2022 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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Executive Summary

1. *Stock: species/area*

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

2. *Catches: trends and current levels.*

Legal-sized male Tanner crab are caught and retained in the directed (male-only) Tanner crab fishery in the EBS. The NPFMC annually determines the overfishing limit (OFL) and acceptable biological catch (ABC) levels for Tanner crab in the EBS, while the Alaska Department of Fish and Game (ADFG) determines total allowable catches (TACs) 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 adopted by its Board of Fisheries. The OFL and ABC apply to "total catch mortality", which includes estimated bycatch mortality on discarded males and females in all fisheries that capture Tanner crab as well as retained catch.The TAC applies to retained catch only, 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, in the groundfish fisheries and, to a very minor extent, in the scallop fishery. In order to account for mortality of discarded crab, handling mortality rates are assumed to be 32.1% for Tanner crab discarded in the crab fisheries, 50% for Tanner crab in the groundfish fisheries using fixed gear, and 80% for Tanner crab discarded in the groundfish fisheries to account 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) in accordance with its harvest strategy. Prior to the 2010/11 closure, the retained catch averaged 0.766 thousands t per year between 2005/06-2009/10 and total catch mortality averaged 1.94 thousands t. In 2012, NMFS declared the stock was overfished.

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 the State's harvest strategy for Tanner crab. 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 2,271 t. Since then, the stock has remained above its Minimum Stock Size Threshold (MSST) and has not been considered overfished by federal standards. OFLs have ranged from ~21,000 t to ~31,000 t while ABCs have ranged from ~17,000 t to ~25,000 t; neither have constrained fishery TACs. However, the directed fishery has been closed by ADFG based on its harvest strategies in 6 out of 9 years in the eastern region (i.e., all years following the 2015/16 season) and 2 out of 9 years (2016/17 and 2019/20) in the western region based on criteria incorporating minimum 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 (~12,000 t) but has been less than (~2,000 t) since then.

For 2021/22, the eastern region was closed to directed fishing (TAC=0) while TAC in the western region was set at 499 t; the OFL was 27.17 thousand t and the ABC was 21.74 t. Retained catch was 494.25 t and total fishing mortality was 783.19 t.

3. *Stock biomass: trends and current levels relative to virgin or historic levels*

For EBS Tanner crab, spawning stock biomass is expressed as mature male biomass (MMB) at the time of mating (mid-February). From the author's preferred model (22.03), estimated MMB for 2021/22 was 62 thousands t. MMB has been on a declining trend since 2014/15 when it peaked at 117.3 thousand t, and it is approaching the very low levels seen in the mid-1990s to early 2000s (1993 to 2003 average: 37.6 thousand t).

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

From the author's preferred model (22.03), estimated total recruitment (the number of crab entering the population on July 1) has been increasing since 2020, when it reached its lowest level (67 million) since 2012. For 2022, estimated recruitment is 1,362 million crab. Average recruitment over the previous 10 years (2012-2021; not including 2022) is 313 million crab, which is ~13% less than the long-term (1982-2021) mean of 408 million crab.

5. *Management performance*

Historical status and catch specifications for eastern Bering Sea Tanner crab, with 2022/23 values based on the author's recommended model, 22.03, and MLE results are given in the following tables:

Table. Management quantities (in 1,000s t) based on the author's preferred model, 22.03. TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	15.15	64.09	1.13	1.13	2.37	25.42	20.33
2018/19	20.54	82.61	1.11	1.11	1.90	20.87	16.70
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	NA	47.58	NA	NA	NA	32.81	24.61

Table. Management quantities (in millions of pounds) based on the author's preferred model, 22.03. TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	33.40	95.49	2.50	2.50	5.22	56.03	44.83
2018/19	45.27	182.09	2.44	2.44	4.18	46.01	36.82
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	NA	104.88	NA	NA	NA	72.34	54.25

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

6. ***Basis for the 2022/23 OFL:***

Table. Basis for the OFL, based on the author's preferred model, 22.03. Biomnass units are in 1,000s t.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2017/18	3a	29.17	47.04	1.49	0.75	1982-2017	0.23
2018/19	3a	21.87	23.53	1.08	0.93	1982-2018	0.23
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	34.73	47.58	1.37	1.17	1982-2021	0.23

Table. Basis for the OFL, based on the author's preferred model, 22.03. Biomnass units are in millions of lbs.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2017/18	3a	64.30	103.70	1.49	0.75	1982-2017	0.23
2018/19	3a	48.21	51.87	1.08	0.93	1982-2018	0.23
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

Notes: Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year. Values are calculated from the assessment reviewed by the Crab Plan Team in 20XX of 20XX/(XX+1) or based on the author's preferred model for 2022/23. Values for natural mortality are nominal. Actual rates used in the assessment are estimated and may be different.

B_{MSY} for this stock is calculated to be 35 thousands t, so MSST is 17 thousands t. Because current MMB (62 thousands t) > MSST, the stock is not overfished. Model-estimated total catch mortality (retained + discard mortality in all fisheries, using a discard mortality rate of 0.321 for pot gear and 0.8 for trawl gear) was 0.783 thousands t, which was less than the OFL for 2021/22 (27 thousands t); consequently, overfishing did not occur.

The OFL for 2022/23, based on the author's preferred model (22.03), is 33 thousands t, which results in a projected MMB of 48 thousands t. The ABC_{max} for 2022/23, based on the p^* ABC, is 33 thousands t. In 2014, the 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 and overly-optimistic model estimates for recent survey biomass trends. Based on this buffer, the ABC would be 25 thousands t.

7. *Rebuilding analyses summary.*

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

A. Summary of Major Changes

1. *Changes (if any) to the management of the fishery.*

The SOA's harvest control rule (HCR) for setting TAC in the directed Tanner crab fisheries has undergone three revisions in the past 6 years (Daly et al., 2020). In 2015, the minimum preferred harvest size used to compute TAC for the area east of 166^oW 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^oW longitude. In 2017, the criteria used to determine mature female biomass (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 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 a requirement to close the fisheries when MFB fell below the 40% threshold; ADF&G, 2017; Daly et al., 2020). In March 2020, the harvest control rule was again changed 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; Shipley et al., 2021). The current HCR (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.

The directed Tanner crab fishery east of 166^{o}W longitude has been closed since 2016/17 because mature female Tanner crab biomass in the area has consistently failed to meet the criteria defined in the State's harvest strategy to open the fishery. The directed fishery west of 166^{o}W longitude was also closed in 2016/17 and 2019/20, but was prosecuted in 2017/18, 2018/19, and 2020/21. The directed fishery in the western area was open for 2021/22.

2. *Changes to the input data*

Changes to the input data to the assessment consist of:

- area-swept biomass and size compositions from the 2022 NMFS EBS shelf bottom trawl survey
- male maturity ogives from the 2022 NMFS survey based on chela height/carapace width data;
- new retained catch biomass and size compositions in the 2021/22 directed fishery;
- expanded total catch and bycatch biomass and size compositions for 2021/22 crab fishery observer sampling in the directed, snow crab, and Bristol Bay red king crab fisheries;
- expanded total bycatch biomass and size compositions for 2021/22 groundfish observer sampling.

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

Table. Data sources that have been updated for this assessment.

Description	Data types	Time frame	Notes	Source
NMFS EBS Bottom Trawl Survey	area-swept abundance, biomass	1975-2019, 2021-22	no 2020 survey	NMFS
	size compositions	1975-2019, 2021-22	no 2020 survey	
	male maturity data	2006+		
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)	2005/06-2021/22	East of W166 closed 2021/22	ADFG
	retained catch size compositions	2013/14-2021/22	East of W166 closed 2021/22	ADFG
	total catch (abundance, biomass)	1991/92-2021/22	East of W166 closed 2021/22	ADFG
	total catch size compositions	1991/92-2021/22	East of W166 closed 2021/22	ADFG
Snow Crab Fishery	historical effort	1978/79/1989/90	not updated	2018 assessment
	effort	1990/91-2021/22		ADFG
	total bycatch (abundance, biomass)	1990/91-2021/22		ADFG
	total bycatch size compositions	1990/91-2021/22		ADFG
Bristol Bay Red King Crab Fishery	historical effort	1953/54-1989/90	not updated	2018 assessment
	effort	1990/91-2021/22		ADFG
	total bycatch (abundance, biomass)	1990/91-2021/22		ADFG
	total bycatch size compositions	1990/91-2021/22		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)	1991/92-2021/22	now using AKRO algorithm for 2016/17+	NMFS/AKFIN
	total bycatch size compositions	1991/92-2021/22		

3. *Changes to the assessment methodology.*

The assessment model framework, TCSAM02, is described in detail in Appendix A. There have been a number of recent changes to the model structure as new capabilities have been developed and new data types have been added. The model accepted for the 2019 assessment, “19.03”, differed rather substantially from the 2017 and 2018 assessment models by:

- adding a likelihood component to fit annual male maturity ogives determined from chela height-to-carapace width ratios in the NMFS survey (the maturity ogives represent a new data source);
- eliminating fits to survey biomass and size composition data for male crab classified as mature/immature based on a maturity ogive determined outside the model; and
- instead fitting to time series of undifferentiated male survey biomass, abundance, and size compositions.

In addition, this model fit revised time series data for retained and total catch biomass since 1990/91 provided by ADFG for the directed Tanner crab, snow crab and Bristol Bay red king crab fisheries.

The model accepted for the 2020 assessment, “20.07”, built on 19.03 by incorporating BSFRF trawl survey data from its cooperative “side-by-side” (SBS) catch comparison studies with the NMFS EBS shelf bottom trawl survey in order to better fix the scale of the NMFS survey data. Empirical availability curves for the BSFRF surveys were determined outside the assessment model (Stockhausen, 2020; Appendix 3). These were used in the model to relate the BSFRF estimates of absolute abundance (over areas smaller than the NMFS EBS shelf survey) and the stock abundance estimated by the assessment model.

The model accepted for the 2021 assessment, "21.22a", included the following modifications to Model 20.07:

- the likelihoods used to fit fishery (by)catch biomass (and abundance, for the groundfish fisheries) data were changed from normal distributions with an assumed standard deviation of 0.64 thousand t to lognormal distributions with assumed CVs of 0.1 during 1965-1979, 0.025 durning 1980-1995, and 0.01 after 2004/05 (the directed fishery was closed until 2005/06) for retained catch data; 0.2 for total catch data from crab fishery observers (with a minimum standard deviation of 100 t), and 0.2 for total catch data from ground fisheries observers.
- maximum retention rates were fixed to 1 (no longer estimated)
- the functions describing selectivity for male bycatch in the snow crab fishery were changed from a double logistic to a double normal
- the functions describing selectivity for bycatch in the BBRKC fishery were changed from ascending logistic to ascending double normal, and the size at the asymptote for male selectivity was fixed to the model size limit
- the functions describing selectivity in the NMFS EBS shelf survey were changed from ascending logistic to ascending double normal, fully-selected sizes were fixed at 180 mm CW for males and130 mm CW for females
- The Dirichlet-Multinomial function was used to fit size composition data from the BSFRF SBS surveys

In 2022, the AKRO modified its algorithms used to estimate crab bycatch in the groundfish fisheries and applied the new algorithm retroactively back to 2016/17. This change resulted in small changes to the estimates of Tanner crab bycatch in the groundfish fisheries back to 2016/17, but these changes had almost no effect when the 2021 assessment model was re-run with the updated bycatch estimates. However, because the change in algorithms is essentially a change in the model, the model name was changed from "21.22a" to "22.01" to reflect this difference. Thus, model "22.01" is the base model for this assessment, and represents the 2021 assessment model, 21.22a, with revised bycatch data in the groundfish fisheries and the addition of new fishery and survey data for 2021/22 as outlined in the previous section.

The author's preferred model, "22.03", slightly revised 22.01 by changing the manner in which crab fishery observer-based total catch data was fit. Model 21.22a fit the total catch data separately by sex using lognormal likelihoods. It also converted the associated size composition data to proportions separately by sex and fit them separately by sex. With Model 22.03, the total catch data was first summed across sex and then fit using lognormal likelihoods. In addition, the associated size composition data was first converted to proportions across both sexes (thus preserving the observed sex ratio) and fit as an "extended" set of proportions. Thus, Model 22.03 fits the crab fishery data in the same manner as it fits the bycatch data from the groundfish fisheries (groundfish fisheries observers don't categorize bulk bycatch abundance/biomass data by sex but do collect sex-specific size frequency information, whereas crab fisheries observers categorize both bulk total catch data and size frequency data by sex).

4. *Changes to the assessment results*

Except for the OFL and ABC, changes in the assessment results are minimal reflecting the general similarity between last year's model and this year's preferred assessment model. Average recruitment was estimated at 390 million (1982-2018) in last year's assessment, but it was slightly higher at 396 million (1982-2020) from the author's preferred model this year. F_{MSY} remained essentially the same (1.17 yr^{-1}), but B_{MSY} was slightly smaller (35 thousands t vs. 35.94 thousand t). The stock remained in Tier 3a because the ratio of projected MMB (35 thousands t) to B_{MSY} was above 1, as it was last year. Because current MMB this year (62 thousands t) was estimated larger than current MMB last year (56.34 thousand t), the 2022/23 OFL (33 thousands t) ended up being larger than the 2021/22OFL (27.17 thousand t).

B. Responses to SSC and CPT Comments

1. Responses to the most recent two sets (May/June 2022, February 2022, September/October 2021) of SSC and CPT comments on assessments in general.

[Note: for continuity with previous assessments, the following may include comments prior to the most recent two sets.]

June 2022 SSC Meeting

SSC Comment: he 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 (9/22): Noted.

February 2022 SSC Meeting

SSC Comment: 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 (9/22): Results from the base model are provided. Management quantities for the base model are provided, in addition to those for the author's preferred model.

SSC Comment: 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.

SSC Comment: 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.

June 2021 SSC Meeting

SSC Comment: Crab assessment should generally follow the default groundfish practice of projecting the current year's catches if one or more fisheries are incomplete at the time of the assessment.

Response (9/22): This does not apply to Tanner crab with the current timing of assessments.

May 2021 CPT Meeting

CPT Comment: No general comments.

Oct 2020 SSC Meeting

SSC Comment: the SSC requests that the CPT consider developing a standard approach for projecting the upcoming year's biomass that does not include removing the entire OFL for stocks where recent mortality has been substantially below the OFL. This may appreciably change the projected biomass levels for stocks such as Tanner crab, where actual catch mortality has been less than 10% of the OFL.

Response (updated 9/22): The code to project the stock forward for fishing mortality models other than the OFL has now been developed for Tanner crab. 20-year projections from the MLE were run for the base and author-preferred models.

SSC Comment: the SSC encouraged authors to work together to create a standard approach for creating priors on selectivity and catchability from these (BSFRF/NMFS side-by-side trawl) data for use in the respective assessments. A hierarchical comparison of all species pooled, separated species, and separated sexes may be helpful for understanding where statistically supported differences exist. Where sample sizes are modest (e.g., snow crab), bootstrapping, or a sample size-weighted estimate rather than a raw average may be useful for aggregating across years.

Response (updated 9/22): Finalizing this work is a priority for the author, but he has not been able to obtain the 2018 BSFRF data yet. Including that study in the analysis important because it substantially expanded the spatial coverage for the Tanner crab stock into the Pribilof Islands, whereas earlier studies were focused on a more eastern component of the stock and BBRKC.

Response (updated 9/21): A substantial amount of work has been done to develop a standard approach, using Tanner crab as a test case. See the eAgenda item from the May 2021 CPT Meeting. Response (updated 9/20): An option to use such priors has also been added to the Tanner crab assessment model code, but has not yet been utilized. Results from a preliminary attempt to develop priors on sex/size-specific catchability (q x selectivity) and availability were presented for Tanner crab in the May 2020 CPT Report. Further work estimating catchability outside the assessment model using catch ratio analysis of the BSFRF/NMFS side-by-side trawl data using GAMMs is underway but incomplete (see Appendix 4 for an interim report). A model (20.10) using the "best" estimates (from a limited, preliminary set of candidate models) of sex-specific catchability from this analysis is presented in this chapter, however, the estimated catchability curves are used as "known" in the assessment model rather than as priors partly because the uncertainty associated with the curves has not yet been adequately characterized and partly because assuming the curves are known reduces the complexity of the model. The suggested hierarchical comparison is an intriguing suggestion, and can be addressed in future research.

2. Responses to the most recent two sets (May/June 2022, September/October 2021) of SSC and CPT comments specific to the assessment.

[Note: for continuity with the previous assessment, the following may include comments prior to the most recent two sets of comments.]

June 2022 SSC Meeting

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

SSC Comment: 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.

SSC Comment: 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 has begun. The SSC's other recommendations are appreciated and the author notes that these are active areas of research.

SSC Comment: 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): Noted.

May 2022 CPT Meeting

CPT Comment: 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.

CPT Comment: 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 (9/22): These continue to be areas of active investigation.

October 2021 SSC Meeting

SSC Comment: The SSC broadly supports these suggested areas of future model development and research, highlighting in particular: 1) efforts to simplify the model structure; 2) continued investigation of the use of VAST estimates of survey biomass and size composition to inform the assessment; 3) implementation of the EBS Tanner crab model in GMACS.

Response (9/22): Noted. See more detailed responses for research in each area in related comments below.

SSC Comment: The SSC reiterates its suggestion from October 2020 to prioritize development of a projection model for crab that doesn't assume the entire OFL is removed, which is especially important for the EBS Tanner crab stock where exploitation is routinely below the OFL.

Response (9/22): A projection model of the type described has been implemented. 20-year projections at 0, 0.25, 0.5, 0.75, 1, and 1.25 times F_{OFL} for the directed fishery have been included in the assessment for the base and author-preferred models.

SSC Comment: With respect to the treatment of selectivity within this assessment the SSC supports continued exploration of alternative ways to approximate temporal variation, given known, among-year differences in the location of fishery prosecution, including through direct comparison of random walk and time block specifications where appropriate. However, the SSC suggests balancing model complexity exploration of the extent to which survey or fishery selectivities may be shared among time periods or sexes is warranted, drawing particular attention to NMFS survey selectivity.

Response (9/22): Noted. With respect to "sharing" selectivity characteristics, this is probably best implemented by applying a penalty to the divergence of the functions used to describe, say, sex-specific survey selectivity over specific size ranges, i.e., sharing functional characteristics over some size range rather than parameters. This is not a current capability of the model code, but can be added in the future.

SSC Comment: The SSC highlights that determining the right level of model complexity is a challenging task, and appreciates when authors explore the use of simpler alternatives to explore the degree of explanatory power gained by adding specific model variations that increase complexity of the model with the hope of capturing process nuances. The SSC recommends incorporating this approach as a regular practice in framing the degree of complexity subscribed to for a particular assessment. The 1998 NRC report Improving Fish Stock Assessments recommended having alternative model formulations at hand, which can be used to provide a reality check regarding model complexity, but also provide better understanding of contributions to model fit, as well as levels of uncertainty and the reliability of predictions.

Response (9/22): Most of the model complexity in the Tanner crab models revolves around: 1) older, uncertain data associated with changes in gear and fishing practices and 2) the need to model multiple bycatch fisheries to achieve total catch mortality accounting. Models that drop fitting the older data and simplify structure have been implemented (Models 22.07, 22.08, and 22.11 here). A model that fits to only NMFS survey data and directed fishery data will be implemented to explore possible temporal variation in natural mortality; results will be presented at the January 2023 Modeling workshop (if completed).

SSC Comment: The SSC continues to support the investigation of model outputs that better inform State management, especially males of industry-preferred size to ensure proper scaling.

Response (9/22): Models 22.04a and b presented at the May 2022 CPT meeting modeled the directed fishery using the "fleets as areas" concept, but the models as formulated were problematic in terms of achieving convergence and parameters at bounds. However, this remains a topic of active research.

September 2021 CPT Meeting

CPT Comment : The following author's suggestions were endorsed by the CPT: 1) the ability to conduct multi-year projections should be added to the model; 2) a delta approximation method should be incorporated in the model to estimate the uncertainty associated with the OFL and ABC as an alternative to MCMC; 3) the analysis to create a standard approach for using BSFRF/NMFS side-by-side trawl data to inform NMFS survey catchability in assessments needs to be completed; the 2018 BSFRF data should be obtained and included in the analysis; 4) a model in which the model simulation (i.e., projection) starts in 1982 should be created; 5) nonparametric approaches to determine selectivity should be explored; 6) EBS Tanner crab should be implemented in GMACS (this could occur once the model for snow crab has transitioned to GMACS).

Response (9/22): Items 1, 2, and 4 have been completed and results are presented in this assessment. Item 3 awaits receipt of the 2018 BSFRF SBS survey data to complete the analysis. Items 5 and 6 are in very preliminary stages of development.

CPT Comment: Indicate important time periods (e.g., start of NMFS survey data, selectivity time blocks, etc.) on relevant plots for better reference.

Response (9/22): Great suggestion and will be implemented in the future. Th author apologizes for not having worked out how to do this yet.

CPT Comment: Further examine weighting schemes, including scenarios in which the input sample sizes are larger in the D-M weighting scheme.

Response (9/22): Model 22.08 (and Model 22.02 presented at the May 2022 CPT meeting) included input sample sizes for NMFS EBS survey size compositions based on booootstrapped effective sample sizes that were larger than the default input sample sizes. However, Dirichlet-multinomial likelihoods were not used to fit the data. Model 22.08 will be re-fit to address this issue and results presented at the January 2023 Modeling Workshop (if warranted).

CPT Comment: Continue to investigate the use of VAST estimates of survey biomass and size-composition in the assessment.

Response (9/22): Estimating VAST-based size compositions has not been possible due to computer limitations on memory and speed.

CPT Comment: Simplify the model structure.

Response (9/22): Models which start in 1982, dropping fits to older, more uncertain data and simplifying model structure by eliminating some time blocks were have been implemented (e.g., Models 22.07 and 22.08 in this assessment) but not yet adopted.

CPT Comment: Develop a model for EBS Tanner crab that incorporates important aspects of State management for Tanner crab, perhaps using the "fleets as areas" concept to reflect the State's two-area management.

Response (9/22): Models implementing this approach were presented at the May 2022 CPT Meeting. There were problems with convergence and parameters at bounds, but this remains an area of research.

June 2021 SSC Meeting

SSC Comment: The SSC also cautions that fixing the Dirichlet-multinomial variance parameter at a large value (specifying the nominal sample size) makes sense, but that support for this weighting must be re-checked for every new alternative model considered in future assessments to ensure data weighting remains consistent with model fit.

Response (9/22): This suggestion makes sense if input sample sizes were dramatically changed, but seems a relatively lower priority issue if sample sizes were not changed substantially from previous models. For this assessment,the input sample sizes were "substantially" changed only in Model 22.08 (for NMFS EBS shelf survey data using bootstrapped estimates of effective sample size) but Dirichlet-multinomial likelihoods were not employed when fitting the model (multinomial likelihoods were used). This model will be re-run using the Dirichlet-multinomial likelihood as a research topic for the January 2023 modeling workshop or the May 2023 CPT meeting.

Response (9/21): Alternative models with nominal Dirichlet-multinomial likelihoods were first run with the variance parameter estimated. If found to be at the upper bound for a particular dataset, the likelihood was converted to multinomial to allow more straightforward comparison with the base model that used only multinomial likelihoods.

SSC Comment: The SSC supports continued exploration of VAST indices within this assessment and research to evaluate optimal methods for addressing changes in index uncertainty in the context of data weighting.

Response (9/22): No models using VAST indices were requested for this assessment. This topic remains to be addressed satisfactorily, but other issues/requests (e.g. projections, initial conditions, two-area models) took priority.

Response (9/21): No models using VAST indices were requested for this assessment. Jon Richar (NMFS, Kodiak) was able to provide the indices to the assessment author, but time constraints did not allow running models with these data. Continued exploration of the use of VAST data for this assessment will continue.

May 2021 CPT Meeting

CPT Comment: The data may not support so many selectivity parameters. A reduction in the number of selectivity parameters may be needed.

Response (9/21): The author assumes this comment refers to the number of estimated parameters, and agrees. The number of estimated selectivity parameters in the author's preferred model for 2021 (21.22a) has been reduced that in the 2020 assessment model by re-parameterizing functions used to describe selectivity in the NMFS EBS shelf survey, the snow crab fishery, the BBRKC fishery, and groundfish fisheries from logistic functions to ascending half-normal functions and fixing the size at which crab are fully-selected when these parameters were estimated at upper bounds in intermediate model formulations.

CPT Comment: The CVs for the VAST-based index could be selected about a loess-based smoother rather than the VAST output.

Response (9/22): This remains to be addressed.

Response (9/21): This is an interesting idea and will be examined for the January 2022 CPT Meeting.

CPT Comment: Some selectivity parameters may be estimated with an AR1 or random walk approach within some year blocks.

Response (9/21): The size at 50% selected for males in the directed fishery is currently modeled as a random walk process, which provides some ability to deal with the growing number of instances in which the directed fishery is conducted in only one management area. In this instance, the author is concerned that selectivity changes functional shape in for a particular year from asymptotic to dome-shaped depending on which combination of management areas is open, rather than that the parameters for a given shape vary. In his recently-defended dissertation, Lee Cronin-Fine found that using time blocks may be more effective from a practical standpoint than using random walks/AR1 processes to model temporal variability in selectivity. However, this is certainly an area open to continued research.

CPT Comment: The early data is not very good and may have an inappropriate influence on some parameter estimates. One approach is to start the model in 1982 and to estimate size compositions and total abundance in the initial year.

Response (9/22): The capability to estimate initial abundances to start the model at any time has been implemented. Initial abundances can either be based on equilibrium assumptions (and fixed) or estimated using one of two parameter schemes. Models 22.07, 22.08, and 22.11 estimated initial abundance to start the mdoel in 1982.

Response (9/21): This is a good suggestion but requires either a new capability added to the existing stock assessment model or transition to GMACS. If the former, this will be addressed at either the January or May 2022 CPT meeting. If the latter, it will probably not be addressed until 2023.

CPT Comment: It may be beneficial to look at the early assessments to see how earlier models fit the data, especially the early data.

Response (9/22): Plots of current estimates of recruitment and MMB time series from the base and author-preferred models are compared with previous assessment results in Section 4.f.ii.

Response (9/21): The data fitted in the model has undergone a number of changes over the years (e.g., survey "MMB" was originally, now total male survey biomass is fit; the survey data underwent "standardization" in 2015, etc.), so direct comparisons make little sense. However, doing so would reveal "change points" in the assessment, which may help diagnostically.

October 2020 SSC Meeting

SSC Comment: Serious concerns remain about model convergence. A small percentage of models converge and it is not clear if the model is converging on a global minimum. This should remain a top priority for future work. Efforts should strive to reduce the number of parameters and minimize the number of parameters hitting bounds. Posterior correlations should be thoroughly examined to look for potential sources of the convergence issues.

Response (9/22): All the models considered for this assessment had more than 50% of "jittered" runs converging to the same solution. In addition, most models had one parameter at most on a bound at the MLE (one had three). Thus model convergence seems to be less of an issue currently than it has been in previous assessments.

Response (9/21): Selectivity functions have been re-parameterized from logistic-based functions, which only approach 1 (and thus the size at full selection) asymptotically to ones based on the half-normal that have a maximum value of 1 and reach it at a well-defined size without extraneous normalization. Parameters defining the fully-selected size in the NMFS EBS shelf survey and BBRKC fishery have been fixed at defensible maximum sizes (~largest size seen in the data) when they would otherwise have been estimated at an upper bound. The author's preferred model, 21.22a, has no parameters on a bound.

SSC Comment: The assessment should include retrospective analyses of each viable candidate model.

Response (9/22): Retrospective analyses were conducted for all models considered in this assessment.

Response (9/21): Retrospective analyses were conducted for both 21.22a (the only viable candidate with no parameters at bounds) and 20.07u, the base model with 2020/21 data.

SSC Comment: The SSC agreed with the CPT not to use the MCMC runs, and asks that next year's assessment include a rationale if MCMC is used to recommend management advice.

Response (9/22): The capability to use the delta-approximation to estimate uncertainty for the OFL and other management-related quantities has been implemented. The management advice provided this year is based on this approach, rather than on MCMC runs.

Response (9/21): Using the delta-approximation to estimate uncertainty in a complex model can result in biased estimates. Thus, basing the OFL and max ABC (the p-star ABC) on MCMC runs should be, when possible, the preferred approach (as used in this assessment). However, MCMC runs entail a considerable processing burden and it would simplify the assessment process if they could be avoided. This will involve a fair amount of re-coding because the OFL/ABC calculations using MCMC do not use ADMB's automatic diferentiation ("AD") variables (AD is not used to obtain derived quantities like the OFL and ABC, so it was more efficient from a computer memory standpoint to code them as non-AD variables). However, it will be relatively efficient to, at the same time as converting the OFL/ABC calculations to AD variables, add some form of the requested projection code to the assessment model.

SSC Comment: The SSC also endorses Alaska Bering Sea Crabbers' (ABSC) request to include raw numbers used for PSC limits in a table in the EBS Tanner crab SAFE consistent with EBS snow crab (see Table 11 in the EBS snow crab SAFE), if it is practical to do so.

Response (9/21): The requested information has been added to the SAFE chapter (Table 51). Note that the abundance information is also (and has been in previous assessments) provided in csv format by year, sex, maturity state, shell condition, and size as a zipped file ("TannerCrab.PopSizeStructure.csv.zip") on the eAgenda web page for this meeting (and previous meetings).

SSC Comment: The State of Alaska's harvest control rule was recently changed and involves females. This leads to a disconnect between the federal catch specification process represented by this assessment and state fishery management. Thus, regarding future research, the SSC recommends exploring a stock-recruit relationship incorporating females, including an examination of different hypotheses about the roles of females in stock dynamics. Also, as noted in the assessment, the State manages this fishery as two separate areas but this assessment considers a single EBS-wide stock. In summary, modifications to the assessment should be considered to the extent practicable that bridge these state-federal disconnects and facilitate application of the stock assessment to the State's harvest strategy for fishery management.

Response (9/22): Preliminary models that reflected the State's two-area management system using the "fleets-as-areas" approach were presented at the May 2022 CPT meeting. The results were problematic and the models were not selected for consideration in September. However, development of these models will continue.

Response (9/21): The author supports the ideas for future research outlined in this comment. As a note, the State's harvest strategy has always involved consideration of females—although previously as thresholds to opening the fisheries and currently to determine the maximum exploitation rate allowed on males.

SSC Comment: In response to SSC comments, the authors suggested that the current model cannot do likelihood profiles because of lack of functionality of ADMB. The SSC suggests that ADMB has the functionality to do likelihood profiles through the software, and looks forward to reporting of these results in next year's SAFE. It may be helpful to help diagnose convergence issues if the sensitivity to each data source is explored.

Response (9/21): In the author's experience, the ADMB software provides the ability to perform likelihood profiling on a specific variable, with the output written to a file being the total objective function values (the likelihood profile) as a function of the variable profiled over. Several variables can be profiled simultaneously. However, what is of interest here is not only how the total objective function depends on the variable being profiled, but on how the individual components of the likelihood change. The author has developed R code that allows one to obtain the values for the individual components (and any other model output). Results from likelihood profiling on male mean growth parameters were presented to the CPT in the Tanner crab report for the May 2021 CPT Meeting.

SSC Comment: In Table 35 on p. 94, the heading refers to old model numbering, but the column headings utilize new model naming conventions. Please revise the header to utilize the new model naming conventions. The same applies to Table 36 on p. 95. Please check for other instances.

Response (9/21): The author appreciates the notification. Table captions have been checked in this document for consistency with model naming conventions.

September 2020 CPT Meeting

CPT Comment: Evaluate the use of half-normal curves for selectivity rather than logistic functions.

Response (9/21): Half-normal curves have been adopted for use to describe selectivity of both sexes in the NMFS EBS Shelf Survey and BBRKC fishery bycatch. This process is taking a step-by-step approach, as well as an "if it ain't broke, don't rush to fix it" sense of prioritization. The logistic function descriptions for the aforementioned surveys and fisheries were problematic in one form or another. The change to half-normal seems to be an improvement, and applying it to the other fleets will continue.

CPT Comment: To improve model performance, evaluate the use of a bounding function to the likelihood to keep parameters from approaching bounds.

Response (9/22): This remains to be addressed.

Response (9/21): This is a good suggestion and will be followed up on prior to the May 2022 CPT Meeting.

CPT Comment: It is somewhat disconcerting how many model parameters are devoted to modeling bycatch, which is not important in the stock dynamics (see report section on PSC limits). Consider ways to model bycatch fisheries more parsimoniously. It was noted that using a low accumulator size might help to address these issues.

Response (9/21): The author similarly finds it disconcerting and supports this research suggestion. There would probably be no impact on current stock dynamics if current bycatch in the BBRKC fishery (at least) were completely ignored. However, the assessment uses data (and associated annual parameter estimates) on current bycatch and effort to estimate bycatch levels in the past (pre-1990, when bycatch was thought to be much larger) based on contemporaneous effort data and a bycatch-to-effort ratio estimated from current data. Consequently, the parameters influencing estimates of current bycatch need to themselves be estimated. It will be worthwhile determining if anything is lost by estimating a constant fishing mortality rate, rather than an annually varying one, for (say) the post-1996 period for bycatch in the BBRKC fishery.

CPT Comment: Survey catchability in the early period is still hitting the parameter bound. Evaluate using a prior for survey catchability in the early period that is the same as the prior for catchability used for the main part of the survey time series.

Response (9/21): Given the different spatial coverage of the NMFS survey in pre-1982 and post-1981 periods, it seems unlikely that using the same prior on catchability for both periods can be justified. Fortunately, this issue became moot (for the time being) because catchability is no longer estimated at its lower bound (the bounds on these parameters were increased in the new models presented at the May 2021 CPT Meeting and considered here—the 21.XX models).

CPT Comment: Evaluate potential conflicts between data sets in the assessment using likelihood profiles and other approaches.

Response (9/21): Likelihood profiles were used to examine the conflicts among datasets with regard to changes in the estimated mean post-molt growth parameter for males, with results reported at the May 2021 CPT Meeting.

CPT Comment: Evaluate methods for model tuning or estimation of additional variance terms to address issues with model giving too much weight to fitting survey biomass estimates.

Response (9/21): The models considered in this assessment do not fit to VAST model-based survey estimates, so additional variance terms were not employed. This remains an area for future research, however.

C. Introduction

1. Scientific name

Chionocoetes bairdi. Tanner crab is one of five species in the genus Chionoecetes (Rathbun, 1924). The common name "Tanner crab" for *C. bairdi* (Williams et al. 1989) was recently modified to "southern Tanner crab" (McLaughlin et al. 2005). Prior to this change, the term "Tanner crab" had also been used to refer to other members of the genus, or the genus as a whole. Hereafter, the common name "Tanner crab" will be used in reference to "southern Tanner crab".

2. Description of general distribution

Tanner crabs are found in continental shelf waters of the north Pacific. In the east, their range extends as far south as Oregon (Hosie and Gaumer 1974) and in the west as far south as Hokkaido, Japan (Kon 1996). The northern extent of their range is in the Bering Sea (Somerton 1981a), where they are found along the Kamchatka peninsula (Slizkin 1990) to the west and in Bristol Bay to the east.

In the eastern Bering Sea (EBS), the Tanner crab distribution may be limited by water temperature (Somerton, 1981a; Murphy, 2020). The unit stock is that defined across the geographic range of the EBS continental shelf, and managed as a single unit (Table 1, Figure 1). *C. bairdi* is common in the southern half of Bristol Bay, around the Pribilof Islands, and along the shelf break, although males less than the industry-preferred size (>125 mm CW) and ovigerous and immature females of all sizes are distributed broadly from southern Bristol Bay northwest to St. Matthew Island (Rugolo and Turnock, 2011a). The southern range of the cold water congener the snow crab, *C. opilio*, in the EBS is near the Pribilof Islands (Turnock and Rugolo, 2011). The distributions of snow and Tanner crab overlap on the shelf from approximately 56° to 60°N, and in this area, the two species hybridize (Karinen and Hoopes 1971).

3. Evidence of stock structure

Tanner crabs in the EBS are considered to be a separate stock distinct from Tanner crabs in the eastern and western Aleutian Islands (NPFMC 1998). 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 be 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. Life history characteristics

a. Molting and Shell Condition

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

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

b. Growth

Work by Somerton (1981a) estimated growth for EBS Tanner crab based on modal size frequency analysis of Tanner crab in survey data assuming no terminal molt at maturity. Somerton's approach did not directly measure molt increments and his findings are constrained by not considering that the progression of modal lengths between years was biased because crab ceased growing after their terminal molt to maturity.

Growth in immature Tanner crab larger than approximately 25 mm CW proceeds by a series of annual molts, up to a final (terminal) molt to maturity (Tamone et al., 2007). Rugolo and Turnock (2012a) derived growth relationships for male and female Tanner crab 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, 2012; 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 of gpm for both males and females was characterized by a higher rate of growth to an intermediate size (90-100 mm CW) followed by a decrease in growth rate from that size thereafter. Similarly-shaped growth curves were found by Somerton (1981a) and Donaldson et al. (1981), as well.

Molt increment data was collected for Tanner crab in the EBS during 2015, 2016, 2017 and 2019 in cooperative research between NMFS and the Bering Sea Research Foundation (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, 2017). 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.

c. Weight at Size

Weight-at-size relationships used in this assessment were revised in 2014 based on a comprehensive re-evaluation of data from the NMFS EBS Bottom Trawl Survey (Daly et al., 2014). Weight-at-size is described by a power-law model of the form $w = a \cdot z^b$, where w is weight in kg, z is the size in mm CW, and a and b are estimated coefficients (Daly et al., 2016; table below). Jon Richar (AFSC Kodiak) has recently (May, 2021) conducted a revised analysis of the weight-at-size data for Tanner crab that incorporates shell condition as a factor in the analysis. 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 the following table:

Table. Weight-at-size regression parameters.

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

d. Maturity and Reproduction

It is now generally accepted that both Tanner crab males (Tamone et al. 2007) and females (Donaldson and Adams 1989) undergo a terminal molt to maturity, as in most majid crabs. Maturity in females can be determined visually rather unambiguously from the relative size of the abdomen. Females usually undergo their terminal molt from their last juvenile, or pubescent, instar while being grasped by a male (Donaldson and Adams 1989). Subsequent mating takes place annually in a hard shell state (Hilsinger 1976) and after extruding the female's clutch of eggs. While mating involving old-shell adult females has been documented (Donaldson and Hicks 1977), fertile egg clutches can be produced in the absence of males by using sperm stored in the spermathacae (Adams and Paul 1983, Paul and Paul 1992). Two or more consecutive egg fertilization events can follow a single copulation using stored sperm to self-fertilize the new clutch (Paul 1982, Adams and Paul 1983), although egg viability decreases with time and age of the stored sperm (Paul 1984).

Maturity in males can be classified either physiologically or morphometrically, but is not as easily determined as with females. Physiological maturity refers to the presence or absence of spermataphores in the gonads whereas morphometric maturity refers to the presence or absence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). The ratio of chela height (CH) to carapace width (CW) has been used to classify male Tanner crab as to morphometric maturity. While many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow, there is now substantial evidence supporting a terminal molt for males (Otto 1998, Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never achieve legal size (NPFMC 2007).

In this assessment, all models include fits to size-specific annual proportions of mature, new shell male crab to all new shell male crab in the NMFS EBS bottom trawl survey, based on classification using CH:CW ratios (J. Richar, AFSC Kodiak, pers. comm.), to inform size-specific probabilities of terminal molt.

Although observations are lacking in the EBS, seasonal differences have been observed between mating periods for pubescent and multiparous females in the Gulf of Alaska and Prince William Sound. There, pubescent molting and mating takes place over a protracted period from winter through early summer, whereas multiparous mating occurs over a relatively short period during mid April to early June (Hilsinger 1976, Munk et al. 1996, and Stevens 2000). In the EBS, egg condition for multiparous Tanner crabs assessed between April and July 1976 also suggested that hatching and extrusion of new clutches for this maturity state begins in April and ends sometime in mid-June (Somerton 1981a).

e. Fecundity

A variety of factors affect female fecundity, including somatic size, maturity status (primiparous vs. multiparous), age post terminal molt, and egg loss (NMFS 2004). Of these factors, somatic size is the most important, with estimates of 89 to 424 thousand eggs for females 75 to 124 mm CW, respectively (Haynes et al. 1976). Maturity status is another important factor affecting fecundity, with primiparous females being only ~70% as fecund as equal size multiparous females (Somerton and Meyers 1983). The number of years post maturity molt, and whether or not a female has had to use stored sperm from that first mating can also affect egg counts (Paul 1984, Paul and Paul 1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., are barren) suggesting that female crab reproductive output is a concave function of age (NMFS 2004).

f. Size at Maturity

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

g. Mortality

Due to the lack of age information for crab, Somerton (1981a) estimated mortality separately for individual EBS cohorts of immature and adult Tanner crab. Somerton postulated that age five crab (mean CW = 95 mm) were the first cohort to be fully recruited to the NMFS trawl survey sampling gear and estimated an instantaneous natural mortality rate of 0.35 for this size class using catch curve analysis. Using this analysis with two different data sets, Somerton estimated natural mortality rates of adult male crab from the fished stock to range from 0.20 to 0.28. When using CPUE data from the Japanese fishery, estimates of M ranged from 0.13 to 0.18. Somerton concluded that estimates of M from 0.22 to 0.28 obtained from models that used both the survey and fishery data were the most representative.

Rugolo and Turnock (2011a) examined empirical evidence for reliable estimates of oldest observed age for male Tanner crab. Unlike its congener the snow crab, information on longevity of the Tanner crab is lacking. They reasoned that longevity in a virgin population of Tanner crab would be analogous to that of the snow crab, where longevity would be at least 20 years, given the close analogues in population dynamic and life-history characteristics (Turnock and Rugolo 2011a). Employing 20 years as a proxy for longevity and assuming that this age represented the upper 98.5th percentile of the distribution of ages in an unexploited population, M was estimated to be 0.23 based on Hoenig's (1983) method. 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 (NPFMC 2007).

5. Brief summary of management history

A complete summary of the management history is provided in the ADFG Area Management Report appended to the annual SAFE. Fisheries have historically taken place for Tanner crab throughout their range in Alaska, but currently only the fishery in the EBS is managed under a federal Fishery Management Plan (FMP; NPFMC 2011). The plan defers certain management controls for Tanner crab to the State of Alaska (SOA), with federal oversight (Bowers et al. 2008). The SOA manages Tanner crab based on registration areas divided into districts. Under the FMP, the state can adjust districts as needed to avoid overharvest in a particular area, change size limits from other stocks in the registration area, change fishing seasons, or encourage exploration (NPFMC 2011).

The Bering Sea District of Tanner crab Registration Area J (Figure 1) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36'N and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173°W. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008). In this report, the terms "east region" and "west region" are used in shorthand fashion to refer to the regions demarcated by 166^oW longitude.

In March 2011, the Alaska Board of Fisheries (BOF) approved a new minimum size limit harvest strategy for Tanner crab effective for the 2011/12 fishery. Prior to this change, the minimum legal size limit was 5.5" (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 size limit 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 SOA'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 (ADFG 2014). 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 subdistrict could be opened. Minimum thresholds for opening the fishery in a subdistrict were also defined using the ratio subdistrict-specific MMB to its associated long-term average. Finally, the harvest strategy defined subdistrict-specific sloping harvest control rules to determine the maximum allowable exploitation rate on mature males in each subdistrict based on the ratio of MFB to average MFB, together with limits on the maximum exploitation rate (Figure 2).

Subsequently, the SOA's harvest strategy has undergone three revisions in the past 7 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; ADF&G, 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; 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 (Table 3). The SOA 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. However, following a change in Tier level from 4 to 3 based on development and acceptance of a Tier 3 assessment model later in 2012, the stock was declared to no longer be overfished under Tier 3 rules. The female stock metrics surpassed the State harvest strategy thresholds in fall 2013 and the directed fishery was opened in 2013/14. TAC was set at 1,645,000 lbs (746 t) for the area west of 166^o W and at 1,463,000 lbs (664 t) for the area east of 166^o W in the Eastern Subdistrict of Tanner crab Registration Area J. The fisheries opened on October 15 and closed on March 31. On closing, 79.6% (594 t) of the TAC had been taken in the western area while 98.6% (654 t) had been taken in the eastern area. In 2014, TAC was set at 6,625,000 lbs (3,005 t) for the area west of 166^o W and at 8,480,000 lbs (3,846 t) for the area east of 166^o W. On closing, 77.5% (2,329 t) of the TAC was taken in the western area while 99.6% (3,829 t) were taken in the eastern area. In 2015, TAC was set at 8,396,000 lbs (3,808 t) in the western area and

11,272,000 lbs (5,113 t) in the eastern area. On closing, essentially 100% of the TAC was taken in each area (3,798 t in the west, 5,111 t in the east). The total retained catch in 2015/16 (8,910 t) was the largest taken in the fishery since 1992/93 (Tables 1 and 2; Figures 4 and 5).

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 SOA's harvest strategy to allow them to open. Total retained catch was thus 0 in 2016/17. In 2017/18, the SOA allowed a limited directed fishery west of 166^o W longitude but closed the fishery east of 166^o W. Essentially, the entire TAC (1,130 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 thousand t). The entire TAC was again harvested in 2018/19. The directed fisheries in both subdistricts were again closed in 2019/20 because mature male biomass failed to achieve the required threshold in either the eastern or western management areas. In 2020/21, the State criteria for opening the fishery were met in the western area, and the TAC was set to 1,065 t. At the close of the fishery (March 31, by State regulation), 655 t had been harvested. In 2021/22, the eastern region was closed to directed fishing (TAC=0) while TAC in the western region was set at 499 t; the OFL was 27.17 thousand t and the ABC was 21.74 t. Retained catch was 494.25 t and total fishing mortality was 783.19 t.

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 that of the directed fishery (Table 4, Figure 5), although the snow crab fishery was responsible for a sizable fraction of the landed catch in 2005/06 and 2006/07.

Bycatch and discard losses of Tanner crab originate from the directed pot fishery, non-directed snow crab and Bristol Bay red king crab pot fisheries, and the groundfish fisheries (Tables 5-8; Figures 8 and 9). Within the assessment model, 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 (if bycatch is distinguished by gear type, then 80% for trawl fisheries and 50% 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, however, the snow crab fishery has generally accounted for the largest proportion of Tanner crab taken as bycatch, accounting for 638 t on average over the past 5 years (compared with 522 t for the directed fishery and 157 t for the groundfish fisheries, respectively, during the same time frame).

D. 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 (and hosted by AKFIN); 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.

1. Summary of new information

Fishery data for total and retained catch in the directed fishery, and for bycatch in the snow crab and BBRKC fisheries was provided by ADFG (Ben Daly, ADFG, pers. comm.). Data on bycatch in the groundfish fisheries from the groundfish observer program and the AKRO was downloaded from AKFIN Answers (https://akfin.psmfc.org) on Aug. 3, 2021.

Annual retained catch data, state GHLs and TACs, and federal OFLs and ABCs since the inception of the Tanner crab fishery are summarized in Tables 1-3 and illustrated in Figures 4-5. The directed fishery in 2021/22 was conducted only in the area west of 166^{o}W longitude. Retained catch in the directed fishery was 494 t, about 99% of the TAC (499 t; Tables 3, 4; Figures 4, 5). The snow crab and BBRKC fisheries are allowed to retain incidentally-caught, legal-sized Tanner crab males up to 5% of the target catch. In 2021/22, the snow crab fishery harvested 0.8 t of incidentally-retained Tanner crab while the BBRKC fishery was closed and so caught none (Table 4).

Annual retained catch size compositions from dockside crab observer sampling (starting in 1980) are illustrated in Figure 6. The mode for the size composition of retained catch in 2021/22 was shifted substantially toward smaller sizes when compared with those for previous years (2017/18 and 2018/19 in particular). In contrast to 2020/21, when only about 40% of the retained catch was new shell crab, this percentage was much higher (> 80%) in 2021/22–among the highest since rationalization (Figure 7).

Trends in estimated annual total catch, discards, catch mortality, and discard mortality for Tanner crab in the directed and bycatch fisheries, based on crab and groundfish fishery observer sampling, are summarized in Tables 5-12 and illustrated in Figures 8-9. The total catch of Tanner crab (females, sublegal males, legal males) during 2021/22 in the directed, snow crab, BBRKC, and groundfish fisheries was 1,096 t (Table 6, Figure 8). Using the subtraction method ($D = T - R$, where D is discards, T is total catch, and R is retained catch) and applying gear-specific discard mortality rates of 0.321 for pot and fixed gear and 0.800 for trawl gear, total Tanner crab mortality due to all fisheries in 2021/22 was 741 t (Table 10, Figure 9), with the majority due to retention in the directed fishery. The total mortality associated with Tanner crab bycatch was 247 t in 2021/22, almost half that in 2020/21 (429 t; Table 12). The majority of bycatch mortality in 2021/22 was attributed to the the directed fishery (112 t) and the groundfish fisheries (108 t), while in 2020/21 the majority was also attributed to bycatch in the directed fishery (297 t), which was more than three times that attributed to the groundfish fisheries.

Plots of annual total catch size compositions from at-sea crab observer and groundfish observer sampling are shown in Figures 10-15. The mode for the male total catch size compositions in the directed fishery was similar to that in 2020/21 (Figures 10 and 11), as was that for females. The scale of bycatch in the snow crab fishery was so small in 2021/22 (27 t), and consequently observer sampling was so limited, that little can be drawn from the bycatch compositions for that fishery while the BBRKC fishery was closed so there is no size composition data for 2021/22 from that fishery (Figures 12 and 13). Tanner crab bycatch in the groundfish fisheries was shifted toward somewhat larger sizes for both males and females in 2021/22 relative to 2020/21, but smaller than those in 2019/20 (Figures 14, 15).

Annual effort (potlifts) in the crab fisheries is summarized in Tables 13-14. Effort in the 2021/22 directed fishery was about 2/3 that in 2020/21 (19,000 vs. 35,000 potlifts, respectively; Table 14), while effort was drastically reduced from last year in the snow crab fishery (37,000 this year vs. 172,000 last year) and the BRKC fishery (closed this year vs. 21,000 last year).

Sample sizes for fishery size composition data are presented in Tables 15-17. Over 2,300 male crab were sampled for size composition in the retained catch data in 2021/22, about 2/3 of that sampled in 2020/21 (Table 15). However, this resulted in the 2021/22 retained catch size composition being weighted about 10% in the likelihood compared with those of size compositions from the early 1990s. For total catch size compositions, approximately 19,000 males and 1,000 females were sampled at sea by crab fishery observers in the directed fishery. In contrast, only 632 males and 30 females were sampled in 2021/22 as bycatch in the snow crab fishery (similar to that in 2020/21, but 10% of those sampled in 2019/20). Of course, no crab were sampled in the BRKC fishery in 2021/22 because the fishery was closed. (Table 16). In the groundfish fisheries, observers sampled approximately 2,000 females and 7,600 males taken as bycatch for size composition data in 2020/21 (Table 17).

Trends in aggregated catch data (biomass, abundance) in the NMFS EBS shelf bottom trawl survey are summarized in Tables 18-25 for male crab, female crab, and large males $>$ 125 mm CW (“industry-preferred males”), as well as illustrated in Figures 16 and 17. Male survey biomass west of 166^{o}W was down 21% in 2022 from that in 2021 (14,493 t vs. 18,411 t) but up 16% east of 166^{o}W (14,761 t vs. 12,727 t), resulting in an overall small decline in total male Tanner crab biomass from 2021 to 2022 (from 31,138 t to 29,254 t). Females exhibited declines in both areas from 2021 to 2022 (14% in the west, 36% in the east). Changes in survey abundance followed a similar pattern, except that abundance increased from 2021 for females east of 166^{o}W by 29%. For preferred-size males, survey biomass exhibited a substantial increase in new shell crab over that in 2021 (4,512 t vs. 1,863 t) accompanied by a smaller drop in old shell crab from 2,546 t to 1,741 t. Most of the large male biomass was east of 166^{o}W (75%). The fraction of large males in the survey that were new shell increased substantially from 2021 to 2022 in both areas (Figure 18). The biomass of large males west of 166^{o}W estimated in the survey was only slightly larger in 2022 than that captured in the directed fishery in 2021/22 (19), similar to the comparison for the previous year. Comparison of the fraction of new shell crab retained in the fishery with the proportion of large new shell male crab (Figure 20) indicates the fishery retained a much higher percentage of new shell crab than found in the survey.

Size composition data from the NMFS EBS bottom trawl survey are illustrated in Figures 21-23. Recent size compositions (2017-2021) exhibit relatively large numbers of small crab entering the stock in the western management area (Figure 23) compared with both the eastern management area and surveys in 2015 and 2016. In contrast, the 2022 size compositions exhibit a recruitment pulse in both management areas. However, these recruitment pulses are not particularly evident in subsequent years and have not contributed to increases in stock biomass as may have been expected.

Male maturity ogives, based on individual chela heights and carapace widths taken in the NMFS EBS bottom trawl survey, were updated with data from the 2022 survey and are illustrated in Figure 24.

No new molt increment (growth) data was collected this year (Figure 25). The last collection occurred in 2019.

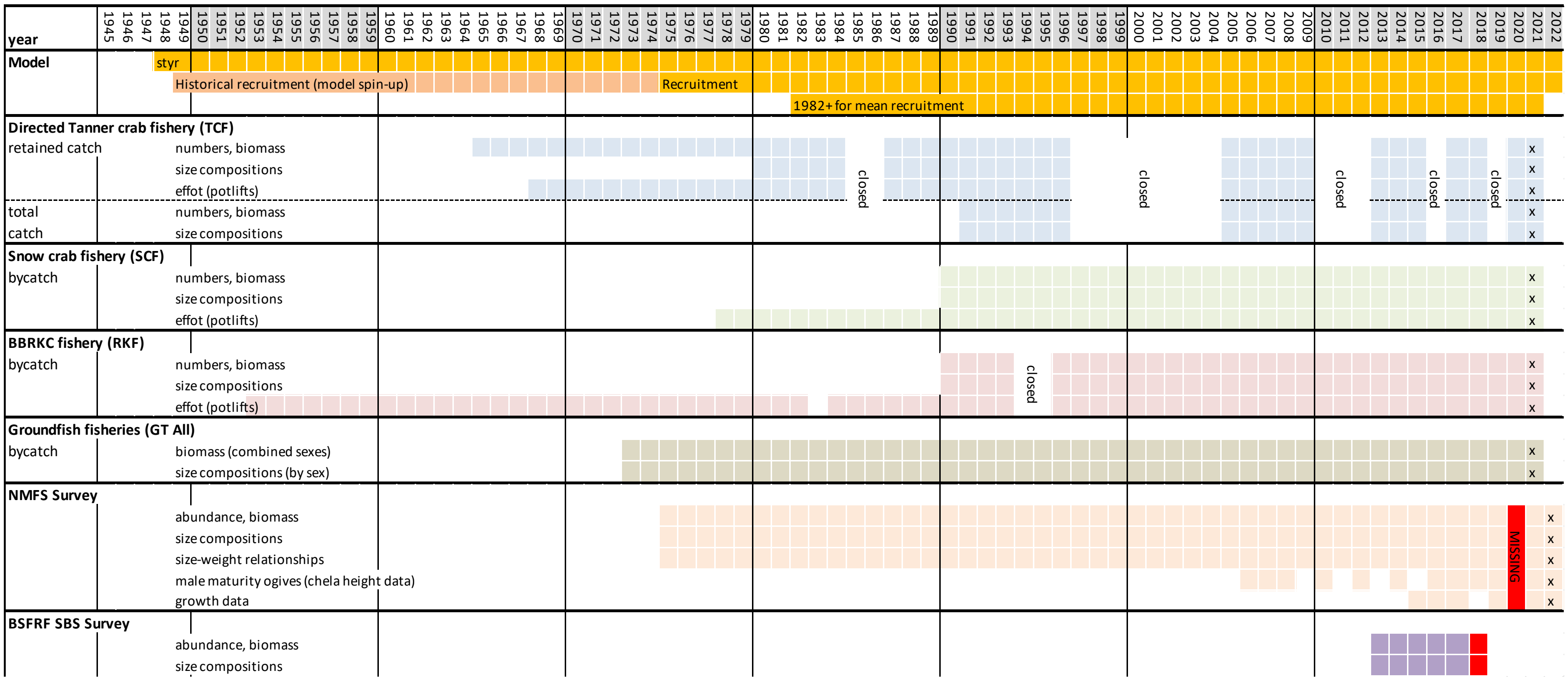
The following table summarizes data sources that have been updated for this assessment:

Table. Data sources updated for this assessment.

Description	Data types	Time frame	Notes	Source
NMFS EBS Bottom Trawl Survey	area-swept abundance, biomass	1975-2019, 2021-22	no 2020 survey	NMFS
	size compositions	1975-2019, 2021-22	no 2020 survey	
	male maturity data	2006+		
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)	2005/06-2021/22	East of W166 closed 2021/22	ADFG
	retained catch size compositions	2013/14-2021/22	East of W166 closed 2021/22	ADFG
	total catch (abundance, biomass)	1991/92-2021/22	East of W166 closed 2021/22	ADFG
	total catch size compositions	1991/92-2021/22	East of W166 closed 2021/22	ADFG
Snow Crab Fishery	historical effort	1978/79/1989/90	not updated	2018 assessment
	effort	1990/91-2021/22		ADFG
	total bycatch (abundance, biomass)	1990/91-2021/22		ADFG
	total bycatch size compositions	1990/91-2021/22		ADFG
Bristol Bay Red King Crab Fishery	historical effort	1953/54-1989/90	not updated	2018 assessment
	effort	1990/91-2021/22		ADFG
	total bycatch (abundance, biomass)	1990/91-2021/22		ADFG
	total bycatch size compositions	1990/91-2021/22		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)	1991/92-2021/22	now using AKRO algorithm for 2016/17+	NMFS/AKFIN
	total bycatch size compositions	1991/92-2021/22		

The following table summarizes the data coverage in the assessment:

Table. Data coverage in the assessment model (shading highlights different model time periods and data components, x's denote new data).



2. Data presented as time series

For the data presented in this document, the convention is that 'year' refers to the year in which the NMFS bottom trawl survey was conducted (nominally July 1, yyyy), while the fishery data are those subsequent to the survey (July 1, yyyy to June 30, yyyy+1)–e.g., 2015/16 indicates the 2015 bottom trawl survey and the winter 2015/16 fishery.

a. Retained catch

Retained catch in the directed fisheries for Tanner crab conducted by the foreign fisheries (Japan and Russia) and the domestic fleet, starting in 1965/66, is presented in Table 1 by fishery year. More detailed information on retained catch in the directed domestic pot fishery prior to the crab fishery rationalization in 2005 is provided in Table 2, which lists total annual catches in numbers of crab and biomass (in lbs), as well as the SOA's Guideline Harvest Level (GHL), number of vessels participating in the directed fishery, and the fishery season. Table 3 lists federal overfishing limits and acceptable biological catch limits (OFLs and ABCs), State total allowable catches (TACs) by management area, and retained catch by management area following rationalization in 2005. Figures 4 and 5 summarize the retained catch history.

Directed fisheries for Tanner crab in the EBS began in 1965. Retained catch has followed a "boom-and-bust" cycle over the years, with the fishery experiencing periods of rapidly increasing catches followed by rapidly declining ones, after which it is closed for a time during which the stock partially recovers. Retained catch increased rapidly from 1965 to 1975, reaching ~ 25,000 t in 1970. It declined to ~13,000 t in 1973/74 coinciding with the termination of Russian fishing and the beginning of the domestic pot fishery. It increased again, this time to its highest level, in 1977/78 (~35,000 t) as the domestic fishery developed rapidly, but it subsequently declined and the fishery was closed in 1985/86 and 1986/87. In the late 1980s and early 1990s, the fishery experienced another, somewhat smaller, "boom" followed by a "bust" and closure of the fishery from 1997/98 to 2004/05. From 2005/06 to 2009/10, the fishery experienced its smallest boom-and-bust cycle, peaking at only ~1,000 t retained catch, and was closed again from 2010/11 to 2012/13. The fishery was re-opened in 2013/14, and retained catch increased each subsequent year until 2016/17 as TACs increased (Table 3). The retained catch for 2015/16 (8,878 t) was the largest since 1992/1993. However, ADFG closed the directed fishery in both areas for the 2016/17 fishing season because mature female biomass in the 2016 NMFS EBS bottom trawl survey did not meet the SOA's criteria for opening the fisheries. In 2017/18, ADFG allowed the fishery to commence in the western area (TAC was set at 1,130 t), but it was closed in the eastern area. The directed fishery essentially caught the entire TAC. The 2018/19 fishery was similar to that in 2017/18 in that the eastern area was closed and the entire TAC (1,100 t) was taken west of 166^{o}W longitude. In 2019/20, the directed fisheries in both areas were closed because mature male biomass failed to exceed the threshold in either management to open the fishery. Finally, in 2020/21 and 2021/22, the fishery in the eastern management area remained closed to directed fishing while TACs of 1,065 t and 499 t were set for the western area in the two years. At the end of the seasons, only 655 t (~65% of the TAC) was harvested in 2020/21, while 494 t was harvested in 2021/22 (99% of the TAC).

Retention of legal-sized male Tanner crab incidentally-caught in the snow crab and BBRKC fisheries is allowed up to 5% of the target species. In general, incidental retention of Tanner crab in these fisheries has been small relative to retention in the directed fishery (Table 4). To simplify the assessment, all incidentally-retained catch is attributed to the directed fishery.

b. Information on bycatch and discards

Total catch estimates for Tanner crab in the directed Tanner crab, snow crab, BBRKC, and groundfish fisheries are provided in Tables 5 and 6 and Figure 8. 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. A value of 0.321 is used in the assessment model for "discard mortality" in the crab fisheries to convert observed bycatch to (unobserved) mortality (Stockhausen, 2014). For the groundfish fisheries, a value of 0.800 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. When gear type is distinguished, a value of 0.321 is used for bycatch by fixed gear and 0.800 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 (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 7-12 and illustrated in Figure 9

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, 2017). 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 (~108 t in 2021/22).

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

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

Retained (male) catch-at-size in the directed Tanner crab fishery, from ADFG dockside observer sampling and scaled to annual catch abundance, is shown in Figure 6 for the entire EBS from 1980/81 to 1996/97 and by fishery management area since rationalization of the crab fisheries in 2005/06. These indicate a shift to somewhat smaller sizes in 2013/14, compared with 2005/06-2009/10, reflecting a smaller minimum "industry-preferred" size of 125 mm CW east of 166°W longitude. In 2021/22, crab smaller than the "industry-preferred" size were accepted by some processors. The proportion of new shell crab in the retained catch had been decreasing since 2013/14, when the stock was declared no longer overfished, but 2020/21 and 2021/22 saw successive increases in this proportion relative to the previous open fishing season (Figure 7).

Expanded total catch (retained + discards) size compositions from at-sea crab fishery observer sampling are presented by sex for the directed fishery in Figures 10 and 11, in the snow crab fishery in Figure 12, in the BBRKC fishery in Figure 13. 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 (as 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.

Sex-specific size compositions from observer sampling for bycatch in the groundfish fisheries, expanded to total bycatch, are shown in Figures 14 and 15 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 does the pot gear used in the crab fisheries—perhaps even providing some evidence for recruitment events (see, e.g., the peaks in relative abundance at small sizes in the size compositions for 2003/04 and 2004/05; Figure 14).

Raw (number of individuals measured) and scaled sample sizes for size composition data from the various fisheries are given in Tables 15-17. It is worthwhile 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 14) and catch in those fisheries.

d. Survey biomass estimates

Time series trends from the NMFS EBS bottom trawl survey suggest the Tanner crab stock in the EBS has undergone decadal-scale fluctuations (Tables 18 and 19, Figures 16 and 17). 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 8). 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 (28 thousand t) since 2000. In 2021, male survey biomass increased over the low in 2019 by ~10% to 31 thousand t, but it declined again to 29 thousand t in 2022 so it basically held steady since 2019. 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). Changes in biomass in the eastern and western management areas were also fairly synchronized. Preferred-size male survey biomass has exhibited a steady decline east of 166^oW (and in the EBS as a whole) starting in 2014, but 2022 finally saw an increase (from 2,403 t in 2021 to 4,676 t). In the western area, preferred-size male survey biomass was increasing up to 2016 but has been declining since then, with the estimate for 2022 (1,576 t) being the lowest since 2002. The ratio of new shell to old shell preferred-size males crab in the survey dropped dramatically after 2015, when the ratio was almost 1:1 (Figure 18). In 2018 and 2019, the ratio was almost 1:18 new shell to old shell crab in terms of biomass. However, it has increased substantially in both 2021 and 2022, suggesting some recruitment into the preferred size range as well as some mortality on oldshell males.

Data from the BSFRF-NMFS cooperative side-by-side (SBS) catchability studies are incorporated into all models in this assessment. 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 spatial footprints of the SBS studies for 2013-2017 are illustrated in Figure 26, while estimates of area-swept biomass for the study areas are compared in Figure 27 for the BSFRF and NMFS gear. Although the BSFRF gear is assumed to provide estimates of absolute abundance with the area surveyed, the relationship between these estimates and Tanner crab stock biomass is confounded by changes in the availability of Tanner crab to the BSFRF gear because the studies did not sample across the entire spatial extent of the population (in contrast to the full NMFS EBS bottom trawl survey).

e. Survey catch-at-length

Bubble and line plots of NMFS EBS bottom survey size compositions for Tanner crab by sex and fishery region are shown in Figures 21-23. Distinct recruitment events (late 1970s, early 1990s, mid-2000s, early 2010s and possibly late 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 2017-2022, with perhaps some spillover to the eastern area lagged by a year at slightly larger sizes. However, the 2017-2019 cohorts seem to be absent from, or much reduced in, the 2021 and 2022 surveys. Based on the total abundance size compositions from the BSFRF-NMFS SBS studies (Figure 28 and 29), 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 does (e.g., Figure 28, 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 26. Given the large number of individuals sampled, 200 is the standard value 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.

f. Other time series data

Annual maturity ogives for new shell males, based on chela height collections from the NMFS EBS bottom trawl survey, are shown in Figure 24 (Table 28) for years in which chela heights were measured to 0.1 mm precision (i.e., since 2006). For each year, chela height:carapace width ratios for individual new shell crab were binned into 10 mm size bins, with the data split based on which management area (east or west of 166^{o}W longitude) it was collected in. The resulting histograms were analyzed to determine threshold sizes to discriminate mature from immature crab, and the fraction of mature crab was taken as the value of the resulting maturity ogive in the associated size bin (J. Richar, NMFS, pers. comm.). The area-specific ogives were combined to obtain one for the entire EBS by weighting each by the estimated abundance of new shell males in each area by size bin.

Annual effort in the snow crab and BBRKC fisheries is used in the model to "project" bycatch fishing mortality rates backward in time from the period when data on bycatch in these fisheries exists (1992-present; Tables 13-14).

Annual sex/size-specific curves describing empirical availability for the BSFRF SBS surveys relative to the NMFS EBS survey are illustrated in Figures 30 and 31 for males and females, respectively. Previous work suggested that fitting the NMFS survey data from the SBS study areas to estimate availability to the BSFRF gear led to confounding in the assessment because of the circular relationships among availability, catchability, and the SBS and EBS-level survey data, so these curves were determined outside the assessment model to break the confounding and allow the BSFRF SBS data to inform NMFS EBS-level survey catchability.

3. Data which may be aggregated over time

a. Growth-per-molt

Molt increment data collected for Tanner crab in the EBS in 2015-2017 and 2019 (Figure 25) is included in the parameter optimization for every model considered in this assessment and is assumed to reflect growth rates over the entire model period.

b. Weight-at size

Weight-at-size relationships used in the assessment model for males, immature females, and mature females are depicted in Figure 32.

c. Recruitment size distribution

The nominal size distribution at recruitment is illustrated in Figure 33.

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

Annual estimates of biomass and abundance in the NMFS EBS bottom trawl survey using VAST software were provided by Jon Richar (AFSC Kodiak). These estimates represent an alternative to the design-based expansion of survey catch data that is currently used to provide stock-level indices of abundance to the assessment. Recent attempts to fit the VAST estimates in the assessment model in place of the design-based ones (e.g., see the May 2021 CPT Report) has been have been problematic, at best. If the VAST estimates can be used with the assessment model, it is clear that this is not simply a matter of "plugging them in" in place of the design-based ones. A model acceptable to the CPT and SSC that uses the VAST estimates has yet to be developed.

Recent spatial patterns of catch and CPUE in the directed fishery and bycatch fisheries are presented in Appendix B, while patterns in the NMFS bottom trawl surveys are given in Appendix C. The assessment model does not explicitly consider space, so although these patterns may be informative in a holistic sense, they are not utilized directly in the assessment. There has been some suggestion that an extensive cold pool in the middle region of the EBS shelf may act to diminish relative Tanner crab densities in this region, particularly for mature males. The cold pool on the EBS shelf was extensive during the 2017 and 2022 surveys, and more or less absent during the 2018, 2019, and 2021 surveys, but the distribution of mature males did not change markedly.

The 1974 NMFS trawl survey was dropped entirely from the standardized survey dataset in 2015 due to inconsistencies in spatial coverage with the standardized dataset. Molt increment data from the Kodiak area in the Gulf of Alaska were not included in the assessment given the current use of molt increment data from the EBS to inform growth estimates. BSFRF survey data focused on Tanner crab recruitment (size compositions) have not yet been incorporated into the assessment.

E. Analytic Approach

1. History of modeling approaches for this stock

Prior to the 2012 stock assessment, Tanner crab was managed as a Tier-4 stock using a survey-based assessment approach (Rugolo and Turnock 2011b). The Tier 3 Tanner Crab Stock Assessment Model (TCSAM) was developed by Rugolo and Turnock and presented for review in February 2011 to the Crab Modeling Workshop (Martel and Stram 2011), to the SSC in March 2011, to the CPT in May 2011, and to the CPT and SSC in September 2011. The model was revised after May 2011 and the report to the CPT in September 2011 (Rugolo and Turnock 2011a) described the developments in the model per recommendations of the CPT, SSC and Crab Modeling Workshop through September 2011. In January 2012, the TCSAM was reviewed at a second Crab Modeling Workshop. Model revisions were made during the Workshop based on consensus recommendations. The model resulting from the Workshop was presented to the SSC in January 2012. Recommendations from the January 2012 Workshop and the SSC, as well as the authors' research plans, guided changes to the model. A model incorporating all revisions recommended by the CPT, the SSC and both Crab Modeling Workshops was presented to the SSC in March 2012.

In May 2012 and June 2012, respectively, the TCSAM was presented to the CPT and SSC to determine its suitability for stock assessment and the rebuilding analysis (Rugolo and Turnock 2012b). The CPT agreed that the model could be accepted for management of the stock in the 2011/12 cycle, and that the stock should be promoted to Tier-3 status. The CPT also agreed that the TCSAM could be used as the basis for rebuilding analyses to underlie a rebuilding plan developed in 2012. In June 2012, the SSC reviewed the model and accepted the recommendations of the CPT. The Council subsequently approved the SSC recommendations in June 2012. For 2011/12, the Tanner crab was assessed as a Tier-3 stock and the model was used for the first time to estimate status determination criteria and overfishing levels.

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. A detailed description of the 2013 model (TCSAM2013) is presented in Appendix 3 of the 2014 SAFE chapter (Stockhausen, 2014). Following the 2014 assessment, the model code was put under version control using "git" software.

The current model "framework", TCSAM02, was reviewed by the CPT and SSC in May/June 2017 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, 2016) was also added as an option when fitting size composition data, as was the ability to specify apply "tail compression" to the composition data.

In the past year, the ability to do multi-year projections under different fishing mortality rates was added to the model in response to CPT and SSC requests. 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.

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

2. Model Description

a. Overall modeling approach

TCSAM02 is a stage/size-based population dynamics model that incorporates sex (male, female), shell condition (new shell, old shell), and maturity (immature, mature) as different categories into which the overall stock is divided on a size-specific basis. For details of the model, the reader is referred to Appendix A.

In brief, crab enter the modeled population as recruits following a truncated size distribution based on the gamma probability distribution (see Figure 33 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, bycatch mortality in the bycatch fisheries, and bycatch size compositions in the bycatch fisheries. Data on growth in the EBS from observed molt increments are also (typically) fit.

b. Changes since the previous assessment

Multi-year projections under different fishing mortality rates were added to the model in response to CPT and SSC requests. Multi-year projections for each model scenario were run at 0, 0.25, 0.50, 0.75, 1.0, and 1.25 x the associated F_{OFL} . Several model scenarios this year were started in 1982 to eliminate the need to deal with gear changes in the NMFS EBS bottom trawl survey (among other issues). These models estimated the initial population numbers-at-size for 1982, rather than build up the population over an extended time period from zero using recruitment (as has been the standard approach to date).

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

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

3. Model Selection and Evaluation

a. Description of alternative model configurations

Ordinarily, the model selected for the 2021 assessment (Model 21.22a from Stockhausen, 2021) would provide the baseline model configuration against which subsequent alternative models would be evaluated in this assessment. However, the CPT and SSC approved the use of Model 22.01 as the baseline model for this assessment at their May and June, 2022 meetings (respectively) to simplify the evaluation process somewhat. Model 22.01 is identical to 21.22a with the exception that the estimates of Tanner crab bycatch in the groundfish fisheries since 2016/17 are based on the new expansion algorithm for observer data developed by the AKRO during the past year. The new algorithm had only minor effects on estimates of Tanner crab bycatch and a comparison between the two models presented to the CPT and the SSC in the spring found almost results were almost identical. Results from the 2021 assessment (using the label 21.22a) are included here simply to provide a contrast with the *combined effects* of the new data for 2021/22 and the revised groundfish bycatch data obtained using model 22.01. The following tables summarize the parameterization and time blocks for the biological, fishery, and survey processes incorporated in the base model, 22.01.

Table. Description of population processes and parameterization in the base model, 22.01.

process	time blocks	22.01 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. Description of model characteristics for retention and total catch in the directed ("TCF") fishery and bycatch in the snow crab ("SCF") fishery in the base model, 22.01.

Fishery/process	time blocks	22.01 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. Description of model characteristics for bycatch in the BBRKC ("RKF") and groundfish fisheries ("GF All") in the base model, 22.01.

Fishery/process	time blocks	22.01 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.

Table. Description of model characteristics for the NMFS and BSFRF surveys in the base model, 22.01.

Survey/process	time blocks	22.01 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	2016-2017	fixed at 1 for all sizes
male availability	2016-2017	empirically-determined outside the model
female catchability	2016-2017	fixed at 1 for all sizes
female availability	2016-2017	empirically-determined outside the model

Table. Description of model likelihood components in the base model, 22.01.

Model	Component	Type	included in optimization	Fits	Likelihood distribution
22.01	TCF: retained catch				
		biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	TCF: total catch				
		biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	SCF: total catch				
		biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	RKF: total catch				
		biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	GF All: total catch	abundance	yes	by sex	lognormal
		biomass	yes	by sex	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

Six alternative models, in addition to the base model 22.01, were evaluated in this assessment (Table H). Models 22.03, 22.07, and 22.08 were requested by the CPT at its May, 2022 meeting based on a review of a larger suite of candidate models. Together with the base, these three models form a progression, with each building on the previous model.

Table. Characteristics of models evaluated as part of this assessment.

model configuration	parent	number of parameters	changes to parent model
21.22a	--	346	--
22.01	21.22a	351	using updated bycatch estimates for the groundfish fisheries used in place of old versions; new fishery and survey data for 2021/22
22.03	22.01	351	fits to fishery catch data changed from sex-specific to aggregated, corresponding fits to size composition data changed to extended versions
22.07	22.03	409	Starting model in 1982, estimating initial population size using individual parameters on logistic scale, minimal smoothing on parameters, all data prior to 1982 dropped
22.08	22.07	409	using effective sample sizes estimated by bootstrapping as input sample sizes for NMFS survey data
22.09	22.01	353	added 2021/22 as new time block for retention functions in the directed fishery
22.10	22.03	353	added 2021/22 as new time block for retention functions in the directed fishery
22.11	22.07	411	added 2021/22 as new time block for retention functions in the directed fishery

Model 22.01 describes fishery capture rates for females as proportional to those for males and fits the catch biomass data from the crab fisheries separately by sex using lognormal likelihoods. This combination results in the model minimizing the likelihood by balancing the proportional errors in fitting the data by sex. Because male catch biomass is typically much larger than that for females, the result is that the errors in model fits to male catch biomass are much larger on an absolute scale than the errors in model fits to female catch biomass, even though the errors are similar (and of opposite sign) on a proportional scale. However, it is important to fit the catch data well on an absolute scale in order to accurately quantify removals (mortality) due to fishing. Thus, Model 22.03 differs from 22.01 by fitting to fishery catch biomass data aggregated across sexes, rather than by sex. Lognormal likelihoods are still used to characterize the error in fitting the data, but proportional errors in the fit to the total are now minimized rather than proportional errors to the fits by sex.

Model 22.07 incorporates the changes in Model 22.03 from 22.01, but initializes the model in 1982 by estimating the distribution of population numbers-at-size by sex, maturity state, and shell condition whereas 22.03 and 22.01 build up the population using estimated recruitment over a "burn in" period starting in 1948 (with the first fishery data to inform the model starting in 1965 and the first survey data starting in 1975). Starting the model in 1982 is conceptually appealing principally because the model no longer has to account for the change in NMFS survey gear between 1981 and 1982, but also because the survey footprint varied fairly substantially between 1975 and 1982 and because the accuracy of the early fishery data is questionable. Model 22.08 builds on 22.07 by using input sample sizes for NMFS survey size compositions based on effective sample sizes estimated through bootstrapping (similar to Model 22.02 presented at the May, 2022 CPT Meeting).

The author added models 22.09, 22.10, and 22.11 after reviewing the 2021/22 size composition data from the directed fishery. These data suggested that retention practices in the directed fishery may have been different in 2021/22 compared with other recent years, such that a higher percentage of males smaller than the "industry-preferred" size of 125 mm CW that were retained in the past year. The three models build off 22.01, 22.03, and 22.07 respectively by estimating a logistic retention function that appliesonly to 2021/22 whereas the "parent" models estimate a logistic retention function that applies to the 2013/14-2021/22 period.

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

The change in results from 21.22a to 22.01 due strictly to changes in the bycatch estimates by AKRO for Tanner crab in the groundfish fisheries dating back to 2017 were documented in the Tanner Crab Report to the CPT in May 2022 (Stockhausen, 2022a). The changes in the estimates for Tanner crab only propagated back to 2017 and were small in both relative (< 3%) and absolute terms (< 4 t) for data included in the assessment (i.e.,aggregated to the EBS; Table 2 in Stockhausen, 2022b). With parameter estimates initialized using the final model estimates from the 2021 assessment, the model's optimization criteria were met within a few iterations, resulting in identical values, for all practical purposes, to the assessment. Changes in management-related quantities (e.g., average recruitment, F_MSY, and the OFL) were less than 0.01% (Figure 6 in Stockhausen, 2022b).

The addition of the 2021/22 fishery and survey data to Model 22.01 resulted in small changes (<3%) to equilibrium-related management quantities (average recruitment [$AvgRec$], B_{100}, F_{MSY}, MSY) and (as one would expect) somewhat larger changes (up to 23%) in OFL-related quantities (OFL, projected MMB [$prjB$]), as documented in the following table:

Table. Characteristics of models evaluated as part of this assessment.

type	units	21.22a	22.01	change	% change
avgRec	millions	396.899	401.045	4.14608	1.045
B100	1,000's t	103.632	101.084	−2.54801	− 2.459
Bmsy	1,000's t	36.271	35.379	−0.89180	− 2.459
Fmsy	per yr	1.188	1.152	−0.03644	− 3.067
MSY	1,000's t	16.841	16.556	−0.28427	− 1.688
Fofl	per yr	1.188	1.152	−0.03644	− 3.067
OFL	1,000's t	27.199	33.546	6.34679	23.335
prjB	1,000's t	42.777	48.681	5.90365	13.801

The rather large increase in OFL from 2021/22 to 2022/23 (from 27.2 t to 33.5 t) was driven primarily by continuation into 2022 of an increasing trend in estimated population abundance/biomass that began in 2016 for immature crab and in 2019 for mature crab in both models, the results primarily of higher-than-average estimated recruitment in 2016, 2018, and 2020 in both models (Figure 34). The scale of these recruitment events is somewhat smaller in 22.01 than 21.22a, likely the result of 22.01 better matching (although still overestimating) the 2019 and 2021 NMFS survey biomass estimates (Figure 35).

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

Models 22.07, 22.08, and 22.11 provide an alternative starting point (1982) for the assessment model that reduces the complexity of the model by eliminating 1) the need to estimate a separate survey catchability coefficient and selectivity function for NMFS survey data prior to 1982; 2) the need to fit historical fishery data of questionable accuracy in the 1960's and '70's; and 3) the need to build up the population from zero abundance using highly uncertain estimates for recruitment uninformed by survey data. Making these changes eliminated 67 estimated parameters. However, it also requires that the initial numbers at size by sex, maturity state, and shell condition be estimated, adding 125 estimated parameters and increasing the complexity of the model. On balance, this ended up increasing the number of model parameters by 58, and thus the model complexity.

d. Convergence status and convergence criteria

Convergence to the MLE was evaluated for each model 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 model 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, a sizeable fraction of the runs should achieve the minimum. For this assessment, convergence was partially evaluated by making 800 jitter runs for each model to find the parameter values that resulted in the model's minimum objective function value (i.e., maximum likelihood value). Other factors that were considered were the maximum parameter gradient at model convergence, and whether it was possible to obtain the parameter covariance matrix and uncertainty estimates for parameters and derived quantities by inverting the model hessian.

Summary convergence diagnostics are given in the following table:

Table. Summary convergence diagnostics for all models.

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?
21.22a	--	--	346	--	--	0	3014	5.92E-04	yes
22.01	21.22a	using updated bycatch estimates for the groundfish fisheries used in place of old versions; new fishery and survey data for 2021/22	351	800	731	0	3077	1.98E-03	yes
22.03	22.01	fits to fishery catch data changed from sex-specific to aggregated, corresponding fits to size composition data changed to extended versions	351	800	710	1	3045	2.92E-03	yes
22.07	22.03	Starting model in 1982, estimating initial population size using individual parameters on logistic scale, minimal smoothing on parameters, all data prior to 1982 dropped	409	800	537	1	2943	2.69E-03	yes
22.08	22.07	using effective sample sizes estimated by bootstrapping as input sample sizes for NMFS survey data	409	800	772	3	3602	6.22E-04	yes
22.09	22.01	added 2021/22 as new time block for retention functions in the directed fishery	353	800	788	0	3072	1.39E-03	yes
22.10	22.03	added 2021/22 as new time block for retention functions in the directed fishery	353	800	794	1	3039	8.65E-03	yes
22.11	22.07	added 2021/22 as new time block for retention functions in the directed fishery	411	800	522	1	2938	2.49E-03	yes

All models appeared to converge to a minimum solution, with over 50% of the jittered model runs converging to essentially the same solution. All maximum gradients were less than 0.01, and it was possible to invert the model hessian and obtain uncertainty estimates for parameters and derived quantities. Models 22.01 and 22.09 converged with no estimated parameters at bounds, while the other models–with the exception of Model 22.08–converged with one parameter at a bound (Table 33).

e. Sample sizes assumed for the compositional data

"Raw" (number of measured individuals) sample sizes for survey size compositions are listed in Tables 26 and 27. Except in model 22.08, 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. Effective sample sizes estimated using a bootstrapping approach (Appendix ??) were used as input sample sizes for NMFS survey data in Model 22.08.

Raw and input sample sizes used for fishery-related size composition data are listed in Tables 15-17. The maximum input sample size for fishery data was set to 200. Otherwise, input sample sizes were scaled as described in Stockhausen (2014, Appendix 5) 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.

f. Parameter sensibility

Parameters estimated at a bound are listed in Table 33. Values for all estimated parameters are listed in the following tables:

- 34: parameters for recruitment, growth, and natural mortality
- 35: ln-scale recruitment deviations prior to 1975
- 36: ln-scale recruitment deviations after 1974
- 37: logistic-scale initial numbers-at-size parameters
- 38: logistic-scale parameters for the probability of undergoing the molt-to-maturity
- 39: non-vector parameters related to fishing mortality rates, retention, survey catchability, and the Dirichlet-Multinomial lilekihood
- 40: ln-scale fishing mortality devs for the directed fishery
- 41: ln-scale fishing mortality devs for bycatch in the snow crab fishery
- 42: ln-scale fishing mortality devs for bycatch in the BBRKC fishery
- 43: ln-scale fishing mortality devs for bycatch in the groundfish fisheries
- 44: "pS1" selectivity parameter values
- 45: "pS2" selectivity parameter values
- 46: "pS3" and "pS4" selectivity parameter values, and
- 47: dev parameters for size-at-50% selected for males in the directed fishery

Models 22.01 and 22.09 did not exhibit any parameters estimated at either of the bounds placed on them (Table 33). The remaining models had at least one parameter estimated at a bound; all of these parameters were related to the slope or width (essentially the inverse of the slope) of a selectivity curve. The slope parameter for the logistic function used to describe the size-specific probability of retaining male crab in the directed fishery during the 2005/06-2009/10 period (pS2[28]) was estimated at its upper bound in Models 22.03 and 22.10. Similarly, the slope parameter for the retention function in the period prior to 1991 (pS2[3]) was estimated at its upper bound in Models 22.03 and 22.10. Finally, three parameters were estimated at their upper bounds in Model 22.08: the slope parameter pS2[3], the slope parameter for the retention function during 1991-1996 (pS[4], incorrectly labeled "slope for TCF retention 1997+" in Table 33), and the width (inverse slope) of the ascending half-normal function used to describe selectivity for females in the NMFS EBS shelf survey after 1981 (pS2[2]). That the retention function slope parameters pS2[3] and pS2[28] are hitting their upper bounds indicates that the models are estimating retention as essentially knife-edged in the associated time period–all males smaller than a cutoff are discarded and all males larger than the cutoff are retained. The corresponding parameters in the other models may not be at the upper bound, but they are certainly close (Table 45). All could probably be fixed at the upper limit (i.e., simply assume knife-edged retention, allowing the model to estimate the size at which it occurs) and not impact model results substantially. That 22.08 estimates pS2[2] at its upper bound is more problematic, because this would be consistent with NMFS survey selectivity for females after 1981 approaching non-size selectivity, which does not seem terribly credible given that the survey appears to be size selective for males over the range of female sizes.

Most of the parameters in the models appear to be estimated at reasonable values, and with reasonable uncertainty estimates. The "historical" recruitment devs (rec devs prior to 1975, Table 35) in Models 22.01, 22.03, 22.09, and 22.10 exhibit large confidence intervals, but have no survey data, and little fishery data, to inform the estimates. Similarly, the ln-scale fishing mortality devs estimated in these models prior to 1975 (the first year NMFS survey data is available) exhibit some fairly large values (e.g. at indices 6 and 7 in Table 40 for the directed fishery) and confidence intervals (e.g., at indices 5 and 8 in the same table, as reflected in the estimated standard deviation). The parameters describing the size at full selection for female bycatch in the BBRKC fishery in the periods 1997-2004 and after 2004 also exhibit fairly large confidence intervals across all models (Table 44). All the models suggest fully-selected survey catchability in the standard NMFS EBS survey is small for both sexes (< 0.5 for males, < 0.3 for females), but Model 22.08 suggests these values are even smaller. The values estimated by the majority of the models, while low, are consistent with NMFS survey selectivity estimated outside the model using data from the BSFRF side-by-side studies (an analysis that remains to be finished pending release of the 2018 study data to the author), but the values estimated by Model 22.08 are pushing the bounds of credibility.

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

The first hurdles used to choose among the alternative models were lack of convergence issues, minimization of the number of parameters estimated at bounds, the reasonableness of the parameters and derived quantities, and fits to the data. Retrospective patterns were examined for all the models, and the associated Mohn's rho statistics for recruitment and MMB estimates were compared among the models.

h. 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 all models. Residuals from models that fit the data in similar fashion were compared on the same plot, but not all models fit the data in the manner (e.g., 22.01 and 22.03 employed different fits to the fishery catch biomass data). 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.

i. Objective function values

Objective function values related to data are listed for all models in Table 48, with differences relative to Model 22.01 listed in Table 49. It should be noted, though, that a number of the values are not comparable between different models, so caution is advised when interpreting apparent differences between the models. Fits to catch biomass and size compositions are not comparable between Models 22.01 and 22.3. Models 22.07, 22.08, and 22.11 do not fit data prior to 1982, so these cannot be directly compared with Models 22.01 and 22.03 as to goodness-of-fit based on these values. In similar fashion, the weighting on survey size compositions in Model 22.08 differs from the other models, so these are not directly comparable.

Objective function values related to non-data components are listed for all models in Table 50, with differences relative to Model 22.01 listed in Table 51. The most notable differences among the models are related to the priors put on NMFS survey catchability, with large differences between Models 22.07, 22.08, and 22.11 and the others, but these differences reflect the absence of the early survey time period and associated priors on catchability in these models.

j. Evaluation of the model(s)

No models were distinguished in terms of convergence issues–all appeared to be similarly well-behaved (and much better behaved than models in previous assessments). Model 22.08 stood out from the others as a less desirable candidate because it had more parameters (3) estimated at a bound than the others, which had a maximum of one parameter estimated at a bound. Estimated catchability coefficients for the NMFS survey were smaller in 22.08 than the other models while estimated characteristics for population processes (natural mortality, growth, maturation) were similar; consequently recruitment and mature biomass time series exhibited somewhat higher scales relative to the other models. As noted previously, the fully-selected survey catchability estimates for the standard NMFS survey in Model 22.08 appear less credible than the estimates from the other models, based on an independent (but incomplete) analysis of survey catchability using the BSFRF side-by-side study data. Furthermore, model-estimated effective sample sizes for male size composition data in the NMFS survey suggest that this data is over-weighted in Model 22.08 (it uses the bootstrapped effective sample sizes as input sample sizes) but more appropriately weighted in the other models.

Excluding Model 22.08 from further consideration, then, the remaining models yield remarkably similar fits to the data and estimated population characteristics.

That said, Models 22.07 and 22.11 involve more than 50 more parameters than the other models in order to estimate initial numbers-at-size in the 6 sex/maturity state/shell condition categories used in the model in 1982, making them somewhat more likely to exhibit convergence issues. In addition, because no data is fit by shell condition in the current models, the estimated initial abundances of new shell and old shell mature crab are identical. Although this flaw disappears after a few years of recruitment and growth in the models, it constitutes a further "strike" against these models (at least until they do not aggregate over shell condition in model fits). Of the remaining models, Models 22.09 and 22.10 are somewhat problematic from a procedural standpoint in that: 1) the rationale for adding this additional time block is not strong (the move to retention of smalller crab by some elements of industry has not been universally adopted, justifying an additional time block), 2) the best approach to including the new time block in projecting forward to determine the OFL is unclear, and 3) these are not models the CPT has had a chance to review before. Given these considerations, the improvements in fit in Models 22.09 and 22.10 due to estimating an additional retention time block specific to 2021/22 do not seem to be large enough to justify adopting either of these models at this time.

Of the remaining two models, 22.01 and 22.03, the latter has the advantage that it eliminates the "tail-wagging-the-dog" phenomenon of associated with Model 22.01's tendency to balance relative, rather than absolute, errors in fitting sex-specific catch biomass time series in the crab fisheries. Because catch of females tends to be much smaller than males, balancing the relative errors will increase the absolute errors and thus reduce the accuracy in accounting for fishery-related mortality on the population.

4. Results (best model(s))

Model 22.03 was selected as the author's preferred model for the 2022 assessment, as discussed in detail at the end of the previous section. Results are presented here for Model 22.01, as well. Results for all models are available in a separate appendix.

a. 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 use them 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 15-17.
Observed sample sizes for survey data are listed in Tables 26, 27, and 31. Input sample sizes for survey 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 18 and 19). For fishery-related catch data, the following CV's and minimum standard deviations were assumed to apply:

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

b. Tables of estimates

i. All parameters Parameters estimated at a bound are listed for each model in 33. Parameter estimates and associated standard errors, based on inversion of the converged model's Hessian and the "delta" method, are listed in 34-47.

ii. 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 52 and and 53 for the base model, 22.01, and the preferred model, 22.03.

iii. 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 54-73 for the base and preferred models. Model-estimated values for survey abundance and biomass for the NMFS EBS shelf survey and BSFRF SBS surveys are documented in Tables 74-85. Model-estimated values for annual population abundance and biomass are given by sex, maturity state, and shell condition in Tables 86-89. Model estimates for mature male and female biomass at the time of mating are listed in Tables 90-91.

iv. Recruitment time series Model estimates for recruitment are given in Tables 92 and 93 for the base and preferred models.

v. 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 94-95.

c. Graphs of estimates

i. 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 36, while the associated selectivity functions are illustrated in 37- 39. The estimates of size-selective retention of males captured in the directed fishery are presented in 40. 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 41-43.

ii. Estimated survey catachability and selectivities Graphs of estimated sex-specific survey catchability and the associated selectivity functions for the NMFS EBS survey are shown in Figure 44. Assumed survey availability curves for the BSFRF side-by-side catchability studies are illustrated in Figure 45. 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.

iii. 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 46, 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 is illustrated in Figures 48 and 47.

iv. Estimated population-related time series (male, female, mature male, total and effective mature biomass time series) Estimated time series for recruitment and MMB are shown in Figures 49 and 50. Time series of abundance by sex and maturity state are illustrated in Figure 51.

v. Estimated fishing mortality versus estimated spawning stock biomass Estimated total fishing mortality (retained + discards) is plotted against spawning stock biomass (MMB) for the author's preferred model, 22.03, in Figure 52.

vi. Fit of a stock-recruitment relationship, if feasible Fits to a stock-recruit relationship were not evaluated.

e. Evaluation of the fit to the data

i. Graphs of the fits to observed and model-predicted catches Fits to the observed and model-predicted fishery catch data are presented in Figures 53-64 for the base (22.01) and preferred (22.03) models. Residuals to the fits and summary statistics are also shown on each figure. Fits to total catch/bycatch data from the crab fisheries are shown on different figures for the two models because 22.01 fits the data by sex and 22.03 fits the total catch. Both models fit to total bycatch data from the groundfish fisheries. Graphs of fits to observed catches from the directed fishery are presented in Figures 53-56 for retained catch and total catch. Fits to bycatch data from the snow crab fishery are shown in Figures 57-59. Fits to bycatch data from the BBRKC fishery are shown in Figures 60-62. Fits to bycatch data from the groundfish fisheries are shown in Figures 63-64.

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 65. Residuals to the fits and summary fit statistics are shown in Figures 66-69.

ii. Graphs of model fits to survey numbers 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 70. Residuals to the fits and summary fit statistics are shown in Figures 71-74. Note that these fits are not included in the model objective function but serve as an independent diagnostic of model fit.

iii. 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 75. Model fits to maturity ogive data from the NMFS EBS shelf survey are presented in Figure 76, while Pearson's residuals to the fits are shown in Figure 77.

iv. 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 78-111 for the base (22.01) and preferred (22.03) models.
Fits to the catch/bycatch size composition data from the crab fisheries are shown on different figures for the two models because 22.01 normalizes the data separately by sex and fits the resulting proportions separately by sex while 22.03 normalizes the data across sexes and fits the resulting proportions jointly. Both models fit the bycatch size composition data from the groundfish fisheries by normalizing it data across sexes and fitting the resulting proportions jointly. Graphs for the directed fishery are given in Figures 78-89. Graphs for the snow crab fishery are given in Figures 90-89. Graphs for the BBRKC fishery are given in Figures 98-105. Graphs for the groundfish fisheries are given in Figures 106-111.

v. 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 112-125 for the base (22.01) and preferred (22.03) models.

vi. Marginal distributions for the fits to the compositional data Marginal distributions for fits to the compositional data from the fisheries are shown in Figures 126-129. Marginal distributions for fits to the compositional data from the surveys are shown in Figure 130.

vii. 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 131-135. Similar plots for the survey compositional data are given in Figure 136.

viii. 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 96, 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.

ix. 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 are not available for this assessment.

f. Retrospective and historic analyses

i. Retrospective analysis (retrospective bias in base model or models) Retrospective analyses were conducted for the base and preferred models (22.01 and 22.03, respectively). The analysis used 9 peels (ending in 2013), with the model re-fit after each removal of the previous peel's terminal year's data. The analysis was limited to 2013-2022 because no BSFRF SBS surveys for Tanner crab are available before 2013. For each model, 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. Relative bias in the terminal year estimates was quantified using Mohn's rho (Mohn, 1999). The retrospective patterns donn't indicate any apparent problems with MMB, but additional data (decreasing the number of peels) always reduces the estimates of recruitment (Figures 137 and 138). Mohn's rho for the recruitment patterns was 0.41 for both models, while the values for MMB were -0.002 and -0.005 for the base and preferred models, respectively.

ii. 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, 22.03, are compared with those from previous assessments in Figures 139 and 140. 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.

g. 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.

F. Calculation of the OFL and ABC

1. Status determination and OFL calculation

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

The (total catch) OFL for 2021/22 was 27 thousands t thousand t while the total catch mortality was 0.783 thousands t, based on applying mortality rates of 1.000 for retained catch, 0.321 to bycatch in the crab fisheries, and 0.800 to bycatch in the groundfish fisheries to retained catch data and estimates of discards from the author's preferred model, 22.03(Tables 57, 61, 65, 69, and 73). Therefore overfishing did not occur.

Amendment 24 to the NPFMC fishery management plan (NPFMC 2007) revised the definitions for overfishing for EBS crab stocks. The information provided in this assessment is sufficient to estimate overfishing limits for Tanner crab under Tier 3. The OFL control rule for Tier 3 is (see Figure 141 for a graphical representation):

Table. OFL control rule.

B, $F_{35\%}^*$, $B_{35\%}^*$	**3**	a. $\frac{B}{B_{35\%^*}} > 1$	$F_{OFL} = F_{35\%}^*$	
		b. $\beta < \frac{B}{B_{35\%}^*} \leq 1$	$F_{OFL} = F^*_{35\%} \frac{\frac{B}{B^*_{35\%}} - \alpha}{1-\alpha}$	ABC≤(1-b$_y$) * OFL
		c. $\frac{B}{B_{35\%}^*} \leq \beta$	*Directed fishery F = 0* $F_{OFL} \leq F_{MSY}^{\dagger}$	

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 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 2022/23 require estimates of $B = MMB_{2022/23}$ (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 141). 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 MCMC, one can thus 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 2020).

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 terminal year recruitment, which was subsequently dropped from the averaging time frame. The missing survey continues to influence recruitment estimates near the end of the time series. Last year, the estimate for recruitment entering the population on July 1, 2020 was extremely small in all the models considered, except the accepted model: the associated ln-scale recruitment deviation hit its lower bound in all models. In the accepted model las t year (21.22a), a mild prior was used to prevent the extreme results obtained in the other models. Simulation testing (Stockhausen, 2021, Appendix J) indicated similar effects associated with the missing survey might continue with diminishing effect over several years. Low recruitment in 2020 was again estimated in all models this year (all applied a mild prior to miniimize a parameter on the bound, as in 21.22a). However, the low estimated recruitment also appears to be consistent with size compositions from the NMFS EBS shelf survey over the past two years and the subsequent recruitment values and associated uncertainties do not raise any concerns. Consequently, there does not seem to a strong rationale for changing from the manner in which the time period was determined last year. Consequently, average recruitment for the preferred model was calculated using the period 1982-2021, dropping the terminal year.

The value of $\bar{R}$ for this period from MCMC runs of the author's preferred model is 395.77 million. This estimate of average recruitment is similar to that from the 2021‘ assessment model (389.88 million). The value of $B_{MSY} = B_{35\%}$ for $\bar{R}$ is 35 thousands t, which is somewhat smaller than that obtained in the 2021 assessment (35.94 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. In the absence of uncertainty, the OFL would then be the predicted total catch taken when fishing at $F = F_{OFL}$. When uncertainty (e.g. assessment uncertainty, variability in future recruitment) is taken into account, the OFL is taken as the median total catch mortality when fishing at $F = F_{OFL}$.

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

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

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, 2022 as estimated by the assessment model.

Assessment model uncertainty can be included in the calculation of OFL using MCMC. Conceptually, a random draw from the assessment model's joint posterior distribution for the estimated parameters was taken, and the $\bar{R}$, B0, F_{MSY}, B_MSY, F_{OFL}, OFL, and "current" MMB for 2022/23 were calculated based on the resulting parameter values. This should be repeated a large number of times to approximate the distribution of OFL given the full model uncertainty. For this assessment, however, ADMB's sd_report facility was used to estimate the uncertainty in the OFL via the "delta" method to obtain an estimate of its standard error.

As such, the OFL for 2022/23 from the author's preferred model (22.03) is 33 thousands t (Figure 144).

The B_{MSY} proxy, $B_{35\%}$, from the author's preferred model is 35 thousands t , so $MSST = 0.5 \cdot B_{MSY}$ = 17 thousands t. Because the current B = 62 thousands t > MSST, the stock is not overfished. Because the projected B = 48 thousands t > B_{MSY}, the stock falls into Tier 3a. The population state (directed F vs. MMB) is plotted starting in in Figure 145 against the Tier 3 harvest control rule.

2. ABC calculation

Amendments 38 and 39 to the Fishery Management Plan (NPFMC 2010) established methods for the Council to set Annual Catch Limits (ACLs). The Magnuson-Stevens Act requires that ACLs be established based upon an acceptable biological catch (ABC) control rule that accounts for scientific uncertainty in the OFL such that ACL=ABC and the total allowable catch (TAC) and guideline harvest levels (GHLs) be set below the ABC so as not to exceed the ACL. ABCs must be recommended annually by the Council's SSC.

Two methods for establishing the ABC control rule are: 1) a constant buffer where the ABC is set by applying a multiplier to the OFL to meet a specified buffer below the OFL; and 2) a variable buffer where the ABC is set based on a specified percentile (P^*) of the distribution of the OFL that accounts for uncertainty in the OFL. P^* is the probability that ABC would exceed the OFL and overfishing occur. In 2010, the NPFMC prescribed that ABCs for BSAI crab stocks be established at P^*=0.49 (following Method 2). Thus, annual ACL=ABC levels should be established such that the risk of ovefishing, P[ABC>OFL], is 49%. In 2014, however, the SSC adopted a buffer of 20% on OFL for the Tanner crab stock for calculating ABC. Here, ABCs are provided based on both methods.

For the author's preferred model, 22.03, the P^* ABC (ABC_{max}) is 33 thousands t while the 2 0% Buffer ABC is 25 thousands t. The author remains concerned that the OFL calculation, based on F35% 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 F35% 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 ABC. Consequently, the author's recommended ABC is 25 thousands t.

The following tables summarize the OFL/ABC results for model 22.03:

Table. Management quantities (in 1,000s t) based on the author's preferred model, 22.03. TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	15.15	64.09	1.13	1.13	2.37	25.42	20.33
2018/19	20.54	82.61	1.11	1.11	1.90	20.87	16.70
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	NA	47.58	NA	NA	NA	32.81	24.61

Table. Management quantities (in millions of pounds) based on the author's preferred model, 22.03. TAC is summed across ADFG management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	33.40	95.49	2.50	2.50	5.22	56.03	44.83
2018/19	45.27	182.09	2.44	2.44	4.18	46.01	36.82
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	NA	104.88	NA	NA	NA	72.34	54.25

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 base model (Figure 146) and the author's preferred model (Figure 146). For each model, 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 randomly recruitments randomly resampled from the model-estimated recruitment time series for 1982 to 2020 (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–as might be appropriate in an MSE context. While the stock appears to approach its expected equilibrium biomass when fishing at $f \cdot F_{MSY}$ (where f is the multiplier) in about 15 years, the trajectories are quite different in the first few years but all then exhibit a rapid increase in biomass (along with an expansion of realized biomass levels) that reflects .

G. Rebuilding Analyses

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

H. Data Gaps and Research Priorities

Information on growth-per-molt has been collected in the EBS on Tanner crab and incorporated into the assessment. 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 166o 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 survey data to the assessment author.

Development of a GMACS version of the Tanner crab model is also a priority and will proceed now that a GMACS model for snow crab has been developed.

I. Ecosystem Considerations

Mature male biomass is currently used as the "currency" of Tanner crab spawning biomass for assessment purposes. However, its relationship to stock-level rates of egg production, 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, 2012), suggesting a climatic driver.

1. Ecosystem Effects on Stock

Time series trends in prey availability or abundance are generally unknown for Tanner crab because typical survey gear is not quantitative for Tanner crab prey. On the other hand, Pacific cod (*Gadus macrocephalus*) is thought to account for a substantial fraction of annual mortality on Tanner crab (Aydin et al., 2007). 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.

2. Effects of Tanner crab fishery on ecosystem

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

Table. Potential effects of the Tanner crab fishery on the ecosystem.

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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List of Tables

List of Figures

Tables

Table 1: Retained catch (males, in t) in the directed Tanner crab fisheries during the period when foreign fleets were allowed to fish. Fishing by foreign fleets ended in 1979/80.

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

Table 2: Retained catch (males, t) in the US domestic pot fishery from 1968 to 2004/05 (Fitch et al., 2012). Total crab caught and total harvest include deadloss. The "Fishery Year" YYYY/YY+1 runs from July 1, YYYY to June 30, YYYY+1. The ADFG year (in parentheses, if different from the "Fishery Year") indicates the year ADFG assigned to the fishery season in compiled reports.

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

Table 3: Federal fishery management quantities (OFL, ABC), State of Alaska TACs, and retained catch biomass in the directed Tanner crab following crab fishery rationalization (FMP Amendments 18 and 19, 2005). Revised OFL definitions were approved in 2008; ABCs were not established until 2011 (FMP Amendment 38). TACs set to 0 indicate closure of the directed fishery in the associated State management area.

	OFL	ABC	TAC (mt)			Harvest (mt)			TAC (lbs)			Harvest (lbs)		
year	(mt)	(mt)	East 166W	West166W	total	East 166W	West166W	total	East 166W	West166W	total	East 166W	West166W	total
2005/06	--	--	0	735	735	0	245	245	0	1,620,000	1,620,000	0	539,105	539,105
2006/07	--	--	851	496	1,347	631	156	787	1,875,000	1,093,900	2,968,900	1,391,617	342,888	1,734,505
2007/08	--	--	1,563	987	2,550	710	151	861	3,444,900	2,176,000	5,620,900	1,565,270	333,144	1,898,414
2008/09	7,040	--	1,253	697	1,951	807	47	854	2,763,100	1,537,100	4,300,200	1,778,806	103,963	1,882,769
2009/10	2,270	--	612	0	612	592	0	592	1,350,100	0	1,350,100	1,306,055	0	1,306,055
2010/11	1,610	--	0	0	0	0	0	0	0	0	0	0	0	0
2011/12	2,750	2,480	0	0	0	0	0	0	0	0	0	0	0	0
2012/13	19,020	8,170	0	0	0	0	0	0	0	0	0	0	0	0
2013/14	25,350	17,820	664	746	1,410	654	594	1,248	1,463,000	1,645,100	3,108,100	1,442,420	1,308,701	2,751,121
2014/15	31,480	25,180	3,847	3,005	6,852	3,829	2,369	6,198	8,480,100	6,625,100	15,105,200	8,442,125	5,222,067	13,664,192
2015/16	27,190	21,750	5,113	3,808	8,921	5,108	3,770	8,878	11,272,000	8,396,100	19,668,100	11,260,586	8,312,120	19,572,706
2016/17	25,610	20,490	0	0	0	0	0	0	0	0	0	0	0	0
2017/18	25,420	20,330	0	1,134	1,134	0	1,117	1,118	0	2,500,300	2,500,300	262	2,463,626	2,463,888
2018/19	20,870	16,700	0	1,106	1,106	0	1,104	1,104	0	2,439,000	2,439,000	0	2,433,686	2,433,686
2019/20	28,860	23,090	0	0	0	0	0	0	0	0	0	0	0	0
2020/21	21,130	16,900	0	1,065	1,065	0	655	655	0	2,348,000	2,348,000	0	1,444,410	1,444,410
2021/22	27,170	21,740	0	499	499	0	494	494	0	1,100,000	1,100,000	0	1,088,024	1,088,024

Table 4: Retained catch abundance and biomass in the directed Tanner crab (TCF), snow crab (SCF), and BBRKC (RKF) fisheries since 2005. The directed fishery was completely closed from 2010/11 to 2012/13, as well as in 2016/17 and 2019/20. Legal-sized Tanner crab can be incidentally-retained in the snow crab and BBRKC fisheries up to a cap of 5% the target catch. “year” indicates crab fishery year.

	TCF						SCF		RKF	
	West 166W		East 166W		all EBS		all EBS		all EBS	
year	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)	Abundance	Biomass (kg)
2005	255,859	244,534	0	0	255,859	244,534	188,118	187,689	0	0
2006	164,719	155,532	581,024	631,228	745,743	786,760	175,904	171,439	4,456	4,593
2007	151,525	151,112	677,661	709,995	829,186	861,107	90,148	86,478	7,830	7,978
2008	48,171	47,157	758,002	806,854	806,173	854,011	3,300	2,535	20,896	23,235
2009	0	0	476,668	592,417	476,668	592,417	2,544	1,714	6,751	8,402
2010	0	0	0	0	0	0	1,689	1,154	6	3
2011	0	0	0	0	0	0	3,095	2,092	0	0
2012	0	0	0	0	0	0	1,643	1,111	4	3
2013	722,469	593,617	704,201	654,271	1,426,670	1,247,888	13,256	9,882	5,842	6,322
2014	3,121,442	2,368,693	4,378,199	3,829,288	7,499,641	6,197,981	19,512	14,458	3,691	3,792
2015	4,817,144	3,770,319	5,998,876	5,107,722	10,816,020	8,878,041	39,012	30,253	1,386	1,350
2016	0	0	0	0	0	0	1,733	1,177	33	21
2017	1,322,542	1,117,483	139	119	1,322,681	1,117,602	17,688	15,018	25	17
2018	1,376,977	1,103,903	0	0	1,376,977	1,103,903	4,013	3,409	18	12
2019	0	0	0	0	0	0	125	84	0	0
2020	870,634	655,174	0	0	870,634	655,174	3,017	2,328	1	1
2021	782,983	493,520	0	0	782,983	493,520	970	763	0	0

Table 5: Total catch biomass (retained + discarded) of Tanner crab in various fisheries, as estimated from observer data, prior to 1992. Discard mortality has not been included. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries. All catch in the directed fishery prior to 1991 is retained catch.

	TCF		SCF		RKF		GF			all fleets
	crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	all EBS		all EBS		all EBS		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1965	1,920.0	–	–	–	–	–	–	–	–	1,920.0
1966	2,440.0	–	–	–	–	–	–	–	–	2,440.0
1967	13,590.0	–	–	–	–	–	–	–	–	13,590.0
1968	18,010.0	–	–	–	–	–	–	–	–	18,010.0
1969	27,490.0	–	–	–	–	–	–	–	–	27,490.0
1970	25,500.0	–	–	–	–	–	–	–	–	25,500.0
1971	20,720.0	–	–	–	–	–	–	–	–	20,720.0
1972	16,900.0	–	–	–	–	–	–	–	–	16,900.0
1973	13,030.0	–	–	–	–	–	–	–	17,735.5	30,765.5
1974	15,360.0	–	–	–	–	–	–	–	24,448.6	39,808.6
1975	17,660.0	–	–	–	–	–	–	–	9,407.5	27,067.5
1976	30,020.0	–	–	–	–	–	–	–	4,699.2	34,719.2
1977	35,530.0	–	–	–	–	–	–	–	2,776.0	38,306.0
1978	21,090.0	–	–	–	–	–	–	–	1,868.8	22,958.8
1979	19,000.0	–	–	–	–	–	–	–	3,397.4	22,397.4
1980	13,426.3	–	–	–	–	–	–	–	2,113.7	15,540.1
1981	4,989.5	–	–	–	–	–	–	–	1,474.2	6,463.7
1982	2,390.4	–	–	–	–	–	–	–	449.1	2,839.5
1983	548.8	–	–	–	–	–	–	–	671.3	1,220.2
1984	1,428.8	–	–	–	–	–	–	–	644.1	2,072.9
1985	–	–	–	–	–	–	–	–	399.2	399.2
1986	–	–	–	–	–	–	–	–	648.6	648.6
1987	997.9	–	–	–	–	–	–	–	639.6	1,637.5
1988	3,179.7	–	–	–	–	–	–	–	462.7	3,642.3
1989	11,113.0	–	–	–	–	–	–	–	671.3	11,784.3
1990	18,189.1	–	7,081.2	105.7	3,722.4	35.6	–	–	943.5	30,077.5
1991	25,817.3	1,886.1	8,360.2	144.0	1,970.3	27.2	148.3	2,394.9	2,543.2	40,748.2

Table 6: Total catch biomass (retained + discarded) of Tanner crab in various fisheries, as estimated from observer data, since 1992. Discard mortality has not been included. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF						SCF		RKF		GF			all fleets
	crab pot						crab pot		crab pot		fixed	trawl	all gear	all gear
	West 166W		East 166W		all EBS		all EBS		all EBS		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
1992	–	–	–	–	37,007.4	1,703.6	2,487.2	162.5	1,316.7	19.0	102.7	2,656.9	2,759.6	45,456.1
1993	–	–	–	–	11,853.9	996.3	2,874.4	400.4	3,130.8	149.3	23.5	1,734.5	1,758.0	21,163.0
1994	–	–	–	–	7,315.4	841.6	1,345.1	194.2	–	–	23.9	2,072.1	2,096.0	11,792.4
1995	–	–	–	–	5,065.5	1,064.9	1,021.0	120.9	–	–	127.9	1,397.0	1,524.9	8,797.3
1996	–	–	–	–	300.4	56.7	1,960.7	119.6	270.0	2.4	118.0	1,476.5	1,594.5	4,304.4
1997	–	–	–	–	–	–	1,963.7	92.7	160.1	1.7	63.9	1,116.0	1,180.0	3,398.1
1998	–	–	–	–	–	–	655.9	80.4	115.2	1.7	88.0	847.1	935.0	1,788.2
1999	–	–	–	–	–	–	131.8	11.2	75.1	2.2	84.8	545.9	630.6	850.9
2000	–	–	–	–	–	–	312.8	6.1	66.4	1.4	53.1	688.4	741.5	1,128.2
2001	–	–	–	–	–	–	545.3	20.5	42.2	1.0	124.7	1,060.5	1,185.2	1,794.2
2002	–	–	–	–	–	–	167.2	13.8	61.3	1.6	95.5	623.6	719.1	962.9
2003	–	–	–	–	–	–	64.7	7.0	54.9	1.8	20.4	403.4	423.8	552.3
2004	–	–	–	–	–	–	134.6	39.9	49.8	1.6	64.9	610.2	675.1	901.0
2005	684.6	23.8	–	–	–	–	1,162.8	16.3	41.4	1.0	133.1	488.1	621.2	2,551.0
2006	579.2	72.3	1,132.1	48.8	–	–	1,527.2	85.5	29.5	1.5	345.9	371.2	717.1	4,193.4
2007	679.9	14.8	1,779.1	29.3	–	–	1,861.6	52.1	60.6	1.4	474.4	220.6	694.9	5,173.7
2008	119.1	1.5	1,177.8	6.7	–	–	1,100.3	24.9	279.9	2.5	287.6	245.3	532.9	3,245.6
2009	–	–	664.6	2.3	–	–	1,559.6	15.7	186.5	1.1	225.3	148.8	374.2	2,803.9
2010	–	–	–	–	–	–	1,453.3	9.2	31.9	0.6	117.9	113.5	231.4	1,726.3
2011	–	–	–	–	–	–	2,141.3	13.3	17.5	0.1	76.4	127.6	204.0	2,376.1
2012	–	–	–	–	–	–	1,564.3	10.3	42.1	1.3	46.1	107.2	153.3	1,771.3
2013	933.1	11.4	746.2	12.1	–	–	1,841.8	15.6	128.9	1.3	181.6	166.8	348.4	4,038.7
2014	3,057.0	30.5	5,306.6	8.8	–	–	5,330.0	50.7	305.4	1.0	261.3	174.4	435.7	14,525.7
2015	5,467.6	29.4	6,761.4	28.2	–	–	3,919.2	16.8	205.0	5.6	276.0	85.3	361.2	16,794.3
2016	–	–	–	–	–	–	2,575.7	16.7	175.7	4.2	161.1	145.1	306.2	3,078.6
2017	1,362.5	38.5	–	–	–	–	1,081.7	6.8	183.6	1.4	114.4	49.7	164.1	2,838.6
2018	1,598.4	34.7	–	–	–	–	879.7	8.9	74.0	0.1	122.4	56.5	178.9	2,774.7
2019	–	–	–	–	–	–	1,003.3	15.1	18.0	0.0	44.8	103.1	147.8	1,184.2
2020	1,547.2	33.3	–	–	–	–	130.8	0.7	6.3	0.1	23.4	101.7	125.0	1,843.4
2021	826.0	16.2	–	–	–	–	82.6	1.5	0.1	–	56.9	112.4	169.3	1,095.6

Table 7: Discard catch biomass of Tanner crab in various fisheries as estimated from observer data, prior to 1992. Discard mortality has not been included. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF		SCF		RKF		GF			all fleets
	crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	all EBS		all EBS		all EBS		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1973	–	–	–	–	–	–	–	–	17,735.5	17,735.5
1974	–	–	–	–	–	–	–	–	24,448.6	24,448.6
1975	–	–	–	–	–	–	–	–	9,407.5	9,407.5
1976	–	–	–	–	–	–	–	–	4,699.2	4,699.2
1977	–	–	–	–	–	–	–	–	2,776.0	2,776.0
1978	–	–	–	–	–	–	–	–	1,868.8	1,868.8
1979	–	–	–	–	–	–	–	–	3,397.4	3,397.4
1980	–	–	–	–	–	–	–	–	2,113.7	2,113.7
1981	–	–	–	–	–	–	–	–	1,474.2	1,474.2
1982	–	–	–	–	–	–	–	–	449.1	449.1
1983	–	–	–	–	–	–	–	–	671.3	671.3
1984	–	–	–	–	–	–	–	–	644.1	644.1
1985	–	–	–	–	–	–	–	–	399.2	399.2
1986	–	–	–	–	–	–	–	–	648.6	648.6
1987	–	–	–	–	–	–	–	–	639.6	639.6
1988	–	–	–	–	–	–	–	–	462.7	462.7
1989	–	–	–	–	–	–	–	–	671.3	671.3
1990	–	–	7,081.2	105.7	3,722.4	35.6	–	–	943.5	11,888.5
1991	11,393.1	1,886.1	8,360.2	144.0	1,970.3	27.2	148.3	2,394.9	2,543.2	26,324.0

Table 8: Discard catch biomass of Tanner crab in various fisheries as estimated from observer data, since 1992. Discard mortality has not been included. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF						SCF		RKF		GF			all fleets
	crab pot						crab pot		crab pot		fixed	trawl	all gear	all gear
	West 166W		East 166W		all EBS		all EBS		all EBS		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
1992	–	–	–	–	21,086.3	1,703.6	2,487.2	162.5	1,316.7	19.0	102.7	2,656.9	2,759.6	29,535.0
1993	–	–	–	–	4,188.2	996.3	2,874.4	400.4	3,130.8	149.3	23.5	1,734.5	1,758.0	13,497.3
1994	–	–	–	–	3,777.4	841.6	1,345.1	194.2	–	–	23.9	2,072.1	2,096.0	8,254.4
1995	–	–	–	–	3,146.8	1,064.9	1,021.0	120.9	–	–	127.9	1,397.0	1,524.9	6,878.6
1996	–	–	–	–	–	56.7	1,960.7	119.6	270.0	2.4	118.0	1,476.5	1,594.5	4,003.9
1997	–	–	–	–	–	–	1,963.7	92.7	160.1	1.7	63.9	1,116.0	1,180.0	3,398.1
1998	–	–	–	–	–	–	655.9	80.4	115.2	1.7	88.0	847.1	935.0	1,788.2
1999	–	–	–	–	–	–	131.8	11.2	75.1	2.2	84.8	545.9	630.6	850.9
2000	–	–	–	–	–	–	312.8	6.1	66.4	1.4	53.1	688.4	741.5	1,128.2
2001	–	–	–	–	–	–	545.3	20.5	42.2	1.0	124.7	1,060.5	1,185.2	1,794.2
2002	–	–	–	–	–	–	167.2	13.8	61.3	1.6	95.5	623.6	719.1	962.9
2003	–	–	–	–	–	–	64.7	7.0	54.9	1.8	20.4	403.4	423.8	552.3
2004	–	–	–	–	–	–	134.6	39.9	49.8	1.6	64.9	610.2	675.1	901.0
2005	440.1	23.8	–	–	–	–	975.2	16.3	41.4	1.0	133.1	488.1	621.2	2,118.8
2006	423.7	72.3	500.9	48.8	–	–	1,355.8	85.5	24.9	1.5	345.9	371.2	717.1	3,230.6
2007	528.8	14.8	1,069.1	29.3	–	–	1,775.1	52.1	52.6	1.4	474.4	220.6	694.9	4,218.1
2008	72.0	1.5	370.9	6.7	–	–	1,097.7	24.9	256.7	2.5	287.6	245.3	532.9	2,365.8
2009	–	–	72.2	2.3	–	–	1,557.8	15.7	178.1	1.1	225.3	148.8	374.2	2,201.4
2010	–	–	–	–	–	–	1,452.1	9.2	31.9	0.6	117.9	113.5	231.4	1,725.1
2011	–	–	–	–	–	–	2,139.3	13.3	17.5	0.1	76.4	127.6	204.0	2,374.1
2012	–	–	–	–	–	–	1,563.2	10.3	42.1	1.3	46.1	107.2	153.3	1,770.2
2013	339.5	11.4	91.9	12.1	–	–	1,831.9	15.6	122.6	1.3	181.6	166.8	348.4	2,774.6
2014	688.3	30.5	1,477.3	8.8	–	–	5,315.6	50.7	301.6	1.0	261.3	174.4	435.7	8,309.5
2015	1,697.2	29.4	1,653.7	28.2	–	–	3,888.9	16.8	203.6	5.6	276.0	85.3	361.2	7,884.7
2016	–	–	–	–	–	–	2,574.5	16.7	175.7	4.2	161.1	145.1	306.2	3,077.4
2017	245.0	38.5	–	–	–	–	1,066.6	6.8	183.5	1.4	114.4	49.7	164.1	1,706.1
2018	494.5	34.7	–	–	–	–	876.3	8.9	74.0	0.1	122.4	56.5	178.9	1,667.4
2019	–	–	–	–	–	–	1,003.2	15.1	18.0	0.0	44.8	103.1	147.8	1,184.1
2020	892.0	33.3	–	–	–	–	128.5	0.7	6.3	0.1	23.4	101.7	125.0	1,185.9
2021	332.5	16.2	–	–	–	–	81.8	1.5	0.1	–	56.9	112.4	169.3	601.3

Table 9: Estimated total catch mortality (retained + discarded) of Tanner crab in various fisheries prior to 1992, as estimated using the subtraction method from retained catch and observer data on total catch. Assumed discard mortality rates of 0.321 for crab pot and fixed gear fisheries and 0.800 for trawl fisheries have been applied on a gear-specific basis. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF		SCF		RKF		GF			all fleets
	crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	all EBS		all EBS		all EBS		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1965	1,920.0	–	–	–	–	–	–	–	–	1,920.0
1966	2,440.0	–	–	–	–	–	–	–	–	2,440.0
1967	13,590.0	–	–	–	–	–	–	–	–	13,590.0
1968	18,010.0	–	–	–	–	–	–	–	–	18,010.0
1969	27,490.0	–	–	–	–	–	–	–	–	27,490.0
1970	25,500.0	–	–	–	–	–	–	–	–	25,500.0
1971	20,720.0	–	–	–	–	–	–	–	–	20,720.0
1972	16,900.0	–	–	–	–	–	–	–	–	16,900.0
1973	13,030.0	–	–	–	–	–	–	–	14,188.4	27,218.4
1974	15,360.0	–	–	–	–	–	–	–	19,558.9	34,918.9
1975	17,660.0	–	–	–	–	–	–	–	7,526.0	25,186.0
1976	30,020.0	–	–	–	–	–	–	–	3,759.4	33,779.4
1977	35,530.0	–	–	–	–	–	–	–	2,220.8	37,750.8
1978	21,090.0	–	–	–	–	–	–	–	1,495.0	22,585.0
1979	19,000.0	–	–	–	–	–	–	–	2,717.9	21,717.9
1980	13,426.3	–	–	–	–	–	–	–	1,691.0	15,117.3
1981	4,989.5	–	–	–	–	–	–	–	1,179.3	6,168.9
1982	2,390.4	–	–	–	–	–	–	–	359.2	2,749.7
1983	548.8	–	–	–	–	–	–	–	537.1	1,085.9
1984	1,428.8	–	–	–	–	–	–	–	515.3	1,944.1
1985	–	–	–	–	–	–	–	–	319.3	319.3
1986	–	–	–	–	–	–	–	–	518.9	518.9
1987	997.9	–	–	–	–	–	–	–	511.7	1,509.6
1988	3,179.7	–	–	–	–	–	–	–	370.1	3,549.8
1989	11,113.0	–	–	–	–	–	–	–	537.1	11,650.1
1990	18,189.1	–	2,273.1	33.9	1,194.9	11.4	–	–	754.8	22,457.2
1991	18,081.4	605.4	2,683.6	46.2	632.5	8.7	47.6	1,915.9	1,963.5	24,021.4

Table 10: Estimated total catch mortality (retained + discarded) of Tanner crab in various fisheries since 1992, as estimated using the subtraction method from retained catch and observer data on total catch. Assumed discard mortality rates of 0.321 for crab pot and fixed gear fisheries and 0.800 for trawl fisheries have been applied on a gear-specific basis. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF						SCF		RKF		GF			all fleets
	crab pot						crab pot		crab pot		fixed	trawl	all gear	all gear
	West 166W		East 166W		all EBS		all EBS		all EBS		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
1992	–	–	–	–	22,689.8	546.8	798.4	52.2	422.7	6.1	33.0	2,125.5	2,158.5	26,674.5
1993	–	–	–	–	9,010.1	319.8	922.7	128.5	1,005.0	47.9	7.5	1,387.6	1,395.1	12,829.2
1994	–	–	–	–	4,750.6	270.2	431.8	62.3	–	–	7.7	1,657.7	1,665.4	7,180.2
1995	–	–	–	–	2,928.8	341.8	327.8	38.8	–	–	41.0	1,117.6	1,158.7	4,795.9
1996	–	–	–	–	821.0	18.2	629.4	38.4	86.7	0.8	37.9	1,181.2	1,219.1	2,813.5
1997	–	–	–	–	–	–	630.3	29.7	51.4	0.5	20.5	892.8	913.3	1,625.4
1998	–	–	–	–	–	–	210.6	25.8	37.0	0.5	28.2	677.7	705.9	979.8
1999	–	–	–	–	–	–	42.3	3.6	24.1	0.7	27.2	436.7	463.9	534.6
2000	–	–	–	–	–	–	100.4	1.9	21.3	0.4	17.1	550.7	567.8	691.9
2001	–	–	–	–	–	–	175.0	6.6	13.5	0.3	40.0	848.4	888.4	1,083.9
2002	–	–	–	–	–	–	53.7	4.4	19.7	0.5	30.7	498.8	529.5	607.8
2003	–	–	–	–	–	–	20.8	2.3	17.6	0.6	6.6	322.7	329.3	370.5
2004	–	–	–	–	–	–	43.2	12.8	16.0	0.5	20.8	488.2	509.0	581.5
2005	385.8	7.6	–	–	–	–	500.7	5.2	13.3	0.3	42.7	390.5	433.2	1,346.2
2006	291.5	23.2	792.0	15.7	–	–	606.7	27.5	12.6	0.5	111.0	297.0	408.0	2,177.6
2007	320.8	4.8	1,053.2	9.4	–	–	656.3	16.7	24.9	0.5	152.3	176.4	328.7	2,415.2
2008	70.3	0.5	925.9	2.1	–	–	354.9	8.0	105.6	0.8	92.3	196.2	288.6	1,756.7
2009	–	–	615.6	0.7	–	–	501.8	5.0	65.6	0.4	72.3	119.1	191.4	1,380.5
2010	–	–	–	–	–	–	467.3	2.9	10.2	0.2	37.8	90.8	128.6	609.3
2011	–	–	–	–	–	–	688.8	4.3	5.6	0.0	24.5	102.1	126.6	825.3
2012	–	–	–	–	–	–	502.9	3.3	13.5	0.4	14.8	85.7	100.5	620.7
2013	702.6	3.6	683.8	3.9	–	–	597.9	5.0	45.7	0.4	58.3	133.5	191.7	2,234.7
2014	2,589.6	9.8	4,303.5	2.8	–	–	1,720.8	16.3	100.6	0.3	83.9	139.5	223.4	8,967.1
2015	4,315.1	9.4	5,638.6	9.1	–	–	1,278.6	5.4	66.7	1.8	88.6	68.2	156.8	11,481.5
2016	–	–	–	–	–	–	827.6	5.4	56.4	1.4	51.7	116.1	167.8	1,058.6
2017	1,196.1	12.4	–	–	–	–	357.4	2.2	58.9	0.5	36.7	39.8	76.5	1,704.0
2018	1,262.6	11.1	–	–	–	–	284.7	2.8	23.8	0.0	39.3	45.2	84.5	1,669.6
2019	–	–	–	–	–	–	322.1	4.8	5.8	0.0	14.4	82.4	96.8	429.6
2020	941.5	10.7	–	–	–	–	43.6	0.2	2.0	0.0	7.5	81.3	88.8	1,086.9
2021	600.2	5.2	–	–	–	–	27.0	0.5	0.0	–	18.3	89.9	108.2	741.1

Table 11: Estimated discard mortality of Tanner crab in various fisheries prior to 1992, as estimated using the subtraction method from retained catch and observer data on total catch. Assumed discard mortality rates of 0.321 for crab pot and fixed gear fisheries and 0.800 for trawl fisheries have been applied on a gear-specific basis. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF		SCF		RKF		GF			all fleets
	crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	all EBS		all EBS		all EBS		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1973	–	–	–	–	–	–	–	–	14,188.4	14,188.4
1974	–	–	–	–	–	–	–	–	19,558.9	19,558.9
1975	–	–	–	–	–	–	–	–	7,526.0	7,526.0
1976	–	–	–	–	–	–	–	–	3,759.4	3,759.4
1977	–	–	–	–	–	–	–	–	2,220.8	2,220.8
1978	–	–	–	–	–	–	–	–	1,495.0	1,495.0
1979	–	–	–	–	–	–	–	–	2,717.9	2,717.9
1980	–	–	–	–	–	–	–	–	1,691.0	1,691.0
1981	–	–	–	–	–	–	–	–	1,179.3	1,179.3
1982	–	–	–	–	–	–	–	–	359.2	359.2
1983	–	–	–	–	–	–	–	–	537.1	537.1
1984	–	–	–	–	–	–	–	–	515.3	515.3
1985	–	–	–	–	–	–	–	–	319.3	319.3
1986	–	–	–	–	–	–	–	–	518.9	518.9
1987	–	–	–	–	–	–	–	–	511.7	511.7
1988	–	–	–	–	–	–	–	–	370.1	370.1
1989	–	–	–	–	–	–	–	–	537.1	537.1
1990	–	–	2,273.1	33.9	1,194.9	11.4	–	–	754.8	4,268.1
1991	3,657.2	605.4	2,683.6	46.2	632.5	8.7	47.6	1,915.9	1,963.5	9,597.2

Table 12: Estimated discard mortality of Tanner crab in various fisheries since 1992, as estimated using the subtraction method from retained catch and observer data on total catch. Assumed discard mortality rates of 0.321 for crab pot and fixed gear fisheries and 0.800 for trawl fisheries have been applied on a gear-specific basis. Units are metric tons. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery; GF: groundfish fisheries.

	TCF						SCF		RKF		GF			all fleets
	crab pot						crab pot		crab pot		fixed	trawl	all gear	all gear
	West 166W		East 166W		all EBS		all EBS		all EBS		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
1992	–	–	–	–	6,768.7	546.8	798.4	52.2	422.7	6.1	33.0	2,125.5	2,158.5	10,753.4
1993	–	–	–	–	1,344.4	319.8	922.7	128.5	1,005.0	47.9	7.5	1,387.6	1,395.1	5,163.5
1994	–	–	–	–	1,212.5	270.2	431.8	62.3	–	–	7.7	1,657.7	1,665.4	3,642.2
1995	–	–	–	–	1,010.1	341.8	327.8	38.8	–	–	41.0	1,117.6	1,158.7	2,877.2
1996	–	–	–	–	–	18.2	629.4	38.4	86.7	0.8	37.9	1,181.2	1,219.1	1,992.5
1997	–	–	–	–	–	–	630.3	29.7	51.4	0.5	20.5	892.8	913.3	1,625.4
1998	–	–	–	–	–	–	210.6	25.8	37.0	0.5	28.2	677.7	705.9	979.8
1999	–	–	–	–	–	–	42.3	3.6	24.1	0.7	27.2	436.7	463.9	534.6
2000	–	–	–	–	–	–	100.4	1.9	21.3	0.4	17.1	550.7	567.8	691.9
2001	–	–	–	–	–	–	175.0	6.6	13.5	0.3	40.0	848.4	888.4	1,083.9
2002	–	–	–	–	–	–	53.7	4.4	19.7	0.5	30.7	498.8	529.5	607.8
2003	–	–	–	–	–	–	20.8	2.3	17.6	0.6	6.6	322.7	329.3	370.5
2004	–	–	–	–	–	–	43.2	12.8	16.0	0.5	20.8	488.2	509.0	581.5
2005	141.3	7.6	–	–	–	–	313.0	5.2	13.3	0.3	42.7	390.5	433.2	913.9
2006	136.0	23.2	160.8	15.7	–	–	435.2	27.5	8.0	0.5	111.0	297.0	408.0	1,214.8
2007	169.7	4.8	343.2	9.4	–	–	569.8	16.7	16.9	0.5	152.3	176.4	328.7	1,459.7
2008	23.1	0.5	119.1	2.1	–	–	352.4	8.0	82.4	0.8	92.3	196.2	288.6	876.9
2009	–	–	23.2	0.7	–	–	500.1	5.0	57.2	0.4	72.3	119.1	191.4	777.9
2010	–	–	–	–	–	–	466.1	2.9	10.2	0.2	37.8	90.8	128.6	608.1
2011	–	–	–	–	–	–	686.7	4.3	5.6	0.0	24.5	102.1	126.6	823.2
2012	–	–	–	–	–	–	501.8	3.3	13.5	0.4	14.8	85.7	100.5	619.6
2013	109.0	3.6	29.5	3.9	–	–	588.0	5.0	39.4	0.4	58.3	133.5	191.7	970.6
2014	220.9	9.8	474.2	2.8	–	–	1,706.3	16.3	96.8	0.3	83.9	139.5	223.4	2,750.9
2015	544.8	9.4	530.8	9.1	–	–	1,248.3	5.4	65.4	1.8	88.6	68.2	156.8	2,571.8
2016	–	–	–	–	–	–	826.4	5.4	56.4	1.4	51.7	116.1	167.8	1,057.4
2017	78.7	12.4	–	–	–	–	342.4	2.2	58.9	0.5	36.7	39.8	76.5	571.5
2018	158.7	11.1	–	–	–	–	281.3	2.8	23.8	0.0	39.3	45.2	84.5	562.3
2019	–	–	–	–	–	–	322.0	4.8	5.8	0.0	14.4	82.4	96.8	429.5
2020	286.3	10.7	–	–	–	–	41.2	0.2	2.0	0.0	7.5	81.3	88.8	429.4
2021	106.7	5.2	–	–	–	–	26.3	0.5	0.0	–	18.3	89.9	108.2	246.8

Table 13: Effort data (potlifts) in the crab fisheries prior to 1990, by area. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery. Hyphens indicate years with no effort.

year	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
1983	173,591	–
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

Table 14: Effort data (potlifts) in the crab fisheries since 1990, by area. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: Bristol Bay red king crab fishery. Hyphens indicate years with no effort.

	TCF			SCF	RKF
year	West 166W	East 166W	all EBS	all EBS	all EBS
1990	479	493,820	494,299	1,382,908	262,761
1991	140,050	360,864	500,914	1,278,502	227,555
1992	166,670	508,922	675,592	969,209	206,815
1993	40,100	286,620	326,720	716,524	254,389
1994	21,282	228,254	249,536	507,603	697
1995	46,454	201,988	248,442	520,685	547
1996	8,533	64,989	73,522	754,140	77,081
1997	–	–	–	930,794	91,085
1998	–	–	–	945,533	145,689
1999	–	–	–	182,634	151,212
2000	–	–	–	191,200	104,056
2001	–	–	–	326,977	66,947
2002	–	–	–	153,862	72,514
2003	–	–	–	123,709	134,515
2004	–	–	–	75,095	97,621
2005	6,346	–	6,346	117,375	116,320
2006	4,517	15,273	19,790	86,328	72,404
2007	7,268	26,441	33,709	140,857	113,948
2008	2,336	19,401	21,737	163,537	139,937
2009	–	6,635	6,635	137,292	119,261
2010	–	–	–	147,478	132,183
2011	–	–	–	270,602	45,784
2012	–	–	–	225,627	38,842
2013	23,062	16,613	39,675	225,245	46,589
2014	68,695	72,768	141,463	279,183	57,725
2015	84,933	130,302	215,235	202,526	48,763
2016	–	–	–	118,548	33,608
2017	19,284	11	19,295	114,673	49,169
2018	29,833	–	29,833	119,484	31,975
2019	–	–	–	188,958	35,033
2020	34,914	–	34,914	171,678	21,346
2021	19,252	–	19,252	36,878	294

Table 15: Sample sizes for retained and total catch-at-size in the directed fishery. raw = number of individuals sampled. input = scaled sample size used in assessment.

	Retained Catch		Total Catch			
	male		male		female	
year	raw	input	raw	input	raw	input
1980	13,310	96	–	–	–	–
1981	11,311	81	–	–	–	–
1982	13,519	97	–	–	–	–
1983	1,675	12	–	–	–	–
1984	2,542	18	–	–	–	–
1988	12,380	89	–	–	–	–
1989	35,956	200	–	–	–	–
1990	83,590	200	51	0	34	0
1991	127,227	200	31,252	170	5,605	30
1992	125,395	200	54,836	172	8,755	28
1993	71,622	200	40,388	159	10,471	41
1994	27,658	199	5,792	42	2,132	15
1995	19,276	139	5,589	40	3,119	22
1996	4,430	32	352	3	168	1
2005	705	5	19,715	142	1,107	8
2006	2,940	21	24,226	169	4,432	31
2007	5,827	42	61,546	190	3,318	10
2008	3,490	25	29,166	196	646	4
2009	2,417	17	17,289	124	147	1
2013	4,761	34	17,291	124	710	5
2014	14,371	103	85,120	197	1,191	3
2015	24,320	175	119,843	197	1,624	3
2017	3,470	25	18,785	135	1,721	12
2018	3,306	24	28,338	187	2,036	13
2020	3,323	24	17,639	127	1,054	8
2021	2,344	17	19,214	138	1,008	7

Table 16: Sample sizes for total bycatch-at-size in the snow crab ("SCF") and Bristol Bay red king crab ("RKF) fisheries, from crab observer sampling. raw = number of individuals. input = scaled sample size used in assessment.

	SCF				RKF			
	male		female		male		female	
year	raw	input	raw	input	raw	input	raw	input
1990	14,032	101	478	3	1,580	11	43	0
1991	11,708	84	686	5	2,273	16	89	1
1992	6,280	45	859	6	2,056	15	105	1
1993	6,969	50	1,542	11	7,359	53	1,196	9
1994	2,982	21	1,523	11	–	–	–	–
1995	1,898	14	428	3	–	–	–	–
1996	3,265	23	662	5	114	1	5	0
1997	3,970	29	657	5	1,030	7	41	0
1998	1,911	14	324	2	457	3	20	0
1999	976	7	82	1	207	1	14	0
2000	1,237	9	74	1	845	6	44	0
2001	3,113	22	160	1	456	3	39	0
2002	982	7	118	1	750	5	50	0
2003	688	5	152	1	555	4	46	0
2004	833	6	707	5	487	3	44	0
2005	9,807	70	368	3	983	7	70	1
2006	10,391	75	1,256	9	746	5	68	0
2007	13,797	99	728	5	1,360	10	89	1
2008	8,455	61	722	5	3,797	27	121	1
2009	11,057	79	474	3	2,871	21	70	1
2010	12,073	87	250	2	582	4	28	0
2011	9,453	68	189	1	323	2	4	0
2012	11,004	79	270	2	618	4	48	0
2013	12,935	93	356	3	2,110	15	60	0
2014	24,878	179	804	6	3,110	22	32	0
2015	19,839	143	230	2	2,175	16	186	1
2016	16,369	118	262	2	3,220	23	246	2
2017	5,598	40	109	1	3,782	27	86	1
2018	6,145	44	233	2	1,283	9	6	0
2019	8,881	64	423	3	357	3	3	0
2020	820	6	10	0	106	1	4	0
2021	632	5	30	0	–	–	–	–

Table 17: Sample sizes for total catch-at-size in the groundfish fisheries, from groundfish observer sampling. raw = number of individuals measured. input = scaled sample size used in the assessment.

	fixed				trawl				total			
	female		male		female		male		female		male	
year	raw	input	raw	input	raw	input	raw	input	raw	input	raw	input
1973	0	0.0000	0	0.000	0	0.000	0	0.000	4554	32.729	6310	45.349
1974	0	0.0000	0	0.000	0	0.000	0	0.000	3200	22.998	4984	35.819
1975	0	0.0000	0	0.000	0	0.000	0	0.000	1678	12.060	2502	17.981
1976	0	0.0000	0	0.000	0	0.000	0	0.000	13366	96.059	13900	99.897
1977	0	0.0000	0	0.000	0	0.000	0	0.000	16772	120.538	21370	153.583
1978	0	0.0000	0	0.000	0	0.000	0	0.000	27330	169.431	37192	230.569
1979	0	0.0000	0	0.000	0	0.000	0	0.000	22698	149.285	38120	250.715
1980	0	0.0000	0	0.000	0	0.000	0	0.000	11834	85.049	25612	184.069
1981	0	0.0000	0	0.000	0	0.000	0	0.000	8130	58.429	12196	87.651
1982	0	0.0000	0	0.000	0	0.000	0	0.000	16012	115.076	26878	193.168
1983	0	0.0000	0	0.000	0	0.000	0	0.000	16610	119.373	36726	263.944
1984	0	0.0000	0	0.000	0	0.000	0	0.000	27542	133.783	54806	266.217
1985	0	0.0000	0	0.000	0	0.000	0	0.000	25456	141.990	46256	258.010
1986	0	0.0000	0	0.000	0	0.000	0	0.000	15252	109.614	29720	213.593
1987	0	0.0000	0	0.000	0	0.000	0	0.000	31714	161.128	47016	238.872
1988	0	0.0000	0	0.000	0	0.000	0	0.000	14252	102.427	21172	152.160
1989	0	0.0000	0	0.000	0	0.000	0	0.000	82468	163.017	119886	236.983
1990	0	0.0000	0	0.000	0	0.000	0	0.000	22424	129.033	47090	270.967
1991	290	2.0842	1116	8.021	3189	22.919	5701	40.972	3479	25.003	6817	48.993
1992	39	0.2803	601	4.319	1136	8.164	2527	18.161	1175	8.445	3128	22.480
1993	25	0.1797	683	4.909	333	2.393	534	3.838	358	2.573	1217	8.746
1994	126	0.9055	1133	8.143	1694	12.174	2495	17.931	1820	13.080	3628	26.074
1995	44	0.3162	162	1.164	2625	18.865	3742	26.893	2669	19.182	3904	28.057
1996	439	3.1550	2442	17.550	2961	21.280	5864	42.144	3400	24.435	8306	59.694
1997	217	1.5595	1650	11.858	3683	26.469	8299	59.644	3900	28.029	9949	71.502
1998	627	4.5061	3870	27.813	3813	27.403	8235	59.184	4440	31.910	12105	86.997
1999	719	5.1673	3553	25.535	3803	27.332	7500	53.901	4522	32.499	11053	79.436
2000	227	1.6314	5144	36.969	2860	20.554	7751	55.705	3087	22.186	12895	92.674
2001	303	2.1776	6950	49.948	2780	19.979	8838	63.517	3083	22.157	15788	113.466
2002	831	5.9723	8571	61.598	2418	17.378	6830	49.086	3249	23.350	15401	110.684
2003	923	6.6334	4589	32.980	1810	13.008	4983	35.812	2733	19.642	9572	68.792
2004	560	4.0246	5413	38.902	3900	28.029	8431	60.592	4460	32.053	13844	99.495
2005	389	2.7957	8816	63.359	3320	23.860	8969	64.459	3709	26.656	17785	127.818
2006	824	5.9220	9270	66.622	2223	15.976	6633	47.670	3047	21.898	15903	114.292
2007	1175	8.4445	7235	51.997	2644	19.002	8913	64.056	3819	27.447	16148	116.053
2008	1770	11.6424	15832	104.137	2465	16.214	10339	68.006	4235	27.856	26171	172.144
2009	688	4.9445	12916	92.825	2013	14.467	6127	44.034	2701	19.412	19043	136.859
2010	956	6.8706	11264	80.952	1648	11.844	4402	31.636	2604	18.715	15666	112.589
2011	386	2.7741	8709	62.590	3877	27.863	7650	54.979	4263	30.637	16359	117.569
2012	836	6.0082	9192	66.061	2267	16.293	3994	28.704	3103	22.301	13186	94.766
2013	3489	19.9434	22471	128.446	2592	14.816	6437	36.794	6081	34.759	28908	165.241
2014	2061	9.4676	33529	154.022	2201	10.111	5747	26.400	4262	19.578	39276	180.422
2015	5152	30.7729	24488	146.267	629	3.757	3215	19.203	5781	34.530	27703	165.470
2016	1206	8.6673	14811	106.444	3224	23.170	3920	28.172	4430	31.838	18731	134.617
2017	1265	9.0913	11555	83.044	478	3.435	2036	14.632	1743	12.527	13591	97.676
2018	350	2.5154	4633	33.297	1135	8.157	3069	22.056	1485	10.672	7702	55.353
2019	214	1.5380	2788	20.037	2460	17.680	5366	38.565	2674	19.218	8154	58.601
2020	503	3.6150	2461	17.687	2563	18.420	6404	46.024	3066	22.035	8865	63.711
2021	462	3.3203	2994	21.517	1534	11.025	4600	33.059	1996	14.345	7594	54.577

Table 18: Trends in Tanner crab biomass (metric tons) in the NMFS EBS summer bottom trawl survey prior to 2001, by sex and area.

	male			female		
year	W166	E166	all EBS	W166	E166	all EBS
1975	80,689	214,202	294,891	13,374	27,594	40,968
1976	55,092	101,958	157,050	12,140	25,420	37,560
1977	51,038	87,463	138,501	21,613	31,435	53,048
1978	25,394	72,913	98,308	14,167	18,406	32,574
1979	32,058	17,978	50,036	19,701	3,448	23,149
1980	103,505	48,979	152,484	64,420	12,883	77,303
1981	56,540	23,390	79,930	35,525	8,577	44,102
1982	49,255	16,602	65,856	57,757	8,107	65,864
1983	24,708	13,337	38,045	17,418	5,350	22,769
1984	18,490	12,020	30,510	12,358	4,800	17,158
1985	6,676	8,231	14,907	3,393	3,160	6,554
1986	11,986	9,625	21,612	2,570	3,504	6,074
1987	16,648	28,863	45,511	5,137	15,009	20,146
1988	41,093	58,130	99,223	12,668	22,885	35,553
1989	45,106	87,718	132,824	12,254	18,975	31,230
1990	55,539	76,879	132,418	22,532	25,022	47,554
1991	55,986	89,825	145,811	20,445	31,341	51,787
1992	37,674	89,918	127,592	16,857	11,358	28,215
1993	19,877	53,394	73,271	7,382	5,325	12,707
1994	16,032	32,303	48,335	5,716	5,332	11,048
1995	15,310	19,672	34,982	7,474	5,982	13,456
1996	10,790	19,979	30,770	4,470	6,548	11,019
1997	5,561	9,088	14,649	1,893	2,914	4,806
1998	6,604	8,404	15,008	2,489	1,752	4,241
1999	6,719	14,835	21,554	3,347	3,360	6,708
2000	6,903	16,429	23,332	2,999	3,613	6,613

Table 19: Trends in Tanner crab biomass (metric tons) in the NMFS EBS summer bottom trawl survey since 2001, by sex and area.

	male			female		
year	W166	E166	all EBS	W166	E166	all EBS
2001	13,089	16,231	29,320	6,989	3,931	10,920
2002	13,010	14,402	27,411	6,499	3,469	9,968
2003	20,661	17,164	37,825	10,297	2,795	13,092
2004	26,468	12,455	38,923	7,731	1,131	8,862
2005	46,313	17,443	63,756	17,469	4,493	21,962
2006	72,907	28,636	101,543	21,723	6,476	28,198
2007	76,285	27,938	104,223	12,465	6,612	19,076
2008	47,736	37,177	84,913	9,444	5,079	14,523
2009	32,653	14,786	47,439	6,495	4,553	11,048
2010	34,601	14,426	49,027	6,366	2,910	9,276
2011	39,321	23,390	62,712	9,190	6,615	15,805
2012	34,764	45,367	80,131	9,787	14,245	24,032
2013	38,839	64,580	103,420	10,866	13,398	24,264
2014	50,739	58,196	108,936	8,728	8,648	17,377
2015	39,158	35,093	74,251	7,574	5,304	12,878
2016	43,315	25,520	68,835	7,133	1,479	8,612
2017	29,685	23,952	53,637	6,274	2,144	8,418
2018	32,734	13,769	46,503	8,213	1,588	9,801
2019	17,503	10,790	28,293	7,452	2,133	9,585
2021	18,411	12,727	31,138	7,842	3,879	11,721
2022	14,493	14,761	29,254	6,742	2,490	9,232

Table 20: Trends in Tanner crab abundance (numbers of individuals) in the NMFS EBS summer bottom trawl survey prior to 2001, by sex and area.

	male			female		
year	W166	E166	all EBS	W166	E166	all EBS
1975	138.814	398.843	537.657	72.862	179.541	252.403
1976	152.409	231.307	383.716	134.647	165.103	299.749
1977	218.104	163.029	381.133	309.737	156.982	466.719
1978	166.910	125.124	292.034	197.238	92.771	290.010
1979	164.030	32.790	196.820	167.300	20.753	188.053
1980	556.254	90.857	647.111	539.580	66.075	605.655
1981	212.903	55.395	268.299	278.950	51.276	330.226
1982	145.547	44.534	190.081	448.570	45.850	494.420
1983	142.561	53.870	196.431	206.372	48.478	254.850
1984	93.036	40.451	133.487	129.134	35.820	164.955
1985	37.012	20.463	57.475	39.587	16.177	55.764
1986	62.731	57.820	120.551	32.397	46.107	78.505
1987	107.198	151.665	258.863	87.804	136.549	224.354
1988	237.862	187.456	425.318	168.010	140.710	308.720
1989	206.609	333.150	539.759	145.227	240.905	386.132
1990	195.564	235.472	431.035	182.543	200.222	382.765
1991	227.961	213.623	441.584	193.300	187.707	381.007
1992	145.024	160.397	305.421	145.647	59.026	204.672
1993	81.545	93.812	175.357	69.043	27.795	96.838
1994	66.779	52.188	118.967	63.469	29.669	93.139
1995	53.724	34.659	88.383	63.720	35.858	99.578
1996	39.265	51.145	90.409	41.229	47.062	88.291
1997	31.827	44.344	76.171	31.592	45.825	77.418
1998	56.468	32.758	89.226	51.264	20.154	71.419
1999	88.367	60.248	148.614	89.794	33.913	123.707
2000	77.476	49.559	127.035	64.273	31.565	95.838

Table 21: Trends in Tanner crab abundance (metric tons) in the NMFS EBS summer bottom trawl survey since 2001, by sex and area.

	male			female		
year	W166	E166	all EBS	W166	E166	all EBS
2001	154.998	132.565	287.563	148.270	119.356	267.626
2002	137.937	58.959	196.896	130.684	47.198	177.882
2003	187.919	56.675	244.594	172.304	25.578	197.881
2004	236.732	30.548	267.281	197.612	13.149	210.761
2005	290.526	59.360	349.886	276.389	55.380	331.769
2006	359.300	104.083	463.383	254.557	51.044	305.601
2007	359.599	76.932	436.530	165.747	42.013	207.761
2008	172.920	79.881	252.801	102.063	33.593	135.655
2009	141.034	48.878	189.912	100.583	45.979	146.563
2010	159.891	54.354	214.245	113.568	40.252	153.820
2011	229.497	151.234	380.732	177.927	100.972	278.899
2012	252.509	190.311	442.820	147.665	118.156	265.821
2013	223.536	179.636	403.172	145.126	94.026	239.151
2014	208.392	137.791	346.182	134.066	59.794	193.860
2015	125.115	80.164	205.279	81.734	42.094	123.828
2016	137.389	54.142	191.530	84.708	9.141	93.849
2017	142.181	50.361	192.542	136.747	15.478	152.226
2018	214.794	57.460	272.254	196.581	38.481	235.062
2019	160.994	46.940	207.934	178.921	34.016	212.937
2021	155.236	59.288	214.524	132.913	37.556	170.468
2022	133.331	75.073	208.405	124.450	48.521	172.971

Table 22: Trends in biomass for preferred-size (> 125 mm CW) male Tanner crab in the NMFS EBS summer bottom trawl survey (in metric tons) prior to 2001.

	W166			E166			all EBS		
year	new shell	old shell	all shell	new shell	old shell	all shell	new shell	old shell	all shell
1975	56,181	2,509	58,691	152,683	6,522	159,205	208,864	9,032	217,896
1976	38,107	1,534	39,640	57,034	9,674	66,709	95,141	11,208	106,349
1977	26,511	6,808	33,319	50,855	7,543	58,399	77,366	14,351	91,717
1978	3,221	6,626	9,847	40,633	9,780	50,413	43,853	16,406	60,259
1979	4,115	3,745	7,860	9,767	3,426	13,192	13,882	7,171	21,052
1980	11,210	1,677	12,887	23,184	10,857	34,041	34,394	12,534	46,927
1981	5,884	2,167	8,050	3,445	11,286	14,731	9,329	13,452	22,781
1982	5,763	5,859	11,622	3,009	4,851	7,860	8,772	10,710	19,481
1983	2,416	3,240	5,655	5,151	2,082	7,233	7,566	5,322	12,889
1984	571	3,159	3,730	4,348	3,077	7,424	4,919	6,236	11,154
1985	588	870	1,458	4,055	1,046	5,101	4,642	1,917	6,559
1986	142	674	816	734	2,546	3,280	876	3,219	4,096
1987	3,505	658	4,163	4,911	3,473	8,385	8,416	4,132	12,548
1988	9,690	929	10,618	15,698	2,715	18,413	25,387	3,644	29,031
1989	13,758	2,741	16,499	37,364	3,740	41,104	51,122	6,481	57,603
1990	21,082	3,274	24,356	35,903	7,084	42,987	56,985	10,358	67,343
1991	13,386	8,430	21,816	32,973	14,476	47,449	46,359	22,906	69,265
1992	9,851	6,461	16,311	41,423	16,242	57,665	51,274	22,703	73,977
1993	3,716	2,596	6,312	22,942	11,990	34,932	26,658	14,586	41,244
1994	1,248	4,143	5,391	10,000	13,912	23,912	11,248	18,054	29,303
1995	370	5,392	5,761	1,241	13,516	14,757	1,611	18,907	20,518
1996	100	3,580	3,680	330	13,912	14,242	430	17,492	17,922
1997	163	958	1,121	316	4,245	4,561	478	5,203	5,681
1998	441	644	1,085	1,001	2,604	3,605	1,442	3,247	4,689
1999	256	356	612	1,645	1,838	3,483	1,902	2,194	4,095
2000	250	377	627	4,484	3,045	7,529	4,734	3,422	8,156

Table 23: Trends in biomass for preferred-size (> 125 mm CW) male Tanner crab in the NMFS EBS summer bottom trawl survey (in metric tons) since 2001.

	W166			E166			all EBS		
year	new shell	old shell	all shell	new shell	old shell	all shell	new shell	old shell	all shell
2001	418	1,361	1,780	4,473	3,600	8,073	4,892	4,961	9,853
2002	384	838	1,222	944	7,102	8,046	1,328	7,940	9,268
2003	434	2,227	2,661	1,558	6,433	7,991	1,992	8,660	10,652
2004	980	1,825	2,805	1,597	4,916	6,513	2,577	6,741	9,318
2005	8,776	5,062	13,839	2,368	5,822	8,190	11,145	10,884	22,029
2006	3,755	15,328	19,083	2,134	6,794	8,927	5,889	22,122	28,011
2007	8,523	7,757	16,281	4,143	5,314	9,457	12,666	13,071	25,737
2008	8,688	4,457	13,145	15,476	3,288	18,764	24,163	7,745	31,909
2009	6,657	4,156	10,812	2,644	5,139	7,783	9,300	9,295	18,595
2010	9,593	4,867	14,460	3,006	4,576	7,582	12,599	9,443	22,042
2011	9,023	6,637	15,660	1,513	6,987	8,500	10,536	13,624	24,160
2012	2,368	3,997	6,365	3,352	5,026	8,378	5,720	9,023	14,743
2013	5,383	2,837	8,220	10,871	3,527	14,397	16,254	6,364	22,618
2014	7,163	4,604	11,766	14,899	9,310	24,210	22,062	13,914	35,976
2015	8,380	5,925	14,306	9,084	10,217	19,301	17,464	16,143	33,607
2016	5,799	12,527	18,326	2,640	8,055	10,695	8,439	20,582	29,021
2017	894	11,659	12,553	1,629	10,841	12,470	2,523	22,500	25,024
2018	996	11,875	12,871	102	7,253	7,355	1,097	19,128	20,225
2019	202	4,799	5,001	315	4,455	4,769	517	9,254	9,771
2021	416	1,590	2,006	1,447	956	2,403	1,863	2,546	4,409
2022	750	827	1,576	3,762	914	4,676	4,512	1,741	6,253

Table 24: Trends in abundance for preferred-size (> 125 mm CW) male Tanner crab in the NMFS EBS summer bottom trawl survey (millions of crab) prior to 2001.

	W166			E166			all EBS		
year	new shell	old shell	all shell	new shell	old shell	all shell	new shell	old shell	all shell
1975	66.706	3.129	69.835	156.363	7.320	163.683	223.068	10.450	233.518
1976	42.108	1.754	43.862	63.542	10.425	73.967	105.650	12.179	117.829
1977	26.617	7.258	33.875	55.271	8.487	63.759	81.888	15.745	97.633
1978	3.591	7.183	10.774	44.489	11.691	56.180	48.080	18.874	66.955
1979	5.335	4.610	9.945	11.108	4.047	15.156	16.443	8.658	25.101
1980	14.802	1.916	16.718	24.363	13.118	37.481	39.165	15.034	54.199
1981	7.784	2.903	10.688	4.026	14.097	18.123	11.811	17.000	28.811
1982	8.065	8.210	16.275	3.492	6.377	9.869	11.557	14.587	26.144
1983	3.357	4.704	8.061	6.917	2.732	9.649	10.274	7.436	17.710
1984	0.820	4.520	5.340	4.898	3.946	8.845	5.719	8.466	14.185
1985	0.784	1.283	2.067	4.413	1.381	5.795	5.197	2.664	7.861
1986	0.213	0.870	1.083	0.981	2.742	3.723	1.194	3.612	4.806
1987	4.658	0.917	5.575	6.307	4.039	10.345	10.965	4.956	15.921
1988	12.210	1.241	13.451	18.560	3.515	22.074	30.769	4.756	35.525
1989	17.061	3.608	20.670	46.330	4.812	51.141	63.391	8.420	71.811
1990	26.645	4.216	30.860	38.932	9.361	48.293	65.577	13.576	79.153
1991	17.264	11.383	28.647	39.106	18.355	57.462	56.371	29.738	86.109
1992	11.892	8.616	20.509	50.821	21.453	72.274	62.713	30.069	92.782
1993	5.078	3.723	8.801	27.129	16.372	43.501	32.207	20.095	52.302
1994	1.575	5.751	7.326	10.707	18.458	29.165	12.282	24.209	36.491
1995	0.569	7.622	8.191	1.370	16.935	18.305	1.939	24.558	26.497
1996	0.154	5.271	5.425	0.302	17.040	17.343	0.456	22.312	22.768
1997	0.220	1.323	1.543	0.454	4.957	5.411	0.674	6.280	6.954
1998	0.619	0.922	1.541	1.395	3.155	4.550	2.014	4.077	6.091
1999	0.387	0.505	0.892	2.022	2.256	4.278	2.409	2.760	5.169
2000	0.347	0.544	0.891	5.647	3.921	9.567	5.994	4.465	10.459

Table 25: Trends in abundance for preferred-size (> 125 mm CW) male Tanner crab in the NMFS EBS summer bottom trawl survey (millions of crab) since 2001.

	W166			E166			all EBS		
year	new shell	old shell	all shell	new shell	old shell	all shell	new shell	old shell	all shell
2001	0.635	1.785	2.419	5.136	4.621	9.757	5.770	6.406	12.176
2002	0.546	1.140	1.686	1.087	8.110	9.197	1.633	9.250	10.883
2003	0.615	3.019	3.634	1.895	7.156	9.051	2.510	10.175	12.685
2004	1.431	2.626	4.057	2.150	5.277	7.426	3.581	7.903	11.484
2005	11.621	7.088	18.710	3.110	6.588	9.698	14.731	13.676	28.407
2006	5.239	20.689	25.928	2.674	8.262	10.936	7.913	28.951	36.864
2007	11.886	10.728	22.614	5.023	6.765	11.788	16.909	17.493	34.401
2008	12.211	6.294	18.505	17.411	4.518	21.929	29.622	10.812	40.435
2009	9.162	5.856	15.018	3.293	6.402	9.695	12.455	12.258	24.713
2010	12.360	6.754	19.114	3.702	5.364	9.066	16.062	12.118	28.180
2011	10.018	8.845	18.863	1.866	8.110	9.976	11.884	16.954	28.839
2012	3.051	5.218	8.269	4.229	6.042	10.270	7.279	11.259	18.539
2013	7.150	3.614	10.764	15.045	4.524	19.569	22.195	8.138	30.334
2014	9.947	6.192	16.140	18.764	11.735	30.499	28.711	17.927	46.639
2015	11.343	8.298	19.641	11.442	12.676	24.119	22.785	20.975	43.760
2016	7.580	17.080	24.661	3.349	10.545	13.894	10.929	27.625	38.554
2017	1.231	15.589	16.819	2.054	13.889	15.943	3.284	29.478	32.762
2018	1.422	15.823	17.245	0.149	9.100	9.250	1.571	24.923	26.494
2019	0.301	6.608	6.909	0.460	5.666	6.125	0.761	12.274	13.034
2021	0.632	2.243	2.875	2.047	1.311	3.357	2.679	3.553	6.232
2022	1.065	1.224	2.289	4.938	1.324	6.262	6.003	2.548	8.551

Table 26: Raw sample sizes for NMFS survey size composition data prior to 2001. In the assessment model, an input sample size of 200 is used for all survey-related compositional data.

		male		female		
		undetermined		immature	mature	
year	no. hauls	new shell	old shell	new shell	new shell	old shell
1975	136	6,499	319	1,023	1,860	699
1976	214	4,250	203	1,097	1,303	311
1977	155	3,647	359	694	1,180	616
1978	230	4,090	679	1,949	632	1,259
1979	237	1,383	206	387	290	304
1980	320	6,839	522	1,418	1,468	568
1981	305	6,014	872	522	1,097	1,201
1982	342	3,076	2,045	754	409	2,382
1983	353	3,424	1,095	2,112	180	2,153
1984	355	2,331	1,378	1,879	258	1,530
1985	353	1,369	367	745	198	449
1986	353	2,418	432	1,484	181	330
1987	355	5,605	436	4,230	445	391
1988	370	7,837	385	3,735	1,753	520
1989	373	7,246	912	3,089	1,241	869
1990	370	7,615	1,195	3,102	1,502	1,300
1991	371	6,805	2,881	2,259	1,283	2,568
1992	355	4,616	1,905	1,494	808	2,204
1993	374	3,495	1,700	753	540	1,335
1994	374	1,705	1,795	920	109	1,291
1995	375	1,040	1,530	745	136	1,057
1996	374	1,143	1,393	815	95	961
1997	375	1,551	448	1,326	167	502
1998	374	2,359	561	1,710	154	273
1999	372	3,366	465	2,628	194	508
2000	371	3,373	575	2,249	242	345

Table 27: Raw sample sizes for NMFS survey size composition data since 2001. In the assessment model, an input sample size of 200 is used for all survey-related compositional data.

		male		female		
		undetermined		immature	mature	
year	no. hauls	new shell	old shell	new shell	new shell	old shell
2001	374	4,614	767	3,678	364	644
2002	374	4,363	1,079	3,585	335	498
2003	375	5,652	1,340	2,832	916	751
2004	374	5,355	1,665	3,922	357	656
2005	372	5,776	1,265	3,352	634	906
2006	375	7,980	3,384	4,363	1,332	1,321
2007	375	6,679	2,905	2,429	1,310	1,394
2008	374	4,872	1,950	1,646	564	1,776
2009	375	3,886	1,919	2,408	362	1,316
2010	375	4,656	1,510	3,050	242	941
2011	375	7,210	1,938	5,044	470	702
2012	375	7,078	1,271	3,611	941	526
2013	375	8,266	1,316	2,917	1,396	996
2014	375	6,977	2,807	2,211	482	1,584
2015	375	4,445	2,815	1,302	440	1,361
2016	375	3,109	3,661	1,175	370	1,247
2017	375	2,433	3,537	1,984	189	1,125
2018	375	5,503	2,551	4,666	434	702
2019	375	4,737	1,045	3,810	648	541
2021	375	4,950	777	3,014	1,116	873
2022	375	4,444	945	2,684	336	830

Table 28: Raw sample sizes for NMFS survey size composition data since 2001. In the assessment model, an input sample size of 200 is used for all survey-related compositional data.

	60-70 mm CW		70-80 mm CW		80-90 mm CW		90-100 mm CW		100-110 mm CW		110-120 mm CW		120-130 mm CW		130-140 mm CW	
year	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)	ss	Pr(mature)
2006	208	0.0243	430	0.0950	365	0.2236	275	0.3589	190	0.5059	120	0.6788	71	0.9100	24	0.9591
2007	39	0.0253	119	0.0843	152	0.3439	314	0.4001	243	0.3393	111	0.5828	57	0.8764	21	0.9048
2008	128	0.0312	166	0.0903	105	0.3293	116	0.5092	132	0.5520	105	0.7061	113	0.9559	54	0.9816
2009	38	0.0000	13	0.0769	44	0.0455	31	0.4194	35	0.3143	28	0.6490	33	0.8787	34	0.9412
2010	120	0.0577	94	0.0426	100	0.2504	119	0.5966	101	0.6044	83	0.8069	75	0.7870	53	0.8497
2011	22	0.0455	6	0.0000	4	0.0000	4	0.5000	3	0.3333	2	0.5000	4	1.0000	1	1.0000
2012	196	0.0000	119	0.0763	149	0.1888	118	0.2288	56	0.3016	49	0.5107	26	0.7308	19	1.0000
2014	54	0.0559	56	0.0713	74	0.2431	61	0.4044	80	0.3992	69	0.6087	41	0.8537	21	0.9048
2016	9	0.1111	32	0.1250	42	0.1429	43	0.4419	29	0.5517	57	0.8772	79	0.9873	70	1.0000
2017	91	0.0659	135	0.0370	126	0.1905	122	0.4098	99	0.5556	67	0.7164	60	0.7167	29	0.8966
2018	139	0.1063	116	0.1107	93	0.4098	90	0.4332	66	0.7727	29	0.8966	27	0.9630	16	1.0000
2019	172	0.0174	151	0.0727	152	0.1504	136	0.5644	72	0.6925	46	0.8694	19	0.9469	5	1.0000
2021	213	0.0376	279	0.0503	236	0.1436	250	0.3160	227	0.4670	115	0.7043	73	0.9178	12	1.0000
2022	126	0.0398	136	0.0782	169	0.2661	180	0.4000	181	0.4372	156	0.6795	97	0.7835	51	0.9804

Table 29: Survey biomass estimates (metric tons) and associated CVs from the BSFRF/NMFS collaborative side-by-side catchability studies conducted from 2013-2017.

	females								males			
	immature				mature				undetermined			
	BSFRF		NMFS		BSFRF		NMFS		BSFRF		NMFS	
year	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV
2013	1,562	0.446	522	0.378	8,369	0.484	3,050	0.460	56,571	0.554	21,109	0.381
2014	379	0.329	148	0.334	3,428	0.326	1,252	0.348	42,969	0.210	30,866	0.242
2015	165	0.430	255	0.617	2,633	0.423	713	0.444	23,271	0.204	16,802	0.222
2016	1,275	0.312	202	0.331	11,016	0.286	2,654	0.290	56,414	0.182	29,183	0.145
2017	5,430	0.169	759	0.279	15,984	0.302	4,662	0.334	69,448	0.188	30,719	0.152

Table 30: Survey abundance estimates (numbers of crab) and associated CVs from the BSFRF/NMFS collaborative side-by-side catchability studies conducted from 2013-2017.

	females								males			
	immature				mature				undetermined			
	BSFRF		NMFS		BSFRF		NMFS		BSFRF		NMFS	
year	Abundance	CV	Abundance	CV	Abundance	CV	Abundance	CV	Abundance	CV	Abundance	CV
2013	17,953,150	0.339	4,107,750	0.338	35,131,997	0.488	12,970,123	0.460	139,196,965	0.514	47,029,901	0.356
2014	5,743,414	0.393	2,202,041	0.502	14,409,767	0.328	5,285,271	0.382	90,888,373	0.204	60,447,261	0.243
2015	5,515,649	0.525	3,095,876	0.547	11,801,080	0.466	3,139,849	0.518	48,908,660	0.195	33,320,301	0.247
2016	51,210,787	0.278	5,185,519	0.365	62,792,962	0.307	15,343,471	0.306	170,059,785	0.203	66,643,522	0.166
2017	371,444,912	0.173	40,627,495	0.353	107,464,850	0.291	30,759,624	0.343	443,396,703	0.141	88,021,575	0.146

Table 31: Sample sizes from the BSFRF/NMFS collaborative side-by-side catchability studies conducted from 2013-2017. raw: number of crab measured. input: scaled sample size used as input sample size when fitting assessment model. NOTE: the NMFS size compositions are not fit in the models considered in this assessment.

	females								males			
	immature				mature				undetermined			
	BSFRF		NMFS		BSFRF		NMFS		BSFRF		NMFS	
year	raw	input	raw	input	raw	input	raw	input	raw	input	raw	input
2013	99	22	134	134	167	37	404	404	640	141	1,302	1,302
2014	25	9	58	58	66	25	149	149	441	166	1,814	1,814
2015	29	16	97	97	79	42	101	101	264	142	998	998
2016	318	38	179	179	380	45	503	503	998	118	2,281	2,281
2017	1,902	73	1,020	1,020	723	28	764	764	2,556	99	3,471	3,471

Table 32: Convergence diagnostics for all models.

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?
21.22a	--	--	346	--	--	0	3014	5.92E-04	yes
22.01	21.22a	using updated bycatch estimates for the groundfish fisheries used in place of old versions; new fishery and survey data for 2021/22	351	800	731	0	3077	1.98E-03	yes
22.03	22.01	fits to fishery catch data changed from sex-specific to aggregated, corresponding fits to size composition data changed to extended versions	351	800	710	1	3045	2.92E-03	yes
22.07	22.03	Starting model in 1982, estimating initial population size using individual parameters on logistic scale, minimal smoothing on parameters, all data prior to 1982 dropped	409	800	537	1	2943	2.69E-03	yes
22.08	22.07	using effective sample sizes estimated by bootstrapping as input sample sizes for NMFS survey data	409	800	772	3	3602	6.22E-04	yes
22.09	22.01	added 2021/22 as new time block for retention functions in the directed fishery	353	800	788	0	3072	1.39E-03	yes
22.10	22.03	added 2021/22 as new time block for retention functions in the directed fishery	353	800	794	1	3039	8.65E-03	yes
22.11	22.07	added 2021/22 as new time block for retention functions in the directed fishery	411	800	522	1	2938	2.49E-03	yes

Table 33: Parameters at bounds.

		name	label	21.22a	22.01	22.03	22.07	22.08	22.09	22.10	22.11
selectivity	selectivity	pS2[2]	width for NMFS survey selectivity (females, 1982+)	–	–	–	–	1	–	–	–
		pS2[28]	slope for TCF retention (2005-2009)	–	–	1	–	–	–	1	–
		pS2[3]	slope for TCF retention (pre-1991)	–	–	–	1	1	–	–	1
		pS2[4]	slope for TCF retention (1997+)	–	–	–	–	1	–	–	–

Table 34: 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.

			21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
process	name	label	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
recruitment	pLnR[1]	current recruitment period	–	–	–	–	–	–	5.672e+00	0.06994	5.860e+00	0.06314	–	–	–	–	5.672e+00	0.06994
		historical recruitment period	6.715e+00	0.58547	6.791e+00	0.58816	6.783e+00	0.58809	–	–	–	–	6.792e+00	0.58787	6.783e+00	0.58783	–	–
	pLnR[2]	current recruitment period	5.764e+00	0.07012	5.823e+00	0.07034	5.808e+00	0.07047	–	–	–	–	5.823e+00	0.07034	5.807e+00	0.07046	–	–
	pRa[1]	fixed value	2.235e+00	0.03169	2.228e+00	0.03088	2.230e+00	0.03088	2.213e+00	0.03039	2.250e+00	0.02174	2.228e+00	0.03091	2.230e+00	0.03091	2.213e+00	0.03042
	pRb[1]	fixed value	1.386e+00	0.08001	1.352e+00	0.07846	1.354e+00	0.07835	1.312e+00	0.07653	1.380e+00	0.05784	1.352e+00	0.07851	1.355e+00	0.07840	1.312e+00	0.07661
	pRCV[1]	full model period	−7.000e−01	*NA*	−7.000e−01	*NA*	−7.000e−01	*NA*	−6.931e−01	*NA*	−6.931e−01	*NA*	−7.000e−01	*NA*	−7.000e−01	*NA*	−6.931e−01	*NA*
	pRX[1]	full model period	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*	−1.110e−16	*NA*
N-at-Z	pLnBaseInitN[1]	base class initial N at Z	–	–	–	–	–	–	7.152e+00	0.08088	7.421e+00	0.07352	–	–	–	–	7.152e+00	0.08086
natural mortality	pDM1[1]	multiplier for immature crab	1.021e+00	0.04707	1.030e+00	0.04697	1.028e+00	0.04698	1.015e+00	0.04703	1.027e+00	0.04195	1.030e+00	0.04696	1.028e+00	0.04698	1.015e+00	0.04703
	pDM1[2]	multiplier for mature males	1.303e+00	0.03797	1.320e+00	0.03775	1.328e+00	0.03786	1.310e+00	0.03824	1.359e+00	0.03762	1.320e+00	0.03775	1.328e+00	0.03786	1.309e+00	0.03824
	pDM1[3]	multiplier for mature females	1.335e+00	0.03748	1.331e+00	0.03740	1.336e+00	0.03773	1.357e+00	0.03776	1.321e+00	0.03610	1.331e+00	0.03739	1.336e+00	0.03773	1.357e+00	0.03775
	pDM2[1]	1980-1984 multiplier for mature males	2.353e+00	0.24839	2.344e+00	0.24821	2.367e+00	0.25140	–	–	–	–	2.345e+00	0.24839	2.367e+00	0.25151	–	–
	pDM2[2]	1980-1984 multiplier for mature females	1.957e+00	0.16857	1.978e+00	0.16939	1.951e+00	0.16801	–	–	–	–	1.978e+00	0.16941	1.951e+00	0.16802	–	–
	pM[1]	base ln-scale M	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*	−1.470e+00	*NA*
growth	pGrA[1]	males	3.245e+01	0.25802	3.248e+01	0.26080	3.240e+01	0.25628	3.258e+01	0.27156	3.283e+01	0.27890	3.247e+01	0.26002	3.239e+01	0.25569	3.257e+01	0.27077
	pGrA[2]	females	3.363e+01	0.31445	3.364e+01	0.31457	3.368e+01	0.31414	3.371e+01	0.32555	3.421e+01	0.33436	3.363e+01	0.31419	3.368e+01	0.31378	3.371e+01	0.32508
	pGrB[1]	males	1.663e+02	0.75580	1.657e+02	0.72648	1.659e+02	0.73016	1.648e+02	0.72234	1.642e+02	0.66281	1.657e+02	0.72559	1.659e+02	0.72948	1.648e+02	0.72202
	pGrB[2]	females	1.150e+02	0.61369	1.149e+02	0.61004	1.150e+02	0.61113	1.148e+02	0.62700	1.147e+02	0.58093	1.149e+02	0.60981	1.150e+02	0.61087	1.148e+02	0.62670
	pGrBeta[1]	both sexes	8.501e−01	0.10400	8.296e−01	0.10213	8.302e−01	0.10103	8.044e−01	0.10359	8.778e−01	0.11097	8.288e−01	0.10188	8.294e−01	0.10082	8.037e−01	0.10334

Table 35: Final values for annual recruitment “devs” in the "historical" period up to 1975. Index begins in 1948.

				21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
			index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
recruitment	pDevsLnR	historical recruitment period	1	−0.49592	1.7780	−0.50131	1.7784	−0.49482	1.7793	–	–	–	–	−0.50136	1.7782	−0.49516	1.7791	–	–
			2	−0.49509	1.6452	−0.50048	1.6456	−0.49401	1.6465	–	–	–	–	−0.50053	1.6454	−0.49435	1.6463	–	–
			3	−0.49315	1.5158	−0.49854	1.5162	−0.49212	1.5171	–	–	–	–	−0.49859	1.5159	−0.49245	1.5169	–	–
			4	−0.48977	1.3909	−0.49514	1.3912	−0.48881	1.3921	–	–	–	–	−0.49519	1.3910	−0.48912	1.3919	–	–
			5	−0.48451	1.2718	−0.48983	1.2721	−0.48362	1.2729	–	–	–	–	−0.48987	1.2719	−0.48391	1.2727	–	–
			6	−0.47676	1.1603	−0.48200	1.1606	−0.47597	1.1612	–	–	–	–	−0.48204	1.1604	−0.47623	1.1610	–	–
			7	−0.46579	1.0587	−0.47085	1.0590	−0.46507	1.0593	–	–	–	–	−0.47089	1.0588	−0.46529	1.0591	–	–
			8	−0.45060	0.9698	−0.45536	0.9700	−0.44992	0.9701	–	–	–	–	−0.45539	0.9698	−0.45009	0.9699	–	–
			9	−0.42995	0.8969	−0.43420	0.8970	−0.42922	0.8967	–	–	–	–	−0.43423	0.8968	−0.42933	0.8966	–	–
			10	−0.40226	0.8435	−0.40574	0.8431	−0.40135	0.8427	–	–	–	–	−0.40576	0.8430	−0.40142	0.8426	–	–
			11	−0.36557	0.8126	−0.36798	0.8116	−0.36438	0.8112	–	–	–	–	−0.36799	0.8115	−0.36438	0.8111	–	–
			12	−0.31730	0.8061	−0.31837	0.8042	−0.31577	0.8040	–	–	–	–	−0.31835	0.8041	−0.31570	0.8039	–	–
			13	−0.25349	0.8232	−0.25300	0.8206	−0.25165	0.8208	–	–	–	–	−0.25295	0.8205	−0.25151	0.8207	–	–
			14	−0.16755	0.8594	−0.16547	0.8563	−0.16562	0.8571	–	–	–	–	−0.16538	0.8563	−0.16539	0.8571	–	–
			15	−0.04833	0.9041	−0.04499	0.9014	−0.04680	0.9024	–	–	–	–	−0.04484	0.9014	−0.04647	0.9023	–	–
			16	0.12444	0.9386	0.12800	0.9366	0.12477	0.9370	–	–	–	–	0.12826	0.9364	0.12523	0.9369	–	–
			17	0.39022	0.9368	0.39158	0.9341	0.38836	0.9338	–	–	–	–	0.39203	0.9339	0.38902	0.9336	–	–
			18	0.80303	0.8819	0.79754	0.8778	0.79760	0.8773	–	–	–	–	0.79822	0.8774	0.79845	0.8770	–	–
			19	1.35730	0.7867	1.34129	0.7843	1.34609	0.7825	–	–	–	–	1.34202	0.7839	1.34687	0.7821	–	–
			20	1.67168	0.6671	1.66251	0.6697	1.65752	0.6681	–	–	–	–	1.66234	0.6693	1.65730	0.6678	–	–
			21	1.21092	0.6788	1.22141	0.6810	1.19389	0.6820	–	–	–	–	1.21982	0.6808	1.19261	0.6818	–	–
			22	0.66147	0.6779	0.66421	0.6793	0.64097	0.6800	–	–	–	–	0.66291	0.6790	0.64009	0.6798	–	–
			23	0.36427	0.6566	0.36757	0.6580	0.36284	0.6578	–	–	–	–	0.36701	0.6577	0.36243	0.6576	–	–
			24	−0.09311	0.6611	−0.08203	0.6617	−0.08165	0.6616	–	–	–	–	−0.08252	0.6615	−0.08210	0.6614	–	–
			25	−0.48210	0.6613	−0.46451	0.6627	−0.46256	0.6626	–	–	–	–	−0.46406	0.6624	−0.46208	0.6623	–	–
			26	−0.17208	0.7021	−0.14432	0.6965	−0.14872	0.6970	–	–	–	–	−0.14268	0.6962	−0.14704	0.6967	–	–

Table 36: Final values for annual recruitment “devs” in the “current” period from 1975. The index begins in 1975 for models 22.01 and 22.03 and in 1983 for 22.07 and 22.08.

				21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
			index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
recruitment	pDevsLnR	current recruitment period	1	1.34374	0.31402	1.37866	0.30138	1.371102	0.30656	1.28553	0.10762	1.3109	0.08773	1.37820	0.30213	1.370461	0.30735	1.28657	0.10760
			2	1.95233	0.19762	1.96531	0.19289	1.969927	0.19406	0.95923	0.16584	0.8160	0.14188	1.96670	0.19297	1.971195	0.19414	0.95955	0.16594
			3	1.58569	0.22807	1.62100	0.22100	1.623838	0.22211	1.11363	0.15906	0.9978	0.13279	1.62111	0.22128	1.623559	0.22243	1.11350	0.15920
			4	0.65974	0.40538	0.66035	0.40489	0.637295	0.41376	1.11035	0.14917	0.9998	0.13044	0.65886	0.40574	0.635813	0.41456	1.11091	0.14921
			5	−0.17736	0.55445	−0.13270	0.53890	−0.125692	0.53667	0.94926	0.15702	0.8714	0.12919	−0.13176	0.53899	−0.125219	0.53685	0.94906	0.15716
			6	−0.17714	0.40939	−0.16322	0.40622	−0.163810	0.40665	0.50972	0.20274	0.4458	0.15790	−0.16256	0.40641	−0.163324	0.40684	0.50868	0.20292
			7	−0.01713	0.29742	0.01103	0.29052	0.007512	0.29055	−0.25649	0.25239	−0.1909	0.18369	0.01192	0.29059	0.008238	0.29064	−0.25651	0.25242
			8	−0.15650	0.28750	−0.13276	0.28270	−0.143958	0.28366	−0.91460	0.33515	−0.9324	0.26117	−0.13267	0.28294	−0.143899	0.28391	−0.91565	0.33543
			9	1.08265	0.11734	1.09289	0.11703	1.084432	0.11686	−1.24041	0.32141	−1.0926	0.21894	1.09389	0.11702	1.085473	0.11686	−1.24092	0.32152
			10	0.78270	0.17062	0.81167	0.16603	0.791021	0.16742	−1.16436	0.25490	−0.9184	0.15775	0.81197	0.16614	0.791239	0.16755	−1.16395	0.25490
			11	0.94362	0.16442	0.94717	0.16266	0.931690	0.16375	−1.15206	0.25528	−1.1814	0.18428	0.94699	0.16281	0.931606	0.16390	−1.15191	0.25541
			12	0.95506	0.15599	0.95514	0.15290	0.960184	0.15386	−0.97693	0.23918	−1.0364	0.17266	0.95563	0.15295	0.960737	0.15393	−0.97661	0.23927
			13	0.78670	0.16605	0.77859	0.16331	0.798373	0.16555	−0.49280	0.17803	−0.6177	0.14172	0.77834	0.16345	0.798236	0.16570	−0.49236	0.17807
			14	0.34809	0.21201	0.33073	0.20923	0.410546	0.20385	−0.70425	0.22775	−0.7842	0.18277	0.32969	0.20942	0.409624	0.20406	−0.70431	0.22789
			15	−0.43508	0.27252	−0.42969	0.26588	−0.355926	0.25624	0.19716	0.11734	0.1638	0.09463	−0.42924	0.26585	−0.355976	0.25629	0.19747	0.11736
			16	−0.89838	0.31276	−0.89371	0.30769	−1.065637	0.34866	−0.78518	0.23957	−0.7971	0.17950	−0.89472	0.30799	−1.066695	0.34895	−0.78528	0.23972
			17	−1.32027	0.33282	−1.33295	0.33099	−1.358549	0.32356	0.75140	0.09950	0.7286	0.08558	−1.33384	0.33115	−1.359049	0.32369	0.75194	0.09949
			18	−1.29114	0.26296	−1.29427	0.26078	−1.271511	0.25538	−0.35745	0.27157	−0.3807	0.21086	−1.29382	0.26076	−1.271062	0.25539	−0.35807	0.27184
			19	−1.33088	0.26996	−1.30517	0.26291	−1.300123	0.26409	1.12779	0.10071	1.1063	0.08688	−1.30508	0.26305	−1.300085	0.26425	1.12803	0.10073
			20	−1.11002	0.24409	−1.10653	0.24250	−1.097827	0.24319	−0.05627	0.27633	−0.1547	0.25551	−1.10614	0.24259	−1.097421	0.24328	−0.05623	0.27650
			21	−0.62715	0.18151	−0.61808	0.17978	−0.613559	0.18033	1.22905	0.10496	1.2141	0.08972	−0.61765	0.17982	−0.613120	0.18038	1.22894	0.10500
			22	−0.85127	0.23729	−0.83818	0.23392	−0.837855	0.23503	0.63957	0.14956	0.8951	0.10400	−0.83831	0.23408	−0.837986	0.23520	0.63903	0.14965
			23	0.07983	0.11839	0.07979	0.11791	0.082906	0.11806	−0.42139	0.26378	−0.3347	0.20903	0.08007	0.11793	0.083254	0.11809	−0.42222	0.26396
			24	−0.93610	0.24755	−0.92549	0.24483	−0.924835	0.24585	−0.91568	0.36183	−0.7830	0.25674	−0.92561	0.24497	−0.924933	0.24601	−0.91651	0.36203
			25	0.61543	0.10031	0.62324	0.09961	0.630661	0.09955	−0.39249	0.26413	−0.2745	0.16838	0.62373	0.09960	0.631195	0.09955	−0.39177	0.26412
			26	−0.51012	0.28166	−0.49864	0.27839	−0.499017	0.28012	0.15135	0.26307	−0.2551	0.17960	−0.49922	0.27865	−0.499621	0.28040	0.15212	0.26311
			27	1.00971	0.10116	1.01168	0.10048	1.015797	0.10084	1.51358	0.09611	1.3490	0.07322	1.01194	0.10049	1.016055	0.10086	1.51370	0.09618
			28	−0.24117	0.29403	−0.22794	0.28878	−0.207097	0.28808	0.54271	0.18728	0.6857	0.12659	−0.22798	0.28897	−0.207068	0.28828	0.54249	0.18737
			29	1.09959	0.10849	1.10095	0.10711	1.113741	0.10642	−0.20565	0.20208	−0.2602	0.15467	1.10091	0.10715	1.113619	0.10647	−0.20714	0.20232
			30	0.60042	0.14973	0.58576	0.14834	0.550121	0.15121	−1.47713	0.37748	−1.5041	0.28633	0.58536	0.14842	0.549688	0.15130	−1.47740	0.37754
			31	−0.57916	0.28467	−0.56176	0.27675	−0.578638	0.27676	−0.56529	0.15553	−0.4560	0.10556	−0.56271	0.27697	−0.579621	0.27700	−0.56509	0.15556
			32	−1.04070	0.36952	−1.04552	0.36672	−1.045676	0.36510	−1.11321	0.22139	−0.8364	0.12589	−1.04637	0.36691	−1.046505	0.36530	−1.11313	0.22152
			33	−0.48887	0.26209	−0.50260	0.26209	−0.501220	0.26195	−0.89787	0.19605	−0.9202	0.12781	−0.50191	0.26208	−0.500532	0.26195	−0.89609	0.19601
			34	−0.07782	0.27419	−0.04346	0.26970	−0.051185	0.27025	−0.75562	0.21070	−0.7229	0.13805	−0.04279	0.26976	−0.050758	0.27034	−0.75582	0.21072
			35	1.44627	0.09403	1.42007	0.09415	1.420115	0.09488	1.04444	0.08073	0.9712	0.07176	1.42036	0.09419	1.420291	0.09494	1.04381	0.08078
			36	0.43978	0.19955	0.39984	0.19717	0.430036	0.19448	0.12781	0.18918	0.2873	0.13774	0.39906	0.19733	0.429844	0.19461	0.12869	0.18918
			37	−0.28533	0.20591	−0.32664	0.20352	−0.312367	0.20480	0.58689	0.13788	0.7964	0.10379	−0.32820	0.20373	−0.313780	0.20504	0.58656	0.13796
			38	−1.58460	0.39100	−1.61294	0.38327	−1.608564	0.38500	−1.48532	0.58755	−1.6431	0.58044	−1.61345	0.38332	−1.609000	0.38509	−1.48536	0.58759
			39	−0.62306	0.15758	−0.68313	0.15648	−0.678895	0.15686	0.96503	0.15083	0.9288	0.14900	−0.68319	0.15651	−0.678742	0.15689	0.96526	0.15084
			40	−1.15008	0.22630	−1.22769	0.22421	−1.225380	0.22469	1.52593	0.18615	1.5087	0.18940	−1.22795	0.22434	−1.225196	0.22481	1.52601	0.18618
			41	−0.95307	0.20307	−1.04273	0.20062	−1.043088	0.20096	–	–	–	–	−1.04136	0.20060	−1.041448	0.20094	–	–
			42	−0.78508	0.21293	−0.87704	0.21124	−0.880743	0.21170	–	–	–	–	−0.87724	0.21127	−0.880732	0.21173	–	–
			43	1.03531	0.08603	0.92143	0.08142	0.922963	0.08153	–	–	–	–	0.92077	0.08147	0.922197	0.08159	–	–
			44	0.23456	0.19838	0.02439	0.19151	0.028881	0.19191	–	–	–	–	0.02559	0.19149	0.029746	0.19190	–	–
			45	0.76742	0.14863	0.46425	0.13951	0.465795	0.13972	–	–	–	–	0.46386	0.13959	0.465470	0.13980	–	–
			46	−1.26293	0.62572	−1.59854	0.57965	−1.600973	0.57993	–	–	–	–	−1.59876	0.57968	−1.601156	0.57997	–	–
			47	1.14171	0.17475	0.83266	0.15190	0.835670	0.15200	–	–	–	–	0.83279	0.15192	0.835812	0.15202	–	–
			48	–	–	1.40476	0.18740	1.409518	0.18752	–	–	–	–	1.40479	0.18743	1.409575	0.18755	–	–

Table 37: Estimated logistic-scale parameters describing initial proportions at size.

				21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
		label	index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
N-at-Z	pvLnInitNatZ	females immature new shell	1	–	–	–	–	–	–	−4.549	0.7075	−4.220	0.4194	–	–	–	–	−4.550	0.7075
			2	–	–	–	–	–	–	−3.632	0.4327	−3.439	0.2825	–	–	–	–	−3.632	0.4327
			3	–	–	–	–	–	–	−3.729	0.4499	−3.875	0.3554	–	–	–	–	−3.730	0.4499
			4	–	–	–	–	–	–	−3.548	0.3636	−3.458	0.2672	–	–	–	–	−3.547	0.3635
			5	–	–	–	–	–	–	−3.889	0.4255	−3.767	0.3074	–	–	–	–	−3.889	0.4254
			6	–	–	–	–	–	–	−4.137	0.5241	−4.016	0.3549	–	–	–	–	−4.137	0.5241
			7	–	–	–	–	–	–	−4.300	0.6173	−4.248	0.4237	–	–	–	–	−4.300	0.6172
			8	–	–	–	–	–	–	−4.505	0.7413	−4.483	0.5206	–	–	–	–	−4.505	0.7413
			9	–	–	–	–	–	–	−4.663	0.8305	−4.825	0.6464	–	–	–	–	−4.663	0.8305
			10	–	–	–	–	–	–	−5.344	0.9848	−5.364	0.7260	–	–	–	–	−5.345	0.9848
			11	–	–	–	–	–	–	−5.259	0.8875	−5.104	0.6042	–	–	–	–	−5.259	0.8875
			12	–	–	–	–	–	–	−4.927	0.6679	−4.472	0.4117	–	–	–	–	−4.928	0.6679
			13	–	–	–	–	–	–	−5.285	0.7039	−4.774	0.4330	–	–	–	–	−5.285	0.7038
			14	–	–	–	–	–	–	−6.052	1.0739	−5.657	0.9566	–	–	–	–	−6.052	1.0739
			15	–	–	–	–	–	–	−6.151	1.0695	−5.963	1.0503	–	–	–	–	−6.151	1.0695
			16	–	–	–	–	–	–	−6.331	1.0936	−6.166	1.0874	–	–	–	–	−6.331	1.0936
		females mature new shell	1	–	–	–	–	–	–	−5.463	1.1443	−5.957	1.1404	–	–	–	–	−5.463	1.1443
			2	–	–	–	–	–	–	−5.015	1.0870	−5.529	1.0987	–	–	–	–	−5.015	1.0870
			3	–	–	–	–	–	–	−4.625	1.0453	−5.053	1.0368	–	–	–	–	−4.625	1.0453
			4	–	–	–	–	–	–	−4.691	1.0378	−5.048	1.0235	–	–	–	–	−4.691	1.0378
			5	–	–	–	–	–	–	−3.563	1.0833	−3.675	1.0651	–	–	–	–	−3.564	1.0832
			6	–	–	–	–	–	–	−3.393	1.1057	−3.407	1.1007	–	–	–	–	−3.394	1.1056
			7	–	–	–	–	–	–	−3.713	1.0665	−3.636	1.0714	–	–	–	–	−3.713	1.0664
			8	–	–	–	–	–	–	−3.761	1.0603	−3.598	1.0759	–	–	–	–	−3.761	1.0602
			9	–	–	–	–	–	–	−4.142	1.0272	−3.833	1.0506	–	–	–	–	−4.142	1.0271
			10	–	–	–	–	–	–	−4.592	1.0067	−4.277	1.0158	–	–	–	–	−4.593	1.0067
			11	–	–	–	–	–	–	−5.123	1.0490	−4.591	1.0103	–	–	–	–	−5.123	1.0489
			12	–	–	–	–	–	–	−6.020	1.1681	−6.058	1.1563	–	–	–	–	−6.021	1.1680
			13	–	–	–	–	–	–	−6.040	1.1676	−6.105	1.1563	–	–	–	–	−6.040	1.1675
			14	–	–	–	–	–	–	−6.060	1.1657	−6.151	1.1543	–	–	–	–	−6.061	1.1656
			15	–	–	–	–	–	–	−6.072	1.1642	−6.190	1.1527	–	–	–	–	−6.072	1.1642
			16	–	–	–	–	–	–	−6.081	1.1623	−6.229	1.1507	–	–	–	–	−6.082	1.1623
			17	–	–	–	–	–	–	−6.086	1.1604	−6.264	1.1487	–	–	–	–	−6.086	1.1603
		females mature old shell	1	–	–	–	–	–	–	−5.463	1.1443	−5.957	1.1404	–	–	–	–	−5.463	1.1443
			2	–	–	–	–	–	–	−5.015	1.0870	−5.529	1.0987	–	–	–	–	−5.015	1.0870
			3	–	–	–	–	–	–	−4.625	1.0453	−5.053	1.0368	–	–	–	–	−4.625	1.0453
			4	–	–	–	–	–	–	−4.691	1.0378	−5.048	1.0235	–	–	–	–	−4.691	1.0378
			5	–	–	–	–	–	–	−3.563	1.0833	−3.675	1.0651	–	–	–	–	−3.564	1.0832
			6	–	–	–	–	–	–	−3.393	1.1057	−3.407	1.1007	–	–	–	–	−3.393	1.1056
			7	–	–	–	–	–	–	−3.713	1.0665	−3.636	1.0714	–	–	–	–	−3.713	1.0663
			8	–	–	–	–	–	–	−3.761	1.0603	−3.598	1.0759	–	–	–	–	−3.761	1.0602
			9	–	–	–	–	–	–	−4.142	1.0272	−3.833	1.0506	–	–	–	–	−4.142	1.0271
			10	–	–	–	–	–	–	−4.592	1.0067	−4.277	1.0158	–	–	–	–	−4.593	1.0067
			11	–	–	–	–	–	–	−5.123	1.0490	−4.591	1.0103	–	–	–	–	−5.123	1.0489
			12	–	–	–	–	–	–	−6.020	1.1681	−6.058	1.1563	–	–	–	–	−6.021	1.1680
			13	–	–	–	–	–	–	−6.040	1.1676	−6.105	1.1563	–	–	–	–	−6.040	1.1675
			14	–	–	–	–	–	–	−6.060	1.1657	−6.151	1.1543	–	–	–	–	−6.061	1.1656
			15	–	–	–	–	–	–	−6.072	1.1642	−6.190	1.1527	–	–	–	–	−6.072	1.1642
			16	–	–	–	–	–	–	−6.081	1.1623	−6.229	1.1507	–	–	–	–	−6.082	1.1623
			17	–	–	–	–	–	–	−6.086	1.1604	−6.264	1.1487	–	–	–	–	−6.086	1.1603
		males immature new shell	1	–	–	–	–	–	–	−4.837	1.2772	−5.709	1.2043	–	–	–	–	−4.835	1.2773
			2	–	–	–	–	–	–	−3.778	0.9587	−5.184	1.1985	–	–	–	–	−3.777	0.9584
			3	–	–	–	–	–	–	−2.732	0.3361	−3.062	0.2827	–	–	–	–	−2.731	0.3361
			4	–	–	–	–	–	–	−3.531	0.4258	−3.811	0.4117	–	–	–	–	−3.529	0.4254
			5	–	–	–	–	–	–	−3.808	0.3823	−4.100	0.3035	–	–	–	–	−3.808	0.3822
			6	–	–	–	–	–	–	−4.319	0.4504	−4.690	0.3896	–	–	–	–	−4.319	0.4503
			7	–	–	–	–	–	–	−4.306	0.3956	−4.628	0.3417	–	–	–	–	−4.306	0.3956
			8	–	–	–	–	–	–	−5.117	0.8156	−5.591	0.8173	–	–	–	–	−5.117	0.8155
			9	–	–	–	–	–	–	−5.170	0.8038	−5.711	0.8415	–	–	–	–	−5.170	0.8038
			10	–	–	–	–	–	–	−5.348	0.8926	−5.608	0.8762	–	–	–	–	−5.347	0.8925
			11	–	–	–	–	–	–	−5.445	0.9302	−5.209	0.7616	–	–	–	–	−5.445	0.9301
			12	–	–	–	–	–	–	−5.583	0.9642	−5.530	0.8856	–	–	–	–	−5.583	0.9642
			13	–	–	–	–	–	–	−5.295	0.8671	−5.299	0.7913	–	–	–	–	−5.295	0.8671
			14	–	–	–	–	–	–	−4.742	0.6406	−4.393	0.4310	–	–	–	–	−4.741	0.6404
			15	–	–	–	–	–	–	−5.284	0.8758	−4.989	0.6782	–	–	–	–	−5.285	0.8759
			16	–	–	–	–	–	–	−5.511	0.9375	−5.189	0.7575	–	–	–	–	−5.510	0.9371
			17	–	–	–	–	–	–	−5.398	0.8272	−4.951	0.5778	–	–	–	–	−5.397	0.8269
			18	–	–	–	–	–	–	−5.504	0.8502	−5.350	0.7240	–	–	–	–	−5.505	0.8501
			19	–	–	–	–	–	–	−5.225	0.6739	−5.085	0.5451	–	–	–	–	−5.226	0.6741
			20	–	–	–	–	–	–	−5.867	0.8802	−5.767	0.7867	–	–	–	–	−5.868	0.8805
			21	–	–	–	–	–	–	−6.723	1.0531	−6.589	1.0122	–	–	–	–	−6.723	1.0530
			22	–	–	–	–	–	–	−7.086	1.0597	−6.973	1.0397	–	–	–	–	−7.086	1.0597
			23	–	–	–	–	–	–	−7.134	1.0502	−7.202	1.0380	–	–	–	–	−7.134	1.0501
			24	–	–	–	–	–	–	−7.333	1.0388	−7.383	1.0247	–	–	–	–	−7.332	1.0388
		males mature new shell	1	–	–	–	–	–	–	−5.699	1.0872	−6.142	1.0542	–	–	–	–	−5.699	1.0872
			2	–	–	–	–	–	–	−5.822	1.0713	−6.172	1.0305	–	–	–	–	−5.822	1.0713
			3	–	–	–	–	–	–	−5.581	1.0236	−5.662	0.9797	–	–	–	–	−5.581	1.0236
			4	–	–	–	–	–	–	−5.343	0.9885	−5.213	0.9683	–	–	–	–	−5.343	0.9885
			5	–	–	–	–	–	–	−5.260	0.9708	−5.082	0.9548	–	–	–	–	−5.260	0.9708
			6	–	–	–	–	–	–	−5.119	0.9677	−4.927	0.9580	–	–	–	–	−5.119	0.9677
			7	–	–	–	–	–	–	−4.834	0.9724	−4.617	0.9753	–	–	–	–	−4.834	0.9724
			8	–	–	–	–	–	–	−4.618	0.9768	−4.414	0.9866	–	–	–	–	−4.618	0.9768
			9	–	–	–	–	–	–	−4.516	0.9811	−4.273	0.9971	–	–	–	–	−4.516	0.9810
			10	–	–	–	–	–	–	−4.604	0.9740	−4.394	0.9860	–	–	–	–	−4.604	0.9740
			11	–	–	–	–	–	–	−4.771	0.9633	−4.600	0.9686	–	–	–	–	−4.771	0.9633
			12	–	–	–	–	–	–	−5.011	0.9546	−4.925	0.9503	–	–	–	–	−5.011	0.9545
			13	–	–	–	–	–	–	−5.121	0.9489	−5.046	0.9415	–	–	–	–	−5.121	0.9489
			14	–	–	–	–	–	–	−5.243	0.9388	−5.196	0.9283	–	–	–	–	−5.244	0.9387
			15	–	–	–	–	–	–	−5.452	0.9326	−5.348	0.9193	–	–	–	–	−5.452	0.9326
			16	–	–	–	–	–	–	−5.615	0.9222	−5.924	0.9090	–	–	–	–	−5.616	0.9222
			17	–	–	–	–	–	–	−6.062	0.8978	−6.383	0.8860	–	–	–	–	−6.062	0.8978
			18	–	–	–	–	–	–	−6.117	0.8803	−6.396	0.8609	–	–	–	–	−6.117	0.8803
			19	–	–	–	–	–	–	−6.273	0.8769	−6.562	0.8571	–	–	–	–	−6.273	0.8769
			20	–	–	–	–	–	–	−6.660	0.8720	−6.957	0.8529	–	–	–	–	−6.660	0.8720
			21	–	–	–	–	–	–	−7.783	1.0294	−8.103	1.0135	–	–	–	–	−7.782	1.0294
			22	–	–	–	–	–	–	−8.062	1.0329	−8.329	1.0161	–	–	–	–	−8.062	1.0329
			23	–	–	–	–	–	–	−8.087	1.0323	−8.354	1.0157	–	–	–	–	−8.086	1.0323
			24	–	–	–	–	–	–	−8.106	1.0317	−8.373	1.0152	–	–	–	–	−8.106	1.0317
			25	–	–	–	–	–	–	−8.125	1.0311	−8.391	1.0148	–	–	–	–	−8.124	1.0311
		males mature old shell	1	–	–	–	–	–	–	−5.699	1.0872	−6.142	1.0542	–	–	–	–	−5.699	1.0872
			2	–	–	–	–	–	–	−5.822	1.0713	−6.172	1.0305	–	–	–	–	−5.822	1.0713
			3	–	–	–	–	–	–	−5.581	1.0236	−5.662	0.9797	–	–	–	–	−5.581	1.0236
			4	–	–	–	–	–	–	−5.343	0.9885	−5.213	0.9683	–	–	–	–	−5.344	0.9885
			5	–	–	–	–	–	–	−5.260	0.9708	−5.082	0.9548	–	–	–	–	−5.260	0.9708
			6	–	–	–	–	–	–	−5.119	0.9677	−4.927	0.9580	–	–	–	–	−5.119	0.9677
			7	–	–	–	–	–	–	−4.834	0.9725	−4.617	0.9753	–	–	–	–	−4.834	0.9724
			8	–	–	–	–	–	–	−4.618	0.9768	−4.414	0.9866	–	–	–	–	−4.618	0.9768
			9	–	–	–	–	–	–	−4.516	0.9811	−4.273	0.9970	–	–	–	–	−4.516	0.9810
			10	–	–	–	–	–	–	−4.604	0.9740	−4.394	0.9860	–	–	–	–	−4.604	0.9740
			11	–	–	–	–	–	–	−4.771	0.9633	−4.600	0.9686	–	–	–	–	−4.771	0.9633
			12	–	–	–	–	–	–	−5.011	0.9546	−4.925	0.9503	–	–	–	–	−5.011	0.9545
			13	–	–	–	–	–	–	−5.121	0.9489	−5.046	0.9415	–	–	–	–	−5.121	0.9489
			14	–	–	–	–	–	–	−5.243	0.9388	−5.196	0.9283	–	–	–	–	−5.244	0.9387
			15	–	–	–	–	–	–	−5.452	0.9327	−5.348	0.9193	–	–	–	–	−5.452	0.9326
			16	–	–	–	–	–	–	−5.615	0.9222	−5.924	0.9090	–	–	–	–	−5.616	0.9222
			17	–	–	–	–	–	–	−6.062	0.8978	−6.383	0.8860	–	–	–	–	−6.062	0.8978
			18	–	–	–	–	–	–	−6.117	0.8803	−6.396	0.8609	–	–	–	–	−6.117	0.8803
			19	–	–	–	–	–	–	−6.273	0.8769	−6.562	0.8571	–	–	–	–	−6.273	0.8769
			20	–	–	–	–	–	–	−6.660	0.8720	−6.957	0.8529	–	–	–	–	−6.660	0.8720
			21	–	–	–	–	–	–	−7.783	1.0294	−8.103	1.0135	–	–	–	–	−7.782	1.0294
			22	–	–	–	–	–	–	−8.062	1.0329	−8.329	1.0161	–	–	–	–	−8.062	1.0329
			23	–	–	–	–	–	–	−8.087	1.0323	−8.354	1.0157	–	–	–	–	−8.086	1.0323
			24	–	–	–	–	–	–	−8.106	1.0317	−8.373	1.0152	–	–	–	–	−8.106	1.0317
			25	–	–	–	–	–	–	−8.125	1.0311	−8.391	1.0148	–	–	–	–	−8.124	1.0311

Table 38: 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.

				21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
		label	index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
maturity	pvLgtPrM2M	females 50-105 mmCW (entire model period)	1	−5.34142	1.21490	−5.3743	1.21450	−5.38901	1.21760	−5.38611	1.35500	−5.70364	1.17250	−5.37418	1.21450	−5.38890	1.21760	−5.38592	1.35490
			2	−4.10929	0.56933	−4.1288	0.56884	−4.13264	0.57097	−4.25390	0.62560	−4.48790	0.47598	−4.12881	0.56883	−4.13265	0.57094	−4.25384	0.62557
			3	−2.91568	0.25027	−2.9232	0.24931	−2.91702	0.24930	−3.10480	0.27399	−3.24817	0.21842	−2.92326	0.24931	−2.91714	0.24930	−3.10485	0.27399
			4	−1.71361	0.14724	−1.7196	0.14644	−1.70905	0.14626	−1.86307	0.17178	−1.88195	0.10938	−1.71964	0.14644	−1.70920	0.14626	−1.86318	0.17178
			5	−0.57842	0.09229	−0.5873	0.09143	−0.58231	0.09173	−0.75613	0.10889	−0.79236	0.06605	−0.58732	0.09142	−0.58245	0.09172	−0.75625	0.10889
			6	0.25956	0.09191	0.2533	0.09115	0.25646	0.09149	0.20310	0.10470	0.24272	0.06959	0.25327	0.09115	0.25631	0.09148	0.20296	0.10469
			7	0.57081	0.10367	0.5670	0.10299	0.57052	0.10355	0.63607	0.11866	0.71943	0.08493	0.56702	0.10299	0.57042	0.10354	0.63595	0.11865
			8	1.07017	0.13746	1.0681	0.13631	1.06542	0.13683	1.06699	0.15234	1.12734	0.11410	1.06808	0.13630	1.06532	0.13681	1.06685	0.15231
			9	1.95964	0.22847	1.9502	0.22657	1.96038	0.22786	2.07621	0.26060	2.28683	0.23892	1.95028	0.22657	1.96024	0.22783	2.07597	0.26055
			10	2.86654	0.42636	2.8351	0.41715	2.90741	0.44476	3.27245	0.56980	3.47813	0.60258	2.83507	0.41712	2.90703	0.44464	3.27194	0.56967
			11	3.80481	0.97449	3.7528	0.95577	3.90819	1.00730	4.53283	1.19450	4.72022	1.26130	3.75260	0.95574	3.90752	1.00710	4.53206	1.19430
		males 60-150 mmCW (entire model period)	1	−2.91297	0.21518	−2.8797	0.20677	−2.87552	0.20640	−2.91938	0.21617	−2.96348	0.19475	−2.87929	0.20670	−2.87497	0.20629	−2.91891	0.21608
			2	−3.45450	0.29159	−3.4994	0.29446	−3.51125	0.29649	−3.58977	0.31499	−3.63992	0.28932	−3.49919	0.29446	−3.51156	0.29654	−3.58998	0.31505
			3	−2.91186	0.23918	−2.9575	0.24438	−2.96819	0.24716	−3.07057	0.27238	−3.09112	0.23963	−2.95860	0.24443	−2.96971	0.24726	−3.07196	0.27245
			4	−2.15567	0.13337	−2.1431	0.13019	−2.13738	0.13018	−2.16059	0.13574	−2.20084	0.12197	−2.14300	0.13014	−2.13691	0.13010	−2.16018	0.13567
			5	−1.49020	0.11826	−1.4397	0.11522	−1.43340	0.11561	−1.43106	0.12442	−1.52367	0.10802	−1.44009	0.11522	−1.43356	0.11559	−1.43122	0.12442
			6	−1.29688	0.10527	−1.2919	0.10381	−1.29864	0.10454	−1.28406	0.11138	−1.30284	0.09424	−1.29105	0.10376	−1.29810	0.10450	−1.28357	0.11135
			7	−0.76915	0.09783	−0.7979	0.09692	−0.80810	0.09771	−0.82679	0.10430	−0.85946	0.08855	−0.79679	0.09676	−0.80780	0.09756	−0.82565	0.10413
			8	−0.33395	0.08828	−0.3103	0.08673	−0.29843	0.08707	−0.26686	0.09257	−0.32084	0.07965	−0.31328	0.08667	−0.30067	0.08700	−0.26977	0.09252
			9	−0.29102	0.08975	−0.2921	0.08844	−0.28301	0.08884	−0.26101	0.09380	−0.29278	0.08216	−0.29060	0.08842	−0.28076	0.08883	−0.25850	0.09379
			10	0.01495	0.08980	0.0245	0.08838	0.02778	0.08871	0.04542	0.09316	0.09029	0.08388	0.02412	0.08834	0.02698	0.08867	0.04463	0.09313
			11	0.43636	0.09508	0.4603	0.09375	0.46356	0.09419	0.48283	0.09760	0.51313	0.09115	0.46067	0.09371	0.46360	0.09415	0.48271	0.09755
			12	0.95404	0.12212	0.9536	0.11720	0.93341	0.11718	0.99191	0.11941	1.03376	0.11366	0.95244	0.11702	0.93245	0.11703	0.99110	0.11929
			13	1.69878	0.15390	1.6028	0.14224	1.58958	0.14316	1.60226	0.14281	1.65187	0.14014	1.59732	0.14153	1.58447	0.14246	1.59702	0.14213
			14	2.72566	0.26754	2.6094	0.25619	2.59435	0.25782	2.55681	0.26085	2.54894	0.25613	2.62294	0.25714	2.60851	0.25882	2.57109	0.26189
			15	3.09124	0.28259	3.0848	0.27449	3.06172	0.28054	3.04864	0.28494	3.08891	0.28520	3.08173	0.27529	3.05844	0.28138	3.04540	0.28583
			16	3.68702	0.48607	3.7600	0.50022	3.65900	0.48495	3.63445	0.47985	3.63549	0.46801	3.75173	0.49830	3.65146	0.48317	3.62721	0.47812
			17	4.85579	1.04720	4.9428	1.09130	4.75803	1.07760	4.67267	1.09380	4.58883	1.09550	4.93257	1.08810	4.74947	1.07450	4.66452	1.09070

Table 39: 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.

			21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
process	name	label	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
fisheries	pDC2[1]	TCF: female offset	−2.5050	0.20801	−2.5299	0.20657	−2.6878	0.20849	−2.7302	0.22822	−2.7650	0.22267	−2.5293	0.20631	−2.6853	0.20848	−2.7274	0.22820
	pDC2[2]	SCF: female offset	−2.0173	0.28214	−2.0355	0.28227	−2.6607	0.33135	−2.6064	0.39723	−2.6462	0.38210	−2.0354	0.28227	−2.6606	0.33151	−2.6063	0.39740
	pDC2[3]	GTF: female offset	−0.9898	0.09264	−1.0107	0.09435	−1.0341	0.09450	−1.3051	0.11805	−1.3014	0.11056	−1.0110	0.09438	−1.0343	0.09453	−1.3051	0.11804
	pDC2[4]	RKF: female offset	−2.4803	0.63574	−2.3951	0.63987	−2.3645	0.84252	−2.6763	0.78147	−2.6152	0.77381	−2.3950	0.63988	−2.3636	0.84253	−2.6751	0.78151
	pHM[1]	handling mortality for pot fisheries	0.3210	NA	0.3210	NA	0.3210	NA	0.3210	NA	0.3210	NA	0.3210	NA	0.3210	NA	0.3210	NA
	pHM[2]	handling mortality for groundfish trawl fisheries	0.8000	NA	0.8000	NA	0.8000	NA	0.8000	NA	0.8000	NA	0.8000	NA	0.8000	NA	0.8000	NA
	pLgtRet[1]	TCF: logit-scale max retention (pre-1997)	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA
	pLgtRet[2]	TCF: logit-scale max retention (2005-2009)	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA
	pLgtRet[3]	TCF: logit-scale max retention (2013+)	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA	14.9000	NA
	pLnC[1]	TCF: base capture rate, ALL YEARS	–	–	–	–	–	–	−2.1593	0.05928	−2.3165	0.06166	–	–	–	–	−2.1696	0.05914
		TCF: base capture rate, pre-1965 (=0.05)	−2.9957	NA	−2.9957	NA	−2.9957	NA	–	–	–	–	−2.9957	NA	−2.9957	NA	–	–
	pLnC[2]	SCF: base capture rate, ALL YEARS	–	–	–	–	–	–	−3.7288	0.07237	−3.9172	0.07298	–	–	–	–	−3.7286	0.07235
		TCF: base capture rate, 1965+	−1.3265	0.12814	−1.4210	0.12376	−1.4231	0.12375	–	–	–	–	−1.4265	0.12360	−1.4296	0.12364	–	–
	pLnC[3]	GTF: base capture rate, ALL YEARS	–	–	–	–	–	–	−4.9909	0.06773	−5.1879	0.06716	–	–	–	–	−4.9906	0.06772
		SCF: base capture rate, pre-1978 (=0.01)	−4.6052	NA	−4.6052	NA	−4.6052	NA	–	–	–	–	−4.6052	NA	−4.6052	NA	–	–
	pLnC[4]	RKF: base capture rate, ALL YEARS	–	–	–	–	–	–	−4.6559	0.11061	−4.8247	0.11133	–	–	–	–	−4.6561	0.11059
		SCF: base capture rate, 1992+	−3.6507	0.07028	−3.7562	0.07013	−3.7151	0.07088	–	–	–	–	−3.7563	0.07010	−3.7152	0.07092	–	–
	pLnC[5]	DUMMY CAPTURE RATE	−4.1807	NA	−4.1807	NA	−4.1807	NA	–	–	–	–	−4.1807	NA	−4.1807	NA	–	–
	pLnC[6]	GTF: base capture rate, ALL YEARS	−4.9165	0.05861	−4.9678	0.05935	−4.9429	0.05908	–	–	–	–	−4.9676	0.05935	−4.9427	0.05908	–	–
	pLnC[7]	RKF: base capture rate, pre-1953 (=0.02)	−3.9120	NA	−3.9120	NA	−3.9120	NA	–	–	–	–	−3.9120	NA	−3.9120	NA	–	–
	pLnC[8]	RKF: base capture rate, 1992+	−4.7478	0.09941	−4.7761	0.09915	−4.7553	0.10849	–	–	–	–	−4.7760	0.09913	−4.7554	0.10848	–	–
surveys	pQ[1]	NMFS trawl survey: males, 1975-1981	−0.6549	0.10728	−0.7013	0.10792	−0.6824	0.10739	–	–	–	–	−0.7012	0.10789	−0.6821	0.10734	–	–
		NMFS trawl survey: males, 1982+	–	–	–	–	–	–	−0.6496	0.05291	−0.8293	0.05353	–	–	–	–	−0.6493	0.05289
	pQ[2]	NMFS trawl survey: females, 1982+	–	–	–	–	–	–	−1.3185	0.07561	−1.6150	0.05860	–	–	–	–	−1.3182	0.07559
		NMFS trawl survey: males, 1982+	−0.6343	0.05031	−0.6843	0.05113	−0.6611	0.05067	–	–	–	–	−0.6841	0.05111	−0.6609	0.05065	–	–
	pQ[3]	BSFRF SBS	–	–	–	–	–	–	0.0000	NA	0.0000	NA	–	–	–	–	0.0000	NA
		NMFS trawl survey: females, 1975-1981	−0.9880	0.13293	−1.0718	0.13343	−1.0648	0.13313	–	–	–	–	−1.0723	0.13340	−1.0649	0.13310	–	–
	pQ[4]	NMFS trawl survey: females, 1982+	−1.2543	0.07538	−1.3249	0.07553	−1.3179	0.07557	–	–	–	–	−1.3249	0.07551	−1.3177	0.07554	–	–
	pQ[5]	BSFRF SBS	0.0000	NA	0.0000	NA	0.0000	NA	–	–	–	–	0.0000	NA	0.0000	NA	–	–
Dirichlet-Multinomial	pLnDirMul[1]	ln(theta) parameter for BSFRF SBS M	–	–	0.9403	0.24726	0.9290	0.24659	0.9693	0.24913	0.9552	0.24787	0.9401	0.24725	0.9287	0.24657	0.9690	0.24911
		ln(theta) parameter for NMFS M	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[10]	ln(theta) parameter for RKF total male catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[11]	ln(theta) parameter for RKF total female catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[12]	ln(theta) parameter for GF All total male+female catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[2]	ln(theta) parameter for BSFRF SBS F	–	–	2.5276	0.24473	2.5272	0.24472	2.5292	0.24474	2.5224	0.24460	2.5276	0.24473	2.5272	0.24472	2.5292	0.24474
		ln(theta) parameter for NMFS F	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[3]	ln(theta) parameter for BSFRF SBS M	0.9448	0.24815	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[4]	ln(theta) parameter for BSFRF SBS F	2.5297	0.24481	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[5]	ln(theta) parameter for TCF retained catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[6]	ln(theta) parameter for TCF total male catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[7]	ln(theta) parameter for TCF total female catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[8]	ln(theta) parameter for SCF total male catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	pLnDirMul[9]	ln(theta) parameter for SCF total female catch	0.0000	NA	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 40: 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.

	21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
1	−1.458652	0.8675	−1.36439	0.8735	−1.37702	0.8742	0.02330	0.18861	0.2139	0.17065	−1.35982	0.8733	−1.37122	0.8740	0.03285	0.18853
2	−1.249296	0.7182	−1.15607	0.7229	−1.16825	0.7233	−1.84612	0.11947	−1.9043	0.11391	−1.15153	0.7226	−1.16252	0.7231	−1.83644	0.11935
3	0.592145	0.6597	0.68420	0.6623	0.67197	0.6621	−0.68452	0.11489	−0.7756	0.10569	0.68863	0.6620	0.67756	0.6618	−0.67500	0.11476
4	1.170177	0.6431	1.26029	0.6409	1.24738	0.6401	−0.66422	0.07569	−0.6367	0.07164	1.26457	0.6404	1.25278	0.6396	−0.65504	0.07558
5	2.333972	0.9293	2.41041	0.8906	2.39556	0.8897	0.32942	0.05797	0.3454	0.05369	2.41400	0.8888	2.40017	0.8877	0.33877	0.05786
6	4.121946	0.7829	4.05703	0.7646	4.07690	0.7762	1.48429	0.05668	1.4912	0.05104	4.05796	0.7639	4.07803	0.7754	1.49350	0.05657
7	4.734865	0.6810	4.62867	0.6888	4.64191	0.7286	2.22752	0.06824	2.2005	0.05847	4.62764	0.6908	4.64037	0.7313	2.23666	0.06813
8	2.116776	1.2425	2.15342	1.1937	2.10677	1.2149	2.56248	0.11237	2.5307	0.10581	2.15488	1.1940	2.10851	1.2155	2.57130	0.11220
9	−0.001303	0.3380	0.08275	0.3463	0.06231	0.3458	2.93418	0.12591	2.7907	0.10599	0.08728	0.3465	0.06788	0.3460	2.94296	0.12572
10	−0.344289	0.2172	−0.27171	0.2173	−0.27979	0.2172	2.52499	0.12147	2.4198	0.11654	−0.26691	0.2172	−0.27389	0.2171	2.53352	0.12135
11	−0.215492	0.1837	−0.14739	0.1818	−0.14975	0.1820	1.80948	0.14072	1.7508	0.13992	−0.14252	0.1817	−0.14381	0.1819	1.81803	0.14053
12	0.534756	0.1800	0.60622	0.1780	0.60442	0.1780	1.22113	0.13464	1.1501	0.13680	0.61105	0.1779	0.61031	0.1779	1.22960	0.13440
13	1.287688	0.2078	1.36152	0.2055	1.35489	0.2051	1.16393	0.19499	1.0782	0.19863	1.36609	0.2054	1.36053	0.2049	1.17218	0.19484
14	1.565886	0.2923	1.63135	0.2844	1.61490	0.2820	−1.62921	0.05638	−1.5978	0.05453	1.63507	0.2841	1.61983	0.2816	−1.61930	0.05627
15	2.054475	0.3957	2.08635	0.3661	2.06622	0.3617	−1.00726	0.05649	−0.9755	0.05440	2.08890	0.3651	2.07015	0.3607	−0.99739	0.05637
16	1.776460	0.2686	1.84288	0.2608	1.85052	0.2620	−1.19244	0.05554	−1.1565	0.05363	1.84786	0.2607	1.85657	0.2619	−1.18230	0.05543
17	0.089783	0.1531	0.17745	0.1511	0.18834	0.1515	−1.33011	0.05711	−1.2975	0.05551	0.18304	0.1511	0.19488	0.1515	−1.32060	0.05698
18	−1.027157	0.1355	−0.95787	0.1319	−0.94876	0.1321	−1.29955	0.10086	−1.2652	0.10025	−0.95289	0.1318	−0.94280	0.1320	−1.29155	0.10075
19	−2.447669	0.1371	−2.39123	0.1331	−2.37987	0.1333	−1.21767	0.06250	−1.1962	0.06014	−2.38646	0.1331	−2.37414	0.1332	−1.21452	0.06236
20	−1.143152	0.1495	−1.08618	0.1456	−1.06992	0.1460	0.05043	0.05558	0.1183	0.05336	−1.08144	0.1455	−1.06430	0.1459	0.06060	0.05578
21	−1.532399	0.1310	−1.44644	0.1269	−1.43900	0.1269	0.34971	0.05329	0.4167	0.05212	−1.44185	0.1268	−1.43344	0.1268	0.36300	0.05346
22	−0.586882	0.1305	−0.49606	0.1263	−0.48476	0.1265	−1.36563	0.05409	−1.3003	0.05373	−0.49124	0.1263	−0.47903	0.1264	−1.35570	0.05412
23	0.593532	0.1318	0.67943	0.1278	0.69860	0.1280	−1.21993	0.05321	−1.1748	0.05253	0.68412	0.1277	0.70419	0.1279	−1.20559	0.05334
24	1.331416	0.1377	1.40733	0.1336	1.45771	0.1350	−1.44413	0.05592	−1.4374	0.05457	1.41205	0.1335	1.46325	0.1349	−1.42597	0.05593
25	1.590444	0.1649	1.66565	0.1616	1.75607	0.1605	−1.78007	0.05882	−1.7885	0.05727	1.67024	0.1614	1.76121	0.1603	−2.01357	0.09559
26	1.925011	0.1639	1.96760	0.1587	2.09877	0.1703	–	–	–	–	1.97241	0.1585	2.10393	0.1701	–	–
27	1.621890	0.1732	1.63827	0.1684	1.65436	0.1677	–	–	–	–	1.64270	0.1683	1.65927	0.1676	–	–
28	0.995611	0.1881	1.01308	0.1844	0.90160	0.1766	–	–	–	–	1.01691	0.1842	0.90657	0.1765	–	–
29	0.485739	0.2141	0.50629	0.2116	0.31437	0.1700	–	–	–	–	0.50926	0.2112	0.31928	0.1698	–	–
30	−0.159819	0.1727	−0.13378	0.1694	0.24195	0.2239	–	–	–	–	−0.12935	0.1693	0.24651	0.2237	–	–
31	−2.453514	0.1375	−2.37670	0.1331	−2.43412	0.1282	–	–	–	–	−2.37166	0.1330	−2.42785	0.1281	–	–
32	−1.837678	0.1375	−1.76180	0.1332	−1.81609	0.1282	–	–	–	–	−1.75665	0.1331	−1.80982	0.1281	–	–
33	−2.004581	0.1373	−1.92821	0.1329	−1.99299	0.1279	–	–	–	–	−1.92308	0.1328	−1.98653	0.1278	–	–
34	−2.147043	0.1380	−2.07122	0.1336	−2.15088	0.1279	–	–	–	–	−2.06649	0.1335	−2.14490	0.1278	–	–
35	−1.935934	0.1780	−1.87679	0.1730	−2.17210	0.1494	–	–	–	–	−1.87362	0.1728	−2.16766	0.1492	–	–
36	−2.136240	0.1357	−2.04268	0.1313	−2.02130	0.1306	–	–	–	–	−2.04227	0.1309	−2.02099	0.1303	–	–
37	−0.875653	0.1319	−0.78376	0.1274	−0.74218	0.1281	–	–	–	–	−0.77546	0.1270	−0.73476	0.1278	–	–
38	−0.569367	0.1310	−0.48080	0.1264	−0.43851	0.1270	–	–	–	–	−0.46930	0.1261	−0.42810	0.1267	–	–
39	−2.285763	0.1313	−2.18852	0.1267	−2.15643	0.1270	–	–	–	–	−2.18073	0.1264	−2.14946	0.1268	–	–
40	−2.137527	0.1316	−2.03651	0.1270	−2.00140	0.1274	–	–	–	–	−2.02427	0.1267	−1.99045	0.1271	–	–
41	−2.373162	0.1333	−2.25501	0.1285	−2.21716	0.1290	–	–	–	–	−2.23885	0.1282	−2.20255	0.1287	–	–
42	–	–	−2.60707	0.1300	−2.56524	0.1307	–	–	–	–	−2.80826	0.1503	−2.79355	0.1498	–	–

Table 41: Final values for fishing mortality "devs" for the snow crab fishery. The indices start in 1990.

	21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
1	0.84278	0.1574	0.908995	0.1572	1.4877965	0.1994	1.499893	0.1974	1.484299	0.1983	0.909071	0.1572	1.4878087	0.1996	1.499918	0.1974
2	1.11756	0.1579	1.184287	0.1575	1.7395301	0.2031	1.747452	0.1996	1.706112	0.1997	1.184429	0.1576	1.7395929	0.2033	1.747532	0.1996
3	0.69245	0.1584	0.756307	0.1578	0.7334843	0.2000	0.745148	0.1952	0.708528	0.1980	0.756471	0.1579	0.7335579	0.2002	0.745245	0.1952
4	1.40492	0.1592	1.464444	0.1586	1.1228909	0.1912	1.142790	0.1865	1.098268	0.1895	1.464615	0.1586	1.1229630	0.1915	1.142899	0.1866
5	0.85947	0.1588	0.918531	0.1582	0.5500260	0.1896	0.572437	0.1853	0.534137	0.1891	0.918633	0.1582	0.5500018	0.1899	0.572459	0.1853
6	0.69750	0.1578	0.756404	0.1573	0.4729908	0.1916	0.494814	0.1880	0.450293	0.1916	0.756475	0.1573	0.4728892	0.1918	0.494769	0.1880
7	1.24079	0.1581	1.299268	0.1576	1.3161988	0.2013	1.339348	0.1986	1.275533	0.2013	1.299330	0.1576	1.3160731	0.2015	1.339288	0.1986
8	0.71183	0.1801	0.772562	0.1808	1.1076726	0.2065	1.072166	0.2080	1.057456	0.2075	0.772445	0.1808	1.1075839	0.2066	1.072097	0.2080
9	0.20166	0.1794	0.263775	0.1802	0.1691961	0.1950	0.133668	0.1965	0.128634	0.1963	0.263642	0.1802	0.1691010	0.1950	0.133583	0.1965
10	−1.52264	0.2070	−1.457876	0.2077	−1.4428599	0.2115	−1.473643	0.2130	−1.456684	0.2126	−1.457990	0.2077	−1.4429011	0.2115	−1.473687	0.2130
11	−0.75457	0.2117	−0.687929	0.2124	−0.6966781	0.2148	−0.719811	0.2166	−0.689598	0.2156	−0.687941	0.2124	−0.6966316	0.2148	−0.719784	0.2166
12	−0.40303	0.2023	−0.336713	0.2030	−0.2435431	0.2117	−0.261535	0.2138	−0.231495	0.2121	−0.336627	0.2030	−0.2433864	0.2117	−0.261406	0.2138
13	−1.60559	0.2096	−1.537196	0.2102	−1.5290476	0.2127	−1.542386	0.2149	−1.519414	0.2130	−1.537102	0.2102	−1.5289001	0.2127	−1.542267	0.2149
14	−2.73443	0.2148	−2.666767	0.2154	−2.6471907	0.2426	−2.658330	0.2447	−2.643879	0.2427	−2.666586	0.2154	−2.6469756	0.2426	−2.658152	0.2447
15	−1.70721	0.1885	−1.640272	0.1892	−1.9578556	0.1910	−1.967681	0.1936	−1.954125	0.1912	−1.640198	0.1892	−1.9576450	0.1910	−1.967516	0.1936
16	−0.07628	0.1893	−0.008389	0.1892	0.0007689	0.1978	0.006735	0.1977	0.016704	0.1976	−0.008251	0.1892	0.0009441	0.1978	0.006895	0.1977
17	0.62838	0.1555	0.695935	0.1554	0.1464653	0.1907	0.150121	0.1906	0.168230	0.1904	0.695931	0.1554	0.1465991	0.1908	0.150229	0.1906
18	0.35747	0.1552	0.427058	0.1550	0.1819418	0.1943	0.189265	0.1943	0.196775	0.1943	0.427115	0.1550	0.1821408	0.1943	0.189439	0.1943
19	−0.43950	0.1799	−0.371061	0.1799	−0.4469171	0.1961	−0.442795	0.1960	−0.461113	0.1959	−0.370938	0.1799	−0.4466987	0.1961	−0.442609	0.1960
20	−0.16265	0.1891	−0.094755	0.1891	−0.0622616	0.1979	−0.061055	0.1978	−0.097698	0.1978	−0.094886	0.1891	−0.0623154	0.1979	−0.061127	0.1978
21	−0.06158	0.1945	0.007918	0.1944	0.0362362	0.1987	0.033374	0.1986	−0.007235	0.1986	0.007601	0.1944	0.0360063	0.1987	0.033139	0.1986
22	0.43934	0.1903	0.512700	0.1902	0.5800019	0.1975	0.575812	0.1974	0.538665	0.1974	0.512334	0.1902	0.5796973	0.1975	0.575509	0.1974
23	0.15278	0.1921	0.233728	0.1920	0.2765332	0.1969	0.276831	0.1969	0.270318	0.1964	0.233582	0.1920	0.2764622	0.1969	0.276726	0.1968
24	0.05179	0.1876	0.138086	0.1875	0.1993618	0.1965	0.208063	0.1965	0.256004	0.1958	0.138228	0.1875	0.1996097	0.1965	0.208262	0.1964
25	0.72923	0.1525	0.817009	0.1523	1.0356514	0.1911	1.046558	0.1914	1.103573	0.1900	0.816821	0.1523	1.0353722	0.1911	1.046261	0.1914
26	0.62285	0.1834	0.712559	0.1833	0.8329302	0.1925	0.842251	0.1928	0.893673	0.1920	0.712274	0.1833	0.8326497	0.1925	0.841985	0.1927
27	0.47841	0.1857	0.571526	0.1855	0.6568357	0.1949	0.662376	0.1950	0.717006	0.1948	0.571448	0.1855	0.6567922	0.1950	0.662361	0.1950
28	−0.08018	0.1954	0.018624	0.1952	0.0311341	0.1980	0.032753	0.1980	0.081787	0.1980	0.018481	0.1952	0.0309824	0.1981	0.032640	0.1980
29	−0.08838	0.1952	0.018107	0.1951	0.0293783	0.1986	0.027920	0.1985	0.053790	0.1983	0.017963	0.1951	0.0291638	0.1986	0.027746	0.1985
30	0.20047	0.1907	0.317318	0.1905	0.3322230	0.1981	0.328509	0.1980	0.335885	0.1976	0.317163	0.1905	0.3319269	0.1982	0.328252	0.1980
31	−1.79364	0.2001	−1.655352	0.1996	−1.6671284	0.2125	−1.664481	0.2124	−1.669788	0.2121	−1.655356	0.1996	−1.6672772	0.2126	−1.664625	0.2124
32	–	–	−2.338831	0.2008	−2.3457661	0.2288	−2.336567	0.2287	−2.344641	0.2283	−2.338177	0.2008	−2.3451870	0.2288	−2.336060	0.2287

Table 42: Final values for fishing mortality "devs" for the BBRKC fishery. The indices start in 1990.

	21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
1	3.66550	0.2077	3.60664	0.2081	3.785782	0.2300	3.795303	0.2301	3.73197	0.2285	3.60593	0.2081	3.78493	0.2299	3.794342	0.2300
2	3.36857	0.2219	3.30575	0.2220	3.463910	0.2438	3.491513	0.2448	3.39079	0.2418	3.30524	0.2219	3.46320	0.2438	3.490714	0.2448
3	3.23784	0.2336	3.12667	0.2293	3.267921	0.2469	3.347840	0.2525	3.18712	0.2460	3.12611	0.2293	3.26701	0.2469	3.346805	0.2525
4	4.61607	0.2106	4.44851	0.2030	4.195096	0.2311	4.305819	0.2381	4.15150	0.2344	4.44787	0.2030	4.19424	0.2311	4.304881	0.2381
5	2.35186	0.2362	2.25302	0.2340	2.234787	0.2417	2.331196	0.2454	2.18097	0.2426	2.25206	0.2339	2.23381	0.2417	2.330166	0.2454
6	1.00828	0.2527	0.97708	0.2505	0.973504	0.2604	0.975199	0.2665	0.86288	0.2614	0.97664	0.2505	0.97321	0.2604	0.975014	0.2665
7	0.74615	0.2476	0.72252	0.2461	0.719618	0.2613	0.715509	0.2662	0.61368	0.2620	0.72211	0.2461	0.71934	0.2613	0.715329	0.2662
8	0.31183	0.2440	0.29669	0.2431	0.298402	0.2720	0.291796	0.2758	0.22828	0.2732	0.29637	0.2431	0.29820	0.2719	0.291675	0.2758
9	0.08943	0.2412	0.08036	0.2406	0.074985	0.2787	0.067098	0.2817	0.05079	0.2809	0.08014	0.2406	0.07488	0.2787	0.067053	0.2816
10	−0.51681	0.2672	−0.51685	0.2674	−0.520253	0.3434	−0.527156	0.3453	−0.51772	0.3458	−0.51694	0.2674	−0.52024	0.3434	−0.527100	0.3453
11	−0.33189	0.2365	−0.32978	0.2368	−0.331446	0.2807	−0.340084	0.2827	−0.32051	0.2840	−0.32976	0.2368	−0.33135	0.2807	−0.339951	0.2827
12	−0.63723	0.2355	−0.63146	0.2359	−0.630193	0.2879	−0.635927	0.2897	−0.61962	0.2913	−0.63147	0.2359	−0.63013	0.2879	−0.635827	0.2897
13	−0.95741	0.2352	−0.95258	0.2356	−0.952336	0.2978	−0.960801	0.2994	−0.94564	0.3009	−0.95253	0.2356	−0.95222	0.2978	−0.960654	0.2994
14	−1.32758	0.2473	−1.30651	0.2473	−1.319487	0.3303	−1.333924	0.3308	−1.28294	0.3306	−1.30632	0.2473	−1.31926	0.3303	−1.333709	0.3308
15	−1.82759	0.3301	−1.80752	0.3302	−1.817762	0.4332	−1.832807	0.4336	−1.78016	0.4334	−1.80726	0.3302	−1.81746	0.4332	−1.832506	0.4336
16	−1.27146	0.2116	−1.25112	0.2116	−1.271128	0.2615	−1.285816	0.2621	−1.23031	0.2619	−1.25094	0.2116	−1.27087	0.2615	−1.285566	0.2621
17	0.11382	0.2108	0.13625	0.2109	0.111930	0.2173	0.097752	0.2181	0.13615	0.2179	0.13654	0.2109	0.11231	0.2173	0.098120	0.2181
18	−0.35976	0.2104	−0.34007	0.2104	−0.360498	0.2203	−0.378897	0.2210	−0.36472	0.2207	−0.33990	0.2104	−0.36021	0.2203	−0.378613	0.2210
19	−2.03274	0.3078	−2.01447	0.3078	−2.028213	0.4155	−2.050742	0.4159	−2.05033	0.4157	−2.01454	0.3078	−2.02813	0.4155	−2.050651	0.4159
20	−2.48616	0.5200	−2.46527	0.5201	−2.473755	0.6947	−2.499498	0.6949	−2.50029	0.6950	−2.46543	0.5201	−2.47377	0.6947	−2.499501	0.6949
21	−1.46369	0.2428	−1.43755	0.2427	−1.439698	0.3230	−1.465437	0.3234	−1.45437	0.3230	−1.43767	0.2427	−1.43968	0.3229	−1.465426	0.3234
22	−0.43627	0.2116	−0.39863	0.2116	−0.408557	0.2271	−0.424605	0.2278	−0.36795	0.2270	−0.39847	0.2116	−0.40829	0.2271	−0.424381	0.2278
23	0.21493	0.2117	0.25662	0.2119	0.251287	0.2188	0.240211	0.2197	0.33986	0.2190	0.25723	0.2119	0.25196	0.2188	0.240819	0.2197
24	−0.18815	0.2093	−0.14860	0.2094	−0.160272	0.2162	−0.171695	0.2170	−0.06854	0.2165	−0.14785	0.2094	−0.15954	0.2162	−0.171002	0.2170
25	−0.22713	0.2093	−0.18605	0.2093	−0.199147	0.2179	−0.212542	0.2187	−0.11644	0.2182	−0.18546	0.2093	−0.19863	0.2179	−0.212020	0.2187
26	−0.02109	0.2101	0.02494	0.2101	0.009691	0.2201	−0.006435	0.2209	0.09004	0.2205	0.02541	0.2101	0.01006	0.2201	−0.006049	0.2209
27	−0.73153	0.2107	−0.67950	0.2106	−0.697596	0.2501	−0.715321	0.2508	−0.63287	0.2504	−0.67896	0.2106	−0.69721	0.2501	−0.714917	0.2508
28	−1.99089	0.5083	−1.92933	0.5088	−1.934603	0.6824	−1.954957	0.6827	−1.89446	0.6821	−1.92888	0.5088	−1.93436	0.6824	−1.954696	0.6826
29	−2.91690	1.0891	−2.83974	1.0911	−2.841971	1.3212	−2.862592	1.3215	−2.81717	1.3204	−2.83930	1.0911	−2.84182	1.3211	−2.862352	1.3214

Table 43: Final values for fishing mortality "devs" vectors for the groundfish fisheries. Indices start in 1973.

	21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
1	1.52303	0.2225	1.51908	0.2235	1.51157	0.2237	−0.660998	0.2074	−0.81446	0.2045	1.51884	0.2235	1.51146	0.2237	−0.661128	0.2074
2	1.85199	0.2124	1.84608	0.2130	1.84166	0.2130	−0.175473	0.2049	−0.33686	0.2027	1.84588	0.2130	1.84159	0.2130	−0.175691	0.2049
3	1.00674	0.2103	1.00102	0.2107	0.99814	0.2107	−0.075402	0.2044	−0.21369	0.2021	1.00080	0.2107	0.99804	0.2107	−0.075695	0.2044
4	0.47352	0.2085	0.46939	0.2089	0.46675	0.2088	−0.533682	0.2028	−0.63173	0.2010	0.46910	0.2089	0.46659	0.2088	−0.533992	0.2028
5	0.14544	0.2083	0.14245	0.2087	0.14046	0.2087	−0.189336	0.2000	−0.25075	0.1986	0.14210	0.2087	0.14028	0.2087	−0.189613	0.2000
6	−0.13689	0.2090	−0.13936	0.2094	−0.14026	0.2093	−0.122345	0.2084	−0.15662	0.2077	−0.13968	0.2094	−0.14038	0.2093	−0.122638	0.2084
7	0.45922	0.2129	0.45509	0.2128	0.45459	0.2126	−0.626947	0.2078	−0.63610	0.2070	0.45481	0.2127	0.45456	0.2126	−0.627182	0.2078
8	0.09274	0.2100	0.08911	0.2099	0.09061	0.2098	−0.350994	0.2067	−0.33947	0.2059	0.08898	0.2099	0.09070	0.2098	−0.351186	0.2067
9	−0.08779	0.2038	−0.09007	0.2039	−0.08748	0.2039	0.020417	0.2073	0.03509	0.2062	−0.09019	0.2039	−0.08745	0.2039	0.020344	0.2073
10	−1.02951	0.2018	−1.03127	0.2020	−1.02757	0.2020	0.879513	0.1589	0.89398	0.1573	−1.03145	0.2020	−1.02768	0.2020	0.879496	0.1589
11	−0.30435	0.2036	−0.30493	0.2039	−0.29869	0.2039	1.143468	0.1595	1.14213	0.1576	−0.30514	0.2039	−0.29891	0.2039	1.143439	0.1595
12	−0.03618	0.2082	−0.03421	0.2086	−0.02469	0.2087	0.814525	0.1593	0.80543	0.1577	−0.03440	0.2086	−0.02495	0.2087	0.814471	0.1593
13	−0.52876	0.2044	−0.52421	0.2047	−0.51430	0.2048	1.289760	0.1600	1.27144	0.1584	−0.52439	0.2047	−0.51455	0.2048	1.289652	0.1600
14	−0.26820	0.1987	−0.26119	0.1991	−0.25123	0.1991	1.200229	0.1598	1.17715	0.1583	−0.26137	0.1991	−0.25144	0.1991	1.200058	0.1598
15	−0.40843	0.2031	−0.39372	0.2035	−0.37558	0.2033	1.379438	0.1612	1.34829	0.1595	−0.39383	0.2035	−0.37573	0.2033	1.379241	0.1612
16	−0.90554	0.2026	−0.88993	0.2029	−0.87285	0.2028	1.639202	0.1479	1.64145	0.1470	−0.89002	0.2029	−0.87297	0.2028	1.639125	0.1479
17	−0.61868	0.2015	−0.60111	0.2019	−0.58539	0.2019	1.499037	0.1462	1.50940	0.1453	−0.60117	0.2019	−0.58547	0.2019	1.498963	0.1462
18	−0.24752	0.2017	−0.22819	0.2020	−0.21094	0.2021	0.972875	0.1454	0.99887	0.1446	−0.22815	0.2020	−0.21092	0.2021	0.972828	0.1454
19	0.59753	0.1508	0.61622	0.1511	0.62746	0.1512	1.016137	0.1455	1.05351	0.1448	0.61631	0.1511	0.62754	0.1512	1.016160	0.1455
20	0.86531	0.1513	0.88032	0.1515	0.88908	0.1515	1.242844	0.1456	1.27971	0.1449	0.88038	0.1515	0.88914	0.1515	1.242916	0.1456
21	0.54359	0.1511	0.55626	0.1514	0.56045	0.1512	0.539649	0.1454	0.57379	0.1448	0.55627	0.1514	0.56047	0.1512	0.539748	0.1454
22	1.02084	0.1520	1.03148	0.1522	1.03541	0.1520	−0.009327	0.1452	0.02028	0.1446	1.03142	0.1522	1.03536	0.1520	−0.009194	0.1452
23	0.92520	0.1517	0.93560	0.1519	0.94667	0.1520	0.286056	0.1451	0.30999	0.1444	0.93548	0.1519	0.94656	0.1521	0.286226	0.1451
24	1.09785	0.1533	1.10735	0.1534	1.12221	0.1537	−0.043111	0.1452	−0.02030	0.1445	1.10721	0.1534	1.12207	0.1537	−0.042901	0.1452
25	1.55831	0.1492	1.56482	0.1489	1.56502	0.1491	−0.070036	0.1453	−0.05051	0.1446	1.56470	0.1489	1.56488	0.1491	−0.069800	0.1453
26	1.41470	0.1477	1.42392	0.1474	1.42297	0.1475	0.020637	0.1452	0.02838	0.1445	1.42382	0.1474	1.42283	0.1475	0.020891	0.1452
27	0.88414	0.1468	0.89529	0.1467	0.89267	0.1467	−0.320184	0.1450	−0.32491	0.1443	0.89524	0.1467	0.89257	0.1467	−0.319970	0.1450
28	0.92321	0.1470	0.93584	0.1469	0.93176	0.1469	−0.698662	0.1443	−0.70661	0.1437	0.93588	0.1469	0.93175	0.1469	−0.698572	0.1443
29	1.14678	0.1472	1.16005	0.1470	1.15438	0.1469	−1.046825	0.1441	−1.05294	0.1434	1.16014	0.1470	1.15442	0.1469	−1.046809	0.1441
30	0.44174	0.1470	0.45643	0.1468	0.44921	0.1467	−0.736001	0.1440	−0.72514	0.1434	0.45656	0.1468	0.44928	0.1467	−0.735946	0.1440
31	−0.10832	0.1467	−0.09299	0.1466	−0.10178	0.1465	−1.217426	0.1444	−1.17627	0.1437	−0.09282	0.1466	−0.10168	0.1465	−1.217253	0.1444
32	0.18586	0.1466	0.20180	0.1465	0.19207	0.1463	−0.648342	0.1448	−0.57760	0.1440	0.20199	0.1465	0.19222	0.1463	−0.648090	0.1448
33	−0.14466	0.1466	−0.12775	0.1465	−0.13828	0.1463	−0.562609	0.1445	−0.48136	0.1437	−0.12752	0.1465	−0.13809	0.1463	−0.562423	0.1445
34	−0.17067	0.1467	−0.15304	0.1466	−0.16581	0.1464	−0.699028	0.1441	−0.62204	0.1435	−0.15280	0.1466	−0.16558	0.1464	−0.698913	0.1441
35	−0.08202	0.1466	−0.06313	0.1465	−0.07655	0.1463	−0.607867	0.1441	−0.53809	0.1436	−0.06287	0.1465	−0.07630	0.1463	−0.607815	0.1441
36	−0.42518	0.1461	−0.40569	0.1460	−0.41560	0.1459	−1.182731	0.1439	−1.12334	0.1435	−0.40549	0.1461	−0.41538	0.1459	−1.182718	0.1439
37	−0.80739	0.1452	−0.78640	0.1452	−0.79207	0.1452	−0.885738	0.1442	−0.84697	0.1439	−0.78634	0.1452	−0.79199	0.1452	−0.885761	0.1442
38	−1.15736	0.1449	−1.13389	0.1449	−1.13765	0.1449	−0.769495	0.1447	−0.75310	0.1443	−1.13391	0.1449	−1.13764	0.1449	−0.769470	0.1447
39	−0.85102	0.1451	−0.82380	0.1450	−0.82643	0.1450	−0.851314	0.1460	−0.84694	0.1455	−0.82377	0.1450	−0.82639	0.1450	−0.851058	0.1460
40	−1.34157	0.1457	−1.30923	0.1456	−1.31187	0.1456	−0.859915	0.1473	−0.86308	0.1467	−1.30905	0.1456	−1.31169	0.1456	−0.859740	0.1473
41	−0.78090	0.1459	−0.74382	0.1459	−0.74724	0.1459	–	–	–	–	−0.74355	0.1459	−0.74697	0.1459	–	–
42	−0.69723	0.1454	−0.65703	0.1453	−0.66195	0.1454	–	–	–	–	−0.65681	0.1453	−0.66175	0.1454	–	–
43	−0.83484	0.1450	−0.79145	0.1449	−0.79798	0.1449	–	–	–	–	−0.79127	0.1449	−0.79787	0.1449	–	–
44	−0.76493	0.1451	−0.69853	0.1450	−0.70569	0.1449	–	–	–	–	−0.69840	0.1450	−0.70567	0.1449	–	–
45	−1.34806	0.1450	−1.27225	0.1449	−1.27840	0.1448	–	–	–	–	−1.27214	0.1449	−1.27842	0.1448	–	–
46	−1.05480	0.1455	−0.97458	0.1453	−0.97957	0.1452	–	–	–	–	−0.97448	0.1453	−0.97963	0.1453	–	–
47	−0.95725	0.1463	−0.85827	0.1459	−0.86236	0.1459	–	–	–	–	−0.85810	0.1459	−0.86236	0.1459	–	–
48	−1.05971	0.1482	−0.94357	0.1473	−0.94714	0.1473	–	–	–	–	−0.94316	0.1473	−0.94689	0.1473	–	–
49	–	–	−0.95399	0.1485	−0.95778	0.1485	–	–	–	–	−0.95364	0.1485	−0.95756	0.1485	–	–

Table 44: Final values for the “pS1” parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
	name	label	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
selectivity	pS1[1]	size at 1 for NMFS survey selectivity (males, 1982+)	–	–	–	–	–	–	179.000	*NA*	179.000	*NA*	–	–	–	–	179.000	*NA*
		size at 1 for NMFS survey selectivity (males, pre-1982)	179.000	*NA*	179.000	*NA*	179.000	*NA*	–	–	–	–	179.000	*NA*	179.000	*NA*	–	–
	pS1[10]	ascending z-at-1 for SCF selectivity (males, 2005+)	–	–	–	–	–	–	124.840	1.301000	124.925	1.299700	–	–	–	–	124.862	1.305200
		ascending z-at-1 for SCF selectivity (males, pre-1997)	160.095	2.850900	160.262	2.571900	159.629	4.78010	–	–	–	–	160.256	2.578000	159.616	4.8534	–	–
	pS1[11]	ascending z-at-1 for SCF selectivity (males, 1997-2004)	118.179	6.689500	118.255	6.687700	118.508	6.88950	–	–	–	–	118.254	6.683800	118.510	6.8862	–	–
		ascending z50 for SCF selectivity (females, pre-1997)	–	–	–	–	–	–	82.435	9.227100	81.580	9.288200	–	–	–	–	82.439	9.233100
	pS1[12]	ascending z-at-1 for SCF selectivity (males, 2005+)	124.476	1.277200	124.547	1.275500	124.558	1.27710	–	–	–	–	124.570	1.279100	124.581	1.2812	–	–
		ascending z50 for SCF selectivity (females, 1997-2004)	–	–	–	–	–	–	72.583	4.748600	72.506	4.832900	–	–	–	–	72.584	4.749100
	pS1[13]	ascending z50 for SCF selectivity (females, 2005+)	–	–	–	–	–	–	102.311	9.616700	102.810	9.405700	–	–	–	–	102.309	9.619600
		ascending z50 for SCF selectivity (females, pre-1997)	92.344	8.019100	92.333	8.029400	80.715	6.75630	–	–	–	–	92.341	8.031000	80.717	6.7594	–	–
	pS1[14]	ascending z50 for SCF selectivity (females, 1997-2004)	72.036	5.061000	72.041	5.071900	72.678	4.36170	–	–	–	–	72.043	5.071700	72.678	4.3621	–	–
		z50 for GF.AllGear selectivity (males, pre-1987)	–	–	–	–	–	–	63.084	3.609200	57.805	2.947500	–	–	–	–	63.091	3.608600
	pS1[15]	ascending z50 for SCF selectivity (females, 2005+)	107.784	7.131000	107.964	7.193500	101.466	8.60190	–	–	–	–	107.966	7.193800	101.463	8.6046	–	–
		z50 for GF.AllGear selectivity (males, 1987-1996)	–	–	–	–	–	–	92.316	11.208000	86.906	10.694000	–	–	–	–	92.317	11.205000
	pS1[16]	z50 for GF.AllGear selectivity (males, 1997+)	–	–	–	–	–	–	100.093	2.754800	99.760	2.671700	–	–	–	–	100.101	2.754400
		z50 for GF.AllGear selectivity (males, pre-1987)	59.813	3.067000	60.556	3.241400	60.862	3.28110	–	–	–	–	60.574	3.243800	60.874	3.2827	–	–
	pS1[17]	z50 for GF.AllGear selectivity (females, pre-1987)	–	–	–	–	–	–	42.977	2.272200	40.234	2.016900	–	–	–	–	42.983	2.272400
		z50 for GF.AllGear selectivity (males, 1987-1996)	68.694	6.715100	69.886	6.848300	71.248	6.73720	–	–	–	–	69.908	6.849600	71.262	6.7381	–	–
	pS1[18]	z50 for GF.AllGear selectivity (females, 1987-1996)	–	–	–	–	–	–	39.384	2.101300	37.706	1.817800	–	–	–	–	39.383	2.101300
		z50 for GF.AllGear selectivity (males, 1997+)	97.271	2.553400	97.543	2.545200	97.493	2.51340	–	–	–	–	97.558	2.545100	97.503	2.5134	–	–
	pS1[19]	z50 for GF.AllGear selectivity (females, 1997+)	–	–	–	–	–	–	79.766	3.665600	81.796	3.775900	–	–	–	–	79.770	3.665400
		z50 for GF.AllGear selectivity (females, pre-1987)	43.726	1.858100	43.742	1.853400	43.482	1.83890	–	–	–	–	43.745	1.853700	43.485	1.8392	–	–
	pS1[2]	size at 1 for NMFS survey selectivity (females, 1982+)	–	–	–	–	–	–	129.900	*NA*	129.900	*NA*	–	–	–	–	129.900	*NA*
		size at 1 for NMFS survey selectivity (males, 1982+)	179.000	*NA*	179.000	*NA*	179.000	*NA*	–	–	–	–	179.000	*NA*	179.000	*NA*	–	–
	pS1[20]	size at 1 for RKF selectivity (males, pre-1997)	–	–	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*
		z50 for GF.AllGear selectivity (females, 1987-1996)	39.897	2.162800	39.817	2.142600	40.130	2.17720	–	–	–	–	39.814	2.142100	40.128	2.1772	–	–
	pS1[21]	size at 1 for RKF selectivity (males, 1997-2004)	–	–	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*
		z50 for GF.AllGear selectivity (females, 1997+)	87.373	3.172800	87.409	3.178300	86.992	3.17300	–	–	–	–	87.409	3.179300	86.990	3.1734	–	–
	pS1[22]	size at 1 for RKF selectivity (males, 2005+)	–	–	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*
		size at 1 for RKF selectivity (males, pre-1997)	179.900	*NA*	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–
	pS1[23]	size at 1 for RKF selectivity (females, pre-1997)	–	–	–	–	–	–	139.900	*NA*	139.900	*NA*	–	–	–	–	139.900	*NA*
		size at 1 for RKF selectivity (males, 1997-2004)	179.900	*NA*	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–
	pS1[24]	size at 1 for RKF selectivity (females, 1997-2004)	–	–	–	–	–	–	132.416	37.852000	133.590	38.422000	–	–	–	–	132.429	37.856000
		size at 1 for RKF selectivity (males, 2005+)	179.900	*NA*	179.900	*NA*	179.900	*NA*	–	–	–	–	179.900	*NA*	179.900	*NA*	–	–
	pS1[25]	size at 1 for RKF selectivity (females, 2005+)	–	–	–	–	–	–	129.732	20.498000	131.747	20.804000	–	–	–	–	129.752	20.504000
		size at 1 for RKF selectivity (females, pre-1997)	139.900	*NA*	139.900	*NA*	139.900	*NA*	–	–	–	–	139.900	*NA*	139.900	*NA*	–	–
	pS1[26]	size at 1 for RKF selectivity (females, 1997-2004)	126.015	25.857000	127.879	26.450000	136.867	39.70000	–	–	–	–	127.882	26.451000	136.877	39.7020	–	–
		z50 for TCF retention (2005-2009)	–	–	–	–	–	–	137.649	0.296580	137.659	0.307510	–	–	–	–	137.648	0.294200
	pS1[27]	size at 1 for RKF selectivity (females, 2005+)	126.159	15.816000	128.208	16.223000	134.747	22.54600	–	–	–	–	128.219	16.226000	134.765	22.5500	–	–
		z50 for TCF retention (2013+)	–	–	–	–	–	–	125.545	0.850370	125.653	0.857150	–	–	–	–	125.770	0.784750
	pS1[28]	z50 for TCF retention (2005-2009)	139.725	1.002100	139.627	1.010200	137.634	0.27798	–	–	–	–	139.620	1.011100	137.634	0.2783	–	–
		z50 for TCF retention (2021)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	118.260	2.985500
	pS1[29]	z50 for TCF retention (2013+)	125.060	0.678340	124.839	0.777710	125.401	0.82962	–	–	–	–	125.171	0.668120	125.644	0.7404	–	–
	pS1[3]	size at 1 for NMFS survey selectivity (females, pre-1982)	129.900	*NA*	129.900	*NA*	129.900	*NA*	–	–	–	–	129.900	*NA*	129.900	*NA*	–	–
		z50 for TCF retention (pre-1991)	–	–	–	–	–	–	138.236	0.241230	138.184	0.240930	–	–	–	–	138.236	0.241190
	pS1[30]	z50 for TCF retention (2021)	–	–	–	–	–	–	–	–	–	–	118.473	2.859300	118.148	3.0908	–	–
	pS1[4]	size at 1 for NMFS survey selectivity (females, 1982+)	129.900	*NA*	129.900	*NA*	129.900	*NA*	–	–	–	–	129.900	*NA*	129.900	*NA*	–	–
		z50 for TCF retention (1991-1996)	–	–	–	–	–	–	138.534	1.292500	137.726	0.099852	–	–	–	–	138.531	1.297700
	pS1[5]	DUMMY VALUE	–	–	–	–	–	–	4.500	*NA*	4.500	*NA*	–	–	–	–	4.500	*NA*
		z50 for TCF retention (pre-1991)	138.671	0.777610	138.942	0.684590	138.939	0.69582	–	–	–	–	138.944	0.684250	138.940	0.6956	–	–
	pS1[6]	ln(z50) for TCF selectivity (males)	–	–	–	–	–	–	4.852	0.006476	4.858	0.006609	–	–	–	–	4.851	0.006465
		z50 for TCF retention (1991-1996)	137.746	0.199750	137.745	0.154200	138.600	1.13580	–	–	–	–	137.745	0.184140	138.598	1.1395	–	–
	pS1[7]	DUMMY VALUE	4.500	*NA*	4.500	*NA*	4.500	*NA*	–	–	–	–	4.500	*NA*	4.500	*NA*	–	–
		z50 for TCF selectivity (females)	–	–	–	–	–	–	93.638	2.517800	94.097	2.513100	–	–	–	–	93.638	2.517800
	pS1[8]	ascending z-at-1 for SCF selectivity (males, pre-1997)	–	–	–	–	–	–	160.131	2.609600	159.604	4.737900	–	–	–	–	160.122	2.620000
		ln(z50) for TCF selectivity (males)	4.856	0.007486	4.846	0.007163	4.844	0.00651	–	–	–	–	4.846	0.007144	4.844	0.0065	–	–
	pS1[9]	ascending z-at-1 for SCF selectivity (males, 1997-2004)	–	–	–	–	–	–	118.944	7.187900	117.920	7.154300	–	–	–	–	118.946	7.183900
		z50 for TCF selectivity (females)	93.923	2.545900	93.806	2.544900	92.883	2.30880	–	–	–	–	93.796	2.544700	92.884	2.3089	–	–

Table 45: Final values for the "pS2" parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
	name	label	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
selectivity	pS2[1]	width for NMFS survey selectivity (males, 1982+)	–	–	–	–	–	–	90.94335	3.138000	92.65451	2.692e + 00	–	–	–	–	90.92604	3.135800
		width for NMFS survey selectivity (males, pre-1982)	66.89242	2.558500	66.25297	2.511600	66.14381	2.500500	–	–	–	–	66.23798	2.510100	66.13165	2.499300	–	–
	pS2[10]	ascending width for SCF selectivity (males, 2005+)	–	–	–	–	–	–	14.56550	0.710820	14.69293	7.157e − 01	–	–	–	–	14.57765	0.712520
		ascending width for SCF selectivity (males, pre-1997)	33.18869	1.656400	33.17705	1.594800	32.77627	2.143500	–	–	–	–	33.17216	1.595700	32.76950	2.163800	–	–
	pS2[11]	ascending width for SCF selectivity (males, 1997-2004)	15.52980	3.493300	15.51943	3.477700	15.59980	3.543900	–	–	–	–	15.51867	3.475900	15.60058	3.542300	–	–
		slope for SCF selectivity (females, pre-1997)	–	–	–	–	–	–	0.12013	0.065060	0.11608	6.436e − 02	–	–	–	–	0.12010	0.065063
	pS2[12]	ascending width for SCF selectivity (males, 2005+)	14.45919	0.707270	14.47882	0.703680	14.46431	0.703490	–	–	–	–	14.49174	0.705130	14.47680	0.705170	–	–
		slope for SCF selectivity (females, 1997-2004)	–	–	–	–	–	–	0.31125	0.241520	0.30524	2.401e − 01	–	–	–	–	0.31124	0.241480
	pS2[13]	slope for SCF selectivity (females, 2005+)	–	–	–	–	–	–	0.09417	0.022840	0.09240	2.208e − 02	–	–	–	–	0.09417	0.022845
		slope for SCF selectivity (females, pre-1997)	0.08447	0.024245	0.08419	0.024173	0.13701	0.066731	–	–	–	–	0.08416	0.024163	0.13699	0.066738	–	–
	pS2[14]	slope for GF.AllGear selectivity (males, pre-1987)	–	–	–	–	–	–	0.09273	0.012261	0.10473	1.424e − 02	–	–	–	–	0.09273	0.012258
		slope for SCF selectivity (females, 1997-2004)	0.33273	0.305130	0.33175	0.303620	0.31759	0.241710	–	–	–	–	0.33168	0.303410	0.31759	0.241680	–	–
	pS2[15]	slope for GF.AllGear selectivity (males, 1987-1996)	–	–	–	–	–	–	0.03199	0.004677	0.03276	5.130e − 03	–	–	–	–	0.03199	0.004676
		slope for SCF selectivity (females, 2005+)	0.08079	0.014043	0.08017	0.014039	0.09588	0.022967	–	–	–	–	0.08017	0.014038	0.09589	0.022974	–	–
	pS2[16]	slope for GF.AllGear selectivity (males, 1997+)	–	–	–	–	–	–	0.05673	0.002433	0.05696	2.418e − 03	–	–	–	–	0.05672	0.002433
		slope for GF.AllGear selectivity (males, pre-1987)	0.09069	0.010723	0.08859	0.010693	0.08794	0.010614	–	–	–	–	0.08855	0.010688	0.08792	0.010611	–	–
	pS2[17]	slope for GF.AllGear selectivity (females, pre-1987)	–	–	–	–	–	–	0.15002	0.029842	0.16289	3.477e − 02	–	–	–	–	0.14999	0.029830
		slope for GF.AllGear selectivity (males, 1987-1996)	0.04587	0.008112	0.04473	0.007672	0.04482	0.007299	–	–	–	–	0.04471	0.007665	0.04481	0.007295	–	–
	pS2[18]	slope for GF.AllGear selectivity (females, 1987-1996)	–	–	–	–	–	–	0.18018	0.060149	0.21707	7.841e − 02	–	–	–	–	0.18018	0.060158
		slope for GF.AllGear selectivity (males, 1997+)	0.05913	0.002525	0.05897	0.002488	0.05925	0.002477	–	–	–	–	0.05896	0.002487	0.05925	0.002477	–	–
	pS2[19]	slope for GF.AllGear selectivity (females, 1997+)	–	–	–	–	–	–	0.07016	0.005464	0.06556	5.032e − 03	–	–	–	–	0.07016	0.005463
		slope for GF.AllGear selectivity (females, pre-1987)	0.13438	0.019629	0.13476	0.019649	0.13596	0.019956	–	–	–	–	0.13473	0.019643	0.13593	0.019950	–	–
	pS2[2]	width for NMFS survey selectivity (females, 1982+)	–	–	–	–	–	–	83.16784	7.048800	100.00000	9.535e − 04	–	–	–	–	83.14694	7.044100
		width for NMFS survey selectivity (males, 1982+)	90.86617	3.089800	91.18087	3.139000	90.57288	3.069600	–	–	–	–	91.16194	3.136500	90.55831	3.067900	–	–
	pS2[20]	slope for GF.AllGear selectivity (females, 1987-1996)	0.17126	0.056272	0.17306	0.056964	0.16964	0.055214	–	–	–	–	0.17311	0.056985	0.16965	0.055223	–	–
		width for RKF selectivity (males, pre-1997)	–	–	–	–	–	–	19.39685	0.767230	19.68034	8.002e − 01	–	–	–	–	19.40098	0.767420
	pS2[21]	slope for GF.AllGear selectivity (females, 1997+)	0.06395	0.004224	0.06395	0.004198	0.06414	0.004234	–	–	–	–	0.06394	0.004199	0.06415	0.004235	–	–
		width for RKF selectivity (males, 1997-2004)	–	–	–	–	–	–	27.40886	2.082800	27.56695	2.114e + 00	–	–	–	–	27.41079	2.082900
	pS2[22]	width for RKF selectivity (males, 2005+)	–	–	–	–	–	–	27.14581	0.963730	26.85199	9.421e − 01	–	–	–	–	27.14655	0.963450
		width for RKF selectivity (males, pre-1997)	19.71234	0.794840	20.02067	0.816150	19.95940	0.812260	–	–	–	–	20.02273	0.816140	19.96297	0.812430	–	–
	pS2[23]	width for RKF selectivity (males, 1997-2004)	27.93039	2.149600	27.97100	2.139800	28.03956	2.144800	–	–	–	–	27.97158	2.139800	28.04094	2.144900	–	–
		width for RKF selectivity (males, pre-1997)	–	–	–	–	–	–	18.33291	2.274900	18.44362	2.304e + 00	–	–	–	–	18.33288	2.275000
	pS2[24]	width for RKF selectivity (males, 1997-2004)	–	–	–	–	–	–	17.98789	14.871000	18.16270	1.499e + 01	–	–	–	–	17.99061	14.871000
		width for RKF selectivity (males, 2005+)	27.68538	1.001300	27.53120	0.989570	27.65319	0.993710	–	–	–	–	27.52944	0.989050	27.65288	0.993340	–	–
	pS2[25]	width for RKF selectivity (males, 2005+)	–	–	–	–	–	–	16.63135	7.605500	16.93101	7.619e + 00	–	–	–	–	16.63604	7.606300
		width for RKF selectivity (males, pre-1997)	17.65114	2.029600	17.64562	2.044700	18.03274	2.363900	–	–	–	–	17.64629	2.045000	18.03282	2.363900	–	–
	pS2[26]	slope for TCF retention (2005-2009)	–	–	–	–	–	–	1.99976	0.346910	1.99968	4.292e − 01	–	–	–	–	1.99977	0.326980
		width for RKF selectivity (males, 1997-2004)	16.77483	11.039000	17.20053	11.156000	19.08069	15.010000	–	–	–	–	17.20128	11.156000	19.08242	15.009000	–	–
	pS2[27]	slope for TCF retention (2013+)	–	–	–	–	–	–	0.33165	0.076067	0.32747	7.476e − 02	–	–	–	–	0.46798	0.198440
		width for RKF selectivity (males, 2005+)	16.26298	5.626000	16.72221	5.701700	17.97278	7.939700	–	–	–	–	16.72505	5.702500	17.97684	7.940300	–	–
	pS2[28]	slope for TCF retention (2005-2009)	0.62043	0.228510	0.64118	0.242920	1.99994	0.106210	–	–	–	–	0.64239	0.244000	1.99993	0.113030	–	–
		slope for TCF retention (2021)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.67292	1.132500
	pS2[29]	slope for TCF retention (2013+)	0.59625	0.248760	0.37466	0.087167	0.34038	0.078162	–	–	–	–	0.58639	0.239430	0.49146	0.206940	–	–
	pS2[3]	slope for TCF retention (pre-1991)	–	–	–	–	–	–	1.00000	0.001891	1.00000	1.612e − 03	–	–	–	–	1.00000	0.001883
		width for NMFS survey selectivity (females, pre-1982)	41.33826	2.217500	41.39285	2.224900	41.56184	2.249500	–	–	–	–	41.39451	2.225100	41.56260	2.249700	–	–
	pS2[30]	slope for TCF retention (2021)	–	–	–	–	–	–	–	–	–	–	0.61808	0.836120	0.70774	1.376900	–	–
	pS2[4]	slope for TCF retention (1997+)	–	–	–	–	–	–	1.02570	0.811040	1.99993	1.259e − 01	–	–	–	–	1.02715	0.817060
		width for NMFS survey selectivity (females, 1982+)	78.99429	6.103500	81.71015	6.675300	82.30503	6.808000	–	–	–	–	81.71007	6.675500	82.29224	6.805500	–	–
	pS2[5]	slope for TCF retention (pre-1991)	0.78671	0.301310	0.72224	0.203860	0.72587	0.209180	–	–	–	–	0.72215	0.203570	0.72588	0.209010	–	–
		slope for TCF selectivity (males, pre-1997)	–	–	–	–	–	–	0.12528	0.006667	0.11680	6.081e − 03	–	–	–	–	0.12534	0.006672
	pS2[6]	slope for TCF retention (1997+)	1.99965	0.472120	1.99980	0.329100	0.97849	0.643220	–	–	–	–	1.99973	0.425480	0.97975	0.647320	–	–
		slope for TCF selectivity (males, 1997+)	–	–	–	–	–	–	0.16316	0.007172	0.16118	6.968e − 03	–	–	–	–	0.16359	0.007214
	pS2[7]	slope for TCF selectivity (females)	–	–	–	–	–	–	0.18878	0.025133	0.18433	2.386e − 02	–	–	–	–	0.18878	0.025133
		slope for TCF selectivity (males, pre-1997)	0.11792	0.007139	0.11720	0.007076	0.12098	0.006796	–	–	–	–	0.11727	0.007077	0.12104	0.006801	–	–
	pS2[8]	ascending width for SCF selectivity (males, pre-1997)	–	–	–	–	–	–	32.57166	1.560000	33.22440	2.142e + 00	–	–	–	–	32.56602	1.561700
		slope for TCF selectivity (males, 1997+)	0.16071	0.007370	0.16484	0.007329	0.16782	0.007544	–	–	–	–	0.16519	0.007363	0.16826	0.007587	–	–
	pS2[9]	ascending width for SCF selectivity (males, 1997-2004)	–	–	–	–	–	–	15.85080	3.661500	15.53291	3.695e + 00	–	–	–	–	15.85127	3.659600
		slope for TCF selectivity (females)	0.18040	0.022065	0.17883	0.021668	0.19395	0.025375	–	–	–	–	0.17882	0.021678	0.19394	0.025374	–	–

Table 46: Final values for the “pS3” and pS4 parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
	name	label	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
selectivity	pS3[1]	scaled increment for descending z-at-1 for SCF selectivity (males, pre-1997)	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*
	pS3[2]	scaled increment for descending z-at-1 for SCF selectivity (males, 1997-2004)	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*
	pS3[3]	scaled increment for descending z-at-1 for SCF selectivity (males, 2005+)	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*	0.001	*NA*
	pS4[1]	descending width for SCF selectivity (males, pre-1997)	1.100	*NA*	1.100	*NA*	1.100	*NA*	1.100	*NA*	1.100	*NA*	1.100	*NA*	1.100	*NA*	1.100	*NA*
	pS4[2]	descending width for SCF selectivity (males, 1997-2004)	19.376	8.294	19.424	8.391	20.185	9.071	20.892	10.270	21.233	10.035	19.427	8.389	20.185	9.068	20.892	10.265
	pS4[3]	descending width for SCF selectivity (males, 2005+)	13.255	1.277	13.319	1.293	13.285	1.288	13.359	1.345	13.498	1.378	13.312	1.296	13.280	1.292	13.353	1.349

Table 47: 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.

	21.22a		22.01		22.03		22.07		22.08		22.09		22.10		22.11	
index	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.	estimate	std. dev.
1	0.08749	0.01766	0.09920	0.01766	0.09879	0.01456	0.09445	0.01399	0.10039	0.01432	0.09944	0.01764	0.09905	0.01455	0.09476	0.01398
2	0.06337	0.01589	0.07390	0.01593	0.07608	0.01406	0.07325	0.01357	0.07557	0.01389	0.07418	0.01592	0.07637	0.01405	0.07357	0.01357
3	0.11006	0.01541	0.11938	0.01567	0.11521	0.01310	0.11251	0.01247	0.11800	0.01327	0.11963	0.01566	0.11548	0.01310	0.11281	0.01247
4	0.12025	0.01991	0.12997	0.02013	0.11620	0.01831	0.11882	0.01738	0.12597	0.01800	0.13016	0.02012	0.11648	0.01830	0.11913	0.01738
5	0.11242	0.02942	0.12259	0.02973	0.09088	0.02127	0.09662	0.02024	0.10384	0.02159	0.12265	0.02971	0.09113	0.02126	0.09690	0.02023
6	0.12889	0.01735	0.13912	0.01751	0.19626	0.02047	0.19205	0.01927	0.19684	0.02103	0.13947	0.01751	0.19660	0.02046	0.19243	0.01926
7	−0.05155	0.01480	−0.04248	0.01453	−0.03733	0.01404	−0.03584	0.01390	−0.03799	0.01398	−0.04228	0.01452	−0.03712	0.01404	−0.03563	0.01389
8	−0.05073	0.01517	−0.04221	0.01493	−0.02229	0.01391	−0.01874	0.01387	−0.02049	0.01392	−0.04205	0.01492	−0.02214	0.01390	−0.01860	0.01386
9	−0.09736	0.01421	−0.08835	0.01396	−0.08882	0.01347	−0.08834	0.01339	−0.08936	0.01333	−0.08814	0.01395	−0.08860	0.01346	−0.08810	0.01338
10	0.03028	0.01245	0.03908	0.01217	0.02932	0.01151	0.03084	0.01140	0.03011	0.01138	0.03929	0.01216	0.02954	0.01150	0.03107	0.01139
11	0.17226	0.01356	0.17888	0.01321	0.14773	0.01175	0.14859	0.01147	0.14602	0.01129	0.17903	0.01320	0.14793	0.01175	0.14881	0.01147
12	−0.02214	0.01504	−0.01306	0.01469	−0.01687	0.01408	−0.01607	0.01404	−0.02176	0.01427	−0.01343	0.01476	−0.01728	0.01414	−0.01644	0.01410
13	−0.08221	0.01308	−0.07185	0.01275	−0.07215	0.01237	−0.07271	0.01229	−0.07634	0.01236	−0.07214	0.01277	−0.07270	0.01238	−0.07332	0.01231
14	−0.12057	0.01466	−0.10933	0.01435	−0.10859	0.01401	−0.10862	0.01389	−0.11108	0.01394	−0.11024	0.01435	−0.10978	0.01401	−0.10999	0.01389
15	−0.08746	0.01714	−0.07783	0.01683	−0.07502	0.01603	−0.07369	0.01580	−0.07548	0.01578	−0.07804	0.01685	−0.07495	0.01603	−0.07364	0.01580
16	−0.13241	0.01541	−0.12286	0.01513	−0.12008	0.01448	−0.12053	0.01435	−0.12260	0.01435	−0.12260	0.01512	−0.11970	0.01447	−0.12015	0.01434
17	−0.18047	0.01707	−0.17326	0.01695	−0.17095	0.01635	−0.17306	0.01637	−0.17681	0.01646	−0.17339	0.01691	−0.17093	0.01632	−0.17306	0.01634
18	–	–	−0.16080	0.01516	−0.15826	0.01459	−0.15961	0.01454	−0.16498	0.01470	−0.16145	0.01537	−0.15927	0.01482	−0.16065	0.01478

Table 48: Objective function values for data components.

category	fleet	catch type	data type	22.01	22.03	22.07	22.08	22.09	22.10	22.11
surveys data	NMFS F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	166.995	163.916	124.999	152.696	167.055	163.965	125.037
			n at z	296.833	298.183	247.086	535.371	296.824	298.183	247.092
	NMFS M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	72.358	70.699	69.814	97.698	72.402	70.745	69.861
			n at z	410.411	411.493	297.002	540.856	410.282	411.380	296.963
	SBS BSFRF F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 1.288	− 1.622	− 2.384	4.853	− 1.291	− 1.628	− 2.392
			n at z	231.853	231.943	231.698	233.783	231.849	231.946	231.696
	SBS BSFRF M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 0.940	− 1.151	− 1.636	0.189	− 0.943	− 1.154	− 1.639
			n at z	290.361	290.992	288.384	288.166	290.362	290.999	288.393
	SBS NMFS F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			n at z	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SBS NMFS M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			n at z	0.000	0.000	0.000	0.000	0.000	0.000	0.000
fisheries data	GF All	total catch	abundance	− 37.753	− 37.835	− 38.441	− 38.390	− 37.752	− 37.834	− 38.440
			biomass	− 68.870	− 68.910	− 54.993	− 54.652	− 68.870	− 68.909	− 54.992
			n at z	517.780	515.465	453.651	474.820	517.714	515.429	453.625
	RKF	total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 22.073	− 37.093	− 37.181	− 37.174	− 22.071	− 37.092	− 37.180
			n at z	36.229	38.550	39.625	39.352	36.208	38.528	39.600
	SCF	total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 10.935	− 52.237	− 52.262	− 52.148	− 10.930	− 52.234	− 52.260
			n at z	105.035	132.502	132.483	131.645	104.880	132.355	132.340
	TCF	retained catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	−142.002	−143.049	−101.160	−100.700	−141.993	−143.043	−101.154
			n at z	63.997	64.684	52.851	50.305	58.855	59.371	47.621
		total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	73.588	6.586	7.921	7.546	74.235	6.971	8.265
			n at z	106.764	172.717	165.630	158.233	106.726	172.708	165.583
growth data	not appl	not appl	EBS molt increment data	525.929	526.605	521.958	528.229	525.823	526.514	521.874
maturity ogive data	NMFS M	not appl	EBS mature male ratios	211.944	211.641	208.534	214.404	211.970	211.674	208.566

Table 49: Differences in objective function values for data components, relative to the base scenario. Positive values indicate a better fit than the base.

category	fleet	catch type	data type	22.03	22.07	22.08	22.09	22.10	22.11
surveys data	NMFS F	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	3.079605	41.995944	14.298866	− 0.060264	3.029853	41.958628
			n at z	− 1.350005	49.747502	−238.538132	0.009495	− 1.349752	49.741672
	NMFS M	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	1.659534	2.543936	− 25.339233	− 0.043421	1.613232	2.497164
			n at z	− 1.082568	113.408493	−130.445096	0.128313	− 0.969836	113.447764
	SBS BSFRF F	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	0.333939	1.096025	− 6.141049	0.002478	0.339347	1.103977
			n at z	− 0.090195	0.155064	− 1.929624	0.003899	− 0.092626	0.157098
	SBS BSFRF M	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	0.210991	0.695838	− 1.129162	0.002860	0.213916	0.698531
			n at z	− 0.631487	1.977386	2.195217	− 0.001304	− 0.637557	1.968241
	SBS NMFS F	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			n at z	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	SBS NMFS M	index catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			n at z	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
fisheries data	GF All	total catch	abundance	0.082568	0.688405	0.636780	− 0.000858	0.081338	0.686658
			biomass	0.039132	− 13.877654	− 14.218767	− 0.000455	0.038267	− 13.878937
			n at z	2.315277	64.128682	42.959778	0.066225	2.351081	64.155414
	RKF	total catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	15.019346	15.107798	15.100979	− 0.002518	15.018340	15.106962
			n at z	− 2.321245	− 3.396095	− 3.123018	0.020972	− 2.299486	− 3.371236
	SCF	total catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	41.301439	41.326826	41.212409	− 0.005467	41.299345	41.324909
			n at z	− 27.467460	− 27.447934	− 26.610562	0.154264	− 27.320834	− 27.305414
	TCF	retained catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	1.047437	− 40.841688	− 41.301811	− 0.009040	1.040947	− 40.847641
			n at z	− 0.686260	11.146707	13.692655	5.142945	4.626935	16.376055
		total catch	abundance	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
			biomass	67.002453	65.667741	66.042955	− 0.646271	66.617877	65.323085
			n at z	− 65.953462	− 58.865986	− 51.468781	0.037861	− 65.944402	− 58.818781
growth data	not appl	not appl	EBS molt increment data	− 0.676039	3.970977	− 2.299840	0.106044	− 0.584902	4.055533
maturity ogive data	NMFS M	not appl	EBS mature male ratios	0.303785	3.409995	− 2.459289	− 0.025509	0.270745	3.378111

Table 50: Objective function values for non-data components.

category	type	element	22.01	22.03	22.07	22.08	22.09	22.10	22.11
penalties	devsSumSq	pDevsS1	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001
	initNatZs	sumTo1	0.0000	0.0000	0.0011	0.0011	0.0000	0.0000	0.0011
	maturity	smoothness	2.0125	2.0656	2.2106	2.3352	2.0368	2.0917	2.2316
priors	initNs	pvLnInitNatZ	0.0000	0.0000	198.7802	203.7045	0.0000	0.0000	198.7815
	natural mortality	pDM1	36.3664	37.9890	38.4204	40.3521	36.2953	37.9068	38.3524
	recruitment	pDevsLnR	113.0504	113.1919	53.4687	52.6919	113.0556	113.1945	53.4709
	surveys	pQ	99.4911	97.2863	96.4674	127.9939	99.4815	97.2604	96.4217

Table 51: Differences in objective function values for non-data components, relative to the base scenario. Positive values indicate a better fit than the base.

category	type	element	22.03	22.07	22.08	22.09	22.10	22.11
penalties	devsSumSq	pDevsLnR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		pDevsS1	0.0000	0.0000	− 0.0001	0.0000	0.0000	0.0000
	initNatZs	sumTo1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	maturity	smoothness	− 0.0531	− 0.1981	− 0.3227	− 0.0243	− 0.0792	− 0.2191
	nonParSelFcns	smoothness	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
priors	initNs	pvLnInitNatZ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	natural mortality	pDM1	− 1.6226	− 2.0540	− 3.9857	0.0711	− 1.5404	− 1.9860
	recruitment	pDevsLnR	− 0.1415	− 5.7827	− 5.0059	− 0.0052	− 0.1441	− 5.7849
	selectivity functions	pDevsS1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	surveys	pQ	2.2048	− 70.3377	−101.8642	0.0096	2.2307	− 70.2920

Table 52: Estimated rates of natural mortality (period of elevated M is 1980-1984).

	immature	mature			
	all	female		male	
case	typical	typical	elevated	typical	elevated
22.01	0.237	0.306	0.606	0.304	0.712
22.03	0.236	0.307	0.599	0.305	0.723

Table 53: 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	SBS NMFS F	SBS NMFS M
	female		male		female	male	female	male
case	1975	1982	1975	1982	2013	2013	2013	2013
22.01	0.34	0.27	0.50	0.50	1.00	1.00	0.27	0.50
22.03	0.34	0.27	0.51	0.52	1.00	1.00	0.27	0.52

Table 54: Estimated retained catch abundance (millions; 1965-1989).

y	22.01	22.03
1965	1.871	1.865
1966	2.380	2.373
1967	13.286	13.245
1968	17.765	17.708
1969	27.695	27.599
1970	26.515	26.442
1971	22.125	22.111
1972	17.837	17.821
1973	12.679	12.646
1974	14.240	14.201
1975	16.485	16.436
1976	27.387	27.290
1977	33.342	33.176
1978	21.215	21.084
1979	18.392	18.286
1980	13.744	13.710
1981	4.996	4.986
1982	2.330	2.324
1983	0.526	0.524
1984	1.359	1.354
1987	0.965	0.962
1988	3.093	3.084
1989	10.649	10.639

Table 55: Estimated retained catch abundance (millions; 1990+).

y	22.01	22.03
1990	17.332	17.344
1991	13.733	13.704
1992	15.429	15.456
1993	7.341	7.345
1994	3.402	3.382
1995	1.868	1.852
1996	0.765	0.724
2005	0.421	0.425
2006	0.940	0.946
2007	0.930	0.940
2008	0.846	0.857
2009	0.521	0.543
2013	1.472	1.466
2014	7.489	7.452
2015	10.649	10.602
2017	1.321	1.308
2018	1.309	1.297
2020	0.788	0.780
2021	0.606	0.601

Table 56: Estimated retained catch biomass (1,000's t; 1965-1989).

y	22.01	22.03
1965	1.923	1.923
1966	2.444	2.444
1967	13.583	13.583
1968	17.964	17.964
1969	27.362	27.362
1970	25.337	25.339
1971	20.423	20.424
1972	16.389	16.391
1973	12.664	12.664
1974	14.558	14.558
1975	16.980	16.980
1976	28.140	28.129
1977	33.865	33.819
1978	21.173	21.131
1979	17.990	17.962
1980	13.411	13.412
1981	4.996	4.996
1982	2.391	2.391
1983	0.549	0.549
1984	1.428	1.429
1987	0.996	0.997
1988	3.162	3.163
1989	10.867	10.888

Table 57: Estimated retained catch biomass (1,000's t; 1990+).

y	22.01	22.03
1990	17.528	17.579
1991	14.081	14.086
1992	15.581	15.636
1993	7.583	7.608
1994	3.576	3.558
1995	1.966	1.938
1996	0.816	0.817
2005	0.432	0.432
2006	0.965	0.963
2007	0.956	0.956
2008	0.879	0.880
2009	0.603	0.602
2013	1.264	1.264
2014	6.205	6.218
2015	8.887	8.912
2017	1.134	1.133
2018	1.108	1.108
2020	0.659	0.658
2021	0.494	0.494

Table 58: Estimated discard catch mortality (abundance) in the directed fishery (millions; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.1162	1.0803	0.1019	1.0488
1966	0.1516	1.4017	0.1328	1.3597
1967	1.0294	9.1656	0.9001	8.8721
1968	2.0363	16.8298	1.7745	16.2317
1969	7.5085	52.1916	6.5159	50.0222
1970	46.7866	195.3244	42.1330	189.3556
1971	101.0640	302.5630	91.2231	290.1064
1972	11.3109	57.4308	9.6658	53.7488
1973	1.7519	12.0275	1.5315	11.5570
1974	1.2609	9.4717	1.1096	9.1807
1975	1.3110	10.0230	1.1566	9.7514
1976	2.4222	18.2912	2.1360	17.8061
1977	4.3704	30.6953	3.8322	29.7302
1978	4.9947	31.4920	4.3286	30.1394
1979	7.5886	43.9820	6.5489	41.7592
1980	5.3590	30.9926	4.7857	30.0193
1981	0.8643	5.6346	0.7804	5.4827
1982	0.2215	1.5513	0.2002	1.5101
1983	0.0378	0.2600	0.0342	0.2529
1984	0.0958	0.6280	0.0871	0.6102
1987	0.0762	0.6049	0.0673	0.5832
1988	0.2419	2.0719	0.2139	2.0071
1989	0.9029	7.7108	0.8039	7.5280

Table 59: Estimated discard catch mortality in abundance in the directed fishery (millions; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.9107	5.4226	0.9316	5.9030
1991	1.3617	3.6504	1.4095	4.2320
1992	1.5159	4.6238	1.5233	4.7716
1993	1.0158	2.5927	0.9229	2.3568
1994	0.9820	1.9448	0.8888	1.8430
1995	0.6759	1.3493	0.6192	1.3418
1996	0.4903	1.0059	0.4988	0.9833
1997	0.3216	1.0445	0.3025	1.1816
1998	0.2408	0.7647	0.2193	0.7510
1999	0.1338	0.4077	0.1306	0.4084
2000	0.1567	0.4961	0.1489	0.4964
2001	0.2367	0.7447	0.2258	0.7570
2002	0.1262	0.4048	0.1219	0.4055
2003	0.0853	0.2754	0.0837	0.2758
2004	0.1384	0.4598	0.1306	0.4456
2005	0.0905	0.5016	0.0858	0.4957
2006	0.1117	0.8445	0.0952	0.6346
2007	0.1140	0.8859	0.1023	0.7942
2008	0.0767	0.4833	0.0704	0.4711
2009	0.0623	0.3766	0.0536	0.3890
2010	0.0475	0.3875	0.0428	0.3989
2011	0.0692	0.5362	0.0623	0.5672
2012	0.0489	0.4075	0.0431	0.4238
2013	0.0676	0.4717	0.0624	0.4969
2014	0.1175	1.1507	0.1094	1.3346
2015	0.1148	1.2084	0.1051	1.3146
2016	0.0610	0.6000	0.0552	0.6469
2017	0.0314	0.2743	0.0280	0.2804
2018	0.0340	0.2723	0.0309	0.2778
2019	0.0427	0.2922	0.0385	0.2976
2020	0.0290	0.1702	0.0281	0.1719
2021	0.0407	0.2209	0.0399	0.2230

Table 60: Estimated discard moratlity (biomass) in the directed fishery (1,000's t; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.0532	0.6205	0.0521	0.6031
1966	0.0600	0.6936	0.0586	0.6741
1967	0.1167	1.8103	0.1097	1.7633
1968	0.1860	2.8903	0.1726	2.8095
1969	0.4966	7.4745	0.4486	7.2434
1970	2.5226	22.9732	2.3239	22.5258
1971	5.1626	31.3983	4.7697	30.5380
1972	0.7302	7.8268	0.6540	7.4663
1973	0.7338	5.1341	0.7137	5.0533
1974	0.8763	6.4183	0.8563	6.3214
1975	0.3876	3.9419	0.3739	3.8348
1976	0.3128	4.4673	0.2937	4.3130
1977	0.3763	5.7059	0.3443	5.5116
1978	0.3827	5.1855	0.3443	4.9899
1979	0.5815	6.7483	0.5244	6.4840
1980	0.4082	4.9120	0.3767	4.7805
1981	0.1290	1.6894	0.1224	1.6157
1982	0.0386	0.6121	0.0362	0.5839
1983	0.0369	0.3030	0.0360	0.2978
1984	0.0349	0.3861	0.0336	0.3692
1985	0.0306	0.3508	0.0288	0.3340
1986	0.0453	0.5449	0.0429	0.5169
1987	0.0453	0.6280	0.0424	0.5966
1988	0.0473	0.8217	0.0433	0.7871
1989	0.1004	1.8997	0.0914	1.8369

Table 61: Estimated discard moratlity (biomass) in the directed fishery (1,000's t; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.16681	3.01548	0.16953	3.28888
1991	0.24777	1.93503	0.25620	2.24526
1992	0.29202	2.52472	0.29525	2.62062
1993	0.20251	1.48446	0.18316	1.33690
1994	0.17078	0.91792	0.15116	0.87085
1995	0.10675	0.59898	0.09461	0.60140
1996	0.06759	0.42302	0.07024	0.41035
1997	0.05143	0.45628	0.04805	0.52173
1998	0.03640	0.32038	0.03264	0.31428
1999	0.01779	0.15589	0.01722	0.15638
2000	0.02065	0.18987	0.01934	0.19033
2001	0.02895	0.27183	0.02719	0.27817
2002	0.01550	0.15056	0.01479	0.15116
2003	0.01015	0.10128	0.00986	0.10165
2004	0.01712	0.17435	0.01592	0.16847
2005	0.01263	0.23276	0.01189	0.22876
2006	0.01749	0.42255	0.01466	0.31220
2007	0.01882	0.44625	0.01674	0.39742
2008	0.01359	0.26267	0.01237	0.25543
2009	0.01109	0.20393	0.00929	0.21109
2010	0.00724	0.20491	0.00646	0.21143
2011	0.00994	0.27286	0.00890	0.28990
2012	0.00720	0.19913	0.00631	0.20756
2013	0.01130	0.22841	0.01039	0.24117
2014	0.02306	0.58698	0.02155	0.68322
2015	0.02427	0.61337	0.02230	0.67108
2016	0.01145	0.33175	0.01033	0.35710
2017	0.00596	0.14944	0.00529	0.15317
2018	0.00590	0.13890	0.00535	0.14228
2019	0.00602	0.14522	0.00539	0.14821
2020	0.00422	0.07033	0.00407	0.07150
2021	0.00580	0.08922	0.00567	0.09064

Table 62: Estimated discard catch mortality (abundance) in the snow crab fishery (millions; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.0641	0.4224	0.0506	0.4163
1966	0.0705	0.4484	0.0546	0.4414
1967	0.0814	0.4665	0.0608	0.4583
1968	0.0995	0.4884	0.0715	0.4787
1969	0.1246	0.5089	0.0898	0.4978
1970	0.1543	0.4833	0.1165	0.4699
1971	0.1808	0.5100	0.1453	0.4983
1972	0.2037	0.7877	0.1710	0.7786
1973	0.2112	1.1092	0.1792	1.0934
1974	0.1972	1.1888	0.1668	1.1660
1975	0.1742	1.0892	0.1460	1.0657
1976	0.1528	0.9132	0.1251	0.8932
1977	0.1369	0.7088	0.1090	0.6933
1978	0.2607	1.1601	0.2062	1.1330
1979	0.3521	1.4825	0.2862	1.4467
1980	0.5292	2.3316	0.4446	2.2662
1981	0.4428	2.2791	0.3778	2.2125
1982	0.1979	1.1551	0.1675	1.1188
1983	0.0857	0.5019	0.0699	0.4834
1984	0.1390	0.7365	0.1076	0.7051
1985	0.2036	1.0296	0.1516	0.9859
1986	0.2737	1.4107	0.2054	1.3538
1987	0.3980	2.1960	0.3074	2.1107
1988	0.4062	2.4475	0.3210	2.3550
1989	0.6020	3.7212	0.4877	3.5835

Table 63: Estimated discard catch mortality in abundance in the snow crab fishery (millions; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.9107	5.4226	0.9316	5.9030
1991	1.3617	3.6504	1.4095	4.2320
1992	1.5159	4.6238	1.5233	4.7716
1993	1.0158	2.5927	0.9229	2.3568
1994	0.9820	1.9448	0.8888	1.8430
1995	0.6759	1.3493	0.6192	1.3418
1996	0.4903	1.0059	0.4988	0.9833
1997	0.3216	1.0445	0.3025	1.1816
1998	0.2408	0.7647	0.2193	0.7510
1999	0.1338	0.4077	0.1306	0.4084
2000	0.1567	0.4961	0.1489	0.4964
2001	0.2367	0.7447	0.2258	0.7570
2002	0.1262	0.4048	0.1219	0.4055
2003	0.0853	0.2754	0.0837	0.2758
2004	0.1384	0.4598	0.1306	0.4456
2005	0.0905	0.5016	0.0858	0.4957
2006	0.1117	0.8445	0.0952	0.6346
2007	0.1140	0.8859	0.1023	0.7942
2008	0.0767	0.4833	0.0704	0.4711
2009	0.0623	0.3766	0.0536	0.3890
2010	0.0475	0.3875	0.0428	0.3989
2011	0.0692	0.5362	0.0623	0.5672
2012	0.0489	0.4075	0.0431	0.4238
2013	0.0676	0.4717	0.0624	0.4969
2014	0.1175	1.1507	0.1094	1.3346
2015	0.1148	1.2084	0.1051	1.3146
2016	0.0610	0.6000	0.0552	0.6469
2017	0.0314	0.2743	0.0280	0.2804
2018	0.0340	0.2723	0.0309	0.2778
2019	0.0427	0.2922	0.0385	0.2976
2020	0.0290	0.1702	0.0281	0.1719
2021	0.0407	0.2209	0.0399	0.2230

Table 64: Estimated discard moratlity (biomass) in the snow crab fishery (1,000's t; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.0532	0.6205	0.0521	0.6031
1966	0.0600	0.6936	0.0586	0.6741
1967	0.1167	1.8103	0.1097	1.7633
1968	0.1860	2.8903	0.1726	2.8095
1969	0.4966	7.4745	0.4486	7.2434
1970	2.5226	22.9732	2.3239	22.5258
1971	5.1626	31.3983	4.7697	30.5380
1972	0.7302	7.8268	0.6540	7.4663
1973	0.7338	5.1341	0.7137	5.0533
1974	0.8763	6.4183	0.8563	6.3214
1975	0.3876	3.9419	0.3739	3.8348
1976	0.3128	4.4673	0.2937	4.3130
1977	0.3763	5.7059	0.3443	5.5116
1978	0.3827	5.1855	0.3443	4.9899
1979	0.5815	6.7483	0.5244	6.4840
1980	0.4082	4.9120	0.3767	4.7805
1981	0.1290	1.6894	0.1224	1.6157
1982	0.0386	0.6121	0.0362	0.5839
1983	0.0369	0.3030	0.0360	0.2978
1984	0.0349	0.3861	0.0336	0.3692
1985	0.0306	0.3508	0.0288	0.3340
1986	0.0453	0.5449	0.0429	0.5169
1987	0.0453	0.6280	0.0424	0.5966
1988	0.0473	0.8217	0.0433	0.7871
1989	0.1004	1.8997	0.0914	1.8369

Table 65: Estimated discard moratlity (biomass) in the snow crab fishery (1,000's t; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.16681	3.01548	0.16953	3.28888
1991	0.24777	1.93503	0.25620	2.24526
1992	0.29202	2.52472	0.29525	2.62062
1993	0.20251	1.48446	0.18316	1.33690
1994	0.17078	0.91792	0.15116	0.87085
1995	0.10675	0.59898	0.09461	0.60140
1996	0.06759	0.42302	0.07024	0.41035
1997	0.05143	0.45628	0.04805	0.52173
1998	0.03640	0.32038	0.03264	0.31428
1999	0.01779	0.15589	0.01722	0.15638
2000	0.02065	0.18987	0.01934	0.19033
2001	0.02895	0.27183	0.02719	0.27817
2002	0.01550	0.15056	0.01479	0.15116
2003	0.01015	0.10128	0.00986	0.10165
2004	0.01712	0.17435	0.01592	0.16847
2005	0.01263	0.23276	0.01189	0.22876
2006	0.01749	0.42255	0.01466	0.31220
2007	0.01882	0.44625	0.01674	0.39742
2008	0.01359	0.26267	0.01237	0.25543
2009	0.01109	0.20393	0.00929	0.21109
2010	0.00724	0.20491	0.00646	0.21143
2011	0.00994	0.27286	0.00890	0.28990
2012	0.00720	0.19913	0.00631	0.20756
2013	0.01130	0.22841	0.01039	0.24117
2014	0.02306	0.58698	0.02155	0.68322
2015	0.02427	0.61337	0.02230	0.67108
2016	0.01145	0.33175	0.01033	0.35710
2017	0.00596	0.14944	0.00529	0.15317
2018	0.00590	0.13890	0.00535	0.14228
2019	0.00602	0.14522	0.00539	0.14821
2020	0.00422	0.07033	0.00407	0.07150
2021	0.00580	0.08922	0.00567	0.09064

Table 66: Estimated discard catch mortality (abundance) in the BBRKC fishery (millions; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.02294	0.62430	0.02398	0.55569
1966	0.02442	0.65281	0.02552	0.58068
1967	0.02725	0.62030	0.02850	0.55101
1968	0.04058	0.67515	0.04253	0.59816
1969	0.04348	0.38450	0.04586	0.33845
1970	0.04687	0.12147	0.05031	0.10303
1971	0.04011	0.05377	0.04406	0.04576
1972	0.09121	0.41772	0.09950	0.37319
1973	0.11530	1.58303	0.12257	1.41160
1974	0.13982	2.70168	0.14571	2.39038
1975	0.12884	2.66422	0.13277	2.34665
1976	0.17884	3.32529	0.18347	2.92451
1977	0.21374	2.85084	0.21926	2.50830
1978	0.16377	1.41270	0.16876	1.24463
1979	0.11644	0.70174	0.12107	0.61574
1980	0.18165	1.13303	0.19100	0.97701
1981	0.14995	1.65324	0.15788	1.42975
1982	0.03348	0.58319	0.03495	0.50739
1984	0.01342	0.29102	0.01388	0.25222
1985	0.00897	0.19927	0.00929	0.17312
1986	0.01903	0.43966	0.01975	0.38350
1987	0.02725	0.61136	0.02837	0.53331
1988	0.02202	0.50093	0.02284	0.43512
1989	0.03632	0.76284	0.03746	0.65859

Table 67: Estimated discard catch mortality in abundance in the BBRKC fishery (millions; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.9107	5.4226	0.9316	5.9030
1991	1.3617	3.6504	1.4095	4.2320
1992	1.5159	4.6238	1.5233	4.7716
1993	1.0158	2.5927	0.9229	2.3568
1994	0.9820	1.9448	0.8888	1.8430
1995	0.6759	1.3493	0.6192	1.3418
1996	0.4903	1.0059	0.4988	0.9833
1997	0.3216	1.0445	0.3025	1.1816
1998	0.2408	0.7647	0.2193	0.7510
1999	0.1338	0.4077	0.1306	0.4084
2000	0.1567	0.4961	0.1489	0.4964
2001	0.2367	0.7447	0.2258	0.7570
2002	0.1262	0.4048	0.1219	0.4055
2003	0.0853	0.2754	0.0837	0.2758
2004	0.1384	0.4598	0.1306	0.4456
2005	0.0905	0.5016	0.0858	0.4957
2006	0.1117	0.8445	0.0952	0.6346
2007	0.1140	0.8859	0.1023	0.7942
2008	0.0767	0.4833	0.0704	0.4711
2009	0.0623	0.3766	0.0536	0.3890
2010	0.0475	0.3875	0.0428	0.3989
2011	0.0692	0.5362	0.0623	0.5672
2012	0.0489	0.4075	0.0431	0.4238
2013	0.0676	0.4717	0.0624	0.4969
2014	0.1175	1.1507	0.1094	1.3346
2015	0.1148	1.2084	0.1051	1.3146
2016	0.0610	0.6000	0.0552	0.6469
2017	0.0314	0.2743	0.0280	0.2804
2018	0.0340	0.2723	0.0309	0.2778
2019	0.0427	0.2922	0.0385	0.2976
2020	0.0290	0.1702	0.0281	0.1719
2021	0.0407	0.2209	0.0399	0.2230

Table 68: Estimated discard moratlity (biomass) in the BBRKC fishery (1,000's t; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.0532	0.6205	0.0521	0.6031
1966	0.0600	0.6936	0.0586	0.6741
1967	0.1167	1.8103	0.1097	1.7633
1968	0.1860	2.8903	0.1726	2.8095
1969	0.4966	7.4745	0.4486	7.2434
1970	2.5226	22.9732	2.3239	22.5258
1971	5.1626	31.3983	4.7697	30.5380
1972	0.7302	7.8268	0.6540	7.4663
1973	0.7338	5.1341	0.7137	5.0533
1974	0.8763	6.4183	0.8563	6.3214
1975	0.3876	3.9419	0.3739	3.8348
1976	0.3128	4.4673	0.2937	4.3130
1977	0.3763	5.7059	0.3443	5.5116
1978	0.3827	5.1855	0.3443	4.9899
1979	0.5815	6.7483	0.5244	6.4840
1980	0.4082	4.9120	0.3767	4.7805
1981	0.1290	1.6894	0.1224	1.6157
1982	0.0386	0.6121	0.0362	0.5839
1983	0.0369	0.3030	0.0360	0.2978
1984	0.0349	0.3861	0.0336	0.3692
1985	0.0306	0.3508	0.0288	0.3340
1986	0.0453	0.5449	0.0429	0.5169
1987	0.0453	0.6280	0.0424	0.5966
1988	0.0473	0.8217	0.0433	0.7871
1989	0.1004	1.8997	0.0914	1.8369

Table 69: Estimated discard moratlity (biomass) in the BBRKC fishery (1,000's t; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.16681	3.01548	0.16953	3.28888
1991	0.24777	1.93503	0.25620	2.24526
1992	0.29202	2.52472	0.29525	2.62062
1993	0.20251	1.48446	0.18316	1.33690
1994	0.17078	0.91792	0.15116	0.87085
1995	0.10675	0.59898	0.09461	0.60140
1996	0.06759	0.42302	0.07024	0.41035
1997	0.05143	0.45628	0.04805	0.52173
1998	0.03640	0.32038	0.03264	0.31428
1999	0.01779	0.15589	0.01722	0.15638
2000	0.02065	0.18987	0.01934	0.19033
2001	0.02895	0.27183	0.02719	0.27817
2002	0.01550	0.15056	0.01479	0.15116
2003	0.01015	0.10128	0.00986	0.10165
2004	0.01712	0.17435	0.01592	0.16847
2005	0.01263	0.23276	0.01189	0.22876
2006	0.01749	0.42255	0.01466	0.31220
2007	0.01882	0.44625	0.01674	0.39742
2008	0.01359	0.26267	0.01237	0.25543
2009	0.01109	0.20393	0.00929	0.21109
2010	0.00724	0.20491	0.00646	0.21143
2011	0.00994	0.27286	0.00890	0.28990
2012	0.00720	0.19913	0.00631	0.20756
2013	0.01130	0.22841	0.01039	0.24117
2014	0.02306	0.58698	0.02155	0.68322
2015	0.02427	0.61337	0.02230	0.67108
2016	0.01145	0.33175	0.01033	0.35710
2017	0.00596	0.14944	0.00529	0.15317
2018	0.00590	0.13890	0.00535	0.14228
2019	0.00602	0.14522	0.00539	0.14821
2020	0.00422	0.07033	0.00407	0.07150
2021	0.00580	0.08922	0.00567	0.09064

Table 70: Estimated discard catch mortality (abundance) in the groundfish fisheries (millions; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	1.954	3.704	1.957	3.736
1966	2.330	4.254	2.335	4.286
1967	3.074	5.244	3.087	5.281
1968	4.279	6.868	4.301	6.908
1969	5.382	8.607	5.391	8.636
1970	5.934	9.743	5.918	9.760
1971	5.790	9.815	5.758	9.843
1972	5.249	9.679	5.208	9.723
1973	20.796	41.094	20.449	40.965
1974	24.510	49.671	24.164	49.660
1975	9.327	18.489	9.210	18.506
1976	5.487	10.020	5.432	10.024
1977	4.160	7.024	4.130	7.017
1978	3.159	5.388	3.137	5.380
1979	5.299	9.757	5.253	9.759
1980	2.846	5.564	2.826	5.574
1981	1.656	3.312	1.649	3.316
1982	0.456	0.888	0.456	0.887
1983	0.810	1.427	0.812	1.424
1984	1.067	1.712	1.072	1.706
1985	0.762	1.236	0.762	1.230
1986	1.157	2.008	1.155	2.002
1987	1.238	1.887	1.229	1.868
1988	0.760	1.204	0.761	1.202
1989	0.940	1.548	0.949	1.556

Table 71: Estimated discard catch mortality in abundance in the groundfish fisheries (millions; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.9107	5.4226	0.9316	5.9030
1991	1.3617	3.6504	1.4095	4.2320
1992	1.5159	4.6238	1.5233	4.7716
1993	1.0158	2.5927	0.9229	2.3568
1994	0.9820	1.9448	0.8888	1.8430
1995	0.6759	1.3493	0.6192	1.3418
1996	0.4903	1.0059	0.4988	0.9833
1997	0.3216	1.0445	0.3025	1.1816
1998	0.2408	0.7647	0.2193	0.7510
1999	0.1338	0.4077	0.1306	0.4084
2000	0.1567	0.4961	0.1489	0.4964
2001	0.2367	0.7447	0.2258	0.7570
2002	0.1262	0.4048	0.1219	0.4055
2003	0.0853	0.2754	0.0837	0.2758
2004	0.1384	0.4598	0.1306	0.4456
2005	0.0905	0.5016	0.0858	0.4957
2006	0.1117	0.8445	0.0952	0.6346
2007	0.1140	0.8859	0.1023	0.7942
2008	0.0767	0.4833	0.0704	0.4711
2009	0.0623	0.3766	0.0536	0.3890
2010	0.0475	0.3875	0.0428	0.3989
2011	0.0692	0.5362	0.0623	0.5672
2012	0.0489	0.4075	0.0431	0.4238
2013	0.0676	0.4717	0.0624	0.4969
2014	0.1175	1.1507	0.1094	1.3346
2015	0.1148	1.2084	0.1051	1.3146
2016	0.0610	0.6000	0.0552	0.6469
2017	0.0314	0.2743	0.0280	0.2804
2018	0.0340	0.2723	0.0309	0.2778
2019	0.0427	0.2922	0.0385	0.2976
2020	0.0290	0.1702	0.0281	0.1719
2021	0.0407	0.2209	0.0399	0.2230

Table 72: Estimated discard moratlity (biomass) in the groundfish fisheries (1,000's t; 1965-1989).

	22.01		22.03	
y	female	male	female	male
1965	0.0532	0.6205	0.0521	0.6031
1966	0.0600	0.6936	0.0586	0.6741
1967	0.1167	1.8103	0.1097	1.7633
1968	0.1860	2.8903	0.1726	2.8095
1969	0.4966	7.4745	0.4486	7.2434
1970	2.5226	22.9732	2.3239	22.5258
1971	5.1626	31.3983	4.7697	30.5380
1972	0.7302	7.8268	0.6540	7.4663
1973	0.7338	5.1341	0.7137	5.0533
1974	0.8763	6.4183	0.8563	6.3214
1975	0.3876	3.9419	0.3739	3.8348
1976	0.3128	4.4673	0.2937	4.3130
1977	0.3763	5.7059	0.3443	5.5116
1978	0.3827	5.1855	0.3443	4.9899
1979	0.5815	6.7483	0.5244	6.4840
1980	0.4082	4.9120	0.3767	4.7805
1981	0.1290	1.6894	0.1224	1.6157
1982	0.0386	0.6121	0.0362	0.5839
1983	0.0369	0.3030	0.0360	0.2978
1984	0.0349	0.3861	0.0336	0.3692
1985	0.0306	0.3508	0.0288	0.3340
1986	0.0453	0.5449	0.0429	0.5169
1987	0.0453	0.6280	0.0424	0.5966
1988	0.0473	0.8217	0.0433	0.7871
1989	0.1004	1.8997	0.0914	1.8369

Table 73: Estimated discard moratlity (biomass) in the groundfish fisheries (1,000's t; 1990+).

	22.01		22.03	
y	female	male	female	male
1990	0.16681	3.01548	0.16953	3.28888
1991	0.24777	1.93503	0.25620	2.24526
1992	0.29202	2.52472	0.29525	2.62062
1993	0.20251	1.48446	0.18316	1.33690
1994	0.17078	0.91792	0.15116	0.87085
1995	0.10675	0.59898	0.09461	0.60140
1996	0.06759	0.42302	0.07024	0.41035
1997	0.05143	0.45628	0.04805	0.52173
1998	0.03640	0.32038	0.03264	0.31428
1999	0.01779	0.15589	0.01722	0.15638
2000	0.02065	0.18987	0.01934	0.19033
2001	0.02895	0.27183	0.02719	0.27817
2002	0.01550	0.15056	0.01479	0.15116
2003	0.01015	0.10128	0.00986	0.10165
2004	0.01712	0.17435	0.01592	0.16847
2005	0.01263	0.23276	0.01189	0.22876
2006	0.01749	0.42255	0.01466	0.31220
2007	0.01882	0.44625	0.01674	0.39742
2008	0.01359	0.26267	0.01237	0.25543
2009	0.01109	0.20393	0.00929	0.21109
2010	0.00724	0.20491	0.00646	0.21143
2011	0.00994	0.27286	0.00890	0.28990
2012	0.00720	0.19913	0.00631	0.20756
2013	0.01130	0.22841	0.01039	0.24117
2014	0.02306	0.58698	0.02155	0.68322
2015	0.02427	0.61337	0.02230	0.67108
2016	0.01145	0.33175	0.01033	0.35710
2017	0.00596	0.14944	0.00529	0.15317
2018	0.00590	0.13890	0.00535	0.14228
2019	0.00602	0.14522	0.00539	0.14821
2020	0.00422	0.07033	0.00407	0.07150
2021	0.00580	0.08922	0.00567	0.09064

Table 74: Estimated abundance in the NMFS EBS survey for females (millions; 1975-2000).

	22.01		22.03	
y	immature	mature	immature	mature
1975	71.061	243.415	71.216	243.243
1976	86.246	209.037	86.922	208.689
1977	106.086	178.263	107.008	178.025
1978	114.846	160.521	115.499	160.559
1979	105.190	161.821	105.431	162.242
1980	78.168	172.971	77.898	173.686
1981	49.346	137.317	48.907	138.463
1982	81.743	127.176	80.762	127.843
1983	119.240	87.118	118.161	87.686
1984	143.048	60.103	141.138	60.649
1985	170.850	46.249	168.264	46.745
1986	189.484	55.712	187.483	55.960
1987	188.109	70.853	187.482	70.734
1988	165.028	85.883	167.407	85.329
1989	126.707	97.773	130.168	97.040
1990	88.333	104.681	89.795	104.234
1991	56.181	104.027	56.669	104.182
1992	36.113	94.938	35.898	95.633
1993	26.145	80.394	25.649	81.102
1994	23.680	65.229	23.457	65.598
1995	28.461	52.128	28.508	52.220
1996	31.095	42.040	31.172	42.063
1997	47.724	34.930	47.843	34.936
1998	46.432	30.795	46.470	30.832
1999	76.546	29.282	76.858	29.347
2000	73.567	30.181	73.749	30.262

Table 75: Estimated abundance in the NMFS EBS survey for females (millions; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2001	116.586	32.936	116.963	33.038
2002	108.913	37.601	109.455	37.762
2003	147.853	44.485	149.076	44.708
2004	152.129	53.164	151.603	53.451
2005	125.030	62.877	124.033	63.249
2006	92.981	72.481	91.742	72.943
2007	68.137	80.910	66.965	81.219
2008	59.276	81.693	58.401	81.515
2009	131.892	73.405	131.559	72.863
2010	143.096	62.978	143.913	62.399
2011	132.217	58.993	133.047	58.575
2012	98.800	67.166	99.261	67.018
2013	67.529	80.489	67.709	80.538
2014	41.389	83.713	41.409	83.797
2015	30.892	74.988	30.857	75.018
2016	29.500	62.348	29.415	62.328
2017	77.019	51.370	77.069	51.321
2018	87.011	43.037	87.129	42.970
2019	106.579	38.964	106.674	38.930
2020	86.257	42.485	86.123	42.559
2021	108.245	51.186	108.171	51.310
2022	167.954	57.414	168.352	57.474

Table 76: Estimated biomass in the NMFS EBS survey for females (1,000's t; 1975-2000).

	22.01		22.03	
y	immature	mature	immature	mature
1975	4.430	44.097	4.411	44.093
1976	4.003	38.229	4.013	38.170
1977	4.797	32.520	4.824	32.473
1978	6.290	28.651	6.326	28.654
1979	7.195	28.057	7.219	28.130
1980	6.313	29.853	6.297	29.998
1981	4.181	24.387	4.134	24.620
1982	4.182	21.890	4.110	22.027
1983	3.704	15.328	3.662	15.428
1984	4.364	10.531	4.318	10.621
1985	5.701	7.841	5.632	7.925
1986	7.039	8.986	6.949	9.032
1987	7.652	11.209	7.563	11.205
1988	7.470	13.706	7.443	13.632
1989	6.641	15.769	6.698	15.650
1990	5.250	17.095	5.350	17.005
1991	3.609	17.284	3.699	17.280
1992	2.230	16.068	2.257	16.162
1993	1.387	13.791	1.359	13.912
1994	1.024	11.261	0.994	11.343
1995	0.986	9.008	0.978	9.037
1996	1.085	7.234	1.088	7.244
1997	1.422	5.951	1.426	5.953
1998	1.694	5.161	1.698	5.169
1999	2.296	4.815	2.301	4.827
2000	2.695	4.875	2.701	4.889

Table 77: Estimated biomass in the NMFS EBS survey for females (1,000's t; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2001	3.555	5.260	3.566	5.278
2002	4.114	5.942	4.130	5.967
2003	5.030	6.990	5.055	7.026
2004	5.669	8.351	5.683	8.398
2005	5.760	9.930	5.758	9.990
2006	5.282	11.520	5.245	11.596
2007	4.104	13.019	4.032	13.085
2008	2.795	13.569	2.729	13.565
2009	3.081	12.535	3.048	12.457
2010	4.160	10.774	4.164	10.676
2011	5.501	9.718	5.524	9.641
2012	5.767	10.532	5.790	10.497
2013	4.428	12.734	4.437	12.739
2014	2.594	13.862	2.592	13.879
2015	1.540	12.840	1.536	12.849
2016	1.225	10.796	1.221	10.793
2017	1.755	8.880	1.753	8.872
2018	2.459	7.391	2.462	7.380
2019	3.586	6.490	3.593	6.482
2020	4.130	6.720	4.131	6.728
2021	4.280	8.036	4.270	8.058
2022	4.788	9.265	4.782	9.280

Table 78: Estimated abundance in the NMFS EBS survey for males (millions; 1975-2000).

	22.01		22.03	
y	immature	mature	immature	mature
1975	127.173	305.626	127.386	305.169
1976	150.810	265.421	151.009	264.898
1977	174.795	216.335	174.708	215.946
1978	181.975	174.882	181.437	174.460
1979	171.521	166.095	171.293	165.521
1980	138.510	179.282	138.689	178.762
1981	93.951	145.785	94.232	144.534
1982	117.616	154.160	117.368	152.780
1983	145.187	108.684	143.685	107.357
1984	169.486	73.279	166.667	72.088
1985	203.829	53.259	200.039	52.207
1986	232.669	66.272	229.473	65.208
1987	239.014	87.898	237.511	86.550
1988	216.466	113.444	218.653	111.717
1989	174.724	133.790	178.873	131.901
1990	129.509	142.092	132.403	140.528
1991	86.865	137.148	89.121	135.652
1992	55.793	126.754	56.938	125.912
1993	37.843	103.784	37.802	103.785
1994	31.445	83.203	31.086	83.668
1995	35.150	66.345	35.015	66.410
1996	37.935	53.296	37.928	53.095
1997	56.393	44.067	56.290	43.901
1998	56.648	38.760	56.546	38.469
1999	90.610	37.104	90.531	36.880
2000	90.144	38.883	90.107	38.697

Table 79: Estimated abundance in the NMFS EBS survey for males (millions; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2001	138.560	43.372	138.377	43.214
2002	134.202	50.057	134.516	49.932
2003	179.686	59.962	180.470	59.913
2004	188.482	72.921	187.653	72.954
2005	163.155	87.800	162.349	87.958
2006	130.352	102.866	129.674	103.188
2007	102.135	116.053	101.453	116.750
2008	83.756	123.993	82.996	124.458
2009	152.632	118.185	151.324	118.227
2010	165.298	102.410	165.171	102.187
2011	162.277	90.471	162.649	90.094
2012	137.994	93.105	138.898	92.531
2013	105.892	112.011	107.177	111.439
2014	65.868	127.374	66.981	127.225
2015	43.735	118.662	44.215	118.769
2016	38.218	95.966	38.241	96.053
2017	88.270	79.192	87.776	79.212
2018	100.491	65.721	100.037	65.656
2019	125.958	56.917	125.442	56.771
2020	112.184	57.190	111.996	56.945
2021	139.405	68.201	139.255	67.885
2022	200.817	82.057	200.510	81.822

Table 80: Estimated biomass in the NMFS EBS survey for males (1,000's t; 1975-2000).

	22.01		22.03	
y	immature	mature	immature	mature
1975	16.728	163.998	16.793	164.342
1976	13.154	143.208	13.257	143.399
1977	13.298	112.298	13.342	112.481
1978	17.142	82.275	17.096	82.373
1979	22.403	72.219	22.339	72.202
1980	23.691	77.542	23.713	77.487
1981	18.171	69.526	18.267	69.089
1982	15.737	77.953	15.840	77.662
1983	10.085	59.291	10.107	58.956
1984	9.583	40.613	9.528	40.225
1985	11.902	28.087	11.757	27.707
1986	15.918	32.494	15.687	32.169
1987	19.473	41.163	19.211	40.761
1988	20.355	53.778	20.197	53.200
1989	19.465	64.486	19.507	63.778
1990	17.141	67.485	17.430	66.779
1991	13.132	63.555	13.598	62.537
1992	8.592	59.203	9.009	58.413
1993	5.083	47.486	5.237	47.280
1994	3.226	37.835	3.171	38.171
1995	2.587	30.235	2.537	30.387
1996	2.576	24.236	2.581	24.187
1997	3.096	20.002	3.109	19.945
1998	3.797	17.638	3.803	17.523
1999	5.005	16.912	5.009	16.842
2000	6.169	17.792	6.172	17.752

Table 81: Estimated biomass in the NMFS EBS survey for males (1,000's t; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2001	7.880	20.021	7.890	20.006
2002	9.471	23.272	9.495	23.279
2003	11.736	27.948	11.777	28.014
2004	13.684	34.342	13.731	34.468
2005	14.979	41.805	15.036	42.019
2006	15.162	49.730	15.218	50.043
2007	14.086	56.665	14.063	57.300
2008	10.397	62.975	10.339	63.573
2009	7.470	63.161	7.430	63.516
2010	7.691	55.680	7.660	55.836
2011	11.070	47.574	11.022	47.618
2012	15.383	45.100	15.368	45.022
2013	15.980	52.944	16.101	52.806
2014	10.849	64.206	11.083	64.217
2015	5.649	62.955	5.806	63.118
2016	3.543	51.167	3.596	51.340
2017	3.779	42.448	3.788	42.604
2018	4.645	34.890	4.637	34.977
2019	6.829	29.328	6.800	29.359
2020	9.871	27.412	9.835	27.398
2021	12.018	31.404	12.019	31.345
2022	12.119	39.629	12.167	39.603

Table 82: Estimated abundance in the BSFRF SBS survey for females (millions; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2013	11.422	44.514	11.306	44.169
2014	7.779	28.154	7.674	27.986
2015	5.664	28.116	5.576	27.894
2016	18.465	97.466	18.190	96.554
2017	265.950	149.469	261.927	147.879

Table 83: Estimated biomass in the BSFRF SBS survey for females (1,000's t; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2013	1.030	9.623	1.019	9.551
2014	0.531	6.283	0.522	6.250
2015	0.319	6.791	0.313	6.733
2016	1.189	18.971	1.171	18.800
2017	6.030	23.585	5.943	23.348

Table 84: Estimated abundance in the BSFRF SBS survey for males (millions; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2013	43.069	65.585	42.936	63.942
2014	22.910	86.702	22.992	84.858
2015	16.260	68.242	16.297	67.019
2016	19.252	102.007	19.128	100.137
2017	224.261	112.427	221.210	110.115

Table 85: Estimated biomass in the BSFRF SBS survey for males (1,000's t; 2001+).

	22.01		22.03	
y	immature	mature	immature	mature
2013	7.186	35.080	7.112	34.225
2014	5.258	52.343	5.274	51.275
2015	2.683	40.786	2.715	40.105
2016	3.545	51.127	3.545	50.238
2017	7.960	51.850	7.863	50.749

Table 86: Estimated population abundance (millions; 1948-1990).

	22.01						22.03					
	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	269.611	–	–	269.611	–	–	269.116	–	–	269.116	–	–
1950	481.832	0.618	–	481.975	0.467	–	481.058	0.629	–	481.215	0.464	–
1951	641.572	8.475	0.454	645.609	4.620	0.344	640.476	8.665	0.462	644.786	4.557	0.341
1952	740.560	35.538	6.561	758.710	20.833	3.649	738.790	36.171	6.700	758.080	20.570	3.593
1953	782.230	72.303	30.930	817.460	51.634	17.972	779.729	73.118	31.465	817.248	51.098	17.704
1954	795.063	93.859	75.839	837.383	79.259	50.965	792.152	94.467	76.752	837.474	78.695	50.278
1955	802.067	99.885	124.658	845.335	89.747	95.090	798.937	100.318	125.647	845.388	89.375	93.988
1956	810.816	100.968	164.939	854.275	91.361	134.697	807.460	101.352	165.815	854.121	91.057	133.355
1957	823.100	101.600	195.317	866.834	91.868	164.550	819.435	101.971	196.044	866.384	91.555	163.025
1958	840.205	102.478	218.093	884.343	92.561	186.614	836.112	102.837	218.680	883.482	92.227	184.899
1959	863.818	103.732	235.466	908.530	93.560	203.114	859.127	104.073	235.922	907.098	93.196	201.213
1960	896.296	105.493	249.148	941.812	94.971	215.838	890.772	105.808	249.481	939.583	94.566	213.752
1961	941.259	107.936	260.489	987.889	96.935	226.091	934.574	108.215	260.702	984.549	96.473	223.822
1962	1004.862	111.304	270.607	1053.024	99.648	234.798	996.552	111.532	270.696	1048.130	99.107	232.356
1963	1098.534	115.944	280.506	1148.808	103.387	242.907	1087.937	116.102	280.455	1141.721	102.737	240.287
1964	1246.108	122.408	291.176	1299.324	108.575	251.302	1232.325	122.467	290.961	1289.183	107.772	248.481
1965	1505.512	131.664	303.761	1562.951	115.935	261.198	1487.668	131.593	303.340	1548.940	114.916	258.100
1966	2025.413	145.614	319.794	2089.239	126.829	273.514	2004.075	145.378	319.113	2072.036	125.502	270.043
1967	3125.733	168.483	341.794	3200.090	144.220	289.807	3104.182	168.094	340.781	3183.209	142.451	285.817
1968	4594.832	210.504	374.046	4688.700	174.551	298.625	4548.478	210.192	372.728	4648.156	172.189	294.102
1969	4830.042	294.079	427.812	4963.614	233.338	317.405	4741.898	294.550	426.365	4883.869	230.163	312.237
1970	4218.458	440.986	524.467	4422.759	337.046	339.267	4122.595	442.610	523.910	4339.873	332.818	333.957
1971	3342.622	602.462	673.689	3617.794	454.185	339.765	3261.226	602.702	676.769	3553.618	448.862	334.958
1972	2368.752	643.494	861.907	2644.806	507.187	384.285	2310.551	638.207	869.632	2603.583	501.562	381.469
1973	1595.499	535.117	1097.252	1810.229	523.990	599.713	1560.590	523.777	1099.067	1787.131	514.981	594.455
1974	1259.429	367.038	1189.289	1396.719	387.188	787.720	1237.646	357.418	1181.340	1383.037	378.752	776.173
1975	1409.367	241.303	1130.136	1498.471	250.520	815.614	1382.413	236.304	1116.363	1477.622	245.714	799.858
1976	2143.165	167.952	1002.901	2207.023	171.150	749.633	2111.272	165.849	988.270	2179.847	169.101	733.613
1977	2393.468	146.432	856.952	2453.387	135.170	630.537	2359.315	145.422	844.043	2423.251	133.868	616.859
1978	2019.580	188.880	733.018	2104.957	149.606	503.094	1982.188	187.960	722.497	2072.311	147.191	492.309
1979	1456.879	275.405	673.049	1585.612	212.870	432.536	1428.246	274.154	664.504	1563.928	208.596	423.284
1980	959.891	321.498	689.568	1103.392	274.136	420.030	938.016	319.171	682.497	1089.910	269.217	411.001
1981	654.979	236.402	546.343	761.297	227.343	306.727	638.799	233.621	545.017	751.922	223.203	297.005
1982	500.388	142.510	425.420	556.950	157.881	251.056	487.776	139.546	425.898	548.211	155.341	241.755
1983	809.005	78.248	309.425	839.792	86.314	196.379	789.374	76.541	310.016	822.288	84.936	188.517
1984	953.447	56.703	211.189	978.886	53.239	137.302	925.772	55.916	211.898	952.739	52.268	131.292
1985	1116.320	61.957	145.765	1146.615	50.581	90.887	1082.436	61.306	146.642	1114.271	49.331	86.532
1986	1216.887	100.054	152.631	1263.411	77.673	103.203	1187.382	98.670	152.652	1235.904	75.509	98.935
1987	1187.397	136.543	185.590	1250.274	110.414	131.648	1168.754	133.989	184.412	1234.131	106.941	126.749
1988	1014.116	153.100	236.541	1081.378	135.211	174.825	1018.942	149.754	233.582	1089.095	130.950	168.467
1989	749.011	156.436	286.179	816.829	141.391	221.927	762.530	153.807	281.297	833.852	137.557	213.856
1990	507.327	148.205	324.366	570.631	137.318	248.590	507.173	147.538	318.631	574.860	135.065	239.670

Table 87: Estimated population abundance (millions; 1991+).

	22.01						22.03					
	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	269.611	–	–	269.611	–	–	269.116	–	–	269.116	–	–
1950	481.832	0.618	–	481.975	0.467	–	481.058	0.629	–	481.215	0.464	–
1951	641.572	8.475	0.454	645.609	4.620	0.344	640.476	8.665	0.462	644.786	4.557	0.341
1952	740.560	35.538	6.561	758.710	20.833	3.649	738.790	36.171	6.700	758.080	20.570	3.593
1953	782.230	72.303	30.930	817.460	51.634	17.972	779.729	73.118	31.465	817.248	51.098	17.704
1954	795.063	93.859	75.839	837.383	79.259	50.965	792.152	94.467	76.752	837.474	78.695	50.278
1955	802.067	99.885	124.658	845.335	89.747	95.090	798.937	100.318	125.647	845.388	89.375	93.988
1956	810.816	100.968	164.939	854.275	91.361	134.697	807.460	101.352	165.815	854.121	91.057	133.355
1957	823.100	101.600	195.317	866.834	91.868	164.550	819.435	101.971	196.044	866.384	91.555	163.025
1958	840.205	102.478	218.093	884.343	92.561	186.614	836.112	102.837	218.680	883.482	92.227	184.899
1959	863.818	103.732	235.466	908.530	93.560	203.114	859.127	104.073	235.922	907.098	93.196	201.213
1960	896.296	105.493	249.148	941.812	94.971	215.838	890.772	105.808	249.481	939.583	94.566	213.752
1961	941.259	107.936	260.489	987.889	96.935	226.091	934.574	108.215	260.702	984.549	96.473	223.822
1962	1004.862	111.304	270.607	1053.024	99.648	234.798	996.552	111.532	270.696	1048.130	99.107	232.356
1963	1098.534	115.944	280.506	1148.808	103.387	242.907	1087.937	116.102	280.455	1141.721	102.737	240.287
1964	1246.108	122.408	291.176	1299.324	108.575	251.302	1232.325	122.467	290.961	1289.183	107.772	248.481
1965	1505.512	131.664	303.761	1562.951	115.935	261.198	1487.668	131.593	303.340	1548.940	114.916	258.100
1966	2025.413	145.614	319.794	2089.239	126.829	273.514	2004.075	145.378	319.113	2072.036	125.502	270.043
1967	3125.733	168.483	341.794	3200.090	144.220	289.807	3104.182	168.094	340.781	3183.209	142.451	285.817
1968	4594.832	210.504	374.046	4688.700	174.551	298.625	4548.478	210.192	372.728	4648.156	172.189	294.102
1969	4830.042	294.079	427.812	4963.614	233.338	317.405	4741.898	294.550	426.365	4883.869	230.163	312.237
1970	4218.458	440.986	524.467	4422.759	337.046	339.267	4122.595	442.610	523.910	4339.873	332.818	333.957
1971	3342.622	602.462	673.689	3617.794	454.185	339.765	3261.226	602.702	676.769	3553.618	448.862	334.958
1972	2368.752	643.494	861.907	2644.806	507.187	384.285	2310.551	638.207	869.632	2603.583	501.562	381.469
1973	1595.499	535.117	1097.252	1810.229	523.990	599.713	1560.590	523.777	1099.067	1787.131	514.981	594.455
1974	1259.429	367.038	1189.289	1396.719	387.188	787.720	1237.646	357.418	1181.340	1383.037	378.752	776.173
1975	1409.367	241.303	1130.136	1498.471	250.520	815.614	1382.413	236.304	1116.363	1477.622	245.714	799.858
1976	2143.165	167.952	1002.901	2207.023	171.150	749.633	2111.272	165.849	988.270	2179.847	169.101	733.613
1977	2393.468	146.432	856.952	2453.387	135.170	630.537	2359.315	145.422	844.043	2423.251	133.868	616.859
1978	2019.580	188.880	733.018	2104.957	149.606	503.094	1982.188	187.960	722.497	2072.311	147.191	492.309
1979	1456.879	275.405	673.049	1585.612	212.870	432.536	1428.246	274.154	664.504	1563.928	208.596	423.284
1980	959.891	321.498	689.568	1103.392	274.136	420.030	938.016	319.171	682.497	1089.910	269.217	411.001
1981	654.979	236.402	546.343	761.297	227.343	306.727	638.799	233.621	545.017	751.922	223.203	297.005
1982	500.388	142.510	425.420	556.950	157.881	251.056	487.776	139.546	425.898	548.211	155.341	241.755
1983	809.005	78.248	309.425	839.792	86.314	196.379	789.374	76.541	310.016	822.288	84.936	188.517
1984	953.447	56.703	211.189	978.886	53.239	137.302	925.772	55.916	211.898	952.739	52.268	131.292
1985	1116.320	61.957	145.765	1146.615	50.581	90.887	1082.436	61.306	146.642	1114.271	49.331	86.532
1986	1216.887	100.054	152.631	1263.411	77.673	103.203	1187.382	98.670	152.652	1235.904	75.509	98.935
1987	1187.397	136.543	185.590	1250.274	110.414	131.648	1168.754	133.989	184.412	1234.131	106.941	126.749
1988	1014.116	153.100	236.541	1081.378	135.211	174.825	1018.942	149.754	233.582	1089.095	130.950	168.467
1989	749.011	156.436	286.179	816.829	141.391	221.927	762.530	153.807	281.297	833.852	137.557	213.856
1990	507.327	148.205	324.366	570.631	137.318	248.590	507.173	147.538	318.631	574.860	135.065	239.670

Table 88: Estimated population biomass (1,000's t; 1948-1990).

	22.01						22.03					
	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	3.1870	–	–	3.1919	–	–	3.1843	–	–	3.1894	–	–
1950	8.3991	0.0389	–	8.8633	0.0347	–	8.4097	0.0398	–	8.8321	0.0344	–
1951	15.5568	0.8150	0.0286	18.5178	0.5731	0.0255	15.5893	0.8360	0.0292	18.4188	0.5645	0.0252
1952	22.4918	4.2601	0.6199	31.9995	4.4723	0.4398	22.5147	4.3466	0.6351	31.8156	4.4142	0.4325
1953	26.4737	10.1024	3.5851	43.8524	16.8448	3.6017	26.4494	10.2414	3.6561	43.6607	16.6567	3.5468
1954	27.7255	14.4226	10.0544	48.9222	33.0161	14.9067	27.6632	14.5424	10.1982	48.8152	32.7612	14.6998
1955	28.0292	15.8871	17.9782	49.8743	41.1468	34.7639	27.9532	15.9698	18.1536	49.8046	41.0232	34.3574
1956	28.2584	16.1436	24.8723	50.2191	42.5483	54.8754	28.1763	16.2131	25.0367	50.1444	42.4973	54.3785
1957	28.5758	16.2410	30.1227	50.6808	42.7752	70.2925	28.4862	16.3080	30.2643	50.5937	42.7253	69.7530
1958	29.0228	16.3688	34.0501	51.3380	43.0453	81.5787	28.9229	16.4340	34.1694	51.2337	42.9875	80.9800
1959	29.6447	16.5522	37.0278	52.2587	43.4387	89.8735	29.5304	16.6148	37.1265	52.1305	43.3697	89.2100
1960	30.5035	16.8106	39.3493	53.5355	43.9993	96.1445	30.3691	16.8697	39.4287	53.3739	43.9148	95.4107
1961	31.6891	17.1701	41.2437	55.2997	44.7840	101.0479	31.5266	17.2242	41.3044	55.0920	44.6781	100.2433
1962	33.3430	17.6662	42.8972	57.7508	45.8701	104.9638	33.1413	17.7133	42.9390	57.4788	45.7346	104.1031
1963	35.7116	18.3494	44.4739	61.2202	47.3670	108.3640	35.4551	18.3866	44.4950	60.8581	47.1905	107.4555
1964	39.2754	19.2972	46.1312	66.3270	49.4321	111.6588	38.9428	19.3207	46.1282	65.8387	49.1984	110.7033
1965	45.1146	20.6427	48.0444	74.4037	52.3209	115.5324	44.6823	20.6476	48.0116	73.7415	52.0066	114.4928
1966	55.8914	22.6387	50.4354	88.6262	56.4736	120.2229	55.3559	22.6202	50.3656	87.7466	56.0456	119.0603
1967	77.6565	25.8307	53.6517	116.2293	62.8039	126.0645	77.0758	25.7886	53.5349	115.1196	62.2117	124.7230
1968	113.1164	31.5135	58.1962	162.7433	72.8211	121.4345	112.2890	31.4756	58.0412	161.0805	72.0103	119.9218
1969	145.6457	42.7198	65.5272	216.6180	91.7718	118.0646	144.1912	42.7844	65.3601	213.9004	90.6705	116.3684
1970	162.7203	63.4908	78.1931	267.2768	126.3149	106.7180	160.4702	63.7760	78.1874	263.4531	124.9669	105.1139
1971	153.7290	89.7615	96.2856	289.0872	167.2128	81.5473	150.7351	90.0597	96.9783	284.5278	165.7454	80.2680
1972	120.5941	102.4359	120.6489	256.1032	199.6217	83.3619	117.5441	102.0863	122.3653	251.7832	198.4536	82.9994
1973	83.4434	92.1776	162.0053	191.0099	260.0556	172.2239	81.1302	90.5631	163.0711	187.4234	256.9643	171.6824
1974	57.4995	65.4929	185.0683	127.7612	212.1132	293.2283	56.1779	63.7903	184.5219	125.6939	208.1032	290.2144
1975	46.9081	42.9466	181.8438	92.8839	137.9072	340.2314	46.0641	41.9587	180.0562	91.8301	135.2937	334.7128
1976	53.6295	29.2463	164.2844	87.3186	91.6858	324.7927	52.8498	28.8237	162.1161	86.4457	90.5943	318.5447
1977	67.1671	23.4679	141.4757	99.8080	65.6887	267.1161	66.2851	23.2885	139.4871	98.4410	65.3079	261.7225
1978	76.5558	27.4996	120.2039	121.3622	60.2617	195.9124	75.5004	27.3761	118.5932	119.2635	59.6584	191.9595
1979	73.2283	40.3092	107.4988	136.4678	81.6074	152.7333	72.0960	40.1583	106.2402	134.1615	80.1543	149.7497
1980	55.7598	50.7993	106.9827	124.8628	117.2907	135.2357	54.6360	50.5231	106.0211	123.0839	115.2308	132.5357
1981	35.0963	41.1812	84.9626	87.7298	114.4024	100.8444	34.1793	40.8148	84.9043	86.7168	112.3797	97.5939
1982	21.7960	26.7534	68.4948	51.1873	91.4040	97.4099	21.1961	26.2568	68.7067	50.6050	90.1444	93.9216
1983	21.1353	14.5330	51.8756	37.3762	51.6951	89.1603	20.6378	14.1926	52.0491	36.8137	51.0562	85.9176
1984	25.5029	9.4763	36.1726	38.9665	27.9261	68.1133	24.8877	9.3239	36.3080	38.1187	27.5477	65.4709
1985	32.8767	9.3584	24.8289	49.1552	22.1446	44.9872	32.0300	9.2625	24.9776	47.8377	21.7217	43.0533
1986	39.6217	14.4387	25.1149	63.2121	30.2515	48.7309	38.6135	14.2557	25.1308	61.4399	29.5529	46.9468
1987	42.2524	20.5034	29.0430	73.4824	44.2939	57.0444	41.2881	20.1630	28.8938	71.5578	43.0214	55.1797
1988	40.5282	24.1208	36.3666	74.3914	60.1485	71.9461	40.0002	23.6161	35.9755	72.9725	58.3068	69.6021
1989	35.1720	25.0514	44.4016	68.9218	65.7223	92.0544	35.1642	24.5879	43.7077	68.3394	63.8759	88.9072
1990	27.1445	24.2939	50.8282	58.3235	65.3326	100.5754	27.3705	24.1033	49.9515	58.5798	63.9743	96.8848

Table 89: Estimated population biomass (1,000's t; 1991+).

	22.01						22.03					
	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	3.1870	–	–	3.1919	–	–	3.1843	–	–	3.1894	–	–
1950	8.3991	0.0389	–	8.8633	0.0347	–	8.4097	0.0398	–	8.8321	0.0344	–
1951	15.5568	0.8150	0.0286	18.5178	0.5731	0.0255	15.5893	0.8360	0.0292	18.4188	0.5645	0.0252
1952	22.4918	4.2601	0.6199	31.9995	4.4723	0.4398	22.5147	4.3466	0.6351	31.8156	4.4142	0.4325
1953	26.4737	10.1024	3.5851	43.8524	16.8448	3.6017	26.4494	10.2414	3.6561	43.6607	16.6567	3.5468
1954	27.7255	14.4226	10.0544	48.9222	33.0161	14.9067	27.6632	14.5424	10.1982	48.8152	32.7612	14.6998
1955	28.0292	15.8871	17.9782	49.8743	41.1468	34.7639	27.9532	15.9698	18.1536	49.8046	41.0232	34.3574
1956	28.2584	16.1436	24.8723	50.2191	42.5483	54.8754	28.1763	16.2131	25.0367	50.1444	42.4973	54.3785
1957	28.5758	16.2410	30.1227	50.6808	42.7752	70.2925	28.4862	16.3080	30.2643	50.5937	42.7253	69.7530
1958	29.0228	16.3688	34.0501	51.3380	43.0453	81.5787	28.9229	16.4340	34.1694	51.2337	42.9875	80.9800
1959	29.6447	16.5522	37.0278	52.2587	43.4387	89.8735	29.5304	16.6148	37.1265	52.1305	43.3697	89.2100
1960	30.5035	16.8106	39.3493	53.5355	43.9993	96.1445	30.3691	16.8697	39.4287	53.3739	43.9148	95.4107
1961	31.6891	17.1701	41.2437	55.2997	44.7840	101.0479	31.5266	17.2242	41.3044	55.0920	44.6781	100.2433
1962	33.3430	17.6662	42.8972	57.7508	45.8701	104.9638	33.1413	17.7133	42.9390	57.4788	45.7346	104.1031
1963	35.7116	18.3494	44.4739	61.2202	47.3670	108.3640	35.4551	18.3866	44.4950	60.8581	47.1905	107.4555
1964	39.2754	19.2972	46.1312	66.3270	49.4321	111.6588	38.9428	19.3207	46.1282	65.8387	49.1984	110.7033
1965	45.1146	20.6427	48.0444	74.4037	52.3209	115.5324	44.6823	20.6476	48.0116	73.7415	52.0066	114.4928
1966	55.8914	22.6387	50.4354	88.6262	56.4736	120.2229	55.3559	22.6202	50.3656	87.7466	56.0456	119.0603
1967	77.6565	25.8307	53.6517	116.2293	62.8039	126.0645	77.0758	25.7886	53.5349	115.1196	62.2117	124.7230
1968	113.1164	31.5135	58.1962	162.7433	72.8211	121.4345	112.2890	31.4756	58.0412	161.0805	72.0103	119.9218
1969	145.6457	42.7198	65.5272	216.6180	91.7718	118.0646	144.1912	42.7844	65.3601	213.9004	90.6705	116.3684
1970	162.7203	63.4908	78.1931	267.2768	126.3149	106.7180	160.4702	63.7760	78.1874	263.4531	124.9669	105.1139
1971	153.7290	89.7615	96.2856	289.0872	167.2128	81.5473	150.7351	90.0597	96.9783	284.5278	165.7454	80.2680
1972	120.5941	102.4359	120.6489	256.1032	199.6217	83.3619	117.5441	102.0863	122.3653	251.7832	198.4536	82.9994
1973	83.4434	92.1776	162.0053	191.0099	260.0556	172.2239	81.1302	90.5631	163.0711	187.4234	256.9643	171.6824
1974	57.4995	65.4929	185.0683	127.7612	212.1132	293.2283	56.1779	63.7903	184.5219	125.6939	208.1032	290.2144
1975	46.9081	42.9466	181.8438	92.8839	137.9072	340.2314	46.0641	41.9587	180.0562	91.8301	135.2937	334.7128
1976	53.6295	29.2463	164.2844	87.3186	91.6858	324.7927	52.8498	28.8237	162.1161	86.4457	90.5943	318.5447
1977	67.1671	23.4679	141.4757	99.8080	65.6887	267.1161	66.2851	23.2885	139.4871	98.4410	65.3079	261.7225
1978	76.5558	27.4996	120.2039	121.3622	60.2617	195.9124	75.5004	27.3761	118.5932	119.2635	59.6584	191.9595
1979	73.2283	40.3092	107.4988	136.4678	81.6074	152.7333	72.0960	40.1583	106.2402	134.1615	80.1543	149.7497
1980	55.7598	50.7993	106.9827	124.8628	117.2907	135.2357	54.6360	50.5231	106.0211	123.0839	115.2308	132.5357
1981	35.0963	41.1812	84.9626	87.7298	114.4024	100.8444	34.1793	40.8148	84.9043	86.7168	112.3797	97.5939
1982	21.7960	26.7534	68.4948	51.1873	91.4040	97.4099	21.1961	26.2568	68.7067	50.6050	90.1444	93.9216
1983	21.1353	14.5330	51.8756	37.3762	51.6951	89.1603	20.6378	14.1926	52.0491	36.8137	51.0562	85.9176
1984	25.5029	9.4763	36.1726	38.9665	27.9261	68.1133	24.8877	9.3239	36.3080	38.1187	27.5477	65.4709
1985	32.8767	9.3584	24.8289	49.1552	22.1446	44.9872	32.0300	9.2625	24.9776	47.8377	21.7217	43.0533
1986	39.6217	14.4387	25.1149	63.2121	30.2515	48.7309	38.6135	14.2557	25.1308	61.4399	29.5529	46.9468
1987	42.2524	20.5034	29.0430	73.4824	44.2939	57.0444	41.2881	20.1630	28.8938	71.5578	43.0214	55.1797
1988	40.5282	24.1208	36.3666	74.3914	60.1485	71.9461	40.0002	23.6161	35.9755	72.9725	58.3068	69.6021
1989	35.1720	25.0514	44.4016	68.9218	65.7223	92.0544	35.1642	24.5879	43.7077	68.3394	63.8759	88.9072
1990	27.1445	24.2939	50.8282	58.3235	65.3326	100.5754	27.3705	24.1033	49.9515	58.5798	63.9743	96.8848

Table 90: Comparison of estimates of mature biomass-at-mating by sex (in 1000's t) from the base and preferred models (model start to 1980).

	female		male	
year	22.01	22.03	22.01	22.03
1948	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000
1950	0.032	0.033	0.029	0.028
1951	0.695	0.713	0.493	0.485
1952	4.021	4.102	4.036	3.977
1953	11.278	11.443	16.704	16.484
1954	20.165	20.370	38.956	38.527
1955	27.898	28.094	61.493	60.978
1956	33.787	33.960	78.769	78.219
1957	38.193	38.342	91.416	90.808
1958	41.533	41.660	100.711	100.037
1959	44.137	44.243	107.738	106.990
1960	46.261	46.348	113.233	112.410
1961	48.116	48.182	117.621	116.738
1962	49.885	49.928	121.431	120.497
1963	51.744	51.760	125.123	124.139
1964	53.890	53.874	129.464	128.389
1965	56.571	56.515	134.720	133.510
1966	60.179	60.071	141.266	139.860
1967	65.276	65.128	136.078	134.476
1968	73.499	73.341	132.301	130.492
1969	87.706	87.734	119.587	117.871
1970	108.000	108.819	91.381	90.010
1971	135.327	137.306	93.414	93.073
1972	181.715	182.982	192.991	192.519
1973	207.584	207.052	328.587	325.437
1974	203.967	202.041	381.258	375.336
1975	184.272	181.911	363.958	357.206
1976	158.688	156.519	299.326	293.487
1977	134.828	133.074	219.536	215.257
1978	120.577	119.212	171.151	167.924
1979	119.998	118.966	151.543	148.621
1980	106.622	106.301	131.690	127.985

Table 91: Comparison of estimates of mature biomass-at-mating by sex (in 1000's t) from the base and preferred models (1981 to model end).

	female		male	
year	22.01	22.03	22.01	22.03
1981	85.96	86.02	127.20	123.17
1982	65.10	65.17	116.43	112.67
1983	45.39	45.46	88.95	85.86
1984	31.16	31.27	58.75	56.46
1985	28.17	28.20	54.61	52.64
1986	32.58	32.42	63.92	61.88
1987	40.79	40.37	80.62	78.05
1988	49.80	49.04	103.15	99.70
1989	57.01	56.05	112.70	108.64
1990	61.44	60.51	108.61	103.25
1991	61.62	60.99	109.06	103.34
1992	56.83	56.60	96.12	91.82
1993	48.81	48.84	84.55	82.76
1994	39.96	39.90	71.89	71.01
1995	32.04	31.86	58.67	57.62
1996	25.75	25.52	47.58	46.46
1997	21.28	21.09	39.97	38.80
1998	18.54	18.39	35.44	34.45
1999	17.40	17.27	34.35	33.47
2000	17.67	17.55	36.02	35.15
2001	19.10	18.97	40.28	39.34
2002	21.66	21.54	47.12	46.09
2003	25.53	25.40	56.74	55.62
2004	30.49	30.35	69.41	68.14
2005	36.22	36.08	83.56	82.14
2006	41.96	41.83	98.02	96.83
2007	47.32	47.09	111.76	110.62
2008	49.04	48.54	124.06	122.40
2009	45.06	44.35	123.33	121.15
2010	38.72	38.00	108.81	106.60
2011	35.15	34.54	93.29	91.19
2012	38.49	37.99	90.41	88.20
2013	46.47	46.03	105.65	102.98
2014	50.10	49.67	120.43	117.31
2015	46.09	45.68	113.45	110.80
2016	38.71	38.33	100.10	98.13
2017	31.85	31.52	82.01	80.42
2018	26.54	26.24	67.32	65.93
2019	23.43	23.18	57.89	56.64
2020	24.51	24.30	54.53	53.27
2021	29.37	29.16	63.57	62.05

Table 92: Comparison of estimates of recruitment (in millions) from the base and preferred models (model start to 1980)

year	22.01	22.03
1948	539.22	538.23
1949	539.67	538.67
1950	540.72	539.69
1951	542.56	541.48
1952	545.45	544.29
1953	549.74	548.47
1954	555.90	554.48
1955	564.58	562.95
1956	576.65	574.72
1957	593.30	590.96
1958	616.13	613.22
1959	647.47	643.77
1960	691.21	686.39
1961	754.43	748.06
1962	851.03	842.44
1963	1011.75	1000.12
1964	1316.88	1301.75
1965	1976.30	1960.02
1966	3404.07	3392.09
1967	4693.58	4631.45
1968	3019.49	2913.18
1969	1729.61	1675.86
1970	1285.64	1268.95
1971	820.09	813.59
1972	559.43	555.88
1973	770.56	760.81
1974	1342.10	1311.14
1975	2413.03	2386.25
1976	1710.13	1688.15
1977	654.38	629.45
1978	296.08	293.49
1979	287.18	282.52
1980	341.85	335.31

Table 93: Comparison of estimates of recruitment (in millions) from the base and preferred models (1981 to model end).

year	22.01	22.03
1981	296.06	288.18
1982	1008.50	984.35
1983	761.28	734.05
1984	871.74	844.92
1985	878.72	869.34
1986	736.51	739.46
1987	470.62	501.75
1988	220.00	233.14
1989	138.33	114.65
1990	89.16	85.54
1991	92.67	93.32
1992	91.67	90.69
1993	111.81	111.02
1994	182.23	180.19
1995	146.23	143.98
1996	366.18	361.57
1997	134.00	131.99
1998	630.53	625.29
1999	205.34	202.05
2000	929.84	919.06
2001	269.18	270.55
2002	1016.66	1013.63
2003	607.34	576.90
2004	192.78	186.59
2005	118.84	116.96
2006	204.53	201.61
2007	323.72	316.20
2008	1398.84	1377.00
2009	504.30	511.62
2010	243.88	243.52
2011	67.38	66.62
2012	170.75	168.79
2013	99.05	97.73
2014	119.18	117.27
2015	140.65	137.94
2016	849.59	837.58
2017	346.44	342.55
2018	537.85	530.25
2019	68.36	67.13
2020	777.43	767.56
2021	1377.59	1362.49

Table 94: Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (model start to 1980).

year	22.01	22.03
1949	0.00054	0.00055
1950	0.00095	0.00096
1951	0.00158	0.00159
1952	0.00243	0.00244
1953	0.00410	0.00412
1954	0.00647	0.00651
1955	0.00857	0.00861
1956	0.00988	0.00993
1957	0.01026	0.01034
1958	0.01067	0.01075
1959	0.01077	0.01086
1960	0.01092	0.01100
1961	0.01165	0.01166
1962	0.01236	0.01230
1963	0.01305	0.01292
1964	0.01276	0.01264
1965	0.01297	0.01285
1966	0.01385	0.01374
1967	0.04606	0.04597
1968	0.05407	0.05388
1969	0.08708	0.08634
1970	0.15822	0.15671
1971	0.18991	0.18617
1972	0.05734	0.05584
1973	0.03761	0.03758
1974	0.04647	0.04660
1975	0.04070	0.04074
1976	0.06293	0.06297
1977	0.08755	0.08746
1978	0.07219	0.07169
1979	0.07994	0.07895
1980	0.05871	0.05849

Table 95: Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (from 1981 to model end).

year	22.01	22.03
1981	0.0264	0.0262
1982	0.0140	0.0139
1983	0.0059	0.0059
1984	0.0151	0.0151
1985	0.0062	0.0061
1986	0.0080	0.0078
1987	0.0138	0.0137
1988	0.0216	0.0216
1989	0.0569	0.0573
1990	0.0927	0.0979
1991	0.0774	0.0832
1992	0.1050	0.1085
1993	0.0709	0.0687
1994	0.0427	0.0419
1995	0.0315	0.0315
1996	0.0257	0.0258
1997	0.0157	0.0180
1998	0.0117	0.0116
1999	0.0054	0.0055
2000	0.0060	0.0061
2001	0.0072	0.0074
2002	0.0035	0.0035
2003	0.0019	0.0019
2004	0.0028	0.0027
2005	0.0061	0.0060
2006	0.0107	0.0091
2007	0.0107	0.0100
2008	0.0076	0.0076
2009	0.0058	0.0060
2010	0.0027	0.0028
2011	0.0036	0.0039
2012	0.0025	0.0027
2013	0.0085	0.0088
2014	0.0328	0.0348
2015	0.0491	0.0508
2016	0.0055	0.0059
2017	0.0105	0.0108
2018	0.0112	0.0115
2019	0.0030	0.0031
2020	0.0061	0.0062
2021	0.0043	0.0044

Table 96: Comparison of RMSEs from fits to fishery catch data, survey data, and molt increment data.

				all sexes		female					male			
				all		all	immature		mature		all		immature	
category	fleet	catch type	data type	22.01	22.03	22.01	22.01	22.03	22.01	22.03	22.01	22.03	22.01	22.03
fisheries data	GF All	total catch	abundance	0.896	0.893	–	–	–	–	–	–	–	–	–
			biomass	0.654	0.653	–	–	–	–	–	–	–	–	–
	RKF	total catch	abundance	–	0.706	0.939	–	–	–	–	0.671	–	–	–
			biomass	–	0.222	0.568	–	–	–	–	0.343	–	–	–
	SCF	total catch	abundance	–	1.088	2.938	–	–	–	–	1.110	–	–	–
			biomass	–	0.152	1.533	–	–	–	–	1.345	–	–	–
	TCF	retained catch	abundance	–	–	–	–	–	–	–	4.835	5.158	–	–
			biomass	–	–	–	–	–	–	–	0.441	0.381	–	–
		total catch	abundance	–	2.284	3.859	–	–	–	–	1.900	–	–	–
			biomass	–	2.016	3.124	–	–	–	–	2.013	–	–	–
growth data	–	–	molt incr.	–	–	–	0.297	0.301	–	–	–	–	0.526	0.526
surveys data	NMFS F	index catch	abundance	–	–	–	3.133	3.115	2.468	2.463	–	–	–	–
			biomass	–	–	–	2.835	2.814	2.318	2.315	–	–	–	–
	NMFS M	index catch	abundance	–	–	–	–	–	–	–	3.394	3.363	–	–
			biomass	–	–	–	–	–	–	–	2.637	2.624	–	–
	SBS BSFRF F	index catch	abundance	–	–	–	2.014	2.054	1.547	1.525	–	–	–	–
			biomass	–	–	–	1.009	0.981	1.713	1.690	–	–	–	–
	SBS BSFRF M	index catch	abundance	–	–	–	–	–	–	–	1.780	1.793	–	–
			biomass	–	–	–	–	–	–	–	1.585	1.558	–	–

Figures

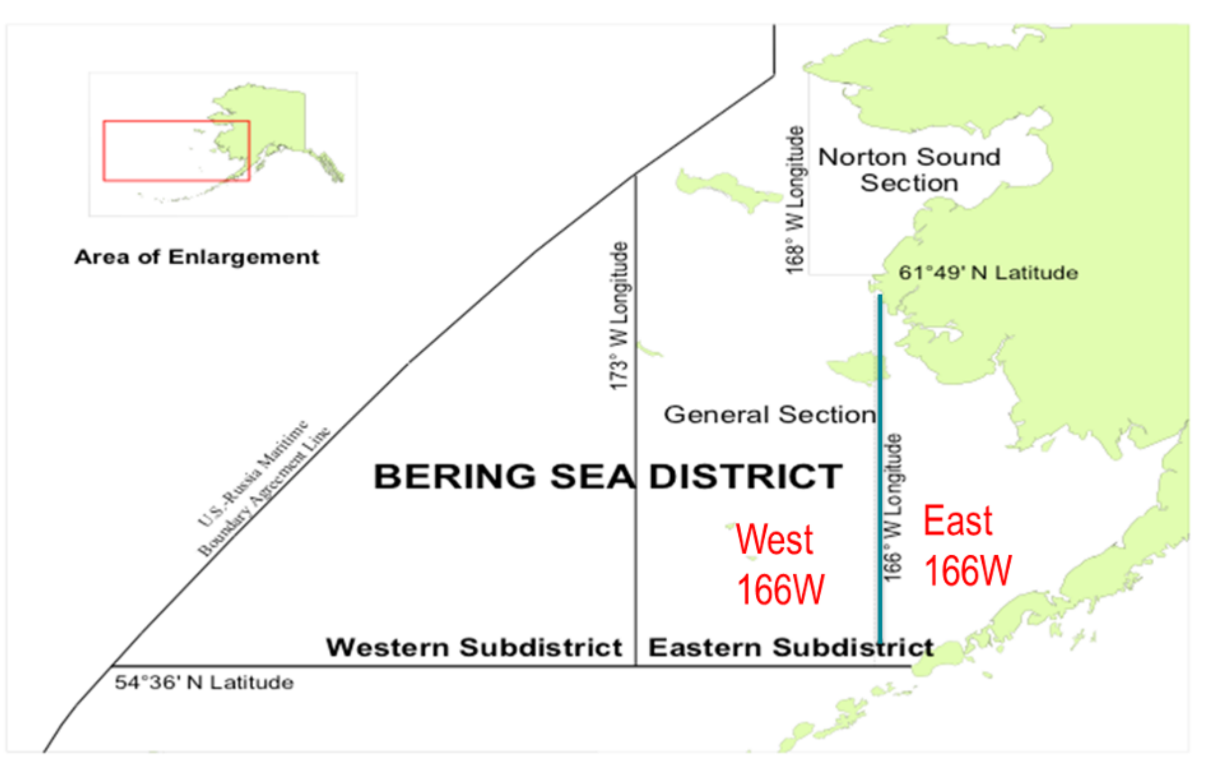

Figure 1: Eastern Bering Sea District of Tanner crab Registration Area J including sub-districts and sections (from Bowers et al. 2008).

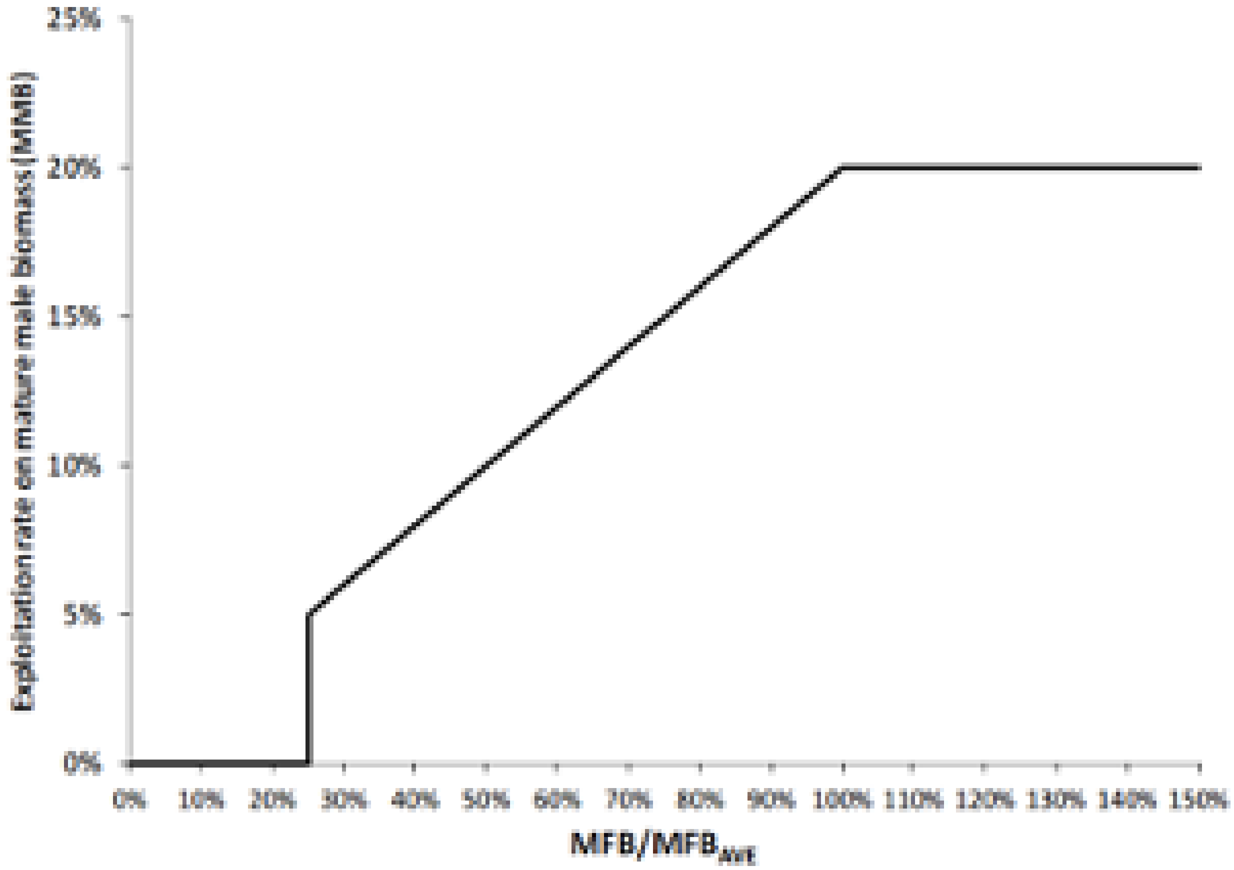

Figure 2: Sloping control rule used by ADFG from 2011 to 2019 as part of its TAC setting process to determine the maximum exploitation rate on mature male biomass as a function of the ratio of current mature female biomass (MFB) to MFB averaged over some time period.

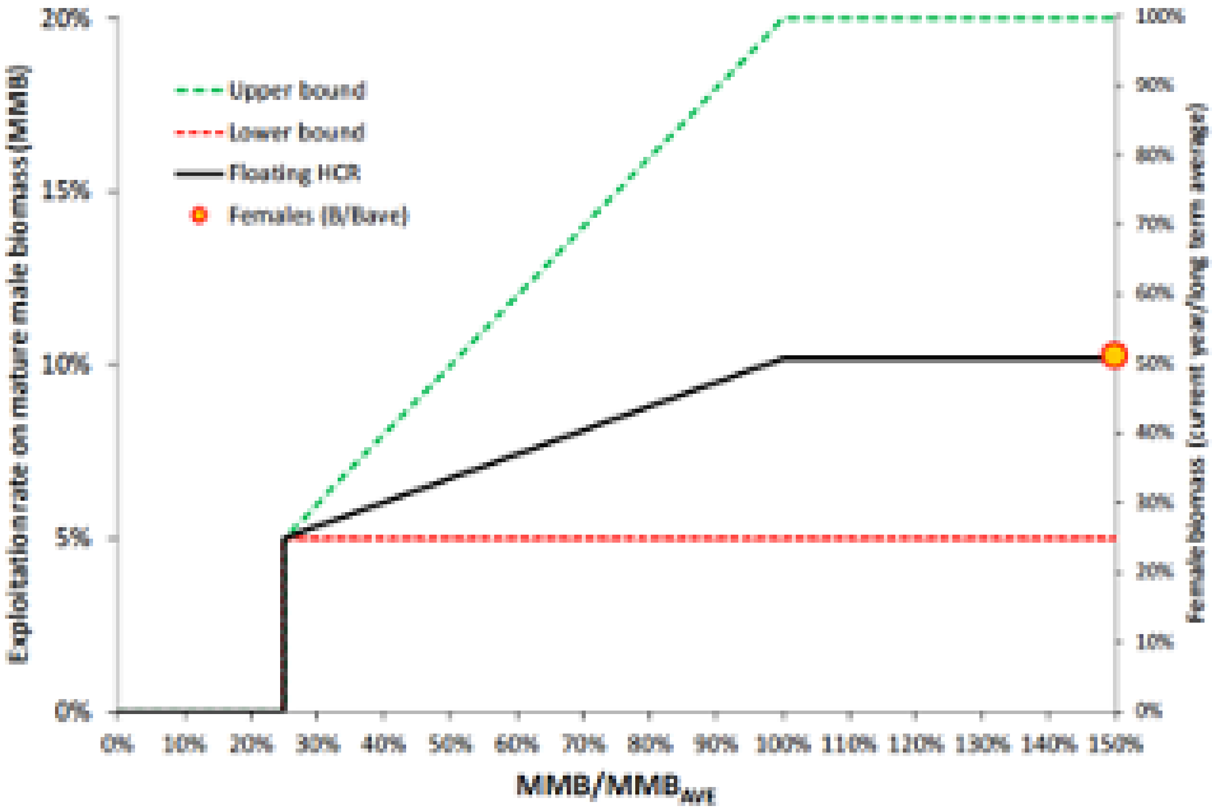

Figure 3: Current ADFG "floating" sloping control rule to determine the maximum exploitation rate on mature male biomass (MMB) as a function of the ratio of current MMB to the average MMB over 1982-2018. The ratio of current mature female biomass (MFB) to MFB averaged over 1982-2018 is used to determine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

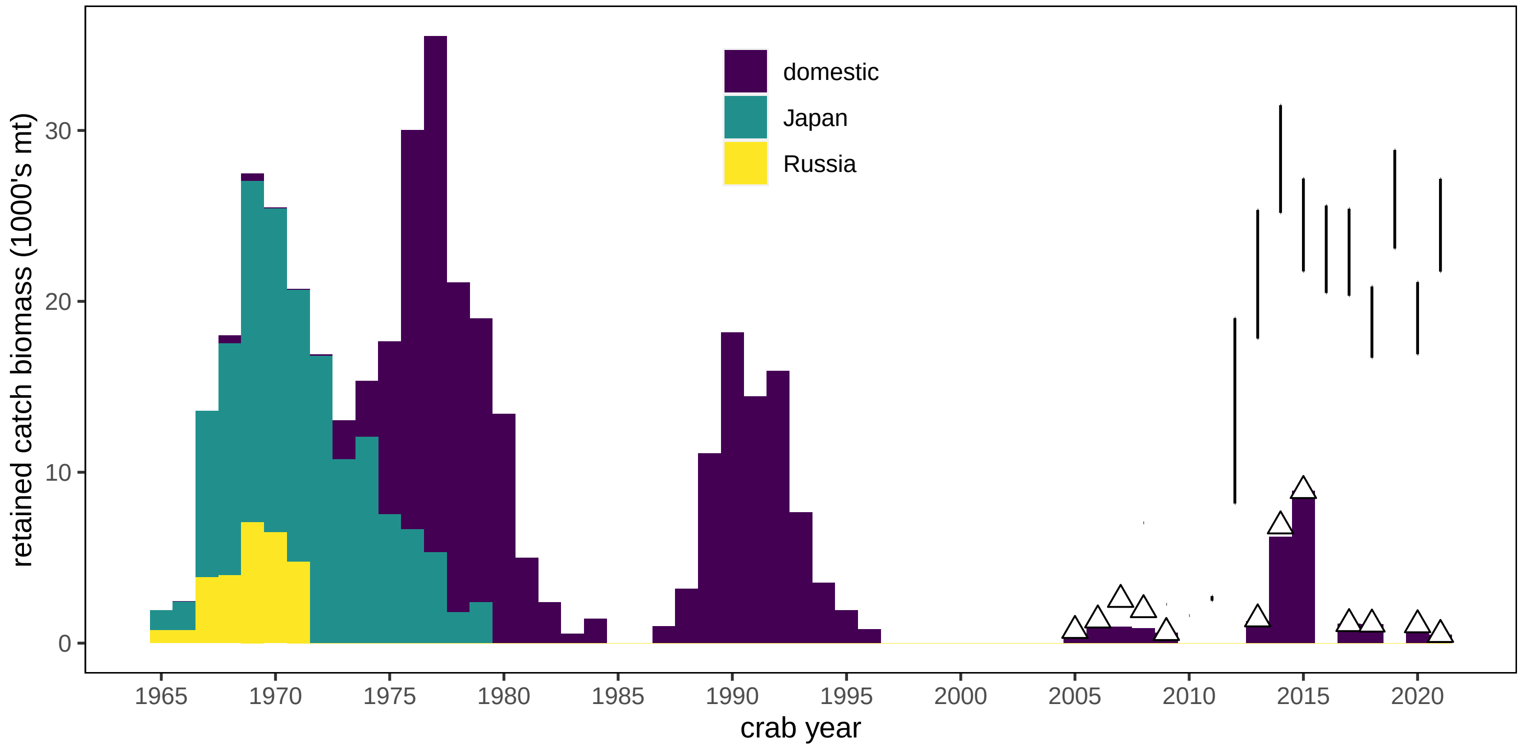

Figure 4: Total retained catch (males, 1000's t) in the directed fisheries (foreign [1965-1979] and domestic [1968-]) for Tanner crab. The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12); the triangles indicate the TAC (values start in 2005/06, following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

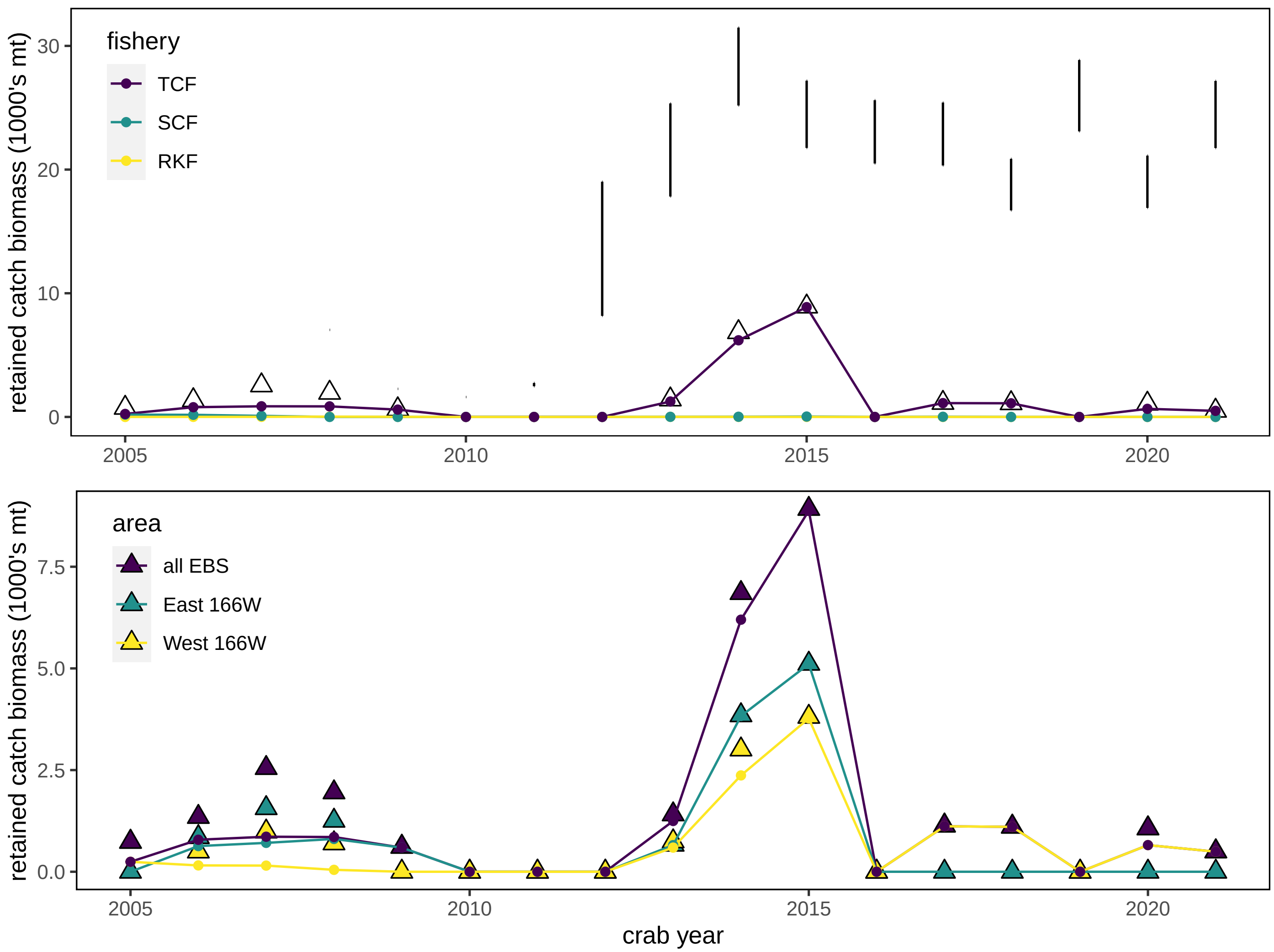

Figure 5: Upper plot: time series of (male-only) retained catch biomass (1000's t) in the directed Tanner crab (TCF), snow crab (SCF), and BBRKC (RKF) fisheries since 2005. The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12); the triangles indicate the total (area-combined) TAC. Legal-sized Tanner crab can be incidentally-retained in the snow crab and BBRKC fisheries up to a cap of 5 percent of the target catch. Lower plot: retained catch biomass (1000's t) by SOA management area. 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, 2021/22.

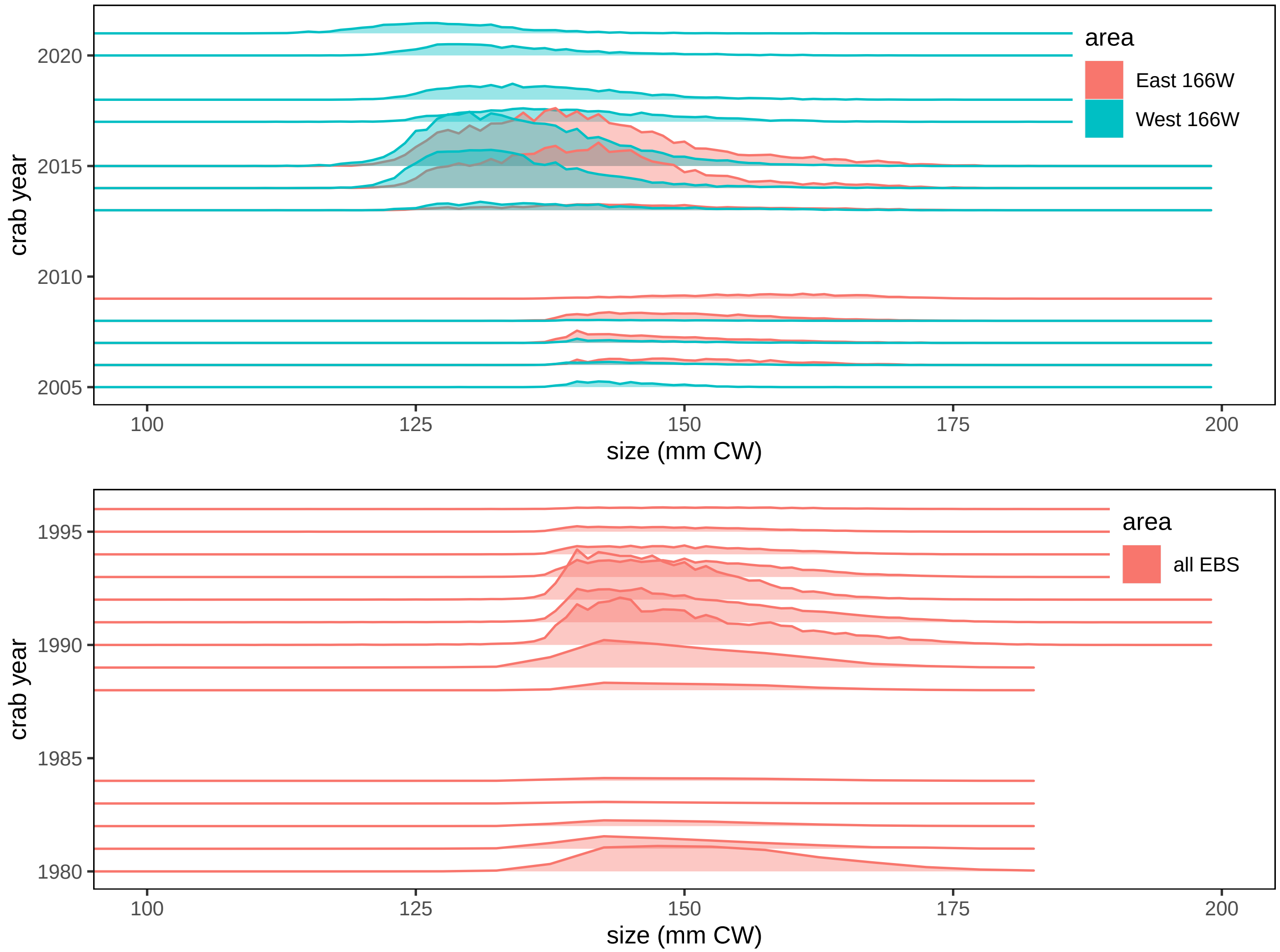

Figure 6: Upper plot: retained catch size compositions in the directed fishery by State management area since rationalization (2005). Lower plot: retained catch size compositions in the directed fishery prior to rationalization (aggregated across management areas). The directed fishery was closed from 1996/97 to 2004/05. The relative height of each size composition reflects retained catch abundance for the associated crab fishery year relative to others within the same plot, but scales differ between the two plots.

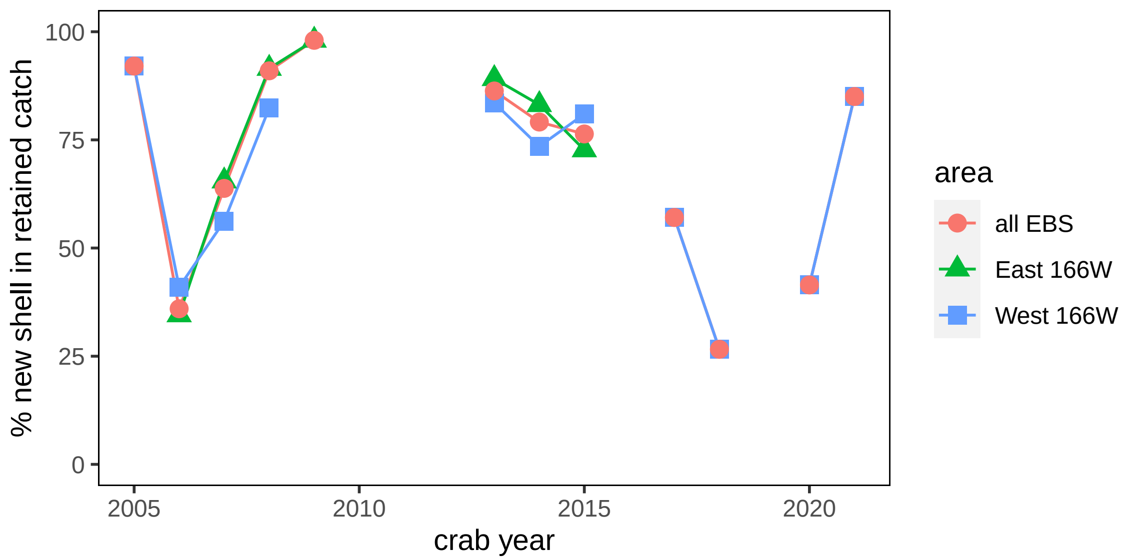

Figure 7: The fraction of new shell males to all males in the retained catch for the directed fishery.

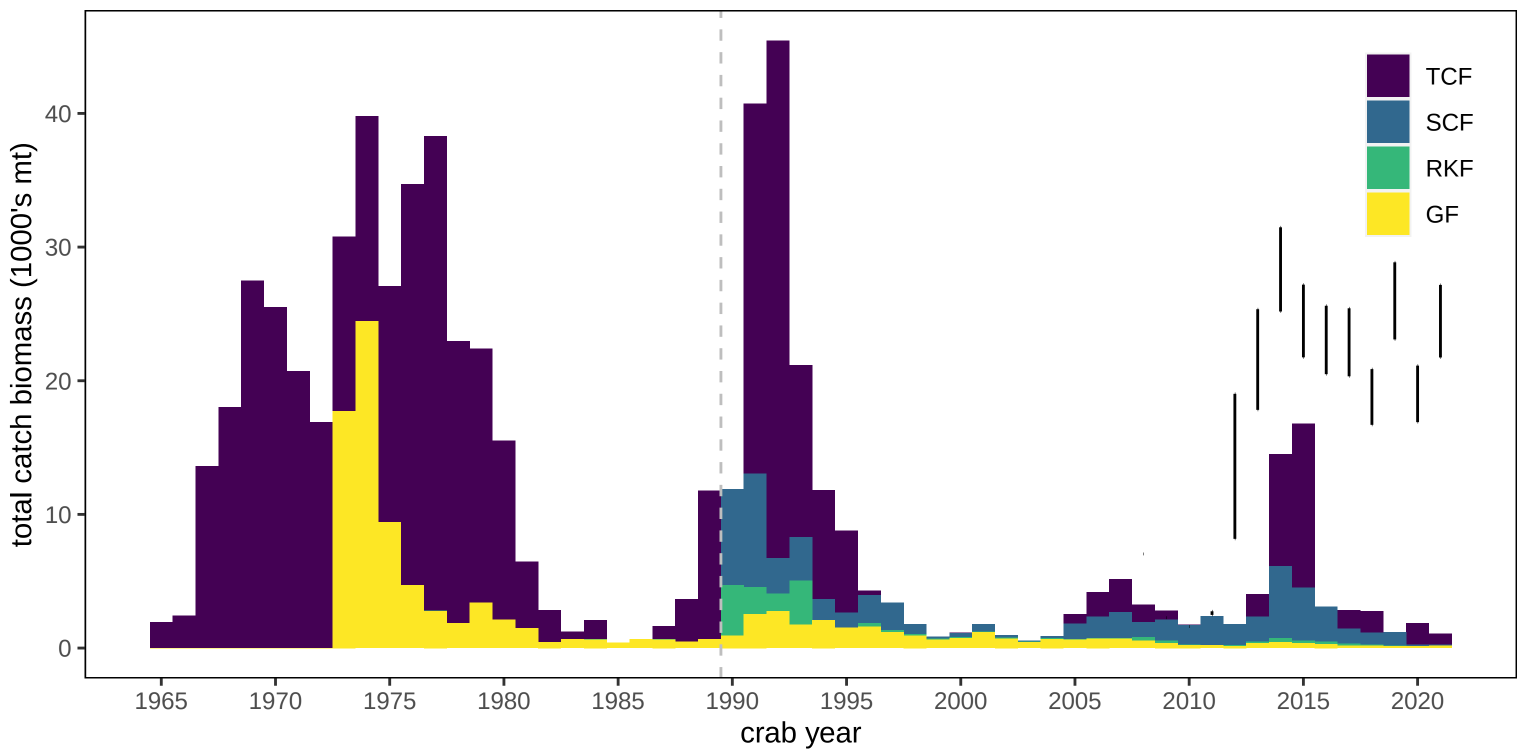

Figure 8: Total catch (retained + discards) estimates for Tanner crab (males and females combined, 1,000's t) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12). Bycatch reporting began in 1973 for the groundfish fisheries and in the 1990/91 for the crab fisheries. **Discard mortality has not been applied to this data (see next figure).**

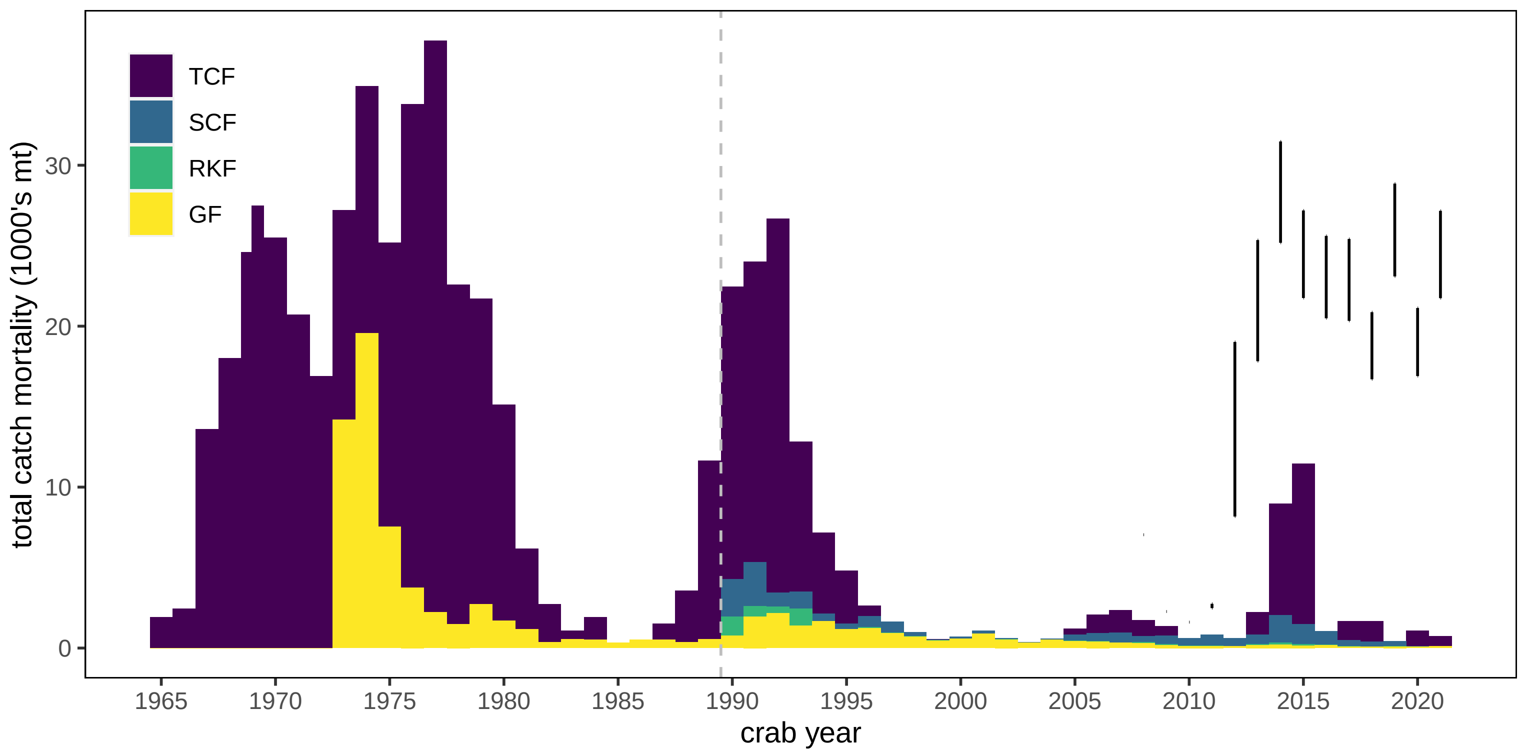

Figure 9: Total catch (retained + discards) estimates for Tanner crab (males and females combined, 1,000's t) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12). Bycatch reporting began in 1973 for the groundfish fisheries and in the 1990/91 for the crab fisheries. Assumed discard mortality rates were applied to discards by gear type (0.321: crab pots and fixed gear in the groundfish fisheries; 0.800: trawl gear in the groundfish fisheries) to estimate total catch mortality. For the directed fishery ("TCF"), annual "discard" mortality was estimated by subtracting the retained catch biomass from the total catch to estimate discards prior to applying handling mortality.

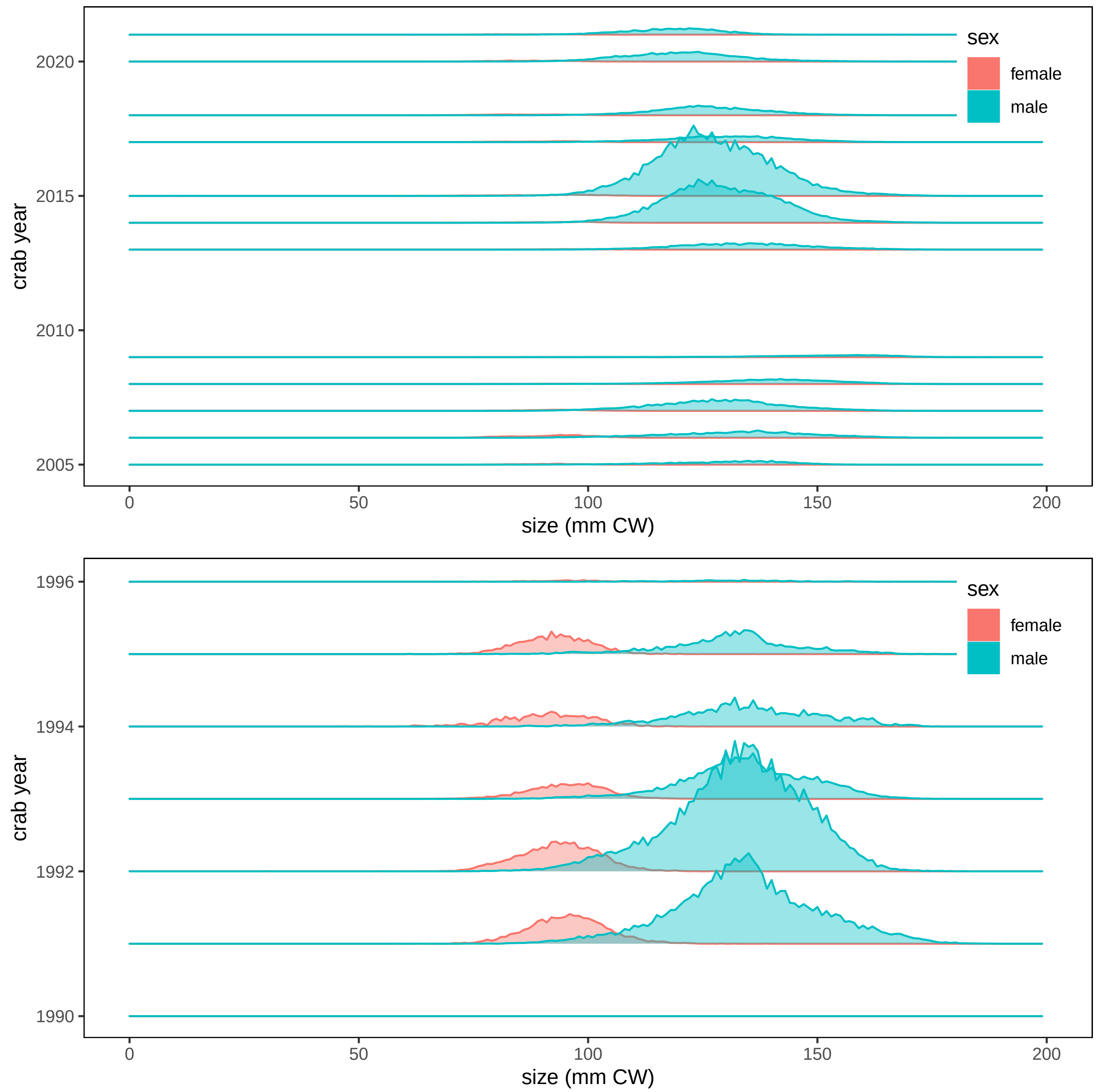

Figure 10: Total catch size compositions in the directed fishery by sex (aggregated over State management area). Data starts in 1991. Upper plot: since rationalization (2005). Lower plot: total catch size compositions in the directed fishery prior to rationalization (aggregated across management areas). The directed fishery was closed from 1996/97 to 2004/05. The relative height of each size composition reflects total catch abundance by sex for the associated crab fishery year relative to others within the same plot, but scales differ between the two plots.

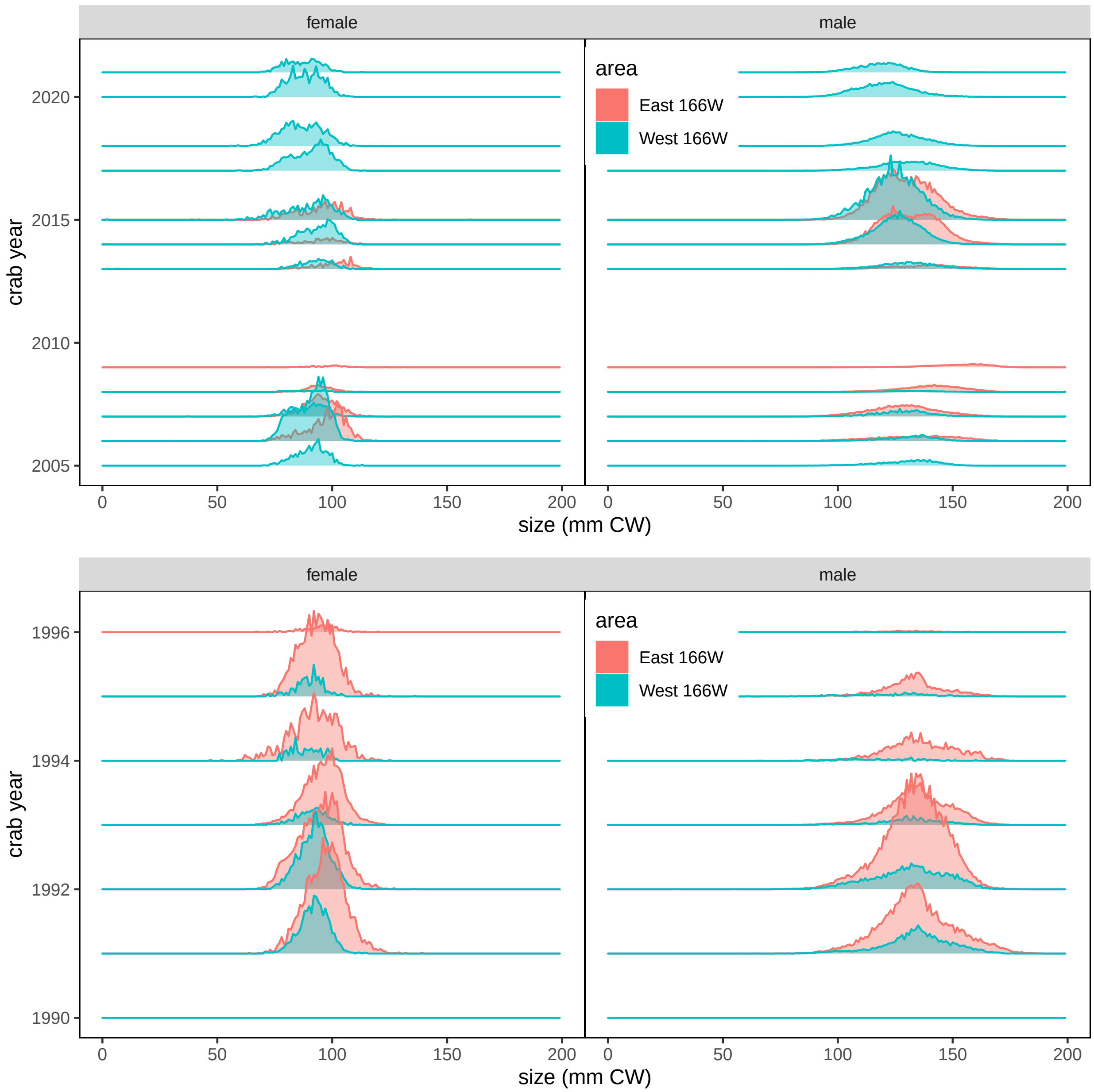

Figure 11: Total catch size compositions in the directed fishery by sex and State management area. Data starts in 1991. Upper plot: since rationalization (2005). Lower plot: total catch size compositions in the directed fishery prior to rationalization (aggregated across management areas). The directed fishery was closed from 1996/97 to 2004/05. The relative height of each size composition reflects total catch abundance by sex for the associated crab fishery year relative to others within the same plot, but scales differ between the two plots.

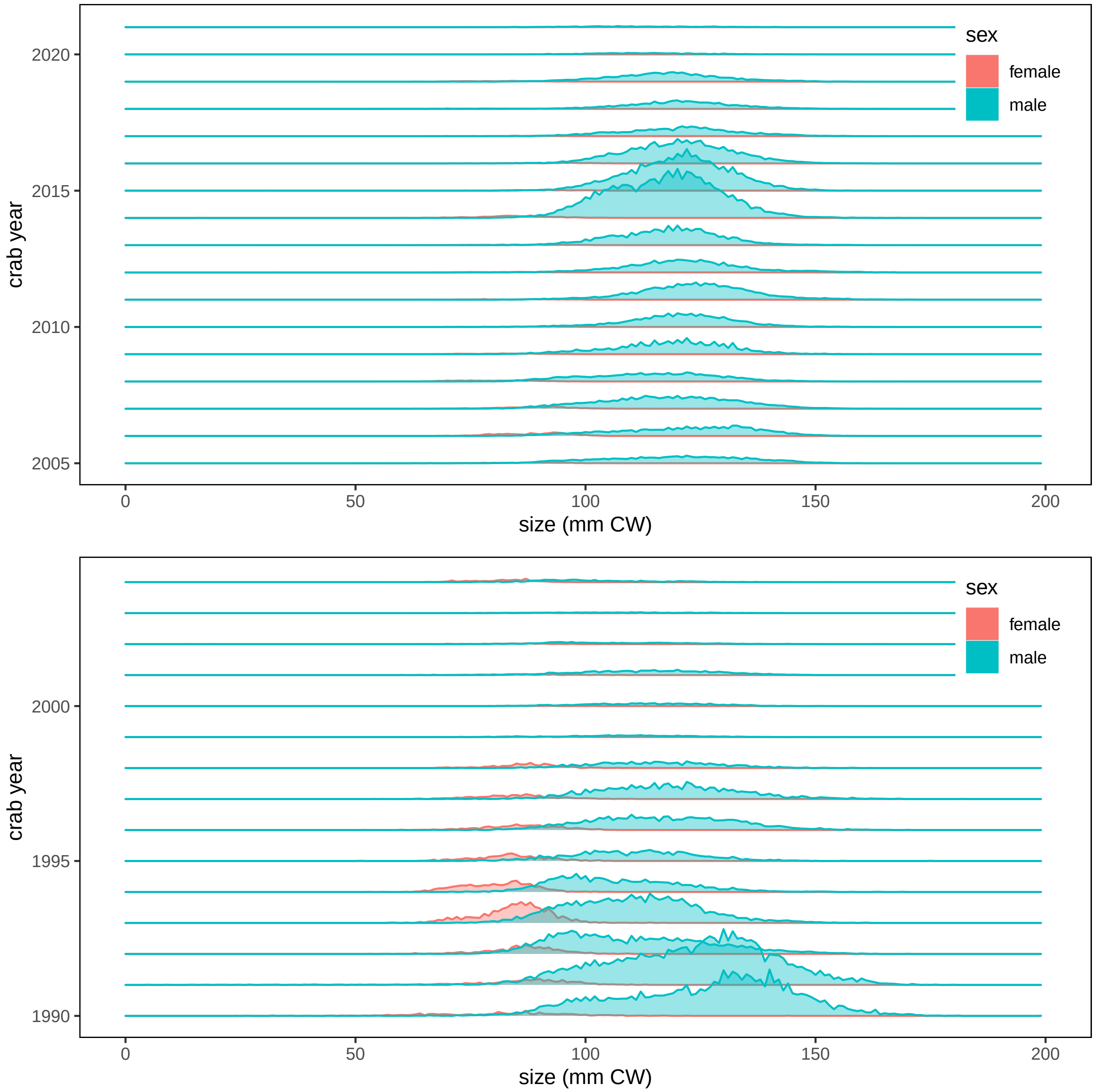

Figure 12: Total bycatch size compositions in the snow crab fishery by sex (1990+). Data starts in 1990. Upper plots: since rationalization (2005). Lower plot: prior to rationalization. The relative height of each size composition reflects total bycatch abundance by sex for the associated crab fishery year relative to others within the same plot, but scales differ between the plots to better show details within a plot.

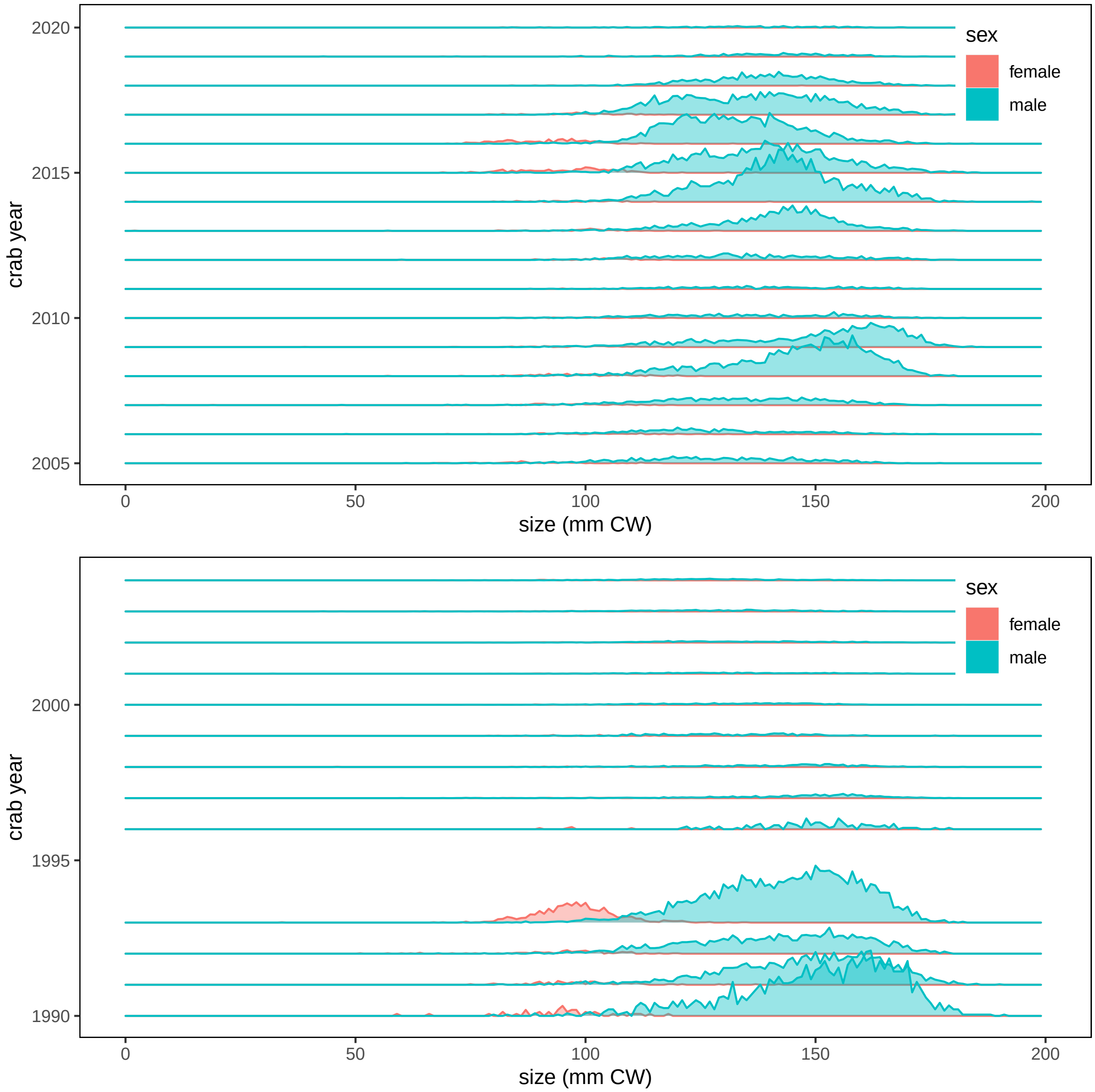

Figure 13: Total bycatch size compositions in the BBRKC fishery by sex (1990+). Data starts in 1990. Upper plots: since rationalization (2005). Lower plot: prior to rationalization. The BBRKC fishery was closed in19964/95 and 1995/96.The relative height of each size composition reflects total bycatch abundance by sex for the associated crab fishery year relative to others within the same plot, but scales differ between the plots to better show details within a plot.

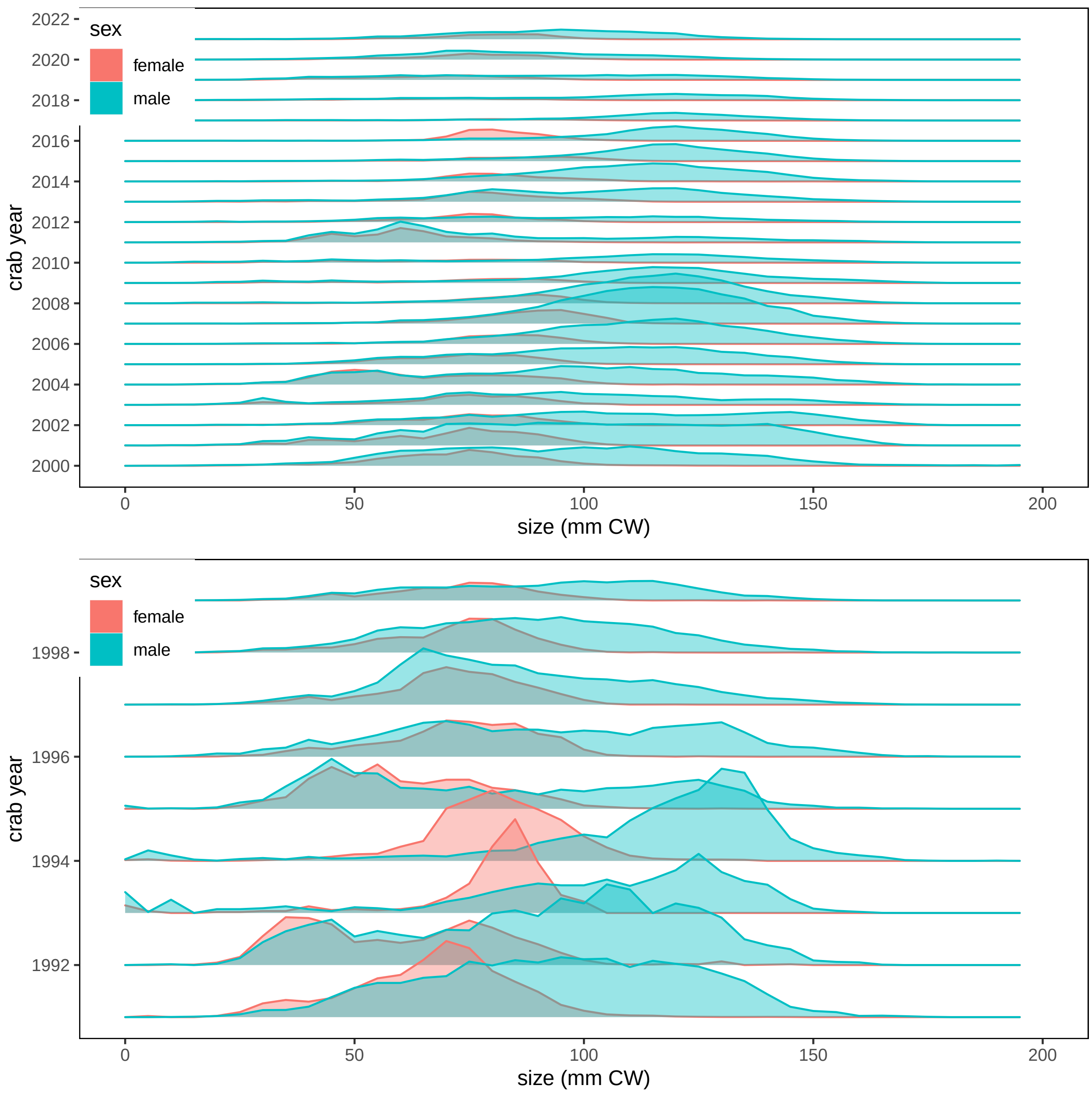

Figure 14: Total bycatch size compositions in the groundfish fisheries by sex, since 1991. Upper plots: since 2000/01. Lower plot: prior to 2000/01. The relative height of each size composition reflects total catch abundance by sex for the associated crab fishery year relative to others within the same plot panel, but scales differ between the panels to better show details within a panel.

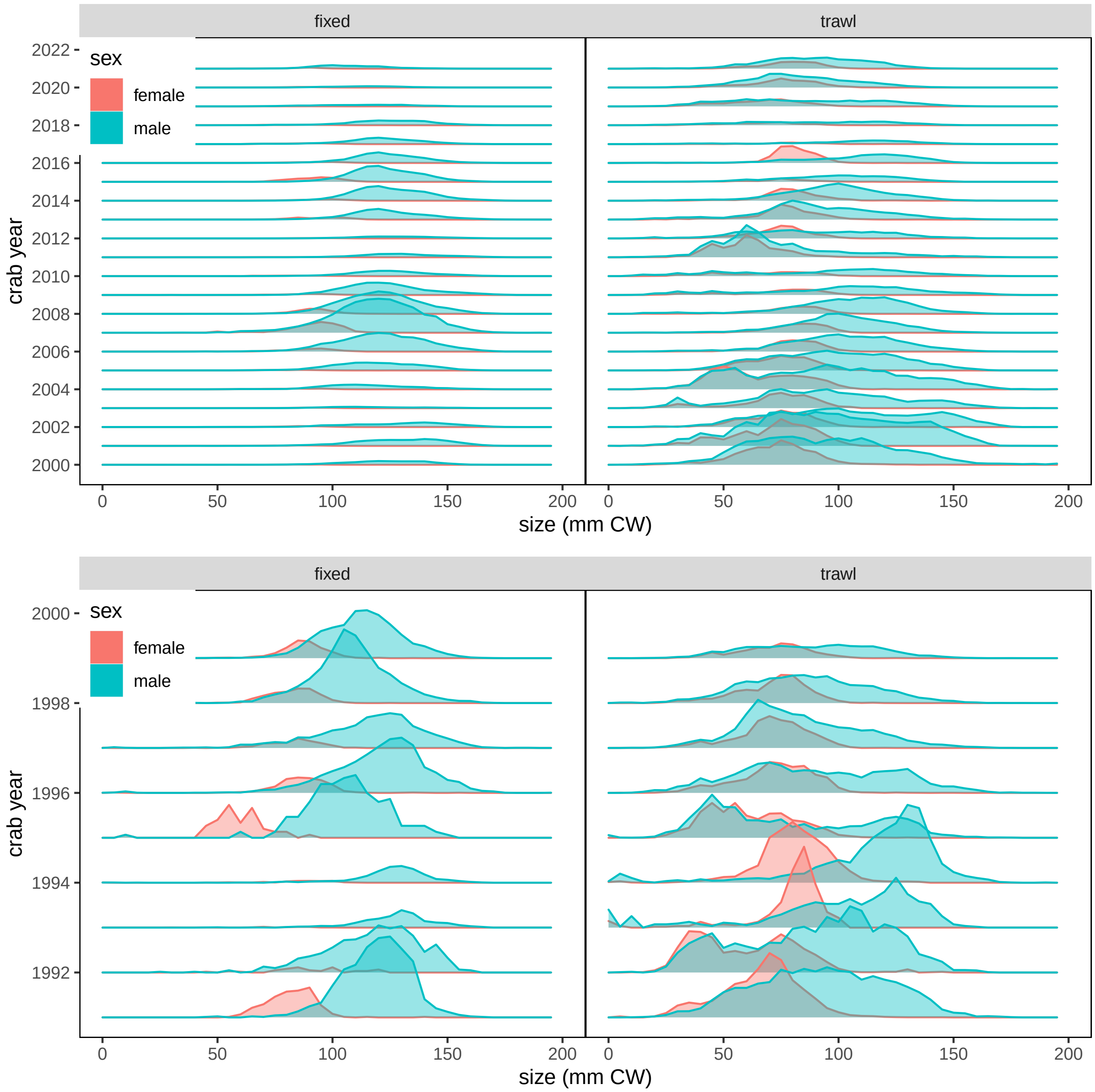

Figure 15: Total bycatch size compositions in the groundfish fisheries by sex and gear type, since 1991. Upper plots: since rationalization (2005). Lower plot: prior to rationalization. The relative height of each size composition reflects total catch abundance by sex for the associated crab fishery year relative to others within the same plot panel, but scales differ between the panels to better show details within a panel.

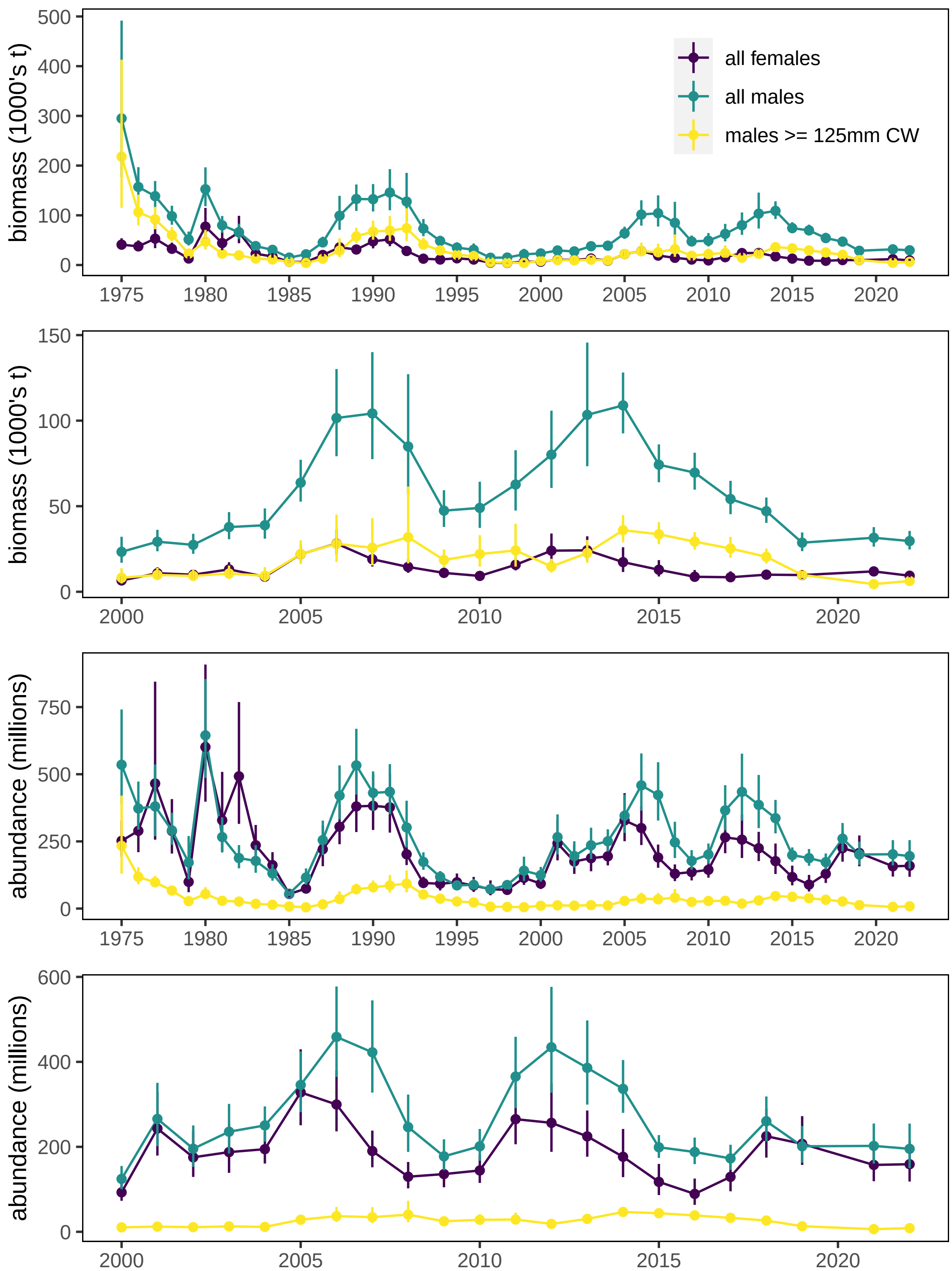

Figure 16: Annual estimates of area-swept biomass (upper plots) and abundance (lower plots) from the NMFS EBS bottom trawl survey by sex. The lower plot in each pair shows the trends since 2000. The biomass/abundance trends for industry-preferred size males (> 125 mm CW) are also shown.

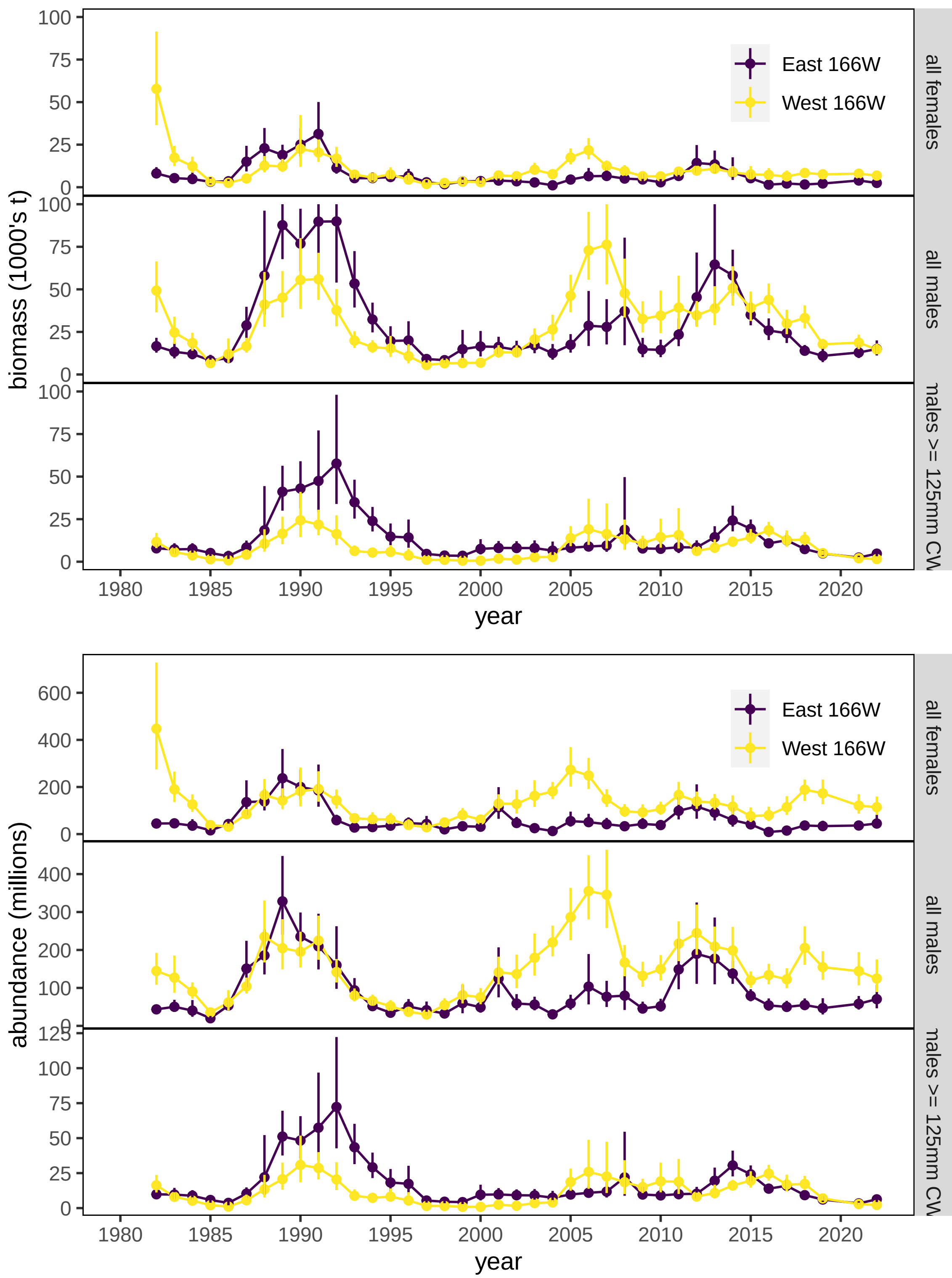

Figure 17: Annual estimates of area-swept biomass (upper plots) and abundance (lower plots) from the NMFS EBS bottom trawl survey by State management area, sex, and maturity state (for females). The biomass/abundance trends for industry-preferred size males are also shown.

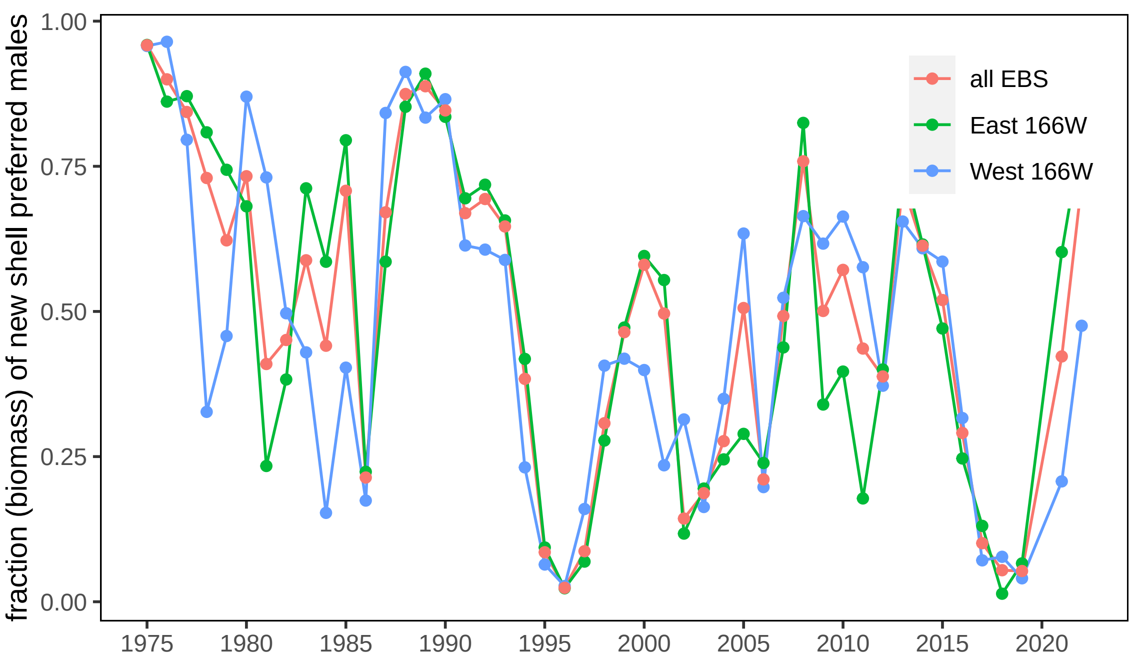

Figure 18: Annual estimates of the fraction of preferred male (>= 125 mm CW) new shell biomass, by area (SOA management areas and total).

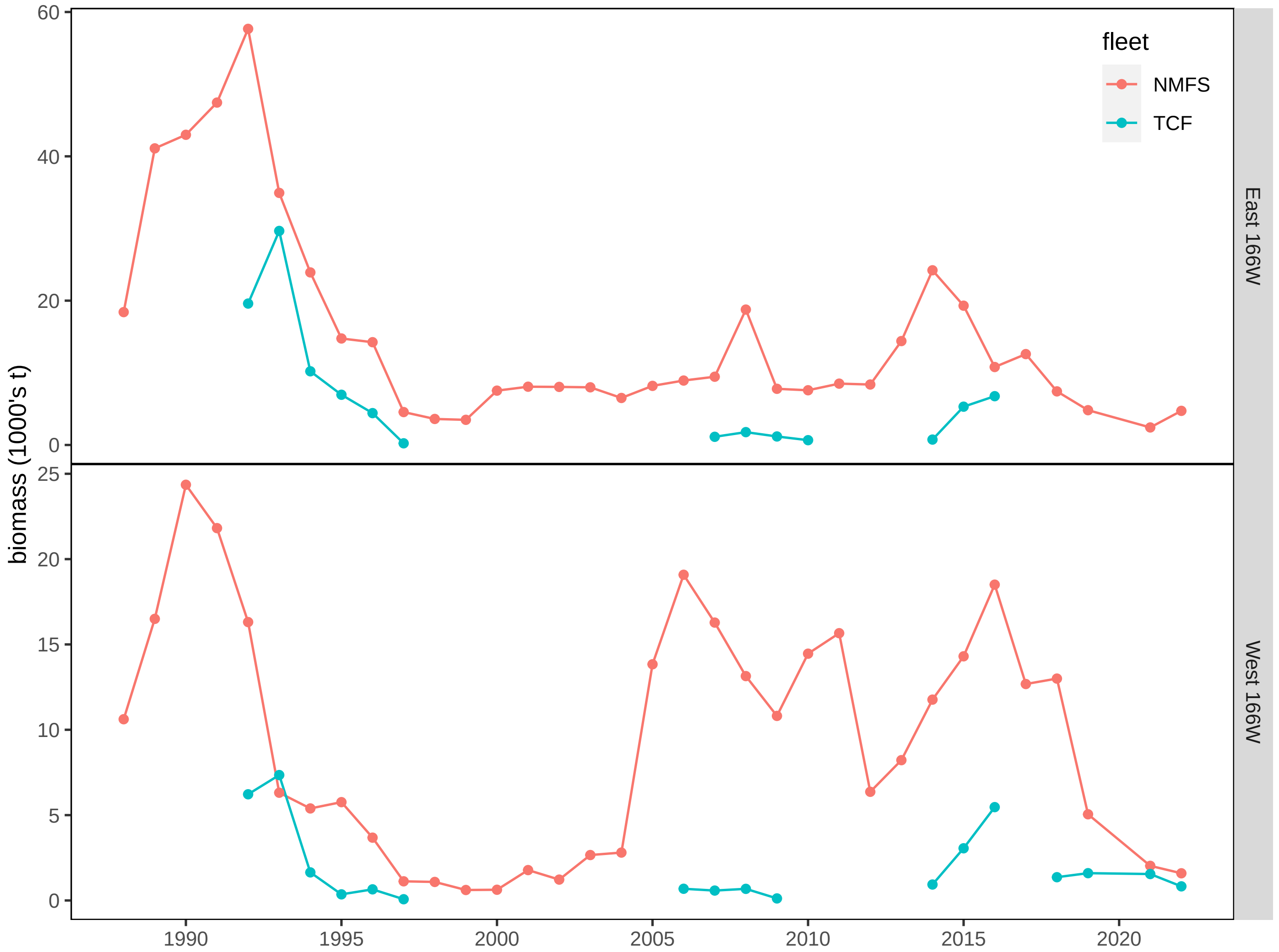

Figure 19: Comparison of preferred male (>= 125 mm CW) biomass estimated in the NMFS EBS survey and total catch biomass taken in the directed fishery, by SOA management areas. Survey timing corresponds to the end of the fishery year.

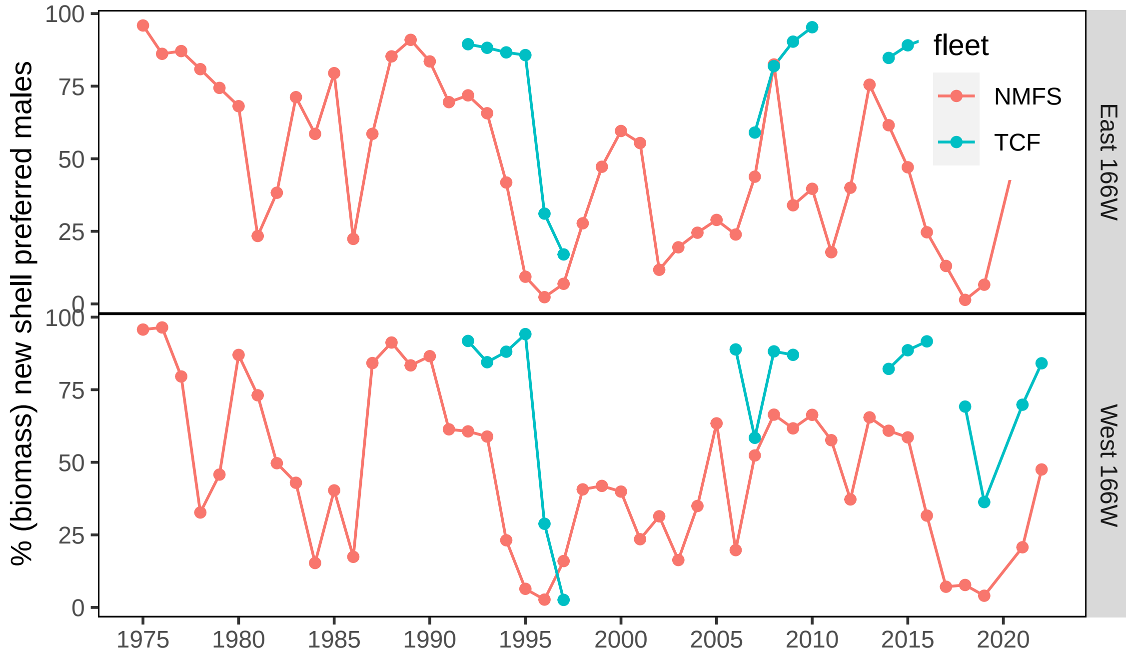

Figure 20: Comparison of the fraction of new shell preferred male (>= 125 mm CW) biomass in the NMFS EBS survey with that caught in the directed fishery, by SOA management area. Survey timing corresponds to the end of the fishery year.

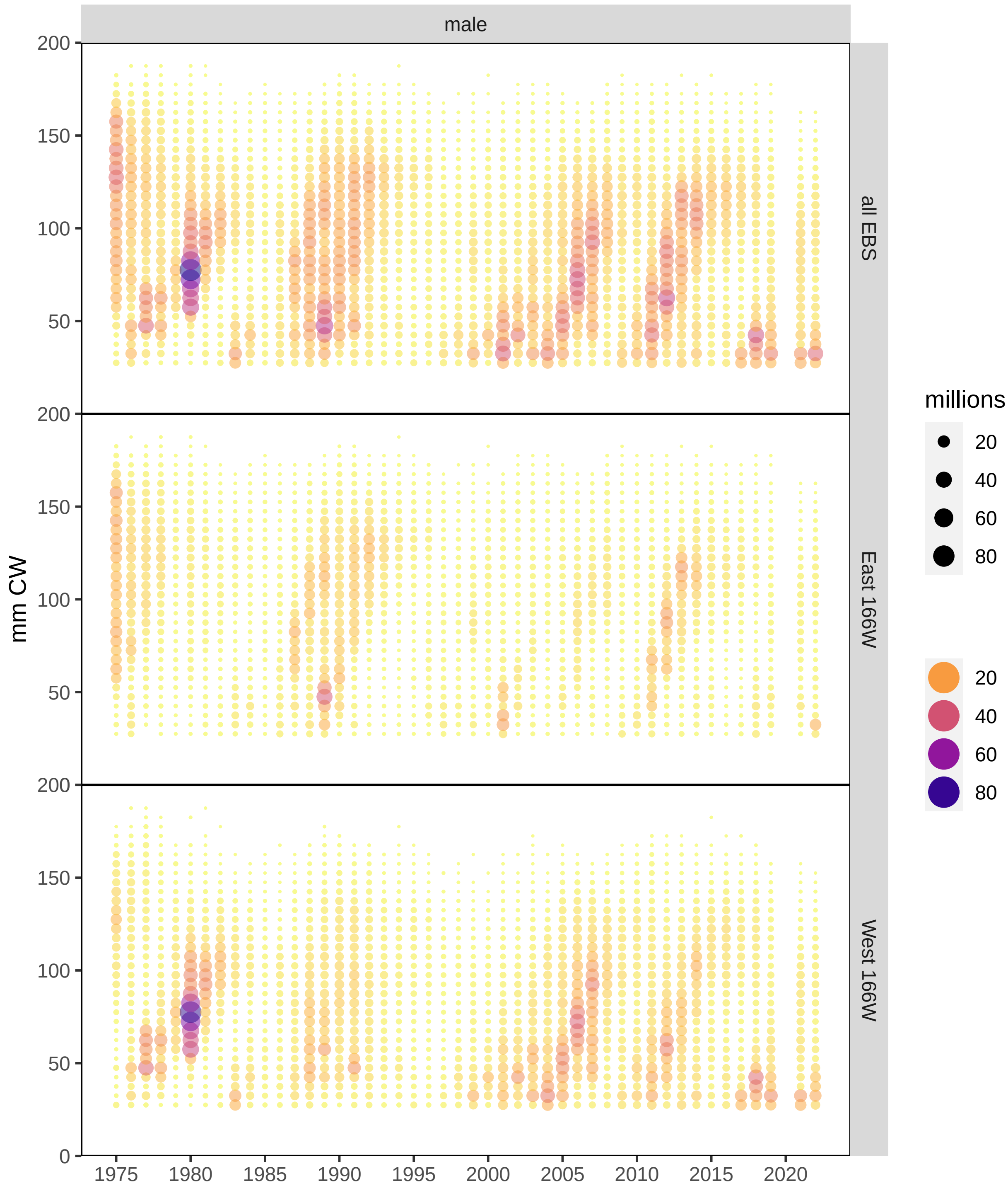

Figure 21: Annual size compositions, by 5-mm CW bin, from the NMFS EBS bottom trawl survey for males by State management area for 1975-2022 as a bubble plot. The size compositions are truncated for crab < 25 mm CW. The assessment model aggregates crab > 185 mm CW into the 180-185 mm CW bin.

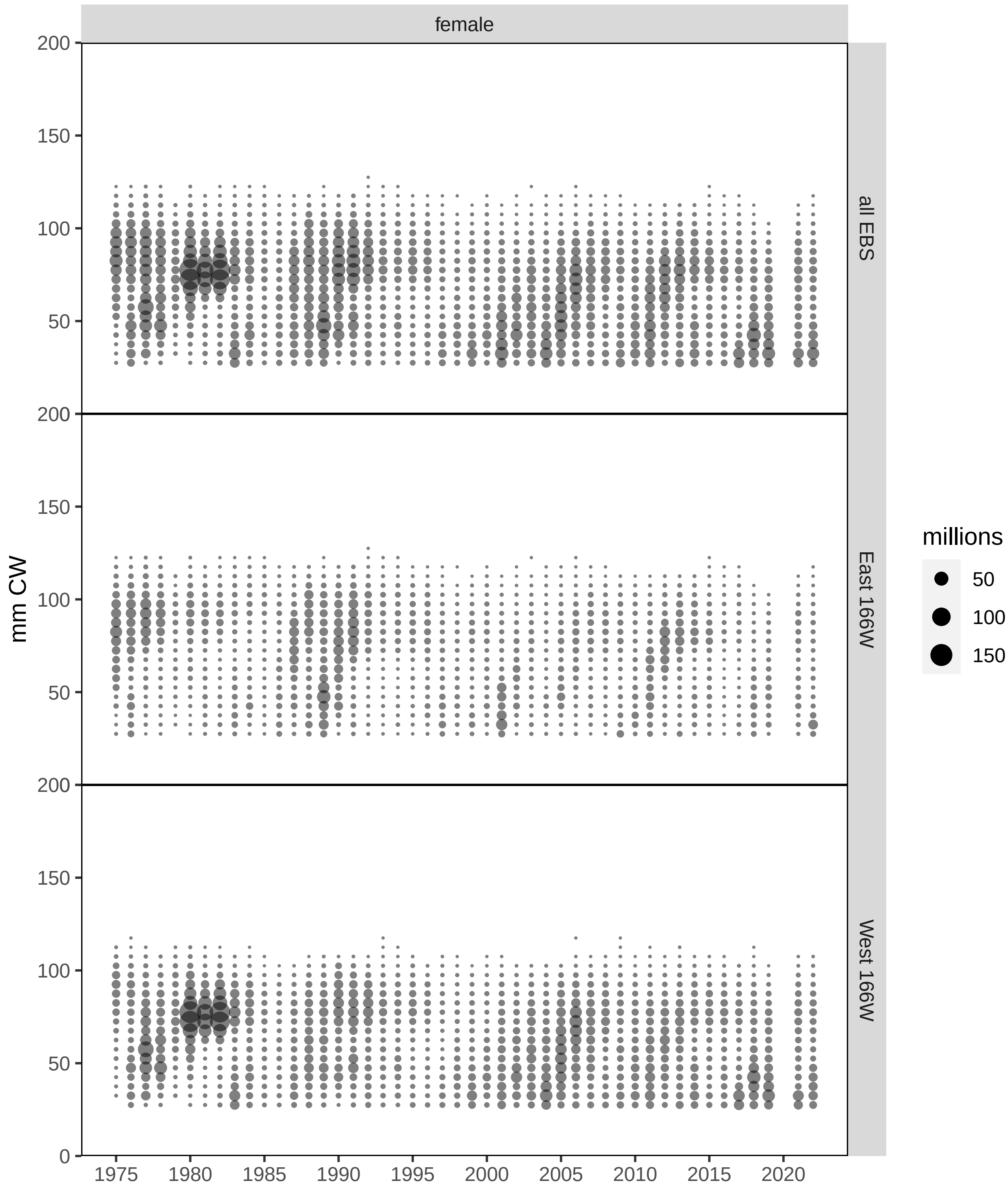

Figure 22: Annual size compositions, by 5-mm CW bin, from the NMFS EBS bottom trawl survey for females by State management area for 1975-2022 as a bubble plot. The size compositions are truncated for crab < 25 mm CW. The assessment model aggregates crab > 185 mm CW into the 180-185 mm CW bin.

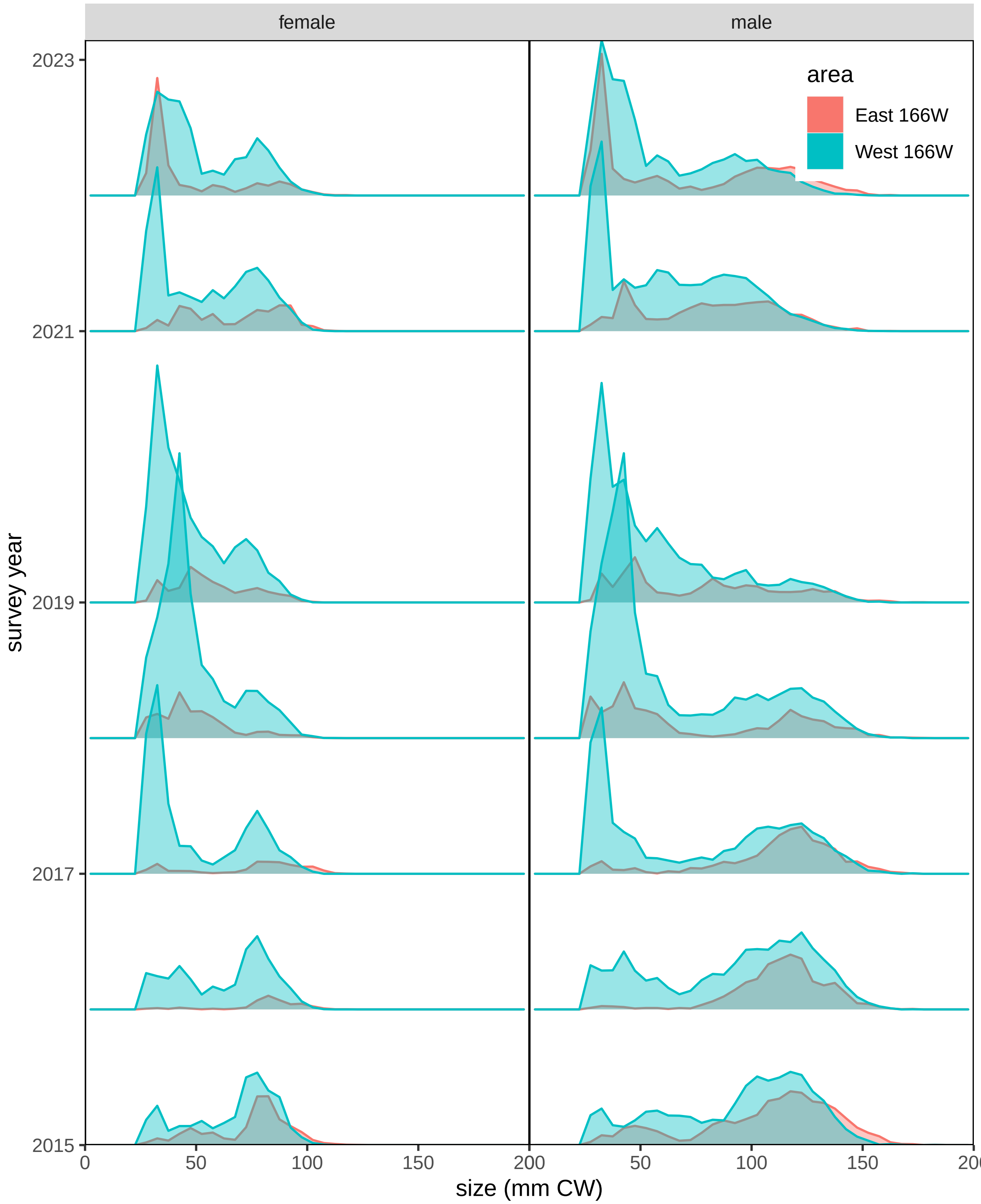

Figure 23: Recent annual size compositions, by 5-mm CW bin, from the NMFS EBS bottom trawl survey by sex and State management area for 1975-2000. The size compositions are truncated for crab < 25 mm CW. The assessment model aggregates crab > 185 mm CW into the 180-185 mm CW bin.

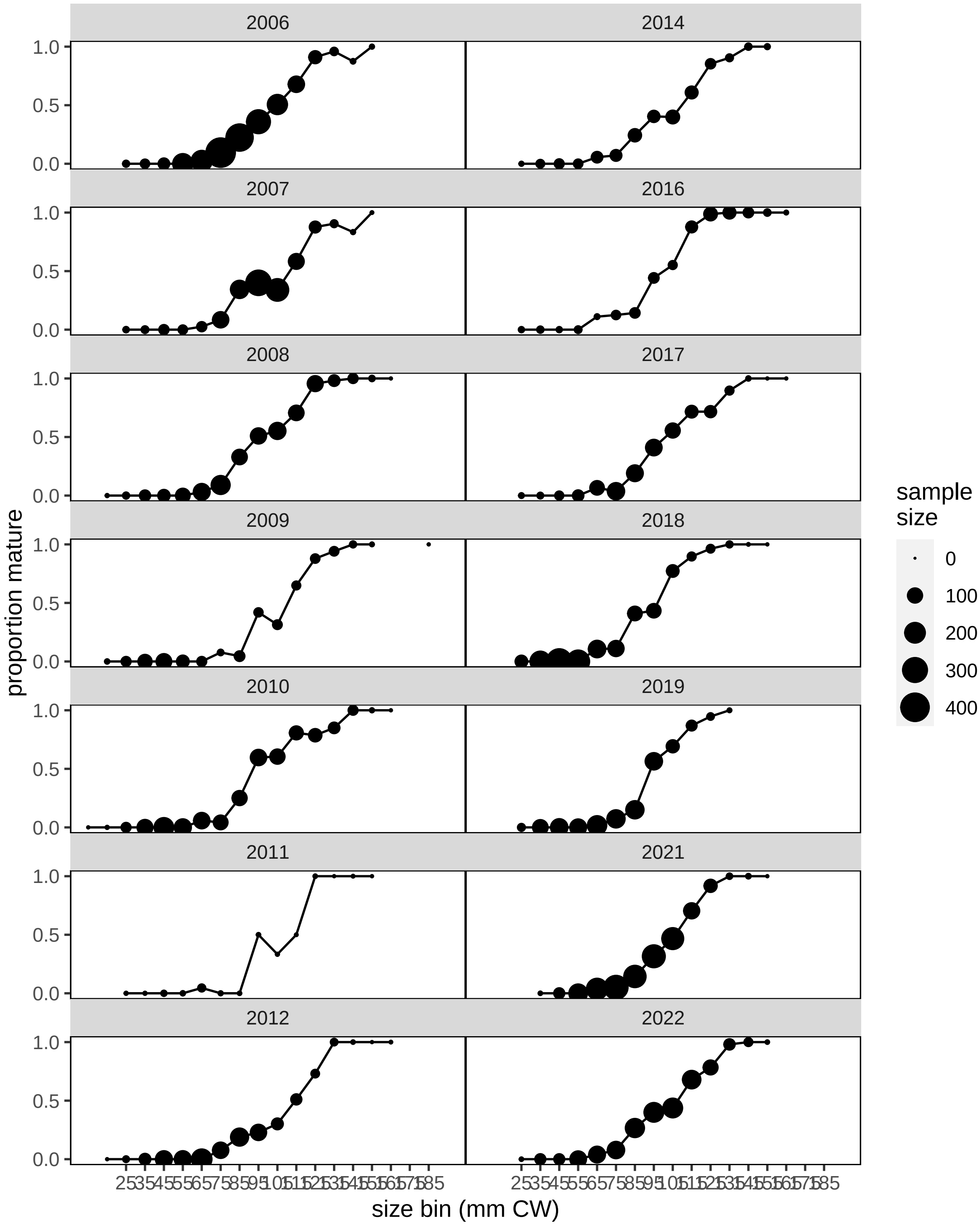

Figure 24: Estimates of the proportion of mature new shell males in the NMFS EBS survey, by 10 mm CW size bin, based on male crab with chela height/carapace width measurements taken. Symbol size (area) indicates the number of crab measured. Chela heights for Tanner crab are not measured every year.

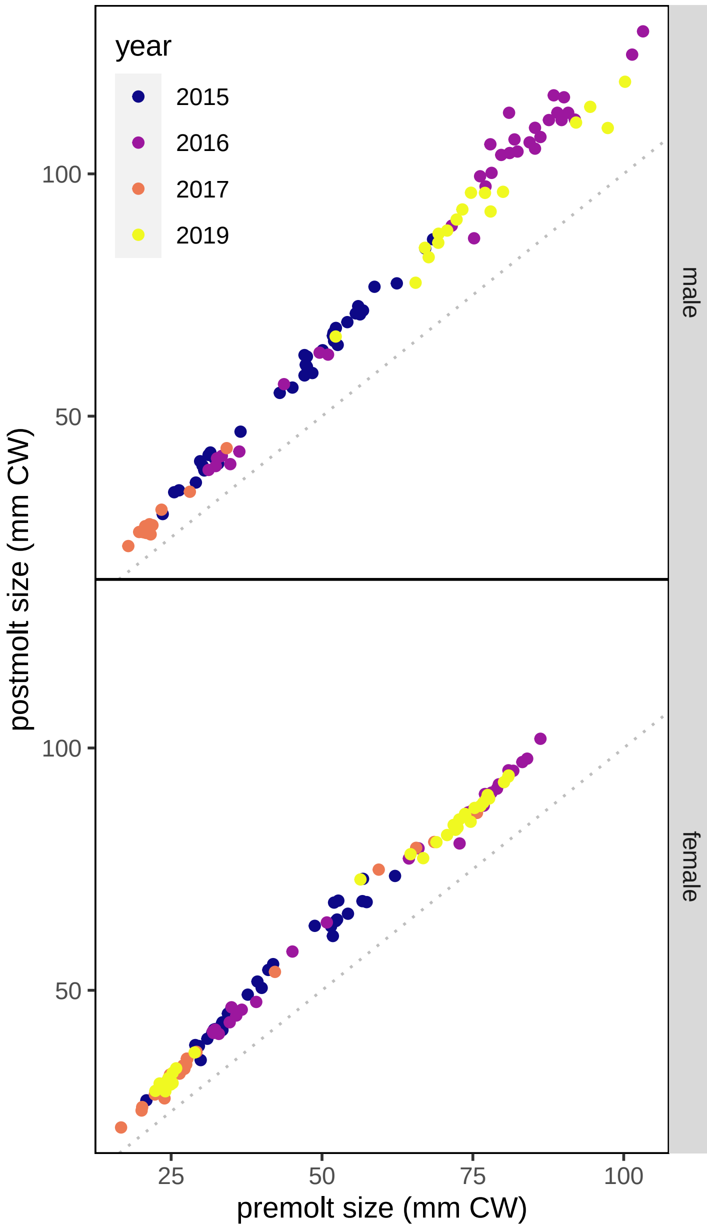

Figure 25: Molt increment data collected collaboratively by NMFS, BSFRF, and ADFG.

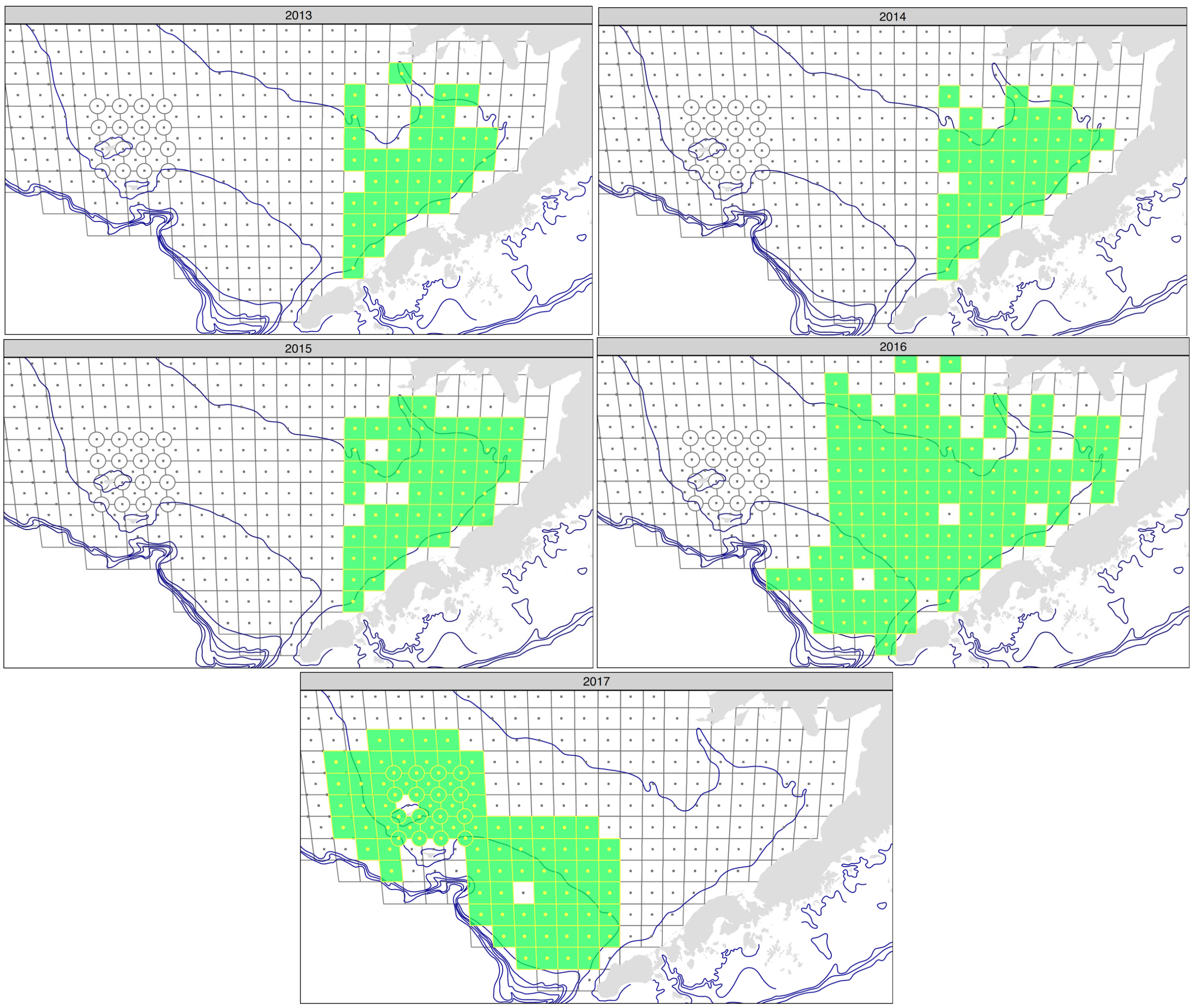

Figure 26: Annual spatial footprints of the BSFRF-NMFS collaborative side-by-side (SBS) catchability studies.

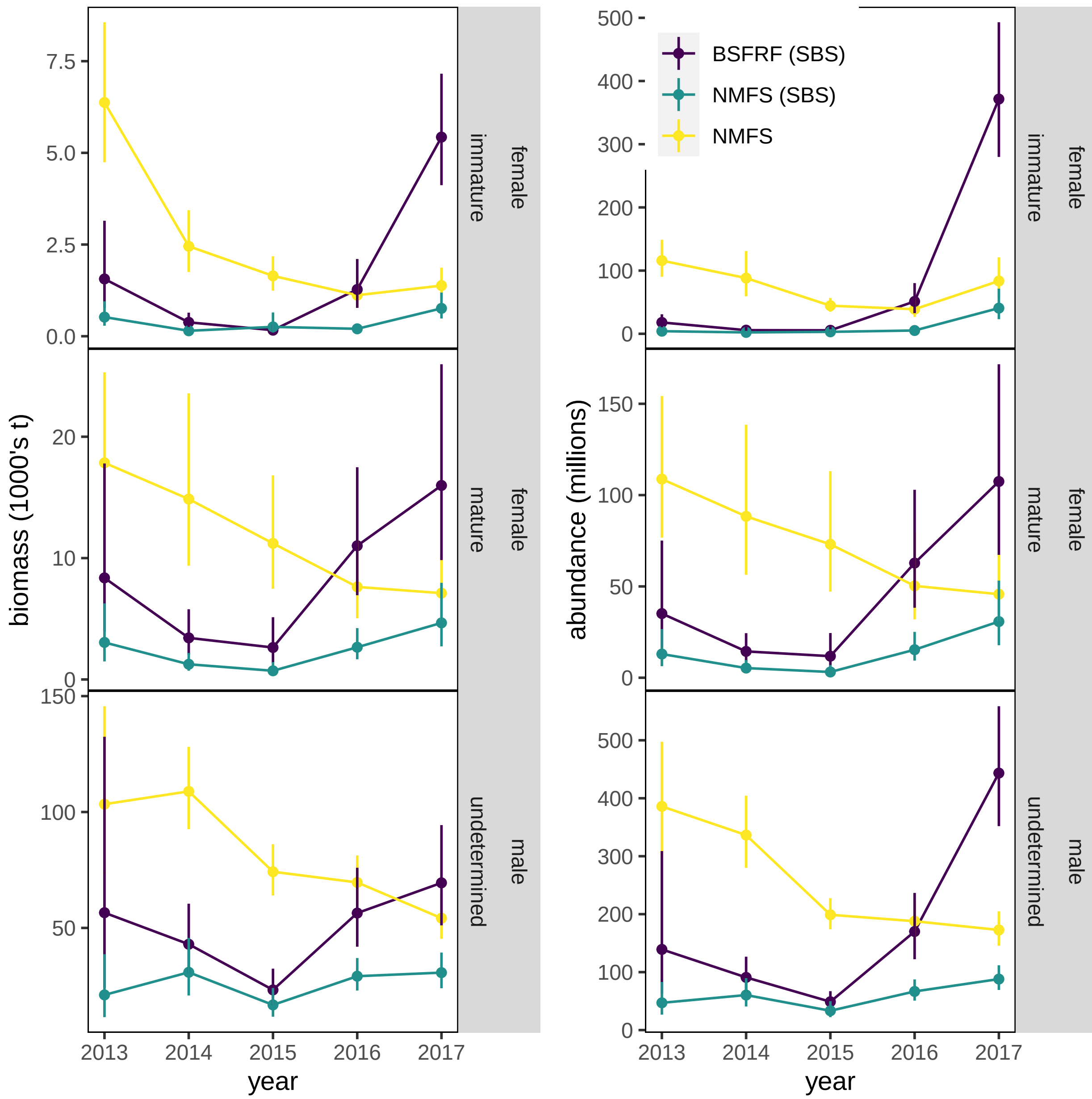

Figure 27: Annual estimates of area-swept biomass (left column) and abundance (right column) from the BSFRF-NMFS cooperative side-by-side (SBS) catchability studies in 2013-2017. The SBS studies had different spatial footprints each year, so annual changes in biomass do not necessarily reflect underlying population trends. Purple: BSFRF; green: NMFS (in SBS study); yellow:NMFS (EBS survey area).

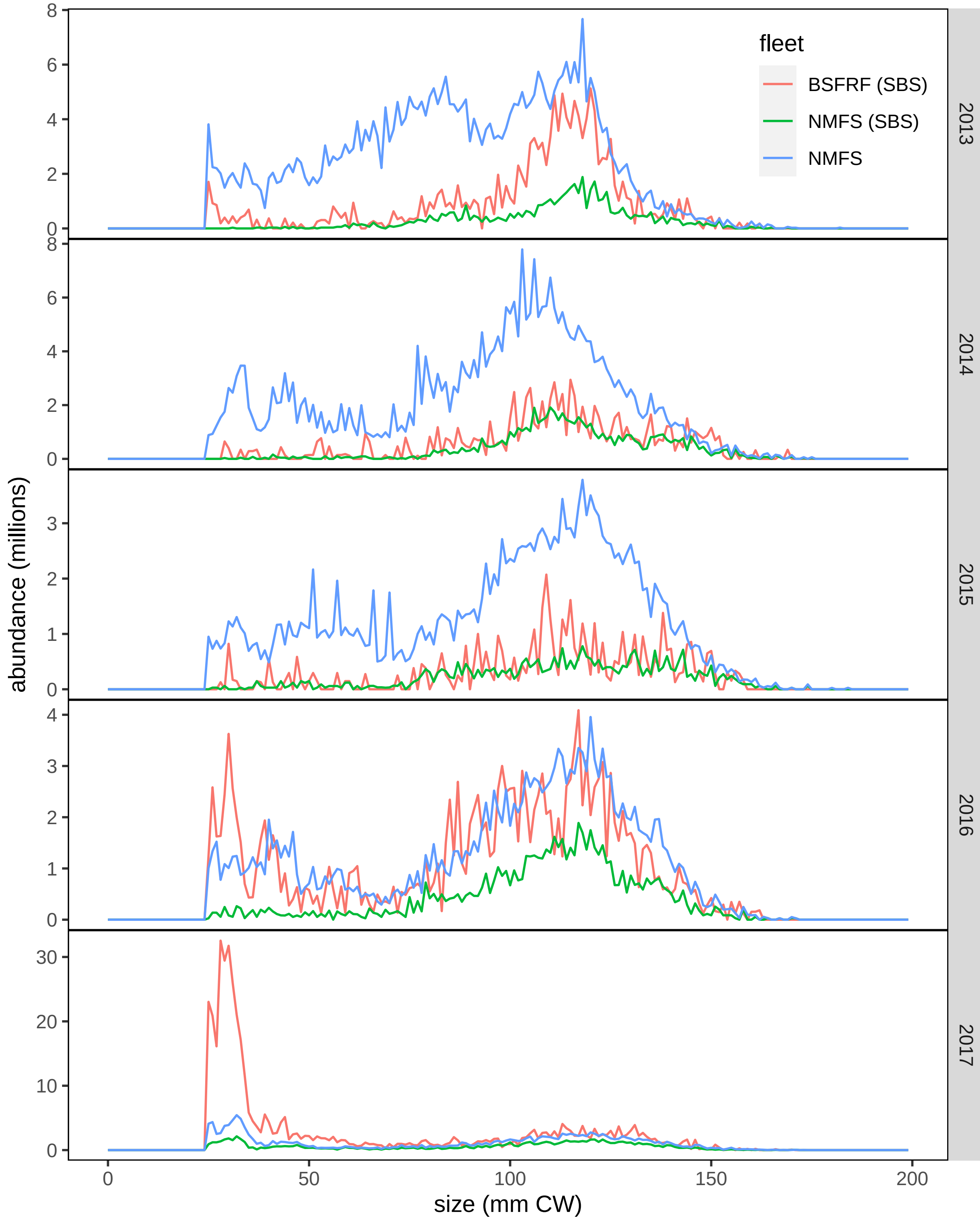

Figure 28: Annual size compositions of area-swept abundance for males from the BSFRF-NMFS cooperative side-by-side (SBS) catchability studies in 2013-2017. BSFRF (SBS): using modified a nephrops bottom trawl (red); NMFS (SBS): standard NMFS survey gear and protocols (green). Also shown is the NMFS survey size composition ("NMFS") for the entire EBS for each year (blue). Size bins are 1-mm.

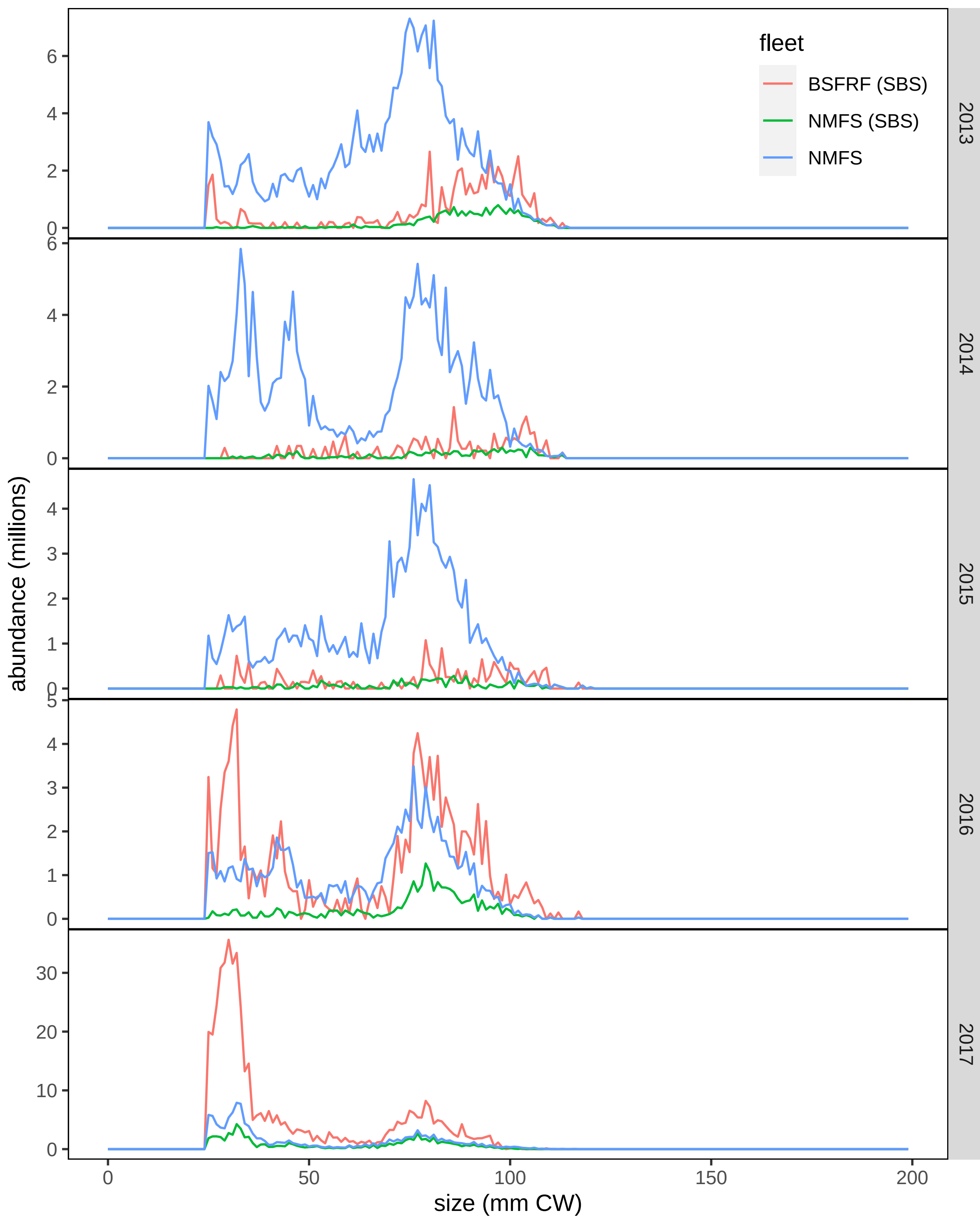

Figure 29: Annual size compositions of area-swept abundance for females from the BSFRF-NMFS cooperative side-by-side (SBS) catchability studies in 2013-2017. BSFRF (SBS): using modified a nephrops bottom trawl (red); NMFS (SBS): standard NMFS survey gear and protocols (green). Also shown is the NMFS survey size composition ("NMFS") for the entire EBS for each year (blue). Size bins are 1-mm.

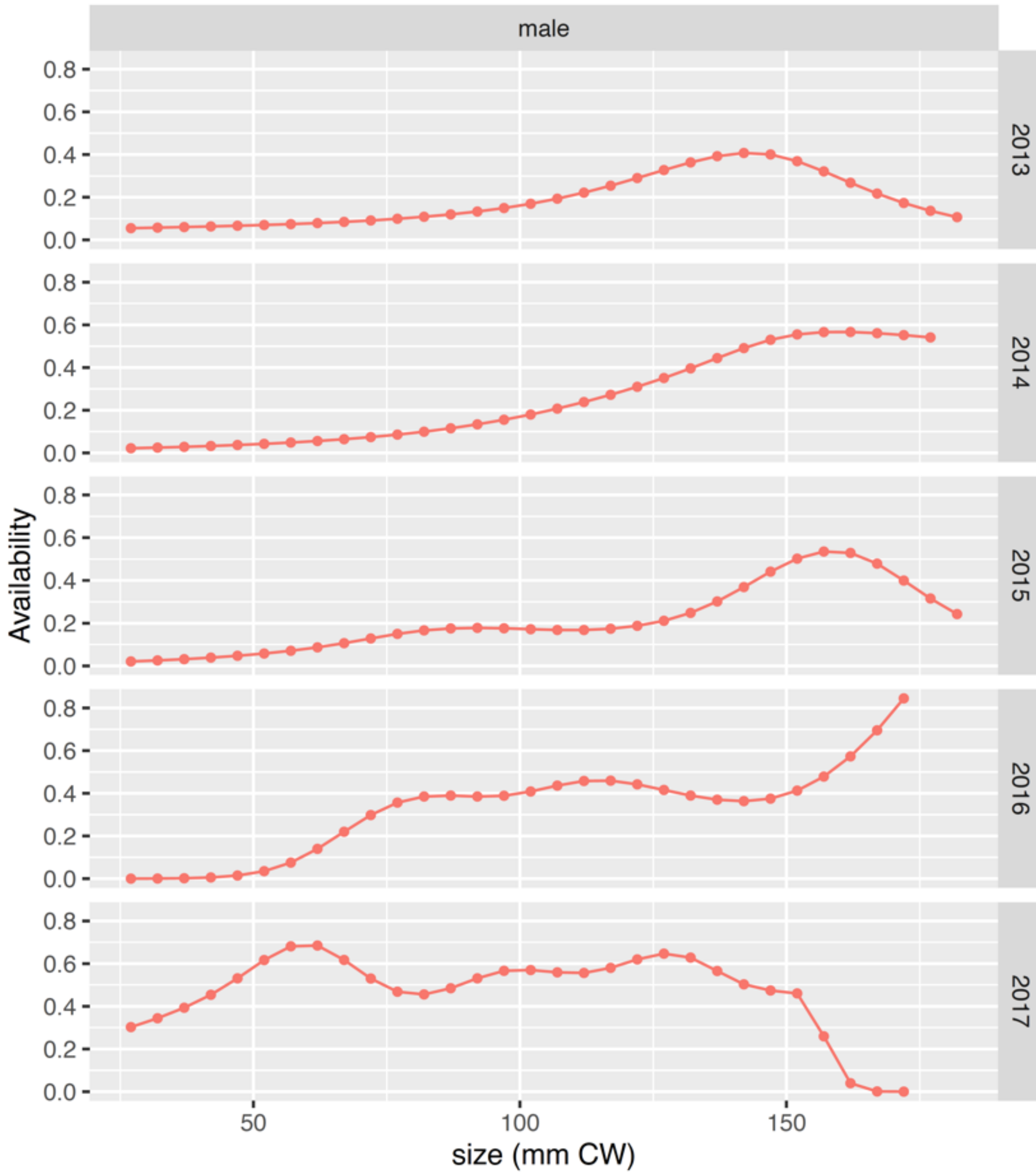

Figure 30: Empirical male availability curves for BSFRF data.

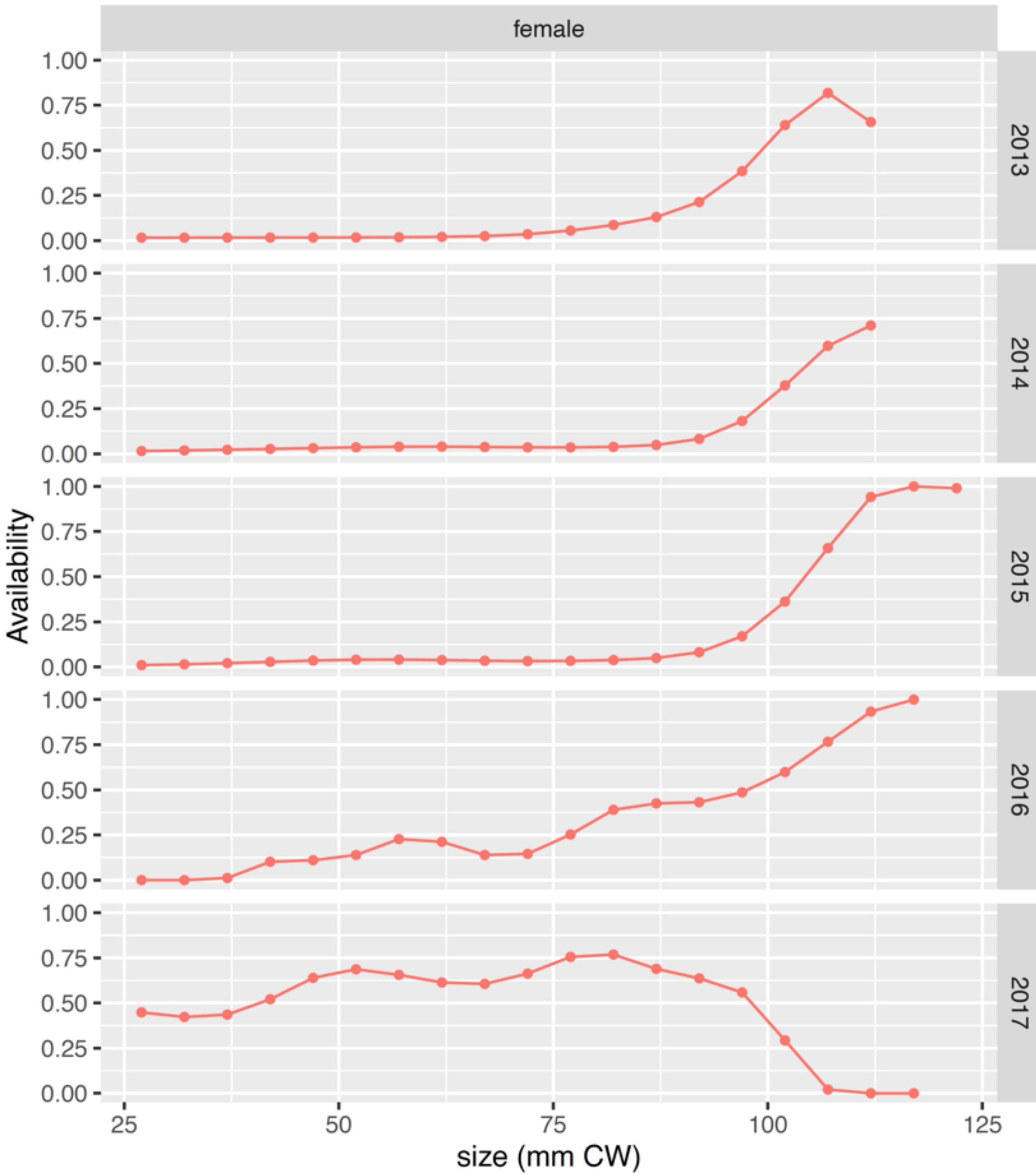

Figure 31: Empirical female availability curves for BSFRF data.

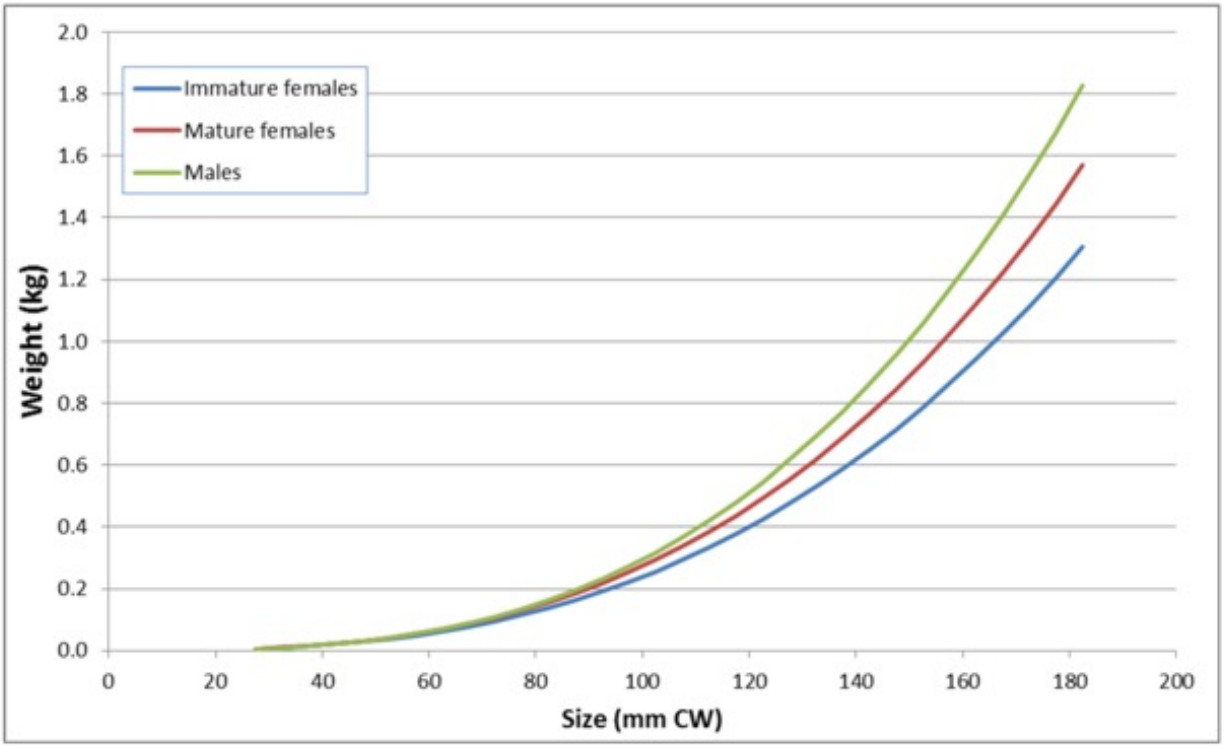

Figure 32: Size-weight relationships for Tanner crab.

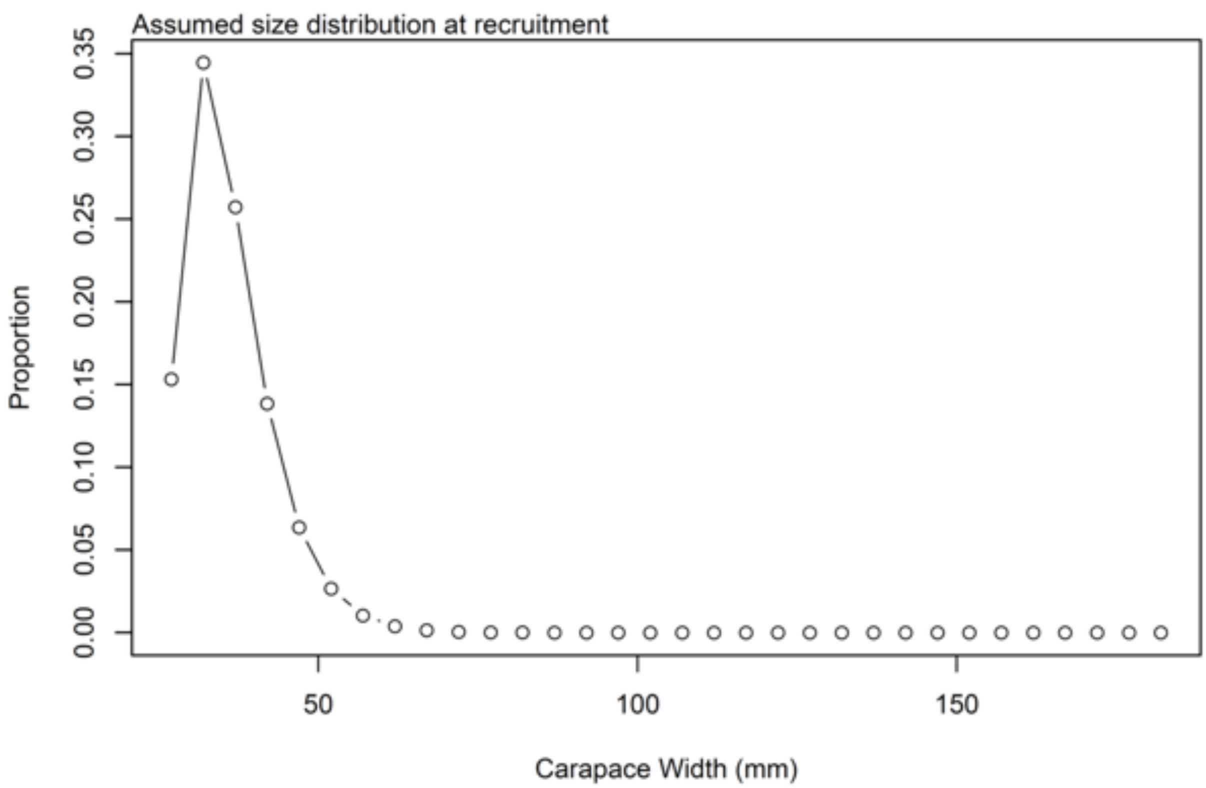

Figure 33: Nominal size distribution at recruitment.

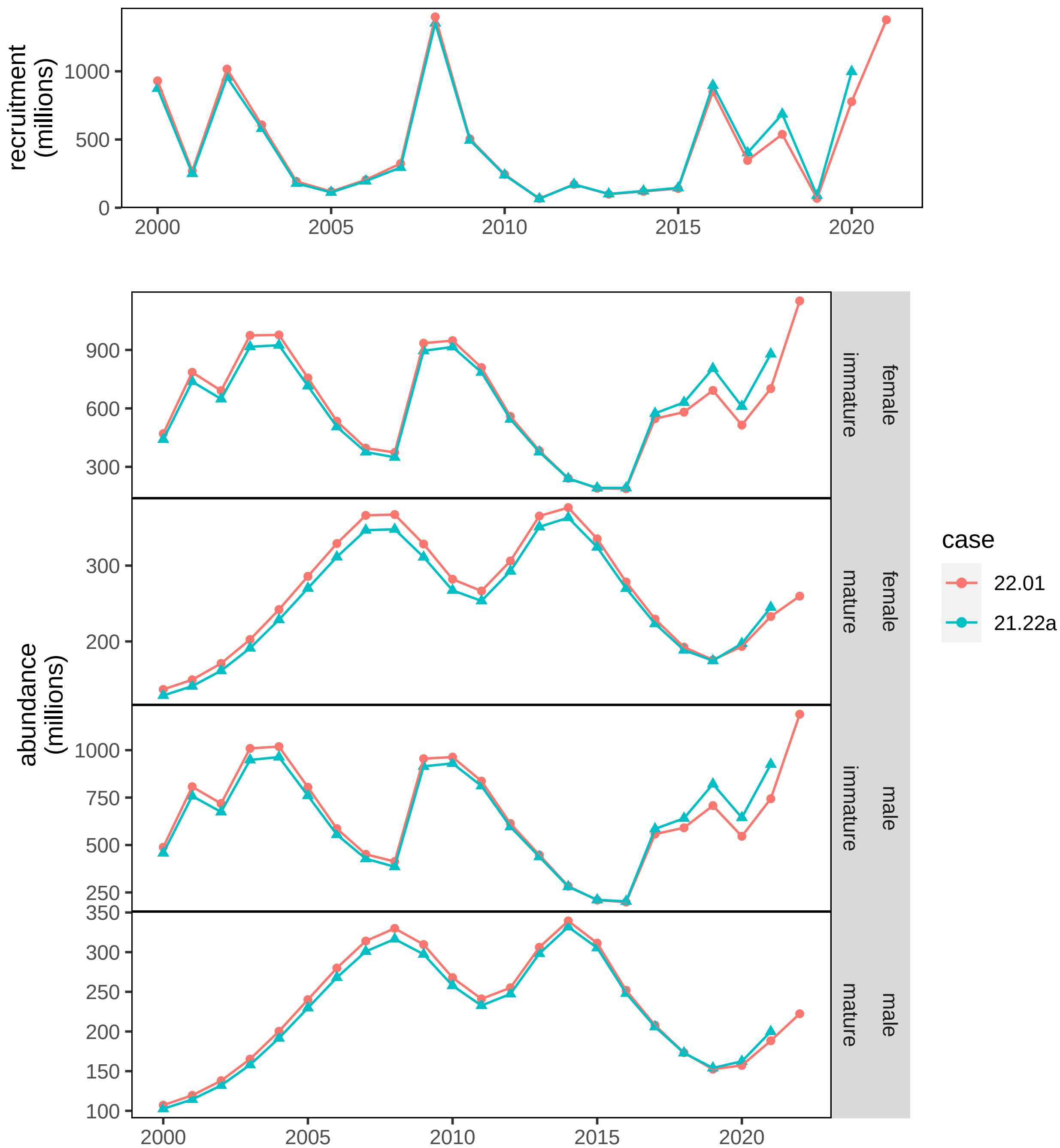

Figure 34: Estimated recent recruitment and population abundance trends, by sex and maturity state. Note that y-axis scales differ among plots.

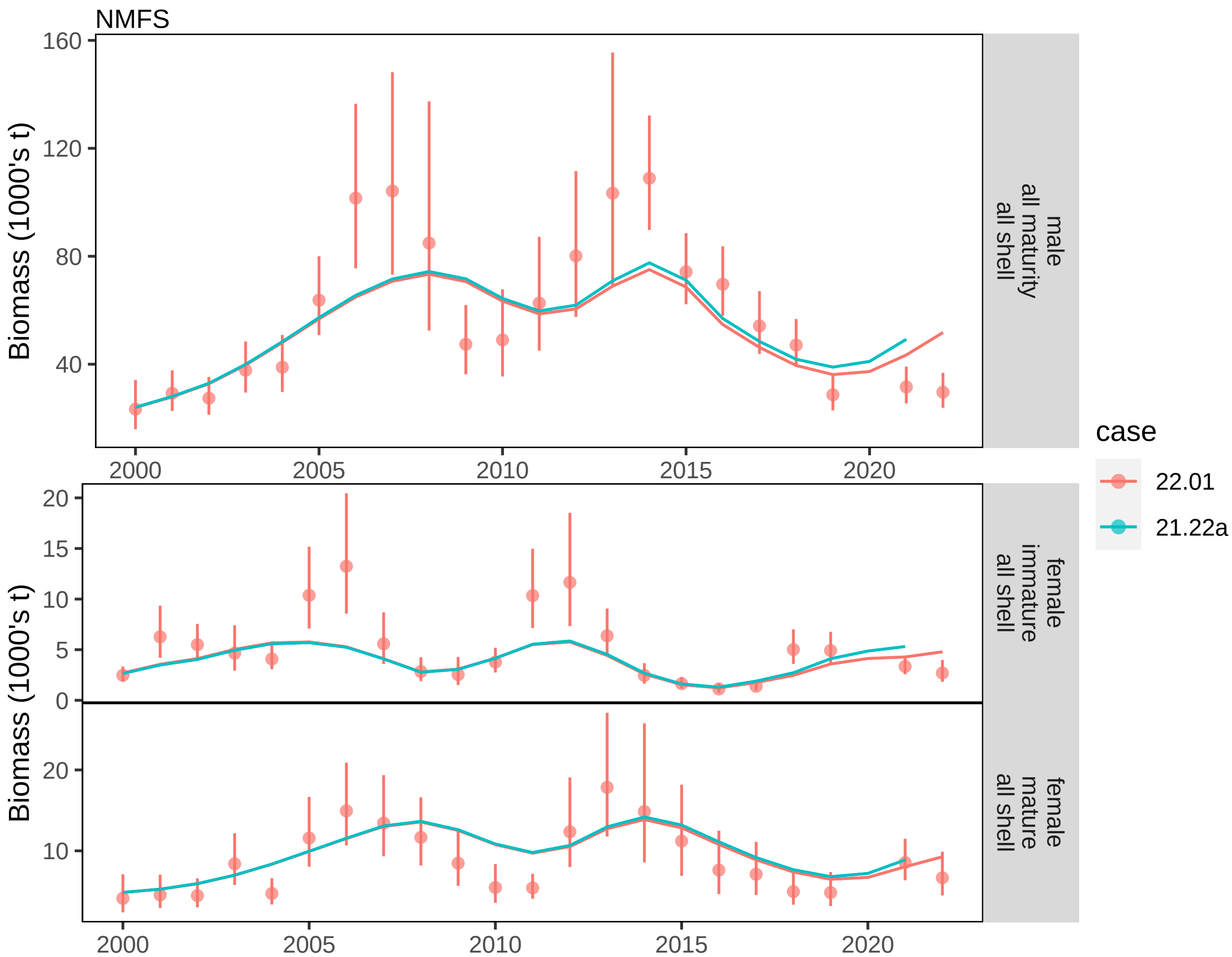

Figure 35: Fits to recent time series of all male (upper graph), immature female (center graph), and mature female (lower plot) biomass from the NMFS EBS shelf survey. Confidence intervals are 95%.

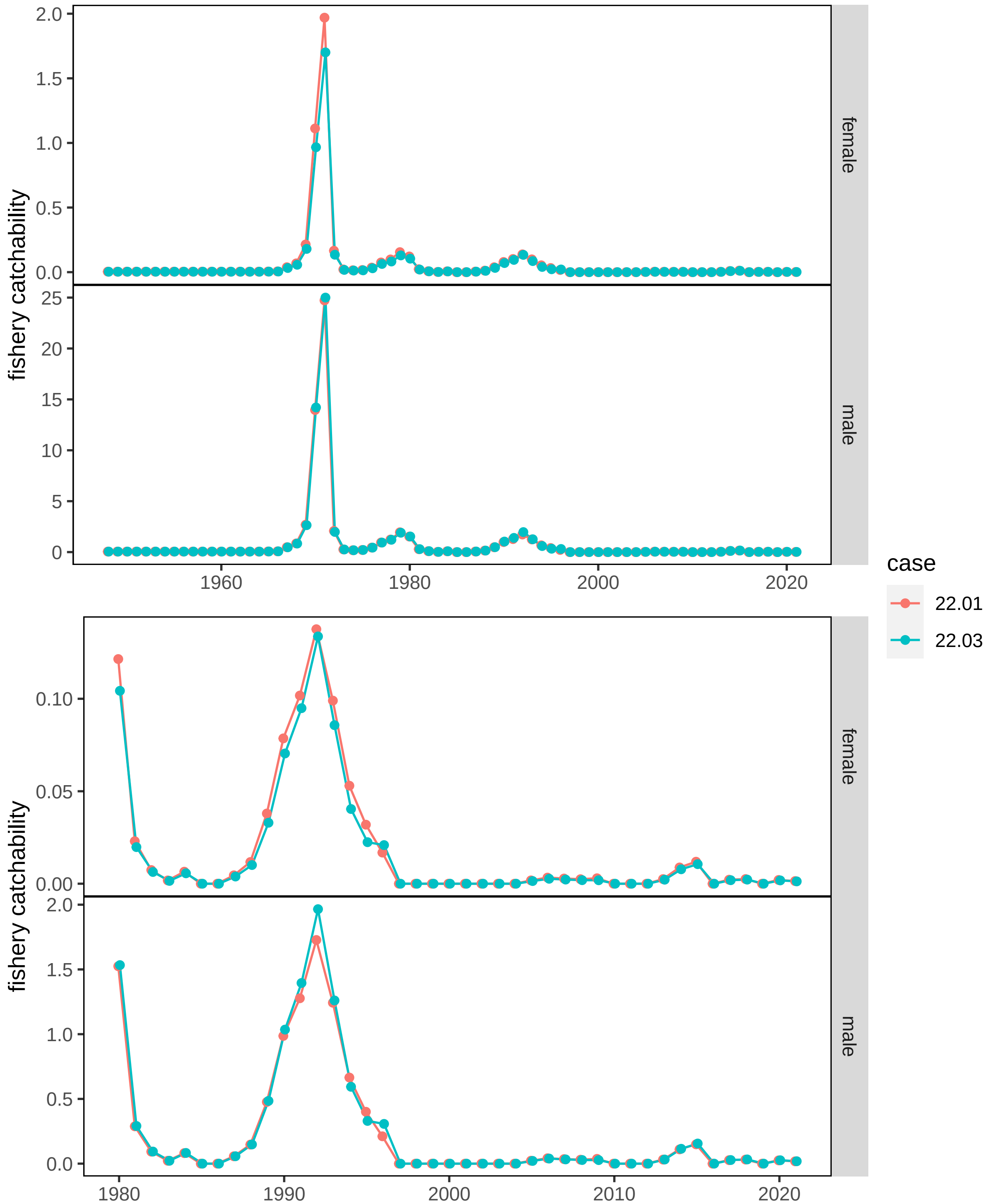

Figure 36: Estimated fully-selected bycatch capture rates (not mortality) in the directed fishery. The lower pair of plots show the estimated time series since 1980. Preferred model is 22.03.

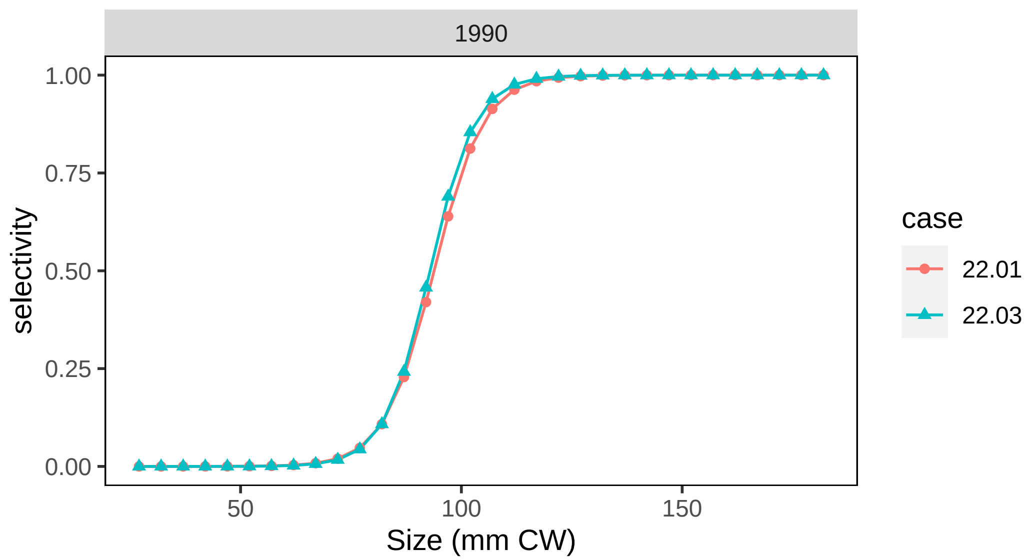

Figure 37: Estimated selectivity for females in the directed fishery for all years. Preferred model is 22.03.

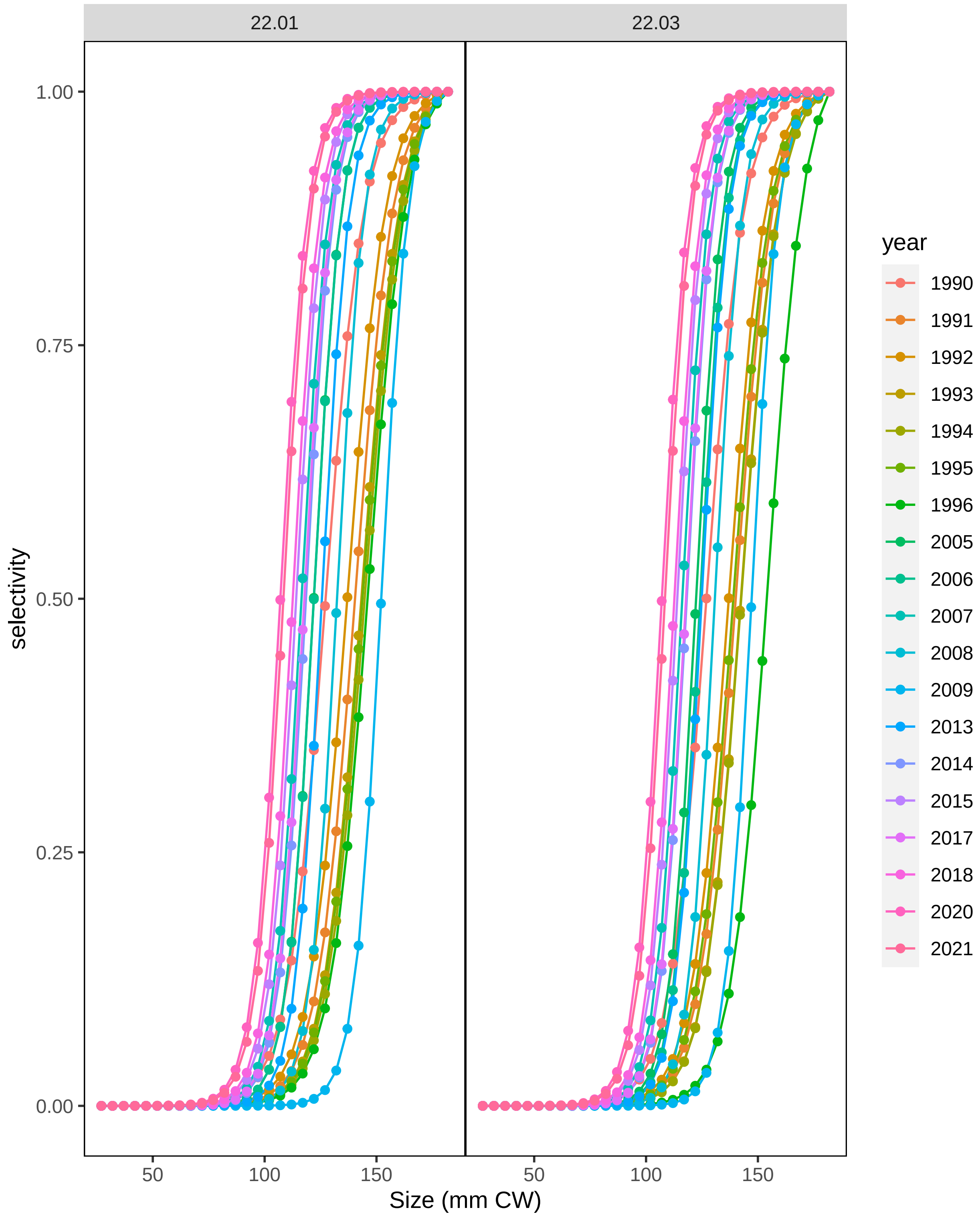

Figure 38: Estimated selectivity curves for males in the directed fishery, faceted by model scenario. Curves labelled 1990 applies to all years before 1991. Others apply in the year indicated in the legend. Preferred model is 22.03.

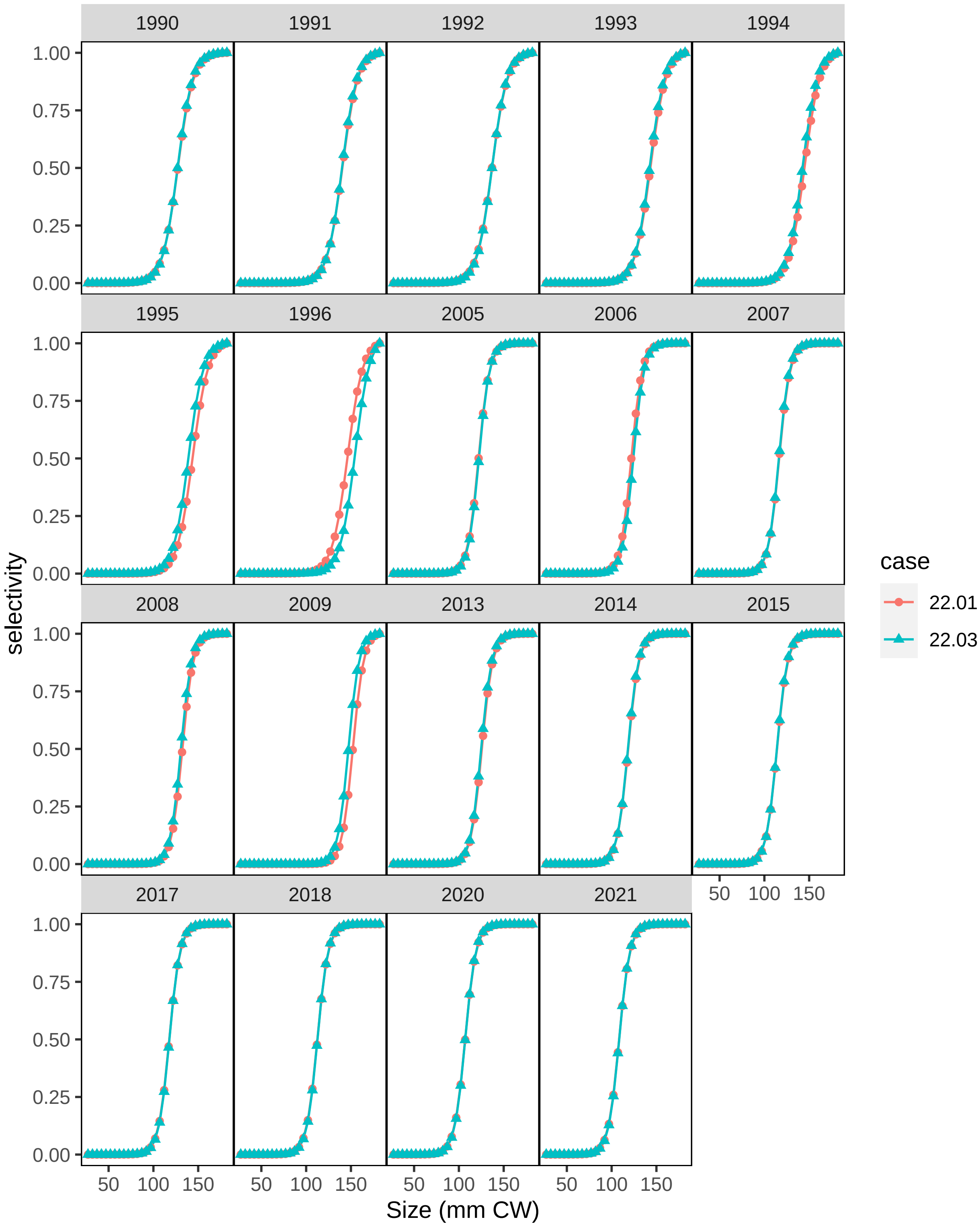

Figure 39: Estimated selectivity curves for males in the directed fishery by year. Curve labelled 1990 applies to all years before 1991. Others apply in the year indicated in the panel. Preferred model is 22.03.

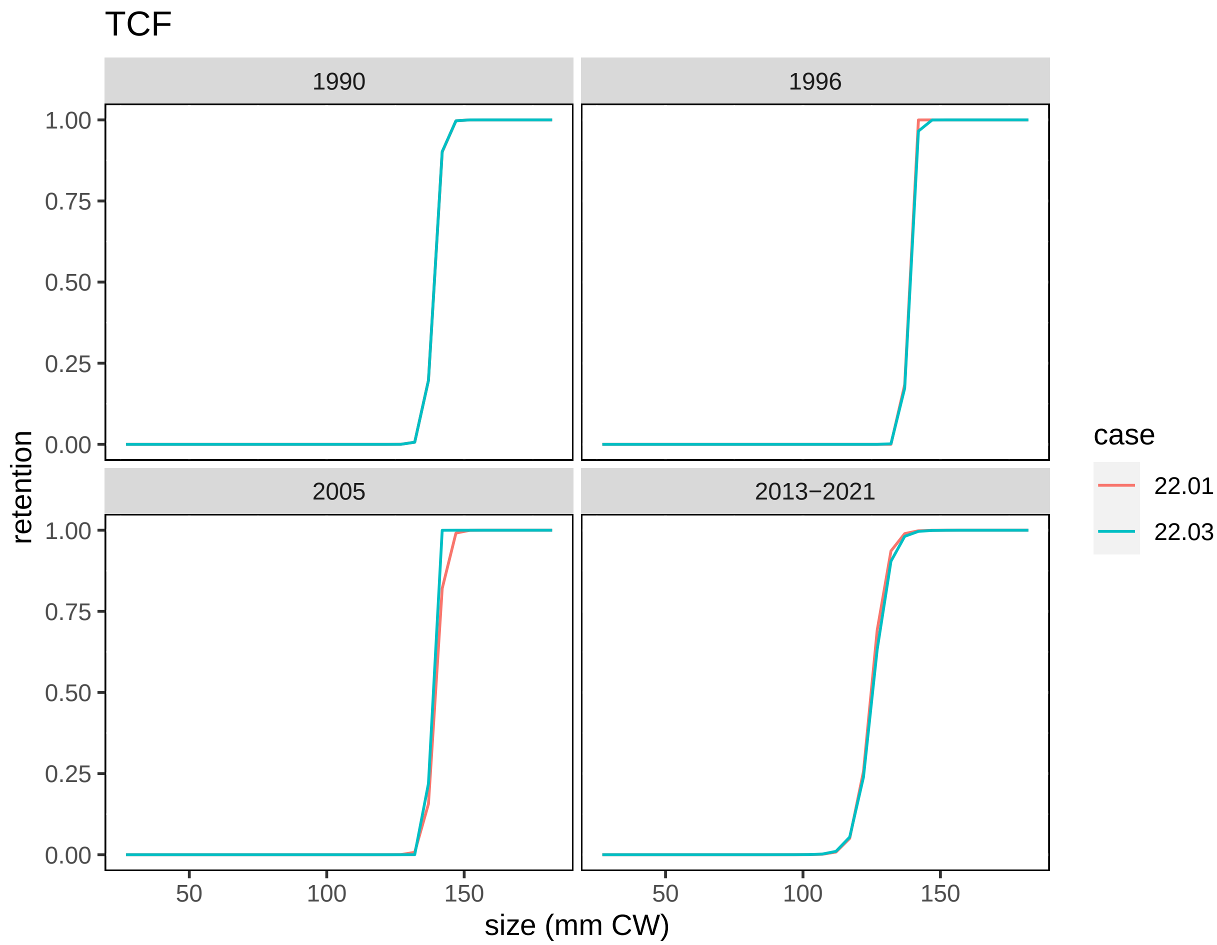

Figure 40: Estimated retention curves for males in the directed fishery by time block. Curve labelled: '1990' - applies to all years before 1991; '1996' - applies to 1991-2006; 2005 - applies to 2005-2009; '2013-2021' - applies to 2013-2021. Preferred model is 22.03.

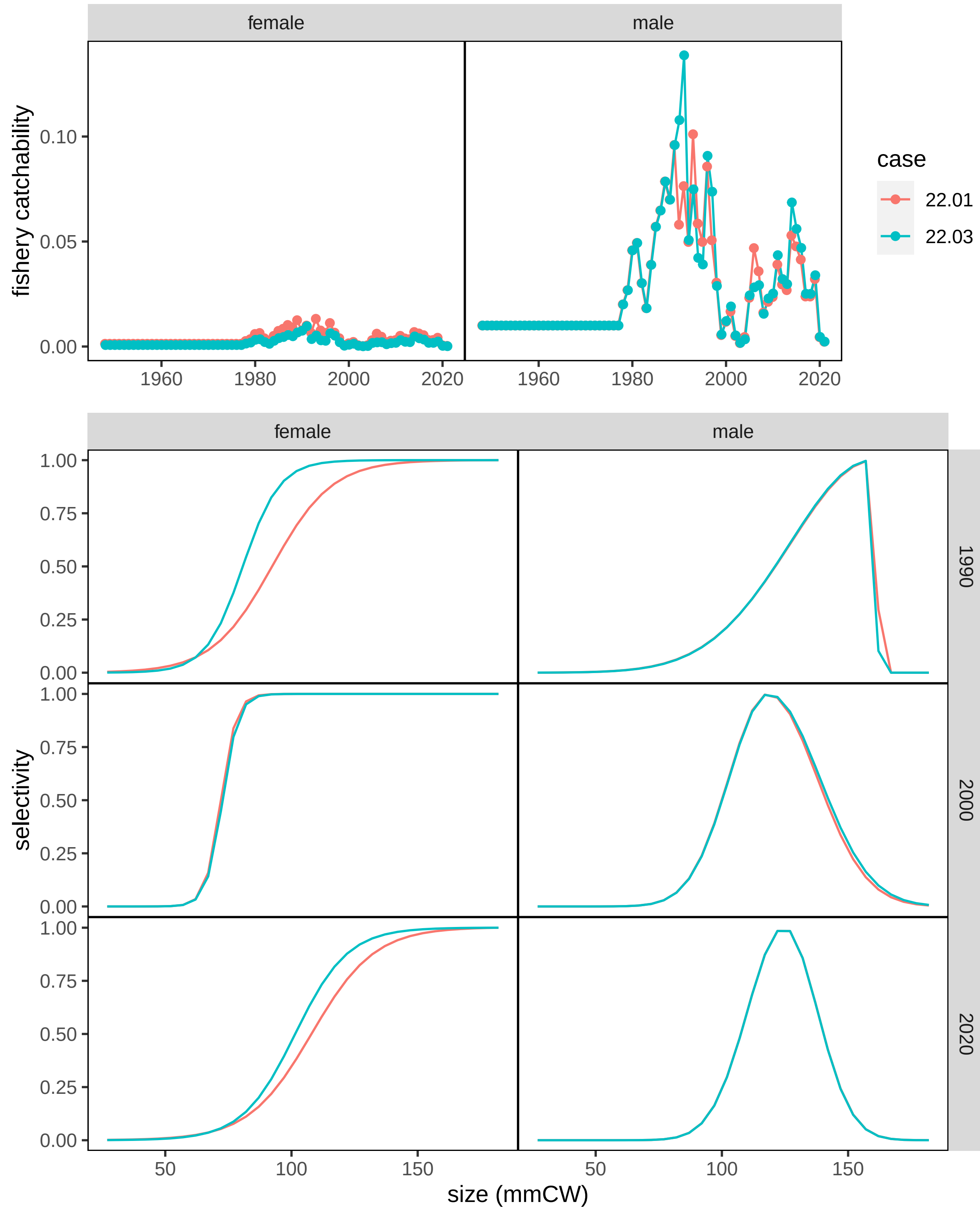

Figure 41: Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the snow crab fishery (SCF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present. Preferred model is 22.03.

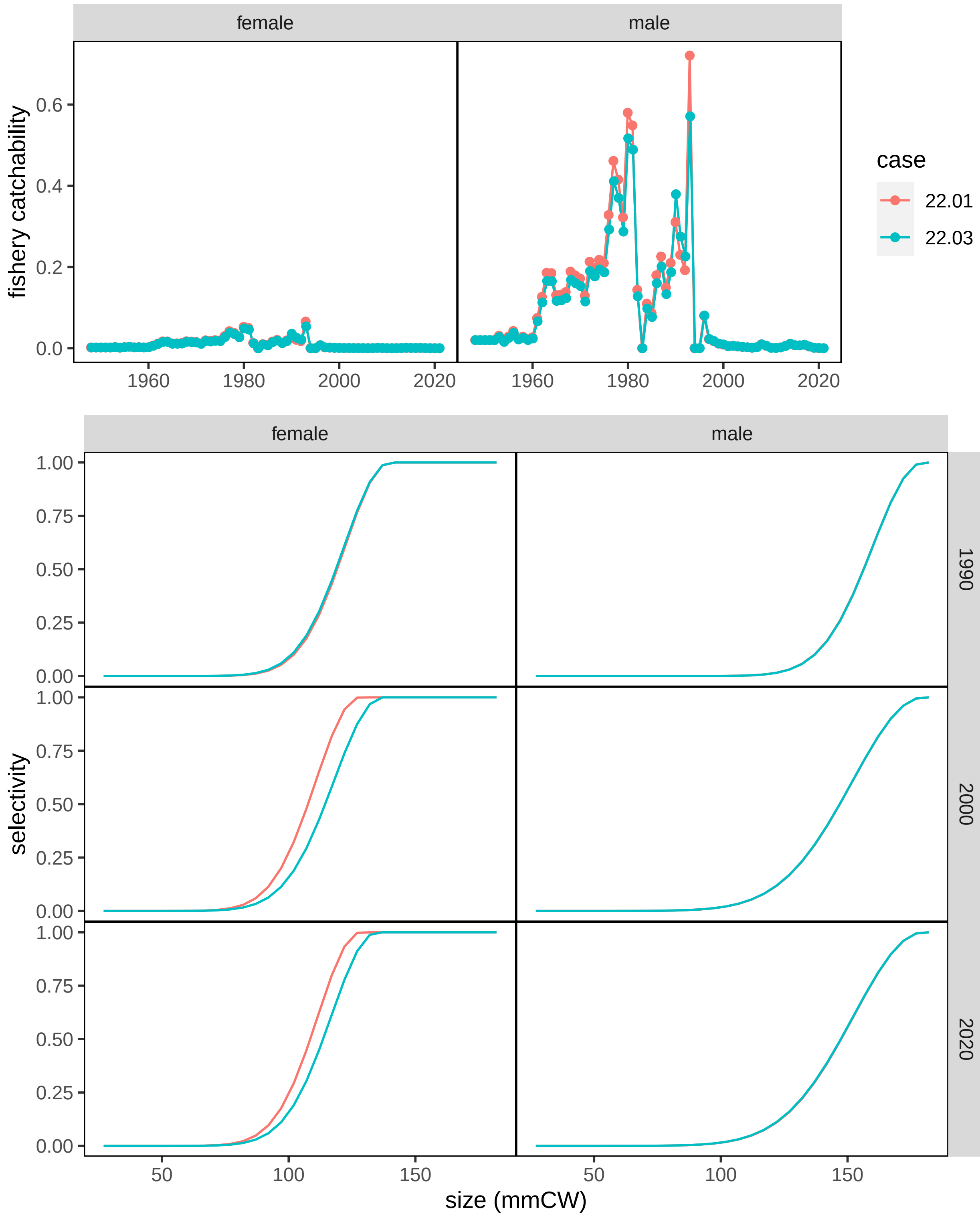

Figure 42: Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the BBRKC fishery (RKF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present. Preferred model is 22.03.

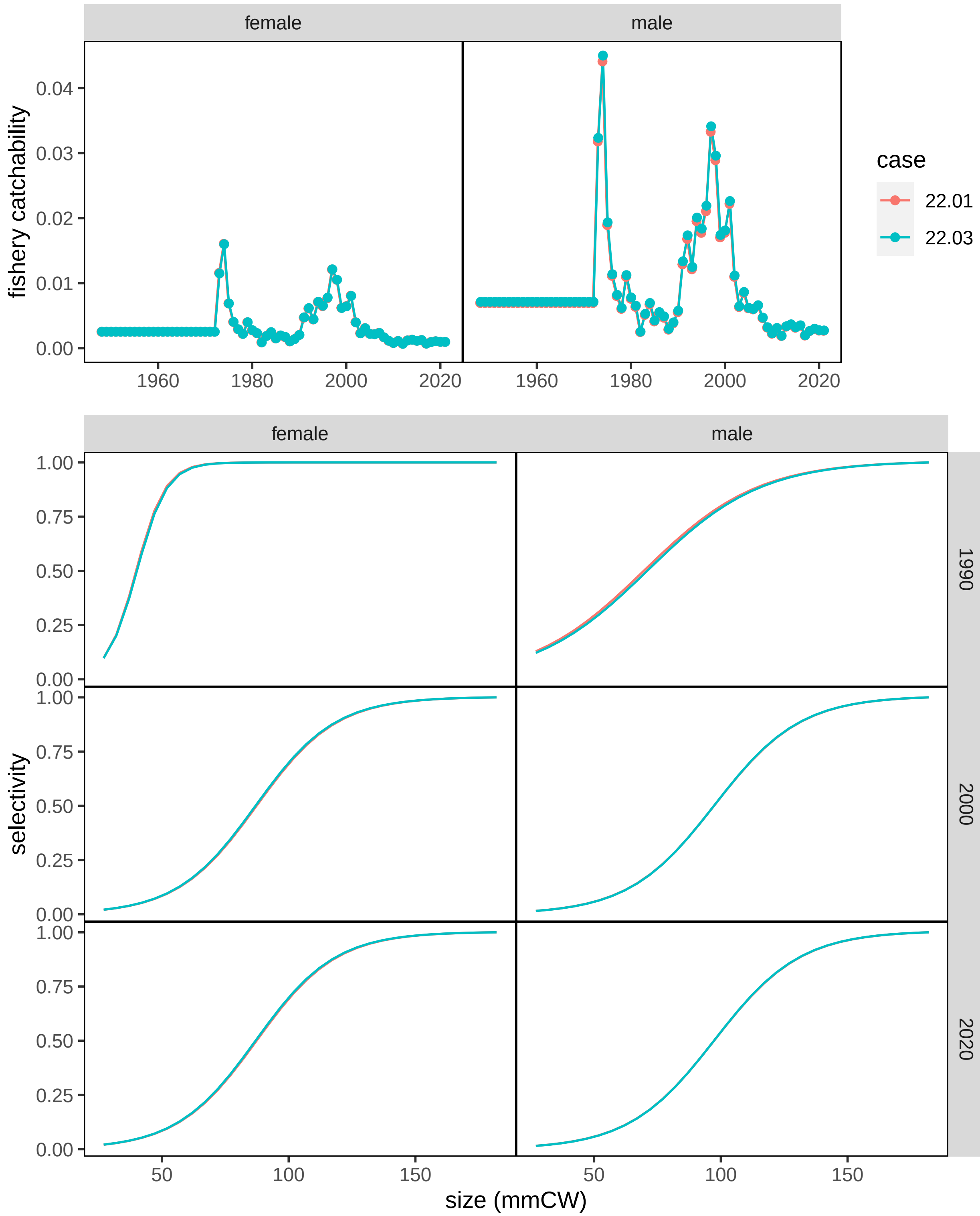

Figure 43: Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the groundfish fisheries (GF All). Time blocks for selectivity functions are labelled: 1980) before 1988; 1990) 1987-1996; 2020) 1997-present. Preferred model is 22.03.

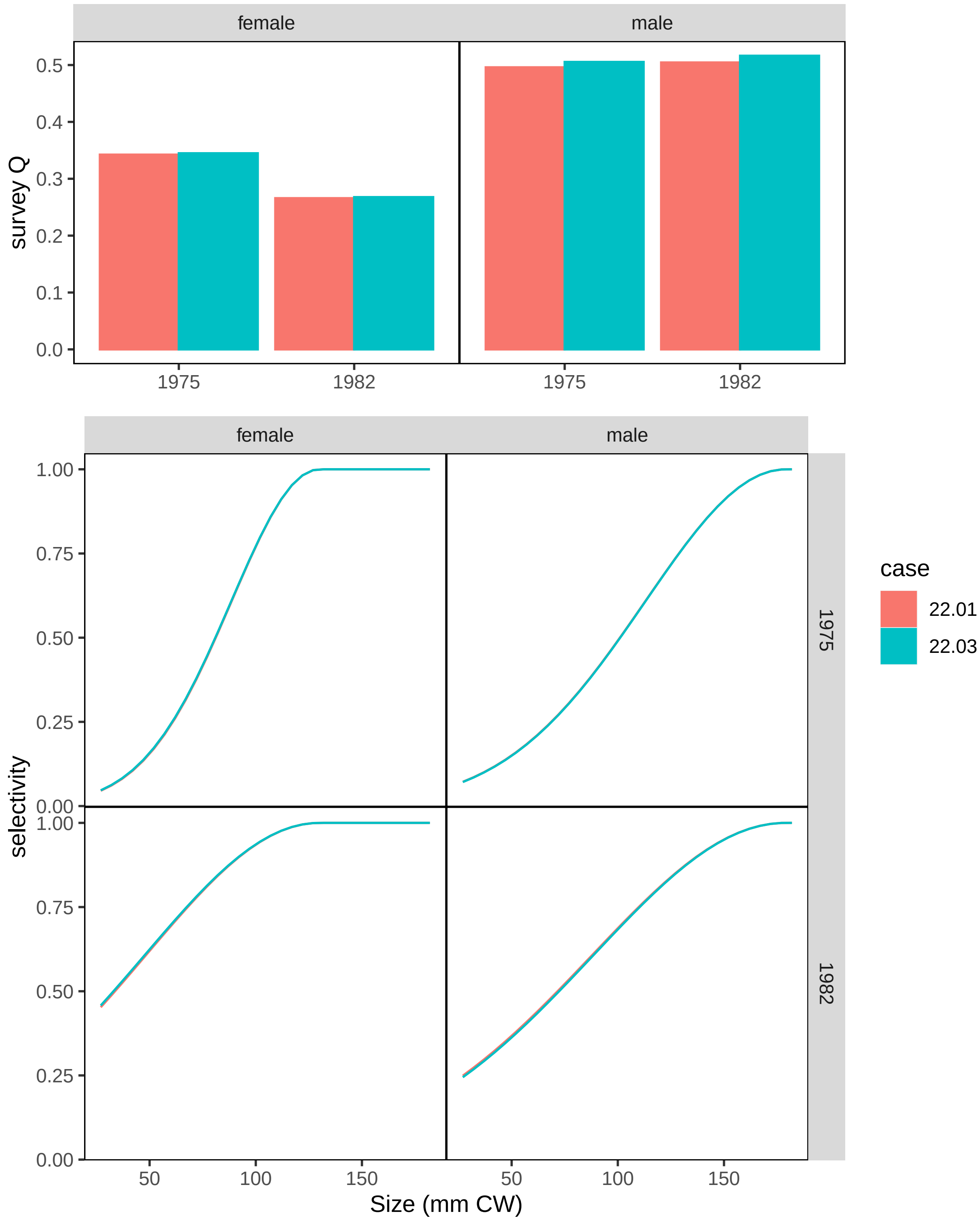

Figure 44: Estimated NMFS EBS Survey fully-selected catchability (survey Q's) and selectivity functions by sex for different time periods. 1975: 1975-1981; 1982: 1982-current. Preferred model is 22.03.

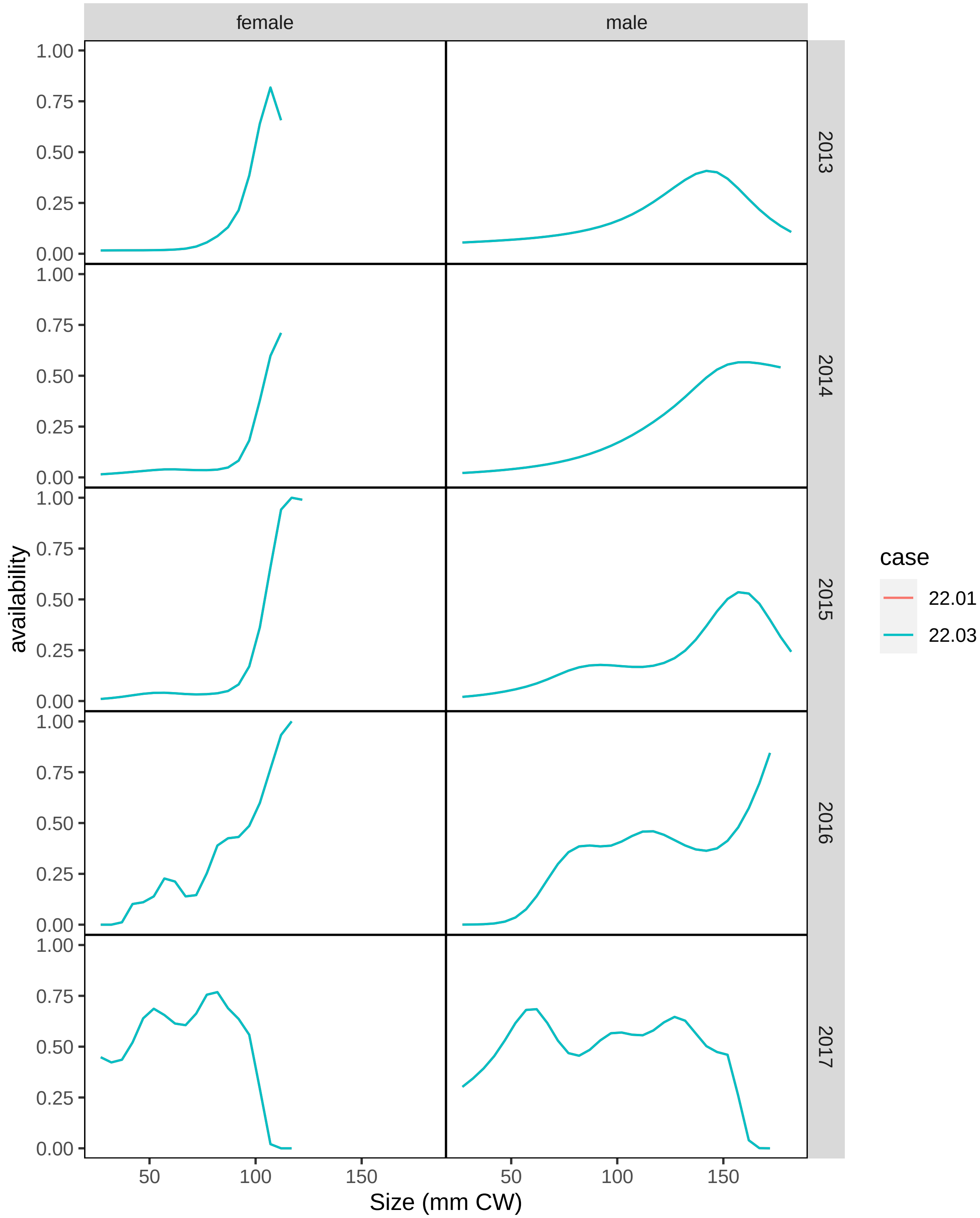

Figure 45: Annual sex-specific availability curves assumed for the BSFRF side-by-side (SBS) data. These were estimated outside the model. Preferred model is 22.03.

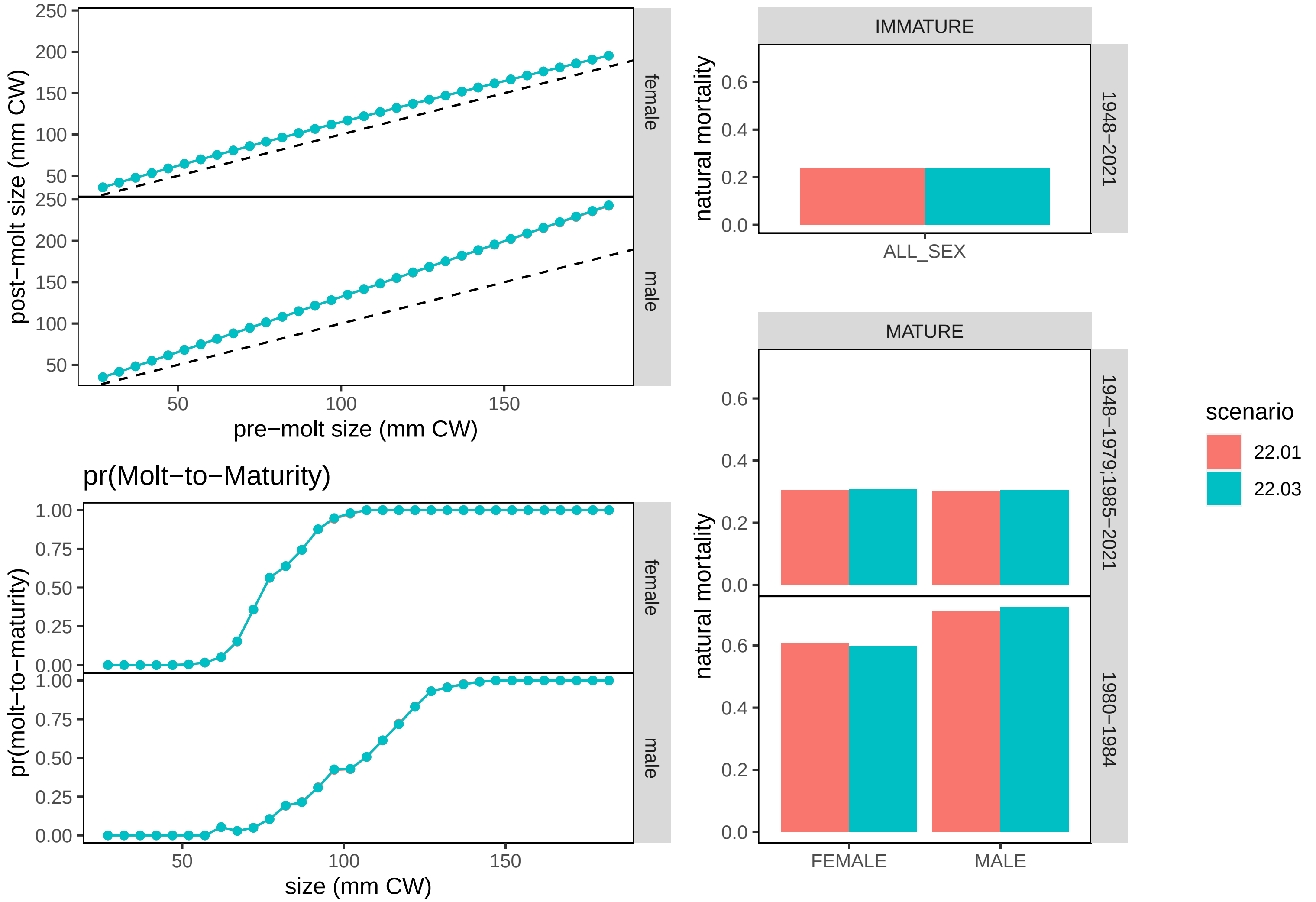

Figure 46: Estimated population processes. Plots in upper lefthand quadrant: sex-specific mean growth; plots in lower lefthand quadrant: sex-specific probability of the molt-to-maturity (i.e., terminal molt)); plots in righthand column: natural mortality rates, by maturity state and sex. Preferred model is 22.03.

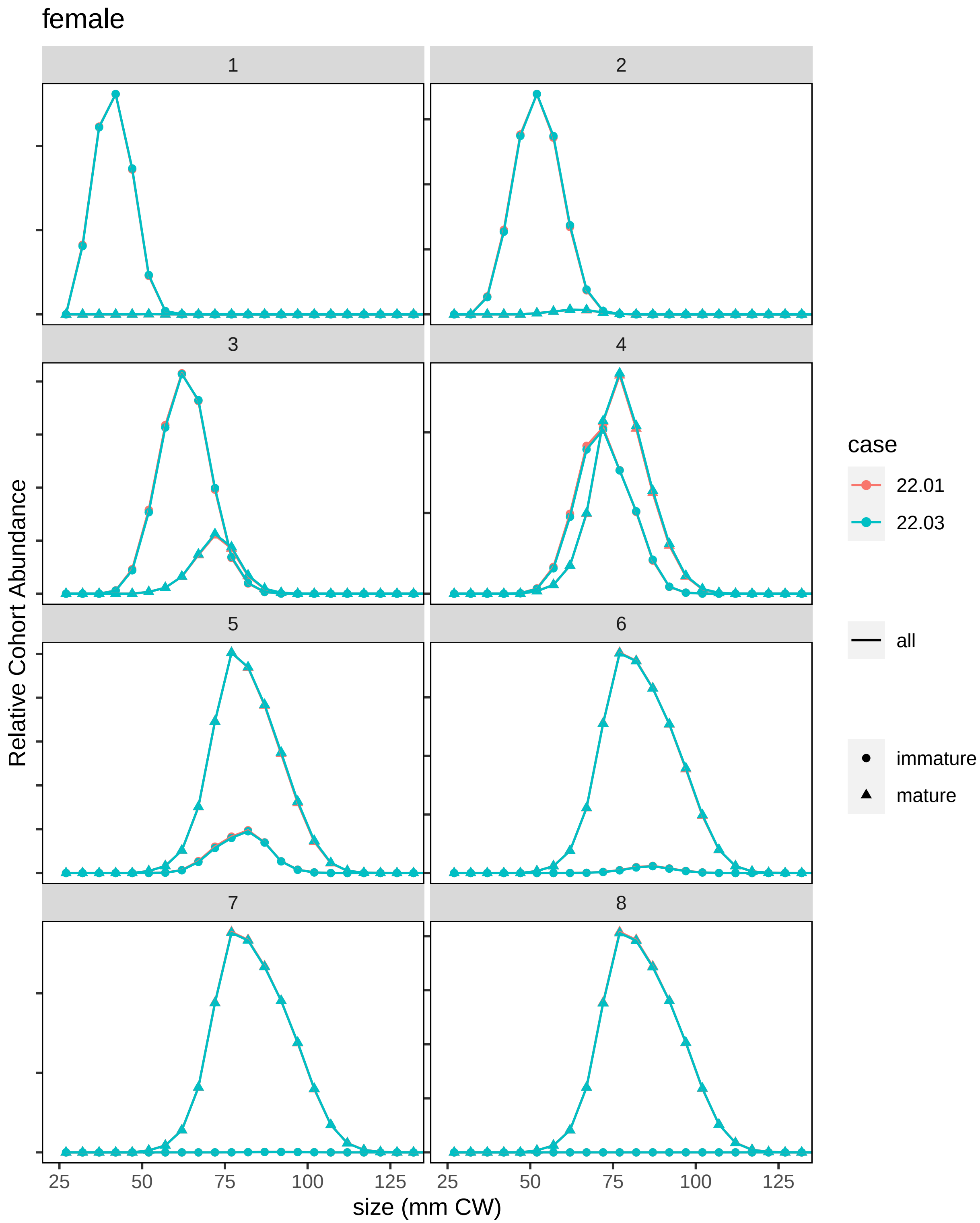

Figure 47: Estimated annual cohort progression for female crab (by year; individual scales are relative). Preferred model is 22.03.

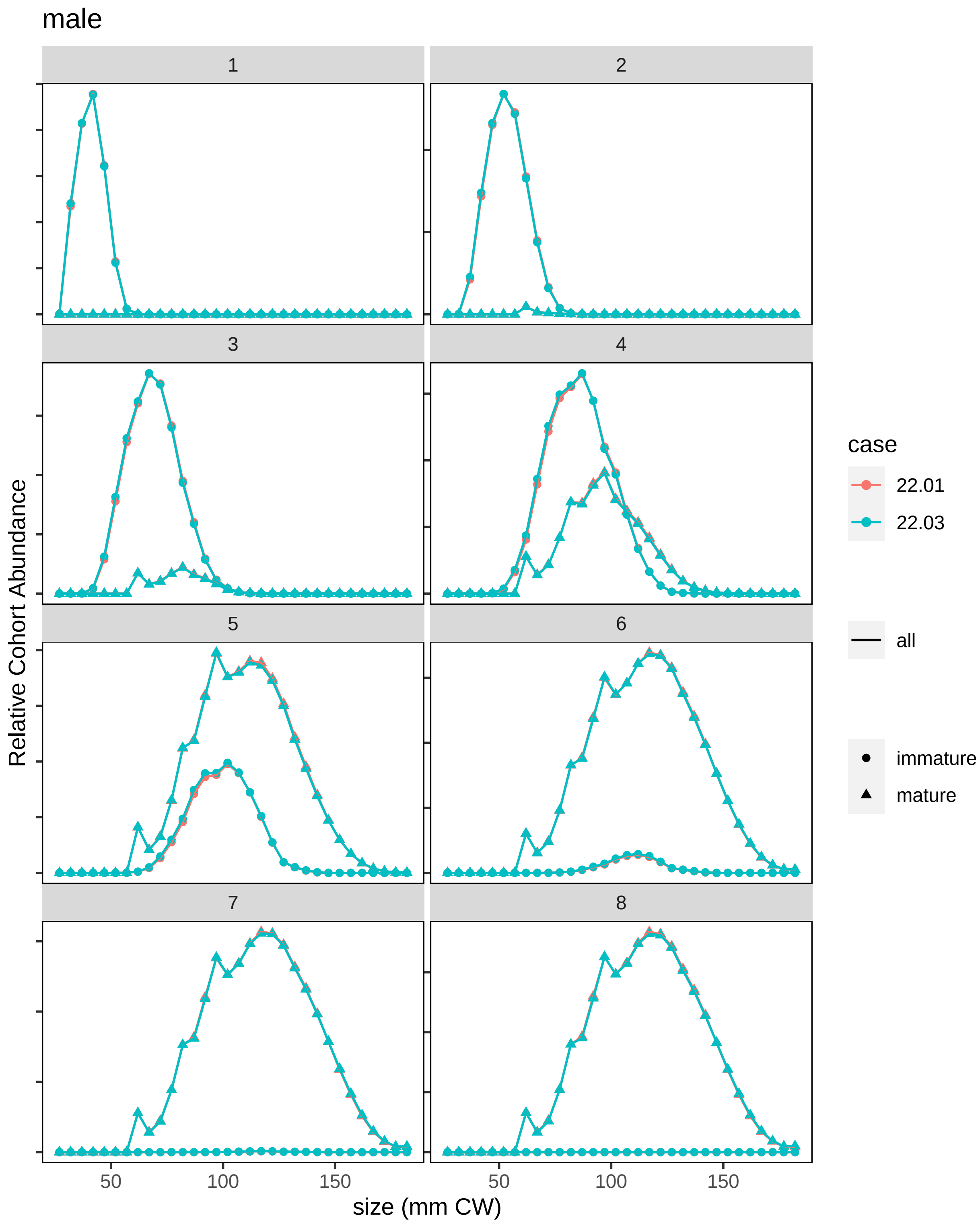

Figure 48: Estimated annual cohort progression for male crab (by year; individual scales are relative). Preferred model is 22.03.

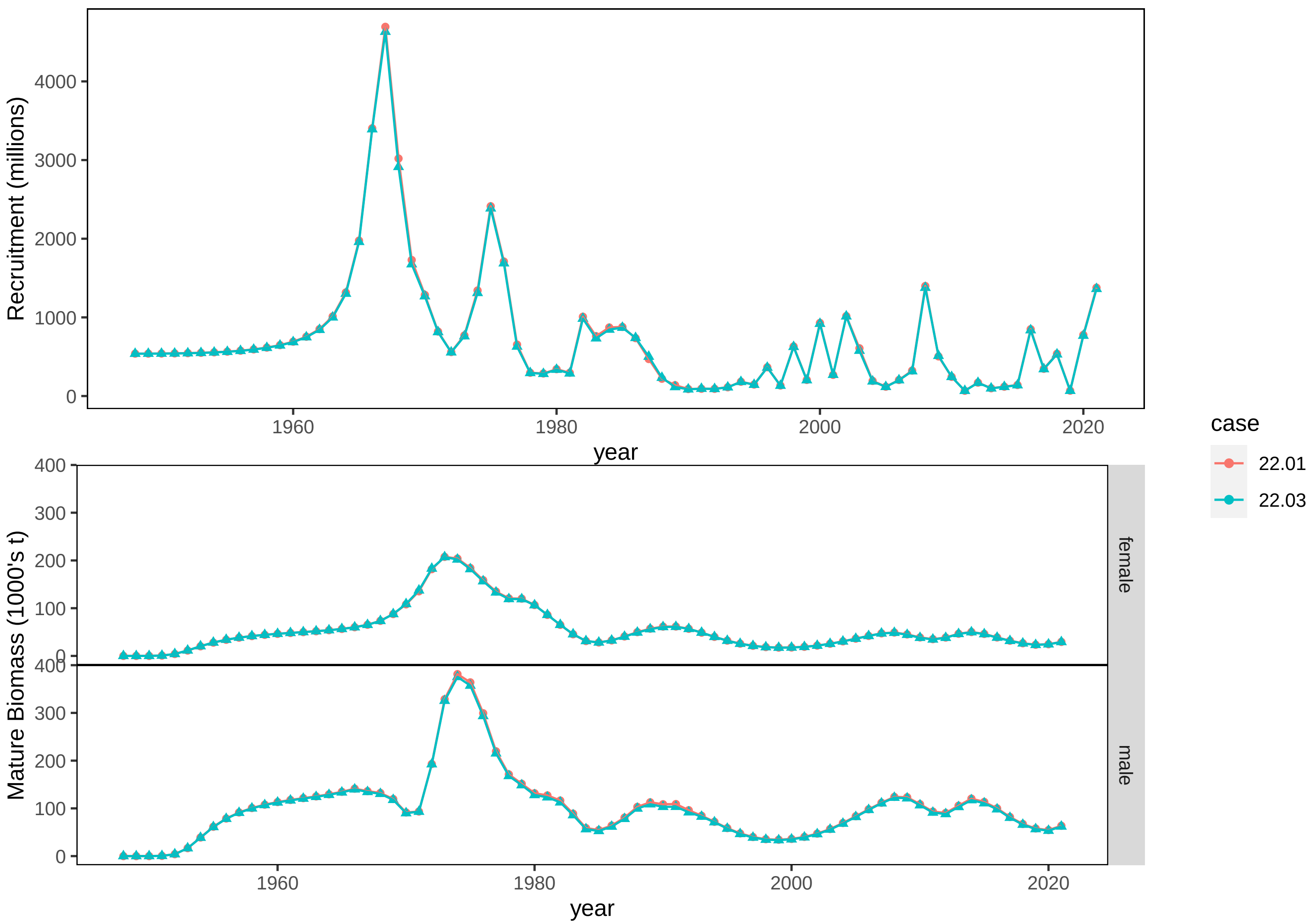

Figure 49: Estimated recruitment and mature biomass time series (all years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03.

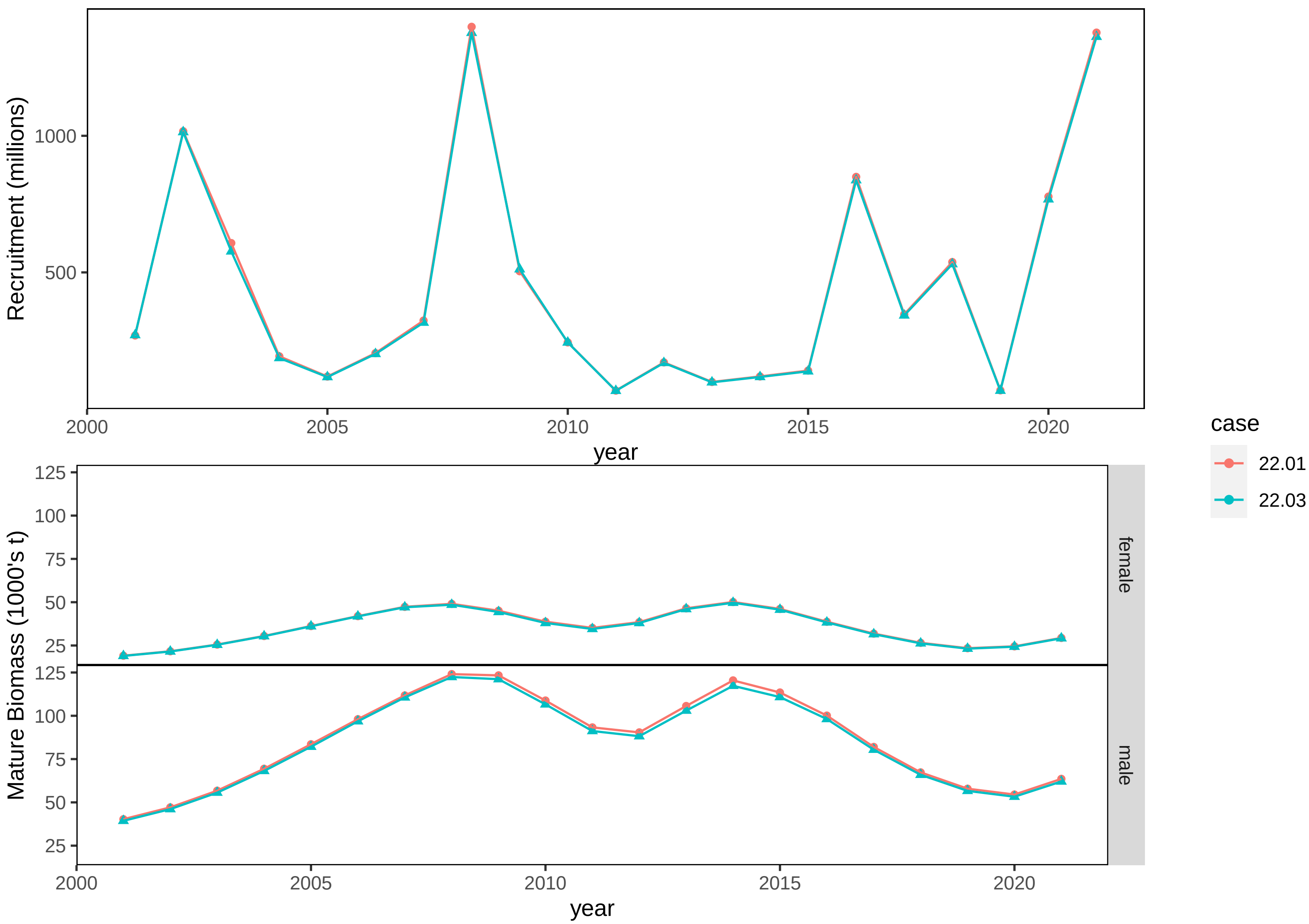

Figure 50: Estimated recruitment and mature biomass time series (recent years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03.

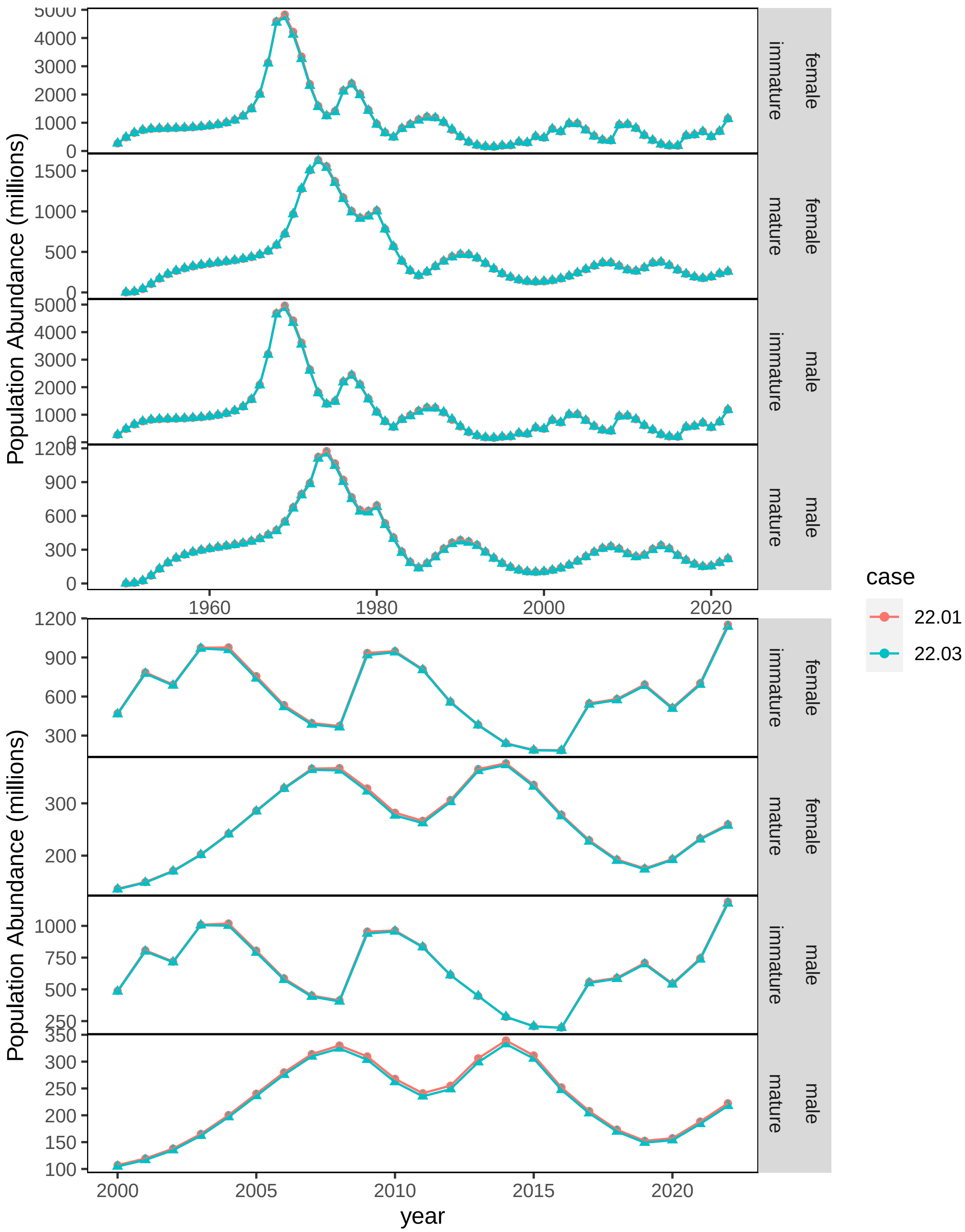

Figure 51: Estimated ppoulation abundance trends, by sex and maturity state. Upper plots: all years; lower plots: recent years. Preferred model is 22.03.

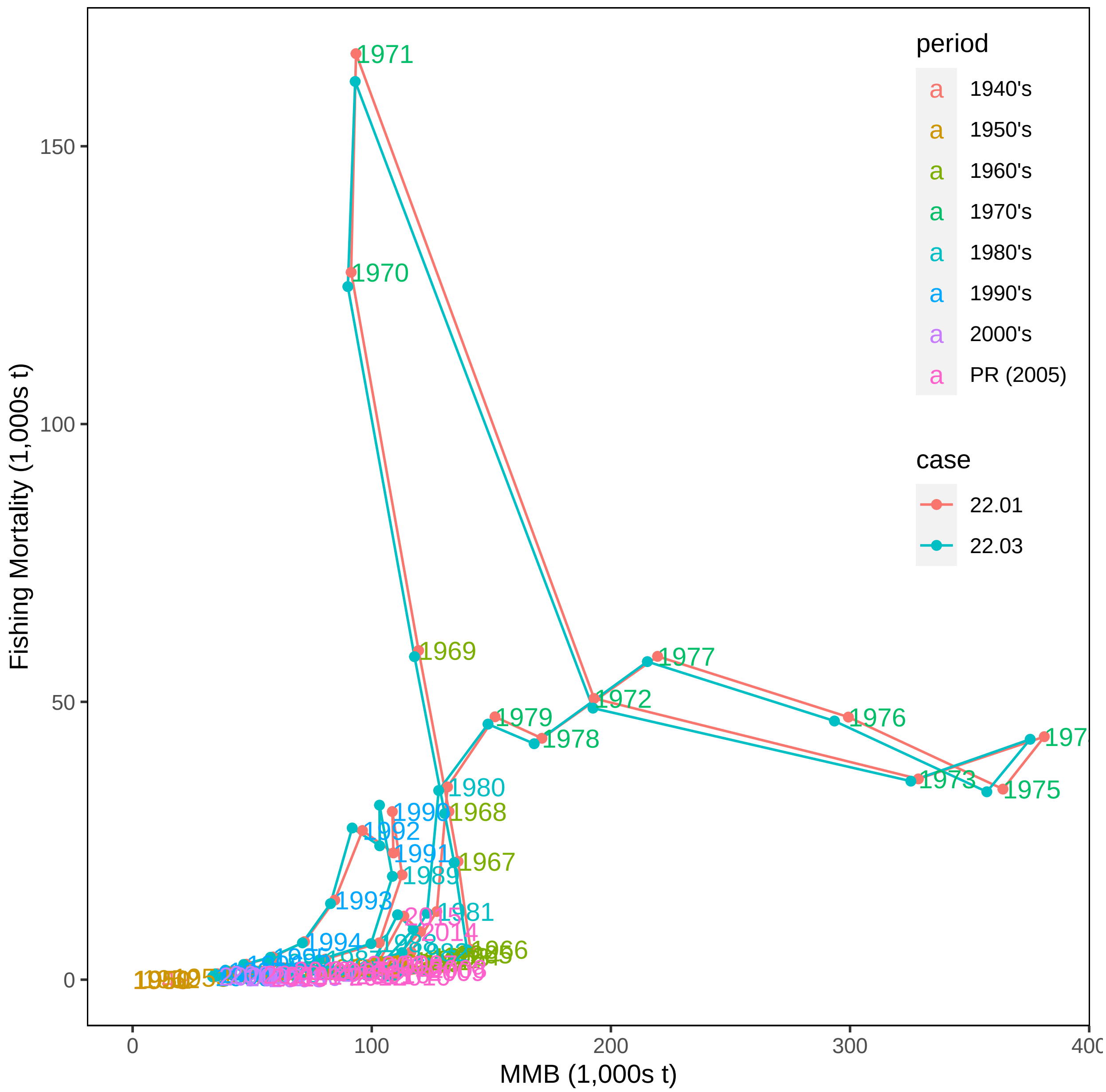

Figure 52: Total estimated fishing mortality vs. MMB. Preferred model is 22.03.

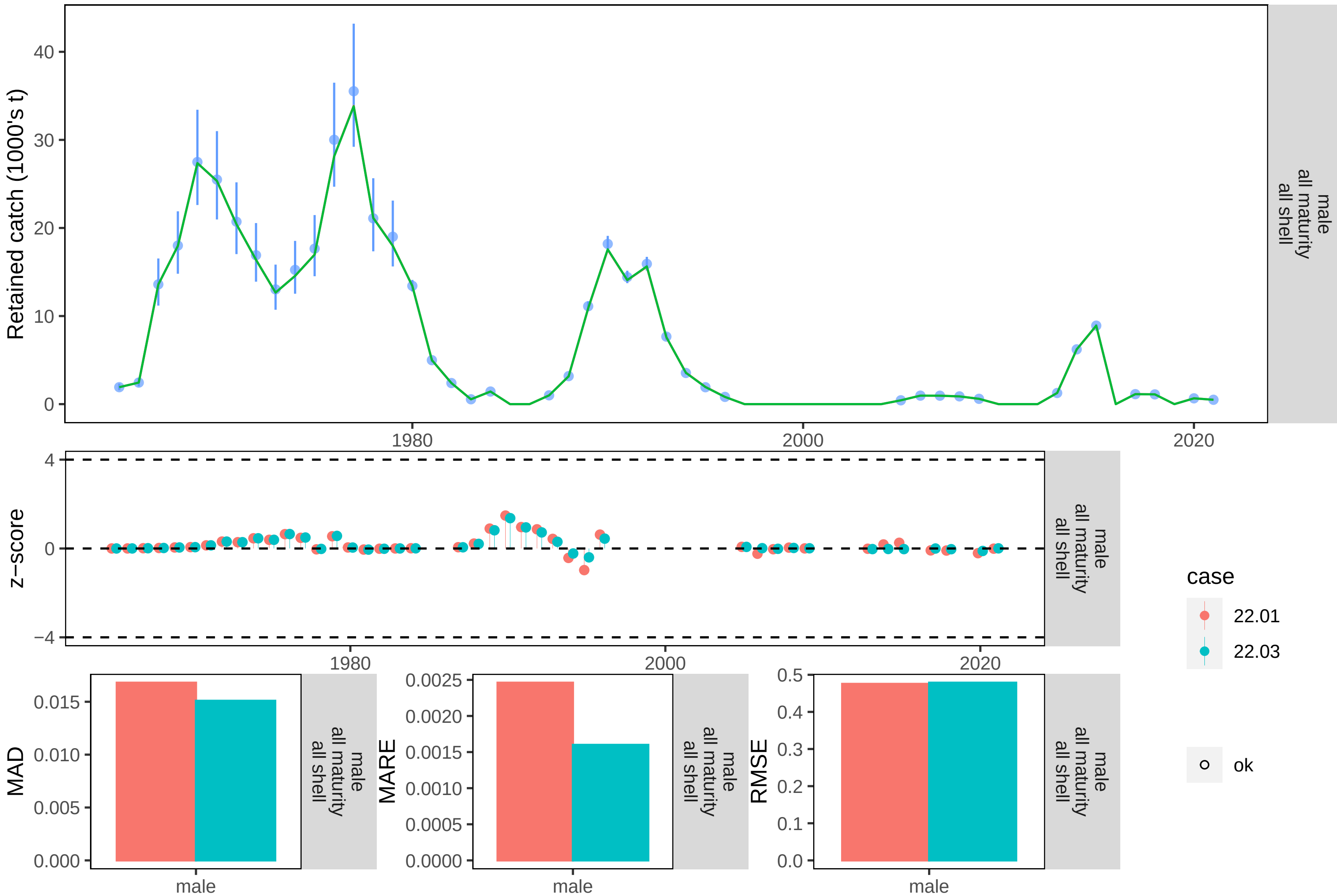

Figure 53: Fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

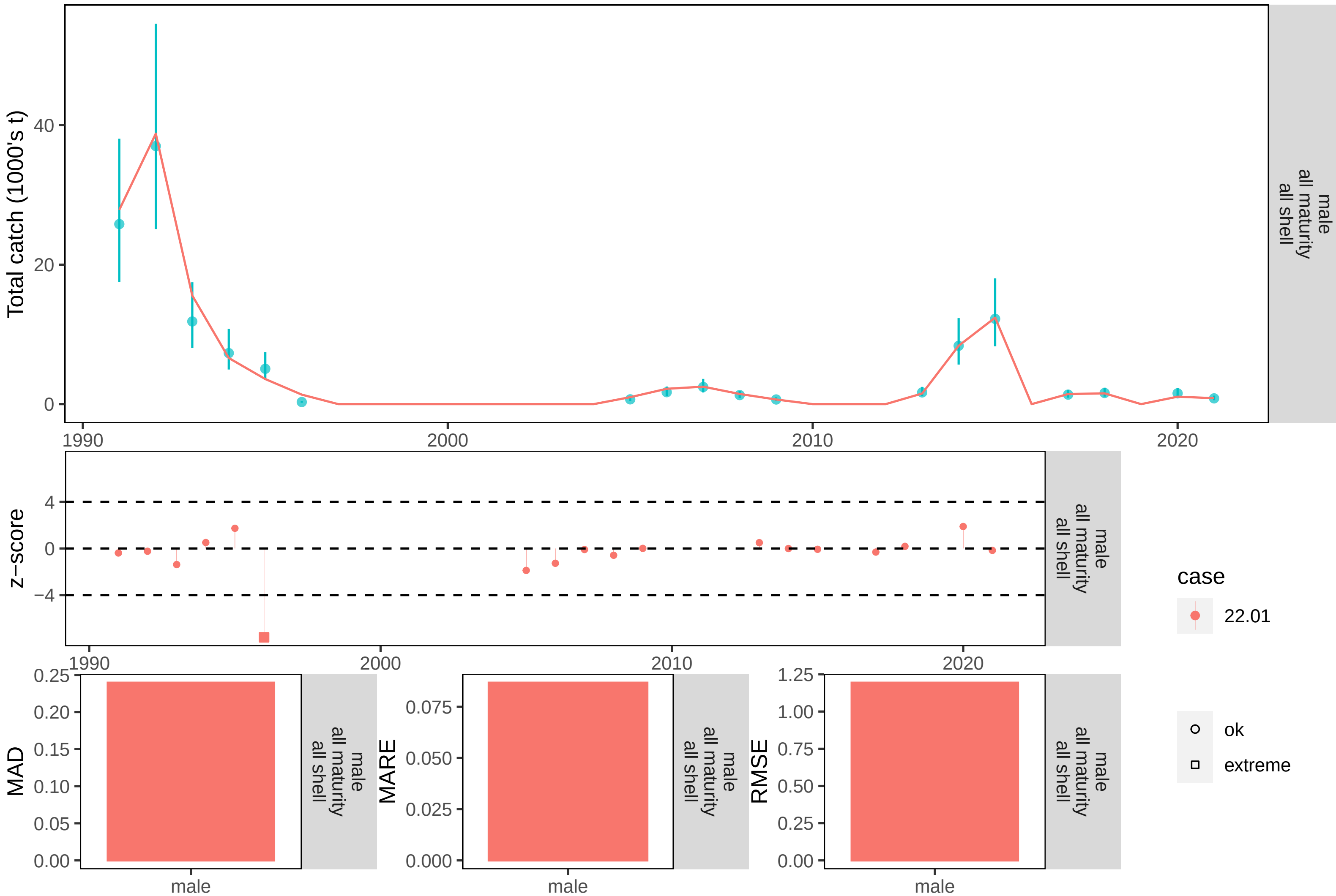

Figure 54: Fits to total catch biomass for male crab in the TCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

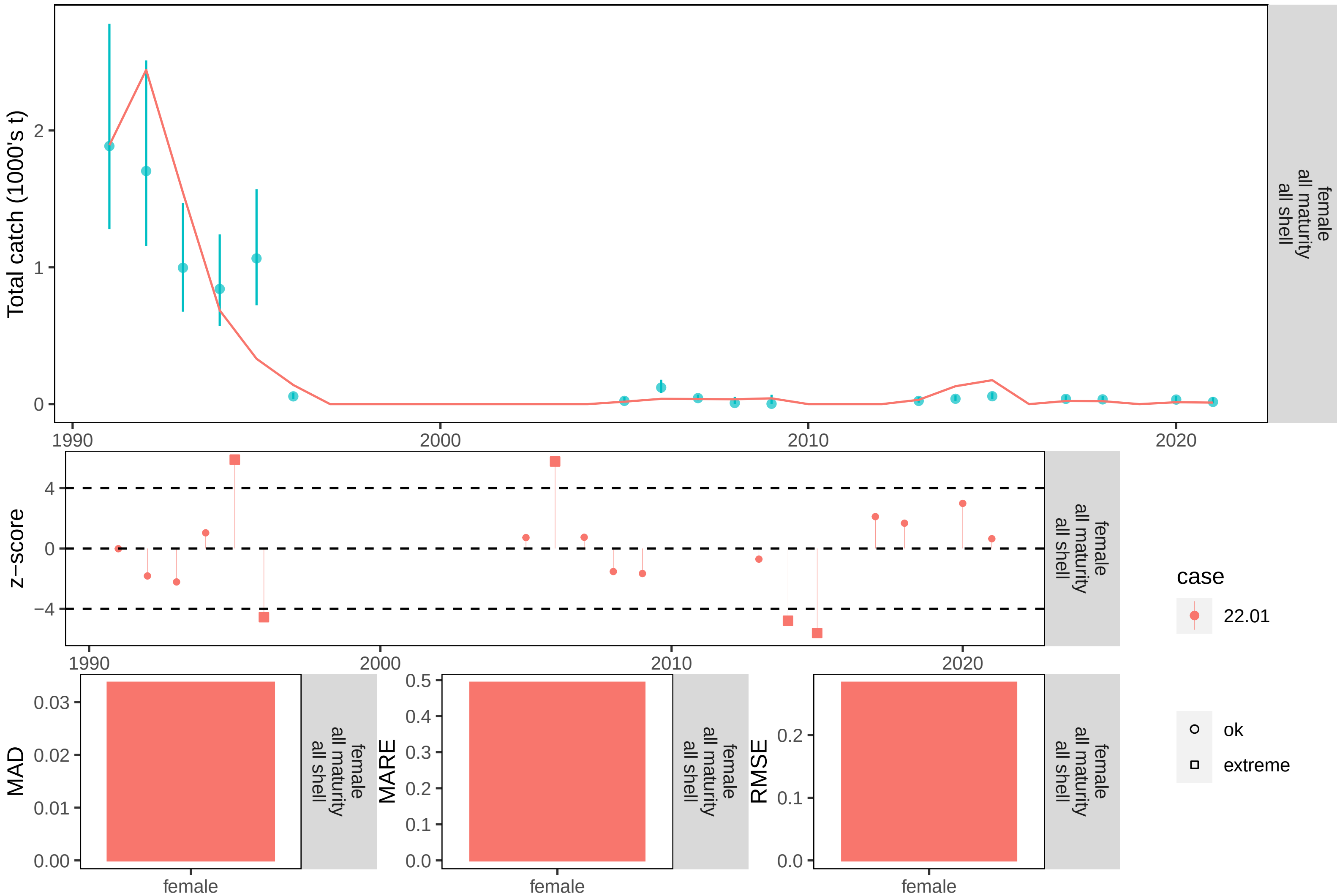

Figure 55: Fits to total catch biomass of female crab in the TCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

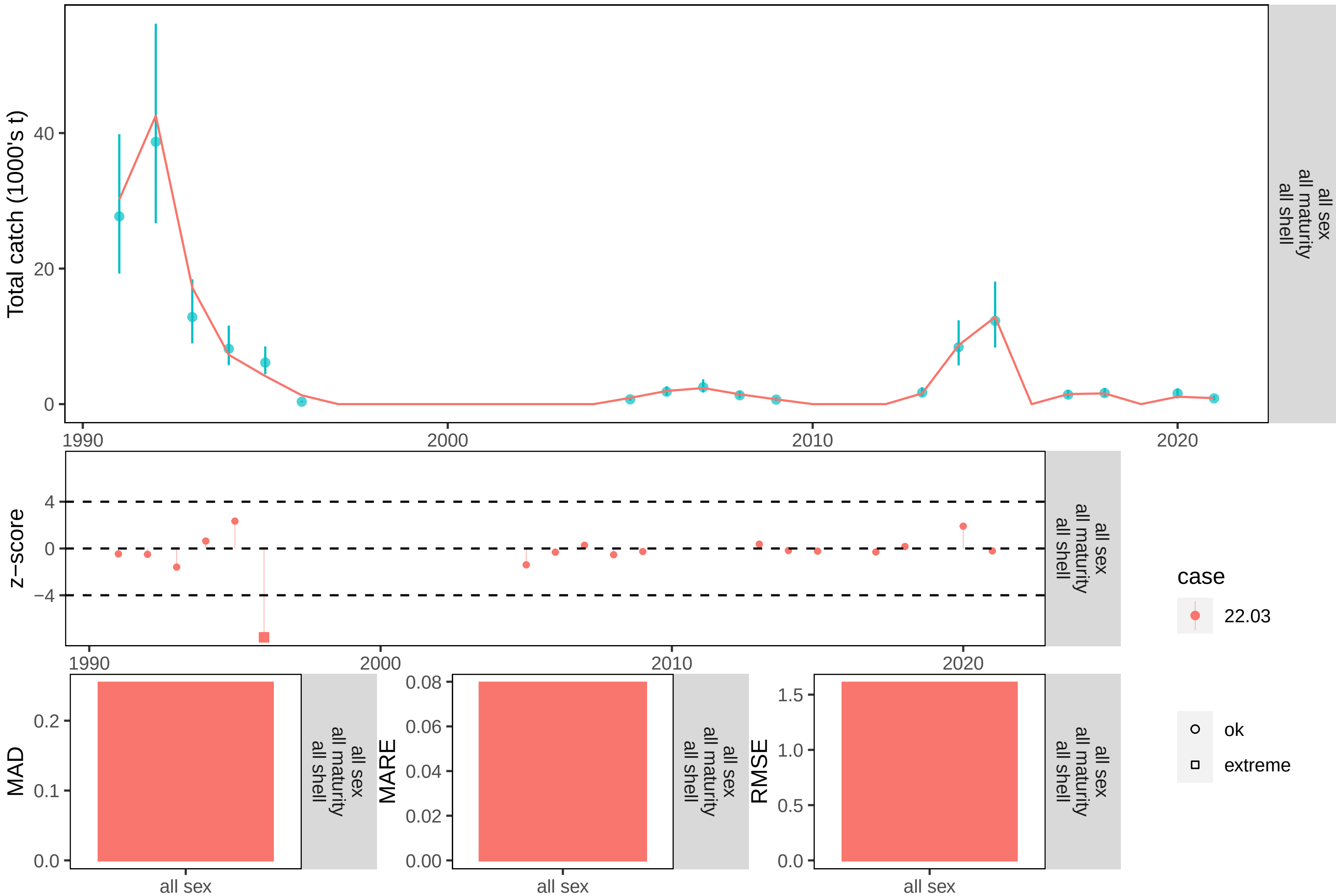

Figure 56: Fits to total catch biomass of all crab in the TCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

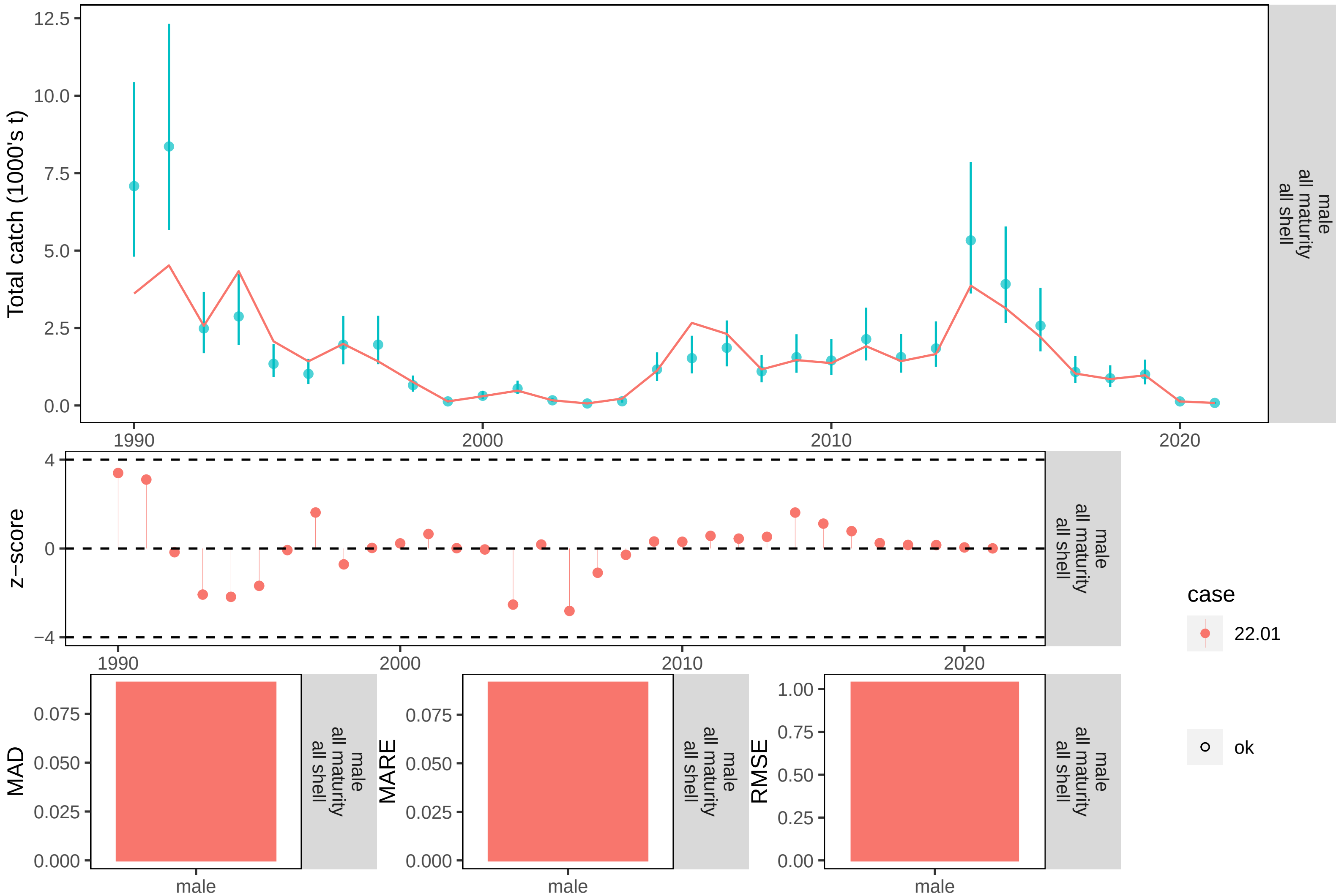

Figure 57: Fits to total catch biomass for male crab in the SCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

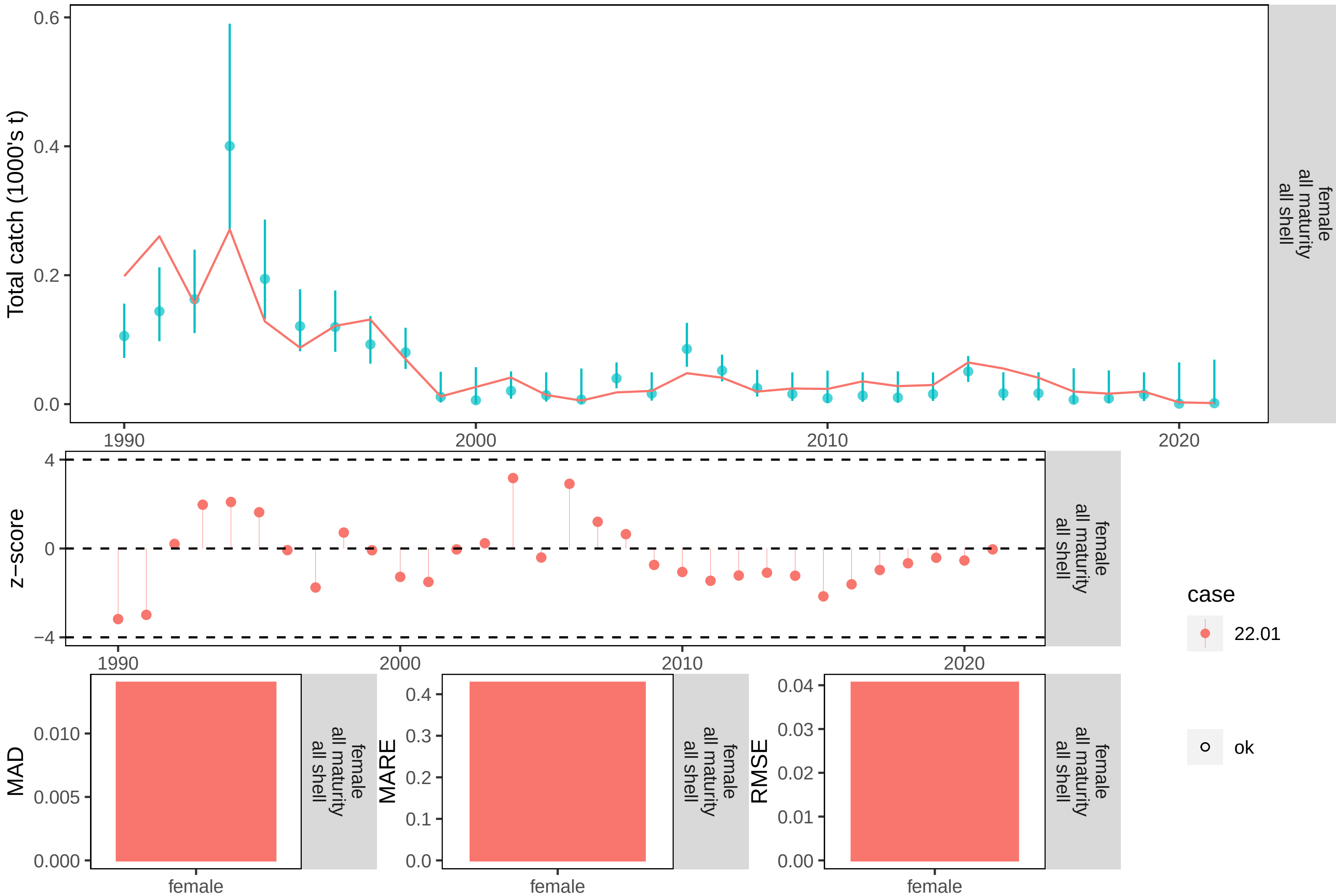

Figure 58: Fits to total catch biomass of female crab in the SCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

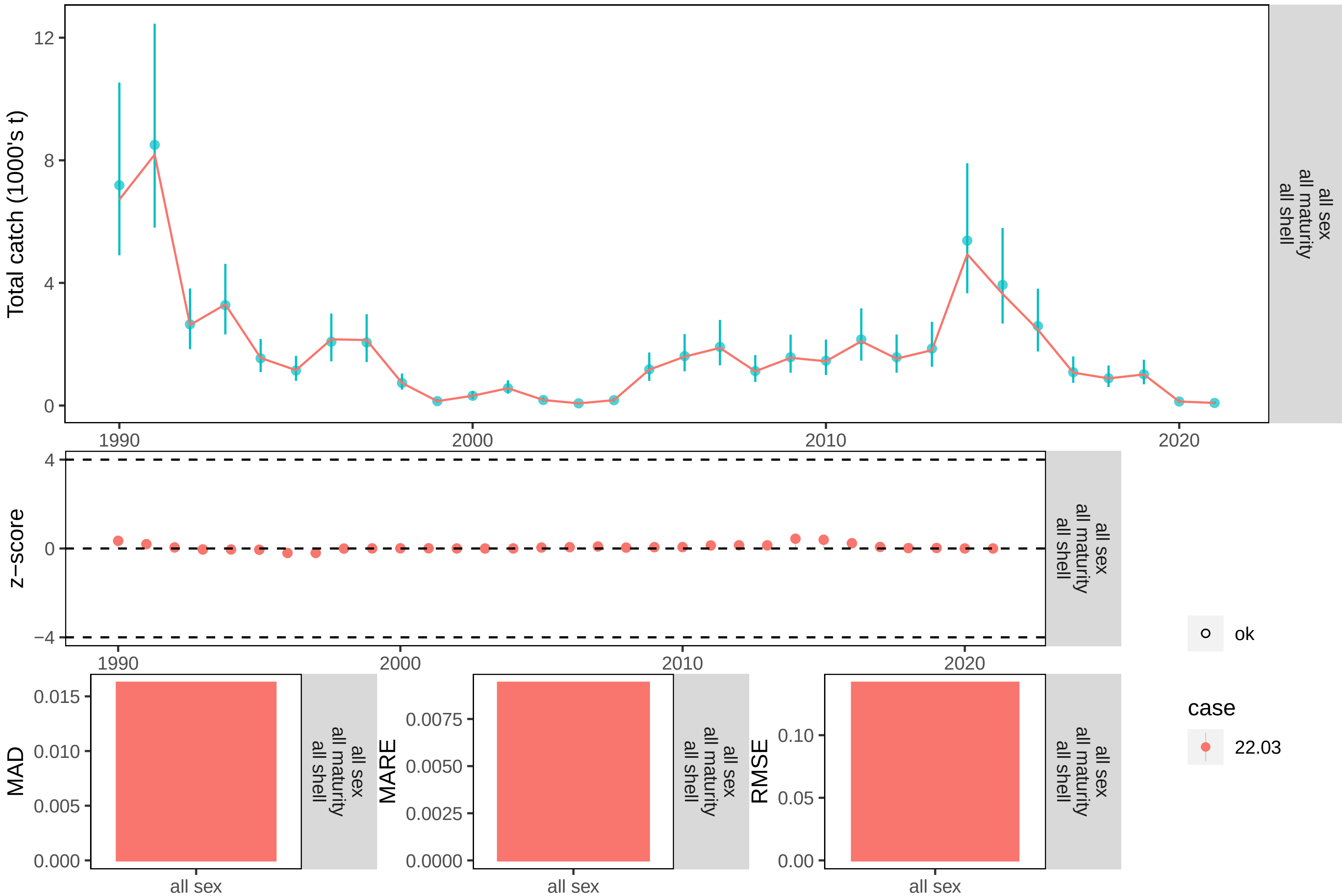

Figure 59: Fits to total catch biomass of all crab in the SCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

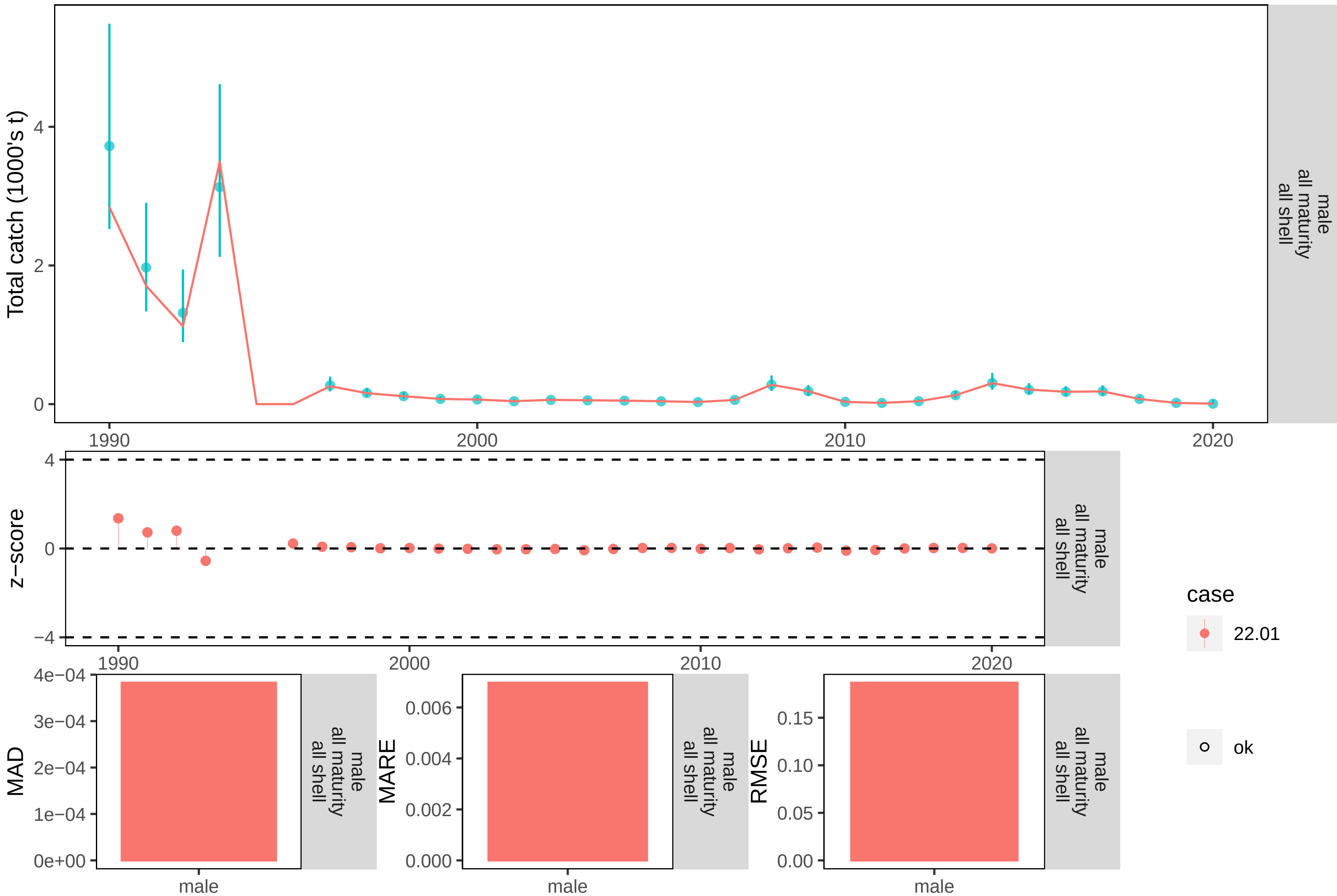

Figure 60: Fits to total catch biomass for male crab in the RKF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

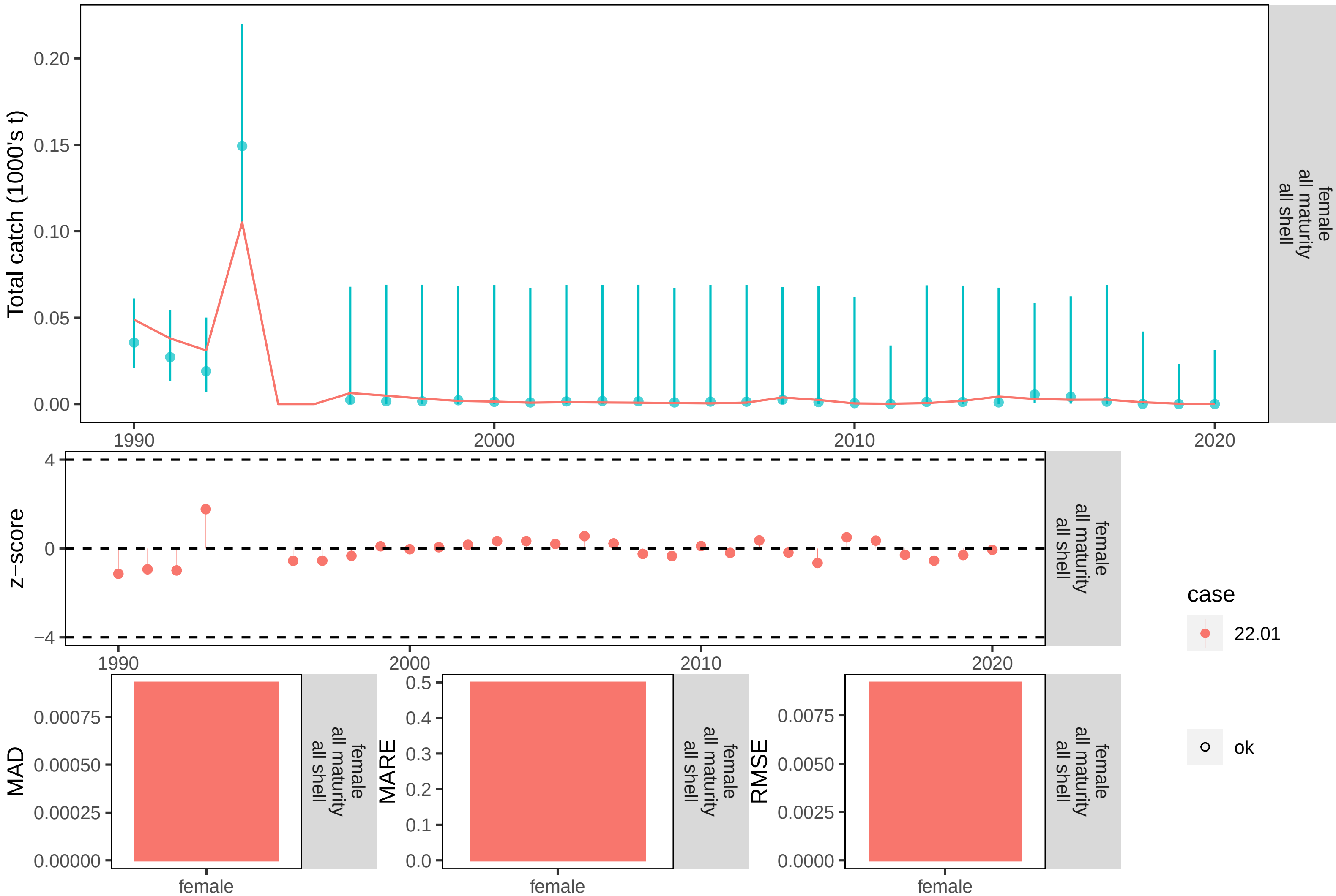

Figure 61: Fits to total catch biomass of female crab in the RKF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

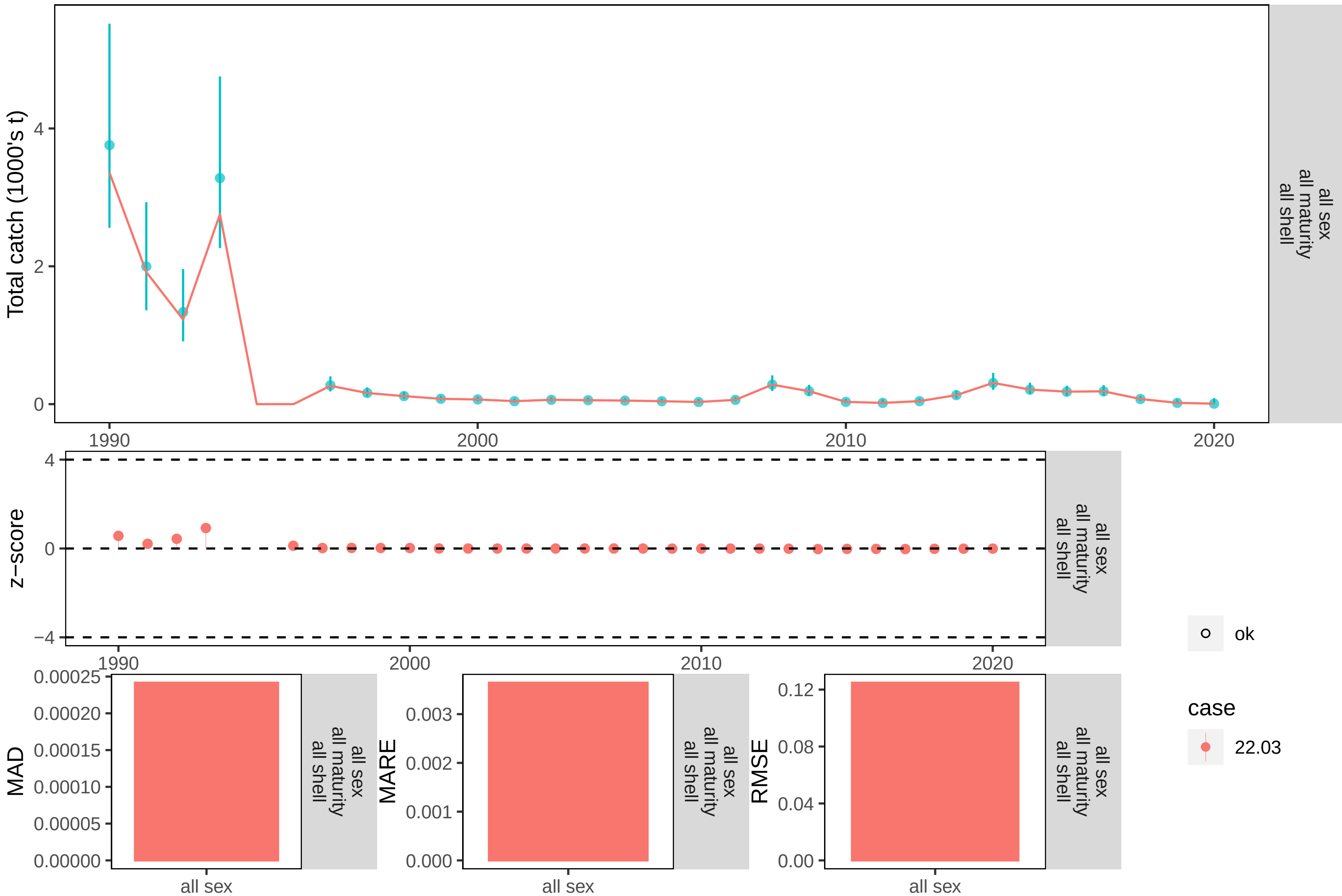

Figure 62: Fits to total catch biomass of all crab in the RKF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

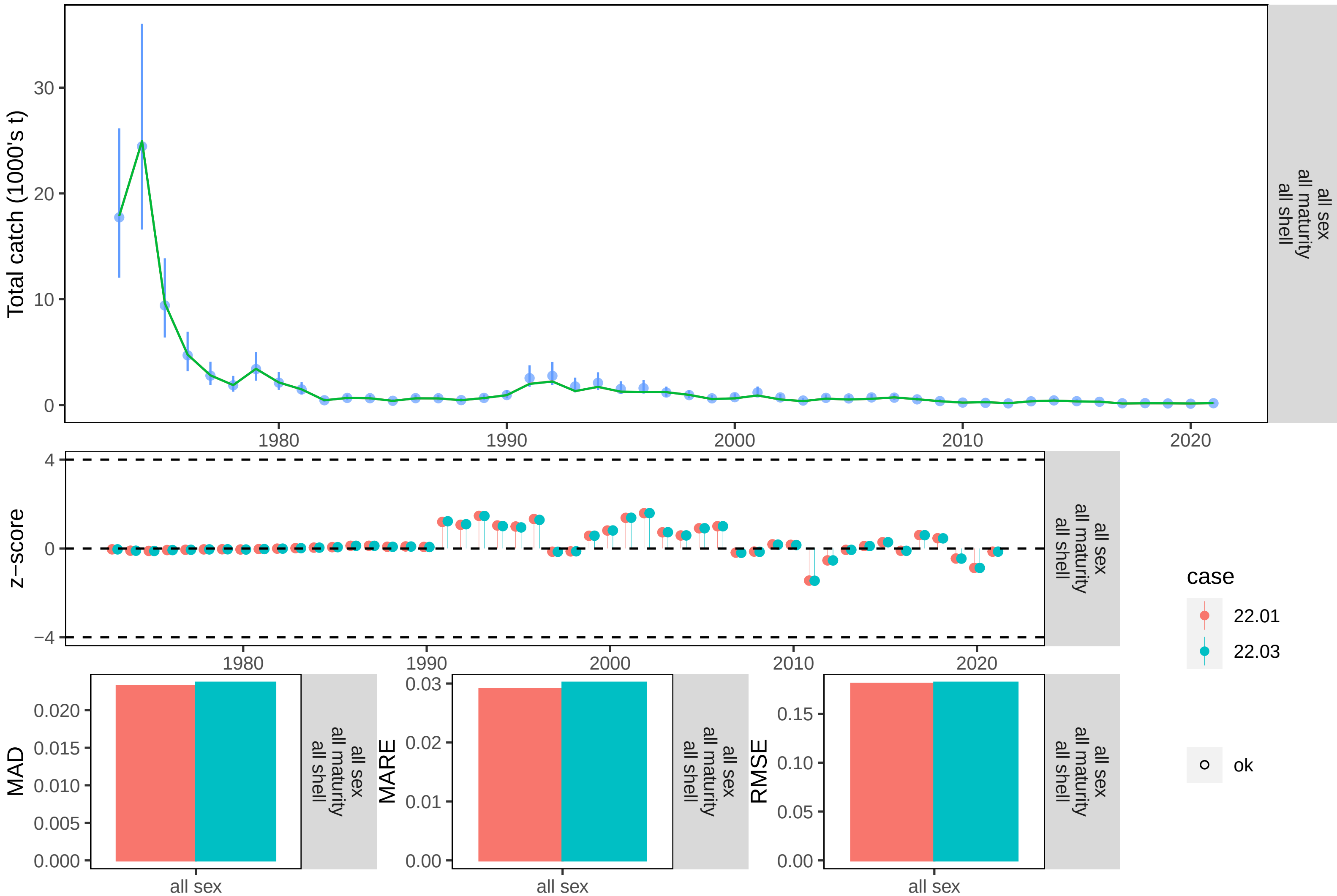

Figure 63: Fits to total catch biomass of all crab in the GF All fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

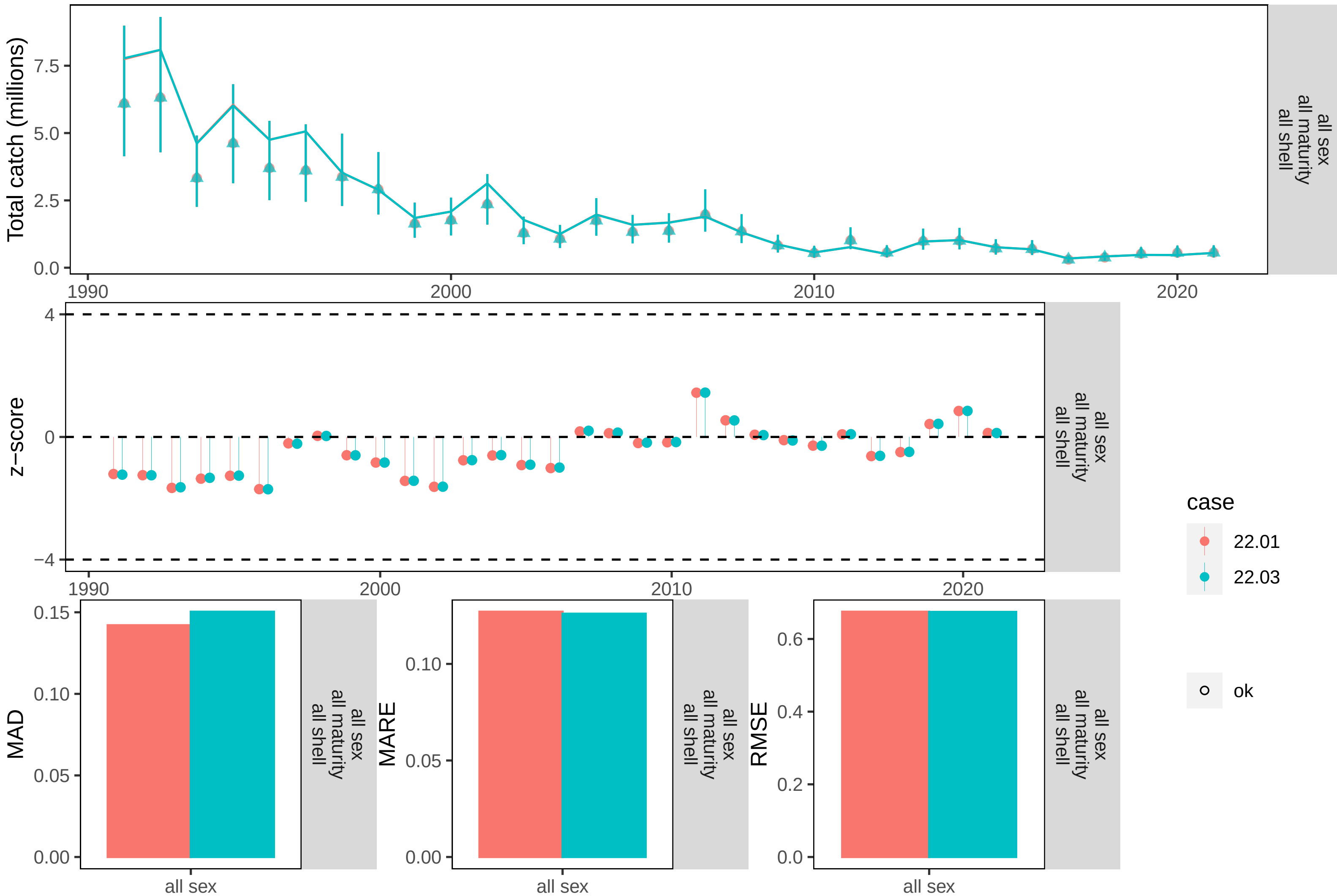

Figure 64: Fits to total catch abundance of all crab in the GF All fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%.

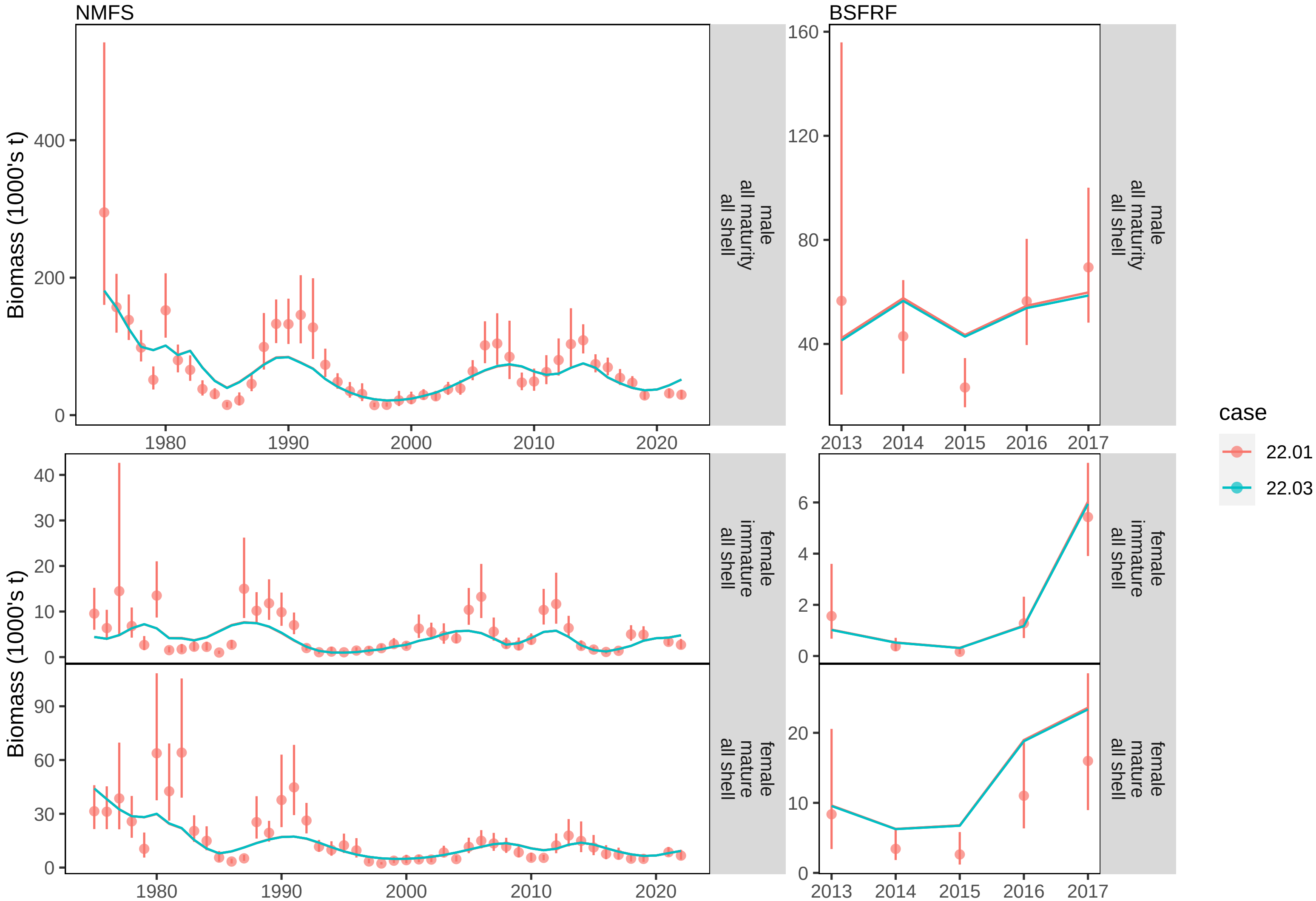

Figure 65: Fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) biomass from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Confidence intervals are 95%.

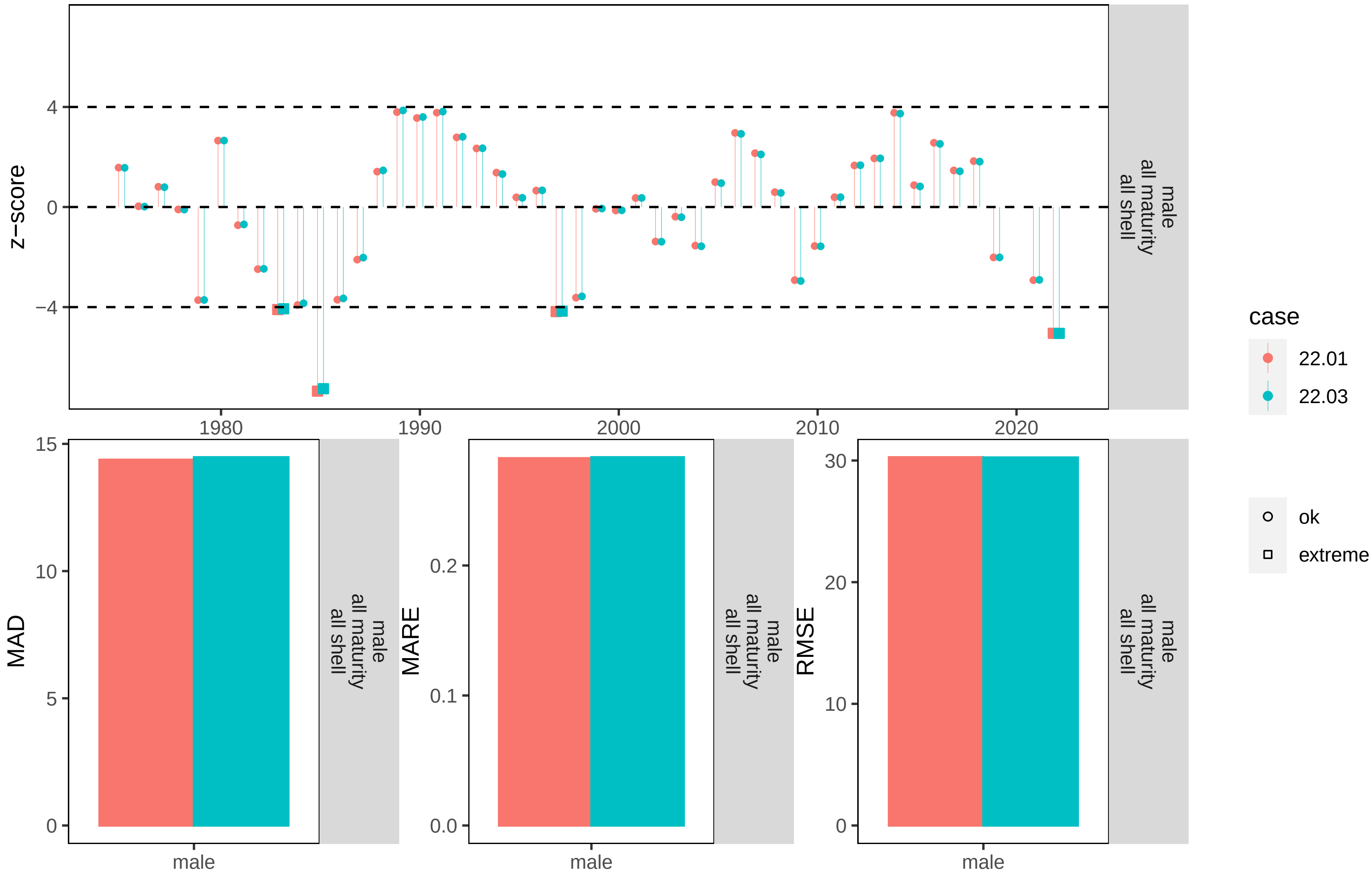

Figure 66: Residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

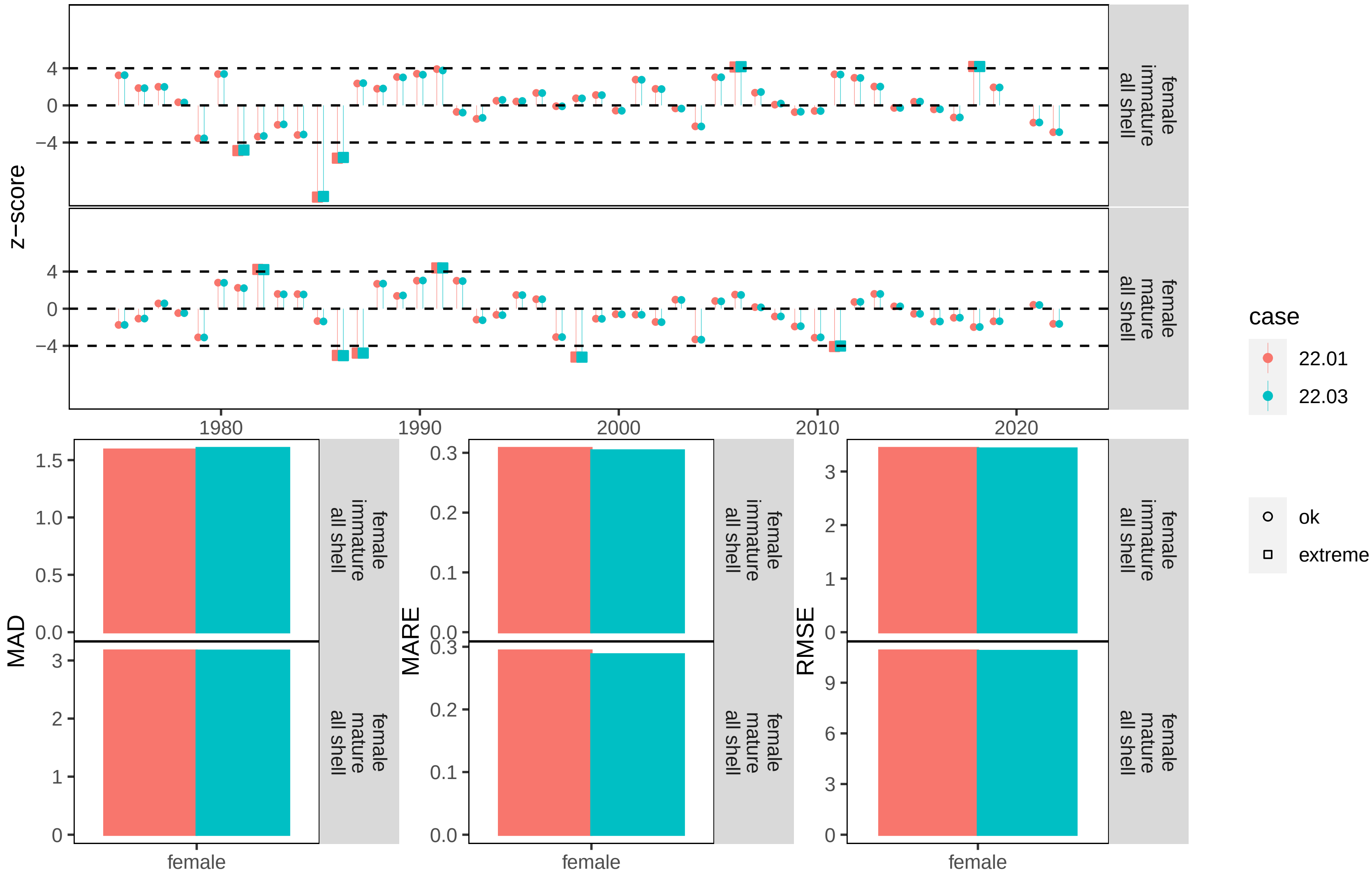

Figure 67: Residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

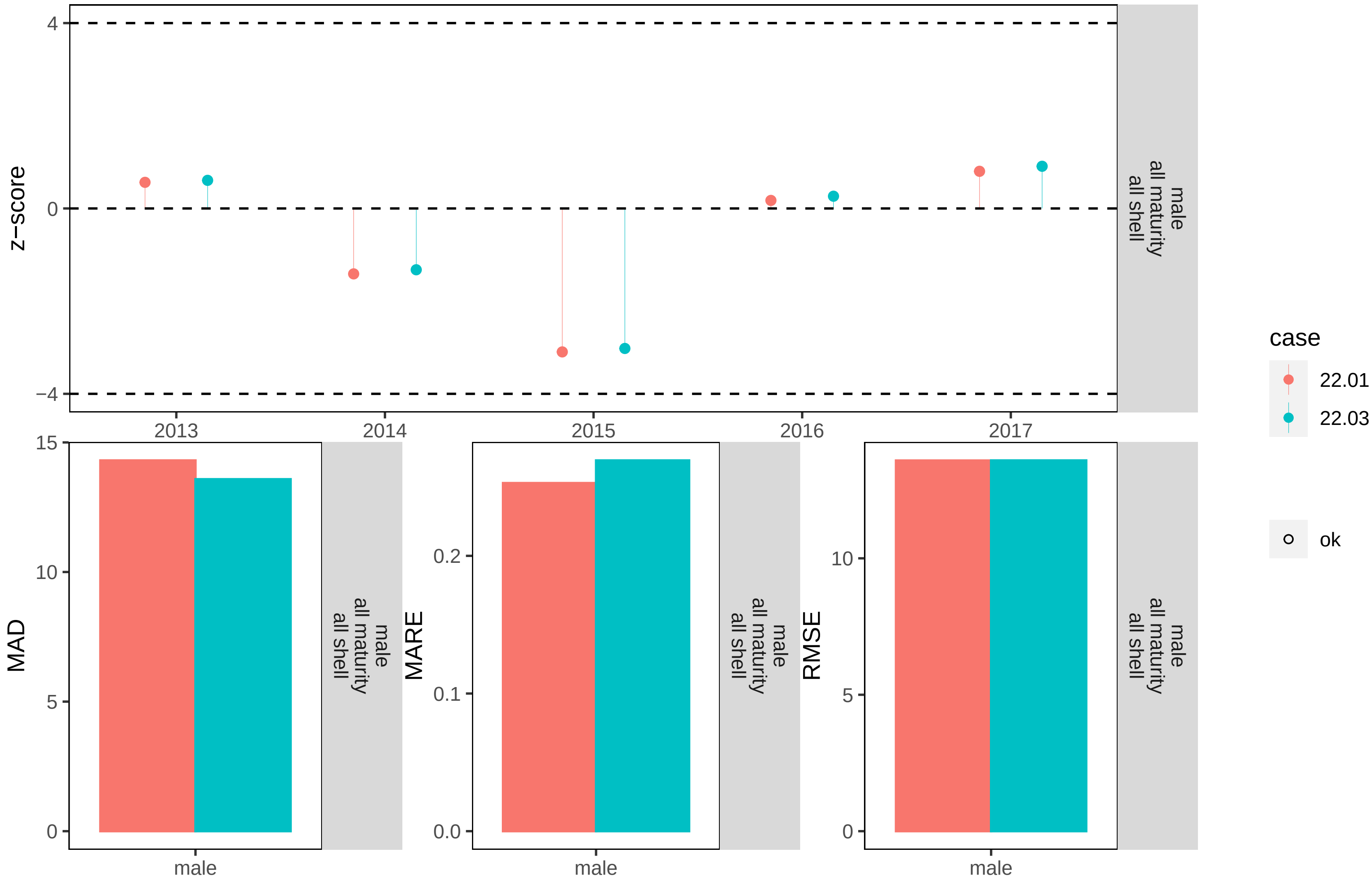

Figure 68: Residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

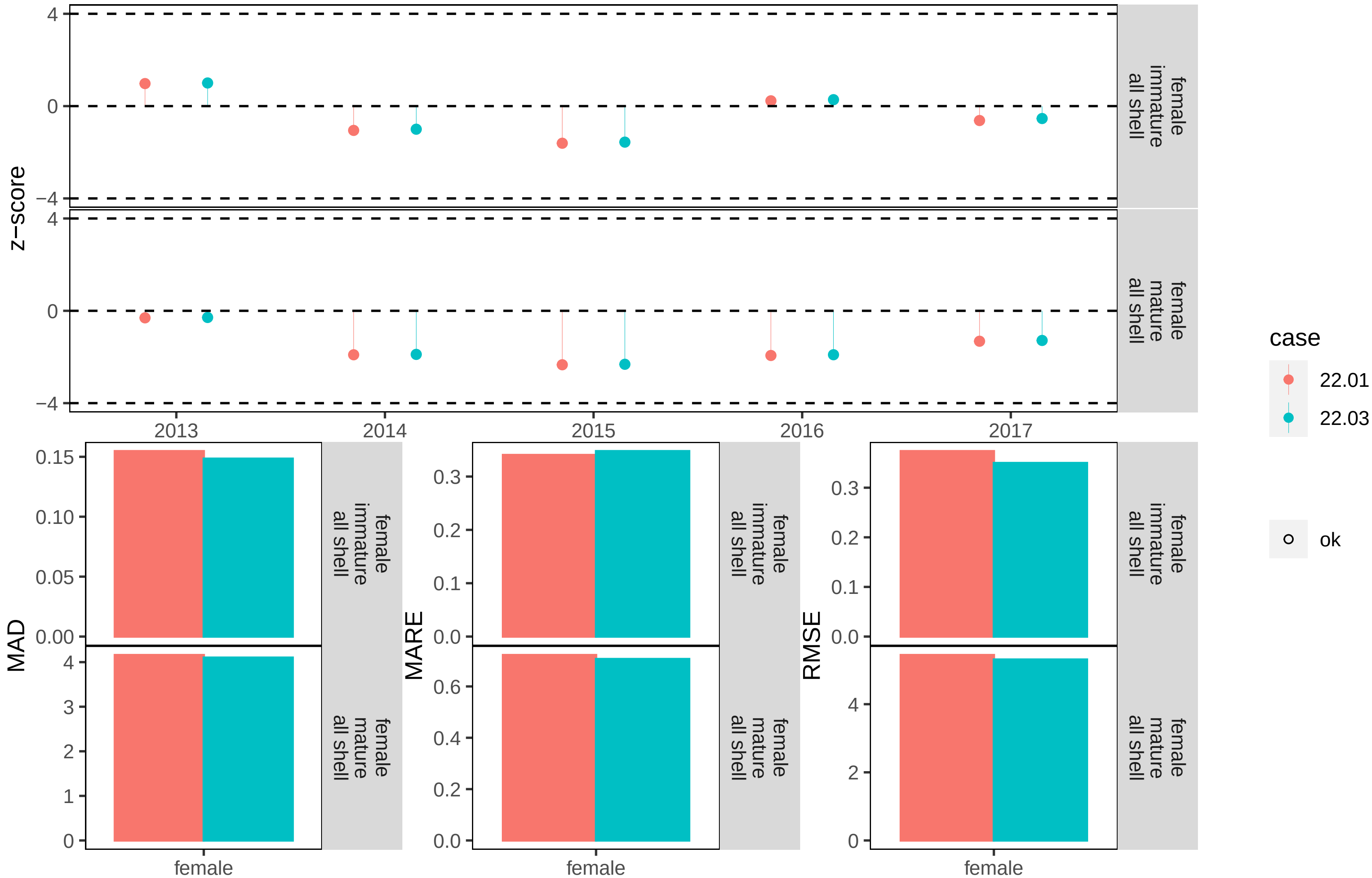

Figure 69: Residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

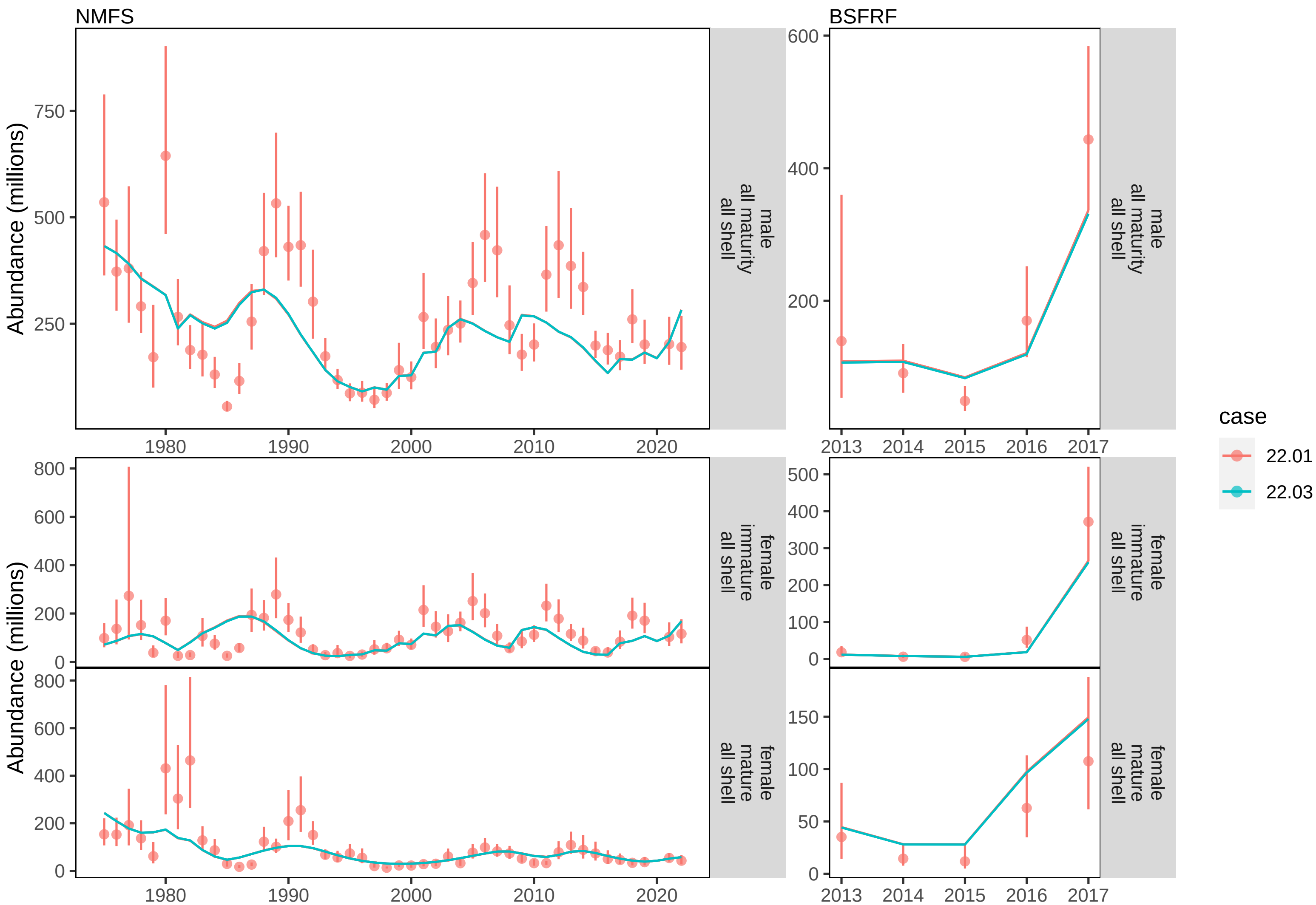

Figure 70: Fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) abundance from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Note that these fits are not included in the model objective function and simply provide a diagnostic check. Confidence intervals are 95%.

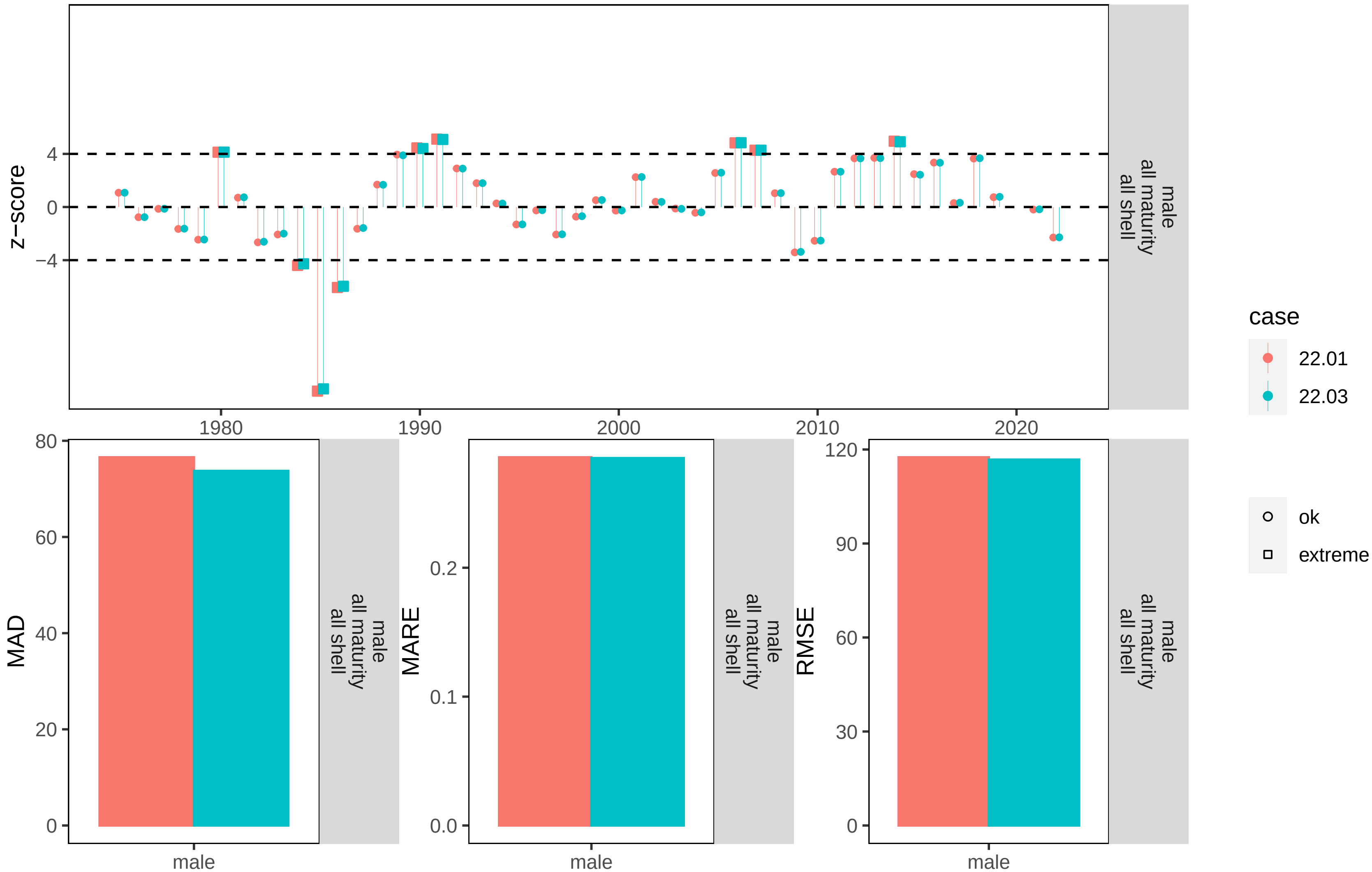

Figure 71: Residuals analysis by model scenario for fits to male abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

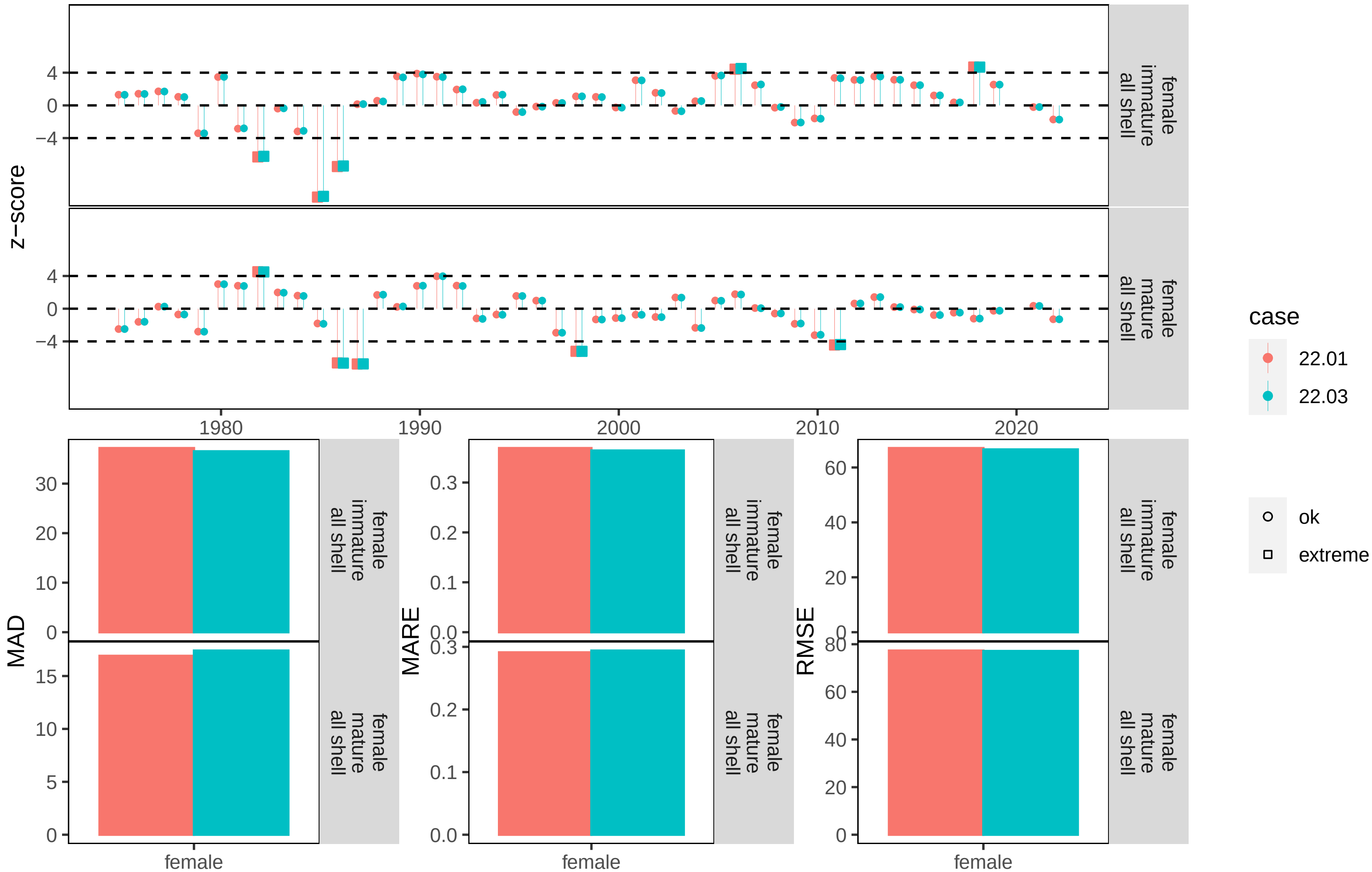

Figure 72: Residuals analysis by model scenario for fits to female abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

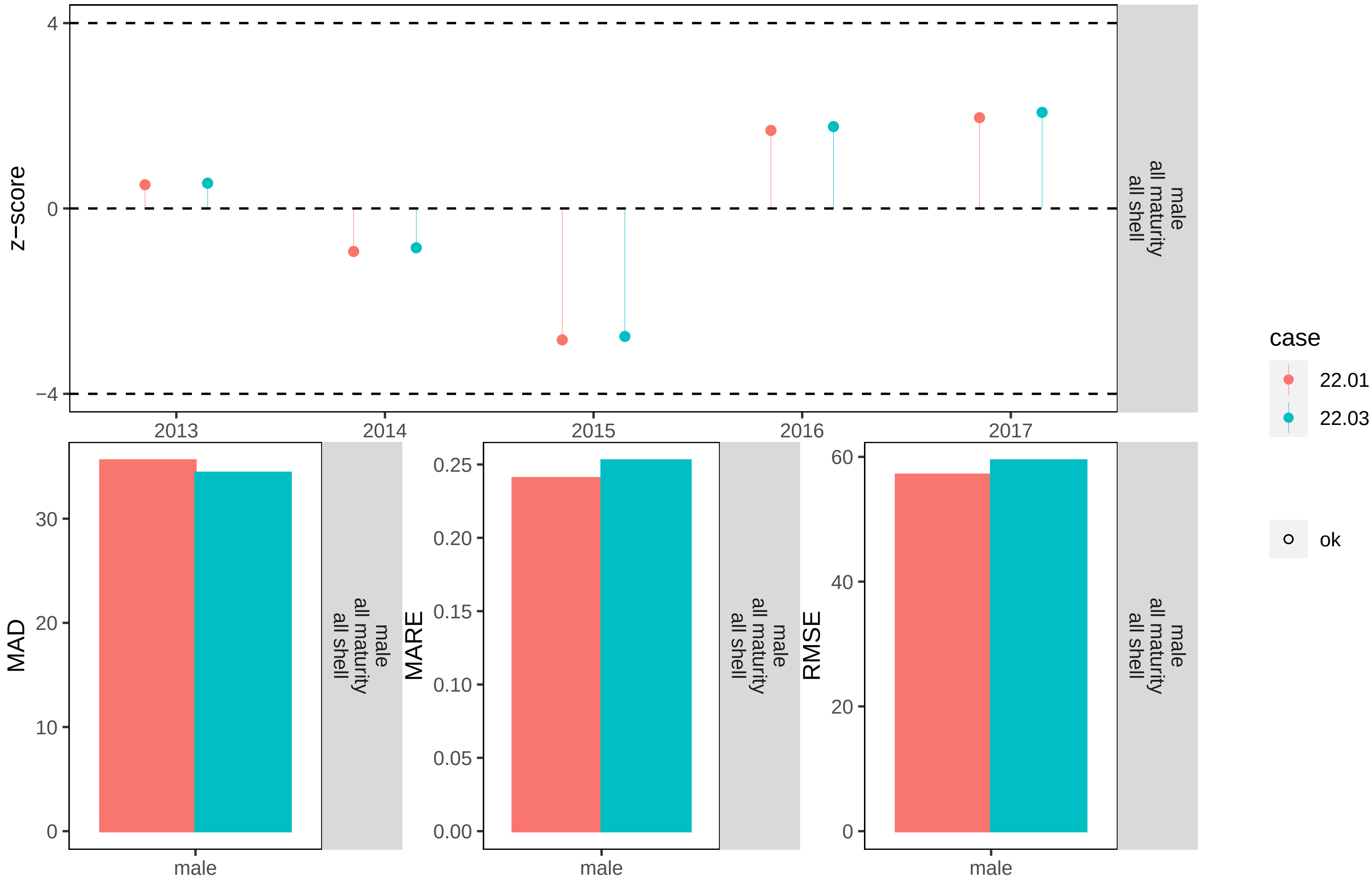

Figure 73: Residuals analysis by model scenario for fits to male abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

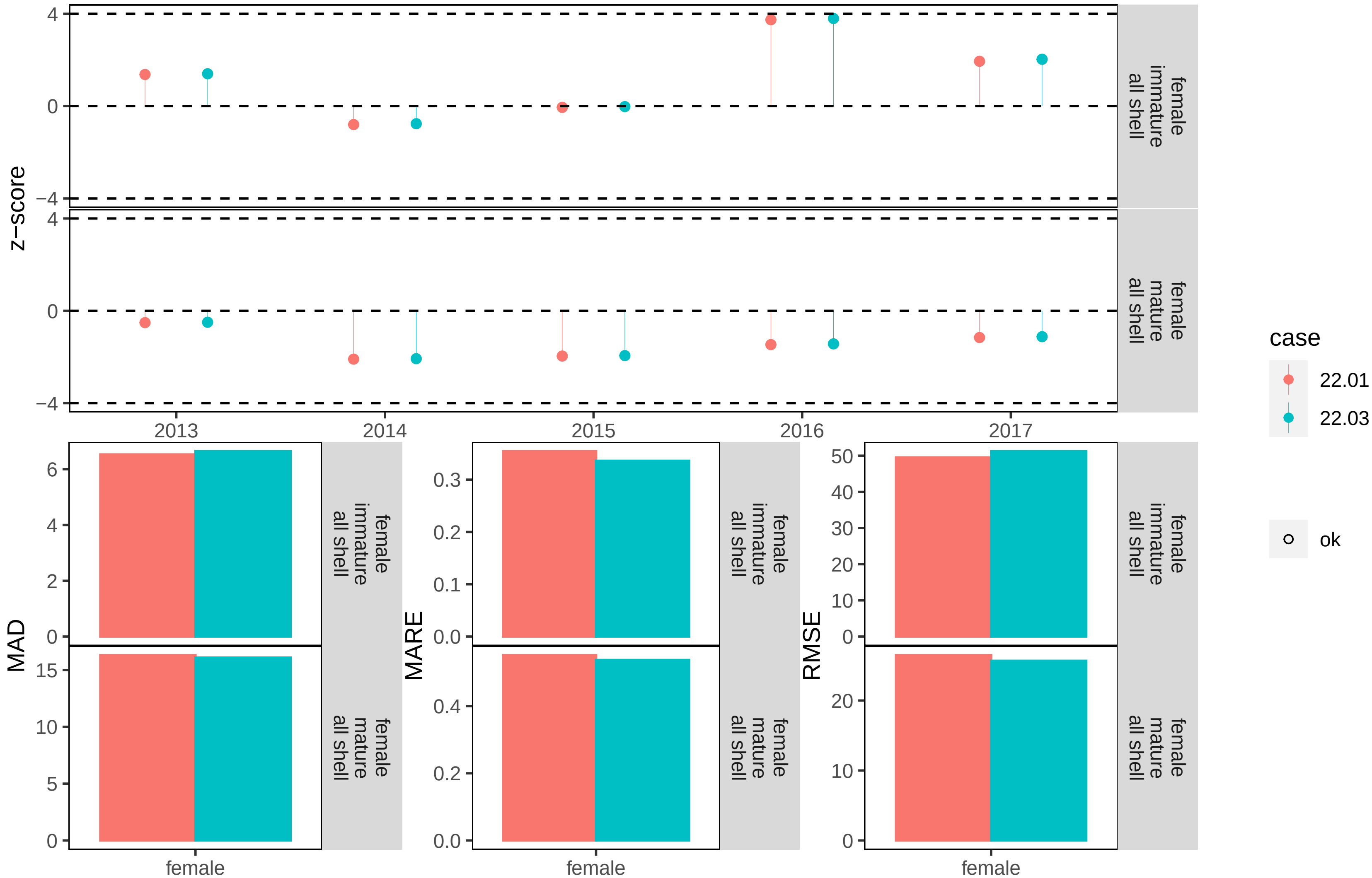

Figure 74: Residuals analysis by model scenario for fits to female abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

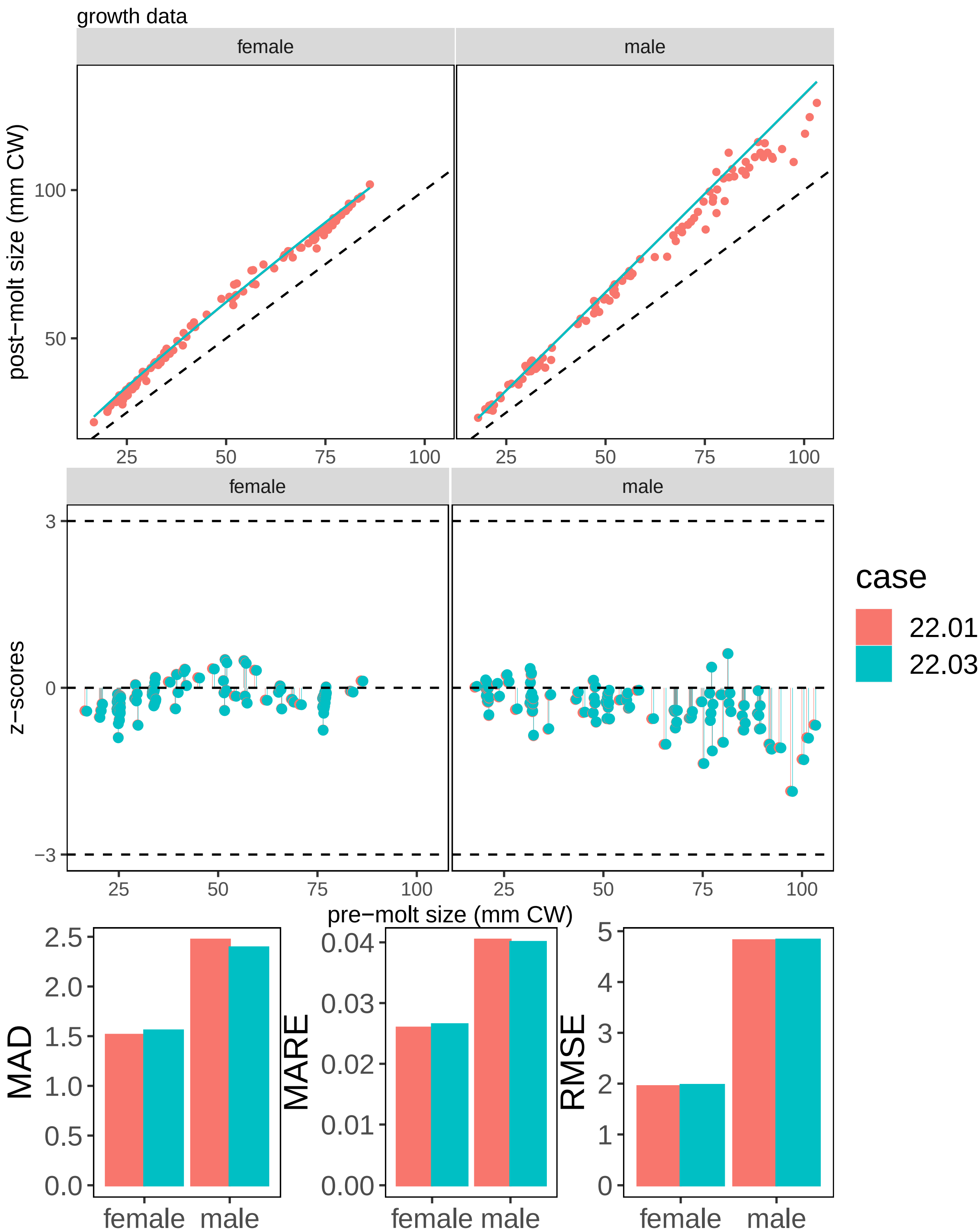

Figure 75: Fits and residuals analysis by model scenario for fits to molt increment data. Upper row: fits to data; center row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

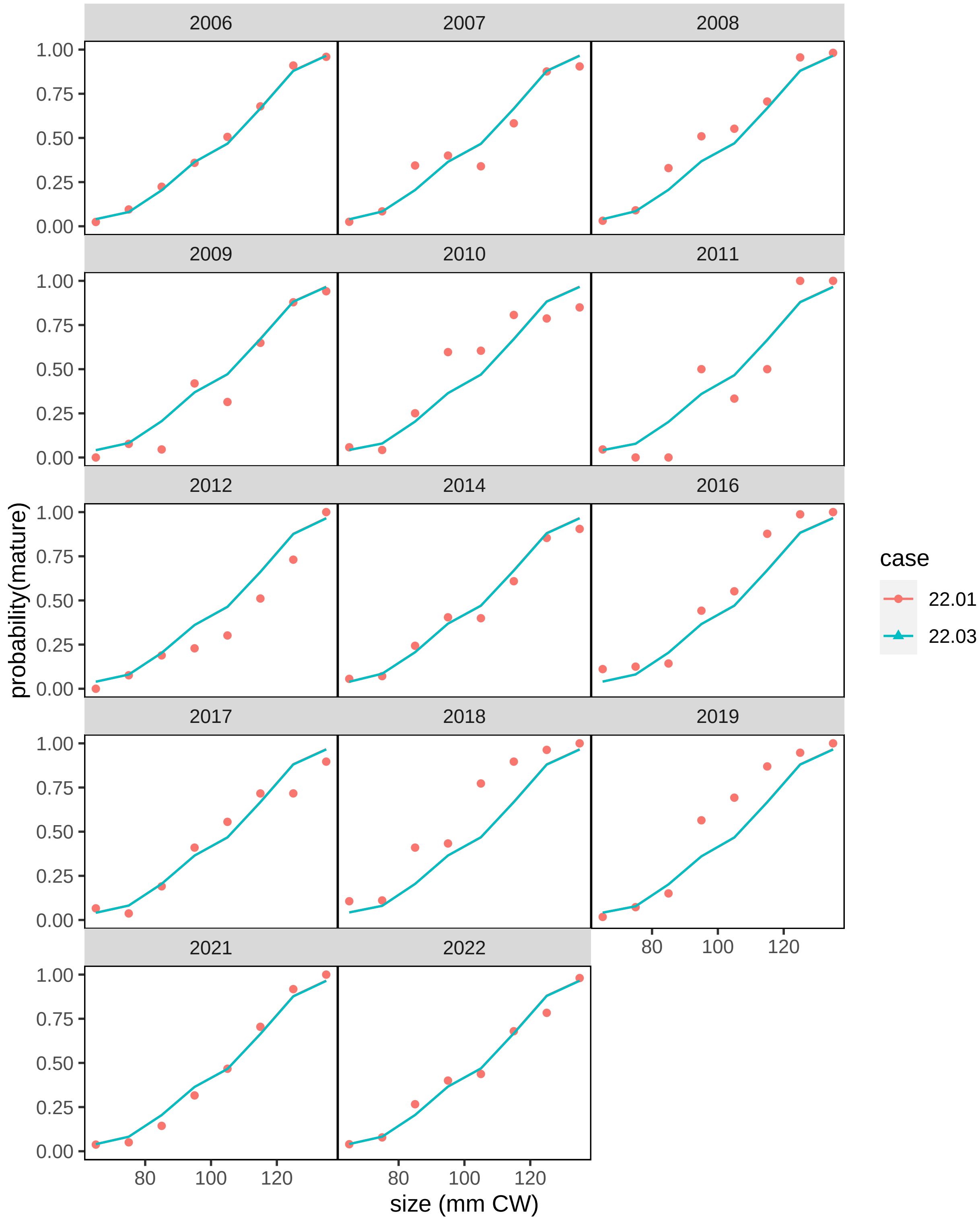

Figure 76: Fits to maturity ogive data by model scenario and year.

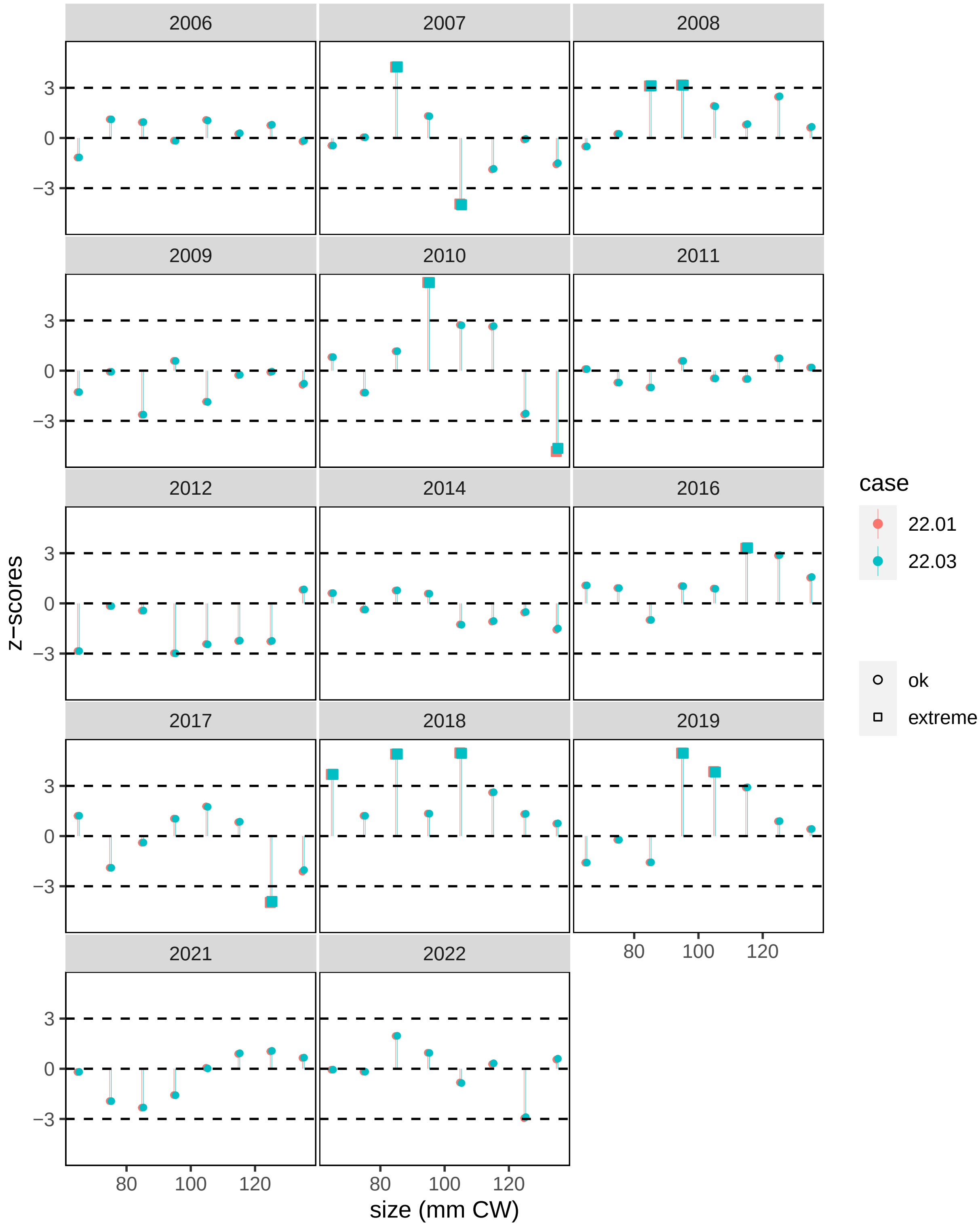

Figure 77: Z-scores for Fits to maturity ogive data, by model scenario and year.

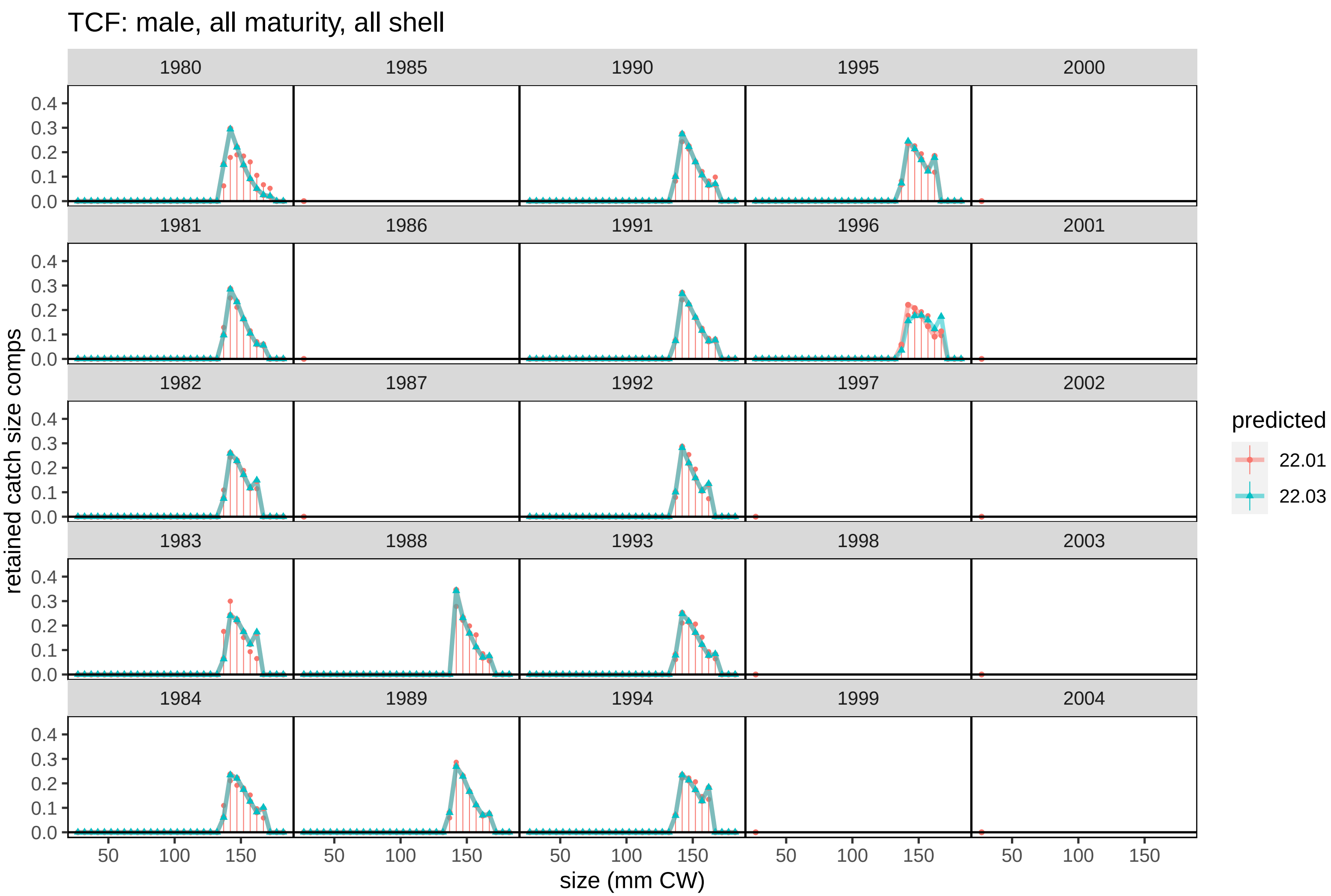

Figure 78: Fits to retained catch size compositiions in the directed fishery. Preferred model is 22.03.

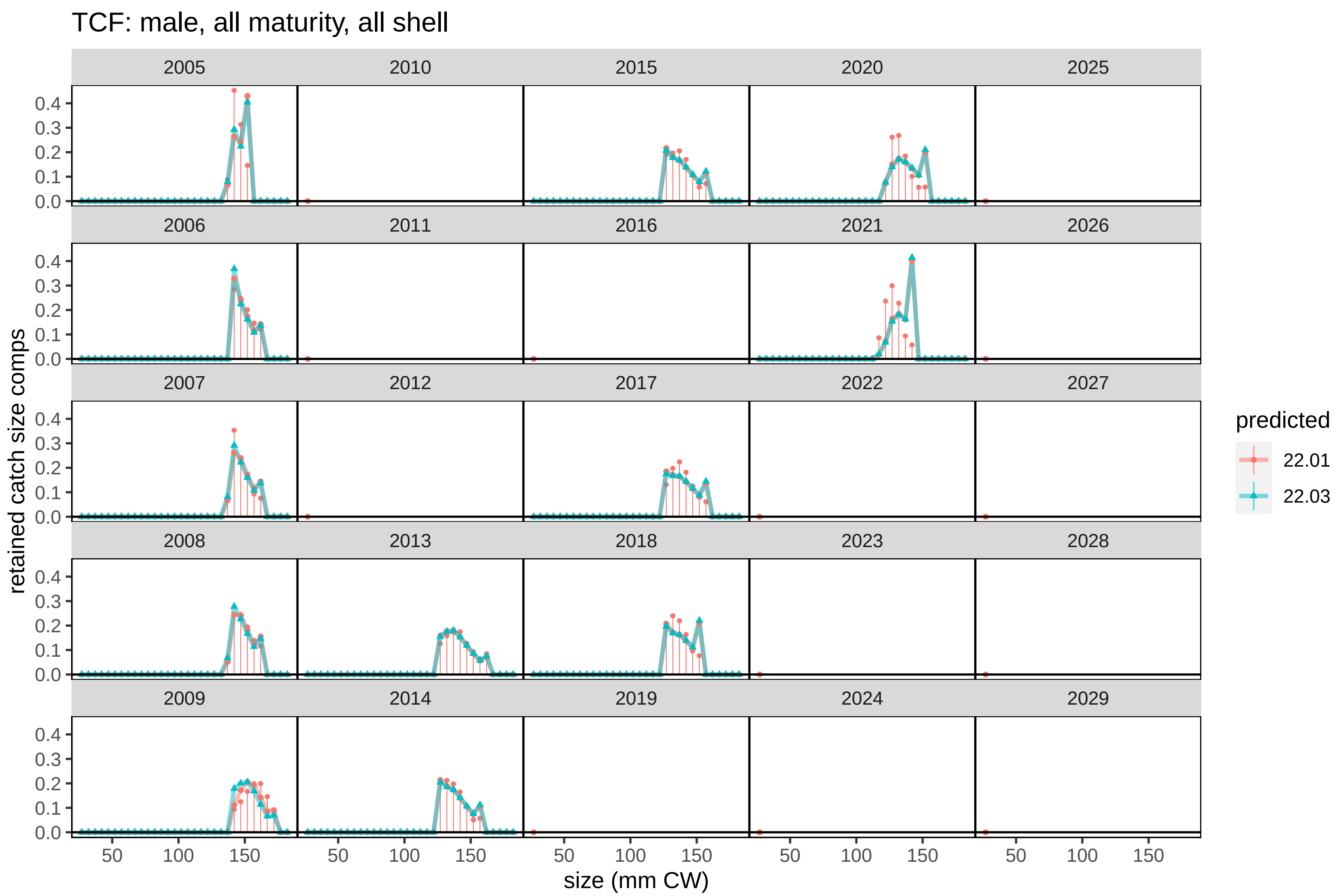

Figure 79: Fits to retained catch size compositiions in the directed fishery. Preferred model is 22.03.

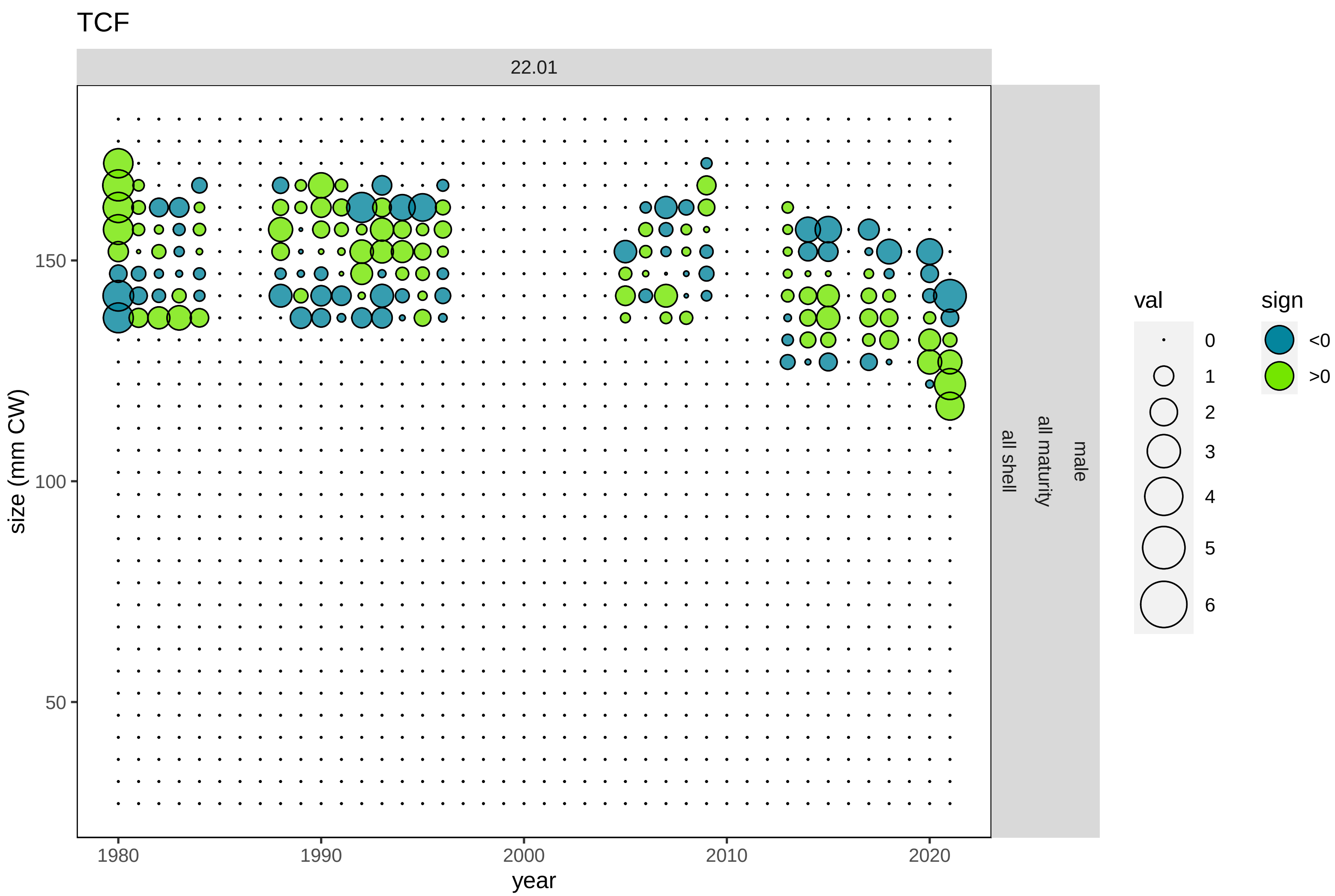

Figure 80: Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

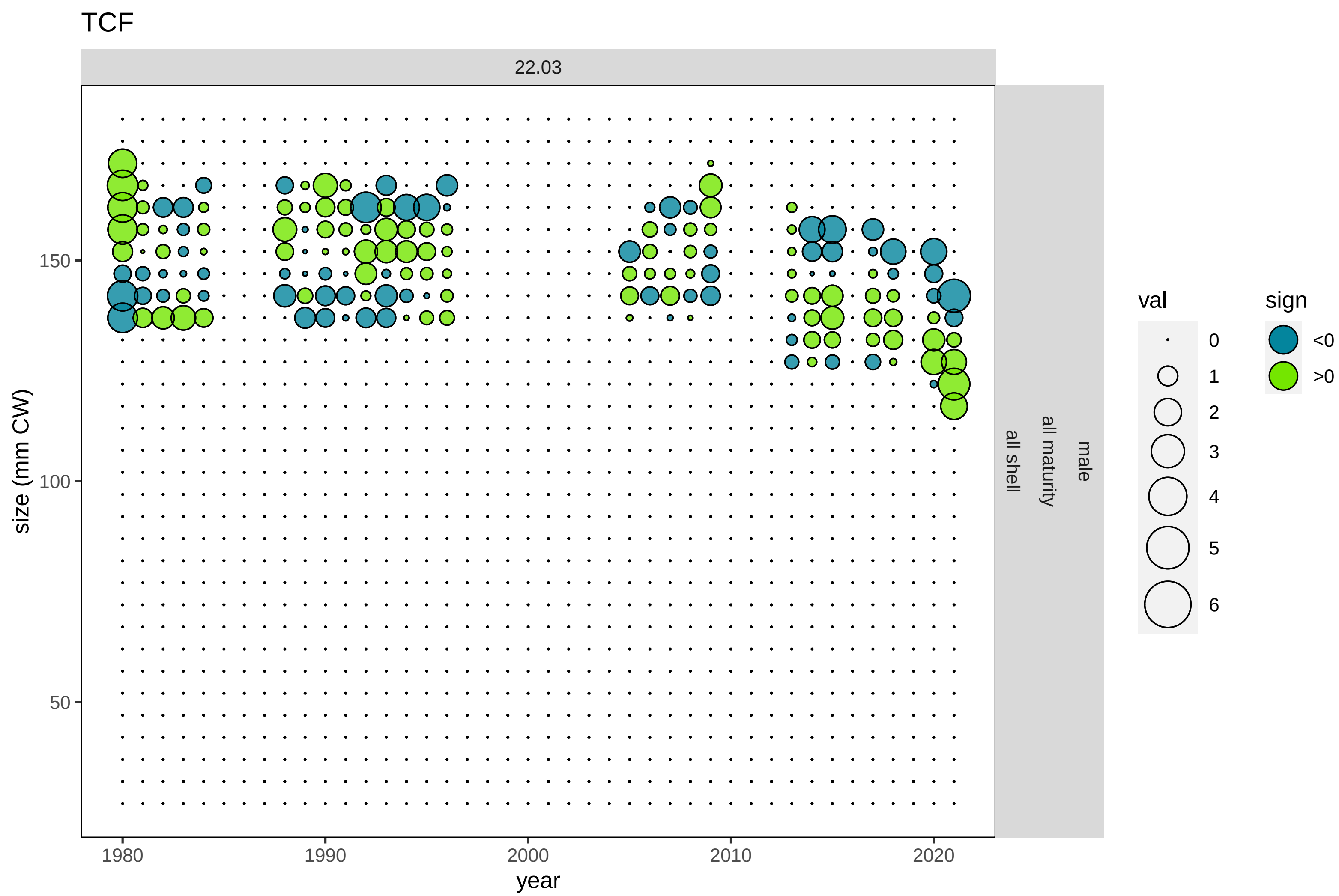

Figure 81: Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

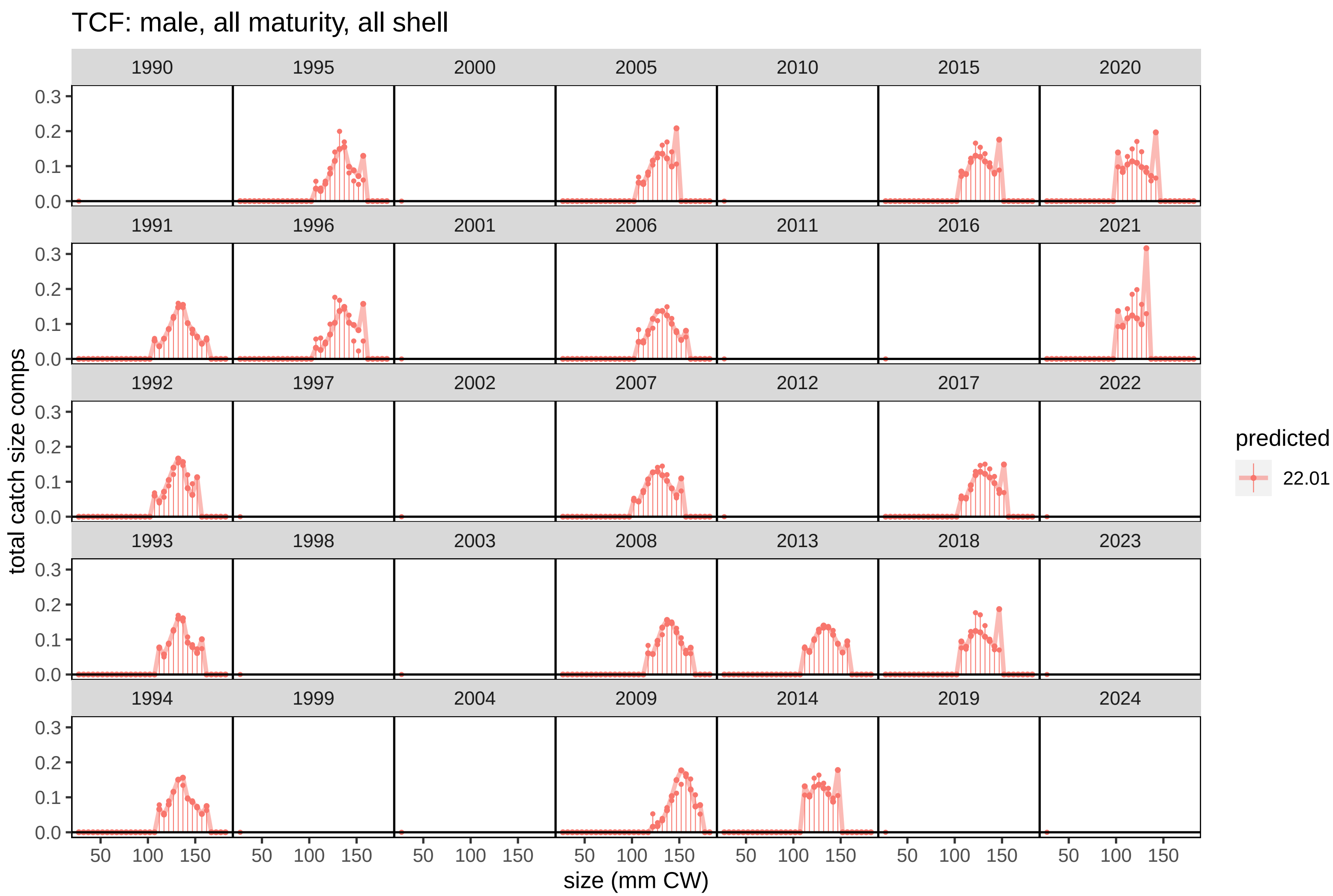

Figure 82: Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03.

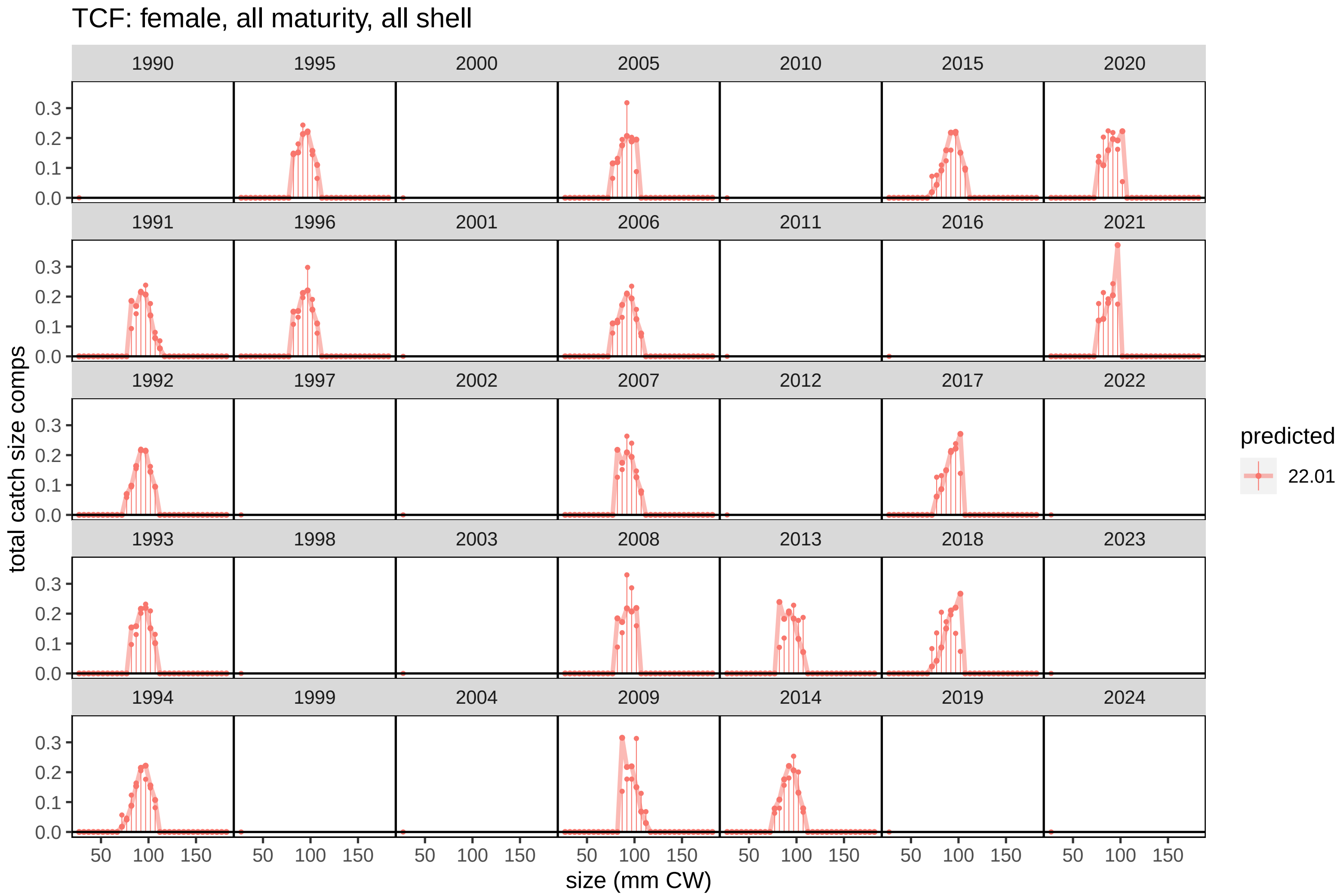

Figure 83: Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03.

Figure 84: Pearson's residuals for fits to total catch size composition data in Model 22.01. 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 22.03.

Figure 85: Pearson's residuals for fits to total catch size composition data in Model 22.01. 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 22.03.

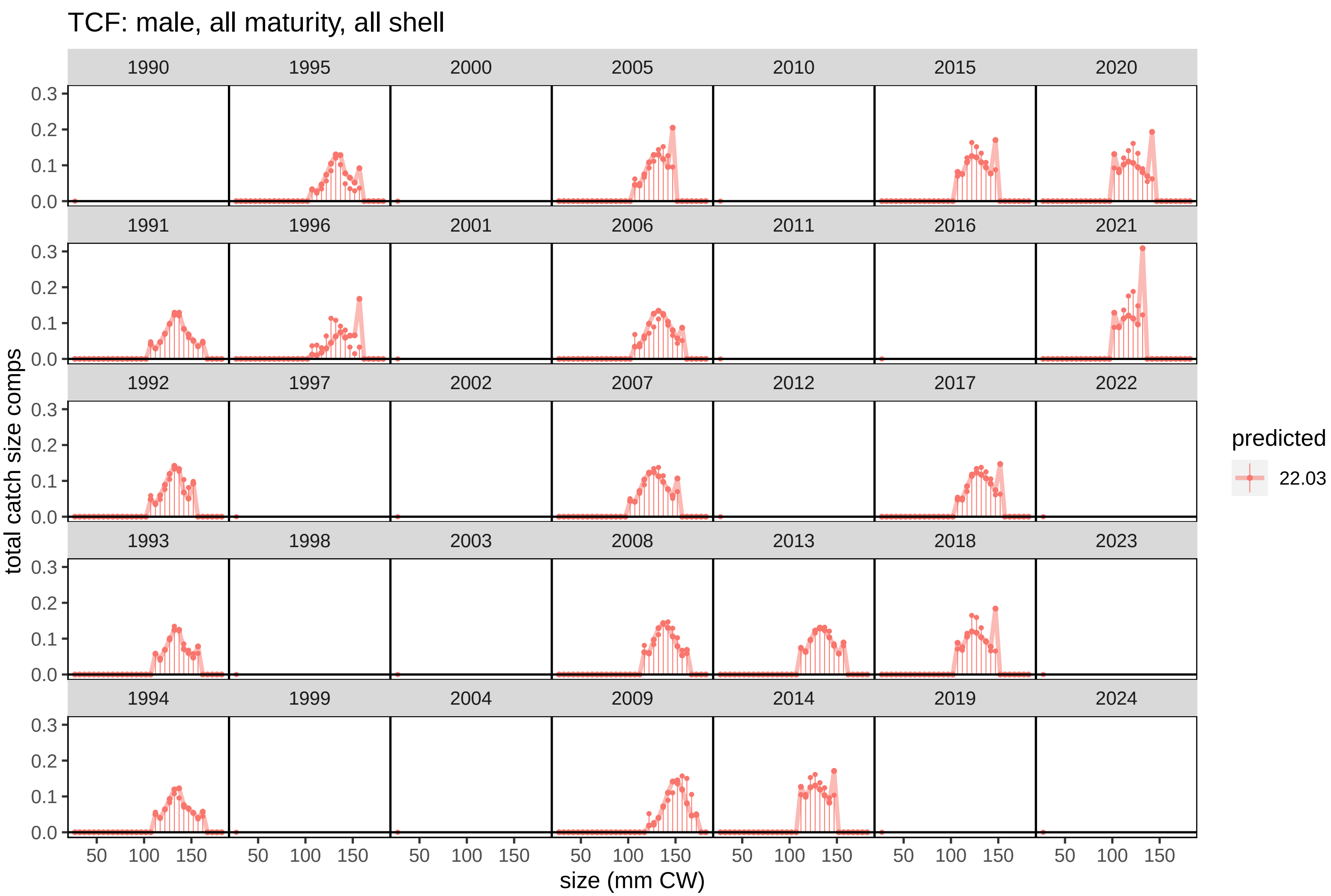

Figure 86: Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03.

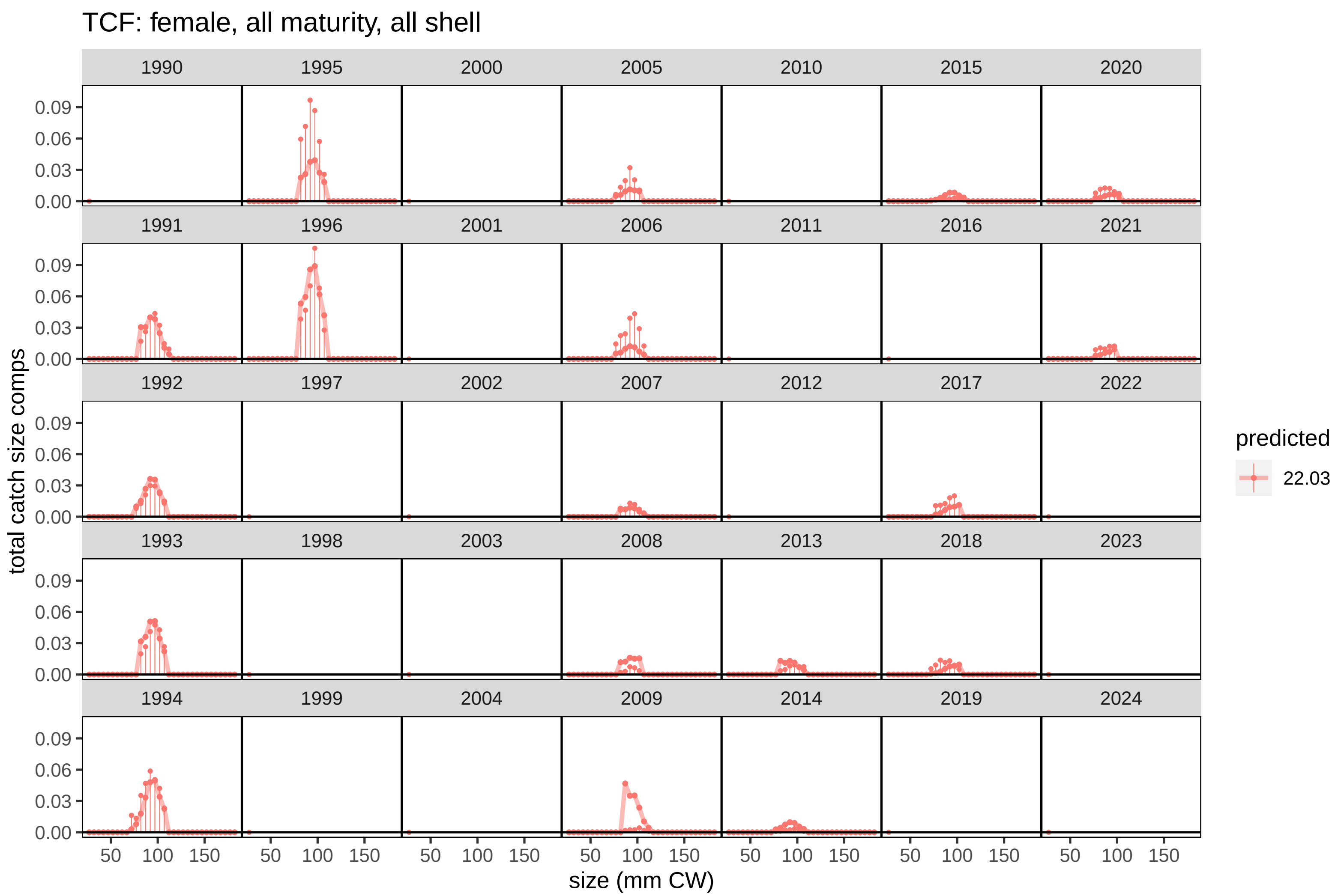

Figure 87: Fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03.

Figure 88: Pearson's residuals for fits to total catch size composition data in Model 22.03. 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 22.03.

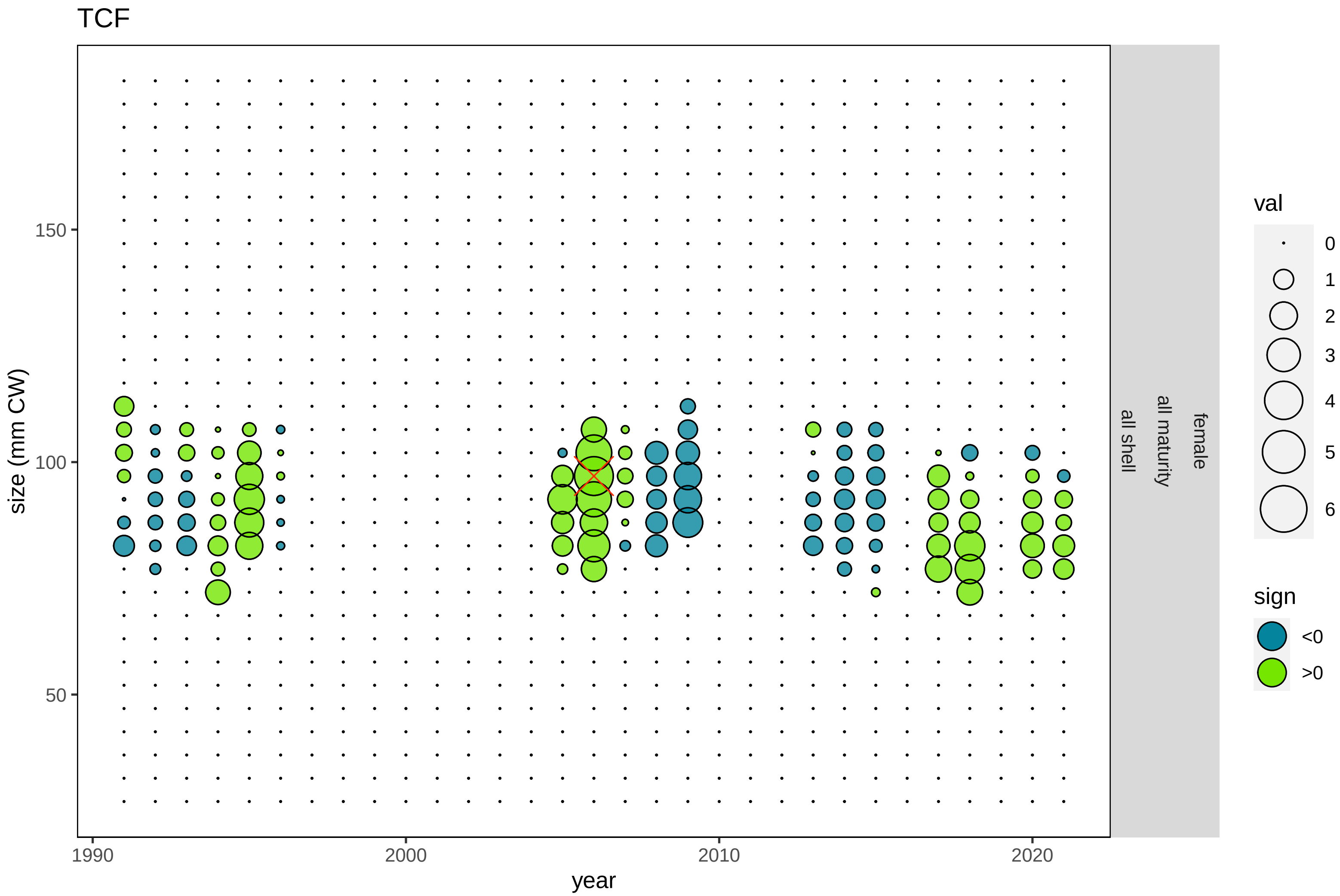

Figure 89: Pearson's residuals for fits to total catch size composition data in Model 22.03. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

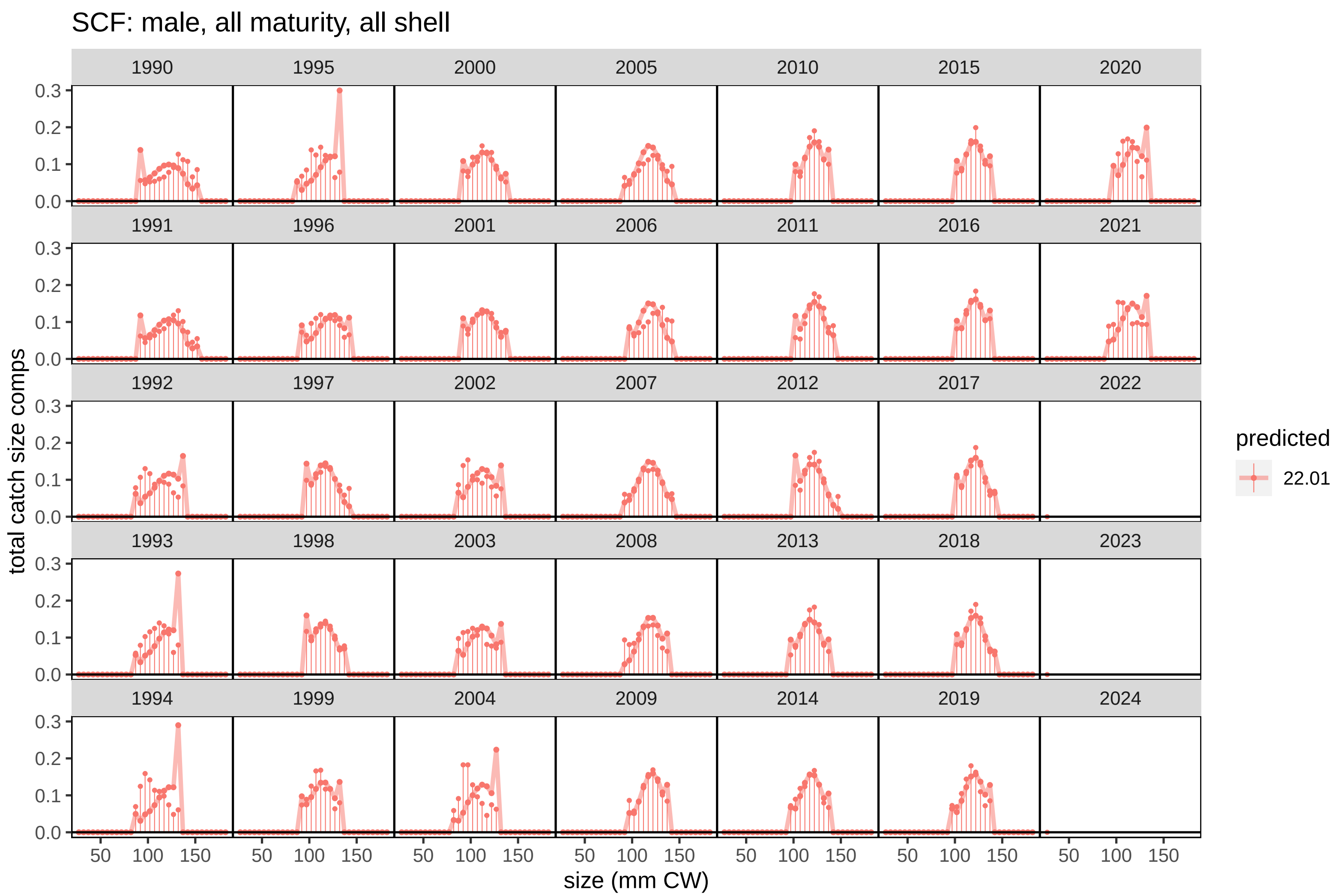

Figure 90: Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03.

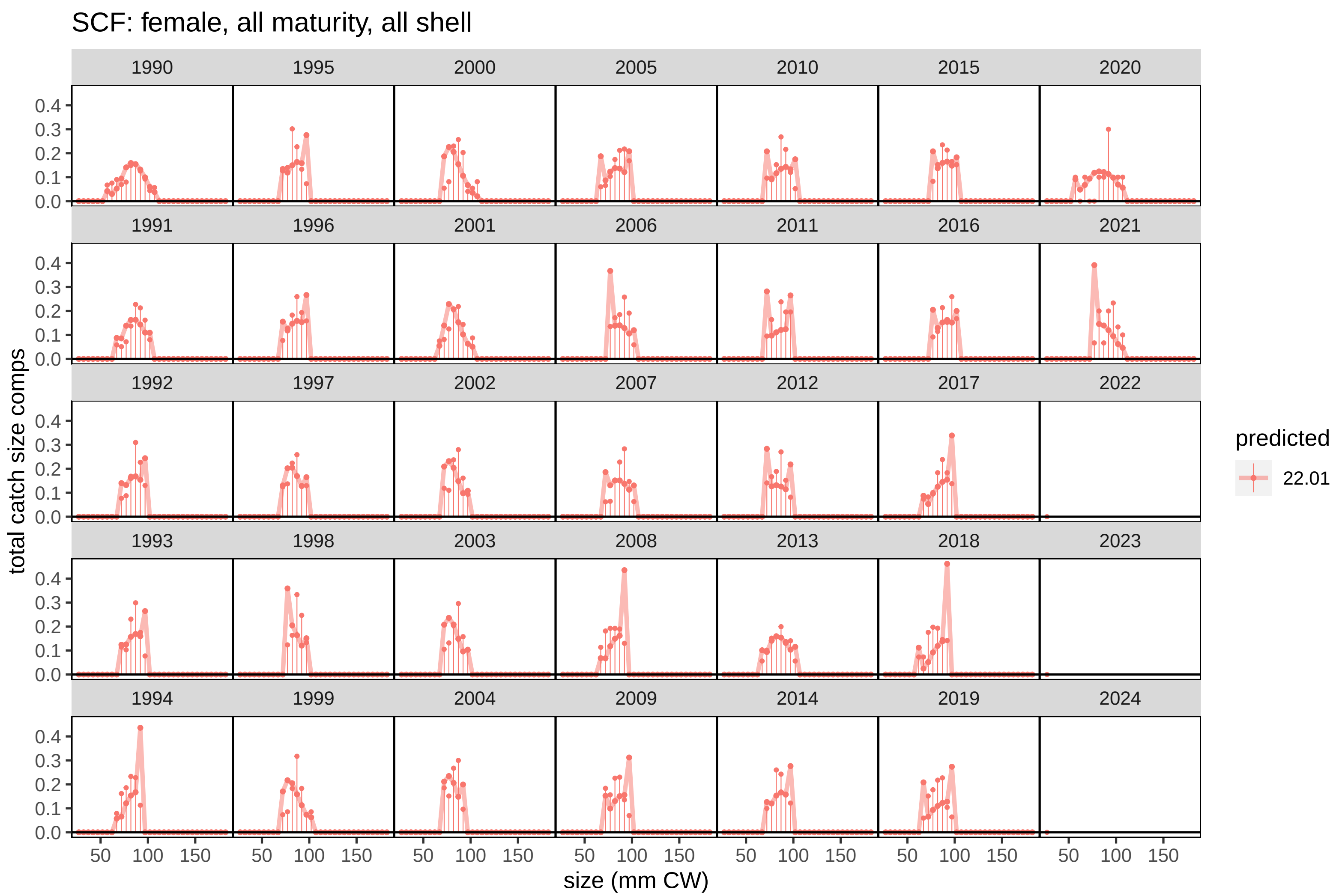

Figure 91: Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03.

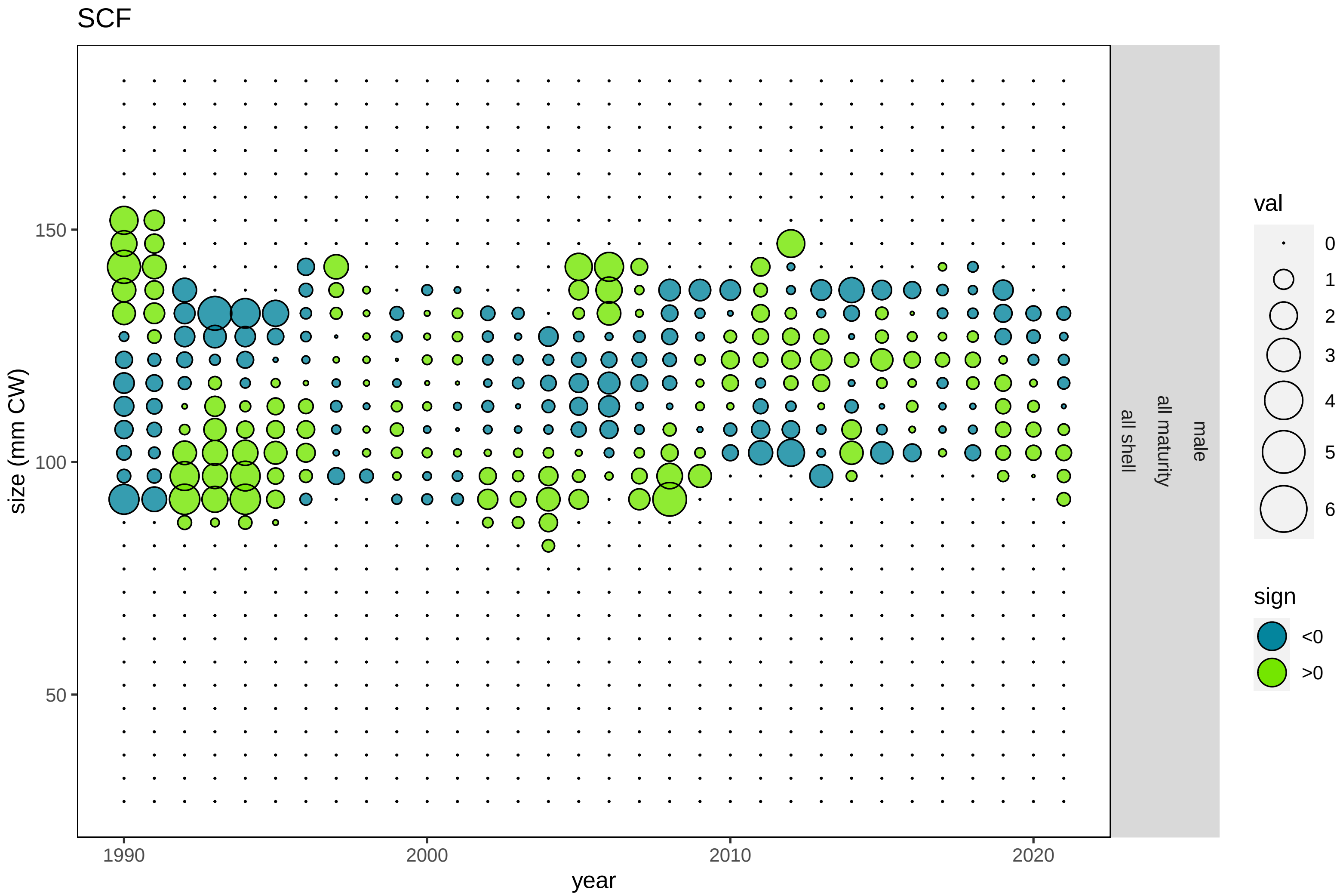

Figure 92: Pearson's residuals for fits to total catch size composition data in Model 22.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

Figure 93: Pearson's residuals for fits to total catch size composition data in Model 22.01. 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 22.03.

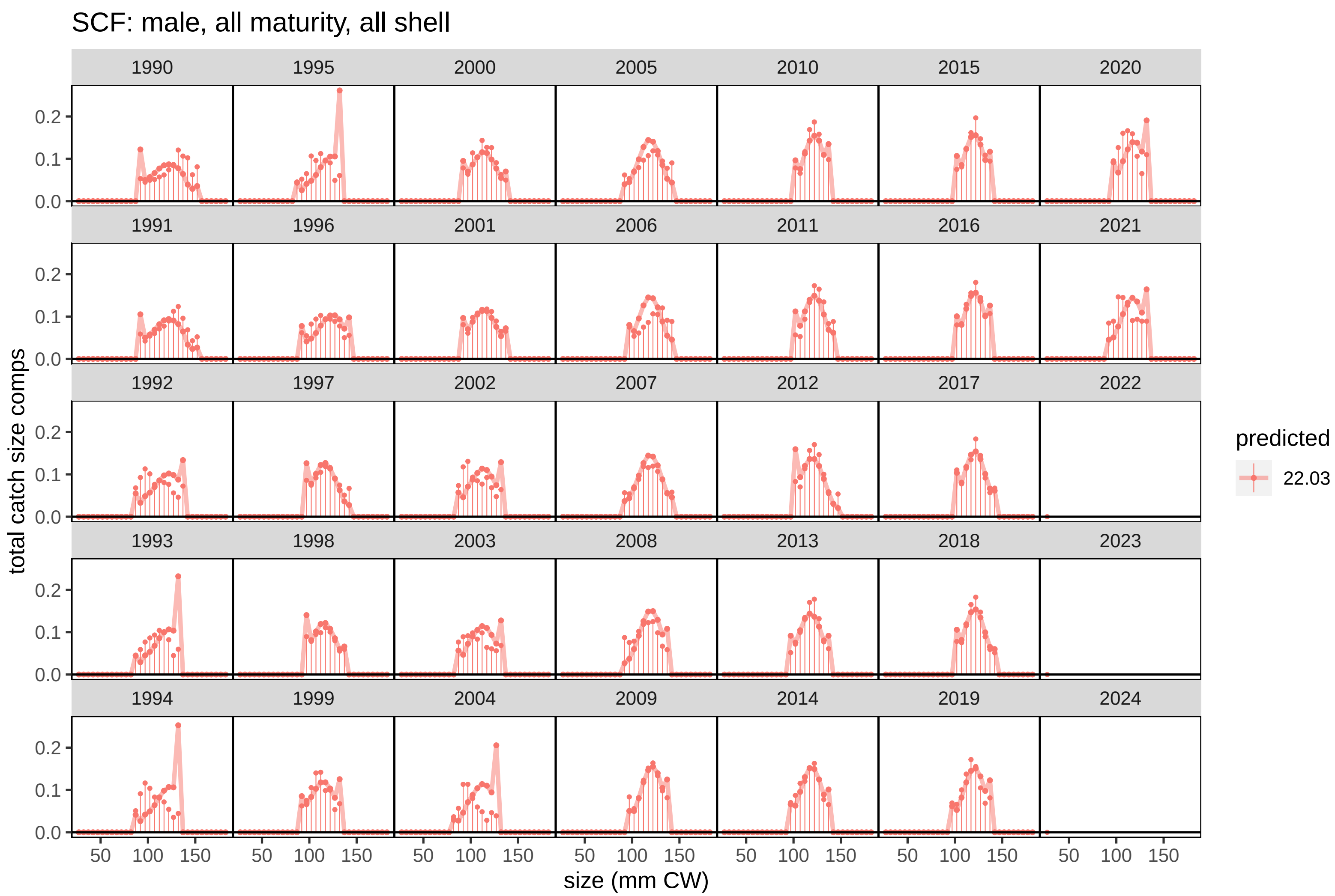

Figure 94: Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03.

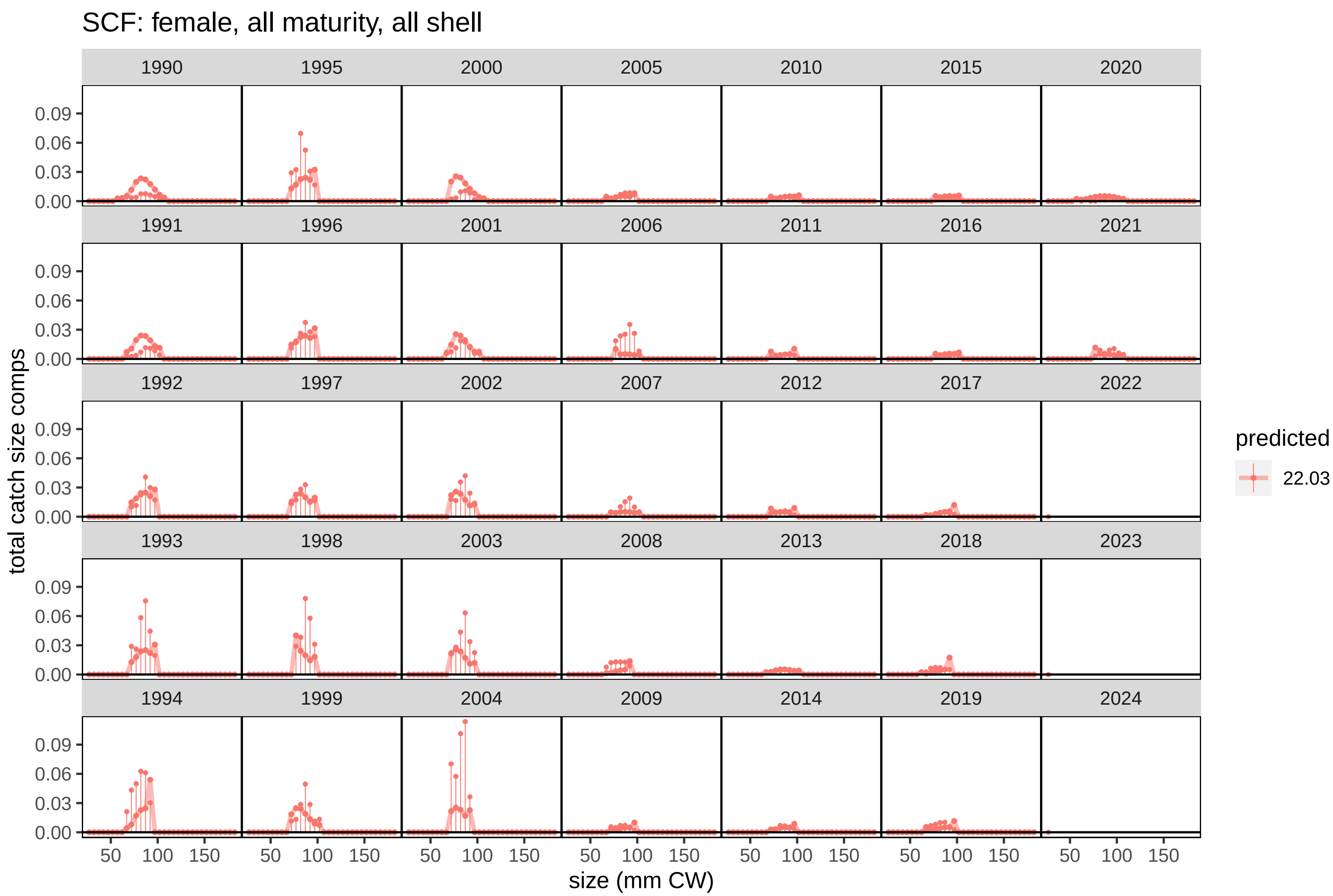

Figure 95: Fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03.

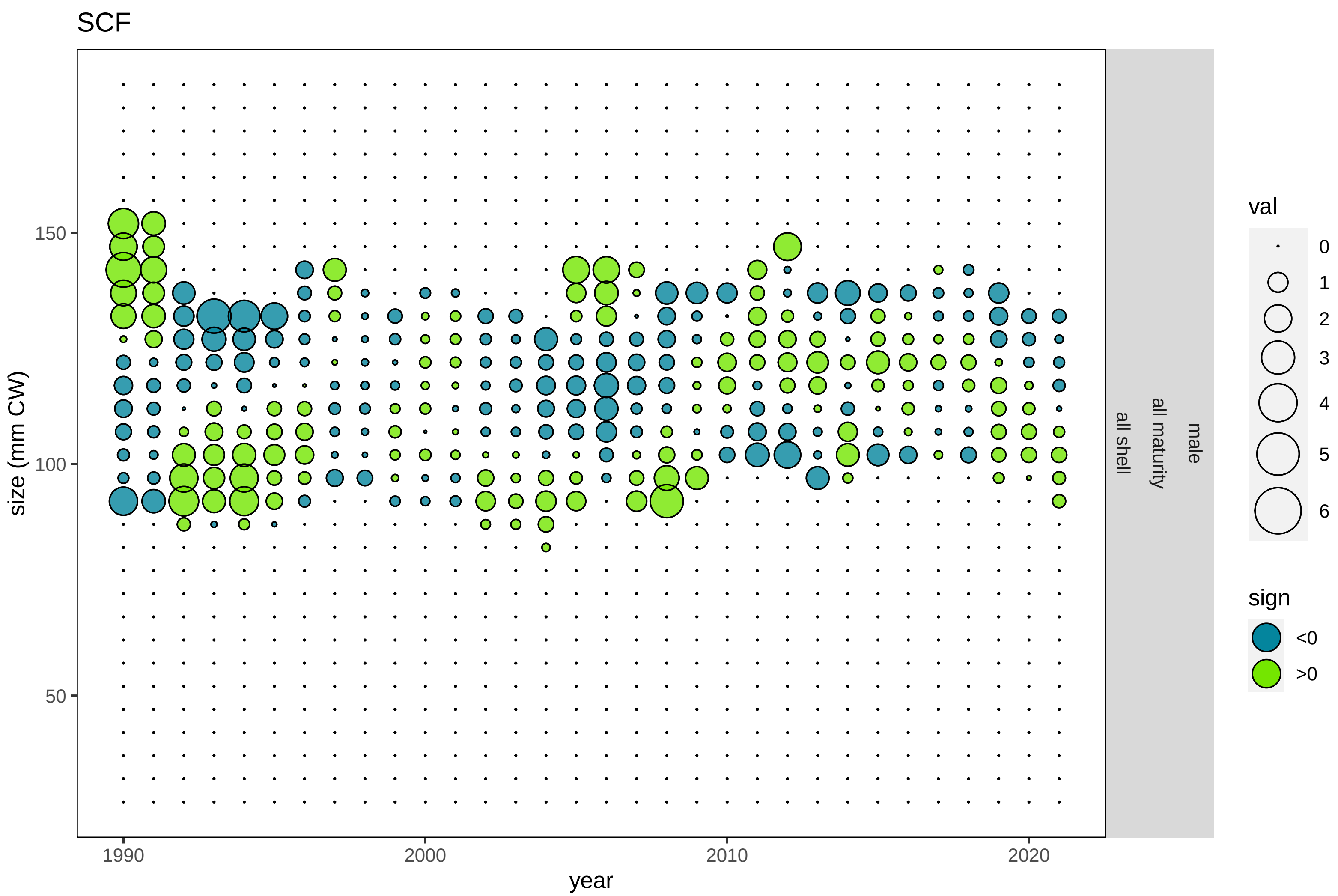

Figure 96: Pearson's residuals for fits to total catch size composition data in Model 22.03. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

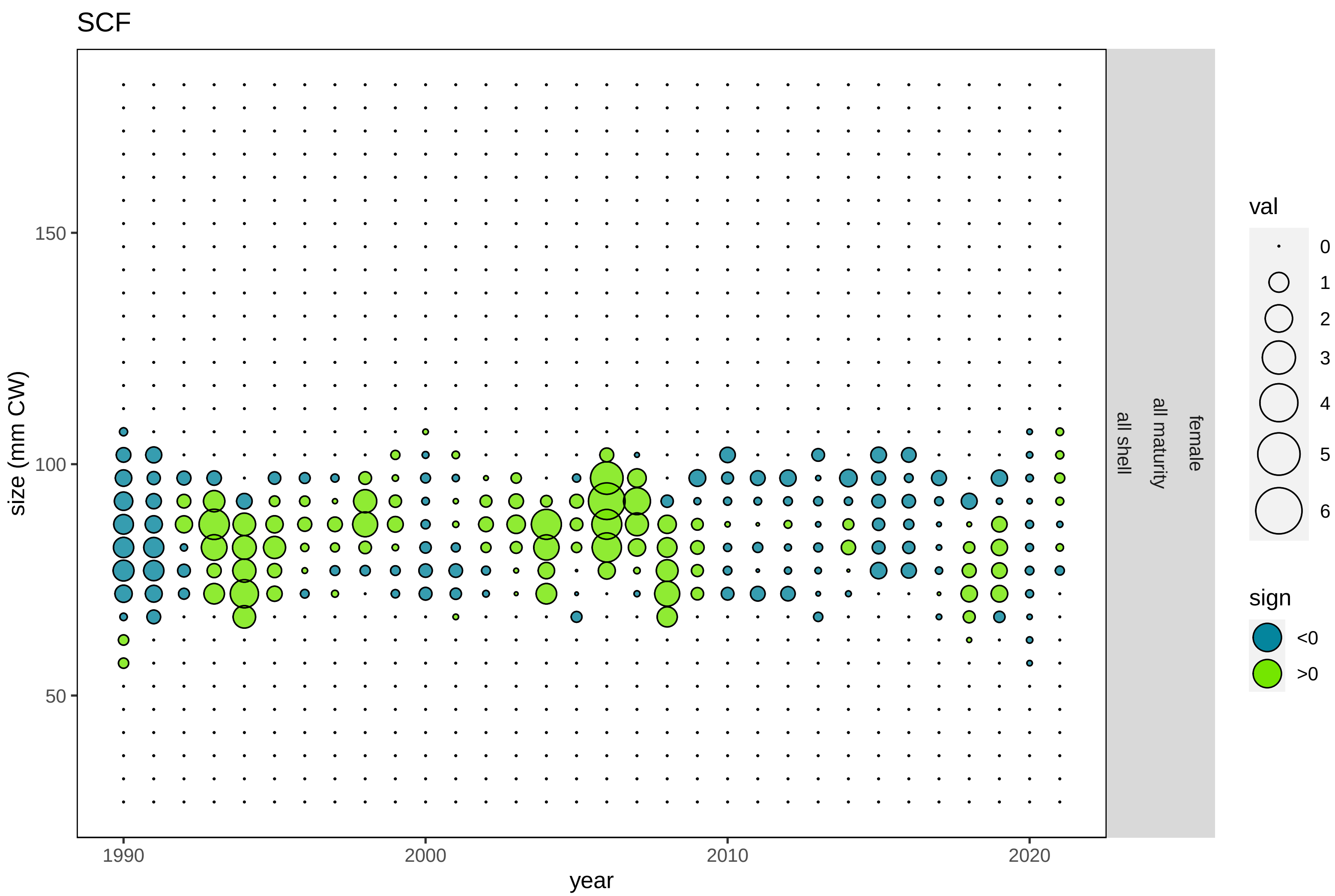

Figure 97: Pearson's residuals for fits to total catch size composition data in Model 22.03. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

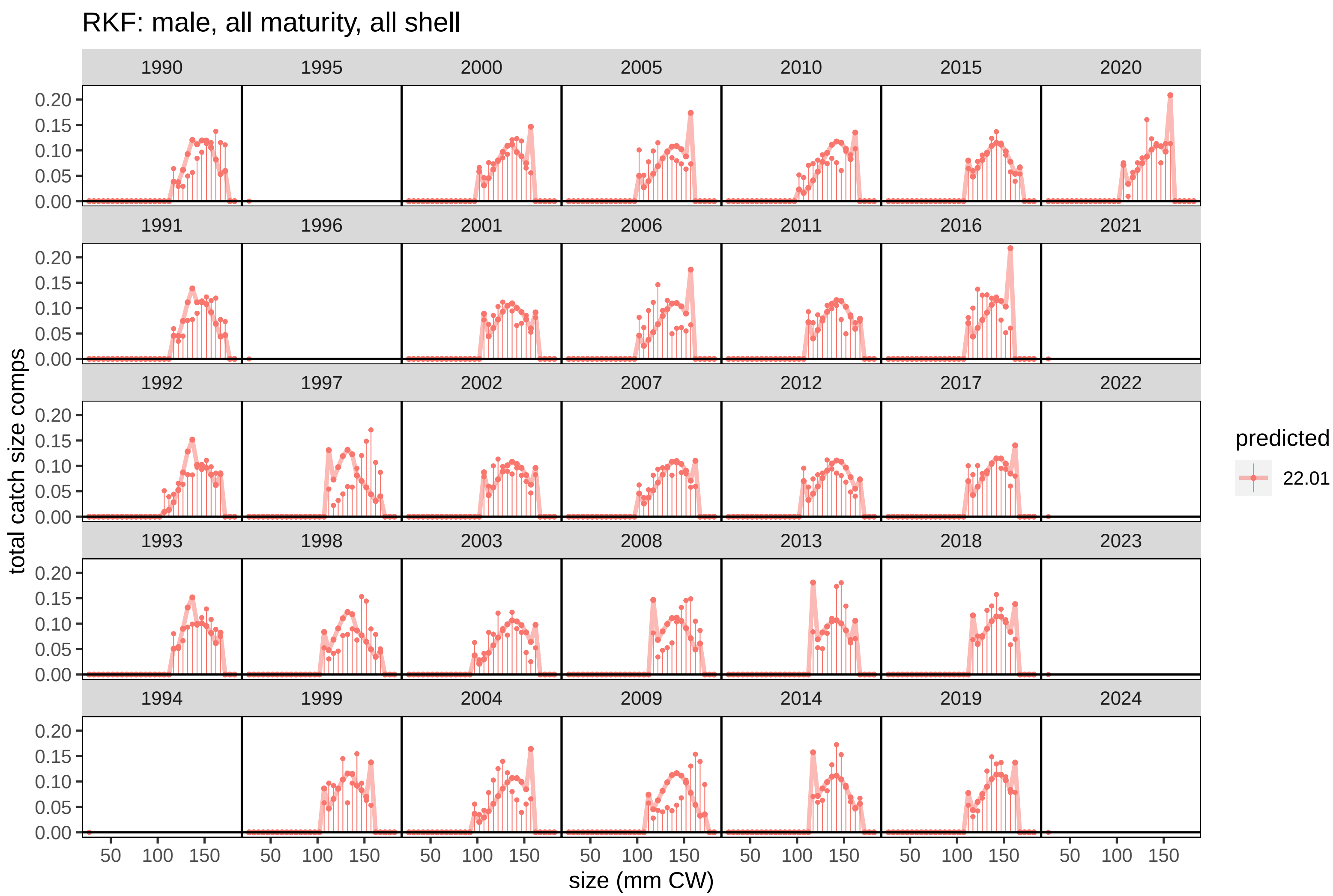

Figure 98: Fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03.

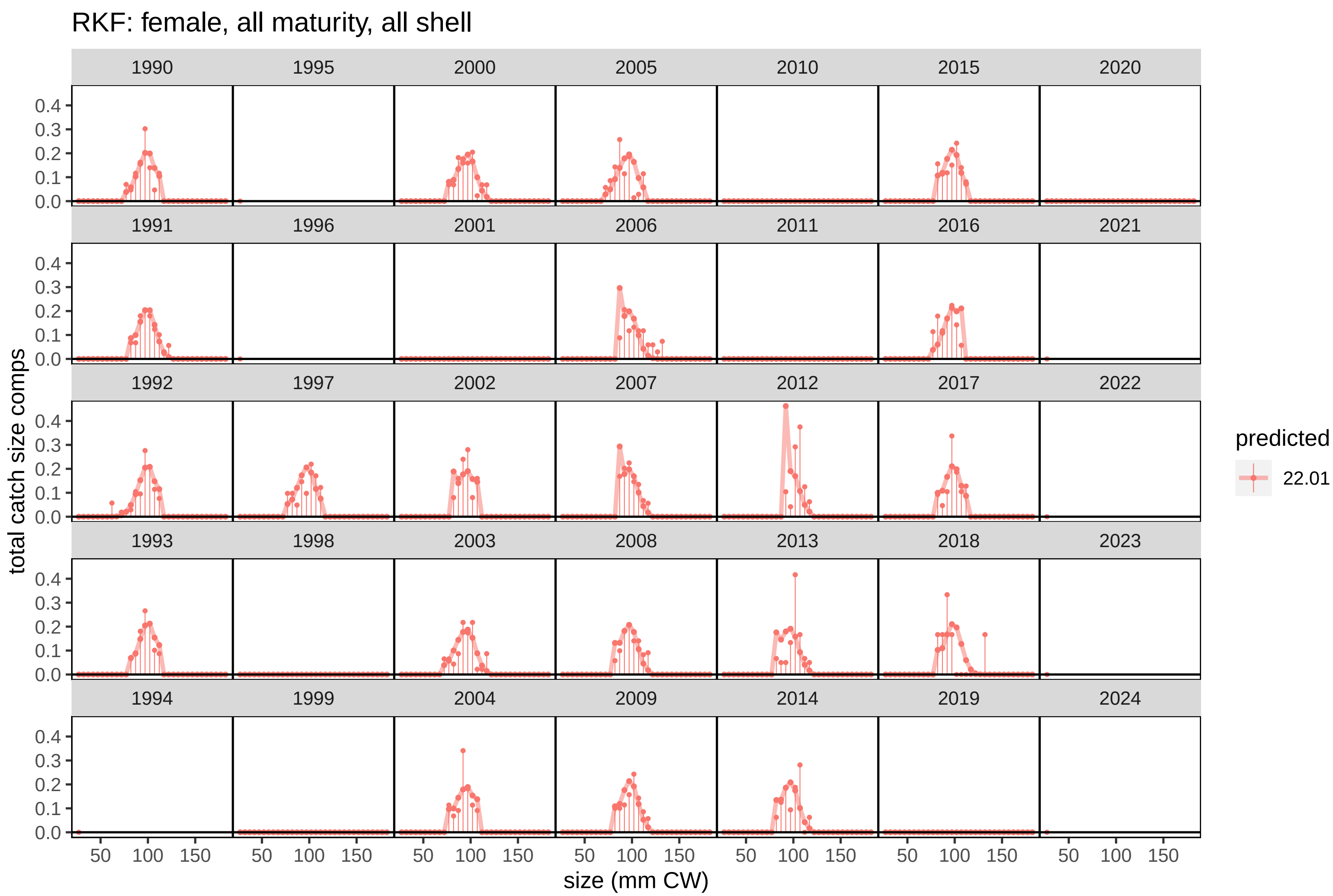

Figure 99: Fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03.

Figure 100: Pearson's residuals for fits to total catch size composition data in Model 22.01. 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 22.03.

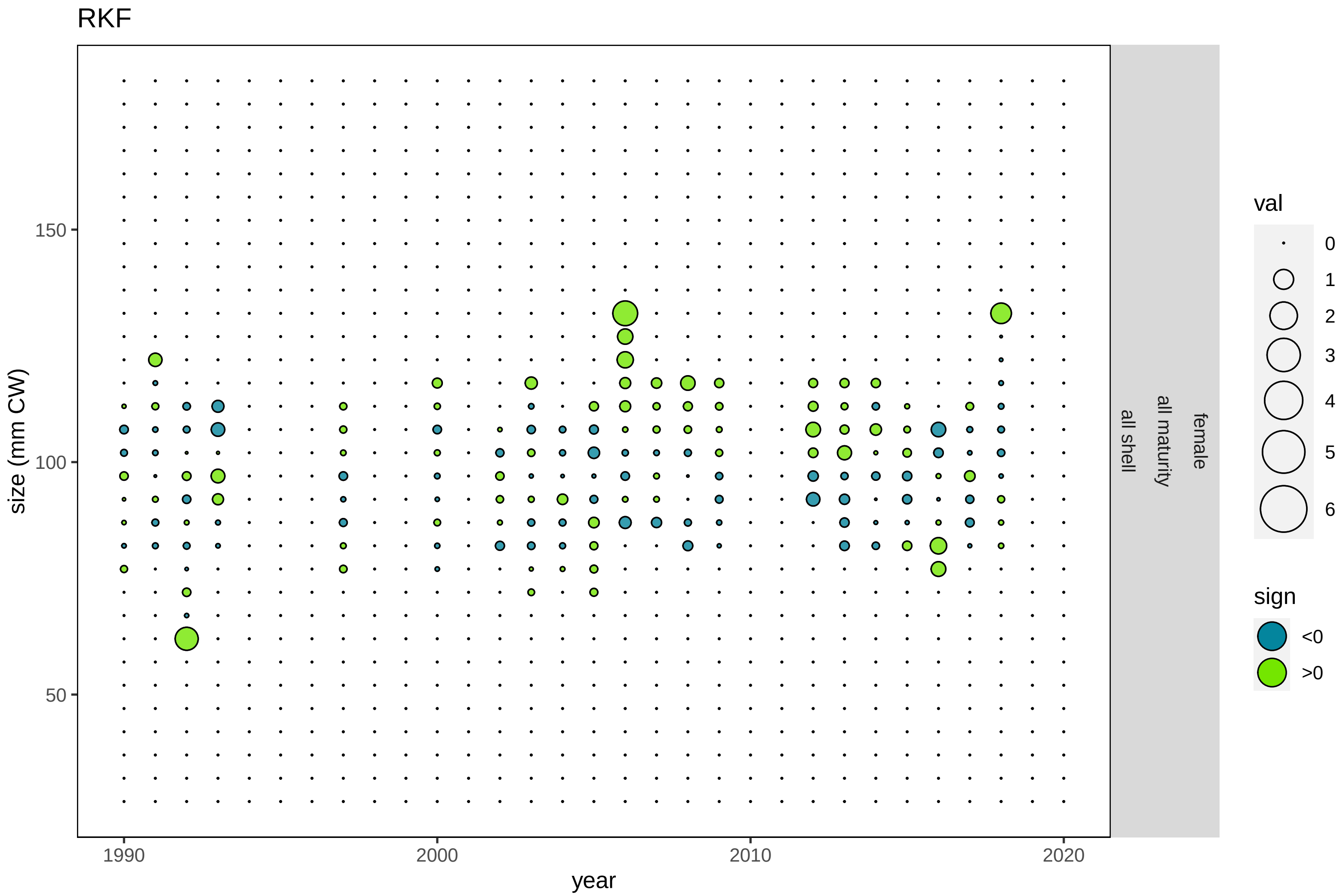

Figure 101: Pearson's residuals for fits to total catch size composition data in Model 22.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

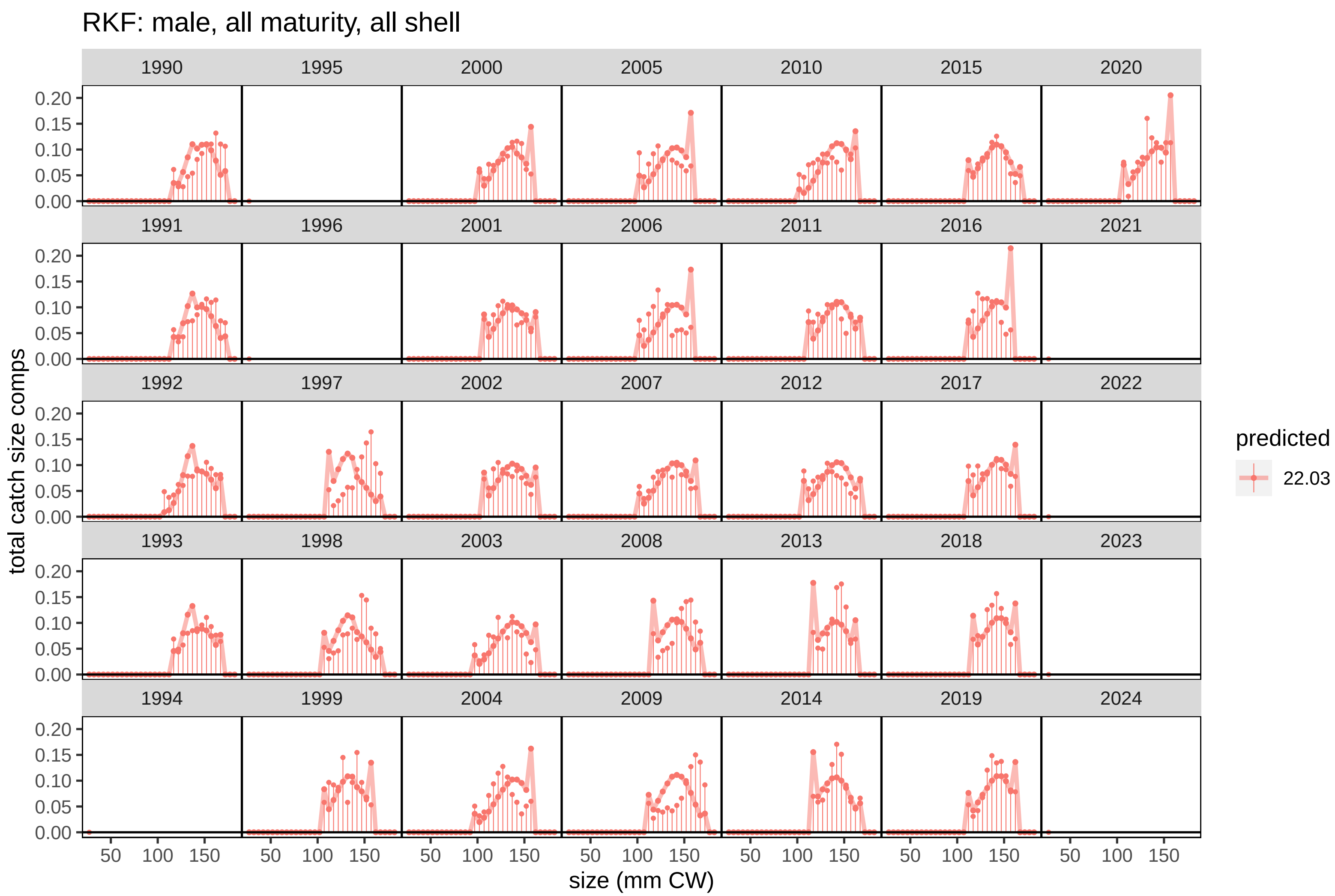

Figure 102: Fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03.

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

Figure 104: Pearson's residuals for fits to total catch size composition data in Model 22.03. 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 22.03.

Figure 105: Pearson's residuals for fits to total catch size composition data in Model 22.03. 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 22.03.

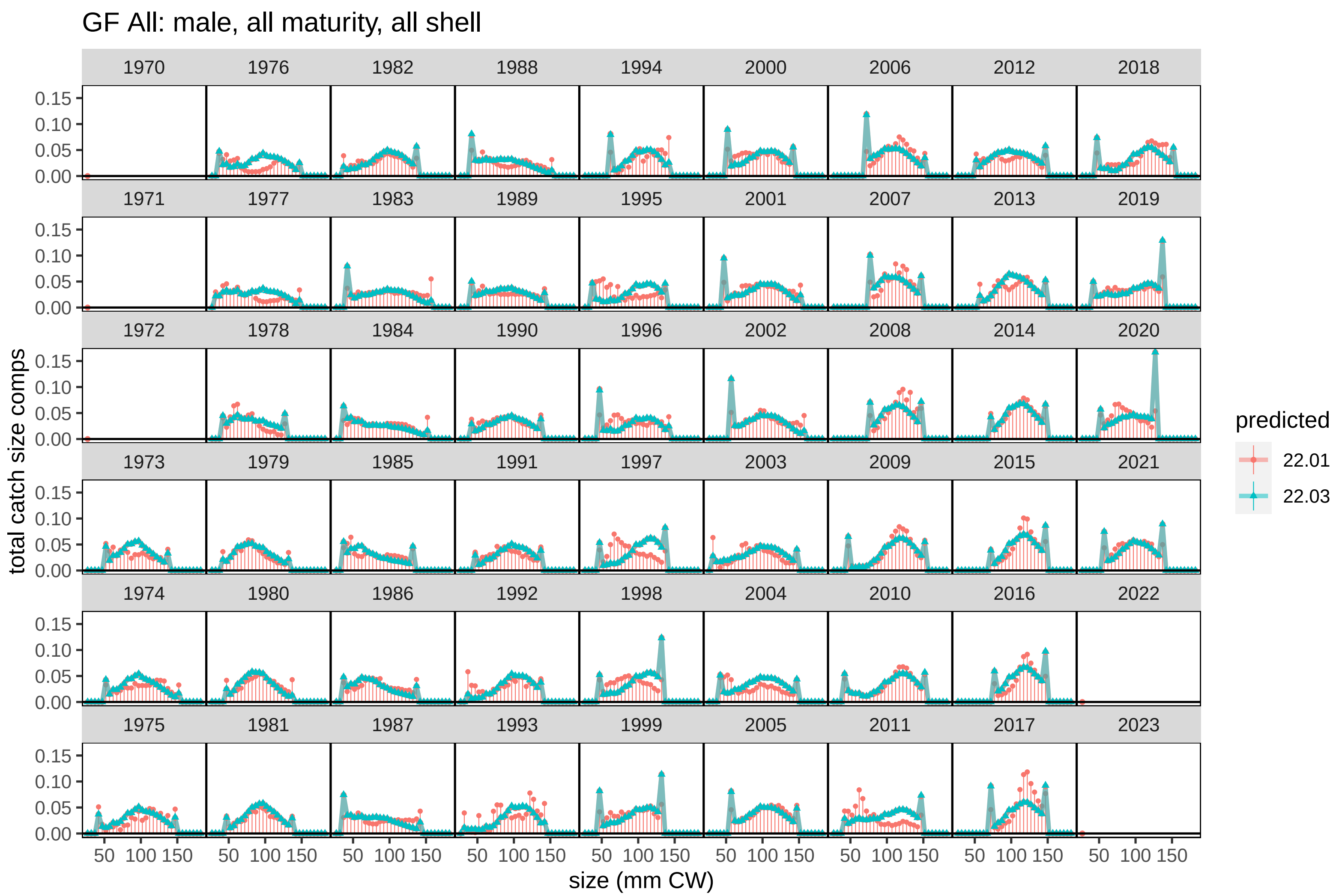

Figure 106: Fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03.

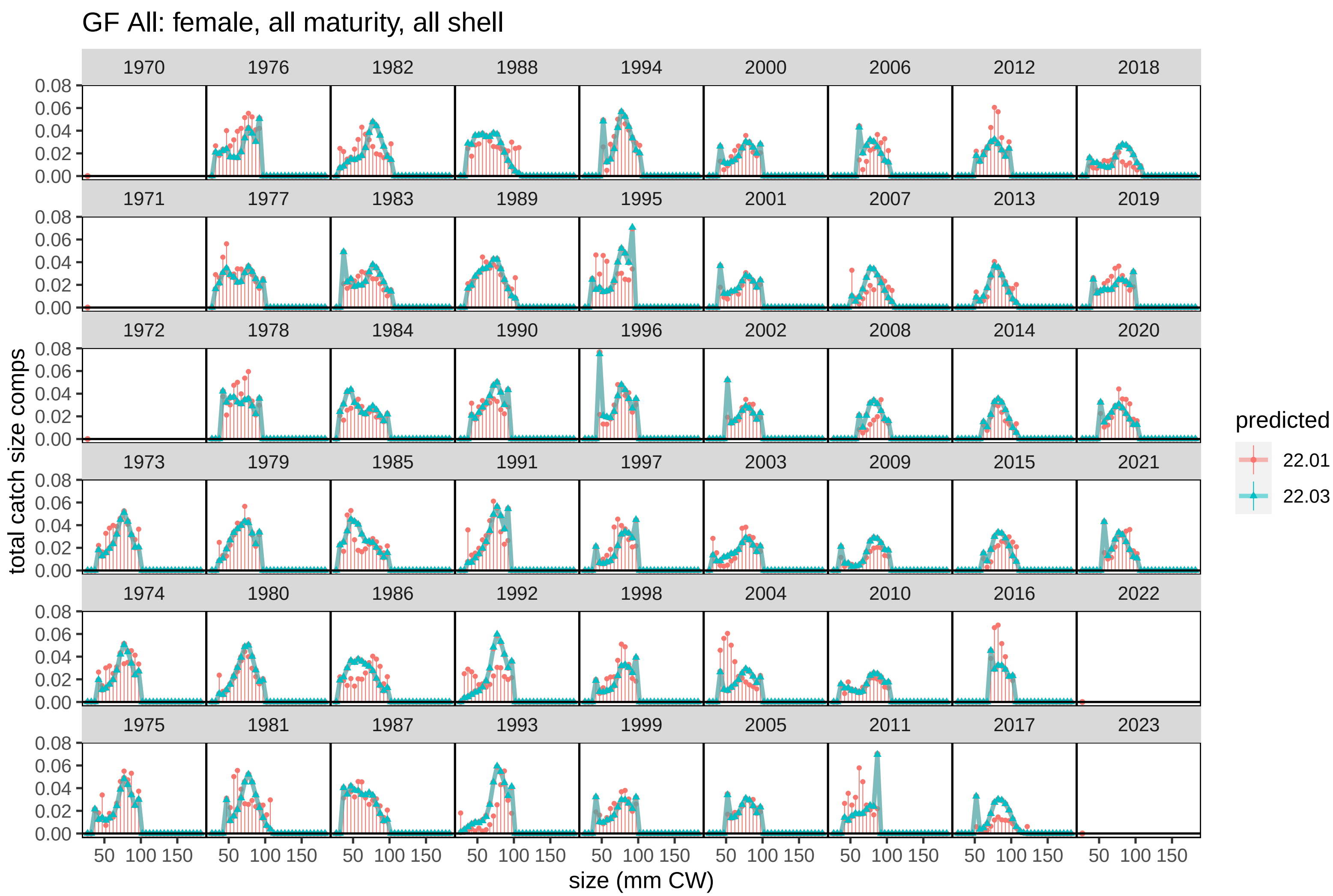

Figure 107: Fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03.

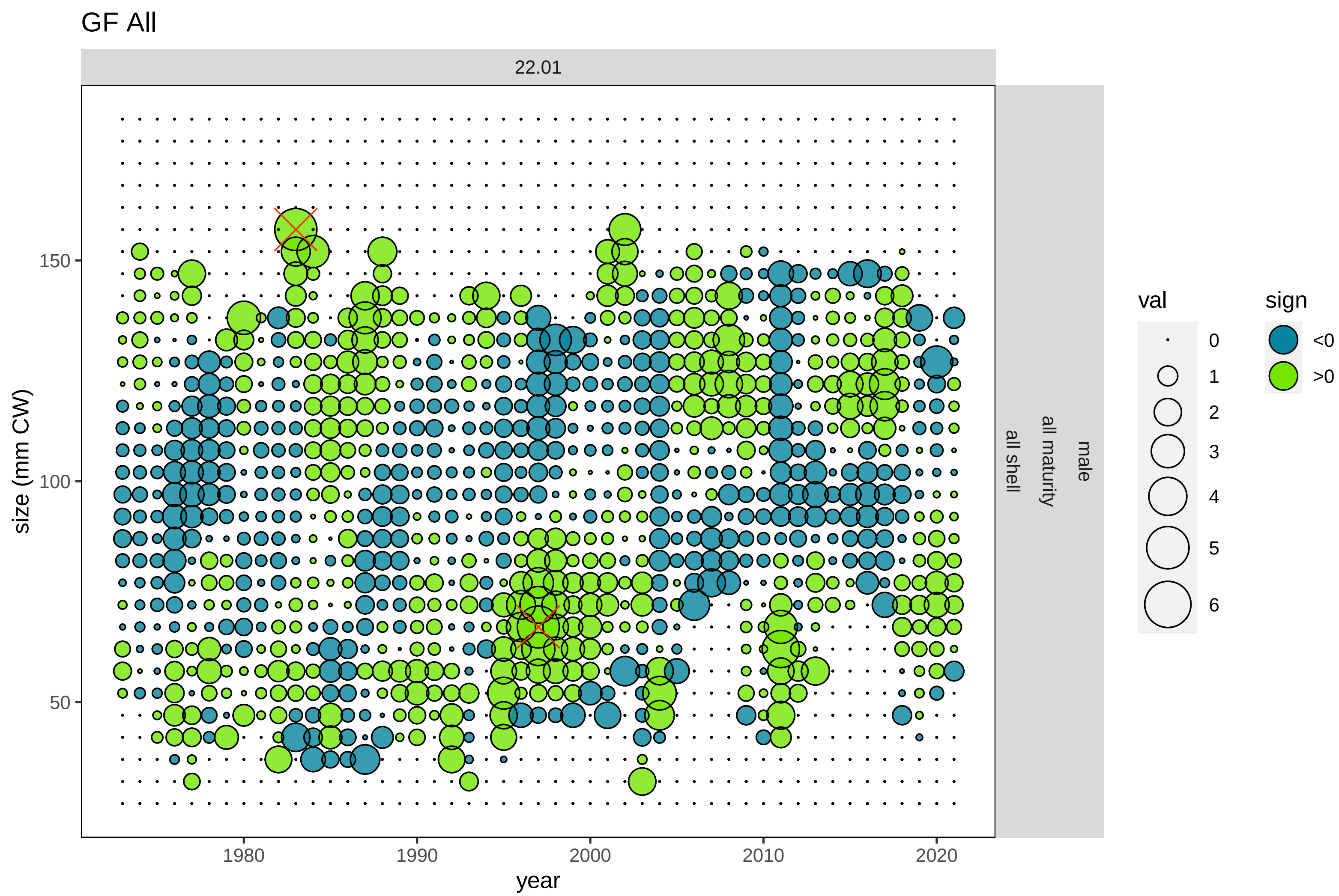

Figure 108: Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

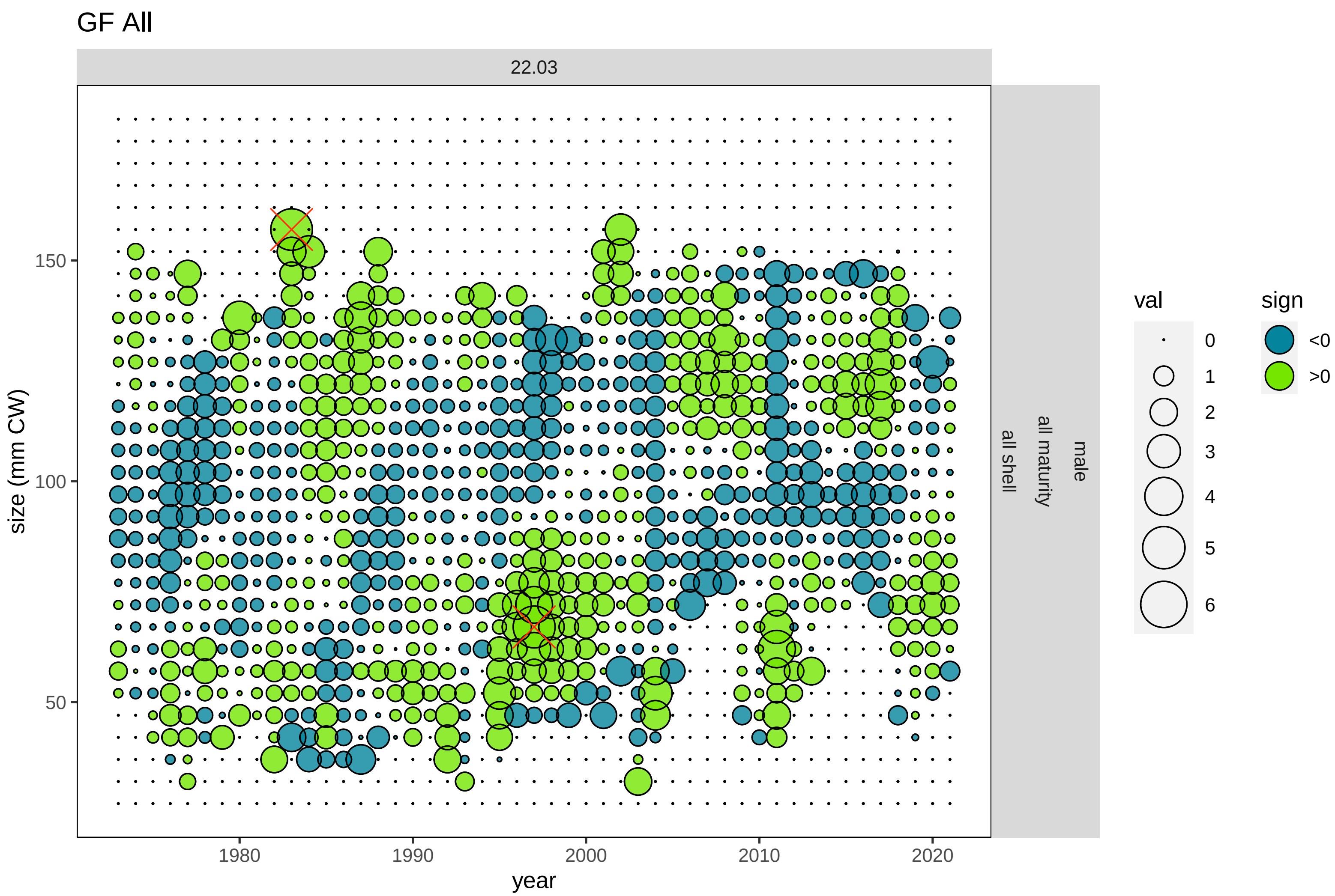

Figure 109: Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

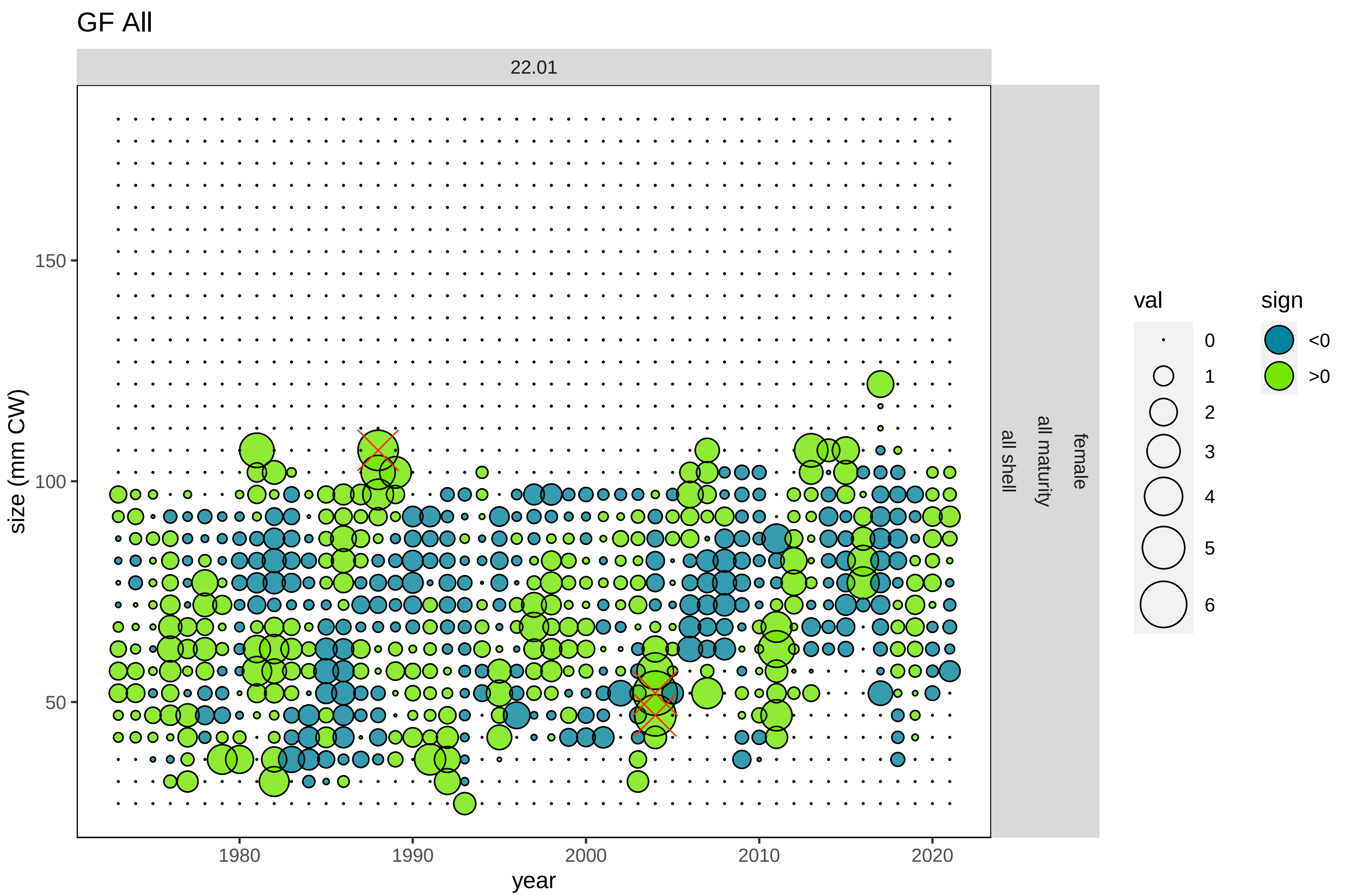

Figure 110: Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

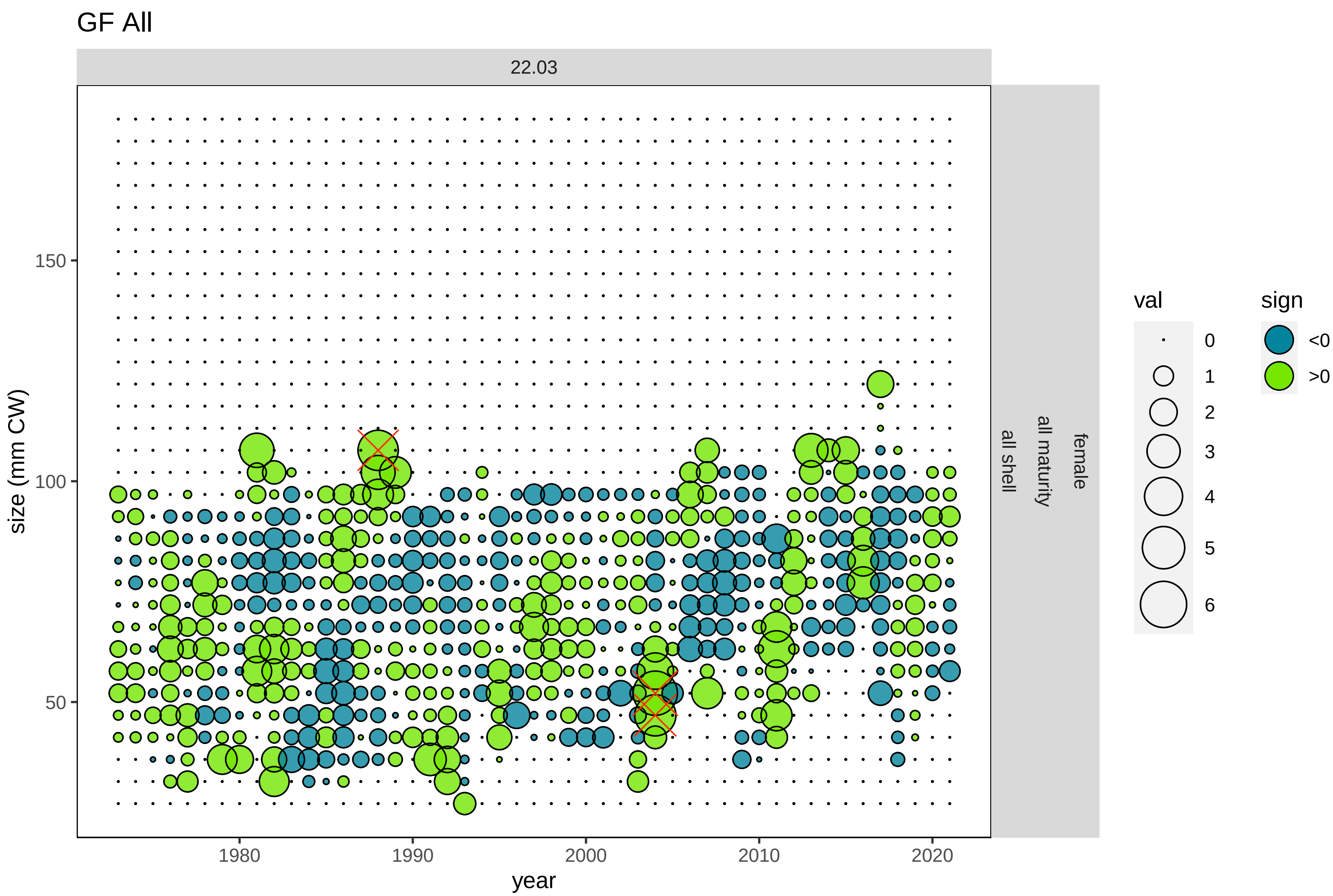

Figure 111: Pearson's residuals for fits to total catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

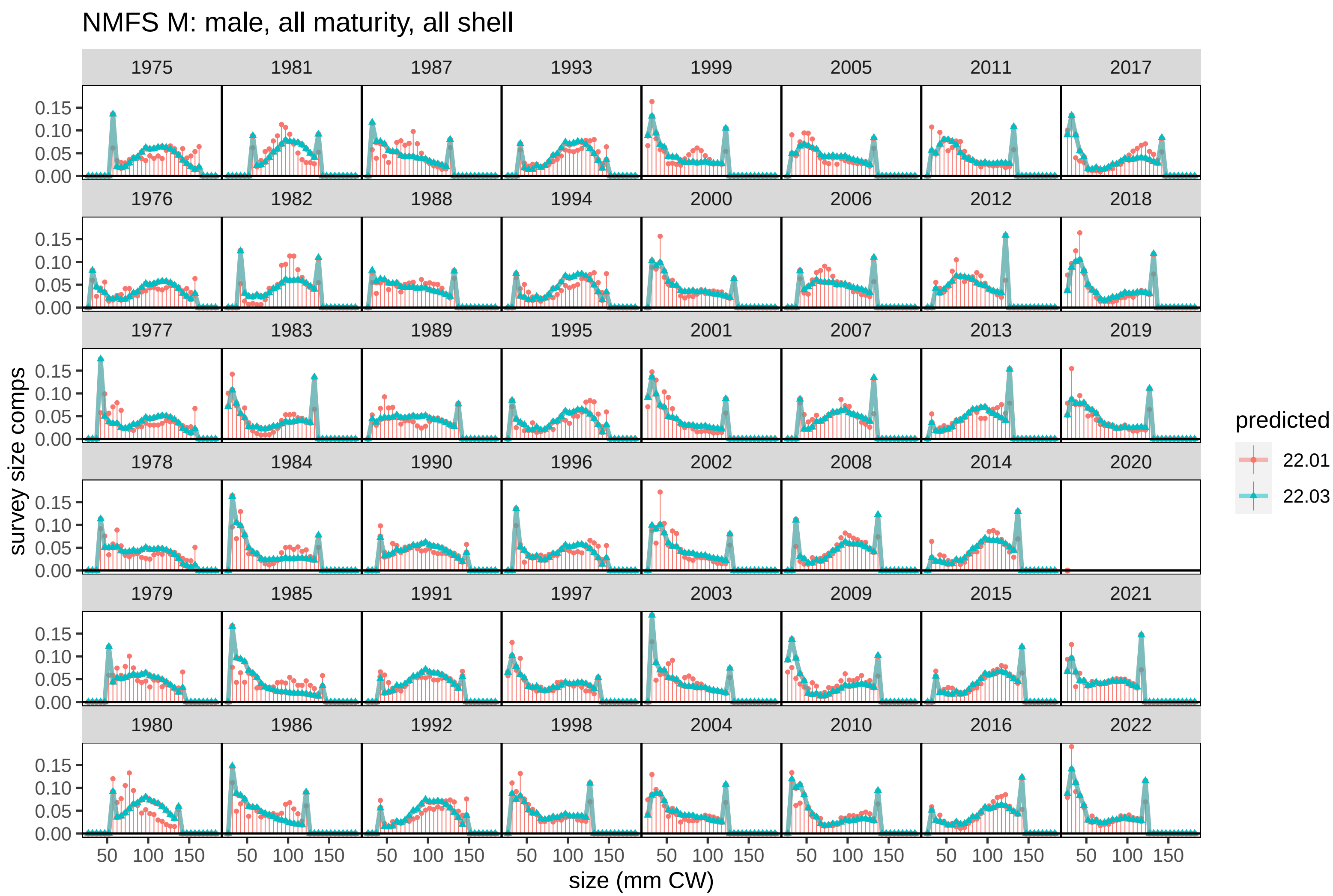

Figure 112: Fits to survey size compositions in the NMFS M survey. Preferred model is 22.03.

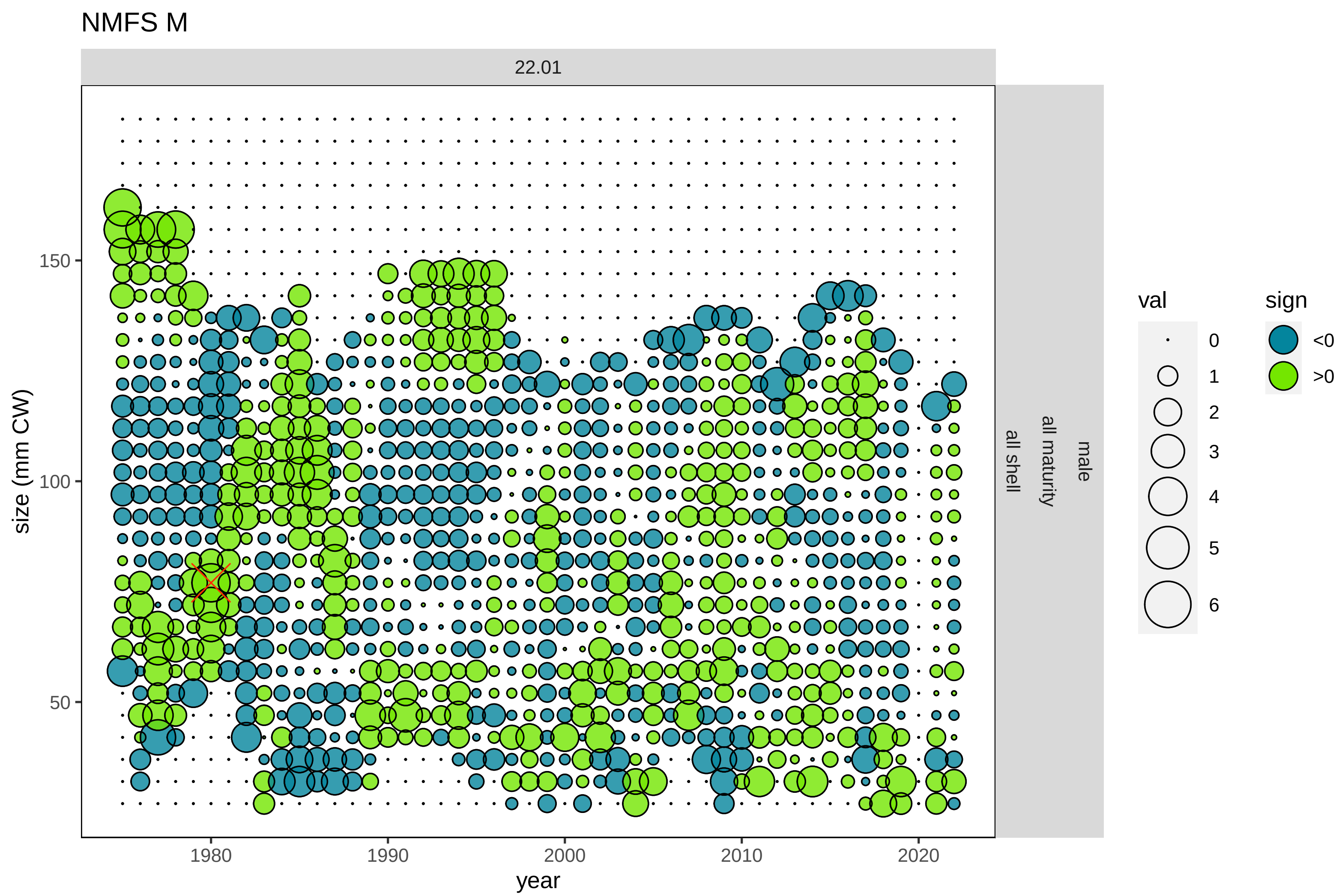

Figure 113: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

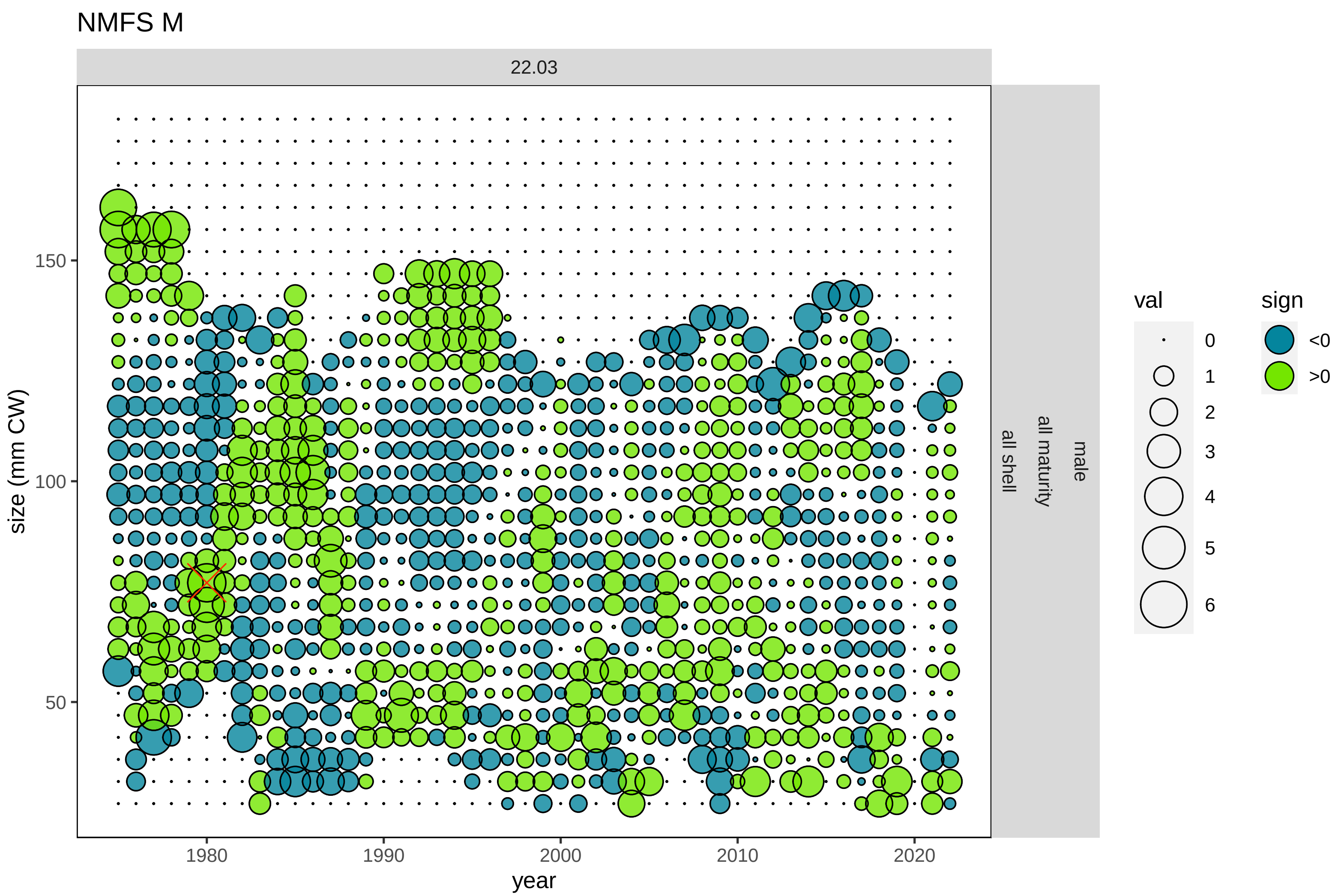

Figure 114: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

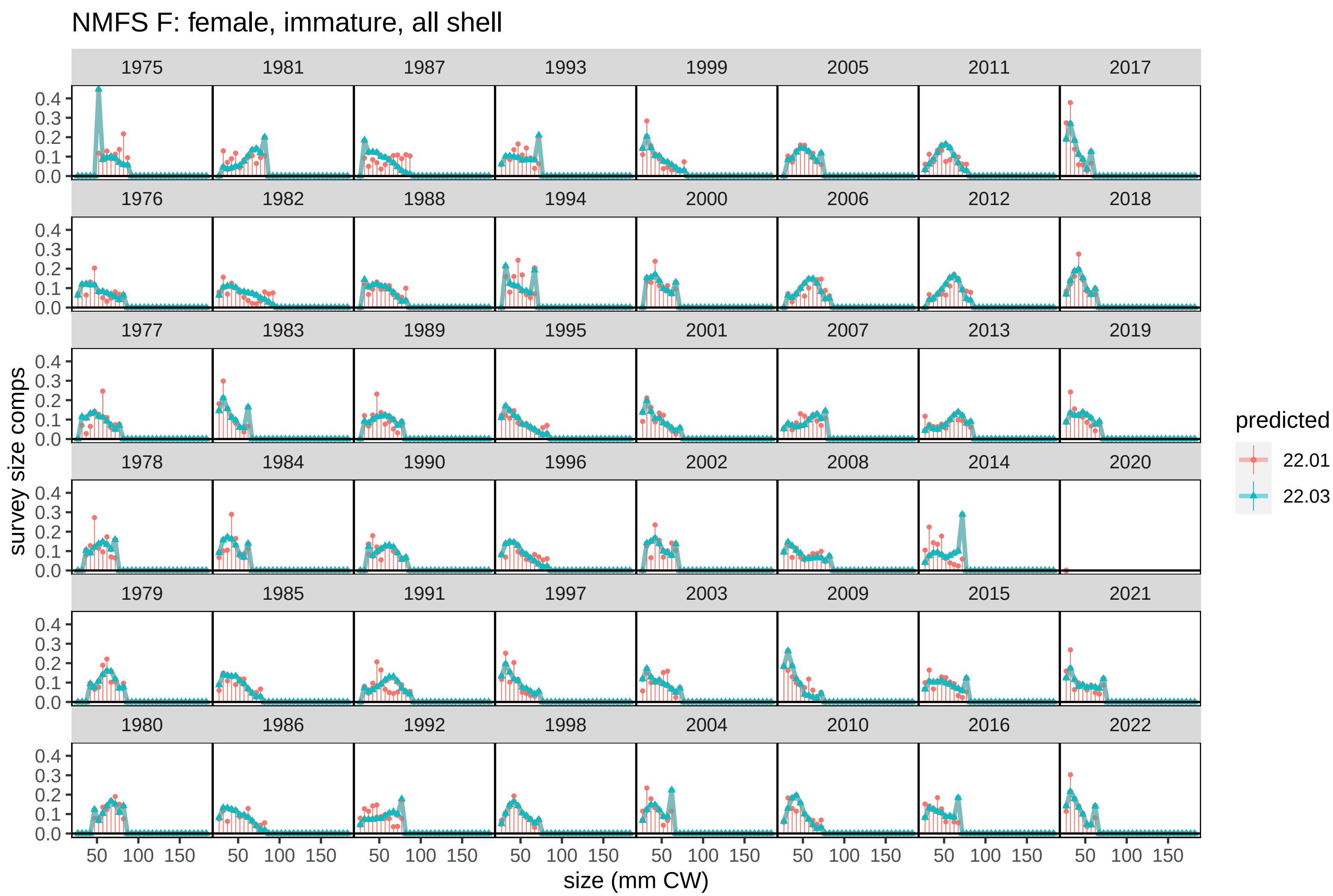

Figure 115: Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03.

Figure 116: Fits to survey size compositions in the NMFS F survey. Preferred model is 22.03.

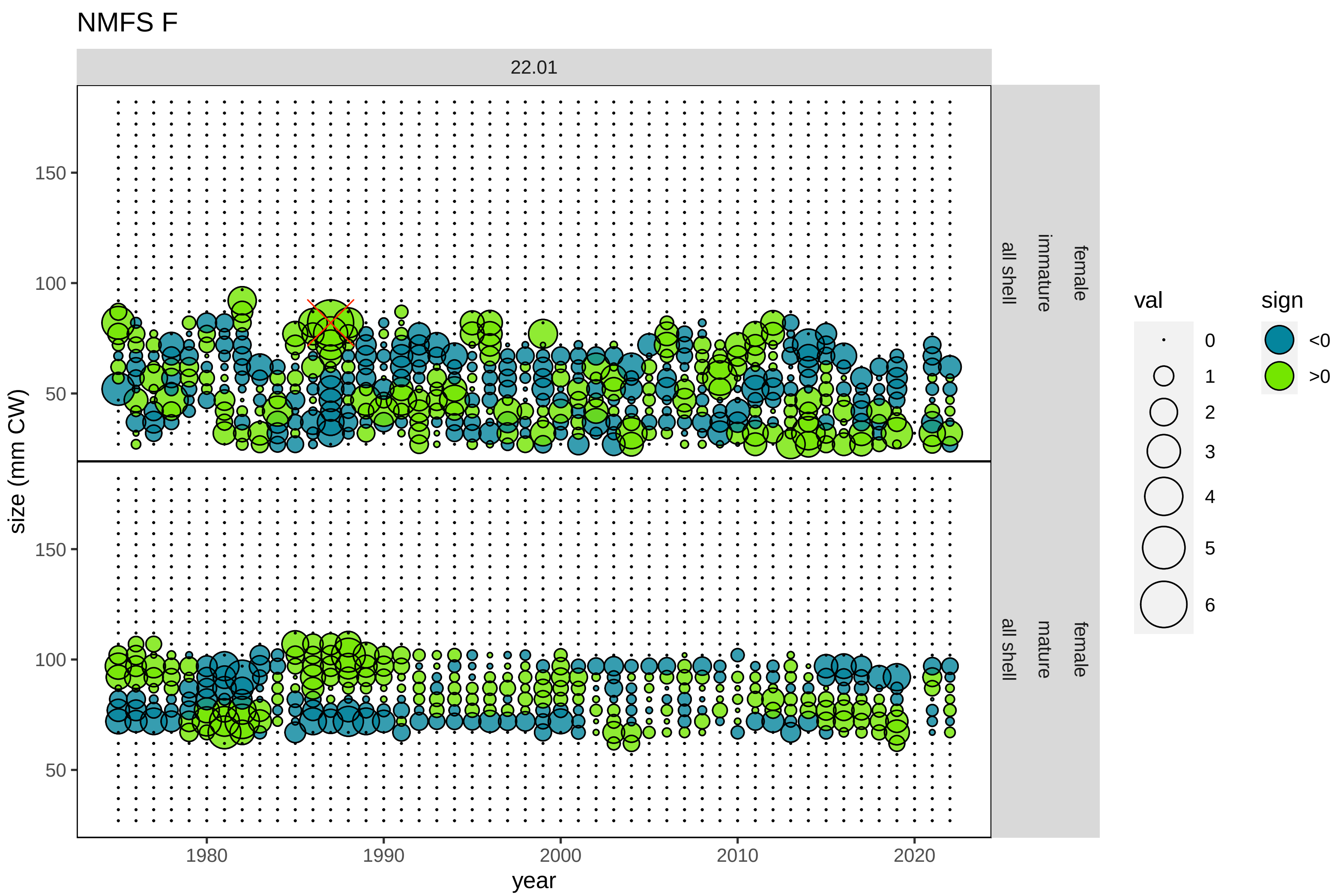

Figure 117: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

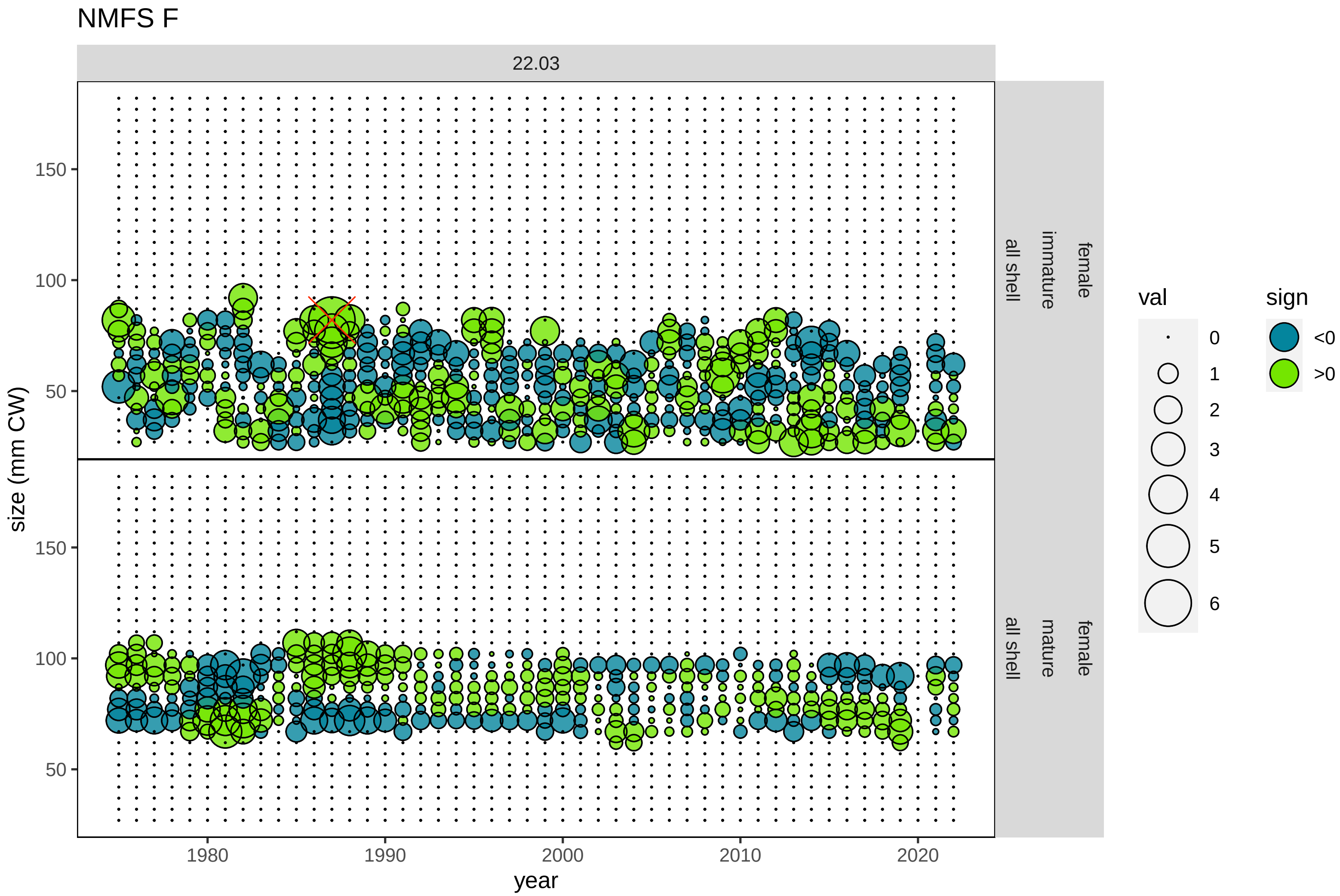

Figure 118: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

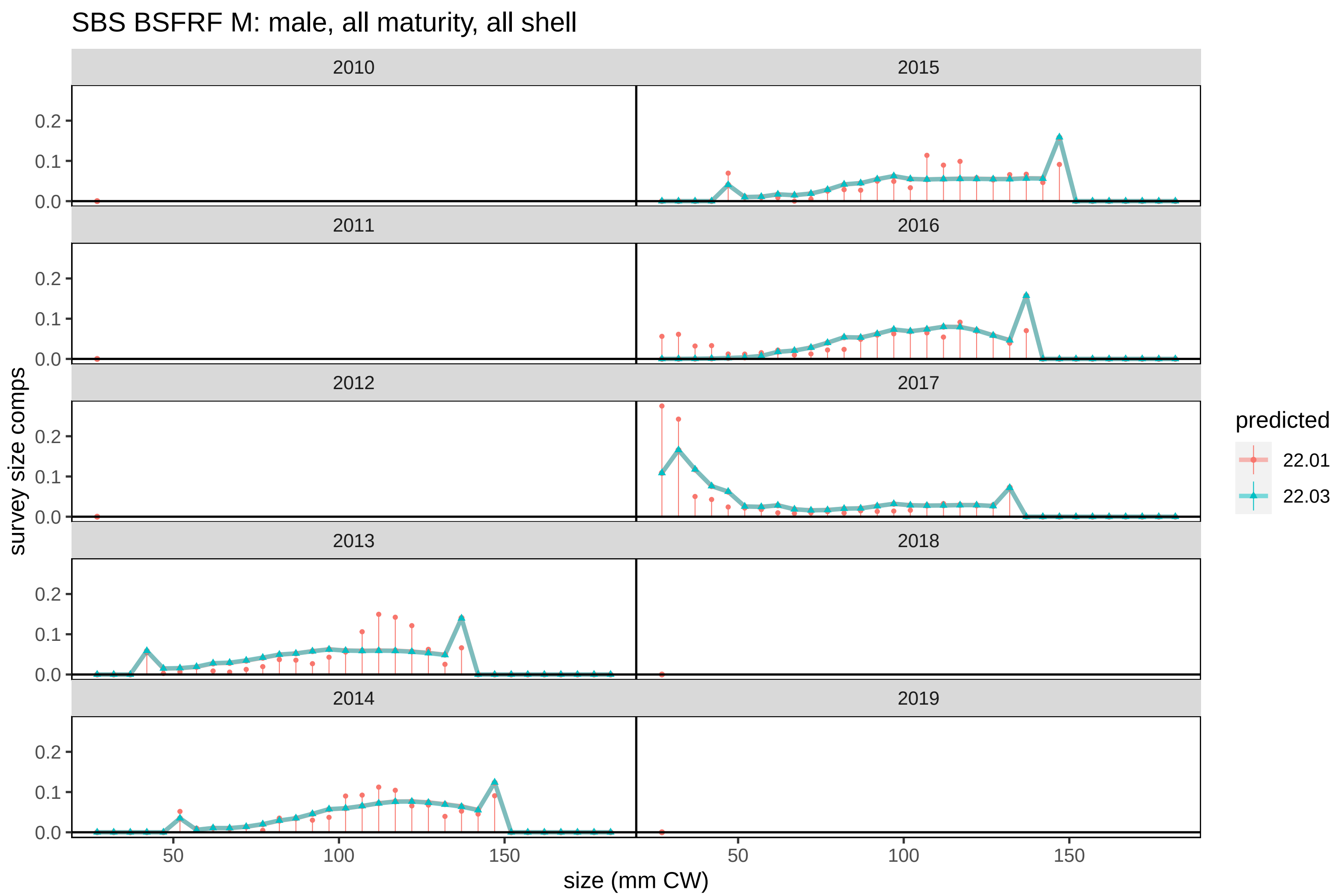

Figure 119: Fits to survey size compositions in the SBS BSFRF M survey. Preferred model is 22.03.

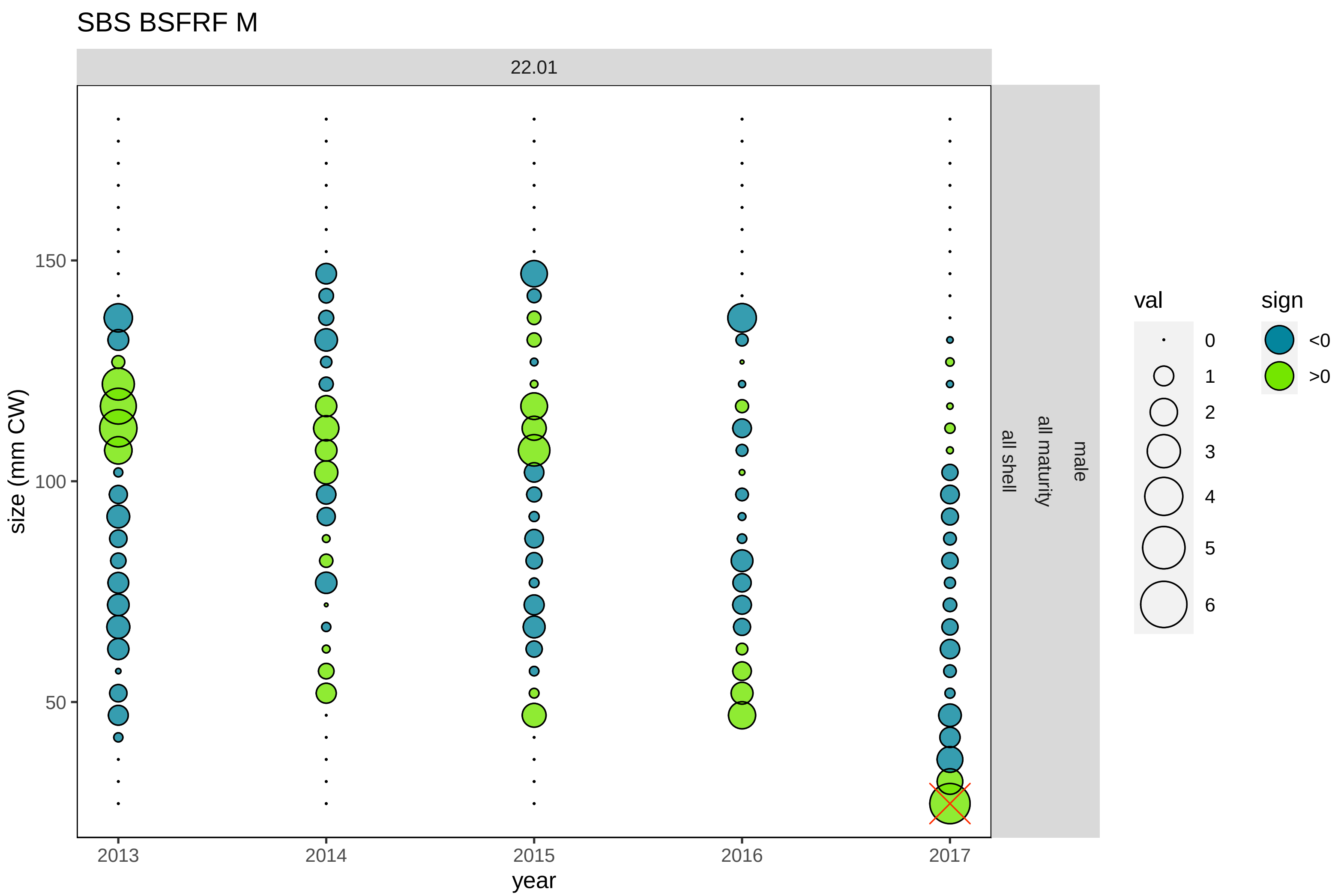

Figure 120: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

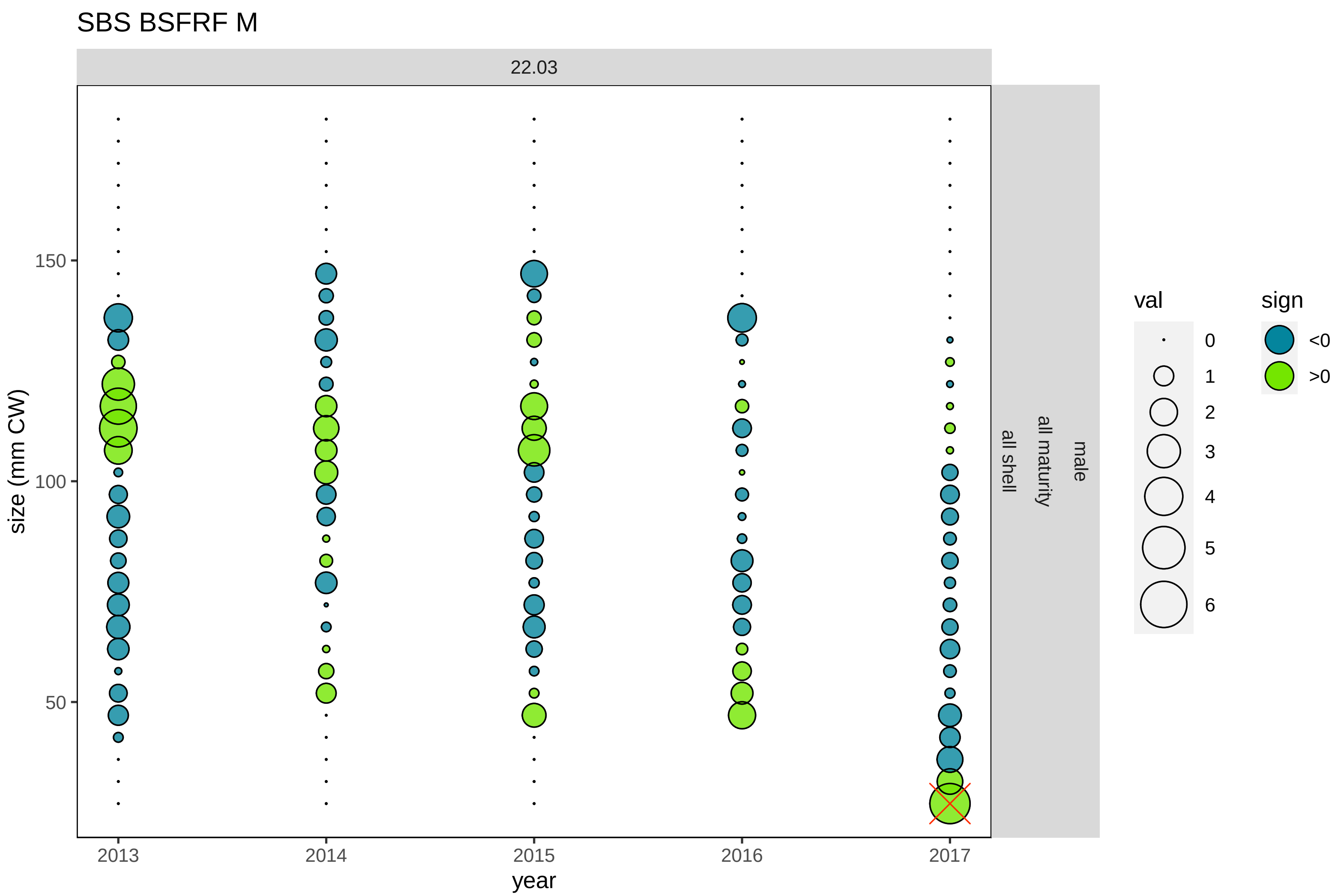

Figure 121: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

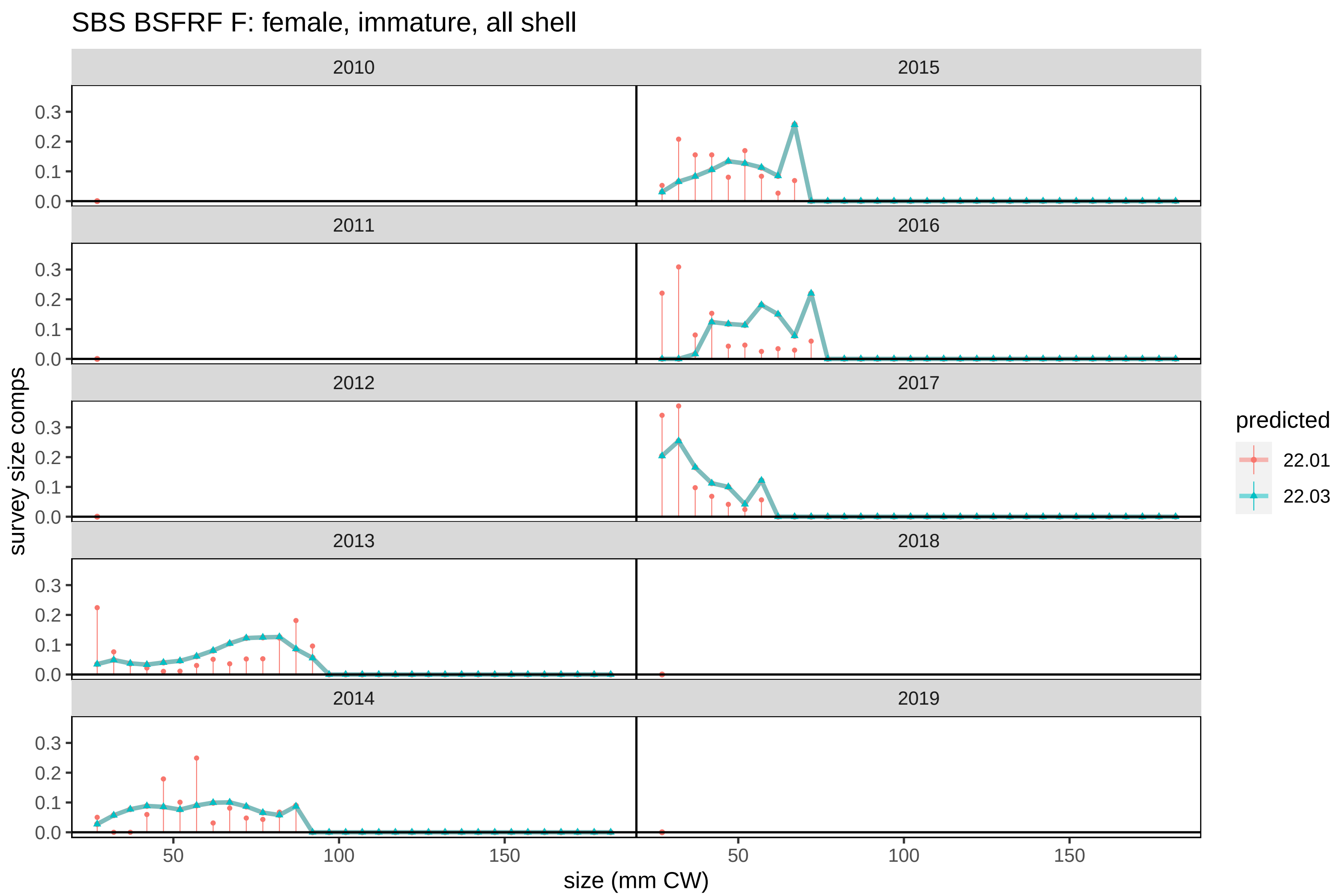

Figure 122: Fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03.

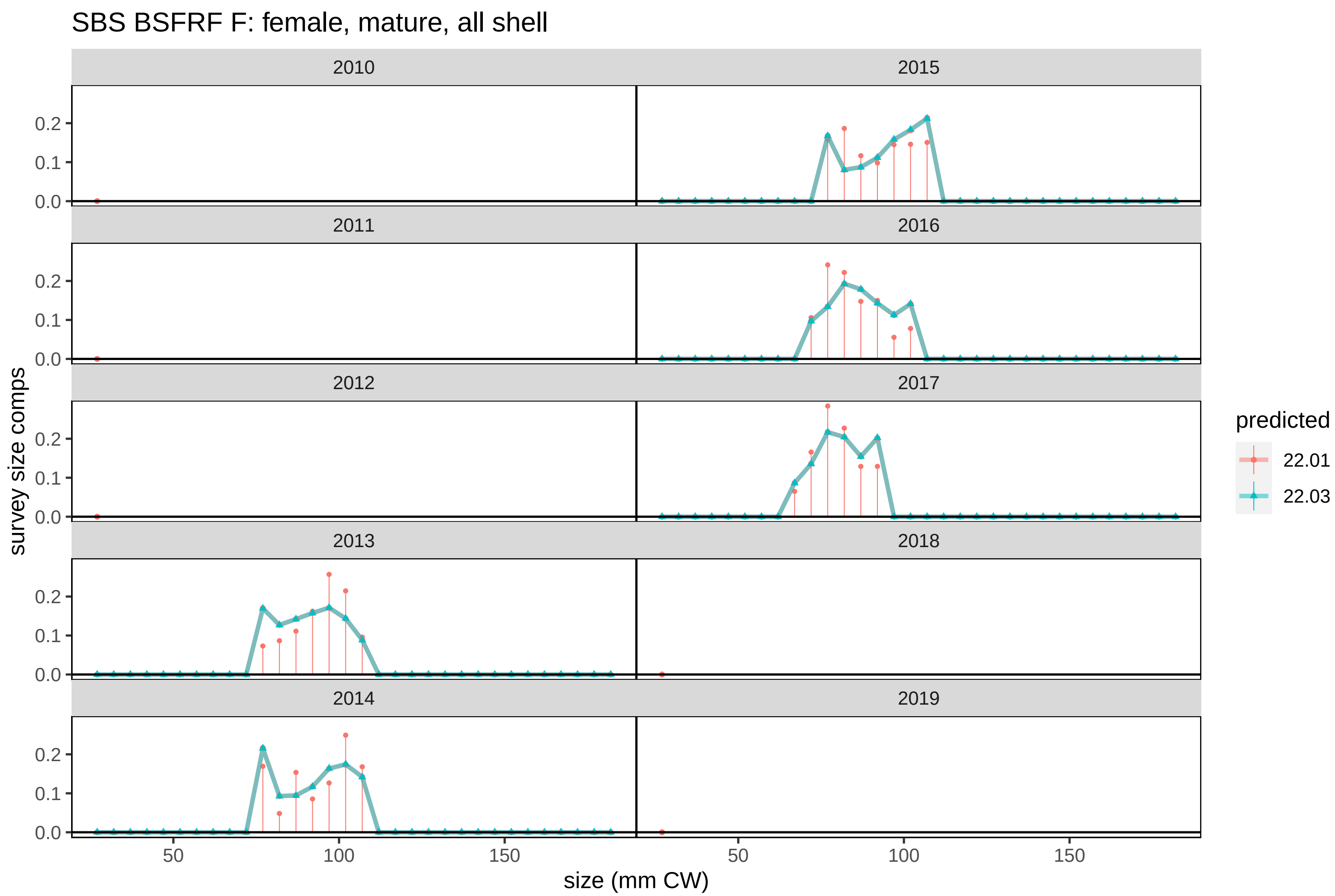

Figure 123: Fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03.

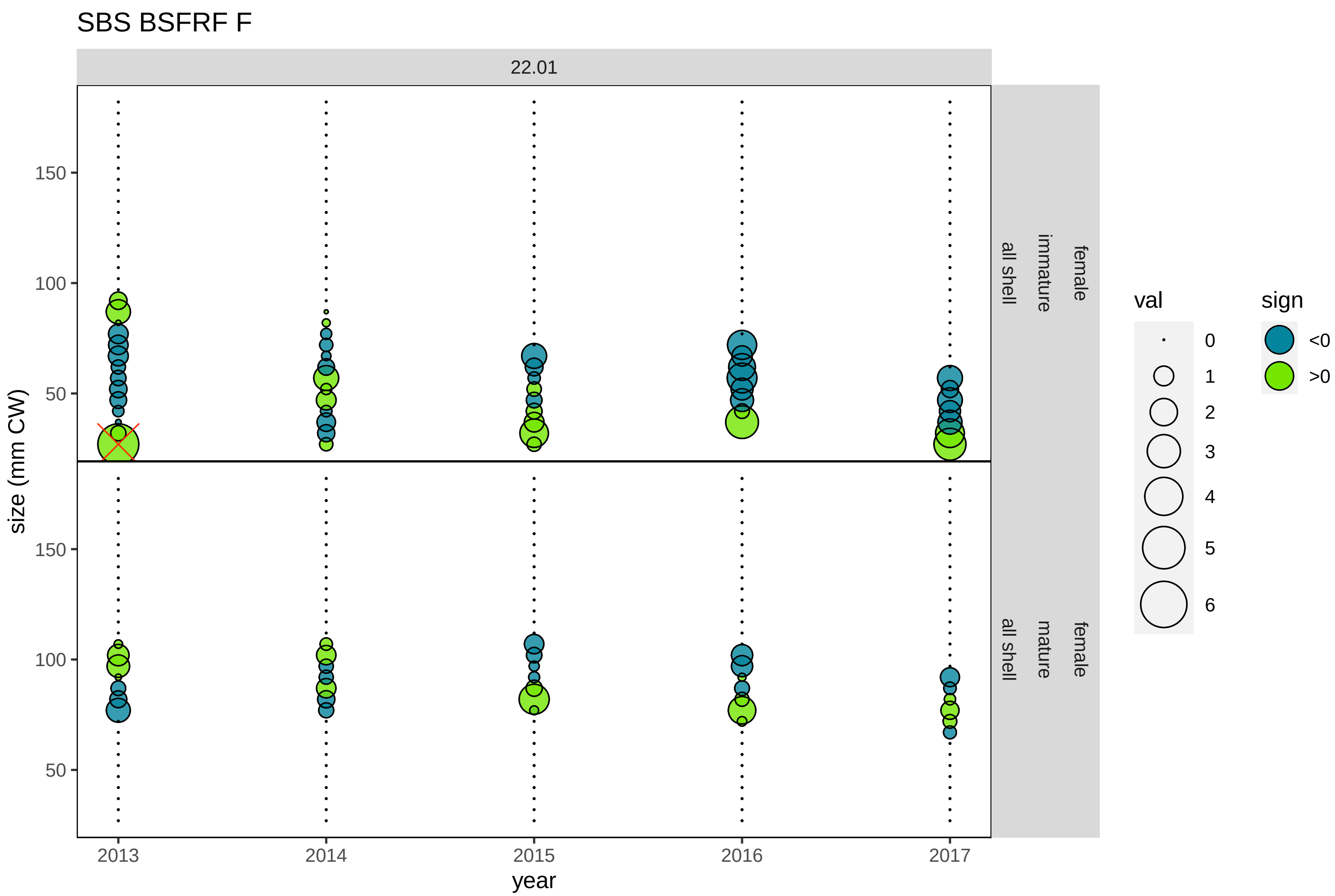

Figure 124: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

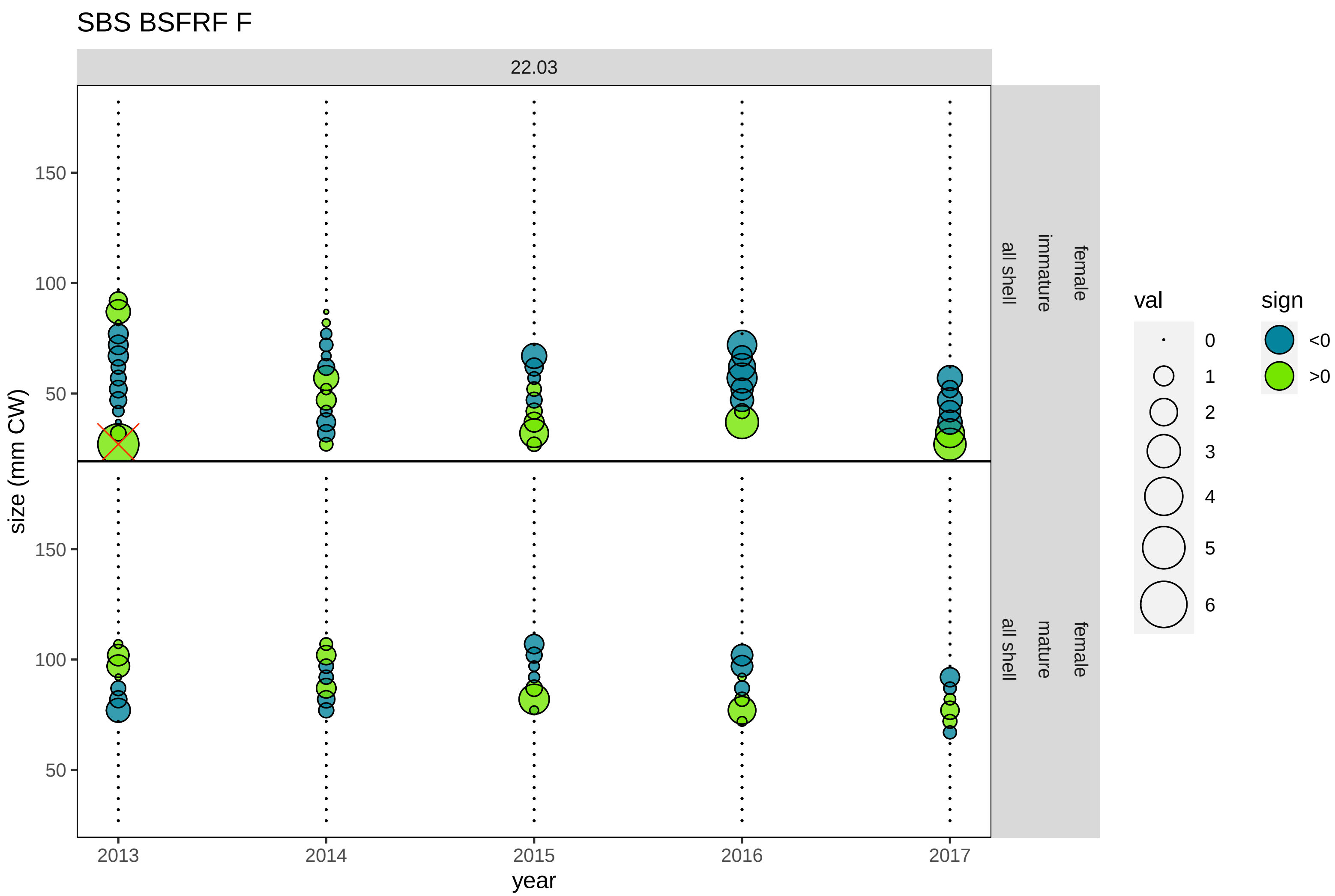

Figure 125: Pearson's residuals for fits to survey size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification. Preferred model is 22.03.

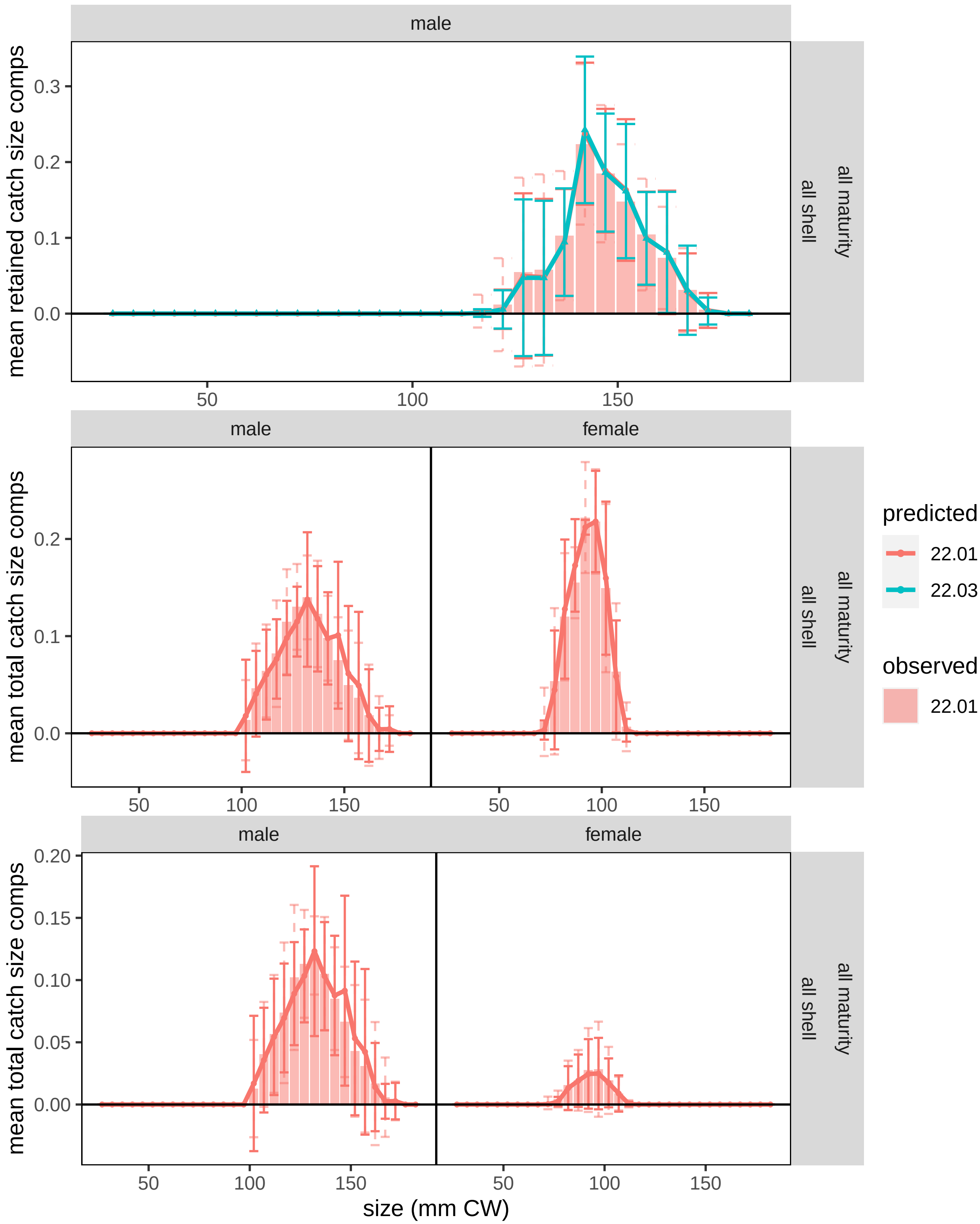

Figure 126: Fits to directed fishery mean size compositions. Upper plot: retained catch; center plot: total catch for scenarios 22.01; lower plot: total catch for 22.03. The total catch size compositions were normalized differently before fitting between 22.01 and 22.03. Model 22.03 is the preferred model.

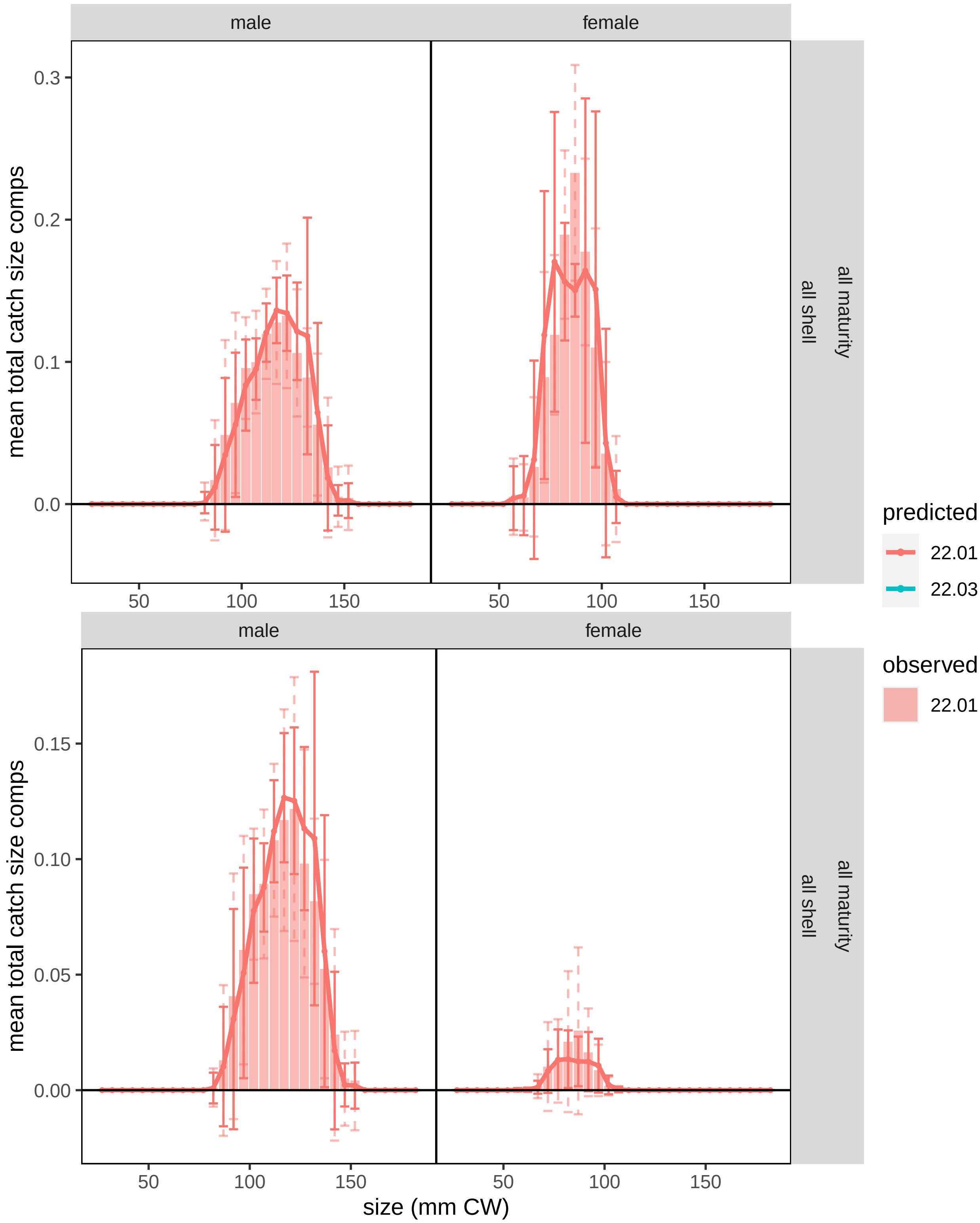

Figure 127: Fits to mean bycatch size compositions from the snow crab fishery. Upper plot: total catch for scenarios 22.01; lower plot: total catch for 22.03. The total catch size compositions were normalized differently before fitting between 22.01 and 22.03.. Model 22.03 is the preferred model.

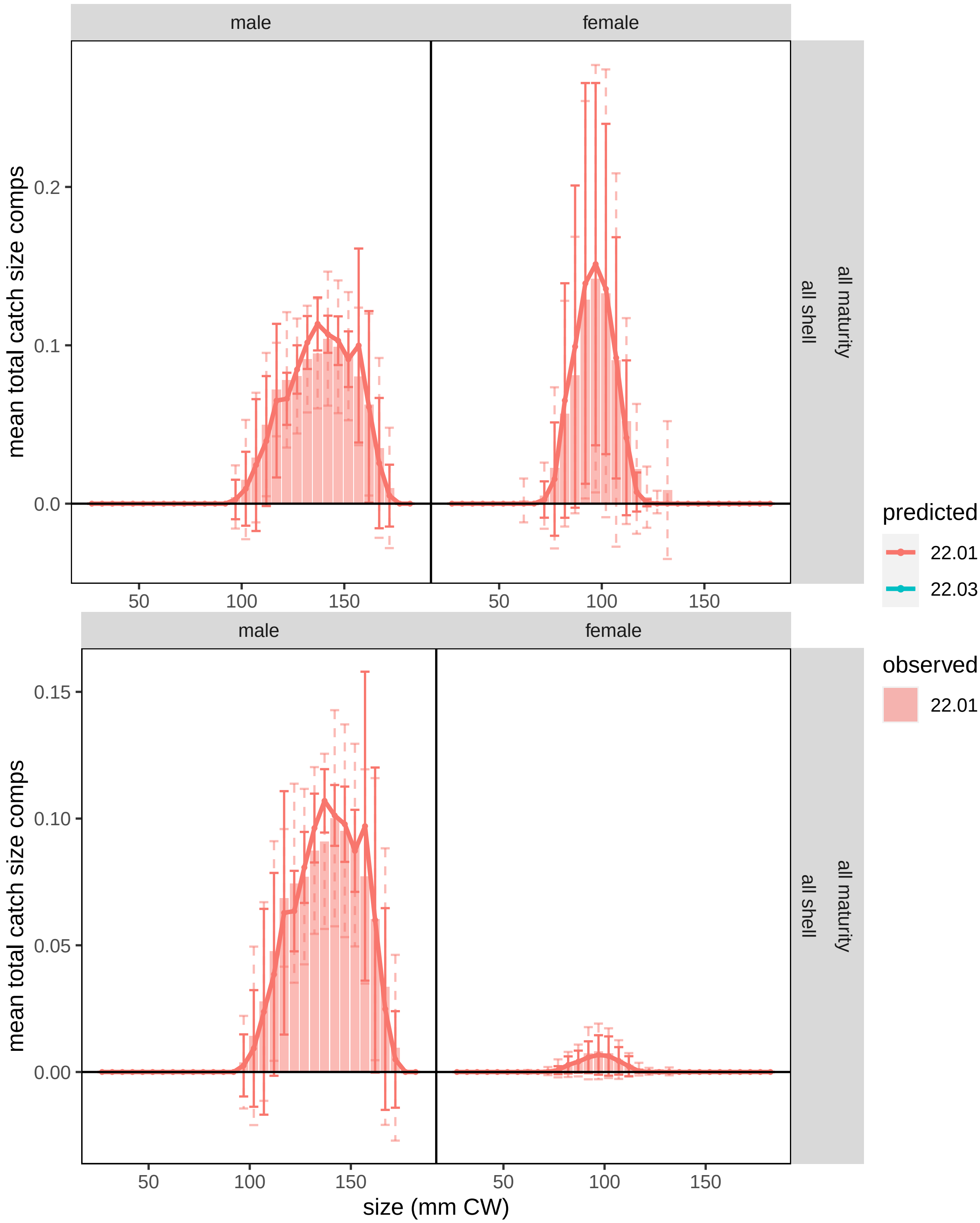

Figure 128: Fits to mean bycatch size compositions from the BBRKC fishery. Upper plot: total catch for scenarios 22.01; lower plot: total catch for 22.03. The total catch size compositions were normalized differently before fitting between 22.01 and 22.03.. Model 22.03 is the preferred model.

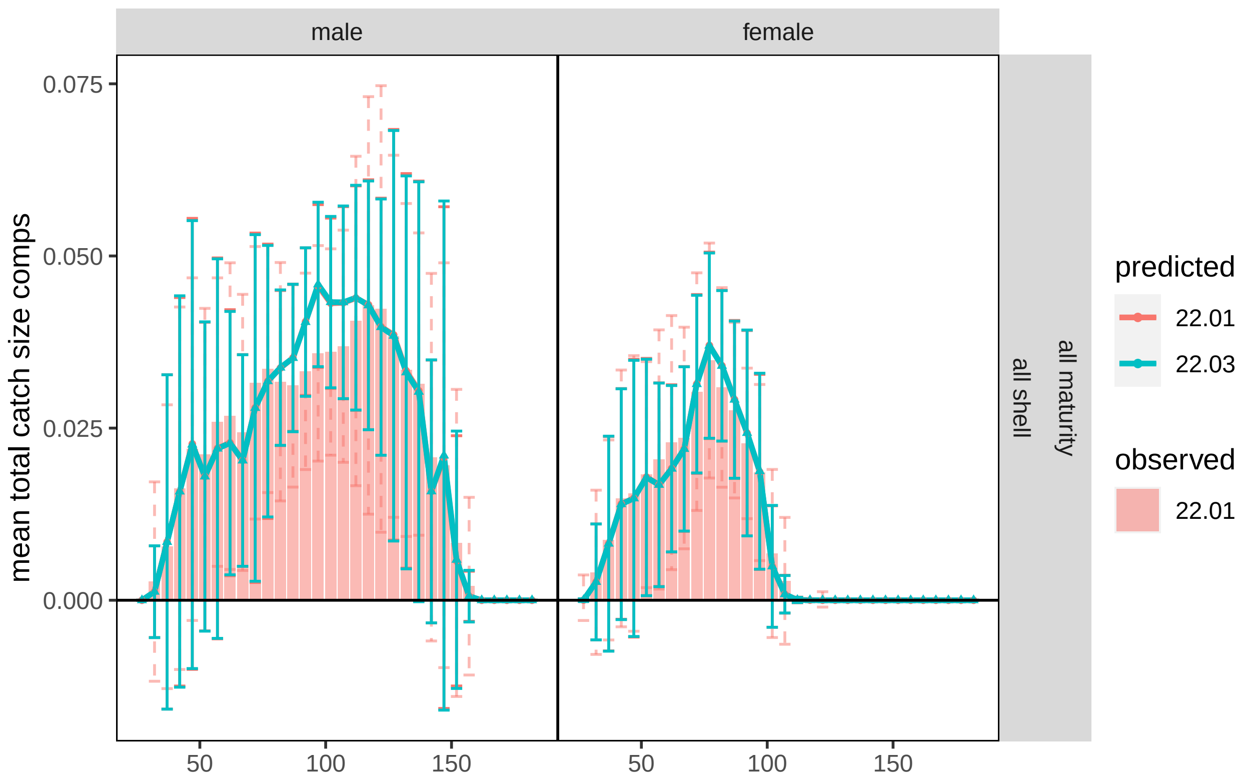

Figure 129: Fits to mean bycatch size compositions from the groundfish fisheries. The total catch size compositions were normalized similarly for all model scenarios. Model 22.03 is the preferred model.

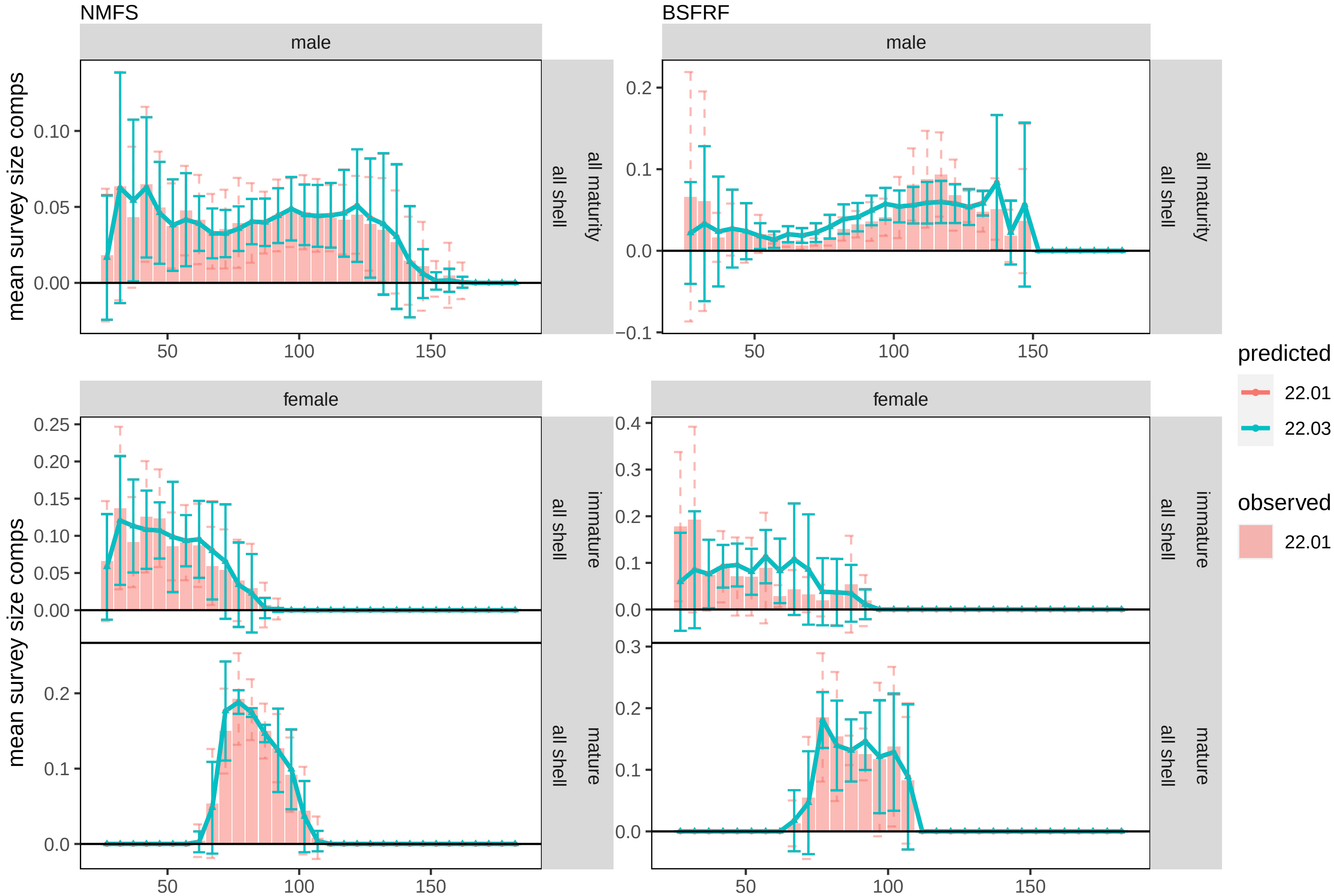

Figure 130: Fits to mean survey size compositions from the NMFS EBS (left column) and BSFRF SBS (right column) surveys. The total catch size compositions were normalized similarly for all model scenarios. Model 22.03 is the preferred model.

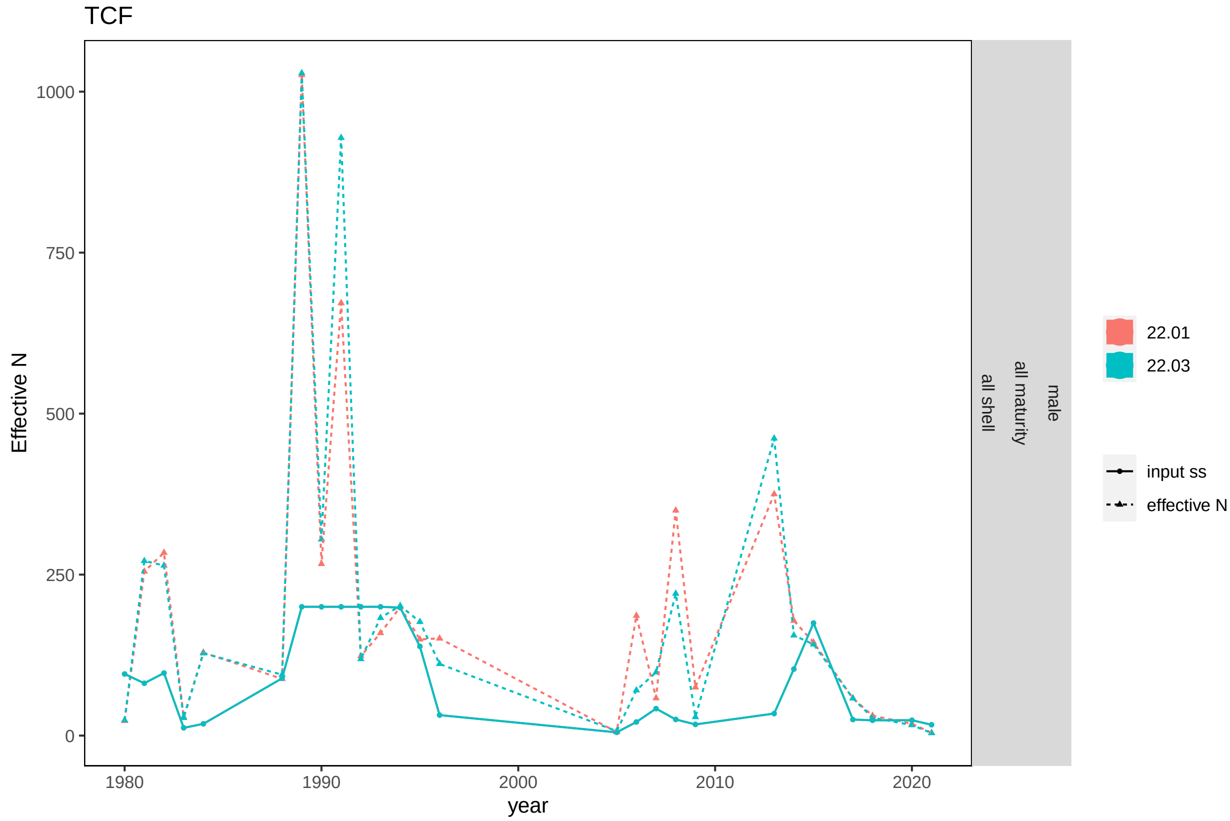

Figure 131: Effective sample sizes compared with input sample sizes for retained catch data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are constrained to a maximum of 200. Model 22.03 is the preferred model.

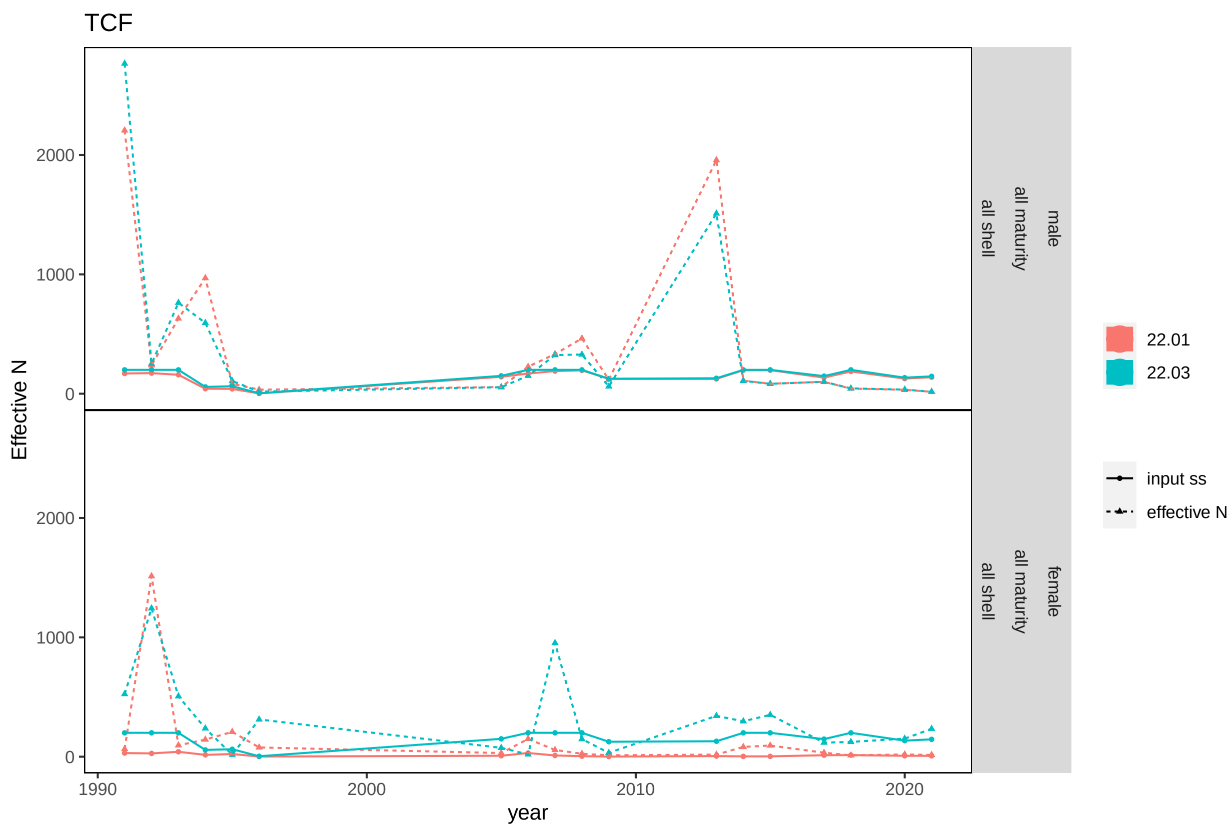

Figure 132: Effective sample sizes compared with input sample sizes for total catch data. from the TCF fishery.Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03 is the preferred model.

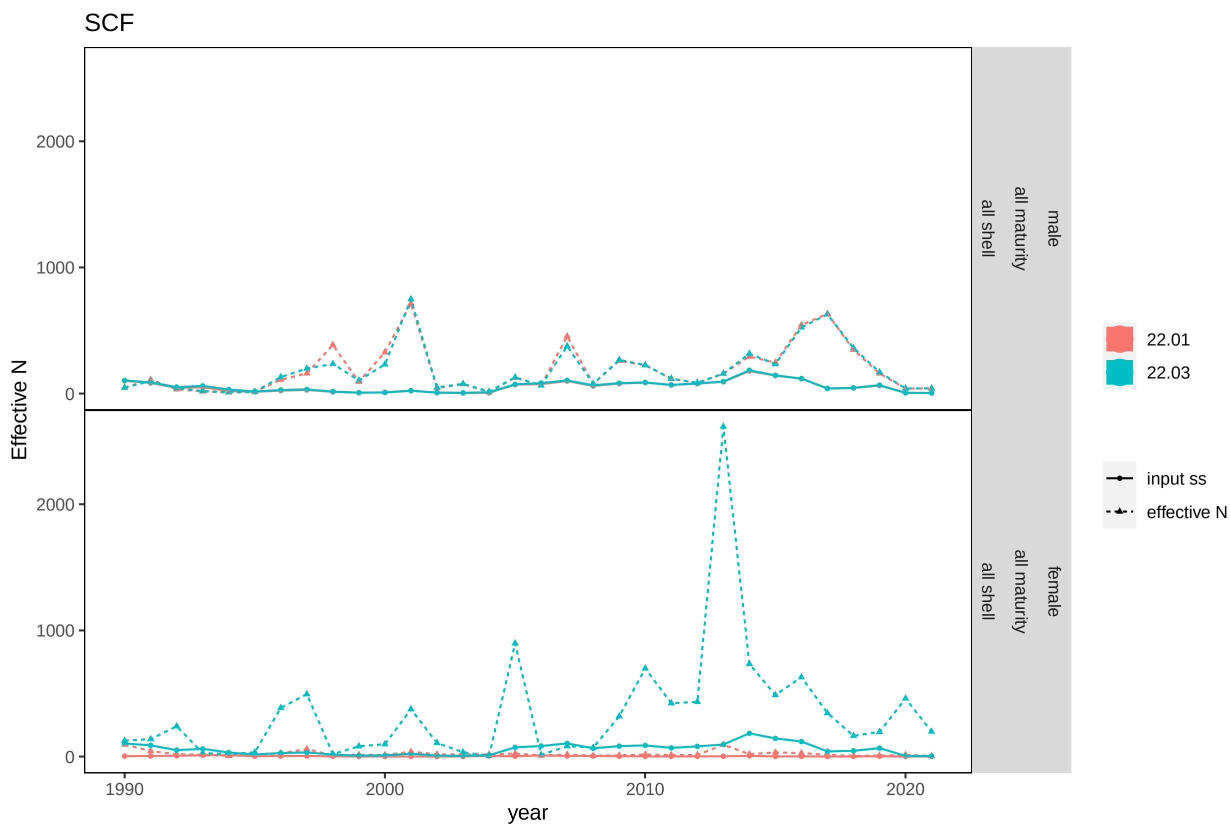

Figure 133: Effective sample sizes compared with input sample sizes for total catch data. from the SCF fishery.Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03 is the preferred model.

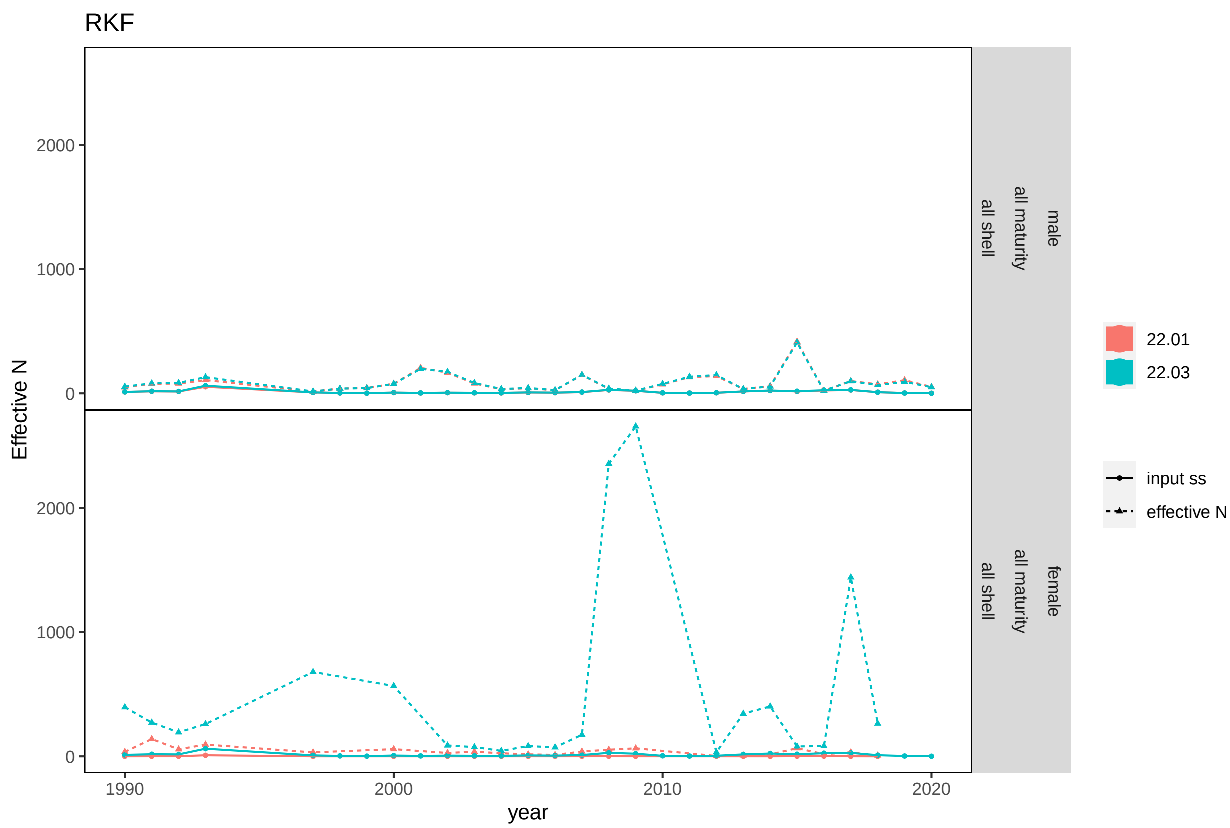

Figure 134: Effective sample sizes compared with input sample sizes for total catch data. from the RKF fishery.Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03 is the preferred model.

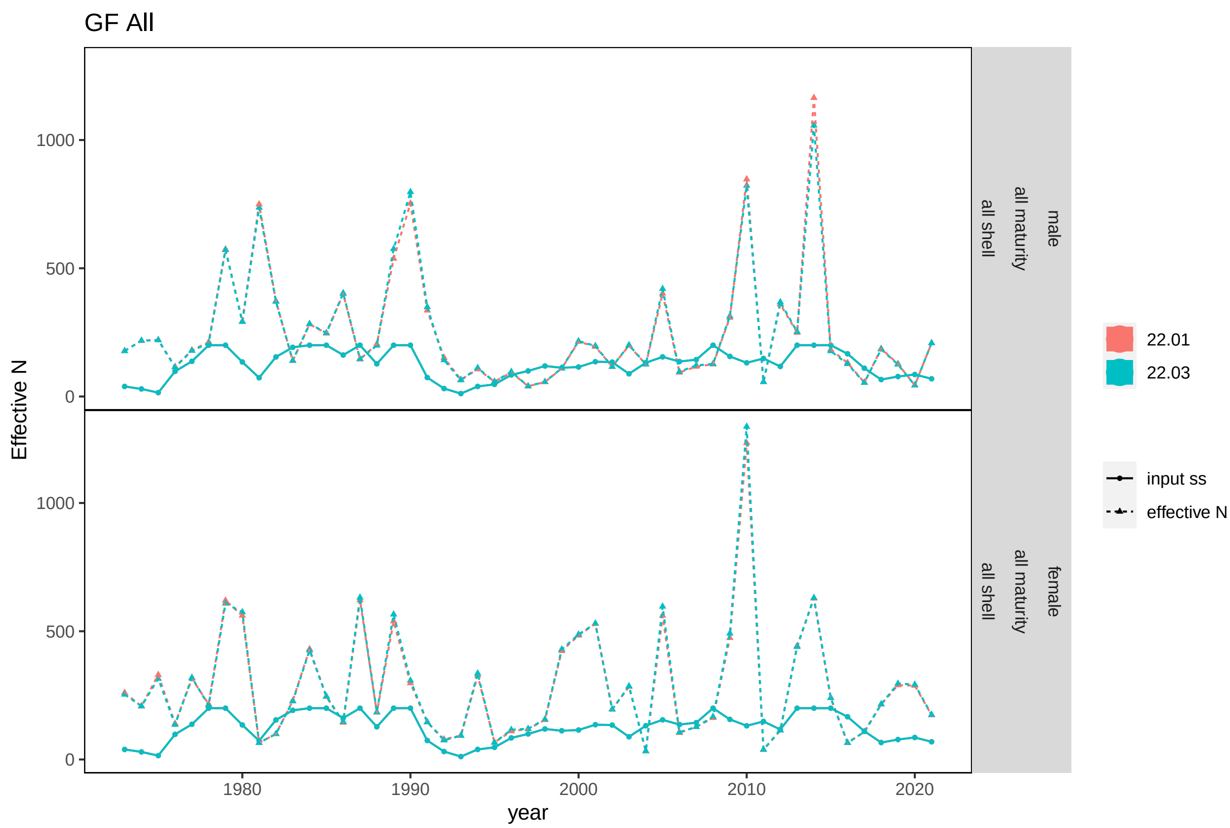

Figure 135: Effective sample sizes compared with input sample sizes for total catch data. from the GF All fishery.Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03 is the preferred model.

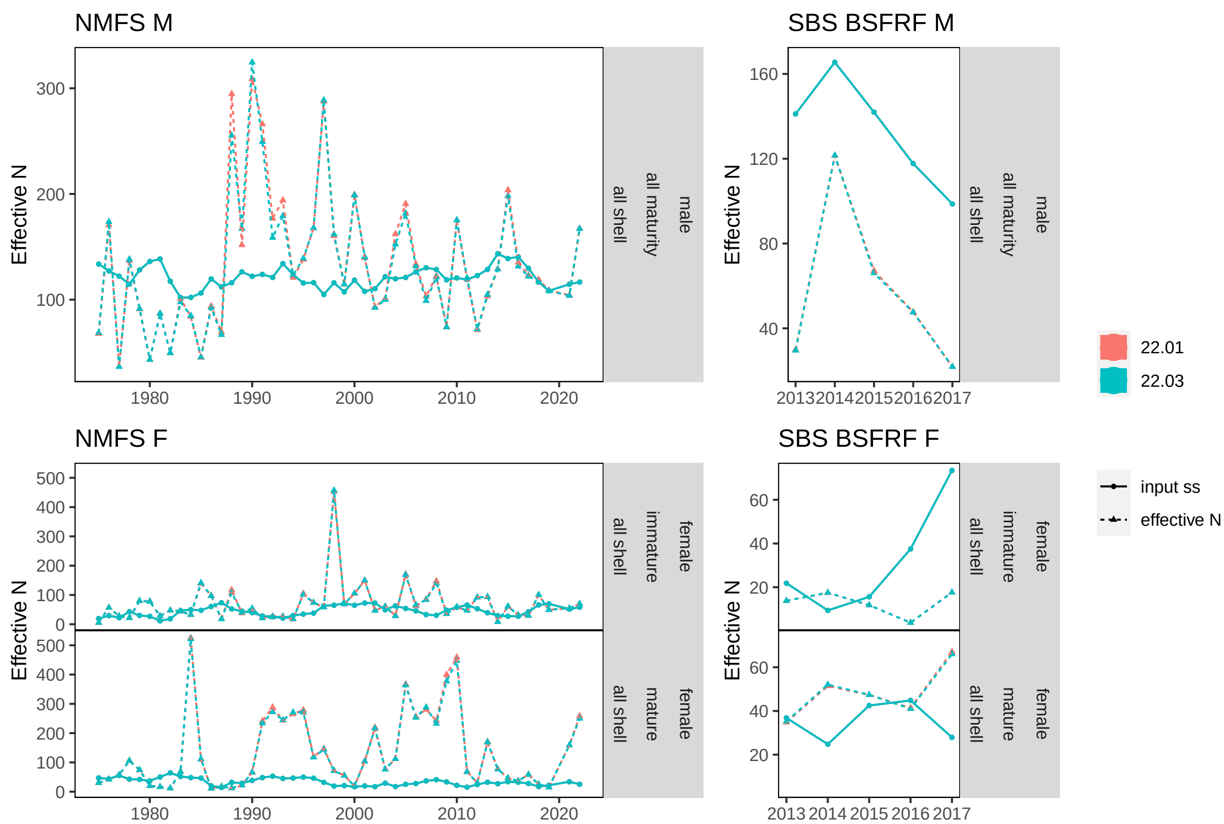

Figure 136: Effective sample sizes compared with input sample sizes for survey data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03 is the preferred model.

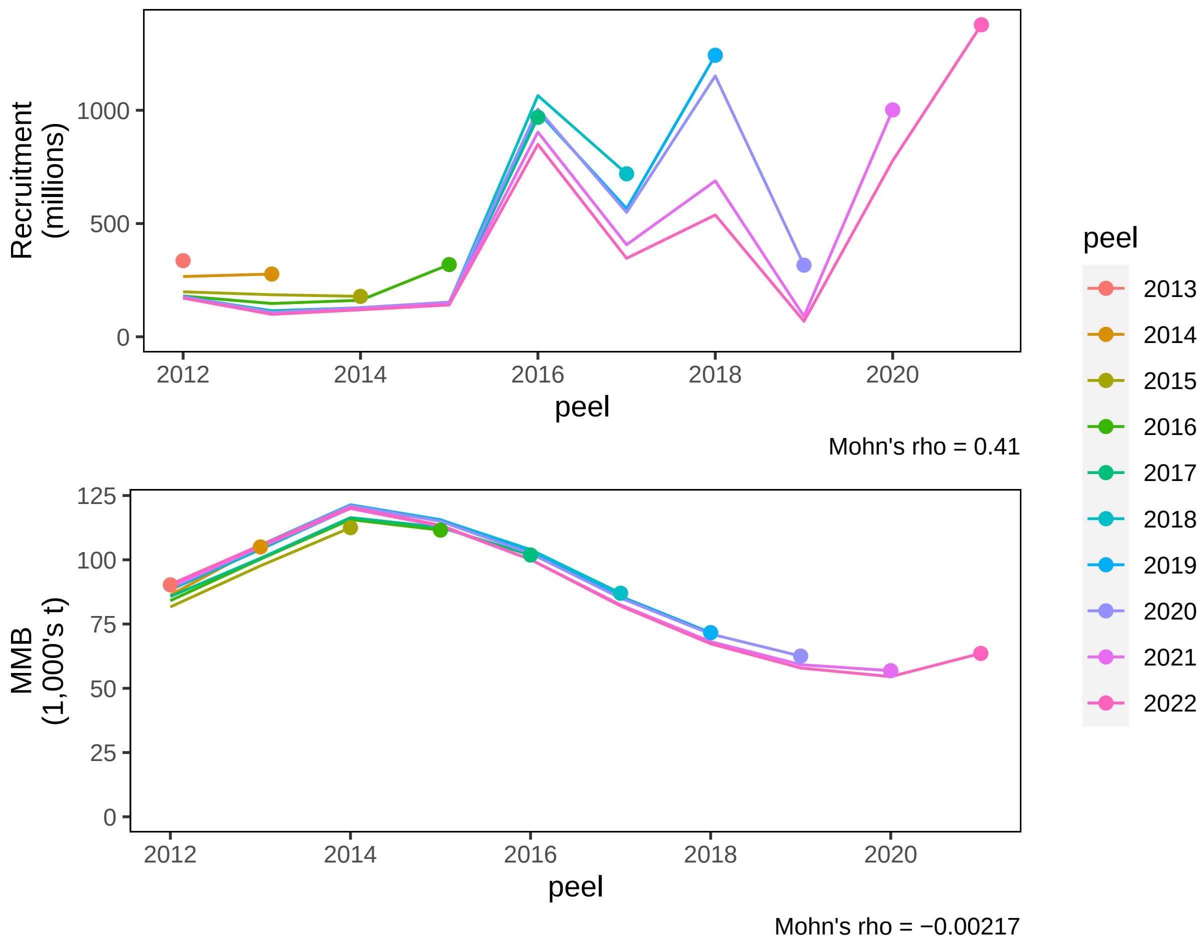

Figure 137: Retrospective analysis for candidate model 22.01. Upper plot: recruitment; lower plot: MMB. The value of Mohn's rho for each time series is given below the respective plot.

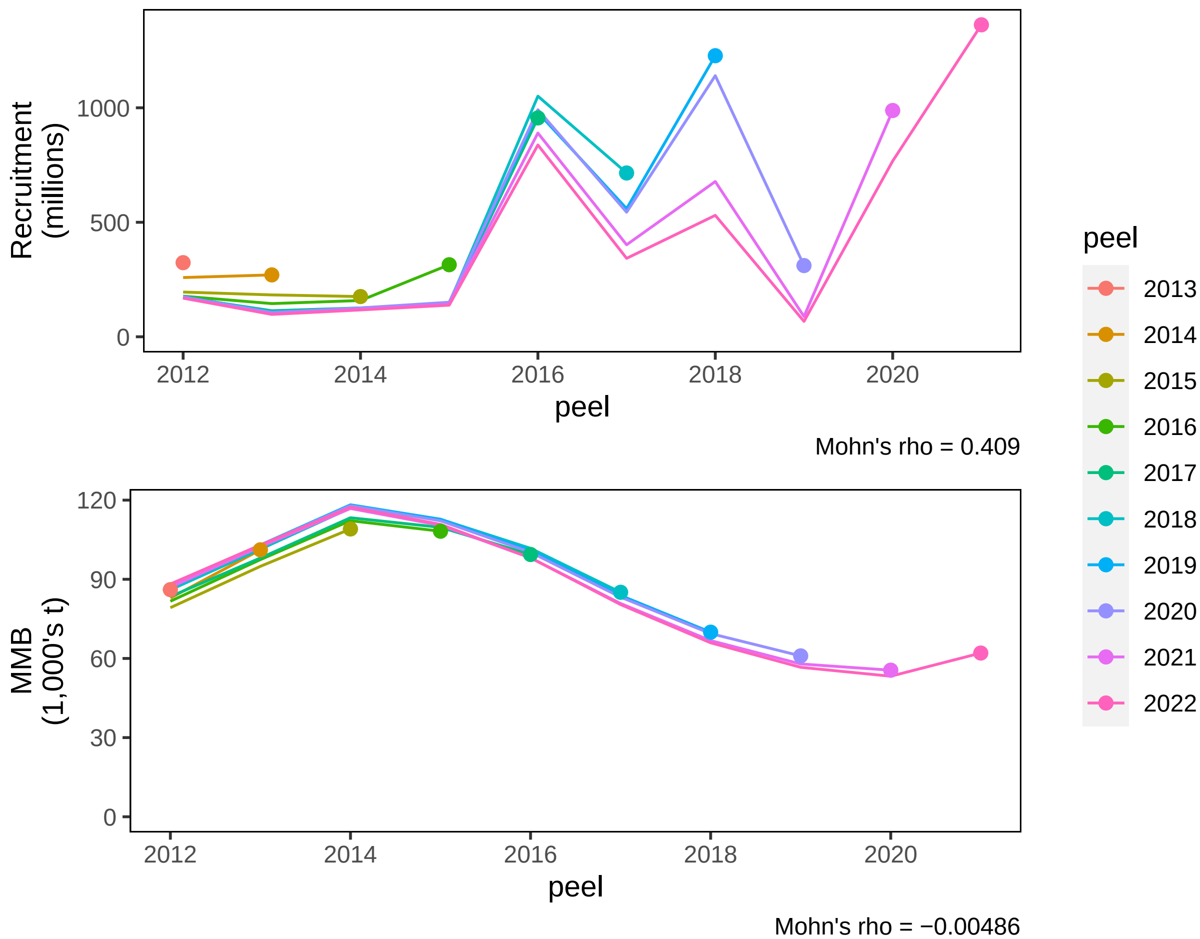

Figure 138: Retrospective analysis for candidate model 22.03. Upper plot: recruitment; lower plot: MMB. The value of Mohn's rho for each time series is given below the respective plot.

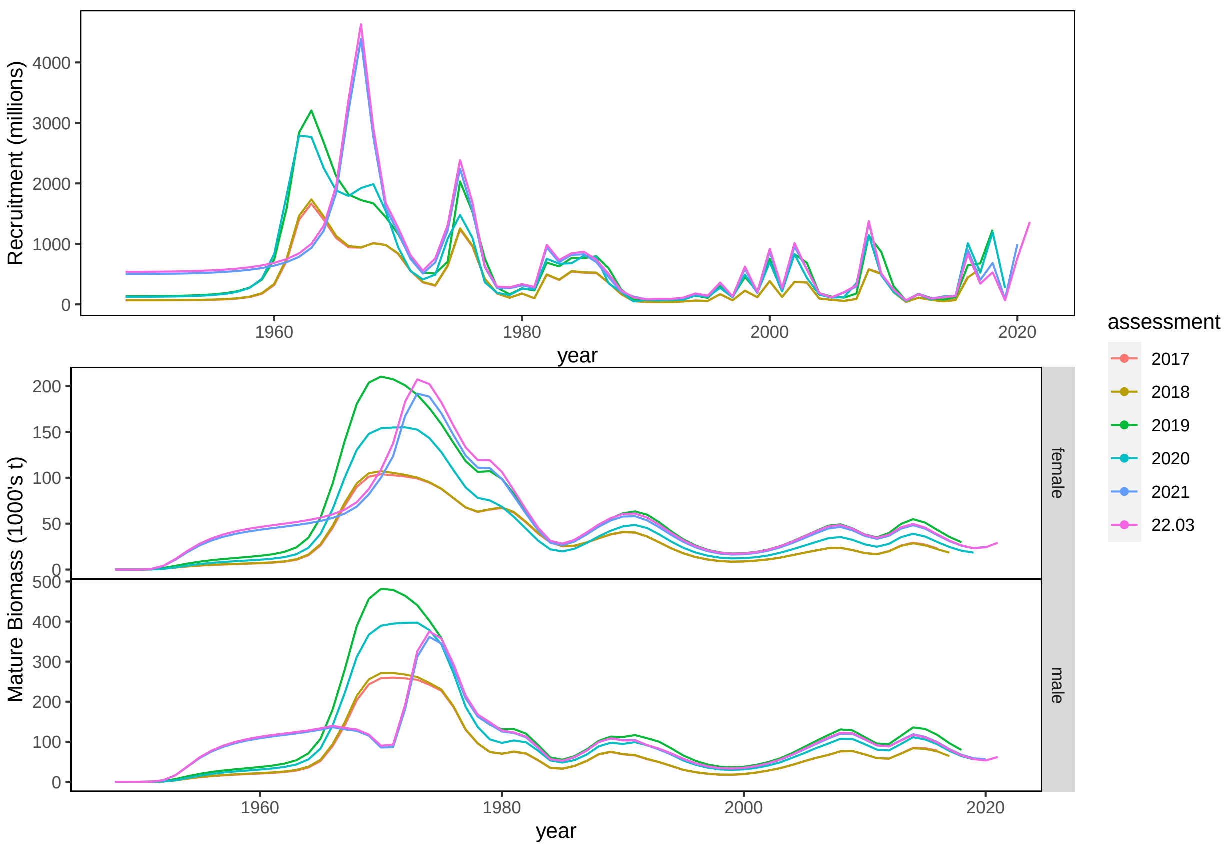

Figure 139: Comparison of the preferred model with results from previous assessments (full model time period).Model 22.03 is the preferred model.

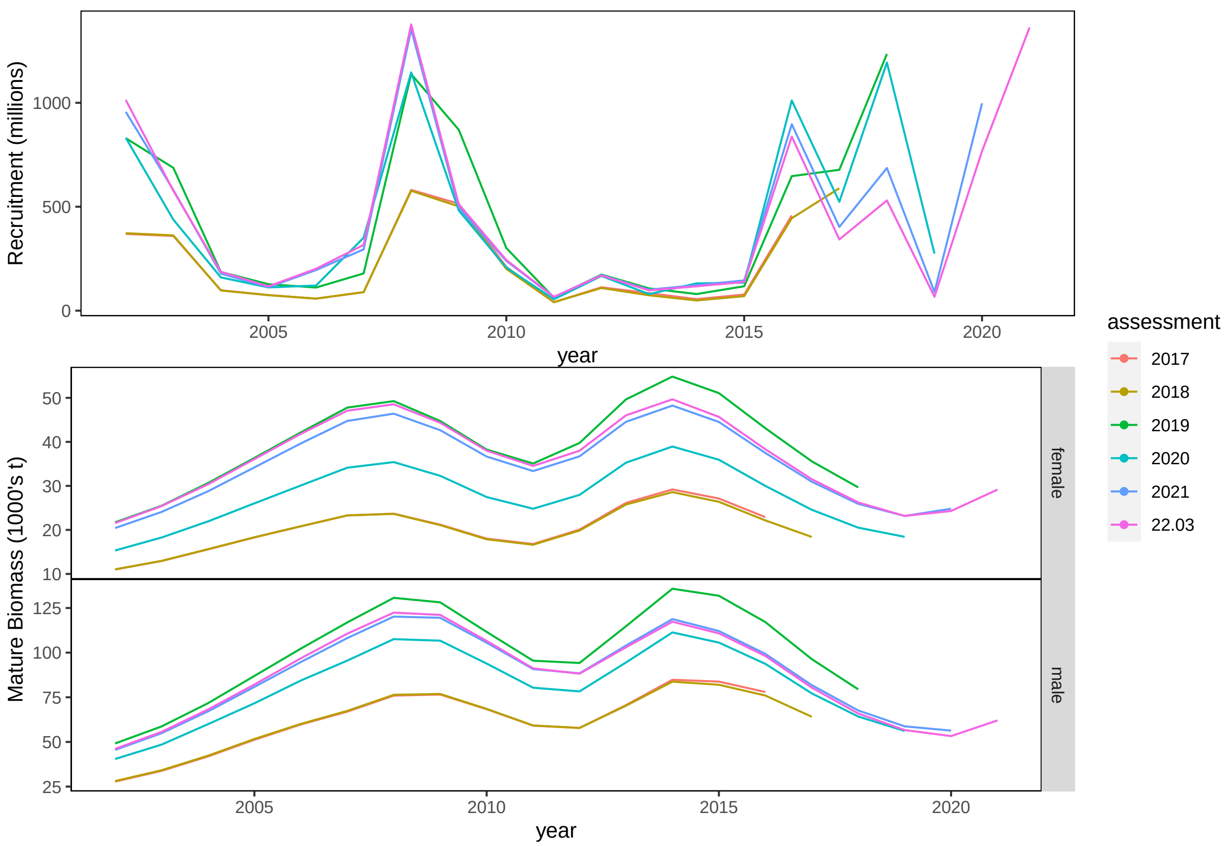

Figure 140: Comparison of the preferred model with results from previous assessments (last 20 years).Model 22.03 is the preferred model.

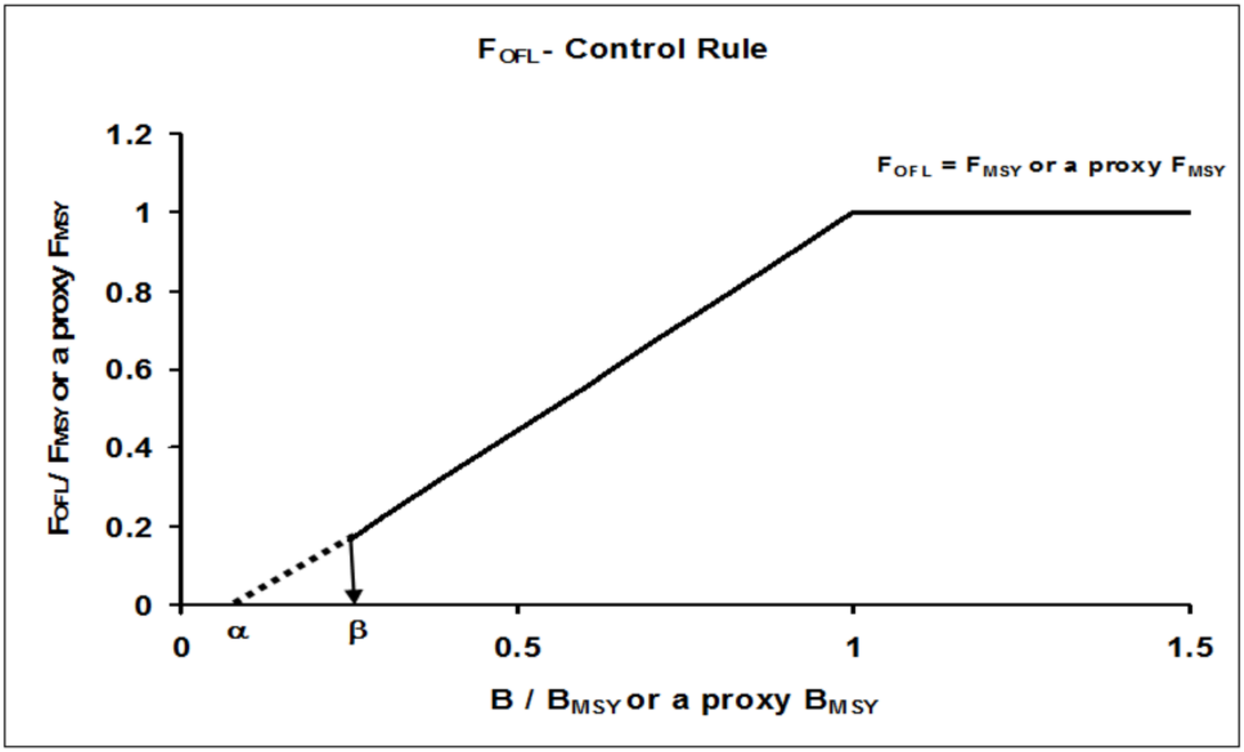

Figure 141: Fofl control rule.

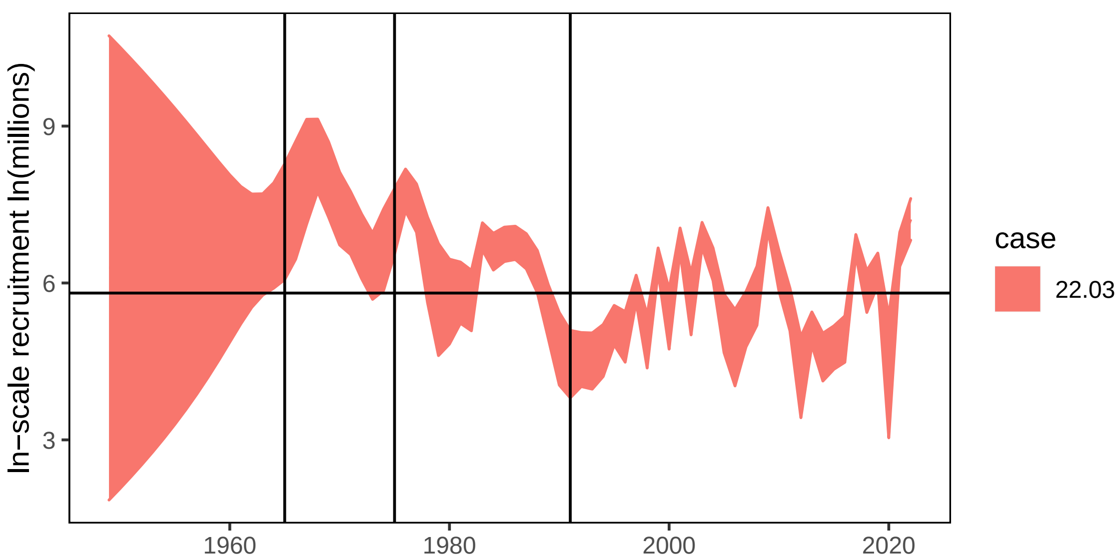

Figure 142: Time series of the estimated ln-scale recruitment, with 95% confidence intervals from the author's preferred model 22.03. Vertical lines indicate 1965, 1975, and 1991.

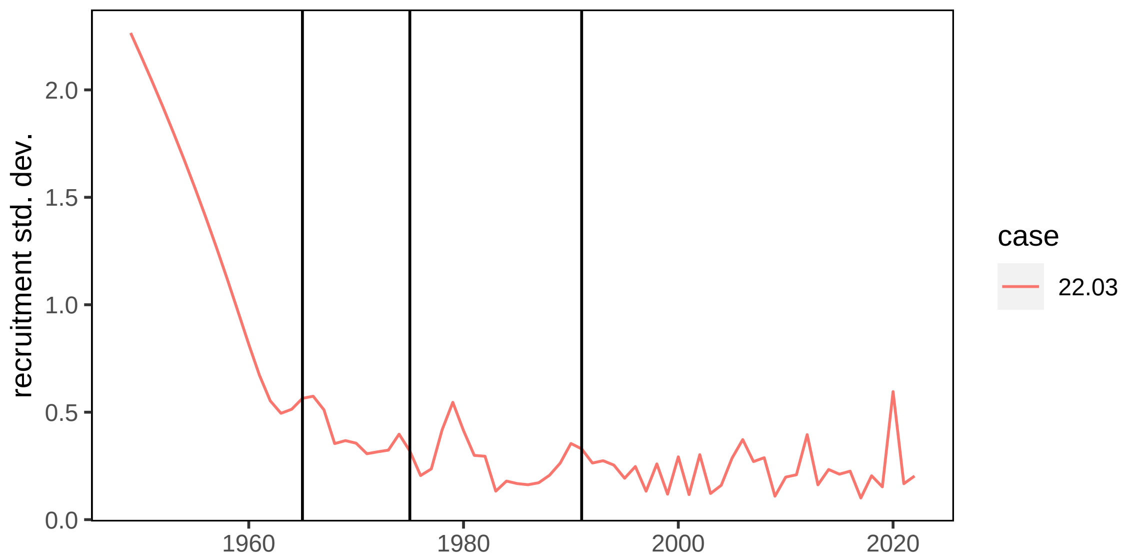

Figure 143: Time series of estimated standard deviation of the ln-scale mean recruitment parameter from the author's preferred model 22.03. Vertical lines indicate 1965, 1975, and 1991.

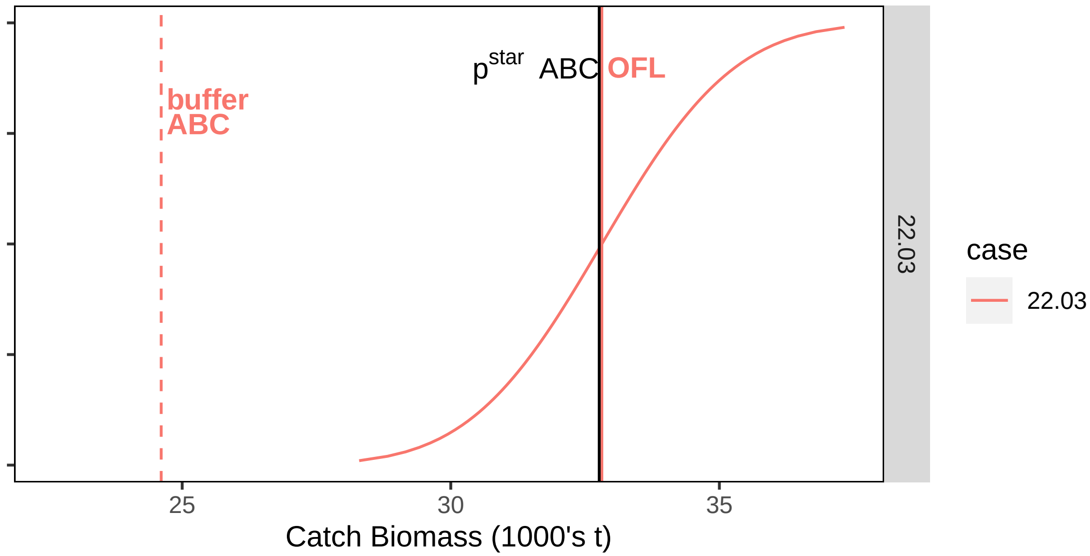

Figure 144: OFL and ABCs for the author's preferred model, 22.03

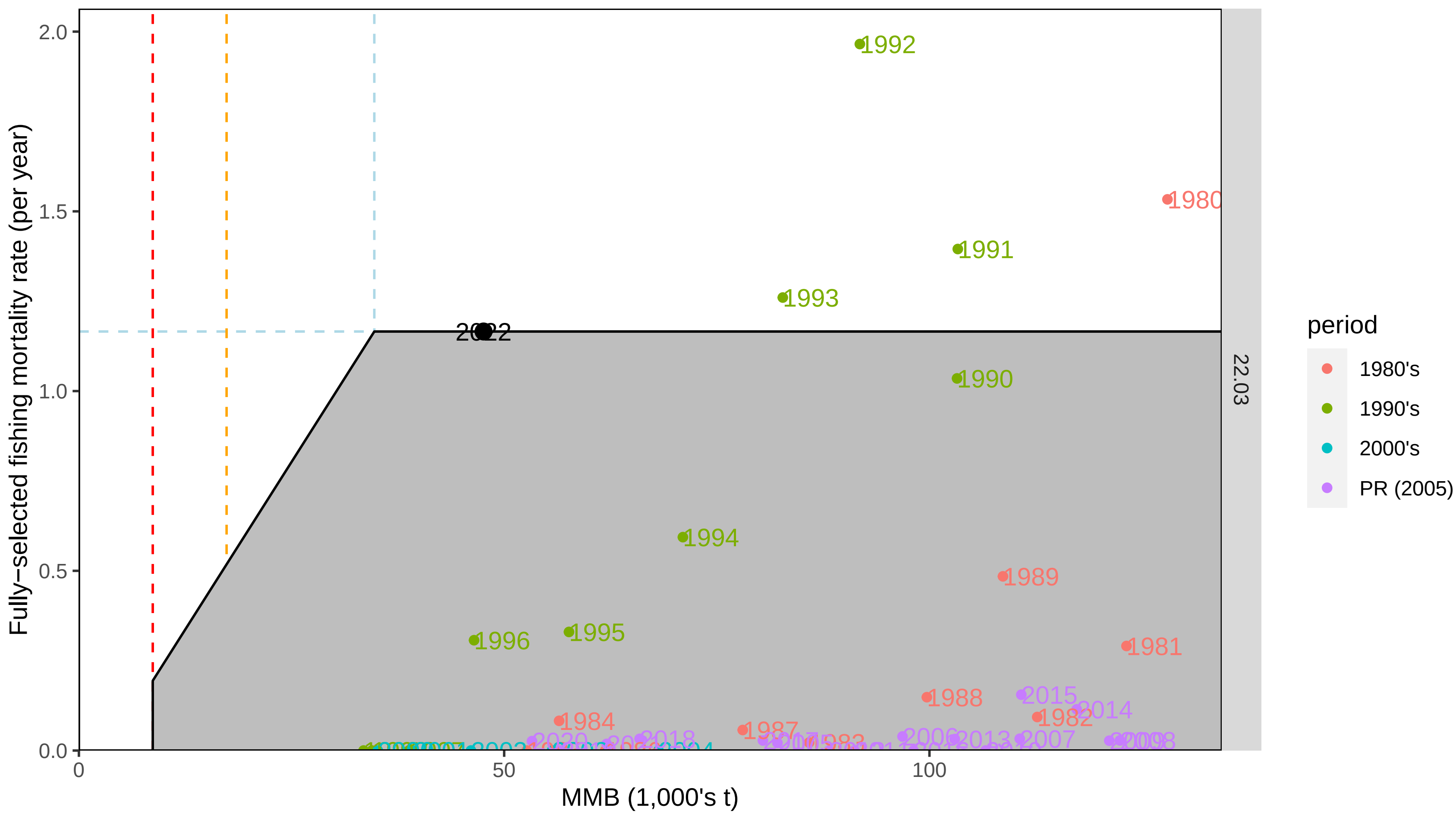

Figure 145: Quad plot for the author's preferred model, 22.03. Estimated values are shown starting in 1980.

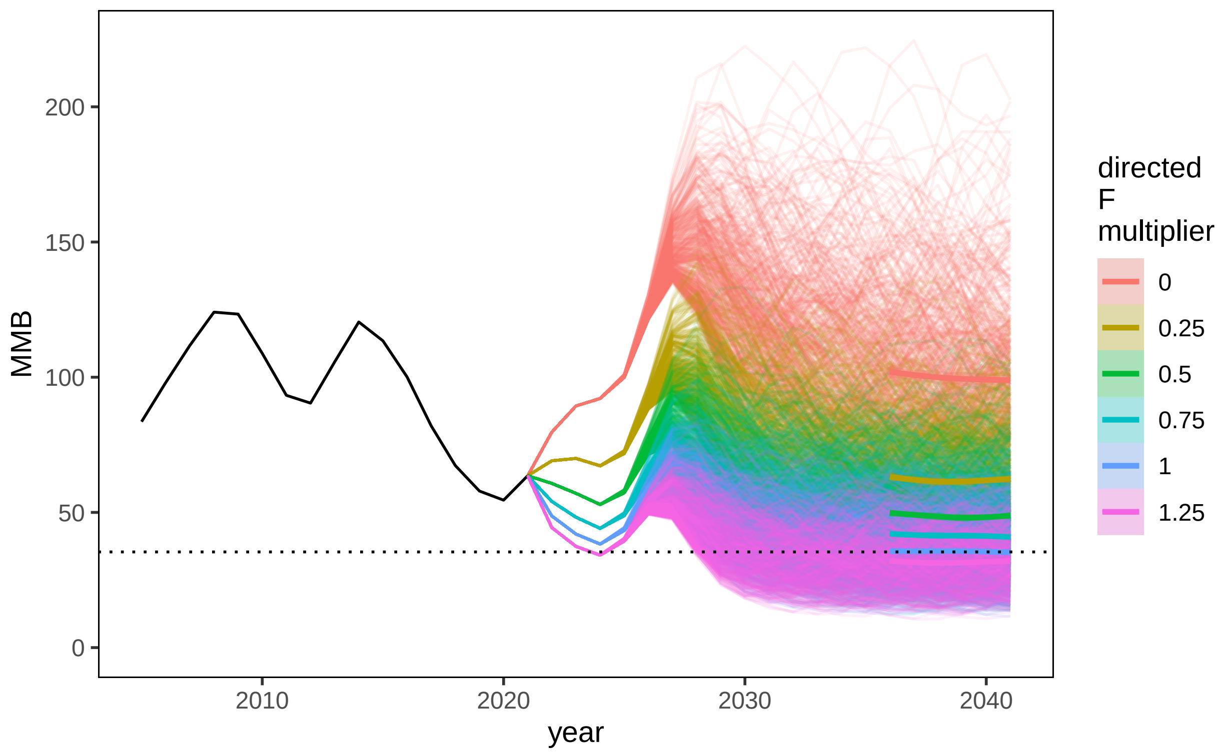

Figure 146: Multi-year projections using resampled recruitment estimates at specified multiples of the directed fishing F_OFL for model scenario 22.01.

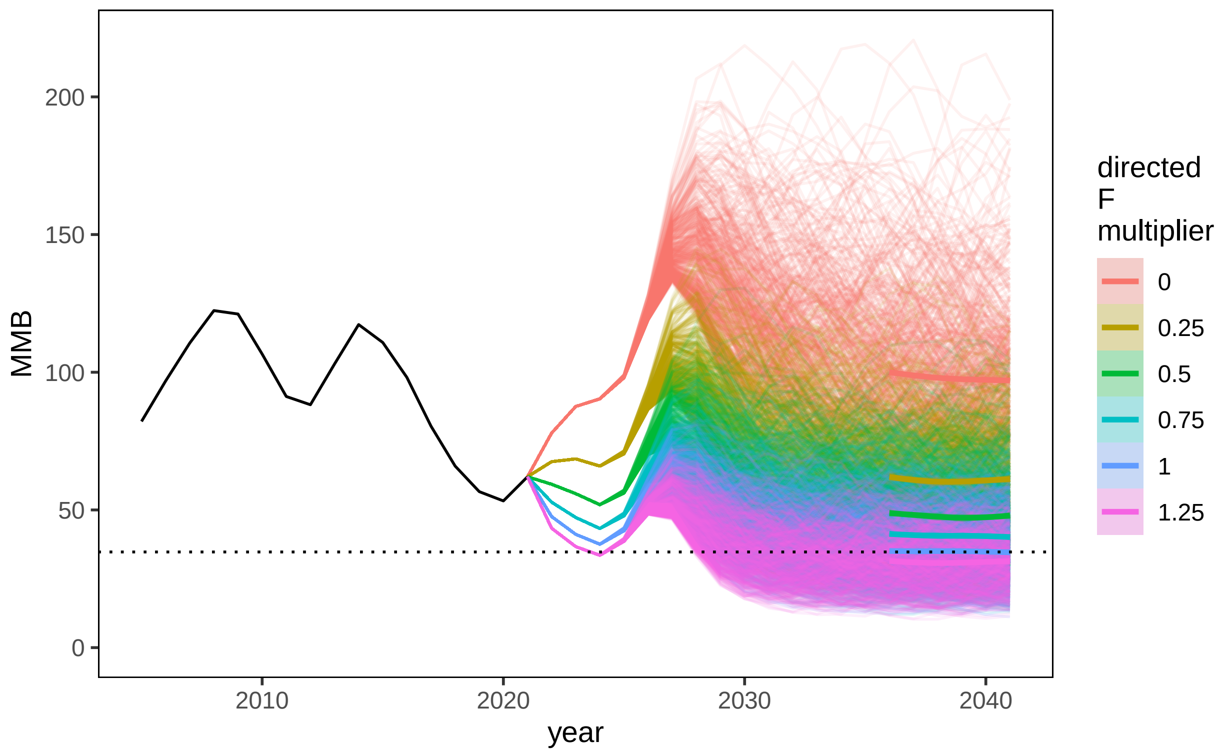

Figure 147: Multi-year projections using resampled recruitment estimates at specified multiples of the directed fishing F_OFL for model scenario 22.03.