2024 Stock Assessment and Fishery Evaluation Report for the Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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1 Executive Summary

1.1 Stock: species/area

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

1.2 Catches: trends and current levels

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

In addition to legal-sized males, females and sub-legal males are caught in the directed fishery as bycatch and must be discarded. Discarding of legal-sized males also occurs, primarily because the minimum size preferred by processors is larger than the minimum legal size, but also because "old shell" crab can be less desirable than "new shell" males. Tanner crab are also taken as bycatch in the snow crab and Bristol Bay red king crab fisheries, the groundfish fisheries, and, to a very minor extent, the scallop fishery. In order to account for mortality of discarded crab, handling mortality rates for Tanner crab are assumed to be 0.321 for crab discarded in the crab fisheries, 0.5 for crab discarded in the groundfish fisheries that use fixed gear, and 0.8 for crab discarded in the groundfish fisheries that use trawl gear (CPT 2014, 2021). Bycatch in the groundfish fisheries is aggregated across gear types in the assessment model and the rate for trawl gear is applied to the aggregated bycatch to estimate discard mortality. These values are intended 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 ADF&G set TACs to 0 in both management areas (thus closing the directed fishery) because stock biomass failed to meet required thresholds in the State's harvest strategy. Prior to the 2010/11 closure, the retained catch averaged 766.6 t per year between 2005/06-2009/10 and total catch mortality averaged 1,868 t. In early 2012, the National Marine Fisheries Service (NMFS) declared the stock overfished because the estimated mature male biomass fell below the federal Minimum Stock Size Threshold (MSST= $\frac{1}{2}B_{MSY}$), which was based at the time on a Tier 4 harvest control rule, with B_{MSY} based on average mature male biomass over a specified time period; (Rugolo and Turnock 2011b).

Subsequently, NMFS determined that the stock was no longer overfished based on a new Tier 3 assessment model with $B_{MSY} = B_{35\%}$. The OFL for 2012/13 was determined to be 19,020 t while the ABC was set to 8,170 t based on a “stair-step approach” adopted to re-open the fishery. ADF&G, however, set the TAC to 0 in both management areas in accordance with the State of Alaska's harvest strategy at the time. The OFL for the following year (2013/14) was determined to be 25,350 t, with an ABC of 17,820 t following the stair-step approach. ADF&G subsequently set the TACs 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 2,267 t. Since then, the stock has remained above its Tier 3 MSST and has not been considered overfished by federal standards. OFLs have ranged from ~21,000 t to ~36,000 t while ABCs have ranged from ~17,000 t to ~27,000 t; none have constrained fishery TACs set by ADF&G. However, ADF&G has closed the directed fishery in the eastern area 6 times since the 2015/16 season (i.e., every year except 2022/23 and 2023/24) and 2 times (2016/17 and 2019/20) in the western region based on harvest strategies with criteria incorporating stock size thresholds for females as well as males.

Since 2013/14, harvests reached a maximum of ~8,900 t (~20 million lbs) in 2015/16, but have subsequently been less than 1,200 t. During this period total catch mortality peaked in 2015/16 as well (~12,000 t) but has been less than (~2,000 t) since then.

For 2023/24, the OFL was 36,200 t and the ABC was 27,150 t. The TAC in the eastern region was 344.7 t and 598.7 t in the western region. Total retained catch was 940.3 t and total fishing mortality was estimated directly from observer data by applying gear-specific handling mortality rates to be 1,086 t.

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

The annual NMFS EBS shelf summer bottom trawl survey has been conducted since 1975. It is the principal source of fishery-independent data on the size of the Tanner crab stock. In 2024, survey biomass was 83.41 thousand t for males, 43.76 thousand t for females, and 11.51 thousand t for industry-preferred males (males ≥ 125 mm CW). Average survey biomass over the past 5 years was 44.78 thousand t for males, 20.40 thousand t for females, and 7.075 thousand t for industry-preferred males. Since the survey gear was standardized in 1982, maximum survey biomass occurred for males occurred in 1991 at 145.8 thousand t, for females in 1982 at 65.85 thousand t, and for industry-preferred males in 1992 at 127.6 thousand t. In general, the stock has fluctuated on a decadal scale imposed on a declining trend since the beginning of the survey. Since 2010, maximum survey biomass for males occurred in 2014 at 108.9 thousand t, for females in 2024 at 43.76 thousand t, and for industry-preferred males in 2014 at 35.98 thousand t.

For EBS Tanner crab, spawning stock biomass is expressed as mature male biomass (MMB) at the time of mating (mid-February), which is a model-estimated quantity. From the author's preferred model (22.03d5), estimated MMB for 2023/24 was 88.21 thousand t. The most recent peak in MMB occurred in 2014/15 at 117.2 thousand t. MMB approached the very low levels seen in the mid-1990s to early 2000s (1993 to 2003 average: 50.89 thousand t) in 2020/21 at 50.86 thousand t but has increased over the past two years.

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

Annual recruitment, the number of small crab (≥ 25 mm CW) entering the population at the beginning of the crab year (July 1), is a model-estimated quantity. From the author's preferred model (22.03d5), estimated total recruitment has increased since 2014, when recruitment reached its lowest level (95 million) since 2011. Average recruitment over the previous 10 years (2014-2023) was 736 million crab, which is ~-32% more than the long-term (1982-2023) mean of 556 million crab. For 2024, estimated recruitment is 431 million crab, which is substantially less than the estimate for the previous year (1,768 million) and below the longterm average. However, estimates of recruitment in the final model year are generally not well-estimated.

1.5 Management performance

Historical status and catch specifications for eastern Bering Sea Tanner crab, with 2024/25 values based on the maximum likelihood estimate (MLE) from the author's recommended model, 22.03d5, are given in the following tables:

Table A. Management quantities (in 1,000's t) from the author's preferred model, 22.03d5, and recommended ABC buffer (20%). The TAC is summed across ADF&G management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	17.97	56.34	1.07	0.66	0.96	21.13	16.90
2021/22	17.37	62.05	0.50	0.49	0.78	27.17	21.74
2022/23	18.19	74.17	0.91	0.91	1.19	32.81	26.25
2023/24	20.00	88.21	0.94	0.94	1.09	36.20	27.15
2024/25	NA	56.06	NA	NA	NA	41.29	33.03

Table B. Management quantities (in millions of pounds) from the author's preferred model, 22.03d5, and recommended ABC buffer (20%). The TAC is summed across ADF&G management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	39.61	124.19	2.35	1.44	2.11	46.58	37.26
2021/22	38.29	136.79	1.10	1.09	1.73	59.89	47.91
2022/23	40.11	163.62	2.02	NA	NA	72.34	54.25
2023/24	44.10	194.46	2.08	2.07	2.39	79.82	59.86
2024/25	NA	123.59	NA	NA	NA	91.03	72.82

Notes: MSST and MMB based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

1.6 Probability density function for the OFL

The probability density function assumed for the Tier 3 OFL to determine the p^* ABC was a normal function with mean 41,289 t and standard deviation 2,440 t. The standard deviation for the OFL was estimated using AD Model Builder's "delta" method.

1.7 Basis for the 2024/25 OFL

Table C. Basis for the OFL from the author's preferred model, 22.03d5. Biomass uints are in 1,000's of metric tons.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2020/21	3b	36.62	35.31	0.96	0.93	1982-2019	0.23
2021/22	3a	35.94	42.57	1.18	1.17	1982-2020	0.23
2022/23	3a	34.70	47.58	1.37	1.17	1982-2021	0.23
2023/24	3a	36.39	48.77	1.34	1.16	1982-2022	0.23
2024/25	3a	40.01	56.06	1.40	1.23	1982-2023	0.23

Table D. Basis for the OFL from the author's preferred model, 22.03d5. Biomass units are in millions of pounds.

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	Natural Mortality
2020/21	3b	80.72	77.84	0.96	0.93	1982-2019	0.23
2021/22	3a	79.23	93.85	1.18	1.17	1982-2020	0.23
2022/23	3a	76.57	104.88	1.37	1.17	1982-2021	0.23
2023/24	3a	80.22	107.52	1.34	1.16	1982-2022	0.23
2024/25	3a	88.20	123.59	1.40	1.23	1982-2023	0.23

B_{MSY} for this stock is calculated to be 40.01 thousand t, so MSST is 20.00 thousand t. Because current MMB (88.21 thousand t) $>$ MSST, **the stock is not overfished**. Estimated total catch mortality (retained + discard mortality in all fisheries, using discard mortality rates of 0.321 for crab pot gear, 0.5 for fixed gear in the groundfish fisheries, and 0.8 for trawl gear) was 1.086 thousand t, which was less than the OFL for 2023/24 (36.20 thousand t); consequently, **overfishing did not occur**.

The OFL for 2024/25, based on the author's preferred model (22.03d5), is 41.29 thousand t, which results in a projected MMB of 56.06 thousand t. The ABC_{max} for 2024/25, based on the p^* ABC, is 41.23 thousand t. In 2014, the NPFMC's Scientific and Statistical Committee (SSC) adopted a 20% buffer to calculate ABC for Tanner crab to incorporate concerns regarding model and environmental uncertainty for this stock. Because environmental uncertainty and overly-optimistic model estimates for recent survey biomass trends remain concerns for this stock and assessment, the author recommends continuing to use the 20% buffer to calculate the ABC. Based on this buffer, the ABC would be 33.03 thousand t.

1.8 Rebuilding analyses results summary

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

2 Summary of Major Changes

2.1 Management

The directed fishery was prosecuted in 2023/24 in both State management areas (i.e., east and west of 166°W longitude in the General Section of the Eastern Subdistrict of the Bering Sea District of the Tanner Crab Registration Area J; Figure 1) in the EBS. This is only the second year since the 2015/16 season that the eastern area has been open to directed fishing (2022/23 was the first). Bycatch of Tanner crab also occurred in the Bristol Bay red king crab (BBRKC) fishery and groundfish fisheries. The snow crab fishery was closed by the State in 2023/24, so no incidental retention or bycatch of Tanner crab occurred in that fishery during the past year.

2.2 Input data

Retained catch time series (catch abundance and biomass) and size compositions were updated with data from the directed Tanner crab fishery for 2023/24. The time series of estimated total catch abundance and biomass, as well as associated size composition data, were updated with information from fishery observer sampling from the 2023/24 season for the directed fishery and for bycatch in the BBRKC fishery and the groundfish fisheries. Fishery-independent time series ("survey" biomass and abundance) and size compositions were updated with data from the 2024 NMFS EBS shelf bottom trawl survey, as were maturity ogives for new shell males. Of note, the NMFS survey this year did not include so-called "corner" stations near the Pribilof Islands and St. Matthew Island. Data from the 2018 collaborative BSFRF/NFS side-by-side (SBS) gear selectivity study were provided by BSFRF and incorporated into the assessment. The complete 2013-2018 SBS dataset was reviewed and minor issues were corrected. A new set of empirical availability curves for the SBS data were developed and incorporated into the assessment. The updates are summarized in Table E.

Table E. Data used in this assessment, with new and updated data noted.

Description	Data types	Time frame	Notes	Source
NMFS EBS Bottom Trawl Survey	area-swept abundance, biomass	1975-2019, 2021-23	2024 added	NMFS
	size compositions	1975-2019, 2021-23	2024 added	
	male maturity data	2006+	2024 added	
NMFS/BSFRF	molt-increment data	2015-17, 2019	no new data	NMFS, BSFRF
BSFRF SBS Bottom Trawl Survey	area-swept abundance, biomass	2013-18	2018 data added	BSFRF
	size compositions	2013-18	2018 data added	
Directed fishery	historical retained catch (numbers, biomass)	1965/66-1996/97	not updated	2018 assessment
	historical retained catch size compositions	1980/81-1996/97	not updated	2018 assessment
	retained catch (numbers, biomass)	2005/06+	2023/24 added	ADFG
	retained catch size compositions	2005/06+	2023/24 added	ADFG
	total catch (abundance, biomass)	1991/92+	2023/24 added	ADFG
	total catch size compositions	1991/92+	2023/24 added	ADFG
Snow Crab Fishery	historical effort	1978/79/1989/90	not updated	2018 assessment
	effort	1990/91+	no 2023/24 fishery	ADFG
	total bycatch (abundance, biomass)	1990/91+	no 2023/24 fishery	ADFG
	total bycatch size compositions	1990/91+	no 2023/24 fishery	ADFG
Bristol Bay Red King Crab Fishery	historical effort	1953/54-1989/90	not updated	2018 assessment
	effort	1990/91+	2023/24 added	ADFG
	total bycatch (abundance, biomass)	1990/91+	2023/24 added	ADFG
	total bycatch size compositions	1990/91+	2023/24 added	ADFG
Groundfish Fisheries (all gear types)	historical total bycatch (abundance, biomass)	1973/74-1990/91	not updated	2018 assessment
	historical total bycatch size compositions	1973/74-1990/91	not updated	
	total bycatch (abundance, biomass)	1991/92+	2023/24 added	NMFS/AKFIN
	total bycatch size compositions	1991/92+	2023/24 added	

2.3 Assessment methodology

The assessment model framework, TCSAM02, is described in detail in Stockhausen (2023b). The only model considered in this assessment, 22.03d5, is basically identical to the accepted model from last year's assessment, 22.03b, but updated with new data. The one functional difference between Models 22.03d5 and 22.03b is that the sex-specific effective sample size parameters for the Dirichlet-Multinomial likelihoods used to evaluate model fits to the BSFRF SBS size compositions were fixed to values near their upper bounds in 22.03d5 to avoid statistical and numerical issues associated with parameters estimated at a bound.

In addition to the Tier 3 model, results from a Tier 4 "fallback" model are provided. The Tier 4 model uses a random walk model to reduce the variance in design-based estimates of survey MMB and applies the appropriate control rule to calculate Tier 4 alternatives to the Tier 3 OFL and ABC.

Finally, a draft Risk Table, as requested by the SSC, is presented in Appendix D. While appended to this document as an appendix, it was not formally used as the basis for determining an ABC buffer.

2.4 Assessment results

Total fishing mortality in 2023/24, based on retained catch information from fish tickets and estimates of discard mortality for Tanner crab in the directed fishery, the snow crab fishery, and the groundfish fisheries, was 1.086 thousand t, which was less than the OFL for 2023/24, so **overfishing did not occur**. Based on results from the author's preferred model, 22.03d5, stock status did not change: the stock remains in Tier 3a and **the stock is not overfished**. The OFL for 2024/25 is 41.29 thousand t. The author-recommended buffer is 20%, which is the same as the buffer applied last year. Thus, the author-recommended ABC for 2024/25 is 33.03 thousand t.

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

3.1 CPT Comments May 2024

CPT Comment (specific to assessment)

The CPT recognized the amount of work [the author] had accomplished in responding to SSC requests to transition to GMACS, but requested that a more complete bridging analysis be undertaken for presentation to the modeling workshop in January 2025. Some features of TCSAM02 will need to be incorporated into GMACS for the CPT to make a more direct comparison between models.

Response

Sept 2024: the author plans to address this request in the given time frame.

CPT Comment (specific to assessment)

The CPT recommended that only TCSAM02 model 22.03d be brought forward to the September final assessment.

Response

Sept 2024: Done. The author's preferred model, 22.03d5, is 22.03d, updated with 2023/24 data and modified to fix the effective sample size parameters for the two Dirichlet-Multinomial likelihoods applied to the sex-specific BSFRF SBS size compositions near their upper bounds.

3.2 SSC Comments June 2024

SSC Comment (general)

The SSC requests the authors and CPT consider coordinating the approach to analyzing the BSFRF data for the two *Chionoecetes* crab and BBRKC stocks, and specifically consider developing the results as a prior on selectivity for use in the models

Response

Sept 2024: With the 2018 BSFRF SBS data for Tanner crab provided this past year, the author is finishing up analyses using the BSFRF SBS data for Tanner crab and BBRKC to inform NMFS survey selectivity. Following completion, a similar approach will be applied to the snow crab data. Products from these analyses will include stock-specific priors for NMFS survey selectivity. The analysis for Tanner crab and BBRKC should be completed in time to present at the January 2025 Modeling Workshop. The analysis for snow crab will potentially be completed by the May 2025 CPT meeting.

SSC Comment (specific to assessment)

The SSC supports the author and CPT recommendation to bring forward Model 23.03d in September, updated with the 2023/24 NMFS survey data, provided that the issues related to parameters on bounds can be resolved.

Response

Sept 2024: The issues involved with parameters on a bound were resolved in the author's preferred model, 22.03d5. Appendices B and C discuss bridging analyses that move from 22.03b to 22.03d, incorporating the 2013-2018 BSFRF SBS data (Appendix B), and from 22.03d to 22.03d5 incorporating the 2023/24 data.

SSC Comment

The SSC recommends the author provide additional detail in the changes to the underlying BSFRF data from 2013-17 that caused parameters to hit bounds, including details on any possible changes to the data weighting.

Response

Sept 2024: Additional details associated with incorporating the 2013-2018 BSFRF SBS data into the assessment are discussed in Appendix A and Appendix B, the first bridging analysis.

SSC Comment

If the author is unable to resolve the parameter bounding issue, the SSC recommends that an alternative model that fixes these parameters at a value of 1.0 and that has no other parameters on bounds be brought forward in addition to Model 22.03d and the Tier 4 approach (using the SSC recommended 2023 method).

Response

Sept 2024: The author's preferred model, 22.03d5, fixes the parameter bounding issue and has no estimated parameters on a bound.

SSC Comment

Consider a smoothed approach instead of the current empirical approach to the terminal molt curve, which assumes no observation error.

Response

Sept 2024: If this comment applies to the current modeling framework (TCSAM02), it seems to be based on a misunderstanding of how the current model deals with terminal molt. The model currently estimates a size-specific curve reflecting the probability of undergoing terminal molt (i.e., the probability that a crab of **pre-molt size** z_{pre} **will undergo** terminal molt), to which 2nd order difference penalties are applied to achieve a "smooth" curve. The parameter values underlying this estimated curve are principally informed by including a likelihood component in the model optimization that compares the "observed" ratio of new shell mature males to all new shell males in the NMFS EBS shelf survey, by 10-mm size bin, in several years to model-predicted ratios based on the parameter values (thus, "observed" vs. estimated probabilities at **post-molt size** z_{post} of **having undergone** terminal molt). The "observed" ratios are, for each survey year with available chela height data, based on classifying new shell mature males within a size bin on the basis of their CH to CW (carapace height to carapace width) ratios. The "observation errors" used in the associated likelihood component are assumed to be binomially-distributed, conditioned on the total number of crab measured within the size bin.

On the other hand, if this comment applies to a model (which is still under development) in the GMACS framework that would be similar to the current snow crab model, then the suggestion is taken under advisement and can be addressed once the CPT and SSC have approved a preliminary GMACS Tanner crab model.

SSC Comment

Show confidence intervals on estimated time series when comparing model runs, in order to allow interpretation of whether differences among alternative models are statistically meaningful.

Response

Sept 2024: Uncertainty estimates are available in ADMB for "sdreport" variables or through MCMC. ADMB only provides sdreport variables up to two dimensions (matrices), so quantities that would require more than two dimensions (e.g., survey-related estimates would require four dimensions: fleet [NMFS or BSFRF, currently], year, sex, maturity state). TCSAM02-based models provide sdreport output only for time series of recruitment (a vector) and spawning biomass (a matrix). Confidence intervals on other estimated time series are only available in TCSAM02-based models if MCMC runs are successful. Andre Punt has suggested that it would be possible to expand GMACS sdreport capabilities to incorporate expanded coverage of estimated time series, but that this will result in substantially increased model run times.

SSC Comment

Remove the connection between 2019 to 2021 when plotting survey time-series estimates and variances.

Response

Sept 2024: The connection has been removed from the relevant plots.

SSC Comment

The SSC concurs with the CPT that these models (i.e., the GMACS models) require further development and with the author and CPT recommendation to conduct a detailed bridging analysis as a next step. The SSC supports the CPT recommendation to make GMACS development the focus of the January 2025 modeling workshop.

Response

Sept 2024: Noted. The author regards the transition to GMACS as the main priority to address in future work. He hopes that a suitable comparison can be presented at the January Modeling Workshop.

SSC Comment

The SSC supports the continued exploration of a geostatistical time-series for Tanner crab.

Response

Sept 2024: The author has tried a number of times to incorporate VAST-based indices of survey abundance/biomass into the assessment model. In general, these indices exhibit only small differences in the individual estimates from their design-based counterparts. The major differences between the VAST indices and the design-based indices is in the CVs; thus, using the VAST indices is really just equivalent to increasing the weight on the survey biomass trends in the model likelihood relative to other data sources. The result is increased model instability and the inability to find the maximum likelihood solution.

SSC Comment

The SSC also recommends that a similar method of the treatment of the BSFRF data be considered for the Tanner GMACS model as in the EBS snow crab model where it is used to inform the prior on survey selectivity, or at minimum an evaluation of the relative merits of each approach.

Response

Sept 2024: This suggestion will be addressed following completion of analysis of the paired haul BSFRF/NMFS selectivity study data for Tanner crab and transition of the assessment to GMACS.

3.3 CPT Comments January 2024

CPT Comments (general)

Responses for unaddressed SSC and CPT comments should include an estimate of the timeline for work, if applicable.

Response

Sept 2024: This is really only possible for the requests given the highest priority. For these requests, a preliminary estimate for completion will generally be the next May CPT meeting.

CPT Comments

Assessments should include a history of modeling approaches, and a table of historical issues addressed.

Response

Sept 2024: A general history of modeling approaches is available in the "History of modeling approaches for this stock" section (Section 6.1. A table of historical issues addressed is under development and will be included in the next assessment, although **it would be helpful if the CPT could provide a template** for all stocks.

CPT Comments

The CPT recommended the stock assessment authors that have final assessments in Sept/Oct bring forward a draft risk table for CPT review at that time.

Response

Sept 2024: A draft risk table is provided as an appendix to the SAFE chapter.

CPT Comments

The CPT recommended that total catch be fitted in the model, after which mortality rates can be applied by weighting gear-specific mortality rates (e.g., trawl vs. fixed gear) by the proportion of bycatch for each gear type.

Response

Sept 2024: In the current assessment model(s), all bycatch in the groundfish fisheries is aggregated across gear types and the bycatch rate for trawl gear is applied. Effectively, this suggestion will mean applying a year, sex, and size-specific handling mortality rates to Tanner crab bycatch in the groundfish fisheries. Addressing this will involve additional data processing and modifying input data files to the assessment model. Because the current emphasis with the assessment is to transition the Tanner crab assessment to GMACS, the author can address this issue in GMACS once the transition has been made, if it is regarded as a high priority. An alternative (and conceptually simpler) solution would be to incorporate gear-specific bycatch information directly into the assessment model as separate fleets.

CPT Comments (specific to assessment)

The CPT recommended that the Tanner assessment use 50% handling mortality rate for groundfish fixed gear (pot and long line) to be consistent with other crab assessments.

Response

Done. This assessment uses handling (discard) mortality rates of 32.1% for bycatch in the crab fisheries, 50% for bycatch in the fixed-gear groundfish fisheries, and 80% for bycatch in the groundfish trawl fisheries when determining total catch mortality directly from observer data. In the current assessment model(s), all bycatch in the groundfish fisheries is aggregated across gear types and the bycatch rate for trawl gear is applied.

3.4 SSC Comments February 2024

SSC Comments (general)

The SSC supports revisiting the topic of VAST or other spatiotemporal model-based methods for the 2025 CPT modeling workshop, as this topic is relevant to several stocks and there have been some updates that might improve applicability to crab assessments.

Response

Sept 2024: Noted.

SSC Comments

The SSC looks forward to seeing draft risk tables for the crab stocks being reviewed in October. The SSC reiterates that the risk table framework is intended to provide a clear and transparent basis for communicating assessment-related and stock condition concerns that are not directly captured in model- based uncertainty, the tier system, or harvest control rules (see Preliminary Guidance and SSC recommendations on risk tables in the June 2021 SSC Report, p.33). Also, the SSC recommends that crab assessment authors follow the same organization scheme as the groundfish assessment authors, where the full risk table is contained in each individual chapter and brief summaries are included in the SAFE introduction.

Response

Sept 2024: A draft risk table is provided as an appendix to the SAFE chapter.

3.5 CPT Comments September 2023

CPT Comments (general)

The CPT recommends that all assessment authors document assumptions and simulate data under those assumptions to test the ability of the model to estimate key parameters in an unbiased manner. These simulations would be used to demonstrate precision and bias in estimated model parameters.

Response

Sept 2024: Model assumptions are discussed in Section 6.2. The ability to simulate data and fit to it within a single model run was implemented in TCSAM02 this summer, but time constraints have not allowed completion of a substantive set of tests. **The author requests that the CPT include the topic of simulation testing as an agenda item for the January Modeling Workshop.**

May 2024: On the "to do" list.

CPT Comment

The CPT recommends that weighting factors be expressed as sigmas or CVs or effective sample sizes. The team requests all authors to follow the Guidelines for SAFE preparation and to follow the Terms of Reference as listed therein as applicable by individual assessment for both content and diagnostics.

Response

May 2024: These requests are generally followed, but the compressed time frame for SAFE preparation in the fall often precludes including analyses that require extended time frames, e.g., MCMC evaluation).

CPT Comment

Authors should focus on displaying information on revised models as compared to last year's model rather than focusing on aspects of the assessment that have not changed from the previous year.

Response

May 2024: This is generally the case, except to highlight issues that remain unresolved from the previous assessment.

CPT Comment

The current approach for fitting length-composition data accounts for sampling error but ignores the fact that selectivity among size classes is not constant within years; a small change in the selectivity on small animals could lead to a very large change in the catch of such animals. Authors are encouraged to develop approaches for accounting for this source of process error. This issue is generic to assessments of crab and groundfish stocks.

Response

Sept 2024: The author notes the CPT rejected several GMACS models that addressed this issue, but that it remains an area of continued effort.

May 2024: Annual survey selectivity curves for the NMFS EBS shelf survey have been estimated using selectivity models derived from the BSFRF “side-by-side” selectivity studies. Several of the GMACS models presented in this report incorporate this source of variability.

CPT Comment

Authors are reminded that assessments should include the time series of stock estimates at the time of survey for at least the author’s recommended model in that year.

Response

Sept 2024: See Tables 92-95 for population abundance and biomass estimates at the start of the crab year (the time of the survey). May 2024: This has generally been the case.

CPT Comment

Consider stepwise changes to data as individual model runs instead of changing multiple parameters at once so that changes in model performance may be attributed to specific data.

Response

Sept 2024: Appendices B and C provide the requested bridging analyses in detail.

May 2024: This has generally been the approach in presenting model results. the GMACS models presented in this report, however, represent enough of a “clean break” from the current assessment model that this incremental approach would have been extremely unwieldy (if not impossible) to implement.

CPT Comments (specific to assessment)

None.

3.6 SSC Comments October 2023

SSC Comments (general)

For the inclusion of trawl survey data, the SSC suggests crab assessment authors and the CPT be more explicit about best practices for which standard years are included for bottom trawl survey data. The SSC suggests that the years recommended by the Groundfish Plan Teams would be a good starting point, which specify using the following bottom trawl survey data years: - Aleutian Islands: 1991 - present (standard gear) - Eastern Bering Sea: 1982 - present (standard gear, grid, and design), 1987 - present for species that inhabit the northwest corner of the survey (which was added in 1987 for snow crab and walleye pollock)

Response

May 2024: As per every assessment since 2015, the current stock assessment model fits NMFS EBS bottom trawl survey biomass indices and size comps using crab-standardized stations starting in 1975. It estimates separate sex-specific parametric selectivity curves and fully-selected catchabilities for the 1975-1981 and gear-standardized 1982+ time periods. Alternative models such as the GMACS models considered in the May 2024 Tanner crab report have used only the 1982+ time period.

SSC Comment

Risk tables would be used to provide a more comprehensive, transparent, and defensible justification for CPT and SSC recommendations on ABC buffers.

Response

Sept 2024: A draft Risk Table is provided in Appendix D.

May 2024: a risk table will be included in the 2024 assessment.

SSC Comment

future BBRKC, Tanner and snow crab assessments routinely include a simple Tier 4 analysis that includes a smoothed time series of survey vulnerable biomass (legal size or smaller to accommodate discard mortality) using the REMA package and not adjusted for natural mortality. This model will provide a consistent alternative should the preferred Tier 3 approach fail in some way and also a point of comparison with Tier 3 and State methods used as a basis for TAC setting.

Response

Sept 2024: See Section 8.

May 2024: The SSC appears to have accepted the author's approach used in the 2023 assessment. This will be repeated for 2024.

SSC Comment

Include uncertainty intervals when showing time series of biomass/abundance estimated by the stock assessment models

Response

Sept 2024: See response above.

May 2024: This will be done for the 2024 assessment.

SSC Comment

The SSC suggests that the CPT and crab authors continue to evaluate whether VAST or similar approaches, when specified carefully for individual crab stocks (i.e., the choice of error distributions and number of knots) might provide more robust survey time-series

Response

May 2024: Previous reports have examined the use of VAST-derived time series for survey abundance/biomass and results from a GMACS model fitting to VAST-derived estimates are presented in the May 2024 Tanner crab report. Using the VAST estimates for the survey biomass time series results in poor model fits and model convergence issues.The VAST and design-based estimates are typically similar but differ mainly in the associated estimates of uncertainty. Thus, the ultimate effect of using the VAST estimates could be achieved heuristically simply by placing more emphasis on the survey indices relative to the fishery catch data than is currently done. However, the estimates themselves suggest that interannual changes in stock biomass much larger than the current model dynamics (constant M, constant probability of terminal molt, constant growth dynamics, constant survey selectivity and fully-selected catchability) can accommodate are credible and should be captured by the model. The introduction of more flexible, time-varying dynamics is the key to better fitting the survey indices (VAST or design-based), but to do so with regard to plausible mechanisms and drivers is an area of ongoing research.

SSC Comments (specific to assessment)

The SSC continues to support development of a parallel or simplified version of the Tanner crab assessment model in the GMACS platform, and the author's proposed development timeline in fall 2023.

Response

Sept 2024: The CPT rejected the simplified GMACS Tanner crab models presented in May and requested full model comparison. This will be presented at the January 2025 Modeling Workshop.

May 2024: Simplified versions of the Tanner crab assessment model using the GMACS framework are presented in the May 2024 Tanner crab report.

SSC Comment

The SSC appreciates the author's development of a simplified Tier 4 model for use as a backup in the event that extreme and insurmountable issues are encountered by the Tier 3 assessment model in the future. The SSC supports the structure of the Tier 4 model as presented, based on the estimate of vulnerable male crab biomass from the NMFS EBS bottom trawl survey and including the use of the coefficient of variation in projected biomass as a reasonable basis for defining the ABC buffer. With respect to the reference time period for calculating BMSY, the SSC concurs with the CPT recommendation to use the entire time series since 1982.

Response

Sept 2024: Results from a Tier 4 analysis are presented in Section 8.

May 2024: Results from this model will be updated for the 2024 assessment.

SSC Comment

Briefly summarize the history of the GOA Tanner crab fishery and stock dynamics, given the possible value of this information for the interpretation of BSAI Tanner crab stock dynamics.

Response

May 2024: Kally Spalinger (ADFG) and Nathaniel Nichols (ADFG) have provided the author with, respectively, data from the Kodiak Large Mesh Survey for Tanner crab and historical landings from GOA Tanner crab fisheries. A "history" has not yet been developed, but time series of abundance and landings are included in the May 2024 Tanner crab report. A preliminary comparison of survey abundnace trends suggests that recruitment in the GOA and EBS is correlated, but whether this is due to a direct linkage or simply environmental mediation is unknown.

SSC Comment

Consider directly incorporating annual molt to maturity data, as implemented in the EBS snow crab assessment, if sufficient data are available.

Response

May 2024: This suggestion is explored in several GMACS models presented in the May 2024 Tanner crab report.

SSC Comment

Consider using the Bering Sea Fisheries Research Foundation (BSFRF) survey data to inform selectivity and catchability, as implemented in the EBS snow crab assessment, as an alternative to fitting these data as a separate index.

Response

May 2024: The BSFRF data has been used to inform NMFS survey selectivity/catchability in several GMACS models presented in the May 2024 Tanner crab report.

SSC Comment

Explore what might be driving the residual pattern in the fit to the NMFS survey data.

Response

May 2024: Because recruitment is freely estimated, the residual patterns are presumably due to the constraints on the model dynamics imposed by 1) constant M and 2) constant growth dynamics, as well (possibly) as variability in weight-at-size.

SSC Comment

With respect to the spatial distribution of Tanner crab captured in the NMFS bottom trawl survey, the SSC appreciates the inclusion of Figures 38-42 which highlight both the large number of small male crab encountered in 2023 and the spatially expansive nature of that increase in CPUE. The SSC encourages exploration of differences in the spatial distribution of small male crab in the NMFS survey, to identify if the distribution of small crab encountered in 2003-2005 and 2008-2010, which successfully propagated to larger sizes, showed differences in habitat use compared with the cohort first observed in 2017-2019, which did not propagate to larger sizes.

Response

May 2024: This is an avenue for future research.

SSC Comment

Likewise, the SSC recommends that a comparison of environmental conditions experienced by small crabs during these periods may help to elucidate why some cohorts appear to propagate and others do not.

Response

May 2024: This is an avenue for future research.

SSC Comment

Fits to length composition data in the recent period remain a concern, exemplified by large negative residuals in length composition fits for the largest observed length bin in recent years and as a strong positive retrospective pattern in recruitment.

Response

May 2024: Large negative residuals in (male) size compositions continue to be a problem with this assessment. The residuals to the estimated mean post-molt size for large males are also (increasingly) negative with pre-molt size. This suggests that something else in the data is forcing male crab to grow to sizes inconsistent with the molt increment and size composition data. Potential sources for this include a biased size-weight regression used to convert abundance to biomass and biased probabilities of terminal molt and suggest avenues for future research.

3.7 CPT comments May 2023

CPT Comments (specific to assessment)

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

Response

Sep 2023: Done.

CPT Comment

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

Response

Sep 2023: Done.

3.8 SSC comments June 2023

SSC Comment (general)

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

Response

Sep 2023: The root cause of ABC recommendations that would remove all legal-sized crab is the combination of an industry-preferred size larger than the average size at maturity, and an SPR-based harvest control rule. Mature males smaller than the industry-preferred size form a "pool" protected from exploitation. As the separation between industry-preferred size and average size of mature males increases, the more the biomass in this protected pool increases relative to unfished biomass and the less is needed in the vulnerable pool of large males to achieve 35% of unfished MMB. The consequence is that the F_{OFL} calculation results in higher and higher F's on industry-preferred males. For king crab, which do not undergo terminal molt, crab in the protected pool will eventually grow into the vulnerable pool–which somewhat reduces the estimated F's. For opilio and bairdi, because they undergo terminal molt, mature males under the industry-preferred size will never grow out of the protected pool of biomass–thus increasing the estimated F's over what they would be for species with similar population characteristics that did not undergo terminal molt.

SSC Comment

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

Response

Sep 2023: The Tier 4 model does not estimate OFLs for "previous years", which would require developing a retrospective analysis capability. If this is a priority, it could be addressed in the future.

SSC Comment

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

Response

Sep 2023: Results for B_{MSY} calculated using several alternative time blocks are presented.

SSC Comment

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

Response

Sep 2023: The author recommends using the cv for terminal year survey biomass from the random walk model as a basis for the ABC buffer. The final value could be based on a P*-like calculation or directly as a fractional buffer (i.e., $ABC = (1 - cv) \cdot OFL$).

SSC Comment (specific to assessment)

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

Response

Sep 2023: Transitioning the assessment to GMACS is the top priority for development in Fall, 2023.

SSC Comment

The SSC requests that a clear justification for the choice of Tier 4 fallback reference time period be provided in the September SAFE document, beyond simple precedent, and that several alternative time periods be considered (each with its own justification).

Response

Sep 2023: Several time blocks were considered for the Tier 4 averaging time period used to calculate B_{MSY}. Justification for using each is discussed.

SSC Comment

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

Response

Sep 2023: Noted.

3.9 CPT comments September 2022

CPT Comment (specific to assessment)

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

Response

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

CPT Comment

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

Response

Sep 2023: A figure representing jitter diagnostics is presented for Model 22.03b.

CPT Comment

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

Response

Sep 2023: Although this is a reasonable idea, it is currently not possible to provide such a plot.

CPT Comment

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

Response

Sep 2023: The small retrospective pattern was with respect to MMB, while the pattern for recruitment was much larger. The larger retrospective pattern for recruitment occurs exactly as a result of the apparent recruitment events disappearing (new data reduces the estimated size of recruitment in any particular year). The small retrospective pattern for MMB is a result of the estimated model dynamics that extend over many cohorts and “damp out” patterns seen in the small size classes in order to better fit patterns seen in the larger size classes. The model places much more emphasis on fitting large size classes better because it fits to survey and fishery *biomass* time series, not abundance time series.

CPT Comment

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

Response

Sep 2023: This suggestion will be explored as part of building a GMACS Tanner crab model.

3.10 SSC comments October 2022

SSC Comment (general)

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

Response

Sep 2023: See Section 3.12.

SSC Comment

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

Response

Sep 2023: Almost all Tanner crab model development occurs between October following the SSC meeting and the subsequent May CPT meeting.

SSC Comment

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

Response

Sep 2023: This seems like a potential topic for the January CPT meeting.

SSC Comment

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

Response

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

SSC Comment

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

Response

Sep 2023: The working group has been formed; meetings are scheduled for October.

SSC Comment

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

Response

Sep 2023: Not yet addressed.

SSC Comment (specific to assessment)

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

Response

Sep 2023: For 1), transition to GMACS will be given the highest priority following the October SSC meeting. For 2), State management occurs on a two-area basis while the assessment model is area-aggregated (a “fleets-as-areas” model incorporating area-specific considerations was previously investigated but fitting the area-specific data was problematic). The correct scaling of (area-aggregated) industry-preferred male abundance in the assessment model depends on correctly estimating survey selectivity and catchability, growth, terminal molt, and natural mortality simultaneously, but this remains problematic due to parameter confounding among these processes. For 3), a Tier 4 model was developed and results are presented in this assessment.

SSC Comment

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

Response

Sep 2023: An issue for the CPT, but noted here.

3.11 CPT comments May 2022

CPT Comment (specific to assessment)

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

Sep 2023: 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

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

3.12 SSC comments June 2022

SSC Comment (general)

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

Response

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

SSC Comment (specific to assessment)

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

Sep 2022: 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

Sep 2022: 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

Sep 2022: GMACS models for snow crab have now been adopted, so development of a GMACS version of the Tanner crab model is underway. The SSC's other recommendations are appreciated and the author notes that these are active areas of research.

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

Sep 2022: See Section 3.12.

3.13 CPT comments January 2022

None

3.14 SSC comments February 2022

SSC Comment (general)

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

Response

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

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

Sep 2022: 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

Sep 2022: Standardization with other stocks will probably remain an issue until the assessment is converted to GMACS. Candidate formats for standardized tables and figures have been developed that GMACS models could implement, if found useful.

4 Introduction

4.1 Stock

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

4.2 Distribution

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

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

4.3 Stock structure

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

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

4.4 Life History

Molting and shell condition

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

Table F. Shell condition classification table.

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

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

Growth

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

Growth in immature Tanner crab larger than approximately 25 mm CW proceeds by a series of annual molts, up to a final (terminal) molt to maturity (Tamone et al. 2007). Rugolo and Turnock (2012b) derived growth relationships for male and female Tanner crab from data on observed growth in males to approximately 140 mm carapace width (CW) and in females to approximately 115 mm CW collected near Kodiak Island in the Gulf of Alaska [J. Munk, unpublished; Donaldson et al. (1981)]. These relationships were used as priors for estimated growth parameters in older (2012-2016) assessments (Rugolo and Turnock 2012a; Stockhausen 2013, 2014, 2015, 2016). Rugolo and Turnock (2010) compared the resulting growth per molt (gpm) relationships with those of Stone et al. (2003) for Tanner crab in southeast Alaska in terms of the overall pattern of gpm over the size range of crab and found that the pattern was characterized for both males and females by a higher rate of growth to an intermediate size (90-100 mm CW), followed by a decrease in growth rate from that size thereafter. Similarly-shaped growth curves were found by Somerton (1981a) and Donaldson et al. (1981), as well.

Molt increment data was collected for Tanner crab from the EBS during 2015, 2016, 2017 and 2019 in cooperative research between NMFS and the Bering Sea Fisheries Research Foundation (BSFRF; R. Foy and E. Fedewa, NMFS, pers. comm.s). Previous analysis of the data suggests it is not substantially different from that obtained near Kodiak Island (Stockhausen 2017a). The EBS molt increment data is fit in the assessment model to inform inferred growth trajectories in all of the models evaluated in this assessment.

Weight at size

Weight-at-size relationships used in this assessment were revised in 2014 based on a comprehensive re-evaluation of data from the NMFS EBS shelf bottom trawl survey (Daly et al. 2014). Weight-at-size is described by a power-law model of the form $w = a \cdot z^b$, where w is weight in kg, z is the size in mm CW, and a and b are estimated coefficients (Daly et al. 2015). In 2021, Jon Richar (AFSC Kodiak) conducted a new analysis of the weight-at-size data for Tanner crab that incorporates shell condition as a factor. Other preliminary analyses suggest that temperature may be a factor, as well. The CPT, however, has not reviewed models based on these new relationships; thus, this assessment uses the previously-established relationships. The parameter values for the relationships used in this assessment are presented in Table G.

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

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

Maturity and reproduction

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

Maturity in males can be classified either physiologically or morphometrically, but is not as easily determined as with females. Physiological maturity refers to the presence or absence of spermataphores in the gonads whereas morphometric maturity refers to the presence or absence of a large claw (Brown and Powell 1972). During the molt to morphometric maturity, there is a disproportionate increase in the size of the chelae in relation to the carapace (Somerton 1981a). The ratio of chela height (CH) to carapace width (CW) has been used to classify male Tanner crab as morphometrically immature or mature. While many earlier studies on Tanner crabs assumed that morphometrically mature male crabs continued to molt and grow, there is now convincing evidence to support a terminal molt for males (Otto 1998; Tamone et al. 2007). A consequence of the terminal molt in male Tanner crab is that a substantial portion of the population may never achieve legal size (NMFS 2008).

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

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

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 elapsed since the molt to maturity, and whether or not a female has had to use stored sperm from that first mating can also affect egg counts Paul and Paul (1992). Additionally, older senescent females often carry small clutches or no eggs (i.e., are barren) suggesting that female crab reproductive output is a concave function of age (NMFS 2004).

Size at maturity

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

Mortality

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

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

0.23 based on Hoenig's (1983) method. Alternatively, if 20 years was assumed to represent the 95% percentile of the distribution of ages in the unexploited stock, the estimate for M would be 0.15. Rugolo and Turnock (2011a) adopted M=0.23 for both male and female Tanner because the value corresponded with the range estimated by Somerton (1981a), as well as the value used in the analysis to estimate the overfishing definitions underlying Amendment 24 to the Crab Fishery Management Plan (NMFS 2008).

4.5 Management history

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

The Bering Sea District of Tanner crab Registration Area J (Figure 1) includes all waters of the Bering Sea north of Cape Sarichef at 54° 36'N latitude and east of the U.S.-Russia Maritime Boundary Line of 1991. This district is divided into the Eastern and Western Subdistricts at 173°W longitude. The Eastern Subdistrict is further divided at the Norton Sound Section north of the latitude of Cape Romanzof and east of 168° W longitude and the General Section to the south and west of the Norton Sound Section (Bowers et al. 2008). The ADF&G sets separate annual values on retained catch, Total Allowable Catch (TAC), in the areas east and west of 166^oW longitude in the General Section. In this report, the terms "east" and "west" (or "East 166W" and "West 166W") are used in shorthand fashion to refer to these management areas demarcated by 166^oW longitude where separate TACs are set.

In March 2011, the Alaska Board of Fisheries (BOF) approved a new minimum size limit harvest strategy for Tanner crab effective for the 2011/12 fishery based on Bechtol et al. (2011) and Zheng and Pengilly (2011). Prior to this change, the minimum legal size limit had been 5.5" (140 mm CW, including lateral spines) throughout the Bering Sea District. The new regulations established different minimum size limits east and west of 166^o W. The minimum legal size for the fishery to the east of 166^oW longitude is now 4.8" (122 mm CW) and that to the west is 4.4" (112 mm CW), where the size measurement includes the lateral spines. For economic reasons, fishers may adopt larger minimum sizes for retention of crab in both areas, and the State's harvest control rules (HCRs) used to determine total allowable catch (TAC) generally incorporate minimum "industry-preferred" sizes that are larger than the legal minimums. In 2011, these minimum preferred sizes were set at 5.5" (140 mm CW) in the east and 5" (127 mm CW) in the west, including the lateral spines (Daly et al. 2020). The harvest strategy also employed a minimum threshold that the mature female biomass (MFB) in the Eastern Subdistrict be larger than 40% of its long-term (1975-2010) average in two subsequent years before the fisheries in either management area could be opened. Minimum thresholds for opening the fishery in a management area were also defined using the ratio of area-specific MMB to its associated long-term average. Finally, the harvest strategy defined area-specific sloping harvest control rules to determine the maximum allowable exploitation rate on mature males in each area based on the ratio of MFB to average MFB, together with limits on the maximum exploitation rate (Figure 2).

Subsequently, the State's harvest strategy has undergone three revisions in the past 8 years (Daly et al. 2020). In 2015, the minimum preferred harvest size used to compute TAC for the area east of 166^o W longitude was changed from 140 mm CW (5.5 inches; including the lateral spines) to 127 mm CW (5.0 inches), the preferred size used to compute TAC for the area west of 166^o W longitude. In 2017, the criteria being used to determine MFB was changed from an area-specific one based on carapace width to one based on morphology (the same as is 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 a management strategy evaluation (MSE) conducted with input from industry stakeholders, NMFS and academic scientists, and ADF&G managers (Daly et al. 2020; Heller-Shipley et al. 2021). The current HCR (Figure 3; HCR 4_1 in Daly et al. (2020)) defines the period for calculating average mature biomass as 1982-2018 and implements sliding scales for exploitation rates on mature males which are functions of the ratios of MMB and MFB to their long-term averages. One particularly notable change is that there is no longer a threshold for opening the fisheries based on MFB.

Landings of Tanner crab in the Japanese pot and tangle net fisheries were reported in the period 1965-1978, peaking at 19.95 thousand t in 1969. The Russian tangle net fishery was prosecuted during 1965-1971 with peak landings in 1969 at 7.08 thousand t. Both the Japanese and Russian Tanner crab fisheries were displaced by the domestic fishery by the late-1970s (Table 1; Figure 4). Foreign fishing for Tanner crab ended in 1980.

The domestic Tanner crab pot fishery developed rapidly in the mid-1970s (Tables 1 and 2; Figure 4). Domestic US landings were first reported for Tanner crab in 1968 at 0.46 thousand t taken incidentally to the EBS red king crab fishery. Tanner crab was targeted thereafter by the domestic fleet and landings rose sharply in the early 1970s, reaching a high of 30.21 thousand t in 1977/78. Landings fell sharply after the peak in 1977/78 through the early 1980s, and domestic fishing was closed in 1985/86 and 1986/87 due to depressed stock status. In 1987/88, the fishery re-opened and landings rose again in the late-1980s to a second peak in 1990/91 at 16.61 thousand t, and then fell sharply through the mid-1990s. It was formally declared overfished by NMFS in 1999. The domestic Tanner crab fishery was closed from 1997/98 to 2004/05 as a result of conservation concerns regarding the depressed status of the stock.

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

Following a change in assessment Tier level from 4 to 3 following the development and acceptance of a Tier 3 assessment model in the fall of 2012, the stock was declared to be not overfished under Tier 3 and an OFL of 19,020 t was determined. The directed fisheries, however, remained closed per the State's harvest strategy. For 2013/14, the Tier 3 OFL was determined to be 25,350 t, with an ABC of 17,820 t. The stock metrics surpassed the State harvest strategy thresholds and the directed fishery was opened in 2013/14 with a TAC was set at 1,645,000 lbs (746 t) for the area west of 166^o W and at 1,463,000 lbs (664 t) for the area east of 166^o W. On closing, 80% (594 t) of the TAC had been taken in the western area while 99% (654 t) had been taken in the eastern area. For 2014/15, the Tier 3 ABC was 25,180 t and TAC was set at 3,005 t for the area west of 166^o W and at 3,846 t for the area east of 166^o W. On closing, 78% (2,329 t) of the TAC was taken in the western area while 100% (3,829 t) was taken in the eastern area. For 2015/16, the ABC was 21,750 while TAC was set at 3,808 t in the western area and 5,113 t in the eastern area. On closing, essentially 100% of the TAC was taken in each area (3,798 t in the west, 5,111 t in the east). The total retained catch in 2015/16 (8,910 t) has been the largest taken in the fishery since 1992/93 (Tables 2 and 3; Figure 4).

The directed fisheries in both areas were closed in 2016/17 because mature female biomass in the 2016 NMFS EBS Bottom Trawl Survey did not exceed the threshold set in the State's harvest strategy to allow a fishery opening. Total retained catch was thus 0 in 2016/17 although the ABC was 20,490 t. In 2017/18, the ABC was set at 20,330 t; the State allowed a directed fishery west of 166^o W longitude but closed the fishery east of 166^o W. Essentially, the entire TAC (1,134 t) was taken in 2017/18. The 2018/19 season followed a similar pattern, with the directed fishery closed in the eastern area and open in the western area (with a TAC of 1,106 t) while the ABC was 16,700 t. The entire TAC was again harvested in 2018/19. Although the ABC for 2019/20 was 23,090 t, the directed fisheries in both areas were again closed in 2019/20 because mature male biomass failed to achieve the required State threshold in either management area. In 2020/21, with an ABC of 16,900, the State criteria for opening the fishery were met in the western area, and the TAC was set to 1,065 t. Only 655 t was harvested. In 2021/22, the ABC was 21,740 t, the eastern area remained closed to directed fishing, and the TAC in the west was 499 t–of which 494 t was landed. In 2022/23 the ABC was 26,250 t and,following a revision of the State harvest strategy, the eastern area was opened to directed fishing for the first time since 2015/16 with a TAC of 528 t; the west was also open with a TAC of 386 t. The entire TAC was taken in both areas. In 2023/24, both areas were open again, with TACs set at 345 and 599 t in the eastern and western areas, respectively. Once again, the entire TAC was taken in each area.

Tanner crab can be incidentally retained in the snow crab and BBRKC fisheries, up to a limit of 5% of the target species. In general, incidental retention in these fisheries has been small compared with retained catch in the directed fishery, although the snow crab fishery was responsible for a sizable fraction of the landed catch in 2005/06 and 2006/07 (Tables 3 and 4, Figure 5). Both fisheries were closed in 2022/23 and only the BBRKC fishery was open in 2023/24.

Information on bycatch and discard losses of Tanner crab originate from observer data taken in the directed Tanner crab pot fishery, the snow crab and Bristol Bay red king crab pot fisheries, and the groundfish fisheries (Tables 7-11; Figures 10-13). Bycatch estimates are converted to discard mortality using assumed handling mortality rates of 32.1% for bycatch in the crab fisheries (CPT 2014) and 80% for bycatch in the groundfish fisheries (when bycatch in the latter can be distinguished by gear type, then 80% for trawl fisheries and 50% for fixed gear fisheries; CPT (2021)). In the early-1970s, the groundfish fisheries contributed substantially to total bycatch losses (although bycatch in the crab fisheries was undocumented at the time). From the early 1990s (when reliable crab fishery bycatch estimates are considered to be first available) to 2004/05, the groundfish fisheries accounted for the largest proportion of discard mortality. Since 2005/06, the snow crab fishery has generally accounted for the largest proportion of Tanner crab taken as bycatch, accounting for 529.0 t on average since 2018/19 (but not including years when the fishery was closed). Average bycatch in the directed fishery over the same time period was 516.7 t, 140.2 t for the groundfish fisheries, and 26.98 t for the BBRKC fishery. After applying assumed discard mortality rates, the snow crab fishery (when open) also accounts for the largest average discard mortality over the past six years (169.8 t vs 165.9 t in the directed fishery, 98.19 t in the groundfish fisheries, and 8.659 t in the BBRKC fishery).

5 Data

Data incorporated into the Tanner crab assessment this year include:

1) annual abundance, biomass and size composition data collected by crab fishery observers for Tanner crab retained in the directed fisheries and taken as bycatch in the directed and other (snow crab, Bristol Bay red king crab) fisheries provided by ADF&G;
2) annual abundance, biomass, and size composition data collected by groundfish fishery observers for bycatch in the groundfish fisheries provided by AFSC's Fisheries Monitoring and Analysis Division and the NMFS Alaska Regional Office (AKRO; hosted by AKFIN, https://akfin.psmfc.org);
3) limited historical (pre-1990) data on annual abundance, biomass, and size compositions for Tanner crab retained in the foreign (1965-1980) and domestic (1968-1989) crab fisheries or taken as bycatch in the groundfish fisheries (1973-1990);
4) annual abundance, biomass and size composition data, as well as limited year-specific male maturity ogives, from the NMFS EBS shelf bottom trawl survey (1975-2024);
5) abundance, biomass, and size composition data from BSFRF/NMFS cooperative side-by-side trawl studies (2013-2018); and
6) molt increment data from NMFS/ADF&G/BSFRF cooperative studies (2015-17, 2019).

5.1 Summary of new information

Retained catch in the 2023/24 directed fishery was provided by ADF&G (Ben Daly, ADF&G, pers. comm.), as well as total Tanner crab catch and effort data for the directed and BBRKC fisheries. The snow crab fishery was closed in 2023/24, so no bycatch of Tanner crab occurred in that fishery. Data on bycatch in the 2023/24 groundfish fisheries from the groundfish observer program and AKRO was downloaded from AKFIN on July 17, 2024. Results from the 2024 NMFS EBS bottom trawl shelf survey were downloaded from AKFIN on August 15, 2024. Male maturity ogives were provided by J. Richar (AFSC, pers. comm.) on August 20, 2023, as well. The 2018 BSFRF SBS data was provided to the author by S. Goodman (BSFRF, pers. comm.) on Septmber 9, 2023. New empirical availability curves were for the 2013-2018 BSFRF SBS data were developed by the author (see Appendix A for details). Datasets and new information are summarized in Table G (Section 2.2).

5.2 Retained Catch

Time Series Data

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

Size Composition Data

Size compositions for retained catch data, scaled to total retained catch, are available from 1980/81-1996/97 aggregated across ADF&G management areas and from 2005/06 identified by management area (Table 6, Figure 6) for seasons when the directed fishery was prosecuted. Median sizes of retained males are similar over the time period up to 2009/10, after which NMFS determined the stock was overfished and ADF&G closed the fishery in both management areas (Figure 6). Median sizes since NMFS declared the stock rebuilt (2012) have been somewhat smaller; the smallest median sizes occurred in the western management area in 2021/22 and 2022/23 while the smallest median size in the eastern management area occurred in 2022/23. Median sizes in both areas were more typical in 2023/24. The fraction of retained catch smaller than the size historically preferred by processors (125 mm CW) increased in the western management area from 2017/18 until 2023/24 (the eastern area was closed during most of this time period; Figures 7 and 8). The fraction of new shell males among the retained crab from the western management area in 2023/24 was high, similar to that in 2021/22 and 2022/23 but much higher than other years since the 2015/16 season (Figure 9). The fraction from the eastern management area was similarly high in 2022/23 and 2023/24.

5.3 Total Catch and Discard Data

Time Series Data

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

All female crab and sub-legal males caught in the directed fishery or taken as bycatch in the other fisheries must be discarded. All legal males taken in the groundfish fisheries and "most" legal males in the other crab fisheries must be discarded as well; some retention of incidentally-caught legal males is allowed in the snow and BBRKC fisheries, but the amount retained in any year tends to be very small. The assessment model fits time series of fishery-specific total catch biomass (and abundance for the groundfish fisheries), but allows for some fraction of discarded crab to survive. In practice, a value of 0.321 is used in the assessment model for "handling mortality" in the crab fisheries to convert observed bycatch to (unobserved) discard mortality (Stockhausen 2014). For the groundfish fisheries, a value of 0.8 is used for handling mortality aggregated across gear types to reflect differences in groundfish gear effects and on-deck operations compared with the crab fleets (bycatch in the groundfish fisheries is typically aggregated across gear types in the assessment model). However, when models in which groundfish bycatch type is identified by gear type are run, a value of 0.5 is used for bycatch by fixed gear and 0.8 for bycatch by trawl gear. However, no models with gear-specific bycatch in the groundfish fisheries were considered in this assessment.

Mortality associated with the handling process can also be estimated outside the assessment model for bycatch in the groundfish and non-directed crab fisheries (because most or all Tanner crab bycatch is discarded), but estimates of "discard mortality" for males in the directed fishery obtained outside the assessment model can be problematic if (due to sampling error) estimated total catch is less than reported retained catch. Annual estimates of bycatch (i.e., non-retained catch) using the "subtraction method" and mortality for the various fisheries are given in Tables 10 and 11 and illustrated in Figures 11 and 12. Estimated bycatch mortality in the groundfish fisheries was highest (~15,000 t) in the early 1970s, but it declined substantially by 1977 to ~2,000 t with the curtailment of foreign fishing fleets (Stockhausen 2017a). Bycatch mortality 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 (75 t in 2023/24). In the crab fisheries, the largest component of bycatch occurs on males. In the early 1990s, female bycatch ranged between 6 and 40% of the bycatch in the directed and snow crab fisheries. Since the directed fishery re-opened in 2013/14, the fraction of bycatch that is female has ranged between 2% and 6% in the directed fishery, between 0.3 and 3% in the BBRKC fishery, and has been below 1% in the snow crab fishery. Estimates of total groundfish bycatch are not currently available by sex.

In 2023/24, the directed fishery was prosecuted in both State management areas for only the second time since 2015/16. Discard mortality on males, estimated using the subtraction method, was 65 t. Discard mortality on females in the directed fishery was 2 t. The snow crab was closed, so no bycatch mortality occurred in that fishery, and only 3 t occurred in the BBRKC fishery. Total bycatch mortality in the groundfish fisheries was 75 t. Total bycatch mortality, then, was 145 t (Table 11) whereas total catch mortality (including retained catch) was 1,086 t.

Size Composition Data

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

Size compositions from observer sampling for bycatch in the groundfish fisheries, expanded to total bycatch, are shown in Figures 24-28 starting in 1991/92. These fisheries, targeting a variety of groundfish stocks and using a variety of gear types, take a much larger size range of Tanner crab as bycatch than the pot gear used in the crab fisheries.

Raw (number of individuals measured) and scaled sample sizes for size composition data from the various fisheries are given in Tables 12-14. Since 2020/21, very few Tanner crab have been measured by observers in either the snow crab or BBRKC fisheries due to small TACs or closures in those fisheries.

Spatial patterns

Recent spatial patterns for retained catch are illustrated in Figure 29. Since 2020/21, retained catch has been concentrated along the 166°W longitude line, in contrast to other years when catch was also distributed along the outer shelf both northwest and southeast of the Pribilof Islands at depths of 100 m or greater.

5.4 Survey Data

The annual NMFS EBS shelf bottom trawl survey (“NMFS survey”) provides the primary source of fishery-independent data for indices of relative population size (“survey” biomass and abundance) and size structure (size compositions). Data from 1975-2024 are included in the assessment. In 2024, the NMFS survey discontinued hauls at the 26 so-called “corner” stations around the Pribilof Islands and around St. Matthew Island (Figure 30). In addition to the NMFS survey, data from the “side-by-side” Tanner crab selectivity studies, conducted collaboratively by BSFRF and NMFS during the 2013-2018 NMFS surveys, provide a secondary data source.

Time Series Data

Design-based estimates (and cv’s) for trends in annual survey biomass and abundance from the NMFS survey are given in Tables 16 and 17 by sex, maturity state, and ADF&G management area. Corresponding time series plots are given in Figures 31 and 32. Time series trends from the NMFS EBS bottom trawl survey suggest the Tanner crab stock in the EBS has undergone decadal-scale fluctuations.

Estimated biomass of male crab in the survey time series started at its maximum (295 thousand t) in 1975, decreased rapidly to a low (15 thousand t) in 1985, and rebounded quickly to a smaller peak (146 thousand t) in 1991 (Table 16). After 1991, male survey biomass decreased again, reaching a minimum of 14,600 t in 1997. Recovery following this decline was slow and male survey biomass did not peak again until 2007 (104 thousand t), after which it has fluctuated more rapidly—decreasing within two years by over 50% to a minimum in 2009 (47 thousand t), followed by a doubling to a peak in 2014 (109 thousand t). Since 2014 the trend had been a steady decline until 2021, with male biomass in 2019 at its lowest point (29 thousand t) since 2000. The survey was not conducted in 2020. In 2021, male survey biomass increased over the low in 2019 by ~10% to 32 thousand t, but it declined slightly to 30 thousand t in 2022. ubsequently, it has increased dramatically to 83 thousand t in 2024, the largest since 2014, although most of this increase occurred in the area west of 166°W. Male survey biomass in the eastern management area in 2023 was the smallest in the time series since 1998, but almost doubled in 2024.

Trends in female survey biomass have generally been in synchrony with those for males, although the changes for females precede those for males by a year or two (reflecting different growth patterns). Immature female biomass in 2024 doubled over that in 2023, while mature female biomass tripled (Table 16).

Survey abundance for males in 2024 increased by 74% over that in 2023. Immature female abundance increased 24% over that in 2023, while mature female abundance increased 250%.

Estimates for trends in industry-preferred males ($\geq$ 125 mm CW) from the NMFS survey are given in Tables 18 and 19; corresponding time series are illustrated in Figures 31 and 32. Compared with results from 2023, industry-preferred male biomass increased in the eastern area in 2024 by 75%, with increases in both new shell and old shell categories. In the western area, survey biomass increased over 100%, again with increases in both new shell biomass and old shell biomass categories (Table 18). Overall, total industry-preferred male biomass in the survey increased 92% from 2023 to 2024 to 11.5 thousand t and is higher than any year since 2018, although it was then 20.4 thousand t. Changes in abundance from 2023 to 2024 followed a similar pattern (Table 19).

The annual percentages (by biomass) of new shell industry-preferred size male from the survey and caught in the directed fishery are contrasted in Figure 33: in general, the fishery is able to catch a much higher percentage of new shell males than is estimated in the survey. The time series of biomass of industry-preferred males caught in the directed fishery is compared with the biomass estimated from the survey in Figure 34: the fishery came very close to catching more than the survey estimates in 2020/21 and 2021/22, but this was no longer the case in 2022/23 and 2023/24.

BSFRF and NMFS engaged in a series of collaborative “side-by-side” selectivity studies (“SBS”) for Tanner crab that coincided with the 2013-2018 NMFS surveys. During the SBS catchability studies, NMFS performed standard survey tows (e.g., 83-122 trawl gear, 30 minute tow duration) as part of its annual EBS bottom trawl survey while BSFRF performed parallel tows within 0.5 nm using a nephrops trawl and 5 minute tow duration. Because the nephrops trawl has better bottom-tending performance than the 83-112 gear, the BSFRF tows are hypothesized to catch all crab within the net path (i.e., to have selectivity equal to 1 at all crab sizes) and thus provide a measure of absolute abundance/biomass. The NMFS surveys provide relative indices of stock size across the entire stock area; the BSFRF SBS data provides (presumed) absolute indices within the smaller (annually-varying) study footprints (Figure 35). The NMFS SBS data (a subset of stations from the full survey each year) provides information on the annual “availability” of Tanner crab across the entire stock area relative to the area included in the associated SBS study. The 2018 data is new to the assessment this year and the associated empirical availability curves have been revised for the entire 2013-2018 dataset (see Appendix A for details). Design-based estimates (and cv's) for absolute biomass and abundance within the SBS study areas from BSFRF and NMFS are given in Tables 20 and 21 by sex and maturity state. Plots of biomass and abundance from the SBS studies are given in Figures 36. Any "trends" from these data are confounded by the varying areal coverage of the survey stations included in the SBS studies.

Size Composition Data

Bubble plots of NMFS EBS bottom survey size compositions for Tanner crab by sex and fishery region are shown in Figures 37 and 38. Distinct recruitment events (late 1970s, early 1990s, mid-2000s, early 2010s, and perhaps starting in 2023) and subsequent cohort progression are evident in the plots, particularly in the western area. The absence of small male crab in the 2010-2016 period is notable, although there was evidence for new recruitment in the western area in 2017-2018, with perhaps some spillover to the eastern area lagged by a year at slightly larger sizes. Unfortunately, the 2017-2018 cohorts seems to be absent from, or much reduced in, the 2021-2024 surveys. On the positive side, there is certainly evidence for a strong recruitment event in the western area in 2023 propagating into larger size classes in 2024.

The survey size compositions provide evidence for a decline in maximum size across the time series for both males and females (Figure 39). For males, maximum size decreased from over 180 mm CW in the late 1970's to less than 160 mm CW in 2023, although it was slightly larger in 2024. For females, maximum size declined from over 120 mm CW to under 115 mm CW in 2024, although the smallest maximum size occurred in 2019.

Based on the total abundance size compositions from the BSFRF-NMFS SBS studies (Figure 40), the BSFRF nephrops gear is in general (as expected) more selective for Tanner crab than the NMFS 83-112 gear, particularly at smaller sizes (< 60 mm CW). However, the size-specific catch ratio of the BSFRF survey to the NMFS survey appears to vary substantially across years, which one would not expect if gear-specific selectivity were, in general, constant. It is worth noting that the nephrops gear appears to give a much better indication of recruitment than the 83-112 gear (e.g., survey years 2017 and 2018).

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

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

Spatial patterns

Recent (2015-2024) spatial patterns of various population components (small males, large males, industry-preferred males, immature females, mature females) are illustrated in Figures 41-45. Small males and immature females exhibit similar spatial patterns during this time period (note that the scales in Figures 41 and 44 are different), predominantly distributed along the western shelf between the shelf edge and the 100 m isobath, but extending eastward to the 50 m isobath from the Pribilof Islands southward. High concentrations of small/immature crab were found along the outer shelf in 2024. Large males were concentrated to the northeast of the Pribilof Islands, but also extended along the Alaska Peninsula and into Bristol Bay (Figure 42). The patterns for industry-preferred males (Figure 43) are generally similar to those for large males. The spatial patterns for immature females generally reflected those for small males (Figure 44). The spatial distribution of mature females was concentrated northeast of the Pribilof Islands as well as straddling the 166°W longitude linenear the Alaska Peninsula (Figure 45).

5.5 Other Data

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

Male maturity ogives

Tanner crab undergo a terminal molt to maturity, after which they no longer molt. The maturity state for females can be unambiguously determined in the field based on abdominal morphology, but the state for males is much less well-defined morphometrically. Here, males taken in the NMFS EBS shelf survey are classified as immature or mature based on the ratio of their chela height to carapace width, with annual size-specific cutlines for this ratio determined statistically after the survey has been completed (Richar and Foy 2022). Chela height measurements can be time-consuming to obtain and data are generally collected biennially rather than annually (chela heights are taken for snow crab in “off” years for Tanner crab). The observed size-specific fraction of males classified as new shell and mature relative to all new shell males (i.e., immature males and new shell mature males) for a survey constitutes the “male maturity ogive” for that year (Figure 46) and provides information to the model on the size-specific probability of immature males undergoing terminal molt.

Molt increment data

Molt increment data for Tanner crab in the EBS were collected as part of collaborative studies by NMFS, BSFRF, and ADF&G during 2015-2017 and 2019 (Figure 47). These are fit in the assessment model to estimate annual growth increments for crab that have not undergone terminal molt.

Weight-at-size

Weight-at-size relationships for Tanner crab are fixed in the assessment model. These were developed by fitting separate power law models ($w = \alpha \cdot z^{\beta}$) for weight-at-size to NMFS EBS shelf survey measurements of individual crab size and weight for males, immature females, and mature females (Table 24, Figure 48).

SBS survey availability

For the purposes of the assessment, the BSFRF gear in the SBS catchability studies is assumed to provide absolute indices of Tanner crab stock biomass and abundance within the area included in each year's study area (Figure 35). However, these areas, which vary among years in the study, do not cover the entire stock area while the assessment model predicts stock abundance by category and size for the entire stock area. To fit the SBS data, the model needs to take into account "survey availability" for the SBS study–i.e., the fraction of the stock (by category and size) within the study area–on an annual basis. Estimating survey availability within the stock assessment for the SBS studies is confounded with estimating survey catchability for the full NMFS survey, but can be estimated empirically outside the assessment model. Consequently, availability of Tanner crab to the BSFRF gear in the SBS catchability studies was determined outside the model on a sex-specific basis from the ratio of area-swept abundance-at-size from the NMFS gear in the study to the same for the entire survey. With the addition of the 2018 SBS data to the assessment this year, the availability curves were re-evaluated (Figures 49 and 50; see Appendix A for details).

6 Analytic Approach

6.1 History of modeling approaches for this stock

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

In May 2012 and June 2012, respectively, the TCSAM was presented to the CPT and SSC to determine model suitability for stock assessment and the rebuilding analysis (Rugolo and Turnock 2012b). The CPT agreed that the model could be accepted for management of the stock in the 2012/13 cycle, and that the stock should be promoted to Tier-3 status. The CPT also agreed that the TCSAM could be used as the basis for rebuilding analyses. In June 2012, the SSC reviewed the model and accepted the recommendations of the CPT. The Council subsequently approved the SSC recommendations and Tanner crab was assessed as a Tier-3 for the 2012 assessment using TCSAM for the first time to estimate status determination criteria and overfishing levels (Rugolo and Turnock 2012a).

For 2013, modifications were made to the TCSAM computer code to improve code readability, computational speed, model output, and user friendliness without altering its underlying dynamics and overall framework (Stockhausen 2013). A detailed description of the 2013 model (TCSAM2013) is presented in Appendix 3 of the 2014 SAFE chapter (Stockhausen 2014). Following the 2014 assessment, the model code was put under version control (at GitHub).

The current model "framework", TCSAM02, was reviewed by the CPT and SSC in May/June 2017 (SSC 2017; CPT 2017; Stockhausen 2017b) and adopted for use in subsequent assessments as a transition to GMACS. This framework is a completely-rewritten basis for the Tanner crab model: substantially different models can be created and run by editing model configuration files rather than modifying the underlying code itself. Most importantly, no time blocks are "hard-wired" into the code–any time blocks are defined in the configuration files. In addition, the framework has been used to incorporate new data types (molt increment data, male maturity ogives), new survey data (the BSFRF surveys), and new fishery data (bycatch in the groundfish fisheries by gear type). The framework also incorporates status determination and OFL calculations directly within a model run, so a follow-on, stand-alone projection model does not need to be run (as was the case with TCSAM2013). This approach has the added benefit of allowing a more complete characterization of model uncertainty in the OFL calculation, because the OFL calculations are now included in the Markov Chain Monte Carlo (MCMC) evaluation of a model's posterior probability distribution. More recently, the model code was restructured to function in a management strategy evaluation (MSE) mode and allow retrospective analyses. The Dirichlet-Multinomial likelihood for size composition data (Thorson et al. 2017) was added as an option when fitting size composition data, as was the ability to apply "tail compression" to the composition data. In 2021/22, the ability to do multi-year projections under different fishing mortality rates was added to the model in response to CPT and SSC requests (Stockhausen 2022). 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. In 2023/24, the ability to fully simulate data and fit it within a model run was implemented to allow models to undergo comprehensive simulation testing.

In May 2024, several preliminary models based on the GMACS framework were presented to the CPT (Stockhausen 2024). The CPT recommended that a comprehensive comparison between the TCSAM02 assessment model and an equivalent GMACS model be completed before the GMACS model could be adopted for Tanner crab. Consequently, the GMACS models were rejected as potential candidates for this assessment and only TCSAM02-based models are considered here.

6.2 Model description

Overall modeling approach

TCSAM02 is a stage/size-based population dynamics model that incorporates sex (male, female), shell condition (new shell, old shell), and maturity (immature, mature) as different categories into which the overall stock is divided on a size-specific basis. For details of the model, the reader is referred to Stockhausen (2023b).

In brief, crab enter the modeled population as recruits following a truncated size distribution based on the gamma probability distribution (see Figure 51 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 February 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 undergoing terminal molt, 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 February 15 through June 30 ($\delta t = 0.375$ yr) to calculate the population numbers (prior to recruitment) on July 1 at the start of the next year.

Model parameters are estimated using a maximum likelihood approach, with Bayesian-like priors on some parameters and penalties for smoothness and regularity on others. Data components in the base model entering the likelihood include fits to survey biomass, survey size compositions, survey-based estimates of the annual size-specific fraction of mature new shall males in the population, retained catch, retained catch size compositions, aggregate total catch in the directed and bycatch fisheries, and total catch size compositions in the directed and bycatch fisheries. Data on growth in the EBS from observed molt increments are also (typically) fit.

Changes since the previous assessment

No substantive changes have been made to the TCSAM02 modeling framework that impact one's ability to define a model and run it. The ability to do simulation testing with a model, with data being simulated and fit within the same run, was added this summer, but no models have yet been subjected to a comprehensive simulation analysis pending CPT discussion on what this should entail. Draft results from testing the 2024 assessment model will be presented at the January 2025 Modeling Workshop for discussion.

The code for the TCSAM02 model framework is described in Appendix A and publicly available on GitHub.

Methods used to validate the code used to implement the model

The TCSAM02 model framework was demonstrated to produce results that were exactly equivalent to those from the 2016 assessment model (Stockhausen 2017b). TCSAM02 also underwent a review in July 2017 conducted by the Center for Independent Experts and was further reviewed by the CPT in May 2017 and September 2017. Changes to model code are validated against results from the previous assessment model to ensure that modifications do not change the results of the previous assessment.

6.3 Model selection and evaluation

Description of alternative model configurations

The model selected for the 2023 assessment, Model 22.03b, provides the base model for this assessment (Stockhausen 2023a). The following three tables summarize the parameterization and time blocks for the biological and fishery processes incorporated in this model:

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

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

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

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

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

Fishery/process	time blocks	22.03b description
RKF	bycatch in BBRKC fishery	
capture rates	pre-1952	nominal rate on males
	1953-1991	extrapolated from effort
	1992+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal, asymptote fixed
	2005+	ascending normal, asymptote fixed
female selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal
	2005+	ascending normal
GTF	bycatch in groundfish fisheries	
capture rates	pre-1973	male ln-scale mean from 1973+
	1973+	male ln-scale mean + annual devs
	1973+	ln-scale female offset
male selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic
female selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic

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

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

Survey/process	time blocks	22.03b description
NMFS EBS trawl survey		
male survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
female survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
male selectivity	1975-1981	ascending normal, fixed fully-selected size at 180
	1982+	ascending normal, fixed fully-selected size at 180
female selectivity	1975-1981	ascending normal, fixed fully-selected size at 130
	1982+	ascending normal, fixed fully-selected size at 130
BSFRF SBS trawl surveys		
male catchability	2013-2017	fixed at 1 for all sizes
male availability	2013-2017	empirically-determined outside the model
female catchability	2013-2017	fixed at 1 for all sizes
female availability	2013-2017	empirically-determined outside the model

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

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

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

As per recommendations by the CPT and SSC at their previous meetings, only one model proposed by the author in May, 22.03d, has been brought forward and evaluated with new data from 2023/24 for this assessment. This model incorporated newly-available data from the 2018 BSFRF side-by-side (SBS) selectivity study, slightly revised data from the 2013-2017 SBS studies, and updated empirical availability curves. However, the effective sample size parameter associated with the Dirichlet-Multinomial likelihood used by 22.03d to characterize the fit to the BSFRF SBS female size compositions was estimated at its upper bound in May. The fact that it was estimated at its upper bound indicated that the effective sample size for this data was larger than the input sample size, in which case the Dirichlet-Multinomial likelihood effectively becomes a simple multinomial likelihood. However, continuing to estimate this parameter could lead to unsatisfactory results if the model achieved a similar result after addition of the 2023/24 data. The CPT and SSC requested that a detailed bridging analysis between 22.03b and 22.03d be provided and a model with no parameters at bounds be developed for September. This analysis was performed with three new, intermediate models (22.03b1, 22.03b2, and 22.03b3) and is provided in Appendix B (Bridging Analysis 1).

Following this first bridging analysis, the author was concerned that addition of the 2023/24 data to the model might render the problematic effective sample size parameter estimable and thus continued to estimate the problematic parameter as the 2023/24 data was added to the model in incremental steps (models 22.03d1, 22.03d2, 22.03d3, 22.03d4, and 22.03d5) and a detailed bridging analysis from 22.03d to the final model with all the new data and no parameters estimated at a bound, 22.03d5. This second briding analysis is documented in Appendix C (Bridging Analysis 2). As described in the appendix, in order to achieve an acceptable model it was ultimately found necessary to fix the effective sample size parameters associated with the Dirichlet-Multinomial likelihoods for fitting both male and female BSFRF SBS size compositions to values near their upper bounds. Model 22.03d5 thus differs from the previous assessment model 22.03b by: 1) the updated 2013-2017 and “new” 2018 BSFRF SBS survey biomass size composition data; 2) the 2023/24 fishery and NMFS EBS shelf survey data; and 3) the two Dirichlet-Multinomial effective sample size parameters for the BSFRF size compositions fixed near their upper bounds.

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

The model used in the previous assessment is the current base model. Results from bridging analyses with intermediate models from 22.03b to 22.03d5 are documented in Appendices B and C.

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

A Tier 4 model based on survey biomass was evaluated as a “backup” for 22.03d5 (Section 8).

Convergence status and convergence criteria

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

For this assessment, convergence was partially evaluated by making 800 jitter runs for 22.03d5 to find the parameter values that resulted in the model's maximum likelihood (i.e., the parameters that minimized the model objective function, which is the negative of the likelihood). The jittering analysis appears to have found the parameter set that achieves the minimum objective function/maximum likelihood (3,182.00), with 99 jittered model runs out of 800 converging to the same minimum value (Figure 52). The large number of runs that converged to the same minimum objective value lends confidence to the assertion that the solution is indeed the global minimum.

Other factors that were considered were the maximum parameter gradient at model convergence, whether it was possible to obtain the parameter covariance matrix and uncertainty estimates for parameters and derived quantities by inverting the model hessian, and whether any parameters were estimated at a bound. The maximum gradient at the MLE was small (0.0178) and it was possible to invert the model hessian and obtain uncertainty estimates for parameters and derived quantities (Table M). No parameters were estimated at a bound for the preferred model, 22.03d5.

Table M. Summary convergence diagnostics. Diagnostics for 22.03b are from the 2023 assessment.

model configuration	parent	changes	number of parameters	no. of jitter runs	no. converged to MLE	no. of param.s at bounds	objective function value	max gradient	invertible for std. devs?
22.03b	--	none: 2023 assessment model	354	800	478	0	3143	8.13E-05	yes
22.03d5	22.03b via 22.03d	2023/24 data; upadted BSFRF SBS data; effective sample size parameters for Dirichlet-Multinomial likelihoods for BSFRF size compositions were fixed near their upper bounds.	357	800	99	0	3182	1.78E-02	yes

Sample sizes assumed for the compositional data

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

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

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

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

Parameter sensibility

No parameters were estimated at a bound for the preferred model, 22.03d5. Values for all estimated parameters are listed in the following tables:

- 25: parameters for recruitment, growth, and natural mortality
- 26: ln-scale recruitment deviations prior to 1975
- 27: ln-scale recruitment deviations after 1974
- 28: logistic-scale parameters for the probability of undergoing the molt-to-maturity
- 29: non-vector parameters related to fishing mortality rates, retention, survey catchability, and the Dirichlet-Multinomial likelihood
- 30: ln-scale fishing mortality devs for the directed fishery
- 31: ln-scale fishing mortality devs for bycatch in the snow crab fishery
- 32: ln-scale fishing mortality devs for bycatch in the BBRKC fishery
- 33: ln-scale fishing mortality devs for bycatch in the groundfish fisheries
- 34: "pS1" selectivity parameter values
- 35: "pS2" selectivity parameter values
- 36: "pS3" and "pS4" selectivity parameter values, and
- 37: dev parameters for size-at-50% selected for males in the directed fishery

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

None of the models presented to the CPT and SSC in the spring, other than 22.03d, were judged to have performed well enough to be considered as viable alternative models for this assessment (SSC 2024; CPT 2024; Stockhausen 2024). Model 22.03d5 is identical to 22.03d with data updated for 2023/24 except that, as noted previously, the effective sample size parameters for the Dirichlet-Multinomial likelihoods characterizing the fits to the BSFRF SBS size compositions were fixed near their upper bounds. Model 22.03d5 appears to have converged to the MLE based on the jitter analysis, the magnitude of the maximum parameter gradient for the objective function at the presumed MLE, and the ability to invert the model hessian to obtain standard errors for parameters and derived quantities using the delta method (Table M). In addition, no parameters were estimated at a bound and none of the estimated parameter values appear to be problematic.

Residual analysis

Standardized residuals for model fits to all aggregated catch data components (e.g., retained catch biomass, survey catch biomass) and the molt increment data were calculated and plotted for both 22.03b and 22.03d5. 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.

Objective function values

Objective function values related to data in the likelihood are listed by component for models 22.03b and 22.03d5 in Tables 50-52; those related to non-data components are listed in Table 53. Objective function differences relative to 22.03b are listed in Tables 54-57. It should be noted, though, that most values are not directly comparable between the models because 22.03d5 incorporates the 2018 BSFRF SBS data, updated empirical availability curves, and new data for 2023/24, so caution must be used when interpreting apparent differences between the models.

Evaluation of the model(s)

As one might expect, model-estimated quantities from 22.03d5 were, on the whole, extremely similar to those from 22.03b. Estimated capture rates in the directed fishery from 22.03d5 were slightly smaller in magnitude than those from 22.03b (Figure 53), while selectivity and retention functions were identical (Figures 54-57). Similar observations hold for bycatch capture rates and selectivity functions in the snow crab, BBRKC, and groundfish fisheries (58-60).

Estimates of sex-specific NMFS EBS shelf survey fully-selected catchabilities were slightly larger from 22.03d5 compared with 22.03b (Table 59, Figure 61), while the corresponding selectivity curves were practically identical (Figure 61). The small differences in catchabilities between the two models appear to account for the small (opposite) differences in the estimated fishery capture rates.

Estimates of natural mortality were slightly higher in 22.03d5, compared with 22.03b while size-specific mean growth, and size-specific probability of undergoing the molt to maturity were almost identical for the two models (Table 58, Figure 63). The estimated recruitment size distribution (panel 1 in Figures 64 and 65) was somewhat narrower with a smaller mean size in 22.03d5 compared with 22.03b. This initial difference decreases across the first few years of cohort development and has disappeared after five years for females and six years for males (panel 5 in Figures 64 and 65).

Estimated recruitment tended to be just slightly higher in 22.03d5 than in 22.03b across the time series (Tables 98 and 99, Figures 66 and 67), as was the case with MMB (Tables 96 and 97; Figures 66 and 67). The estimated recruitments since 2021 exhibited larger differences than typical between the two models: the estimates from 22.03d5 were 63%, 46%, and 24% higher than those from 22.03b in 2021, 2022, and 2023, respectively. Estimated trends in population abundance and biomass by sex and maturity state exhibit characteristics similar to the MMB comparison (Tables 92-95; Figures 68 and 69).

Model 22.03d5 fitted the retained catch and total catch biomass series as well as Model 22.03b did (Figures 71-75), with only the fit to total catch in the directed fishery in 1996/97 (just prior to the closure of the fishery for nine years) as a substantial outlier in both models.

Fits to NMFS EBS shelf survey biomass exhibit similar patterns from 1975 to about 2000 for males, at which point 22.03d5 exhibits slightly larger positive residuals but slightly smaller negative residuals to the data when compared with results from 22.03b (Figures 76 and 77). The fits to immature and mature female survey biomass do not really exhibit this pattern and are similar across the time series (Figures 76 and 78). Of note, both models substantially overestimated male survey biomass in 2022 (z-scores < -4) and 22.03d5 also overestimated male survey biomass in 2023 (z-score < -4). Interestingly, both models estimate male survey abundance rather well in the last two years, even though this data is not included in the model likelihoods (Figures 81 and 82).

Both models fitted the BSFRF SBS biomass data equally well and estimate the abundance data equally well for 2013-2017, but substantially overestimated mature female biomass in 2018 (Figures 76, 79, and 80).

The mean growth curve estimated by 22.03d5 is almost identical to that of 22.03b (Figure 86), with estimated postmolt size exhibiting a slightly convex pattern with pre-molt size for females but an increasing trend in overestimating post-molt size in males. The z-scores are also almost identical.

The two models also fit the male maturity ogive in similar fashion in each year prior to 2024 (Figure 87); neither model fits 2018 or 2023 very well (with at least three size bins under-predicted, with the caveat that Pearson's residuals are not ideal diagnostics for fits to proportions).

As with the fishery catch biomass data, Model 22.03d5 fit the fishery size composition data in a manner almost identical to that of 22.03b (Figures 89-Figure 116). Retained catch size compositions were generally well-fit prior to the fishery closure in 2016/17, but exhibited worse fits afterward (Figures 89 and 89), presumably at least partly due to the fact that the fishery was only prosecuted in the western management area (which exhibits a different size range of males than the combined area) in the intervening period until last year. The fit to this year's size composition is better than the fits back to 2017/18, but still overestimates the proportion of the largest crab in the catch.

Fits to the total catch size compositions in the directed and bycatch fisheries are essentially identical for the two models (excluding 2023/24, of course). The estimated size compositions since 2014/15 for the directed fishery all overestimate the proportion of males in the largest size bin (Figures 93, 95 and 96), although the bias is not really substantial judging by the z-score sizes.

Estimates of bycatch size compositions in the snow crab fishery tend to be fairly reasonable for males, although fits in the early 1990s and mid-2000s are poor (Figures 99, 101 and 102). Fits in 2020/21 and 2021/2 are not as bad, from a statistical viewpoint, as they may appear in Figure 99 (see residuals in 101).

Fits to the bycatch compositions from the BBRKC fishery are rather poor, reflecting the lower sample sizes associated with these data. Starting in 2016/17, coincident with ADF&G closing the Tanner crab fishery east of 166°W longitude, the models consistently overestimated the proportion of large males in the size compositions (Figure 105), which may indicate the interaction among spatial processes (the BBRKC fishery only takes Tanner crab in the eastern management area) not accounted for in the modeling framework. Similar overestimates occurred in 2003/04-2007/08, but the Tanner crab fishery in the eastern management area was not closed during that period.

The groundfish fisheries take a wider range of Tanner crab as bycatch than do the other fisheries (Figures 111-116). In addition, the fixed gear and trawl gear fleets capture different size ranges, so the resulting size compositions could be expected to vary annually, even in the absence of changes in size structure in the Tanner crab population due to recruitment and growth, depending on the relative effort in the two fleets. As such, it is not too surprising that the models exhibit poor (but almost identical) fits to the size compositions from the groundfish fisheries in some years.

The fits to the NMFS EBS shelf survey size compositions for the two models are indistinguishable for all three population components: males, immature females, and mature females (Figures 117-126). While the fits are reasonably good in most instances, both models consistently overestimated the proportion of males or mature females in the largest size bin in the data from 1997 on.

The two models fit identically to the BSFRF SBS size composition data (Figures 127-133). Both models underestimate the proportions of the small males in the 2016 and 2017 surveys and generally fit the proportions for immature females poorly (Figure 130).

The marginal size distributions (i.e., averaged across years for a given dataset) from both fishery and survey data were fit equally well by both models, with little discernible difference in the means (Figures 134-138). The worst agreement between the marginal distributions for the models and the data occurred for the groundfish fisheries male bycatch data and the BSFRF SBS immature female survey data (Figures 137-138).

On the whole, effective sample sizes from both models were very similar for both fishery and survey size composition data and tended to be larger than input sample sizes (Figures 139-145). Exceptions to the latter observation include total catch size compositions for males in the directed fishery since 2014/15, NMFS EBS shelf survey size compositions for males before 1989, and all BSFRF SBS size compositions for males (Figures 140 and 145).

The value of Mohn's rho (Mohn 1999) for recruitment from the retrospective analysis for Model 22.03d5 (Figure 146) was 0.234. Recruitment estimates for a given year tended to decrease as more years of data were added to the model, although this was not true of the 2022 estimate (which increased when 2023 data was added). In contrast, Mohn's rho for MMB was only 0.001, indicating that changes to MMB as data was added tended to cancel out across the time series (Figure 147). Estimates when MMB had a decreasing trend (2015-2020) tended to get slightly smaller when more data was added.

In summary, the author's preferred model 22.03d5 performed, on the whole, very similarly to the 2023 assessment model, 22.03b.

6.4 Results (best model(s))

As the only model evaluated for this assessment, model 22.03d5 is, by default, the author's preferred model for the 2024 assessment. In this section, results not previously discussed are compared with those from the 2023 assessment model, 22.03b.

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

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

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

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

fishery	catch type	time period	CV
directed fishery	retained	1965-1979	10.0%
		1980	2.5%
		1996+	1.0%
	total	1990+	20.0%
snow crab	total	1990+	20.0%
BBRKC	total	1990+	20.0%
groundfish	total	1973	20.0%

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.

Tables of estimates

All parameters

Parameter estimates and associated standard errors, based on inversion of the converged model's Hessian and the "delta" method, are listed in 25-37.

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 58 and 59.

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 60-79. Model-estimated values for survey abundance and biomass for the NMFS EBS shelf survey and BSFRF SBS surveys are documented in Tables 80-91. Model-estimated values for annual population abundance and biomass are given by sex, maturity state, and shell condition in Tables 92-95. Model estimates for mature male and female biomass at the time of mating are listed in Tables 96-97.

Recruitment time series

Model estimates for recruitment are given in Tables 98 and 99.

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 100 and 101.

Graphs of estimates

6.5 Estimated Fishery-related Quantities

Graphs of time series of estimated fully-selected F (total catch capture rates, not necessarily mortality) in the directed fishery are shown in Figure 53, while the associated selectivity functions are illustrated in Figures 54-56. The estimates of size-selective retention for males captured in the directed fishery are presented in Figure 57. 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 58-60.

Estimates for fully-selected F's in the crab fisheries were slightly smaller for the previous assessment model, 22.03b, compared with the preferred model 22.03d5 prior to 2000/01, whereas the differences were negligible afterward (Figures 53, 58, and 59). Differences between the two models in estimated bycatch F's for the groundfish fisheries prior to 2000/01 were also small, but the sign of the difference varied across the time series (Figure 60); after 2000/01, the differences were also negligible. All estimated fishery-related selectivity and retention curves were essentially identical for the two models (Figures 54-60).

6.6 Estimated Survey-related Quantities

Graphs of estimated sex-specific survey catchability and the associated selectivity functions for the NMFS EBS survey are shown in Figure 61. Fully-selected survey catchability was estimated slightly higher in 22.03d5 across both sexes and time blocks than in 22.03b. The estimated selectivity curves for the 1975-1981 time block were essentially identical for the two models whereas 22.03d5 exhibited a slightly steeper descent from full selection with decreasing crab size values compared with 22.03b.

The BSFRF nephrops bottom trawl gear is assumed to be non-size-selective (i.e., selectivity=1 at all sizes) and catch all crab in its swept-area path (i.e., the fully-selected catchability coefficient $q = 1$). Assumed survey availability curves for the BSFRF side-by-side catchability studies are illustrated in Figure 62. These were not estimated; they were determined outside the model (see Appendix A for details).

6.7 Estimated Population-related Quantities

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 63, together with estimated mean post-molt size (as a function of pre-molt size) and natural mortality rates. The cohort progressions (growth and development) resulting from these schedules are illustrated in Figures 64 and 65. The cohort progression curves differ slightly across the models because natural mortality is estimated slightly higher in 22.03d5 than in `rs`$prvMod‘.

Estimated population-related time series

Estimated time series for recruitment and MMB are shown in Figures 66 and 67. Time series of abundance by sex and maturity state are illustrated in Figure 68; time series of biomass by sex and maturity state are illustrated in Figure 69. While the temporal patterns are essentially identical, 22.03d5 exhibits slightly higher estimates of recruitment than 22.03b, but when combined with its slightly higher estimates of natural mortality, the resulting estimates of population abundance and biomass are almost indistinguishable across both models for mature crab.

6.8 Estimated Fishing Mortality versus Estimated Spawning Stock Biomass

Estimated total fishing mortality (retained + discards) is plotted against spawning stock biomass (MMB) for the models in Figure 70.

Fit of a stock-recruitment relationship, if feasible

Fits to a stock-recruit relationship were not evaluated.

Evaluation of the fit to the data

6.9 Fits to Fishery Catch Data

Fits to the observed and model-predicted fishery catch biomass data are presented in Figures 71-75 for the previous assessment (22.03b) and preferred (22.03d5) models. Residuals to the fits and summary statistics are also shown on each figure. Graphs of fits to observed catches from the directed fishery are presented in Figures 71-72 for retained catch and total catch. Fits to bycatch data from the snow crab fishery are shown in Figure 73. Fits to bycatch data from the BBRKC fishery are shown in Figure 74. Fits to bycatch data from the groundfish fisheries are shown in Figure 75. Both models exhibited similar fits to the catch data.

6.10 Fits to Survey Indices and Related Data

Graphs of model fits to survey biomass and numbers

Model fits to the survey biomass time series from the NMFS EBS shelf survey and the BSFRF SBS surveys are shown for the models in Figure 76. Residuals to the fits and summary fit statistics are shown in Figures 77-80. The fits to the NMFS survey data were similar in pattern across the models, with particularly poor fits in 1985 for both males and immature females. The models also substantially overpredict NMFS survey biomass for males in 2022 and 2023. The fits to the BSFRF data are much more acceptable, although both models overpredict mature female biomass in all years.

Model fits to the survey abundance time series for both the NMFS EBS shelf survey and the BSFRF SBS surveys are shown for the models in Figure 81. Residuals to the fits and summary fit statistics are shown in Figures 82-85. Fits to survey abundance were not included in the model objective function but serve as independent diagnostics of model fit. As with survey biomass, both models exhibited fairly similar fits to the abundance data, and these fits generally exhibited temporal patterns that were similar to those for survey biomass. Somewhat unexpectedly, the fits to male abundance in the 2022 and 2023 NMFS surveys were much better than those for biomass.

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 86. The predicted mean growth curves were essentially identical across the models, with both models overpredicting post-molt size for large crab of either sex.

Model fits to maturity ogive data from the NMFS EBS shelf survey are presented in Figure 87, while Pearson's residuals to the fits are shown in Figure 88. The models appear to fit the maturity ogive data to an identical degree.

6.11 Fits to Fishery Size Compositions

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 89-116 for the previous assessment model, 22.03b, and the preferred model 22.03d5. The models fit the total catch size composition data from the directed and bycatch fisheries by normalizing it across sexes and fitting the resulting proportions jointly. Graphs for the directed fishery are given in Figures 89-98. Graphs for the snow crab fishery are given in Figures 99-104. Graphs for the BBRKC fishery are given in Figures 105-110. Graphs for the groundfish fisheries are given in Figures 111-116. On the whole, the fits are very similar across both models.

6.12 Fits to Survey Size Compositions

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 117-133 for the previous assessment model, 22.03b, and the preferred model 22.03d5. Both models exhibit similar fits to the NMFS survey size composition data, with the most salient feature perhaps being that the models overpredict the proportion of crab in the largest size bins for both males and females starting around 2000. The fits to the BSFRF size composition data are similar across the models for males, but exhibit some differences for females–particularly for the 2016 immature females.

6.13 Marginal Distributions for Fits to Compositional Data

Marginal distributions for fits to the compositional data from the fisheries are shown in Figures 134-137. Marginal distributions for fits to the compositional data from the surveys are shown in Figure 138. Except for the BSFRF survey data, the fits to the marginal distributions were practically identical across the models and none exhibit the problem with overpredicting the proportions of large crab noted for the fits to individual years because underpredictions in the early parts of the time series balance out overpredictions in the latter part of those time series. The models did exhibit some variability with respect to the marginal distributions for the BSFRF size compositions, reflecting the differences in fit to the individual size compositions and the relatively few years to available to form the marginal distributions.

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

Implied effective sample sizes were calculated by year for all size compositions using the McAllister-Ianelli method (McAllister and Ianelli 1997). Time series plots of implied and input effective sample sizes for compositional data from the fisheries are shown in Figures 139-143. Similar plots for the survey compositional data are given in Figures 144 and 145. The implied sample sizes were very similar across the two models for the fishery size compositions and are larger than the input sample sizes for most years. This was also the case for the NMFS survey size compositions, although the implied sample sizes from both models were consistently smaller than the input sample sizes for males before 1989. Effective sample sizes for the BSFRF size compositions were larger in 22.03b, compared to 22.03d5, only for males in 2015. The increase in effective sample sizes for the 2013-2018 BSFRF data in 22.03d5 was associated with using the revised empirical availability functions (see Appendix B). These results provide support for fixing the effective sample size parameters in the Dirichlet-Multinomial likelihoods used to fit the BSFRF size compositions (as in 22.03d5) as a practical step to obtaining a model with no parameters estimated at a bound.

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 102, but no comparison is available with the cv's assumed for the indices. The author has previously requested guidance on how the cv's for time series indices should be combined to compare with the RMSEs.

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

Quantile-quantile (q-q) plots and histograms of residuals were not produced for this assessment.

Retrospective and historical analyses

Retrospective analysis

Retrospective analyses were conducted for the base/preferred model 22.03d5. The analysis used 10 peels (ending in 2014), with the model re-fit after each removal of the previous peel's terminal year's data. Time series plots of recruitment and MMB were made to identify potential patterns in how the terminal year's estimate for each peel differed from the model result using the complete dataset (Figures 146 and 147. Relative bias in the terminal year estimates was quantified using Mohn's rho (Mohn 1999). The retrospective patterns don't indicate any apparent problems with MMB (Mohn's rho = -0.00989), but additional data (decreasing the number of peels) almost always reduced the estimates of recruitment. Mohn's rho for the recruitment pattern was 0.234.

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, 22.03d5, are compared with those from previous assessments in Figures 148 and 149. Prior to 1975, when the NMFS EBS shelf survey data begin, the results fall into three groups: 2017 and 2018, 2019 and 2020, and the remainder (2021-2023 plus this assessment's preferred model), with results for the first two groups differing mainly in scale while the latter group differs from the first two in temporal pattern, as well. After 1975, the models differ primarily in scale, while exhibiting similar temporal patterns. The plots indicate a generally-increasing trend in the overall scale of estimated recruitment and mature biomass by assessment.

Uncertainty and sensitivity analyses

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

7 Calculation of the Tier 3 OFL and ABC

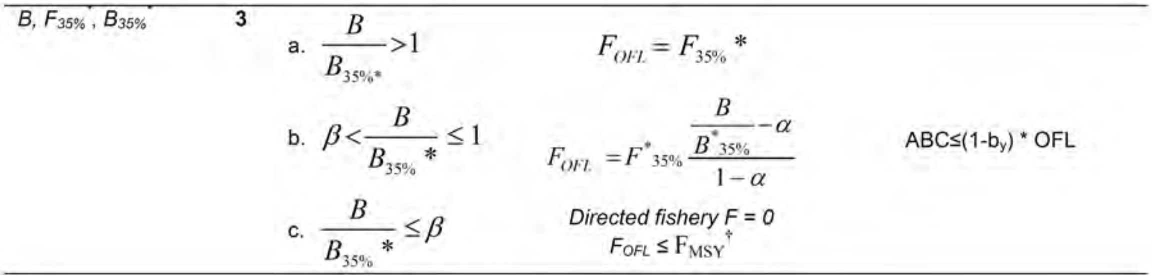
7.1 Status determination and OFL calculation

The (total catch) OFL for 2023/24 was 36.20 thousand t while total catch mortality was 1.086 thousand t, based on applying mortality rates of 1.000 for retained catch, 0.321 to bycatch in the crab fisheries, 0.5 to bycatch in the groundfish fixed gear fisheries, and 0.8 to bycatch in the groundfish trawl fisheries to retained catch data and estimates of discards from fish ticket and observer data (see Tables A, 1, 10, and 11). Because total catch mortality is less than the OFL, **overfishing did not occur in 2023/24**.

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

Amendment 24 to the NPFMC fishery management plan revised the definitions for overfishing for EBS crab stocks (NMFS 2008; NPFMC 2021b). The information provided in this assessment is sufficient to estimate overfishing limits for Tanner crab under Tier 3. The OFL control rule for Tier 3 is outlined in Table O (see Figure 150 for a graphical representation).

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



B, $F_{35\%}{}^*$, $B_{35\%}{}^*$	3	a. $\frac{B}{B_{35\%^*}} > 1$	$F_{OFL} = F_{35\%}$ *	
		b. $\beta < \frac{B}{B_{35\%}{}^*} \leq 1$	$F_{OFL} = F^*_{35\%} \dfrac{\frac{B}{B^*_{35\%}} - \alpha}{1-\alpha}$	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 equations above in O, $\alpha = 0.1$ and $\beta = 0.25$. For Tanner crab, the proxy for F_{MSY} is $F_{35\%}$, the fishing mortality that reduces the SBPR to 35% of its value for an unfished stock. Thus, if $\phi(F)$ is the SBPR at fishing mortality F, then $F_{35\%}$ is the value of fishing mortality that yields $\phi(F) = 0.35 \cdot \phi(0)$. The Tier 3 proxy for B_{MSY} is $B_{35\%}$, the equilibrium biomass achieved when fishing at $F_{35\%}$, where $B_{35\%}$ is simply 35% of the equilibrium (longterm average) unfished stock biomass. Given an estimate of average recruitment, $\bar{R}$, $B_{35\%} = 0.35 \cdot \bar{R} \cdot \phi(0)$.

Thus Tier 3 status determination and OFL setting for 2024/25 require estimates of $B = MMB_{2023/24}$ (the projected MMB at mating time for the coming year), $F_{35\%}$, spawning biomass per recruit in an unfished stock (ϕ_0), and $\bar{R}$. Current stock status is determined by the ratio $B/B_{35\%}$ for Tier 3 stocks. If the ratio is greater than 1, then the stock falls into Tier 3a and $F_{OFL} = F_{MSY} = F_{35\%}$. If the ratio is less than one but greater than β, then the stock falls into Tier 3b and F_{OFL} is reduced from $F_{35\%}$ following the descending limb of the control rule (Figure 150). 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 the Minimum Stock Size Threshold (MSST, = ½ $B_{35\%}$), the stock must be declared overfished and a rebuilding plan subsequently developed.

The OFL is calculated within the assessment model based on equilibrium calculations for F_{MSY} and projecting the state of the population at the end of the modeled time period one year forward assuming fishing mortality at F_{OFL}. Using an estimate of the uncertainty in the OFL and assumptions about the underlying distribution or MCMC, one can estimate the probability distribution of the OFL (and related quantities of interest) and better characterize 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 2022).

The determination of $B_{MSY} = B_{35\%}$ for Tanner crab depends on the selection of an appropriate time period over which to calculate average recruitment ($\bar{R}$). Following discussion in 2012 and 2013, the SSC endorsed an averaging period of 1982+. Starting the average recruitment period in 1982 is consistent with a 5-6 year recruitment lag from 1976/77, when a well-known climate regime shift occurred in the EBS (Rodionov and Overland 2005) that may have affected stock productivity. This issue was revisited at the May 2018 CPT meeting with regard to whether or not the final year should be included in the calculation, but no definitive recommendations were made. In 2020, the NMFS EBS shelf bottom trawl survey was canceled due to health and safety concerns associated with the COVID-19 pandemic. This resulted in enormous uncertainty in the estimate of final year recruitment for that assessment; it was subsequently dropped from the averaging time frame. The missing survey continues to influence recruitment estimates near the end of the time series (Figure 151). However, the estimated low recruitment appears to be consistent with subsequent size compositions from the NMFS EBS shelf survey (Figures 37 and 38). Recruitment estimates and associated uncertainties for the intervening years do not raise any concerns, but the estimated confidence interval and standard deviation for the 2024 recruitment is slightly larger than that for 2022, but it is an outlier in terms of the time series, being the second-largest sin the 1982+ time frame (Figure 151). Consequently, average recruitment for the preferred model was calculated using the period 1982-2023 and dropping the final year estimate.

The value of $\bar{R}$ for this period from the author's preferred model is 526.04 million. This estimate of average recruitment is 8% larger than that from the 2023 assessment model (395.77 million). The value of $B_{MSY} = B_{35\%}$ for $\bar{R}$ is 40.01 thousand t, which is 5% larger than that obtained in the 2022 assessment (34.73 thousand t).

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

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

where C is total catch (biomass), $F_{f,x,z}$ is the fishing mortality in fishery f on crab in size bin z by sex (x), $F_{.,x,z} = \sum_f F_{f,x,z}$ is the total fishing mortality by sex on crab in size bin z, $w_{x,z}$ is the mean weight of crab in size bin z by sex, M_x is the sex-specific rate of natural mortality, δt is the time from July 1 to the time of the fishery (0.625 yr), and $N_{x,z}$ is the numbers by sex in size bin z on July 1, 2024 as estimated by the assessment model. The OFL for 2024/25 from the author's preferred model (22.03d5) is 41.29 thousand t (Figure 152).

The B_{MSY} proxy, $B_{35\%}$, from the author's preferred model is 40.01 thousand t , so $MSST = 0.5 \cdot B_{MSY} = 20.00$ thousand t. Because the current $B = 88.21$ thousand t > MSST, **the stock is not overfished**. Because the projected $B = 56.06$ thousand t $> B_{MSY}$, the stock falls into Tier 3a. The population state (directed F vs. MMB) is plotted starting in in Figure 153 against the Tier 3 harvest control rule.

7.2 ABC calculation

Amendments 38 and 39 to the Fishery Management Plan (NPFMC 2011) established methods for the Council to set Annual Catch Limits (ACLs). The Magnuson-Stevens Act requires that ACLs be established based upon an ABC control rule that accounts for scientific uncertainty in the OFL such that ACL=ABC and the TAC be set below the ABC so as not to exceed the ACL. ABCs must be recommended annually by the Council's SSC.

Two methods for establishing the ABC control rule are: 1) a constant buffer where the ABC is set by applying a multiplier to the OFL to meet a specified buffer below the OFL; and 2) a variable buffer where the ABC is set based on a specified percentile (P^*) of the distribution of the OFL that accounts for uncertainty in the OFL. P^* is the probability that ABC would exceed the OFL and overfishing occur. In 2010, the NPFMC prescribed that maximum ABCs for BSAI crab stocks be established at P^*=0.49. Thus, annual ACL=ABC levels should be established such that the risk of ovefishing, P[ABC>OFL], is 49%. For this assessment, the model-based uncertainty in the OFL was obtained using ADMB's sd_report functionality, which provides standard errors for derived quantities like the OFL based on the "delta method", which approximates the likelihood surface at the MLE as multivariate normal using the estimated parameter covariance matrix. In 2014, however, the SSC adopted a buffer of 20% on OFL for the Tanner crab stock for calculating ABC that included consideration of additional uncertainty in the stock assessment. Here, ABCs are provided based on both methods.

For the author's preferred model, 22.03d5, the P^* ABC (ABC_{max}) is 41.23 thousand t while the 20% Buffer ABC is 33.03 thousand t (Figure 152). The author remains concerned that the OFL calculation, based on $F_{35\%}$ as a proxy for F_{MSY}, is overly optimistic regarding the actual productivity of the stock. Fishery-related mortality similar to the P^* ABC level has occurred only in the latter half of the 1970s and in 1992/93, coincident with collapses in stock biomass to low levels. This suggests that $F_{35\%}$ may not be a realistic proxy for F_{MSY} and/or that MMB may not be a good proxy for reproductive success, as are currently assumed for this stock. In addition, the estimates of survey catchability for this stock remain problematic and contribute to this year's inflated OFL despite a continued decline in survey biomass across the last few years. Furthermore, the model appears overly-optimistic in terms of recent scale and trends. However, these concerns are not new and are reflected in the previous ABC buffer. Given this, the author recommends using the 20% buffer previously adopted by the SSC for this stock to to calculate the ABC. Consequently, **the author's recommended ABC is 33.03 thousand t**.

The following tables summarize the OFL/ABC results for model 22.03d5 (repeating Tables A and B for convenience):

Management quantities (in 1,000s t) based on the author's preferred model, 22.03d5, and recommended ABC buffer (20%). TAC is summed across ADF&G management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	17.97	56.34	1.07	0.66	0.96	21.13	16.90
2021/22	17.37	62.05	0.50	0.49	0.78	27.17	21.74
2022/23	18.19	74.17	0.91	0.91	1.19	32.81	26.25
2023/24	20.00	88.21	0.94	0.94	1.09	36.20	27.15
2024/25	NA	56.06	NA	NA	NA	41.29	33.03

Management quantities (in millions of pounds) based on the author's preferred model, 22.03d5, and recommended ABC buffer (20%). TAC is summed across ADF&G management areas.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	39.61	124.19	2.35	1.44	2.11	46.58	37.26
2021/22	38.29	136.79	1.10	1.09	1.73	59.89	47.91
2022/23	40.11	163.62	2.02	NA	NA	72.34	54.25
2023/24	44.10	194.46	2.08	2.07	2.39	79.82	59.86
2024/25	NA	123.59	NA	NA	NA	91.03	72.82

7.3 Projections

Multi-year projections were made under assumptions of fishing at 0, 0.25, 0.5, 0.75, 1, and 1.25 times the directed fishery F_{OFL} ($= F_{MSY}$ in this case for the models considered) for the preferred model (Figure 154). A total of 500 replicate projections of 20 years were made for each F_{OFL} multiplier. Each projection started at the final population state of the MLE and advanced in time under recruitments that were randomly resampled from the model-estimated recruitment time series for 1982 to 2023 (consistent with the time period to determine average recruitment for the OFL calculation). Characteristics for the fisheries were the same as those used to determine the OFL. The projections did not include any management feedback (e.g., F_{OFL} was not recalculated each year)–which would be appropriate in a management strategy evaluation (MSE) context.

For a given fishing mortality scenario, the projections follow very similar trajectories in the first 5 years before eventually diverging substantially starting around 2028, but the patterns are fairly different across scenarios (Figure 154). With no directed fishing, MMB is projected to increase relatively rapidly until 2028 as the strong recruitment events estimated in 2021 and 2022 grow to maturity, after which individual trajectories diverge substantially (but with the result that the mean MMB across trajectories in any year after 2040 is essentially the unfished value, B_{100}). For any of the non-zero directed F scenarios, MMB decreases initially as fishery-vulnerable larger crab in the terminal year are fished out before the 2021 and 2022 "cohorts" start to grow into the fishery-vulnerable size range. As with the zero-F scenario, individual trajectories in these scenarios begin to diverge in 2028 and reach stochastic equilibrium by about 2040.

8 Tier 4 “fall back” model

8.1 Introduction

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

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

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

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

For the Tier 3 stocks, the “simpler” crab modeling working group recommended using the mean of a smoothed time series for “vulnerable” male crab survey biomass as a very simple B_{MSY} proxy for fallback Tier 4 models, although it also supported authors bringing forward slightly more complex models that captured growth and mortality between the times of the survey and fishery (Anonymous 2023 pp. 4–5). At the May 2023 CPT meeting, the author presented a “slightly more complex” Tier 4 model for Tanner crab that incorporated natural mortality, recruitment, and fishing mortality into estimates of survey-based MMB-at-mating as the currency for the B_{MSY} proxy (Stockhausen 2023c). However, the SSC did not see the need for the additional complexity in a “fallback” model and requested that the author follow the working group’s simpler B_{MSY} proxy recommendation

(SSC 2023 p. 12). It also requested that authors base the averaging period "on the whole time series or develop justification for a better time block that represents current fishing potential for the stock" (SSC 2023 p. 7). For Tanner crab specifically, the SSC further requested that "a clear justification for the choice of reference time period be provided in the September SAFE document, beyond simple precedent, and that several alternative time periods be considered (each with its own justification)" (SSC 2023 p. 12).

Here, fallback Tier 4 management quantities are calculated for the eastern Bering Sea Tanner crab stock using the approach requested by the SSC. First, a time series of "vulnerable" male biomass (VMB) is calculated using data from the NMFS Bering Sea shelf bottom trawl survey, to which a state-space random walk model is applied to reduce observation error and interannual variance (process error). Current B is taken as the estimate of VMB for 2024 from the random walk model. Then B_{MSY} proxies are calculated for several candidate time periods by averaging the random walk time series values over each time period. Finally, other management quantities (e.g., stock status, F_{OFL}, OFL) are calculated based on the Tier 4 rules noted above.

8.2 Vulnerable male biomass time series

A time series of observed survey biomass for male crab classified as "vulnerable" to capture by the directed and bycatch fisheries for Tanner crab was calculated from the annual NMFS EBS shelf bottom trawl survey for 1975-2024 (the survey was not conducted in 2020) using standard methods for design-based biomass indices (Wakabayashi et al. 1985), where male crab greater than 100 mm CW were classified as vulnerable to fishing gear (Table 103; Figure 155). The observed VMB time series is rather noisy; to reduce variability associated with survey sampling error, a state-space/random effects random walk model was fit to the observed time series using the *rema* R package (Sullivan 2022) (Table 103; Figure 155). The model provided an estimate of 31,153 t for current B, as well as the values to average to obtain the B_{MSY} proxy.

8.3 Tier 4 Management Quantities

Candidate values for the Tier 4 management quantities, dependent on the time block chosen for the B_{MSY} proxy, were calculated for the time periods listed in Table 104.

For the time blocks considered, the B_{MSY} proxy ranges from 42 to 111 thousand t (see Figure 156 also). Stock status ranges from 0.28 (Tier b, "overfished") to 0.75 (Tier b, "not overfished"). F_{OFL} and OFL cannot be determined from the control rule when the stock is in level "c" (status < 0.25): in this case, directed fishing is prohibited and an $F_{OFL} \leq F_{MSY}$ would be determined based on all other sources of mortality in the development of the rebuilding plan. However, none of the alternative time frames result in a stock status classification of "c". The maximum F_{OFL} and OFL are 0.16 and 4.735 thousand t, respectively. Under two of the time frames, the stock would be considered "overfished" (status < 0.5).

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

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

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

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

The two time blocks that include the 1975-1980 time period are not recommended because this period encompasses a dramatic decline in VMB over the time period and thus does not appear to reflect the "current fishing potential" of the stock. In addition, the different selectivity/catchability characteristics in the pre- and post-1982 survey gear introduce potential inconsistencies across the time series. The author does not see a strong argument for any of the remaining time periods because none appear to meet the criteria outlined above for the Tier 4 $B_{MSY_{proxy}}$. Consequently, the author recommends using the OFL derived using the SSC-default period 1982-present, which results in an OFL of 4.74 thousand t.

The SSC requested that authors recommend a suitable buffer to apply to the OFL to obtain the ABC. The cv for the estimated B (0.097) provides a natural starting point to define an ABC buffer. After review of the suggestions made at the September 2023 CPT meeting, the CPT recommended, and the SSC accepted, that authors use the cv for the estimated B, rounded to the nearest 0.05 increment (i.e., 5%), as the minimum buffer prior to evaluating any additional concerns. Taking the latter approach, the minimum buffer for ABC would be 10% and the ABC would be 4.27 thousand t.

9 Rebuilding Analyses

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

10 Data Gaps and Research Priorities

A GMACS version of the Tanner crab model is under development. This is considered the highest priority topic for this assessment. Several models were reviewed at the May 2024 Crab Plan Team meeting (CPT 2024), but the CPT requested a more "one-to-one" comparison between the bespoke TCSAM02 model and a new GMACS model prior to adopting any GMACS model. This "one-to-one" comparison will be presented at the January Modeling workshop and May 2025 CPT meeting.

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

The characterization of fisheries in the assessment model also needs to be carefully reconsidered. How, and whether or not, the differences in the directed fishery in areas east and west 166^oW longitude should be explicitly represented in the assessment model need to be addressed. This is particularly relevant because the eastern management area was closed for several years until recently, which has implications for selectivity time blocks and 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 also 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. BSFRF has provided the 2018 survey data to the assessment author and analysis is underway.

11 Ecosystem Considerations

NOTE: With adoption of a Risk Table analysis as the basis for setting the ABC buffer, the information provided in this section will be redundant to that in the Risk Table section. Consequently, this section will be dropped in future assessment documents.

Mature male biomass is currently used as the “currency” of Tanner crab spawning biomass for assessment purposes. However, its relationship to stock-level rates of egg production, a better measure of stock-level reproductive capacity, is unclear. Thus, use of MMB to reflect Tanner crab reproductive potential may be misleading as to stock health. Nor is it likely that mature female biomass has a clear relationship to annual egg production. For Tanner crab, the fraction of barren mature females by shell condition appears to vary at decadal time scales (Rugolo and Turnock 2012a), suggesting a climatic driver.

11.1 Ecosystem Effects on Stock

Time series trends in prey availability or abundance are generally unknown for Tanner crab because typical survey gear is not quantitative for Tanner crab prey. On the other hand, Pacific cod (*Gadus macrocephalus*) is thought to account for a substantial fraction of annual mortality on Tanner crab (Aydin et al. 2007). Pacific cod spawning biomass is estimated to have increased rapidly in the early 1980s, concomitant with a period of rapid decline in Tanner crab biomass (modeled as a period of high but unexplained natural mortality in the assessment). Subsequently, Pacific cod spawning biomass declined rapidly in the late 1980s and early 1990s. At the same time, the Tanner crab stock first increased in the late 1980s but then decreased in the early 1990s, possibly lagging the continued decline in Pacific cod spawning biomass by a year or two. After 1993, Pacific cod spawning biomass continued a very gradual decline until 2010, after which it has been increasing fairly rapidly (Thompson and Siddon 2020). However, Tanner crab biomass began to increase in 2000, reached a relative peak in 2008, and has fluctuated since then. It is not immediately apparent that trends in Pacific cod spawning biomass have a direct effect on Tanner crab biomass.

11.2 Effects of Tanner crab fishery on ecosystem

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

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

12 Information for PSC Limits

Table 105 lists Tanner crab total abundance (in millions of crab) in the NMFS EBS shelf survey using design-based expansion of the abundance of all Tanner crab in the survey, as well as survey abundance estimated by the author's preferred model, 22.03d5. The model only considers crab larger than 25 mm CW in its estimation process (and thus included in the table), while all Tanner crab caught in the survey are included in the survey-estimated abundance in this table. The NMFS Alaska Regional Office will use this information when determining Prohibited Species Catch (PSC) limits.

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Tables

List of Tables

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

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

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

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

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

	TCF		SCF	RKF	all
year	East 166W	West 166W	West 166W	East 166W	all EBS
2005/06	0.0	244.5	187.7	0.0	432.2
2006/07	631.2	155.5	171.4	4.6	962.8
2007/08	710.0	151.1	86.5	8.0	955.6
2008/09	806.9	47.2	2.5	23.2	879.8
2009/10	592.4	0.0	1.7	8.4	602.5
2010/11	0.0	0.0	1.2	0.0	1.2
2011/12	0.0	0.0	2.1	0.0	2.1
2012/13	0.0	0.0	1.1	0.0	1.1
2013/14	654.3	593.6	9.9	6.3	1,264.1
2014/15	3,829.3	2,368.7	14.5	3.8	6,216.2
2015/16	5,107.7	3,770.3	30.3	1.4	8,909.6
2016/17	0.0	0.0	1.2	0.0	1.2
2017/18	0.1	1,117.5	15.0	0.0	1,132.6
2018/19	0.0	1,103.9	3.4	0.0	1,107.3
2019/20	0.0	0.0	0.1	0.0	0.1
2020/21	0.0	655.2	2.3	0.0	657.5
2021/22	0.0	493.5	0.8	0.0	494.3
2022/23	528.4	384.9	0.0	0.0	913.3
2023/24	343.5	596.8	0.0	0.0	940.3

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

	TCF		SCF	RKF	all
year	East 166W	West 166W	West 166W	East 166W	all EBS
2005/06	0	255,859	188,118	0	443,977
2006/07	581,024	164,719	175,904	4,456	926,103
2007/08	677,661	151,525	90,148	7,830	927,164
2008/09	758,002	48,171	3,300	20,896	830,369
2009/10	476,668	0	2,544	6,751	485,963
2010/11	0	0	1,689	6	1,695
2011/12	0	0	3,095	0	3,095
2012/13	0	0	1,643	4	1,647
2013/14	704,201	722,469	13,256	5,842	1,445,768
2014/15	4,378,199	3,121,442	19,512	3,691	7,522,844
2015/16	5,998,876	4,817,144	39,012	1,386	10,856,418
2016/17	0	0	1,733	33	1,766
2017/18	139	1,322,542	17,688	25	1,340,394
2018/19	0	1,376,977	4,013	18	1,381,008
2019/20	0	0	125	0	125
2020/21	0	870,634	3,017	1	873,652
2021/22	0	782,983	970	0	783,953
2022/23	683,223	587,079	0	0	1,270,302
2023/24	404,036	814,417	0	4	1,218,457

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

	OFL	ABC	TAC			Harvest	
year	all EBS	all EBS	all EBS	East 166W	West 166W	East 166W	West 166W
2005/06	–	–	735	–	735	–	245
2006/07	–	–	1,347	850	496	631	156
2007/08	–	–	2,550	1,563	987	710	151
2008/09	7,040	–	1,950	1,253	697	807	47
2009/10	2,270	–	612	612	–	592	–
2010/11	1,610	–	–	–	–	–	–
2011/12	2,750	2,480	–	–	–	–	–
2012/13	19,020	8,170	–	–	–	–	–
2013/14	25,350	17,820	1,410	664	746	654	594
2014/15	31,480	25,180	6,852	3,846	3,005	3,829	2,369
2015/16	27,190	21,750	8,921	5,113	3,808	5,108	3,770
2016/17	25,610	20,490	–	–	–	–	–
2017/18	25,420	20,330	1,134	–	1,134	–	1,117
2018/19	20,870	16,700	1,106	–	1,106	–	1,104
2019/20	28,860	23,090	–	–	–	–	–
2020/21	21,130	16,900	1,065	–	1,065	–	655
2021/22	27,170	21,740	499	–	499	–	494
2022/23	32,810	26,250	913	528	386	528	384
2023/24	36,200	27,150	943	345	599	344	597

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

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1980/81	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,840	85.1	1,470	10.6	13,310	95.7
1981/82	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	10,386	74.6	925	6.6	11,311	81.3
1982/83	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	9,540	68.6	3,979	28.6	13,519	97.2
1983/84	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	679	4.9	996	7.2	1,675	12.0
1984/85	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	1,649	11.9	893	6.4	2,542	18.3
1985/86	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1986/87	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1987/88	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
1988/89	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,277	81.0	1,103	7.9	12,380	89.0
1989/90	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	34,184	190.1	1,772	9.9	35,956	200.0
1990/91	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	78,310	187.4	5,280	12.6	83,590	200.0
1991/92	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	118,583	186.4	8,644	13.6	127,227	200.0
1992/93	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	113,509	181.0	11,886	19.0	125,395	200.0
1993/94	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	67,264	187.8	4,358	12.2	71,622	200.0
1994/95	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	25,585	183.9	2,073	14.9	27,658	198.8
1995/96	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	11,297	81.2	7,979	57.3	19,276	138.5
1996/97	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	2,063	14.8	2,367	17.0	4,430	31.8
2005/06	– –	– –	– –	– –	– –	– –	649	4.7	56	0.4	705	5.1	649	4.7	56	0.4	705	5.1
2006/07	815	5.9	1,544	11.1	2,359	17.0	238	1.7	343	2.5	581	4.2	1,053	7.6	1,887	13.6	2,940	21.1
2007/08	2,730	19.6	1,439	10.3	4,169	30.0	932	6.7	726	5.2	1,658	11.9	3,662	26.3	2,165	15.6	5,827	41.9
2008/09	2,717	19.5	252	1.8	2,969	21.3	429	3.1	92	0.7	521	3.7	3,146	22.6	344	2.5	3,490	25.1
2009/10	2,369	17.0	48	0.3	2,417	17.4	– –	– –	– –	– –	– –	– –	2,369	17.0	48	0.3	2,417	17.4
2010/11	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2011/12	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2012/13	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2013/14	2,250	16.2	274	2.0	2,524	18.1	1,869	13.4	368	2.6	2,237	16.1	4,119	29.6	642	4.6	4,761	34.2
2014/15	6,278	45.1	1,274	9.2	7,552	54.3	5,012	36.0	1,807	13.0	6,819	49.0	11,290	81.1	3,081	22.1	14,371	103.3
2015/16	11,066	79.5	4,159	29.9	15,225	109.4	7,364	52.9	1,731	12.4	9,095	65.4	18,430	132.5	5,890	42.3	24,320	174.8
2016/17	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2017/18	– –	– –	– –	– –	– –	– –	1,980	14.2	1,490	10.7	3,470	24.9	1,980	14.2	1,490	10.7	3,470	24.9
2018/19	– –	– –	– –	– –	– –	– –	879	6.3	2,427	17.4	3,306	23.8	879	6.3	2,427	17.4	3,306	23.8
2019/20	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2020/21	– –	– –	– –	– –	– –	– –	1,378	9.9	1,945	14.0	3,323	23.9	1,378	9.9	1,945	14.0	3,323	23.9
2021/22	– –	– –	– –	– –	– –	– –	1,993	14.3	351	2.5	2,344	16.8	1,993	14.3	351	2.5	2,344	16.8
2022/23	2,073	14.9	258	1.9	2,331	16.8	2,059	14.8	348	2.5	2,407	17.3	4,132	29.7	606	4.4	4,738	34.1
2023/24	1,478	10.6	149	1.1	1,627	11.7	2,505	18.0	389	2.8	2,894	20.8	3,983	28.6	538	3.9	4,521	32.5

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

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

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

	TCF				SCF		RKF				GF	all fleets
	crab pot				crab pot		crab pot		fixed	trawl	all gear	all gear
	East 166W		West 166W		West 166W		East 166W		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	7,082	105	3,723	36	–	–	943	11,889
1991/92	19,597	1,445	6,220	441	8,361	144	1,970	27	148	2,395	–	40,748
1992/93	29,660	1,104	7,347	599	2,488	162	1,316	19	103	2,657	–	45,455
1993/94	10,210	860	1,644	136	2,874	401	3,130	149	23	1,735	–	21,162
1994/95	6,958	729	357	112	1,345	194	–	–	24	2,072	–	11,791
1995/96	4,415	925	650	141	1,021	121	–	–	128	1,397	–	8,798
1996/97	229	56	72	–	1,960	119	270	2	118	1,477	–	4,303
1997/98	–	–	–	–	1,964	93	160	2	64	1,116	–	3,399
1998/99	–	–	–	–	656	80	115	2	88	847	–	1,788
1999/00	–	–	–	–	132	11	75	3	85	546	–	852
2000/01	–	–	–	–	313	6	66	2	53	688	–	1,128
2001/02	–	–	–	–	546	21	42	1	125	1,061	–	1,796
2002/03	–	–	–	–	167	13	61	1	96	624	–	962
2003/04	–	–	–	–	65	7	55	2	20	403	–	552
2004/05	–	–	–	–	134	40	49	2	65	610	–	900
2005/06	–	–	684	24	1,162	16	42	0	133	488	–	2,549
2006/07	1,132	49	579	73	1,527	86	30	2	346	371	–	4,195
2007/08	1,779	30	680	15	1,862	52	61	2	474	221	–	5,176
2008/09	1,178	7	119	1	1,100	25	280	3	288	245	–	3,246
2009/10	664	2	–	–	1,559	15	187	1	225	149	–	2,802
2010/11	–	–	–	–	1,453	9	32	0	118	113	–	1,725
2011/12	–	–	–	–	2,142	13	17	0	76	128	–	2,376
2012/13	–	–	–	–	1,564	10	42	1	46	107	–	1,770
2013/14	746	12	933	11	1,841	16	129	1	182	167	–	4,038
2014/15	5,307	9	3,057	30	5,330	51	305	1	261	174	–	14,525
2015/16	6,761	29	5,468	29	3,919	17	205	6	276	85	–	16,795

(continued)

			TCF		SCF		RKF				GF	all fleets
			crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	East 166W		West 166W		West 166W		East 166W		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2016/17	–	–	–	–	2,576	17	176	4	161	145	–	3,079
2017/18	–	–	1,363	38	1,081	6	183	2	114	50	–	2,837
2018/19	–	–	1,598	34	880	9	74	0	122	57	–	2,774
2019/20	–	–	–	–	1,003	15	18	0	45	103	–	1,184
2020/21	–	–	1,548	33	131	0	6	0	23	102	–	1,843
2021/22	–	–	826	16	82	2	0	0	53	112	–	1,091
2022/23	794	7	677	5	–	–	0	0	26	101	–	1,610
2023/24	416	2	727	4	–	–	10	0	9	88	–	1,256

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

				TCF		SCF		RKF			GF	all fleets
				crab pot		crab pot		crab pot	fixed	trawl	all gear	all gear
		East 166W		West 166W		West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	11,947	629	3,470	144	–	–	4,522	20,712
1991/92	25,791	5,612	8,211	2,001	13,995	752	1,954	95	356	5,756	–	64,523
1992/93	40,385	5,245	10,336	2,719	5,823	884	1,475	76	236	6,109	–	73,288
1993/94	13,438	3,430	2,347	634	6,841	2,315	3,404	567	49	3,595	–	36,620
1994/95	8,907	3,276	666	567	3,513	1,289	–	–	53	4,616	–	22,887
1995/96	6,084	4,058	1,094	684	2,422	727	–	–	312	3,405	–	18,786
1996/97	328	237	102	–	3,916	660	259	9	268	3,357	–	9,136
1997/98	–	–	–	–	3,697	537	164	6	183	3,202	–	7,789
1998/99	–	–	–	–	1,425	435	132	7	275	2,649	–	4,923
1999/00	–	–	–	–	337	62	111	8	222	1,432	–	2,172
2000/01	–	–	–	–	641	27	93	5	127	1,646	–	2,539
2001/02	–	–	–	–	1,196	118	56	4	249	2,118	–	3,741
2002/03	–	–	–	–	408	72	83	6	171	1,117	–	1,857
2003/04	–	–	–	–	172	47	82	7	53	1,038	–	1,399
2004/05	–	–	–	–	420	256	77	7	169	1,591	–	2,520
2005/06	–	–	1,004	113	2,182	90	62	4	285	1,046	–	4,786
2006/07	1,503	187	849	345	2,696	429	46	5	663	711	–	7,434
2007/08	2,682	121	1,060	72	3,642	263	81	5	1,349	627	–	9,902
2008/09	1,378	28	168	8	2,364	169	289	9	731	624	–	5,768
2009/10	622	9	–	–	3,035	97	176	4	381	455	–	4,779
2010/11	–	–	–	–	2,677	49	41	2	167	390	–	3,326
2011/12	–	–	–	–	3,633	73	21	0	105	918	–	4,750
2012/13	–	–	–	–	2,790	63	54	4	69	501	–	3,481
2013/14	898	43	1,343	51	3,641	91	148	4	302	689	–	7,210
2014/15	7,570	37	4,998	133	10,716	296	346	3	414	591	–	25,104
2015/16	10,265	120	9,441	149	7,456	88	256	22	470	249	–	28,516

(continued)

			TCF		SCF		RKF				GF	all fleets
			crab pot		crab pot		crab pot		fixed	trawl	all gear	all gear
	East 166W		West 166W		West 166W		East 166W		all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2016/17	–	–	–	–	4,900	79	252	20	269	428	–	5,948
2017/18	–	–	1,979	181	1,994	39	232	5	178	126	–	4,734
2018/19	–	–	2,562	184	1,621	62	88	0	162	220	–	4,899
2019/20	–	–	–	–	1,989	95	21	0	65	453	–	2,623
2020/21	–	–	2,851	170	289	4	8	0	42	515	–	3,879
2021/22	–	–	1,568	82	183	9	0	0	93	465	–	2,400
2022/23	1,329	37	1,280	29	–	–	0	0	53	503	–	3,231
2023/24	556	8	1,160	20	–	–	13	0	18	540	–	2,315

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

year	GF all gear all EBS all sexes
1973/74	14,188
1974/75	19,559
1975/76	7,526
1976/77	3,759
1977/78	2,221
1978/79	1,495
1979/80	2,718
1980/81	1,691
1981/82	1,179
1982/83	359
1983/84	537
1984/85	515
1985/86	319
1986/87	519
1987/88	512
1988/89	370
1989/90	537

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

	East 166W		West 166W		TCF crab pot all EBS		SCF crab pot West 166W		RKF crab pot East 166W		fixed all EBS	trawl all EBS	GF all gear all EBS	all fleets all gear all EBS
year	male	female	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
1990/91	–	–	–	–	–	–	2,273	34	1,195	11	–	–	755	4,268
1991/92	–	–	–	–	3,657	605	2,684	46	632	9	74	1,916	–	9,624
1992/93	–	–	–	–	6,769	547	798	52	423	6	51	2,126	–	10,772
1993/94	–	–	–	–	1,344	320	923	128	1,005	48	12	1,388	–	5,168
1994/95	–	–	–	–	1,212	270	432	62	–	–	12	1,658	–	3,646
1995/96	–	–	–	–	1,010	342	328	39	–	–	64	1,118	–	2,900
1996/97	–	–	–	–	–	18	629	38	87	1	59	1,181	–	2,014
1997/98	–	–	–	–	–	–	630	30	51	0	32	893	–	1,637
1998/99	–	–	–	–	–	–	211	26	37	0	44	678	–	996
1999/00	–	–	–	–	–	–	42	4	24	1	42	437	–	550
2000/01	–	–	–	–	–	–	100	2	21	0	27	551	–	701
2001/02	–	–	–	–	–	–	175	7	14	0	62	848	–	1,106
2002/03	–	–	–	–	–	–	54	4	20	0	48	499	–	625
2003/04	–	–	–	–	–	–	21	2	18	1	10	323	–	374
2004/05	–	–	–	–	–	–	43	13	16	0	32	488	–	593
2005/06	–	–	141	8	–	–	313	5	13	0	66	390	–	938
2006/07	161	16	136	23	–	–	435	28	8	0	173	297	–	1,277
2007/08	343	9	170	5	–	–	570	17	17	0	237	176	–	1,545
2008/09	119	2	23	0	–	–	352	8	82	1	144	196	–	928
2009/10	23	1	–	–	–	–	500	5	57	0	113	119	–	818
2010/11	–	–	–	–	–	–	466	3	10	0	59	91	–	629
2011/12	–	–	–	–	–	–	687	4	6	–	38	102	–	837
2012/13	–	–	–	–	–	–	502	3	14	0	23	86	–	628
2013/14	30	4	109	4	–	–	588	5	39	0	91	134	–	1,003
2014/15	474	3	221	10	–	–	1,706	16	97	0	131	140	–	2,798
2015/16	531	9	545	9	–	–	1,248	5	65	2	138	68	–	2,621

(continued)

						TCF		SCF		RKF			GF	all fleets
						crab pot		crab pot		crab pot	fixed	trawl	all gear	all gear
	East 166W		West 166W			all EBS		West 166W		East 166W	all EBS	all EBS	all EBS	all EBS
year	male	female	male	female	male	female	male	female	male	female	all sexes	all sexes	all sexes	all sexes
2016/17	–	–	–	–	–	–	826	5	56	1	80	116	–	1,086
2017/18	–	–	79	12	–	–	342	2	59	0	57	40	–	592
2018/19	–	–	159	11	–	–	281	3	24	–	61	45	–	584
2019/20	–	–	–	–	–	–	322	5	6	–	22	82	–	437
2020/21	–	–	286	11	–	–	41	0	2	–	12	81	–	433
2021/22	–	–	107	5	–	–	26	0	–	–	26	90	–	255
2022/23	85	2	94	2	–	–	–	–	–	–	13	81	–	277
2023/24	23	1	42	1	–	–	–	–	3	–	5	70	–	145

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

	East 166W						West 166W						all EBS					
	male		female		all sexes		male		female		all sexes		male		female		all sexes	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1990/91	– –	– –	– –	– –	– –	– –	51	0.4	34	0.2	85	0.6	51	0.4	34	0.2	85	0.6
1991/92	21,600	155.2	3,935	28.3	25,535	183.5	9,652	69.4	1,670	12.0	11,322	81.4	31,252	169.6	5,605	30.4	36,857	200.0
1992/93	42,260	176.2	5,707	23.8	47,967	200.0	12,576	90.4	3,048	21.9	15,624	112.3	54,836	172.5	8,755	27.5	63,591	200.0
1993/94	36,062	158.6	9,417	41.4	45,479	200.0	4,326	31.1	1,054	7.6	5,380	38.7	40,388	158.8	10,471	41.2	50,859	200.0
1994/95	5,657	40.7	2,004	14.4	7,661	55.1	135	1.0	128	0.9	263	1.9	5,792	41.6	2,132	15.3	7,924	56.9
1995/96	5,180	37.2	2,914	20.9	8,094	58.2	409	2.9	205	1.5	614	4.4	5,589	40.2	3,119	22.4	8,708	62.6
1996/97	219	1.6	168	1.2	387	2.8	133	1.0	– –	– –	133	1.0	352	2.5	168	1.2	520	3.7
2005/06	– –	– –	– –	– –	– –	– –	19,715	141.7	1,107	8.0	20,822	149.6	19,715	141.7	1,107	8.0	20,822	149.6
2006/07	12,688	91.2	1,573	11.3	14,261	102.5	11,538	82.9	2,859	20.5	14,397	103.5	24,226	169.1	4,432	30.9	28,658	200.0
2007/08	51,105	191.0	2,415	9.0	53,520	200.0	10,441	75.0	903	6.5	11,344	81.5	61,546	189.8	3,318	10.2	64,864	200.0
2008/09	25,352	182.2	528	3.8	25,880	186.0	3,814	27.4	118	0.8	3,932	28.3	29,166	195.7	646	4.3	29,812	200.0
2009/10	17,289	124.3	147	1.1	17,436	125.3	– –	– –	– –	– –	– –	– –	17,289	124.3	147	1.1	17,436	125.3
2010/11	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2011/12	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2012/13	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2013/14	7,628	54.8	311	2.2	7,939	57.1	9,663	69.4	399	2.9	10,062	72.3	17,291	124.3	710	5.1	18,001	129.4
2014/15	51,217	198.9	286	1.1	51,503	200.0	33,903	194.8	905	5.2	34,808	200.0	85,120	197.2	1,191	2.8	86,311	200.0
2015/16	61,712	197.7	713	2.3	62,425	200.0	58,131	196.9	911	3.1	59,042	200.0	119,843	197.3	1,624	2.7	121,467	200.0
2016/17	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2017/18	– –	– –	– –	– –	– –	– –	18,785	135.0	1,721	12.4	20,506	147.4	18,785	135.0	1,721	12.4	20,506	147.4
2018/19	– –	– –	– –	– –	– –	– –	28,338	186.6	2,036	13.4	30,374	200.0	28,338	186.6	2,036	13.4	30,374	200.0
2019/20	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2020/21	– –	– –	– –	– –	– –	– –	17,639	126.8	1,054	7.6	18,693	134.3	17,639	126.8	1,054	7.6	18,693	134.3
2021/22	– –	– –	– –	– –	– –	– –	19,214	138.1	1,008	7.2	20,222	145.3	19,214	138.1	1,008	7.2	20,222	145.3
2022/23	13,404	96.3	377	2.7	13,781	99.0	17,233	123.9	390	2.8	17,623	126.7	30,637	195.1	767	4.9	31,404	200.0
2023/24	8,500	61.1	129	0.9	8,629	62.0	26,134	187.8	436	3.1	26,570	191.0	34,634	196.8	565	3.2	35,199	200.0

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

						SCF						RKF
						all EBS						all EBS
		male		female		all sexes		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1990/91	14,032	100.85	478	3.44	14,510	104.28	1,580	11.36	43	0.31	1,623	11.66
1991/92	11,708	84.14	686	4.93	12,394	89.07	2,273	16.34	89	0.64	2,362	16.98
1992/93	6,280	45.13	859	6.17	7,139	51.31	2,056	14.78	105	0.75	2,161	15.53
1993/94	6,969	50.09	1,542	11.08	8,511	61.17	7,359	52.89	1,196	8.60	8,555	61.48
1994/95	2,982	21.43	1,523	10.95	4,505	32.38	– –	– –	– –	– –	– –	– –
1995/96	1,898	13.64	428	3.08	2,326	16.72	– –	– –	– –	– –	– –	– –
1996/97	3,265	23.47	662	4.76	3,927	28.22	114	0.82	5	0.04	119	0.86
1997/98	3,970	28.53	657	4.72	4,627	33.25	1,030	7.40	41	0.29	1,071	7.70
1998/99	1,911	13.73	324	2.33	2,235	16.06	457	3.28	20	0.14	477	3.43
1999/00	976	7.01	82	0.59	1,058	7.60	207	1.49	14	0.10	221	1.59
2000/01	1,237	8.89	74	0.53	1,311	9.42	845	6.07	44	0.32	889	6.39
2001/02	3,113	22.37	160	1.15	3,273	23.52	456	3.28	39	0.28	495	3.56
2002/03	982	7.06	118	0.85	1,100	7.91	750	5.39	50	0.36	800	5.75
2003/04	688	4.94	152	1.09	840	6.04	555	3.99	46	0.33	601	4.32
2004/05	833	5.99	707	5.08	1,540	11.07	487	3.50	44	0.32	531	3.82
2005/06	9,807	70.48	368	2.64	10,175	73.13	983	7.06	70	0.50	1,053	7.57
2006/07	10,391	74.68	1,256	9.03	11,647	83.71	746	5.36	68	0.49	814	5.85
2007/08	13,797	99.16	728	5.23	14,525	104.39	1,360	9.77	89	0.64	1,449	10.41
2008/09	8,455	60.76	722	5.19	9,177	65.95	3,797	27.29	121	0.87	3,918	28.16
2009/10	11,057	79.46	474	3.41	11,531	82.87	2,871	20.63	70	0.50	2,941	21.14
2010/11	12,073	86.77	250	1.80	12,323	88.56	582	4.18	28	0.20	610	4.38
2011/12	9,453	67.94	189	1.36	9,642	69.30	323	2.32	4	0.03	327	2.35
2012/13	11,004	79.08	270	1.94	11,274	81.02	618	4.44	48	0.34	666	4.79
2013/14	12,935	92.96	356	2.56	13,291	95.52	2,110	15.16	60	0.43	2,170	15.60
2014/15	24,878	178.79	804	5.78	25,682	184.57	3,110	22.35	32	0.23	3,142	22.58
2015/16	19,839	142.58	230	1.65	20,069	144.23	2,175	15.63	186	1.34	2,361	16.97
2016/17	16,369	117.64	262	1.88	16,631	119.52	3,220	23.14	246	1.77	3,466	24.91
2017/18	5,598	40.23	109	0.78	5,707	41.02	3,782	27.18	86	0.62	3,868	27.80
2018/19	6,145	44.16	233	1.67	6,378	45.84	1,283	9.22	6	0.04	1,289	9.26
2019/20	8,881	63.83	423	3.04	9,304	66.87	357	2.57	3	0.02	360	2.59
2020/21	820	5.89	10	0.07	830	5.97	106	0.76	4	0.03	110	0.79
2021/22	632	4.54	30	0.22	662	4.76	– –	– –	– –	– –	– –	– –
2022/23	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2023/24	– –	– –	– –	– –	– –	– –	233	1.67	11	0.08	244	1.75

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

				fixed				trawl						all gear
		male		female		male		female		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
1973/74	– –	– –	– –	– –	– –	– –	– –	– –	3,155	22.7	2,277	16.4	5,432	39.0
1974/75	– –	– –	– –	– –	– –	– –	– –	– –	2,492	17.9	1,600	11.5	4,092	29.4
1975/76	– –	– –	– –	– –	– –	– –	– –	– –	1,251	9.0	839	6.0	2,090	15.0
1976/77	– –	– –	– –	– –	– –	– –	– –	– –	6,950	49.9	6,683	48.0	13,633	98.0
1977/78	– –	– –	– –	– –	– –	– –	– –	– –	10,685	76.8	8,386	60.3	19,071	137.1
1978/79	– –	– –	– –	– –	– –	– –	– –	– –	18,596	115.3	13,665	84.7	32,261	200.0
1979/80	– –	– –	– –	– –	– –	– –	– –	– –	19,060	125.4	11,349	74.6	30,409	200.0
1980/81	– –	– –	– –	– –	– –	– –	– –	– –	12,806	92.0	5,917	42.5	18,723	134.6
1981/82	– –	– –	– –	– –	– –	– –	– –	– –	6,098	43.8	4,065	29.2	10,163	73.0
1982/83	– –	– –	– –	– –	– –	– –	– –	– –	13,439	96.6	8,006	57.5	21,445	154.1
1983/84	– –	– –	– –	– –	– –	– –	– –	– –	18,363	132.0	8,305	59.7	26,668	191.7
1984/85	– –	– –	– –	– –	– –	– –	– –	– –	27,403	133.1	13,771	66.9	41,174	200.0
1985/86	– –	– –	– –	– –	– –	– –	– –	– –	23,128	129.0	12,728	71.0	35,856	200.0
1986/87	– –	– –	– –	– –	– –	– –	– –	– –	14,860	106.8	7,626	54.8	22,486	161.6
1987/88	– –	– –	– –	– –	– –	– –	– –	– –	23,508	119.4	15,857	80.6	39,365	200.0
1988/89	– –	– –	– –	– –	– –	– –	– –	– –	10,586	76.1	7,126	51.2	17,712	127.3
1989/90	– –	– –	– –	– –	– –	– –	– –	– –	59,943	118.5	41,234	81.5	101,177	200.0
1990/91	– –	– –	– –	– –	– –	– –	– –	– –	23,545	135.5	11,212	64.5	34,757	200.0
1991/92	1,116	8.0	290	2.1	5,701	41.0	3,189	22.9	– –	– –	– –	– –	10,296	74.0
1992/93	601	4.3	39	0.3	2,527	18.2	1,136	8.2	– –	– –	– –	– –	4,303	30.9
1993/94	683	4.9	25	0.2	534	3.8	333	2.4	– –	– –	– –	– –	1,575	11.3
1994/95	1,133	8.1	126	0.9	2,495	17.9	1,694	12.2	– –	– –	– –	– –	5,448	39.2
1995/96	162	1.2	44	0.3	3,742	26.9	2,625	18.9	– –	– –	– –	– –	6,573	47.2
1996/97	2,442	17.6	439	3.2	5,864	42.1	2,961	21.3	– –	– –	– –	– –	11,706	84.1
1997/98	1,650	11.9	217	1.6	8,299	59.6	3,683	26.5	– –	– –	– –	– –	13,849	99.5
1998/99	3,870	27.8	627	4.5	8,235	59.2	3,813	27.4	– –	– –	– –	– –	16,545	118.9
1999/00	3,553	25.5	719	5.2	7,500	53.9	3,803	27.3	– –	– –	– –	– –	15,575	111.9
2000/01	5,144	37.0	227	1.6	7,751	55.7	2,860	20.6	– –	– –	– –	– –	15,982	114.9
2001/02	6,950	49.9	303	2.2	8,838	63.5	2,780	20.0	– –	– –	– –	– –	18,871	135.6
2002/03	8,571	61.6	831	6.0	6,830	49.1	2,418	17.4	– –	– –	– –	– –	18,650	134.0
2003/04	4,589	33.0	923	6.6	4,983	35.8	1,810	13.0	– –	– –	– –	– –	12,305	88.4
2004/05	5,413	38.9	560	4.0	8,431	60.6	3,900	28.0	– –	– –	– –	– –	18,304	131.5
2005/06	8,816	63.4	389	2.8	8,969	64.5	3,320	23.9	– –	– –	– –	– –	21,494	154.5
2006/07	9,270	66.6	824	5.9	6,633	47.7	2,223	16.0	– –	– –	– –	– –	18,950	136.2
2007/08	7,235	52.0	1,175	8.4	8,913	64.1	2,644	19.0	– –	– –	– –	– –	19,967	143.5
2008/09	15,832	104.1	1,770	11.6	10,339	68.0	2,465	16.2	– –	– –	– –	– –	30,406	200.0
2009/10	12,916	92.8	688	4.9	6,127	44.0	2,013	14.5	– –	– –	– –	– –	21,744	156.3
2010/11	11,264	81.0	956	6.9	4,402	31.6	1,648	11.8	– –	– –	– –	– –	18,270	131.3
2011/12	8,709	62.6	386	2.8	7,650	55.0	3,877	27.9	– –	– –	– –	– –	20,622	148.2
2012/13	9,192	66.1	836	6.0	3,994	28.7	2,267	16.3	– –	– –	– –	– –	16,289	117.1
2013/14	22,471	128.4	3,489	19.9	6,437	36.8	2,592	14.8	– –	– –	– –	– –	34,989	200.0
2014/15	33,529	154.0	2,061	9.5	5,747	26.4	2,201	10.1	– –	– –	– –	– –	43,538	200.0
2015/16	24,488	146.3	5,152	30.8	3,215	19.2	629	3.8	– –	– –	– –	– –	33,484	200.0
2016/17	14,811	106.4	1,206	8.7	3,920	28.2	3,224	23.2	– –	– –	– –	– –	23,161	166.5

(continued)

				fixed				trawl						all gear
		male		female		male		female		male		female		all sexes
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
2017/18	11,546	83.0	1,264	9.1	2,035	14.6	477	3.4	– –	– –	– –	– –	15,322	110.1
2018/19	4,130	29.7	198	1.4	3,065	22.0	1,129	8.1	– –	– –	– –	– –	8,522	61.2
2019/20	2,573	18.5	140	1.0	5,363	38.5	2,457	17.7	– –	– –	– –	– –	10,533	75.7
2020/21	2,267	16.3	418	3.0	6,401	46.0	2,561	18.4	– –	– –	– –	– –	11,647	83.7
2021/22	3,427	24.6	460	3.3	5,244	37.7	1,801	12.9	– –	– –	– –	– –	10,932	78.6
2022/23	3,792	27.3	407	2.9	5,461	39.2	1,812	13.0	– –	– –	– –	– –	11,472	82.4
2023/24	613	4.4	81	0.6	2,279	16.4	712	5.1	– –	– –	– –	– –	3,685	26.5

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

year	East 166W	West 166W	TCF all EBS	SCF all EBS	RKF all EBS
1953	–	–	–	–	30,083
1954	–	–	–	–	17,122
1955	–	–	–	–	28,045
1956	–	–	–	–	41,629
1957	–	–	–	–	23,659
1958	–	–	–	–	27,932
1959	–	–	–	–	22,187
1960	–	–	–	–	26,347
1961	–	–	–	–	72,646
1962	–	–	–	–	123,643
1963	–	–	–	–	181,799
1964	–	–	–	–	180,809
1965	–	–	–	–	127,973
1966	–	–	–	–	129,306
1967	–	–	–	–	135,283
1968	–	–	–	–	184,666
1969	–	–	–	–	175,374
1970	–	–	–	–	168,059
1971	–	–	–	–	126,305
1972	–	–	–	–	208,469
1973	–	–	–	–	194,095
1974	–	–	–	–	212,915
1975	–	–	–	–	205,096
1976	–	–	–	–	321,010
1977	–	–	–	–	451,273
1978	–	–	–	190,746	406,165
1979	–	–	–	255,102	315,226
1980	–	–	–	435,742	567,292
1981	–	–	–	469,091	536,646
1982	–	–	–	287,127	140,492
1983	–	–	–	173,591	0
1984	–	–	–	370,082	107,406
1985	–	–	–	542,346	84,443
1986	–	–	–	616,113	175,753
1987	–	–	–	747,395	220,971
1988	–	–	–	665,242	146,179
1989	–	–	–	912,718	205,528
1990	493,820	479	494,299	1,382,908	262,761
1991	360,864	140,050	500,914	1,278,502	227,555
1992	508,922	166,670	675,592	969,209	206,815
1993	286,620	40,100	326,720	716,524	254,389
1994	228,254	21,282	249,536	507,603	697
1995	201,988	46,454	248,442	520,685	547

(continued)

year	East 166W	West 166W	TCF all EBS	SCF all EBS	RKF all EBS
1996	64,989	8,533	73,522	754,140	77,081
1997	0	0	0	930,794	91,085
1998	0	0	0	945,533	145,689
1999	0	0	0	182,634	151,212
2000	0	0	0	191,200	104,056
2001	0	0	0	326,977	66,947
2002	0	0	0	153,862	72,514
2003	0	0	0	123,709	134,515
2004	0	0	0	75,095	97,621
2005	0	6,346	6,346	117,375	116,320
2006	15,273	4,517	19,790	86,328	72,404
2007	26,441	7,268	33,709	140,857	113,948
2008	19,401	2,336	21,737	163,537	139,937
2009	6,635	0	6,635	137,292	119,261
2010	0	0	0	147,478	132,183
2011	0	0	0	270,602	45,784
2012	0	0	0	225,627	38,842
2013	16,613	23,062	39,675	225,245	46,589
2014	72,768	68,695	141,463	279,183	57,725
2015	130,302	84,933	215,235	202,526	48,763
2016	0	0	0	118,548	33,608
2017	11	19,284	19,295	114,673	49,169
2018	0	29,833	29,833	119,484	31,975
2019	0	0	0	188,958	35,033
2020	0	34,914	34,914	171,678	21,346
2021	0	19,252	19,252	36,878	294
2022	19,434	18,130	37,564	0	242
2023	6,336	22,861	29,197	0	15,694

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

					male												female	
					all maturity						immature						mature	
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	214,201	0.42	80,684	0.34	294,884	0.32	9,287	0.25	262	0.51	9,549	0.24	18,306	0.19	13,112	0.39	31,418	0.20
1976	101,952	0.18	55,066	0.20	157,018	0.14	4,448	0.26	1,920	0.57	6,368	0.25	20,967	0.20	10,189	0.42	31,157	0.19
1977	87,462	0.13	51,036	0.24	138,499	0.12	1,133	0.23	13,338	0.65	14,471	0.60	30,302	0.38	8,272	0.36	38,573	0.31
1978	72,913	0.15	25,392	0.18	98,305	0.12	714	0.29	6,099	0.27	6,814	0.24	17,691	0.31	8,062	0.26	25,753	0.23
1979	17,978	0.17	33,439	0.24	51,417	0.17	591	0.49	2,066	0.34	2,657	0.29	2,858	0.36	7,592	0.43	10,450	0.33
1980	48,978	0.31	103,501	0.18	152,479	0.16	1,320	0.26	12,190	0.25	13,510	0.23	11,562	0.38	52,221	0.33	63,783	0.28
1981	23,387	0.19	56,537	0.16	79,924	0.13	890	0.31	631	0.25	1,521	0.21	7,684	0.28	34,893	0.30	42,577	0.25
1982	16,600	0.16	49,252	0.18	65,852	0.14	1,309	0.34	406	0.27	1,715	0.27	6,797	0.26	57,347	0.29	64,143	0.26
1983	13,325	0.21	24,659	0.20	37,984	0.15	902	0.30	1,368	0.34	2,270	0.24	4,438	0.27	15,993	0.22	20,430	0.18
1984	12,019	0.19	18,483	0.17	30,503	0.13	670	0.46	1,563	0.23	2,233	0.21	4,129	0.44	10,785	0.26	14,914	0.22
1985	8,229	0.21	6,671	0.16	14,901	0.13	323	0.30	671	0.22	994	0.18	2,836	0.42	2,718	0.31	5,554	0.26
1986	9,611	0.22	11,983	0.36	21,594	0.22	1,486	0.21	1,207	0.28	2,693	0.17	2,006	0.25	1,360	0.31	3,366	0.20
1987	28,860	0.20	16,639	0.16	45,499	0.14	11,909	0.36	3,085	0.20	14,995	0.29	3,097	0.23	2,042	0.21	5,139	0.16
1988	58,124	0.31	41,083	0.24	99,207	0.21	3,697	0.22	6,475	0.24	10,172	0.17	19,182	0.30	6,184	0.26	25,366	0.23
1989	87,700	0.16	45,100	0.18	132,800	0.12	6,652	0.28	5,157	0.23	11,809	0.19	12,309	0.20	7,090	0.23	19,399	0.15
1990	76,879	0.14	55,538	0.23	132,417	0.13	5,990	0.28	3,869	0.20	9,859	0.19	19,032	0.24	18,663	0.48	37,694	0.27
1991	89,814	0.26	55,976	0.15	145,790	0.17	3,626	0.24	3,384	0.25	7,010	0.17	27,708	0.33	17,056	0.22	44,764	0.22
1992	89,918	0.32	37,665	0.18	127,582	0.23	345	0.29	1,636	0.19	1,981	0.17	11,013	0.22	15,213	0.23	26,226	0.16
1993	53,394	0.19	19,873	0.15	73,266	0.14	153	0.35	908	0.21	1,061	0.19	5,171	0.21	6,470	0.20	11,641	0.14
1994	32,303	0.16	16,029	0.14	48,332	0.12	65	0.33	1,135	0.34	1,199	0.33	5,268	0.30	4,579	0.28	9,846	0.21
1995	19,672	0.22	15,304	0.24	34,976	0.16	249	0.25	802	0.19	1,052	0.16	5,732	0.31	6,667	0.31	12,398	0.22
1996	19,979	0.28	10,785	0.31	30,764	0.21	1,013	0.28	416	0.21	1,430	0.21	5,533	0.36	4,047	0.45	9,580	0.28
1997	9,078	0.16	5,556	0.14	14,634	0.11	956	0.37	434	0.23	1,389	0.27	1,947	0.22	1,451	0.31	3,397	0.18
1998	8,403	0.13	6,600	0.16	15,003	0.10	550	0.21	1,407	0.25	1,957	0.19	1,202	0.21	1,076	0.24	2,278	0.16
1999	14,833	0.36	6,695	0.23	21,529	0.26	1,087	0.39	1,762	0.20	2,848	0.19	2,272	0.33	1,554	0.21	3,826	0.22
2000	16,427	0.27	6,898	0.14	23,325	0.20	728	0.30	1,745	0.18	2,473	0.15	2,885	0.39	1,246	0.25	4,131	0.28
2001	16,203	0.19	13,042	0.17	29,245	0.13	2,594	0.43	3,671	0.18	6,266	0.21	1,314	0.24	3,247	0.30	4,562	0.23
2002	14,401	0.20	13,006	0.17	27,407	0.13	1,768	0.28	3,724	0.20	5,492	0.16	1,701	0.33	2,766	0.25	4,468	0.20
2003	17,161	0.20	20,637	0.17	37,798	0.13	704	0.24	3,954	0.28	4,658	0.24	2,090	0.23	6,313	0.24	8,403	0.19
2004	12,454	0.22	26,417	0.17	38,871	0.14	267	0.38	3,812	0.15	4,079	0.15	863	0.20	3,865	0.21	4,729	0.17
2005	17,442	0.19	46,300	0.14	63,743	0.12	1,672	0.39	8,698	0.22	10,370	0.20	2,820	0.37	8,759	0.22	11,579	0.19
2006	28,635	0.34	72,894	0.17	101,529	0.15	2,450	0.50	10,789	0.25	13,238	0.22	4,025	0.29	10,914	0.21	14,939	0.17
2007	27,938	0.28	76,245	0.22	104,183	0.18	696	0.33	4,885	0.26	5,581	0.23	5,916	0.38	7,521	0.16	13,436	0.19
2008	37,176	0.50	47,720	0.22	84,897	0.25	621	0.52	2,220	0.22	2,841	0.21	4,457	0.31	7,206	0.23	11,663	0.18
2009	14,778	0.23	32,627	0.17	47,405	0.14	524	0.34	2,014	0.33	2,538	0.27	4,021	0.39	4,456	0.18	8,477	0.21
2010	14,420	0.21	34,575	0.22	48,996	0.17	789	0.31	2,986	0.19	3,775	0.16	2,115	0.42	3,358	0.24	5,473	0.22
2011	23,382	0.21	39,282	0.24	62,664	0.17	4,384	0.37	5,960	0.19	10,344	0.19	2,225	0.27	3,189	0.16	5,414	0.14
2012	45,365	0.28	34,747	0.13	80,112	0.17	5,692	0.45	5,959	0.19	11,651	0.24	8,550	0.31	3,805	0.18	12,355	0.22
2013	64,573	0.32	38,798	0.18	103,371	0.21	2,337	0.37	4,036	0.19	6,373	0.18	11,054	0.33	6,795	0.18	17,849	0.21
2014	58,196	0.14	50,711	0.14	108,906	0.10	489	0.20	1,964	0.25	2,453	0.21	8,159	0.47	6,705	0.27	14,864	0.29
2015	35,090	0.12	39,143	0.13	74,233	0.09	625	0.30	1,020	0.21	1,646	0.17	4,675	0.34	6,536	0.35	11,211	0.25
2016	25,813	0.15	43,812	0.12	69,625	0.09	50	0.33	1,068	0.22	1,118	0.22	1,450	0.30	6,176	0.31	7,625	0.26
2017	24,217	0.17	29,985	0.14	54,201	0.11	160	0.39	1,221	0.20	1,381	0.19	2,015	0.20	5,098	0.31	7,113	0.23
2018	13,931	0.13	33,152	0.12	47,083	0.10	1,010	0.25	4,005	0.20	5,015	0.17	607	0.23	4,360	0.23	4,967	0.20

(continued)

year	East 166W		West 166W		male all maturity all EBS		East 166W		West 166W		immature all EBS		East 166W		West 166W		female mature all EBS	
	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2019	10,931	0.26	17,742	0.10	28,673	0.12	1,513	0.33	3,406	0.19	4,919	0.16	662	0.34	4,184	0.25	4,846	0.22
2020	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021	12,900	0.18	18,664	0.14	31,564	0.11	1,083	0.28	2,259	0.15	3,342	0.13	2,858	0.22	5,697	0.20	8,554	0.15
2022	14,940	0.18	14,692	0.13	29,633	0.11	698	0.38	1,996	0.24	2,694	0.20	1,827	0.23	4,842	0.27	6,669	0.20
2023	10,470	0.14	24,046	0.10	34,516	0.08	1,042	0.26	8,221	0.18	9,264	0.17	1,629	0.23	5,697	0.28	7,326	0.23
2024	19,262	0.22	64,151	0.14	83,413	0.12	2,955	0.50	16,162	0.18	19,117	0.17	3,362	0.27	21,277	0.22	24,638	0.19

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

	East 166W		West 166W		male all maturity all EBS		East 166W		West 166W		immature all EBS		East 166W		West 166W		female mature all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	398.59	0.25	136.77	0.27	535.37	0.20	93.91	0.26	4.42	0.45	98.33	0.25	85.53	0.18	68.15	0.35	153.68	0.19
1976	228.63	0.15	143.94	0.29	372.57	0.15	68.77	0.38	67.91	0.55	136.68	0.33	94.28	0.20	58.43	0.40	152.71	0.20
1977	162.87	0.13	217.39	0.36	380.26	0.21	14.44	0.21	258.87	0.63	273.31	0.60	142.44	0.39	49.67	0.38	192.11	0.31
1978	124.72	0.14	166.20	0.19	290.92	0.12	9.32	0.25	142.71	0.29	152.02	0.27	83.00	0.33	53.78	0.28	136.78	0.23
1979	32.79	0.19	138.74	0.34	171.53	0.28	7.67	0.49	30.10	0.36	37.77	0.31	13.04	0.37	48.46	0.44	61.51	0.36
1980	90.26	0.29	554.36	0.19	644.62	0.17	15.42	0.25	154.88	0.25	170.30	0.23	50.51	0.38	380.36	0.35	430.88	0.31
1981	54.16	0.20	211.98	0.18	266.14	0.15	15.08	0.37	9.95	0.22	25.03	0.24	35.15	0.30	268.67	0.32	303.82	0.29
1982	43.53	0.15	144.58	0.18	188.11	0.14	13.76	0.25	14.29	0.23	28.05	0.17	31.09	0.27	433.08	0.31	464.17	0.29
1983	50.24	0.19	127.07	0.23	177.31	0.18	27.31	0.28	80.05	0.35	107.36	0.27	18.30	0.28	109.91	0.22	128.21	0.20
1984	40.24	0.33	90.50	0.14	130.74	0.14	19.32	0.57	56.00	0.19	75.32	0.20	16.33	0.41	70.10	0.27	86.43	0.23
1985	20.05	0.16	35.39	0.15	55.44	0.11	5.17	0.22	19.69	0.21	24.87	0.17	10.77	0.38	18.57	0.34	29.34	0.26
1986	53.63	0.16	61.88	0.26	115.50	0.16	34.08	0.21	23.34	0.25	57.42	0.16	8.65	0.23	8.29	0.28	16.94	0.18
1987	150.92	0.24	104.10	0.12	255.02	0.15	122.49	0.35	71.88	0.15	194.37	0.23	13.42	0.21	12.93	0.21	26.35	0.15
1988	185.58	0.19	234.95	0.21	420.53	0.14	54.49	0.20	127.51	0.23	182.00	0.18	84.40	0.29	38.13	0.25	122.53	0.21
1989	328.22	0.19	204.64	0.19	532.86	0.14	179.37	0.33	99.72	0.21	279.08	0.23	57.76	0.20	43.30	0.23	101.06	0.15
1990	235.20	0.15	195.37	0.15	430.56	0.10	98.52	0.27	74.95	0.18	173.48	0.18	101.55	0.24	107.46	0.43	209.01	0.25
1991	209.64	0.21	224.87	0.16	434.51	0.13	39.32	0.23	82.31	0.31	121.63	0.22	145.92	0.36	109.17	0.23	255.09	0.23
1992	160.01	0.31	141.90	0.13	301.91	0.17	4.97	0.30	46.16	0.20	51.13	0.18	53.88	0.22	97.02	0.23	150.90	0.17
1993	93.72	0.18	79.93	0.13	173.65	0.11	2.90	0.34	24.87	0.21	27.77	0.19	24.87	0.22	42.60	0.20	67.47	0.15
1994	51.96	0.16	65.93	0.14	117.89	0.10	2.67	0.33	33.60	0.37	36.27	0.34	27.00	0.32	29.16	0.27	56.16	0.21
1995	34.55	0.19	51.84	0.16	86.39	0.12	5.46	0.27	19.09	0.22	24.55	0.18	30.24	0.31	43.08	0.31	73.32	0.22
1996	51.02	0.20	37.00	0.19	88.03	0.14	17.73	0.26	12.58	0.21	30.31	0.18	28.92	0.36	26.19	0.43	55.11	0.28
1997	41.37	0.27	30.04	0.13	71.40	0.17	31.89	0.45	20.09	0.21	51.98	0.29	11.14	0.24	8.96	0.31	20.10	0.19
1998	32.57	0.14	54.94	0.17	87.51	0.12	13.39	0.22	42.86	0.22	56.25	0.17	6.74	0.22	6.56	0.24	13.30	0.16
1999	59.89	0.37	81.10	0.19	141.00	0.19	20.75	0.31	70.89	0.21	91.65	0.17	12.62	0.31	10.06	0.20	22.68	0.20
2000	49.05	0.21	75.44	0.17	124.49	0.13	16.27	0.35	54.31	0.18	70.59	0.16	14.97	0.38	7.29	0.25	22.26	0.27
2001	124.71	0.32	141.06	0.16	265.78	0.17	106.49	0.37	108.33	0.17	214.83	0.20	7.13	0.23	21.04	0.28	28.16	0.22
2002	58.90	0.22	136.65	0.20	195.55	0.15	36.36	0.27	109.08	0.24	145.43	0.19	10.76	0.38	19.10	0.29	29.87	0.23
2003	56.03	0.19	179.53	0.19	235.56	0.15	13.21	0.23	113.88	0.25	127.09	0.23	11.97	0.24	48.53	0.28	60.49	0.23
2004	30.39	0.18	219.98	0.11	250.37	0.10	8.38	0.50	153.86	0.13	162.24	0.13	4.53	0.23	27.68	0.25	32.21	0.22
2005	59.04	0.20	286.68	0.15	345.72	0.13	39.05	0.43	212.35	0.22	251.40	0.20	16.10	0.38	60.65	0.23	76.75	0.20
2006	103.52	0.38	355.13	0.14	458.66	0.14	28.83	0.39	172.38	0.19	201.21	0.18	21.91	0.28	76.44	0.21	98.34	0.17
2007	76.79	0.27	345.73	0.18	422.52	0.16	11.45	0.30	96.72	0.21	108.17	0.19	30.54	0.35	51.46	0.16	82.00	0.17
2008	79.61	0.41	166.84	0.15	246.45	0.17	8.74	0.34	47.62	0.21	56.36	0.18	24.65	0.31	48.63	0.23	73.28	0.19
2009	45.63	0.21	131.95	0.15	177.58	0.12	21.11	0.40	63.43	0.25	84.53	0.21	22.10	0.39	29.22	0.17	51.32	0.19
2010	51.73	0.20	149.43	0.14	201.16	0.11	27.59	0.35	84.27	0.17	111.86	0.16	10.60	0.41	21.92	0.23	32.51	0.21
2011	148.75	0.27	216.69	0.15	365.43	0.14	86.81	0.32	145.81	0.19	232.62	0.17	12.18	0.26	20.30	0.15	32.48	0.14
2012	189.77	0.34	244.69	0.16	434.45	0.17	64.98	0.42	113.49	0.18	178.48	0.19	52.40	0.35	25.62	0.18	78.02	0.24
2013	176.80	0.30	209.10	0.14	385.90	0.16	30.47	0.32	85.37	0.17	115.84	0.15	60.82	0.36	47.96	0.18	108.77	0.21
2014	137.61	0.13	198.85	0.17	336.46	0.11	14.94	0.25	73.20	0.29	88.14	0.24	44.74	0.48	43.62	0.28	88.36	0.28
2015	79.06	0.12	119.86	0.11	198.93	0.08	13.69	0.25	30.76	0.18	44.45	0.15	27.61	0.35	45.43	0.38	73.04	0.27
2016	53.97	0.18	133.88	0.12	187.85	0.10	1.25	0.32	37.62	0.24	38.87	0.23	7.71	0.31	42.58	0.33	50.29	0.28
2017	49.93	0.17	122.77	0.13	172.70	0.10	4.73	0.32	78.81	0.24	83.55	0.23	10.17	0.20	35.57	0.31	45.75	0.24
2018	54.89	0.17	205.36	0.15	260.25	0.12	32.97	0.25	158.21	0.20	191.18	0.17	3.46	0.24	30.33	0.22	33.80	0.20

(continued)

					male												female	
					all maturity						immature						mature	
	East 166W		West 166W		all EBS		East 166W		West 166W		all EBS		East 166W		West 166W		all EBS	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2019	46.68	0.27	154.60	0.15	201.28	0.13	30.16	0.34	140.17	0.21	170.32	0.19	3.74	0.34	32.95	0.27	36.69	0.24
2020	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021	58.08	0.19	144.08	0.18	202.16	0.14	21.61	0.38	81.50	0.28	103.10	0.24	14.79	0.22	39.48	0.22	54.27	0.17
2022	70.43	0.26	124.86	0.21	195.29	0.16	35.21	0.47	81.03	0.23	116.24	0.22	9.60	0.24	33.24	0.29	42.84	0.23
2023	51.69	0.18	311.78	0.13	363.47	0.11	35.90	0.28	282.13	0.15	318.03	0.14	8.62	0.23	39.89	0.27	48.50	0.23
2024	93.51	0.28	537.25	0.13	630.77	0.12	48.75	0.35	346.06	0.15	394.81	0.13	21.10	0.30	149.75	0.22	170.85	0.20

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

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	152,683	0.55	6,522	0.40	159,205	0.53	56,181	0.42	2,509	0.33	58,691	0.41	208,864	0.42	9,032	0.30	217,896	0.40
1976	57,463	0.23	9,245	0.47	66,709	0.24	38,231	0.24	1,409	0.36	39,640	0.24	95,695	0.17	10,654	0.41	106,349	0.17
1977	50,855	0.16	7,543	0.24	58,399	0.16	26,511	0.36	6,808	0.30	33,319	0.30	77,366	0.16	14,351	0.19	91,717	0.15
1978	40,761	0.18	9,652	0.21	50,413	0.16	3,221	0.26	6,626	0.32	9,847	0.27	43,981	0.17	16,278	0.18	60,259	0.14
1979	9,816	0.23	3,377	0.26	13,192	0.19	4,456	0.26	5,280	0.38	9,736	0.26	14,272	0.18	8,657	0.25	22,929	0.15
1980	23,184	0.41	10,857	0.53	34,041	0.33	11,210	0.31	1,677	0.69	12,887	0.31	34,394	0.30	12,534	0.47	46,927	0.25
1981	3,445	0.33	11,286	0.27	14,731	0.22	5,884	0.27	2,167	0.38	8,050	0.24	9,329	0.21	13,452	0.23	22,781	0.17
1982	3,009	0.22	4,851	0.23	7,860	0.18	5,775	0.38	5,847	0.25	11,622	0.23	8,783	0.26	10,698	0.17	19,481	0.16
1983	5,151	0.31	2,082	0.29	7,233	0.25	2,429	0.29	3,226	0.26	5,655	0.21	7,580	0.23	5,309	0.19	12,889	0.17
1984	4,348	0.24	3,077	0.40	7,424	0.23	571	0.37	3,159	0.24	3,730	0.22	4,919	0.22	6,236	0.23	11,154	0.17
1985	4,055	0.28	1,046	0.32	5,101	0.26	588	0.34	870	0.29	1,458	0.22	4,642	0.25	1,917	0.22	6,559	0.21
1986	734	0.36	2,546	0.52	3,280	0.43	142	0.41	674	0.33	816	0.30	876	0.31	3,219	0.42	4,096	0.35
1987	4,911	0.23	3,473	0.37	8,385	0.24	3,505	0.41	658	0.27	4,163	0.35	8,416	0.22	4,132	0.32	12,548	0.20
1988	15,698	0.67	2,715	0.25	18,413	0.58	9,690	0.40	929	0.31	10,618	0.37	25,387	0.44	3,644	0.20	29,031	0.39
1989	37,386	0.21	3,718	0.39	41,104	0.19	13,758	0.34	2,741	0.36	16,499	0.29	51,144	0.18	6,459	0.27	57,603	0.16
1990	35,903	0.22	7,084	0.21	42,987	0.19	21,082	0.37	3,274	0.30	24,356	0.33	56,985	0.19	10,358	0.17	67,343	0.17
1991	32,973	0.42	14,476	0.25	47,449	0.30	13,386	0.29	8,430	0.20	21,816	0.21	46,359	0.31	22,906	0.17	69,265	0.22
1992	41,423	0.44	16,242	0.40	57,665	0.33	9,893	0.50	6,418	0.28	16,311	0.32	51,316	0.37	22,660	0.30	73,977	0.27
1993	22,942	0.28	11,990	0.26	34,932	0.20	3,716	0.35	2,596	0.29	6,312	0.26	26,658	0.24	14,586	0.22	41,244	0.17
1994	10,000	0.22	13,912	0.26	23,912	0.18	1,248	0.45	4,143	0.22	5,391	0.21	11,248	0.20	18,054	0.21	29,303	0.15
1995	1,380	0.25	13,377	0.28	14,757	0.26	370	0.41	5,392	0.34	5,761	0.33	1,749	0.22	18,769	0.22	20,518	0.21
1996	330	0.35	13,912	0.35	14,242	0.35	100	0.42	3,580	0.48	3,680	0.47	430	0.29	17,492	0.30	17,922	0.29
1997	316	0.33	4,245	0.22	4,561	0.20	179	0.36	942	0.26	1,121	0.23	495	0.25	5,187	0.18	5,681	0.17
1998	1,001	0.28	2,604	0.19	3,605	0.16	441	0.35	644	0.20	1,085	0.21	1,442	0.22	3,247	0.16	4,689	0.13
1999	1,645	0.39	1,838	0.35	3,483	0.25	256	0.32	356	0.31	612	0.24	1,902	0.34	2,194	0.30	4,095	0.22
2000	4,484	0.52	3,045	0.41	7,529	0.35	250	0.35	377	0.29	627	0.24	4,734	0.49	3,422	0.36	8,156	0.33
2001	4,473	0.35	3,600	0.21	8,073	0.25	418	0.27	1,361	0.37	1,780	0.32	4,892	0.32	4,961	0.18	9,853	0.21
2002	944	0.40	7,102	0.28	8,046	0.25	384	0.42	838	0.25	1,222	0.25	1,328	0.31	7,940	0.25	9,268	0.22
2003	1,558	0.32	6,433	0.33	7,991	0.28	434	0.31	2,227	0.35	2,661	0.31	1,992	0.26	8,660	0.26	10,652	0.22
2004	1,597	0.26	4,916	0.50	6,513	0.38	980	0.26	1,825	0.29	2,805	0.22	2,577	0.19	6,741	0.37	9,318	0.27
2005	2,368	0.22	5,822	0.36	8,190	0.27	8,776	0.33	5,062	0.30	13,839	0.26	11,145	0.27	10,884	0.24	22,029	0.19
2006	2,134	0.34	6,794	0.28	8,927	0.24	3,768	0.37	15,315	0.48	19,083	0.42	5,902	0.26	22,109	0.34	28,011	0.30
2007	4,143	0.61	5,314	0.26	9,457	0.30	8,523	0.84	7,757	0.35	16,281	0.48	12,666	0.60	13,071	0.23	25,737	0.32
2008	15,476	0.78	3,288	0.27	18,764	0.65	8,731	0.56	4,414	0.28	13,145	0.40	24,206	0.54	7,702	0.20	31,909	0.42
2009	2,644	0.26	5,139	0.36	7,783	0.29	6,670	0.29	4,143	0.20	10,812	0.21	9,313	0.22	9,282	0.22	18,595	0.17
2010	3,006	0.49	4,576	0.30	7,582	0.29	9,593	0.47	4,867	0.21	14,460	0.35	12,599	0.38	9,443	0.18	22,042	0.25
2011	1,513	0.25	6,987	0.36	8,500	0.32	9,023	0.74	6,637	0.21	15,660	0.44	10,536	0.64	13,624	0.21	24,160	0.31
2012	3,352	0.49	5,026	0.24	8,378	0.25	2,368	0.32	3,997	0.19	6,365	0.19	5,720	0.32	9,023	0.16	14,743	0.16
2013	10,871	0.29	3,527	0.22	14,397	0.23	5,383	0.43	2,837	0.22	8,220	0.29	16,254	0.24	6,364	0.16	22,618	0.18
2014	14,899	0.26	9,310	0.19	24,210	0.19	7,163	0.17	4,604	0.21	11,766	0.14	22,062	0.19	13,914	0.15	35,976	0.13
2015	9,084	0.22	10,217	0.24	19,301	0.15	8,380	0.27	5,925	0.21	14,306	0.18	17,464	0.17	16,143	0.17	33,607	0.12
2016	2,666	0.17	8,137	0.18	10,803	0.14	5,855	0.18	12,649	0.18	18,504	0.14	8,521	0.14	20,786	0.13	29,308	0.10
2017	1,646	0.74	10,947	0.17	12,593	0.18	904	0.21	11,777	0.24	12,681	0.23	2,550	0.49	22,724	0.15	25,274	0.15
2018	103	0.44	7,324	0.16	7,427	0.16	1,007	0.19	11,993	0.19	13,000	0.18	1,110	0.18	19,318	0.13	20,427	0.13
2019	318	0.36	4,502	0.21	4,821	0.21	204	0.32	4,844	0.16	5,048	0.16	522	0.25	9,347	0.13	9,869	0.13

(continued)

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2020	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021	1,462	0.32	965	0.29	2,427	0.23	420	0.33	1,608	0.22	2,028	0.19	1,883	0.26	2,573	0.18	4,455	0.15
2022	3,803	0.28	924	0.30	4,727	0.23	757	0.26	835	0.21	1,592	0.17	4,560	0.24	1,759	0.19	6,319	0.18
2023	2,514	0.24	1,103	0.24	3,617	0.19	1,166	0.24	1,235	0.23	2,401	0.17	3,680	0.18	2,339	0.17	6,018	0.13
2024	3,386	0.24	2,925	0.26	6,311	0.17	3,387	0.20	1,809	0.22	5,196	0.15	6,773	0.16	4,734	0.18	11,507	0.12

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

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
1975	156.363	0.52	7.320	0.40	163.683	0.50	66.706	0.42	3.129	0.33	69.835	0.40	223.068	0.39	10.450	0.29	233.518	0.37
1976	64.022	0.21	9.945	0.45	73.967	0.22	42.219	0.23	1.643	0.35	43.862	0.23	106.241	0.16	11.588	0.39	117.829	0.16
1977	55.271	0.15	8.487	0.23	63.759	0.15	26.617	0.30	7.258	0.29	33.875	0.26	81.888	0.14	15.745	0.18	97.633	0.13
1978	44.641	0.18	11.539	0.21	56.180	0.15	3.591	0.27	7.183	0.32	10.774	0.28	48.233	0.16	18.722	0.18	66.955	0.14
1979	11.155	0.22	4.001	0.24	15.156	0.19	5.997	0.27	6.398	0.36	12.394	0.25	17.152	0.17	10.398	0.24	27.550	0.15
1980	24.363	0.39	13.118	0.52	37.481	0.32	14.802	0.30	1.916	0.65	16.718	0.30	39.165	0.27	15.034	0.46	54.199	0.24
1981	4.026	0.34	14.097	0.26	18.123	0.22	7.784	0.26	2.903	0.38	10.688	0.23	11.811	0.21	17.000	0.22	28.811	0.16
1982	3.492	0.21	6.377	0.24	9.869	0.19	8.085	0.37	8.190	0.25	16.275	0.23	11.577	0.27	14.567	0.18	26.144	0.16
1983	6.917	0.31	2.732	0.28	9.649	0.25	3.375	0.29	4.685	0.27	8.061	0.21	10.292	0.23	7.418	0.20	17.710	0.17
1984	4.898	0.23	3.946	0.39	8.845	0.23	0.820	0.37	4.520	0.25	5.340	0.22	5.719	0.21	8.466	0.23	14.185	0.17
1985	4.413	0.27	1.381	0.31	5.795	0.25	0.784	0.35	1.283	0.28	2.067	0.22	5.197	0.24	2.664	0.21	7.861	0.19
1986	0.981	0.38	2.742	0.47	3.723	0.38	0.213	0.40	0.870	0.31	1.083	0.28	1.194	0.32	3.612	0.36	4.806	0.30
1987	6.307	0.22	4.039	0.33	10.345	0.22	4.658	0.40	0.917	0.27	5.575	0.34	10.965	0.21	4.956	0.28	15.921	0.19
1988	18.560	0.67	3.515	0.24	22.074	0.56	12.210	0.39	1.241	0.32	13.451	0.36	30.769	0.43	4.756	0.20	35.525	0.37
1989	46.361	0.20	4.780	0.39	51.141	0.19	17.061	0.33	3.608	0.36	20.670	0.28	63.423	0.17	8.388	0.27	71.811	0.16
1990	38.932	0.22	9.361	0.21	48.293	0.19	26.645	0.36	4.216	0.29	30.860	0.32	65.577	0.20	13.576	0.17	79.153	0.17
1991	39.106	0.46	18.355	0.24	57.462	0.33	17.264	0.30	11.383	0.20	28.647	0.21	56.371	0.33	29.738	0.17	86.109	0.23
1992	50.821	0.44	21.453	0.40	72.274	0.33	11.949	0.47	8.559	0.28	20.509	0.29	62.770	0.37	30.012	0.30	92.782	0.26
1993	27.129	0.29	16.372	0.25	43.501	0.20	5.078	0.35	3.723	0.30	8.801	0.26	32.207	0.25	20.095	0.21	52.302	0.17
1994	10.707	0.23	18.458	0.26	29.165	0.19	1.575	0.41	5.751	0.22	7.326	0.21	12.282	0.21	24.209	0.20	36.491	0.16
1995	1.510	0.25	16.795	0.28	18.305	0.26	0.569	0.42	7.622	0.35	8.191	0.34	2.079	0.22	24.418	0.22	26.497	0.21
1996	0.302	0.33	17.040	0.35	17.343	0.35	0.154	0.42	5.271	0.49	5.425	0.48	0.456	0.26	22.312	0.29	22.768	0.29
1997	0.454	0.34	4.957	0.21	5.411	0.20	0.248	0.34	1.296	0.26	1.543	0.23	0.701	0.25	6.253	0.18	6.954	0.16
1998	1.395	0.29	3.155	0.18	4.550	0.16	0.619	0.34	0.922	0.20	1.541	0.20	2.014	0.22	4.077	0.15	6.091	0.13
1999	2.022	0.37	2.256	0.32	4.278	0.24	0.387	0.33	0.505	0.30	0.892	0.24	2.409	0.32	2.760	0.27	5.169	0.20
2000	5.647	0.52	3.921	0.40	9.567	0.35	0.347	0.33	0.544	0.29	0.891	0.24	5.994	0.49	4.465	0.35	10.459	0.32
2001	5.136	0.34	4.621	0.20	9.757	0.23	0.635	0.27	1.785	0.36	2.419	0.30	5.770	0.30	6.406	0.17	12.176	0.20
2002	1.087	0.41	8.110	0.25	9.197	0.23	0.546	0.41	1.140	0.24	1.686	0.25	1.633	0.30	9.250	0.22	10.883	0.20
2003	1.895	0.32	7.156	0.29	9.051	0.25	0.615	0.32	3.019	0.35	3.634	0.31	2.510	0.25	10.175	0.23	12.685	0.20
2004	2.150	0.26	5.277	0.44	7.426	0.31	1.431	0.26	2.626	0.29	4.057	0.21	3.581	0.18	7.903	0.31	11.484	0.22
2005	3.110	0.22	6.588	0.32	9.698	0.24	11.621	0.33	7.088	0.29	18.710	0.25	14.731	0.26	13.676	0.22	28.407	0.19
2006	2.674	0.36	8.262	0.25	10.936	0.22	5.256	0.37	20.672	0.46	25.928	0.40	7.930	0.27	28.934	0.34	36.864	0.29
2007	5.023	0.56	6.765	0.23	11.788	0.28	11.886	0.83	10.728	0.34	22.614	0.47	16.909	0.61	17.493	0.23	34.401	0.33
2008	17.411	0.74	4.518	0.27	21.929	0.60	12.273	0.54	6.233	0.27	18.505	0.39	29.683	0.49	10.751	0.20	40.435	0.37
2009	3.293	0.25	6.402	0.34	9.695	0.28	9.180	0.28	5.838	0.20	15.018	0.21	12.473	0.22	12.240	0.20	24.713	0.17
2010	3.702	0.50	5.364	0.28	9.066	0.29	12.360	0.45	6.754	0.21	19.114	0.33	16.062	0.36	12.118	0.17	28.180	0.24
2011	1.866	0.25	8.110	0.31	9.976	0.28	10.018	0.70	8.845	0.20	18.863	0.39	11.884	0.59	16.954	0.18	28.839	0.27
2012	4.229	0.46	6.042	0.23	10.270	0.24	3.051	0.28	5.218	0.18	8.269	0.18	7.279	0.29	11.259	0.15	18.539	0.16
2013	15.045	0.31	4.524	0.22	19.569	0.24	7.150	0.39	3.614	0.22	10.764	0.27	22.195	0.24	8.138	0.16	30.334	0.18
2014	18.764	0.25	11.735	0.19	30.499	0.18	9.947	0.17	6.192	0.21	16.140	0.14	28.711	0.17	17.927	0.14	46.639	0.13
2015	11.442	0.20	12.676	0.22	24.119	0.14	11.343	0.27	8.298	0.22	19.641	0.18	22.785	0.17	20.975	0.16	43.760	0.11
2016	3.349	0.18	10.545	0.17	13.894	0.14	7.580	0.18	17.080	0.17	24.661	0.14	10.929	0.14	27.625	0.12	38.554	0.10
2017	2.054	0.78	13.889	0.17	15.943	0.18	1.231	0.21	15.589	0.23	16.819	0.22	3.284	0.49	29.478	0.14	32.762	0.14
2018	0.149	0.44	9.100	0.16	9.250	0.16	1.422	0.19	15.823	0.19	17.245	0.18	1.571	0.17	24.923	0.13	26.494	0.13
2019	0.460	0.37	5.666	0.20	6.125	0.20	0.301	0.33	6.608	0.16	6.909	0.16	0.761	0.26	12.274	0.13	13.034	0.13

(continued)

	East 166W						West 166W						all EBS					
	new shell		old shell		all shell		new shell		old shell		all shell		new shell		old shell		all shell	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2020	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021	2.047	0.32	1.311	0.29	3.357	0.23	0.632	0.32	2.243	0.22	2.875	0.19	2.679	0.25	3.553	0.18	6.232	0.15
2022	4.938	0.28	1.324	0.29	6.262	0.23	1.065	0.26	1.224	0.21	2.289	0.17	6.003	0.23	2.548	0.18	8.551	0.17
2023	3.220	0.24	1.504	0.24	4.725	0.18	1.611	0.23	1.819	0.23	3.430	0.17	4.831	0.18	3.323	0.17	8.154	0.13
2024	4.336	0.25	3.854	0.24	8.190	0.17	4.910	0.21	2.588	0.22	7.498	0.16	9.246	0.16	6.442	0.17	15.688	0.12

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

				male								female
				all maturity				immature				mature
	BSFRF	(SBS)	NMFS	(SBS)	BSFRF	(SBS)	NMFS	(SBS)	BSFRF	(SBS)	NMFS	(SBS)
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2013	56,571	0.55	21,109	0.38	1,562	0.45	522	0.38	8,369	0.48	3,050	0.46
2014	42,969	0.21	30,866	0.24	379	0.33	148	0.33	3,428	0.33	1,252	0.35
2015	23,271	0.20	16,802	0.22	165	0.43	255	0.62	2,633	0.42	713	0.44
2016	55,992	0.18	29,037	0.15	1,275	0.31	202	0.33	11,016	0.29	2,649	0.29
2017	63,908	0.20	28,402	0.16	5,411	0.17	759	0.28	15,629	0.31	4,540	0.34
2018	47,051	0.17	25,810	0.15	9,539	0.21	2,425	0.23	12,340	0.24	3,976	0.25

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

	male								female			
	all maturity				immature				mature			
	BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)	
year	value	cv	value	cv	value	cv	value	cv	value	cv	value	cv
2013	139.20	0.51	47.03	0.36	17.95	0.34	4.11	0.34	35.13	0.49	12.97	0.46
2014	90.89	0.20	60.45	0.24	5.74	0.39	2.20	0.50	14.41	0.33	5.29	0.38
2015	48.91	0.19	33.32	0.25	5.52	0.52	3.10	0.55	11.80	0.47	3.14	0.52
2016	168.96	0.20	66.34	0.17	51.21	0.28	5.19	0.37	62.79	0.31	15.32	0.31
2017	430.64	0.15	83.67	0.15	369.06	0.17	40.63	0.35	104.66	0.30	29.96	0.35
2018	442.19	0.19	119.00	0.15	429.49	0.20	86.10	0.22	82.83	0.25	26.84	0.25

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

	East 166W				West 166W				all EBS							
	male		female	all sexes	male		female	all sexes	male				female		all sexes	
	all maturity	immature	mature	all maturity	all maturity	immature	mature	all maturity	all maturity		immature		mature		all maturity	
year	original	original	original	original	original	original	original	original	original	scaled	original	scaled	original	scaled	original	scaled
1975/76	4,973	956	1,664	7,593	2,314	91	903	3,308	7,287	134	1,047	19	2,567	47	10,901	200
1976/77	2,891	510	1,182	4,583	1,843	587	433	2,863	4,734	127	1,097	29	1,615	43	7,446	200
1977/78	2,680	251	1,350	4,281	1,554	525	571	2,650	4,234	122	776	22	1,921	55	6,931	200
1978/79	2,342	175	1,338	3,855	2,885	1,774	607	5,266	5,227	115	1,949	43	1,945	43	9,121	200
1979/80	669	156	272	1,097	1,160	273	325	1,758	1,829	128	429	30	597	42	2,855	200
1980/81	1,986	319	629	2,934	5,544	1,172	1,412	8,128	7,530	136	1,491	27	2,041	37	11,062	200
1981/82	1,279	339	739	2,357	5,709	240	1,786	7,735	6,988	138	579	11	2,525	50	10,092	200
1982/83	1,428	440	1,026	2,894	3,776	383	1,815	5,974	5,204	117	823	19	2,841	64	8,868	200
1983/84	1,687	916	611	3,214	2,961	1,197	1,744	5,902	4,648	102	2,113	46	2,355	52	9,116	200
1984/85	934	319	415	1,668	2,920	1,560	1,400	5,880	3,854	102	1,879	50	1,815	48	7,548	200
1985/86	650	171	359	1,180	1,250	676	470	2,396	1,900	106	847	47	829	46	3,576	200
1986/87	1,501	942	272	2,715	1,636	646	250	2,532	3,137	120	1,588	61	522	20	5,247	200
1987/88	3,074	1,983	401	5,458	3,389	2,247	436	6,072	6,463	112	4,230	73	837	15	11,530	200
1988/89	3,788	1,422	1,484	6,694	4,524	2,313	799	7,636	8,312	116	3,735	52	2,283	32	14,330	200
1989/90	5,615	1,640	1,304	8,559	3,630	1,631	819	6,080	9,245	126	3,271	45	2,123	29	14,639	200
1990/91	5,500	1,521	1,722	8,743	4,098	1,593	1,291	6,982	9,598	122	3,114	40	3,013	38	15,725	200
1991/92	4,748	832	1,735	7,315	5,198	1,427	2,116	8,741	9,946	124	2,259	28	3,851	48	16,056	200
1992/93	2,864	169	1,265	4,298	4,065	1,325	1,760	7,150	6,929	121	1,494	26	3,025	53	11,448	200
1993/94	2,748	104	748	3,600	2,845	765	1,134	4,744	5,593	134	869	21	1,882	45	8,344	200
1994/95	1,471	59	557	2,087	2,361	862	884	4,107	3,832	124	921	30	1,441	47	6,194	200
1995/96	1,041	147	492	1,680	1,748	687	705	3,140	2,789	116	834	35	1,197	50	4,820	200
1996/97	1,404	424	484	2,312	1,301	459	588	2,348	2,705	116	883	38	1,072	46	4,660	200
1997/98	994	501	379	1,874	1,213	828	293	2,334	2,207	105	1,329	63	672	32	4,208	200
1998/99	1,132	482	248	1,862	1,920	1,228	256	3,404	3,052	116	1,710	65	504	19	5,266	200
1999/00	1,462	516	367	2,345	2,471	2,112	398	4,981	3,933	107	2,628	72	765	21	7,326	200
2000/01	1,599	556	312	2,467	2,518	1,693	275	4,486	4,117	118	2,249	65	587	17	6,953	200
2001/02	1,844	1,093	216	3,153	3,638	2,585	792	7,015	5,482	108	3,678	72	1,008	20	10,168	200
2002/03	1,816	1,097	260	3,173	3,643	2,488	590	6,721	5,459	110	3,585	72	850	17	9,894	200
2003/04	1,812	453	415	2,680	5,191	2,381	1,260	8,832	7,003	122	2,834	49	1,675	29	11,512	200
2004/05	1,020	213	168	1,401	6,448	3,709	915	11,072	7,468	120	3,922	63	1,083	17	12,473	200
2005/06	1,859	641	437	2,937	5,670	2,711	1,125	9,506	7,529	121	3,352	54	1,562	25	12,443	200
2006/07	2,422	715	603	3,740	9,613	3,649	2,056	15,318	12,035	126	4,364	46	2,659	28	19,058	200
2007/08	2,120	348	768	3,236	7,466	2,082	1,939	11,487	9,586	130	2,430	33	2,707	37	14,723	200
2008/09	1,991	254	674	2,919	5,398	1,493	1,689	8,580	7,389	129	1,747	30	2,363	41	11,499	200
2009/10	1,545	507	554	2,606	4,432	1,901	1,126	7,459	5,977	119	2,408	48	1,680	33	10,065	200
2010/11	1,562	623	410	2,595	5,062	2,557	776	8,395	6,624	121	3,180	58	1,186	22	10,990	200
2011/12	2,923	1,610	391	4,924	6,228	3,434	785	10,447	9,151	119	5,044	66	1,176	15	15,371	200
2012/13	2,709	977	848	4,534	5,677	2,634	814	9,125	8,386	123	3,611	53	1,662	24	13,659	200
2013/14	3,478	746	972	5,196	6,133	2,171	1,447	9,751	9,611	129	2,917	39	2,419	32	14,947	200
2014/15	4,309	440	740	5,489	6,552	1,771	1,326	9,649	10,861	143	2,211	29	2,066	27	15,138	200
2015/16	2,606	479	781	3,866	4,807	976	1,027	6,810	7,413	139	1,455	27	1,808	34	10,676	200
2016/17	1,821	43	277	2,141	5,268	1,358	1,341	7,967	7,089	140	1,401	28	1,618	32	10,108	200
2017/18	1,778	175	366	2,319	4,482	1,915	972	7,369	6,260	129	2,090	43	1,338	28	9,688	200

(continued)

				East 166W				West 166W								all EBS
	male		female	all sexes	male		female	all sexes		male				female		all sexes
	all maturity	immature	mature	all maturity	all maturity	immature	mature	all maturity		all maturity		immature		mature		all maturity
year	original	original	original	original	original	original	original	original	original	scaled	original	scaled	original	scaled	original	scaled
2018/19	1,918	1,153	121	3,192	6,384	3,548	1,107	11,039	8,302	117	4,701	66	1,228	17	14,231	200
2019/20	1,303	731	132	2,166	4,633	3,102	1,058	8,793	5,936	108	3,833	70	1,190	22	10,959	200
2020/21	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
2021/22	1,823	511	520	2,854	4,928	2,533	1,471	8,932	6,751	115	3,044	52	1,991	34	11,786	200
2022/23	1,935	794	345	3,074	3,498	1,927	827	6,252	5,433	117	2,721	58	1,172	25	9,326	200
2023/24	1,690	984	308	2,982	7,899	5,662	1,101	14,662	9,589	109	6,646	75	1,409	16	17,644	200
2024/25	1,876	748	482	3,106	6,961	3,981	1,841	12,783	8,837	111	4,729	60	2,323	29	15,889	200

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

	male				female								all sexes			
	all maturity				immature				mature				all maturity			
	BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)		BSFRF (SBS)		NMFS (SBS)	
year	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled	original	scaled
2013/14	640	141	1,302	142	99	22	134	15	167	37	404	44	906	200	1,840	200
2014/15	441	166	1,814	180	25	9	58	6	66	25	149	15	532	200	2,021	200
2015/16	264	142	998	167	29	16	97	16	79	42	101	17	372	200	1,196	200
2016/17	992	117	2,270	154	318	38	179	12	380	45	502	34	1,690	200	2,951	200
2017/18	2,472	98	3,277	130	1,886	75	1,020	41	699	28	729	29	5,057	200	5,026	200
2018/19	2,334	92	4,306	112	2,121	84	2,406	63	618	24	969	25	5,073	200	7,681	200

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

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

Table 25. TCSAM02 models final values for non-vector parameters related to recruitment, initial abundance, natural mortality, and growth. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03b		22.03d5
process	name	label	estimate	std. dev.	estimate	std. dev.
recruitment	pLnR[1]	historical recruitment period	6.862	0.59	6.960	0.60
	pLnR[2]	current recruitment period	5.901	0.071	6.016	0.066
	pRa[1]	fixed value	2.233	0.031	2.201	0.030
	pRb[1]	fixed value	1.351	0.077	1.360	0.081
	pRCV[1]	full model period	-0.7000	NA	-0.7000	NA
	pRX[1]	full model period	0.000	NA	0.000	NA
natural mortality	pDM1[1]	multiplier for immature crab	1.029	0.047	1.104	0.046
	pDM1[2]	multiplier for mature males	1.349	0.038	1.391	0.037
	pDM1[3]	multiplier for mature females	1.341	0.038	1.372	0.037
	pDM2[1]	1980-1984 multiplier for mature males	2.345	0.24	2.325	0.23
	pDM2[2]	1980-1984 multiplier for mature females	1.966	0.17	1.962	0.16
	pM[1]	base ln-scale M	-1.470	NA	-1.470	NA
growth	pGrA[1]	males	32.33	0.25	32.27	0.24
	pGrA[2]	females	33.69	0.31	33.66	0.31
	pGrB[1]	males	166.0	0.73	166.3	0.70
	pGrB[2]	females	114.9	0.61	115.1	0.61
	pGrBeta[1]	both sexes	0.8166	0.099	0.8488	0.10

Table 26. TCSAM02 models final values for annual recruitment “devs” in the “historical” period up to 1975. Index begins in 1948.

	22.03b		22.03d5	
index	estimate	std. dev.	estimate	std. dev.
1	-0.4961	1.8	-0.4902	1.8
2	-0.4953	1.6	-0.4895	1.7
3	-0.4935	1.5	-0.4879	1.5
4	-0.4903	1.4	-0.4852	1.4
5	-0.4852	1.3	-0.4808	1.3
6	-0.4778	1.2	-0.4742	1.2
7	-0.4671	1.1	-0.4647	1.1
8	-0.4523	0.97	-0.4513	0.98
9	-0.4319	0.90	-0.4327	0.90
10	-0.4045	0.84	-0.4072	0.84
11	-0.3680	0.81	-0.3725	0.81
12	-0.3199	0.80	-0.3258	0.80
13	-0.2563	0.82	-0.2625	0.82
14	-0.1707	0.86	-0.1753	0.86
15	-0.05195	0.90	-0.05186	0.91
16	0.1205	0.94	0.1297	0.94
17	0.3872	0.93	0.4090	0.94
18	0.8028	0.88	0.8339	0.89
19	1.362	0.78	1.380	0.79
20	1.678	0.67	1.654	0.67
21	1.200	0.68	1.157	0.69
22	0.6397	0.68	0.6000	0.69
23	0.3565	0.66	0.3358	0.67
24	-0.07634	0.66	-0.09246	0.67
25	-0.4516	0.66	-0.4496	0.67
26	-0.1578	0.70	-0.1056	0.70

Table 27. TCSAM02 models final values for annual recruitment “devs” in the “current” period from 1975. The index begins in 1975.

	22.03b		22.03d5	
index	estimate	std. dev.	estimate	std. dev.
1	1.363	0.31	1.339	0.32
2	1.978	0.19	1.956	0.20
3	1.630	0.22	1.572	0.23
4	0.6179	0.42	0.5632	0.43
5	-0.1172	0.53	-0.1558	0.53
6	-0.1723	0.41	-0.2070	0.41
7	-0.001938	0.29	-0.03973	0.29
8	-0.1593	0.28	-0.1927	0.29
9	1.069	0.12	1.044	0.12
10	0.7746	0.17	0.7401	0.17
11	0.9094	0.16	0.8817	0.17
12	0.9429	0.15	0.9181	0.16
13	0.7695	0.17	0.7504	0.17
14	0.3943	0.20	0.3312	0.21
15	-0.3706	0.26	-0.4062	0.26
16	-1.083	0.35	-1.118	0.35
17	-1.366	0.32	-1.402	0.33
18	-1.297	0.26	-1.317	0.26
19	-1.293	0.26	-1.317	0.26
20	-1.118	0.24	-1.146	0.25
21	-0.6249	0.18	-0.6497	0.18
22	-0.8545	0.23	-0.8782	0.24
23	0.06910	0.12	0.02524	0.12
24	-0.9424	0.25	-0.9865	0.25
25	0.6167	0.099	0.5806	0.099
26	-0.5172	0.28	-0.5720	0.29
27	1.003	0.10	0.9543	0.10
28	-0.2241	0.29	-0.2663	0.29
29	1.099	0.11	1.058	0.11
30	0.5298	0.15	0.4481	0.15
31	-0.6041	0.28	-0.6667	0.28
32	-1.068	0.36	-1.121	0.37
33	-0.5162	0.26	-0.5692	0.26
34	-0.06014	0.27	-0.08877	0.27
35	1.394	0.095	1.341	0.097
36	0.3749	0.20	0.3290	0.20
37	-0.3674	0.20	-0.4083	0.21
38	-1.665	0.38	-1.660	0.38
39	-0.7416	0.16	-0.7161	0.15
40	-1.291	0.22	-1.467	0.24
41	-1.129	0.20	-1.359	0.21
42	-1.006	0.21	-0.6903	0.14
43	0.7964	0.080	0.7621	0.074
44	-0.1233	0.19	0.2075	0.13
45	0.3454	0.13	0.3513	0.14
46	-1.587	0.57	-1.158	0.59
47	0.7880	0.14	1.162	0.14
48	1.469	0.15	1.732	0.14
49	1.365	0.23	1.462	0.19

(continued)

	22.03b		22.03d5	
index	estimate	std. dev.	estimate	std. dev.
50	–	–	0.05030	0.44

Table 28. TCSAM02 models final values for parameters related to the probability of terminal molt. Index corresponds to 5-mm size bin starting at 50 mm CW for females and 60 mm CW for males.

			22.03b		22.03d5
label	index	estimate	std. dev.	estimate	std. dev.
females 50-105 mmCW (entire model period)	1	-5.425	1.2	-5.302	1.2
	2	-4.159	0.57	-4.084	0.56
	3	-2.931	0.25	-2.895	0.25
	4	-1.711	0.15	-1.682	0.15
	5	-0.5840	0.091	-0.5442	0.090
	6	0.2544	0.091	0.2982	0.091
	7	0.5724	0.10	0.6017	0.10
	8	1.063	0.14	1.094	0.14
	9	1.949	0.23	2.001	0.23
	10	2.904	0.44	2.961	0.46
	11	3.922	1.0	3.964	1.0
males 60-150 mmCW (entire model period)	1	-2.988	0.21	-3.162	0.21
	2	-3.561	0.30	-3.722	0.31
	3	-3.016	0.25	-3.164	0.26
	4	-2.139	0.13	-2.230	0.13
	5	-1.342	0.11	-1.564	0.12
	6	-1.236	0.10	-1.313	0.10
	7	-0.7567	0.096	-0.7913	0.095
	8	-0.2357	0.086	-0.2803	0.086
	9	-0.2080	0.088	-0.1960	0.088
	10	0.1413	0.089	0.1521	0.088
	11	0.5439	0.094	0.5834	0.094
	12	1.020	0.12	1.088	0.12
	13	1.620	0.14	1.682	0.14
	14	2.640	0.26	2.706	0.26
	15	3.129	0.28	3.147	0.28
	16	3.715	0.49	3.652	0.47
	17	4.786	1.1	4.665	1.1

Table 29. TCSAM02 models final values for non-vector parameters related to fisheries, surveys, and the Dirichlet-Multinomial likelihood. Parameters with values whose standard error is NA are fixed, not estimated.

				22.03b		22.03d5
process	name	label	estimate	std. dev.	estimate	std. dev.
fisheries	pDC2[1]	TCF: female offset	-2.757	0.21	-2.798	0.20
	pDC2[2]	SCF: female offset	-2.682	0.34	-2.670	0.34
	pDC2[3]	GTF: female offset	-1.045	0.097	-1.044	0.092
	pDC2[4]	RKF: female offset	-2.399	0.84	-2.418	0.84
	pHM[1]	handling mortality for pot fisheries	0.3210	NA	0.3210	NA
	pHM[2]	handling mortality for groundfish trawl fisheries	0.8000	NA	0.8000	NA
	pLgtRet[1]	TCF: logit-scale max retention (pre-1997)	14.90	NA	14.90	NA
	pLgtRet[2]	TCF: logit-scale max retention (2005-2009)	14.90	NA	14.90	NA
	pLgtRet[3]	TCF: logit-scale max retention (2013+)	14.90	NA	14.90	NA
	pLnC[1]	TCF: base capture rate, pre-1965 (=0.05)	-2.996	NA	-2.996	NA
	pLnC[2]	TCF: base capture rate, 1965+	-1.501	0.12	-1.500	0.12
	pLnC[3]	SCF: base capture rate, pre-1978 (=0.01)	-4.605	NA	-4.605	NA
	pLnC[4]	SCF: base capture rate, 1992+	-3.752	0.071	-3.730	0.068
	pLnC[5]	DUMMY CAPTURE RATE	-4.181	NA	-4.181	NA
	pLnC[6]	GTF: base capture rate, ALL YEARS	-5.008	0.060	-5.032	0.057
	pLnC[7]	RKF: base capture rate, pre-1953 (=0.02)	-3.912	NA	-3.912	NA
	pLnC[8]	RKF: base capture rate, 1992+	-4.750	0.11	-4.798	0.11
surveys	pQ[1]	NMFS trawl survey: males, 1975-1981	-0.7497	0.11	-0.7080	0.11
	pQ[2]	NMFS trawl survey: males, 1982+	-0.7258	0.052	-0.6834	0.048
	pQ[3]	NMFS trawl survey: females, 1975-1981	-1.155	0.14	-1.100	0.13
	pQ[4]	NMFS trawl survey: females, 1982+	-1.391	0.076	-1.301	0.071
	pQ[5]	BSFRF SBS	0.000	NA	0.000	NA
Dirichlet-Multinomial	pLnDirMul[1]	ln(theta) parameter for BSFRF SBS M	0.9312	0.25	10.68	NA
	pLnDirMul[2]	ln(theta) parameter for BSFRF SBS F	2.523	0.24	10.99	NA

Table 30. TCSAM02 models final values for fishing mortality "devs" for the directed fishery. The index starts in 1965 (or 1982 for models 22.07 and 22.08) and does not include years when the fishery was completely closed.

		22.03b		22.03d5
index	estimate	std. dev.	estimate	std. dev.
1	-1.302	0.88	-1.287	0.89
2	-1.093	0.73	-1.076	0.73
3	0.7475	0.66	0.7694	0.68
4	1.323	0.64	1.351	0.65
5	2.471	0.89	2.520	0.94
6	4.127	0.76	4.177	0.73
7	4.631	0.79	4.723	0.67
8	2.075	1.2	2.212	1.2
9	0.08760	0.35	0.1312	0.34
10	-0.2471	0.21	-0.2104	0.21
11	-0.1150	0.18	-0.07379	0.18
12	0.6381	0.18	0.6904	0.17
13	1.373	0.20	1.454	0.20
14	1.597	0.28	1.723	0.28
15	2.014	0.35	2.146	0.35
16	1.819	0.26	1.914	0.25
17	0.2080	0.15	0.2556	0.15
18	-0.9157	0.13	-0.8804	0.13
19	-2.341	0.13	-2.306	0.13
20	-1.027	0.14	-0.9879	0.14
21	-1.381	0.12	-1.346	0.12
22	-0.4222	0.12	-0.3883	0.12
23	0.7617	0.13	0.7957	0.12
24	1.518	0.13	1.563	0.13
25	1.828	0.16	1.907	0.16
26	2.157	0.17	2.235	0.17
27	1.711	0.17	1.787	0.17
28	0.9555	0.17	1.028	0.18
29	0.3663	0.17	0.4313	0.17
30	0.2977	0.22	0.3685	0.23
31	-2.362	0.13	-2.332	0.12
32	-1.744	0.13	-1.708	0.12
33	-1.921	0.12	-1.885	0.12
34	-2.079	0.12	-2.039	0.12
35	-2.104	0.15	-2.051	0.14
36	-1.953	0.13	-1.900	0.13
37	-0.6772	0.12	-0.6279	0.12
38	-0.3711	0.12	-0.3274	0.12
39	-2.076	0.12	-2.033	0.12
40	-1.917	0.12	-1.875	0.12
41	-2.119	0.13	-2.065	0.12
42	-2.448	0.13	-2.423	0.12
43	-2.090	0.13	-2.105	0.12
44	–	–	-2.256	0.12

Table 31. TCSAM02 models final values for fishing mortality "devs" for the snow crab fishery. The indices start in 1990.

		22.03b		22.03d5
index	estimate	std. dev.	estimate	std. dev.
1	1.500	0.20	1.495	0.20
2	1.748	0.20	1.745	0.20
3	0.7377	0.19	0.7345	0.19
4	1.121	0.18	1.119	0.18
5	0.5481	0.18	0.5489	0.18
6	0.4713	0.19	0.4753	0.19
7	1.312	0.20	1.321	0.20
8	1.082	0.21	1.083	0.21
9	0.1489	0.20	0.1492	0.20
10	-1.460	0.21	-1.462	0.21
11	-0.7120	0.21	-0.7177	0.21
12	-0.2581	0.21	-0.2641	0.21
13	-1.543	0.21	-1.550	0.21
14	-2.660	0.24	-2.667	0.24
15	-1.971	0.19	-1.979	0.19
16	-0.009352	0.20	-0.01337	0.20
17	0.1356	0.19	0.1315	0.19
18	0.1713	0.19	0.1683	0.19
19	-0.4576	0.20	-0.4585	0.20
20	-0.07353	0.20	-0.07280	0.20
21	0.02648	0.20	0.03084	0.20
22	0.5734	0.20	0.5841	0.20
23	0.2741	0.20	0.2875	0.20
24	0.2001	0.20	0.2125	0.20
25	1.038	0.19	1.043	0.19
26	0.8372	0.19	0.8413	0.19
27	0.6638	0.20	0.6668	0.20
28	0.04276	0.20	0.04418	0.20
29	0.04770	0.20	0.05323	0.20
30	0.3588	0.20	0.3750	0.20
31	-1.622	0.21	-1.620	0.21
32	-2.272	0.23	-2.304	0.23

Table 32. TCSAM02 models final values for fishing mortality "devs" for the BBRKC fishery. The indices start in 1990.

		22.03b		22.03d5
index	estimate	std. dev.	estimate	std. dev.
1	3.773	0.23	3.875	0.23
2	3.451	0.24	3.567	0.25
3	3.243	0.25	3.359	0.25
4	4.164	0.23	4.269	0.23
5	2.205	0.24	2.316	0.24
6	0.9511	0.26	1.041	0.26
7	0.7002	0.26	0.7882	0.27
8	0.2824	0.27	0.3673	0.28
9	0.06274	0.28	0.1436	0.28
10	-0.5299	0.34	-0.4514	0.35
11	-0.3393	0.28	-0.2595	0.28
12	-0.6368	0.29	-0.5569	0.29
13	-0.9578	0.30	-0.8766	0.30
14	-1.319	0.33	-1.232	0.33
15	-1.817	0.43	-1.727	0.43
16	-1.271	0.26	-1.181	0.26
17	0.1124	0.22	0.2055	0.22
18	-0.3592	0.22	-0.2631	0.22
19	-2.025	0.41	-1.925	0.42
20	-2.468	0.69	-2.363	0.70
21	-1.431	0.32	-1.322	0.33
22	-0.3982	0.23	-0.2892	0.23
23	0.2625	0.22	0.3700	0.22
24	-0.1473	0.22	-0.04319	0.22
25	-0.1820	0.22	-0.08059	0.22
26	0.03261	0.22	0.1336	0.22
27	-0.6683	0.25	-0.5653	0.25
28	-1.897	0.68	-1.786	0.68
29	-2.793	1.3	-2.678	1.3
30	–	–	-2.836	1.1

Table 33. TCSAM02 models final values for fishing mortality “devs” vectors for the groundfish fisheries. Indices start in 1973.

	22.03b		22.03d5	
index	estimate	std. dev.	estimate	std. dev.
1	1.495	0.23	1.599	0.17
2	1.829	0.21	1.831	0.16
3	0.9887	0.21	1.018	0.15
4	0.4594	0.21	0.6122	0.15
5	0.1311	0.21	0.2508	0.15
6	-0.1531	0.21	0.04728	0.15
7	0.4365	0.21	0.5368	0.16
8	0.07031	0.21	0.05682	0.16
9	-0.1028	0.20	-0.01527	0.15
10	-1.036	0.20	-0.8601	0.15
11	-0.3013	0.20	-0.3805	0.15
12	-0.02304	0.21	-0.08338	0.15
13	-0.5094	0.20	-0.4822	0.15
14	-0.2439	0.20	-0.2927	0.15
15	-0.3566	0.20	-0.4426	0.15
16	-0.8523	0.20	-0.9339	0.15
17	-0.5638	0.20	-0.5198	0.15
18	-0.1902	0.20	-0.1114	0.15
19	0.6432	0.15	0.6683	0.15
20	0.9007	0.15	0.9291	0.15
21	0.6129	0.15	0.6450	0.15
22	1.046	0.15	1.083	0.15
23	0.9548	0.15	0.9958	0.15
24	1.130	0.15	1.174	0.15
25	1.583	0.15	1.614	0.15
26	1.445	0.15	1.475	0.15
27	0.9188	0.15	0.9467	0.15
28	0.9573	0.15	0.9828	0.15
29	1.180	0.15	1.206	0.15
30	0.4750	0.15	0.4999	0.15
31	-0.06963	0.15	-0.04478	0.15
32	0.2206	0.15	0.2464	0.15
33	-0.1107	0.15	-0.08458	0.15
34	-0.1376	0.15	-0.1111	0.15
35	-0.04778	0.15	-0.02027	0.15
36	-0.3839	0.15	-0.3534	0.14
37	-0.7573	0.14	-0.7209	0.14
38	-1.095	0.14	-1.053	0.14
39	-0.7880	0.14	-0.7442	0.14
40	-1.269	0.15	-1.228	0.14
41	-0.7032	0.15	-0.6683	0.14
42	-0.6180	0.15	-0.5856	0.14
43	-0.7509	0.14	-0.7171	0.14
44	-0.6526	0.14	-0.6185	0.14
45	-1.218	0.14	-1.181	0.14
46	-0.9073	0.14	-0.8748	0.14
47	-0.7780	0.15	-0.7521	0.14
48	-0.8471	0.15	-0.8464	0.15
49	-0.8609	0.15	-0.9053	0.15

(continued)

		22.03b		22.03d5
index	estimate	std. dev.	estimate	std. dev.
50	-1.150	0.15	-1.254	0.15
51	–	–	-1.530	0.15

Table 34. TCSAM02 models final values for the “pS1” parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			22.03b		22.03d5
name	label	estimate	std. dev.	estimate	std. dev.
pS1[1]	size at 1 for NMFS survey selectivity (males, pre-1982)	179.0	NA	179.0	NA
pS1[10]	ascending z-at-1 for SCF selectivity (males, pre-1997)	160.1	2.8	160.3	2.4
pS1[11]	ascending z-at-1 for SCF selectivity (males, 1997-2004)	119.3	6.9	119.7	7.0
pS1[12]	ascending z-at-1 for SCF selectivity (males, 2005+)	125.0	1.3	125.3	1.3
pS1[13]	ascending z50 for SCF selectivity (females, pre-1997)	81.08	7.1	81.28	6.8
pS1[14]	ascending z50 for SCF selectivity (females, 1997-2004)	72.69	4.4	72.85	4.3
pS1[15]	ascending z50 for SCF selectivity (females, 2005+)	101.6	8.8	100.9	8.5
pS1[16]	z50 for GF.AllGear selectivity (males, pre-1987)	61.28	3.5	61.74	3.1
pS1[17]	z50 for GF.AllGear selectivity (males, 1987-1996)	72.57	6.9	72.50	6.5
pS1[18]	z50 for GF.AllGear selectivity (males, 1997+)	98.51	2.6	97.24	2.5
pS1[19]	z50 for GF.AllGear selectivity (females, pre-1987)	43.48	1.8	44.57	1.9
pS1[2]	size at 1 for NMFS survey selectivity (males, 1982+)	179.0	NA	179.0	NA
pS1[20]	z50 for GF.AllGear selectivity (females, 1987-1996)	40.25	2.2	41.39	2.4
pS1[21]	z50 for GF.AllGear selectivity (females, 1997+)	87.48	3.2	86.28	3.0
pS1[22]	size at 1 for RKF selectivity (males, pre-1997)	179.9	NA	179.9	NA
pS1[23]	size at 1 for RKF selectivity (males, 1997-2004)	179.9	NA	179.9	NA
pS1[24]	size at 1 for RKF selectivity (males, 2005+)	179.9	NA	179.9	NA
pS1[25]	size at 1 for RKF selectivity (females, pre-1997)	139.9	NA	139.9	NA
pS1[26]	size at 1 for RKF selectivity (females, 1997-2004)	137.1	40.	136.2	39.
pS1[27]	size at 1 for RKF selectivity (females, 2005+)	135.2	23.	134.8	22.
pS1[28]	z50 for TCF retention (2005-2009)	137.6	0.28	137.6	0.28
pS1[29]	z50 for TCF retention (2013+)	125.1	0.81	125.1	0.78
pS1[3]	size at 1 for NMFS survey selectivity (females, pre-1982)	129.9	NA	129.9	NA
pS1[4]	size at 1 for NMFS survey selectivity (females, 1982+)	129.9	NA	129.9	NA
pS1[5]	z50 for TCF retention (pre-1991)	139.0	0.67	139.1	0.66
pS1[6]	z50 for TCF retention (1991-1996)	138.6	1.2	138.5	1.2
pS1[7]	DUMMY VALUE	4.500	NA	4.500	NA
pS1[8]	ln(z50) for TCF selectivity (males)	4.839	0.0062	4.838	0.0059
pS1[9]	z50 for TCF selectivity (females)	92.89	2.3	92.90	2.2

Table 35. TCSAM02 models final values for the "pS2" parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			22.03b		22.03d5
name	label	estimate	std. dev.	estimate	std. dev.
pS2[1]	width for NMFS survey selectivity (males, pre-1982)	65.69	2.5	64.18	2.2
pS2[10]	ascending width for SCF selectivity (males, pre-1997)	32.62	1.6	32.65	1.5
pS2[11]	ascending width for SCF selectivity (males, 1997-2004)	15.90	3.5	16.14	3.5
pS2[12]	ascending width for SCF selectivity (males, 2005+)	14.54	0.70	14.71	0.70
pS2[13]	slope for SCF selectivity (females, pre-1997)	0.1345	0.067	0.1371	0.065
pS2[14]	slope for SCF selectivity (females, 1997-2004)	0.3180	0.24	0.3171	0.23
pS2[15]	slope for SCF selectivity (females, 2005+)	0.09552	0.023	0.09882	0.024
pS2[16]	slope for GF.AllGear selectivity (males, pre-1987)	0.08671	0.011	0.08943	0.010
pS2[17]	slope for GF.AllGear selectivity (males, 1987-1996)	0.04363	0.0069	0.04668	0.0073
pS2[18]	slope for GF.AllGear selectivity (males, 1997+)	0.05839	0.0024	0.06058	0.0025
pS2[19]	slope for GF.AllGear selectivity (females, pre-1987)	0.1356	0.020	0.1343	0.019
pS2[2]	width for NMFS survey selectivity (males, 1982+)	90.17	3.0	84.99	2.4
pS2[20]	slope for GF.AllGear selectivity (females, 1987-1996)	0.1649	0.054	0.1563	0.049
pS2[21]	slope for GF.AllGear selectivity (females, 1997+)	0.06409	0.0042	0.06774	0.0042
pS2[22]	width for RKF selectivity (males, pre-1997)	19.87	0.80	19.73	0.79
pS2[23]	width for RKF selectivity (males, 1997-2004)	27.79	2.1	27.71	2.1
pS2[24]	width for RKF selectivity (males, 2005+)	27.34	0.97	27.20	0.95
pS2[25]	width for RKF selectivity (males, pre-1997)	17.99	2.4	17.95	2.3
pS2[26]	width for RKF selectivity (males, 1997-2004)	19.09	15.	18.79	15.
pS2[27]	width for RKF selectivity (males, 2005+)	18.05	7.9	17.87	7.8
pS2[28]	slope for TCF retention (2005-2009)	1.990	NA	1.990	NA
pS2[29]	slope for TCF retention (2013+)	0.3345	0.070	0.3312	0.066
pS2[3]	width for NMFS survey selectivity (females, pre-1982)	41.58	2.3	40.39	2.1
pS2[4]	width for NMFS survey selectivity (females, 1982+)	84.76	7.4	73.17	4.6
pS2[5]	slope for TCF retention (pre-1991)	0.7107	0.19	0.6959	0.17
pS2[6]	slope for TCF retention (1997+)	1.003	0.73	1.004	0.74
pS2[7]	slope for TCF selectivity (males, pre-1997)	0.1216	0.0067	0.1212	0.0066
pS2[8]	slope for TCF selectivity (males, 1997+)	0.1718	0.0074	0.1730	0.0071
pS2[9]	slope for TCF selectivity (females)	0.1935	0.025	0.1961	0.025

Table 36. TCSAM02 models final values for the “pS3” and “pS4” parameters related to selectivity functions. Parameters with values whose standard error is NA are fixed, not estimated.

			22.03b		22.03d5
name	label	estimate	std. dev.	estimate	std. dev.
pS3[1]	scaled increment for descending z-at-1 for SCF selectivity (males, pre-1997)	0.001000	NA	0.001000	NA
pS3[2]	scaled increment for descending z-at-1 for SCF selectivity (males, 1997-2004)	0.001000	NA	0.001000	NA
pS3[3]	scaled increment for descending z-at-1 for SCF selectivity (males, 2005+)	0.001000	NA	0.001000	NA
pS4[1]	descending width for SCF selectivity (males, pre-1997)	1.100	NA	1.100	NA
pS4[2]	descending width for SCF selectivity (males, 1997-2004)	19.93	9.3	19.82	9.4
pS4[3]	descending width for SCF selectivity (males, 2005+)	13.26	1.3	13.17	1.4

Table 37. TCSAM02 models final values for the devs parameters related to selectivity in the directed fishery. Parameters with values whose standard error is NA are fixed, not estimated.

	22.03b		22.03d5	
index	estimate	std. dev.	estimate	std. dev.
1	0.1072	0.014	0.1138	0.014
2	0.08506	0.014	0.09158	0.014
3	0.1236	0.013	0.1297	0.013
4	0.1242	0.018	0.1305	0.018
5	0.09926	0.021	0.1058	0.021
6	0.2029	0.021	0.2069	0.021
7	-0.02991	0.014	-0.02782	0.013
8	-0.01494	0.013	-0.01218	0.013
9	-0.08091	0.013	-0.07863	0.013
10	0.03598	0.011	0.03836	0.011
11	0.1523	0.011	0.1548	0.011
12	-0.009697	0.014	-0.007004	0.014
13	-0.06388	0.012	-0.06034	0.012
14	-0.09887	0.014	-0.09504	0.013
15	-0.06597	0.015	-0.06247	0.015
16	-0.1108	0.014	-0.1084	0.014
17	-0.1649	0.016	-0.1602	0.016
18	-0.1523	0.014	-0.1472	0.014
19	-0.1383	0.013	-0.1325	0.013
20	–	–	-0.07948	0.013

Table 38. Assumed size-specific availability for males in the 2013 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0553	0.0016
32	0.0579	0.0034
37	0.0606	0.0064
42	0.0635	0.0106
47	0.0667	0.0140
52	0.0703	0.0155
57	0.0744	0.0166
62	0.0791	0.0198
67	0.0848	0.0286
72	0.0915	0.0447
77	0.0994	0.0662
82	0.1087	0.0830
87	0.1199	0.0899
92	0.1333	0.0932
97	0.1497	0.1021
102	0.1696	0.1241
107	0.1936	0.1582
112	0.2218	0.1987
117	0.2543	0.2347
122	0.2902	0.2644
127	0.3276	0.2946
132	0.3634	0.3348
137	0.3927	0.3855
142	0.4076	0.4278
147	0.4007	0.4395
152	0.3692	0.4035
157	0.3213	0.3304
162	0.2681	0.2444
167	0.2174	0.1681
172	0.1733	–
177	0.1366	–
182	0.1070	–

Table 39. Assumed size-specific availability for males in the 2014 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0217	0.0029
32	0.0248	0.0067
37	0.0283	0.0137
42	0.0324	0.0223
47	0.0370	0.0266
52	0.0424	0.0245
57	0.0485	0.0211
62	0.0558	0.0207
67	0.0642	0.0259
72	0.0740	0.0378
77	0.0856	0.0559
82	0.0993	0.0746
87	0.1152	0.0903
92	0.1338	0.1075
97	0.1553	0.1357
102	0.1797	0.1836
107	0.2074	0.2426
112	0.2382	0.2874
117	0.2723	0.2900
122	0.3097	0.2684
127	0.3508	0.2605
132	0.3959	0.3031
137	0.4441	0.4152
142	0.4909	0.5515
147	0.5300	0.6403
152	0.5550	0.6409
157	0.5660	0.5801
162	0.5665	0.5049
167	0.5608	0.4691
172	0.5518	0.4924
177	0.5410	0.5563

Table 40. Assumed size-specific availability for males in the 2015 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0204	0.0132
32	0.0252	0.0285
37	0.0311	0.0531
42	0.0383	0.0751
47	0.0470	0.0730
52	0.0576	0.0537
57	0.0704	0.0396
62	0.0864	0.0396
67	0.1061	0.0626
72	0.1281	0.1206
77	0.1495	0.2060
82	0.1659	0.2520
87	0.1751	0.2324
92	0.1777	0.1880
97	0.1757	0.1563
102	0.1715	0.1490
107	0.1679	0.1548
112	0.1677	0.1630
117	0.1736	0.1635
122	0.1873	0.1615
127	0.2109	0.1695
132	0.2479	0.2030
137	0.3015	0.2746
142	0.3688	0.3749
147	0.4411	0.4728
152	0.5020	0.5325
157	0.5353	0.5471
162	0.5288	0.5204
167	0.4785	0.4558
172	0.3993	0.3634
177	0.3154	–
182	0.2423	–

Table 41. Assumed size-specific availability for males in the 2016 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0003	0.1199
32	0.0008	0.1093
37	0.0022	0.1018
42	0.0059	0.0993
47	0.0149	0.1037
52	0.0354	0.1172
57	0.0755	0.1424
62	0.1399	0.1844
67	0.2200	0.2470
72	0.2982	0.3193
77	0.3565	0.3769
82	0.3851	0.3943
87	0.3895	0.3788
92	0.3851	0.3590
97	0.3886	0.3628
102	0.4087	0.4018
107	0.4363	0.4538
112	0.4579	0.4880
117	0.4593	0.4780
122	0.4420	0.4357
127	0.4158	0.3916
132	0.3895	0.3737
137	0.3702	0.3895
142	0.3634	0.4177
147	0.3751	0.4336
152	0.4127	0.4188
157	0.4785	0.3959
162	0.5731	0.4003
167	0.6952	0.4680
172	0.8448	0.6084

Table 42. Assumed size-specific availability for males in the 2017 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.3022	0.3115
32	0.3438	0.3168
37	0.3929	0.3344
42	0.4536	0.3783
47	0.5308	0.4641
52	0.6163	0.5751
57	0.6806	0.6624
62	0.6844	0.6895
67	0.6168	0.6434
72	0.5299	0.5548
77	0.4680	0.4752
82	0.4554	0.4571
87	0.4842	0.4970
92	0.5309	0.5573
97	0.5659	0.5996
102	0.5696	0.6051
107	0.5588	0.5904
112	0.5560	0.5753
117	0.5797	0.5777
122	0.6195	0.5936
127	0.6464	0.6081
132	0.6277	0.6073
137	0.5651	0.5830
142	0.5026	0.5361
147	0.4737	0.4692
152	0.4601	0.3901
157	0.2592	0.3220
162	0.0394	0.2859
167	0.0008	0.2972
172	0.0000	0.3629

Table 43. Assumed size-specific availability for males in the 2018 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03d5
27	0.5152
32	0.4294
37	0.3628
42	0.3297
47	0.3405
52	0.3925
57	0.4693
62	0.5477
67	0.6080
72	0.6502
77	0.6780
82	0.6951
87	0.7031
92	0.7025
97	0.6934
102	0.6773
107	0.6596
112	0.6472
117	0.6458
122	0.6518
127	0.6575
132	0.6551
137	0.6407
142	0.6167
147	0.5859
152	0.5511
157	0.5115
162	0.4652
167	0.4110

Table 44. Assumed size-specific availability for females in the 2013 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0163	0.0018
32	0.0166	0.0060
37	0.0169	0.0120
42	0.0170	0.0106
47	0.0171	0.0074
52	0.0176	0.0088
57	0.0186	0.0134
62	0.0206	0.0133
67	0.0251	0.0107
72	0.0355	0.0149
77	0.0557	0.0365
82	0.0864	0.0854
87	0.1304	0.1483
92	0.2141	0.2262
97	0.3845	0.3582
102	0.6400	0.6181
107	0.8178	0.8293
112	0.6568	0.7130

Table 45. Assumed size-specific availability for females in the 2014 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0151	0.0029
32	0.0185	0.0060
37	0.0225	0.0115
42	0.0269	0.0191
47	0.0315	0.0274
52	0.0361	0.0348
57	0.0393	0.0381
62	0.0395	0.0354
67	0.0376	0.0301
72	0.0357	0.0274
77	0.0355	0.0285
82	0.0383	0.0338
87	0.0486	0.0467
92	0.0826	0.0791
97	0.1815	0.1597
102	0.3785	0.3290
107	0.5978	0.5771
112	0.7107	0.7928

Table 46. Assumed size-specific availability for females in the 2015 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0102	0.0069
32	0.0147	0.0130
37	0.0208	0.0231
42	0.0282	0.0367
47	0.0356	0.0509
52	0.0402	0.0603
57	0.0408	0.0587
62	0.0380	0.0450
67	0.0344	0.0329
72	0.0326	0.0318
77	0.0337	0.0405
82	0.0380	0.0502
87	0.0493	0.0577
92	0.0816	0.0769
97	0.1702	0.1385
102	0.3622	0.3236
107	0.6583	0.6810
112	0.9415	0.9184
117	1.0000	0.9830
122	0.9901	0.9965

Table 47. Assumed size-specific availability for females in the 2016 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.0000	0.0884
32	0.0000	0.0968
37	0.0117	0.0990
42	0.1017	0.0928
47	0.1102	0.1013
52	0.1390	0.1615
57	0.2271	0.2385
62	0.2123	0.1869
67	0.1391	0.1088
72	0.1454	0.1327
77	0.2528	0.2892
82	0.3893	0.4083
87	0.4249	0.3735
92	0.4314	0.4010
97	0.4860	0.5593
102	0.5985	0.6279
107	0.7664	0.6548
112	0.9329	0.9615
117	1.0000	1.0000

Table 48. Assumed size-specific availability for females in the 2017 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03b	22.03d5
27	0.4480	0.3872
32	0.4225	0.3874
37	0.4358	0.4087
42	0.5208	0.4673
47	0.6392	0.5433
52	0.6865	0.6023
57	0.6556	0.6215
62	0.6137	0.5882
67	0.6057	0.5459
72	0.6628	0.5744
77	0.7555	0.6502
82	0.7682	0.6721
87	0.6891	0.6216
92	0.6363	0.5617
97	0.5586	0.4806
102	0.2931	0.2508
107	0.0205	0.0449
112	0.0000	–
117	0.0000	–

Table 49. Assumed size-specific availability for females in the 2018 BSFRF SBS survey. The value for size (in mm CW) indicates the midpoint of the associated size bin. The availability curves were estimated outside the models.

size	22.03d5
27	0.4296
32	0.4682
37	0.4691
42	0.4106
47	0.3615
52	0.4007
57	0.5163
62	0.6394
67	0.7253
72	0.7670
77	0.7873
82	0.8195
87	0.8582
92	0.8751
97	0.8634
102	0.8311
107	0.7842
112	0.7273

Table 58. Estimated rates of natural mortality (period of elevated M is 1980-1984).

	immature				mature
	all		female		male
case	typical	typical	elevated	typical	elevated
22.03b	0.237	0.309	0.607	0.310	0.728
22.03d5	0.254	0.316	0.619	0.320	0.744

Table 50. Objective function data component values for TCSAM02 models 22.03b, 22.03d5. Table 1 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03b	22.03d5
surveys data	NMFS M	index catch	abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	79.29	91.38
			n.at.z	male	415.48	424.54
	NMFS F		abundance	female	–	–
				male	–	–
			biomass	female	165.61	178.95
				male	–	–
			n.at.z	female	299.20	308.84
	SBS BSFRF M		abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	-0.81	-2.85
			n.at.z	male	290.59	280.00
	SBS BSFRF F		abundance	female	–	–
				male	–	–
			biomass	female	-0.19	1.17
				male	–	–

Table 51. Objective function data component values for TCSAM02 models 22.03b, 22.03d5. Table 2 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03b	22.03d5
surveys data	SBS BSFRF F	index catch	n.at.z	female	232.90	173.22
fisheries data	TCF	retained catch	abundance	female	–	–
				male	–	–
			biomass	female	–	–
				male	-147.65	-151.91
			n.at.z	male	66.94	67.75
		total catch	abundance	all sexes	–	–
			biomass	all sexes	4.79	3.50
			n.at.z	female	91.38	94.86
				male	93.48	92.85
	SCF		abundance	all sexes	–	–
			biomass	all sexes	-52.25	-52.26
			n.at.z	female	52.39	52.43
				male	80.30	81.03
	GF All		abundance	all sexes	-39.43	-67.88
			biomass	all sexes	-70.21	-69.41
			n.at.z	female	224.62	228.67
				male	307.29	321.13
	RKF		abundance	all sexes	–	–

Table 52. Objective function data component values for TCSAM02 models 22.03b, 22.03d5. Table 3 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries. Components not included in the objective function are indicated by "–".

category	fleet	catch type	data type	sex	22.03b	22.03d5
fisheries data	RKF	total catch	biomass	all sexes	-37.08	-36.92
			n.at.z	female	6.88	6.93
				male	31.47	31.94
growth data			EBS molt increment data	female	246.16	247.52
				male	280.00	280.21
maturity ogive data	NMFS M		EBS mature male ratios	male	255.63	325.54

Table 53. Objective function non-data component values for TCSAM02 models 22.03b, 22.03d5. Table 1 of 1. Abbreviations: devsSumSq: sum of squared annual deviations ("devs"); pDevsLnC: fishery capture probablity devs; pDevsLnR: recruitment devs; pDevsM: natural mortality devs; pDevsS1: selectivity deviations; pDM1: natural mortality multiplier; pQ: survey catchability. Components not included in the objective function are indicated by "–".

category	type	element	22.03b	22.03d5
penalties	devsSumSq	pDevsLnC	0.000	0.000
		pDevsLnR	0.000	0.000
		pDevsS1	0.000	0.000
	maturity	smoothness	2.090	1.982
priors	natural mortality	pDM1	41.676	54.188
	recruitment	pDevsLnR	115.363	116.728
	surveys	pQ	106.871	97.878

Table 54. Differences between objective function data component values for 22.03d5 relative to 22.03b. Negative values indicate better fits. Table 1 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b	22.03d5
surveys data	NMFS M	index catch	abundance	female	0.000	0.000
				male	0.000	0.000
			biomass	female	0.000	0.000
				male	79.289	12.092
			n.at.z	male	415.477	9.066
	NMFS F		abundance	female	0.000	0.000
				male	0.000	0.000
			biomass	female	165.612	13.338
				male	0.000	0.000
			n.at.z	female	299.199	9.642
	SBS BSFRF M		abundance	female	0.000	0.000
				male	0.000	0.000
			biomass	female	0.000	0.000
				male	-0.814	-2.037
			n.at.z	male	290.592	-10.594
	SBS BSFRF F		abundance	female	0.000	0.000
				male	0.000	0.000
			biomass	female	-0.185	1.355
				male	0.000	0.000

Table 55. Differences between objective function data component values for 22.03d5 relative to 22.03b. Negative values indicate better fits. Table 2 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b	22.03d5
surveys data	SBS BSFRF F	index catch	n.at.z	female	232.897	-59.678
fisheries data	TCF	retained catch	abundance	female	0.000	0.000
				male	0.000	0.000
			biomass	female	0.000	0.000
				male	-147.653	-4.256
			n.at.z	male	66.936	0.812
		total catch	abundance	all sexes	0.000	0.000
			biomass	all sexes	4.793	-1.294
			n.at.z	female	91.380	3.484
				male	93.482	-0.632
	SCF		abundance	all sexes	0.000	0.000
			biomass	all sexes	-52.247	-0.010
			n.at.z	female	52.392	0.035
				male	80.300	0.729
	GF All		abundance	all sexes	-39.433	-28.449
			biomass	all sexes	-70.213	0.802
			n.at.z	female	224.620	4.052
				male	307.289	13.836
	RKF		abundance	all sexes	0.000	0.000

Table 56. Differences between objective function data component values for 22.03d5 relative to 22.03b. Negative values indicate better fits. Table 3 of 3. Abbreviations: n.at.z: size composition data; M: males only; F: females only; NMFS: NMFS EBS shelf survey; SBS BSFRF: BSFRF side-by-side catchability study survey; TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: combined groundfish fisheries.

category	fleet	catch type	data type	sex	22.03b	22.03d5
fisheries data	RKF	total catch	biomass	all sexes	-37.077	0.162
			n.at.z	female	6.876	0.056
				male	31.474	0.464
growth data			EBS molt increment data	female	246.159	1.356
				male	279.997	0.214
maturity ogive data	NMFS M		EBS mature male ratios	male	255.629	69.912

Table 57. Differences between objective function non-data component values for 22.03d5 relative to 22.03b. Negative values indicate better fits. Table 1 of 1. Abbreviations: devsSumSq: sum of squared annual deviations (“devs”); pDevsLnC: fishery capture probablity devs; pDevsLnR: recruitment devs; pDevsM: natural mortality devs; pDevsS1: selectivity deviations; pDM1: natural mortality multiplier; pQ: survey catchability.

category	type	element	22.03b	22.03d5
penalties	devsSumSq	pDevsLnC	0.000	0.000
		pDevsLnR	0.000	0.000
		pDevsS1	0.000	0.000
	maturity	smoothness	2.090	-0.107
priors	natural mortality	pDM1	41.676	12.512
	recruitment	pDevsLnR	115.363	1.365
	surveys	pQ	106.871	-8.993

Table 59. Estimated fully-selected survey catchability. The year indicates the start of the time block in which the value is used.

	NMFS F		NMFS M		SBS BSFRF F	SBS BSFRF M
	female		male		female	male
case	1975	1982	1975	1982	2013	2013
22.03b	0.32	0.25	0.47	0.48	1.00	1.00
22.03d5	0.33	0.27	0.49	0.50	1.00	1.00

Table 60. Estimated retained catch abundance (millions; 1965-1989).

y	22.03b	22.03d5
1965	1.9	1.9
1966	2.4	2.4
1967	13.3	13.3
1968	17.7	17.7
1969	27.6	27.7
1970	26.5	26.5
1971	22.1	22.2
1972	17.8	17.9
1973	12.6	12.7
1974	14.2	14.2
1975	16.4	16.4
1976	27.3	27.2
1977	33.1	33.1
1978	21.0	21.1
1979	18.3	18.2
1980	13.7	13.7
1981	5.0	5.0
1982	2.3	2.3
1983	0.5	0.5
1984	1.4	1.4
1987	1.0	1.0
1988	3.1	3.1
1989	10.6	10.6

Table 61. Estimated retained catch abundance (millions; 1990+).

y	22.03b	22.03d5
1990	17.3	17.3
1991	13.7	13.7
1992	15.5	15.5
1993	7.3	7.3
1994	3.4	3.4
1995	1.9	1.9
1996	0.7	0.7
2005	0.4	0.4
2006	0.9	0.9
2007	0.9	0.9
2008	0.9	0.9
2009	0.5	0.5
2013	1.5	1.5
2014	7.5	7.5
2015	10.7	10.7
2017	1.3	1.3
2018	1.3	1.3
2020	0.8	0.8
2021	0.6	0.6
2022	1.1	1.1
2023	–	1.1

Table 62. Estimated retained catch biomass (1,000's t; 1965-1989).

y	22.03b	22.03d5
1965	1.9	1.9
1966	2.4	2.4
1967	13.6	13.6
1968	18.0	18.0
1969	27.4	27.4
1970	25.3	25.4
1971	20.4	20.4
1972	16.4	16.4
1973	12.7	12.7
1974	14.6	14.5
1975	17.0	17.0
1976	28.1	28.1
1977	33.8	33.7
1978	21.1	21.1
1979	18.1	17.9
1980	13.4	13.4
1981	5.0	5.0
1982	2.4	2.4
1983	0.5	0.5
1984	1.4	1.4
1987	1.0	1.0
1988	3.2	3.2
1989	10.9	10.9

Table 63. Estimated retained catch biomass (1,000's t; 1990+).

y	22.03b	22.03d5
1990	17.6	17.5
1991	14.1	14.1
1992	15.6	15.6
1993	7.6	7.6
1994	3.6	3.6
1995	1.9	1.9
1996	0.8	0.8
2005	0.4	0.4
2006	1.0	1.0
2007	1.0	1.0
2008	0.9	0.9
2009	0.6	0.6
2013	1.3	1.3
2014	6.2	6.2
2015	8.9	8.9
2017	1.1	1.1
2018	1.1	1.1
2020	0.7	0.7
2021	0.5	0.5
2022	0.9	0.9
2023	–	0.9

Table 64. Estimated discard catch mortality (abundance) in the directed fishery (millions; 1965-1989).

		22.03b		22.03d5
y	female	male	female	male
1965	0.10	1.14	0.10	1.18
1966	0.13	1.48	0.13	1.53
1967	0.90	9.66	0.86	10.05
1968	1.77	17.68	1.72	18.54
1969	6.51	54.49	6.50	58.43
1970	41.53	204.04	41.70	217.35
1971	86.41	306.34	90.04	331.44
1972	9.01	55.21	9.73	62.78
1973	1.50	12.44	1.46	12.97
1974	1.09	9.90	1.05	10.25
1975	1.13	10.49	1.09	10.89
1976	2.08	19.05	2.02	19.94
1977	3.67	31.33	3.66	33.53
1978	4.00	30.77	4.18	34.20
1979	5.85	41.65	6.17	46.32
1980	4.37	30.73	4.43	33.00
1981	0.75	5.87	0.72	6.08
1982	0.19	1.63	0.18	1.68
1983	0.03	0.27	0.03	0.28
1984	0.08	0.66	0.08	0.68
1987	0.07	0.63	0.06	0.66
1988	0.21	2.18	0.20	2.27
1989	0.79	8.16	0.76	8.53

Table 65. Estimated discard catch mortality in abundance in the directed fishery (millions; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.93	6.23	0.93	6.50
1991	1.41	4.21	1.41	4.22
1992	1.51	4.71	1.51	4.74
1993	0.93	2.36	0.93	2.36
1994	0.89	1.84	0.88	1.84
1995	0.62	1.34	0.62	1.33
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.76
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.64	0.10	0.64
2007	0.10	0.80	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.43
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.10	1.30	0.10	1.31
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.18
2021	0.04	0.22	0.04	0.23
2022	0.06	0.36	0.06	0.37
2023	–	–	0.04	0.17

Table 66. Estimated discard mortality (biomass) in the directed fishery (1,000's t; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.05	0.61	0.05	0.61
1966	0.06	0.68	0.06	0.69
1967	0.11	1.86	0.11	1.91
1968	0.17	2.98	0.17	3.09
1969	0.45	7.77	0.45	8.24
1970	2.29	23.97	2.30	25.24
1971	4.53	32.12	4.73	34.25
1972	0.62	7.63	0.66	8.50
1973	0.71	5.18	0.76	5.42
1974	0.86	6.42	0.83	6.29
1975	0.37	3.94	0.37	3.97
1976	0.29	4.49	0.30	4.69
1977	0.34	5.73	0.34	6.03
1978	0.33	5.07	0.35	5.54
1979	0.48	6.46	0.51	7.04
1980	0.35	4.88	0.35	5.10
1981	0.12	1.68	0.12	1.71
1982	0.04	0.60	0.04	0.62
1983	0.04	0.30	0.03	0.29
1984	0.03	0.38	0.03	0.37
1985	0.03	0.33	0.03	0.33
1986	0.04	0.51	0.04	0.50
1987	0.04	0.60	0.04	0.59
1988	0.04	0.80	0.04	0.81
1989	0.09	1.91	0.09	1.96

Table 67. Estimated discard mortality (biomass) in the directed fishery (1,000's t; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.168	3.455	0.167	3.586
1991	0.256	2.226	0.256	2.228
1992	0.291	2.578	0.291	2.594
1993	0.183	1.331	0.182	1.330
1994	0.150	0.864	0.148	0.863
1995	0.094	0.596	0.093	0.594
1996	0.070	0.408	0.069	0.409
1997	0.048	0.519	0.048	0.520
1998	0.033	0.313	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.277	0.027	0.277
2002	0.015	0.150	0.015	0.150
2003	0.010	0.101	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.313	0.015	0.313
2007	0.017	0.399	0.017	0.401
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.007	0.211	0.007	0.212
2011	0.009	0.290	0.009	0.290
2012	0.006	0.207	0.006	0.208
2013	0.010	0.240	0.010	0.240
2014	0.021	0.679	0.021	0.678
2015	0.022	0.666	0.021	0.669
2016	0.010	0.357	0.010	0.358
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.090	0.006	0.089
2022	0.008	0.151	0.008	0.150
2023	–	–	0.005	0.071

Table 68. Estimated discard catch mortality (abundance) in the snow crab fishery (millions; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.05	0.42	0.05	0.42
1966	0.06	0.45	0.06	0.45
1967	0.06	0.47	0.06	0.47
1968	0.07	0.49	0.07	0.49
1969	0.09	0.51	0.09	0.51
1970	0.12	0.48	0.12	0.48
1971	0.15	0.52	0.15	0.50
1972	0.18	0.82	0.18	0.79
1973	0.19	1.15	0.19	1.12
1974	0.18	1.23	0.17	1.20
1975	0.15	1.12	0.15	1.09
1976	0.13	0.94	0.13	0.91
1977	0.11	0.73	0.11	0.70
1978	0.21	1.14	0.21	1.13
1979	0.29	1.47	0.29	1.44
1980	0.45	2.30	0.45	2.27
1981	0.38	2.24	0.38	2.23
1982	0.17	1.13	0.17	1.13
1983	0.07	0.49	0.07	0.49
1984	0.11	0.71	0.11	0.71
1985	0.15	0.98	0.15	0.98
1986	0.21	1.34	0.20	1.35
1987	0.31	2.09	0.31	2.10
1988	0.32	2.32	0.32	2.35
1989	0.49	3.53	0.49	3.58

Table 69. Estimated discard catch mortality in abundance in the snow crab fishery (millions; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.93	6.23	0.93	6.50
1991	1.41	4.21	1.41	4.22
1992	1.51	4.71	1.51	4.74
1993	0.93	2.36	0.93	2.36
1994	0.89	1.84	0.88	1.84
1995	0.62	1.34	0.62	1.33
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.76
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.64	0.10	0.64
2007	0.10	0.80	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.43
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.10	1.30	0.10	1.31
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.18
2021	0.04	0.22	0.04	0.23
2022	0.06	0.36	0.06	0.37
2023	–	–	0.04	0.17

Table 70. Estimated discard mortality (biomass) in the snow crab fishery (1,000's t; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.05	0.61	0.05	0.61
1966	0.06	0.68	0.06	0.69
1967	0.11	1.86	0.11	1.91
1968	0.17	2.98	0.17	3.09
1969	0.45	7.77	0.45	8.24
1970	2.29	23.97	2.30	25.24
1971	4.53	32.12	4.73	34.25
1972	0.62	7.63	0.66	8.50
1973	0.71	5.18	0.76	5.42
1974	0.86	6.42	0.83	6.29
1975	0.37	3.94	0.37	3.97
1976	0.29	4.49	0.30	4.69
1977	0.34	5.73	0.34	6.03
1978	0.33	5.07	0.35	5.54
1979	0.48	6.46	0.51	7.04
1980	0.35	4.88	0.35	5.10
1981	0.12	1.68	0.12	1.71
1982	0.04	0.60	0.04	0.62
1983	0.04	0.30	0.03	0.29
1984	0.03	0.38	0.03	0.37
1985	0.03	0.33	0.03	0.33
1986	0.04	0.51	0.04	0.50
1987	0.04	0.60	0.04	0.59
1988	0.04	0.80	0.04	0.81
1989	0.09	1.91	0.09	1.96

Table 71. Estimated discard mortality (biomass) in the snow crab fishery (1,000's t; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.168	3.455	0.167	3.586
1991	0.256	2.226	0.256	2.228
1992	0.291	2.578	0.291	2.594
1993	0.183	1.331	0.182	1.330
1994	0.150	0.864	0.148	0.863
1995	0.094	0.596	0.093	0.594
1996	0.070	0.408	0.069	0.409
1997	0.048	0.519	0.048	0.520
1998	0.033	0.313	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.277	0.027	0.277
2002	0.015	0.150	0.015	0.150
2003	0.010	0.101	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.313	0.015	0.313
2007	0.017	0.399	0.017	0.401
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.007	0.211	0.007	0.212
2011	0.009	0.290	0.009	0.290
2012	0.006	0.207	0.006	0.208
2013	0.010	0.240	0.010	0.240
2014	0.021	0.679	0.021	0.678
2015	0.022	0.666	0.021	0.669
2016	0.010	0.357	0.010	0.358
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.090	0.006	0.089
2022	0.008	0.151	0.008	0.150
2023	–	–	0.005	0.071

Table 72. Estimated discard catch mortality (abundance) in the BBRKC fishery (millions; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.024	0.540	0.024	0.555
1966	0.025	0.564	0.026	0.579
1967	0.028	0.535	0.029	0.546
1968	0.042	0.581	0.043	0.590
1969	0.046	0.328	0.047	0.328
1970	0.051	0.101	0.052	0.099
1971	0.045	0.047	0.047	0.044
1972	0.103	0.391	0.105	0.368
1973	0.126	1.438	0.127	1.432
1974	0.149	2.419	0.149	2.429
1975	0.135	2.368	0.134	2.371
1976	0.186	2.952	0.184	2.923
1977	0.222	2.560	0.219	2.472
1978	0.171	1.298	0.169	1.215
1979	0.123	0.657	0.122	0.608
1980	0.193	1.031	0.192	0.980
1981	0.159	1.463	0.158	1.446
1982	0.035	0.513	0.035	0.516
1984	0.014	0.253	0.013	0.254
1985	0.009	0.173	0.009	0.174
1986	0.020	0.381	0.019	0.383
1987	0.028	0.527	0.028	0.530
1988	0.023	0.428	0.023	0.431
1989	0.037	0.647	0.037	0.652

Table 73. Estimated discard catch mortality in abundance in the BBRKC fishery (millions; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.93	6.23	0.93	6.50
1991	1.41	4.21	1.41	4.22
1992	1.51	4.71	1.51	4.74
1993	0.93	2.36	0.93	2.36
1994	0.89	1.84	0.88	1.84
1995	0.62	1.34	0.62	1.33
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.76
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.64	0.10	0.64
2007	0.10	0.80	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.43
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.10	1.30	0.10	1.31
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.18
2021	0.04	0.22	0.04	0.23
2022	0.06	0.36	0.06	0.37
2023	–	–	0.04	0.17

Table 74. Estimated discard mortality (biomass) in the BBRKC fishery (1,000's t; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.05	0.61	0.05	0.61
1966	0.06	0.68	0.06	0.69
1967	0.11	1.86	0.11	1.91
1968	0.17	2.98	0.17	3.09
1969	0.45	7.77	0.45	8.24
1970	2.29	23.97	2.30	25.24
1971	4.53	32.12	4.73	34.25
1972	0.62	7.63	0.66	8.50
1973	0.71	5.18	0.76	5.42
1974	0.86	6.42	0.83	6.29
1975	0.37	3.94	0.37	3.97
1976	0.29	4.49	0.30	4.69
1977	0.34	5.73	0.34	6.03
1978	0.33	5.07	0.35	5.54
1979	0.48	6.46	0.51	7.04
1980	0.35	4.88	0.35	5.10
1981	0.12	1.68	0.12	1.71
1982	0.04	0.60	0.04	0.62
1983	0.04	0.30	0.03	0.29
1984	0.03	0.38	0.03	0.37
1985	0.03	0.33	0.03	0.33
1986	0.04	0.51	0.04	0.50
1987	0.04	0.60	0.04	0.59
1988	0.04	0.80	0.04	0.81
1989	0.09	1.91	0.09	1.96

Table 75. Estimated discard mortality (biomass) in the BBRKC fishery (1,000's t; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.168	3.455	0.167	3.586
1991	0.256	2.226	0.256	2.228
1992	0.291	2.578	0.291	2.594
1993	0.183	1.331	0.182	1.330
1994	0.150	0.864	0.148	0.863
1995	0.094	0.596	0.093	0.594
1996	0.070	0.408	0.069	0.409
1997	0.048	0.519	0.048	0.520
1998	0.033	0.313	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.277	0.027	0.277
2002	0.015	0.150	0.015	0.150
2003	0.010	0.101	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.313	0.015	0.313
2007	0.017	0.399	0.017	0.401
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.007	0.211	0.007	0.212
2011	0.009	0.290	0.009	0.290
2012	0.006	0.207	0.006	0.208
2013	0.010	0.240	0.010	0.240
2014	0.021	0.679	0.021	0.678
2015	0.022	0.666	0.021	0.669
2016	0.010	0.357	0.010	0.358
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.090	0.006	0.089
2022	0.008	0.151	0.008	0.150
2023	–	–	0.005	0.071

Table 76. Estimated discard catch mortality (abundance) in the groundfish fisheries (millions; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	2.0	3.7	1.9	3.6
1966	2.3	4.3	2.3	4.2
1967	3.1	5.3	3.1	5.2
1968	4.4	6.9	4.3	6.8
1969	5.5	8.7	5.3	8.5
1970	6.0	9.9	5.9	9.6
1971	5.9	10.0	5.7	9.6
1972	5.3	9.9	5.1	9.5
1973	20.4	41.0	21.9	43.5
1974	24.1	49.8	23.4	47.8
1975	9.2	18.6	9.2	18.3
1976	5.5	10.1	6.1	11.2
1977	4.2	7.1	4.5	7.6
1978	3.1	5.4	3.7	6.3
1979	5.2	9.8	5.6	10.3
1980	2.8	5.6	2.7	5.3
1981	1.6	3.3	1.7	3.5
1982	0.5	0.9	0.5	1.0
1983	0.8	1.4	0.7	1.3
1984	1.1	1.7	1.0	1.5
1985	0.8	1.2	0.8	1.2
1986	1.2	2.0	1.1	1.8
1987	1.2	1.9	1.1	1.7
1988	0.8	1.2	0.7	1.1
1989	1.0	1.6	1.0	1.6

Table 77. Estimated discard catch mortality in abundance in the groundfish fisheries (millions; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.93	6.23	0.93	6.50
1991	1.41	4.21	1.41	4.22
1992	1.51	4.71	1.51	4.74
1993	0.93	2.36	0.93	2.36
1994	0.89	1.84	0.88	1.84
1995	0.62	1.34	0.62	1.33
1996	0.50	0.98	0.50	0.98
1997	0.30	1.18	0.30	1.18
1998	0.22	0.75	0.22	0.76
1999	0.13	0.41	0.13	0.41
2000	0.15	0.50	0.15	0.50
2001	0.23	0.76	0.23	0.76
2002	0.12	0.41	0.12	0.41
2003	0.08	0.28	0.08	0.28
2004	0.13	0.45	0.13	0.45
2005	0.09	0.50	0.09	0.50
2006	0.10	0.64	0.10	0.64
2007	0.10	0.80	0.10	0.80
2008	0.07	0.47	0.07	0.47
2009	0.05	0.39	0.05	0.39
2010	0.04	0.40	0.04	0.40
2011	0.06	0.57	0.06	0.57
2012	0.04	0.42	0.04	0.43
2013	0.06	0.50	0.06	0.50
2014	0.11	1.33	0.11	1.33
2015	0.10	1.30	0.10	1.31
2016	0.06	0.65	0.06	0.65
2017	0.03	0.28	0.03	0.28
2018	0.03	0.28	0.03	0.28
2019	0.04	0.30	0.04	0.30
2020	0.03	0.17	0.03	0.18
2021	0.04	0.22	0.04	0.23
2022	0.06	0.36	0.06	0.37
2023	–	–	0.04	0.17

Table 78. Estimated discard mortality (biomass) in the groundfish fisheries (1,000's t; 1965-1989).

	22.03b		22.03d5	
y	female	male	female	male
1965	0.05	0.61	0.05	0.61
1966	0.06	0.68	0.06	0.69
1967	0.11	1.86	0.11	1.91
1968	0.17	2.98	0.17	3.09
1969	0.45	7.77	0.45	8.24
1970	2.29	23.97	2.30	25.24
1971	4.53	32.12	4.73	34.25
1972	0.62	7.63	0.66	8.50
1973	0.71	5.18	0.76	5.42
1974	0.86	6.42	0.83	6.29
1975	0.37	3.94	0.37	3.97
1976	0.29	4.49	0.30	4.69
1977	0.34	5.73	0.34	6.03
1978	0.33	5.07	0.35	5.54
1979	0.48	6.46	0.51	7.04
1980	0.35	4.88	0.35	5.10
1981	0.12	1.68	0.12	1.71
1982	0.04	0.60	0.04	0.62
1983	0.04	0.30	0.03	0.29
1984	0.03	0.38	0.03	0.37
1985	0.03	0.33	0.03	0.33
1986	0.04	0.51	0.04	0.50
1987	0.04	0.60	0.04	0.59
1988	0.04	0.80	0.04	0.81
1989	0.09	1.91	0.09	1.96

Table 79. Estimated discard mortality (biomass) in the groundfish fisheries (1,000's t; 1990+).

	22.03b		22.03d5	
y	female	male	female	male
1990	0.168	3.455	0.167	3.586
1991	0.256	2.226	0.256	2.228
1992	0.291	2.578	0.291	2.594
1993	0.183	1.331	0.182	1.330
1994	0.150	0.864	0.148	0.863
1995	0.094	0.596	0.093	0.594
1996	0.070	0.408	0.069	0.409
1997	0.048	0.519	0.048	0.520
1998	0.033	0.313	0.033	0.313
1999	0.017	0.156	0.017	0.156
2000	0.019	0.190	0.019	0.190
2001	0.027	0.277	0.027	0.277
2002	0.015	0.150	0.015	0.150
2003	0.010	0.101	0.010	0.101
2004	0.016	0.168	0.016	0.168
2005	0.012	0.229	0.012	0.229
2006	0.015	0.313	0.015	0.313
2007	0.017	0.399	0.017	0.401
2008	0.012	0.255	0.012	0.255
2009	0.009	0.211	0.009	0.211
2010	0.007	0.211	0.007	0.212
2011	0.009	0.290	0.009	0.290
2012	0.006	0.207	0.006	0.208
2013	0.010	0.240	0.010	0.240
2014	0.021	0.679	0.021	0.678
2015	0.022	0.666	0.021	0.669
2016	0.010	0.357	0.010	0.358
2017	0.005	0.153	0.005	0.153
2018	0.005	0.142	0.005	0.142
2019	0.005	0.148	0.005	0.148
2020	0.004	0.072	0.004	0.072
2021	0.006	0.090	0.006	0.089
2022	0.008	0.151	0.008	0.150
2023	–	–	0.005	0.071

Table 80. Estimated abundance in the NMFS EBS survey for females (millions; 1975-2000).

	22.03b		22.03d5	
y	immature	mature	immature	mature
1975	70.8	243.4	71.2	244.8
1976	87.1	208.4	87.4	209.0
1977	107.6	177.4	107.2	178.0
1978	116.3	159.9	115.8	160.9
1979	106.3	161.7	105.8	163.4
1980	78.5	173.8	77.9	175.7
1981	49.1	138.2	48.5	138.8
1982	83.9	130.3	82.5	132.7
1983	123.0	88.9	119.6	89.9
1984	146.6	61.2	142.8	61.7
1985	174.0	47.0	170.5	47.5
1986	193.6	56.5	190.6	57.6
1987	192.8	71.5	190.9	73.5
1988	172.0	86.2	170.0	89.1
1989	133.5	98.0	132.6	101.5
1990	91.9	105.1	91.7	109.0
1991	58.1	105.0	57.9	108.7
1992	36.9	96.3	36.7	99.4
1993	26.6	81.7	26.4	83.9
1994	24.3	66.1	24.0	67.5
1995	29.7	52.6	29.1	53.5
1996	32.4	42.4	31.9	43.0
1997	49.8	35.2	48.2	35.7
1998	48.1	31.1	47.0	31.6
1999	79.9	29.7	77.1	30.2
2000	76.4	30.6	74.2	31.2

Table 81. Estimated abundance in the NMFS EBS survey for females (millions; 2001+).

	22.03b		22.03d5	
y	immature	mature	immature	mature
2001	121.6	33.4	116.6	34.1
2002	113.4	38.2	109.9	39.1
2003	154.7	45.3	149.1	46.3
2004	156.8	54.1	150.6	55.4
2005	127.7	64.1	123.7	65.5
2006	94.1	73.9	91.8	75.4
2007	68.7	82.2	66.8	83.8
2008	60.4	82.4	58.4	83.6
2009	136.0	73.5	128.4	74.2
2010	147.1	62.9	140.8	63.2
2011	134.8	59.0	131.2	59.3
2012	99.7	67.5	98.8	68.0
2013	67.4	80.8	67.7	81.8
2014	40.9	83.7	40.5	84.9
2015	30.3	74.6	28.4	75.6
2016	28.3	61.7	29.8	62.5
2017	72.4	50.6	71.3	51.1
2018	80.7	42.2	88.9	42.3
2019	98.7	37.8	107.2	38.2
2020	79.9	40.4	90.8	42.1
2021	104.7	47.8	135.6	51.7
2022	178.1	53.0	233.4	59.2
2023	236.2	54.6	294.1	63.0
2024	–	–	265.7	73.8

Table 82. Estimated biomass in the NMFS EBS survey for females (1,000's t; 1975-2000).

		22.03b		22.03d5
y	immature	mature	immature	mature
1975	4.4	44.1	4.4	44.3
1976	4.0	38.1	4.0	38.1
1977	4.8	32.4	4.9	32.4
1978	6.4	28.5	6.4	28.6
1979	7.3	28.0	7.2	28.2
1980	6.4	30.0	6.3	30.3
1981	4.2	24.5	4.1	24.6
1982	4.2	22.4	4.2	22.9
1983	3.8	15.6	3.7	15.8
1984	4.5	10.7	4.4	10.8
1985	5.8	8.0	5.7	8.0
1986	7.1	9.1	7.1	9.3
1987	7.7	11.3	7.7	11.6
1988	7.6	13.7	7.6	14.2
1989	6.8	15.8	6.9	16.3
1990	5.4	17.1	5.5	17.7
1991	3.8	17.4	3.8	18.0
1992	2.3	16.2	2.3	16.8
1993	1.4	14.0	1.4	14.4
1994	1.0	11.4	1.0	11.7
1995	1.0	9.1	1.0	9.2
1996	1.1	7.3	1.1	7.4
1997	1.5	6.0	1.5	6.1
1998	1.7	5.2	1.7	5.3
1999	2.4	4.9	2.3	4.9
2000	2.8	4.9	2.7	5.0

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

		22.03b		22.03d5
y	immature	mature	immature	mature
2001	3.7	5.3	3.6	5.4
2002	4.2	6.0	4.2	6.2
2003	5.2	7.1	5.1	7.3
2004	5.8	8.5	5.7	8.7
2005	5.9	10.1	5.8	10.3
2006	5.4	11.7	5.3	12.0
2007	4.1	13.2	4.0	13.5
2008	2.8	13.7	2.7	13.9
2009	3.1	12.5	3.0	12.7
2010	4.3	10.7	4.1	10.8
2011	5.6	9.7	5.5	9.7
2012	5.8	10.5	5.8	10.6
2013	4.4	12.8	4.4	12.9
2014	2.6	13.8	2.6	14.0
2015	1.5	12.7	1.5	12.9
2016	1.2	10.7	1.2	10.8
2017	1.7	8.7	1.6	8.8
2018	2.3	7.2	2.4	7.3
2019	3.3	6.3	3.6	6.3
2020	3.8	6.4	4.2	6.6
2021	4.0	7.5	4.7	8.1
2022	4.7	8.5	6.0	9.5
2023	6.5	8.9	8.4	10.2
2024	–	–	10.9	11.4

Table 84. Estimated abundance in the NMFS EBS survey for males (millions; 1975-2000).

		22.03b		22.03d5
y	immature	mature	immature	mature
1975	125.4	308.4	129.2	305.8
1976	149.7	266.7	153.7	264.0
1977	174.0	217.2	176.6	214.1
1978	181.0	176.0	183.1	172.3
1979	171.3	167.8	173.6	163.7
1980	138.5	182.6	141.0	178.5
1981	93.7	147.8	95.7	145.6
1982	118.2	156.6	116.9	153.5
1983	144.3	109.3	141.0	107.4
1984	167.2	73.1	162.5	71.6
1985	200.1	52.8	195.0	51.4
1986	229.4	65.8	224.6	63.9
1987	236.6	87.3	233.2	85.1
1988	217.7	112.3	214.3	110.3
1989	178.0	132.3	176.1	130.5
1990	131.6	140.8	131.0	139.1
1991	88.6	135.9	88.5	134.1
1992	56.6	126.3	56.6	124.8
1993	37.8	104.5	37.8	102.9
1994	31.2	84.3	30.9	82.6
1995	35.2	66.8	34.6	65.2
1996	38.1	53.3	37.4	51.7
1997	56.5	44.0	54.8	42.5
1998	56.7	38.6	55.1	37.2
1999	90.8	37.0	87.8	35.6
2000	90.3	38.8	87.3	37.5

Table 85. Estimated abundance in the NMFS EBS survey for males (millions; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2001	138.8	43.3	133.2	41.9
2002	134.9	50.0	130.0	48.4
2003	180.9	60.0	174.2	58.2
2004	187.8	73.1	179.9	70.8
2005	162.3	88.1	156.1	85.4
2006	129.4	103.3	125.4	100.2
2007	101.0	116.9	98.4	113.5
2008	82.7	124.4	80.7	121.1
2009	150.5	117.6	143.1	114.5
2010	163.2	101.2	155.3	98.1
2011	160.2	89.1	153.7	85.4
2012	136.3	91.7	133.0	87.2
2013	104.1	110.6	103.9	105.7
2014	64.4	125.6	64.3	121.6
2015	42.1	116.6	40.4	113.6
2016	35.8	93.8	37.3	91.3
2017	79.6	76.9	78.7	74.7
2018	89.7	63.4	97.4	61.1
2019	112.4	54.2	120.6	51.9
2020	100.8	53.6	112.3	51.8
2021	129.0	62.8	163.2	62.9
2022	201.6	74.5	262.0	78.0
2023	262.2	80.1	325.7	86.9
2024	–	–	311.6	94.9

Table 86. Estimated biomass in the NMFS EBS survey for males (1,000's t; 1975-2000).

	22.03b		22.03d5	
y	immature	mature	immature	mature
1975	16.3	164.1	16.7	164.9
1976	12.9	142.6	13.3	142.9
1977	13.1	112.0	13.5	111.6
1978	16.8	82.5	17.2	81.7
1979	22.0	72.8	22.5	72.0
1980	23.4	78.7	23.8	78.0
1981	18.0	70.1	18.3	70.0
1982	15.7	78.6	15.8	78.6
1983	10.0	59.2	10.0	59.3
1984	9.5	40.2	9.3	40.1
1985	11.7	27.6	11.5	27.5
1986	15.5	32.0	15.3	31.9
1987	18.9	40.5	18.8	40.4
1988	19.8	52.7	19.8	52.9
1989	19.1	63.0	19.2	63.5
1990	17.0	65.9	17.2	66.5
1991	13.3	61.8	13.4	62.2
1992	8.8	57.8	8.9	58.3
1993	5.1	47.1	5.2	47.3
1994	3.1	38.1	3.2	38.1
1995	2.5	30.3	2.5	30.2
1996	2.6	24.1	2.6	23.9
1997	3.1	19.8	3.1	19.6
1998	3.8	17.4	3.7	17.2
1999	5.0	16.7	4.9	16.5
2000	6.1	17.6	6.0	17.4

Table 87. Estimated biomass in the NMFS EBS survey for males (1,000's t; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2001	7.8	19.8	7.6	19.7
2002	9.4	23.0	9.2	22.9
2003	11.6	27.6	11.4	27.5
2004	13.6	34.0	13.2	33.8
2005	14.8	41.4	14.5	41.2
2006	15.0	49.3	14.7	49.0
2007	13.8	56.4	13.6	56.1
2008	10.1	62.5	10.0	62.0
2009	7.3	62.1	7.1	61.6
2010	7.5	54.4	7.2	53.7
2011	10.8	46.3	10.4	45.4
2012	15.0	43.9	14.6	42.8
2013	15.5	51.6	15.3	50.4
2014	10.6	62.4	10.6	61.4
2015	5.5	61.0	5.6	60.4
2016	3.4	49.4	3.4	48.8
2017	3.5	40.7	3.5	40.3
2018	4.2	33.2	4.2	32.7
2019	6.1	27.7	6.3	27.0
2020	8.7	25.6	9.4	25.0
2021	10.6	28.7	12.1	29.1
2022	11.1	35.6	13.3	37.6
2023	12.3	39.8	15.5	43.6
2024	–	–	21.2	46.4

Table 88. Estimated abundance in the BSFRF SBS survey for females (millions; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2013	11.9	47.1	7.9	42.5
2014	8.0	29.7	6.5	25.7
2015	5.7	29.5	7.1	28.6
2016	18.6	101.8	27.6	98.9
2017	255.6	155.4	252.8	133.7
2018	–	–	306.3	155.5

Table 89. Estimated biomass in the BSFRF SBS survey for females (1,000's t; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2013	1.1	10.2	0.8	9.4
2014	0.5	6.6	0.5	5.8
2015	0.3	7.1	0.4	6.7
2016	1.2	19.8	1.3	19.1
2017	5.9	24.5	5.5	21.0
2018	–	–	7.9	26.2

Table 90. Estimated abundance in the BSFRF SBS survey for males (millions; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2013	44.7	67.4	23.2	55.8
2014	23.6	88.7	18.9	82.5
2015	16.7	69.9	18.6	65.5
2016	19.5	105.2	38.2	101.3
2017	216.2	114.8	220.3	112.9
2018	–	–	287.7	108.2

Table 91. Estimated biomass in the BSFRF SBS survey for males (1,000's t; 2001+).

		22.03b		22.03d5
y	immature	mature	immature	mature
2013	7.3	35.5	5.1	31.4
2014	5.3	52.7	5.0	50.0
2015	2.7	41.0	2.9	37.9
2016	3.6	51.9	4.1	49.7
2017	7.8	52.3	7.9	52.5
2018	–	–	10.6	49.7

Table 92. Estimated population abundance (millions; 1948-1990).

						22.03b						22.03d5
y	immature new shell	new shell	female mature old shell	immature new shell	new shell	male mature old shell	immature new shell	new shell	female mature old shell	immature new shell	new shell	male mature old shell
1949	290.8	–	–	290.8	–	–	322.8	–	–	322.8	–	–
1950	519.8	0.7	–	520.0	0.5	–	572.7	0.7	–	573.0	0.4	–
1951	692.0	9.3	0.5	696.8	4.7	0.3	757.5	9.8	0.5	763.5	4.2	0.3
1952	798.1	39.0	7.2	819.0	22.3	3.7	869.9	40.8	7.5	894.7	20.9	3.2
1953	842.2	79.0	33.9	882.2	55.7	19.0	915.9	82.3	35.2	963.1	54.6	17.4
1954	855.5	102.0	82.7	903.6	85.3	54.3	929.4	106.1	85.5	986.2	85.6	51.9
1955	862.7	108.3	135.4	912.0	96.6	101.3	936.3	112.5	139.5	994.7	97.8	98.8
1956	871.7	109.4	178.6	921.2	98.4	143.3	945.1	113.6	183.4	1003.7	99.8	141.1
1957	884.3	110.0	211.1	934.2	98.9	174.8	957.6	114.2	216.1	1016.5	100.2	172.5
1958	902.0	110.9	235.3	952.3	99.6	197.9	975.3	115.0	240.4	1034.6	100.9	195.4
1959	926.5	112.3	253.8	977.4	100.6	215.1	1000.1	116.2	258.6	1060.1	101.8	212.1
1960	960.1	114.1	268.3	1011.9	102.1	228.3	1035.0	117.9	272.8	1095.9	103.1	224.8
1961	1006.9	116.6	280.2	1059.9	104.1	238.8	1084.4	120.4	284.4	1146.6	104.9	234.7
1962	1073.1	120.2	290.9	1127.8	106.9	247.7	1156.1	123.8	294.6	1220.2	107.5	243.0
1963	1171.1	125.0	301.2	1228.1	110.8	256.0	1264.8	128.6	304.5	1331.6	111.1	250.6
1964	1326.8	131.8	312.4	1387.1	116.1	264.6	1441.8	135.5	315.2	1512.3	116.3	258.4
1965	1604.3	141.6	325.5	1669.2	123.8	274.7	1761.9	145.6	328.0	1838.0	123.8	267.8
1966	2170.3	156.4	342.3	2242.4	135.1	287.3	2414.1	161.4	344.7	2498.9	135.1	279.5
1967	3389.5	180.9	365.4	3473.5	153.4	304.1	3773.9	188.0	368.2	3873.6	153.6	295.5
1968	4998.4	226.7	399.7	5104.8	185.6	313.4	5436.4	238.2	404.2	5564.3	186.5	303.9
1969	5199.5	319.4	457.7	5352.4	249.2	333.4	5545.1	338.1	466.2	5730.1	250.7	323.3
1970	4508.1	483.5	564.5	4743.3	363.6	358.2	4737.3	508.6	580.3	5018.8	364.5	345.2
1971	3551.1	662.0	736.2	3867.3	495.6	362.7	3703.4	684.3	760.3	4072.8	493.0	341.6
1972	2509.0	702.1	959.3	2824.4	558.3	421.4	2610.0	712.1	982.8	2971.0	550.2	386.0
1973	1692.8	572.3	1210.8	1934.3	565.4	660.8	1771.8	572.3	1226.1	2045.9	561.8	617.8
1974	1337.8	387.9	1297.5	1492.0	411.7	856.8	1445.6	386.0	1298.5	1621.1	409.3	813.4
1975	1499.2	255.7	1222.5	1600.3	266.0	877.9	1633.5	256.4	1213.7	1750.2	265.4	837.5
1976	2315.4	179.6	1079.1	2388.5	182.8	801.2	2526.1	183.0	1065.6	2612.0	183.8	763.6
1977	2595.7	157.5	919.8	2664.2	144.7	672.1	2776.8	164.1	905.6	2859.2	146.0	637.8
1978	2175.5	204.2	786.2	2272.8	159.9	536.8	2293.3	213.6	775.0	2409.4	159.8	505.5
1979	1569.2	300.3	722.6	1716.0	229.1	462.4	1635.3	309.8	715.8	1806.6	226.7	432.0
1980	1028.2	351.4	744.1	1192.2	298.0	452.4	1066.1	357.7	740.3	1254.4	295.7	420.6
1981	697.5	256.5	592.5	818.8	246.4	328.7	727.5	257.2	586.3	865.8	246.2	305.9
1982	530.3	152.5	461.1	594.8	169.8	266.7	558.8	151.6	452.5	632.4	170.7	251.4
1983	854.9	83.3	334.0	890.1	92.2	206.5	920.3	83.1	324.7	960.8	92.5	196.3
1984	1000.9	60.7	227.1	1029.9	56.8	142.8	1073.1	61.2	219.2	1106.6	56.4	135.9
1985	1166.7	66.3	156.5	1200.9	53.5	93.8	1249.8	67.3	150.5	1289.7	52.3	88.9
1986	1279.7	106.6	163.3	1331.6	81.9	106.8	1371.0	109.0	158.6	1431.4	79.7	101.4
1987	1254.9	144.6	197.9	1324.4	116.1	136.6	1345.7	147.8	194.7	1426.3	114.0	129.8
1988	1094.9	161.3	251.0	1169.2	141.5	181.5	1160.2	164.7	249.3	1246.5	140.4	173.3
1989	819.8	165.4	302.2	895.2	148.2	229.9	863.2	169.0	301.3	950.8	147.8	221.0
1990	545.6	158.4	342.0	616.8	145.4	257.5	570.2	162.0	341.7	653.0	145.7	247.8

Table 93. Estimated population abundance (millions; 1991+).

y	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03b male mature old shell	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03d5 male mature old shell
1991	339.8	133.1	365.0	397.4	129.2	260.9	353.6	135.3	364.7	420.1	130.3	250.7
1992	220.9	93.7	361.8	259.2	99.0	261.3	231.8	94.3	360.6	275.6	100.1	252.1
1993	166.7	55.5	329.9	188.0	62.9	235.7	177.1	55.6	327.1	201.6	63.6	227.3
1994	158.9	31.2	280.1	170.8	35.5	204.8	170.1	31.4	276.2	183.8	35.9	197.2
1995	201.1	21.1	226.7	209.8	21.5	169.0	216.6	21.5	222.4	226.8	21.6	162.1
1996	216.4	19.1	180.8	224.8	17.4	135.1	232.8	19.6	176.6	242.7	17.3	128.9
1997	344.4	20.9	145.6	353.9	17.8	108.5	368.3	21.5	141.9	379.4	17.7	103.0
1998	316.3	25.9	121.7	328.2	21.1	90.0	334.8	26.5	118.5	348.9	20.9	85.1
1999	553.8	33.1	108.0	569.3	26.9	80.0	591.3	33.9	105.4	609.3	26.5	75.4
2000	502.1	42.6	103.4	522.2	34.7	77.7	529.9	43.3	101.4	553.1	34.0	73.3
2001	839.7	52.8	107.1	864.4	43.9	81.5	888.6	53.5	105.3	917.1	42.8	77.1
2002	740.6	66.1	117.1	771.6	54.3	90.7	777.8	66.8	115.5	813.5	52.9	85.9
2003	1047.5	82.8	134.4	1086.5	68.3	105.7	1108.0	83.6	132.8	1152.8	66.5	100.2
2004	1033.9	100.3	159.4	1081.0	84.1	127.2	1077.2	100.8	157.7	1131.1	81.8	120.6
2005	796.1	116.4	190.6	850.3	99.5	154.2	821.2	116.9	188.3	883.1	96.7	146.3
2006	559.3	128.3	225.3	618.7	111.7	184.3	572.2	128.6	222.4	639.9	108.8	174.8
2007	414.0	132.7	259.5	475.1	118.4	214.4	424.4	132.2	255.7	493.3	115.8	203.4
2008	393.1	102.8	287.8	436.2	107.2	240.9	413.1	101.3	282.7	461.3	105.7	228.6
2009	984.6	60.3	286.6	1007.3	71.1	253.0	1043.4	59.1	279.9	1069.0	70.4	240.6
2010	999.3	42.4	254.7	1016.8	42.6	235.9	1051.2	42.1	247.1	1071.4	41.6	224.2
2011	850.4	63.1	218.1	881.3	46.3	203.3	886.8	63.5	210.8	922.5	43.8	192.1
2012	584.9	117.6	206.4	644.8	82.8	181.7	606.1	118.0	200.0	674.1	78.4	170.0
2013	396.0	148.6	237.9	466.9	125.3	193.0	418.2	148.7	231.9	498.2	121.6	179.5
2014	246.6	113.0	283.8	293.2	121.7	230.7	256.2	112.8	277.4	309.2	121.1	216.0
2015	191.4	60.6	291.1	213.4	74.2	247.8	189.2	60.8	284.2	214.6	75.2	234.3
2016	184.3	32.7	258.0	196.8	36.8	222.5	215.3	33.4	251.3	230.2	37.6	211.2
2017	524.6	25.2	213.4	535.6	24.0	188.5	580.3	25.4	207.5	592.9	24.2	179.0
2018	551.0	23.8	175.1	561.6	22.0	153.7	678.4	23.5	169.8	690.2	21.4	145.5
2019	658.7	33.3	146.1	674.6	25.8	126.7	781.6	35.2	140.9	801.1	24.9	119.2
2020	493.4	62.1	131.7	525.0	43.5	111.2	600.8	68.3	128.3	640.3	44.4	104.0
2021	701.9	86.8	142.2	744.0	69.9	112.3	1021.3	98.0	143.4	1075.2	75.0	106.6
2022	1261.1	84.4	168.2	1298.7	79.9	132.6	1850.4	98.3	176.0	1900.6	89.9	130.9
2023	1634.1	74.6	185.4	1666.3	71.9	154.4	2225.3	92.2	200.0	2271.6	84.7	159.0
2024	–	–	–	–	–	–	1805.4	133.4	213.1	1879.5	95.8	175.6

Table 94. Estimated population biomass (1,000's t; 1948-1990).

y	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03b male mature old shell	immature new shell	new shell	female mature old shell	immature new shell	new shell	22.03d5 male mature old shell
1949	3.44	–	–	3.44	–	–	3.72	–	–	3.71	–	–
1950	9.08	0.04	–	9.51	0.03	–	9.73	0.05	–	10.14	0.03	–
1951	16.85	0.90	0.03	19.81	0.60	0.02	17.90	0.94	0.03	20.93	0.54	0.02
1952	24.33	4.68	0.68	34.07	4.82	0.46	25.70	4.87	0.71	35.87	4.66	0.40
1953	28.58	11.04	3.93	46.53	17.98	3.84	30.08	11.43	4.06	49.04	17.98	3.65
1954	29.89	15.68	10.97	51.91	34.95	15.81	31.41	16.17	11.27	54.84	35.54	15.52
1955	30.20	17.21	19.53	52.95	43.57	36.59	31.71	17.73	19.97	55.96	44.70	36.46
1956	30.43	17.47	26.93	53.31	45.11	57.59	31.93	17.98	27.44	56.30	46.39	57.77
1957	30.76	17.57	32.54	53.78	45.35	73.66	32.24	18.07	33.05	56.74	46.62	74.00
1958	31.22	17.70	36.72	54.44	45.62	85.34	32.68	18.19	37.20	57.37	46.86	85.68
1959	31.87	17.89	39.88	55.38	46.02	93.86	33.30	18.37	40.31	58.28	47.22	94.10
1960	32.76	18.16	42.34	56.69	46.59	100.26	34.18	18.62	42.70	59.55	47.74	100.34
1961	33.99	18.54	44.34	58.50	47.39	105.24	35.42	18.97	44.62	61.35	48.47	105.12
1962	35.71	19.06	46.07	61.01	48.49	109.21	37.19	19.47	46.28	63.91	49.51	108.87
1963	38.19	19.77	47.72	64.58	50.02	112.67	39.80	20.17	47.84	67.62	50.96	112.07
1964	41.94	20.76	49.46	69.87	52.13	116.04	43.85	21.16	49.48	73.25	53.01	115.17
1965	48.14	22.18	51.45	78.31	55.09	119.98	50.69	22.61	51.40	82.46	55.95	118.84
1966	59.78	24.29	53.95	93.40	59.37	124.73	63.65	24.83	53.85	99.14	60.28	123.31
1967	83.70	27.70	57.32	123.24	65.92	130.67	89.84	28.48	57.24	131.78	67.06	129.02
1968	122.74	33.87	62.15	173.61	76.43	126.04	130.71	35.18	62.23	185.02	78.09	124.21
1969	158.05	46.26	70.06	231.23	96.65	122.86	165.98	48.50	70.58	244.32	99.32	121.08
1970	176.06	69.45	84.09	284.97	134.29	111.88	181.96	72.66	85.50	297.89	138.16	109.68
1971	165.10	98.73	105.48	306.97	180.16	86.95	168.12	101.72	108.01	317.34	183.38	83.28
1972	128.25	112.32	135.57	270.36	218.61	92.72	129.26	113.44	137.88	276.92	217.70	85.71
1973	88.08	99.00	180.17	199.76	277.90	192.00	88.65	98.37	181.25	204.29	277.71	181.73
1974	60.82	69.26	203.02	133.48	222.56	318.47	62.04	68.26	201.79	137.29	222.31	307.12
1975	49.93	45.35	197.41	97.70	143.96	363.88	51.97	44.93	194.47	101.93	144.10	352.25
1976	57.61	31.16	177.13	92.72	96.14	344.26	60.87	31.29	173.45	98.01	96.98	332.44
1977	72.58	25.20	152.05	106.26	69.50	282.64	76.13	25.87	148.35	112.00	70.80	271.17
1978	82.90	29.67	129.10	128.99	63.90	208.52	85.80	30.82	125.95	134.58	65.50	197.97
1979	79.33	43.84	115.56	145.12	86.54	163.90	81.01	45.02	113.22	149.97	87.94	154.13
1980	60.08	55.50	115.57	132.76	125.26	146.76	60.65	56.18	113.81	136.52	126.02	137.47
1981	37.45	44.77	92.26	93.05	121.85	108.43	37.63	44.62	90.53	95.63	122.28	101.92
1982	23.13	28.69	74.37	54.10	96.87	103.06	23.39	28.29	72.43	55.71	97.45	98.42
1983	22.42	15.44	56.09	39.43	54.50	93.10	23.11	15.21	54.12	40.86	54.87	89.63
1984	26.96	10.12	38.92	40.84	29.44	70.27	27.93	10.08	37.26	42.34	29.63	67.72
1985	34.61	10.01	26.65	51.15	23.26	46.05	35.88	10.07	25.41	53.00	23.25	44.20
1986	41.67	15.39	26.88	65.52	31.66	50.04	43.14	15.59	25.82	67.89	31.53	48.21
1987	44.46	21.74	30.97	75.98	46.04	58.72	46.00	22.04	30.13	78.86	45.98	56.76
1988	43.02	25.41	38.61	77.27	61.99	74.05	44.38	25.72	37.95	80.24	62.30	71.87
1989	37.79	26.41	46.90	72.20	67.66	94.36	38.84	26.74	46.32	74.97	68.33	92.05
1990	29.41	25.84	53.57	61.71	67.65	102.89	30.02	26.20	53.01	64.04	68.50	100.46

Table 95. Estimated population biomass (1,000's t; 1991+).

						22.03b						22.03d5
			female			male			female			male
	immature		mature	immature		mature	immature		mature	immature		mature
y	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell	new shell	new shell	old shell
1991	20.0	22.6	57.8	46.2	63.2	98.1	20.2	22.8	57.2	47.8	64.2	95.5
1992	12.2	16.7	58.2	29.9	52.4	98.5	12.3	16.7	57.6	30.9	53.3	96.3
1993	7.5	10.3	54.1	17.7	35.5	88.0	7.7	10.2	53.2	18.3	35.9	86.1
1994	5.8	5.8	46.7	11.5	20.5	79.3	5.9	5.7	45.6	12.0	20.8	77.4
1995	5.9	3.6	38.1	10.1	11.5	67.8	6.1	3.6	37.1	10.5	11.7	66.0
1996	6.6	3.1	30.4	10.6	8.2	54.9	6.9	3.1	29.5	11.1	8.3	53.2
1997	8.9	3.2	24.4	13.4	7.8	44.2	9.2	3.3	23.5	14.0	7.9	42.6
1998	10.3	3.9	20.2	16.0	8.7	36.8	10.6	4.0	19.4	16.6	8.8	35.3
1999	14.3	5.0	17.6	21.6	11.0	32.6	14.7	5.0	17.0	22.3	11.1	31.3
2000	16.3	6.4	16.5	25.7	14.2	31.6	16.8	6.5	16.0	26.4	14.2	30.4
2001	22.1	8.0	16.8	33.7	18.3	33.2	22.6	8.0	16.4	34.6	18.2	32.0
2002	24.9	10.0	18.2	39.4	22.6	37.1	25.4	10.0	17.7	40.3	22.4	35.8
2003	30.7	12.5	20.6	48.8	28.3	43.4	31.3	12.6	20.2	49.9	28.1	41.9
2004	34.0	15.3	24.3	55.8	35.5	52.3	34.5	15.3	23.9	56.8	35.2	50.6
2005	33.4	18.0	29.1	58.5	42.8	64.1	33.7	18.0	28.5	59.4	42.3	62.0
2006	29.3	20.0	34.6	56.4	49.4	77.2	29.3	19.9	33.8	57.2	48.8	74.6
2007	22.0	21.4	40.1	49.0	53.6	91.0	21.8	21.2	39.2	49.5	53.2	87.8
2008	15.3	18.2	45.1	35.2	54.7	103.9	15.2	17.8	44.0	35.7	54.2	100.3
2009	19.6	11.3	46.4	30.8	41.1	114.7	20.0	11.0	45.0	31.4	40.8	110.5
2010	26.3	7.0	42.4	35.4	22.8	113.0	26.9	6.9	40.8	36.1	22.6	108.6
2011	32.6	8.6	36.2	47.7	17.3	99.0	33.1	8.6	34.7	48.4	16.9	94.7
2012	31.9	16.3	32.9	58.2	28.0	84.5	32.1	16.3	31.6	58.9	27.2	80.4
2013	23.3	23.4	36.2	54.3	51.4	82.0	23.5	23.2	34.9	55.4	50.4	77.6
2014	13.5	20.3	43.7	35.2	63.0	96.0	13.6	20.1	42.3	36.2	62.5	91.1
2015	8.2	11.7	47.0	18.9	44.3	108.9	8.3	11.6	45.5	19.6	44.7	104.0
2016	6.7	6.0	43.0	12.7	21.6	102.3	7.0	6.0	41.5	13.4	22.1	98.0
2017	10.4	4.2	36.0	15.5	12.1	89.9	11.0	4.2	34.7	16.3	12.5	86.3
2018	14.2	3.8	29.5	19.5	10.2	73.3	16.0	3.7	28.3	21.4	10.2	70.2
2019	19.8	4.7	24.4	27.8	10.2	59.7	22.6	4.8	23.4	31.1	9.9	56.9
2020	21.4	8.5	21.3	35.6	14.7	50.9	24.8	9.3	20.5	40.6	15.1	48.1
2021	22.7	13.2	21.9	41.4	27.3	47.3	28.5	14.7	21.7	50.2	29.4	45.1
2022	28.9	13.9	25.8	46.3	37.4	54.0	39.4	16.0	26.5	60.4	41.7	53.5
2023	40.2	12.2	29.2	56.3	35.1	66.0	55.0	14.6	31.0	75.8	41.0	68.1
2024	–	–	–	–	–	–	66.2	18.4	33.2	97.8	38.5	78.2

Table 96. Comparison of estimates of mature biomass-at-mating by sex (in 1,000's t) from the base and preferred models (model start to 1980).

	female		male	
year	22.03b	22.03d5	22.03b	22.03d5
1948	0.000	0.000	0.000	0.000
1949	0.000	0.000	0.000	0.000
1950	0.035	0.038	0.027	0.023
1951	0.763	0.800	0.512	0.455
1952	4.412	4.569	4.317	4.118
1953	12.320	12.689	17.763	17.500
1954	21.928	22.483	41.111	41.109
1955	30.231	30.883	64.702	65.130
1956	36.528	37.203	82.747	83.426
1957	41.224	41.877	95.868	96.595
1958	44.775	45.376	105.448	106.097
1959	47.533	48.066	112.638	113.133
1960	49.776	50.229	118.225	118.518
1961	51.725	52.090	122.689	122.740
1962	53.578	53.850	126.577	126.358
1963	55.522	55.701	130.363	129.852
1964	57.763	57.860	134.785	133.983
1965	60.569	60.616	140.130	139.027
1966	64.356	64.431	146.795	145.461
1967	69.778	70.049	141.596	140.041
1968	78.649	79.448	138.024	136.512
1969	94.401	96.247	125.687	123.660
1970	118.414	121.582	97.677	93.895
1971	152.201	155.203	104.160	96.628
1972	202.268	204.028	215.695	204.885
1973	227.929	227.142	357.779	346.258
1974	221.624	218.904	408.791	397.144
1975	198.864	195.243	386.752	374.807
1976	170.706	166.989	317.520	305.734
1977	144.935	141.780	234.259	223.198
1978	129.740	127.446	184.125	173.774
1979	129.741	128.114	164.870	154.991
1980	115.834	114.190	142.452	134.692

Table 97. Comparison of estimates of mature biomass-at-mating by sex (in 1,000's t) from the base and preferred models (1981 to model end).

		female		male
year	22.03b	22.03d5	22.03b	22.03d5
1981	93.4	91.4	135.4	130.1
1982	70.4	68.3	122.3	118.5
1983	48.9	47.0	92.3	89.5
1984	33.5	32.1	60.5	58.4
1985	30.2	29.1	56.2	54.4
1986	34.8	33.9	66.0	64.0
1987	43.3	42.7	83.2	81.0
1988	52.7	52.1	106.0	103.8
1989	60.1	59.7	115.6	113.3
1990	64.9	64.4	110.2	107.6
1991	65.4	64.8	110.6	108.5
1992	60.7	59.9	98.9	97.1
1993	52.4	51.4	89.0	87.2
1994	42.8	41.7	76.2	74.4
1995	34.2	33.2	61.7	59.9
1996	27.4	26.5	49.6	48.0
1997	22.6	21.9	41.3	39.9
1998	19.7	19.1	36.6	35.3
1999	18.5	18.0	35.5	34.3
2000	18.9	18.4	37.2	36.1
2001	20.4	20.0	41.6	40.4
2002	23.1	22.7	48.7	47.3
2003	27.3	26.8	58.8	57.1
2004	32.6	32.1	72.0	69.9
2005	38.8	38.1	86.8	84.1
2006	45.0	44.1	102.2	99.0
2007	50.6	49.5	116.8	113.1
2008	52.1	50.7	128.8	124.6
2009	47.6	45.9	126.9	122.5
2010	40.7	39.1	111.2	106.8
2011	37.0	35.5	94.9	90.6
2012	40.6	39.3	92.1	87.5
2013	49.1	47.7	107.8	102.7
2014	52.7	51.2	122.4	117.2
2015	48.3	46.8	114.9	110.5
2016	40.4	39.0	101.0	97.3
2017	33.1	31.9	82.3	79.1
2018	27.4	26.3	67.1	64.2
2019	24.0	23.1	57.2	54.3
2020	24.6	24.4	53.1	50.9
2021	28.9	29.8	60.7	60.3
2022	32.7	34.9	74.2	76.8
2023	–	37.4	–	88.2

Table 98. Comparison of estimates of recruitment (in millions) from the base and preferred models (model start to 1980)

year	22.03b	22.03d5
1949	581.6	645.6
1950	582.0	646.1
1951	583.1	647.1
1952	585.0	648.9
1953	587.9	651.7
1954	592.4	656.0
1955	598.7	662.3
1956	607.7	671.2
1957	620.1	683.8
1958	637.4	701.5
1959	661.1	726.3
1960	693.6	761.0
1961	739.2	810.7
1962	805.3	884.6
1963	906.8	1000.8
1964	1077.5	1200.1
1965	1406.8	1586.8
1966	2131.7	2426.9
1967	3727.6	4190.0
1968	5116.1	5508.9
1969	3171.4	3353.4
1970	1810.8	1920.7
1971	1364.2	1474.7
1972	884.9	961.0
1973	608.0	672.4
1974	815.7	948.4
1975	1427.0	1563.6
1976	2639.1	2898.1
1977	1864.5	1975.1
1978	677.6	720.1
1979	324.9	350.8
1980	307.5	333.4

Table 99. Comparison of estimates of recruitment (in millions) from the base and preferred models (1981 to model end).

year	22.03b	22.03d5
1981	364.6	394.0
1982	311.5	338.2
1983	1064.4	1164.4
1984	792.6	859.4
1985	906.9	990.2
1986	937.8	1026.9
1987	788.6	868.4
1988	541.9	571.0
1989	252.2	273.1
1990	123.7	134.0
1991	93.2	100.9
1992	99.9	109.9
1993	100.2	109.9
1994	119.5	130.3
1995	195.6	214.1
1996	155.4	170.4
1997	391.4	420.5
1998	142.4	152.9
1999	676.8	732.8
2000	217.8	231.4
2001	995.8	1064.8
2002	291.9	314.2
2003	1096.4	1180.5
2004	620.5	641.8
2005	199.7	210.5
2006	125.6	133.6
2007	218.0	232.0
2008	344.0	375.2
2009	1472.7	1567.1
2010	531.4	569.7
2011	253.0	272.6
2012	69.1	78.0
2013	174.0	200.4
2014	100.5	94.6
2015	118.1	105.3
2016	133.6	205.6
2017	810.1	878.5
2018	322.9	504.6
2019	516.0	582.6
2020	74.7	128.8
2021	803.3	1311.1
2022	1587.6	2317.6
2023	1430.8	1768.2
2024	–	431.2

Table 100. Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (model start to 1980).

year	22.03b	22.03d5
1949	0.00051	0.00044
1950	0.00089	0.00079
1951	0.00147	0.00135
1952	0.00227	0.00213
1953	0.00387	0.00370
1954	0.00616	0.00594
1955	0.00817	0.00793
1956	0.00943	0.00919
1957	0.00984	0.00959
1958	0.01022	0.00998
1959	0.01033	0.01009
1960	0.01047	0.01022
1961	0.01107	0.01084
1962	0.01165	0.01143
1963	0.01222	0.01200
1964	0.01195	0.01171
1965	0.01216	0.01196
1966	0.01301	0.01275
1967	0.04390	0.04297
1968	0.05143	0.05038
1969	0.08307	0.08287
1970	0.15146	0.15299
1971	0.17703	0.18334
1972	0.05158	0.05517
1973	0.03493	0.03619
1974	0.04335	0.04306
1975	0.03811	0.03854
1976	0.05911	0.06056
1977	0.08198	0.08407
1978	0.06636	0.06969
1979	0.07226	0.07614
1980	0.05400	0.05585

Table 101. Comparison of exploitation rates (i.e., catch divided by biomass) from the model scenarios (from 1981 to model end).

year	22.03b	22.03d5
1981	0.0245	0.0250
1982	0.0130	0.0134
1983	0.0056	0.0054
1984	0.0142	0.0141
1985	0.0057	0.0056
1986	0.0072	0.0070
1987	0.0128	0.0126
1988	0.0204	0.0204
1989	0.0547	0.0550
1990	0.0940	0.0951
1991	0.0780	0.0780
1992	0.1012	0.1017
1993	0.0641	0.0646
1994	0.0390	0.0394
1995	0.0293	0.0296
1996	0.0240	0.0244
1997	0.0167	0.0169
1998	0.0108	0.0110
1999	0.0051	0.0051
2000	0.0057	0.0057
2001	0.0069	0.0069
2002	0.0033	0.0033
2003	0.0018	0.0018
2004	0.0025	0.0025
2005	0.0057	0.0057
2006	0.0085	0.0086
2007	0.0095	0.0096
2008	0.0072	0.0073
2009	0.0056	0.0057
2010	0.0026	0.0027
2011	0.0037	0.0038
2012	0.0025	0.0026
2013	0.0084	0.0085
2014	0.0332	0.0339
2015	0.0488	0.0500
2016	0.0057	0.0059
2017	0.0105	0.0107
2018	0.0113	0.0113
2019	0.0032	0.0031
2020	0.0063	0.0061
2021	0.0045	0.0041
2022	0.0060	0.0052
2023	–	0.0041

Table 102. Comparison of RMSEs from fits to fishery catch data, survey data, and molt increment data.

				all sexes		female				male			
				all		immature		mature		all		immature	
category	fleet	catch type	data type	22.03b	22.03d5	22.03b	22.03d5	22.03b	22.03d5	22.03b	22.03d5	22.03b	22.03d5
fisheries data	GF All	total catch	abundance	0.880	0.759	–	–	–	–	–	–	–	–
			biomass	0.656	0.719	–	–	–	–	–	–	–	–
	RKF	total catch	abundance	0.706	0.697	–	–	–	–	–	–	–	–
			biomass	0.224	0.232	–	–	–	–	–	–	–	–
	SCF	total catch	abundance	1.090	1.087	–	–	–	–	–	–	–	–
			biomass	0.150	0.148	–	–	–	–	–	–	–	–
	TCF	retained catch	abundance	–	–	–	–	–	–	5.285	5.212	–	–
			biomass	–	–	–	–	–	–	0.376	0.393	–	–
		total catch	abundance	2.217	2.165	–	–	–	–	–	–	–	–
			biomass	1.957	1.916	–	–	–	–	–	–	–	–
growth data	–	–	molt incr.	–	–	0.303	0.645	–	–	–	–	0.528	1.064
surveys data	NMFS F	index catch	abundance	–	–	3.143	3.126	2.444	2.515	–	–	–	–
			biomass	–	–	2.823	2.845	2.290	2.352	–	–	–	–
	NMFS M	index catch	abundance	–	–	–	–	–	–	3.380	3.414	–	–
			biomass	–	–	–	–	–	–	2.684	2.763	–	–
	SBS BSFRF F	index catch	abundance	–	–	2.039	1.795	1.676	1.694	–	–	–	–
			biomass	–	–	1.004	1.141	1.840	1.948	–	–	–	–
	SBS BSFRF M	index catch	abundance	–	–	–	–	–	–	1.832	1.524	–	–
			biomass	–	–	–	–	–	–	1.601	1.426	–	–

Table 103. Observed and random walk model-estimated time series for vulnerable male biomass from the NMFS EBS shelf survey. All values are in 1,000s t. lci: lower confidence interval; uci: upper confidence interval. Confidence intervals are 80%.

	observed			rema		
year	value	lci	uci	value	lci	uci
1975	269.1	174.6	414.7	206.6	146.9	290.7
1976	139.5	115.1	169.0	142.8	120.0	170.0
1977	119.2	100.9	140.7	117.0	100.4	136.3
1978	82.6	70.0	97.5	80.5	69.1	93.7
1979	37.5	31.3	44.9	43.2	36.6	51.0
1980	88.7	69.5	113.3	73.1	59.3	90.0
1981	51.8	44.2	60.7	53.1	45.8	61.5
1982	51.7	43.0	62.3	49.2	41.6	58.1
1983	30.2	24.9	36.7	31.0	26.1	36.9
1984	24.2	20.3	28.9	23.4	19.9	27.4
1985	11.7	9.6	14.2	13.0	10.9	15.5
1986	13.6	10.1	18.4	15.2	12.0	19.2
1987	22.9	19.0	27.7	24.2	20.4	28.8
1988	68.1	48.4	96.0	58.2	45.1	75.2
1989	104.4	87.3	124.8	98.5	83.6	116.0
1990	103.2	85.2	125.0	103.5	87.2	123.0
1991	116.7	90.0	151.5	111.3	89.5	138.4
1992	112.2	82.1	153.4	99.6	77.9	127.2
1993	64.2	52.6	78.4	64.6	54.1	77.2
1994	43.1	36.5	50.9	43.4	37.3	50.5
1995	31.1	24.7	39.2	31.2	25.6	38.1
1996	26.0	19.1	35.4	22.7	17.8	28.9
1997	10.7	9.2	12.5	11.4	9.8	13.1
1998	10.5	9.1	12.0	10.6	9.3	12.1
1999	11.8	9.2	15.0	12.2	9.9	14.9
2000	16.9	12.4	23.0	15.8	12.4	20.2
2001	17.5	14.4	21.2	17.3	14.5	20.6
2002	16.5	13.5	20.2	17.2	14.4	20.5
2003	21.8	17.9	26.5	21.7	18.2	25.9
2004	25.6	20.4	32.2	26.9	22.1	32.7
2005	43.4	36.2	52.1	42.6	36.1	50.3
2006	60.9	48.1	77.0	58.1	47.5	71.1
2007	67.5	50.8	89.7	63.7	50.4	80.4
2008	66.9	46.7	95.9	58.0	44.4	75.7
2009	37.2	30.5	45.4	39.5	33.0	47.2
2010	40.0	31.1	51.3	40.1	32.4	49.5
2011	41.1	30.6	55.2	41.2	32.5	52.2
2012	39.3	31.5	49.0	42.7	35.1	51.8
2013	76.2	55.3	104.9	68.9	53.9	88.0
2014	88.8	77.9	101.2	86.0	75.9	97.3
2015	64.5	57.1	73.0	65.3	58.1	73.4
2016	60.4	53.6	68.1	60.0	53.5	67.2
2017	48.2	41.7	55.7	48.0	42.0	55.0
2018	37.8	32.9	43.4	36.8	32.3	41.9
2019	18.3	15.7	21.3	19.3	16.7	22.3
2020	— —	— —	— —	18.3	12.6	26.7
2021	17.2	14.7	20.0	17.4	15.1	20.2
2022	19.9	16.9	23.5	19.6	16.9	22.8

(continued)

	observed			rema		
year	value	lci	uci	value	lci	uci
2023	18.6	16.6	20.9	19.1	17.1	21.3
2024	32.1	28.3	36.5	31.2	27.5	35.3

Table 104. Tier 4 management quantities for candidate B_{MSY} averaging periods. Biomass quantities (B, B_{MSY}, OFL) are in 1,000s t.

time block	M	B	B_{MSY}	status	F_{OFL}	OFL
1975:2024	0.23	31.15	50.28	0.62	0.13	3.87
1975:1980	0.23	31.15	110.53	0.28	0.05	1.41
1982:2024	0.23	31.15	41.81	0.75	0.16	4.74
1987:1995,2005:2009,2013:2015	0.23	31.15	65.68	0.47	0.10	2.84
2005:2009,2013:2015	0.23	31.15	60.25	0.52	0.11	3.15

Table 105. Abundance measures for PSC. "model": preferred model-based estimates of total survey abundance (excludes crab < 25 mm CW). "survey": design-based estimates of total survey abdundance (includes crab < 25 mm CW). Abundance units are millions of crab. The survey was not conducted in 2020.

year	model millions	survey millions
1975	751.0	790.1
1976	714.2	683.5
1977	675.9	847.9
1978	632.1	582.0
1979	606.5	270.8
1980	573.1	1252.8
1981	428.7	598.5
1982	485.5	684.5
1983	457.8	451.3
1984	438.5	298.4
1985	464.2	113.2
1986	536.7	199.1
1987	582.7	483.2
1988	583.7	734.1
1989	540.7	925.9
1990	470.8	813.8
1991	389.3	822.6
1992	317.5	510.2
1993	250.9	272.3
1994	205.1	212.2
1995	182.4	188.0
1996	164.0	178.8
1997	181.3	153.7
1998	170.8	168.0
1999	230.7	272.3
2000	230.2	222.9
2001	325.8	555.2
2002	327.4	374.8
2003	427.8	442.5
2004	456.7	478.1
2005	430.8	681.7

(continued)

year	model millions	survey millions
2006	392.9	769.0
2007	362.4	644.3
2008	343.8	388.5
2009	460.4	336.5
2010	457.5	368.5
2011	429.6	659.6
2012	386.9	708.6
2013	359.2	642.8
2014	311.3	540.0
2015	258.0	329.2
2016	220.9	285.4
2017	275.9	344.8
2018	289.8	509.7
2019	317.9	420.9
2020	297.0	NA
2021	413.4	385.0
2022	632.5	381.4
2023	769.7	774.8
2024	746.0	1215.7

Figures

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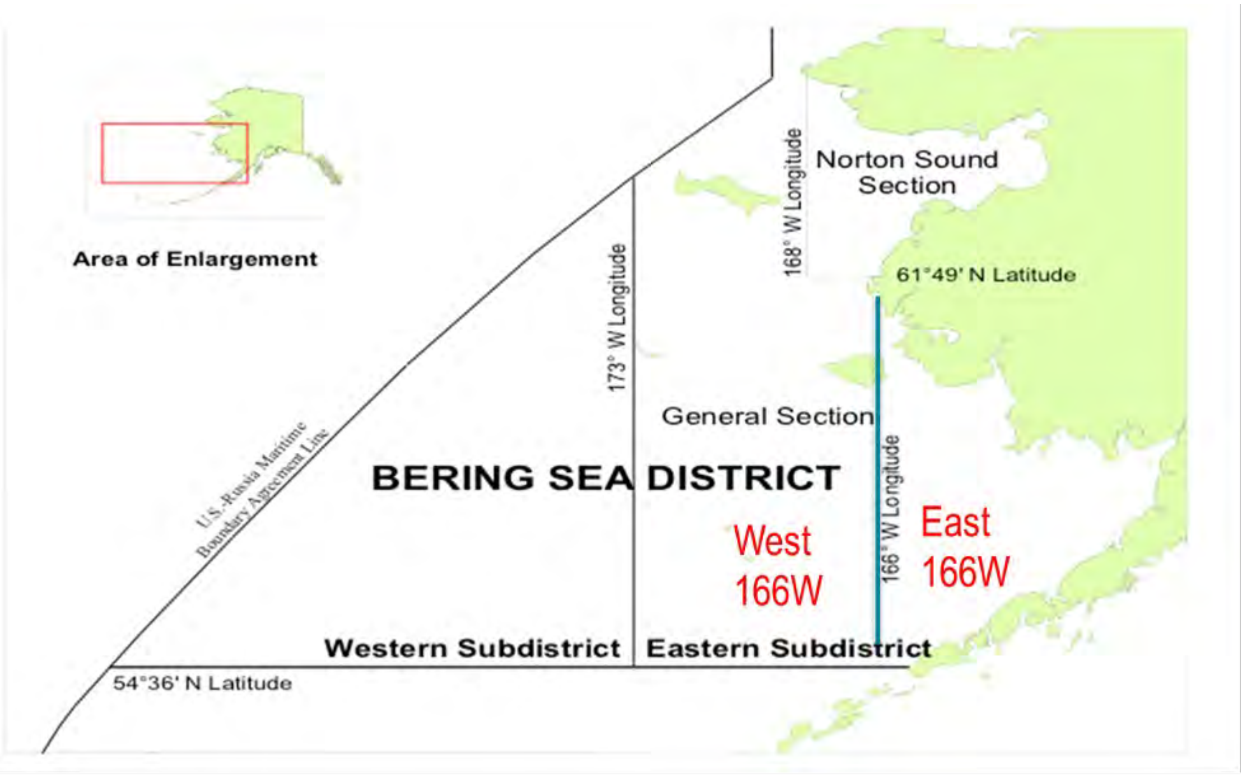

Figure 1. Eastern Bering Sea District of the ADF&G Tanner crab Registration Area J, including sub-districts and sections (from Bowers et al. 2008). Separate TACs are set annually for the areas east and west of 166^{o}W in the General Section. These management areas are identified in the text, tables,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

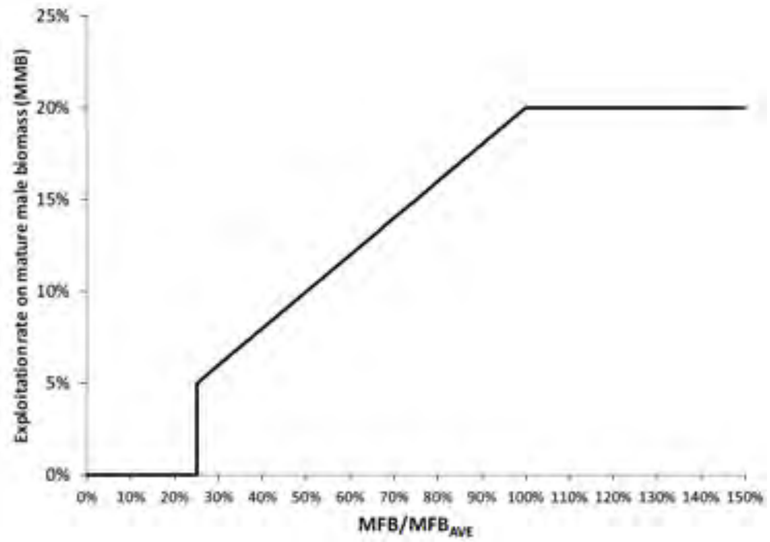

Figure 2. Sloping control rule used by ADF&G from 2011 to 2019 as part of its TAC setting process to determine the maximum exploitation rate on mature male biomass as a function of the ratio of current mature female biomass (MFB) to MFB averaged over some time period.

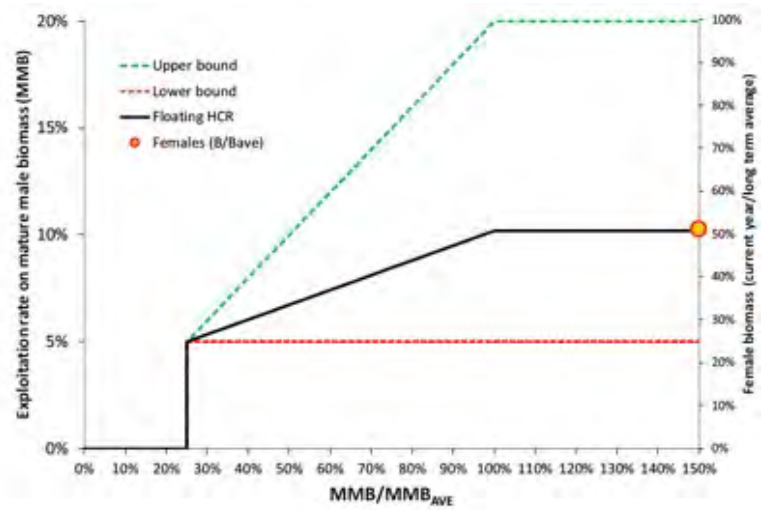

Figure 3. Current ADF&G “floating” sloping control rule to determine the maximum exploitation rate on mature male biomass (MMB) as a function of the ratio of current MMB to the average MMB over 1982-2018. The ratio of current mature female biomass (MFB) to MFB averaged over 1982-2018 is used to determine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

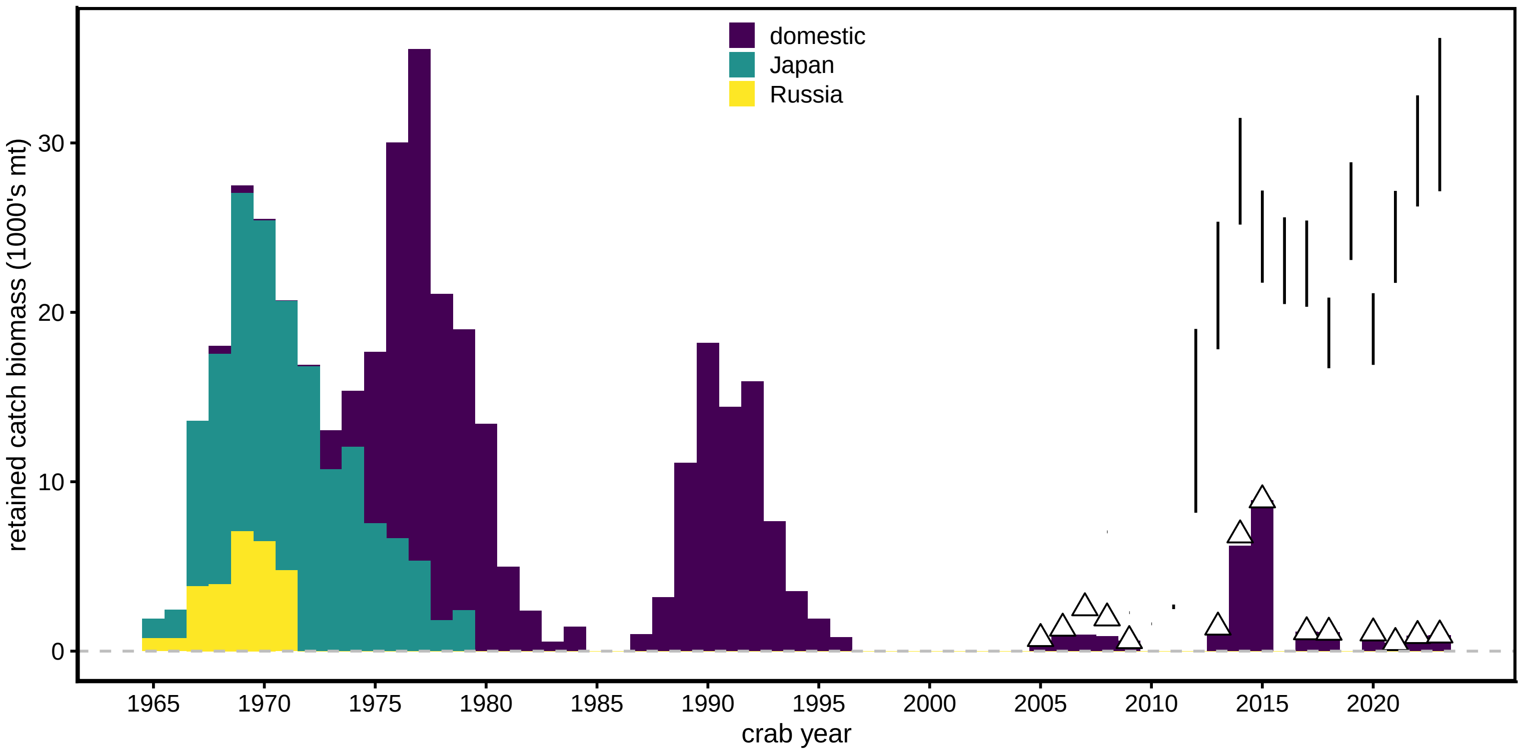

Figure 4. Total retained catch (males, 1000's t) in the directed fisheries (foreign [1965-1979] and domestic [1968-]) for Tanner crab (aggregated across State management areas). The bars indicate the Tier 3 OFL and ABC (upper and lower limits, respectively; (values start in 2011/12); the triangles indicate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

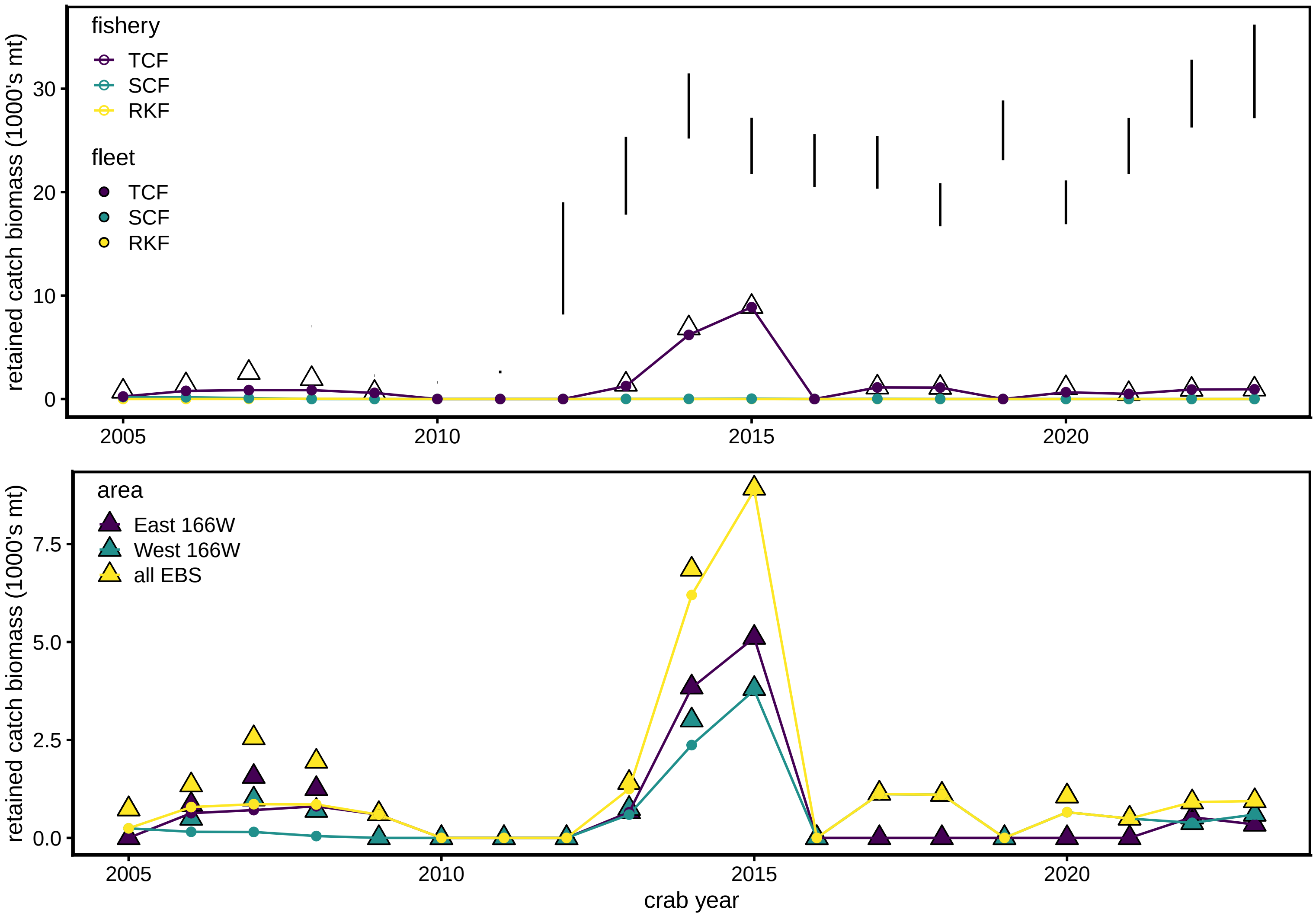

Figure 5. Upper plot: time series of retained catch biomass (1000's t) in the directed Tanner crab (TCF), snow crab (SCF), and BBRKC (RKF) fisheries since 2005. The bars indicate the OFL and ABC (upper and lower limits, respectively; values start in 2011/12); the triangles indicate the total (area-combined)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

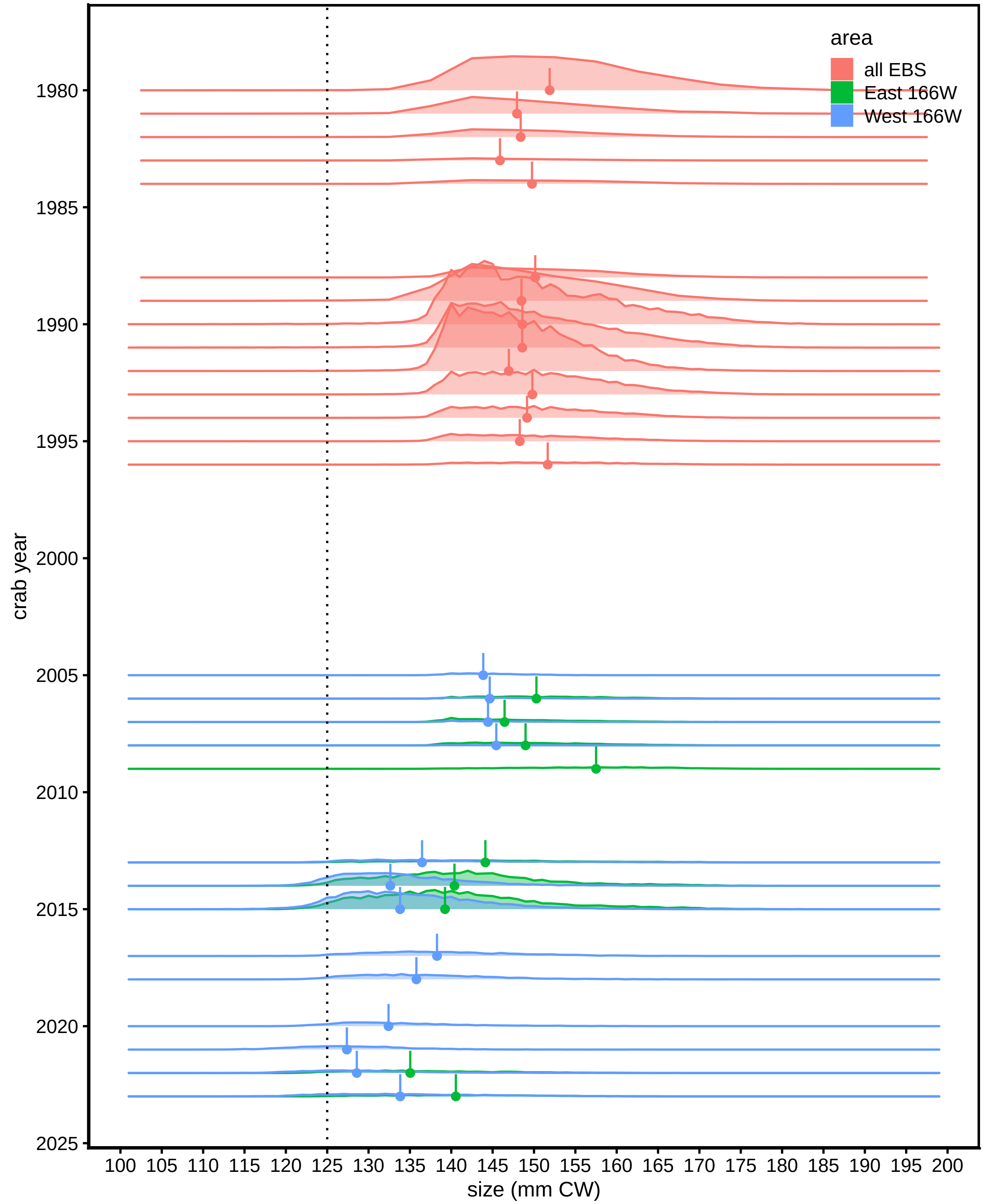

Figure 6. Retained catch size compositions, scaled to total abundance by area and year. Vertical bars and points indicate median sizes, dotted vertical line indicates recent industry-preferred size.

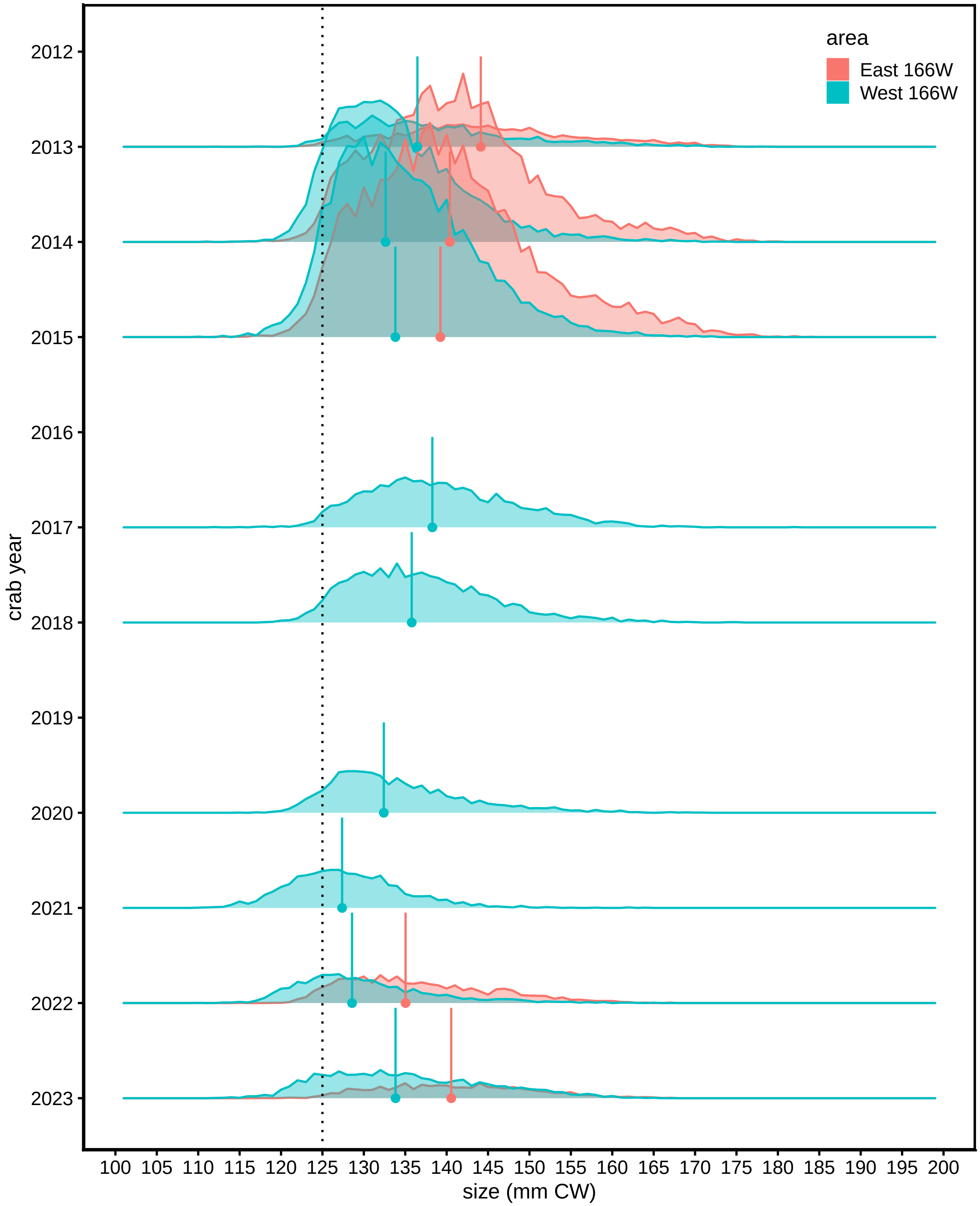

Figure 7. Retained catch size compositions, scaled to total retained abundance by area and year from recent seasons. Vertical bars and points indicate median sizes.Vertical dotted line indicates recent industry-preferred size.

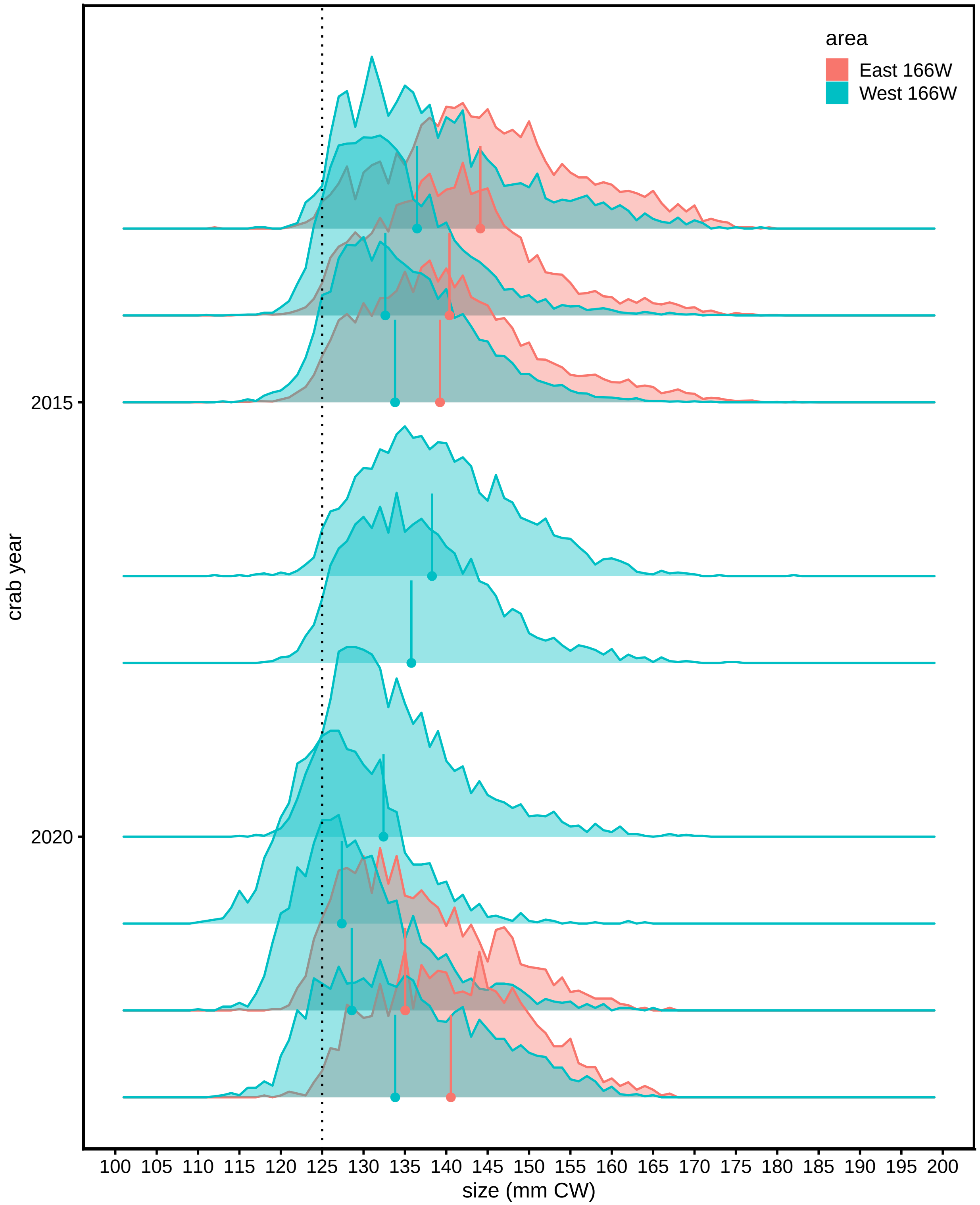

Figure 8. Retained catch size compositions from recent seasons, normalized to sum to 1 by area and year to show contrast. Vertical bars and points indicate median size. Dotted line indicates recent industry-preferred size.

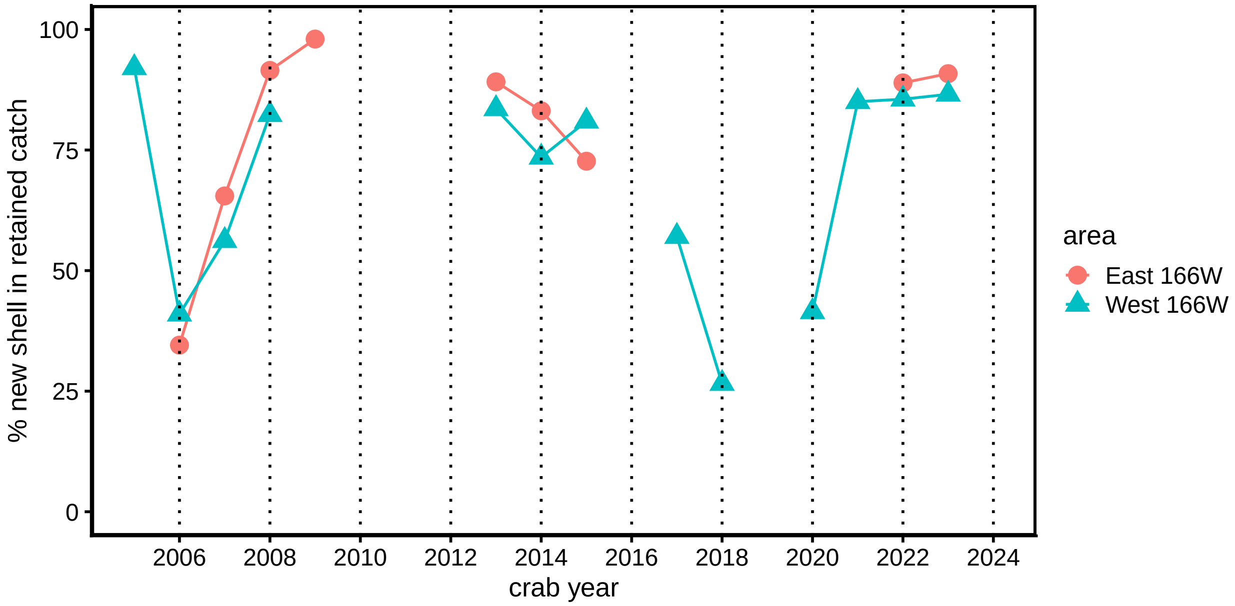

Figure 9. The fraction of new shell males in the retained catch, by management area, for the directed fishery since 2005/06.

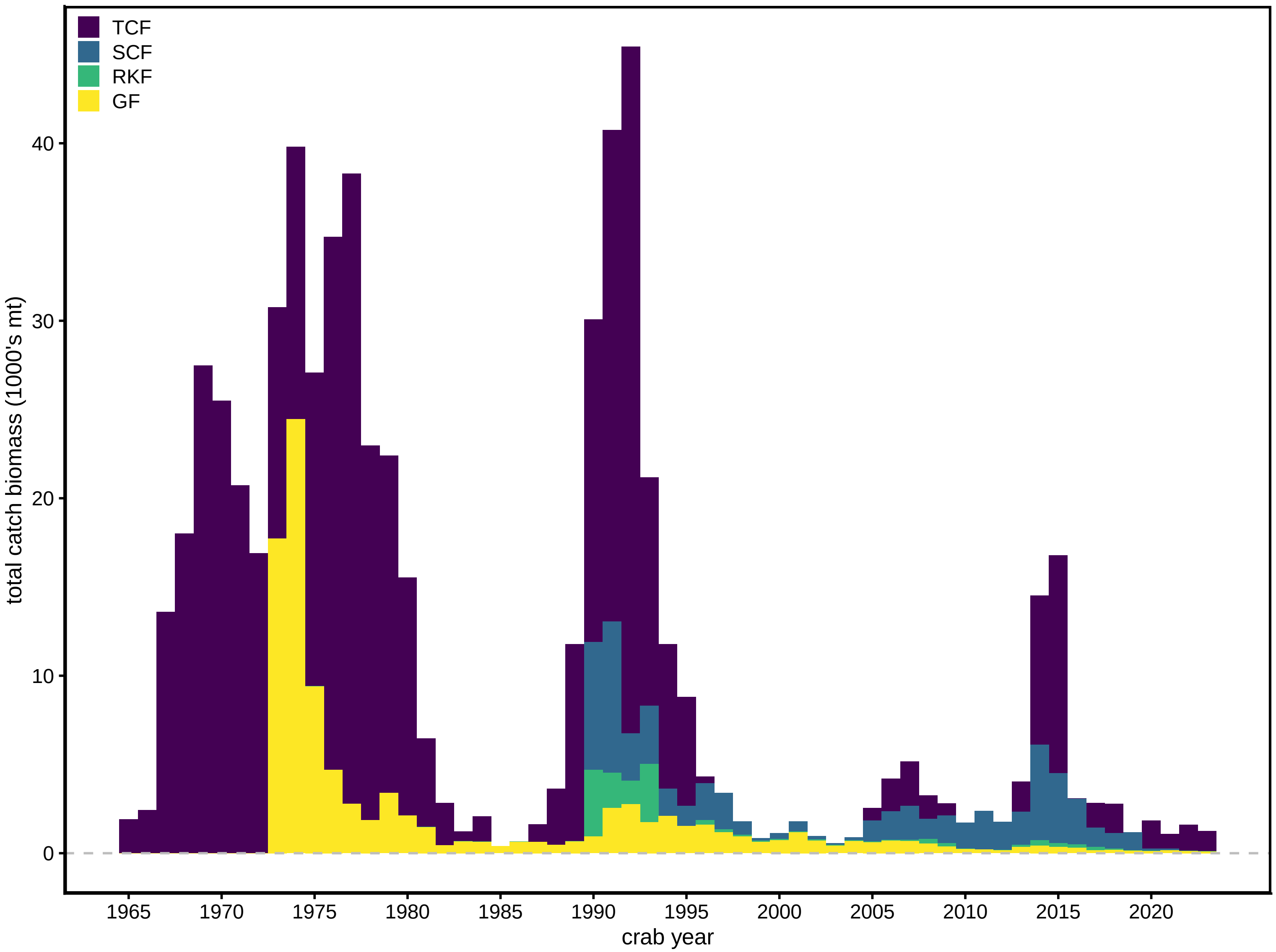

Figure 10. Total catch (retained + discards) biomass estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). Values for the directed fishery prior to 1991/92 do not include bycatch. **Discard mortality rates have not been applied to these estimates.**

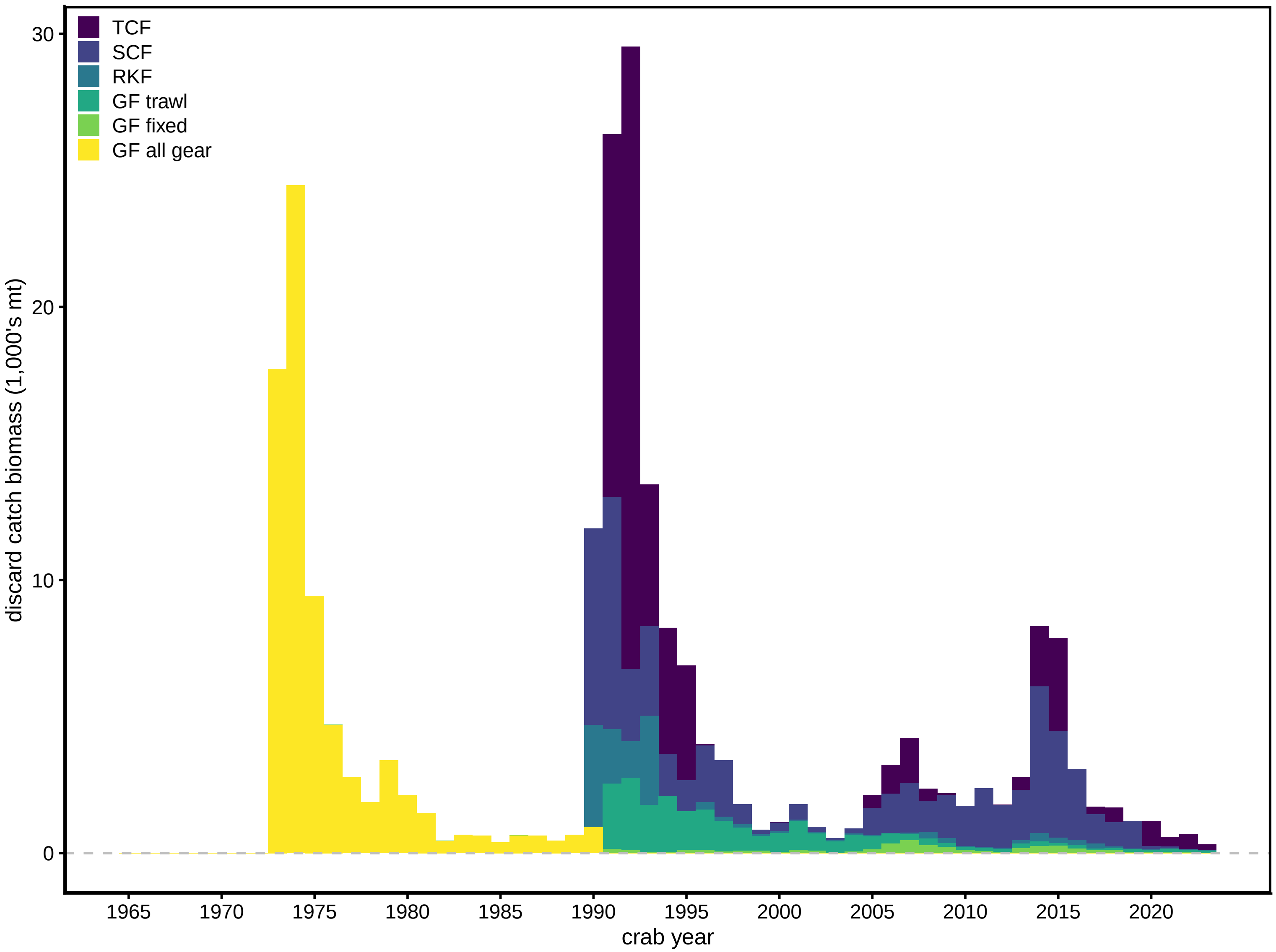

Figure 11. Discard biomass estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). Discard estimates for the directed fishery were derived using the subtraction method. **Discard mortality rates have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

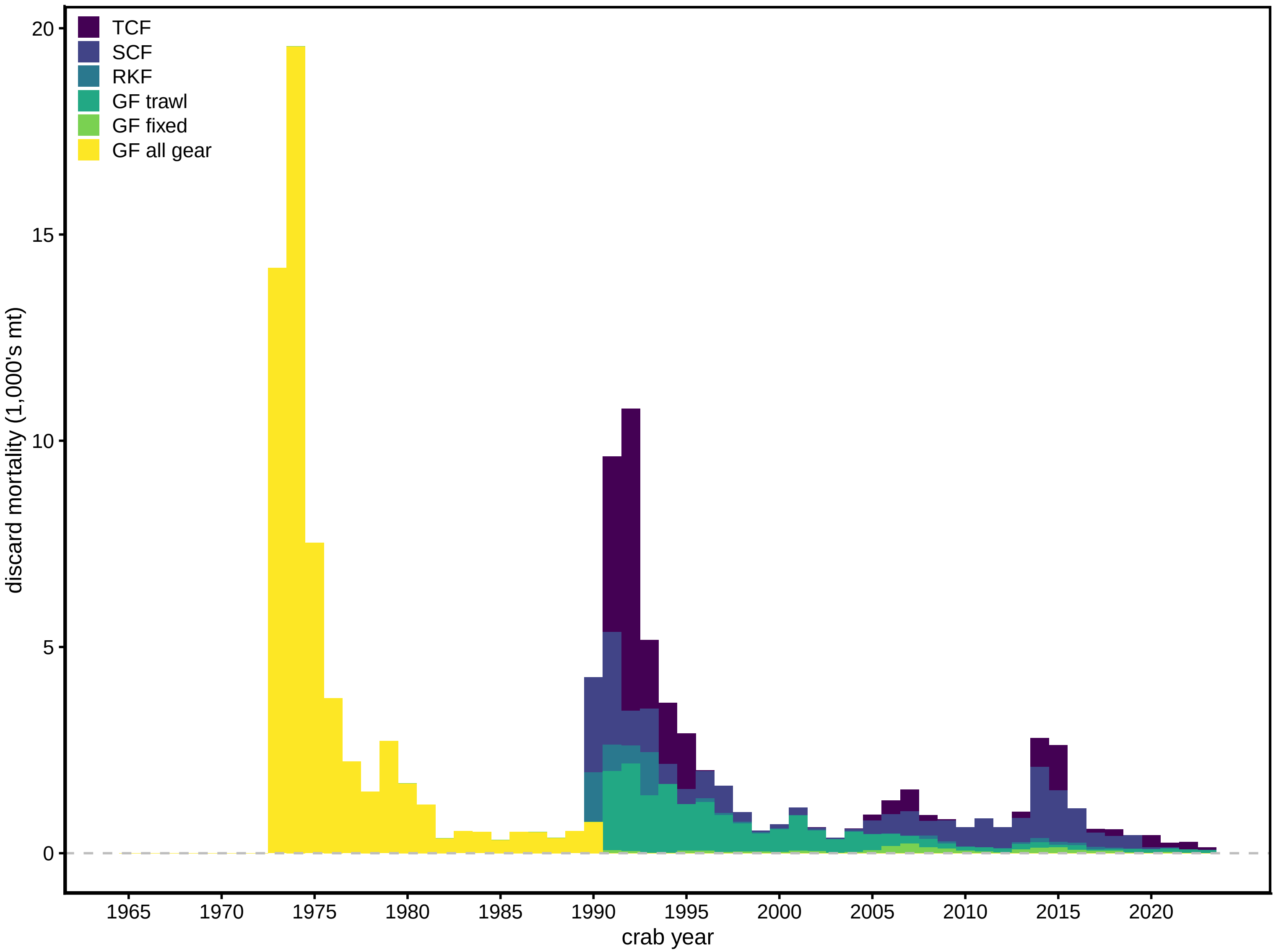

Figure 12. Discard mortality (biomass) estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). Discard estimates for the directed fishery were derived using the subtraction method. **Gear-specific assumed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

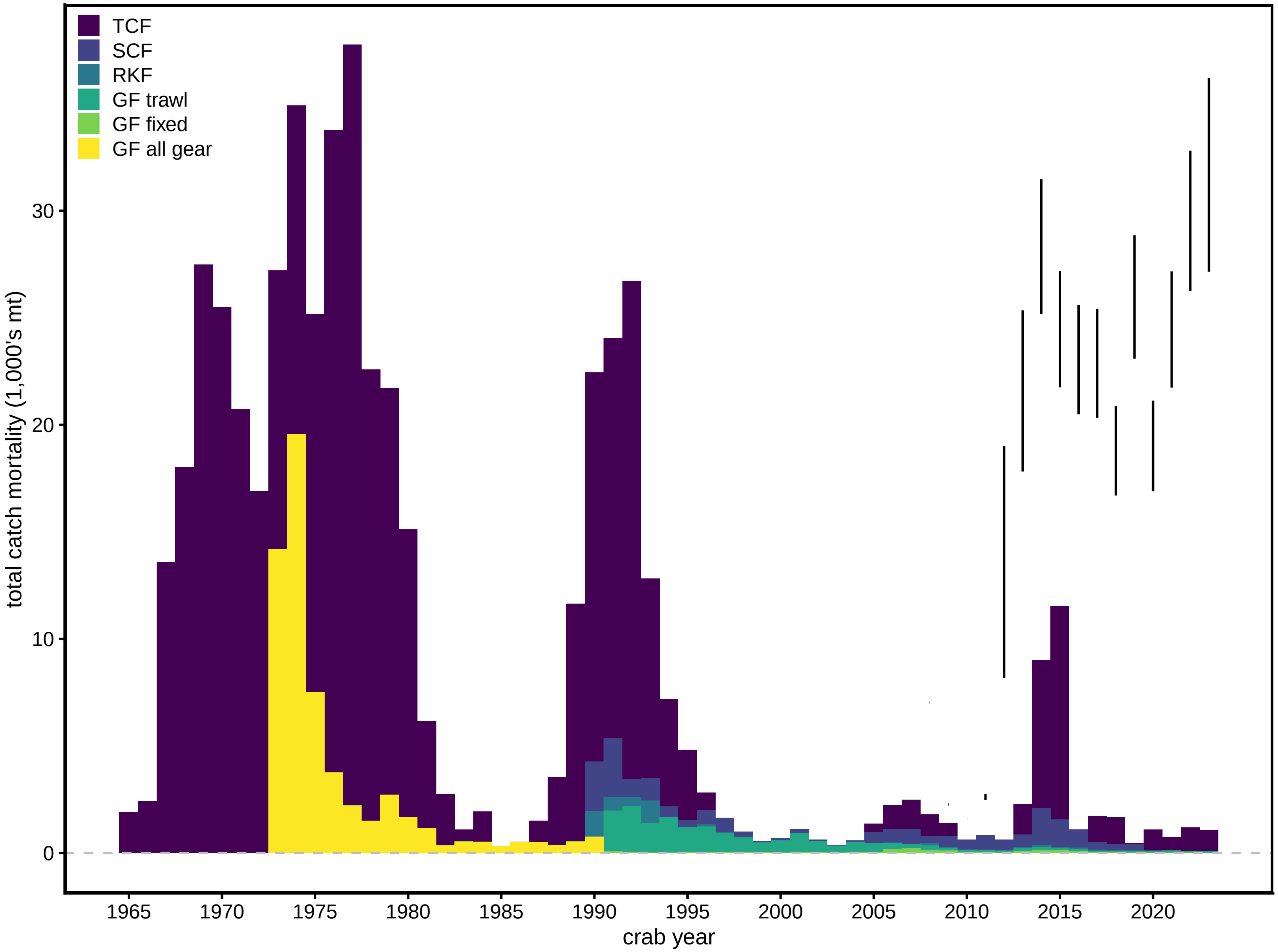

Figure 13. Total catch mortality (biomass) estimates for Tanner crab (sexes combined) in the directed Tanner crab (TCF), snow crab (SCF), Bristol Bay red king crab (RKF), and groundfish fisheries (GF). The bars indicate the Tier 3 OFL and ABC (upper and lower limits, respectively; values start in 2011/12). Values for discards in the crab fisheries are not available prior to 1991/92.

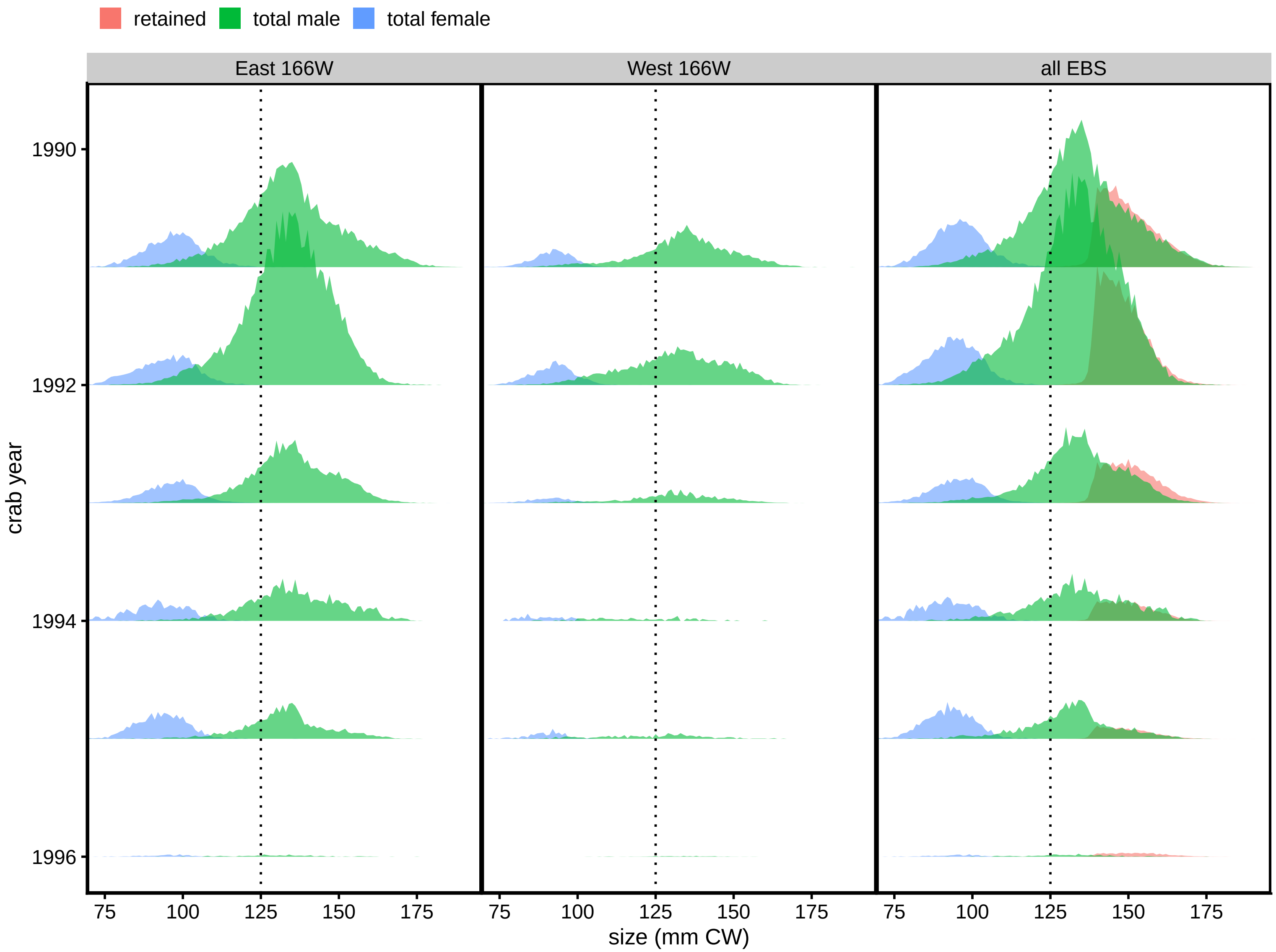

Figure 14. Comparison of expanded size compositions for retained and total catch in the directed fishery prior to 1997/98. Retained catch has already been aggregated across ADF&G management areas. Dotted line indicates recent industry-preferred size.

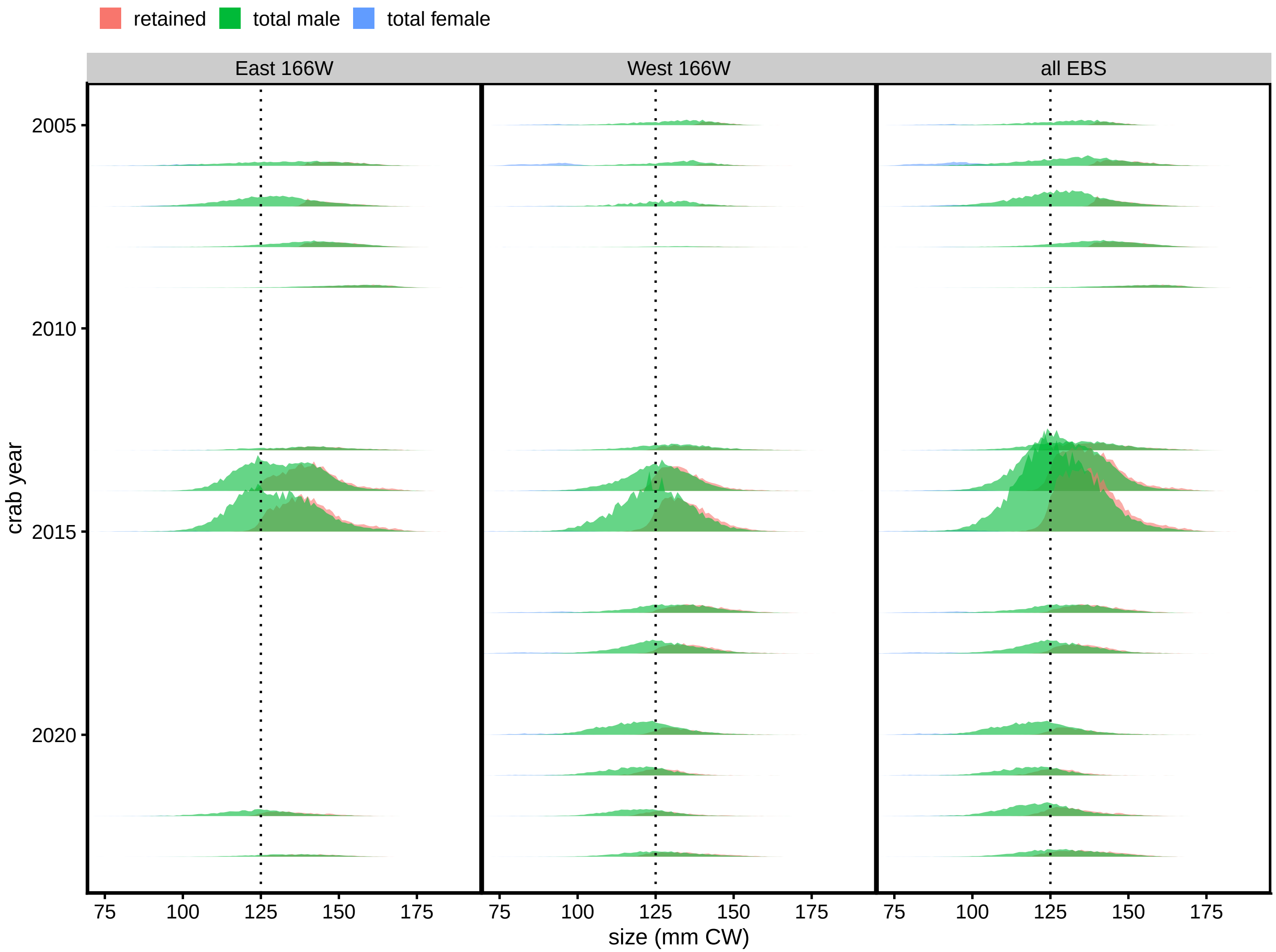

Figure 15. Comparison of expanded size compositions for retained and total catch in the directed fishery after 2004/05. Dotted line indicates recent industry-preferred size.

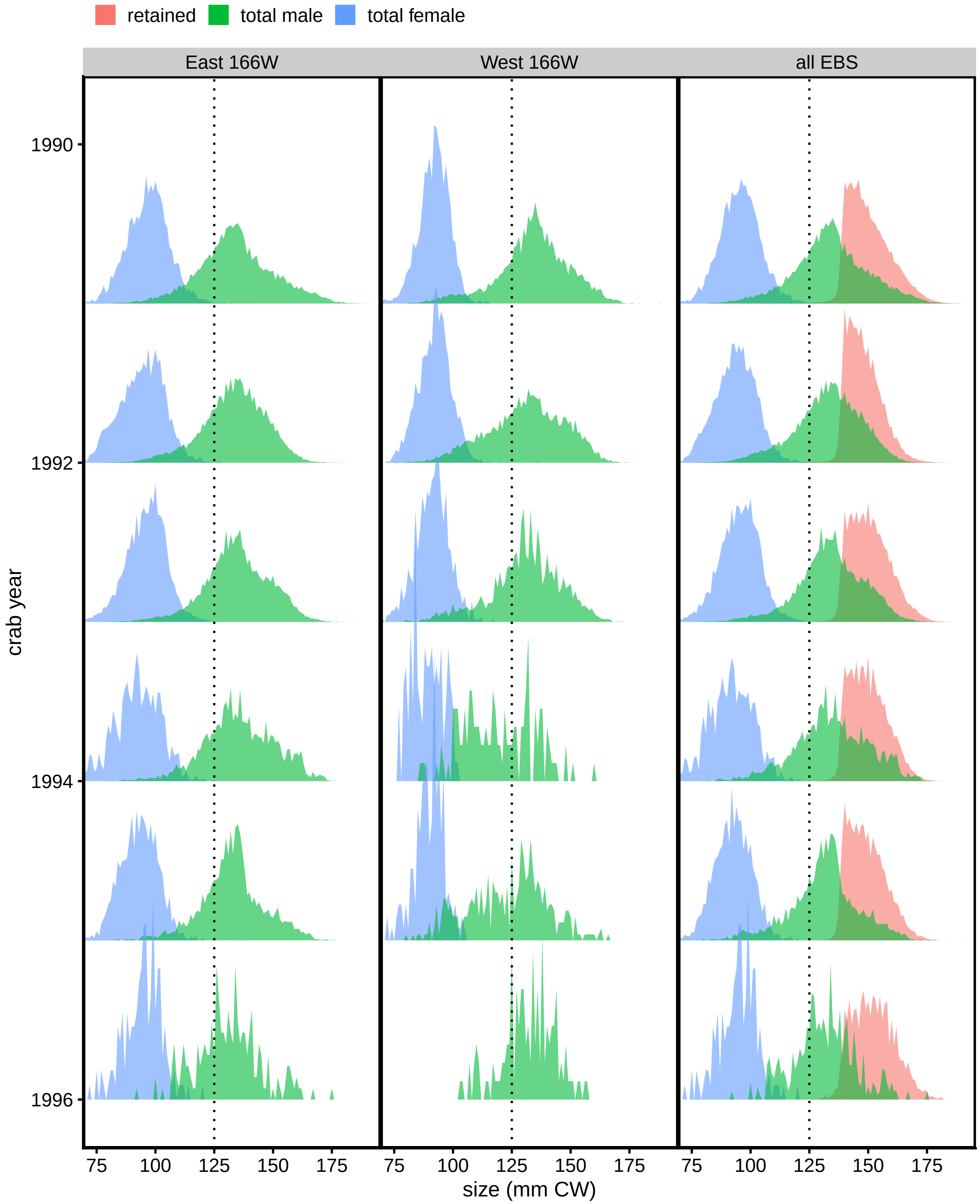

Figure 16. Comparison of *relative* size compositions for retained and total catch in the directed fishery prior to 1997/98. Individual compositions are scaled to sum to 1 across sizes. Retained catch has already been aggregated across ADF&G management areas. Dotted line indicates recent industry-preferred size.

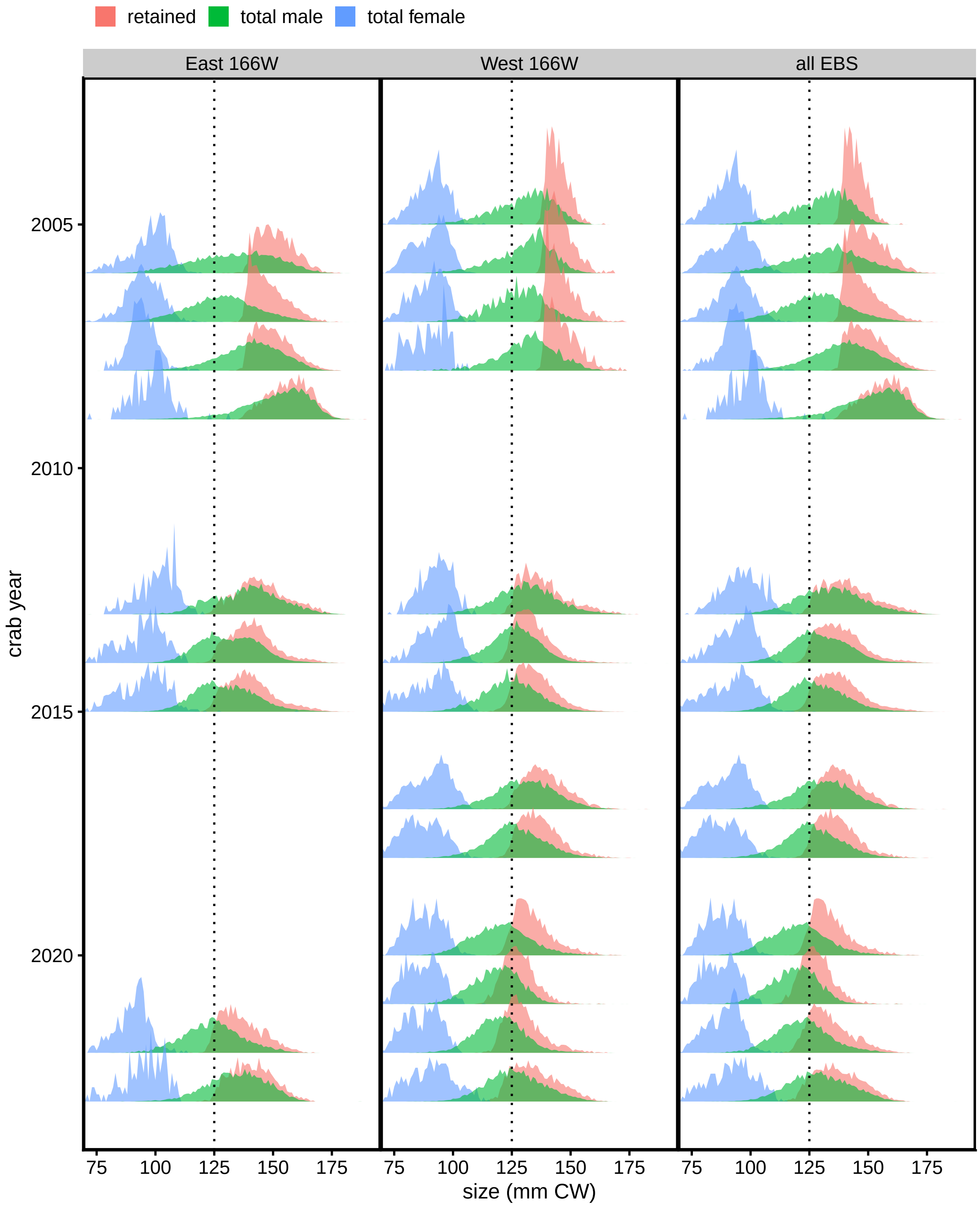

Figure 17. Comparison of *relative* size compositions for retained and total catch in the directed fishery after 2004/05. Individual compositions are scaled to sum to 1 across sizes. Dotted line indicates recent industry-preferred size.

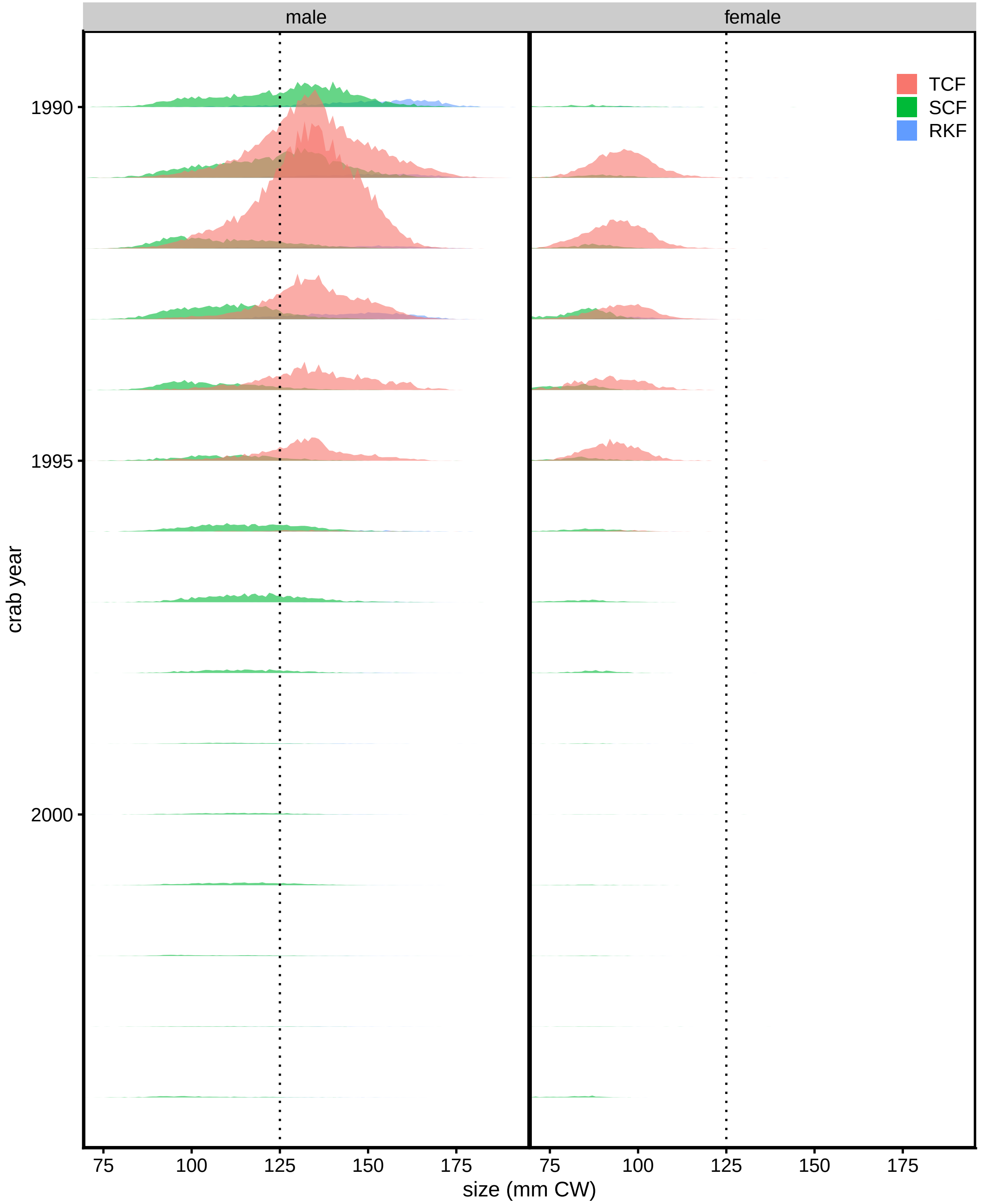

Figure 18. Comparison of expanded size compositions for total catch of Tanner crab in the crab fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery.

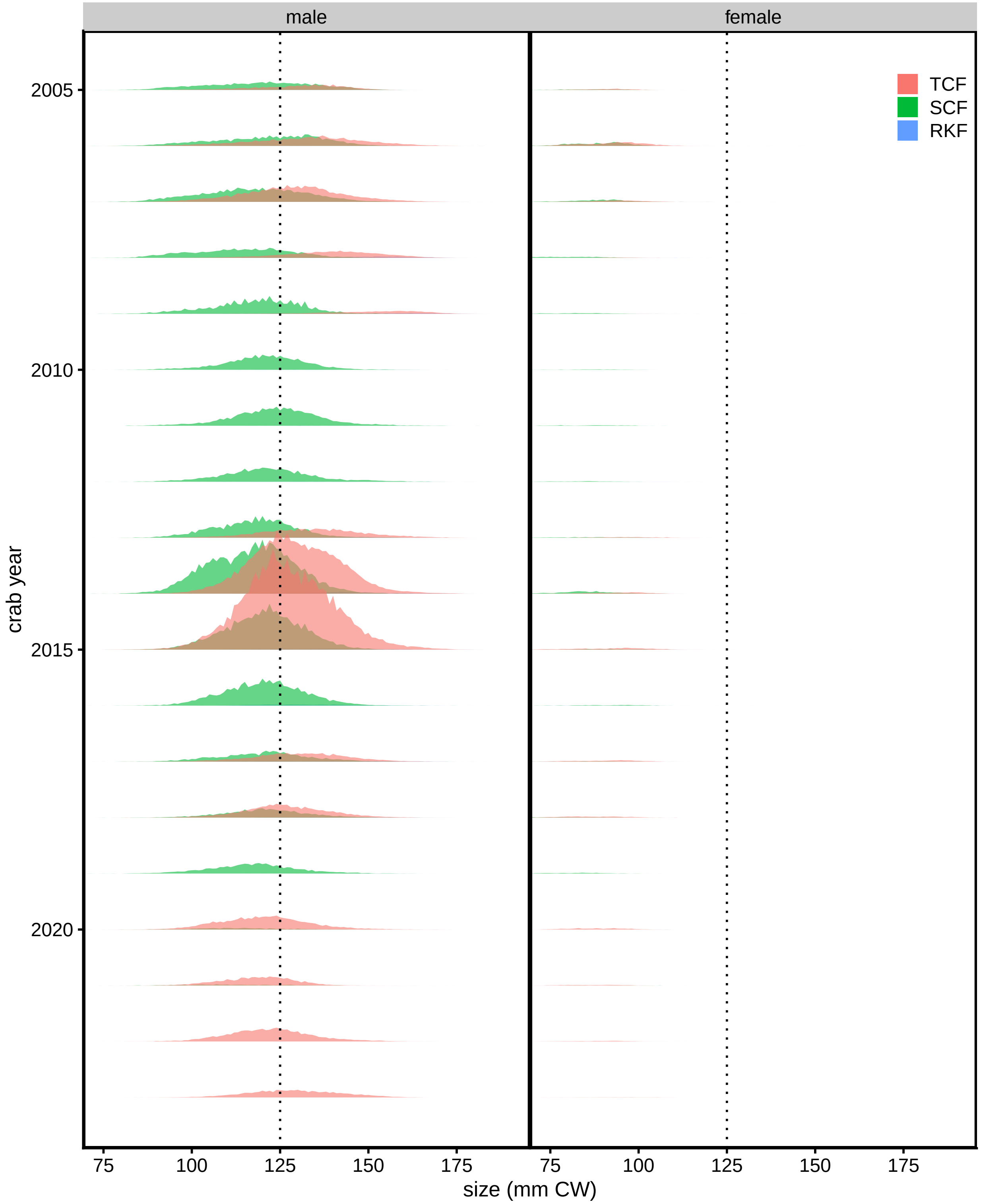

Figure 19. Comparison of expanded size compositions for total catch of Tanner crab in the crab fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; SCF: snow crab fishery;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

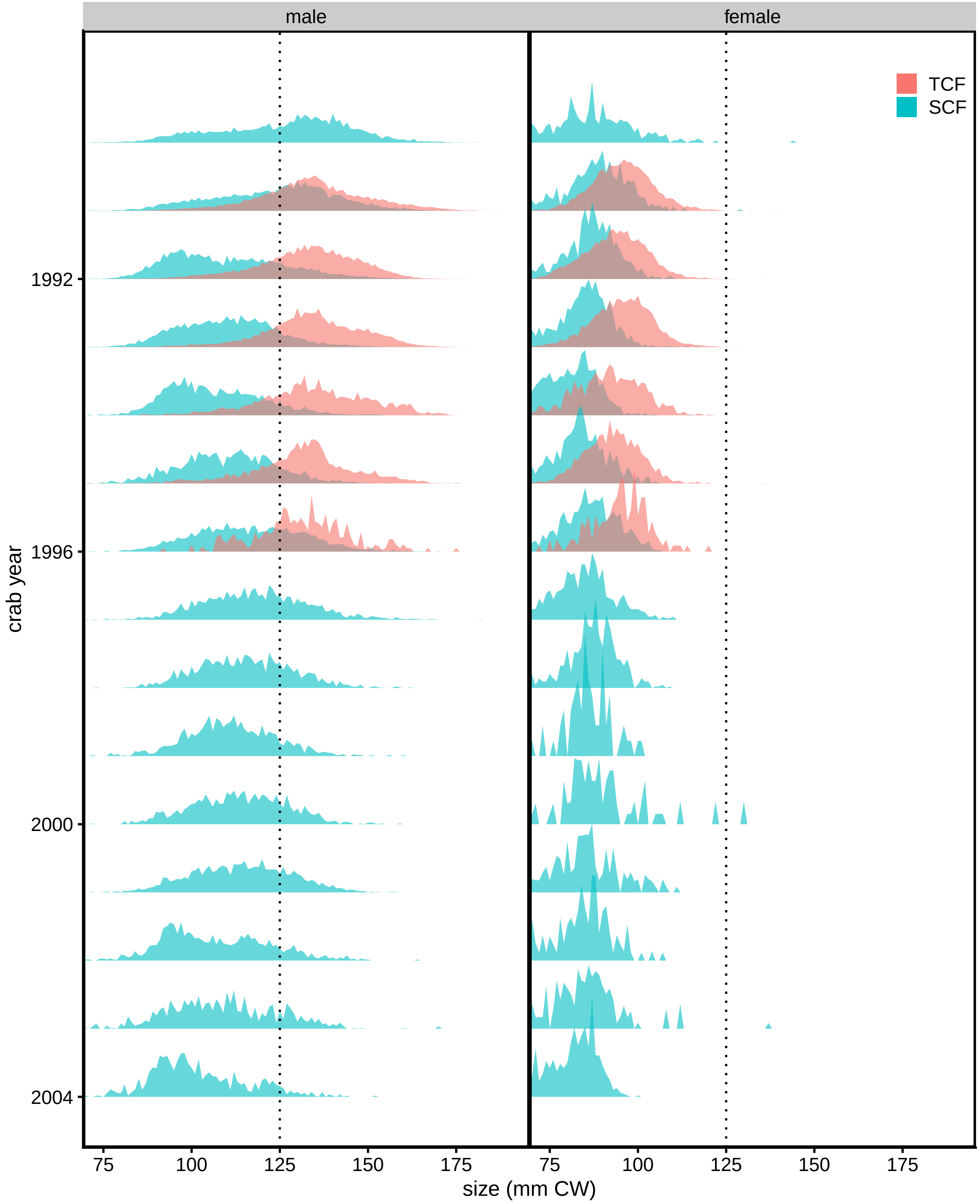

Figure 20. Comparison of *relative* size compositions for total catch of Tanner crab in the directed and snow crab fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Individual compositions are scaled to sum to 1 across sizes. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; SCF: snow crab fishery.

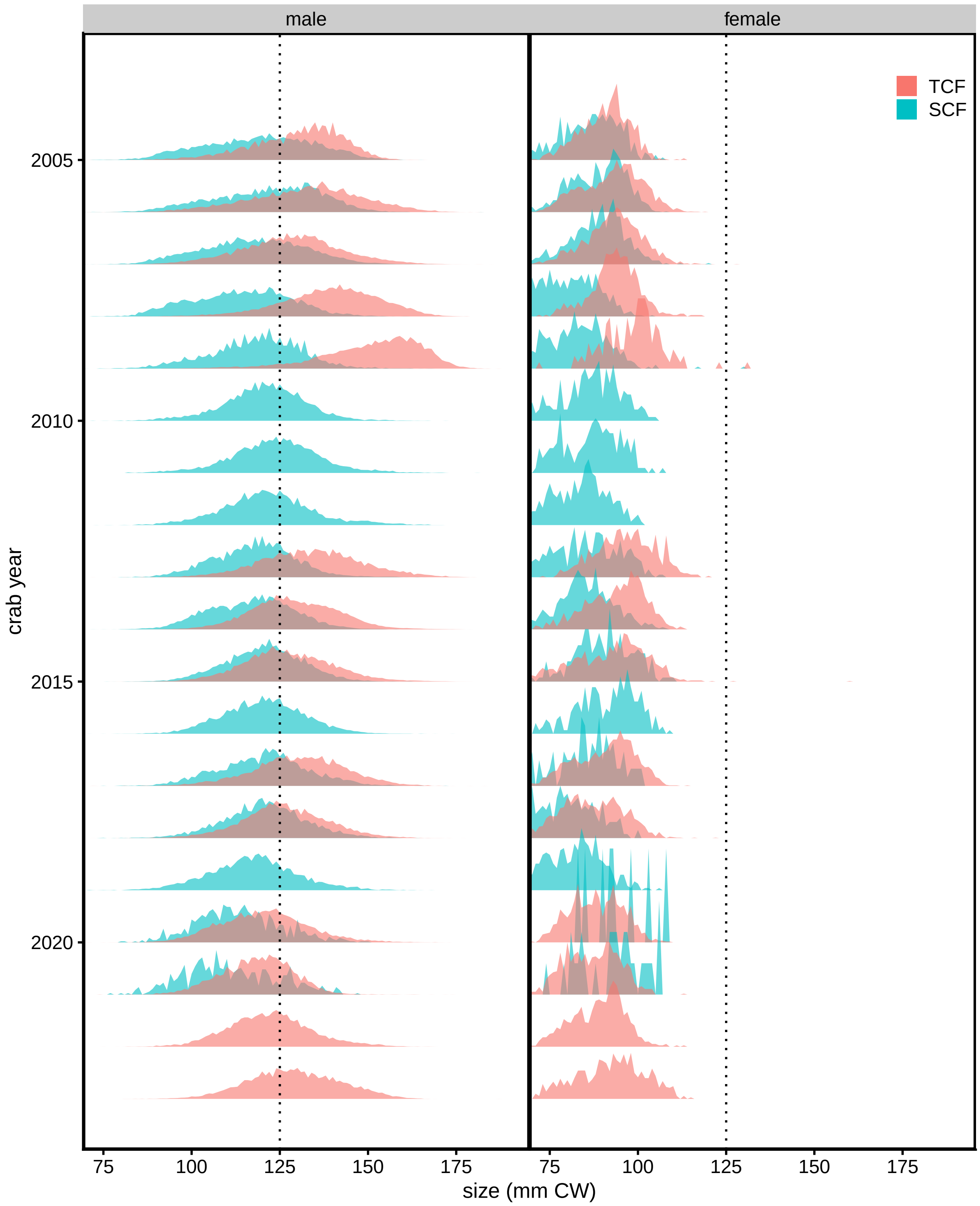

Figure 21. Comparison of *relative* size compositions for total catch of Tanner crab in the crab fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Individual compositions are scaled to sum to 1 across sizes. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery.

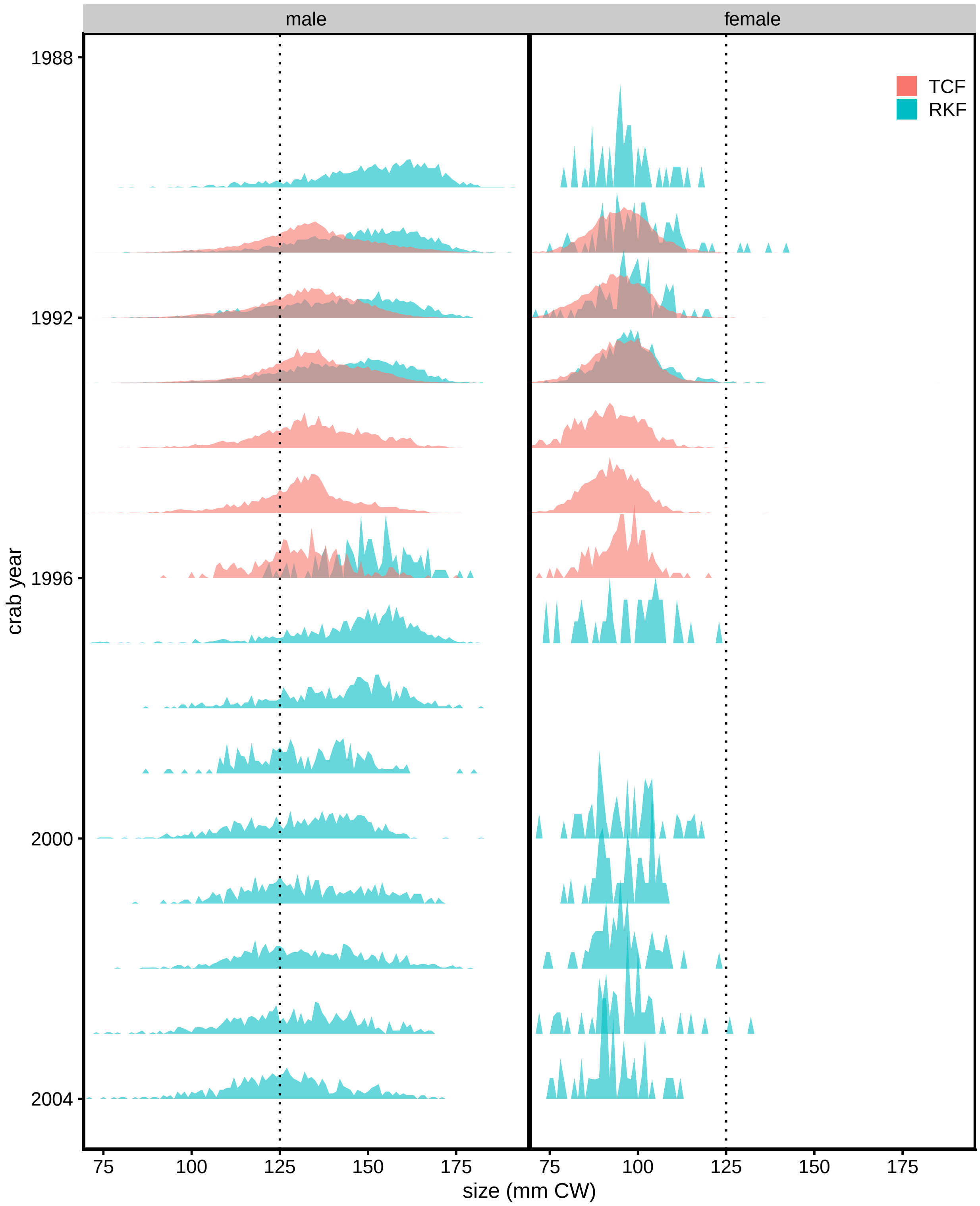

Figure 22. Comparison of *relative* size compositions for total catch of Tanner crab in the directed and BBRKC fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Individual compositions are scaled to sum to 1 across sizes. Size compositions limited to a few samples are not plotted to improve clarity. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; RKF: BBRKCb fishery.

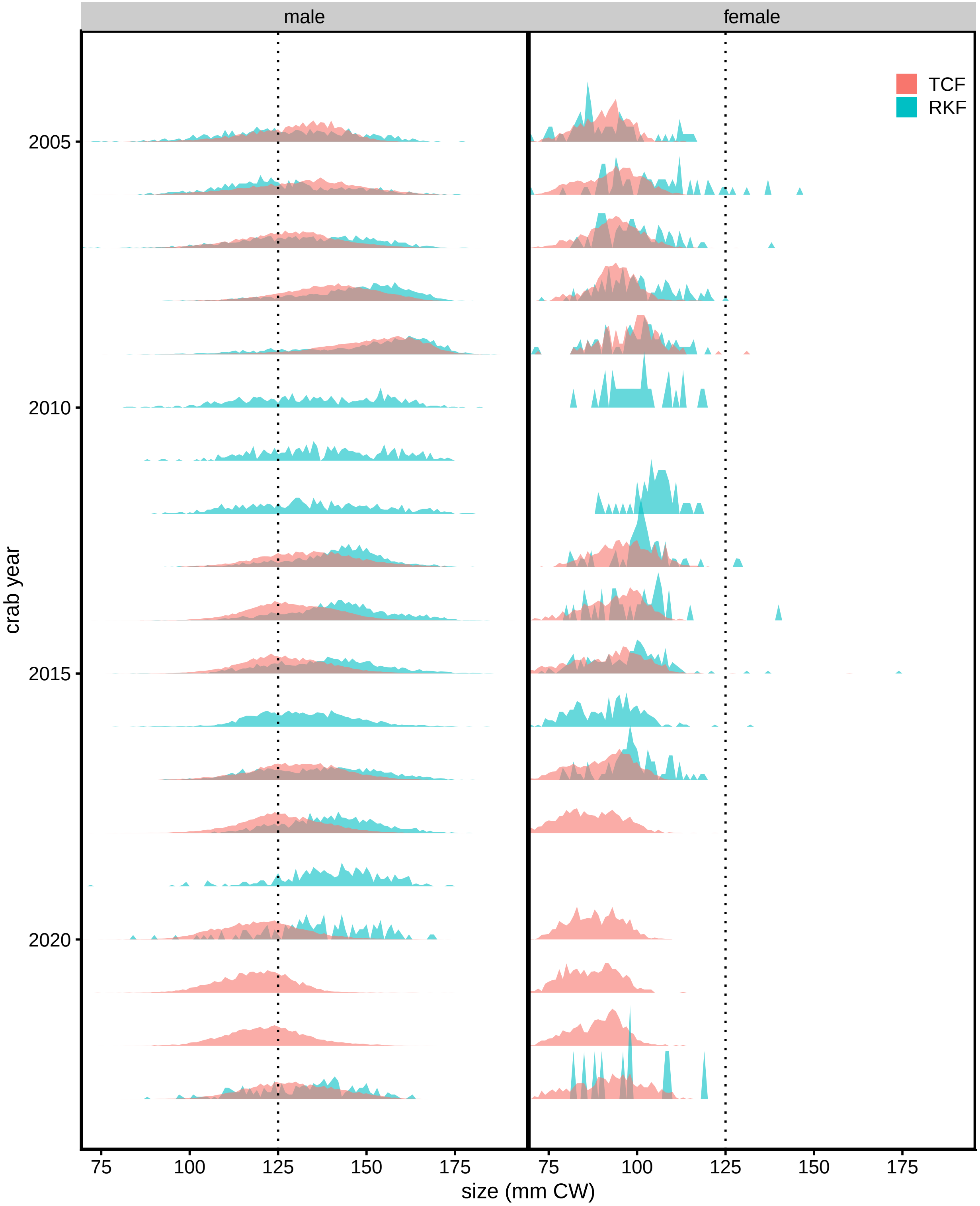

Figure 23. Comparison of *relative* size compositions for total catch of Tanner crab in the directed and BBRKC fisheries prior to 2005/06. Catch has already been aggregated across ADF&G management areas. Individual compositions are scaled to sum to 1 across sizes. Size compositions lmited to a few samples are not plotted to improve clarity. Dotted line indicates recent industry-preferred size. TCF: directed Tanner crab fishery; RKF: BBRKC fishery.

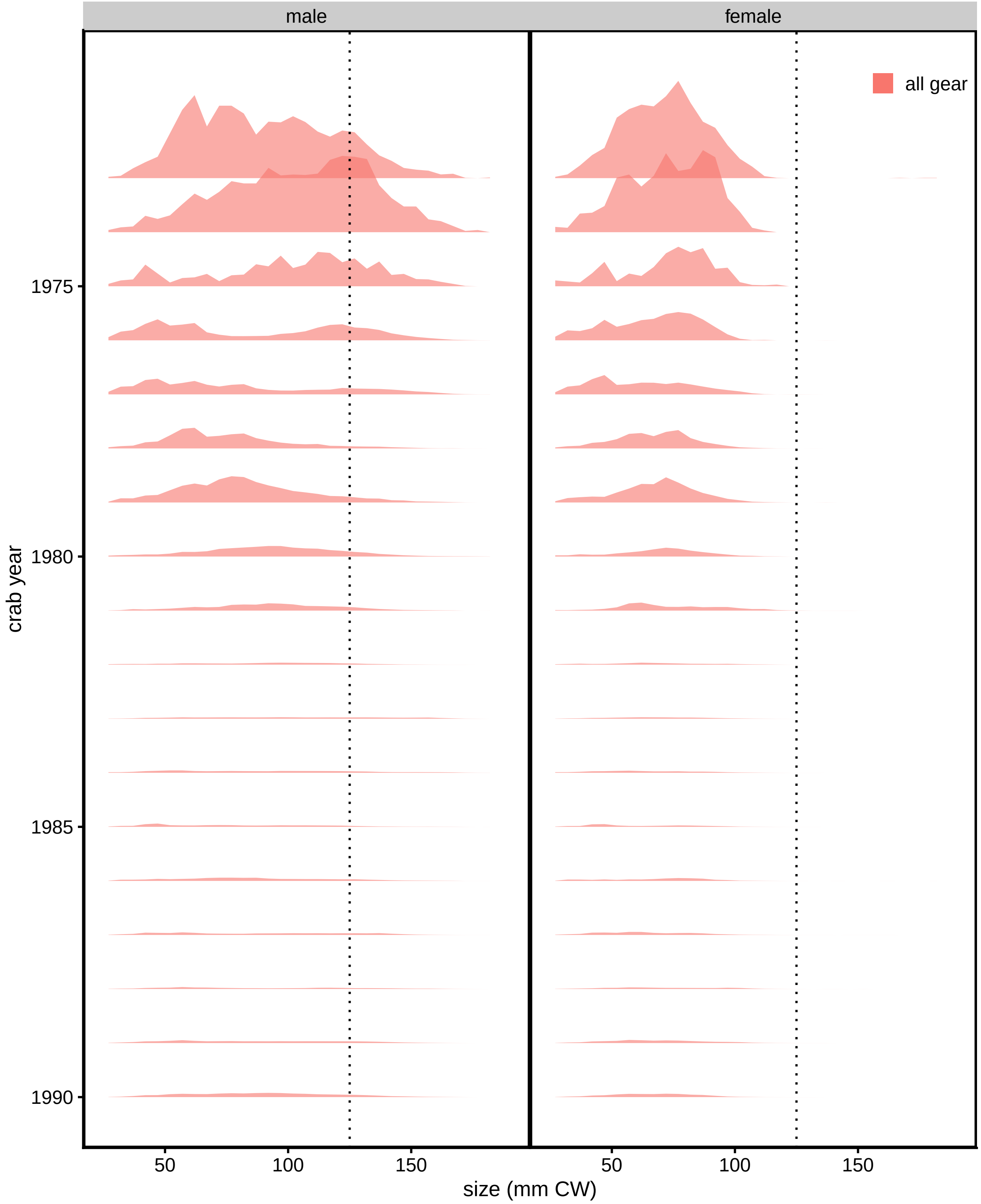

Figure 24. Expanded size compositions for total catch of Tanner crab in the groundfish fisheries prior to 1990/91. Dotted line indicates recent industry-preferred size.

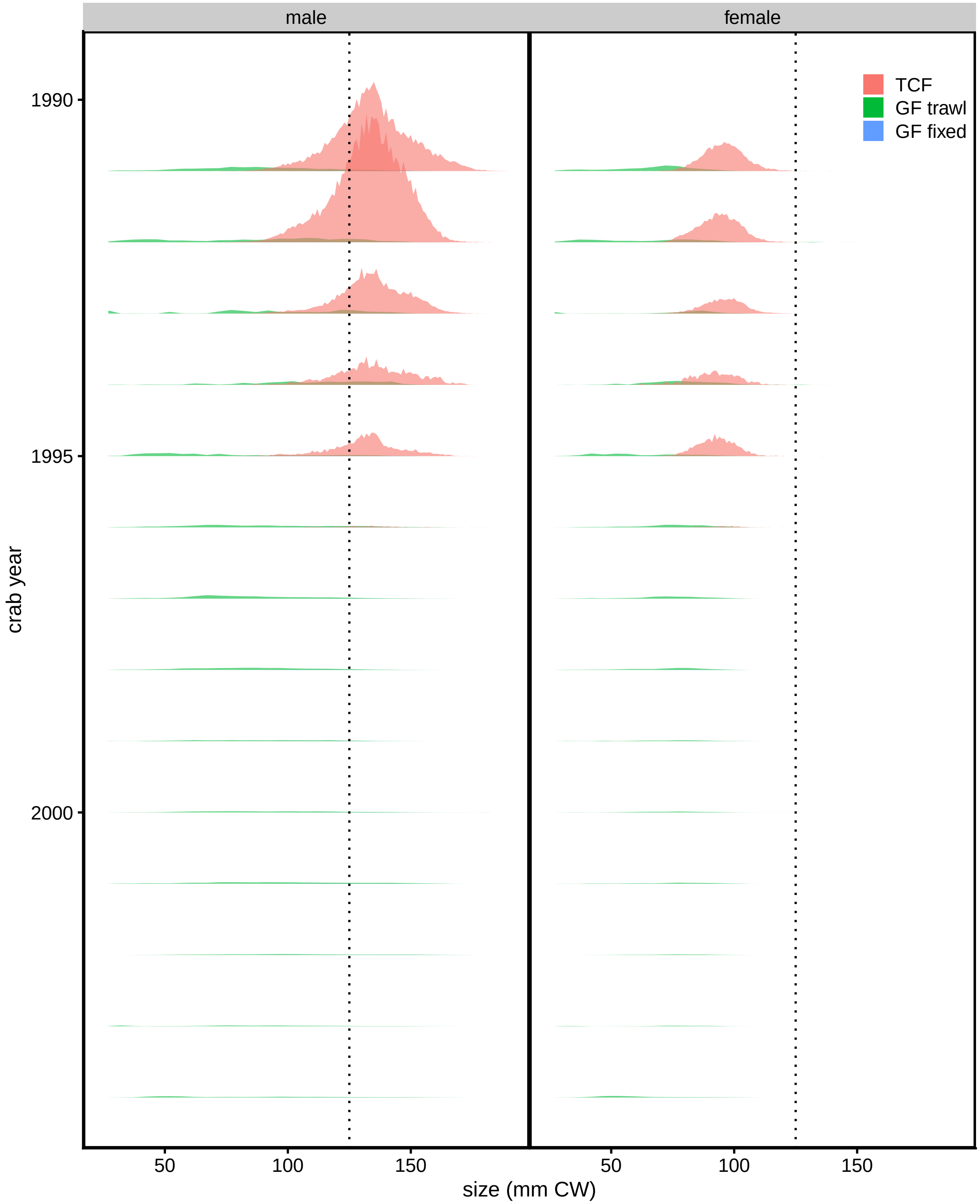

Figure 25. Comparison of expanded size compositions for total catch of Tanner crab in the directed ('TCF') and groundfish ('GF') fisheries during 1991/92-2004/05. Dotted line indicates recent industry-preferred size.

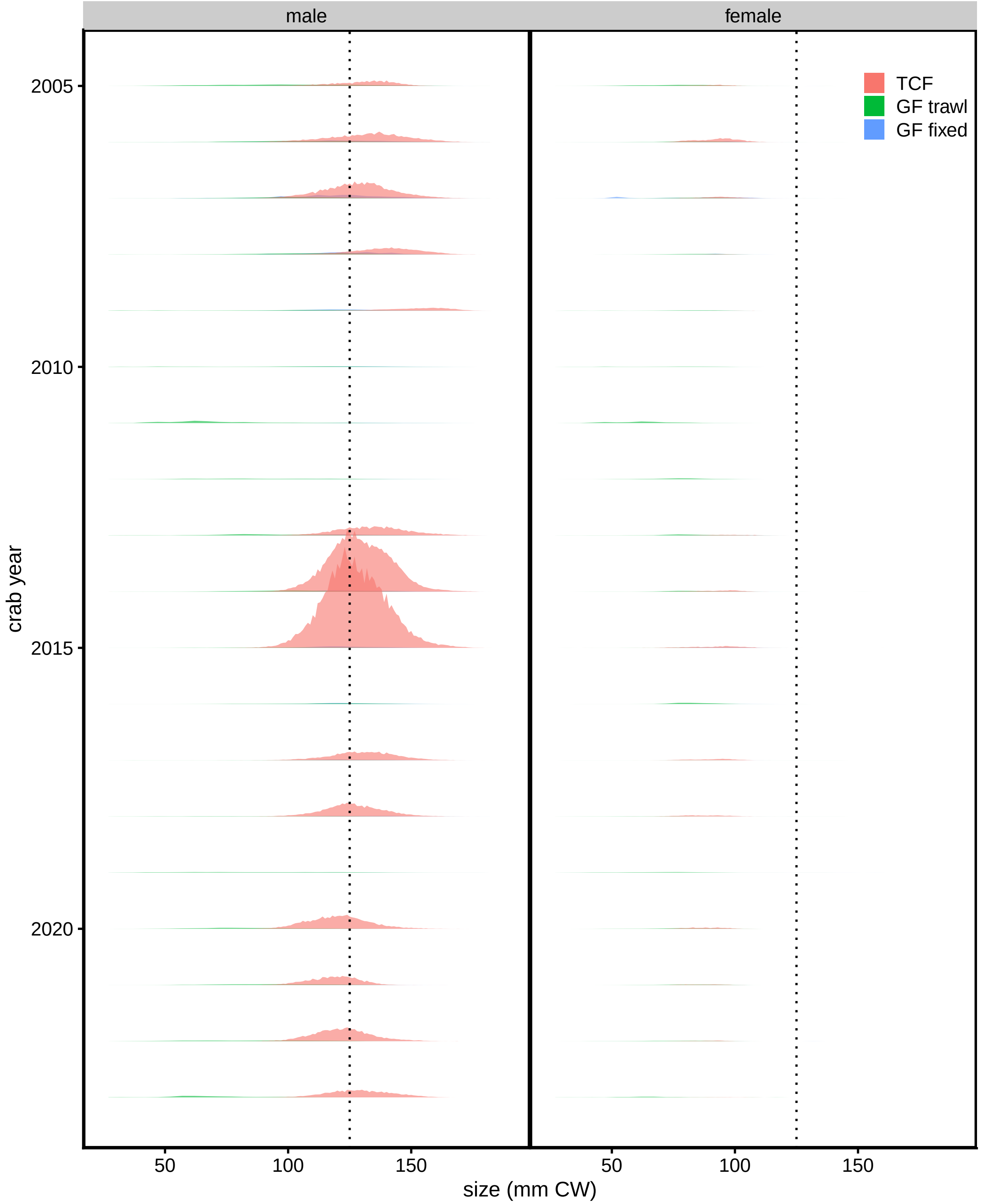

Figure 26. Comparison of expanded size compositions for total catch of Tanner crab in the directed ('TCF') and groundfish ('GF') fisheries since 2005/06. Dotted line indicates recent industry-preferred size.

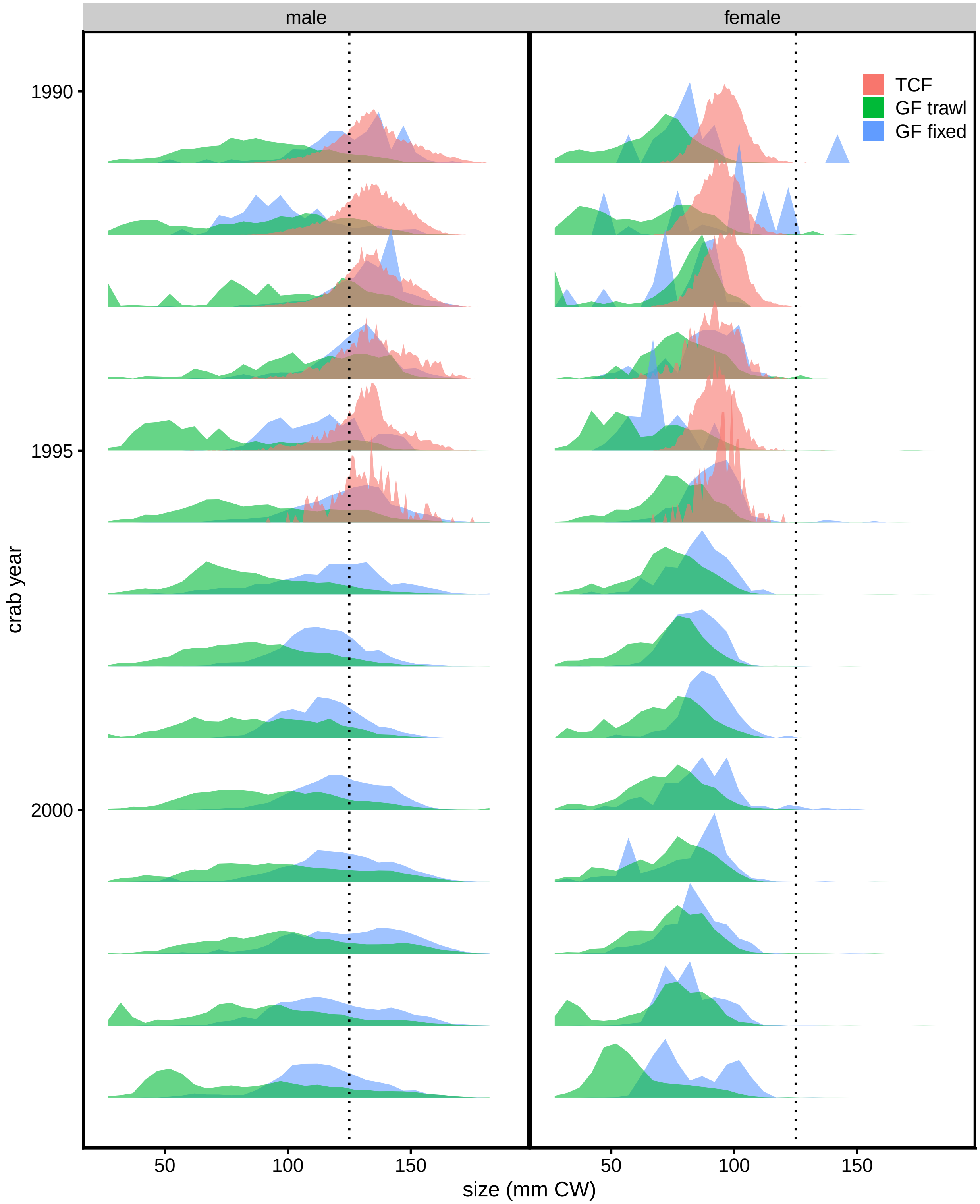

Figure 27. Comparison of *relative* size compositions for total catch of Tanner crab in the directed ('TCF') and groundfish ('GF') fisheries during 1991/92-2004/05. Dotted line indicates recent industry-preferred size.

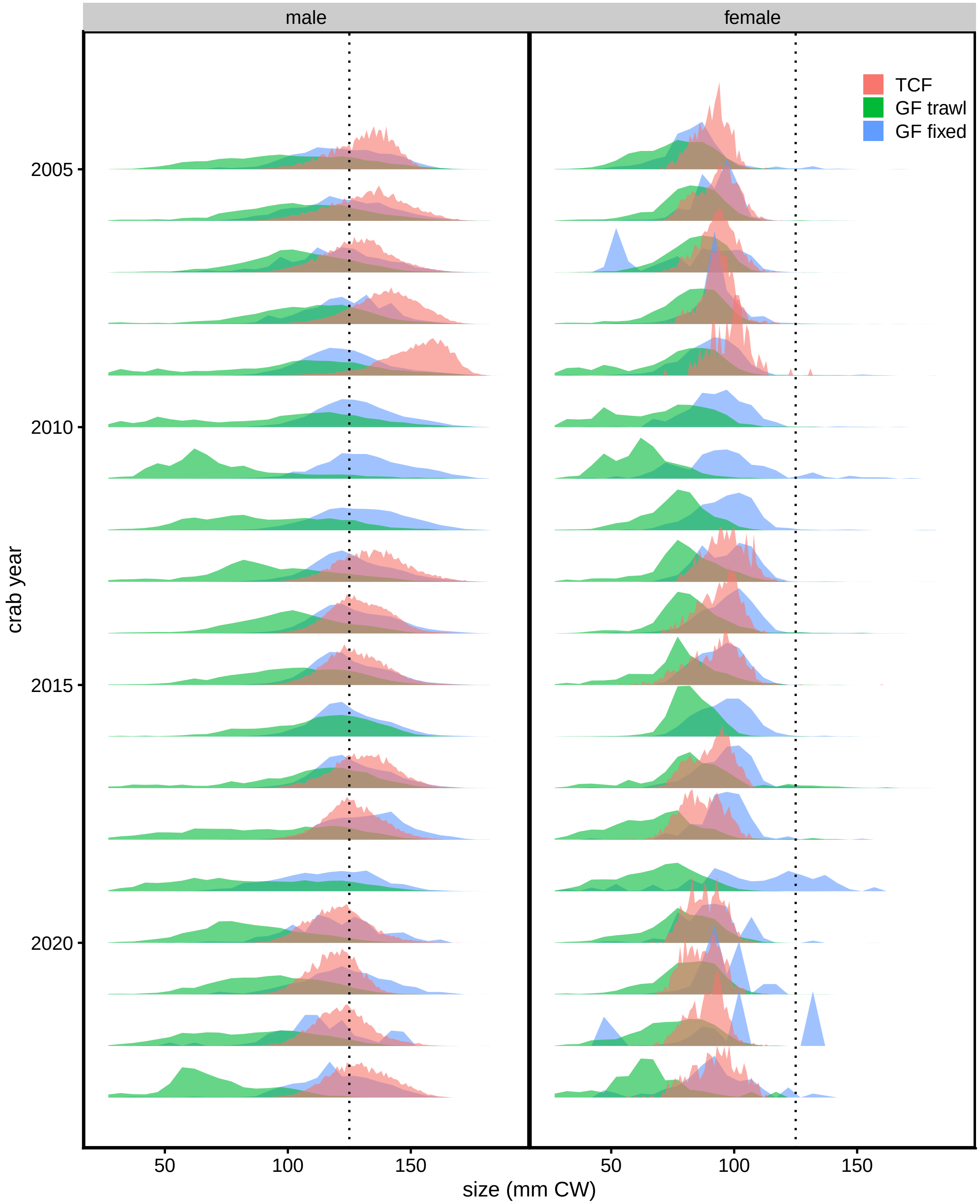

Figure 28. Comparison of *relative* size compositions for total catch of Tanner crab in the directed ('TCF') and groundfish ('GF') fisheries since 2005/06. Dotted line indicates recent industry-preferred size.

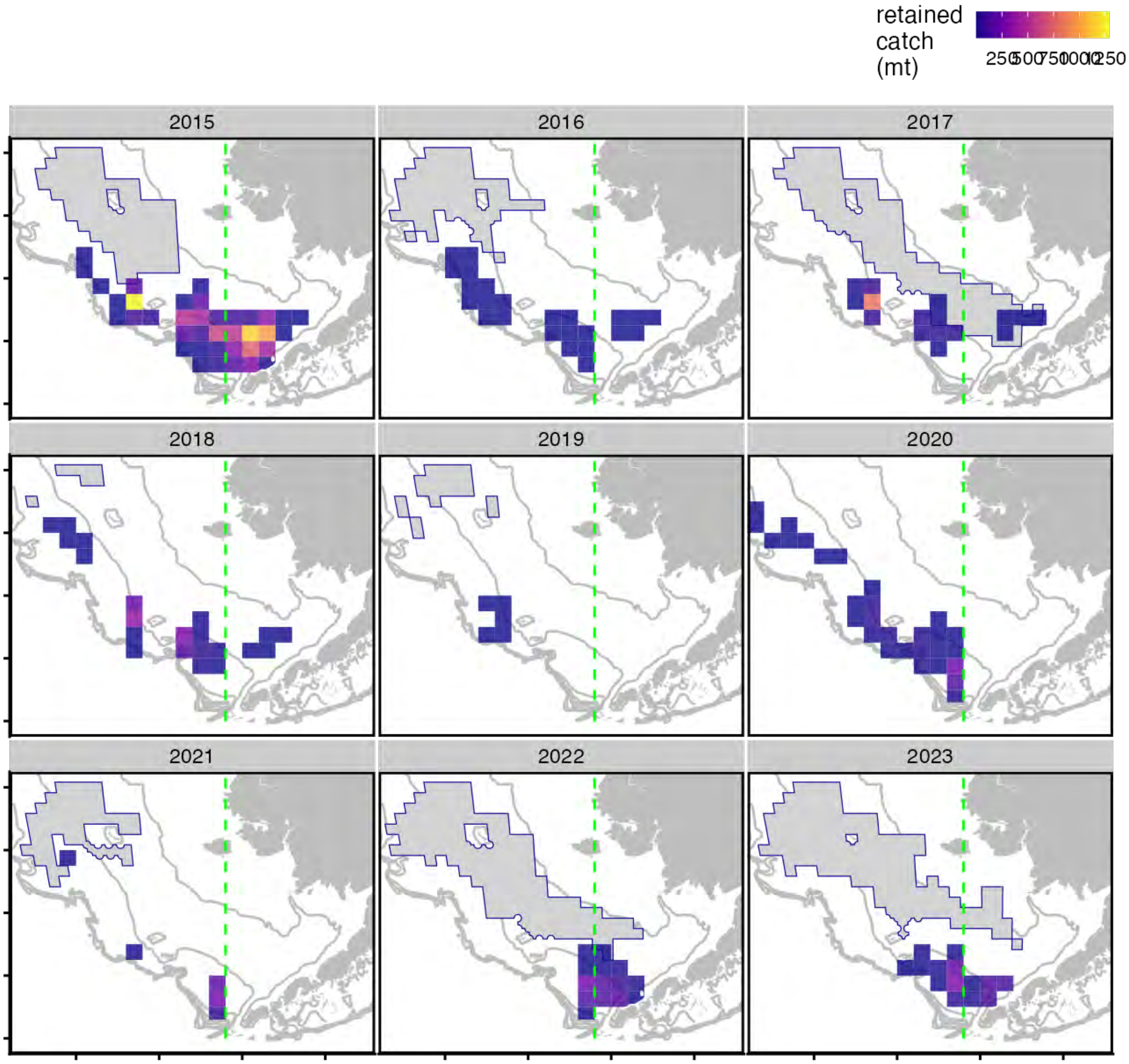

Figure 29. Retained catch in the directed fishery (min 3 vessels/stat area/year). The directed fishery east of 166°W longitude was closed in 2016/17-2021/22. Retained catch in the area was incidentally taken in the BBRKC fishery. The grey polygon with blue outline indicates the summer cold pool location.

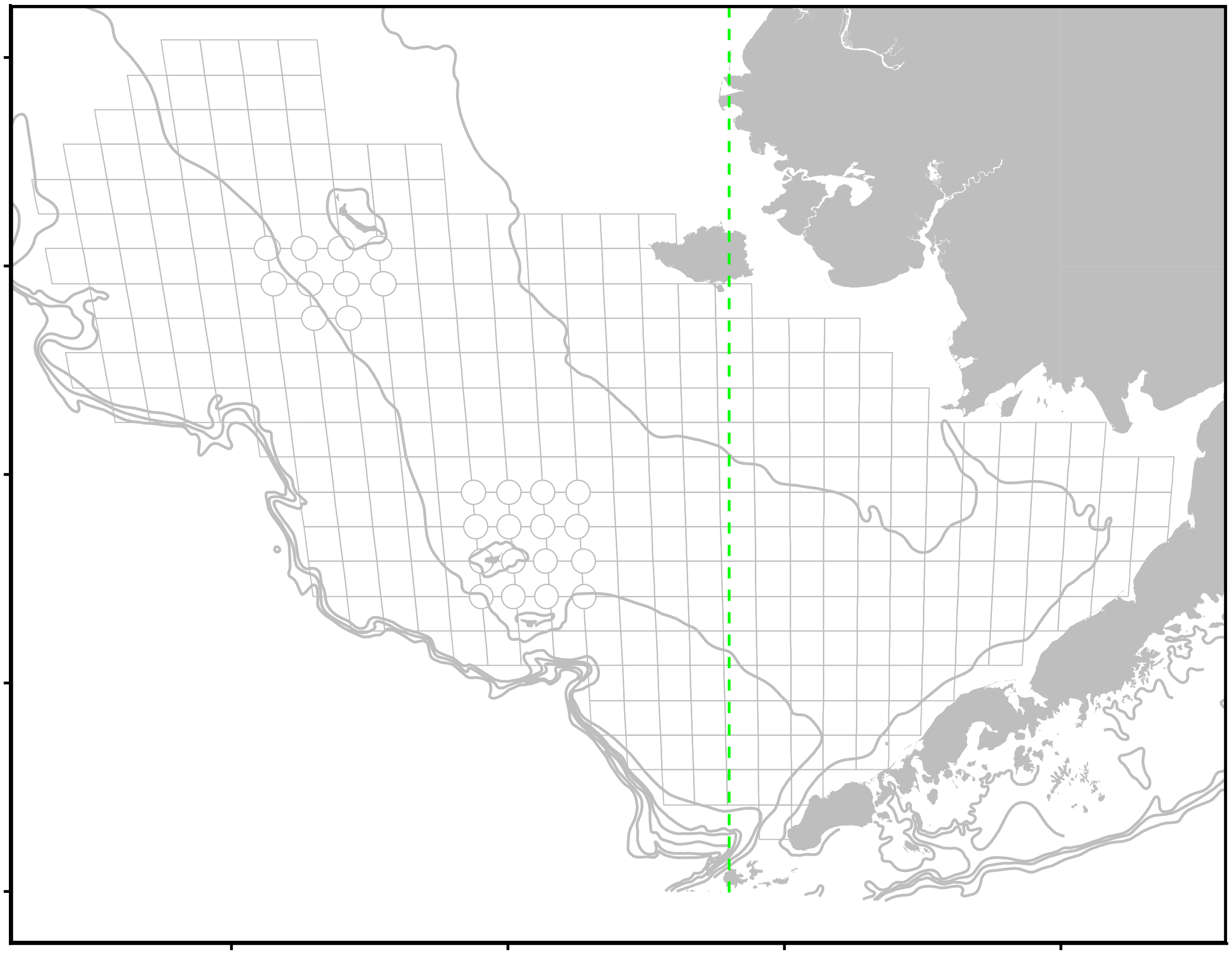

Figure 30. NMFS EBS shelf startion grid (squares and circles). Hauls at the 26 so-called "corner" stations (circles) near the Pribilof Islands and St. Matthew Island were discontinued in 2024.

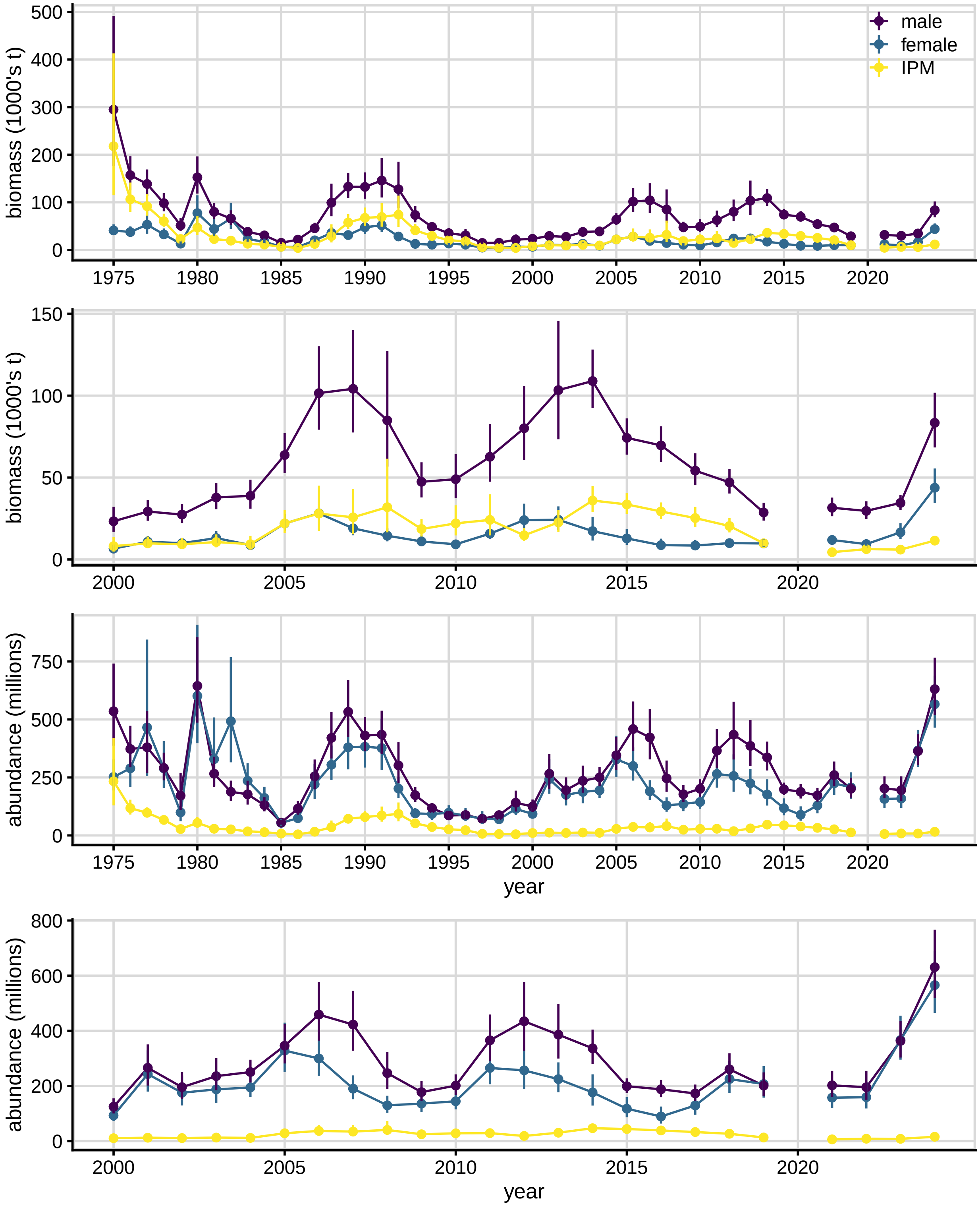

Figure 31. Annual estimates of design-based area-swept biomass (upper plots) and abundance (lower plots) from the NMFS EBS bottom trawl survey by sex. The lower plot in each pair shows the trends since 2000. The biomass/abundance trends for industry-preferred size males (> 125 mm CW; 'IPM') are also shown.

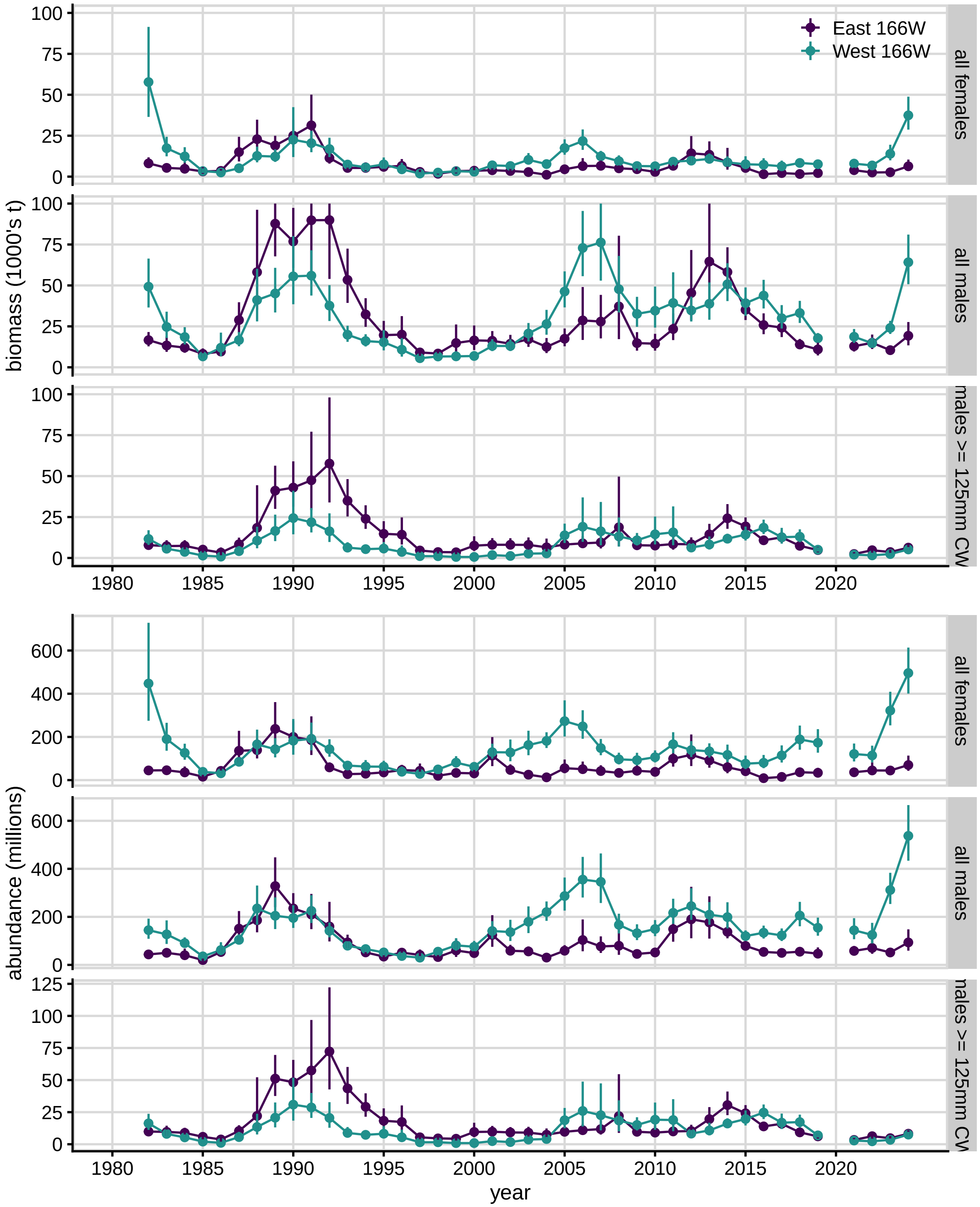

Figure 32. Annual estimates of design-based area-swept biomass (upper plots) and abundance (lower plots) from the NMFS EBS bottom trawl survey by population category and management area.

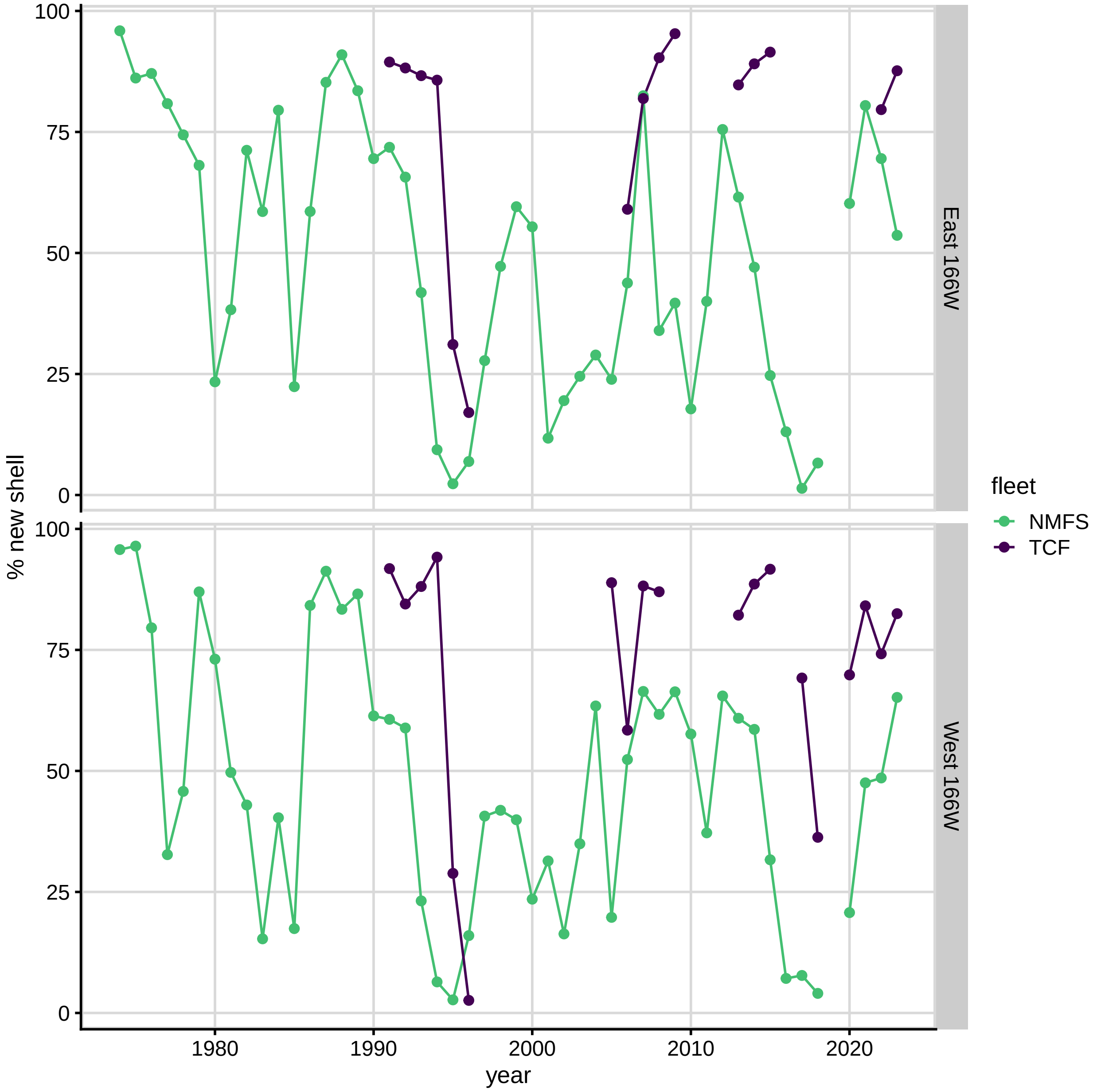

Figure 33. Comparison of the annual percent of new shell industry-preferred size males caught in the NMFS EBS shelf survey and the directed fishery ('TCF'), by ADF&G management area. The survey values have been lagged a year to align visually with the fishery values.

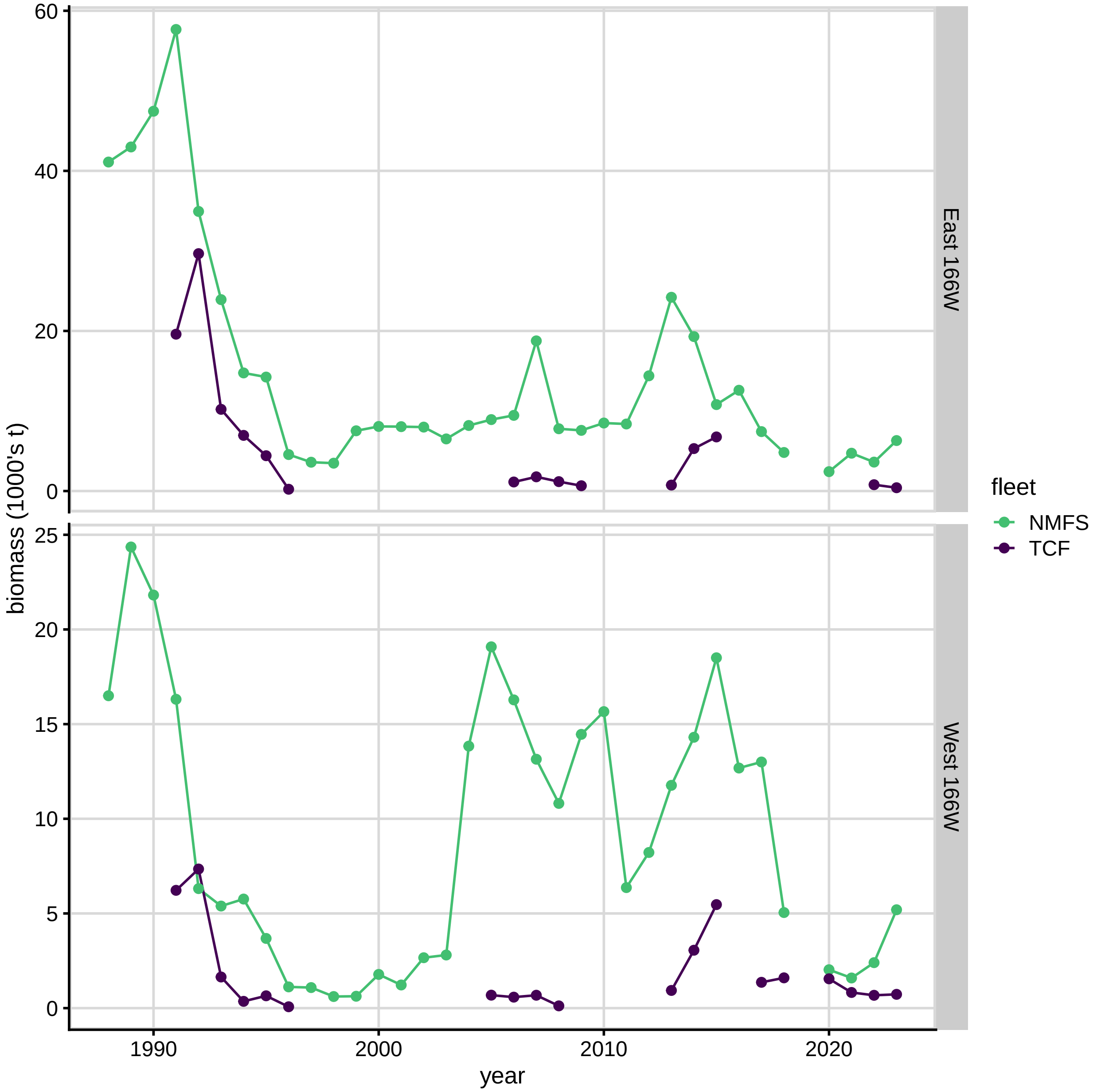

Figure 34. Comparison of the biomass of industry-preferred size males estimated from the NMFS EBS shelf survey and caught in the directed fishery ('TCF'), by ADF&G management area. The survey values have been lagged a year to align visually with the fishery values.

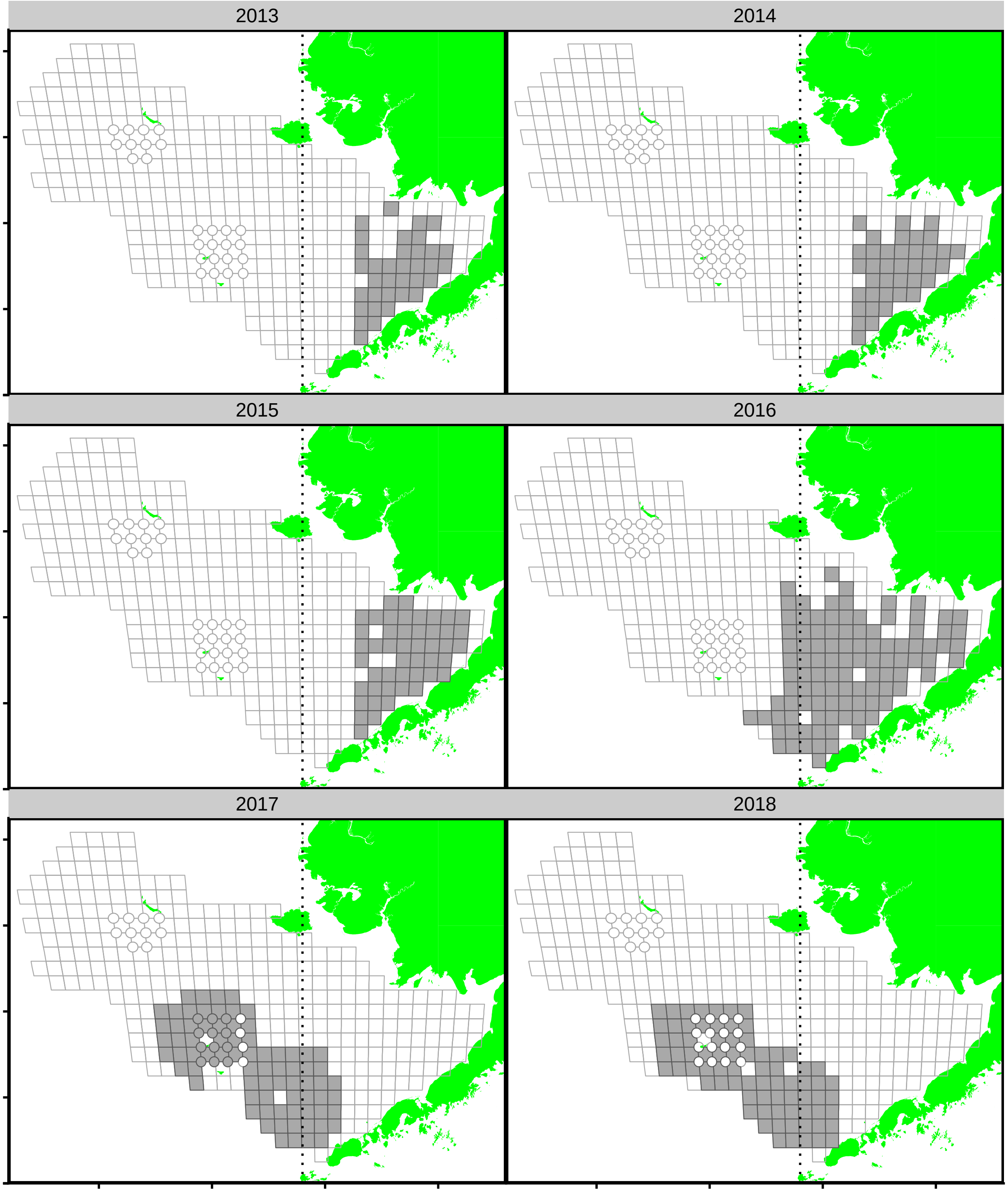

Figure 35. Annual spatial footprints of the BSFRF-NMFS collaborative side-by-side (SBS) Tanner crab catchability studies (2013-2018). BSFRF SBS tows were made in parallel to standard NMFS survey tows at a (different) subset of standard NMFS stations each year of the study. The BSFRF vessel used a modified nephrops bottom trawl assumed to capture all crab within the area swept.

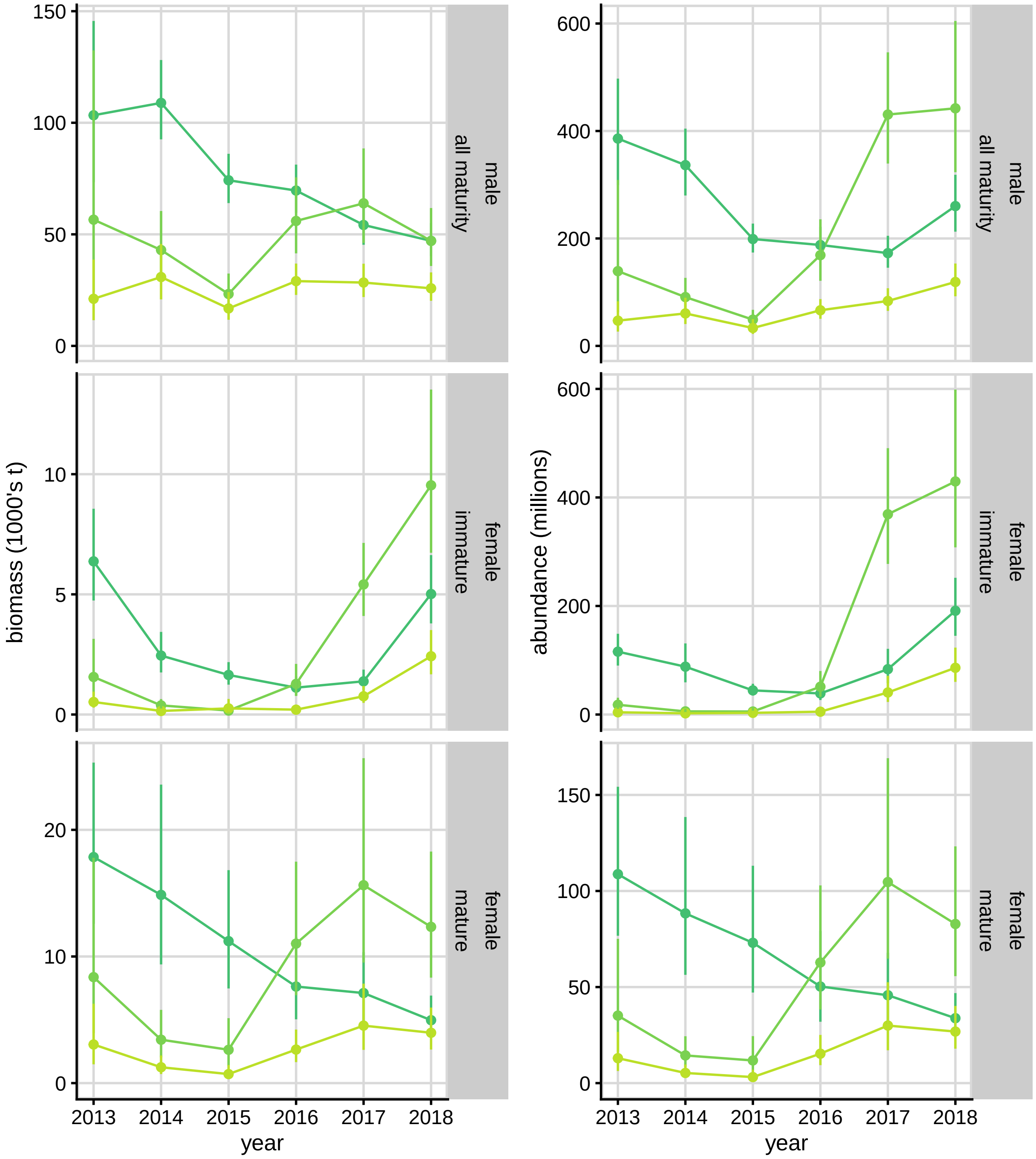

Figure 36. Comparison of estimates of area-swept biomass (left column) and abundance (right column) from the BSFRF-NMFS cooperative side-by-side (SBS) catchability studies and the full NMFS survey in 2013-2018. The SBS studies had different spatial footprints each year, so annual changes in biomass do not necessarily reflect underlying population trends.

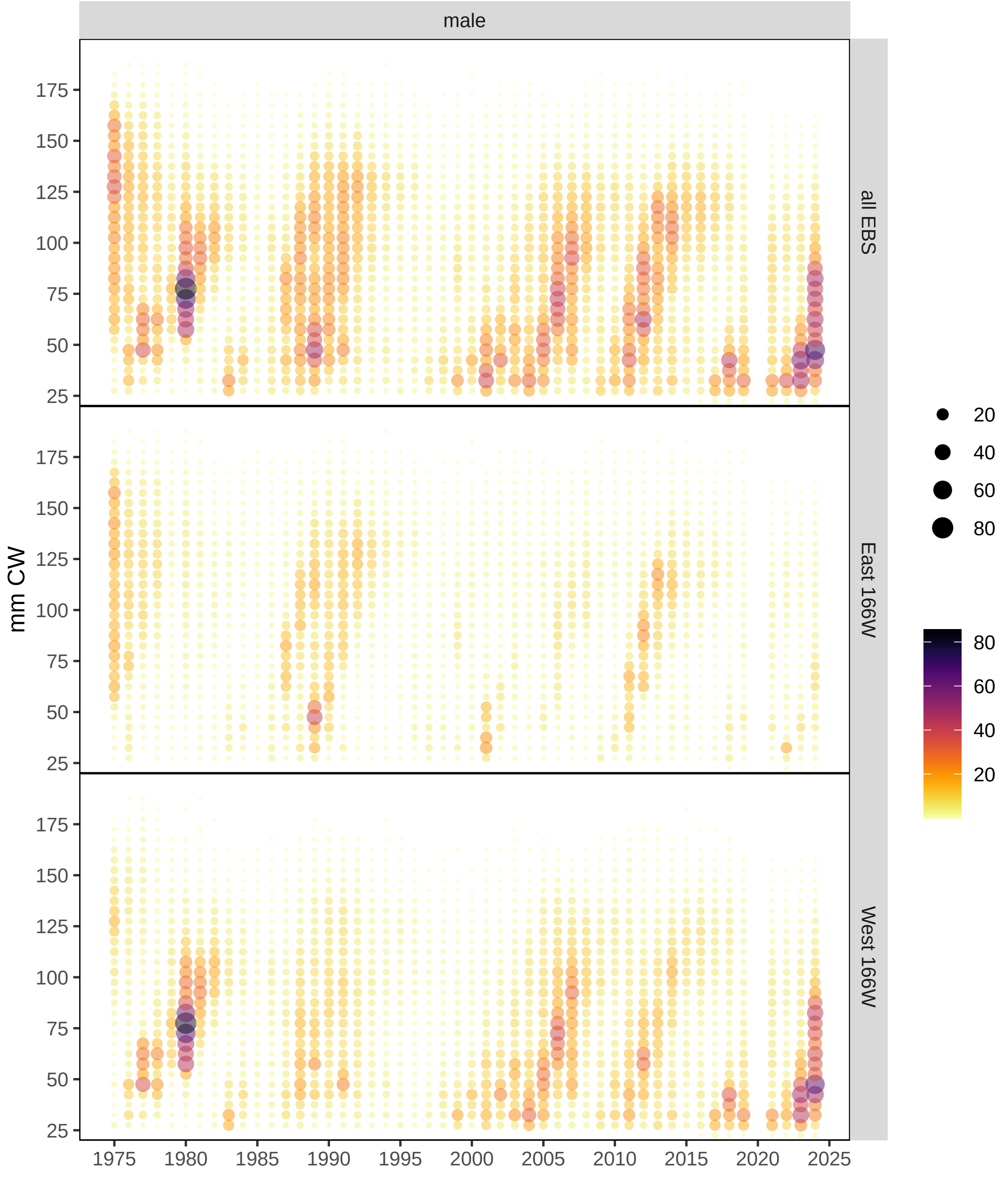

Figure 37. Annual size compositions, by 5-mm CW bin, from the NMFS EBS shelf bottom trawl survey for males by ADF&G management area for 1975-2024 as a bubble plot. The size compositions are truncated for crab < 25 mm CW.

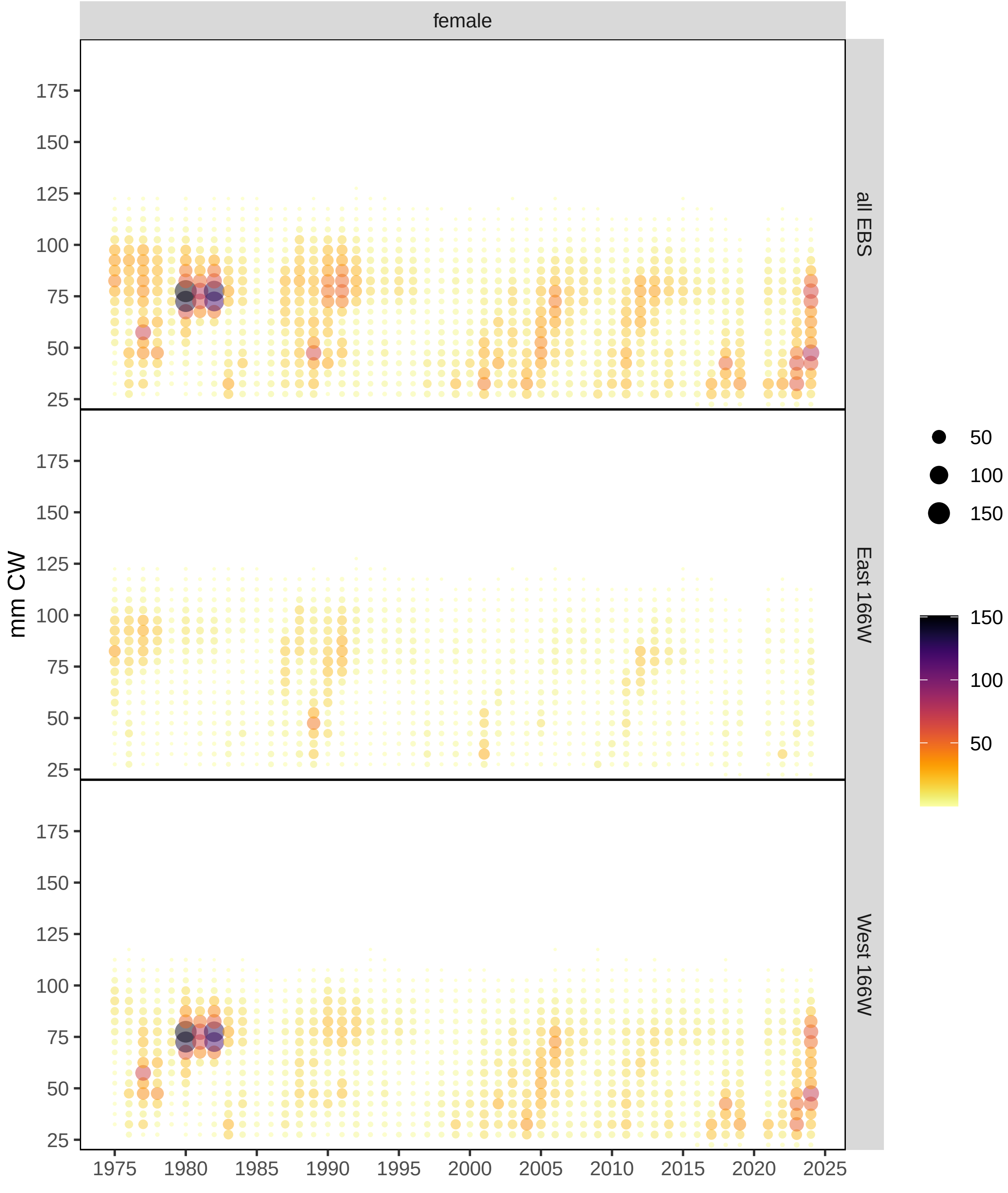

Figure 38. Annual size compositions, by 5-mm CW bin, from the NMFS EBS shelf bottom trawl survey for females by ADF&G management area for 1975-2024 as a bubble plot. The size compositions are truncated for crab < 25 mm CW.

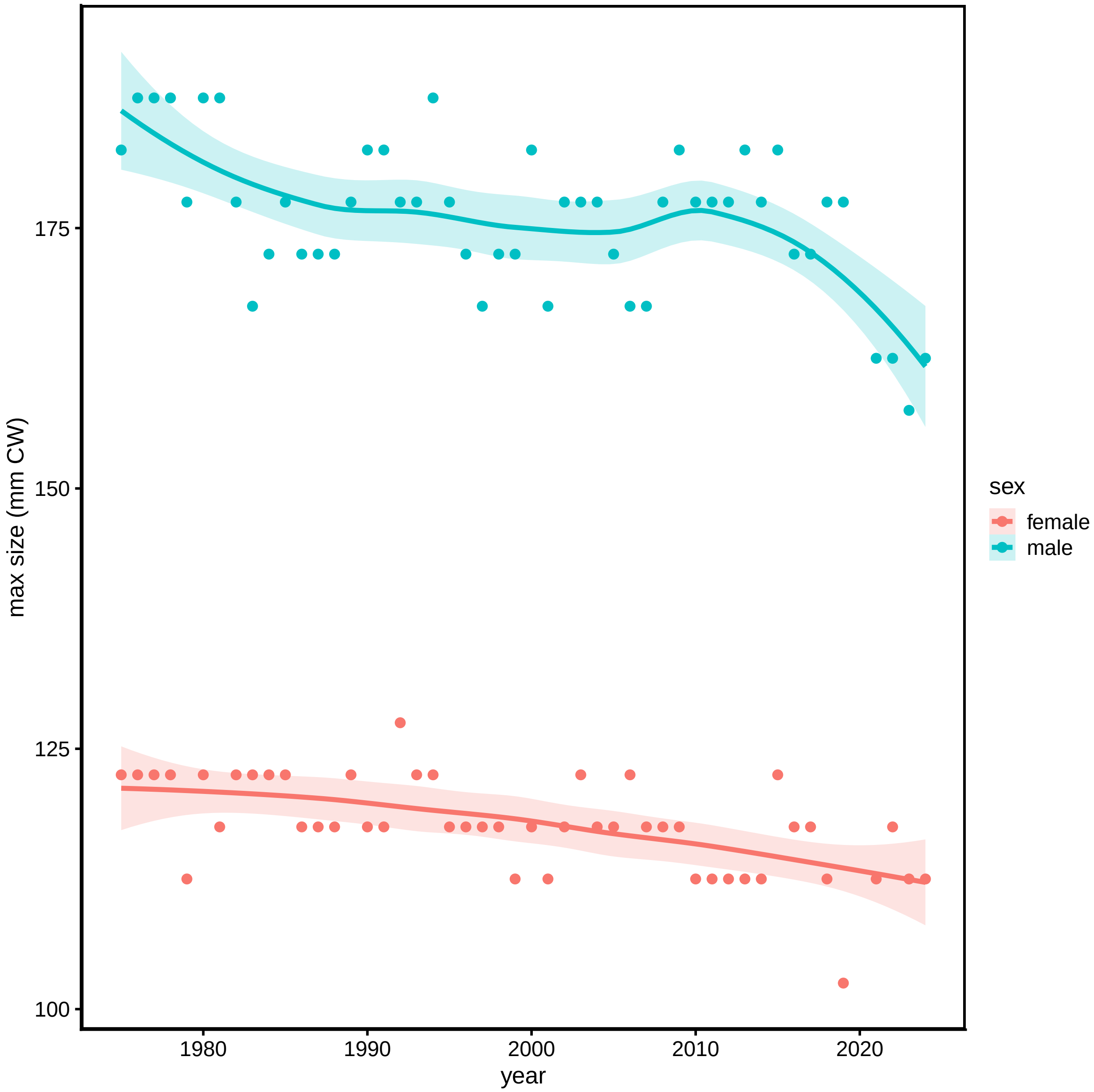

Figure 39. Maximum size in the annual 5-mm CW binned size compositions from the NMFS EBS shelf bottom trawl survey by sex for 1975-2024. Circles: annual values; lines and shading: loess-smoothed trends.

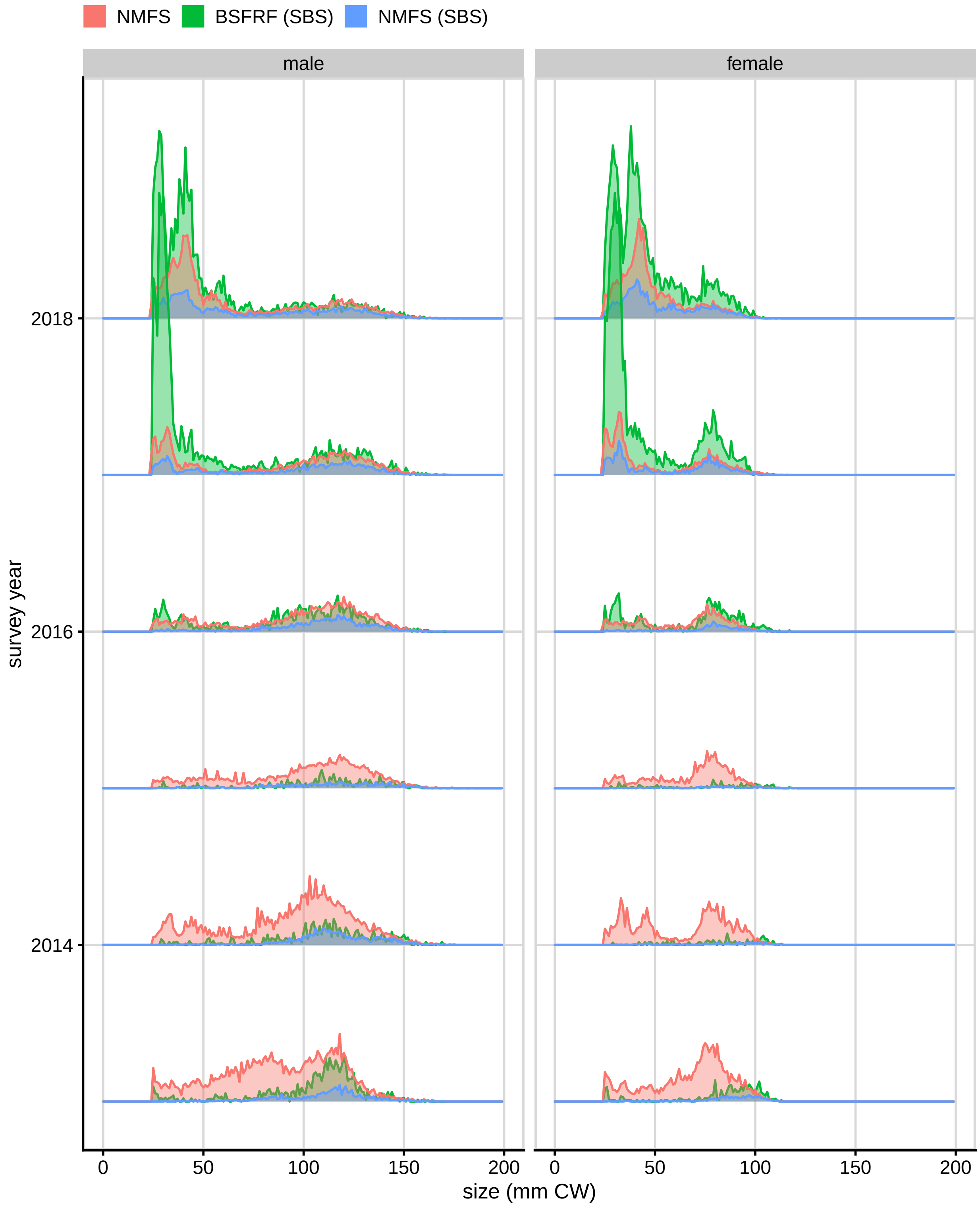

Figure 40. Comparison of size compositions from the SBS catchability study and the corresponding full NMFS EBS shelf survey. The size compositions are truncated for crab < 25 mm CW.

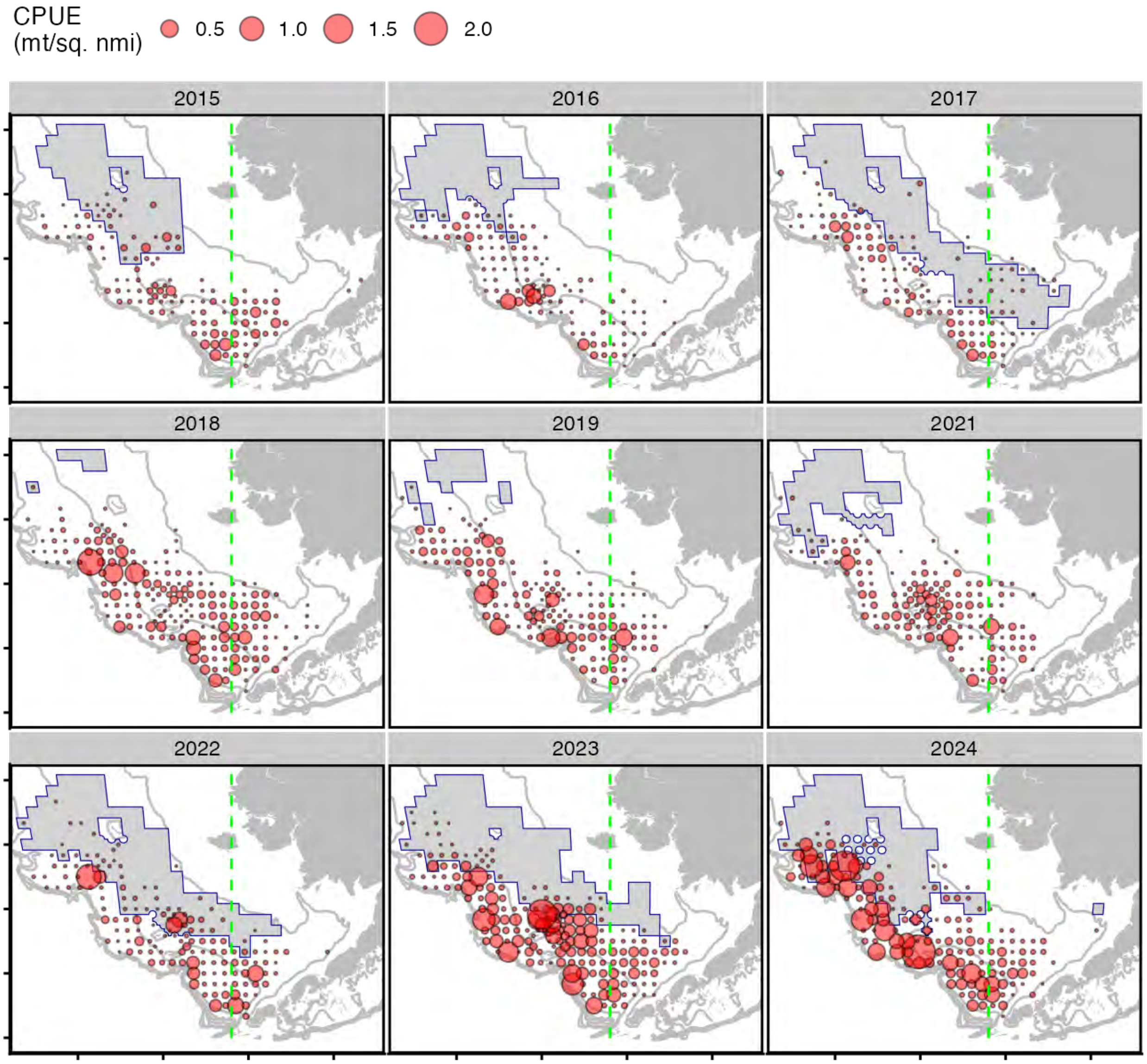

Figure 41. Spatial CPUE of small males (< 60 mm CW) in the NMFS EBS survey. The grey area with blue outline indicates the summer cod pool.

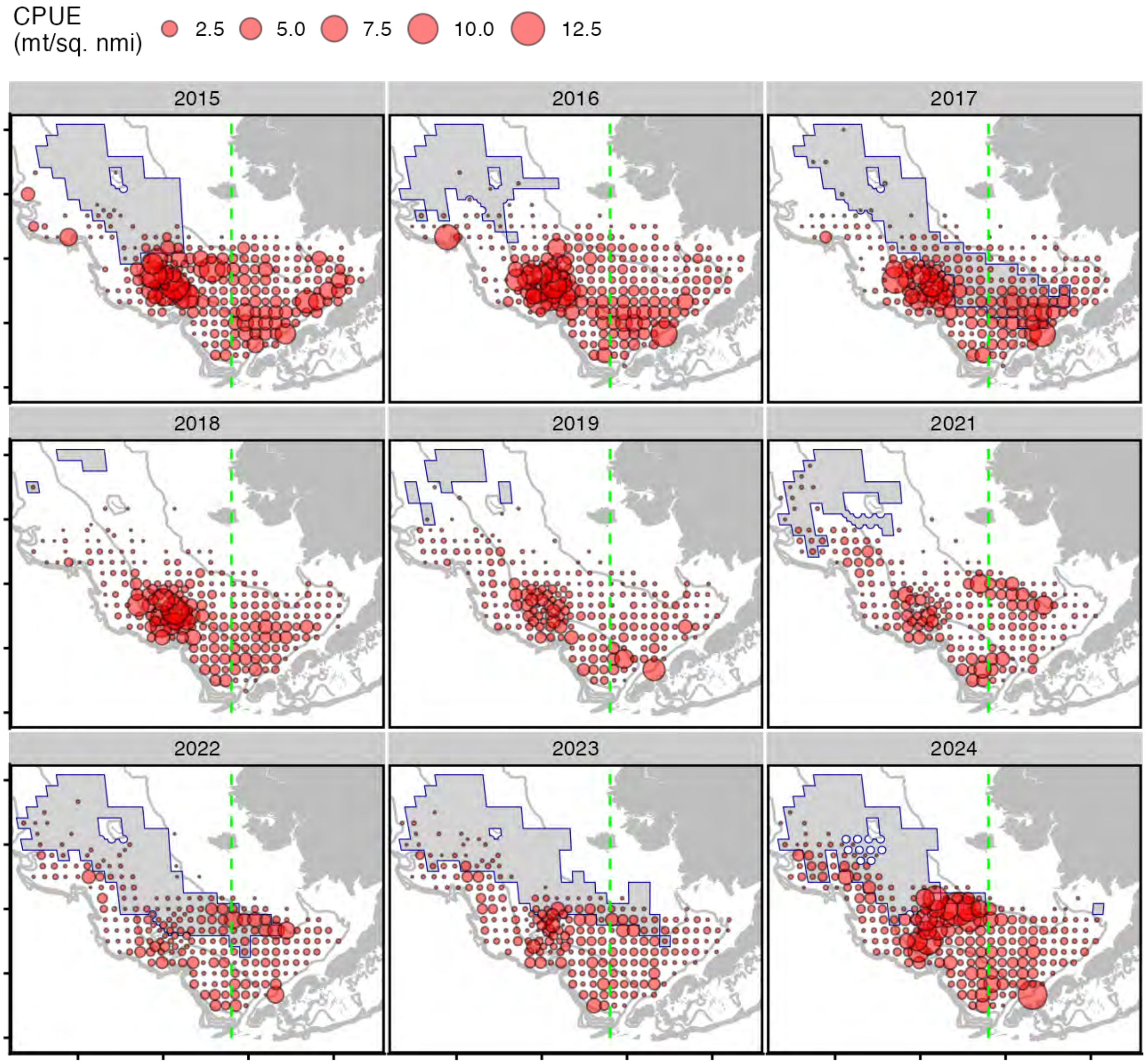

Figure 42. Spatial CPUE of large males (> 60 mm CW) in the NMFS EBS survey. The grey area with blue outline indicates the summer cod pool.

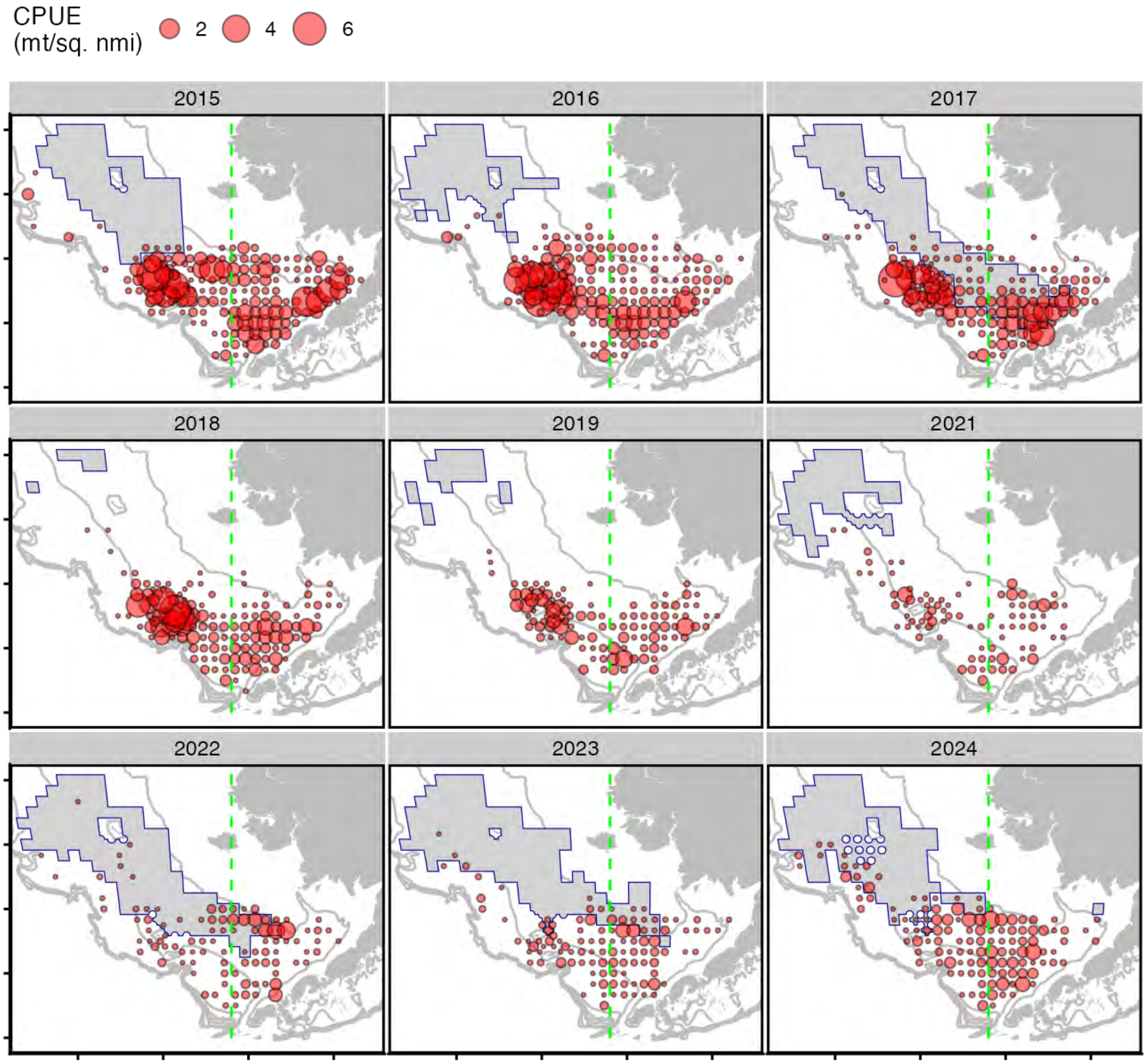

Figure 43. Spatial CPUE of industry-preferred ($\geq$ 125 mm CW) in the NMFS EBS survey. The grey area with blue outline indicates the summer cod pool.

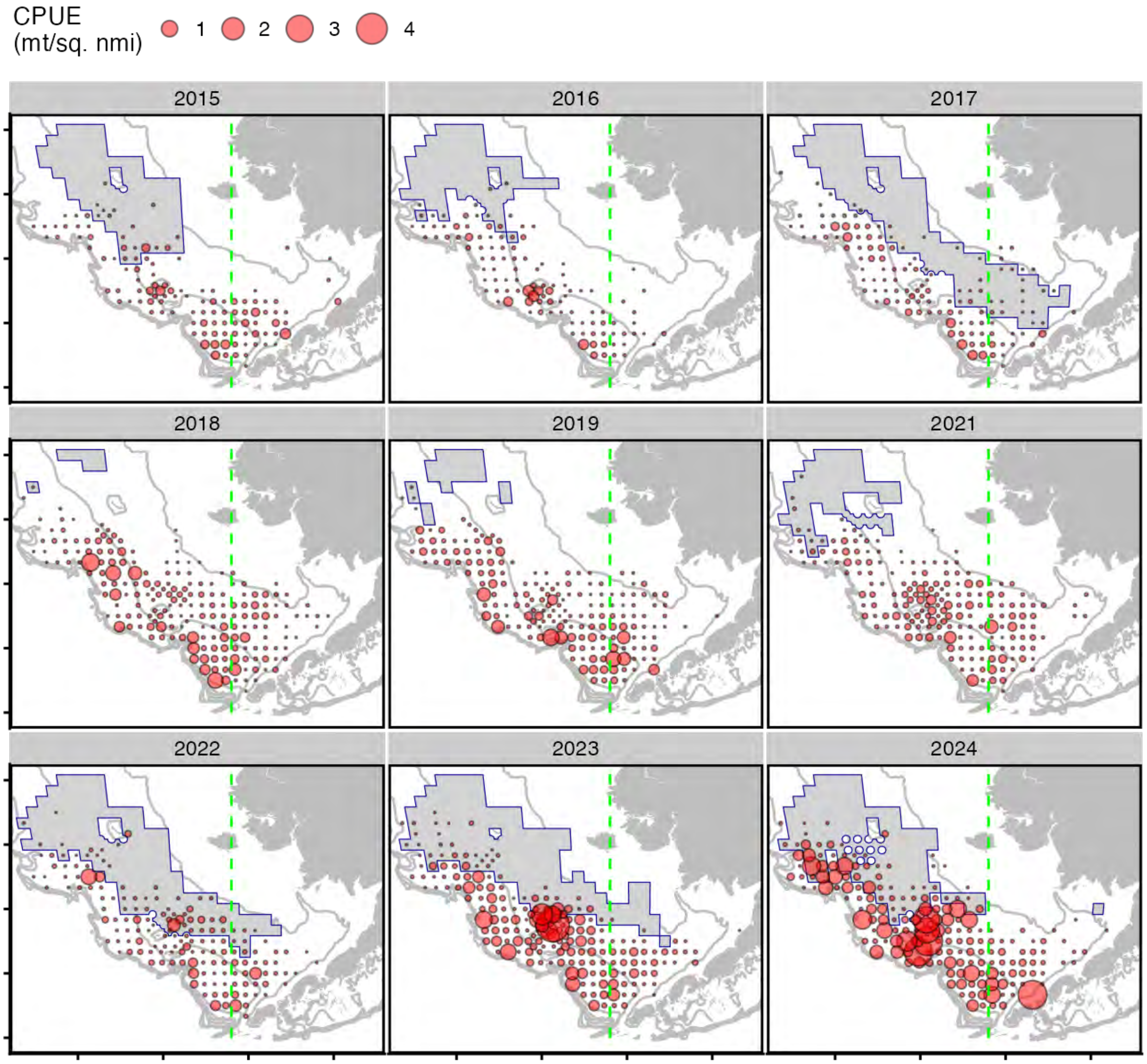

Figure 44. Spatial CPUE of immature females in the NMFS EBS survey. The grey area with blue outline indicates the summer cod pool.

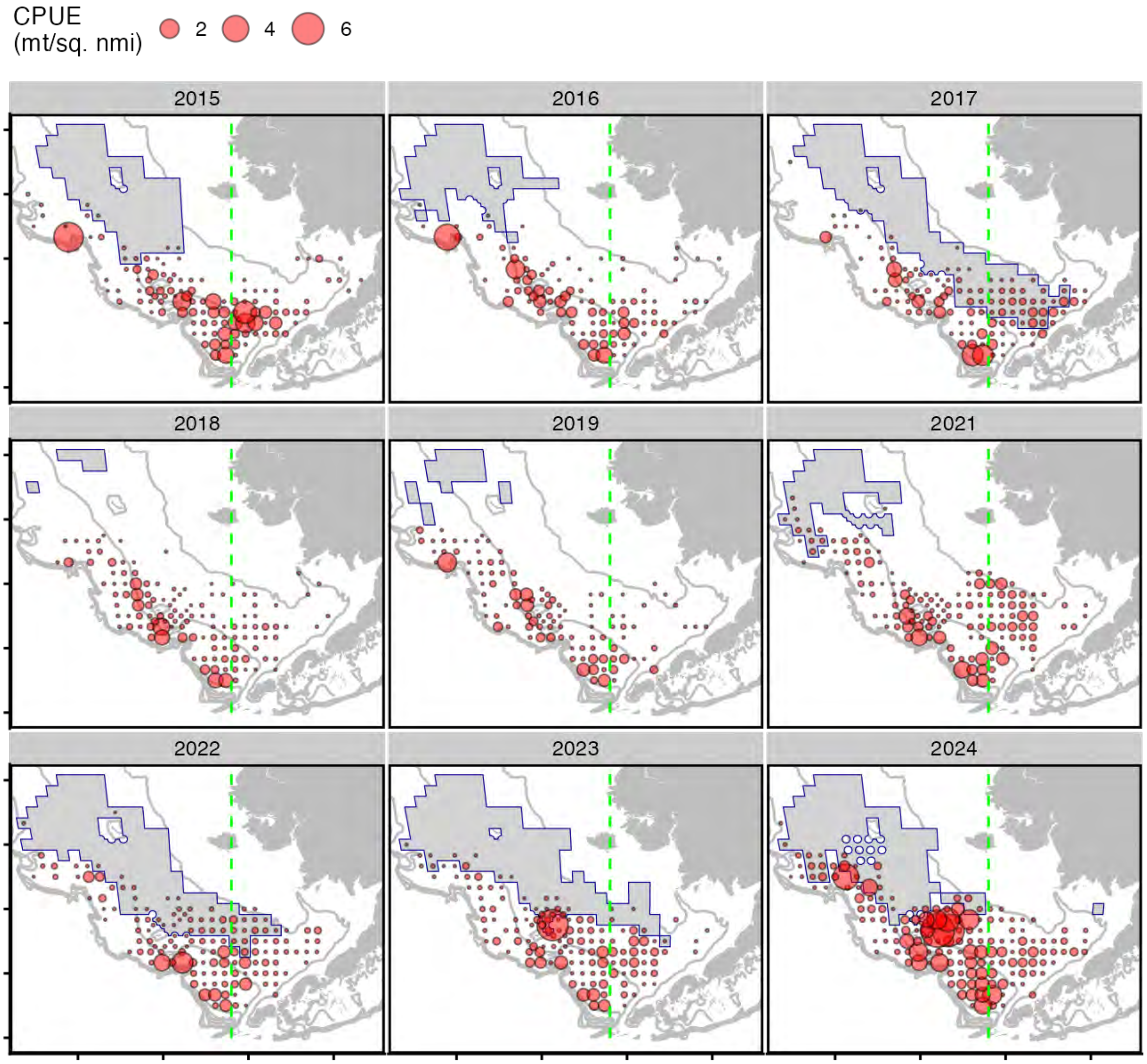

Figure 45. Spatial CPUE of mature females in the NMFS EBS survey. The grey area with blue outline indicates the summer cod pool.

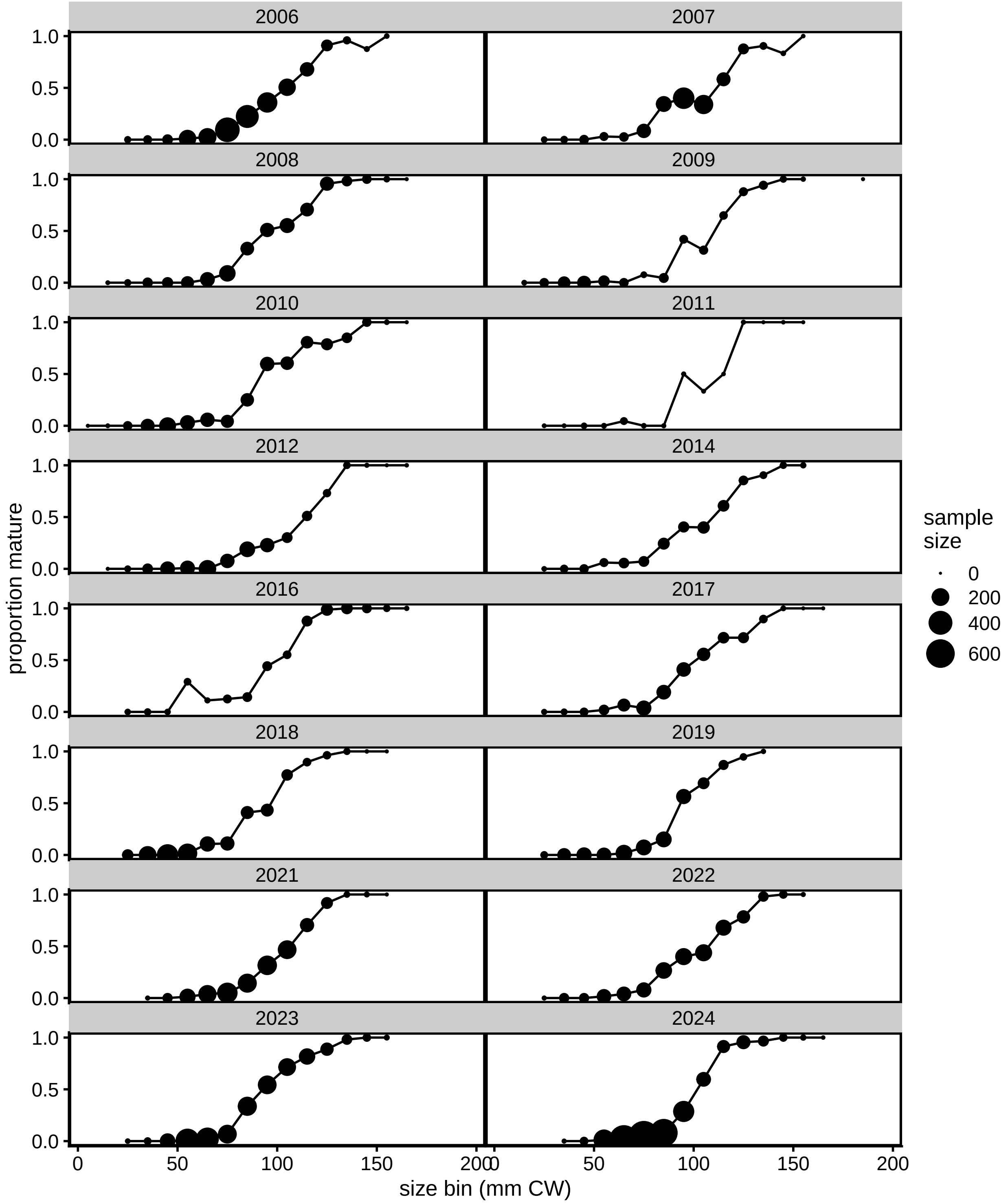

Figure 46. Estimates of the proportion of mature new shell males in the NMFS EBS shelf survey, by 10 mm CW size bin, based on male crab with chela height/carapace width measurements taken with 0.1 mm precision. Symbol size (area) indicates the number of crab measured. Chela heights for Tanner crab are not measured every year.

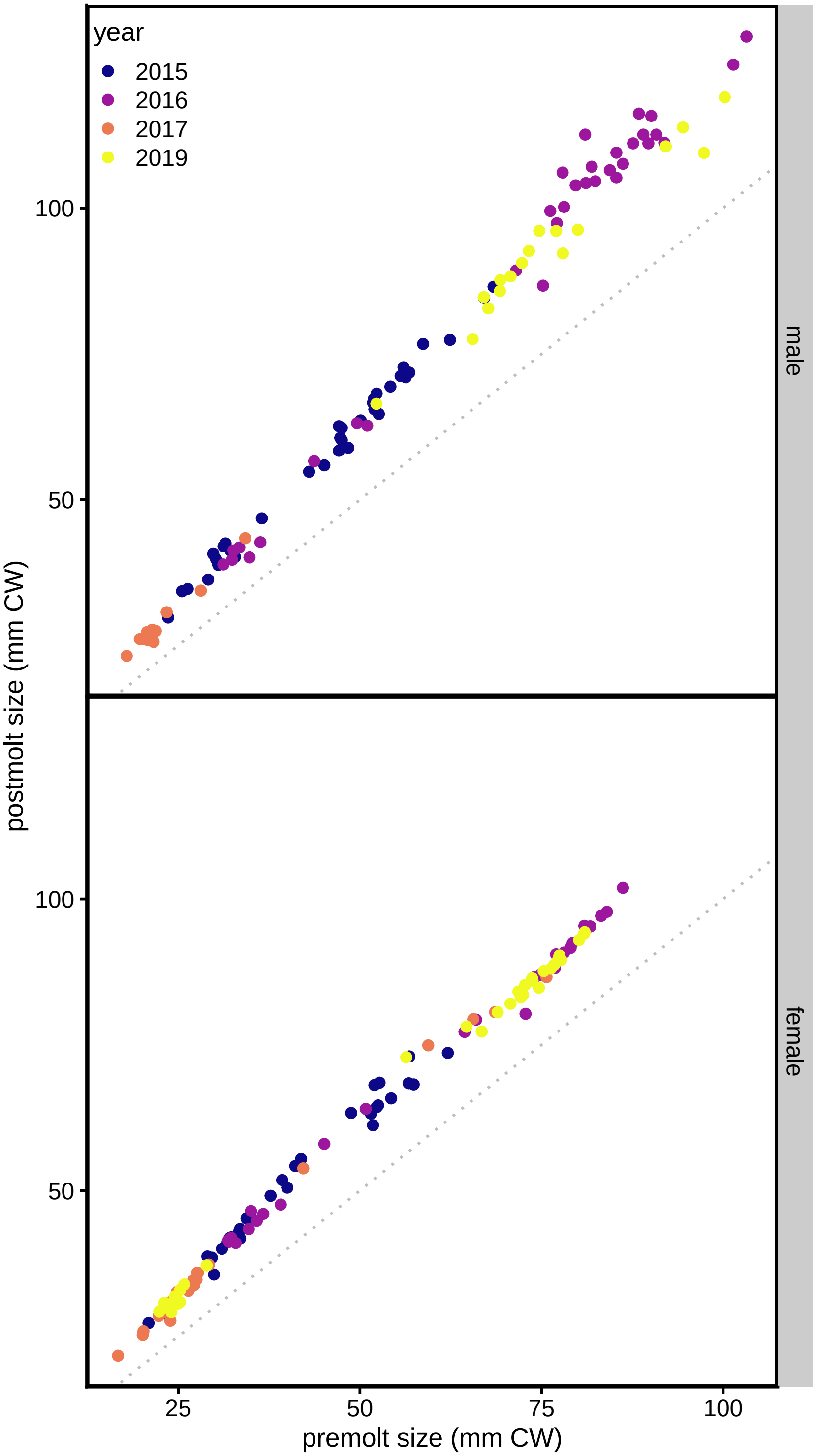

Figure 47. Molt increment data collected collaboratively by NMFS, BSFRF, and ADF&G.

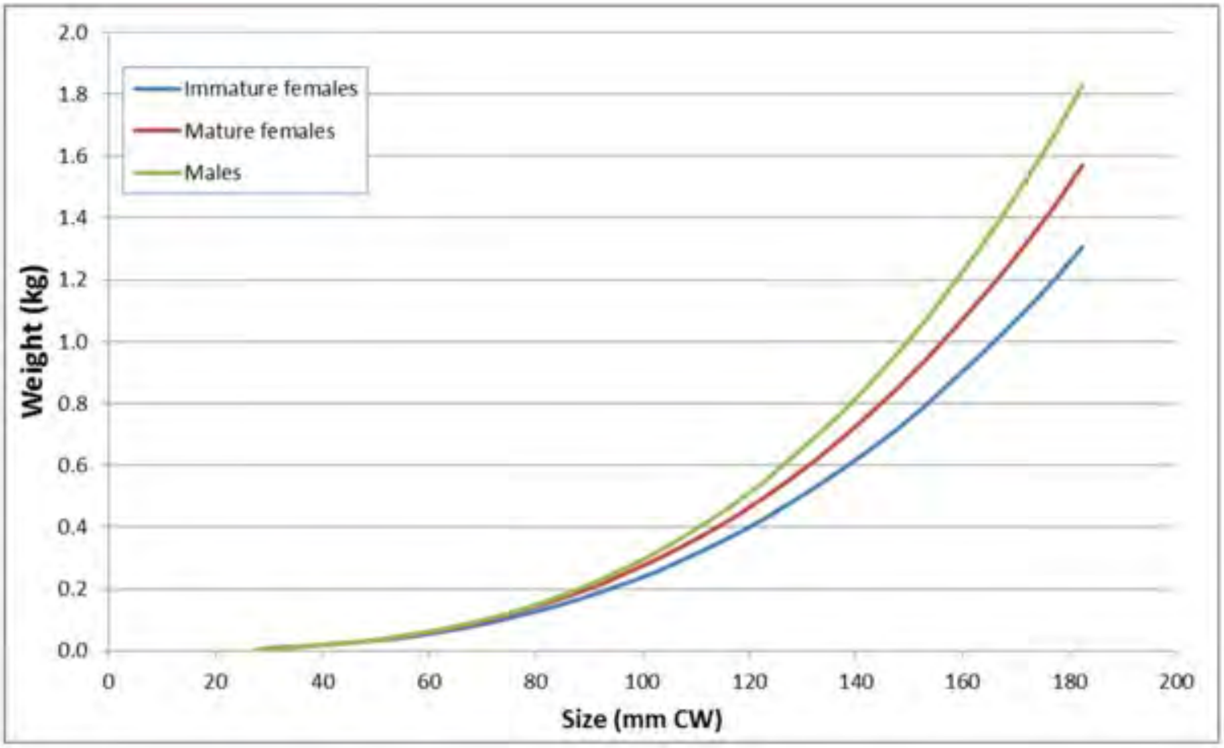

Figure 48. Size-weight relationships for Tanner crab.

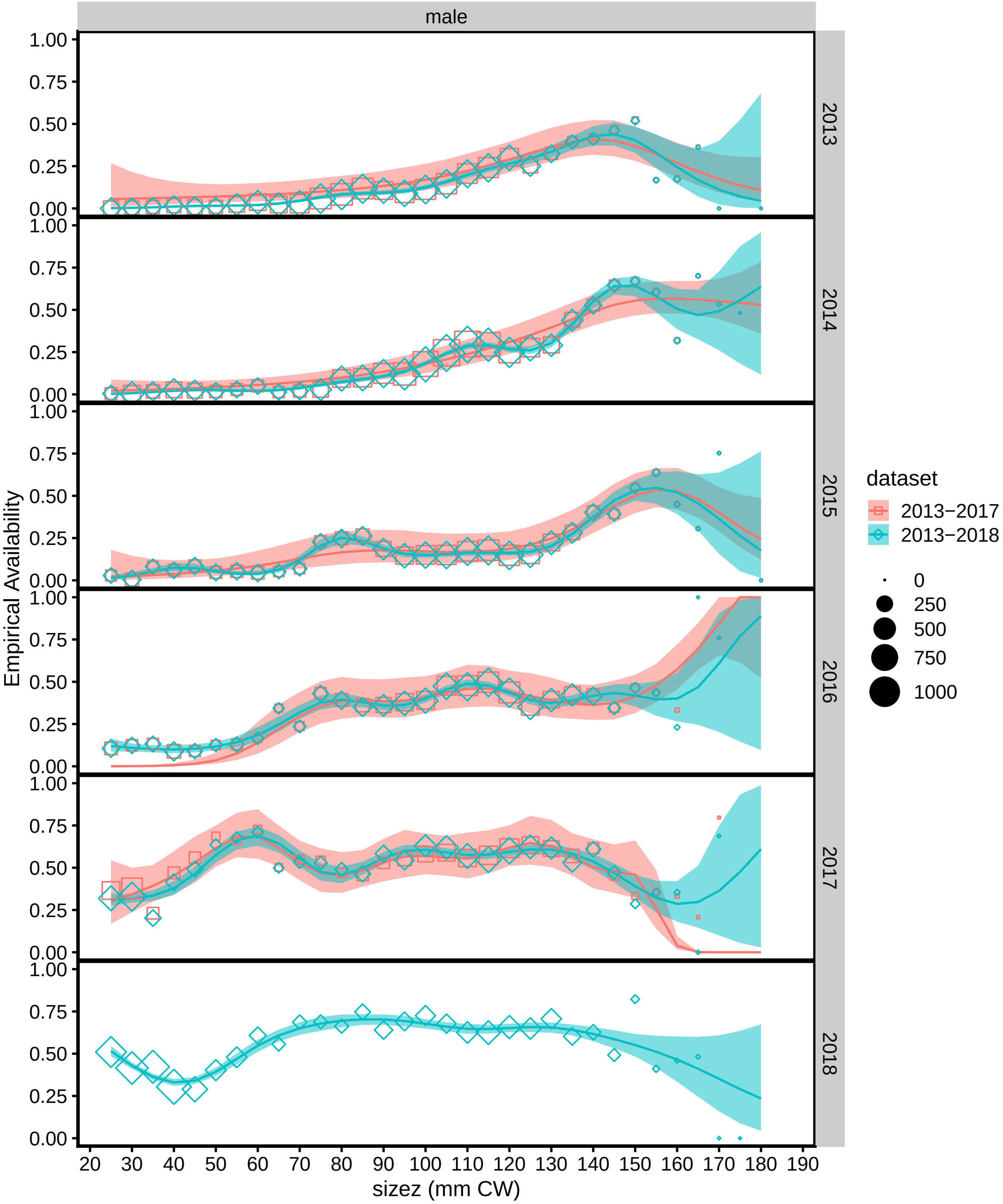

Figure 49. Empirical male availability curves for BSFRF SBS data. Colors: SBS dataset from which curves were derived. Shapes: "raw" empirical availability estimates. Size: total number of individual crab sampled. Lines/fills: smooth GAM model fits to "raw" data, with 95% confidence intervals.

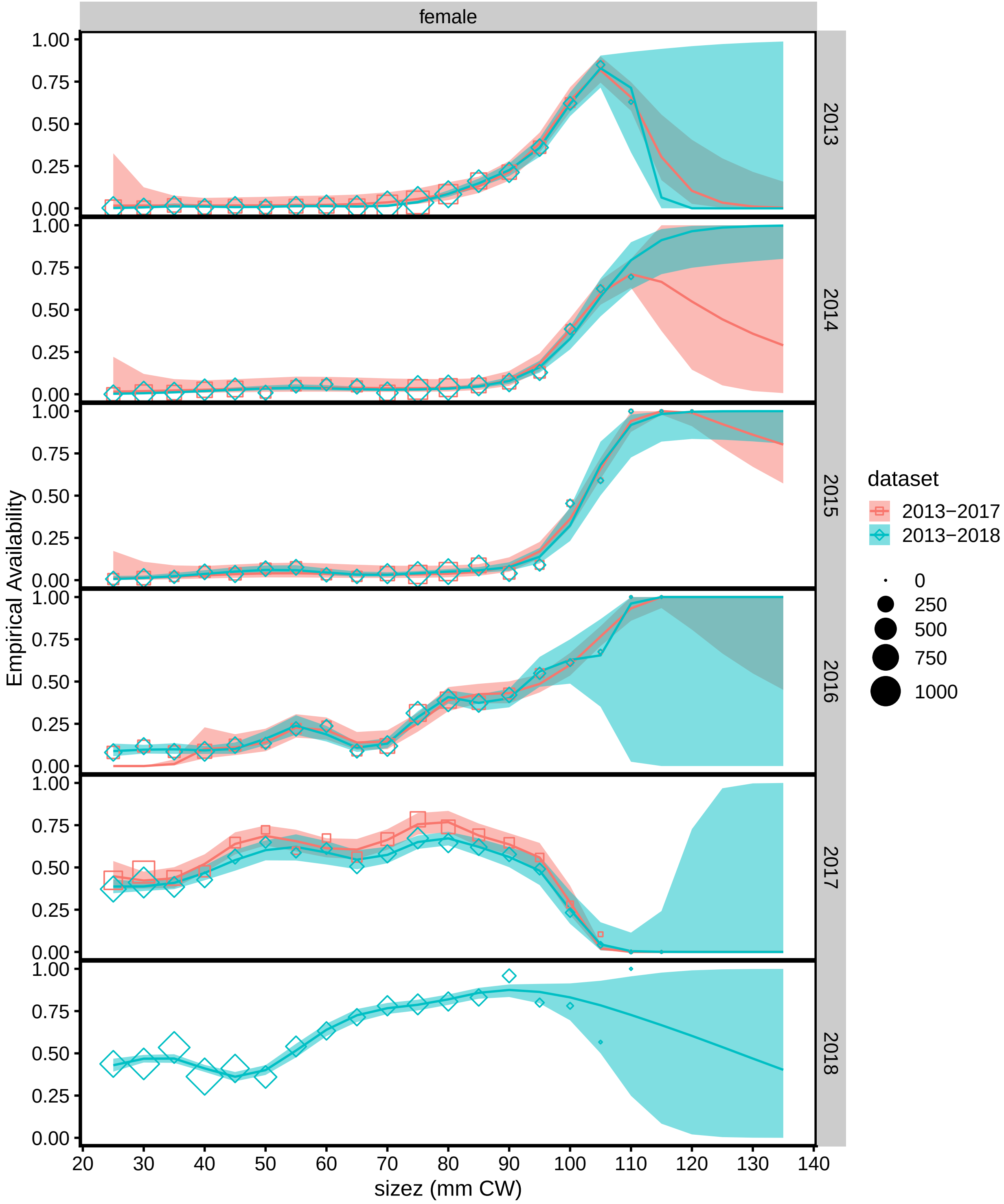

Figure 50. Empirical female availability curves for BSFRF SBS data. Colors: SBS dataset from which curves were derived. Shapes: “raw” empirical availability estimates. Size: total number of individual crab sampled. Lines/fills: smooth GAM model fits to “raw” data, with 95% confidence intervals.

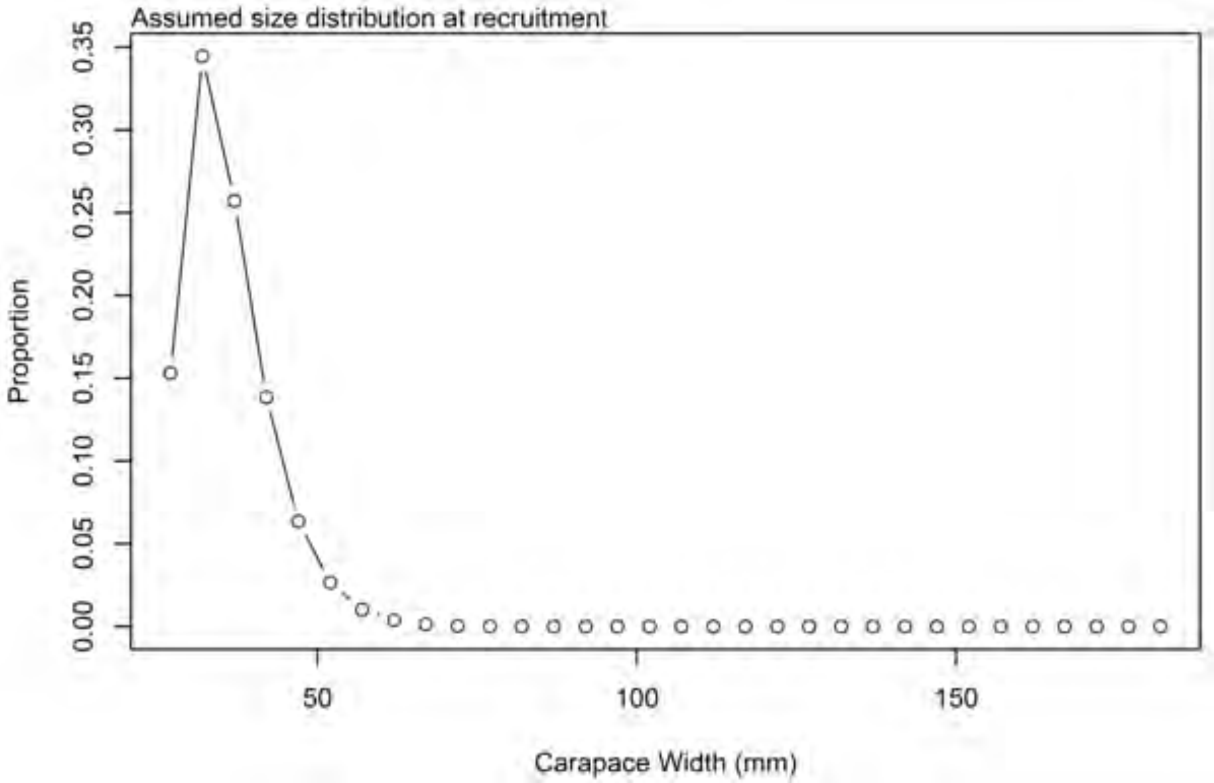

Figure 51. The nominal shape (a truncated gamma distribution) for the assumed size distribution of Tanner crab at recruitment to the model.

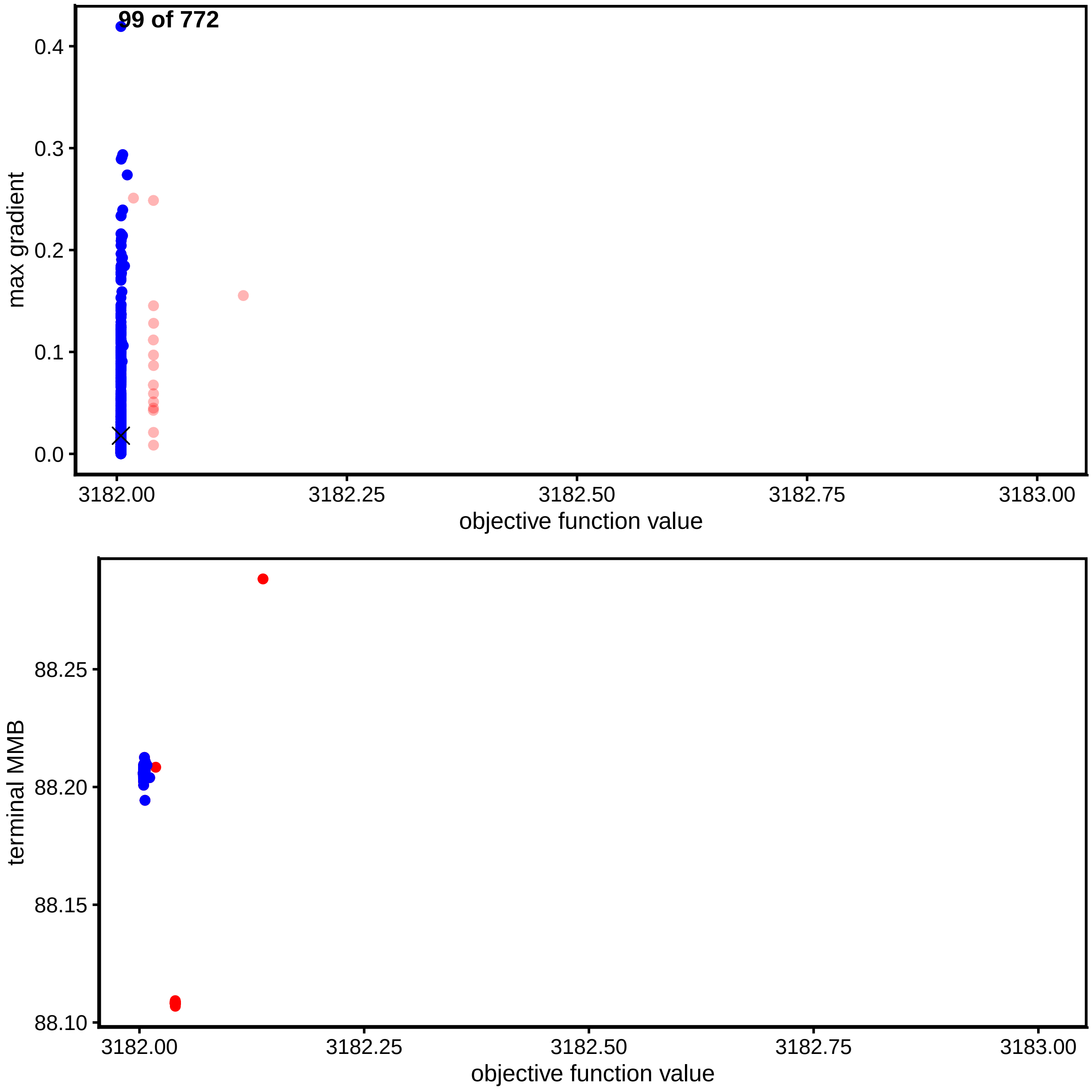

Figure 52. Results from 800 jitter runs for Model 22.03d5. Of these, 99 appear to have converged to the MLE (blue dots). The minimum objective function found was 3,182.00; the maximum gradient for that model run was 0.0178. 28 failed to finish.

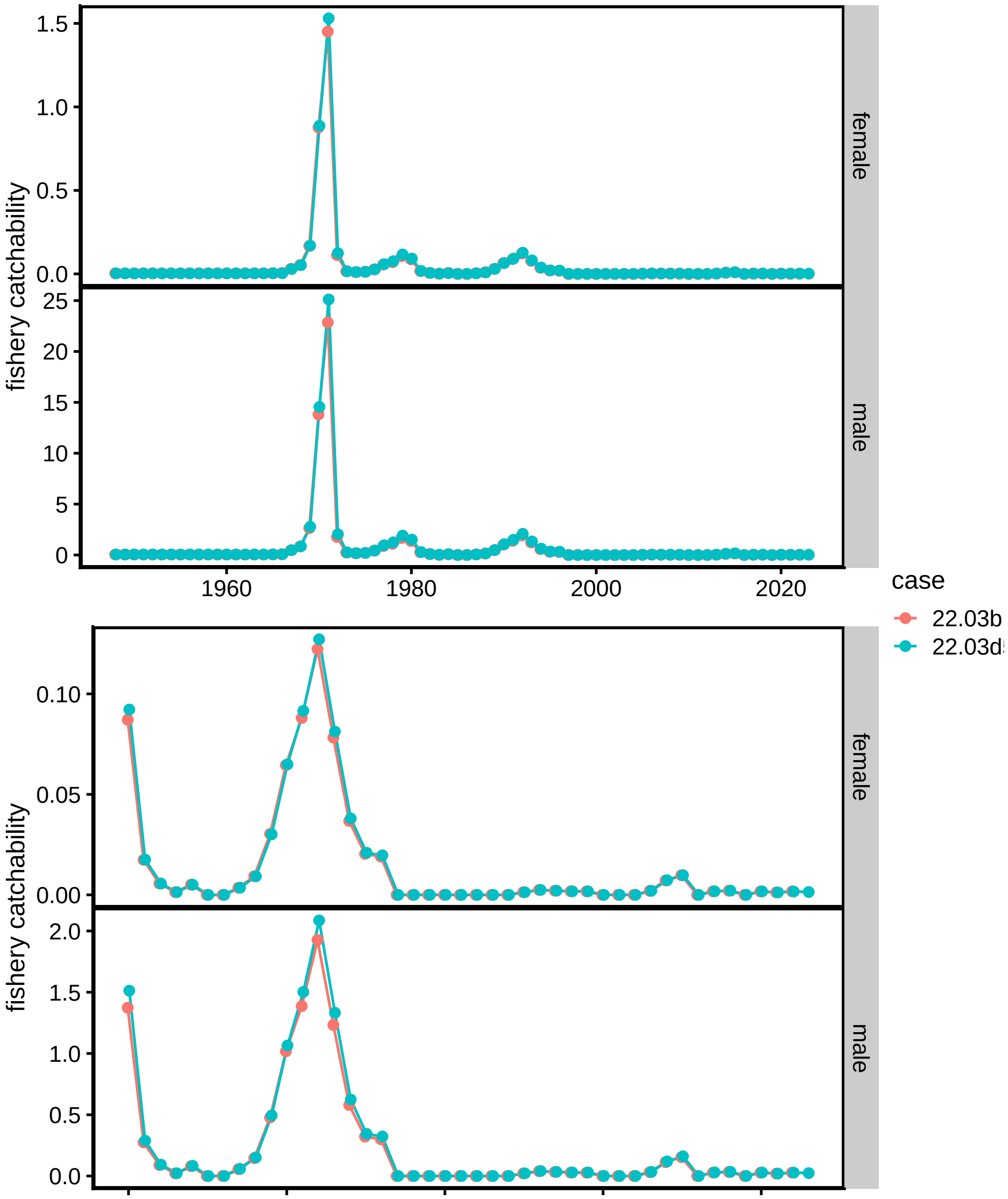

Figure 53. Estimated fully-selected capture rates (not mortality) in the directed fishery. The lower pair of plots show the estimated time series since 1980. Preferred model is 22.03d5.

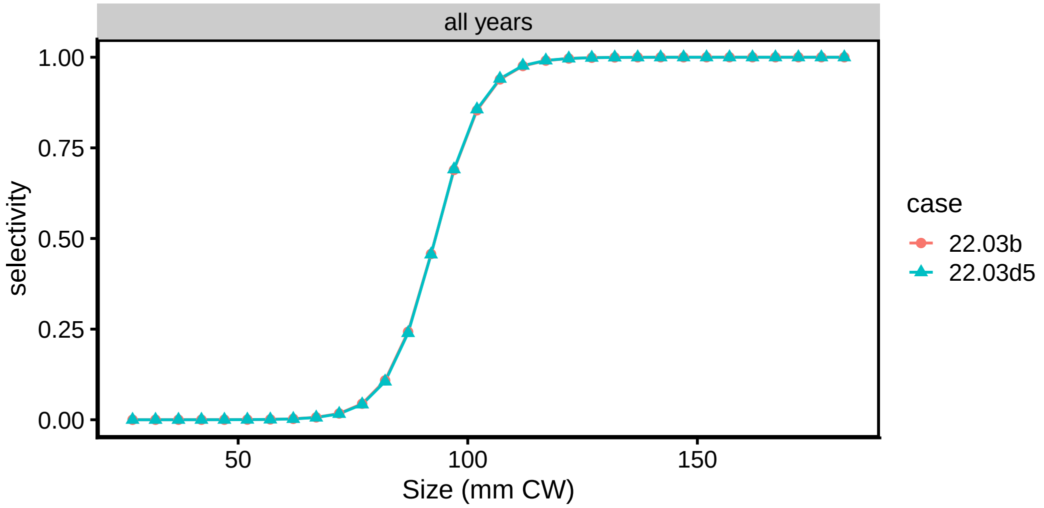

Figure 54. Estimated selectivity for females in the directed fishery for all years. Preferred model is 22.03d5.

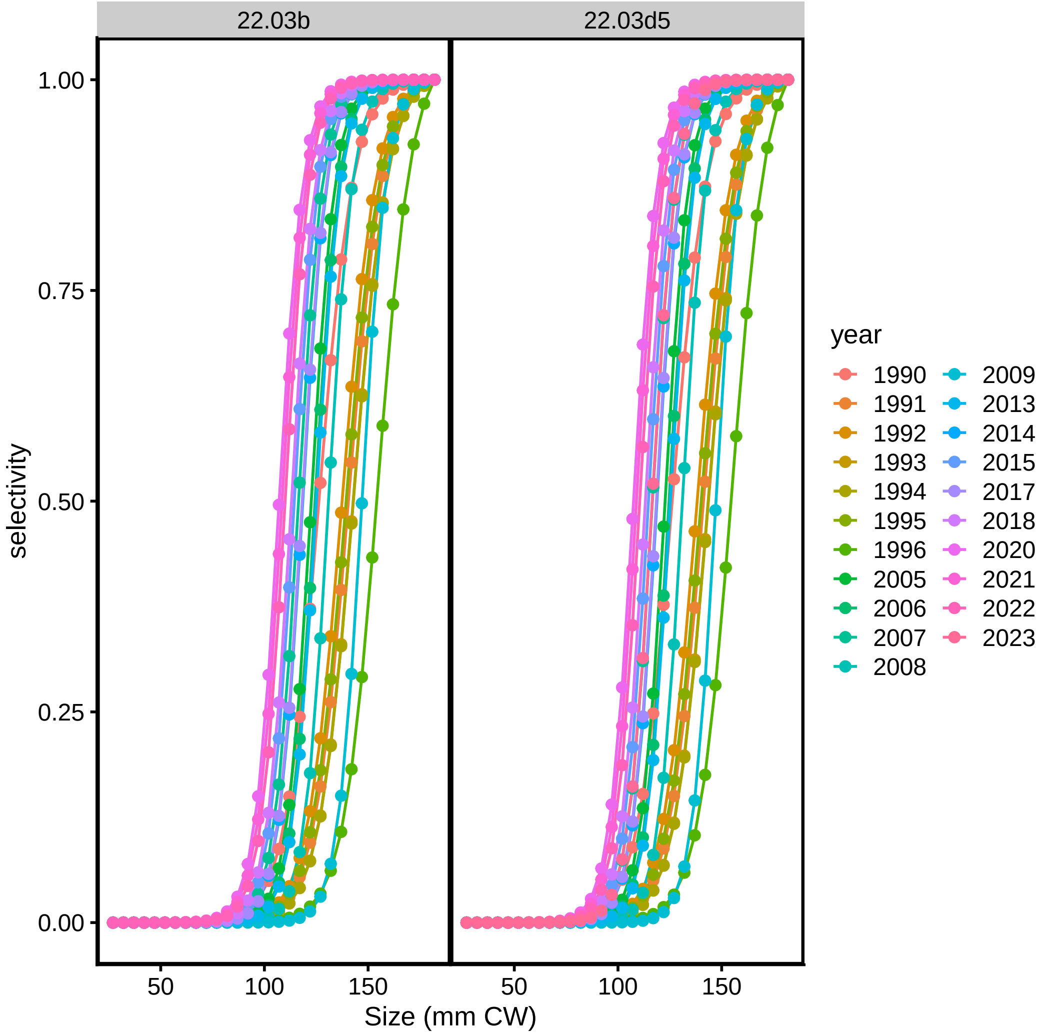

Figure 55. Estimated selectivity curves for males in the directed fishery, faceted by model scenario. Curves labelled 1990 applies to all years before 1991. Others apply in the year indicated in the legend. Preferred model is 22.03d5.

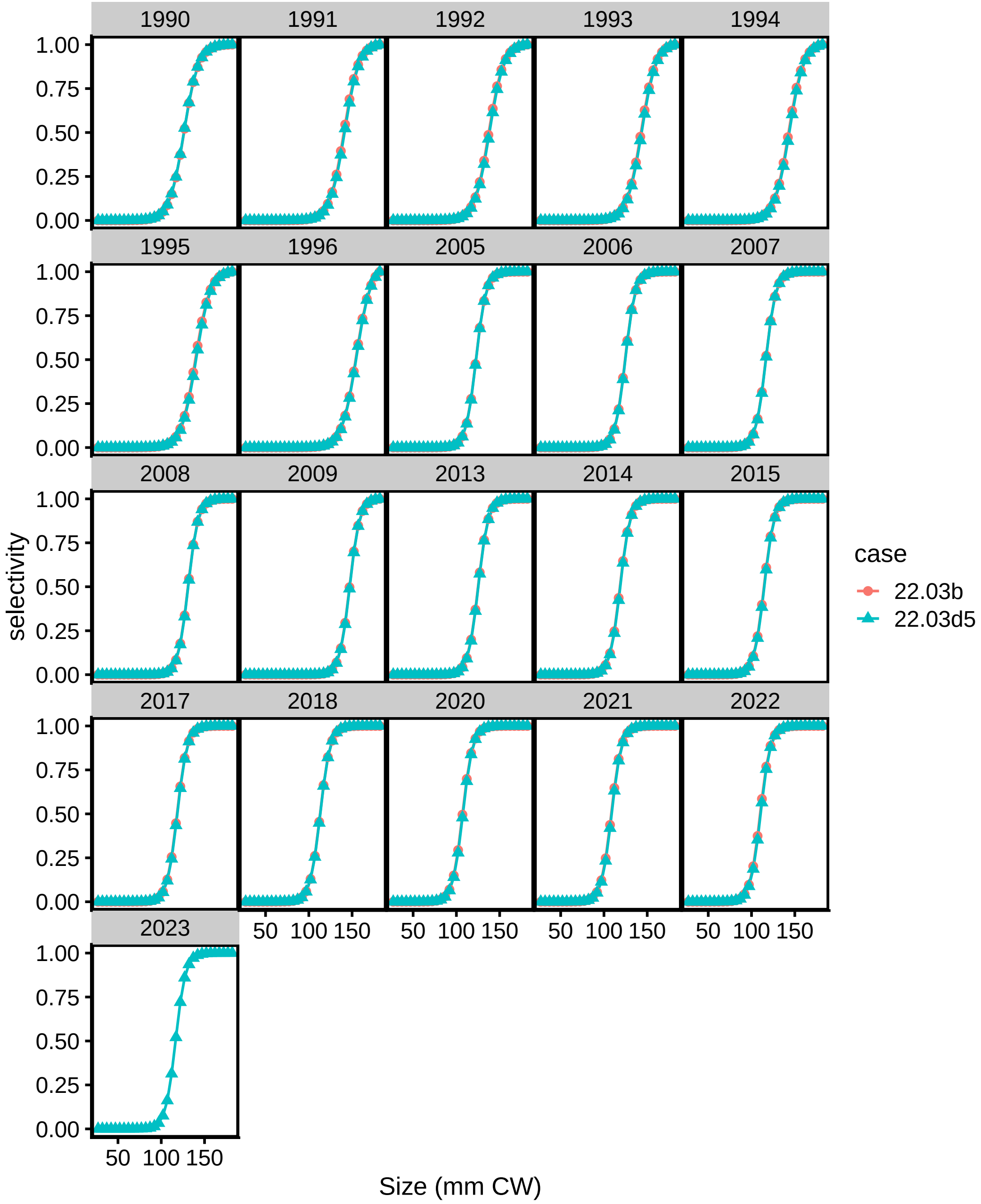

Figure 56. Estimated selectivity curves for males in the directed fishery by year. Curve labelled 1990 applies to all years before 1991. Others apply in the year indicated in the panel. Preferred model is 22.03d5.

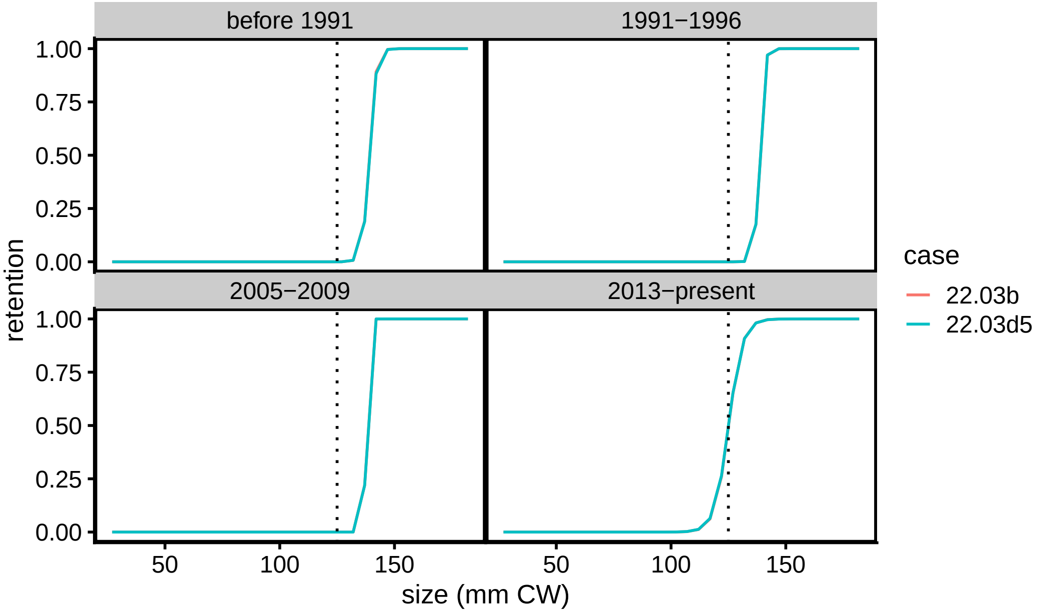

Figure 57. TCSAM02 models estimated retention curves for males in the directed fishery by time block. The dotted line indicates the current industry-preferred size (125 mm CW). Preferred model is 22.03d5.

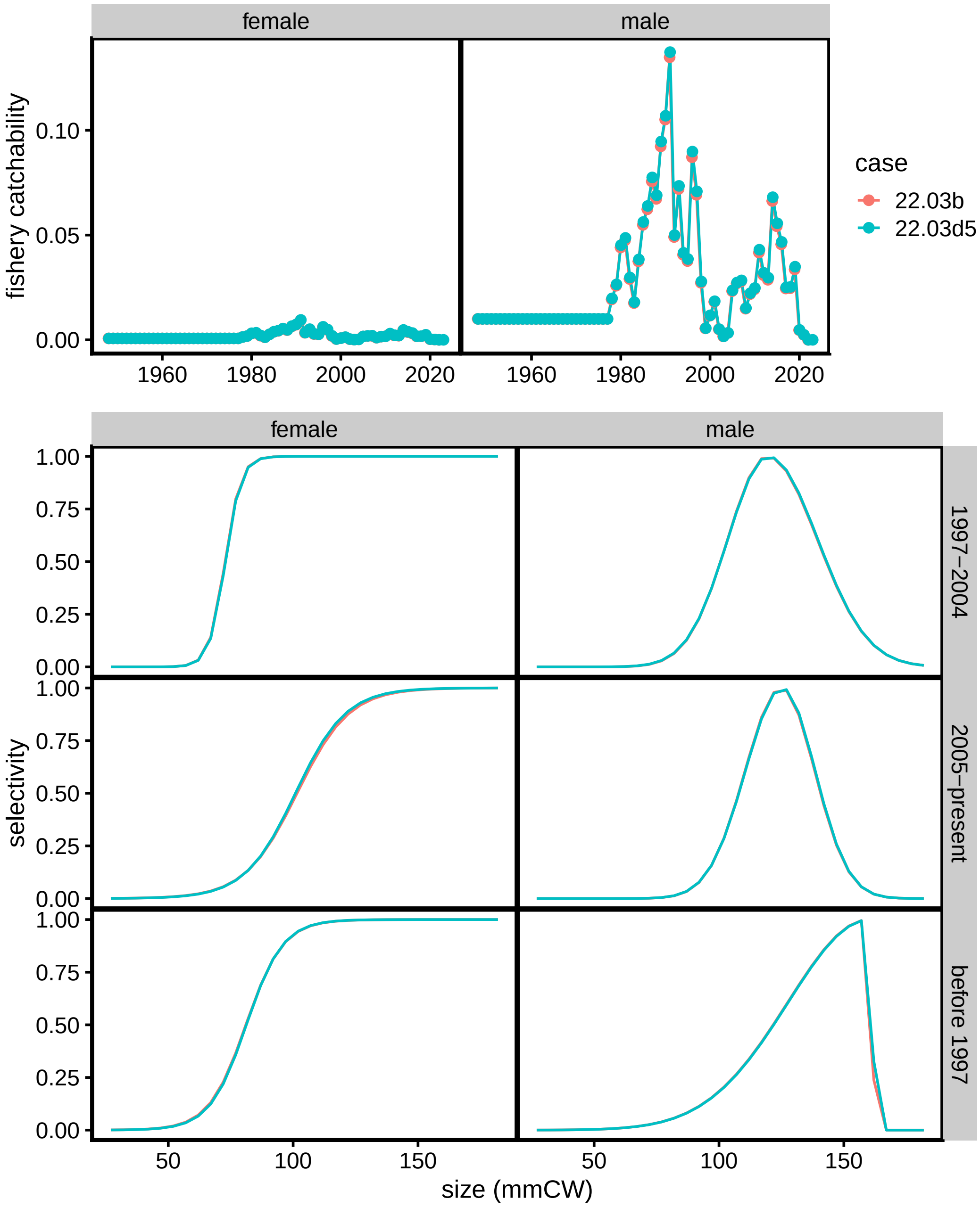

Figure 58. TCSAM02 models estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the snow crab fishery. Time blocks for selectivity functions are labelled: 1) before 1997; 2) 1997-2004; 3) 2005-present. Preferred model is 22.03d5.

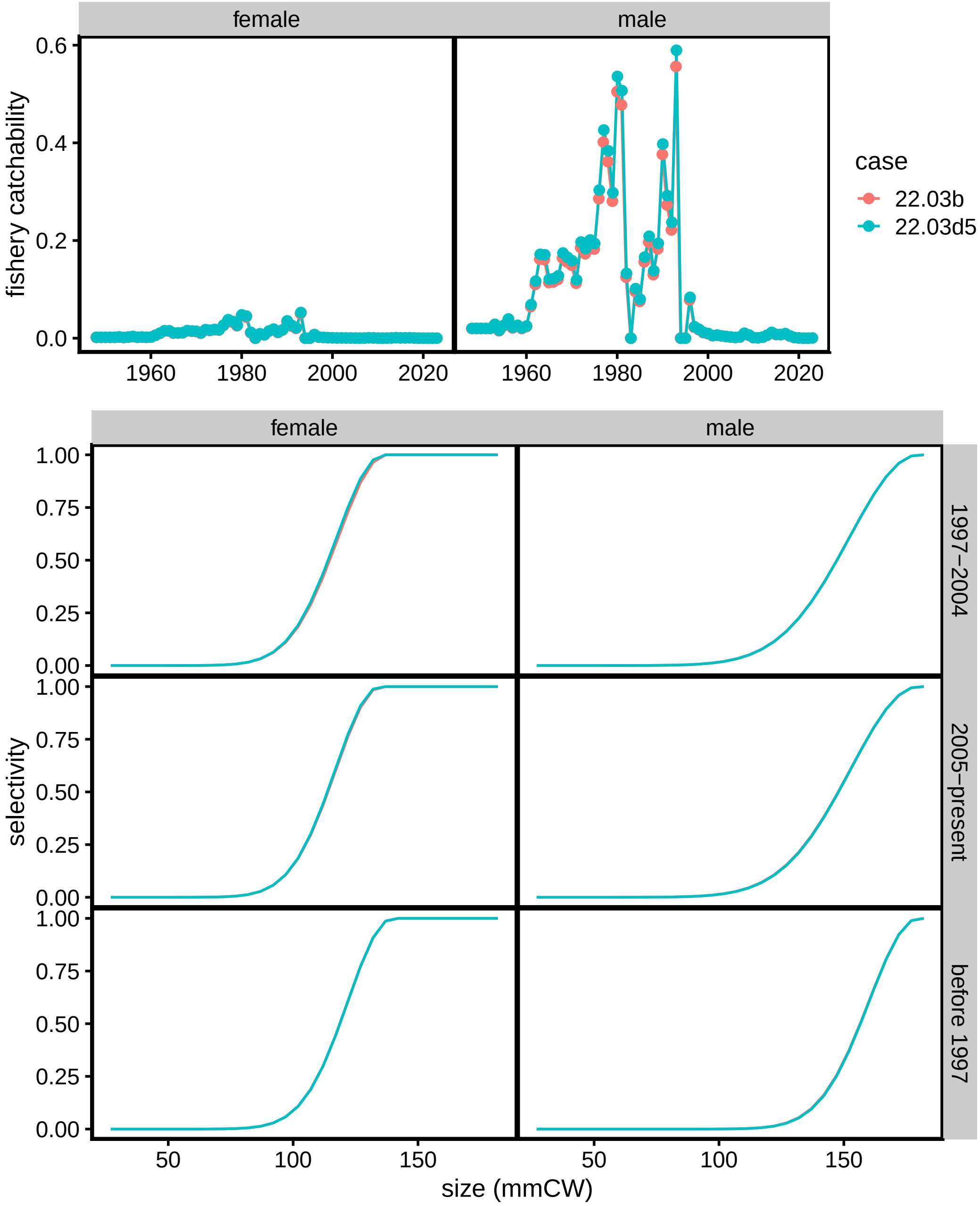

Figure 59. TCSAM02 models estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the BBRKC fishery. Time blocks for selectivity functions are 1) before 1997; 2) 1997-2004; 3) 2005-present. Preferred model is 22.03d5.

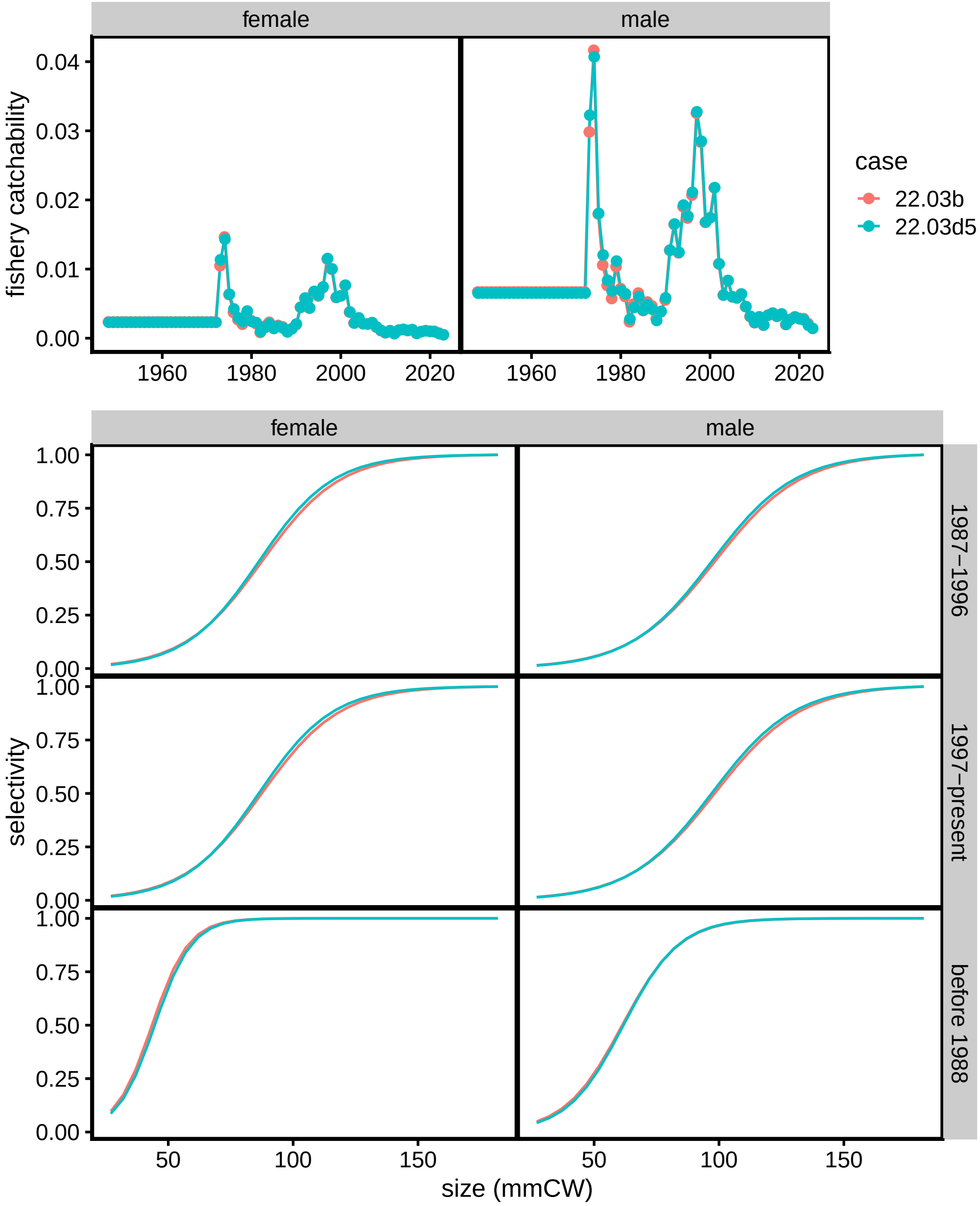

Figure 60. TCSAM02 models estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the groundfish fisheries. Time blocks for selectivity functions are : 1) before 1988; 2) 1987-1996; 3) 1997-present. Preferred model is 22.03d5.

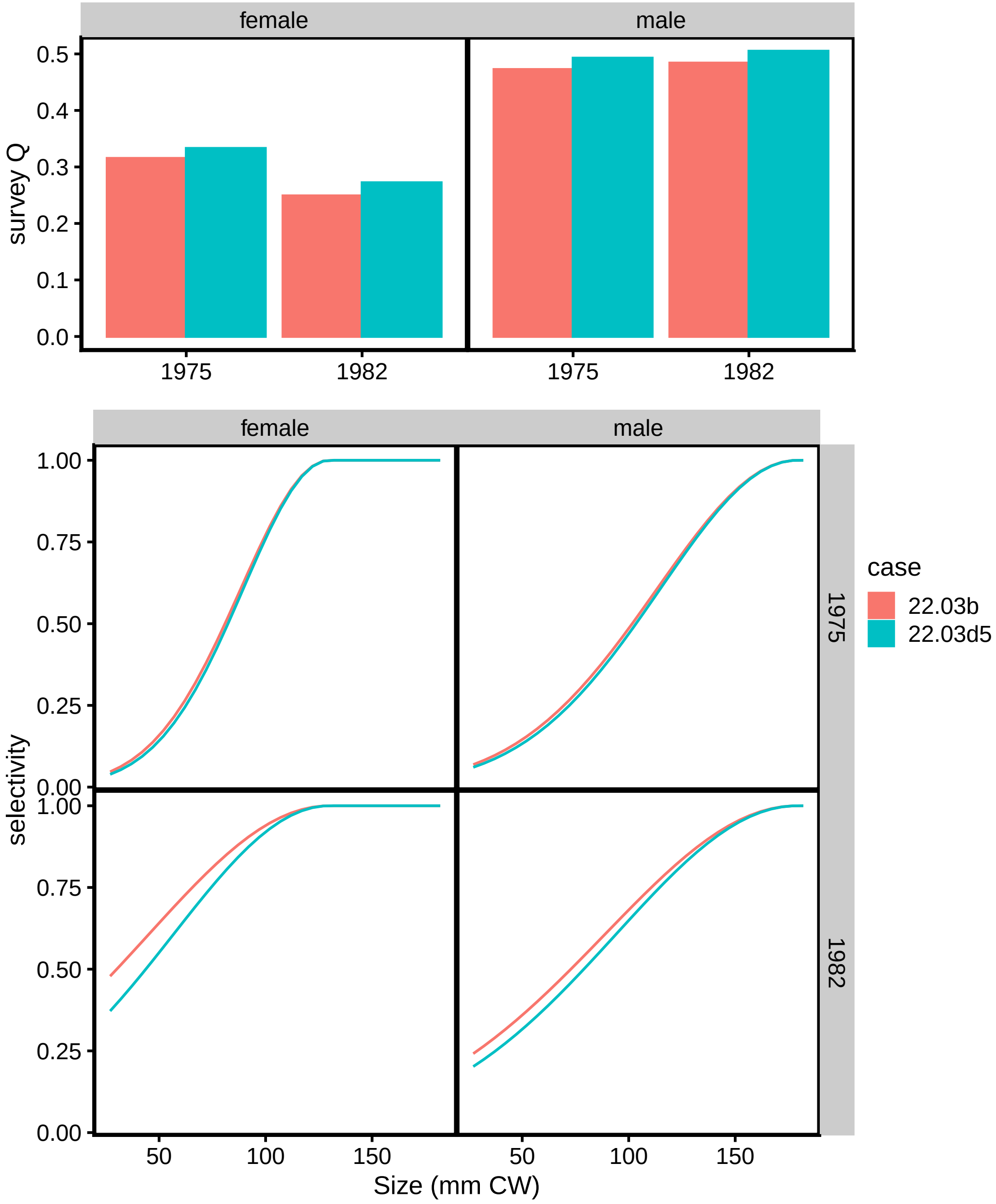

Figure 61. Estimated NMFS EBS Survey fully-selected catchability (survey Q's) and selectivity functions by sex for different time periods. 1975: 1975-1981; 1982: 1982-current. Preferred model is 22.03d5.

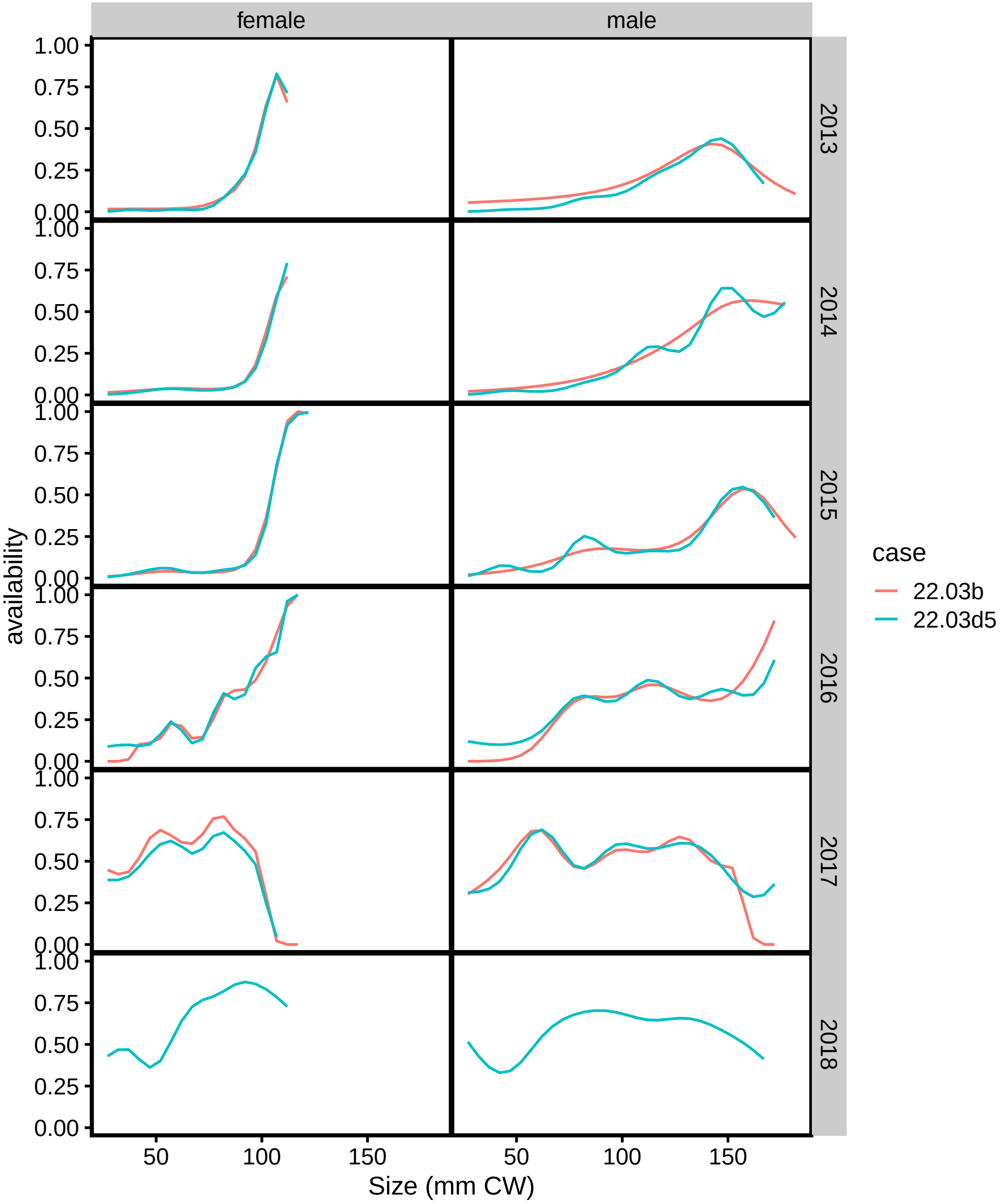

Figure 62. Annual sex-specific availability curves assumed for the BSFRF side-by-side (SBS) survey data. The availability curves were estimated outside the TCSAM02 models. Preferred model is 22.03d5.

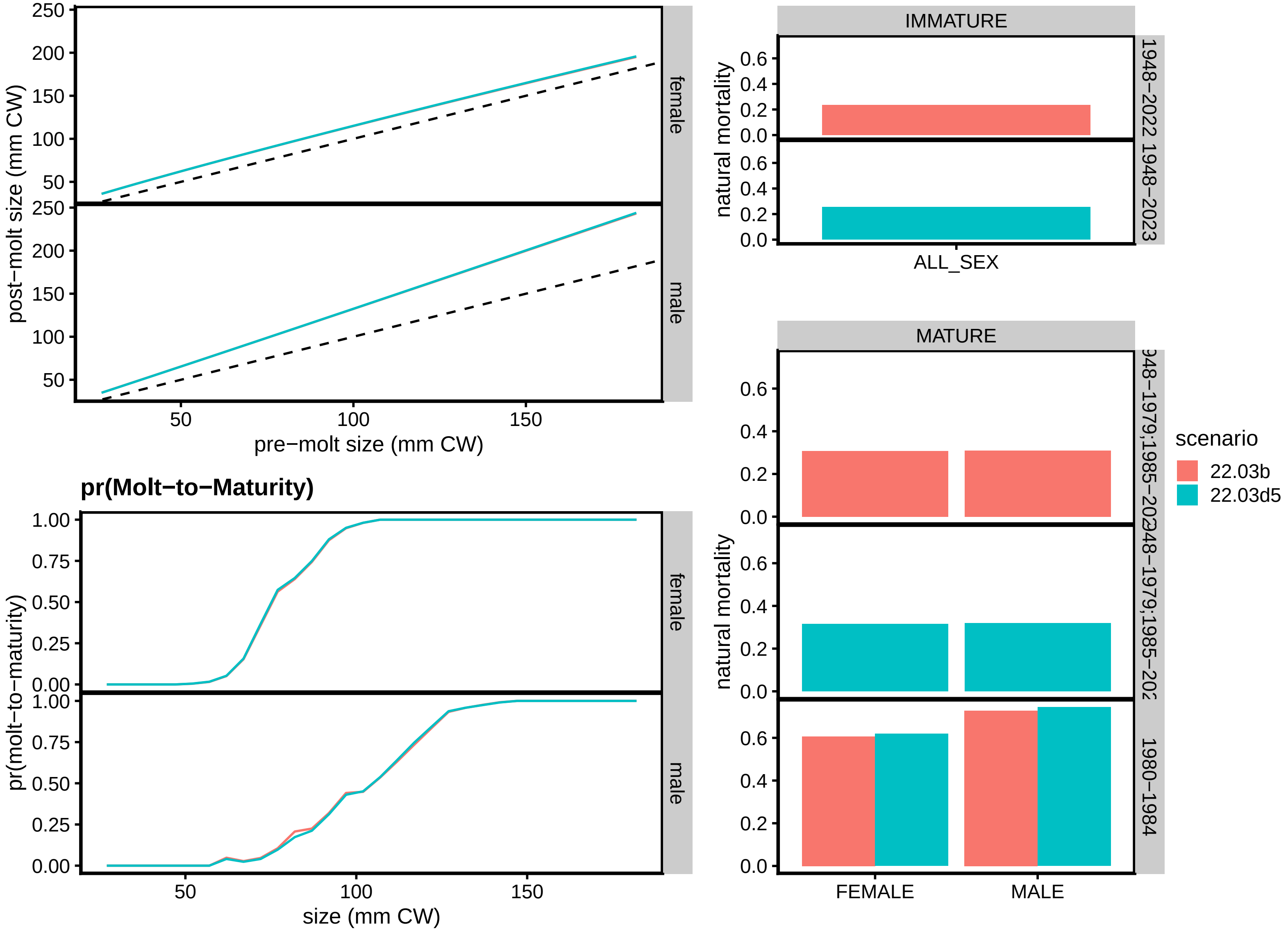

Figure 63. Estimated population processes. Plots in upper lefthand quadrant: sex-specific mean growth; plots in lower lefthand quadrant: sex-specific probability of the molt-to-maturity (i.e., terminal molt); plots in righthand column: natural mortality rates, by maturity state and sex. Preferred model is 22.03d5.

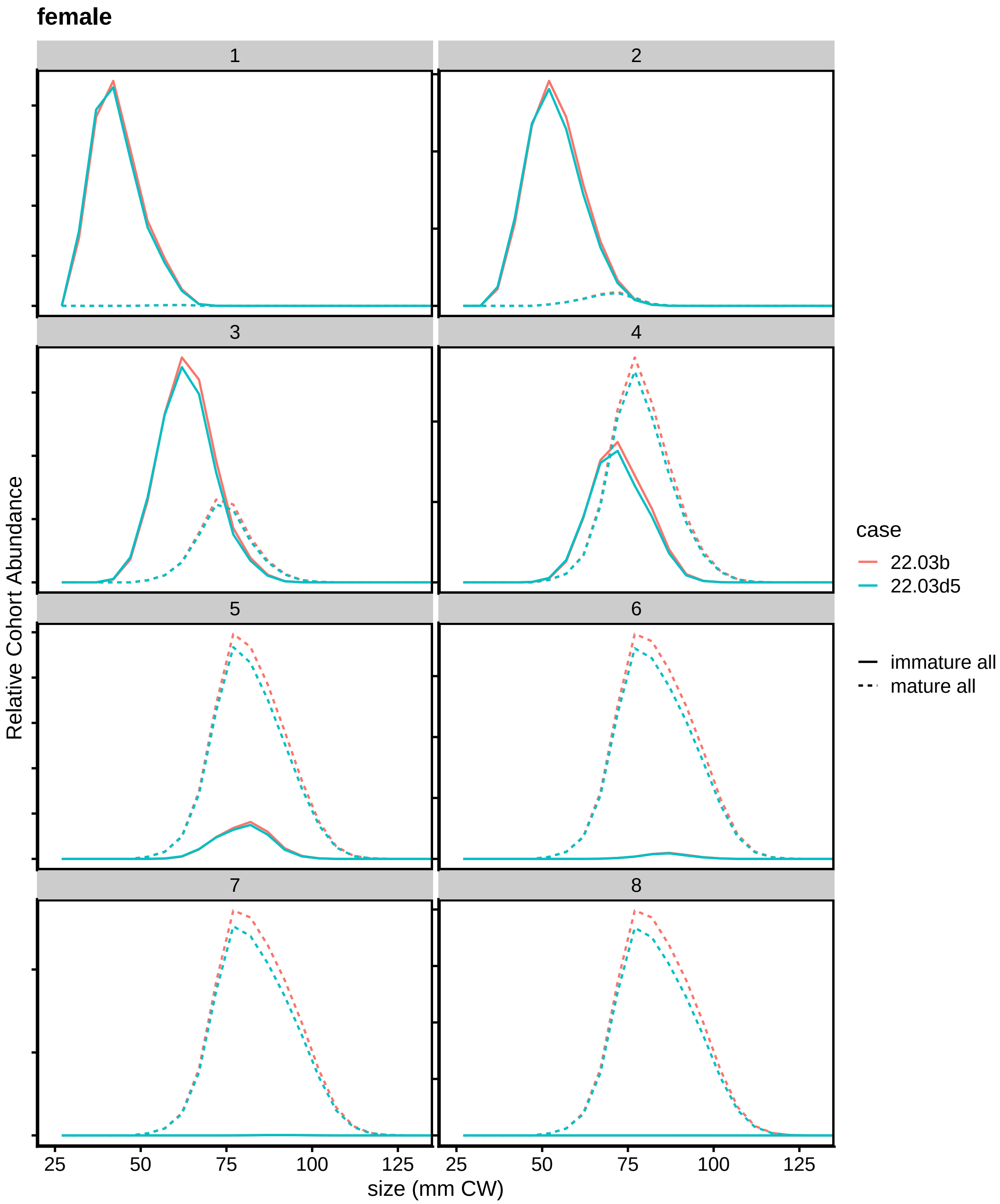

Figure 64. Estimated annual cohort progression for female crab based on rates from final model year (by age; individual scales are relative). Preferred model is 22.03d5.

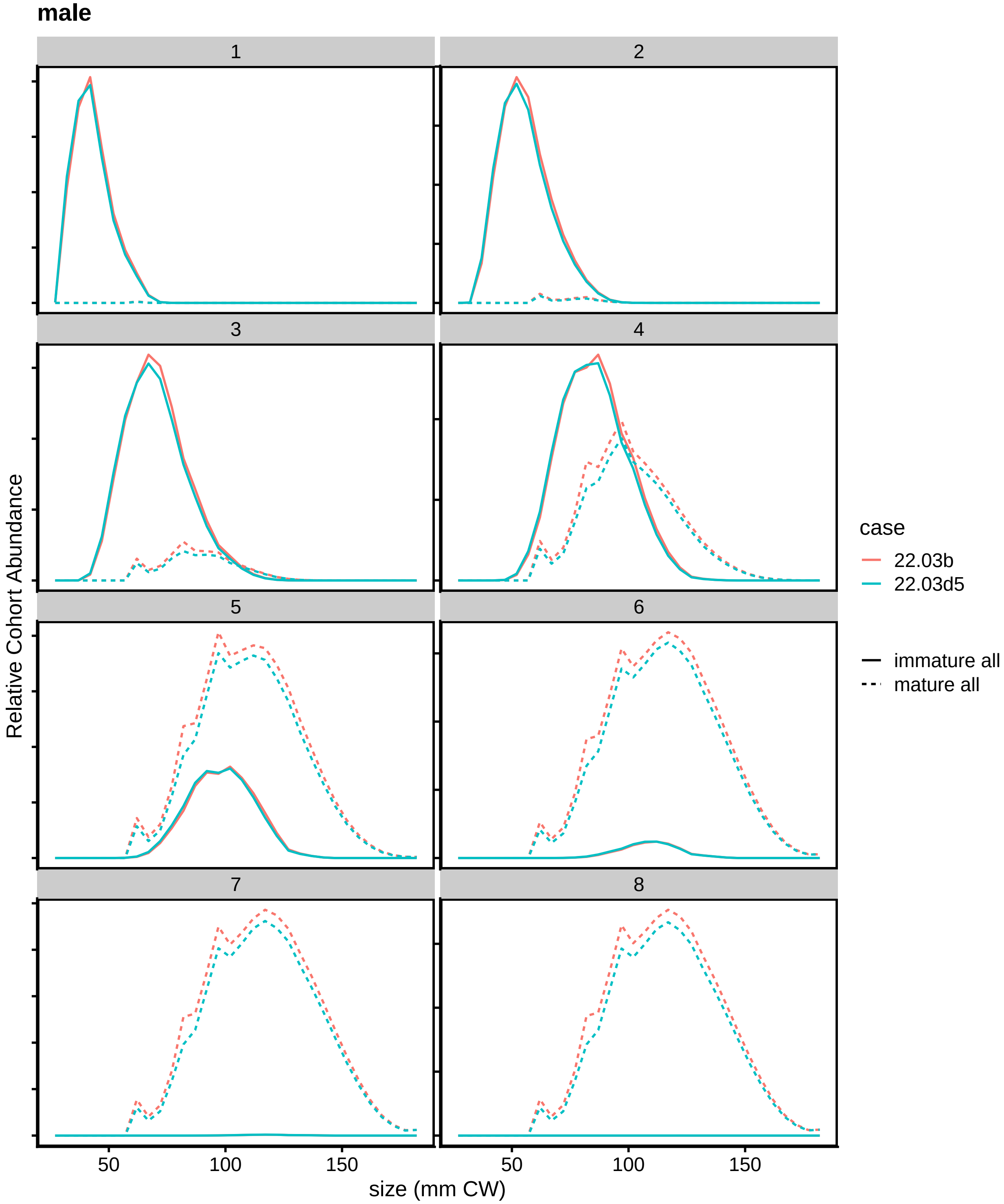

Figure 65. Estimated annual cohort progression for male crab based on rates from final model year (by age; individual scales are relative). Preferred model is 22.03d5.

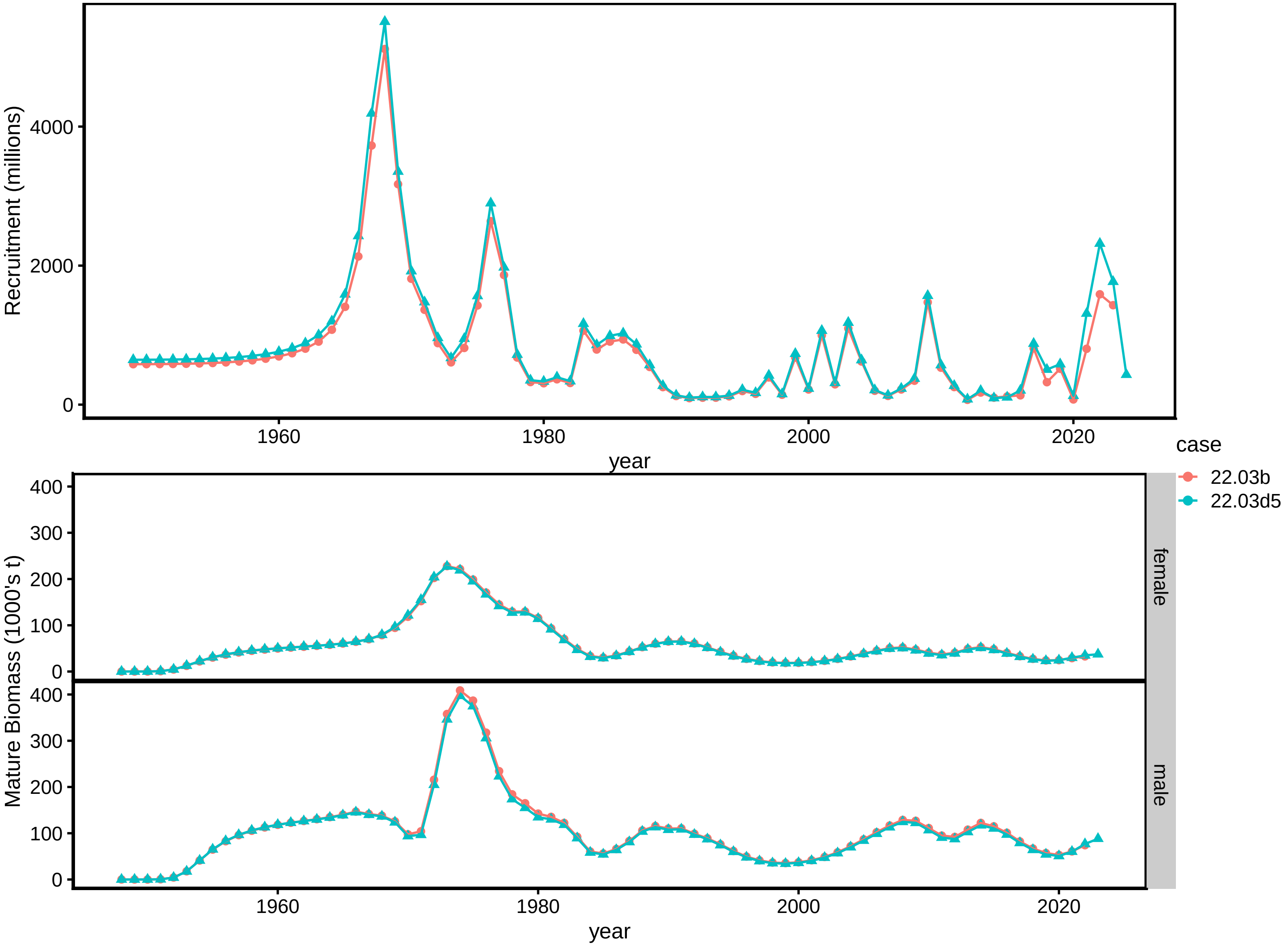

Figure 66. Estimated recruitment and mature biomass time series (all years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03d5.

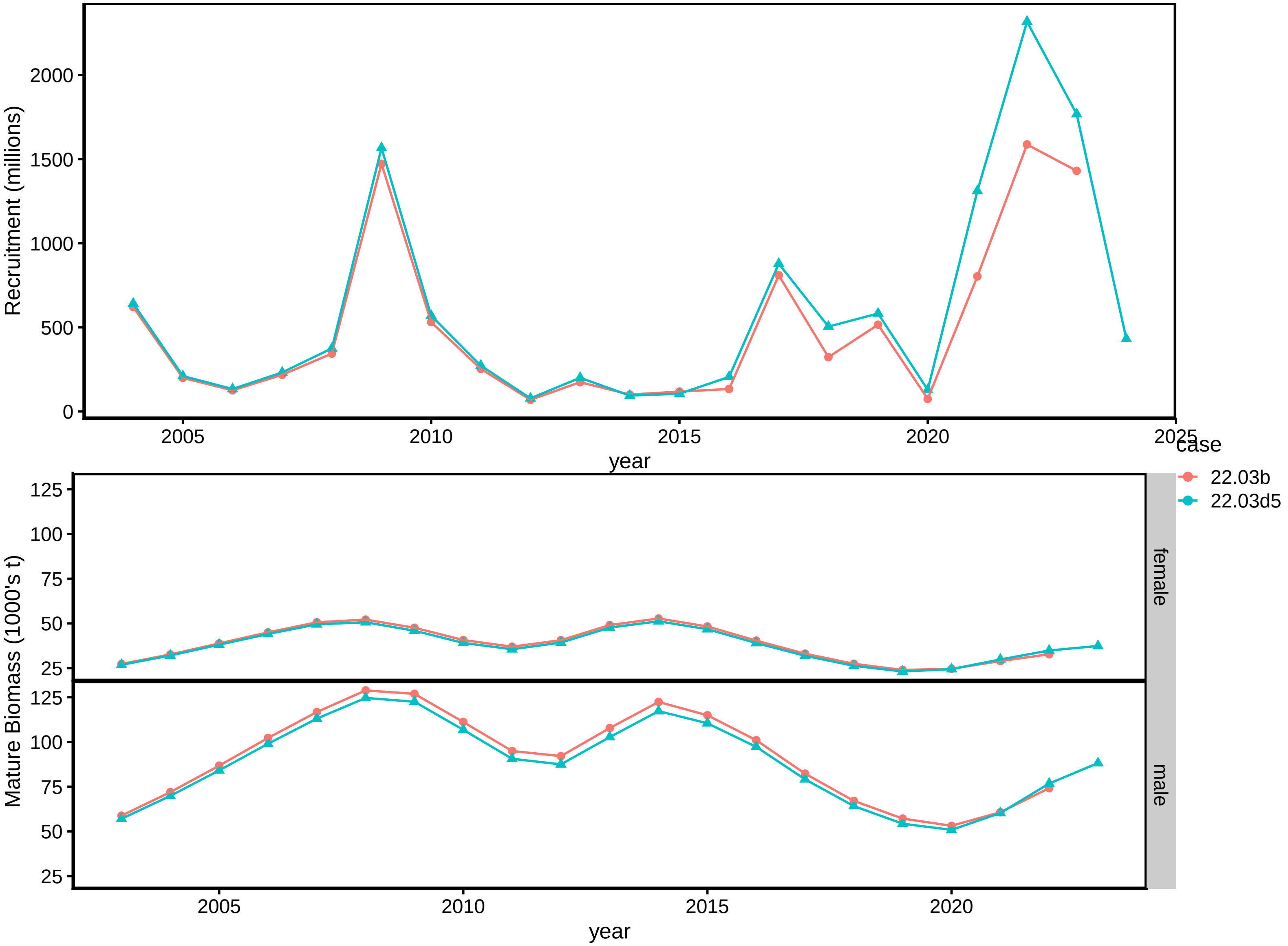

Figure 67. Estimated recruitment and mature biomass time series (recent years). Upper plot: recruitment; lower plots: sex-specific mature biomass-at-mating. Preferred model is 22.03d5.

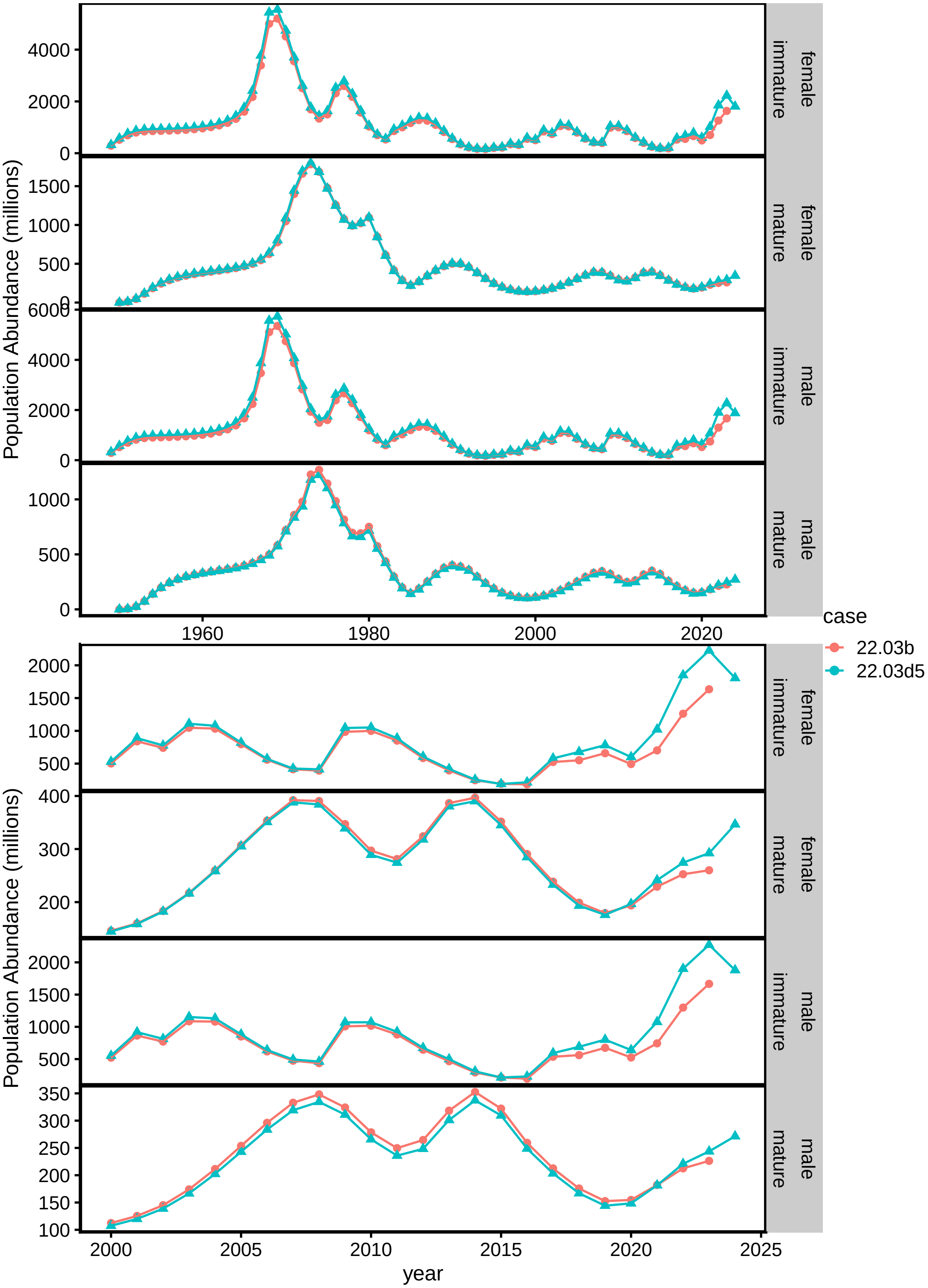

Figure 68. Estimated population abundance trends, by sex and maturity state. Upper plots: all years; lower plots: recent years. Preferred model is 22.03d5.

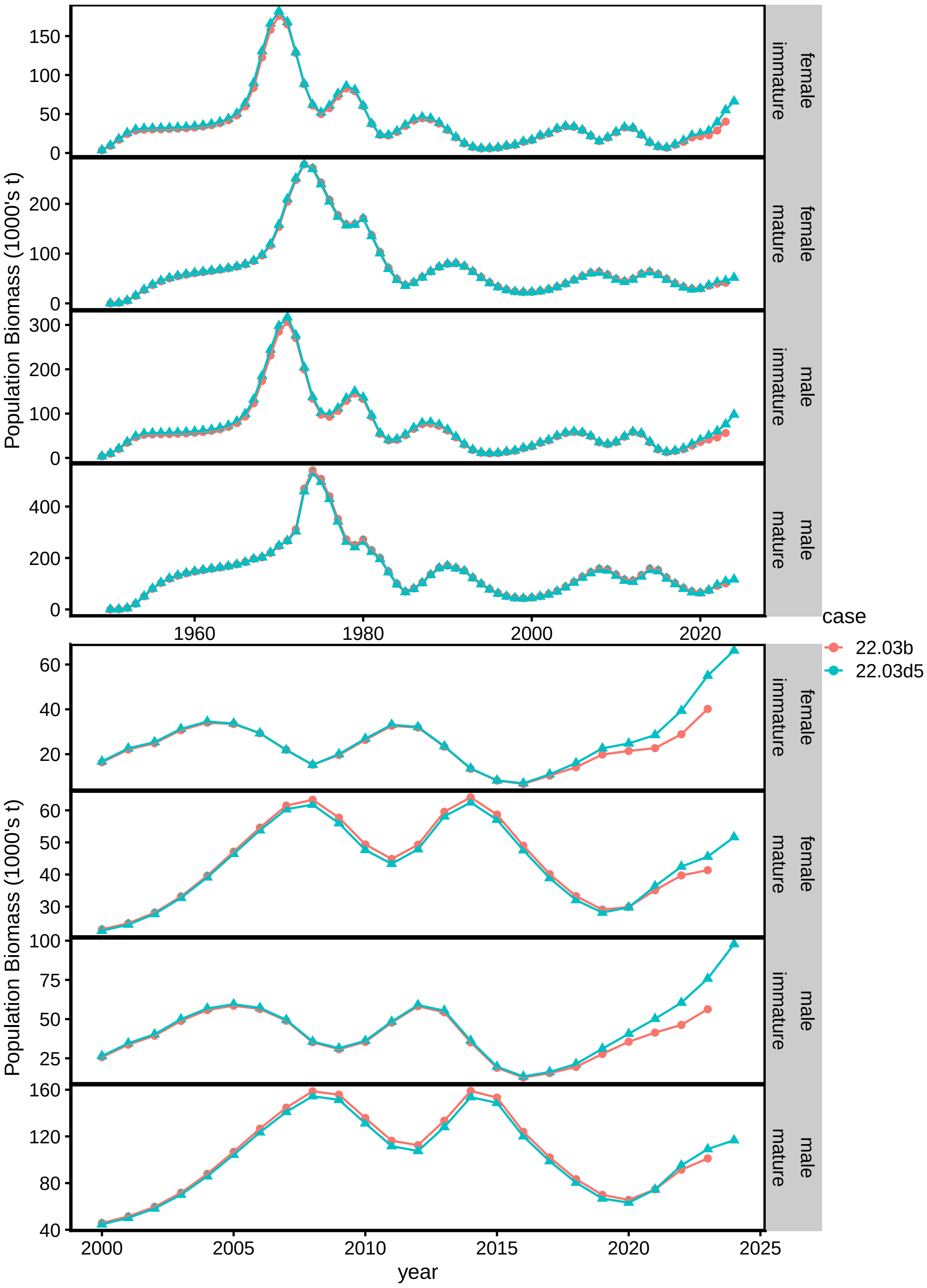

Figure 69. Estimated population biomass trends, by sex and maturity state. Upper plots: all years; lower plots: recent years. Preferred model is 22.03d5.

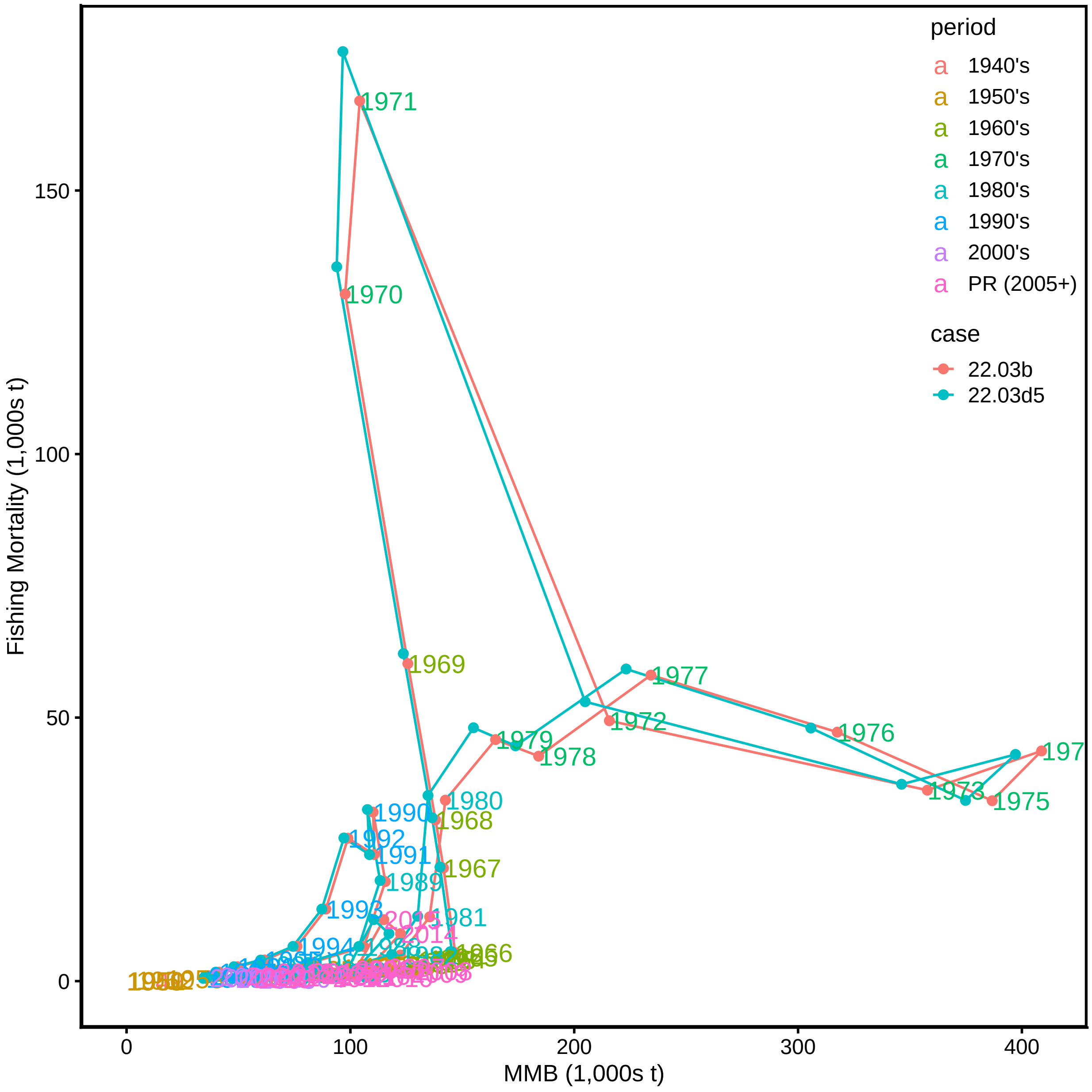

Figure 70. Estimated total fishing mortality vs. MMB. Decades prior to rationalization are grouped by color; the post-rationalization period (“PR”), 2005+, is also highlighted. Data to inform fishing mortality is only available from 1965 on. Preferred model is 22.03d5.

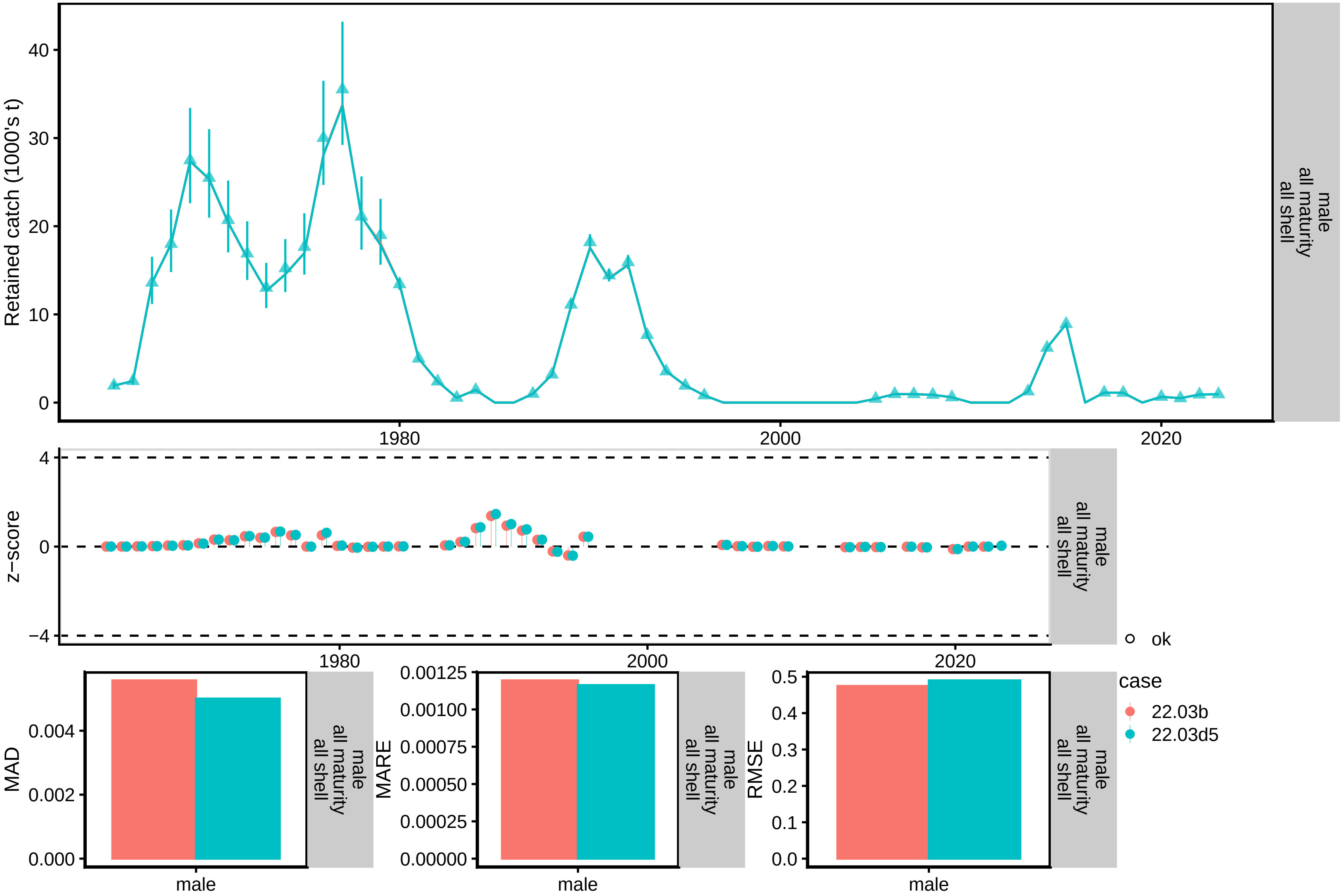

Figure 71. TCSAM02 models fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Preferred model is 22.03d5.

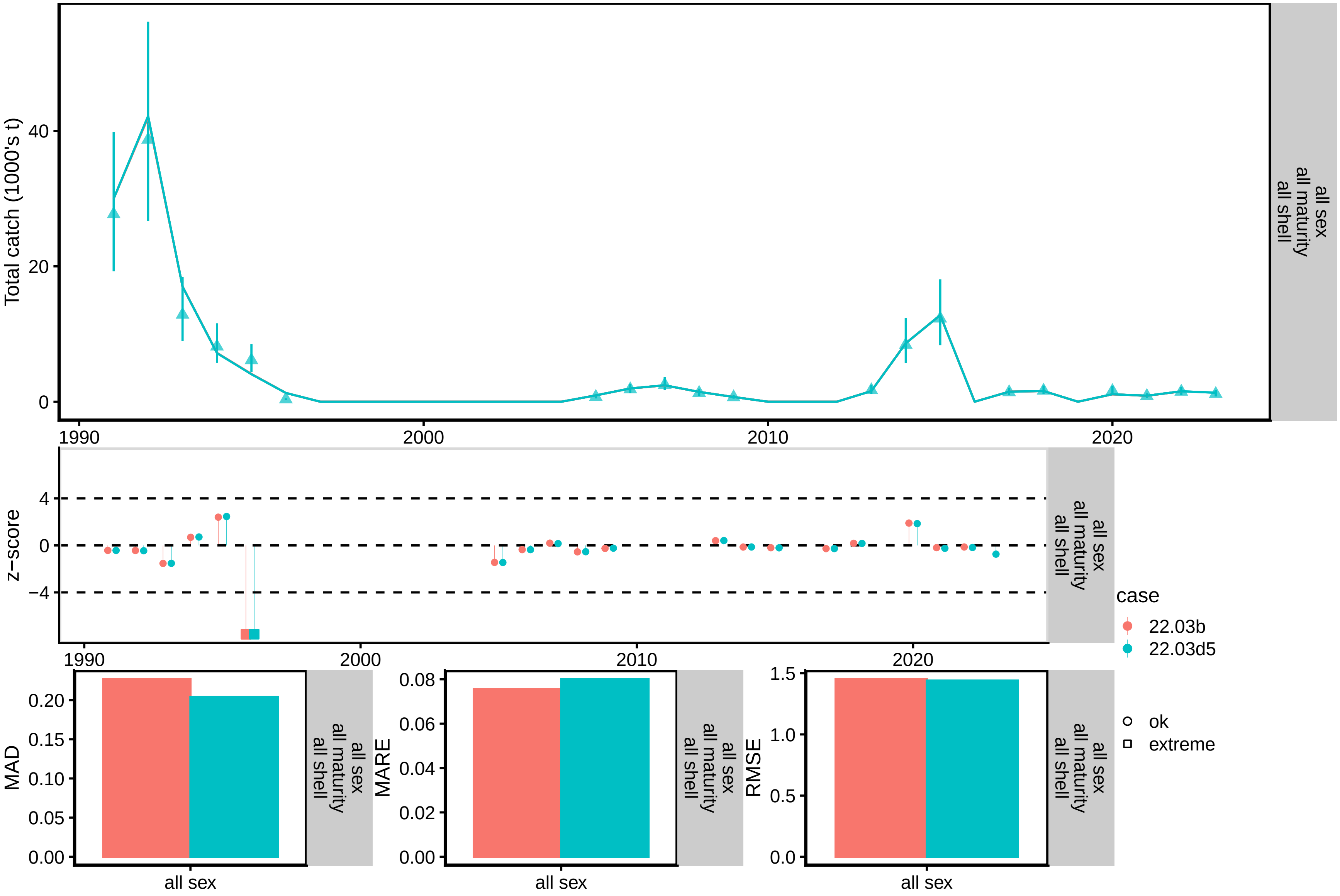

Figure 72. TCSAM02 models fits to total catch biomass of all crab in the TCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Preferred model is 22.03d5.

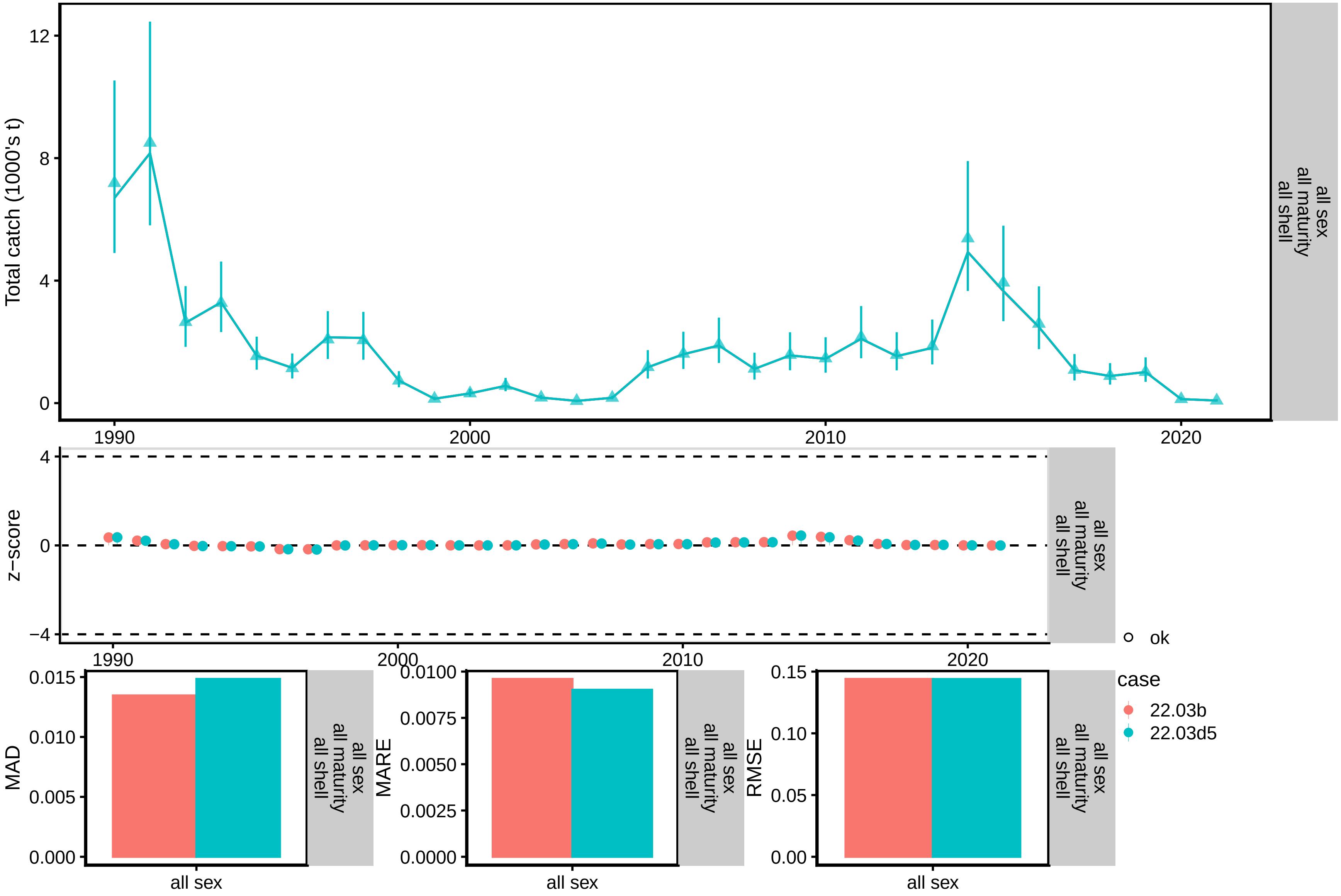

Figure 73. TCSAM02 models fits to total catch biomass of all crab in the SCF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Preferred model is 22.03d5.

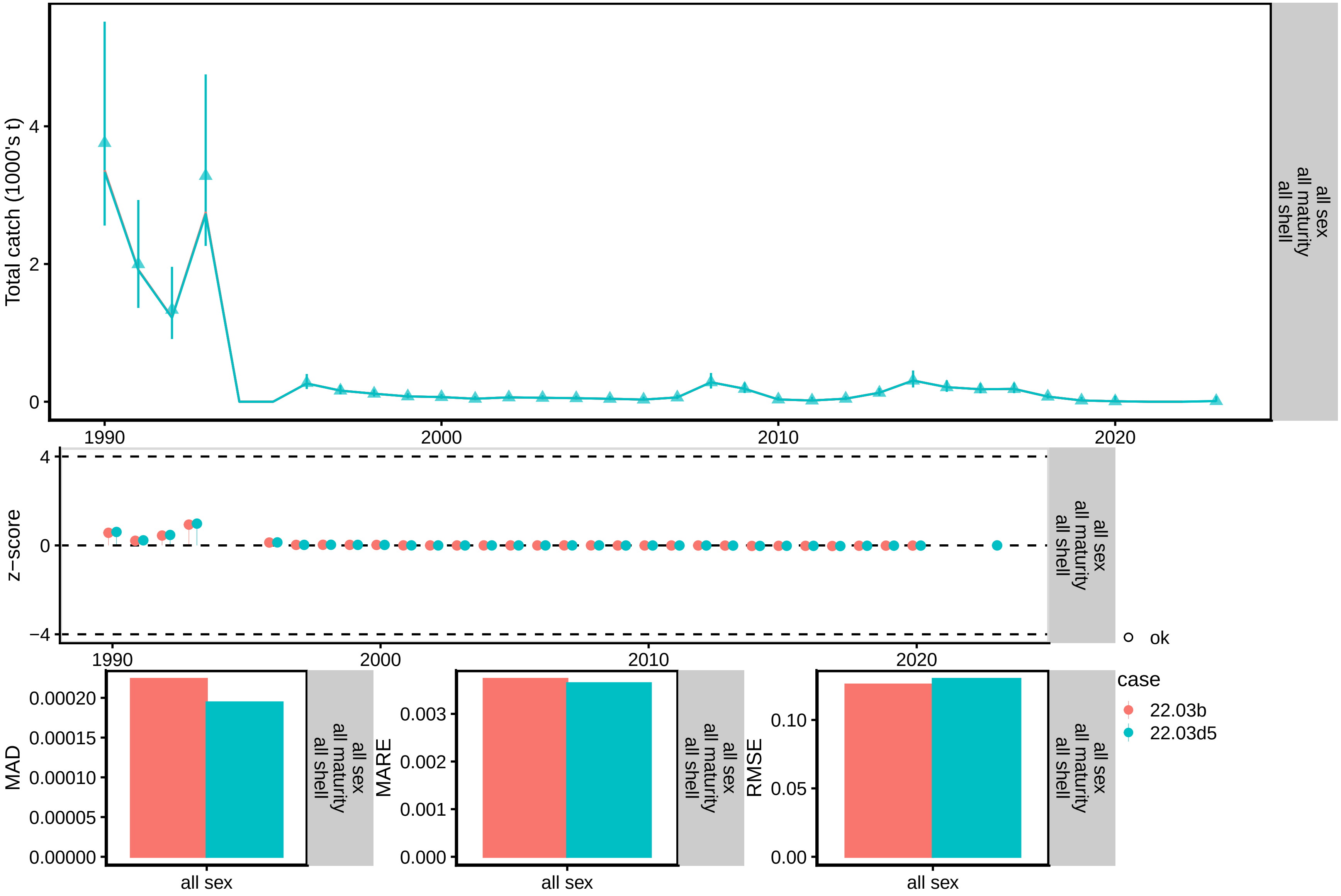

Figure 74. TCSAM02 models fits to total catch biomass of all crab in the RKF fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Preferred model is 22.03d5.

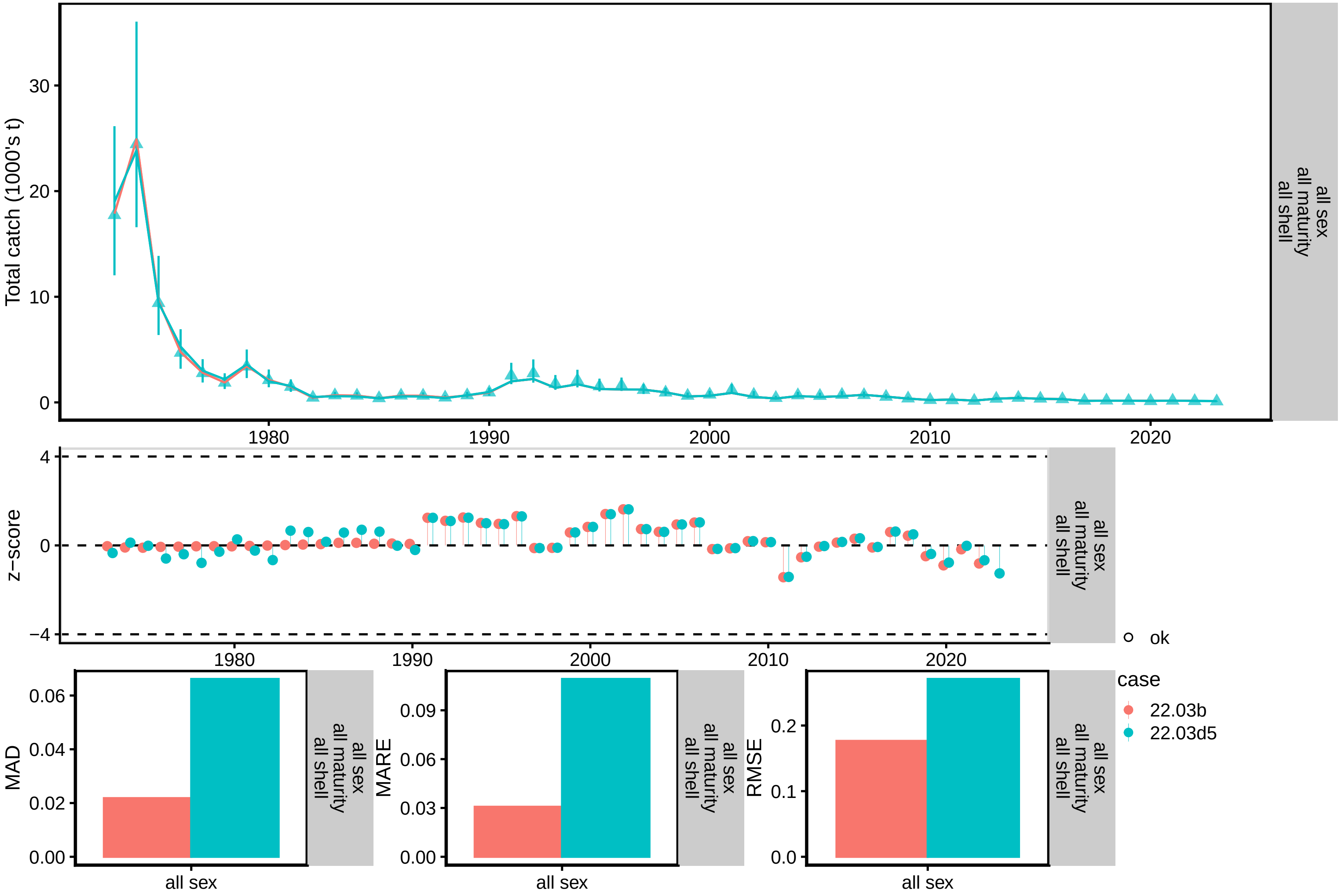

Figure 75. TCSAM02 models fits to total catch biomass of all crab in the GF All fishery (upper row) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Preferred model is 22.03d5.

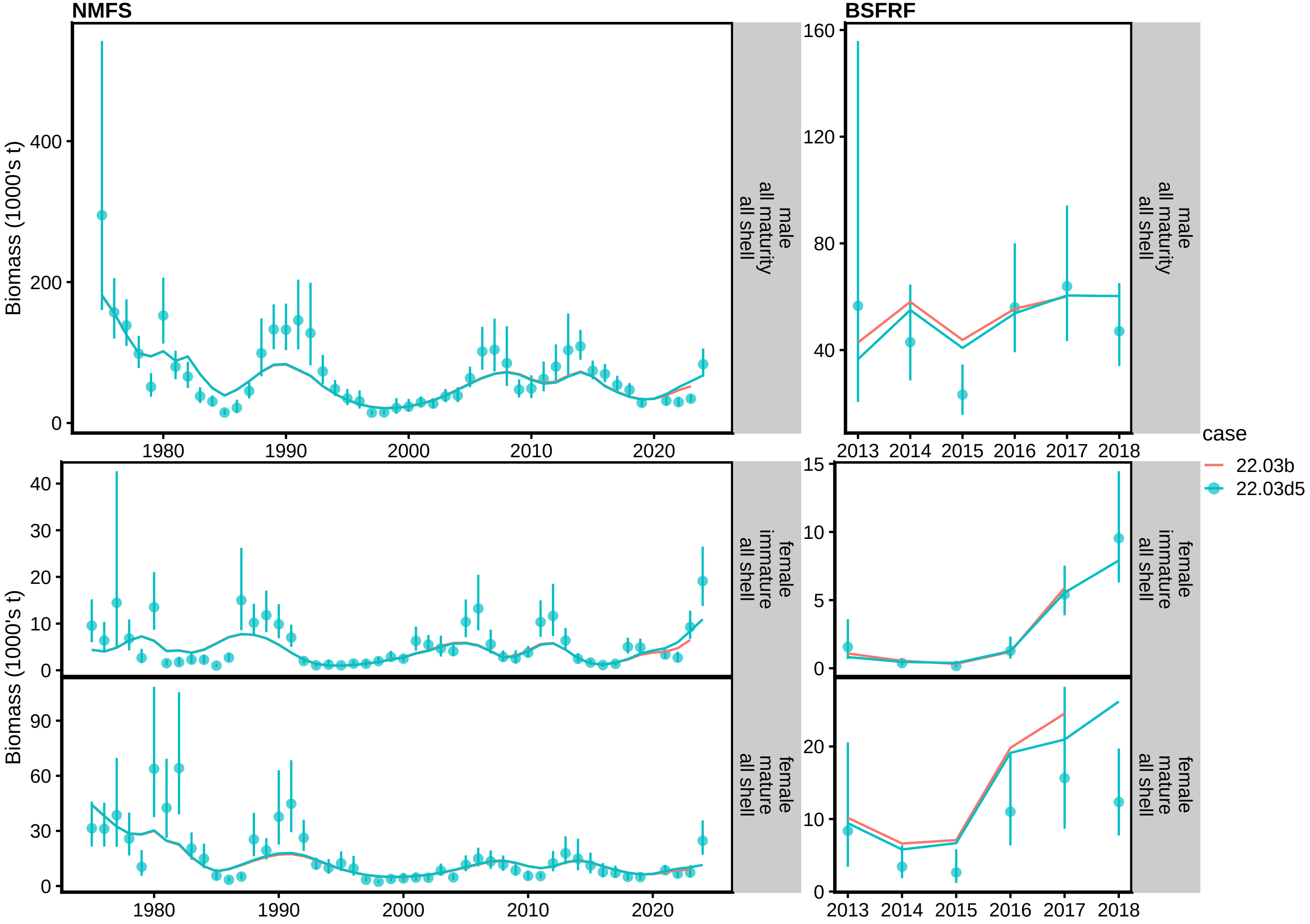

Figure 76. TCSAM02 models fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) biomass from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Confidence intervals are 95%.

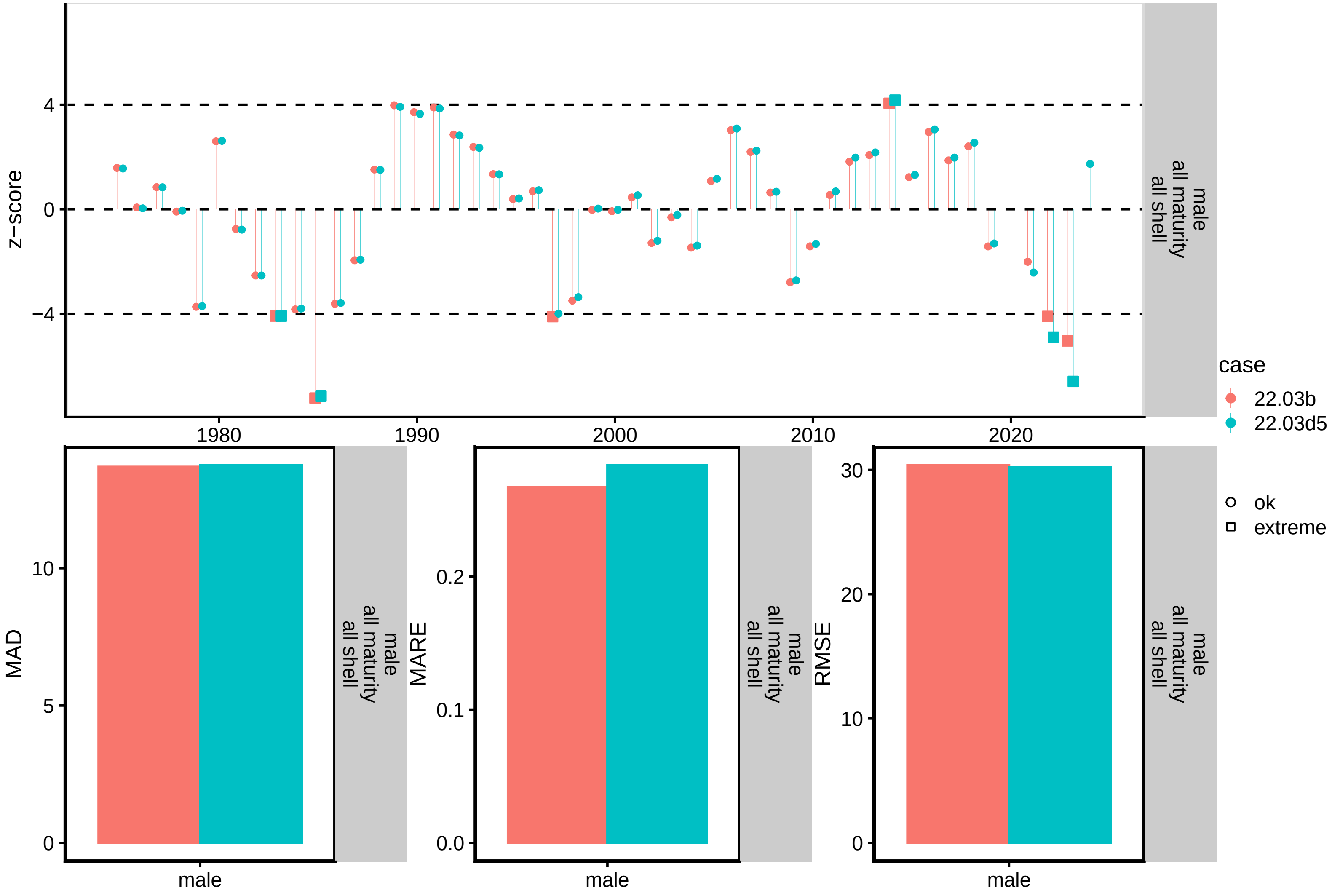

Figure 77. TCSAM02 models residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

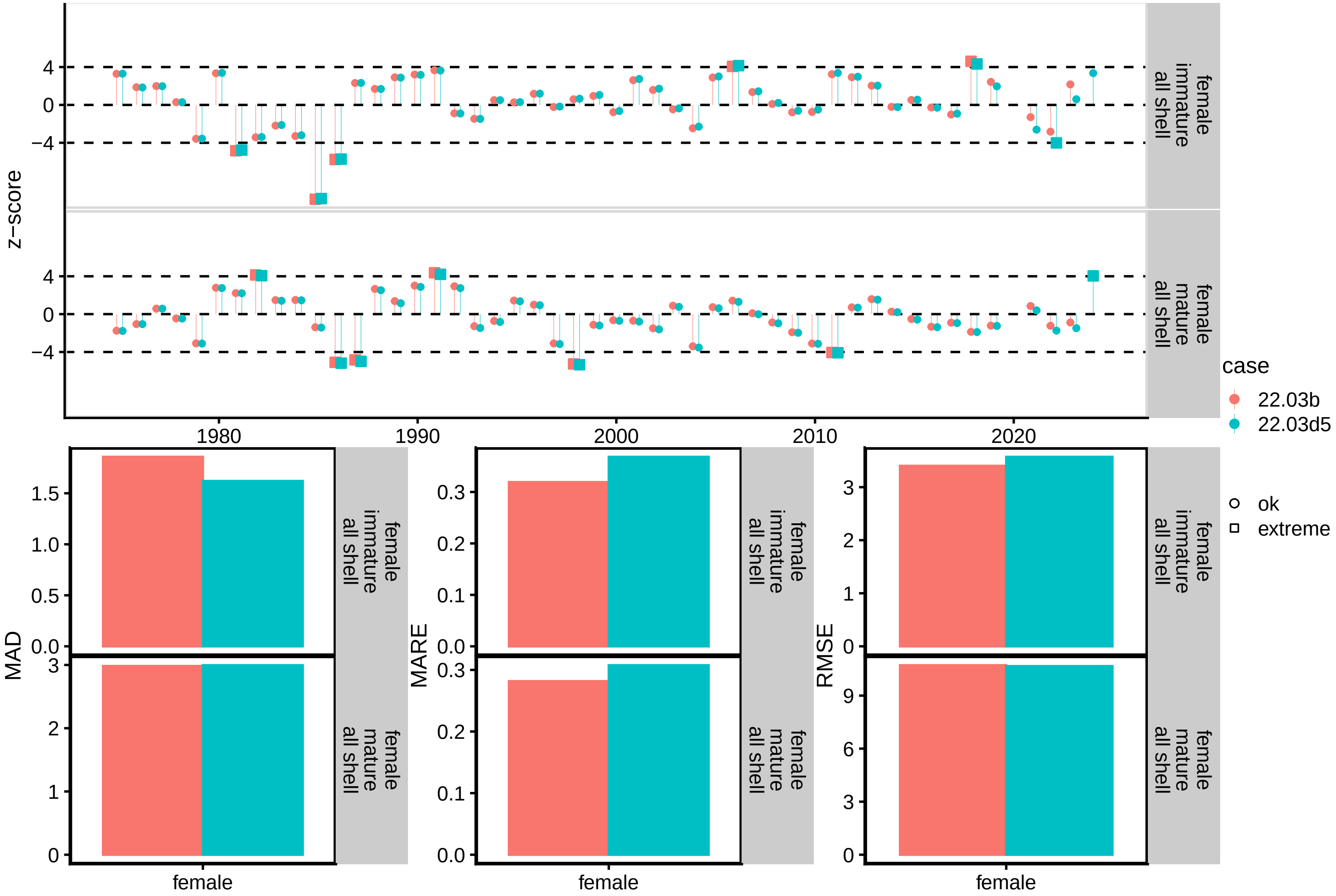

Figure 78. TCSAM02 models residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

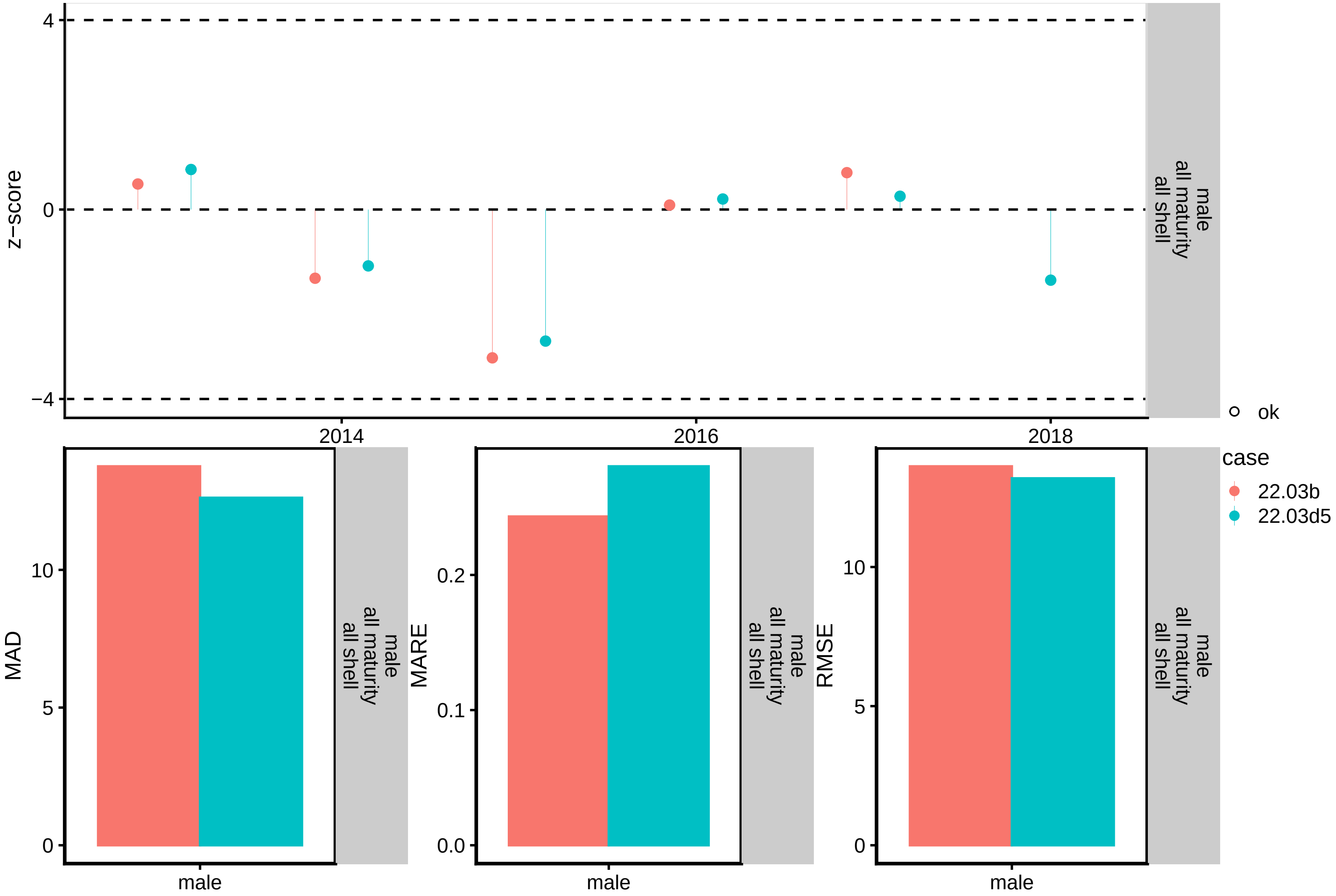

Figure 79. TCSAM02 models residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

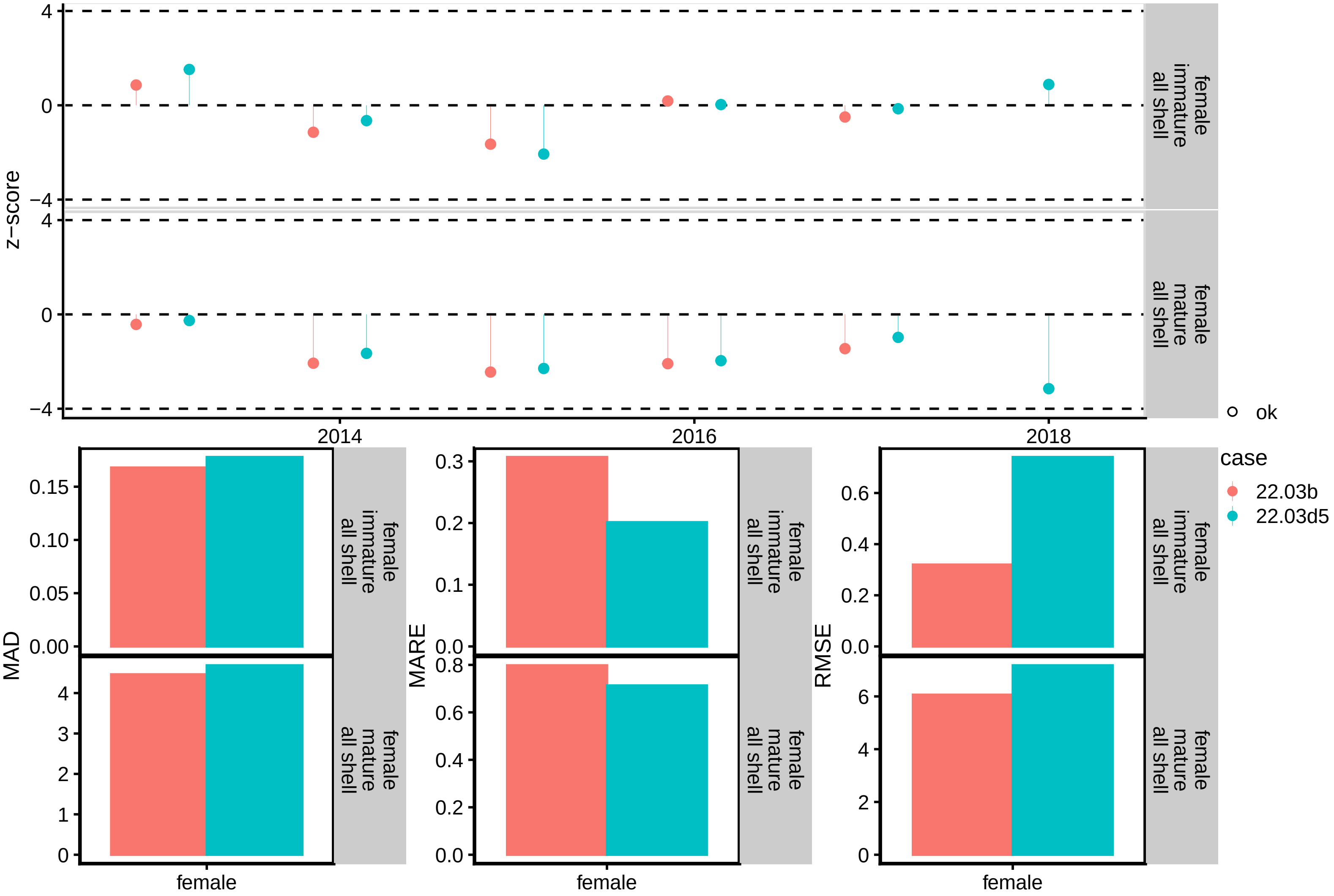

Figure 80. TCSAM02 models residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

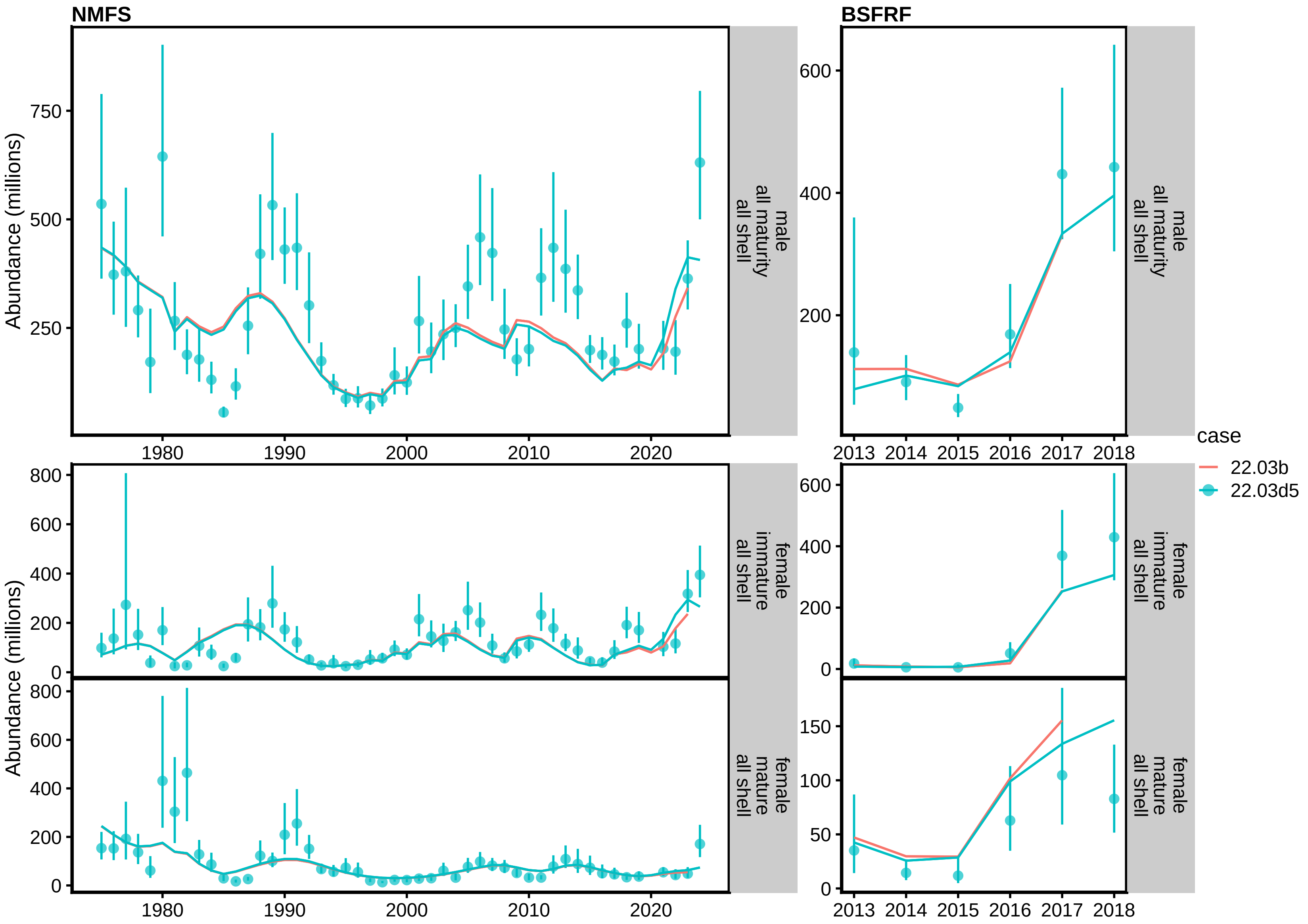

Figure 81. TCSAM02 models fits to time series of all male (upper graph), immature female (center graph), and mature female (lower plot) abundance from the NMFS EBS shelf bottom trawl survey (left column) and the BSFRF SBS trawl survey (right column). Note that these fits are not included in the model objective function and simply provide a diagnostic check. Confidence intervals are 95%.

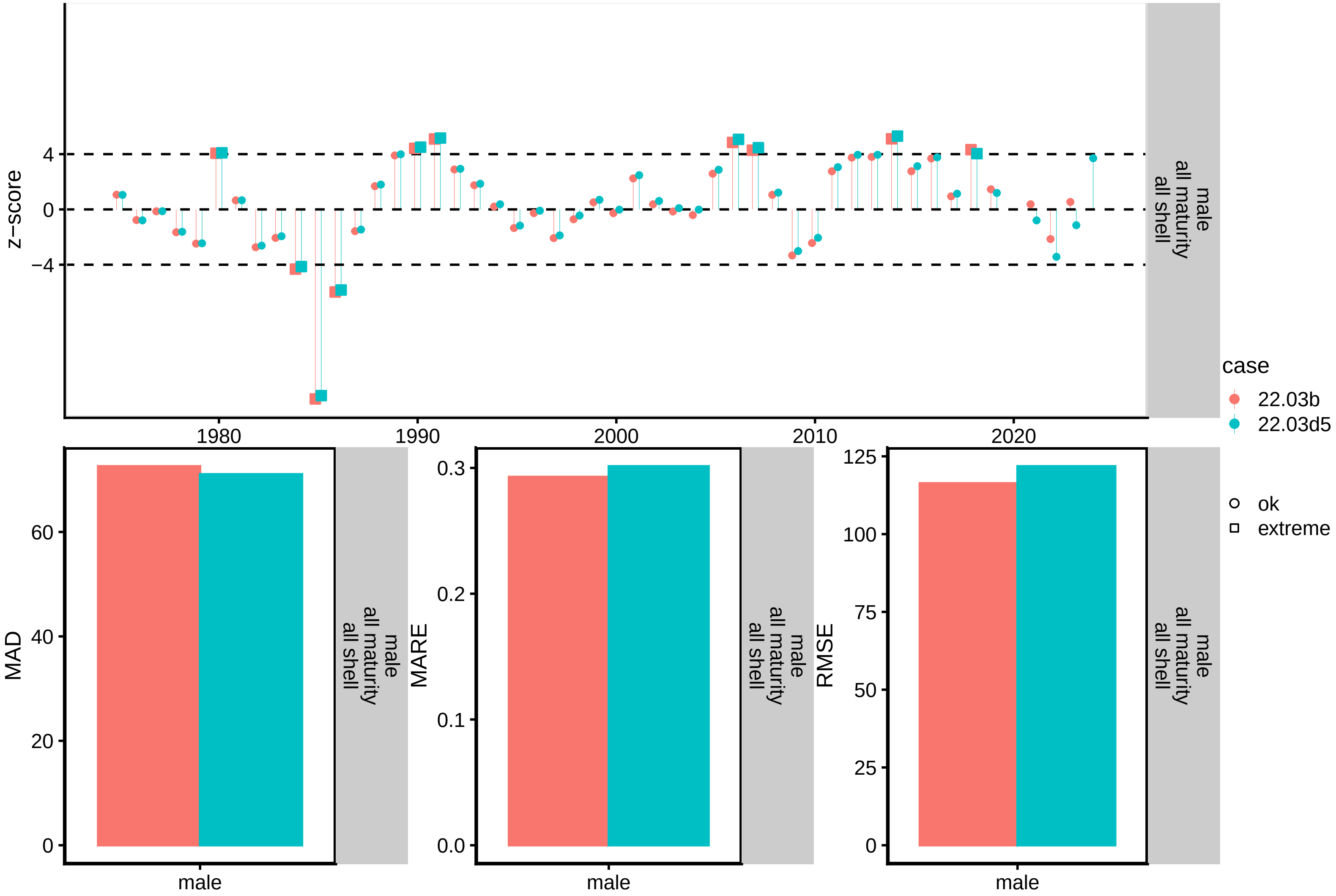

Figure 82. TCSAM02 models residuals analysis by model scenario for fits to male abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

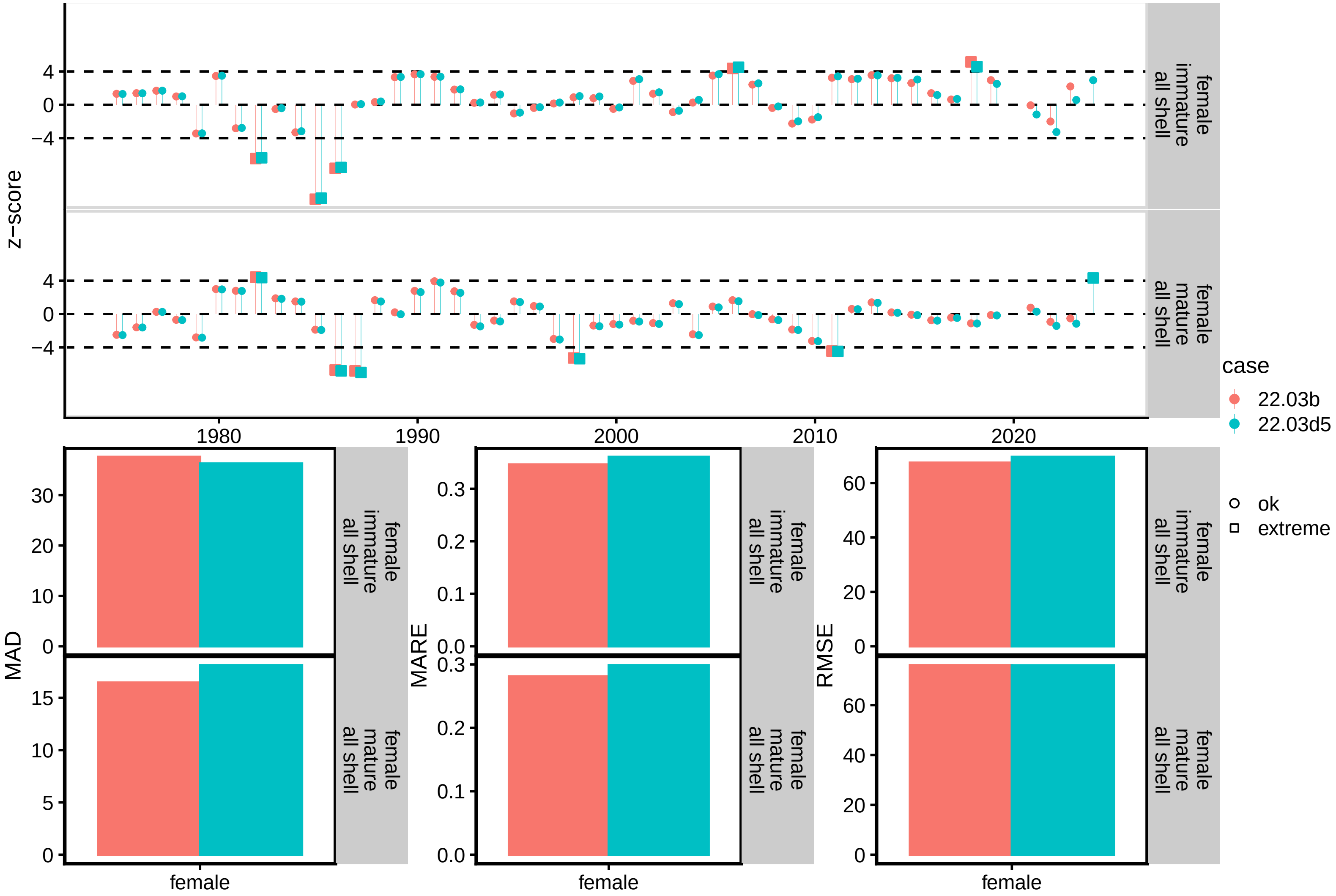

Figure 83. TCSAM02 models residuals analysis by model scenario for fits to female abundance in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

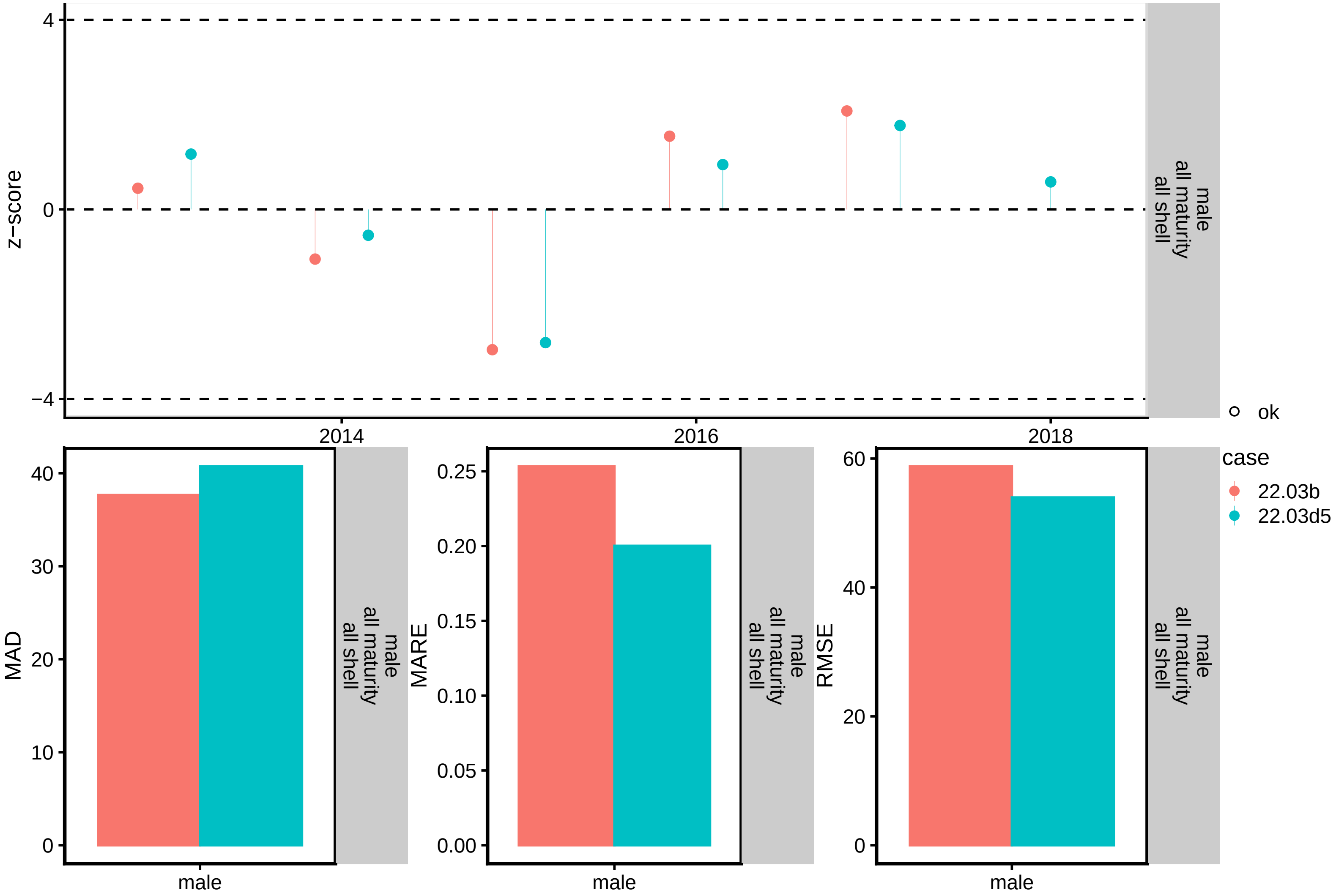

Figure 84. TCSAM02 models residuals analysis by model scenario for fits to male abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

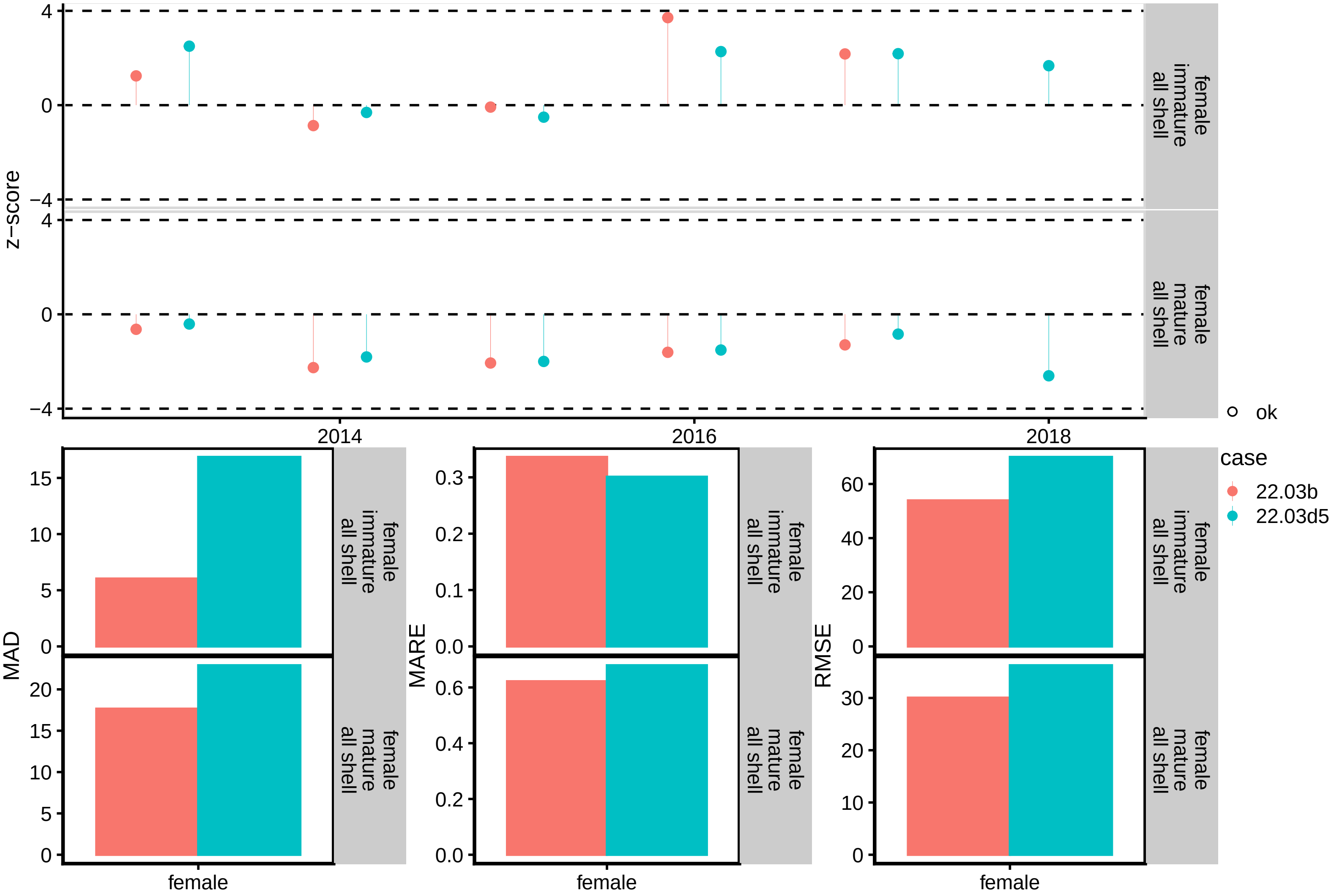

Figure 85. TCSAM02 models residuals analysis by model scenario for fits to female abundance in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

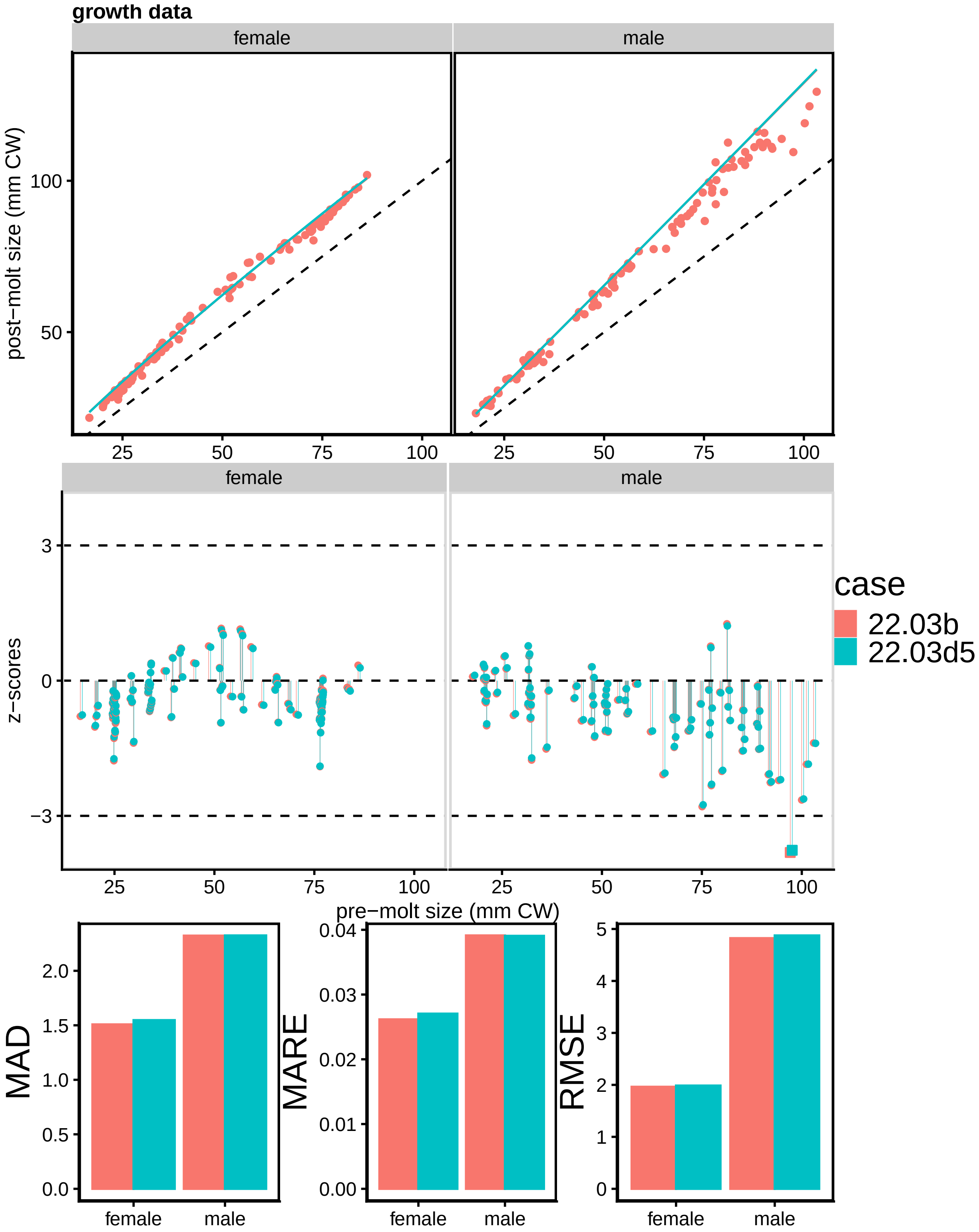

Figure 86. TCSAM02 models fits and residuals analysis by model scenario for fits to molt increment data. Upper row: fits to data; center row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

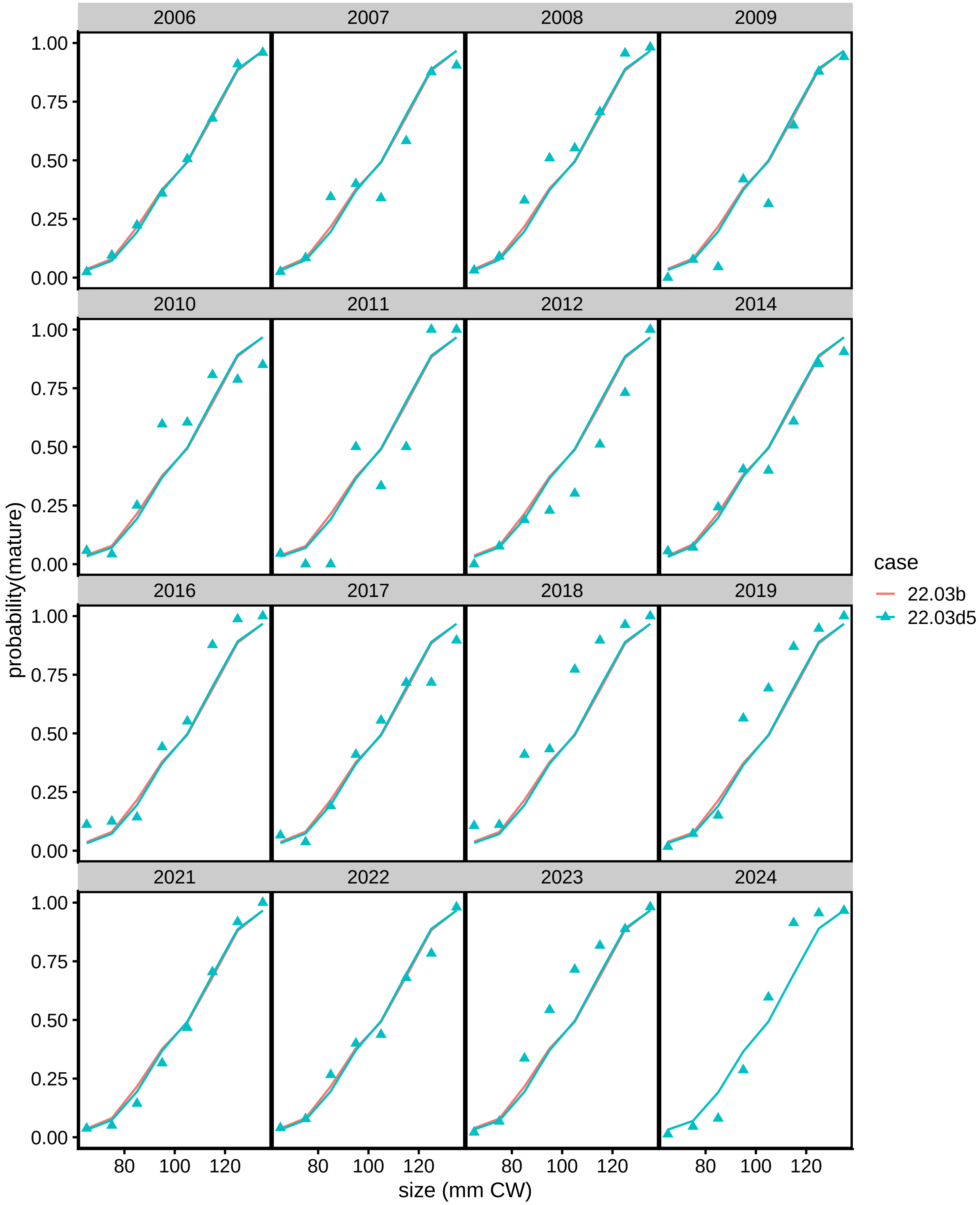

Figure 87. TCSAM02 models fits to maturity ogive data by model scenario and year.

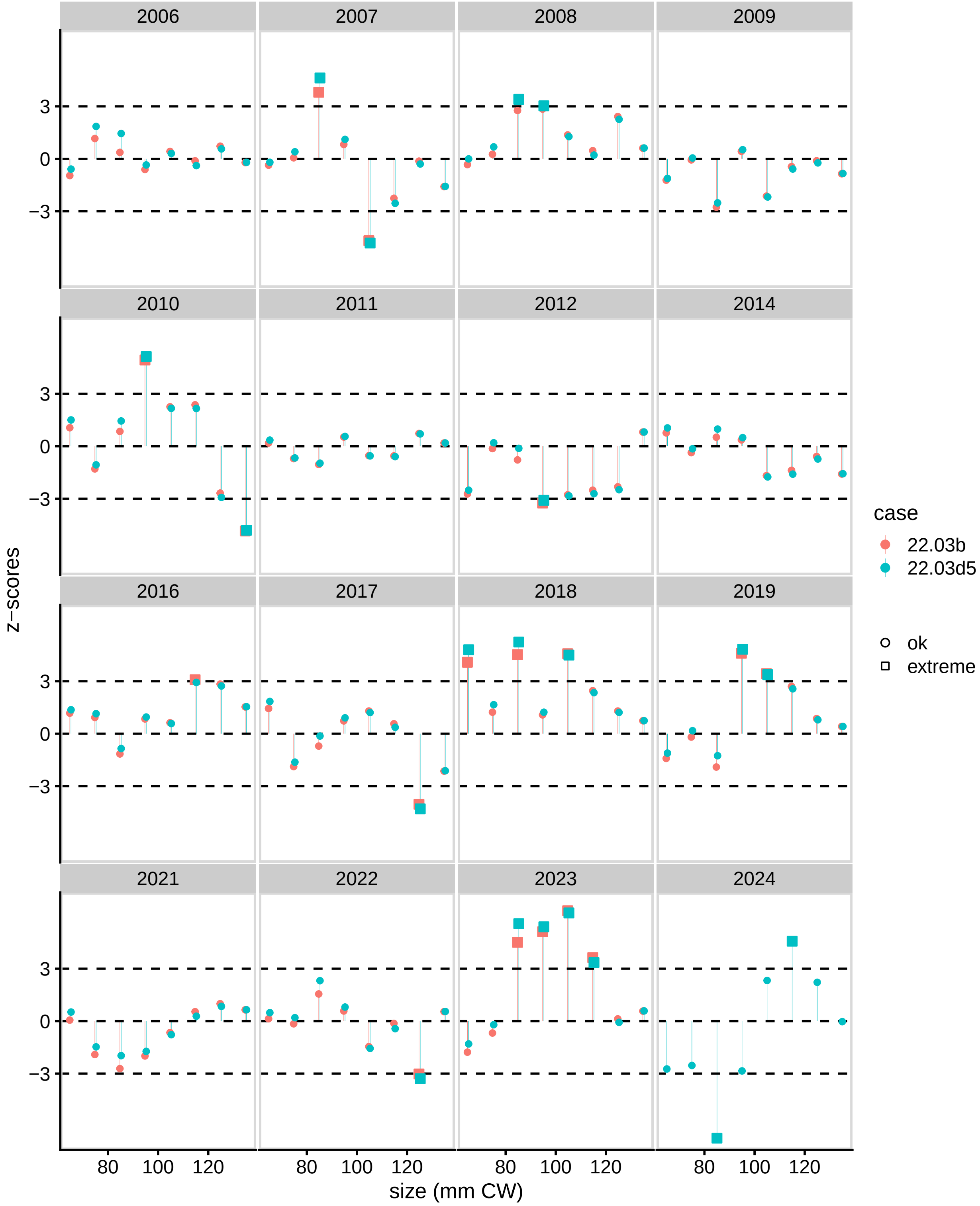

Figure 88. TCSAM02 models residuals analysis for maturity ogive data, by model scenario and year.

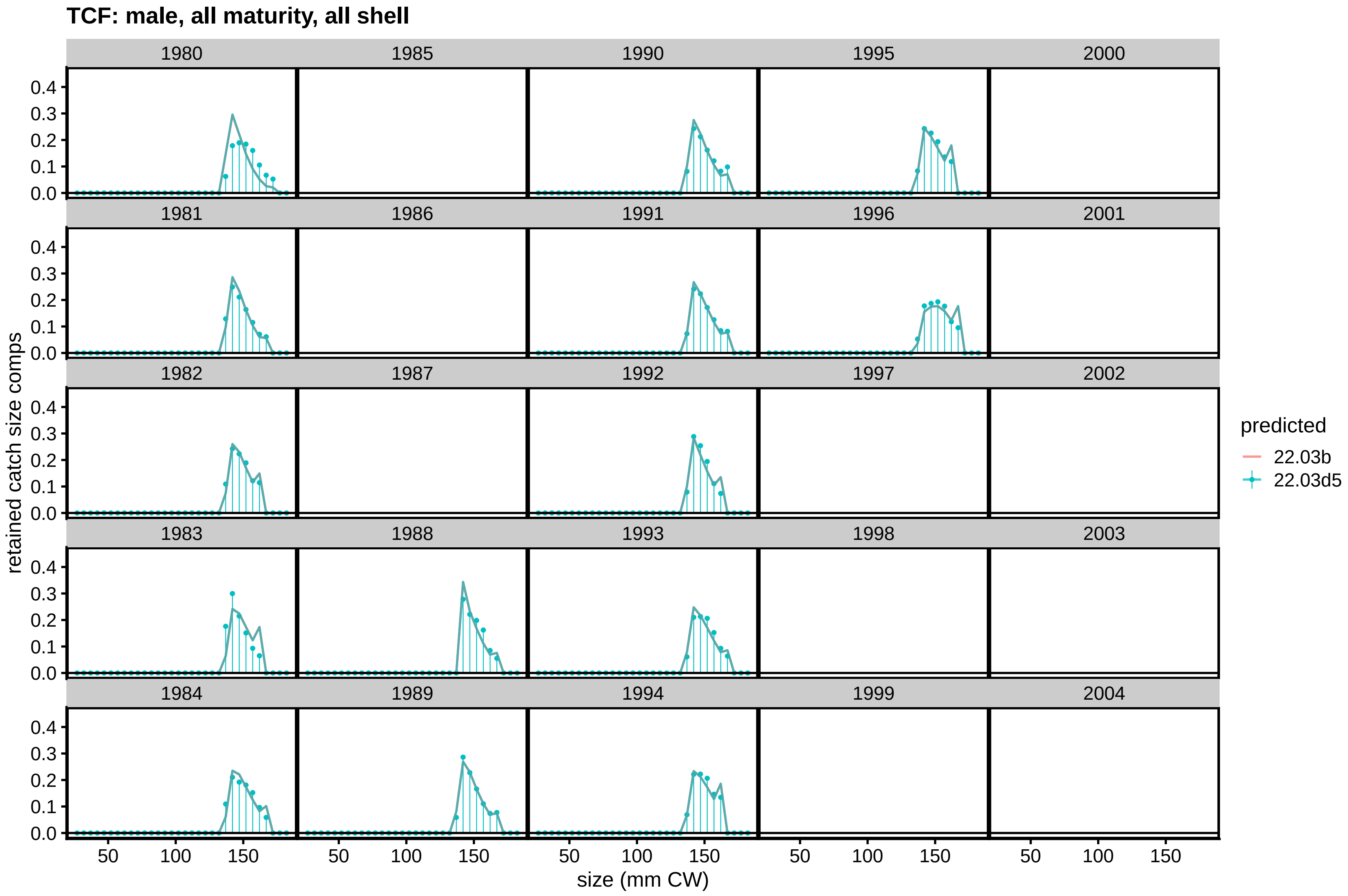

Figure 89. TCSAM02 models fits to retained catch size compositions in the directed fishery. Preferred model is 22.03d5.

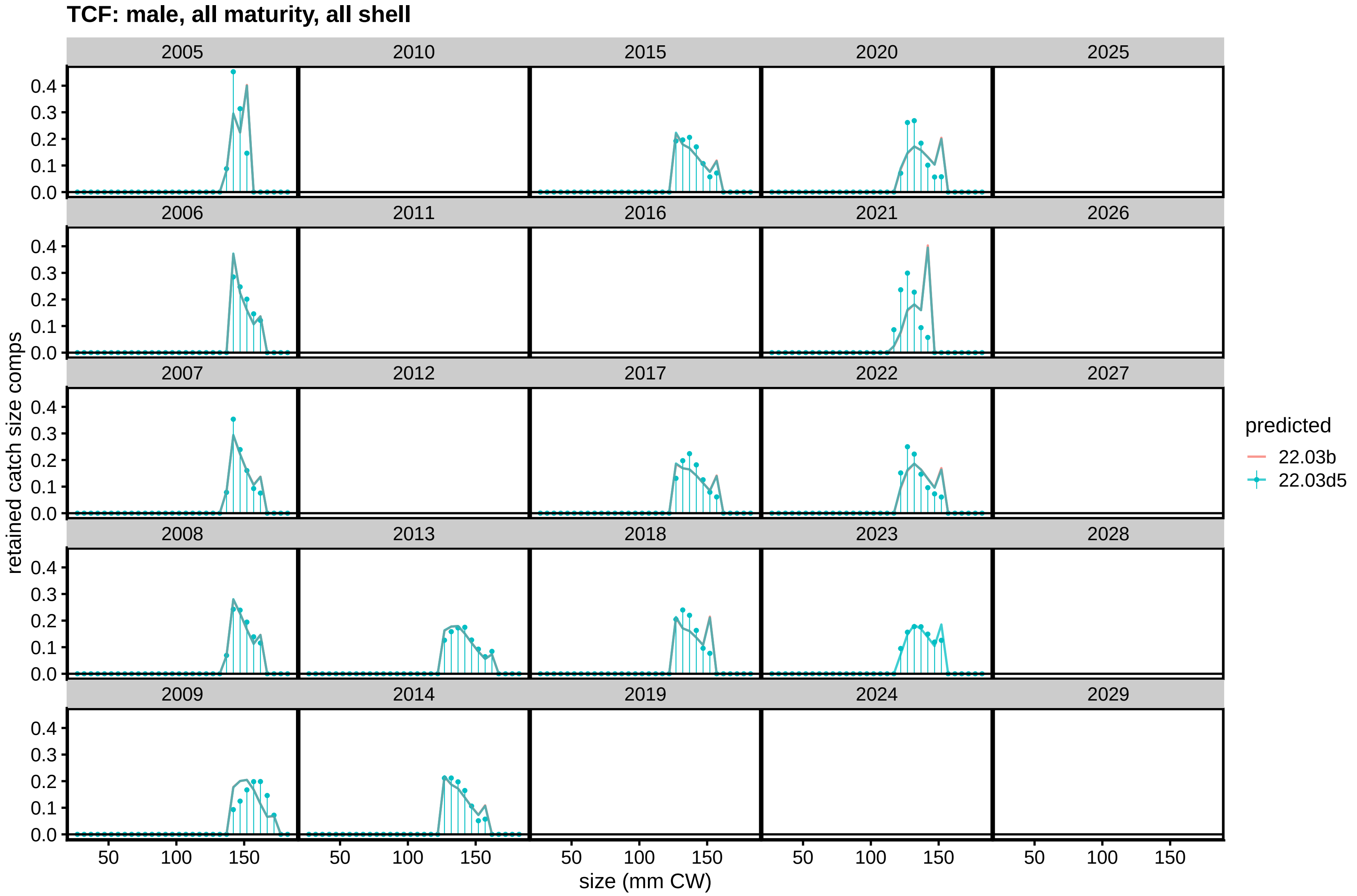

Figure 90. TCSAM02 models fits to retained catch size compositions in the directed fishery. Preferred model is 22.03d5.

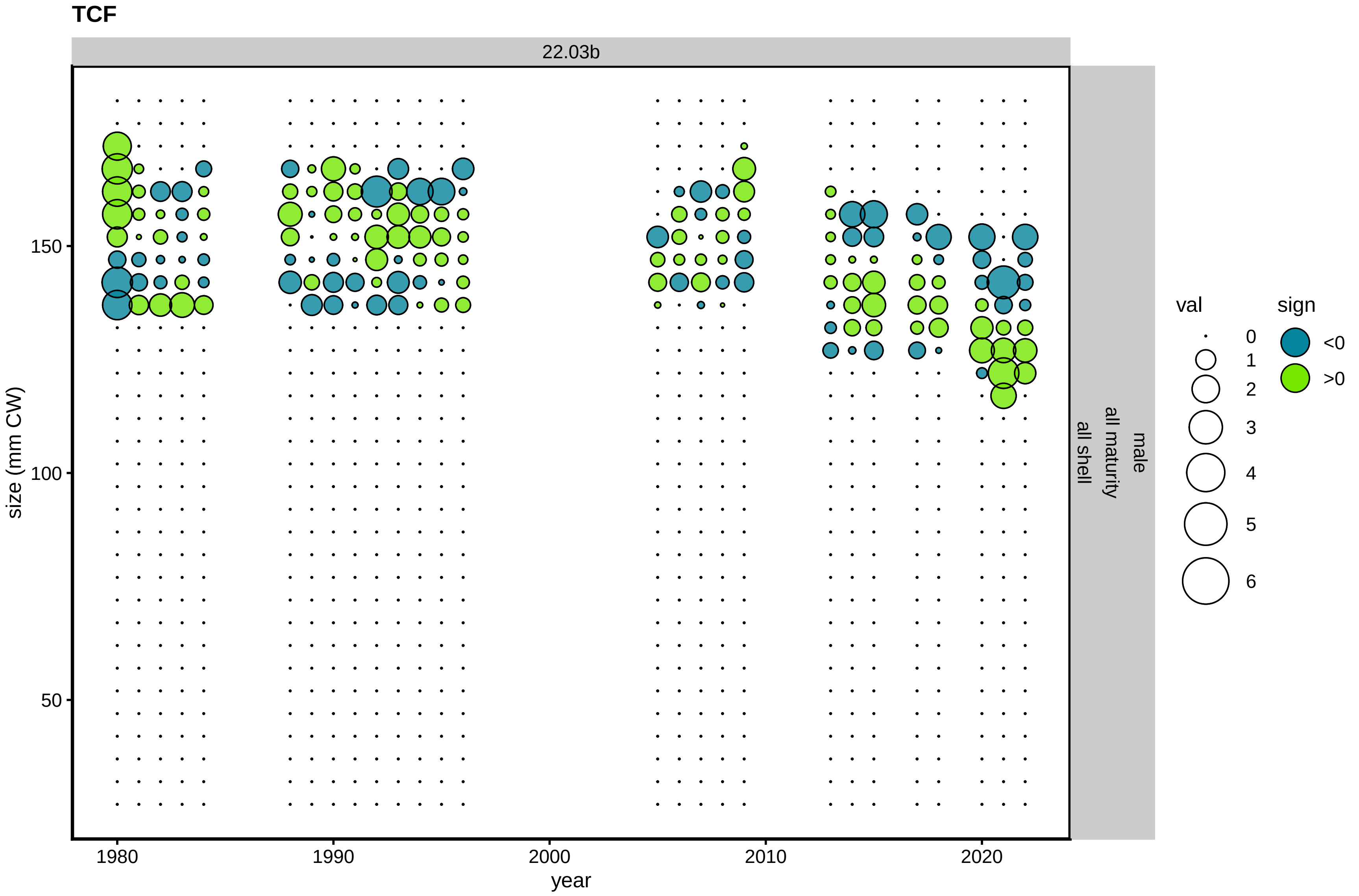

Figure 91. Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

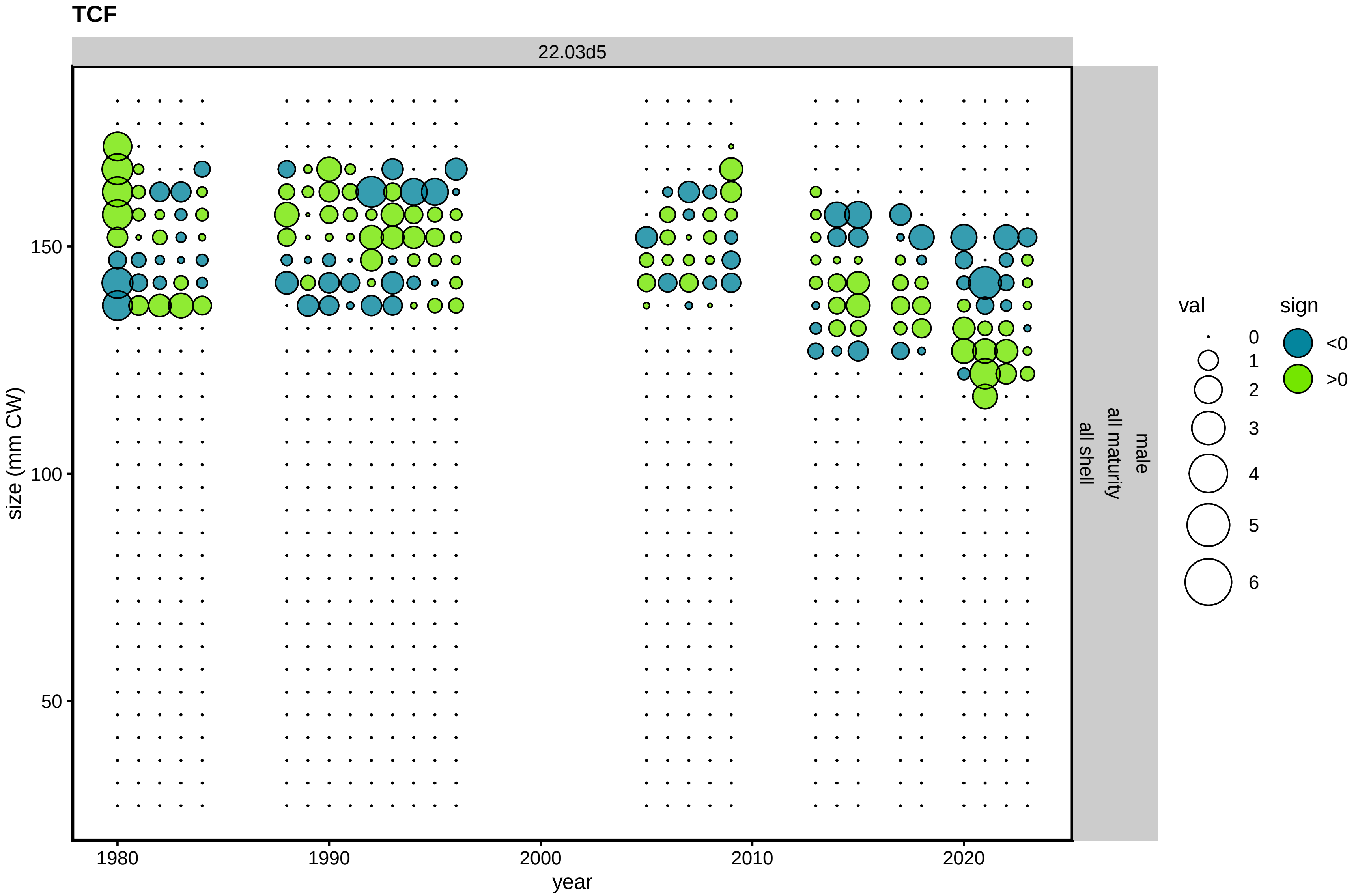

Figure 92. Pearson's residuals for fits to retained catch size composition data. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

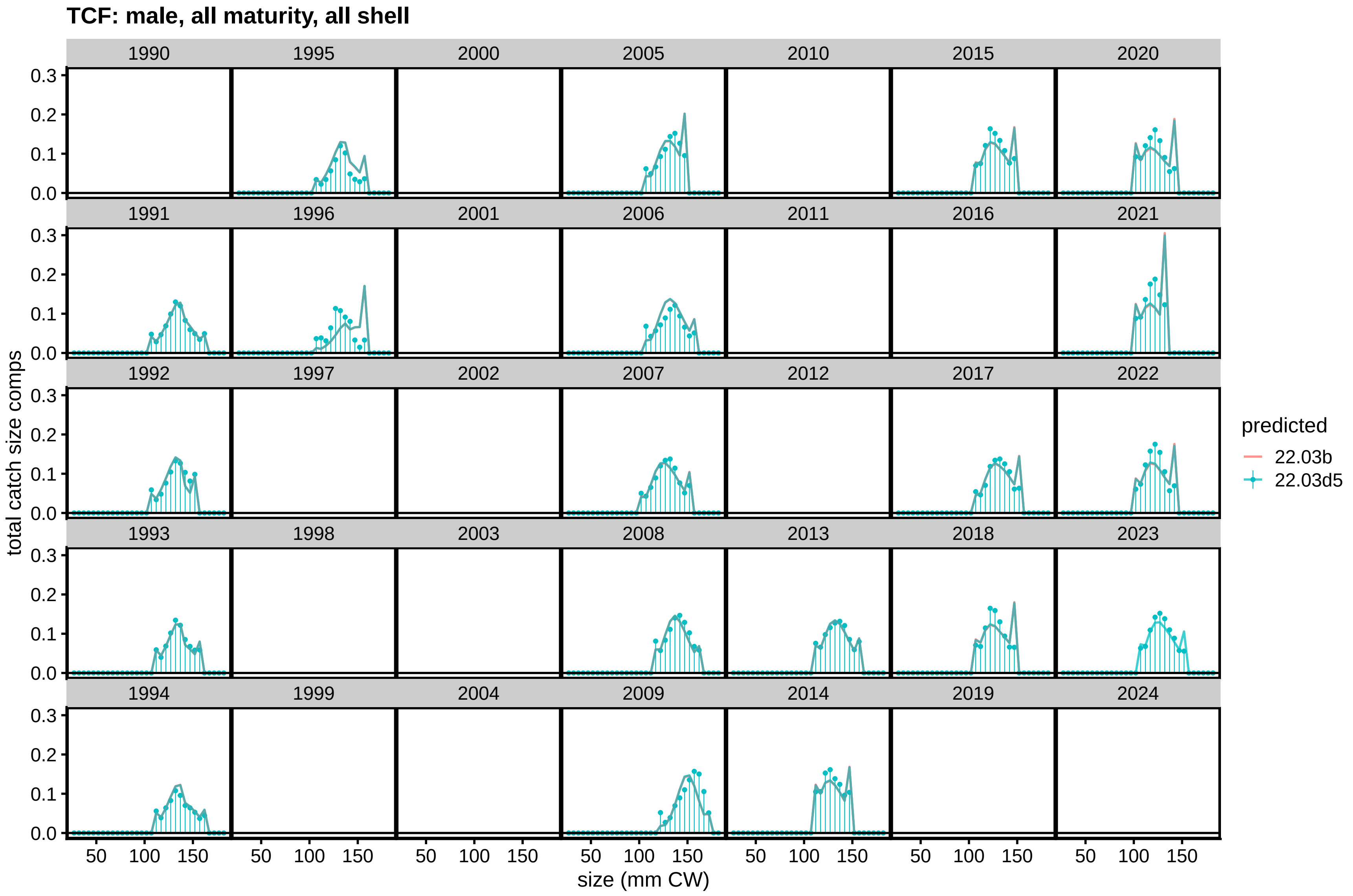

Figure 93. TCSAM02 models fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03d5.

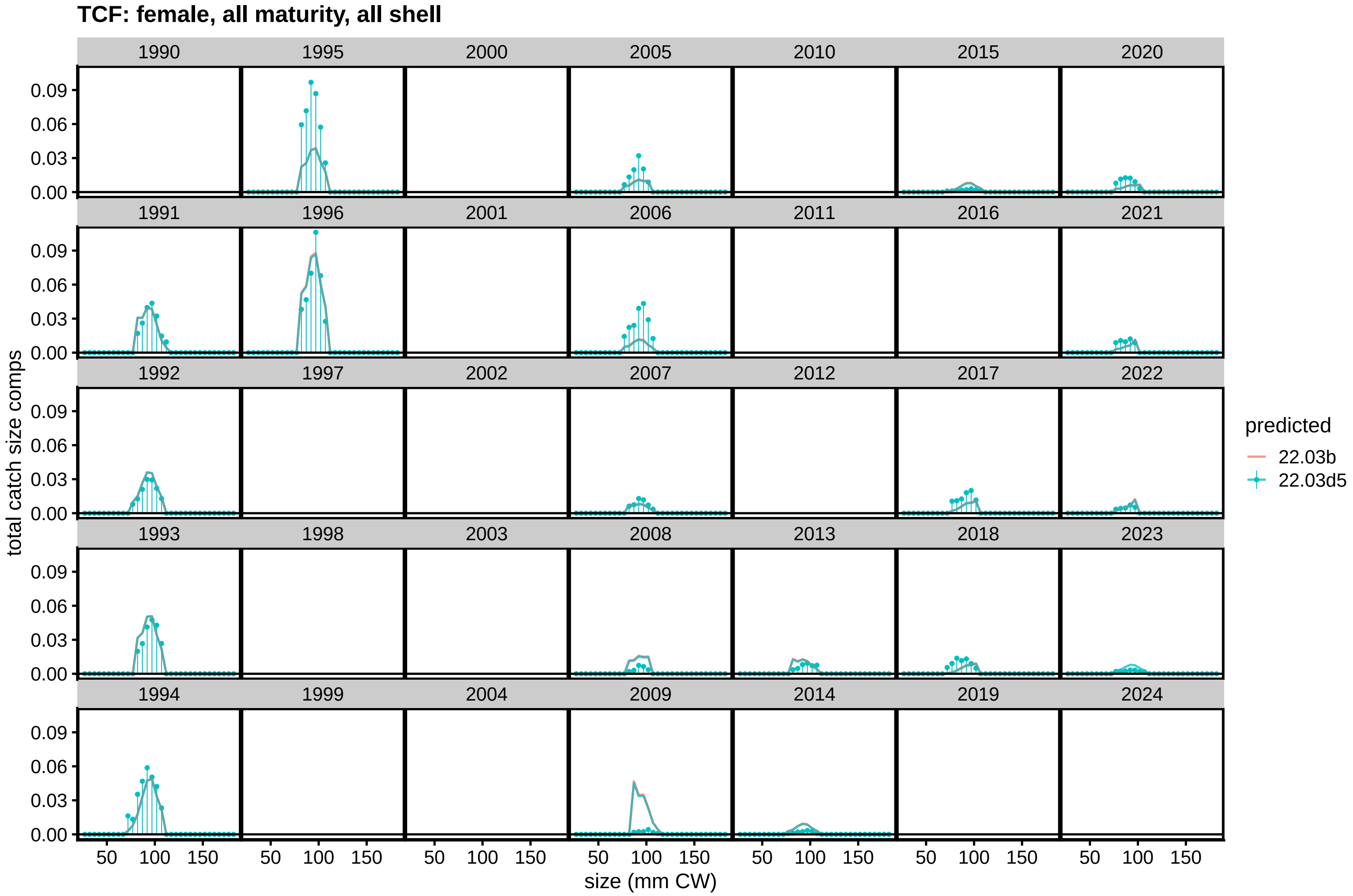

Figure 94. TCSAM02 models fits to total catch size compostiions in the TCF fishery. Preferred model is 22.03d5.

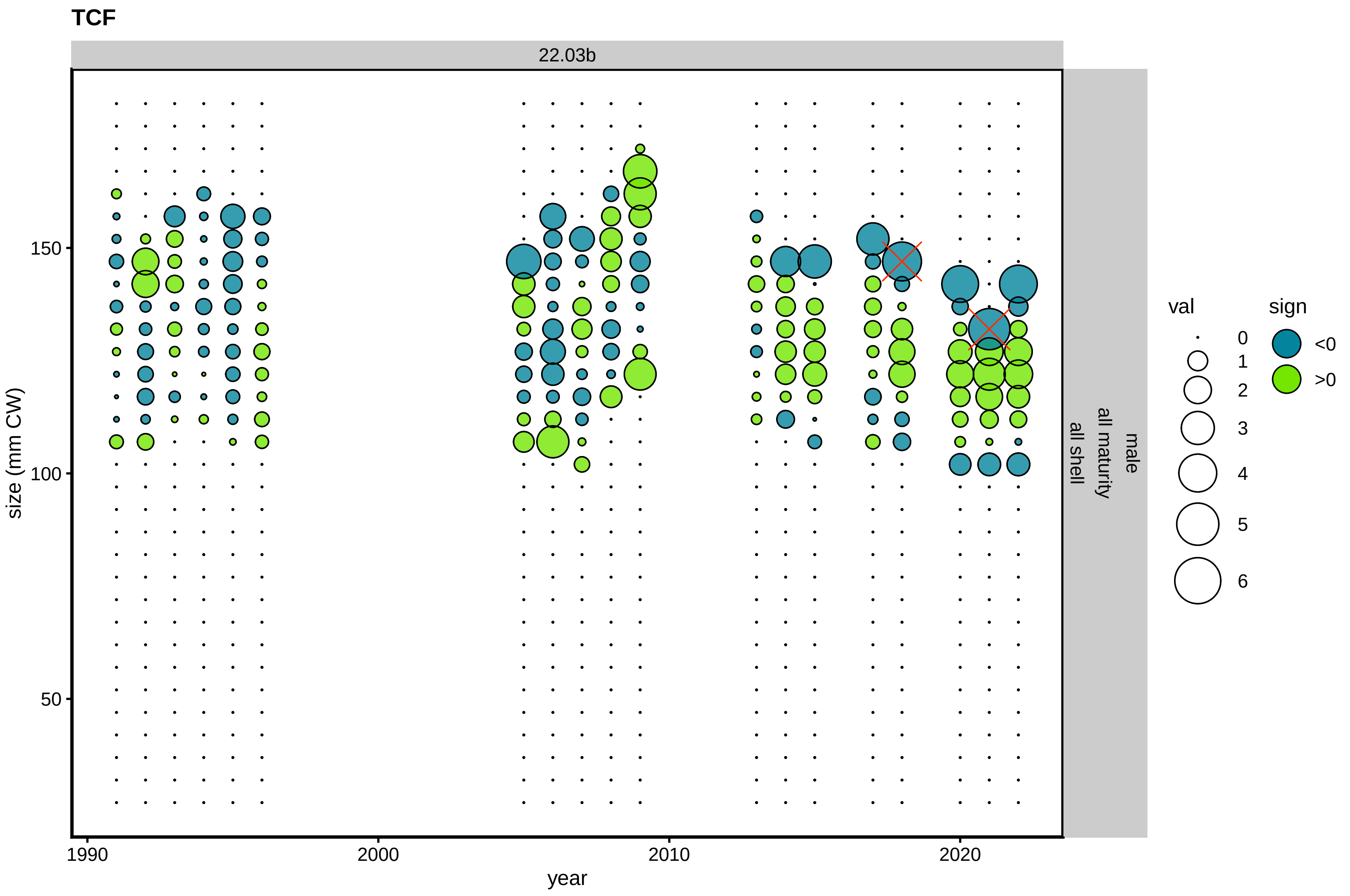

Figure 95. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

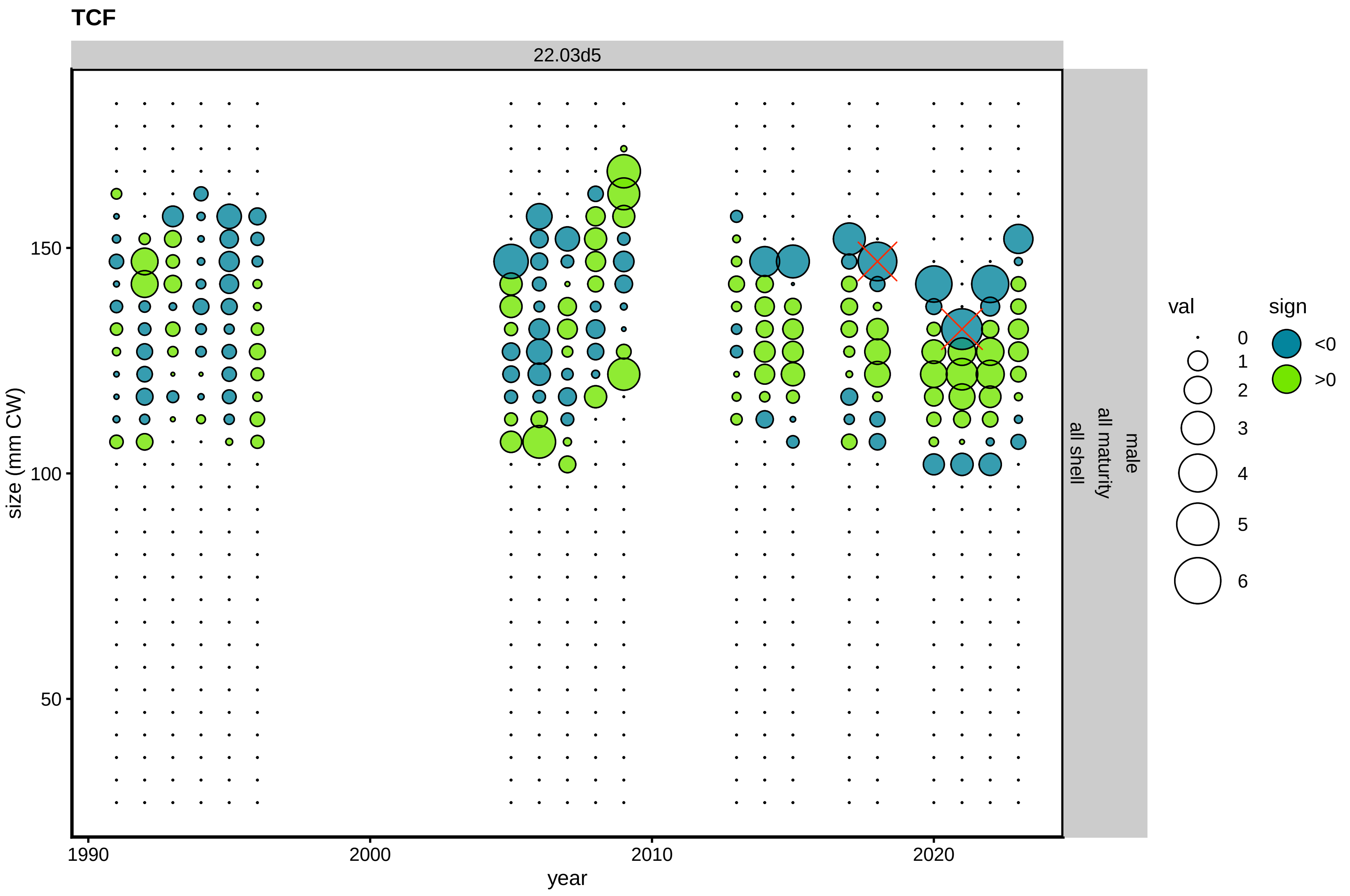

Figure 96. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

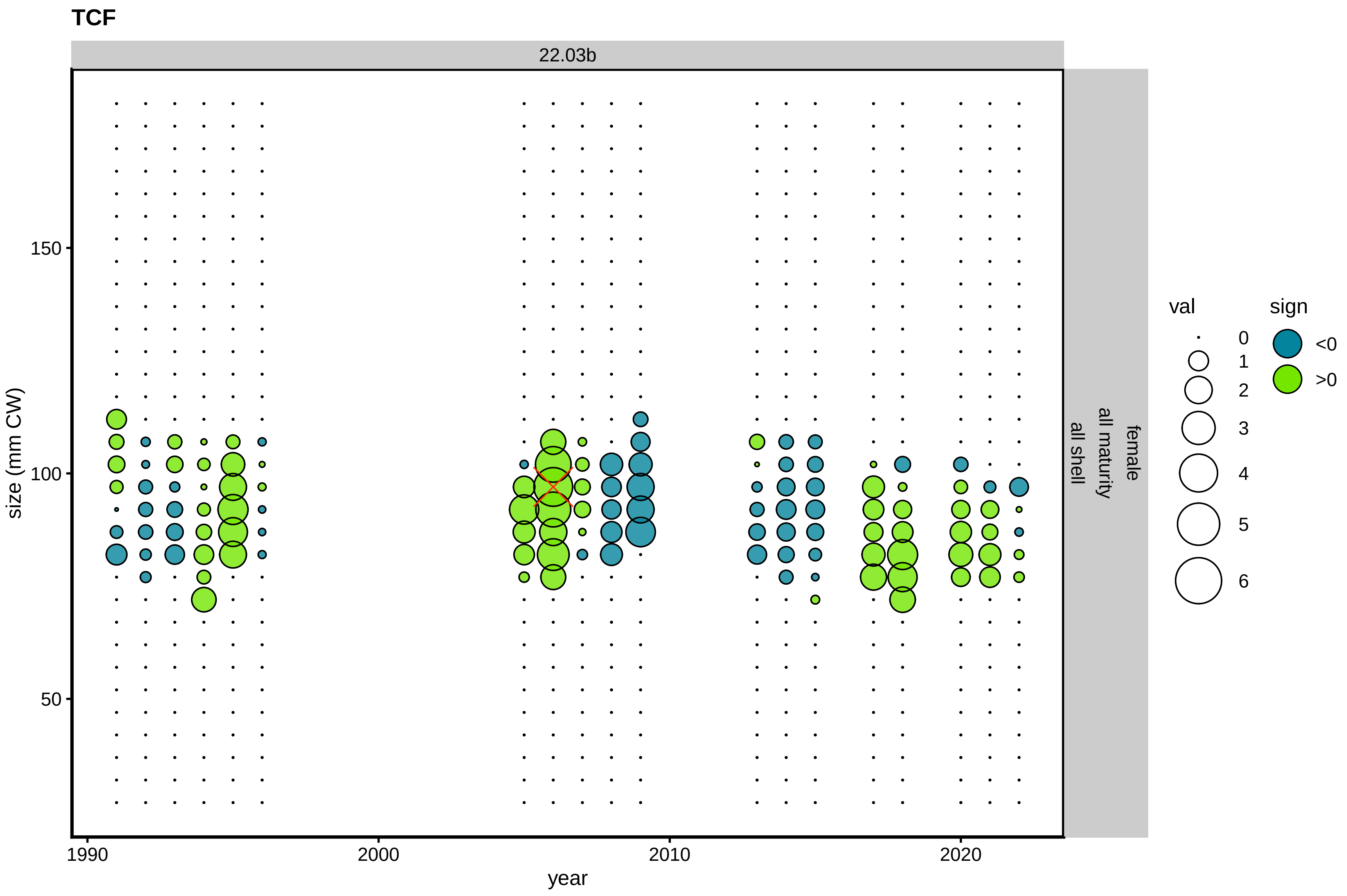

Figure 97. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

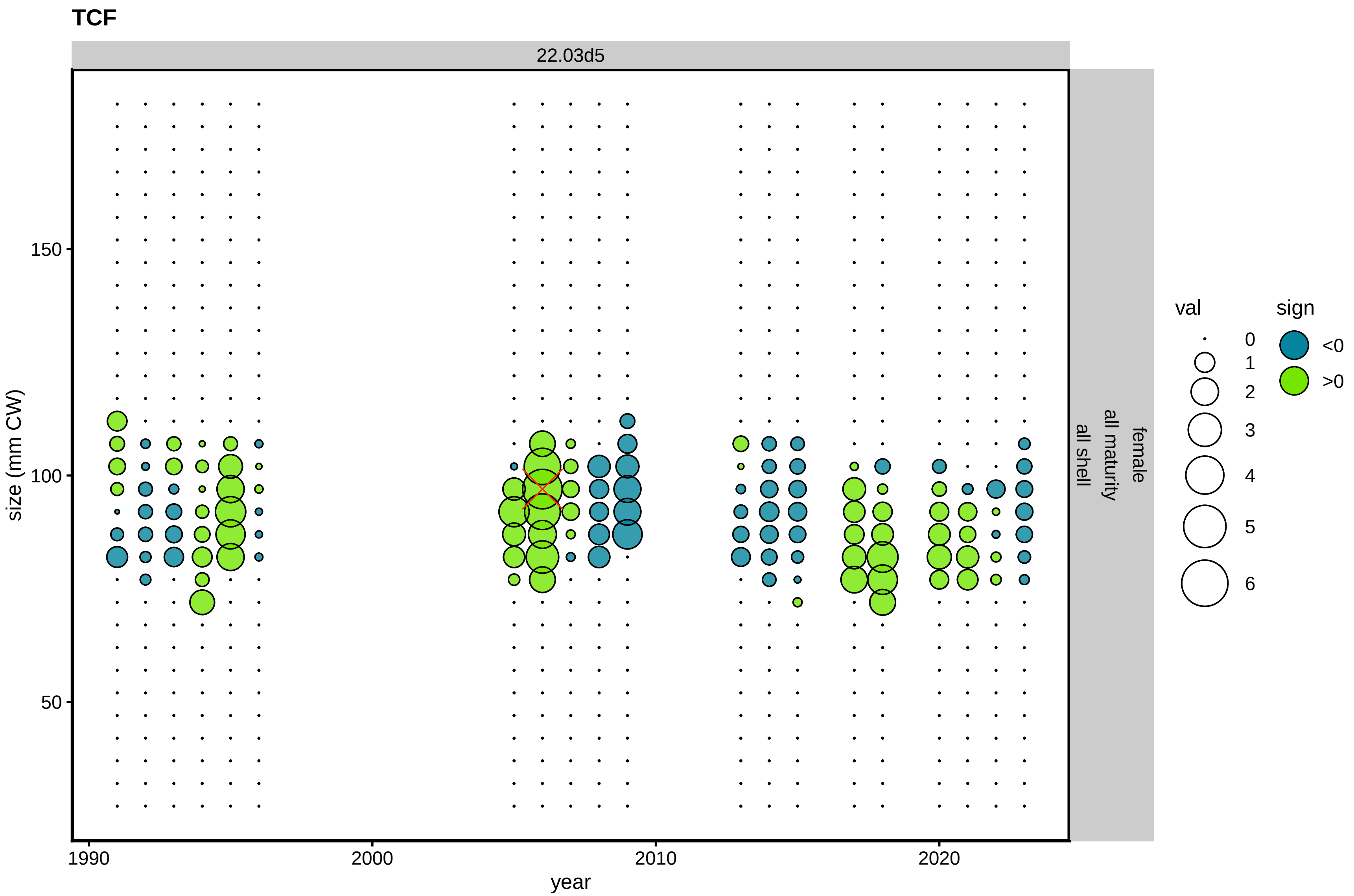

Figure 98. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

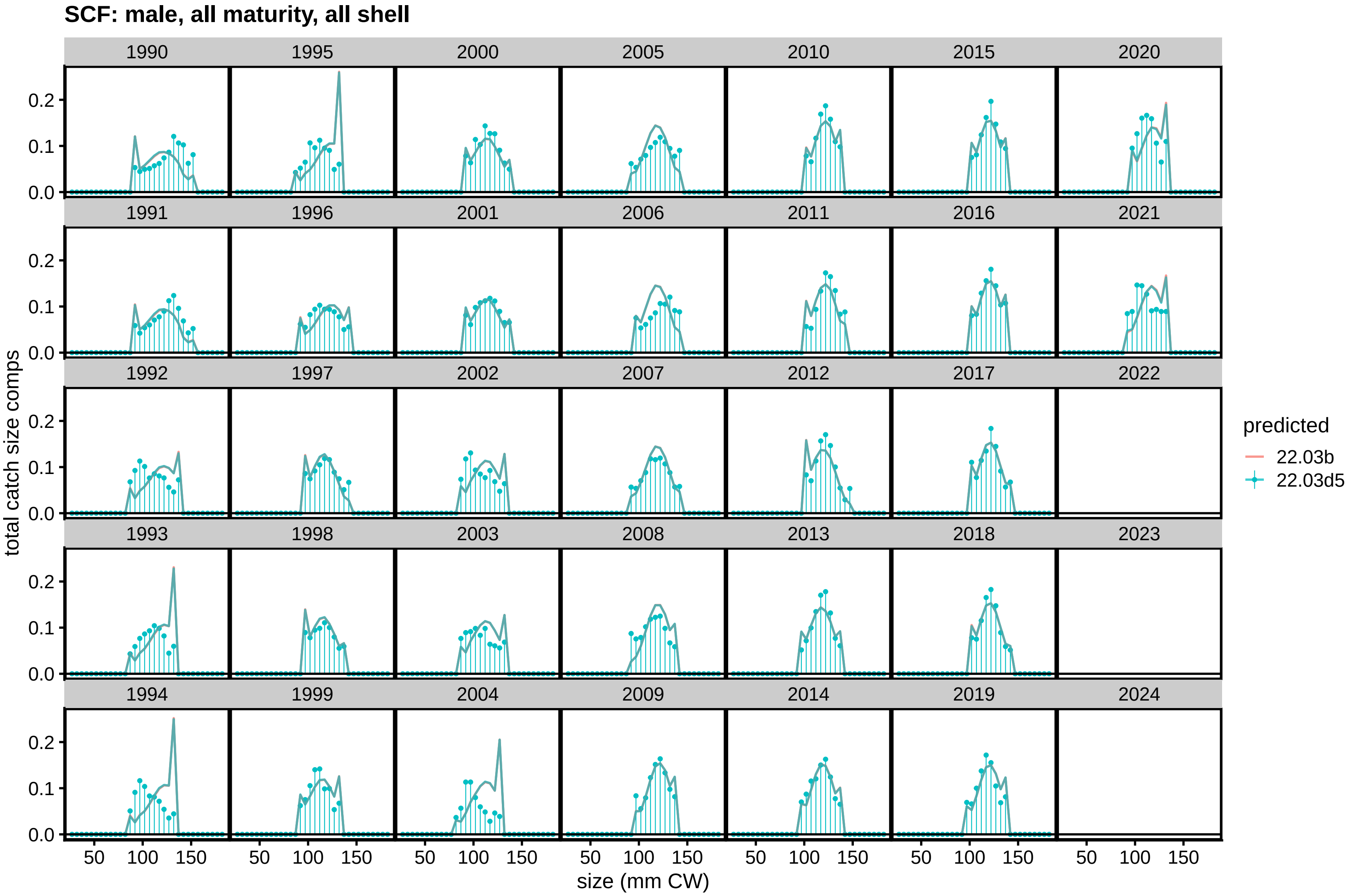

Figure 99. TCSAM02 models fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03d5.

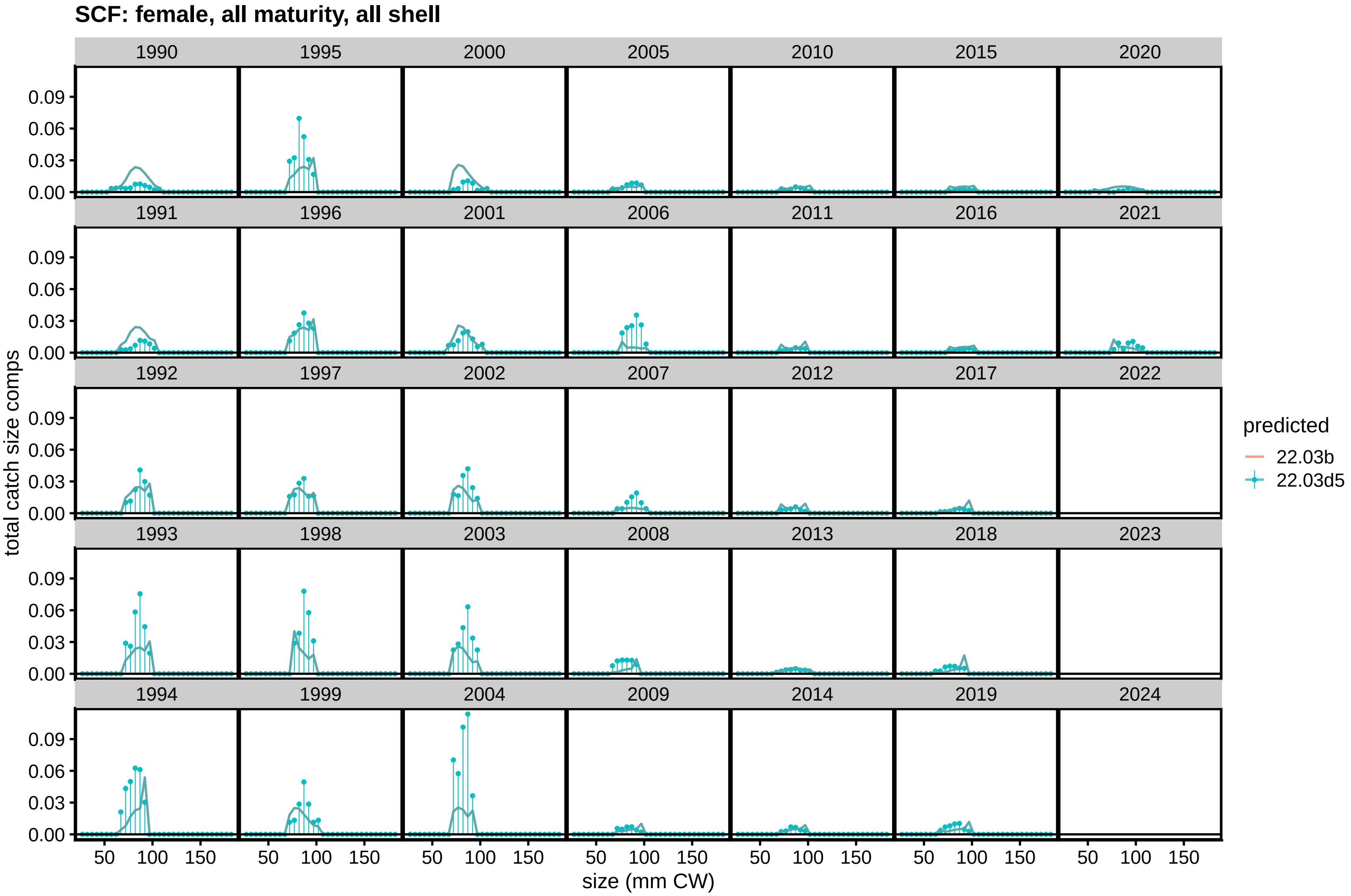

Figure 100. TCSAM02 models fits to total catch size compostiions in the SCF fishery. Preferred model is 22.03d5.

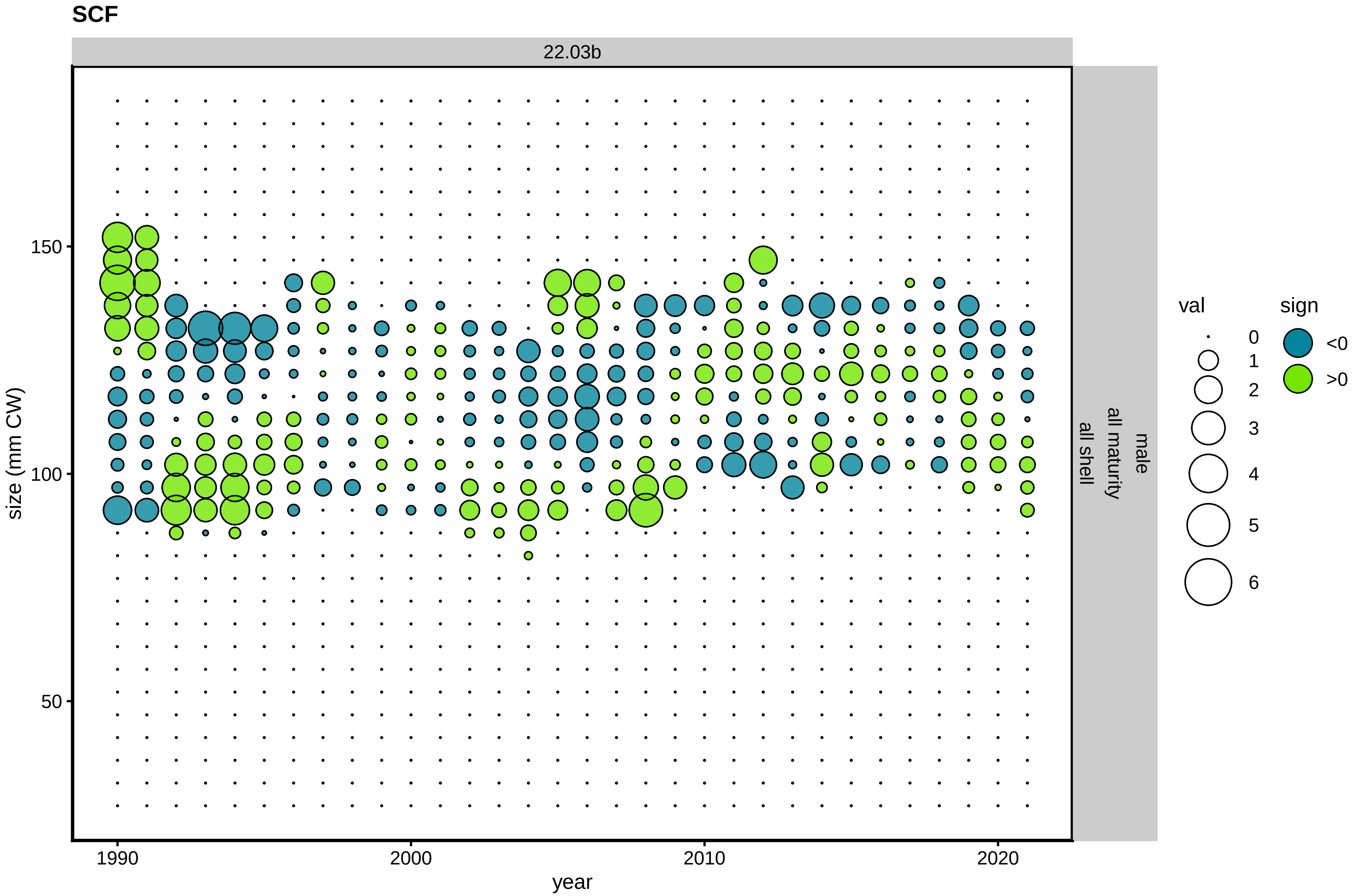

Figure 101. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

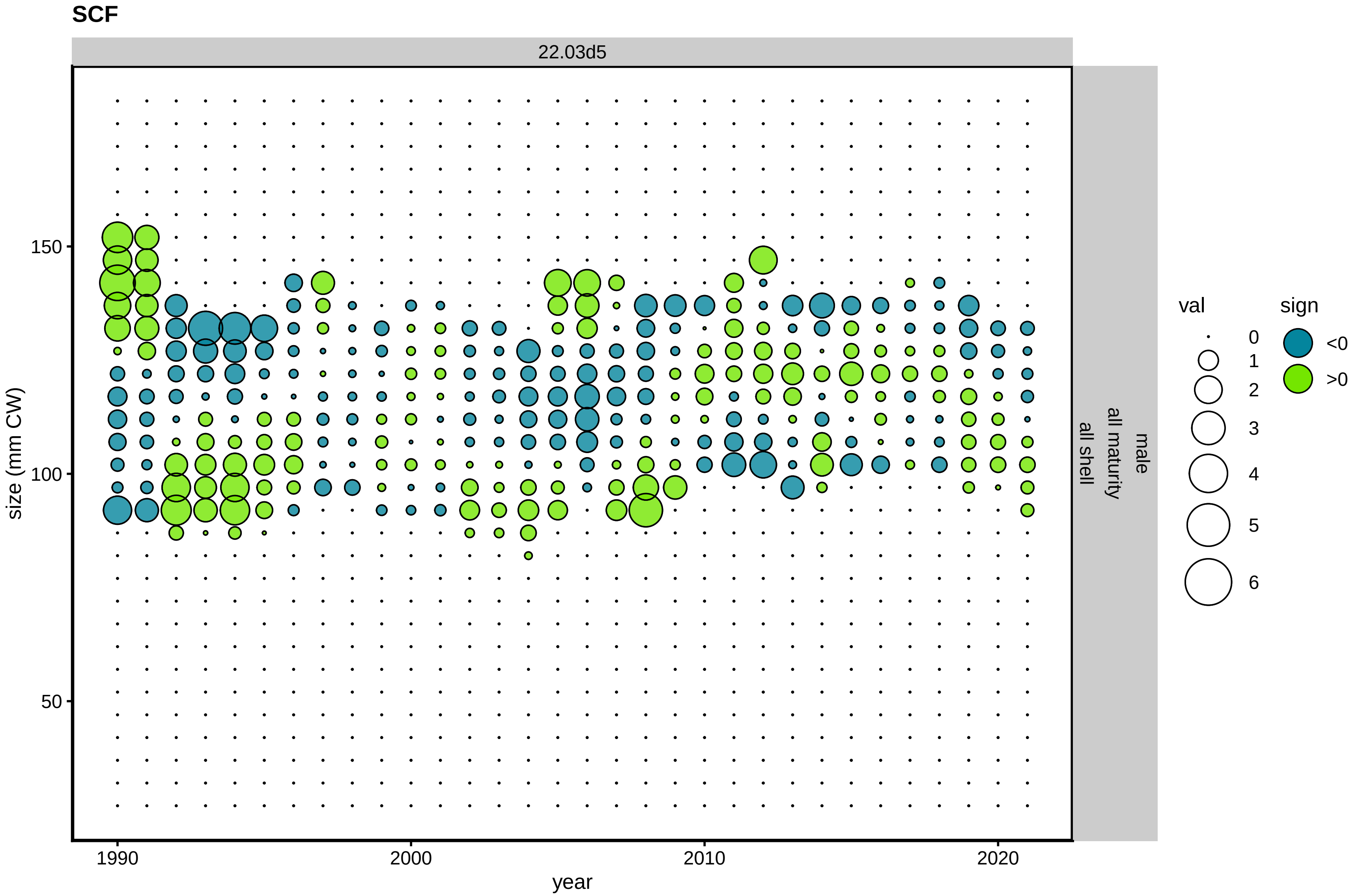

Figure 102. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

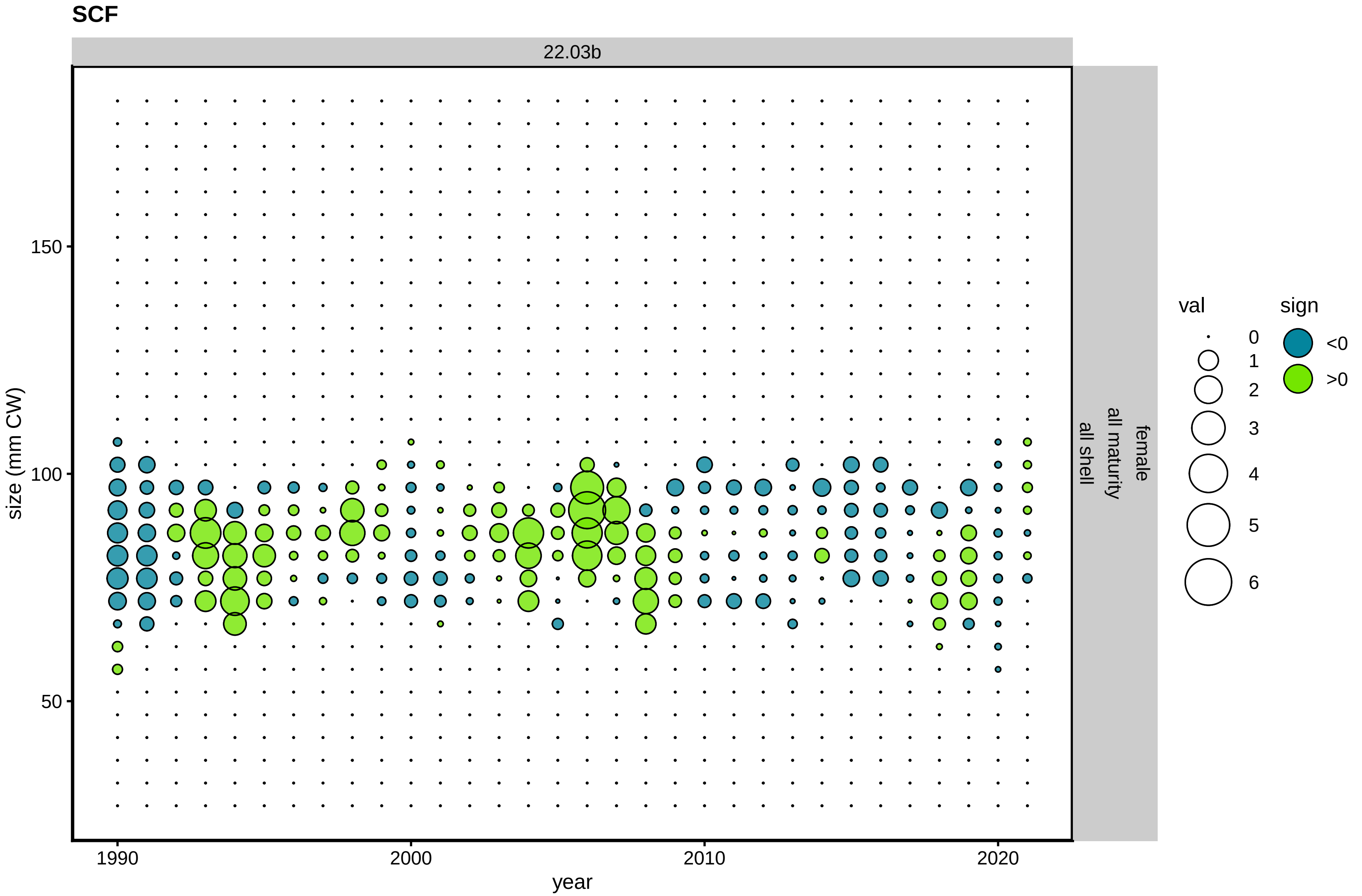

Figure 103. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

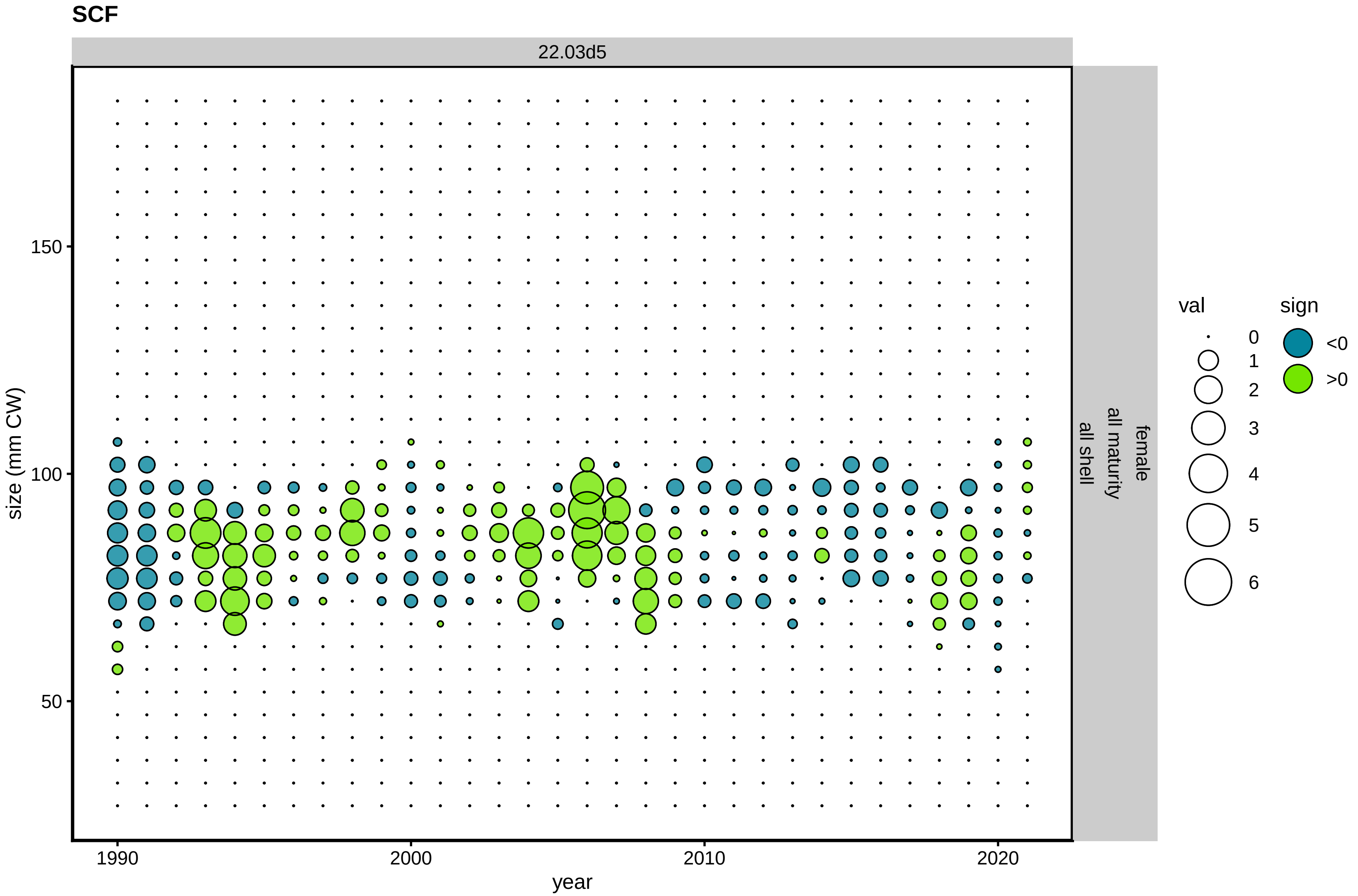

Figure 104. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

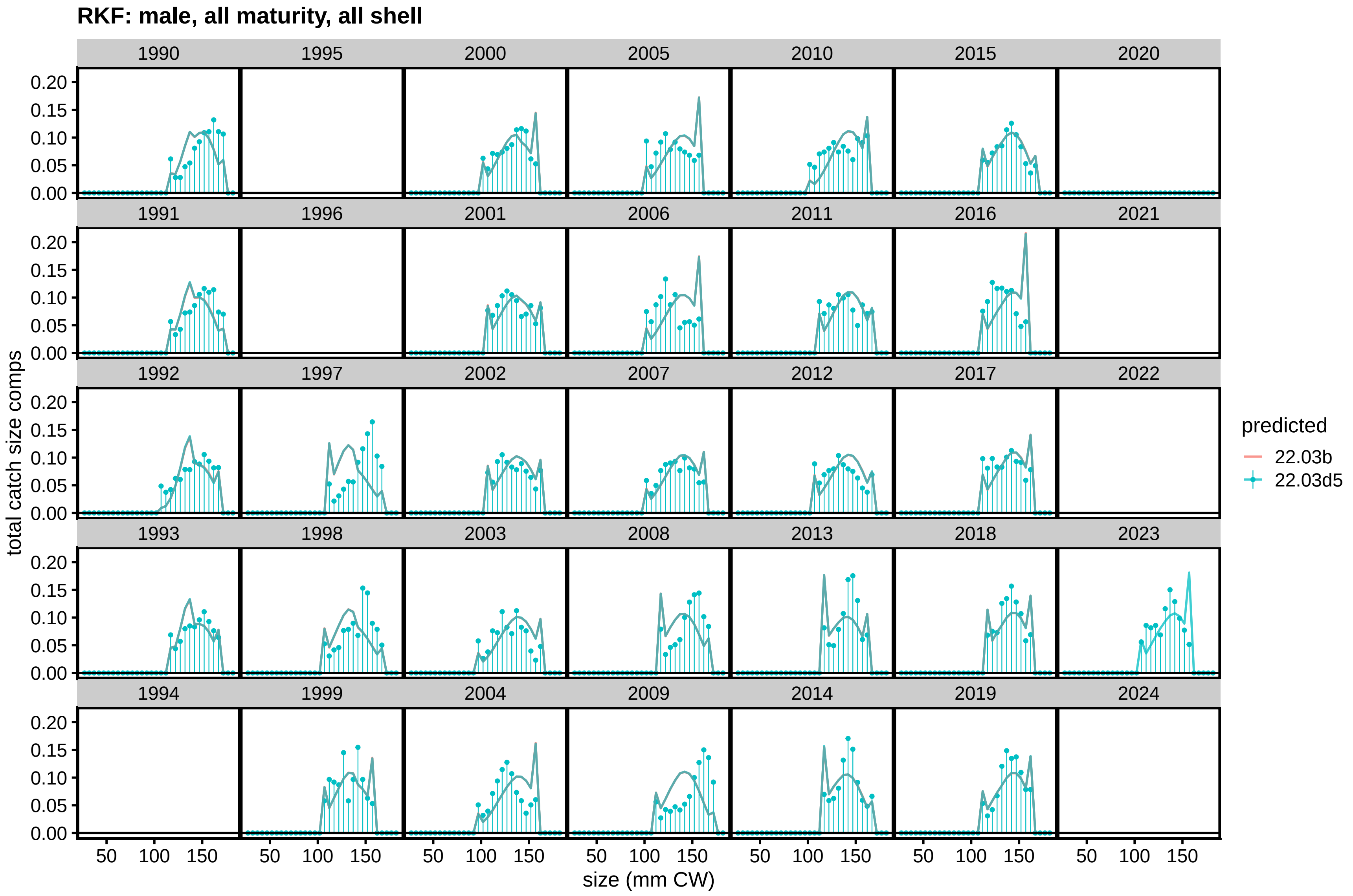

Figure 105. TCSAM02 models fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03d5.

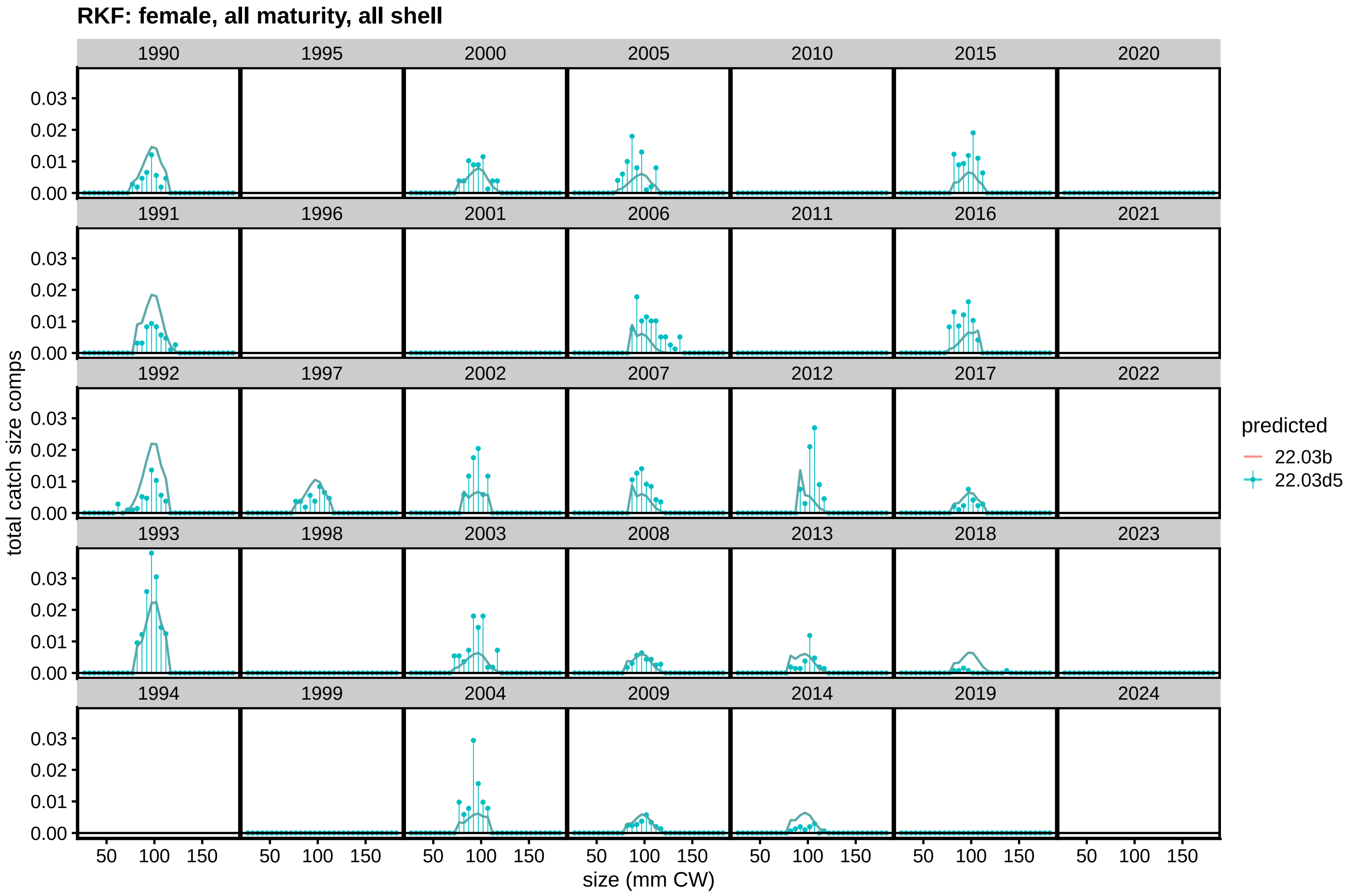

Figure 106. TCSAM02 models fits to total catch size compostiions in the RKF fishery. Preferred model is 22.03d5.

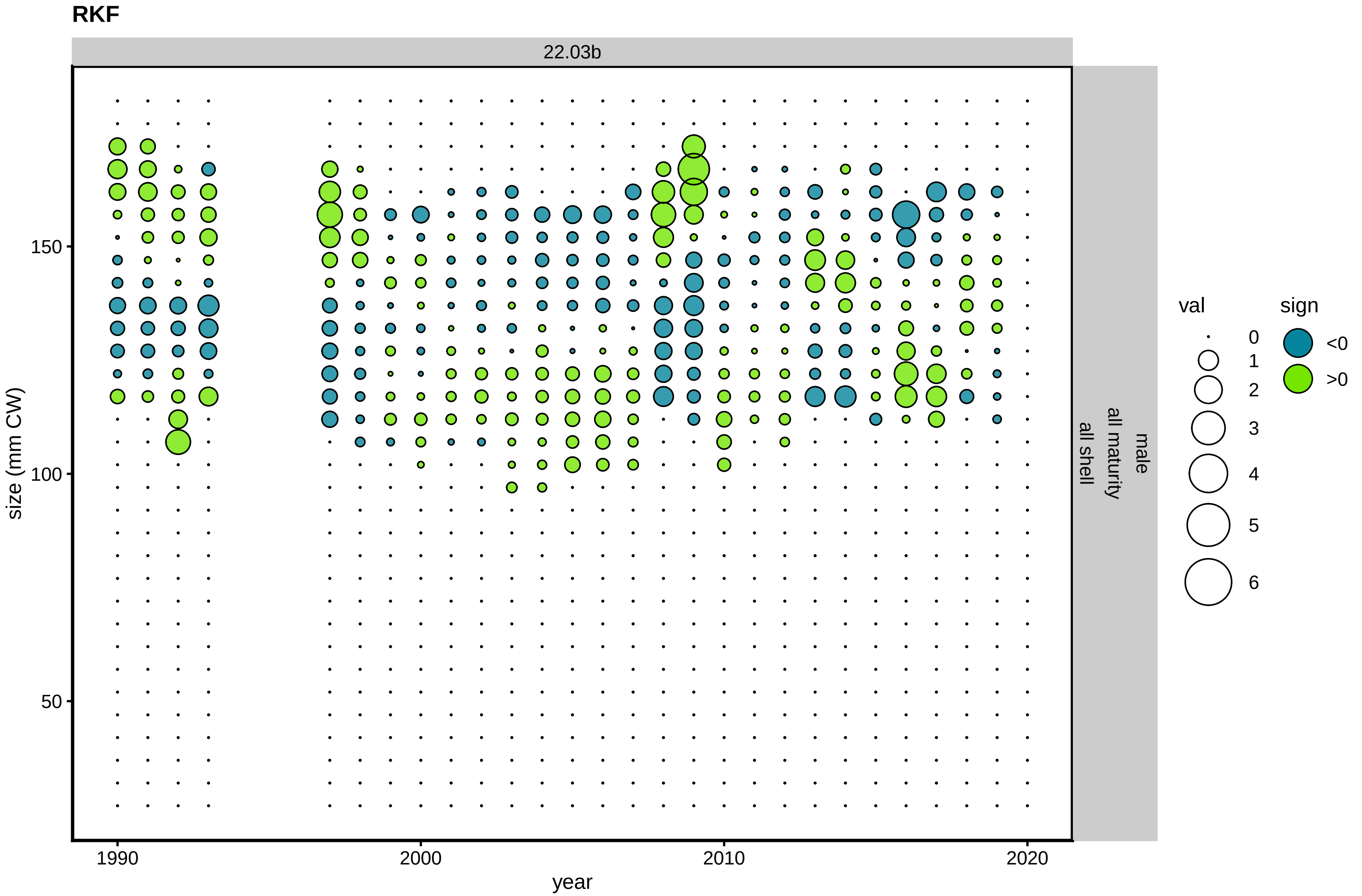

Figure 107. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

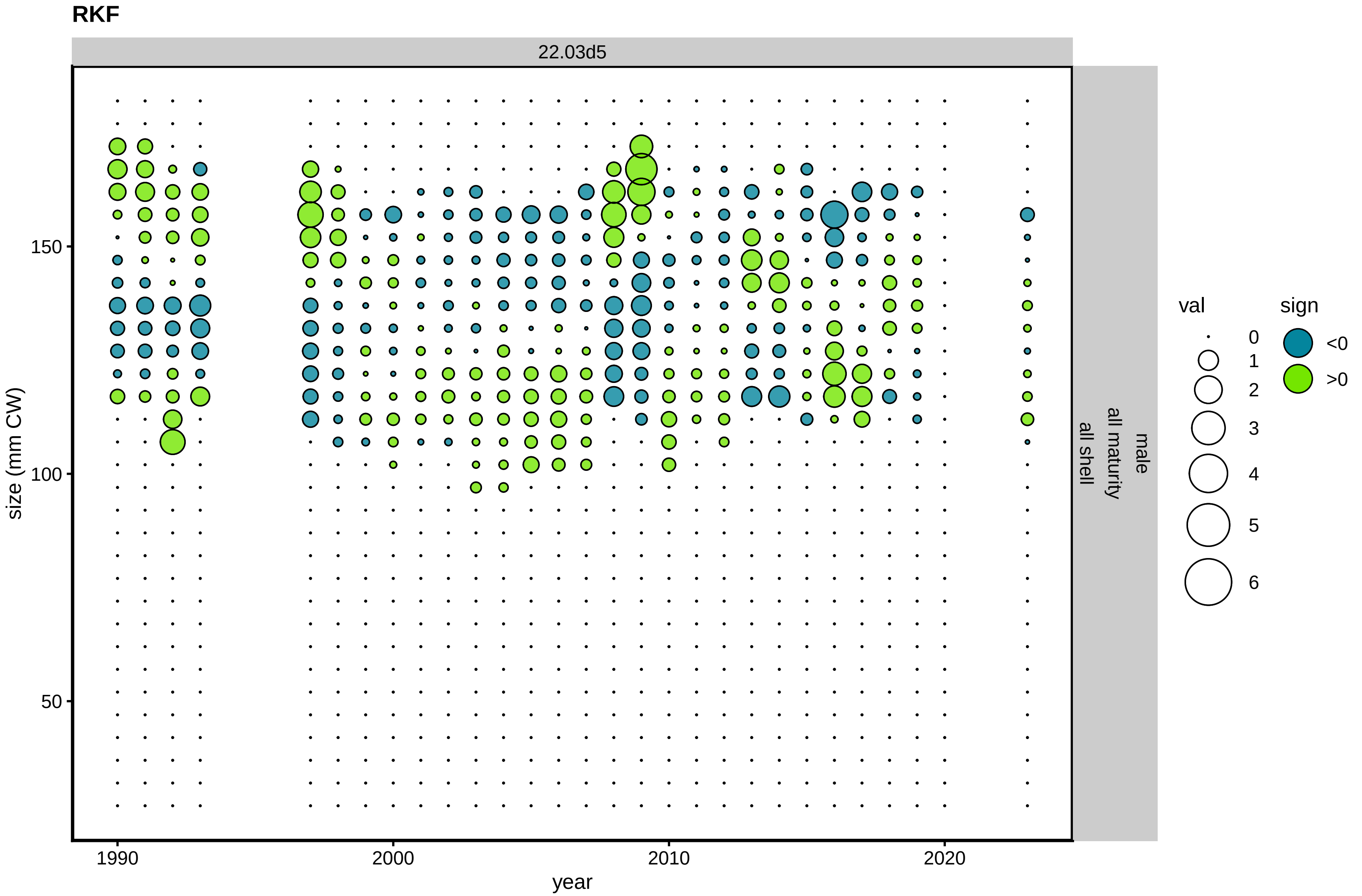

Figure 108. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

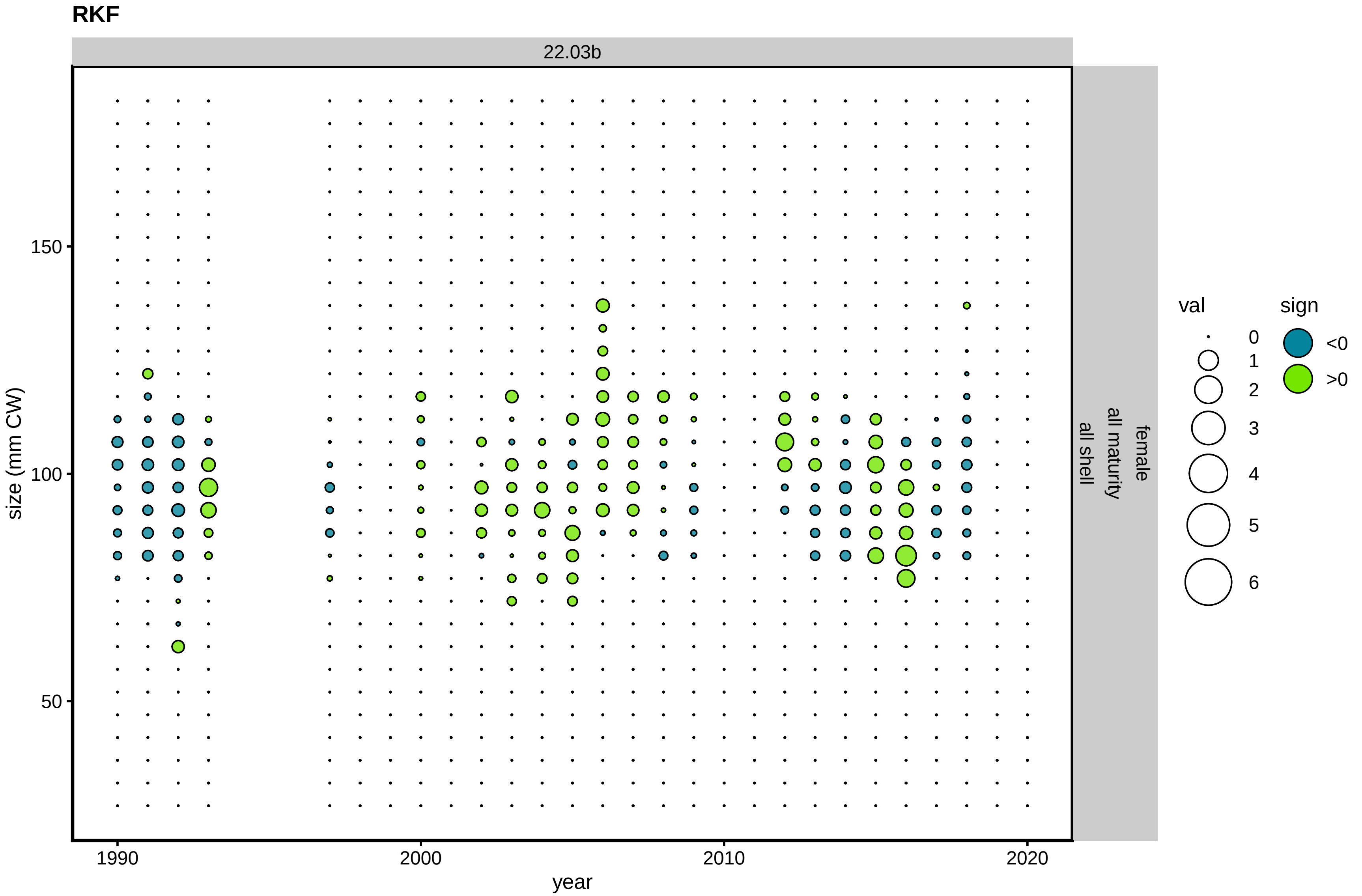

Figure 109. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

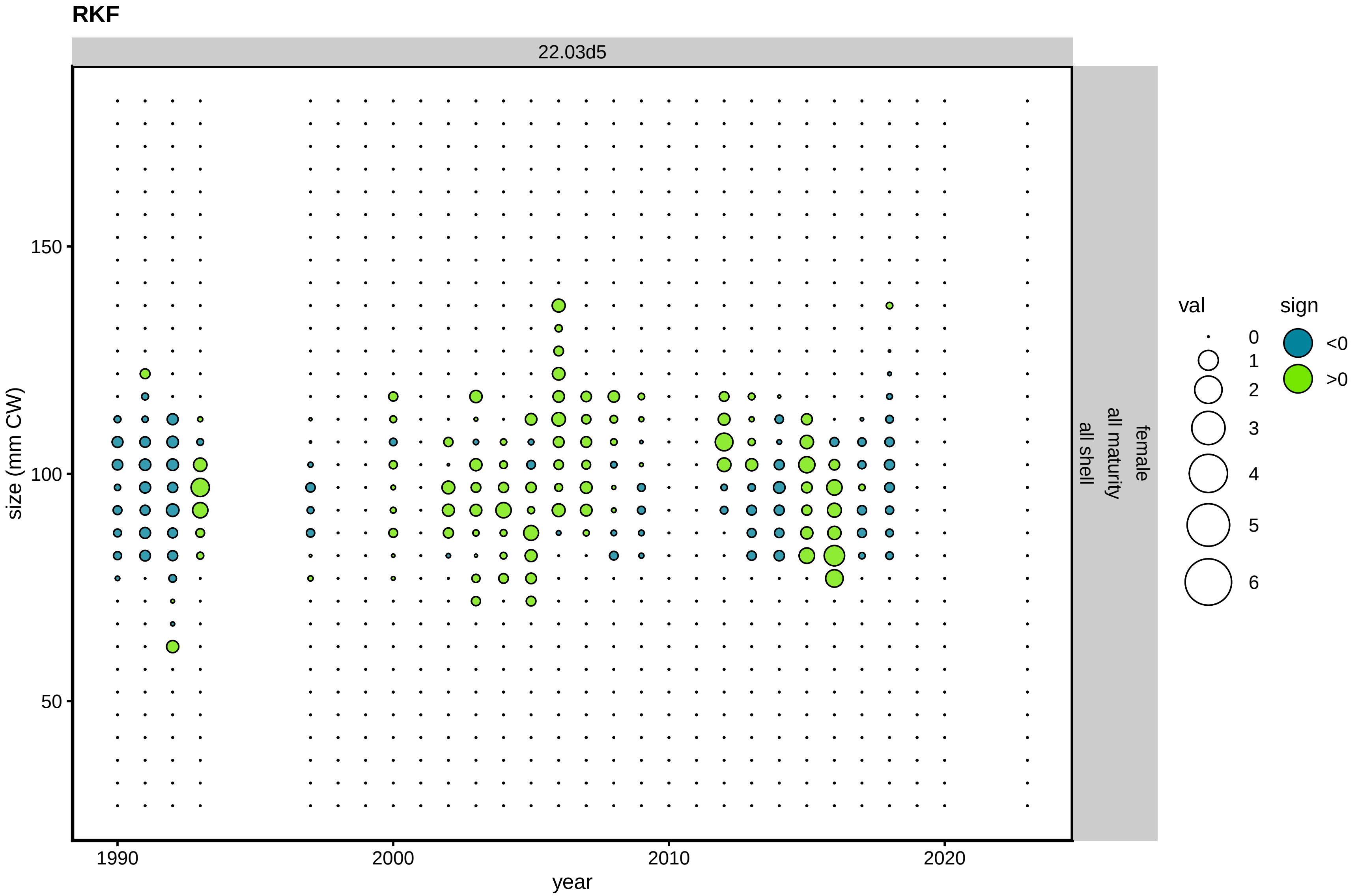

Figure 110. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

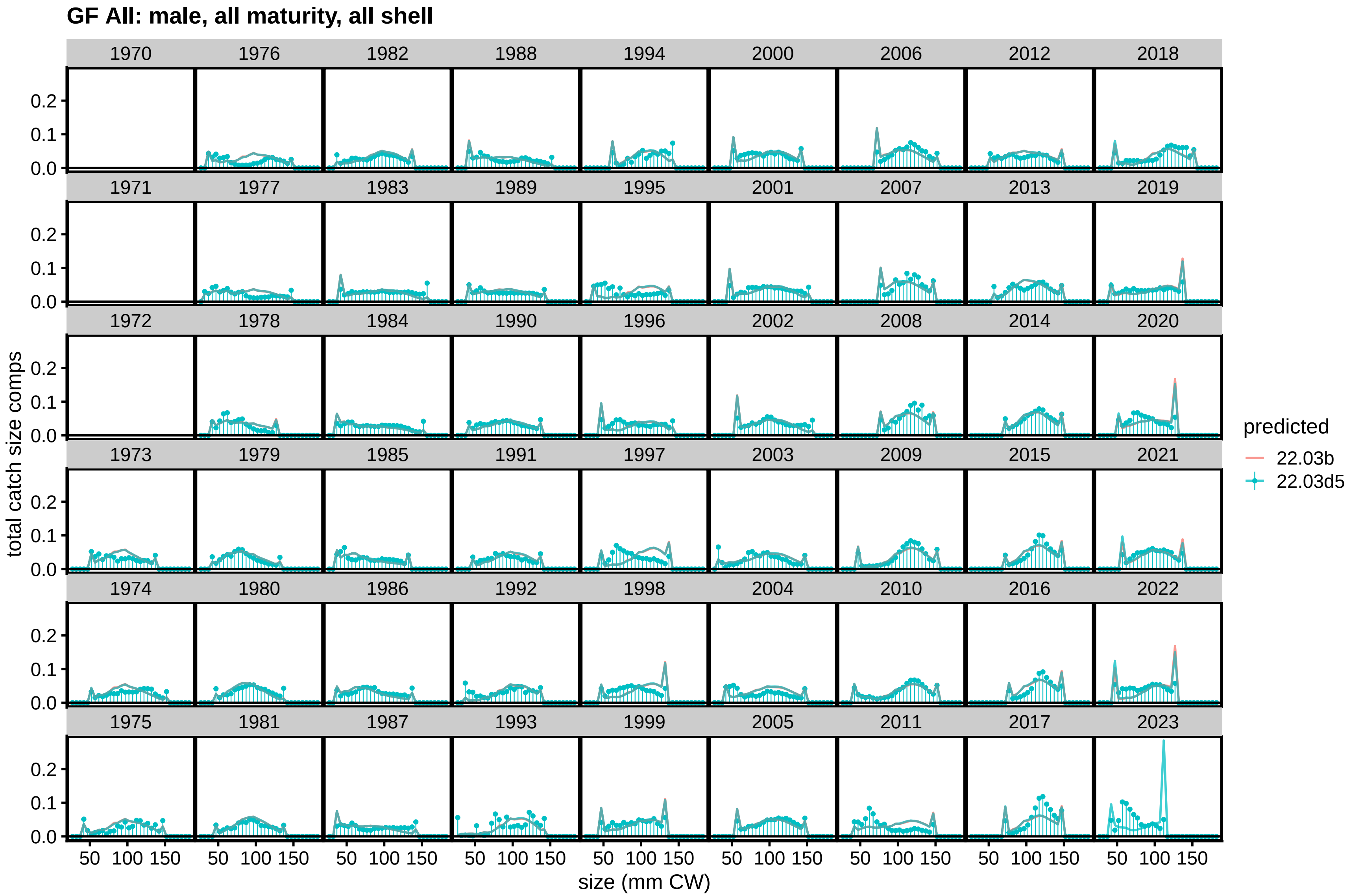

Figure 111. TCSAM02 models fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03d5.

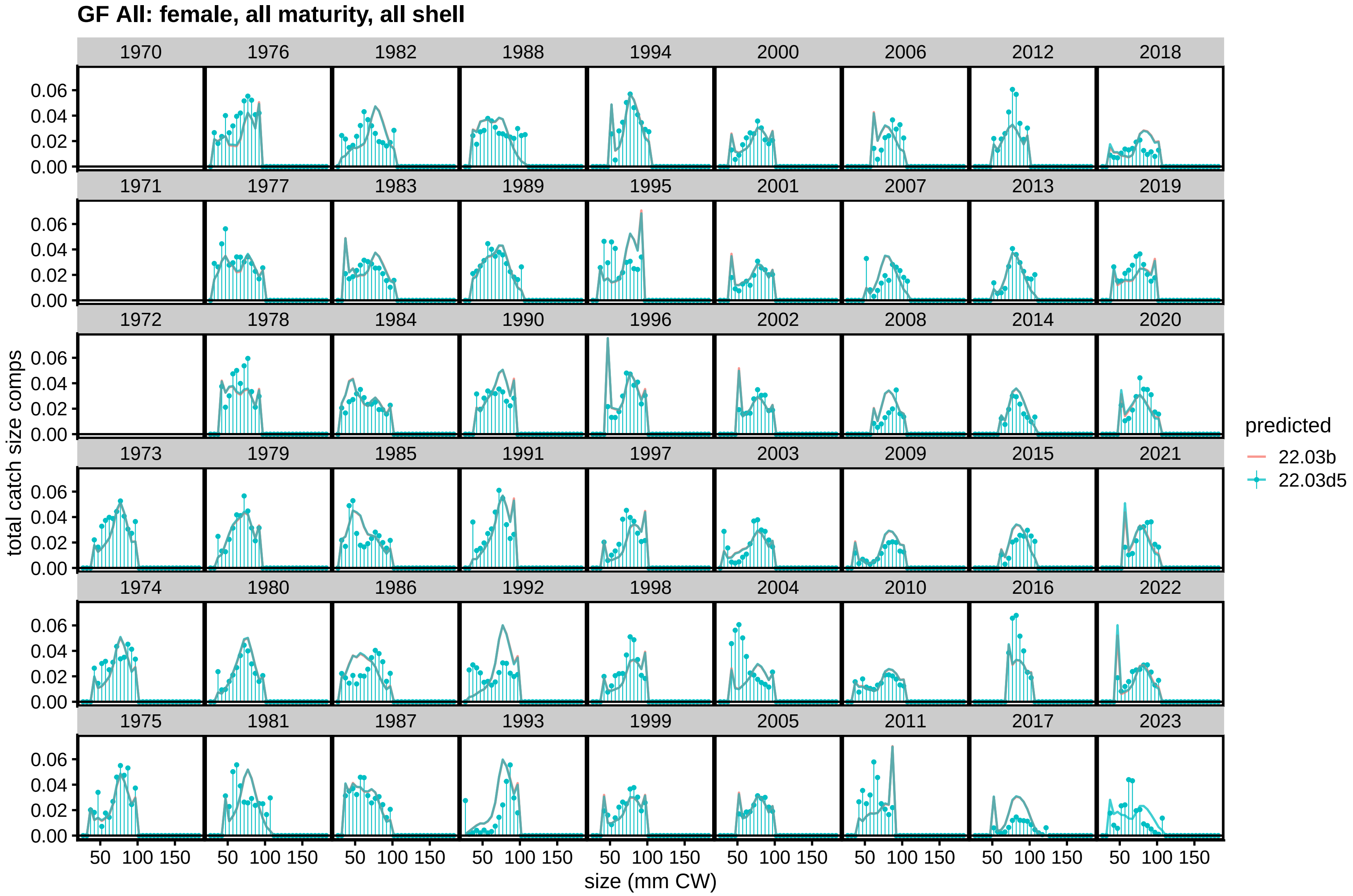

Figure 112. TCSAM02 models fits to total catch size compostiions in the GF All fishery. Preferred model is 22.03d5.

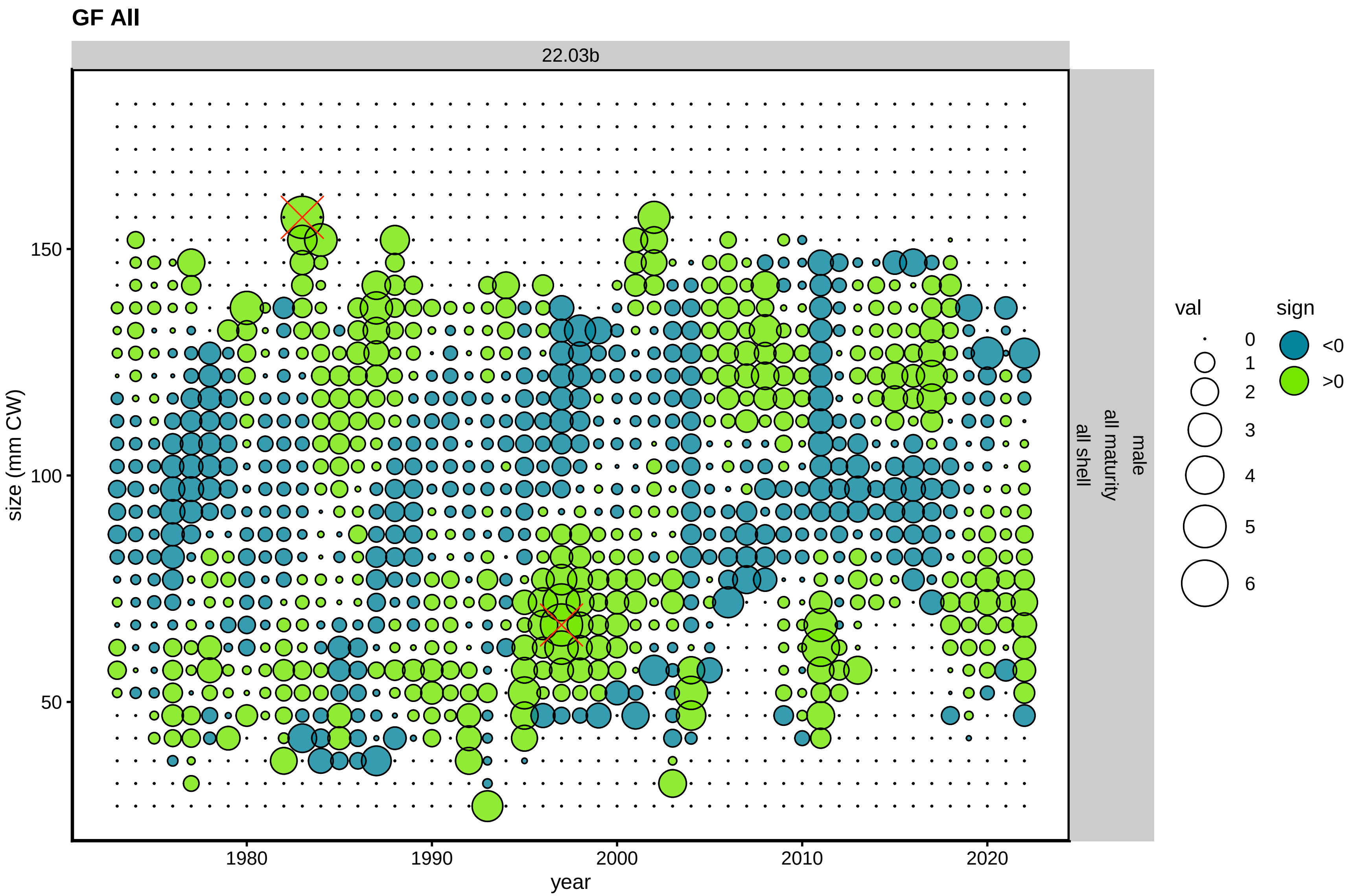

Figure 113. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

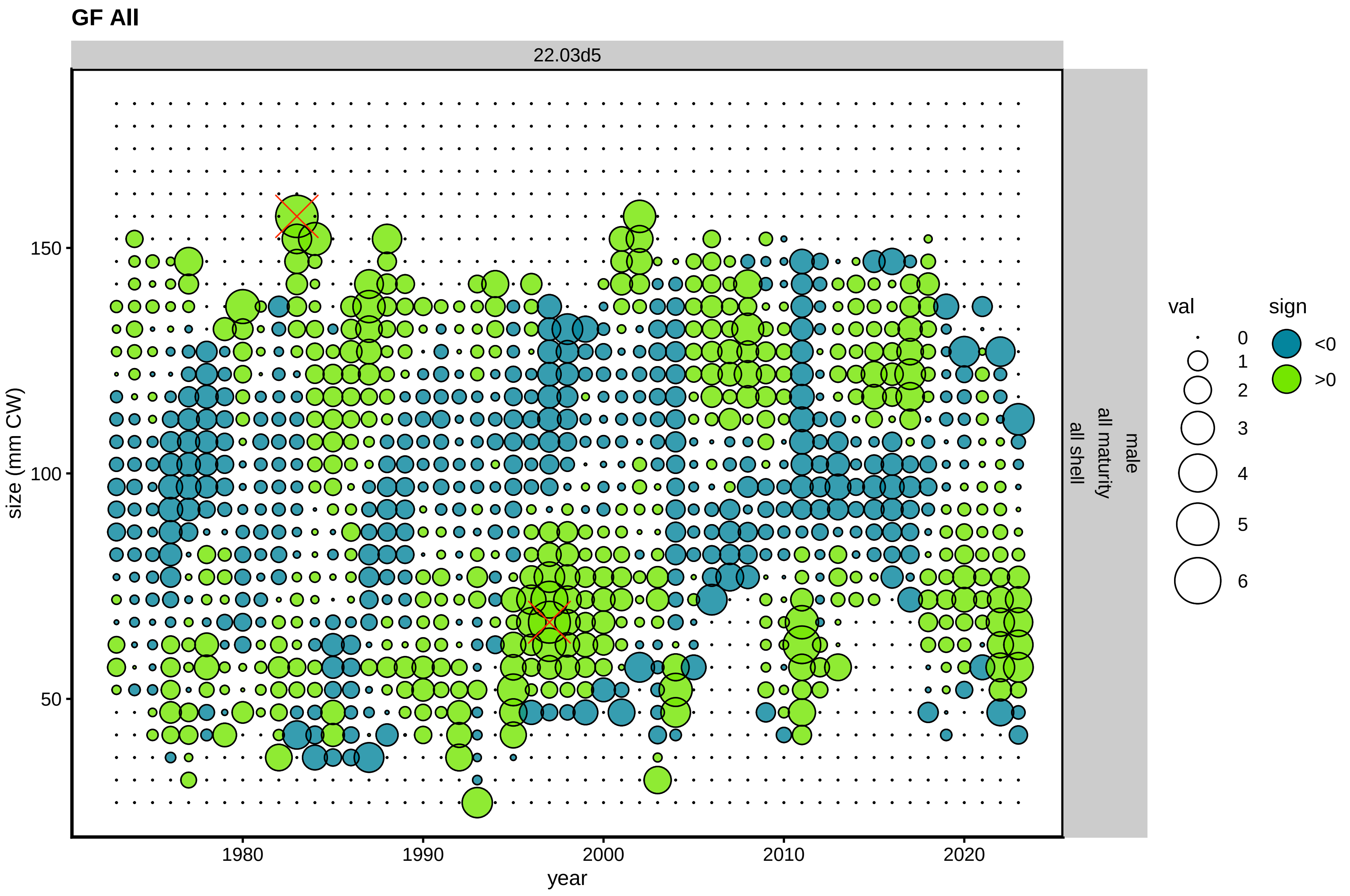

Figure 114. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

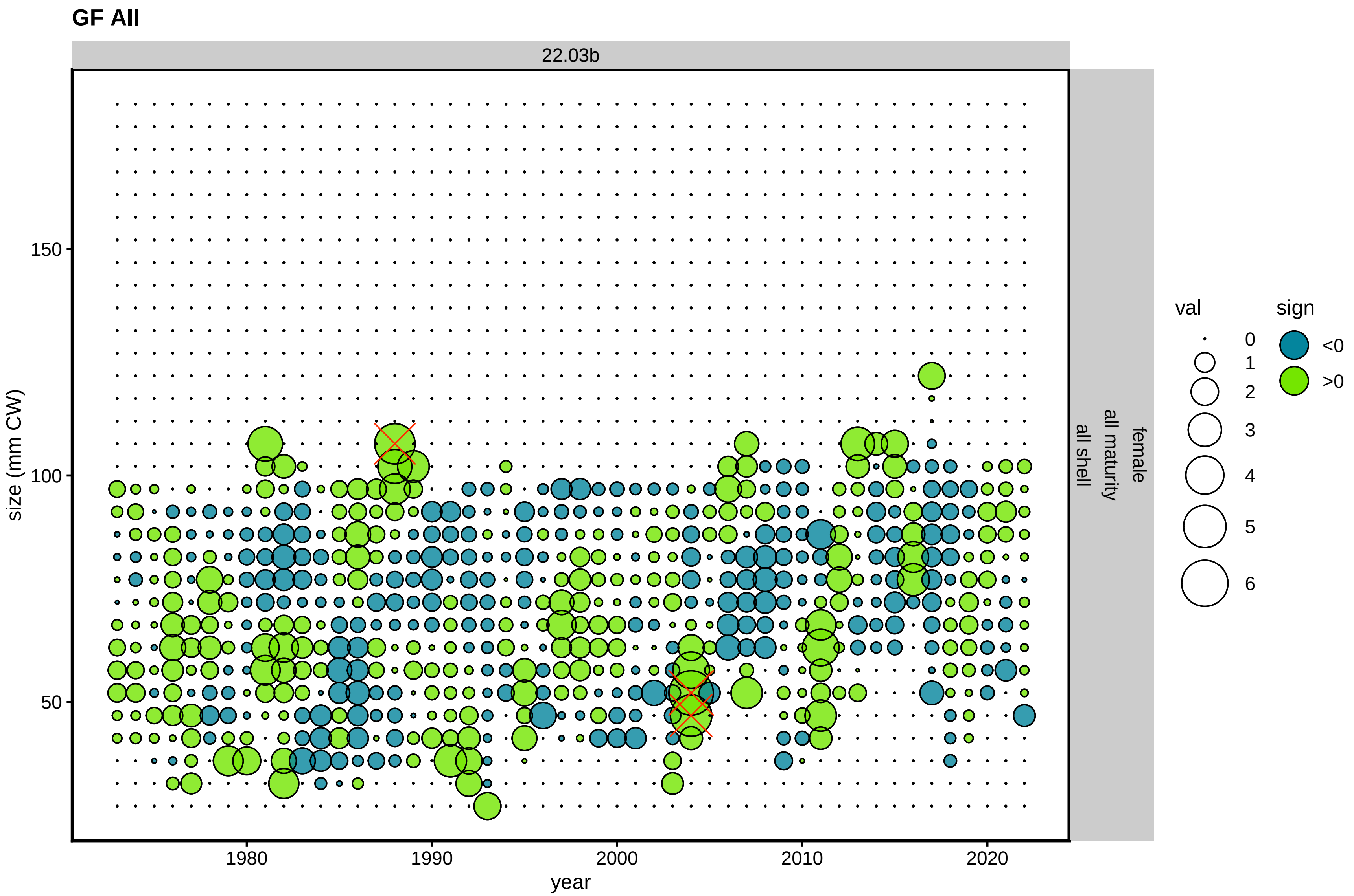

Figure 115. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

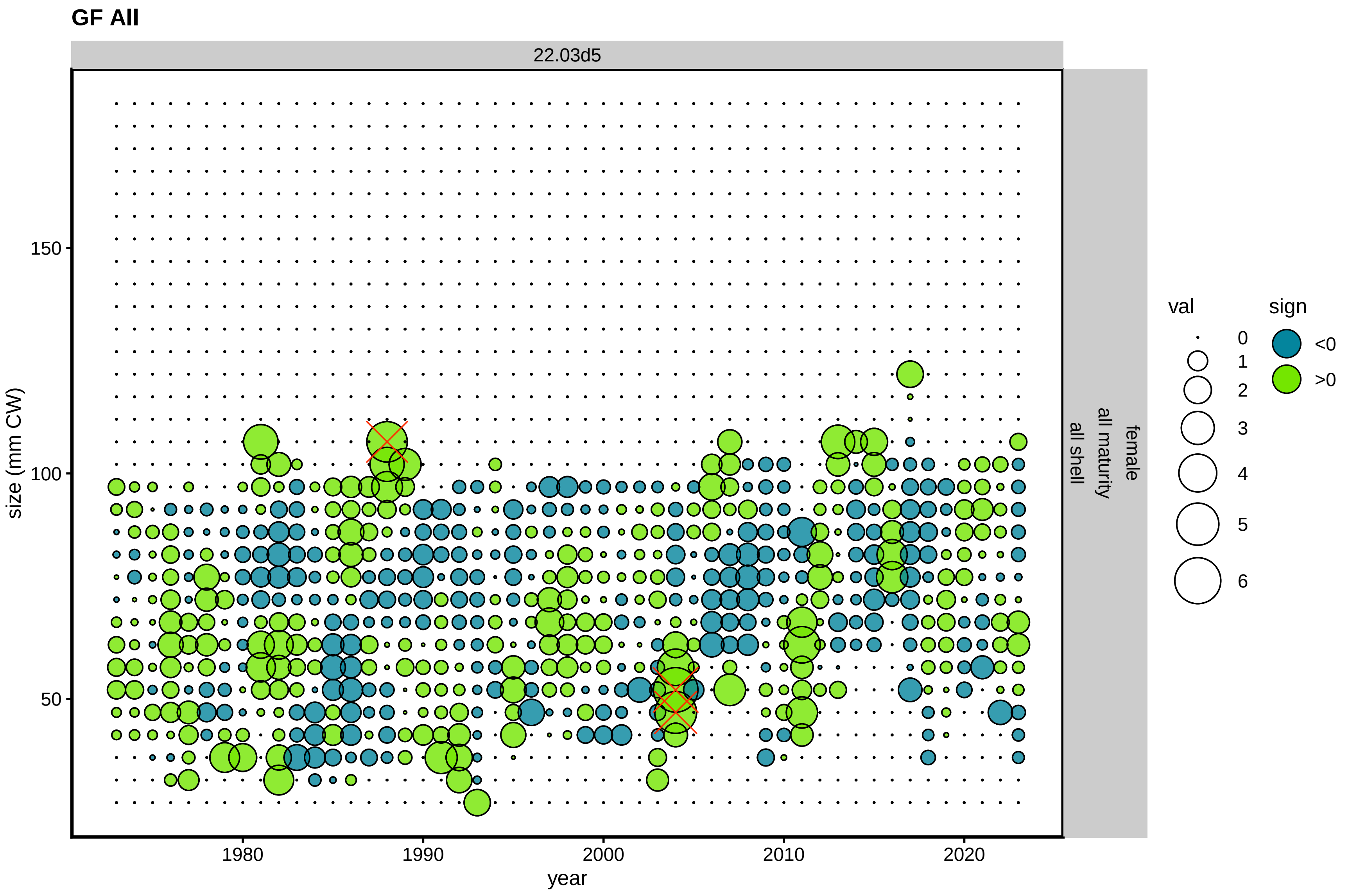

Figure 116. Pearson's residuals for fits to total catch size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

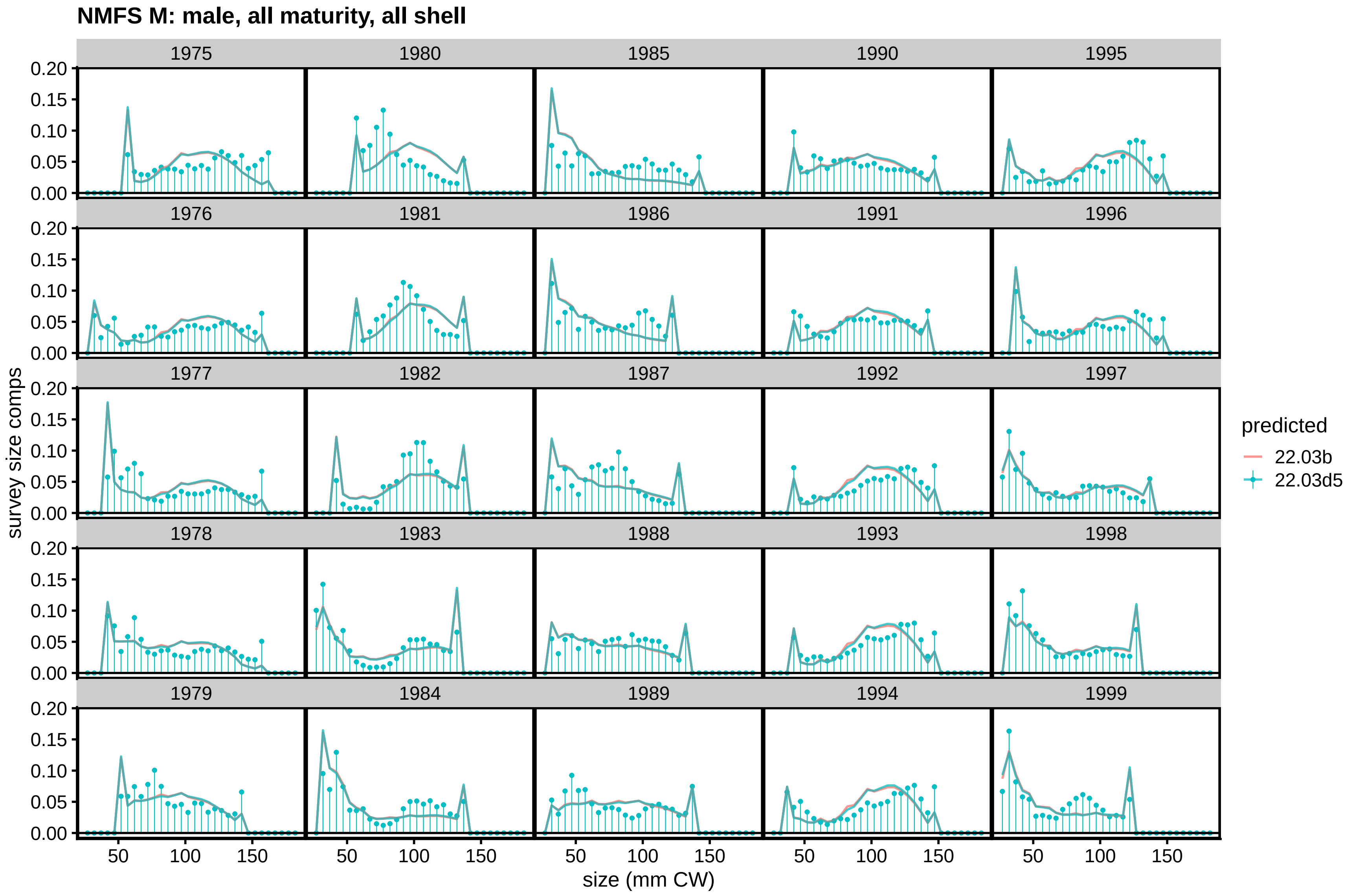

Figure 117. TCSAM02 models fits to survey size compositions in the NMFS M survey. Preferred model is 22.03d5.

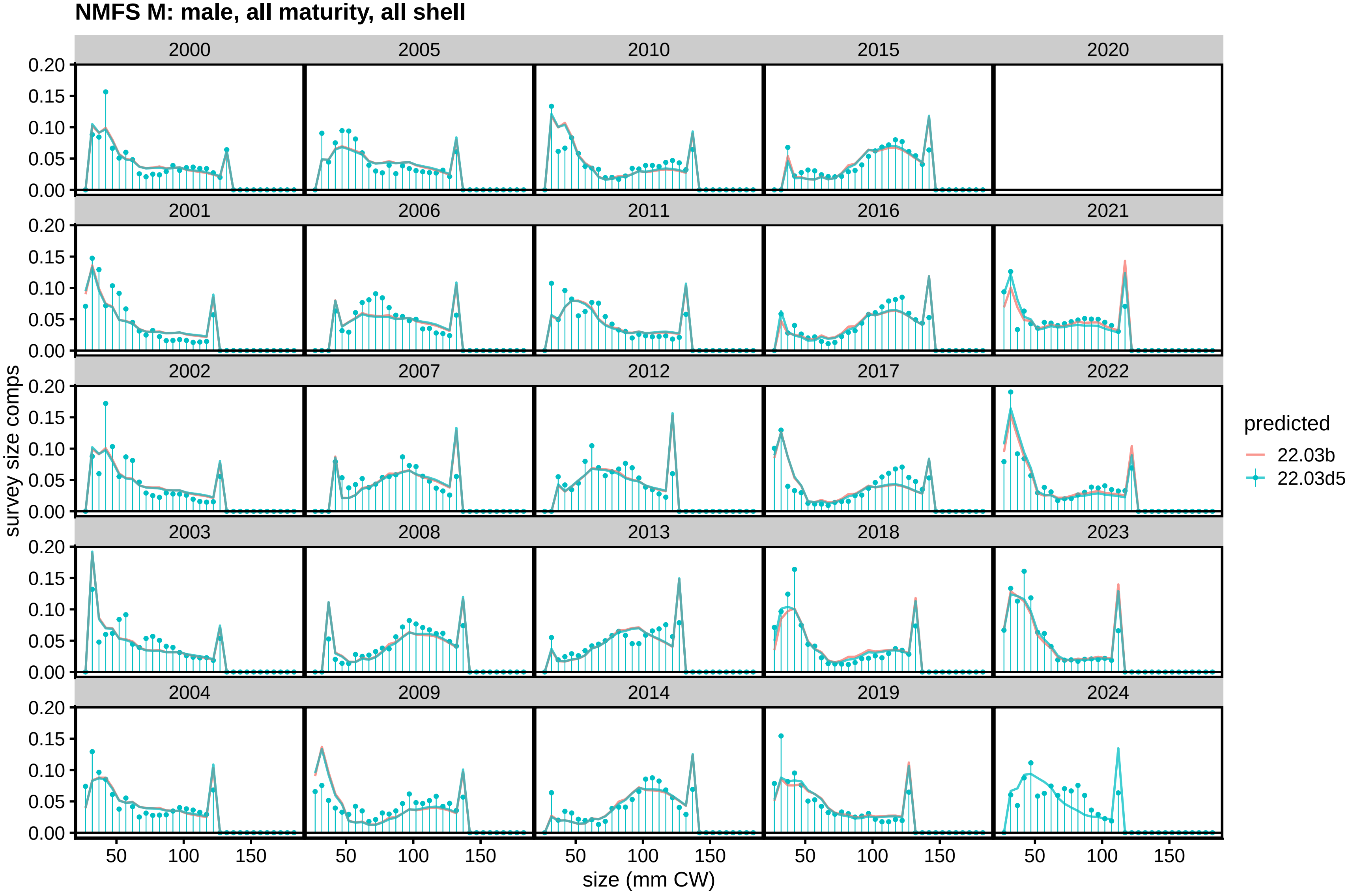

Figure 118. TCSAM02 models fits to survey size compositions in the NMFS M survey. Preferred model is 22.03d5.

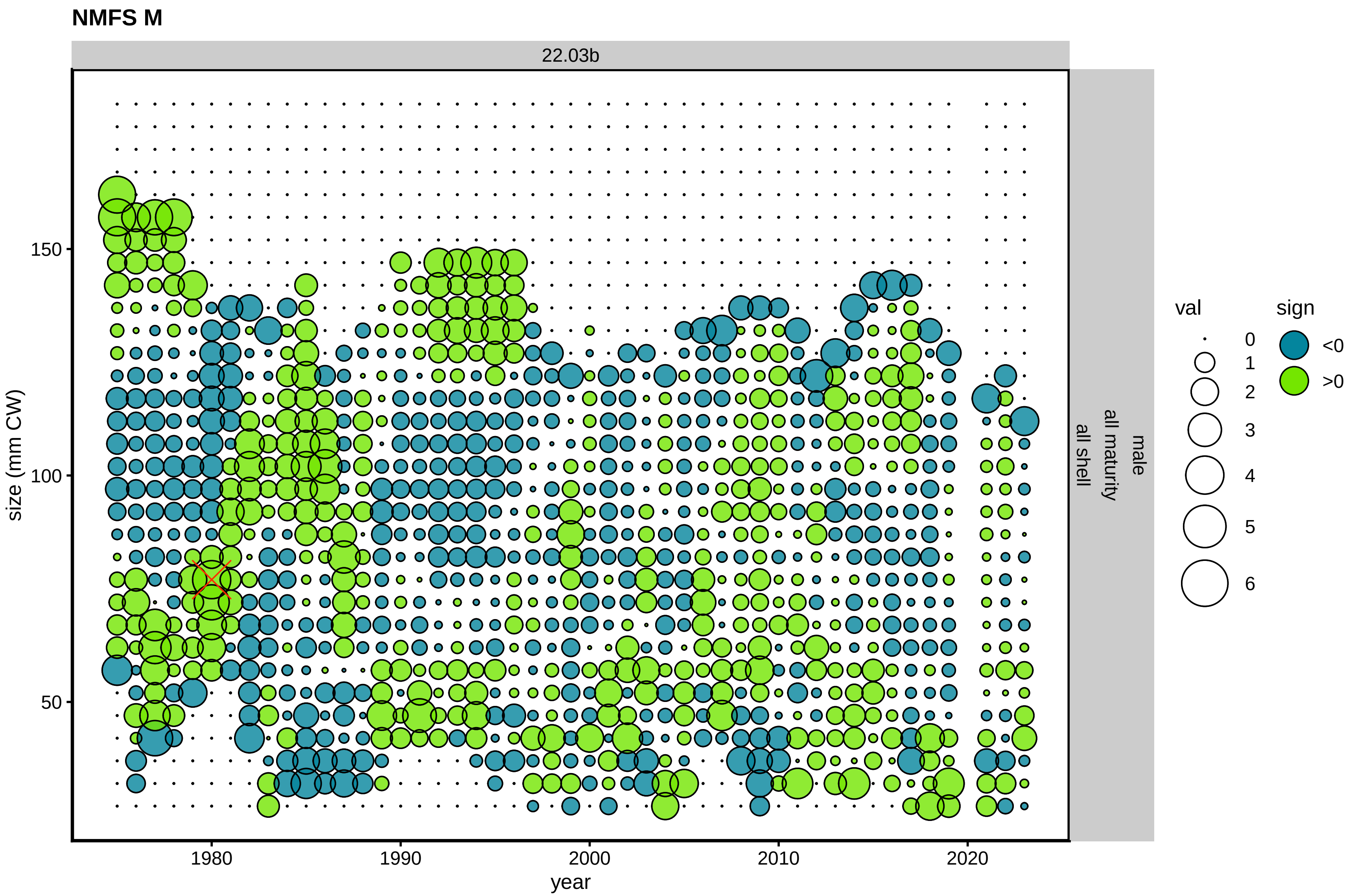

Figure 119. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

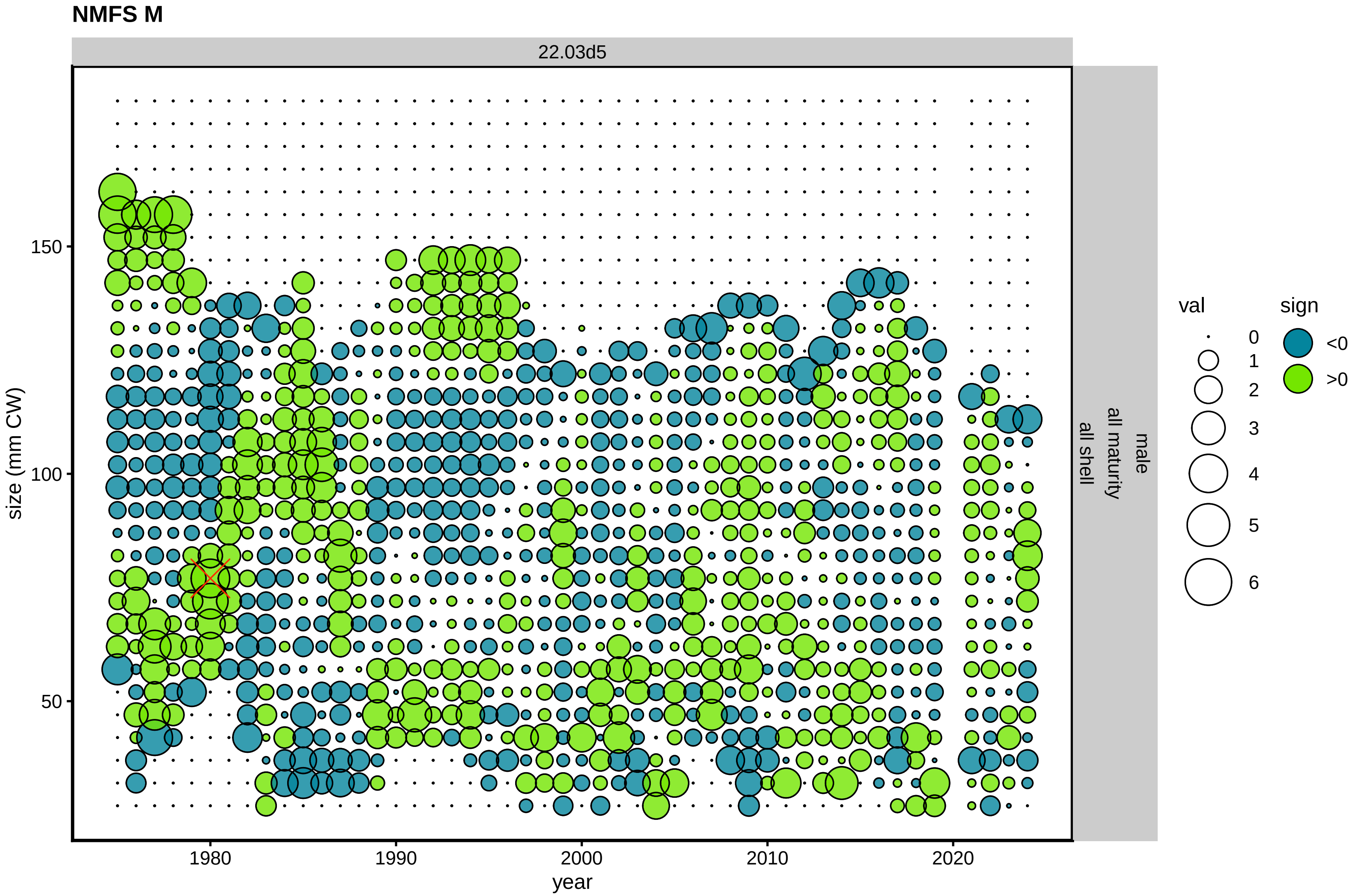

Figure 120. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

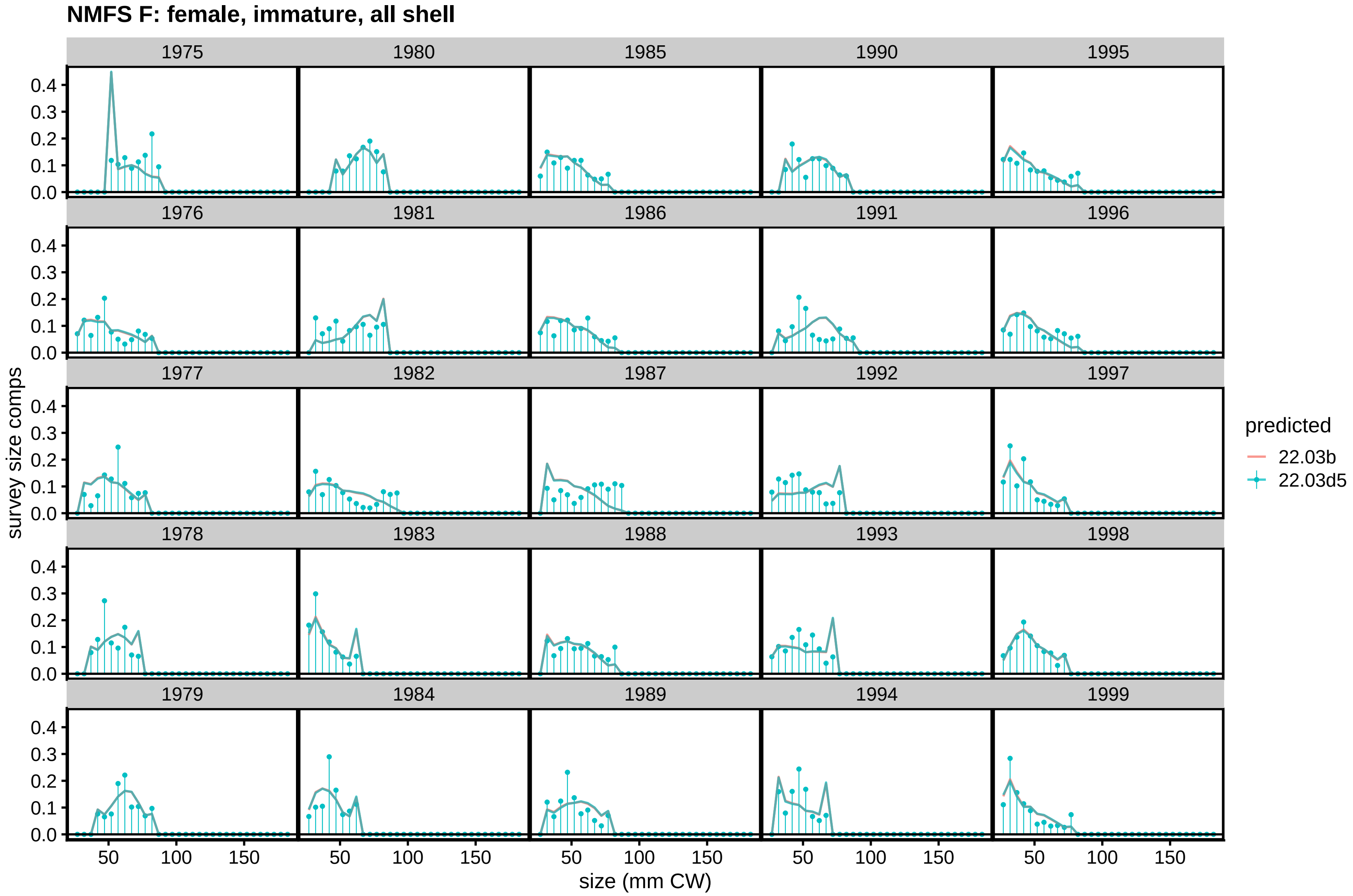

Figure 121. TCSAM02 models fits to survey size compositions in the NMFS F survey. Preferred model is 22.03d5.

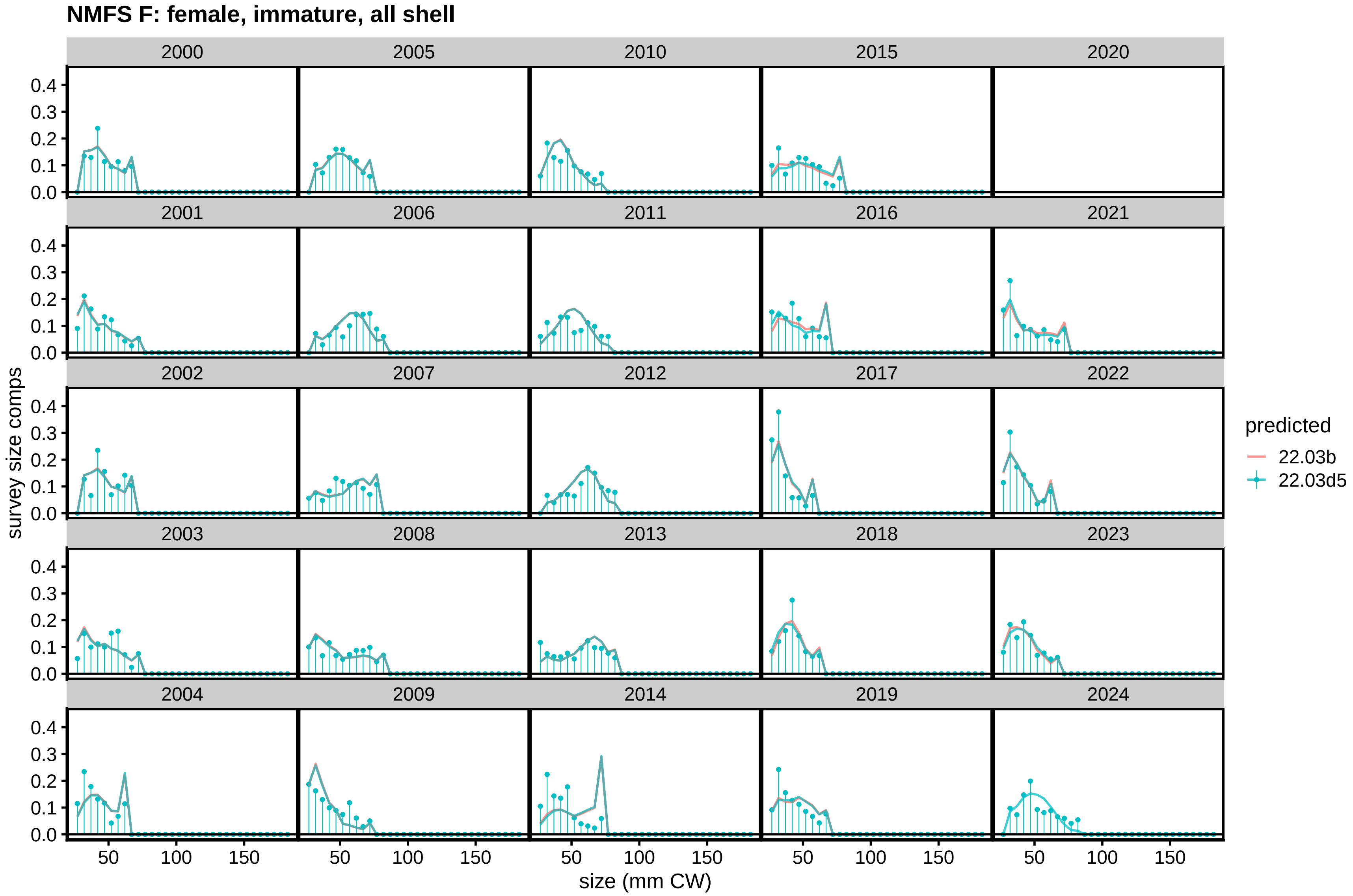

Figure 122. TCSAM02 models fits to survey size compositions in the NMFS F survey. Preferred model is 22.03d5.

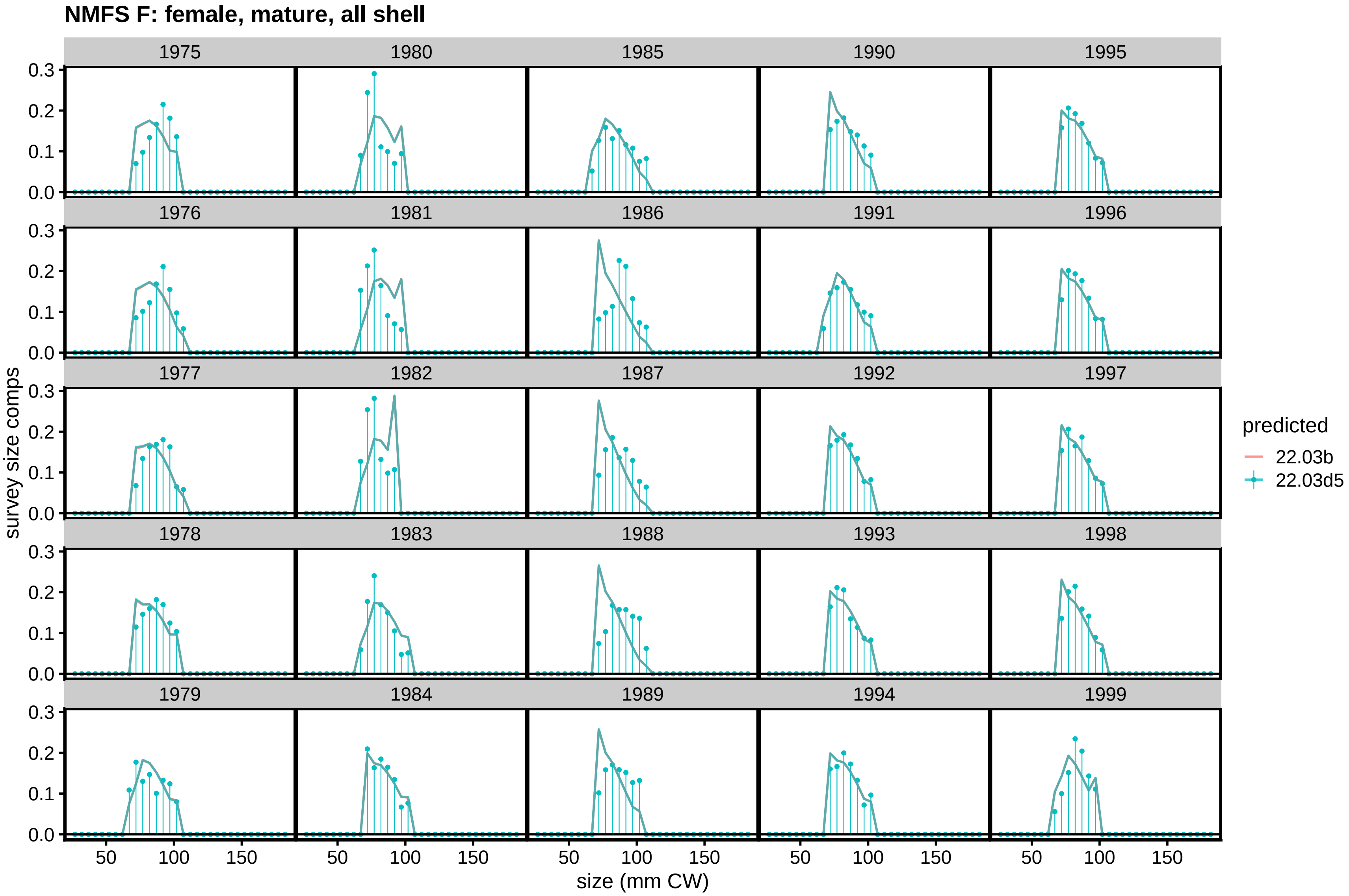

Figure 123. TCSAM02 models fits to survey size compositions in the NMFS F survey. Preferred model is 22.03d5.

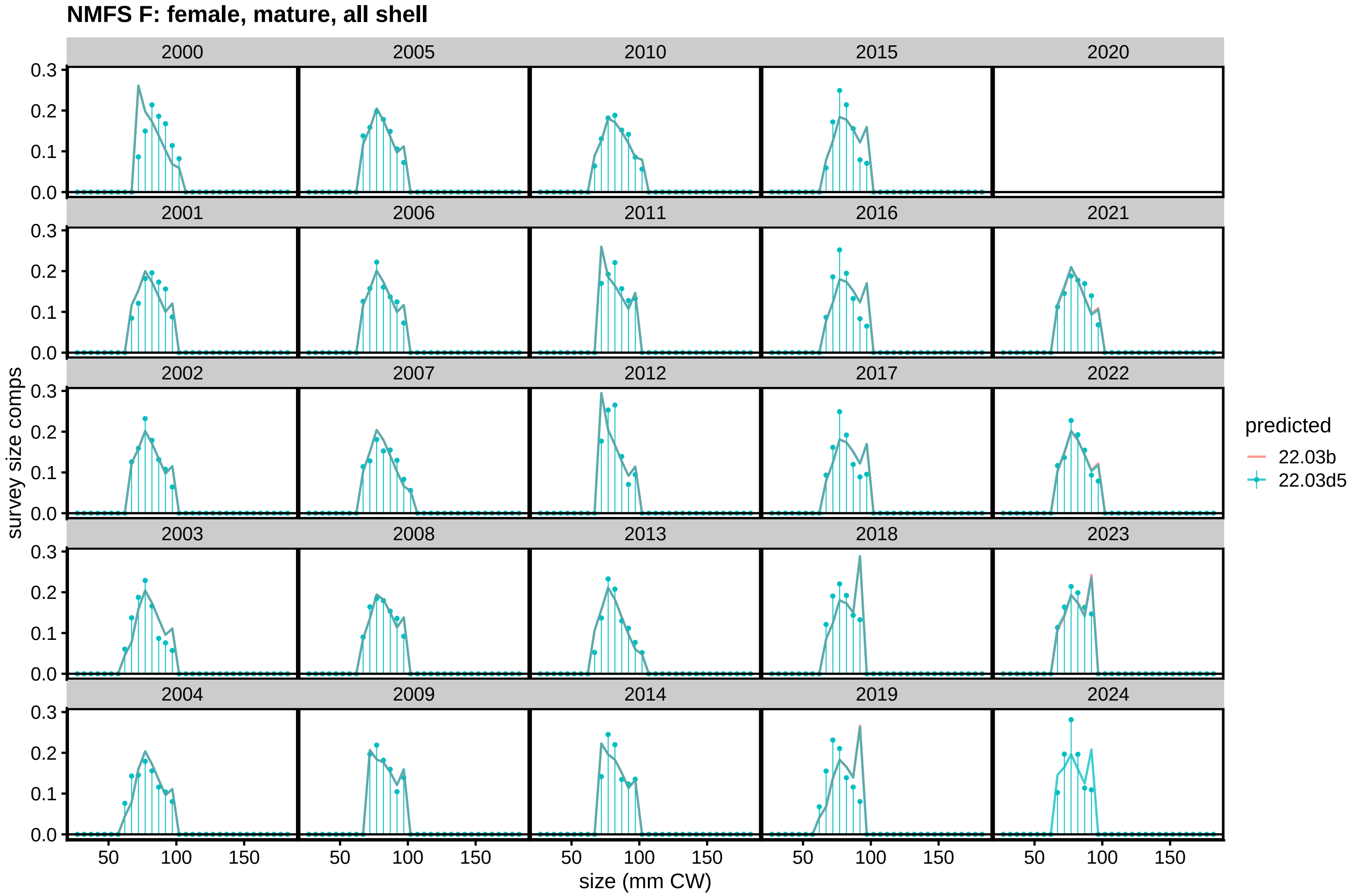

Figure 124. TCSAM02 models fits to survey size compositions in the NMFS F survey. Preferred model is 22.03d5.

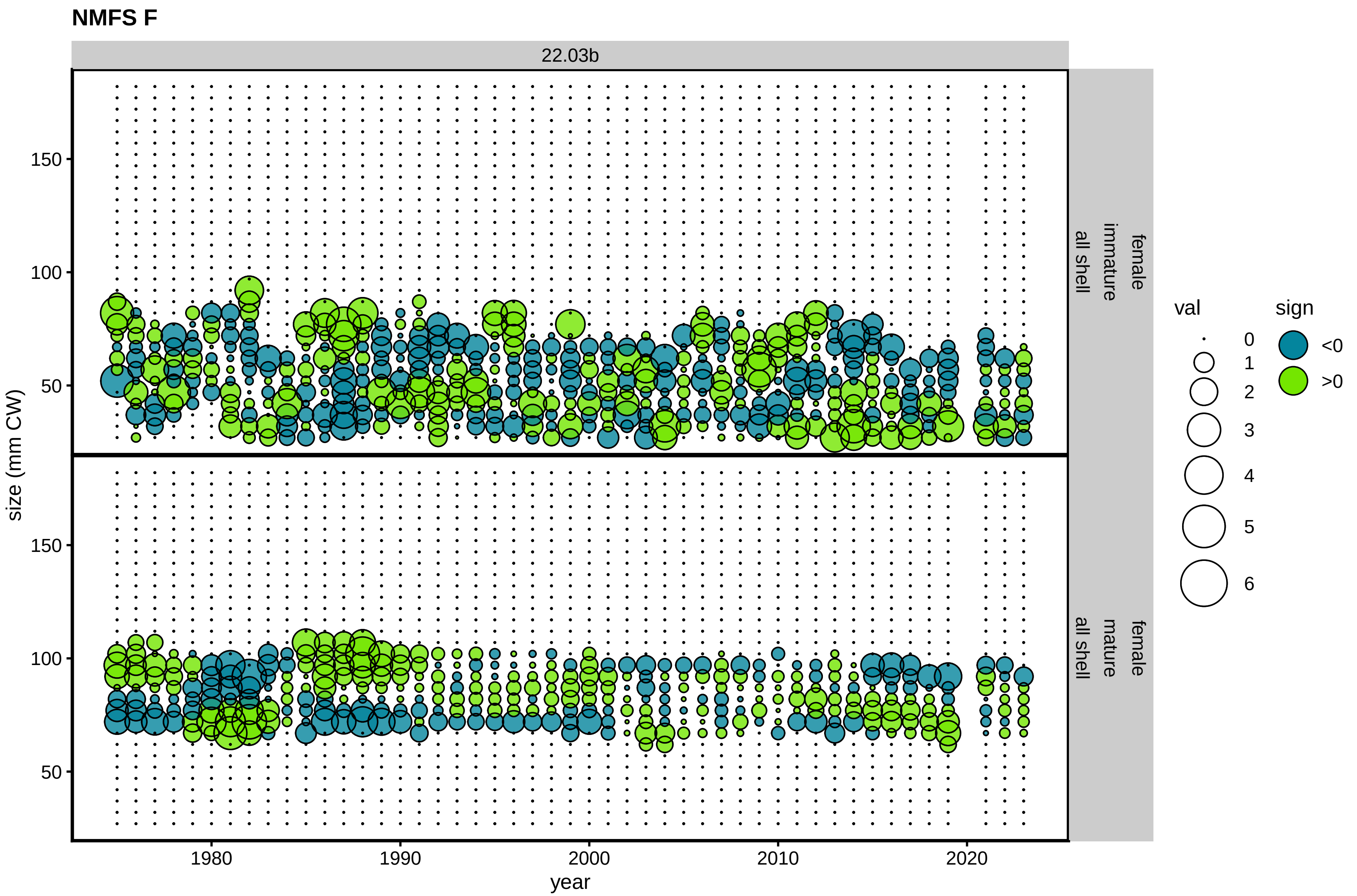

Figure 125. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

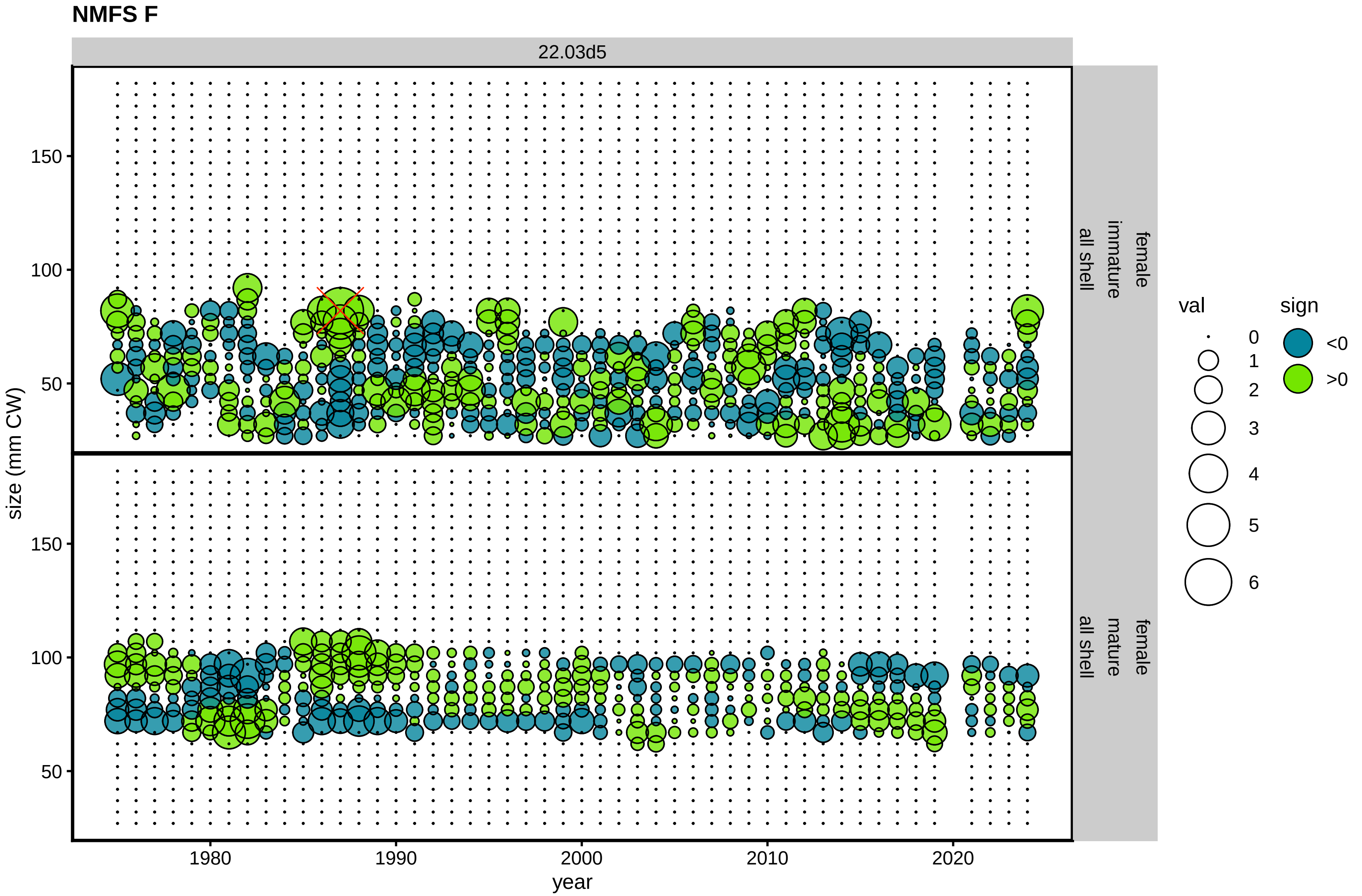

Figure 126. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification. Preferred model is 22.03d5.

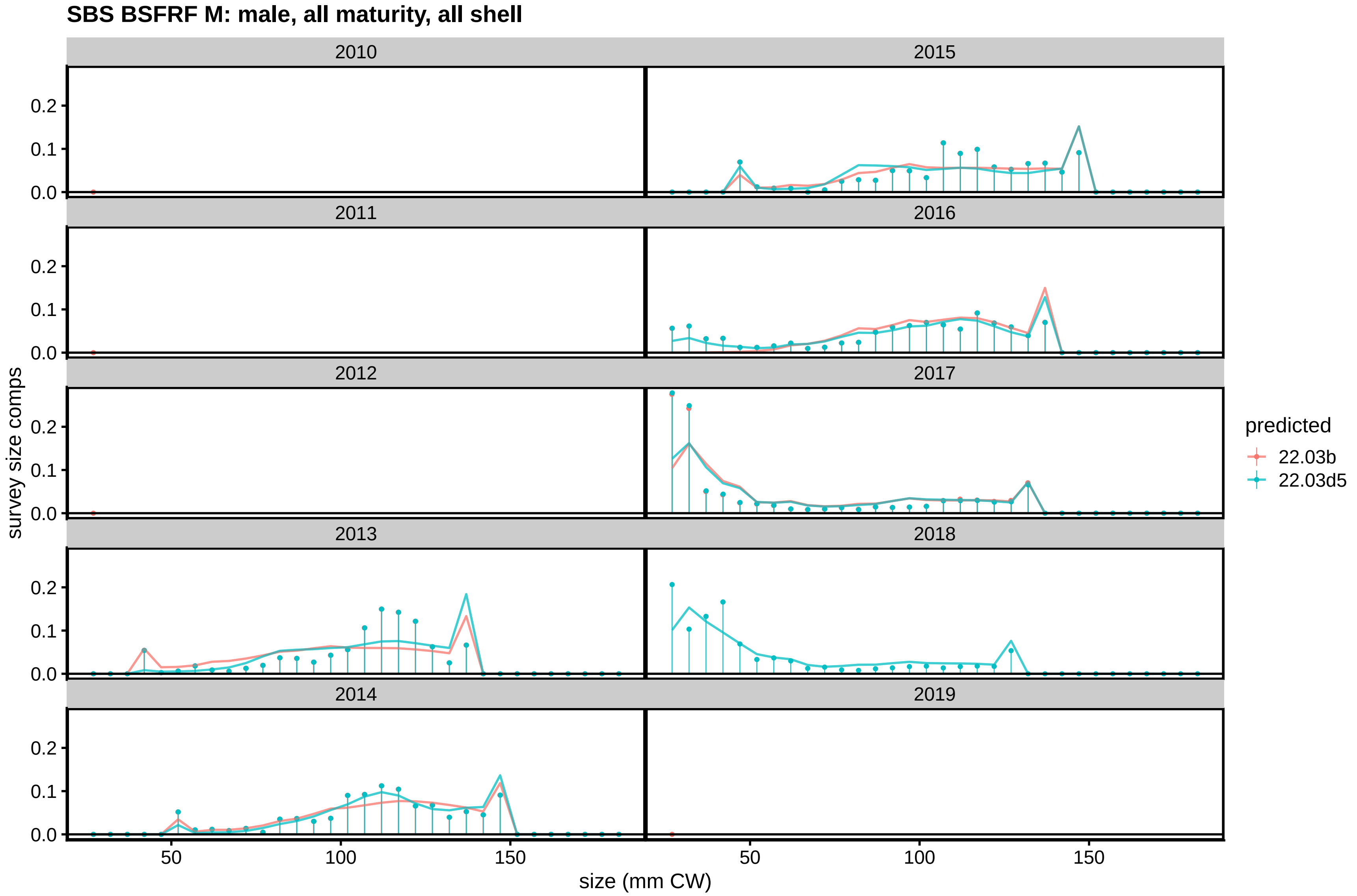

Figure 127. TCSAM02 model fits to survey size compositions in the SBS BSFRF M survey. Preferred model is 22.03d5.

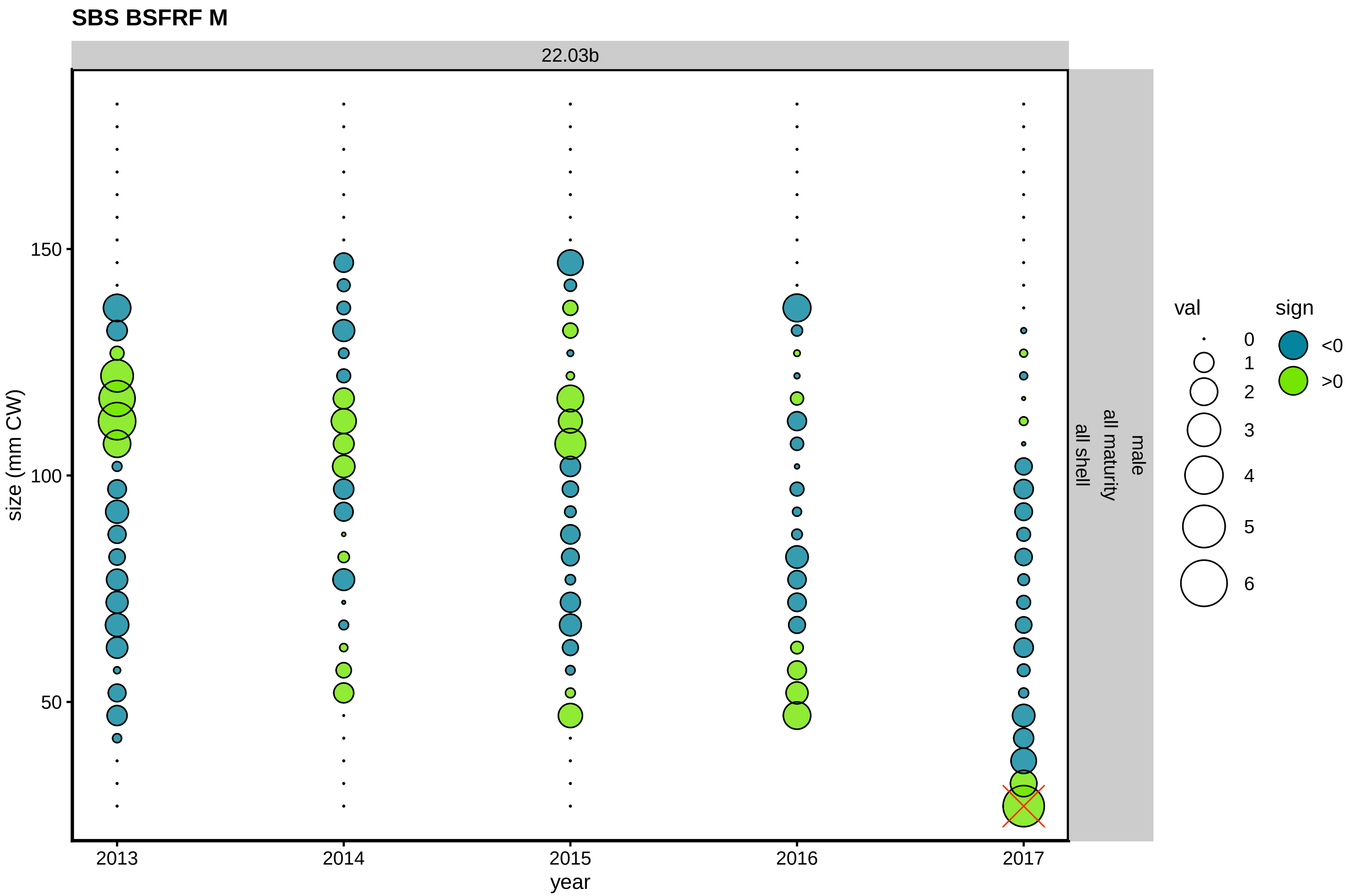

Figure 128. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification.

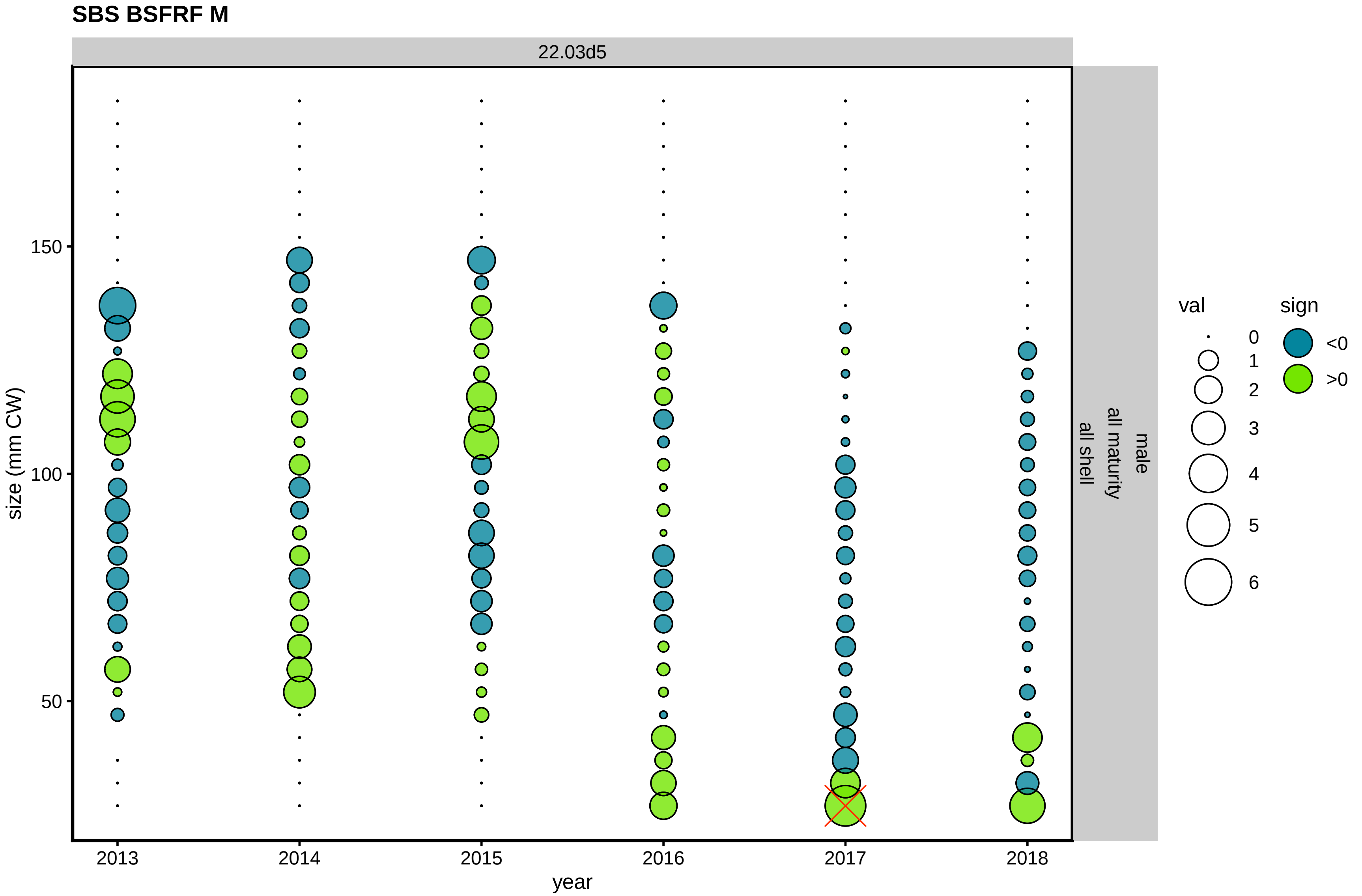

Figure 129. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification.

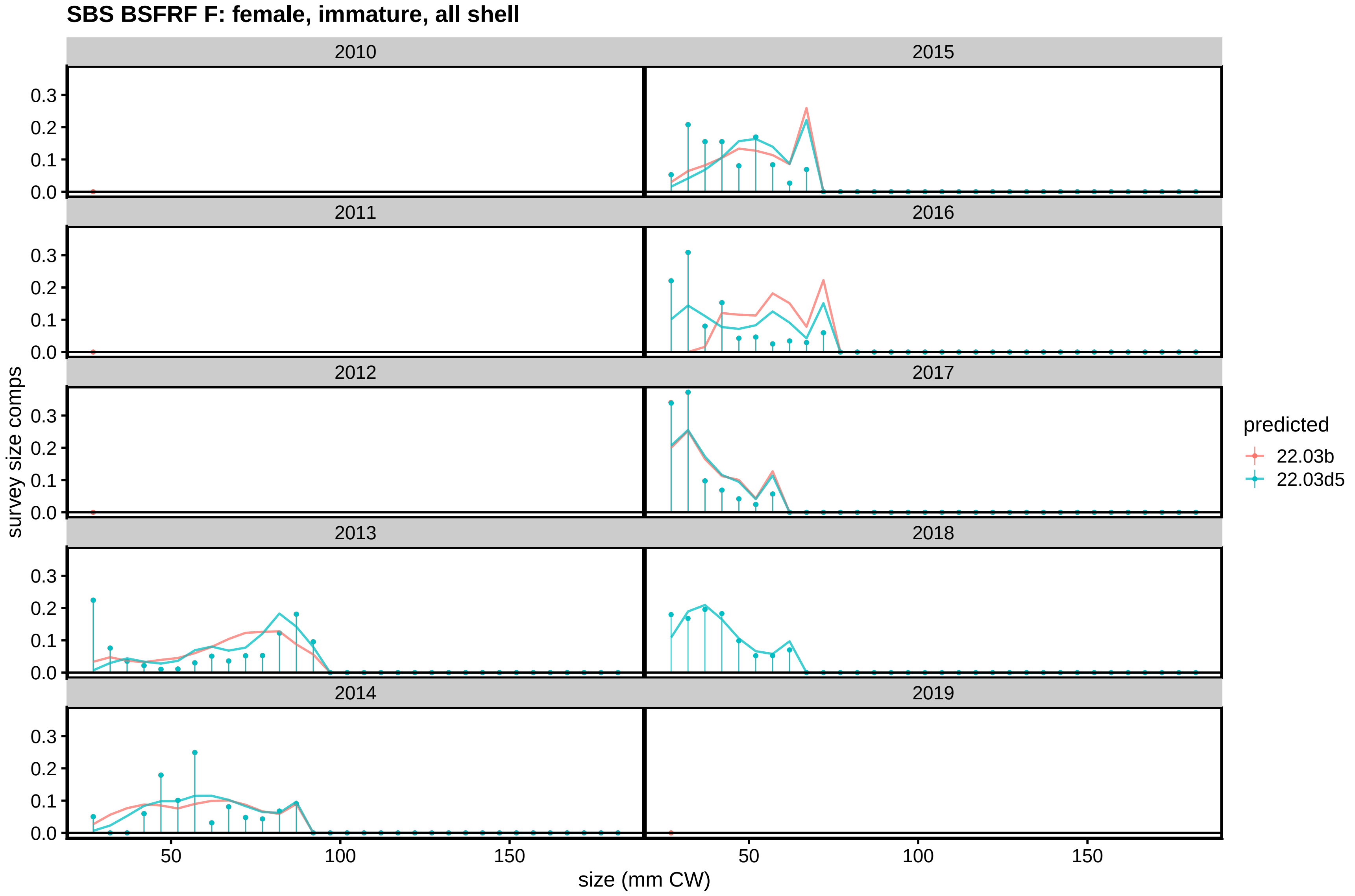

Figure 130. TCSAM02 model fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03d5.

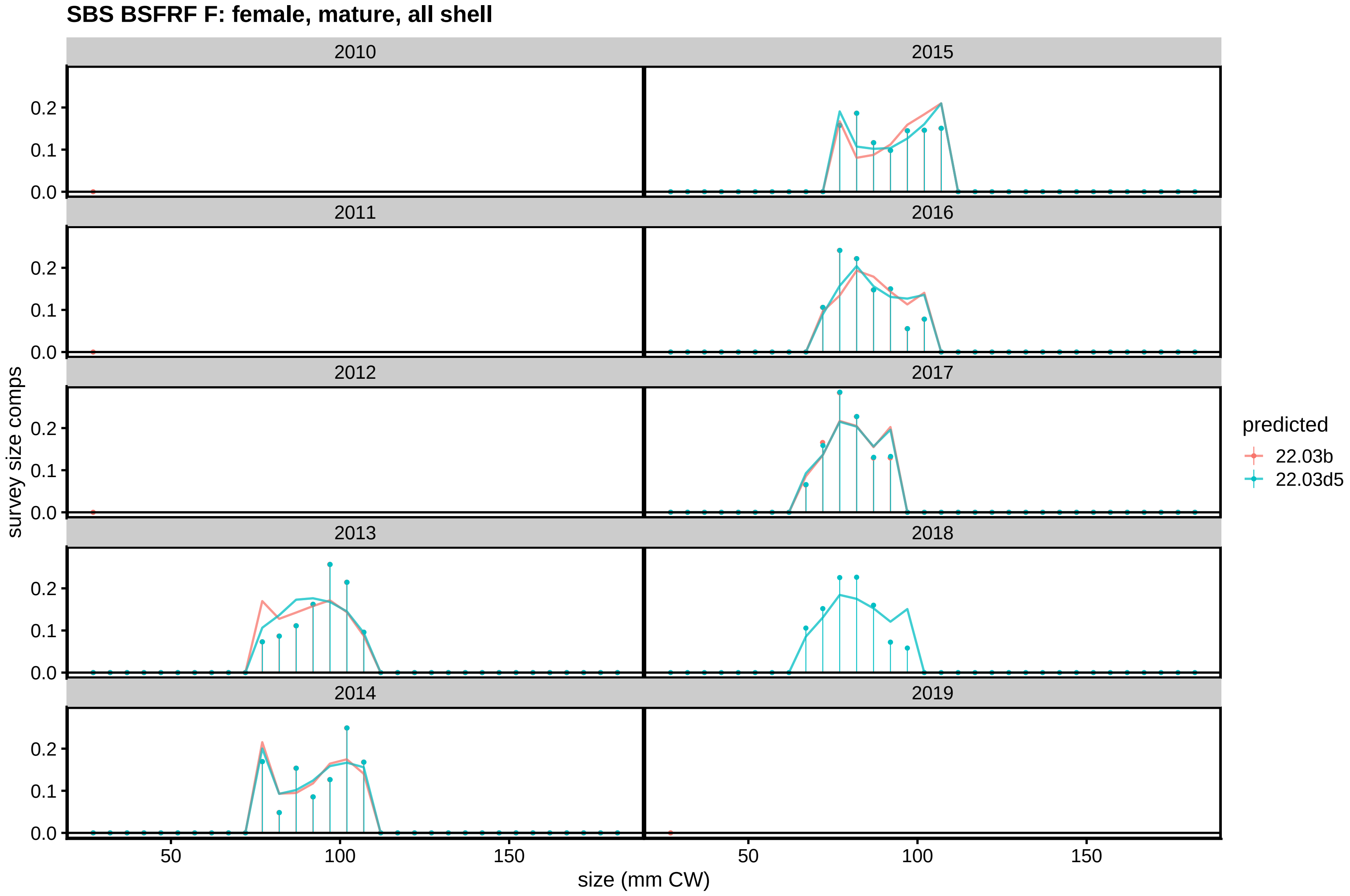

Figure 131. TCSAM02 model fits to survey size compositions in the SBS BSFRF F survey. Preferred model is 22.03d5.

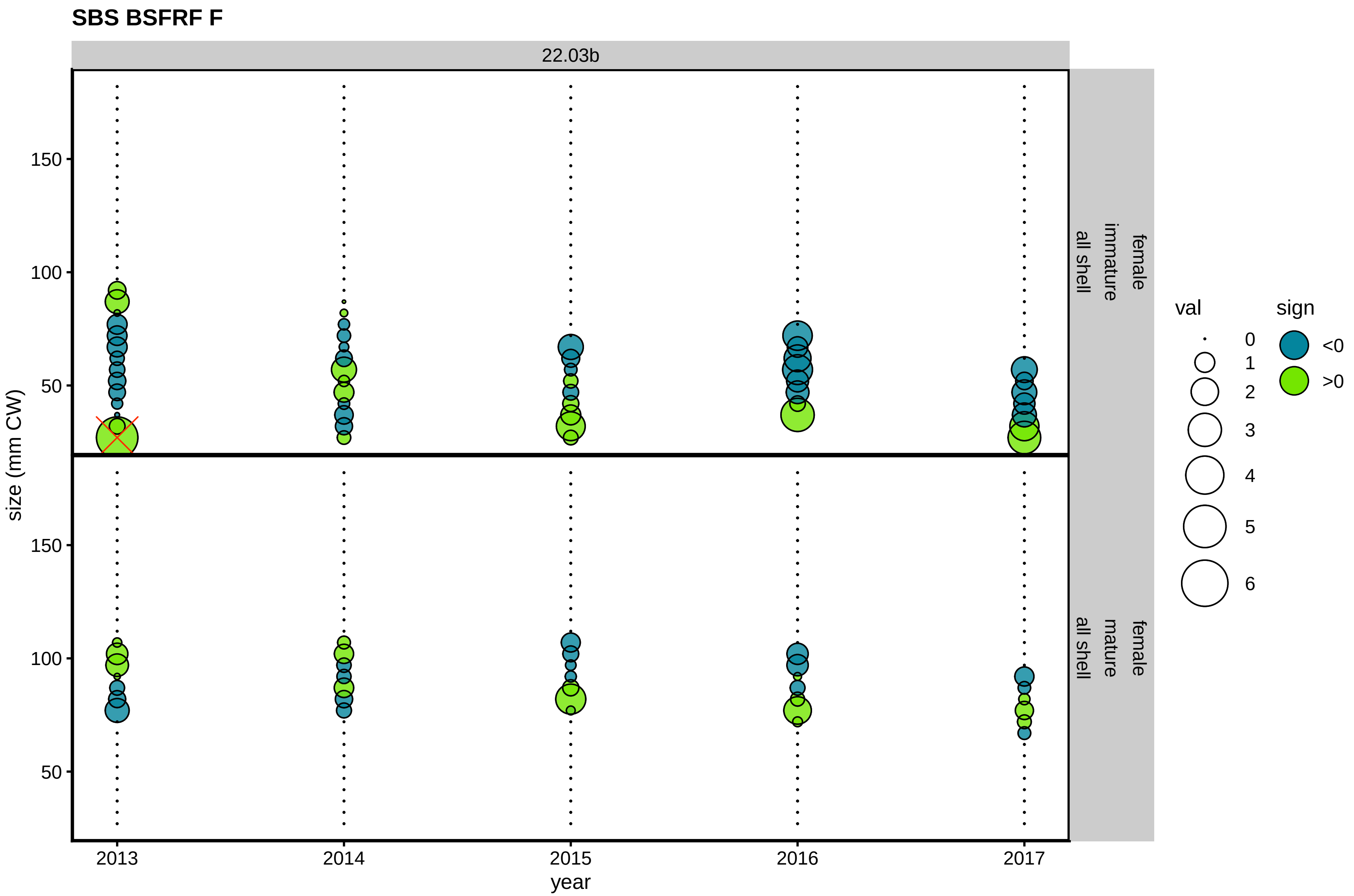

Figure 132. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification.

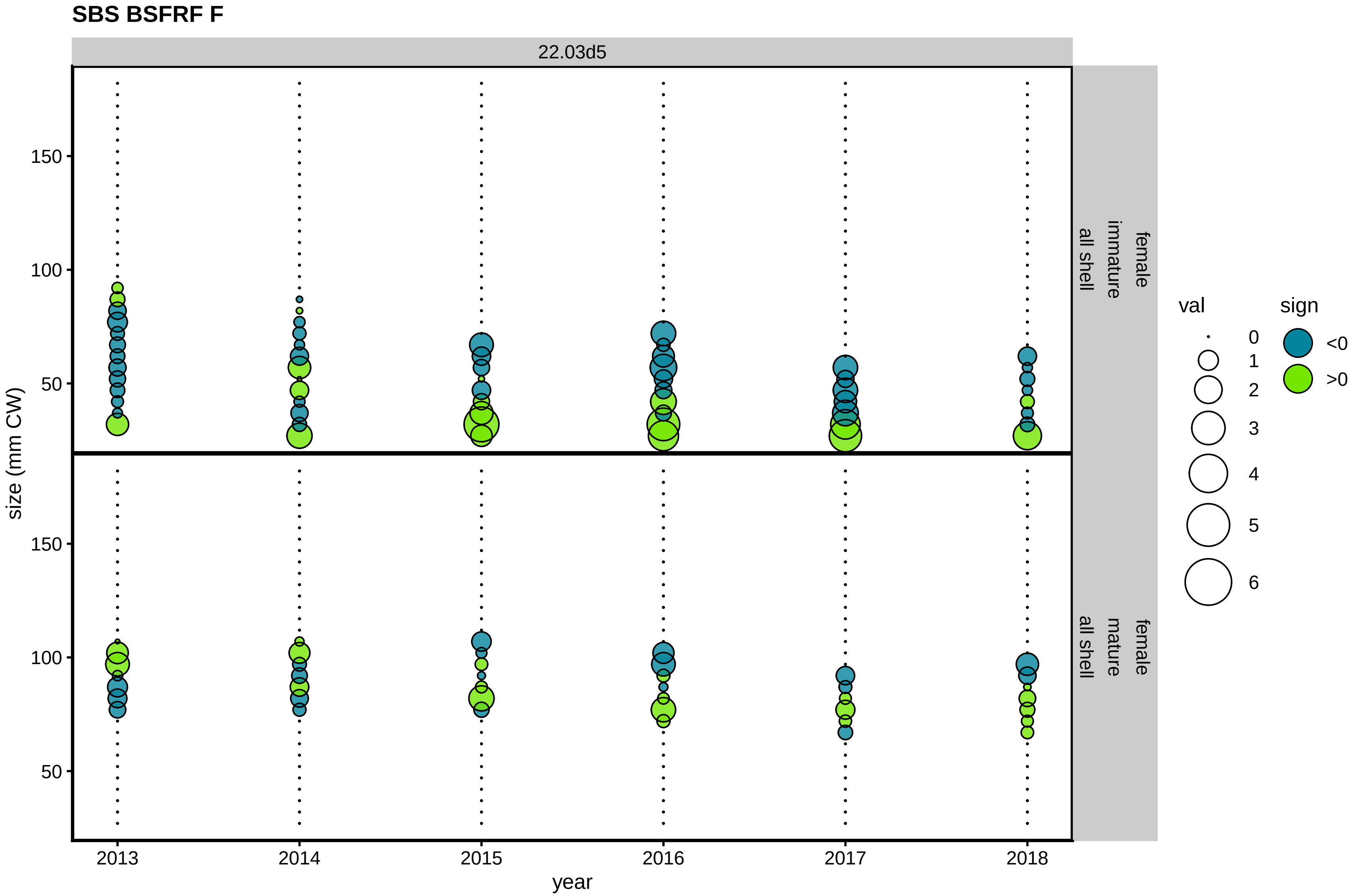

Figure 133. Pearson's residuals for fits to survey size composition data in the TCSAM02 models. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X'to facilitate identification.

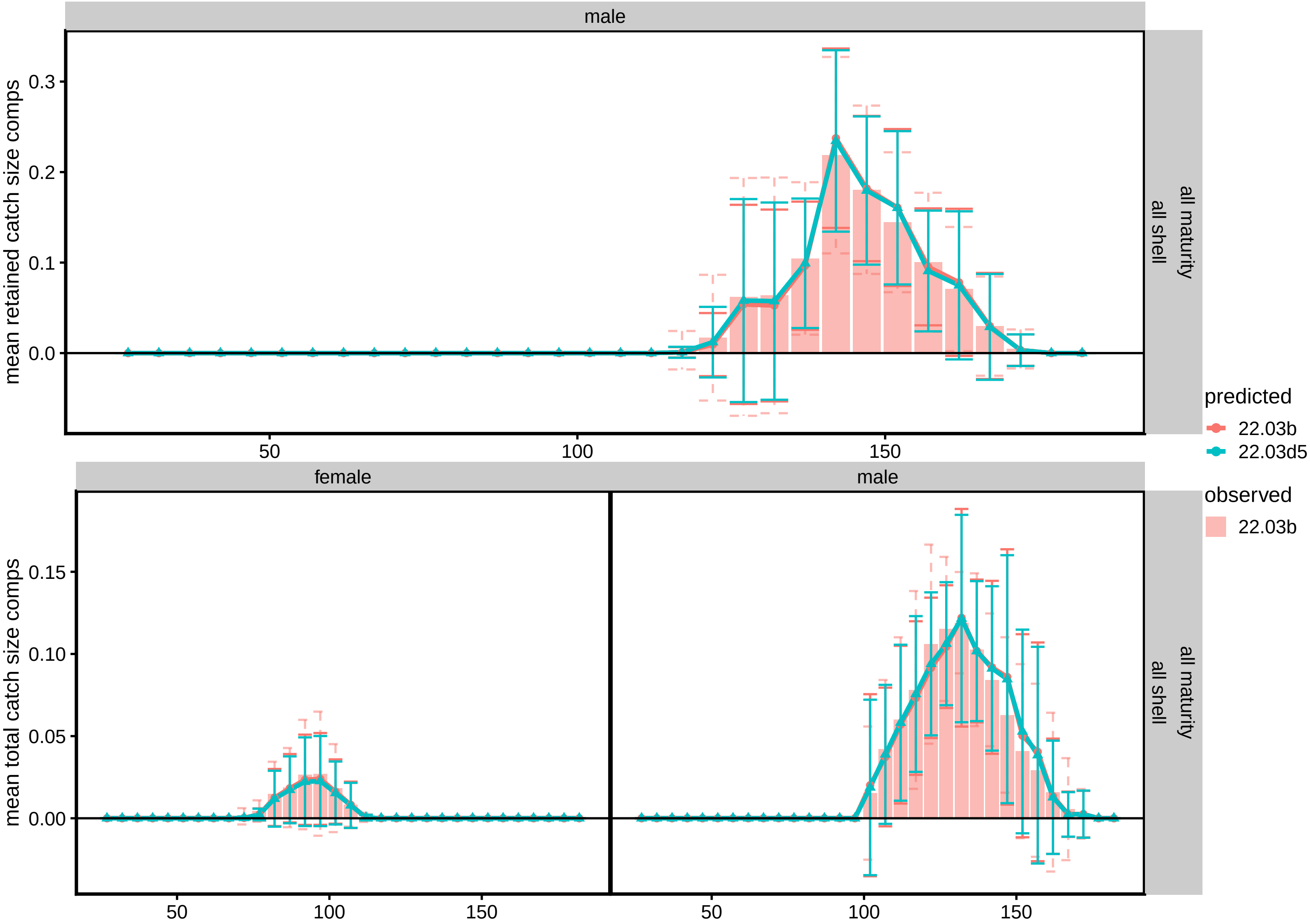

Figure 134. TCSAM02 models fits to directed fishery mean size compositions. Upper plot: retained catch; lower plot: total catch. Model 22.03d5 is the preferred model.

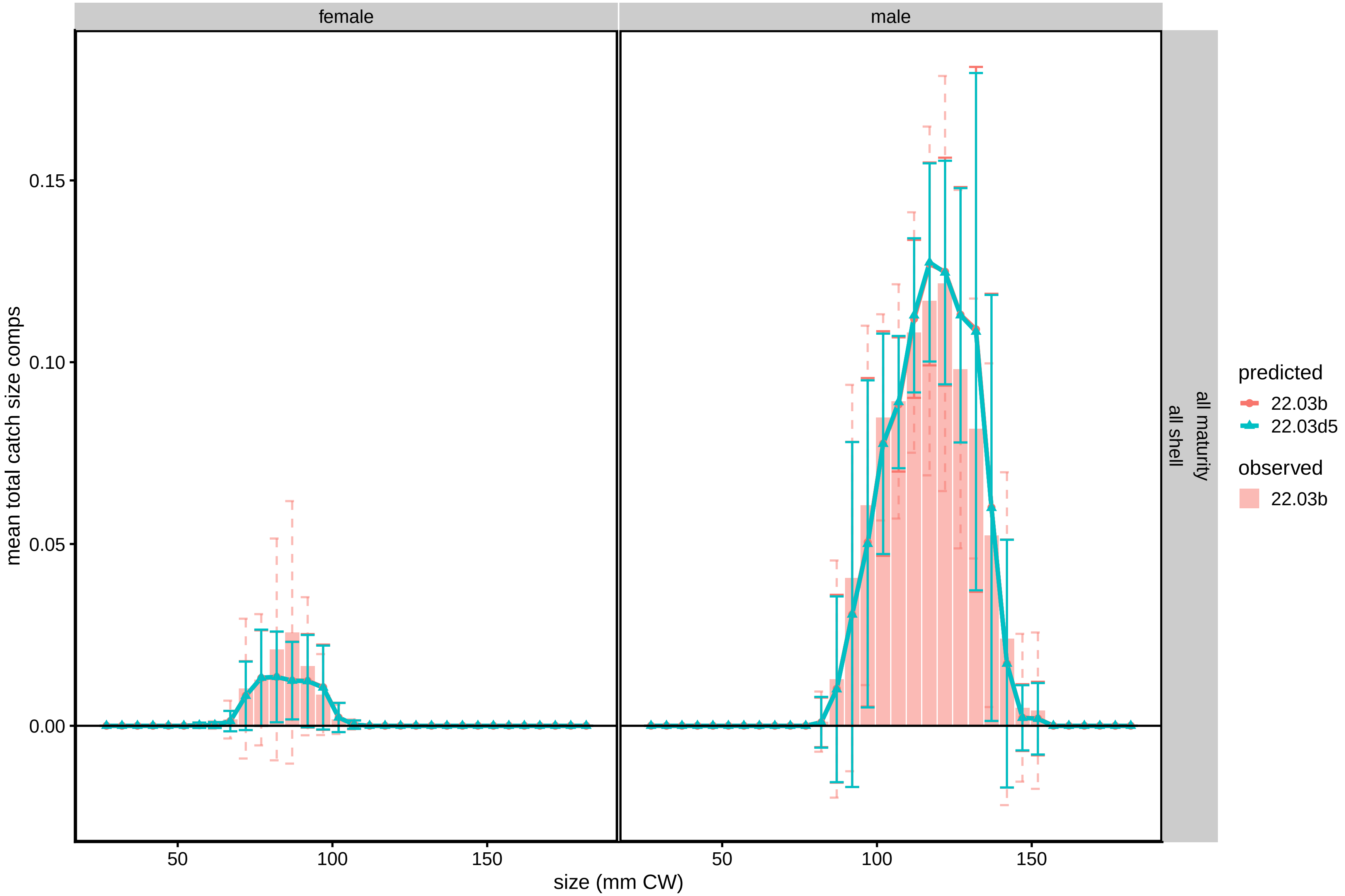

Figure 135. TCSAM02 models fits to mean bycatch size compositions from the snow crab fishery. Model 22.03d5 is the preferred model.

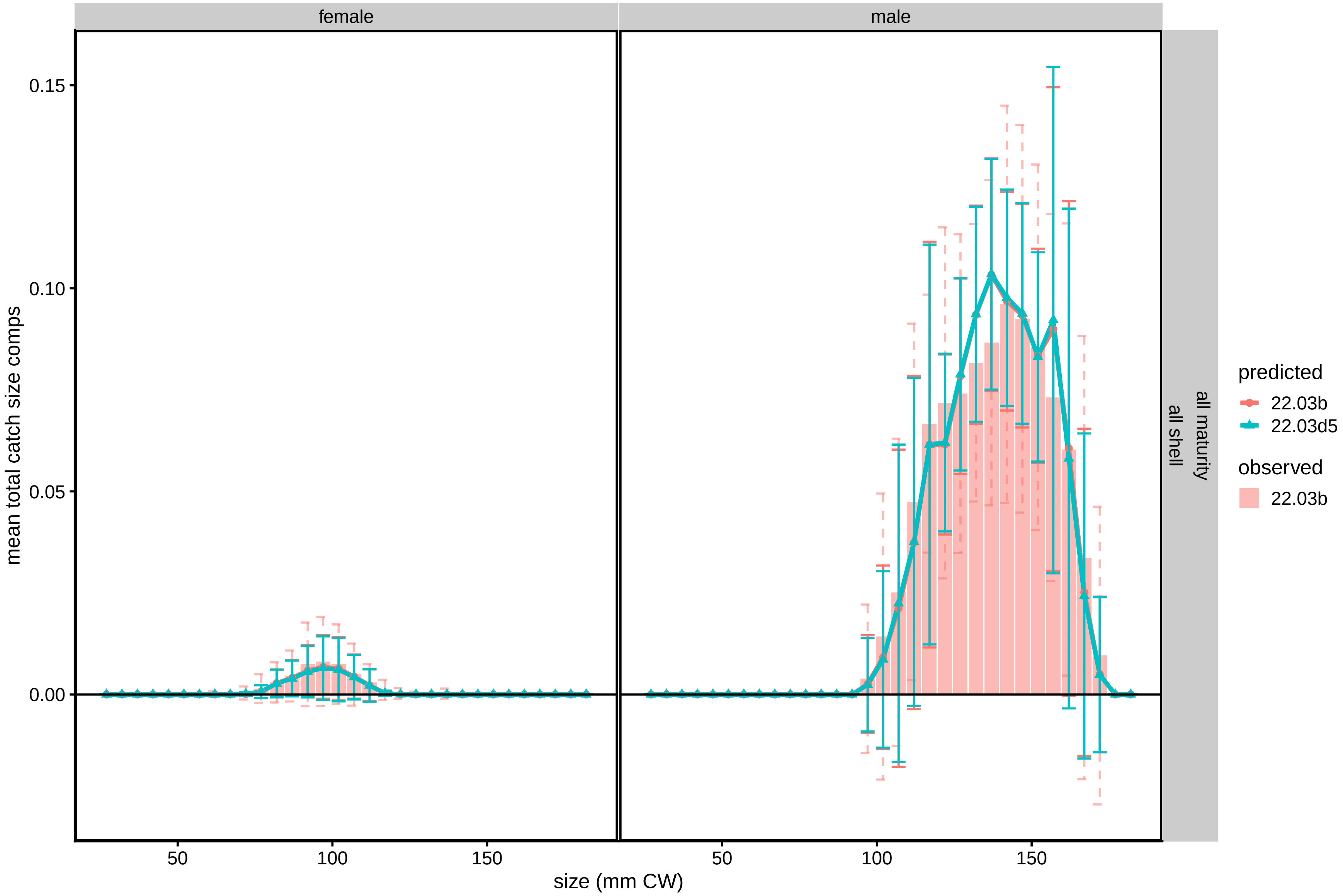

Figure 136. TCSAM02 models fits to mean bycatch size compositions from the BBRKC fishery. Model 22.03d5 is the preferred model.

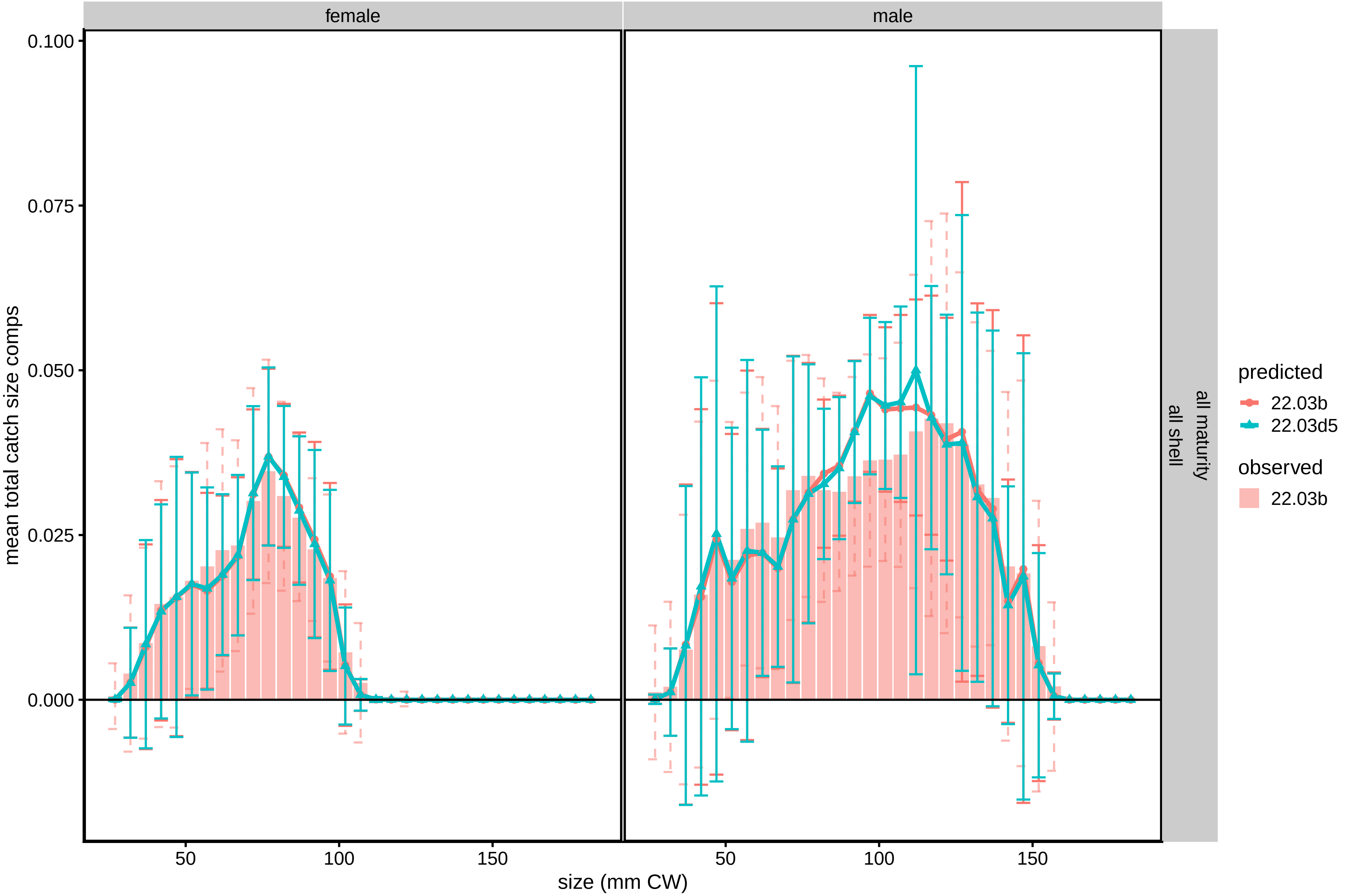

Figure 137. TCSAM02 models fits to mean bycatch size compositions from the groundfish fisheries. The total catch size compositions were normalized similarly for all model scenarios. Model 22.03d5 is the preferred model.

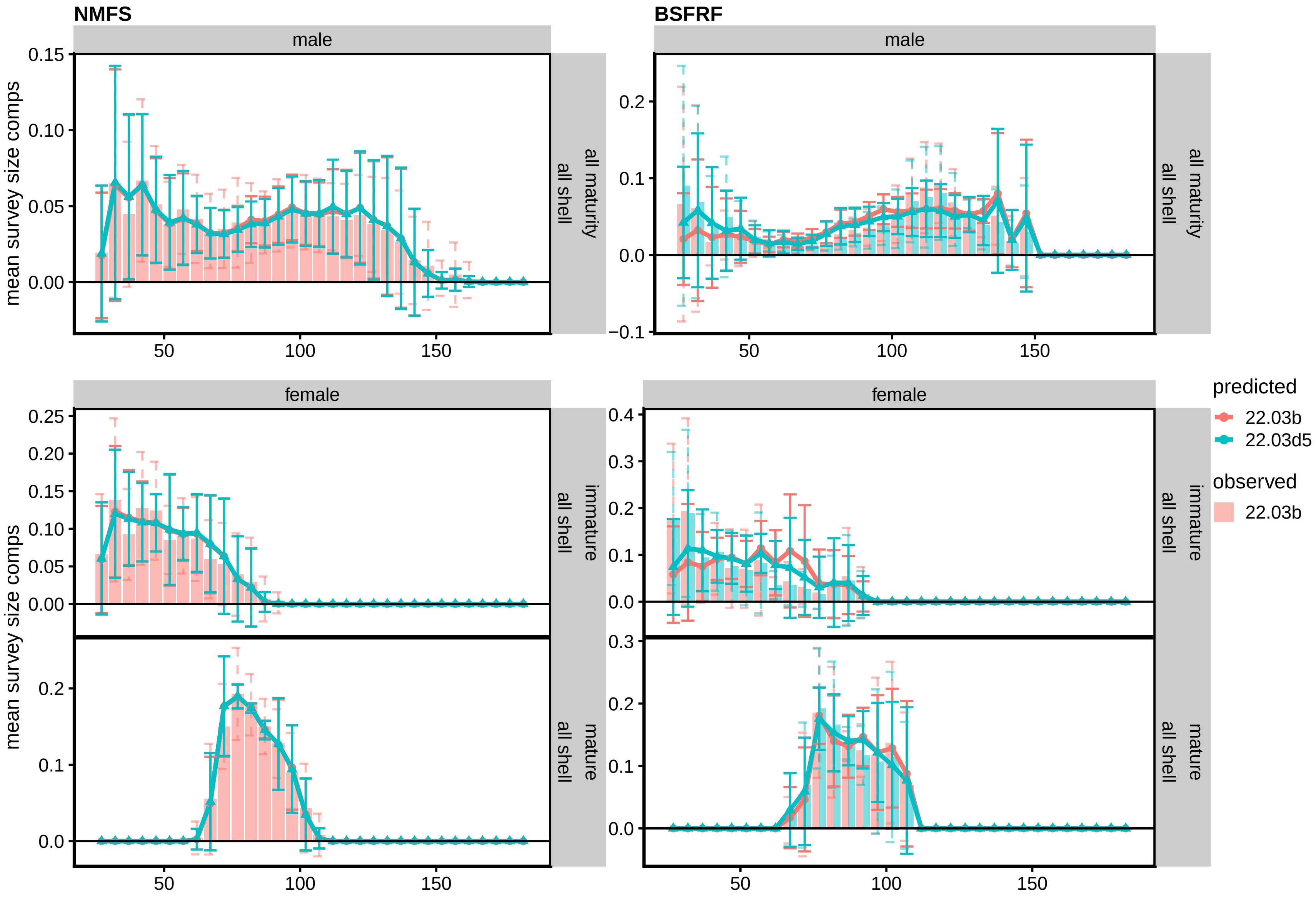

Figure 138. TCSAM02 models fits to mean survey size compositions from the NMFS EBS (left column) and BSFRF SBS (right column) surveys. The total catch size compositions were normalized similarly for all model scenarios.

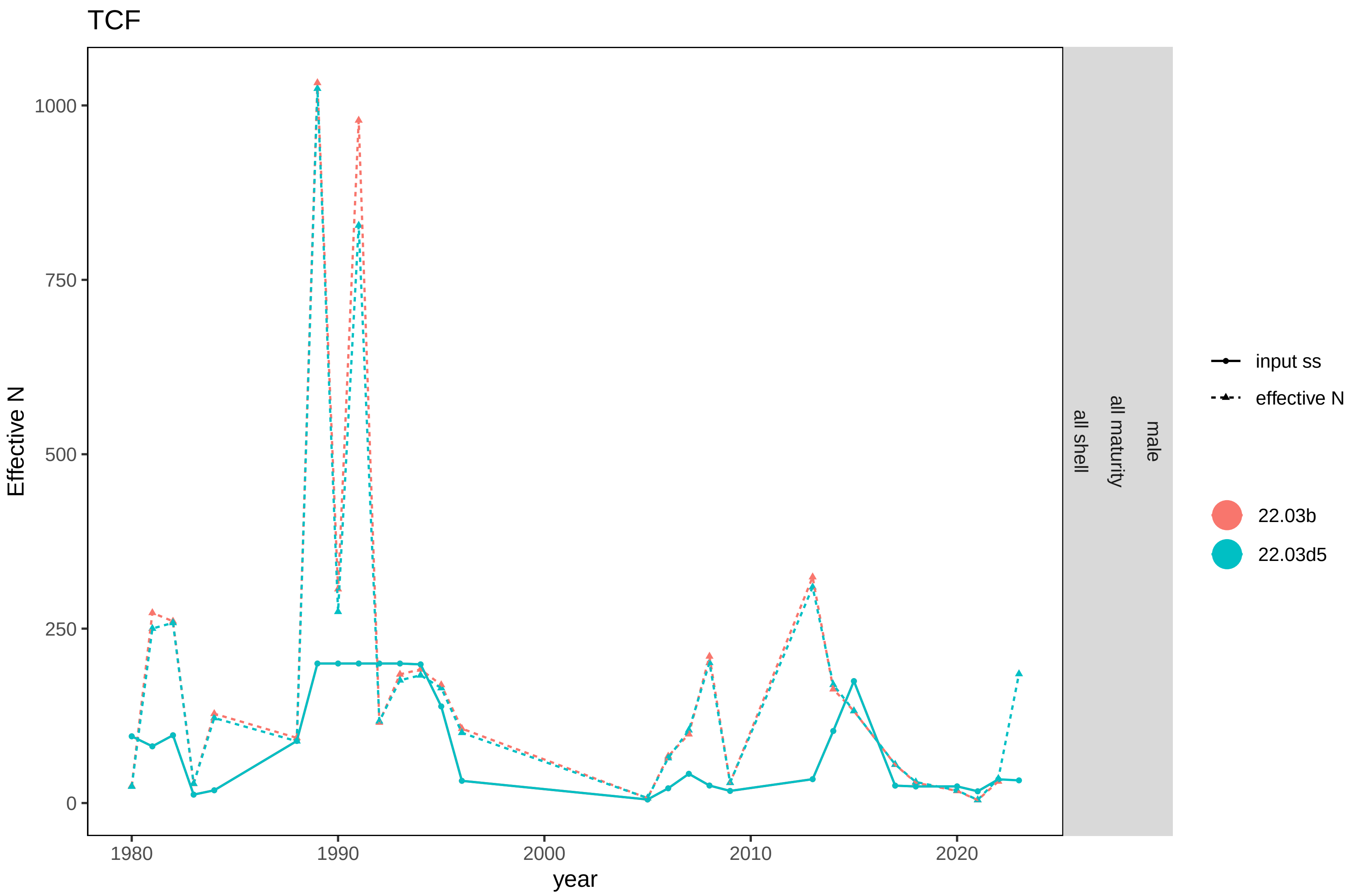

Figure 139. Effective sample sizes compared with input sample sizes for retained catch data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are constrained to a maximum of 200. Model 22.03d5 is the preferred model.

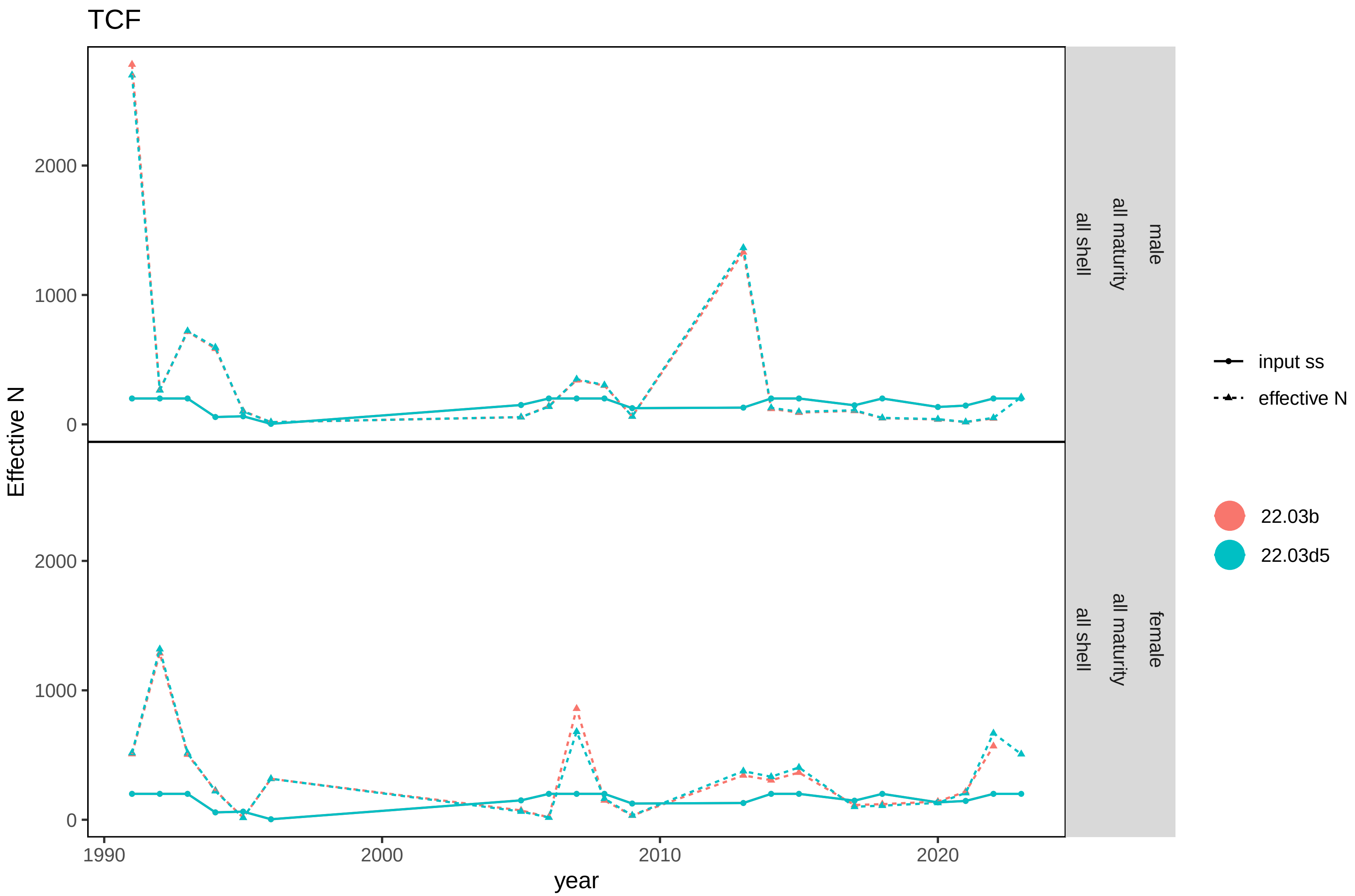

Figure 140. Effective sample sizes compared with input sample sizes for total catch data from the TCF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03d5 is the preferred model.

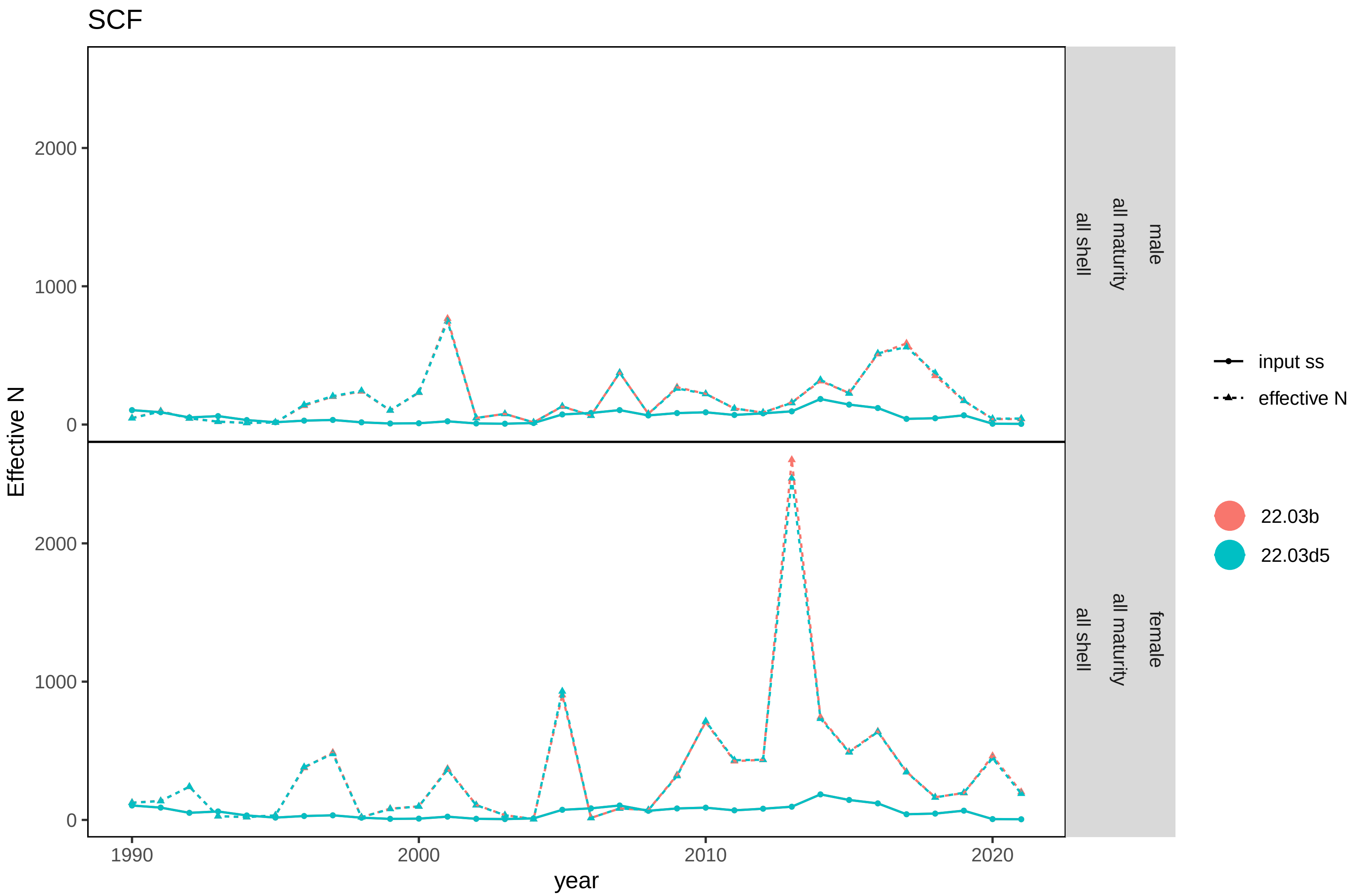

Figure 141. Effective sample sizes compared with input sample sizes for total catch data from the SCF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03d5 is the preferred model.

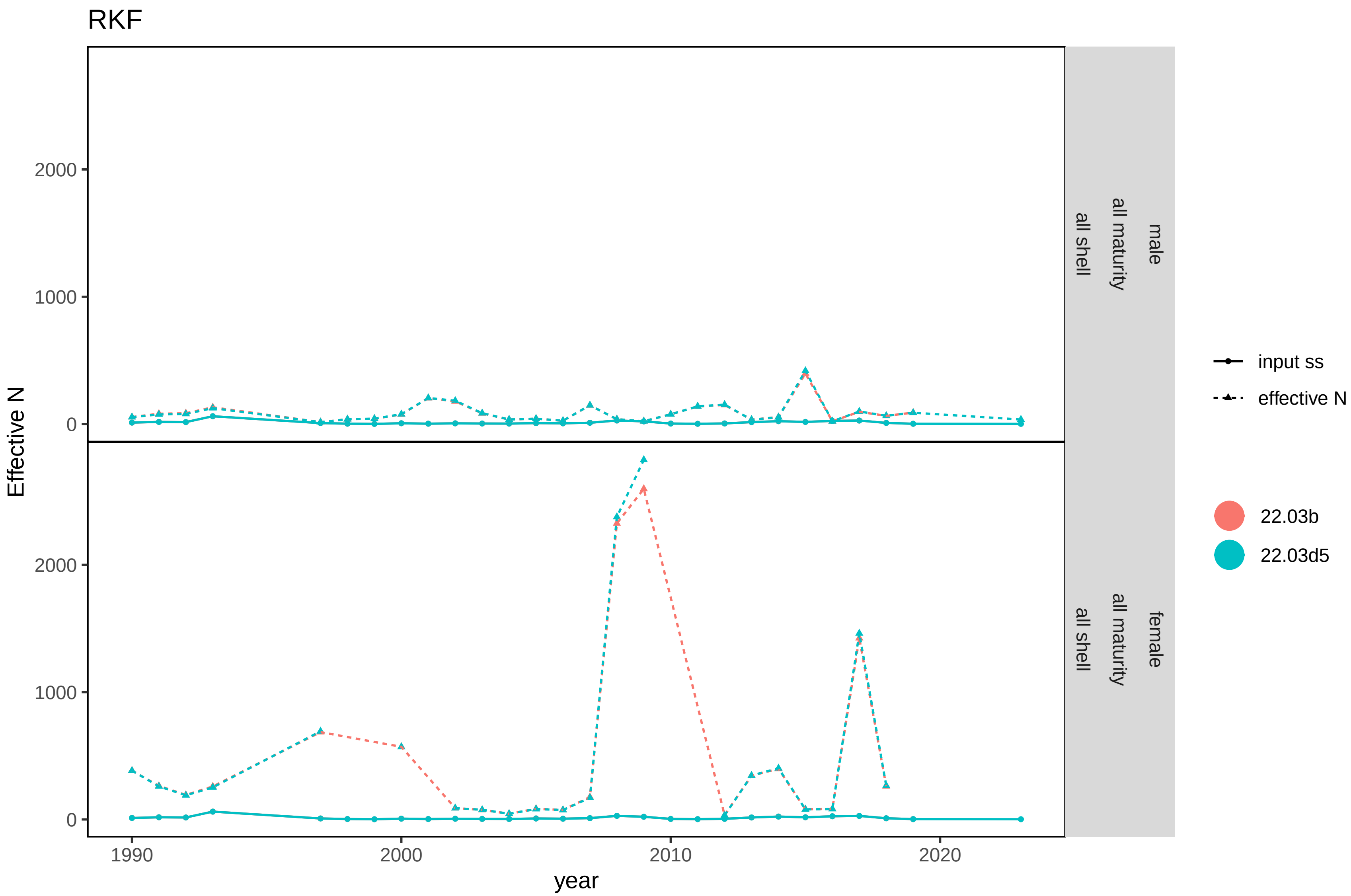

Figure 142. Effective sample sizes compared with input sample sizes for total catch data from the RKF fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03d5 is the preferred model.

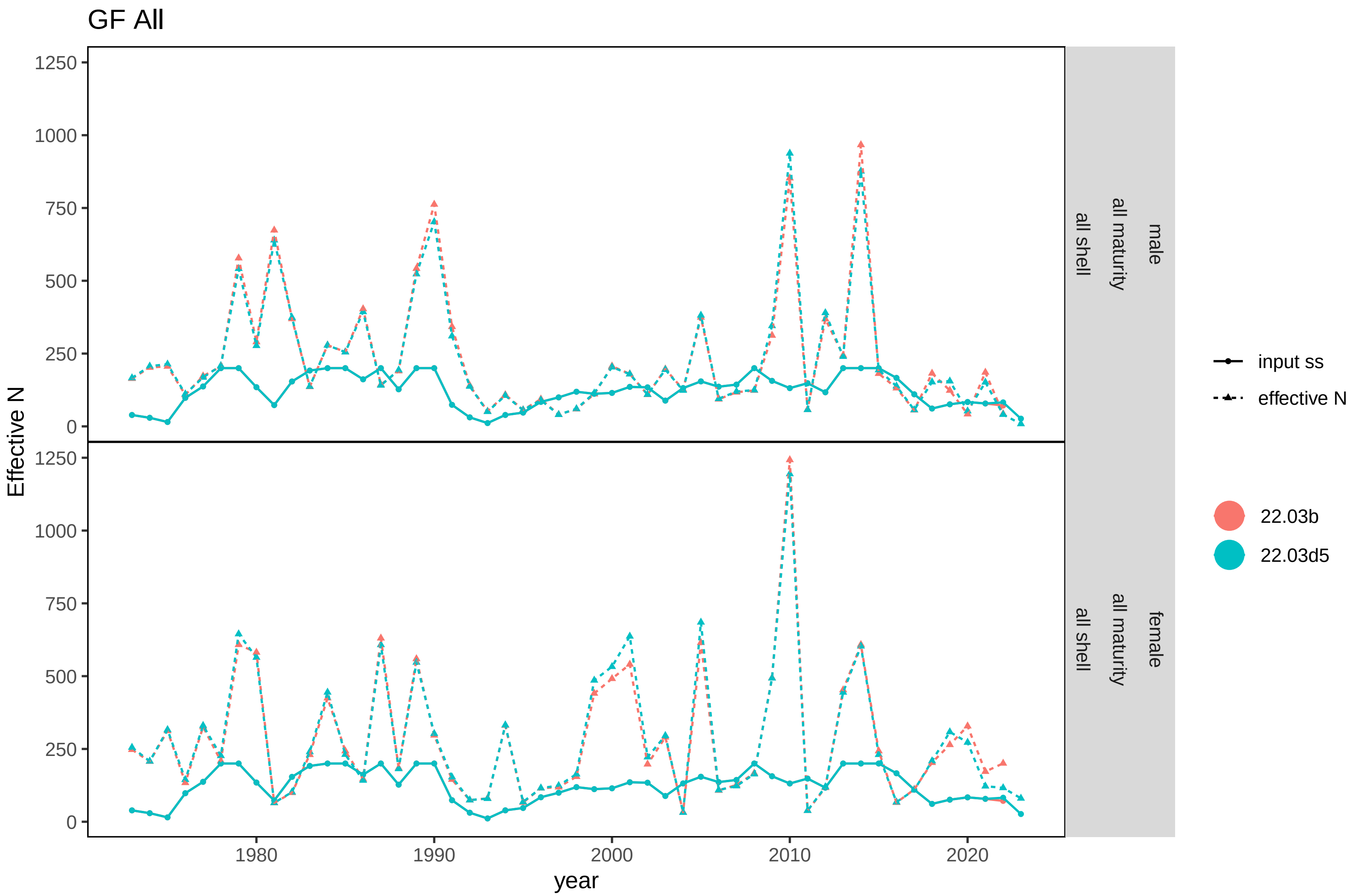

Figure 143. Effective sample sizes compared with input sample sizes for total catch data from the GF All fishery. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories. Model 22.03d5 is the preferred model.

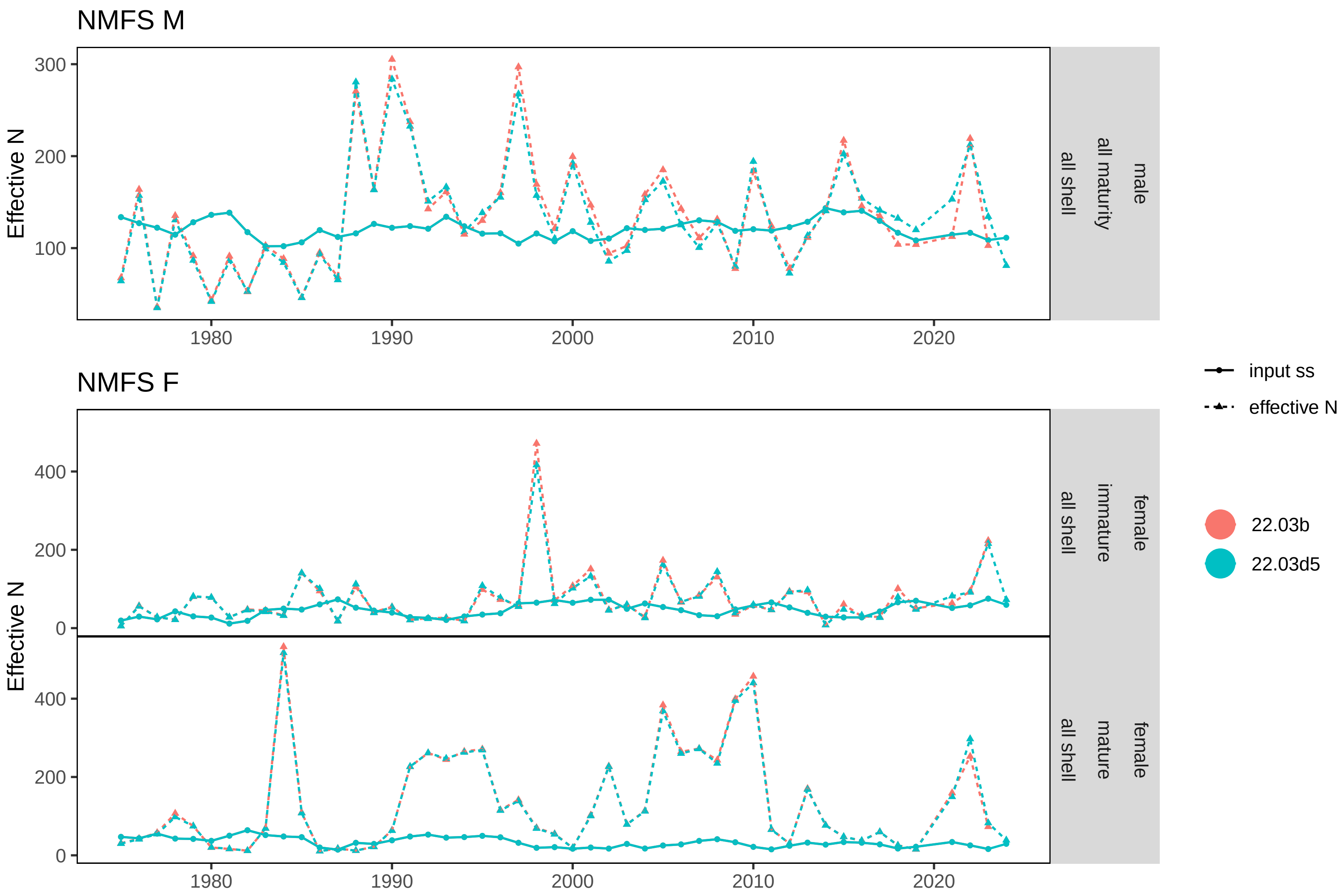

Figure 144. Effective sample sizes compared with input sample sizes for NMFS survey data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories.

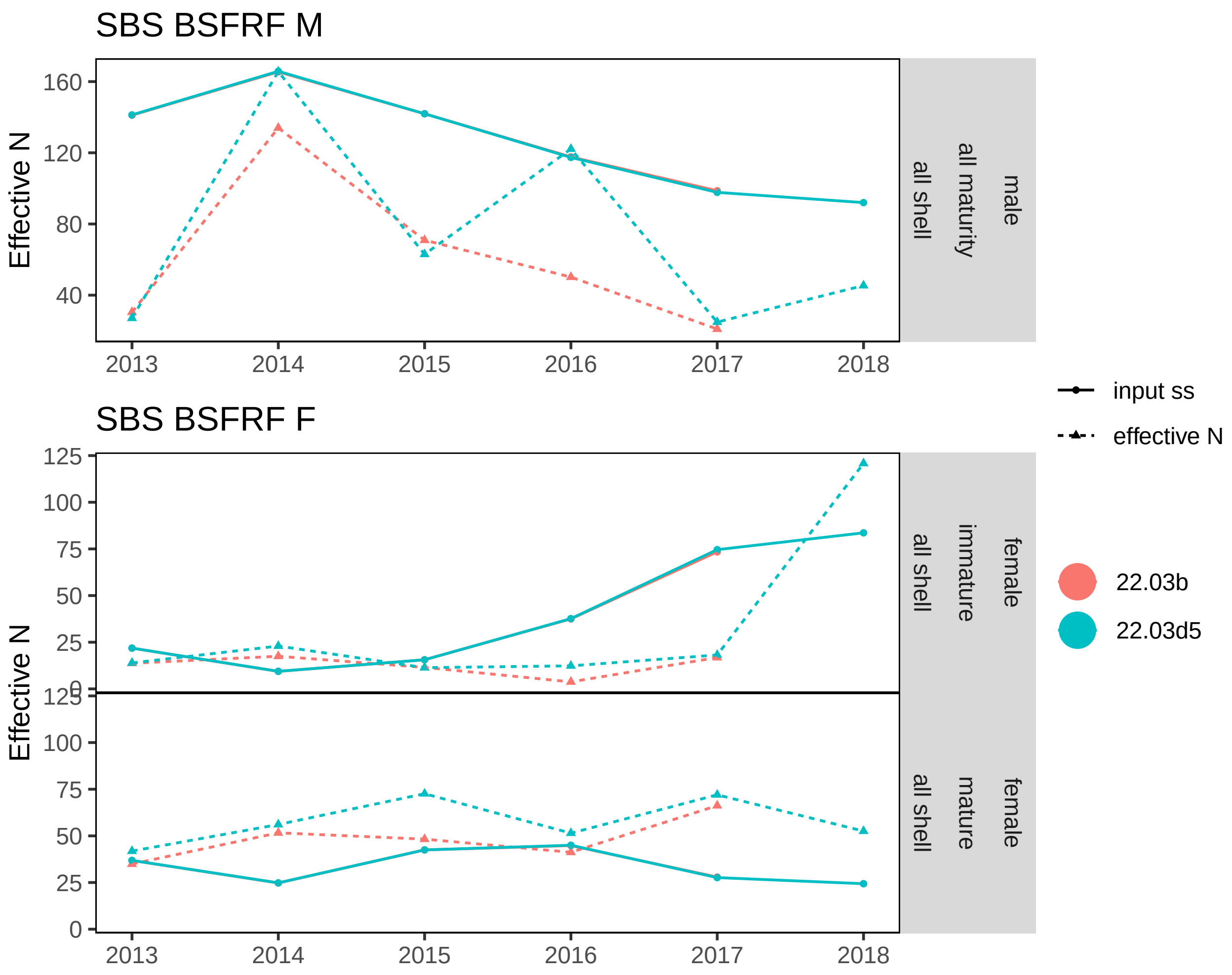

Figure 145. Effective sample sizes compared with input sample sizes for the BSFRF survey data. Dotted lines are effective N's, solid lines are input sample sizes. Input sample sizes are scaled to sum to 200 in each year across categories.

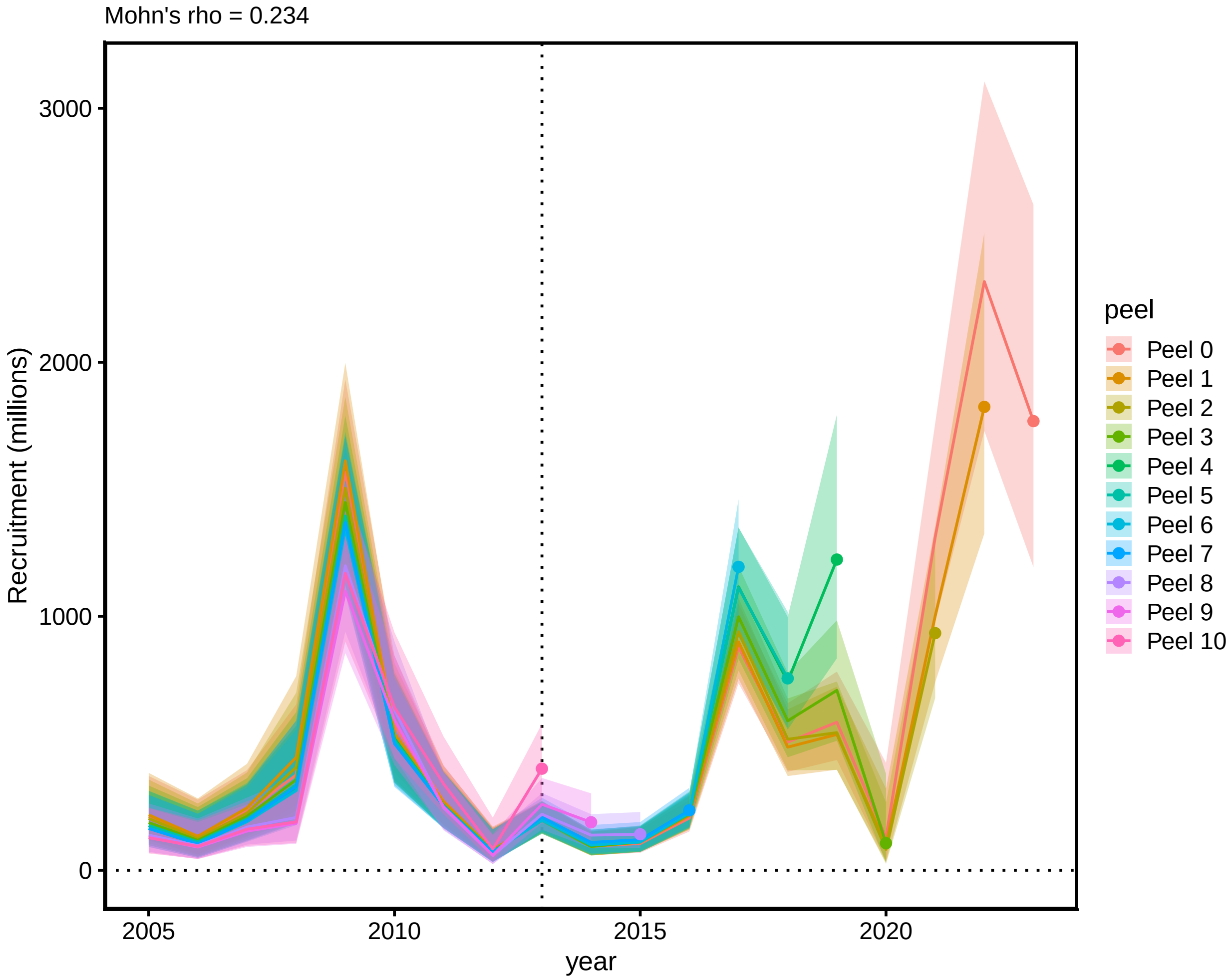

Figure 146. Retrospective analysis for recruitment time series, with Mohn's Rho value (0.234). Each "peel" represents results from the model run with that number of years of data removed from the complete data series. Lines: estimates; fills: 80% confidence intervals; points: end point of estimated time series for each peel.

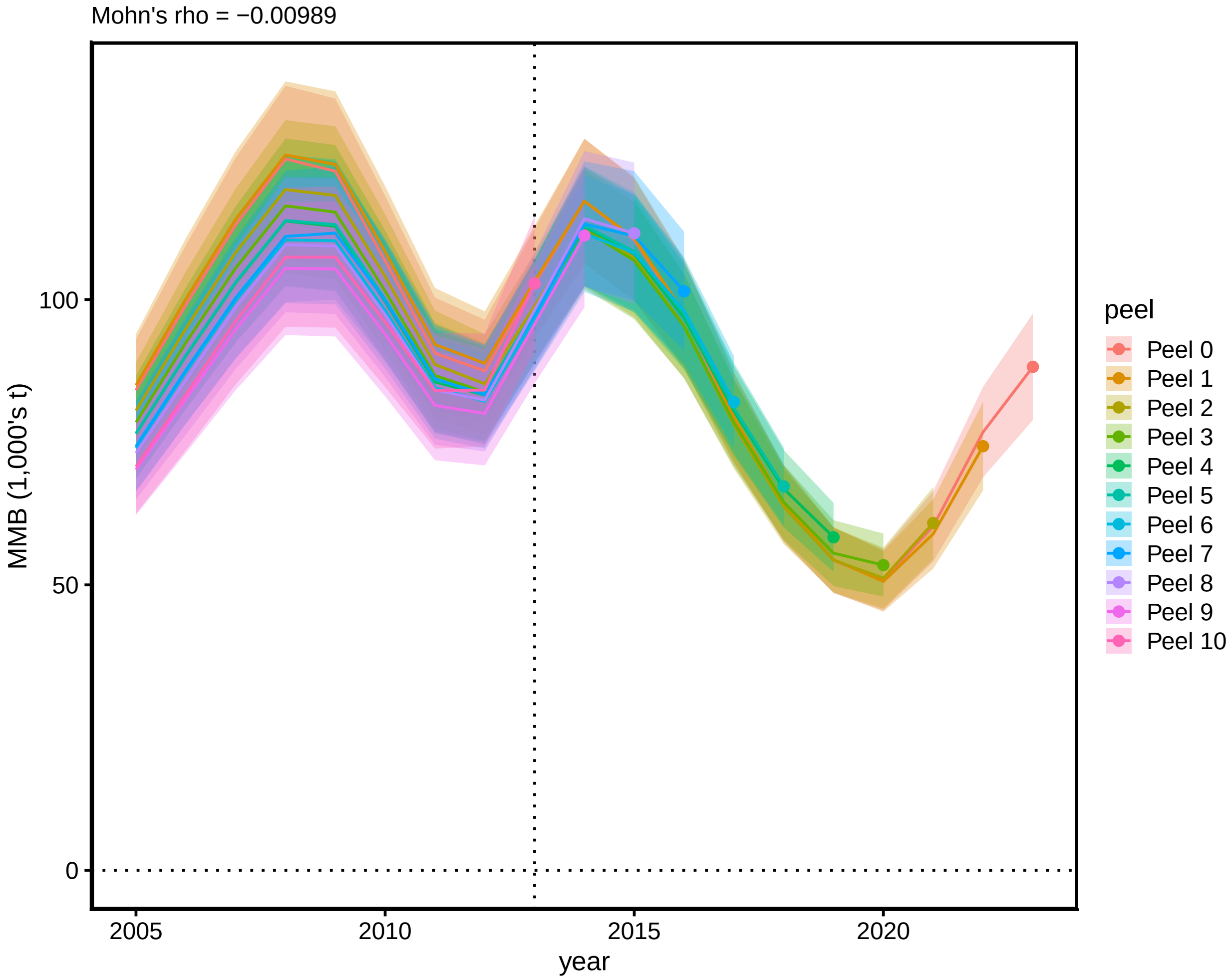

Figure 147. Retrospective analysis for mature male biomass time series, with Mohn's Rho value (-0.00989). Each "peel" represents results from the model run with that number of years of data removed from the complete data series. Lines: estimates; fills: 80% confidence intervals; points: end point of estimated time series for each peel.

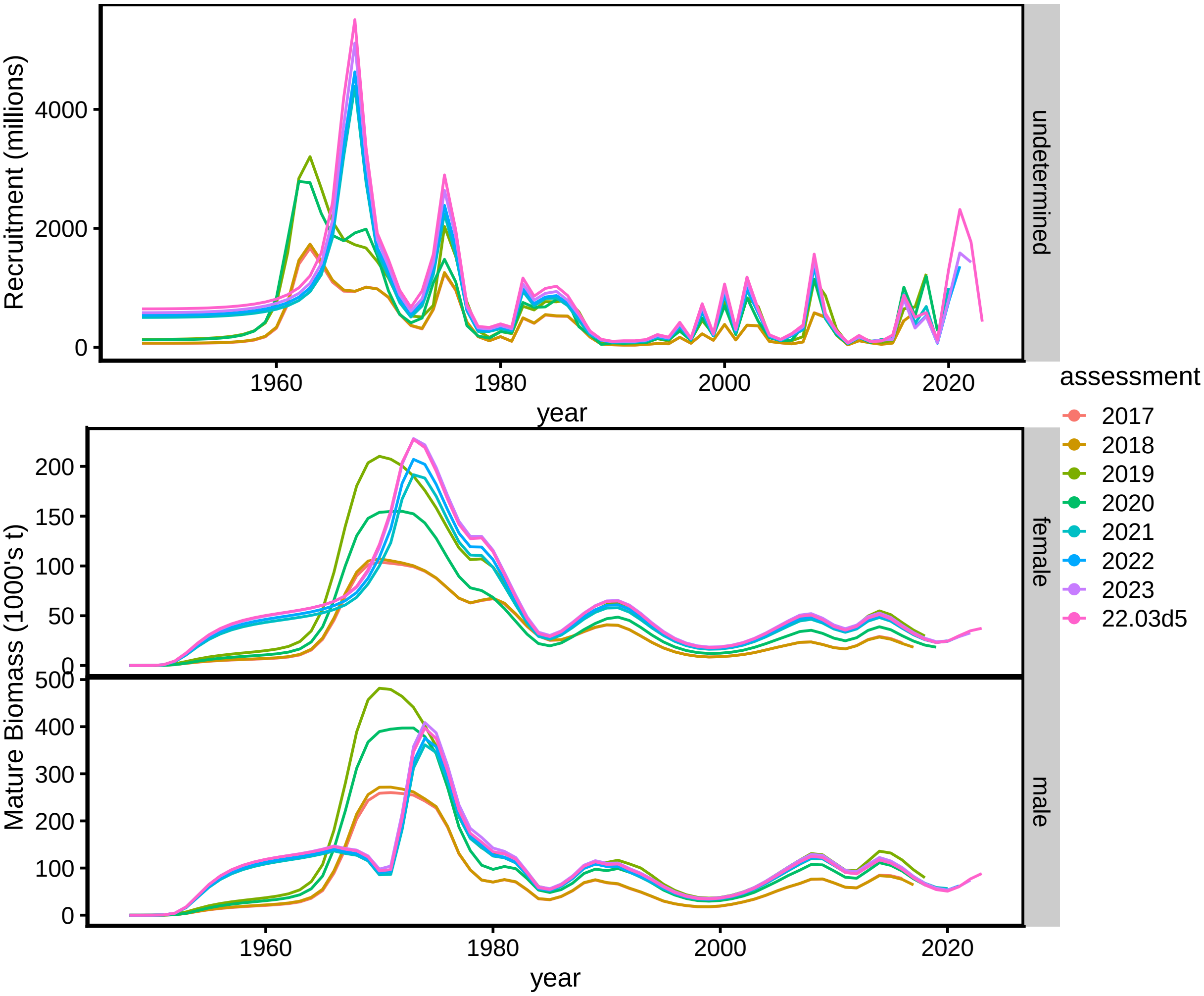

Figure 148. Comparison of estimated recruitment (upper plot) and mature biomass (lower plot) for the full model time period from the preferred model and previous assessments. Model 22.03d5 is the preferred model for this assessment.

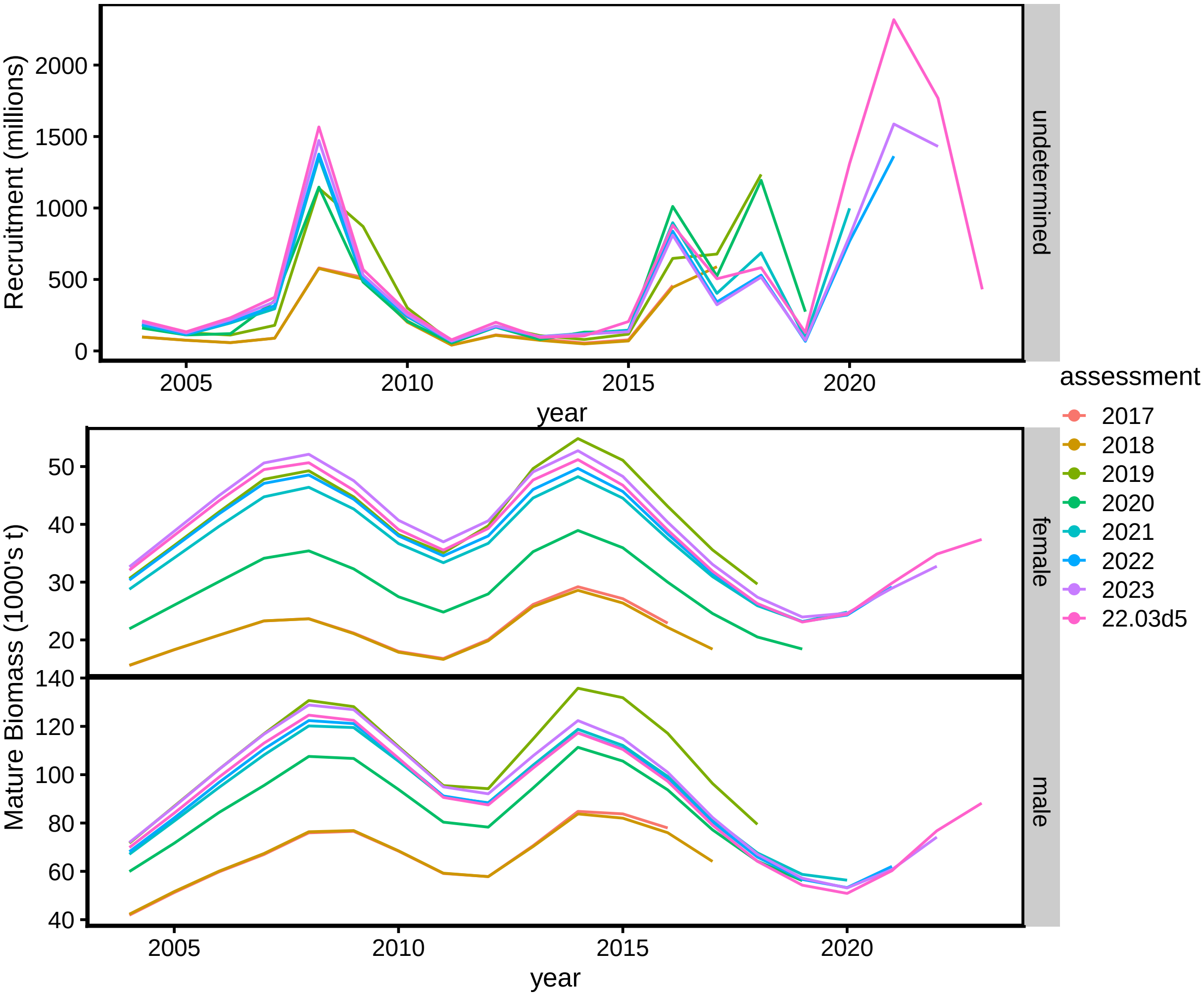

Figure 149. Comparison of estimated recruitment (upper plot) and mature biomass (lower plot) for the last 20 years from the preferred model and previous assessments. Model 22.03d5 is the preferred model for this assessment.

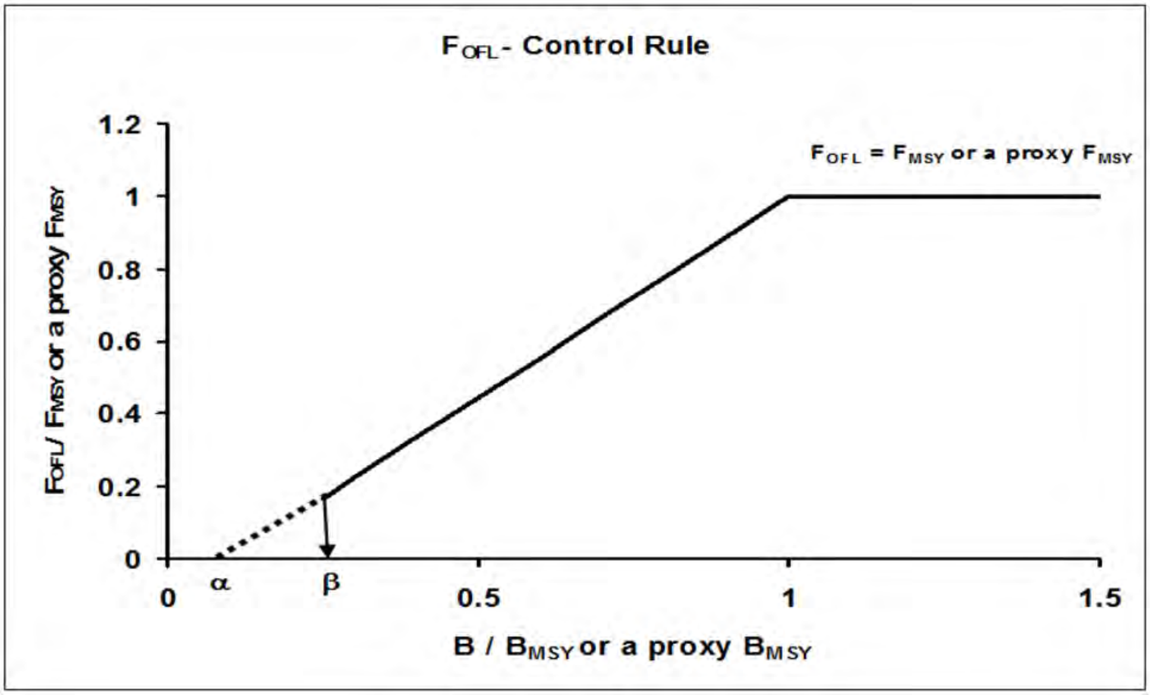

Figure 150. The F_{OFL} control rule.

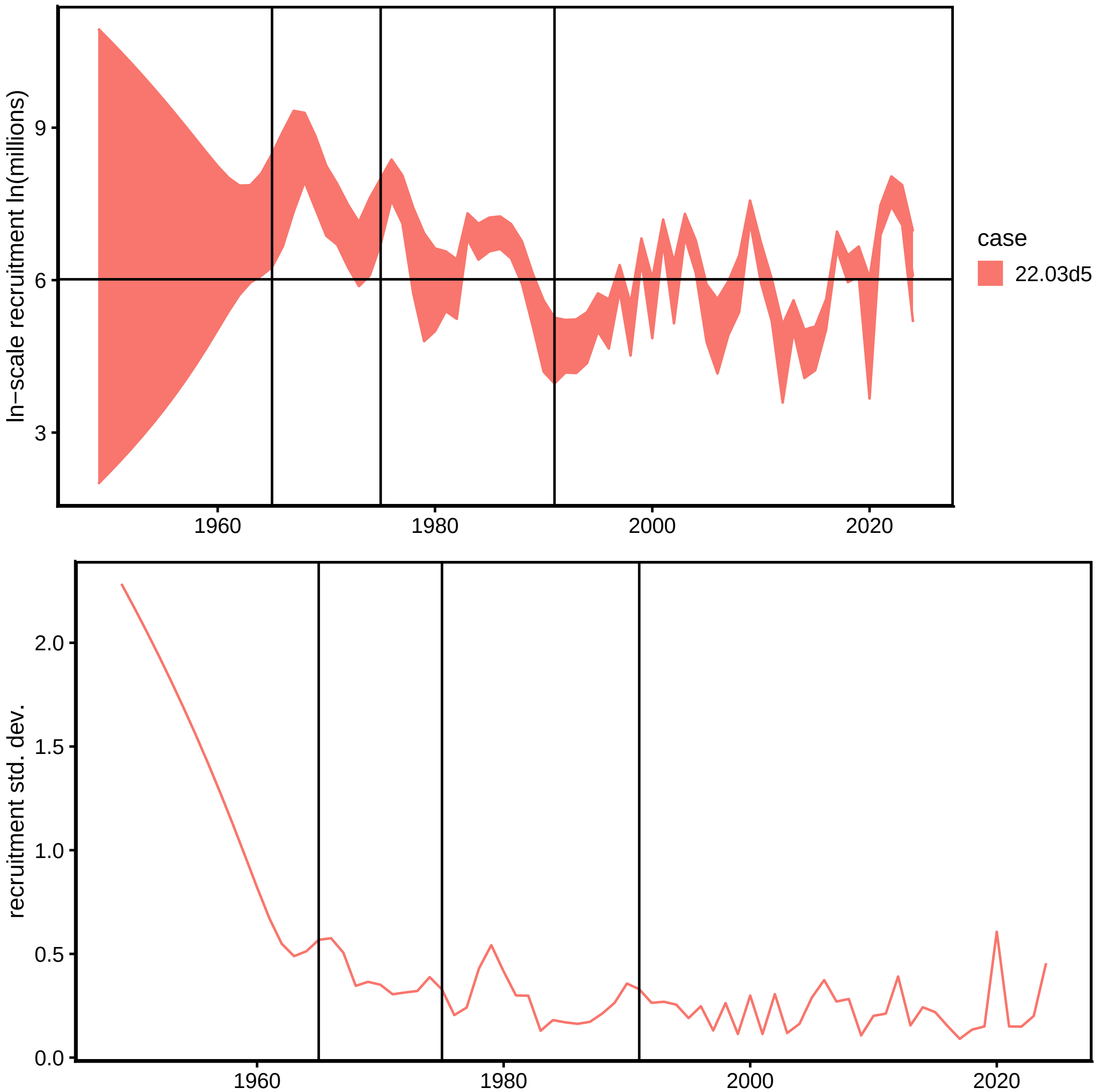

Figure 151. Upper plot: Time series of the estimated ln-scale recruitment, with 95% confidence intervals from the author's preferred model 22.03d5. Lower plot: time series of the estimated standard deviation for the ln-scale mean recruitment parameter from the author's preferred model 22.03d5. Vertical lines indicate 1965, 1975, and 1991.

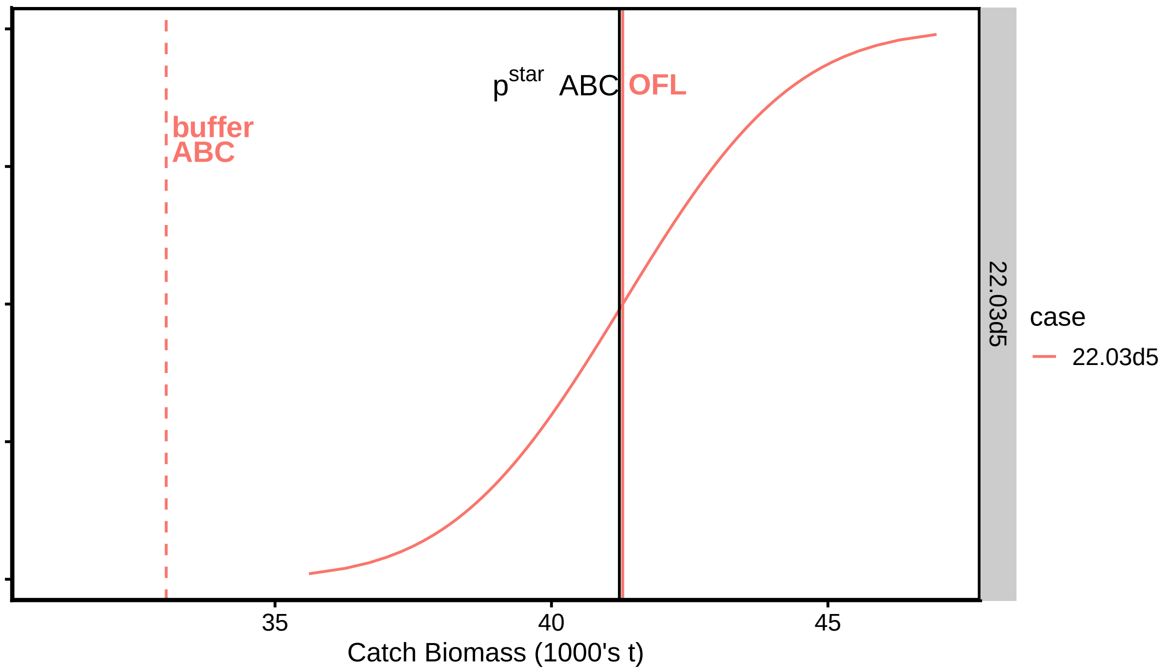

Figure 152. OFL and ABCs for the author's preferred model, 22.03d5

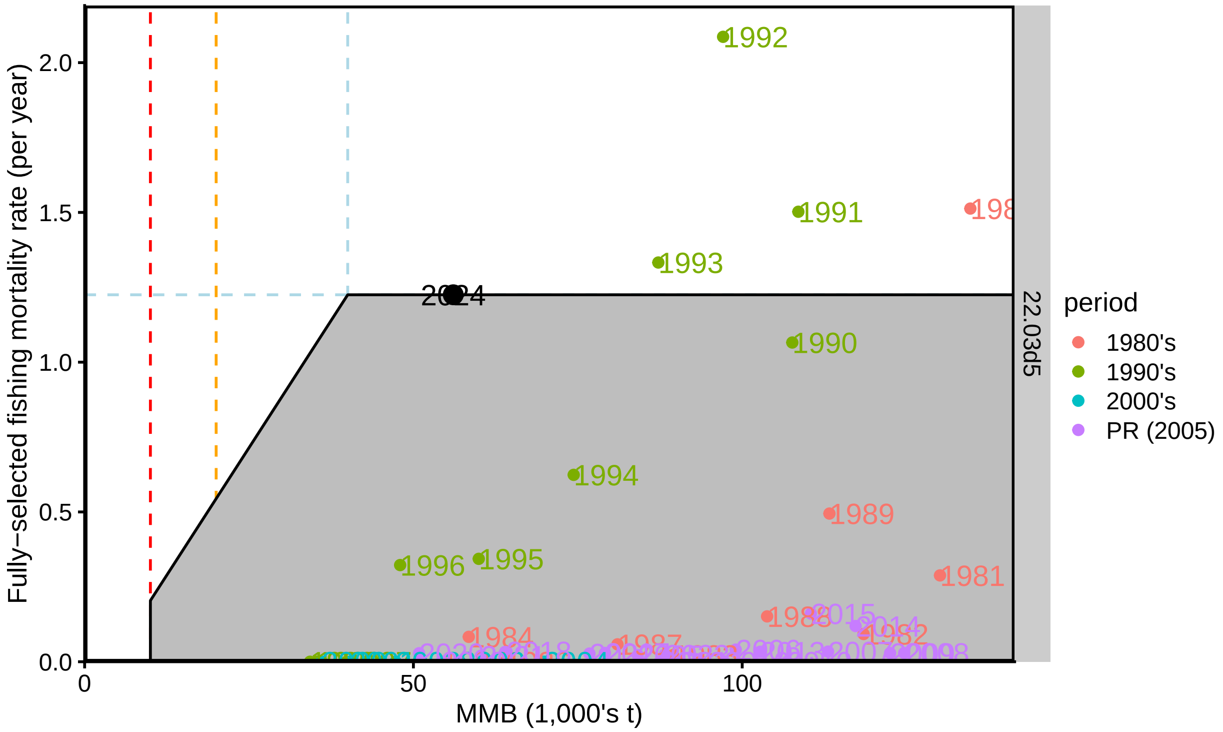

Figure 153. Quad plot for the author's preferred model, 22.03d5. Estimated values are shown starting in 1980. The value for 2024 assumes the OFL is taken in the upcoming fishing season. Colors refer to different time periods (PR: post-rationalization). Vertical dashed lines indicate: red–β; orange–MSST; blue–B_{MSY}. Horizontal dashed line indicates F_{MSY}.

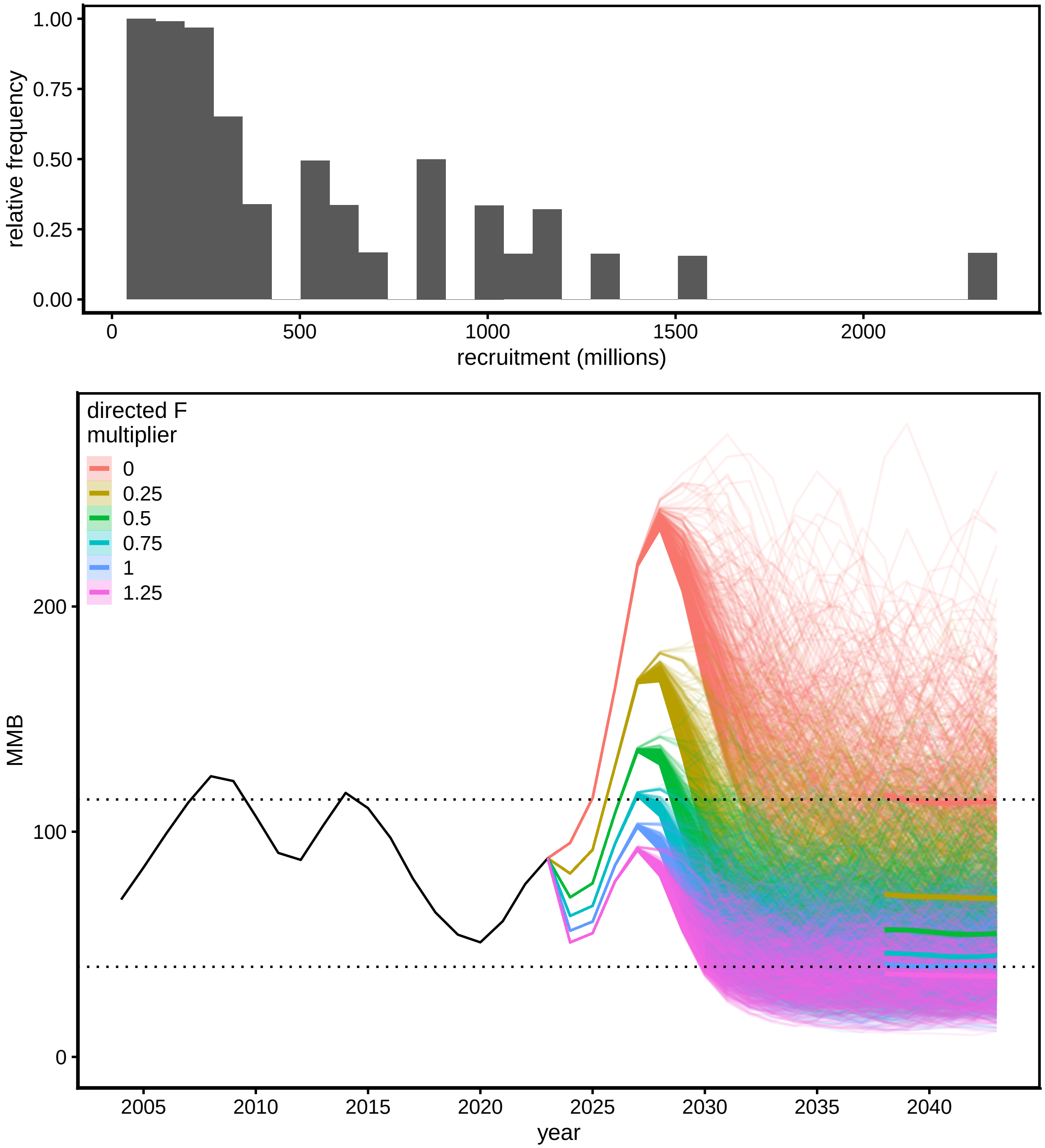

Figure 154. Multi-year projections using the preferred model, 22.03d5 under a range of directed F multipliers using randomly-resampled recruitment values. Upper plot: histogram of randomly-resampled recruitments. Lower plot: projected MMB trajectories under different F scenarios (colored lines); black line: ML estimate of MMB time series up to 2023/24 upper dotted line: expected mean unfished MMB (B_{100}), lower dotted line: $B_{MSY} = B_{35}$, thick colored lines at righthand side: scenario-specific annual means (last 5 years).

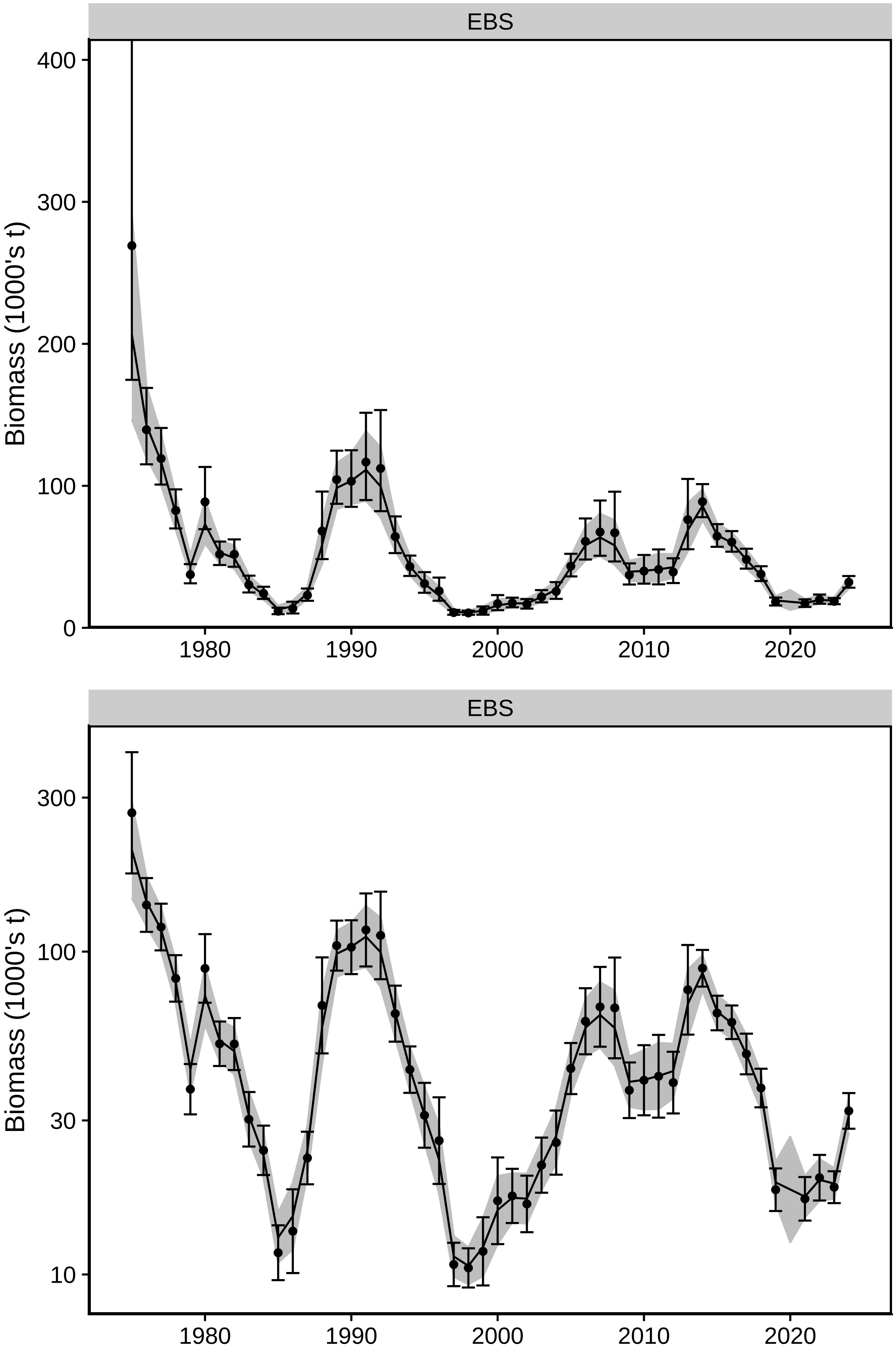

Figure 155. Estimated time series for vulnerable male biomass from the NMFS EBS shelf survey: 1) design based estimates (circles) and 80% lognormal confidence intervals (vertical bars); 2) random walk model-estimated time series (line) and 80% confidence intervals (shading). Upper plot: y-axis on arithmetic scale; lower plot: y-axis on log-scale.

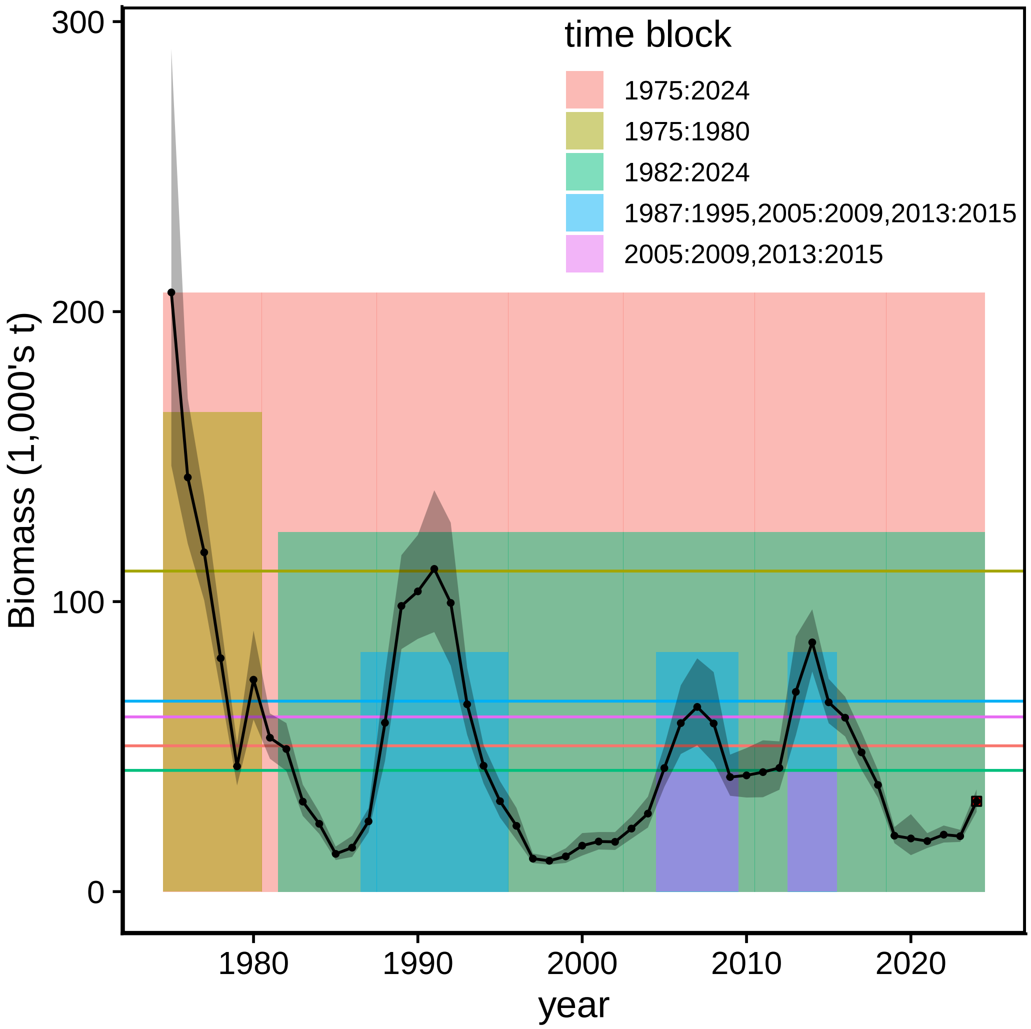

Figure 156. B_{MSY} proxies for different averaging time blocks. REMA-estimated vulnerable male biomass time series: black line and points (estimates), grey shading (80% confidence intervals). Colored rectangles indicate averaging time periods. Colored horizontal colored lines indicate resulting B_{MSY} proxy value.