2023 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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1 Executive Summary

1.1 Stock: species/area

Southern Tanner crab , *Chionoecetes bairdi*, in the eastern Bering Sea (EBS).

1.2 Catches: trends and current levels

Legal-sized male Tanner crab are caught and retained in the directed (male-only) Tanner crab fishery in the eastern Bering Sea (EBS). The North Pacific Fishery Management Council (NPFMC) annually determines the overfishing limit (OFL) and acceptable biological catch (ABC) levels for Tanner crab in the EBS. The Alaska Department of Fish and Game (ADFG) sets the total allowable catch (TAC) separately for areas east and west of 166^{o}W longitude in the Eastern Subdistrict of the Bering Sea District Tanner crab Registration Area J based on the State's harvest strategy, which is determined by its Board of Fisheries. The OFL and ABC apply to "total catch mortality", which includes estimated bycatch mortality on discarded males and females from all fisheries that capture Tanner crab, as well as retained catch. The TAC applies only to retained catch, but is constrained by the ABC.

In addition to legal-sized males, females and sub-legal males are taken in the directed fishery as bycatch and must be discarded. Discarding of legal-sized males also occurs, primarily because the minimum size preferred by processors is larger than the minimum legal size but also because "old shell" crab can be less desirable than "new shell" males. Tanner crab are also taken as bycatch in the snow crab and Bristol Bay red king crab fisheries, the groundfish fisheries and, to a very minor extent, the scallop fishery. In order to account for mortality of discarded crab, handling mortality rates for Tanner crab are assumed to be 0.321 for crab discarded in the crab fisheries, 0.321 for crab discarded in the groundfish fisheries that use fixed gear, and 0.8 for crab discarded in the groundfish fisheries that use trawl gear. These valuesaccount for differences in gear and handling procedures used in the various fisheries.

Following rationalization of the Bering Sea and Aleutian Islands (BSAI) crab fisheries in 2005/06, the directed fishery for Tanner crab was prosecuted through 2009/10, after which ADFG set TACs to 0 in both management areas (thus closing the directed fishery) because stock biomass failed to meet required thresholds in the State's harvest strategy. Prior to the 2010/11 closure, the retained catch averaged 0.767 thousand t per year between 2005/06-2009/10 and total catch mortality averaged 1.815 thousand t. In early 2012, the National Marine Fisheries Service (NMFS) declared the stock overfished because the estimated mature male biomass fell below the federal Minimum Stock Size Threshold (MSST), which was based on a Tier 4 harvest control rule at the time (i.e., B_{MSY}, and thus MSST, was based on average mature male biomass over a specified time period; (Rugolo and Turnock 2011b)).

Later in 2012, NMFS determined that the stock was no longer overfished based on a new Tier 3 assessment model. The OFL for 2012/13 was determined to be 19,020 t while the ABC was set to 8,170 t based on an adopted "stair-step approach" to re-opening the fishery. ADFG, however, set the TAC to 0 in both management areas in accordance with its harvest strategy. The OFL for the following year (2013/14) was determined to be 25,350 t, with an ABC of 17,820 t set following the stair-step approach. ADFG subsequently set the TAC at 746 t (1,645,100 lbs) for the western area and at 664 t (1,463,000 lbs) for the eastern area and the directed fishery was prosecuted for the first season since 2009/10. On closing, 80% (594 t) of the TAC was taken in the western area while 99% (654 t) was taken in the eastern area. Total catch mortality was 2,235 t. Since then, the stock has remained above its Tier 3 MSST and has not been considered overfished by federal standards. OFLs have ranged from ~21,000 t to ~32,000 t while ABCs have ranged from ~17,000 t to ~27,000 t; none have constrained fishery TACs set by ADFG. However, the directed fishery has been closed by ADFG in 6 out of 10 years in the eastern region (i.e., all years following the 2015/16 season except 2022/23) and 2 out of 9 years (2016/17 and 2019/20) in the western region based on harvest strategies with criteria incorporating stock size thresholds for females as well as males.

Since 2013/14, harvests reached a maximum of ~8,900 t (~20 million lbs) in 2015/16, but have subsequently been less than 1,200 t. During this period total catch mortality peaked in 2015/16 as well (~11,000 t) but has been less than (~2,000 t) since then.

For 2022/23, the OFL was 32,810 t and the ABC was 26,250 t. TAC in the eastern region was 528.0 t and 386.0 t in the western region. Total retained catch was 913.3 t and total fishing mortality was 1,186 t.

1.3 Stock biomass: trends and current levels relative to virgin or historic levels

The annual NMFS EBS shelf summer bottom trawl survey has been conducted since 1975. It is the principal source of fishery-independent data on the size of the Tanner crab stock. In 2023, survey biomass was 34.52 thousand t for males, 16.59 thousand t for females, and 6.018 thousand t for industry-preferred males (males $\geq$ 125 mm CW). Average survey biomass over the past 5 years was 31.10 thousand t for males, 11.90 thousand t for females, and 6.665 thousand t for industry-preferred males. Since the survey gear was standardized in 1982, maximum survey biomass occurred for males occurred in 1991 at 145.8 thousand t, for females in 1982 at 65.85 thousand t, and for industry-preferred males in 1992 at 127.6 thousand t. In general, the stock has fluctuated on a decadal scale imposed on a declining trend since the beginning of the survey. Since 2010, maximum survey biomass for males occurred in 2014 at 108.9 thousand t, for females in 2013 at 24.22 thousand t, and for industry-preferred males in 2014 at 35.98 thousand t.

For EBS Tanner crab, spawning stock biomass is expressed as mature male biomass (MMB) at the time of mating (mid-February), which is a model-estimated quantity. From the author's preferred model (22.03b), estimated MMB for 2022/23 was 74.17 thousand t. The most recent peak in MMB occurred in 2014/15 at 122.4 thousand t. It approached the very low levels seen in the mid-1990s to early 2000s (1993 to 2003 average: 52.40 thousand t) in 2020/21 at 53.12 thousand t but has increased over the past two years.

1.4 Recruitment: trends and current levels relative to virgin or historic levels.

Annual recruitment, the number of small crab ($\geq$ 25 mm CW) entering the population at the beginning of the crab year (July 1), is a model-estimated quantity. From the author's preferred model (22.03b), estimated total recruitment has increased since 2020, when it reached its lowest level (75 million) since 2011. Average recruitment over the previous 10 years (2012-2022) was 428 million crab, which is ~6% less than the long-term (1982-2022) mean of 458 million crab. For 2023, estimated recruitment is 1,431 million crab, which is slightly less than the estimate for the previous year (1,588 million) but substantially above the longterm average. However, estimates of recruitment in the final model year are generally not well-estimated and retrospective analysis indicates the estimates tend to decrease as data from subsequent years is added.

1.5 Management performance

Historical status and catch specifications for eastern Bering Sea Tanner crab, with 2023/24 values based on the maximum likelihood estimate (MLE) from the author's recommended model, 22.03b, are given in the following tables:

Table A. Management quantities (in 1,000's t) from the author's preferred model, 22.03b, and recommended ABC buffer (25%). TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2019/20	18.31	56.15	0.00	0.00	0.54	28.86	23.09
2020/21	17.97	56.34	1.07	0.66	0.96	21.13	16.90
2021/22	17.37	62.05	0.50	0.49	0.78	27.17	21.74
2022/23	18.19	74.17	0.91	0.91	1.19	32.81	26.25
2023/24	–	48.77	–	–	–	36.20	27.15

Table B. Management quantities (in millions of pounds) from the author's preferred model, 22.03b, and recommended ABC buffer (25%). TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2019/20	40.36	123.77	0.00	0.00	1.20	63.62	50.89
2020/21	39.61	124.19	2.35	1.44	2.11	46.58	37.26
2021/22	38.29	136.79	1.10	1.09	1.73	59.89	47.91
2022/23	40.11	163.52	2.02	2.01	2.62	72.34	54.25
2023/24	–	107.52	–	–	–	79.82	59.86

Notes: Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

1.6 Probability density function for the OFL

The probability density function assumed for the Tier 3 OFL to determine the p^* ABC was a normal function with mean 36,204 t and standard deviation 2,208 t. The standard deviation for the OFL was estimated using AD Model Builder's "delta" method.

1.7 Basis for the 2023/24 OFL

Table C. Basis for the OFL from the author's preferred model, 22.03b. Biomass uints are in 1,000's of metric tons.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2019/20	3b	41.07	39.55	0.96	1.08	1982-2019	0.23
2020/21	3b	36.62	35.31	0.96	0.93	1982-2019	0.23
2021/22	3a	35.94	42.57	1.18	1.17	1982-2020	0.23
2022/23	3a	34.70	47.58	1.37	1.17	1982-2021	0.23
2023/24	3a	36.39	48.77	1.34	1.16	1982-2022	0.23

Table D. Basis for the OFL from the author's preferred model, 22.03b. Biomass units are in millions of pounds.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2019/20	3b	90.53	87.18	0.96	1.08	1982-2019	0.23
2020/21	3b	80.72	77.84	0.96	0.93	1982-2019	0.23
2021/22	3a	79.23	93.85	1.18	1.17	1982-2020	0.23
2022/23	3a	76.57	104.88	1.37	1.17	1982-2021	0.23
2023/24	3a	80.22	107.52	1.34	1.16	1982-2022	0.23

B_{MSY} for this stock is calculated to be 36.39 thousand t, so MSST is 18.19 thousand t. Because current MMB (74.17 thousand t) > MSST, the stock is not overfished. Estimated total catch mortality (retained + discard mortality in all fisheries, using discard mortality rates of 0.321 for crab pot gear, 0.321 for fixed gear in the groundfish fisheries, and 0.8 for trawl gear) was 1.186 thousand t, which was less than the OFL for 2022/23 (32.81 thousand t); consequently, overfishing did not occur.

The OFL for 2023/24, based on the author's preferred model (22.03b), is 36.20 thousand t, which results in a projected MMB of 48.77 thousand t. The ABC_{max} for 2023/24, based on the p^* ABC, is 36.15 thousand t. In 2014, the NPFMC's Scientific and Statistical Committee (SSC) adopted a 20% buffer to calculate ABC for Tanner crab to incorporate concerns regarding model uncertainty for this stock. However, the assessment author recommends increasing this buffer to 25% based on concerns regarding increased environmental uncertainty, possible model convergence issues, and overly-optimistic model estimates for recent survey biomass trends. Based on this buffer, the ABC would be 27.15 thousand t.

1.8 Rebuilding analyses results summary

The Tanner crab stock was found to be above MSST (and B_{MSY}) in the 2012 assessment (Rugolo and Turnock 2012a) and was subsequently declared rebuilt. The stock remains not overfished. Consequently, no rebuilding analyses were conducted.

2 Summary of Major Changes

2.1 Management

The directed fishery was prosecuted in 2022/23 in both State management areas (i.e., east and west of 166°W longitude in the General Section of the Eastern Subdistrict of the Bering Sea District of the Tanner Crab Registration Area J; Figure 1) in the EBS. This is the first time that the eastern area has been open to directed fishing since the 2015/16 season. The snow crab and Bristol Bay red king crab (BBRKC) fisheries were closed by the State in 2022/23, so no incidental retention or bycatch of Tanner crab occurred in these fisheries during the past year.

2.2 Input data

Retained catch time series (catch abundance and biomass) and size compositions were updated with data from the directed Tanner crab for 2022/23. Time series of estimated total catch abundance and biomass, as well as associated size composition data, from fishery observer sampling were updated with information from the 2022/23 season for the directed fishery and the groundfish fisheries. The snow crab and BBRKC fisheries were closed in 2022/23, so no bycatch or observer sampling occurred in these fisheries. Fishery-independent time series ("survey" biomass and abundance) and size compositions were updated with data from the 2023 NMFS EBS shelf bottom trawl survey, as were proportions-at-size for new shell males. The updates are summarized in Table E.

Table E. Data updated for this assessment.

Description	Data types	Time frame	Notes	Source
NMFS EBS Bottom Trawl Survey	area-swept abundance, biomass	1975-2019, 2021-23	2023 added	NMFS
	size compositions	1975-2019, 2021-23	2023 added	
	male maturity data	2006+	2023 added	
NMFS/BSFRF	molt-increment data	2015-17, 2019	no new data	NMFS, BSFRF
BSFRF SBS Bottom Trawl Survey	area-swept abundance, biomass	2013-17	no new data	BSFRF
	size compositions	2013-17	no new data	
Directed fishery	historical retained catch (numbers, biomass)	1965/66-1996/97	not updated	2018 assessment
	historical retained catch size compositions	1980/81-2009/10	not updated	2018 assessment
	retained catch (numbers, biomass)	2005/06-2022/23	2022/23 added	ADFG
	retained catch size compositions	2013/14-2022/23	2022/23 added	ADFG
	total catch (abundance, biomass)	1991/92-2022/23	2022/23 added	ADFG
	total catch size compositions	1991/92-2022/23	2022/23 added	ADFG
Snow Crab Fishery	historical effort	1978/79/1989/90	not updated	2018 assessment
	effort	1990/91-2022/23	no 2022/23 fishery	ADFG
	total bycatch (abundance, biomass)	1990/91-2022/23	no 2022/23 fishery	ADFG
	total bycatch size compositions	1990/91-2022/23	no 2022/23 fishery	ADFG
Bristol Bay Red King Crab Fishery	historical effort	1953/54-1989/90	not updated	2018 assessment
	effort	1990/91-2022/23	no 2022/23 fishery	ADFG
	total bycatch (abundance, biomass)	1990/91-2022/23	no 2022/23 fishery	ADFG
	total bycatch size compositions	1990/91-2022/23	no 2022/23 fishery	ADFG
Groundfish Fisheries (all gear types)	historical total bycatch (abundance, biomass)	1973/74-1990/91	not updated	2018 assessment
	hostorical total bycatch size compositions	1973/74-1990/91	not updated	
	total bycatch (abundance, biomass)	1991/92-2022/23	now using AKRO algorithm for 2016/17+; 2022/23 added	NMFS/AKFIN
	total bycatch size compositions	1991/92-2022/23	2022/23 added	

2.3 Assessment methodology

The assessment model framework, TCSAM02, is described in detail in Stockhausen (2023a). Changes to the framework were reviewed in May and June by the Crab Plan Team (CPT) and SSC, respectively (CPT 2023; see Stockhausen 2023b; and SSC 2023), but no models incorporating those changes were selected as candidates for this assessment. The only model, 22.03b, considered in this assessment is basically identical to the accepted model from last year's assessment, 22.03, but updated with new data. The one functional difference between Models 22.03b and 22.03 is that the parameter controlling the slope of the curve describing retention in the directed fishery during 2006/06-2009/10 that was estimated at its upper bound in 22.03 was fixed to that bound in 22.03b to avoid statistical and numerical issues associated with parameters estimated at a bound.

In addition to the Tier 3 model, results from a Tier 4 "fallback" model were also developed to address a request by the SSC to develop such a model. The model uses a random walk model to reduce the variance in design-based estimates of survey MMB and applies the Tier 4 control rule to calculate Tier 4 alternatives to the Tier 3 OFL and ABC.

2.4 Assessment results

Total fishing mortality in 2022/23, based on retained catch information from fish tickets and estimates of discard mortality for Tanner crab in the directed fishery, the snow crab fishery, and the groundfish fisheries, was 1.186 thousand t, which was less than the OFL for 2022/23, so overfishing did not occur. Based on results from the author's preferred model, 22.03b, stock status did not change: the stock remains in Tier 3a and the stock is not overfished. The OFL for 2023/24 is 36.20

thousand t. The author-recommended buffer is 25%, which is larger than the buffer applied last year (20%). The author-recommended ABC for 2023/24 is 27.15 thousand t.

3 Responses to the most recent two set of SSC and CPT Comments

3.1 CPT comments May 2023:

3.1.1 CPT Comments (specific to assessment)

The CPT commends the author for the large amount of exploration and work done on model runs and recommends that the author bring forward model 22.03b as the base model for specifications in the fall.

Response (9/23)

Done.

3.1.2 CPT Comment

The CPT encouraged the author to bring forward in September the Tier 4 option that was decided upon at the simpler modeling workshop. This involved using smoothing of the area-swept MMB estimates and applying F = M for OFL determination. There was discussion upon which set of years to use for setting status determination using this method, and CPT members suggested reviewing the last accepted Tier 4 model – i.e., before the Tier 3 model was accepted – for reasoning as to the years that were used for status determination at that time.

Response (9/23)

Done–see Section 8.

3.2 SSC comments June 2023:

3.2.1 SSC Comment (general)

The SSC highlights that the estimation of unrealistically high instantaneous fishing mortality rates appears to be an emergent property of several crab assessments…These estimates result in ABC recommendations that would remove virtually all legal sized crab from the population. The SSC encourages collaboration among assessment authors to identify the root causes of this common issue and potential solutions and suggests potentially using a hypothesis driven approach…a high priority topic for the crab modeling workshop planned for January 2024.

Response (9/23)

The root cause of ABC recommendations that would remove all legal-sized crab is the combination of an industry-preferred size larger than the average size at maturity, and an SPR-based harvest control rule. Mature males smaller than the industry-preferred size form a "pool" protected from exploitation. As the separation between industry-preferred size and average size of mature males increases, the more the biomass in this protected pool increases relative to unfished biomass and the less is needed in the vulnerable pool of large males to achieve 35% of unfished MMB. The consequence is that the F_{OFL} calculation results in higher and higher F's on industry-preferred males. For king crab, which do not undergo terminal molt, crab in the protected pool will eventually grow into the vulnerable pool–which somewhat reduces the estimated F's. For opilio and bairdi, because they undergo terminal molt, mature males under the industry-preferred size will never grow out of the protected pool of biomass–thus increasing the estimated F's over what they would be for species with similar population characteristics that did not undergo terminal molt.

3.2.2 SSC Comment

The SSC recommends that when "fallback" Tier 4 alternatives are provided, as recommended by the crab Simpler Modelling Workshop, plots that compare the OFLs predicted by the existing status quo Tier 3 model against the OFLs recommended by Tier 4 models for previous years be included.

Response (9/23)

The Tier 4 model does not estimate OFLs for "previous years", which would require developing a retrospective analysis capability. If this is a priority, it could be addressed in the future.

3.2.3 SSC Comment (general)

In addition, when estimating biomass for Tier 4 models, the SSC recommends that the authors base these on the whole time series or develop justification for a better time block that represents current fishing potential for the stock.

Response (9/23)

Results for B_{MSY} calculated using several aternative time blocks are presented in Section 8.

3.2.4 SSC Comment (general)

The SSC also recommends that, for "fallback" Tier 4 models, the authors and CPT recommend an appropriate ABC buffer.

Response (9/23)

The author recommends using the cv for terminal year survey biomass from the random walk model as a basis for the ABC buffer. The final value could be based on a P*-like calculation or directly as a fractional buffer (i.e., $ABC = (1 - cv) \cdot OFL$).

3.2.5 SSC Comment (specific)

The SSC reiterates its support for transitioning this model, or a simplified version thereof, into the standardized GMACS platform. The SSC feels that transitioning this assessment into GMACS is a higher priority at this point than continued exploration of model alternatives (e.g. 23.02, 23.05) within the existing framework. The SSC further reiterates its recommendation from October 2022 that the GMACS implementation of the Tanner crab model could represent a simplified version of the current model structure, as a foundation upon which additional features may be explored and incorporated sequentially.

Response (9/23)

Transitioning the assessment to GMACS will be the top priority for development in the fall.

3.2.6 SSC Comment(specific)

The SSC requests that a clear justification for the choice of reference time period be provided in the September SAFE document, beyond simple precedent, and that several alternative time periods be considered (each with its own justification).

Response (9/23)

Several time blocks were considered for the Tier 4 averaging time period used to calculate B_{MSY} (see Section 8.3). Justification for using each was discussed.

3.2.7 SSC Comment (specific)

The SSC concurs with the CPT that continued exploration of constrained time-varying natural mortality may be appropriate, when paired with external estimation of growth and use of BSFRF data to inform priors on selectivity. This may represent a suitable balance in terms of the added complexity of time-varying natural mortality, against reductions in the complexity of growth and selectivity estimation. However, the SSC recommends that these explorations be conducted using a GMACS version of the assessment model, when successfully implemented.

Response (9/23)

Noted.

3.3 CPT comments September 2022:

3.3.1 CPT Comment (specific)

The author identified several avenues of research to be pursued in the coming year, including: transitioning to GMACS, completing the BSFRF/NMFS survey selectivity analysis, exploring time-varying natural mortality, investigating non-parametric approaches to selectivity, and a more thorough evaluation of a model that starts in 1982. The CPT was supportive of these pursuits.

Response (9/23)

Models that investigated time-varying M were presented at the May, 2023 CPT meeting. Completing the survey selectivity analysis awaits acquisition of the 2018 BSFRF survey data. Transitioning to GMACS will be top priority following the 2023 assessment; other areas for investigation will be lower priority.

3.3.2 CPT Comment (specific)

Show plots for jitter analyses that could demonstrate (or rule out) bimodality in management quantities (the author noted that the models presented converged to the MLE over 50% of the time in 800 jitter runs, but diagnostic plots were not presented).

Response (9/23)

Jitter diagnostics are presented in Figure 49 for Model 22.03b.

3.3.3 CPT Comment (specific)

Provide a plot of the fits to male and female components separately when they are fit in an aggregated fashion (as in 22.03). Are the fits to either sex substantially degraded?

Response (9/23)

Although this is a reasonable idea, it is currently not possible to provide such a plot.

3.3.4 CPT Comment (specific)

Provide some discussion as to why there was an exceptionally small retrospective pattern in spite of the issues with recruitments that appear and then do not propagate through the population.

Response (9/23)

The small retrospective pattern was with respect to MMB, while the pattern for recruitment was much larger. The larger retrospective pattern for recruitment occurs exactly as a result of the apparent recruitment events disappearing (new data reduces the estimated size of recruitment in any particular year). The small retrospective pattern for MMB is a result of the estimated model dynamics that extend over many cohorts and "damp out" patterns seen in the small size classes in order to better fit patterns seen in the larger size classes. The model places much more emphasis on fitting large size classes better because it fits to survey and fishery *biomass* time series, not abundance time series.

3.3.5 CPT Comment (specific)

Continue to explore ways to eliminate the overestimates of large crab (the interplay between growth estimates and non-parametric selectivity might be a useful avenue to explore)

Response (9/23)

This suggestion will be explored as part of building a GMACS Tanner crab model.

3.4 SSC comments October 2022:

3.4.1 SSC Comment (general)

The SSC supports the CPT plans to discuss appropriate model start dates as well as reference periods for B_{MSY} (e.g., SMBKC and PIRKC) at their January 2023 meeting to provide guidance to stock assessment authors. The SSC recommends that the CPT explore a consistent approach across all EBS stocks to use trawl survey data after 1982 when gear and sampling designs were more standardized

Response (9/23)

See Section 3.6.1.

3.4.2 SSC Comment (general)

The SSC encourages crab authors to continue to move as much of the research and model development as possible to earlier in the year, as this would streamline reviews in the fall and facilitate the use of VAST models and inclusion of Northern Bering Sea (NBS) survey data into crab assessments.

Response (9/23)

Almost all Tanner crab model development occurs between October following the SSC meeting and the subsequent May CPT meeting.

3.4.3 SSC Comment (general)

The SSC encourages further considerations or ideas on potential cooperative pot surveys for different crab stocks.

Response (9/23)

This seems like a potential topic for the January CPT meeting.

3.4.4 SSC Comment (general/specific)

The SSC suggests that fitting a range of simpler models and data limited approaches, such as the Tier 4 calculation, can also provide insight into the differences between raw survey observations and integrated assessment model output…The SSC recommends a working group to address the use of simpler models for at least snow crab, Tanner crab and BBRKC.

Response (9/23)

The suggested working group was convened in March, 2023 at the AFSC. Methodology for and results from a "fallback" Tier 4 model for Tanner crab are presented in Section 8.

3.4.5 SSC Comment (general)

The SSC recommends the formation of a working group to develop a framework for how to estimate the magnitude of unobserved mortality for crab stocks and how these estimations may be utilized in BSAI crab stock assessments.

Response (9/23)

The working group has been formed; meetings are scheduled for October.

3.4.6 SSC Comment (general)

The SSC recommends that all crab authors plot length compositions over years with the most recent year at the bottom of the plot.

Response (9/23)

Not yet addressed.

3.4.7 SSC Comment (specific)

The SSC highlights the following areas as highest priority for the Tanner crab assessment: 1) transition the Tanner assessment model to GMACS; 2) the investigation of model outputs that better inform State management, especially males of industry-preferred size to ensure proper scaling; 3) The SSC suggests fitting a range of simpler models or data limited approaches;

Response (9/23)

For 1), transition to GMACS will be given the highest priority following the October SSC meeting. For 2), State management occurs on a two-area basis while the assessment model is area-aggregated (a "fleets-as-areas" model incorporating area-specific considerations was previously investigated but fitting the area-specific data was problematic). The correct scaling of (area-aggregated) industry-preferred male abundance in the assessment model depends on correctly estimating survey selectivity and catchability, growth, terminal molt, and natural mortality simultaneously, but this remains problematic due to parameter confounding among these processes. For 3), a Tier 4 model was developed and results are presented in this assessment.

3.4.8 SSC Comment (specific)

The SSC recommends that the CPT review the assessment frequency (see also Stock Prioritization section) for Tanner crab and provide the SSC their recommendation.

Response (9/23)

An issue for the CPT, but noted here.

3.5 CPT comments May 2022:

3.5.1 CPT Comment (specific)

Four models are requested by the CPT for the September CPT meeting: 1) Model 22.01: Base model from last year updated with new data; 2) Model 22.03: updated bycatch estimates for the groundfish fisheries, and fitting to fishery aggregate biomass; 3) modified model 22.06a: Initial size composition in 1982 with a smoothing weight of 0.1, and initial composition parameters estimated on a logit scale, but also including the features of model 22.03; and 4) modified model 22.06a as described above plus bootstrap estimates of input sample sizes.

Response (9/22)

All requested models were implemented and results are provided in this assessment. The latter two models were numbered as 22.07 and 22.08 because they differ from models presented in May.

3.5.2 CPT Comment (specific)

The CPT also encourages Buck to continue exploring alternative approaches to incorporating the BSFRF survey data in the assessment, attempting to model the ADF&G management areas as separate fisheries, and to continue making progress on a GMACS implementation for Tanner crab.

Response (9/23)

These continue to be areas of active investigation. Implementing a Tanner crab model in GMACS will be given the highest priority following the 2023 assessment.

3.6 SSC comments June 2022:

3.6.1 SSC Comment (general)

The SSC suggests that the CPT develop guidelines for when to change model start dates. Both BBRKC and Tanner crab assessment authors proposed changes to model start dates with similar, but not identical rationales. While changing start dates may lead to improved model fits to available data and allow for reduced model complexity in terms of removing time blocks for natural mortality or other parameters, there is a potential to lose historical context or the ability to better understand what might have caused model difficulties or demographic changes (e.g., increased mortality events). Thus, the overall goal of these guidelines would be to ensure a full discussion and consistent criteria be applied for proposed changes across stocks into the future. The SSC recommends that these guidelines for start date changes should consider data availability, model complexity, impacts to estimates of the average level and variation in recruitment, loss of historical context and perspective on natural mortality changes and how this would impact short and long-term projections for stock dynamics.

Response (9/23)

The CPT discussed developing general and consistent guidelines on changing model start date at its January 2023 meeting. The issues discussed were very stock-specific and the CPT was unable to make any firm recommendations on general guidelines.

3.6.2 SSC Comment (specific)

Even though the estimation of input sample sizes did not perform as expected (it produced even higher sample sizes than default values in the base model), the SSC supports the CPT recommendation to revisit this approach with the revised start date (1982).

Response (9/22)

Model 22.08 addresses this request, but results remained problematic. The author notesthat multinomial likelihoods were used in fitting this model and that it should be reconsidered using the Dirichlet-multinomial likelihood.

3.6.3 SSC Comment (specific)

The SSC commends the authors for proposing two models (22.01 and 22.03) with no parameters hitting bounds and the remaining models having only two or three parameters at bounds (depending on smoothing). The SSC recommends continued efforts to examine and address the remaining parameters that are still estimated at their bounds.

Response (9/22)

The author appreciates the SSC comment and notes that remaining parameters at bounds involve limits on selectivity-related parameters reflecting knife-edge like selectivity patterns (e.g., retention functions) or full selected sizes that would go beyond observed sizes in the data. Implementation of a well-behaved bounding function is an area of active (although incomplete) research.

3.6.4 SSC Comment (specific)

The SSC supports CPT recommendations to continue exploring alternative approaches to incorporating the BSFRF survey data in the assessment, attempting to model the ADF&G management areas as separate fisheries, and to continue making progress on a GMACS implementation for Tanner crab. However, the SSC recognizes that there may be benefits of waiting until additional improvements in GMACS occur, specifically the adoption of a GMACS model for snow crab.

Response (9/22)

GMACS models for snow crab have now been adopted, so development of a GMACS version of the Tanner crab model is underway. The SSC's other recommendations are appreciated and the author notes that these are active areas of research.

3.6.5 SSC Comment (specific)

The SSC also suggests that the CPT develop guidelines for changing model start dates. Both BBRKC and Tanner crab assessments proposed changes to their starting dates with similar rationales. Please refer to the General Comments for Crab Assessment Authors section above for a more detailed SSC recommendation.

Response (9/22)

See Section 3.6.1.

3.7 CPT comments January 2022

3.8 SSC comments February 2022

3.8.1 SSC Comment (general)

The SSC supports the CPT general recommendations that all stock assessments include results from the currently accepted model with new data (base model) so that changes in model performance can be assessed. Values for management-related quantities for all models that may be recommended by the CPT or SSC should also be available.

Response (9/23)

The author's preferred model, 22.03b (and the only Tier 3 model evaluated for this assessment) is essentially identical to the model from last year's assessment (22.03). Consequently, results are compared between 22.03b with data updated for 2023 and results for 22.03 from last year's assessment.

3.8.2 SSC Comment (general)

The SSC supports the CPT's proposed changes to the terms of reference for SAFE chapters for BSAI crab stocks, including efforts to clarify and standardize summary tables that include management performance, status, and catch specifications. Specifically, summary tables in the main body of a SAFE chapter for a given stock will provide information for each model run. In addition, the SSC recommends that the executive summary of the SAFE chapter will provide information for the author recommended model only and the BSAI Crab SAFE Introduction Chapter will provide information for the CPT recommended model, specifying if that differs from the author-recommended model. The SSC references its recommendation from December 2021 that assessment authors do not change recommendations in documents between the Plan Team and the SSC meetings and that deliberations and disagreements over assessment and other recommendations be documented in the Plan Team minutes. This ensures that changes between author recommendations and Plan Team recommendations are clearly documented and easily tracked.

Response (9/22)

Noted.

3.8.3 SSC Comment (general)

The SSC also appreciates the CPT's discussion regarding efforts to develop a standardized table and figure output for all SAFE chapters and encourages coordination with Groundfish Plan Teams to, as much as reasonably possible, strive for consistency, standardization, and reproducible documentation across all stocks.

Response (9/22)

Standardization with other stocks will probably remain an issue until the assessment is converted to GMACS. Candidate formats for standardized tables and figures have been developed that GMACS models could implement, if found useful.

4 Introduction

4.1 Stock

Chionoecetes 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 and Co-authors 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".

4.2 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 EBS, the unit stock is defined as the geographic range of the EBS continental shelf. *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 carapace width [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 Tanner crab distribution may be limited in its northward extent by water temperature (Somerton 1981a; Murphy 2020). The southern range of snow crab, the cold water congener *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).

4.3 Stock structure

Tanner crab in the EBS are considered to be a separate stock distinct from Tanner crab in the eastern and western Aleutian Islands (NPFMC 1998). Clinal differences across the EBS shelf in some biological characteristics such as mean mature size exist across the range of the unit stock, leading some authors to argue for a division into eastern and western stocks in the EBS (Somerton 1981b; Zheng 2008; Zheng and Pengilly 2011). However, it was not generally recognized at the time of these analyses that this species undergoes a terminal molt at maturity (Tamone et al. 2007), nor were the implications of ontogenetic movement considered. Thus, biological characteristics estimated using comparisons of length frequency distributions across the range of the stock, or on modal length analysis over time, may have been confounded as a result and do not provide definitive evidence of stock structure.

Simulated patterns of larval dispersal suggest that Tanner crab in Bristol Bay may be somewhat isolated from other areas on the shelf, and that this component of the stock relies heavily on local retention of larvae for recruitment, suggesting that Tanner crab on the shelf may exist as a metapopulation of weakly-connected sub-stocks (Richar et al. 2015). However, recent genetic analysis has failed to distinguish multiple non-intermixing, non-interbreeding sub-stocks on the EBS shelf (Johnson 2019), suggesting that Tanner crab in the EBS form a single unit stock.

4.4 Life History

4.4.1 Molting and shell condition

Tanner crab, 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 Table F.

Table F. Shell condition classification table.

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 that have certainly (SCs 0 and 1), or are likely to have (SC 2), molted within the previous year.

4.4.2 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 (2012b) derived growth relationships for male and female Tanner crab from data on observed growth in males to approximately 140 mm carapace width (CW) and in females to approximately 115 mm CW collected near Kodiak Island in the Gulf of Alaska [Munk, unpublished.; Donaldson et al. (1981)]. These relationships were used as priors for estimated growth parameters in older (2012-2016) assessments (Rugolo and Turnock 2012a; Stockhausen 2013, 2014, 2015, 2016). 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 was characterized for both males and females 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 from the EBS during 2015, 2016, 2017 and 2019 in cooperative research between NMFS and the Bering Sea Fisheries Research Foundation (BSFRF; R. Foy and E. Fedewa, NMFS, pers. comm.s). Previous analysis of the data suggests it is not substantially different from that obtained near Kodiak Island (Stockhausen 2017a). The EBS molt increment data is fit in the assessment model to inform inferred growth trajectories in all of the alternative models evaluated in this assessment.

4.4.3 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 shelf 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, z is the size in mm CW, and a and b are estimated coefficients [Daly et al. (2015); table below]. In 2021, Jon Richar (AFSC Kodiak) conducted a new analysis of the weight-at-size data for Tanner crab that incorporates shell condition as a factor. Other preliminary analyses suggest that temperature may be a factor, as well. The CPT, however, has not reviewed models based on these new relationships; thus, this assessment uses the previously-established relationships. The parameter values for the relationships used in this assessment are presented in Table G.

Table G. Weight-at-size parameters ($w = a \cdot z^b$) for Tanner crab, in grams.

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

4.4.4 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 (Adams and Paul 1983; Paul 1992), although egg viability decreases with time and age of the stored sperm (Paul 1992).

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). The ratio of chela height (CH) to carapace width (CW) has been used to classify male Tanner crab as morphometrically immature or mature. While many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow, there is now convincing evidence to support 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 (NMFS 2008).

In this assessment, all models include fits to size-specific annual proportions of mature, new shell male crab to all new shell male from the NMFS EBS bottom trawl survey, based on classification by 10 mm CW size bin using CH:CW ratios to inform size-specific probabilities of terminal molt. The classifications are based on techniques described in Richar and Foy (2022).

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; 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 begins in April and ends sometime in mid-June (Somerton 1981a).

4.4.5 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 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).

4.4.6 Size at maturity

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

4.4.7 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, he 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 (Somerton 1981a).

Unlike its congener the snow crab, information on longevity of the Tanner crab is lacking. Rugolo and Turnock (2011a) examined empirical evidence for reliable estimates of oldest observed age for male Tanner crab. 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 (Rugolo and Turnock 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. Alternatively, if 20 years was assumed to represent the 95% percentile of the distribution of ages in the unexploited stock, the estimate for M would be 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 the overfishing definitions underlying Amendment 24 to the Crab Fishery Management Plan (NMFS 2008).

4.5 Management history

Fisheries for Tanner crab have historically taken place throughout their range in Alaska, but currently only the fishery in the EBS is managed under a federal Fishery Management Plan (FMP, NPFMC 2021a). The plan defers certain management controls for Tanner crab to the State of Alaska ("State"), with federal oversight (ADFG 2008; NPFMC 2021a). The State manages Tanner crab based on registration areas divided into districts. Under the FMP, the State can adjust districts as needed to avoid overharvesting in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration NPFMC (2021a).

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 (ADFG 2008). ADFG sets separate annual TACs east and west of 166^oW longitude in the General Section on retained catch. In this report, the terms "east" and "west" (or "East 166W" and "West 166W") are used in shorthand fashion to refer to these management areas demarcated by 166^oW longitude where separate TACs are set.

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 based on Zheng and Pengilly (2011). Prior to this change, the minimum legal size limit had been 5.5" (140 mm CW, including lateral spines) throughout the Bering Sea District. The new regulations established different minimum size limits east and west of 166^o W. The minimum legal size for the fishery to the east of 166^oW 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 State's harvest control rules (HCRs) used to determine total allowable catch (TAC) generally incorporate minimum "industry-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 (Daly et al. 2020). The harvest strategy also employed a minimum threshold that the mature female biomass (MFB) in the Eastern Subdistrict be larger than 40% of its long-term (1975-2010) average in two subsequent years before the fisheries in either management area could be opened. Minimum thresholds for opening the fishery in a management area were also defined using the ratio of area-specific MMB to its associated long-term average. Finally, the harvest strategy defined area-specific sloping harvest control rules to determine the maximum allowable exploitation rate on mature males in each area based on the ratio of MFB to average MFB, together with limits on the maximum exploitation rate (Figure 2).

Subsequently, the State's harvest strategy has undergone three revisions in the past 8 years (Daly et al. 2020). In 2015, the minimum preferred harvest size used to compute TAC for the area east of 166^o W longitude was changed from 140 mm CW (5.5 inches; including the lateral spines) to 127 mm CW (5.0 inches), the preferred size used to compute TAC for the area west of 166^o W longitude. In 2017, the criteria used to determine MFB was changed from an area-specific one based on carapace width to one based on morphology (the same as that used by the NMFS EBS shelf bottom trawl survey), the definition of 'long-term average' for calculating average mature biomass was changed from 1975-2010 to 1982-2016, the spatial range for calculating average MFB was expanded to include the entire NMFS EBS shelf bottom trawl survey area, and a so-called 'error band system' was introduced in the HCR to account for survey uncertainty such that the exploitation rate on industry preferred-size males used to calculate was gradually reduced when the lower 95% confidence interval of the point estimate of MFB fell below 40% of the long-term average (replacing the requirement to close the fisheries when MFB fell below the 40% threshold; ADFG (2017); Daly et al. (2020)).

Most recently, the harvest strategy was changed in March 2020 based on results from an extensive management strategy evaluation (MSE) conducted with input from industry stakeholders, NMFS and academic scientists, and ADF&G managers (Daly et al. 2020; Heller-Shipley et al. 2021). The current HCR (Figure 3; HCR 4_1 in Daly et al. (2020)) defines the period for calculating average mature biomass as 1982-2018 and implements sliding scales for exploitation rates on mature males which are functions of the ratios of MMB and MFB to their long-term averages. One particularly notable change is that there is no longer a threshold for opening the fisheries based on MFB.

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 4). 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 4). Domestic US landings were first reported for Tanner crab in 1968 at 0.46 thousand t taken incidentally to the EBS red king crab fishery. 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 re-opened and landings rose again in the late-1980s to a second peak in 1990/91 at 16.61 thousand t, and then fell sharply through the mid-1990s. It was formally declared overfished by NMFS in 1999. The domestic Tanner crab fishery was closed between 1997/98 and 2004/05 as a result of conservation concerns regarding the depressed status of the stock.

The domestic fishery re-opened in 2005/06 coincident with rationalization of the crab fisheries and averaged 0.77 thousand t retained catch between 2005/06-2009/10 (Tables 3-5). The State closed directed commercial fishing for Tanner crab during the 2010/11-2012/13 seasons because estimated female stock metrics fell below thresholds adopted in the state harvest strategy. Additionally, the stock was once again declared overfished by NMFS in 2012 based on low survey estimates of mature male biomass.

Following a change in assessment Tier level from 4 to 3 following the development and acceptance of a Tier 3 assessment model in the fall of 2012, the stock was declared to be not overfished under Tier 3 and an OFL of 19,020 t was determined. The directed fisheries, however, remained closed per the State's harvest strategy. For 2013/14, the Tier 3 OFL was determined to be 25,350 t, with an ABC of 17,820 t. The stock metrics surpassed the State harvest strategy thresholds and the directed fishery was opened in 2013/14. TAC was set at 1,645,000 lbs (746 t) for the area west of 166^o W and at 1,463,000 lbs (664 t) for the area east of 166^o W. On closing, 80% (594 t) of the TAC had been taken in the western area while 99% (654 t) had been taken in the eastern area. Since then, ABCs (and OFLs) have been substantially higher than the sum of the area-specific TACs set by the State. For 2014/15, the Tier 3 ABC was 25,180 t and TAC was set at 3,005 t for the area west of 166^o W and at 3,846 t for the area east of 166^o W. On closing, 78% (2,329 t) of the TAC was taken in the western area while 100% (3,829 t) was taken in the eastern area. For 2015/16, the ABC was 21,750 while TAC was set at 3,808 t in the western area and 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) has been the largest taken in the fishery since 1992/93 (Tables 2 and 3; Figure 4).

The directed fisheries in both areas were closed in 2016/17 because mature female biomass in the 2016 NMFS EBS Bottom Trawl Survey did not exceed the threshold set in the State's harvest strategy to allow them to open. Total retained catch was thus 0 in 2016/17 although the ABC was 20,490 t. In 2017/18, the ABC was set at 20,330 t; the State allowed a directed fishery west of 166^o W longitude but closed the fishery east of 166^o W. Essentially, the entire TAC (1,134 t) was taken in 2017/18. The 2018/19 season followed a similar pattern, with the directed fishery closed in the eastern area and open in the western area (with a TAC of 1,106 t) while the ABC was 16,700 t. The entire TAC was again harvested in 2018/19. Although the ABC for 2019/20 was 23,090 t, the directed fisheries in both areas were again closed in 2019/20 because mature male biomass failed to achieve the required State threshold in either management area. In 2020/21, with an ABC of 16,900, the State criteria for opening the fishery were met in the western area, and the TAC was set to 1,065 t. Only 655 t was harvested. In 2021/22, the ABC was 21,740 t, the eastern area remained closed to directed fishing, and the TAC in the west was 499 t–of which 494 t was landed. In 2022/23 the ABC was 26,250 t and,following a revision of the State harvest strategy, the eastern area was opened to directed fishing for the first time since 2015/16 with a TAC of 528 t; the west was also open with a TAC of 386 t. The entire TAC was taken in both areas.

Tanner crab can be incidentally retained in the snow crab and BBRKC fisheries, up to a limit of 5% of the target species. In general, incidental retention in these fisheries has been small compared with retained catch in the directed fishery, although the snow crab fishery was responsible for a sizable fraction of the landed catch in 2005/06 and 2006/07 (Tables 3 and 4, Figure 5).

Bycatch and discard losses of Tanner crab originate from observer data taken in the directed pot fishery, non-directed snow crab and Bristol Bay red king crab pot fisheries, and the groundfish fisheries (Tables 7-11; Figures 10-13). 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 (when bycatch can be distinguished by gear type, then 80% for trawl fisheries and 32.1% for fixed gear fisheries). In the early-1970s, the groundfish fisheries contributed substantially to total bycatch losses (although bycatch in the crab fisheries was undocumented at the time). From the early 1990s (when reliable crab fishery bycatch estimates are considered to be first available) to 2004/05, the groundfish fisheries accounted for the largest proportion of discard mortality. Since 2005/06, the snow crab fishery has generally accounted for the largest proportion of Tanner crab taken as bycatch, accounting for 531.6 t on average since 2017/18 (not including the past year when the fishery was closed) compared with 442.9 t for the directed fishery and 151.8 t for the groundfish fisheries, respectively, during the same time frame). After applying assumed discard mortality rates, the snow crab fishery also accounts for the largest average discard mortality over the past six years (170.6 t vs 142.2 t in the directed fishery and 90.57 t in the groundfish fisheries). However, the snow crab fishery was closed in 2022/23.

5 Data

Data incorporated into the Tanner crab assessment this year include: 1) annual abundance, biomass and size composition data collected by crab fishery observers for Tanner crab retained in the directed fisheries and taken as bycatch in the directed and other (snow crab, Bristol Bay red king crab) fisheries provided by ADFG; 2) annual abundance, biomass, and size composition data collected by groundfish fishery observers for bycatch in the groundfish fisheries provided by AFSC's Fisheries Monitoring and Analysis Division and the NMFS Alaska Regional Office (AKRO; hosted by AKFIN, https://akfin.psmfc.org); 3) limited historical (pre-1990) data on annual abundance, biomass, and size compositions for Tanner crab retained in the foreign (1965-1980) and domestic (1968-1989) crab fisheries or taken as bycatch in the groundfish fisheries (1973-1990); 4) annual abundance, biomass and size composition data, as well as limited year-specific male maturity ogives, from the NMFS EBS shelf bottom trawl survey; 5) abundance, biomass, and size composition data from BSFRF/NMFS cooperative side-by-side trawl studies; and 6) molt increment data from NMFS/ADFG/BSFRF cooperative studies.

5.1 Summary of new information

Fishery data for total and retained catch in the 2022/23 directed fishery was provided by ADFG (Ben Daly, ADFG, pers. comm.). The snow crab and BBRKC fisheries were closed in 2022/23, so no bycatch of Tanner crab occurred in these fisheries. Data on bycatch in the 2022/23 groundfish fisheries from the groundfish observer program and AKRO was downloaded from AKFIN on July 27, 2023. Results from the 2023 NMFS EBS bottom trawl shelf survey were downloaded from AKFIN on Aug. 15, 2023. Male maturity ogives were provided by J. Richar (AFSC, pers. comm.) on Aug. 10, 2023. Datasets and new information are summarized in Table E (Section 2.2).

5.2 Retained Catch

5.2.1 Time Series Data

Retained catch in the Tanner crab fishery is male-only. Annual time series for retained catch extend back to 1965 (Table 1; Figure 4), with historical retained catch biomass available for the domestic and foreign fleet fisheries up to 1979, when the latter fisheries ended. Time series for annual retained catch abundance, as well as biomass, in the domestic fisheries were provided by ADFG for the 1980 to 1996 time period (Table 2). The fishery was closed from 1997/98 to 2004/05 due to concerns regarding stock biomass levels, during which time no retained catch occurred. The fishery was re-opened following rationalization of the crab fisheries in 2005. Time series of annual retained catch abundance and biomass taken in the directed fishery, as well as incidentally-retained in the snow crab and BBRKC fisheries, has been provided by ADFG by management area starting with the 2005/06 season (Tables 3 and 4; Figure 5) for subsequent seasons when the fishery was prosecuted in either area. Since 2013/14, most of the TAC has been taken each year in areas open to fishing, while the TACs have generally been substantially lower than the corresponding Tier 3 OFLs and ABCs (Table 5, upper plot of Figure 5).

5.2.2 Size Composition Data

Size compositions for retained catch data, scaled to total retained catch, are available from 1980/81-1996/97 aggregated across ADFG management areas and from 2005/06 identified by management area (Table 6, Figure 6) for seasons when the directed fishery was prosecuted. Median sizes of retained males are similar over the time period up to 2009/10, after which NMFS determined the stock was overfished and ADFG closed the fishery in both management areas (Figure 6). Median sizes since NMFS declared the stock rebuilt (2012) have been somewhat smaller, with the median size in the western management area in 2022/23 the second smallest in the time series (the smallest occurred in 2021/22) while the median size in the eastern management area in 2022/23 was the smallest in the time series. The fraction of retained catch smaller than the size historically preferred by processors (125 mm CW) has increased in the western management area since 2017/18 (the eastern area was closed during most of this time period; Figures 7 and 8). The fraction of new shell males among the retained crab from the western management area in 2022/23 was high, similar to that in 2021/22 but much higher than other years since the 2015/16 season (Figure 9). The fraction from the eastern management area was similarly high in 2022/23.

5.3 Total Catch and Discard Data

5.3.1 Time Series Data

Total catch estimates for Tanner crab in the directed Tanner crab, snow crab, BBRKC, and groundfish fisheries are provided in Tables 7-9 and Figure 10. ADFG "at-sea" crab observer sampling programs started in 1989 but sampling in the different fisheries was initially inconsistent. The assessment uses catch data from the snow crab and BBRKC fisheries starting in 1990/91 and in 1991/92 from the directed fishery. Annual bycatch in the groundfish fisheries, based on NMFS groundfish observer programs, is available starting in 1973/74, but crab sex is not distinguished and is not distinguished by gear type until estimates are available from the Regional Office's Catch Accounting System (CAS) database (starting in 1991).

All female crab and sub-legal males caught in the directed fishery or taken as bycatch in the other fisheries must be discarded. All legal males taken in the groundfish fisheries and "most" legal males in the other crab fisheries must be discarded as well; some retention of incidentally-caught legal males is allowed in the snow and BBRKC fisheries, but the amount retained in any year tends to be very small. The assessment model fits time series of fishery-specific total catch biomass (and abundance for the groundfish fisheries), but allows for some fraction of discarded crab to survive. In practice, a value of 0.321 is used in the assessment model for "handling mortality" in the crab fisheries to convert observed bycatch to (unobserved) discard mortality (Stockhausen 2014). For the groundfish fisheries, a value of 0.8 is used for handling mortality aggregated across gear types to reflect differences in groundfish gear effects and on-deck operations compared with the crab fleets (bycatch in the groundfish fisheries is typically aggregated across gear types in the assessment model). However, when groundfish gear type can be identified (i.e., after 1990), a value of 0.321 can be used for bycatch by fixed gear and 0.8 for bycatch by trawl gear.

Mortality associated with the handling process can also be estimated outside the assessment model for bycatch in the groundfish and non-directed crab fisheries (because most or all Tanner crab bycatch is discarded), but estimates of "discard mortality" for males in the directed fishery obtained outside the assessment model can be problematic if (due to sampling error) estimated total catch is less than reported retained catch. Annual estimates of bycatch (i.e., non-retained catch) using the "subtraction method" and mortality for the various fisheries are given in Tables 10 and 11 and illustrated in Figures 11 and 12. Estimated bycatch mortality in the groundfish fisheries (gear type not distinguished) was highest (~15,000 t) in the early 1970s, but it declined substantially by 1977 to ~2,000 t with the curtailment of foreign fishing fleets (Stockhausen 2017a). 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 another (gradual) decline until 2008, after which it has fluctuated annually below ~300 t to the present (~101 t in 2022/23). 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.

In 2022/23, the directed fishery was prosecuted in both State management areas for the first time since 2015/16. Discard mortality on males, estimated using the subtraction method, was 179 t. Discard mortality on females in the directed fishery was 4 t. Both the snow crab and BBRKC fisheries were closed, so no bycatch mortality occurred in those fisheries. Total bycatch mortality in the groundfish fisheries was 90 t. Total bycatch mortality, then, was 273 t (Table 11); retained catch mortality was 913 t (Table 5).

5.3.2 Size Composition Data

Expanded total catch (retained + discards) size compositions from at-sea crab fishery observer sampling are presented by sex for the directed fishery in Figures 14-17 and in the snow crab fishery and BBRKC fisheries in Figures 18-23. The snow crab fishery, conducted primarily in the northern and western parts of the EBS shelf, catches predominantly small males while the BBRKC fishery, conducted to the south and east in Bristol Bay, predominantly catches large males. The size compositions in the snow crab fishery clearly reflect some sort of "dome-shaped" selectivity pattern for males (assumed in the assessment model), with selectivity small for small and large males and highest for intermediate-sized males. In contrast, selectivity in the BBRKC fishery appears more consistent with asymptotic selection. The directed fishery, which extends across the shelf from west of the Pribilof Islands into Bristol Bay in the east, catches somewhat larger males than the snow crab fishery, but somewhat smaller males than the BBRKC fishery (although many more than either of the other two), with about half the new shell males caught larger than the industry-preferred size of 125 mm CW. Similar patterns are apparent for females, as well.

Size compositions from observer sampling for bycatch in the groundfish fisheries, expanded to total bycatch, are shown in Figures 24-26 for 1991/92 to 2020/21. These fisheries, targeting a variety of groundfish stocks and using a variety of gear types, take a much larger size range of Tanner crab as bycatch than the pot gear used in the crab fisheries.

Raw (number of individuals measured) and scaled sample sizes for size composition data from the various fisheries are given in Tables 12-14. It is worth pointing out the small number of Tanner crab measured by observers in both the snow crab and BBRKC fisheries in 2020/21 and 2021/22, although these were expected given the concomitant reductions in overall effort (Table 15) and catch in those fisheries.

5.3.3 Spatial patterns

Recent spatial patterns for retained catch are illustrated in Figure 27. Retained catch was concentrated along the 166°W longitude line in 2022/23, in contrast to recent years when only the western management area was open to fishing and catch was distributed northwest and southeast of the Pribilof Islands deeper than 100 m.

5.4 Survey Data

The annual NMFS EBS shelf bottom trawl survey ("NMFS survey") provides the primary source of fishery-independent data for indices of relative population size ("survey" biomass and abundance) and size structure (size compositions). Data from 1975-2023 are included in the assessment. In addition, data from the "side-by-side" Tanner crab selectivity studies, conducted collaboratively by BSFRF and NMFS during the 2013-2017 NMFS surveys, provide a secondary source.

5.4.1 Time Series Data

Design-based estimates (and cv's) for trends in annual survey biomass and abundance from the NMFS survey are given in Tables 16 and 17 by sex, maturity state, and ADFG management area. Corresponding time series plots are given in Figures 28 and 29. Time series trends from the NMFS EBS bottom trawl survey suggest the Tanner crab stock in the EBS has undergone decadal-scale fluctuations.

Estimated biomass of male crab in the survey time series started at its maximum (295 thousand t) in 1975, decreased rapidly to a low (15 thousand t) in 1985, and rebounded quickly to a smaller peak (146 thousand t) in 1991 (Table 16). After 1991, male survey biomass decreased again, reaching a minimum of 14,600 t in 1997. Recovery following this decline was slow and male survey biomass did not peak again until 2007 (104 thousand t), after which it has fluctuated more rapidly—decreasing within two years by over 50% to a minimum in 2009 (47 thousand t), followed by a doubling to a peak in 2014 (109 thousand t). Since 2014 the trend has been a steady decline until 2021, with male biomass in 2019 at its lowest point (29 thousand t) since 2000. In 2021, male survey biomass increased over the low in 2019 by ~10% to 32 thousand t, but it declined to 30 thousand t in 2022; in

2023, it increased to 35 thousand t. Additionally, male survey biomass in the eastern management area was the smallest value in the time series since 1998 but was the largest value in the western management area since 2018.

Trends in female survey biomass have generally been in synchrony with those for males, although the changes for females precede those for males by a year or two (reflecting different growth patterns). Immature female biomass in 2023 showed large increases over 2022, while mature female biomass increased ~18% in the western area but decreased ~10% in the eastern area (Table 16).

Survey abundance for males in the eastern area was less remarkable than biomass: it was the smallest value only since 2019; survey abundance for females in the eastern area was unchanged from 2022 (Table 17). In contrast, male survey abundance in the western area was 250% larger than in 2022, while abundance of immature females was 350% larger–indicative of a strong recruitment event of small crab west of 166ºW longitude.

Estimates for trends in industry-preferred males ($\geq$ 125 mm CW) from the NMFS survey are given in Tables 18 and 19; corresponding time series are illustrated in Figures 28 and 29. Compared with results from 2022, industry-preferred male biomass increased in the western area in 2023 in both new shell and old shell categories, while new shell biomass decreased but old shell biomass increased in the eastern area (Table 18). Overall, total industry-preferred male biomass in the survey decreased 5% from 2022 to 2023. Changes in abundance from 2022 to 2023 followed a similar pattern (Table 19).

The annual percentages (by biomass) of new shell industry-preferred size male from the survey and caught in the directed fishery are contrasted in Figure 30: in general, the fishery is able to catch a much higher percentage of new shell males than is estimated in the survey. The time series of biomass of industry-preferred males caught in the directed fishery is compared with the biomass estimated from the survey in Figure 31: the fishery came very close to catching more than the survey estimates in 2020/21 and 2021/22.

BSFRF and NMFS engaged in a series of collaborative "side-by-side" selectivity studies ("SBS") for Tanner crab that coincided with the 2013-2017 NMFS surveys. During the SBS catchability studies, NMFS performed standard survey tows (e.g., 83-122 trawl gear, 30 minute tow duration) as part of its annual EBS bottom trawl survey while BSFRF performed parallel tows within 0.5 nm using a nephrops trawl and 5 minute tow duration. Because the nephrops trawl has better bottom-tending performance than the 83-112 gear, the BSFRF tows are hypothesized to catch all crab within the net path (i.e., to have selectivity equal to 1 at all crab sizes) and thus provide a measure of absolute abundance/biomass. The NMFS surveys provide relative indices of stock size across the entire stock area; the BSFRF SBS data provides (presumed) absolute indices within the smaller (annually-varying) study footprints (Figure 32). The NMFS SBS data (a subset of stations from the full survey each year) provides information on the annual "availability" of Tanner crab across the entire stock area relative to the area included in the associated SBS study. Design-based estimates (and cv's) for absolute biomass and abundance within the SBS study areas from BSFRF and NMFS are given in Tables 20 and 21 by sex and maturity state. Plots of biomass and abundance from the SBS studies are given in Figures 33. Any "trends" from these data are confounded by the varying areal coverage of the survey stations included in the SBS studies.

5.4.2 Size Composition Data

Bubble plots of NMFS EBS bottom survey size compositions for Tanner crab by sex and fishery region are shown in Figures 34 and 35. Distinct recruitment events (late 1970s, early 1990s, mid-2000s, early 2010s) and subsequent cohort progression are evident in the plots, particularly in the western area. The absence of small male crab in the 2010-2016 period is notable, although there was evidence for new recruitment in the western area in 2017-2018, with perhaps some spillover to the eastern area lagged by a year at slightly larger sizes. Unfortunately, the 2017-2018 cohorts seem to be absent from, or much reduced in, the 2021-2023 surveys. On the positive side, there is certainly evidence for a strong recruitment event in 2023 in the western area.

The survey size compositions provide evidence for a decline in maximum size across the time series for both males and females (Figure 36). For males, maximum size decreases from over 180 mm CW in the late 1970's to less than 160 mm CW in 2023 while it declines from over 120 mm CW to under 115 mm CW for females.

Based on the total abundance size compositions from the BSFRF-NMFS SBS studies (Figure 37), the BSFRF nephrops gear is in general (as expected) more selective for Tanner crab than the NMFS 83-112 gear, particularly at smaller sizes (< 60 mm CW). However, the size-specific catch ratio of the BSFRF survey to the NMFS survey appears to vary substantially across years, which one would not expect if gear-specific selectivity were, in general, constant. It is worth noting that the nephrops gear appears to give a much better indication of recruitment than the 83-112 gear (e.g., survey year 2017).

Observed sample sizes for the NMFS survey size compositions, aggregated to the EBS regional level used in the assessment, are presented in Table 22. Given the large number of individuals sampled, a standard value of 200 is used as the input total input sample size for annual survey size compositions in the assessment model to prevent convergence issues associated with using the actual sample sizes. Input sample sizes for size compositions fit that are fit independently by individual category (e.g., sex) are then based on the ratio of the number of measured individuals in the category to the total number of individuals measured in the survey, such that the sum of input sample sizes over all categories for a given year would be 200.

Sample size for the SBS studies are given in Table 23.

5.4.3 Spatial patterns

Recent (2014-2023) spatial patterns of various population components (small males, large males, industry-preferred males, immature females, mature females) are illustrated in Figures 38-42. Small males and immature females exhibit similar spatial patterns during this time period (note that the scales in Figures 38 and 41 are different), predominantly distributed along the western shelf between the shelf edge and the 100 m isobath, but extending eastward to the 50 m isobath from the Pribilof Islands southward. High concentrations of small/immature crab were found near the Pribilof Islands in 2023. Large males are concentrated around the Pribilof Islands, but also extend somewhat further eastward along the Alaska Peninsula and into Bristol Bay than smaller males

(Figure 39). Since 2014, however, their range has contracted westward towards the Pribilof Islands. The patterns for industry-preferred males (Figure 40) are similar to those for large males. The spatial distribution of mature females exhibited a ~3-year fluctuating pattern over this time period, extending eastward into Bristol Bay in 2014, 2017, and 2021 followed by a coalescence westward in the subsequent two years (Figure 42).

5.5 Other Data

Other data incorporated into the assessment model include male maturity ogives, molt increment data, weight-at-size relationships, and SBS survey availability. The first two are fit in the model estimation process while the latter two are determined outside the model framework.

5.5.1 Male maturity ogives

Tanner crab undergo a terminal molt to maturity, after which they no longer molt. The maturity state for females can be unambiguously determined in the field based on abdominal morphology, but the state for males is much less well-defined morphometrically. Here, males taken in the NMFS EBS shelf survey are classified as immature or mature based on the ratio of their chela height to carapace width, with annual size-specific cutlines for this ratio determined statistically after the survey has been completed (Richar and Foy 2022). Chela height measurements can be time-consuming to obtain and data are generally collected biennially rather than annually (chela heights are taken for snow crab in "off" years for Tanner crab). The observed size-specific fraction of males classified as new shell and mature relative to all new shell males (i.e., immature males and new shell mature males) for a survey constitutes the "male maturity ogive" for that year (Figure 43) and provides information to the model on the size-specific probability of immature males undergoing terminal molt.

5.5.2 Molt increment data

Molt increment data for Tanner crab in the EBS were collected as part of collaborative studies by NMFS, BSFRF, and ADFG during 2015-2017 and 2019 (Figure 44). These are fit in the assessment model to estimate annual growth increments for crab that have not undergone terminal molt.

5.5.3 Weight-at-size

Weight-at-size relationships for Tanner crab are fixed in the assessment model. These were developed by fitting separate power law models ($w = \alpha \cdot z^{\beta}$) for weight-at-size to NMFS EBS shelf survey measurements of individual crab size and weight for males, immature females, and mature females (Table 24, Figure 45).

5.5.4 SBS survey availability

For the purposes of the assessment, the BSFRF gear in the SBS catchability studies is assumed to provide absolute indices of Tanner crab stock biomass and abundance within the area included in each year's study area (Figure 32). However, these areas, which vary among years in the study, do not cover the entire stock area while the assessment model predicts stock abundance by category and size for the entire stock area. To fit the SBS data, then, the model needs to take into account "survey availability" for the SBS study–i.e., the fraction of the stock (by category and size) within the study area–on an annual basis. Estimating survey availability within the stock assessment for the SBS studies is confounded with estimating survey catchability for the full NMFS survey, but can be estimated empirically outside the assessment model. Consequently, availability of Tanner crab to the BSFRF gear in the SBS catchability studies was determined outside the model on a sex-specific basis from the ratio of area-swept abundance-at-size from the NMFS gear in the study to the same for the entire survey (i.e., the EBS shelf; Figures 46 and 47; Stockhausen (2019)).

6 Analytic Approach

6.1 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, 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 2011b) 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 2012/13 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 2012/13, 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 (Rugolo and Turnock 2012a).

For 2013, modifications were 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 (Stockhausen 2013). 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 (at GitHub).

The current model "framework", TCSAM02, was reviewed by the CPT and SSC in May/June 2017 (SSC 2017; CPT 2017; Stockhausen 2017b) and adopted for use in subsequent assessments as a transition to GMACS. This framework is a completely-rewritten basis for the Tanner crab model: substantially different models 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 framework has been used to incorporate new data types (molt increment data, male maturity ogives), new survey data (the BSFRF surveys), and new fishery data (bycatch in the groundfish fisheries by gear type). The framework also incorporates status determination and OFL calculations directly within a model run, so a follow-on, stand-alone projection model does not need to be run (as was the case 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 are now included in the Markov Chain Monte Carlo (MCMC) evaluation of a model's posterior probability distribution. More recently, the model code was restructured to function in a management strategy evaluation (MSE) mode and allow retrospective analyses. The Dirichlet-Multinomial likelihood for size composition data (Thorson et al. 2017) was added as an option when fitting size composition data, as was the ability to apply "tail compression" to the composition data. In 2021/22, the ability to do multi-year projections under different fishing mortality rates was added to the model in response to CPT and SSC requests (Stockhausen 2022a). The ability to estimate initial numbers-at-size, rather than build up the population from zero using recruitment (as has been the approach to date), was also implemented.

6.2 Model description

6.2.1 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 (Stockhausen 2023a).

In brief, crab enter the modeled population as recruits following a truncated size distribution based on the gamma probability distribution (see Figure 48 for the nominal shape). An equal (50:50) sex ratio is generally assumed at recruitment (although it can be set otherwise or estimated), 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 capture 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 then 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 (mature) 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 survey biomass, survey size compositions, survey-based estimates of the annual size-specific fraction of mature new shall males in the population, retained catch, retained catch size compositions, aggregate total catch in the directed and bycatch fisheries, and total catch size compositions in the directed and bycatch fisheries. Data on growth in the EBS from observed molt increments are also (typically) fit.

6.2.2 Changes since the previous assessment

In 2022/23, the ability to estimate annual deviations in natural mortality (M) within multi-year time blocks was added, as was the ability to specify the size of model size bins (previously fixed at 5 mm CW; Stockhausen (2022b)). Candidate models presented to the CPT and the SSC in Spring 2023 included ones that incorporated annually-varying M and finer-scale (1-mm) model size bins, fit VAST model estimates of NMFS survey biomass, and fixed growth and/or size-specific survey catchability based on other analysis. The only model selected by the SSC (and recommended by the CPT and author) as a candidate for this assessment was 22.03b, which was identical to the 2022 assessment model (22.03) except that a parameter describing the slope of the logistic function describing retention in the directed fishery during 2005/06-2009/10 was fixed to a value just inside the upper bound, with the result that retention during this period was essentially a step function in crab size (i.e., males caught in the directed fishery were, depending on their size, either all discarded or all retained). This parameter was estimated at its upper bound in Model 22.03, which can be problematic for further statistical inference.

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

6.2.3 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 (Stockhausen 2017b). TCSAM02 also underwent a review in July 2017 conducted by the Center for Independent Experts and was further reviewed by the CPT in May 2017 and September 2017. Changes to model code are validated against results from the previous assessment model to ensure that modifications do not change the results of the previous assessment.

6.3 Model selection and evaluation

6.3.1 Description of alternative model configurations

The model selected for the 2022 assessment, Model 22.03, provides the base model for this assessment (Stockhausen 2022a). The following three tables summarize the parameterization and time blocks for the biological and fishery processes incorporated in this model:

Table H. Population processes and parameterization in the base model, 22.03.

process	time blocks	22.03 description
Population rates and quantities		
Population built from annual recruitment		
Recruitment	1949-1974	ln-scale mean + annual devs constrained as AR1 process
	1975+	ln-scale mean + annual devs
	1949+	sigma-R fixed, sex ratio fixed at 1:1
Growth	1949+	sex-specific
		mean post-molt size: power function of pre-molt size
		post-molt size: gamma distribution conditioned on pre-molt size
Maturity	1949+	sex-specific
		size-specific probability of terminal molt
		logit-scale parameterization
Natural mortalty	1949-1979,	estimated sex/maturity state-specific multipliers on base rate
	1985+	priors on multipliers based on uncertainty in max age
	1980-1984	estimated "enhanced mortality" period multipliers

Table I. Characteristics for retention and total catch in the directed ("TCF") fishery and bycatch in the snow crab ("SCF") fishery in the base model, 22.03.

Fishery/process	time blocks	22.03 description
TCF	directed Tanner crab fishery	
capture rates	pre-1965	male nominal rate
	1965+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1990	ascending logistic
	1991-1996	annually-varying ascending logistic
	2005+	annually-varying ascending logistic
female selectivity	1949+	ascending logistic
male retention	1949-1990; 1991-1996; 2005-2009; 2013+	ascending logistic
% retained	pre-1988	fixed at 100%
	1991-1996	fixed at 100%
	2005-2009	fixed at 100%
	2013+	fixed at 100%
SCF	bycatch in snow crab fishery	
capture rates	pre-1978	nominal rate on males
	1979-1991	extrapolated from effort
	1992+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1996	dome-shaped (double normal)
		--plateau width fixed to 0
		--descending limb width fixed to 1
	1997-2004	dome-shaped (double normal)
	2005+	dome-shaped (double normal)
female selectivity	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005+	ascending logistic

Table J. Characteristics for bycatch in the BBRKC (“RKF”) and groundfish fisheries (“GF All”) in the base model, 22.03.

Fishery/process	time blocks	22.03 description
RKF	bycatch in BBRKC fishery	
capture rates	pre-1952	nominal rate on males
	1953-1991	extrapolated from effort
	1992+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal, asymptote fixed
	2005+	ascending normal, asymptote fixed
female selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal
	2005+	ascending normal
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

Unlike females, the maturity state of individual male Tanner crab is not readily identifiable in the field and is not provided as part of the annual NMFS EBS shelf survey datasets. Consequently, while data from the survey can be characterized by maturity state for females and treated differently in the likelihood depending on maturity state, this is not possible for males. Thus, the assessment model characterizes the NMFS EBS shelf survey data separately by sex, referring to the male-specific dataset (with no information on maturity state) as the "NMFS M" survey and the female-specific dataset (with females characterized as immature or mature based on abdominal shape) as the "NMFS F" survey. Similar conventions hold for survey data from BSFRF. The following table summarizes the parameterization and time blocks for the survey processes incorporated into 22.03.

Table K. Characteristics for the NMFS and BSFRF surveys in the base model, 22.03.

Survey/process	time blocks	22.03 description
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 normal, fixed fully-selected size at 180
	1982+	ascending normal, fixed fully-selected size at 180
female selectivity	1975-1981	ascending normal, fixed fully-selected size at 130
	1982+	ascending normal, fixed fully-selected size at 130
BSFRF SBS trawl surveys		
male catchability	2013-2017	fixed at 1 for all sizes
male availability	2013-2017	empirically-determined outside the model
female catchability	2013-2017	fixed at 1 for all sizes
female availability	2013-2017	empirically-determined outside the model

Finally, the components included in the model likelihood are summarized in the following table:

Table L. Likelihood components in the base model, 22.03.

Model	Component	Type	included in optimization	Fits	Likelihood distribution
22.03	TCF: retained catch	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	TCF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	SCF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	RKF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	GF All: total catch	abundance	yes	total	lognormal
		biomass	yes	total	lognormal
		size comp.s	yes	by sex	multinomial
	NMFS "M" survey (males only, no maturity)	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	NMFS "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal
		size comp.s	yes	by maturity classification	multinomial
	BSFRF "M" survey (males only, no maturity)	biomass	yes	males only	lognormal
		size comp.s	yes	males only	D-M
	BSFRF "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal
		size comp.s	yes	by maturity classification	D-M
	growth data	EBS only	yes	by sex	gamma
	male maturity ogive data	EBS only	yes	males only	binomial

As per recommendations by the SSC in June, only one model, 22.03b, has been evaluated with new data for 2022/23 for this assessment. Other than fixing the value for one parameter estimated at its upper bound in Model 22.03, Model 22.03b is identical in formulation to the 2022 assessment model.

6.3.2 Progression of results from the previous assessment to the current base model

The model used in the previous assessment is the current base model.

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

A Tier 4 model based on survey biomass was evaluated as a “backup” for 22.03b (Section 8).

6.3.4 Convergence status and convergence criteria

Convergence to the MLE was evaluated using parameter jittering to initialize a set of model runs at starting parameter values randomly-selected from within a large fraction of the available parameter space and selecting the run which minimized the final objective function value (i.e., maximized the likelihood) over the set of jittered model runs. Ideally, all runs should arrive at the same global minimum on the objective function hypersurface. In practice, some runs will converge to a local minimum on the hypersurface, rather than the global minimum, and some runs will simply fail to converge at all. The latter can be distinguished because the final gradient of the objective function with respect to the parameters exhibits values that are not close to zero. However, runs that converge to any minimum on the hypersurface should have gradient values that are identically zero (or "close" to zero, from a practical numerical standpoint). Thus, runs that end at a local minimum cannot be distinguished from runs that end at the global minimum based solely on the size of the final gradients. Consequently, the global minimum solution can only be selected by starting the model at many locations within the available parameter space and selecting the "one" run that achieves the minimum over all the model runs. Ideally, though, a sizable fraction of the runs should achieve the minimum.

Table M. Summary convergence diagnostics. Diagnostics for 22.03 are from the 2022 assessment.

model configuration	parent	changes	number of parameters	no. of jitter runs	no. converged to MLE	no. of param.s at bounds	objective function value	max gradient	invertible for std. devs?
22.03	--	none: 2022 assessment model	351	800	710	1	3045	2.92E-03	yes
22.03b	22.03	logistic function slope parameter fixed to upper limit for function describing size-dependent retention in the directed fishery during 2005/06-2009/10.	354	800	478	0	3143	8.13E-05	yes

For this assessment, convergence was partially evaluated by making 800 jitter runs for 22.03b to find the parameter values that resulted in the model's maximum likelihood (i.e., the parameters that minimized the model objective function, which is the negative of the likelihood). Other factors that were considered were the maximum parameter gradient at model convergence, whether any parameters were estimated at a bound, and whether it was possible to obtain the parameter covariance matrix and uncertainty estimates for parameters and derived quantities by inverting the model hessian. The jittering analysis appears to have found the parameter set that achieves the minimum objective function/maximum likelihood (`r`wtsQMD::num(mnOF,n=2)‘), with 478 jittered model runs out of 800 converging to the same minimum value. The large number of runs that converged to the same minimum objective value lends confidence to the assertion that the solution is indeed the global minimum. In addition, the maximum gradient at the MLE was very small (8.13e-05) and it was possible to invert the model hessian and obtain uncertainty estimates for parameters and derived quantities. This model run also converged with no parameters at bounds (Table 25).

6.3.5 Sample sizes assumed for the compositional data

"Raw" (number of measured individuals) sample sizes for survey size compositions are listed in Tables 16 and 20. Input sample sizes for all survey size compositions were set to sum to 200 for each survey year, with the sample size for an individual population component (e.g., immature females) reflecting its raw sample size relative to the total raw sample size for the year in question.

Raw and input sample sizes used for fishery-related size composition data are listed in **Tables 6 and 12-14**. The maximum input sample size for fishery data was set to 200. Otherwise, input sample sizes were scaled as described in Stockhausen (2014) using the formula:

$$SS_y{}^{inp} = min[200, \frac{SS_y}{\bar{SS}/200}]$$

where $\bar{SS}$ is the mean sample size for all males from dockside sampling in the directed fishery.

6.3.6 Parameter sensibility

No parameters were estimated at a bound (Table 25). Values for all estimated parameters are listed in the following tables:

- 26: parameters for recruitment, growth, and natural mortality
- 27: ln-scale recruitment deviations prior to 1975
- 28: ln-scale recruitment deviations after 1974
- 29: logistic-scale parameters for the probability of undergoing the molt-to-maturity
- 30: non-vector parameters related to fishing mortality rates, retention, survey catchability, and the Dirichlet-Multinomial likelihood
- 31: ln-scale fishing mortality devs for the directed fishery
- 32: ln-scale fishing mortality devs for bycatch in the snow crab fishery
- 33: ln-scale fishing mortality devs for bycatch in the BBRKC fishery
- 34: ln-scale fishing mortality devs for bycatch in the groundfish fisheries
- 35: "pS1" selectivity parameter values

- 36: "pS2" selectivity parameter values
- 37: "pS3" and "pS4" selectivity parameter values, and
- 38: dev parameters for size-at-50% selected for males in the directed fishery

6.3.7 Criteria used to evaluate the model or to choose among alternative models

None of the models presented to the CPT and SSC in the spring, other than 22.03b, were judged to have performed well enough to be considered as viable alternative models for this assessment (SSC 2023; CPT 2023; Stockhausen 2023b). Model 22.03b is identical to the 2022 assessment model, 22.03, except that the parameter describing the slope of the retention curve in the 2005/06-2009/10 period has been fixed near its upper bound (this parameter was estimated in Model 22.03 at its upper bound, indicating that retention during this period was essentially a step function in size). Model 22.03b appears to have converged to the MLE based on the jitter analysis, the magnitude of the maximum parameter gradient for the objective function at the presumed MLE, and the ability to invert the model hessian to obtain standard errors for parameters and derived quantities using the delta method (Table M). In addition, no parameters were estimated at a bound and none of the estimated parameter values appear to be problematic.

6.3.8 Residual analysis

Standardized residuals for model fits to all aggregated catch data components (e.g., retained catch biomass, survey catch biomass) and the molt increment data were calculated and plotted for both models. Median absolute deviation (MAD), median absolute relative error (MARE), and root mean square error (RMSE) statistics were used to summarize overall model fit to a data component (in addition, of course, to the associated likelihood). Pearson's residuals were examined for fits to all size composition data and the male maturity ogive data. Outliers were "flagged" graphically.

6.3.9 Objective function values

Objective function values related to data in the likelihood are listed by component for Models 22.03 and 22.03b in Tables 39-41; those related to non-data components are listed in Table 42. Objective function differences relative to Model 22.03 are listed in Tables 43-46. It should be noted, though, that most values are not directly comparable between the models because 22.03b incorporates new data for 2022/23, so caution must be used when interpreting apparent differences between the models.

6.3.10 Evaluation of the model(s)

As one might expect, model-estimated quantities from 22.03b were, on the whole, extremely similar to those from 22.03. Estimated capture rates in the directed fishery from 22.03b were slightly smaller in magnitude than those from 22.03 (Figure 50), while selectivity and retention functions were identical (Figures 51-54). Similar observations hold for bycatch capture rates and selectivity functions in the snow crab, BBRKC, and groundfish fisheries (55-57).

Estimates of sex-specific NMFS EBS shelf survey catchabilities were slightly smaller from 22.03b compared with 22.03 (Table 48, Figure 58), while the corresponding selectivity curves were practically identical (Figure 58). The small differences in catchabilities between the two models appear to account for the small (opposite) differences in the estimated fishery capture rates.

Estimates of natural mortality, size-specific mean growth, and size-specific probability of undergoing the molt to maturity are also essentially identical for the two models (Table 47, Figure 60). The estimated recruitment size distribution (panel 1 in Figures 61 and 62) is somewhat narrower with a smaller mean size in Model 22.03b compared with 22.03. This initial difference decreases across the first few years of cohort development and has disappeared after five years for females and six years for males (panel 5 in Figures 61 and 62).

Estimated recruitment tends to be just slightly higher in 22.03b than in 22.03 across the time series (Tables 87 and 88, Figures 63 and 64), as is the case with MMB (Tables 85 and 86; Figures 63 and 64). The estimated recruitment for 2022 exhibited a larger difference than typical between the two models: the estimate from 22.03b was 17% higher than that from 22.03. Estimated trends in population abundance and biomass by sex and maturity state exhibit characteristics similar to the MMB comparison (Tables 81-84; Figures 65 and 66).

Model 22.03b fitted the retained catch and total catch biomass series as well as Model 22.03 did (Figures 68-72), with only the fit to total catch in the directed fishery in 1996/97 (just prior to the closure of the fishery for nine years) as a substantial outlier in both models.

Fits to NMFS EBS shelf survey biomass exhibit similar patterns from 1975 to about 2000 for males, at which point 22.03b exhibits slightly larger positive residuals but slightly smaller negative residuals to the data when compared with results from 22.03 (Figures 73 and 74). The fits to immature and mature female survey biomass do not really exhibit this pattern and are similar across the time series (Figures 73 and 75). Of note, both models substantially overestimated male survey biomass in 2022 (z-scores $<$ -4) and 22.03b also overestimated male survey biomass in 2023 (z-score $<$ -4). Interestingly, both models estimate male survey abundance rather well in the last two years, even though this data is not included in the model likelihoods (Figures 78 and 79).

Both models fit the BSFRF SBS biomass data equally well and estimate the abundance data equally well (Figures 73, 76, and 77).

Model 22.03b fits the growth data almost identically to 22.03 (Figure 83), with estimated postmolt size exhibiting a slightly convex pattern with pre-molt size for females but an increasing trend in overestimating post-molt size in males. The two models also fit the male maturity ogive in similar fashion in each year prior to 2003 (Figure 84); 22.03b does not fit the data for 2023 very well (four out of eight data points are substantially underestimated, with the caveat that pearson residuals are not ideal diagnostics for fits to proportions).

As with the fishery catch biomass data, Model 22.03b fits the fishery size composition data in a manner almost identical to that of 22.03 (Figures 86-Figure 113). Retained catch size compositions are generally well-fit prior to the fishery closure in 2016/17, but exhibit worse fits afterward (Figures 86 and 86), presumably at least partly due to the fact that the fishery was only prosecuted in the western management area (which exhibits a different size range of males than the combined area) in the intervening period until this year. The fit to this year's size composition is much better than the fit to the previous two years, but still overestimates the proportion of the largest crab in the catch.

Fits to the total catch size compositions in the directed and bycatch fisheries are essentially identical for the two models (excluding 2023, of course). The estimated size compositions since 2014/15 for the directed fishery all overestimate the proportion of males in the largest size bin (Figures 90, 92 and 93), although the bias is not really substantial based on the z-score sizes.

Estimates of bycatch size compositions in the snow crab fishery tend to be fairly reasonable for males, although fits in the early 1990s and mid-2000s are poor (Figures 96, 98 and 99). Fits in 2020/21 and 2021/2 are not as bad, from a statistical viewpoint, as they may appear in Figure 96 (see residuals in 98).

Fits to the bycatch compositions from the BBRKC fishery are rather poor, reflecting the lower sample sizes associated with these data. Starting in 2016/17, coincident with ADFG closing the Tanner crab fishery east of 166ºW longitude, the models consistently overestimated the proportion of large males in the size compositions (Figure 102), which may indicate the interaction among spatial processes (the BBRKC fishery only takes Tanner crab in the eastern management area) not accounted for in the modeling framework. Similar overestimates occurred in 2003/04-2007/08, but the Tanner crab fishery in the eastern management area was not closed during that period.

The groundfish fisheries take a wider range of Tanner crab as bycatch than do the other fisheries (Figures 108-113). In addition, the fixed gear and trawl gear fleets capture different size ranges, so the resulting size compositions could be expected to vary annually, even in the absence of changes in size structure in the Tanner crab population due to recruitment and growth, depending on the relative effort in the two fleets. As such, it is not too surprising that the models exhibit poor (but almost identical) fits to the size compositions from the groundfish fisheries in some years.

The fits to the NMFS EBS shelf survey size compositions for the two models are indistinguishable for all three population components: males, immature females, and mature females (Figures 114-123). While the fits are reasonably good in most instances, since 1997 both models consistently overestimated the proportion of males or mature females in the largest size bin in the data.

The two models fit identically to the BSFRF SBS size composition data (Figures 124-130). Both models underestimate the proportions of the small males in the 2016 and 2017 surveys and generally fit the proportions for immature females poorly (Figure 127).

The marginal size distributions (i.e., averaged across years for a given dataset) from both fishery and survey data were fit equally well by both models, with little discernible difference in the means (Figures 131-135). The worst agreement between the marginal distributions for the models and the data seems to have occurred for the groundfish fisheries male bycatch data and the BSFRF SBS male survey data (Figures 134-135).

On the whole, effective sample sizes from both models were very similar for both fishery and survey size composition data and tended to be larger than input sample sizes (Figures 136-141). Exceptions to the latter observation include total catch size compositions for males in the directed fishery since 2014/15, NMFS EBS shelf survey size compositions for males before 1989, and all BSFRF SBS size compositions for males (Figures 137 and 141).

The value of Mohn's rho (Mohn 1999) for recruitment from the retrospective analysis for Model 22.03b (Figure 142) was 0.326. Recruitment estimates for a given year tended to decrease as more years of data were added to the model, although this was not true of the 2022 estimate (which increased when 2023 data was added). In contrast, Mohn's rho for MMB was only -0.0339, indicating that changes to MMB as data was added tended to cancel out across the time series

(Figure 143). Estimates when MMB had an increasing trend tended to get larger when more data was added while estimates when MMB was on a decline tended to get smaller.

In summary, Model 22.03b performed slightly better on the whole than the 2022 assessment model, 22.03.

6.4 Results (best model(s))

As the only model evaluated for this assessment, Model 22.03b is, by default, the author's preferred model for the 2023 assessment. In this section, results not previously discussed are compared with those from the 2022 assessment model, 22.03.

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

Sample sizes were not adjusted as part of the model-fitting process (iterative re-scaling by either the Francis or McAllister-Ianelli approaches have not been successful in past attempts to re-weight size composition data), thus input and effective sample sizes were identical. Input sample sizes for fishery size composition data fit in the model are listed in Tables 6 and 12-14 . Observed sample sizes for survey data are listed in Tables 22 and 23. Input sample sizes for survey composition data were set to 200 for each annual survey and apportioned across population components (sex, maturity state, and shell condition) by the proportion of samples taken in the category relative to the total number of samples.

In all model scenarios, lognormal likelihoods were used to fit aggregated biomass and, where appropriate, abundance data. For survey data, CV's based on design-based considerations were used (see Tables 16-20). For fishery-related catch data, the following CV's and minimum standard deviations were assumed to apply:

Table N. Assumed CV's for fishery catch abundance and biomass data.

fishery	catch type	time period	CV
directed fishery	retained	1965-1979	10%
		1980	3%
		1996+	1%
	total	1990+	20%
snow crab	total	1990+	20%
BBRKC	total	1990+	20%
groundfish	total	1973	20%

A weighting factor of 1 million was applied to the square of the sum of each "devs" vector to force it to sum to 0.

6.4.2 Tables of estimates

All parameters

Parameter estimates and associated standard errors, based on inversion of the converged model's Hessian and the "delta" method, are listed in 26-38.

Derived values (natural mortality, survey catchability)

Estimated values for rates of natural mortality and sex-specific catchabilities for the NMFS EBS shelf survey are given in Tables 47 and 48.

Abundance and biomass time series, including spawning biomass and MMB

Model-estimated values for annual retained catch and discard mortality (abundance and biomass) in the directed and bycatch fisheries are given in Tables 49-68. Model-estimated values for survey abundance and biomass for the NMFS EBS shelf survey and BSFRF SBS surveys are documented in Tables 69-80. Model-estimated values for annual population abundance and biomass are given by sex, maturity state, and shell condition in Tables 81-84. Model estimates for mature male and female biomass at the time of mating are listed in Tables 85-86.

Recruitment time series

Model estimates for recruitment are given in Tables 87 and 88.

Time series of catch divided by biomass

Model estimated time series for total fishing mortality divided by population biomass (i.e., exploitation rate) are documented in Tables 89 and 90.

6.4.3 Graphs of estimates

Estimated full selection F over time and fishery selectivities

Graphs of time series of estimated fully-selected F (total catch capture rates, not necessarily mortality) in the directed fishery are shown in Figure 50, while the associated selectivity functions are illustrated in Figures 51- 53. The estimates of size-selective retention of males captured in the directed fishery are presented in Figure 54. Graphs of time series of estimated fully-selected F (again, total catch capture rates, not mortality) and the associated selectivity functions for the bycatch fisheries are shown in Figures 55-57.

Estimated survey catchability and selectivities

Graphs of estimated sex-specific survey catchability and the associated selectivity functions for the NMFS EBS survey are shown in Figure 58. Assumed survey availability curves for the BSFRF side-by-side catchability studies are illustrated in Figure 59. These are not estimated; they were determined outside the model. The BSFRF nephrops bottom trawl gear is assumed to be non-size-selective and catch all crab in its swept-area path.

Molting probabilities, growth, and other schedules depending on parameter estimates

Immature crab are assumed to molt annually. The estimated sex/size-specific probability of undergoing the molt to maturity (terminal molt) is shown in Figure 60, together with estimated mean molt increments (as a function of pre-molt size) and natural mortality rates. The cohort progressions (growth and development) resulting from these schedules are illustrated in Figures 61 and 62.

Estimated population-related time series

Estimated time series for recruitment and MMB are shown in Figures 63 and 64. Time series of abundance by sex and maturity state are illustrated in Figure 65, while time series of biomass by sex and maturity state are illustrated in Figure 66.

Estimated fishing mortality versus estimated spawning stock biomass

Estimated total fishing mortality (retained + discards) is plotted against spawning stock biomass (MMB) for the previous assessment (22.03) and preferred (22.03b) models in Figure 67.

Fit of a stock-recruitment relationship, if feasible

Fits to a stock-recruit relationship were not evaluated.

6.4.4 Evaluation of the fit to the data

Graphs of the fits to observed and model-predicted fishery catches

Fits to the observed and model-predicted fishery catch biomass data are presented in Figures 68-72. for the previous assessment (22.03) and preferred (22.03b) models. Residuals to the fits and summary statistics are also shown on each figure. Graphs of fits to observed catches from the directed fishery are presented in Figures 68-69 for retained catch and total catch. Fits to bycatch data from the snow crab fishery are shown in Figure 70. Fits to bycatch data from the BBRKC fishery are shown in Figure 71. Fits to bycatch data from the groundfish fisheries are shown in Figure 72.

Graphs of model fits to survey biomass and numbers

Model fits to survey biomass time series from the NMFS EBS shelf survey and the BSFRF SBS surveys are shown for the base and preferred models in Figure 73. Residuals to the fits and summary fit statistics are shown in Figures 74-77.

Model fits to the survey abundance time series for both the NMFS EBS shelf survey and the BSFRF SBS surveys are shown for the base and preferred models in Figure 78. Residuals to the fits and summary fit statistics are shown in Figures 79-82. Note that the fits to survey abundance are not included in the model objective function but serve as independent diagnostics of model fit.

Graphs of model fits to other data

Model fits to molt increment growth data, as well as residual patterns and summary fit statistics, are illustrated in Figure 83. Model fits to maturity ogive data from the NMFS EBS shelf survey are presented in Figure 84, while Pearson's residuals to the fits are shown in Figure 85.

Graphs of model fits to catch proportions by size class

Fits to the observed and model-predicted fishery catch proportions by size class, as well as the resulting patterns of residuals, are presented in Figures 86-113 for the previous assessment (22.03) and preferred (22.03b) models. Both models fit the total catch size composition data from the directed and bycatch fisheries by normalizing it across sexes and fitting the resulting proportions jointly. Graphs for the directed fishery are given in Figures 86-95. Graphs for the snow crab fishery are given in Figures 96-101. Graphs for the BBRKC fishery are given in Figures 102-107. Graphs for the groundfish fisheries are given in Figures 108-113.

Graphs of model fits to survey proportions by size class

Fits to the observed and model-predicted survey proportions by size class/sex/maturity state, as well as the resulting patterns of residuals, from the NMFS EBS shelf survey and the BSFRF SBS survey are presented in Figures 114-130 for the previous assessment (22.03) and preferred (22.03b) models.

Marginal distributions for the fits to the compositional data

Marginal distributions for fits to the compositional data from the fisheries are shown in Figures 131-134. Marginal distributions for fits to the compositional data from the surveys are shown in Figure 135.

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

Time series plots of input and implied effective sample sizes for compositional data from the fisheries are shown in Figures 136-140. Similar plots for the survey compositional data are given in Figure 141.

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

Root mean square error (RMSEs) for fits to various datasets are provided in Table 91, but no comparison is available with the cv's assumed for the indices. The author requests guidance on how the cv's for time series indices should be combined to compare with the RMSEs.

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 produced for this assessment.

6.4.5 Retrospective and historic analyses

Retrospective analysis

Retrospective analyses were conducted for the base/preferred model 22.03b. The analysis used 10 peels (ending in 2013), with the model re-fit after each removal of the previous peel's terminal year's data. Time series plots of recruitment and MMB were made to identify potential patterns in how the terminal year's estimate for each peel differed from the model result using the complete dataset (Figures 142 and 143. Relative bias in the terminal year estimates was quantified using Mohn's rho (Mohn 1999). The retrospective patterns don't indicate any apparent problems with MMB (Mohn's rho = -0.0339), but additional data (decreasing the number of peels) almost always reduced the estimates of recruitment. Mohn's rho for the recruitment pattern was 0.326.

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

The estimated time series of recruitment and mature biomass for the author's preferred model, 22.03b, are compared with those from previous assessments in Figures 144 and 145. The plots indicate a general increasing trend in the overall scale of recruitment and population size by assessment, while the patterns in temporal variation once the NMFS survey data fully informs the models (i.e., by about 1980) are consistent across assessments.

6.4.6 Uncertainty and sensitivity analyses

MCMC runs were not completed in time to include in the assessment. Uncertainty has been characterized using ADMB's sd_report functionality for parameters, recruitment estimates, MMB time series, and management quantities. This uses the so-called "delta approximation" to estimate uncertainty associated with parameters and derived quantities after inverting the model Hessian at the MLE and obtaining the covariance matrix.

7 Calculation of the Tier 3 OFL and ABC

7.1 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 2022/23 was 32.81 thousand t while the total catch mortality was 1.186 thousand t, based on applying mortality rates of 1.000 for retained catch, 0.321 to bycatch in the crab fisheries, 0.321 to bycatch in the groundfish fixed gear fisheries, and 0.8 to bycatch in the groundfish trawl fisheries to retained catch data and estimates of discards from fish ticket and observer data (see Tables A, 1, 10, and 11). Therefore overfishing did not occur.

Amendment 24 to the NPFMC fishery management plan revised the definitions for overfishing for EBS crab stocks (NMFS 2008; NPFMC 2021b). 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 outlined in Table O (see Figure 146 for a graphical representation).

Table O. Tier 3 F_{OFL} control rule.

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 the projected 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, $\alpha = 0.1$ and $\beta = 0.25$. 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 equilibrium (longterm average) 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 2023/24 require estimates of $B = MMB_{2023/24}$ (the projected MMB at mating time for the coming year), $F_{35\%}$, spawning biomass per recruit in an unfished stock (ϕ_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 146). 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.

The OFL is calculated within the assessment model based on equilibrium calculations for F_{MSY} 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 an estimate of the uncertainty in the OFL and assumptions about the underlying distribution or MCMC, one can estimate the probability distribution of the OFL (and related quantities of interest) and better characterize full model uncertainty.

To calculate F_{MSY}, the fishery capture rate for males in the directed fishery is adjusted until the long term (equilibrium) MMB-at-mating is 35% of its unfished value (i.e., $B = 0.35 \cdot B_0 = B_{35\%} = B_{MSY}$). This calculation depends on the assumed bycatch F's on Tanner crab in the snow crab, BBRKC and groundfish fisheries. Since 2017, the average F over the last 5 years for each of the bycatch fisheries is used in these calculations. Fishery selectivity curves were set using the average curve over the last 5 years for each fishery, as in previous assessments (e.g., Stockhausen 2021).

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 ($\bar{R}$). Following 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. This issue was revisited at the May 2018 CPT meeting with regard to whether or not the final year should be included in the calculation, but no definitive recommendations were made.In 2020, the NMFS EBS shelf bottom trawl survey was canceled due to health and safety concerns associated with the COVID-19 pandemic. This resulted in enormous uncertainty in the estimate of final year recruitment for that assessment; it was subsequently dropped from the averaging time frame. The missing survey continues to influence recruitment estimates near the end of the time series (Figure 147). However, the estimated low recruitment appears to be consistent with subsequent size compositions from the NMFS EBS shelf survey (Figures 34 and 35). Recruitment estimates and associated uncertainties for subsequent years do not raise any concerns. The estimated confidence interval and standard deviation for the 2023 recruitment is slightly larger than that for 2022, but it is not an outlier in terms of the time series (Figure 147). In contrast, the retrospective pattern for recruitment suggests this estimate will drop in the future (Figure 142), but this is not a new phenomenon for this assessment. Consequently, average recruitment for the preferred model was calculated following the precedent of the 2022 assessment using the period 1982-2022 and dropping the final year estimate.

The value of $\bar{R}$ for this period from the author's preferred model is 429.57 million. This estimate of average recruitment is 8% larger than that from the 2022 assessment model (395.77 million). The value of $B_{MSY} = B_{35\%}$ for $\bar{R}$ is 36.39 thousand t, which is 5% larger than that obtained in the 2022 assessment (34.73 thousand t).

Once F_{MSY} and B_{MSY} are determined, the (total catch) OFL can be calculated iteratively based on projecting the population forward one year assuming an F, calculating the catch and projected biomass B, comparing the stock's position on the harvest control rule's phase plane and adjusting F and recalculating the projected B until the point (F, B) lies on the control rule. The OFL is then the predicted total catch mortality taken when fishing at $F = F_{OFL}$, which is calculated as

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

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), $F_{\cdot,x,z} = \sum_f F_{f,x,z}$ 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, 2023 as estimated by the assessment model. The OFL for 2023/24 from the author's preferred model (22.03b) is 36.20 thousand t (Figure 148).

The B_{MSY} proxy, $B_{35\%}$, from the author's preferred model is 36.39 thousand t , so $MSST = 0.5 \cdot B_{MSY} = 18.19$ thousand t. Because the current $B = 74.17$ thousand t > MSST, **the stock is not overfished**. Because the projected $B = 48.77$ thousand t > B_{MSY}, the stock falls into Tier 3a. The population state (directed F vs. MMB) is plotted starting in in Figure 149 against the Tier 3 harvest control rule.

7.2 ABC calculation

Amendments 38 and 39 to the Fishery Management Plan (NPFMC 2011) established methods for the Council to set Annual Catch Limits (ACLs). The Magnuson-Stevens Act requires that ACLs be established based upon an ABC control rule that accounts for scientific uncertainty in the OFL such that ACL=ABC and the TAC 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 maximum ABCs for BSAI crab stocks be established at P^*=0.49. Thus, annual ACL=ABC levels should be established such that the risk of ovefishing, P[ABC>OFL], is 49%. For this assessment, the model-based uncertainty in the OFL was obtained using ADMB's sd_report functionality, which provides standard errors for derived quantities like the OFL based on the "delta method", which approximates the likelihood surface at the MLE as multivariate normal using the estimated parameter covariance matrix. In 2014, however, the SSC adopted a buffer of 20% on OFL for the Tanner crab stock for calculating ABC that included consideration of additional uncertainty in the stock assessment. Here, ABCs are provided based on both methods.

For the author's preferred model, 22.03b, the P^* ABC (ABC_{max}) is 36.15 thousand t while the 20% Buffer ABC is 28.96 thousand t (Figure 148). 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. In addition, the estimates of survey catchability for this stock remain problematic and contribute to this year's inflated OFL despite a continued decline in survey biomass across the last few years. Furthermore, the model appears overly-optimistic in terms of recent scale and trends. Given this uncertainty concerning the stock, the author recommends increasing the buffer on ABC from the 20% buffer previously adopted by the SSC for this stock to 25% to calculate the ABC. Consequently, **the author's recommended ABC is 27.15 thousand t**.

The following tables summarize the OFL/ABC results for model 22.03b (repeating Tables A and B for convenience):

Management quantities (in 1,000s t) based on the author's preferred model, 22.03b, and recommended ABC buffer (25%). TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2019/20	18.31	56.15	0.00	0.00	0.54	28.86	23.09
2020/21	17.97	56.34	1.07	0.66	0.96	21.13	16.90
2021/22	17.37	62.05	0.50	0.49	0.78	27.17	21.74
2022/23	18.19	74.17	0.91	0.91	1.19	32.81	26.25
2023/24	–	48.77	–	–	–	36.20	27.15

Management quantities (in millions of pounds) based on the author's preferred model, 22.03b, and recommended ABC buffer (25%). TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2019/20	40.36	123.77	0.00	0.00	1.20	63.62	50.89
2020/21	39.61	124.19	2.35	1.44	2.11	46.58	37.26
2021/22	38.29	136.79	1.10	1.09	1.73	59.89	47.91
2022/23	40.11	163.52	2.02	2.01	2.62	72.34	54.25
2023/24	–	107.52	–	–	–	79.82	59.86

7.3 Projections

Multi-year projections were made under assumptions of fishing at 0, 0.25, 0.5, 0.75, 1, and 1.25 times the directed fishery F_{OFL} ($= F_{MSY}$ in this case for the models considered) for the preferred model (Figure 150). 500 replicate projections of 20 years were made for each F_{OFL} multiplier. Each projection started at the final population state of the MLE and advanced in time under recruitments that were randomly resampled from the model-estimated recruitment time series for 1982 to 2021 (consistent with the time period to determine average recruitment for the OFL calculation). Characteristics for the fisheries were the same as those used to determine the OFL. The projections did not include any management feedback (e.g., F_{OFL} was not recalculated each year)–which would be appropriate in a management strategy evaluation (MSE) context.

For a given fishing mortality scenario, the projections follow very similar trajectories in the first 5 years before eventually diverging substantially starting around 2028, but the patterns are fairly different across scenarios (Figure 150). With no directed fishing, MMB is projected to increase relatively rapidly until 2028 as the strong recruitment events estimated in 2021 and 2022 grow to maturity, after which individual trajectories diverge substantially (but with the result that the mean MMB across trajectories in any year after 2040 is essentially the unfished value, B_{100}). For any of the non-zero directed F scenarios, MMB decreases initially as fishery-vulnerable larger crab in the terminal year are fished out before the 2021 and 2022 "cohorts" start to grow into the fishery-vulnerable size range. As with the zero-F scenario, individual trajectories in these scenarios begin to diverge in 2028 and reach stochastic equilibrium by about 2040.

8 Tier 4 "fall back" model

8.1 Introduction

For crab stocks managed by the NPFMC, *overfished* status is assessed with respect to the Minimum Stock Size Threshold (MSST, CPT 2022). If stock biomass drops below the MSST, the stock is considered to be overfished. For crab stocks, MSST is one-half of B_{MSY}, where B_{MSY} is the long-term equilibrium biomass (assumed to reflect the reproductive potential for the stock) when the stock is fished at maximum sustainable yield (MSY). Thus, the stock is overfished if $B/B_{MSY} < 0.5$, where B is the "current" biomass. In general, the overfishing limit (OFL) for the subsequent year is based on B/B_{MSY} and an F_{OFL} harvest control rule, where F_{OFL} is the fishing mortality rate that yields the OFL and $F_{OFL} \leq F_{MSY}$, the fishing mortality that yields the long-term maximum sustainable yield (MSY). Furthermore, if $B/B_{MSY} < \beta(= 0.25)$, directed fishing on the stock is prohibited. Tanner crab has been considered a "Tier 3" stock for status determination and fishery management since 2012/13 (SSC 2012) because the available biological and fishery information have been deemed sufficiently informative that Tier 3 proxies for B_{MSY} and F_{MSY} (i.e., spawner-per-recruit proxies $B_{35\%}$ and $F_{35\%}$ based on mature male biomass) can be reliably estimated.

However, the SSC has expressed concerns regarding the complexity of the current Tier 3 models for Tanner and other crab stocks and has requested that simpler "Tier 4" models be developed as a fallback in the event that a candidate Tier 3 model is deemed unreliable (SSC 2022). Approaches to implement a "fallback" Tier 4 model were discussed at the March, 2023 meeting of the "simpler" crab modeling working group, a joint inter-agency and SSC working group (Anonymous 2023). The working group was formed in response to a recommendation made by the SSC during its October 2022 meeting that SSC members and stock assessments authors jointly explore model parsimony and legacy assumptions for the BBRKC, Tanner, and snow crab stocks (SSC 2022).

For Tier 4 stocks, the estimate of "current survey biomass" is considered to be reliable and the proxy B_{MSY} is defined as "average biomass over a specified time period" ((CPT 2022), p. 8). F_{MSY} is taken to be $\gamma \cdot M$, where M is the assumed rate of natural mortality and γ is a constant (taken as 1 by default). Once the $B_{MSY_{proxy}}$ has been calculated, the overfished status is then determined by the ratio $B/B_{MSY_{proxy}}$: the stock is overfished if the ratio is less than 0.5, where B is taken as "current" biomass. The ratio also determines F_{OFL} relative to F_{MSY}:

1. if $B/B_{MSY_{proxy}} \geq 1$ then $F_{OFL} = F_{MSY}$;
2. if $0.25 < B/B_{MSY_{proxy}} < 1$, then $F_{OFL} < F_{MSY}$ as determined by a sloping F_{OFL} control rule (CPT 2022); or
3. $F_{OFL} = 0$ if $B/B_{MSY_{proxy}} < 0.25$.

For the Tier 3 stocks, the "simpler" crab modeling working group recommended using the mean of a smoothed time series for "vulnerable" male crab survey biomass as a very simple B_{MSY} proxy for fallback Tier 4 models, although it also supported authors bringing forward slightly more complex models that captured growth and mortality between the times of the survey and fishery ((Anonymous 2023), pp.4-5). At the May 2023 CPT meeting, the author presented a "slightly more complex" Tier 4 model for Tanner crab that incorporated natural mortality, recruitment, and fishing mortality into estimates of survey-based MMB-at-mating as the currency for the B_{MSY} proxy (Stockhausen 2023c). However, the SSC did not see the need for the additional complexity in a "fallback" model and requested that the author follow the working group's simpler B_{MSY} proxy recommendation ((SSC 2023), p. 12). It also requested that authors base the averaging period "on the whole time series or develop justification for a better time block that represents current fishing potential for the stock" ((SSC 2023), p. 7). For Tanner crab specifically, the SSC further requested that "a clear justification for the choice of reference time period be provided in the September SAFE document, beyond simple precedent, and that several alternative time periods be considered (each with its own justification)" ((SSC 2023), p. 12).

Here, fallback Tier 4 management quantities are calculated for the eastern Bering Sea Tanner crab stock using the approach requested by the SSC. First, a time series of "vulnerable" male biomass (VMB) is calculated using data from the NMFS Bering Sea shelf bottom trawl survey, to which a state-space random walk model is applied to reduce observation error and interannual variance (process error). Current B is taken as the estimate of VMB for 2023 from the random walk model. Then B_{MSY} proxies are calculated for several candidate time periods by averaging the random walk time series values over each time period. Finally, other management quantities (e.g., stock status, F_{OFL}, OFL) are calculated based on the Tier 4 rules noted above.

8.2 Vulnerable male biomass time series

A time series of observed survey biomass for male crab classified as "vulnerable" to capture by the directed and bycatch fisheries for Tanner crab was calculated from the annual NMFS EBS shelf bottom trawl survey for 1975-2023 (the survey was not conducted in 2020) using standard methods for design-based biomass indices (Wakabayashi et al. 1985), where male crab greater than 100 were classified as vulnerable to fishing gear (Table 92; Figure 151). The observed VMB time series is rather noisy; to reduce variability associated with survey sampling error, a state-space/random effects random walk model was fit to the observed time series using the *rema* R package (Sullivan 2022) (Table 92; Figure 151). The model provided an estimate of 18,680 t for current B, as well as the values to average to obtain the B_{MSY} proxy.

8.3 Tier 4 Management Quantities

Candidate values for the Tier 4 management quantities, dependent on the time block chosen for the B_{MSY} proxy, were calculated for the time periods listed in Table 93.

For the time blocks considered, the B_{MSY} proxy ranges from 42 t to 110 t (see Figure 152 also). Stock status ranges from 0.17 (Tier c, "overfished") to 0.44 (Tier b, "overfished"). F_{OFL} and OFL cannot be determined from the control rule when the stock is in level "c" (status < 0.25): in this case, directed fishing is prohibited and an $F_{OFL} \leq F_{MSY}$ would be determined based on all other sources of mortality in the development of the rebuilding plan. The maximum F_{OFL} and OFL are 0.09 and 1.574, respectively. In all cases, the stock would be considered "overfished" (status < 0.5) under Tier 4.

The time period for calculating the B_{MSY} proxy should ideally correspond to a time period at which the stock was in equilibrium and fished at F_{MSY} (NPFMC 2021a). In 2008 for the previous Tier 4 model, the SSC recommended two time periods, 1969-1980 and 1969-2007 (i.e., "the present", at the time of the recommendation) as candidates for the time block to use to calculate the B_{MSY} proxy (SSC 2008); both time blocks included survey results from 1969, 1970, and 1972-1975 based on associated INPFC reports in addition to subsequent NMFS EBS shelf surveys. The rationale for this time period seems to have included the importance of the pre-1975 time period as indicative of unexploited stock size and the effects of fishing down the stock from unexploited levels. Rugolo and Turnock (2008) noted that both the authors and the CPT expressed concerns regarding the quality and availability of the data from the pre-1975 period, and suggested dropping the pre-1975 data. In addition (Rugolo and Turnock 2008), "the authors and CPT are not able to recommend…"the 1969-2007 period

> "for OFL setting. From 1980-2007, the EBS Tanner crab stock collapsed twice resulting in two periods of fishery closures and a rebuilding plan by the Council. During this period, the stock experienced exploitation rates in excess of current FMSY estimates."

Rugolo and Turnock (2010) reiterated the criticism that "during 1980-2009, the stock has not maintained itself at a level that could be reasonably construed as in dynamic equilibrium or at a level indicative of B_{MSY} capable of providing MSY to the fisheries."

The Tanner crab stock does not appear to have been in equilibrium under any fishing mortality rates since the inception of the fishery. The fishery has been closed a number of times (1985-1986, 1997/98-2004/05, 2010/11-2012/13, 2016/16, 2019/20), was declared overfished in 1999 and again in 2010, and was under rebuilding plans during 2001-2007 and 2012. Thus, it does not seem possible to identify a time period associated with the stock being at equilibrium while being fished at F_{MSY}. Thus, the selection of an averaging time period must consider other criteria. The SSC has recommended that authors base this calculation for "fallback" Tier 4 calculations on the "whole time series or develop justification for a better time block that represents current fishing potential for the stock" (SSC 2023). The "whole time period" would be 1975-present or 1982-present, depending on whether the survey gear change in 1982 is a matter for concern for the consistency of the VMB time series. Results for both of these time periods are included in the analysis. The time block 1975-1980 was included in the analysis for historical continuity with the previous Tier 4 model. Two other time blocks were included in the analysis: 1987-1995 + 2005-2009 + 2013-2015 and 2005-2009 + 2013-2015, the latter a subset of the former that drops the 1987-1995 time period. These time blocks exclude the presumed "enhanced mortality" period (1980-1984) as well as periods when the fishery (as a whole) was closed.

The two time blocks that include the 1975-1980 time period are not recommended because this period encompasses a dramatic decline in VMB over the time period and thus does not appear to reflect the "current fishing potential" of the stock. In addition, the different selectivity/catchability characteristics in the pre- and post-1982 survey gear introduce potential inconsistencies across the time series. The 1982-present period recommended as a default by the SSC is not recommended by the author because it includes the presumed "enhanced mortality" period (1980-1984) as well as periods when the fishery (as a whole) was closed. Consequently, the author recommends using either of the two remaining time blocks (1987-1995 + 2005-2009 + 2013-2015 or 2005-2009 + 2013-2015) as the averaging time period to determine B_{MSY}.

The SSC requested that authors recommend a suitable buffer to apply to the OFL to obtain the ABC. The cv for the estimated B provides a natural starting point to define an ABC buffer. One approach would be to use the cv to determine a P^* under assumptions regarding the distribution of the estimated OFL with respect to the "true" OFL. A simpler approach in keeping with the "fallback" approach would be to use the cv as the minimum buffer for determining the ABC (i.e., $ABC = (1-cv) \cdot OFL$), modified (perhaps) with additional concerns regarding uncertainty. Taking the latter approach, the minimum buffer for ABC would be 8.9%, which seems reasonable given that the Tier 4 calculation itself results in a value for the OFL much smaller than the Tier 3 value.

9 Rebuilding Analyses

The Tanner crab stock is not overfished, so no rebuilding analyses are required.

10 Data Gaps and Research Priorities

A GMACS version of the Tanner crab model is under development. This is considered the highest priority topic for this assessment. An initial version will be reviewed at the January 2024 Crab Modeling Workshop.

Information on growth-per-molt has been collected in the EBS on Tanner crab and incorporated into the assessment. It would be helpful to have more information on growth associated with the terminal molt, because it seems likely this has different characteristics than previous molts. A better understanding of drivers of natural mortality and recruitment variability is another key to improving the ecological basis for the assessment. More comprehensive information regarding thermal tolerances and temperature-dependent effects on molting frequency and movement would be helpful to assess potential impacts of the EBS cold pool on recruitment processes and the stock distribution. Furthermore, it would be worthwhile to develop a "better" index of reproductive potential than MMB that can be calculated in the assessment model, as well as to revisit the issue of MSY proxies for this stock.

The characterization of fisheries in the assessment model also needs to be carefully reconsidered. How, and whether or not, the differences in the directed fishery in areas east and west 166^{o}W longitude should be explicitly represented in the assessment model need to be addressed. This is particularly relevant now that the eastern management area has been closed for several years, which has implications for whether an asymptotic function remains a reasonable description of selectivity in the directed fishery. The question of whether or not bycatch in the groundfish fisheries should be split into fixed gear- and trawl-related components to better capture changes in bycatch selectivity needs to be revisited.

Incorporating the BSFRF side-by-side (SBS) surveys into the assessment in the best way possible is also a matter for continued exploration. A catch ratio analysis using the SBS survey data outside the model (presented at the May, 2021 CPT meeting) provided initial estimates of year-specific NMFS survey selectivity that account for variations in stock abundance across different depths and benthic substrates. This analysis needs to be drawn to a conclusion and incorporated, at least as an option, into the assessment model framework. However, this requires that BSFRF provide the 2018 survey data to the assessment author.

11 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, a better 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 at decadal time scales (Rugolo and Turnock 2012a), suggesting a climatic driver.

11.1 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). Pacific cod spawning biomass is estimated to have increased rapidly in the early 1980s, concomitant with a period of rapid decline in Tanner crab biomass (modeled as a period of high but unexplained natural mortality in the assessment). Subsequently, Pacific cod spawning biomass declined rapidly in the late 1980s and early 1990s. At the same time, the Tanner crab stock first increased in the late 1980s but then decreased in the early 1990s, possibly lagging the continued decline in Pacific cod spawning biomass by a year or two. After 1993, cod spawning biomass continued a very gradual decline until 2010, after which it has been increasing fairly rapidly (Thompson et al. 2021). However, Tanner crab biomass began to increase in 2000, reached a relative peak in 2008, and has fluctuated since then. It is not immediately apparent that trends in Pacific cod spawning biomass have a direct effect on Tanner crab biomass.

11.2 Effects of Tanner crab fishery on ecosystem

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

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

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References

Adams, A.E., and Paul, A.J. 1983. Male parent size, sperm storage and egg production in the crab Chionoecetes bairdi (Decapoda, Majidae). INT. J. INVERTEBR. REPROD. **6**(3): 181–187.

ADFG. 2008. Annual management report for the commercial and subsistence shellfsh fisheries of the Aleutian Islands, Bering Sea and the westward region's shellfsh ObserverProgram, 2006/07. Alaska Department of Fish; Game, Juneau, AK.

ADFG. 2017. 2017-2019 king and Tanner crab commercial fishing regulations. Alaska Department of Fish; Game.

Anonymous. 2023. Crab modeling workgroup report. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=707cf4ac-266d-4213-bd9d-b4002e96012d.pdf&fileName=Crab%20Modeling%20Working%20group%20Report.pdf.

Brown, R.B., and Powell, G.C. 1972. Size at maturity in the male Alaskan Tanner crab, Chionoecetes bairdi, as determined by chela allometry, reproductive tract weights, and size of precopulatory males. Journal of the Fisheries Research Board of Canada **29**(4): 423–427.

CPT. 2017. Crab Plan Team report. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=27175b87-79d8-43dd-ae8a-4d16284953b7.pdf&fileName=C7%20Crab%20Plan%20Team%20Report%20May%202017.pdf.

CPT. 2022. Introduction. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2022 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 1–43. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2022/TannerCrabSAFE2022.pdf.

CPT. 2023. Crab Plan Team report. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=4ace502c-f13b-411f-8301-978c09746e6a.pdf&fileName=C1%20CPT%20Report%20May%202023.pdf.

Daly, B., Armistead, C., and Foy, R. 2014. The 2014 eastern Bering Sea continental shelf bottom trawl survey: Results for commercial crab species. NOAA.

Daly, B., Armistead, C., and Foy, R. 2015. The 2015 eastern Bering Sea continental shelf bottom trawl survey: Results for commercial crab species. NOAA. Available from https://repository.library.noaa.gov/view/noaa/5214/noaa_5214_DS1.pdf.

Daly, B., Heller-Shipley, M., Stichert, M., Stockhausen, W., Punt, A., and Goodman, S. 2020. Recommended harvest strategy for Bering Sea Tanner crab. Alaska Department of Fish; Game, Anchorage, AK.

Donaldson, W.E., and Adams, A.E. 1989. Ethogram of behavior with emphasis on mating for the Tanner crab Chionoecetes bairdi rathbun. Journal of crustacean biology. Washington DC **9**(1): 37–53.

Donaldson, W.E., Cooney, R.T., and Hilsinger, J.R. 1981. Growth, age and size at maturity of Tanner crab, Chionoecetes bairdi m. J. Rathbun, in the northern gulf of Alaska (Decapoda, brachyura). Crustaceana **40**(3): 286–301.

Donaldson, W.E., and Hicks, D.M. 1977. Technical report to industry on the kodiak crab population surveys. Results, life history, information, and history of the fishery for Tanner crab. Alaska Department of Fish; Game, Kodiak, AK.

Haynes, E., Karinen, J.F., Watson, J., and Hopson, D.J. 1976. Relation of number of eggs and egg length to carapace width in thebrachyuran crabs Chionoecetes bairdi and c. Opilio from the southeastern Bering Sea and c. Opilio from the gulf of st.lawrence. Journal of the Fisheries Research Board of Canada **33**(11): 2592–2595.

Heller-Shipley, M.A., Stockhausen, W.T., Daly, B.J., Punt, A.E., and Goodman, S.E. 2021. Should harvest control rules for male-only fisheries include reproductive buffers? A Bering Sea Tanner crab (Chionoecetes bairdi) case study. Fisheries Research **243**: 106049. doi:https://doi.org/10.

1016/j.fishres.2021.106049.

Hilsinger, J.R. 1976. Aspects of the reproductive biology of female snow crabs, Chionoecetes bairdi, from prince william sound and the adjacent gulf of Alaska. Mar. Sci. Commun. **2**(3-4): 201–225.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin **82**: 898–903.

Hosie, M.J., and Gaumer, T.F. 1974. Southern range extension of the baird crab (Chionoecetes bairdi rathbun). California Fish and Game **60**(1): 44–47.

Johnson, G.M. 2019. Population genetics of Tanner crab (Chionoecetes bairdi) in Alaskan waters. Master's thesis, University of Alaska Fairbanks, Fairbanks, AK.

Karinen, J.F., and Hoopes, D.T. 1971. Occurrence of Tanner crabs (chionoecetes sp.) in the eastern Bering Sea with characteristics intermediate between c. Bairdi and c. opilio. Proc. Natl. Shellfish Assoc **61**: 8–9.

Kon, T. 1996. Overview of Tanner crab fisheries around the japanese archipelago. *In* High latitude crabs: Biology, management, and economics. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA. pp. 13–24.

McLaughlin, P.A., and Co-authors, 39. 2005. Common and scientific names of aquatic invertebrates from the united states and canada: crustaceans. American Fisheries Society.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science **56**(4): 473–488. doi:10.1006/jmsc.1999.0481.

Munk, J.E., Payne, S.A., and Stevens, B.G. 1996. Timing and duration of the mating and molting season for shallow water Tanner crab (Chionoecetes bairdi). *In* High latitude crabs: Biology, management, and economics. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA. p. 341.

Murphy, J.T. 2020. Climate change, interspecific competition, and poleward vs. Depth distribution shifts: Spatial analyses of the eastern Bering Sea snow and Tanner crab (Chionoecetes opilio and c. bairdi). Fisheries Research **223**: 105417. doi:https://doi.org/10.1016/j.fishres.2019.105417.

Nevisi, A., Orensanz, J.M., Paul, A.J., and Armstrong, D.A. 1996. Radiometric estimation of shell age in chionoecetes spp. From the eastern Bering Sea, and its use to interpret shell condition indices: Preliminary results. *In* High latitude crabs: Biology, management, and economics. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA. pp. 389–396.

NMFS. 2004. Final Environmental Impact Statement for Bering Sea and Aleutian Islands Crab Fisheries. National Marine Fisheries Service, P.O. Box 21668, Juneau, AK 99802-1668.

NMFS. 2008. Final Environmental Assessment for Amendment 24 to the Fishery Management Plan for Bering Sea/ Aleutian Islands King and Tanner Crabs to Revise Overfishing Definitions. National Marine Fisheries Service. Available from https://repository.library.noaa.gov/view/noaa/18139/noaa_18139_DS1.pdf.

NPFMC. 1998. Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. North Pacific Fishery Management Council, 605 W. 4th Avenue, Suite, 306, Anchorage, AK 99501.

NPFMC. 2011. Amendment 38 and 39 To the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. North Pacific Fishery Management Council. Available from https://www.regulations.gov/document/NOAA-NMFS-2011-0033-0007.

NPFMC. 2021a. Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/fmp/Crab/CrabFMP.pdf.

NPFMC. 2021b. BSAI Crab Fishery Management Plan Amendment Summaries. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/Publications/Crab_Amendment_Summaries.pdf.

Otto, R.S. 1998. Assessment of the eastern Bering Sea snow crab, Chionoecetes opilio, stock under the terminal molting hypothesis. *In* Proceedings of the north pacific symposium on invertebrate stock assessment and management. *Edited by* G.S. Jamieson and A.C. (eds). pp. 109–124. Available from https://publications.gc.ca/collections/collection_2016/mpo-dfo/Fs41-31-125-eng.pdf.

Paul, A.J. 1984. Mating frequency and viability of stored sperm in the Tanner crab Chionoecetes bairdi (Decapoda, Majidae). Journal of crustacean biology. Washington DC **4**(3): 375–381.

Paul, A.J. 1992. A review of size at maturity in male Tanner (Chionoecetes bairdi) and king (paralithodes camtschaticus) crabs and the methods used to determine maturity. American Zoologist **32**(3): 534–540.

Paul, A.J., and Paul, J.M. 1992. Second clutch viability of Chionoecetes bairdi rathbun (Decapoda: Majidae) inseminated only at the maturity molt. Journal of crustacean biology. Washington DC **12**(3): 438–441.

Rathbun, M.J. 1924. New species and subspecies of spider crabs. Proceedings of U.S. Nat. Museum **64**: 1–5. doi:https://doi.org/10.5479/si.00963801.2504.

Richar, J.I., and Foy, R.J. 2022. A novel morphometry-based method for assessing maturity in male Tanner crab, Chionoecetes bairdi. FACETS **7**: 1598–1616. doi:https://doi.org/10.1139/facets-2021-0061.

Richar, J.I., Kruse, G.H., Curchitser, E., and Hermann, A.J. 2015. Patterns in connectivity and retention of simulated Tanner crab (Chionoecetes bairdi) larvae in the eastern Bering Sea. Progress in Oceanography **138**: 475–485. doi:https://doi.org/10.1016/j.pocean.2014.08.001.

Rodionov, S., and Overland, J.E. 2005. Application of a sequential regime shift detection method to the Bering Sea ecosystem. ICES Journal of Marine Science **62**(3): 328–332. doi:10.1016/j.icesjms.2005.01.013.

Rugolo, L.J., and Turnock, B.J. 2008. 2008 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2008 BSAI crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 195–250. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CRABSAFE2010.pdf.

Rugolo, L.J., and Turnock, B.J. 2010. 2010 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2010 draft crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 247–308. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CRABSAFE2010.pdf.

Rugolo, L.J., and Turnock, B.J. 2011a. Length-based stock assessment model of eastern Bering Sea Tanner crab: Report to subgroup of NPFMC Crab Plan Team. North Pacific Fishery Management Council, Anchorage, AK.

Rugolo, L.J., and Turnock, B.J. 2011b. 2011 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering

Sea and Aleutian Islands regions 2011 draft crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 285–354. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2011.pdf.

Rugolo, L.J., and Turnock, B.J. 2012b. Length-based stock assessment model of eastern Bering Sea Tanner crab: Report to subgroup of NPFMC Crab Plan Team. North Pacific Fishery Management Council, Anchorage, AK.

Rugolo, L.J., and Turnock, B.J. 2012a. 2012 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2012 draft crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 269–425. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2012.pdf.

Slizkin, A.G. 1990. Tanner crabs (Chionoecetes opilio, c. Bairdi) of the northwest pacific: Distribution, biological peculiarities, and population structure. *In* Proceedings of the international symposium on king and Tanner crabs. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA. pp. 27–33.

Somerton, D.A. 1981a. Life history and population dynamics of two species of Tanner crab, Chionoecetes bairdi and c. Opilio, in the eastern Bering Sea with implications for the management of the commercial harvest. PhD thesis, University of Washington, Seattle, WA.

Somerton, D.A. 1981b. Regional variation in the size of maturity of two species of Tanner crab (Chionoecetes bairdi and c. Opilio) in the eastern Bering Sea, and its use in defining management subareas. Canadian Journal of Fisheries and Aquatic Sciences **38**(2): 163–174.

Somerton, D.A., and Meyers, W.S. 1983. Fecundity differences between primiparous and multiparous female Alaskan Tanner crab (Chionoecetes bairdi). Journal of crustacean biology. Washington DC **3**(2): 183–186.

SSC. 2008. SCIENTIFIC AND STATISTICAL COMMITTEE FINAL REPORT TO THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=d95d28fe-3540-4e74-baa3-f029ce6a3a7d.pdf&fileName=SSC%20Report%20June%202008_Final.pdf.

SSC. 2012. FINAL REPORT of the SCIENTIFIC AND STATISTICAL COMMITTEE FINAL REPORT to the NORTH PACIFIC FISHERY MANAGEMENT COUNCIL. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=d95d28fe-3540-4e74-baa3-f029ce6a3a7d.pdf&fileName=SSC%20Report%20Oct%202012_Final.pdf.

SSC. 2017. SCIENTIFIC AND STATISTICAL COMMITTEE FINAL REPORT TO THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=9cec6021-c359-4383-a841-68cf7603fbd2.pdf&fileName=SSC%20Report%20June%202017_FINAL.pdf.

SSC. 2022. SCIENTIFIC AND STATISTICAL COMMITTEE FINAL REPORT TO THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=d95d28fe-3540-4e74-baa3-f029ce6a3a7d.pdf&fileName=SSC%20Report%20Oct%202022_Final.pdf.

SSC. 2023. SCIENTIFIC AND STATISTICAL COMMITTEE DRAFT REPORT TO THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/

DownloadFile?p=db628102-a423-4d9b-b2d9-8d4a906ac4dc.pdf&fileName=SSC%20Report%20June%202023%20DRAFT.pdf.

Stevens, B.G. 2000. Moonlight madness and larval launch pads: Tidal synchronization of mound formation and hatching by Tanner crabs, Chionoecetes bairdi. Journal of Shellfish Research **19**(1): 640–641.

Stockhausen, W.T. 2013. 2013 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2013 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2013.pdf.

Stockhausen, W.T. 2014. 2014 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2014 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=84a80bf9-a465-4e91-8da7-b84e414c0e3e.pdf&fileName=C3%20CRAB%20SAFE%202014_reduced.pdf.

Stockhausen, W.T. 2015. 2015 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2015 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2015.pdf.

Stockhausen, W.T. 2016. 2016 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2016 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2016CrabSAFE_final.pdf.

Stockhausen, W.T. 2017a. 2017 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2017 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2017.pdf.

Stockhausen, W.T. 2017b. Tanner crab assessment report for the may 2017 CPT meeting. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=be0e37c1-97da-4def-a7cd-0d3e79c93106.pdf&fileName=TannerCrab201705_CPTMeeting.pdf.

Stockhausen, W.T. 2019. 2019 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2019 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2019/SAFE_2019_Complete.pdf.

Stockhausen, W.T. 2021. 2021 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock

Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2021 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 217. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=55d56b05-4f74-4c5d-9372-28ced4a2bfc2.pdf&fileName=C1%20Tanner%20Crab%20SAFE.pdf.

Stockhausen, W.T. 2022a. 2022 Stock Assessment and Fishery Evaluation Report for the Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2022 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 597. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2022/TannerCrabSAFE2022.pdf.

Stockhausen, W.T. 2022b. May 2022 Tanner crab report: Updates on issues and proposed models for september. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=3d4c9731-4ff4-4151-b2b0-5b80a981541d.pdf&fileName=%7BTanner%7D%20Crab%20Report_Updated%205_17.pdf.

Stockhausen, W.T. 2023b. Candidate assessment models for Tanner crab. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=89cf6e8a-29c8-49f5-974a-72e37ab1de3f.pdf&fileName=Tanner%20Crab%202023%20proposed%20model.pdf.

Stockhausen, W.T. 2023c. Example tier 4 status determination for the Tanner crab stock. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=9a2353b6-6bc1-465f-9d44-b295136b3391.pdf&fileName=Tanner%20Crab_Appendix%20D_Tier4Model.pdf.

Stockhausen, W.T. 2023a. Appendix c: Description of the Tanner crab stock assessment model, version 2. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=e5c38588-2e56-421d-bc34-d476d589feac.pdf&fileName=Tanner%20Crab_Appendix%20C_TCSAM02Description.pdf.

Stone, R.P., Masuda, M.M., and Clark, J.E. 2003. Growth of male Tanner crabs Chionoecetes bairdi in a southeast Alaska estuary. Alaska Fishery Research Bulletin **10**(2): 137–148.

Sullivan, J. 2022. rema: A generalized framework to fit the random effects (RE) model, a state-space random walk model developed at the Alaska Fisheries Science Center (AFSC) for apportionment and biomass estimation of groundfish and crab stocks. Available from https://github.com/JaneSullivan-NOAA/rema, https://afsc-assessments.github.io/rema/.

Tamone, S.L., Taggart, Sj., Andrews, A.G., Mondragon, J., and Nielsen, J.K. 2007. THE RELATIONSHIP BETWEEN CIRCULATING ECDYSTEROIDS AND CHELA ALLOMETRY IN MALE Tanner crabs: EVIDENCE FOR a TERMINAL MOLT IN THE GENUS CHIONOECETES. Journal of Crustacean Biology **27**(4): 635–642. doi:http://dx.doi.org/10.1651/S-2802.1.

Thorson, J.T., Johnson, K.F., Methot, R.D., and Taylor, I.G. 2017. Model-based estimates of effective sample size in stock assessment models using the dirichlet-multinomial distribution. Fisheries Research **192**: 84–93. doi:https://doi.org/10.1016/j.fishres.2016.06.005.

Turnock, B.J., and Rugolo, L.J. 2011. Stock assessment of eastern Bering Sea snow crab. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2011 draft crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. pp. 37–168. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2011.pdf.

Wakabayashi, K., Bakkala, R.G., and Alton, M.S. 1985. Methods of the U.S.-Japan demersal trawl surveys. *In* Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during may-august 1979. *Edited by* K. Wakabayashi. Int. North Pac. Fish. Comm. Bull. pp. 7–29.

Williams, A.B., B., A., Abele, L.G., Felder, D.L., H. H. Hobbs, Jr., Manning, R.B., McLaughlin, P.A., and Farfante, I.P. 1989. Common and scientific names of aquatic invertebrates from the united states and canada: Decapod crustaceans. American Fisheries Society.

Zheng, J. 2008. Temporal changes in size at maturity and their implications for fisheries management for eastern Bering Sea Tanner crab. Journal of Northwest Atlantic Fishery Science **41**: 137–149. doi:http://dx.doi.org/10.2960/J.v41.m623.

Zheng, J., and Kruse, G.H. 1999. Evaluation of harvest strategies for Tanner crab stocks that exhibit periodic recruitment. Journal of Shellfish Research **18**(2): 667–679.

Zheng, J., and Pengilly, D. 2011. Overview of proposed harvest strategy and minimum size limits for Bering Sea district Tanner crab. Alaska Department of Fish; Game, Anchorage, AK.

Tables

List of Tables

Table 1. Retained catch (metric tons) during the period when fishing by foreign fleets was allowed (1965-1979; historical data).

year	domestic	Japan	Russia	Total
1965/66	0	1,170	750	1,920
1966/67	0	1,690	750	2,440
1967/68	0	9,750	3,840	13,590
1968/69	460	13,590	3,960	18,010
1969/70	460	19,950	7,080	27,490
1970/71	80	18,930	6,490	25,500
1971/72	50	15,900	4,770	20,720
1972/73	100	16,800	0	16,900
1973/74	2,290	10,740	0	13,030
1974/75	3,300	12,060	0	15,360
1975/76	10,120	7,540	0	17,660
1976/77	23,360	6,660	0	30,020
1977/78	30,210	5,320	0	35,530
1978/79	19,280	1,810	0	21,090
1979/80	16,600	2,400	0	19,000

Table 2. Retained catch in the directed Tanner crab fishery during the period 1980-1996. The directed fishery was closed in 1985/86 and 1986/87 and from 1997/98-2004/05. Abundance units: number of individuals; biomass units: metric tons.

year	abundance	biomass
1980/81	12,928,112	13,426
1981/82	4,830,980	4,990
1982/83	2,286,756	2,390
1983/84	516,877	549
1984/85	1,272,501	1,429
1985/86	–	–
1986/87	–	–
1987/88	957,318	998
1988/89	2,894,480	3,180
1989/90	10,672,607	11,113
1990/91	16,609,286	18,189
1991/92	12,924,102	14,424
1992/93	15,265,865	15,921
1993/94	7,236,054	7,666
1994/95	3,351,639	3,538
1995/96	1,881,525	1,919
1996/97	734,303	821

Table 3. Retained catch biomass (metric tons) following rationalization of the crab fisheries in 2005, by ADFG management area and fishery. Annual totals are also given. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery. Incidental catch of Tanner crab, up to a fraction of the retained target by trip, is allowed to be retained in the snow crab and red king crab fisheries.

	TCF		SCF	RKF	all
year	East 166W	West 166W	West 166W	East 166W	all EBS
2005/06	0.0	244.5	187.7	0.0	432.2
2006/07	631.2	155.5	171.4	4.6	962.8
2007/08	710.0	151.1	86.5	8.0	955.6
2008/09	806.9	47.2	2.5	23.2	879.8
2009/10	592.4	0.0	1.7	8.4	602.5
2010/11	0.0	0.0	1.2	0.0	1.2
2011/12	0.0	0.0	2.1	0.0	2.1
2012/13	0.0	0.0	1.1	0.0	1.1
2013/14	654.3	593.6	9.9	6.3	1,264.1
2014/15	3,829.3	2,368.7	14.5	3.8	6,216.2
2015/16	5,107.7	3,770.3	30.3	1.4	8,909.6
2016/17	0.0	0.0	1.2	0.0	1.2
2017/18	0.1	1,117.5	15.0	0.0	1,132.6
2018/19	0.0	1,103.9	3.4	0.0	1,107.3
2019/20	0.0	0.0	0.1	0.0	0.1
2020/21	0.0	655.2	2.3	0.0	657.5
2021/22	0.0	493.5	0.8	0.0	494.3
2022/23	528.4	384.9	0.0	0.0	913.3

Table 4. Retained catch abundance (number of crab) following rationalization of the crab fisheries in 2005, by ADFG management area and fishery. Annual totals are also given. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery. Incidental catch of Tanner crab, up to a fraction of the retained target by trip, is allowed to be retained in the snow crab and red king crab fisheries.

	TCF		SCF	RKF	all
year	East 166W	West 166W	West 166W	East 166W	all EBS
2005/06	0	255,859	188,118	0	443,977
2006/07	581,024	164,719	175,904	4,456	926,103
2007/08	677,661	151,525	90,148	7,830	927,164
2008/09	758,002	48,171	3,300	20,896	830,369
2009/10	476,668	0	2,544	6,751	485,963
2010/11	0	0	1,689	6	1,695
2011/12	0	0	3,095	0	3,095
2012/13	0	0	1,643	4	1,647
2013/14	704,201	722,469	13,256	5,842	1,445,768
2014/15	4,378,199	3,121,442	19,512	3,691	7,522,844
2015/16	5,998,876	4,817,144	39,012	1,386	10,856,418
2016/17	0	0	1,733	33	1,766
2017/18	139	1,322,542	17,688	25	1,340,394
2018/19	0	1,376,977	4,013	18	1,381,008
2019/20	0	0	125	0	125
2020/21	0	870,634	3,017	1	873,652
2021/22	0	782,983	970	0	783,953
2022/23	683,223	587,079	0	0	1,270,302

Table 5. Federal management quantities (OFL, ABC), State of Alaska TACs, and harvest (retained catch biomass) in the Tanner crab fisheries following rationalization in 2005. OFL and ABC values apply to the entire EBS Tanner crab stock area, TAC values apply to individual ADFG management areas. Harvest is retained catch in the directed fisheries. Fishery closures are indicated by "–". All quantities are in metric tons.

	OFL	ABC	TAC			Harvest	
year	all EBS	all EBS	all EBS	East 166W	West 166W	East 166W	West 166W
2005/06	–	–	735	–	735	–	245
2006/07	–	–	1,347	850	496	631	156
2007/08	–	–	2,550	1,563	987	710	151
2008/09	7,040	–	1,950	1,253	697	807	47
2009/10	2,270	–	612	612	–	592	–
2010/11	1,610	–	–	–	–	–	–
2011/12	2,750	2,480	–	–	–	–	–
2012/13	19,020	8,170	–	–	–	–	–
2013/14	25,350	17,820	1,410	664	746	654	594
2014/15	31,480	25,180	6,852	3,846	3,005	3,829	2,369
2015/16	27,190	21,750	8,921	5,113	3,808	5,108	3,770
2016/17	25,610	20,490	–	–	–	–	–
2017/18	25,420	20,330	1,134	–	1,134	–	1,117
2018/19	20,870	16,700	1,106	–	1,106	–	1,104
2019/20	28,860	23,090	–	–	–	–	–
2020/21	21,130	16,900	1,065	–	1,065	–	655
2021/22	27,170	21,740	499	–	499	–	494
2022/23	32,810	26,250	913	528	386	528	384

Table 6. Original and scaled (input) sample sizes for retained catch size compositions. Only information aggregated to the EBS is available prior to 1990.'–': no data due to prior aggregation or lack of sampling (e.g. the fishery was closed.In addition to the closures noted here, the directed fishery was closed from 1997/98 to 2004/05.

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1980/81	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,840	85.1	1,470	10.6	13,310	95.7
1981/82	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	10,386	74.6	925	6.6	11,311	81.3
1982/83	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	9,540	68.6	3,979	28.6	13,519	97.2
1983/84	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	679	4.9	996	7.2	1,675	12.0
1984/85	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	1,649	11.9	893	6.4	2,542	18.3
1985/86	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1986/87	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1987/88	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1988/89	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,277	81.0	1,103	7.9	12,380	89.0
1989/90	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	34,184	190.1	1,772	9.9	35,956	200.0
1990/91	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	78,310	187.4	5,280	12.6	83,590	200.0
1991/92	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	118,583	186.4	8,644	13.6	127,227	200.0
1992/93	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	113,509	181.0	11,886	19.0	125,395	200.0
1993/94	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	67,264	187.8	4,358	12.2	71,622	200.0
1994/95	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	25,585	183.9	2,073	14.9	27,658	198.8
1995/96	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,297	81.2	7,979	57.3	19,276	138.5
1996/97	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	2,063	14.8	2,367	17.0	4,430	31.8
2005/06	– –	– –	– –	– –	– –	– –	649	4.7	56	0.4	705	5.1	649	4.7	56	0.4	705	5.1
2006/07	815	5.9	1,544	11.1	2,359	17.0	238	1.7	343	2.5	581	4.2	1,053	7.6	1,887	13.6	2,940	21.1
2007/08	2,730	19.6	1,439	10.3	4,169	30.0	932	6.7	726	5.2	1,658	11.9	3,662	26.3	2,165	15.6	5,827	41.9
2008/09	2,717	19.5	252	1.8	2,969	21.3	429	3.1	92	0.7	521	3.7	3,146	22.6	344	2.5	3,490	25.1
2009/10	2,369	17.0	48	0.3	2,417	17.4	– –	– –	– –	– –	– –	– –	2,369	17.0	48	0.3	2,417	17.4
2010/11	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2011/12	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2012/13	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2013/14	2,250	16.2	274	2.0	2,524	18.1	1,869	13.4	368	2.6	2,237	16.1	4,119	29.6	642	4.6	4,761	34.2
2014/15	6,278	45.1	1,274	9.2	7,552	54.3	5,012	36.0	1,807	13.0	6,819	49.0	11,290	81.1	3,081	22.1	14,371	103.3
2015/16	11,066	79.5	4,159	29.9	15,225	109.4	7,364	52.9	1,731	12.4	9,095	65.4	18,430	132.5	5,890	42.3	24,320	174.8
2016/17	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2017/18	– –	– –	– –	– –	– –	– –	1,980	14.2	1,490	10.7	3,470	24.9	1,980	14.2	1,490	10.7	3,470	24.9
2018/19	– –	– –	– –	– –	– –	– –	879	6.3	2,427	17.4	3,306	23.8	879	6.3	2,427	17.4	3,306	23.8
2019/20	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2020/21	– –	– –	– –	– –	– –	– –	1,378	9.9	1,945	14.0	3,323	23.9	1,378	9.9	1,945	14.0	3,323	23.9
2021/22	– –	– –	– –	– –	– –	– –	1,993	14.3	351	2.5	2,344	16.8	1,993	14.3	351	2.5	2,344	16.8
2022/23	2,073	14.9	258	1.9	2,331	16.8	1,962	14.1	346	2.5	2,308	16.6	4,035	29.0	604	4.3	4,639	33.3

Table 7. Annual total catch biomass estimates of Tanner crab, expanded from at-sea fishery observer data, in the groundfish fisheries (GF) prior to 1990. Units are metric tons. Groundfish bycatch data is from historical sources.

year	GF all gear all EBS all sexes
1973/74	17,735
1974/75	24,449
1975/76	9,408
1976/77	4,699
1977/78	2,776
1978/79	1,869
1979/80	3,397
1980/81	2,114
1981/82	1,474
1982/83	449
1983/84	671
1984/85	644
1985/86	399
1986/87	649
1987/88	640
1988/89	463
1989/90	671

Table 8. Annual total catch biomass (retained + discarded) estimates of Tanner crab, expanded from at-sea fishery observer data in all fleets after 1989. Units are metric tons. "TCF": Tanner crab fishery; "SCF": snow crab fishery; "RKF": BBRKC fishery; "GF": groundfish fisheries. Crab fishery values based on data provided by ADFG. Groundfish bycatch estimates based on data provided by AKFIN and the AKRO.

				TCF		SCF		RKF			GF	all fleets
				crab pot		crab pot		crab pot	fixed	trawl	all gear	all gear
		East 166W		West 166W		West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	7,082	105	3,723	36	–	–	943	11,889
1991/92	19,597	1,445	6,220	441	8,361	144	1,970	27	148	2,395	–	40,748
1992/93	29,660	1,104	7,347	599	2,488	162	1,316	19	103	2,657	–	45,455
1993/94	10,210	860	1,644	136	2,874	401	3,130	149	23	1,735	–	21,162
1994/95	6,958	729	357	112	1,345	194	–	–	24	2,072	–	11,791
1995/96	4,415	925	650	141	1,021	121	–	–	128	1,397	–	8,798
1996/97	229	56	72	–	1,960	119	270	2	118	1,477	–	4,303
1997/98	–	–	–	–	1,964	93	160	2	64	1,116	–	3,399
1998/99	–	–	–	–	656	80	115	2	88	847	–	1,788
1999/00	–	–	–	–	132	11	75	3	85	546	–	852
2000/01	–	–	–	–	313	6	66	2	53	688	–	1,128
2001/02	–	–	–	–	546	21	42	1	125	1,061	–	1,796
2002/03	–	–	–	–	167	13	61	1	96	624	–	962
2003/04	–	–	–	–	65	7	55	2	20	403	–	552
2004/05	–	–	–	–	134	40	49	2	65	610	–	900
2005/06	–	–	684	24	1,162	16	42	0	133	488	–	2,549
2006/07	1,132	49	579	73	1,527	86	30	2	346	371	–	4,195
2007/08	1,779	30	680	15	1,862	52	61	2	474	221	–	5,176
2008/09	1,178	7	119	1	1,100	25	280	3	288	245	–	3,246
2009/10	664	2	–	–	1,559	15	187	1	225	149	–	2,802
2010/11	–	–	–	–	1,453	9	32	0	118	113	–	1,725
2011/12	–	–	–	–	2,142	13	17	0	76	128	–	2,376
2012/13	–	–	–	–	1,564	10	42	1	46	107	–	1,770
2013/14	746	12	933	11	1,841	16	129	1	182	167	–	4,038

(continued)

				TCF		SCF		RKF				GF	all fleets
				crab pot		crab pot		crab pot	fixed	trawl	all gear	all gear
		East 166W		West 166W		West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2014/15	5,307	9	3,057	30	5,330	51	305	1	261	174	–	14,525
2015/16	6,761	29	5,468	29	3,919	17	205	6	276	85	–	16,795
2016/17	–	–	–	–	2,576	17	176	4	161	145	–	3,079
2017/18	–	–	1,363	38	1,081	6	183	2	114	50	–	2,837
2018/19	–	–	1,598	34	880	9	74	0	122	57	–	2,774
2019/20	–	–	–	–	1,003	15	18	0	45	103	–	1,184
2020/21	–	–	1,548	33	131	0	6	0	23	102	–	1,843
2021/22	–	–	826	16	82	2	0	0	53	112	–	1,091
2022/23	794	7	677	5	–	–	0	0	29	101	–	1,613

Table 9. Annual total catch abundance (retained + discarded) estimates of Tanner crab, expanded from at-sea fishery observer data, in all fleets after 1989. Units are 1,000s of crab. “TCF”: Tanner crab fishery; “SCF”: snow crab fishery; “RKF”: BBRKC fishery; “GF”: groundfish fisheries. Crab fishery values based on data provided by ADFG. Groundfish bycatch estimates based on data provided by AKFIN and the AKRO.

	TCF crab pot				SCF crab pot		RKF crab pot		GF			all fleets
	East 166W		West 166W		West 166W		East 166W		fixed all EBS	trawl all EBS	all gear all EBS	all gear all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	11,947	629	3,470	144	–	–	4,522	20,712
1991/92	25,791	5,612	8,211	2,001	13,995	752	1,954	95	356	5,756	–	64,523
1992/93	40,385	5,245	10,336	2,719	5,823	884	1,475	76	236	6,109	–	73,288
1993/94	13,438	3,430	2,347	634	6,841	2,315	3,404	567	49	3,595	–	36,620
1994/95	8,907	3,276	666	567	3,513	1,289	–	–	53	4,616	–	22,887
1995/96	6,084	4,058	1,094	684	2,422	727	–	–	312	3,405	–	18,786
1996/97	328	237	102	–	3,916	660	259	9	268	3,357	–	9,136
1997/98	–	–	–	–	3,697	537	164	6	183	3,202	–	7,789
1998/99	–	–	–	–	1,425	435	132	7	275	2,649	–	4,923
1999/00	–	–	–	–	337	62	111	8	222	1,432	–	2,172
2000/01	–	–	–	–	641	27	93	5	127	1,646	–	2,539
2001/02	–	–	–	–	1,196	118	56	4	249	2,118	–	3,741
2002/03	–	–	–	–	408	72	83	6	171	1,117	–	1,857
2003/04	–	–	–	–	172	47	82	7	53	1,038	–	1,399
2004/05	–	–	–	–	420	256	77	7	169	1,591	–	2,520
2005/06	–	–	1,004	113	2,182	90	62	4	285	1,046	–	4,786
2006/07	1,503	187	849	345	2,696	429	46	5	663	711	–	7,434
2007/08	2,682	121	1,060	72	3,642	263	81	5	1,349	627	–	9,902
2008/09	1,378	28	168	8	2,364	169	289	9	731	624	–	5,768
2009/10	622	9	–	–	3,035	97	176	4	381	455	–	4,779
2010/11	–	–	–	–	2,677	49	41	2	167	390	–	3,326
2011/12	–	–	–	–	3,633	73	21	0	105	918	–	4,750
2012/13	–	–	–	–	2,790	63	54	4	69	501	–	3,481
2013/14	898	43	1,343	51	3,641	91	148	4	302	689	–	7,210

(continued)

			TCF			SCF		RKF			GF	all fleets
			crab pot			crab pot		crab pot	fixed	trawl	all gear	all gear
	East 166W		West 166W			West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2014/15	7,570	37	4,998	133	10,716	296	346	3	414	591	–	25,104
2015/16	10,265	120	9,441	149	7,456	88	256	22	470	249	–	28,516
2016/17	–	–	–	–	4,900	79	252	20	269	428	–	5,948
2017/18	–	–	1,979	181	1,994	39	232	5	178	126	–	4,734
2018/19	–	–	2,562	184	1,621	62	88	0	162	220	–	4,899
2019/20	–	–	–	–	1,989	95	21	0	65	453	–	2,623
2020/21	–	–	2,851	170	289	4	8	0	42	515	–	3,879
2021/22	–	–	1,568	82	183	9	0	0	93	465	–	2,400
2022/23	1,329	37	1,280	29	–	–	0	0	58	503	–	3,236

Table 10. Annual discard mortality (biomass) estimates of Tanner crab in the groundfish fisheries ("GF") prior to 1990. Handling mortality rates for trawl gear have been applied. Units are metric tons.

year	TCF crab pot all EBS male	GF all gear all EBS all sexes
1965/66	0	–
1966/67	0	–
1967/68	0	–
1968/69	0	–
1969/70	0	–
1970/71	0	–
1971/72	0	–
1972/73	0	–
1973/74	0	14,188
1974/75	0	19,559
1975/76	0	7,526
1976/77	0	3,759
1977/78	0	2,221
1978/79	0	1,495
1979/80	0	2,718
1980/81	0	1,691
1981/82	0	1,179
1982/83	0	359
1983/84	0	537
1984/85	0	515
1985/86	–	319
1986/87	–	519
1987/88	0	512
1988/89	0	370
1989/90	0	537

Table 11. Annual discard mortality (biomass) estimates of Tanner crab, expanded from at-sea fishery observer data in all fleets after 1989. Assumed gear-specific handling mortality rates have been applied after (where appropriate) subtracting retained catch biomass from total catch biomass. “TCF”: Tanner crab fishery; “SCF”: snow crab fishery; “RKF”: BBRKC fishery; “GF”: groundfish fisheries. Units are metric tons.

	East 166W		West 166W		TCF crab pot all EBS		SCF crab pot West 166W		RKF crab pot East 166W		fixed all EBS	trawl all EBS	GF all gear all EBS	all fleets all gear all EBS
year	male	female	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	0	–	2,273	34	1,195	11	–	–	755	4,268
1991/92	–	–	–	–	3,657	605	2,684	46	632	9	48	1,916	–	9,597
1992/93	–	–	–	–	6,769	547	798	52	423	6	33	2,126	–	10,754
1993/94	–	–	–	–	1,344	320	923	129	1,005	48	8	1,388	–	5,165
1994/95	–	–	–	–	1,213	270	432	62	–	–	8	1,658	–	3,643
1995/96	–	–	–	–	1,010	342	328	39	–	–	41	1,118	–	2,878
1996/97	–	–	–	–	0	18	629	38	87	1	38	1,181	–	1,992
1997/98	–	–	–	–	–	–	630	30	51	1	21	893	–	1,626
1998/99	–	–	–	–	–	–	211	26	37	1	28	678	–	981
1999/00	–	–	–	–	–	–	42	4	24	1	27	437	–	535
2000/01	–	–	–	–	–	–	100	2	21	0	17	551	–	691
2001/02	–	–	–	–	–	–	175	7	14	0	40	848	–	1,084
2002/03	–	–	–	–	–	–	54	4	20	1	31	499	–	609
2003/04	–	–	–	–	–	–	21	2	18	1	7	323	–	372
2004/05	–	–	–	–	–	–	43	13	16	1	21	488	–	582
2005/06	0	–	141	8	–	–	313	5	13	0	43	390	–	913
2006/07	161	16	136	23	–	–	435	27	8	0	111	297	–	1,214
2007/08	343	9	170	5	–	–	570	17	17	0	152	176	–	1,459
2008/09	119	2	23	0	–	–	352	8	82	1	92	196	–	875
2009/10	23	1	0	–	–	–	500	5	57	0	72	119	–	777
2010/11	0	–	0	–	–	–	466	3	10	0	38	91	–	608
2011/12	0	–	0	–	–	–	687	4	6	0	25	102	–	824
2012/13	0	–	0	–	–	–	502	3	14	0	15	86	–	620
2013/14	30	4	109	4	–	–	588	5	39	0	58	133	–	970

(continued)

						TCF		SCF		RKF				GF	all fleets
						crab pot		crab pot		crab pot	fixed	trawl	all gear	all gear
	East 166W		West 166W			all EBS		West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2014/15	474	3	221	10	–	–	1,706	16	97	0	84	140	–	2,751
2015/16	531	9	545	9	–	–	1,248	5	65	2	89	68	–	2,571
2016/17	0	–	0	–	–	–	826	5	56	1	52	116	–	1,056
2017/18	0	–	79	12	–	–	342	2	59	0	37	40	–	571
2018/19	0	–	159	11	–	–	281	3	24	0	39	45	–	562
2019/20	0	–	0	–	–	–	322	5	6	0	14	82	–	429
2020/21	0	–	286	11	–	–	41	0	2	0	8	81	–	429
2021/22	0	–	107	5	–	–	26	0	0	0	17	90	–	245
2022/23	85	2	94	2	–	–	0	–	0	0	9	81	–	273

Table 12. Original and scaled (input) sample sizes for Tanner crab total catch size compositions in the directed fishery. Observer information starts in 1990/91. '–': no data due to prior aggregation or lack of sampling (e.g. the fishery was closed.

	East 166W						West 166W						all EBS					
	male		female		all sexes		male		female		all sexes		male		female		all sexes	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1990/91	– –	– –	– –	– –	– –	– –	51	0.4	34	0.2	85	0.6	51	0.4	34	0.2	85	0.6
1991/92	21,600	155.2	3,935	28.3	25,535	183.5	9,652	69.4	1,670	12.0	11,322	81.4	31,252	169.6	5,605	30.4	36,857	200.0
1992/93	42,260	176.2	5,707	23.8	47,967	200.0	12,576	90.4	3,048	21.9	15,624	112.3	54,836	172.5	8,755	27.5	63,591	200.0
1993/94	36,062	158.6	9,417	41.4	45,479	200.0	4,326	31.1	1,054	7.6	5,380	38.7	40,388	158.8	10,471	41.2	50,859	200.0
1994/95	5,657	40.7	2,004	14.4	7,661	55.1	135	1.0	128	0.9	263	1.9	5,792	41.6	2,132	15.3	7,924	56.9
1995/96	5,180	37.2	2,914	20.9	8,094	58.2	409	2.9	205	1.5	614	4.4	5,589	40.2	3,119	22.4	8,708	62.6
1996/97	219	1.6	168	1.2	387	2.8	133	1.0	– –	– –	133	1.0	352	2.5	168	1.2	520	3.7
2005/06	– –	– –	– –	– –	– –	– –	19,715	141.7	1,107	8.0	20,822	149.6	19,715	141.7	1,107	8.0	20,822	149.6
2006/07	12,688	91.2	1,573	11.3	14,261	102.5	11,538	82.9	2,859	20.5	14,397	103.5	24,226	169.1	4,432	30.9	28,658	200.0
2007/08	51,105	191.0	2,415	9.0	53,520	200.0	10,441	75.0	903	6.5	11,344	81.5	61,546	189.8	3,318	10.2	64,864	200.0
2008/09	25,352	182.2	528	3.8	25,880	186.0	3,814	27.4	118	0.8	3,932	28.3	29,166	195.7	646	4.3	29,812	200.0
2009/10	17,289	124.3	147	1.1	17,436	125.3	– –	– –	– –	– –	– –	– –	17,289	124.3	147	1.1	17,436	125.3
2010/11	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2011/12	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2012/13	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2013/14	7,628	54.8	311	2.2	7,939	57.1	9,663	69.4	399	2.9	10,062	72.3	17,291	124.3	710	5.1	18,001	129.4
2014/15	51,217	198.9	286	1.1	51,503	200.0	33,903	194.8	905	5.2	34,808	200.0	85,120	197.2	1,191	2.8	86,311	200.0
2015/16	61,712	197.7	713	2.3	62,425	200.0	58,131	196.9	911	3.1	59,042	200.0	119,843	197.3	1,624	2.7	121,467	200.0
2016/17	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2017/18	– –	– –	– –	– –	– –	– –	18,785	135.0	1,721	12.4	20,506	147.4	18,785	135.0	1,721	12.4	20,506	147.4
2018/19	– –	– –	– –	– –	– –	– –	28,338	186.6	2,036	13.4	30,374	200.0	28,338	186.6	2,036	13.4	30,374	200.0
2019/20	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2020/21	– –	– –	– –	– –	– –	– –	17,639	126.8	1,054	7.6	18,693	134.3	17,639	126.8	1,054	7.6	18,693	134.3
2021/22	– –	– –	– –	– –	– –	– –	19,214	138.1	1,008	7.2	20,222	145.3	19,214	138.1	1,008	7.2	20,222	145.3
2022/23	13,404	96.3	377	2.7	13,781	99.0	17,233	123.9	390	2.8	17,623	126.7	30,637	195.1	767	4.9	31,404	200.0

Table 13. Original and scaled (input) sample sizes for Tanner crab total catch size compositions in the snow crab ('SCF') and BBRKC ('RKF') fisheries. Observer information starts in 1990/91 in the snow crab and BBRKC fisheries. '–': no data due to prior aggregation or lack of sampling (e.g. the fishery was closed.

						SCF all EBS						RKF all EBS
		male		female		all sexes		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1990/91	14, 032	100.85	478	3.44	14, 510	104.28	1, 580	11.36	43	0.31	1, 623	11.66
1991/92	11, 708	84.14	686	4.93	12, 394	89.07	2, 273	16.34	89	0.64	2, 362	16.98
1992/93	6, 280	45.13	859	6.17	7, 139	51.31	2, 056	14.78	105	0.75	2, 161	15.53
1993/94	6, 969	50.09	1, 542	11.08	8, 511	61.17	7, 359	52.89	1, 196	8.60	8, 555	61.48
1994/95	2, 982	21.43	1, 523	10.95	4, 505	32.38	– –	– –	– –	– –	– –	– –
1995/96	1, 898	13.64	428	3.08	2, 326	16.72	– –	– –	– –	– –	– –	– –
1996/97	3, 265	23.47	662	4.76	3, 927	28.22	114	0.82	5	0.04	119	0.86
1997/98	3, 970	28.53	657	4.72	4, 627	33.25	1, 030	7.40	41	0.29	1, 071	7.70
1998/99	1, 911	13.73	324	2.33	2, 235	16.06	457	3.28	20	0.14	477	3.43
1999/00	976	7.01	82	0.59	1, 058	7.60	207	1.49	14	0.10	221	1.59
2000/01	1, 237	8.89	74	0.53	1, 311	9.42	845	6.07	44	0.32	889	6.39
2001/02	3, 113	22.37	160	1.15	3, 273	23.52	456	3.28	39	0.28	495	3.56
2002/03	982	7.06	118	0.85	1, 100	7.91	750	5.39	50	0.36	800	5.75
2003/04	688	4.94	152	1.09	840	6.04	555	3.99	46	0.33	601	4.32
2004/05	833	5.99	707	5.08	1, 540	11.07	487	3.50	44	0.32	531	3.82
2005/06	9, 807	70.48	368	2.64	10, 175	73.13	983	7.06	70	0.50	1, 053	7.57
2006/07	10, 391	74.68	1, 256	9.03	11, 647	83.71	746	5.36	68	0.49	814	5.85
2007/08	13, 797	99.16	728	5.23	14, 525	104.39	1, 360	9.77	89	0.64	1, 449	10.41
2008/09	8, 455	60.76	722	5.19	9, 177	65.95	3, 797	27.29	121	0.87	3, 918	28.16
2009/10	11, 057	79.46	474	3.41	11, 531	82.87	2, 871	20.63	70	0.50	2, 941	21.14
2010/11	12, 073	86.77	250	1.80	12, 323	88.56	582	4.18	28	0.20	610	4.38
2011/12	9, 453	67.94	189	1.36	9, 642	69.30	323	2.32	4	0.03	327	2.35
2012/13	11, 004	79.08	270	1.94	11, 274	81.02	618	4.44	48	0.34	666	4.79
2013/14	12, 935	92.96	356	2.56	13, 291	95.52	2, 110	15.16	60	0.43	2, 170	15.60
2014/15	24, 878	178.79	804	5.78	25, 682	184.57	3, 110	22.35	32	0.23	3, 142	22.58
2015/16	19, 839	142.58	230	1.65	20, 069	144.23	2, 175	15.63	186	1.34	2, 361	16.97
2016/17	16, 369	117.64	262	1.88	16, 631	119.52	3, 220	23.14	246	1.77	3, 466	24.91
2017/18	5, 598	40.23	109	0.78	5, 707	41.02	3, 782	27.18	86	0.62	3, 868	27.80
2018/19	6, 145	44.16	233	1.67	6, 378	45.84	1, 283	9.22	6	0.04	1, 289	9.26
2019/20	8, 881	63.83	423	3.04	9, 304	66.87	357	2.57	3	0.02	360	2.59
2020/21	820	5.89	10	0.07	830	5.97	106	0.76	4	0.03	110	0.79
2021/22	632	4.54	30	0.22	662	4.76	– –	– –	– –	– –	– –	– –

Table 14. Original and scaled (input) sample sizes for Tanner crab total catch size compositions in the groundfish fisheries. Observer information starts in 1973/74 in the groundfish fisheries, but is unclassified by gear type unitl 1991/92. '–': no data for respective gear type.

				fixed				trawl						all gear
		male		female		male		female		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1973/74	– –	– –	– –	– –	– –	– –	– –	– –	3,155	22.7	2,277	16.4	5,432	39.0
1974/75	– –	– –	– –	– –	– –	– –	– –	– –	2,492	17.9	1,600	11.5	4,092	29.4
1975/76	– –	– –	– –	– –	– –	– –	– –	– –	1,251	9.0	839	6.0	2,090	15.0
1976/77	– –	– –	– –	– –	– –	– –	– –	– –	6,950	49.9	6,683	48.0	13,633	98.0
1977/78	– –	– –	– –	– –	– –	– –	– –	– –	10,685	76.8	8,386	60.3	19,071	137.1
1978/79	– –	– –	– –	– –	– –	– –	– –	– –	18,596	115.3	13,665	84.7	32,261	200.0
1979/80	– –	– –	– –	– –	– –	– –	– –	– –	19,060	125.4	11,349	74.6	30,409	200.0
1980/81	– –	– –	– –	– –	– –	– –	– –	– –	12,806	92.0	5,917	42.5	18,723	134.6
1981/82	– –	– –	– –	– –	– –	– –	– –	– –	6,098	43.8	4,065	29.2	10,163	73.0
1982/83	– –	– –	– –	– –	– –	– –	– –	– –	13,439	96.6	8,006	57.5	21,445	154.1
1983/84	– –	– –	– –	– –	– –	– –	– –	– –	18,363	132.0	8,305	59.7	26,668	191.7
1984/85	– –	– –	– –	– –	– –	– –	– –	– –	27,403	133.1	13,771	66.9	41,174	200.0
1985/86	– –	– –	– –	– –	– –	– –	– –	– –	23,128	129.0	12,728	71.0	35,856	200.0
1986/87	– –	– –	– –	– –	– –	– –	– –	– –	14,860	106.8	7,626	54.8	22,486	161.6
1987/88	– –	– –	– –	– –	– –	– –	– –	– –	23,508	119.4	15,857	80.6	39,365	200.0
1988/89	– –	– –	– –	– –	– –	– –	– –	– –	10,586	76.1	7,126	51.2	17,712	127.3
1989/90	– –	– –	– –	– –	– –	– –	– –	– –	59,943	118.5	41,234	81.5	101,177	200.0
1990/91	– –	– –	– –	– –	– –	– –	– –	– –	23,545	135.5	11,212	64.5	34,757	200.0
1991/92	1,116	8.0	290	2.1	5,701	41.0	3,189	22.9	– –	– –	– –	– –	10,296	74.0
1992/93	601	4.3	39	0.3	2,527	18.2	1,136	8.2	– –	– –	– –	– –	4,303	30.9
1993/94	683	4.9	25	0.2	534	3.8	333	2.4	– –	– –	– –	– –	1,575	11.3
1994/95	1,133	8.1	126	0.9	2,495	17.9	1,694	12.2	– –	– –	– –	– –	5,448	39.2
1995/96	162	1.2	44	0.3	3,742	26.9	2,625	18.9	– –	– –	– –	– –	6,573	47.2
1996/97	2,442	17.6	439	3.2	5,864	42.1	2,961	21.3	– –	– –	– –	– –	11,706	84.1
1997/98	1,650	11.9	217	1.6	8,299	59.6	3,683	26.5	– –	– –	– –	– –	13,849	99.5
1998/99	3,870	27.8	627	4.5	8,235	59.2	3,813	27.4	– –	– –	– –	– –	16,545	118.9
1999/00	3,553	25.5	719	5.2	7,500	53.9	3,803	27.3	– –	– –	– –	– –	15,575	111.9
2000/01	5,144	37.0	227	1.6	7,751	55.7	2,860	20.6	– –	– –	– –	– –	15,982	114.9
2001/02	6,950	49.9	303	2.2	8,838	63.5	2,780	20.0	– –	– –	– –	– –	18,871	135.6
2002/03	8,571	61.6	831	6.0	6,830	49.1	2,418	17.4	– –	– –	– –	– –	18,650	134.0
2003/04	4,589	33.0	923	6.6	4,983	35.8	1,810	13.0	– –	– –	– –	– –	12,305	88.4
2004/05	5,413	38.9	560	4.0	8,431	60.6	3,900	28.0	– –	– –	– –	– –	18,304	131.5
2005/06	8,816	63.4	389	2.8	8,969	64.5	3,320	23.9	– –	– –	– –	– –	21,494	154.5
2006/07	9,270	66.6	824	5.9	6,633	47.7	2,223	16.0	– –	– –	– –	– –	18,950	136.2
2007/08	7,235	52.0	1,175	8.4	8,913	64.1	2,644	19.0	– –	– –	– –	– –	19,967	143.5
2008/09	15,832	104.1	1,770	11.6	10,339	68.0	2,465	16.2	– –	– –	– –	– –	30,406	200.0
2009/10	12,916	92.8	688	4.9	6,127	44.0	2,013	14.5	– –	– –	– –	– –	21,744	156.3
2010/11	11,264	81.0	956	6.9	4,402	31.6	1,648	11.8	– –	– –	– –	– –	18,270	131.3
2011/12	8,709	62.6	386	2.8	7,650	55.0	3,877	27.9	– –	– –	– –	– –	20,622	148.2
2012/13	9,192	66.1	836	6.0	3,994	28.7	2,267	16.3	– –	– –	– –	– –	16,289	117.1
2013/14	22,471	128.4	3,489	19.9	6,437	36.8	2,592	14.8	– –	– –	– –	– –	34,989	200.0
2014/15	33,529	154.0	2,061	9.5	5,747	26.4	2,201	10.1	– –	– –	– –	– –	43,538	200.0

(continued)

				fixed				trawl						all gear
		male		female		male		female		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
2015/16	24, 488	146.3	5, 152	30.8	3, 215	19.2	629	3.8	– –	– –	– –	– –	33, 484	200.0
2016/17	14, 811	106.4	1, 206	8.7	3, 920	28.2	3, 224	23.2	– –	– –	– –	– –	23, 161	166.5
2017/18	11, 546	83.0	1, 264	9.1	2, 035	14.6	477	3.4	– –	– –	– –	– –	15, 322	110.1
2018/19	4, 130	29.7	198	1.4	3, 065	22.0	1, 129	8.1	– –	– –	– –	– –	8, 522	61.2
2019/20	2, 573	18.5	140	1.0	5, 363	38.5	2, 457	17.7	– –	– –	– –	– –	10, 533	75.7
2020/21	2, 267	16.3	418	3.0	6, 401	46.0	2, 561	18.4	– –	– –	– –	– –	11, 647	83.7
2021/22	3, 427	24.6	460	3.3	5, 244	37.7	1, 801	12.9	– –	– –	– –	– –	10, 932	78.6
2022/23	3, 708	26.6	402	2.9	4, 427	31.8	1, 419	10.2	– –	– –	– –	– –	9, 956	71.6

Table 15. Annual effort (potlifts) in the crab fisheries. "TCF": Tanner crab fishery; "SCF": snow crab fishery; "RKF": BBRKC fishery.

year	East 166W	West 166W	TCF all EBS	SCF all EBS	RKF all EBS
1953	–	–	–	–	30,083
1954	–	–	–	–	17,122
1955	–	–	–	–	28,045
1956	–	–	–	–	41,629
1957	–	–	–	–	23,659
1958	–	–	–	–	27,932
1959	–	–	–	–	22,187
1960	–	–	–	–	26,347
1961	–	–	–	–	72,646
1962	–	–	–	–	123,643
1963	–	–	–	–	181,799
1964	–	–	–	–	180,809
1965	–	–	–	–	127,973
1966	–	–	–	–	129,306
1967	–	–	–	–	135,283
1968	–	–	–	–	184,666
1969	–	–	–	–	175,374
1970	–	–	–	–	168,059
1971	–	–	–	–	126,305
1972	–	–	–	–	208,469
1973	–	–	–	–	194,095
1974	–	–	–	–	212,915
1975	–	–	–	–	205,096
1976	–	–	–	–	321,010
1977	–	–	–	–	451,273
1978	–	–	–	190,746	406,165
1979	–	–	–	255,102	315,226
1980	–	–	–	435,742	567,292
1981	–	–	–	469,091	536,646
1982	–	–	–	287,127	140,492

(continued)

year	East 166W	West 166W	TCF all EBS	SCF all EBS	RKF all EBS
1983	–	–	–	173,591	0
1984	–	–	–	370,082	107,406
1985	–	–	–	542,346	84,443
1986	–	–	–	616,113	175,753
1987	–	–	–	747,395	220,971
1988	–	–	–	665,242	146,179
1989	–	–	–	912,718	205,528
1990	493,820	479	494,299	1,382,908	262,761
1991	360,864	140,050	500,914	1,278,502	227,555
1992	508,922	166,670	675,592	969,209	206,815
1993	286,620	40,100	326,720	716,524	254,389
1994	228,254	21,282	249,536	507,603	697
1995	201,988	46,454	248,442	520,685	547
1996	64,989	8,533	73,522	754,140	77,081
1997	0	0	0	930,794	91,085
1998	0	0	0	945,533	145,689
1999	0	0	0	182,634	151,212
2000	0	0	0	191,200	104,056
2001	0	0	0	326,977	66,947
2002	0	0	0	153,862	72,514
2003	0	0	0	123,709	134,515
2004	0	0	0	75,095	97,621
2005	0	6,346	6,346	117,375	116,320
2006	15,273	4,517	19,790	86,328	72,404
2007	26,441	7,268	33,709	140,857	113,948
2008	19,401	2,336	21,737	163,537	139,937
2009	6,635	0	6,635	137,292	119,261
2010	0	0	0	147,478	132,183
2011	0	0	0	270,602	45,784
2012	0	0	0	225,627	38,842
2013	16,613	23,062	39,675	225,245	46,589

(continued)

year	East 166W	West 166W	TCF all EBS	SCF all EBS	RKF all EBS
2014	72,768	68,695	141,463	279,183	57,725
2015	130,302	84,933	215,235	202,526	48,763
2016	0	0	0	118,548	33,608
2017	11	19,284	19,295	114,673	49,169
2018	0	29,833	29,833	119,484	31,975
2019	0	0	0	188,958	35,033
2020	0	34,914	34,914	171,678	21,346
2021	0	19,252	19,252	36,878	294
2022	19,434	18,130	37,564	0	242

Table 16. Design-based survey biomass trends (estimates and cv's) from the NMFS EBS shelf bottom trawl survey, by sex, maturity state, and management area. Biomass units are metric tons. The survey was not conducted in 2020.

						male all maturity						immature						female mature
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	214,201	0.42	80,684	0.34	294,884	0.32	9,287	0.25	262	0.51	9,549	0.24	18,306	0.19	13,112	0.39	31,418	0.20
1976	101,952	0.18	55,066	0.20	157,018	0.14	4,448	0.26	1,920	0.57	6,368	0.25	20,967	0.20	10,189	0.42	31,157	0.19
1977	87,462	0.13	51,036	0.24	138,499	0.12	1,133	0.23	13,338	0.65	14,471	0.60	30,302	0.38	8,272	0.36	38,573	0.31
1978	72,913	0.15	25,392	0.18	98,305	0.12	714	0.29	6,099	0.27	6,814	0.24	17,691	0.31	8,062	0.26	25,753	0.23
1979	17,978	0.17	33,439	0.24	51,417	0.17	591	0.49	2,066	0.34	2,657	0.29	2,858	0.36	7,592	0.43	10,450	0.33
1980	48,978	0.31	103,501	0.18	152,479	0.16	1,320	0.26	12,190	0.25	13,510	0.23	11,562	0.38	52,221	0.33	63,783	0.28
1981	23,387	0.19	56,537	0.16	79,924	0.13	890	0.31	631	0.25	1,521	0.21	7,684	0.28	34,893	0.30	42,577	0.25
1982	16,600	0.16	49,252	0.18	65,852	0.14	1,309	0.34	406	0.27	1,715	0.27	6,797	0.26	57,347	0.29	64,143	0.26
1983	13,325	0.21	24,659	0.20	37,984	0.15	902	0.30	1,368	0.34	2,270	0.24	4,438	0.27	15,993	0.22	20,430	0.18
1984	12,019	0.19	18,483	0.17	30,503	0.13	670	0.46	1,563	0.23	2,233	0.21	4,129	0.44	10,785	0.26	14,914	0.22
1985	8,229	0.21	6,671	0.16	14,901	0.13	323	0.30	671	0.22	994	0.18	2,836	0.42	2,718	0.31	5,554	0.26
1986	9,611	0.22	11,983	0.36	21,594	0.22	1,486	0.21	1,207	0.28	2,693	0.17	2,006	0.25	1,360	0.31	3,366	0.20
1987	28,860	0.20	16,639	0.16	45,499	0.14	11,909	0.36	3,085	0.20	14,995	0.29	3,097	0.23	2,042	0.21	5,139	0.16
1988	58,124	0.31	41,083	0.24	99,207	0.21	3,697	0.22	6,475	0.24	10,172	0.17	19,182	0.30	6,184	0.26	25,366	0.23
1989	87,700	0.16	45,100	0.18	132,800	0.12	6,652	0.28	5,157	0.23	11,809	0.19	12,309	0.20	7,090	0.23	19,399	0.15
1990	76,879	0.14	55,538	0.23	132,417	0.13	5,990	0.28	3,869	0.20	9,859	0.19	19,032	0.24	18,663	0.48	37,694	0.27
1991	89,814	0.26	55,976	0.15	145,790	0.17	3,626	0.24	3,384	0.25	7,010	0.17	27,708	0.33	17,056	0.22	44,764	0.22
1992	89,918	0.32	37,665	0.18	127,582	0.23	345	0.29	1,636	0.19	1,981	0.17	11,013	0.22	15,213	0.23	26,226	0.16
1993	53,394	0.19	19,873	0.15	73,266	0.14	153	0.35	908	0.21	1,061	0.19	5,171	0.21	6,470	0.20	11,641	0.14
1994	32,303	0.16	16,029	0.14	48,332	0.12	65	0.33	1,135	0.34	1,199	0.33	5,268	0.30	4,579	0.28	9,846	0.21
1995	19,672	0.22	15,304	0.24	34,976	0.16	249	0.25	802	0.19	1,052	0.16	5,732	0.31	6,667	0.31	12,398	0.22
1996	19,979	0.28	10,785	0.31	30,764	0.21	1,013	0.28	416	0.21	1,430	0.21	5,533	0.36	4,047	0.45	9,580	0.28
1997	9,078	0.16	5,556	0.14	14,634	0.11	956	0.37	434	0.23	1,389	0.27	1,947	0.22	1,451	0.31	3,397	0.18
1998	8,403	0.13	6,600	0.16	15,003	0.10	550	0.21	1,407	0.25	1,957	0.19	1,202	0.21	1,076	0.24	2,278	0.16
1999	14,833	0.36	6,695	0.23	21,529	0.26	1,087	0.39	1,762	0.20	2,848	0.19	2,272	0.33	1,554	0.21	3,826	0.22
2000	16,427	0.27	6,898	0.14	23,325	0.20	728	0.30	1,745	0.18	2,473	0.15	2,885	0.39	1,246	0.25	4,131	0.28
2001	16,203	0.19	13,042	0.17	29,245	0.13	2,594	0.43	3,671	0.18	6,266	0.21	1,314	0.24	3,247	0.30	4,562	0.23
2002	14,401	0.20	13,006	0.17	27,407	0.13	1,768	0.28	3,724	0.20	5,492	0.16	1,701	0.33	2,766	0.25	4,468	0.20
2003	17,161	0.20	20,637	0.17	37,798	0.13	704	0.24	3,954	0.28	4,658	0.24	2,090	0.23	6,313	0.24	8,403	0.19
2004	12,454	0.22	26,417	0.17	38,871	0.14	267	0.38	3,812	0.15	4,079	0.15	863	0.20	3,865	0.21	4,729	0.17
2005	17,442	0.19	46,300	0.14	63,743	0.12	1,672	0.39	8,698	0.22	10,370	0.20	2,820	0.37	8,759	0.22	11,579	0.19
2006	28,635	0.34	72,894	0.17	101,529	0.15	2,450	0.50	10,789	0.25	13,238	0.22	4,025	0.29	10,914	0.21	14,939	0.17
2007	27,938	0.28	76,245	0.22	104,183	0.18	696	0.33	4,885	0.26	5,581	0.23	5,916	0.38	7,521	0.16	13,436	0.19
2008	37,176	0.50	47,720	0.22	84,897	0.25	621	0.52	2,220	0.22	2,841	0.21	4,457	0.31	7,206	0.23	11,663	0.18
2009	14,778	0.23	32,627	0.17	47,405	0.14	524	0.34	2,014	0.33	2,538	0.27	4,021	0.39	4,456	0.18	8,477	0.21
2010	14,420	0.21	34,575	0.22	48,996	0.17	789	0.31	2,986	0.19	3,775	0.16	2,115	0.42	3,358	0.24	5,473	0.22
2011	23,382	0.21	39,282	0.24	62,664	0.17	4,384	0.37	5,960	0.19	10,344	0.19	2,225	0.27	3,189	0.16	5,414	0.14
2012	45,365	0.28	34,747	0.13	80,112	0.17	5,692	0.45	5,959	0.19	11,651	0.24	8,550	0.31	3,805	0.18	12,355	0.22
2013	64,573	0.32	38,798	0.18	103,371	0.21	2,337	0.37	4,036	0.19	6,373	0.18	11,054	0.33	6,795	0.18	17,849	0.21
2014	58,196	0.14	50,711	0.14	108,906	0.10	489	0.20	1,964	0.25	2,453	0.21	8,159	0.47	6,705	0.27	14,864	0.29
2015	35,090	0.12	39,143	0.13	74,233	0.09	625	0.30	1,020	0.21	1,646	0.17	4,675	0.34	6,536	0.35	11,211	0.25
2016	25,813	0.15	43,812	0.12	69,625	0.09	50	0.33	1,068	0.22	1,118	0.22	1,450	0.30	6,176	0.31	7,625	0.26
2017	24,217	0.17	29,985	0.14	54,201	0.11	160	0.39	1,221	0.20	1,381	0.19	2,015	0.20	5,098	0.31	7,113	0.23

(continued)

					male												female	
					all maturity						immature						mature	
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2018	13,931	0.13	33,152	0.12	47,083	0.10	1,010	0.25	4,005	0.20	5,015	0.17	607	0.23	4,360	0.23	4,967	0.20
2019	10,931	0.26	17,742	0.10	28,673	0.12	1,513	0.33	3,406	0.19	4,919	0.16	662	0.34	4,184	0.25	4,846	0.22
2020	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
2021	12,900	0.18	18,664	0.14	31,564	0.11	1,083	0.28	2,259	0.15	3,342	0.13	2,858	0.22	5,697	0.20	8,554	0.15
2022	14,940	0.18	14,692	0.13	29,633	0.11	698	0.38	1,996	0.24	2,694	0.20	1,827	0.23	4,842	0.27	6,669	0.20
2023	10,470	0.14	24,046	0.10	34,516	0.08	1,042	0.26	8,221	0.18	9,264	0.17	1,629	0.23	5,697	0.28	7,326	0.23

Table 17. Design-based survey abundance trends (estimates and cv's) from the NMFS EBS shelf bottom trawl survey, by sex, maturity state, and management area. Abundance units are millions of crab. The survey was not conducted in 2020.

						male												female
						all maturity						immature						mature
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	398.59	0.25	136.77	0.27	535.37	0.20	93.91	0.26	4.42	0.45	98.33	0.25	85.53	0.18	68.15	0.35	153.68	0.19
1976	228.63	0.15	143.94	0.29	372.57	0.15	68.77	0.38	67.91	0.55	136.68	0.33	94.28	0.20	58.43	0.40	152.71	0.20
1977	162.87	0.13	217.39	0.36	380.26	0.21	14.44	0.21	258.87	0.63	273.31	0.60	142.44	0.39	49.67	0.38	192.11	0.31
1978	124.72	0.14	166.20	0.19	290.92	0.12	9.32	0.25	142.71	0.29	152.02	0.27	83.00	0.33	53.78	0.28	136.78	0.23
1979	32.79	0.19	138.74	0.34	171.53	0.28	7.67	0.49	30.10	0.36	37.77	0.31	13.04	0.37	48.46	0.44	61.51	0.36
1980	90.26	0.29	554.36	0.19	644.62	0.17	15.42	0.25	154.88	0.25	170.30	0.23	50.51	0.38	380.36	0.35	430.88	0.31
1981	54.16	0.20	211.98	0.18	266.14	0.15	15.08	0.37	9.95	0.22	25.03	0.24	35.15	0.30	268.67	0.32	303.82	0.29
1982	43.53	0.15	144.58	0.18	188.11	0.14	13.76	0.25	14.29	0.23	28.05	0.17	31.09	0.27	433.08	0.31	464.17	0.29
1983	50.24	0.19	127.07	0.23	177.31	0.18	27.31	0.28	80.05	0.35	107.36	0.27	18.30	0.28	109.91	0.22	128.21	0.20
1984	40.24	0.33	90.50	0.14	130.74	0.14	19.32	0.57	56.00	0.19	75.32	0.20	16.33	0.41	70.10	0.27	86.43	0.23
1985	20.05	0.16	35.39	0.15	55.44	0.11	5.17	0.22	19.69	0.21	24.87	0.17	10.77	0.38	18.57	0.34	29.34	0.26
1986	53.63	0.16	61.88	0.26	115.50	0.16	34.08	0.21	23.34	0.25	57.42	0.16	8.65	0.23	8.29	0.28	16.94	0.18
1987	150.92	0.24	104.10	0.12	255.02	0.15	122.49	0.35	71.88	0.15	194.37	0.23	13.42	0.21	12.93	0.21	26.35	0.15
1988	185.58	0.19	234.95	0.21	420.53	0.14	54.49	0.20	127.51	0.23	182.00	0.18	84.40	0.29	38.13	0.25	122.53	0.21
1989	328.22	0.19	204.64	0.19	532.86	0.14	179.37	0.33	99.72	0.21	279.08	0.23	57.76	0.20	43.30	0.23	101.06	0.15
1990	235.20	0.15	195.37	0.15	430.56	0.10	98.52	0.27	74.95	0.18	173.48	0.18	101.55	0.24	107.46	0.43	209.01	0.25
1991	209.64	0.21	224.87	0.16	434.51	0.13	39.32	0.23	82.31	0.31	121.63	0.22	145.92	0.36	109.17	0.23	255.09	0.23
1992	160.01	0.31	141.90	0.13	301.91	0.17	4.97	0.30	46.16	0.20	51.13	0.18	53.88	0.22	97.02	0.23	150.90	0.17
1993	93.72	0.18	79.93	0.13	173.65	0.11	2.90	0.34	24.87	0.21	27.77	0.19	24.87	0.22	42.60	0.20	67.47	0.15
1994	51.96	0.16	65.93	0.14	117.89	0.10	2.67	0.33	33.60	0.37	36.27	0.34	27.00	0.32	29.16	0.27	56.16	0.21
1995	34.55	0.19	51.84	0.16	86.39	0.12	5.46	0.27	19.09	0.22	24.55	0.18	30.24	0.31	43.08	0.31	73.32	0.22
1996	51.02	0.20	37.00	0.19	88.03	0.14	17.73	0.26	12.58	0.21	30.31	0.18	28.92	0.36	26.19	0.43	55.11	0.28
1997	41.37	0.27	30.04	0.13	71.40	0.17	31.89	0.45	20.09	0.21	51.98	0.29	11.14	0.24	8.96	0.31	20.10	0.19
1998	32.57	0.14	54.94	0.17	87.51	0.12	13.39	0.22	42.86	0.22	56.25	0.17	6.74	0.22	6.56	0.24	13.30	0.16
1999	59.89	0.37	81.10	0.19	141.00	0.19	20.75	0.31	70.89	0.21	91.65	0.17	12.62	0.31	10.06	0.20	22.68	0.20
2000	49.05	0.21	75.44	0.17	124.49	0.13	16.27	0.35	54.31	0.18	70.59	0.16	14.97	0.38	7.29	0.25	22.26	0.27
2001	124.71	0.32	141.06	0.16	265.78	0.17	106.49	0.37	108.33	0.17	214.83	0.20	7.13	0.23	21.04	0.28	28.16	0.22
2002	58.90	0.22	136.65	0.20	195.55	0.15	36.36	0.27	109.08	0.24	145.43	0.19	10.76	0.38	19.10	0.29	29.87	0.23
2003	56.03	0.19	179.53	0.19	235.56	0.15	13.21	0.23	113.88	0.25	127.09	0.23	11.97	0.24	48.53	0.28	60.49	0.23
2004	30.39	0.18	219.98	0.11	250.37	0.10	8.38	0.50	153.86	0.13	162.24	0.13	4.53	0.23	27.68	0.25	32.21	0.22
2005	59.04	0.20	286.68	0.15	345.72	0.13	39.05	0.43	212.35	0.22	251.40	0.20	16.10	0.38	60.65	0.23	76.75	0.20
2006	103.52	0.38	355.13	0.14	458.66	0.14	28.83	0.39	172.38	0.19	201.21	0.18	21.91	0.28	76.44	0.21	98.34	0.17
2007	76.79	0.27	345.73	0.18	422.52	0.16	11.45	0.30	96.72	0.21	108.17	0.19	30.54	0.35	51.46	0.16	82.00	0.17
2008	79.61	0.41	166.84	0.15	246.45	0.17	8.74	0.34	47.62	0.21	56.36	0.18	24.65	0.31	48.63	0.23	73.28	0.19
2009	45.63	0.21	131.95	0.15	177.58	0.12	21.11	0.40	63.43	0.25	84.53	0.21	22.10	0.39	29.22	0.17	51.32	0.19
2010	51.73	0.20	149.43	0.14	201.16	0.11	27.59	0.35	84.27	0.17	111.86	0.16	10.60	0.41	21.92	0.23	32.51	0.21
2011	148.75	0.27	216.69	0.15	365.43	0.14	86.81	0.32	145.81	0.19	232.62	0.17	12.18	0.26	20.30	0.15	32.48	0.14
2012	189.77	0.34	244.69	0.16	434.45	0.17	64.98	0.42	113.49	0.18	178.48	0.19	52.40	0.35	25.62	0.18	78.02	0.24
2013	176.80	0.30	209.10	0.14	385.90	0.16	30.47	0.32	85.37	0.17	115.84	0.15	60.82	0.36	47.96	0.18	108.77	0.21
2014	137.61	0.13	198.85	0.17	336.46	0.11	14.94	0.25	73.20	0.29	88.14	0.24	44.74	0.48	43.62	0.28	88.36	0.28
2015	79.06	0.12	119.86	0.11	198.93	0.08	13.69	0.25	30.76	0.18	44.45	0.15	27.61	0.35	45.43	0.38	73.04	0.27
2016	53.97	0.18	133.88	0.12	187.85	0.10	1.25	0.32	37.62	0.24	38.87	0.23	7.71	0.31	42.58	0.33	50.29	0.28
2017	49.93	0.17	122.77	0.13	172.70	0.10	4.73	0.32	78.81	0.24	83.55	0.23	10.17	0.20	35.57	0.31	45.75	0.24

(continued)

					male												female	
					all maturity						immature						mature	
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2018	54.89	0.17	205.36	0.15	260.25	0.12	32.97	0.25	158.21	0.20	191.18	0.17	3.46	0.24	30.33	0.22	33.80	0.20
2019	46.68	0.27	154.60	0.15	201.28	0.13	30.16	0.34	140.17	0.21	170.32	0.19	3.74	0.34	32.95	0.27	36.69	0.24
2020	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —
2021	58.08	0.19	144.08	0.18	202.16	0.14	21.61	0.38	81.50	0.28	103.10	0.24	14.79	0.22	39.48	0.22	54.27	0.17
2022	70.43	0.26	124.86	0.21	195.29	0.16	35.21	0.47	81.03	0.23	116.24	0.22	9.60	0.24	33.24	0.29	42.84	0.23
2023	51.66	0.18	311.78	0.13	363.44	0.11	35.90	0.28	282.13	0.15	318.03	0.14	8.62	0.23	39.89	0.27	48.50	0.23

Table 18. Design-based survey biomass trends (estimates and cv's) from the NMFS EBS shelf bottom trawl survey for industry-preferred males by management area. Biomass units are metric tons. The survey was not conducted in 2020.

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	152,683	0.55	6,522	0.40	159,205	0.53	56,181	0.42	2,509	0.33	58,691	0.41	208,864	0.42	9,032	0.30	217,896	0.40
1976	57,463	0.23	9,245	0.47	66,709	0.24	38,231	0.24	1,409	0.36	39,640	0.24	95,695	0.17	10,654	0.41	106,349	0.17
1977	50,855	0.16	7,543	0.24	58,399	0.16	26,511	0.36	6,808	0.30	33,319	0.30	77,366	0.16	14,351	0.19	91,717	0.15
1978	40,761	0.18	9,652	0.21	50,413	0.16	3,221	0.26	6,626	0.32	9,847	0.27	43,981	0.17	16,278	0.18	60,259	0.14
1979	9,816	0.23	3,377	0.26	13,192	0.19	4,456	0.26	5,280	0.38	9,736	0.26	14,272	0.18	8,657	0.25	22,929	0.15
1980	23,184	0.41	10,857	0.53	34,041	0.33	11,210	0.31	1,677	0.69	12,887	0.31	34,394	0.30	12,534	0.47	46,927	0.25
1981	3,445	0.33	11,286	0.27	14,731	0.22	5,884	0.27	2,167	0.38	8,050	0.24	9,329	0.21	13,452	0.23	22,781	0.17
1982	3,009	0.22	4,851	0.23	7,860	0.18	5,775	0.38	5,847	0.25	11,622	0.23	8,783	0.26	10,698	0.17	19,481	0.16
1983	5,151	0.31	2,082	0.29	7,233	0.25	2,429	0.29	3,226	0.26	5,655	0.21	7,580	0.23	5,309	0.19	12,889	0.17
1984	4,348	0.24	3,077	0.40	7,424	0.23	571	0.37	3,159	0.24	3,730	0.22	4,919	0.22	6,236	0.23	11,154	0.17
1985	4,055	0.28	1,046	0.32	5,101	0.26	588	0.34	870	0.29	1,458	0.22	4,642	0.25	1,917	0.22	6,559	0.21
1986	734	0.36	2,546	0.52	3,280	0.43	142	0.41	674	0.33	816	0.30	876	0.31	3,219	0.42	4,096	0.35
1987	4,911	0.23	3,473	0.37	8,385	0.24	3,505	0.41	658	0.27	4,163	0.35	8,416	0.22	4,132	0.32	12,548	0.20
1988	15,698	0.67	2,715	0.25	18,413	0.58	9,690	0.40	929	0.31	10,618	0.37	25,387	0.44	3,644	0.20	29,031	0.39
1989	37,386	0.21	3,718	0.39	41,104	0.19	13,758	0.34	2,741	0.36	16,499	0.29	51,144	0.18	6,459	0.27	57,603	0.16
1990	35,903	0.22	7,084	0.21	42,987	0.19	21,082	0.37	3,274	0.30	24,356	0.33	56,985	0.19	10,358	0.17	67,343	0.17
1991	32,973	0.42	14,476	0.25	47,449	0.30	13,386	0.29	8,430	0.20	21,816	0.21	46,359	0.31	22,906	0.17	69,265	0.22
1992	41,423	0.44	16,242	0.40	57,665	0.33	9,893	0.50	6,418	0.28	16,311	0.32	51,316	0.37	22,660	0.30	73,977	0.27
1993	22,942	0.28	11,990	0.26	34,932	0.20	3,716	0.35	2,596	0.29	6,312	0.26	26,658	0.24	14,586	0.22	41,244	0.17
1994	10,000	0.22	13,912	0.26	23,912	0.18	1,248	0.45	4,143	0.22	5,391	0.21	11,248	0.20	18,054	0.21	29,303	0.15
1995	1,380	0.25	13,377	0.28	14,757	0.26	370	0.41	5,392	0.34	5,761	0.33	1,749	0.22	18,769	0.22	20,518	0.21
1996	330	0.35	13,912	0.35	14,242	0.35	100	0.42	3,580	0.48	3,680	0.47	430	0.29	17,492	0.30	17,922	0.29
1997	316	0.33	4,245	0.22	4,561	0.20	179	0.36	942	0.26	1,121	0.23	495	0.25	5,187	0.18	5,681	0.17
1998	1,001	0.28	2,604	0.19	3,605	0.16	441	0.35	644	0.20	1,085	0.21	1,442	0.22	3,247	0.16	4,689	0.13
1999	1,645	0.39	1,838	0.35	3,483	0.25	256	0.32	356	0.31	612	0.24	1,902	0.34	2,194	0.30	4,095	0.22
2000	4,484	0.52	3,045	0.41	7,529	0.35	250	0.35	377	0.29	627	0.24	4,734	0.49	3,422	0.36	8,156	0.33
2001	4,473	0.35	3,600	0.21	8,073	0.25	418	0.27	1,361	0.37	1,780	0.32	4,892	0.32	4,961	0.18	9,853	0.21
2002	944	0.40	7,102	0.28	8,046	0.25	384	0.42	838	0.25	1,222	0.25	1,328	0.31	7,940	0.25	9,268	0.22
2003	1,558	0.32	6,433	0.33	7,991	0.28	434	0.31	2,227	0.35	2,661	0.31	1,992	0.26	8,660	0.26	10,652	0.22
2004	1,597	0.26	4,916	0.50	6,513	0.38	980	0.26	1,825	0.29	2,805	0.22	2,577	0.19	6,741	0.37	9,318	0.27
2005	2,368	0.22	5,822	0.36	8,190	0.27	8,776	0.33	5,062	0.30	13,839	0.26	11,145	0.27	10,884	0.24	22,029	0.19
2006	2,134	0.34	6,794	0.28	8,927	0.24	3,768	0.37	15,315	0.48	19,083	0.42	5,902	0.26	22,109	0.34	28,011	0.30
2007	4,143	0.61	5,314	0.26	9,457	0.30	8,523	0.84	7,757	0.35	16,281	0.48	12,666	0.60	13,071	0.23	25,737	0.32
2008	15,476	0.78	3,288	0.27	18,764	0.65	8,731	0.56	4,414	0.28	13,145	0.40	24,206	0.54	7,702	0.20	31,909	0.42
2009	2,644	0.26	5,139	0.36	7,783	0.29	6,670	0.29	4,143	0.20	10,812	0.21	9,313	0.22	9,282	0.22	18,595	0.17
2010	3,006	0.49	4,576	0.30	7,582	0.29	9,593	0.47	4,867	0.21	14,460	0.35	12,599	0.38	9,443	0.18	22,042	0.25
2011	1,513	0.25	6,987	0.36	8,500	0.32	9,023	0.74	6,637	0.21	15,660	0.44	10,536	0.64	13,624	0.21	24,160	0.31
2012	3,352	0.49	5,026	0.24	8,378	0.25	2,368	0.32	3,997	0.19	6,365	0.19	5,720	0.32	9,023	0.16	14,743	0.16
2013	10,871	0.29	3,527	0.22	14,397	0.23	5,383	0.43	2,837	0.22	8,220	0.29	16,254	0.24	6,364	0.16	22,618	0.18
2014	14,899	0.26	9,310	0.19	24,210	0.19	7,163	0.17	4,604	0.21	11,766	0.14	22,062	0.19	13,914	0.15	35,976	0.13
2015	9,084	0.22	10,217	0.24	19,301	0.15	8,380	0.27	5,925	0.21	14,306	0.18	17,464	0.17	16,143	0.17	33,607	0.12
2016	2,666	0.17	8,137	0.18	10,803	0.14	5,855	0.18	12,649	0.18	18,504	0.14	8,521	0.14	20,786	0.13	29,308	0.10
2017	1,646	0.74	10,947	0.17	12,593	0.18	904	0.21	11,777	0.24	12,681	0.23	2,550	0.49	22,724	0.15	25,274	0.15
2018	103	0.44	7,324	0.16	7,427	0.16	1,007	0.19	11,993	0.19	13,000	0.18	1,110	0.18	19,318	0.13	20,427	0.13

(continued)

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2019	318	0.36	4,502	0.21	4,821	0.21	204	0.32	4,844	0.16	5,048	0.16	522	0.25	9,347	0.13	9,869	0.13
2020	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
2021	1,462	0.32	965	0.29	2,427	0.23	420	0.33	1,608	0.22	2,028	0.19	1,883	0.26	2,573	0.18	4,455	0.15
2022	3,803	0.28	924	0.30	4,727	0.23	757	0.26	835	0.21	1,592	0.17	4,560	0.24	1,759	0.19	6,319	0.18
2023	2,514	0.24	1,103	0.24	3,617	0.19	1,166	0.24	1,235	0.23	2,401	0.17	3,680	0.18	2,339	0.17	6,018	0.13

Table 19. Design-based survey abundance trends (estimates and cv's) from the NMFS EBS shelf bottom trawl survey for industry-preferred males by management area. Abundance units are millions of crab. The survey was not conducted in 2020.

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	156.363	0.52	7.320	0.40	163.683	0.50	66.706	0.42	3.129	0.33	69.835	0.40	223.068	0.39	10.450	0.29	233.518	0.37
1976	64.022	0.21	9.945	0.45	73.967	0.22	42.219	0.23	1.643	0.35	43.862	0.23	106.241	0.16	11.588	0.39	117.829	0.16
1977	55.271	0.15	8.487	0.23	63.759	0.15	26.617	0.30	7.258	0.29	33.875	0.26	81.888	0.14	15.745	0.18	97.633	0.13
1978	44.641	0.18	11.539	0.21	56.180	0.15	3.591	0.27	7.183	0.32	10.774	0.28	48.233	0.16	18.722	0.18	66.955	0.14
1979	11.155	0.22	4.001	0.24	15.156	0.19	5.997	0.27	6.398	0.36	12.394	0.25	17.152	0.17	10.398	0.24	27.550	0.15
1980	24.363	0.39	13.118	0.52	37.481	0.32	14.802	0.30	1.916	0.65	16.718	0.30	39.165	0.27	15.034	0.46	54.199	0.24
1981	4.026	0.34	14.097	0.26	18.123	0.22	7.784	0.26	2.903	0.38	10.688	0.23	11.811	0.21	17.000	0.22	28.811	0.16
1982	3.492	0.21	6.377	0.24	9.869	0.19	8.085	0.37	8.190	0.25	16.275	0.23	11.577	0.27	14.567	0.18	26.144	0.16
1983	6.917	0.31	2.732	0.28	9.649	0.25	3.375	0.29	4.685	0.27	8.061	0.21	10.292	0.23	7.418	0.20	17.710	0.17
1984	4.898	0.23	3.946	0.39	8.845	0.23	0.820	0.37	4.520	0.25	5.340	0.22	5.719	0.21	8.466	0.23	14.185	0.17
1985	4.413	0.27	1.381	0.31	5.795	0.25	0.784	0.35	1.283	0.28	2.067	0.22	5.197	0.24	2.664	0.21	7.861	0.19
1986	0.981	0.38	2.742	0.47	3.723	0.38	0.213	0.40	0.870	0.31	1.083	0.28	1.194	0.32	3.612	0.36	4.806	0.30
1987	6.307	0.22	4.039	0.33	10.345	0.22	4.658	0.40	0.917	0.27	5.575	0.34	10.965	0.21	4.956	0.28	15.921	0.19
1988	18.560	0.67	3.515	0.24	22.074	0.56	12.210	0.39	1.241	0.32	13.451	0.36	30.769	0.43	4.756	0.20	35.525	0.37
1989	46.361	0.20	4.780	0.39	51.141	0.19	17.061	0.33	3.608	0.36	20.670	0.28	63.423	0.17	8.388	0.27	71.811	0.16
1990	38.932	0.22	9.361	0.21	48.293	0.19	26.645	0.36	4.216	0.29	30.860	0.32	65.577	0.20	13.576	0.17	79.153	0.17
1991	39.106	0.46	18.355	0.24	57.462	0.33	17.264	0.30	11.383	0.20	28.647	0.21	56.371	0.33	29.738	0.17	86.109	0.23
1992	50.821	0.44	21.453	0.40	72.274	0.33	11.949	0.47	8.559	0.28	20.509	0.29	62.770	0.37	30.012	0.30	92.782	0.26
1993	27.129	0.29	16.372	0.25	43.501	0.20	5.078	0.35	3.723	0.30	8.801	0.26	32.207	0.25	20.095	0.21	52.302	0.17
1994	10.707	0.23	18.458	0.26	29.165	0.19	1.575	0.41	5.751	0.22	7.326	0.21	12.282	0.21	24.209	0.20	36.491	0.16
1995	1.510	0.25	16.795	0.28	18.305	0.26	0.569	0.42	7.622	0.35	8.191	0.34	2.079	0.22	24.418	0.22	26.497	0.21
1996	0.302	0.33	17.040	0.35	17.343	0.35	0.154	0.42	5.271	0.49	5.425	0.48	0.456	0.26	22.312	0.29	22.768	0.29
1997	0.454	0.34	4.957	0.21	5.411	0.20	0.248	0.34	1.296	0.26	1.543	0.23	0.701	0.25	6.253	0.18	6.954	0.16
1998	1.395	0.29	3.155	0.18	4.550	0.16	0.619	0.34	0.922	0.20	1.541	0.20	2.014	0.22	4.077	0.15	6.091	0.13
1999	2.022	0.37	2.256	0.32	4.278	0.24	0.387	0.33	0.505	0.30	0.892	0.24	2.409	0.32	2.760	0.27	5.169	0.20
2000	5.647	0.52	3.921	0.40	9.567	0.35	0.347	0.33	0.544	0.29	0.891	0.24	5.994	0.49	4.465	0.35	10.459	0.32
2001	5.136	0.34	4.621	0.20	9.757	0.23	0.635	0.27	1.785	0.36	2.419	0.30	5.770	0.30	6.406	0.17	12.176	0.20
2002	1.087	0.41	8.110	0.25	9.197	0.23	0.546	0.41	1.140	0.24	1.686	0.25	1.633	0.30	9.250	0.22	10.883	0.20
2003	1.895	0.32	7.156	0.29	9.051	0.25	0.615	0.32	3.019	0.35	3.634	0.31	2.510	0.25	10.175	0.23	12.685	0.20
2004	2.150	0.26	5.277	0.44	7.426	0.31	1.431	0.26	2.626	0.29	4.057	0.21	3.581	0.18	7.903	0.31	11.484	0.22
2005	3.110	0.22	6.588	0.32	9.698	0.24	11.621	0.33	7.088	0.29	18.710	0.25	14.731	0.26	13.676	0.22	28.407	0.19
2006	2.674	0.36	8.262	0.25	10.936	0.22	5.256	0.37	20.672	0.46	25.928	0.40	7.930	0.27	28.934	0.34	36.864	0.29
2007	5.023	0.56	6.765	0.23	11.788	0.28	11.886	0.83	10.728	0.34	22.614	0.47	16.909	0.61	17.493	0.23	34.401	0.33
2008	17.411	0.74	4.518	0.27	21.929	0.60	12.273	0.54	6.233	0.27	18.505	0.39	29.683	0.49	10.751	0.20	40.435	0.37
2009	3.293	0.25	6.402	0.34	9.695	0.28	9.180	0.28	5.838	0.20	15.018	0.21	12.473	0.22	12.240	0.20	24.713	0.17
2010	3.702	0.50	5.364	0.28	9.066	0.29	12.360	0.45	6.754	0.21	19.114	0.33	16.062	0.36	12.118	0.17	28.180	0.24
2011	1.866	0.25	8.110	0.31	9.976	0.28	10.018	0.70	8.845	0.20	18.863	0.39	11.884	0.59	16.954	0.18	28.839	0.27
2012	4.229	0.46	6.042	0.23	10.270	0.24	3.051	0.28	5.218	0.18	8.269	0.18	7.279	0.29	11.259	0.15	18.539	0.16
2013	15.045	0.31	4.524	0.22	19.569	0.24	7.150	0.39	3.614	0.22	10.764	0.27	22.195	0.24	8.138	0.16	30.334	0.18
2014	18.764	0.25	11.735	0.19	30.499	0.18	9.947	0.17	6.192	0.21	16.140	0.14	28.711	0.17	17.927	0.14	46.639	0.13
2015	11.442	0.20	12.676	0.22	24.119	0.14	11.343	0.27	8.298	0.22	19.641	0.18	22.785	0.17	20.975	0.16	43.760	0.11
2016	3.349	0.18	10.545	0.17	13.894	0.14	7.580	0.18	17.080	0.17	24.661	0.14	10.929	0.14	27.625	0.12	38.554	0.10
2017	2.054	0.78	13.889	0.17	15.943	0.18	1.231	0.21	15.589	0.23	16.819	0.22	3.284	0.49	29.478	0.14	32.762	0.14
2018	0.149	0.44	9.100	0.16	9.250	0.16	1.422	0.19	15.823	0.19	17.245	0.18	1.571	0.17	24.923	0.13	26.494	0.13

(continued)

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2019	0.460	0.37	5.666	0.20	6.125	0.20	0.301	0.33	6.608	0.16	6.909	0.16	0.761	0.26	12.274	0.13	13.034	0.13
2020	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021	2.047	0.32	1.311	0.29	3.357	0.23	0.632	0.32	2.243	0.22	2.875	0.19	2.679	0.25	3.553	0.18	6.232	0.15
2022	4.938	0.28	1.324	0.29	6.262	0.23	1.065	0.26	1.224	0.21	2.289	0.17	6.003	0.23	2.548	0.18	8.551	0.17
2023	3.220	0.24	1.504	0.24	4.725	0.18	1.611	0.23	1.819	0.23	3.430	0.17	4.831	0.18	3.323	0.17	8.154	0.13

Table 20. Design-based survey biomass estimates (and cv's) from the SBS studies, by sex, maturity state, and fleet. Biomass units are metric tons. Tanner crab SBS studies were conducted annually during 2013-2018, but the 2018 BSFRF data is unavailable. Different areas were included in the studies each year.

				male								female
				all maturity				immature				mature
	BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2013	56,571	0.55	21,109	0.38	1,562	0.45	522	0.38	8,369	0.48	3,050	0.46
2014	42,969	0.21	30,866	0.24	379	0.33	148	0.33	3,428	0.33	1,252	0.35
2015	23,271	0.20	16,802	0.22	165	0.43	255	0.62	2,633	0.42	713	0.44
2016	56,414	0.18	29,183	0.15	1,275	0.31	202	0.33	11,016	0.29	2,654	0.29
2017	69,448	0.19	30,719	0.15	5,430	0.17	759	0.28	15,984	0.30	4,662	0.33
2018	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−

Table 21. Design-based survey abundance estimates (and cv's) from the SBS studies, by sex, maturity state, and fleet. Abundance units are millions of crab. Tanner crab SBS studies were conducted annually during 2013-2018, but the 2018 BSFRF data is unavailable. Different areas were included in the studies each year.

				male								female
				all maturity				immature				mature
	BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2013	139.20	0.51	47.03	0.36	17.95	0.34	4.11	0.34	35.13	0.49	12.97	0.46
2014	90.89	0.20	60.45	0.24	5.74	0.39	2.20	0.50	14.41	0.33	5.29	0.38
2015	48.91	0.19	33.32	0.25	5.52	0.52	3.10	0.55	11.80	0.47	3.14	0.52
2016	170.06	0.20	66.64	0.17	51.21	0.28	5.19	0.37	62.79	0.31	15.34	0.31
2017	443.40	0.14	88.02	0.15	371.44	0.17	40.63	0.35	107.47	0.29	30.76	0.34
2018	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−

Table 22. Original and scaled (input) sample sizes for Tanner crab size compositions in the NMFS EBS shelf bottom trawl survey. Scaled sample sizes are only shown for size compositions aggregated across ADFG management areas (i.e., ‘all EBS’).’–’: no survey conducted.

	East 166W				West 166W				all EBS							
	male		female	all sexes	male		female	all sexes	male				female		all sexes	
	all maturity	immature	mature	all maturity	all maturity	immature	mature	all maturity	all maturity		immature		mature		all maturity	
year	original	original	original	original	original	original	original	original	original	scaled	original	scaled	original	scaled	original	scaled
1975/76	4,973	956	1,664	7,593	2,314	91	903	3,308	7,287	134	1,047	19	2,567	47	10,901	200
1976/77	2,891	510	1,182	4,583	1,843	587	433	2,863	4,734	127	1,097	29	1,615	43	7,446	200
1977/78	2,680	251	1,350	4,281	1,554	525	571	2,650	4,234	122	776	22	1,921	55	6,931	200
1978/79	2,342	175	1,338	3,855	2,885	1,774	607	5,266	5,227	115	1,949	43	1,945	43	9,121	200
1979/80	669	156	272	1,097	1,160	273	325	1,758	1,829	128	429	30	597	42	2,855	200
1980/81	1,986	319	629	2,934	5,544	1,172	1,412	8,128	7,530	136	1,491	27	2,041	37	11,062	200
1981/82	1,279	339	739	2,357	5,709	240	1,786	7,735	6,988	138	579	11	2,525	50	10,092	200
1982/83	1,428	440	1,026	2,894	3,776	383	1,815	5,974	5,204	117	823	19	2,841	64	8,868	200
1983/84	1,687	916	611	3,214	2,961	1,197	1,744	5,902	4,648	102	2,113	46	2,355	52	9,116	200
1984/85	934	319	415	1,668	2,920	1,560	1,400	5,880	3,854	102	1,879	50	1,815	48	7,548	200
1985/86	650	171	359	1,180	1,250	676	470	2,396	1,900	106	847	47	829	46	3,576	200
1986/87	1,501	942	272	2,715	1,636	646	250	2,532	3,137	120	1,588	61	522	20	5,247	200
1987/88	3,074	1,983	401	5,458	3,389	2,247	436	6,072	6,463	112	4,230	73	837	15	11,530	200
1988/89	3,788	1,422	1,484	6,694	4,524	2,313	799	7,636	8,312	116	3,735	52	2,283	32	14,330	200
1989/90	5,615	1,640	1,304	8,559	3,630	1,631	819	6,080	9,245	126	3,271	45	2,123	29	14,639	200
1990/91	5,500	1,521	1,722	8,743	4,098	1,593	1,291	6,982	9,598	122	3,114	40	3,013	38	15,725	200
1991/92	4,748	832	1,735	7,315	5,198	1,427	2,116	8,741	9,946	124	2,259	28	3,851	48	16,056	200
1992/93	2,864	169	1,265	4,298	4,065	1,325	1,760	7,150	6,929	121	1,494	26	3,025	53	11,448	200
1993/94	2,748	104	748	3,600	2,845	765	1,134	4,744	5,593	134	869	21	1,882	45	8,344	200
1994/95	1,471	59	557	2,087	2,361	862	884	4,107	3,832	124	921	30	1,441	47	6,194	200
1995/96	1,041	147	492	1,680	1,748	687	705	3,140	2,789	116	834	35	1,197	50	4,820	200
1996/97	1,404	424	484	2,312	1,301	459	588	2,348	2,705	116	883	38	1,072	46	4,660	200
1997/98	994	501	379	1,874	1,213	828	293	2,334	2,207	105	1,329	63	672	32	4,208	200
1998/99	1,132	482	248	1,862	1,920	1,228	256	3,404	3,052	116	1,710	65	504	19	5,266	200
1999/00	1,462	516	367	2,345	2,471	2,112	398	4,981	3,933	107	2,628	72	765	21	7,326	200
2000/01	1,599	556	312	2,467	2,518	1,693	275	4,486	4,117	118	2,249	65	587	17	6,953	200
2001/02	1,844	1,093	216	3,153	3,638	2,585	792	7,015	5,482	108	3,678	72	1,008	20	10,168	200
2002/03	1,816	1,097	260	3,173	3,643	2,488	590	6,721	5,459	110	3,585	72	850	17	9,894	200
2003/04	1,812	453	415	2,680	5,191	2,381	1,260	8,832	7,003	122	2,834	49	1,675	29	11,512	200
2004/05	1,020	213	168	1,401	6,448	3,709	915	11,072	7,468	120	3,922	63	1,083	17	12,473	200
2005/06	1,859	641	437	2,937	5,670	2,711	1,125	9,506	7,529	121	3,352	54	1,562	25	12,443	200
2006/07	2,422	715	603	3,740	9,613	3,649	2,056	15,318	12,035	126	4,364	46	2,659	28	19,058	200
2007/08	2,120	348	768	3,236	7,466	2,082	1,939	11,487	9,586	130	2,430	33	2,707	37	14,723	200
2008/09	1,991	254	674	2,919	5,398	1,493	1,689	8,580	7,389	129	1,747	30	2,363	41	11,499	200
2009/10	1,545	507	554	2,606	4,432	1,901	1,126	7,459	5,977	119	2,408	48	1,680	33	10,065	200
2010/11	1,562	623	410	2,595	5,062	2,557	776	8,395	6,624	121	3,180	58	1,186	22	10,990	200
2011/12	2,923	1,610	391	4,924	6,228	3,434	785	10,447	9,151	119	5,044	66	1,176	15	15,371	200
2012/13	2,709	977	848	4,534	5,677	2,634	814	9,125	8,386	123	3,611	53	1,662	24	13,659	200
2013/14	3,478	746	972	5,196	6,133	2,171	1,447	9,751	9,611	129	2,917	39	2,419	32	14,947	200
2014/15	4,309	440	740	5,489	6,552	1,771	1,326	9,649	10,861	143	2,211	29	2,066	27	15,138	200
2015/16	2,606	479	781	3,866	4,807	976	1,027	6,810	7,413	139	1,455	27	1,808	34	10,676	200

(continued)

				East 166W				West 166W								all EBS
	male		female	all sexes	male		female	all sexes		male				female		all sexes
	all maturity	immature	mature	all maturity	all maturity	immature	mature	all maturity		all maturity		immature		mature		all maturity
year	original	original	original	original	original	original	original	original	original	scaled	original	scaled	original	scaled	original	scaled
2016/17	1,821	43	277	2,141	5,252	1,330	1,341	7,923	7,073	141	1,373	27	1,618	32	10,064	200
2017/18	1,775	175	366	2,316	4,431	1,858	972	7,261	6,206	130	2,033	42	1,338	28	9,577	200
2018/19	1,904	1,147	121	3,172	6,347	3,519	1,107	10,973	8,251	117	4,666	66	1,228	17	14,145	200
2019/20	1,301	730	132	2,163	4,612	3,080	1,058	8,750	5,913	108	3,810	70	1,190	22	10,913	200
2020/21	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−
2021/22	1,820	509	520	2,849	4,901	2,506	1,471	8,878	6,721	115	3,015	51	1,991	34	11,727	200
2022/23	1,919	778	345	3,042	3,474	1,906	827	6,207	5,393	117	2,684	58	1,172	25	9,249	200
2023/24	1,686	983	308	2,977	7,833	5,605	1,101	14,539	9,519	109	6,588	75	1,409	16	17,516	200

Table 23. Original and scaled (input) sample sizes for Tanner crab size compositions in the SBS selectivity studies. '–': no survey conducted.

	male				female								all sexes			
	all maturity				immature				mature				all maturity			
	BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
2013/14	640	141	1,302	142	99	22	134	15	167	37	404	44	906	200	1,840	200
2014/15	441	166	1,814	180	25	9	58	6	66	25	149	15	532	200	2,021	200
2015/16	264	142	998	167	29	16	97	16	79	42	101	17	372	200	1,196	200
2016/17	998	118	2,281	154	318	38	179	12	380	45	503	34	1,696	200	2,963	200
2017/18	2,556	99	3,471	132	1,902	73	1,020	39	723	28	764	29	5,181	200	5,255	200

Table 24. Weight-at-size parameters ($w = a \cdot z^b$) for Tanner crab weight in grams.

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

Table 25. Parameters at bounds.

				22.03	22.03b
selectivity	selectivity	pS2[28]	slope for TCF retention (2005-2009)	1	–

Table 26. Final values for non-vector parameters related to recruitment, initial abundance, natural mortality, and growth. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03		22.03b
process	name	label	estimate	std. dev.	estimate	std. dev.
recruitment	pLnR[1]	historical recruitment period	6.783e+00	0.58809	6.862e+00	0.58959
	pLnR[2]	current recruitment period	5.808e+00	0.07047	5.901e+00	0.07059
	pRa[1]	fixed value	2.230e+00	0.03088	2.233e+00	0.03056
	pRb[1]	fixed value	1.354e+00	0.07835	1.351e+00	0.07662
	pRCV[1]	full model period	−7.000e−01	−−	−7.000e−01	−−
	pRX[1]	full model period	−1.110e−16	−−	−1.110e−16	−−
natural mortality	pDM1[1]	multiplier for immature crab	1.028e+00	0.04698	1.029e+00	0.04696
	pDM1[2]	multiplier for mature males	1.328e+00	0.03786	1.349e+00	0.03756
	pDM1[3]	multiplier for mature females	1.336e+00	0.03773	1.342e+00	0.03768
	pDM2[1]	1980-1984 multiplier for mature males	2.367e+00	0.25140	2.345e+00	0.24361
	pDM2[2]	1980-1984 multiplier for mature females	1.951e+00	0.16801	1.966e+00	0.16789
	pM[1]	base ln-scale M	−1.470e+00	−−	−1.470e+00	−−
growth	pGrA[1]	males	3.240e+01	0.25628	3.233e+01	0.24703
	pGrA[2]	females	3.368e+01	0.31414	3.369e+01	0.31124
	pGrB[1]	males	1.659e+02	0.73016	1.660e+02	0.72905
	pGrB[2]	females	1.150e+02	0.61113	1.149e+02	0.60748
	pGrBeta[1]	both sexes	8.302e−01	0.10103	8.167e−01	0.09878

Table 27. Final values for annual recruitment "devs" in the "historical" period up to 1975. Index begins in 1948.

		22.03		22.03b
index	estimate	std. dev.	estimate	std. dev.
1	−0.49482	1.7793	−0.49611	1.7810
2	−0.49401	1.6465	−0.49532	1.6483
3	−0.49212	1.5171	−0.49349	1.5189
4	−0.48881	1.3921	−0.49028	1.3938
5	−0.48362	1.2729	−0.48523	1.2745
6	−0.47597	1.1612	−0.47776	1.1626
7	−0.46507	1.0593	−0.46711	1.0604
8	−0.44992	0.9701	−0.45226	0.9708
9	−0.42922	0.8967	−0.43192	0.8971
10	−0.40135	0.8427	−0.40449	0.8427
11	−0.36438	0.8112	−0.36800	0.8108
12	−0.31577	0.8040	−0.31992	0.8035
13	−0.25165	0.8208	−0.25633	0.8204
14	−0.16562	0.8571	−0.17071	0.8569
15	−0.04680	0.9024	−0.05195	0.9025
16	0.12477	0.9370	0.12054	0.9373
17	0.38836	0.9338	0.38719	0.9341
18	0.79760	0.8773	0.80279	0.8777
19	1.34609	0.7825	1.36164	0.7828
20	1.65752	0.6681	1.67828	0.6689
21	1.19389	0.6820	1.20007	0.6840
22	0.64097	0.6800	0.63968	0.6817
23	0.36284	0.6578	0.35647	0.6598
24	−0.08165	0.6616	−0.07634	0.6629
25	−0.46256	0.6626	−0.45161	0.6639
26	−0.14872	0.6970	−0.15782	0.6994

Table 28. Final values for annual recruitment “devs” in the “current” period from 1975. The index begins in 1975.

	22.03		22.03b	
index	estimate	std. dev.	estimate	std. dev.
1	1.371102	0.30656	1.362651	0.30809
2	1.969927	0.19406	1.977479	0.19372
3	1.623838	0.22211	1.630053	0.22167
4	0.637295	0.41376	0.617879	0.41999
5	−0.125692	0.53667	−0.117219	0.53149
6	−0.163810	0.40665	−0.172264	0.40717
7	0.007512	0.29055	−0.001938	0.28988
8	−0.143958	0.28366	−0.159304	0.28347
9	1.084432	0.11686	1.069499	0.11612
10	0.791021	0.16742	0.774648	0.16720
11	0.931690	0.16375	0.909358	0.16411
12	0.960184	0.15386	0.942858	0.15346
13	0.798373	0.16555	0.769501	0.16687
14	0.410546	0.20385	0.394347	0.20282
15	−0.355926	0.25624	−0.370642	0.25536
16	−1.065637	0.34866	−1.082569	0.34818
17	−1.358549	0.32356	−1.366220	0.32084
18	−1.271511	0.25538	−1.296918	0.25591
19	−1.300123	0.26409	−1.293311	0.25854
20	−1.097827	0.24319	−1.117749	0.24411
21	−0.613559	0.18033	−0.624885	0.17974
22	−0.837855	0.23503	−0.854492	0.23543
23	0.082906	0.11806	0.069097	0.11766
24	−0.924835	0.24585	−0.942354	0.24612
25	0.630661	0.09955	0.616724	0.09899
26	−0.499017	0.28012	−0.517161	0.28054
27	1.015797	0.10084	1.002790	0.10026
28	−0.207097	0.28808	−0.224142	0.28848
29	1.113741	0.10642	1.099043	0.10605
30	0.550121	0.15121	0.529807	0.15114
31	−0.578638	0.27676	−0.604113	0.27708
32	−1.045676	0.36510	−1.067656	0.36417
33	−0.501220	0.26195	−0.516157	0.26111
34	−0.051185	0.27025	−0.060139	0.26951
35	1.420115	0.09488	1.394125	0.09446
36	0.430036	0.19448	0.374899	0.19598
37	−0.312367	0.20480	−0.367442	0.20482
38	−1.608564	0.38500	−1.664783	0.38287
39	−0.678895	0.15686	−0.741572	0.15664
40	−1.225380	0.22469	−1.290960	0.22375
41	−1.043088	0.20096	−1.128840	0.20004
42	−0.880743	0.21170	−1.005887	0.21176
43	0.922963	0.08153	0.796400	0.07950
44	0.028881	0.19191	−0.123278	0.18954
45	0.465795	0.13972	0.345363	0.13248
46	−1.600973	0.57993	−1.587038	0.56981

(continued)

index	estimate	22.03 std. dev.	estimate	22.03b std. dev.
47	0.835670	0.15200	0.787998	0.14187
48	1.409518	0.18752	1.469258	0.14645
49	–	–	1.365256	0.22490

Table 29. Final values for parameters related to the probability of terminal molt. Index corresponds to 5-mm size bin starting at 50 mm CW for females and 60 mm CW for males.

			22.03		22.03b
label	index	estimate	std. dev.	estimate	std. dev.
females 50-105 mmCW (entire model period)	1	−5.38901	1.21760	−5.4252	1.22780
	2	−4.13264	0.57097	−4.1594	0.57479
	3	−2.91702	0.24930	−2.9311	0.24926
	4	−1.70905	0.14626	−1.7111	0.14581
	5	−0.58231	0.09173	−0.5840	0.09110
	6	0.25646	0.09149	0.2544	0.09108
	7	0.57052	0.10355	0.5724	0.10319
	8	1.06542	0.13683	1.0632	0.13587
	9	1.96038	0.22786	1.9492	0.22660
	10	2.90741	0.44476	2.9039	0.44187
	11	3.90819	1.00730	3.9224	0.99795
males 60-150 mmCW (entire model period)	1	−2.87552	0.20640	−2.9880	0.20865
	2	−3.51125	0.29649	−3.5614	0.30039
	3	−2.96819	0.24716	−3.0163	0.25135
	4	−2.13738	0.13018	−2.1387	0.12768
	5	−1.43340	0.11561	−1.3417	0.11112
	6	−1.29864	0.10454	−1.2363	0.10216
	7	−0.80810	0.09771	−0.7566	0.09562
	8	−0.29843	0.08707	−0.2357	0.08592
	9	−0.28301	0.08884	−0.2080	0.08766
	10	0.02778	0.08871	0.1413	0.08885
	11	0.46356	0.09419	0.5439	0.09393
	12	0.93341	0.11718	1.0202	0.11861
	13	1.58958	0.14316	1.6200	0.14004
	14	2.59435	0.25782	2.6398	0.25848
	15	3.06172	0.28054	3.1286	0.28083
	16	3.65900	0.48495	3.7152	0.48741
	17	4.75803	1.07760	4.7864	1.09170

Table 30. Final values for non-vector parameters related to fisheries, surveys, and the Dirichlet-Multinomial likelihood. Parameters with values whose standard error is NA are fixed, not estimated.

			22.03		22.03b	
process	name	label	estimate	std. dev.	estimate	std. dev.
fisheries	pDC2[1]	TCF: female offset	− 2.6878	0.20849	− 2.7573	0.20807
	pDC2[2]	SCF: female offset	− 2.6607	0.33135	− 2.6820	0.34163
	pDC2[3]	GTF: female offset	− 1.0341	0.09450	− 1.0451	0.09663
	pDC2[4]	RKF: female offset	− 2.3645	0.84252	− 2.3993	0.84484
	pHM[1]	handling mortality for pot fisheries	0.3210	− −	0.3210	− −
	pHM[2]	handling mortality for groundfish trawl fisheries	0.8000	− −	0.8000	− −
	pLgtRet[1]	TCF: logit-scale max retention (pre-1997)	14.9000	− −	14.9000	− −
	pLgtRet[2]	TCF: logit-scale max retention (2005-2009)	14.9000	− −	14.9000	− −
	pLgtRet[3]	TCF: logit-scale max retention (2013+)	14.9000	− −	14.9000	− −
	pLnC[1]	TCF: base capture rate, pre-1965 (=0.05)	− 2.9957	− −	− 2.9957	− −
	pLnC[2]	TCF: base capture rate, 1965+	− 1.4231	0.12375	− 1.5014	0.12128
	pLnC[3]	SCF: base capture rate, pre-1978 (=0.01)	− 4.6052	− −	− 4.6052	− −
	pLnC[4]	SCF: base capture rate, 1992+	− 3.7151	0.07088	− 3.7521	0.07061
	pLnC[5]	DUMMY CAPTURE RATE	− 4.1807	− −	− 4.1807	− −
	pLnC[6]	GTF: base capture rate, ALL YEARS	− 4.9429	0.05908	− 5.0076	0.06037
	pLnC[7]	RKF: base capture rate, pre-1953 (=0.02)	− 3.9120	− −	− 3.9120	− −
	pLnC[8]	RKF: base capture rate, 1992+	− 4.7553	0.10849	− 4.7501	0.10885
surveys	pQ[1]	NMFS trawl survey: males, 1975-1981	− 0.6824	0.10739	− 0.7497	0.11151
	pQ[2]	NMFS trawl survey: males, 1982+	− 0.6611	0.05067	− 0.7258	0.05159
	pQ[3]	NMFS trawl survey: females, 1975-1981	− 1.0648	0.13313	− 1.1546	0.13483
	pQ[4]	NMFS trawl survey: females, 1982+	− 1.3179	0.07557	− 1.3906	0.07566
	pQ[5]	BSFRF SBS	0.0000	− −	0.0000	− −
Dirichlet-Multinomial	pLnDirMul[1]	ln(theta) parameter for BSFRF SBS M	0.9290	0.24659	0.9312	0.24624
	pLnDirMul[2]	ln(theta) parameter for BSFRF SBS F	2.5272	0.24472	2.5228	0.24458

Table 31. Final values for fishing mortality "devs" for the directed fishery. The index starts in 1965 (or 1982 for models 22.07 and 22.08) and does not include years when the fishery was completely closed.

	22.03		22.03b	
index	estimate	std. dev.	estimate	std. dev.
1	−1.37702	0.8742	−1.3024	0.8776
2	−1.16825	0.7233	−1.0933	0.7262
3	0.67197	0.6621	0.7475	0.6643
4	1.24738	0.6401	1.3231	0.6410
5	2.39556	0.8897	2.4706	0.8847
6	4.07690	0.7762	4.1270	0.7588
7	4.64191	0.7286	4.6307	0.7935
8	2.10677	1.2149	2.0750	1.2196
9	0.06231	0.3458	0.0876	0.3458
10	−0.27979	0.2172	−0.2471	0.2148
11	−0.14975	0.1820	−0.1150	0.1802
12	0.60442	0.1780	0.6381	0.1768
13	1.35489	0.2051	1.3730	0.2046
14	1.61490	0.2820	1.5968	0.2793
15	2.06622	0.3617	2.0137	0.3539
16	1.85052	0.2620	1.8186	0.2594
17	0.18834	0.1515	0.2080	0.1501
18	−0.94876	0.1321	−0.9157	0.1295
19	−2.37987	0.1333	−2.3408	0.1304
20	−1.06992	0.1460	−1.0268	0.1427
21	−1.43900	0.1269	−1.3810	0.1244
22	−0.48476	0.1265	−0.4222	0.1240
23	0.69860	0.1280	0.7617	0.1256
24	1.45771	0.1350	1.5184	0.1326
25	1.75607	0.1605	1.8283	0.1590
26	2.09877	0.1703	2.1574	0.1683
27	1.65436	0.1677	1.7106	0.1663
28	0.90160	0.1766	0.9555	0.1753
29	0.31437	0.1700	0.3663	0.1686
30	0.24195	0.2239	0.2977	0.2234
31	−2.43412	0.1282	−2.3622	0.1256
32	−1.81609	0.1282	−1.7441	0.1257
33	−1.99299	0.1279	−1.9208	0.1254
34	−2.15088	0.1279	−2.0788	0.1254
35	−2.17210	0.1494	−2.1041	0.1467
36	−2.02130	0.1306	−1.9530	0.1281
37	−0.74218	0.1281	−0.6772	0.1251
38	−0.43851	0.1270	−0.3711	0.1239
39	−2.15643	0.1270	−2.0756	0.1240
40	−2.00140	0.1274	−1.9171	0.1242
41	−2.21716	0.1290	−2.1193	0.1257
42	−2.56524	0.1307	−2.4481	0.1270
43	–	–	−2.0898	0.1275

Table 32. Final values for fishing mortality “devs” for the snow crab fishery. The indices start in 1990.

		22.03		22.03b
index	estimate	std. dev.	estimate	std. dev.
1	1.4877965	0.1994	1.499544	0.1967
2	1.7395301	0.2031	1.748508	0.1989
3	0.7334843	0.2000	0.737667	0.1945
4	1.1228909	0.1912	1.120595	0.1855
5	0.5500260	0.1896	0.548102	0.1843
6	0.4729908	0.1916	0.471325	0.1870
7	1.3161988	0.2013	1.312022	0.1971
8	1.1076726	0.2065	1.081800	0.2063
9	0.1691961	0.1950	0.148882	0.1953
10	−1.4428599	0.2115	−1.460058	0.2118
11	−0.6966781	0.2148	−0.711990	0.2151
12	−0.2435431	0.2117	−0.258091	0.2120
13	−1.5290476	0.2127	−1.542773	0.2130
14	−2.6471907	0.2426	−2.659883	0.2428
15	−1.9578556	0.1910	−1.970617	0.1912
16	0.0007689	0.1978	−0.009352	0.1974
17	0.1464653	0.1907	0.135607	0.1904
18	0.1819418	0.1943	0.171331	0.1940
19	−0.4469171	0.1961	−0.457572	0.1957
20	−0.0622616	0.1979	−0.073530	0.1975
21	0.0362362	0.1987	0.026479	0.1983
22	0.5800019	0.1975	0.573444	0.1971
23	0.2765332	0.1969	0.274078	0.1966
24	0.1993618	0.1965	0.200145	0.1961
25	1.0356514	0.1911	1.037949	0.1908
26	0.8329302	0.1925	0.837212	0.1923
27	0.6568357	0.1949	0.663814	0.1946
28	0.0311341	0.1980	0.042758	0.1977
29	0.0293783	0.1986	0.047697	0.1982
30	0.3322230	0.1981	0.358810	0.1978
31	−1.6671284	0.2125	−1.622089	0.2121
32	−2.3457661	0.2288	−2.271816	0.2282

Table 33. Final values for fishing mortality "devs" for the BBRKC fishery. The indices start in 1990.

		22.03		22.03b
index	estimate	std. dev.	estimate	std. dev.
1	3.785782	0.2300	3.77318	0.2298
2	3.463910	0.2438	3.45124	0.2438
3	3.267921	0.2469	3.24332	0.2463
4	4.195096	0.2311	4.16364	0.2307
5	2.234787	0.2417	2.20545	0.2412
6	0.973504	0.2604	0.95107	0.2604
7	0.719618	0.2613	0.70022	0.2614
8	0.298402	0.2720	0.28243	0.2721
9	0.074985	0.2787	0.06274	0.2789
10	−0.520253	0.3434	−0.52992	0.3436
11	−0.331446	0.2807	−0.33932	0.2811
12	−0.630193	0.2879	−0.63681	0.2882
13	−0.952336	0.2978	−0.95779	0.2981
14	−1.319487	0.3303	−1.31913	0.3304
15	−1.817762	0.4332	−1.81754	0.4332
16	−1.271128	0.2615	−1.27102	0.2616
17	0.111930	0.2173	0.11235	0.2173
18	−0.360498	0.2203	−0.35922	0.2204
19	−2.028213	0.4155	−2.02521	0.4155
20	−2.473755	0.6947	−2.46792	0.6946
21	−1.439698	0.3230	−1.43082	0.3230
22	−0.408557	0.2271	−0.39816	0.2272
23	0.251287	0.2188	0.26248	0.2189
24	−0.160272	0.2162	−0.14729	0.2162
25	−0.199147	0.2179	−0.18201	0.2180
26	0.009691	0.2201	0.03261	0.2202
27	−0.697596	0.2501	−0.66832	0.2502
28	−1.934603	0.6824	−1.89735	0.6829
29	−2.841971	1.3212	−2.79289	1.3231

Table 34. Final values for fishing mortality “devs” vectors for the groundfish fisheries. Indices start in 1973.

	22.03		22.03b	
index	estimate	std. dev.	estimate	std. dev.
1	1.51157	0.2237	1.49528	0.2248
2	1.84166	0.2130	1.82915	0.2140
3	0.99814	0.2107	0.98871	0.2117
4	0.46675	0.2088	0.45943	0.2099
5	0.14046	0.2087	0.13106	0.2100
6	−0.14026	0.2093	−0.15310	0.2107
7	0.45459	0.2126	0.43653	0.2137
8	0.09061	0.2098	0.07031	0.2104
9	−0.08748	0.2039	−0.10279	0.2043
10	−1.02757	0.2020	−1.03622	0.2024
11	−0.29869	0.2039	−0.30132	0.2042
12	−0.02469	0.2087	−0.02304	0.2089
13	−0.51430	0.2048	−0.50945	0.2051
14	−0.25123	0.1991	−0.24387	0.1995
15	−0.37558	0.2033	−0.35656	0.2039
16	−0.87285	0.2028	−0.85226	0.2034
17	−0.58539	0.2019	−0.56383	0.2025
18	−0.21094	0.2021	−0.19017	0.2028
19	0.62746	0.1512	0.64318	0.1519
20	0.88908	0.1515	0.90072	0.1521
21	0.56045	0.1512	0.61294	0.1519
22	1.03541	0.1520	1.04581	0.1525
23	0.94667	0.1520	0.95481	0.1525
24	1.12221	0.1537	1.12991	0.1541
25	1.56502	0.1491	1.58276	0.1489
26	1.42297	0.1475	1.44480	0.1475
27	0.89267	0.1467	0.91883	0.1468
28	0.93176	0.1469	0.95730	0.1469
29	1.15438	0.1469	1.17978	0.1470
30	0.44921	0.1467	0.47500	0.1469
31	−0.10178	0.1465	−0.06963	0.1467
32	0.19207	0.1463	0.22062	0.1465
33	−0.13828	0.1463	−0.11070	0.1466
34	−0.16581	0.1464	−0.13758	0.1466
35	−0.07655	0.1463	−0.04778	0.1465
36	−0.41560	0.1459	−0.38385	0.1462
37	−0.79207	0.1452	−0.75726	0.1454
38	−1.13765	0.1449	−1.09494	0.1451
39	−0.82643	0.1450	−0.78804	0.1452
40	−1.31187	0.1456	−1.26886	0.1458
41	−0.74724	0.1459	−0.70320	0.1461
42	−0.66195	0.1454	−0.61797	0.1456
43	−0.79798	0.1449	−0.75091	0.1451
44	−0.70569	0.1449	−0.65261	0.1451
45	−1.27840	0.1448	−1.21759	0.1449
46	−0.97957	0.1452	−0.90725	0.1453

(continued)

		22.03		22.03b
index	estimate	std. dev.	estimate	std. dev.
47	−0.86236	0.1459	−0.77804	0.1458
48	−0.94714	0.1473	−0.84706	0.1469
49	−0.95778	0.1485	−0.86092	0.1476
50	–	–	−1.15012	0.1476

Table 35. Final values for the "pS1" parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03		22.03b
	name	label	estimate	std. dev.	estimate	std. dev.
selectivity	pS1[1]	size at 1 for NMFS survey selectivity (males, pre-1982)	179.000	– –	179.000	– –
	pS1[10]	ascending z-at-1 for SCF selectivity (males, pre-1997)	159.629	4.78010	160.113	2.804400
	pS1[11]	ascending z-at-1 for SCF selectivity (males, 1997-2004)	118.508	6.88950	119.338	6.864600
	pS1[12]	ascending z-at-1 for SCF selectivity (males, 2005+)	124.558	1.27710	124.976	1.282100
	pS1[13]	ascending z50 for SCF selectivity (females, pre-1997)	80.715	6.75630	81.083	7.128200
	pS1[14]	ascending z50 for SCF selectivity (females, 1997-2004)	72.678	4.36170	72.688	4.388700
	pS1[15]	ascending z50 for SCF selectivity (females, 2005+)	101.466	8.60190	101.570	8.801900
	pS1[16]	z50 for GF.AllGear selectivity (males, pre-1987)	60.862	3.28110	61.277	3.453000
	pS1[17]	z50 for GF.AllGear selectivity (males, 1987-1996)	71.248	6.73720	72.567	6.933800
	pS1[18]	z50 for GF.AllGear selectivity (males, 1997+)	97.493	2.51340	98.512	2.585400
	pS1[19]	z50 for GF.AllGear selectivity (females, pre-1987)	43.482	1.83890	43.475	1.841000
	pS1[2]	size at 1 for NMFS survey selectivity (males, 1982+)	179.000	– –	179.000	– –
	pS1[20]	z50 for GF.AllGear selectivity (females, 1987-1996)	40.130	2.17720	40.248	2.226400
	pS1[21]	z50 for GF.AllGear selectivity (females, 1997+)	86.992	3.17300	87.484	3.217700
	pS1[22]	size at 1 for RKF selectivity (males, pre-1997)	179.900	– –	179.900	– –
	pS1[23]	size at 1 for RKF selectivity (males, 1997-2004)	179.900	– –	179.900	– –
	pS1[24]	size at 1 for RKF selectivity (males, 2005+)	179.900	– –	179.900	– –
	pS1[25]	size at 1 for RKF selectivity (females, pre-1997)	139.900	– –	139.900	– –
	pS1[26]	size at 1 for RKF selectivity (females, 1997-2004)	136.867	39.70000	137.118	39.686000
	pS1[27]	size at 1 for RKF selectivity (females, 2005+)	134.747	22.54600	135.215	22.622000
	pS1[28]	z50 for TCF retention (2005-2009)	137.634	0.27798	137.638	0.277070
	pS1[29]	z50 for TCF retention (2013+)	125.401	0.82962	125.131	0.804650
	pS1[3]	size at 1 for NMFS survey selectivity (females, pre-1982)	129.900	– –	129.900	– –
	pS1[4]	size at 1 for NMFS survey selectivity (females, 1982+)	129.900	– –	129.900	– –
	pS1[5]	z50 for TCF retention (pre-1991)	138.939	0.69582	139.036	0.671090
	pS1[6]	z50 for TCF retention (1991-1996)	138.600	1.13580	138.548	1.209900
	pS1[7]	DUMMY VALUE	4.500	– –	4.500	– –
	pS1[8]	ln(z50) for TCF selectivity (males)	4.844	0.00651	4.839	0.006154
	pS1[9]	z50 for TCF selectivity (females)	92.883	2.30880	92.885	2.312000

Table 36. Final values for the "pS2" parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03		22.03b
	name	label	estimate	std. dev.	estimate	std. dev.
selectivity	pS2[1]	width for NMFS survey selectivity (males, pre-1982)	66.14381	2.500500	65.69466	2.469600
	pS2[10]	ascending width for SCF selectivity (males, pre-1997)	32.77627	2.143500	32.61933	1.613900
	pS2[11]	ascending width for SCF selectivity (males, 1997-2004)	15.59980	3.543900	15.89583	3.493300
	pS2[12]	ascending width for SCF selectivity (males, 2005+)	14.46431	0.703490	14.53642	0.698620
	pS2[13]	slope for SCF selectivity (females, pre-1997)	0.13701	0.066731	0.13452	0.066789
	pS2[14]	slope for SCF selectivity (females, 1997-2004)	0.31759	0.241710	0.31802	0.242020
	pS2[15]	slope for SCF selectivity (females, 2005+)	0.09588	0.022967	0.09552	0.023114
	pS2[16]	slope for GF.AllGear selectivity (males, pre-1987)	0.08794	0.010614	0.08671	0.010866
	pS2[17]	slope for GF.AllGear selectivity (males, 1987-1996)	0.04482	0.007299	0.04363	0.006930
	pS2[18]	slope for GF.AllGear selectivity (males, 1997+)	0.05925	0.002477	0.05839	0.002414
	pS2[19]	slope for GF.AllGear selectivity (females, pre-1987)	0.13596	0.019956	0.13561	0.019888
	pS2[2]	width for NMFS survey selectivity (males, 1982+)	90.57288	3.069600	90.16616	3.017000
	pS2[20]	slope for GF.AllGear selectivity (females, 1987-1996)	0.16964	0.055214	0.16494	0.054248
	pS2[21]	slope for GF.AllGear selectivity (females, 1997+)	0.06414	0.004234	0.06409	0.004173
	pS2[22]	width for RKF selectivity (males, pre-1997)	19.95940	0.812260	19.86997	0.799520
	pS2[23]	width for RKF selectivity (males, 1997-2004)	28.03956	2.144800	27.78532	2.096600
	pS2[24]	width for RKF selectivity (males, 2005+)	27.65319	0.993710	27.33672	0.965950
	pS2[25]	width for RKF selectivity (males, pre-1997)	18.03274	2.363900	17.99006	2.356400
	pS2[26]	width for RKF selectivity (males, 1997-2004)	19.08069	15.010000	19.09402	14.953000
	pS2[27]	width for RKF selectivity (males, 2005+)	17.97278	7.939700	18.04778	7.940400
	pS2[28]	slope for TCF retention (2005-2009)	1.99994	0.106210	1.99000	– –
	pS2[29]	slope for TCF retention (2013+)	0.34038	0.078162	0.33453	0.070516
	pS2[3]	width for NMFS survey selectivity (females, pre-1982)	41.56184	2.249500	41.58357	2.255100
	pS2[4]	width for NMFS survey selectivity (females, 1982+)	82.30503	6.808000	84.75982	7.371900
	pS2[5]	slope for TCF retention (pre-1991)	0.72587	0.209180	0.71066	0.187540
	pS2[6]	slope for TCF retention (1997+)	0.97849	0.643220	1.00288	0.730330
	pS2[7]	slope for TCF selectivity (males, pre-1997)	0.12098	0.006796	0.12160	0.006684
	pS2[8]	slope for TCF selectivity (males, 1997+)	0.16782	0.007544	0.17182	0.007366
	pS2[9]	slope for TCF selectivity (females)	0.19395	0.025375	0.19349	0.025201

Table 37. Final values for the “pS3” and “pS4” parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03		22.03b
	name	label	estimate	std. dev.	estimate	std. dev.
selectivity	pS3[1]	scaled increment for descending z-at-1 for SCF selectivity (males, pre-1997)	0.001	– –	0.001	– –
	pS3[2]	scaled increment for descending z-at-1 for SCF selectivity (males, 1997-2004)	0.001	– –	0.001	– –
	pS3[3]	scaled increment for descending z-at-1 for SCF selectivity (males, 2005+)	0.001	– –	0.001	– –
	pS4[1]	descending width for SCF selectivity (males, pre-1997)	1.100	– –	1.100	– –
	pS4[2]	descending width for SCF selectivity (males, 1997-2004)	20.185	9.071	19.931	9.257
	pS4[3]	descending width for SCF selectivity (males, 2005+)	13.285	1.288	13.262	1.324

Table 38. Final values for the devs parameters related to selectivity in the directed fishery. Parameters with values whose standard error is NA are fixed, not estimated.

	22.03		22.03b	
index	estimate	std. dev.	estimate	std. dev.
1	0.09879	0.01456	0.107248	0.01440
2	0.07608	0.01406	0.085061	0.01389
3	0.11521	0.01310	0.123586	0.01302
4	0.11620	0.01831	0.124213	0.01805
5	0.09088	0.02127	0.099257	0.02101
6	0.19626	0.02047	0.202913	0.02046
7	−0.03733	0.01404	−0.029914	0.01367
8	−0.02229	0.01391	−0.014945	0.01351
9	−0.08882	0.01347	−0.080912	0.01311
10	0.02932	0.01151	0.035978	0.01117
11	0.14773	0.01175	0.152329	0.01149
12	−0.01687	0.01408	−0.009697	0.01373
13	−0.07215	0.01237	−0.063885	0.01198
14	−0.10859	0.01401	−0.098871	0.01356
15	−0.07502	0.01603	−0.065972	0.01551
16	−0.12008	0.01448	−0.110832	0.01399
17	−0.17095	0.01635	−0.164934	0.01615
18	−0.15826	0.01459	−0.152261	0.01430
19	–	–	−0.138278	0.01298

Table 39. Objective function data component values for models 22.03, 22.03b. Table 1 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03	22.03b
surveys data	NMFS M	index catch	abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	70.699	79.289
			n.at.z	male	411.493	415.477
	NMFS F		abundance	female	–	–
				male	–	–
			biomass	female	163.916	165.612
				male	–	–
			n.at.z	female	298.183	299.199
	SBS BSFRF M		abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	-1.151	-0.814
			n.at.z	male	290.992	290.592
	SBS BSFRF F		abundance	female	–	–
				male	–	–
			biomass	female	-1.622	-0.185
				male	–	–

Table 40. Objective function data component values for models 22.03, 22.03b. Table 2 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03	22.03b
surveys data	SBS BSFRF F	index catch	n.at.z	female	231.943	232.897
fisheries data	TCF	retained catch	abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	-143.049	-147.653
			n.at.z	male	64.684	66.936
		total catch	abundance	all sexes	–	–
			biomass	all sexes	6.586	4.793
			n.at.z	female	89.435	91.380
				male	83.283	93.482
	SCF		abundance	all sexes	–	–
			biomass	all sexes	-52.237	-52.247
			n.at.z	female	52.316	52.392
				male	80.186	80.300
	GF All		abundance	all sexes	-37.835	-39.433
			biomass	all sexes	-68.910	-70.213
			n.at.z	female	224.001	224.620
				male	291.464	307.289
	RKF		abundance	all sexes	–	–

Table 41. Objective function data component values for models 22.03, 22.03b. Table 3 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03	22.03b
fisheries data	RKF	total catch	biomass	all sexes	-37.093	-37.077
			n.at.z	female	6.904	6.876
				male	31.646	31.474
growth data			EBS molt increment data	female	246.735	246.159
				male	279.870	279.997
maturity ogive data	NMFS M		EBS mature male ratios	male	211.641	255.629

Table 42. Objective function non-data component values for models 22.03, 22.03b. Table 1 of 1. Abbreviations: devsSumSq: sum of squared annual deviations (“devs”); pDevsLnC: fishery capture probablity devs; pDevsLnR: recruitment devs; pDevsM: natural mortality devs; pDevsS1: selectivity deviations; pDM1: natural mortality multiplier; pQ: survey catchability. Components not included in the objective function are indicated by “–”.

category	type	element	22.03	22.03b
penalties	devsSumSq	pDevsLnC	0.000	0.000
		pDevsLnR	0.000	0.000
		pDevsS1	0.000	0.000
	maturity	smoothness	2.066	2.090
priors	natural mortality	pDM1	37.989	41.676
	recruitment	pDevsLnR	113.192	115.363
	surveys	pQ	97.286	106.871

Table 43. Differences in objective function data component values between models 22.03b and 22.03. Negative values indicate better fits. Table 1 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b
surveys data	NMFS M	index catch	abundance	female	0.000
				male	0.000
			biomass	female	0.000
				male	8.590
			n.at.z	male	3.984
	NMFS F		abundance	female	0.000
				male	0.000
			biomass	female	1.696
				male	0.000
			n.at.z	female	1.016
	SBS BSFRF M		abundance	female	0.000
				male	0.000
			biomass	female	0.000
				male	0.338
			n.at.z	male	-0.400
	SBS BSFRF F		abundance	female	0.000
				male	0.000
			biomass	female	1.437
				male	0.000

Table 44. Differences in objective function data component values between models 22.03b and 22.03. Negative values indicate better fits. Table 2 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b
surveys data	SBS BSFRF F	index catch	n.at.z	female	0.953
fisheries data	TCF	retained catch	abundance	female	0.000
				male	0.000
			biomass	female	0.000
				male	-4.604
			n.at.z	male	2.252
		total catch	abundance	all sexes	0.000
			biomass	all sexes	-1.793
			n.at.z	female	1.945
				male	10.199
	SCF		abundance	all sexes	0.000
			biomass	all sexes	-0.010
			n.at.z	female	0.075
				male	0.114
	GF All		abundance	all sexes	-1.597
			biomass	all sexes	-1.304
			n.at.z	female	0.619
				male	15.826
	RKF		abundance	all sexes	0.000

Table 45. Differences in objective function data component values between models 22.03b and 22.03. Negative values indicate better fits. Table 3 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b
fisheries data	RKF	total catch	biomass	all sexes	0.016
			n.at.z	female	-0.028
				male	-0.172
growth data			EBS molt increment data	female	-0.576
				male	0.127
maturity ogive data	NMFS M		EBS mature male ratios	male	43.988

Table 46. Differences in objective function non-data component values between models 22.03b and 22.03. Negative values indicate better fits. Table 1 of 1. Abbreviations: devsSumSq: sum of squared annual deviations (“devs”); pDevsLnC: fishery capture probablity devs; pDevsLnR: recruitment devs; pDevsM: natural mortality devs; pDevsS1: selectivity deviations; pDM1: natural mortality multiplier; pQ: survey catchability.

category	type	element	22.03b
penalties	devsSumSq	pDevsLnC	0.000
		pDevsLnR	0.000
		pDevsS1	0.000
	maturity	smoothness	0.024
priors	natural mortality	pDM1	3.687
	recruitment	pDevsLnR	2.171
	surveys	pQ	9.585

Table 47. Estimated rates of natural mortality (period of elevated M is 1980-1984).

	immature				mature
	all		female		male
case	typical	typical	elevated	typical	elevated
22.03	0.236	0.307	0.599	0.305	0.723
22.03b	0.237	0.309	0.607	0.310	0.728

Table 48. Estimated fully-selected survey catchability. The year indicates the start of the time block in which the value is used.

	NMFS F		NMFS M		SBS BSFRF F	SBS BSFRF M
	female		male		female	male
case	1975	1982	1975	1982	2013	2013
22.03	0.34	0.27	0.51	0.52	1.00	1.00
22.03b	0.32	0.25	0.47	0.48	1.00	1.00

Table 49. Estimated retained catch abundance (millions; 1965-1989).

y	22.03	22.03b
1965	1.9	1.9
1966	2.4	2.4
1967	13.2	13.3
1968	17.7	17.7
1969	27.6	27.6
1970	26.4	26.5
1971	22.1	22.1
1972	17.8	17.8
1973	12.6	12.6
1974	14.2	14.2
1975	16.4	16.4
1976	27.3	27.3
1977	33.2	33.1
1978	21.1	21.0
1979	18.3	18.3
1980	13.7	13.7
1981	5.0	5.0
1982	2.3	2.3
1983	0.5	0.5
1984	1.4	1.4
1987	1.0	1.0
1988	3.1	3.1
1989	10.6	10.6

Table 50. Estimated retained catch abundance (millions; 1990+).

y	22.03	22.03b
1990	17.3	17.3
1991	13.7	13.7
1992	15.5	15.5
1993	7.3	7.3
1994	3.4	3.4
1995	1.9	1.9
1996	0.7	0.7
2005	0.4	0.4
2006	0.9	0.9
2007	0.9	0.9
2008	0.9	0.9
2009	0.5	0.5
2013	1.5	1.5
2014	7.5	7.5
2015	10.6	10.7
2017	1.3	1.3
2018	1.3	1.3
2020	0.8	0.8
2021	0.6	0.6
2022	–	1.1

Table 51. Estimated retained catch biomass (1,000's t; 1965-1989).

y	22.03	22.03b
1965	1.9	1.9
1966	2.4	2.4
1967	13.6	13.6
1968	18.0	18.0
1969	27.4	27.4
1970	25.3	25.3
1971	20.4	20.4
1972	16.4	16.4
1973	12.7	12.7
1974	14.6	14.6
1975	17.0	17.0
1976	28.1	28.1
1977	33.8	33.8
1978	21.1	21.1
1979	18.0	18.1
1980	13.4	13.4
1981	5.0	5.0
1982	2.4	2.4
1983	0.5	0.5
1984	1.4	1.4
1987	1.0	1.0
1988	3.2	3.2
1989	10.9	10.9

Table 52. Estimated retained catch biomass (1,000's t; 1990+).

y	22.03	22.03b
1990	17.6	17.6
1991	14.1	14.1
1992	15.6	15.6
1993	7.6	7.6
1994	3.6	3.6
1995	1.9	1.9
1996	0.8	0.8
2005	0.4	0.4
2006	1.0	1.0
2007	1.0	1.0
2008	0.9	0.9
2009	0.6	0.6
2013	1.3	1.3
2014	6.2	6.2
2015	8.9	8.9
2017	1.1	1.1
2018	1.1	1.1
2020	0.7	0.7
2021	0.5	0.5
2022	–	0.9

Table 53. Estimated discard catch mortality (abundance) in the directed fishery (millions; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.10	1.05	0.10	1.14
1966	0.13	1.36	0.13	1.48
1967	0.90	8.87	0.90	9.66
1968	1.77	16.23	1.77	17.68
1969	6.52	50.02	6.51	54.49
1970	42.13	189.36	41.53	204.04
1971	91.22	290.11	86.41	306.34
1972	9.67	53.75	9.01	55.21
1973	1.53	11.56	1.50	12.44
1974	1.11	9.18	1.09	9.90
1975	1.16	9.75	1.13	10.49
1976	2.14	17.81	2.08	19.05
1977	3.83	29.73	3.67	31.33
1978	4.33	30.14	4.00	30.77
1979	6.55	41.76	5.85	41.65
1980	4.79	30.02	4.37	30.73
1981	0.78	5.48	0.75	5.87
1982	0.20	1.51	0.19	1.63
1983	0.03	0.25	0.03	0.27
1984	0.09	0.61	0.08	0.66
1987	0.07	0.58	0.07	0.63
1988	0.21	2.01	0.21	2.18
1989	0.80	7.53	0.79	8.16

Table 54. Estimated discard catch mortality in abundance in the directed fishery (millions; 1990+).

		22.03		22.03b
y	female	male	female	male
1990	0.93	5.90	0.93	6.23
1991	1.41	4.23	1.41	4.21
1992	1.52	4.77	1.51	4.71
1993	0.92	2.36	0.93	2.36
1994	0.89	1.84	0.89	1.84
1995	0.62	1.34	0.62	1.34
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.75
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.63	0.10	0.64
2007	0.10	0.79	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.42
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.11	1.31	0.10	1.30
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.17
2021	0.04	0.22	0.04	0.22
2022	–	–	0.06	0.36

Table 55. Estimated discard mortality (biomass) in the directed fishery (1,000's t; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.05	0.60	0.05	0.61
1966	0.06	0.67	0.06	0.68
1967	0.11	1.76	0.11	1.86
1968	0.17	2.81	0.17	2.98
1969	0.45	7.24	0.45	7.77
1970	2.32	22.53	2.29	23.97
1971	4.77	30.54	4.53	32.12
1972	0.65	7.47	0.62	7.63
1973	0.71	5.05	0.71	5.18
1974	0.86	6.32	0.86	6.42
1975	0.37	3.83	0.37	3.94
1976	0.29	4.31	0.29	4.49
1977	0.34	5.51	0.34	5.73
1978	0.34	4.99	0.33	5.07
1979	0.52	6.48	0.48	6.46
1980	0.38	4.78	0.35	4.88
1981	0.12	1.62	0.12	1.68
1982	0.04	0.58	0.04	0.60
1983	0.04	0.30	0.04	0.30
1984	0.03	0.37	0.03	0.38
1985	0.03	0.33	0.03	0.33
1986	0.04	0.52	0.04	0.51
1987	0.04	0.60	0.04	0.60
1988	0.04	0.79	0.04	0.80
1989	0.09	1.84	0.09	1.91

Table 56. Estimated discard mortality (biomass) in the directed fishery (1,000's t; 1990+).

		22.03		22.03b
y	female	male	female	male
1990	0.170	3.289	0.168	3.455
1991	0.256	2.245	0.256	2.226
1992	0.295	2.621	0.291	2.578
1993	0.183	1.337	0.183	1.331
1994	0.151	0.871	0.150	0.864
1995	0.095	0.601	0.094	0.596
1996	0.070	0.410	0.070	0.408
1997	0.048	0.522	0.048	0.519
1998	0.033	0.314	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.278	0.027	0.277
2002	0.015	0.151	0.015	0.150
2003	0.010	0.102	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.312	0.015	0.313
2007	0.017	0.397	0.017	0.399
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.006	0.211	0.007	0.211
2011	0.009	0.290	0.009	0.290
2012	0.006	0.208	0.006	0.207
2013	0.010	0.241	0.010	0.240
2014	0.022	0.683	0.021	0.679
2015	0.022	0.671	0.022	0.666
2016	0.010	0.357	0.010	0.357
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.091	0.006	0.090
2022	–	–	0.008	0.151

Table 57. Estimated discard catch mortality (abundance) in the snow crab fishery (millions; 1965-1989).

	22.03		22.03b	
y	female	male	female	male
1965	0.05	0.42	0.05	0.42
1966	0.05	0.44	0.06	0.45
1967	0.06	0.46	0.06	0.47
1968	0.07	0.48	0.07	0.49
1969	0.09	0.50	0.09	0.51
1970	0.12	0.47	0.12	0.48
1971	0.15	0.50	0.15	0.52
1972	0.17	0.78	0.18	0.82
1973	0.18	1.09	0.19	1.15
1974	0.17	1.17	0.18	1.23
1975	0.15	1.07	0.15	1.12
1976	0.13	0.89	0.13	0.94
1977	0.11	0.69	0.11	0.73
1978	0.21	1.13	0.21	1.14
1979	0.29	1.45	0.29	1.47
1980	0.44	2.27	0.45	2.30
1981	0.38	2.21	0.38	2.24
1982	0.17	1.12	0.17	1.13
1983	0.07	0.48	0.07	0.49
1984	0.11	0.71	0.11	0.71
1985	0.15	0.99	0.15	0.98
1986	0.21	1.35	0.21	1.34
1987	0.31	2.11	0.31	2.09
1988	0.32	2.36	0.32	2.32
1989	0.49	3.58	0.49	3.53

Table 58. Estimated discard catch mortality in abundance in the snow crab fishery (millions; 1990+).

		22.03		22.03b
y	female	male	female	male
1990	0.93	5.90	0.93	6.23
1991	1.41	4.23	1.41	4.21
1992	1.52	4.77	1.51	4.71
1993	0.92	2.36	0.93	2.36
1994	0.89	1.84	0.89	1.84
1995	0.62	1.34	0.62	1.34
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.75
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.63	0.10	0.64
2007	0.10	0.79	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.42
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.11	1.31	0.10	1.30
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.17
2021	0.04	0.22	0.04	0.22
2022	–	–	0.06	0.36

Table 59. Estimated discard mortality (biomass) in the snow crab fishery (1,000's t; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.05	0.60	0.05	0.61
1966	0.06	0.67	0.06	0.68
1967	0.11	1.76	0.11	1.86
1968	0.17	2.81	0.17	2.98
1969	0.45	7.24	0.45	7.77
1970	2.32	22.53	2.29	23.97
1971	4.77	30.54	4.53	32.12
1972	0.65	7.47	0.62	7.63
1973	0.71	5.05	0.71	5.18
1974	0.86	6.32	0.86	6.42
1975	0.37	3.83	0.37	3.94
1976	0.29	4.31	0.29	4.49
1977	0.34	5.51	0.34	5.73
1978	0.34	4.99	0.33	5.07
1979	0.52	6.48	0.48	6.46
1980	0.38	4.78	0.35	4.88
1981	0.12	1.62	0.12	1.68
1982	0.04	0.58	0.04	0.60
1983	0.04	0.30	0.04	0.30
1984	0.03	0.37	0.03	0.38
1985	0.03	0.33	0.03	0.33
1986	0.04	0.52	0.04	0.51
1987	0.04	0.60	0.04	0.60
1988	0.04	0.79	0.04	0.80
1989	0.09	1.84	0.09	1.91

Table 60. Estimated discard mortality (biomass) in the snow crab fishery (1,000's t; 1990+).

	22.03		22.03b	
y	female	male	female	male
1990	0.170	3.289	0.168	3.455
1991	0.256	2.245	0.256	2.226
1992	0.295	2.621	0.291	2.578
1993	0.183	1.337	0.183	1.331
1994	0.151	0.871	0.150	0.864
1995	0.095	0.601	0.094	0.596
1996	0.070	0.410	0.070	0.408
1997	0.048	0.522	0.048	0.519
1998	0.033	0.314	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.278	0.027	0.277
2002	0.015	0.151	0.015	0.150
2003	0.010	0.102	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.312	0.015	0.313
2007	0.017	0.397	0.017	0.399
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.006	0.211	0.007	0.211
2011	0.009	0.290	0.009	0.290
2012	0.006	0.208	0.006	0.207
2013	0.010	0.241	0.010	0.240
2014	0.022	0.683	0.021	0.679
2015	0.022	0.671	0.022	0.666
2016	0.010	0.357	0.010	0.357
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.091	0.006	0.090
2022	–	–	0.008	0.151

Table 61. Estimated discard catch mortality (abundance) in the BBRKC fishery (millions; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.024	0.556	0.024	0.540
1966	0.026	0.581	0.025	0.564
1967	0.029	0.551	0.028	0.535
1968	0.043	0.598	0.042	0.581
1969	0.046	0.338	0.046	0.328
1970	0.050	0.103	0.051	0.101
1971	0.044	0.046	0.045	0.047
1972	0.099	0.373	0.103	0.391
1973	0.123	1.412	0.126	1.438
1974	0.146	2.390	0.149	2.419
1975	0.133	2.347	0.135	2.368
1976	0.183	2.925	0.186	2.952
1977	0.219	2.508	0.222	2.560
1978	0.169	1.245	0.171	1.298
1979	0.121	0.616	0.123	0.657
1980	0.191	0.977	0.193	1.031
1981	0.158	1.430	0.159	1.463
1982	0.035	0.507	0.035	0.513
1984	0.014	0.252	0.014	0.253
1985	0.009	0.173	0.009	0.173
1986	0.020	0.383	0.020	0.381
1987	0.028	0.533	0.028	0.527
1988	0.023	0.435	0.023	0.428
1989	0.037	0.659	0.037	0.647

Table 62. Estimated discard catch mortality in abundance in the BBRKC fishery (millions; 1990+).

	22.03		22.03b	
y	female	male	female	male
1990	0.93	5.90	0.93	6.23
1991	1.41	4.23	1.41	4.21
1992	1.52	4.77	1.51	4.71
1993	0.92	2.36	0.93	2.36
1994	0.89	1.84	0.89	1.84
1995	0.62	1.34	0.62	1.34
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.75
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.63	0.10	0.64
2007	0.10	0.79	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.42
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.11	1.31	0.10	1.30
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.17
2021	0.04	0.22	0.04	0.22
2022	–	–	0.06	0.36

Table 63. Estimated discard mortality (biomass) in the BBRKC fishery (1,000's t; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.05	0.60	0.05	0.61
1966	0.06	0.67	0.06	0.68
1967	0.11	1.76	0.11	1.86
1968	0.17	2.81	0.17	2.98
1969	0.45	7.24	0.45	7.77
1970	2.32	22.53	2.29	23.97
1971	4.77	30.54	4.53	32.12
1972	0.65	7.47	0.62	7.63
1973	0.71	5.05	0.71	5.18
1974	0.86	6.32	0.86	6.42
1975	0.37	3.83	0.37	3.94
1976	0.29	4.31	0.29	4.49
1977	0.34	5.51	0.34	5.73
1978	0.34	4.99	0.33	5.07
1979	0.52	6.48	0.48	6.46
1980	0.38	4.78	0.35	4.88
1981	0.12	1.62	0.12	1.68
1982	0.04	0.58	0.04	0.60
1983	0.04	0.30	0.04	0.30
1984	0.03	0.37	0.03	0.38
1985	0.03	0.33	0.03	0.33
1986	0.04	0.52	0.04	0.51
1987	0.04	0.60	0.04	0.60
1988	0.04	0.79	0.04	0.80
1989	0.09	1.84	0.09	1.91

Table 64. Estimated discard mortality (biomass) in the BBRKC fishery (1,000's t; 1990+).

		22.03		22.03b
y	female	male	female	male
1990	0.170	3.289	0.168	3.455
1991	0.256	2.245	0.256	2.226
1992	0.295	2.621	0.291	2.578
1993	0.183	1.337	0.183	1.331
1994	0.151	0.871	0.150	0.864
1995	0.095	0.601	0.094	0.596
1996	0.070	0.410	0.070	0.408
1997	0.048	0.522	0.048	0.519
1998	0.033	0.314	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.278	0.027	0.277
2002	0.015	0.151	0.015	0.150
2003	0.010	0.102	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.312	0.015	0.313
2007	0.017	0.397	0.017	0.399
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.006	0.211	0.007	0.211
2011	0.009	0.290	0.009	0.290
2012	0.006	0.208	0.006	0.207
2013	0.010	0.241	0.010	0.240
2014	0.022	0.683	0.021	0.679
2015	0.022	0.671	0.022	0.666
2016	0.010	0.357	0.010	0.357
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.091	0.006	0.090
2022	–	–	0.008	0.151

Table 65. Estimated discard catch mortality (abundance) in the groundfish fisheries (millions; 1965-1989).

	22.03		22.03b	
y	female	male	female	male
1965	2.0	3.7	2.0	3.7
1966	2.3	4.3	2.3	4.3
1967	3.1	5.3	3.1	5.3
1968	4.3	6.9	4.4	6.9
1969	5.4	8.6	5.5	8.7
1970	5.9	9.8	6.0	9.9
1971	5.8	9.8	5.9	10.0
1972	5.2	9.7	5.3	9.9
1973	20.4	41.0	20.4	41.0
1974	24.2	49.7	24.1	49.8
1975	9.2	18.5	9.2	18.6
1976	5.4	10.0	5.5	10.1
1977	4.1	7.0	4.2	7.1
1978	3.1	5.4	3.1	5.4
1979	5.3	9.8	5.2	9.8
1980	2.8	5.6	2.8	5.6
1981	1.6	3.3	1.6	3.3
1982	0.5	0.9	0.5	0.9
1983	0.8	1.4	0.8	1.4
1984	1.1	1.7	1.1	1.7
1985	0.8	1.2	0.8	1.2
1986	1.2	2.0	1.2	2.0
1987	1.2	1.9	1.2	1.9
1988	0.8	1.2	0.8	1.2
1989	0.9	1.6	1.0	1.6

Table 66. Estimated discard catch mortality in abundance in the groundfish fisheries (millions; 1990+).

	22.03		22.03b	
y	female	male	female	male
1990	0.93	5.90	0.93	6.23
1991	1.41	4.23	1.41	4.21
1992	1.52	4.77	1.51	4.71
1993	0.92	2.36	0.93	2.36
1994	0.89	1.84	0.89	1.84
1995	0.62	1.34	0.62	1.34
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.75
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.63	0.10	0.64
2007	0.10	0.79	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.42
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.11	1.31	0.10	1.30
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.17
2021	0.04	0.22	0.04	0.22
2022	–	–	0.06	0.36

Table 67. Estimated discard mortality (biomass) in the groundfish fisheries (1,000's t; 1965-1989).

		22.03		22.03b
y	female	male	female	male
1965	0.05	0.60	0.05	0.61
1966	0.06	0.67	0.06	0.68
1967	0.11	1.76	0.11	1.86
1968	0.17	2.81	0.17	2.98
1969	0.45	7.24	0.45	7.77
1970	2.32	22.53	2.29	23.97
1971	4.77	30.54	4.53	32.12
1972	0.65	7.47	0.62	7.63
1973	0.71	5.05	0.71	5.18
1974	0.86	6.32	0.86	6.42
1975	0.37	3.83	0.37	3.94
1976	0.29	4.31	0.29	4.49
1977	0.34	5.51	0.34	5.73
1978	0.34	4.99	0.33	5.07
1979	0.52	6.48	0.48	6.46
1980	0.38	4.78	0.35	4.88
1981	0.12	1.62	0.12	1.68
1982	0.04	0.58	0.04	0.60
1983	0.04	0.30	0.04	0.30
1984	0.03	0.37	0.03	0.38
1985	0.03	0.33	0.03	0.33
1986	0.04	0.52	0.04	0.51
1987	0.04	0.60	0.04	0.60
1988	0.04	0.79	0.04	0.80
1989	0.09	1.84	0.09	1.91

Table 68. Estimated discard mortality (biomass) in the groundfish fisheries (1,000's t; 1990+).

		22.03		22.03b
y	female	male	female	male
1990	0.170	3.289	0.168	3.455
1991	0.256	2.245	0.256	2.226
1992	0.295	2.621	0.291	2.578
1993	0.183	1.337	0.183	1.331
1994	0.151	0.871	0.150	0.864
1995	0.095	0.601	0.094	0.596
1996	0.070	0.410	0.070	0.408
1997	0.048	0.522	0.048	0.519
1998	0.033	0.314	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.278	0.027	0.277
2002	0.015	0.151	0.015	0.150
2003	0.010	0.102	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.312	0.015	0.313
2007	0.017	0.397	0.017	0.399
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.006	0.211	0.007	0.211
2011	0.009	0.290	0.009	0.290
2012	0.006	0.208	0.006	0.207
2013	0.010	0.241	0.010	0.240
2014	0.022	0.683	0.021	0.679
2015	0.022	0.671	0.022	0.666
2016	0.010	0.357	0.010	0.357
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.091	0.006	0.090
2022	–	–	0.008	0.151

Table 69. Estimated abundance in the NMFS EBS survey for females (millions; 1975-2000).

	22.03		22.03b	
y	immature	mature	immature	mature
1975	71.2	243.2	70.8	243.4
1976	86.9	208.7	87.1	208.4
1977	107.0	178.0	107.6	177.4
1978	115.5	160.6	116.3	159.9
1979	105.4	162.2	106.3	161.7
1980	77.9	173.7	78.5	173.8
1981	48.9	138.5	49.1	138.2
1982	80.8	127.8	83.9	130.3
1983	118.2	87.7	123.0	88.9
1984	141.1	60.6	146.6	61.2
1985	168.3	46.7	174.0	47.0
1986	187.5	56.0	193.6	56.5
1987	187.5	70.7	192.8	71.5
1988	167.4	85.3	172.0	86.2
1989	130.2	97.0	133.5	98.0
1990	89.8	104.2	91.9	105.1
1991	56.7	104.2	58.1	105.0
1992	35.9	95.6	36.9	96.3
1993	25.6	81.1	26.6	81.7
1994	23.5	65.6	24.3	66.1
1995	28.5	52.2	29.7	52.6
1996	31.2	42.1	32.4	42.4
1997	47.8	34.9	49.8	35.2
1998	46.5	30.8	48.1	31.1
1999	76.9	29.3	79.9	29.7
2000	73.7	30.3	76.4	30.6

Table 70. Estimated abundance in the NMFS EBS survey for females (millions; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2001	117.0	33.0	121.6	33.4
2002	109.5	37.8	113.4	38.2
2003	149.1	44.7	154.7	45.3
2004	151.6	53.5	156.8	54.1
2005	124.0	63.2	127.7	64.1
2006	91.7	72.9	94.1	73.9
2007	67.0	81.2	68.7	82.2
2008	58.4	81.5	60.4	82.4
2009	131.6	72.9	136.0	73.5
2010	143.9	62.4	147.1	62.9
2011	133.0	58.6	134.8	59.0
2012	99.3	67.0	99.7	67.5
2013	67.7	80.5	67.4	80.8
2014	41.4	83.8	40.9	83.7
2015	30.9	75.0	30.3	74.6
2016	29.4	62.3	28.3	61.7
2017	77.1	51.3	72.4	50.6
2018	87.1	43.0	80.7	42.2
2019	106.7	38.9	98.7	37.8
2020	86.1	42.6	79.9	40.4
2021	108.2	51.3	104.7	47.8
2022	168.4	57.5	178.1	53.0
2023	–	–	236.2	54.6

Table 71. Estimated biomass in the NMFS EBS survey for females (1,000's t; 1975-2000).

	22.03		22.03b	
y	immature	mature	immature	mature
1975	4.4	44.1	4.4	44.1
1976	4.0	38.2	4.0	38.1
1977	4.8	32.5	4.8	32.4
1978	6.3	28.7	6.4	28.5
1979	7.2	28.1	7.3	28.0
1980	6.3	30.0	6.4	30.0
1981	4.1	24.6	4.2	24.5
1982	4.1	22.0	4.2	22.4
1983	3.7	15.4	3.8	15.6
1984	4.3	10.6	4.5	10.7
1985	5.6	7.9	5.8	8.0
1986	6.9	9.0	7.1	9.1
1987	7.6	11.2	7.7	11.3
1988	7.4	13.6	7.6	13.7
1989	6.7	15.7	6.8	15.8
1990	5.4	17.0	5.4	17.1
1991	3.7	17.3	3.8	17.4
1992	2.3	16.2	2.3	16.2
1993	1.4	13.9	1.4	14.0
1994	1.0	11.3	1.0	11.4
1995	1.0	9.0	1.0	9.1
1996	1.1	7.2	1.1	7.3
1997	1.4	6.0	1.5	6.0
1998	1.7	5.2	1.7	5.2
1999	2.3	4.8	2.4	4.9
2000	2.7	4.9	2.8	4.9

Table 72. Estimated biomass in the NMFS EBS survey for females (1,000's t; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2001	3.6	5.3	3.7	5.3
2002	4.1	6.0	4.2	6.0
2003	5.1	7.0	5.2	7.1
2004	5.7	8.4	5.8	8.5
2005	5.8	10.0	5.9	10.1
2006	5.2	11.6	5.4	11.7
2007	4.0	13.1	4.1	13.2
2008	2.7	13.6	2.8	13.7
2009	3.0	12.5	3.1	12.5
2010	4.2	10.7	4.3	10.7
2011	5.5	9.6	5.6	9.7
2012	5.8	10.5	5.8	10.5
2013	4.4	12.7	4.4	12.8
2014	2.6	13.9	2.6	13.8
2015	1.5	12.8	1.5	12.7
2016	1.2	10.8	1.2	10.7
2017	1.8	8.9	1.7	8.7
2018	2.5	7.4	2.3	7.2
2019	3.6	6.5	3.3	6.3
2020	4.1	6.7	3.8	6.4
2021	4.3	8.1	4.0	7.5
2022	4.8	9.3	4.7	8.5
2023	–	–	6.5	8.9

Table 73. Estimated abundance in the NMFS EBS survey for males (millions; 1975-2000).

	22.03		22.03b	
y	immature	mature	immature	mature
1975	127.4	305.2	125.4	308.4
1976	151.0	264.9	149.7	266.7
1977	174.7	215.9	174.0	217.2
1978	181.4	174.5	181.0	176.0
1979	171.3	165.5	171.3	167.8
1980	138.7	178.8	138.5	182.6
1981	94.2	144.5	93.7	147.8
1982	117.4	152.8	118.2	156.6
1983	143.7	107.4	144.3	109.3
1984	166.7	72.1	167.2	73.1
1985	200.0	52.2	200.1	52.8
1986	229.5	65.2	229.4	65.8
1987	237.5	86.6	236.6	87.3
1988	218.7	111.7	217.7	112.3
1989	178.9	131.9	178.0	132.3
1990	132.4	140.5	131.6	140.8
1991	89.1	135.7	88.6	135.9
1992	56.9	125.9	56.6	126.3
1993	37.8	103.8	37.8	104.5
1994	31.1	83.7	31.2	84.3
1995	35.0	66.4	35.2	66.8
1996	37.9	53.1	38.1	53.3
1997	56.3	43.9	56.5	44.0
1998	56.5	38.5	56.7	38.6
1999	90.5	36.9	90.8	37.0
2000	90.1	38.7	90.3	38.8

Table 74. Estimated abundance in the NMFS EBS survey for males (millions; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2001	138.4	43.2	138.8	43.3
2002	134.5	49.9	134.9	50.0
2003	180.5	59.9	180.9	60.0
2004	187.7	73.0	187.8	73.1
2005	162.3	88.0	162.3	88.1
2006	129.7	103.2	129.4	103.3
2007	101.5	116.7	101.0	116.9
2008	83.0	124.5	82.7	124.4
2009	151.3	118.2	150.5	117.6
2010	165.2	102.2	163.2	101.2
2011	162.6	90.1	160.2	89.1
2012	138.9	92.5	136.3	91.7
2013	107.2	111.4	104.1	110.6
2014	67.0	127.2	64.4	125.6
2015	44.2	118.8	42.1	116.6
2016	38.2	96.1	35.8	93.8
2017	87.8	79.2	79.6	76.9
2018	100.0	65.7	89.7	63.4
2019	125.4	56.8	112.4	54.2
2020	112.0	56.9	100.8	53.6
2021	139.3	67.9	129.0	62.8
2022	200.5	81.8	201.6	74.5
2023	–	–	262.2	80.1

Table 75. Estimated biomass in the NMFS EBS survey for males (1,000's t; 1975-2000).

		22.03		22.03b
y	immature	mature	immature	mature
1975	16.8	164.3	16.3	164.1
1976	13.3	143.4	12.9	142.6
1977	13.3	112.5	13.1	112.0
1978	17.1	82.4	16.8	82.5
1979	22.3	72.2	22.0	72.8
1980	23.7	77.5	23.4	78.7
1981	18.3	69.1	18.0	70.1
1982	15.8	77.7	15.7	78.6
1983	10.1	59.0	10.0	59.2
1984	9.5	40.2	9.5	40.2
1985	11.8	27.7	11.7	27.6
1986	15.7	32.2	15.5	32.0
1987	19.2	40.8	18.9	40.5
1988	20.2	53.2	19.8	52.7
1989	19.5	63.8	19.1	63.0
1990	17.4	66.8	17.0	65.9
1991	13.6	62.5	13.3	61.8
1992	9.0	58.4	8.8	57.8
1993	5.2	47.3	5.1	47.1
1994	3.2	38.2	3.1	38.1
1995	2.5	30.4	2.5	30.3
1996	2.6	24.2	2.6	24.1
1997	3.1	19.9	3.1	19.8
1998	3.8	17.5	3.8	17.4
1999	5.0	16.8	5.0	16.7
2000	6.2	17.8	6.1	17.6

Table 76. Estimated biomass in the NMFS EBS survey for males (1,000's t; 2001+).

	22.03		22.03b	
y	immature	mature	immature	mature
2001	7.9	20.0	7.8	19.8
2002	9.5	23.3	9.4	23.0
2003	11.8	28.0	11.6	27.6
2004	13.7	34.5	13.6	34.0
2005	15.0	42.0	14.8	41.4
2006	15.2	50.0	15.0	49.3
2007	14.1	57.3	13.8	56.4
2008	10.3	63.6	10.1	62.5
2009	7.4	63.5	7.3	62.1
2010	7.7	55.8	7.5	54.4
2011	11.0	47.6	10.8	46.3
2012	15.4	45.0	15.0	43.9
2013	16.1	52.8	15.5	51.6
2014	11.1	64.2	10.6	62.4
2015	5.8	63.1	5.5	61.0
2016	3.6	51.3	3.4	49.4
2017	3.8	42.6	3.5	40.7
2018	4.6	35.0	4.2	33.2
2019	6.8	29.4	6.1	27.7
2020	9.8	27.4	8.7	25.6
2021	12.0	31.3	10.6	28.7
2022	12.2	39.6	11.1	35.6
2023	–	–	12.3	39.8

Table 77. Estimated abundance in the BSFRF SBS survey for females (millions; 2001+).

	22.03		22.03b	
y	immature	mature	immature	mature
2013	11.3	44.2	11.9	47.1
2014	7.7	28.0	8.0	29.7
2015	5.6	27.9	5.7	29.5
2016	18.2	96.6	18.6	101.8
2017	261.9	147.9	255.6	155.4

Table 78. Estimated biomass in the BSFRF SBS survey for females (1,000's t; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2013	1.0	9.6	1.1	10.2
2014	0.5	6.2	0.5	6.6
2015	0.3	6.7	0.3	7.1
2016	1.2	18.8	1.2	19.8
2017	5.9	23.3	5.9	24.5

Table 79. Estimated abundance in the BSFRF SBS survey for males (millions; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2013	42.9	63.9	44.7	67.4
2014	23.0	84.9	23.6	88.7
2015	16.3	67.0	16.7	69.9
2016	19.1	100.1	19.5	105.2
2017	221.2	110.1	216.2	114.8

Table 80. Estimated biomass in the BSFRF SBS survey for males (1,000's t; 2001+).

		22.03		22.03b
y	immature	mature	immature	mature
2013	7.1	34.2	7.3	35.5
2014	5.3	51.3	5.3	52.7
2015	2.7	40.1	2.7	41.0
2016	3.5	50.2	3.6	51.9
2017	7.9	50.7	7.8	52.3

Table 81. Estimated population abundance (millions; 1948-1990).

						22.03						22.03b
			female			male			female			male
	immature		mature	immature		mature	immature		mature	immature		mature
y	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell
1949	269.1	–	–	269.1	–	–	290.8	–	–	290.8	–	–
1950	481.1	0.6	–	481.2	0.5	–	519.8	0.7	–	520.0	0.5	–
1951	640.5	8.7	0.5	644.8	4.6	0.3	692.0	9.3	0.5	696.8	4.7	0.3
1952	738.8	36.2	6.7	758.1	20.6	3.6	798.1	39.0	7.2	819.0	22.3	3.7
1953	779.7	73.1	31.5	817.2	51.1	17.7	842.2	79.0	33.9	882.2	55.7	19.0
1954	792.2	94.5	76.8	837.5	78.7	50.3	855.5	102.0	82.7	903.6	85.3	54.3
1955	798.9	100.3	125.6	845.4	89.4	94.0	862.7	108.3	135.4	912.0	96.6	101.3
1956	807.5	101.4	165.8	854.1	91.1	133.4	871.7	109.4	178.6	921.2	98.4	143.3
1957	819.4	102.0	196.0	866.4	91.6	163.0	884.3	110.0	211.1	934.2	98.9	174.8
1958	836.1	102.8	218.7	883.5	92.2	184.9	902.0	110.9	235.3	952.3	99.6	197.9
1959	859.1	104.1	235.9	907.1	93.2	201.2	926.5	112.3	253.8	977.4	100.6	215.1
1960	890.8	105.8	249.5	939.6	94.6	213.8	960.1	114.1	268.3	1011.9	102.1	228.3
1961	934.6	108.2	260.7	984.5	96.5	223.8	1006.9	116.6	280.2	1059.9	104.1	238.8
1962	996.6	111.5	270.7	1048.1	99.1	232.4	1073.1	120.2	290.9	1127.8	106.9	247.7
1963	1087.9	116.1	280.5	1141.7	102.7	240.3	1171.1	125.0	301.2	1228.1	110.8	256.0
1964	1232.3	122.5	291.0	1289.2	107.8	248.5	1326.8	131.8	312.4	1387.1	116.1	264.6
1965	1487.7	131.6	303.3	1548.9	114.9	258.1	1604.3	141.6	325.5	1669.2	123.8	274.7
1966	2004.1	145.4	319.1	2072.0	125.5	270.0	2170.3	156.4	342.3	2242.4	135.1	287.3
1967	3104.2	168.1	340.8	3183.2	142.5	285.8	3389.5	180.9	365.4	3473.5	153.4	304.1
1968	4548.5	210.2	372.7	4648.2	172.2	294.1	4998.4	226.7	399.7	5104.8	185.6	313.4
1969	4741.9	294.6	426.4	4883.9	230.2	312.2	5199.5	319.4	457.7	5352.4	249.2	333.4
1970	4122.6	442.6	523.9	4339.9	332.8	334.0	4508.1	483.5	564.5	4743.3	363.6	358.2
1971	3261.2	602.7	676.8	3553.6	448.9	335.0	3551.1	662.0	736.2	3867.3	495.6	362.7
1972	2310.6	638.2	869.6	2603.6	501.6	381.5	2509.0	702.1	959.3	2824.4	558.3	421.4
1973	1560.6	523.8	1099.1	1787.1	515.0	594.5	1692.8	572.3	1210.8	1934.3	565.4	660.8
1974	1237.6	357.4	1181.3	1383.0	378.8	776.2	1337.8	387.9	1297.5	1492.0	411.7	856.8
1975	1382.4	236.3	1116.4	1477.6	245.7	799.9	1499.2	255.7	1222.5	1600.3	266.0	877.9
1976	2111.3	165.8	988.3	2179.8	169.1	733.6	2315.4	179.6	1079.1	2388.5	182.8	801.2
1977	2359.3	145.4	844.0	2423.3	133.9	616.9	2595.7	157.5	919.8	2664.2	144.7	672.1
1978	1982.2	188.0	722.5	2072.3	147.2	492.3	2175.5	204.2	786.2	2272.8	159.9	536.8
1979	1428.2	274.2	664.5	1563.9	208.6	423.3	1569.2	300.3	722.6	1716.0	229.1	462.4
1980	938.0	319.2	682.5	1089.9	269.2	411.0	1028.2	351.4	744.1	1192.2	298.0	452.4
1981	638.8	233.6	545.0	751.9	223.2	297.0	697.5	256.5	592.5	818.8	246.4	328.7
1982	487.8	139.5	425.9	548.2	155.3	241.8	530.3	152.5	461.1	594.8	169.8	266.7
1983	789.4	76.5	310.0	822.3	84.9	188.5	854.9	83.3	334.0	890.1	92.2	206.5
1984	925.8	55.9	211.9	952.7	52.3	131.3	1000.9	60.7	227.1	1029.9	56.8	142.8
1985	1082.4	61.3	146.6	1114.3	49.3	86.5	1166.7	66.3	156.5	1200.9	53.5	93.8
1986	1187.4	98.7	152.7	1235.9	75.5	98.9	1279.7	106.6	163.3	1331.6	81.9	106.8
1987	1168.8	134.0	184.4	1234.1	106.9	126.7	1254.9	144.6	197.9	1324.4	116.1	136.6
1988	1018.9	149.8	233.6	1089.1	131.0	168.5	1094.9	161.3	251.0	1169.2	141.5	181.5
1989	762.5	153.8	281.3	833.9	137.6	213.9	819.8	165.4	302.2	895.2	148.2	229.9
1990	507.2	147.5	318.6	574.9	135.1	239.7	545.6	158.4	342.0	616.8	145.4	257.5

Table 82. Estimated population abundance (millions; 1991+).

	22.03						22.03b					
		female			male			female			male	
	immature		mature	immature		mature	immature		mature	immature		mature
y	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell
1991	315.1	124.0	340.3	370.0	120.3	242.6	339.8	133.1	365.0	397.4	129.2	260.9
1992	204.9	87.2	337.4	241.4	92.3	242.7	220.9	93.7	361.8	259.2	99.0	261.3
1993	153.5	51.5	307.6	173.7	58.6	218.0	166.7	55.5	329.9	188.0	62.9	235.7
1994	146.7	28.9	261.2	157.9	33.0	189.7	158.9	31.2	280.1	170.8	35.5	204.8
1995	185.4	19.6	211.4	193.6	19.9	156.9	201.1	21.1	226.7	209.8	21.5	169.0
1996	199.8	17.6	168.6	207.7	16.0	125.7	216.4	19.1	180.8	224.8	17.4	135.1
1997	318.2	19.3	135.7	327.0	16.4	101.1	344.4	20.9	145.6	353.9	17.8	108.5
1998	292.5	23.9	113.4	303.7	19.4	84.0	316.3	25.9	121.7	328.2	21.1	90.0
1999	511.9	30.6	100.6	526.4	24.8	74.7	553.8	33.1	108.0	569.3	26.9	80.0
2000	464.5	39.5	96.3	483.4	32.0	72.6	502.1	42.6	103.4	522.2	34.7	77.7
2001	775.9	48.9	99.6	799.1	40.5	76.2	839.7	52.8	107.1	864.4	43.9	81.5
2002	684.7	61.2	108.9	713.8	50.2	84.8	740.6	66.1	117.1	771.6	54.3	90.7
2003	968.5	76.6	124.9	1005.1	63.1	98.8	1047.5	82.8	134.4	1086.5	68.3	105.7
2004	957.7	92.8	148.1	1001.9	77.7	118.9	1033.9	100.3	159.4	1081.0	84.1	127.2
2005	738.6	107.7	177.1	789.6	91.9	144.1	796.1	116.4	190.6	850.3	99.5	154.2
2006	519.5	118.8	209.3	575.4	103.3	172.2	559.3	128.3	225.3	618.7	111.7	184.3
2007	384.5	123.0	241.0	442.4	109.2	200.4	414.0	132.7	259.5	475.1	118.4	214.4
2008	363.6	95.5	267.5	404.7	99.5	225.0	393.1	102.8	287.8	436.2	107.2	240.9
2009	917.8	56.2	266.7	939.5	66.6	236.9	984.6	60.3	286.6	1007.3	71.1	253.0
2010	939.9	39.5	237.3	956.2	40.0	221.9	999.3	42.4	254.7	1016.8	42.6	235.9
2011	803.5	58.7	203.5	832.2	43.3	192.0	850.4	63.1	218.1	881.3	46.3	203.3
2012	554.8	109.8	192.7	611.5	76.6	172.1	584.9	117.6	206.4	644.8	82.8	181.7
2013	379.0	139.6	222.4	447.3	116.6	182.3	396.0	148.6	237.9	466.9	125.3	193.0
2014	238.0	107.2	266.2	283.5	115.1	217.5	246.6	113.0	283.8	293.2	121.7	230.7
2015	186.9	58.0	274.2	208.5	71.2	234.5	191.4	60.6	291.1	213.4	74.2	247.8
2016	184.0	31.6	244.0	196.4	35.6	211.7	184.3	32.7	258.0	196.8	36.8	222.5
2017	539.0	24.5	202.6	549.9	23.3	180.6	524.6	25.2	213.4	535.6	24.0	188.5
2018	572.6	23.5	166.9	583.2	21.6	148.1	551.0	23.8	175.1	561.6	22.0	153.7
2019	682.4	33.8	140.0	698.7	26.1	123.0	658.7	33.3	146.1	674.6	25.8	126.7
2020	506.5	64.1	127.8	539.4	44.4	109.2	493.4	62.1	131.7	525.0	43.5	111.2
2021	691.1	90.1	141.0	735.7	71.9	112.0	701.9	86.8	142.2	744.0	69.9	112.3
2022	1136.9	87.5	170.0	1176.7	83.0	134.6	1261.1	84.4	168.2	1298.7	79.9	132.6
2023	–	–	–	–	–	–	1634.1	74.6	185.4	1666.3	71.9	154.4

Table 83. Estimated population biomass (1,000's t; 1948-1990).

y	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03 male mature old shell	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03b male mature old shell
1949	3.18	–	–	3.19	–	–	3.44	–	–	3.44	–	–
1950	8.41	0.04	–	8.83	0.03	–	9.08	0.04	–	9.51	0.03	–
1951	15.59	0.84	0.03	18.42	0.56	0.03	16.85	0.90	0.03	19.81	0.60	0.02
1952	22.51	4.35	0.64	31.82	4.41	0.43	24.33	4.68	0.68	34.07	4.82	0.46
1953	26.45	10.24	3.66	43.66	16.66	3.55	28.58	11.04	3.93	46.53	17.98	3.84
1954	27.66	14.54	10.20	48.82	32.76	14.70	29.89	15.68	10.97	51.91	34.95	15.81
1955	27.95	15.97	18.15	49.80	41.02	34.36	30.20	17.21	19.53	52.95	43.57	36.59
1956	28.18	16.21	25.04	50.14	42.50	54.38	30.43	17.47	26.93	53.31	45.11	57.59
1957	28.49	16.31	30.26	50.59	42.73	69.75	30.76	17.57	32.54	53.78	45.35	73.66
1958	28.92	16.43	34.17	51.23	42.99	80.98	31.22	17.70	36.72	54.44	45.62	85.34
1959	29.53	16.61	37.13	52.13	43.37	89.21	31.87	17.89	39.88	55.38	46.02	93.86
1960	30.37	16.87	39.43	53.37	43.91	95.41	32.76	18.16	42.34	56.69	46.59	100.26
1961	31.53	17.22	41.30	55.09	44.68	100.24	33.99	18.54	44.34	58.50	47.39	105.24
1962	33.14	17.71	42.94	57.48	45.73	104.10	35.71	19.06	46.07	61.01	48.49	109.21
1963	35.46	18.39	44.49	60.86	47.19	107.46	38.19	19.77	47.72	64.58	50.02	112.67
1964	38.94	19.32	46.13	65.84	49.20	110.70	41.94	20.76	49.46	69.87	52.13	116.04
1965	44.68	20.65	48.01	73.74	52.01	114.49	48.14	22.18	51.45	78.31	55.09	119.98
1966	55.36	22.62	50.37	87.75	56.05	119.06	59.78	24.29	53.95	93.40	59.37	124.73
1967	77.08	25.79	53.53	115.12	62.21	124.72	83.70	27.70	57.32	123.24	65.92	130.67
1968	112.29	31.48	58.04	161.08	72.01	119.92	122.74	33.87	62.15	173.61	76.43	126.04
1969	144.19	42.78	65.36	213.90	90.67	116.37	158.05	46.26	70.06	231.23	96.65	122.86
1970	160.47	63.78	78.19	263.45	124.97	105.11	176.06	69.45	84.09	284.97	134.29	111.88
1971	150.74	90.06	96.98	284.53	165.75	80.27	165.10	98.73	105.48	306.97	180.16	86.95
1972	117.54	102.09	122.37	251.78	198.45	83.00	128.25	112.32	135.57	270.36	218.61	92.72
1973	81.13	90.56	163.07	187.42	256.96	171.68	88.08	99.00	180.17	199.76	277.90	192.00
1974	56.18	63.79	184.52	125.69	208.10	290.21	60.82	69.26	203.02	133.48	222.56	318.47
1975	46.06	41.96	180.06	91.83	135.29	334.71	49.93	45.35	197.41	97.70	143.96	363.88
1976	52.85	28.82	162.12	86.45	90.59	318.54	57.61	31.16	177.13	92.72	96.14	344.26
1977	66.29	23.29	139.49	98.44	65.31	261.72	72.58	25.20	152.05	106.26	69.50	282.64
1978	75.50	27.38	118.59	119.26	59.66	191.96	82.90	29.67	129.10	128.99	63.90	208.52
1979	72.10	40.16	106.24	134.16	80.15	149.75	79.33	43.84	115.56	145.12	86.54	163.90
1980	54.64	50.52	106.02	123.08	115.23	132.54	60.08	55.50	115.57	132.76	125.26	146.76
1981	34.18	40.81	84.90	86.72	112.38	97.59	37.45	44.77	92.26	93.05	121.85	108.43
1982	21.20	26.26	68.71	50.61	90.14	93.92	23.13	28.69	74.37	54.10	96.87	103.06
1983	20.64	14.19	52.05	36.81	51.06	85.92	22.42	15.44	56.09	39.43	54.50	93.10
1984	24.89	9.32	36.31	38.12	27.55	65.47	26.96	10.12	38.92	40.84	29.44	70.27
1985	32.03	9.26	24.98	47.84	21.72	43.05	34.61	10.01	26.65	51.15	23.26	46.05
1986	38.61	14.26	25.13	61.44	29.55	46.95	41.67	15.39	26.88	65.52	31.66	50.04
1987	41.29	20.16	28.89	71.56	43.02	55.18	44.46	21.74	30.97	75.98	46.04	58.72
1988	40.00	23.62	35.98	72.97	58.31	69.60	43.02	25.41	38.61	77.27	61.99	74.05
1989	35.16	24.59	43.71	68.34	63.88	88.91	37.79	26.41	46.90	72.20	67.66	94.36
1990	27.37	24.10	49.95	58.58	63.97	96.88	29.41	25.84	53.57	61.71	67.65	102.89

Table 84. Estimated population biomass (1,000's t; 1991+).

y	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03 male mature old shell	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03b male mature old shell
1991	18.5	21.1	53.9	43.9	60.0	92.1	20.0	22.6	57.8	46.2	63.2	98.1
1992	11.3	15.6	54.3	28.4	49.8	92.2	12.2	16.7	58.2	29.9	52.4	98.5
1993	7.0	9.6	50.4	16.7	33.7	81.9	7.5	10.3	54.1	17.7	35.5	88.0
1994	5.3	5.3	43.5	10.8	19.5	73.8	5.8	5.8	46.7	11.5	20.5	79.3
1995	5.5	3.4	35.6	9.4	10.8	63.3	5.9	3.6	38.1	10.1	11.5	67.8
1996	6.1	2.8	28.4	9.9	7.7	51.4	6.6	3.1	30.4	10.6	8.2	54.9
1997	8.2	3.0	22.7	12.5	7.3	41.4	8.9	3.2	24.4	13.4	7.8	44.2
1998	9.5	3.6	18.8	15.0	8.1	34.6	10.3	3.9	20.2	16.0	8.7	36.8
1999	13.2	4.6	16.4	20.2	10.3	30.7	14.3	5.0	17.6	21.6	11.0	32.6
2000	15.1	5.9	15.4	24.1	13.3	29.8	16.3	6.4	16.5	25.7	14.2	31.6
2001	20.4	7.4	15.6	31.5	17.1	31.3	22.1	8.0	16.8	33.7	18.3	33.2
2002	23.0	9.2	16.9	36.9	21.2	35.1	24.9	10.0	18.2	39.4	22.6	37.1
2003	28.4	11.6	19.2	45.8	26.5	41.1	30.7	12.5	20.6	48.8	28.3	43.4
2004	31.5	14.2	22.6	52.3	33.4	49.6	34.0	15.3	24.3	55.8	35.5	52.3
2005	30.9	16.7	27.1	55.0	40.1	60.8	33.4	18.0	29.1	58.5	42.8	64.1
2006	27.2	18.6	32.2	53.1	46.5	73.2	29.3	20.0	34.6	56.4	49.4	77.2
2007	20.4	19.8	37.3	46.4	50.4	86.4	22.0	21.4	40.1	49.0	53.6	91.0
2008	14.2	16.9	42.0	33.4	51.7	98.6	15.3	18.2	45.1	35.2	54.7	103.9
2009	18.2	10.5	43.3	29.1	39.2	109.1	19.6	11.3	46.4	30.8	41.1	114.7
2010	24.6	6.5	39.5	33.4	21.7	108.0	26.3	7.0	42.4	35.4	22.8	113.0
2011	30.6	8.0	33.9	45.1	16.3	95.1	32.6	8.6	36.2	47.7	17.3	99.0
2012	30.0	15.3	30.8	55.5	26.1	81.3	31.9	16.3	32.9	58.2	28.0	84.5
2013	22.2	22.0	33.9	52.4	48.5	78.7	23.3	23.4	36.2	54.3	51.4	82.0
2014	12.9	19.3	41.0	34.4	60.5	91.8	13.5	20.3	43.7	35.2	63.0	96.0
2015	8.0	11.2	44.3	18.6	43.2	104.6	8.2	11.7	47.0	18.9	44.3	108.9
2016	6.6	5.8	40.7	12.6	21.2	98.8	6.7	6.0	43.0	12.7	21.6	102.3
2017	10.6	4.1	34.2	15.7	11.9	87.5	10.4	4.2	36.0	15.5	12.1	89.9
2018	14.6	3.7	28.1	20.1	10.1	71.7	14.2	3.8	29.5	19.5	10.2	73.3
2019	20.5	4.7	23.4	28.9	10.3	58.8	19.8	4.7	24.4	27.8	10.2	59.7
2020	22.2	8.8	20.7	37.3	15.1	50.5	21.4	8.5	21.3	35.6	14.7	50.9
2021	23.1	13.7	21.7	43.2	28.4	47.5	22.7	13.2	21.9	41.4	27.3	47.3
2022	27.5	14.5	26.0	46.2	39.6	55.3	28.9	13.9	25.8	46.3	37.4	54.0
2023	–	–	–	–	–	–	40.2	12.2	29.2	56.3	35.1	66.0

Table 85. Comparison of estimates of mature biomass-at-mating by sex (in 1,000's t) from the base and preferred models (model start to 1980).

	female		male	
year	22.03	22.03b	22.03	22.03b
1948	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000
1950	0.033	0.035	0.028	0.027
1951	0.713	0.763	0.485	0.512
1952	4.102	4.412	3.977	4.317
1953	11.443	12.320	16.484	17.763
1954	20.370	21.928	38.527	41.111
1955	28.094	30.231	60.978	64.702
1956	33.960	36.528	78.219	82.747
1957	38.342	41.224	90.808	95.868
1958	41.660	44.775	100.037	105.448
1959	44.243	47.533	106.990	112.638
1960	46.348	49.776	112.410	118.225
1961	48.182	51.725	116.738	122.689
1962	49.928	53.578	120.497	126.577
1963	51.760	55.522	124.139	130.363
1964	53.874	57.763	128.389	134.785
1965	56.515	60.569	133.510	140.130
1966	60.071	64.356	139.860	146.795
1967	65.128	69.778	134.476	141.596
1968	73.341	78.649	130.492	138.024
1969	87.734	94.401	117.871	125.687
1970	108.819	118.414	90.010	97.677
1971	137.306	152.201	93.073	104.160
1972	182.982	202.268	192.519	215.695
1973	207.052	227.929	325.437	357.779
1974	202.041	221.624	375.336	408.791
1975	181.911	198.864	357.206	386.752
1976	156.519	170.706	293.487	317.520
1977	133.074	144.935	215.257	234.259
1978	119.212	129.740	167.924	184.125
1979	118.966	129.741	148.621	164.870
1980	106.301	115.834	127.985	142.452

Table 86. Comparison of estimates of mature biomass-at-mating by sex (in 1,000's t) from the base and preferred models (1981 to model end).

	female		male	
year	22.03	22.03b	22.03	22.03b
1981	86.0	93.4	123.2	135.4
1982	65.2	70.4	112.7	122.3
1983	45.5	48.9	85.9	92.3
1984	31.3	33.5	56.5	60.5
1985	28.2	30.2	52.6	56.2
1986	32.4	34.8	61.9	66.0
1987	40.4	43.3	78.0	83.2
1988	49.0	52.7	99.7	106.0
1989	56.1	60.1	108.6	115.6
1990	60.5	64.9	103.2	110.2
1991	61.0	65.4	103.3	110.6
1992	56.6	60.7	91.8	98.9
1993	48.8	52.4	82.8	89.0
1994	39.9	42.8	71.0	76.2
1995	31.9	34.2	57.6	61.7
1996	25.5	27.4	46.5	49.6
1997	21.1	22.6	38.8	41.3
1998	18.4	19.7	34.5	36.6
1999	17.3	18.5	33.5	35.5
2000	17.6	18.9	35.1	37.2
2001	19.0	20.4	39.3	41.6
2002	21.5	23.1	46.1	48.7
2003	25.4	27.3	55.6	58.8
2004	30.4	32.6	68.1	72.0
2005	36.1	38.8	82.1	86.8
2006	41.8	45.0	96.8	102.2
2007	47.1	50.6	110.6	116.8
2008	48.5	52.1	122.4	128.8
2009	44.3	47.6	121.1	126.9
2010	38.0	40.7	106.6	111.2
2011	34.5	37.0	91.2	94.9
2012	38.0	40.6	88.2	92.1
2013	46.0	49.1	103.0	107.8
2014	49.7	52.7	117.3	122.4
2015	45.7	48.3	110.8	114.9
2016	38.3	40.4	98.1	101.0
2017	31.5	33.1	80.4	82.3
2018	26.2	27.4	65.9	67.1
2019	23.2	24.0	56.6	57.2
2020	24.3	24.6	53.3	53.1
2021	29.2	28.9	62.0	60.7
2022	–	32.7	–	74.2

Table 87. Comparison of estimates of recruitment (in millions) from the base and preferred models (model start to 1980)

year	22.03	22.03b
1949	538.2	581.6
1950	538.7	582.0
1951	539.7	583.1
1952	541.5	585.0
1953	544.3	587.9
1954	548.5	592.4
1955	554.5	598.7
1956	562.9	607.7
1957	574.7	620.1
1958	591.0	637.4
1959	613.2	661.1
1960	643.8	693.6
1961	686.4	739.2
1962	748.1	805.3
1963	842.4	906.8
1964	1000.1	1077.5
1965	1301.8	1406.8
1966	1960.0	2131.7
1967	3392.1	3727.6
1968	4631.4	5116.1
1969	2913.2	3171.4
1970	1675.9	1810.8
1971	1269.0	1364.2
1972	813.6	884.9
1973	555.9	608.0
1974	760.8	815.7
1975	1311.1	1427.0
1976	2386.2	2639.1
1977	1688.1	1864.5
1978	629.4	677.6
1979	293.5	324.9
1980	282.5	307.5

Table 88. Comparison of estimates of recruitment (in millions) from the base and preferred models (1981 to model end).

year	22.03	22.03b
1981	335.3	364.6
1982	288.2	311.5
1983	984.4	1064.4
1984	734.0	792.6
1985	844.9	906.9
1986	869.3	937.8
1987	739.5	788.6
1988	501.7	541.9
1989	233.1	252.2
1990	114.7	123.7
1991	85.5	93.2
1992	93.3	99.9
1993	90.7	100.2
1994	111.0	119.5
1995	180.2	195.6
1996	144.0	155.4
1997	361.6	391.4
1998	132.0	142.4
1999	625.3	676.8
2000	202.1	217.8
2001	919.1	995.8
2002	270.5	291.9
2003	1013.6	1096.4
2004	576.9	620.5
2005	186.6	199.7
2006	117.0	125.6
2007	201.6	218.0
2008	316.2	344.0
2009	1377.0	1472.7
2010	511.6	531.4
2011	243.5	253.0
2012	66.6	69.1
2013	168.8	174.0
2014	97.7	100.5
2015	117.3	118.1
2016	137.9	133.6
2017	837.6	810.1
2018	342.6	322.9
2019	530.2	516.0
2020	67.1	74.7
2021	767.6	803.3
2022	1362.5	1587.6
2023	–	1430.8

Table 89. Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (model start to 1980).

year	22.03	22.03b
1949	0.00055	0.00051
1950	0.00096	0.00089
1951	0.00159	0.00147
1952	0.00244	0.00227
1953	0.00412	0.00387
1954	0.00651	0.00616
1955	0.00861	0.00817
1956	0.00993	0.00943
1957	0.01034	0.00984
1958	0.01075	0.01022
1959	0.01086	0.01033
1960	0.01100	0.01047
1961	0.01166	0.01107
1962	0.01230	0.01165
1963	0.01292	0.01222
1964	0.01264	0.01195
1965	0.01285	0.01216
1966	0.01374	0.01301
1967	0.04597	0.04390
1968	0.05388	0.05143
1969	0.08634	0.08307
1970	0.15671	0.15146
1971	0.18617	0.17703
1972	0.05584	0.05158
1973	0.03758	0.03493
1974	0.04660	0.04335
1975	0.04074	0.03811
1976	0.06297	0.05911
1977	0.08746	0.08198
1978	0.07169	0.06636
1979	0.07895	0.07226
1980	0.05849	0.05400

Table 90. Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (from 1981 to model end).

year	22.03	22.03b
1981	0.0262	0.0245
1982	0.0139	0.0130
1983	0.0059	0.0056
1984	0.0151	0.0142
1985	0.0061	0.0057
1986	0.0078	0.0072
1987	0.0137	0.0128
1988	0.0216	0.0204
1989	0.0573	0.0547
1990	0.0979	0.0940
1991	0.0832	0.0780
1992	0.1085	0.1012
1993	0.0687	0.0641
1994	0.0419	0.0390
1995	0.0315	0.0293
1996	0.0258	0.0240
1997	0.0180	0.0167
1998	0.0116	0.0108
1999	0.0055	0.0051
2000	0.0061	0.0057
2001	0.0074	0.0069
2002	0.0035	0.0033
2003	0.0019	0.0018
2004	0.0027	0.0025
2005	0.0060	0.0057
2006	0.0091	0.0085
2007	0.0100	0.0095
2008	0.0076	0.0072
2009	0.0060	0.0056
2010	0.0028	0.0026
2011	0.0039	0.0037
2012	0.0027	0.0025
2013	0.0088	0.0084
2014	0.0348	0.0332
2015	0.0508	0.0488
2016	0.0059	0.0057
2017	0.0108	0.0105
2018	0.0115	0.0113
2019	0.0031	0.0032
2020	0.0062	0.0063
2021	0.0044	0.0045
2022	–	0.0060

Table 91. Comparison of RMSEs from fits to fishery catch data, survey data, and molt increment data.

				all sexes		female				male			
				all		immature		mature		all		immature	
category	fleet	catch type	data type	22.03	22.03b	22.03	22.03b	22.03	22.03b	22.03	22.03b	22.03	22.03b
fisheries data	GF All	total catch	abundance	0.893	0.880	–	–	–	–	–	–	–	–
			biomass	0.653	0.656	–	–	–	–	–	–	–	–
	RKF	total catch	abundance	0.706	0.706	–	–	–	–	–	–	–	–
			biomass	0.222	0.224	–	–	–	–	–	–	–	–
	SCF	total catch	abundance	1.088	1.090	–	–	–	–	–	–	–	–
			biomass	0.152	0.150	–	–	–	–	–	–	–	–
	TCF	retained catch	abundance	–	–	–	–	–	–	5.158	5.285	–	–
			biomass	–	–	–	–	–	–	0.381	0.376	–	–
		total catch	abundance	2.284	2.217	–	–	–	–	–	–	–	–
			biomass	2.016	1.957	–	–	–	–	–	–	–	–
growth data	–	–	molt incr.	–	–	0.301	0.303	–	–	–	–	0.526	0.528
surveys data	NMFS F	index catch	abundance	–	–	3.115	3.143	2.463	2.444	–	–	–	–
			biomass	–	–	2.814	2.823	2.315	2.290	–	–	–	–
	NMFS M	index catch	abundance	–	–	–	–	–	–	3.363	3.380	–	–
			biomass	–	–	–	–	–	–	2.624	2.684	–	–
	SBS BSFRF F	index catch	abundance	–	–	2.054	2.039	1.525	1.676	–	–	–	–
			biomass	–	–	0.981	1.004	1.690	1.840	–	–	–	–
	SBS BSFRF M	index catch	abundance	–	–	–	–	–	–	1.793	1.832	–	–
			biomass	–	–	–	–	–	–	1.558	1.601	–	–

Table 92. Observed and random walk model-estimated time series for vulnerable male biomass from the NMFS EBS shelf survey. All values are in 1,000s t. lci: lower confidence interval; uci: upper confidence interval. Confidence intervals are 80%.

year	observed value	lci	uci	rema value	lci	uci
1975	269.1	174.6	414.7	206.1	146.6	289.6
1976	139.5	115.1	169.0	142.8	120.0	170.0
1977	119.2	100.9	140.7	116.9	100.4	136.2
1978	82.6	70.0	97.5	80.5	69.1	93.6
1979	37.5	31.3	44.9	43.3	36.7	51.1
1980	88.7	69.5	113.3	72.9	59.2	89.8
1981	51.8	44.2	60.7	53.1	45.8	61.4
1982	51.7	43.0	62.3	49.1	41.6	58.1
1983	30.2	24.9	36.7	31.0	26.1	36.9
1984	24.2	20.3	28.9	23.4	19.9	27.4
1985	11.7	9.6	14.2	13.0	10.9	15.6
1986	13.6	10.1	18.4	15.2	12.0	19.2
1987	22.9	19.0	27.7	24.3	20.4	28.8
1988	68.1	48.4	96.0	58.1	45.0	75.0
1989	104.4	87.3	124.8	98.4	83.6	115.9
1990	103.2	85.2	125.0	103.5	87.2	122.9
1991	116.7	90.0	151.5	111.2	89.5	138.2
1992	112.2	82.1	153.4	99.4	77.8	127.0
1993	64.2	52.6	78.4	64.6	54.1	77.1
1994	43.1	36.5	50.9	43.4	37.3	50.5
1995	31.1	24.7	39.2	31.2	25.6	38.0
1996	26.0	19.1	35.4	22.6	17.8	28.8
1997	10.7	9.2	12.5	11.4	9.8	13.1
1998	10.5	9.1	12.0	10.6	9.3	12.1
1999	11.8	9.2	15.0	12.2	9.9	14.9
2000	16.9	12.4	23.0	15.8	12.4	20.2
2001	17.5	14.4	21.2	17.3	14.5	20.5
2002	16.5	13.5	20.2	17.2	14.4	20.5
2003	21.8	17.9	26.5	21.7	18.2	25.9
2004	25.6	20.4	32.2	26.9	22.1	32.8
2005	43.4	36.2	52.1	42.6	36.1	50.2
2006	60.9	48.1	77.0	58.1	47.4	71.1
2007	67.5	50.8	89.7	63.6	50.4	80.3
2008	66.9	46.7	95.9	57.9	44.4	75.5
2009	37.2	30.5	45.4	39.5	33.1	47.3
2010	40.0	31.1	51.3	40.1	32.5	49.5
2011	41.1	30.6	55.2	41.2	32.6	52.1
2012	39.3	31.5	49.0	42.7	35.2	51.9
2013	76.2	55.3	104.9	68.8	53.9	87.9
2014	88.8	77.9	101.2	85.9	75.9	97.3
2015	64.5	57.1	73.0	65.3	58.1	73.4
2016	60.4	53.6	68.1	60.0	53.5	67.2
2017	48.2	41.7	55.7	48.0	42.0	54.9
2018	37.8	32.9	43.4	36.8	32.3	41.8
2019	18.3	15.7	21.3	19.3	16.7	22.3
2020	— —	— —	— —	18.3	12.6	26.6
2021	17.2	14.7	20.0	17.4	15.1	20.2
2022	19.9	16.9	23.5	19.6	16.9	22.7

(continued)

	observed			rema		
year	value	lci	uci	value	lci	uci
2023	18.6	16.6	20.9	18.7	16.7	20.9

Table 93. Tier 4 management quantities for candidate B_{MSY} averaging periods. Biomass quantities (B, B_{MSY}, OFL) are in 1,000s t.

time block	M	B	Bmsy	status	Fofl	OFL
1975:2023	0.23	18.68	50.63	0.37	0.07	1.24
1975:1980	0.23	18.68	110.42	0.17	NA	NA
1982:2023	0.23	18.68	42.03	0.44	0.09	1.57
1987:1995,2005:2009,2013:2015	0.23	18.68	65.64	0.28	0.05	0.86
2005:2009,2013:2015	0.23	18.68	60.21	0.31	0.05	0.98

Figures

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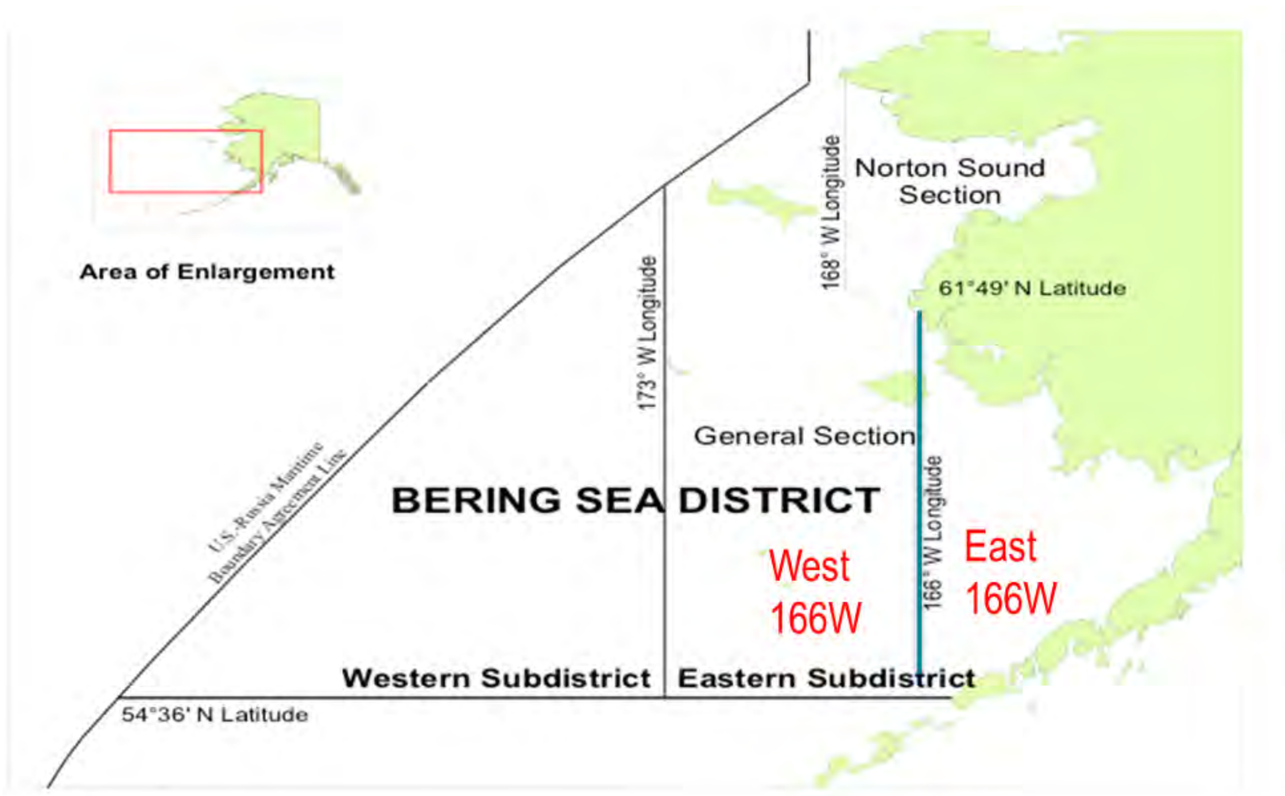


Figure 1. Eastern Bering Sea District of the ADFG Tanner crab Registration Area J, including sub-districts and sections (from Bowers et al. 2008). Separate TACs are set annually for the areas east and west of 166^{o}W in the General Section. These management areas are identified in the text, tables, and figures as 'East 166W' and 'West 166W', respectively based on the split at 166^{o}W longitude.

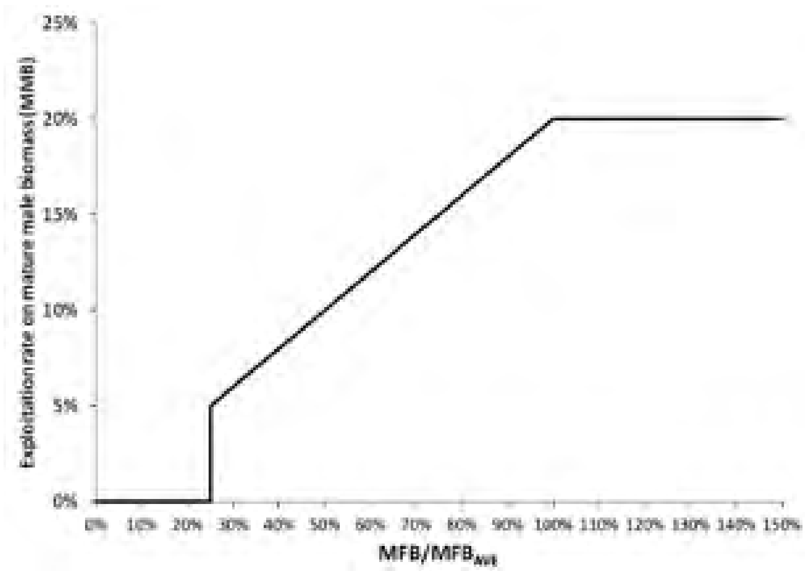


Figure 2. Sloping control rule used by ADFG from 2011 to 2019 as part of its TAC setting process to determine the maximum exploitation rate on mature male biomass as a function of the ratio of current mature female biomass (MFB) to MFB averaged over some time period.

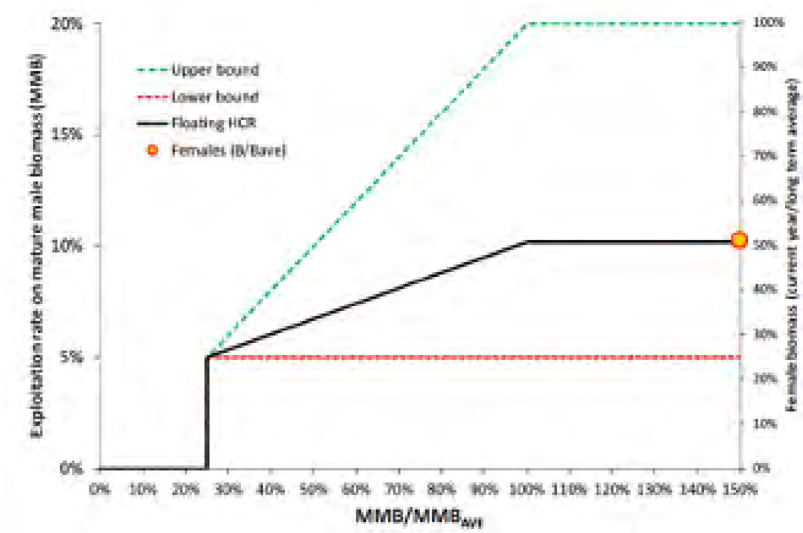


Figure 3. Current ADFG "floating" sloping control rule to determine the maximum exploitation rate on mature male biomass (MMB) as a function of the ratio of current MMB to the average MMB over 1982-2018. The ratio of current mature female biomass (MFB) to MFB averaged over 1982-2018 is used to determine the value of the maximum exploitation rate for the control rule, up to a maximum of 20%.

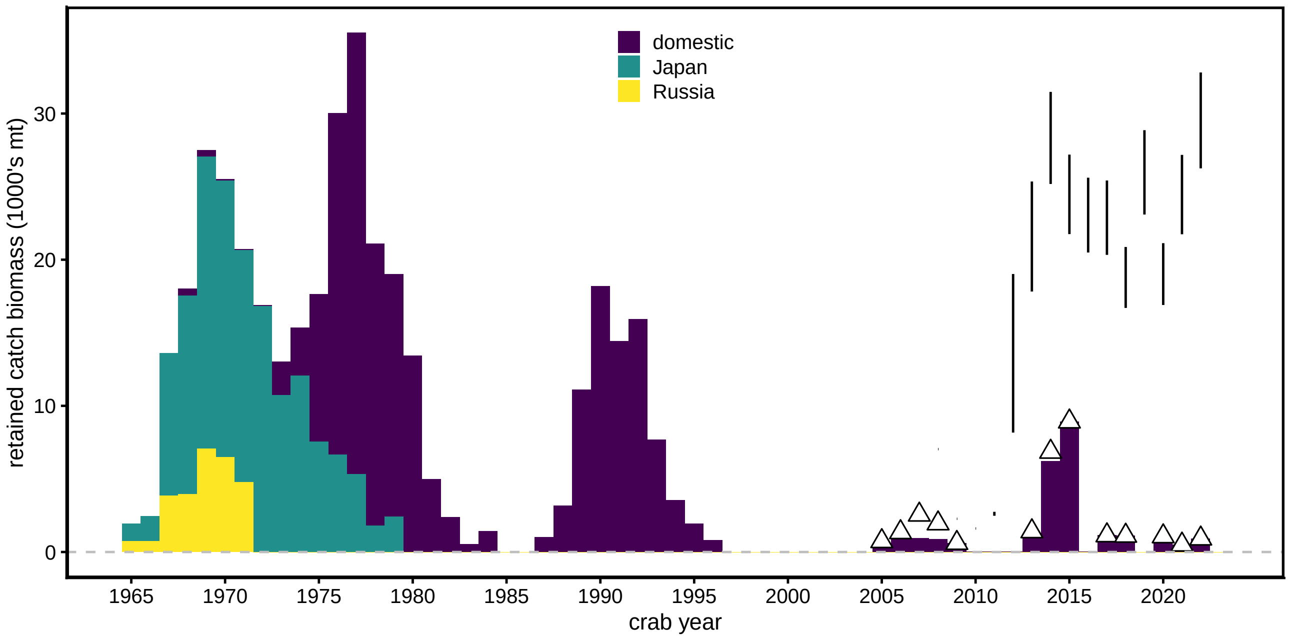


Figure 4. Total retained catch (males, 1000's t) in the directed fisheries (foreign [1965-1979] and domestic [1968-]) for Tanner crab (aggregated across State management areas). The bars indicate the Tier 3 OFL and ABC (upper and lower limits, respectively; (values start in 2011/12); the triangles indicate the area-aggregated TAC (values start in 2005/06, following rationalization).

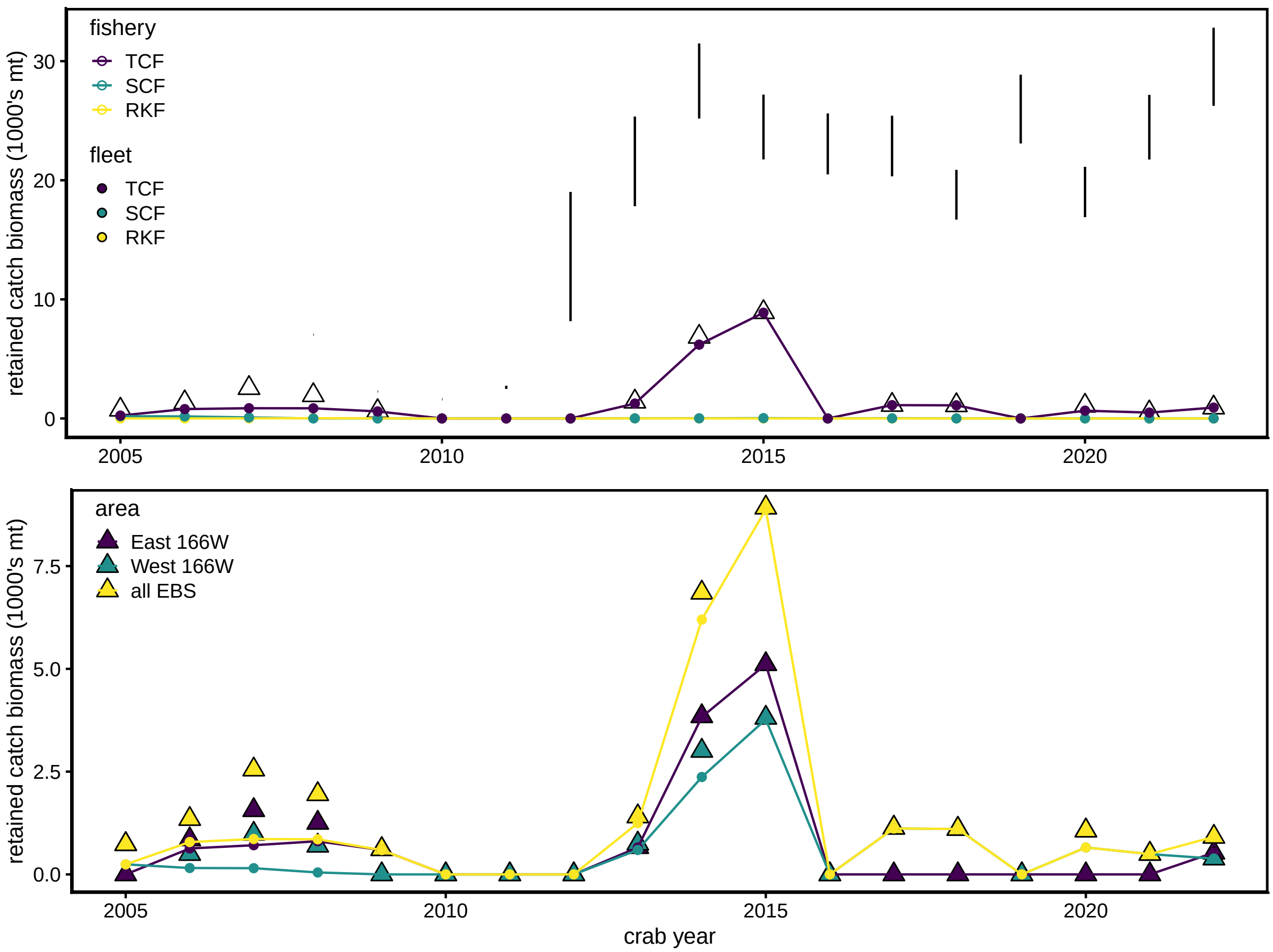


Figure 5. Upper plot: time series of retained catch biomass (1000's t) in the directed Tanner crab (TCF), snow crab (SCF), and BBRKC (RKF) fisheries since 2005. The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12); the triangles indicate the total (area-combined) TAC. Legal-sized Tanner crab can be incidentally-retained in the snow crab and BBRKC fisheries up to a cap of 5% the target catch. Lower plot: retained catch biomass (1000's t) by SOA management area and combined. The triangles indicate the area-combined ("all EBS") and area-specific ("East 166W", "West 166W") TACS. The directed fisheries in both SOA management areas were both closed from 2010/11 to 2012/13, as well as in 2016/17 and 2019/20. The directed fishery in the eastern area was also closed in 2005/06, 2017/18, 2018/19, 2020/21, and 2021/22.

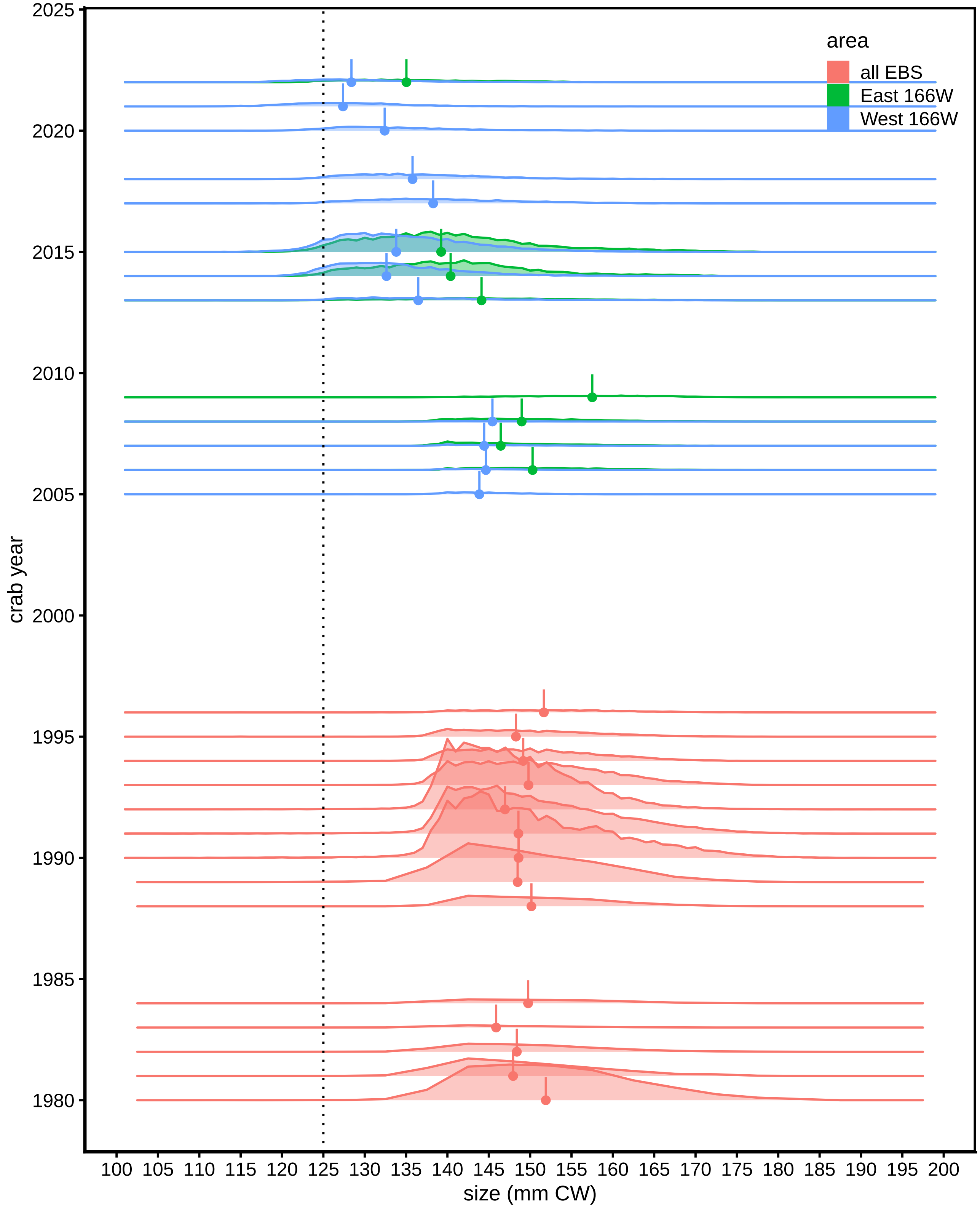
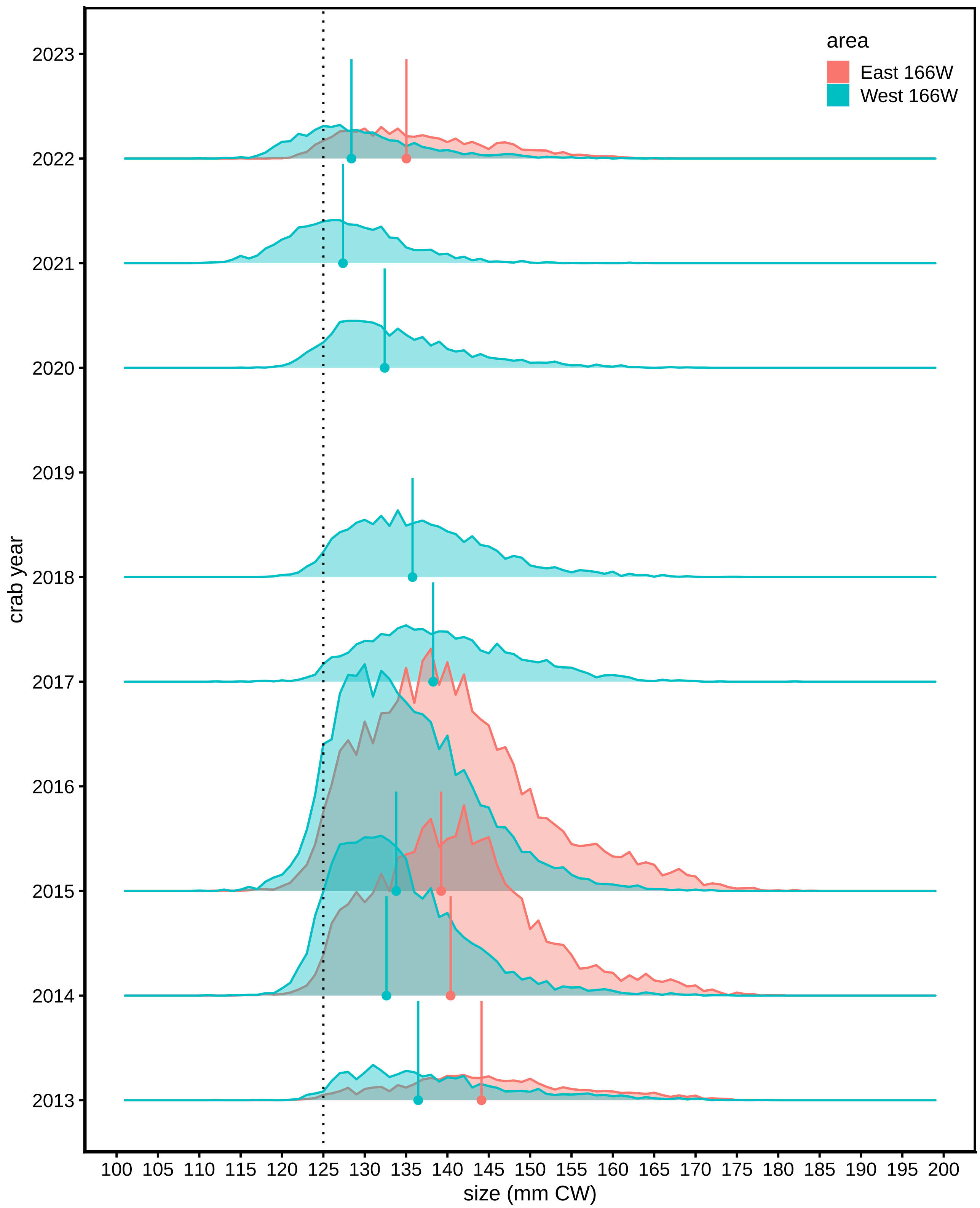


Figure 6. Retained catch size compositions, scaled to total abundance by area and year. Vertical bars and points indicate median sizes, dotted vertical line indicates recent industry-preferred size.



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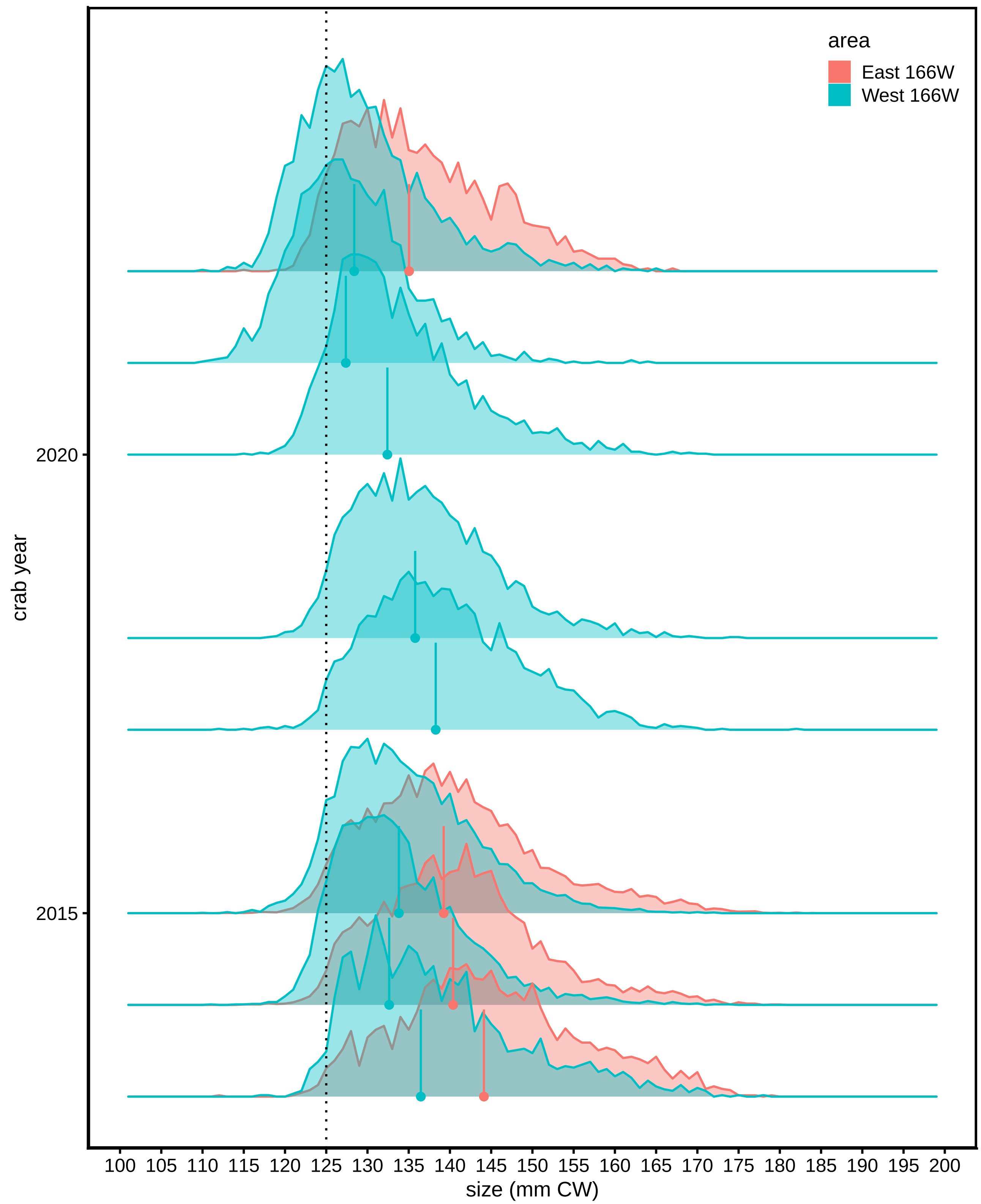
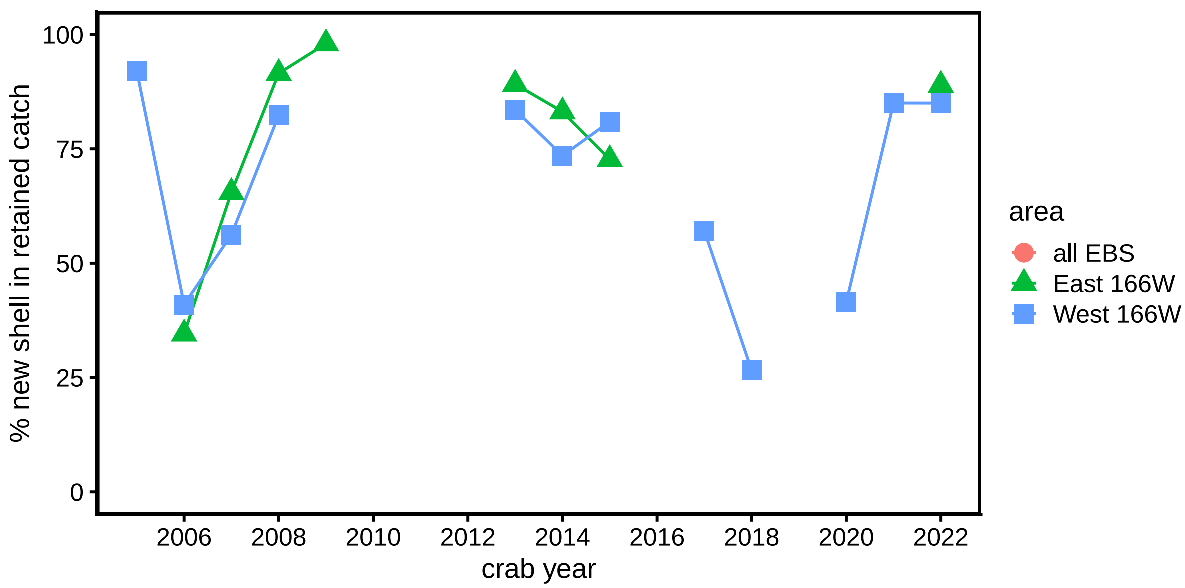


Figure 8. Retained catch size compositions from recent seasons, normalized to sum to 1 by area and year to show contrast. Vertical bars and points indicate median size. Dotted line indicates recent industry-preferred size.



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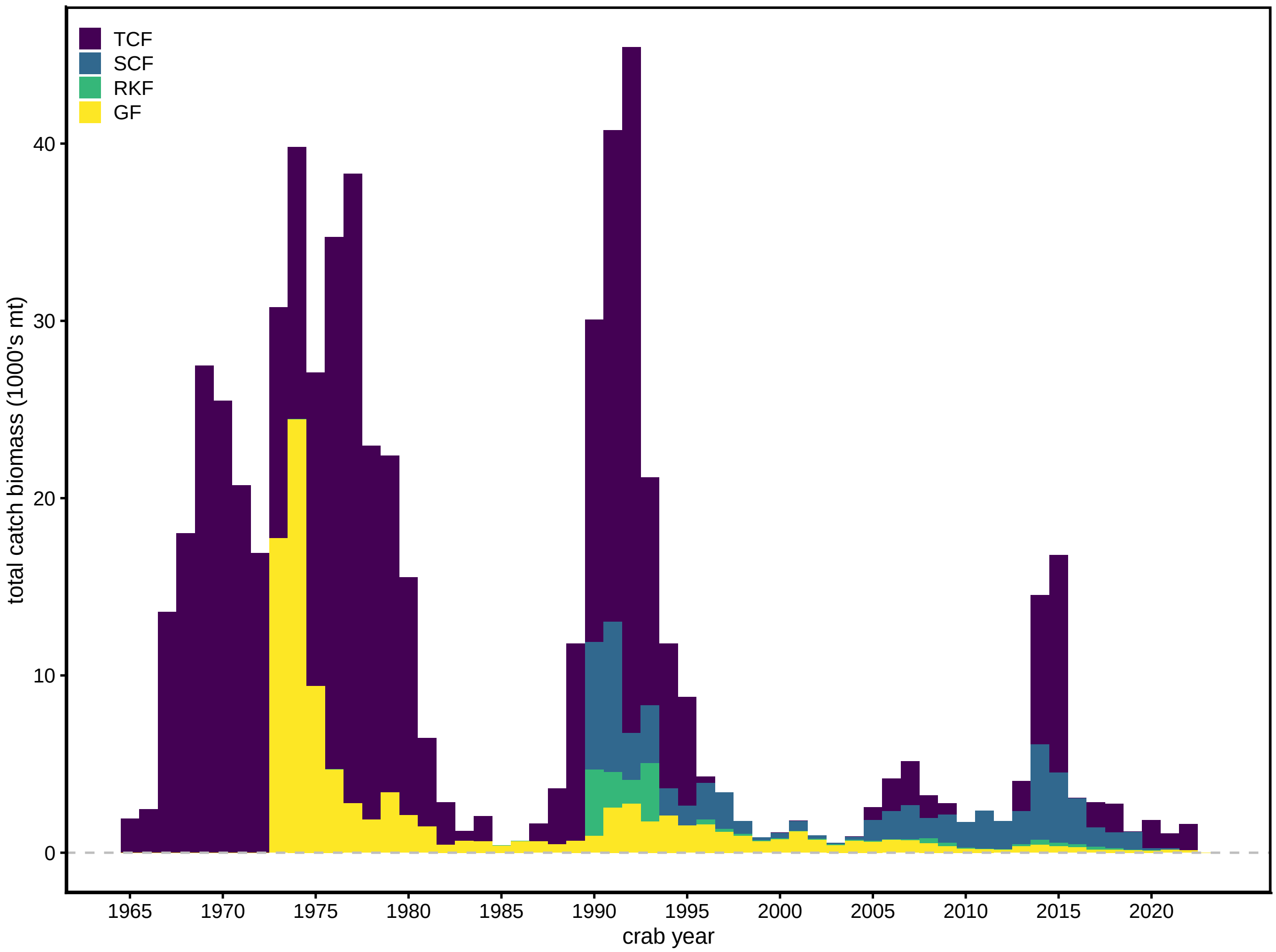

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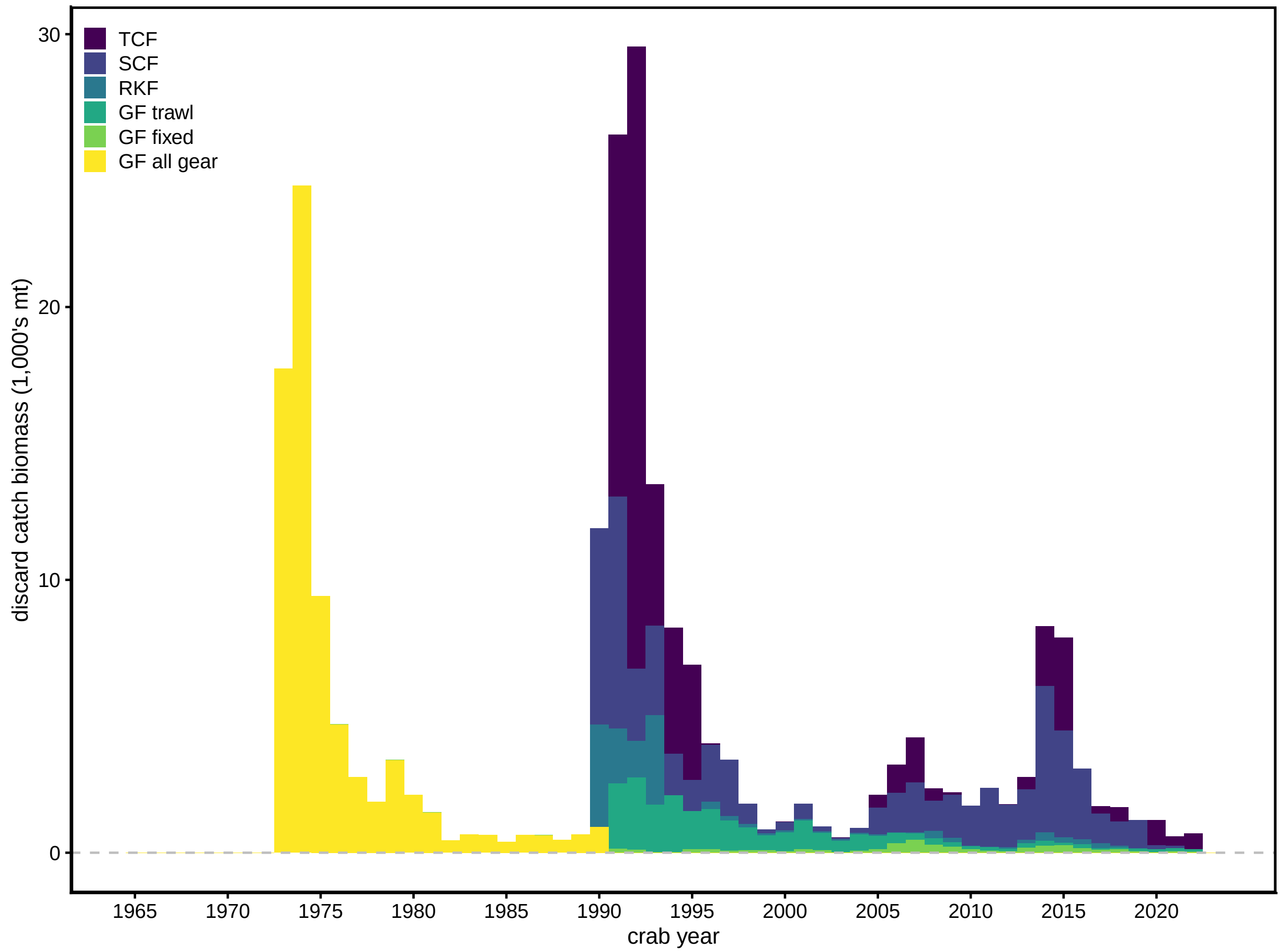


Figure 11. Discard biomass estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). Discard estimates for the directed fishery were derived using the subtraction method. **Discard mortality rates have not been applied to these estimates.**

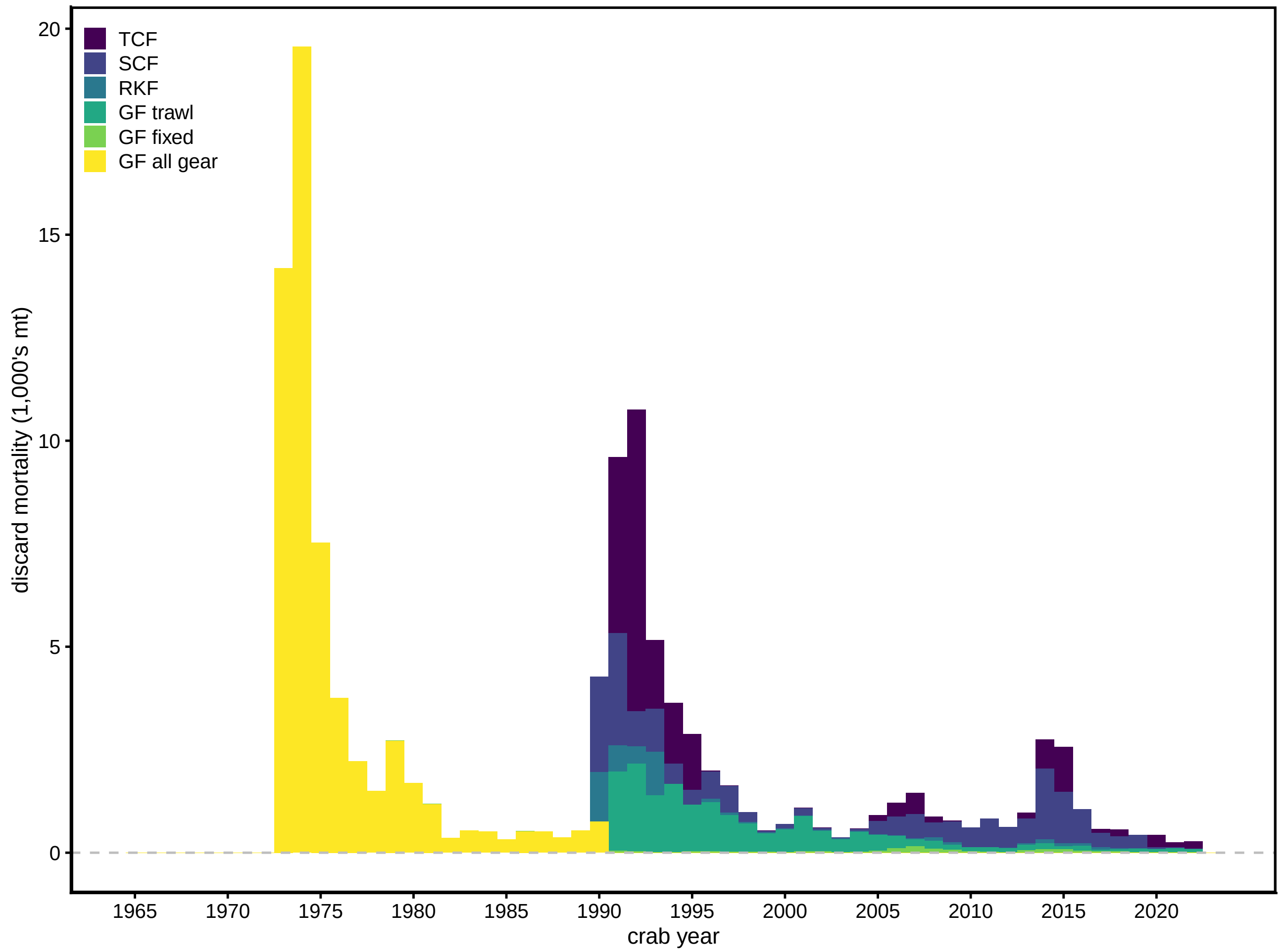
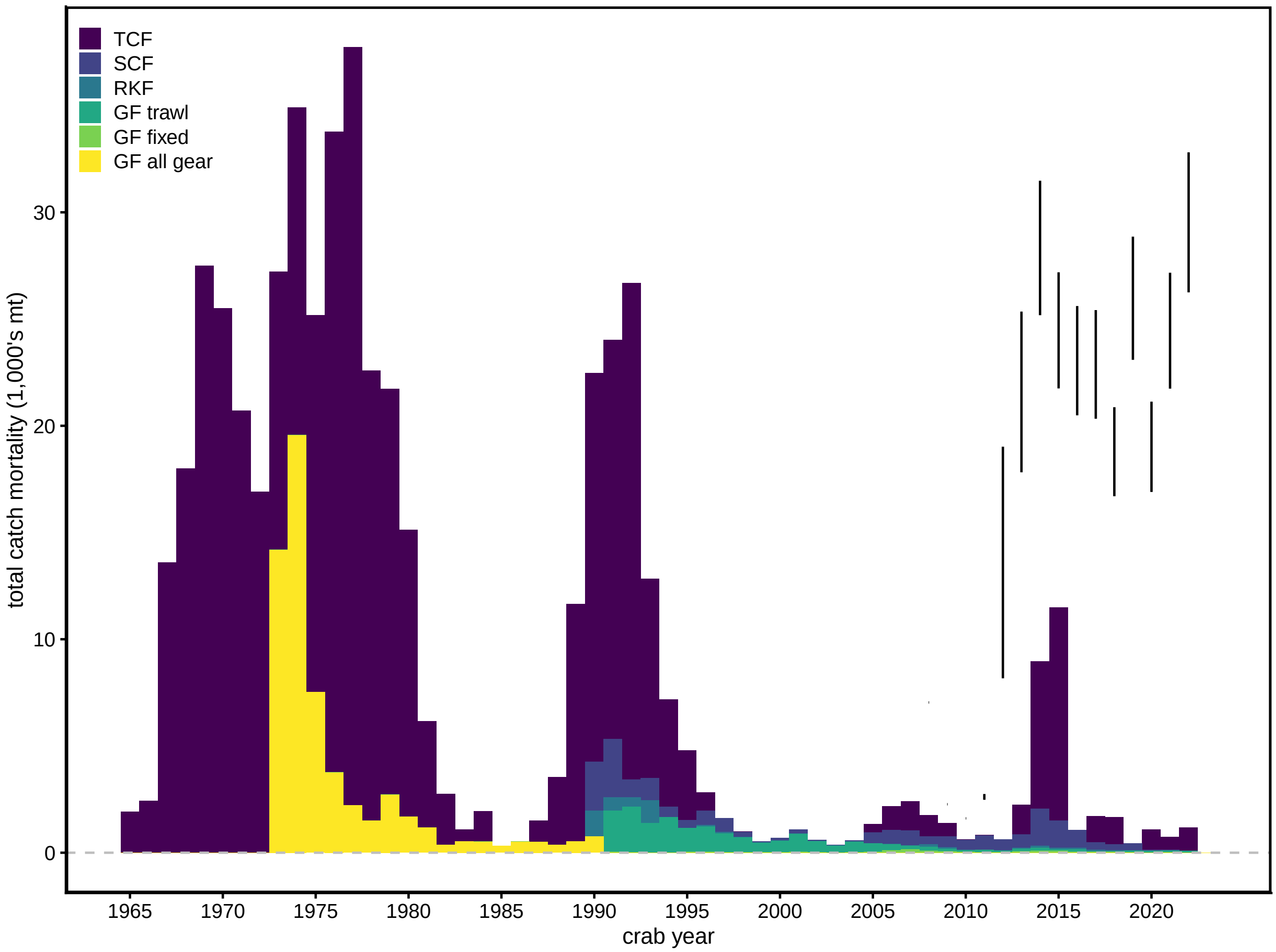


Figure 12. Discard mortality (biomass) estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). Discard estimates for the directed fishery were derived using the subtraction method. **Gear-specific assumed discard mortality rates have been applied.**



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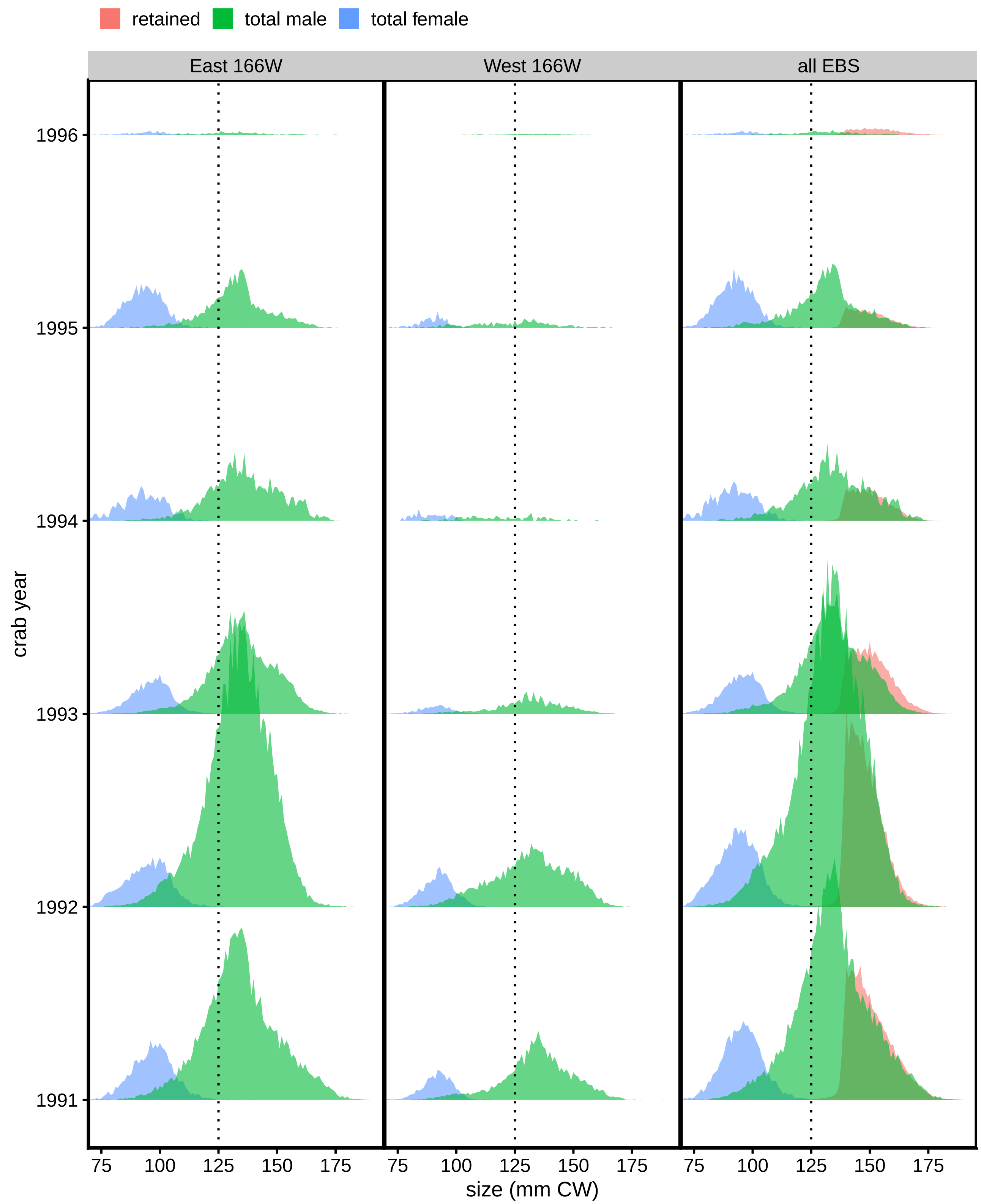

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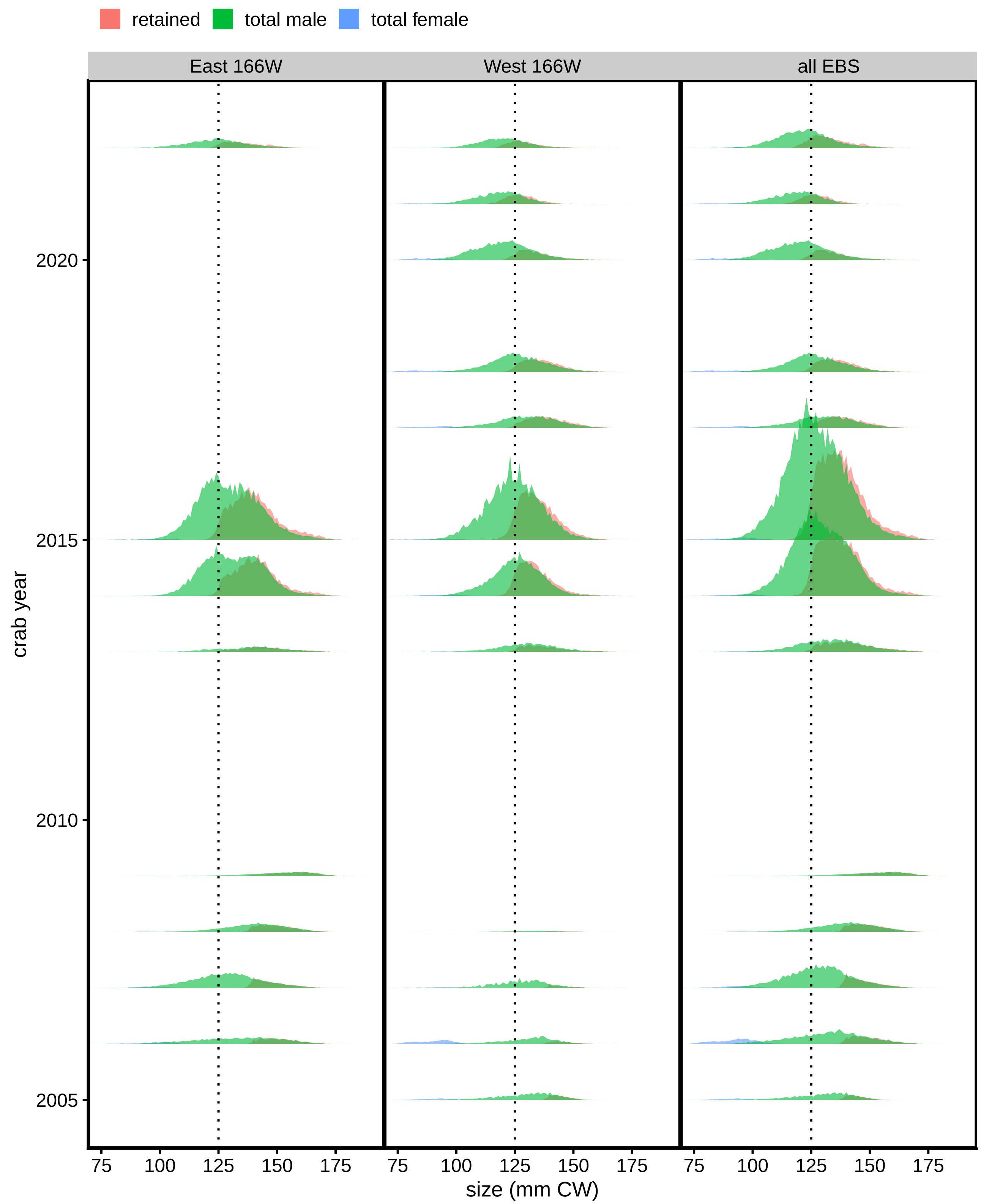
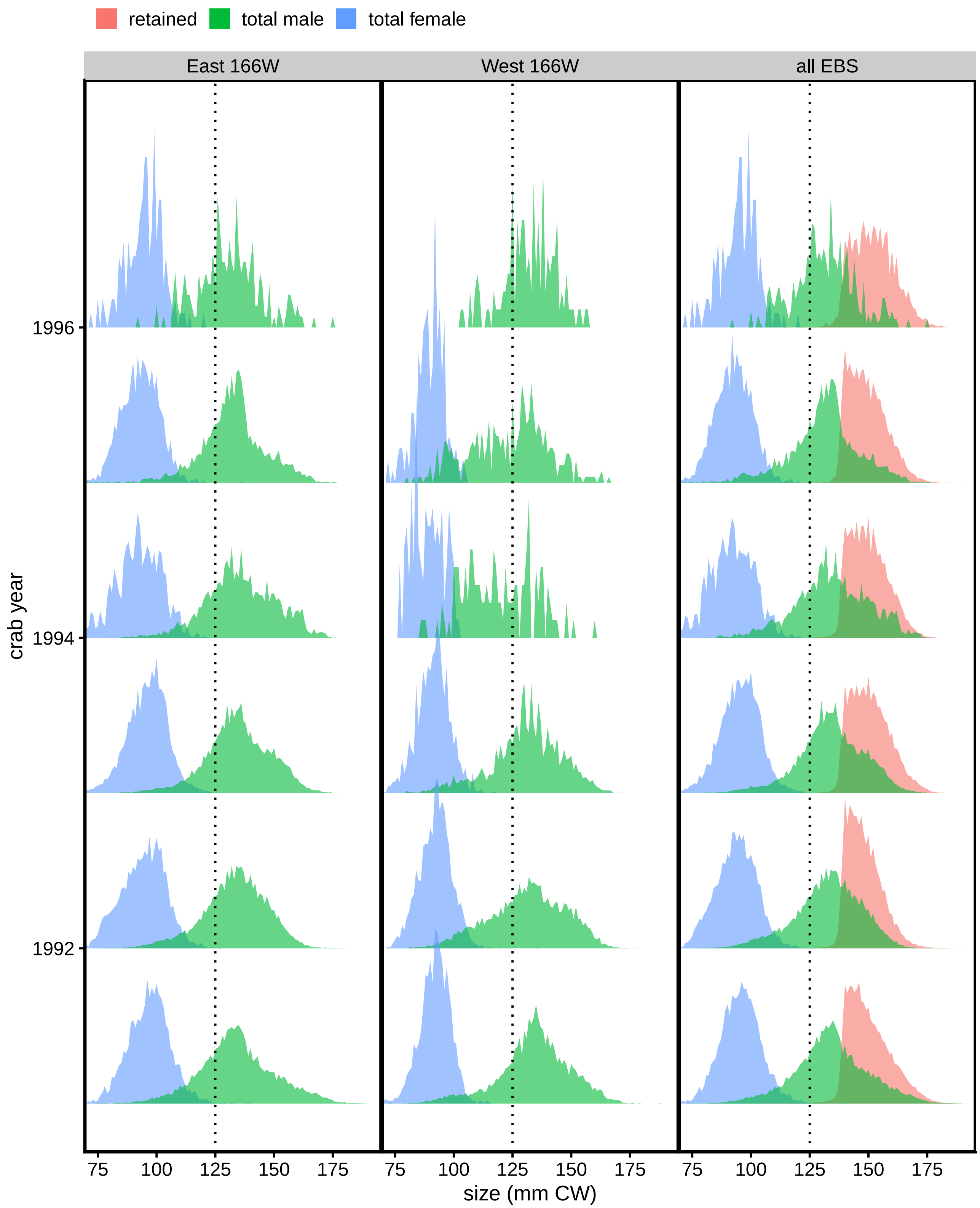


Figure 15. Comparison of expanded size compositions for retained and total catch in the directed fishery after 2004/05. Dotted line indicates recent industry-preferred size.



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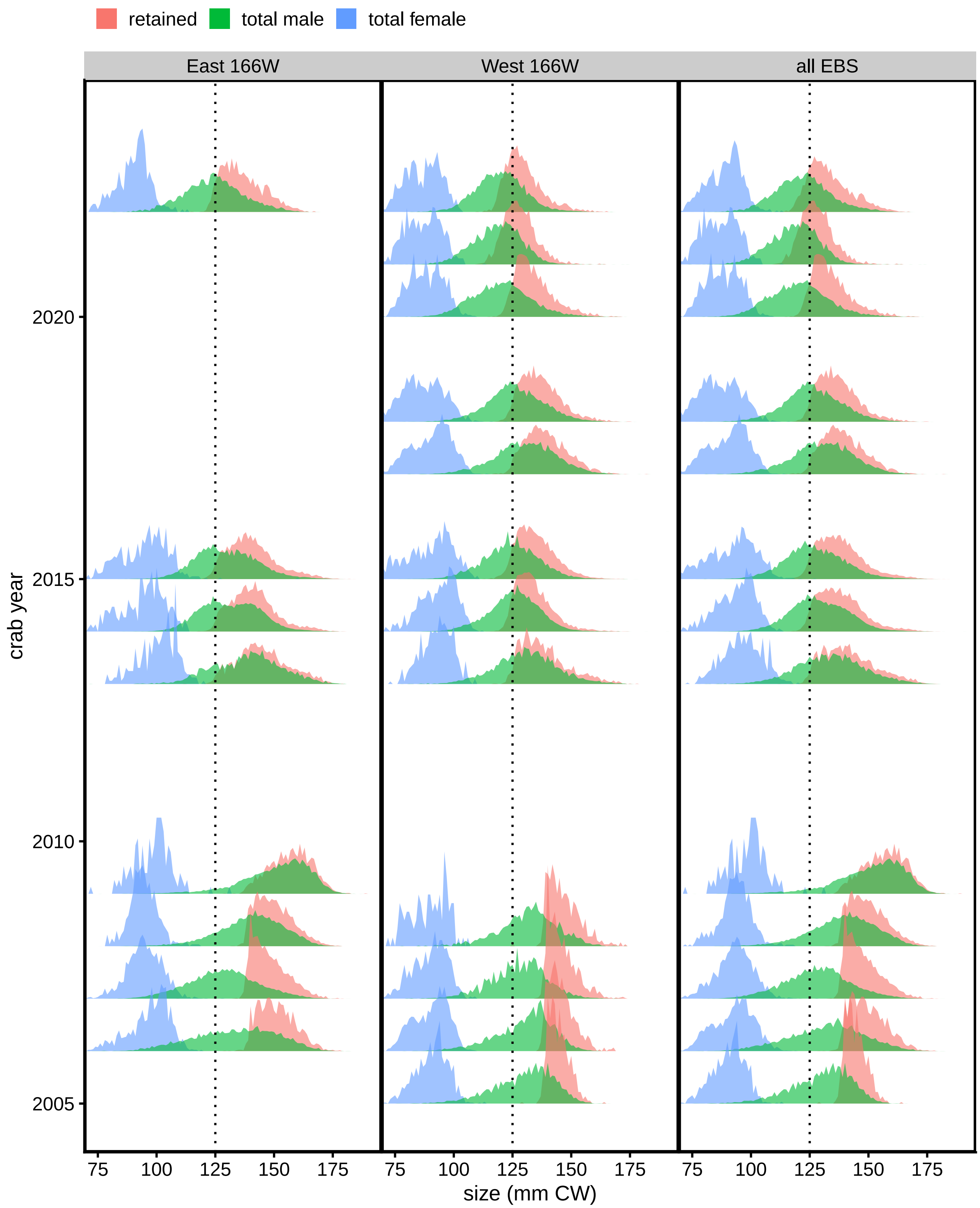

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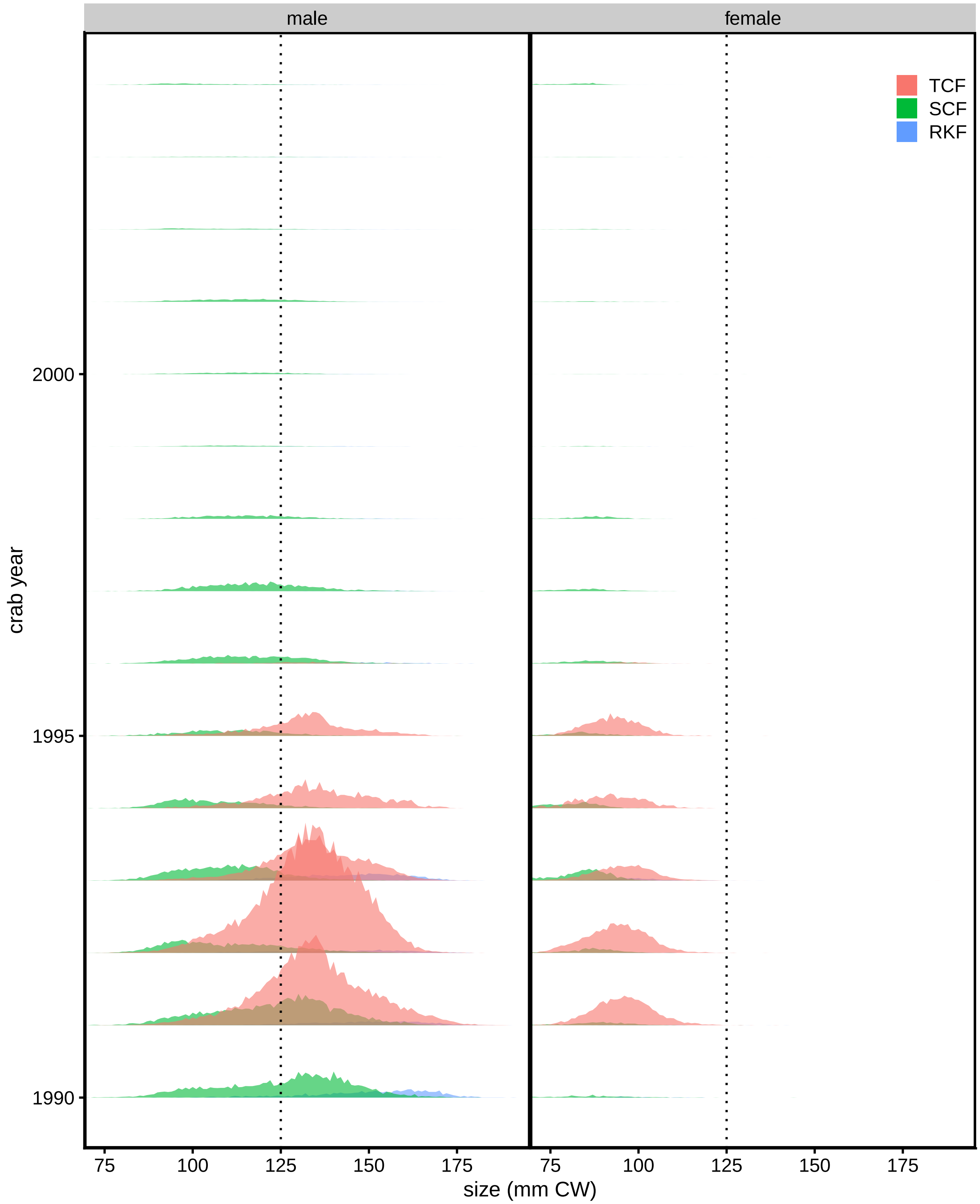

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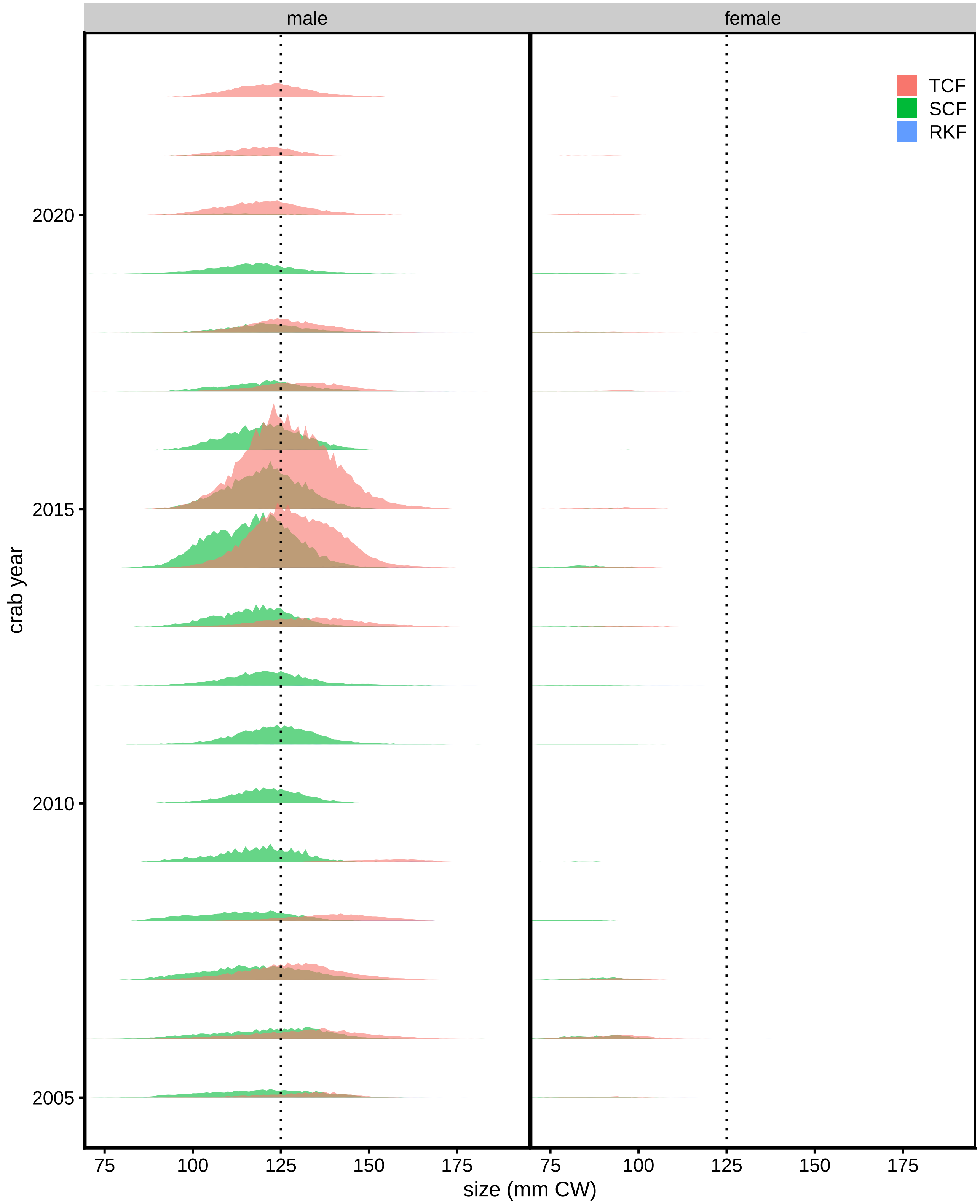
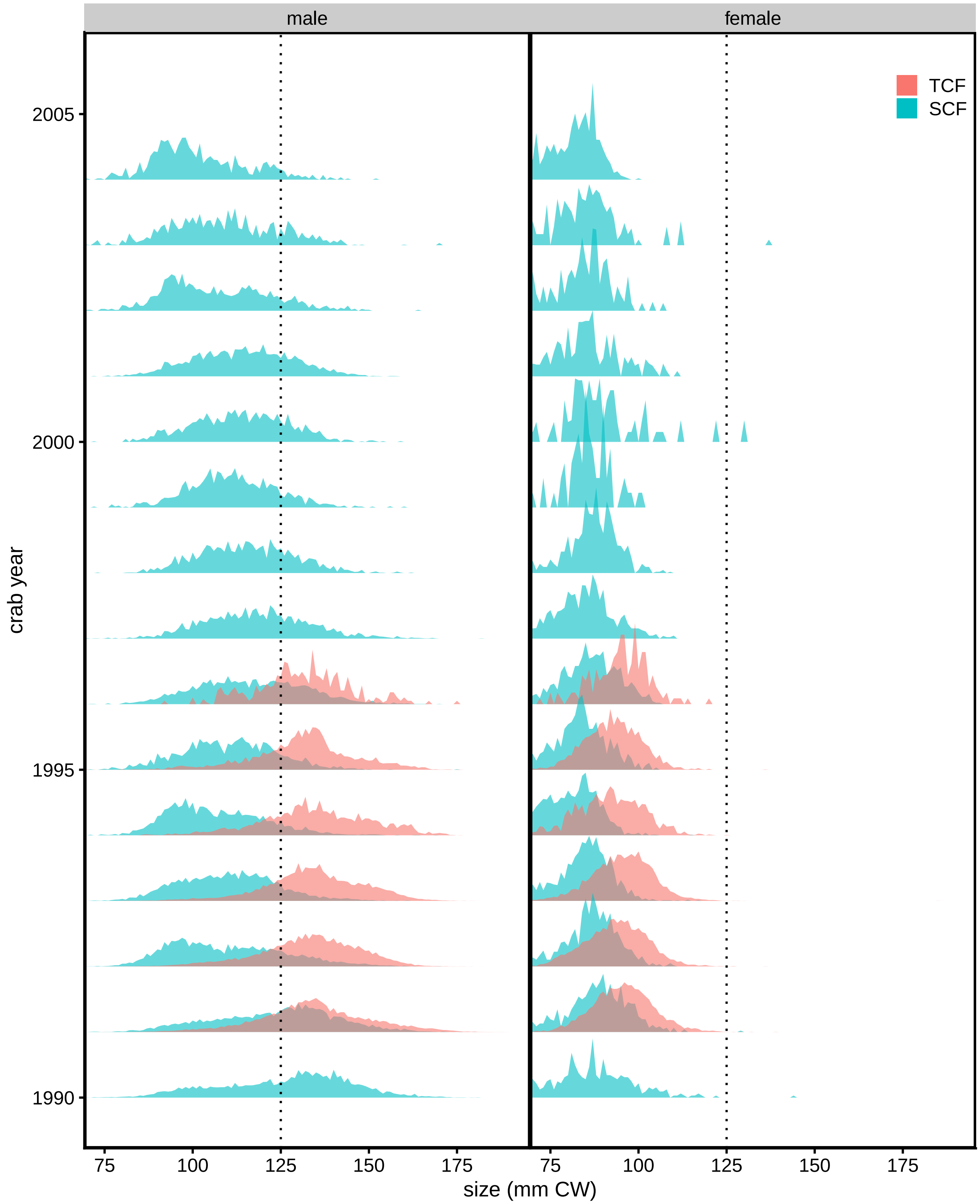


Figure 19. Comparison of expanded size compositions for total catch of Tanner crab in the crab fisheries prior to 2005/06. Catch has already been aggregated across ADFG management areas. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery.



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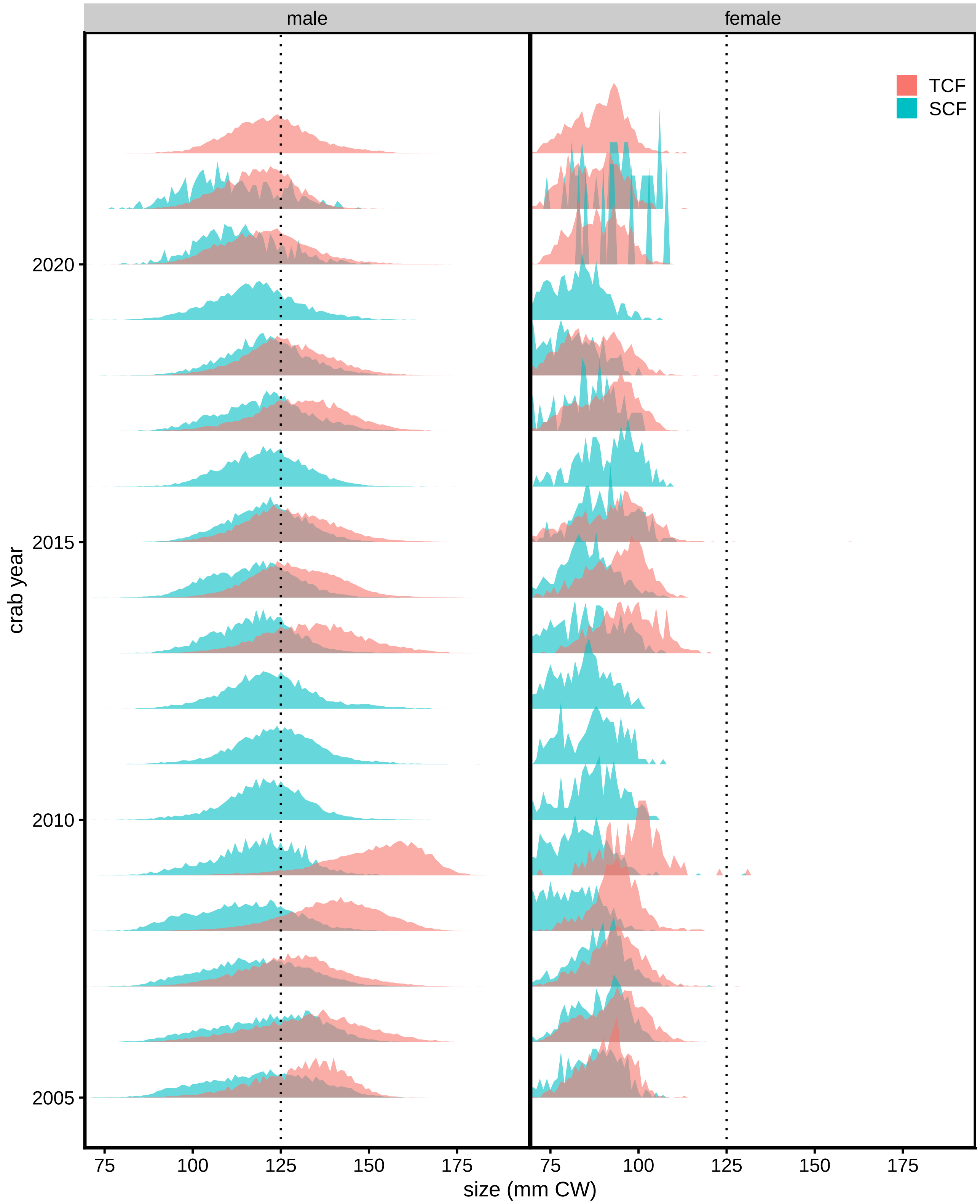

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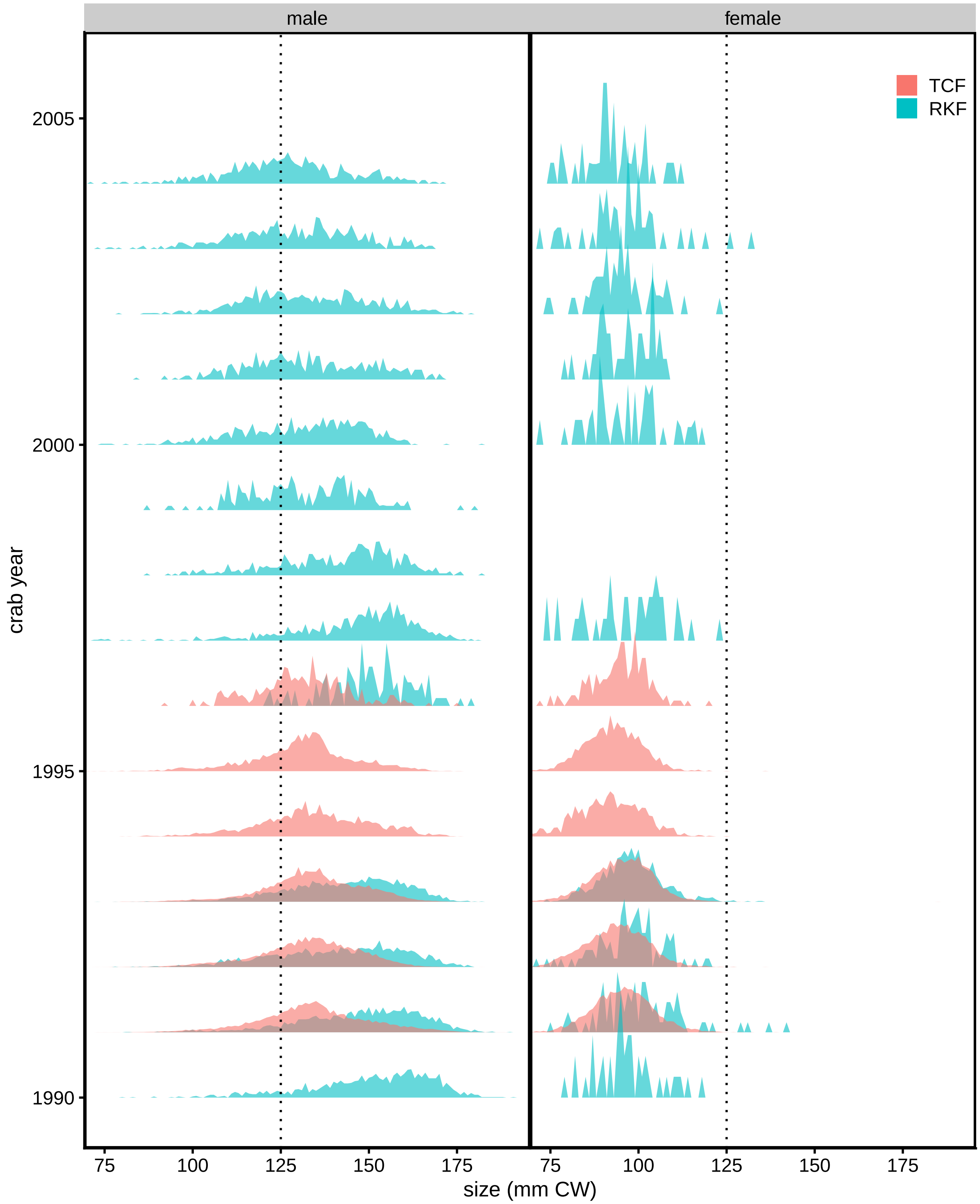

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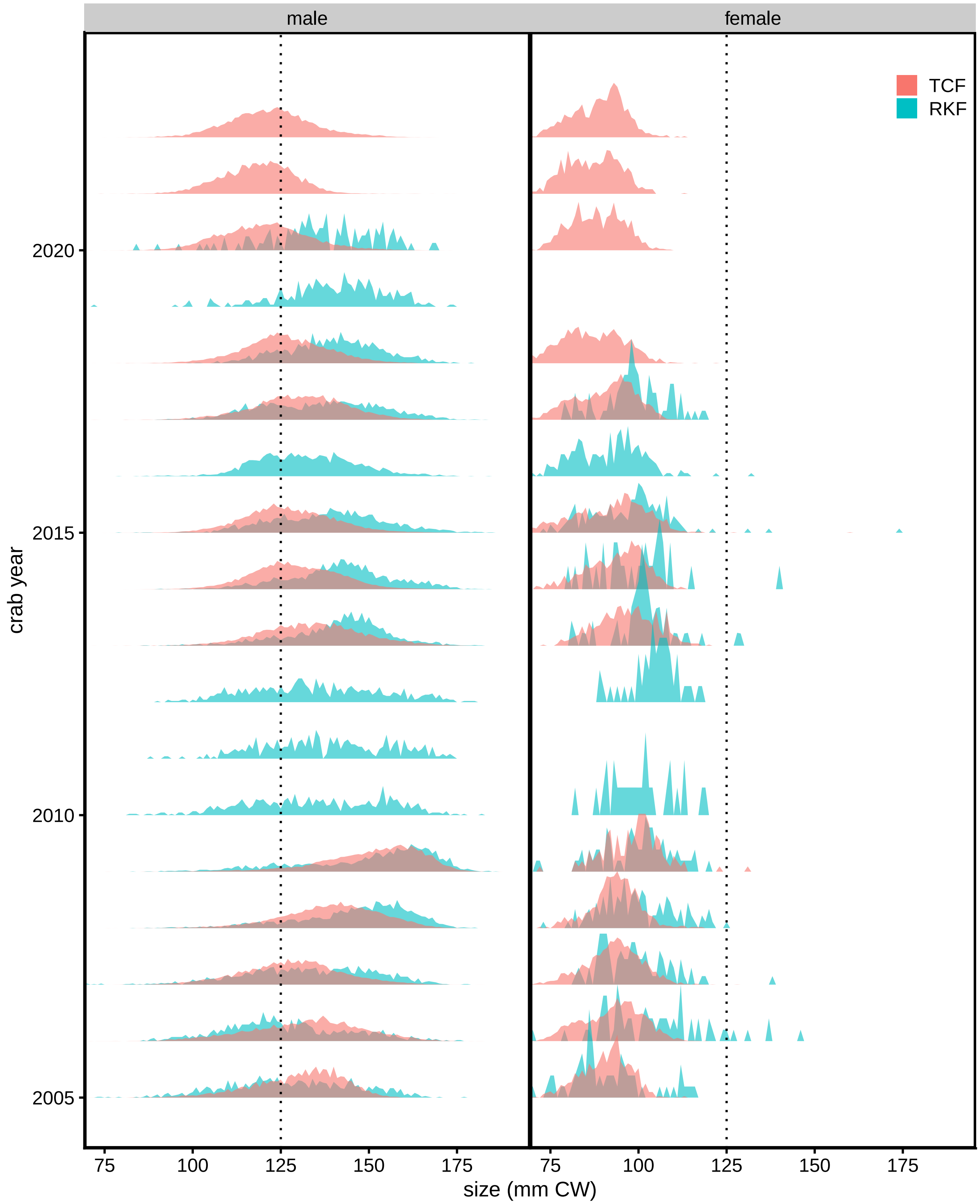

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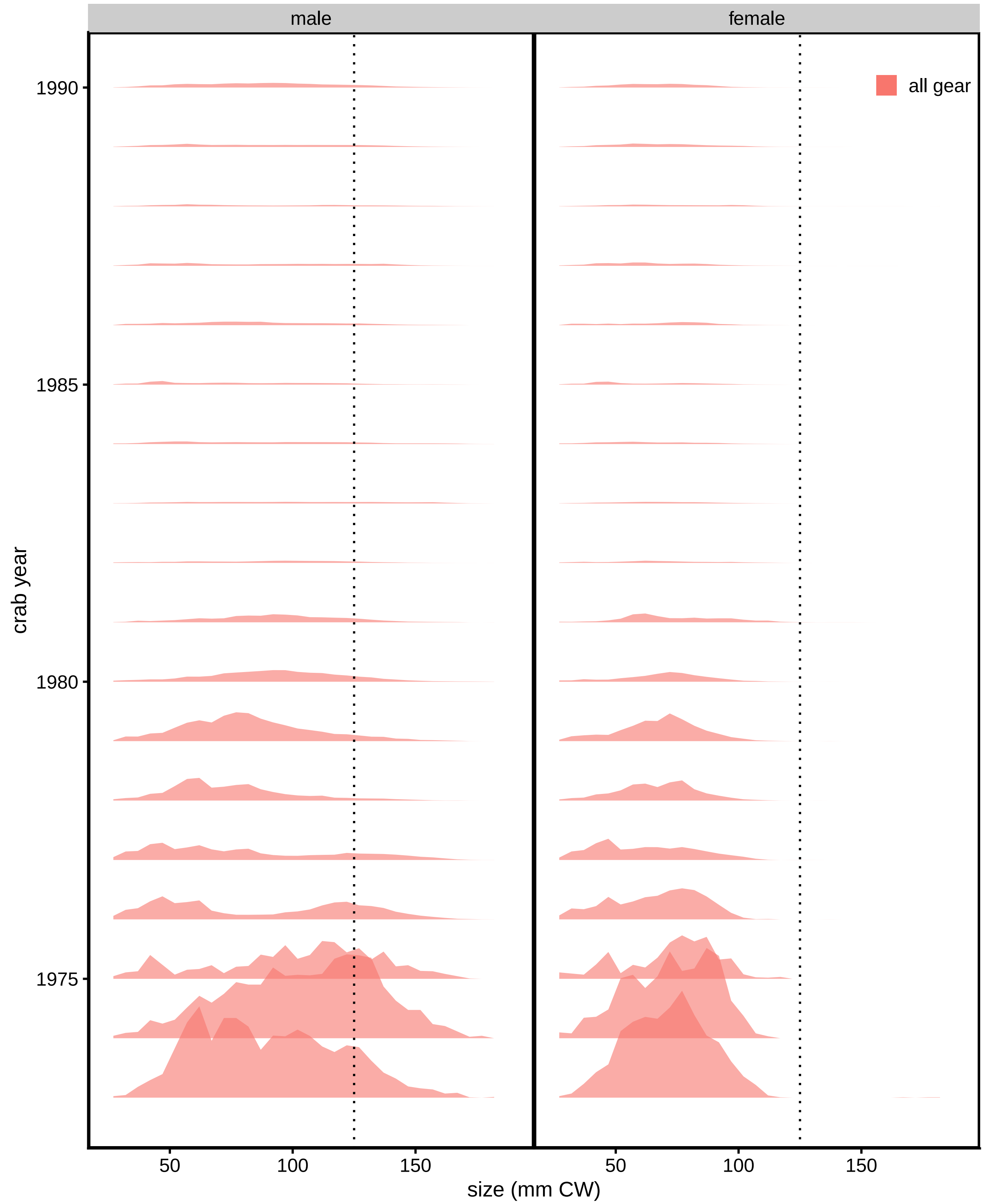
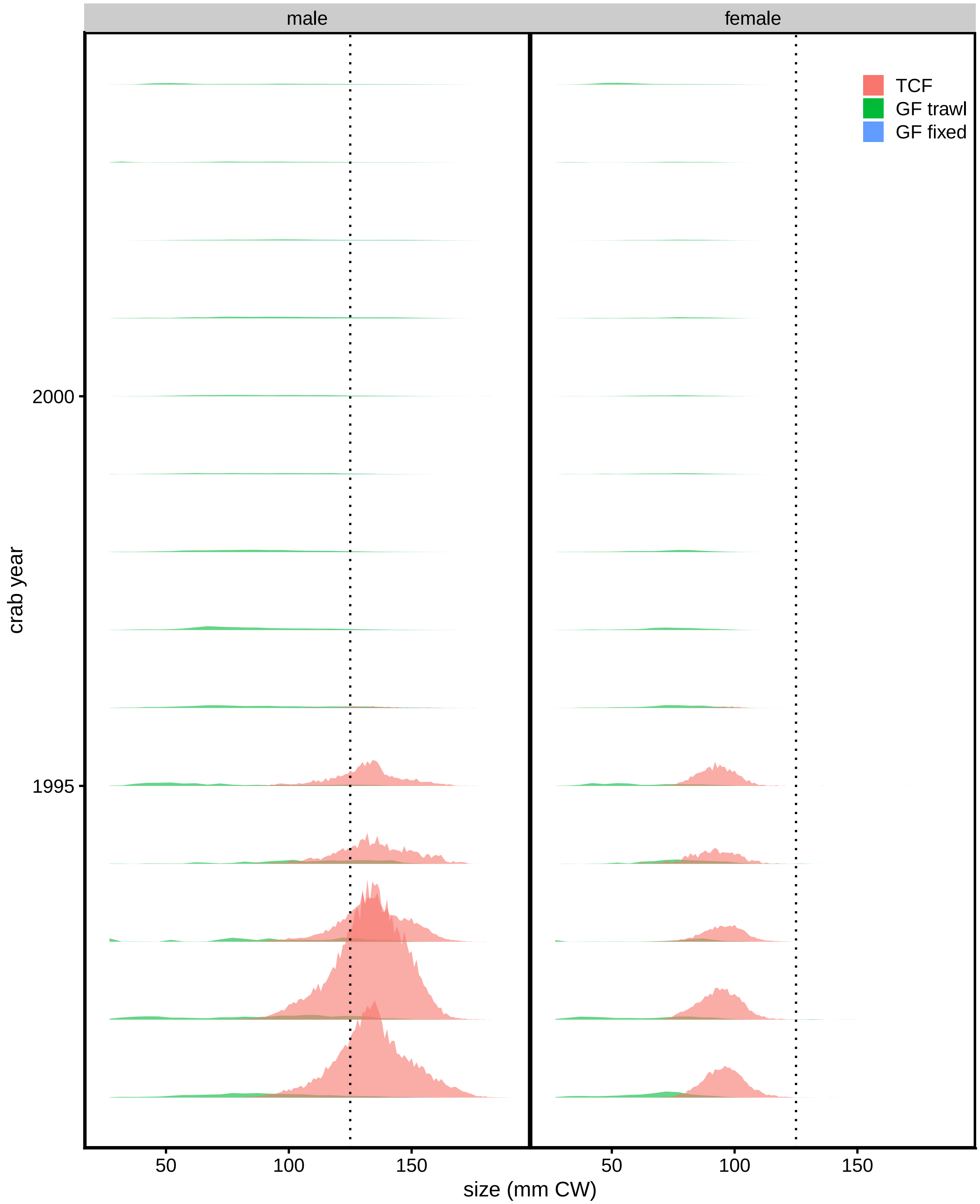


Figure 24. Expanded size compositions for total catch of Tanner crab in the groundfish fisheries prior to 1990/91. Dotted line indicates recent industry-preferred size.



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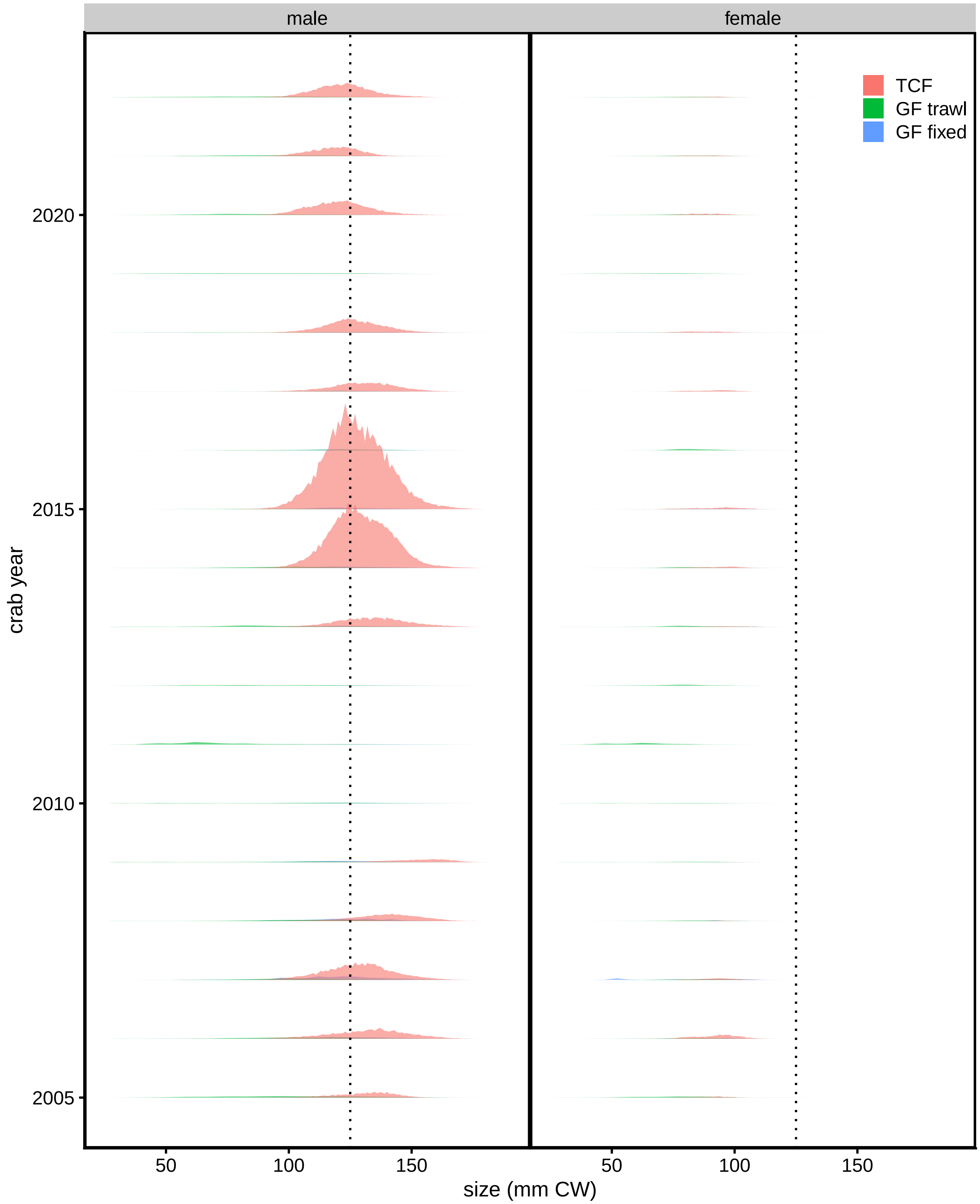

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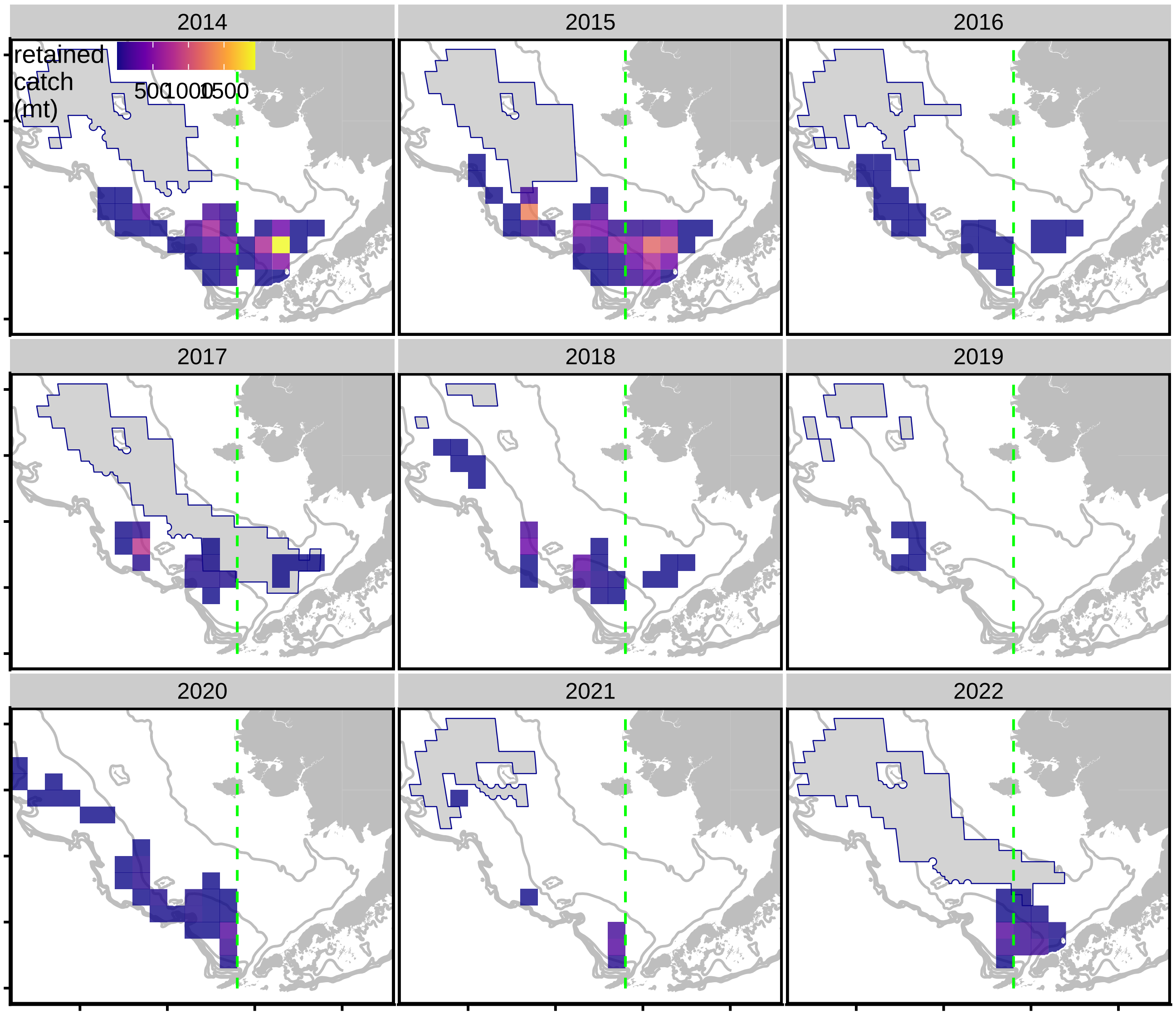

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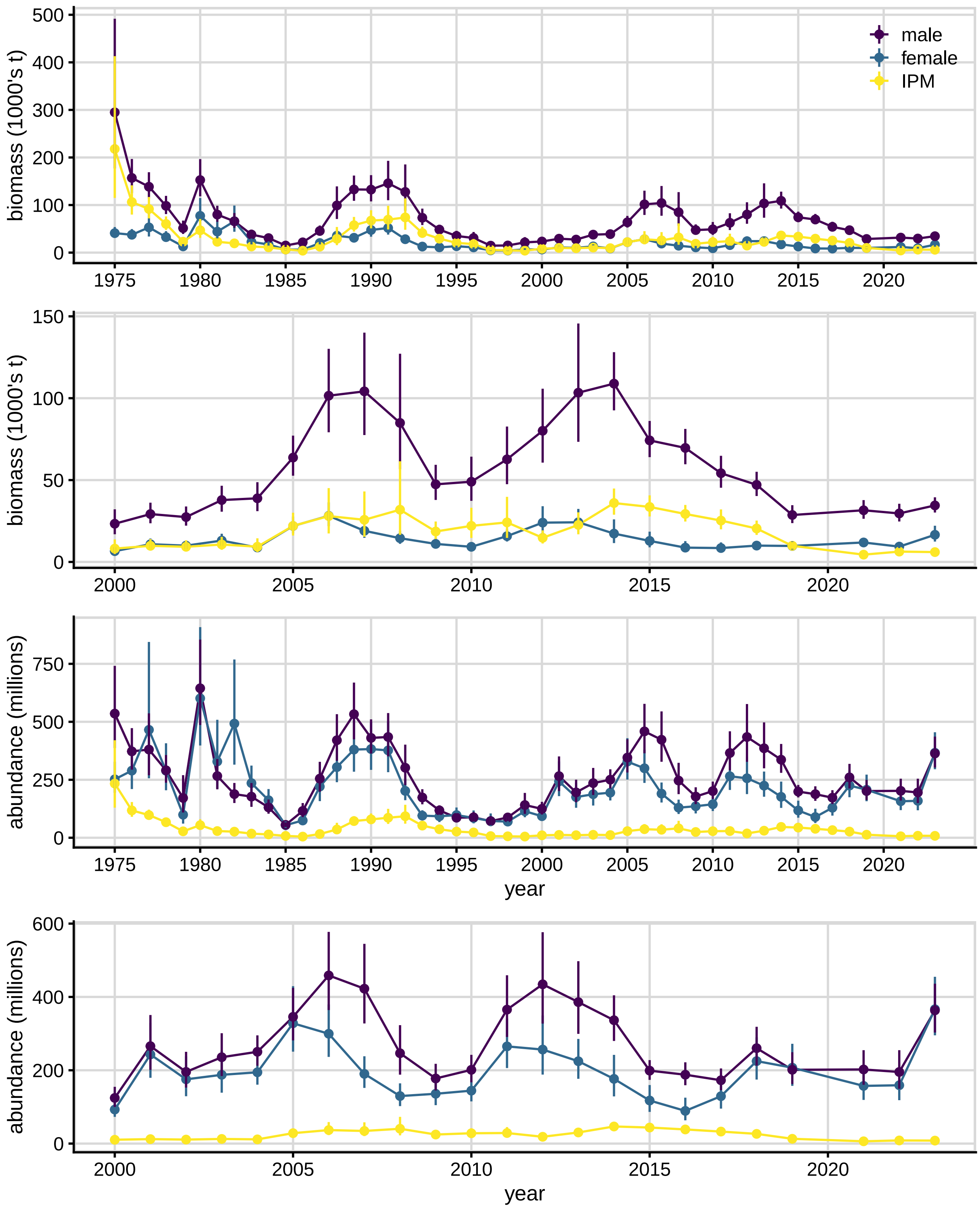

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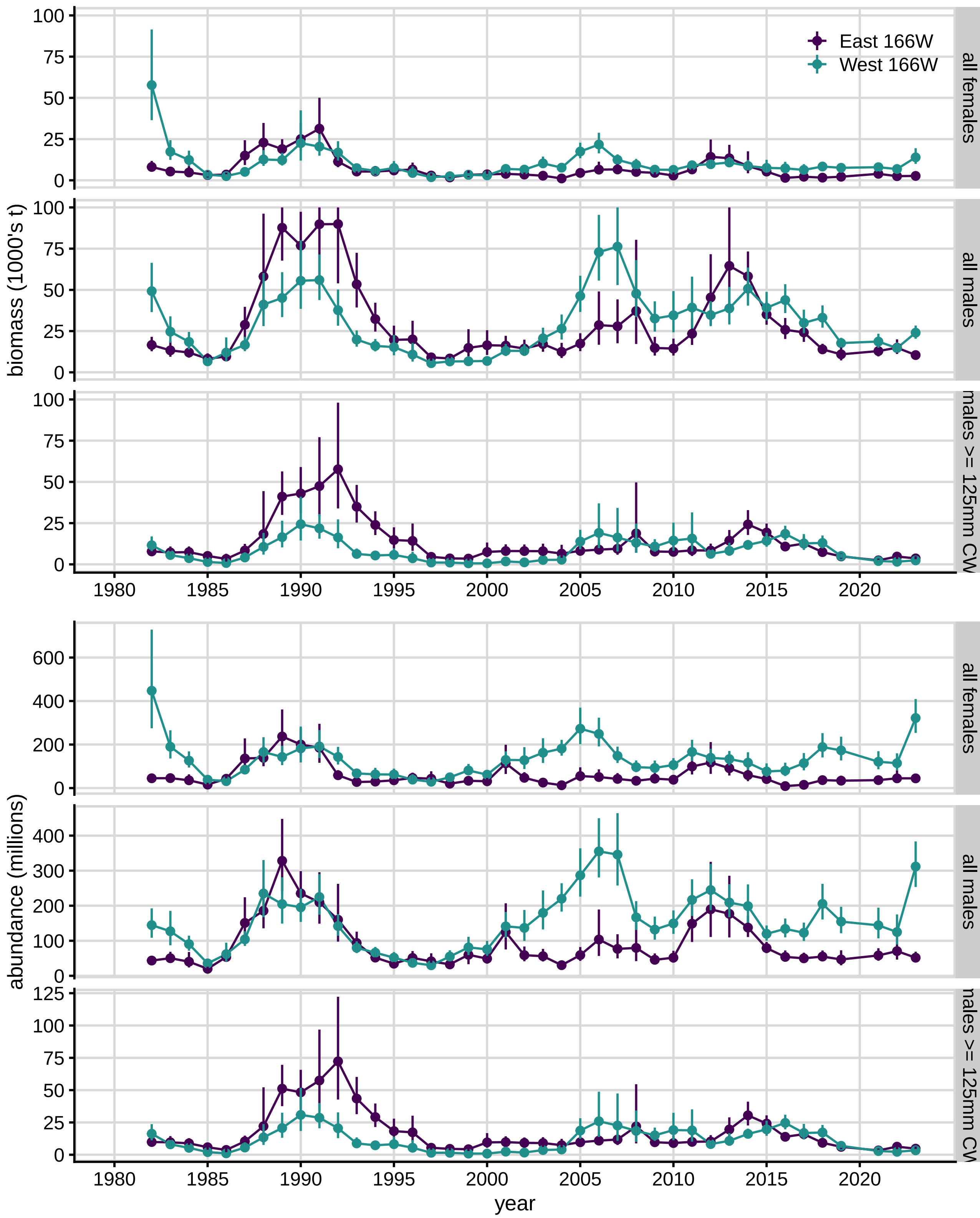
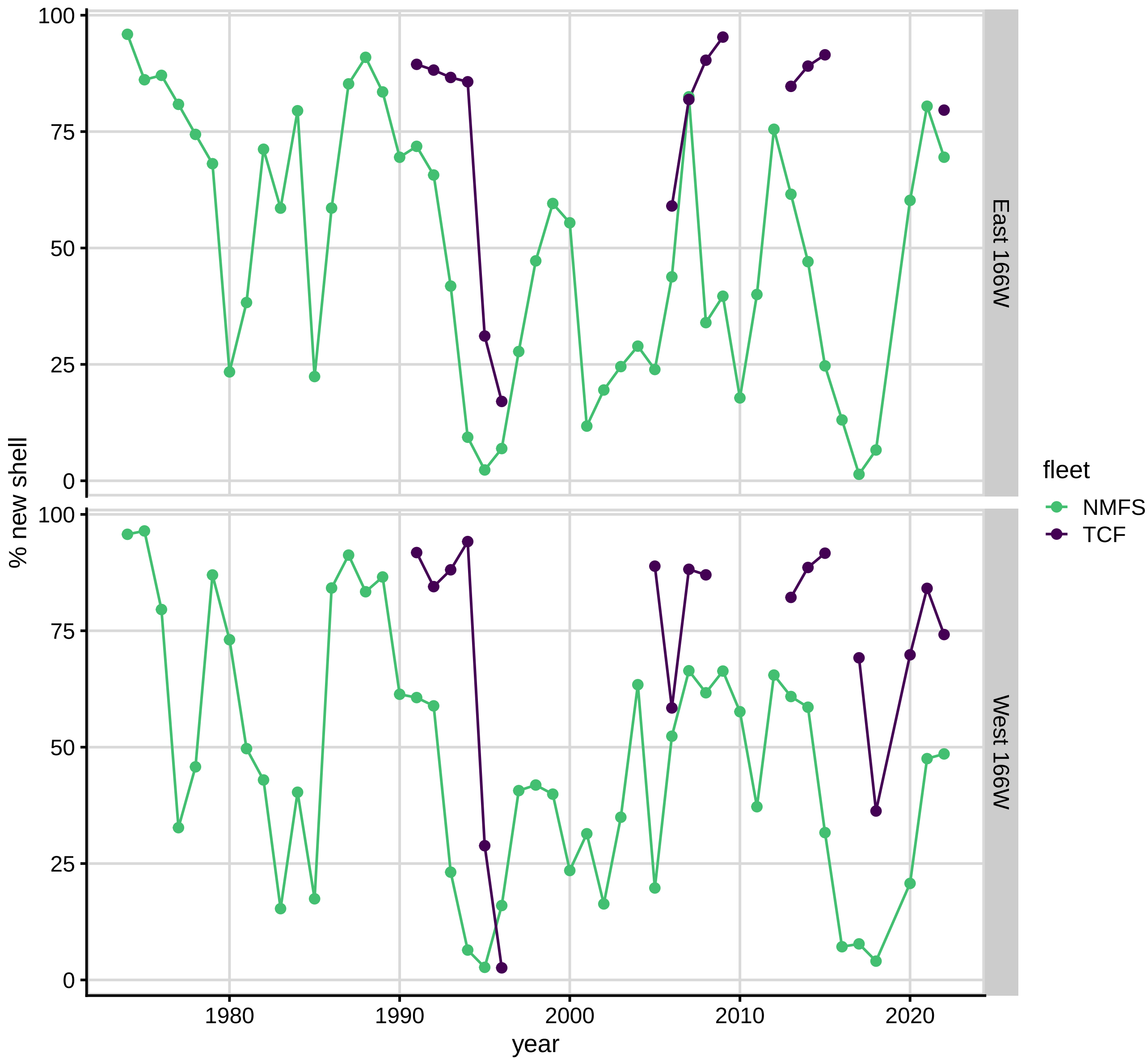


Figure 29. Annual estimates of design-based area-swept biomass (upper plots) and abundance (lower plots) from the NMFS EBS bottom trawl survey by population category and management area.



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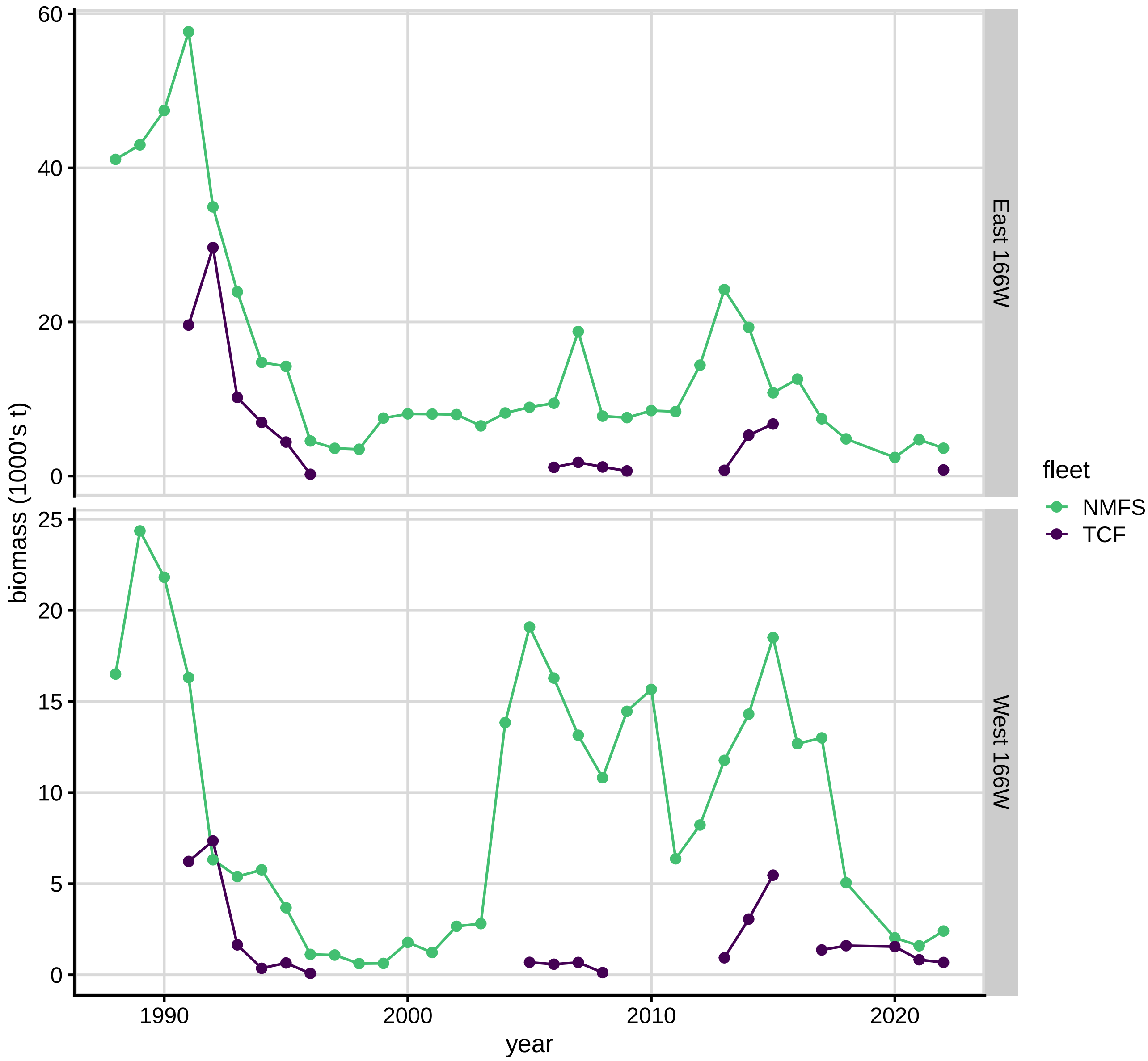


Figure 31. Comparison of the biomass of industry-preferred size males estimated from the NMFS EBS shelf survey and caught in the directed fishery ('TCF'), by ADFG management area. The survey values have been lagged a year to align visually with the fishery values.

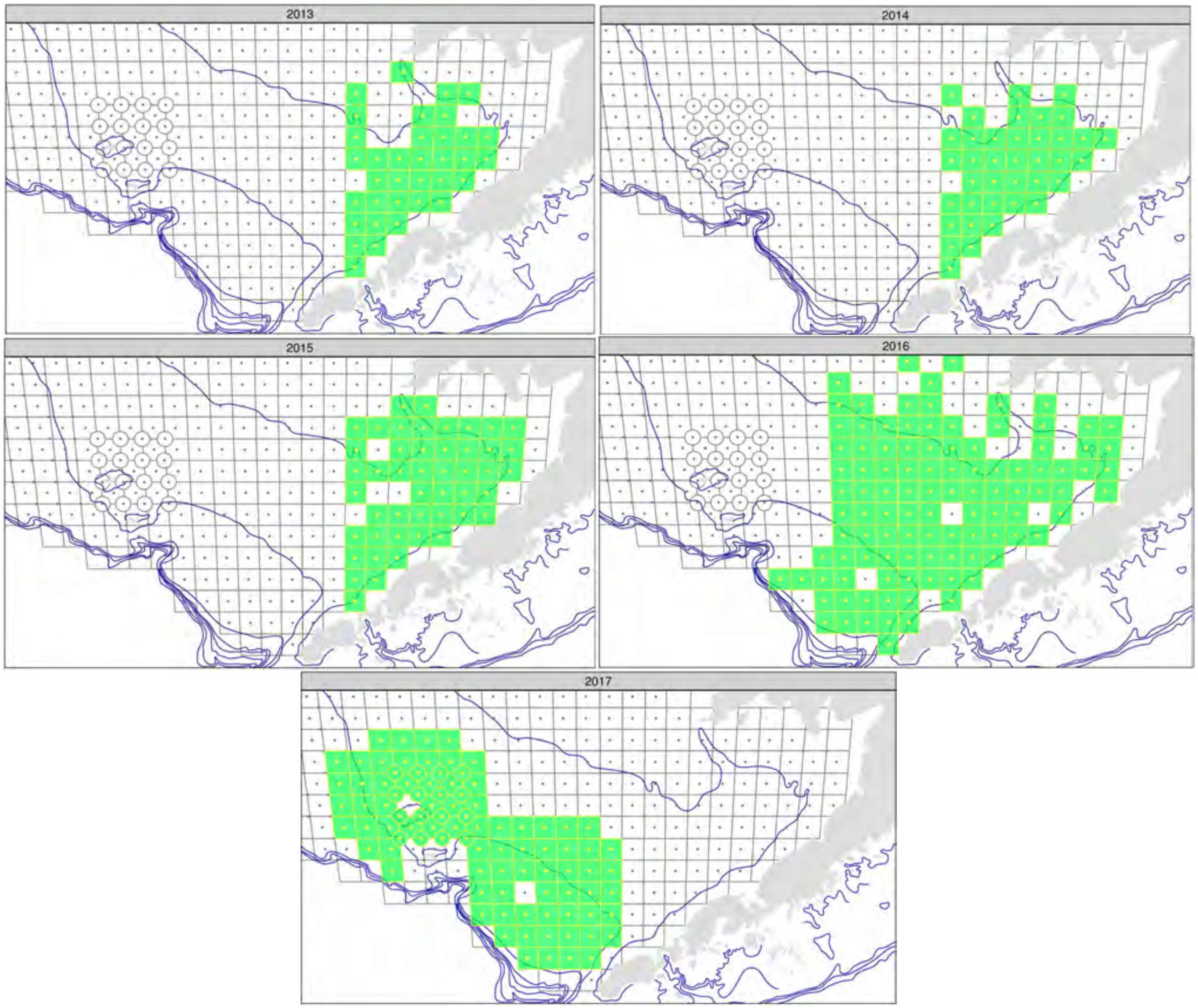
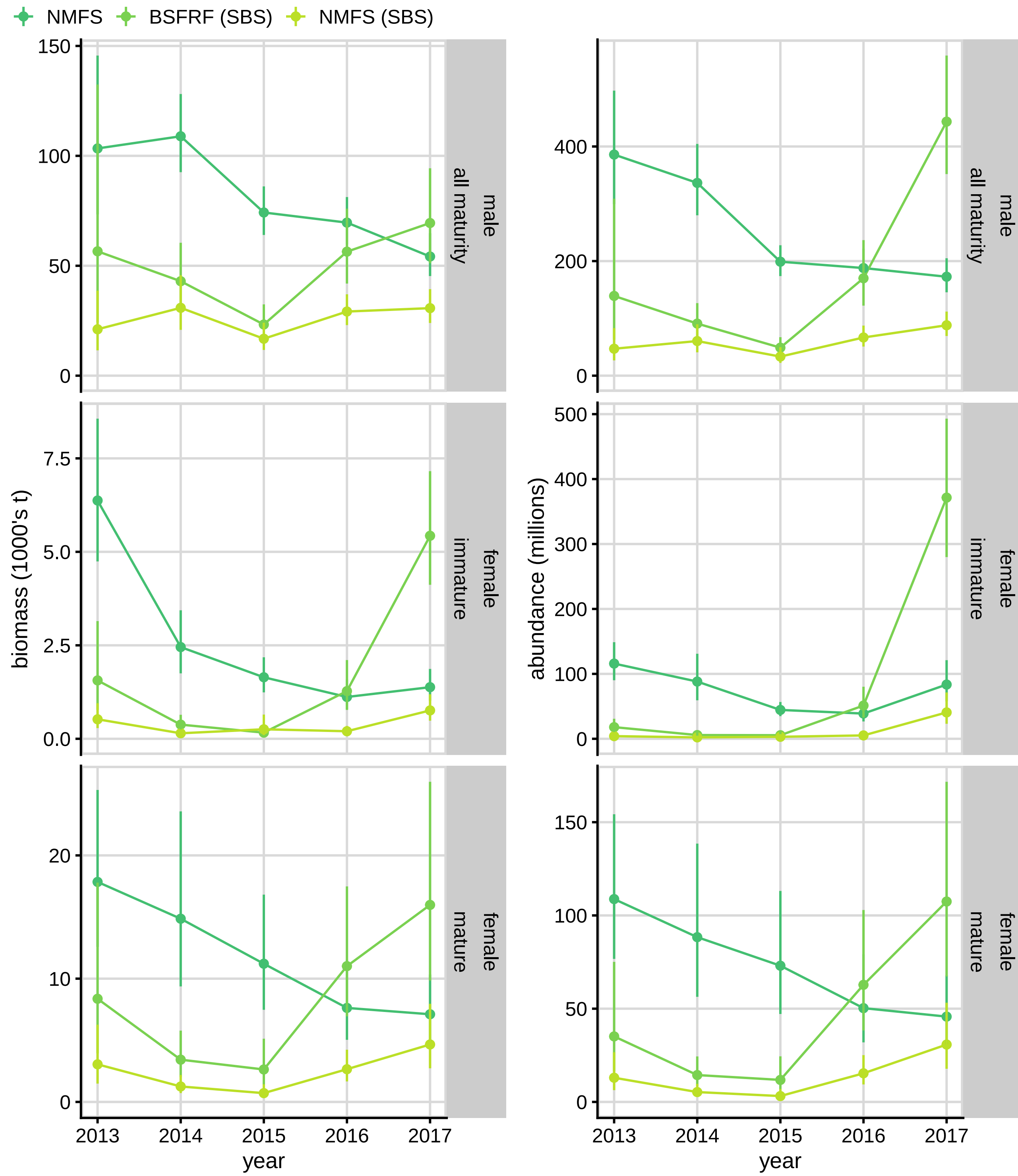


Figure 32. Annual spatial footprints of the BSFRF-NMFS collaborative side-by-side (SBS) Tanner crab catchability studies (2013-2017). BSFRF SBS tows were made in parallel to standard NMFS survey tows at a (different) subset of standard NMFS stations each year of the study. The BSFRF vessel used a modified nephrops bottom trawl assumed to capture all crab within the area swept.



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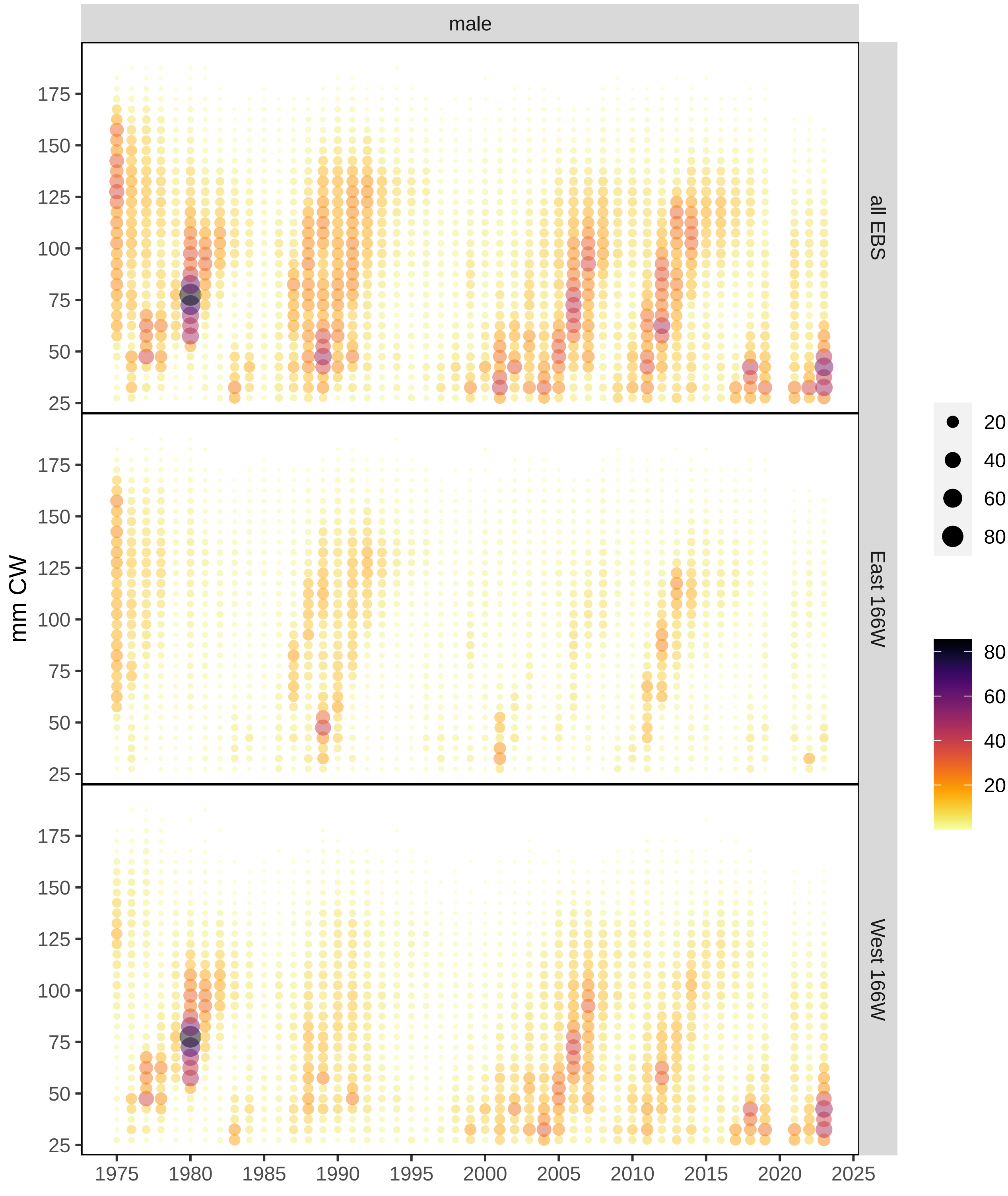


Figure 34. Annual size compositions, by 5-mm CW bin, from the NMFS EBS shelf bottom trawl survey for males by ADFG management area for 1975-2023 as a bubble plot. The size compositions are truncated for crab < 25 mm CW.

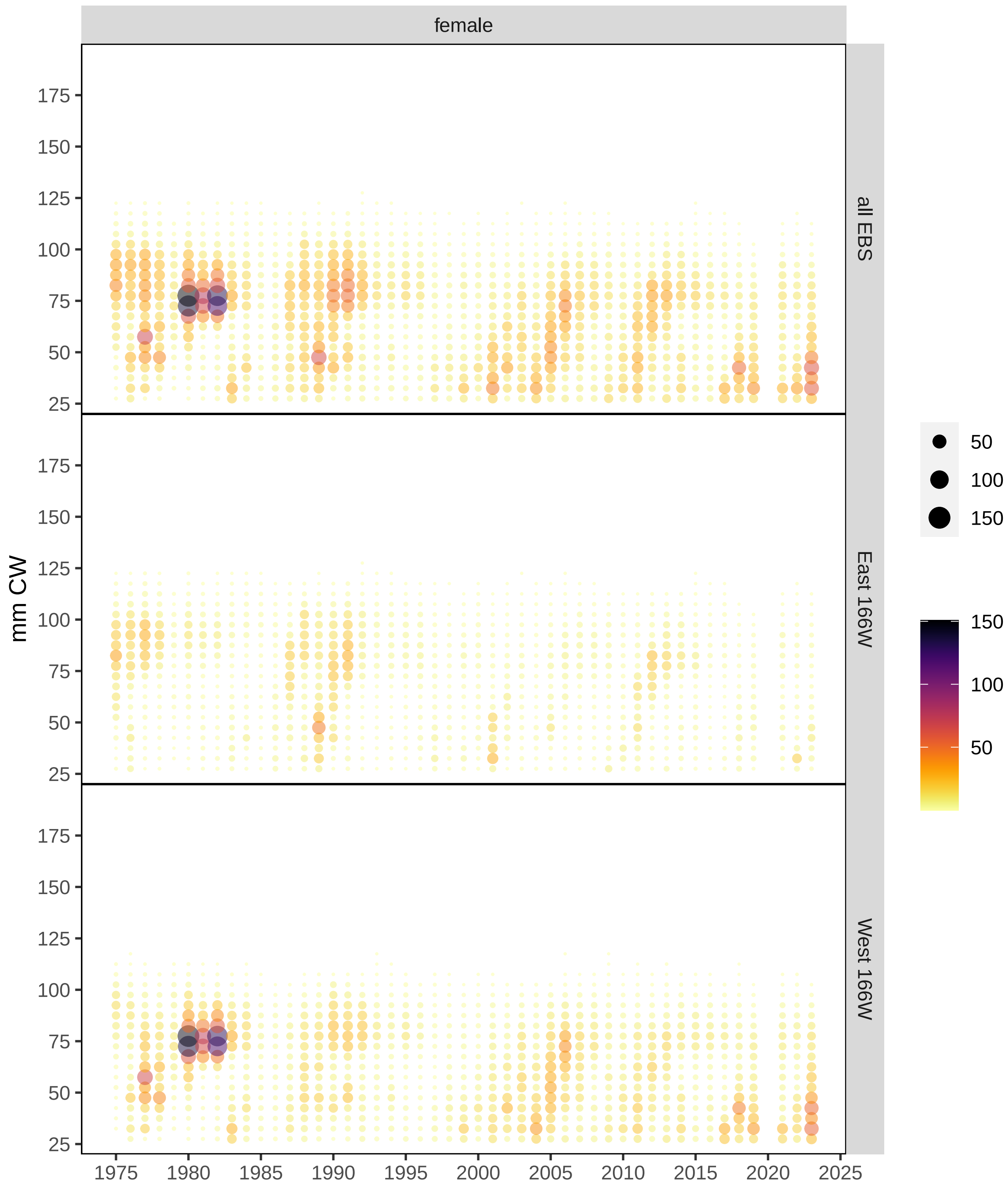
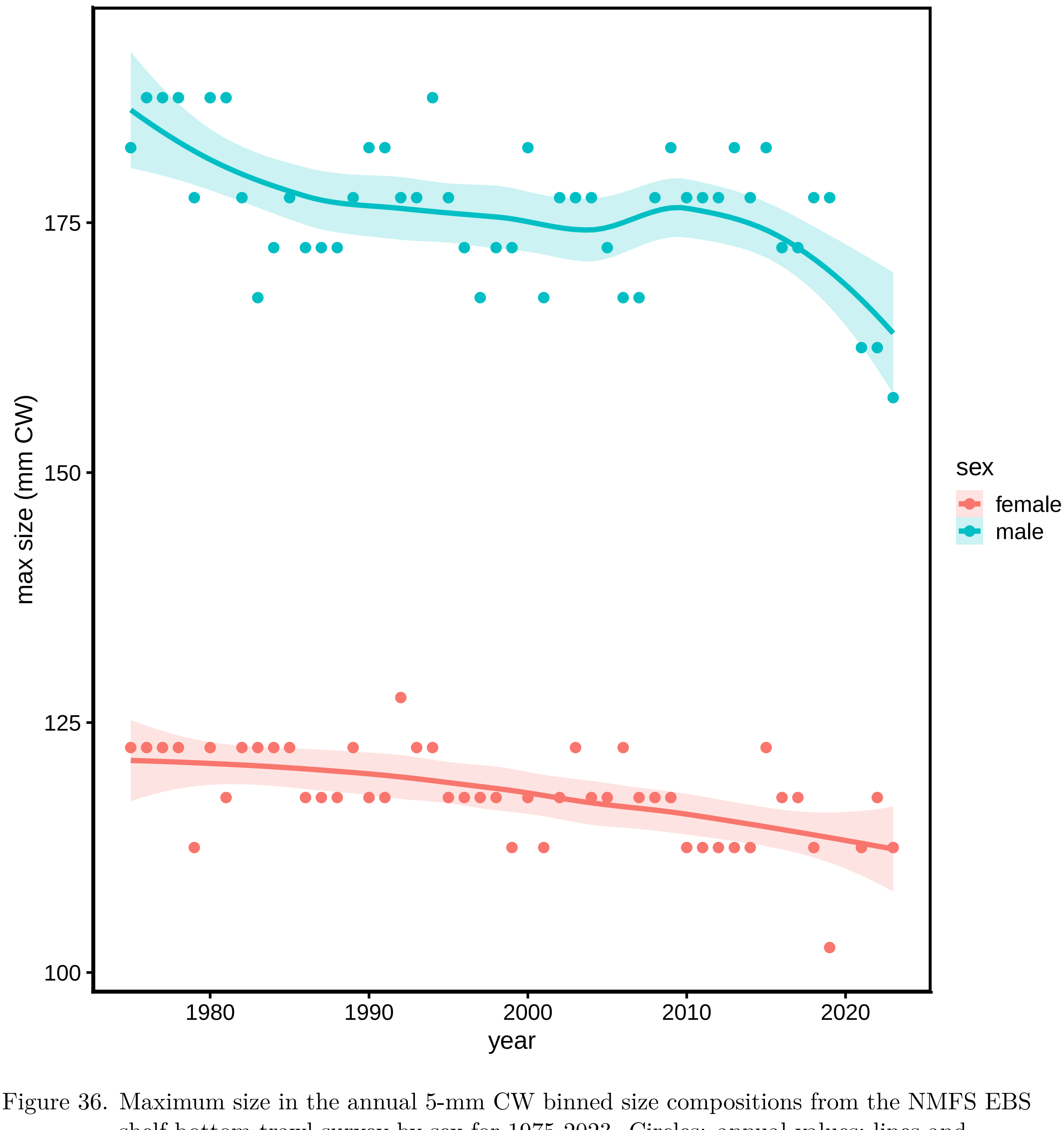


Figure 35. Annual size compositions, by 5-mm CW bin, from the NMFS EBS shelf bottom trawl survey for females by ADFG management area for 1975-2023 as a bubble plot. The size compositions are truncated for crab < 25 mm CW.



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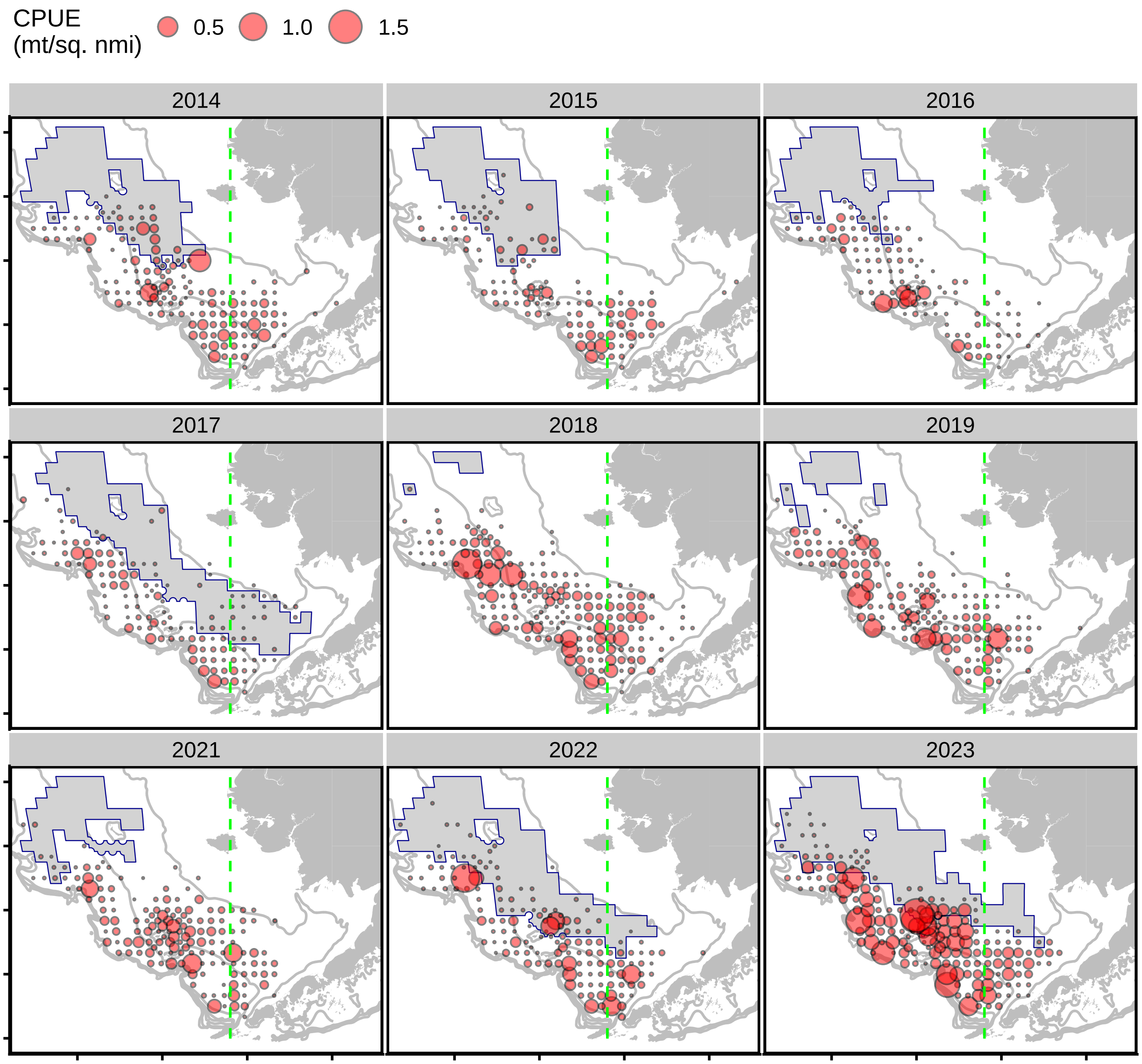

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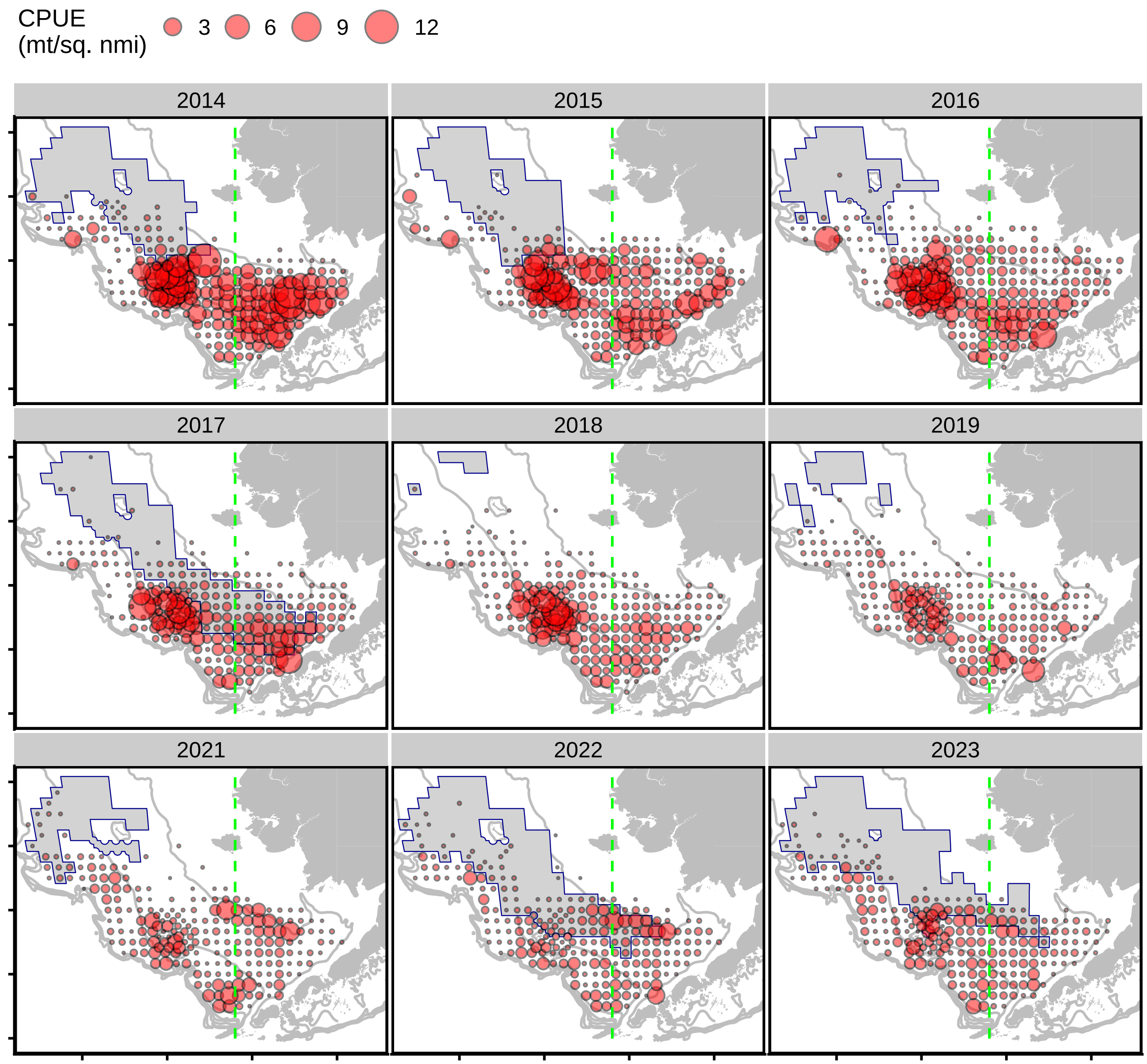


Figure 39. Spatial CPUE of large males (> 60 mm CW) in the NMFS EBS survey. Grey area indicates summer cod pool.

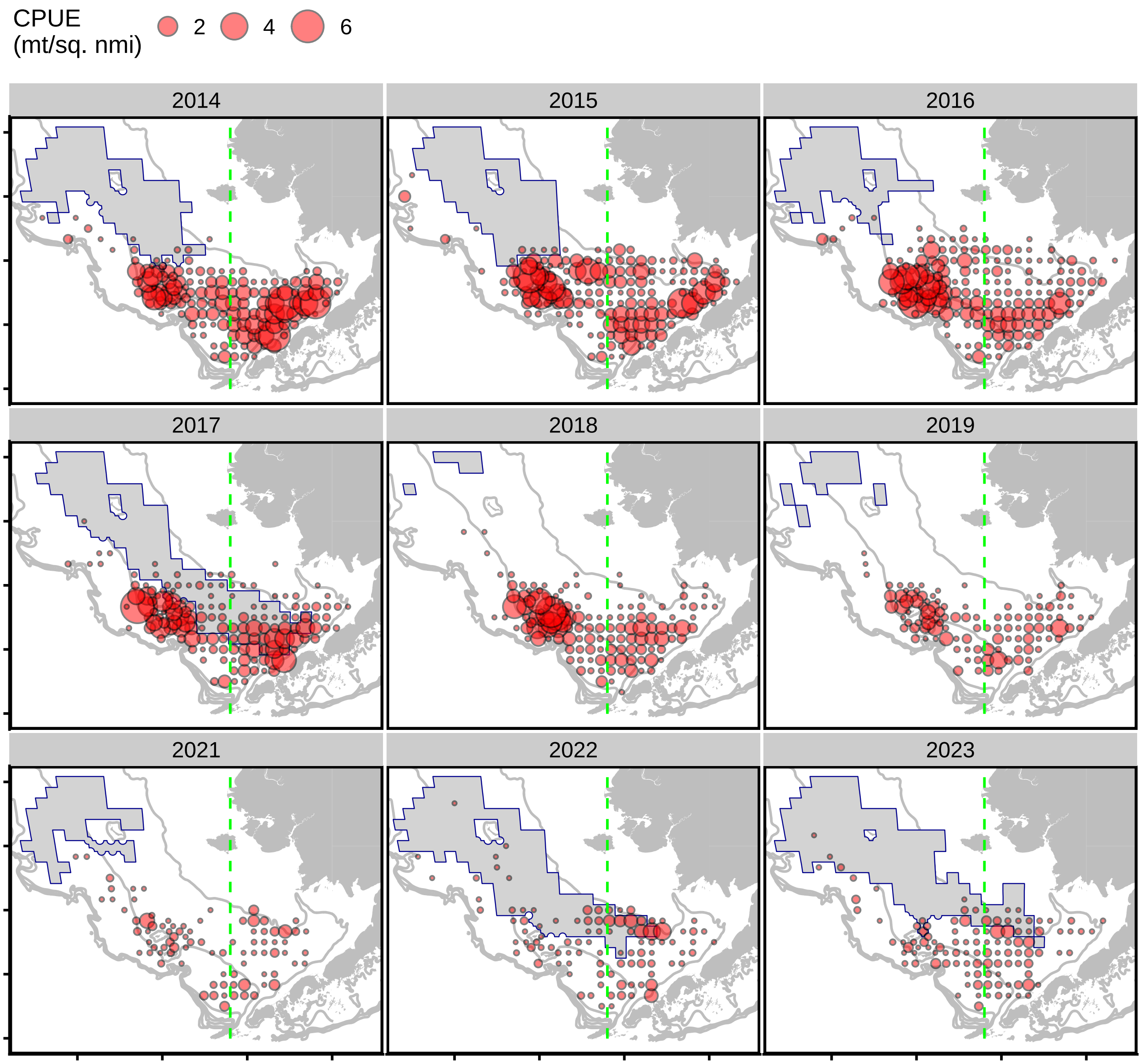


Figure 40. Spatial CPUE of industry-preferred (≥ 125 mm CW) in the NMFS EBS survey. Grey area indicates summer cod pool.

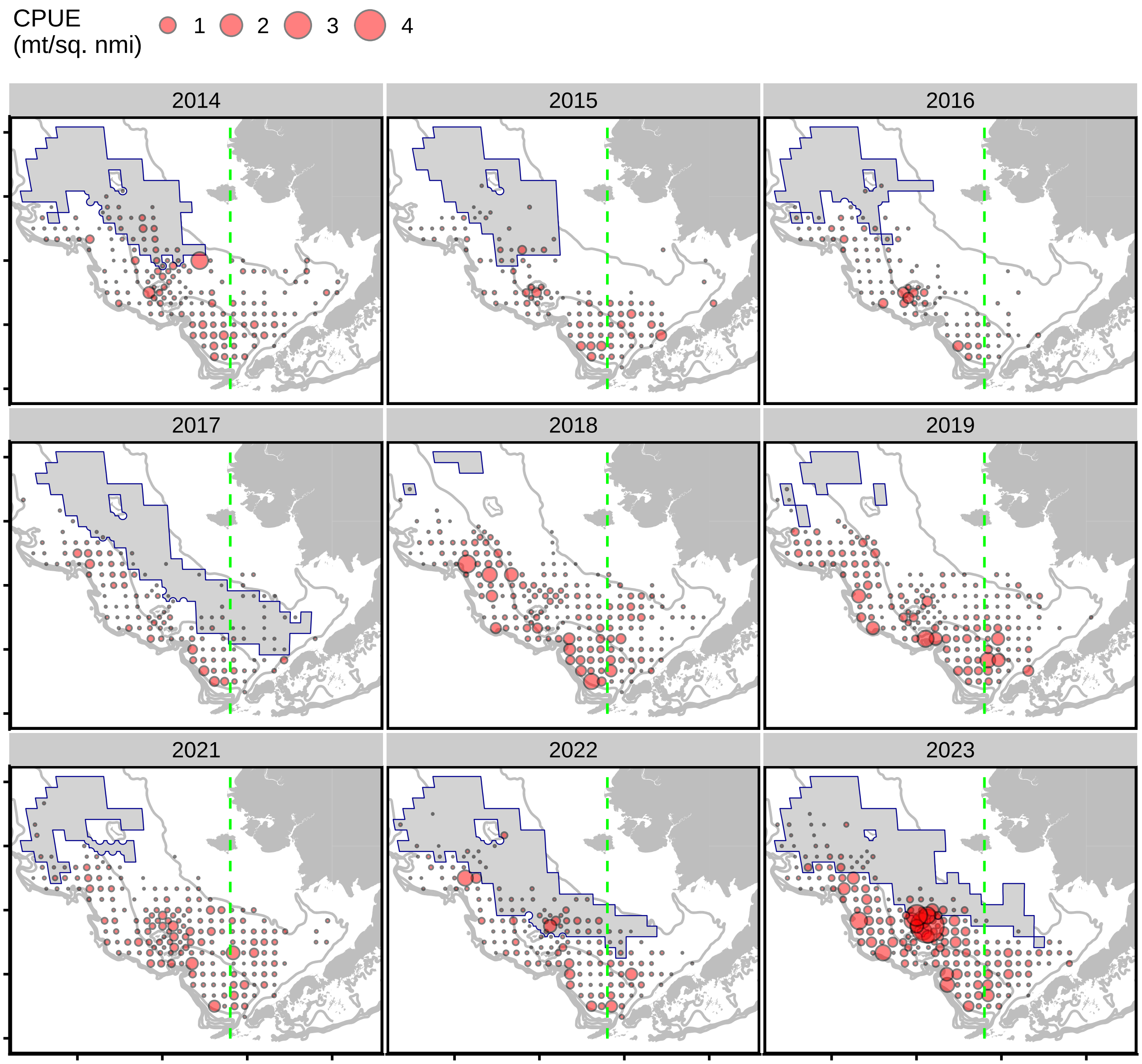
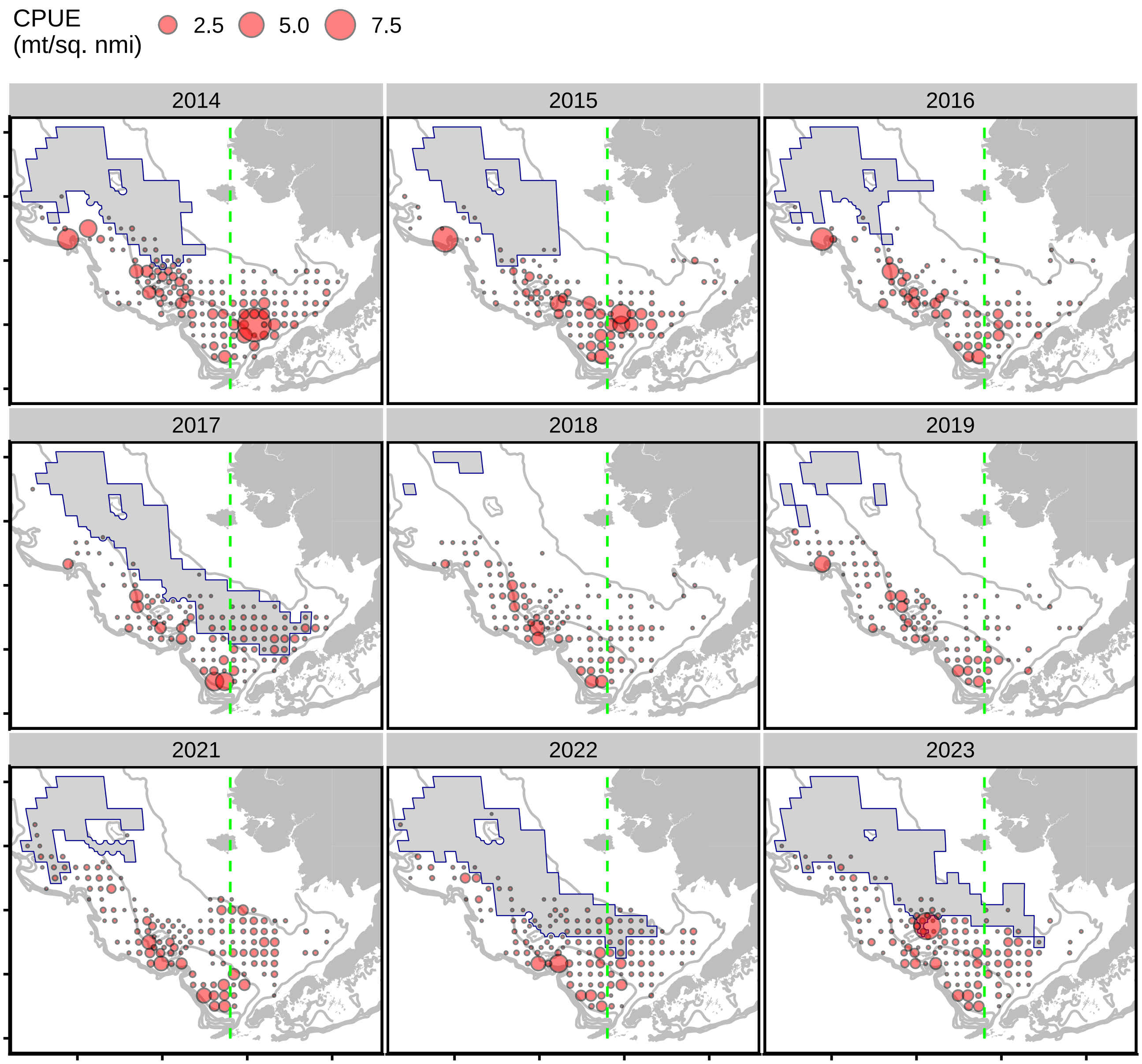


Figure 41. Spatial CPUE of immature females in the NMFS EBS survey. Grey area indicates summer cod pool.



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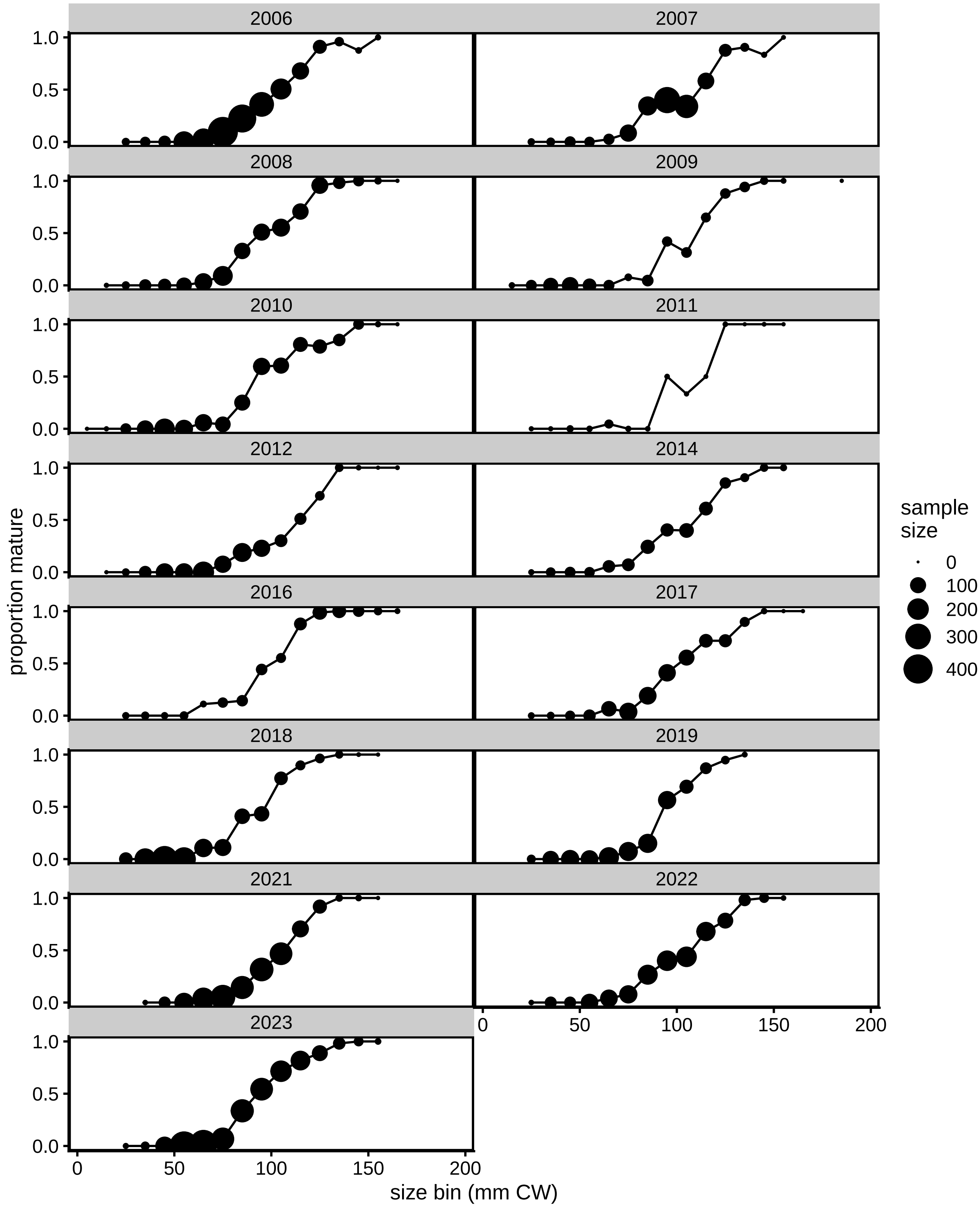

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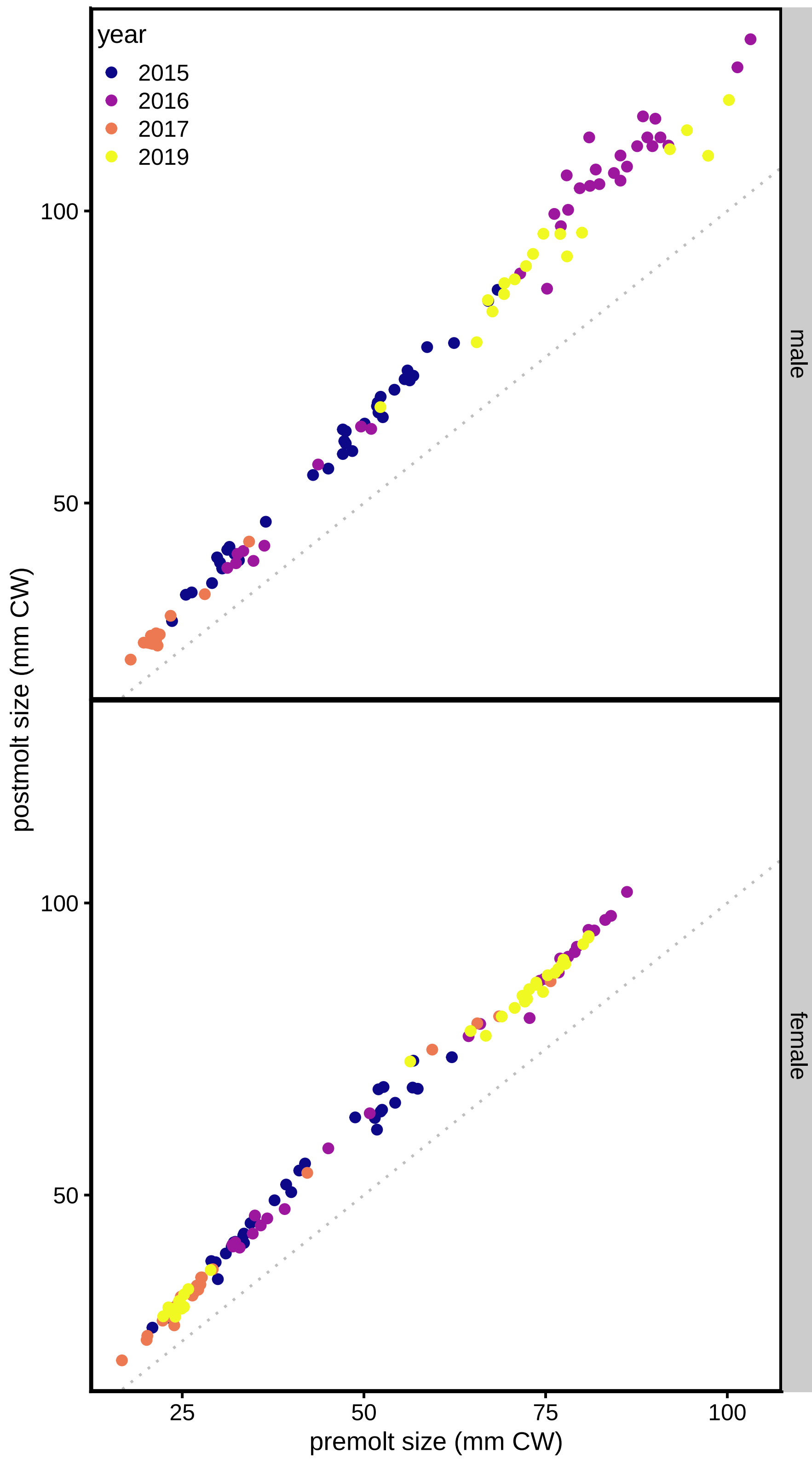

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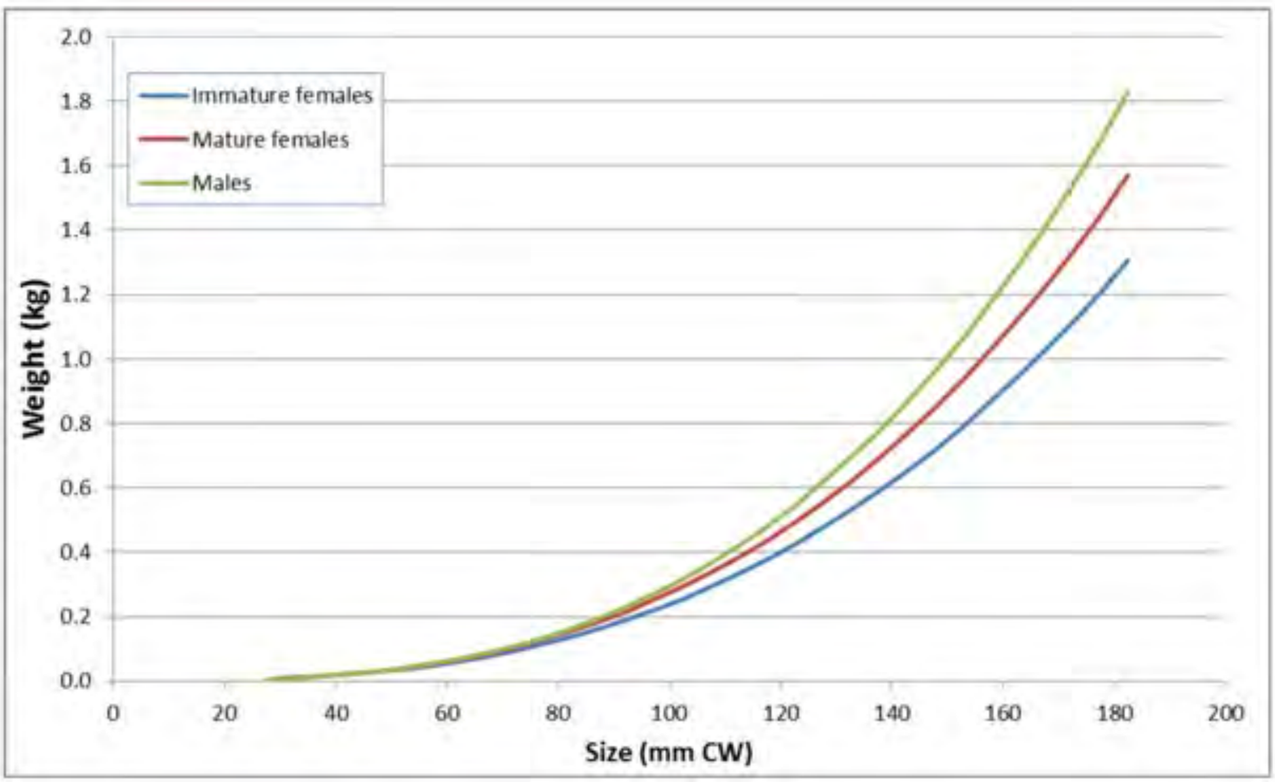

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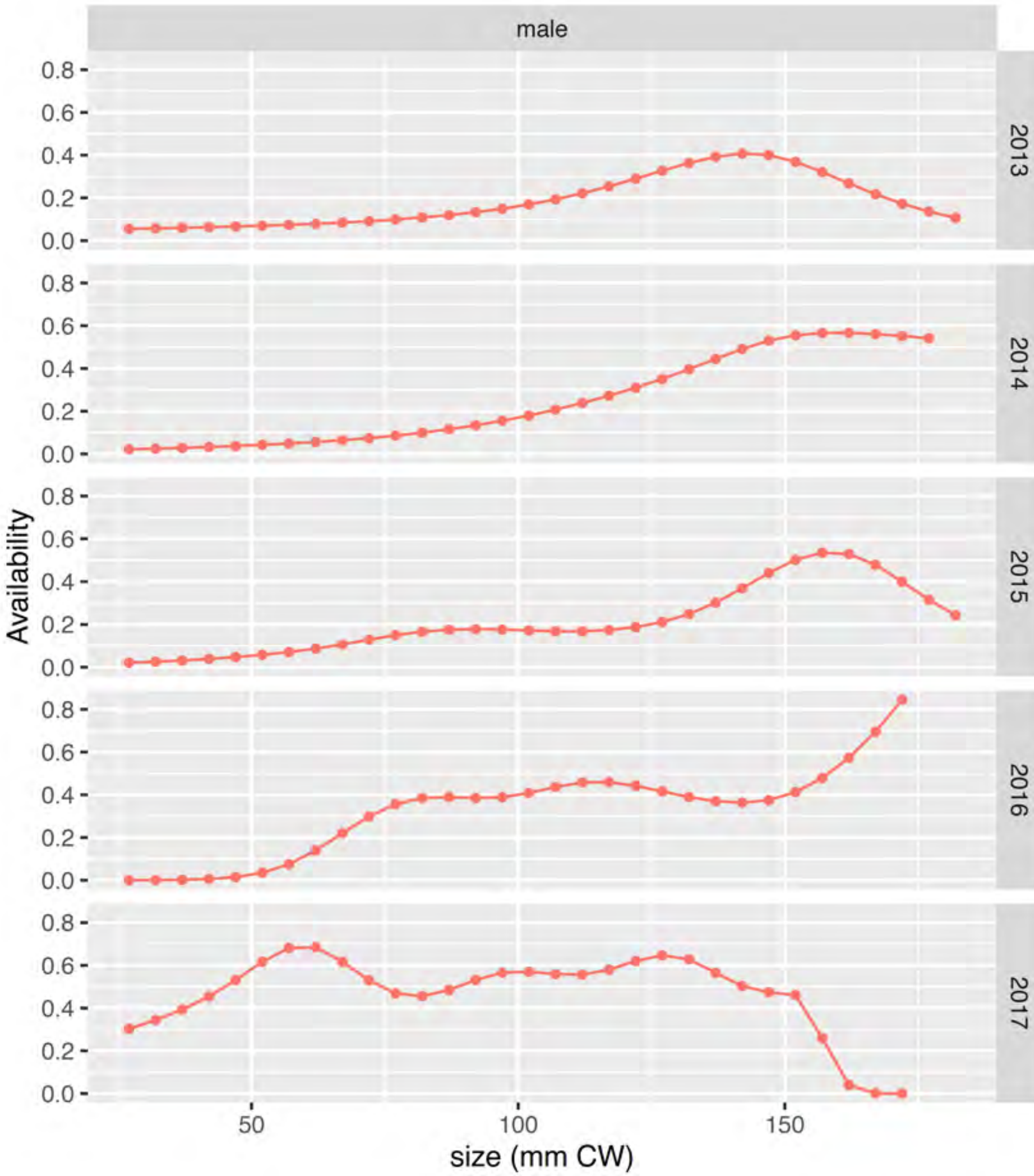

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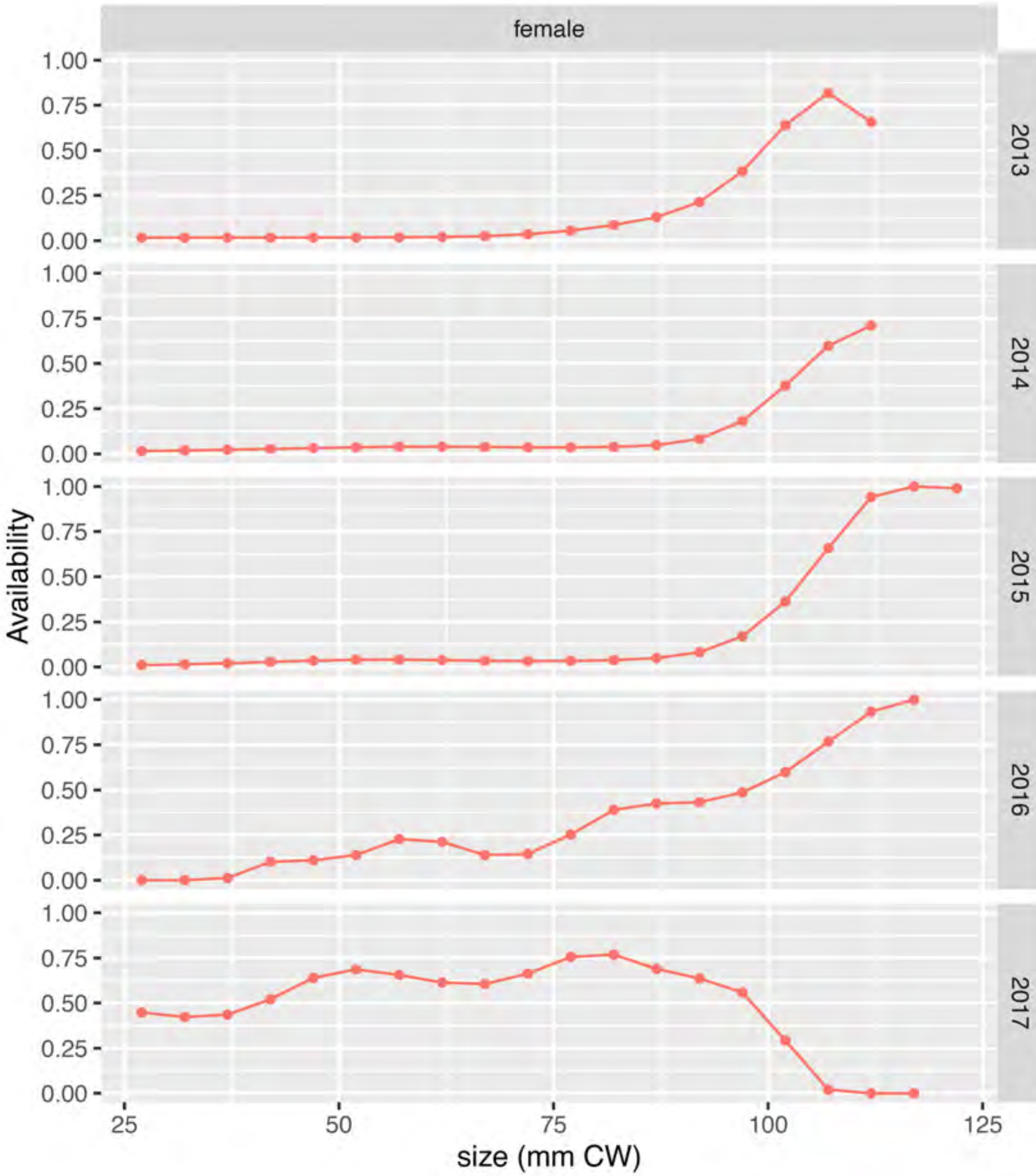

Figure 47. Empirical female availability curves for BSFRF SBS data.

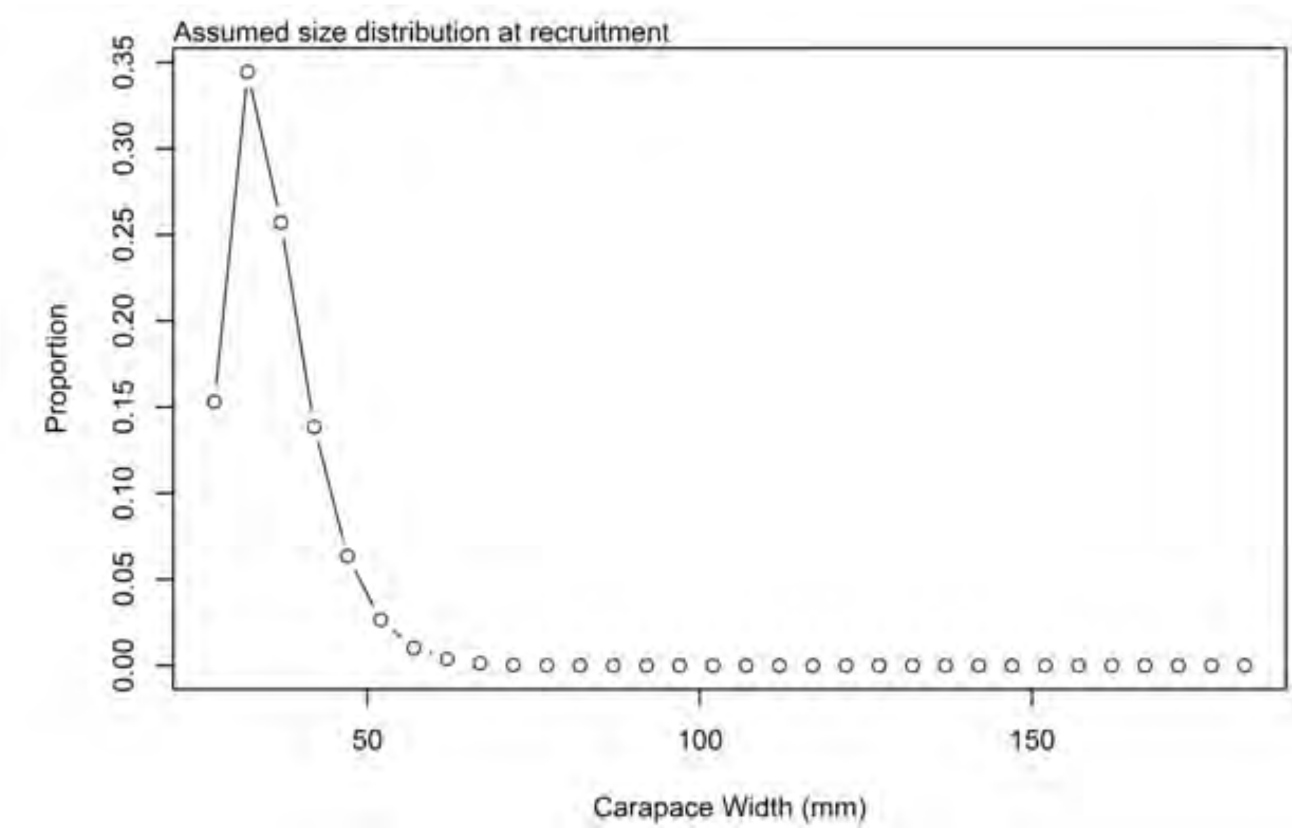

Figure 48. The nominal shape (a truncated gamma distribution) for the assumed size distribution of Tanner crab at recruitment to the model.

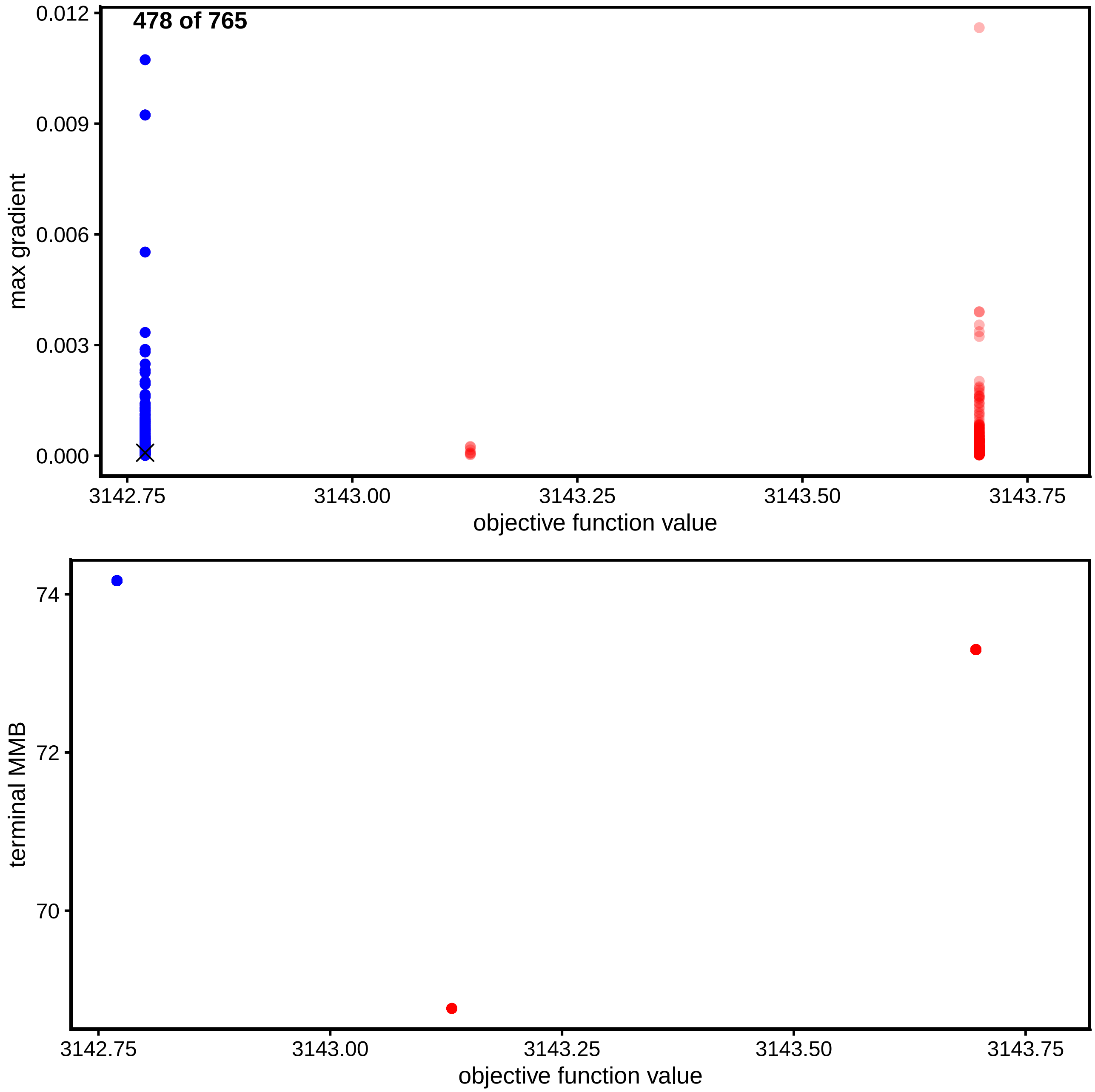

Figure 49. Results from 800 jitter runs for Model 22.03b. Of these, 478 appear to have converged to the MLE (blue dots). The minimum objective function found was 3,142.77; the maximum gradient for that model run was 8.13e-05. 35 failed to finish.

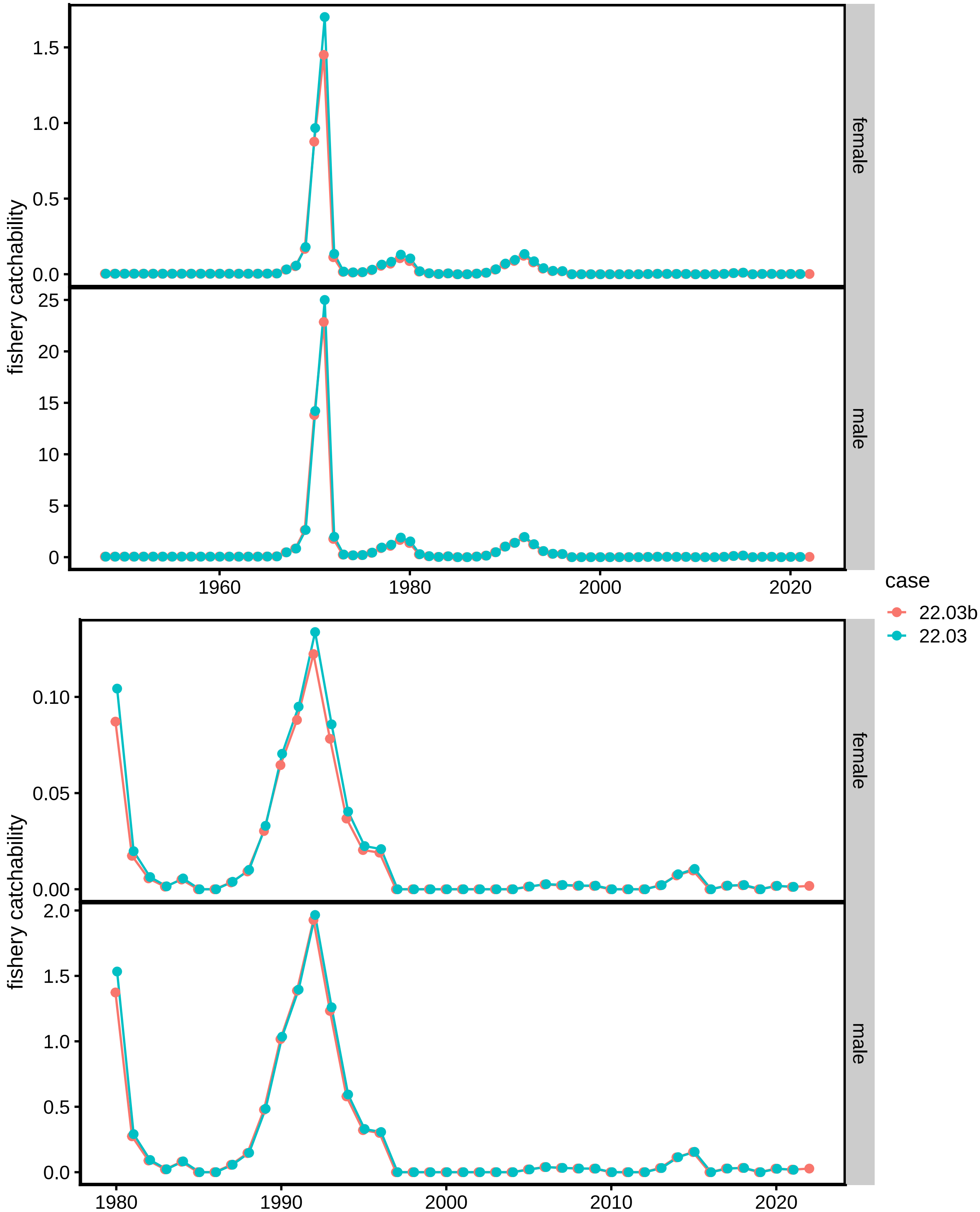

Figure 50. Estimated fully-selected capture rates (not mortality) in the directed fishery. The lower pair of plots show the estimated time series since 1980. Preferred model is 22.03b.

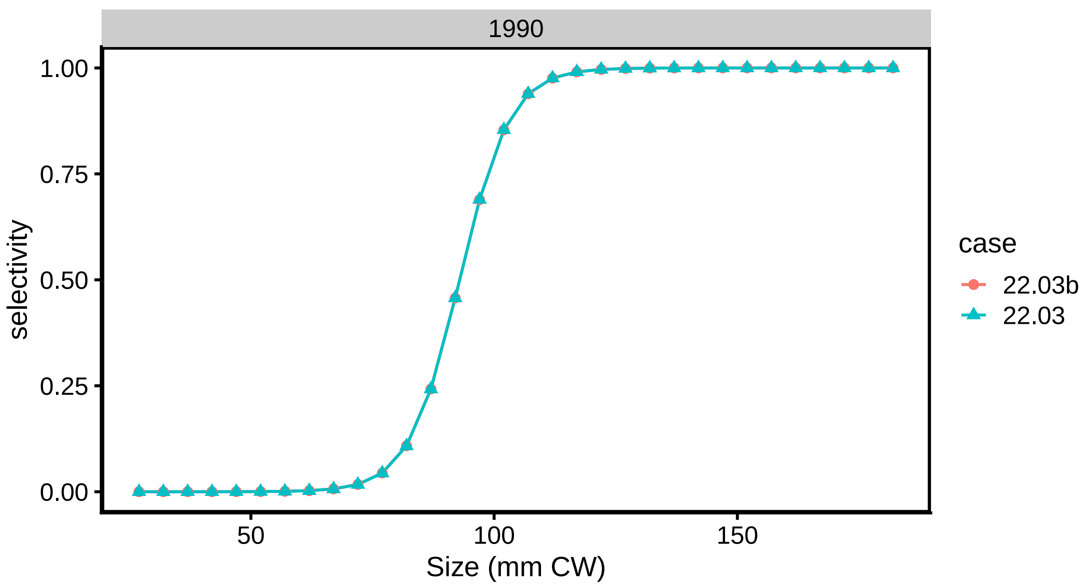

Figure 51. Estimated selectivity for females in the directed fishery for all years. Preferred model is 22.03b.

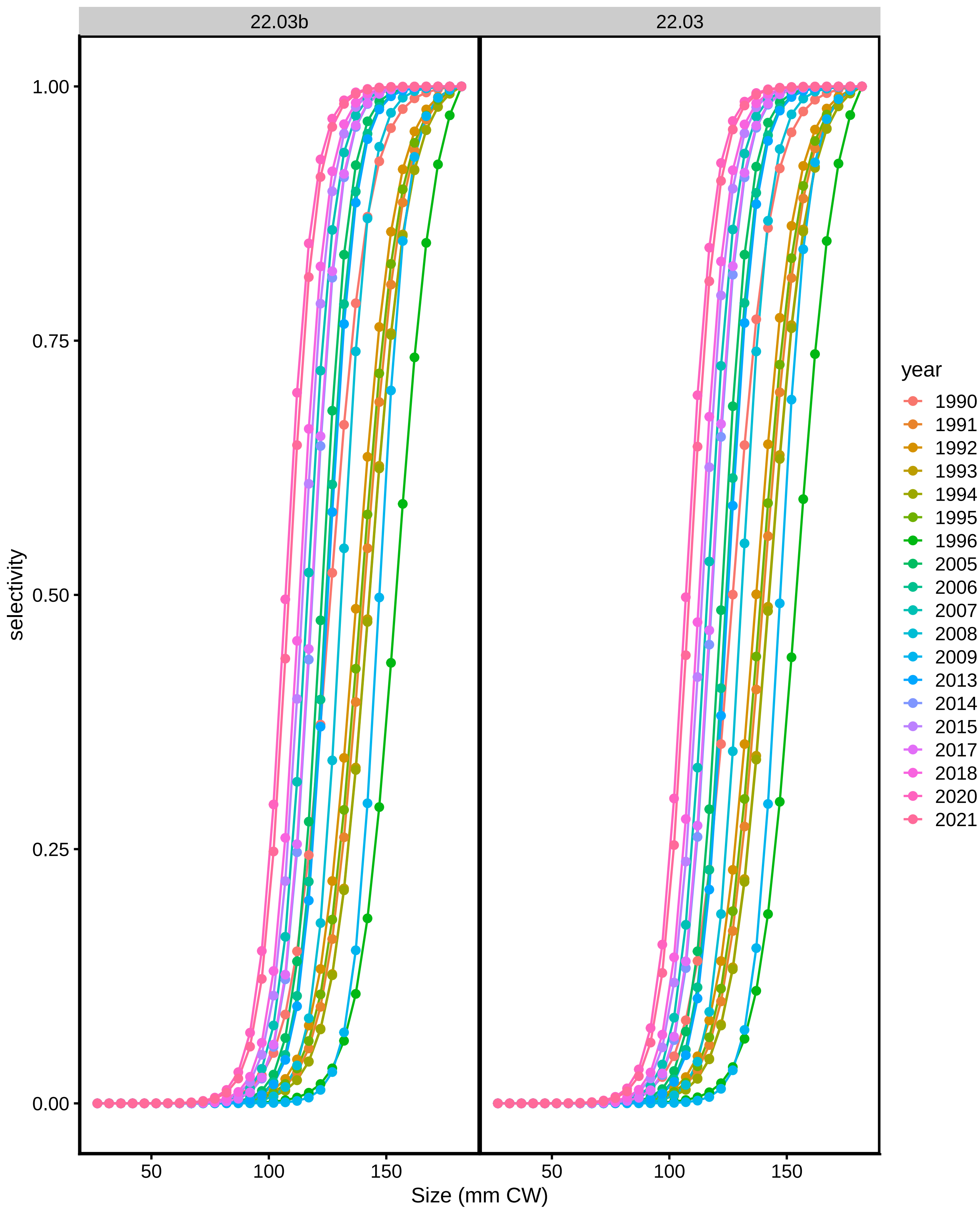

Figure 52. Estimated selectivity curves for males in the directed fishery, faceted by model scenario. Curves labelled 1990 applies to all years before 1991. Others apply in the year indicated in the legend. Preferred model is 22.03b.

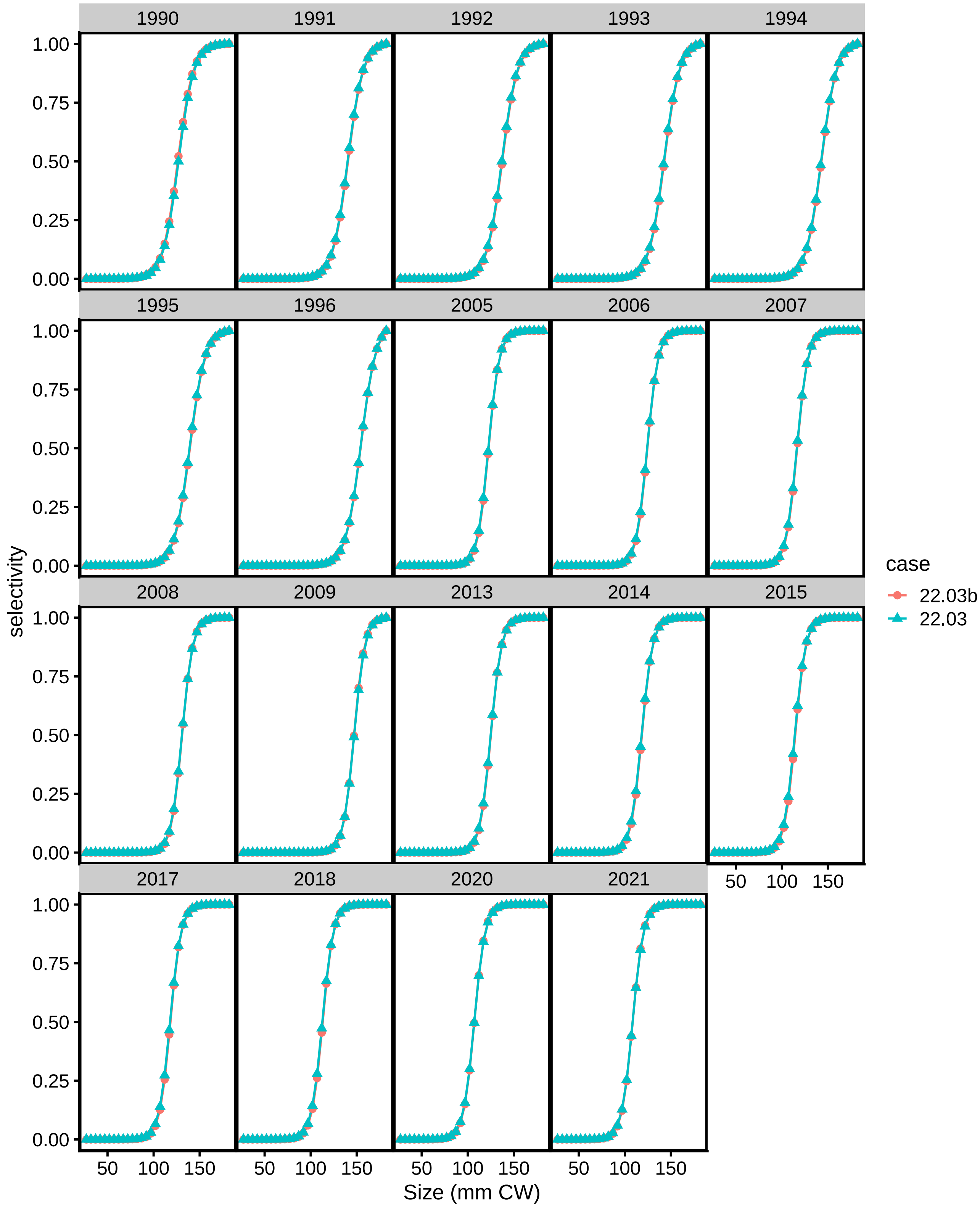

Figure 53. Estimated selectivity curves for males in the directed fishery by year. Curve labelled 1990 applies to all years before 1991. Others apply in the year indicated in the panel. Preferred model is 22.03b.

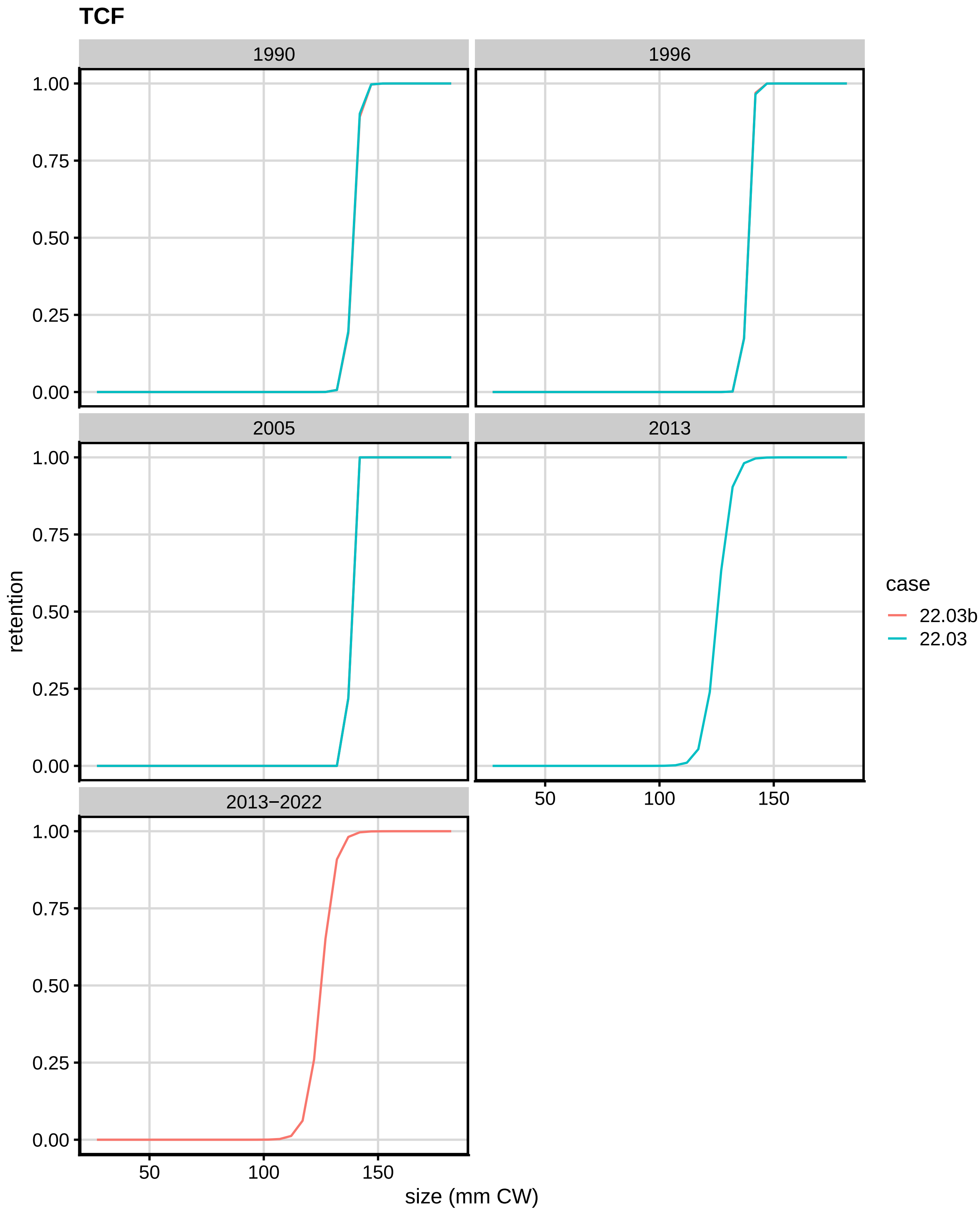

Figure 54. Estimated retention curves for males in the directed fishery by time block. Curve labelled: '1990' - applies to all years before 1991; '1996' - applies to 1991-2006; 2005 - applies to 2005-2009; 2013 - applies to 2013-present. Preferred model is 22.03b.

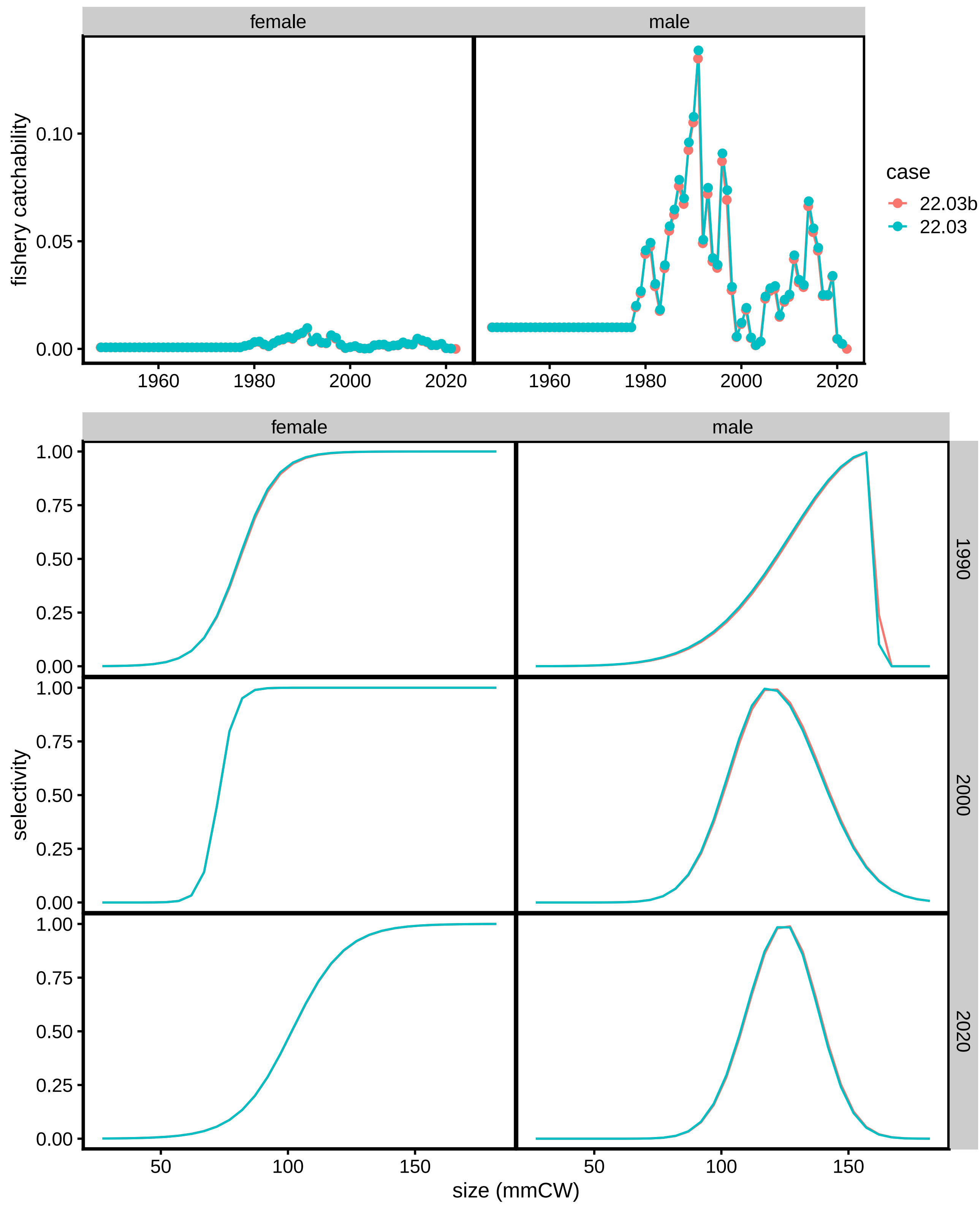

Figure 55. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the snow crab fishery (SCF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present. Preferred model is 22.03b.

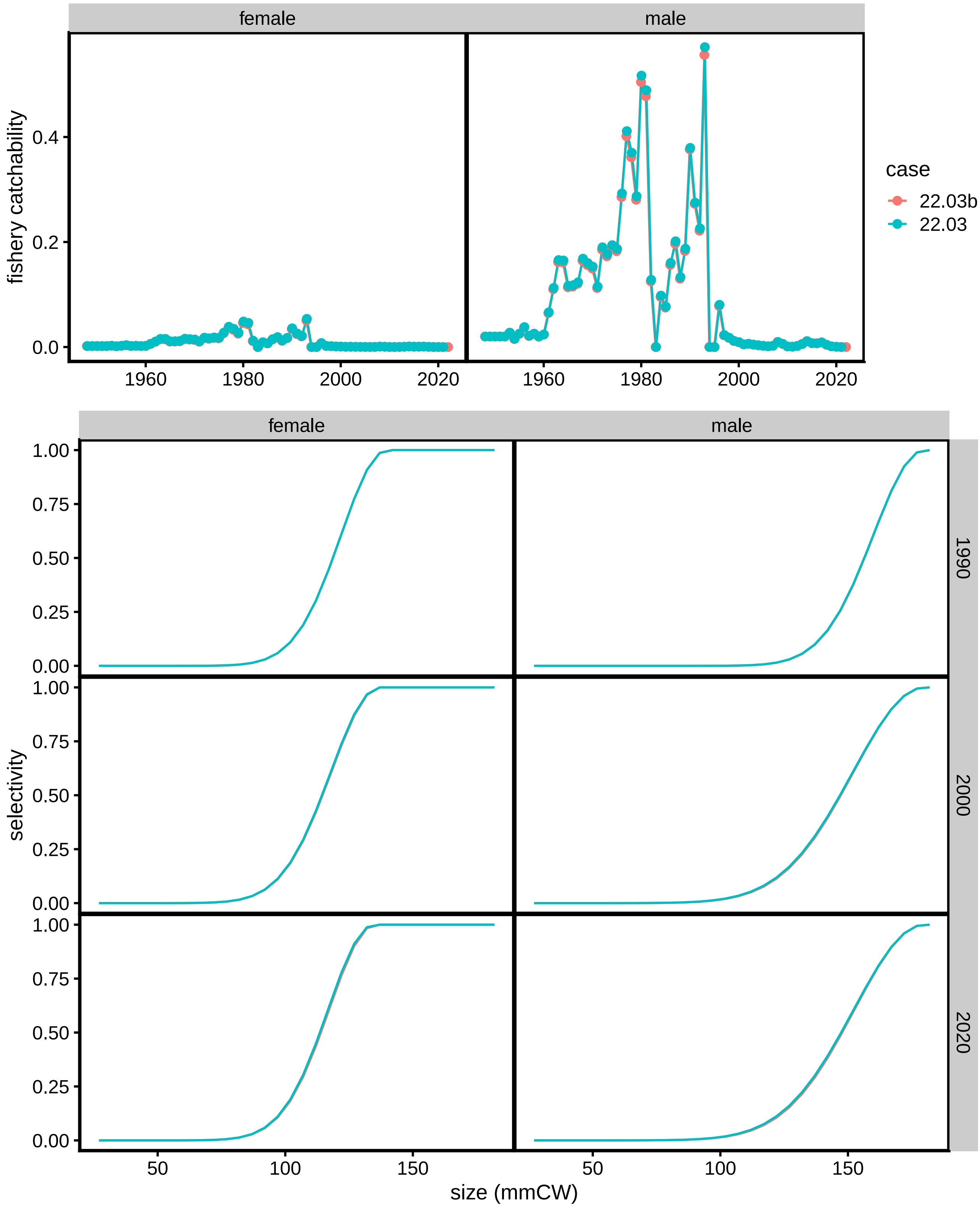

Figure 56. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the BBRKC fishery (RKF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present. Preferred model is 22.03b.

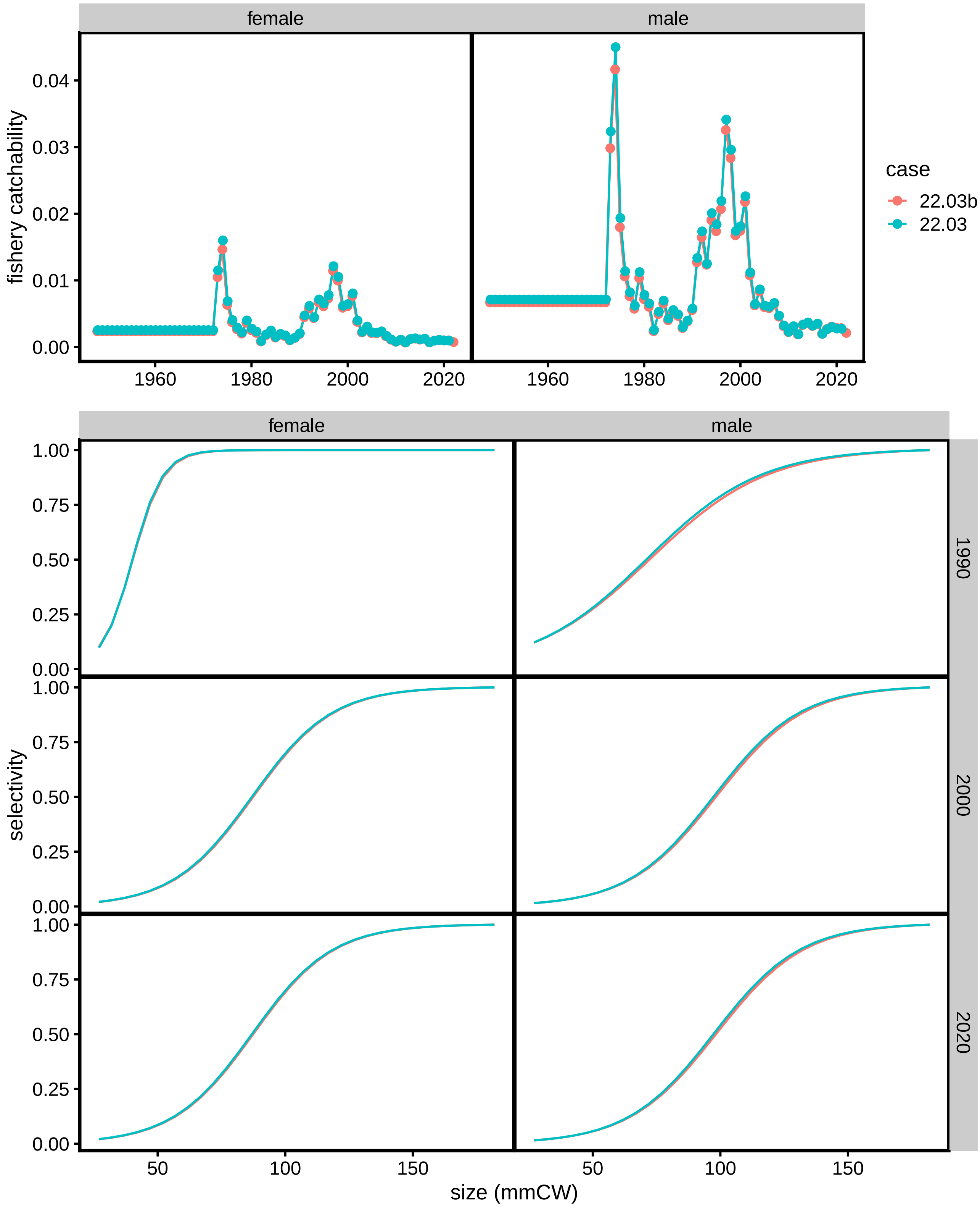

Figure 57. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the groundfish fisheries (GF All). Time blocks for selectivity functions are labelled: 1980) before 1988; 1990) 1987-1996; 2020) 1997-present. Preferred model is 22.03b.

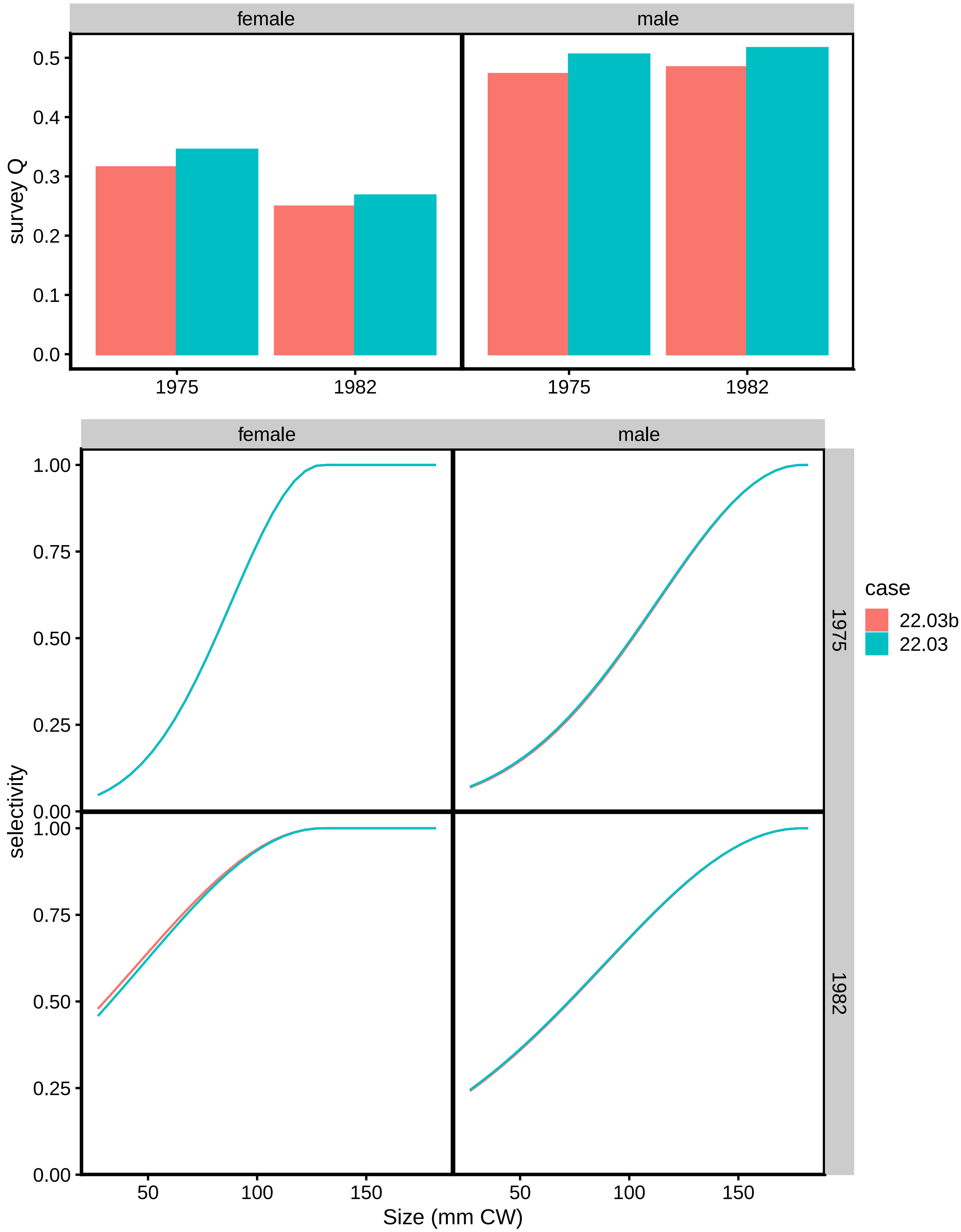

Figure 58. Estimated NMFS EBS Survey fully-selected catchability (survey Q's) and selectivity functions by sex for different time periods. 1975: 1975-1981; 1982: 1982-current. Preferred model is 22.03b.

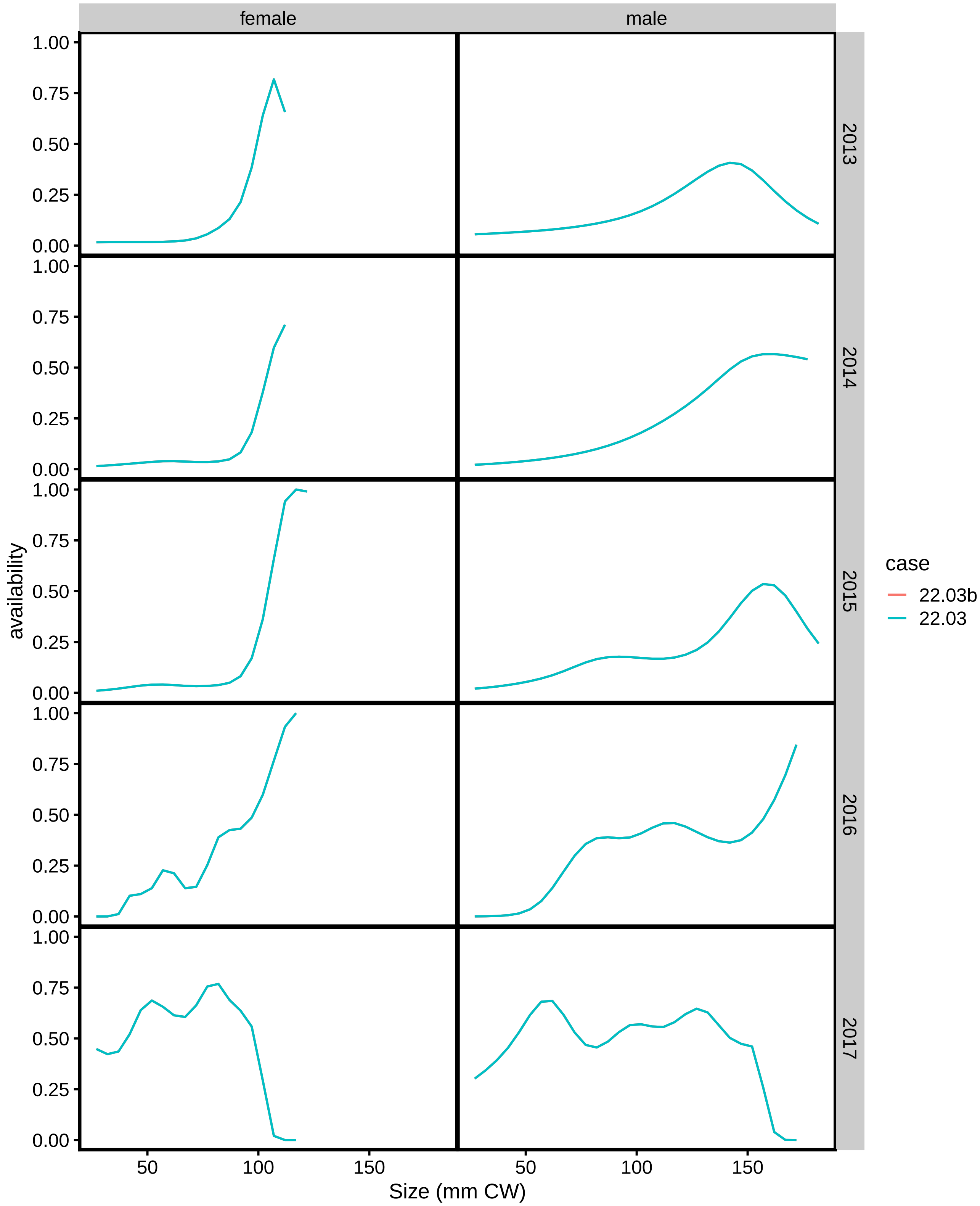

Figure 59. Annual sex-specific availability curves assumed for the BSFRF side-by-side (SBS) survey data. The availability curves were estimated outside the model. Preferred model is 22.03b.

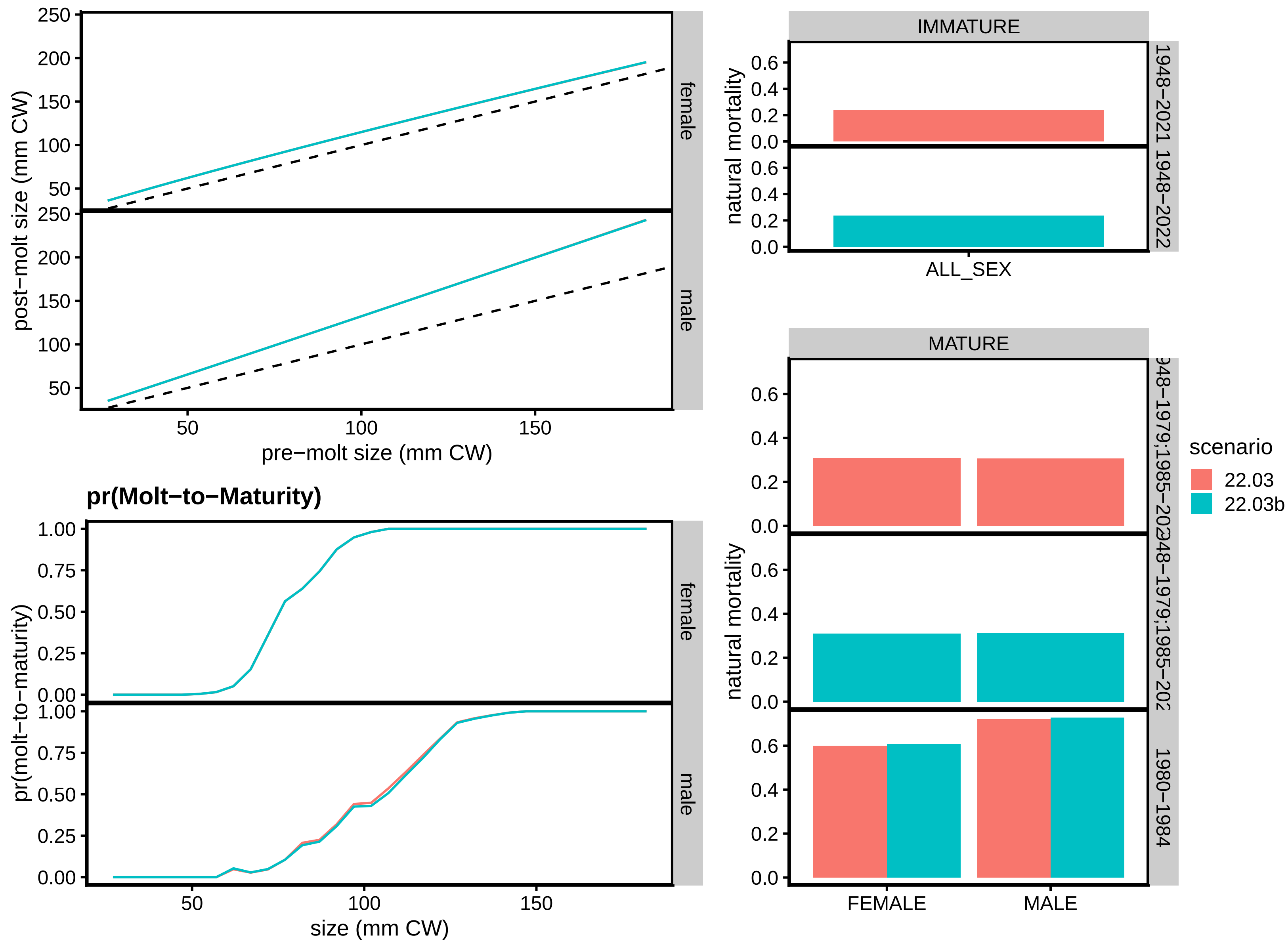

Figure 60. Estimated population processes. Plots in upper lefthand quadrant: sex-specific mean growth; plots in lower lefthand quadrant: sex-specific probability of the molt-to-maturity (i.e., terminal molt); plots in righthand column: natural mortality rates, by maturity state and sex. Preferred model is 22.03b.

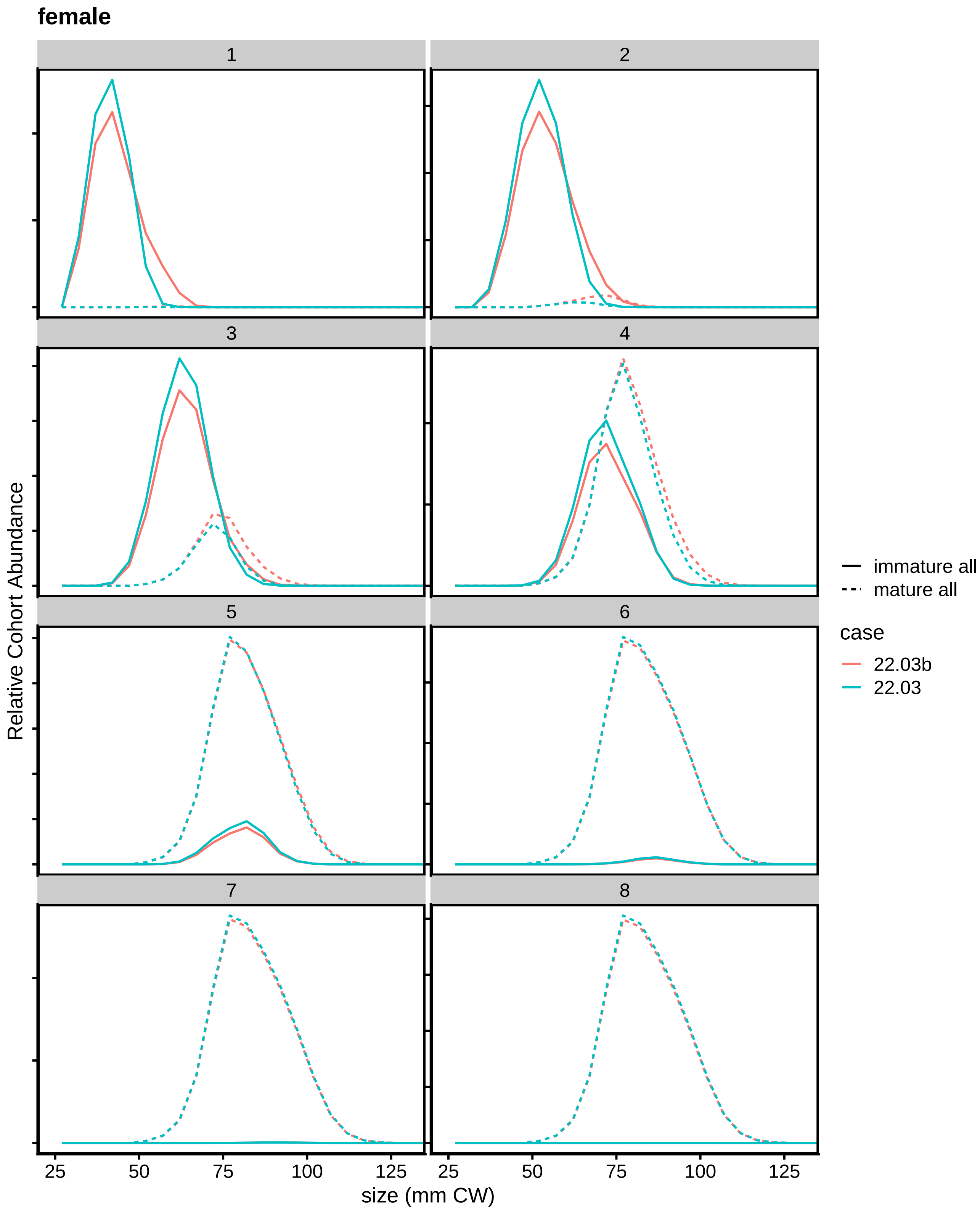

Figure 61. Estimated annual cohort progression for female crab based on rates from final model year (by age; individual scales are relative). Preferred model is 22.03b.

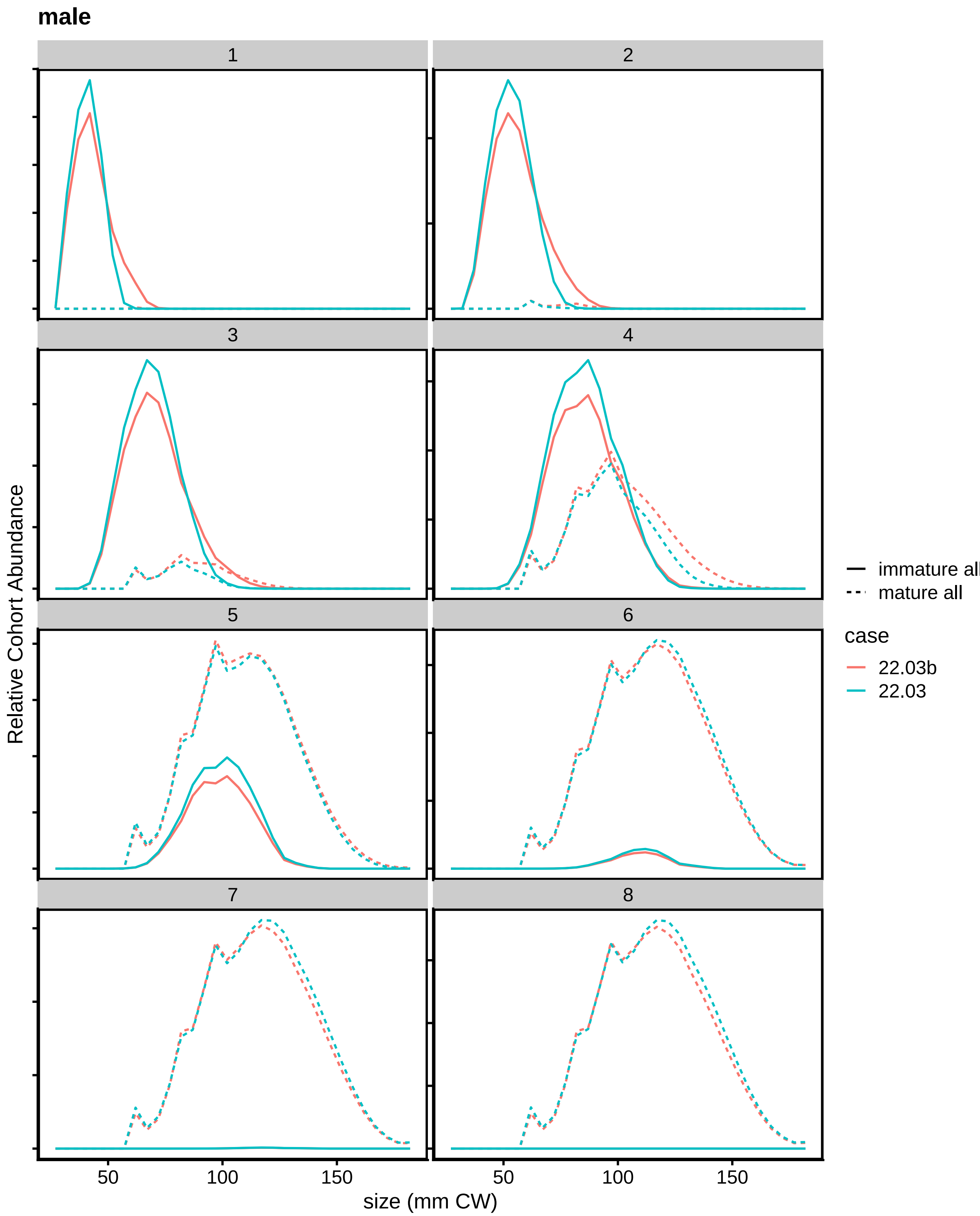

Figure 62. Estimated annual cohort progression for male crab based on rates from final model year (by age; individual scales are relative). Preferred model is 22.03b.

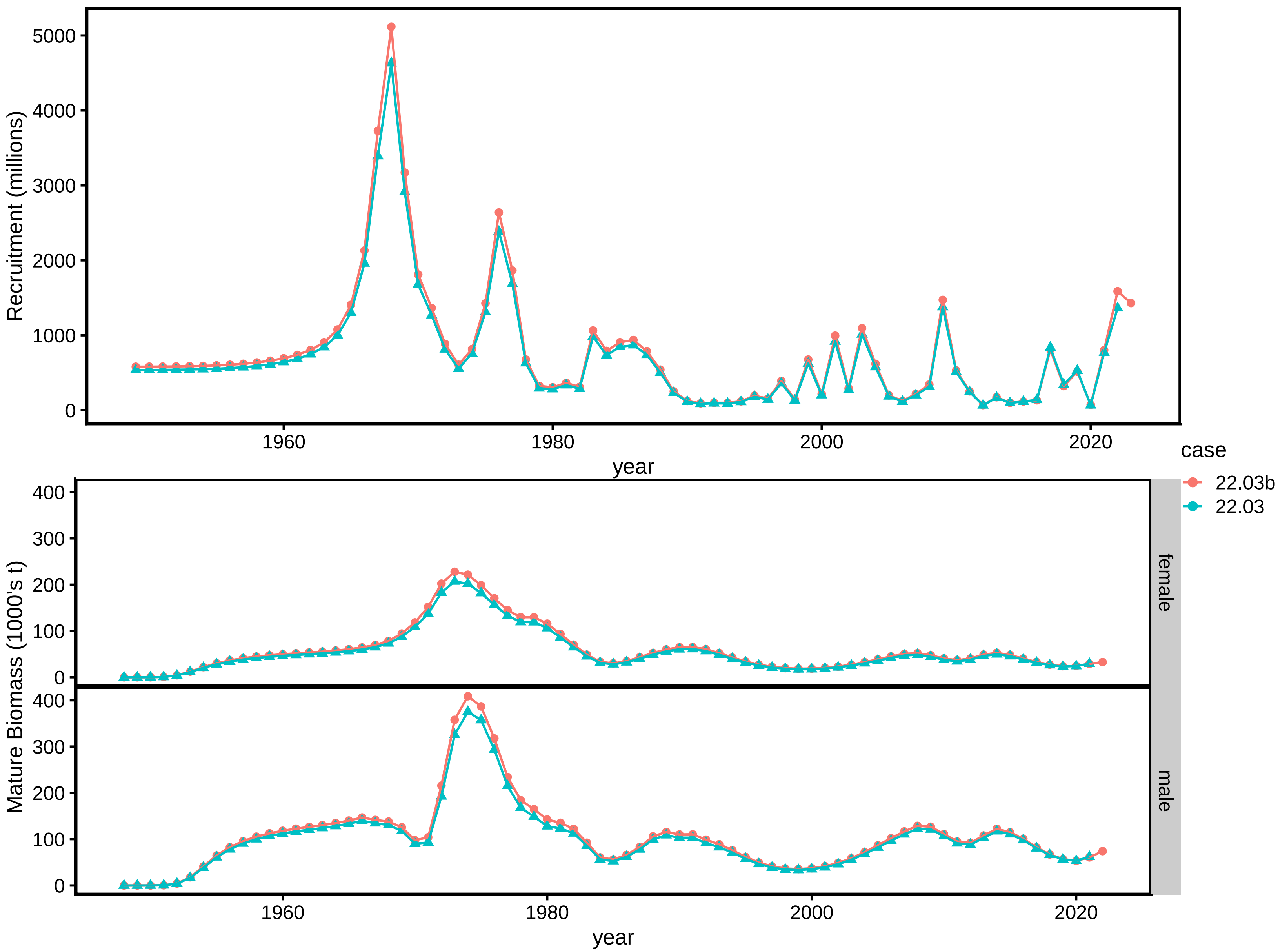

Figure 63. Estimated recruitment and mature biomass time series (all years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03b.

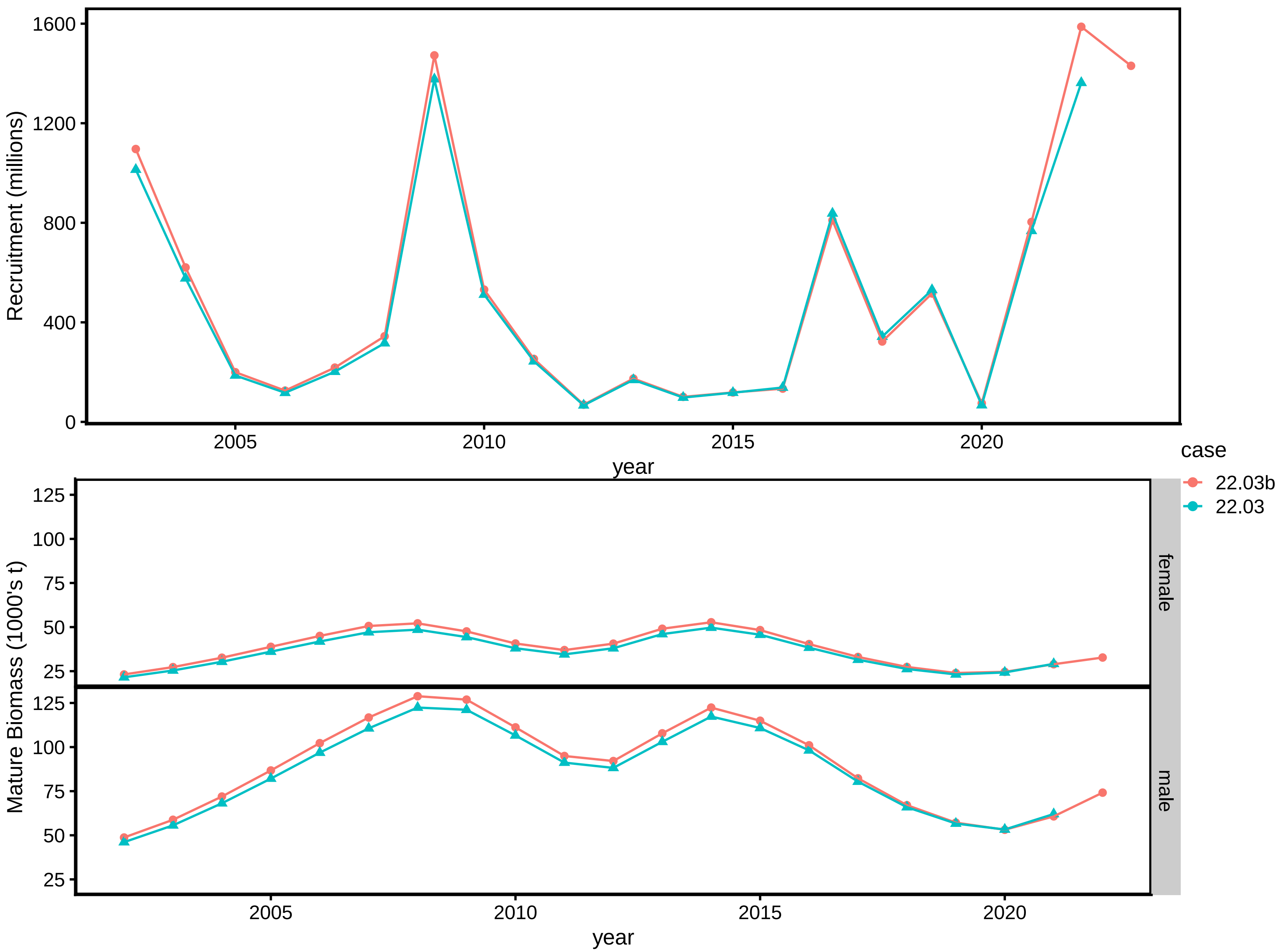

Figure 64. Estimated recruitment and mature biomass time series (recent years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03b.

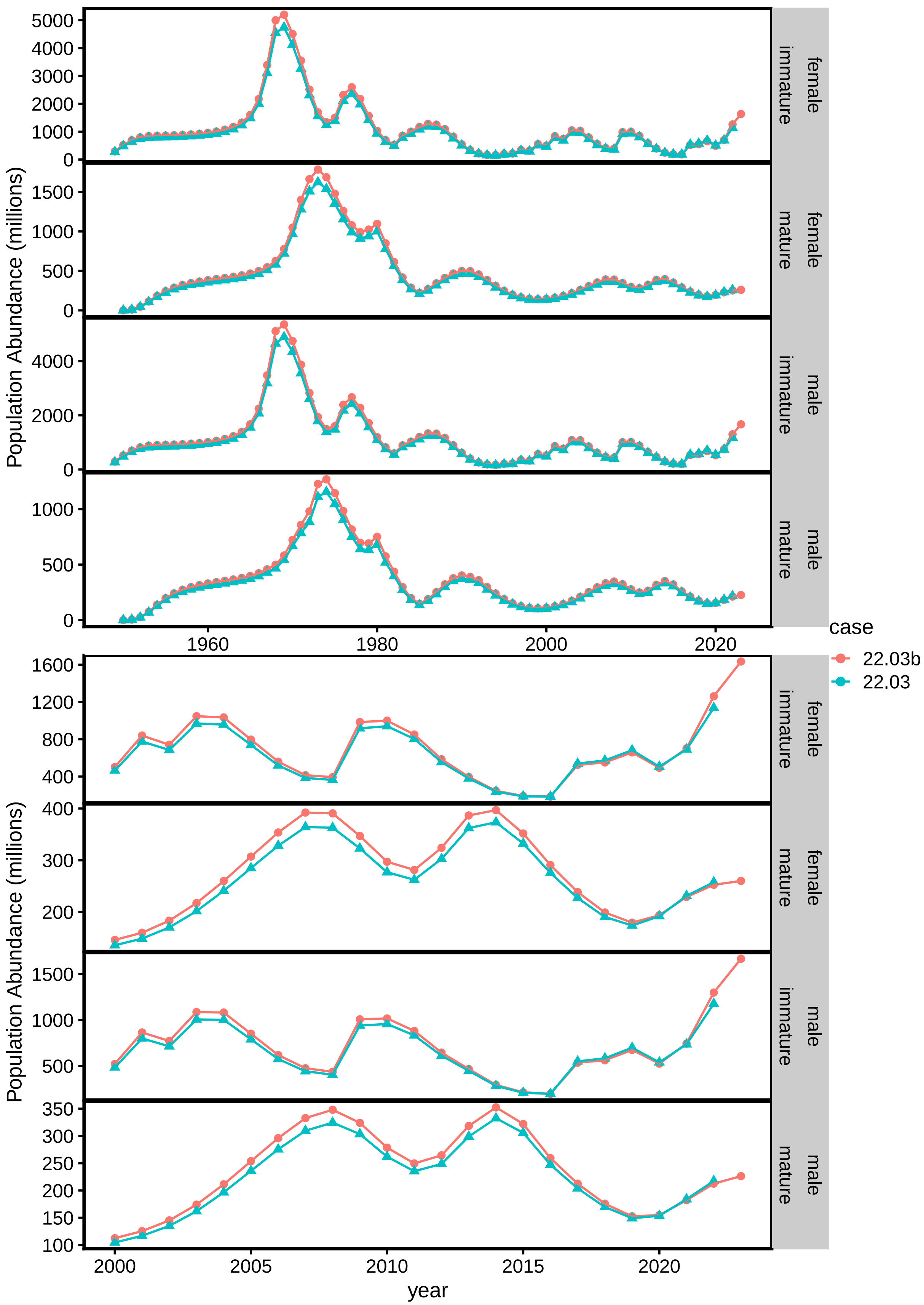

Figure 65. Estimated population abundance trends, by sex and maturity state. Upper plots: all years; lower plots: recent years. Preferred model is 22.03b.

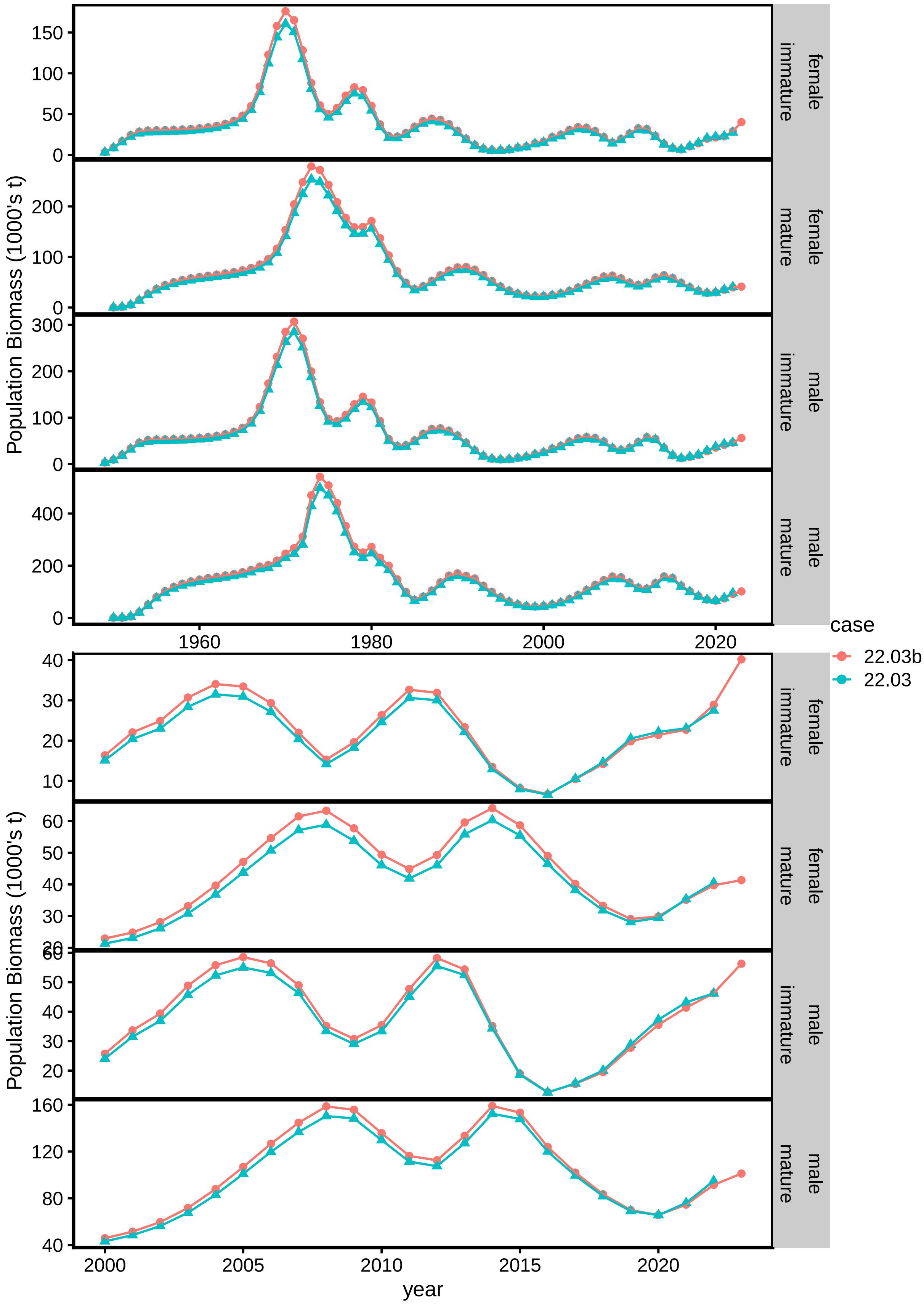

Figure 66. Estimated population biomass trends, by sex and maturity state. Upper plots: all years; lower plots: recent years. Preferred model is 22.03b.

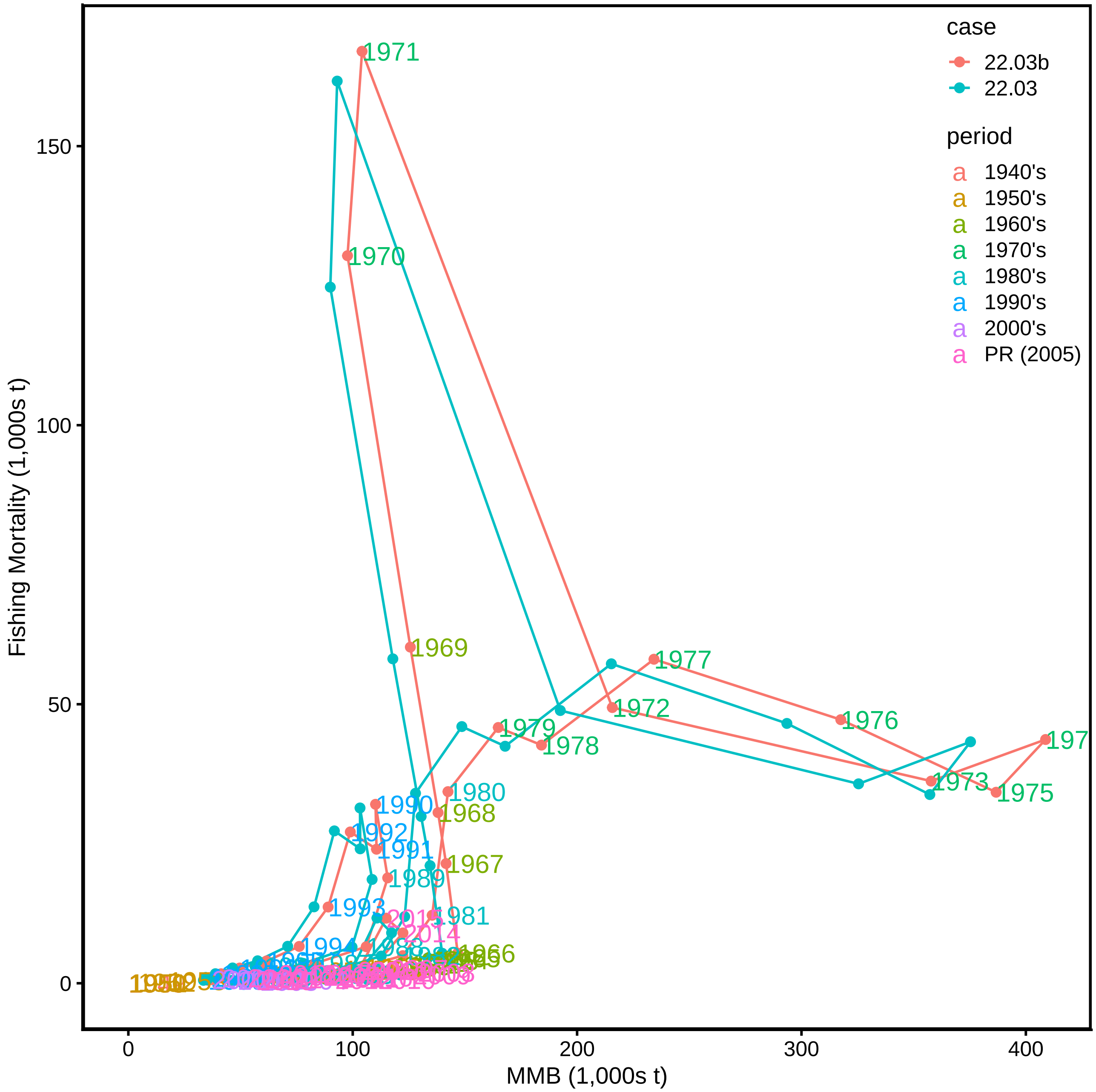

Figure 67. Total estimated fishing mortality vs. MMB. Preferred model is 22.03b.

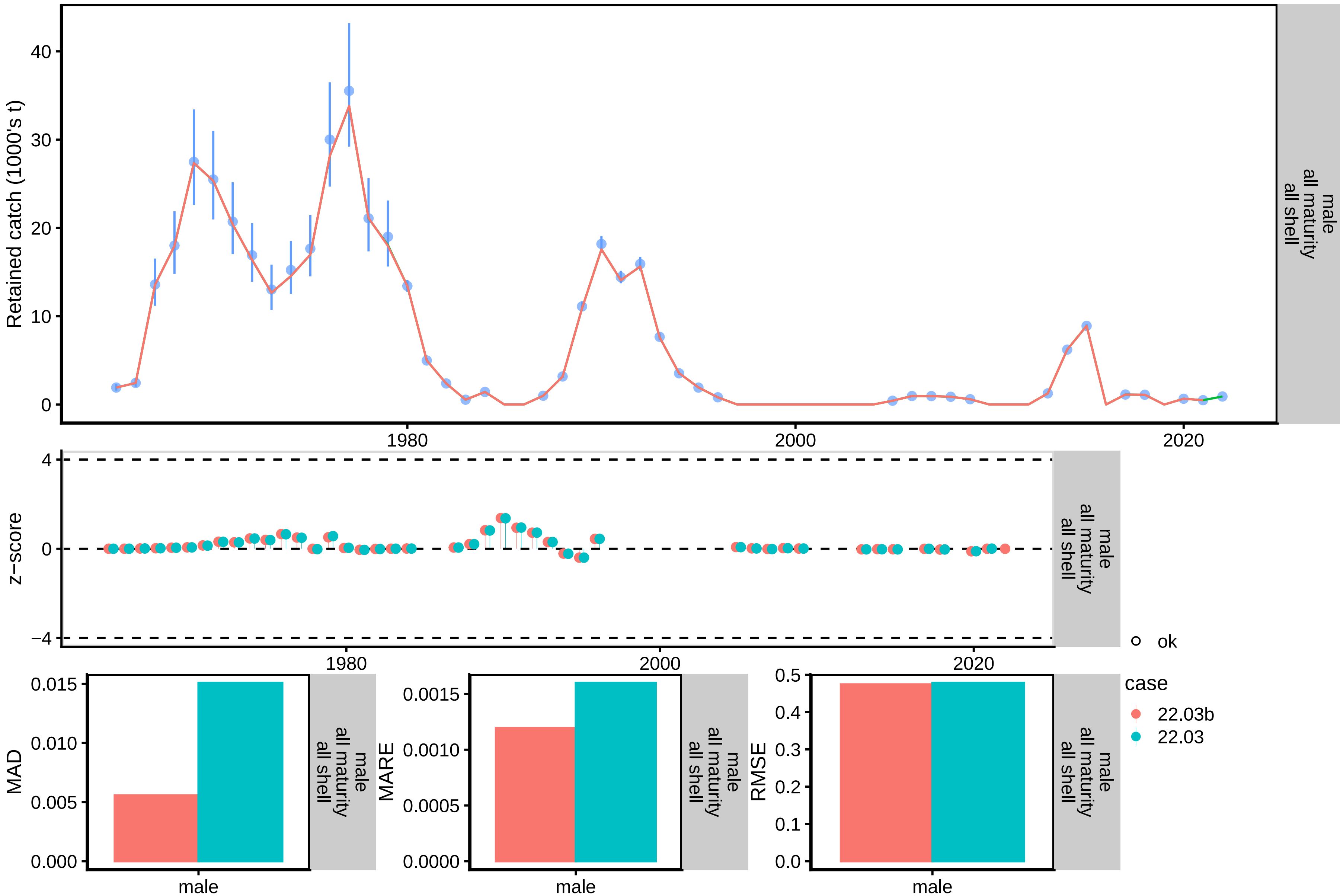

Figure 68. Fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

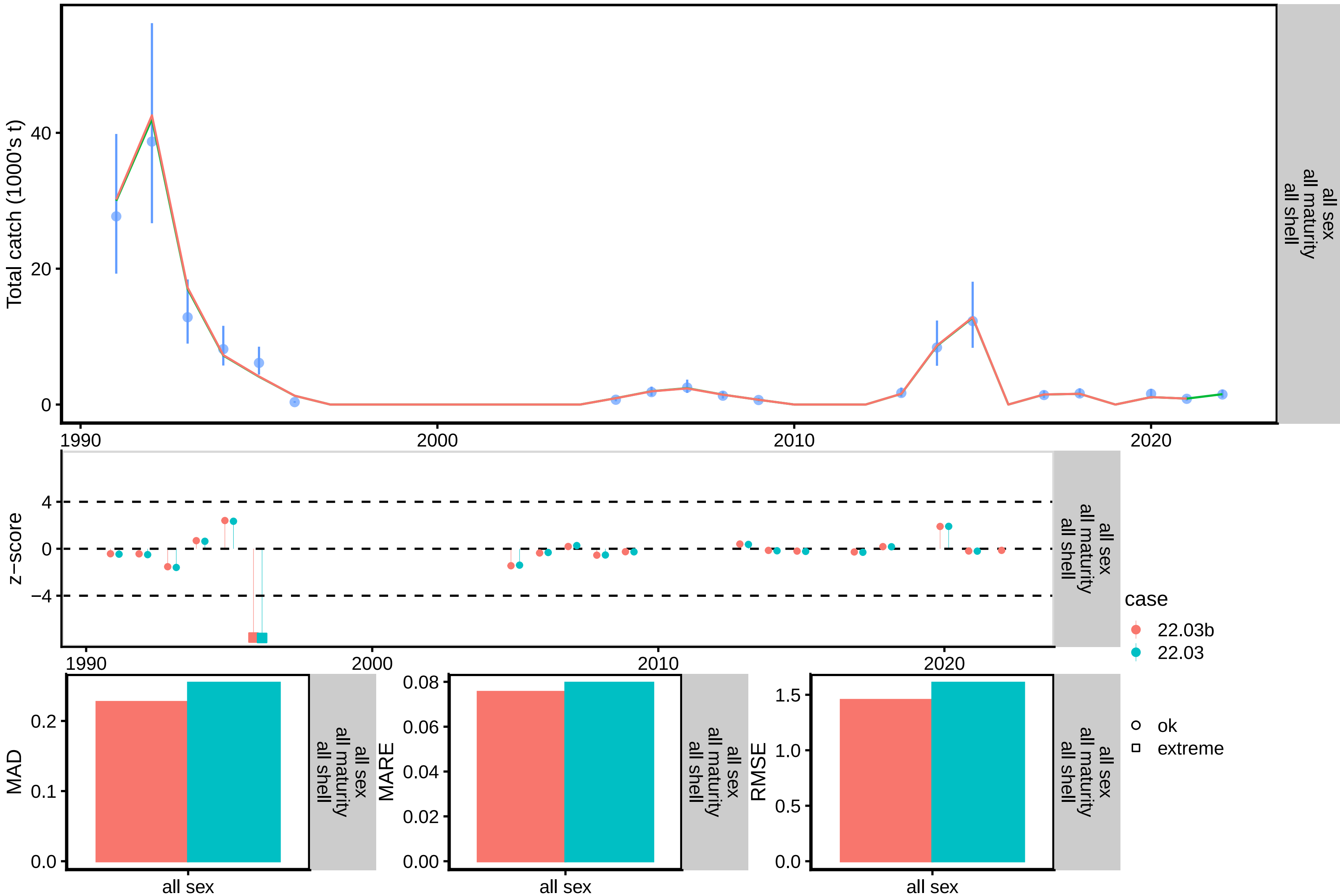

Figure 69. Fits to total catch biomass of all crab in the TCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

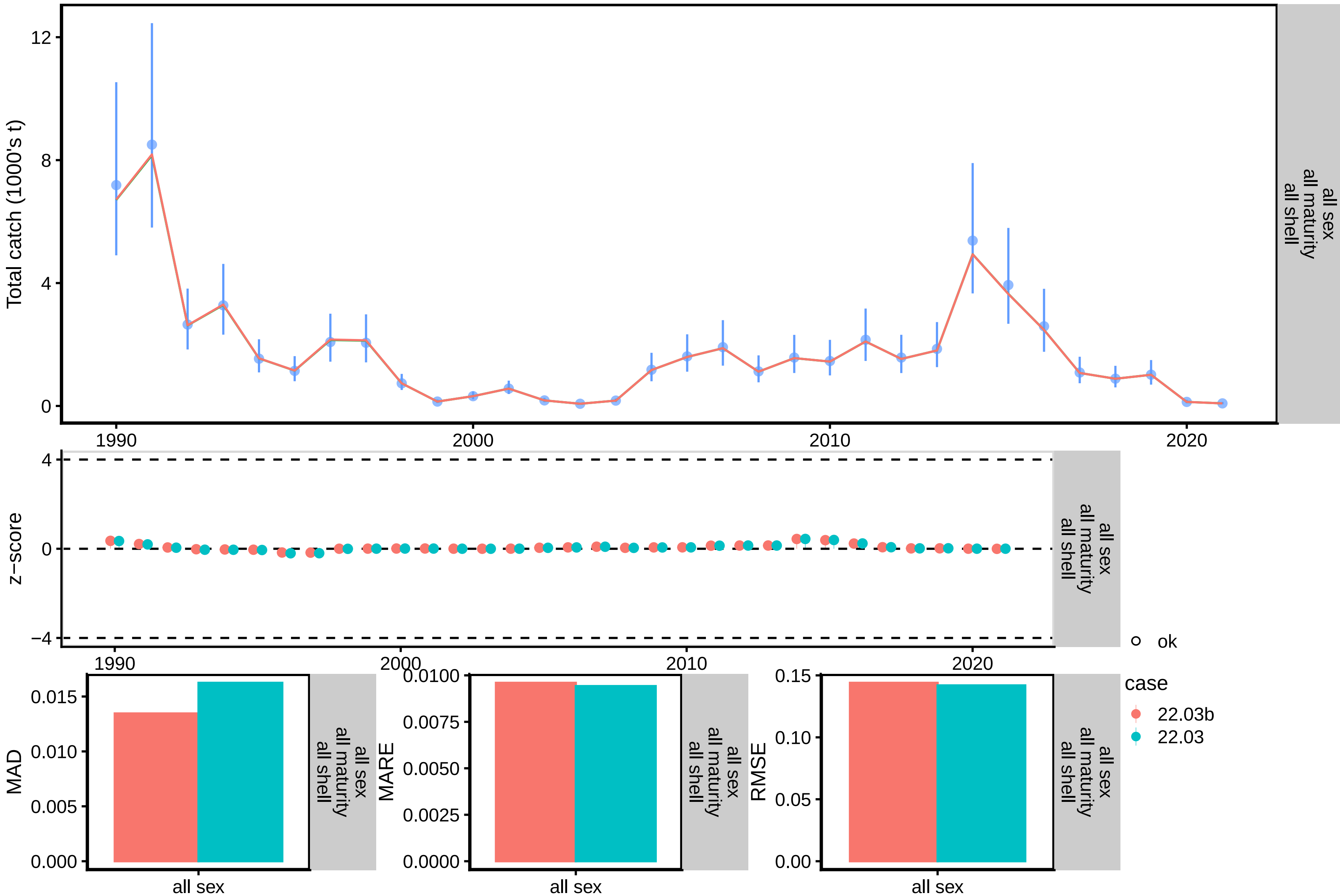

Figure 70. Fits to total catch biomass of all crab in the SCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

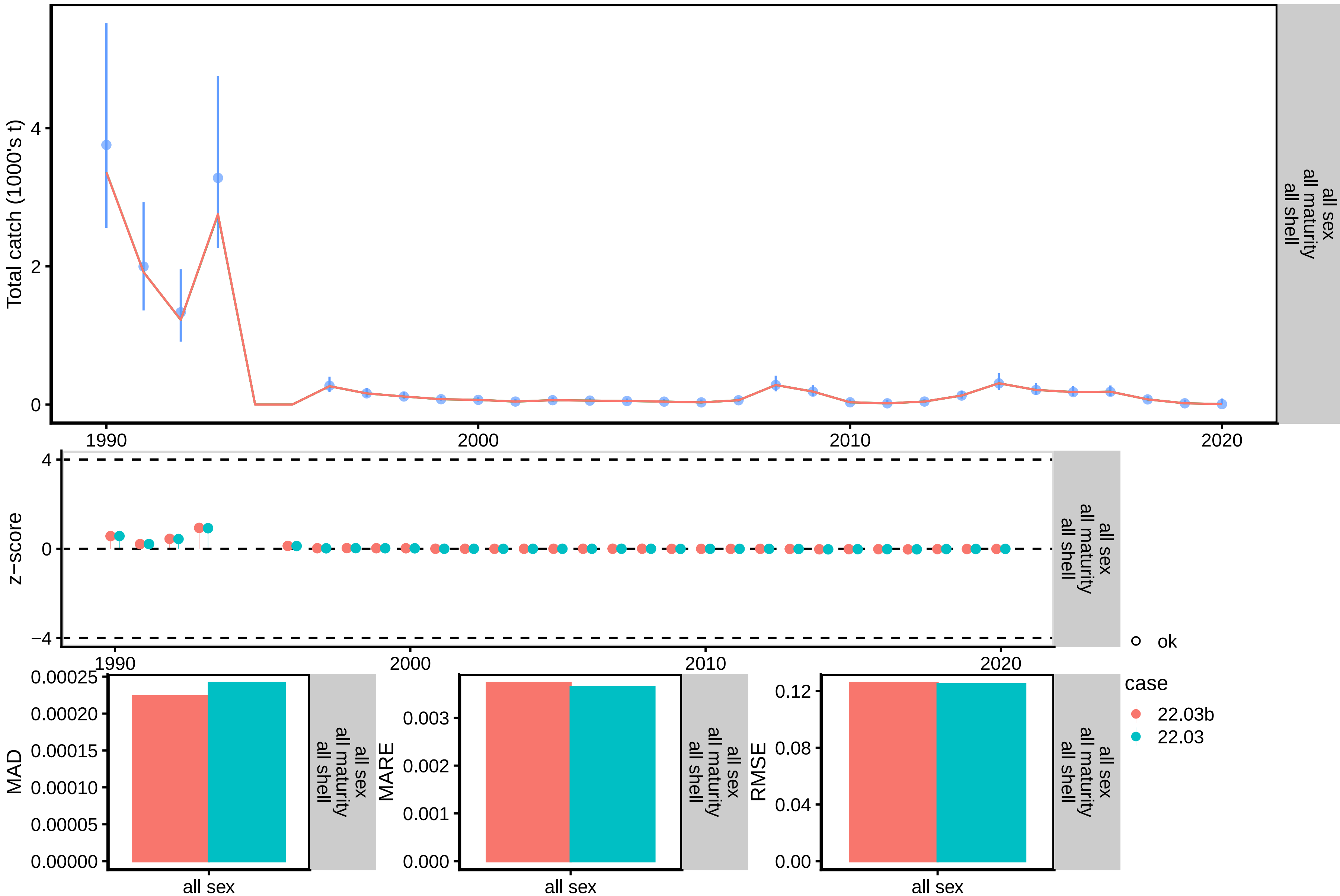

Figure 71. Fits to total catch biomass of all crab in the RKF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

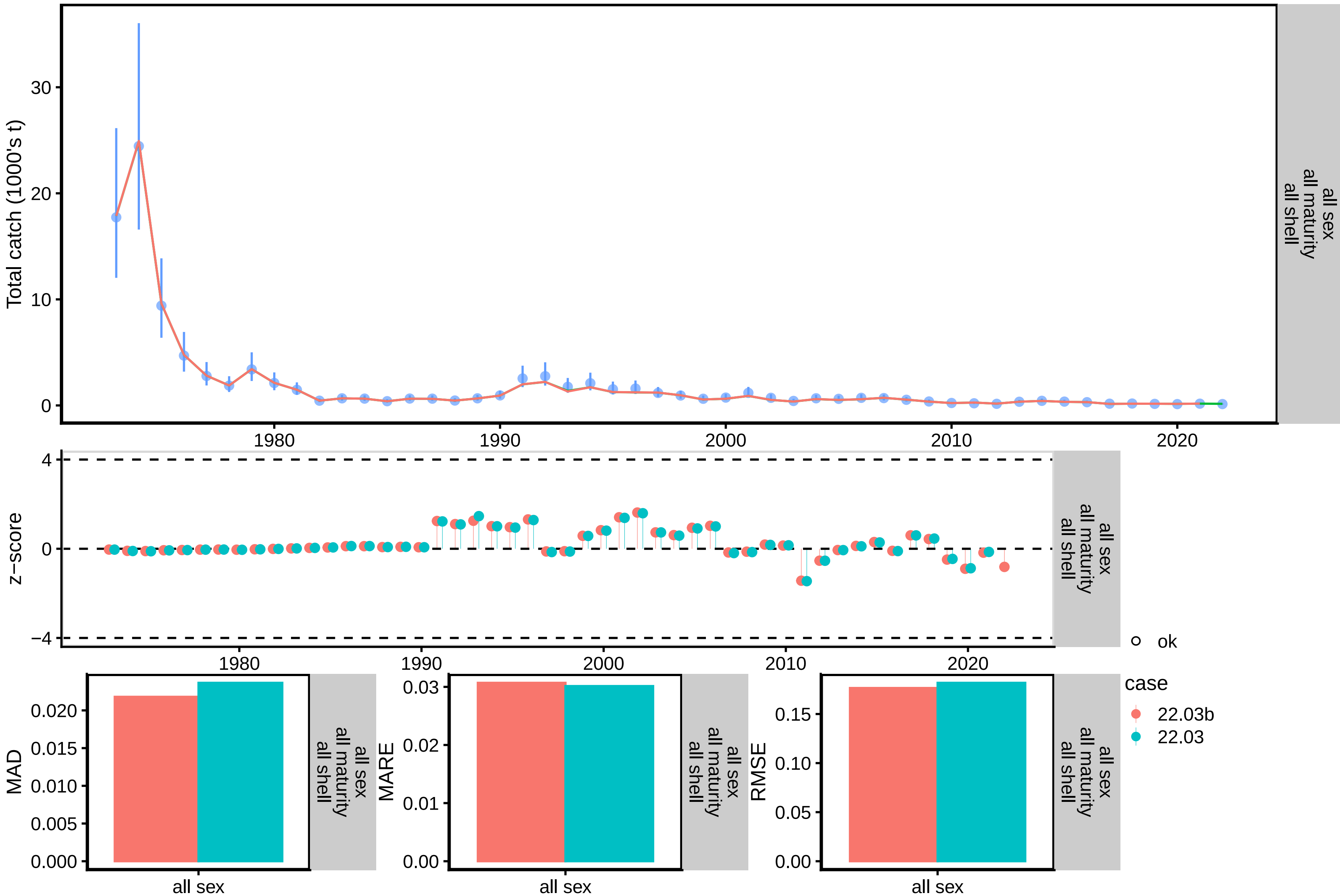

Figure 72. Fits to total catch biomass of all crab in the GF All fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

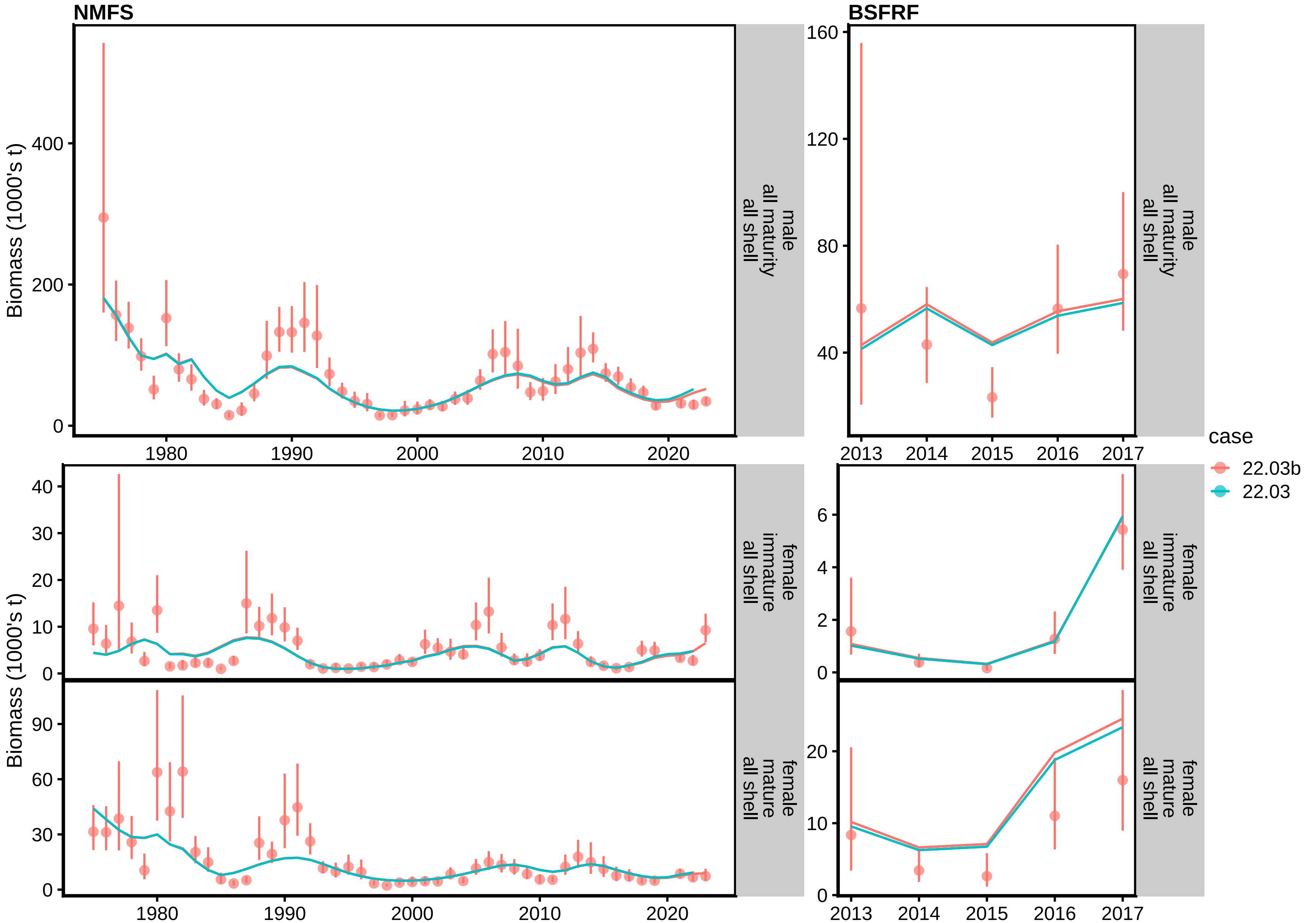

Figure 73. Fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) biomass from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Confidence intervals are 95%.

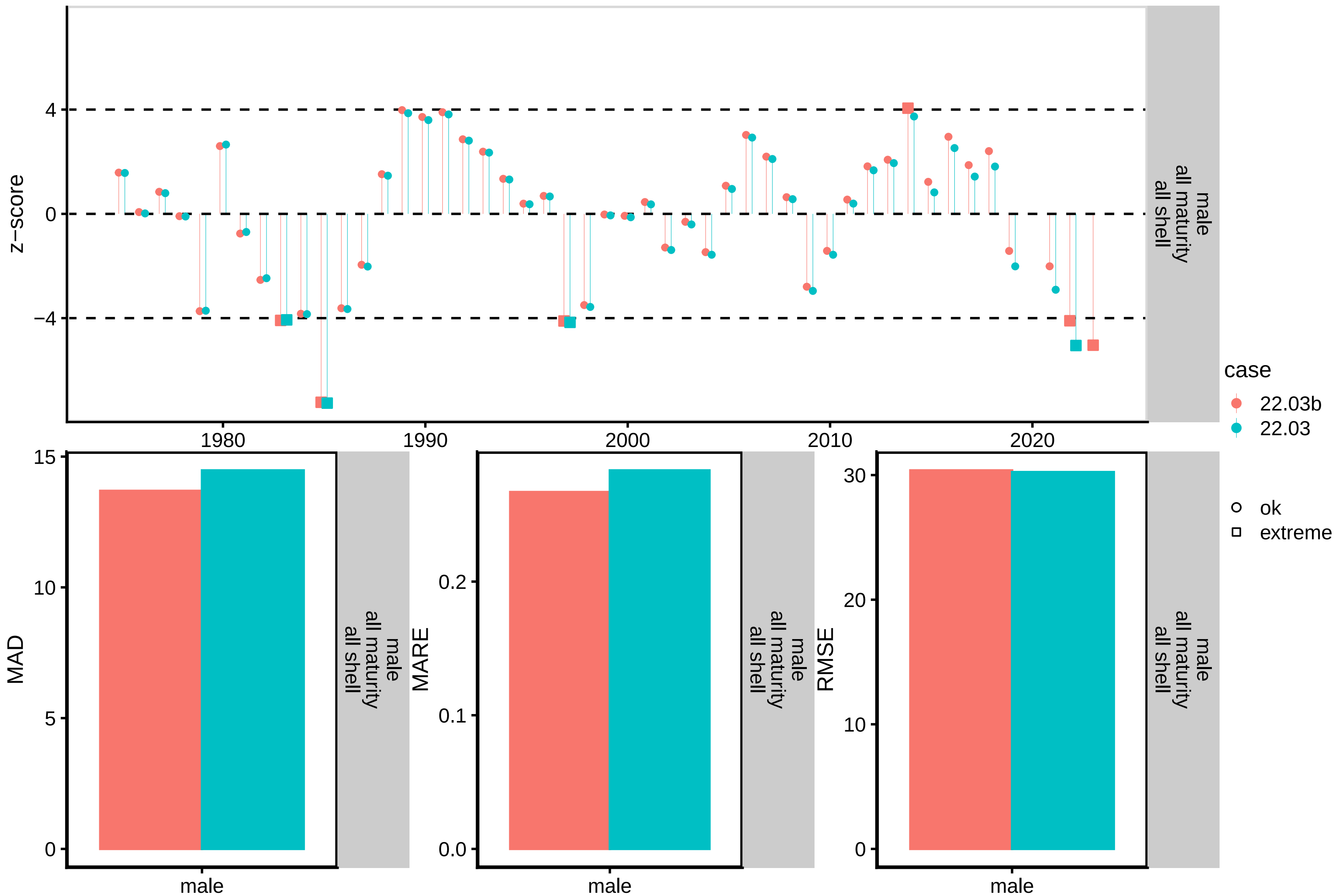

Figure 74. Residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

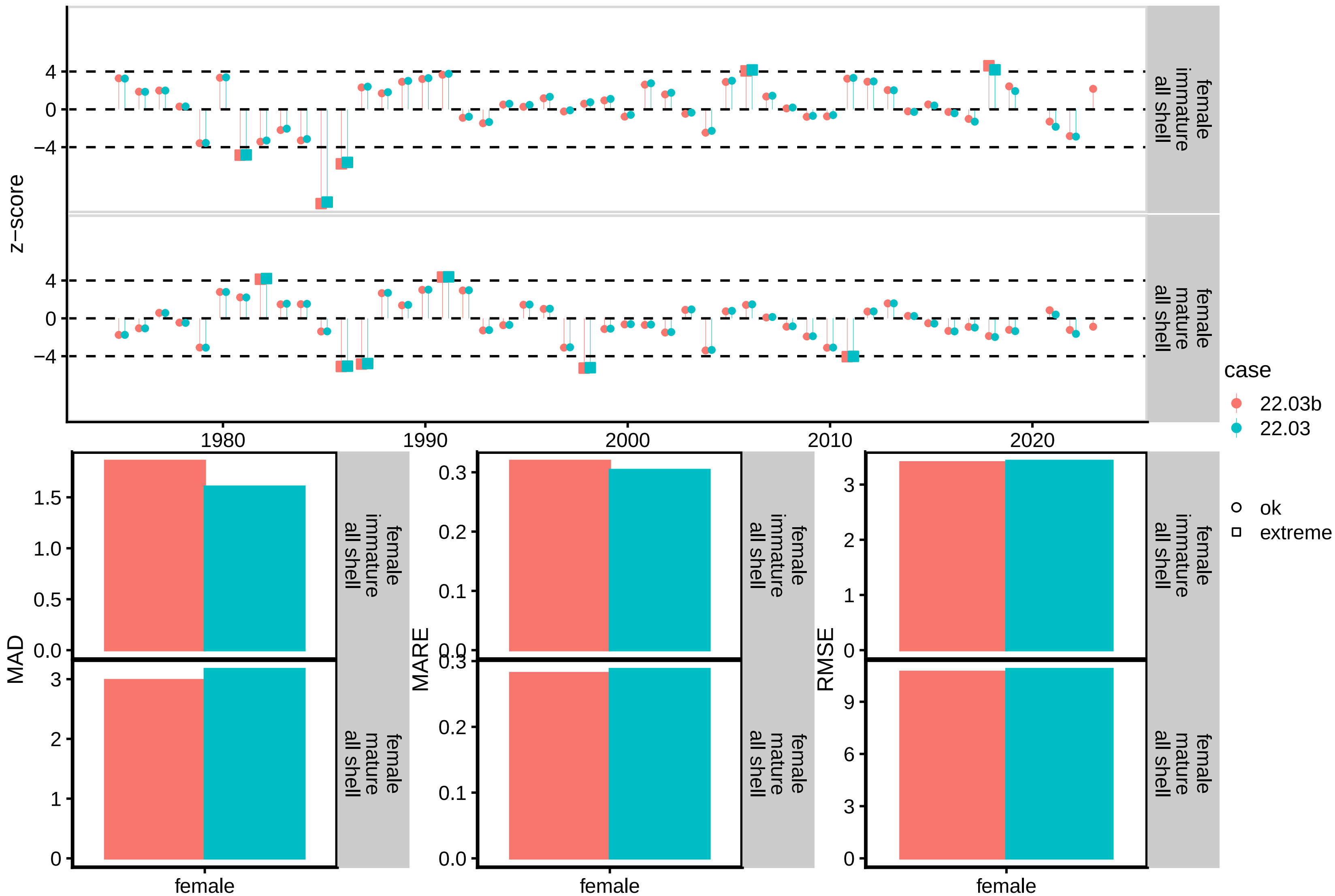

Figure 75. Residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

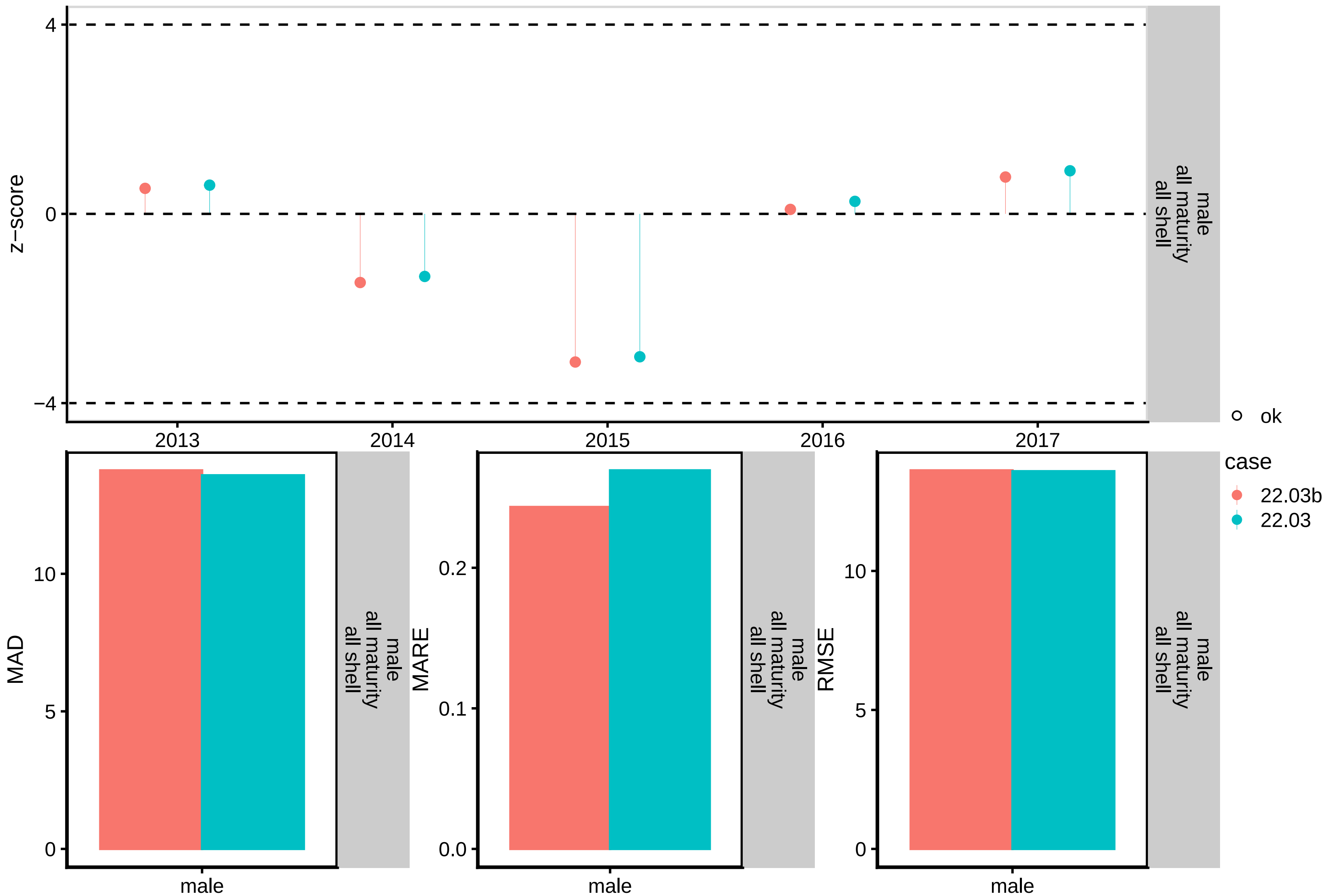

Figure 76. Residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

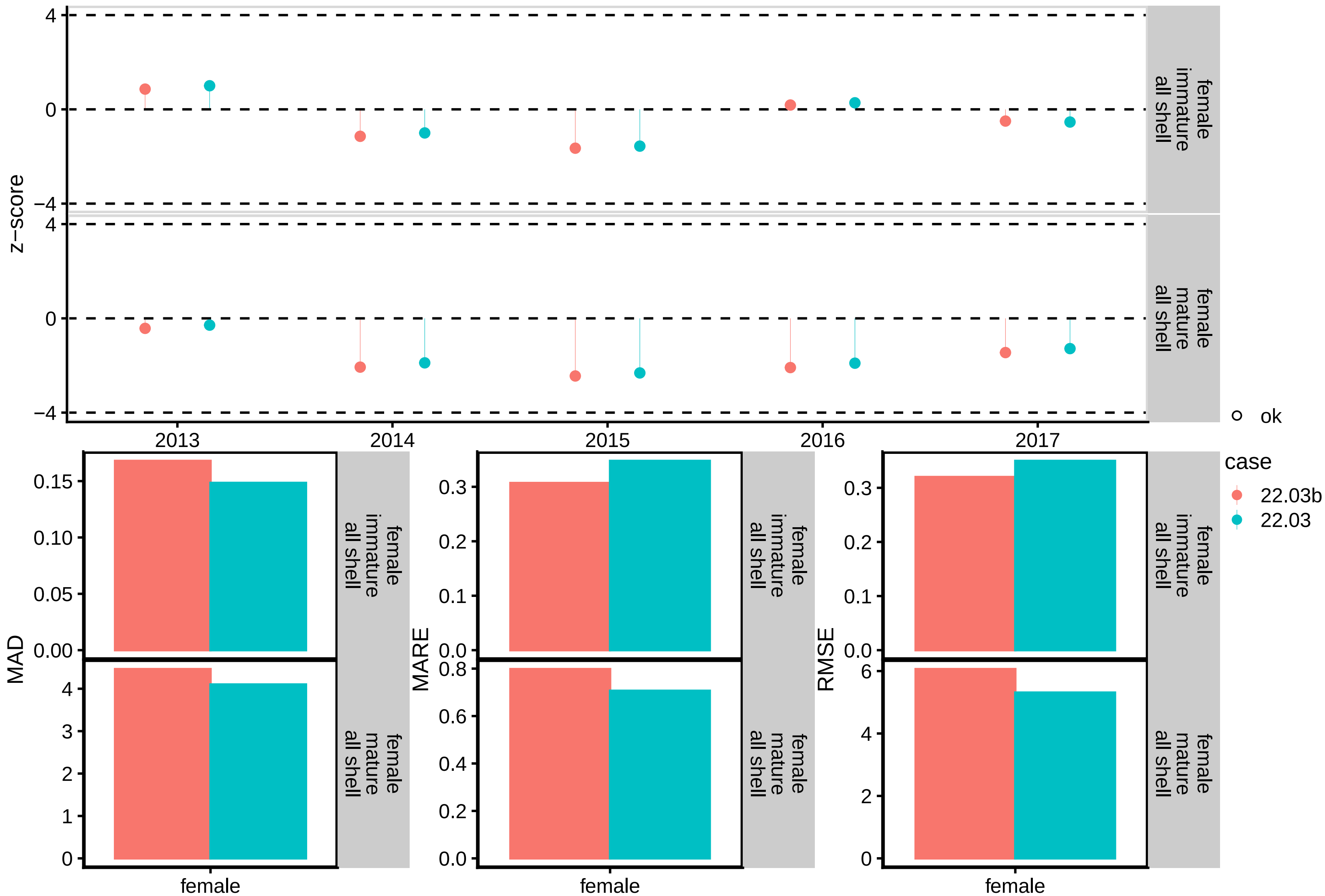

Figure 77. Residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

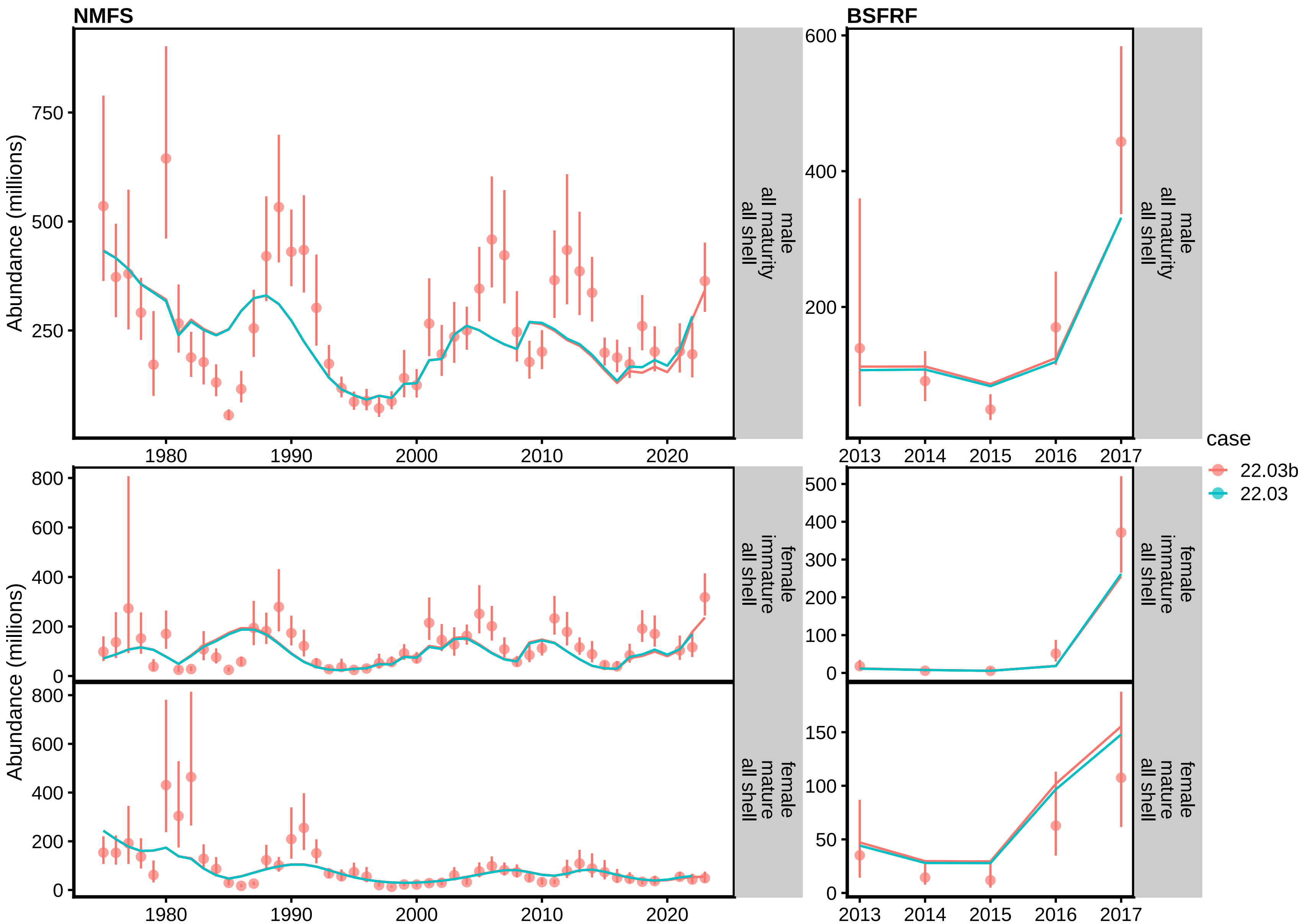

Figure 78. Fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) abundance from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Note that these fits are not included in the model objective function and simply provide a diagnostic check. Confidence intervals are 95%.

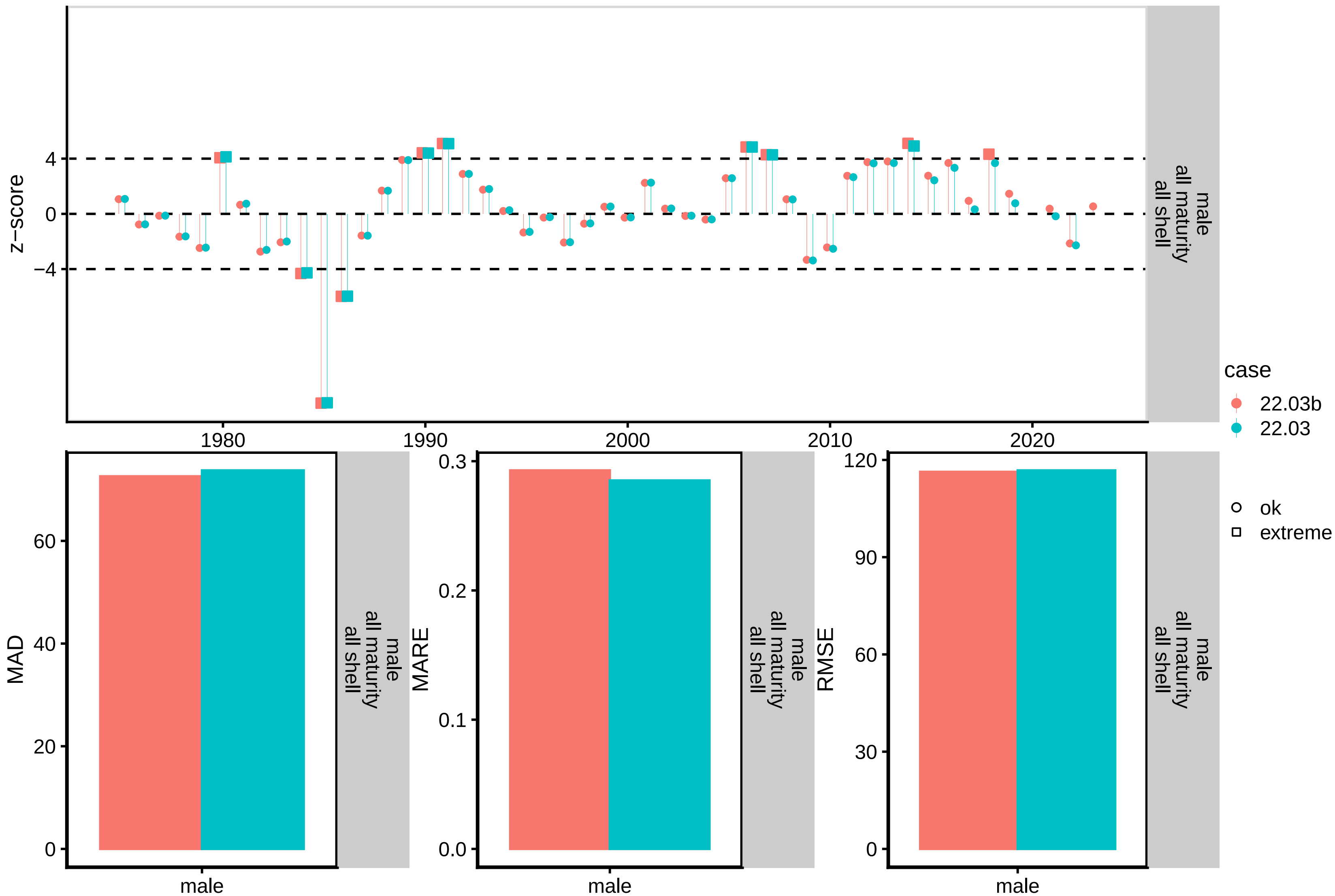

Figure 79. Residuals analysis by model scenario for fits to male abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

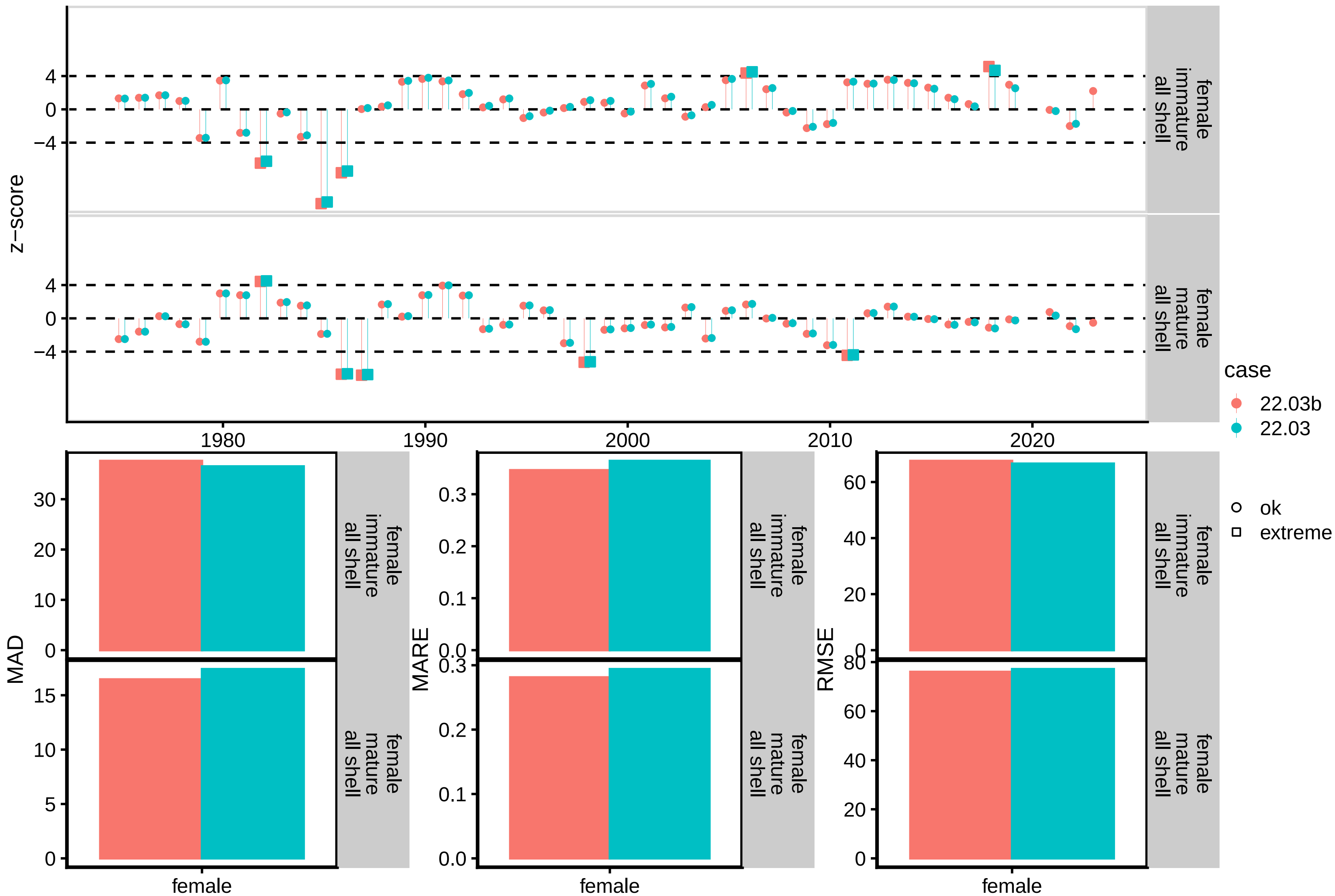

Figure 80. Residuals analysis by model scenario for fits to female abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

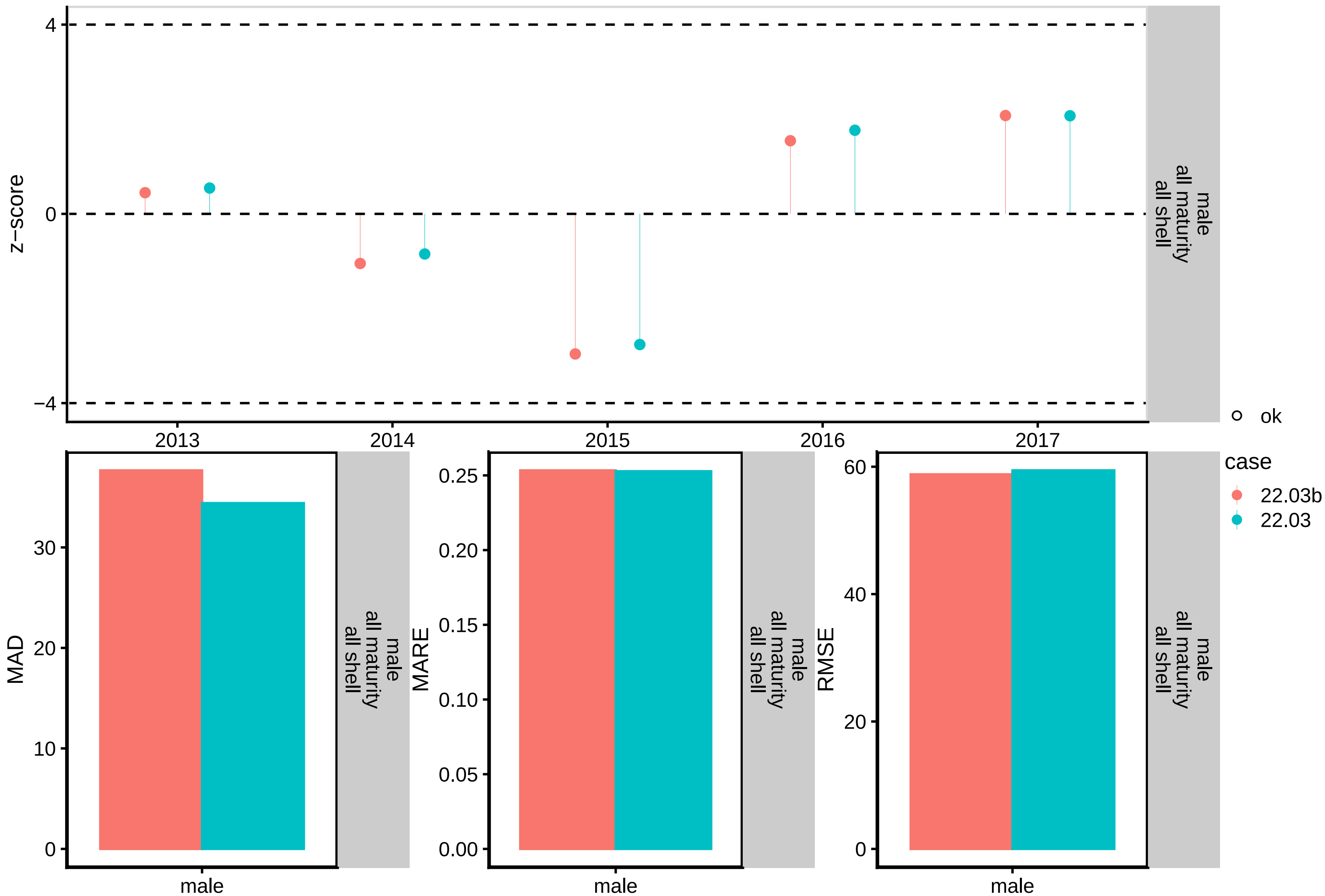

Figure 81. Residuals analysis by model scenario for fits to male abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

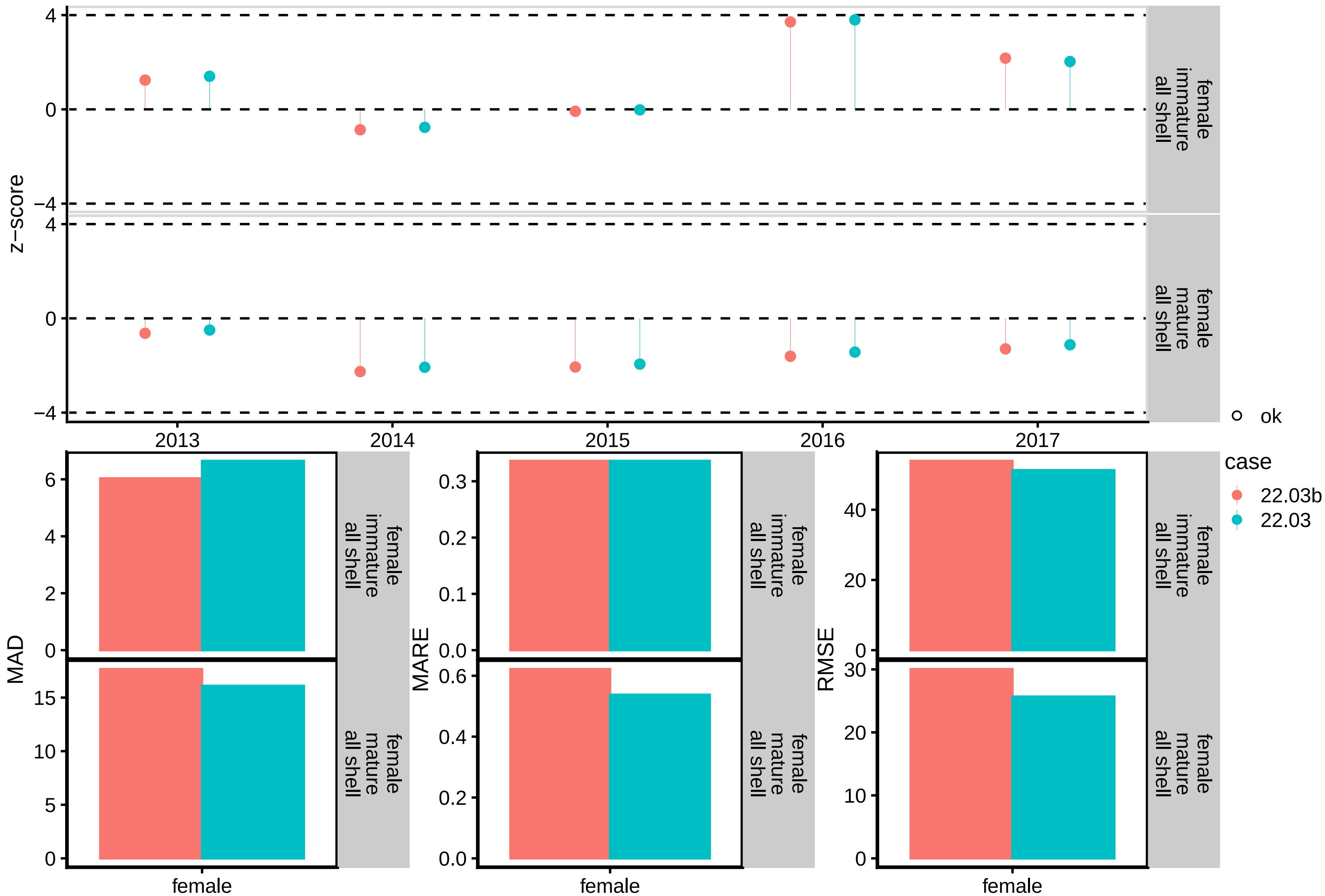

Figure 82. Residuals analysis by model scenario for fits to female abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

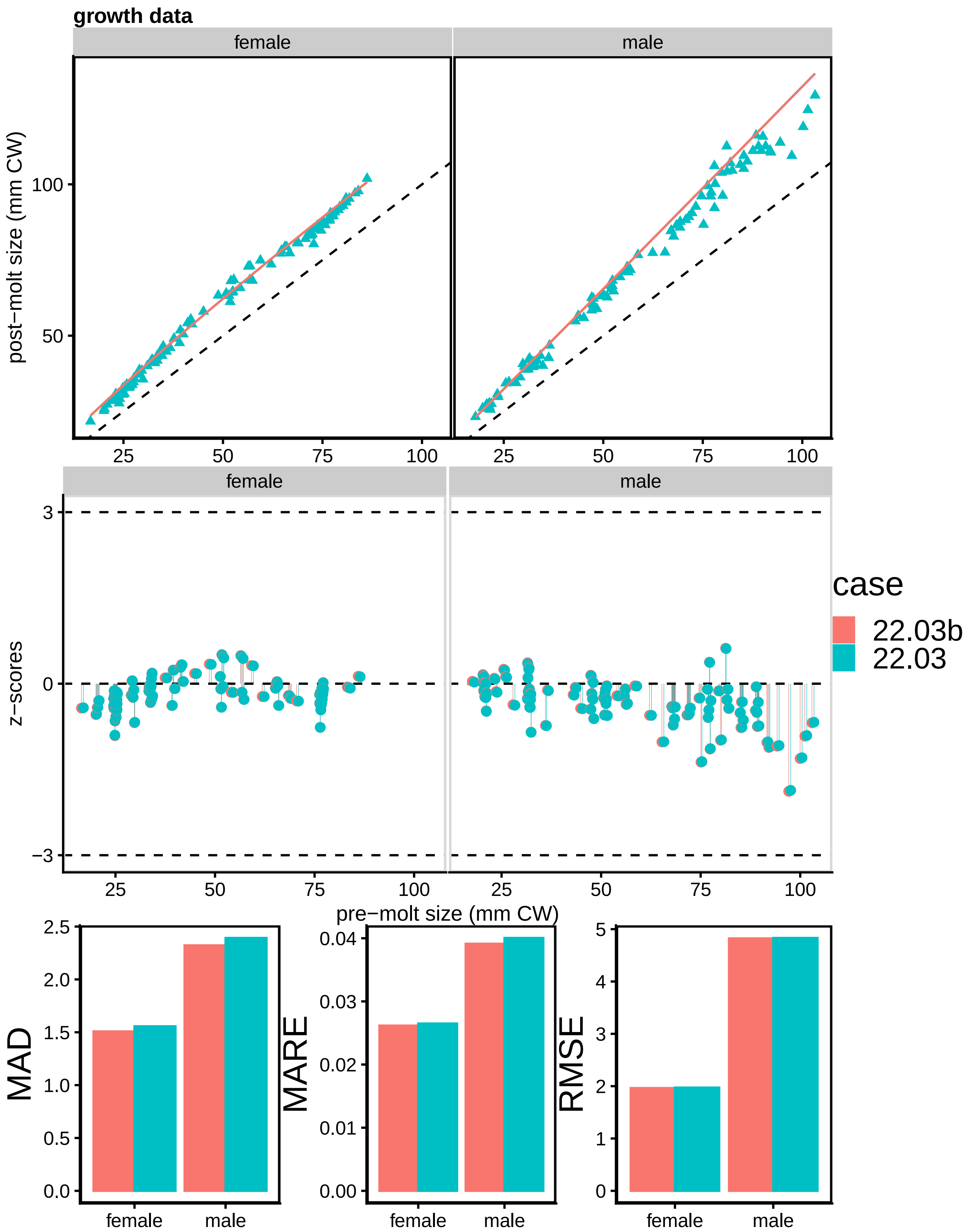

Figure 83. Fits and residuals analysis by model scenario for fits to molt increment data. Upper row: fits to data; center row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

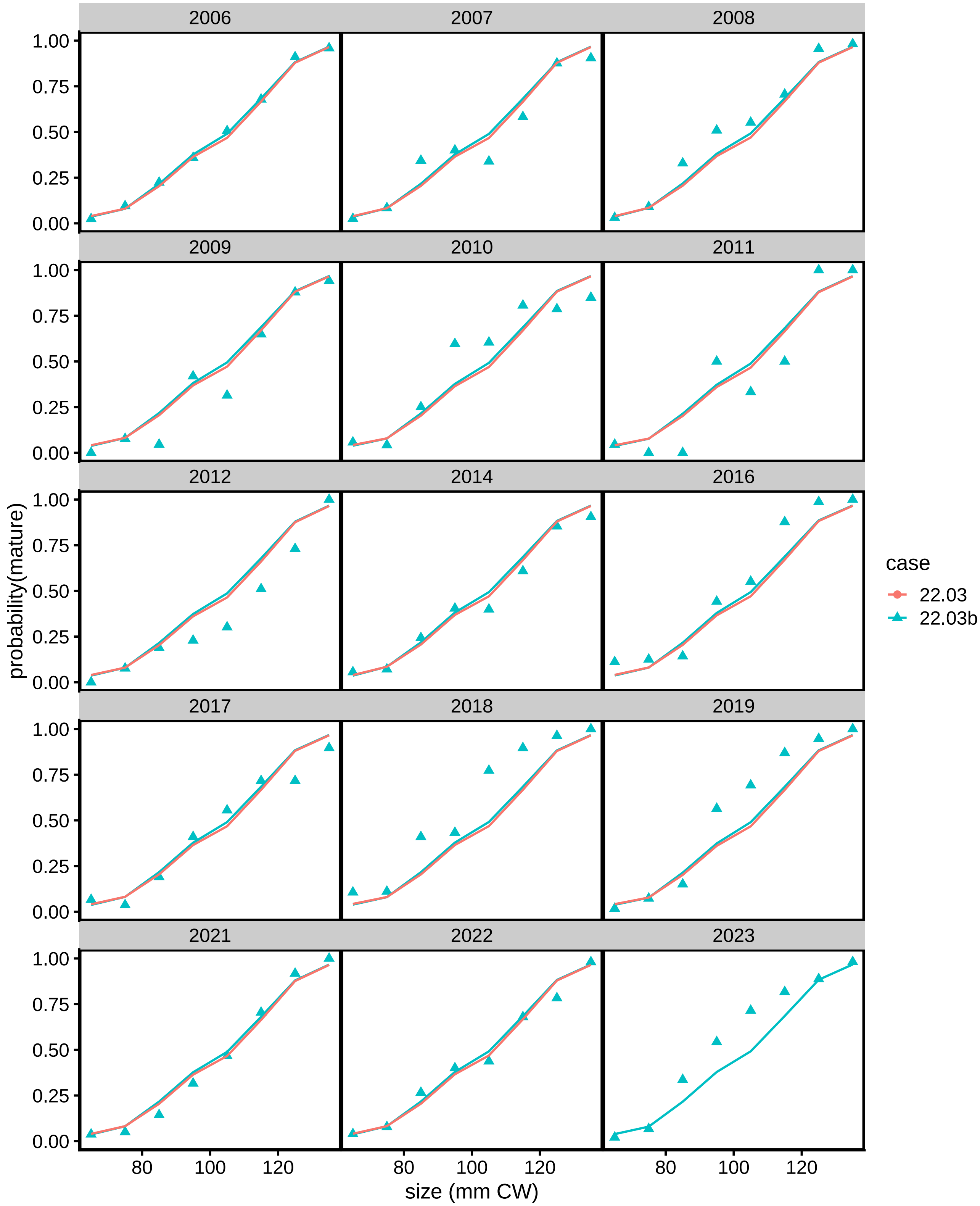

Figure 84. Fits to maturity ogive data by model scenario and year.

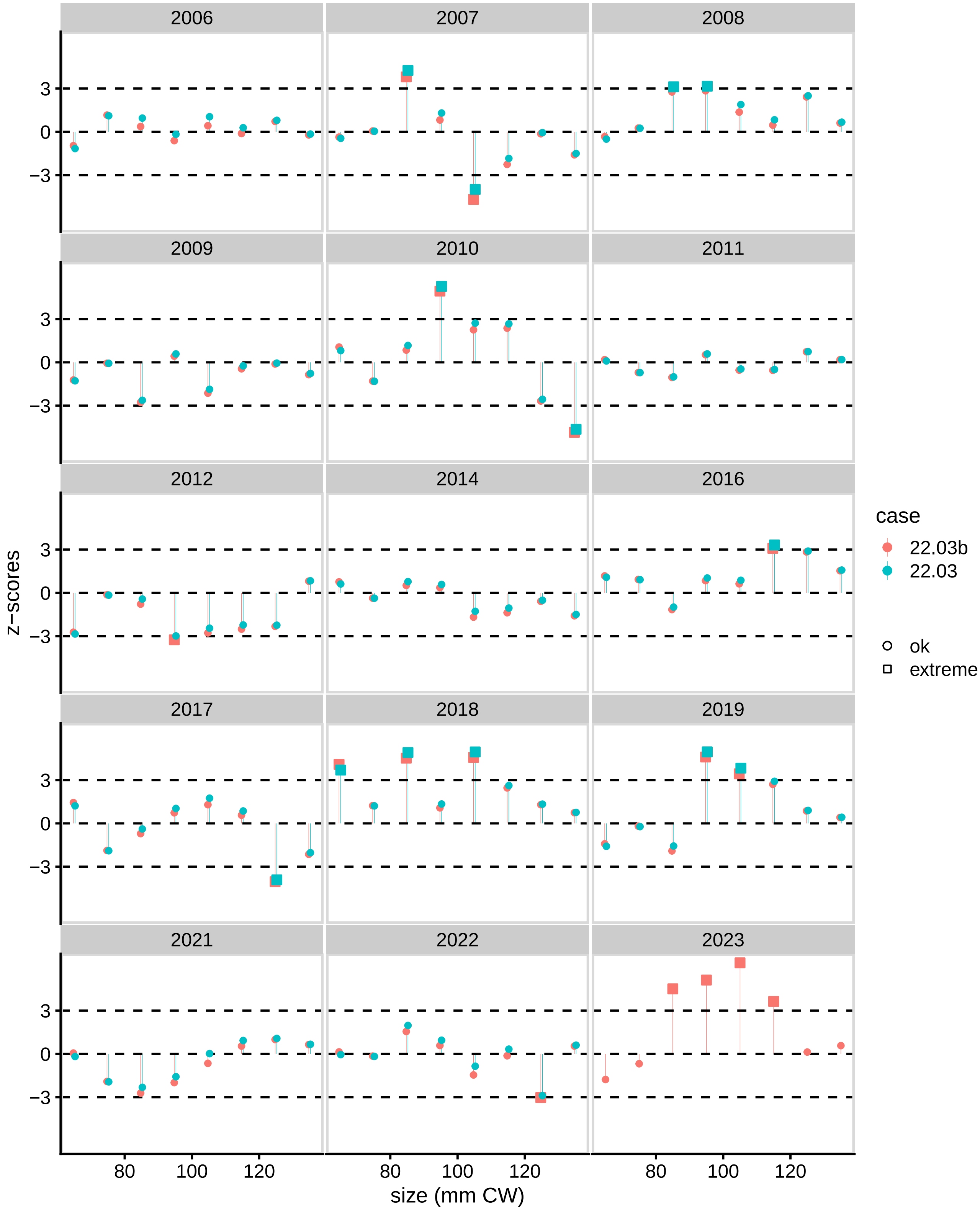

Figure 85. Z-scores for Fits to maturity ogive data, by model scenario and year.

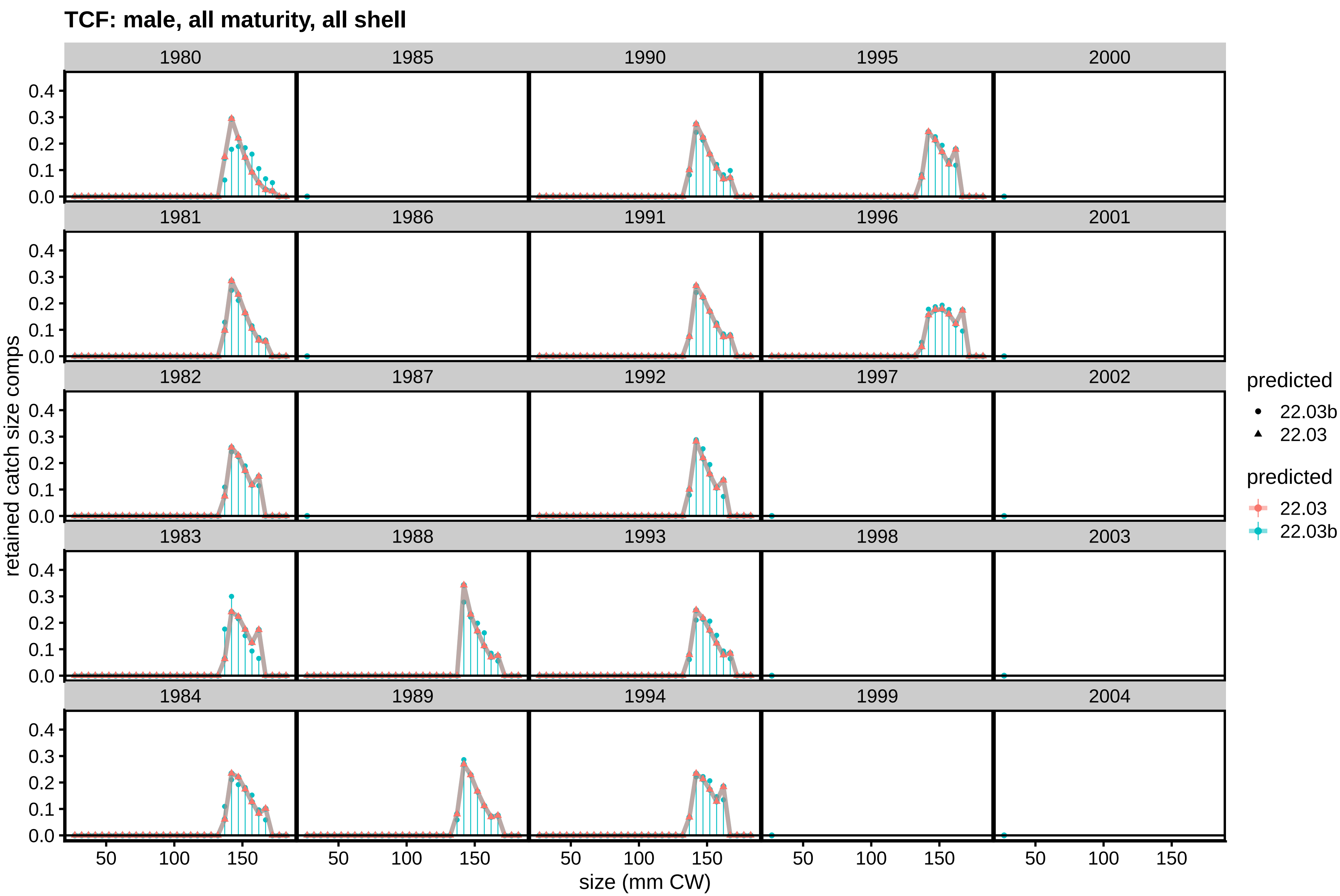

Figure 86. Fits to retained catch size compositions in the directed fishery. Preferred model is 22.03b.

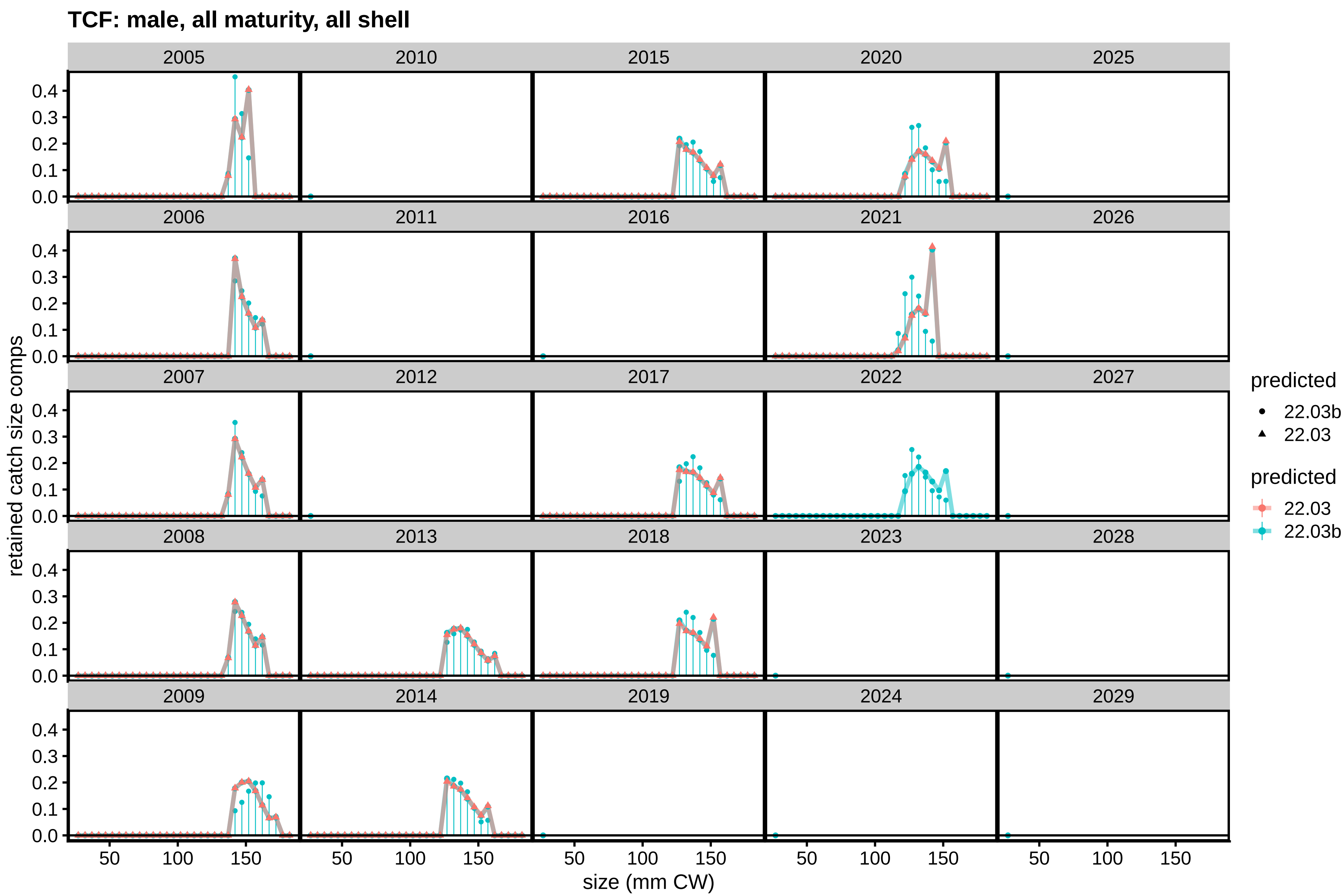

Figure 87. Fits to retained catch size compositions in the directed fishery. Preferred model is 22.03b.

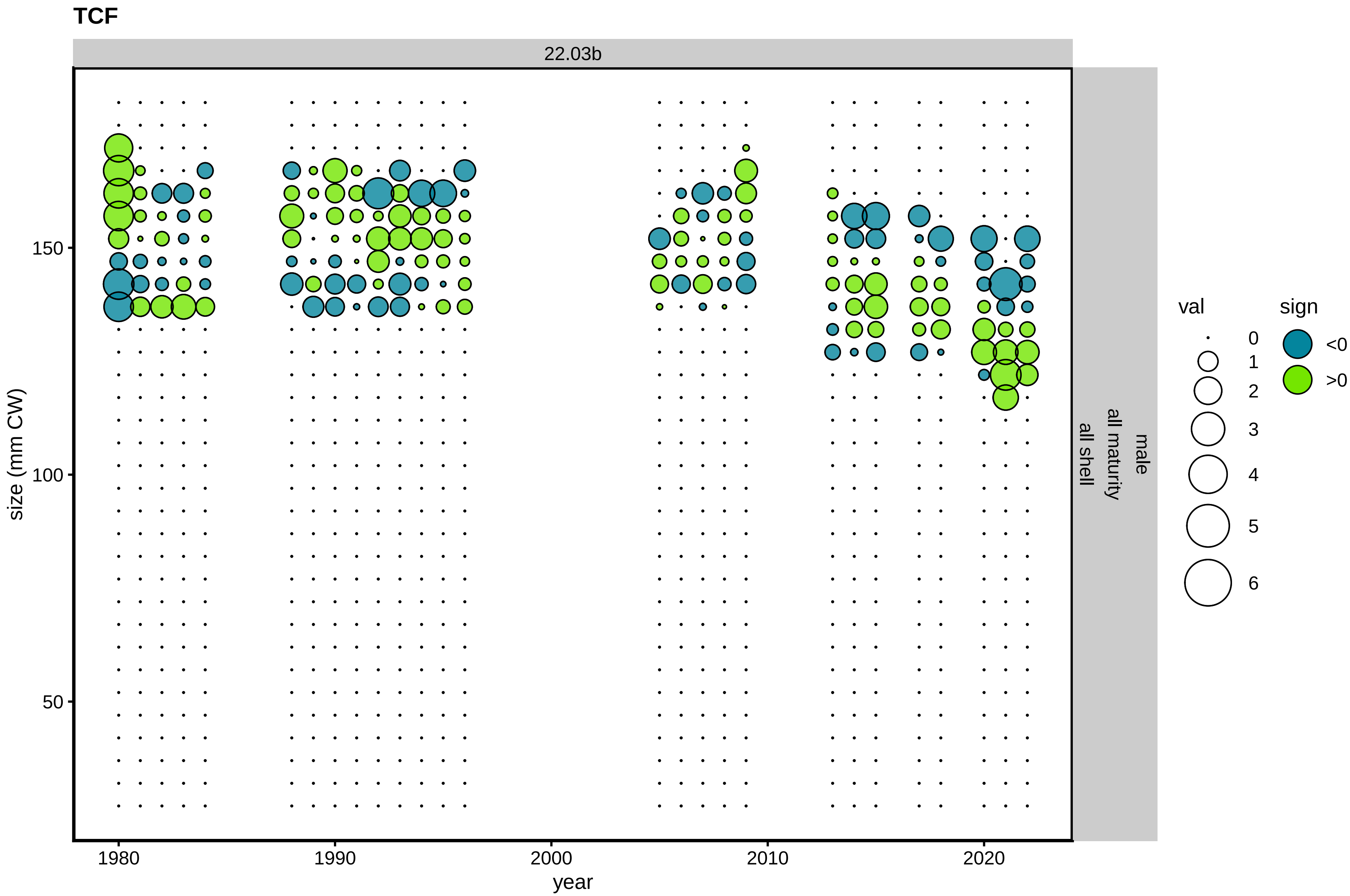

Figure 88. Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

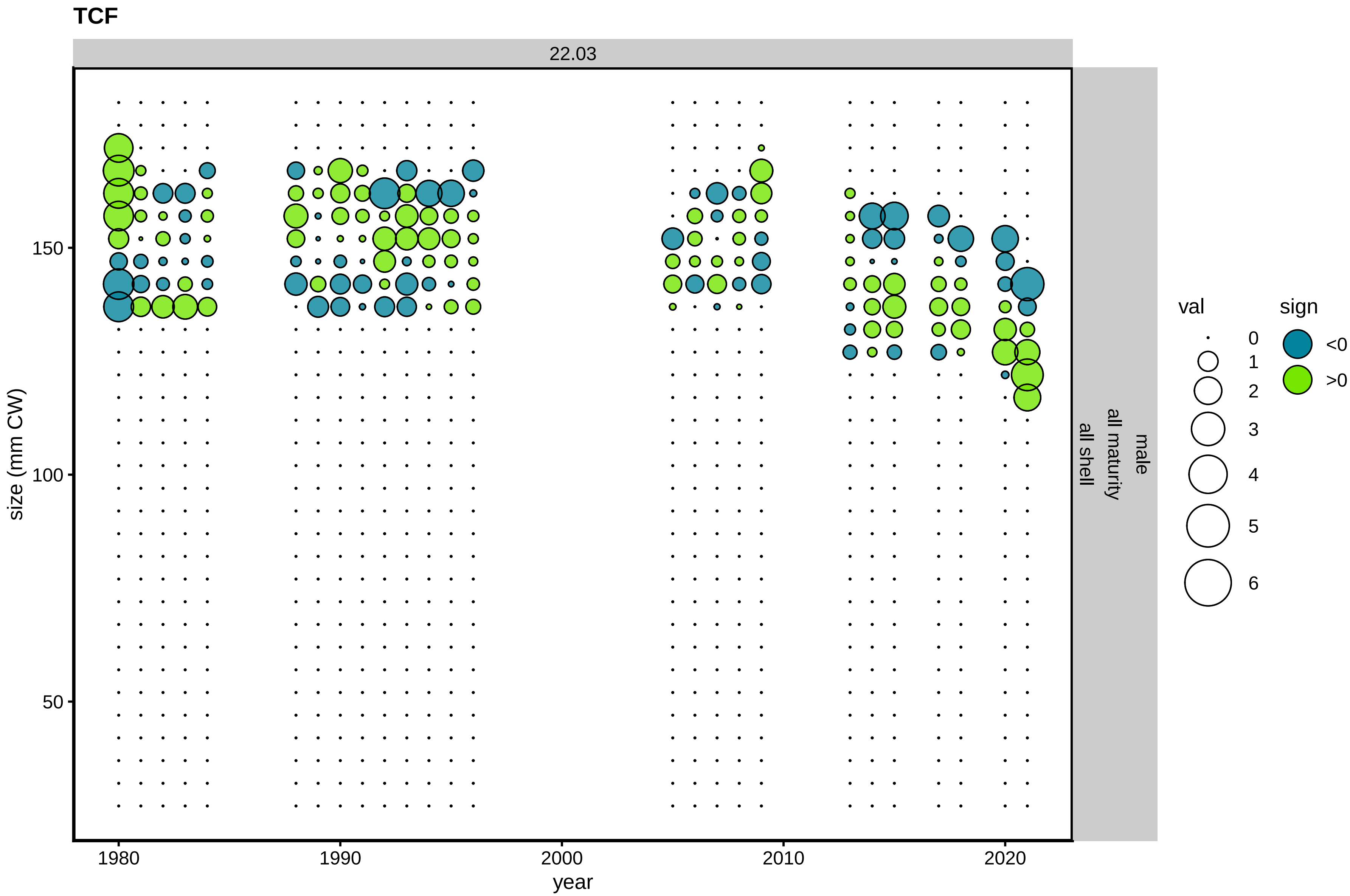

Figure 89. Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

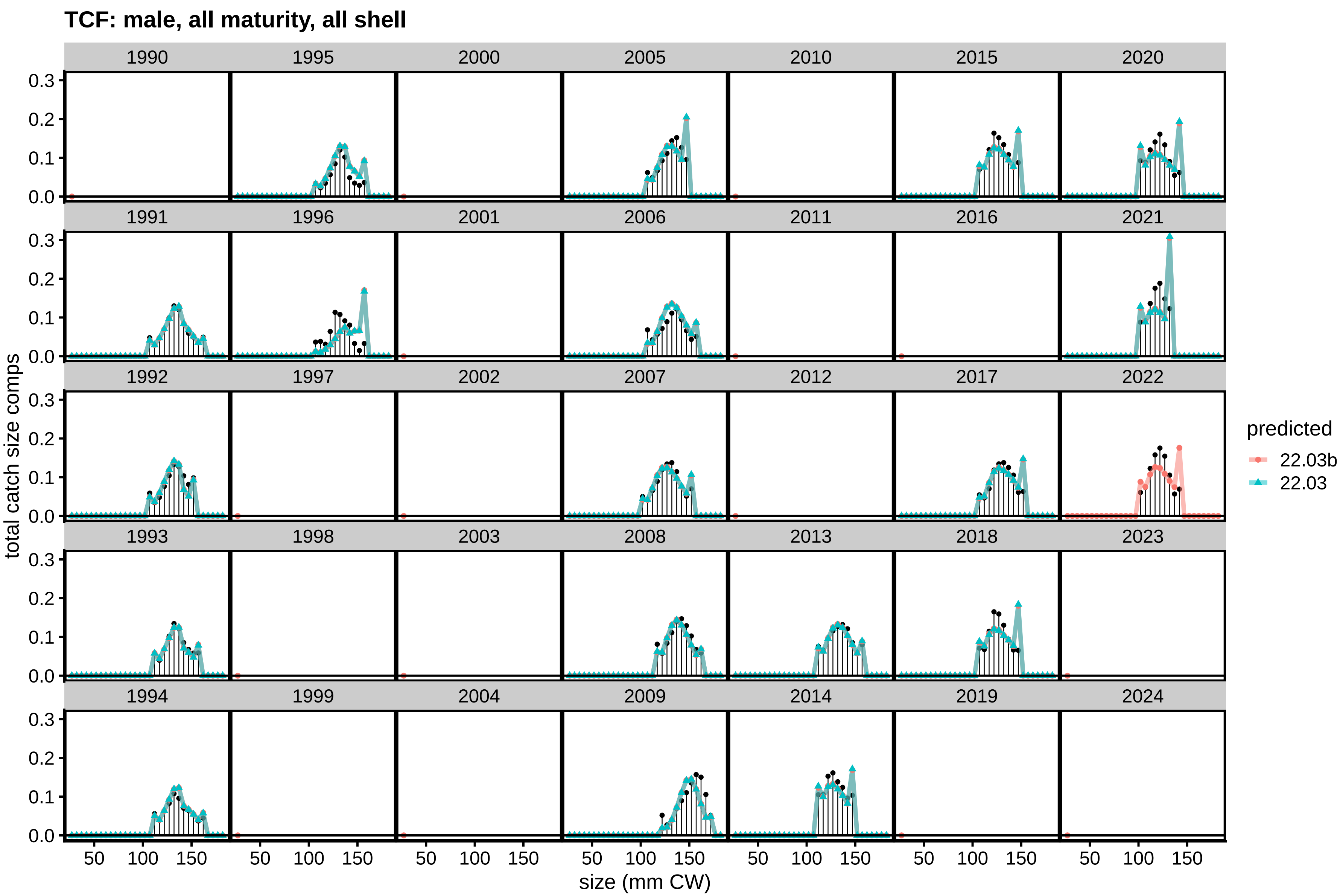

Figure 90. Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03b.

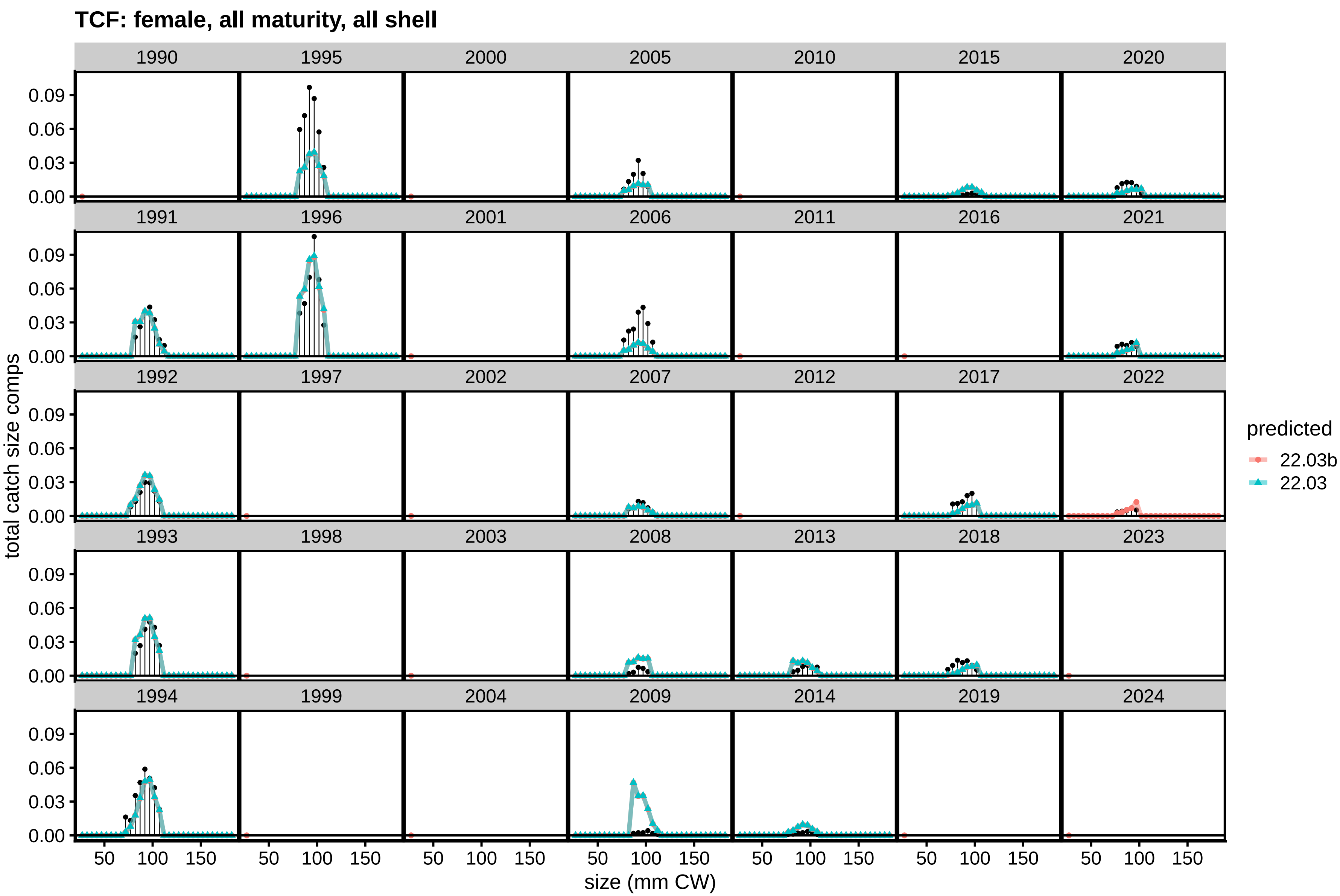

Figure 91. Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03b.

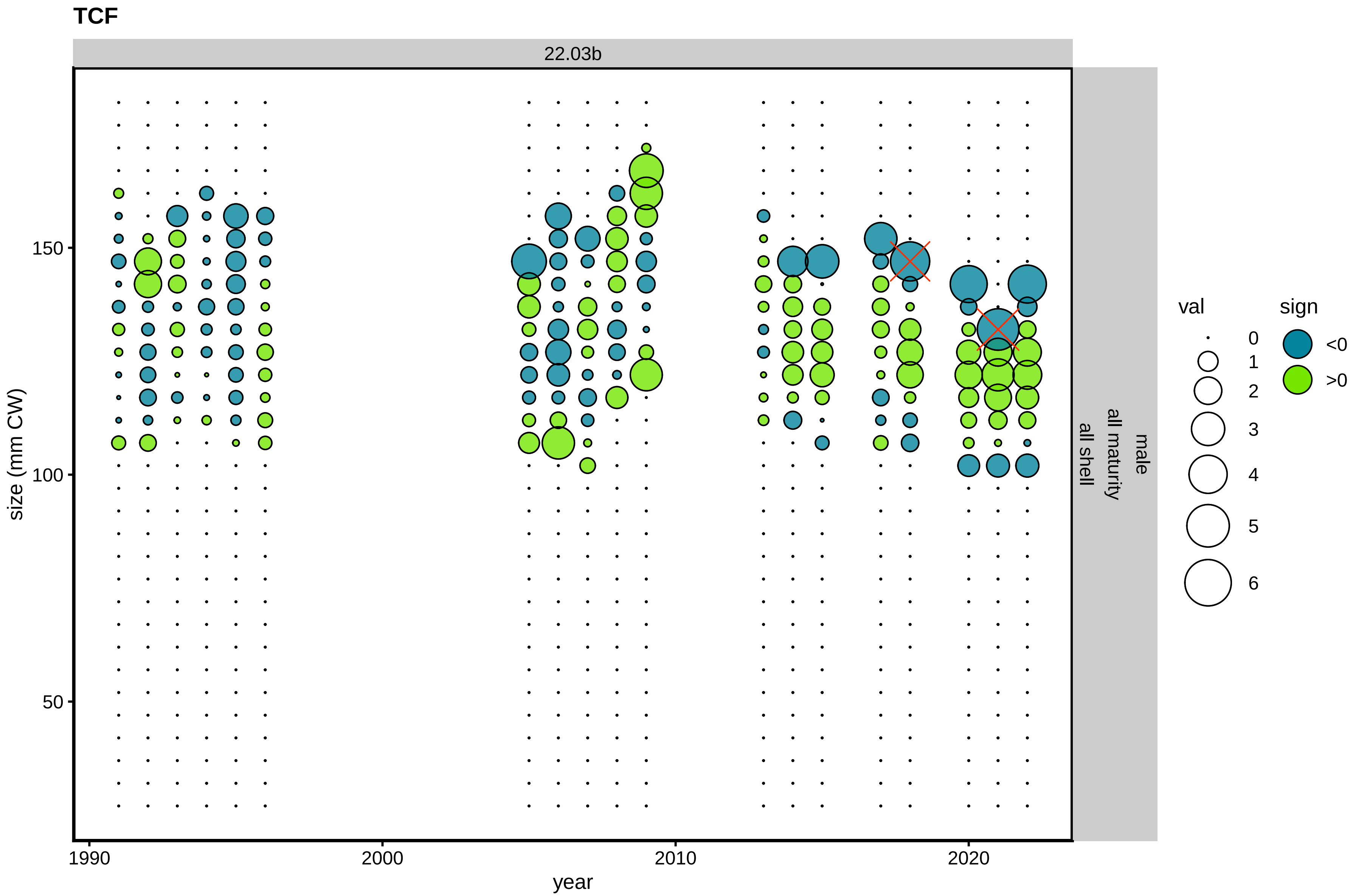

Figure 92. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

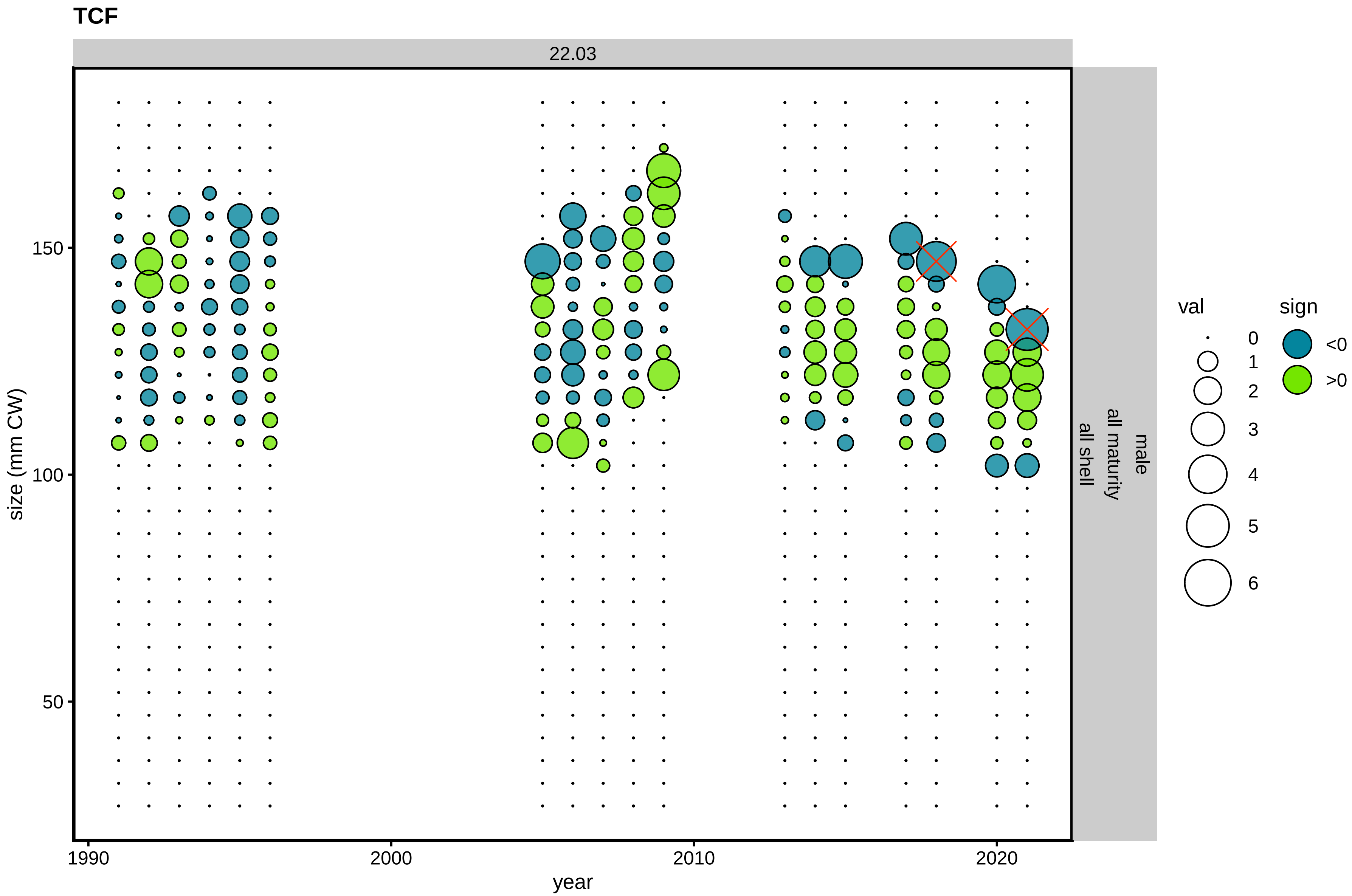

Figure 93. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

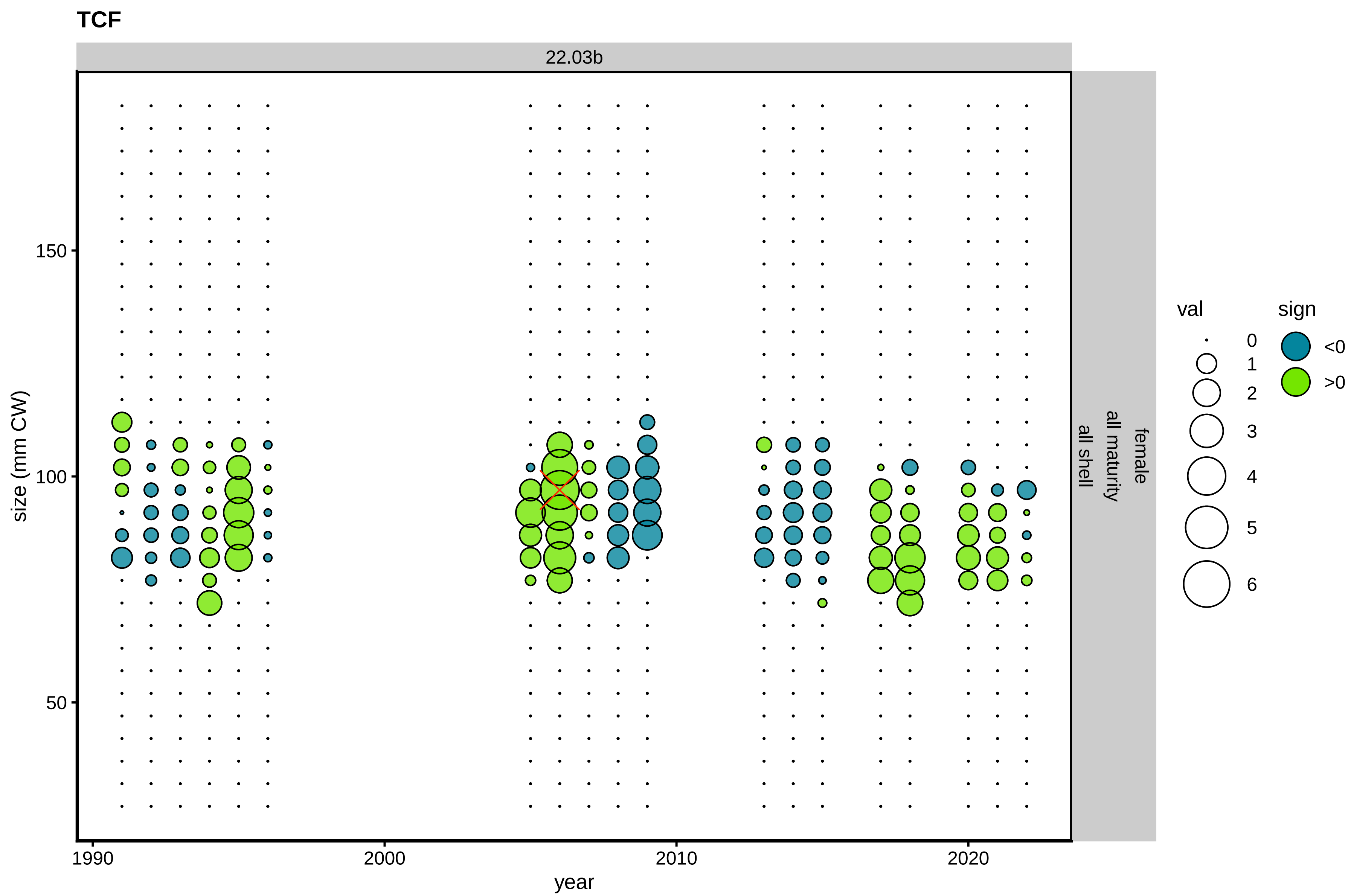

Figure 94. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

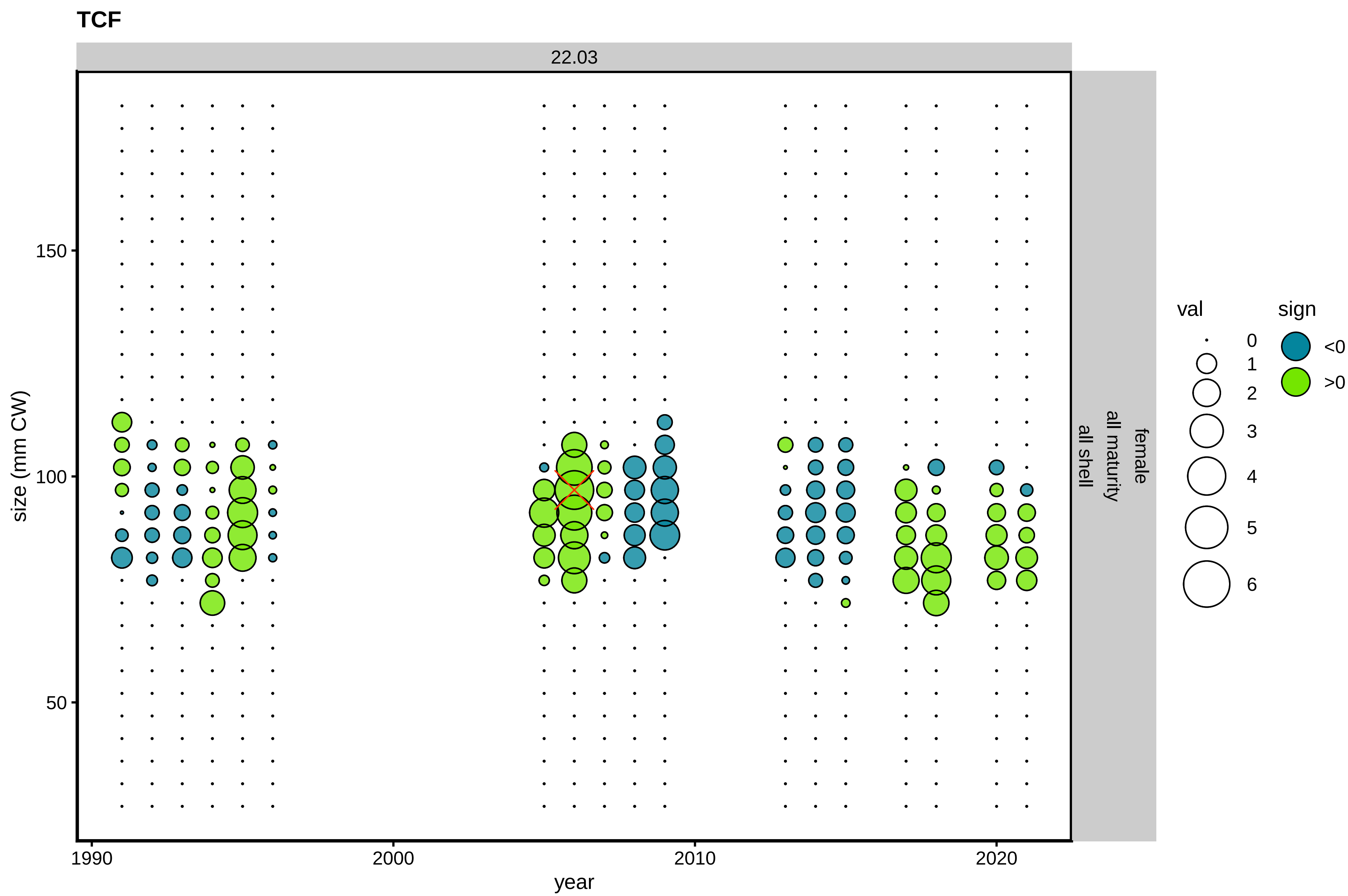

Figure 95. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

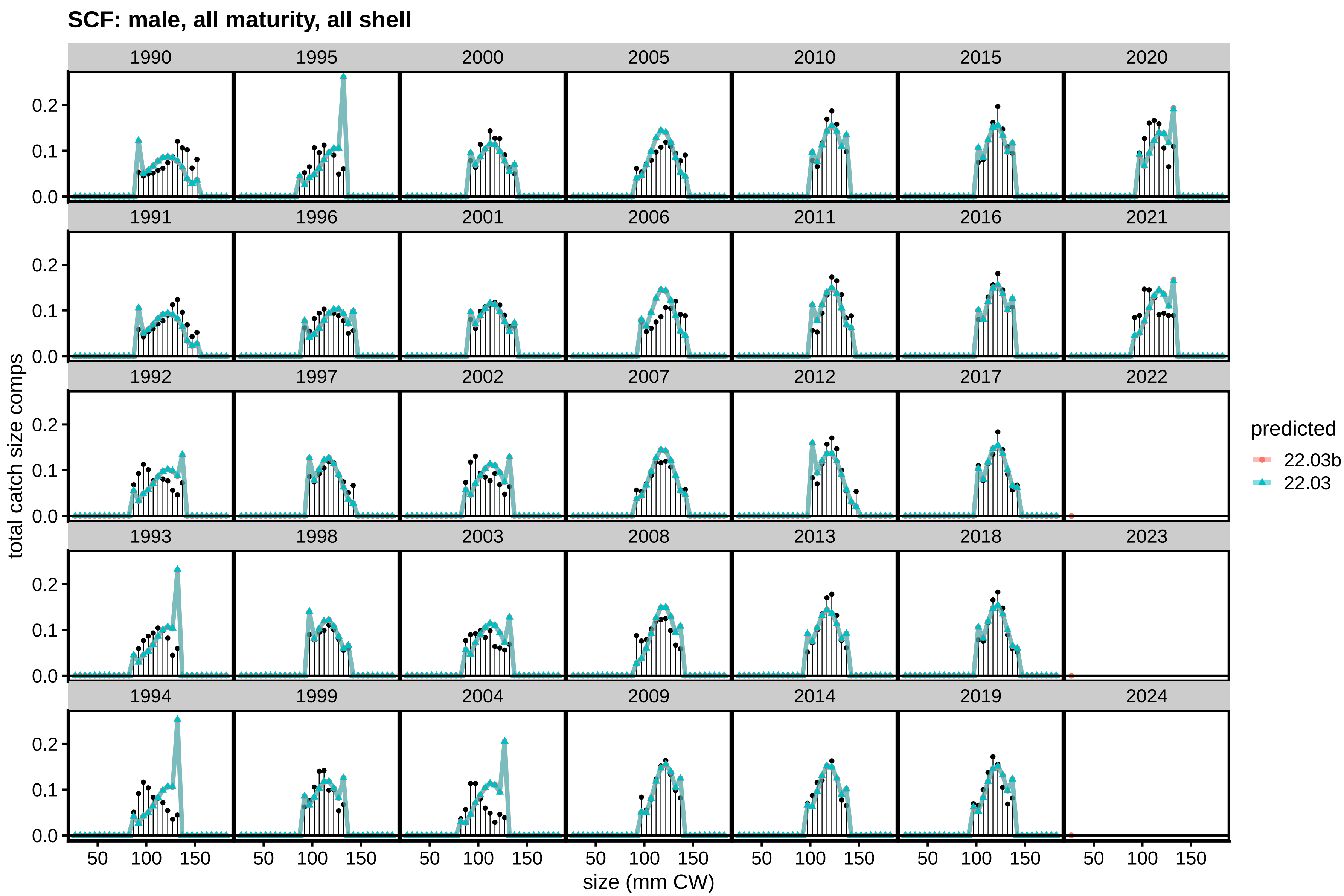

Figure 96. Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03b.

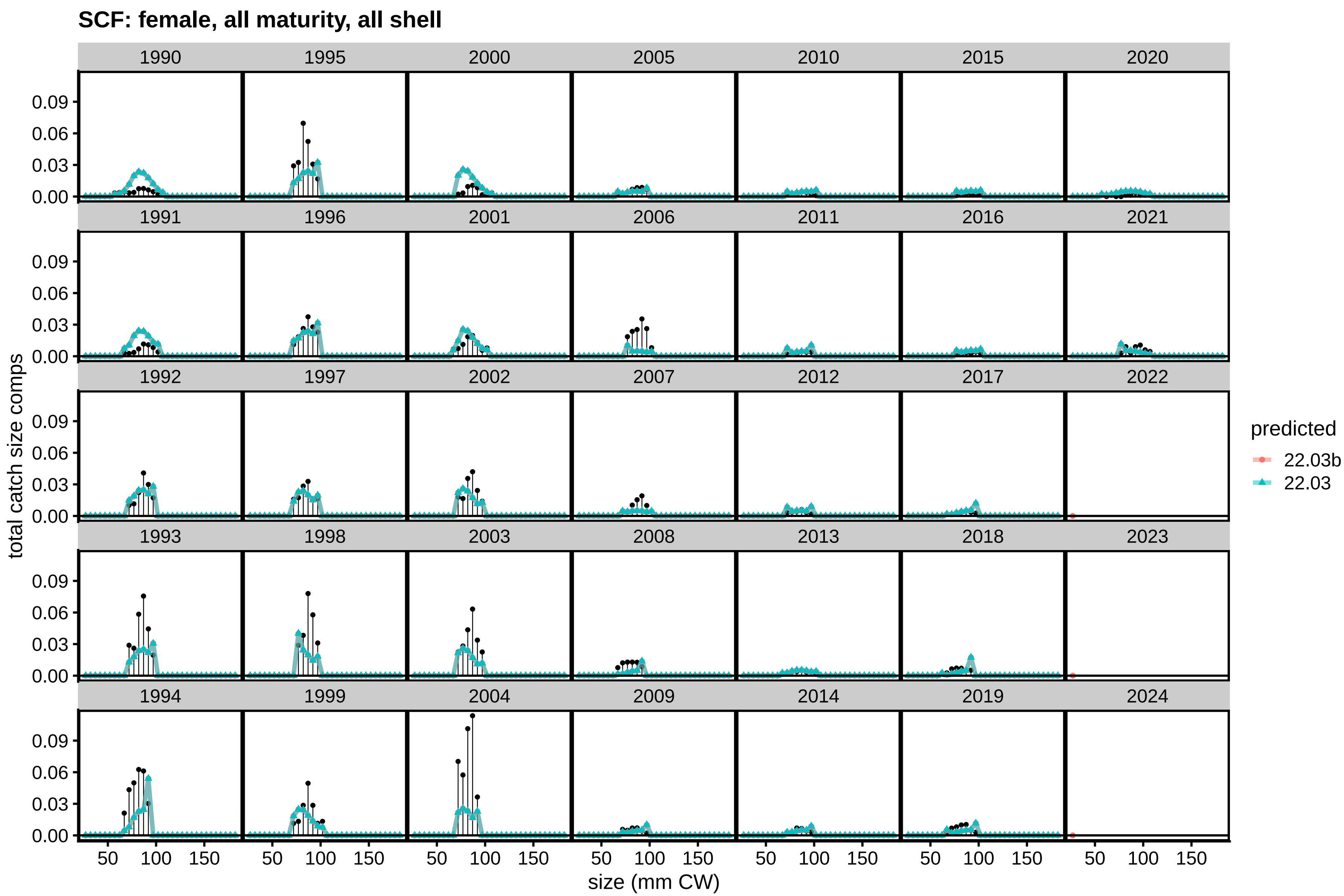

Figure 97. Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03b.

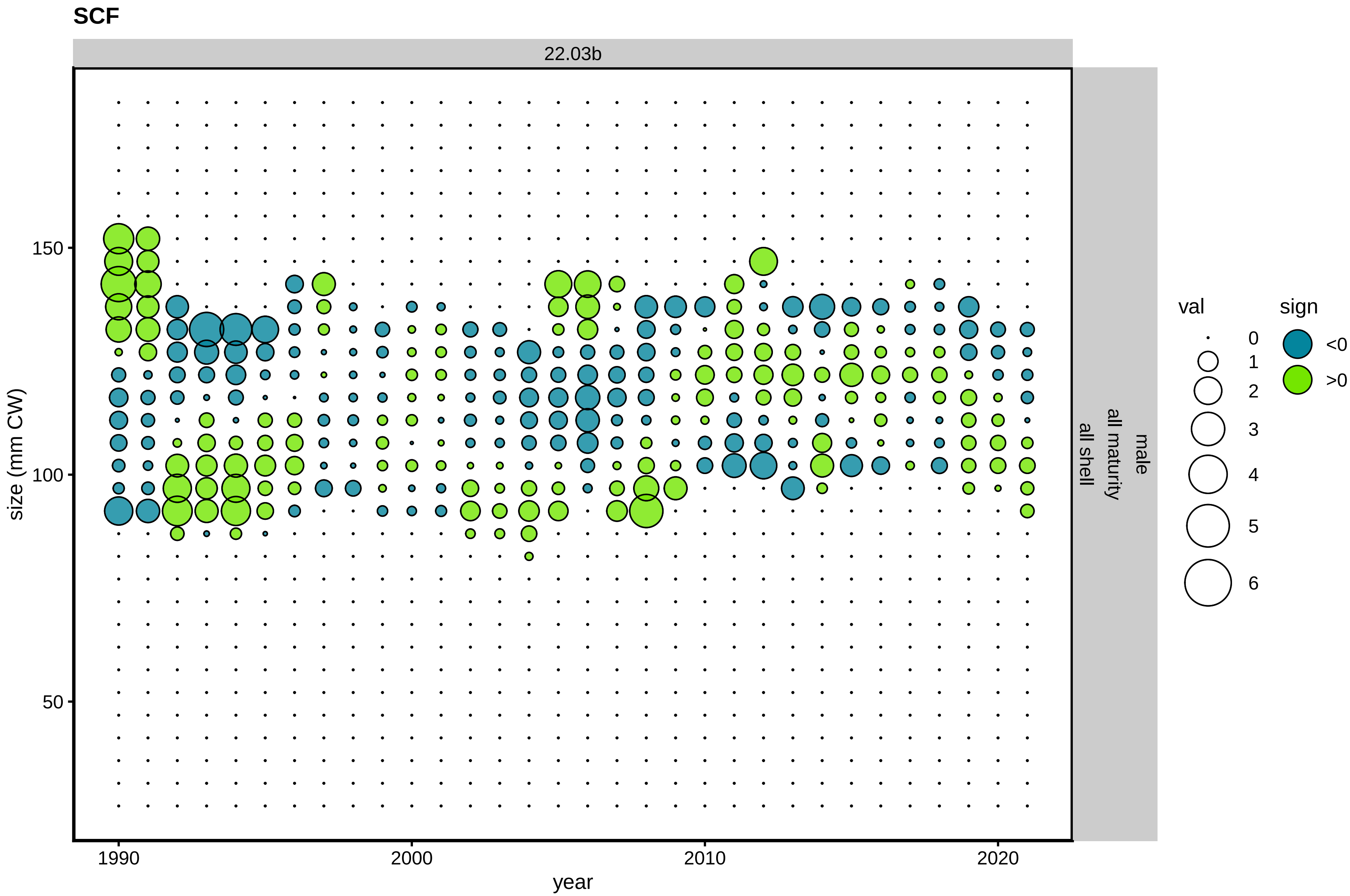

Figure 98. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

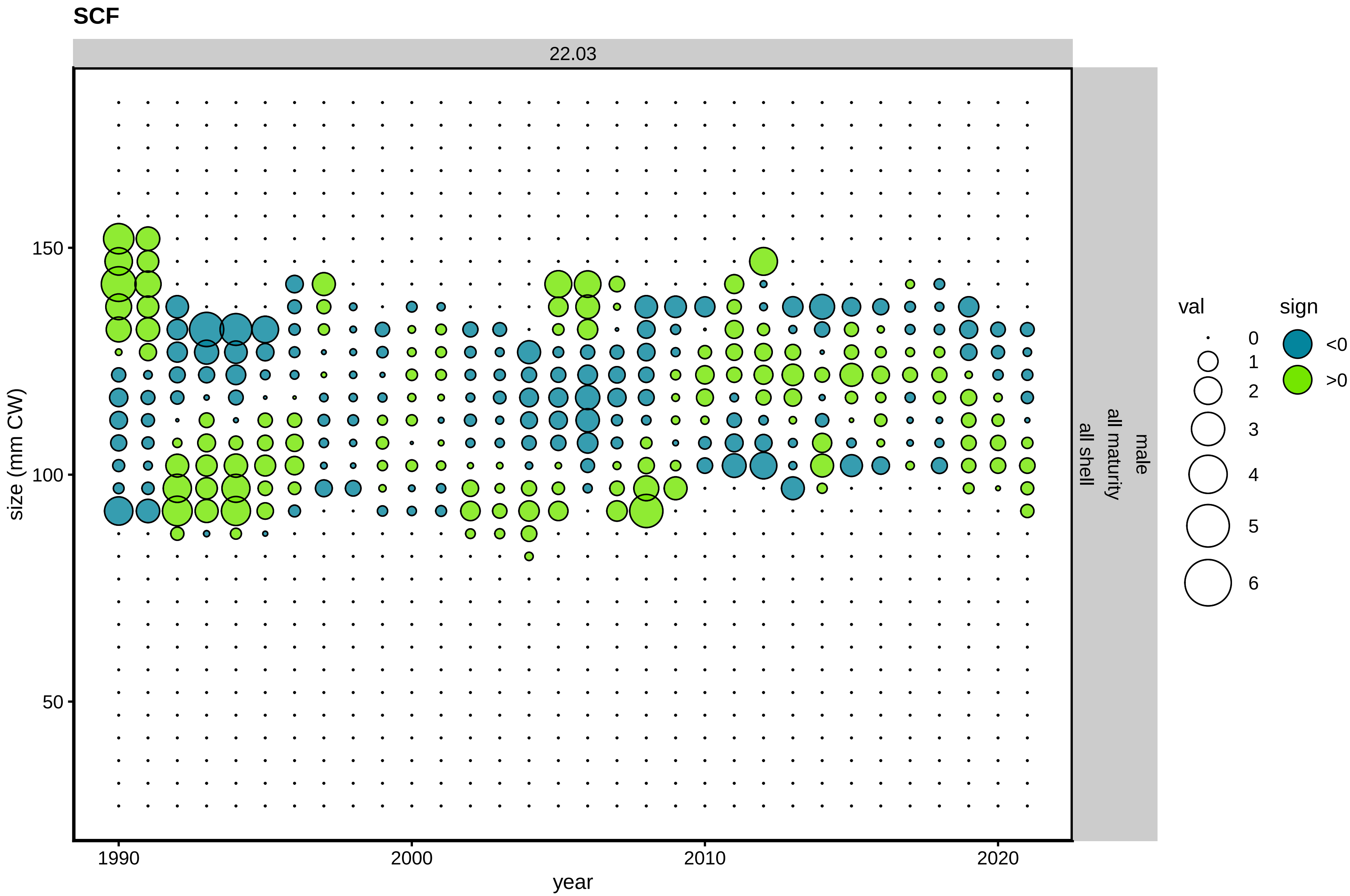

Figure 99. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

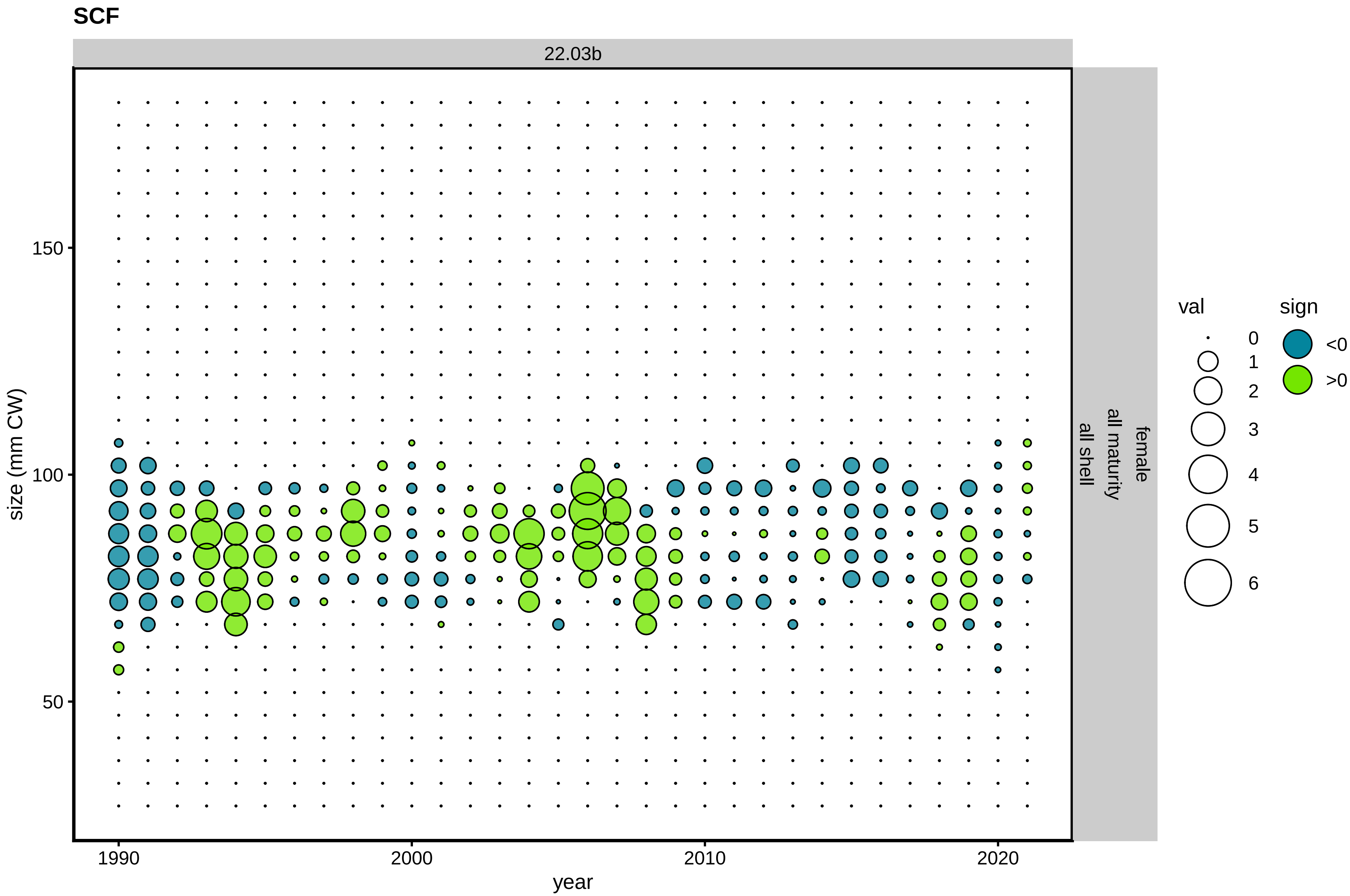

Figure 100. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

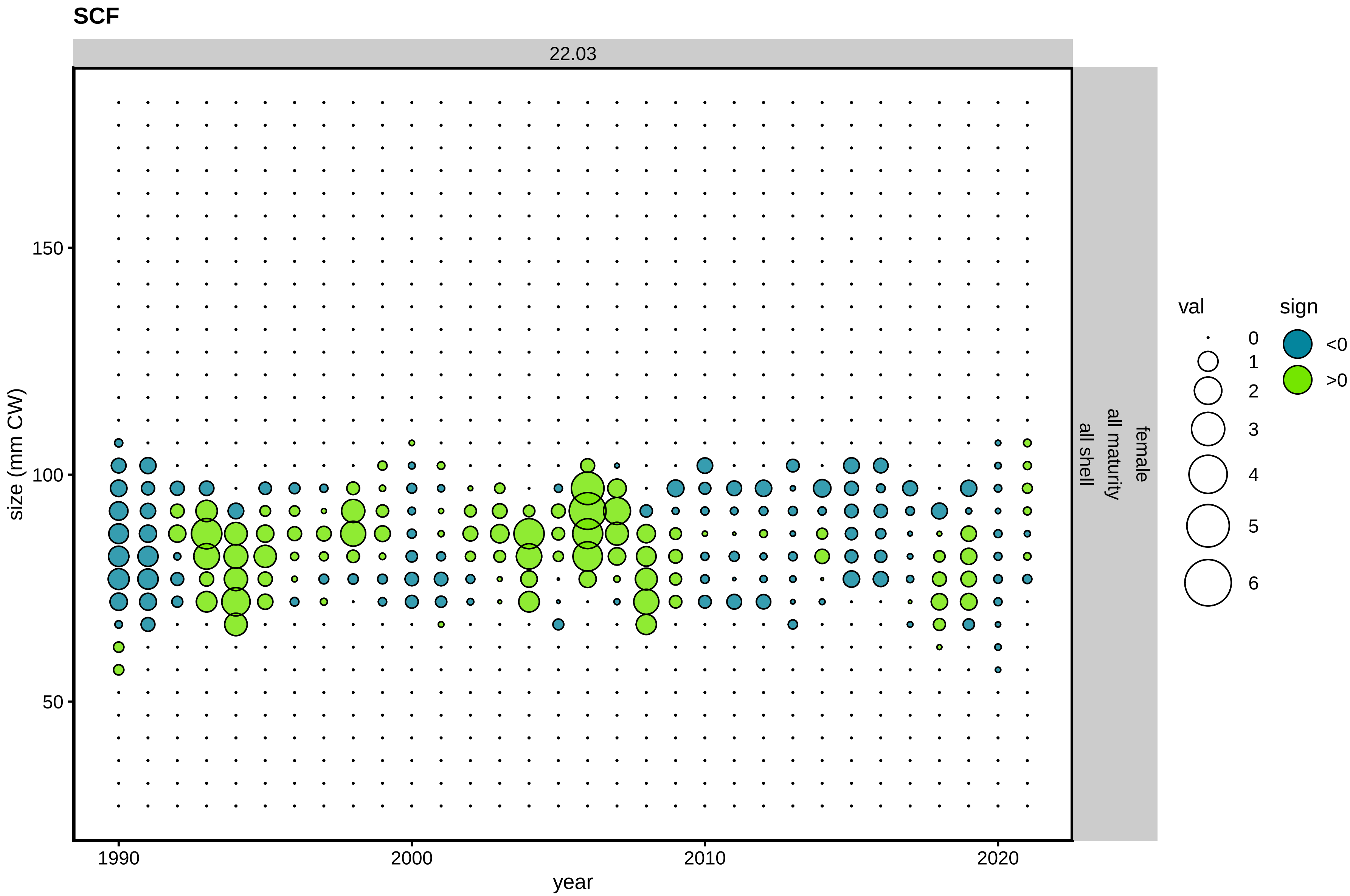

Figure 101. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

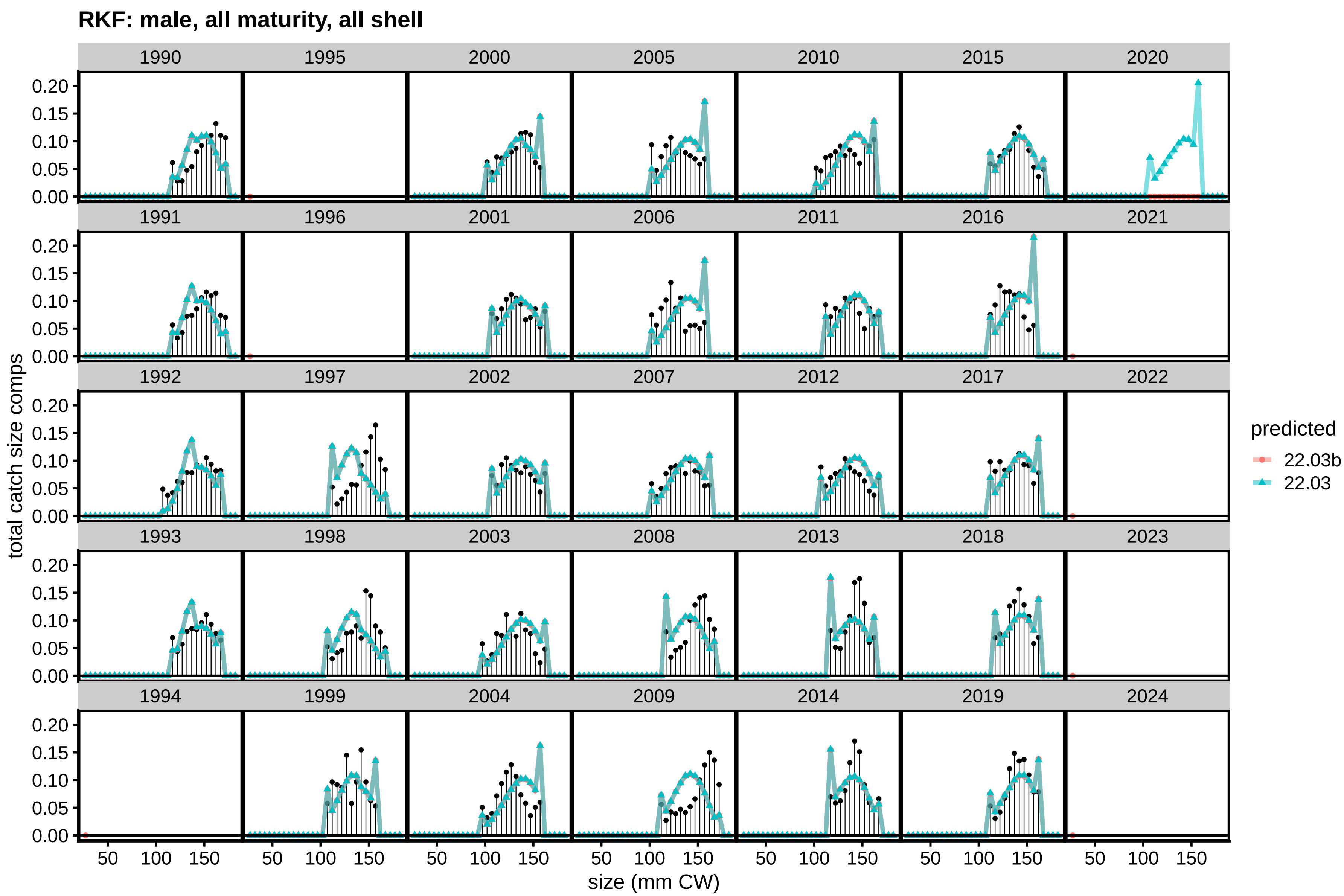

Figure 102. Fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03b.

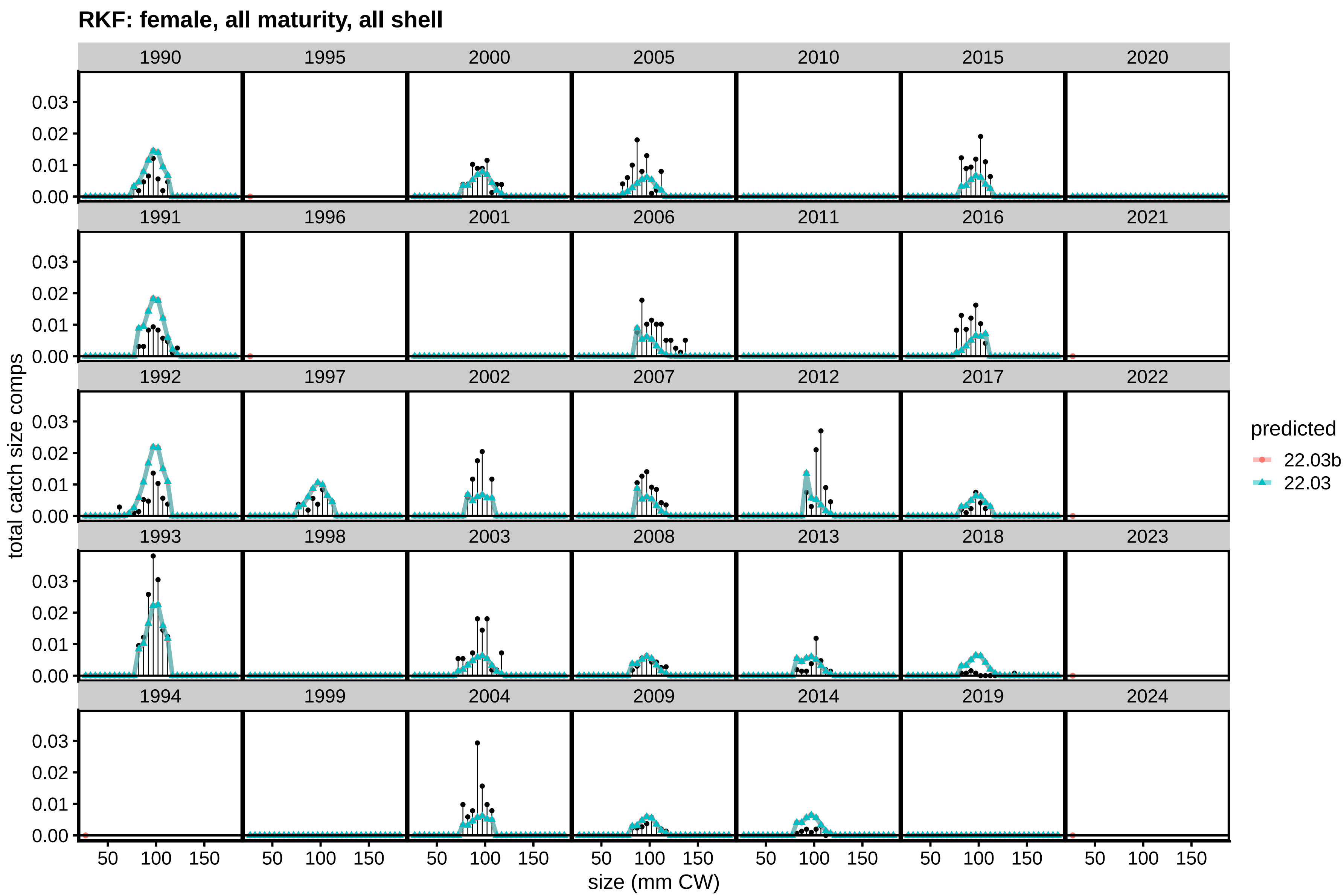

Figure 103. Fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03b.

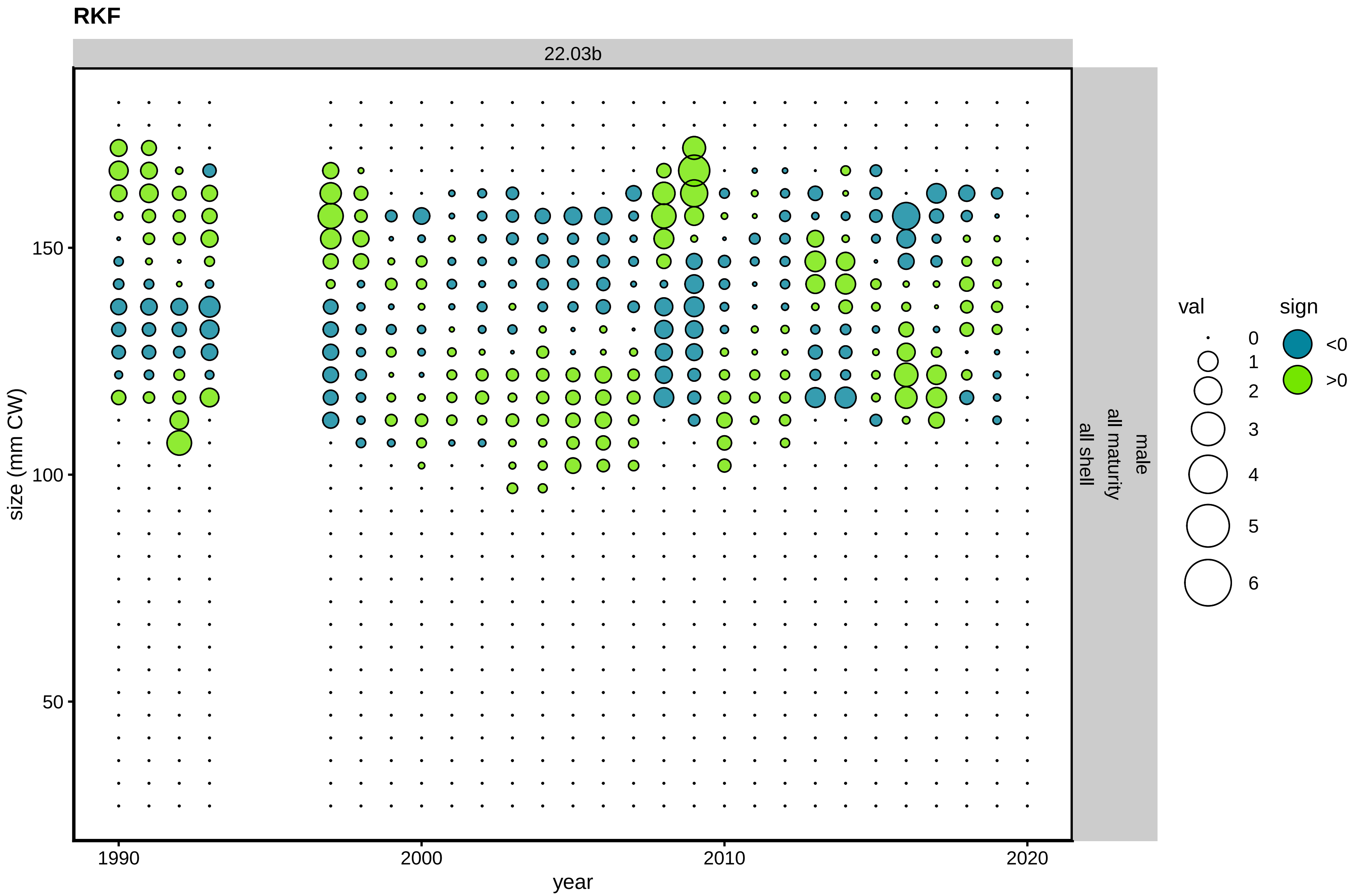

Figure 104. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

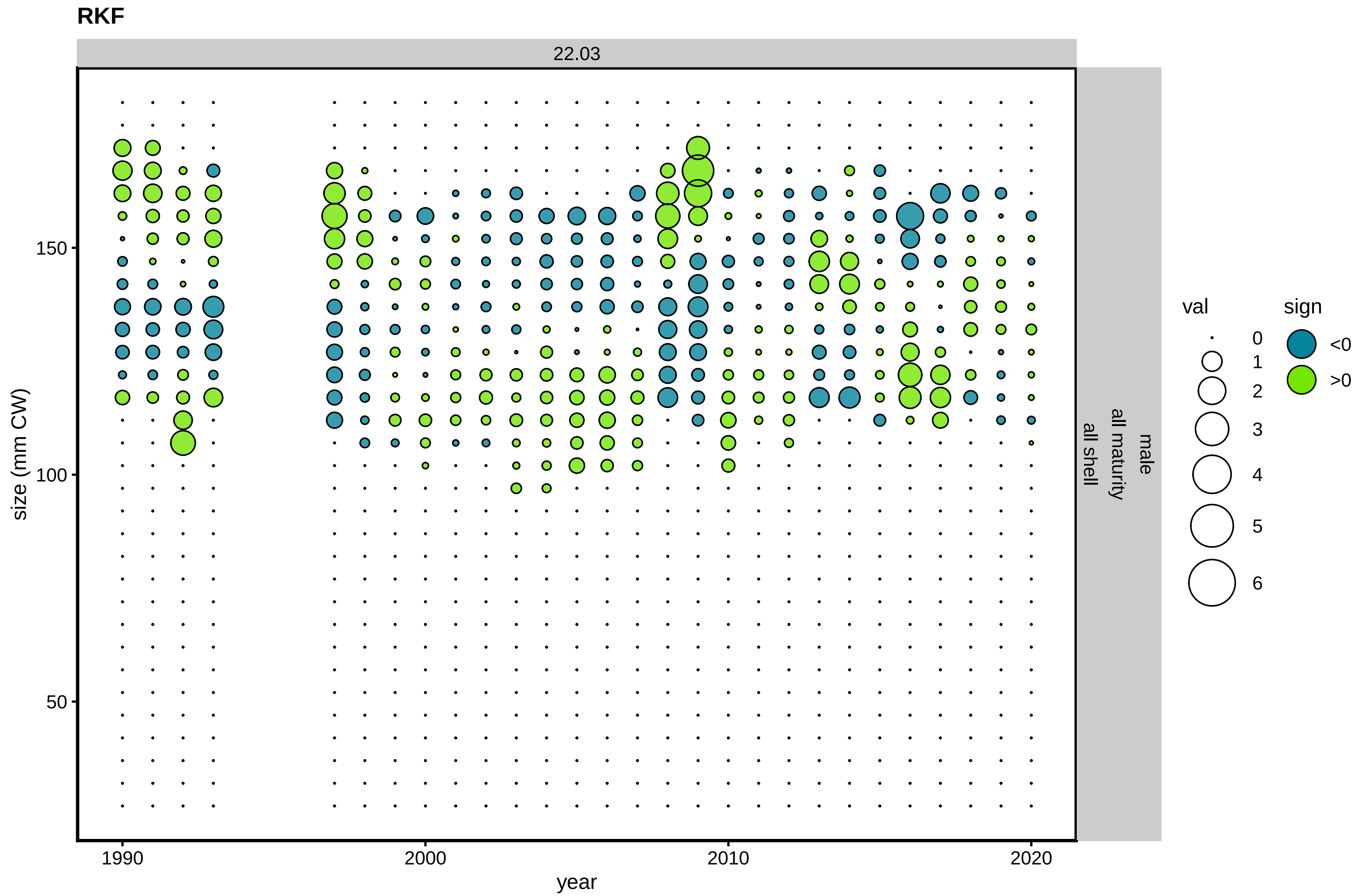

Figure 105. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

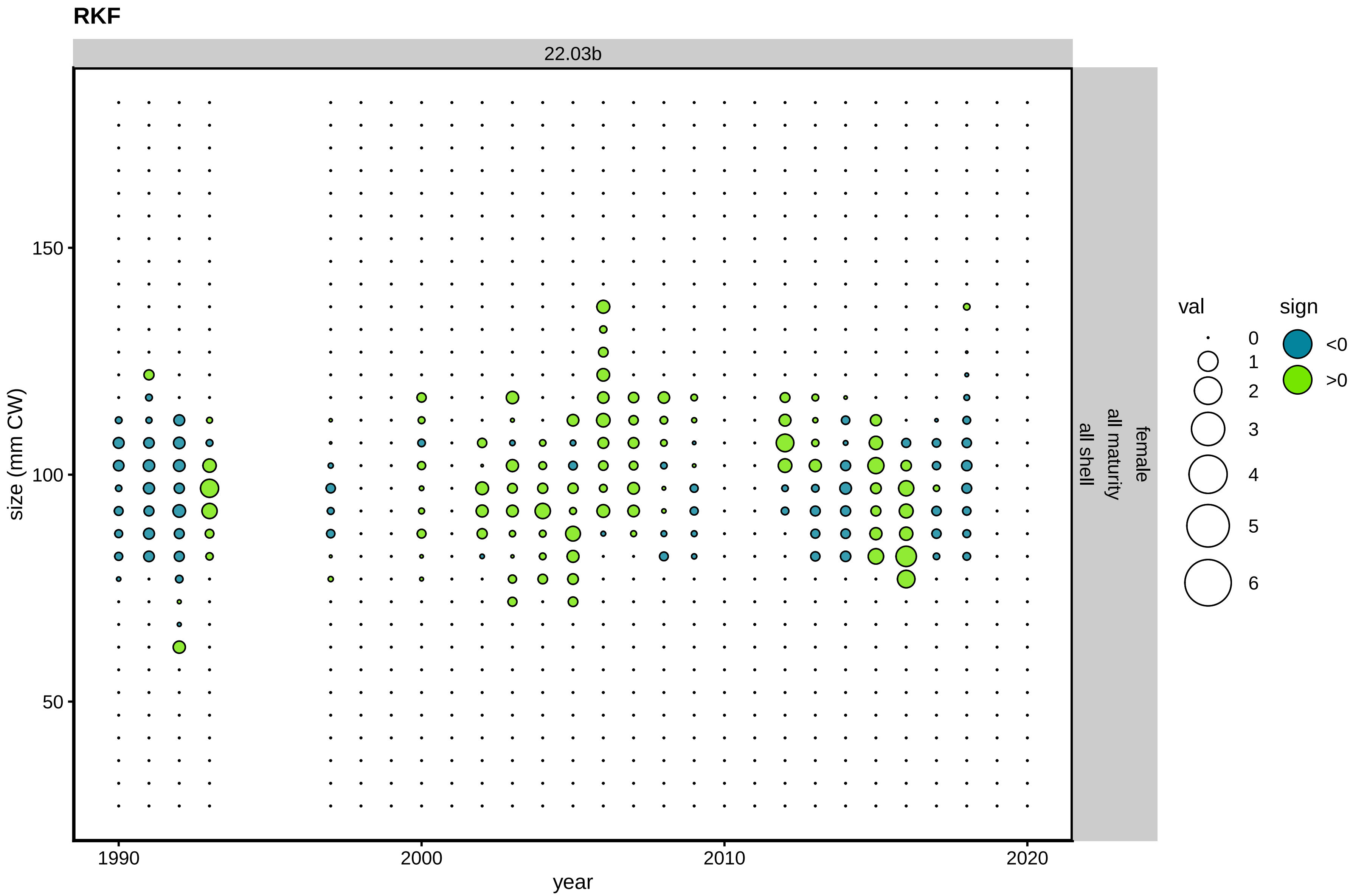

Figure 106. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

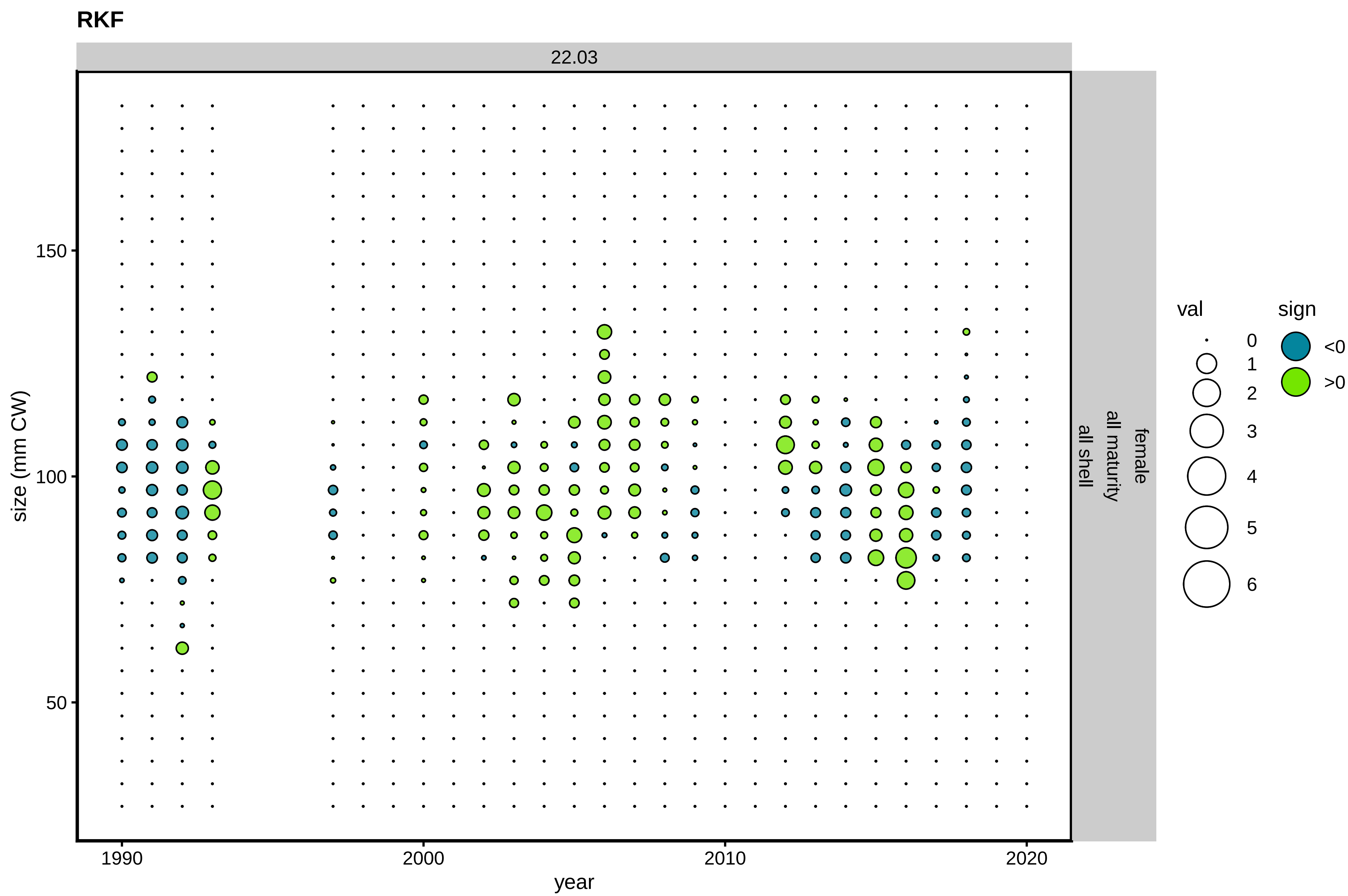

Figure 107. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

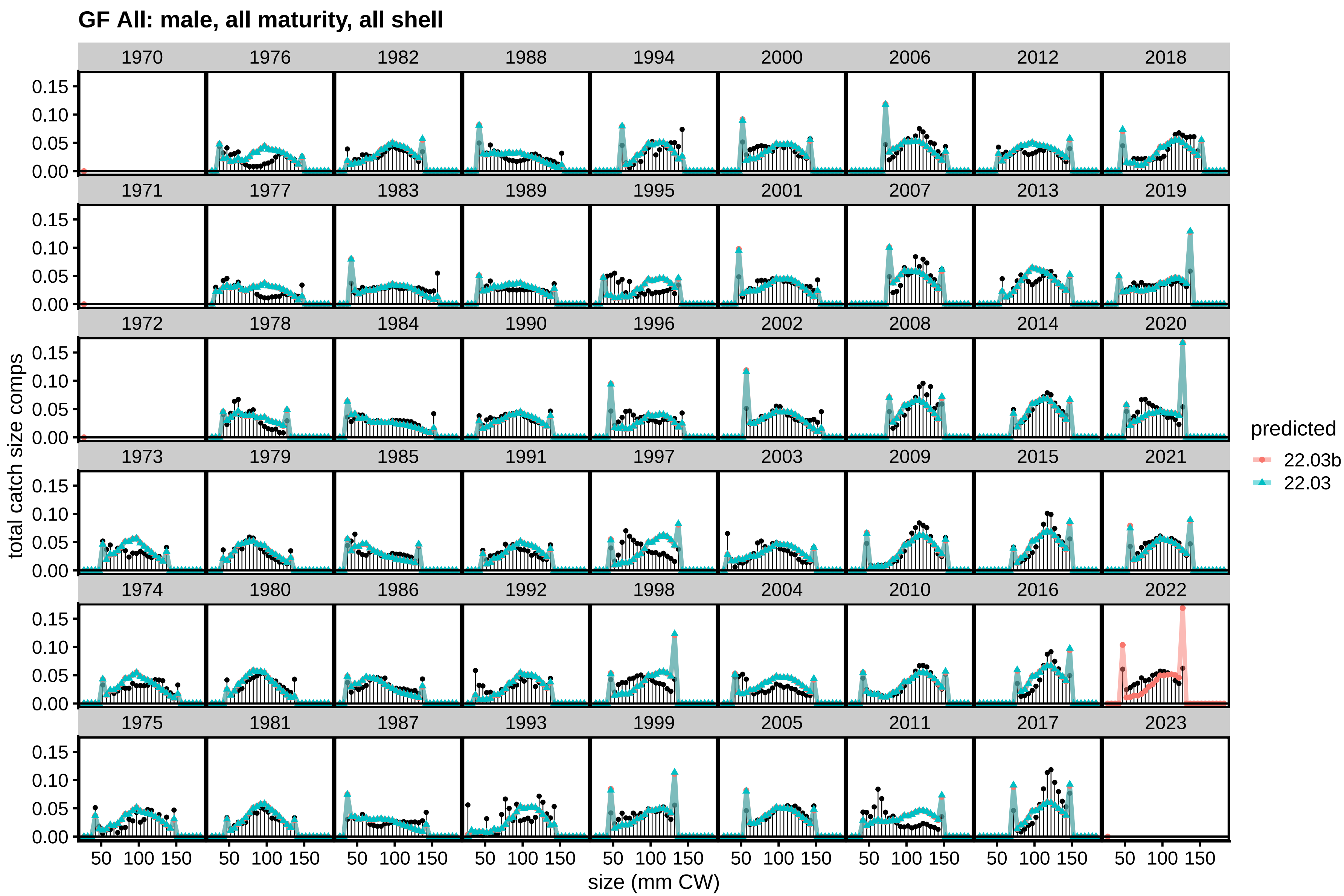

Figure 108. Fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03b.

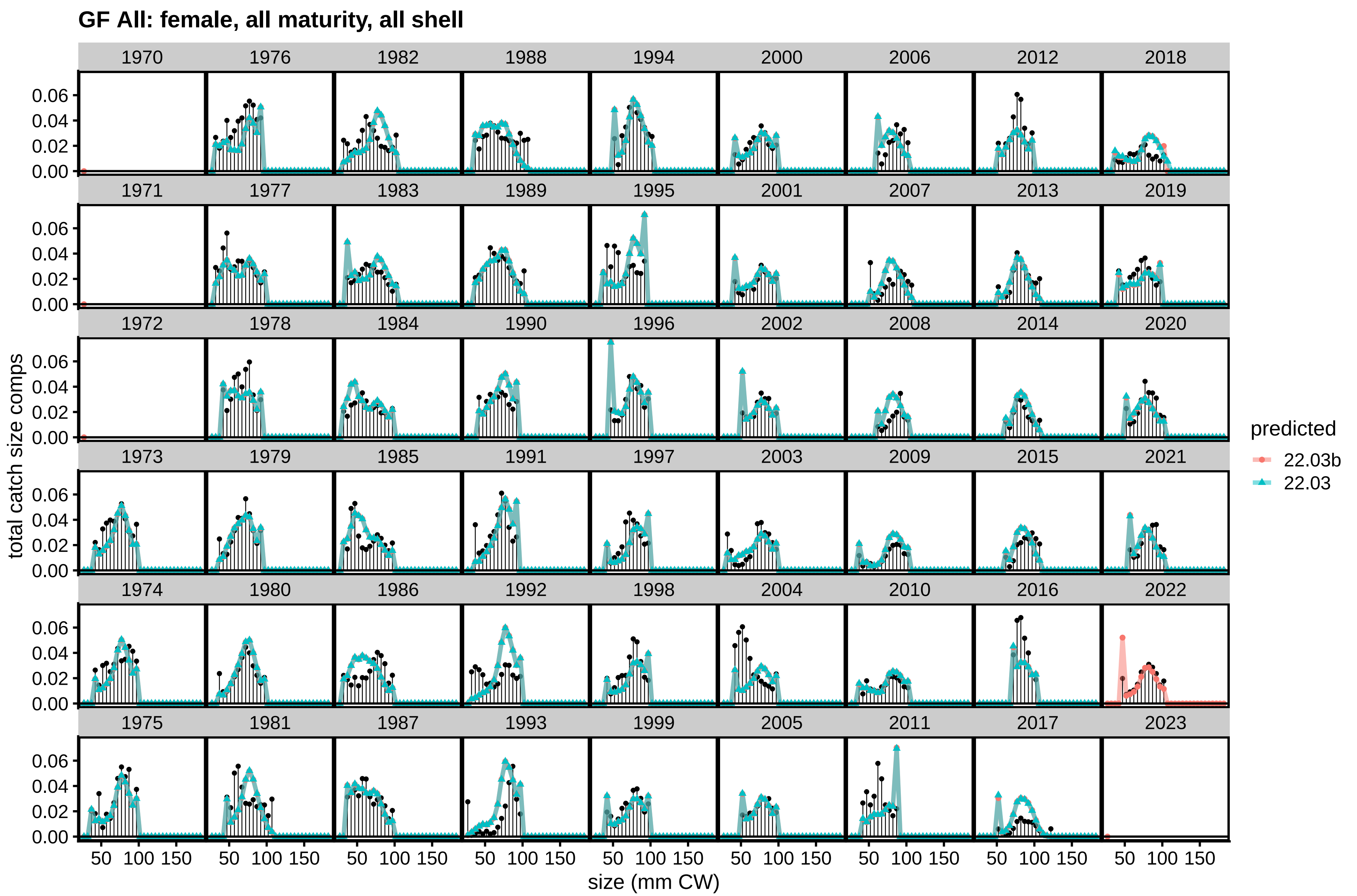

Figure 109. Fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03b.

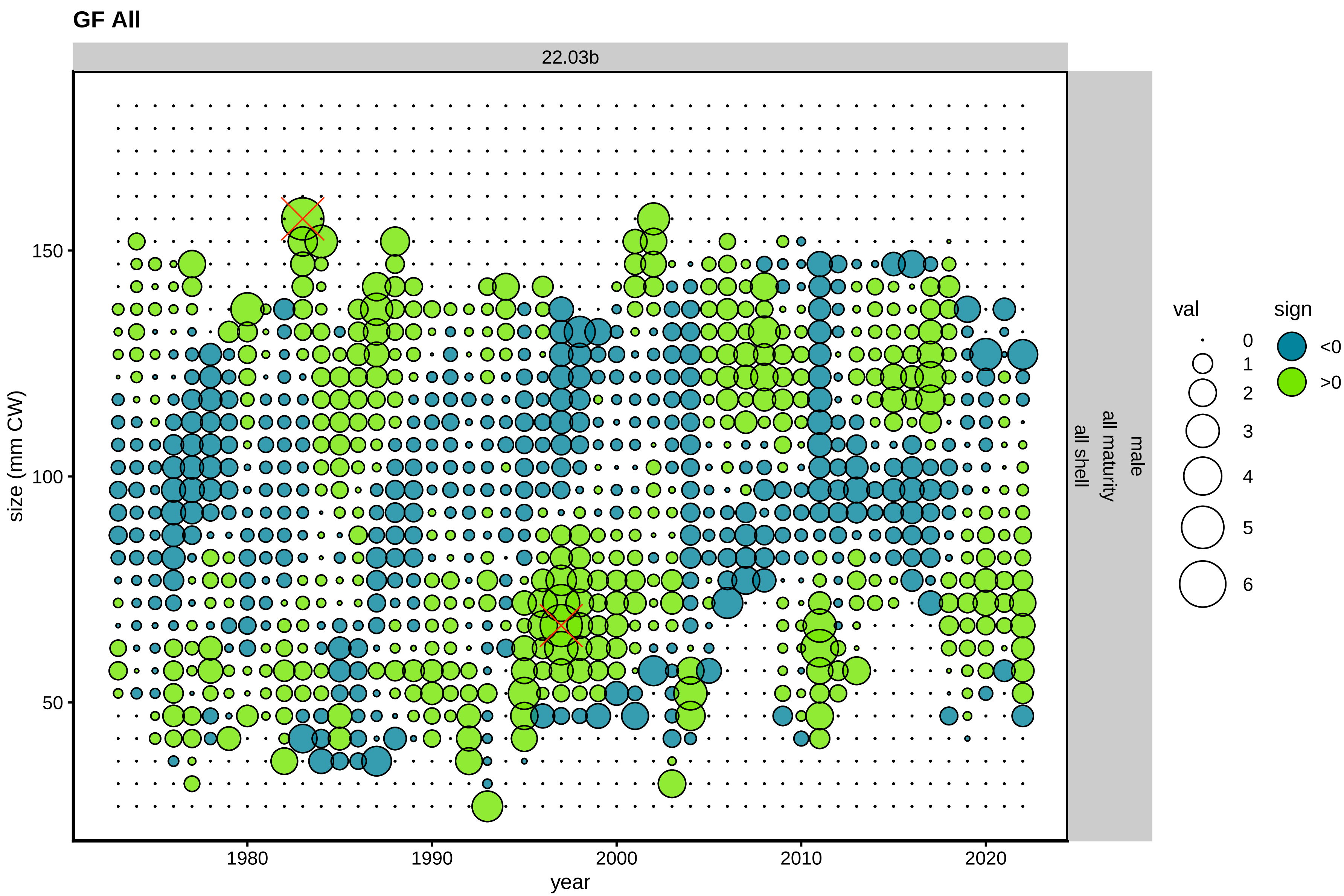

Figure 110. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

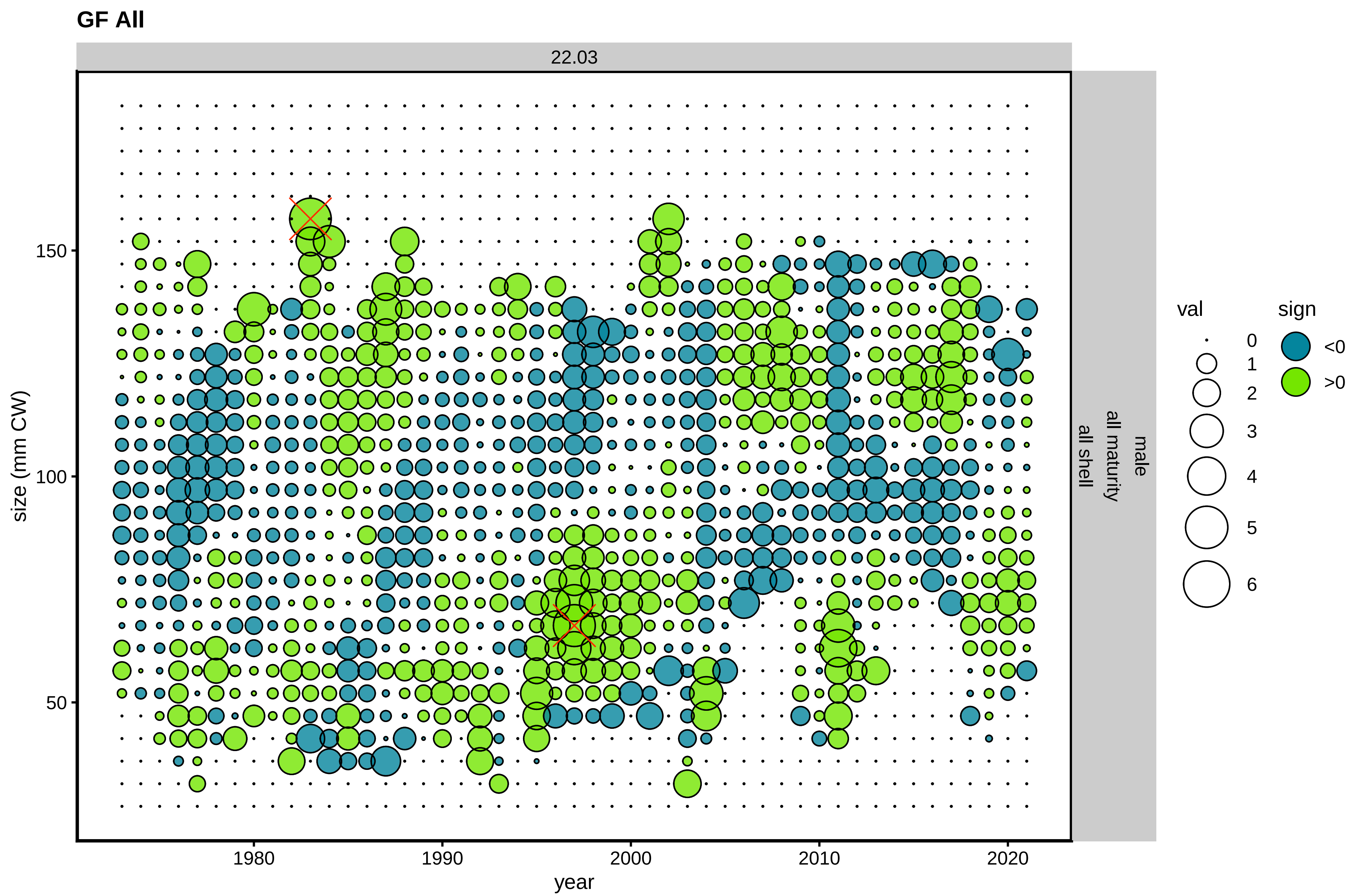

Figure 111. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

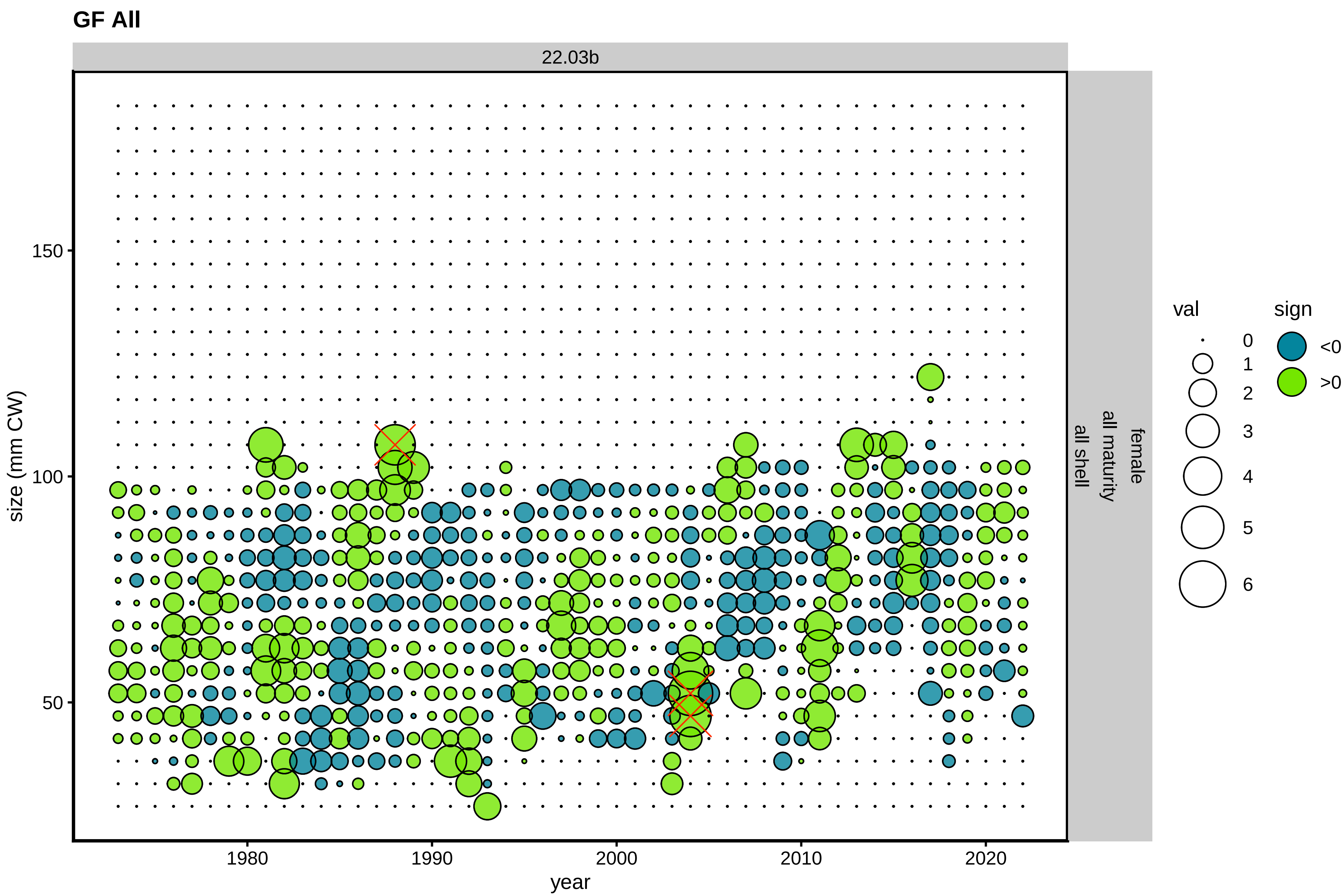

Figure 112. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

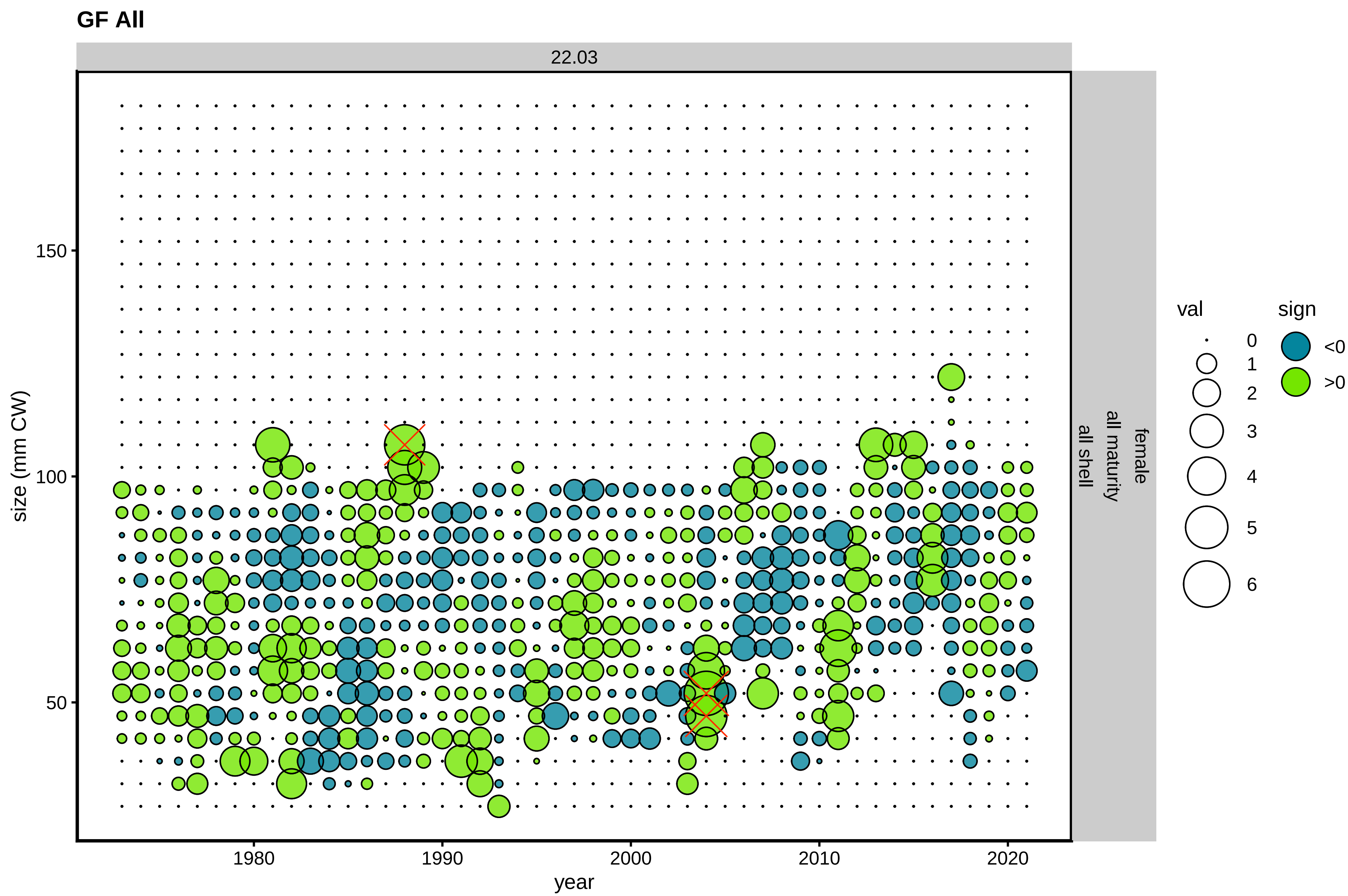

Figure 113. Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

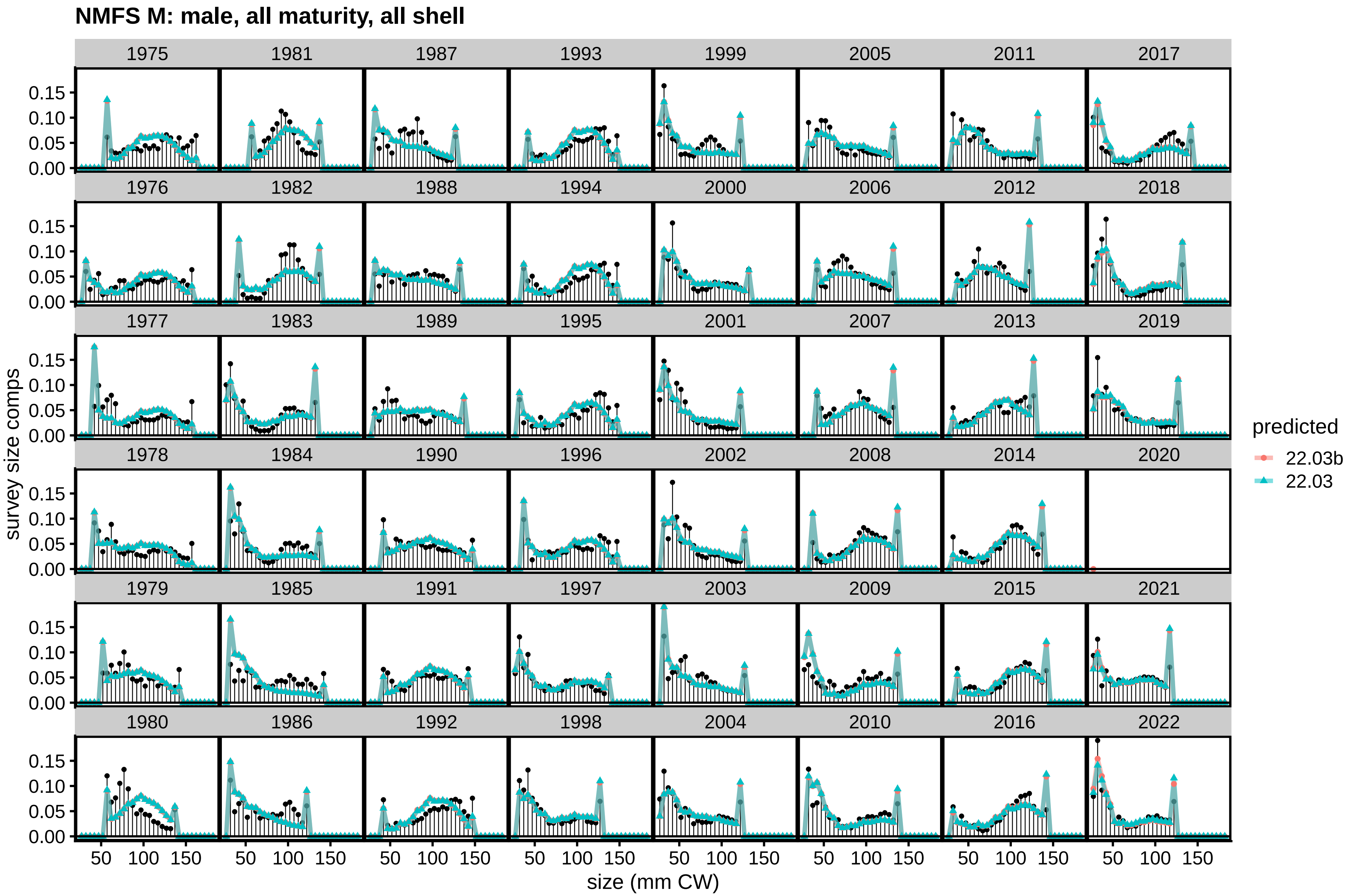

Figure 114. Fits to survey size compositions in the NMFS M survey. Preferred model is 22.03b.

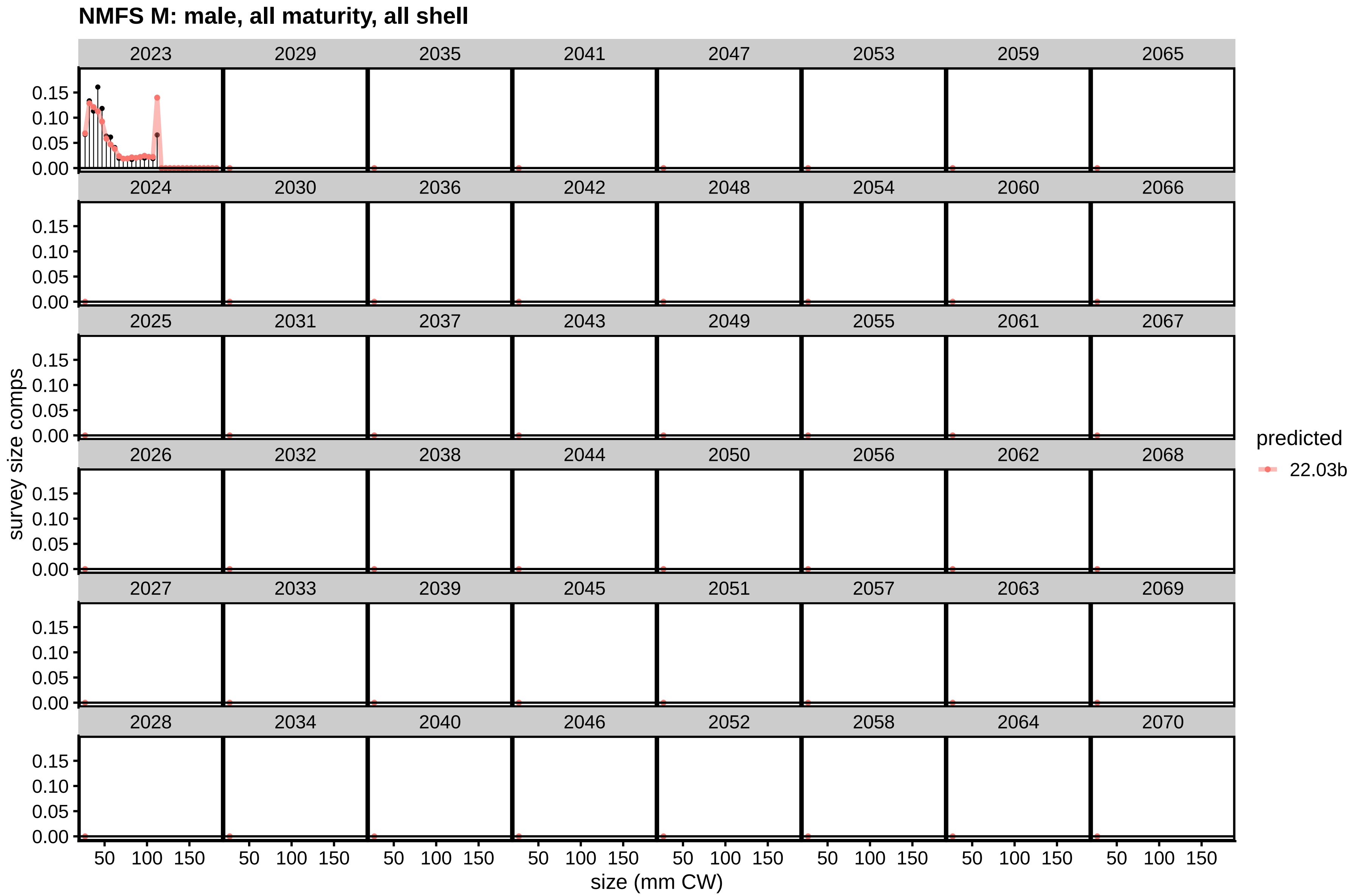

Figure 115. Fits to survey size compositions in the NMFS M survey. Preferred model is 22.03b.

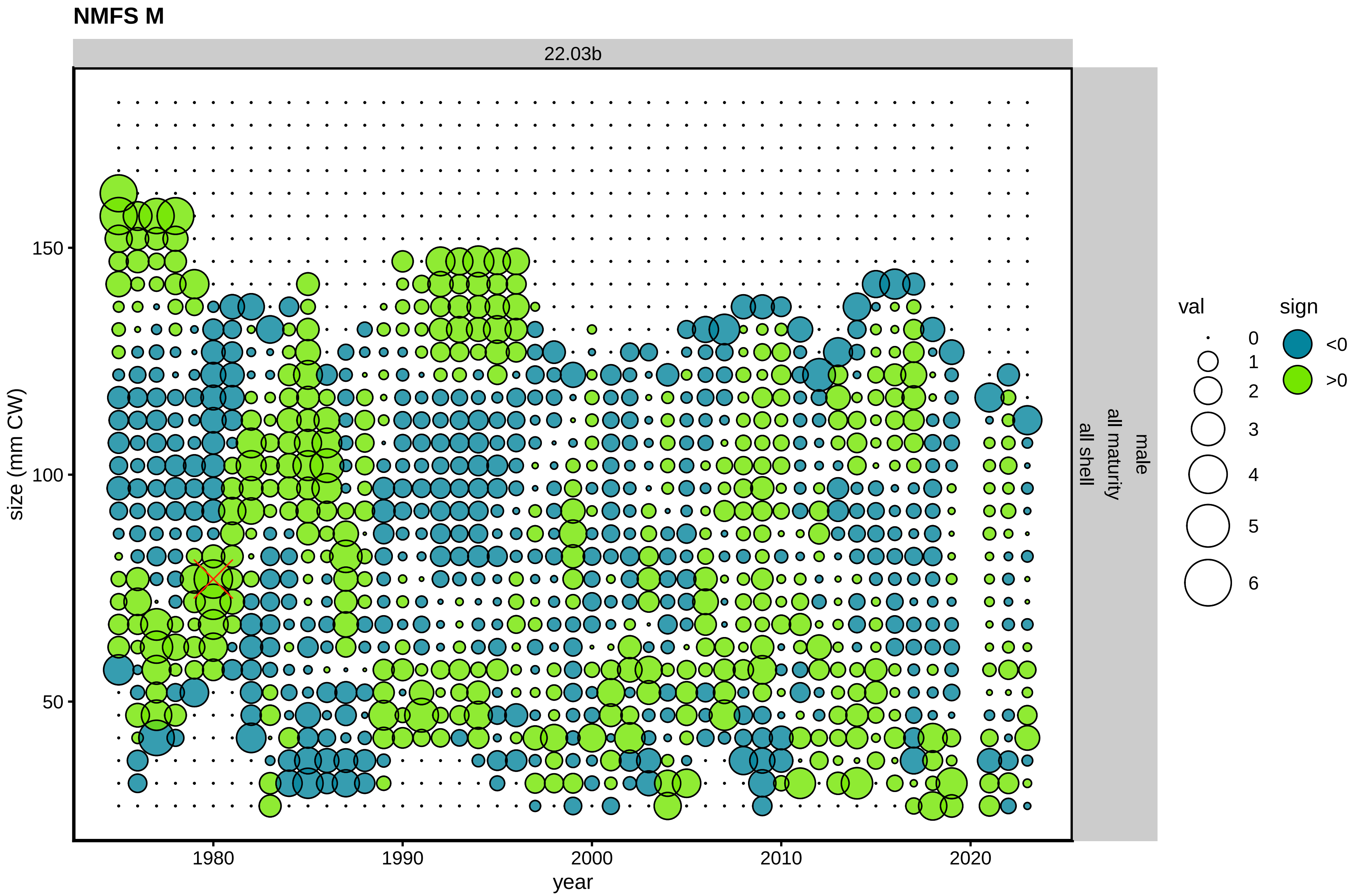

Figure 116. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

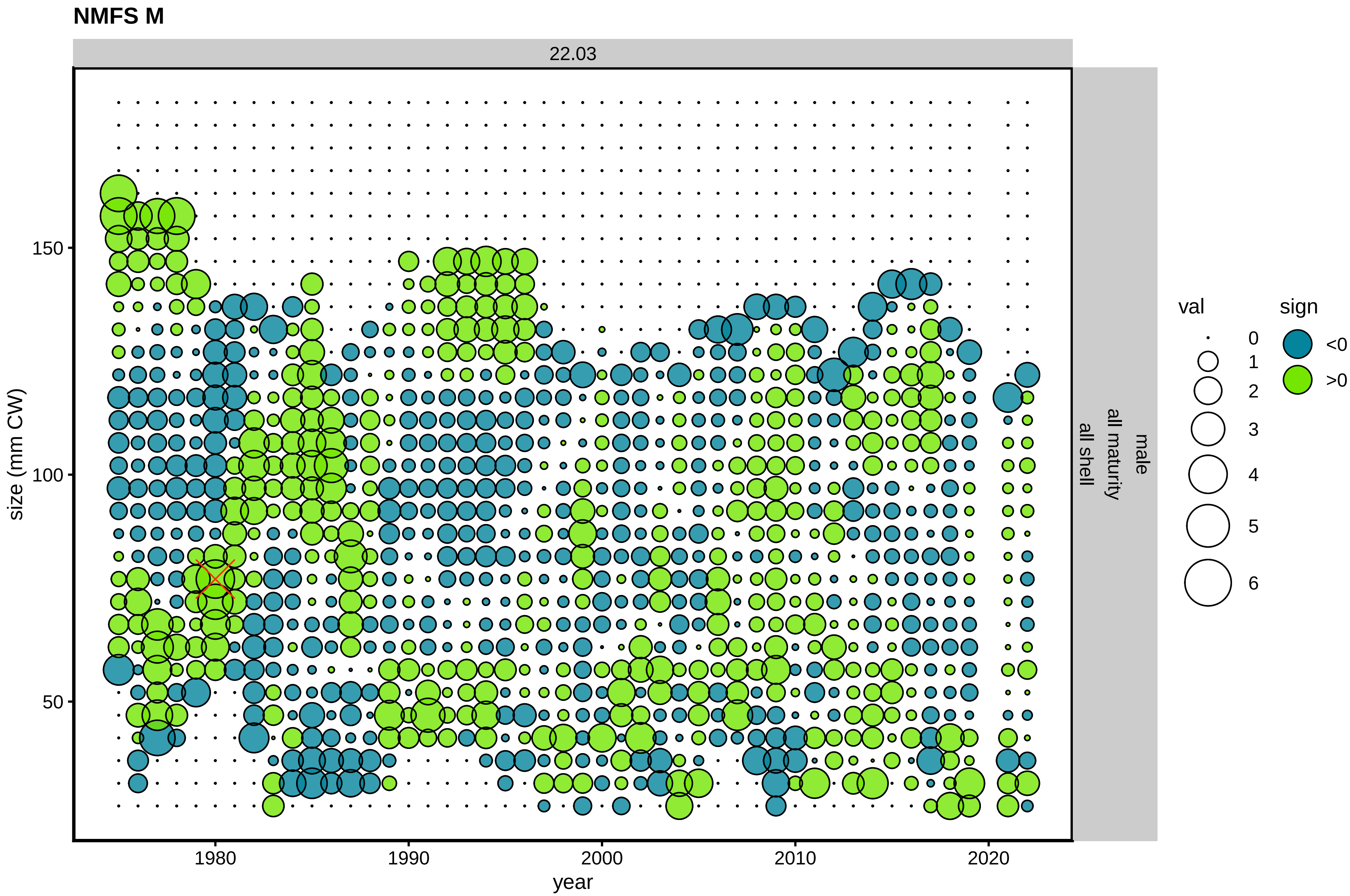

Figure 117. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

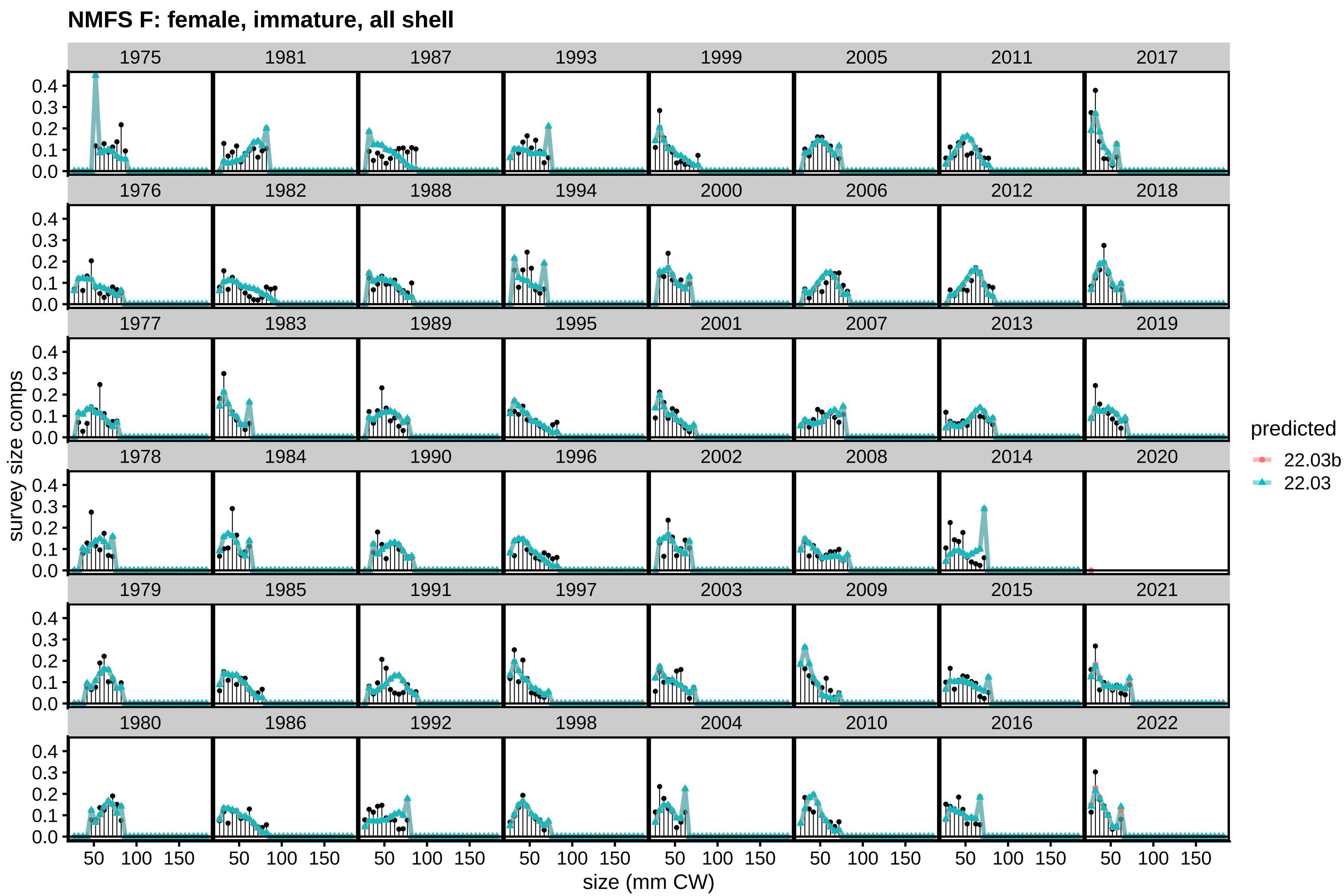

Figure 118. Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03b.

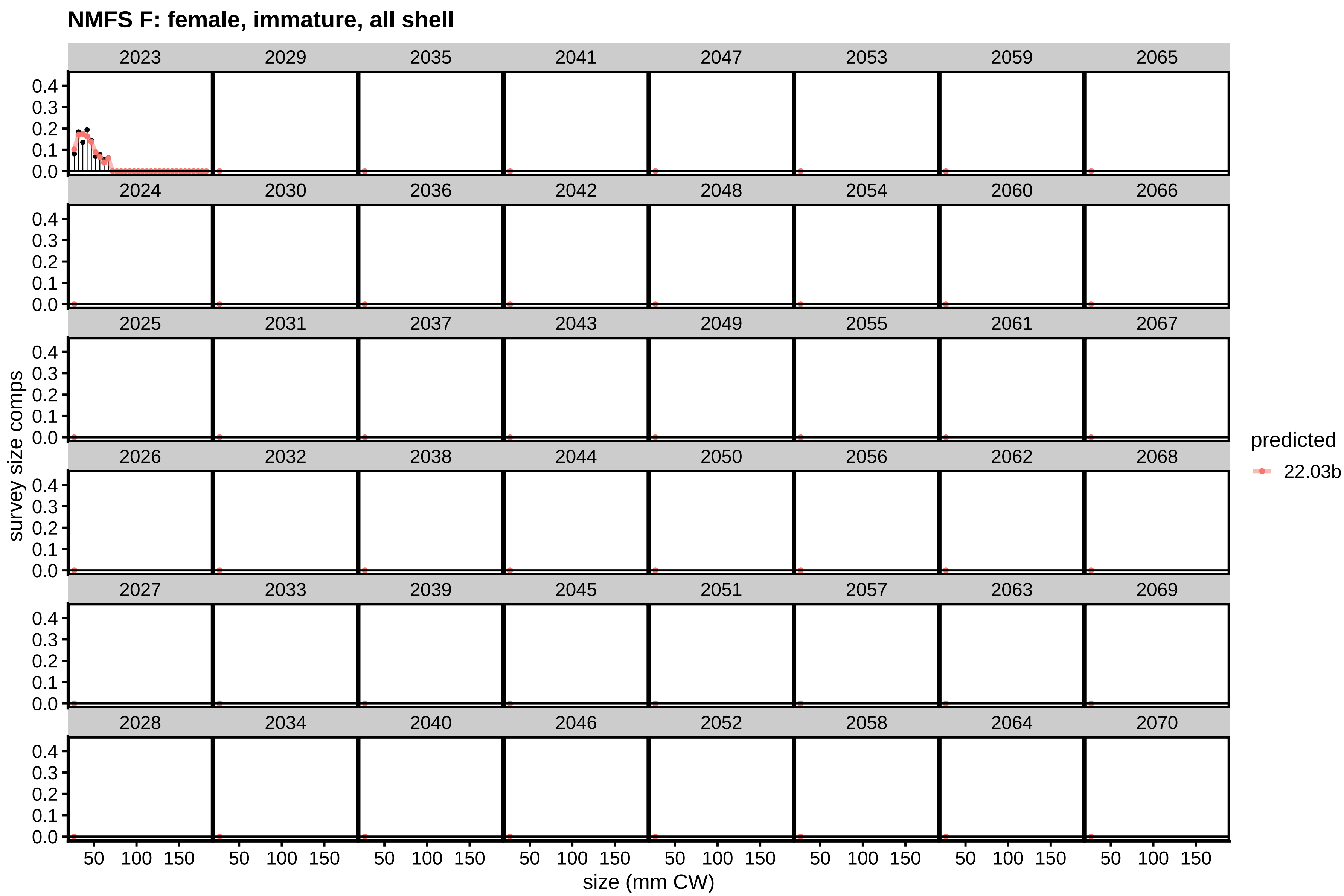

Figure 119. Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03b.

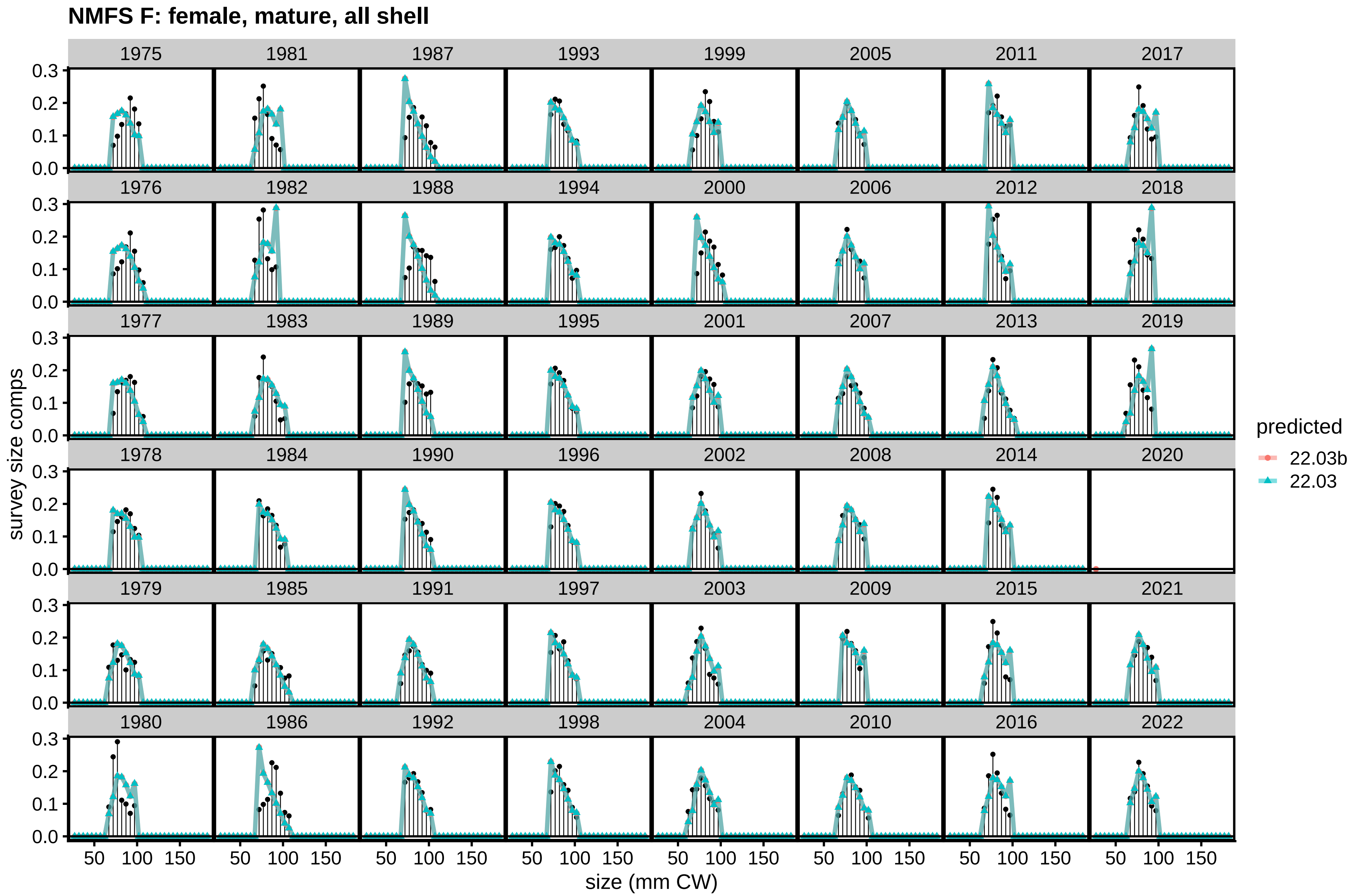

Figure 120. Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03b.

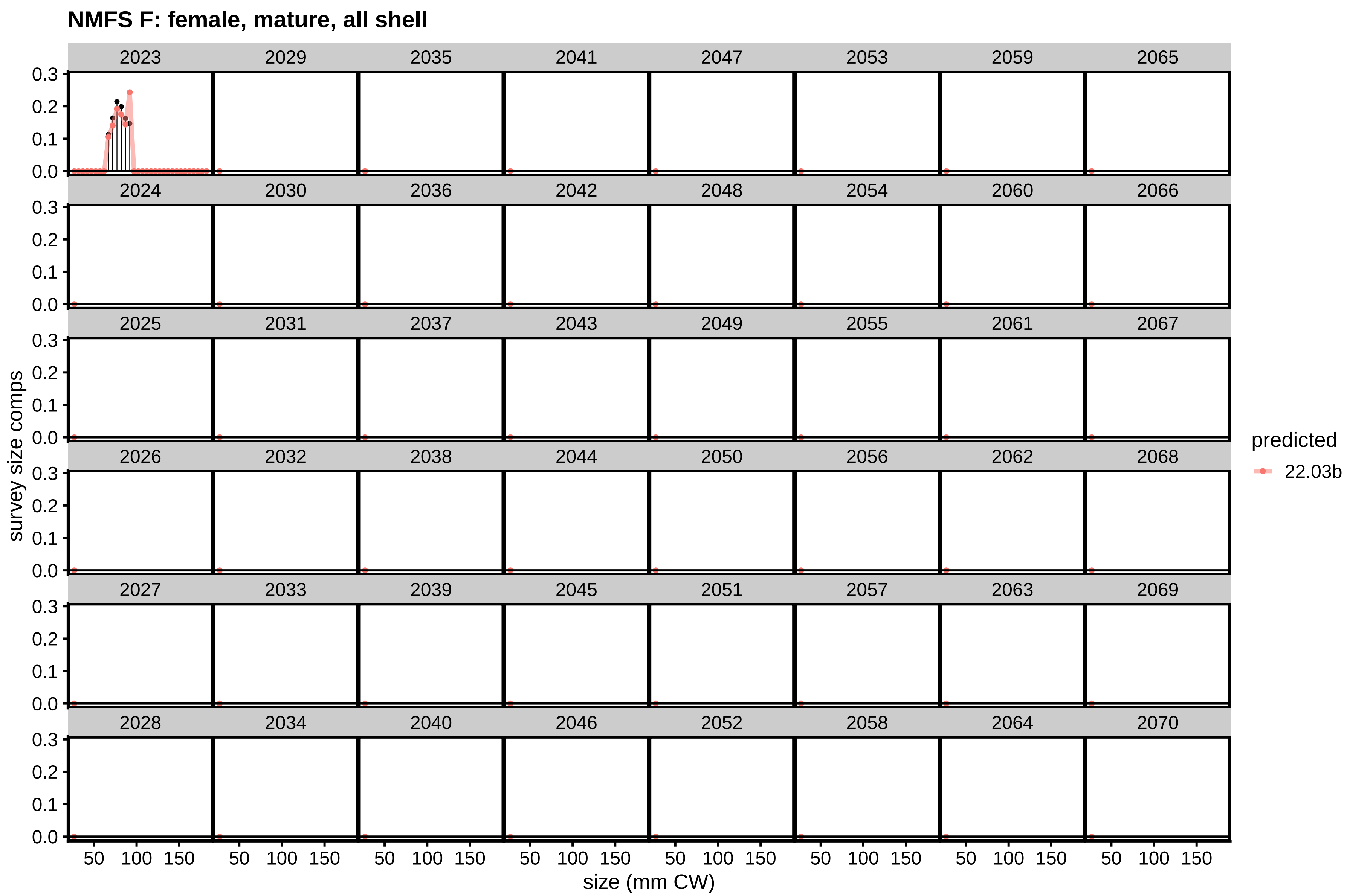

Figure 121. Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03b.

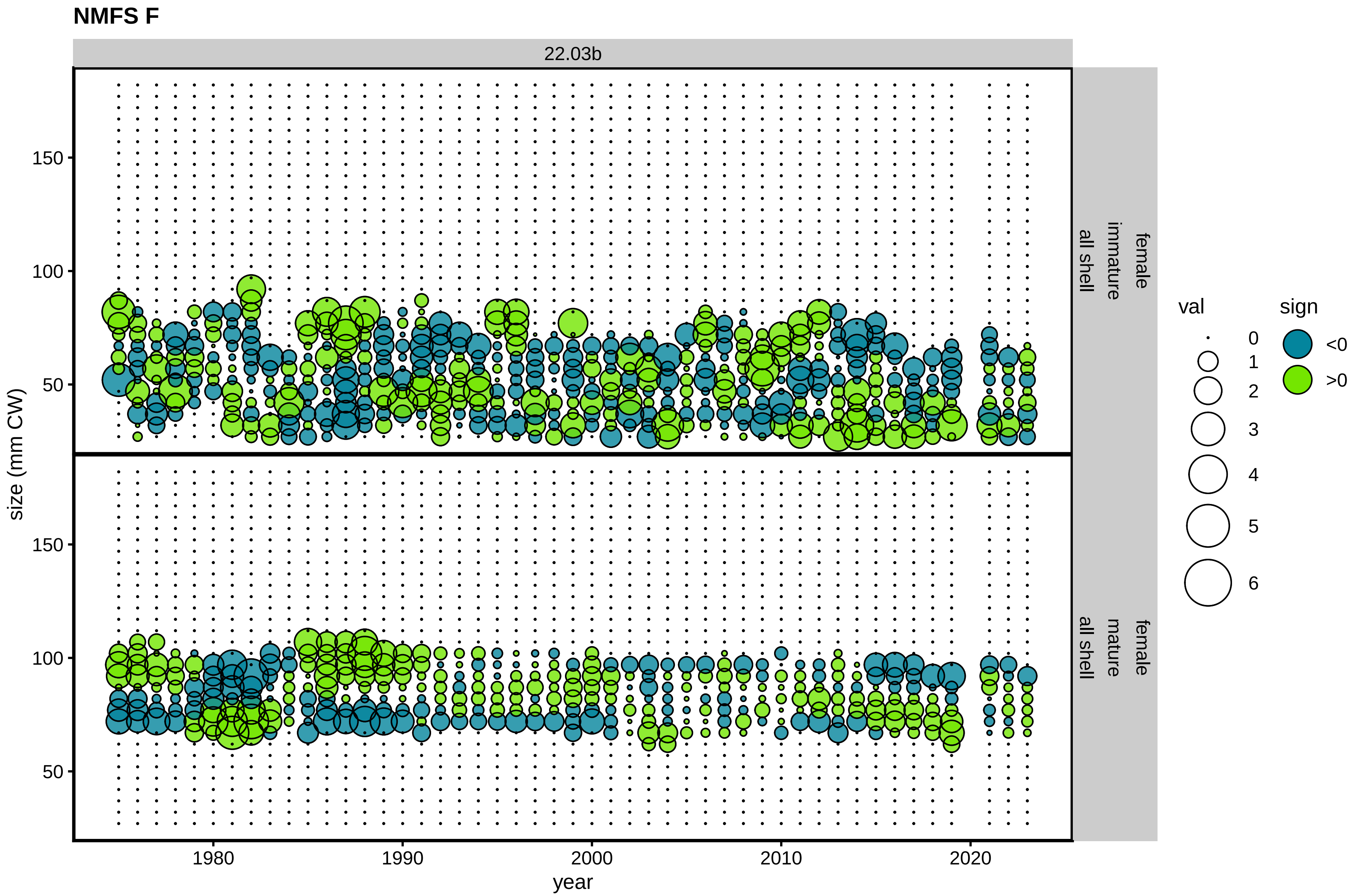

Figure 122. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

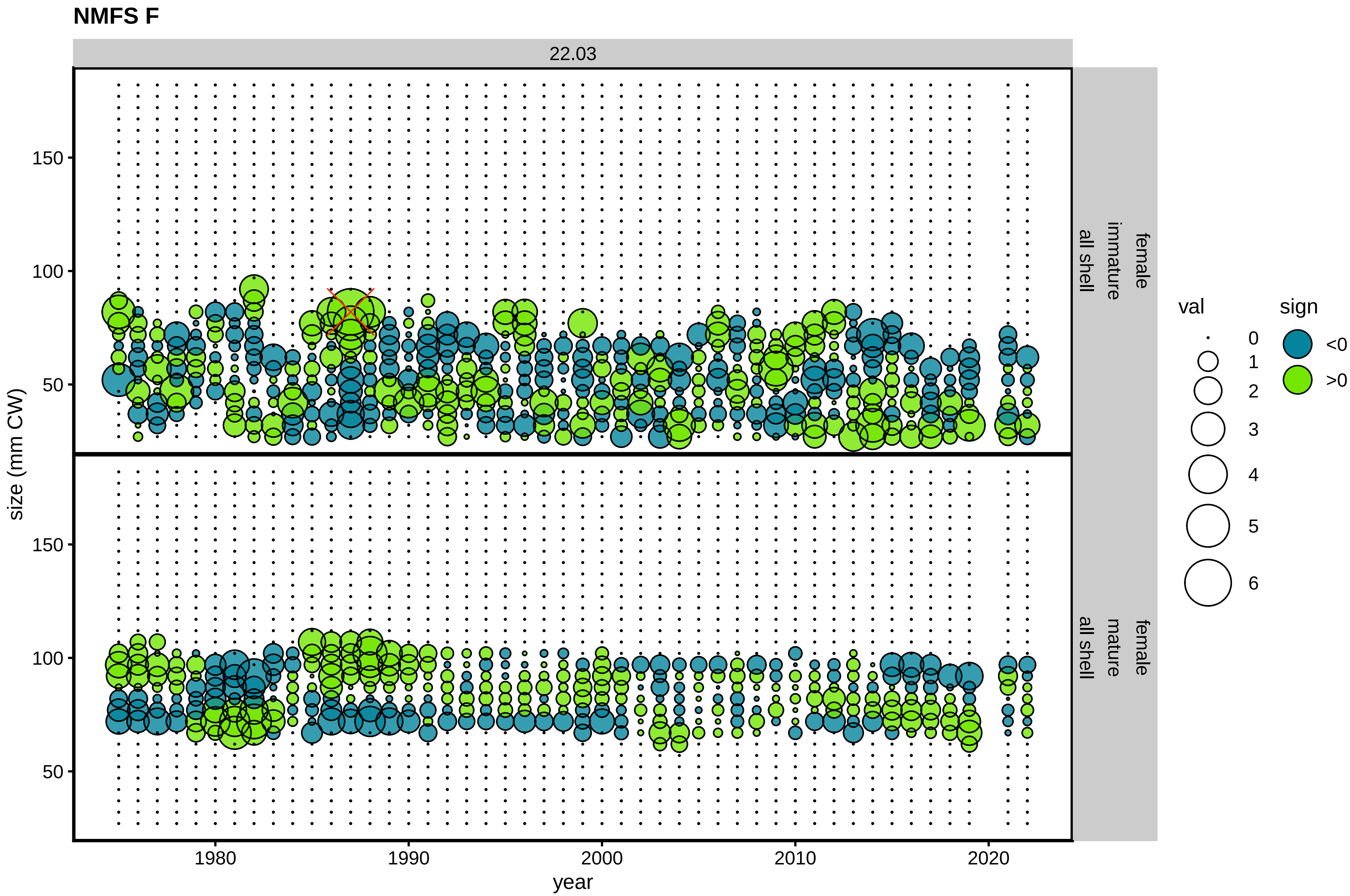

Figure 123. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

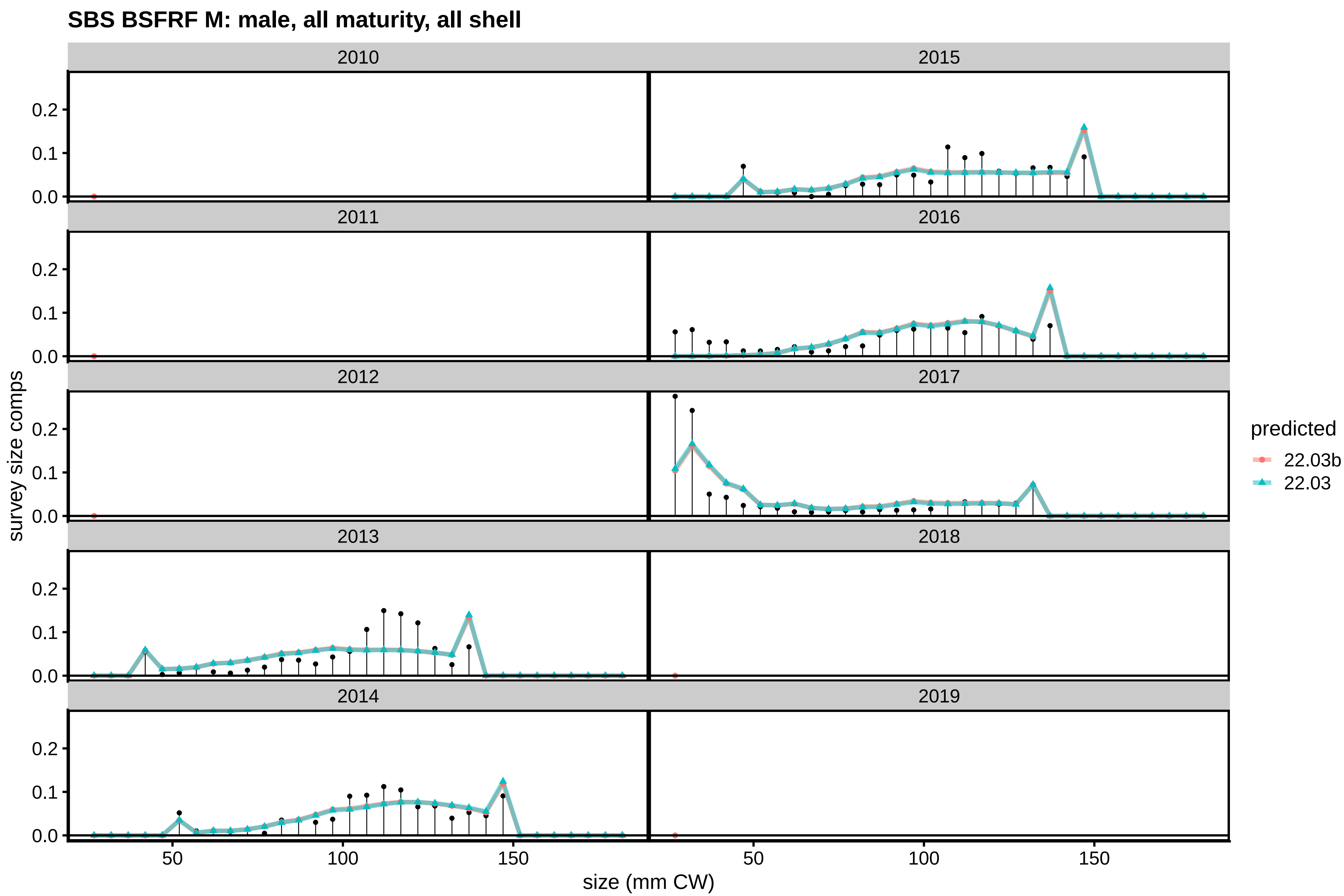

Figure 124. Fits to survey size compositions in the SBS BSFRF M survey. Preferred model is 22.03b.

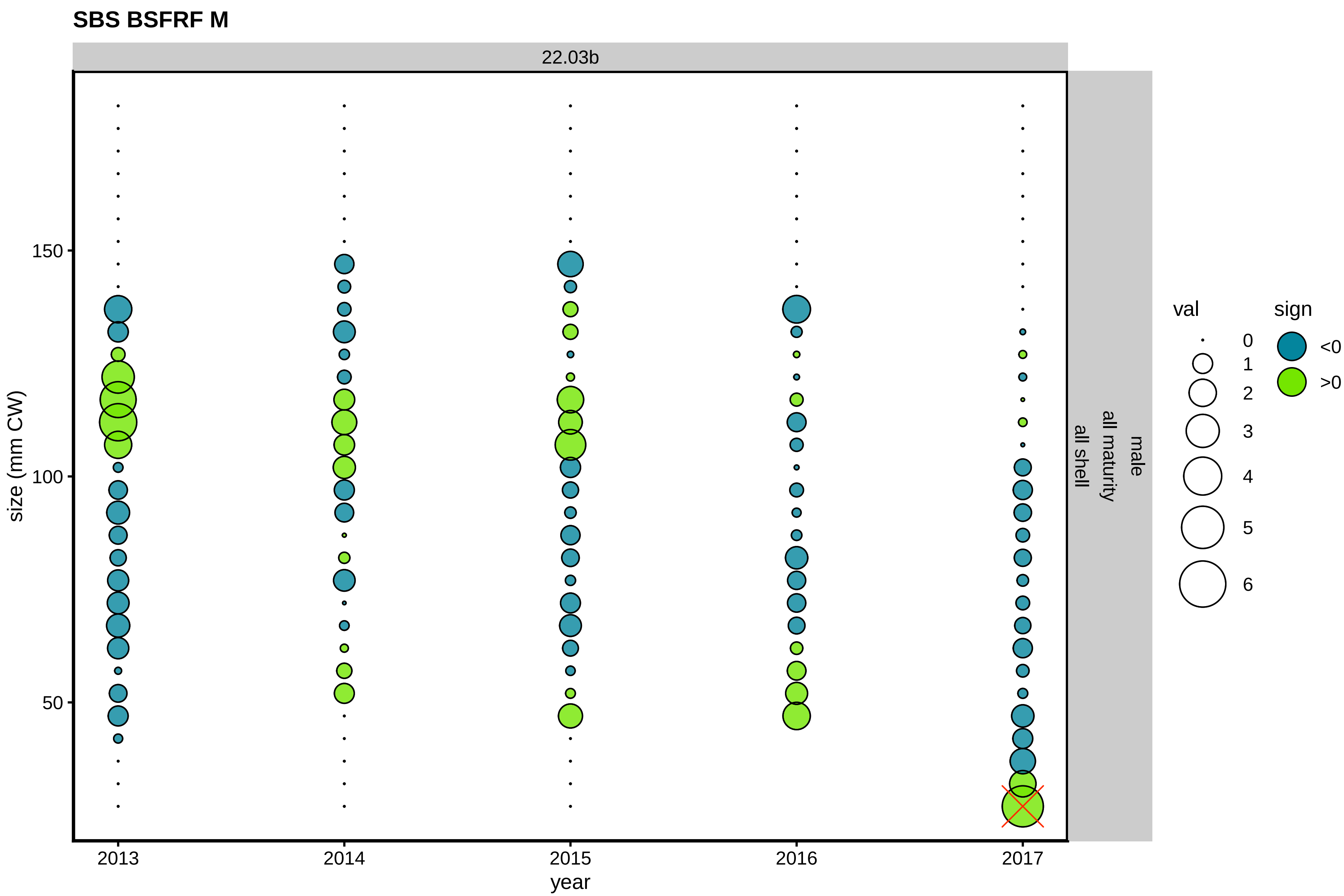

Figure 125. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

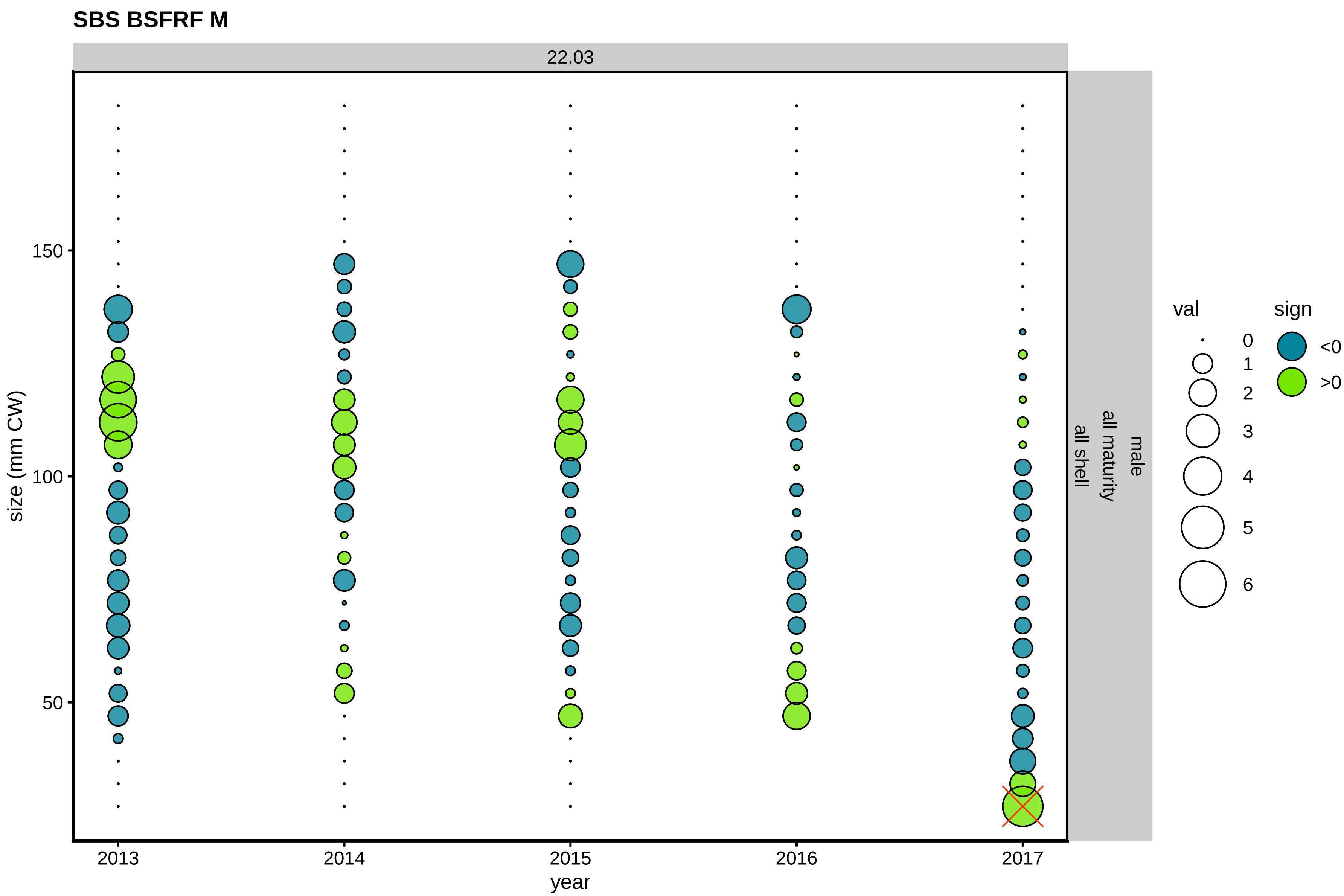

Figure 126. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

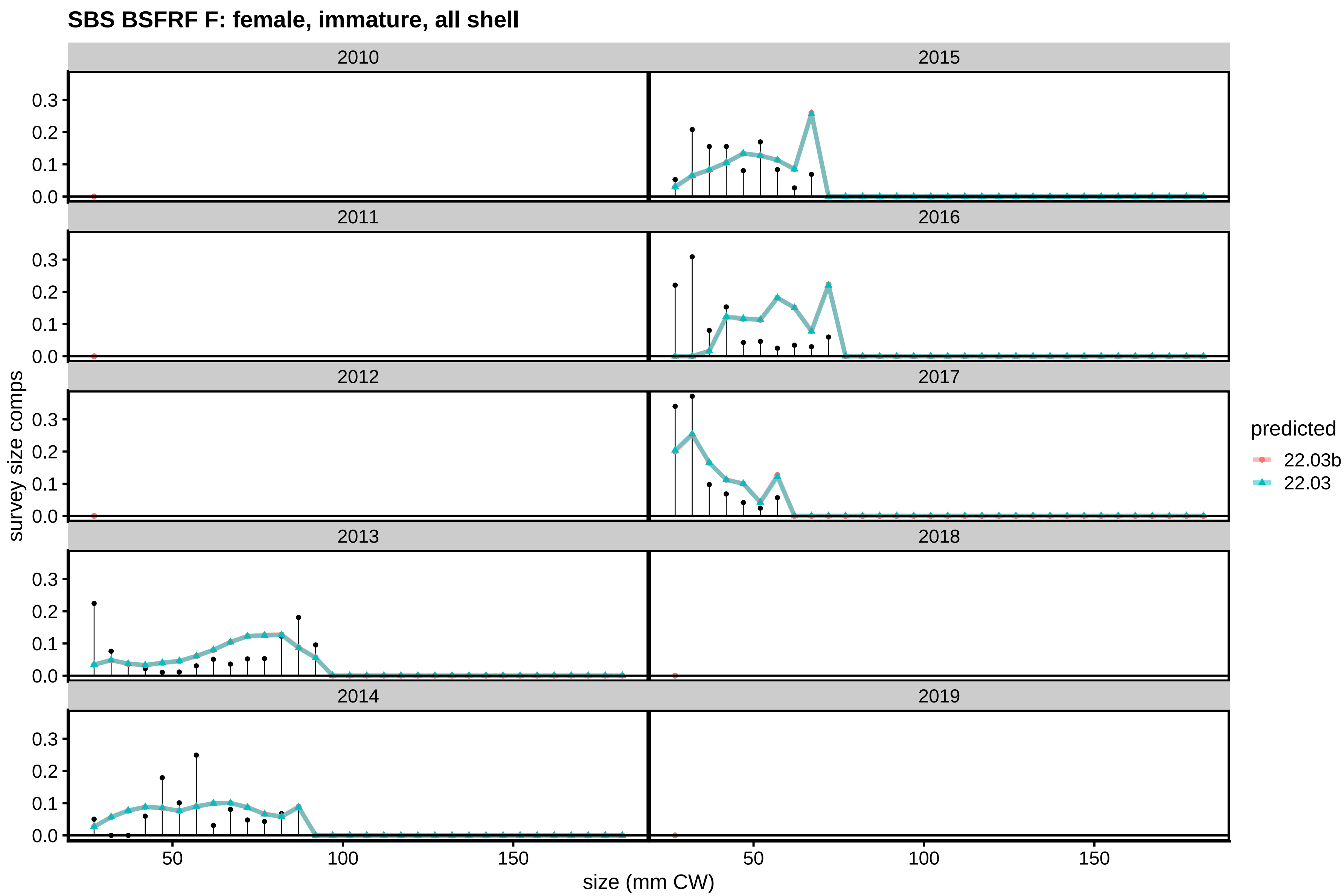

Figure 127. Fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03b.

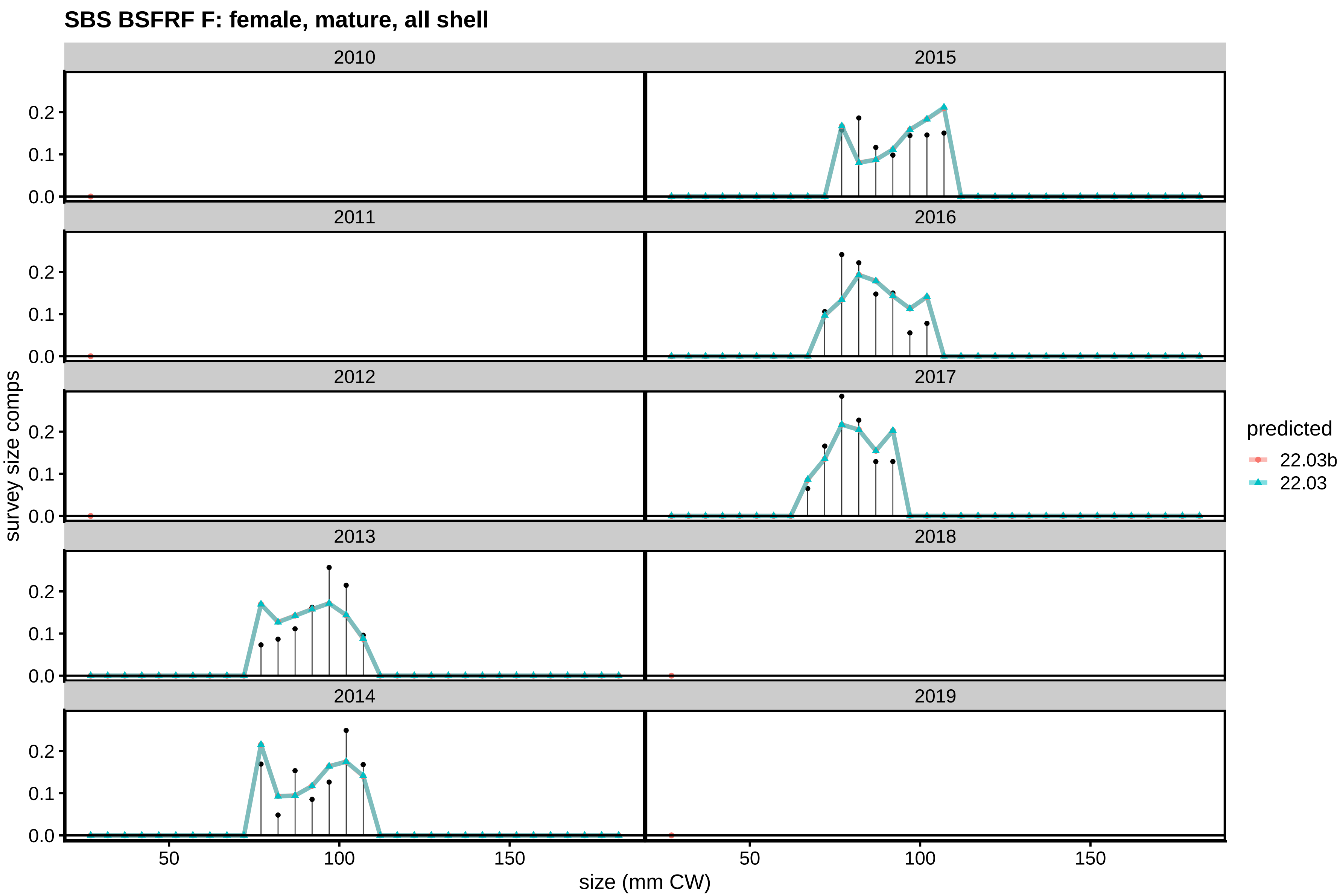

Figure 128. Fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03b.

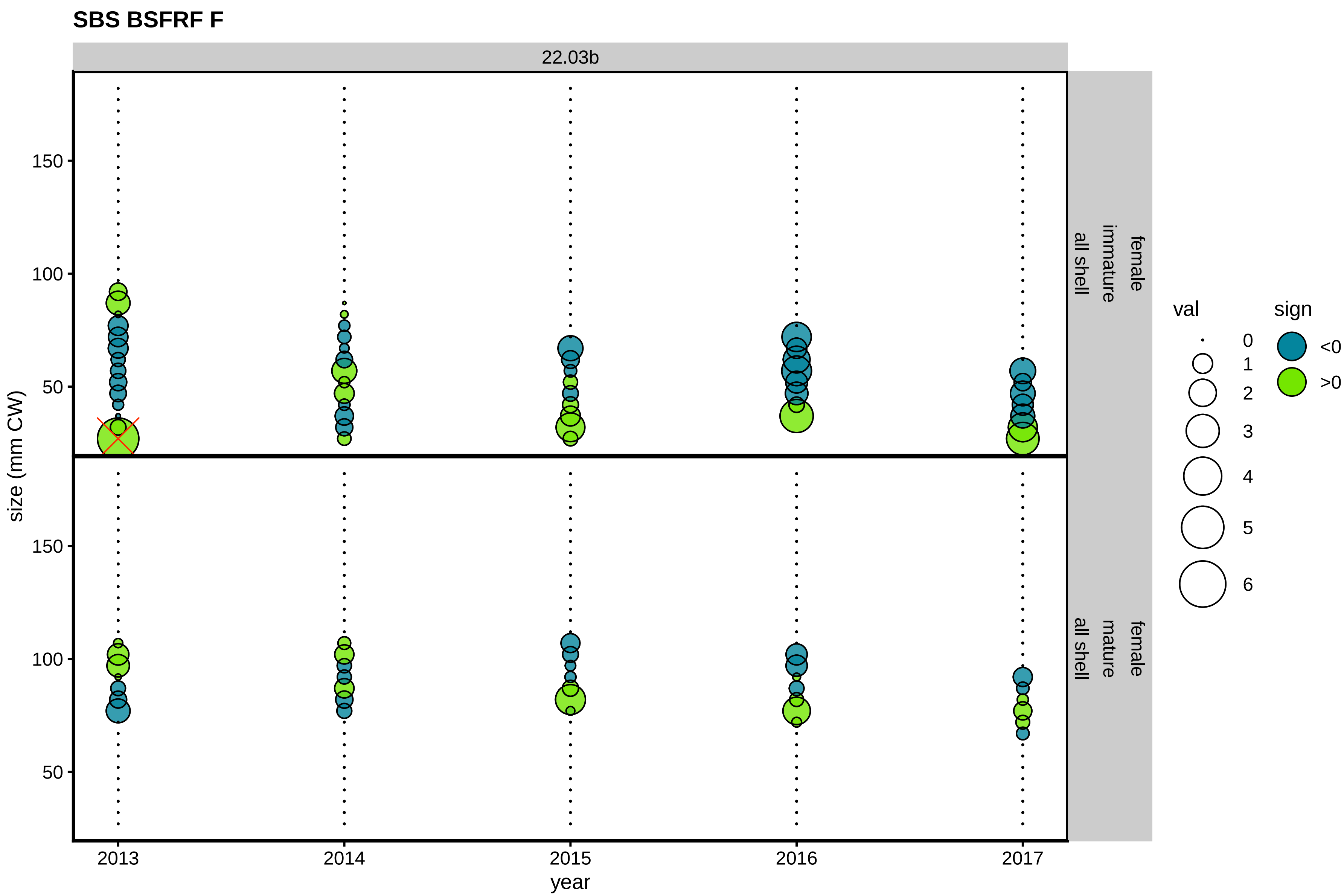

Figure 129. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

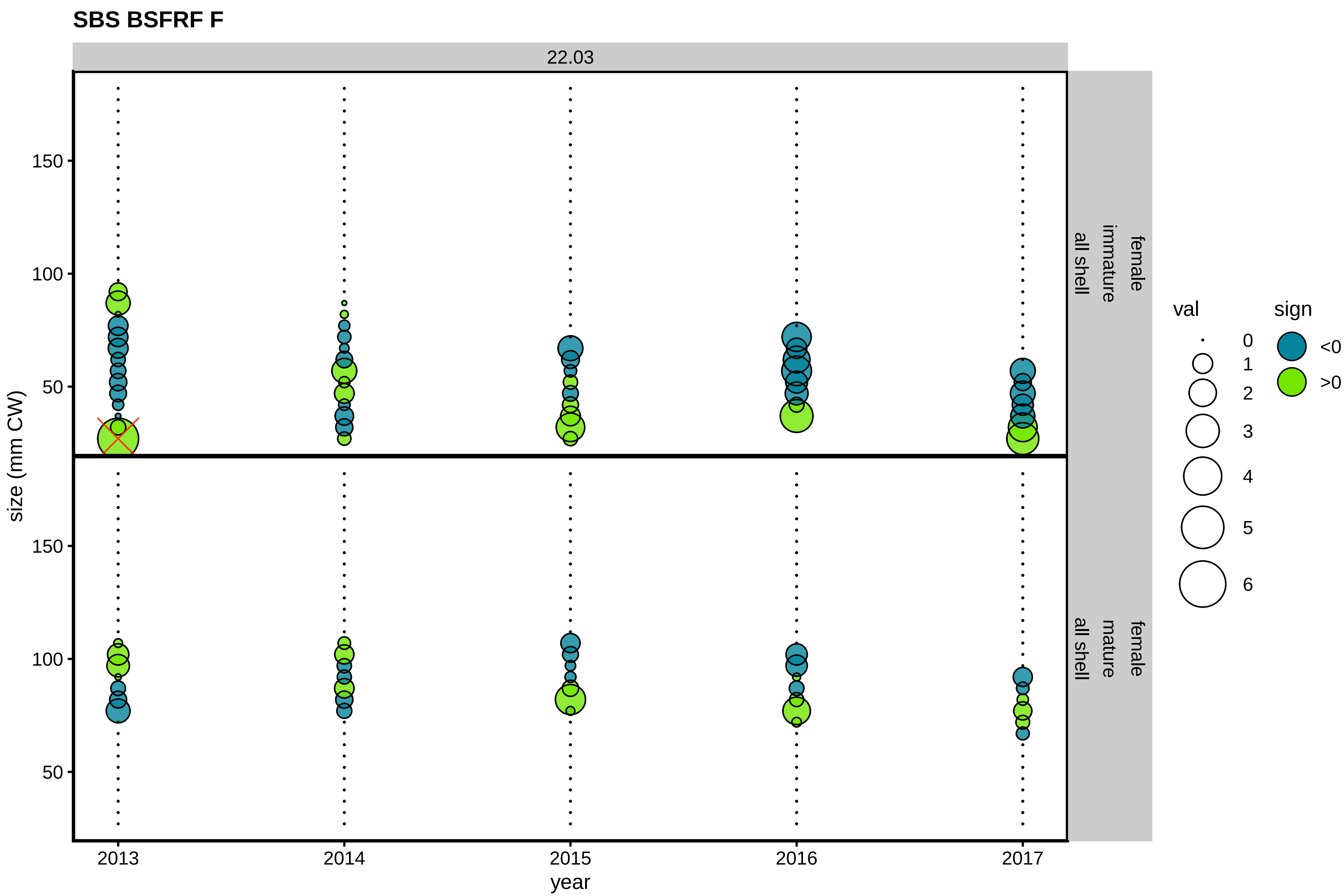

Figure 130. Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03b.

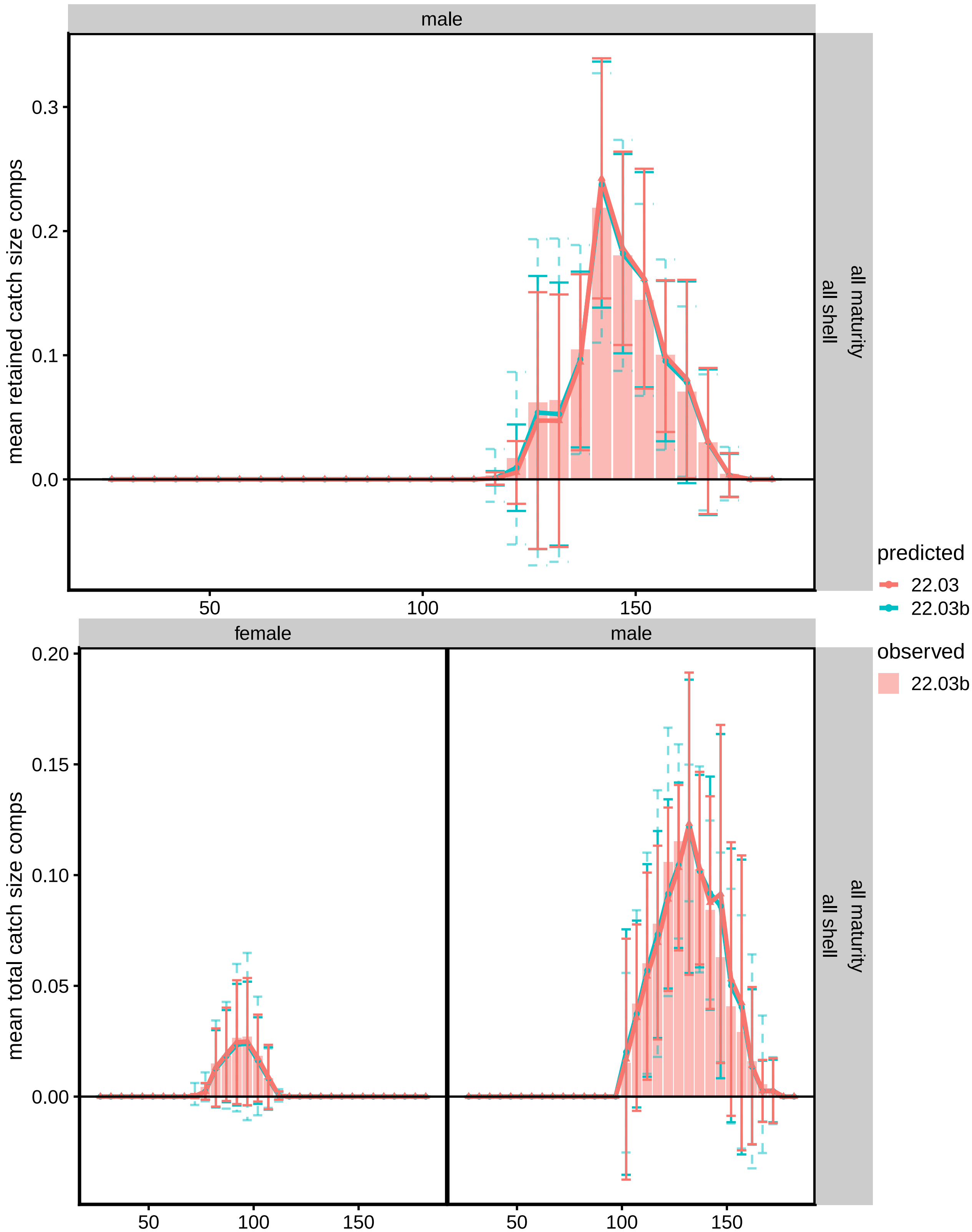

Figure 131. Fits to directed fishery mean size compositions. Upper plot: retained catch; lower plot: total catch. Model 22.03b is the preferred model.

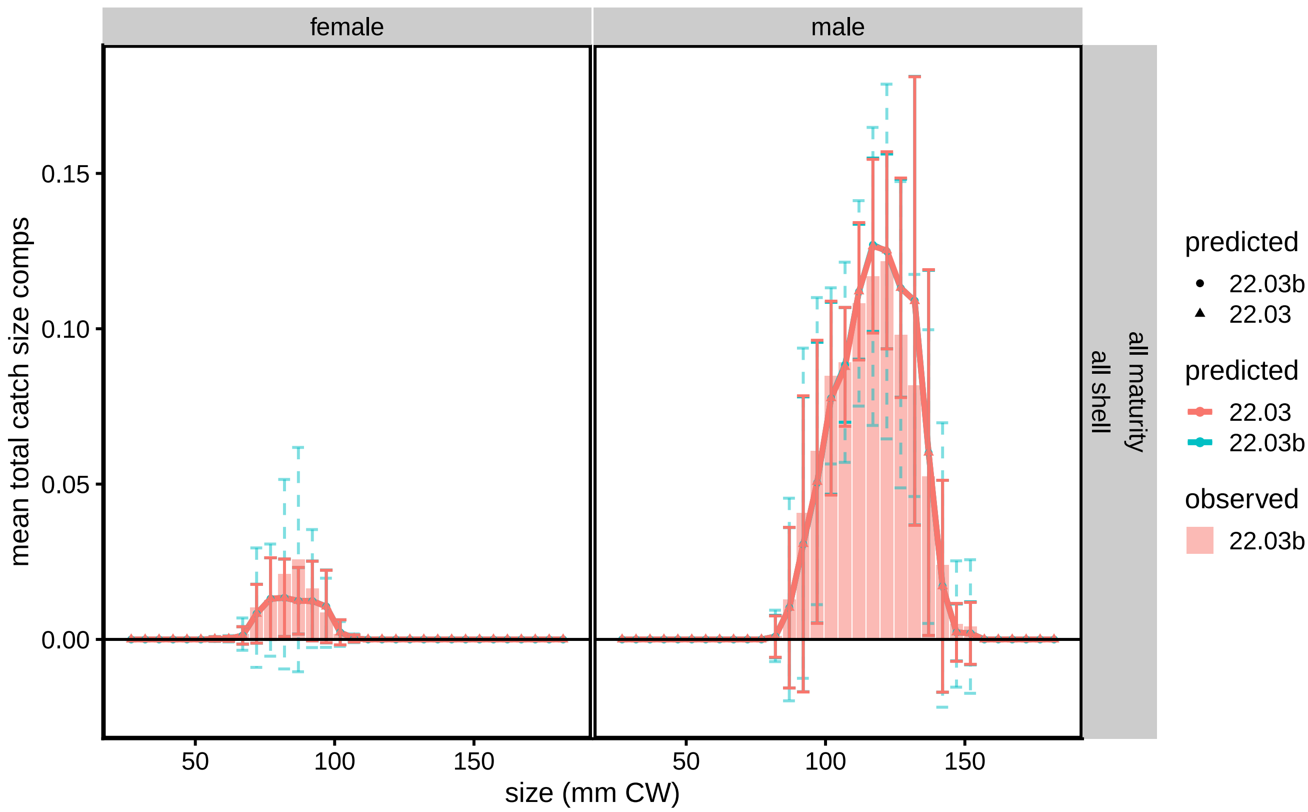

Figure 132. Fits to mean bycatch size compositions from the snow crab fishery. Model 22.03b is the preferred model.

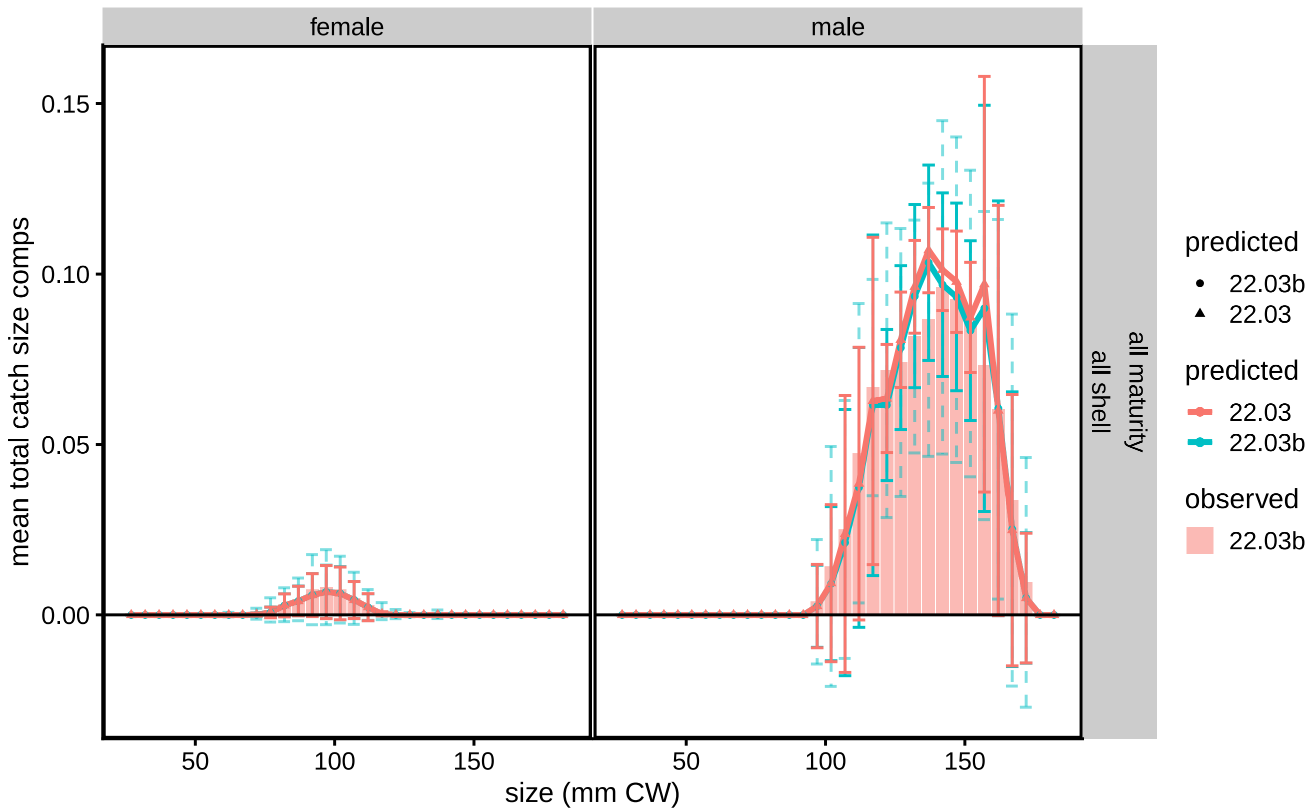

Figure 133. Fits to mean bycatch size compositions from the BBRKC fishery. Model 22.03 is the preferred model.

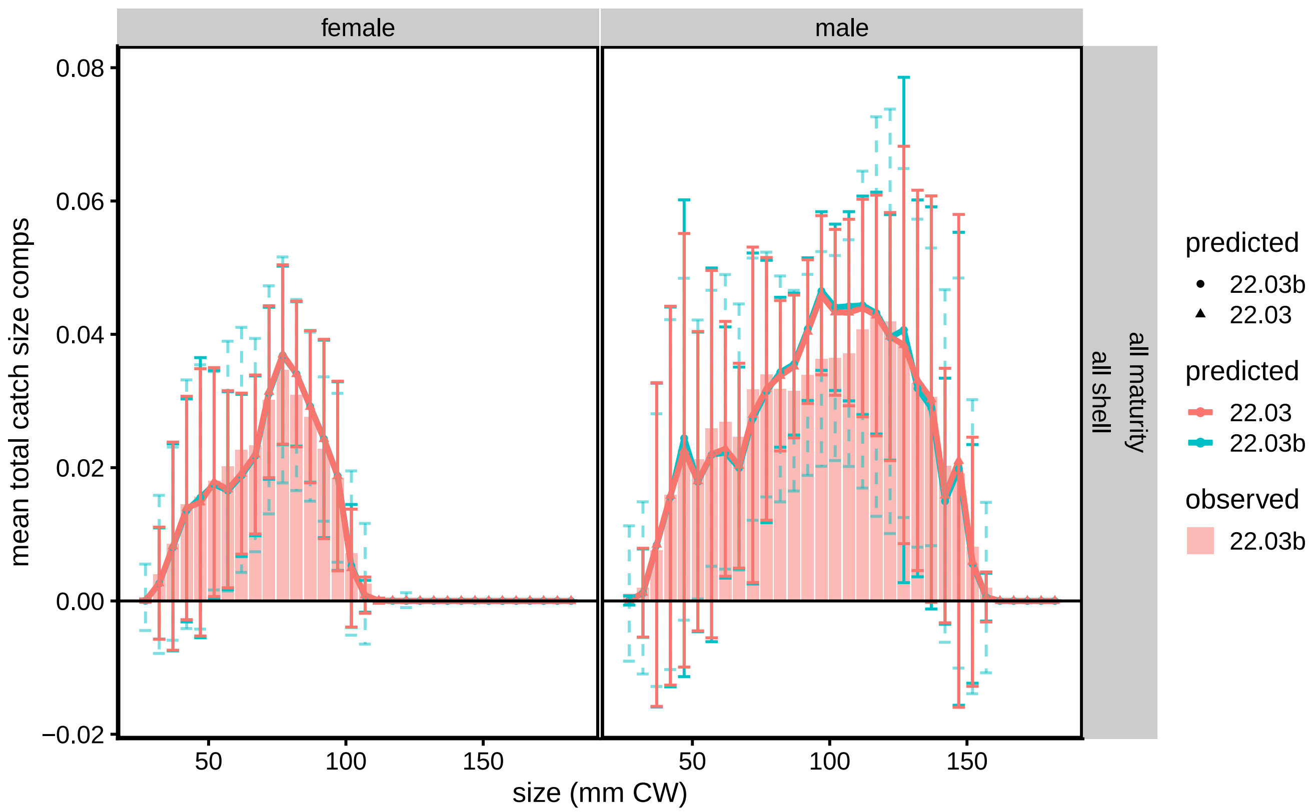

Figure 134. Fits to mean bycatch size compositions from the groundfish fisheries. The total catch size compositions were normalized similarly for all model scenarios. Model 22.03b is the preferred model.

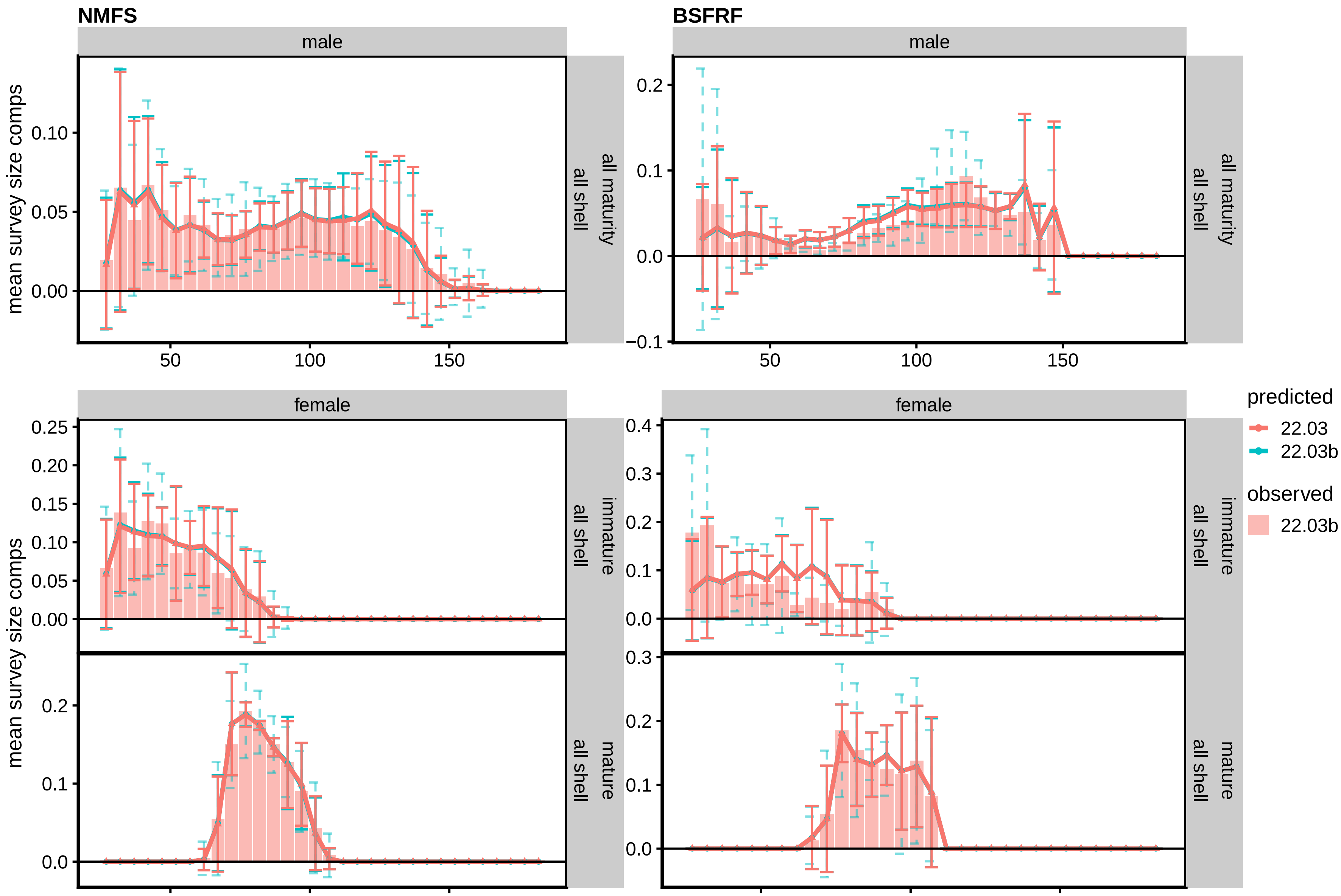

Figure 135. Fits to mean survey size compositions from the NMFS EBS (left column) and BSFRF SBS (right column) surveys. The total catch size compositions were normalized similarly for all model scenarios. Model 22.03b is the preferred model.

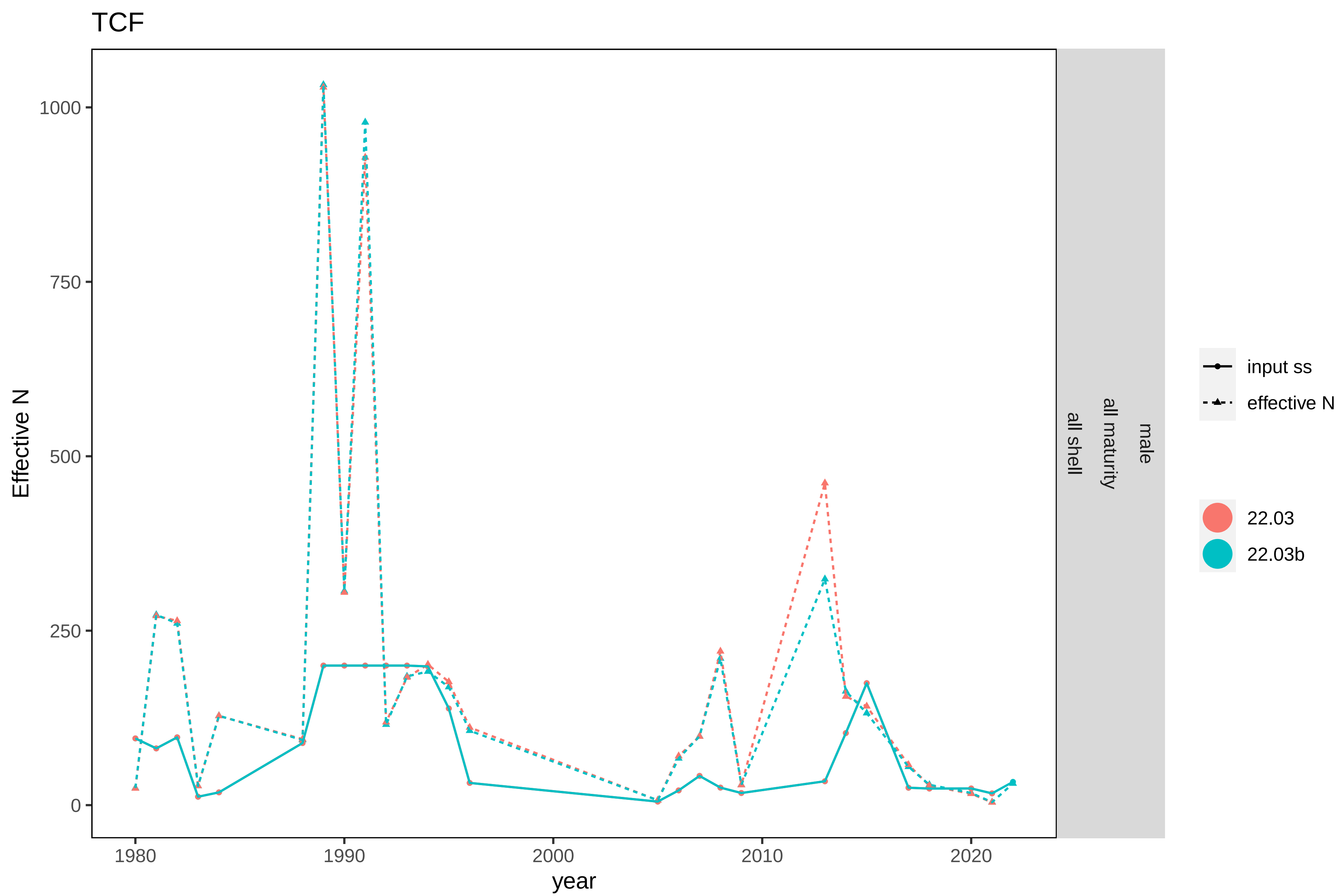

Figure 136. Effective sample sizes compared with input sample sizes for retained catch data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are constrained to a maximum of 200. Model 22.03 is the preferred model.

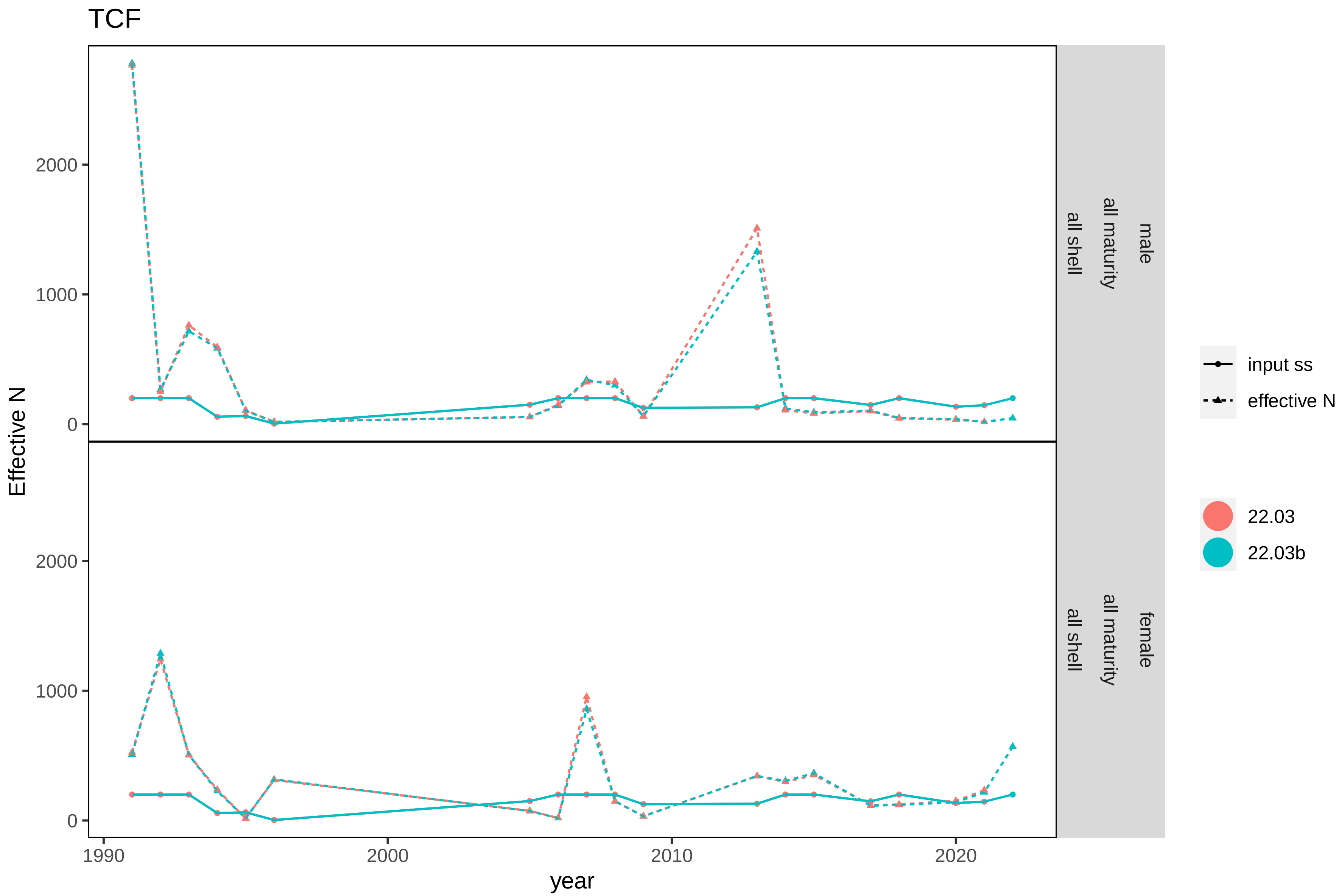

Figure 137. Effective sample sizes compared with input sample sizes for total catch data from the TCF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03b is the preferred model.

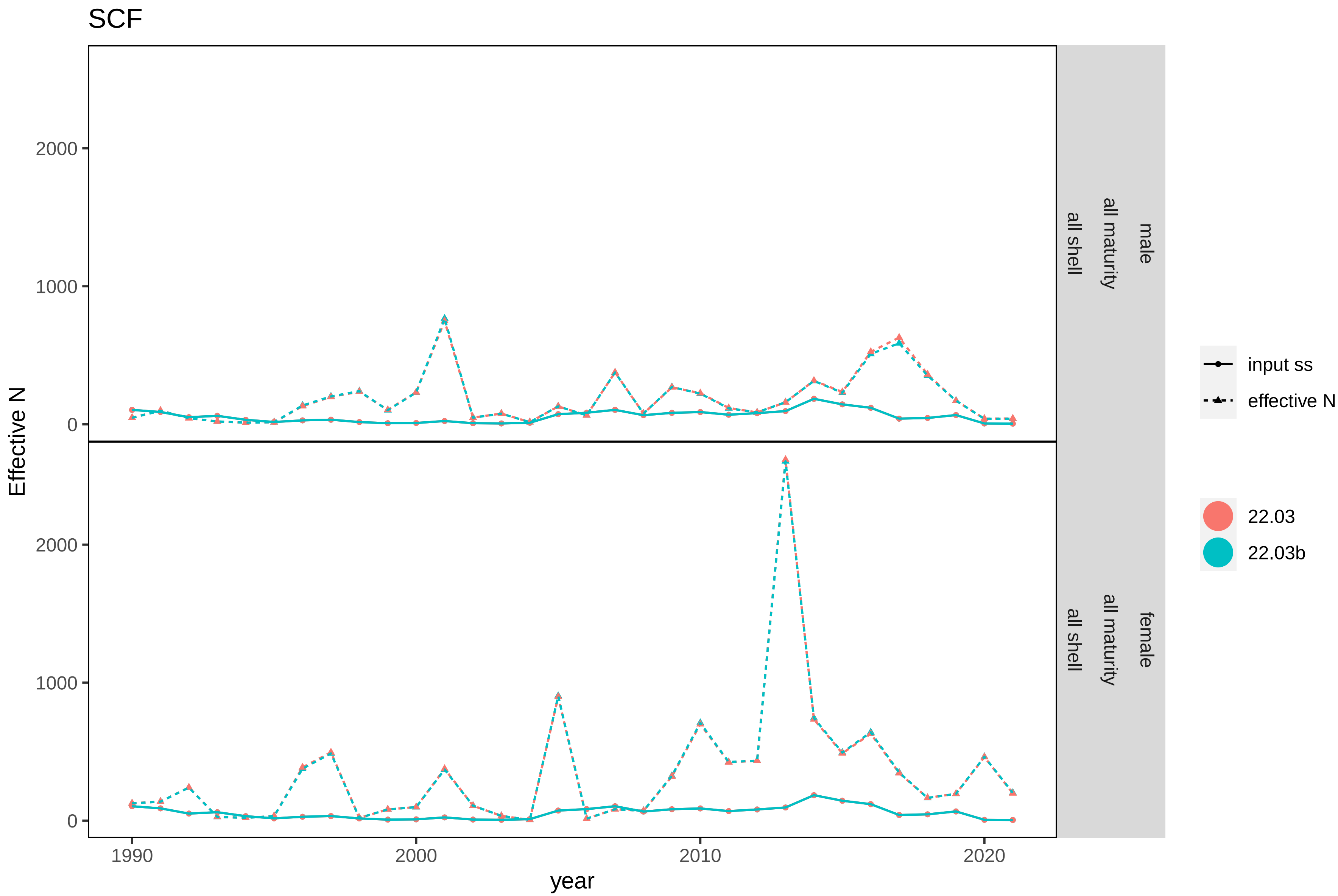

Figure 138. Effective sample sizes compared with input sample sizes for total catch data from the SCF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03b is the preferred model.

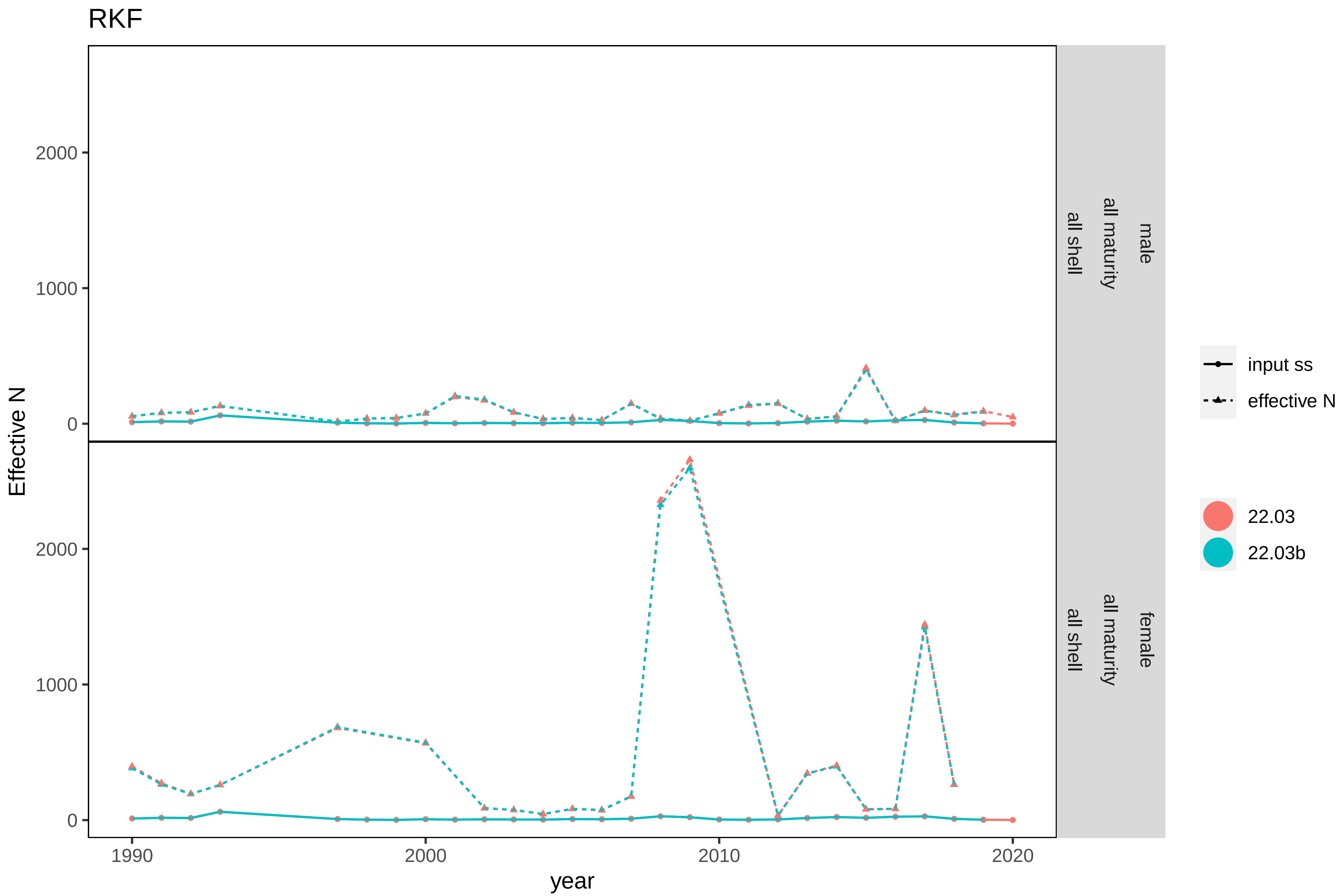

Figure 139. Effective sample sizes compared with input sample sizes for total catch data from the RKF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03b is the preferred model.

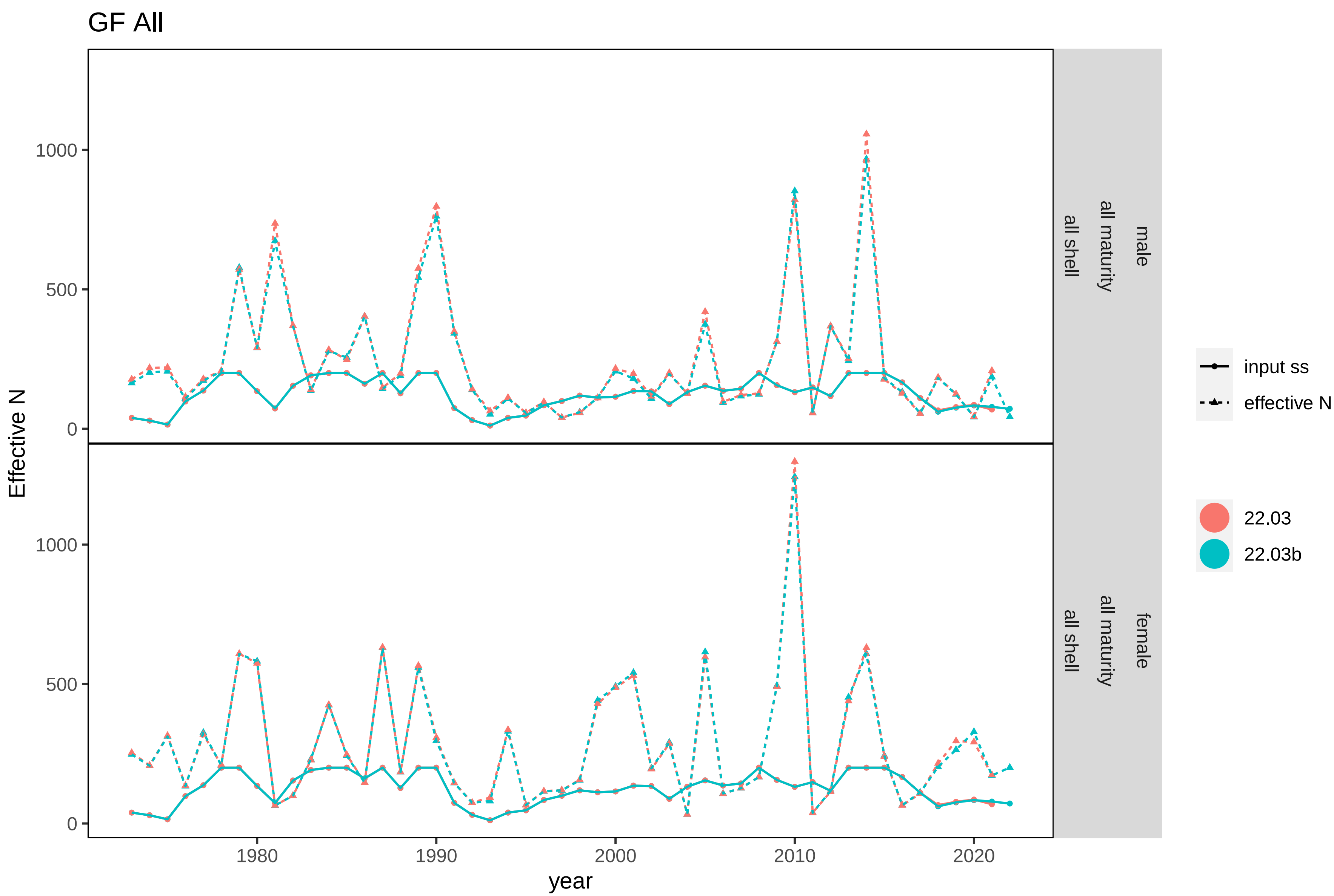

Figure 140. Effective sample sizes compared with input sample sizes for total catch data from the GF All fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03b is the preferred model.

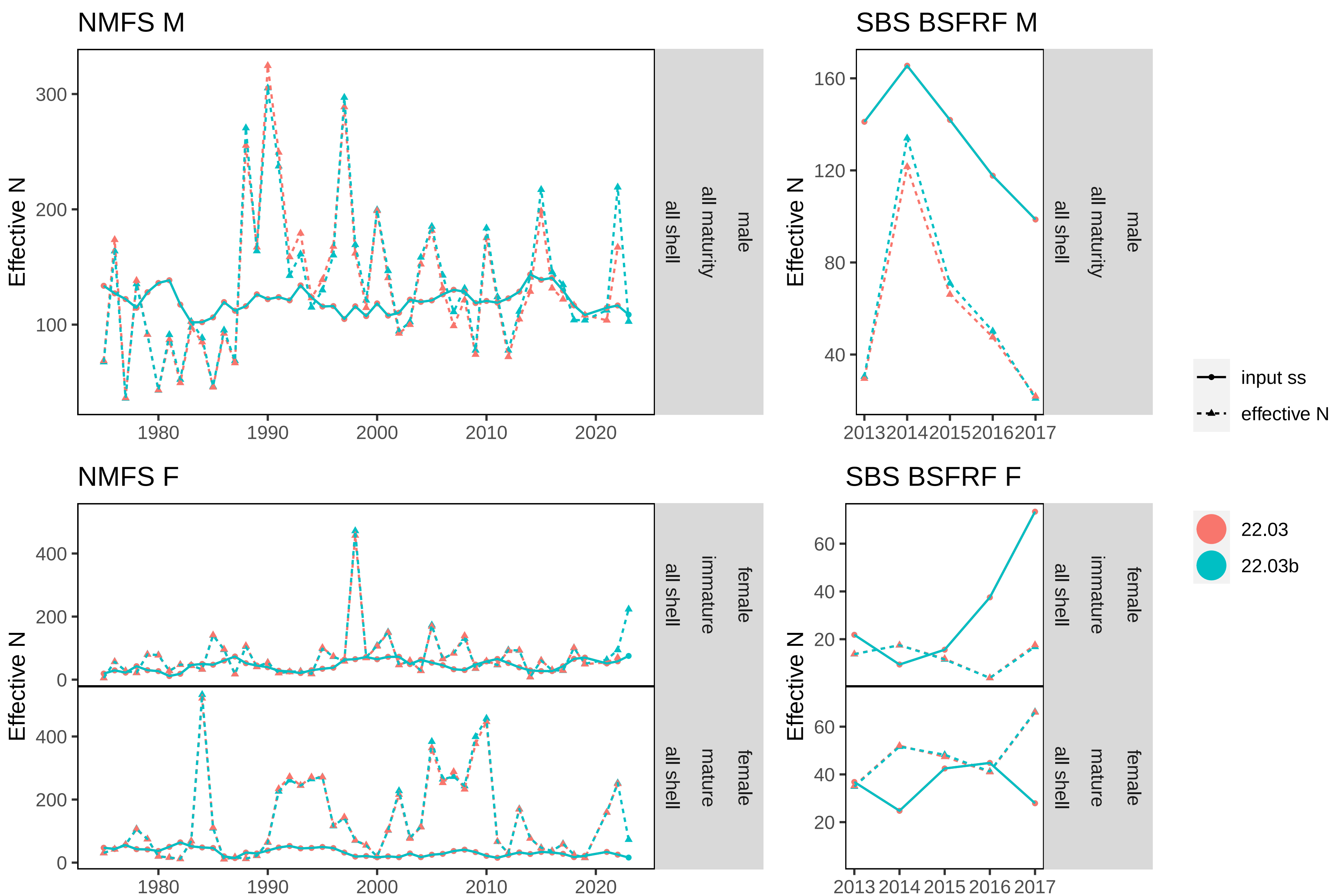

Figure 141. Effective sample sizes compared with input sample sizes for survey data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03b is the preferred model.

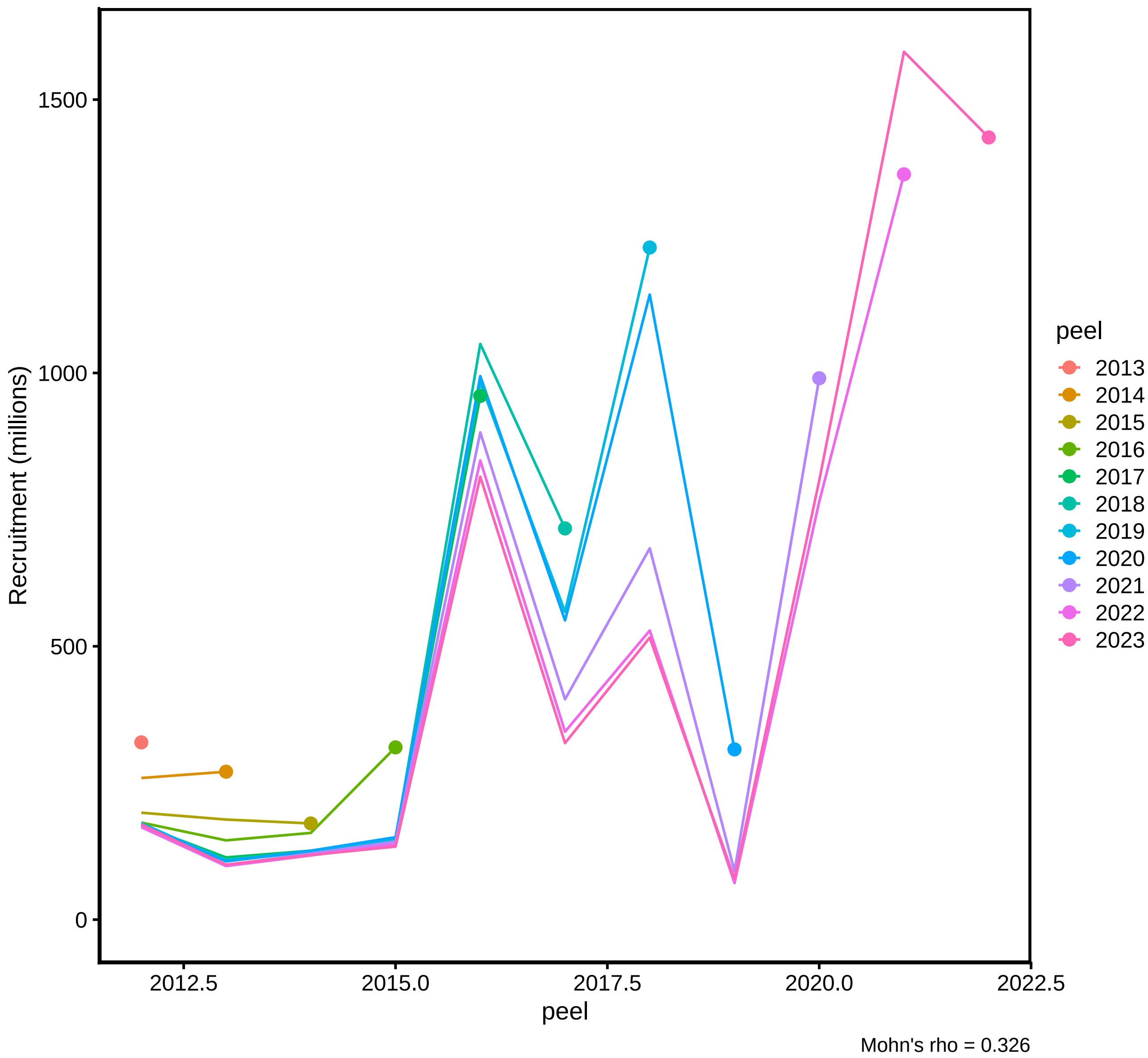

Figure 142. Retrospective analysis for recruitment time series, with Mohn's Rho value (0.326).

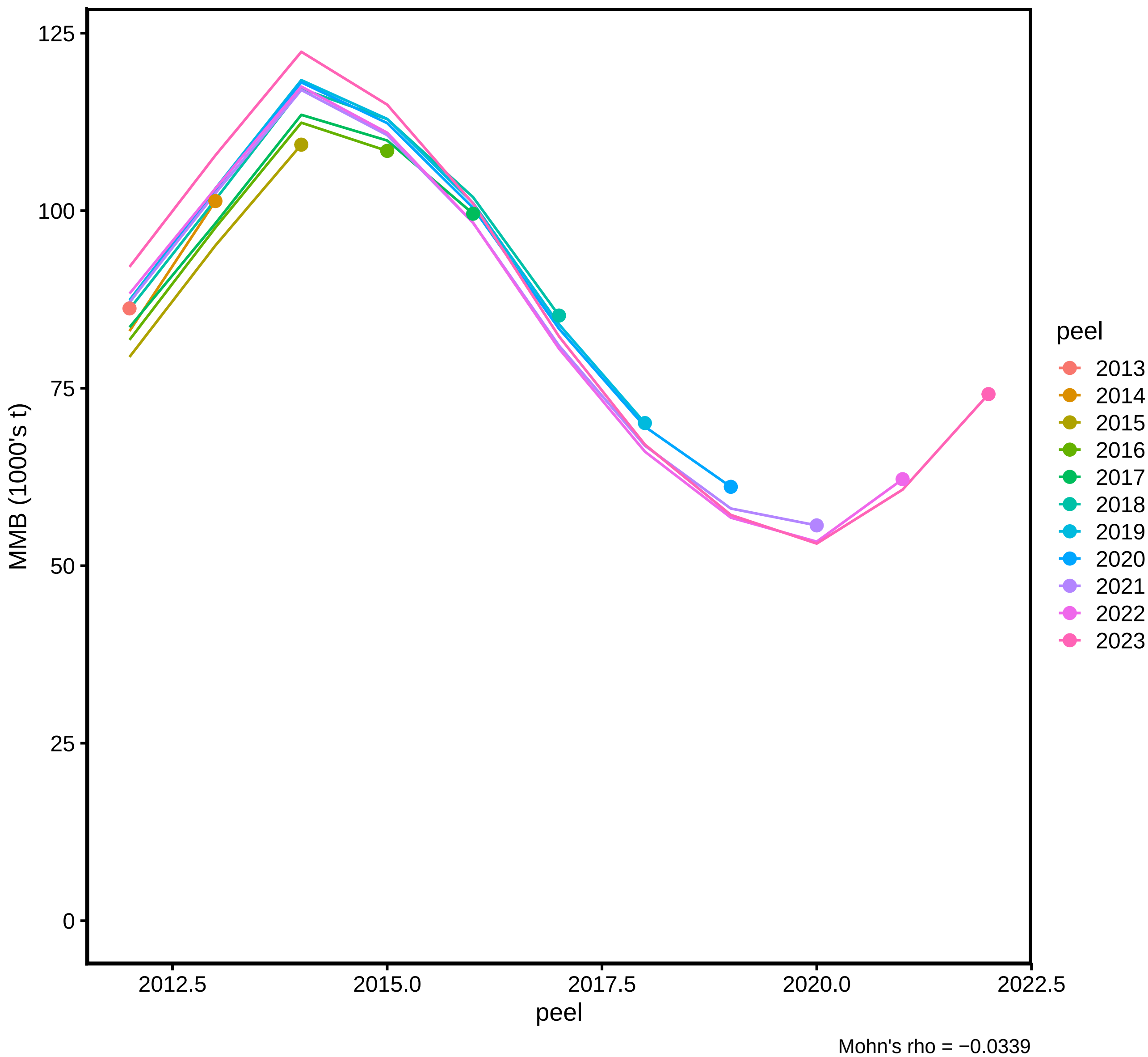

Figure 143. Retrospective analysis for mature male biomass time series, with Mohn's Rho value (-0.0339).

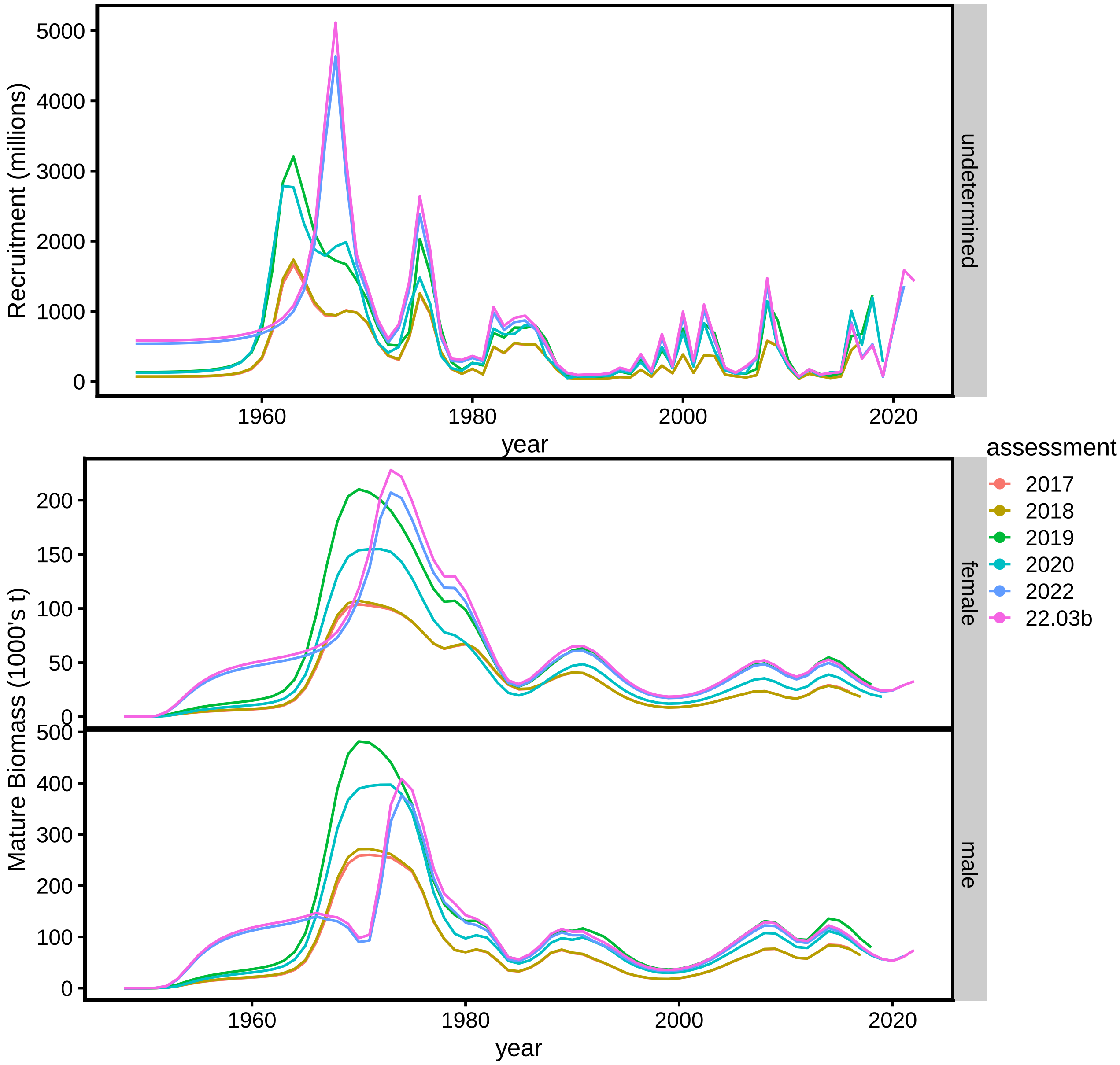

Figure 144. Comparison of the preferred model with results from previous assessments (full model time period).Model 22.03b is the preferred model for this assessment.

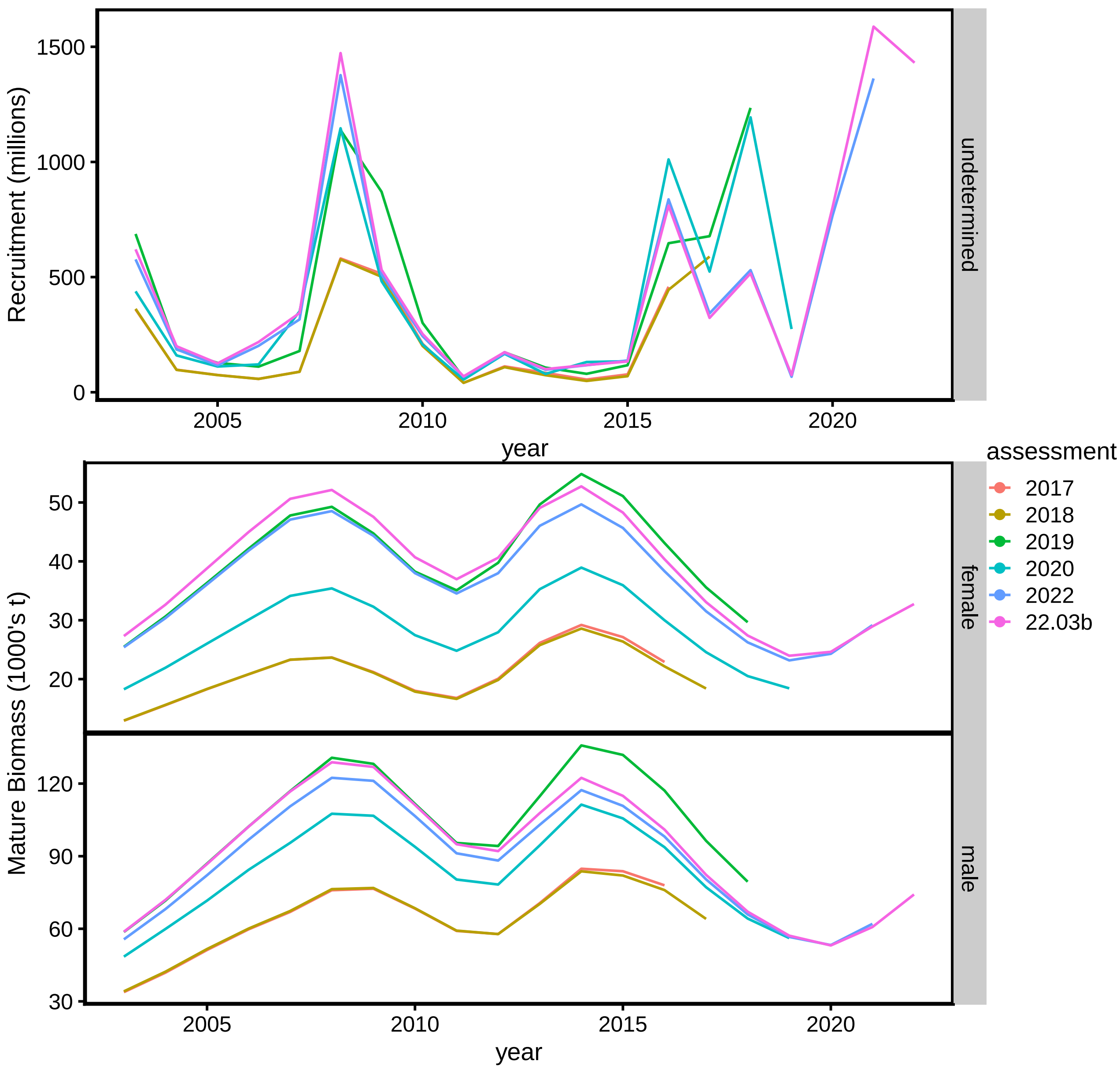

Figure 145. Comparison of the preferred model with results from previous assessments (last 20 years).Model 22.03b is the preferred model.

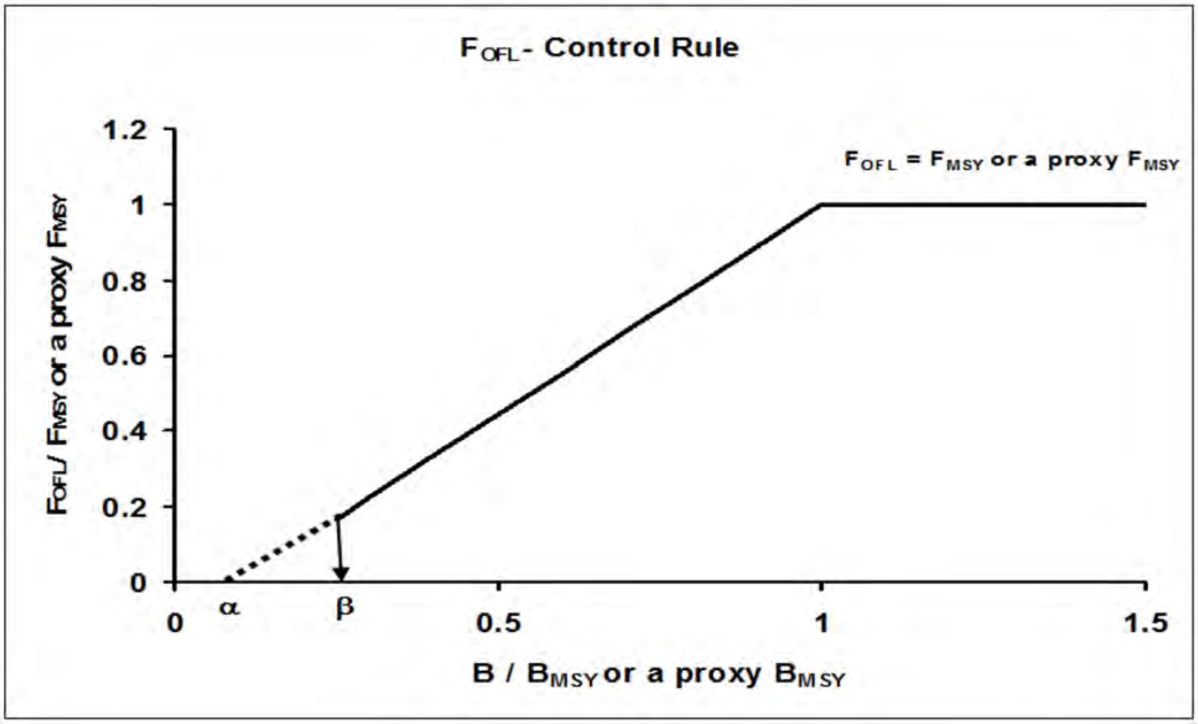

Figure 146. The F_{OFL} control rule.

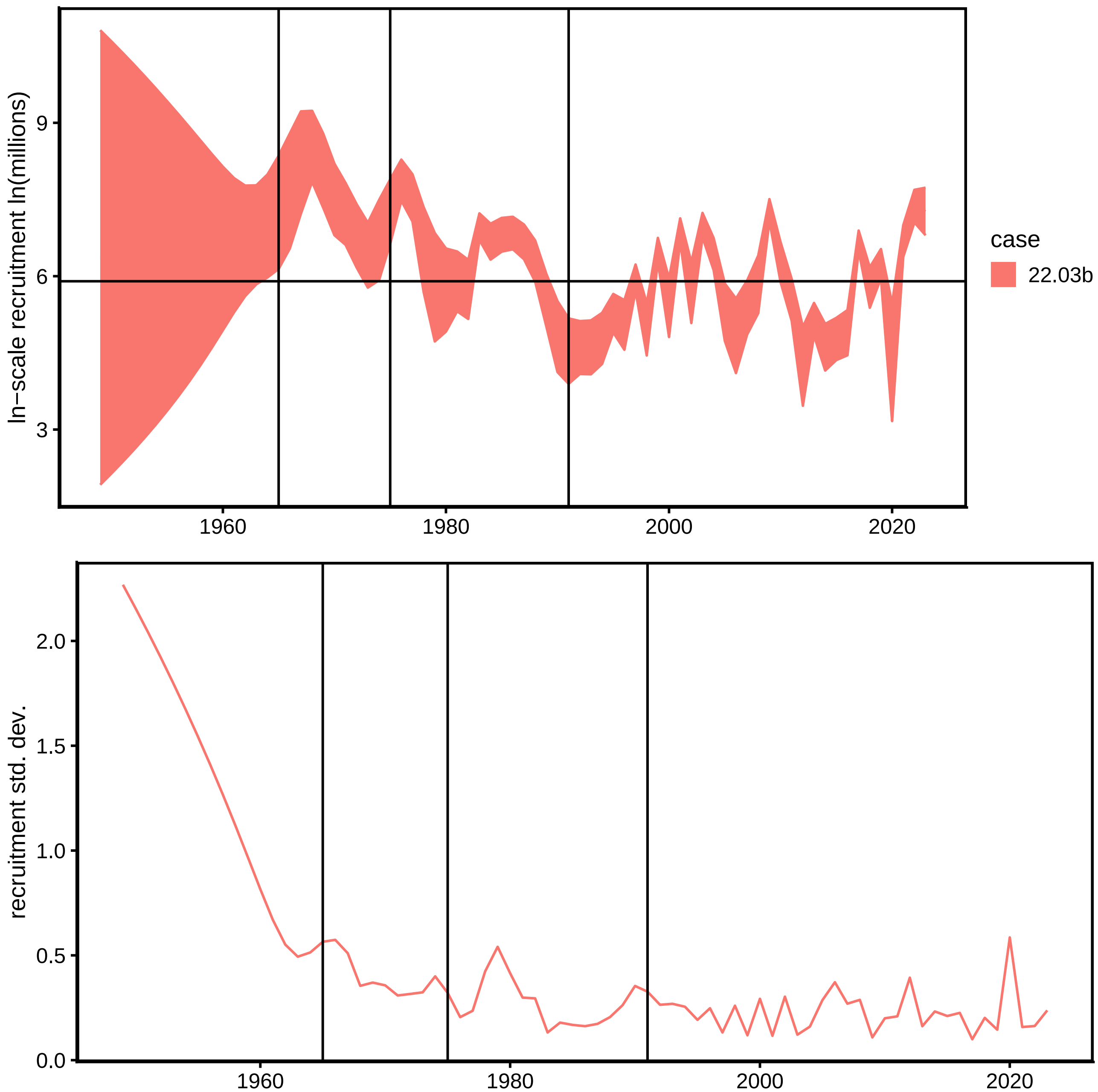

Figure 147. Upper plot: Time series of the estimated ln-scale recruitment, with 95% confidence intervals from the author's preferred model 22.03b. Lower plot: time series of the estimated standard deviation for the ln-scale mean recruitment parameter from the author's preferred model 22.03b. Vertical lines indicate 1965, 1975, and 1991.

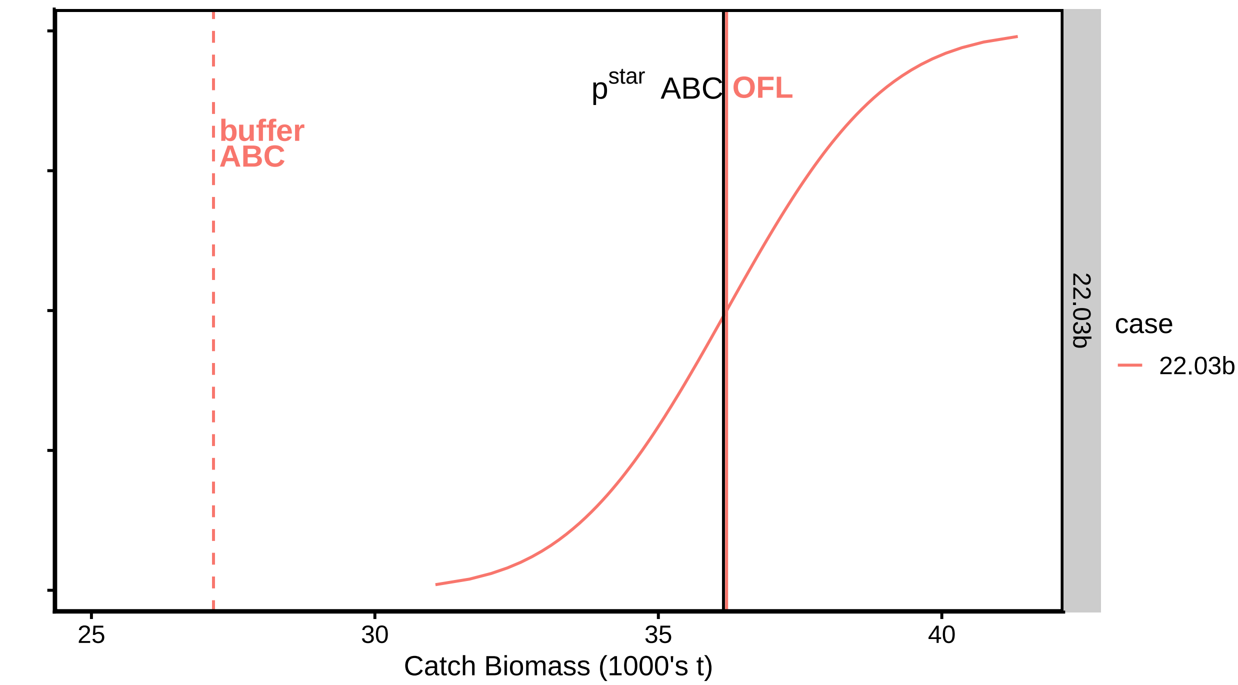

Figure 148. OFL and ABCs for the author's preferred model, 22.03b

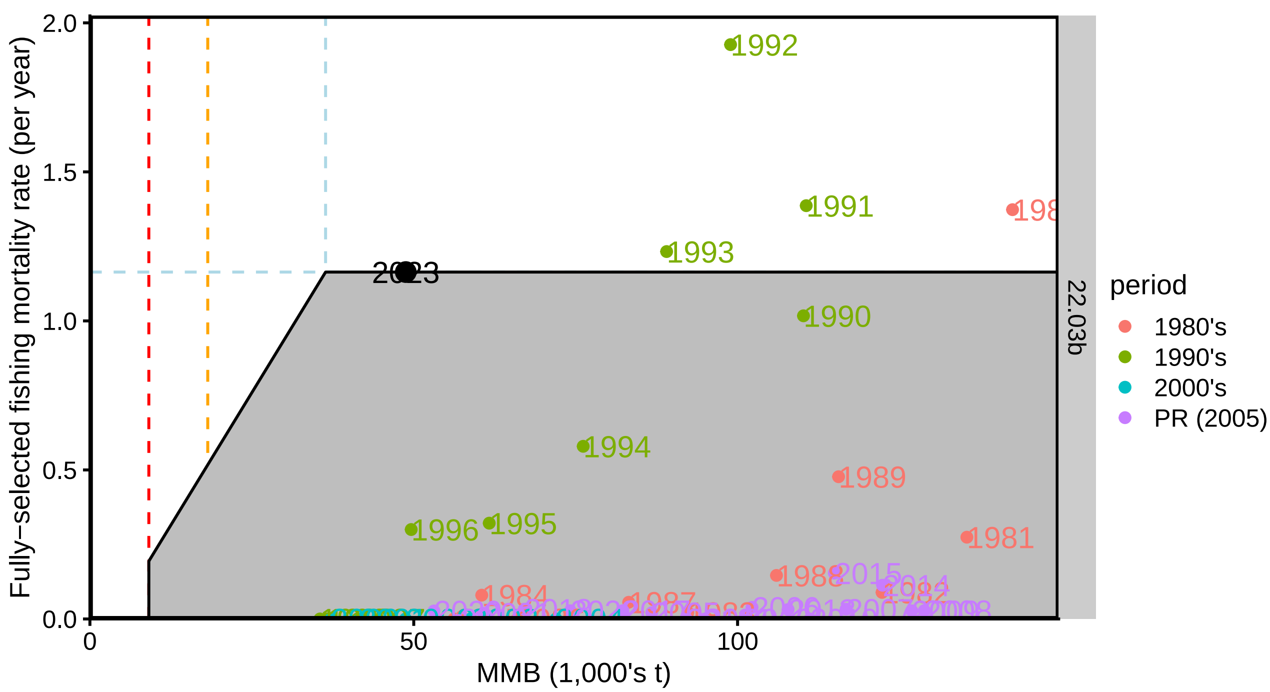

Figure 149. Quad plot for the author's preferred model, 22.03b. Estimated values are shown starting in 1980. The value for 2023 assumes the OFL is taken in the upcoming fishing season. Colors refer to different time periods (PR: post-rationalization). Vertical dashed lines indicate: red–β; orange–MSST; blue–B_{MSY}. Horizontal dashed line indicates F_{MSY}.

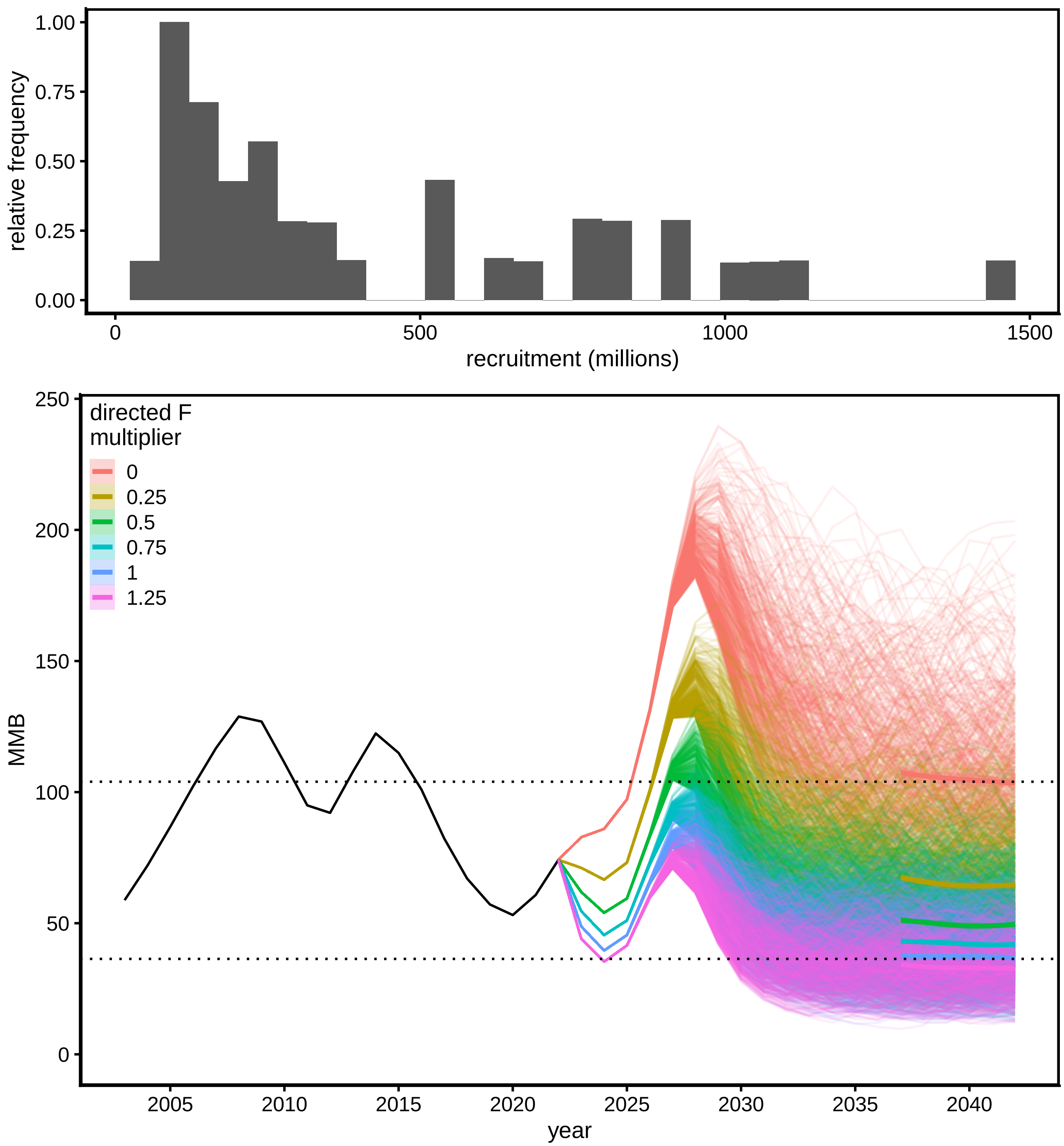

Figure 150. Multi-year projections using the preferred model, 22.03b under a range of directed F multipliers using randomly-resampled recruitment values. Upper plot: histogram of randomly-resampled recruitments. Lower plot: projected MMB trajectories under different F scenarios (colored lines); black line: ML estimate of MMB time series up to 2022/23 upper dotted line: expected mean unfished MMB (B_{100}), lower dotted line: $B_{MSY} = B_{35}$, thick colored lines at righthand side: scenario-specific annual means (last 5 years).

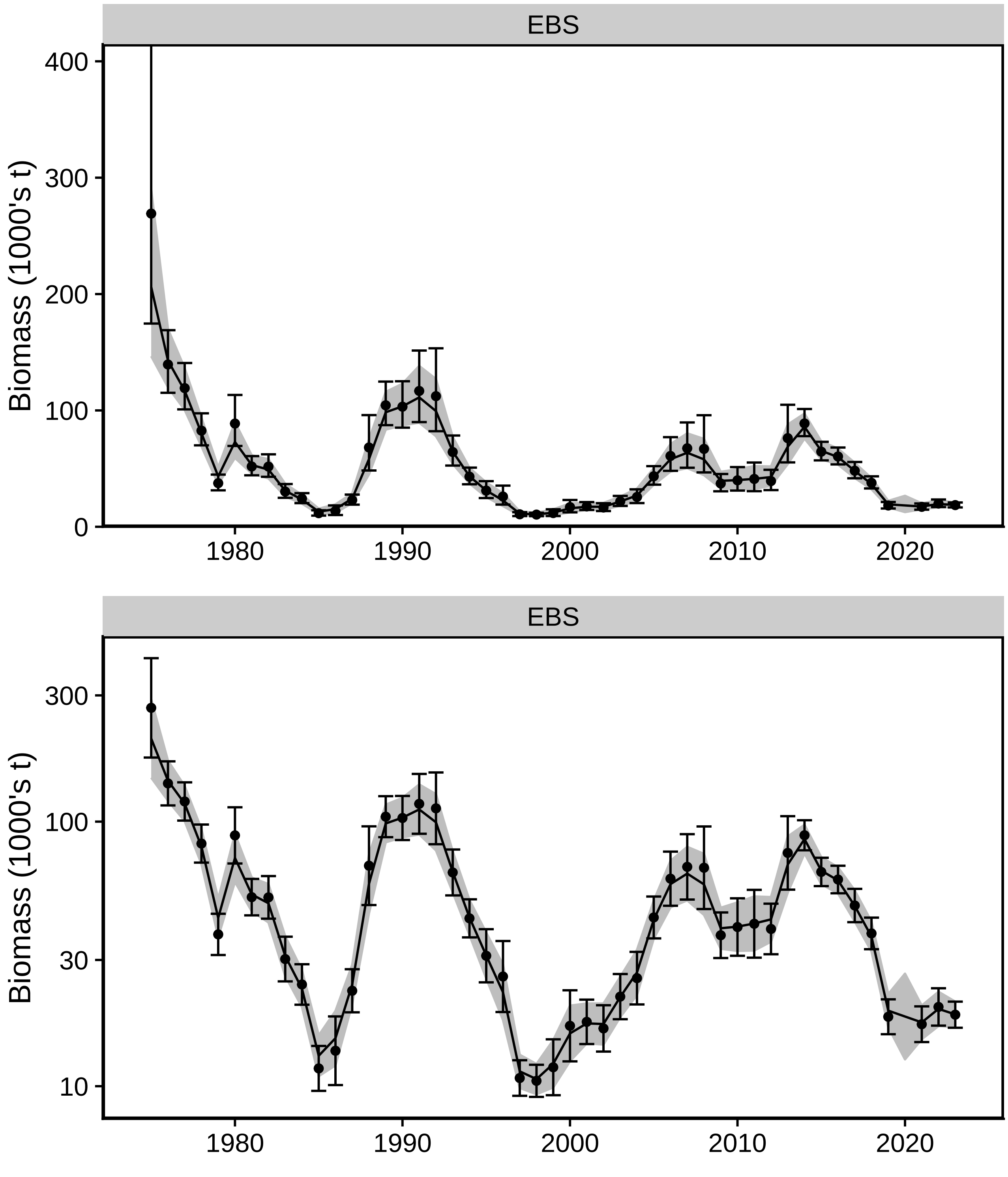

Figure 151. Estimated time series for vulnerable male biomass from the NMFS EBS shelf survey: 1) design based estimates (circles) and 80% lognormal confidence intervals (vertical bars); 2) random walk model-estimated time series (line) and 80% confidence intervals (shading). Upper plot: y-axis on arithmetic scale; lower plot: y-axis on log-scale.

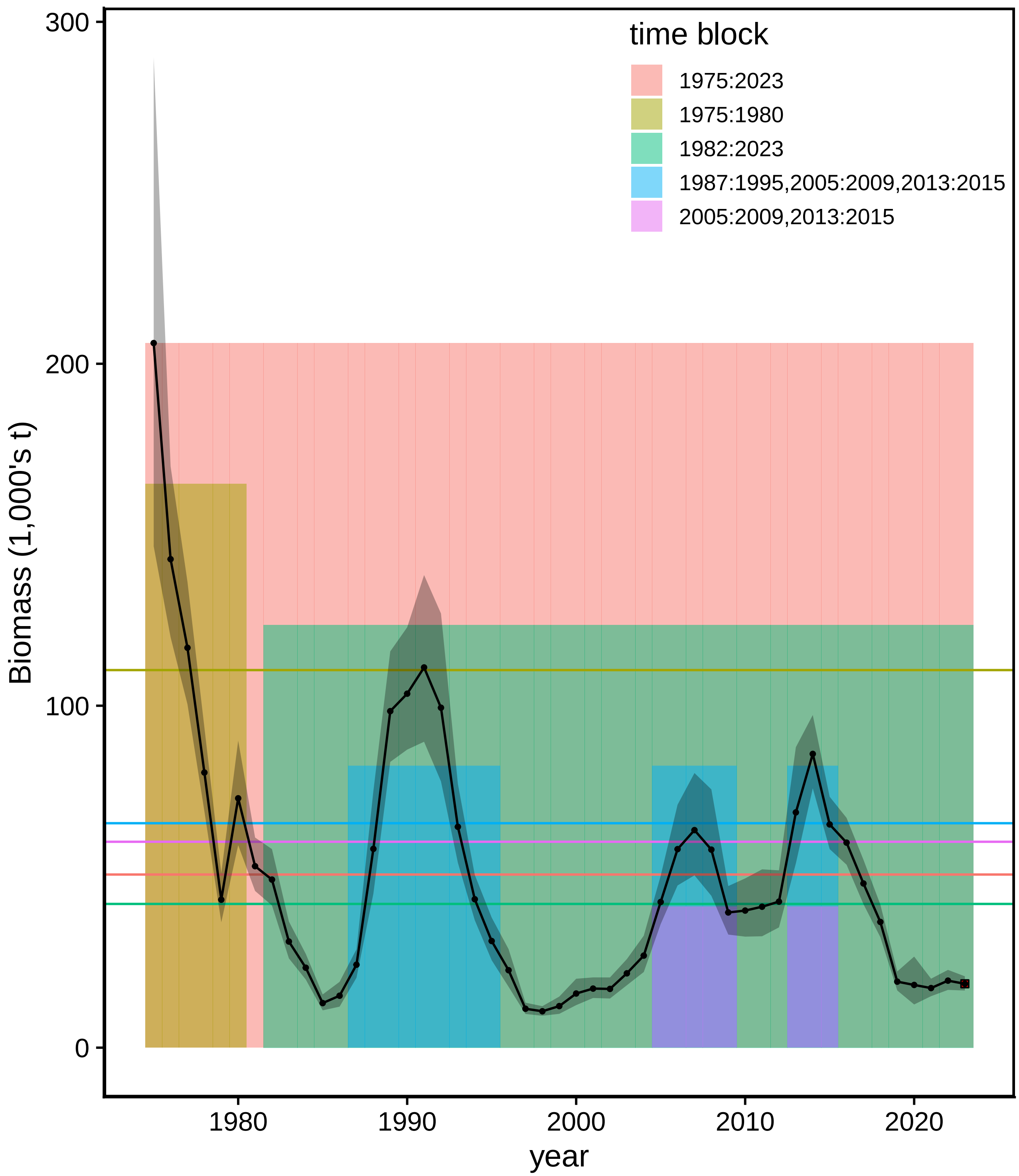

Figure 152. B_{MSY} proxies for different averaging time blocks. REMA-estimated vulnerable male biomass time series: black line and points (estimates), grey shading (80% confidence intervals). Colored rectangles indicate averaging time periods. Colored horizontal colored lines indicate resulting B_{MSY} proxy value.