2017 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

William T. Stockhausen
Alaska Fisheries Science Center
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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 t) for the area west of 166º W and at 1,463,000 lbs (664 t) for the area east of 166º 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% (594 t) of the TAC was taken in the western area while 98.6% (654 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 2014 assessment (Stockhausen, 2014), TAC was set at 6,625,000 lbs (2,329 t) for the area west of 166º W and at 8,480,000 lbs (3,829 t) for the area east of 166º W. On closing, 77.5% (2,329 t) of the TAC was taken in the western area while 99.6% (3,829 t) were taken in the eastern area.

Following the 2015 assessment (Stockhausen, 2015), TAC was set at 11,272,000 lbs (5,113 t) for the eastern area and 8,396,000 lbs (3,808 t) for the western area. On closing, essentially 100% of the TAC was taken in both areas (11,268,885 lbs [5,111 t] in the eastern area, 8,373,493 lbs [3,798 t] in the western area based on the 5/20/2016 in-season catch report).

Following the 2016 assessment (Stockhausen, 2016), the Alaska Department of Fish and Game (ADFG) determined that mature female Tanner crab biomass did not meet their criteria for opening a fishery; thus, the fishery was closed and the TAC was set to 0. No directed harvest occurred in 2016/17.

Non-retained females and sub-legal males are caught in the directed fishery, when it occurs, as bycatch and discarded. Because it was closed, no bycatch occurred in the directed fishery in 2016/17. 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 1,500 t for the 5-year period 2012/13-2016/17. Bycatch in the snow crab fishery in 2016/17 was 2,592 t. The groundfish fisheries have been the next major source of Tanner crab bycatch over the same five year time period, averaging 360 t. Bycatch in the groundfish fisheries in 2016/17 was 318 t. The Bristol Bay red king crab fishery has typically been the smallest source of Tanner crab bycatch among these fisheries, averaging 85 t over the 5-year time period, although 297 t caught and discarded in 2014/15. In 2016/17, this fishery accounted for 180 t of Tanner crab bycatch.

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, 50% for Tanner crab in the groundfish fisheries using fixed gear, and 80% for Tanner crab discarded in the groundfish fisheries using trawl gear 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 B2b), estimated MMB for 2016/17 was 78.0 thousand t (Table 34, Figures 217-220 in Appendix F). This was smaller than those for 2014/15 and 2015/16 (84.8 and 83.8 thousand t, respectively), but larger than that for 2013/14 (70.6 thousand t). MMB may have had a recent peak in 2014/15, but it remains above the very low levels seen in the mid-1990s to early 2000s (1990 to 2005 average: 36.5 thousand t) and the 2014/15 estimate is the largest since 1978/79. However, it is considerably below model-estimated historic levels in the early 1970s when MMB peaked at ~259 thousand t (1971).

4. Recruitment: trends and current levels relative to virgin or historic levels.
From the author's preferred model (Model B2b), the estimated total recruitment for 2017/18 (the number of crab entering the population on July 1) is 414.88 million crab (Table 37, Figures 213-216 in Appendix F), however, this value is highly uncertain. The average recruitment during the recent 2012/13-2016/17 period was 74.0 million crab. The longterm (1982+) mean is 214.0 million crab.

5. Management performance
Historical status and catch specifications for eastern Bering Sea Tanner crab.

(a) in 1000's t.

Year	MSST	Biomass (MMB)	TAC (East + West)	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	16.98	72.70[A]	1.41	1.26	2.78	25.35	17.82
2014/15	13.40	71.57[A]	6.85	6.16	9.16	31.48	25.18
2015/16	12.82	73.93[A]	8.92	8.91	11.38	27.19	21.75
2016/17	14.58 [C]	80.57[A]	0	0	1.14	25.61	20.49
2017/18		43.31[B]				25.42[C]	20.33[C]

(b) in millions lbs.

Year	MSST	Biomass (MMB)	TAC (East + West)	Retained Catch	Total Catch Mortality	OFL	ABC
2013/14	37.43	160.28[A]	3.11	2.78	6.14	55.89	39.29
2014/15	29.53	157.78[A]	15.10	13.58	20.19	69.40	55.51
2015/16	28.27	162.99[A]	19.67	19.64	25.09	59.94	47.95
2016/17	32.15[C]	177.63[A]	0	0	2.52	56.46	45.17
2017/18		95.49[B]				56.03[C]	44.83[C]

A—Estimated at time of mating for the year concerned. This is a revised estimate, based on the subsequent assessment.
B—Projected biomass from the current stock assessment. This value will be updated next year.
C—Based on the author's preferred model (Model B2b).

6. Basis for the OFL

a) in 1000's t.

Year	Tier[A]	B_{MSY}[A]	Current MMB[A]	B/B_{MSY}[A]	F_{OFL}[A] (yr^{-1})	Years to define B_{MSY}[A]	Natural Mortality[A,B] (yr^{-1})
2013/14	3a	33.54	59.35	1.77	0.73	1982-2013	0.23
2014/15	3a	29.82	63.80	2.14	0.61	1982-2014	0.23
2015/16	3a	26.79	53.70	2.00	0.58	1982-2015	0.23
2016/17	3a	25.65	45.34	1.77	0.79	1982-2016	0.23
2017/18	3a	29.17	43.31	1.49	0.75	1982-2017	0.23

b) in millions lbs.

Year	Tier[A]	B_{MSY}[A]	Current MMB[A]	B/B_{MSY}[A]	F_{OFL}[A] (yr^{-1})	Years to define B_{MSY}[A]	Natural Mortality[A,B] (yr^{-1})
2013/14	3a	73.94	130.84	1.77	0.73	1982-2013	0.23
2014/15	3a	65.74	140.66	2.14	0.61	1982-2014	0.23
2015/16	3a	59.06	118.38	2.00	0.58	1982-2015	0.23
2016/17	3a	56.54	99.95	1.77	0.79	1982-2016	0.23
2017/18	3a	64.30	95.49	1.49	0.75	1982-2017	0.23

A—Calculated from the assessment reviewed by the Crab Plan Team in 20XX of 20XX/(XX+1) or based on the author's preferred model for 2016/17.
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 2017/18, is estimated at 43.31 thousand t. B_{MSY} for this stock is calculated to be 29.17 thousand t, so MSST is 14.58 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 0.321 for pot gear and 0.8 for trawl gear) in 2016/17 was 1.14 thousand t, which was less than the OFL for 2016/17 (25.61 thousand t); consequently **overfishing did not occur**. The OFL for 2017/18 based on the author's preferred model (Model B2b) is 25.42 thousand t. The ABC_{max} for 2017/18, based on the p^* ABC, is 25.57 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 20.33 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. The stock remains not overfished. Consequently no rebuilding analyses were conducted.

A. Summary of Major Changes

1. Changes (if any) to the management of the fishery.
At the March, 2015 SOA Board of Fish (BOF) 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).

The directed Tanner crab fisheries in the EBS (i.e., east and west of 166° W longitude) were closed in 2016/17 because mature female Tanner crab biomass in 2016 failed to meet the criteria defined in the SOA's harvest strategy to open the fisheries. [Note: These criteria were not among the changes to the harvest strategy adopted by the BOF in March, 2015.]

2. Changes to the input data
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	area-swept abundance, biomass size compositions	1975-2017	recalculated, new	NMFS
NMFS/BSFRF	molt-increment data	2014-16	new	NMFS, BSFRF
Directed fishery	retained catch (numbers, biomass)	2005/06-2016/17	updated, new	ADFG
	retained catch size compositions	2013/14-2015/16	updated	ADFG
	effort	2015/16, 2016/17	updated, new	ADFG
	total catch (abundance, biomass)	2015/16, 2016/17	updated, new	ADFG
	total catch size compositions	2015/16, 2016/17	updated, new	ADFG
Snow Crab Fishery	effort	1990/91-2013/14	updated, new	ADFG
	total bycatch (abundance, biomass)	1990/91-2016/17	updated, new	ADFG
	total bycatch size compositions	2016/17	new	ADFG
Bristol Bay	effort	1990/91-2013/14	updated, new	ADFG
Red King Crab Fishery	total bycatch (abundance, biomass)	1990/91-2016/17	updated, new	ADFG
	total bycatch size compositions	2016/17	new	ADFG
Groundfish Fisheries	total bycatch (abundance, biomass)	1991/92-2016/17	updated, new	NMFS/AKFIN
(all gear types)	total bycatch size compositions	1991/92-2016/17	updated, new	
Groundfish Fixed-Gear	total bycatch (abundance, biomass)	1991/92--2016/17	new	NMFS/AKFIN
Fisheries	total bycatch size compositions	1991/92--2016/17	new	
Groundfish Trawl	total bycatch (abundance, biomass)	1991/92--2016/17	new	NMFS/AKFIN
Fisheries	total bycatch size compositions	1991/92--2016/17	new	

3. Changes to the assessment methodology.
Following a considerable development effort and substantial review by the CPT at the January 2017 Modeling Workshop and the May 2017 CPT Meeting, with additional review by the SSC at its February and June 2017 meetings, a new modeling "framework", TCSAM02, was recommended by the CPT at its May 2017 meeting (and approved by the SSC at its June 2017 meeting) for use in this assessment. TCSAM02, while based on the previous assessment model (TCSAM2013), constitutes a completely rewritten code library for the Tanner crab assessment model. Results presented at the May CPT meeting

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

demonstrated that TCSAM02 could be configured to exactly match results from the TCSAM2013 code, thus providing continuity with the old model code. However, demonstrating this “exact equivalence” required some minor modifications to the 2016 assessment model. These changes were reviewed and approved at the May CPT meeting, with the understanding that the “exactly equivalent” TCSAM02 model would be the base model for this assessment (rather than the 2016 assessment model).

The changes from the 2016 assessment model to the “exactly equivalent” base model are discussed in detail in the May CPT report (Stockhausen, 2017) and included: 1) removing a size-specific reclassification of “old shell” males with regards to the survey data used in the model; 2) fitting to total capture size composition data, rather than trying to incorporate handling mortality prior to fitting the data; 3) fitting to total capture biomass, rather than mortality; 4) seasonally applying natural mortality rates for mature crab from spring to summer to crab that underwent terminal molt in the spring; 5) basing aggregated survey biomass on 1-mm size bins, not the 5mm size bins used to fit size compositions; 6) using a more-precise value to convert from pounds to kilograms; 7) setting bycatch capture rates in the Bristol Bay red king crab fishery explicitly to 0 for years when the fishery was closed, 8) using the estimated median (rather than the mean) size-at-50% selected for males in the directed fishery after 1990 to males in the directed fishery prior to 1991; and 9) using the estimated median (rather than the mean) bycatch F for the groundfish fisheries post-1972 as the value pre-1973. The resulting model is the base model, B0, for this assessment.

The author’s preferred model, B2b, builds on B0 principally by: 1) fitting EBS model-increment data inside the model to inform growth parameters, b) estimating separate retention functions for three time periods (pre-1997/98, 2005/06-2009/10, and 2013/14-2015/16), and c) estimating the asymptotic value for the fraction of male crab retained in the directed fishery (in the same three time periods as (b)), rather than assuming it was 1 (i.e., 100% retention at large sizes).

4. Changes to the assessment results

Results from the author’s preferred model this year (Model B2b) are reasonably similar to those from the previous assessment, considering the large number of changes in the model. Perhaps the largest change is due to somewhat higher recruitment estimates in this year’s preferred model. Average recruitment (1982-present) was estimated at 182 million in last year’s model, whereas it was estimated at 214 million in the author’s preferred model this year. B_{MSY} was consequently estimated somewhat larger than last year (29.17 thousand t vs. 25.65 thousand t) and F_{MSY} was smaller (0.75 yr^{-1} this year vs. 0.79 yr^{-1} last 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 unaddressed comments prior to the most recent two sets of comments.]

June 2017 SSC Meeting
The SSC requested an evaluation of all parameters estimated to be at or very near bounds, or substantially limited by priors (unless those priors can be logically defended).

Response: An initial approach to evaluating parameters at or near bounds using ADMB's likelihood profiling capability revealed that errors had apparently been introduced to the profiling algorithm in a recent version (11.2) of the ADMB libraries. These errors have subsequently been resolved, and will be incorporated in the next scheduled version release (11.7). However, likelihood profiling results from the author's version (11.5/11.6) would provide erroneous results.

May 2017 Crab Plan Team Meeting
No general comments.

October 2016 SSC Meeting
No general comments.

September 2016 Crab Plan Team Meeting
No general comments.

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 2017 SSC Meeting
The SSC endorsed the CPT suggestions from its May meeting.
Response: none.

The SSC requested an evaluation of all parameters estimated to be at or very near bounds, or substantially limited by priors (unless those priors can be logically defended).
Response: See response above to general comments from the June 2017 SSC Meeting.

May2017 Crab Plan Team Meeting
The CPT noted that the EBS growth data should be used in the assessment if at all possible, that the growth increment function should be adopted, and that the scale parameter should be estimated rather than being set to 0.75.
Response: All three requests have been addressed in the assessment (Model B1 and subsequent models).

The CPT noted that there was a tendency for the model to overpredict the abundance of large crab and recommended that the issue be evaluated by modeling retention with a logistic curve that asymptotes to a value less than one.
Response: The option of fitting a retention curve that asymptotes less than one has been implemented in the model framework. Models B2a, B2b and B3 incorporate this option and address this issue. Results from these models suggest that retention is indeed asymptotically less than one.

The CPT outlined the base model to be used for this assessment, based on results presented by the author for a suite of models.
Response: The base model recommended by the CPT is the base model used here (Model B0).

The CPT outlined a number of alternative models built on its recommended base model to be evaluated.
Response: Models B1, B2, and B3 were evaluated for this assessment. Requests to address time-varying retention and potential less-than-complete retention of legal-size crab were also addressed (models B2, B2a, and B2b). It was not possible to address the potential use of Francis-style iterative re-weighting for size composition data.

October 2016 SSC Meeting

Comment: “The SSC endorses all of the CPT recommendations with respect to the poor fits to some of the retained catch time series, poor fits to the size composition data for retained catch and survey data, and issues with the total directed fishery selectivity curve for males (in particular the 1996 ‘outlier’).”
Response: With respect to the 1996 ‘outlier’, this was a result of the combination of a very small sample size for the 1996 size compositions and the using the mean size-st-50%-selected for 1991-1996 as the value for the size-at-50%-selected prior to 1991. Because the sample size for 1996 was small, the 1996 size-at-50%-selected essentially became a free parameter uninformed by the 1996 data but sensitive to changes in the overall likelihood through changes in the mean value. Regarding the other issues, see the responses to CPT comments below.

September 2016 CPT Meeting

Comment: “The model fits total catch well, but does a poorer job in fitting retained catch, catch of females, and catch in the bycatch fisheries.”
Response: Catch of females was improved by estimating a female-specific offset to fully-selected male capture rates in the fisheries. There appears to be a conflict in the model between fitting total (male) catch and retained catch in the directed fishery. In this assessment, I’ve explored the use of varying the estimated retention function annually and within time blocks, as well as the possibility that retention is not 100% for the largest male crab (i.e., the retention function asymptotes at less than 1). These options seem to reduce the conflict, but not eliminate it.

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 males less than the industry-preferred size (>125 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°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

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.

Growth in immature Tanner crab larger than approximately 25 mm CW proceeds by a series of annual molts, up to a final (terminal) molt to maturity (Tamone et al., 2007). Rugolo and Turnock (2012a) derived growth relationships for male and female Tanner crab used as priors for estimated growth parameters 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, unpublished.; Donaldson et al. 1981). 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.

Molt increment data was collected for Tanner crab in the EBS during 2015, 2016, and 2017 in cooperative research between NMFS and the Bering Sea Research Foundation (R. Foy, NMFS, pers. comm.). Preliminary analysis of the data suggests it is not substantially different from that obtained near Kodiak Island (see Appendix D). However, this data is incorporated for the first time to inform inferred growth trajectories within several of the alternative models evaluated in this assessment.

c. Weight at Size

Weight-at-size relationships used in this assessment were revised in 2014 based on a comprehensive re-evaluation of data from the NMFS EBS Bottom Trawl Survey (Daly et al., 2014). Weight-at-size is described by a power-law model of the form $w = a \cdot z^b$, where w is weight in kg and z is size in mm CW (Daly et al., 2016; table below). Parameter values are presented in the following table:

sex	maturity	a	b
males		0.000270	3.022134
females	immature (non-ovigerous)	0.000562	2.816928
	mature (ovigerous)	0.000441	2.898686

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. Maturity in females can be determined visually rather unambiguously from the relative size of the abdomen. 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, but is not as easily determined as with females. 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 166ºW, 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 166ºW), 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.

Some preliminary work towards incorporating chela height measurements on male crab directly into the assessment has been done, but not completed. One concern is the representativeness of this data for the entire stock, given the somewhat haphazard nature of collections in previous years. To address this issue, substantial effort was devoted during the 2017 NMFS EBS bottom trawl survey to obtain chela heights on all male Tanner crab collected during the survey (R. Foy, NMFS, pers. comm.). However, this data is not yet available to incorporate into the assessment.

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 ADFG 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 2011). 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 2011).

The Bering Sea District of Tanner crab Registration Area J (Figure 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 166ºW.

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 166º W. The minimum size limit for the fishery to the east of 166ºW 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 166º W longitude to 5" (127 mm CW), the same as that in the western area. These new "preferred" sizes were used to set the TAC for the 2015/16 fishery season.

In assessments prior to 2016, 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. In this assessment, I use the term "legal males" to refer to crab 125 mm CW, the minimum "preferred" size used in both eastern and western areas the SOA's harvest strategy, and larger.

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 1; Figure 3). Foreign fishing for Tanner crab ended in 1980.

The domestic Tanner crab pot fishery developed rapidly in the mid-1970s (Tables 1 and 2; Figure 3). 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. 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. 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 1 and 2). 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 t) for the area west of 166º W and at 1,463,000 lbs (664 t) for the area east of 166º 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% (594 t) of the TAC had been taken in the western area while 98.6% (654 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. In 2014, TAC was set at 6,625,000 lbs (3,005 t) for the area west of 166º W and at 8,480,000 lbs (3,846 t) for the area east of 166º W. On closing, 77.5% (2,329 t) of the TAC was taken in the western area while 99.6% (3,829 t) were taken in the eastern area. In 2015, TAC was set at 8,396,000 lbs (3,808 t) in the western area and 11,272,000 lbs (5,113 t) in the eastern area. On closing, essentially 100% of the TAC was taken in each area (3,798 t in the west, 5,111 t in the east). The total retained catch in 2015/16 (8,910 t) was the largest taken in the fishery since 1992/93 (Tables 1, 2; Figure 2). The directed fisheries in both areas were closed in 2016/17 because mature female biomass in the NMFS EBS Bottom Trawl Survey did not exceed the threshold set in the SOA's harvest strategy to allow them to open. Total retained catch was thus 0 in 2016/17.

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 (Tables 3 and 4; Figures 5-7). 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 (although bycatch in the crab fisheries was undocumented at the time). 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

Because the directed fisheries were closed in 2016/17, retained catch abundance and biomass for the previous year were both 0 and no retained catch size composition data was available. Similarly, total catch (retained + discards) abundance and biomass in the directed fishery were both 0 for 2016/17, and no total catch size composition data from at-sea sampling was available. Updated estimates of total retained biomass and abundance in the 2015/16 directed fisheries, as well as retained size frequencies by shell condition, based on fish ticket data and dockside observer sampling were provided by ADFG (B. Daly, ADFG, pers. comm.).

ADFG also provided estimates of Tanner crab bycatch (abundance, biomass and size compositions) in the 2016/17 snow crab and Bristol Bay red king crab fisheries by several categories (e.g., by sex and shell condition), as well as updated estimates of total bycatch abundance and biomass, total fishery (potlifts) and observer sampling (pots examined) effort in both fisheries for 1990/91 to 2015/16.

Tanner crab bycatch data in the groundfish fisheries (abundance, biomass, size compositions) were extracted for 1991/92-2016/17 from the groundfish observer and AKRO databases on AKFIN. One model scenario for this assessment explored the use of fitting gear-specific data types, but most scenarios fit the data aggregated over gear types (see below). More details of this data are discussed in Appendix A.

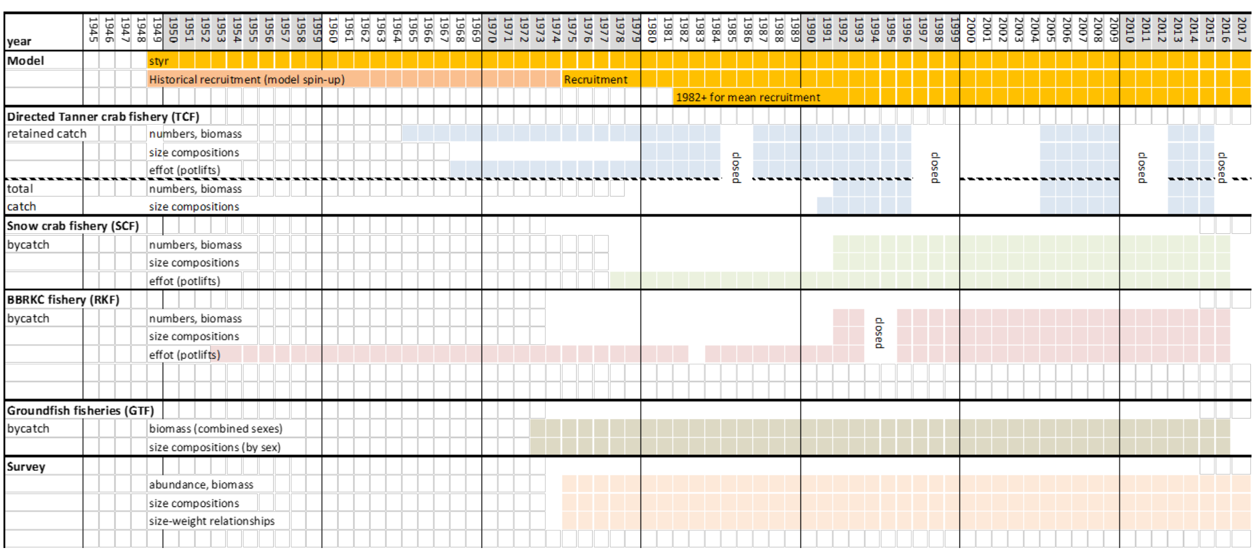
Swept-area abundance, biomass and size composition data from the 2017 NMFS EBS Bottom Trawl Survey were added to the assessment. Survey results for the assessment were calculated directly from the survey "crab haul" data files and station strata file to incorporate assessment criteria (e.g., excluding crab < 25 mm CW, aggregating crab > 185 mm CW into the upper-most size bin in size compositions) and facilitate comparisons across multiple areas and population categories. More details are provided in Appendices B and C.

For the first time, molt increment data from growth studies conducted in the EBS as cooperative research by NMFS and BSFRF are fit in a number of the model scenarios included in this assessment. These data are examined in more detail in Appendix D.

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

Data source	Data types	Time frame	Notes	Agency
NMFS EBS Bottom Trawl Survey	area-swept abundance, biomass size compositions	1975-2017	recalculated, new	NMFS
NMFS/BSFRF	molt-increment data	2014-16	new	NMFS, BSFRF
Directed fishery	retained catch (numbers, biomass)	2005/06-2016/17	updated, new	ADFG
	retained catch size compositions	2013/14-2015/16	updated	ADFG
	effort	2015/16, 2016/17	updated, new	ADFG
	total catch (abundance, biomass)	2015/16, 2016/17	updated, new	ADFG
	total catch size compositions	2015/16, 2016/17	updated, new	ADFG
Snow Crab Fishery	effort	1990/91-2013/14	updated, new	ADFG
	total bycatch (abundance, biomass)	1990/91-2016/17	updated, new	ADFG
	total bycatch size compositions	2016/17	new	ADFG
Bristol Bay Red King Crab Fishery	effort	1990/91-2013/14	updated, new	ADFG
	total bycatch (abundance, biomass)	1990/91-2016/17	updated, new	ADFG
	total bycatch size compositions	2016/17	new	ADFG
Groundfish Fisheries (all gear types)	total bycatch (abundance, biomass)	1991/92-2016/17	updated, new	NMFS/AKFIN
	total bycatch size compositions	1991/92-2016/17	updated, new	
Groundfish Fixed-Gear Fisheries	total bycatch (abundance, biomass)	1991/92--2016/17	new	NMFS/AKFIN
	total bycatch size compositions	1991/92--2016/17	new	
Groundfish Trawl Fisheries	total bycatch (abundance, biomass)	1991/92--2016/17	new	NMFS/AKFIN
	total bycatch size compositions	1991/92--2016/17	new	

The following table summarizes the data coverage in the assessment model (color shading highlights different model time periods and data components):



2. Data presented as time series

For the 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., 2015/16 indicates the 2015 bottom trawl survey and the winter 2015/16 fishery.

a. Total catch

Retained catch 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 1 and Figure 2 by fishery year. More detailed information on retained catch in the directed domestic pot fishery is provided in Table 2, 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.

Directed fisheries for Tanner crab in the EBS began in 1965. Retained catch has followed a "boom-and-bust" cycle over the years, with the fishery experiencing periods of rapidly increasing catches followed by rapidly declining ones, after which it is closed for a time during which the stock partially recovers. Retained catch increased rapidly from 1965 to 1975, reaching ~ 25,000 t in 1970. It declined to ~13,000 t in 1973/74 coinciding with the termination of Russian fishing and the beginning of the domestic pot fishery. It increased again, this time to its highest level, in 1977/78 (~35,000 t) as the domestic fishery developed rapidly, but it subsequently declined again and the fishery was closed in 1985/86 and 1986/87. In the late 1980s and early 1990s, the fishery experienced another, somewhat smaller, "boom" followed by a "bust" and closure of the fishery from 1997/98 to 2004/05. From 2005/06 to 2009/10, the fishery experienced its smallest boom-and-bust cycle, peaking at only ~1,000 t retained catch, and was closed again from 2010/11 to 2012/13. The fishery was re-opened in 2013/14, and retained catch increased each subsequent year until 2016/17 as TACs increased (Figures 2 and 6). The retained catch for 2015/16 (8,910 t) was the largest since 1992/1993 (15,920 t; Table 1). However, the TAC for both directed fisheries was set at 0, and both fisheries closed for the year, by ADFG prior to the start of the 2016/17 fishing season because mature female biomass in the 2016 NMFS EBS bottom trawl survey did not meet the SOA's criteria for opening the fisheries.

b. Information on bycatch and discards

Annual bycatch (discards) of Tanner crab are provided in Tables 3 and 4 and Figures 3-5 based on ADFG 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, based on NMFS groundfish observer programs, are also provided starting in 1973/74, but sex is undifferentiated. A value of 0.321 is used for "handling mortality" in the crab fisheries to convert observed bycatch to (unobserved) mortality (Stockhausen, 2014). For the groundfish fisheries, values of 0.5, 0.8, and 0.8 for handling mortality are used to reflect differences in gear effects and on-deck operations compared with the crab fleets for fixed gear fleets, trawl gear fleets, and aggregated gear fleets, respectively.

Estimated bycatch mortality in the groundfish fisheries (without distinguishing gear type) was highest (~15,000 t) in the early 1970s, but was substantially reduced by1977 to ~2,000 t with the curtailment of foreign fishing fleets. It declined further in the 1980s (to ~500 t) but increased somewhat in the late 1980s to a peak of ~2,000 t in the early 1990s before undergoing a slow but rather steady decline to the present (255 t in 2016/17). Since reliable at-sea ADFG crab observer data has been available (1992), the snow crab fishery has consistently accounted for the highest fraction of bycatch mortality among the crab fisheries, followed by the directed fishery and the BBRKC fishery (Table 4, Figure 4). Estimated bycatch mortality was highest for all crab fisheries in the early 1990s (~12,000 t total) but subsequently declined as (presumably) the stock declined and the directed fishery was curtailed. Since the directed fishery re-opened in 2013/14, bycatch mortality has averaged 325 t in the directed fishery, 554 t in the snow crab fishery, 32 t in the BBRKC fishery, and 309 t in the groundfish fisheries.

In the crab fisheries, the largest component of bycatch occurs on males. In the early 1990s, female bycatch ranged between 6 and 40% of the bycatch in the directed and snow crab fisheries. Since the directed fishery re-opened in 2013/14, the fraction of bycatch that is female has ranged between 2% and 6% in the directed fishery, between 0.3 and 3% in the BBRKC fishery, and has been below 1% in the snow crab fishery. Estimates of total groundfish bycatch are not currently available by sex.

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

Retained (male) catch-at-size in the directed Tanner crab fishery from ADFG crab observer sampling is presented in Figure 6 by fishery region (and total) for the two most recent periods the fishery was open (spanning 2005/06-2015/16). These appear to indicate a shift to retaining somewhat smaller minimum sizes since 2013/14, compared with 2005/06-2009/10. In fact, the BOF in 2014/15, in response to a petition by industry, changed its harvest strategy for calculating TACs to reflect a smaller minimum industry-preferred size of 125 mm CW east of 166W longitude.

Size compositions expanded to total catch (retained + discards) from at-sea crab fishery observer sampling in the directed fishery are presented by shell condition and fishery region in Figure 7 for male crab and in Figure 8 for female crab. The male size compositions suggest that about half the males caught in the directed fishery in 2015/16 were less than the minimum preferred size of 125 mm CW. If old shell males really are males at least one year past their terminal molt (as assumed in the assessment model), the size compositions for these crab suggest that 30-50% of these crab (which will not grow) are less than the preferred size.

Size compositions expanded to total bycatch of Tanner crab in the snow crab fishery, based on at-sea crab fishery observer sampling, are presented by sex and shell condition in Figure 9. Because this fishery is prosecuted further north and west, on average, than the directed fishery, its bycatch composition consists of somewhat smaller males than in the directed fishery. Conversely, the expanded bycatch size compositions for the BBRKC fishery tend to be shifted toward somewhat larger males than the directed fisheries because the BBRKC fishery is prosecuted further to the south and east on average than the directed fishery (Figure 10). Figure 11 presents size compositions expanded to total bycatch based on observer sampling in the groundfish fisheries for 1991/92 to the present. Size compositions prior to 1991/92 have not been expanded to total bycatch; thus, the scales are incompatible with those after 1990/91. Male bycatch size compositions in the snow crab fishery clearly reflect some sort of "dome-shaped" selectivity pattern (as assumed in the assessment model), with selectivity small for small and large males and highest for intermediate-sized males. In contrast, the BBRKC fishery appears to catch mostly larger Tanner crab males (consistent with asymptotic selection), while the groundfish fisheries take a wide range of sizes as bycatch.

Raw and input sample sizes (number of individuals measured) for the various fisheries are presented in Tables 5-9.

d. Survey biomass estimates

Time series trends from the NMFS EBS bottom trawl survey suggest the Tanner crab stock in the EBS has undergone decadal-scale fluctuations (Table 10, Figure 12; see also Appendix B, Figures 1-12). Estimated biomass of mature crab in the survey time series started at its maximum (277,000 t) in 1975, decreased rapidly to a low (17,000 t) in 1986, and rebounded quickly to a smaller peak (157,000 t) in 1991. After 1991, mature survey biomass decreased again, reaching a minimum of 13,100 t in 1998. Recovery following this decline was slow and mature survey biomass did not peak again until 2008 (82,900 t), after which it has fluctuated more rapidly—decreasing within two years by almost 50% and reaching a minimum in 2010 (44,600 t), followed by an increase of almost 50% to reach a peak in 2014

(97,300 t). The most recent trend (2014-2017) has been a declining one (Figures 12 and 13). Trends in the male and female components of mature survey biomass, as well as legal male abundance, have primarily been in synchrony with one another (Appendix B, Figures 5, 6, 9 and 10), as have changes in the eastern and western fishery regions (east and west of 166^{o}W longitude; Figures 14 and 15; Appendix B, Figures 5, 6), although the magnitudes differ.

e. Survey catch-at-length

Plots of survey size compositions for male crab, expanded to total abundance by shell condition and fishery region, in Figures 16 and 17. The absence of small (new shell) crab in the eastern region since 2009 is notable, as is the progression of a possible cohort (with two size modes) through the new shell size classes in both regions starting in 2009 that starts to show up, but much reduced in amplitude, in the old shell crab size comps in 2014. Plots of survey size compositions for female crab, expanded to total abundance by maturity status (based on morphometric characteristics) and fishery region, are shown in Figures 18 and 19. Similar to males, a cohort progression of immature females starting in 2009 is evident in both regions, although it is much clearer in the eastern region. It can also be tracked into the mature female size comps starting in 2013. A potential new cohort is also evident in the size comps for both sexes in the western region, but not the eastern region, in 2017.

Observed sample sizes for the size compositions, aggregated to the EBS regional level used in the assessment, are presented in Table 11. Given the large number of individuals sampled, a sample size of 200 is used to fit survey size compositions in the assessment model to prevent convergence issues associated with using the actual sample sizes.

f. Other time series data.

Spatial patterns of abundance in the 1975-2017 NMFS bottom trawl surveys are mapped in Appendix C for immature males, mature males, immature females, mature females and legal males. There is some suggestion that an extensive cold pool in the middle region of the EBS shelf may act to diminish relative crab densities in this region, particularly for mature males (e.g., Appendix C: compare 1984, Figure 11 vs. 2016, Figure 43).

Annual effort in the snow crab and BBRKC fisheries is used in the model to "project" bycatch fishing mortality rates backward in time from the period when data on bycatch in these fisheries exists (1992-present). 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) provide the basis for priors on sex-specific growth estimated within the assessment model. Molt increment data is now available to fit in the model (see Appendix D), but it is assumed to reflect growth rates over the entire model period.

b. Weight-at size

Weight-at-size relationships used in the assessment model for males, immature females, and mature females is depicted in Figure 21.

c. Size distribution at recruitment

The assumed size distribution for recruits to the population in the assessment model is presented in Figure 22.

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 standardized survey dataset in 2015 due to inconsistencies in spatial coverage with the standardized dataset. Chela height data from the NMFS survey are not yet fit in the model, although a subset of the available data forms the basis for the maturity ogive used to assign a probability of maturity to male crab collected in NMFS surveys. Data collected on Tanner crab abundance and size compositions collected in BSFRF surveys are not yet incorporated in the assessment.

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 the authors' 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.

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].

A new model "framework", TCSAM02, has been under development for the past two years. In May 2017, the CPT reviewed this framework and recommended its use in this assessment. At its June 2017 meeting, the SSC concurred. The new framework is a completely-rewritten basis for the Tanner crab model: substantially different model scenarios can be created and run by editing model configuration files rather than modifying the underlying code itself. Most importantly, no time blocks are "hard-wired" into the code—any time blocks are defined in the configuration files. In addition, the new frame work can incorporate new data types (e.g., molt increment data), new survey data (e.g., the BSFRF surveys), and new fishery data (e.g., bycatch in the groundfish fisheries by gear type). The new model framework also incorporates status determination and OFL calculation directly within a model run, so a follow-on, stand-

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

alone projection model does not need to be run, as with TCSAM2013. This approach has the added benefit of allowing a more complete characterization of model uncertainty in the OFL calculation, because the OFL calculations can now be included in Markov Chain Monte Carlo (MCMC) evaluation of a model's posterior probability distribution. Although TCSAM02 is a new model framework, it was demonstrated at the May 2017 CPT meeting that it could exactly reproduce an "exactly equivalent" model developed using the old TCSAM2013 model code. This "exactly equivalent" model, while not identical to the 2016 assessment model, provides the base model (B0) for this assessment.

The code for the TCSAM02 model framework is publicly available on GitHub[3].

2. Model Description

a. Overall modeling approach

TCSAM02 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 E.

In brief, crab enter the modeled population as recruits following the size distribution in Figure 22. 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 in the base model entering the likelihood include fits to mature survey biomass, survey size compositions, retained catch, retained catch size compositions, bycatch mortality in the bycatch fisheries, and bycatch size compositions in the bycatch fisheries.

b. Changes since the previous assessment.

As noted above, this assessment uses the TCSAM02 model framework, a completely re-written basis for the Tanner crab assessment. Substantive changes from the 2016 TCSAM2013 assessment model to the base model addressed here (with 2016 data: B0.2016) were fully documented in a set of incremental-change models in the May 2017 report to the CPT (Stockhausen, 2017). These are summarized here briefly in the following table:

[3] https://github.com/wStockhausen/wtsTCSAM02.git

TCSAM2013 Model	Incremental change
AM	2016 assessment model
AMa	AM + removed size-specific "old shell" re-classification for input data
AMb	AMa + fit to total capture (not mortality) size compositions
AMc	AMb + fit to total capture (not mortality) biomass
AMd	AMc + apply seasonal M after molt-to-maturity
B0	same as AMd
B1	B0 + fit to input survey biomass based on 1-mm size bins
B2	B1 + using 2.20462262 to convert from kg to lbs
B3	B2 + capture rates in RKF not explicitly set to 0 for 1984,1985 and 1994, 1995
B4	B3 + corrected retained size comps for 2015/16
B5	B4 + using median size-at-50% selected for TCF males pre1991 (not average)
B6	B5 + using post-1972 median F for GTF before 1973 (not average)

The TCSAM2013 model B6 was demonstrated to be "exactly equivalent" to the TCSAM02 base model for this assessment, B0, using 2016 data.

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

The TCSAM02 model framework was demonstrated to produce results that were exactly equivalent to those from the 2016 assessment model incorporating the changes listed in the previous table. TCSAM02 also underwent a review in July 2017 conducted by the Center for Independent Experts.

3. Model Selection and Evaluation

a. Description of alternative model configurations

The following tables provide a summary of the baseline model configuration, B0, for this assessment.

Model B0: Model description of population processes and survey characteristics.

process	time blocks	description
Population rates and quantities		
Population built from annual recruitment		
Recruitment	1949-1974	ln-scale mean + annual devs constrained as AR1 process
	1975-2017	ln-scale mean + annual devs
Growth	1949-2016	sex-specific
		mean post-molt size: power function of pre-molt size
		priors on mean post-molt parameters from Kodiak growth data
		post-molt size: gamma distribution conditioned on pre-molt size
Maturity	1949-2016	sex-specific
		size-specific probability of terminal molt
		logit-scale parameterization
Natural mortalty	1949-1979, 1985-2	estimated sex/maturity state-specific multipliers on base rate
		priors on multipliers based on uncertainty in max age
	1980-1984	estimated "enhanced mortality" period multipliers
Surveys		
NMFS EBS trawl survey		
male survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
female survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
male selectivity	1975-1981	ascending logistic
	1982+	ascending logistic
female selectivity	1975-1981	ascending logistic
	1982+	ascending logistic

Model B0: Model description of fishery characteristics.

Fishery/process	time blocks	description
TCF	directed Tanner crab fishery	
capture rates	pre-1965	male nominal rate
	1965-2016	male ln-scale mean + annual devs
	1949-2016	ln-scale female offset
male selectivity	1949-1990	ascending logistic
	1991-1996	annually-varying ascending logistic
	2005-2016	annually-varying ascending logistic
female selectivity	1949-2016	ascending logistic
male retention	1949-1990	ascending logistic
	1991-2016	ascending logistic
SCF	bycatch in snow crab fishery	
capture rates	pre-1978	nominal rate on males
	1979-1991	extrapolated from effort
	1992-2016	male ln-scale mean + annual devs
	1949-2016	ln-scale female offset
male selectivity	1949-1996	dome-shaped
	1997-2004	dome-shaped
	2005-2016	dome-shaped
female selectivity	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005-2016	ascending logistic
RKF	bycatch in BBRKC fishery	
capture rates	pre-1952	nominal rate on males
	1953-1991	extrapolated from effort
	1992-2016	male ln-scale mean + annual devs
	1949-2016	ln-scale female offset
male selectivity	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005-2016	ascending logistic
female selectivity	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005-2016	ascending logistic
GTF	bycatch in groundfish fisheries	
capture rates	pre-1973	male ln-scale mean from 1973+
	1973+	male ln-scale mean + annual devs
	1973+	ln-scale female offset
male selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic
female selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic

The following alternative model scenarios were evaluated as part of this assessment:

Description of the alternative model scenarios evaluated for this assessment. The number of estimated parameters and the final value of the objective function for each converged model are also listed. B2b is the author's preferred model.

model scenario	number of parameters	objective function value	description
B0.2016	332	2,665.27	"fully-equivalent" model from May 2017 CPT meeting
B0	336	2,765.43	Base model for 2017 assessment (B0.2016 + 2017 data)
B0a	336	2,763.31	B0 + new growth parameterization (growth data not fit)
B1	337	3,109.39	B0 + fit to EBS growth data, drop riors on growth, estimate growth scale parameter
B1a	337	3,108.64	B1 + new growth parameterization
B1b	337	3,110.35	B1a + new parameterization for RKF selectivity
B1c	337	8,367.14	B1b + 20 *x* higher likelihood weight on EBS growth data
B2	350	2,872.42	B1b + annual devs on retention function z50's
B2a	353	2,870.33	B2 + 3 time blocks for asymptotic retention level
B2b	344	2,894.80	B2a + 3 time blocks for retention function substituted for annual devs
B3	391	2,381.20	B2b + bycatch in groundfish fisheries by gear type (1991+)

Scenario B0.2016 is the baseline model scenario without the updated and new data for 2017. It is identical to the "exactly equivalent" model from the May 2017 CPT meeting. Scenario B0 is the baseline model with new and updated data for 2017. Scenario B0a introduces a new parameterization for mean growth to address CPT and SSC concerns with B0.2016 and previous assessments that some growth parameters ended up at one of the bounds set on them.

The "old" parameterization for mean growth estimated the asymptote (a) and slope (b) of the following log-log (or power law, on the arithmetic scale) model for post-molt size in terms of pre-molt size:

$$\ln(\bar{z}_{post}) = a + b \cdot \ln(z_{pre}) \tag{1}$$

Note that the interpretation of a here is that e^a is the mean post-molt size for a crab of pre-molt size 1. The "new" parameterization for mean growth estimates the mean post-molt sizes ($\bar{z}_{post_{min}}$ and $\bar{z}_{post_{max}}$) at two pre-molt sizes ($z_{pre_{min}}$ and $z_{pre_{max}}$) based on an alternative form for the linear (in ln-space) relationship:

$$\ln(\bar{z}_{post}) = \ln(\bar{z}_{post_{min}}) + \frac{\left[\ln(\bar{z}_{post_{max}}) - \ln(\bar{z}_{post_{min}})\right]}{\left[\ln(z_{pre_{max}}) - \ln(z_{pre_{min}})\right]} \cdot \left[\ln(z_{pre}) - \ln(z_{pre_{min}})\right] \tag{2}$$

The new parameters are much more easily interpreted, as would priors put on them. I chose 25 mm CW for $z_{pre_{min}}$ for both sexes, and 100 and 125 mm CW for $z_{pre_{max}}$ for females and males, respectively, so the estimated parameters are the mean post-molt sizes corresponding to the associated z_{pre}'s. No priors were placed on the new parameters in scenario B0a.

Scenario B1 and subsequent scenarios included the molt-increment data from the EBS in their model fitting procedures. B1 used the "old" growth parameterization, but the priors placed on the growth parameters were removed and the scale parameter for the growth model's gamma probability distribution was estimated. Scenario B1a replaced the "old" growth parameterization with the new parameterization.

Several of the parameters estimated for the ascending logistic functions used to describe bycatch selectivity in the BBRKC fishery (denoted RKF here) also had a tendency to end up at one of the bounds placed on them in the B0 scenarios and previous assessment models. Scenario B1b introduced a new parameterization for an ascending logistic curve based on the size-at-95%-selected (z_{95}) and the ln-scale interval between the sizes at 50%-selected and 95%-selected ($\ln(\Delta z_{95-50})$), rather than the more common size-at-50%-selected and scale parameter, to try to eliminate this behavior.

In scenarios B1, B1a and B1b, the EBS molt-increment data was added to the model objective function using a log-likelihood function appropriate for a gamma distribution without any additional weighting (i.e., a likelihood weight of 1). However, it is unclear whether or not this is an appropriate weight for this data vis-à-vis other components contributing to the objective function. To explore the implications of increasing the weight placed on the molt-increment data in fitting the model, scenario B1c increased the weight on the molt-increment data in the likelihood by a factor of 20 (essentially decreasing variances by a factor of 4.5). As discussed below, this model performed unsatisfactorily and subsequent scenarios (B2, B2a, B2b and B3) kept the weight on the molt-increment data in the likelihood at 1.

Scenario B2 was based on scenario B1b, but allowed the value of the size-at-50% retention for males in the directed fishery to vary annually during the 1991/92-2015/16 time period. Scenario B2a built on B2 by estimating parameters reflecting the maximum fraction of crab retained in the directed fishery in three time periods: 1) 1965/66-1996/97, 2) 2005/06-2009/10, and 3) 2013/14-2015/16. The latter two time blocks reflect potentially different fleet composition and fishing practices following fishery closures (1997/98-2004/05, 2010/11-2012/13) and rationalization of the fishery (2005). Scenario B2b attempted to reduce the number of parameters used to model retention in the directed fishery by replacing the annual deviations in size-at-50%-retention from 1991/92 to 2015/16 with the three time blocks associated with the maximum retention parameters (1965/66-1996/97, 2005/06-2009/10, and 2013/14-2015/16) for the same reasons.

Finally, scenario B3, otherwise based on B2b, decomposed the bycatch in the groundfish fisheries after 1990/91 into fixed gear and trawl gear components to try to better resolve handling mortality on discarded Tanner crab in these fisheries. In prior scenarios, bycatch in the groundfish fisheries was aggregated across gear types and a handling mortality rate appropriate to trawl gear (80%) was assumed to apply to the total. In B3, bycatch in the fixed gear fleets was separated from that in the trawl gear fleets and a separate handling mortality rate (equal to the handling mortality rate for crab pot gear, 32.1%) was assumed to apply. Separate sex-specific selectivity functions were estimated in two time blocks (1991/92-1996/97 and 1997/98-2016/17) for each gear type. Ascending logistic functions were used for all six fixed gear selectivity functions, as well as the three trawl gear selectivities applied to females. Dome-shaped double-logistic functions were fit to the three trawl gear selectivity functions applied to males.

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

The following table summarizes basic model results from the 2016 assessment model (2016AM) and the 11 scenarios considered here:

model scenario	number of parameters	objective function	average recruitment	Final MMB	B0	Bmsy	Fmsy	MSY	Fofl	OFL	projected MMB	projected MMB / Bmsy	projected MMB / Final MMB
			millions	1000's t	1000's t	1000's t		1000's t		1000's t	1000's t		
2016AM	341	2,406.75	182.27	73.90	73.29	25.65	0.79	11.13	0.79	25.61	45.34	1.77	0.61
B02016	332	2,665.27	175.94	85.19	75.83	26.54	0.93	11.21	0.93	27.38	45.47	1.71	0.53
B0	336	2,765.43	174.64	68.57	76.90	26.91	0.92	11.21	0.92	21.87	36.88	1.37	0.54
B0a	336	2,763.31	172.24	66.92	75.27	26.35	0.93	11.10	0.93	21.40	35.82	1.36	0.54
B1	337	3,109.39	194.58	74.26	79.67	27.89	0.94	11.48	0.94	24.02	39.72	1.42	0.53
B1a	337	3,108.64	194.80	73.82	79.22	27.73	0.94	11.46	0.94	23.90	39.40	1.42	0.53
B1b	337	3,110.35	195.26	73.83	79.14	27.70	0.95	11.47	0.95	23.95	39.35	1.42	0.53
B1c	337	8,367.14	270.31	98.70	91.09	31.88	1.21	13.08	1.21	35.57	49.19	1.54	0.50
B2	350	2,872.42	198.97	74.51	80.14	28.05	0.74	11.58	0.74	23.20	40.59	1.45	0.54
B2a	353	2,870.33	208.35	78.73	82.38	28.83	0.75	12.03	0.75	24.74	42.57	1.48	0.54
B2b	344	2,894.80	213.95	80.57	83.34	29.17	0.75	12.25	0.75	25.42	43.31	1.49	0.54
B3	391	2,381.20	263.90	87.47	88.82	31.09	0.89	13.40	0.89	29.76	44.67	1.44	0.51

The author's preferred model, B2b, is highlighted for reference. The number of estimated parameters reported in the table is larger for the 2016 assessment model than B02016 because the final "dev" in a TCSAM02 devs vector is not counted as an estimable parameter (the vector is constrained to sum to 0) whereas it was counted in the 2016 assessment model based on TCSAM2013.

All new model scenarios were evaluated using 200 runs with jittered initial parameter values to select the run with the smallest objective function value and smallest maximum gradient. For each model, the selected run was re-run to invert the hessian and obtain standard deviations for parameter estimates. All models resulted in hessians that were invertible and provided uncertainty estimates associated with the parameter estimates.

Results of the progression from the 2016 assessment model to the base model here using the 2016 data, B0.2016, were presented and discussed at the May 2017 CPT meeting (Stockhausen, 2017). Results from the model progression from B0.2016 to B3 are presented in Appendix F.

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

The characteristics of retention of male crab in the directed fishery in the base model, B0, were assumed to be different before and after 1991, primarily reflecting changes in fleet composition and effort, and parameters describing two independent logistic functions were estimated for those time periods. Model B2 allowed potentially-annual changes in the retention curve after 1991 by estimating annual deviations in the size-at-50%-retained. Because B2 was possibly over-parameterized, model B2b eliminated the annual deviations and instead estimated parameters for independent retention functions in three time blocks across 1991-present (1991-1996, 2005-2009, 2013-2015).

d. Convergence status and convergence criteria

Convergence in all models was assessed by running each model at least 200 times with randomly-selected ("jittered") initial parameter values for each run. For each model, a number of these jitter runs failed, primarily because the initial values for the growth parameters resulted in the mean post-molt size being smaller than the pre-molt size. Of those that converged, the run with the smallest objective function value and smallest maximum gradient was selected as the "converged" model, if it was also possible to invert the associated hessian and obtain standard deviation estimates for parameter values. Theoretically, all gradients at a minimum of the objective function would be zero. However, because numerical methods have finite precision, the numerical search for the minimum is terminated after achieving a minimum threshold for the max gradient or exceeding the maximum number of iterations. Typically, 5-10 jittered runs converged to the same minimum value, but sets of runs also converged to larger values—emphasizing the need to jitter to evaluate convergence to the minimum objective function value in the first place.

e. Sample sizes assumed for the compositional data

Input sample sizes used for compositional data are listed in Tables 5-9 for fishery-related size compositions. Input 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 described in 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.

f. Parameter sensibility

Limits were placed on all estimated parameters in all model scenarios primarily to provide ranges for jittering initial parameter values. Although these limits, for the most part, did not constrain parameter estimates in the converged models, some parameters were found to be at, or very close, to one of the bounds placed on them. These parameters are listed for the alternative scenarios in Tables 13 and 14 (values for all parameters are listed in Tables 15-24). The CPT and SSC have both expressed concerns regarding parameters estimated at their bounds, as such results frequently violate assumptions regarding model convergence, parameter uncertainty estimates, and suggest that model suitability may be improved by widening the bounds or re-parameterizing the model.

Models B3 and B1c had the most parameters at a bound (19 and 13, respectively), while B2 had the least (9)(Tables 13 and 14). The author's preferred model, B2b, had 11, but the two parameters that differed from B2 in this regard were the logit-scale probability of terminal model in the largest size class (the parameters for both models essentially yielded a probability of 1; Table 17) and the descending slope of the dome-shaped bycatch selectivity for males in the snow crab fishery (pS4[1]; Table).

In Table 13, the logit-scale parameters pLgtRet[1], pLgtPrM2M[1], and pLgtPrM2M[2] are estimated at one of the bounds placed on them. For these parameters, being at the upper bound (15) suggests the parameter could be replaced by 1 on the arithmetic scale without affecting the remaining parameters whereas those that are at the lower bound (-15) could be replaced by 0 on the arithmetic scale. The result would be, for the model scenarios concerned, assuming max retention prior to 1997 is 100% (i.e., 1; pLgtRet[1]), the probability of terminal molt for males in the largest model size class (180+ mm CW) is 100% (pLgtPrM2M[1]), and the probability of terminal molt for females in the smallest size class (25-30 mm CW) is 0 (pLgtPrM2M[2]).

That the growth parameters (pGrA, pGrB, and pGrBeta) are estimated at their bounds in some scenarios is somewhat concerning, but the problems with pGrA and pGrB have been dealt with by re-parameterizing mean post-molt size as a function of pre-molt size from Equation 1 (scenarios B0.2016, B0, B1) above to Equation 2 (scenarios B0a, B1a, and subsequent ones). Of more concern is that pLnQ[1] and pLnQ[2], the ln-scale parameters for survey catchability for both males and females in the pre-1982 period, are estimated at the lower bound in all scenarios considered here. The lower limit corresponds to a survey "q" of 0.5, and the models all want go lower, but this is likely to result in increased population abundance/biomass estimates in the pre-1982 period.

A number of selectivity parameters are also estimated at, or very close to, one of the bounds placed on them (Table 14). Most selectivity functions in all scenarios were ascending logistic functions, which would be expected to increase from near 0 at small crab sizes to 1 at large crab sizes. Upper limits on size-related selectivity parameters for female crab reflect the fact that they attain smaller final sizes than males, so their associated selectivity functions should asymptote at smaller sizes. In general, bounds on selectivity parameters were selected to reflect these characteristics. That parameters associated with sizes at 50%-selected or 95%-selected (pS[1], pS1[22], pS1[23], pS1[24], pS1[25], pS1[26], pS1[27], pS1[33], pS2[1], pS2[2], pS2[4]) end up at their upper bounds suggests that the associated fully-selected fishery capture rate or survey catchability may be confounded with value for selectivity in the largest size bin. This is certainly the case for bycatch selectivity for females in the BBRKC fishery. It also appears that the re-parameterization of bycatch selectivity for the BBRKC fishery from size-at-50-%-selected (z_{50}) and slope to size-at-95%-selected (z_{95}) and increment from z_{50} to z_{95} rarely succeeded in moving the estimated parameters away from the bounds.

Estimates of parameter uncertainty, approximations calculated by inverting the model hessian and using the "delta" method, were obtained from each converged model's ADMB "std" file (Tables 15-24). Extremely large uncertainties were obtained for parameters related to the NMFS trawl survey selectivity for females after 1981 for scenario B0a (Table 27) and the slope of bycatch selectivity for females in the groundfish trawl gear fleet during 1991-1996 for scenario B3 (Table 24).

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

Criteria used to evaluate the alternative models were based primarily on: 1) goodness of fit and likelihood criteria, 2) parameter sensibility, and 3) biological realism.

The author's preferred model, B2b, fits the EBS growth data and has reasonable parameter estimates. It is more parsimonious than models B2 and B2a, using fewer parameters to model time-varying retention in the directed fishery.

h. Residual analysis

Residuals for the author's preferred model, Model B2b, are discussed below under the Results section.

i. Evaluation of the model(s)

Of the models evaluated with data for 2017, B0 provided a link to the "exactly equivalent" TCSAM02 model presented at the May 2017 CPT meeting (B0.2016 here). Model B0a tested a new parameterization of mean growth designed to eliminate estimated growth parameters constrained by their bounds (it did). Model B1 introduced fitting molt-increment data for the EBS for the first time, but used the "old" growth parameterization of B0 for consistency with that scenario—with the continued result of growth parameters hitting their bounds. Model B1a used the new parameterization of mean growth and again eliminated the problem with growth parameters estimated at their bounds. By incorporating the growth data and removing the issue with some estimated parameters hitting one of their bounds, B1a became the de facto "model to beat". Model B1b was an attempt to eliminate additional parameters hitting their bounds by introducing re-parameterized logistic selectivity functions for bycatch in the BBRKC fishery. Although these changes proved unsuccessful, B1b was essentially identical to B1a and formed the basis for scenario B2. Scenario B1c was an unsuccessful attempt to put more emphasis on fitting the growth data in the model—the large weight placed on the growth data forced a number of parameters to one of their bounds and resulted in generally poorer fits to other data components (NMFS trawl survey size compositions for immature crab being the exceptions; Tables 25 and 26). Scenario B2 introduced annually-varying retention curves which, not surprisingly, improved the fit to retained catch size compositions dramatically over scenario B1b (187 likelihood units) but also improved fits to retained catch biomass (30 likelihood units), total catch biomass of both males and females in the directed fishery (36 likelihood units), and total catch size compositions for males in the directed fishery (Tables 25 and 26). Scenario B2a allowed maximum retention to be less than 1, and estimated logit-scale parameters reflecting this for three different time periods. This improved fits to retained catch biomass and size compositions (12 likelihood units) and size compositions for immature males in the NMFS trawl survey (8 likelihood units), but degraded the fit to total catch biomass of females in the directed fishery (27 likelihood units). Scenario B2b attempted to simplify B2a by reducing the allowed variability in the retention function for the directed fishery from annual changes in size-at-50%-retained to changes between three time blocks coinciding with changes in the directed fishery. This resulted in an improved fit to the retained catch size compositions over B2a (9 likelihood units), but worse fits to retained catch biomass, female total catch biomass in the directed fishery, and total catch size compositions for males in the directed fishery (25 likelihood units). Scenario B3 disaggregated bycatch in the groundfish fisheries by gear type after 1990/91 to try to disentangle potential changes in bycatch selectivity in the groundfish fisheries due to changes in the relative amount of Tanner crab taken by the trawl- and fixed-gear fleets. B3 was not really successful, resulting in the largest number of parameters at bounds among the 11 model scenarios.

4. Results (best model(s))
Model B2b was selected as the author's preferred model for the 2017 assessment.

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

Input and effective sample sizes for size composition data fit in the model are listed in Tables 27-32 from the 2016 assessment model and Model B2b. A weighting factor of 20 (corresponding to a standard deviation of 0.158) was applied to all fishery catch biomass likelihood components to achieve close fits to catch biomass time series.

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 Tables 15-24.

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

Estimates for mature survey biomass, by sex, are listed in Table 33 and for mature biomass at mating, by sex, in Table 34 for the 2016 assessment model and the author's preferred model, B2b. Numbers at size for females and males are given by year in 5 mm CW size bins for scenario B2b in Tables 35 and 36, respectively.

iii. Recruitment time series

The estimated recruitment time series from the 2016 assessment and Model B2b are listed in Table 37.

iv. Time series of catch divided by biomass.

A comparison of catch divided by biomass (i.e., exploitation rate) from the 2016 assessment and Model B2b is listed in Table 34.

c. Graphs of estimates

Direct comparisons between the 2016 assessment model and scenario B2b are not available because the 2016 assessment model results files are incompatible with the R packages developed to plot TCSAM02 model results. Instead, comparisons between B0.2016, the "exactly equivalent" model and B2b are provided (along with results from the other scenarios) in Appendix F. However, results from B0.2016, although very similar in most respects, are not identical to the 2016 assessment model results.

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

Estimated natural mortality rates are shown in Figure F1 (i.e., Appendix F, Figure 1). 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 were estimated by sex across two time periods: 1949-1979/80+1985/86-2016/17 and 1980/81-1984/85. 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 for B0.2016 and B2b:

Stock component	Normal period		High Mortality	
	B0.2016	B2b	B0.2016	B2b
immature crab	0.23	0.23	0.23	0.23
mature females	0.33	0.32	0.46	0.42
mature males	0.26	0.26	0.72	0.69

Estimated sex- and size-specific probabilities of the terminal molt-to-maturity (Figure F2) are quite similar for all the models, with the exceptions that the curves are right-shifted to larger sizes in scenarios B1c and B3.

Mean growth curves from scenarios B0.2016 and B2b are nearly identical for males and very similar for females, although B2b estimates slightly smaller growth increments at large sizes relative to B0.2016 (Figure F3). A similar result holds for the distribution of post-molt sizes conditioned on pre-molt size (Figures F4-F11). Mean growth curves in both scenarios appear to overestimate the molt increment at the largest pre-molt size in both the EBS data (fit in B2b, Figures F13-F15) and the Kodiak data (Figures F6-F18) for males, and to a lesser extent for females.

Estimated catchability in the NMFS trawl survey (Figure F169) is smaller in B2b in the standardized net period (1982+) for both males and females (0.64 and 0.40, respectively) than in B0.2016 (0.72 and 0.50). The associated selectivity curves estimated in the two scenarios are quite similar, although female selectivity post-1981 is slightly higher at small sizes in B2b compared with B0.2016, while the opposite true for males Figure F170).

iii. Estimated full selection F over time

Estimated time series of fully-selected F (*capture rates*, not mortality) on males in the directed fishery and bycatch in the snow crab, BBRKC and groundfish fisheries are compared among the model scenarios in Figures F171-F176. Rates for the directed fishery (Figure 174) are generally similar between B0.2016 and B2b, except during the period 1978/79-1979/80, when they are substantially higher in B0.2016 (Figure F158). For the bycatch fisheries, F's tend to be slightly higher across the model time period for B0.2016 compared with B2b (Figures F171-173).

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

Time series of recruitment estimates from the model scenarios evaluated here are illustrated in Figure F213-F216. The time series for scenarios B0.2016 and B2b are quite similar in trend and timing of fluctuations, but B2b tends to estimate somewhat higher peaks than B0.2016. B2b estimates a large spike in recruitment occurred this last year.

As with recruitment, estimates of population abundance time series from B0.2016 and B2b exhibit very similar patterns of variability, although B2b tends to be slightly higher than B0.2016 in almost all years (Figures F221-224).

As with population abundance, estimates of mature biomass time series from the B0.2016 and B2b also exhibit similar patterns of variability (Figures 217-220), being basically smoothed versions of the population abundance trajectories.

iv. Estimated fishing mortality versus estimated spawning stock biomass
See Section F (Calculation of the OFL; Figure 27).

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
Model fit to retained catch is shown in Figures F31-F32 for all scenarios. The fits are generally very good, but B2b fits the retained catch abundance almost perfectly in recent years (Figure F31), while B0.2016 overestimates retained catch in 2005/06-2009/10 and underestimates during 2013/14-2015/6.

Fits to total catch data from the directed fishery are also better in recent years for B2b compared with B0.2016, although the differences are fairly small (Figures F34-F35). Fits to total male bycatch data in the snow crab fishery is very good for both B0.2016 and B2b (Figures F36-F37). Fits to the BBRKC fishery male bycatch data are also good, although they look somewhat worse because the values are small relative to the assumed uncertainties. (Figures F40-F41).

Fits to female bycatch data in all the crab fisheries (Figures F34-F37, F40-F41) tend to be very good because the majority of the estimates are well within the confidence intervals assumed for the data, but this is because female bycatch levels in all the crab fisheries are much smaller than the assumed uncertainty level associated with the total catch data . When the fits are poor, it is because the observed female bycatch is larger than the uncertainty associated with it and its temporal pattern does not track that of male bycatch—in the model, the predicted female bycatch is constrained to follow the same temporal pattern as males.

Bycatch in the groundfish fisheries is not sex-specific. Fits to total bycatch mortality in the groundfish fisheries are very good both B2b and B0.2016 (Figures F38-39). Both models nicely capture the peak at the beginning of the time series, followed by the rapid decline and subsequent fluctuations. Since 2008/09, total bycatch has been less than 500 t and B2b has predicted it slightly better than B0.2016.

The “goodness of fit” to the fishery catch data, as it influence the likelihoods in models, is also evident of plots of z-scores for the fishery catch data (Figures F33, F46-49). Almost all the z-scores are < 1, indicating that little improvement to the current fits in terms of absolute (rather than relative) error will occur without changing the assumed uncertainty levels for the fishery data. The two z-scores that are greater than 1 in magnitude both occur in 1994/94 for females, one in the directed fishery and the other in the snow crab fishery.

ii. Graphs of model fits to survey numbers
Time series of observed biomass of mature crab in the NMFS bottom trawl surveys are compared by sex with model-predicted values in Figures F28-F29. None of the scenarios completely follow the wide swings in biomass before 1995, but that is partly because the observed survey biomass gives conflicting information in the male and female time series, particularly in 1975 and in the early 1980s. The models do a better job of capturing the swing from low to high biomass in the mid-1980s to early 1990s, but all overestimate the valley in 1986 and underestimate the peak in 1991. More recently, the fits of all scenarios are pretty good but still don’t quite capture the full extent of swings in biomass (Figure F29).

iii. Graphs of model fits to catch proportions by size class

Model fits to proportions at size for retained catch are summarized in Figures F106 and F110 as Pearson's residuals. Compared with B0.2016, B2b fits the retained catch much better than B0.2016. The pattern of over-predicting the retained catch proportions for smaller males and under-predicting proportions for larger males is much reduced in the period prior to 2011, as is the opposite pattern of over-predicting retained catch proportions for large crab during 2013/14-2015/16.

Similar improvement is not evident in the fits to proportions at size for total catch in the directed fishery (Figures F118-F126). B2b fits the proportions at length somewhat better before 1996/97 than B0.2016 does, but little change is evident in the more recent time periods when the directed fishery was prosecuted. There also appears to be little change (if any) in the fits to proportions at size for bycatch in the snow crab fishery (Figures F129 and 137). For the BBRKC fishery, B2b fits the proportions-at-size slightly worse than B0.2016 for 1992/93 and 1993/94, but otherwise the fits are almost identical (Figures 151 and 159). Finally, B2b shows an improvement in the fits to proportions-at-size for larger-sized crab bycatch in the groundfish fisheries in the 1990-2005 time period, but with a corresponding worsening of the fits for smaller-sized crab in this time period (Figures F140 and F148).

iv. Graphs of model fits to survey proportions by size class

Model fits to proportions-at-size in the NMFS trawl survey for immature male crab show little change from B0.2016 to B2b (Figures F61 and F69), although there is a small improvement fitting proportions for crab larger than 100 mm CW for 2013-2015—but with a corresponding worsening for small crab < 30 mm CW. The fits to mature male proportions-at-size (Figures F72 and F80) indicate virtually no change between the two model scenarios. Similar results hold for fits to both immature and mature female proportions-at-size (Figures F83 and F91, F94 and F102 respectively).

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

Marginal plots of the composition data from the NMFS survey indicate almost no differences between scenarios B0.2016 and B2b (Figure F52). Both scenarios exhibit a small tendency to under-predict the proportions of larger immature crab and over-predict the proportions of larger mature crab—and slightly more so for males than females.

The marginal plot of the retained catch composition data (Figure 53) indicates B2b fits the marginal retained catch composition data much better (almost exactly) than B0.2016 does, which over-predicts proportions at small crab sizes (< 140 mm CW) and under-predicts proportions of larger crab.

The marginal plots of the total catch composition data in the directed fishery (Figure F57) indicate B2b and B0.2016 fit the marginal female composition data equally well. For males, B2b provides a better fit to the peak of the distribution than B0.2016 does, but both scenarios under-predict the proportions in the 125-135 mm CW range and over-predict them for larger crab.

The marginal plots for bycatch size compositions in the snow crab fishery (Figure 56) are essentially identical for scenarios B2b and B0.2016 for both males and females, and both fit the distributions well, except at the peak of the female distribution (85 mm CW), where both under-estimate the proportions. For bycatch in the BBRKC fishery (Figure 55), B2b and B0.2016 both fit the female marginal size composition data equally well, but both similarly under-predict proportions of small males (< 125 mm CW) caught in the fishery while over-predicting proportions of medium-sized males (130-155 mm CW) and under-predicting proportions for large crabs (> 155 mm CW). For the groundfish fishery (Figure F54), both scenarios tended to slightly under-predict male proportions at small sizes (< 75 mm CW) but over predict proportions at medium sizes (75-110 mm CW). For females, the opposite was true as both under-predicted proportions for small females (< 60 mm CW) but over-predicted proportions for medium-sized females (60-80 mm CW).

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

Time series of implied effective sample sizes using the McAllister-Ianelli method are shown for retained catch (Figure F116), total catch size compositions in the directed fishery (Figure F163), bycatch size compositions in the snow crab, BBRKC and groundfish fisheries (Figures 164-166), and the NMFS EBS bottom trawl survey (Figure F104). For the most part, the implied effective sample sizes tend to be substantially larger than the input values.

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

Tables of the RMSEs for the indices were not completed for the assessment, but will be provided at the May 2018 CPT meeting.

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.

Quantile-quantile (q-q) plots and histograms of residuals were not completed for the assessment, but will be provided at the May 2018 CPT meeting.

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).

Retrospective analyses were not completed for the assessment, but will be provided at the May 2018 CPT meeting.

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

An historical analysis was not completed for the assessment due to incompatibilities between TCSAM02 and formats of previous assessment results. One will be provided at the May 2018 CPT meeting.

g. Uncertainty and sensitivity analyses

MCMC runs were completed for scenarios B0, B2b and B3 to explore model uncertainty. Each model was run for a single chain, which was set to run 10 million iterations, keeping results for every 1,000th to reduce serial autocorrelation, with a burn-in period of 2,000 iterations. After ~48 hours, the runs were stopped at about 4.5 million iterations. Mixing appeared to be sufficient, but this can be difficult to evaluate with only single chains. These runs provide empirical posterior distributions for model parameters and selected derived quantities, including OFL-related quantities.

Time constraints did not allow a full exploration of the MCMC results. Summary results for the objective function and parameters related to survey catchability and selectivity are shown in Figure 23. As noted above, based on the trace for the objective function, mixing seems to have been sufficient. The posterior distributions for the survey parameters show the impact of the bounds placed on several of the parameters and support continued investigation and further model development to improve their characteristics: their distributions are skewed, with multiple maxima and minima. However, a similar plot for OFL-related quantities (Figure 24) indicates that they are much closer to normally-distributed and do not exhibit unexpected correlation structures (e.g., F_{OFL} and F_{MSY} are expected to be highly correlated).

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 2016/17 was 25.61 thousand t while the total catch mortality was 1.14 thousand t, based on applying discard mortality rates of 1.000 for retained catch, 0.321 to bycatch in the crab fisheries, and 0.800 to bycatch in the groundfish fisheries to the reported catch by fleet for 2016/17 (Tables 1 and 4). 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 (Figure 25):

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 2017/18 require estimates of $B = MMB_{2017/18}$ (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 $F_{OFL} = F_{MSY} = F_{35\%}$. 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 (Figure 25). 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). In previous assessments, an attempt was made to account for retention of slightly (10 mm CW) smaller crab in the directed fishery in the western area. Because the preferred size is now the same in both areas, the OFL is calculated assuming both selectivity (as previously) and retention (new) curves are the same in both areas.

In previous years, a separate “projection model” has been used to determine OFL based on results from the assessment model. The estimated coefficient of variation for the estimate of final MMB was used to characterize model uncertainty and provided a calculational basis for determining an empirical probability density function (pdf) for OFL based on sampling final MMB from its assumed pdf. With the transition to TCSAM02, OFL is calculated within the assessment model based on equilibrium calculations for F_{OFL}

and projecting the state of the population at the end of the modeled time period one year forward assuming fishing mortality at F_{OFL}. Using MCMC, one can thus estimate the pdf of OFL (and related quantities of interest) incorporating full model uncertainty.

To calculate the F_{OFL}, the fishery capture rate for males in the directed fishery is adjusted until the longterm (equilibrium) MMB-at-mating is 35% of its unfished value. This calculation also depends on the assumed bycatch F's on Tanner crab in the snow crab, BBRKC and groundfish fisheries. This year, the average F over the last 5 years for each of the bycatch fisheries is used in the calculations. In previous years, a different approach was used to determine the F to use for the snow crab fishery. For that fishery, the ratio of the F_{OFL} from the snow crab assessment author's preferred model to the average F over the last 5 years was used to scale the 5-year average bycatch F on Tanner crab. For last year's assessment, the snow crab F_{OFL} was 1.24 yr^{-1} (Szuwalski, 2016) and the 5-year average F is 0.979 yr^{-1}, resulting in a scaling factor of 1.27. For this assessment, the snow crab assessment author's preferred F_{OFL} was 0.89 yr^{-1}T and the five-year average was1.05 (Cody Szuwalski, UCSB, pers. comm.), resulting in a scaling factor of 1.18. However, this scaling was not operational for TCSAM02 models at the time of this assessment, so the unscaled 5-year average bycatch F in the snow crab fishery was used instead.

Selectivity curves in the bycatch fisheries were set using the average curves over the last 5 years for each fishery, the same approach as in previous assessments (Rugolo and Turnock, 2012b; Stockhausen 2015).

Results from OFL calculations from the converged model run for each scenario (i.e., based on the MLE solution, not MCMC) are compared for illustrative purposes in Table 39. Scenario B1c stands out particularly from the others because estimated average recruitment and F_{OFL} are quite a bit larger than for the other scenarios. The other scenarios appear to fall into two general groupings: 1) B0.2016, B0, B0a, B1, B1a, and B1b and 2) B2, B2a, B2b, and B3. The former group exhibits somewhat lower estimated average recruitments and higher F_{MSY}'s than the latter. Primarily because estimated average recruitments are higher, the second group yields higher B0's, B_{MSY}'s, MSY's, and OFLs.

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 213.95 million. The estimates of average recruitment are reasonably similar between the 2016 assessment model and the author's preferred model (Table 37). The value of $B_{MSY}=B_{35\%}$ for $\bar{R}$ is 25.42 thousand t, which is almost identical to that from the 2016 assessment (25.65 thousand t).

Once F_{OFL} is determined using the control rule (Figure 25), 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, 2016 as estimated by the assessment model.

Assessment model uncertainty was included in the calculation of OFL using MCMC. Conceptually, a random draw from the assessment model's joint posterior distribution for the estimated parameters was taken, and the B_0, F_{MSY}, B_{MSY}, F_{OFL}, OFL, and "current" MMB for 2017/18 were calculated based on resulting model parameter values. This would be repeated a large number of times to approximate the distribution of OFL given the full model uncertainty. In practice, a single (due to time constraints) chain of over 4 million MCMC steps was generated, with the OFL and associated quantities calculated at each step. The chain was initialized from the converged model state using a "burn in" of 2,000 steps and subsequently thinned by a factor of 1,000 to reduce serial autocorrelation in the MCMC sampling. This resulted in about 4,500 MCMC samples with which to characterize the distribution of the OFL. **The median value of this distribution was taken as the OFL for 2017/18. Thus, the OFL for 2017/18 from the author's preferred model (Model B2b) is 25.42 thousand t** (Figure 26)**.** This value for the OFL is identical (to two decimal places) to the value calculated using the converged model parameters (i.e., the "MLE" estimate of OFL).

The B_{MSY} proxy, $B_{35\%}$, from the author's preferred model is 29.17 thousand t, so MSST = 0.5 B_{MSY} = 14.58 thousand t. Because current B = 43.31 thousand t > MSST, **the stock is not overfished**. The population state (directed F vs. MMB) is plotted for each year from 1965/66-2016/17 in Figure 27 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%. In 2014, 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.

For the author's preferred model, Model C, the P* ABC (ABC_{max}) is 25.37 thousand t while the 20% Buffer ABC is 20.33 thousand t. The author remains concerned that the OFL calculation, 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 the P* ABC level 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 previously adopted by the SSC for this stock to calculate ABC. Consequently, the author's recommended ABC is 20.33 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

Information on growth-per-molt has been collected in the EBS on Tanner crab and incorporated into the assessment. More data regarding temperature-dependent effects on molting frequency would be helpful to assess potential impacts of the EBS cold pool on the stock. Information on temperature-dependent changes in crab movement and survey catchability would also be of value. In addition, it would be extremely worthwhile to develop a "better" index of reproductive potential than MMB that can be calculated in the assessment model 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 166ºW and West 166ºW directed fisheries should be explicitly represented in the assessment model should be addressed. In addition, the question of whether or not bycatch in the groundfish fisheries should be split into pot- and trawl-related components should be resolved.

With the implementation of TCSAM02, several research avenues can be explored much more efficiently: 1) time-varying growth; 2) incorporating chela height data for male maturity classification, 3) decomposing the currently "lumped" directed fishery into its eastern and western components, and 4) incorporating the BSFRF surveys into the assessment. Development of a fully-Gmacs version of the Tanner crab model will also begin.

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	unlikely to have substantial effects at the stock level	minimal to none

	it is pulled, although halibut can be		
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 1. Retained catch (males) in directed Tanner crab fisheries.

Eastern Bering Sea	*Chionoecetes bairdi*	Retained Catch (1,000's t)		
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
2015/16	8.91			8.91
2016/17	0.00			0.00

Table 2. 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 ADFG year (in parentheses, if different from the "Fishery Year") indicates the year ADFG assigned to the fishery season in compiled reports.

year (ADFG 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----------				
1986/87 (1987)	----------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
2015/16	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----------				
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----------				
2011/12	----------closed----------				
2012/13	----------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
2015/16	10,856,418	19,642,462	19.668	112	10/15-03/31
2016/17	----------closed----------				

Table 3. Total bycatch (discards, 1000's t) of Tanner crab in various fisheries.

	Discards (1,000's t) of Tanner Crab by Fishery							Total Discards
	Tanner Crab		Snow Crab		Red King Crab		Groundfish	
Year	Male	Female	Male	Female	Male	Female	All	(1,000's t)
1973/74							17.735	17.735
1974/75							24.449	24.449
1975/76							9.408	9.408
1976/77							4.699	4.699
1977/78							2.776	2.776
1978/79							1.869	1.869
1979/80							3.397	3.397
1980/81							2.114	2.114
1981/82							1.474	1.474
1982/83							0.449	0.449
1983/84							0.671	0.671
1984/85							0.644	0.644
1985/86							0.399	0.399
1986/87							0.649	0.649
1987/88							0.640	0.640
1988/89							0.463	0.463
1989/90							0.671	0.671
1990/91							0.943	0.943
1991/92							2.545	2.545
1992/93	6.175	1.005	25.759	1.787	1.188	0.029	2.865	38.808
1993/94	3.870	1.028	14.530	1.814	2.967	0.198	1.511	25.917
1994/95	3.130	1.270	7.124	1.271	0.000	0.000	2.096	14.892
1995/96	2.762	1.760	4.797	1.759	0.000	0.000	1.678	12.756
1996/97	0.116	0.045	0.833	0.229	0.027	0.004	1.638	2.892
1997/98	0.000	0.000	1.750	0.226	0.165	0.003	1.531	3.675
1998/99	0.000	0.000	1.989	0.175	0.119	0.003	1.321	3.607
1999/00	0.000	0.000	0.695	0.145	0.076	0.004	0.744	1.665
2000/01	0.000	0.000	0.146	0.022	0.067	0.002	0.801	1.037
2001/02	0.000	0.000	0.323	0.011	0.043	0.002	1.070	1.449
2002/03	0.000	0.000	0.557	0.037	0.062	0.003	0.584	1.242
2003/04	0.000	0.000	0.193	0.026	0.056	0.003	0.488	0.767
2004/05	0.000	0.000	0.078	0.014	0.048	0.003	0.795	0.937
2005/06	0.462	0.044	0.968	0.043	0.042	0.002	0.603	2.164
2006/07	1.370	0.355	1.462	0.169	0.026	0.003	0.623	4.008
2007/08	2.041	0.097	1.872	0.102	0.056	0.009	0.895	5.073
2008/09	0.431	0.014	1.119	0.050	0.269	0.004	0.612	2.498
2009/10	0.071	0.002	1.324	0.014	0.150	0.001	0.377	1.940
2010/11	0.000	0.000	1.344	0.016	0.033	0.001	0.231	1.625
2011/12	0.000	0.000	2.119	0.014	0.017	0.000	0.248	2.398
2012/13	0.000	0.000	1.187	0.009	0.042	0.001	0.256	1.495
2013/14	0.387	0.023	1.832	0.015	0.113	0.001	0.447	2.818
2014/15	2.515	0.039	5.383	0.050	0.296	0.001	0.455	8.738
2015/16	3.045	0.059	3.919	0.017	0.205	0.006	0.326	7.576
2016/17	0.000	0.000	2.576	0.017	0.176	0.004	0.318	3.091

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

Discard Mortality (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							14.188	14.188
1974/75							19.559	19.559
1975/76							7.526	7.526
1976/77							3.759	3.759
1977/78							2.221	2.221
1978/79							1.495	1.495
1979/80							2.718	2.718
1980/81							1.691	1.691
1981/82							1.179	1.179
1982/83							0.359	0.359
1983/84							0.537	0.537
1984/85							0.515	0.515
1985/86							0.319	0.319
1986/87							0.519	0.519
1987/88							0.512	0.512
1988/89							0.370	0.370
1989/90							0.537	0.537
1990/91							0.755	0.755
1991/92							2.036	2.036
1992/93	1.982	0.322	8.269	0.574	0.381	0.009	2.292	13.830
1993/94	1.242	0.330	4.664	0.582	0.952	0.063	1.209	9.043
1994/95	1.005	0.408	2.287	0.408	0.000	0.000	1.677	5.784
1995/96	0.887	0.565	1.540	0.565	0.000	0.000	1.342	4.898
1996/97	0.037	0.014	0.267	0.074	0.009	0.001	1.310	1.713
1997/98	0.000	0.000	0.562	0.073	0.053	0.001	1.225	1.913
1998/99	0.000	0.000	0.638	0.056	0.038	0.001	1.057	1.791
1999/00	0.000	0.000	0.223	0.047	0.025	0.001	0.595	0.891
2000/01	0.000	0.000	0.047	0.007	0.021	0.001	0.641	0.717
2001/02	0.000	0.000	0.104	0.004	0.014	0.001	0.856	0.977
2002/03	0.000	0.000	0.179	0.012	0.020	0.001	0.467	0.678
2003/04	0.000	0.000	0.062	0.008	0.018	0.001	0.391	0.480
2004/05	0.000	0.000	0.025	0.004	0.015	0.001	0.636	0.682
2005/06	0.148	0.014	0.311	0.014	0.014	0.001	0.483	0.983
2006/07	0.440	0.114	0.469	0.054	0.008	0.001	0.498	1.585
2007/08	0.655	0.031	0.601	0.033	0.018	0.003	0.716	2.057
2008/09	0.138	0.004	0.359	0.016	0.086	0.001	0.489	1.095
2009/10	0.023	0.001	0.425	0.005	0.048	0.000	0.301	0.803
2010/11	0.000	0.000	0.431	0.005	0.011	0.000	0.185	0.632
2011/12	0.000	0.000	0.680	0.004	0.006	0.000	0.199	0.889
2012/13	0.000	0.000	0.381	0.003	0.013	0.000	0.205	0.603
2013/14	0.124	0.007	0.588	0.005	0.036	0.000	0.357	1.119
2014/15	0.807	0.012	1.728	0.016	0.095	0.000	0.364	3.023
2015/16	0.977	0.019	1.258	0.005	0.066	0.002	0.261	2.588
2016/17	0.000	0.000	0.827	0.005	0.056	0.001	0.255	1.144

Table 5. Sample sizes for retained catch-at-size in the directed fishery. N = number of individuals. N` = scaled sample size used in assessment. The directed fishery was closed in 2016/17.

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
2015/16	24,420	200.0
2016/17	--	–

Table 6. Sample sizes 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
2015/16	119,846	1,622	200.0	11.9
2016/17	--	–	–	--

Table 7. Sample sizes 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	46.4	6.3
1993/94	6,969	1,542	51.5	11.4
1994/95	2,982	1,523	22.0	11.2
1995/96	1,898	428	14.0	3.2
1996/97	3,265	662	24.1	4.9
1997/98	3,970	657	29.3	4.9
1998/99	1,911	324	14.1	2.4
1999/00	976	82	7.2	0.6
2000/01	1,237	74	9.1	0.5
2001/02	3,113	160	23.0	1.2
2002/03	982	118	7.2	0.9
2003/04	688	152	5.1	1.1
2004/05	848	707	6.3	5.2
2005/06	9,792	368	72.3	2.7
2006/07	10,391	1,256	76.7	9.3
2007/08	13,797	728	101.9	5.4
2008/09	8,455	722	62.4	5.3
2009/10	11,057	474	81.6	3.5
2010/11	12,073	250	89.1	1.8
2011/12	9,453	189	69.8	1.4
2012/13	7,336	190	54.2	1.4
2013/14	12,932	356	95.5	2.6
2014/15	24,877	804	183.7	5.9
2015/16	19,838	230	146.5	1.7
2016/17	19,346	804	142.8	1.7

Table 8. Sample sizes 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	7.3	0.5
2006/07	798	76	5.9	0.6
2007/08	1,399	91	10.3	0.7
2008/09	3,797	121	28.0	0.9
2009/10	3,395	72	25.1	0.5
2010/11	595	30	4.4	0.2
2011/12	344	4	2.5	0.0
2012/13	618	48	4.6	0.4
2013/14	2,110	60	15.6	0.4
2014/15	3,110	32	23.0	0.2
2015/16	2,176	182	16.1	1.3
2016/17	3,048	245	22.5	1.8

Table 9. Sample sizes 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	23.3	16.8
1974/75	2,492	1,600	18.4	11.8
1975/76	1,251	839	9.2	6.2
1976/77	6,950	6,683	51.3	49.3
1977/78	10,685	8,386	78.9	61.9
1978/79	18,596	13,665	137.3	100.9
1979/80	19,060	11,349	140.7	83.8
1980/81	12,806	5,917	94.5	43.7
1981/82	6,098	4,065	45.0	30.0
1982/83	13,439	8,006	99.2	59.1
1983/84	18,363	8,305	135.6	61.3
1984/85	27,403	13,771	200.0	101.7
1985/86	23,128	12,728	170.7	94.0
1986/87	14,860	7,626	109.7	56.3
1987/88	23,508	15,857	173.6	117.1
1988/89	10,586	7,126	78.2	52.6
1989/90	59,943	41,234	200.0	200.0
1990/91	23,545	11,212	173.8	82.8
1991/92	6,806	3,477	50.2	25.7
1992/93	3,027	1,109	22.3	8.2
1993/94	1,217	358	9.0	2.6
1994/95	3,628	1,820	26.8	13.4
1995/96	3,896	2,666	28.8	19.7
1996/97	8,264	3,375	61.0	24.9
1997/98	9,835	3,859	72.6	28.5
1998/99	11,937	4,310	88.1	31.8
1999/00	10,687	4,411	78.9	32.6
2000/01	12,746	2,988	94.1	22.1
2001/02	15,478	2,859	114.3	21.1
2002/03	15,208	3,099	112.3	22.9
2003/04	9,441	2,664	69.7	19.7
2004/05	13,805	4,441	101.9	32.8
2005/06	17,682	3,654	130.5	27.0
2006/07	15,855	3,016	117.1	22.3
2007/08	16,066	3,786	118.6	28.0
2008/09	26,095	4,185	192.7	30.9
2009/10	19,036	2,694	140.5	19.9
2010/11	15,122	2,260	111.6	16.7
2011/12	16,115	4,237	119.0	31.3
2012/13	12,983	3,080	95.9	22.7
2013/14	28,781	6,064	200.0	44.8
2014/15	39,119	4,212	200.0	31.1
2015/16	27,427	5,734	200.0	42.3
2016/17	17,768	4,193	131.2	31.0

Table 10. Trends in mature and total Tanner crab biomass (1000's t) in the NMFS summer bottom trawl survey.

Observed Survey Mature Male and Female Biomass and Legal Male Abundance				
	Mature Biomass (1000 t)			Legal males
Year	Male	Female	Total	(10^6 crab)
1974	–	–	–	–
1975	246.00	31.42	277.42	233.52
1976	126.25	31.16	157.40	117.83
1977	111.27	38.57	149.84	97.63
1978	77.91	25.75	103.66	66.95
1979	32.62	19.32	51.94	25.10
1980	86.81	63.78	150.59	54.20
1981	50.25	42.58	92.83	28.81
1982	51.66	64.14	115.81	26.14
1983	29.90	20.43	50.33	17.71
1984	25.80	14.91	40.72	14.18
1985	11.86	5.55	17.42	7.86
1986	13.31	3.37	16.67	4.81
1987	24.55	5.14	29.69	15.92
1988	61.01	25.37	86.38	35.53
1989	93.28	19.40	112.68	71.81
1990	97.84	37.69	135.54	79.15
1991	112.61	44.76	157.37	86.11
1992	105.50	26.23	131.72	92.78
1993	62.05	11.64	73.69	52.30
1994	43.82	9.85	53.67	36.49
1995	32.70	12.40	45.09	26.50
1996	27.53	9.58	37.11	22.77
1997	11.26	3.40	14.66	6.95
1998	10.86	2.28	13.14	6.09
1999	13.00	3.83	16.83	5.17
2000	16.88	4.13	21.01	10.46
2001	18.68	4.56	23.24	12.18
2002	18.95	4.47	23.42	10.88
2003	24.59	8.40	32.99	12.69
2004	27.04	4.73	31.77	11.48
2005	45.16	11.58	56.74	28.41
2006	67.87	14.94	82.81	36.86
2007	69.50	13.44	82.93	34.40
2008	65.13	11.66	76.79	40.43
2009	38.15	8.48	46.63	24.71
2010	39.10	5.47	44.57	28.18
2011	43.27	5.41	48.68	28.84
2012	42.20	12.36	54.56	18.54
2013	67.01	17.85	84.86	30.33
2014	82.42	14.86	97.29	46.64
2015	62.95	11.21	74.16	43.76
2016	61.62	7.63	69.25	38.55
2017	50.17	7.11	57.28	32.71

Table 11. Sample sizes for NMFS survey size composition data. 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	91	1,861	39	706	127	2,895	127	3,993	80	399
1976	214	87	1,095	91	1,304	39	311	130	2,023	130	2,469	47	242
1977	155	66	765	76	1,183	60	738	114	1,778	114	1,971	79	485
1978	230	87	1,932	82	638	65	1,307	147	2,957	147	1,570	104	700
1979	307	71	725	62	735	42	341	138	1,805	138	808	68	306
1980	320	101	1,476	95	1,471	49	570	164	4,602	164	2,359	71	569
1981	305	71	579	79	1,319	94	1,206	158	3,809	158	2,293	116	886
1982	342	85	814	72	457	103	2,384	181	1,751	181	1,371	147	2,082
1983	353	102	2,108	56	201	102	2,154	166	2,484	166	983	132	1,181
1984	355	135	1,867	53	284	94	1,531	171	1,965	171	490	126	1,399
1985	353	140	846	52	228	65	601	179	1,060	179	381	86	459
1986	353	162	1,581	64	191	68	331	213	2,141	213	528	115	468
1987	355	189	4,230	105	445	73	392	226	4,659	226	1,306	103	498
1988	370	206	3,733	149	1,753	100	530	252	5,627	252	2,210	101	475
1989	373	204	3,264	144	1,241	108	882	237	4,977	237	3,201	135	1,067
1990	370	197	3,105	155	1,502	126	1,511	247	5,107	247	3,149	151	1,342
1991	371	159	2,227	138	1,283	141	2,568	227	4,361	227	2,692	181	2,893
1992	355	107	1,494	119	820	123	2,205	215	2,958	215	2,047	177	1,924
1993	374	99	865	96	545	122	1,337	207	2,051	207	1,677	180	1,865
1994	374	97	909	52	148	104	1,293	175	1,281	175	724	174	1,827
1995	375	113	830	35	140	107	1,057	153	958	153	220	137	1,611
1996	374	114	869	57	109	98	963	148	1,069	148	222	134	1,414
1997	375	116	1,325	62	168	83	504	161	1,336	161	289	125	582
1998	374	146	1,704	53	160	73	344	176	2,032	176	396	128	624
1999	372	137	2,608	52	255	85	510	170	2,816	170	550	124	567
2000	371	142	2,249	61	242	55	345	188	2,836	188	628	133	653
2001	374	164	3,675	83	364	72	644	211	4,036	211	629	145	817
2002	374	154	3,583	81	350	70	500	186	3,912	186	458	154	1,089
2003	375	153	2,830	111	923	83	752	203	4,754	203	900	153	1,349
2004	374	173	3,563	90	427	80	656	236	4,568	236	1,027	179	1,873
2005	372	201	3,349	103	634	74	928	254	4,496	254	1,280	185	1,753
2006	375	210	4,355	143	1,332	125	1,327	254	6,224	254	1,757	211	4,054
2007	375	185	2,420	138	1,311	136	1,396	261	4,697	261	1,982	201	2,907
2008	374	153	1,747	104	580	120	1,783	240	3,127	240	2,116	196	2,146
2009	375	171	2,408	75	363	115	1,317	216	2,879	216	1,144	187	1,954
2010	375	186	3,171	67	245	104	941	223	3,654	223	1,268	166	1,702
2011	375	193	5,044	90	471	102	705	210	6,095	210	1,115	167	1,941
2012	375	195	3,577	100	942	97	720	215	5,526	215	1,564	139	1,296
2013	375	163	2,900	116	1,417	101	1,002	207	5,592	207	2,675	137	1,344
2014	375	165	2,207	98	482	121	1,584	222	4,746	222	3,286	167	2,829
2015	375	118	1,455	60	445	94	1,363	225	2,737	225	1,859	200	2,817
2016	375	110	1,372	56	370	82	1,248	222	2,235	222	1,170	218	3,668
2017	375	129	2,027	50	213	99	1,125	185	2,233	185	423	204	3,529

Table 12. Effort data (1000's potlifts) in the snow crab and BBRKC fisheries.

	Effort (1000's Potlifts)			Effort (1000's Potlifts)	
Year	BBRKC Fishery	Snow Crab Fishery	Year	BBRKC Fishery	Snow Crab Fishery
1951/52			1986/87	175.753	616.113
1952/53			1987/88	220.971	747.395
1953/54	30.083	–	1988/89	146.179	665.242
1954/55	17.122	–	1989/90	205.528	912.718
1955/56	28.045	–	1990/91	262.761	1382.908
1956/57	41.629	–	1991/92	227.555	1278.502
1957/58	23.659	–	1992/93	206.815	969.209
1958/59	27.932	–	1993/94	254.389	716.524
1959/60	22.187	–	1994/95	0.697	507.603
1960/61	26.347	–	1995/96	0.547	520.685
1961/62	72.646	–	1996/97	77.081	754.14
1962/63	123.643	–	1997/98	91.085	930.794
1963/64	181.799	–	1998/99	145.689	945.533
1964/65	180.809	–	1999/00	151.212	182.634
1965/66	127.973	–	2000/01	104.056	191.2
1966/67	129.306	–	2001/02	66.947	326.977
1967/68	135.283	–	2002/03	72.514	153.862
1968/69	184.666	–	2003/04	134.515	123.709
1969/70	175.374	–	2004/05	97.621	75.095
1970/71	168.059	–	2005/06	116.32	117.375
1971/72	126.305	–	2006/07	72.404	86.288
1972/73	208.469	–	2007/08	113.948	140.857
1973/74	194.095	–	2008/09	139.937	163.537
1974/75	212.915	–	2009/10	118.521	136.477
1975/76	205.096	–	2010/11	131.627	147.244
1976/77	321.01	–	2011/12	45.166	270.602
1977/78	451.273	–	2012/13	38.159	225.489
1978/79	406.165	190.746	2013/14	45.927	225.245
1979/80	315.226	255.102	2014/15	57.725	279.183
1980/81	567.292	435.742	2015/16	48.665	199.133
1981/82	536.646	469.091	2016/17	33.165	118.548

Table 13.Non-selectivity parameters estimated within 1% of bounds.

category	name	case	test	bound	description
fisheries	pLgtRet[1]	B2a	at upper bound	15	TCF: logit-scale max retention (pre-1997)
		B2b	at upper bound	15	
		B3	at upper bound	15	
population processes	pGrA[1]	B1	at lower bound	0.3	a coefficient, males
	pGrA[2]	B0	at upper bound	0.7	a coefficient, females
		B0.2016	at upper bound	0.7	
		B1	at upper bound	0.7	
	pGrBeta[1]	B1c	at lower bound	0.5	growth scale parameter
		B3	at lower bound	0.5	
	pLgtPrM2M[1]	B0	at upper bound	15	pr(terminal molt, males)
		B0.2016	at upper bound	15	
		B0a	at upper bound	15	
		B1	at upper bound	15	
		B1a	at upper bound	15	
		B1b	at upper bound	15	
		B1c	at upper bound	15	
		B2	at upper bound	15	
		B2a	at upper bound	15	
		B2b	at upper bound	15	
		B3	at upper bound	15	
	pLgtPrM2M[2]	B0	at lower bound	-15	pr(terminal molt, females)
		B0.2016	at lower bound	-15	
		B0a	at lower bound	-15	
		B1	at lower bound	-15	
		B1a	at lower bound	-15	
		B1b	at lower bound	-15	
		B1c	at lower bound	-15	
		B2	at lower bound	-15	
		B2a	at lower bound	-15	
		B2b	at lower bound	-15	
		B3	at lower bound	-15	
surveys	pLnQ[1]	B0	at lower bound	-0.693	NMFS survey Q: males, pre-1982
		B0.2016	at lower bound	-0.693	
		B0a	at lower bound	-0.693	
		B1	at lower bound	-0.693	
		B1a	at lower bound	-0.693	
		B1b	at lower bound	-0.693	
		B1c	at lower bound	-0.693	
		B2	at lower bound	-0.693	
		B2a	at lower bound	-0.693	
		B2b	at lower bound	-0.693	
		B3	at lower bound	-0.693	
	pLnQ[3]	B0	at lower bound	-0.693	NMFS survey Q: females, pre-1982
		B0.2016	at lower bound	-0.693	
		B0a	at lower bound	-0.693	
		B1	at lower bound	-0.693	
		B1a	at lower bound	-0.693	
		B1b	at lower bound	-0.693	
		B1c	at lower bound	-0.693	
		B2	at lower bound	-0.693	
		B2a	at lower bound	-0.693	
		B2b	at lower bound	-0.693	
		B3	at lower bound	-0.693	

Table 14.Selectivity-related parameters estimated within 1% of bounds.

name	case	test	bound	label
pS1[1]	B1c	at upper bound	90	z50 for NMFS survey selectivity (males, pre-1982)
pS1[19]	B0a	at lower bound	40	z50 for GTF.AllGear selectivity (males, pre-1987)
pS1[20]	B0	at lower bound	40	z50 for GTF.AllGear selectivity (males, 1987-1996)
	B0.2016	at lower bound	40	
	B0a	at lower bound	40	
	B1	at lower bound	40	
	B1a	at lower bound	40	
	B1b	at lower bound	40	
	B1c	at lower bound	40	
	B2	at lower bound	40	
	B2a	at lower bound	40	
	B2b	at lower bound	40	
pS1[22]	B3	at upper bound	180	z95 for RKF selectivity (males, 1997-2004)
pS1[23]	B0	at upper bound	150	z50 for RKF selectivity (males, 1997-2004)
	B0.2016	at upper bound	150	
	B0a	at upper bound	150	
	B1	at upper bound	150	
	B1a	at upper bound	150	
	B1b	at upper bound	180	z95 for RKF selectivity (males, 1997-2004)
	B1c	at upper bound	180	
	B2	at upper bound	180	
	B2a	at upper bound	180	
	B2b	at upper bound	180	
	B3	at upper bound	180	z95 for RKF selectivity (males, 2005+)
pS1[24]	B0	at upper bound	150	z50 for RKF selectivity (males, 2005+)
	B0.2016	at upper bound	150	
	B0a	at upper bound	150	
	B1	at upper bound	150	
	B1a	at upper bound	150	
	B1b	at upper bound	180	
	B1c	at upper bound	180	
	B2	at upper bound	180	
	B2a	at upper bound	180	
	B2b	at upper bound	180	
pS1[25]	B0a	at upper bound	150	z50 for RKF selectivity (females, pre-1997)
pS1[26]	B3	at upper bound	140	z95 for RKF selectivity (females, 2005+)
pS1[27]	B0	at upper bound	170	z50 for RKF selectivity (females, 2005+)
	B1	at upper bound	170	
	B1a	at upper bound	170	
	B1b	at upper bound	140	
	B1c	at upper bound	140	
	B2	at upper bound	140	
	B2a	at upper bound	140	
	B2b	at upper bound	140	
pS1[29]	B3	at lower bound	40	z50 for GTF.AllGear selectivity (females, pre-1987)
pS1[30]	B3	at lower bound	40	z50 for GTF.AllGear selectivity (females, 1987-1990)
pS1[33]	B3	at upper bound	120	z50 for GTF.FixedGear selectivity (females, 1991-1996)
pS1[4]	B3	at lower bound	-50	z50 for NMFS survey selectivity (females, 1982+)
pS2[1]	B3	at upper bound	100	z95-z50 for NMFS survey selectivity (males, pre-1982)
pS2[2]	B1c	at upper bound	100	z95-z50 for NMFS survey selectivity (males, 1982+)
pS2[4]	B0	at upper bound	100	z95-z50 for NMFS survey selectivity (females, 1982+)
	B0.2016	at upper bound	100	
	B1	at upper bound	100	
	B1a	at upper bound	100	
	B1b	at upper bound	100	
	B1c	at upper bound	100	
	B2	at upper bound	100	
	B2a	at upper bound	100	
	B2b	at upper bound	100	
	B3	at upper bound	100	
pS3[4]	B3	at upper bound	4.5	ln(dz50-az50) for GTF.FixedGear selectivity (males, 1991-1996)
pS4[1]	B0	at upper bound	0.5	descending slope for SCF selectivity (males, pre-1997)
	B0.2016	at upper bound	0.5	
	B0a	at upper bound	0.5	
	B1	at upper bound	0.5	
	B1a	at upper bound	0.5	
	B1b	at upper bound	0.5	
	B1c	at upper bound	0.5	
	B2b	at upper bound	0.5	
	B3	at upper bound	0.5	
pS4[4]	B3	at upper bound	0.5	descending slope for GTF.FixedGear selectivity (males, 1991-1996)
pS4[5]	B3	at lower bound	0.1	descending slope for GTF.FixedGear selectivity (males, 1997+)

Table 15. Comparison of estimated growth and natural mortality parameters for all model scenarios.

			case: Values																					
			B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
process	name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
growth	pGrA[1]	a coefficient, males	0.413	0.022	0.413	0.022	34.913	0.456	0.300	0.000														
		lower mean size, males									33.191	0.360	33.182	0.360	32.129	0.085	33.409	0.372	33.222	0.365	33.135	0.360	32.455	0.264
	pGrA[2]	a coefficient, females	0.700	0.000	0.700	0.000	36.629	0.508	0.700	0.000														
		lower mean size, females									34.474	0.435	34.469	0.435	33.503	0.091	34.532	0.444	34.457	0.437	34.421	0.436	33.950	0.309
	pGrB[1]	b coefficient, males	0.977	0.005	0.976	0.005	170.116	1.248	0.997	0.001														
		upper mean size, males									166.886	1.062	166.875	1.064	158.500	0.331	166.856	1.086	166.537	1.126	166.784	1.123	162.965	1.159
	pGrB[2]	b coefficient, females	0.885	0.001	0.885	0.001	114.775	0.999	0.880	0.001														
		upper mean size, females									115.239	0.852	115.241	0.852	114.113	0.234	115.177	0.865	115.157	0.855	115.144	0.853	113.882	0.737
	pGrBeta[1]	growth scale parameter	0.750	0.000	0.750	0.000	0.750	0.000	0.830	0.108	0.830	0.129	0.828	0.129	0.500	0.000	0.890	0.140	0.831	0.132	0.819	0.129	0.500	0.000
natural mortality	pDM1[1]	multiplier for immature crab	1.014	0.050	1.015	0.050	1.017	0.045	0.995	0.051	0.994	0.051	0.995	0.051	0.977	0.051	1.005	0.051	0.999	0.051	1.000	0.051	1.000	0.044
	pDM1[2]	multiplier for mature males	1.125	0.039	1.141	0.039	1.138	0.039	1.113	0.040	1.118	0.040	1.120	0.040	1.121	0.042	1.125	0.040	1.137	0.040	1.150	0.040	1.186	0.044
	pDM1[3]	multiplier for mature females	1.434	0.035	1.441	0.035	1.438	0.034	1.378	0.035	1.375	0.035	1.375	0.035	1.278	0.034	1.374	0.035	1.374	0.036	1.374	0.036	1.311	0.035
	pDM2[1]	1980-1984 multiplier for mature males	2.749	0.244	2.748	0.245	2.820	0.238	2.745	0.255	2.763	0.256	2.761	0.256	3.313	0.314	2.771	0.252	2.658	0.248	2.602	0.243	2.732	0.295
	pDM2[2]	1980-1984 multiplier for mature females	1.412	0.099	1.396	0.099	1.428	0.095	1.371	0.102	1.373	0.102	1.372	0.102	1.500	0.112	1.388	0.102	1.340	0.101	1.323	0.101	0.979	0.108

Table 16. Comparison of recruitment parameter estimates from all model scenarios.

			case	Values																						
			B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
name	label	index	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pDevsLnR[1]	rec devs, pre-1975	1	-1.555	1.626	-1.546	1.627	-1.551	1.631	-1.586	1.599	-1.585	1.600	-1.584	1.600	-1.618	1.549	-1.621	1.603	-1.559	1.603	-1.541	1.605	-1.563	1.589
		2	-1.552	1.483	-1.544	1.484	-1.548	1.488	-1.582	1.455	-1.581	1.456	-1.581	1.456	-1.613	1.401	-1.618	1.459	-1.556	1.459	-1.538	1.461	-1.559	1.443
		3	-1.545	1.346	-1.537	1.347	-1.542	1.352	-1.574	1.317	-1.573	1.318	-1.573	1.318	-1.602	1.261	-1.610	1.322	-1.548	1.321	-1.530	1.323	-1.551	1.304
		4	-1.532	1.217	-1.525	1.218	-1.530	1.222	-1.559	1.188	-1.559	1.189	-1.558	1.189	-1.582	1.131	-1.595	1.192	-1.534	1.191	-1.516	1.193	-1.536	1.173
		5	-1.513	1.098	-1.505	1.098	-1.511	1.103	-1.536	1.069	-1.535	1.070	-1.535	1.070	-1.551	1.013	-1.573	1.073	-1.511	1.072	-1.494	1.073	-1.512	1.053
		6	-1.483	0.991	-1.476	0.991	-1.482	0.995	-1.500	0.964	-1.500	0.964	-1.500	0.964	-1.503	0.910	-1.538	0.967	-1.477	0.966	-1.460	0.967	-1.475	0.945
		7	-1.439	0.899	-1.432	0.899	-1.440	0.903	-1.448	0.874	-1.448	0.875	-1.448	0.875	-1.431	0.824	-1.487	0.877	-1.425	0.876	-1.409	0.876	-1.419	0.855
		8	-1.375	0.825	-1.369	0.824	-1.378	0.828	-1.371	0.803	-1.372	0.803	-1.372	0.803	-1.326	0.757	-1.412	0.805	-1.351	0.803	-1.335	0.804	-1.337	0.783
		9	-1.281	0.770	-1.275	0.769	-1.287	0.772	-1.260	0.750	-1.261	0.750	-1.261	0.750	-1.171	0.708	-1.303	0.752	-1.241	0.750	-1.226	0.750	-1.214	0.730
		10	-1.144	0.733	-1.139	0.731	-1.154	0.735	-1.096	0.715	-1.097	0.715	-1.097	0.715	-0.935	0.678	-1.142	0.716	-1.078	0.715	-1.065	0.715	-1.027	0.697
		11	-0.939	0.711	-0.933	0.710	-0.955	0.714	-0.847	0.696	-0.849	0.696	-0.848	0.696	-0.566	0.667	-0.898	0.697	-0.831	0.696	-0.818	0.696	-0.735	0.681
		12	-0.621	0.704	-0.612	0.703	-0.645	0.706	-0.454	0.692	-0.456	0.693	-0.455	0.693	0.008	0.669	-0.512	0.693	-0.440	0.693	-0.428	0.694	-0.264	0.683
		13	-0.099	0.709	-0.085	0.709	-0.136	0.712	0.167	0.697	0.163	0.698	0.165	0.698	0.779	0.665	0.101	0.698	0.178	0.700	0.188	0.700	0.438	0.687
		14	0.682	0.708	0.699	0.708	0.634	0.712	0.990	0.690	0.985	0.691	0.987	0.691	1.480	0.646	0.932	0.691	0.995	0.693	1.001	0.695	1.234	0.675
		15	1.500	0.690	1.508	0.689	1.466	0.693	1.668	0.667	1.665	0.667	1.666	0.667	1.748	0.626	1.647	0.666	1.666	0.670	1.668	0.672	1.725	0.652
		16	1.870	0.661	1.863	0.661	1.865	0.665	1.845	0.644	1.845	0.644	1.846	0.644	1.632	0.627	1.858	0.641	1.841	0.648	1.841	0.650	1.765	0.645
		17	1.797	0.656	1.781	0.657	1.813	0.659	1.668	0.649	1.669	0.649	1.670	0.649	1.421	0.633	1.694	0.646	1.664	0.652	1.664	0.654	1.591	0.656
		18	1.542	0.667	1.526	0.668	1.567	0.670	1.426	0.656	1.428	0.657	1.430	0.657	1.287	0.623	1.456	0.656	1.422	0.659	1.420	0.660	1.430	0.658
		19	1.332	0.670	1.321	0.670	1.358	0.673	1.288	0.650	1.292	0.650	1.293	0.650	1.263	0.604	1.327	0.651	1.278	0.652	1.271	0.652	1.361	0.640
		20	1.269	0.657	1.265	0.656	1.293	0.660	1.304	0.631	1.311	0.631	1.311	0.631	1.249	0.601	1.362	0.632	1.281	0.634	1.265	0.635	1.335	0.624
		21	1.374	0.635	1.376	0.634	1.393	0.638	1.416	0.614	1.421	0.614	1.419	0.614	1.054	0.585	1.499	0.613	1.373	0.618	1.345	0.620	1.190	0.637
		22	1.527	0.608	1.521	0.607	1.534	0.612	1.402	0.588	1.400	0.589	1.396	0.589	0.870	0.536	1.499	0.590	1.344	0.592	1.315	0.593	0.916	0.599
		23	1.389	0.565	1.368	0.564	1.385	0.571	1.216	0.540	1.218	0.540	1.216	0.540	0.859	0.493	1.292	0.544	1.174	0.542	1.151	0.542	0.871	0.537
		24	1.055	0.541	1.039	0.541	1.089	0.543	0.809	0.532	0.806	0.534	0.804	0.535	0.434	0.503	0.883	0.536	0.765	0.536	0.738	0.537	0.715	0.522
		25	0.543	0.547	0.526	0.547	0.579	0.547	0.369	0.537	0.373	0.537	0.371	0.537	0.302	0.500	0.445	0.540	0.341	0.539	0.308	0.539	0.400	0.522
pDevsLnR[2]	rec devs, 1975+	1	1.446	0.198	1.410	0.193	1.415	0.197	1.415	0.218	1.421	0.219	1.420	0.219	1.293	0.324	1.413	0.218	1.354	0.225	1.324	0.227	1.068	0.387
		2	1.970	0.129	1.961	0.128	1.969	0.124	2.066	0.140	2.074	0.142	2.074	0.142	2.318	0.143	2.062	0.142	2.031	0.142	2.011	0.143	2.104	0.188
		3	1.845	0.131	1.828	0.131	1.896	0.121	1.792	0.155	1.806	0.156	1.806	0.156	1.781	0.181	1.812	0.154	1.769	0.156	1.748	0.157	1.778	0.200
		4	1.237	0.176	1.217	0.177	1.278	0.168	0.992	0.246	0.974	0.255	0.973	0.255	0.702	0.339	1.020	0.246	0.949	0.254	0.928	0.257	0.821	0.336
		5	0.305	0.280	0.267	0.284	0.369	0.260	0.086	0.398	0.101	0.396	0.101	0.396	0.282	0.378	0.119	0.391	0.076	0.396	0.064	0.398	-1.004	1.123
		6	-0.446	0.391	-0.455	0.388	-0.364	0.348	-0.398	0.473	-0.389	0.472	-0.388	0.472	-0.156	0.457	-0.395	0.474	-0.414	0.475	-0.425	0.479	-1.959	2.031
		7	-0.061	0.218	-0.089	0.220	-0.112	0.215	0.084	0.247	0.080	0.250	0.080	0.250	0.280	0.261	0.078	0.248	0.069	0.250	0.066	0.251	-0.403	0.403
		8	-0.489	0.259	-0.493	0.257	-0.448	0.234	-0.494	0.334	-0.488	0.333	-0.488	0.333	-0.312	0.359	-0.499	0.331	-0.496	0.333	-0.503	0.336	-1.612	0.756
		9	0.847	0.102	0.826	0.101	0.788	0.105	1.073	0.104	1.072	0.109	1.073	0.109	1.307	0.101	1.062	0.108	1.072	0.109	1.077	0.109	1.595	0.118
		10	0.759	0.129	0.738	0.129	0.729	0.124	0.886	0.141	0.883	0.142	0.884	0.142	0.932	0.149	0.878	0.143	0.882	0.142	0.883	0.143	1.209	0.196
		11	1.200	0.110	1.196	0.109	1.186	0.106	1.192	0.128	1.190	0.129	1.190	0.129	0.951	0.152	1.220	0.127	1.186	0.129	1.180	0.131	1.371	0.187
		12	1.132	0.120	1.130	0.120	1.134	0.114	1.139	0.135	1.142	0.135	1.142	0.135	1.153	0.124	1.158	0.135	1.137	0.135	1.145	0.135	1.408	0.163
		13	1.123	0.118	1.149	0.117	1.107	0.116	1.143	0.129	1.147	0.129	1.147	0.129	0.703	0.156	1.185	0.126	1.142	0.130	1.138	0.131	1.102	0.179
		14	1.086	0.110	1.086	0.111	1.144	0.107	0.791	0.144	0.794	0.151	0.792	0.151	0.346	0.165	0.793	0.151	0.790	0.152	0.757	0.155	0.405	0.217
		15	0.160	0.156	0.157	0.158	0.190	0.149	0.056	0.184	0.057	0.184	0.056	0.184	-0.169	0.191	-0.104	0.195	0.010	0.187	0.025	0.186	0.007	0.211
		16	-0.740	0.249	-0.715	0.246	-0.687	0.231	-1.064	0.357	-1.080	0.366	-1.082	0.367	-1.662	0.526	-1.152	0.364	-1.133	0.372	-1.158	0.382	-1.301	0.484
		17	-1.198	0.272	-1.294	0.294	-1.208	0.261	-1.343	0.329	-1.346	0.329	-1.347	0.330	-1.563	0.361	-1.196	0.293	-1.372	0.330	-1.382	0.333	-1.416	0.384
		18	-1.479	0.261	-1.480	0.264	-1.486	0.249	-1.502	0.295	-1.502	0.295	-1.502	0.295	-1.474	0.294	-1.497	0.297	-1.505	0.293	-1.504	0.294	-1.372	0.306
		19	-1.586	0.245	-1.602	0.251	-1.560	0.227	-1.516	0.274	-1.504	0.272	-1.504	0.272	-1.374	0.277	-1.515	0.272	-1.507	0.272	-1.502	0.273	-1.319	0.271
		20	-1.367	0.201	-1.377	0.207	-1.380	0.193	-1.245	0.222	-1.243	0.222	-1.243	0.223	-1.086	0.231	-1.254	0.221	-1.234	0.222	-1.227	0.223	-1.376	0.271
		21	-1.136	0.175	-1.083	0.175	-1.176	0.171	-0.998	0.190	-1.002	0.192	-1.002	0.192	-0.834	0.196	-1.012	0.191	-0.989	0.192	-0.979	0.192	-1.093	0.227
		22	-1.132	0.194	-1.039	0.189	-1.146	0.185	-1.086	0.222	-1.084	0.222	-1.085	0.222	-1.084	0.254	-1.096	0.221	-1.071	0.222	-1.063	0.223	-0.937	0.231
		23	-0.142	0.100	-0.112	0.100	-0.173	0.099	-0.021	0.106	-0.020	0.107	-0.021	0.107	0.109	0.109	-0.026	0.106	-0.005	0.107	0.006	0.107	0.069	0.125
		24	-0.952	0.174	-1.008	0.180	-0.937	0.164	-0.932	0.200	-0.932	0.200	-0.933	0.200	-0.855	0.219	-0.939	0.199	-0.917	0.200	-0.909	0.201	-0.823	0.220
		25	0.109	0.099	0.054	0.101	0.056	0.102	0.271	0.103	0.271	0.106	0.271	0.106	0.498	0.102	0.255	0.105	0.287	0.106	0.299	0.106	0.545	0.118
		26	-0.432	0.172	-0.465	0.173	-0.390	0.159	-0.380	0.199	-0.376	0.199	-0.377	0.199	-0.333	0.228	-0.387	0.198	-0.360	0.199	-0.354	0.201	-0.198	0.227
		27	0.680	0.092	0.641	0.091	0.636	0.094	0.807	0.095	0.806	0.096	0.805	0.096	0.880	0.099	0.795	0.096	0.820	0.097	0.831	0.097	1.030	0.110
		28	-0.236	0.190	-0.306	0.189	-0.201	0.177	-0.330	0.236	-0.327	0.235	-0.328	0.236	-0.223	0.248	-0.323	0.233	-0.308	0.235	-0.303	0.237	-0.222	0.260
		29	0.618	0.110	0.315	0.128	0.586	0.111	0.757	0.111	0.761	0.113	0.761	0.113	0.847	0.112	0.753	0.113	0.784	0.113	0.796	0.113	0.748	0.144
		30	0.768	0.092	0.801	0.088	0.780	0.089	0.749	0.107	0.749	0.107	0.748	0.108	0.638	0.119	0.761	0.107	0.764	0.108	0.770	0.108	1.099	0.114
		31	-0.396	0.190	-0.453	0.196	-0.391	0.182	-0.553	0.243	-0.557	0.244	-0.557	0.244	-0.654	0.268	-0.547	0.242	-0.536	0.244	-0.533	0.245	-0.328	0.267
		32	-0.697	0.215	-0.735	0.218	-0.665	0.200	-0.806	0.265	-0.818	0.269	-0.819	0.270	-1.059	0.343	-0.795	0.264	-0.799	0.269	-0.799	0.272	-0.688	0.315
		33	-1.129	0.279	-1.113	0.275	-1.171	0.271	-1.088	0.316	-1.087	0.315	-1.087	0.316	-0.845	0.312	-1.088	0.314	-1.066	0.315	-1.056	0.316	-0.678	0.305
		34	-0.885	0.251	-0.908	0.255	-0.904	0.241	-0.663	0.261	-0.661	0.263	-0.660	0.263	-0.158	0.241	-0.683	0.262	-0.637	0.263	-0.625	0.263	-0.226	0.266
		35	0.975	0.098	1.002	0.100	0.917	0.105	1.216	0.094	1.222	0.101	1.223	0.101	1.463	0.089	1.198	0.102	1.238	0.101	1.250	0.101	1.384	0.115
		36	1.125	0.092	1.205	0.093	1.140	0.088	1.091	0.107	1.091	0.109	1.091	0.109	0.757	0.139	1.128	0.106	1.123	0.108	1.128	0.108	1.072	0.135
		37	0.493	0.132	0.601	0.133	0.513	0.131	0.226	0.170	0.211	0.175	0.211	0.176	-0.053	0.195	0.257	0.173	0.234	0.176	0.233	0.178	0.271	0.190
		38	-1.141	0.354	-1.147	0.386	-1.106	0.331	-1.391	0.460	-1.405	0.463	-1.403	0.463	-1.549	0.511	-1.407	0.466	-1.402	0.468	-1.402	0.471	-1.241	0.474
		39	-0.433	0.172	-0.244	0.177	-0.457	0.168	-0.413	0.186	-0.414	0.186	-0.413	0.186	-0.420	0.196	-0.410	0.185	-0.400	0.186	-0.394	0.186	-0.248	0.204
		40	-0.722	0.193	-0.424	0.197	-0.714	0.184	-0.703	0.212	-0.702	0.212	-0.701	0.212	-0.677	0.225	-0.697	0.210	-0.687	0.212	-0.683	0.212	-0.426	0.218
		41	-1.124	0.250	-0.788	0.262	-1.131	0.241	-1.121	0.275	-1.123	0.275	-1.122	0.275	-1.093	0.292	-1.122	0.274	-1.109	0.275	-1.105	0.276	-0.878	0.283
		42	-0.849	0.239			-0.876	0.233	-0.780	0.247	-0.783	0.248	-0.782	0.248	-0.708	0.254	-0.786	0.247	-0.770	0.248	-0.764	0.248	-0.573	0.256
pLnR[1]	ln-scale mean, pre-1975	1	5.337	0.490	5.360	0.490	5.328	0.494	5.490	0.465	5.492	0.466	5.496	0.466	5.949	0.419	5.443	0.469	5.556	0.468	5.577	0.468	5.903	0.452
pLnR[2]	ln-scale mean, 1975+	1	4.950	0.062	4.971	0.063	4.944	0.057	5.031	0.069	5.032	0.070	5.034	0.070	5.374	0.082	5.051	0.070	5.092	0.072	5.115	0.072	5.178	0.102

Table 17. Comparison of logit-scale parameters for the probability of terminal molt.

process	name	label	index	B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
				estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
maturity	pLgtPrM2M[1]	pr(terminal molt, males)	1	-12.203	7.680	-11.933	7.543	-12.316	7.754	-12.116	7.441	-12.127	7.443	-12.124	7.441	-12.027	7.334	-12.092	7.459	-12.105	7.454	-12.086	7.440	-12.455	7.593
			2	-11.005	5.819	-10.765	5.701	-11.100	5.882	-10.921	5.611	-10.931	5.615	-10.928	5.613	-10.822	5.524	-10.901	5.629	-10.910	5.624	-10.891	5.612	-11.217	5.753
			3	-9.807	4.182	-9.597	4.086	-9.883	4.234	-9.726	4.011	-9.736	4.016	-9.732	4.014	-9.617	3.946	-9.710	4.028	-9.715	4.024	-9.696	4.013	-9.980	4.141
			4	-8.609	2.806	-8.430	2.736	-8.667	2.843	-8.532	2.675	-8.541	2.681	-8.537	2.680	-8.414	2.631	-8.519	2.691	-8.521	2.687	-8.503	2.678	-8.744	2.790
			5	-7.419	1.716	-7.271	1.671	-7.458	1.737	-7.349	1.622	-7.357	1.629	-7.353	1.627	-7.225	1.586	-7.340	1.636	-7.338	1.631	-7.320	1.624	-7.517	1.723
			6	-6.253	0.953	-6.142	0.925	-6.272	0.957	-6.191	0.909	-6.198	0.915	-6.194	0.914	-6.058	0.880	-6.186	0.916	-6.180	0.913	-6.162	0.909	-6.316	0.981
			7	-5.168	0.547	-5.094	0.532	-5.160	0.546	-5.134	0.541	-5.140	0.543	-5.137	0.543	-4.992	0.515	-5.129	0.540	-5.120	0.541	-5.104	0.541	-5.207	0.583
			8	-4.455	0.364	-4.417	0.359	-4.426	0.364	-4.508	0.364	-4.505	0.364	-4.503	0.364	-4.320	0.352	-4.484	0.363	-4.485	0.364	-4.477	0.364	-4.493	0.389
			9	-4.045	0.288	-4.008	0.288	-4.035	0.289	-4.115	0.290	-4.103	0.290	-4.101	0.290	-3.956	0.287	-4.087	0.289	-4.094	0.290	-4.090	0.290	-4.091	0.307
			10	-3.477	0.225	-3.466	0.227	-3.493	0.227	-3.470	0.224	-3.465	0.224	-3.463	0.224	-3.474	0.224	-3.472	0.224	-3.465	0.224	-3.448	0.224	-3.513	0.238
			11	-2.981	0.175	-2.979	0.177	-2.980	0.176	-2.942	0.175	-2.950	0.175	-2.947	0.175	-2.902	0.173	-2.955	0.175	-2.936	0.175	-2.913	0.175	-2.872	0.185
			12	-2.468	0.145	-2.467	0.147	-2.428	0.147	-2.526	0.144	-2.525	0.144	-2.522	0.144	-2.296	0.140	-2.502	0.144	-2.497	0.144	-2.487	0.144	-2.340	0.156
			13	-1.925	0.124	-1.910	0.127	-1.880	0.124	-2.050	0.124	-2.032	0.125	-2.031	0.125	-1.949	0.120	-2.006	0.125	-2.022	0.125	-2.021	0.125	-1.896	0.132
			14	-1.337	0.103	-1.329	0.105	-1.313	0.102	-1.448	0.108	-1.427	0.108	-1.427	0.108	-1.592	0.102	-1.417	0.107	-1.435	0.109	-1.430	0.109	-1.374	0.114
			15	-0.905	0.094	-0.894	0.095	-0.906	0.094	-0.950	0.095	-0.941	0.095	-0.939	0.095	-1.199	0.093	-0.958	0.095	-0.956	0.096	-0.937	0.095	-0.889	0.111
			16	-0.697	0.090	-0.697	0.092	-0.710	0.090	-0.676	0.092	-0.685	0.092	-0.681	0.092	-0.740	0.090	-0.718	0.092	-0.703	0.092	-0.668	0.092	-0.468	0.102
			17	-0.512	0.091	-0.530	0.091	-0.479	0.095	-0.574	0.088	-0.574	0.088	-0.571	0.088	-0.371	0.089	-0.549	0.089	-0.548	0.089	-0.536	0.089	-0.363	0.107
			18	0.059	0.111	0.009	0.110	0.146	0.123	-0.139	0.095	-0.109	0.101	-0.107	0.101	-0.250	0.082	-0.050	0.103	-0.080	0.101	-0.093	0.100	-0.145	0.100
			19	0.758	0.144	0.677	0.141	0.896	0.165	0.482	0.118	0.537	0.131	0.537	0.131	0.101	0.086	0.597	0.133	0.528	0.131	0.512	0.130	0.301	0.112
			20	1.712	0.204	1.613	0.201	1.910	0.223	1.324	0.173	1.423	0.200	1.420	0.200	0.644	0.098	1.481	0.202	1.370	0.202	1.362	0.202	0.930	0.143
			21	3.221	0.344	3.144	0.340	3.483	0.361	2.663	0.316	2.848	0.357	2.840	0.357	1.126	0.119	2.874	0.357	2.696	0.369	2.708	0.366	1.644	0.259
			22	5.298	0.622	5.227	0.618	5.530	0.654	4.889	0.568	5.066	0.601	5.058	0.601	2.046	0.189	5.130	0.594	4.962	0.591	4.957	0.591	3.503	0.575
			23	7.261	1.118	7.202	1.111	7.443	1.165	7.035	1.024	7.178	1.062	7.169	1.061	4.096	0.468	7.267	1.061	7.122	1.043	7.096	1.048	5.704	0.853
			24	8.950	1.740	8.902	1.731	9.086	1.795	8.870	1.633	8.979	1.675	8.971	1.674	6.340	0.849	9.078	1.687	8.956	1.662	8.917	1.667	7.691	1.326
			25	10.355	2.368	10.316	2.358	10.452	2.423	10.378	2.267	10.459	2.308	10.452	2.307	8.277	1.411	10.560	2.327	10.459	2.302	10.412	2.305	9.359	1.919
			26	11.501	2.889	11.471	2.879	11.569	2.939	11.591	2.801	11.649	2.839	11.643	2.838	9.880	1.996	11.746	2.859	11.664	2.836	11.615	2.838	10.729	2.470
			27	12.425	3.214	12.402	3.206	12.471	3.256	12.549	3.142	12.590	3.174	12.584	3.173	11.188	2.455	12.678	3.193	12.613	3.174	12.566	3.175	11.839	2.858
			28	13.163	3.277	13.146	3.271	13.192	3.310	13.295	3.222	13.322	3.247	13.318	3.246	12.248	2.683	13.397	3.263	13.348	3.248	13.306	3.248	12.732	2.998
			29	13.753	3.027	13.740	3.022	13.770	3.050	13.870	2.988	13.888	3.006	13.884	3.005	13.110	2.604	13.947	3.018	13.911	3.007	13.877	3.007	13.451	2.828
			30	14.231	2.424	14.223	2.421	14.240	2.438	14.318	2.400	14.328	2.411	14.326	2.411	13.823	2.164	14.369	2.419	14.345	2.412	14.321	2.412	14.040	2.301
			31	14.634	1.439	14.630	1.438	14.638	1.445	14.680	1.428	14.685	1.433	14.684	1.433	14.436	1.324	14.706	1.437	14.694	1.434	14.682	1.434	14.542	1.384
			32	15.000	0.005	15.000	0.005	15.000	0.005	15.000	0.004	15.000	0.004	15.000	0.004	15.000	0.004	15.000	0.004	15.000	0.004	15.000	0.004	15.000	0.004
	pLgtPrM2M[2]	pr(terminal molt, females)	1	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002	-15.000	0.002
			2	-13.766	0.786	-13.758	0.786	-13.744	0.786	-13.768	0.784	-13.765	0.784	-13.765	0.784	-13.788	0.783	-13.764	0.784	-13.765	0.784	-13.764	0.784	-13.859	0.789
			3	-12.478	1.190	-12.462	1.189	-12.436	1.190	-12.482	1.186	-12.477	1.186	-12.477	1.186	-12.520	1.185	-12.475	1.186	-12.475	1.186	-12.475	1.186	-12.658	1.197
			4	-11.079	1.294	-11.057	1.294	-11.023	1.295	-11.087	1.289	-11.080	1.289	-11.080	1.289	-11.142	1.287	-11.078	1.289	-11.078	1.288	-11.077	1.288	-11.337	1.305
			5	-9.516	1.160	-9.489	1.159	-9.451	1.160	-9.530	1.153	-9.522	1.153	-9.522	1.153	-9.597	1.151	-9.519	1.153	-9.520	1.152	-9.518	1.152	-9.836	1.174
			6	-7.737	0.870	-7.707	0.869	-7.674	0.870	-7.760	0.864	-7.753	0.864	-7.753	0.864	-7.837	0.863	-7.751	0.864	-7.750	0.863	-7.749	0.863	-8.099	0.884
			7	-5.716	0.529	-5.685	0.529	-5.666	0.528	-5.753	0.526	-5.748	0.526	-5.748	0.526	-5.835	0.528	-5.747	0.526	-5.745	0.525	-5.744	0.525	-6.090	0.541
			8	-3.525	0.243	-3.499	0.243	-3.500	0.242	-3.589	0.243	-3.588	0.243	-3.588	0.243	-3.674	0.246	-3.588	0.243	-3.586	0.243	-3.584	0.243	-3.869	0.257
			9	-1.654	0.113	-1.636	0.114	-1.668	0.112	-1.775	0.110	-1.781	0.110	-1.781	0.110	-1.865	0.107	-1.781	0.110	-1.781	0.110	-1.780	0.110	-1.938	0.116
			10	-0.268	0.090	-0.257	0.091	-0.318	0.092	-0.417	0.087	-0.431	0.087	-0.431	0.087	-0.535	0.077	-0.430	0.088	-0.434	0.087	-0.433	0.087	-0.527	0.089
			11	0.449	0.092	0.439	0.092	0.385	0.096	0.321	0.091	0.303	0.092	0.303	0.092	0.177	0.078	0.306	0.093	0.300	0.092	0.302	0.092	0.197	0.091
			12	0.768	0.110	0.754	0.111	0.650	0.109	0.606	0.101	0.583	0.103	0.583	0.103	0.497	0.089	0.582	0.104	0.582	0.103	0.586	0.103	0.536	0.106
			13	1.743	0.205	1.736	0.206	1.346	0.181	1.339	0.161	1.275	0.166	1.276	0.166	1.083	0.118	1.277	0.168	1.269	0.165	1.274	0.165	1.184	0.153
			14	3.488	0.428	3.481	0.429	2.621	0.370	2.760	0.344	2.604	0.353	2.600	0.351	2.068	0.202	2.630	0.363	2.581	0.350	2.575	0.347	2.274	0.275
			15	5.351	0.904	5.349	0.902	3.990	0.687	4.338	0.706	4.093	0.686	4.077	0.684	3.210	0.361	4.148	0.714	4.046	0.678	4.025	0.670	3.356	0.446
			16	7.229	1.667	7.231	1.662	5.383	1.284	5.947	1.362	5.618	1.305	5.591	1.304	4.417	0.794	5.700	1.352	5.548	1.294	5.512	1.279	4.418	0.877

Table 18. Comparison of NMFS survey catchability parameters for all model scenarios.

		case	Values																				
		B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pLnQ[1]	survey: males, pre-1982	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000
pLnQ[2]	survey: males, 1982+	-0.319	0.048	-0.333	0.049	-0.298	0.048	-0.363	0.050	-0.358	0.051	-0.357	0.051	-0.524	0.057	-0.371	0.052	-0.418	0.053	-0.443	0.054	-0.448	0.063
pLnQ[3]	survey: females, pre-1982	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000	-0.693	0.000
pLnQ[4]	survey: females, 1982+	-0.709	0.062	-0.691	0.063	-0.745	0.057	-0.808	0.068	-0.823	0.069	-0.824	0.069	-1.170	0.081	-0.832	0.070	-0.886	0.073	-0.911	0.073	-1.143	0.088

Table 19. Comparison of NMFS survey selectivity parameters for all model scenarios.

		case	Values										
		B0		B0.2016		B0a		B1		B1a		B1b	
name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pS1[1]	z50 for NMFS survey selectivity (males, pre-1982)	50.027	1.883	50.158	1.897	50.071	1.891	51.830	2.036	52.033	2.084	52.062	2.087
pS1[2]	z50 for NMFS survey selectivity (males, 1982+)	27.532	3.509	29.357	3.331	27.841	3.273	33.531	3.847	34.298	4.091	34.452	4.101
pS1[3]	z50 for NMFS survey selectivity (females, pre-1982)	52.934	2.543	53.187	2.573	52.917	2.842	55.274	2.694	55.636	2.806	55.681	2.810
pS1[4]	z50 for NMFS survey selectivity (females, 1982+)	36.716	27.628	15.634	17.028	41.525	121440.000	25.697	22.819	32.016	28.484	31.712	28.297
pS2[1]	z95-z50 for NMFS survey selectivity (males, pre-1982)	21.668	3.168	21.819	3.196	21.532	3.125	23.230	3.449	23.287	3.448	23.313	3.454
pS2[2]	z95-z50 for NMFS survey selectivity (males, 1982+)	62.857	9.260	62.361	9.062	61.847	8.986	74.551	10.237	74.182	9.964	74.423	9.992
pS2[3]	z95-z50 for NMFS survey selectivity (females, pre-1982)	33.694	5.213	34.303	5.300	36.758	6.195	37.704	5.466	38.878	5.728	38.939	5.732
pS2[4]	z95-z50 for NMFS survey selectivity (females, 1982+)	100.000	0.002	100.000	0.001	1.609	22385.000	100.000	0.002	100.000	0.002	100.000	0.002

		B1c		B2		B2a		B2b		B3	
name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pS1[1]	z50 for NMFS survey selectivity (males, pre-1982)	90.000	0.000	51.955	2.078	52.179	2.118	52.322	2.118	87.671	8.712
pS1[2]	z50 for NMFS survey selectivity (males, 1982+)	49.512	5.234	33.776	4.046	34.556	4.159	34.925	4.150	47.230	6.513
pS1[3]	z50 for NMFS survey selectivity (females, pre-1982)	77.761	2.970	55.738	2.792	56.070	2.853	56.309	2.856	77.139	6.489
pS1[4]	z50 for NMFS survey selectivity (females, 1982+)	31.570	28.913	31.183	27.924	30.693	27.840	29.120	26.955	50.000	0.006
pS2[1]	z95-z50 for NMFS survey selectivity (males, pre-1982)	81.749	6.231	23.210	3.438	23.497	3.515	23.519	3.499	100.000	0.002
pS2[2]	z95-z50 for NMFS survey selectivity (males, 1982+)	100.000	0.001	73.341	10.048	75.067	10.312	75.089	10.257	99.151	16.251
pS2[3]	z95-z50 for NMFS survey selectivity (females, pre-1982)	59.453	5.889	38.896	5.703	39.824	5.876	40.004	5.870	77.157	10.924
pS2[4]	z95-z50 for NMFS survey selectivity (females, 1982+)	100.000	0.002	100.000	0.002	100.000	0.002	100.000	0.002	100.000	0.005

Table 20. Comparison of fishery capture rate and max retention parameter estimates for all fisheries for all model scenarios.

name	label	B0 estimate	B0 std dev	B0.2016 estimate	B0.2016 std dev	B0a estimate	B0a std dev	B1 estimate	B1 std dev	B1a estimate	B1a std dev	B1b estimate	B1b std dev	B1c estimate	B1c std dev	B2 estimate	B2 std dev	B2a estimate	B2a std dev	B2b estimate	B2b std dev	B3 estimate	B3 std dev
pDC2[1]	TCF: female offset	-2.085	0.255	-2.059	0.250	-1.986	0.291	-2.096	0.283	-2.086	0.289	-2.085	0.289	-2.283	0.317	-2.288	0.291	-2.094	0.291	-2.324	0.304	-1.895	0.467
pDC2[2]	SCF: female offset	-1.740	0.144	-1.733	0.143	-1.774	0.143	-1.771	0.150	-1.784	0.151	-1.785	0.151	-1.820	0.159	-1.817	0.156	-1.791	0.156	-1.759	0.151	-1.851	0.158
pDC2[3]	GTF: female offset	-0.882	0.065	-0.958	0.067	-0.926	0.063	-0.935	0.069	-0.955	0.071	-0.956	0.071	-1.063	0.081	-0.947	0.072	-0.954	0.072	-0.956	0.072		
	RKF: female offset																					-0.385	4.783
pDC2[4]	GF.AllGear: female offset																					-1.337	0.187
	RKF: female offset	-0.944	2.048	-0.896	2.127	4.698	1.999	-0.885	2.592	-0.865	2.744	-0.799	3.013	-1.091	2.650	-1.046	2.704	-0.868	2.925	-0.835	2.864		
pDC2[5]	GF.FixedGear: female offset																					0.501	2.175
pDC2[6]	GF.TrawlGear: female offset																					-1.331	0.307
pLgtRet[1]	TCF: logit-scale max retention (pre-1997)																	14.999	2.905	14.999	2.252	14.999	2.440
pLgtRet[2]	TCF: logit-scale max retention (2005-2009)																	2.259	1.444	2.010	1.197	1.858	1.061
pLgtRet[3]	TCF: logit-scale max retention (2013-2015)																	3.395	1.128	4.160	2.558	4.393	3.301
pLnC[1]	TCF: base capture rate, pre-1965 (=0.05)	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000	-2.996	0.000
pLnC[2]	TCF: base capture rate, 1965+	-1.148	0.092	-1.165	0.092	-1.137	0.093	-1.202	0.090	-1.200	0.090	-1.201	0.090	-1.357	0.093	-1.064	0.092	-1.307	0.089	-1.353	0.086	-1.434	0.095
pLnC[3]	SCF: base capture rate, pre-1978 (=0.01)	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000	-4.605	0.000
pLnC[4]	SCF: base capture rate, 1992+	-2.701	0.092	-2.726	0.093	-2.682	0.091	-2.757	0.095	-2.754	0.094	-2.754	0.094	-3.008	0.099	-2.782	0.094	-2.817	0.098	-2.834	0.102	-2.890	0.114
pLnC[5]	RKF: base capture rate, pre-1953 (=0.02)																					-3.912	0.000
pLnC[6]	GTF: base capture rate, ALL YEARS	-4.197	0.063	-4.181	0.065	-4.170	0.063	-4.264	0.064	-4.256	0.064	-4.255	0.064	-4.471	0.067	-4.267	0.065	-4.312	0.065	-4.331	0.065		
	RKF: base capture rate, 1992+																					-3.956	0.165
pLnC[7]	GF.AllGear: base capture rate, pre-1991																					-4.405	0.177
	RKF: base capture rate, pre-1953 (=0.02)	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000	-3.912	0.000		
pLnC[8]	GF.FixedGear: base capture rate, 1991+																					-5.556	0.395
	RKF: base capture rate, 1992+	-3.782	0.156	-3.726	0.161	-3.761	0.157	-3.822	0.157	-3.816	0.157	-3.867	0.163	-3.951	0.165	-3.820	0.164	-3.914	0.163	-3.958	0.162		
pLnC[9]	GF.TrawlGear: base capture rate, 1991+																					-4.645	0.233

Table 21. Comparison of selectivity and retention function parameter estimates for the directed Tanner crab fishery (TCF) for all model scenarios.

		case / Values																						
			B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
name	label	index	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pDevsS1[1]	ln(z50 devs) for TCF selectivity (males, 1991+)	1	0.094	0.022	0.102	0.022	0.094	0.022	0.092	0.021	0.092	0.021	0.092	0.021	0.094	0.020	0.035	0.021	0.037	0.019	0.029	0.017	0.030	0.017
		2	0.075	0.013	0.077	0.013	0.076	0.013	0.077	0.013	0.077	0.013	0.076	0.013	0.078	0.013	0.082	0.013	0.087	0.013	0.116	0.012	0.107	0.012
		3	0.080	0.017	0.080	0.017	0.078	0.016	0.088	0.017	0.088	0.017	0.088	0.017	0.094	0.017	0.109	0.015	0.100	0.014	0.097	0.014	0.090	0.013
		4	0.148	0.024	0.147	0.026	0.146	0.025	0.151	0.025	0.150	0.025	0.150	0.025	0.152	0.026	0.125	0.025	0.080	0.020	0.077	0.021	0.072	0.021
		5	-0.036	0.038	-0.048	0.039	-0.036	0.037	-0.052	0.037	-0.051	0.036	-0.051	0.036	-0.078	0.034	0.193	0.024	0.016	0.031	-0.010	0.027	-0.017	0.027
		6	0.163	0.037	0.168	0.039	0.161	0.037	0.163	0.037	0.162	0.037	0.162	0.037	0.153	0.037	0.137	0.043	0.109	0.047	0.120	0.040	0.115	0.040
		7	-0.111	0.019	-0.113	0.019	-0.111	0.019	-0.107	0.018	-0.107	0.018	-0.107	0.018	-0.105	0.017	-0.118	0.018	-0.087	0.018	-0.087	0.017	-0.080	0.016
		8	-0.115	0.019	-0.122	0.019	-0.113	0.019	-0.117	0.019	-0.117	0.019	-0.117	0.019	-0.104	0.017	-0.125	0.018	-0.095	0.018	-0.095	0.018	-0.087	0.017
		9	-0.153	0.018	-0.152	0.017	-0.152	0.018	-0.154	0.017	-0.154	0.017	-0.154	0.017	-0.153	0.016	-0.164	0.017	-0.132	0.017	-0.132	0.016	-0.128	0.015
		10	-0.006	0.015	-0.004	0.015	-0.005	0.015	-0.005	0.015	-0.005	0.015	-0.005	0.015	-0.007	0.014	-0.019	0.015	0.011	0.015	0.010	0.014	0.011	0.013
		11	0.168	0.018	0.166	0.018	0.168	0.018	0.167	0.017	0.167	0.017	0.167	0.017	0.161	0.016	0.156	0.018	0.182	0.017	0.180	0.016	0.178	0.016
		12	-0.072	0.017	-0.069	0.017	-0.072	0.017	-0.073	0.017	-0.073	0.017	-0.073	0.017	-0.081	0.016	-0.080	0.018	-0.050	0.017	-0.048	0.017	-0.054	0.016
		13	-0.108	0.014	-0.105	0.014	-0.106	0.014	-0.104	0.013	-0.104	0.013	-0.104	0.013	-0.092	0.012	-0.143	0.015	-0.108	0.015	-0.109	0.014	-0.101	0.013
pDevsS1[2]	z50 devs for TCF retention (males, 1991+)	1															2.601	0.729	3.061	0.669				
		2															-2.118	0.782	-1.260	0.806				
		3															2.109	0.667	2.542	0.640				
		4															3.203	0.664	3.495	0.619				
		5															5.704	1.370	3.399	1.399				
		6															4.302	1.738	3.592	1.480				
		7															2.737	2.314	2.959	2.226				
		8															4.455	1.512	4.474	1.546				
		9															3.539	1.010	3.643	0.951				
		10															2.789	1.462	2.974	1.352				
		11															2.586	3.899	2.743	3.453				
		12															-9.807	1.757	-9.537	1.859				
		13															-10.559	0.911	-10.612	0.990				
pS1[13]	z50 for TCF selectivity (females, pre-1997)	1																					101.348	4.641
pS1[14]	z50 for TCF selectivity (females, 2005+)	1																					97.119	3.947
pS1[28]	z50 for TCF retention (2005-2009)	1																			138.717	1.632		
pS1[29]	z50 for TCF retention (2013-2015)	1																			125.037	0.758		
pS1[5]	z50 for TCF retention (pre-1991)	1	137.955	0.436	137.993	0.435	137.929	0.434	137.874	0.421	137.868	0.420	137.865	0.420	138.156	0.432	137.861	0.408	138.093	0.420	137.987	0.416	138.504	0.465
pS1[6]	z50 for TCF retention (1991-1996)	1																			137.497	0.249	137.636	0.243
	z50 for TCF retention (1991+)	1	132.907	0.404	132.947	0.406	132.903	0.405	132.917	0.401	132.913	0.401	132.911	0.401	132.914	0.399	136.081	0.509	135.560	0.521				
pS1[7]	z50 for TCF retention (2005-2009)	1																					138.697	1.649
pS1[8]	ln(z50) for TCF selectivity (males)	1	4.886	0.010	4.884	0.010	4.884	0.010	4.888	0.009	4.887	0.009	4.887	0.009	4.897	0.009	4.899	0.010	4.867	0.009	4.865	0.008		
	z50 for TCF retention (2013+)	1																					124.943	0.771
pS1[9]	ln(z50) for TCF selectivity (males, 1991+)	1																					4.868	0.009
	z50 for TCF selectivity (females)	1	95.025	2.232	94.761	2.198	96.563	2.724	96.257	2.517	96.515	2.601	96.508	2.599	97.463	2.800	96.492	2.588	96.549	2.609	96.580	2.622		
pS2[10]	slope for TCF selectivity (males, 1991-1996)	1																					0.161	0.008
pS2[13]	slope for TCF selectivity (females, pre-1997)	1																					0.167	0.020
pS2[14]	slope for TCF selectivity (females, 2004+)	1																					0.193	0.028
pS2[28]	slope for TCF retention (2005-2009)	1																			0.894	0.725		
pS2[29]	slope for TCF retention (2013-2015)	1																			0.576	0.126		
pS2[5]	slope for TCF retention (pre-1991)	1	0.656	0.122	0.661	0.123	0.658	0.123	0.682	0.126	0.681	0.126	0.682	0.126	0.719	0.129	0.680	0.125	0.684	0.124	0.691	0.126	0.709	0.127
pS2[6]	slope for TCF retention (1991-1996)	1																					0.981	0.219
	slope for TCF retention (1997+)	1	0.269	0.019	0.266	0.018	0.269	0.019	0.267	0.018	0.267	0.018	0.267	0.019	0.262	0.018	0.667	0.079	0.747	0.116	0.956	0.192		
pS2[7]	slope for TCF retention (2005-2009)	1																					0.899	0.748
	slope for TCF selectivity (males, pre-1997)	1	0.130	0.006	0.099	0.006	0.101	0.006	0.102	0.006	0.102	0.006	0.102	0.006	0.105	0.005	0.104	0.006	0.115	0.007	0.118	0.006		
pS2[8]	slope for TCF retention (2013-2015)	1																					0.588	0.133
	slope for TCF selectivity (males, 1997+)	1	0.149	0.008	0.152	0.008	0.150	0.008	0.152	0.008	0.152	0.008	0.152	0.008	0.155	0.007	0.152	0.008	0.153	0.008	0.155	0.008		
pS2[9]	slope for TCF selectivity (females)	1	0.194	0.020	0.195	0.020	0.184	0.019	0.188	0.019	0.187	0.019	0.187	0.019	0.185	0.019	0.187	0.019	0.187	0.019	0.187	0.019		
	slope for TCF selectivity (males, pre-1991)	1																					0.119	0.007

Table 22. Comparison of selectivity parameter estimates for the snow crab fishery (SCF) for all model scenarios.

		case	Values																				
		B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pS1[10]	ascending z50 for SCF selectivity (males, pre-1997)	86.723	1.531	86.508	1.542	86.192	1.595	88.031	1.532	87.872	1.519	87.883	1.519	88.459	2.243	87.330	1.613	87.652	1.605	87.705	1.564		
pS1[11]	ascending z50 for SCF selectivity (males, 1997-2004)	94.657	3.458	94.597	3.456	94.489	3.474	95.399	3.532	95.355	3.512	95.362	3.509	96.569	3.621	94.904	3.398	95.344	3.558	95.698	3.754		
pS1[12]	ascending z50 for SCF selectivity (males, 2005+)	104.436	1.377	104.390	1.438	104.265	1.374	105.387	1.397	105.260	1.390	105.286	1.390	107.882	1.455	105.090	1.374	105.433	1.406	105.607	1.419		
pS1[13]	ascending z50 for SCF selectivity (females, pre-1997)	69.435	5.294	69.006	5.513	68.712	5.673	70.171	5.074	70.092	5.134	70.093	5.134	71.122	4.743	69.637	5.245	70.238	5.079	70.264	5.030		
pS1[14]	ascending z50 for SCF selectivity (females, 1997-2004)	75.611	4.607	75.390	4.602	75.767	4.702	76.157	4.529	76.201	4.538	76.204	4.538	76.779	4.481	76.230	4.558	76.223	4.531	76.295	4.524		
pS1[15]	ascending z50 for SCF selectivity (females, 2005+)	83.110	4.948	82.324	4.752	83.697	5.303	84.346	5.291	84.429	5.348	84.444	5.349	87.181	6.331	84.031	5.179	84.634	5.425	85.218	5.644		
	ascending z50 for SCF selectivity (males, pre-1997)																					87.640	1.958
pS1[16]	ascending z50 for SCF selectivity (males, 1997-2004)																					97.060	4.057
pS1[17]	ascending z50 for SCF selectivity (males, 2005+)																					108.215	1.553
pS1[18]	ascending z50 for SCF selectivity (females, pre-1997)																					69.712	5.444
pS1[19]	ascending z50 for SCF selectivity (females, 1997-2004)																					76.821	4.637
pS1[20]	ascending z50 for SCF selectivity (females, 2005+)																					87.903	6.541
pS2[10]	ascending slope for SCF selectivity (males, pre-1997)	0.450	0.164	0.452	0.165	0.478	0.182	0.370	0.125	0.383	0.131	0.383	0.131	0.258	0.078	0.390	0.140	0.373	0.131	0.374	0.129		
pS2[11]	ascending slope for SCF selectivity (males, 1997-2004)	0.219	0.070	0.219	0.071	0.221	0.072	0.212	0.064	0.213	0.065	0.213	0.065	0.204	0.059	0.219	0.067	0.213	0.065	0.208	0.063		
pS2[12]	ascending slope for SCF selectivity (males, 2005+)	0.179	0.016	0.178	0.016	0.180	0.016	0.176	0.015	0.177	0.015	0.177	0.015	0.165	0.012	0.177	0.015	0.176	0.015	0.175	0.015		
pS2[13]	slope for SCF selectivity (females, pre-1997)	0.223	0.141	0.222	0.147	0.224	0.154	0.219	0.129	0.218	0.129	0.218	0.129	0.221	0.118	0.224	0.138	0.218	0.127	0.220	0.128		
pS2[14]	slope for SCF selectivity (females, 1997-2004)	0.269	0.138	0.271	0.142	0.263	0.135	0.266	0.131	0.265	0.130	0.265	0.130	0.262	0.124	0.264	0.130	0.265	0.130	0.264	0.129		
pS2[15]	ascending slope for SCF selectivity (males, pre-1997)																					0.294	0.095
	slope for SCF selectivity (females, 2005+)	0.166	0.054	0.173	0.056	0.161	0.053	0.161	0.051	0.160	0.051	0.160	0.051	0.147	0.045	0.164	0.052	0.159	0.051	0.156	0.049		
pS2[16]	ascending slope for SCF selectivity (males, 1997-2004)																					0.193	0.056
pS2[17]	ascending slope for SCF selectivity (males, 2005+)																					0.164	0.017
pS2[18]	slope for SCF selectivity (females, pre-1997)																					0.217	0.133
pS2[19]	slope for SCF selectivity (females, 1997-2004)																					0.256	0.124
pS2[20]	slope for SCF selectivity (females, 2005+)																					0.145	0.044
pS3[1]	ln(dz50-az50) for SCF selectivity (males, pre-1997)	3.963	0.038	3.966	0.038	3.972	0.038	3.941	0.039	3.944	0.038	3.943	0.038	3.944	0.052	3.923	0.064	3.935	0.057	3.956	0.040	3.972	0.048
pS3[2]	ln(dz50-az50) for SCF selectivity (males, 1997-2004)	3.783	0.173	3.773	0.169	3.788	0.171	3.765	0.179	3.766	0.179	3.767	0.178	3.762	0.176	3.773	0.178	3.752	0.190	3.730	0.210	3.716	0.219
pS3[3]	ln(dz50-az50) for SCF selectivity (males, 2005+)	3.495	0.074	3.510	0.077	3.507	0.073	3.453	0.081	3.461	0.080	3.461	0.080	3.387	0.089	3.472	0.077	3.454	0.080	3.446	0.082	3.352	0.097
pS4[1]	descending slope for SCF selectivity (males, pre-1997)	0.500	0.000	0.500	0.001	0.500	0.000	0.500	0.000	0.500	0.000	0.500	0.000	0.500	0.001	0.315	0.187	0.368	0.226	0.500	0.001	0.500	0.004
pS4[2]	descending slope for SCF selectivity (males, 1997-2004)	0.148	0.095	0.151	0.091	0.150	0.096	0.147	0.092	0.147	0.092	0.147	0.092	0.156	0.100	0.138	0.086	0.135	0.082	0.130	0.081	0.135	0.086
pS4[3]	descending slope for SCF selectivity (males, 2005+)	0.188	0.025	0.187	0.027	0.191	0.026	0.182	0.024	0.184	0.025	0.184	0.025	0.187	0.025	0.186	0.025	0.185	0.024	0.185	0.024	0.185	0.025

Table 23. Comparison of selectivity parameter estimates for the BBRKC fishery (RKF) for all model scenarios.

		case Values																					
		B0		B0.2016		B0a		B1		B1a		B1b		B1c		B2		B2a		B2b		B3	
name	label	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev	estimate	std dev
pS1[21]	z95 for RKF selectivity (males, pre-1997)																					158.359	6.338
pS1[22]	z50 for RKF selectivity (males, pre-1997)	135.838	4.139	136.678	4.244	135.934	4.124	136.146	4.112	136.143	4.103												
	z95 for RKF selectivity (males, 1997-2004)																					180.000	0.007
	z95 for RKF selectivity (males, pre-1997)											157.289	6.905	157.887	6.424	159.740	6.381	158.337	6.491	158.212	6.549		
pS1[23]	z50 for RKF selectivity (males, 1997-2004)	150.000	0.015	150.000	0.006	150.000	0.022	150.000	0.016	150.000	0.017												
	z95 for RKF selectivity (males, 1997-2004)											180.000	0.005	180.000	0.004	180.000	0.003	180.000	0.004	180.000	0.005		
	z95 for RKF selectivity (males, 2005+)																					180.000	0.000
pS1[24]	z50 for RKF selectivity (males, 2005+)	150.000	0.000	150.000	0.000	150.000	0.000	150.000	0.000	150.000	0.000												
	z95 for RKF selectivity (females, pre-1997)																					127.111	51.645
	z95 for RKF selectivity (males, 2005+)											180.000	0.000	180.000	0.000	180.000	0.000	180.000	0.000	180.000	0.000		
pS1[25]	z50 for RKF selectivity (females, pre-1997)	102.478	19.812	102.608	21.065	150.000	0.778	104.616	24.462	105.074	25.856												
	z95 for RKF selectivity (females, 1997-2004)																					129.948	75.615
	z95 for RKF selectivity (females, pre-1997)											121.737	39.674	121.317	32.216	121.035	35.810	121.667	38.349	121.572	37.669		
pS1[26]	z50 for RKF selectivity (females, 1997-2004)	100.499	30.591	99.506	27.706	136.283	27.584	103.008	36.531	103.466	37.689												
	z95 for RKF selectivity (females, 1997-2004)											120.537	51.375	123.746	59.046	121.926	56.991	121.105	53.411	121.215	53.484		
	z95 for RKF selectivity (females, 2005+)																					140.000	0.031
pS1[27]	z50 for RKF selectivity (females, 2005+)	169.998	21.907	168.564	1195.400	149.599	37.115	169.998	17.533	169.999	14.765												
	z95 for RKF selectivity (females, 2005+)											140.000	0.035	140.000	0.033	140.000	0.035	140.000	0.035	140.000	0.034		
pS2[21]	ln(z95-z50) for RKF selectivity (males, pre-1997)																					3.063	0.158
pS2[22]	ln(z95-z50) for RKF selectivity (males, 1997-2004)																					3.535	0.082
	ln(z95-z50) for RKF selectivity (males, pre-1997)											3.069	0.169	3.044	0.158	3.088	0.155	3.075	0.161	3.077	0.162		
	slope for RKF selectivity (males, pre-1997)	0.134	0.023	0.130	0.022	0.134	0.023	0.135	0.023	0.136	0.023												
pS2[23]	ln(z95-z50) for RKF selectivity (males, 1997-2004)											3.551	0.085	3.519	0.081	3.522	0.088	3.546	0.086	3.552	0.085		
	ln(z95-z50) for RKF selectivity (males, 2005+)																					3.462	0.043
	slope for RKF selectivity (males, 1997-2004)	0.078	0.010	0.077	0.010	0.078	0.010	0.079	0.010	0.079	0.010												
pS2[24]	ln(z95-z50) for RKF selectivity (males, 2005+)											3.483	0.044	3.439	0.042	3.474	0.044	3.482	0.044	3.487	0.044		
	ln(z95-z50) for RKF selectivity (males, pre-1997)																					2.823	0.648
	slope for RKF selectivity (males, 2005+)	0.082	0.005	0.087	0.006	0.082	0.005	0.083	0.005	0.083	0.005												
pS2[25]	ln(z95-z50) for RKF selectivity (males, 1997-2004)																					2.901	0.766
	ln(z95-z50) for RKF selectivity (males, pre-1997)											2.787	0.710	2.763	0.596	2.780	0.673	2.786	0.691	2.785	0.684		
	slope for RKF selectivity (males, pre-1997)	0.191	0.127	0.189	0.131	0.140	0.035	0.185	0.123	0.183	0.123												
pS2[26]	ln(z95-z50) for RKF selectivity (males, 1997-2004)											2.840	0.901	2.861	0.860	2.856	0.919	2.848	0.907	2.849	0.903		
	ln(z95-z50) for RKF selectivity (males, 2005+)																					2.923	0.219
	slope for RKF selectivity (males, 1997-2004)	0.178	0.168	0.180	0.169	0.143	0.067	0.173	0.157	0.172	0.155												
pS2[27]	ln(z95-z50) for RKF selectivity (males, 2005+)											2.996	0.221	2.964	0.218	2.997	0.221	2.994	0.221	2.991	0.220		

Table 24. Comparison of selectivity parameter estimates for the groundfish fisheries (GTF) for all model scenarios.

name	label	B0 estimate	B0 std dev	B0.2016 estimate	B0.2016 std dev	B0a estimate	B0a std dev	B1 estimate	B1 std dev	B1a estimate	B1a std dev	B1b estimate	B1b std dev	B1c estimate	B1c std dev	B2 estimate	B2 std dev	B2a estimate	B2a std dev	B2b estimate	B2b std dev	B3 estimate	B3 std dev
pS1[16]	z50 for GTF.AllGear selectivity (males, pre-1987)	52.831	1.705	53.794	1.790	53.042	1.713	54.744	1.799	55.004	1.866	55.046	1.869	60.207	2.298	54.861	1.858	54.944	1.866	55.031	1.860		
pS1[17]	z50 for GTF.AllGear selectivity (males, 1987-1996)	55.438	4.290	63.424	4.938	57.091	4.231	58.583	4.765	59.379	4.803	59.489	4.816	68.237	6.753	58.641	4.989	59.152	4.851	59.085	4.852		
pS1[18]	z50 for GTF.AllGear selectivity (males, 1997+)	76.946	2.098	84.281	2.054	76.855	2.099	80.422	2.168	80.469	2.171	80.580	2.176	90.127	2.424	80.341	2.184	80.680	2.179	80.844	2.175		
pS1[19]	z50 for GTF.AllGear selectivity (males, pre-1987)	41.148	1.523	40.508	1.474	40.000	0.001	41.375	1.605	41.119	1.652	41.124	1.652	41.841	1.846	41.285	1.650	41.117	1.653	41.203	1.661		
pS1[20]	z50 for GTF.AllGear selectivity (males, 1987-1996)	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000	40.000	0.000		
pS1[21]	z50 for GTF.AllGear selectivity (males, 1997+)	73.988	2.537	79.375	2.400	74.106	2.562	75.732	2.529	75.678	2.537	75.726	2.538	80.092	2.739	75.784	2.548	75.927	2.536	76.110	2.531		
pS1[28]	z50 for GTF.AllGear selectivity (males, 1987-1990)																					108.386	46.454
pS1[29]	z50 for GTF.AllGear selectivity (females, pre-1987)																					40.000	0.018
pS1[30]	z50 for GTF.AllGear selectivity (females, 1987-1990)																					40.000	0.001
pS1[31]	ascending z50 for GTF.FixedGear selectivity (males, 1991-1996)																					122.263	33.741
pS1[32]	ascending z50 for GTF.FixedGear selectivity (males, 1997+)																					107.186	2.918
pS1[33]	z50 for GTF.FixedGear selectivity (females, 1991-1996)																					120.000	0.013
pS1[34]	z50 for GTF.FixedGear selectivity (females, 1997+)																					113.339	23.647
pS1[35]	z50 for GTF.TrawlGear selectivity (males, 1991-1996)																					59.061	6.722
pS1[36]	z50 for GTF.TrawlGear selectivity (males, 1997+)																					77.121	11.625
pS1[37]	z50 for GTF.TrawlGear selectivity (females, 1991-1996)																					35.869	21.336
pS1[38]	z50 for GTF.TrawlGear selectivity (females, 1997+)																					61.404	8.036
pS2[16]	slope for GTF.AllGear selectivity (males, pre-1987)	0.110	0.011	0.106	0.010	0.110	0.010	0.104	0.010	0.104	0.010	0.104	0.010	0.086	0.008	0.104	0.010	0.104	0.010	0.104	0.010		
pS2[17]	slope for GTF.AllGear selectivity (males, 1987-1996)	0.066	0.015	0.050	0.009	0.064	0.013	0.057	0.012	0.057	0.012	0.057	0.012	0.039	0.007	0.056	0.012	0.057	0.012	0.057	0.012		
pS2[18]	slope for GTF.AllGear selectivity (males, 1997+)	0.077	0.005	0.074	0.004	0.077	0.005	0.074	0.004	0.074	0.004	0.074	0.004	0.065	0.003	0.074	0.004	0.074	0.004	0.074	0.004		
pS2[19]	slope for GTF.AllGear selectivity (females, pre-1987)	0.142	0.022	0.148	0.022	0.149	0.022	0.137	0.022	0.137	0.022	0.137	0.022	0.122	0.021	0.138	0.022	0.138	0.022	0.137	0.022		
pS2[20]	slope for GTF.AllGear selectivity (females, 1987-1996)	0.184	0.037	0.182	0.038	0.189	0.038	0.184	0.038	0.184	0.038	0.184	0.038	0.180	0.039	0.185	0.038	0.185	0.038	0.185	0.038		
pS2[21]	slope for GTF.AllGear selectivity (females, 1997+)	0.074	0.006	0.077	0.006	0.071	0.006	0.073	0.006	0.073	0.006	0.073	0.006	0.069	0.005	0.072	0.006	0.072	0.006	0.072	0.006		
pS2[27]	slope for GTF.AllGear selectivity (males, pre-1987)																					0.103	0.025
pS2[28]	slope for GTF.AllGear selectivity (males, 1987-1990)																					0.024	0.012
pS2[29]	slope for GTF.AllGear selectivity (males, pre-1987)																					0.163	0.072
pS2[30]	slope for GTF.AllGear selectivity (males, 1987-1990)																					0.171	0.137
pS2[31]	ascending slope for GTF.FixedGear selectivity (males, 1991-1996)																					0.067	0.055
pS2[32]	ascending slope for GTF.FixedGear selectivity (males, 1997+)																					0.148	0.029
pS2[33]	slope for GTF.FixedGear selectivity (females, 1991-1996)																					0.130	0.104
pS2[34]	slope for GTF.FixedGear selectivity (females, 1997+)																					0.121	0.032
pS2[35]	slope for GTF.TrawlGear selectivity (males, 1991-1996)																					0.080	0.053
pS2[36]	slope for GTF.TrawlGear selectivity (males, 1997+)																					0.076	0.025
pS2[37]	slope for GTF.TrawlGear selectivity (females, 1991-1996)																					0.256	121.270
pS2[38]	slope for GTF.TrawlGear selectivity (females, 1997+)																					0.105	0.039
pS3[4]	ln(dz50-az50) for GTF.FixedGear selectivity (males, 1991-1996)																					4.500	0.000
pS3[5]	ln(dz50-az50) for GTF.FixedGear selectivity (males, 1997+)																					4.225	0.320
pS4[4]	descending slope for GTF.FixedGear selectivity (males, 1991-1996)																					0.500	0.009
pS4[5]	descending slope for GTF.FixedGear selectivity (males, 1997+)																					0.100	0.000

Table 25. Objective function data components from the model scenarios. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GTF: groundfish fisheries.

category	fleet	catch.type	data.type	x	m	B0.2016	B0	B0a	B1	B1a	B1b	B1c	B2	B2a	B2b	B3
effort data	RKF	fishery		all sexes	all maturity states	434.88	528.69	529.96	543.28	543.97	556.13	562.55	594.29	570.88	565.96	539.54
effort data	SCF	fishery		all sexes	all maturity states	836.33	892.17	878.69	912.90	906.94	906.56	988.65	939.16	919.11	890.89	927.76
fisheries data	GTF.FixedGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
fisheries data	GTF.FixedGear	total catch	biomass	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
fisheries data	GTF.FixedGear	total catch	n.at.z	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.10
fisheries data	GTF.FixedGear	total catch	n.at.z	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.31
fisheries data	GTF.TrawlGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60
fisheries data	GTF.TrawlGear	total catch	biomass	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.87
fisheries data	GTF.TrawlGear	total catch	n.at.z	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.65
fisheries data	GTF.TrawlGear	total catch	n.at.z	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.62
fisheries data	GTF.AllGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	GTF.AllGear	total catch	biomass	all sexes	all maturity states	1.86	1.49	1.51	1.43	1.44	1.44	1.34	1.45	1.44	1.44	0.30
fisheries data	GTF.AllGear	total catch	n.at.z	female	all maturity states	203.93	245.57	248.45	248.62	249.53	249.54	255.59	250.57	250.73	251.57	17.95
fisheries data	GTF.AllGear	total catch	n.at.z	male	all maturity states	265.74	274.06	271.25	279.65	279.08	279.18	293.16	280.81	280.78	282.78	21.78
fisheries data	RKF	total catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	RKF	total catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	RKF	total catch	biomass	female	all maturity states	0.07	0.05	0.16	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01
fisheries data	RKF	total catch	biomass	male	all maturity states	6.76	7.09	7.07	7.22	7.24	7.50	7.56	8.04	7.83	7.71	7.28
fisheries data	RKF	total catch	n.at.z	female	all maturity states	2.01	2.73	2.82	2.71	2.71	2.76	2.77	2.75	2.75	2.75	2.74
fisheries data	RKF	total catch	n.at.z	male	all maturity states	35.83	42.46	41.84	44.39	44.19	45.25	46.43	49.58	45.76	45.99	44.61
fisheries data	SCF	total catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	SCF	total catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	SCF	total catch	biomass	female	all maturity states	23.76	23.64	23.77	24.42	24.46	24.45	26.13	24.87	25.10	25.33	25.04
fisheries data	SCF	total catch	biomass	male	all maturity states	1.64	1.81	1.82	1.75	1.75	1.75	1.66	1.68	1.72	1.74	1.65
fisheries data	SCF	total catch	n.at.z	female	all maturity states	12.37	12.45	12.41	12.26	12.25	12.25	12.19	12.16	12.26	12.34	11.60
fisheries data	SCF	total catch	n.at.z	male	all maturity states	53.43	56.62	56.29	54.39	53.95	53.94	52.38	54.12	54.10	55.32	51.39
fisheries data	TCF	retained catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	biomass	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	biomass	male	all maturity states	44.04	43.27	43.14	44.79	44.70	44.71	47.91	15.09	9.41	17.30	15.22
fisheries data	TCF	retained catch	n.at.z	male	all maturity states	262.00	266.48	266.09	268.65	268.17	268.18	262.23	81.02	74.28	65.44	59.10
fisheries data	TCF	total catch	biomass	female	all maturity states	31.84	30.59	31.01	31.66	31.75	31.78	33.68	8.12	34.83	40.07	39.17
fisheries data	TCF	total catch	biomass	male	all maturity states	15.22	14.80	14.69	15.39	15.33	15.33	16.48	3.19	3.39	5.30	4.99
fisheries data	TCF	total catch	n.at.z	female	all maturity states	9.48	9.34	9.82	9.63	9.69	9.69	9.80	9.48	9.72	9.74	9.70
fisheries data	TCF	total catch	n.at.z	male	all maturity states	91.91	89.06	90.83	87.19	87.90	87.91	82.89	75.27	75.35	87.58	87.65
growth data			EBS	female	immature	0.00	0.00	0.00	127.32	127.51	127.46	2,328.56	128.67	127.32	126.92	117.07
growth data			EBS	male	immature	0.00	0.00	0.00	191.47	191.66	191.52	3,149.25	193.56	190.55	190.59	170.57
surveys data	NMFS trawl survey	index catch	biomass	female	mature	104.26	102.50	100.92	110.36	110.17	110.23	119.80	109.26	111.17	111.33	123.93
surveys data	NMFS trawl survey	index catch	biomass	male	mature	86.54	89.91	88.17	102.17	101.81	101.82	128.05	101.47	103.00	102.19	76.44
surveys data	NMFS trawl survey	index catch	n.at.z	female	immature	288.06	290.19	271.16	253.04	247.22	247.32	221.75	250.97	249.49	249.62	252.04
surveys data	NMFS trawl survey	index catch	n.at.z	female	mature	146.01	156.32	154.81	192.97	193.75	193.99	247.37	193.42	194.55	194.06	153.10
surveys data	NMFS trawl survey	index catch	n.at.z	male	immature	226.08	245.41	254.65	195.64	199.42	199.08	171.34	206.29	198.34	201.07	235.25
surveys data	NMFS trawl survey	index catch	n.at.z	male	mature	290.89	285.97	288.70	323.54	323.83	323.55	349.45	318.19	319.58	316.34	292.66

Table 26. Differences between objective function data components from the model scenarios. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GTF: groundfish fisheries. Green highlights indicate differences smaller than -5 likelihood units. Red highlights indicate differences greater than 5 likelihood units.

category	fleet	catch.type	data.type	x	maturity	B0-B0.2016	B0a-B0	B1-B0a	B1a-B1	B1b-B1a	B1c-B1b	B2-B1b	B2a-B2	B2b-B2a	B3-B2b
effort data	RKF	fishery		all sexes	all maturity states	93.81	1.27	13.32	0.69	12.16	6.42	38.16	-23.40	-4.93	-26.42
effort data	SCF	fishery		all sexes	all maturity states	55.83	-13.48	34.21	-5.96	-0.37	82.09	32.60	-20.05	-28.22	36.87
fisheries data	GTF.FixedGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
fisheries data	GTF.FixedGear	total catch	biomass	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
fisheries data	GTF.FixedGear	total catch	n.at.z	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.10
fisheries data	GTF.FixedGear	total catch	n.at.z	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.31
fisheries data	GTF.TrawlGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60
fisheries data	GTF.TrawlGear	total catch	biomass	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.87
fisheries data	GTF.TrawlGear	total catch	n.at.z	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.65
fisheries data	GTF.TrawlGear	total catch	n.at.z	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.62
fisheries data	GTF.AllGear	total catch	abundance	all sexes	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	GTF.AllGear	total catch	biomass	all sexes	all maturity states	-0.37	0.02	-0.08	0.01	0.00	-0.10	0.01	-0.01	0.00	-1.14
fisheries data	GTF.AllGear	total catch	n.at.z	female	all maturity states	41.65	2.87	0.17	0.91	0.01	6.05	1.03	0.16	0.85	-233.63
fisheries data	GTF.AllGear	total catch	n.at.z	male	all maturity states	8.33	-2.82	8.40	-0.57	0.10	13.98	1.62	-0.03	2.00	-261.01
fisheries data	RKF	total catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	RKF	total catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	RKF	total catch	biomass	female	all maturity states	-0.02	0.11	-0.14	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.01
fisheries data	RKF	total catch	biomass	male	all maturity states	0.33	-0.02	0.15	0.02	0.26	0.06	0.54	-0.21	-0.12	-0.43
fisheries data	RKF	total catch	n.at.z	female	all maturity states	0.72	0.09	-0.11	0.00	0.04	0.01	-0.01	0.01	0.00	-0.01
fisheries data	RKF	total catch	n.at.z	male	all maturity states	6.63	-0.61	2.55	-0.21	1.06	1.18	4.33	-3.82	0.23	-1.38
fisheries data	SCF	total catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	SCF	total catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	SCF	total catch	biomass	female	all maturity states	-0.13	0.13	0.65	0.05	-0.01	1.68	0.42	0.23	0.23	-0.29
fisheries data	SCF	total catch	biomass	male	all maturity states	0.17	0.00	-0.06	0.00	0.00	-0.09	-0.06	0.04	0.02	-0.09
fisheries data	SCF	total catch	n.at.z	female	all maturity states	0.08	-0.04	-0.15	-0.01	0.00	-0.06	-0.09	0.09	0.08	-0.74
fisheries data	SCF	total catch	n.at.z	male	all maturity states	3.20	-0.33	-1.91	-0.44	-0.01	-1.56	0.17	-0.02	1.22	-3.93
fisheries data	TCF	retained catch	abundance	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	abundance	male	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	biomass	female	all maturity states	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fisheries data	TCF	retained catch	biomass	male	all maturity states	-0.78	-0.13	1.65	-0.08	0.01	3.20	-29.62	-5.69	7.89	-2.08
fisheries data	TCF	retained catch	n.at.z	male	all maturity states	4.48	-0.39	2.56	-0.48	0.01	-5.95	-187.16	-6.74	-8.85	-6.34
fisheries data	TCF	total catch	biomass	female	all maturity states	-1.25	0.42	0.65	0.10	0.03	1.90	-23.66	26.71	5.24	-0.90
fisheries data	TCF	total catch	biomass	male	all maturity states	-0.41	-0.11	0.69	-0.06	0.00	1.15	-12.14	0.20	1.91	-0.31
fisheries data	TCF	total catch	n.at.z	female	all maturity states	-0.14	0.48	-0.19	0.07	-0.01	0.12	-0.21	0.24	0.02	-0.03
fisheries data	TCF	total catch	n.at.z	male	all maturity states	-2.85	1.77	-3.65	0.72	0.00	-5.02	-12.63	0.08	12.23	0.07
growth data			EBS	female	immature	0.00	0.00	127.32	0.19	-0.05	2,201.11	1.21	-1.35	-0.40	-9.85
growth data			EBS	male	immature	0.00	0.00	191.47	0.19	-0.13	2,957.73	2.04	-3.01	0.04	-20.02
surveys data	NMFS trawl survey	index catch	biomass	female	mature	-1.76	-1.58	9.44	-0.19	0.06	9.56	-0.97	1.91	0.16	12.60
surveys data	NMFS trawl survey	index catch	biomass	male	mature	3.36	-1.74	14.00	-0.36	0.01	26.23	-0.35	1.53	-0.80	-25.75
surveys data	NMFS trawl survey	index catch	n.at.z	female	immature	2.13	-19.03	-18.12	-5.83	0.10	-25.57	3.66	-1.48	0.13	2.42
surveys data	NMFS trawl survey	index catch	n.at.z	female	mature	10.30	-1.50	38.16	0.78	0.24	53.38	-0.56	1.13	-0.50	-40.96
surveys data	NMFS trawl survey	index catch	n.at.z	male	immature	19.33	9.24	-59.01	3.78	-0.34	-27.74	7.20	-7.95	2.73	34.18
surveys data	NMFS trawl survey	index catch	n.at.z	male	mature	-4.92	2.73	34.84	0.29	-0.29	25.90	-5.36	1.39	-3.24	-23.68

Table 27. Effective sample sizes used for NMFS EBS trawl survey size composition data for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

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Table 28. Effective sample sizes used for retained catch size composition data from the directed fishery for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

year	2016AM		Model B2b	
	input	effective	input	effective
1980	97.8	20.2	97.8	26.0
1981	83.1	805.1	83.1	1690.2
1982	99.3	1622.3	99.3	1469.8
1983	12.3	50.3	12.3	48.9
1984	18.7	342.1	18.7	476.3
1988	91.0	141.1	91.0	134.8
1989	30.3	1042.2	30.3	1665.1
1990	200.0	263.6	200.0	267.8
1991	200.0	20.7	200.0	154.8
1992	200.0	17.8	200.0	96.0
1993	200.0	23.2	200.0	138.2
1994	200.0	47.8	200.0	149.2
1995	11.2	15.5	11.2	186.9
1996	32.6	12.6	32.6	185.5
2005	5.2	6.6	5.2	14.2
2006	21.6	15.0	21.6	303.6
2007	51.0	17.0	51.0	1927.1
2008	25.6	19.3	25.6	967.2
2009	17.8	70.6	17.8	128.0
2013	35.0	141.1	35.0	705.1
2014	103.3	34.5	103.3	209.2
2015	200.0	39.3	200.0	157.8

Table 29. Effective sample sizes used for total catch size composition data from the directed fishery for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

year	2016AM				Model B2b			
	female		male		female		male	
	input	effective	input	effective	input	effective	input	effective
1991	41.2	322.9	200.0	12.0	41.2	512.9	200.0	1325.1
1992	64.3	940.8	200.0	13.3	64.3	459.3	200.0	120.2
1993	76.9	296.2	200.0	12.9	76.9	346.3	200.0	266.9
1994	15.7	78.7	42.6	10.9	15.7	58.5	42.6	592.5
1995	22.9	152.1	41.1	80.8	22.9	90.4	41.1	298.0
1996	2.5	149.0	5.0	37.2	2.5	261.0	5.0	30.9
2005	8.1	34.3	144.9	7.8	8.1	39.4	144.9	97.5
2006	32.6	279.0	178.0	65.0	32.6	422.5	178.0	287.6
2007	24.4	310.7	200.0	10.2	24.4	317.5	200.0	374.4
2008	4.7	41.7	200.0	13.8	4.7	45.8	200.0	1150.1
2009	1.1	28.2	127.0	10.9	1.1	24.4	127.0	164.7
2013	5.2	82.1	127.0	15.7	5.2	64.7	127.0	1339.7
2014	8.8	208.1	200.0	7.6	8.8	188.6	200.0	199.5
2015	11.9	69.6	200.0	6.1	11.9	73.0	200.0	127.6

Table 30. Effective sample sizes used for bycatch size composition data from the snow crab fishery for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

year	2016AM				Model B2b			
	female		male		female		male	
	input	effective	input	effective	input	effective	input	effective
1992	6.3	16.5	46.1	185.3	6.3	18.3	46.1	191.7
1993	11.3	27.4	51.2	170.8	11.3	30.7	51.2	118.1
1994	11.2	49.6	21.9	42.6	11.2	40.7	21.9	38.1
1995	3.1	38.1	13.9	122.2	3.1	41.8	13.9	87.3
1996	4.9	36.2	24.0	290.7	4.9	46.1	24.0	281.4
1997	4.8	134.6	29.2	345.9	4.8	111.2	29.2	446.9
1998	2.4	19.5	14.0	617.1	2.4	21.4	14.0	1013.9
1999	0.6	27.6	7.2	134.1	0.6	30.2	7.2	131.6
2000	0.5	29.9	9.1	224.8	0.5	30.5	9.1	273.2
2001	1.2	139.0	22.9	1123.1	1.2	121.1	22.9	558.4
2002	0.9	45.2	7.2	61.9	0.9	45.4	7.2	59.5
2003	1.1	43.8	5.1	102.8	1.1	44.8	5.1	109.2
2004	5.2	30.1	6.2	24.5	5.2	30.6	6.2	23.0
2005	2.7	95.1	72.0	127.4	2.7	158.0	72.0	122.6
2006	9.2	33.6	76.4	86.8	9.2	51.8	76.4	77.1
2007	5.3	28.8	101.4	455.6	5.3	45.6	101.4	380.5
2008	5.3	18.4	62.1	92.9	5.3	14.7	62.1	95.9
2009	3.5	31.0	81.2	430.0	3.5	20.6	81.2	456.1
2010	1.8	87.0	88.7	339.6	1.8	74.0	88.7	370.0
2011	1.4	53.7	69.5	186.9	1.4	61.7	69.5	231.5
2012	1.4	49.1	53.9	139.7	1.4	46.5	53.9	205.9
2013	2.6	128.8	95.0	222.5	2.6	210.5	95.0	248.2
2014	5.9	118.9	182.8	525.0	5.9	65.1	182.8	537.6
2015	1.7	61.8	145.8	475.2	1.7	111.3	146.5	519.1
2016					1.7	115.7	142.8	448.6

Table 31. Effective sample sizes used for bycatch size composition data from the BBRKC fishery for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

year	2016AM				Model B2b			
	female		male		female		male	
	input	effective	input	effective	input	effective	input	effective
1992	0.8	47.2	15.1	154.7	0.8	83.0	15.1	34.6
1993	8.8	326.2	54.1	432.7	8.8	279.5	54.1	34.7
1996	0.0	3.8	0.8	60.8	0.0	3.4	0.8	13.2
1997	0.3	17.3	7.6	24.7	0.3	24.3	7.6	20.3
1998	0.1	19.3	3.4	67.2	0.1	20.9	3.4	58.3
1999	0.1	16.6	1.5	63.0	0.1	17.4	1.5	50.3
2000	0.3	37.0	6.2	190.0	0.3	40.4	6.2	130.2
2001	0.3	46.9	3.4	131.0	0.3	50.5	3.4	112.0
2002	0.4	45.9	5.5	110.4	0.4	36.4	5.5	85.5
2003	0.3	49.0	4.1	76.5	0.3	53.5	4.1	57.0
2004	0.3	22.2	3.6	41.5	0.3	20.6	3.6	31.1
2005	0.5	8.2	7.2	38.4	0.5	12.7	7.2	37.8
2006	0.6	19.7	5.9	20.1	0.6	23.9	5.9	20.3
2007	0.7	64.9	10.3	79.0	0.7	102.1	10.3	73.0
2008	0.9	55.9	27.9	79.8	0.9	92.4	27.9	76.0
2009	0.5	119.6	24.9	21.6	0.5	108.0	24.9	20.5
2010	0.2	29.0	4.4	49.8	0.2	36.0	4.4	46.3
2011	0.0	6.4	2.5	63.8	0.0	6.0	2.5	59.8
2012	0.4	9.3	4.5	65.1	0.4	6.8	4.5	55.2
2013	0.4	14.3	15.5	83.7	0.4	9.7	15.5	94.4
2014	0.2	23.2	22.9	139.6	0.2	19.2	22.9	156.6
2015	0.2	66.4	22.9	163.2	1.3	86.7	16.1	140.0
2016					1.8	19.2	22.5	22.0

Table 32. Effective sample sizes used for bycatch size composition data from the groundfish fisheries for the 2016 assessment model (2016AM) and the author's preferred model (Model B2b). Effective sample sizes were estimated using the McAllister-Ianelli approach.

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Table 33. Comparison of fits to mature survey biomass by sex (in 1000's t) from the 2016 assessment model (2016AM) and the author's preferred model (B2b).

year	mature female biomass (Kt)			mature male biomass (Kt)		
	observed	2016AM	Model B2b	observed	2016AM	Model B2b
1975	31.4	47.8	47.6	246.0	148.1	151.1
1976	31.2	42.0	42.2	126.2	133.6	135.4
1977	38.6	35.8	36.8	111.3	105.5	108.1
1978	25.8	32.7	34.1	77.9	75.1	79.4
1979	19.3	34.7	35.8	32.6	67.0	71.2
1980	63.8	36.5	38.8	86.8	63.0	74.2
1981	42.6	31.5	35.7	50.3	53.8	65.6
1982	64.1	25.7	26.1	51.7	68.1	71.8
1983	20.4	19.2	19.9	29.9	49.1	53.0
1984	14.9	14.5	15.1	25.8	32.6	36.0
1985	5.6	11.7	12.1	11.9	23.0	24.9
1986	3.4	12.3	12.3	13.3	28.8	30.2
1987	5.1	14.3	14.0	24.6	40.7	40.8
1988	25.4	17.0	16.2	61.0	55.2	55.2
1989	19.4	19.8	18.4	93.3	70.2	68.3
1990	37.7	21.4	19.8	97.8	74.4	73.2
1991	44.8	21.2	19.7	112.6	64.8	67.4
1992	26.2	19.1	17.8	105.5	60.1	60.5
1993	11.6	15.3	14.6	62.0	45.1	46.5
1994	9.8	11.6	11.3	43.8	32.9	34.9
1995	12.4	8.6	8.6	32.7	23.9	25.7
1996	9.6	6.5	6.7	27.5	17.3	19.1
1997	3.4	5.1	5.3	11.3	13.9	15.8
1998	2.3	4.3	4.5	10.9	12.5	13.9
1999	3.8	4.0	4.1	13.0	12.4	13.3
2000	4.1	4.3	4.2	16.9	14.1	14.3
2001	4.6	4.7	4.6	18.7	17.4	17.2
2002	4.5	5.2	5.2	19.0	20.0	20.8
2003	8.4	6.0	6.1	24.6	23.7	25.1
2004	4.7	7.2	7.4	27.0	29.0	31.2
2005	11.6	8.3	8.7	45.2	36.3	38.6
2006	14.9	9.3	9.9	67.9	41.0	45.7
2007	13.4	10.6	11.1	69.5	45.4	51.3
2008	11.7	10.8	11.3	65.1	51.3	57.4
2009	8.5	9.6	10.1	38.2	50.7	57.6
2010	5.5	8.1	8.6	39.1	44.3	51.0
2011	5.4	7.7	8.0	43.3	38.8	44.4
2012	12.4	9.8	9.5	42.2	39.4	42.9
2013	17.8	13.5	12.4	67.0	53.4	53.5
2014	14.9	15.6	13.9	82.4	71.1	68.9
2015	11.2	14.6	12.9	62.9	72.2	70.0
2016	7.6	12.4	10.9	61.6	59.1	58.4
2017	7.1		9.1	50.2		50.4

Table 34. Comparison of estimates of mature biomass-at-mating by sex (in 1000's t) from the 2016 assessment model (2016AM) and the author's preferred model (B2b).

year	MMB (1000's t)		MFB (1000's t)	
	2016AM	Model B2b	2016AM	Model B2b
1949	0.0	0.0	0.0	0.0
1950	0.0	0.0	0.0	0.0
1951	0.1	0.1	0.3	0.2
1952	1.2	0.8	1.1	0.8
1953	4.1	3.1	2.2	1.8
1954	7.8	6.6	3.2	2.9
1955	10.6	9.7	4.0	3.7
1956	12.7	12.1	4.5	4.3
1957	14.4	14.0	5.0	4.8
1958	15.8	15.6	5.3	5.2
1959	17.0	17.0	5.7	5.7
1960	18.2	18.4	6.2	6.2
1961	19.7	20.1	6.7	6.8
1962	21.8	22.4	7.7	7.9
1963	25.4	26.3	9.5	10.1
1964	32.5	34.2	13.9	15.1
1965	47.5	50.6	24.3	25.9
1966	84.2	87.8	43.7	45.1
1967	136.5	139.7	68.6	69.3
1968	200.1	203.2	89.0	89.9
1969	235.6	242.7	98.4	101.0
1970	244.9	258.2	98.9	103.7
1971	240.8	259.6	96.4	102.5
1972	236.2	257.6	93.9	101.2
1973	235.9	254.3	92.7	99.1
1974	229.8	242.0	89.4	94.6
1975	219.6	227.0	83.0	87.7
1976	179.3	186.3	71.8	77.6
1977	119.0	129.8	60.0	67.5
1978	81.1	95.7	55.3	62.8
1979	54.7	74.5	57.4	65.3
1980	44.9	70.2	56.0	67.0
1981	56.6	75.0	49.7	61.9
1982	54.9	70.1	40.5	51.2
1983	41.0	53.4	30.8	39.2
1984	25.7	34.6	23.1	29.5
1985	26.2	32.6	20.0	25.3

year	MMB (1000's t)		MFB (1000's t)	
	2016AM	Model B2b	2016AM	Model B2b
1986	32.6	39.3	20.6	25.7
1987	44.4	51.5	23.8	29.3
1988	58.5	68.3	28.5	33.9
1989	63.3	74.4	32.6	38.2
1990	54.3	68.6	34.3	40.6
1991	52.5	65.9	34.0	40.2
1992	45.2	56.6	30.6	36.0
1993	39.5	48.8	25.0	29.7
1994	31.4	39.4	19.0	23.2
1995	23.1	29.7	14.2	17.7
1996	18.1	23.9	10.8	13.7
1997	15.2	20.1	8.5	11.0
1998	13.9	17.7	7.3	9.3
1999	14.3	17.5	6.9	8.6
2000	16.3	19.1	7.3	8.9
2001	19.8	22.8	7.9	9.7
2002	23.1	27.8	8.8	11.0
2003	27.7	33.8	10.2	12.9
2004	33.8	41.9	12.4	15.6
2005	41.6	51.2	14.4	18.3
2006	46.3	59.8	16.0	20.8
2007	51.3	67.0	18.2	23.3
2008	58.9	75.9	18.5	23.7
2009	58.5	76.5	16.4	21.2
2010	51.7	68.3	13.9	18.0
2011	45.2	59.1	13.3	16.8
2012	46.2	57.8	17.0	20.1
2013	61.2	70.6	23.4	26.1
2014	75.4	84.8	26.7	29.2
2015	73.9	83.8	24.9	27.1
2016	--	78.0	--	22.9

Table 35. Estimated population size (thousands) for females on July 1 of year. from the author’s preferred model, Model B2b.

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
1949	4.34E+00	9.75E+00	7.28E+00	3.92E+00	1.80E+00	7.51E-01	2.94E-01	1.10E-01	3.99E-02	1.41E-02	4.87E-03	1.66E-03	5.55E-04	1.84E-04	6.01E-05	1.95E-05
1950	4.35E+00	1.05E+01	1.05E+01	9.73E+00	7.14E+00	4.34E+00	2.31E+00	1.12E+00	5.06E-01	2.15E-01	8.72E-02	3.42E-02	1.30E-02	4.77E-03	1.72E-03	6.05E-04
1951	4.39E+00	1.06E+01	1.06E+01	1.03E+01	9.01E+00	7.71E+00	6.16E+00	4.36E+00	2.75E+00	1.57E+00	7.95E-01	3.51E-01	1.33E-01	4.53E-02	1.50E-02	4.60E-03
1952	4.45E+00	1.07E+01	1.07E+01	1.05E+01	9.14E+00	8.08E+00	7.13E+00	6.26E+00	5.50E+00	4.51E+00	3.12E+00	1.78E+00	8.30E-01	3.36E-01	1.26E-01	3.95E-02
1953	4.55E+00	1.10E+01	1.10E+01	1.06E+01	9.28E+00	8.18E+00	7.24E+00	6.54E+00	6.38E+00	6.39E+00	5.48E+00	3.86E+00	2.30E+00	1.20E+00	5.61E-01	2.08E-01
1954	4.71E+00	1.14E+01	1.13E+01	1.09E+01	9.49E+00	8.34E+00	7.37E+00	6.70E+00	6.83E+00	7.47E+00	6.96E+00	5.30E+00	3.58E+00	2.19E+00	1.21E+00	5.17E-01
1955	4.95E+00	1.19E+01	1.18E+01	1.14E+01	9.83E+00	8.59E+00	7.57E+00	6.89E+00	7.21E+00	8.28E+00	8.04E+00	6.32E+00	4.50E+00	2.95E+00	1.74E+00	7.98E-01
1956	5.33E+00	1.28E+01	1.26E+01	1.21E+01	1.04E+01	8.99E+00	7.87E+00	7.16E+00	7.59E+00	8.97E+00	8.90E+00	7.11E+00	5.19E+00	3.52E+00	2.14E+00	1.01E+00
1957	5.94E+00	1.43E+01	1.40E+01	1.31E+01	1.12E+01	9.61E+00	8.34E+00	7.55E+00	8.03E+00	9.61E+00	9.64E+00	7.76E+00	5.75E+00	3.96E+00	2.45E+00	1.17E+00
1958	6.98E+00	1.67E+01	1.62E+01	1.50E+01	1.25E+01	1.06E+01	9.09E+00	8.14E+00	8.60E+00	1.03E+01	1.04E+01	8.37E+00	6.24E+00	4.34E+00	2.70E+00	1.30E+00
1959	8.93E+00	2.13E+01	2.02E+01	1.82E+01	1.49E+01	1.23E+01	1.03E+01	9.08E+00	9.43E+00	1.12E+01	1.12E+01	9.02E+00	6.72E+00	4.69E+00	2.93E+00	1.41E+00
1960	1.32E+01	3.12E+01	2.88E+01	2.48E+01	1.95E+01	1.55E+01	1.26E+01	1.07E+01	1.08E+01	1.24E+01	1.23E+01	9.84E+00	7.29E+00	5.07E+00	3.16E+00	1.53E+00
1961	2.44E+01	5.72E+01	5.08E+01	4.09E+01	3.03E+01	2.26E+01	1.73E+01	1.40E+01	1.32E+01	1.45E+01	1.40E+01	1.10E+01	8.07E+00	5.56E+00	3.44E+00	1.66E+00
1962	5.51E+01	1.28E+02	1.11E+02	8.42E+01	5.86E+01	4.06E+01	2.88E+01	2.15E+01	1.85E+01	1.86E+01	1.70E+01	1.30E+01	9.30E+00	6.29E+00	3.85E+00	1.84E+00
1963	1.07E+02	2.51E+02	2.21E+02	1.74E+02	1.23E+02	8.40E+01	5.75E+01	4.03E+01	3.13E+01	2.79E+01	2.35E+01	1.71E+01	1.17E+01	7.58E+00	4.53E+00	2.13E+00
1964	1.28E+02	3.05E+02	2.94E+02	2.66E+02	2.09E+02	1.55E+02	1.13E+02	8.10E+01	6.12E+01	5.01E+01	3.90E+01	2.66E+01	1.69E+01	1.03E+01	5.90E+00	2.69E+00
1965	1.07E+02	2.62E+02	2.75E+02	2.81E+02	2.48E+02	2.11E+02	1.74E+02	1.38E+02	1.12E+02	9.44E+01	7.26E+01	4.81E+01	2.91E+01	1.67E+01	9.03E+00	3.95E+00
1966	8.38E+01	2.07E+02	2.21E+02	2.36E+02	2.22E+02	2.10E+02	1.92E+02	1.72E+02	1.61E+02	1.52E+02	1.25E+02	8.65E+01	5.30E+01	3.02E+01	1.60E+01	6.80E+00
1967	7.22E+01	1.77E+02	1.84E+02	1.91E+02	1.80E+02	1.74E+02	1.67E+02	1.64E+02	1.74E+02	1.90E+02	1.75E+02	1.30E+02	8.56E+01	5.14E+01	2.81E+01	1.22E+01
1968	7.18E+01	1.74E+02	1.75E+02	1.72E+02	1.56E+02	1.45E+02	1.37E+02	1.37E+02	1.59E+02	1.97E+02	1.98E+02	1.58E+02	1.12E+02	7.28E+01	4.23E+01	1.91E+01
1969	7.78E+01	1.87E+02	1.84E+02	1.76E+02	1.52E+02	1.35E+02	1.22E+02	1.19E+02	1.41E+02	1.87E+02	1.98E+02	1.64E+02	1.24E+02	8.58E+01	5.26E+01	2.48E+01
1970	7.54E+01	1.83E+02	1.85E+02	1.82E+02	1.58E+02	1.38E+02	1.22E+02	1.14E+02	1.33E+02	1.78E+02	1.91E+02	1.61E+02	1.24E+02	8.93E+01	5.65E+01	2.74E+01
1971	6.40E+01	1.57E+02	1.64E+02	1.69E+02	1.53E+02	1.39E+02	1.25E+02	1.17E+02	1.33E+02	1.75E+02	1.86E+02	1.56E+02	1.21E+02	8.81E+01	5.64E+01	2.77E+01
1972	4.24E+01	1.06E+02	1.19E+02	1.34E+02	1.29E+02	1.24E+02	1.17E+02	1.14E+02	1.34E+02	1.76E+02	1.86E+02	1.55E+02	1.20E+02	8.64E+01	5.53E+01	2.72E+01
1973	2.76E+01	6.92E+01	7.83E+01	9.00E+01	9.18E+01	9.50E+01	9.58E+01	9.95E+01	1.24E+02	1.71E+02	1.83E+02	1.54E+02	1.19E+02	8.58E+01	5.47E+01	2.68E+01
1974	2.43E+01	5.93E+01	6.16E+01	6.43E+01	6.27E+01	6.43E+01	6.66E+01	7.42E+01	1.03E+02	1.53E+02	1.71E+02	1.46E+02	1.15E+02	8.38E+01	5.37E+01	2.64E+01
1975	4.79E+01	1.12E+02	9.86E+01	7.93E+01	6.18E+01	5.25E+01	4.87E+01	5.27E+01	7.84E+01	1.27E+02	1.48E+02	1.30E+02	1.05E+02	7.83E+01	5.09E+01	2.52E+01
1976	9.53E+01	2.22E+02	1.95E+02	1.53E+02	1.09E+02	7.68E+01	5.68E+01	4.95E+01	6.55E+01	1.05E+02	1.25E+02	1.11E+02	9.18E+01	7.01E+01	4.64E+01	2.33E+01
1977	7.33E+01	1.81E+02	1.93E+02	2.00E+02	1.68E+02	1.30E+02	9.75E+01	7.52E+01	7.54E+01	9.98E+01	1.10E+02	9.56E+01	7.86E+01	6.03E+01	4.02E+01	2.03E+01
1978	3.23E+01	8.50E+01	1.09E+02	1.40E+02	1.45E+02	1.43E+02	1.31E+02	1.14E+02	1.09E+02	1.20E+02	1.17E+02	9.40E+01	7.23E+01	5.31E+01	3.45E+01	1.72E+01
1979	1.36E+01	3.61E+01	4.77E+01	6.52E+01	7.78E+01	9.28E+01	1.02E+02	1.09E+02	1.25E+02	1.47E+02	1.42E+02	1.10E+02	7.88E+01	5.35E+01	3.27E+01	1.56E+01
1980	8.34E+00	2.11E+01	2.45E+01	3.00E+01	3.49E+01	4.31E+01	5.25E+01	6.69E+01	9.71E+01	1.39E+02	1.49E+02	1.23E+02	9.02E+01	6.02E+01	3.54E+01	1.62E+01
1981	1.36E+01	3.21E+01	2.92E+01	2.53E+01	2.21E+01	2.22E+01	2.49E+01	3.31E+01	5.82E+01	1.00E+02	1.19E+02	1.05E+02	8.31E+01	5.90E+01	3.63E+01	1.70E+01
1982	7.71E+00	1.97E+01	2.30E+01	2.63E+01	2.37E+01	2.01E+01	1.78E+01	2.00E+01	3.59E+01	6.79E+01	8.53E+01	7.84E+01	6.60E+01	5.03E+01	3.29E+01	1.63E+01
1983	3.75E+01	8.55E+01	6.87E+01	4.60E+01	3.09E+01	2.41E+01	2.04E+01	1.95E+01	2.83E+01	4.95E+01	6.14E+01	5.64E+01	4.86E+01	3.85E+01	2.62E+01	1.34E+01
1984	3.09E+01	7.57E+01	7.93E+01	7.90E+01	6.23E+01	4.33E+01	2.96E+01	2.32E+01	2.73E+01	4.11E+01	4.80E+01	4.28E+01	3.62E+01	2.86E+01	1.96E+01	1.01E+01
1985	4.15E+01	9.86E+01	9.29E+01	8.37E+01	7.12E+01	6.23E+01	5.22E+01	4.13E+01	3.66E+01	4.11E+01	4.23E+01	3.57E+01	2.89E+01	2.22E+01	1.49E+01	7.65E+00
1986	4.01E+01	9.72E+01	9.82E+01	9.58E+01	8.13E+01	6.79E+01	5.77E+01	5.14E+01	5.15E+01	5.56E+01	5.19E+01	4.00E+01	2.93E+01	2.09E+01	1.35E+01	6.78E+00
1987	3.98E+01	9.63E+01	9.68E+01	9.51E+01	8.39E+01	7.45E+01	6.53E+01	5.76E+01	5.77E+01	6.47E+01	6.25E+01	4.91E+01	3.52E+01	2.37E+01	1.44E+01	6.87E+00
1988	2.72E+01	6.80E+01	7.54E+01	8.31E+01	7.79E+01	7.18E+01	6.54E+01	6.08E+01	6.42E+01	7.38E+01	7.16E+01	5.64E+01	4.08E+01	2.77E+01	1.69E+01	7.99E+00
1989	1.31E+01	3.40E+01	4.25E+01	5.35E+01	5.64E+01	5.86E+01	5.81E+01	5.74E+01	6.46E+01	7.88E+01	7.91E+01	6.35E+01	4.65E+01	3.17E+01	1.94E+01	9.21E+00
1990	4.01E+00	1.12E+01	1.68E+01	2.48E+01	2.99E+01	3.56E+01	3.97E+01	4.46E+01	5.75E+01	7.73E+01	8.13E+01	6.69E+01	5.03E+01	3.49E+01	2.16E+01	1.03E+01
1991	3.20E+00	7.88E+00	8.54E+00	1.00E+01	1.22E+01	1.61E+01	2.02E+01	2.66E+01	4.20E+01	6.61E+01	7.49E+01	6.43E+01	5.02E+01	3.59E+01	2.26E+01	1.09E+01
1992	2.84E+00	6.92E+00	7.17E+00	7.38E+00	7.00E+00	7.24E+00	8.53E+00	1.28E+01	2.63E+01	4.96E+01	6.09E+01	5.47E+01	4.49E+01	3.36E+01	2.18E+01	1.07E+01
1993	2.84E+00	6.87E+00	6.89E+00	6.78E+00	6.08E+00	5.63E+00	5.52E+00	7.32E+00	1.67E+01	3.52E+01	4.53E+01	4.19E+01	3.59E+01	2.79E+01	1.86E+01	9.31E+00
1994	3.74E+00	8.90E+00	8.40E+00	7.55E+00	6.29E+00	5.44E+00	4.98E+00	5.95E+00	1.26E+01	2.62E+01	3.37E+01	3.12E+01	2.72E+01	2.17E+01	1.47E+01	7.48E+00
1995	4.79E+00	1.14E+01	1.08E+01	9.70E+00	7.82E+00	6.32E+00	5.33E+00	5.61E+00	1.03E+01	2.04E+01	2.59E+01	2.37E+01	2.06E+01	1.64E+01	1.12E+01	5.72E+00
1996	4.41E+00	1.07E+01	1.10E+01	1.09E+01	9.33E+00	7.80E+00	6.53E+00	6.21E+00	9.37E+00	1.67E+01	2.05E+01	1.85E+01	1.58E+01	1.26E+01	8.51E+00	4.35E+00
1997	1.28E+01	2.96E+01	2.48E+01	1.81E+01	1.28E+01	9.80E+00	8.00E+00	7.28E+00	9.41E+00	1.48E+01	1.72E+01	1.51E+01	1.27E+01	9.90E+00	6.64E+00	3.37E+00
1998	5.14E+00	1.37E+01	1.81E+01	2.24E+01	1.98E+01	1.53E+01	1.13E+01	9.18E+00	1.02E+01	1.41E+01	1.56E+01	1.33E+01	1.08E+01	8.18E+00	5.39E+00	2.71E+00
1999	1.72E+01	3.96E+01	3.29E+01	2.41E+01	1.90E+01	1.75E+01	1.60E+01	1.38E+01	1.34E+01	1.55E+01	1.56E+01	1.27E+01	9.85E+00	7.23E+00	4.67E+00	2.31E+00
2000	8.96E+00	2.31E+01	2.77E+01	3.18E+01	2.72E+01	2.07E+01	1.61E+01	1.43E+01	1.57E+01	1.86E+01	1.81E+01	1.41E+01	1.03E+01	7.13E+00	4.45E+00	2.16E+00
2001	2.93E+01	6.73E+01	5.60E+01	4.07E+01	3.06E+01	2.62E+01	2.27E+01	1.90E+01	1.78E+01	2.00E+01	1.97E+01	1.58E+01	1.17E+01	7.95E+00	4.83E+00	2.28E+00
2002	9.42E+00	2.62E+01	3.74E+01	4.89E+01	4.40E+01	3.41E+01	2.61E+01	2.20E+01	2.23E+01	2.47E+01	2.33E+01	1.79E+01	1.29E+01	8.75E+00	5.38E+00	2.56E+00
2003	2.83E+01	6.52E+01	5.49E+01	4.20E+01	3.59E+01	3.61E+01	3.44E+01	3.00E+01	2.78E+01	2.92E+01	2.75E+01	2.14E+01	1.54E+01	1.03E+01	6.18E+00	2.90E+00
2004	2.76E+01	6.68E+01	6.71E+01	6.40E+01	5.07E+01	3.76E+01	2.99E+01	2.82E+01	3.16E+01	3.66E+01	3.45E+01	2.63E+01	1.84E+01	1.22E+01	7.33E+00	3.45E+00
2005	7.49E+00	2.15E+01	3.32E+01	4.74E+01	4.92E+01	4.68E+01	4.08E+01	3.40E+01	3.25E+01	3.74E+01	3.76E+01	3.05E+01	2.23E+01	1.50E+01	8.97E+00	4.18E+00
2006	5.74E+00	1.42E+01	1.56E+01	1.89E+01	2.37E+01	3.06E+01	3.47E+01	3.62E+01	3.97E+01	4.52E+01	4.31E+01	3.35E+01	2.44E+01	1.68E+01	1.04E+01	4.98E+00
2007	4.44E+00	1.10E+01	1.18E+01	1.27E+01	1.25E+01	1.34E+01	1.60E+01	2.14E+01	3.18E+01	4.51E+01	4.76E+01	3.88E+01	2.84E+01	1.92E+01	1.17E+01	5.55E+00
2008	6.83E+00	1.61E+01	1.48E+01	1.29E+01	1.08E+01	9.90E+00	9.64E+00	1.13E+01	1.93E+01	3.41E+01	4.11E+01	3.66E+01	2.92E+01	2.10E+01	1.32E+01	6.37E+00
2009	4.45E+01	1.01E+02	7.98E+01	5.00E+01	2.88E+01	1.72E+01	1.16E+01	1.01E+01	1.49E+01	2.63E+01	3.24E+01	2.94E+01	2.49E+01	1.93E+01	1.29E+01	6.49E+00
2010	3.94E+01	9.62E+01	9.88E+01	9.60E+01	7.41E+01	4.93E+01	3.06E+01	1.97E+01	1.79E+01	2.41E+01	2.75E+01	2.43E+01	2.05E+01	1.61E+01	1.10E+01	5.64E+00
2011	1.61E+01	4.29E+01	5.66E+01	7.31E+01	7.42E+01	7.05E+01	6.06E+01	4.69E+01	3.71E+01	3.41E+01	3.05E+01	2.37E+01	1.83E+01	1.37E+01	9.18E+00	4.71E+00
2012	3.14E+00	9.80E+00	1.77E+01	2.96E+01	3.85E+01	4.77E+01	5.25E+01	5.38E+01	5.54E+01	5.59E+01	4.79E+01	3.39E+01	2.23E+01	1.45E+01	8.81E+00	4.27E+00
2013	8.61E+00	1.99E+01	1.70E+01	1.42E+01	1.49E+01	1.95E+01	2.54E+01	3.32E+01	4.58E+01	5.99E+01	6.03E+01	4.73E+01	3.25E+01	2.04E+01	1.16E+01	5.25E+00
2014	6.45E+00	1.60E+01	1.72E+01	1.78E+01	1.48E+01	1.19E+01	1.13E+01	1.48E+01	2.68E+01	4.63E+01	5.45E+01	4.77E+01	3.69E+01	2.56E+01	1.56E+01	7.28E+00
2015	4.23E+00	1.06E+01	1.20E+01	1.36E+01	1.34E+01	1.30E+01	1.19E+01	1.17E+01	1.82E+01	3.35E+01	4.20E+01	3.86E+01	3.26E+01	2.49E+01	1.63E+01	8.11E+00
2016	5.94E+00	1.41E+01	1.32E+01	1.19E+01	1.05E+01	1.02E+01	1.02E+01	1.12E+01	1.70E+01	2.87E+01	3.43E+01	3.07E+01	2.61E+01	2.07E+01	1.41E+01	7.26E+00
2017	3.51E+01	7.99E+01	6.33E+01	4.02E+01	2.38E+01	1.48E+01	1.05E+01	9.72E+00	1.43E+01	2.45E+01	2.94E+01	2.63E+01	2.20E+01	1.71E+01	1.16E+01	5.98E+00

year	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	6.29E-06	2.01E-06	6.40E-07	2.02E-07	6.37E-08	1.99E-08	6.22E-09	1.93E-09	5.99E-10	1.85E-10	5.70E-11	1.75E-11	5.36E-12	1.64E-12	5.00E-13	1.52E-13
1950	2.09E-04	7.07E-05	2.35E-05	7.70E-06	2.48E-06	7.88E-07	2.47E-07	7.65E-08	2.34E-08	7.07E-09	2.11E-09	6.26E-10	1.83E-10	5.32E-11	1.53E-11	5.95E-12
1951	1.16E-03	2.52E-04	5.62E-05	1.47E-05	4.34E-06	1.35E-06	4.22E-07	1.31E-07	3.99E-08	1.21E-08	3.61E-09	1.07E-09	3.13E-10	9.06E-11	2.60E-11	1.02E-11
1952	9.05E-03	1.50E-03	2.08E-04	3.11E-05	6.44E-06	1.80E-06	5.52E-07	1.70E-07	5.21E-08	1.57E-08	4.70E-09	1.39E-09	4.07E-10	1.18E-10	3.39E-11	1.32E-11
1953	5.32E-02	9.34E-03	1.22E-03	1.32E-04	1.41E-05	2.41E-06	6.57E-07	2.00E-07	6.12E-08	1.85E-08	5.53E-09	1.63E-09	4.78E-10	1.39E-10	3.98E-11	1.55E-11
1954	1.52E-01	3.04E-02	4.49E-03	5.02E-04	4.26E-05	4.00E-06	7.78E-07	2.25E-07	6.84E-08	2.07E-08	6.18E-09	1.83E-09	5.35E-10	1.55E-10	4.45E-11	1.74E-11
1955	2.51E-01	5.46E-02	8.81E-03	1.06E-03	8.88E-05	6.51E-06	9.19E-07	2.47E-07	7.46E-08	2.25E-08	6.73E-09	1.99E-09	5.83E-10	1.69E-10	4.85E-11	1.89E-11
1956	3.27E-01	7.35E-02	1.23E-02	1.53E-03	1.29E-04	8.73E-06	1.05E-06	2.67E-07	8.03E-08	2.43E-08	7.25E-09	2.14E-09	6.27E-10	1.82E-10	5.22E-11	2.04E-11
1957	3.84E-01	8.78E-02	1.50E-02	1.89E-03	1.59E-04	1.05E-05	1.16E-06	2.88E-07	8.65E-08	2.61E-08	7.80E-09	2.31E-09	6.76E-10	1.96E-10	5.62E-11	2.20E-11
1958	4.30E-01	9.90E-02	1.71E-02	2.16E-03	1.83E-04	1.19E-05	1.29E-06	3.15E-07	9.43E-08	2.85E-08	8.51E-09	2.52E-09	7.37E-10	2.14E-10	6.13E-11	2.39E-11
1959	4.69E-01	1.08E-01	1.88E-02	2.39E-03	2.03E-04	1.32E-05	1.44E-06	3.53E-07	1.06E-07	3.19E-08	9.53E-09	2.82E-09	8.25E-10	2.39E-10	6.87E-11	2.68E-11
1960	5.06E-01	1.17E-01	2.03E-02	2.60E-03	2.21E-04	1.47E-05	1.66E-06	4.15E-07	1.24E-07	3.76E-08	1.12E-08	3.32E-09	9.73E-10	2.82E-10	8.10E-11	3.16E-11
1961	5.49E-01	1.27E-01	2.20E-02	2.81E-03	2.42E-04	1.68E-05	2.08E-06	5.37E-07	1.62E-07	4.88E-08	1.46E-08	4.32E-09	1.27E-09	3.67E-10	1.05E-10	4.11E-11
1962	6.05E-01	1.39E-01	2.41E-02	3.08E-03	2.71E-04	2.08E-05	3.05E-06	8.29E-07	2.51E-07	7.57E-08	2.26E-08	6.70E-09	1.96E-09	5.70E-10	1.64E-10	6.37E-11
1963	6.93E-01	1.58E-01	2.72E-02	3.51E-03	3.22E-04	2.98E-05	5.52E-06	1.58E-06	4.80E-07	1.45E-07	4.33E-08	1.28E-08	3.76E-09	1.09E-09	3.14E-10	1.22E-10
1964	8.58E-01	1.92E-01	3.27E-02	4.23E-03	4.13E-04	4.67E-05	1.02E-05	3.00E-06	9.14E-07	2.76E-07	8.26E-08	2.44E-08	7.16E-09	2.08E-09	5.96E-10	2.32E-10
1965	1.22E+00	2.64E-01	4.36E-02	5.55E-03	5.48E-04	6.51E-05	1.47E-05	4.36E-06	1.33E-06	4.02E-07	1.20E-07	3.55E-08	1.04E-08	3.01E-09	8.65E-10	3.38E-10
1966	2.03E+00	4.27E-01	6.79E-02	8.31E-03	7.71E-04	8.13E-05	1.70E-05	4.98E-06	1.52E-06	4.58E-07	1.37E-07	4.05E-08	1.19E-08	3.43E-09	9.86E-10	3.85E-10
1967	3.66E+00	7.64E-01	1.20E-01	1.43E-02	1.23E-03	1.04E-04	1.79E-05	5.05E-06	1.53E-06	4.63E-07	1.38E-07	4.09E-08	1.20E-08	3.47E-09	9.96E-10	3.89E-10
1968	5.94E+00	1.28E+00	2.05E-01	2.45E-02	2.03E-03	1.42E-04	1.86E-05	4.88E-06	1.47E-06	4.44E-07	1.33E-07	3.92E-08	1.15E-08	3.33E-09	9.55E-10	3.74E-10
1969	8.01E+00	1.79E+00	2.98E-01	3.66E-02	3.03E-03	1.91E-04	1.98E-05	4.77E-06	1.43E-06	4.31E-07	1.29E-07	3.80E-08	1.11E-08	3.23E-09	9.26E-10	3.62E-10
1970	9.10E+00	2.10E+00	3.60E-01	4.54E-02	3.79E-03	2.31E-04	2.11E-05	4.79E-06	1.42E-06	4.29E-07	1.28E-07	3.79E-08	1.11E-08	3.22E-09	9.23E-10	3.61E-10
1971	9.32E+00	2.18E+00	3.82E-01	4.89E-02	4.11E-03	2.48E-04	2.15E-05	4.76E-06	1.41E-06	4.25E-07	1.27E-07	3.75E-08	1.10E-08	3.18E-09	9.14E-10	3.57E-10
1972	9.17E+00	2.16E+00	3.80E-01	4.90E-02	4.12E-03	2.47E-04	2.09E-05	4.54E-06	1.34E-06	4.05E-07	1.21E-07	3.58E-08	1.05E-08	3.03E-09	8.70E-10	3.41E-10
1973	9.01E+00	2.11E+00	3.72E-01	4.79E-02	4.02E-03	2.37E-04	1.90E-05	4.01E-06	1.18E-06	3.56E-07	1.06E-07	3.15E-08	9.20E-09	2.67E-09	7.65E-10	2.99E-10
1974	8.86E+00	2.08E+00	3.64E-01	4.68E-02	3.91E-03	2.26E-04	1.68E-05	3.36E-06	9.82E-07	2.96E-07	8.84E-08	2.61E-08	7.65E-09	2.22E-09	6.36E-10	2.49E-10
1975	8.52E+00	2.01E+00	3.53E-01	4.55E-02	3.79E-03	2.15E-04	1.49E-05	2.82E-06	8.20E-07	2.47E-07	7.38E-08	2.18E-08	6.39E-09	1.85E-09	5.31E-10	2.08E-10
1976	7.95E+00	1.89E+00	3.36E-01	4.35E-02	3.65E-03	2.09E-04	1.49E-05	2.88E-06	8.40E-07	2.53E-07	7.57E-08	2.24E-08	6.55E-09	1.90E-09	5.46E-10	2.13E-10
1977	6.99E+00	1.68E+00	3.01E-01	3.94E-02	3.35E-03	2.01E-04	1.69E-05	3.66E-06	1.08E-06	3.26E-07	9.73E-08	2.88E-08	8.42E-09	2.44E-09	7.01E-10	2.74E-10
1978	5.86E+00	1.40E+00	2.53E-01	3.32E-02	2.84E-03	1.76E-04	1.63E-05	3.71E-06	1.10E-06	3.33E-07	9.94E-08	2.94E-08	8.60E-09	2.49E-09	7.15E-10	2.80E-10
1979	5.15E+00	1.20E+00	2.13E-01	2.76E-02	2.35E-03	1.45E-04	1.33E-05	3.03E-06	9.01E-07	2.72E-07	8.12E-08	2.40E-08	7.02E-09	2.03E-09	5.83E-10	2.28E-10
1980	5.12E+00	1.14E+00	1.93E-01	2.43E-02	2.01E-03	1.19E-04	9.89E-06	2.13E-06	6.28E-07	1.89E-07	5.65E-08	1.67E-08	4.89E-09	1.42E-09	4.06E-10	1.59E-10
1981	5.47E+00	1.23E+00	2.05E-01	2.53E-02	2.06E-03	1.15E-04	7.78E-06	1.45E-06	4.20E-07	1.26E-07	3.78E-08	1.12E-08	3.27E-09	9.47E-10	2.72E-10	1.06E-10
1982	5.46E+00	1.27E+00	2.22E-01	2.81E-02	2.31E-03	1.26E-04	7.33E-06	1.18E-06	3.34E-07	1.00E-07	3.00E-08	8.87E-09	2.59E-09	7.52E-10	2.16E-10	8.44E-11
1983	4.65E+00	1.13E+00	2.04E-01	2.67E-02	2.23E-03	1.21E-04	6.49E-06	9.36E-07	2.61E-07	7.83E-08	2.34E-08	6.92E-09	2.03E-09	5.88E-10	1.69E-10	6.58E-11
1984	3.58E+00	8.84E-01	1.63E-01	2.18E-02	1.85E-03	1.05E-04	6.92E-06	1.25E-06	3.62E-07	1.09E-07	3.25E-08	9.62E-09	2.82E-09	8.17E-10	2.34E-10	9.15E-11
1985	2.69E+00	6.62E-01	1.22E-01	1.64E-02	1.41E-03	8.32E-05	6.49E-06	1.34E-06	3.92E-07	1.18E-07	3.54E-08	1.05E-08	3.06E-09	8.88E-10	2.55E-10	9.95E-11
1986	2.34E+00	5.69E-01	1.04E-01	1.39E-02	1.20E-03	7.54E-05	7.25E-06	1.68E-06	5.01E-07	1.51E-07	4.52E-08	1.34E-08	3.91E-09	1.13E-09	3.26E-10	1.27E-10
1987	2.28E+00	5.34E-01	9.49E-02	1.24E-02	1.07E-03	7.06E-05	7.74E-06	1.90E-06	5.70E-07	1.72E-07	5.14E-08	1.52E-08	4.45E-09	1.29E-09	3.70E-10	1.45E-10
1988	2.60E+00	5.93E-01	1.02E-01	1.29E-02	1.10E-03	7.26E-05	8.20E-06	2.04E-06	6.13E-07	1.85E-07	5.53E-08	1.63E-08	4.78E-09	1.39E-09	3.98E-10	1.56E-10
1989	3.01E+00	6.87E-01	1.18E-01	1.49E-02	1.25E-03	7.94E-05	8.10E-06	1.94E-06	5.79E-07	1.75E-07	5.22E-08	1.54E-08	4.51E-09	1.31E-09	3.75E-10	1.47E-10
1990	3.39E+00	7.74E-01	1.33E-01	1.67E-02	1.39E-03	8.34E-05	7.24E-06	1.60E-06	4.73E-07	1.43E-07	4.26E-08	1.26E-08	3.69E-09	1.07E-09	3.06E-10	1.20E-10
1991	3.60E+00	8.30E-01	1.43E-01	1.81E-02	1.49E-03	8.51E-05	6.08E-06	1.18E-06	3.45E-07	1.04E-07	3.11E-08	9.18E-09	2.69E-09	7.78E-10	2.23E-10	8.75E-11
1992	3.60E+00	8.40E-01	1.46E-01	1.86E-02	1.54E-03	8.51E-05	5.21E-06	8.84E-07	2.53E-07	7.61E-08	2.27E-08	6.72E-09	1.97E-09	5.69E-10	1.63E-10	6.40E-11
1993	3.18E+00	7.56E-01	1.34E-01	1.73E-02	1.44E-03	7.82E-05	4.31E-06	6.47E-07	1.81E-07	5.45E-08	1.63E-08	4.81E-09	1.41E-09	4.08E-10	1.17E-10	4.58E-11
1994	2.59E+00	6.26E-01	1.13E-01	1.49E-02	1.24E-03	6.73E-05	3.53E-06	4.94E-07	1.37E-07	4.10E-08	1.23E-08	3.62E-09	1.06E-09	3.07E-10	8.82E-11	3.45E-11
1995	2.00E+00	4.90E-01	9.00E-02	1.20E-02	1.01E-03	5.49E-05	2.92E-06	4.15E-07	1.15E-07	3.45E-08	1.03E-08	3.05E-09	8.93E-10	2.59E-10	7.42E-11	2.90E-11
1996	1.52E+00	3.73E-01	6.87E-02	9.16E-03	7.76E-04	4.27E-05	2.43E-06	3.76E-07	1.06E-07	3.18E-08	9.50E-09	2.81E-09	8.22E-10	2.38E-10	6.84E-11	2.67E-11
1997	1.17E+00	2.87E-01	5.27E-02	7.02E-03	5.95E-04	3.33E-05	2.05E-06	3.46E-07	9.90E-08	2.98E-08	8.91E-09	2.63E-09	7.71E-10	2.24E-10	6.43E-11	2.50E-11
1998	9.34E-01	2.26E-01	4.13E-02	5.49E-03	4.69E-04	2.78E-05	2.21E-06	4.61E-07	1.36E-07	4.09E-08	1.22E-08	3.61E-09	1.06E-09	3.06E-10	8.79E-11	3.44E-11
1999	7.87E-01	1.88E-01	3.40E-02	4.47E-03	3.81E-04	2.30E-05	1.94E-06	4.21E-07	1.24E-07	3.75E-08	1.12E-08	3.32E-09	9.72E-10	2.82E-10	8.10E-11	3.15E-11
2000	7.24E-01	1.71E-01	3.03E-02	3.96E-03	3.41E-04	2.24E-05	2.43E-06	5.97E-07	1.79E-07	5.40E-08	1.61E-08	4.77E-09	1.40E-09	4.04E-10	1.16E-10	4.54E-11
2001	7.46E-01	1.71E-01	2.97E-02	3.81E-03	3.26E-04	2.15E-05	2.40E-06	5.96E-07	1.79E-07	5.40E-08	1.61E-08	4.77E-09	1.40E-09	4.06E-10	1.17E-10	4.54E-11
2002	8.41E-01	1.92E-01	3.29E-02	4.18E-03	3.61E-04	2.61E-05	3.51E-06	9.28E-07	2.80E-07	8.45E-08	2.53E-08	7.47E-09	2.19E-09	6.33E-10	1.82E-10	7.11E-11
2003	9.44E-01	2.15E-01	3.70E-02	4.69E-03	4.01E-04	2.74E-05	3.32E-06	8.47E-07	2.55E-07	7.69E-08	2.30E-08	6.80E-09	1.99E-09	5.77E-10	1.66E-10	6.47E-11
2004	1.12E+00	2.54E-01	4.32E-02	5.43E-03	4.65E-04	3.28E-05	4.25E-06	1.11E-06	3.35E-07	1.01E-07	3.02E-08	8.93E-09	2.61E-09	7.58E-10	2.18E-10	8.49E-11
2005	1.35E+00	3.03E-01	5.14E-02	6.47E-03	5.53E-04	3.87E-05	4.93E-06	1.28E-06	3.86E-07	1.16E-07	3.48E-08	1.03E-08	3.01E-09	8.72E-10	2.50E-10	9.79E-11
2006	1.63E+00	3.71E-01	6.29E-02	7.86E-03	6.58E-04	4.20E-05	4.40E-06	1.07E-06	3.19E-07	9.61E-08	2.87E-08	8.49E-09	2.48E-09	7.19E-10	2.06E-10	8.08E-11
2007	1.82E+00	4.18E-01	7.20E-02	9.11E-03	7.61E-04	4.57E-05	3.98E-06	8.80E-07	2.61E-07	7.86E-08	2.35E-08	6.94E-09	2.03E-09	5.88E-10	1.69E-10	6.61E-11
2008	2.09E+00	4.77E-01	8.14E-02	1.02E-02	8.43E-04	4.84E-05	3.61E-06	7.24E-07	2.12E-07	6.39E-08	1.91E-08	5.64E-09	1.65E-09	4.78E-10	1.37E-10	5.37E-11
2009	2.21E+00	5.19E-01	9.08E-02	1.16E-02	9.57E-04	5.38E-05	3.63E-06	6.73E-07	1.95E-07	5.88E-08	1.76E-08	5.20E-09	1.52E-09	4.42E-10	1.27E-10	4.94E-11
2010	1.97E+00	4.79E-01	8.67E-02	1.14E-02	9.72E-04	6.01E-05	5.56E-06	1.27E-06	3.77E-07	1.14E-07	3.40E-08	1.00E-08	2.94E-09	8.52E-10	2.45E-10	9.55E-11
2011	1.65E+00	4.02E-01	7.36E-02	9.79E-03	8.54E-04	5.71E-05	6.43E-06	1.60E-06	4.79E-07	1.45E-07	4.32E-08	1.28E-08	3.74E-09	1.08E-09	3.11E-10	1.22E-10
2012	1.45E+00	3.46E-01	6.22E-02	8.21E-03	7.16E-04	4.87E-05	5.68E-06	1.43E-06	4.30E-07	1.30E-07	3.88E-08	1.15E-08	3.35E-09	9.71E-10	2.79E-10	1.09E-10
2013	1.66E+00	3.69E-01	6.24E-02	7.86E-03	6.63E-04	4.28E-05	4.53E-06	1.10E-06	3.29E-07	9.93E-08	2.97E-08	8.77E-09	2.57E-09	7.43E-10	2.13E-10	8.35E-11
2014	2.32E+00	5.10E-01	8.37E-02	1.02E-02	8.29E-04	4.94E-05	4.31E-06	9.57E-07	2.84E-07	8.55E-08	2.56E-08	7.55E-09	2.21E-09	6.40E-10	1.84E-10	7.19E-11
2015	2.72E+00	6.28E-01	1.08E-01	1.35E-02	1.11E-03	6.22E-05	4.31E-06	8.19E-07	2.38E-07	7.17E-08	2.14E-08	6.33E-09	1.85E-09	5.36E-10	1.54E-10	6.03E-11
2016	2.53E+00	6.11E-01	1.10E-01	1.42E-02	1.19E-03	6.57E-05	4.02E-06	6.79E-07	1.94E-07	5.84E-08	1.74E-08	5.15E-09	1.51E-09	4.37E-10	1.25E-10	4.91E-11
2017	2.10E+00	5.14E-01	9.41E-02	1.24E-02	1.05E-03	5.86E-05	3.62E-06	6.15E-07	1.76E-07	5.30E-08	1.58E-08	4.69E-09	1.37E-09	3.98E-10	1.15E-10	4.45E-11

Table 36. Estimated population size (thousands) for males on July 1 of year. from the author’s preferred mode, Model B2b.

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	4.34E+00	9.75E+00	7.28E+00	3.92E+00	1.80E+00	7.51E-01	2.94E-01	1.10E-01	3.99E-02	1.41E-02	4.87E-03	1.66E-03	5.55E-04	1.84E-04	6.01E-05	1.95E-05	6.29E-06	2.01E-06	6.40E-07	2.02E-07	6.37E-08	1.99E-08	6.22E-09	1.93E-09	5.99E-10	1.85E-10	5.70E-11	1.75E-11	5.36E-12	1.64E-12	5.00E-13	1.52E-13
1950	4.35E+00	1.10E+01	1.04E+01	9.35E+00	6.54E+00	4.11E+00	2.41E+00	1.32E+00	6.92E-01	3.52E-01	1.75E-01	8.48E-02	4.05E-02	1.90E-02	8.84E-03	4.06E-03	1.85E-03	8.36E-04	3.75E-04	1.67E-04	7.38E-05	3.25E-05	1.43E-05	6.25E-06	2.72E-06	1.17E-06	5.01E-07	2.11E-07	8.70E-08	3.47E-08	1.32E-08	9.55E-09
1951	4.39E+00	1.10E+01	1.06E+01	1.01E+01	8.13E+00	6.61E+00	5.42E+00	4.11E+00	2.92E+00	2.01E+00	1.34E+00	8.58E-01	5.36E-01	3.28E-01	1.97E-01	1.16E-01	6.73E-02	3.84E-02	2.15E-02	1.17E-02	6.25E-03	3.30E-03	1.75E-03	9.24E-04	4.77E-04	2.34E-04	1.06E-04	4.27E-05	1.46E-05	3.80E-06	6.12E-07	7.25E-08
1952	4.45E+00	1.12E+01	1.08E+01	1.02E+01	8.27E+00	6.92E+00	6.01E+00	5.07E+00	4.27E+00	3.64E+00	3.07E+00	2.49E+00	1.96E+00	1.50E+00	1.12E+00	8.17E-01	5.80E-01	4.04E-01	2.74E-01	1.81E-01	1.16E-01	7.32E-02	4.63E-02	2.91E-02	1.77E-02	1.01E-02	5.27E-03	2.44E-03	9.51E-04	2.81E-04	5.10E-05	5.87E-06
1953	4.55E+00	1.14E+01	1.10E+01	1.04E+01	8.40E+00	7.01E+00	6.10E+00	5.19E+00	4.47E+00	3.96E+00	3.55E+00	3.16E+00	2.81E+00	2.52E+00	2.23E+00	1.92E+00	1.60E+00	1.32E+00	1.06E+00	8.27E-01	6.20E-01	4.54E-01	3.31E-01	2.39E-01	1.65E-01	1.06E-01	6.25E-02	3.24E-02	1.41E-02	4.67E-03	9.68E-04	1.34E-04
1954	4.71E+00	1.18E+01	1.13E+01	1.07E+01	8.59E+00	7.16E+00	6.22E+00	5.30E+00	4.56E+00	4.07E+00	3.69E+00	3.35E+00	3.07E+00	2.90E+00	2.75E+00	2.51E+00	2.22E+00	2.02E+00	1.83E+00	1.60E+00	1.35E+00	1.10E+00	8.83E-01	7.00E-01	5.31E-01	3.75E-01	2.41E-01	1.36E-01	6.41E-02	2.31E-02	5.31E-03	8.58E-04
1955	4.95E+00	1.24E+01	1.18E+01	1.11E+01	8.91E+00	7.39E+00	6.41E+00	5.45E+00	4.69E+00	4.20E+00	3.83E+00	3.49E+00	3.25E+00	3.16E+00	3.08E+00	2.88E+00	2.59E+00	2.46E+00	2.34E+00	2.18E+00	1.94E+00	1.65E+00	1.38E+00	1.13E+00	8.90E-01	6.55E-01	4.38E-01	2.58E-01	1.27E-01	4.84E-02	1.18E-02	2.11E-03
1956	5.33E+00	1.33E+01	1.27E+01	1.18E+01	9.39E+00	7.74E+00	6.68E+00	5.66E+00	4.86E+00	4.35E+00	3.98E+00	3.65E+00	3.43E+00	3.38E+00	3.35E+00	3.17E+00	2.89E+00	2.81E+00	2.74E+00	2.63E+00	2.40E+00	2.08E+00	1.75E+00	1.45E+00	1.16E+00	8.67E-01	5.90E-01	3.53E-01	1.77E-01	6.84E-02	1.71E-02	3.18E-03
1957	5.94E+00	1.48E+01	1.40E+01	1.29E+01	1.02E+01	8.29E+00	7.11E+00	5.99E+00	5.12E+00	4.57E+00	4.18E+00	3.84E+00	3.61E+00	3.60E+00	3.61E+00	3.44E+00	3.14E+00	3.09E+00	3.07E+00	2.98E+00	2.76E+00	2.41E+00	2.05E+00	1.70E+00	1.37E+00	1.03E+00	7.03E-01	4.24E-01	2.14E-01	8.33E-02	2.10E-02	3.97E-03
1958	6.99E+00	1.73E+01	1.62E+01	1.46E+01	1.14E+01	9.18E+00	7.78E+00	6.49E+00	5.51E+00	4.89E+00	4.45E+00	4.08E+00	3.84E+00	3.84E+00	3.86E+00	3.69E+00	3.39E+00	3.35E+00	3.35E+00	3.29E+00	3.07E+00	2.69E+00	2.28E+00	1.89E+00	1.53E+00	1.15E+00	7.91E-01	4.79E-01	2.43E-01	9.48E-02	2.40E-02	4.57E-03
1959	8.94E+00	2.20E+01	2.02E+01	1.78E+01	1.36E+01	1.07E+01	8.90E+00	7.32E+00	6.14E+00	5.39E+00	4.87E+00	4.43E+00	4.16E+00	4.14E+00	4.17E+00	3.98E+00	3.65E+00	3.62E+00	3.63E+00	3.57E+00	3.34E+00	2.94E+00	2.49E+00	2.06E+00	1.67E+00	1.26E+00	8.65E-01	5.25E-01	2.66E-01	1.04E-01	2.64E-02	5.05E-03
1960	1.32E+01	3.21E+01	2.88E+01	2.43E+01	1.78E+01	1.36E+01	1.09E+01	8.79E+00	7.22E+00	6.23E+00	5.54E+00	4.99E+00	4.63E+00	4.57E+00	4.56E+00	4.34E+00	3.97E+00	3.93E+00	3.93E+00	3.87E+00	3.62E+00	3.19E+00	2.70E+00	2.23E+00	1.80E+00	1.36E+00	9.35E-01	5.67E-01	2.88E-01	1.13E-01	2.86E-02	5.48E-03
1961	2.44E+01	5.85E+01	5.08E+01	4.01E+01	2.79E+01	2.00E+01	1.53E+01	1.18E+01	9.32E+00	7.79E+00	6.76E+00	5.95E+00	5.41E+00	5.25E+00	5.17E+00	4.87E+00	4.42E+00	4.35E+00	4.33E+00	4.24E+00	3.96E+00	3.47E+00	2.93E+00	2.41E+00	1.95E+00	1.47E+00	1.01E+00	6.12E-01	3.11E-01	1.22E-01	3.08E-02	5.91E-03
1962	5.51E+01	1.31E+02	1.11E+02	8.25E+01	5.45E+01	3.66E+01	2.61E+01	1.89E+01	1.41E+01	1.12E+01	9.30E+00	7.88E+00	6.93E+00	6.49E+00	6.22E+00	5.76E+00	5.16E+00	5.00E+00	4.91E+00	4.76E+00	4.41E+00	3.85E+00	3.24E+00	2.66E+00	2.13E+00	1.61E+00	1.10E+00	6.67E-01	3.38E-01	1.32E-01	3.34E-02	6.39E-03
1963	1.07E+02	2.56E+02	2.21E+02	1.70E+02	1.14E+02	7.61E+01	5.29E+01	3.69E+01	2.64E+01	1.98E+01	1.55E+01	1.25E+01	1.04E+01	9.21E+00	8.41E+00	7.53E+00	6.58E+00	6.19E+00	5.94E+00	5.64E+00	5.15E+00	4.45E+00	3.72E+00	3.03E+00	2.42E+00	1.81E+00	1.24E+00	7.46E-01	3.77E-01	1.47E-01	3.70E-02	7.05E-03
1964	1.28E+02	3.16E+02	2.93E+02	2.59E+02	1.90E+02	1.38E+02	1.02E+02	7.42E+01	5.39E+01	4.02E+01	3.08E+01	2.39E+01	1.91E+01	1.59E+01	1.37E+01	1.17E+01	9.86E+00	8.85E+00	8.12E+00	7.43E+00	6.59E+00	5.58E+00	4.61E+00	3.71E+00	2.94E+00	2.18E+00	1.48E+00	8.84E-01	4.43E-01	1.72E-01	4.30E-02	8.11E-03
1965	1.07E+02	2.75E+02	2.75E+02	2.74E+02	2.23E+02	1.82E+02	1.51E+02	1.20E+02	9.35E+01	7.40E+01	5.91E+01	4.71E+01	3.78E+01	3.12E+01	2.62E+01	2.17E+01	1.78E+01	1.53E+01	1.34E+01	1.17E+01	9.95E+00	8.18E+00	6.61E+00	5.25E+00	4.08E+00	2.98E+00	1.99E+00	1.18E+00	5.83E-01	2.23E-01	5.51E-02	1.02E-02
1966	8.38E+01	2.17E+02	2.22E+02	2.31E+02	1.99E+02	1.77E+02	1.61E+02	1.38E+02	1.18E+02	1.02E+02	8.82E+01	7.52E+01	6.38E+01	5.51E+01	4.78E+01	4.05E+01	3.36E+01	2.88E+01	2.48E+01	2.12E+01	1.76E+01	1.41E+01	1.12E+01	8.62E+00	6.57E+00	4.70E+00	3.08E+00	1.79E+00	8.71E-01	3.27E-01	7.93E-02	1.42E-02
1967	7.22E+01	1.85E+02	1.85E+02	1.88E+02	1.62E+02	1.47E+02	1.37E+02	1.24E+02	1.12E+02	1.04E+02	9.65E+01	8.80E+01	8.03E+01	7.47E+01	6.92E+01	6.18E+01	5.36E+01	4.79E+01	4.26E+01	3.72E+01	3.14E+01	2.55E+01	2.03E+01	1.58E+01	1.21E+01	8.65E+00	5.66E+00	3.27E+00	1.59E+00	5.92E-01	1.42E-01	2.49E-02
1968	7.18E+01	1.81E+02	1.75E+02	1.69E+02	1.41E+02	1.23E+02	1.13E+02	1.02E+02	9.38E+01	8.92E+01	8.58E+01	8.18E+01	7.89E+01	7.87E+01	7.79E+01	7.33E+01	6.63E+01	6.25E+01	5.86E+01	5.34E+01	4.67E+01	3.88E+01	3.09E+01	2.36E+01	1.82E+01	1.32E+01	8.74E+00	5.10E+00	2.49E+00	9.37E-01	2.26E-01	3.94E-02
1969	7.78E+01	1.94E+02	1.84E+02	1.72E+02	1.38E+02	1.16E+02	1.03E+02	9.00E+01	8.05E+01	7.59E+01	7.31E+01	7.06E+01	6.99E+01	7.27E+01	7.53E+01	7.33E+01	6.81E+01	6.73E+01	6.62E+01	6.33E+01	5.74E+01	4.90E+01	3.93E+01	3.00E+01	2.35E+01	1.74E+01	1.18E+01	7.01E+00	3.49E+00	1.34E+00	3.30E-01	5.93E-02
1970	7.54E+01	1.91E+02	1.85E+02	1.77E+02	1.43E+02	1.19E+02	1.04E+02	8.86E+01	7.71E+01	7.08E+01	6.70E+01	6.39E+01	6.32E+01	6.67E+01	7.03E+01	6.94E+01	6.50E+01	6.58E+01	6.67E+01	6.56E+01	6.07E+01	5.24E+01	4.16E+01	3.07E+01	2.42E+01	1.82E+01	1.24E+01	7.51E+00	3.80E+00	1.48E+00	3.71E-01	6.86E-02
1971	6.41E+01	1.64E+02	1.64E+02	1.65E+02	1.38E+02	1.19E+02	1.06E+02	9.13E+01	7.92E+01	7.20E+01	6.72E+01	6.32E+01	6.16E+01	6.45E+01	6.78E+01	6.67E+01	6.23E+01	6.35E+01	6.50E+01	6.45E+01	6.02E+01	5.21E+01	4.07E+01	2.93E+01	2.31E+01	1.74E+01	1.20E+01	7.29E+00	3.72E+00	1.46E+00	3.70E-01	6.98E-02
1972	4.24E+01	1.13E+02	1.20E+02	1.31E+02	1.16E+02	1.05E+02	9.78E+01	8.73E+01	7.79E+01	7.23E+01	6.84E+01	6.46E+01	6.28E+01	6.53E+01	6.82E+01	6.67E+01	6.19E+01	6.28E+01	6.41E+01	6.36E+01	5.92E+01	5.12E+01	3.96E+01	2.81E+01	2.21E+01	1.66E+01	1.15E+01	6.97E+00	3.56E+00	1.40E+00	3.56E-01	6.77E-02
1973	2.76E+01	7.35E+01	7.88E+01	8.85E+01	8.22E+01	7.93E+01	7.81E+01	7.32E+01	6.81E+01	6.57E+01	6.41E+01	6.20E+01	6.15E+01	6.49E+01	6.83E+01	6.71E+01	6.24E+01	6.33E+01	6.44E+01	6.36E+01	5.91E+01	5.09E+01	3.93E+01	2.79E+01	2.19E+01	1.64E+01	1.13E+01	6.84E+00	3.48E+00	1.37E+00	3.47E-01	6.60E-02
1974	2.43E+01	6.21E+01	6.20E+01	6.34E+01	5.65E+01	5.39E+01	5.39E+01	5.21E+01	5.06E+01	5.12E+01	5.21E+01	5.24E+01	5.38E+01	5.86E+01	6.32E+01	6.30E+01	5.93E+01	6.07E+01	6.23E+01	6.19E+01	5.78E+01	4.99E+01	3.89E+01	2.81E+01	2.21E+01	1.66E+01	1.14E+01	6.90E+00	3.50E+00	1.37E+00	3.49E-01	6.61E-02
1975	4.79E+01	1.14E+02	9.88E+01	7.82E+01	5.70E+01	4.56E+01	4.07E+01	3.72E+01	3.53E+01	3.61E+01	3.76E+01	3.90E+01	4.17E+01	4.76E+01	5.33E+01	5.43E+01	5.19E+01	5.42E+01	5.66E+01	5.70E+01	5.36E+01	4.66E+01	3.64E+01	2.63E+01	2.08E+01	1.56E+01	1.07E+01	6.53E+00	3.32E+00	1.30E+00	3.31E-01	6.30E-02
1976	9.53E+01	2.27E+02	1.95E+02	1.50E+02	1.01E+02	6.94E+01	5.12E+01	3.95E+01	3.25E+01	3.01E+01	2.98E+01	3.03E+01	3.25E+01	3.80E+01	4.37E+01	4.53E+01	4.37E+01	4.67E+01	4.98E+01	5.10E+01	4.85E+01	4.23E+01	3.28E+01	2.33E+01	1.84E+01	1.39E+01	9.61E+00	5.86E+00	3.00E+00	1.18E+00	3.02E-01	5.77E-02
1977	7.33E+01	1.91E+02	1.93E+02	1.93E+02	1.52E+02	1.16E+02	8.87E+01	6.63E+01	5.00E+01	4.03E+01	3.46E+01	3.13E+01	3.06E+01	3.38E+01	3.77E+01	3.85E+01	3.68E+01	3.94E+01	4.21E+01	4.30E+01	4.06E+01	3.49E+01	2.54E+01	1.62E+01	1.26E+01	9.46E+00	6.54E+00	4.00E+00	2.05E+00	8.11E-01	2.08E-01	3.96E-02
1978	3.23E+01	9.24E+01	1.10E+02	1.36E+02	1.29E+02	1.20E+02	1.11E+02	9.45E+01	7.77E+01	6.48E+01	5.48E+01	4.67E+01	4.15E+01	4.03E+01	4.06E+01	3.87E+01	3.52E+01	3.56E+01	3.62E+01	3.52E+01	3.15E+01	2.57E+01	1.59E+01	8.25E+00	6.15E+00	4.53E+00	3.09E+00	1.87E+00	9.48E-01	3.71E-01	9.39E-02	1.72E-02
1979	1.36E+01	3.93E+01	4.84E+01	6.48E+01	6.90E+01	7.53E+01	8.07E+01	7.91E+01	7.54E+01	7.23E+01	6.82E+01	6.27E+01	5.75E+01	5.49E+01	5.28E+01	4.83E+01	4.23E+01	3.96E+01	3.70E+01	3.30E+01	2.73E+01	2.07E+01	1.16E+01	6.17E+00	4.53E+00	3.22E+00	2.10E+00	1.22E+00	5.91E-01	2.21E-01	5.29E-02	8.73E-03
1980	8.35E+00	2.24E+01	2.48E+01	3.00E+01	3.13E+01	3.52E+01	4.03E+01	4.35E+01	4.64E+01	5.00E+01	5.28E+01	5.38E+01	5.46E+01	5.69E+01	5.81E+01	5.52E+01	4.94E+01	4.56E+01	4.06E+01	3.39E+01	2.62E+01	1.90E+01	1.14E+01	7.89E+00	5.87E+00	4.05E+00	2.52E+00	1.37E+00	6.15E-01	2.09E-01	4.42E-02	5.66E-03
1981	1.36E+01	3.29E+01	2.93E+01	2.50E+01	2.03E+01	1.88E+01	1.94E+01	2.04E+01	2.19E+01	2.46E+01	2.75E+01	2.99E+01	3.26E+01	3.63E+01	3.92E+01	3.91E+01	3.67E+01	3.53E+01	3.26E+01	2.84E+01	2.32E+01	1.83E+01	1.30E+01	9.72E+00	7.63E+00	5.57E+00	3.67E+00	2.12E+00	1.02E+00	3.71E-01	8.54E-02	1.30E-02
1982	7.72E+00	2.10E+01	2.30E+01	2.54E+01	2.13E+01	1.76E+01	1.52E+01	1.33E+01	1.25E+01	1.28E+01	1.38E+01	1.49E+01	1.66E+01	1.92E+01	2.18E+01	2.28E+01	2.23E+01	2.28E+01	2.28E+01	2.16E+01	1.93E+01	1.65E+01	1.33E+01	1.08E+01	8.88E+00	6.80E+00	4.72E+00	2.87E+00	1.46E+00	5.67E-01	1.42E-01	2.58E-02
1983	3.75E+01	8.63E+01	6.89E+01	4.58E+01	2.90E+01	2.08E+01	1.71E+01	1.42E+01	1.20E+01	1.08E+01	1.01E+01	9.75E+00	9.95E+00	1.10E+01	1.24E+01	1.29E+01	1.27E+01	1.34E+01	1.41E+01	1.42E+01	1.35E+01	1.21E+01	1.03E+01	8.69E+00	7.37E+00	5.81E+00	4.15E+00	2.60E+00	1.36E+00	5.45E-01	1.42E-01	2.80E-02
1984	3.09E+01	7.95E+01	7.90E+01	7.60E+01	5.67E+01	3.96E+01	2.76E+01	1.94E+01	1.46E+01	1.20E+01	1.06E+01	9.52E+00	8.88E+00	8.84E+00	9.05E+00	8.89E+00	8.41E+00	8.65E+00	8.98E+00	9.12E+00	8.82E+00	8.06E+00	6.99E+00	6.03E+00	5.17E+00	4.12E+00	2.98E+00	1.89E+00	9.99E-01	4.07E-01	1.08E-01	2.21E-02
1985	4.15E+01	1.02E+02	9.31E+01	8.22E+01	6.46E+01	5.30E+01	4.49E+01	3.56E+01	2.72E+01	2.07E+01	1.60E+01	1.26E+01	1.04E+01	9.22E+00	8.59E+00	7.95E+00	7.22E+00	6.99E+00	6.84E+00	6.63E+00	6.21E+00	5.56E+00	4.76E+00	4.02E+00	3.39E+00	2.67E+00	1.91E+00	1.20E+00	6.32E-01	2.57E-01	6.80E-02	1.39E-02
1986	4.01E+01	1.01E+02	9.82E+01	9.33E+01	7.37E+01	5.90E+01	4.92E+01	4.08E+01	3.45E+01	3.00E+01	2.62E+01	2.24E+01	1.89E+01	1.62E+01	1.41E+01	1.21E+01	1.02E+01	9.24E+00	8.59E+00	8.02E+00	7.32E+00	6.42E+00	5.49E+00	4.70E+00	3.92E+00	3.04E+00	2.14E+00	1.33E+00	6.91E-01	2.77E-01	7.24E-02	1.46E-02
1987	3.98E+01	1.00E+02	9.70E+01	9.30E+01	7.58E+01	6.37E+01	5.53E+01	4.64E+01	3.89E+01	3.36E+01	2.97E+01	2.63E+01	2.37E+01	2.20E+01	2.06E+01	1.86E+01	1.63E+01	1.47E+01	1.33E+01	1.19E+01	1.03E+01	8.68E+00	7.22E+00	6.07E+00	4.92E+00	3.69E+00	2.53E+00	1.54E+00	7.82E-01	3.08E-01	7.89E-02	1.55E-02
1988	2.72E+01	7.20E+01	7.56E+01	8.10E+01	6.99E+01	6.11E+01	5.48E+01	4.75E+01	4.13E+01	3.71E+01	3.36E+01	3.03E+01	2.75E+01	2.58E+01	2.44E+01	2.24E+01	2.00E+01	1.87E+01	1.74E+01	1.60E+01	1.42E+01	1.21E+01	1.01E+01	8.51E+00	6.84E+00	5.08E+00	3.43E+00	2.04E+00	1.02E+00	3.92E-01	9.76E-02	1.83E-02
1989	1.31E+01	3.68E+01	4.28E+01	5.25E+01	5.02E+01	4.87E+01	4.74E+01	4.34E+01	3.93E+01	3.64E+01	3.40E+01	3.16E+01	2.96E+01	2.87E+01	2.80E+01	2.62E+01	2.36E+01	2.24E+01	2.12E+01	1.97E+01	1.77E+01	1.51E+01	1.27E+01	1.05E+01	8.45E+00	6.28E+00	4.25E+00	2.54E+00	1.27E+00	4.90E-01	1.22E-01	2.30E-02
1990	4.01E+00	1.26E+01	1.70E+01	2.45E+01	2.65E+01	2.90E+01	3.12E+01	3.12E+01	3.06E+01	3.06E+01	3.04E+01	2.95E+01	2.87E+01	2.88E+01	2.89E+01	2.76E+01	2.53E+01	2.44E+01	2.35E+01	2.21E+01	1.98E+01	1.69E+01	1.37E+01	1.06E+01	8.41E+00	6.21E+00	4.18E+00	2.49E+00	1.24E+00	4.76E-01	1.18E-01	2.18E-02
1991	3.20E+00	8.29E+00	8.69E+00	1.01E+01	1.09E+01	1.30E+01	1.54E+01	1.69E+01	1.82E+01	1.99E+01	2.15E+01	2.24E+01	2.32E+01	2.47E+01	2.60E+01	2.57E+01	2.40E+01	2.36E+01	2.30E+01	2.16E+01	1.93E+01	1.63E+01	1.24E+01	8.72E+00	6.80E+00	4.99E+00	3.35E+00	1.98E+00	9.85E-01	3.77E-01	9.29E-02	1.66E-02
1992	2.84E+00	7.24E+00	7.19E+00	7.25E+00	6.37E+00	6.22E+00	6.79E+00	7.57E+00	8.59E+00	1.03E+01	1.22E+01	1.37E+01	1.53E+01	1.75E+01	1.97E+01	2.04E+01	1.96E+01	2.02E+01	2.04E+01	1.97E+01	1.78E+01	1.51E+01	1.11E+01	7.58E+00	5.94E+00	4.36E+00	2.94E+00	1.75E+00	8.70E-01	3.34E-01	8.26E-02	1.48E-02
1993	2.84E+00	7.15E+00	6.91E+00	6.64E+00	5.52E+00	4.90E+00	4.77E+00	4.69E+00	4.75E+00	5.52E+00	6.65E+00	7.78E+00	8.97E+00	1.08E+01	1.29E+01	1.38E+01	1.37E+01	1.48E+01	1.56E+01	1.56E+01	1.45E+01	1.24E+01	8.73E+00	5.49E+00	4.06E+00	2.85E+00	1.88E+00	1.11E+00	5.59E-01	2.18E-01	5.51E-02	1.01E-02
1994	3.74E+00	9.18E+00	8.41E+00	7.40E+00	5.75E+00	4.77E+00	4.37E+00	4.05E+00	3.86E+00	4.22E+00	4.86E+00	5.46E+00	6.06E+00	7.19E+00	8.66E+00	9.38E+00	9.33E+00	1.04E+01	1.13E+01	1.17E+01	1.10E+01	9.44E+00	6.49E+00	3.94E+00	2.90E+00	2.04E+00	1.36E+00	8.21E-01	4.19E-01	1.66E-01	4.31E-02	8.26E-03
1995	4.79E+00	1.18E+01	1.08E+01	9.46E+00	7.14E+00	5.59E+00	4.74E+00	4.10E+00	3.67E+00	3.78E+00	4.14E+00	4.49E+00	4.80E+00	5.52E+00	6.52E+00	6.96E+00	6.85E+00	7.61E+00	8.35E+00	8.66E+00	8.21E+00	7.01E+00	4.69E+00	2.73E+00	2.01E+00	1.42E+00	9.57E-01	5.82E-01	3.01E-01	1.21E-01	3.20E-02	6.37E-03
1996	4.41E+00	1.12E+01	1.10E+01	1.06E+01	8.44E+00	6.82E+00	5.77E+00	4.84E+00	4.13E+00	3.92E+00	3.99E+00	4.08E+00	4.16E+00	4.57E+00	5.22E+00	5.48E+00	5.32E+00	5.82E+00	6.29E+00	6.45E+00	6.05E+00	5.13E+00	3.35E+00	1.93E+00	1.45E+00	1.04E+00	7.04E-01	4.30E-01	2.22E-01	8.94E-02	2.35E-02	4.72E-03
1997	1.28E+01	3.00E+01	2.48E+01	1.79E+01	1.19E+01	8.60E+00	6.93E+00	5.71E+00	4.83E+00	4.44E+00	4.29E+00	4.17E+00	4.07E+00	4.27E+00	4.67E+00	4.76E+00	4.55E+00	4.88E+00	5.20E+00	5.29E+00	4.95E+00	4.19E+00	2.79E+00	1.67E+00	1.25E+00	8.85E-01	5.90E-01	3.55E-01	1.81E-01	7.19E-02	1.87E-02	3.72E-03
1998	5.15E+00	1.50E+01	1.80E+01	2.14E+01	1.78E+01	1.37E+01	1.04E+01	7.85E+00	6.14E+00	5.27E+00	4.83E+00	4.51E+00	4.29E+00	4.33E+00	4.53E+00	4.46E+00	4.16E+00	4.31E+00	4.49E+00	4.49E+00	4.18E+00	3.56E+00	2.48E+00	1.61E+00	1.23E+00	8.86E-01	5.96E-01	3.59E-01	1.83E-01	7.23E-02	1.87E-02	3.68E-03
1999	1.72E+01	4.01E+01	3.30E+01	2.41E+01	1.75E+01	1.46E+01	1.33E+01	1.13E+01	9.32E+00	7.79E+00	6.64E+00	5.73E+00	5.08E+00	4.81E+00	4.75E+00	4.50E+00	4.10E+00	4.12E+00	4.17E+00	4.11E+00	3.80E+00	3.25E+00	2.38E+00	1.66E+00	1.29E+00	9.43E-01	6.37E-01	3.82E-01	1.94E-01	7.60E-02	1.95E-02	3.78E-03
2000	8.97E+00	2.48E+01	2.76E+01	3.05E+01	2.46E+01	1.86E+01	1.44E+01	1.14E+01	9.69E+00	8.89E+00	8.32E+00	7.65E+00	6.95E+00	6.48E+00	6.11E+00	5.55E+00	4.87E+00	4.65E+00	4.52E+00	4.33E+00	3.94E+00	3.35E+00	2.56E+00	1.89E+00	1.48E+00	1.09E+00	7.38E-01	4.43E-01	2.23E-01	8.71E-02	2.21E-02	4.24E-03
2001	2.93E+01	6.83E+01	5.62E+01	4.05E+01	2.82E+01	2.22E+01	1.91E+01	1.58E+01	1.28E+01	1.06E+01	9.05E+00	7.95E+00	7.30E+00	7.13E+00	7.06E+00	6.67E+00	6.05E+00	5.81E+00	5.59E+00	5.25E+00	4.71E+00	3.98E+00	3.13E+00	2.40E+00	1.88E+00	1.38E+00	9.24E-01	5.50E-01	2.75E-01	1.06E-01	2.66E-02	5.03E-03
2002	9.43E+00	2.91E+01	3.72E+01	4.66E+01	3.94E+01	3.05E+01	2.35E+01	1.82E+01	1.49E+01	1.30E+01	1.18E+01	1.05E+01	9.41E+00	8.76E+00	8.26E+00	7.52E+00	6.67E+00	6.40E+00	6.24E+00	5.99E+00	5.48E+00	4.72E+00	3.86E+00	3.10E+00	2.47E+00	1.83E+00	1.24E+00	7.39E-01	3.70E-01	1.43E-01	3.55E-02	6.62E-03
2003	2.83E+01	6.61E+01	5.52E+01	4.22E+01	3.28E+01	2.96E+01	2.82E+01	2.46E+01	2.05E+01	1.70E+01	1.44E+01	1.24E+01	1.10E+01	1.05E+01	1.01E+01	9.41E+00	8.44E+00	8.04E+00	7.71E+00	7.27E+00	6.58E+00	5.63E+00	4.64E+00	3.77E+00	3.01E+00	2.24E+00	1.52E+00	9.14E-01	4.60E-01	1.79E-01	4.50E-02	8.54E-03
2004	2.76E+01	6.96E+01	6.69E+01	6.19E+01	4.62E+01	3.39E+01	2.62E+01	2.15E+01	1.91E+01	1.82E+01	1.73E+01	1.60E+01	1.47E+01	1.37E+01	1.29E+01	1.17E+01	1.02E+01	9.68E+00	9.29E+00	8.82E+00	8.03E+00	6.93E+00	5.80E+00	4.79E+00	3.84E+00	2.86E+00	1.95E+00	1.17E+00	5.85E-01	2.26E-01	5.65E-02	1.06E-02
2005	7.50E+00	2.43E+01	3.33E+01	4.59E+01	4.36E+01	3.96E+01	3.52E+01	2.89E+01	2.32E+01	1.92E+01	1.66E+01	1.49E+01	1.41E+01	1.43E+01	1.45E+01	1.39E+01	1.27E+01	1.23E+01	1.18E+01	1.12E+01	1.01E+01	8.67E+00	7.25E+00	5.99E+00	4.78E+00	3.55E+00	2.42E+00	1.45E+00	7.27E-01	2.82E-01	7.07E-02	1.34E-02
2006	5.74E+00	1.49E+01	1.59E+01	1.91E+01	2.10E+01	2.44E+01	2.71E+01	2.67E+01	2.50E+01	2.34E+01	2.15E+01	1.93E+01	1.74E+01	1.64E+01	1.58E+01	1.46E+01	1.32E+01	1.29E+01	1.29E+01	1.26E+01	1.17E+01	1.03E+01	8.77E+00	7.33E+00	5.92E+00	4.44E+00	3.03E+00	1.82E+00	9.15E-01	3.54E-01	8.86E-02	1.66E-02
2007	4.44E+00	1.15E+01	1.18E+01	1.25E+01	1.13E+01	1.13E+01	1.23E+01	1.34E+01	1.48E+01	1.65E+01	1.76E+01	1.80E+01	1.81E+01	1.86E+01	1.88E+01	1.78E+01	1.61E+01	1.55E+01	1.50E+01	1.44E+01	1.32E+01	1.15E+01	9.73E+00	8.02E+00	6.47E+00	4.87E+00	3.35E+00	2.03E+00	1.03E+00	4.01E-01	1.02E-01	1.95E-02
2008	6.83E+00	1.66E+01	1.48E+01	1.27E+01	9.92E+00	8.50E+00	8.02E+00	7.66E+00	7.63E+00	8.32E+00	9.36E+00	1.05E+01	1.20E+01	1.42E+01	1.60E+01	1.64E+01	1.58E+01	1.61E+01	1.64E+01	1.61E+01	1.51E+01	1.33E+01	1.13E+01	9.29E+00	7.49E+00	5.62E+00	3.84E+00	2.31E+00	1.16E+00	4.52E-01	1.14E-01	2.16E-02
2009	4.45E+01	1.02E+02	7.98E+01	4.95E+01	2.77E+01	1.60E+01	1.05E+01	7.76E+00	6.45E+00	6.23E+00	6.50E+00	6.93E+00	7.81E+00	9.64E+00	1.15E+01	1.22E+01	1.20E+01	1.31E+01	1.43E+01	1.51E+01	1.48E+01	1.34E+01	1.17E+01	9.81E+00	8.06E+00	6.15E+00	4.27E+00	2.60E+00	1.33E+00	5.20E-01	1.32E-01	2.53E-02
2010	3.94E+01	1.01E+02	9.84E+01	9.24E+01	6.75E+01	4.56E+01	3.00E+01	1.93E+01	1.28E+01	9.29E+00	7.60E+00	6.84E+00	6.92E+00	8.06E+00	9.39E+00	9.82E+00	9.54E+00	1.05E+01	1.17E+01	1.27E+01	1.27E+01	1.17E+01	1.04E+01	8.84E+00	7.33E+00	5.64E+00	3.93E+00	2.41E+00	1.24E+00	4.93E-01	1.27E-01	2.52E-02
2011	1.61E+01	4.69E+01	5.69E+01	7.12E+01	6.60E+01	5.94E+01	5.24E+01	4.20E+01	3.18E+01	2.39E+01	1.81E+01	1.39E+01	1.13E+01	1.04E+01	1.02E+01	9.68E+00	8.87E+00	9.34E+00	1.01E+01	1.08E+01	1.08E+01	9.98E+00	8.86E+00	7.58E+00	6.30E+00	4.87E+00	3.41E+00	2.10E+00	1.08E+00	4.33E-01	1.12E-01	2.25E-02
2012	3.14E+00	1.14E+01	1.82E+01	2.95E+01	3.39E+01	3.84E+01	4.14E+01	4.01E+01	3.73E+01	3.44E+01	3.10E+01	2.69E+01	2.30E+01	2.01E+01	1.78E+01	1.53E+01	1.28E+01	1.17E+01	1.13E+01	1.09E+01	1.03E+01	9.21E+00	8.01E+00	6.78E+00	5.58E+00	4.27E+00	2.97E+00	1.82E+00	9.38E-01	3.73E-01	9.67E-02	1.93E-02
2013	8.61E+00	2.02E+01	1.72E+01	1.44E+01	1.35E+01	1.57E+01	1.89E+01	2.12E+01	2.32E+01	2.51E+01	2.62E+01	2.61E+01	2.57E+01	2.56E+01	2.50E+01	2.31E+01	2.04E+01	1.87E+01	1.72E+01	1.57E+01	1.38E+01	1.17E+01	9.75E+00	7.98E+00	6.33E+00	4.69E+00	3.17E+00	1.89E+00	9.51E-01	3.70E-01	9.35E-02	1.81E-02
2014	6.45E+00	1.68E+01	1.71E+01	1.71E+01	1.35E+01	1.07E+01	9.46E+00	9.31E+00	1.01E+01	1.19E+01	1.38E+01	1.56E+01	1.75E+01	2.02E+01	2.22E+01	2.24E+01	2.13E+01	2.12E+01	2.10E+01	2.01E+01	1.83E+01	1.57E+01	1.33E+01	1.11E+01	8.81E+00	6.51E+00	4.38E+00	2.59E+00	1.28E+00	4.89E-01	1.20E-01	2.22E-02
2015	4.23E+00	1.13E+01	1.20E+01	1.33E+01	1.20E+01	1.10E+01	1.03E+01	9.01E+00	7.84E+00	7.56E+00	7.91E+00	8.64E+00	1.01E+01	1.28E+01	1.54E+01	1.64E+01	1.62E+01	1.74E+01	1.86E+01	1.90E+01	1.78E+01	1.57E+01	1.38E+01	1.18E+01	9.69E+00	7.35E+00	5.05E+00	3.04E+00	1.53E+00	5.91E-01	1.47E-01	2.75E-02
2016	5.94E+00	1.45E+01	1.32E+01	1.17E+01	9.59E+00	8.64E+00	8.39E+00	7.96E+00	7.55E+00	7.60E+00	7.79E+00	7.94E+00	8.49E+00	1.01E+01	1.18E+01	1.23E+01	1.19E+01	1.30E+01	1.43E+01	1.51E+01	1.40E+01	1.25E+01	1.12E+01	9.83E+00	8.23E+00	6.38E+00	4.48E+00	2.75E+00	1.41E+00	5.53E-01	1.40E-01	2.71E-02
2017	3.51E+01	8.05E+01	6.33E+01	3.99E+01	2.27E+01	1.36E+01	9.36E+00	7.27E+00	6.32E+00	6.27E+00	6.58E+00	6.94E+00	7.64E+00	9.17E+00	1.06E+01	1.10E+01	1.04E+01	1.12E+01	1.21E+01	1.27E+01	1.19E+01	1.07E+01	9.59E+00	8.49E+00	7.15E+00	5.57E+00	3.94E+00	2.44E+00	1.26E+00	5.01E-01	1.29E-01	2.55E-02

Table 37. Comparison of estimates of recruitment (in millions) from the 2016 assessment model (2016AM) and the author's preferred model (Model B2b).

year	2016AM	Model B2b
1949	55.50	49.97
1950	55.65	50.14
1951	55.99	50.55
1952	56.62	51.29
1953	57.66	52.50
1954	59.30	54.38
1955	61.84	57.29
1956	65.80	61.81
1957	72.11	69.07
1958	82.65	81.37
1959	101.70	104.34
1960	141.25	154.58
1961	242.89	287.25
1962	537.86	653.60
1963	1,177.44	1,289.55
1964	1,614.85	1,543.25
1965	1,449.54	1,293.94
1966	1,119.12	1,017.60
1967	914.80	888.15
1968	862.81	903.75
1969	946.34	1,007.31
1970	1,044.72	984.49
1971	887.85	821.55
1972	653.80	544.20
1973	402.42	352.97
1974	303.08	308.86
1975	606.32	635.47
1976	1,093.57	1,222.05
1977	863.94	934.64
1978	441.60	406.27
1979	175.21	169.83
1980	93.15	104.12
1981	134.32	166.37
1982	90.73	94.30
1983	345.19	448.94
1984	321.76	371.69
1985	505.73	504.81
1986	466.24	481.25
1987	451.01	483.44
1988	439.75	339.13
1989	190.87	162.34
1990	73.68	52.05
1991	42.90	39.94
1992	32.61	34.18
1993	30.27	34.11
1994	37.96	44.32
1995	50.53	56.38
1996	51.67	51.89
1997	127.63	150.42
1998	52.35	60.40
1999	152.69	201.24
2000	90.77	105.35
2001	276.55	343.49
2002	104.95	110.60
2003	209.31	328.66
2004	322.05	324.53
2005	93.97	87.98
2006	72.47	67.68
2007	48.53	51.77
2008	60.51	79.34
2009	395.16	521.63
2010	492.06	457.31
2011	286.78	189.62
2012	49.61	37.73
2013	124.11	101.59
2014	99.47	76.13
2015	69.67	49.99
2016	120.01	70.22
2017		414.88

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Table 38. Comparison of exploitation rates (i.e., catch divided by biomass) from the 2016 assessment model (2016AM) and the author's preferred model (Model B2b).

year	2016AM	Model B2b
1949	0.003	0.002
1950	0.005	0.003
1951	0.009	0.004
1952	0.013	0.007
1953	0.016	0.010
1954	0.020	0.013
1955	0.022	0.015
1956	0.023	0.016
1957	0.023	0.017
1958	0.023	0.017
1959	0.023	0.017
1960	0.022	0.016
1961	0.022	0.016
1962	0.021	0.014
1963	0.018	0.012
1964	0.016	0.011
1965	0.024	0.017
1966	0.024	0.017
1967	0.059	0.045
1968	0.064	0.050
1969	0.082	0.066
1970	0.077	0.061
1971	0.066	0.052
1972	0.060	0.046
1973	0.065	0.056
1974	0.084	0.075
1975	0.074	0.065
1976	0.118	0.101
1977	0.172	0.140
1978	0.159	0.118
1979	0.227	0.151
1980	0.160	0.093
1981	0.070	0.047
1982	0.035	0.025
1983	0.017	0.013
1984	0.033	0.026
1985	0.019	0.016
1986	0.027	0.019
1987	0.042	0.032
1988	0.052	0.041
1989	0.117	0.092
1990	0.197	0.152
1991	0.171	0.147
1992	0.208	0.175
1993	0.153	0.130
1994	0.118	0.098
1995	0.110	0.087
1996	0.073	0.048
1997	0.047	0.039
1998	0.037	0.038
1999	0.019	0.017
2000	0.018	0.014
2001	0.023	0.016
2002	0.016	0.010
2003	0.011	0.007
2004	0.011	0.007
2005	0.018	0.012
2006	0.025	0.018
2007	0.027	0.022
2008	0.020	0.015
2009	0.017	0.012
2010	0.009	0.006
2011	0.010	0.009
2012	0.006	0.005
2013	0.018	0.015
2014	0.060	0.052
2015	0.082	0.071
2016	--	0.010

Table 39. Values required to determine Tier level and OFL for the models considered here. These values are presented only to illustrate the effect of incremental changes in the model scenarios. Results from the author's preferred model (Model B2b) are highlighted in green.

Model Scenario	average recruitment	Final MMB	B0	Bmsy	Fmsy	MSY	Fofl	OFL	projected MMB	projected MMB / Bmsy
	millions	1000's t	1000's t	1000's t		1000's t		1000's t	1000's t	
2016 Model	182.27	73.90	73.29	25.65	0.79	11.13	0.79	25.61	45.34	1.77
B0.2016	175.94	85.19	75.83	26.54	0.93	11.21	0.93	27.38	45.47	1.71
B0	174.64	68.57	76.90	26.91	0.92	11.21	0.92	21.87	36.88	1.37
B0a	172.24	66.92	75.27	26.35	0.93	11.10	0.93	21.40	35.82	1.36
B1	194.58	74.26	79.67	27.89	0.94	11.48	0.94	24.02	39.72	1.42
B1a	194.80	73.82	79.22	27.73	0.94	11.46	0.94	23.90	39.40	1.42
B1b	195.26	73.83	79.14	27.70	0.95	11.47	0.95	23.95	39.35	1.42
B1c	270.31	98.70	91.09	31.88	1.21	13.08	1.21	35.57	49.19	1.54
B2	198.97	74.51	80.14	28.05	0.74	11.58	0.74	23.20	40.59	1.45
B2a	208.35	78.73	82.38	28.83	0.75	12.03	0.75	24.74	42.57	1.48
B2b	213.95	80.57	83.34	29.17	0.75	12.25	0.75	25.42	43.31	1.49
B3	263.90	87.47	88.82	31.09	0.89	13.40	0.89	29.76	44.67	1.44

Figures

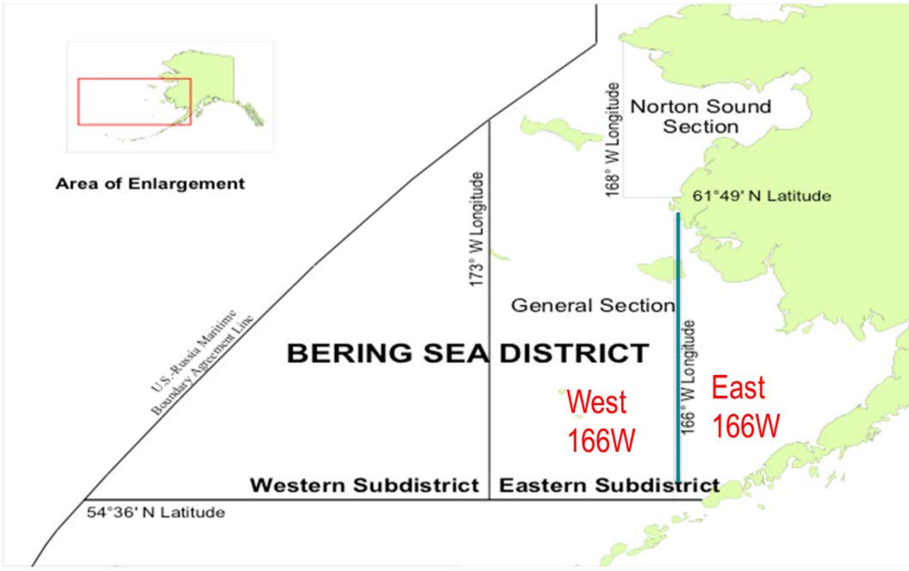

Figure 1. Eastern Bering Sea District of Tanner crab Registration Area J including sub-districts and sections (from Bowers et al. 2008).

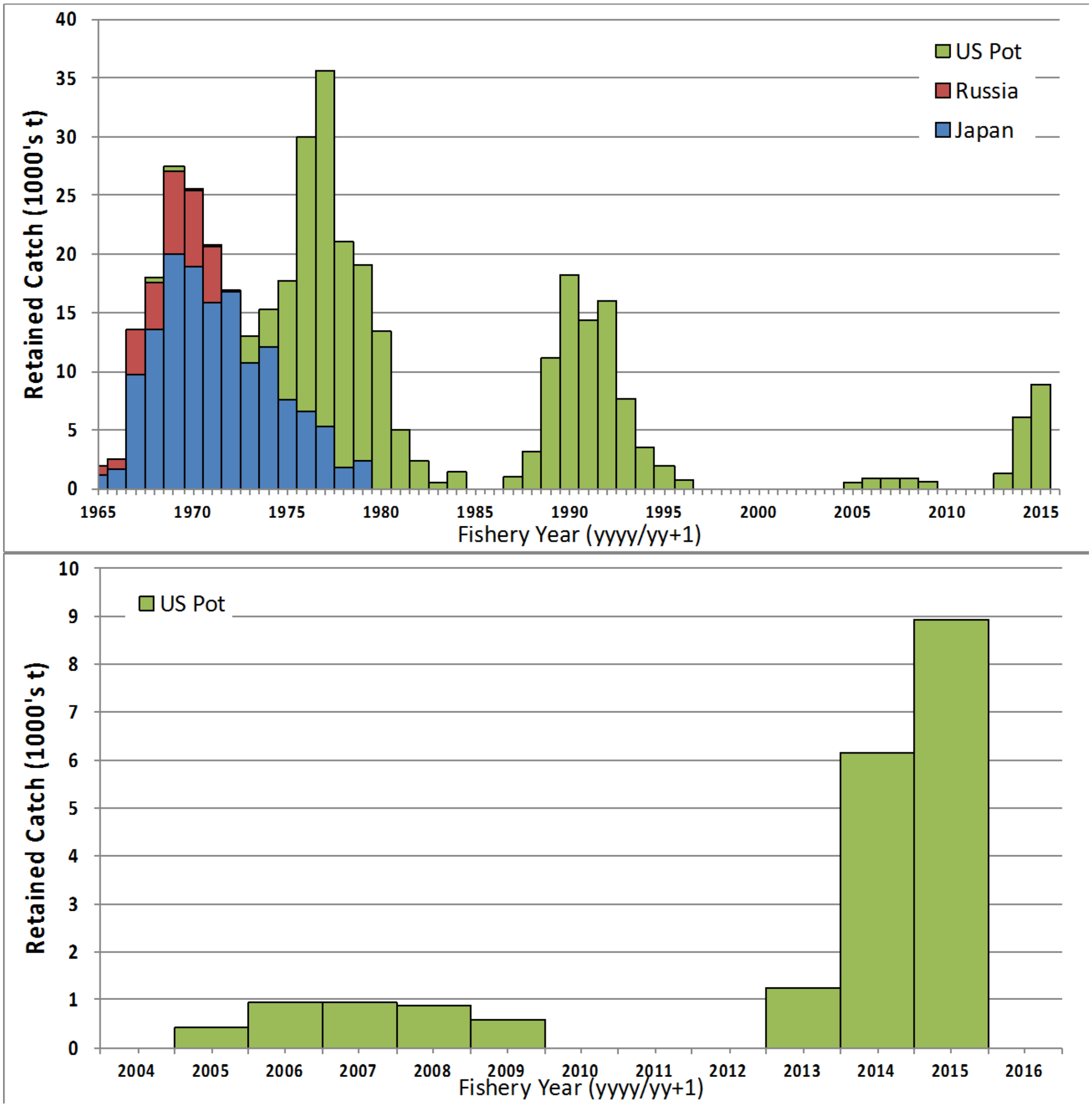

Figure 2. Upper: retained catch (males, 1000's t) in the directed fisheries (US pot fishery [green bars], Russian tangle net fishery [red bars], and Japanese tangle net fisheries [blue bars]) for Tanner crab since 1965/66. Lower: Retained catch (males, 1000's t) in directed fishery since 2001/02. The directed fishery was closed from 1996/97 to 2004/05, from 2010/11 to 2012/13, and in 2016/17.

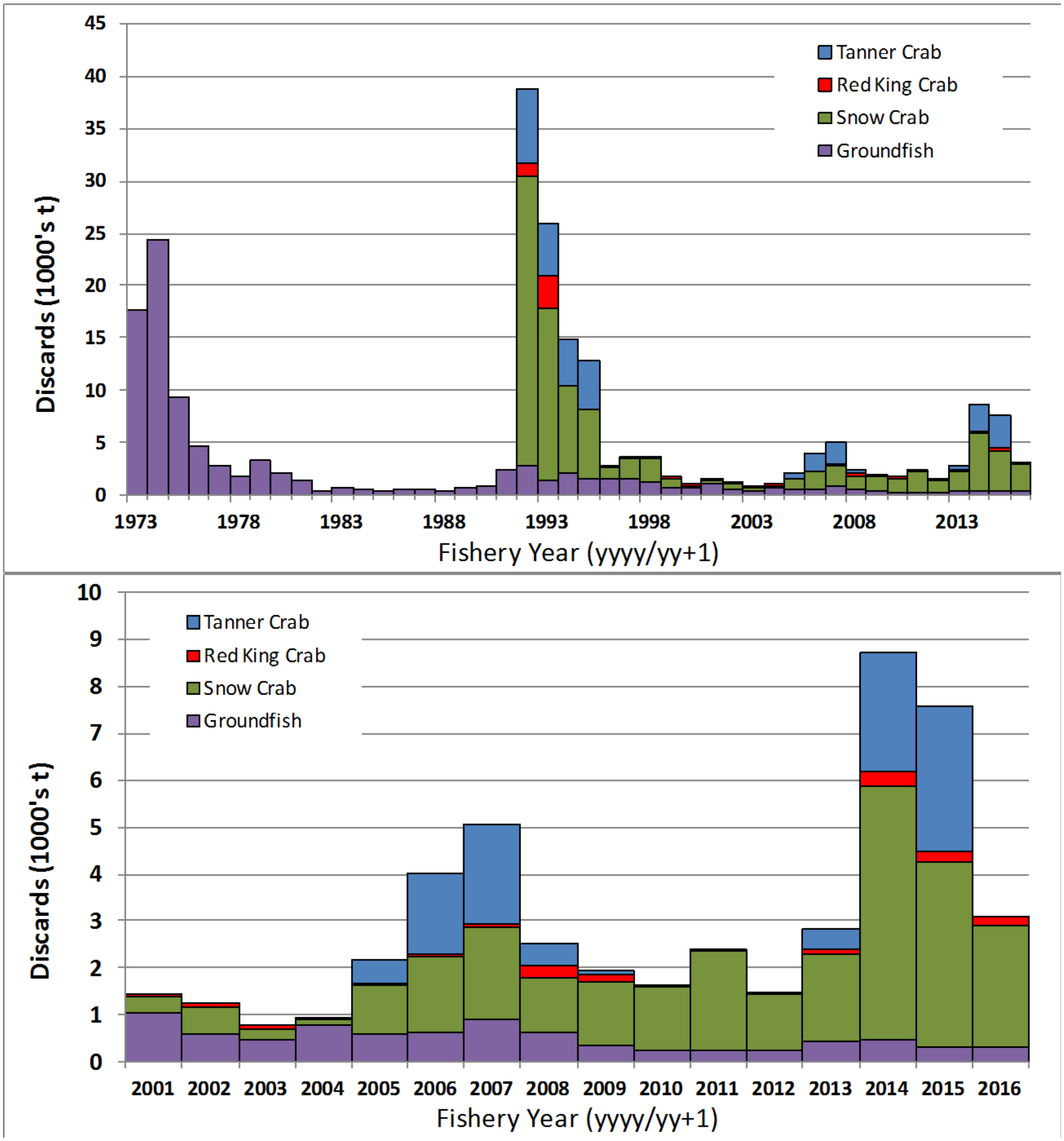

Figure 3. Upper: Tanner crab discards (males and females, 1000's t) in the directed Tanner crab, snow crab, Bristol Bay red king crab, and groundfish fisheries. Discard reporting began in 1973 for the groundfish fisheries and in 1992 for the crab fisheries. Lower: detail since 2001.

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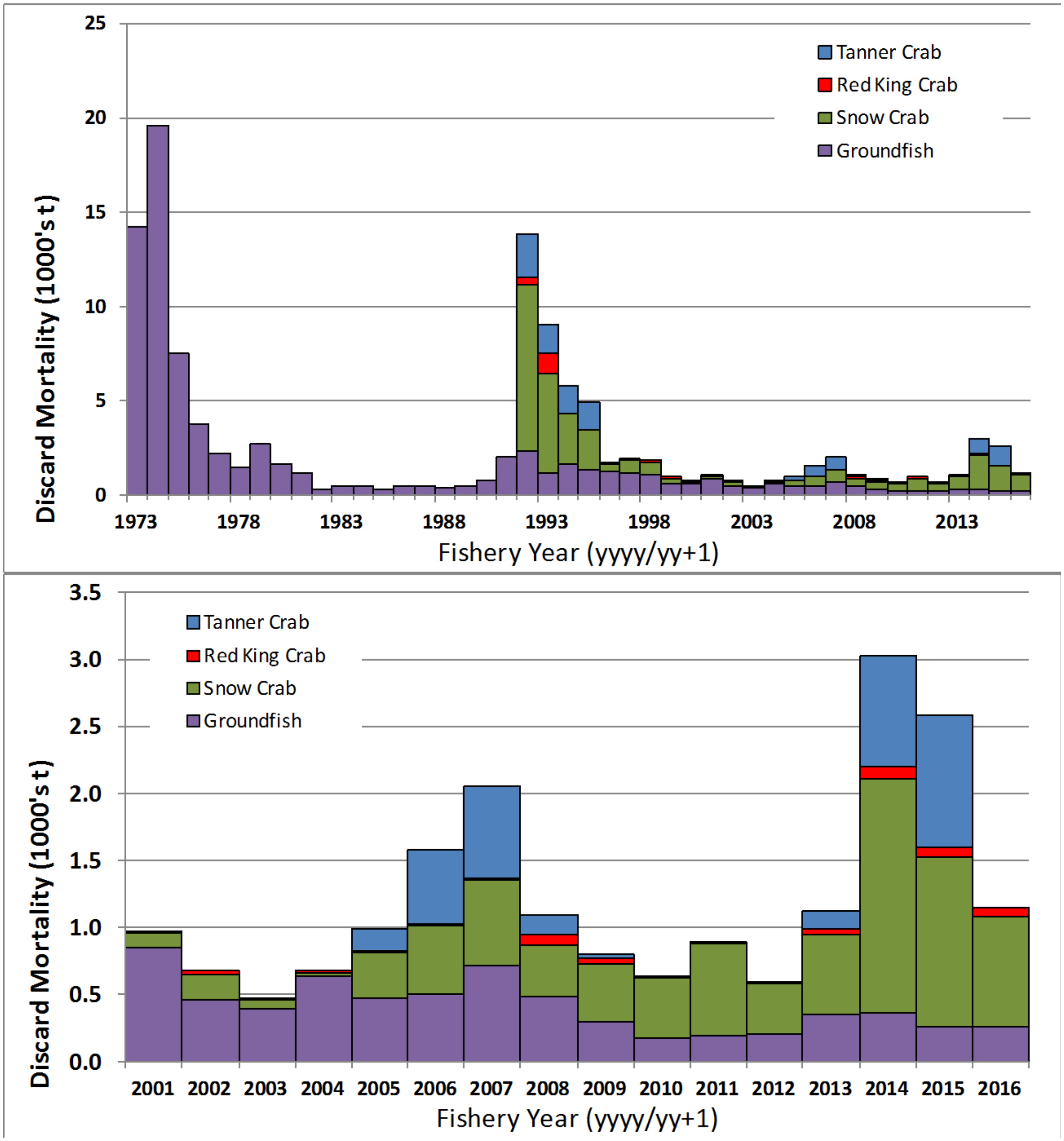

Figure 4. Upper: Tanner crab discard mortality (males and females, 1000's t) in the directed Tanner crab, snow crab, Bristol Bay red king crab, and groundfish fisheries. Assumed handling mortality rates of 0.321 for the crab fisheries and 0.80 for the groundfish fisheries were applied to discard biomass to obtain discard mortality. Lower: detail since 2001.

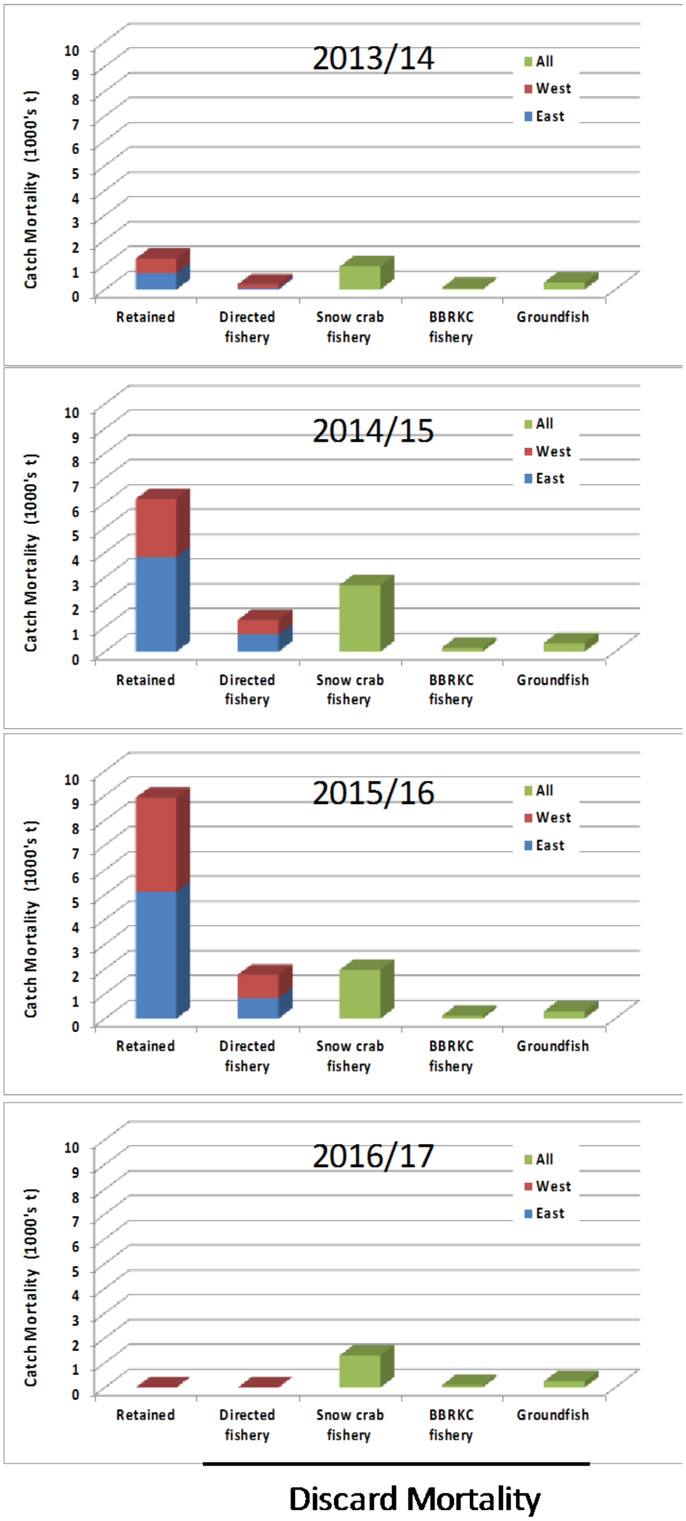

Figure 5. Retained and discard catch mortality (1000's t) in the directed, snow crab, BBRKC and groundfish fisheries. Handling mortality rates of 0.321 for the crab fisheries and 0.8 for the groundfish fisheries were applied to estimated discards.

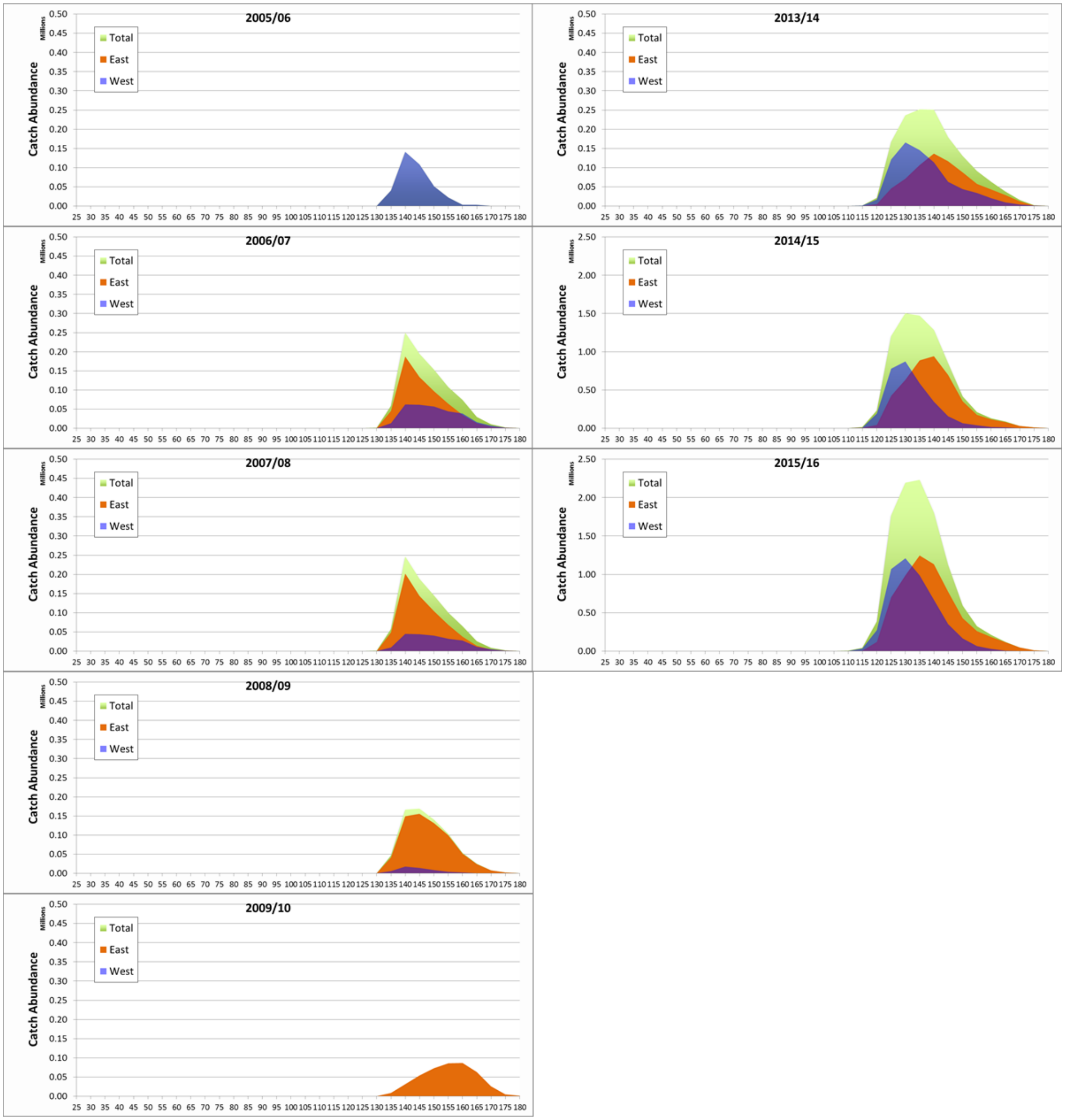

Figure 6. Size compositions, by 5 mm CW bins and expanded to total retained catch, for retained (male) crab in the directed Tanner crab pot fisheries since 2006/07, from dockside crab fishery observer sampling. Fishing occurred only east of 166ºW in 2009/10. The entire fishery was closed in 2010/11-2012/13 and in 2016/17. Note scale change in 2014/15.

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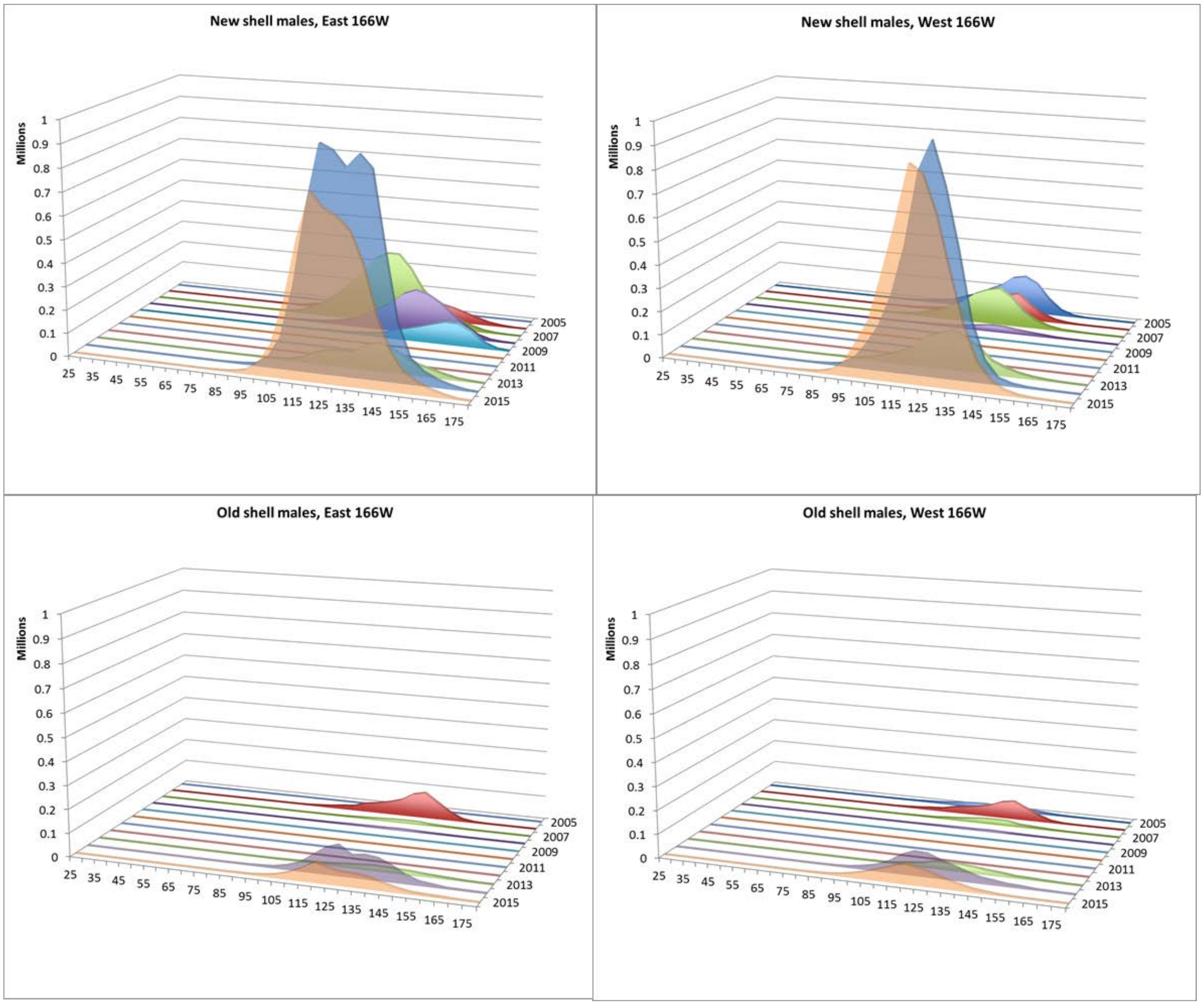

Figure 7. Male Tanner crab catch size compositions, expanded to total catch, by 5 mm CW bins in the directed Tanner crab pot fishery since 2005/06, from at-sea crab fishery observer sampling. Note that the directed fishery was closed in 2010/11-2012/13 and in 2016/17.

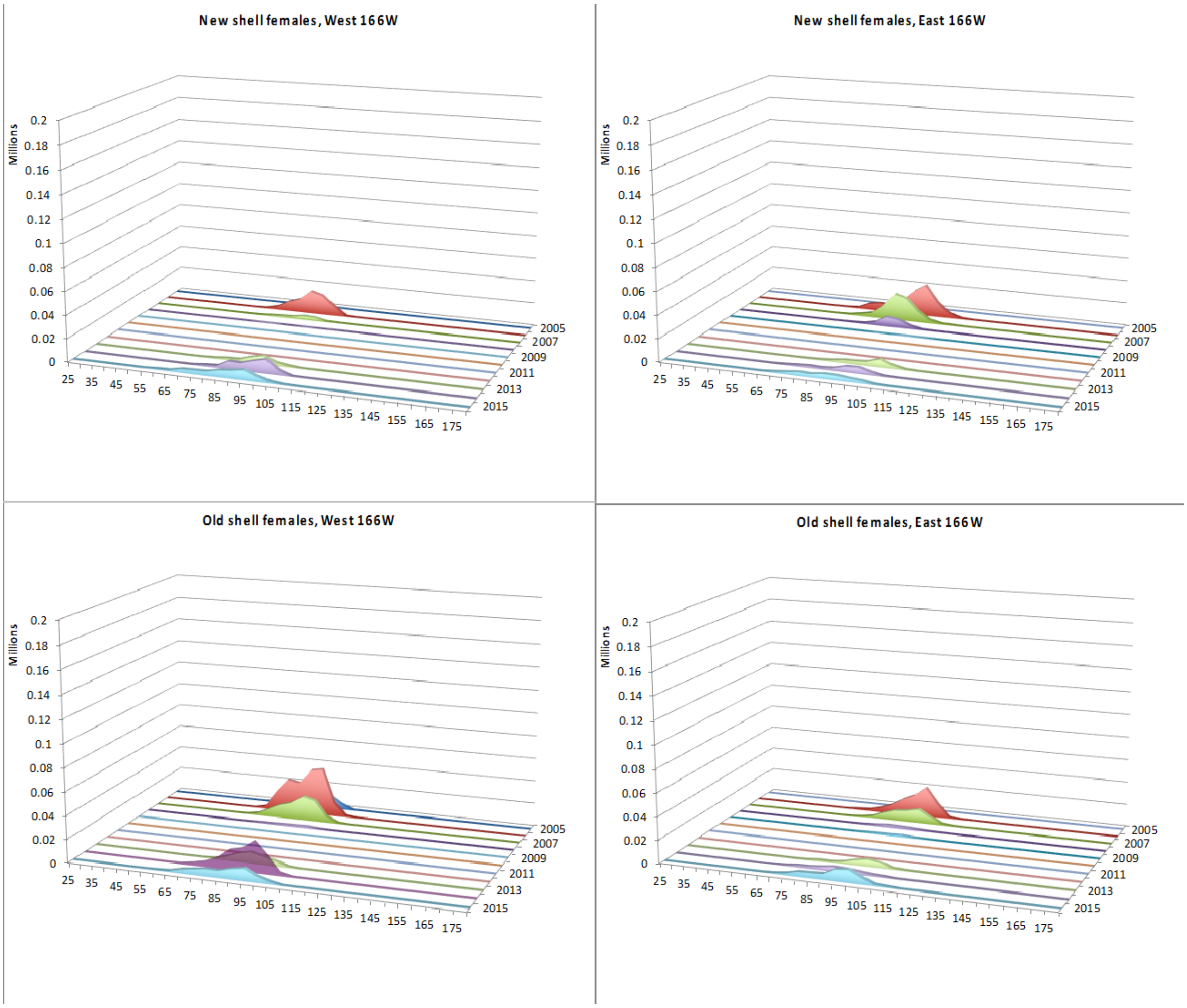

Figure 8. Female Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the directed Tanner crab pot fishery since 2005/06, from at-sea crab fishery observer sampling. Note that the directed fishery was closed in 2010/11-2012/13 and in 2016/17.

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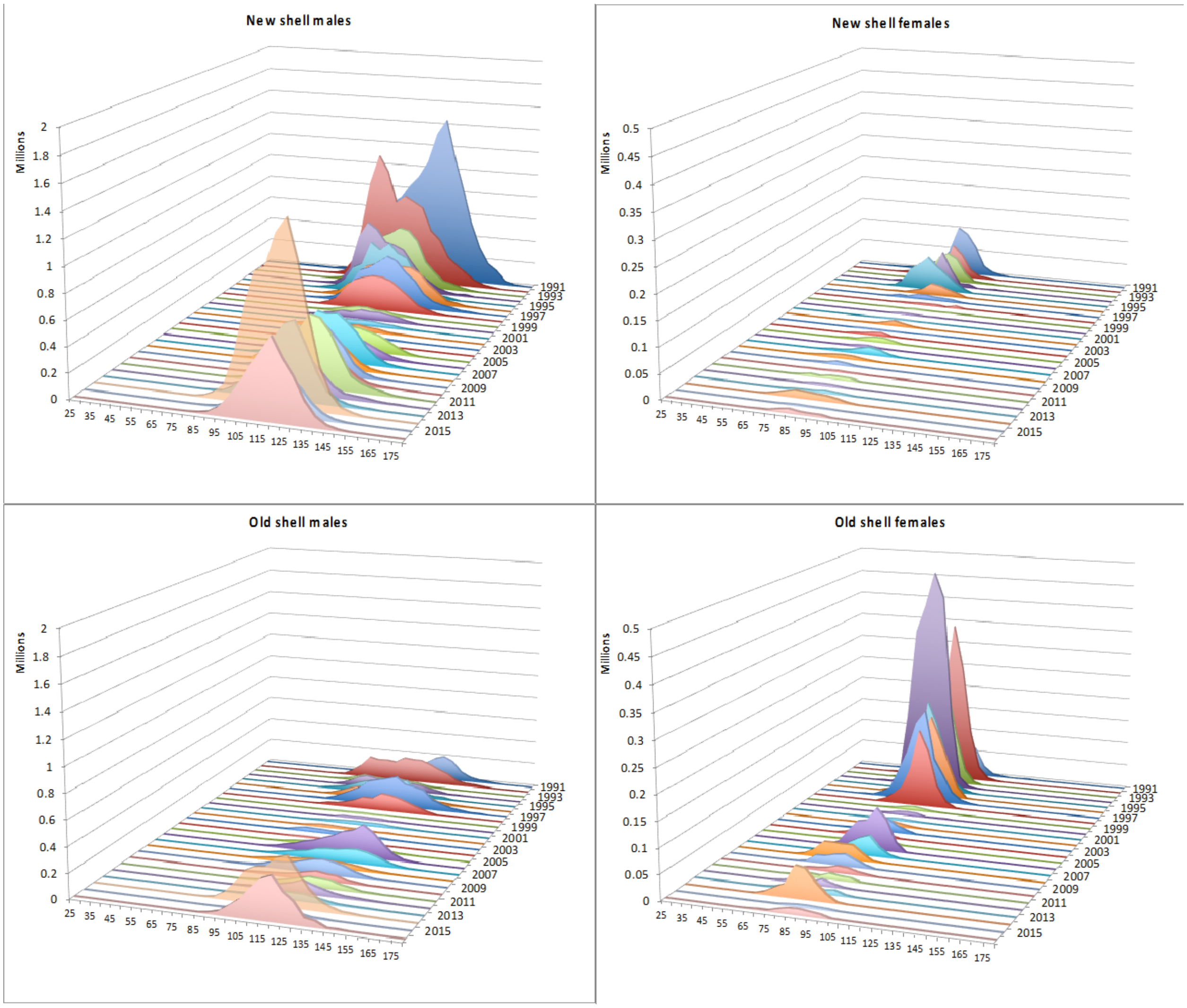

Figure 9. Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the snow crab pot fishery, from at-sea crab fishery observer sampling.

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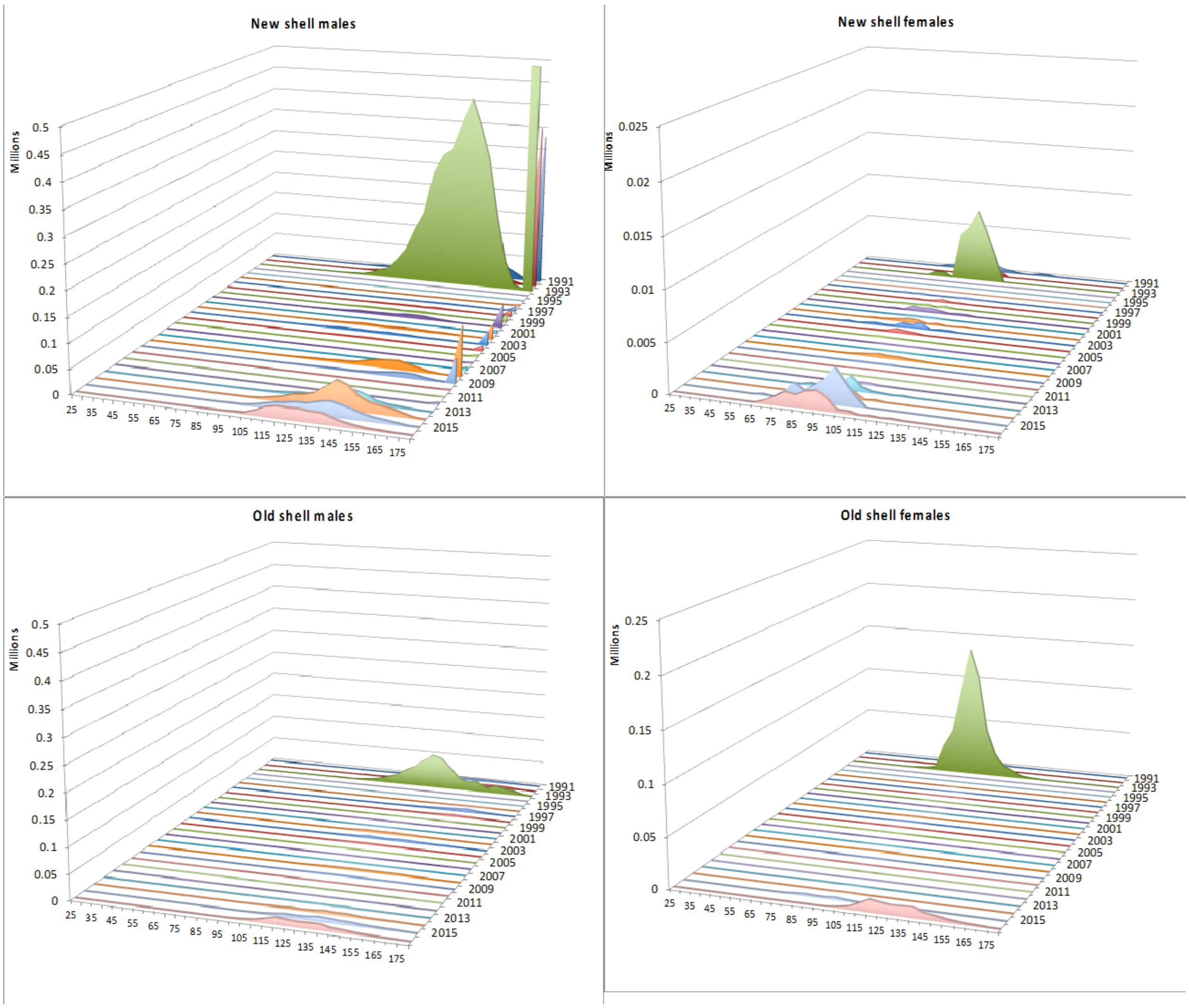

Figure 10. Tanner crab bycatch size compositions, expanded to total catch, by 5 mm CW bins in the BBRKC pot fishery, from at-sea crab fishery observer sampling.

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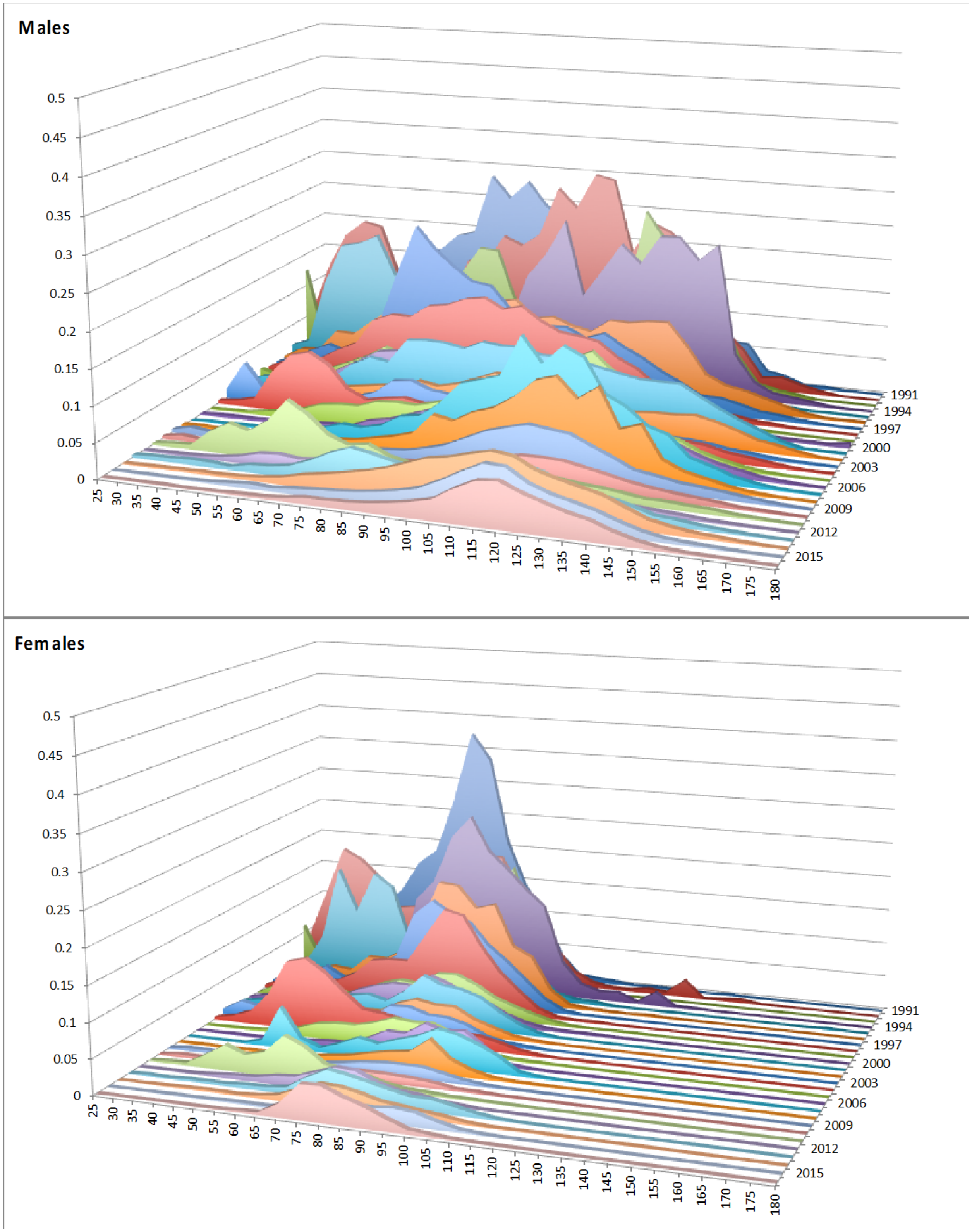

Figure 11. Normalized Tanner crab bycatch size compositions in the groundfish fisheries, from groundfish observer sampling. Size compositions have been normalized to sum to 1 for each year.

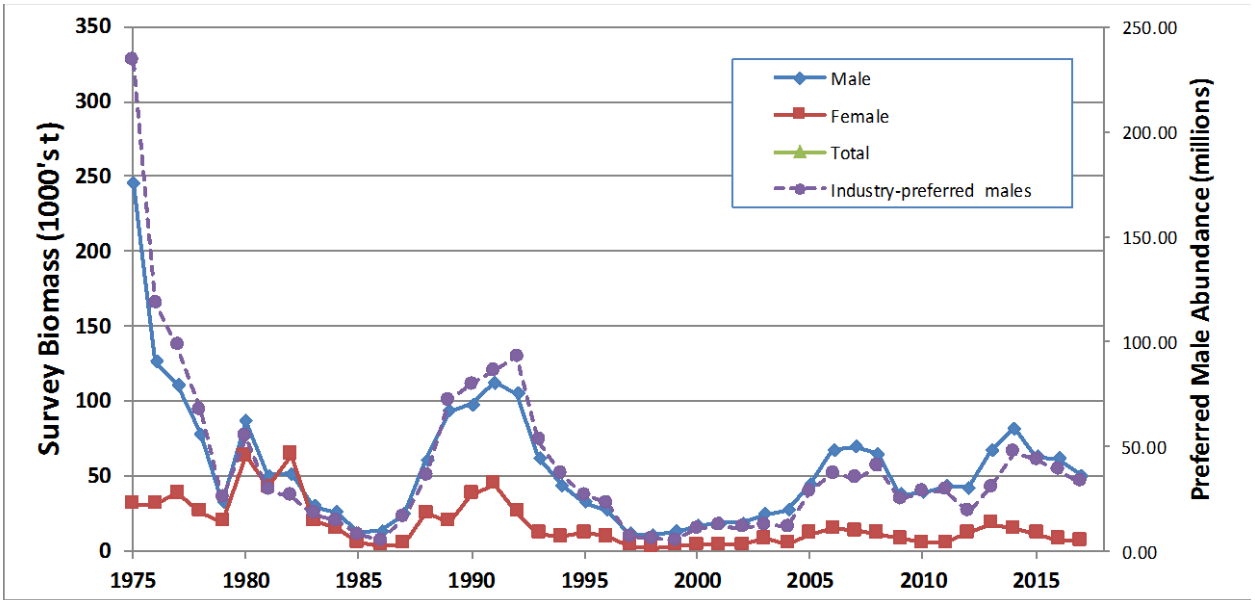

Figure 12. Trends in survey biomass for mature male and female Tanner crab, and in abundance for industry preferred-size (≥125 mm CW) males, based on the NMFS EBS bottom trawl survey.

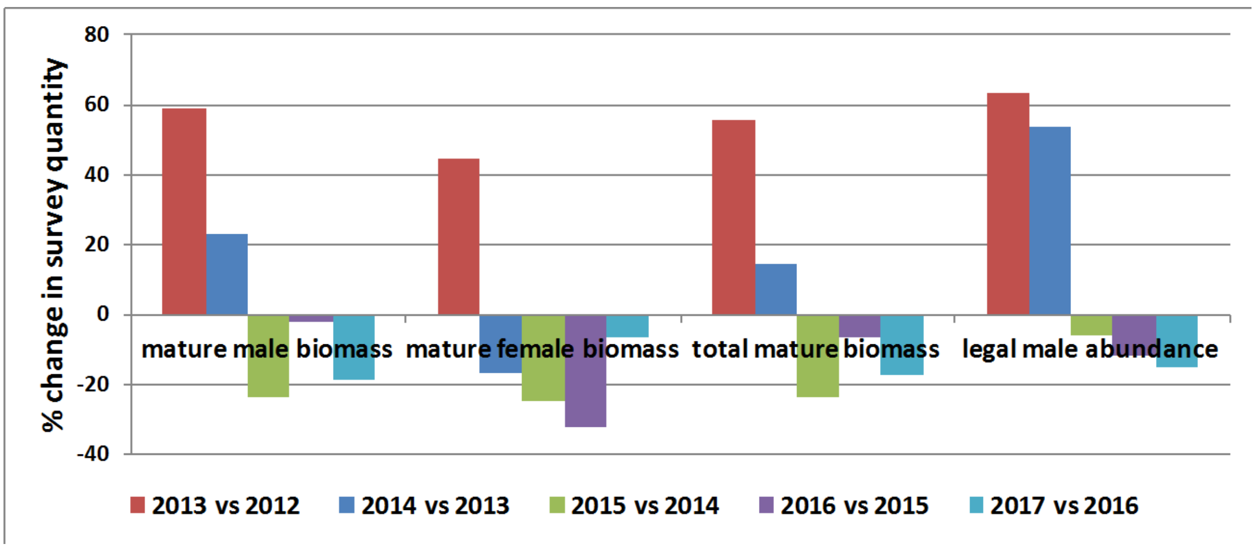

Figure 13. Percent change in mature male biomass, mature female biomass, total mature biomass and abundance of legal crab observed in the NMFS bottom trawl survey during the past five surveys.

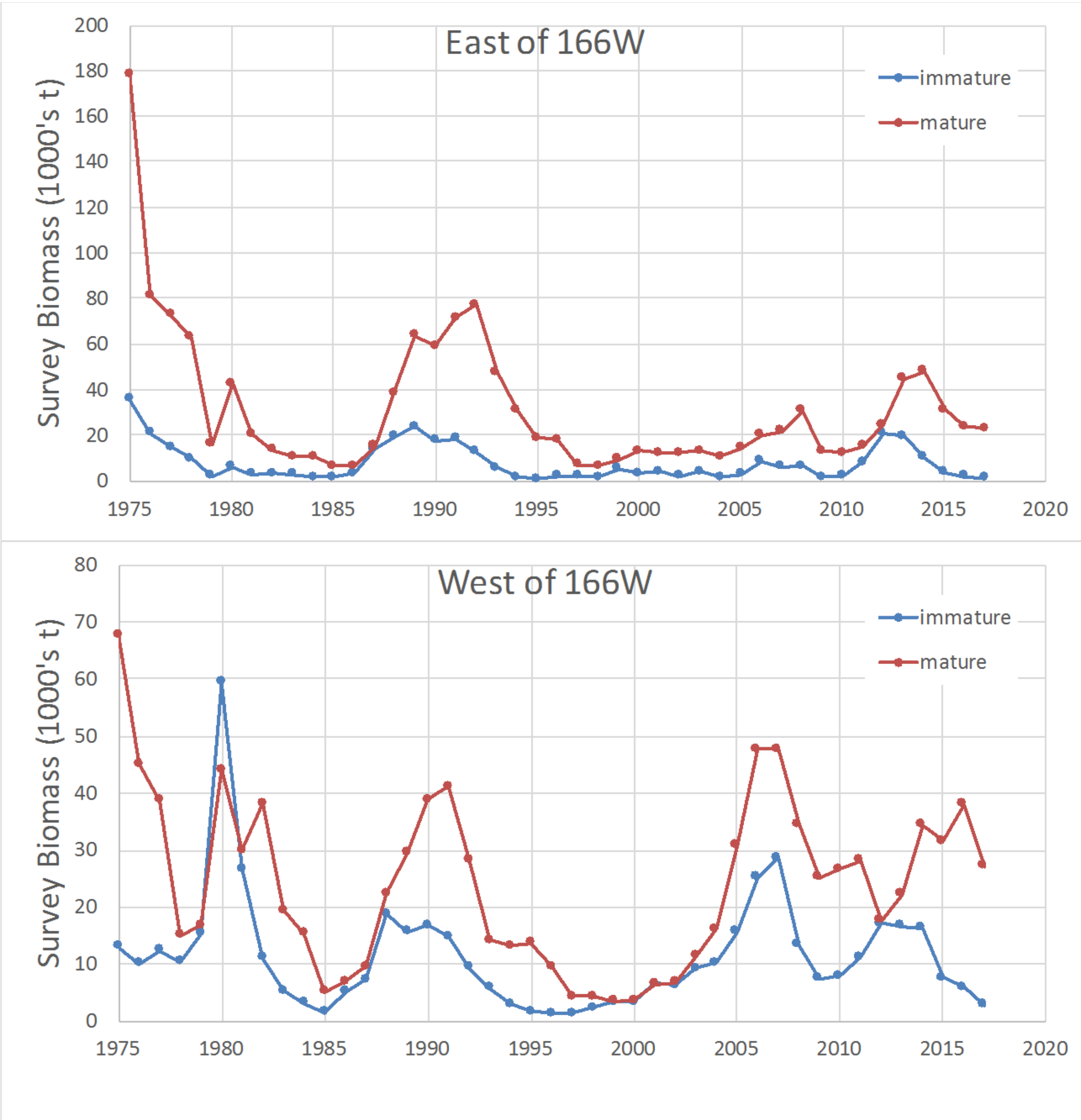

Figure 14. Trends in survey biomass for male Tanner crab in areas east and west of 166ºW longitude, based on the NMFS EBS bottom trawl survey.

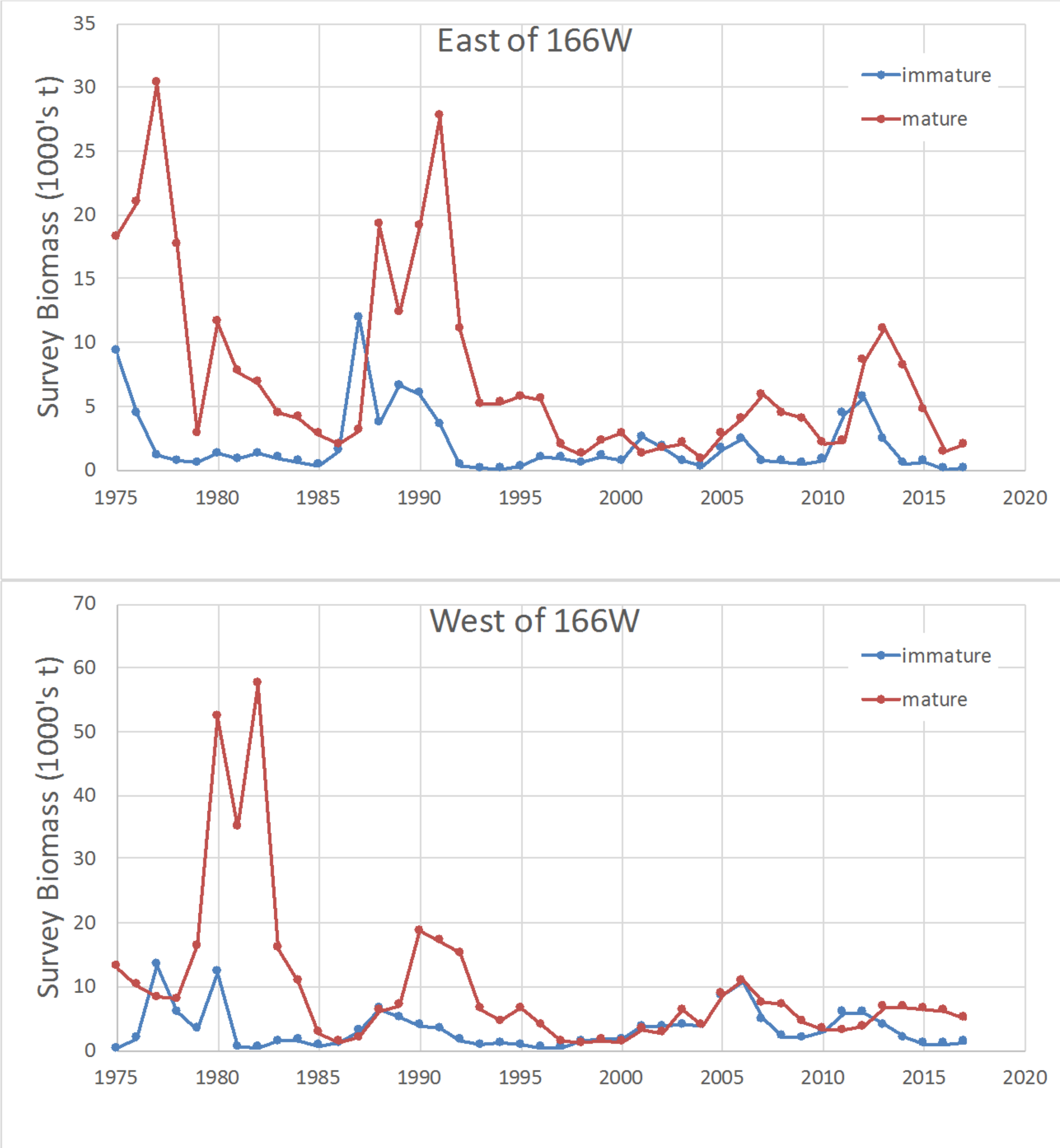

Figure 15. Trends in survey biomass for female Tanner crab in areas east and west of 166ºW longitude, based on the NMFS EBS bottom trawl survey.

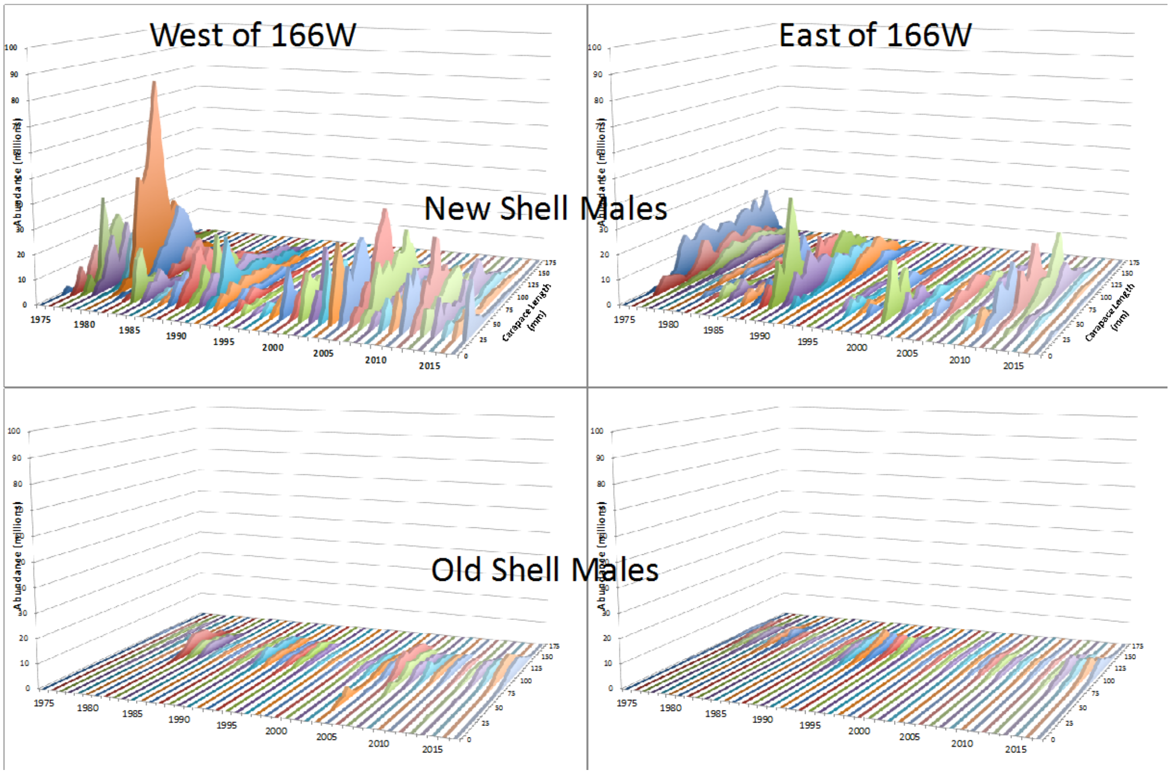

Figure 16. Numbers at size (millions) by area and shell condition for male Tanner crab in the NMFS summer bottom trawl survey, binned by 5 mm CW.

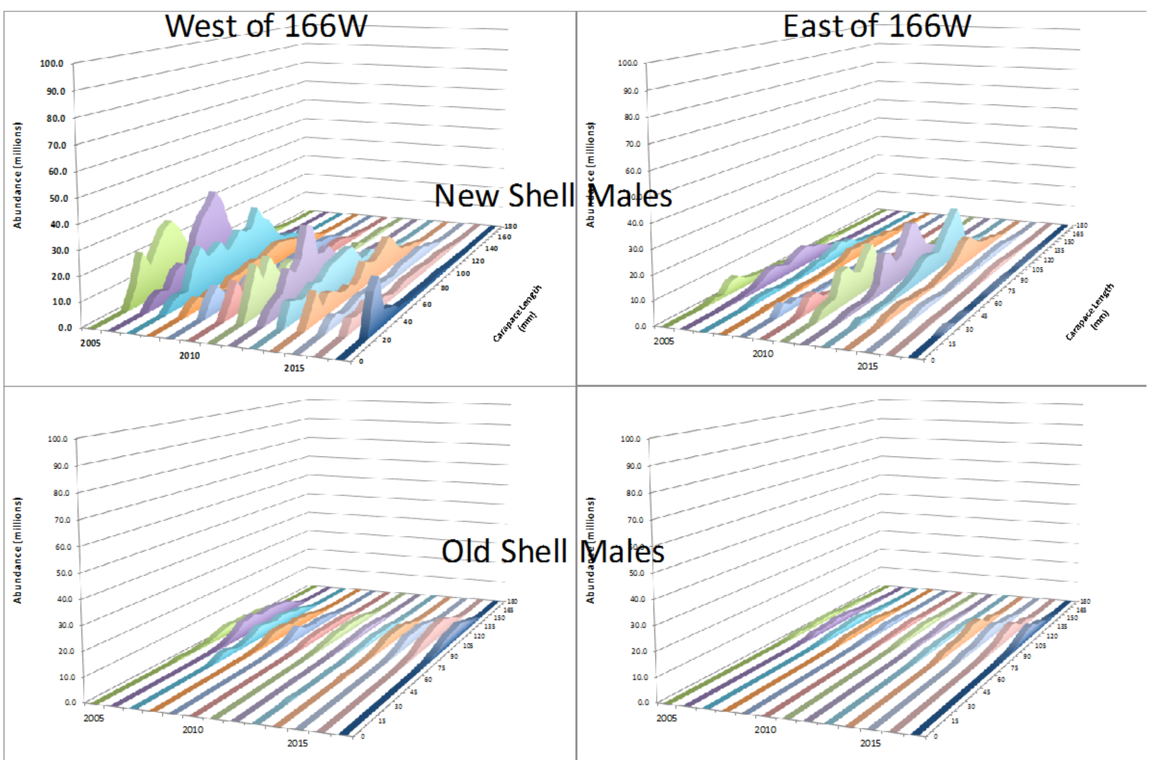

Figure 17. Numbers at size (millions) by area and shell condition for male Tanner crab in the NMFS summer bottom trawl survey, binned by 5 mm CW, since 2005.

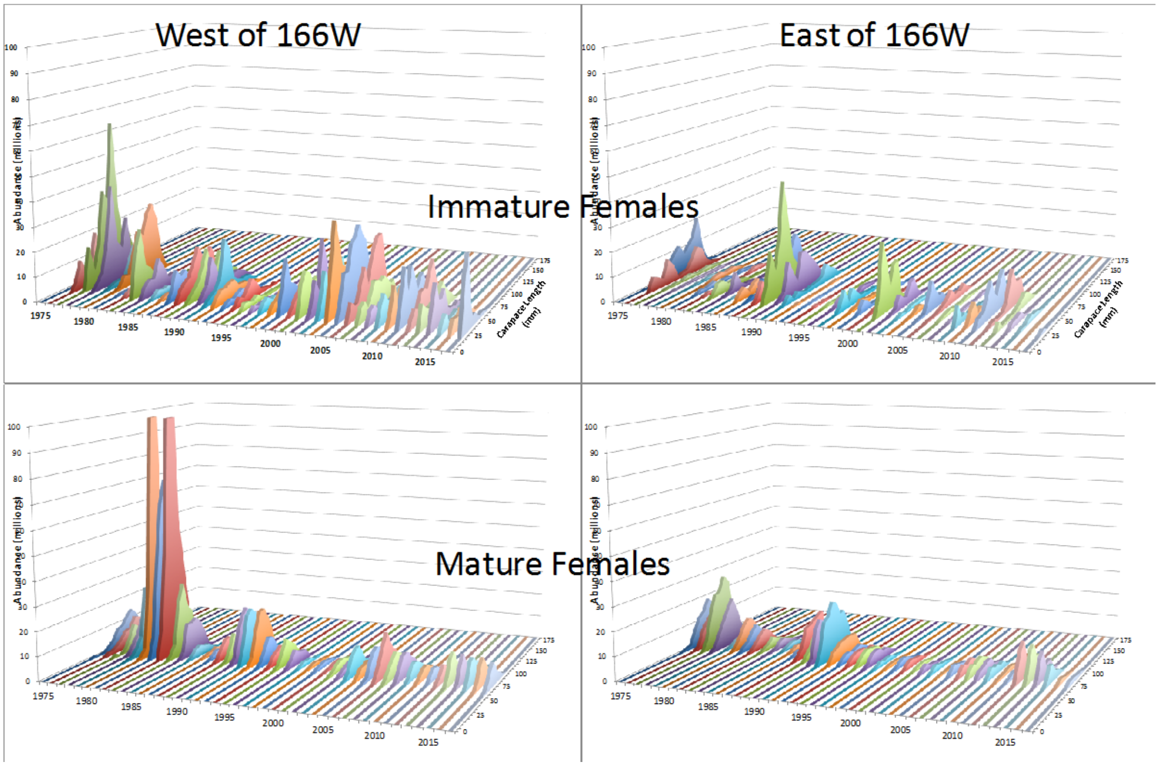

Figure 18. Numbers at size (millions) by area and shell condition for female Tanner crab in the NMFS summer bottom trawl survey, binned by 5 mm CW.

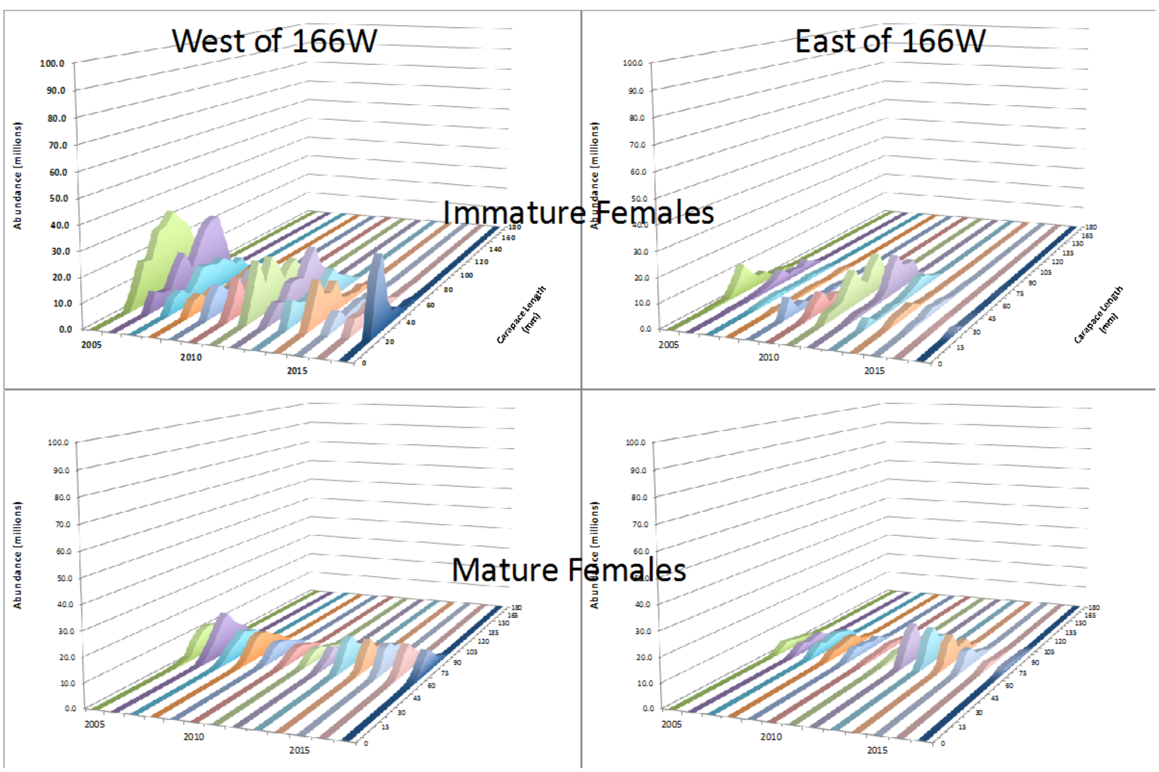

Figure 19. Numbers at size (millions) by area and shell condition for female Tanner crab in the NMFS summer bottom trawl survey, binned by 5 mm CW, since 2005.

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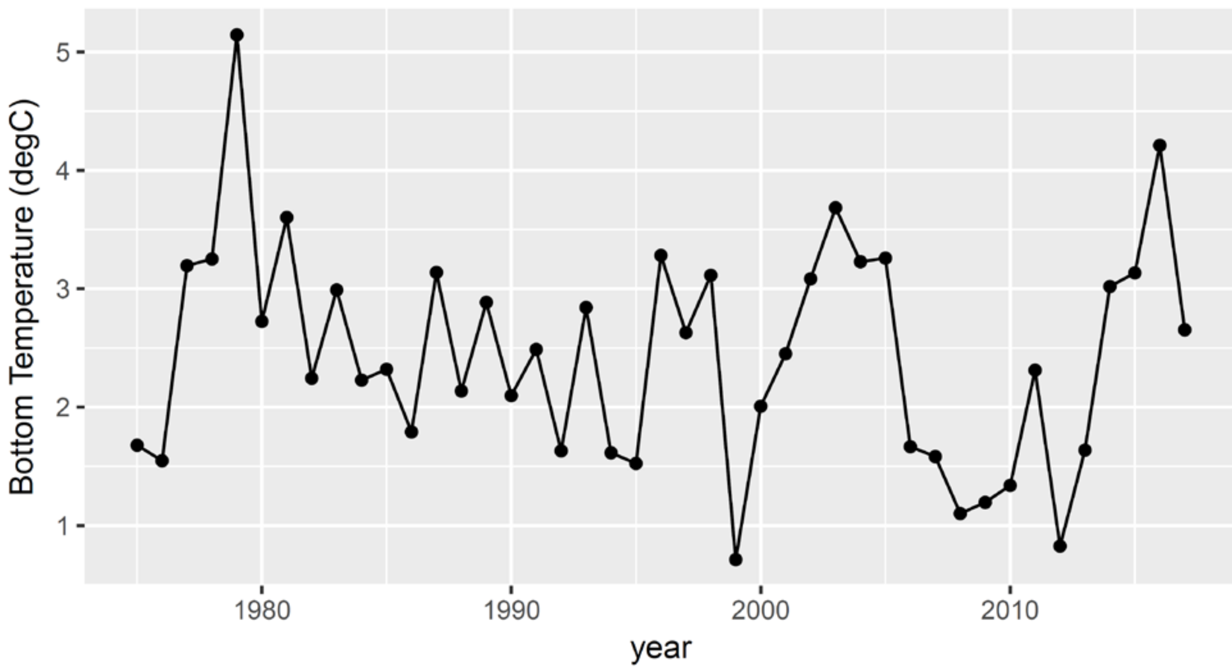

Figure 20. Average bottom temperatures (ºC) in the NMFS EBS summer trawl survey for 1975-2017.

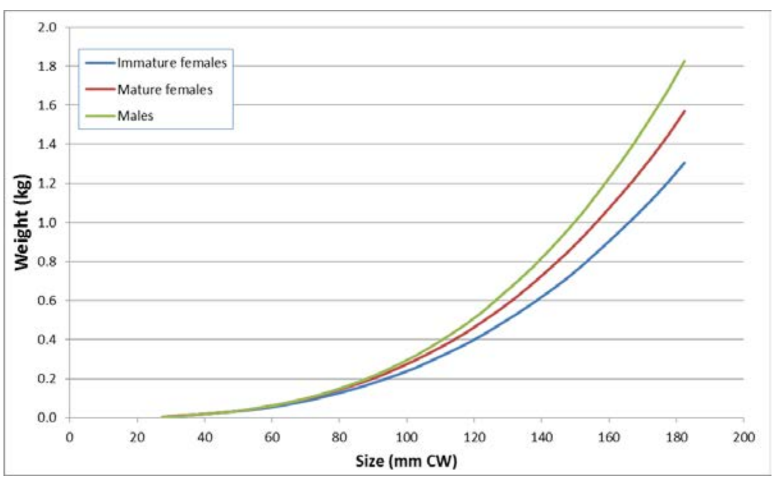

Figure 21. Size-weight relationships developed from NMFS EBS summer trawl survey data.

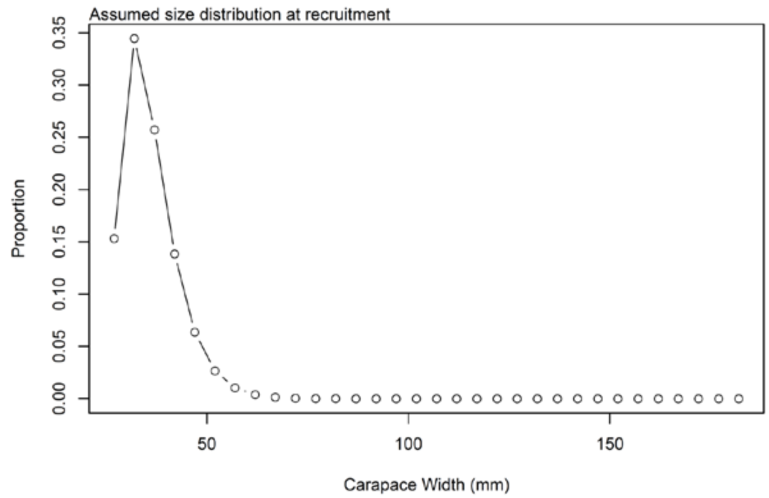

Figure 22. Assumed size distribution for recruits entering the population.

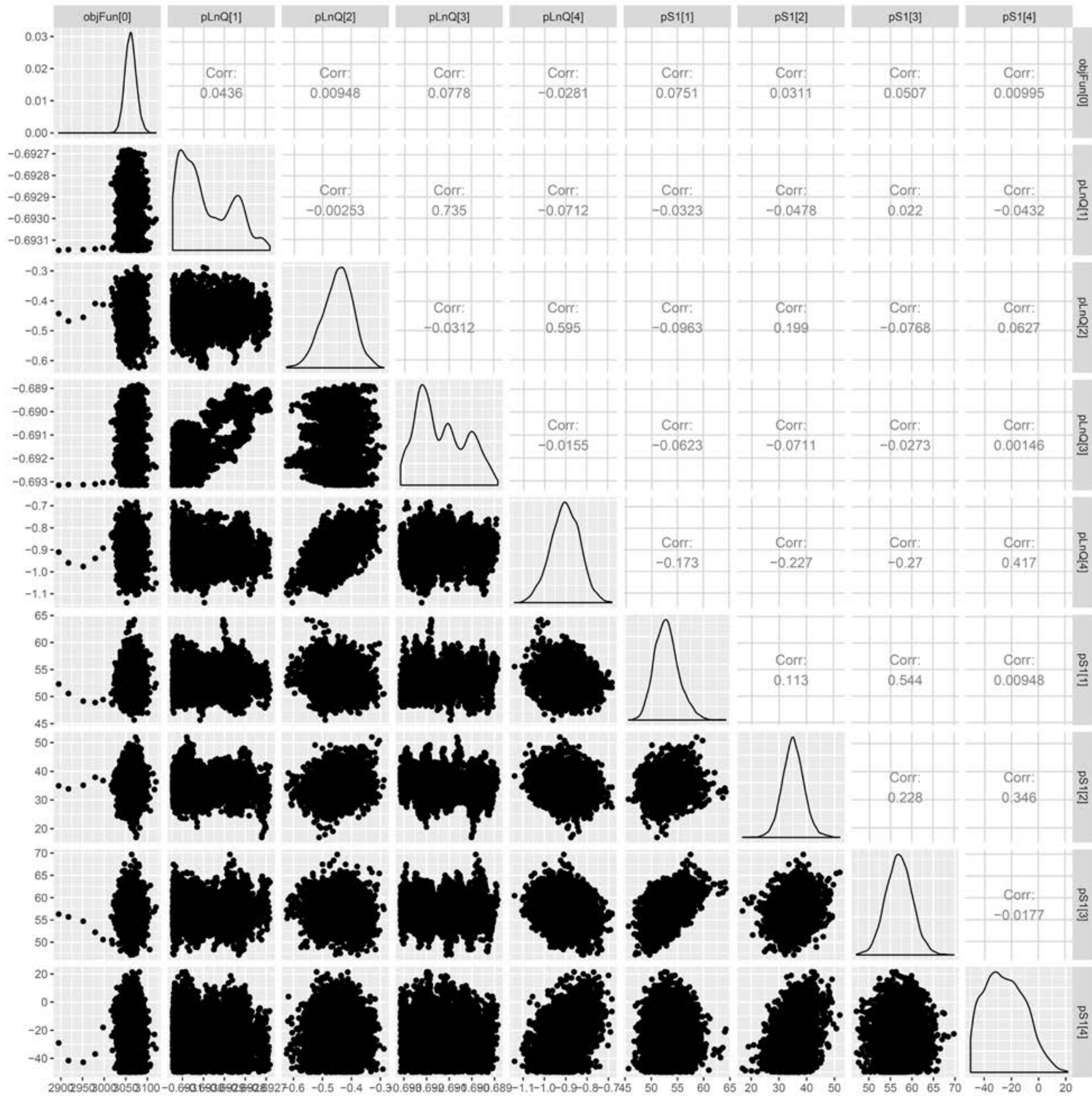

Figure 23. MCMC results from scenario B2b, the author's preferred model, for survey catchability and selectivity parameters.

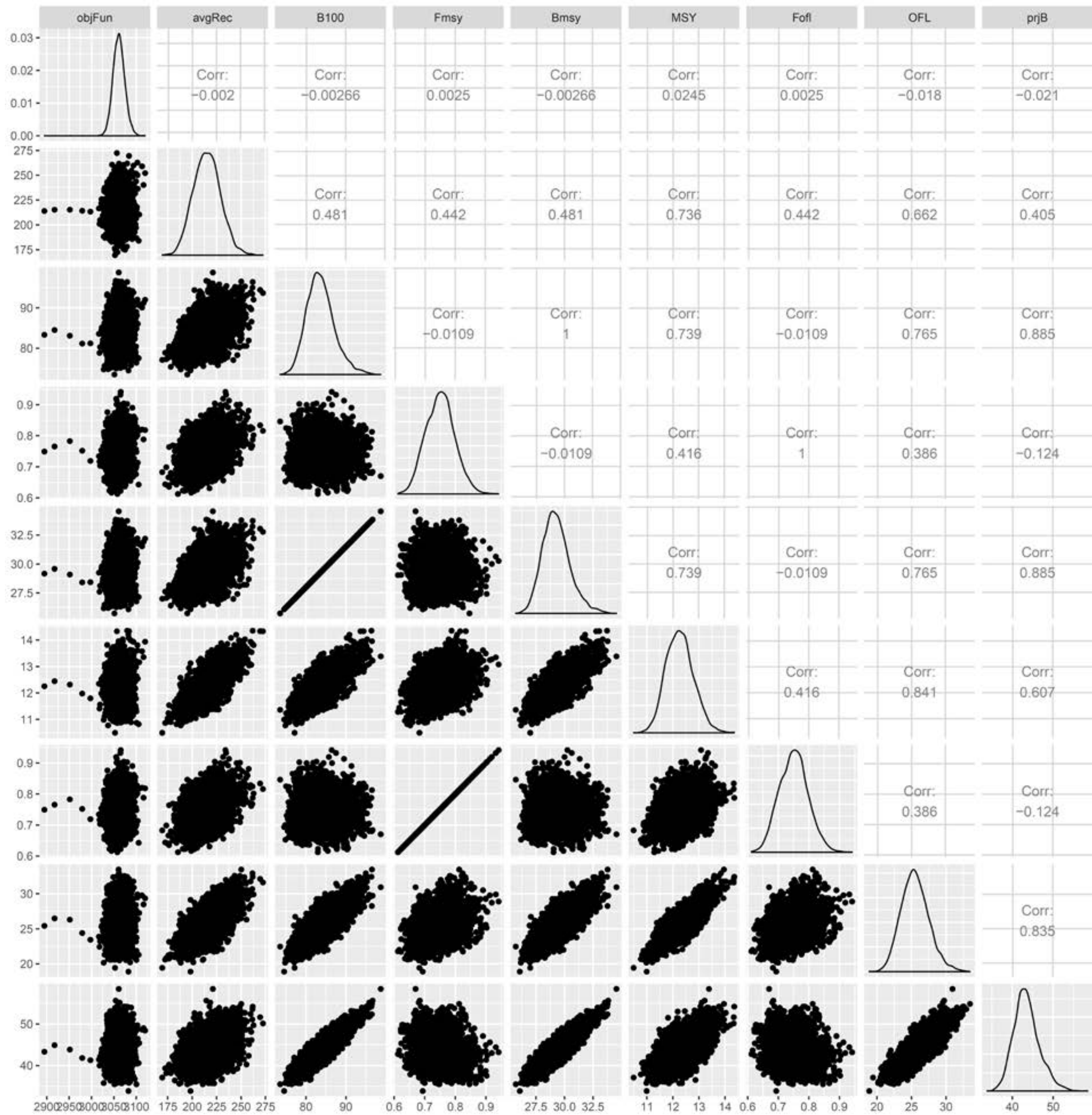

Figure 24. MCMC results from scenario B2b, the author's preferred model, for OFL-related quantities.

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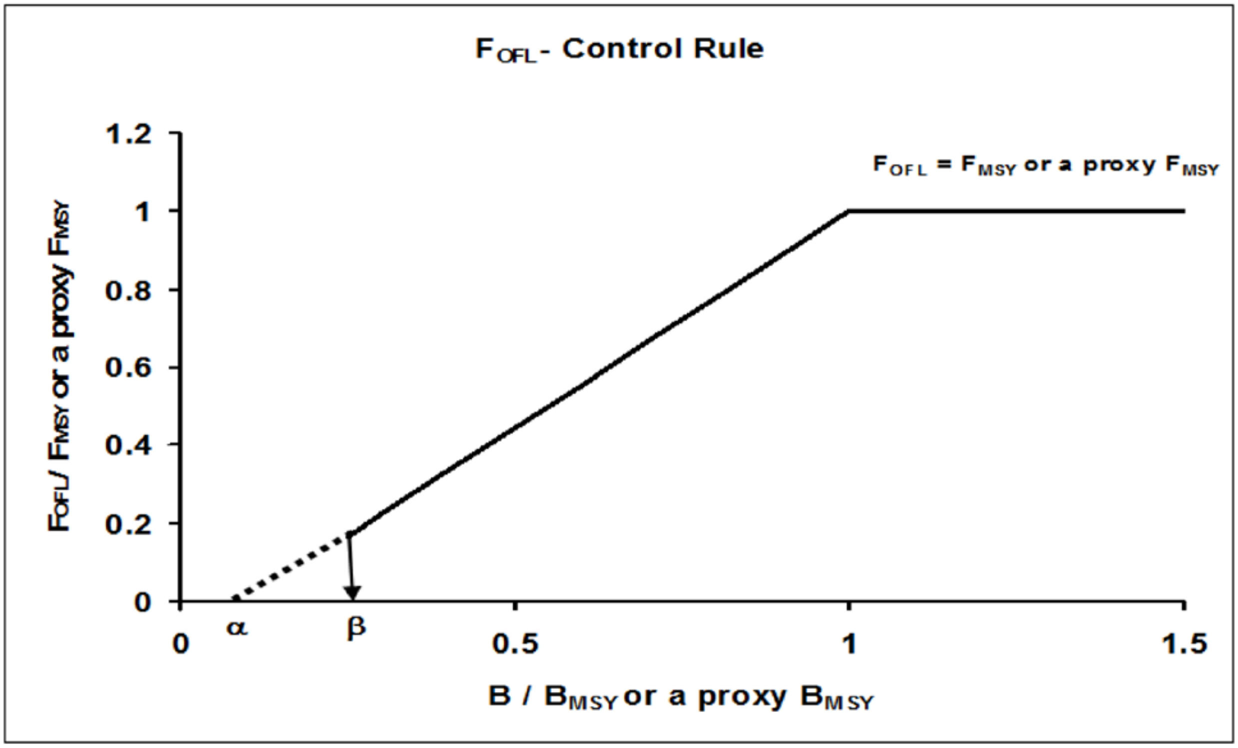

Figure 25. The F_{OFL} harvest control rule.

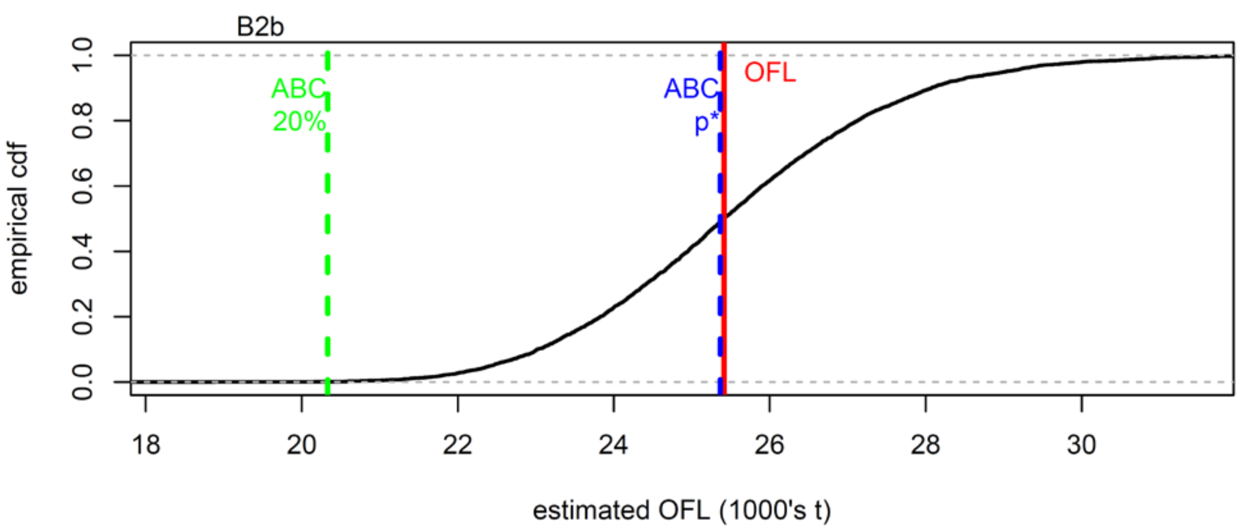

Figure 26. The OFL and ABC from the author's preferred model, scenario B2b.

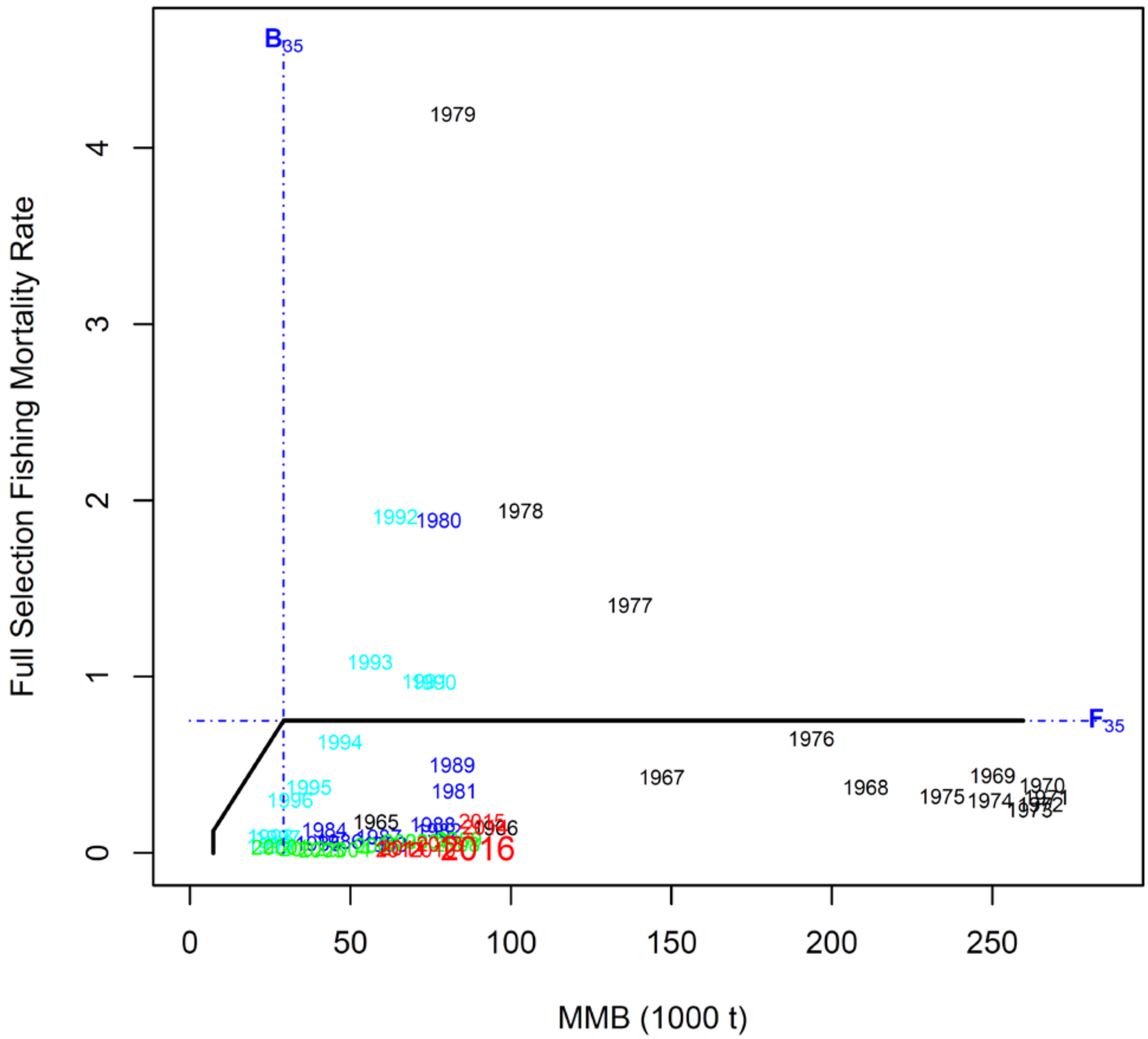

Figure 27. Quad plot for the author's preferred model, scenario B2b.