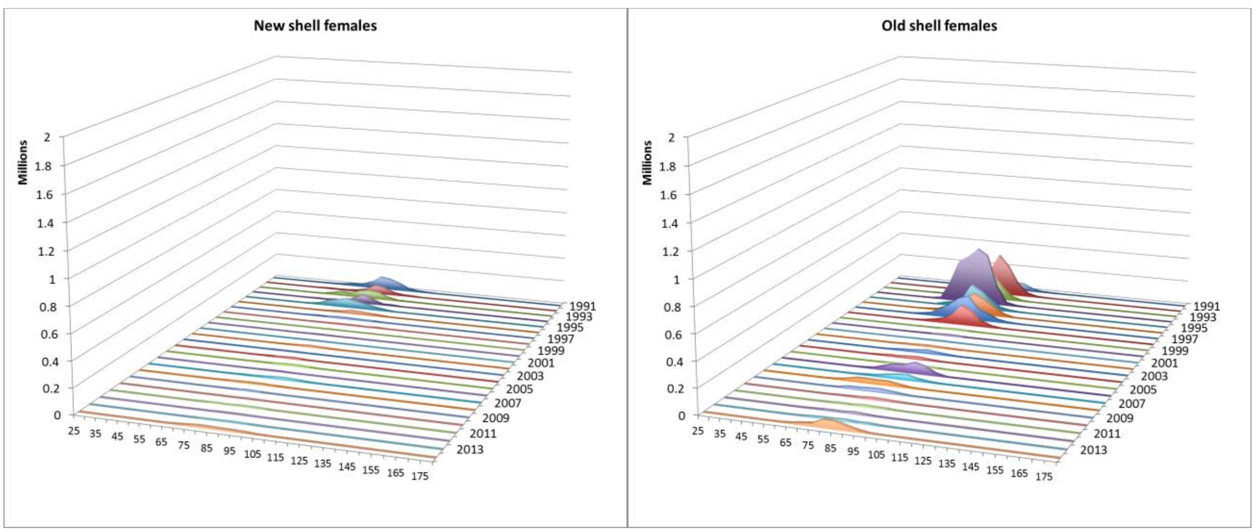


Figure 11. Female Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the snow crab pot fishery, from at-sea crab fishery observer sampling.

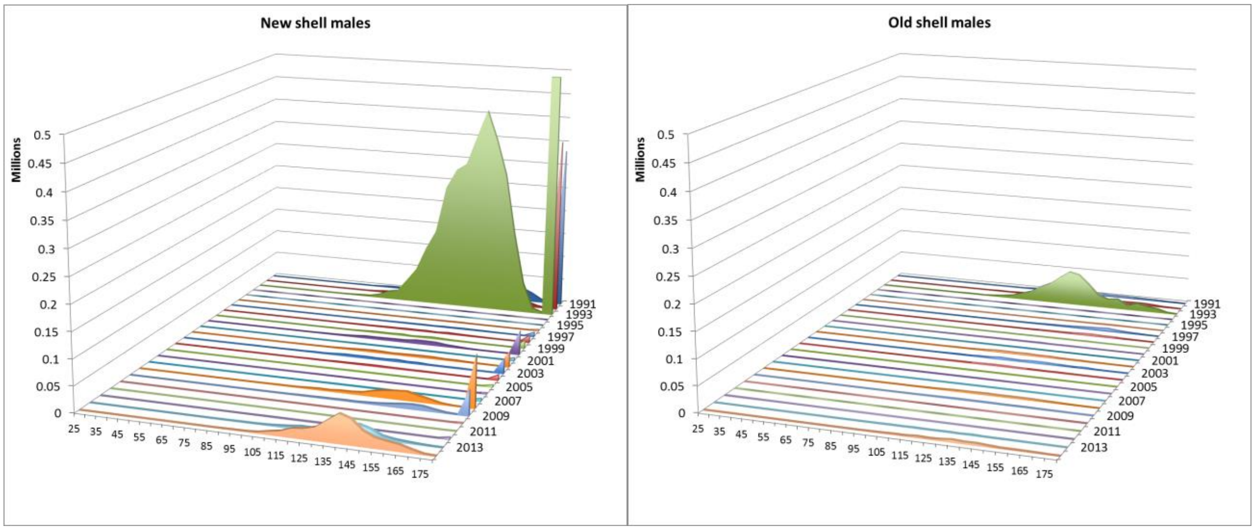


Figure 12. Male Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the BBRKC pot fishery, from at-sea crab fishery observer sampling.

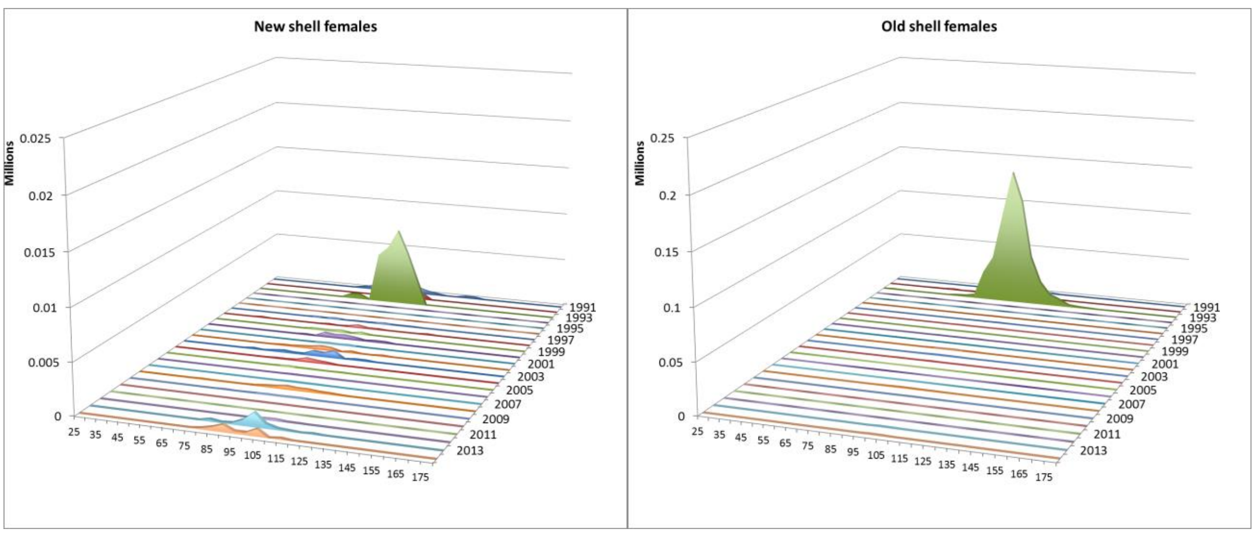


Figure 13. Female Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the BBRKC pot fishery, from at-sea crab fishery observer sampling.

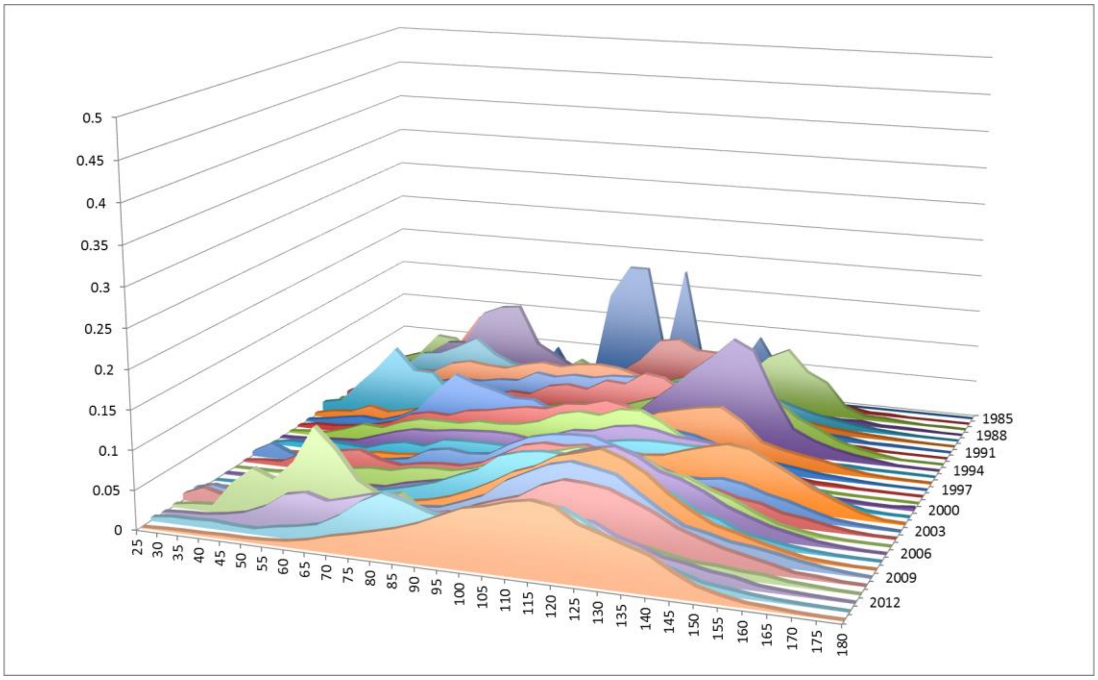


Figure 14. Normalized male Tanner crab bycatch size compositions in the groundfish fisheries, from groundfish observer sampling. Size compositions have been normalized to sum to 1 for each year.

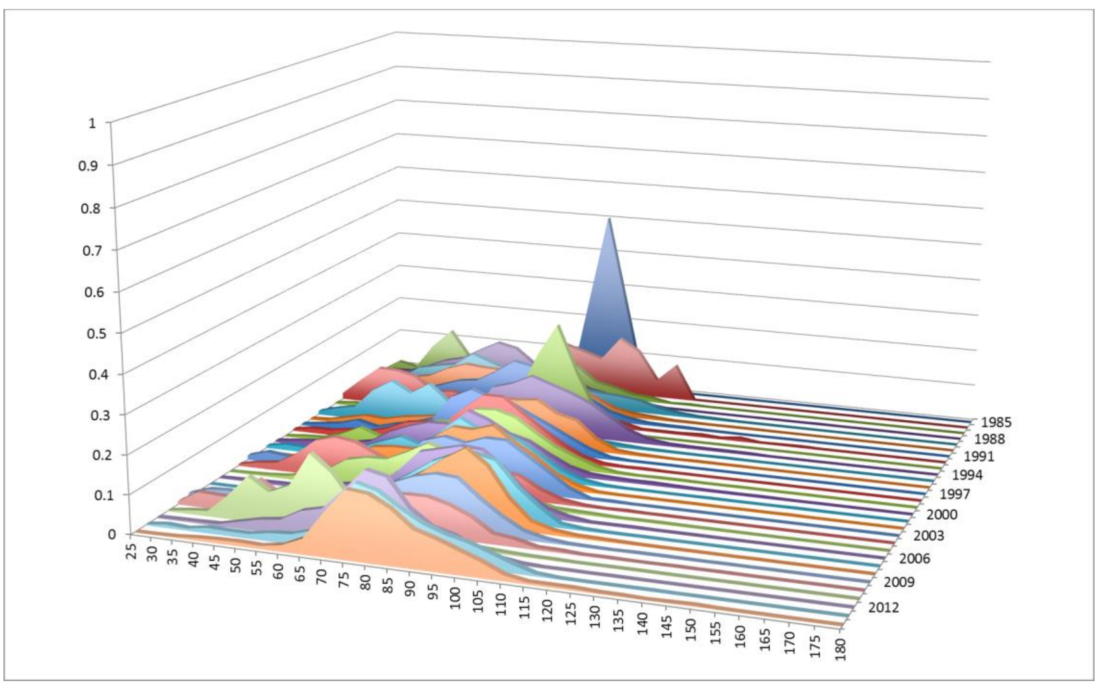


Figure 15. Normalized female Tanner crab bycatch size compositions in the groundfish fisheries, from groundfish observer sampling. Size compositions have been normalized to sum to 1 for each year.

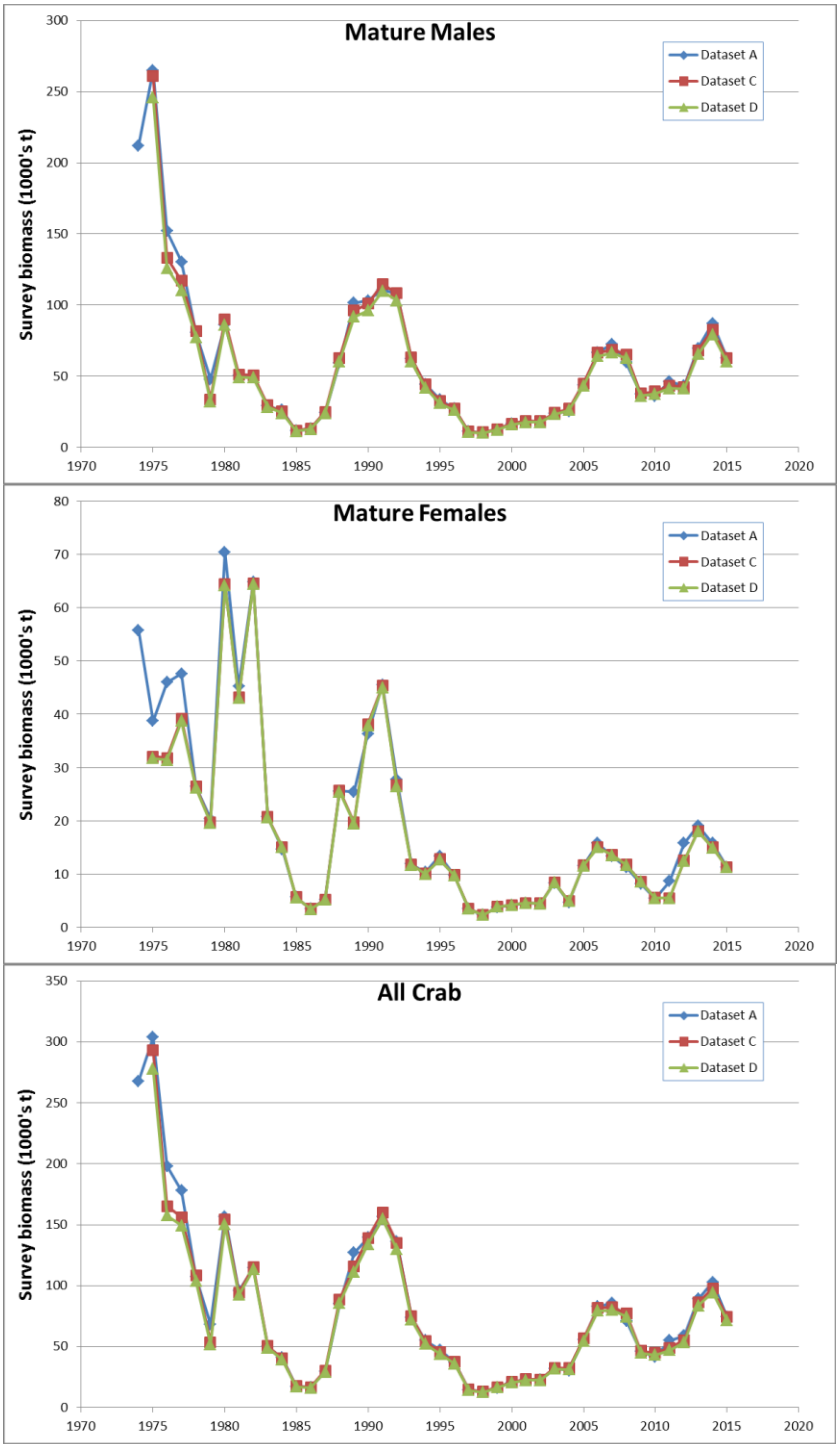


Figure 16. Trends in mature Tanner crab biomass based on size compositions from the NMFS bottom trawl survey. Datasets A and C use the Rugolo and Turnock (2012a) weight-at-size regressions; Datset D uses the new standardized regressions. Dataset A uses the old trawl survey stations/hauls, Datasets C and D use the new standardized stations/hauls.

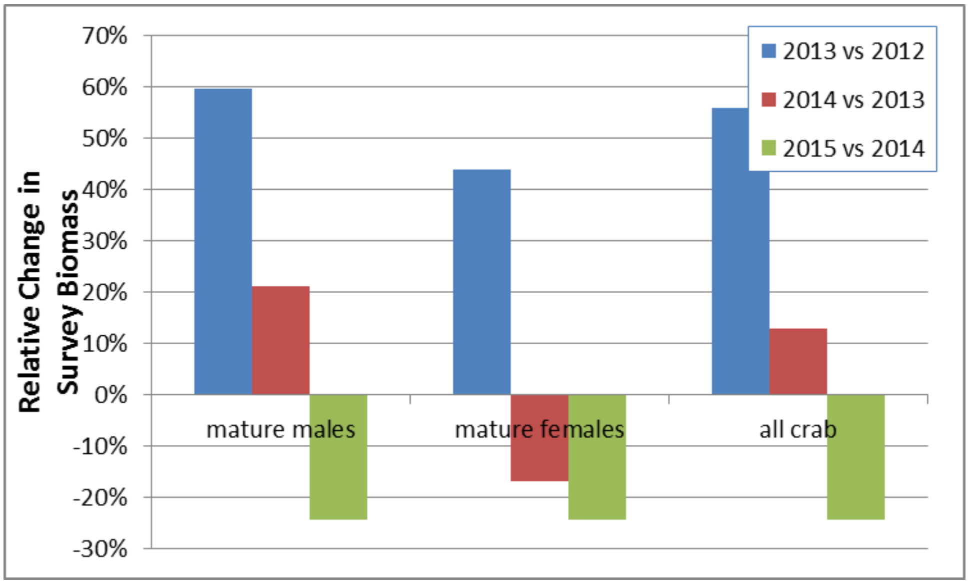
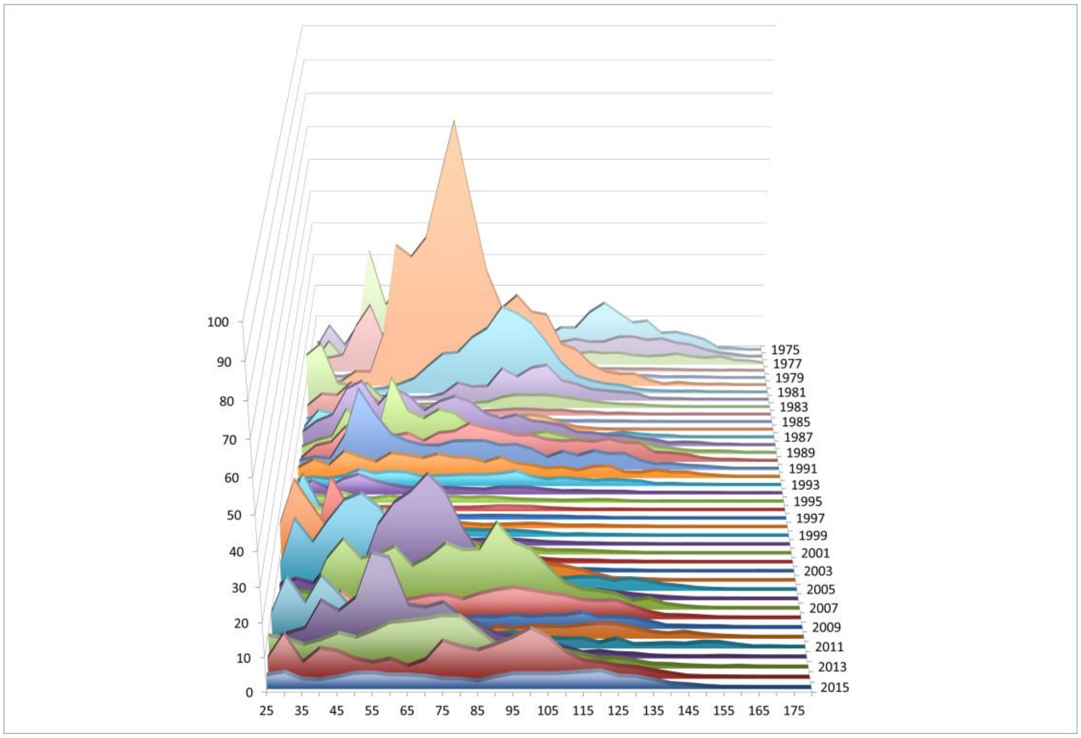


Figure 17. Percent change in mature male biomass, mature female biomass, total mature biomass and number of legal male crab observed in the NMFS bottom trawl survey during the past 3 years.

West of 166° W



East of 166° W

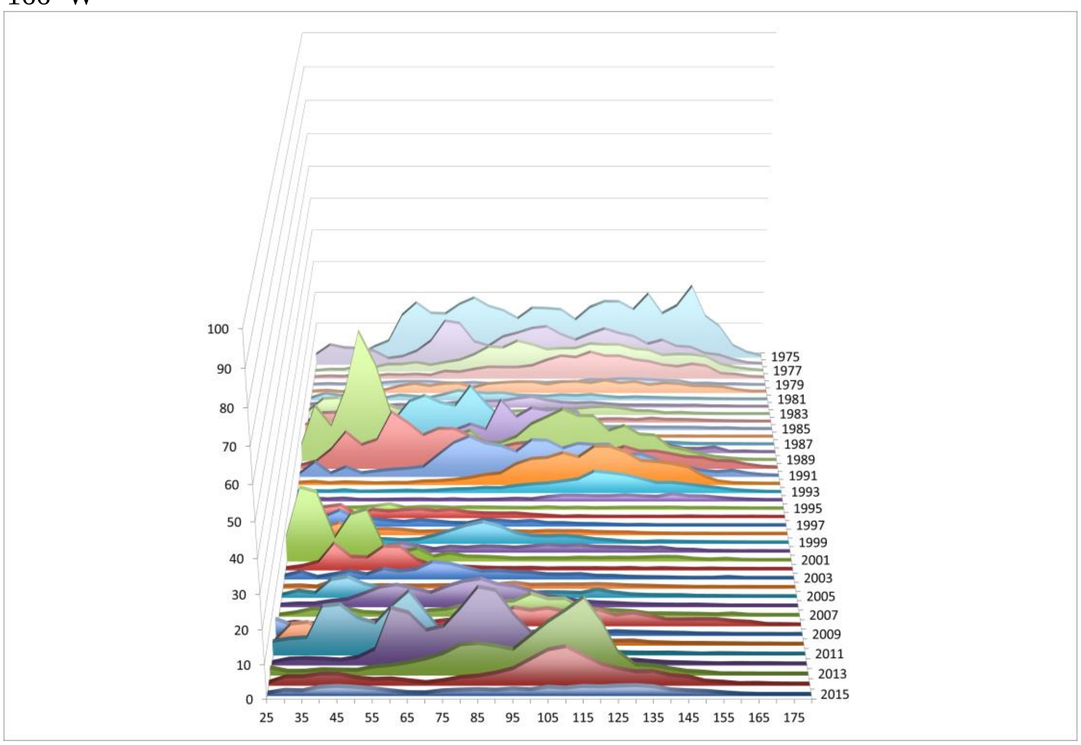
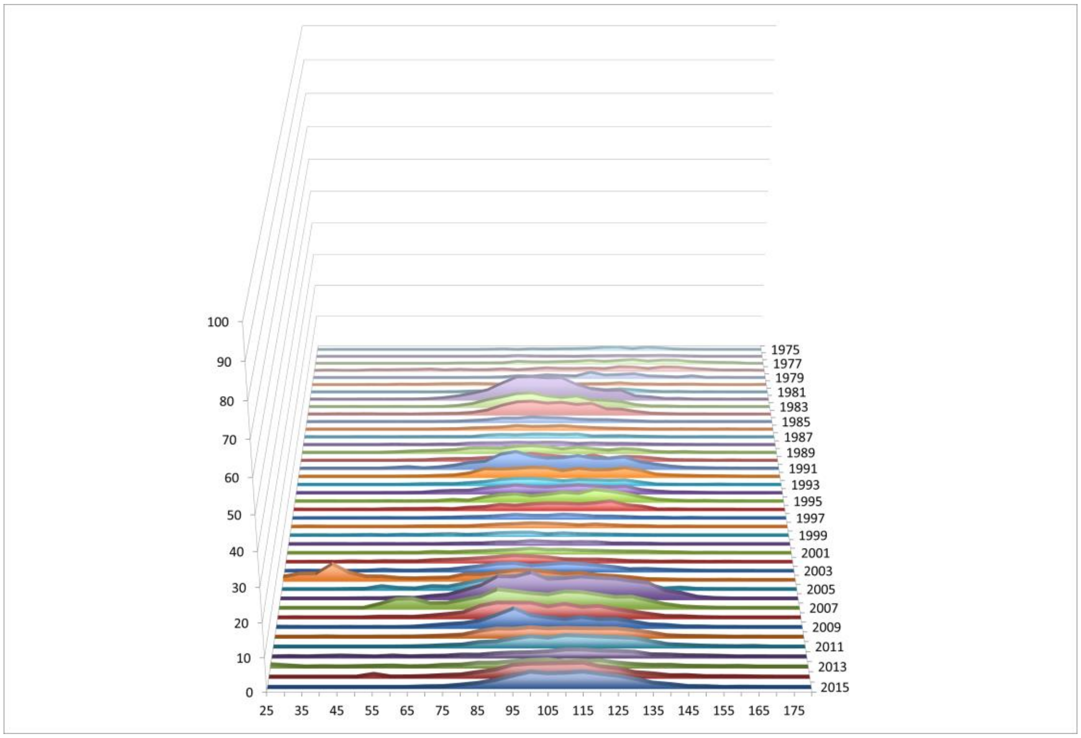


Figure 18a. Numbers at size (millions) by area for new shell male Tanner crab in the NMFS summer bottom trawl survey (new time series), binned by 5 mm CW.

West of 166° W



East of 166° W

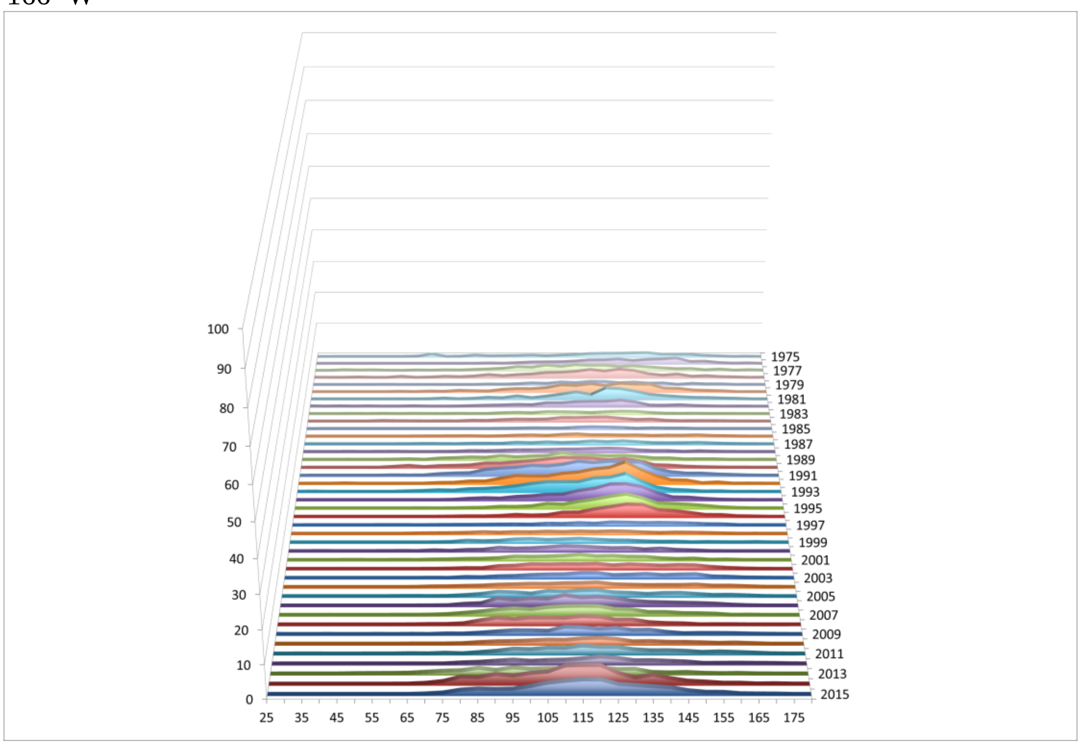
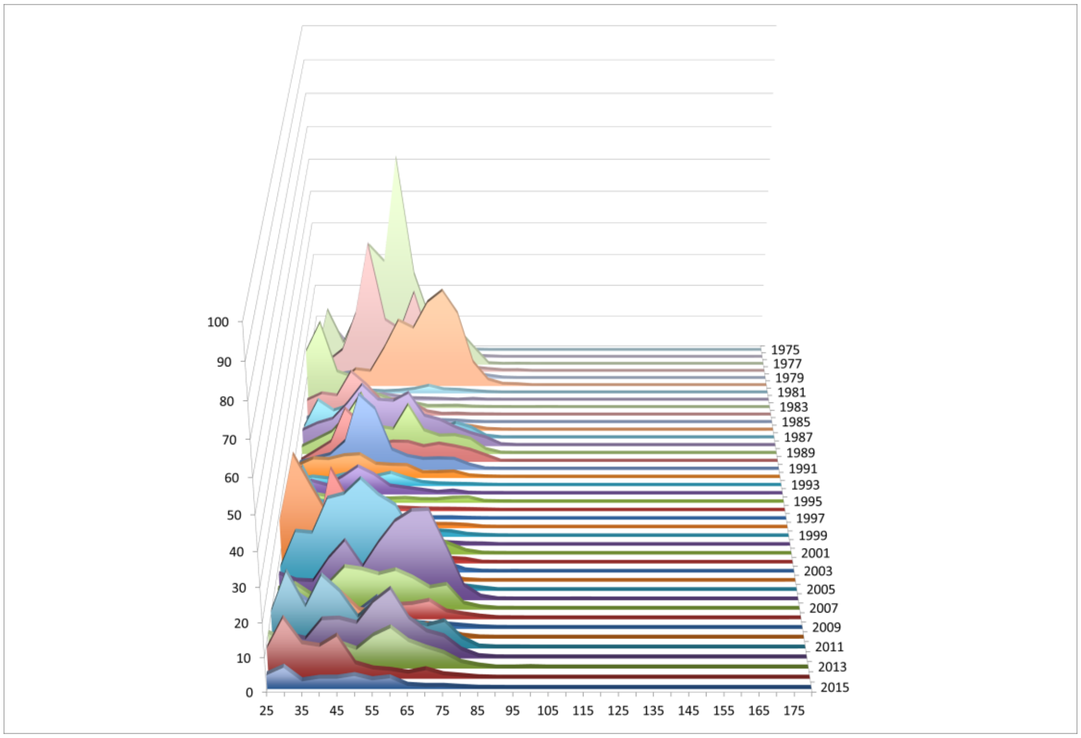


Figure 18b. Numbers at size (millions) by area for old shell male Tanner crab in the NMFS summer bottom trawl survey (new time series), binned by 5 mm CW.

West of 166° W



East of 166° W

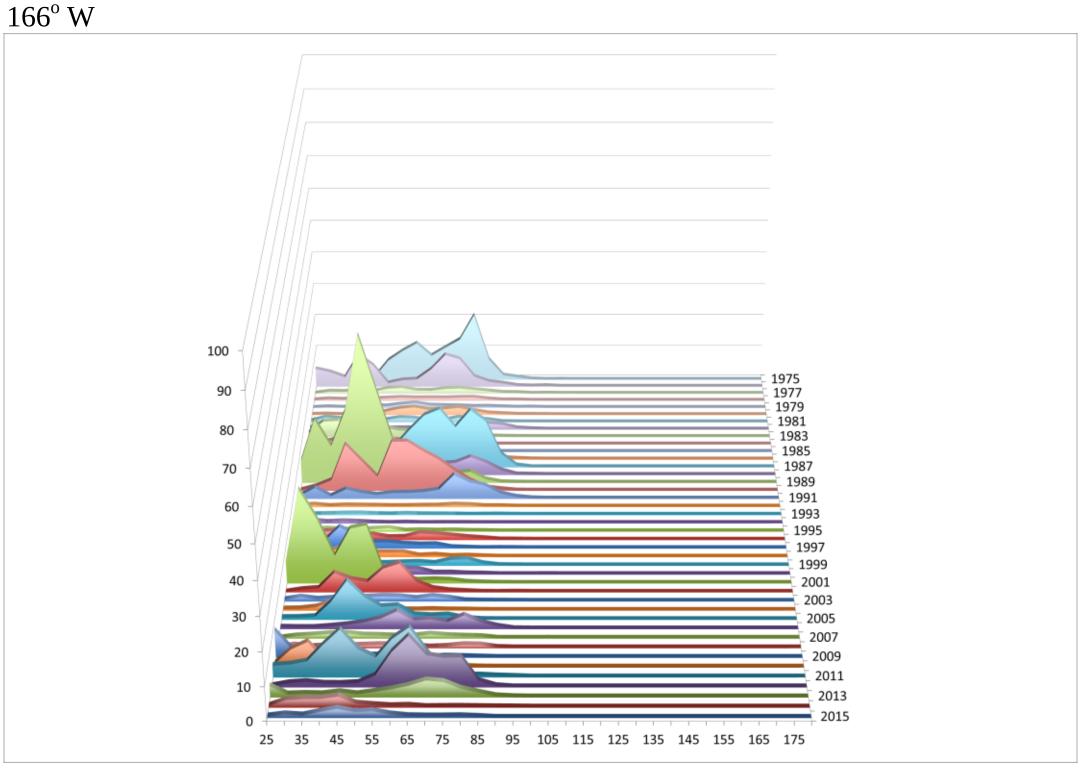
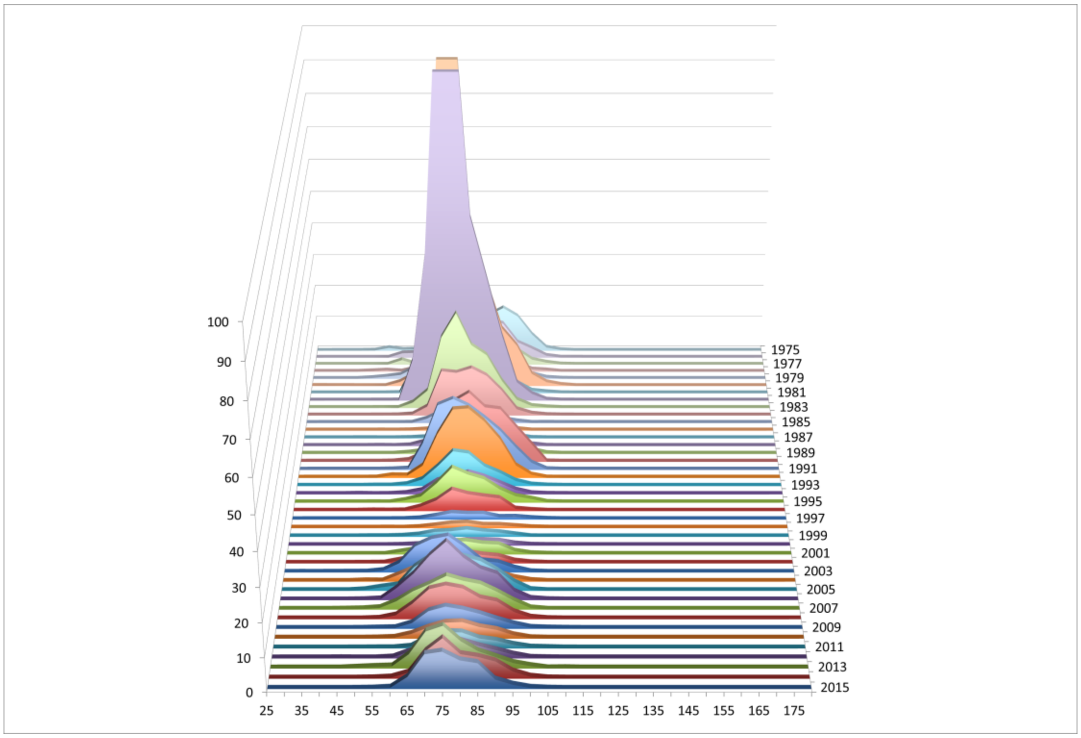


Figure 19a. Numbers at size (millions) by area for immature female Tanner crab in the NMFS summer bottom trawl survey (new time series), binned by 5 mm CW.

West of 166° W



East of 166° W

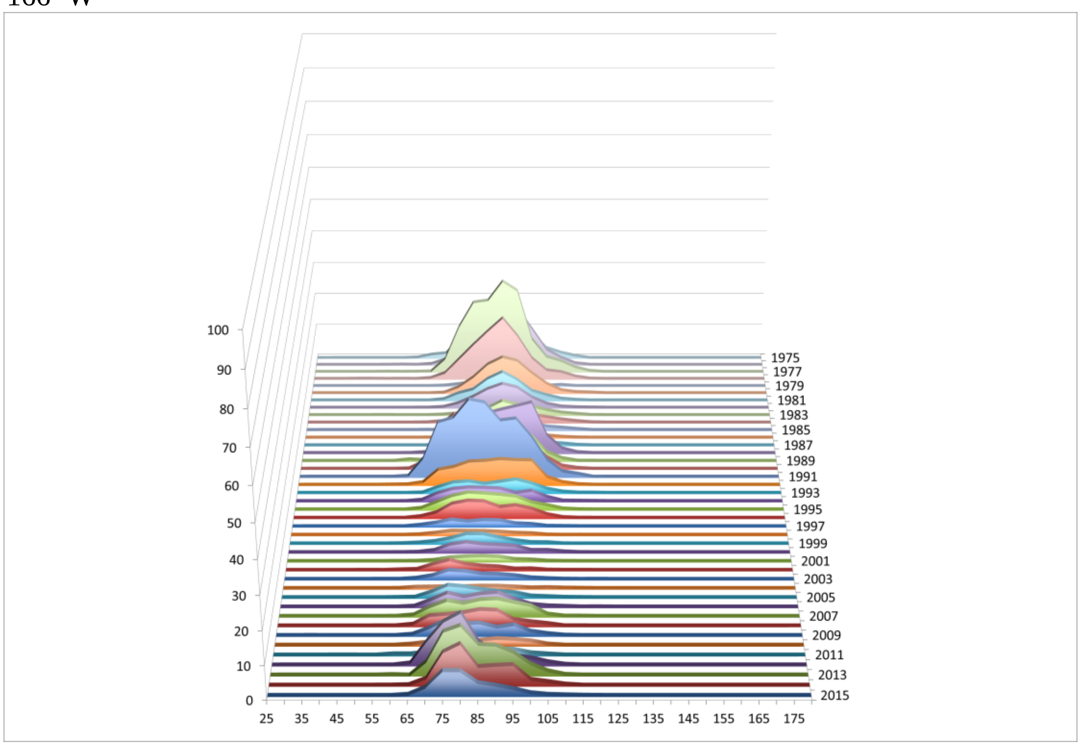


Figure 19b. Numbers at size (millions) by area for mature female Tanner crab in the NMFS summer bottom trawl survey (new time series), binned by 5 mm CW.

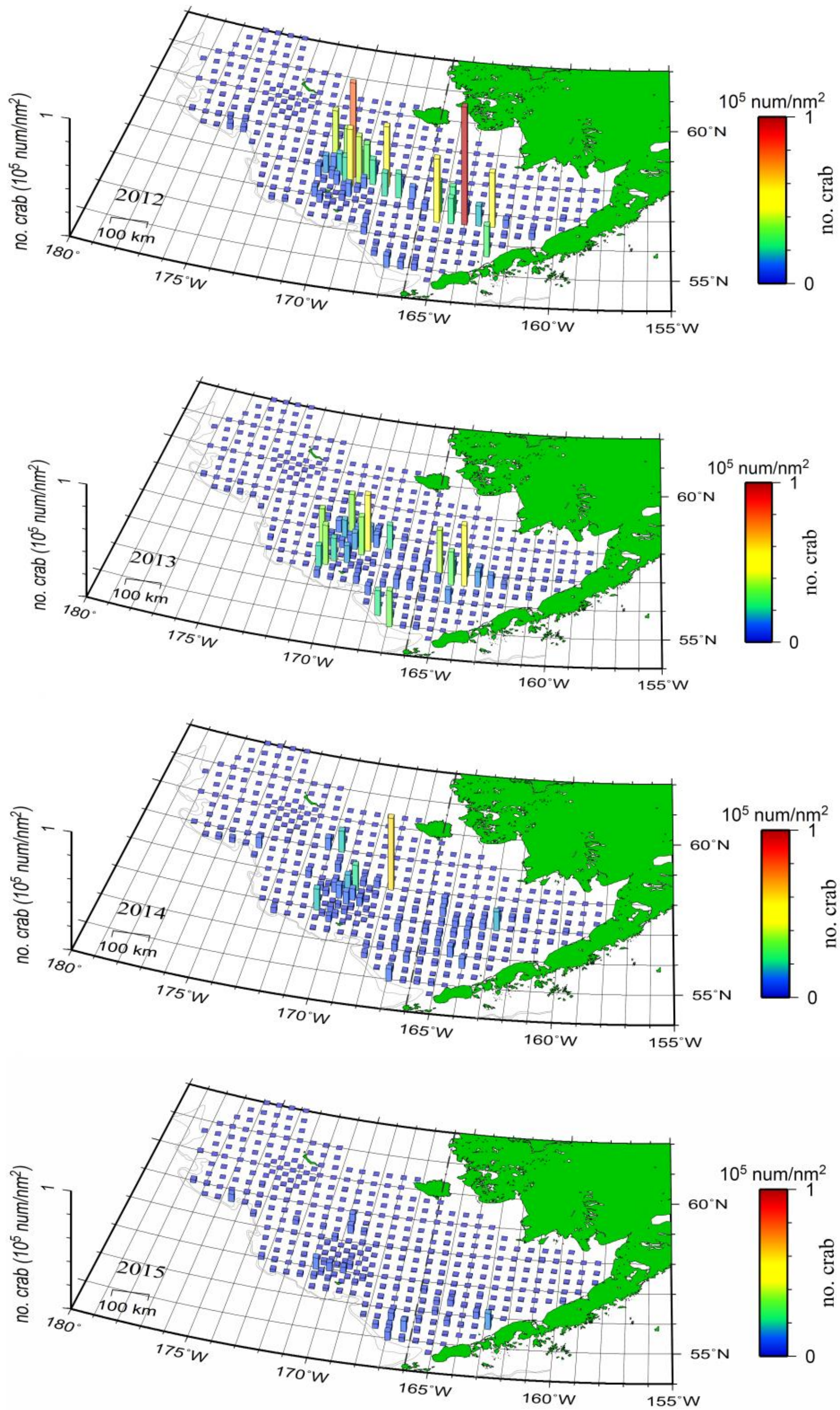


Figure 20. Distribution of immature males (number/ sq. nm) in the summer trawl survey for 2012-15.

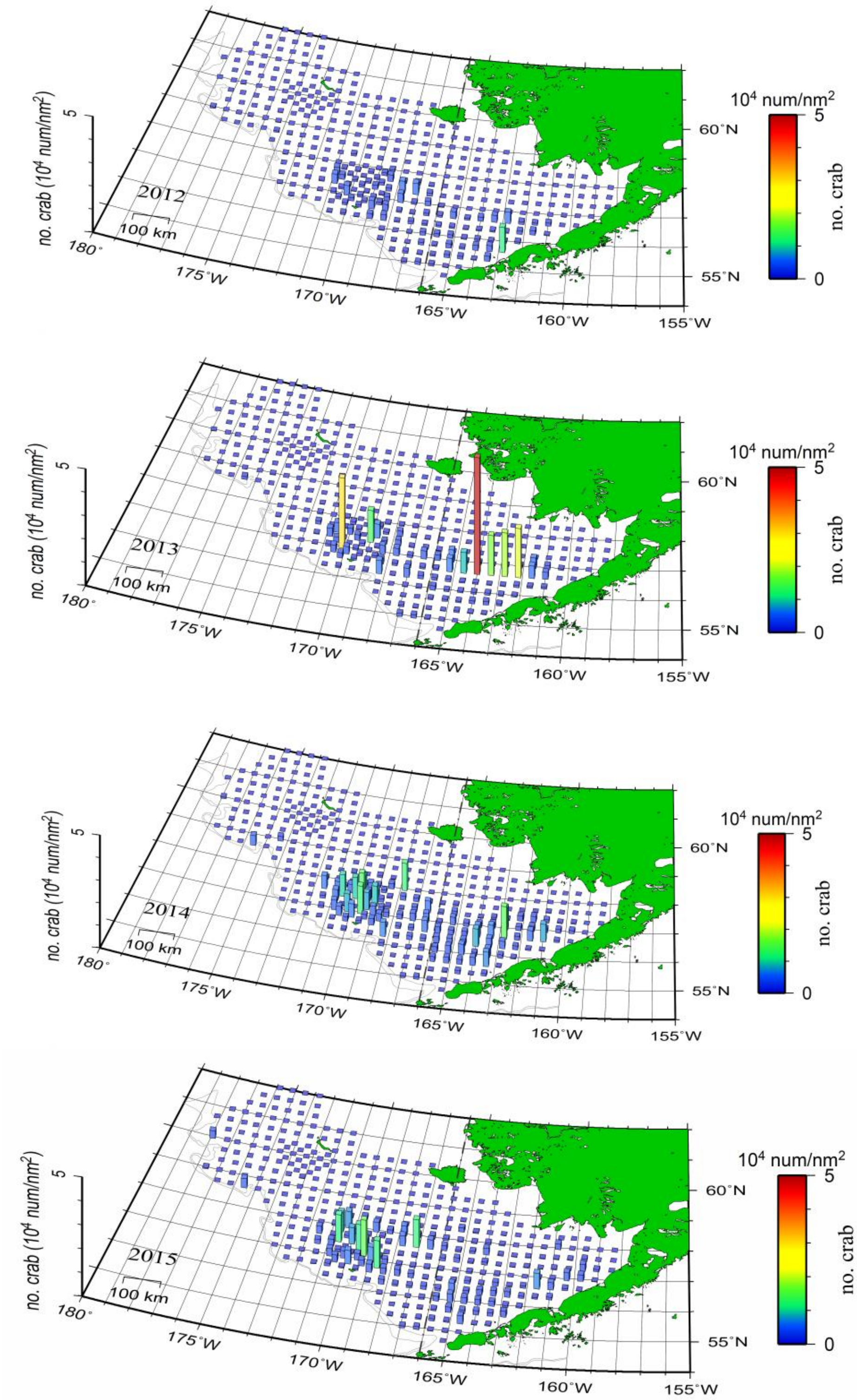


Figure 21. Distribution of mature males (number/ sq. nm) in the summer trawl survey for 2012-15.

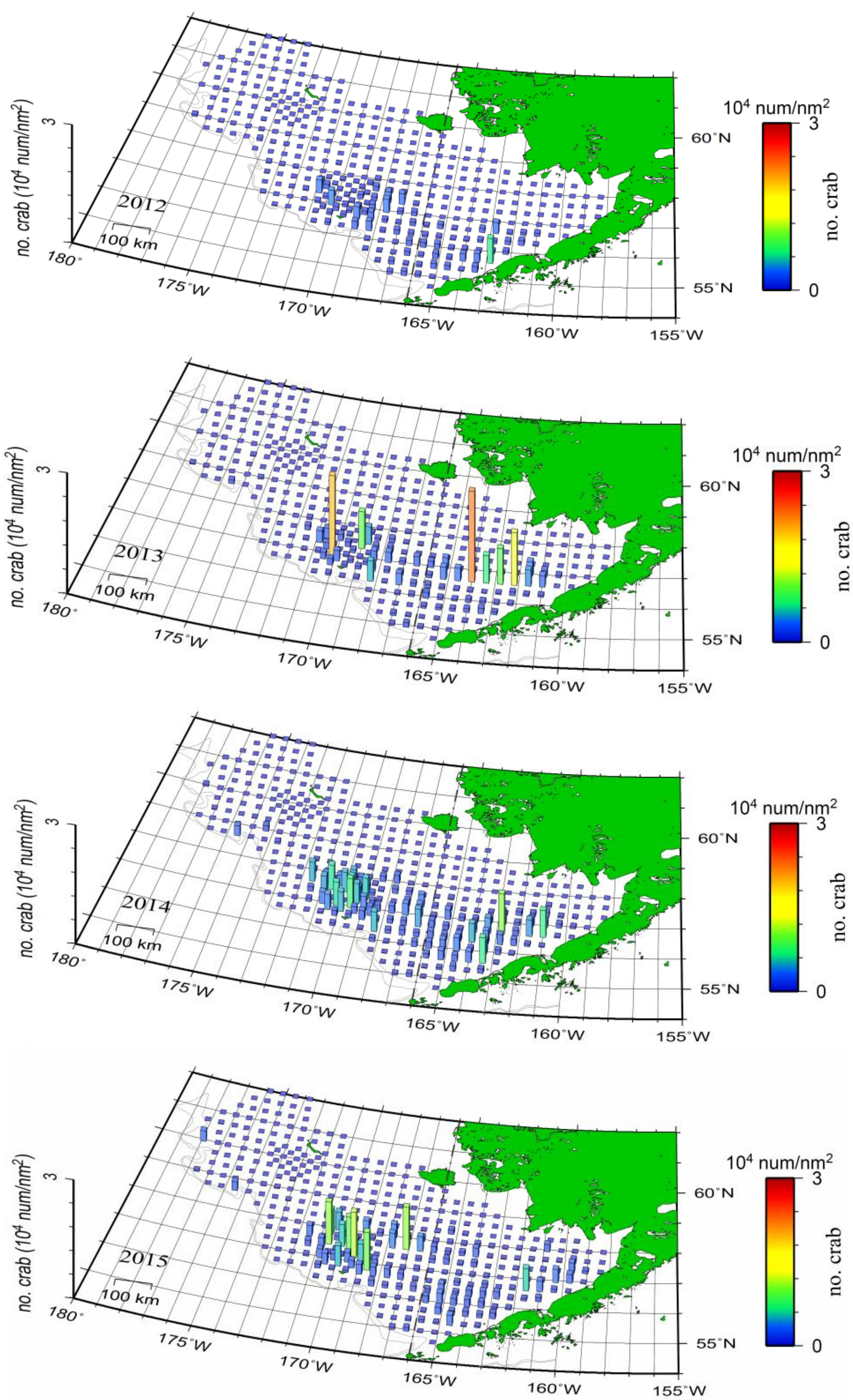


Figure 22. Distribution of legal males (≥ 110 mm CW west of 166°W, ≥ 120 mm CW east of 166°W; number/ sq. nm) in the summer trawl survey for 2012-15.

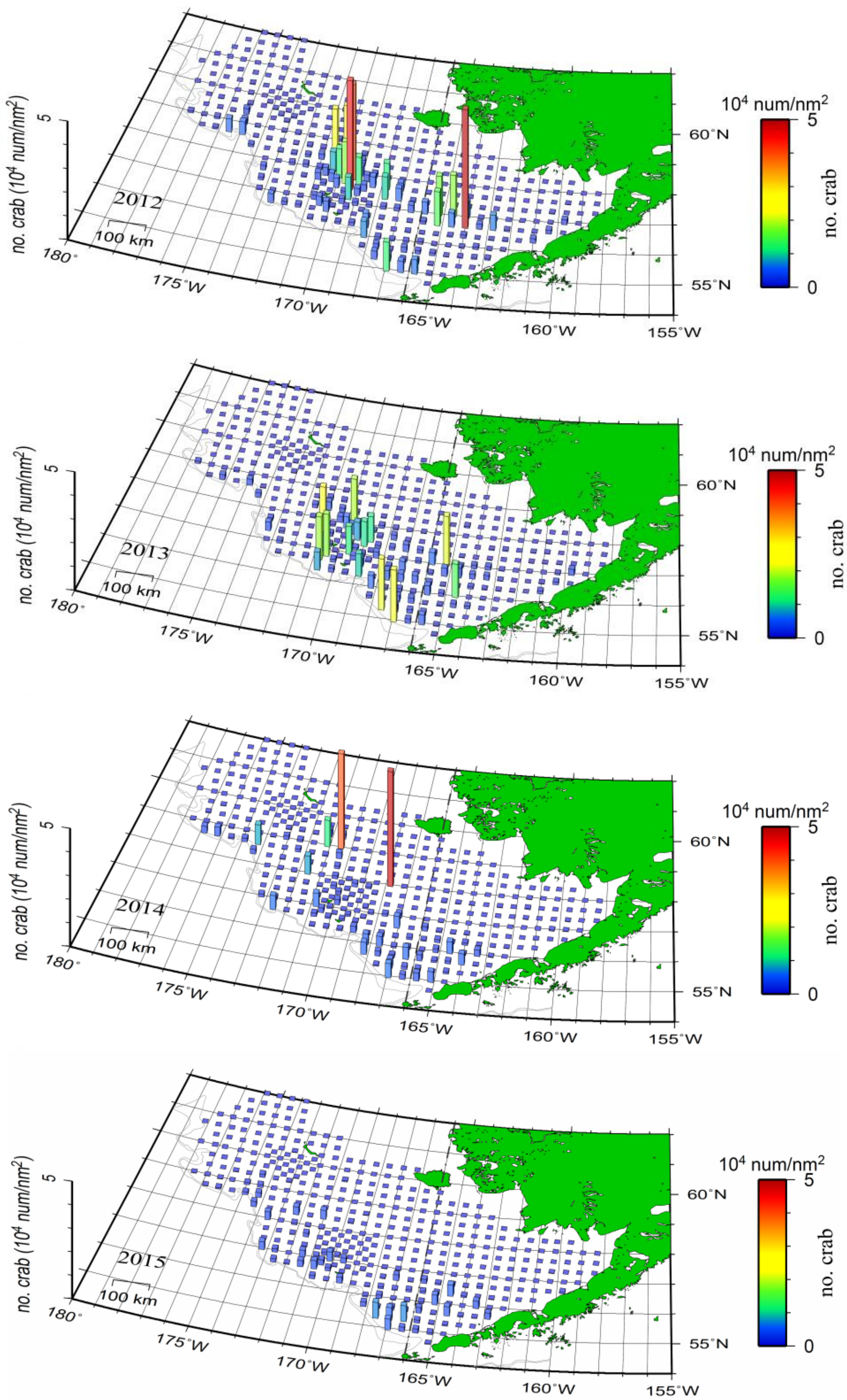


Figure 23. Distribution of immature females (number/ sq. nm) in the summer trawl survey for 2012-15.

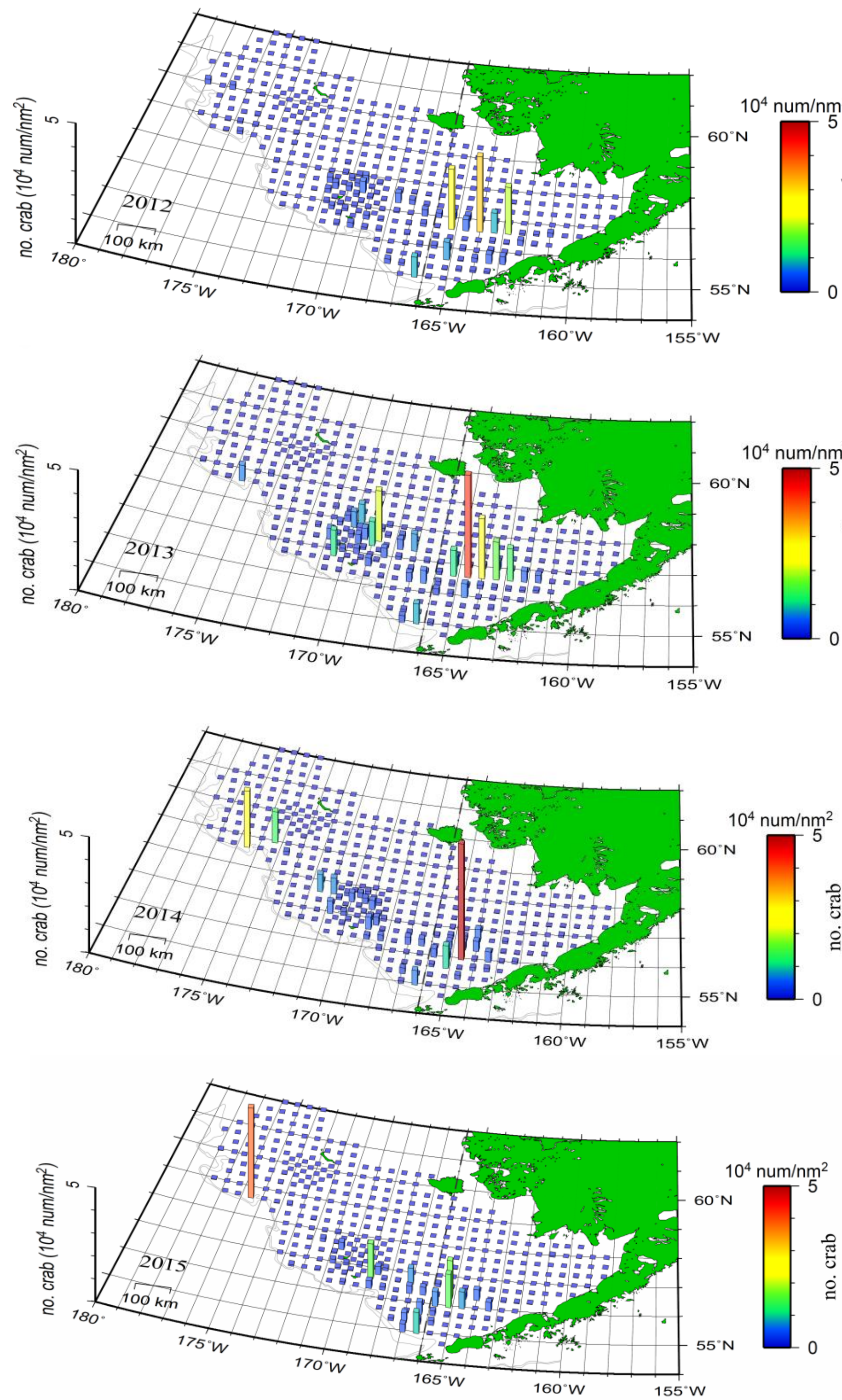
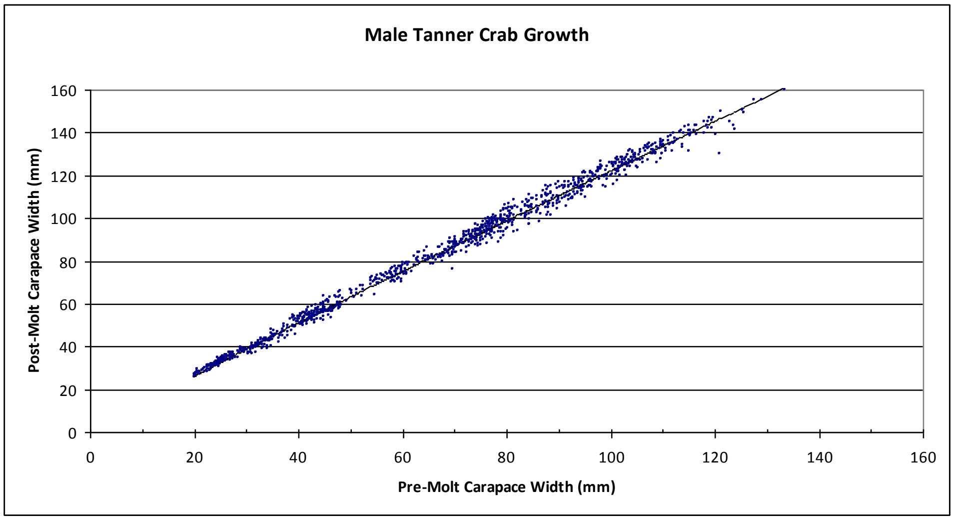


Figure 24. Distribution of mature females (number/ sq. nm) in the summer trawl survey for 2012-15.

(a)



(b)

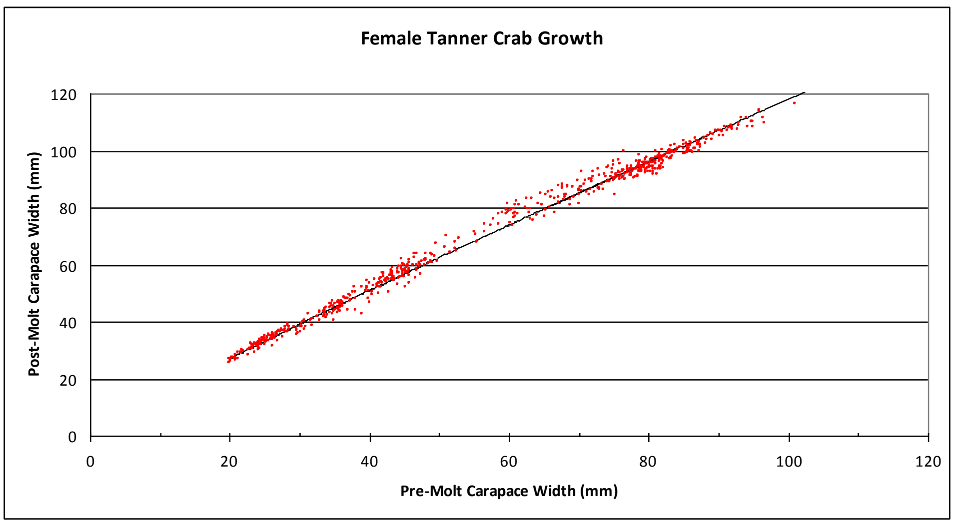


Figure 25. Growth of male (a) and female (b) Tanner crab as a function of premolt size. Estimated by Rugolo and Turnock (2010) based on data from Gulf of Alaska Tanner crab (Munk, unpublished data).

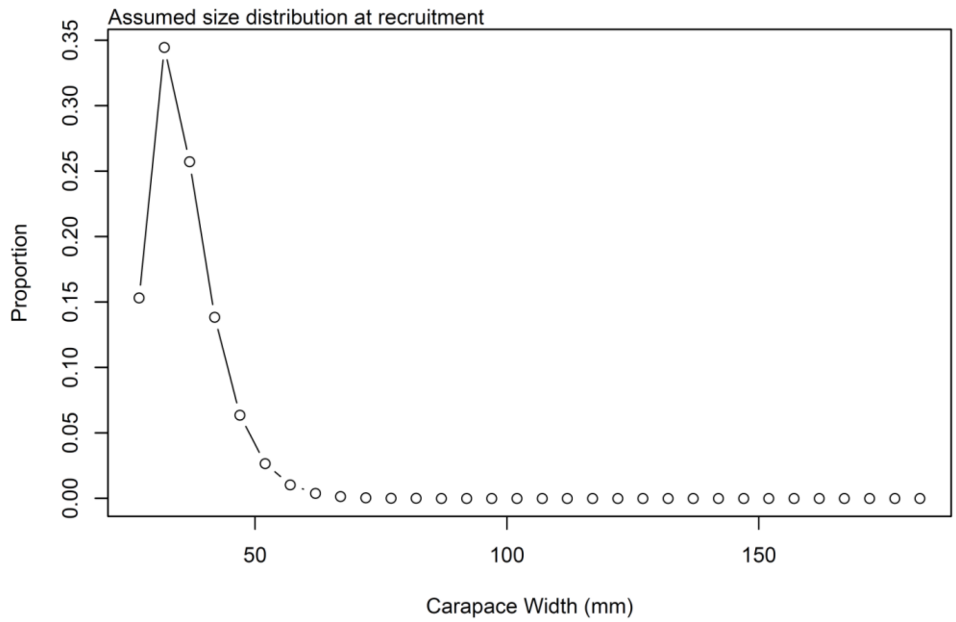


Figure 26. Assumed size distribution for recruits entering the population.

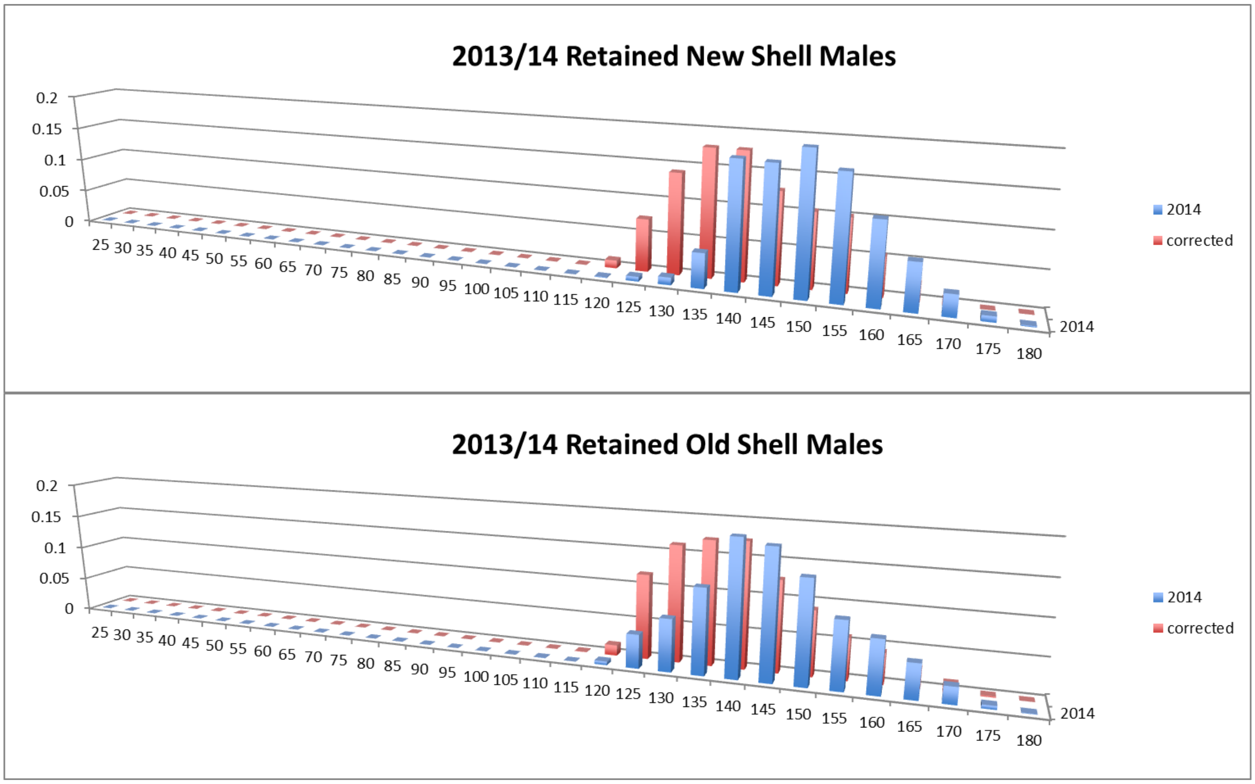


Figure 27. Comparison of 2013/14 size compositions by shell condition for retained males in the directed fishery: blue bars: those used in the 2014 assessment; red bars: corrected versions.

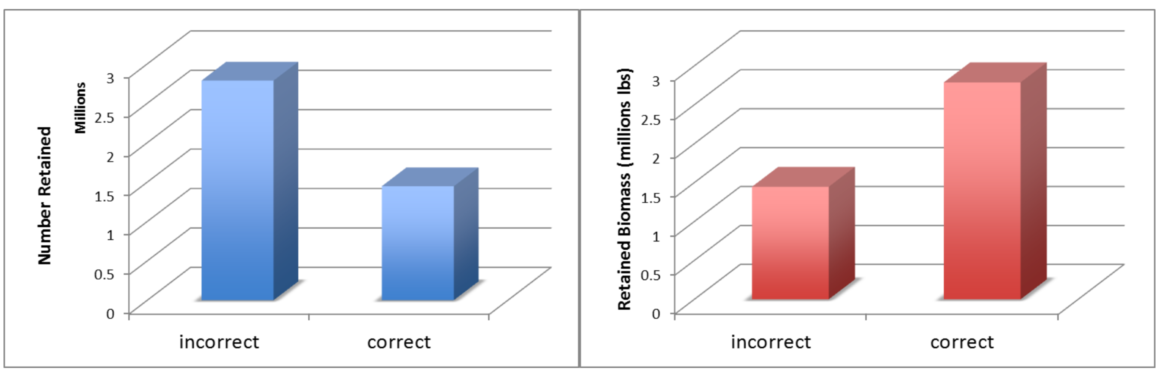


Figure 28. Comparison of 2013/14 retained numbers and biomass used in the 2014 assessment ("incorrect") and the correct values.

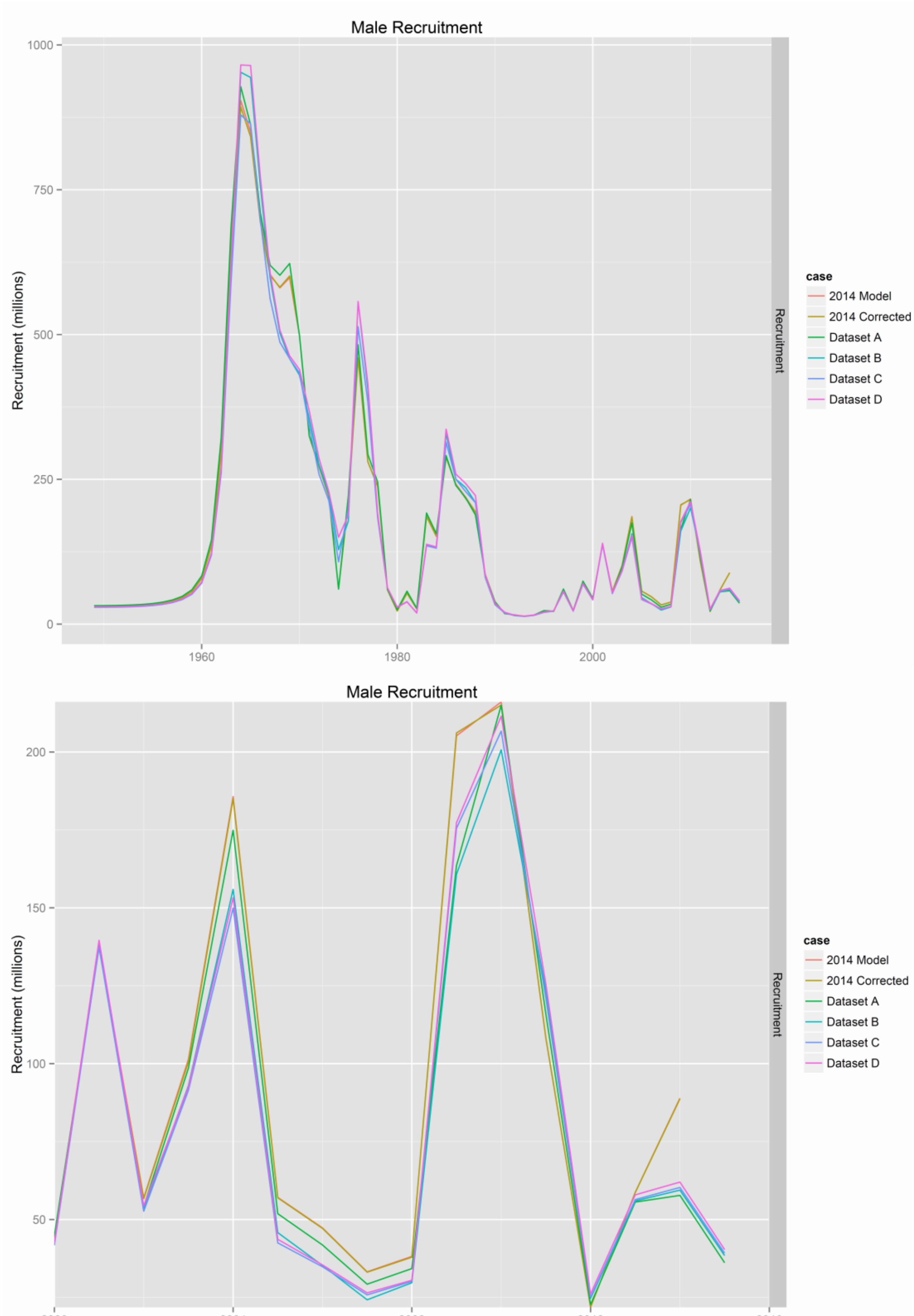
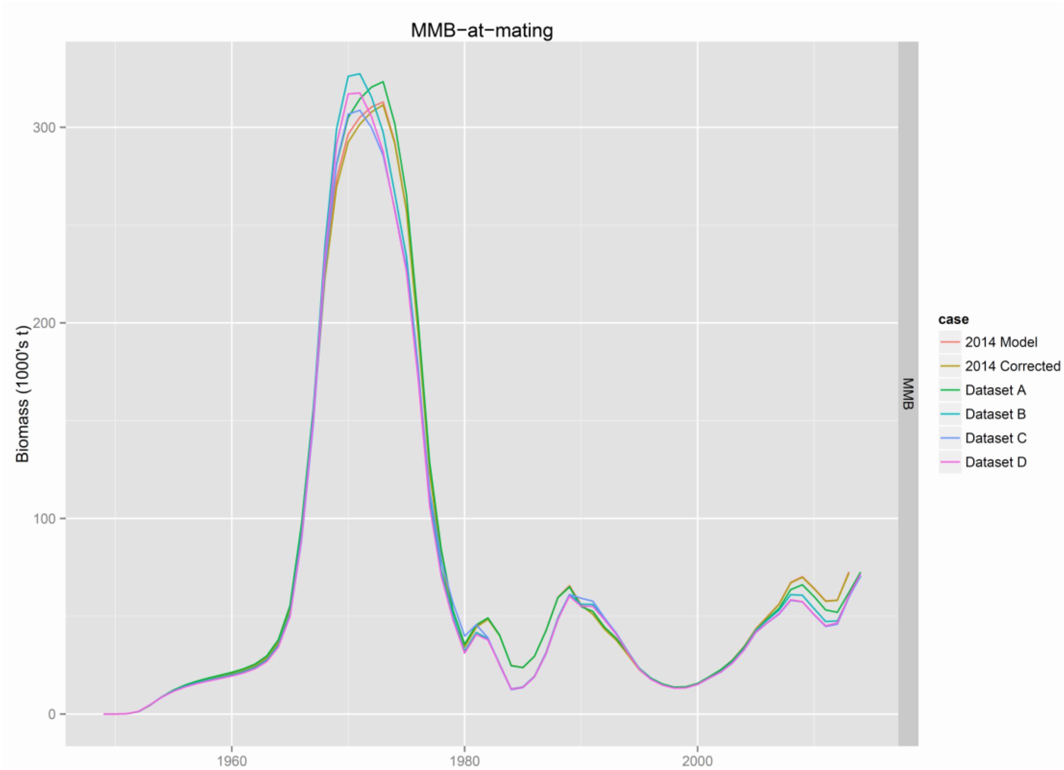


Figure 29. Estimated time series for male recruitment from running Model A on the six datasets considered in the assessment, showing the incremental progression of data changes on model results. Upper graph: entire model time period. Lower graph: 2000-present.



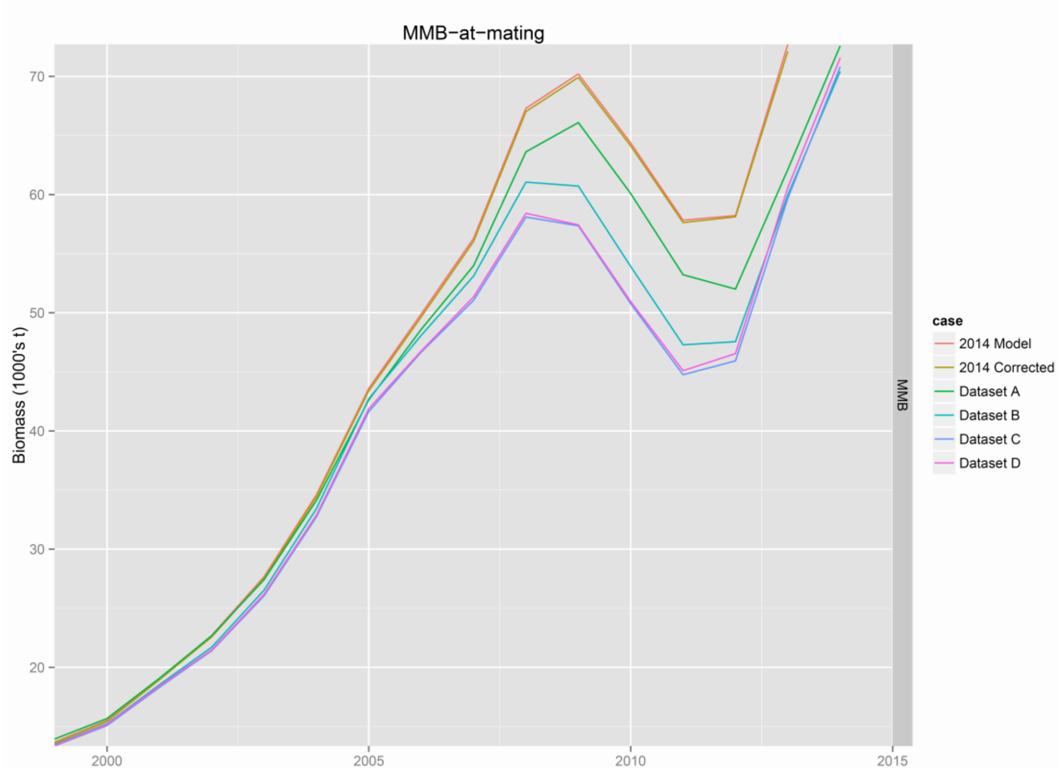


Figure 30. Estimated time series for MMB-at-mating from running Model A on the six datasets considered in the assessment, showing the incremental progression of data changes on model results. Upper graph: entire model time period. Lower graph: 1999-present.

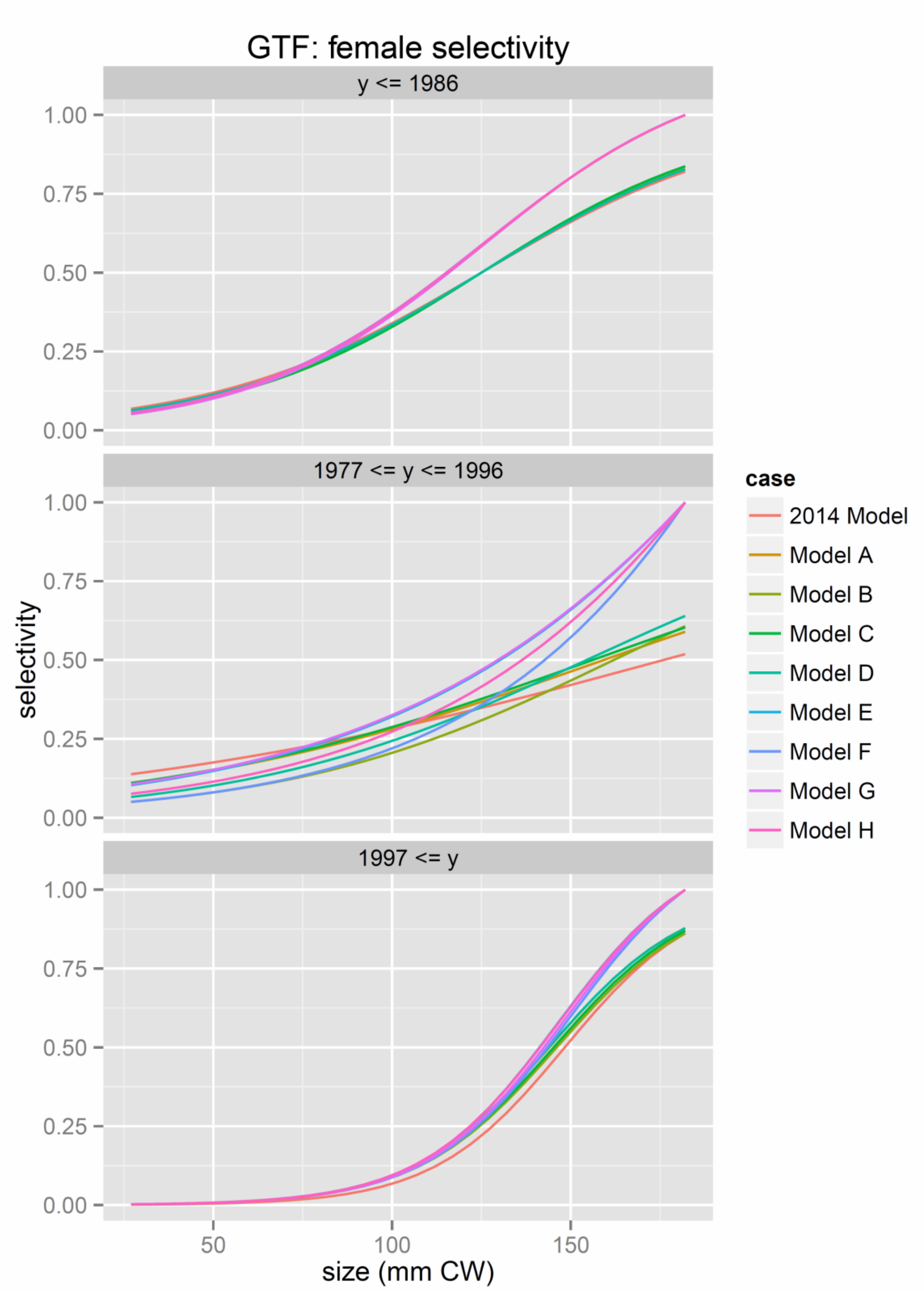


Figure 31. Comparison of estimated logistic curves for female bycatch selectivity in the groundfish trawl fisheries, illustrating the effects of forcing asymptotic selectivity to 1 in the largest model size bin.

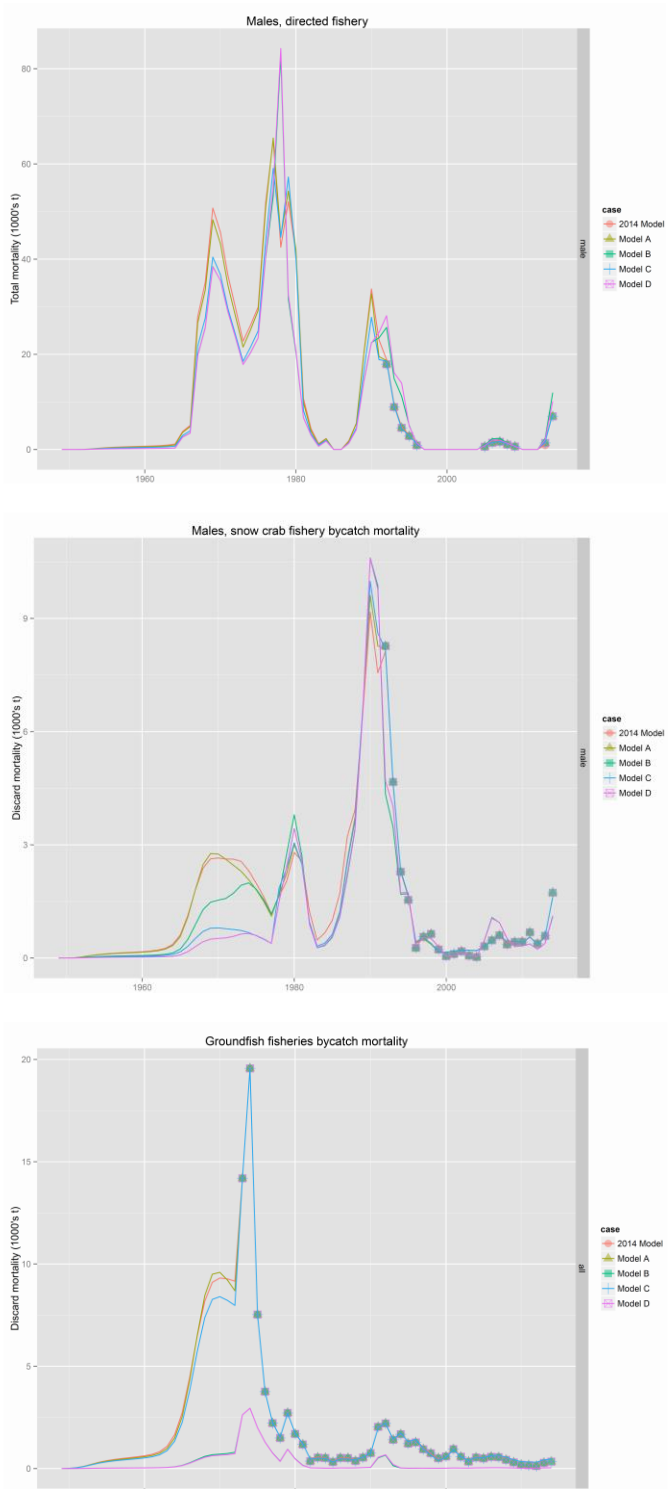


Figure 32. Comparison of fits to bycatch mortality time series in the directed fishery (top graph), the snow crab fishery (center graph) , and the groundfish fisheries (bottom graph) from the 2014 assessment and the alternative models A-D run against Dataset D.

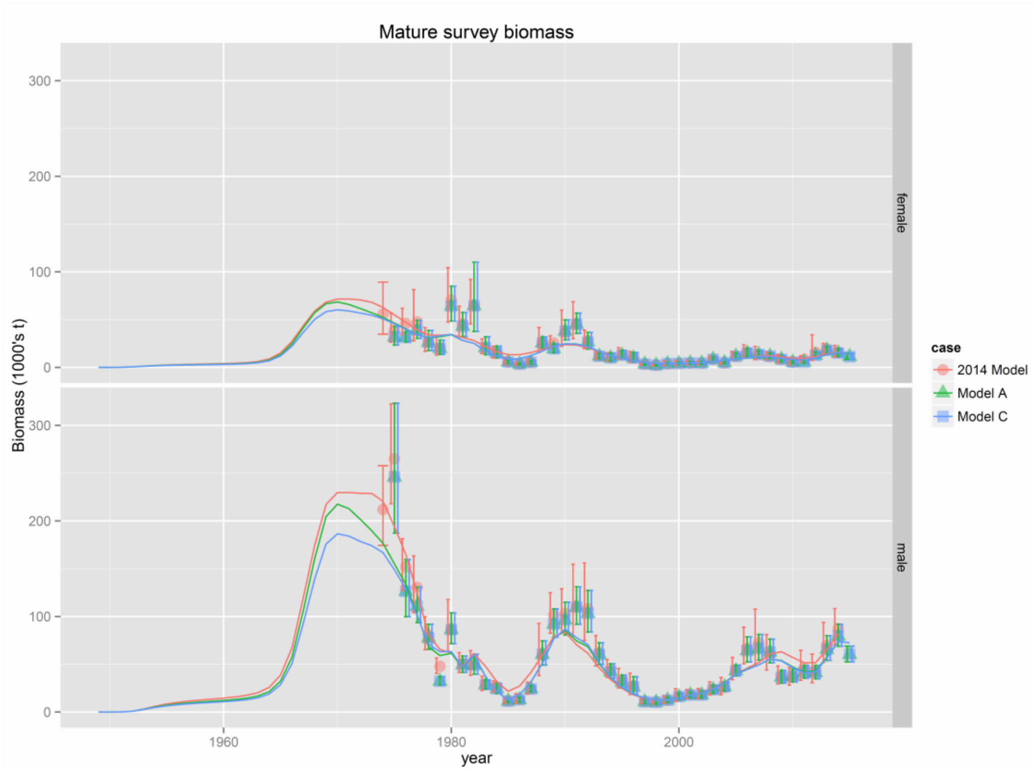


Figure 33. Comparison for fits to mature survey biomass from the 2014 assessment and Models A and C run against Dataset D. Error bars represent 80% confidence intervals based on cv's for survey biomass. They have also been offset slightly horizontally so they don't overlap completely.

Figure 34. Estimates of mature survey biomass from the 2014 assessment and Models A and C run against Dataset D since 2000.

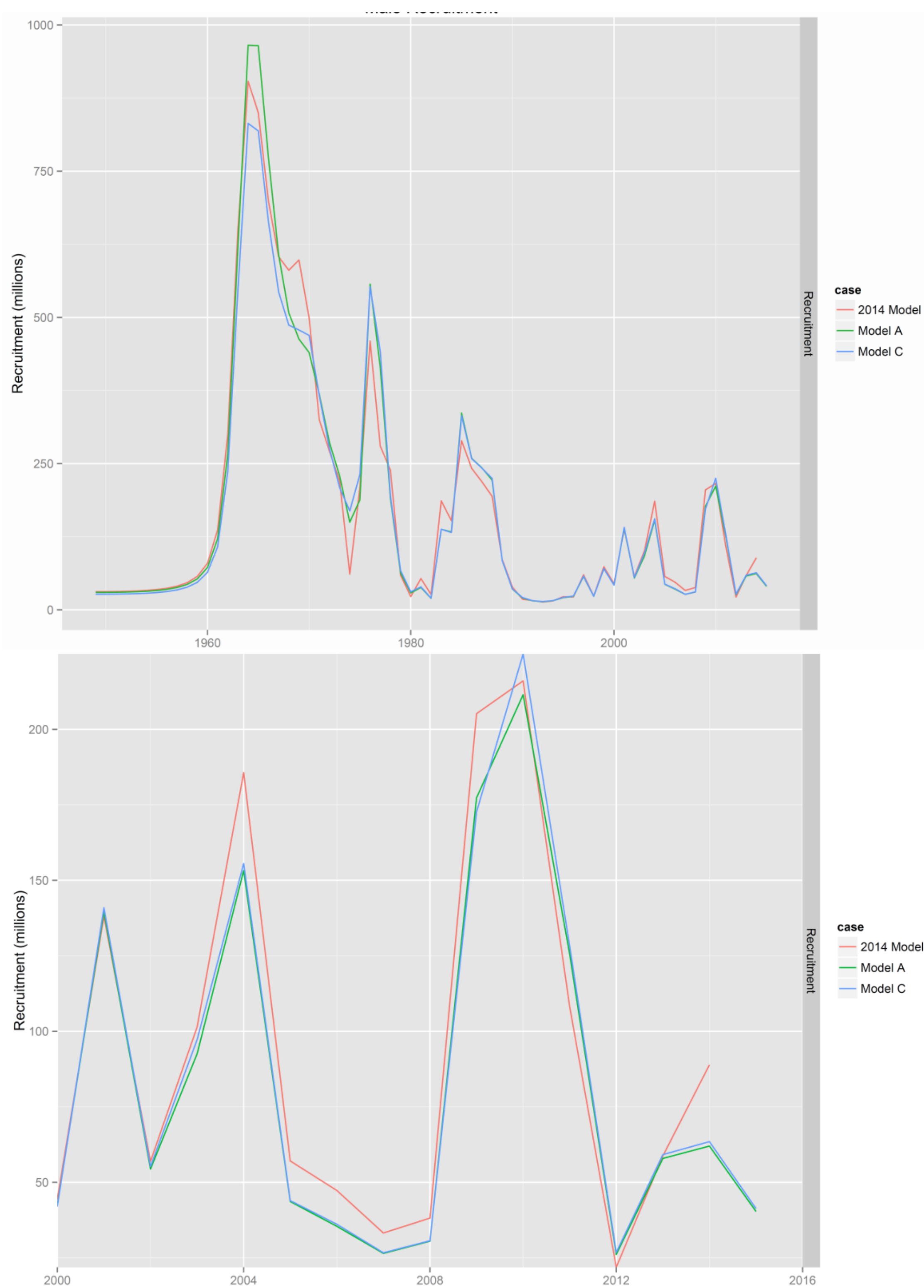


Figure 35. Estimates of male recruitment from the 2014 assessment and Models A and C run against Dataset D since 2000.

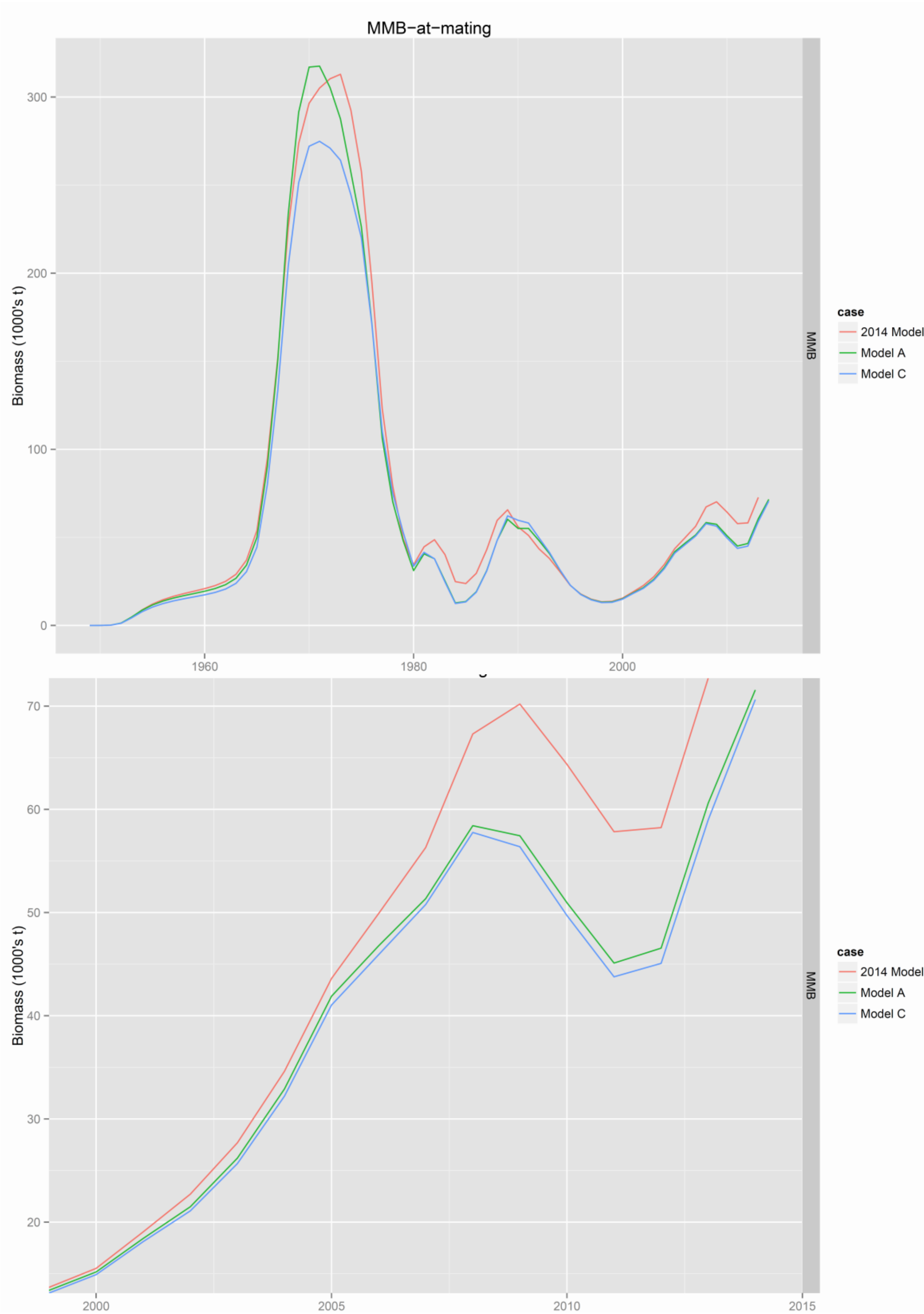


Figure 36. Estimates of MMB-at-mating from the 2014 assessment and Models A and C run against Dataset D since 2000.

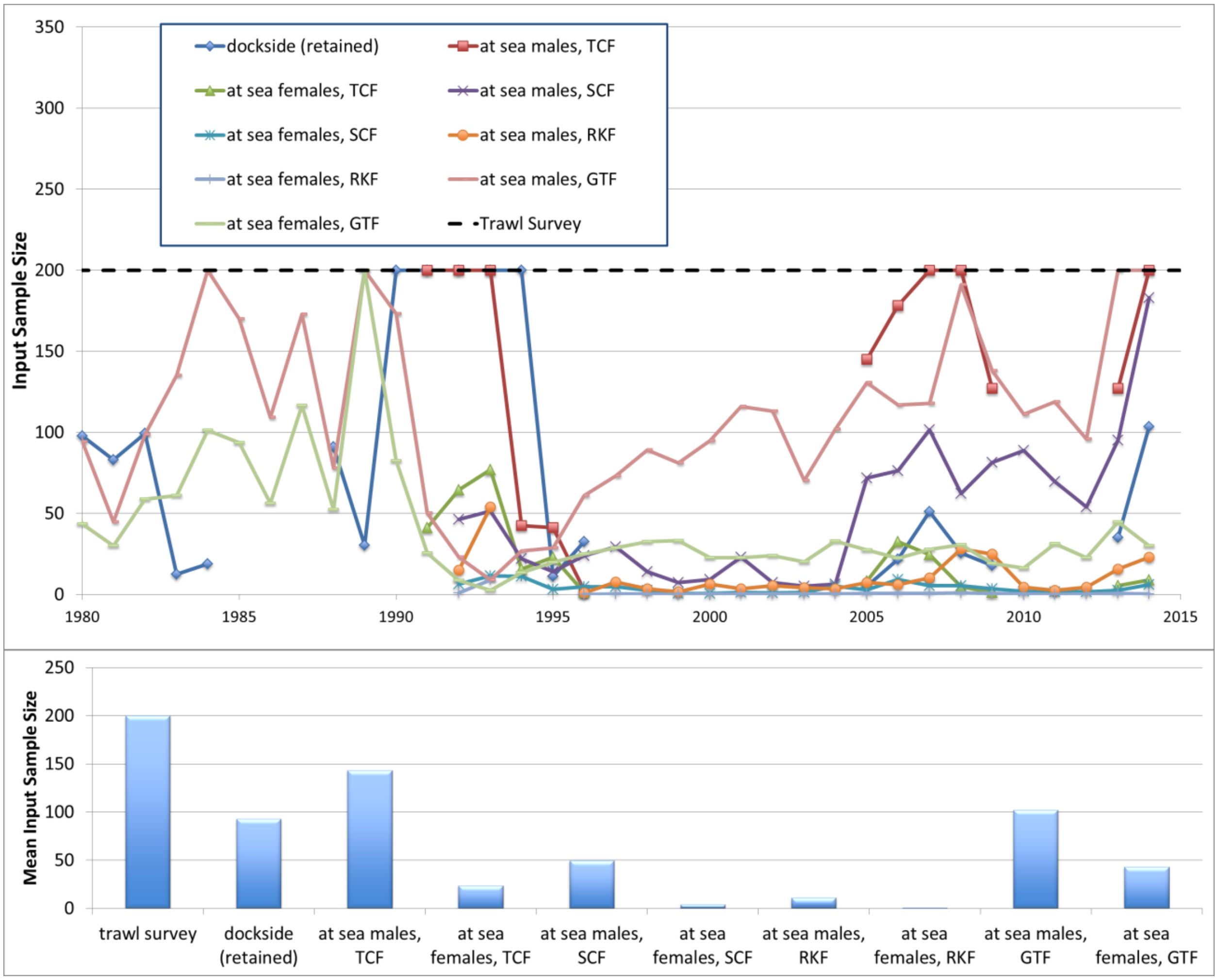


Figure 37. Input sample sizes for by size composition in Dataset D. Upper graph: by year. Lower graph: mean values.

Figure 38.Objective function penalties for Model C, relative to Model A (Model C – Model A). Positive values indicate Model A has a smaller penalty than Model C.

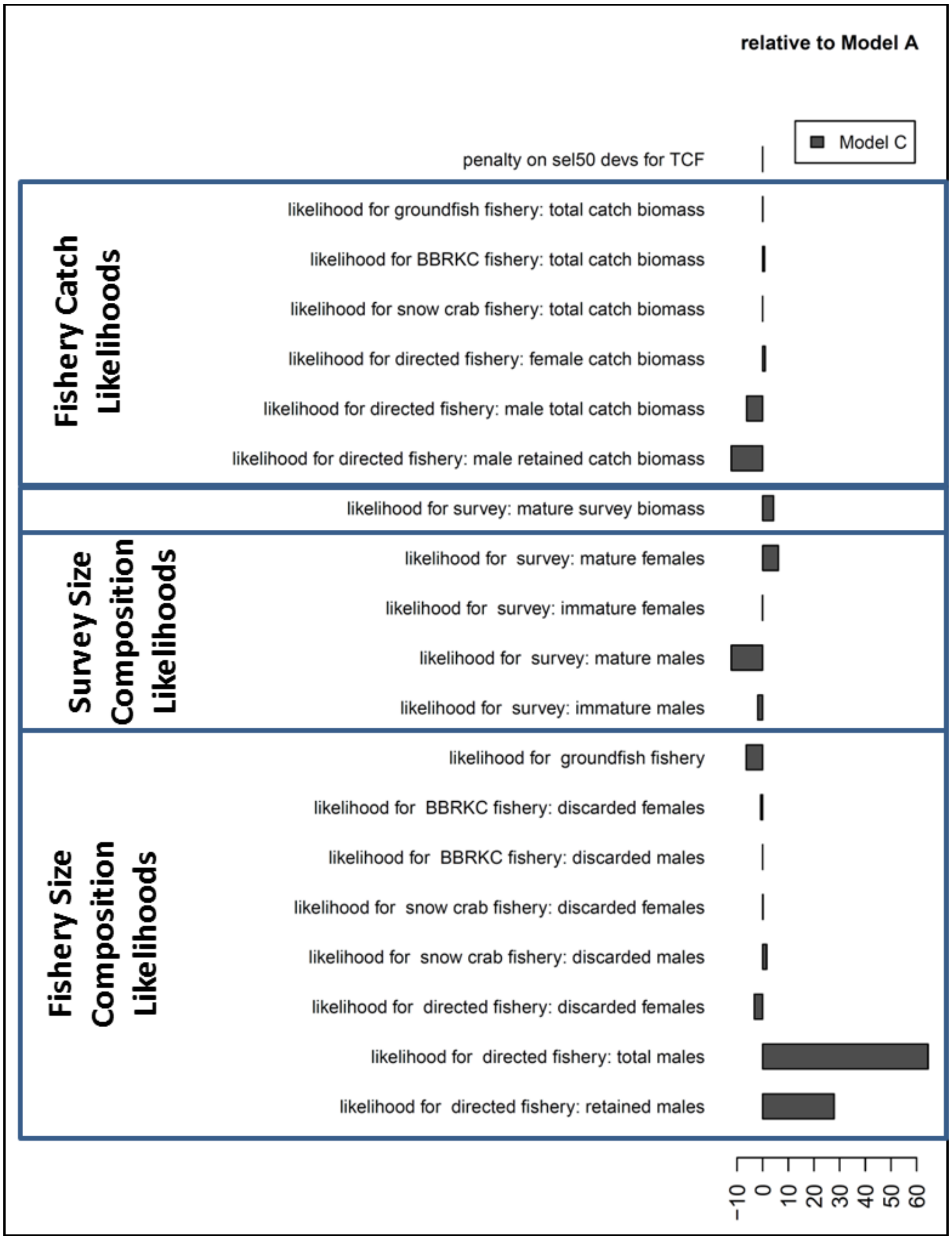


Figure 39.Objective function penalty and data (weighted negative log-likelihood) components for Model C relative to Model A (Model C – Model A). Positive values indicate Model A has a smaller penalty or fits the data better than Model C (this convention is opposite to that used in Table 23).

Model A Model C

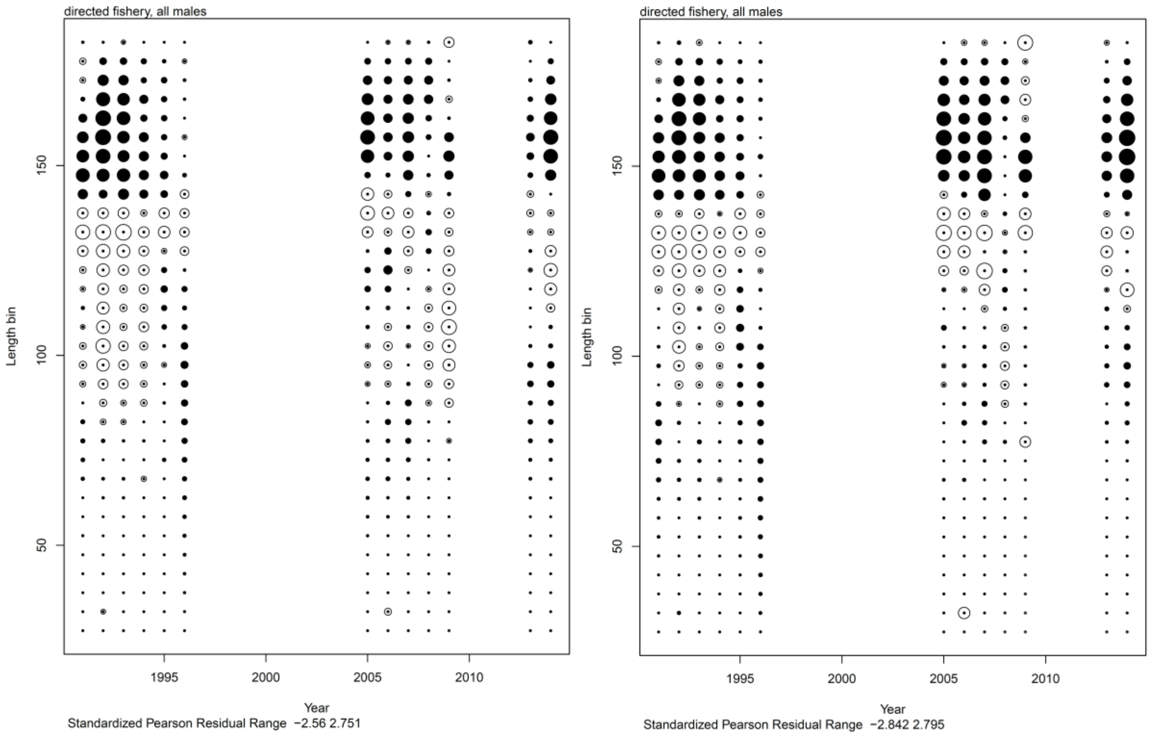


Figure 40.Comparison of Pearson's residuals from the fits to total male catch size compositions in the directed fishery for Models A (left) and C (right). Scales for Model C are slightly larger than for A.

Model A Model C

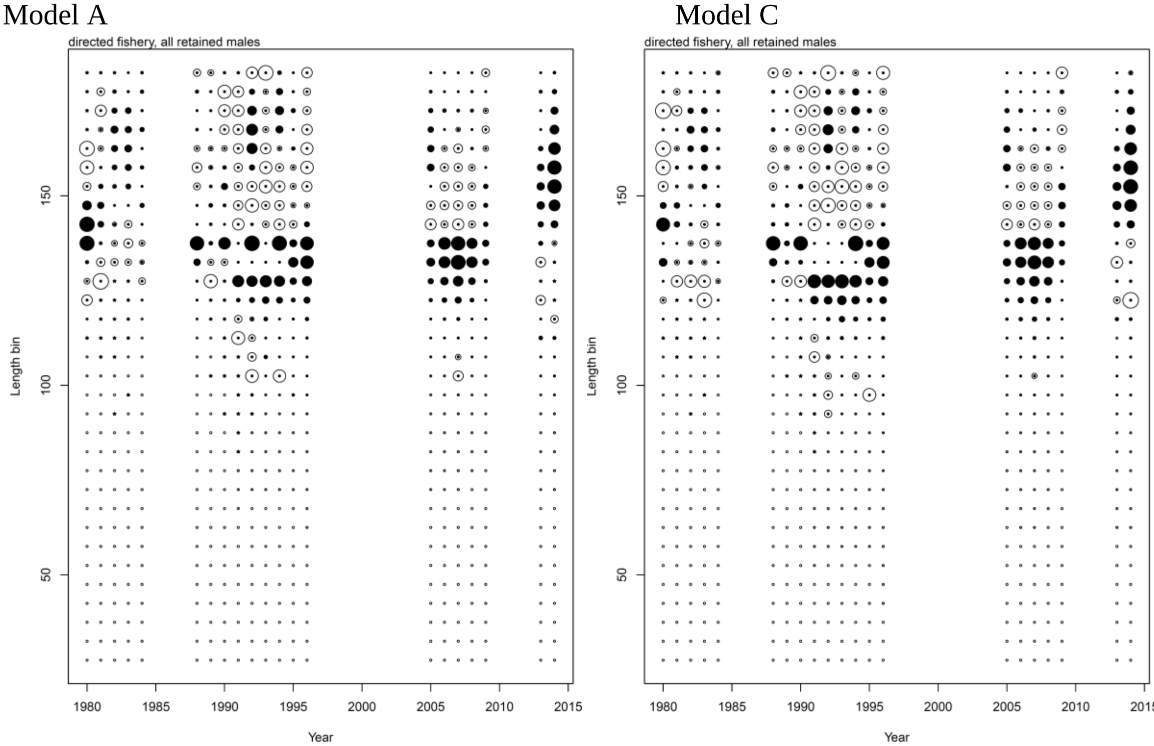


Figure 41.Comparison of Pearson's residuals from the fits to retained catch size compositions for Models A (left) and C (right). Note: the scales are not quite identical.

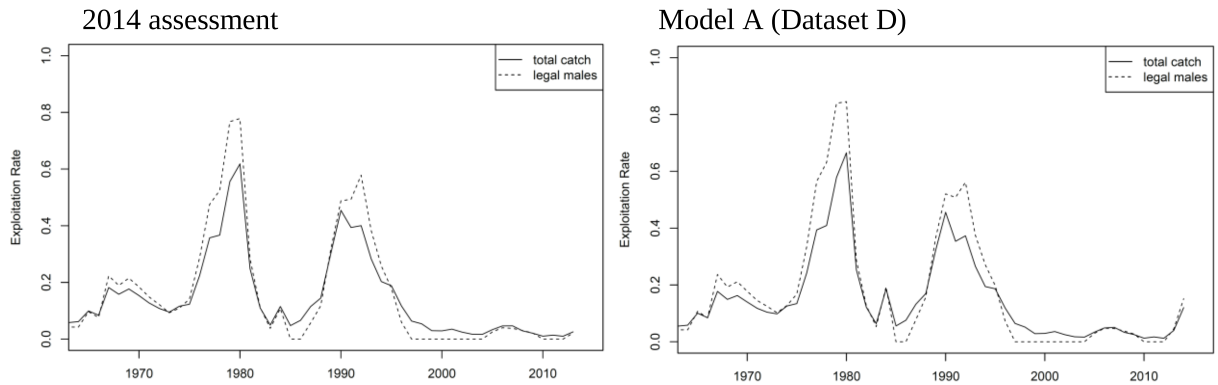


Figure 42. Estimated exploitation rates in the directed fishery for total catch and males ≥ 138 mm CW from the 2014 assessment and the author's preferred model.

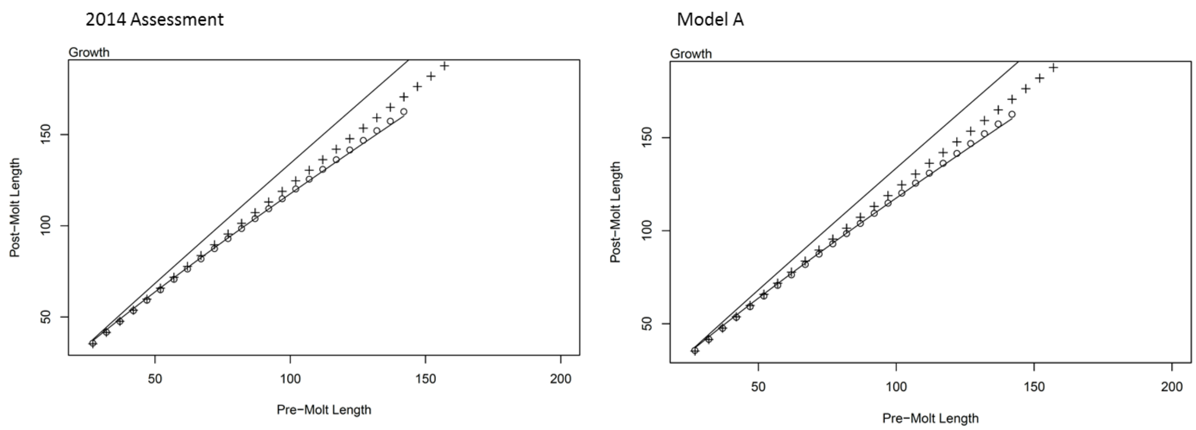


Figure 43. Comparison of mean growth curves from the 2014 assessment and Model A (Dataset D). Solid lines: model estimates (upper = males, lower=females). Symbols: empirical curves (“+”: males, “o”=females) developed from Tanner crab growth data near Kodiak Island in the Gulf of Alaska (Courtesy of E. Munk, AFSC Kodiak).

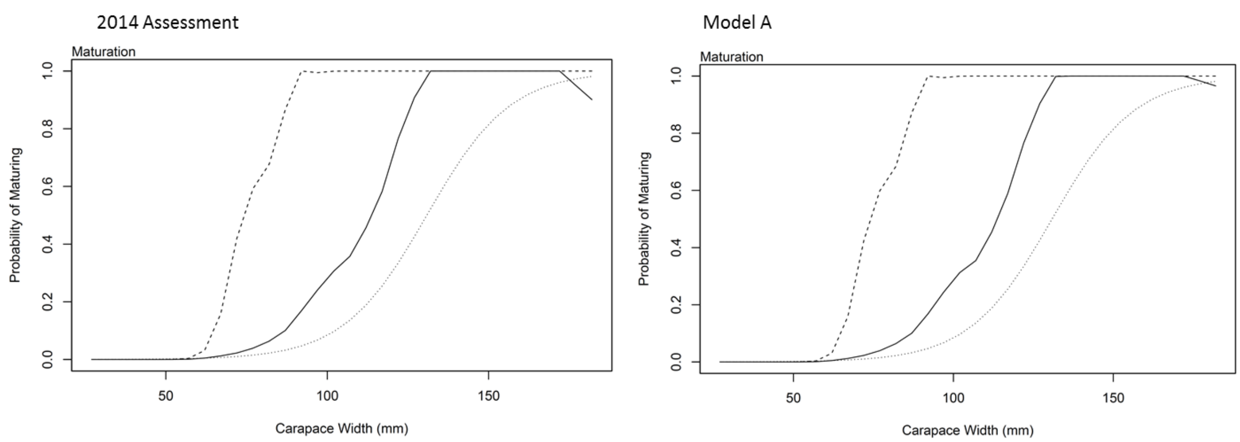


Figure 44. Comparison of probability of maturing from the 2014 assessment and Model A (Dataset D). Solid lines: males, dashed lines=females. The dotted line was used in the analysis for Amendment 24.

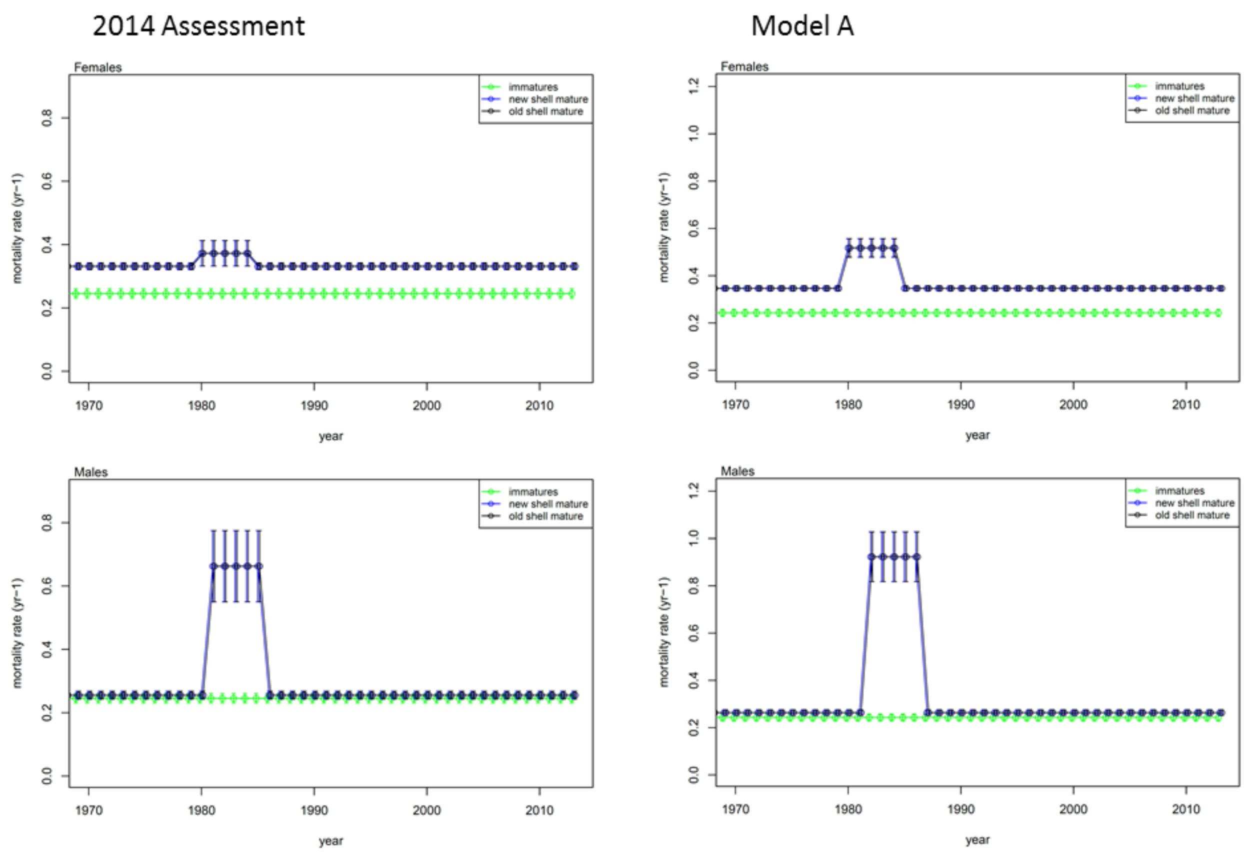


Figure 45. Estimated natural mortality for immature (single time period: 1949-2013) and mature (two time periods: 1949-1979+2005-2013 and 1980-1984) crab by sex (upper graph: females; lower graph: males).

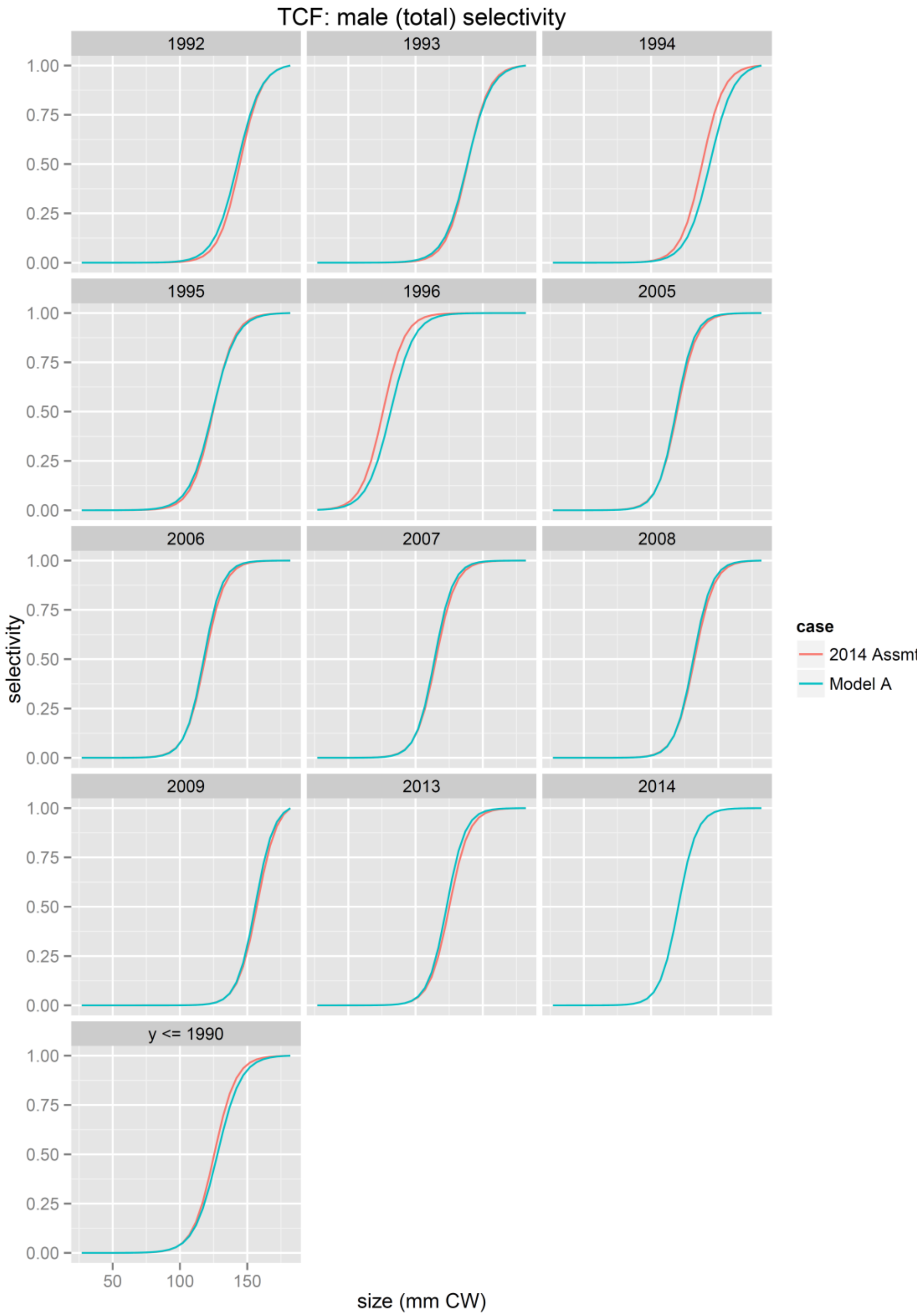


Figure 46. Comparison of estimated total male fishing mortality selectivity curves in the directed fishery.

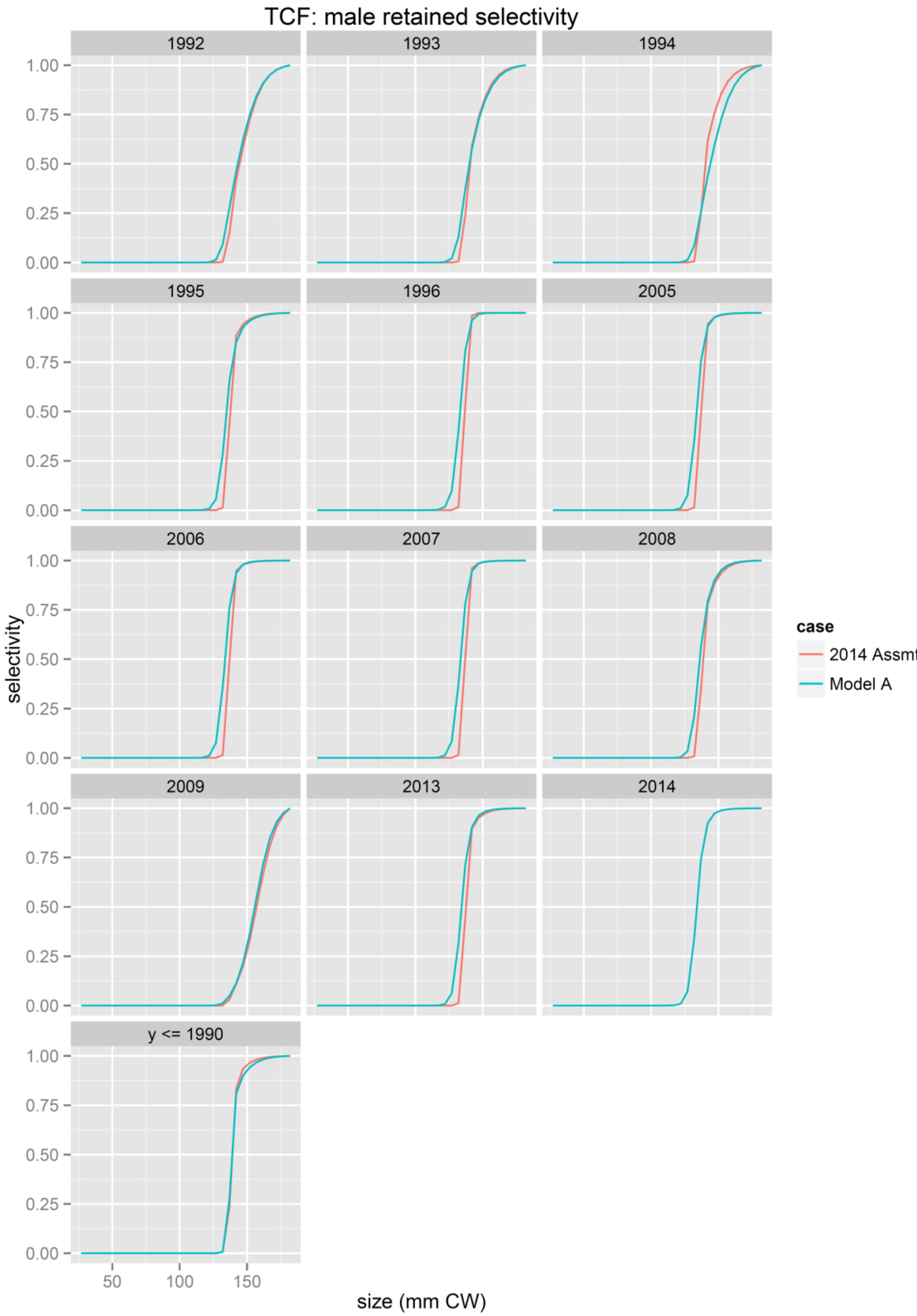


Figure 47. Comparison of estimated male retained mortality selectivity curves in the directed fishery (TCF = Tanner crab fishery).

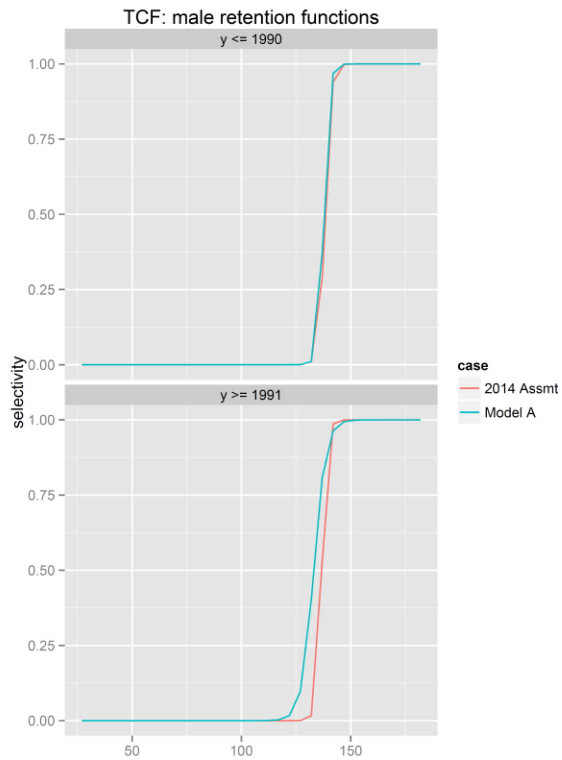


Figure 48. Comparison of retention curves in the directed Tanner crab fishery (TCF).

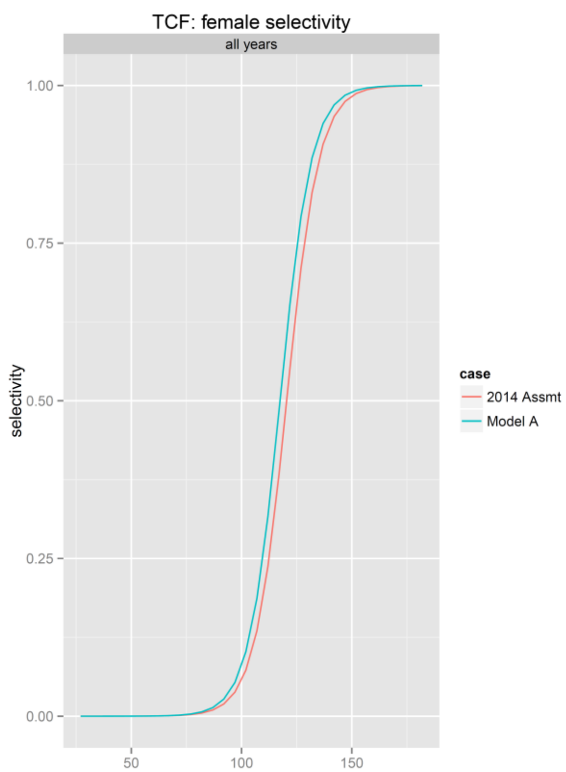


Figure 49. Comparison of estimated female bycatch selectivity in the directed Tanner crab fishery (TCF).

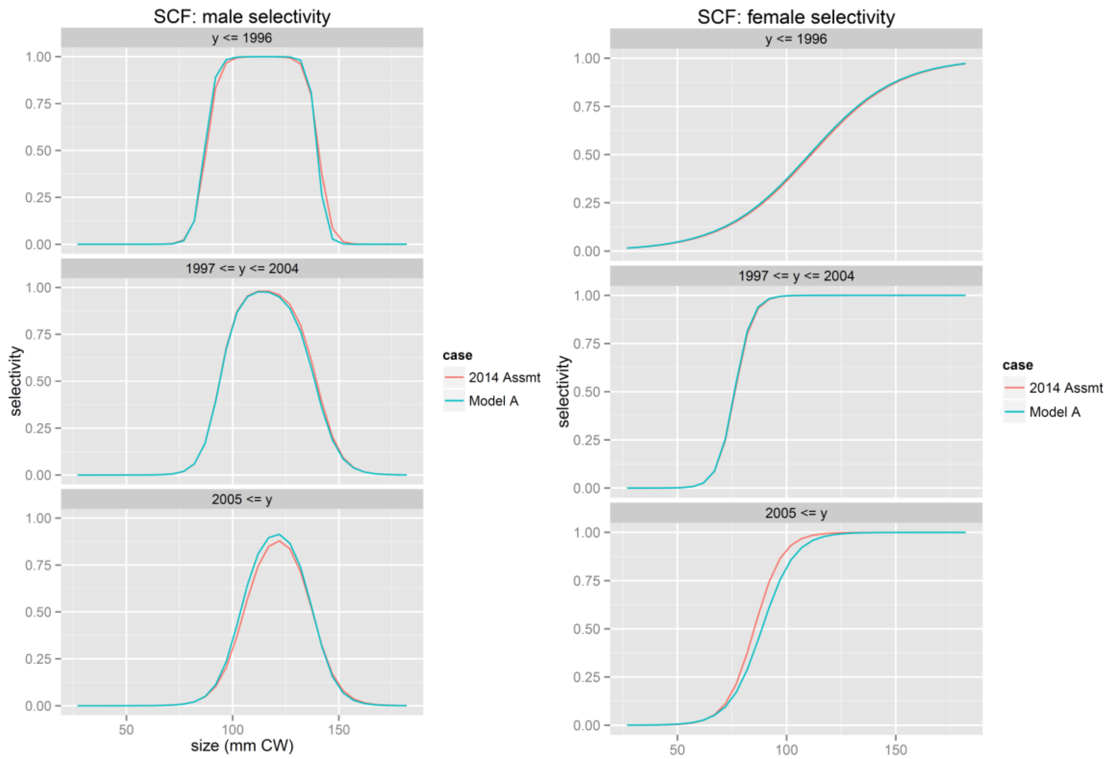


Figure 50. Estimated sex-specific bycatch selectivity functions in the snow crab fishery (SCF).

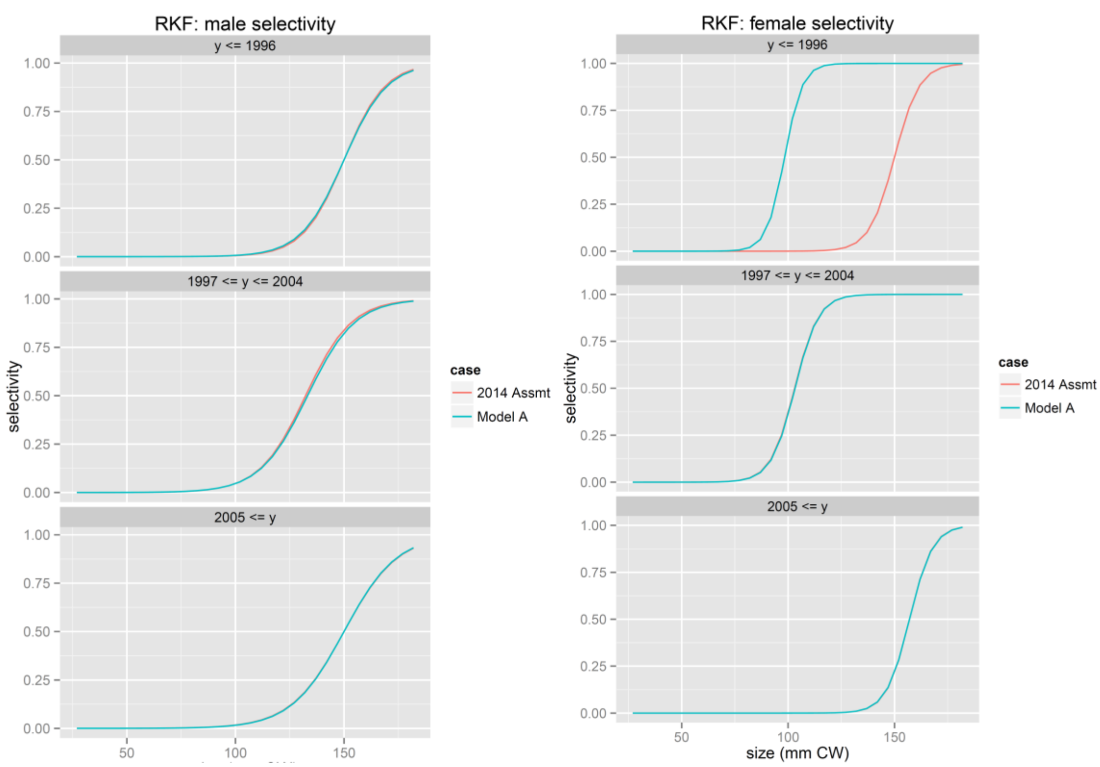


Figure 51. Estimated bycatch selectivity functions in theBBRKC fishery (RKF).

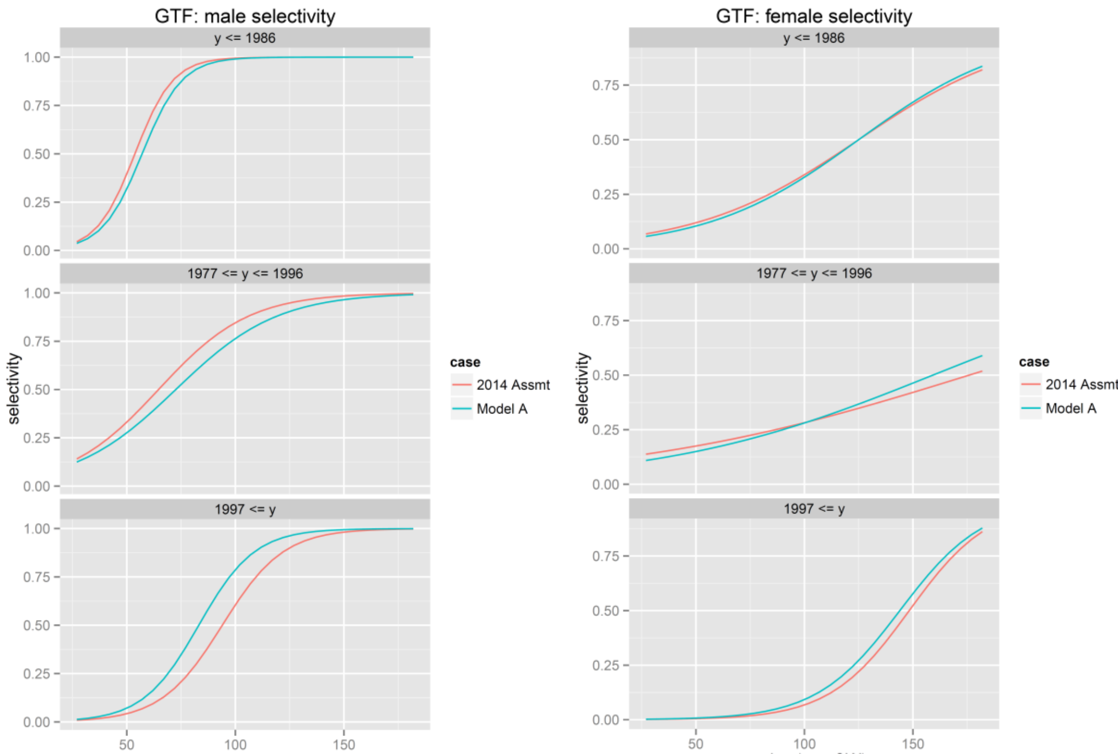


Figure 52. Estimated bycatch selectivity in the groundfish fisheries (GTF).

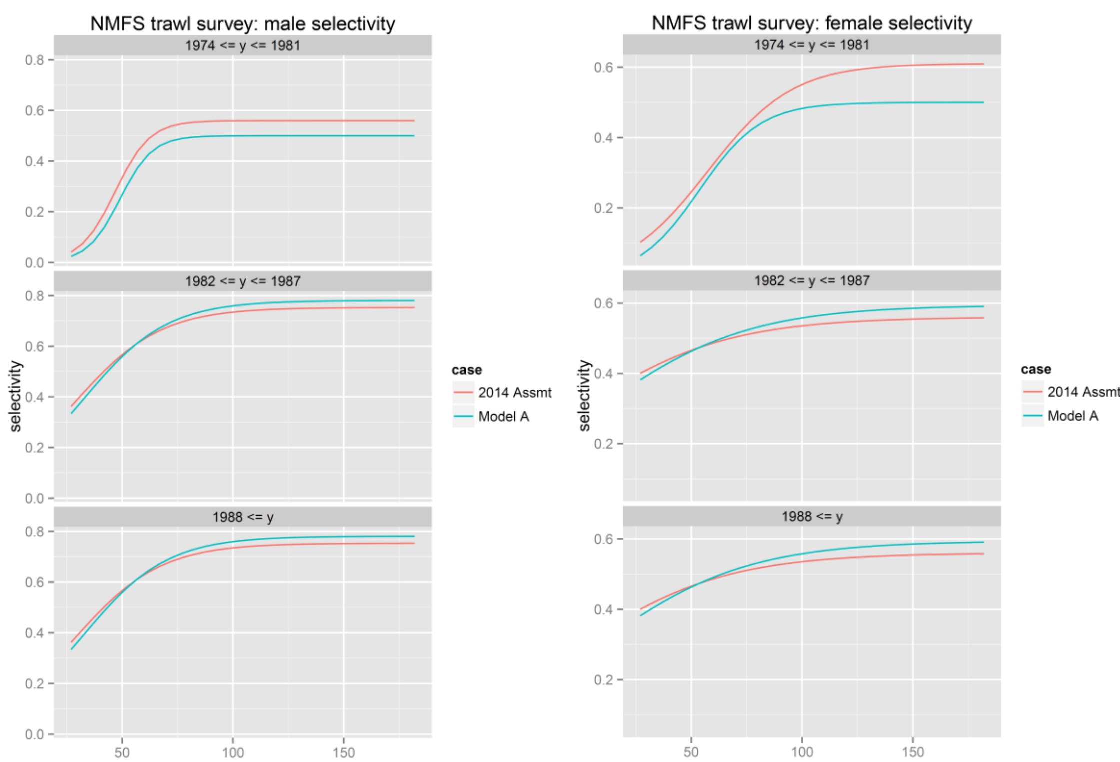


Figure 53. Estimated NMFS trawl survey selectivities, scaled by sex-specific catchability.

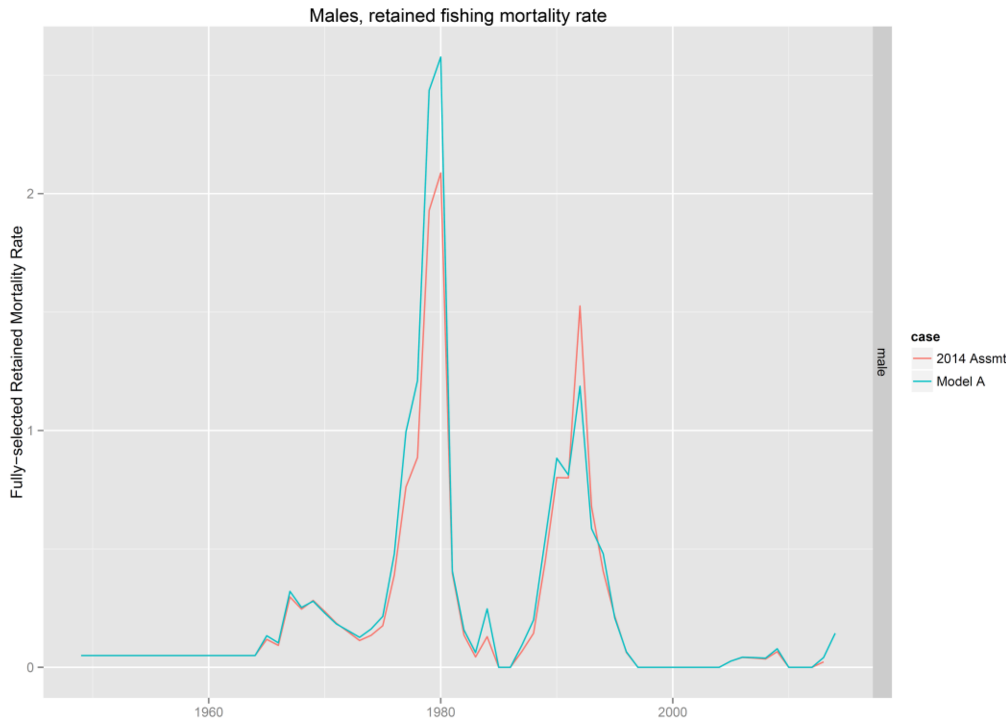


Figure 54. Comparison of estimated fully-selected fishing mortality rate on males in the directed fishery.

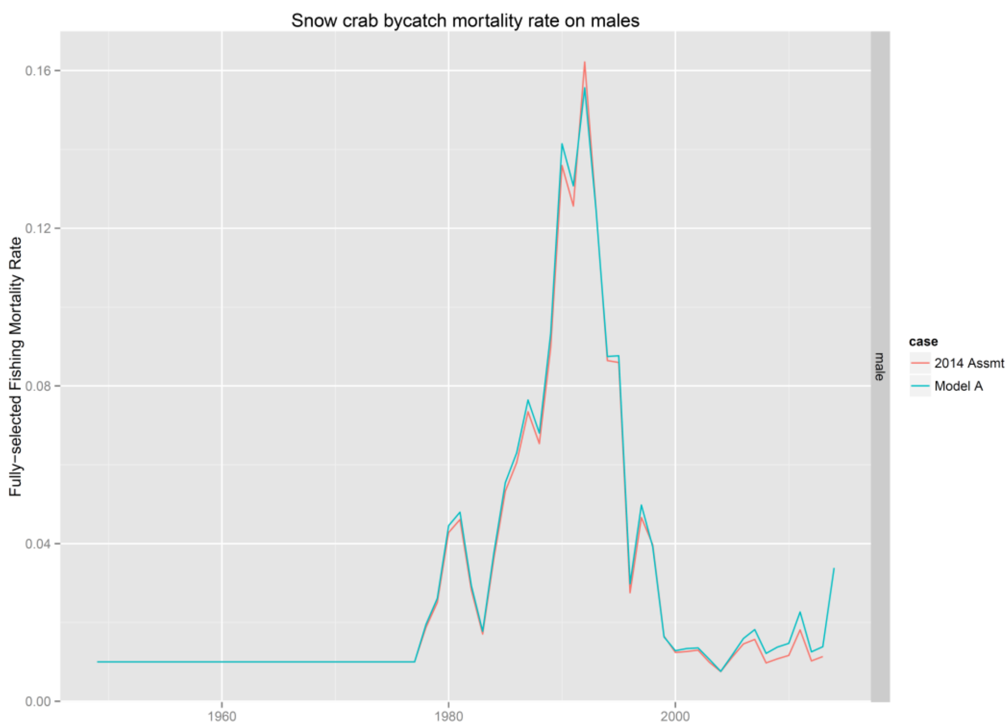


Figure 55. Comparison of estimated fully-selected bycatch mortality rate on males in the snow crab fishery.

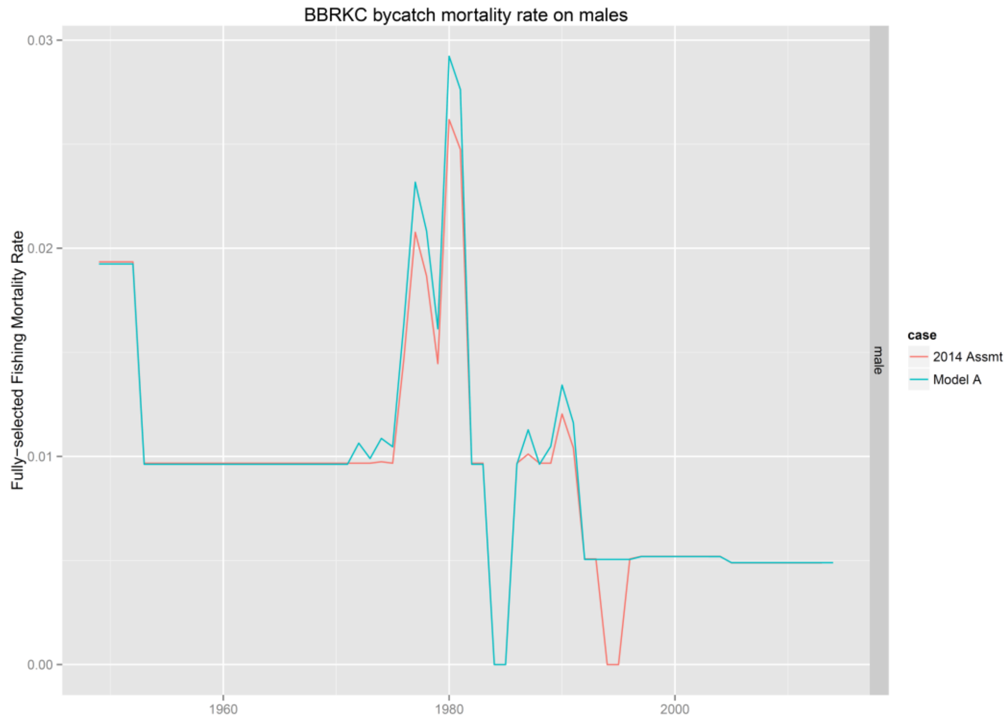


Figure 56. Comparison of estimated fully-selected bycatch mortality rate on males in the BBRKC fishery.

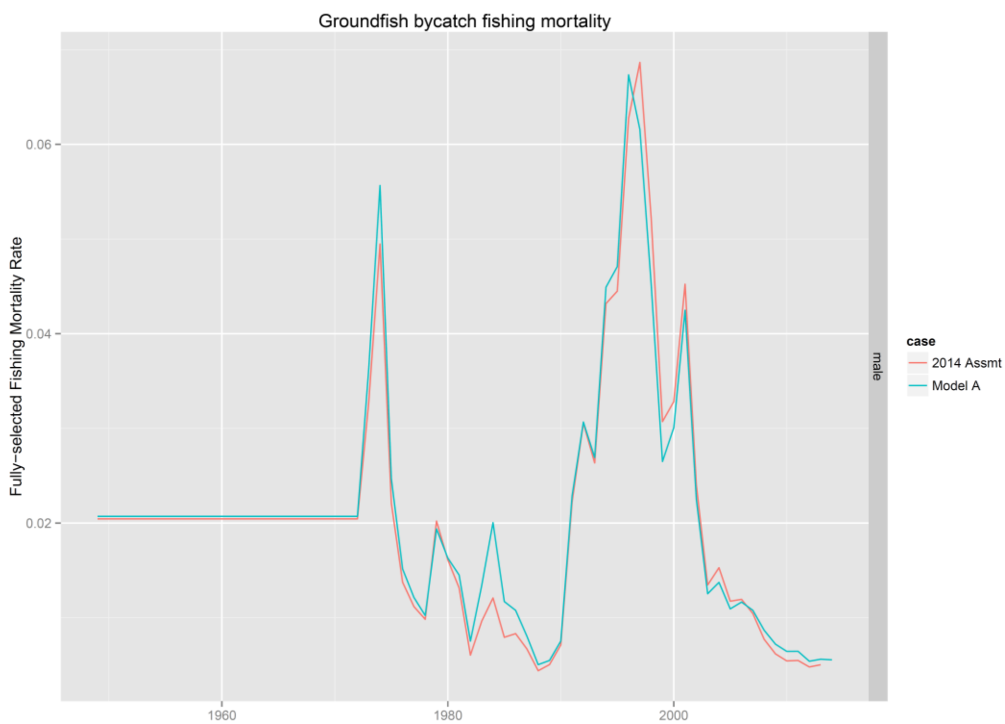


Figure 57. Comparison of estimated fully-selected bycatch mortality rate on males in the groundfish fisheries.

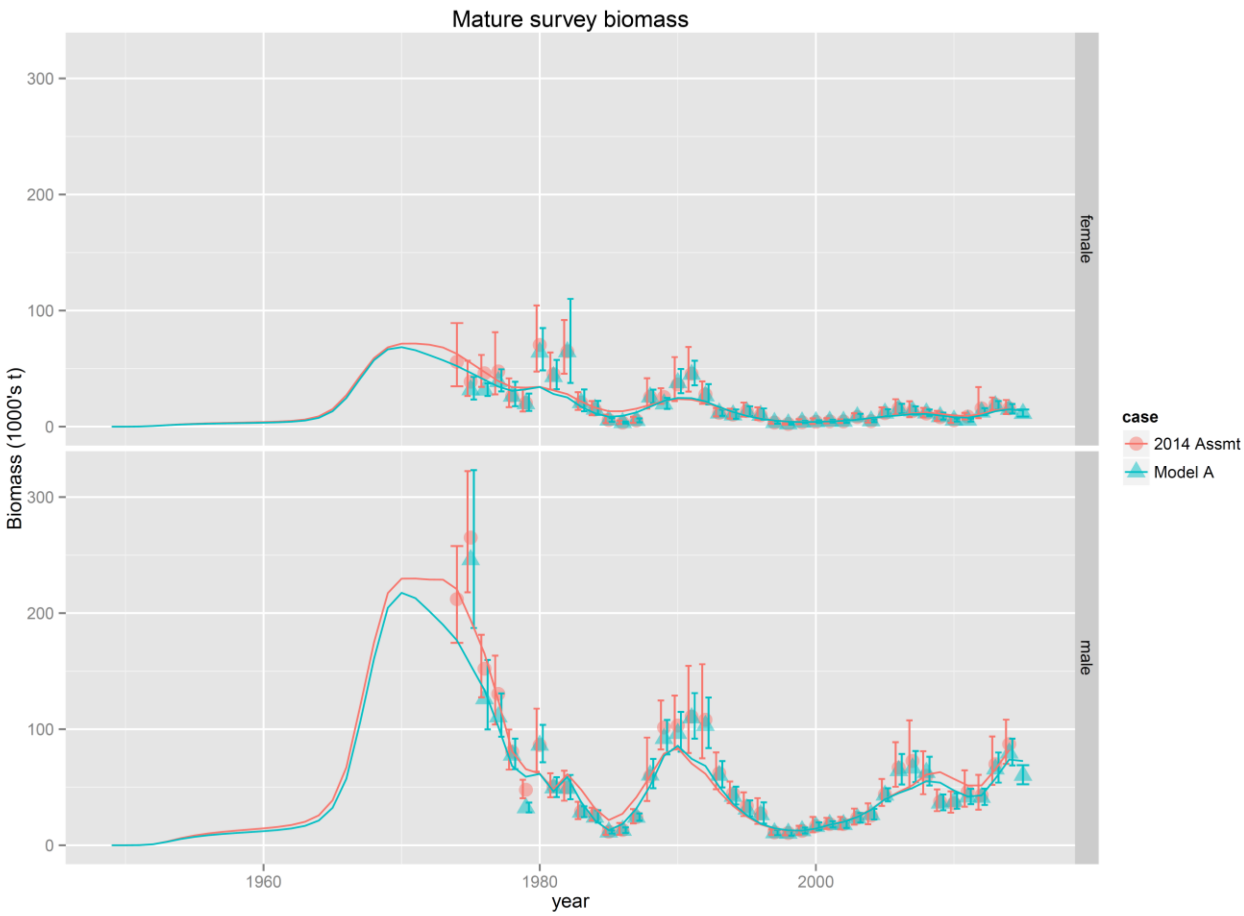


Figure 58. Comparison of time series of mature survey spawning biomass from the 2014 assessment and Model A (Dataset D). Error bars are 80% confidence intervals, and are slightly offset to prevent overlap.

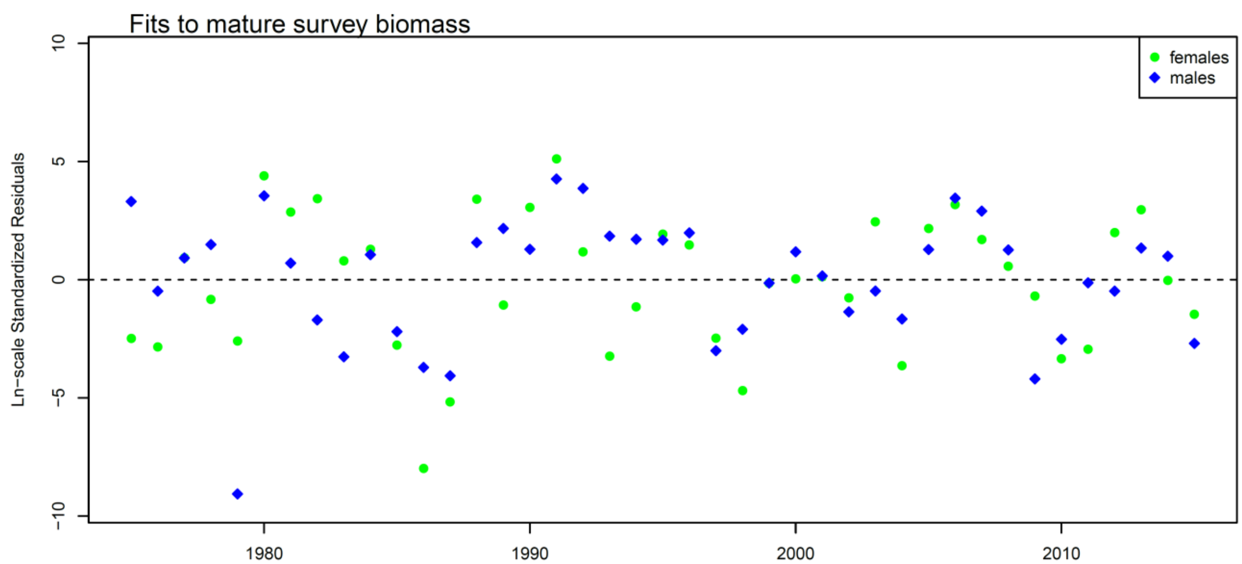


Figure 59.Residuals from the sex-specific fits to mature survey spawning biomass for Model A (Dataset D).

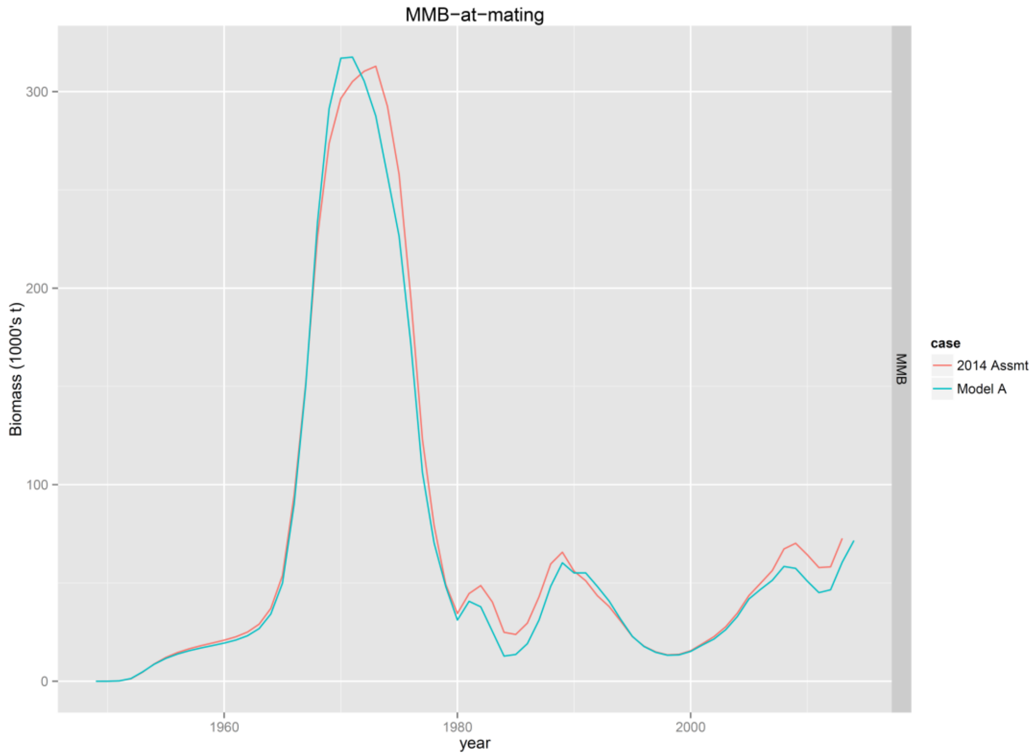


Figure 60. Comparison of time series of estimated MMB-at-mating from the 2014 assessment and Model A (Dataset D).

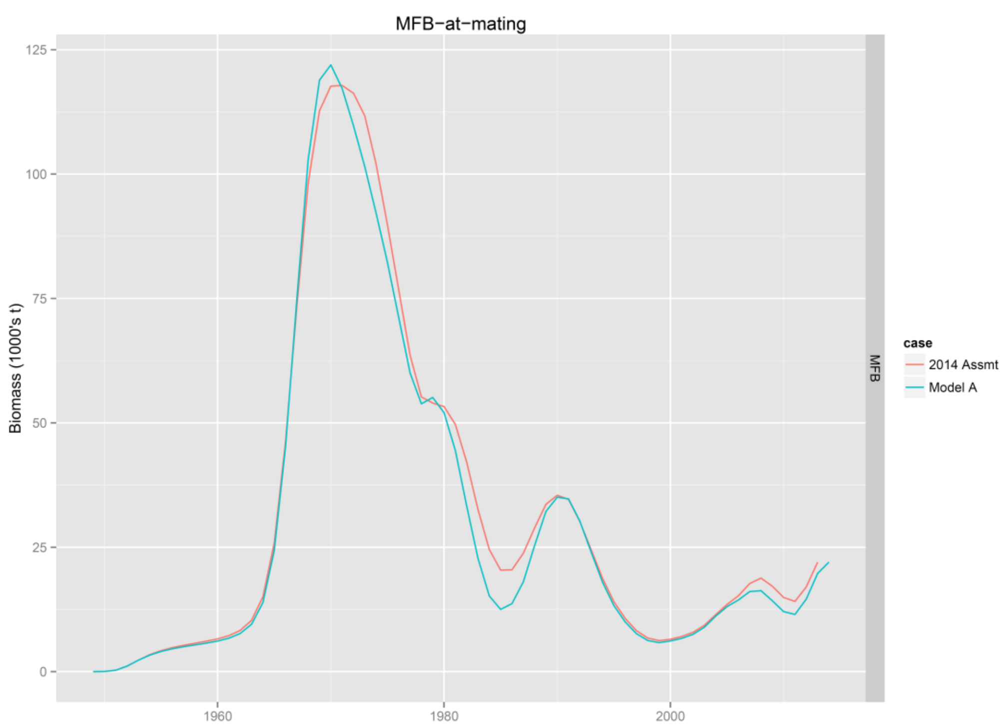
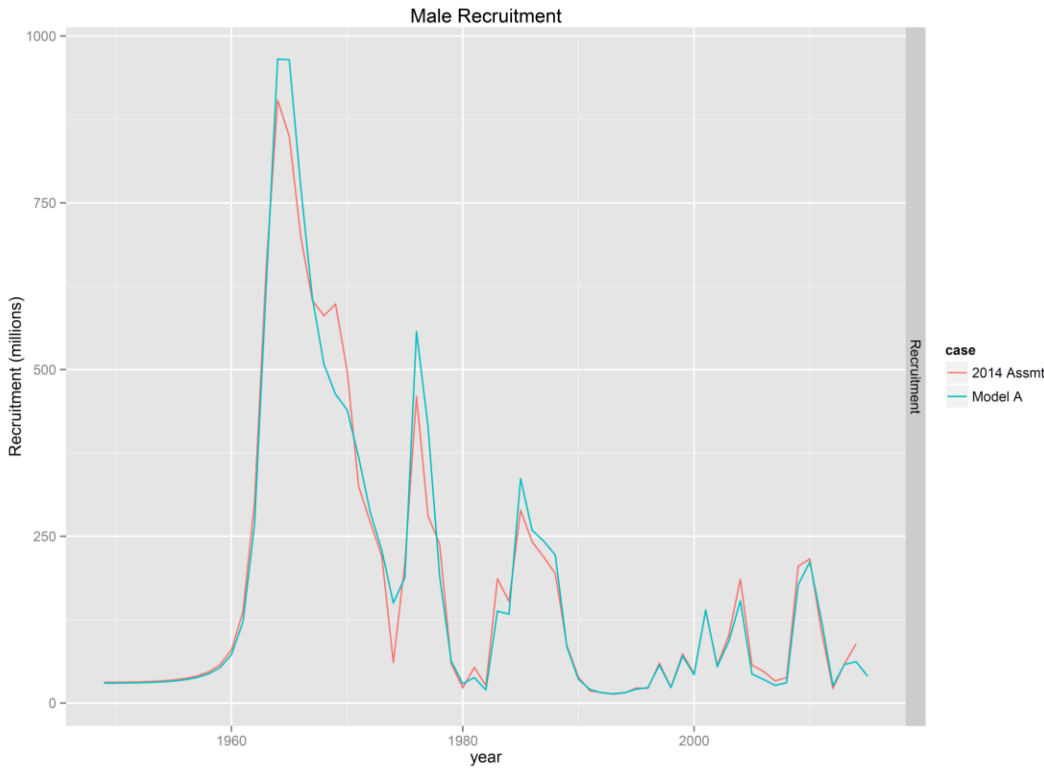
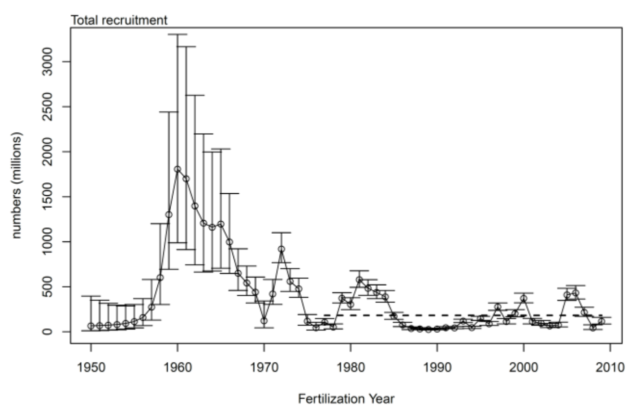


Figure 61. Comparison of time series of estimated mature female biomass-at-mating from the 2014 assessment and Model A (Dataset D).



2014 Assessment Model Model A



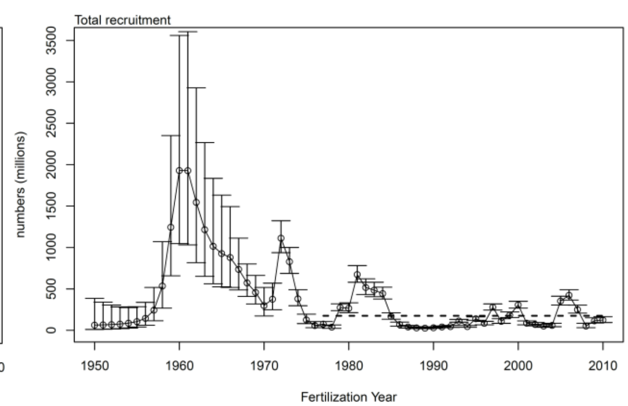


Figure 62. Comparison of model-estimated time series for (male) recruitment from the 2014 assessment and Model A (Dataset D).

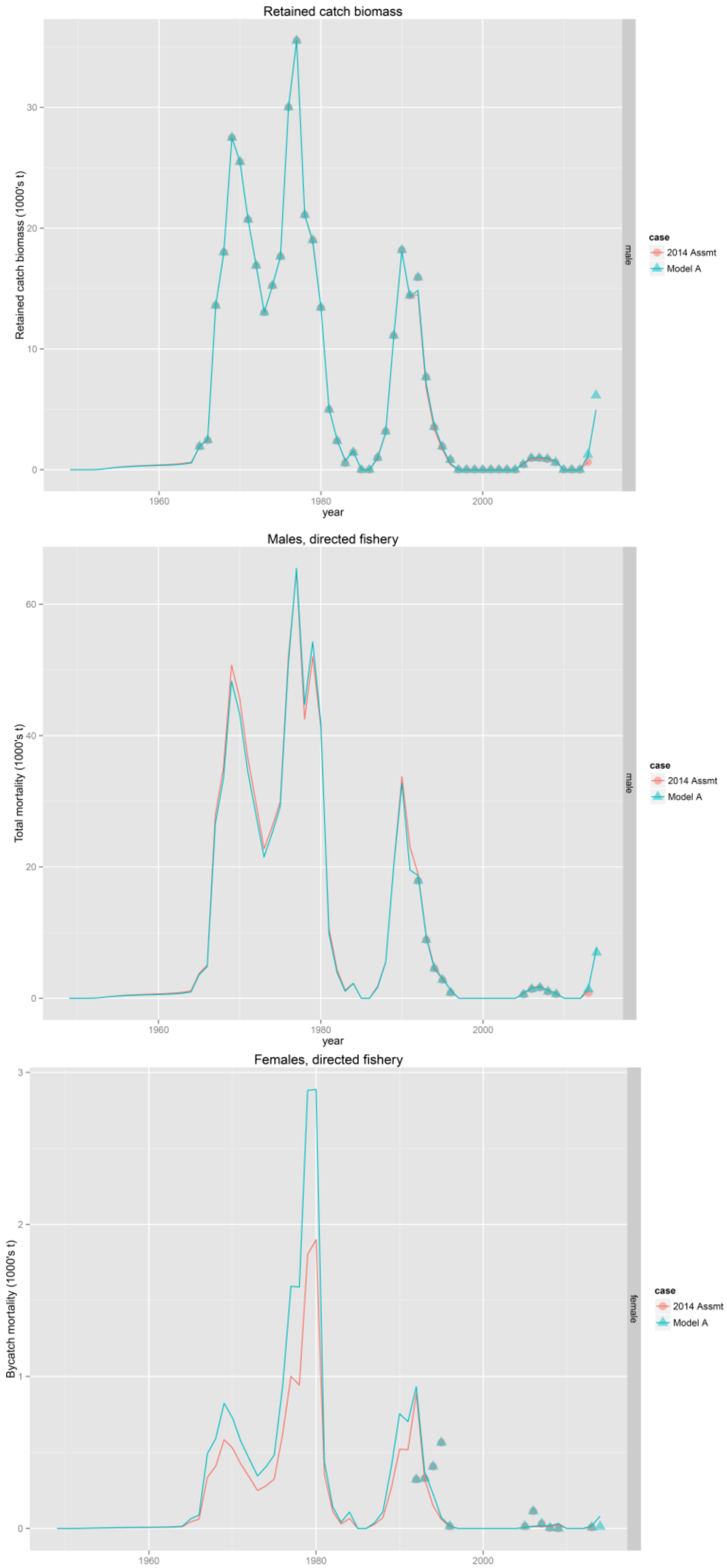
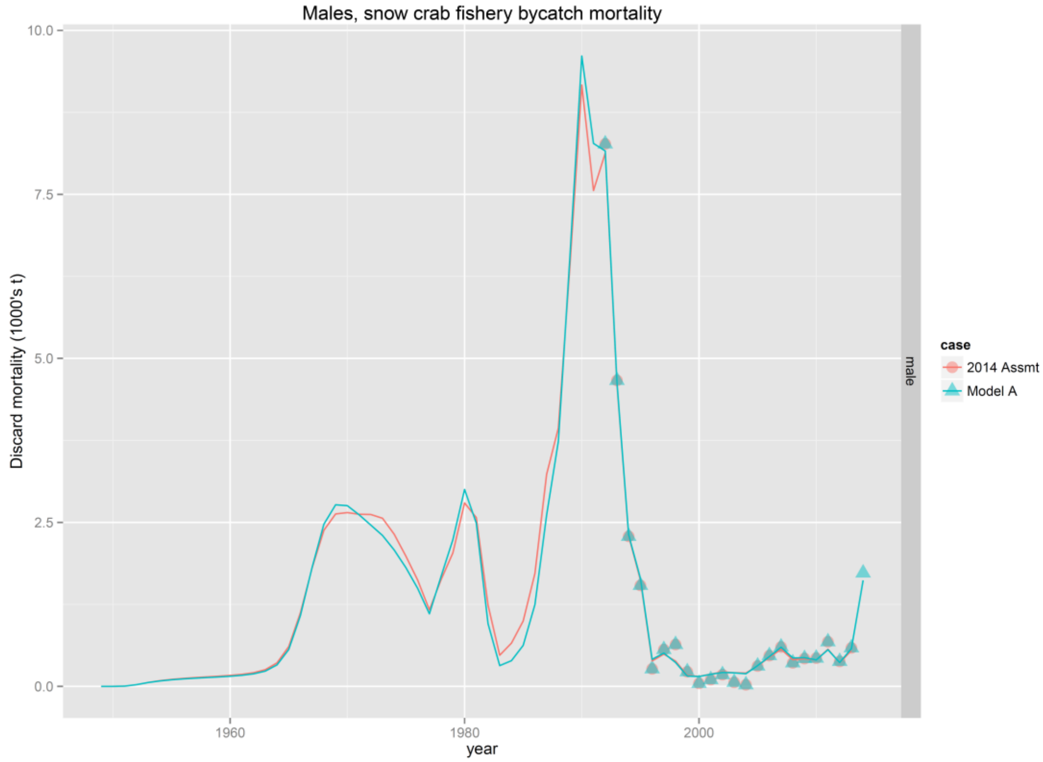


Figure 63 Comparison of model-estimated time series for fits to data from the directed fishery: 1) retained catch (upper graph), 2) total male mortality (retained + discard), and 3) female discard mortality (lower graph).



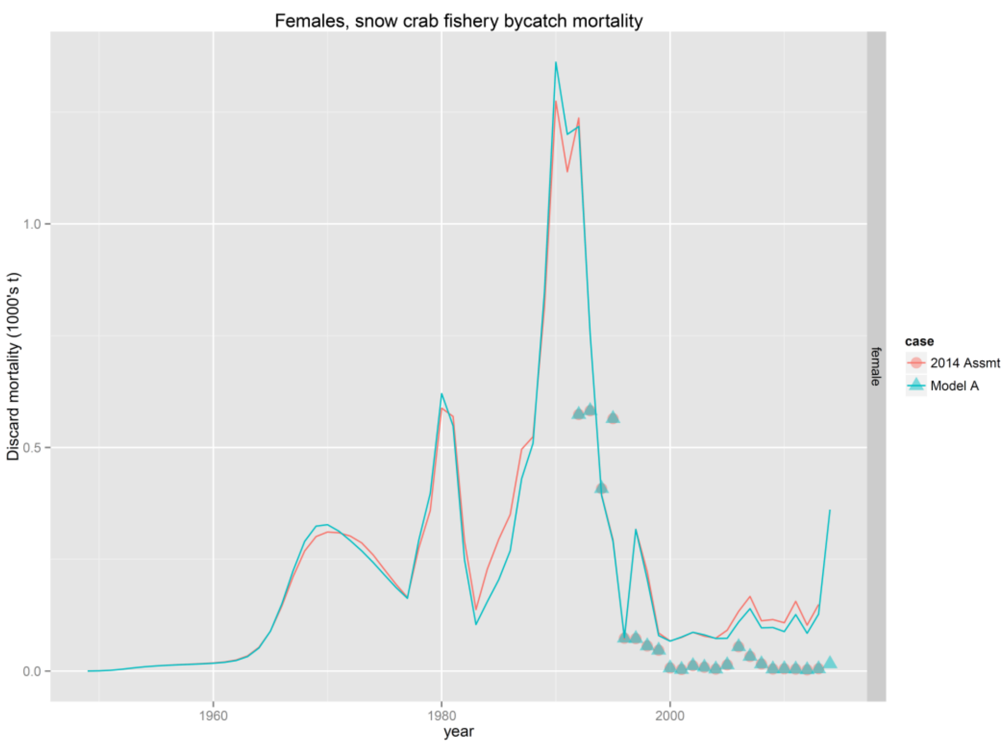


Figure 64. Comparison of model-estimated time series for fits to data for bycatch mortality in the snow crab fishery for the 2014 assessment Model A (Dataset D). Upper graph: males. Lower graph: females.

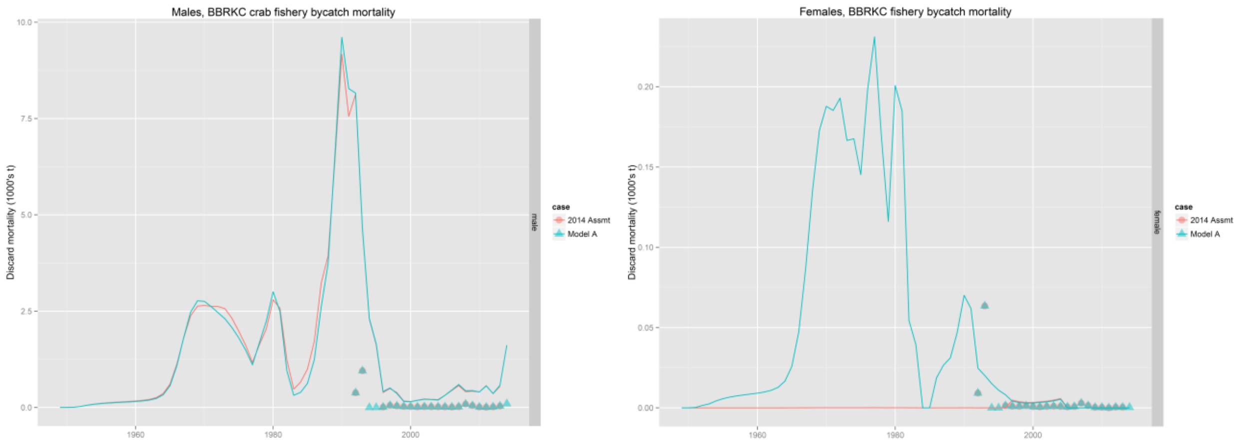


Figure 65. Comparison of fits to discard mortality time series in the BBRKC fishery from the 2014 assessment and Model A (Dataset D).

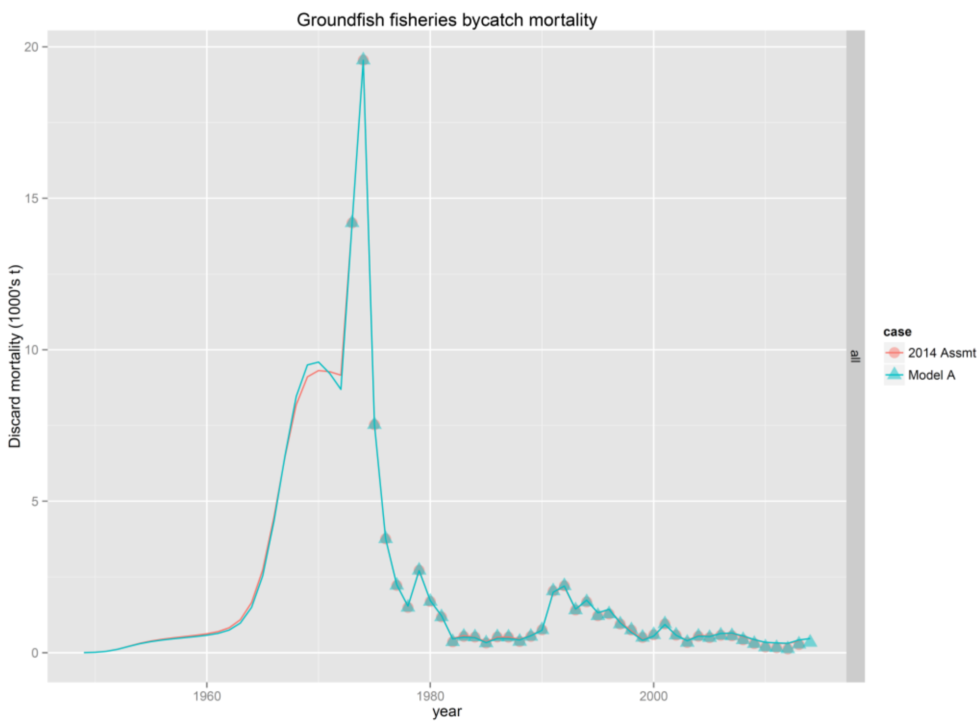


Figure 66. Comparison of fits to discard mortality in the groundfish fisheries from the 2014 assessment and Model A (Dataset D).

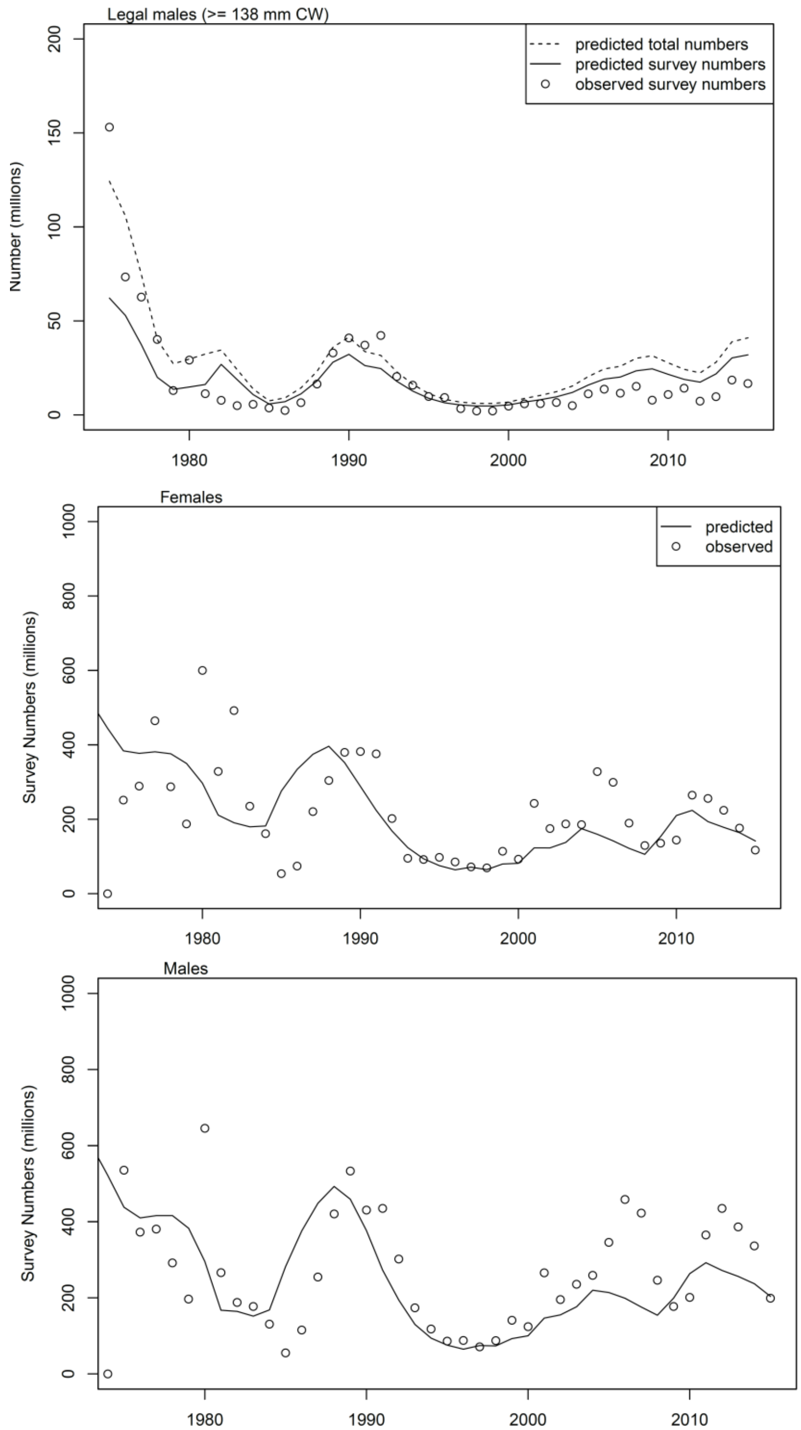


Figure 67. Comparison of observed numbers (circles) from the survey for large males, females, and males with corresponding predictions (lines) from Model A (Dataset D). Note that these data are not directly fit in the model.

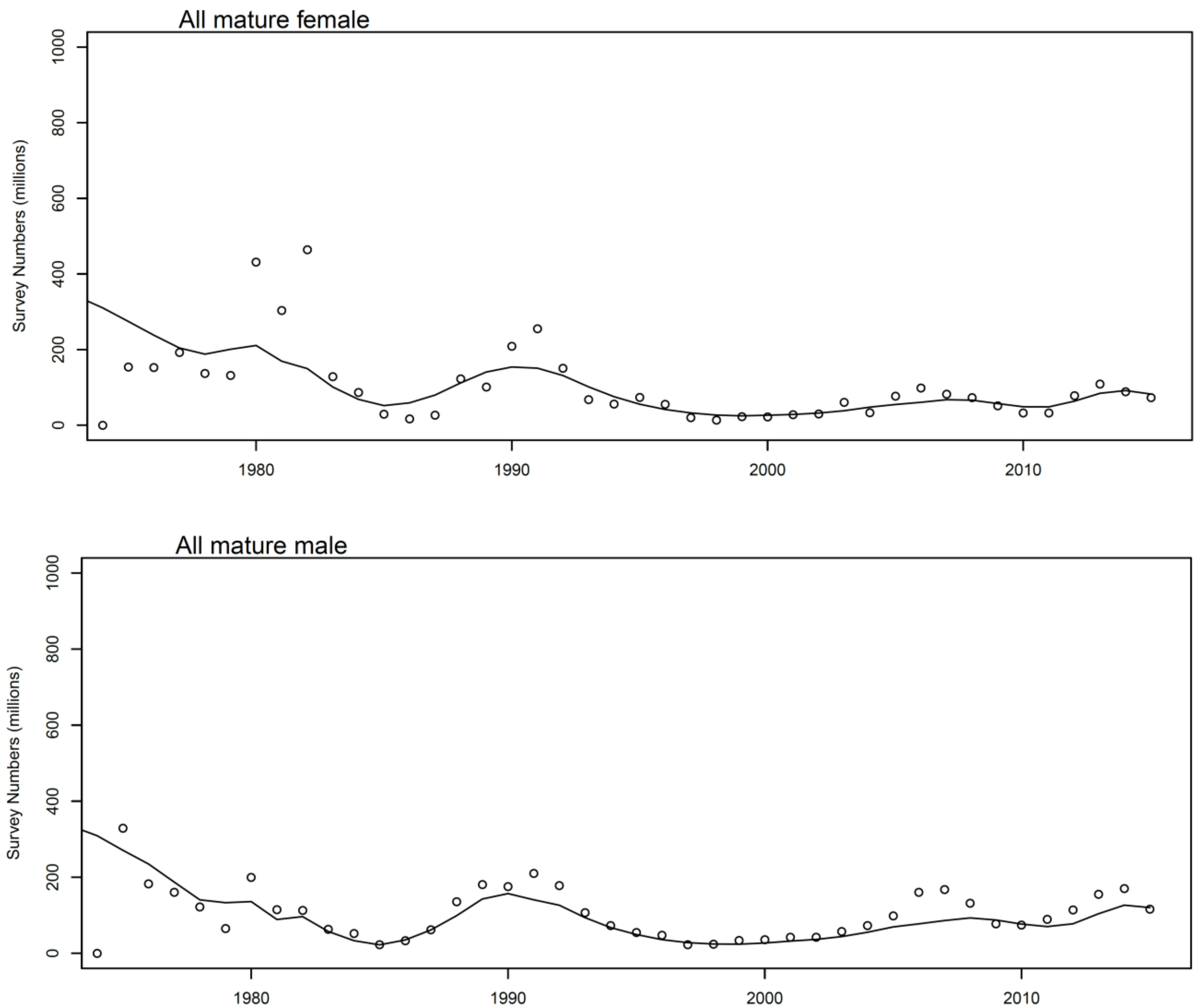


Figure 68. Comparison of observed numbers (circles) from the survey for mature females and males with corresponding predictions (lines) from Model A (Dataset D). Note that these data are not directly fit in the model.

2014 assessment

Model A (Dataset D)

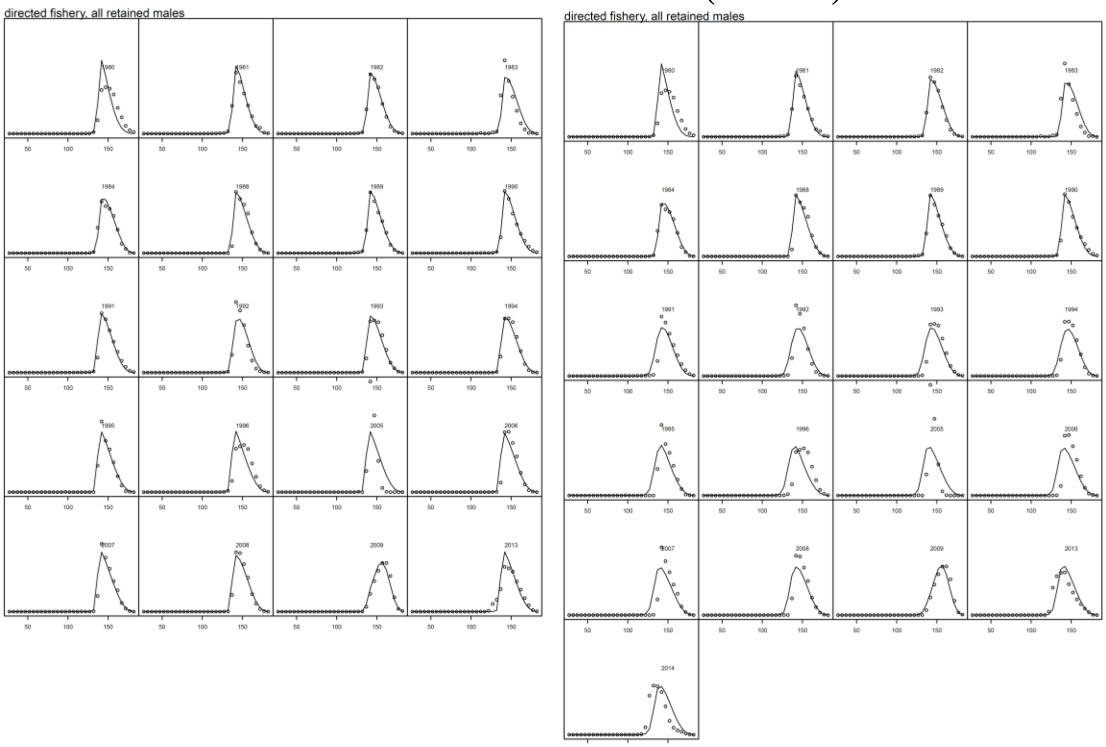


Figure 69.F its to retained catch size compositions from the 2014 assessment and Model A (Dataset D).

2014 assessment

Model A (Dataset D)

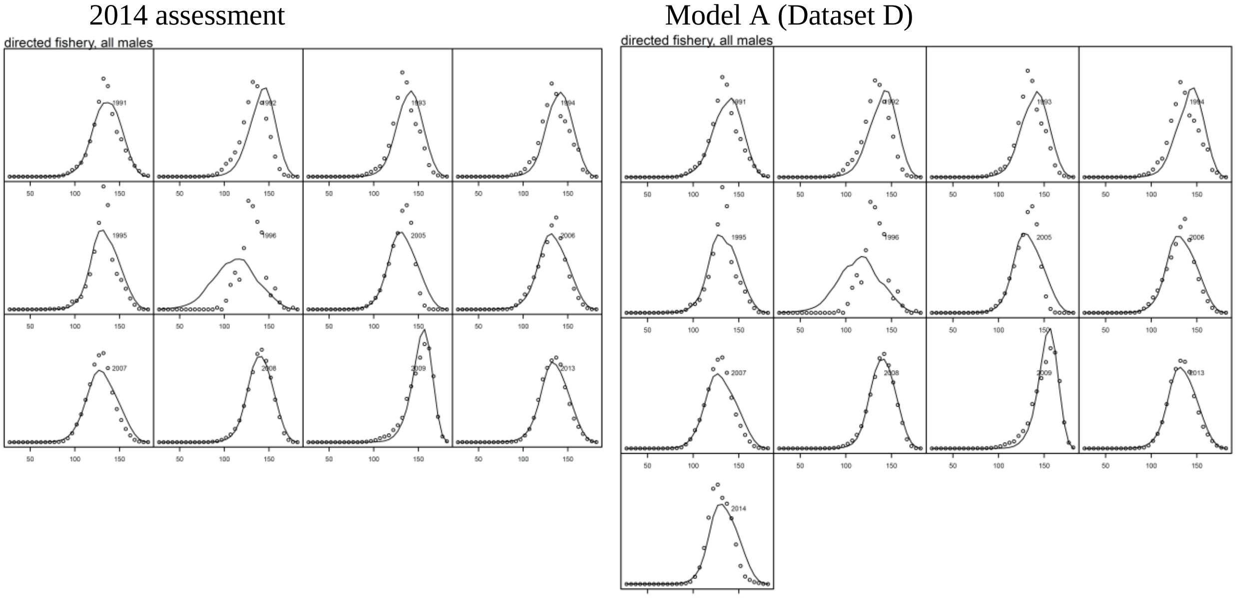
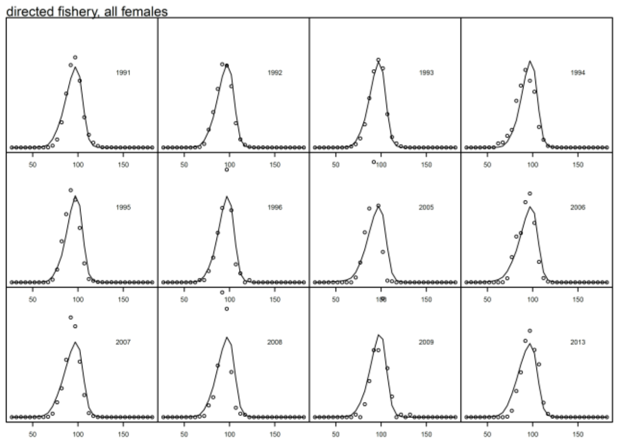


Figure 70. Fits total male catch size compositions in the directed fishery from the 2014 assessment and Model A (Dataset D).

2014 assessment



Model A (Dataset D)

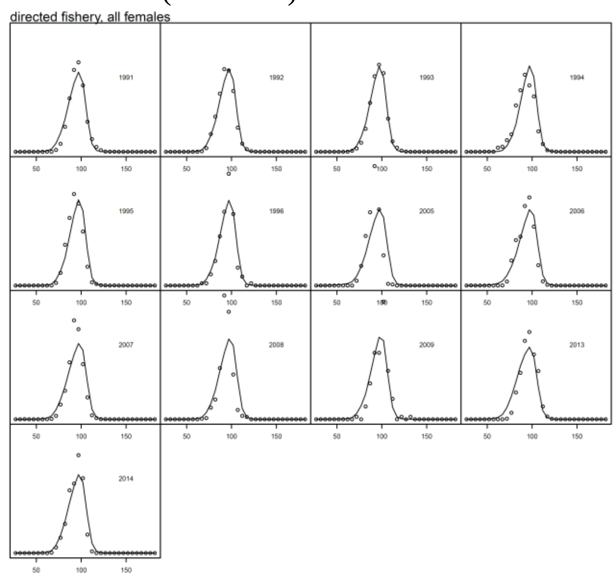


Figure 71. Fits to female bycatch size compositions in the directed fishery from the 2014 assessment and Model A (Dataset D).

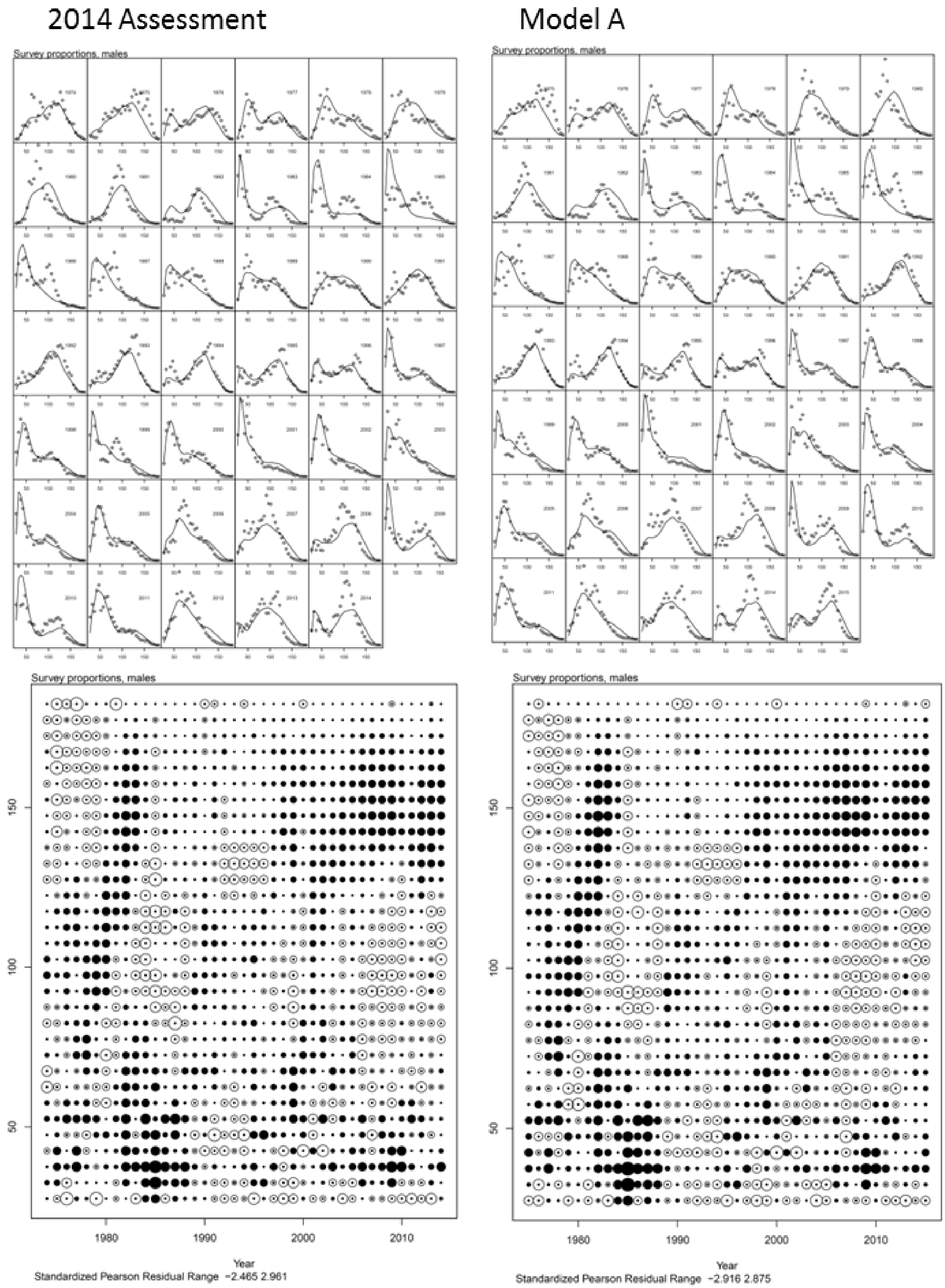


Figure 72.Fits to male size compositions in the NMFS trawl survey.

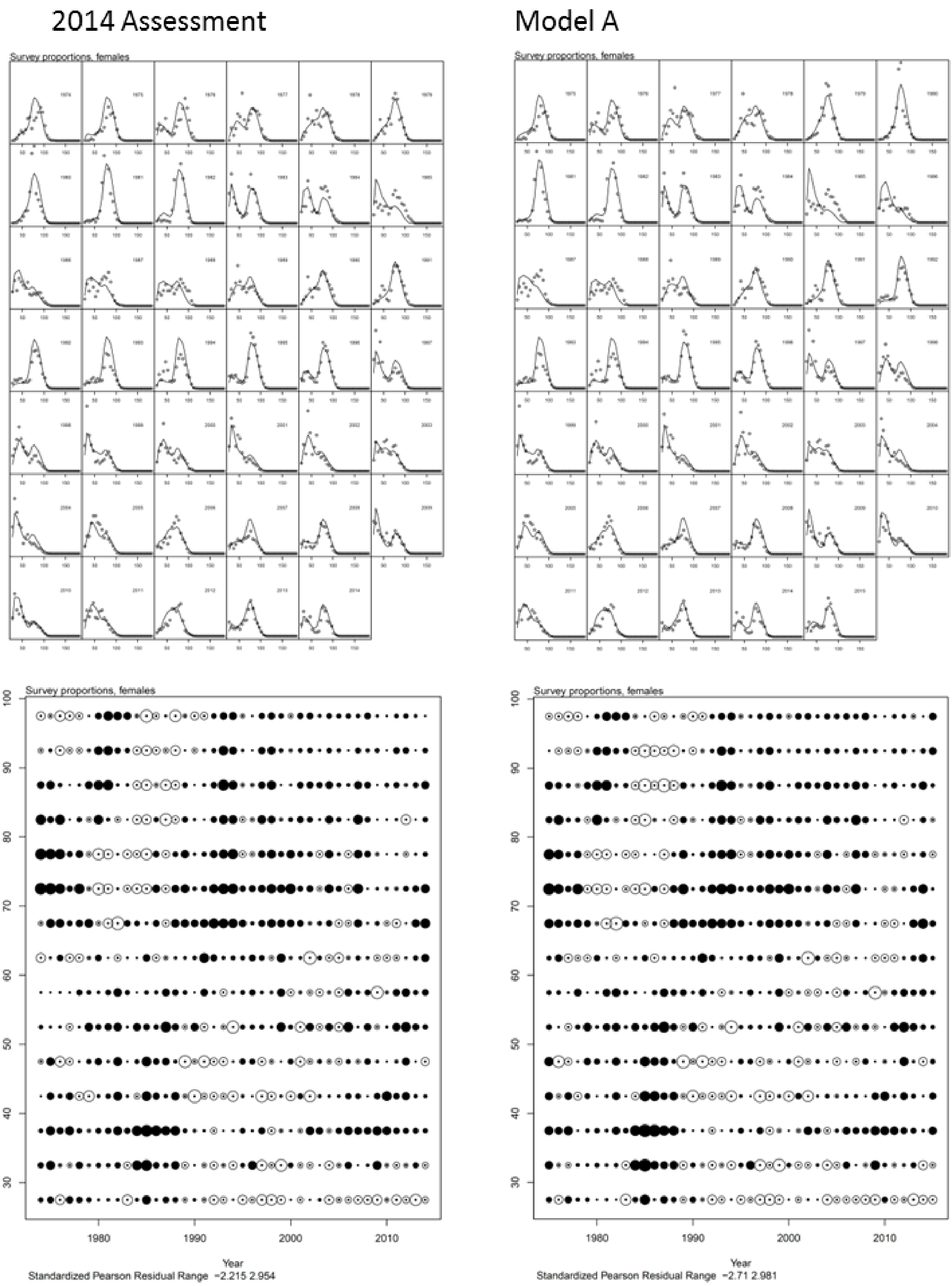


Figure 73. Alt4b model fits to female size compositions in the NMFS trawl survey.

2014 assessment Model A (Dataset D)

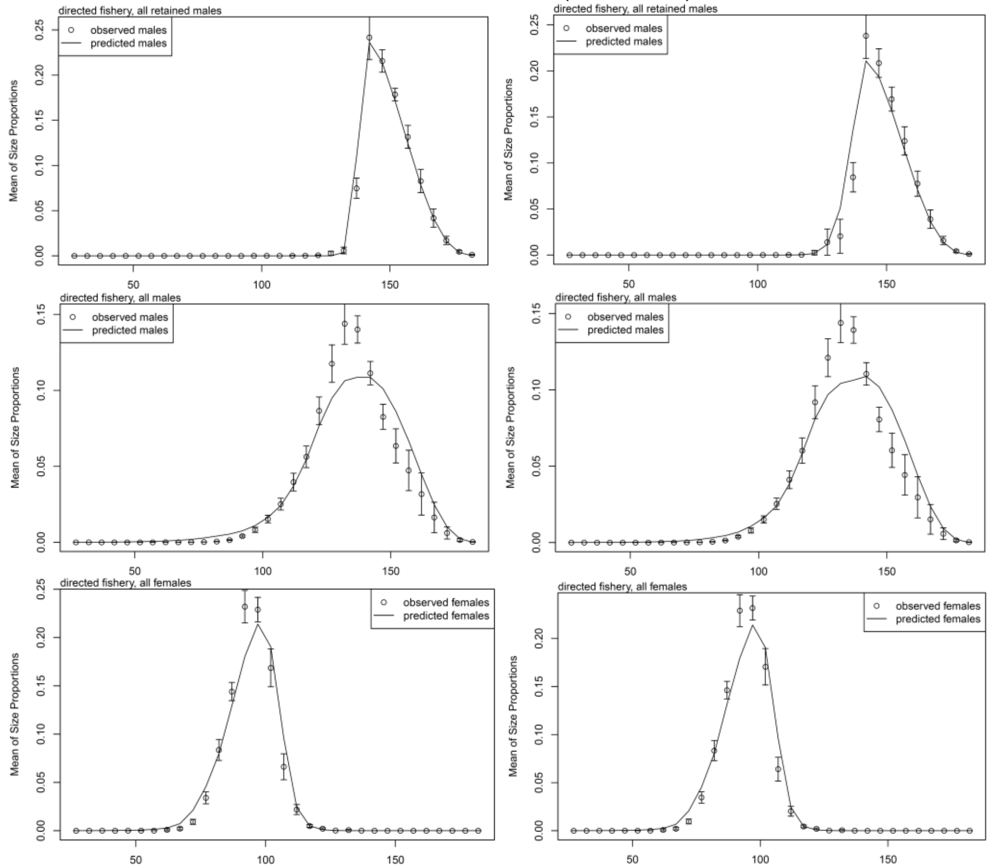


Figure 74. Comparison of marginal size compositions in the directed fishery. Circles with error bars are based on observer sampling.

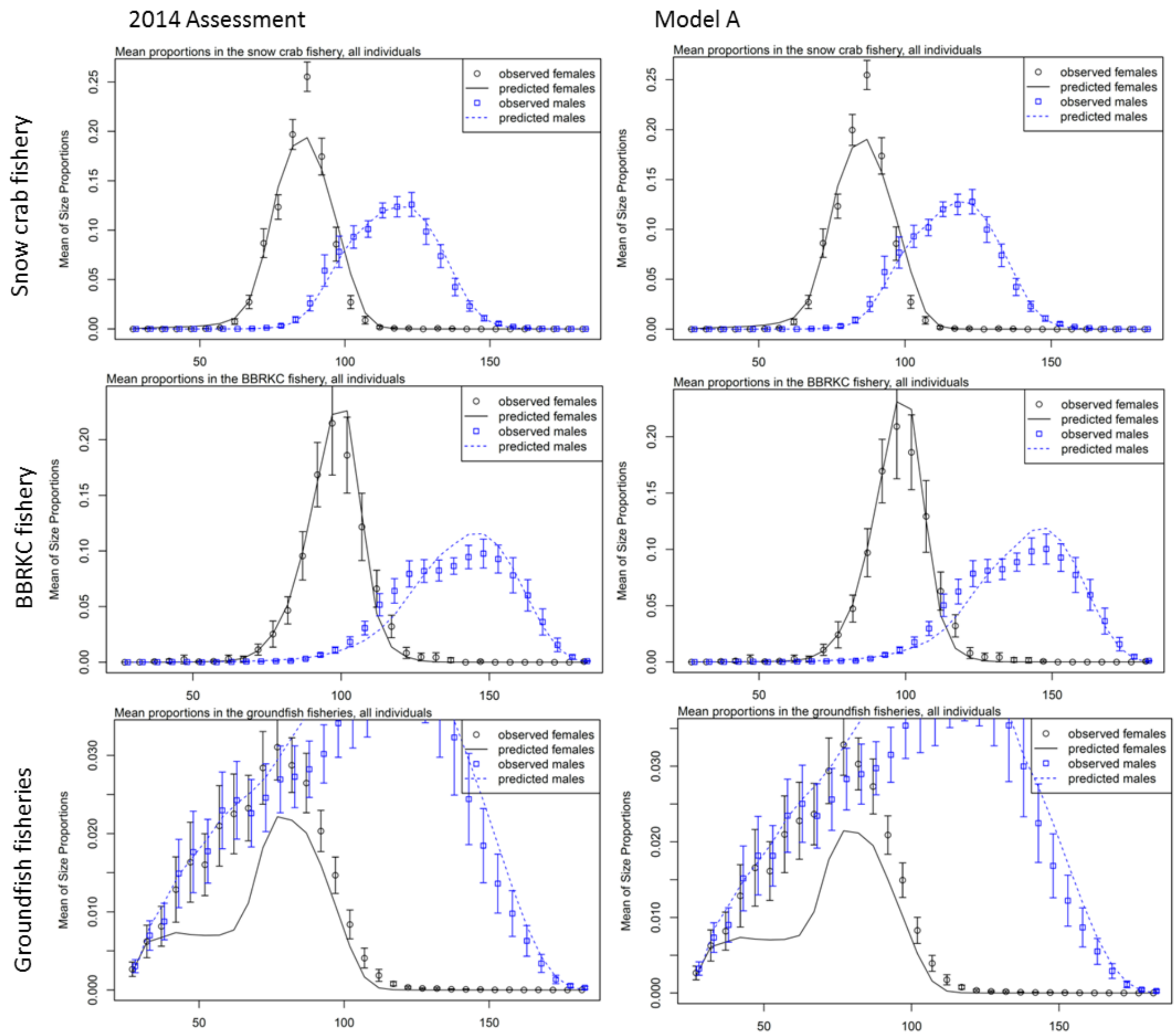


Figure 75. Comparison of marginal size compositions in the bycatch fisheries. Circles with error bars are based on observer sampling.

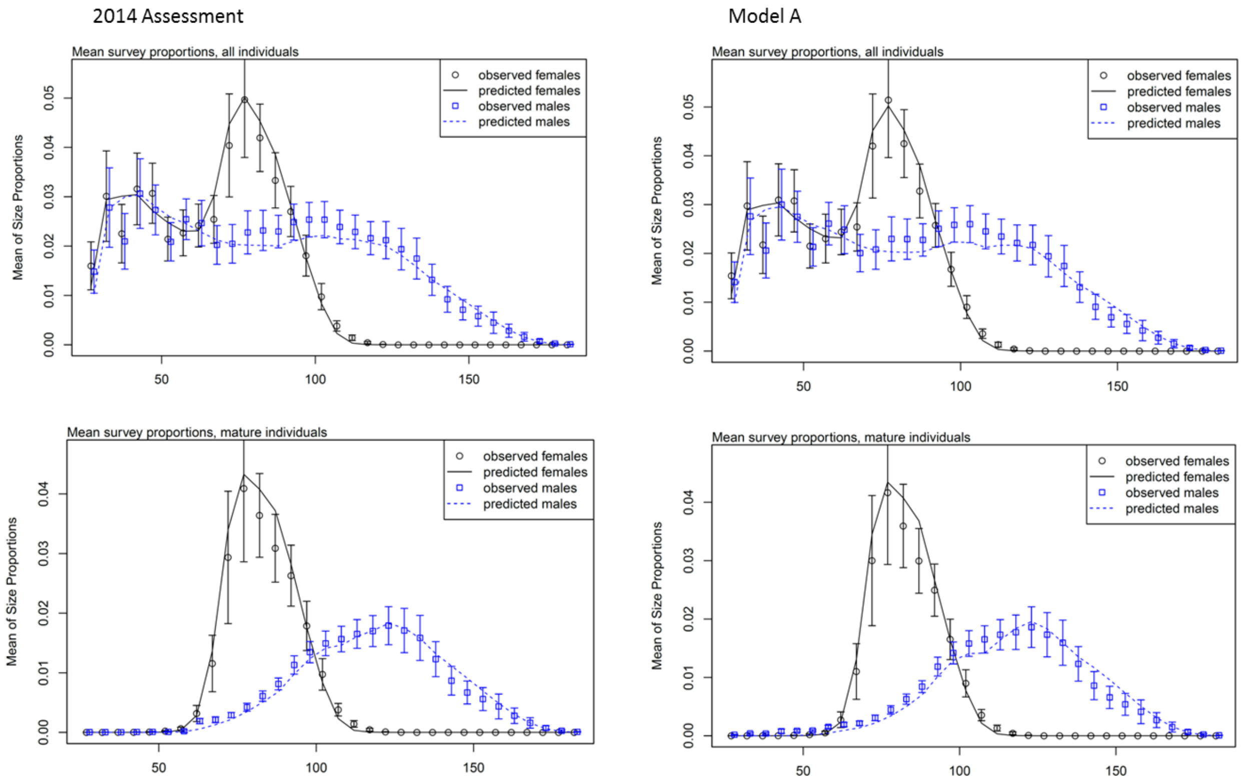


Figure 76. Comparison of marginal size compositions in the NMFS trawl survey.

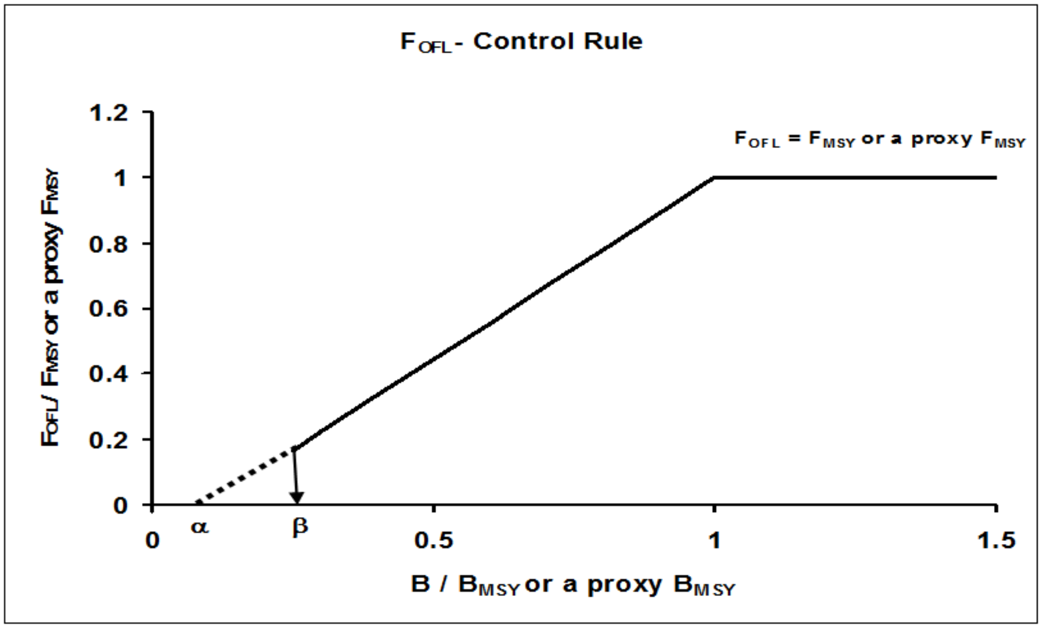


Figure 77. The F_{OFL} harvest control rule. For Tier 3 stocks such as EBS Tanner crab, F_{MSY} and B_{MSY} are based on spawning biomass per recruit proxies, where $F_{MSY} = F_{35\%}$, $B_{MSY}Y = B_{35\%}$, and MMB at mating time is used as a surrogate for egg production/spawning biomass.

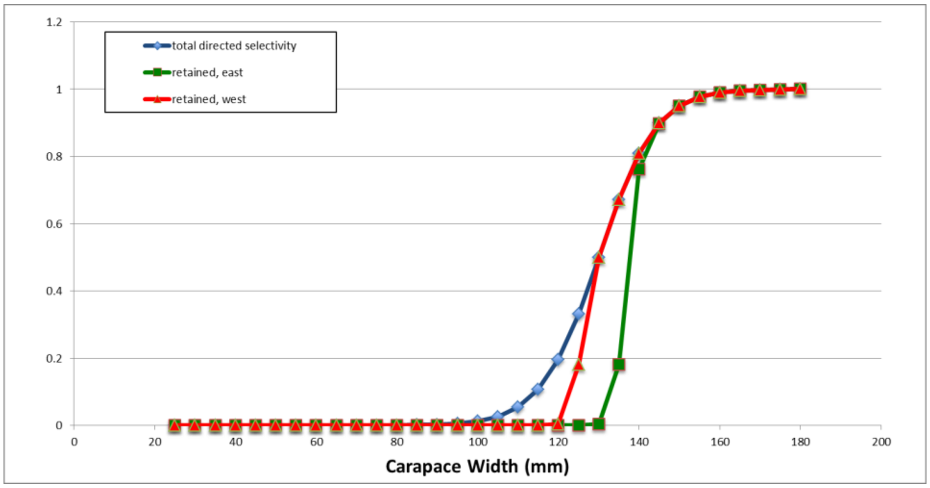


Figure 78. Selectivity functions for males in the directed fishery using the 2014 projection approach.

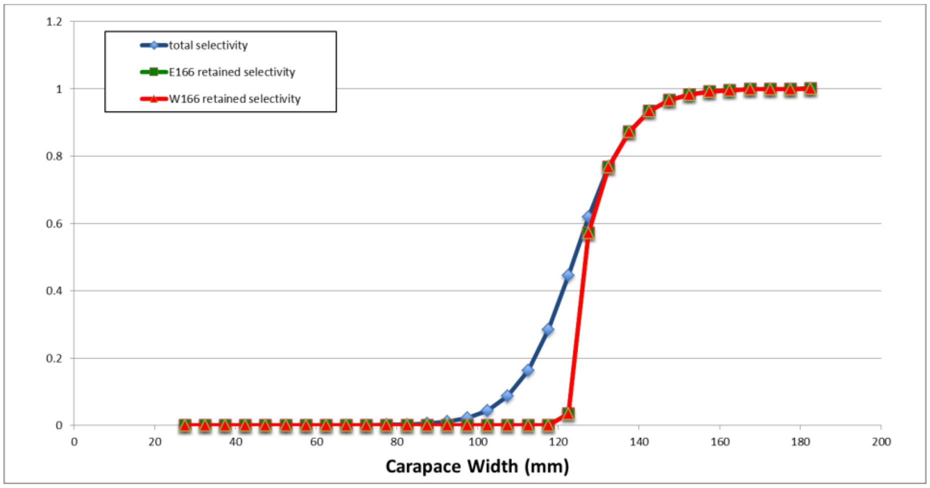


Figure 79. Selectivity functions for males in the directed fishery using the new (1) projection approach.

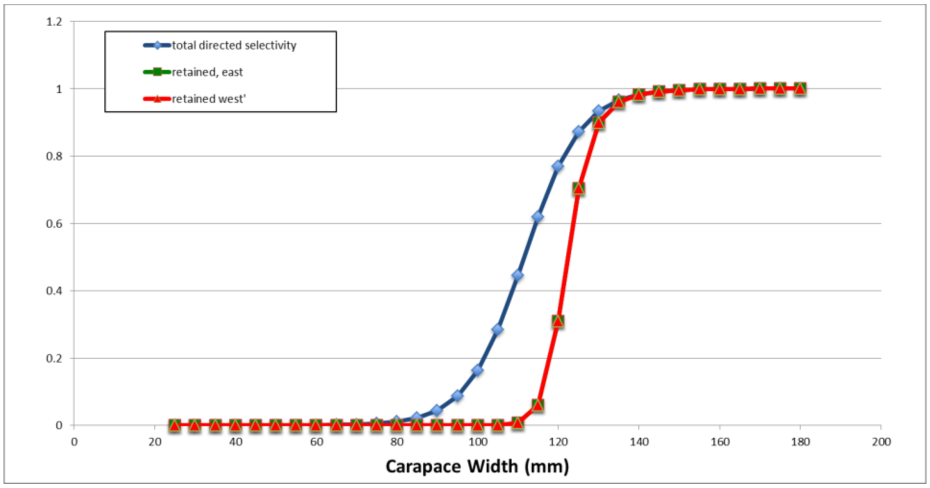


Figure 80. Selectivity functions for males in the directed fishery using the new (2) projection approach.

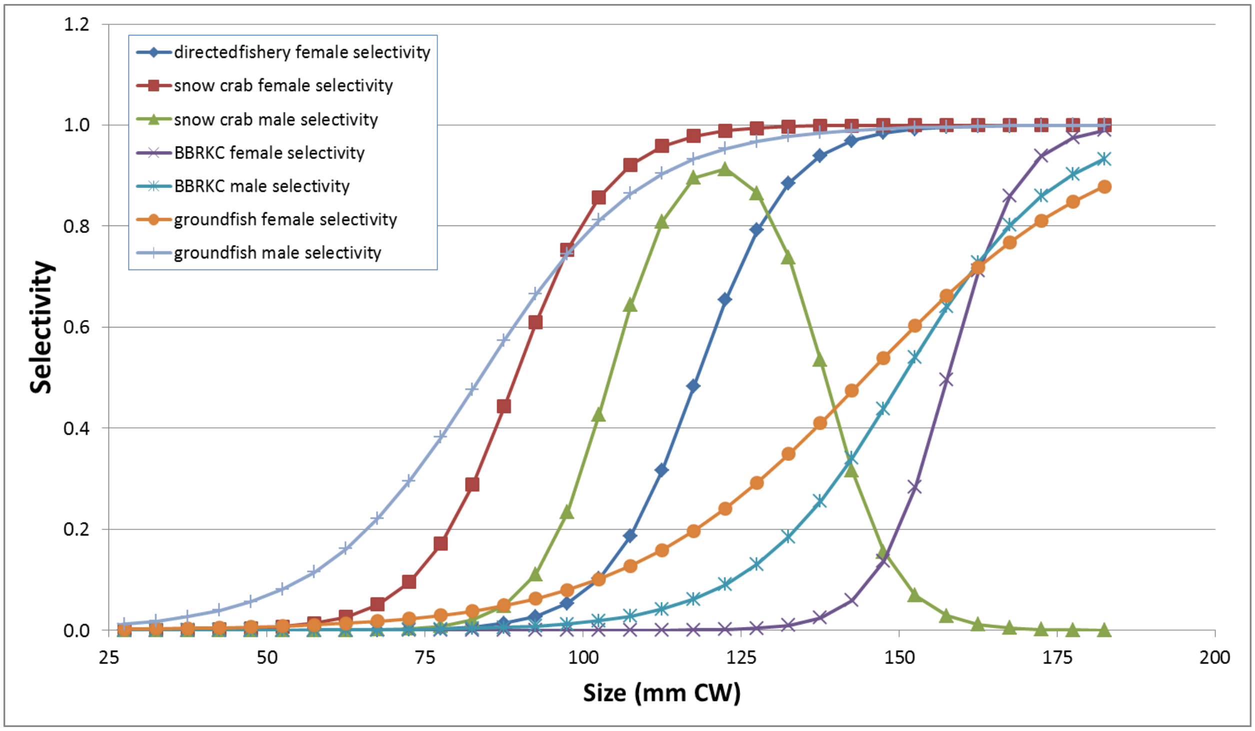


Figure 81. Selectivity curves for bycatch fisheries used in the Model A, Dataset D projection model.

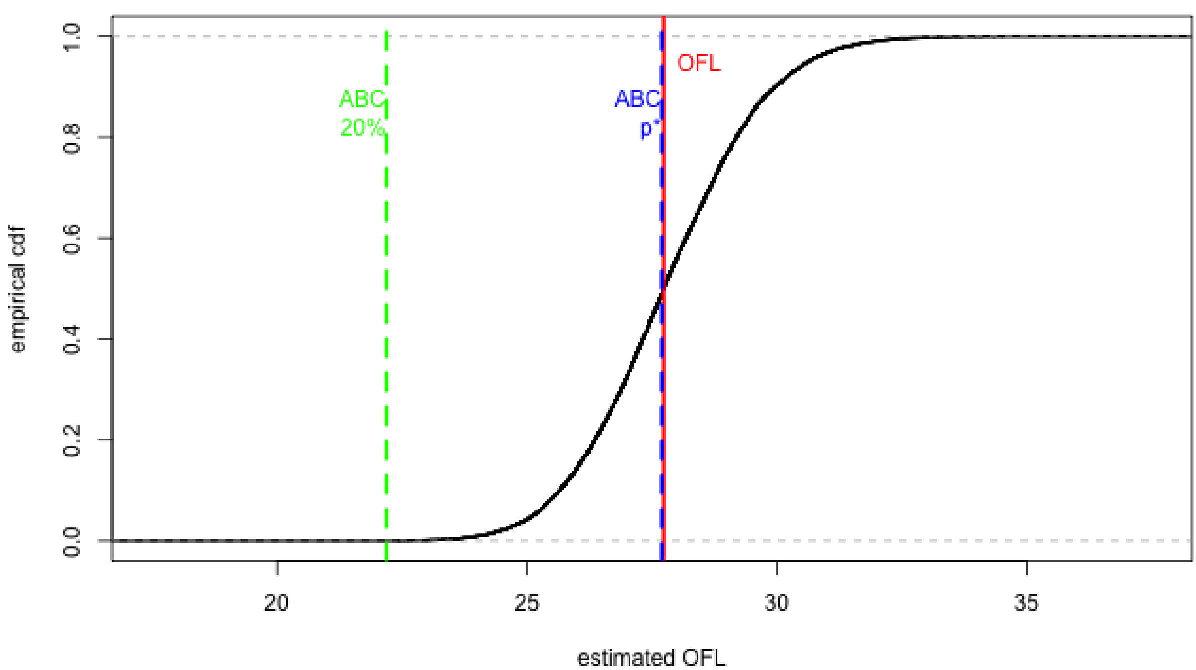


Figure 82. Distribution of OFL, illustrating the estimated p* ABC and 20%-buffer ABC, for scenario Model A (Dataset D), based on Turnock's preferred snow crab model and the 2014 projection approach.

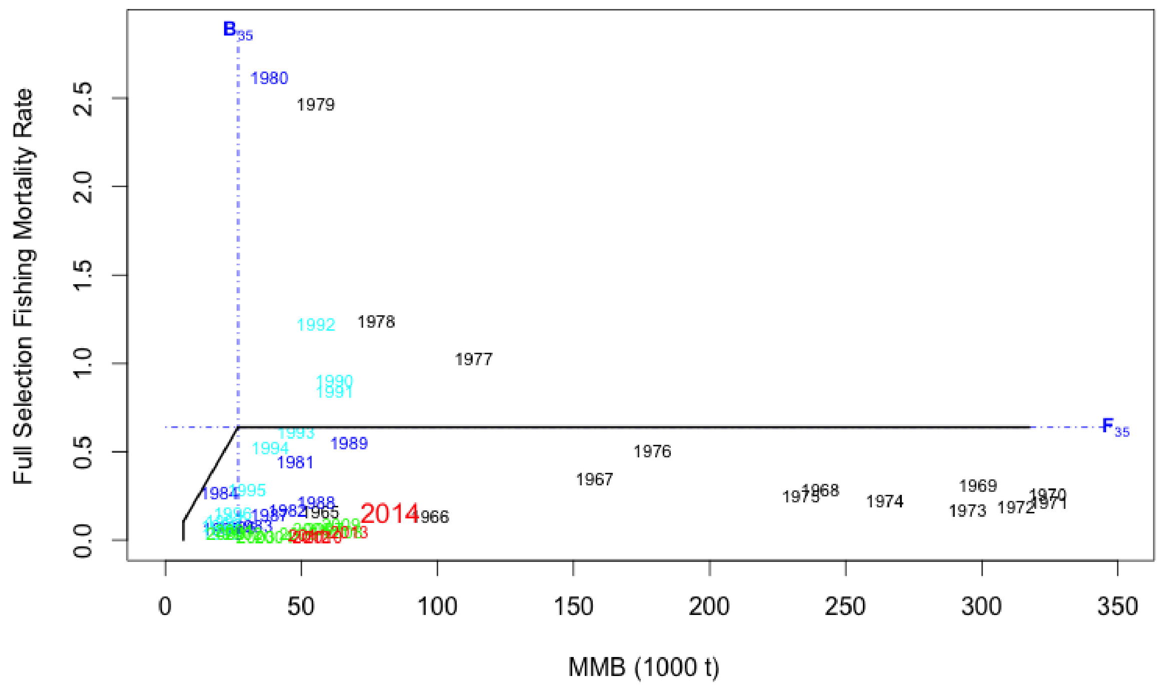


Figure 83. Tier 3 quad plot for the author's preferred model, Model A (Dataset D). Colors indicate different time periods. Black: 1965-1979; blue: 1980-1989; cyan: 1990-1999; green: 2000-2009; red: 2010-2014.

Appendix A: Fishing mortality model

Introduction

The "retention curve" estimated in TCSAM2013 using its standard fishing mortality model does not directly reflect the on-deck process of sorting crab into retained and discarded components. However, the alternative fishing mortality model used in Gmacs does reflect this process. This has implications for what can (and cannot) be done using TCSAM2013's projection model, because the projection model is based on the TCSAM2013 fishing mortality model. Specifically, adjusting the "retention curve" to reflect changes in preference for the size of retained crab does NOT result in changes to the OFL—contrary to one's expectation (and as it would if the projection model were based on the Gmacs fishing mortality model).

Fishing mortality models

"Standard" TCSAM

The "standard" TCSAM fishing mortality model (used since the 2012 assessment, "TCSAM2013" here) is based on the assumption that the rate of mortality on crab due to retaining them in the directed fishery is proportional to the rate of total fishing *mortality* (retained +discarded mortality) in that fishery (see Stockhausen, 2014, Appendix 3 for details). Using a slightly simplified description, TCSAM2013 models the rate of fishing mortality on male crab of size *z* due to retention, $r_{y,z}$, as

$$r_{y,z} = r_z \cdot F_{y,z} \tag{1}$$

where $F_{y,z}$ is the total fishing mortality rate (retained + discard mortality) in year *y* on male crabs of size *z* and r_z is the size-specific "retention function", which takes values between 0 (no retention) and 1 (complete retention). The retention function r_z is modeled using an increasing 2-parameter logistic function (retention is 0 for "small" crab and 100% for "large" crab), and the two parameters are estimated as part of the model fitting process. $F_{y,z}$ is expressed (again, a simplification) as

$$F_{y,z} = S_z \cdot f_y \tag{2}$$

where S_z is the size-specific total fishery selectivity and f_y is the year-specific fully-selected total fishing mortality rate. Parameters associated with r_z, S_z and f_y are estimated by fitting to retained and total (retained + discard) fishing mortality in the directed fishery. This is fine, as far as it goes, because it simply represents a somewhat non-standard model for retained fishing mortality.

However, the expectation has been that r_z reflects the process of sorting and retaining legal crab on deck, and thus it represents the fraction of crab caught at size *z* that were retained. If this *were* the case, r_z would be independent of handling mortality because what's retained is not affected by what's discarded (rather it's the other way around: what's discarded is simply what's left over after crab to be retained have been selected). However, **this is not the correct interpretation of $\boldsymbol{r_z}$** as it is used in TCSAM2013 and Eq. 1 above. Rather, as illustrated in Fig. 1, r_z simply reflects the fraction of crab killed at size *z* that were killed *because* they were retained, as opposed to being killed as part of the discard process. As such, it is actually a function of the assumed handling mortality on discarded crab whereas the function that describes the on-deck sorting process is not.

As an illustration to make this last point, if handling mortality were 0 then all fishing mortality $F_{y,z}$ would be due to retention ($r_{y,z} = F_{y,z}$) and r_z would be identically 1 irrespective of any sorting process that occurred on deck (e.g., all sub-legals being discarded). In Fig. 1, this would be equivalent to the "fishing mortality pie" shrinking in size but turning completely red, while the only change to the "fishing capture pie" would be that the discard mortality slice turns blue (all discards survive). The fraction of the latter pie representing retention would not change.

Gmacs-style

In Gmacs, the size-specific fishing mortality rate in the directed fishery is modeled using:

$$F_{y,z} = (h \cdot [1 - \rho_z] + \rho_z) \cdot \phi_{y,z} \tag{3}$$

where h is handling mortality, ρ_z is the (true) size-specific retention function that reflects the on-board sorting process, and $\phi_{y,z}$ is the size-specific fishery *capture rate* for crab of size z in year y. In this formulation, $\phi_{y,z}$ reflects the rate at which crab are brought on deck, ρ_z is the fraction of crab captured (not killed) that are retained (and thus die), and h is the fraction of discarded crab ($[1 - \rho_z]$) that die due to handling. The equation that describes the fishing mortality rate due to retention is

$$r_{y,z} = \rho_z \cdot \phi_{y,z} \tag{4}$$

which looks identical to Eq. 1, but is not because $\phi_{y,z}$ in Eq. 4 represents the *capture rate* while $F_{y,z}$ in Eq. 1 is the *total mortality rate*. The fishery capture rate $\phi_{y,z}$ in the revised model is treated in the same fashion that $F_{y,z}$ is treated in TCSAM2013: it is modeled as a separable function of size and year

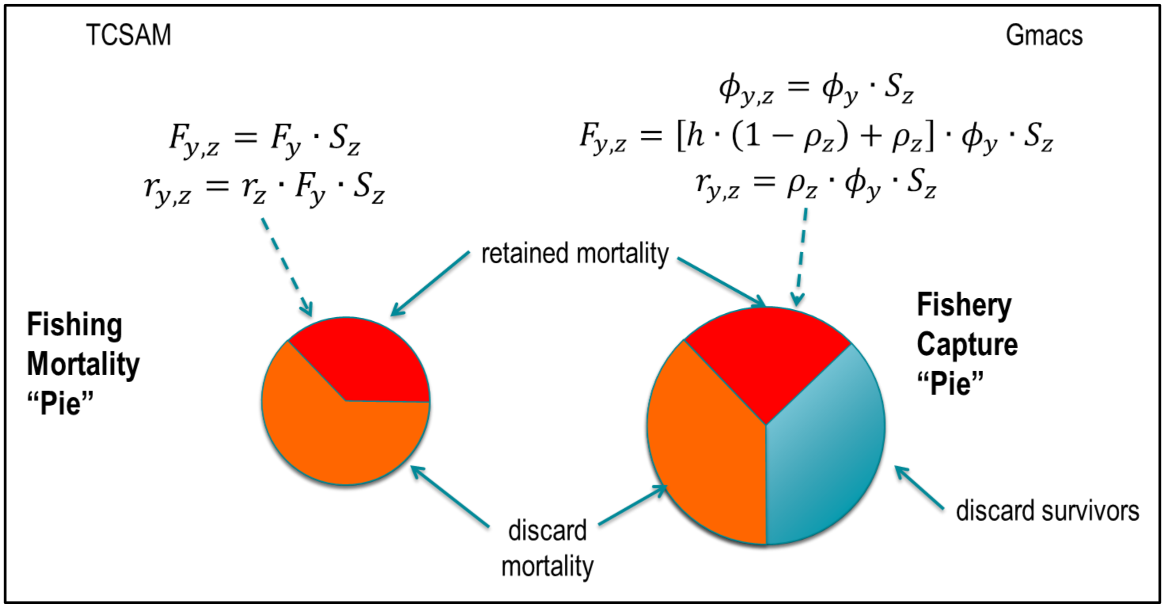
$$\phi_{y,z} = \phi_y \cdot S_z \tag{5}$$

where ϕ_y is the "fully-selected" capture rate in year y and S_z is the size-specific capture selectivity. ϕ_y is also parameterized in a similar fashion to the fully-selected fishing mortality rate F_y in TCSAM2013. The capture selectivity S_z and retention function ρ_z are also parameterized in the same way as selectivity and the retention function r_z in TCSAM2013. The parameters associated with ρ_z, S_z, and ϕ_y can be fit using the same data (retained catch and discard mortality) used to fit the standard TCSAM model.

Note that, for the Gmacs-style fishing mortality model, the total fishing mortality rate $F_{y,z}$ in Eq. 3 is a derived quantity dependent on the estimated retention rate ρ_z, whereas in the standard TCSAM approach $F_{y,z}$ is itself an estimated quantity (essentially) and is independent of r_z.

Another aspect of this model is that the *total* fishing mortality $F_{y,z}$ is independent of the "retention curve" r_z. As a consequence, changing r_z does not change the OFL (as calculated using the TCSAM Projection Model, which uses this fishing mortality model). The OFL only depends on $F_{y,z}$. Changing r_z only changes the *proportion* of the OFL that is accounted for by retention. Thus, changing r_z to reflect changes in preferred crab size (without also changing $F_{y,z}$) does not lead to a change in the OFL (contrary to one's expectation).

Figures



Appendix A. Figure 1. Comparison of models for fishing mortality in TCSAM2013 (left) and Gmacs (right). The *areas* associated with retained mortality and discard mortality are the same in both pies. r_z is the fraction of the fishing mortality pie related to retained crab. ρ_z is the fraction of the fishery capture pie related to retained crab.

Appendix B: Projection model strategies for dealing with changes in preferred sizes

Introduction

The Tanner crab stock in the eastern Bering Sea is partitioned by the State of Alaska (SOA) into two fishery regions (east and west of 166°W longitude) for management purposes, with separate legal size limits and separate harvest strategies. In particular, until 2015/16, the SOA has used a minimum preferred male crab size of 125 mm CW (not including lateral spines) for the western area TAC calculations and a minimum preferred size of 138 mm CW in the eastern area. The TCSAM2013 assessment model, however, currently ignores the spatial aspects of the directed fishery and estimates a directed fishery total mortality selectivity curve and a retention curve for the entire stock. In the projection model used to determine OFL, however, an attempt has been made to incorporate the effect of the differences in TAC setting between the two areas on the OFL. In particular, the projection model assumes that total (retained+discards) directed fishing mortality on males is the same in both areas and, but that retention functions for the two areas will be different—with the western region retaining smaller crab. In practice, this was implemented in the projection model by assuming that 1) the most recent 4-year average of total selectivity on all males in the directed fishery, as estimated in the assessment model, could be applied to the entire stock in the future, 2) that the future retention curve in the eastern area was the same as the most recent 4-year average from the assessment model, 3) that the future retention curve in the western area was simply that in the eastern area, but shifted to smaller sizes by 10 mm (reflecting the smaller preferred size), and 4) that the proportion of crab caught at a given size in the east vs the west would be equal to the same proportion of crab caught in the NMFS bottom trawl survey. This strategy has been possible to implement because it was based on information available from the assessment model.

For 2015/16, the State of Alaska has modified its TAC-setting calculations from prior years. In particular, the minimum size of "preferred" male crab used in these calculations will now be the same in both fishery areas (125 mm CW, not including the lateral spines) whereas in previous years a larger minimum size was used to set the TAC in the east region (138 mm CW). To "correctly" calculate the OFL for 2015/16, one needs to predict how this will change current selectivity and retention patterns in the east and west regions from those estimated by the assessment model. As it turns out, this does not appear to be possible using the TCSAM2013 fishing mortality model as the basis for the projection model

Projection model description

The projection model used to determine the OFL associated with a model is based on the TCSAM2013 fishing mortality model (Appendix A). For each fishery, TCSAM2013 models the rate of fishing mortality, $F_{y,xz}$, on crab of sex *x* and size *z* in year *y* as

$$F_{y,x,z} = S_{x,z} \cdot f_{y,x} \tag{1}$$

where $S_{x,z}$ is the sex/size-specific total fishery selectivity function and $f_{y,x}$ is a sex/year-specific fully-selected total fishing mortality rate (except for bycatch in the groundfish fisheries, where *f* is not sex-specific). In the directed fishery, *S* also varies by year. For males in the directed Tanner crab fishery (TCF), the retained mortality rate $r_{y,z}$ (i.e., the mortality rate associated with being retained, rather than discarded), is expressed as

$$r_{y,z} = r_z \cdot F^{TCF}_{y,male,z} = r_z \cdot S^{TCF}_{y,male,z} \cdot f^{TCF}_{y,male} \tag{2}$$

where r_z is the size-specific "retention function", which takes values between 0 (no retention) and 1 (complete retention).

The OFL appropriate to a given assessment model is determined in the projection model using an iterative process to find the value for the fully-selected total fishing mortality rate on males in the directed fishery,

$f_{\cdot,male}^{TCF}$ or (more conventionally) F_{MSY}, that reduces stock biomass to B_{MSY} when fished at $f_{\cdot,male}^{TCF}$ (F_{MSY}) in the long term. In doing so, it is assumed that (in the long term) bycatch rates in the snow crab fishery will be as if it were fished at its F_{OFL}, the BBRKC fishery and groundfish fisheries will be fished at rates similar to those in the recent past (based on a four year average), and female bycatch rates in the directed fishery will be similar to those in the recent past (based on four-year average). Selectivity functions for all fisheries in the projection model are the same as those estimated in the assessment model, except that a 4-year average is used for total male selectivity and retention functions in the directed fishery.

Equations 1 and 2 in the projection model for fishing mortality are identical in form to those used in the TCSAM2013 assessment model. However, the equations are *used* in the projection model in one importantly different aspect from those in the assessment model: they are prognostic (they tell us what *will* happen) in the projection model whereas they are diagnostic (they tell us what *did* happen) in the assessment model. If one anticipates changes in fishing behavior, such as new discard procedures that will change handling mortality or a gear that will change fishery selectivity or a change in consumer habits that will change the retention curve, the projection model should be able to accommodate such changes.

The assessment model handles changes that have already occurred quite well, assuming data is available, because it *estimates* their effects on total (retained + discard) and retained fishing mortality. Unfortunately, as currently formulated using the TCSAM2013 fishing mortality model, it is not possible to consider *future* changes in either handling mortality rates or retention characteristics. First, future changes in handling mortality rates cannot be incorporated in the framework of Equations 1 and 2 because they are independent of handling mortality! Handling mortality is not an explicit parameter in the equations, even as an assumed value—it is applied to the *observed* discards in the assessment model to calculate observed total fishing mortality, which is then fit to estimate the components to $F_{y,x,z}$, $S_{x,z}$ and $f_{y,x}$. Consequently, the OFL calculated by the projection model is independent of projected changes in handling mortality. Second, the OFL calculated by the projection model is independent of the retention function r_z. The OFL depends on the total size-specific fishing mortality rate in each fishery, but it doesn't depend on the proportion of retained to discard mortality. Consequently, projected changes in the retention function affect the proportion of the OFL that is retained, but not the OFL itself.

It should be noted that these observations do not apply to a projection model formulated using the Gmacs fishing mortality model (Appendix A). This is because the Gmacs fishing mortality model is really a size-specific fishery capture (what's landed on deck) model, which is then partitioned into retained mortality and discards (what's thrown overboard), the latter of which is partitioned into discard mortality and discard survivors using an (assumed) handling mortality rate. One can postulate future changes in handling mortality (adjust the rate) or retention (adjust the retention ogive) without postulating changes in the way the fishery captures crab: the OFL will change because the characteristics of fishing mortality changes, even if the characteristics of the fishery capture process do not.