2025 Tanner Crab Assessment Considerations

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2025-05-05

1 Introduction

The next full assessment for the Tanner crab stock will be reviewed by the Crab Plan Team (CPT) in September 2025 and the NPFMC's (North Pacific Fishery Management Council) Science and Statistical Committee (SSC) in October 2025. The stock is on an annual cycle for assessment, with the last full assessment conducted in September 2024 (Stockhausen 2024).

This report addresses several topics, including new analyses, potential (bespoke) Tanner Crab Stock Assessment Model (v.2; TCSAM02) models for the Fall 2025 stock assessment, and work to develop a Generalized Model for Assessing Crab Stocks (GMACS) version of the Tanner crab assessment model. Among new analyses (Section 3), the AFSC's Shellfish Assessment Program (SAP) has developed an R package, `crabpack`, as a replacement to AKFIN Answers (https://akfin.psmfc.org) for obtaining crab-related survey data in a standard format. SAP staff requested that assessment authors test the package and compare results of data pulls using the package with data pulled using the authors' previous methods. Results of this comparison are presented in Section 3.1. Model-based size compositions from the National Marine Fisheries Service (NMFS) Eastern Bering Seae (EBS) bottom trawl survey and estimated using the Vector Autoregressive Spatiotemporal (VAST; (Thorson et al. 2015)) `R` package are compared with standard design-based estimates in Section 3.4. Finally, in response to an SSC request to compare spatial ranges and environmental conditions between juvenile cohorts that succeed and those that fail, Section 3.5 provides a preliminary attempt to look at temperature and geographic conditions for two successful and one unsuccessful cohort of juvenile crab. Results from two models using the bespoke TCSAM02 framework are compared with results from the 2024 assessment assessment model in Section 4 to provide potential alternative models for the 2025 assessment. Finally, results from a GMACS model that attempts (but doesn't quite succeed) to duplicate the 2024 assessment model in the GMACS framework are presented in Section 5.

This report is organized into the following sections: Responses to previous CPT and SSC Comments (Section 2), Analyses (Section 3), TCSAM02 model runs and results (Section 4), GMACS model run and comparison with the current assessment model (Section 5), Summary (Section 6), and Acknowledgments (Section 7).

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

2.1 CPT Comments September 2024

2.1.1 CPT Comment (general)

None.

2.1.2 CPT Comment (specific to assessment)

The high priorities for future work includes completion of the BSFRF selectivity analysis to incorporate into the assessment model and work towards an acceptable GMACS Tanner crab model.

Response: (May 2025) The BSFRF selectivity analysis was presented at the January 2025 Modeling Workshop and is nearly complete. Curves based on the survey-level (not haul-level) analysis were used in alternative TCSAM02 model 25_02 as pre-specified capture probability (fully-selected catchability * selectivity). Model results are discussed in Section 4. Significant progress has been made towards an acceptable GMACS model (Section 5).

2.2 SSC Comments October 2024

2.2.1 SSC Comment (general)

The SSC would like to see additional residual diagnostics other than raw residuals for length composition data from GMACS models. The SSC encourages crab authors to collaborate with groundfish assessment authors regarding the use of One-Step-Ahead and Pearson residuals.

Response: (May 2025) One-Step-Ahead (OSA) residuals and DHARMa residual statistics are provided for most of the models discussed herein.

2.2.2 SSC Comment (general)

The SSC requests that the CPT consider whether distinguishing between full and update assessments, as in the protocol recently adopted for groundfish assessments, would be useful for crab assessments.

Response: (May 2025) As an author or reviewer, this distinction might be useful if the requirements for update assessments were reduced from those for full assessments.

2.2.3 SSC Comment (general)

The SSC suggests the CPT live link assessments and other documents in their report to facilitate review.

Response: (May 2025) If the SSC is requesting that links to figures and tables be provided in the text, that has been done in the Tanner crab assessment and other reports for several assessment cycles now (just tap the figure/table number). Otherwise, it is unclear to what the request refers.

2.2.4 SSC Comment (general)

CPT develop a process for ensuring that authors have provided a response to all previous (including at least, the last assessment) SSC recommendations.

Response: (May 2025) It would be helpful if SSC requests were extracted into a table. In particular, SSC comments that pertain to multiple stocks may only occur in the review for a single stock.

2.2.5 SSC Comment (specific to assessment)

While the SSC appreciates the author's attention to detail, the SSC highlights that the SAFE and the included Appendices are over 700 pages long, which makes review a daunting task. The SSC suggests that consideration should be given to streamlining the material included in future assessment documents.

Response: (May 2025) Specific suggestions for streamlining the assessment would be welcome. The SAFE guidelines prescribe a substantial number of topics to be addressed in an assessment, and this has grown in recent years with incorporation of risk tables and ESPs. The Appendices generally provide supplementary information related to, but not necessarily critical to, understanding and evaluating the assessment (e.g., exhaustive residuals plots) or they provide results from requested analyses. They should be regarded the same as "Supplementary Material" in a published paper.

2.2.6 SSC Comment (specific to assessment)

While this [fixing Dirichlet-Multinomial parameters] addresses the immediate issue [of the parameters hitting an upper bound], fixing parameters is not a long-term solution, and evaluation of whether these parameters can be reliably estimated should continue.

Response: (May 2025) Agreed, although a D-M parameter hitting an upper bound simply implies that the size composition and associated sample size being evaluated are consistent with a multinomial distribution. The input sample sizes for most size compositions fit in the Tanner crab model have already been substantially down-weighted from the number of crab sampled, so an associated D-M parameter hitting its upper bound is not surprising.

2.2.7 SSC Comment (specific to assessment)

The draft risk table noted increased concern for population dynamics in part due to uncertainty in the quantification of reproductive output. The SSC suggests this uncertainty is more associated with the stock assessment, rather than population dynamics.

Response: (May 2025) Noted. The concern will be moved to the "stock assessment" column of the table.

2.2.8 SSC Comment (specific to assessment)

Directly incorporate annual molt to maturity data, as implemented in the EBS snow crab assessment, if sufficient data are available.

Response: (May 2025) As has been noted previously (see below), this would require substantial development work to implement in TCSAM02. A GMACS model implementing *annual* molt to maturity data has been developed but time did not allow re-running the model for this report after issues with the GMACS code were identified (and subsequently corrected). The GMACS model discussed in this report (Section 5) uses the mean molt to maturity curve based on the annual data.

2.2.9 SSC Comment (specific to assessment)

Explore 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. 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 2025) A preliminary analysis (see Section 3.5) suggests differences in temperatures experienced by the "successful" and "unsuccessful" cohorts.

2.2.10 SSC Comment (specific to assessment)

[…] the SSC notes that for a number of years, the author and CPT have expressed concerns that the recommended models are overly optimistic. The SSC recommends exploring the reason for this characterization through exploring likelihood profiles and other diagnostics and sensitivities of important scale related parameters (e.g., natural mortality, catchability and mean recruitment).

Response: (May 2025) Likelihood profiles were run for log-scale mean recruitment, male survey catchability, and base natural mortality. Preliminary results suggest that the three are substantially correlated (Figures 1 and 2). Further analysis will be presented in September.

2.3 CPT Comments May 2024

2.3.1 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: (May 2025) While substantial progress has been made toward a more complete bridging analysis (including debugging new features in GMACS required to implement a Tanner crab model), the task is not yet complete.

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

2.3.2 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 Bering Sea Research Foundation side-by-side (BSFRF SBS) haul study size compositions near their upper bounds.

2.4 SSC Comments June 2024

2.4.1 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 Bristol Bay red king crab) BBRKC stocks, and specifically consider developing the results as a prior on selectivity for use in the models

Response: (May 2025) The analysis is almost complete for Tanner and BBRKC crab. It appears that incorporating haul-level environmental effects may not be possible, presumably due to small joint size-specific sample sizes between the BSFRF and NMFS hauls.

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.

2.4.2 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.

2.4.3 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.

2.4.4 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.

2.4.5 SSC Comment

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

Response: (May 2025) See related response above.

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.

2.4.6 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.

2.4.7 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.

2.4.8 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: (May 2025) See response to CPT comment above.

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.

2.4.9 SSC Comment

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

Response: (May 2025) VAST-derived size compositions for Tanner crab are compared with their design-based counterparts in Section 3.4. Given time constraints, a model incorporating the VAST-derived size compositions has not yet been developed.

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.

2.4.10 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: (May 2025) See response to Oct 2024 comment above. 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.

2.5 CPT Comments January 2024

2.5.1 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.

2.5.2 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 (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.

2.5.3 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.

2.5.4 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: (May 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.

2.5.5 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: (May 2025) 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.

2.6 SSC Comments February 2024

2.6.1 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: (May 2025) VAST-derived size comps are compared with their design-based counterparts in Section 3.4. Time constraints did not allow incorporation into an assessment model.

Sept 2024: Noted.

2.6.2 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 Analyses

3.1 `crabpack`

The ASFC's Shellfish Assessment Program (SAP) has introduced `crabpack`, a new `R` package (R Core Team 2022) to access NMFS EBS crab survey data and subsequently estimate annual abundance, biomass, and size compositions by year for several population categories (e.g., sex, maturity state). The tcsamSurveyData `R` package has been used previously with survey haul data files downloaded from AKFIN Answers to provide similar information for the Tanner crab assessment (e.g., Stockhausen 2024). Here, the two approaches are compared for EBS-wide abundance, biomass, and size compositions for NMFS EBS crab survey data from 1975 to 2024.

3.2 Survey abundance estimates

Estimates of EBS-wide abundance from the NMFS bottom trawl survey for male and female Tanner crab by maturity state are compared by year in Figure 3 for calculations made in the 2024 assessment (Stockhausen 2024) and with the `crabpack` R package. Absolute differences and percent differences between the two methods are shown in Figures 4 and 5. The percent differences are also shown in Table 1. The figures and table show excellent agreement between the two methods in all survey years except 1979, when estimates from the two methods differ substantially ($> 10\%$). The estimates from the assessment are less than those from `crabpack` in 1979. The differences in the two methods apparently reflect differences in the hauls included in the calculation (`crabpack` appears to include hauls at corner stations that were only conducted in 1979, while these were excluded in the standardized time series used in the assessment).

3.3 Survey biomass estimates

Estimates of EBS-wide biomass from the NMFS bottom trawl survey for male and female Tanner crab by maturity state are compared by year in Figure 6 for calculations made in the 2024 assessment (Stockhausen 2024) and with the `crabpack` R package. Absolute differences and percent differences between the two methods are shown, respectively, in Figures 7 and 8. The percent differences are also shown in Table 2 to two decimal places.

As with abundance, the figures and table demonstrate excellent agreement between the two methods in all survey years prior to 2016 except 1979, when estimates from the two methods differ substantially (> 10%). Unlike the abundance estimates, the two methods also exhibit small differences (< 5 %) in 2016 and subsequent years. The estimates from the assessment for 2016 and later are larger than those from `crabpack` in all years. The post-2015 differences may reflect differences in the size used to calculate the weight of individual crab: the assessment uses carapace width to the first decimal place while `crabpack` apparently uses the carapace width to 1-mm.

3.4 VAST size compositions

Size data from the annual NMFS EBS bottom trawl survey provides important information on the size distribution of Tanner crab on the EBS shelf. Tracking changes in size composition through time allows the Tanner crab assessment model (e.g., Stockhausen 2024) to estimate growth and natural mortality, determine stock status and recommended harvest levels, and predict legal biomass. To date, the assessment has used design-based estimates of total abundance-at-size in 5-mm size bins from 25 mm to 180 mm to characterize the annual survey size distributions by sex and maturity state for the Tanner crab stock in the EBS. However, model-based methods provide alternative ways to calculate these size distributions. Recently, J. Richar (AFSC) used the `VAST` [the Vector Autogressive Spatiotemporal; Thorson et al. (2015); Thorson and Barnett (2016); Thorson and Kristensen (2016)] `R` package to estimate survey size compositions for males, immature females, and mature females. Below, the results from `VAST` are compared with the design-based size compositions for Tanner crab in the NMFS EBS crab survey data from 1975 to 2024.

3.4.1 Size compositions

While size compositions estimated using the design-based and `VAST` methods generally agree with each other in the overall shape, the design-based estimates tend to be somewhat larger than the `VAST` estimates–most noticeably at peaks in the individual (annual) compositions (Figures 9-11).

3.4.2 Total abundance comparisons

Comparisons of the time series of total abundance (i.e., the size compositions summed over size) by year and population category better reveal the differences in overall scale between the design-based and `VAST` size compositions (Figure 12). The design-based values can be substantially different from the `VAST`-based values (>20% difference; Table 3) and are generally larger for all three population categories, although counter-examples (1979, for example) are evident as well.

3.5 Small crab success

Small Tanner crab encountered during the NMFS EBS bottom trawl surveys in 2003-2005 and 2008-2010 successfully propagated to larger sizes while the cohort first observed in 2017-2019 did not (Figure 13). The SSC requested that the author explore whether the “successful” cohorts showed differences in habitat use compared with the “unsuccessful” one that may have contributed to their success. Furthermore, the SSC recommended 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. Below, I present some simple comparisons between the cohorts using NMFS EBS bottom trawl survey data with regards to the bottom temperatures experienced by small crab (Figures 14 and 15), overlap with large crab (Figures 16 and 17), the distribution of small crab with respect to the joint distribution of bottom temperature and large crab abundance (Figures 18-20), and finally the geographic distributions of the cohorts with respect to location on the EBS shelf and relation to the cold pool (i.e., bottom temperature < 2°C; Figure 21). Bottom temperature was chosen because it is important for physiological processes and regulating feeding, respiration, and growth. Large crab CPUE was chosen because of the possibility that predation by, or competition with, large crab might have a substantial effect on small crab survival. Both were co-extensive with small crab abundance in the survey data.

The small crab in all three cohorts were exposed to a range of bottom temperatures from ~-2 to ~6°C. Survey CPUE peaked in the 4 to 6°C range for all three cohorts (Figure 14), but crab in the "successful" cohorts experienced lower mean temperatures across the range of crab densities (Figure 15) when compared with the 2017-2019 "unsuccessful" cohort.

There seemed to be little difference between the cohorts in terms of the densities of large crab experienced by small crab, or the densities of small crab associated with large crab (Figures 16 and 17). The "successful" cohorts appeared to occupy a wider range of temperature and large crab densities than the "unsuccessful" cohort, in which most crab were associated with warm temperatures and low large crab densities (Figures 18-20). The location and size of the cold pool varied annually in relation to spatial extent of the three cohorts, with no clear pattern apparent (Figure 21). It was small and located to the northwest during 2003-05, extensive during 2008-10, and started out extensive but then essentially disappeared after the first year in 2017-2019.

The one clear difference between the "successful" cohorts and the "unsuccessful" cohort is mean bottom temperature, with the "successful" cohorts experiencing colder temperatures relative to those experienced by the "unsuccessful" cohort. A more nuanced analysis might pull out more subtle relationships, but any further analysis faces the issue of small sample size (only three cohorts) and the potential for identifying spurious relationships. Expanding the time frame considered to the entire period covered by the NMF survey might increase the sample size by a factor of three or four successful/unsuccessful cohorts over the 50 year extent of the survey. Further work needs to be done in coordination with SAP and perhaps be led by analysts developing the Tanner crab Ecosystem and Socioeconomic Profile (ESP).

4 TCSAM02 alternative models

4.0.1 Base model: 22.03d5

The model selected for the 2024 assessment, Model 22.03d5, provides the base model for the alternative models considered here. A detailed description of the model is given in Stockhausen (2024). The following three tables briefly summarize the parameterization and time blocks for the biological and fishery processes incorporated in this model:

Table A. Population processes and parameterization in the base model, 22.03d5.

process	time blocks	22.03d5 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 B. Characteristics for retention and total catch in the directed ("TCF") fishery and bycatch in the snow crab ("SCF") fishery in the base model, 22.03d5.

Fishery/process	time blocks	22.03d5 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 C. Characteristics for bycatch in the BBRKC ("RKF") and groundfish fisheries ("GF All") in the base model, 22.03d5.

Fishery/process	time blocks	22.03d5 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
GF All	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 22.03d5.

Table D. Characteristics for the NMFS and BSFRF surveys in the base model, 22.03d5.

Survey/process	time blocks	22.03d5 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	2013-2018	fixed at 1 for all sizes
male availability	2013-2018	empirically-determined outside the model
female catchability	2013-2018	fixed at 1 for all sizes
female availability	2013-2018	empirically-determined outside the model

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

Table E. Likelihood components in the base model, 22.03d5.

Model	Component	Type	included in optimization	Fits	Likelihood distribution
22.03d5	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

4.0.2 Alternative models

Three models were considered as alternatives to 22.03d5 for the 2025 stock assessment. Every size composition in 22.03d5 had 5% compression applied to each tail prior to calculating the associated likelihood. Model 25_01 eliminated this compression. The observation errors associated with the aggregate survey biomass indices in 22.03d5 were assumed to be lognormally distributed, with the implication that model prediction errors for these data were scored on a relative scale (i.e., a 20% error at high observed biomass was scored the same as a 20% error at low observed biomass). Model 25_01a was built on 25_01 but assumed that observation errors in the survey biomass time series were normally distributed, with the implication that model prediction errors were scored on an absolute scale (thus, a 5t error at high biomass was scored the same as a 5t error at low biomass).

Model 25_02 partially addresses an SSC request to drop the BSFRF side-by-side data from the model but use it to provide a prior on NMFS survey capture probabilities. Model 25_02 was also built on 25_01, but dropped fitting the BSFRF data and replaced estimating sex-specific NMFS survey selectivity curves and fully-selected catchability coefficients in the 1982-2024 time frame with sex-specific NMFS survey "capture probability" (fully-selected catchability ∗ size-specific selectivity) curves estimated from the BSFRF side-by-side haul studies (Figure 22). The estimated capture probabilities were based on the "survey level" analysis of the side-by-side data. However, the estimated curves suggest that capture probabilities are somewhat dome-shaped and decrease from maxima at intermediate sizes, although the uncertainty associated with these declines is very large due to the relatively small number of large crab caught in the surveys. Whether this tendency is real, and not an artifact of the data, seems unlikely. Consequently, the capture probability curves used in Model 25_02 were assumed to reach asymptotes at the maxima (the dotted lines in Figure 22).

The three alternative models appeared to converge to their maximum likelihood estimates (MLEs): maximum gradients for all three models were 0 after the ADMB "hess_step" procedure and standard errors were obtained for all estimated parameters (Table F). Parameter jittering was not attempted due to time limitations. Model 25_01a converged with a single parameter estimated at its (upper) bound, but the remaining alternative models converged with no parameters at a bound. Results for Model 22.03d5 were taken from the 2024 assessment.

Table F. Convergence results for the TCSAM02 models.

model configuration	**number of parameters**	**no. of param.s at bounds**	**objective function value**	**max gradient**	**invertible for std. devs?**
22_03d5	357	0	3182.00	1.78E-02	yes
25_01	357	0	3452.13	0.00E+00	yes
25_01a	357	1	3836.80	0.00E+00	yes
25_02	353	0	3057.96	0.00E+00	yes

Estimates of size-specific growth and probability of undergoing the molt to maturity were nearly identical for all models (Figure 23). Estimates of natural mortality rates by sex and maturity stage were also very similar between the base model and 25_01, with slightly larger differences between it and the other two models (< 0.025, though).

Large scale differences occurred among the models for estimated recruitment and mature biomass, with the largest estimates from Model 25_01a (~28% larger, on average after 1981), the smallest from 25_02 (~11% smaller); the base model and 25_01 had more similar estimates (25_01 on average ~6% larger; Figure 24). For mature biomass, the differences between 25_01a and 25_02 and the other two models increased, with estimates from Mopdel 25_01a ~33% larger on average, and 25_02 ~28% smaller, than 22.03d5 (Figure 25). However, the estimated recruitment and mature biomass trends followed similar overall trajectories in all four models.

The estimated fully-selected fishery capture rates (not necessarily mortality) in the models exhibited essentially the same temporal behavior across the models, but differed somewhat in scale (Figure 26). The scales generally exhibited the opposite relationship to those for recruitment and mature biomass: rates from 25_02 were generally higher than those from the base model but rates from 25_01a were generally lower. The estimated selectivity and curves (not shown) were extremely similar among the four models for all four fisheries, so the scales of the fishery capture rates, for a given fishery, were not related to differences in selectivity patterns among the models.

The differences in the scales of recruitment, mature biomass, and fishing mortality appear to be directly related to the differences among the models in the estimates of NMFS survey capture probability (Figures 27 and 28). Similar to the fully-selected fishing mortality rates, the capture probabilities are larger for 25_02 and smaller for 25_01a compared with the base, while the curves for 25_01 are very similar to the base.

The fits to fishery retained and total catch biomass are very good and display no significant differences among the models (Figure 29).

Given the difference in the scales of recruitment and mature biomass between 25_02, 25_01, and the base model, as well as the opposite (but offsetting) differences in NMFS survey capture probabilities, the degree of similarity in fits to NMFS survey biomass is somewhat surprising (Figures 30 and 31). 25_02 has a small tendency to fit the NMFS survey biomass better than the base and 25_01 when the observed survey biomass is high (e.g.1988-1992), but otherwise the estimates are very similar. In contrast, estimates for NMFS survey biomass from 25_01a are almost always lower than the other three models; it also has the poorest performance following the semi-decadal fluctuations in observed survey biomass.

Residual diagnostics for NMFS survey size compositions (one-step ahead [OSA] residuals using the `afscOSA` R package) appear to be satisfactory for all of the models (Figures 32- 34). Any differences between the models due to tail compression (22.03d5) or lack thereof (the alternative models) are not discernable. Some cohort effects are evident in the OSA residuals for males (e.g., the right-sloping band of positive residuals that start ~1980), but these are similar in the residuals for all the models.

Residual diagnostics for fishery size compositions (Figures 35-41) exhibit a consistent feature in the male size compositions in all fisheries across all of the models: the mean proportions in the 50-75 mm carapace width (CW) range are underpredicted and in the 75-120 mm CW are overpredicted. This pattern may also occur in the female fishery size compositions, but to a much less notable degree. Interestingly, the SDNRs (Standard Deviation of Normalized Residuals) for the male compositions are, on the whole, much closer to 1 than the female compositions are, where 1 is the expected value if the OSAs were truly normally-distributed.

Of the three alternative TCSAM02 models evaluated here, only 25_02 may be worth considering for use in the 2025 assessment–although the case to be made is not particularly strong. "To tail compress or not to tail compress" does not seem to be an issue given the overall similarity in results between the base model and 25_01. Characterizing errors in fitting biomass trends using normal distributions and likelihoods is clearly a not a good choice to characterize Tanner crab survey data, given the inability of 25_01a to follow the semi-decadal swings in the NMFS survey biomass data. Model 25_02 demonstrates, more than anything else, I think, the uncertainty attached to overall scale in the Tanner crab survey data. This is apparent, as well, from the uncertainty intervals on the estimated curves (Figure 22) from which the capture probabilities used in 25_02 were derived.

5 Progress toward a GMACS model for Tanner crab

Several very preliminary GMACS models were presented to the CPT and SSC in early 2024. These models were developed with the idea of providing a "simpler" alternative to the current Tanner crab model implemented in the TCSAM02 ADMB/C++ framework and thus were built using the concept that model processes could be defined for a single time block starting in 1982 with the NMFS EBS bottom trawl survey gear change. However, the models proved unsatisfactory for a number of reasons, but mainly because starting a model in 1982 ignored large apparent changes in population size captured in earlier (1975-1981) NMFS survey data, foreign fleet catch data (starting in 1965), and observer data on bycatch in the groundfish fisheries (starting in 1973). In addition, previous bespoke models (e.g., Bristol Bay red king crab, snow crab) that transitioned to GMACS underwent detailed comparison processes that resulted in a GMACS model that performed "as close as possible" to the bespoke model. Thus, the recommendations from the CPT and SSC to move forward for Tanner crab was to develop a GMACS model that matched the bespoke model as closely as possible.

Since then, GMACS itself has undergone substantial development, including the implementation of random walk behavior and environmental covariates to implement time-varying parameters, additional selectivity functions, and tail compression for size composition data, among others. To implement a model in GMACS as "close as possible" to the bespoke TCSAM02 model, I added an option to start the model from zero population abundance and build it up over time, an ascending normal selectivity curve and additional parameterizations for double normal curves, and recently debugged an issue with how time-blocked catchability coefficients were used to predict survey catches.

At first glance, the GMACS model referred to here as "G25_05" (or simply "GMACS") should be "close enough" in construction to the bespoke TCSAM02 model 22.03d5, the 2024 assessment model, to satisfy the CPT and SSC. The biological processes captured in both models are, by design, very similar (Table G). One (minor) difference is that mean molt increment size is estimated as a function of pre-molt size in 22.03d5 while the relationship is pre-specified in G25_05, but the pre-specified relationship is based on the same data fit to in the assessment model. Another (minor) difference is that the probability of *having undergone* the terminal molt to maturity (based on post-molt size) is pre-specified in G25_05 based on annual maturity ogive curves from the NMFS EBS trawl survey whereas the probability of *undergoing* terminal molt (based on pre-molt size) is estimated in the bespoke model from those curves. Both models build up the population from zero using annual recruitment starting in 1948; what appears to be a major difference is that the annual recruitment deviations are treated as uncorrelated deviations from the mean whereas the bespoke model treats them as a random walk process. This difference leads to large differences in the population trajectories of the two models prior to the introduction of the NMFS survey data in 1975 (see Figure 57).

Table G. Population processes and parameterizations in the 2024 assessment model, 22.03d5, and GMACS model G25_05.

process	time blocks	G25_05 description	time blocks	22.03d5 description
Population rates and quantities				
Population built from annual recruitment				
Recruitment	1949+	ln-scale mean + annual devs	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	1949+	sigma-R fixed, sex ratio fixed at 1:1
Growth	1949+	sex-specific, pre-specified	1949+	sex-specific
		mean post-molt size: power function of pre-molt size		mean post-molt size: power function of pre-molt size
		post-molt size: gamma distribution conditioned on pre-molt size		post-molt size: gamma distribution conditioned on pre-molt size
Maturity	1949+	sex-specific, pre-specified	1949+	sex-specific
		size-specific probability of having undergone terminal molt		size-specific probability of terminal molt
				logit-scale parameterization
Natural mortalty	1949-1979,	estimated sex/maturity state-specific multipliers on mature male:	1949-1979,	estimated sex/maturity state-specific multipliers on base rate
	1985+	priors on base and multipliers based on uncertainty in max age	1985+	priors on multipliers based on uncertainty in max age
	1980-1984	estimated "enhanced mortality" period multipliers	1980-1984	estimated "enhanced mortality" period multipliers

Fishery processes (mortality, selectivity and retention) are modeled in similar fashion in both models (Tables H and I) for the same four fleets (the directed fishery, the snow crab fishery, the BBRKC fishery, and a catchall "groundfish" fishery). Time blocks for changes in selectivity and retention in the fisheries are the same in both models, as are the functions used to describe those curves. The NMFS and BSFRF trawl surveys are also described with the same functions and time blocks in both models (Table J)

Table H. Characteristics for retention and total catch in the directed ("TCF") fishery and bycatch in the snow crab ("SCF") fishery in the 2024 assessment model, 22.03d5, and GMACS model G25_05.

Fishery/process	time blocks	G25_05 description	22.03d5 description
TCF	directed Tanner crab fishery		
capture rates	pre-1965		male nominal rate
	1965+	male ln-scale mean + annual devs	male ln-scale mean + annual devs
	1949+	ln-scale female offset	ln-scale female offset
male selectivity	1949-1990	ascending logistic	ascending logistic
	1991-1996	annually-varying ascending logistic	annually-varying ascending logistic
	2005+	annually-varying ascending logistic	annually-varying ascending logistic
female selectivity	1949+	ascending logistic	ascending logistic
male retention	1949-1990; 1991-1996; 2005-2009; 2013+	ascending logistic	ascending logistic
% retained	pre-1988	fixed at 100%	fixed at 100%
	1991-1996	fixed at 100%	fixed at 100%
	2005-2009	fixed at 100%	fixed at 100%
	2013+	fixed at 100%	fixed at 100%
SCF	bycatch in snow crab fishery		
capture rates	pre-1978		nominal rate on males
	1979-1991	extrapolated from effort	extrapolated from effort
	1992+	male ln-scale mean + annual devs	male ln-scale mean + annual devs
	1949+	ln-scale female offset	ln-scale female offset
male selectivity	1949-1996	dome-shaped (double normal)	dome-shaped (double normal)
		--plateau width fixed to 0	--plateau width fixed to 0
		--descending limb width fixed to 1	--descending limb width fixed to 1
	1997-2004	dome-shaped (double normal)	dome-shaped (double normal)
	2005+	dome-shaped (double normal)	dome-shaped (double normal)
female selectivity	1949-1996	ascending logistic	ascending logistic
	1997-2004	ascending logistic	ascending logistic
	2005+	ascending logistic	ascending logistic

Table I. Characteristics for bycatch in the BBRKC ("RKF") and groundfish fisheries ("GF All") in the 2024 assessment model, 22.03d5, and GMACS model G25_05.

Fishery/process	time blocks	G25_05 description	22.03d5 description
RKF	bycatch in BBRKC fishery		
capture rates	pre-1952		nominal rate on males
	1953-1991	extrapolated from effort	extrapolated from effort
	1992+	male ln-scale mean + annual devs	male ln-scale mean + annual devs
	1949+	ln-scale female offset	ln-scale female offset
male selectivity	1949-1996	ascending normal, asymptote fixed	ascending normal, asymptote fixed
	1997-2004	ascending normal, asymptote fixed	ascending normal, asymptote fixed
	2005+	ascending normal, asymptote fixed	ascending normal, asymptote fixed
female selectivity	1949-1996	ascending normal, asymptote fixed	ascending normal, asymptote fixed
	1997-2004	ascending normal	ascending normal
	2005+	ascending normal	ascending normal
GF All	bycatch in groundfish fisheries		
capture rates	pre-1973	male ln-scale mean from 1973+	male ln-scale mean from 1973+
	1973+	male ln-scale mean + annual devs	male ln-scale mean + annual devs
	1973+	ln-scale female offset	ln-scale female offset
male selectivity	1949-1986	ascending logistic	ascending logistic
	1987-1996	ascending logistic	ascending logistic
	1997+	ascending logistic	ascending logistic
female selectivity	1949-1986	ascending logistic	ascending logistic
	1987-1996	ascending logistic	ascending logistic
	1997+	ascending logistic	ascending logistic

Table J. Characteristics for the NMFS and BSFRF surveys in the 2024 assessment model, 22.03d5, and GMACS model G25_05.

Survey/process	time blocks	G25_05	22.03d5 description
NMFS EBS trawl survey			
male survey q	1975-1981	ln-scale	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment	ln-scale w/ prior based on Somerton's underbag experiment
female survey q	1975-1981	ln-scale	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment	ln-scale w/ prior based on Somerton's underbag experiment
male selectivity	1975-1981	ascending normal, fixed fully-selected size at 180	ascending normal, fixed fully-selected size at 180
	1982+	ascending normal, fixed fully-selected size at 180	ascending normal, fixed fully-selected size at 180
female selectivity	1975-1981	ascending normal, fixed fully-selected size at 130	ascending normal, fixed fully-selected size at 130
	1982+	ascending normal, fixed fully-selected size at 130	ascending normal, fixed fully-selected size at 130
BSFRF SBS trawl surveys			
male catchability	2013-2018	fixed at 1 for all sizes	fixed at 1 for all sizes
male availability	2013-2018	empirically-determined outside the model	empirically-determined outside the model
female catchability	2013-2018	fixed at 1 for all sizes	fixed at 1 for all sizes
female availability	2013-2018	empirically-determined outside the model	empirically-determined outside the model

Similar error distributions are also used for the various components of the model likelihoods (Table K), although the consistency across the models regarding various penalties (improper priors) applied by to components in the total likelihood has not been satisfactorily resolved and remains an araea of uncertainty.

Table K. Likelihood components in the 2024 assessment model, 22.03d5, and GMACS model G25_05.

		G25_05			22.03d5		
Component	Type	included in optimization	Fits	Likelihood distribution	included in optimization	Fits	Likelihood distribution
TCF: retained catch	biomass	yes	males only	lognormal	yes	males only	lognormal
	size comp.s	yes	males only	multinomial	yes	males only	multinomial
TCF: total catch	biomass	yes	total	lognormal	yes	total	lognormal
	size comp.s	yes	by sex (extended)	multinomial	yes	by sex (extended)	multinomial
SCF: total catch	biomass	yes	total	lognormal	yes	total	lognormal
	size comp.s	yes	by sex (extended)	multinomial	yes	by sex (extended)	multinomial
RKF: total catch	biomass	yes	total	lognormal	yes	total	lognormal
	size comp.s	yes	by sex (extended)	multinomial	yes	by sex (extended)	multinomial
GF All: total catch	abundance	yes	total	lognormal	yes	total	lognormal
	biomass	yes	total	lognormal	yes	total	lognormal
	size comp.s	yes	by sex	multinomial	yes	by sex	multinomial
NMFS "M" survey (males only, no maturity)	biomass	yes	males only	lognormal	yes	males only	lognormal
	size comp.s	yes	males only	multinomial	yes	males only	multinomial
NMFS "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal	yes	by maturity classification	lognormal
	size comp.s	yes	by maturity classification	multinomial	yes	by maturity classification	multinomial
BSFRF "M" survey (males only, no maturity)	biomass	yes	males only	lognormal	yes	males only	lognormal
	size comp.s	yes	males only	D-M	yes	males only	D-M
BSFRF "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal	yes	by maturity classification	lognormal
	size comp.s	yes	by maturity classification	D-M	yes	by maturity classification	D-M
growth data	EBS only	no			yes	by sex	gamma
male maturity ogive data	EBS only	no			yes	males only	binomial

However, G25_05 superficially appears to differ from the bespoke model in what should be only relatively minor ways.

To compare results from the two models, G25_05 was subjected to a parameter jittering exercise and the resulting "best" model was selected. Of 197 model runs, 43 converged to essentially the same minimum negative log likelihood value (within 0.001 likelihood units of the absolute minimum; Figure 42).

The run resulting in the absolute minimum had a maximum parameter gradient of 0.021 and was used as the starting point for ADMB's "hess_step" algorithm, which uses information on the curvature of the likelihood surface (the model hessian) at the "converged" point to further adjust its location to the true minimum at which all first-order parameter gradients are 0. Although this adjustment was successful, the GMACS model disappointingly had 4 parameters that were estimated at their upper bounds, all of which were selectivity parameters for the NMFS survey or females in the snow crab fishery (Table 4). The full list of estimated parameters is given in Table 5.

The fits of both GMACS and and the bespoke TCSAM02 model to fishery catch data are generally excellent (Figures 43 and 44).

The GMACS model also fits the NMFS survey biomass time series in a very similar manner to the TCSAM02 model, although some differences are evident prior to 1982 (Figures 45 and 46), but the fits to the data themselves are rather mediocre. While both models exhibit the semi-decadal shifts evident in the NMFS survey biomass time series, both underestimate the dynamic range of the swings in male, immature female, and mature female biomass. The GMACS model predictions for the BSFRF data follow the same temporal pattern as the TCSAM02 model predictions (Figure 47), but they are offset either above (for males) or below (for mature females).

Based on OSA residuals and comparison with the observed mean proportions (Figures 48-50), the GMACS model fits the size composition data from the NMFS EBS trawl survey equally as well as the bespoke TCSAM02 model. The plots highlight two differences in configuration between the two models: 1) female size comps are limited to a smaller maximum size in the GMACS model and 2) tail compression (5%) is applied in the TCSAM02 model but not the GMACS model, although any effects these differences introduce should be minor (as the comparison between the bespoke model and the 25_01 TCSAM02 model showed in the previous section). Both models exhibit an alternating ~ 5-year pattern of misfits to the male size compositions in the 75-125 mm CW size range from 1975-2000, after 2000 the residuals are mainly positive and small. The proportions for immature females are substantially overestimated in 1987 in both models (Figure 49); both models also exhibit semi-decadal scale patterns of misfits for mature females (Figure 50) prior to 1990 similar to those for males, but at smaller sizes.

The GMACS model overestimates, on average, the mean proportions of the retained catch size compositions under 140 mm CW and underpredicts the mean proportions in the 140-160 mm CW size range (Figure 51) whereas the TCSAM02 model appears to do a better job, on average. The GMACS model exhibits fairly large residuals in the 1980-1984 and 1989-1996 at sizes larger than 120 mm CW that are not evident in the TCSAM02 model. A similar pattern occurs, to a lesser extent, in the residuals to the total catch male size compositions in the directed fishery (Figure 52). Both models, however, show a prevalence of positive residuals since 2012 at sizes above 120 mm CW and both overpredict the mean proportions at sizes larger than ~130 mm CW. Although the residuals from both models show some large-ish deviations in the 1990-1995 time period near 100 mm CW, the remaining patterns with respect to male bycatch size compositions in the snow crab fishery appear to be reasonable and similar for both models (Figure 53). For male bycatch in the groundfish fisheries, both models exhibit semi-decadal scale alternating patterns that may follow pseudocohorts in the size composition residuals (Figure 54). OSA residual calculations failed for male bycatch size compositions in the BBRKC fishery and for all female total catch size compositions in the fisheries except for the groundfish fisheries (Figure 55). The reason for this is unclear, but may have to do with relatively small sample sizes. For the female bycatch size compositions in the groundfish fisheries, the GMACS model exhibits smaller residuals than the bespoke model but fails to capture the mean proportions well.The bespoke model exhibits rather strong "cohort" patterns across the time block.

Given the relative similarity in fits to the data, the two models might be expected to agree closely with respect to predicted population processes, but this is not the case. Mean growth and the annual probability of having undergone terminal molt were estimated outside the GMACS model (Figure 56) but agree well with the estimated quantities in the bespoke model. Natural mortality rates were estimated for immature crab and mature crab by sex, as well as separately for the 1980-84 "enhanced mortality" time block, as in the bespoke model but the "base" class from which deviations were estimated was different between the two models: mature males in the GMACS model and a fixed value of 0.23 independent of population category in the TCSAM02 model.

Relative to the bespoke model, the GMACS model estimated much lower rates of M for immature crab and mostly larger rates for mature crab (mature males being the one exception).

Following a "spin-up" period in both models to ~1975, both models exhibit strikingly similar temporal variation in annual recruitment, although the relative scale of the GMACS model is about one-third of that of the TCSAM02 model (Figure 57). The lower estimates for immature crab M contribute to the disparity in scale between the two models' estimate for annual recruitment, as do differences in estimated survey catchability (see Figure 59 below). The buildup of mature male biomass in the GMACS model to 1980, followed by the extremely steep decline across the next five years would seem to be highly suspect as anything but an artifact of the manner in which the model is initialized (Figure 58). The use of a random walk for the recruitment deviations prior to 1975 in the bespoke model allows the model to "react" to the directed (foreign fleets) fishery and accompanying fishing mortality that starts in 1965. The major differences in the patterns of the biomass trajectories disappear by 1985, but this is ten years after the NMSF survey data become available to inform the models. Because the period to calculate mean recruitment for the Tier 3 harvest control rule for Tanner crab extends back to 1982, the manner in which recruitment is treated during the "spin up" period is important.

Two periods, before and after the survey gear change in 1982, are used to model NMFS survey selectivity and fully-selected catchability in both models. These are shown in combination as capture probability curves in Figure 59. The curves from the GMACS model are substantially different from those from the TCSAM02 model except for females in the post-gear change time period (i.e., 1982+). These differences contribute to, and are influenced by, the differences in recruitment scale and natural mortality rates between the two models.

The bespoke model estimates selectivity and retention curves across a number of time blocks for both the fisheries and the NMFS survey. For the fisheries, the selection of time blocks is based on a combination of data availability and fleet behavioral changes (possibly in response to regulatory actions). The retention curves estimated using the GMACS model show good agreement with those from the bespoke model (Figure 60), as do the annually-varying selectivity curves for males estimated after rationalization of the crab fisheries in 2005 (Figure 61). The male bycatch selectivity curves estimated by the GMACS model for the bycatch fisheries in the periods after 1996 also show good agreement with the TCSAM02 model (Figure 62). However, the agreement prior to 1987 and for all female selectivity curves (Figure 63) is poor, with all GMACS curves right-shifted to larger sizes. This may represent a tradeoff with estimated fishing mortality on females, allowing larger estimated mean parameters while applying similar effective size-specific capture rates (and subsequent discard mortality) to females because selectivity-at-size has been reduced proportionately. Defining the size at "full selection" for the fishery selectivity curves to be within the range of female sizes may reduce or eliminate this ambiguity.

Estimates of annual fully-selected fishery capture rates from the GMACS model for males (Figures 64-65) differ substantially from those from the TCSAM02 model prior to 1997, but are much more similar after 1996 when the majority of the male fishery selectivity curves also agree between the two models. In contrast, the estimates of the equivalent rates for females show little agreement between the two models (Figures 66-67), except for the BBRKC fishery prior 1997, when the estimated fishery selectivity curves for the two models are reasonably similar (Figure 63). These results reinforce the suggestion that defining consistent sizes at full-selection between the two models would remove much of this ambiguity.

6 Summary

In summary,

- with regard to the `crabpack` R package developed by SAP, I
  - recommend using the full-precision carapace length measurements with the current length-weight regressions to calculate biomass from NMFS EBS survey abundance and size data.
  - recommend limiting the survey stations in 1979 to the 375 stations previously adopted as "standard" by the CPT for calculating crab survey abundance and biomass indices or size compositions using design-based methods.
  - recommend using data from all the available stations when calculating survey biomass and abundance indices or size compositions using model-based geostatistical (e.g., `VAST`, `sdmTMB`) methods.
- with regard to using `VAST`-derived size compositions in the stock assessment, I recommend that a model using `VAST`-derived indices and size compositions be developed as an alternative model in 2026 pending further work to streamline the process of estimating and reviewing the results
- with regard to "small crab success", I thank the SSC for the suggestion and hope the small overview given here provides some basis for further research on this topic, although further work needs to be done in coordination with SAP and perhaps led by analysts developing the Tanner crab ESP
- with regard to alternative TCSAM02 models for the consideration as part of the 2025 stock assessment, I recommend including 25_02 as an alternative model in addition to the base. This model is attractive because using capture probability functions derived from the BSFRF data reduces overall model complexity by eliminating several selectivity/catchability-related parameters as well as the necessity to fit the BSFRF biomass indices and size compositions.
- with regard to a GMACS alternative to the bespoke TCSAM02 model, substantial progress has been made on this: it feels like we're "almost there". I propose to continue to work on this over the summer and present an update on further progress at the 2025 stock assessment.

The author looks forward to discussions with the CPT and SSC regarding model choices for the September assessment and further refinements to address on a longer timescale.

7 Acknowledgments

The author would like to acknowledge Andre Punt (UW) and Matthieu Veron (previously at the AFSC-Seattle, now at the Institut Agro Rennes-Angers) for recent improvements to GMACS; Jon Richar (AFSC-SAP) for developing the VAST size compositions for Tanner crab; Shannon Hennessey (AFSC-SAP) and SAP for developing the `crabpack` R package; Cole Monnahan (AFSC-SSMA), Jim Ianelli (AFSC-SSMA), Andre, and other crab assessment authors for discussions on use and debugging of GMACS; and Cole for developing the ADMB "hess_step" routine and providing help with OSA residuals. I would also like to thank Lee Cronin-Fine (AFSC-SSMA) for providing an internal review of a draft version of this report.

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Tables

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Table 1. Percent differences (to two decimal places), by year, in design-based NMFS survey abundance trends from the 2024 assessment and the `crabpack` R package, by sex and maturity state.

year	immature female	mature female	undetermined male
1975	0	0.0	0.0
1976	0	0.0	0.0
1977	0	0.0	0.0
1978	0	0.0	0.0
1979	−40	−72.4	−13.7
1980	0	0.0	0.0
1981	0	0.0	0.0
1982	0	0.0	0.0
1983	0	0.0	0.0
1984	0	0.0	0.0
1985	0	0.0	0.0
1986	0	0.0	0.0
1987	0	0.0	0.0
1988	0	0.0	0.0
1989	0	0.0	0.0
1990	0	0.0	0.0
1991	0	0.0	0.0
1992	0	0.0	0.0
1993	0	0.0	0.0
1994	0	0.0	0.0
1995	0	0.0	0.0
1996	0	0.0	0.0
1997	0	0.0	0.0
1998	0	0.0	0.0
1999	0	0.0	0.0
2000	0	0.0	0.0
2001	0	0.0	0.0
2002	0	0.0	0.0
2003	0	0.0	0.0
2004	0	0.0	0.0
2005	0	0.0	0.0
2006	0	0.0	0.0
2007	0	0.0	0.0
2008	0	0.0	0.0
2009	0	0.0	0.0
2010	0	0.0	0.0
2011	0	0.0	0.0
2012	0	0.0	0.0
2013	0	0.0	0.0
2014	0	0.0	0.0
2015	0	0.0	0.0
2016	0	0.0	0.0

(continued)

year	immature female	mature female	undetermined male
2017	0	0.0	0.0
2018	0	0.0	0.0
2019	0	0.0	0.0
2021	0	0.0	0.0
2022	0	0.0	0.0
2023	0	0.0	0.0
2024	0	0.0	0.0

Table 2. Percent difference, by year, in design-based NMFS survey biomass trends from the 2024 assessment and the `crabpack` R package, by sex and maturity state.

year	immature female	mature female	undetermined male
1975	0.0	0.0	0.4
1976	0.0	0.0	0.0
1977	0.0	0.0	0.0
1978	0.0	0.0	0.0
1979	−36.1	−59.6	2.7
1980	0.0	0.0	0.0
1981	0.0	0.0	0.0
1982	0.0	0.0	0.0
1983	0.0	0.0	0.0
1984	0.0	0.0	0.0
1985	0.0	0.0	0.0
1986	0.0	0.0	0.0
1987	0.0	0.0	0.0
1988	0.0	0.0	0.0
1989	0.0	0.0	0.0
1990	0.0	0.0	0.0
1991	0.0	0.0	0.0
1992	0.0	0.0	0.0
1993	0.0	0.0	0.0
1994	0.0	0.0	0.0
1995	0.0	0.0	0.0
1996	0.0	0.0	0.0
1997	0.0	0.0	0.0
1998	0.0	0.0	0.0
1999	0.0	0.0	0.0
2000	0.0	0.0	0.0
2001	0.0	0.0	0.0
2002	0.0	0.0	0.0
2003	0.0	0.0	0.0
2004	0.0	0.0	0.0
2005	0.0	0.0	0.0
2006	0.0	0.0	0.0
2007	0.0	0.0	0.0
2008	0.0	0.0	0.0
2009	0.0	0.0	0.0
2010	0.0	0.0	0.0
2011	0.0	0.0	0.0
2012	0.0	0.0	0.0
2013	0.0	0.0	0.0
2014	0.0	0.0	0.0
2015	0.0	0.0	0.0
2016	2.5	1.6	1.2
2017	3.0	1.5	1.2
2018	2.6	1.6	1.3
2019	2.4	1.7	1.4
2021	2.3	1.6	1.5
2022	2.8	1.5	1.4
2023	2.5	1.6	1.6
2024	2.0	1.6	1.6

Table 3. Percent difference, by year, in NMFS EBS survey total abundance trends for Tanner crab based on summing the size compositions from the design-based and VAST methods, by sex and maturity state.

year	all male	immature female	mature female
1975	−17.3	−17.0	23.9
1976	− 7.4	−18.6	30.4
1977	−19.1	−22.4	14.8
1978	3.4	9.3	33.6
1979	− 9.9	−40.5	−56.6
1980	18.9	14.7	40.3
1981	18.6	11.2	40.4
1982	13.0	10.3	31.9
1983	2.5	− 4.5	28.0
1984	12.4	12.1	29.7
1985	3.3	− 1.3	22.5
1986	− 4.9	− 1.9	20.1
1987	12.1	20.1	18.2
1988	13.5	20.4	26.8
1989	15.4	24.6	36.2
1990	18.1	30.4	34.3
1991	19.1	25.4	43.3
1992	17.2	17.0	40.1
1993	14.3	12.8	39.9
1994	9.1	15.5	34.1
1995	8.2	8.0	34.2
1996	10.2	8.5	37.9
1997	7.1	8.0	34.3
1998	10.6	14.8	31.8
1999	14.4	16.3	33.6
2000	14.1	17.4	30.5
2001	13.5	15.0	37.2
2002	13.0	20.5	32.4
2003	10.3	6.7	39.9
2004	2.7	3.8	33.2
2005	13.8	21.8	37.4
2006	26.2	34.7	52.8
2007	18.7	15.3	50.0
2008	12.7	13.8	44.6
2009	7.0	15.7	39.9
2010	7.6	16.4	36.5
2011	16.0	21.0	39.0
2012	14.6	13.9	41.5
2013	8.9	9.4	39.4
2014	6.7	7.1	41.2
2015	0.8	9.9	42.3
2016	− 0.8	0.1	36.7
2017	0.7	5.7	36.1
2018	14.2	27.3	36.4
2019	17.6	26.2	41.8
2020	− −	− −	− −
2021	17.0	13.3	43.3
2022	15.5	16.0	36.0
2023	22.6	24.2	29.2
2024	30.4	33.9	50.2

Table 4. Parameters estimated at a bound in the GMACS model.

parameter description	bound	lb	ub	GMACS
Sel NMFS male Ascending normal par 1 block group 2 block 1	upper	0.00	3.91	3.91
Sel SCF female Logistic mean block group 6 block 2	upper	1.61	5.01	5.01
Sel NMFS female base Ascending normal par 2	upper	1.61	5.01	5.01
Sel NMFS female Ascending normal par 1 block group 2 block 1	upper	0.00	3.91	3.91

Table 5. Parameters estimates from the GMACS model.

parameter description	estimate	se	lb	ub	phase
Log(R0)	8.000	NA	NA	NA	-2
Log(Rinitial)	8.000	NA	NA	NA	-1
Log(Rbar)	6.295	0.102	0.000	20.000	1
Recruitment ra-males	35.197	NA	NA	NA	-4
Recruitment rb-males	3.898	NA	NA	NA	-4
Recruitment ra-females	NA	NA	NA	NA	NA
Recruitment rb-females	NA	NA	NA	NA	NA
log(SigmaR)	0.000	NA	NA	NA	-4
Steepness	0.750	NA	NA	NA	-2
Rho	0.010	NA	NA	NA	-3
Alpha0 base male	25.000	NA	NA	NA	-1
Alpha male	32.000	NA	NA	NA	-4
Beta0 base male	125.000	NA	NA	NA	-1
Beta male	166.000	NA	NA	NA	-4
Gscale male (ln-scale)	0.820	NA	NA	NA	-5
Alpha0 base female	25.000	NA	NA	NA	-1
Alpha female	32.000	NA	NA	NA	-4
Beta0 base female	100.000	NA	NA	NA	-1
Beta female	115.000	NA	NA	NA	-4
Gscale female (ln-scale)	0.850	NA	NA	NA	-5
M base male mature	0.249	0.004	0.100	1.500	4
M male mature block group 1 block 1	0.651	0.045	-1.000	2.000	4
M base male immature	-0.666	0.115	-1.000	1.000	4
M base female mature	0.680	0.047	-1.000	2.000	4
M female mature block group 1 block 1	0.671	0.092	-1.000	1.000	4
Sel TCF male base Logistic mean	4.976	0.005	1.609	5.011	4
Sel TCF male base Logistic cv	1.744	0.029	0.000	3.912	4
Sel SCF male base Double normal par 1	3.271	0.110	0.000	3.912	4
Sel SCF male base Double normal par 2	4.933	0.047	1.609	5.011	4
Sel SCF male base Double normal par 3	3.531	0.955	0.000	3.912	4
Sel SCF male Double normal par 1 block group 6 block 1	2.809	0.161	0.000	3.912	4
Sel SCF male Double normal par 1 block group 6 block 2	2.688	0.040	0.000	3.912	4
Sel SCF male Double normal par 2 block group 6 block 1	4.795	0.043	1.609	5.011	4
Sel SCF male Double normal par 2 block group 6 block 2	4.831	0.008	1.609	5.011	4
Sel SCF male Double normal par 3 block group 6 block 1	2.835	0.285	0.000	3.912	4
Sel SCF male Double normal par 3 block group 6 block 2	2.632	0.074	0.000	3.912	4
Sel RKF male base Logistic mean	4.970	0.021	1.609	5.136	4
Sel RKF male base Logistic cv	1.987	0.099	0.000	3.912	4
Sel RKF male Logistic mean block group 7 block 1	5.011	0.055	1.609	5.136	4
Sel RKF male Logistic mean block group 7 block 2	5.054	0.044	1.609	5.136	4
Sel RKF male Logistic cv block group 7 block 1	2.452	0.161	0.000	3.912	4
Sel RKF male Logistic cv block group 7 block 2	2.510	0.095	0.000	3.912	4
Sel GFA male base Logistic mean	3.884	0.032	1.609	5.011	4
Sel GFA male base Logistic cv	2.127	0.101	0.000	3.912	4
Sel GFA male Logistic mean block group 8 block 1	3.745	0.048	1.609	5.011	4
Sel GFA male Logistic mean block group 8 block 2	4.566	0.030	1.609	5.011	4
Sel GFA male Logistic cv block group 8 block 1	2.017	0.210	0.000	3.912	4
Sel GFA male Logistic cv block group 8 block 2	2.985	0.044	0.000	3.912	4
Sel NMFS male base Ascending normal par 1	3.027	0.120	0.000	3.912	4
Sel NMFS male base Ascending normal par 2	4.309	0.056	1.609	5.075	4
Sel NMFS male Ascending normal par 1 block group 2 block 1	3.912	0.000	0.000	3.912	4
Sel NMFS male Ascending normal par 2 block group 2 block 1	4.405	0.045	1.609	5.011	4
Sel TCF female base Logistic mean	4.820	0.025	1.609	5.011	4

Sel TCF female base Logistic cv	2.038	0.088	0.000	3.912	4
Sel SCF female base Logistic mean	4.947	0.151	1.609	5.011	4
Sel SCF female base Logistic cv	2.737	0.315	0.000	3.912	4
Sel SCF female Logistic mean block group 6 block 1	4.718	0.098	1.609	5.011	4
Sel SCF female Logistic mean block group 6 block 2	5.011	0.000	1.609	5.011	4
Sel SCF female Logistic cv block group 6 block 1	2.292	0.307	0.000	3.912	4
Sel SCF female Logistic cv block group 6 block 2	2.319	0.087	0.000	3.912	4
Sel RKF female base Logistic mean	4.888	0.135	1.609	5.011	4
Sel RKF female base Logistic cv	1.920	0.478	0.000	3.912	4
Sel RKF female Logistic mean block group 7 block 1	4.935	0.444	1.609	5.011	4
Sel RKF female Logistic mean block group 7 block 2	4.976	0.285	1.609	5.011	4
Sel RKF female Logistic cv block group 7 block 1	1.956	1.324	0.000	3.912	4
Sel RKF female Logistic cv block group 7 block 2	1.966	0.813	0.000	3.912	4
Sel GFA female base Logistic mean	4.307	0.043	1.609	5.011	4
Sel GFA female base Logistic cv	2.915	0.107	0.000	3.912	4
Sel GFA female Logistic mean block group 8 block 1	4.363	0.075	1.609	5.011	4
Sel GFA female Logistic mean block group 8 block 2	4.827	0.036	1.609	5.011	4
Sel GFA female Logistic cv block group 8 block 1	3.289	0.182	0.000	3.912	4
Sel GFA female Logistic cv block group 8 block 2	2.837	0.071	0.000	3.912	4
Sel NMFS female base Ascending normal par 1	3.718	0.035	0.000	3.912	4
Sel NMFS female base Ascending normal par 2	5.011	0.000	1.609	5.011	4
Sel NMFS female Ascending normal par 1 block group 2 block 1	3.912	0.000	0.000	3.912	4
Sel NMFS female Ascending normal par 2 block group 2 block 1	4.621	0.046	1.609	5.011	4
Ret TCF male base Logistic mean	4.850	0.006	1.609	5.075	4
Ret TCF male base Logistic cv	1.264	0.110	0.000	3.912	4
Ret TCF male Logistic mean block group 4 block 1	4.943	0.003	1.609	5.075	4
Ret TCF male Logistic mean block group 4 block 2	4.931	0.007	1.609	5.075	4
Ret TCF male Logistic mean block group 4 block 3	4.861	0.028	1.609	5.075	4
Ret TCF male Logistic cv block group 4 block 1	0.578	0.094	0.000	3.912	4
Ret TCF male Logistic cv block group 4 block 2	0.068	0.523	0.000	3.912	4
Ret TCF male Logistic cv block group 4 block 3	1.247	0.685	0.000	3.912	4
Log fbar TCF	-2.265	0.059	-1000.000	1000.000	1
Log fbar SCF	-4.032	0.067	-1000.000	1000.000	1
Log fbar RKF	-4.759	0.178	-1000.000	1000.000	1
Log fbar GFA	-5.270	0.055	-1000.000	1000.000	1
Log fbar NMFS	-4.000	NA	NA	NA	-1
Log fbar BSFRF	-4.000	NA	NA	NA	-1
Log fdev TCF year 1965 season 2	-1.700	0.037	-1000.000	1000.000	1
Log fdev TCF year 1966 season 2	-1.462	0.037	-1000.000	1000.000	1
Log fdev TCF year 1967 season 2	0.294	0.039	-1000.000	1000.000	1
Log fdev TCF year 1968 season 2	0.657	0.041	-1000.000	1000.000	1
Log fdev TCF year 1969 season 2	1.205	0.046	-1000.000	1000.000	1
Log fdev TCF year 1970 season 2	1.257	0.053	-1000.000	1000.000	1
Log fdev TCF year 1971 season 2	1.122	0.057	-1000.000	1000.000	1
Log fdev TCF year 1972 season 2	0.938	0.058	-1000.000	1000.000	1
Log fdev TCF year 1973 season 2	0.669	0.057	-1000.000	1000.000	1
Log fdev TCF year 1974 season 2	0.837	0.057	-1000.000	1000.000	1
Log fdev TCF year 1975 season 2	1.020	0.059	-1000.000	1000.000	1
Log fdev TCF year 1976 season 2	1.660	0.068	-1000.000	1000.000	1
Log fdev TCF year 1977 season 2	2.011	0.084	-1000.000	1000.000	1
Log fdev TCF year 1978 season 2	1.544	0.086	-1000.000	1000.000	1
Log fdev TCF year 1979 season 2	1.408	0.080	-1000.000	1000.000	1
Log fdev TCF year 1980 season 2	1.278	0.069	-1000.000	1000.000	1
Log fdev TCF year 1981 season 2	0.223	0.057	-1000.000	1000.000	1
Log fdev TCF year 1982 season 2	-0.676	0.051	-1000.000	1000.000	1
Log fdev TCF year 1983 season 2	-2.015	0.054	-1000.000	1000.000	1
Log fdev TCF year 1984 season 2	-0.709	0.066	-1000.000	1000.000	1
Log fdev TCF year 1987 season 2	-0.938	0.048	-1000.000	1000.000	1
Log fdev TCF year 1988 season 2	0.091	0.047	-1000.000	1000.000	1
Log fdev TCF year 1989 season 2	1.272	0.050	-1000.000	1000.000	1
Log fdev TCF year 1990 season 2	1.912	0.057	-1000.000	1000.000	1
Log fdev TCF year 1991 season 2	1.695	0.065	-1000.000	1000.000	1
Log fdev TCF year 1992 season 2	2.023	0.080	-1000.000	1000.000	1
Log fdev TCF year 1993 season 2	1.523	0.093	-1000.000	1000.000	1
Log fdev TCF year 1994 season 2	0.843	0.094	-1000.000	1000.000	1
Log fdev TCF year 1995 season 2	0.329	0.088	-1000.000	1000.000	1
Log fdev TCF year 1996 season 2	0.067	0.147	-1000.000	1000.000	1
Log fdev TCF year 2005 season 2	-1.899	0.060	-1000.000	1000.000	1
Log fdev TCF year 2006 season 2	-1.268	0.059	-1000.000	1000.000	1
Log fdev TCF year 2007 season 2	-1.430	0.059	-1000.000	1000.000	1
Log fdev TCF year 2008 season 2	-1.563	0.058	-1000.000	1000.000	1

Log fdev TCF year 2009 season 2	-1.563	0.091	-1000.000	1000.000	1
Log fdev TCF year 2013 season 2	-1.379	0.133	-1000.000	1000.000	1
Log fdev TCF year 2014 season 2	-0.029	0.055	-1000.000	1000.000	1
Log fdev TCF year 2015 season 2	0.291	0.055	-1000.000	1000.000	1
Log fdev TCF year 2017 season 2	-1.482	0.055	-1000.000	1000.000	1
Log fdev TCF year 2018 season 2	-1.351	0.054	-1000.000	1000.000	1
Log fdev TCF year 2020 season 2	-1.602	0.055	-1000.000	1000.000	1
Log fdev TCF year 2021 season 2	-1.896	0.056	-1000.000	1000.000	1
Log fdev TCF year 2022 season 2	-1.522	0.058	-1000.000	1000.000	1
Log fdev TCF year 2023 season 2	-1.687	0.059	-1000.000	1000.000	1
Log fdev SCF year 1978 season 2	-0.346	0.188	-1000.000	1000.000	1
Log fdev SCF year 1979 season 2	-0.077	0.187	-1000.000	1000.000	1
Log fdev SCF year 1980 season 2	0.423	0.188	-1000.000	1000.000	1
Log fdev SCF year 1981 season 2	0.491	0.188	-1000.000	1000.000	1
Log fdev SCF year 1982 season 2	0.029	0.187	-1000.000	1000.000	1
Log fdev SCF year 1983 season 2	-0.442	0.187	-1000.000	1000.000	1
Log fdev SCF year 1984 season 2	0.255	0.186	-1000.000	1000.000	1
Log fdev SCF year 1985 season 2	0.598	0.185	-1000.000	1000.000	1
Log fdev SCF year 1986 season 2	0.706	0.184	-1000.000	1000.000	1
Log fdev SCF year 1987 season 2	0.868	0.183	-1000.000	1000.000	1
Log fdev SCF year 1988 season 2	0.756	0.183	-1000.000	1000.000	1
Log fdev SCF year 1989 season 2	1.035	0.181	-1000.000	1000.000	1
Log fdev SCF year 1990 season 2	0.973	0.201	-1000.000	1000.000	1
Log fdev SCF year 1991 season 2	1.199	0.202	-1000.000	1000.000	1
Log fdev SCF year 1992 season 2	0.250	0.205	-1000.000	1000.000	1
Log fdev SCF year 1993 season 2	0.607	0.206	-1000.000	1000.000	1
Log fdev SCF year 1994 season 2	0.051	0.206	-1000.000	1000.000	1
Log fdev SCF year 1995 season 2	-0.053	0.207	-1000.000	1000.000	1
Log fdev SCF year 1996 season 2	0.696	0.209	-1000.000	1000.000	1
Log fdev SCF year 1997 season 2	0.861	0.200	-1000.000	1000.000	1
Log fdev SCF year 1998 season 2	-0.015	0.197	-1000.000	1000.000	1
Log fdev SCF year 1999 season 2	-1.499	0.197	-1000.000	1000.000	1
Log fdev SCF year 2000 season 2	-0.773	0.198	-1000.000	1000.000	1
Log fdev SCF year 2001 season 2	-0.309	0.198	-1000.000	1000.000	1
Log fdev SCF year 2002 season 2	-1.471	0.199	-1000.000	1000.000	1
Log fdev SCF year 2003 season 2	-2.481	0.199	-1000.000	1000.000	1
Log fdev SCF year 2004 season 2	-1.825	0.199	-1000.000	1000.000	1
Log fdev SCF year 2005 season 2	-0.062	0.192	-1000.000	1000.000	1
Log fdev SCF year 2006 season 2	0.088	0.191	-1000.000	1000.000	1
Log fdev SCF year 2007 season 2	0.145	0.191	-1000.000	1000.000	1
Log fdev SCF year 2008 season 2	-0.416	0.191	-1000.000	1000.000	1
Log fdev SCF year 2009 season 2	-0.079	0.191	-1000.000	1000.000	1
Log fdev SCF year 2010 season 2	-0.024	0.191	-1000.000	1000.000	1
Log fdev SCF year 2011 season 2	0.454	0.190	-1000.000	1000.000	1
Log fdev SCF year 2012 season 2	0.192	0.190	-1000.000	1000.000	1
Log fdev SCF year 2013 season 2	0.200	0.189	-1000.000	1000.000	1
Log fdev SCF year 2014 season 2	1.018	0.185	-1000.000	1000.000	1
Log fdev SCF year 2015 season 2	0.824	0.187	-1000.000	1000.000	1
Log fdev SCF year 2016 season 2	0.632	0.189	-1000.000	1000.000	1
Log fdev SCF year 2017 season 2	0.016	0.191	-1000.000	1000.000	1
Log fdev SCF year 2018 season 2	-0.011	0.192	-1000.000	1000.000	1
Log fdev SCF year 2019 season 2	0.256	0.192	-1000.000	1000.000	1
Log fdev SCF year 2020 season 2	-1.582	0.192	-1000.000	1000.000	1
Log fdev SCF year 2021 season 2	-2.156	0.192	-1000.000	1000.000	1
Log fdev RKF year 1953 season 2	-1.109	0.189	-1000.000	1000.000	1
Log fdev RKF year 1954 season 2	-1.633	0.189	-1000.000	1000.000	1
Log fdev RKF year 1955 season 2	-1.176	0.189	-1000.000	1000.000	1
Log fdev RKF year 1956 season 2	-0.809	0.189	-1000.000	1000.000	1
Log fdev RKF year 1957 season 2	-1.333	0.189	-1000.000	1000.000	1
Log fdev RKF year 1958 season 2	-1.180	0.189	-1000.000	1000.000	1
Log fdev RKF year 1959 season 2	-1.393	0.189	-1000.000	1000.000	1
Log fdev RKF year 1960 season 2	-1.234	0.189	-1000.000	1000.000	1
Log fdev RKF year 1961 season 2	-0.294	0.189	-1000.000	1000.000	1
Log fdev RKF year 1962 season 2	0.199	0.189	-1000.000	1000.000	1
Log fdev RKF year 1963 season 2	0.557	0.189	-1000.000	1000.000	1
Log fdev RKF year 1964 season 2	0.551	0.189	-1000.000	1000.000	1
Log fdev RKF year 1965 season 2	0.231	0.189	-1000.000	1000.000	1
Log fdev RKF year 1966 season 2	0.240	0.189	-1000.000	1000.000	1
Log fdev RKF year 1967 season 2	0.281	0.189	-1000.000	1000.000	1
Log fdev RKF year 1968 season 2	0.568	0.188	-1000.000	1000.000	1
Log fdev RKF year 1969 season 2	0.521	0.188	-1000.000	1000.000	1

Log fdev RKF year 1970 season 2	0.481	0.188	-1000.000	1000.000	1
Log fdev RKF year 1971 season 2	0.217	0.188	-1000.000	1000.000	1
Log fdev RKF year 1972 season 2	0.679	0.188	-1000.000	1000.000	1
Log fdev RKF year 1973 season 2	0.611	0.188	-1000.000	1000.000	1
Log fdev RKF year 1974 season 2	0.695	0.188	-1000.000	1000.000	1
Log fdev RKF year 1975 season 2	0.663	0.188	-1000.000	1000.000	1
Log fdev RKF year 1976 season 2	1.078	0.188	-1000.000	1000.000	1
Log fdev RKF year 1977 season 2	1.396	0.188	-1000.000	1000.000	1
Log fdev RKF year 1978 season 2	1.301	0.189	-1000.000	1000.000	1
Log fdev RKF year 1979 season 2	1.066	0.189	-1000.000	1000.000	1
Log fdev RKF year 1980 season 2	1.611	0.189	-1000.000	1000.000	1
Log fdev RKF year 1981 season 2	1.564	0.189	-1000.000	1000.000	1
Log fdev RKF year 1982 season 2	0.319	0.189	-1000.000	1000.000	1
Log fdev RKF year 1984 season 2	0.068	0.189	-1000.000	1000.000	1
Log fdev RKF year 1985 season 2	-0.156	0.189	-1000.000	1000.000	1
Log fdev RKF year 1986 season 2	0.521	0.188	-1000.000	1000.000	1
Log fdev RKF year 1987 season 2	0.729	0.188	-1000.000	1000.000	1
Log fdev RKF year 1988 season 2	0.347	0.188	-1000.000	1000.000	1
Log fdev RKF year 1989 season 2	0.657	0.187	-1000.000	1000.000	1
Log fdev RKF year 1990 season 2	2.361	0.245	-1000.000	1000.000	1
Log fdev RKF year 1991 season 2	1.945	0.250	-1000.000	1000.000	1
Log fdev RKF year 1992 season 2	1.766	0.254	-1000.000	1000.000	1
Log fdev RKF year 1993 season 2	2.766	0.257	-1000.000	1000.000	1
Log fdev RKF year 1996 season 2	0.848	0.252	-1000.000	1000.000	1
Log fdev RKF year 1997 season 2	0.474	0.263	-1000.000	1000.000	1
Log fdev RKF year 1998 season 2	0.245	0.260	-1000.000	1000.000	1
Log fdev RKF year 1999 season 2	-0.116	0.259	-1000.000	1000.000	1
Log fdev RKF year 2000 season 2	-0.285	0.258	-1000.000	1000.000	1
Log fdev RKF year 2001 season 2	-0.781	0.276	-1000.000	1000.000	1
Log fdev RKF year 2002 season 2	-0.581	0.256	-1000.000	1000.000	1
Log fdev RKF year 2003 season 2	-0.831	0.256	-1000.000	1000.000	1
Log fdev RKF year 2004 season 2	-1.110	0.256	-1000.000	1000.000	1
Log fdev RKF year 2005 season 2	-1.230	0.243	-1000.000	1000.000	1
Log fdev RKF year 2006 season 2	-1.542	0.306	-1000.000	1000.000	1
Log fdev RKF year 2007 season 2	-1.191	0.214	-1000.000	1000.000	1
Log fdev RKF year 2008 season 2	0.120	0.214	-1000.000	1000.000	1
Log fdev RKF year 2009 season 2	-0.316	0.214	-1000.000	1000.000	1
Log fdev RKF year 2010 season 2	-1.748	0.289	-1000.000	1000.000	1
Log fdev RKF year 2011 season 2	-1.698	0.421	-1000.000	1000.000	1
Log fdev RKF year 2012 season 2	-1.369	0.239	-1000.000	1000.000	1
Log fdev RKF year 2013 season 2	-0.389	0.214	-1000.000	1000.000	1
Log fdev RKF year 2014 season 2	0.302	0.215	-1000.000	1000.000	1
Log fdev RKF year 2015 season 2	-0.071	0.214	-1000.000	1000.000	1
Log fdev RKF year 2016 season 2	-0.131	0.213	-1000.000	1000.000	1
Log fdev RKF year 2017 season 2	0.034	0.213	-1000.000	1000.000	1
Log fdev RKF year 2018 season 2	-0.650	0.213	-1000.000	1000.000	1
Log fdev RKF year 2019 season 2	-1.353	0.415	-1000.000	1000.000	1
Log fdev RKF year 2020 season 2	-0.992	0.591	-1000.000	1000.000	1
Log fdev RKF year 2023 season 2	-1.309	0.540	-1000.000	1000.000	1
Log fdev GFA year 1973 season 2	1.637	0.191	-1000.000	1000.000	1
Log fdev GFA year 1974 season 2	1.971	0.192	-1000.000	1000.000	1
Log fdev GFA year 1975 season 2	1.155	0.198	-1000.000	1000.000	1
Log fdev GFA year 1976 season 2	0.536	0.198	-1000.000	1000.000	1
Log fdev GFA year 1977 season 2	0.067	0.198	-1000.000	1000.000	1
Log fdev GFA year 1978 season 2	-0.311	0.197	-1000.000	1000.000	1
Log fdev GFA year 1979 season 2	0.209	0.197	-1000.000	1000.000	1
Log fdev GFA year 1980 season 2	-0.097	0.195	-1000.000	1000.000	1
Log fdev GFA year 1981 season 2	-0.249	0.194	-1000.000	1000.000	1
Log fdev GFA year 1982 season 2	-1.112	0.194	-1000.000	1000.000	1
Log fdev GFA year 1983 season 2	-0.424	0.195	-1000.000	1000.000	1
Log fdev GFA year 1984 season 2	-0.145	0.197	-1000.000	1000.000	1
Log fdev GFA year 1985 season 2	-0.554	0.194	-1000.000	1000.000	1
Log fdev GFA year 1986 season 2	-0.233	0.191	-1000.000	1000.000	1
Log fdev GFA year 1987 season 2	-0.414	0.191	-1000.000	1000.000	1
Log fdev GFA year 1988 season 2	-0.836	0.191	-1000.000	1000.000	1
Log fdev GFA year 1989 season 2	-0.553	0.191	-1000.000	1000.000	1
Log fdev GFA year 1990 season 2	-0.221	0.191	-1000.000	1000.000	1
Log fdev GFA year 1991 season 2	0.784	0.193	-1000.000	1000.000	1
Log fdev GFA year 1992 season 2	1.024	0.195	-1000.000	1000.000	1
Log fdev GFA year 1993 season 2	0.776	0.196	-1000.000	1000.000	1
Log fdev GFA year 1994 season 2	1.131	0.199	-1000.000	1000.000	1

Log fdev GFA year 1995 season 2	0.991	0.198	-1000.000	1000.000	1
Log fdev GFA year 1996 season 2	1.196	0.199	-1000.000	1000.000	1
Log fdev GFA year 1997 season 2	1.357	0.197	-1000.000	1000.000	1
Log fdev GFA year 1998 season 2	1.193	0.194	-1000.000	1000.000	1
Log fdev GFA year 1999 season 2	0.839	0.193	-1000.000	1000.000	1
Log fdev GFA year 2000 season 2	0.949	0.193	-1000.000	1000.000	1
Log fdev GFA year 2001 season 2	1.299	0.193	-1000.000	1000.000	1
Log fdev GFA year 2002 season 2	0.713	0.193	-1000.000	1000.000	1
Log fdev GFA year 2003 season 2	0.067	0.192	-1000.000	1000.000	1
Log fdev GFA year 2004 season 2	0.326	0.192	-1000.000	1000.000	1
Log fdev GFA year 2005 season 2	0.095	0.191	-1000.000	1000.000	1
Log fdev GFA year 2006 season 2	0.104	0.192	-1000.000	1000.000	1
Log fdev GFA year 2007 season 2	-0.014	0.192	-1000.000	1000.000	1
Log fdev GFA year 2008 season 2	-0.306	0.192	-1000.000	1000.000	1
Log fdev GFA year 2009 season 2	-0.607	0.192	-1000.000	1000.000	1
Log fdev GFA year 2010 season 2	-0.957	0.192	-1000.000	1000.000	1
Log fdev GFA year 2011 season 2	-0.979	0.191	-1000.000	1000.000	1
Log fdev GFA year 2012 season 2	-1.238	0.191	-1000.000	1000.000	1
Log fdev GFA year 2013 season 2	-0.571	0.191	-1000.000	1000.000	1
Log fdev GFA year 2014 season 2	-0.426	0.191	-1000.000	1000.000	1
Log fdev GFA year 2015 season 2	-0.526	0.191	-1000.000	1000.000	1
Log fdev GFA year 2016 season 2	-0.531	0.192	-1000.000	1000.000	1
Log fdev GFA year 2017 season 2	-0.958	0.191	-1000.000	1000.000	1
Log fdev GFA year 2018 season 2	-0.727	0.192	-1000.000	1000.000	1
Log fdev GFA year 2019 season 2	-0.796	0.192	-1000.000	1000.000	1
Log fdev GFA year 2020 season 2	-0.938	0.192	-1000.000	1000.000	1
Log fdev GFA year 2021 season 2	-0.814	0.192	-1000.000	1000.000	1
Log fdev GFA year 2022 season 2	-1.249	0.193	-1000.000	1000.000	1
Log fdev GFA year 2023 season 2	-1.634	0.193	-1000.000	1000.000	1
Log foff TCF	-6.409	16.951	-1000.000	1000.000	4
Log foff SCF	-4.676	16.422	-1000.000	1000.000	4
Log foff RKF	-0.500	0.000	-1000.000	1000.000	4
Log foff GFA	-5.908	14.468	-1000.000	1000.000	4
Log foff NMFS	-5.250	NA	NA	NA	-1
Log foff BSFRF	-5.250	NA	NA	NA	-1
Rec dev est 1974	-0.580	0.345	-8.000	8.000	1
Rec dev est 1975	0.930	0.109	-8.000	8.000	1
Rec dev est 1976	-0.236	0.272	-8.000	8.000	1
Rec dev est 1977	-0.813	0.294	-8.000	8.000	1
Rec dev est 1978	-1.514	0.344	-8.000	8.000	1
Rec dev est 1979	-1.694	0.335	-8.000	8.000	1
Rec dev est 1980	-1.350	0.247	-8.000	8.000	1
Rec dev est 1981	-1.320	0.239	-8.000	8.000	1
Rec dev est 1982	-0.250	0.115	-8.000	8.000	1
Rec dev est 1983	-0.727	0.186	-8.000	8.000	1
Rec dev est 1984	-0.703	0.185	-8.000	8.000	1
Rec dev est 1985	-0.522	0.154	-8.000	8.000	1
Rec dev est 1986	-0.900	0.194	-8.000	8.000	1
Rec dev est 1987	-1.237	0.203	-8.000	8.000	1
Rec dev est 1988	-1.892	0.236	-8.000	8.000	1
Rec dev est 1989	-2.769	0.343	-8.000	8.000	1
Rec dev est 1990	-2.693	0.270	-8.000	8.000	1
Rec dev est 1991	-2.658	0.246	-8.000	8.000	1
Rec dev est 1992	-2.630	0.253	-8.000	8.000	1
Rec dev est 1993	-2.428	0.242	-8.000	8.000	1
Rec dev est 1994	-1.887	0.174	-8.000	8.000	1
Rec dev est 1995	-2.174	0.241	-8.000	8.000	1
Rec dev est 1996	-1.312	0.129	-8.000	8.000	1
Rec dev est 1997	-2.092	0.235	-8.000	8.000	1
Rec dev est 1998	-0.732	0.109	-8.000	8.000	1
Rec dev est 1999	-1.703	0.270	-8.000	8.000	1
Rec dev est 2000	-0.438	0.113	-8.000	8.000	1
Rec dev est 2001	-1.493	0.275	-8.000	8.000	1
Rec dev est 2002	-0.415	0.118	-8.000	8.000	1
Rec dev est 2003	-1.155	0.162	-8.000	8.000	1
Rec dev est 2004	-2.280	0.280	-8.000	8.000	1
Rec dev est 2005	-2.366	0.286	-8.000	8.000	1
Rec dev est 2006	-2.040	0.279	-8.000	8.000	1
Rec dev est 2007	-1.086	0.184	-8.000	8.000	1
Rec dev est 2008	-0.228	0.102	-8.000	8.000	1
Rec dev est 2009	-1.510	0.202	-8.000	8.000	1

Rec dev est 2010	-2.166	0.206	-8.000	8.000	1
Rec dev est 2011	-3.135	0.312	-8.000	8.000	1
Rec dev est 2012	-2.307	0.158	-8.000	8.000	1
Rec dev est 2013	-2.846	0.225	-8.000	8.000	1
Rec dev est 2014	-2.748	0.220	-8.000	8.000	1
Rec dev est 2015	-1.988	0.166	-8.000	8.000	1
Rec dev est 2016	-0.539	0.090	-8.000	8.000	1
Rec dev est 2017	-1.258	0.148	-8.000	8.000	1
Rec dev est 2018	-0.953	0.149	-8.000	8.000	1
Rec dev est 2019	-2.058	0.470	-8.000	8.000	1
Rec dev est 2020	-0.088	0.141	-8.000	8.000	1
Rec dev est 2021	0.308	0.155	-8.000	8.000	1
Rec dev est 2022	0.091	0.203	-8.000	8.000	1
Rec dev est 2023	-1.047	0.393	-8.000	8.000	1
Logit rec prop est 1974	0.000	NA	NA	NA	-2
Logit rec prop est 1975	0.000	NA	NA	NA	-2
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Logit rec prop est 2017	0.000	NA	NA	NA	-2
Logit rec prop est 2018	0.000	NA	NA	NA	-2
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Logit rec prop est 2020	0.000	NA	NA	NA	-2
Logit rec prop est 2021	0.000	NA	NA	NA	-2
Logit rec prop est 2022	0.000	NA	NA	NA	-2
Logit rec prop est 2023	0.000	NA	NA	NA	-2
Log vn size comp 1	0.000	NA	NA	NA	-4
Log vn size comp 2	0.000	NA	NA	NA	-4
Log vn size comp 3	0.000	NA	NA	NA	-4
Log vn size comp 4	0.000	NA	NA	NA	-4
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Log vn size comp 8	0.000	NA	NA	NA	-4
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Log vn size comp 10	0.000	NA	NA	NA	-4
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Log vn size comp 12	0.000	NA	NA	NA	-4
Log vn size comp 13	0.000	NA	NA	NA	-4
Log vn size comp 14	0.000	NA	NA	NA	-4
Log vn size comp 15	0.000	NA	NA	NA	-4
Survey q survey 1	0.184	0.015	0.010	1.100	5
Survey q survey 2	0.269	0.012	0.010	1.100	5
Survey q survey 3	0.832	0.102	0.010	1.100	5
Survey q survey 4	0.314	0.020	0.010	1.100	5
Survey q survey 5	1.000	NA	NA	NA	-5
Log add cvt survey 1	-9.210	NA	NA	NA	-4
Log add cvt survey 2	-9.210	NA	NA	NA	-4
Log add cvt survey 3	-9.210	NA	NA	NA	-4
Selectivity selectivity male TCF par 1 dev for year 1991	-0.025	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 1992	-0.027	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 1993	-0.019	0.002	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 1994	-0.018	0.004	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 1995	-0.022	0.004	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 1996	0.003	0.004	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2005	-0.036	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2006	-0.035	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2007	-0.045	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2008	-0.020	0.002	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2009	0.004	0.002	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2013	-0.031	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2014	-0.041	0.002	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2015	-0.047	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2017	-0.041	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2018	-0.050	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2020	-0.062	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2021	-0.059	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2022	-0.055	0.003	-12.000	12.000	8
Selectivity selectivity male TCF par 1 dev for year 2023	-0.043	0.003	-12.000	12.000	8

Figures

List of Figures

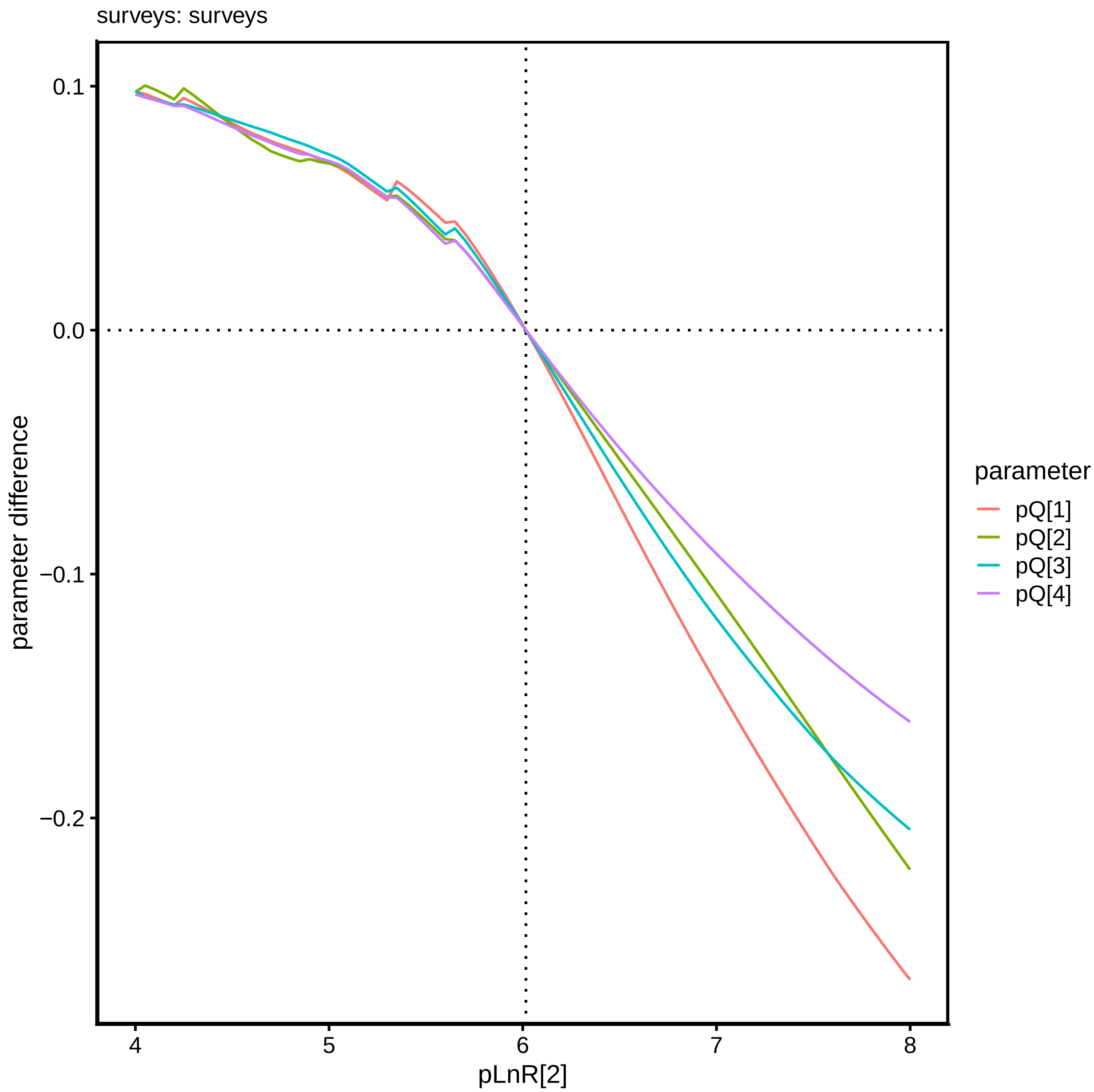


Figure 1. The change in estimated fully-selected survey catchability parameters with log-scale mean recruitment after 1974 (pLnR[2]) from a likelihood profile on the latter. pQ[1]: male crab, NMFS trawl survey 1975-1981; pQ[2]: male crab, NMFS trawl survey 1982+; pQ[3]: female crab, NMFS trawl survey 1975-1981; pQ[4]: female crab, NMFS trawl survey 1982+.

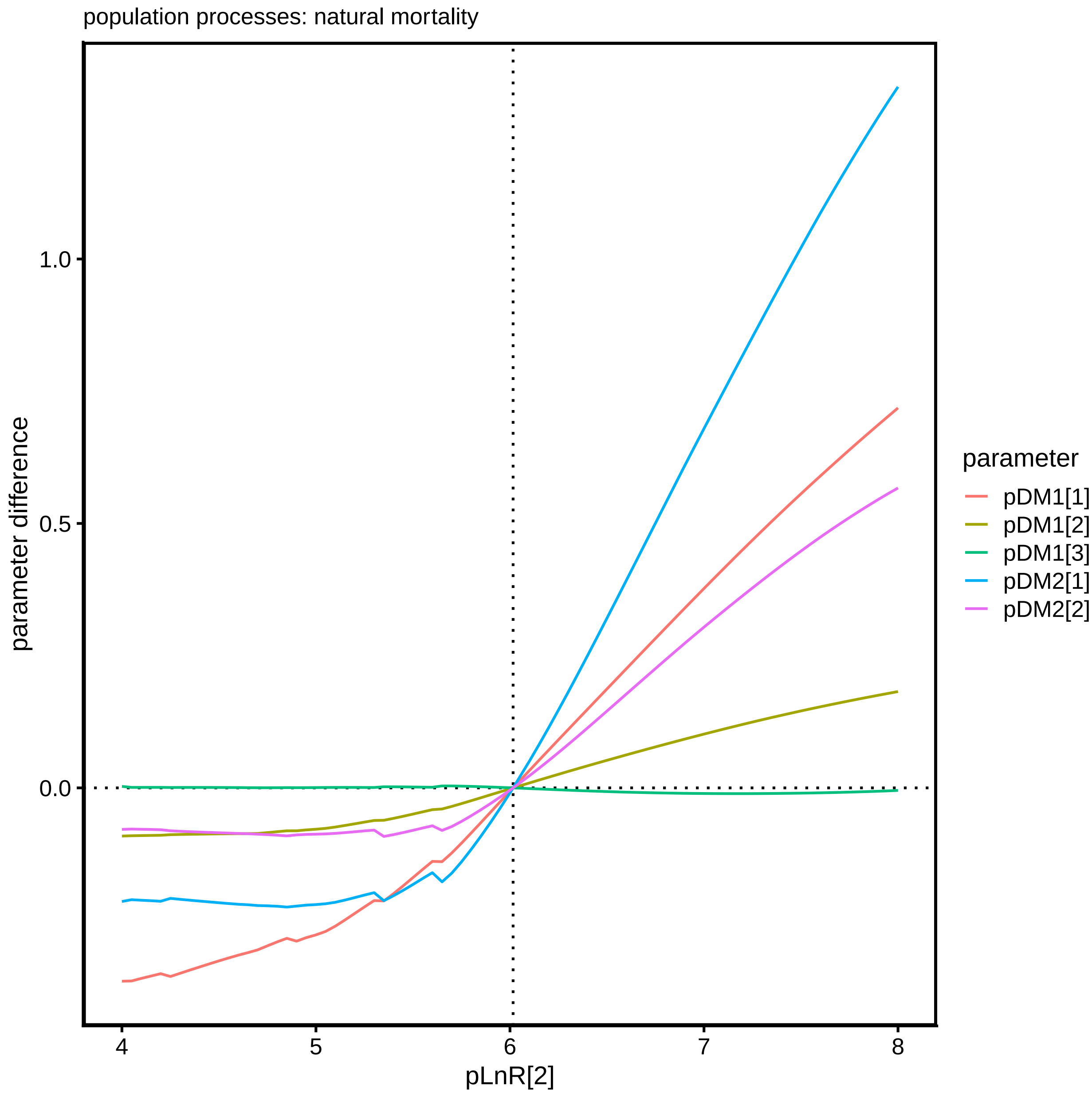


Figure 2. The change in estimated natural mortality parameters with log-scale mean recruitment after 1974 (pLnR[2]) from a likelihood profile on the latter. pDM1[1]: multiplier on base M for immature crab; pDM1[2]: multiplier on base M for mature males; pDM1[3]: multiplier on base M for mature females; pDM2[1]: multiplier on base M for mature males in enhanced mortality time block (1980-1984); pDM2[2]: multiplier on base M for mature females in enhanced mortality time block (1980-1984).

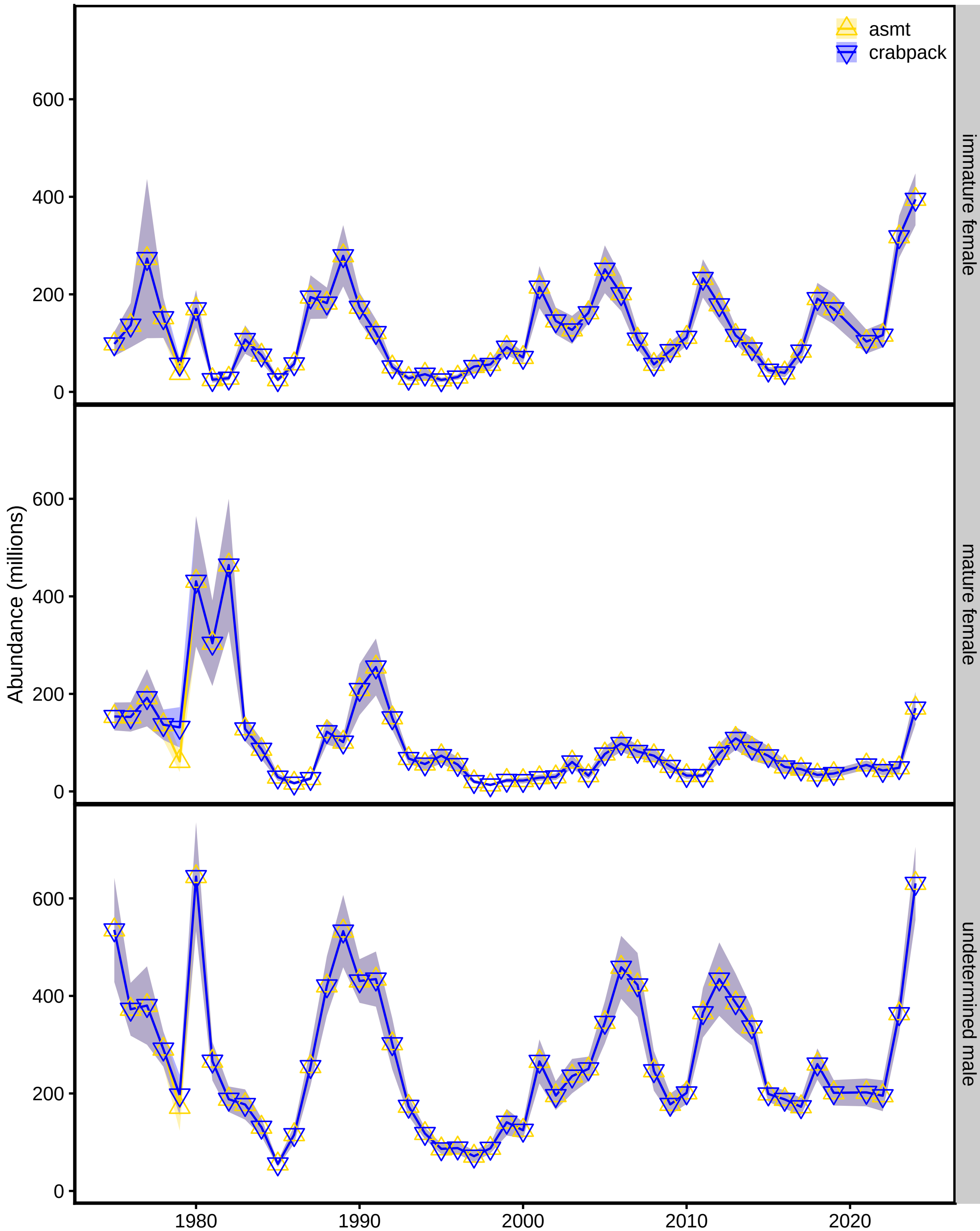


Figure 3. Comparison of annual estimates of design-based area-swept abundance from the NMFS EBS bottom trawl survey by the 2024 assessment (*asmt*) and the `crabpack` R package (*crabpack*), by sex and maturity state.

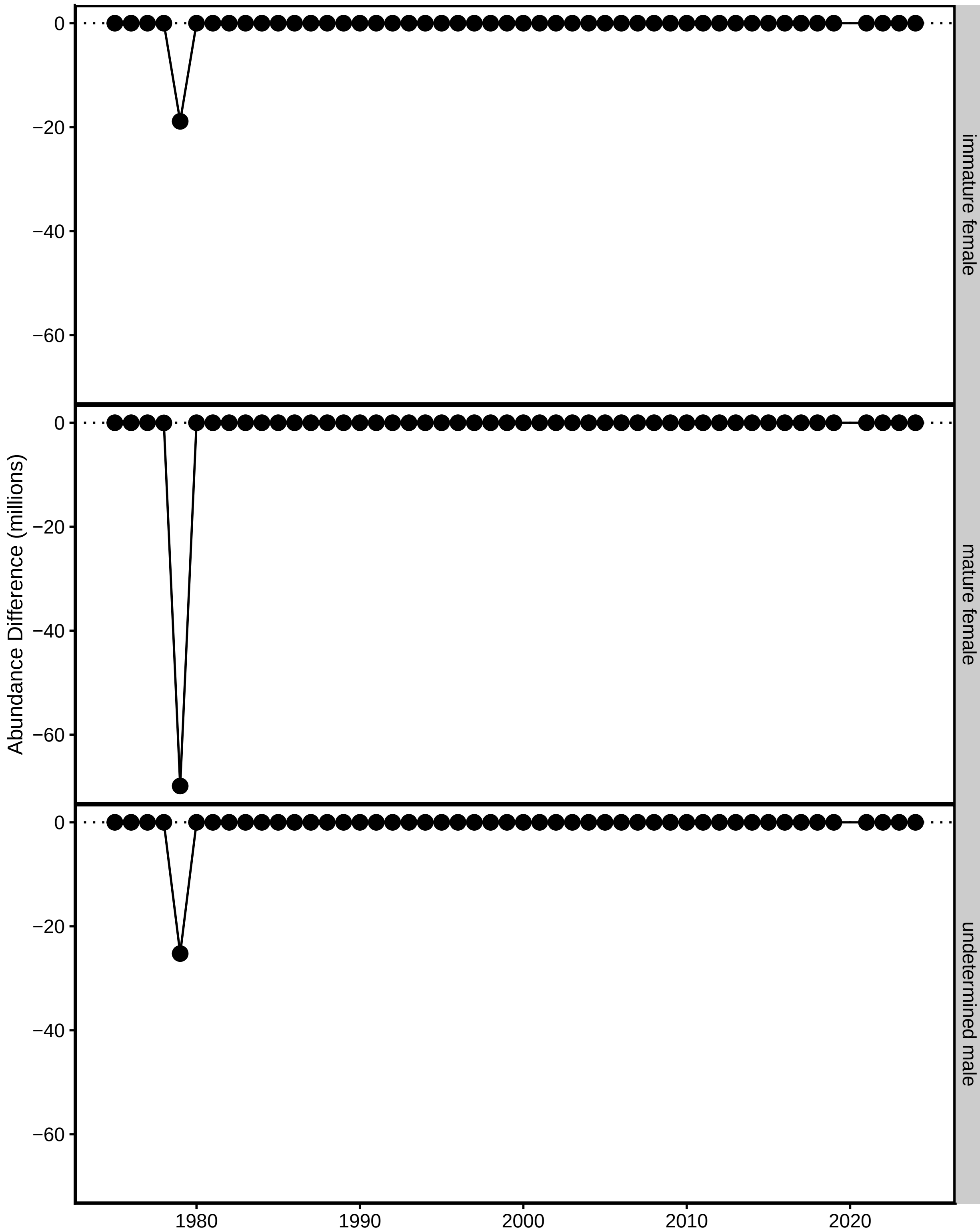


Figure 4. Differences in annual estimates of design-based area-swept abundance from the NMFS EBS bottom trawl survey by the 2024 assessment and the `crabpack` R package, by sex and maturity state.

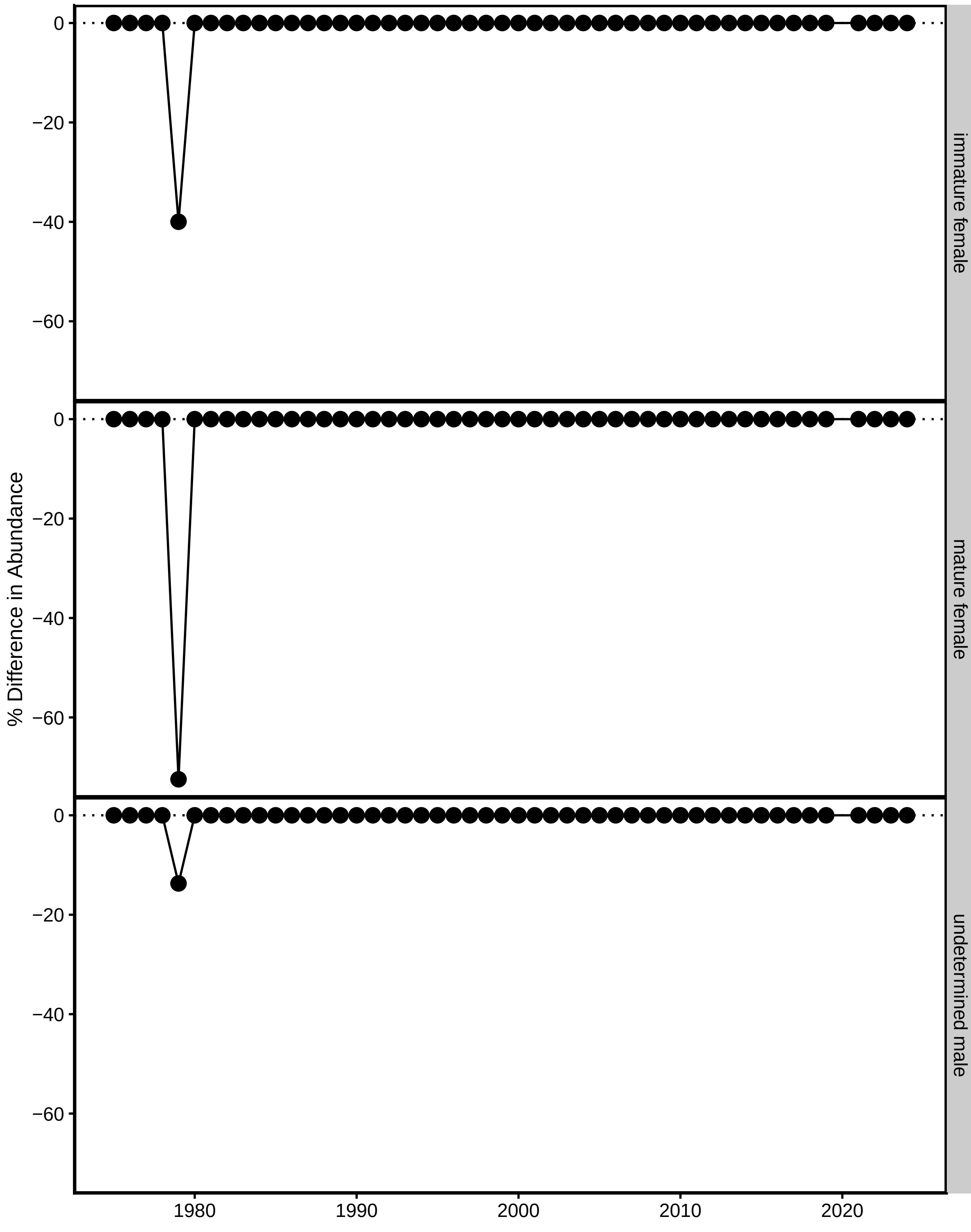


Figure 5. Percent differences in annual estimates of design-based area-swept abundance from the NMFS EBS bottom trawl survey by the 2024 assessment and the `crabpack` R package, by sex and maturity state.

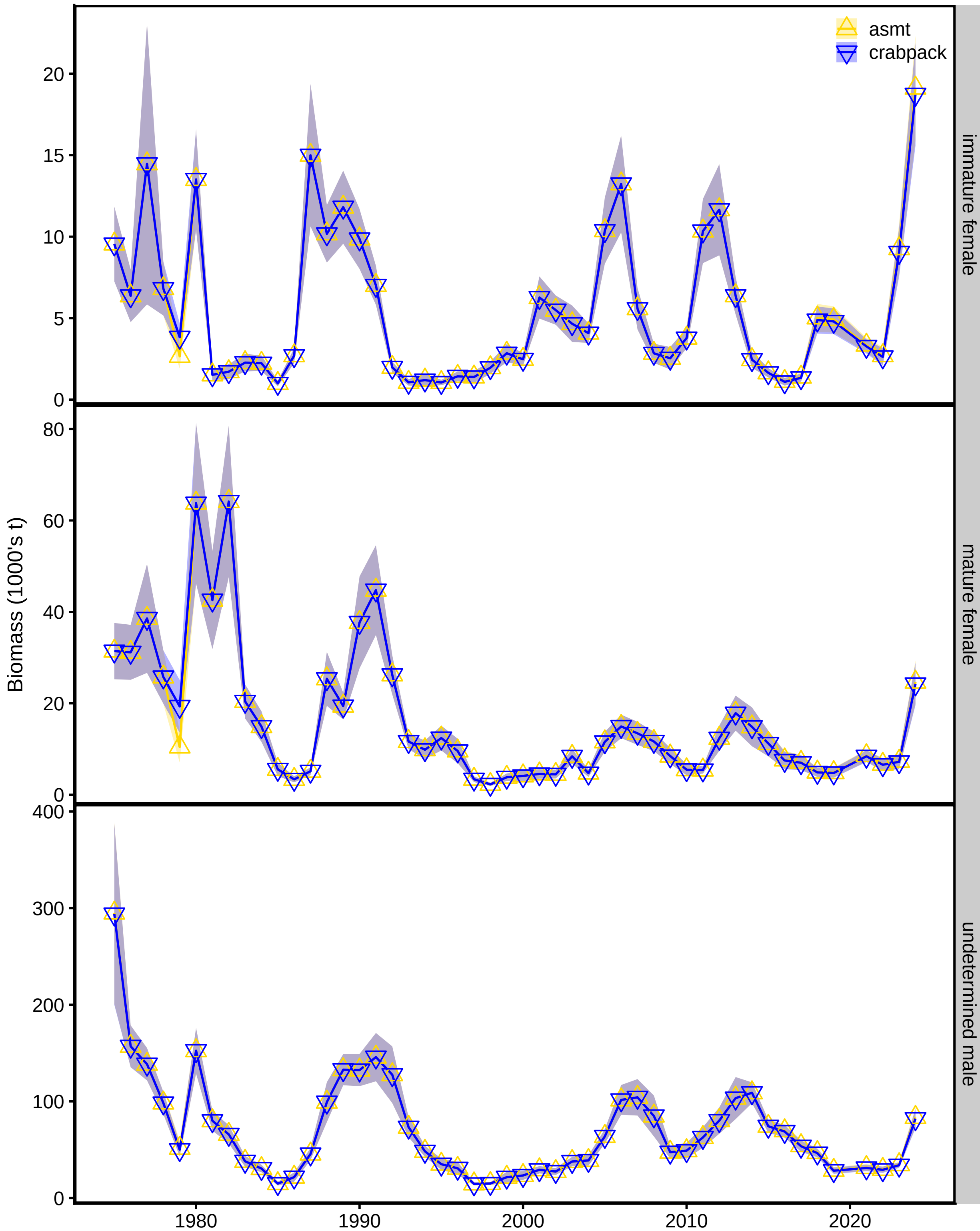


Figure 6. Comparison of annual estimates of design-based area-swept biomass from the NMFS EBS bottom trawl survey by the 2024 assessment (*asmt*) and the `crabpack` R package (*crabpack*), by sex and maturity state.

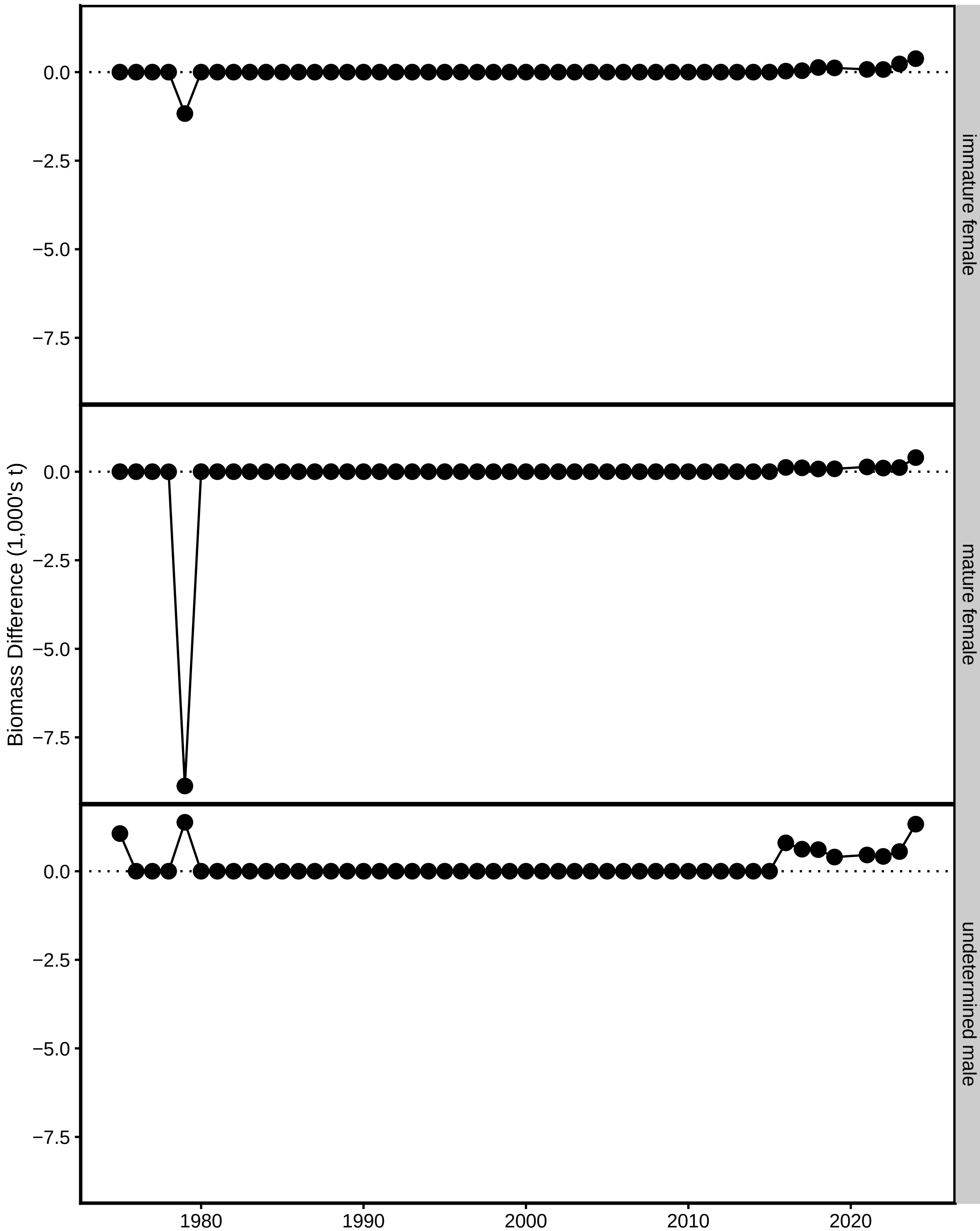


Figure 7. Differences in annual estimates of design-based area-swept biomass from the NMFS EBS bottom trawl survey by the 2024 assessment and the `crabpack` R package, by sex and maturity state.

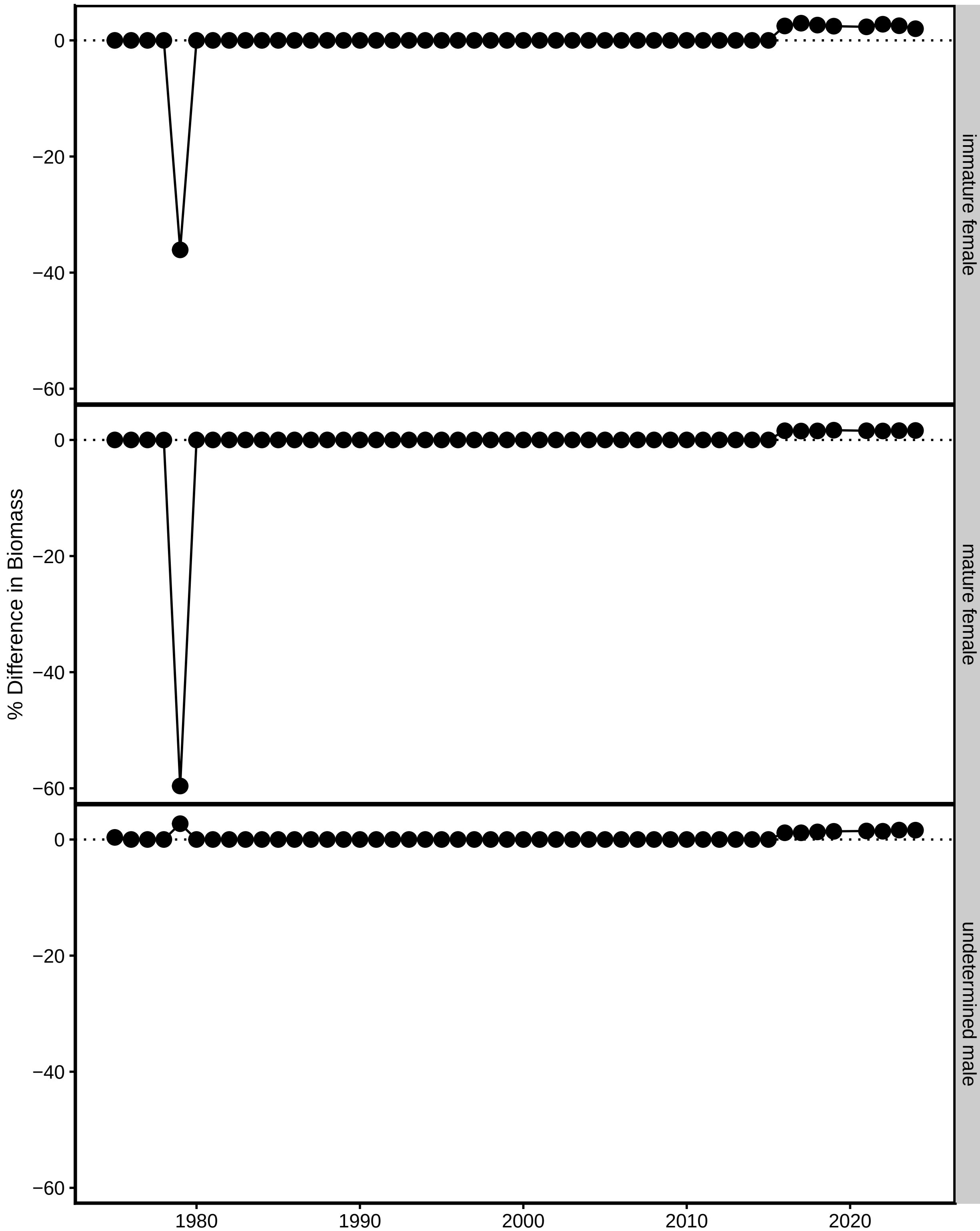


Figure 8. Percent differences in annual estimates of design-based area-swept biomass from the NMFS EBS bottom trawl survey by the 2024 assessment and the `crabpack` R package, by sex and maturity state.

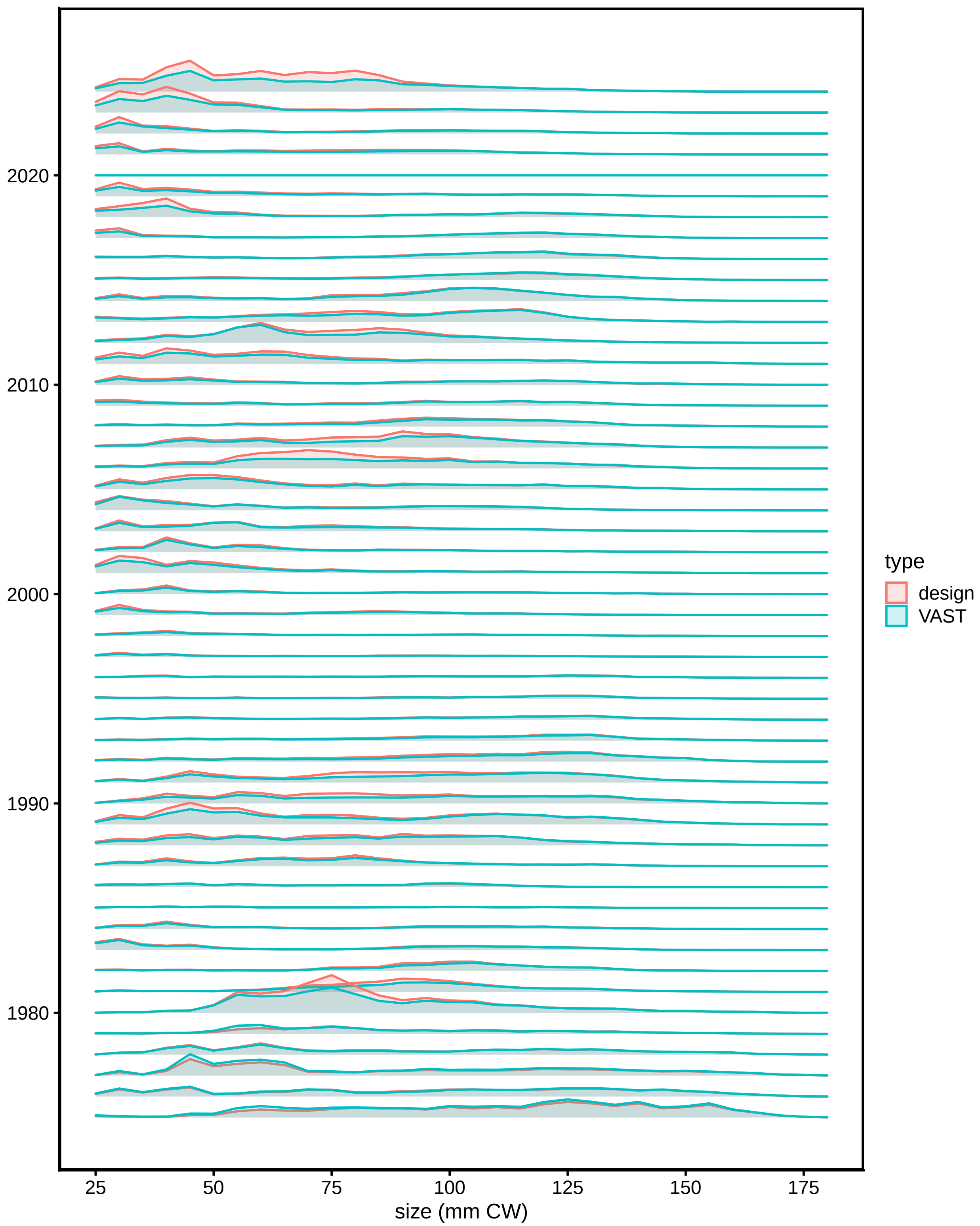


Figure 9. Comparison of annual estimates of male Tanner crab size compositions from the NMFS EBS bottom trawl survey using design-based methods (*design*) and VAST.

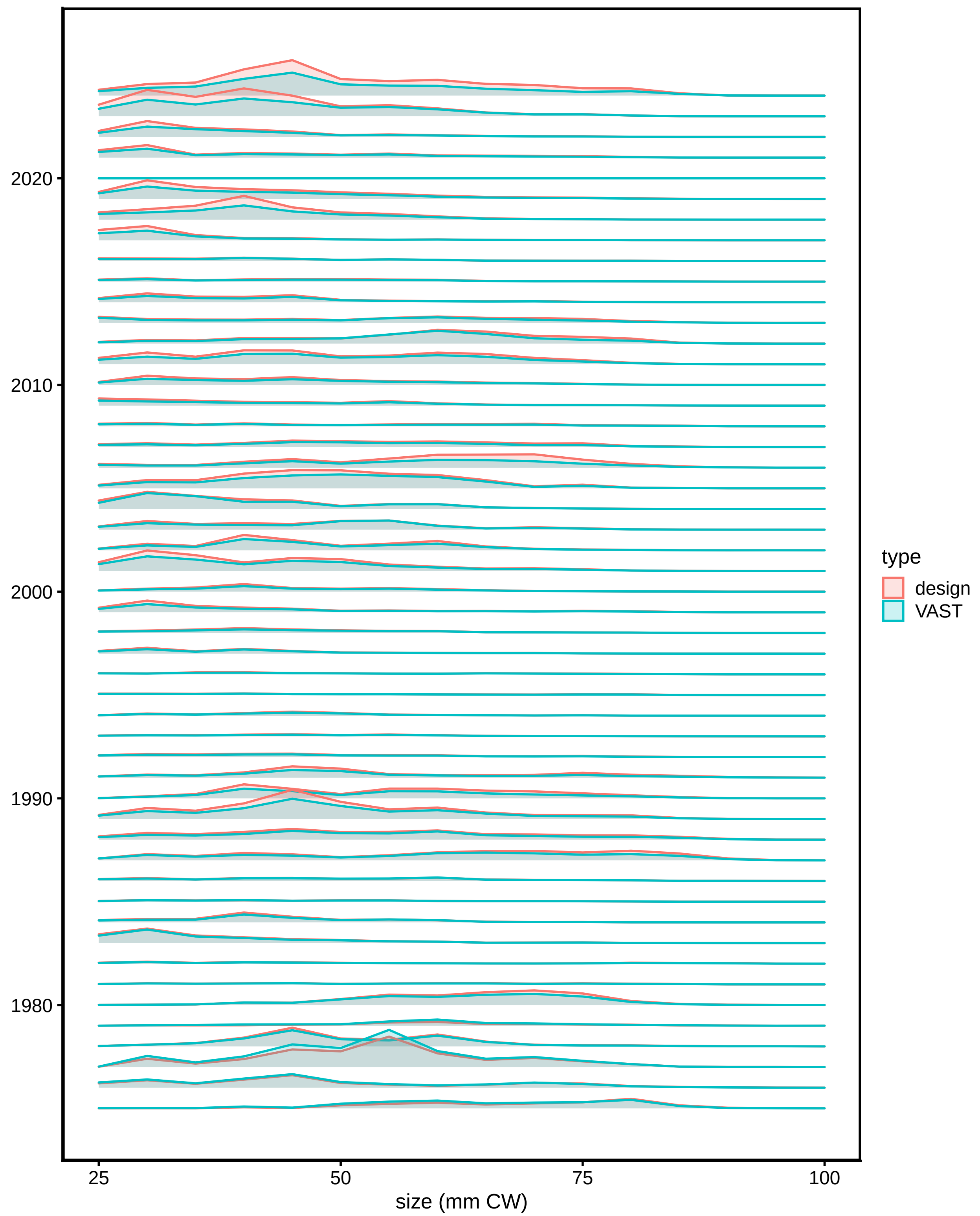


Figure 10. Comparison of annual estimates of immature female Tanner crab size compositions from the NMFS EBS bottom trawl survey using design-based methods (*design*) and VAST.

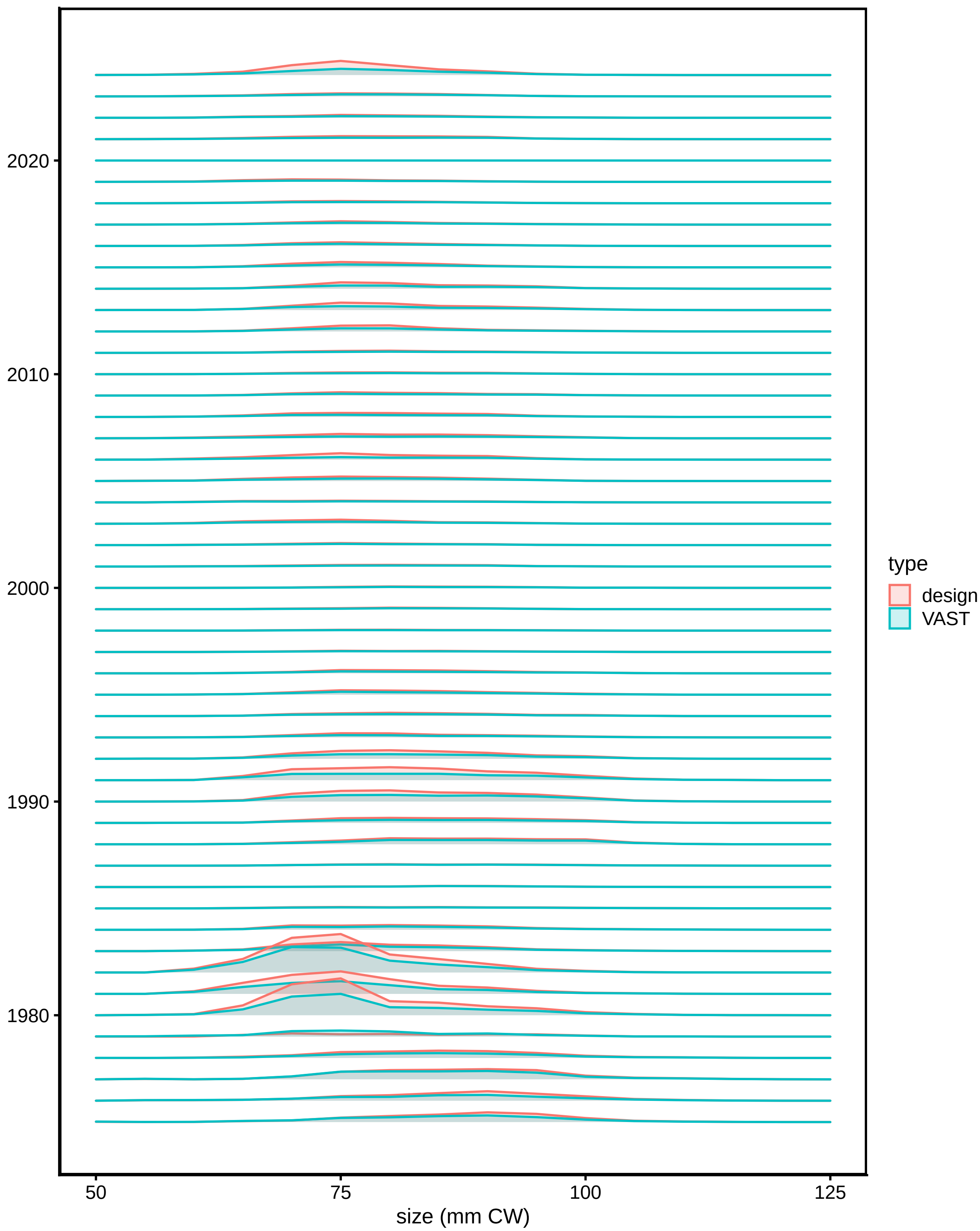


Figure 11. Comparison of annual estimates of mature female Tanner crab size compositions from the NMFS EBS bottom trawl survey using design-based methods (*design*) and VAST.

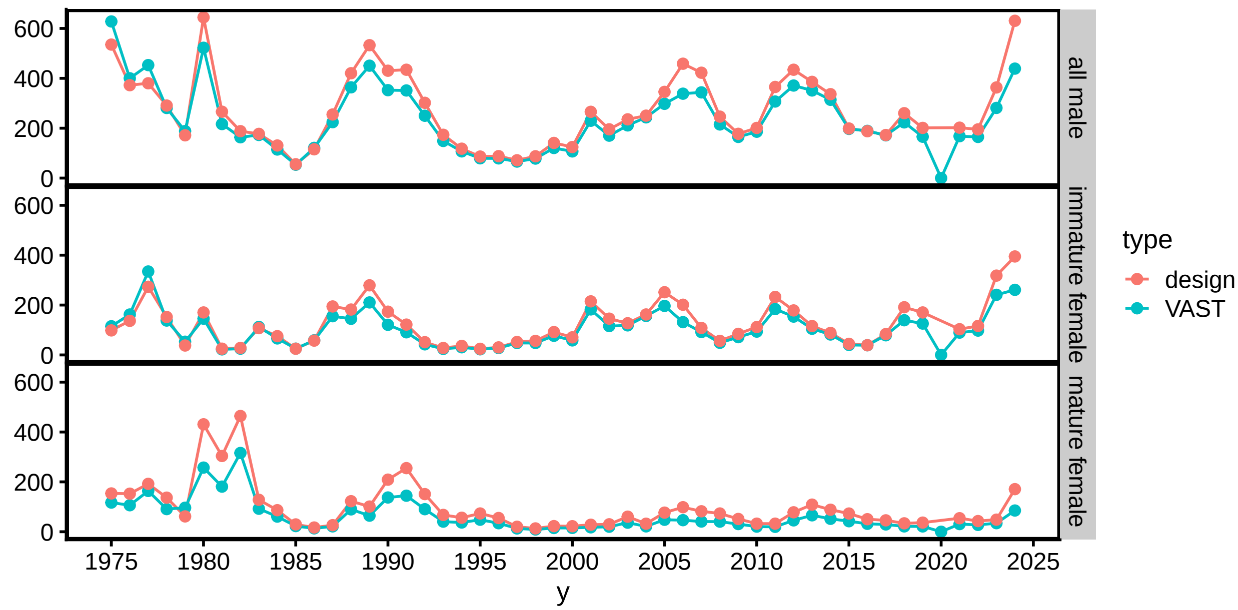


Figure 12. Comparison of total abundance as derived from the design-based and VAST size compositions, by population category. Note that the design-based value for 2020 is missing because no survey was conducted that year.

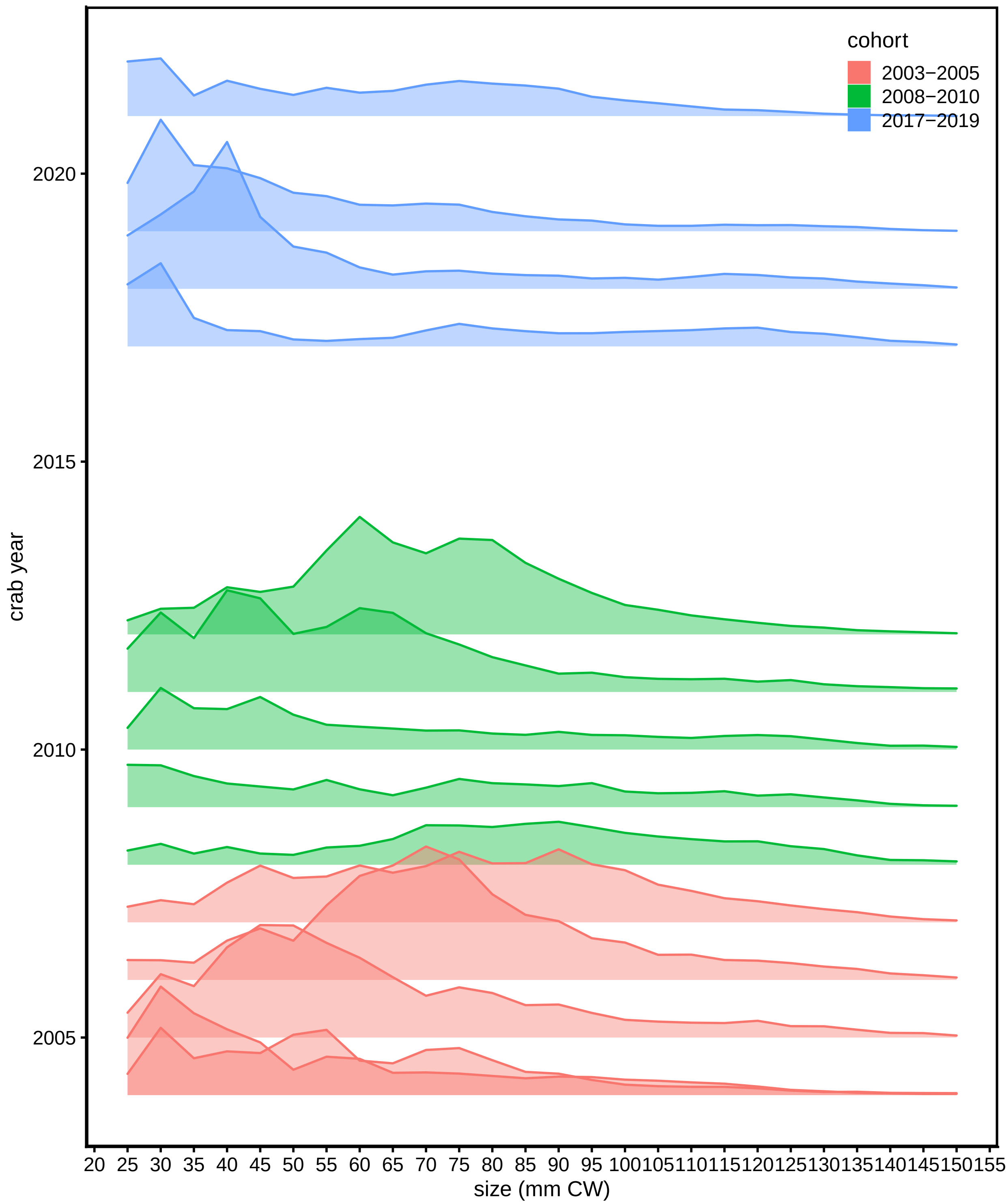


Figure 13. Progression of Tanner crab size compositions for successful (2003-2005; 2008-2010) and unsuccessful (2017-2021) pseudocohorts from the NMFS EBS bottom trawl survey across five years.

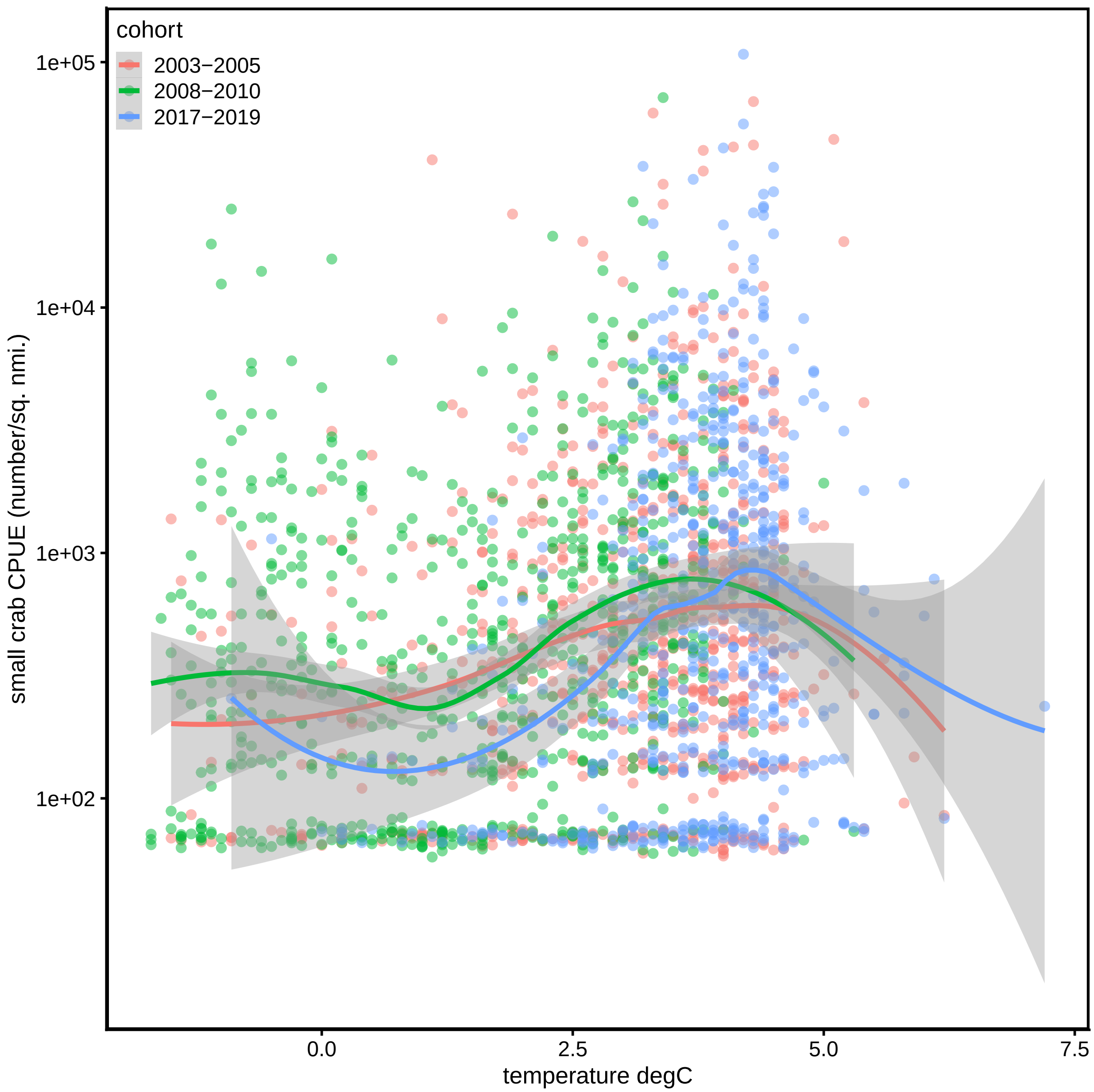


Figure 14. Small crab haul-specific CPUE plotted against bottom temperature for the successful 2003-2005 and 2008-2010 pseudocohorts and the unsuccessful 2017-2019 one. Lines and shading represent smooth fits to the ln-scale CPUE data as a function of temperature.

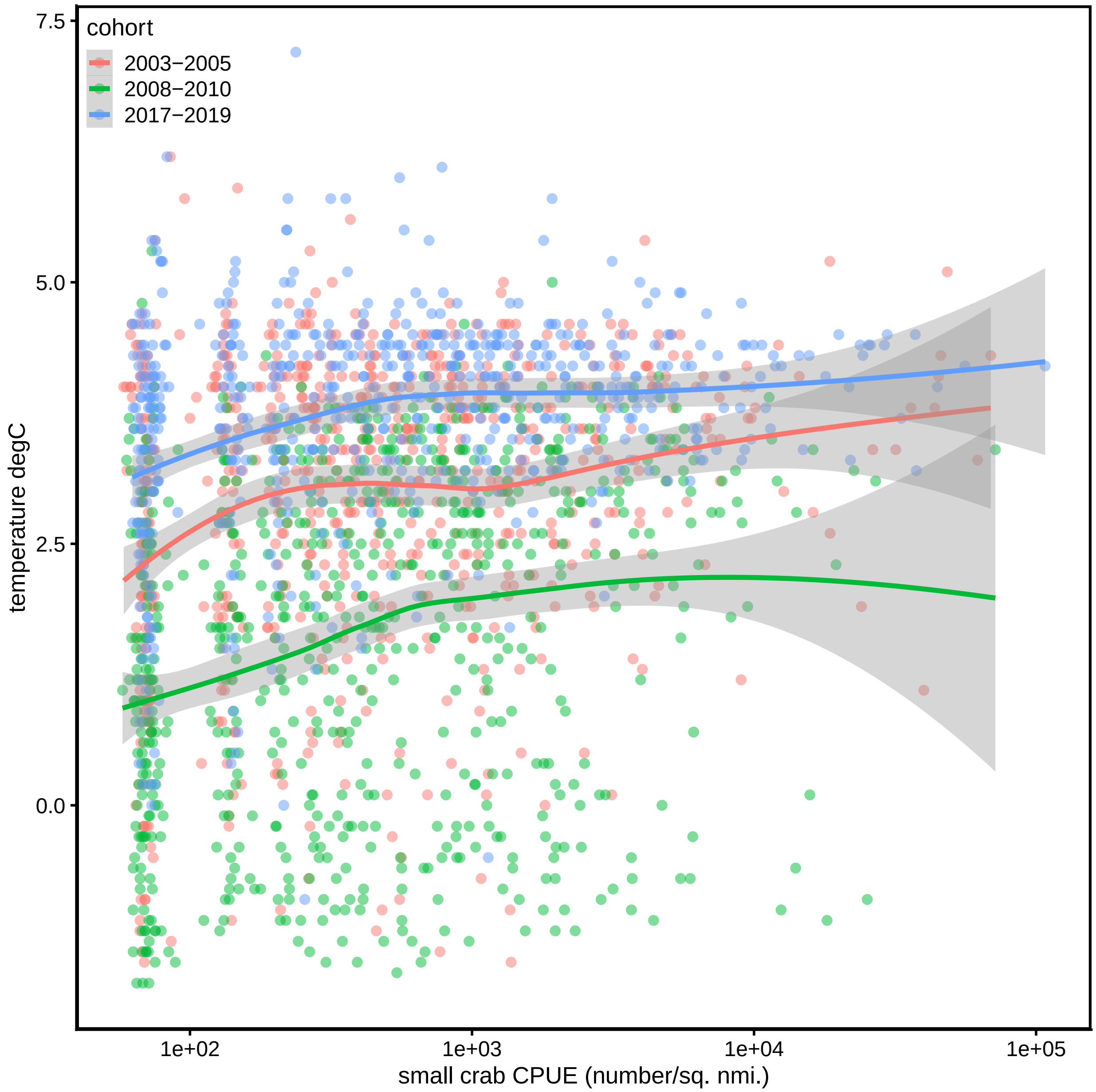


Figure 15. Bottom temperature plotted against small crab haul-specific CPUE for the successful 2003-2005 and 2008-2010 pseudocohorts and the unsuccessful 2017-2019 one. Lines and shading represent smooth fits to the temperature data as a function of ln-scale CPUE.

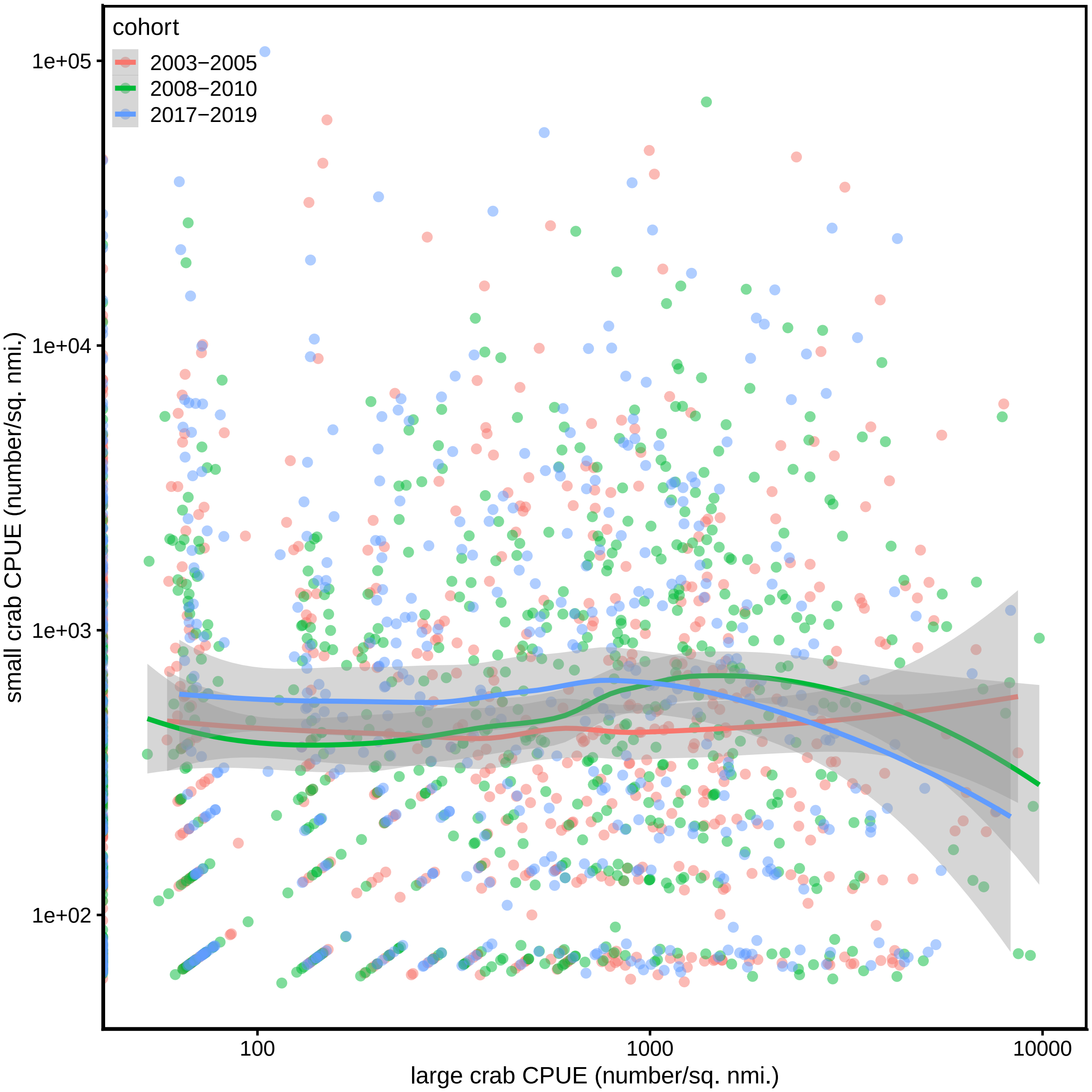


Figure 16. Small crab haul-specific CPUE plotted against large crab haul-specific CPUE for the successful 2003-2005 and 2008-2010 pseudocohorts and the unsuccessful 2017-2019 one. Lines and shading represent smooth fits to the small crab CPUE data as a function of the large crab CPUE data.

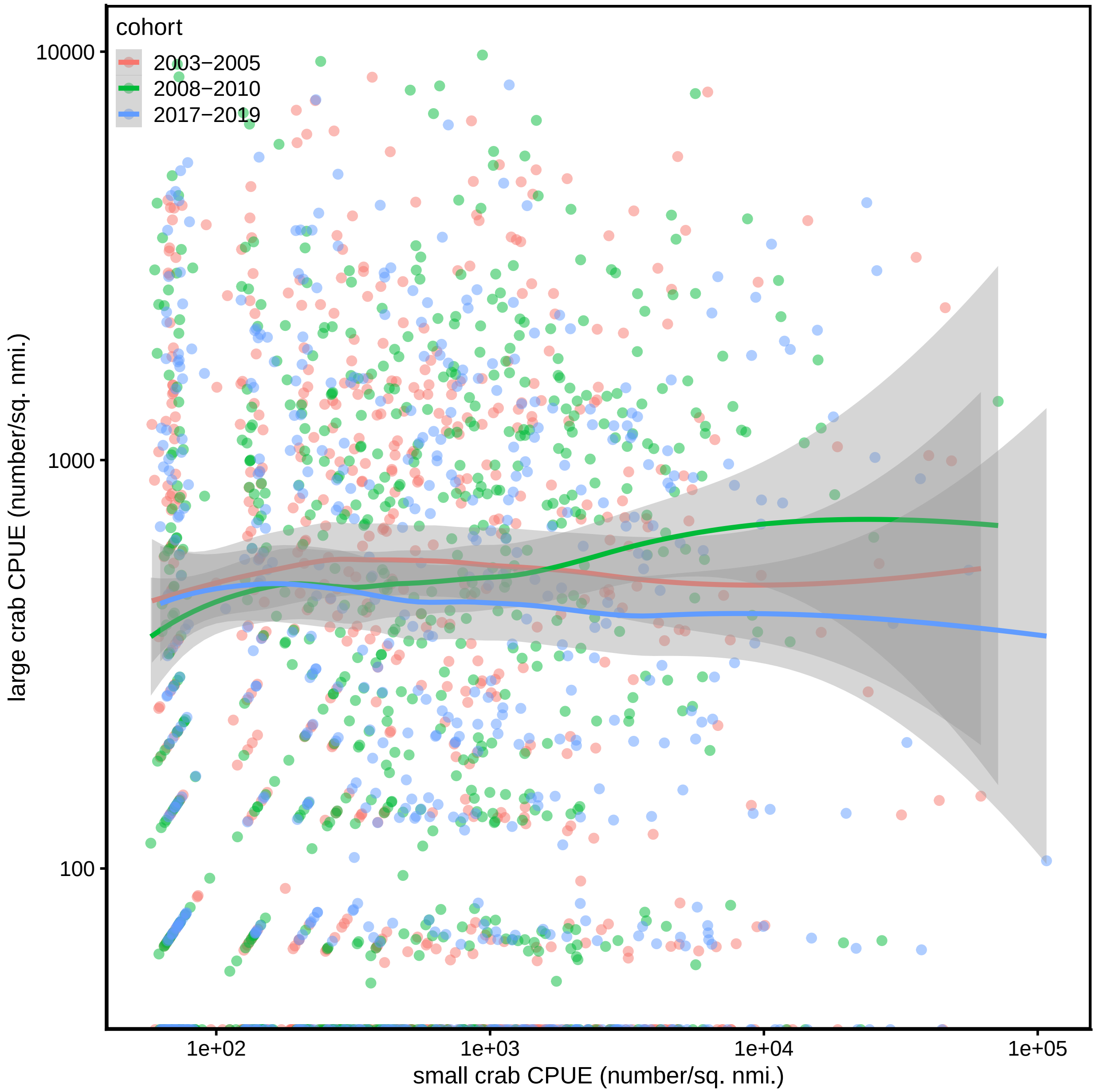


Figure 17. Large crab haul-specific CPUE plotted against small crab haul-specific CPUE for the successful 2003-2005 and 2008-2010 pseudocohorts and the unsuccessful 2017-2019 one. Lines and shading represent smooth fits to the ln-scale large crab CPUE data as a function of the ln-scale small crab CPUE data.

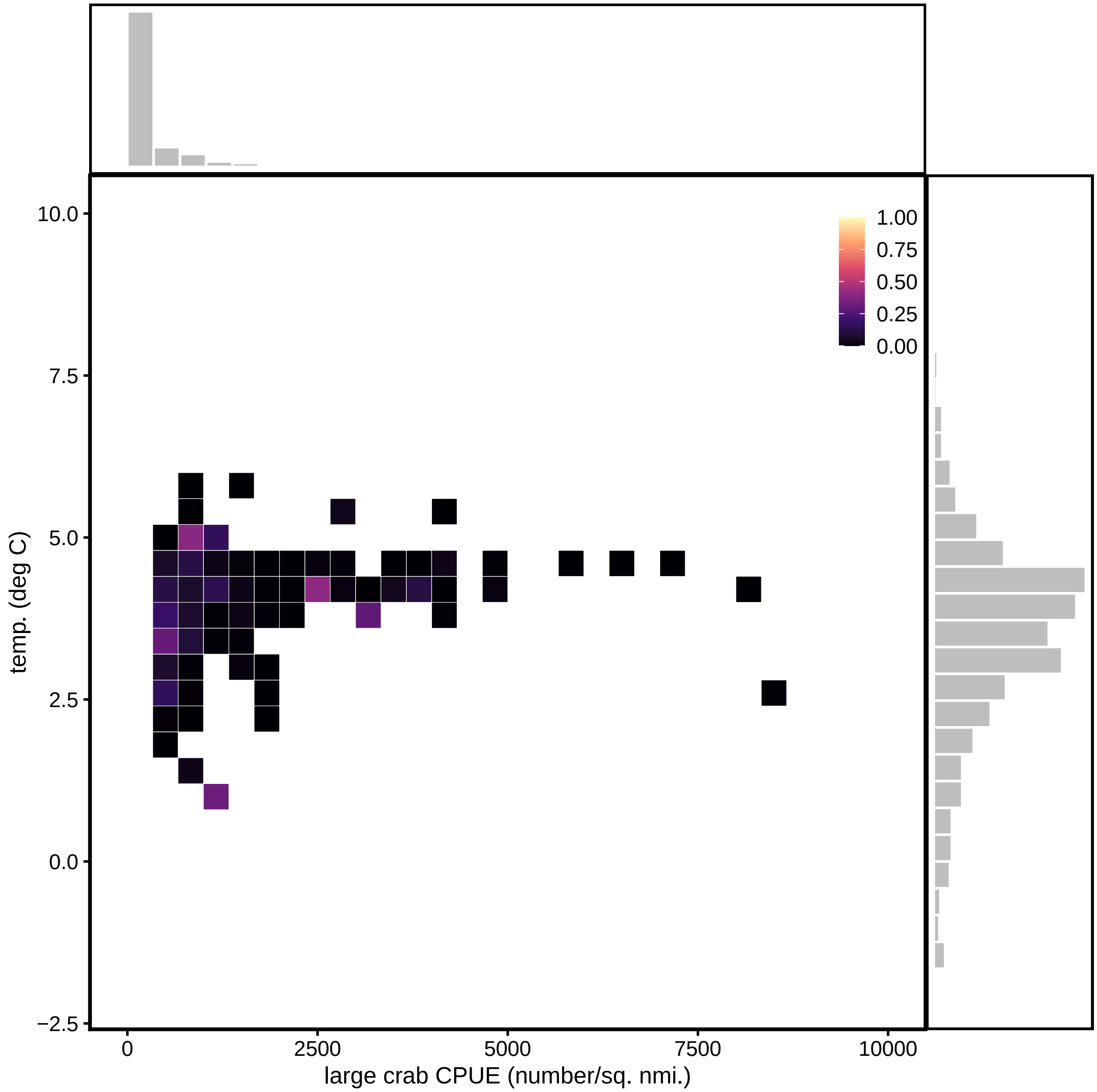


Figure 18. Relative abundance of small crab as a function of large crab CPUE and temperature for the successful 2003-2005 pseudocohort.

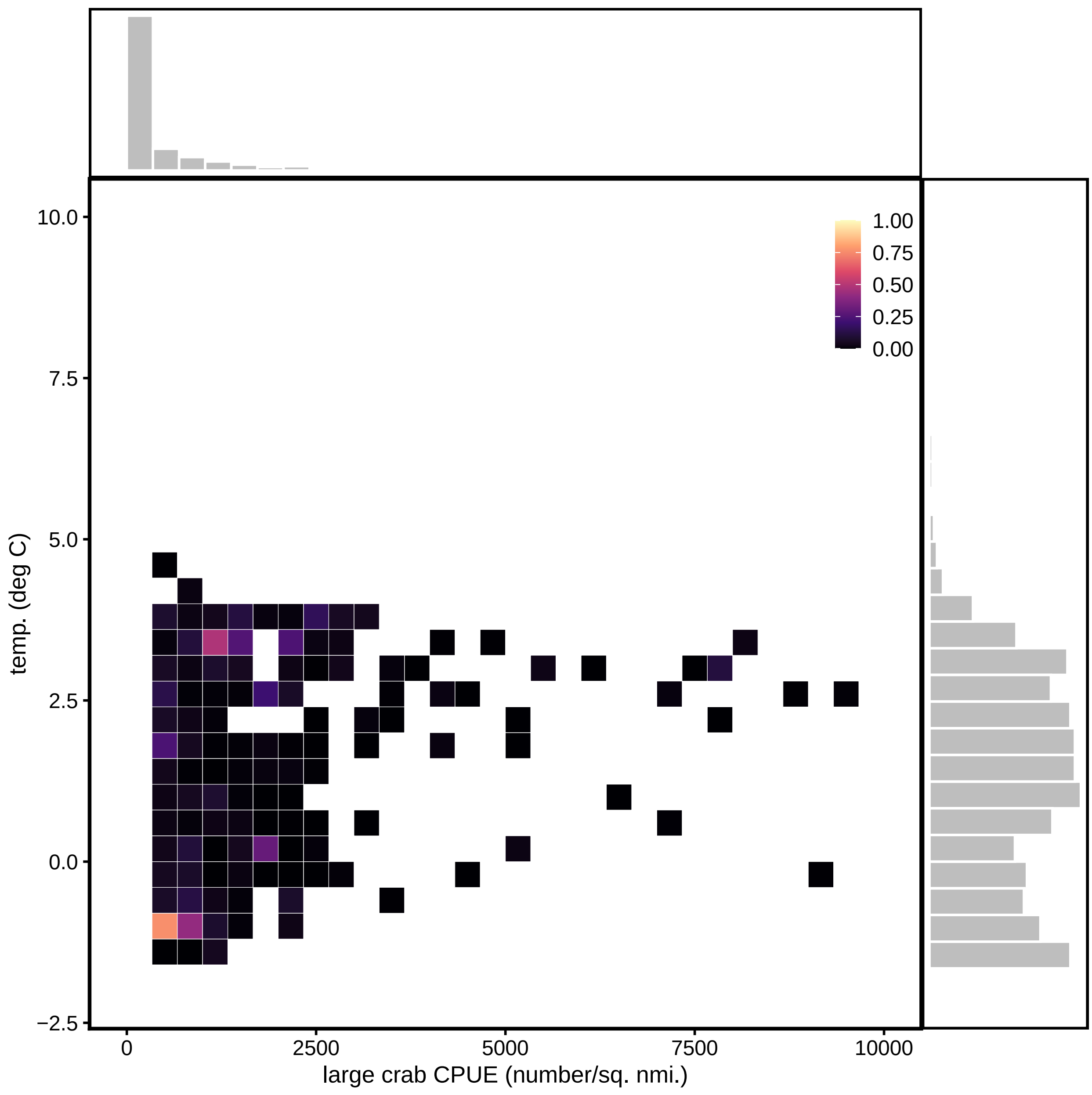


Figure 19. Relative abundance of small crab as a function of large crab CPUE and temperature for the successful 2008-2010 pseudocohort.

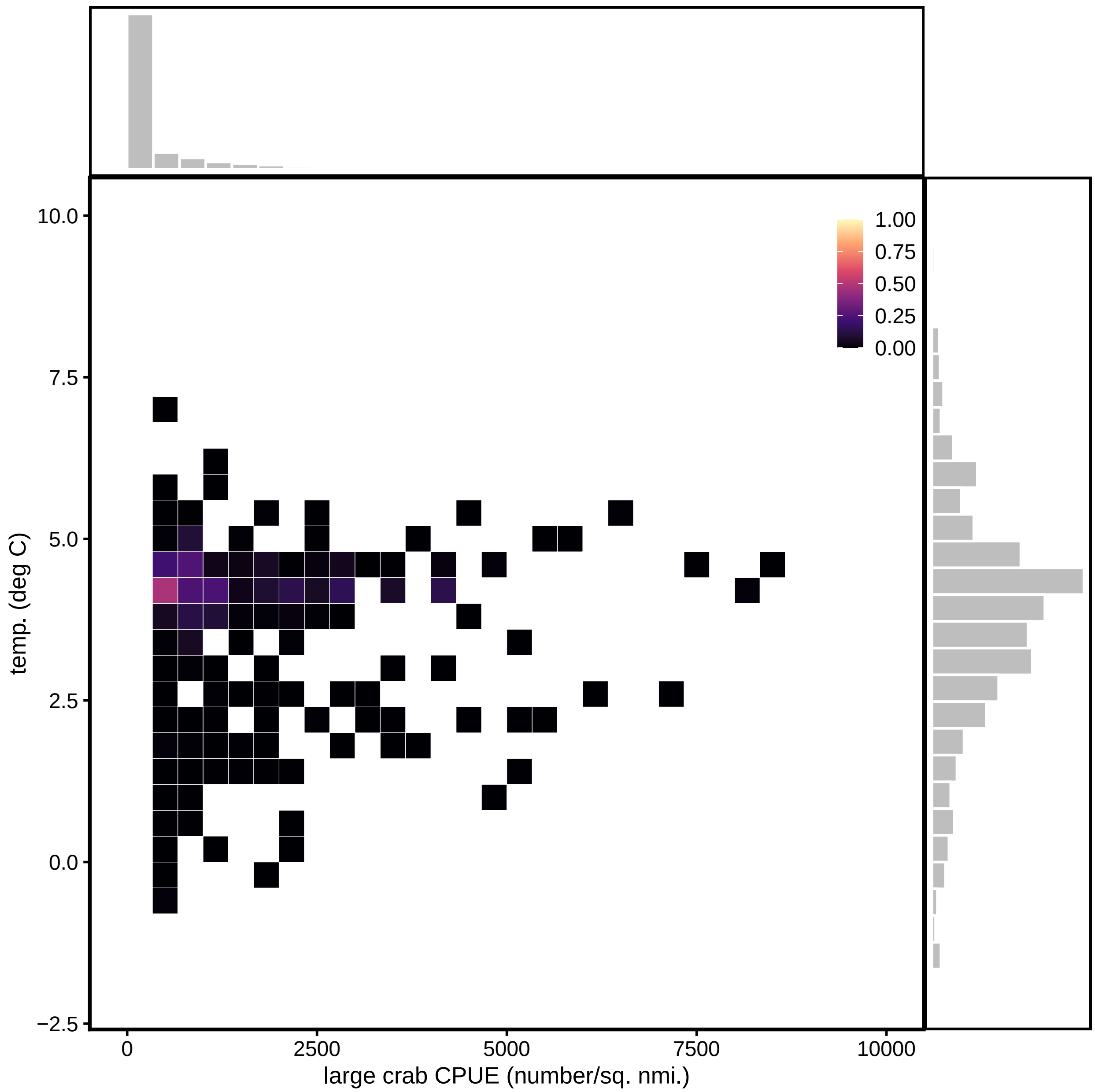


Figure 20. Relative abundance of small crab as a function of large crab CPUE and temperature for the unsuccessful 2017-2019 pseudocohort.

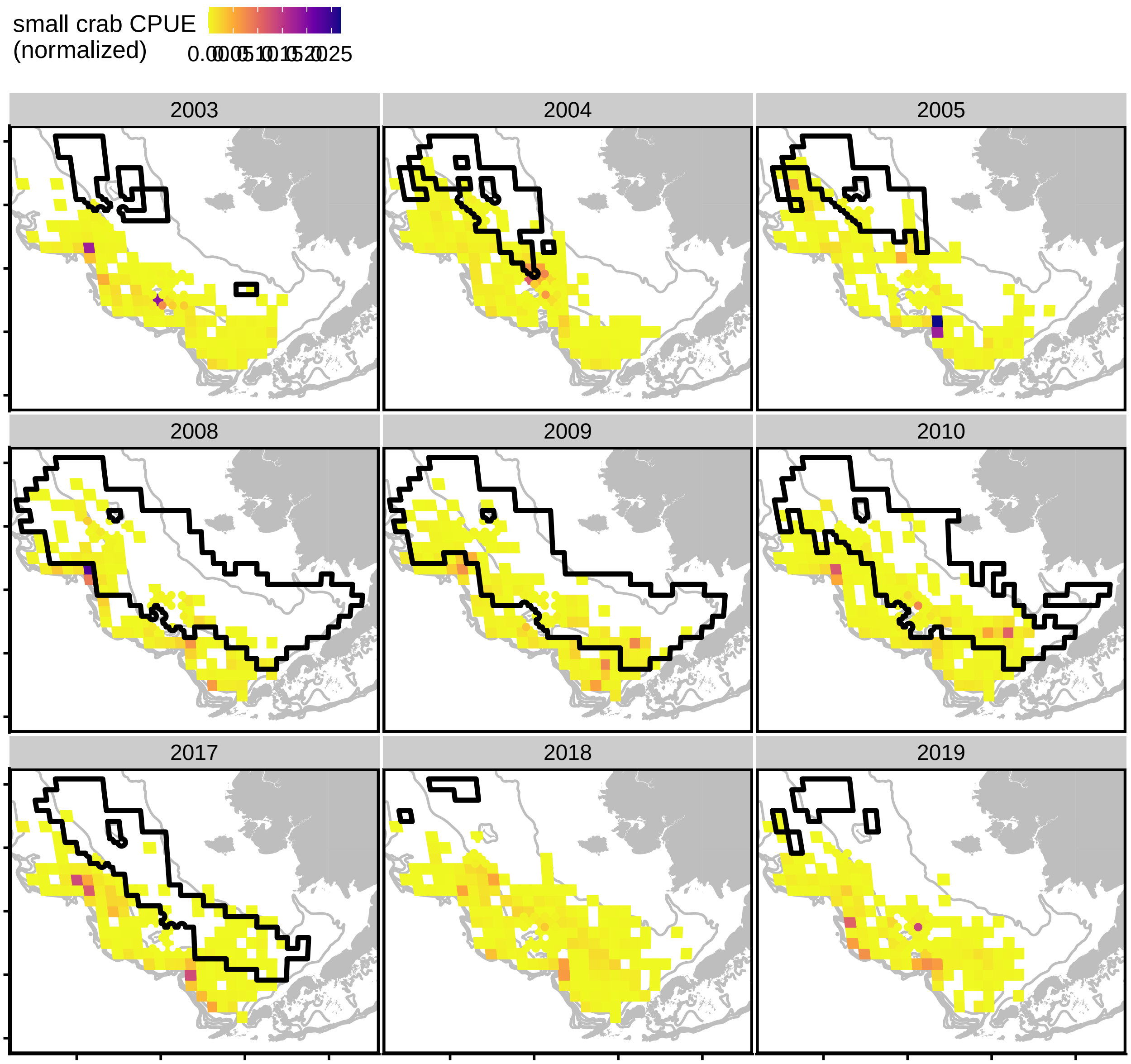


Figure 21. Relative abundance of small crab (color scale) at NMF EBS bottom trawl survey stations for the two successful (2003-2005, 2008-2010) and one unsuccessful (2017-2019) psuedocohort. The annual extent of 2 deg C or colder 'cold pool'water (as determined by bottom temperature at the survey stations) is indicated by the black outline.

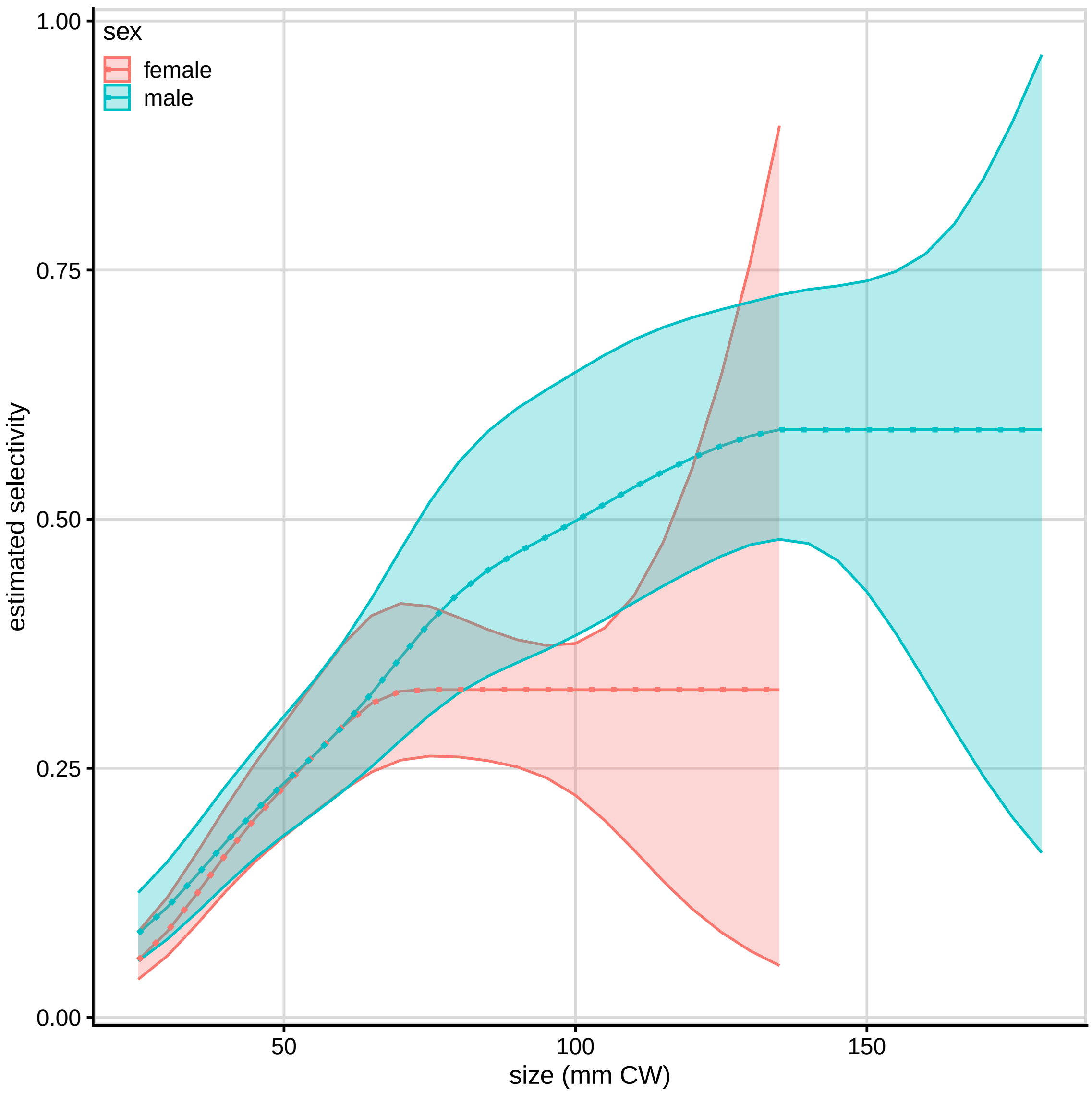


Figure 22. Estimated sex/size-specific capture probability for the 1982+ NMFS EBS bottom trawl survey, based on a survey-level analysis of the cooperative BSFRF/NMFS side-by-side haul data for Tanner crab.

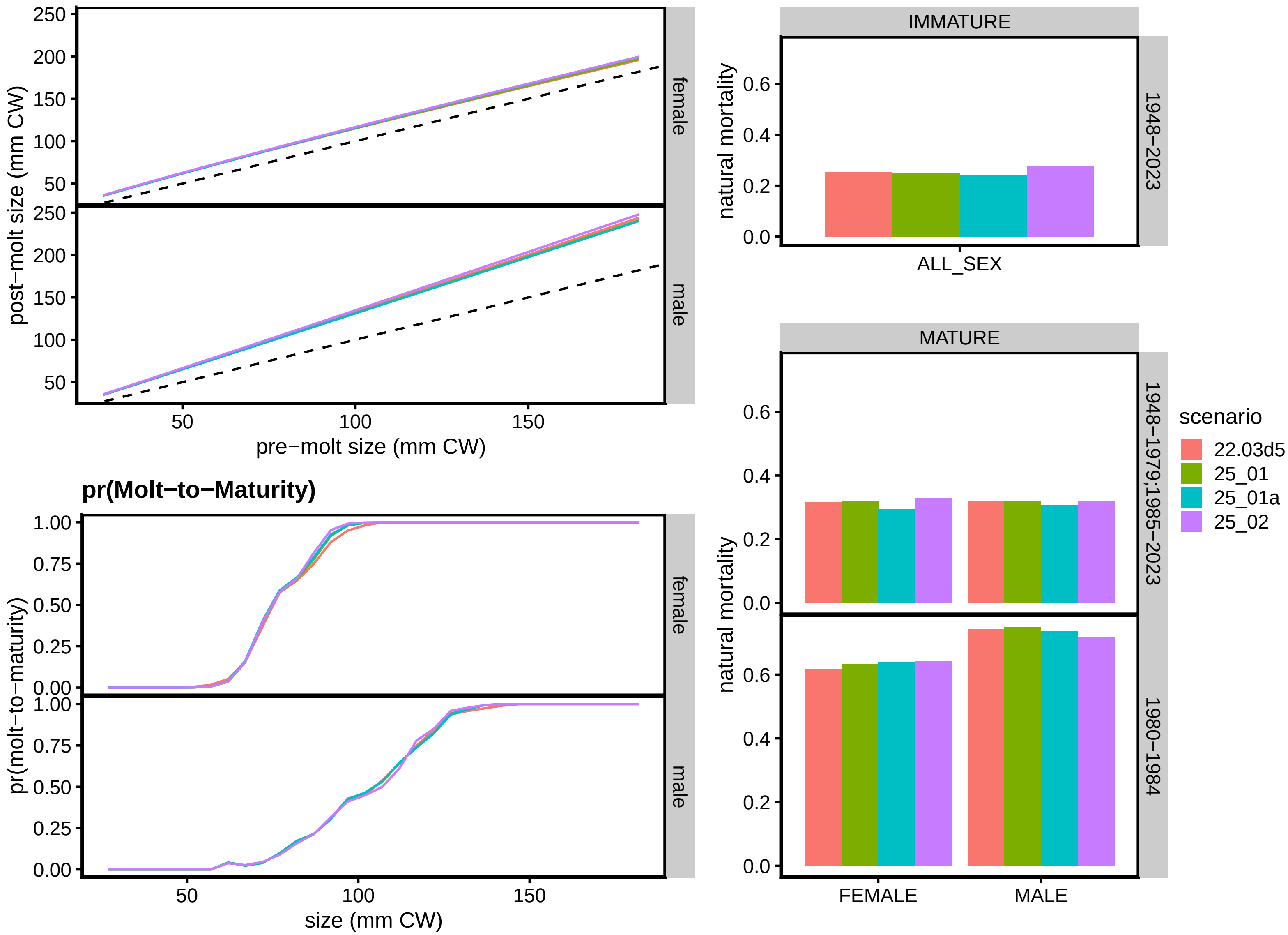
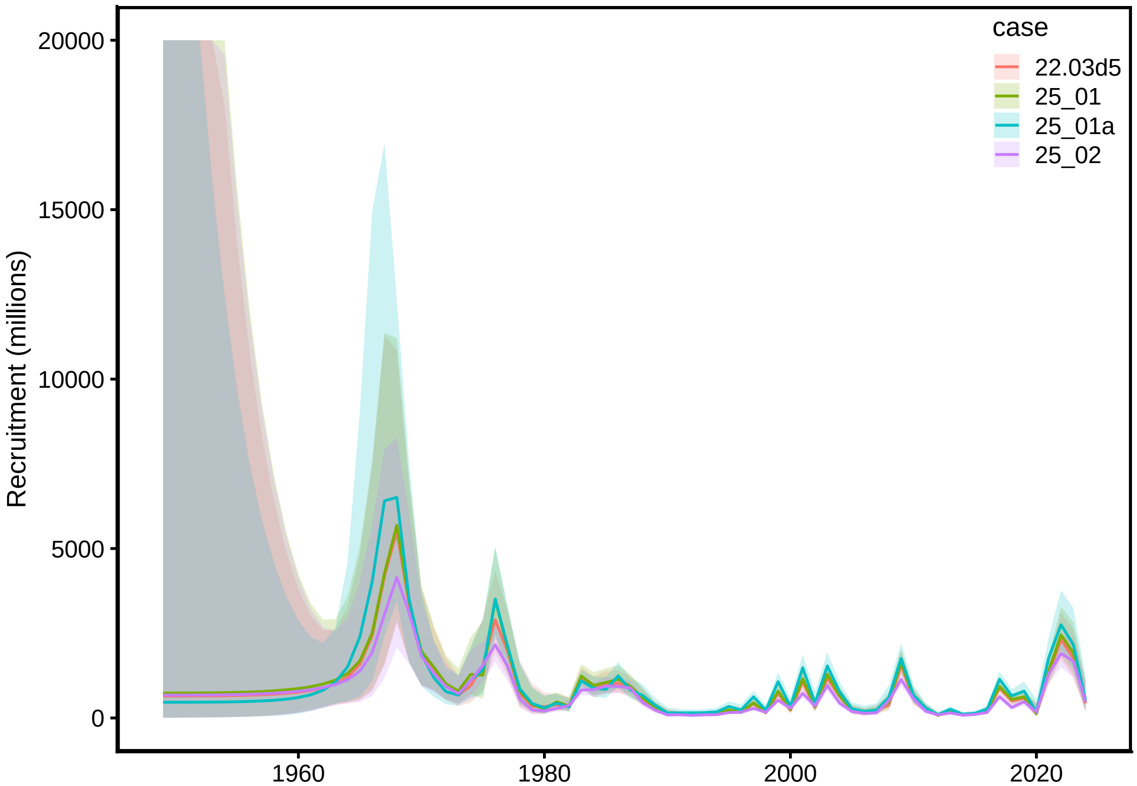


Figure 23. Estimated population processes from the TCSAM02 models. Plots in upper lefthand quadrant: sex-specific mean growth; plots in lower lefthand quadrant: sex-specific probability of the molt-to-maturity (i.e., terminal molt); plots in righthand column: natural mortality rates, by maturity state and sex.



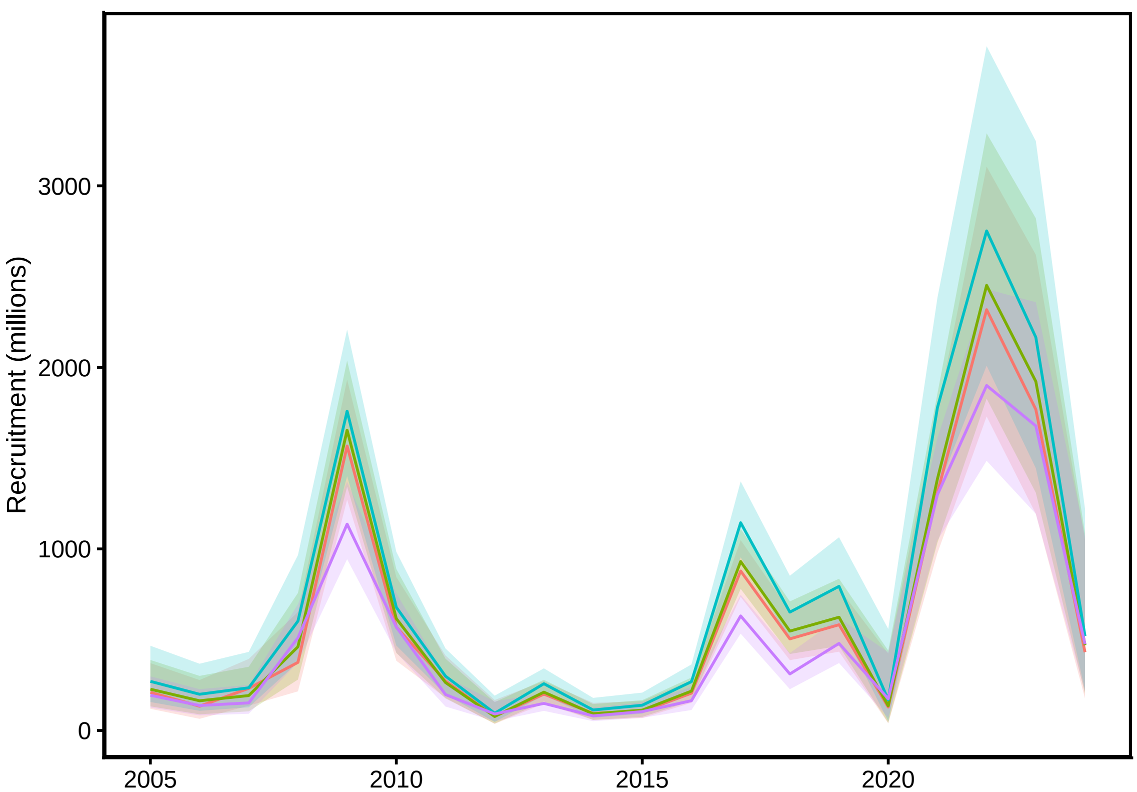


Figure 24. Estimated recruitment trends from the TCSAM02 models. Fills indicate confidence intervals.

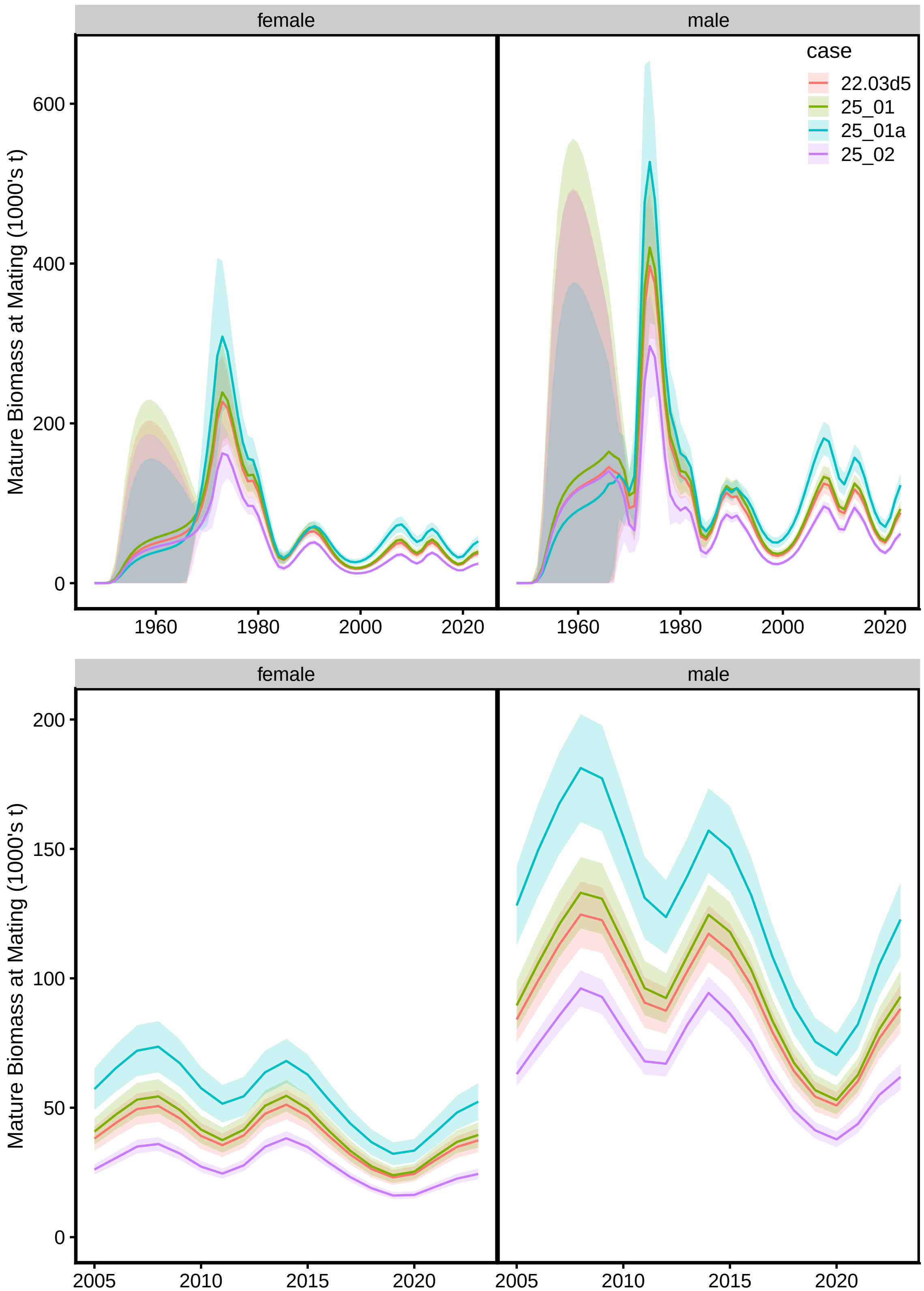


Figure 25. Estimated mature biomass trends from the TCSAM02 models. Fills indicate confidence intervals.

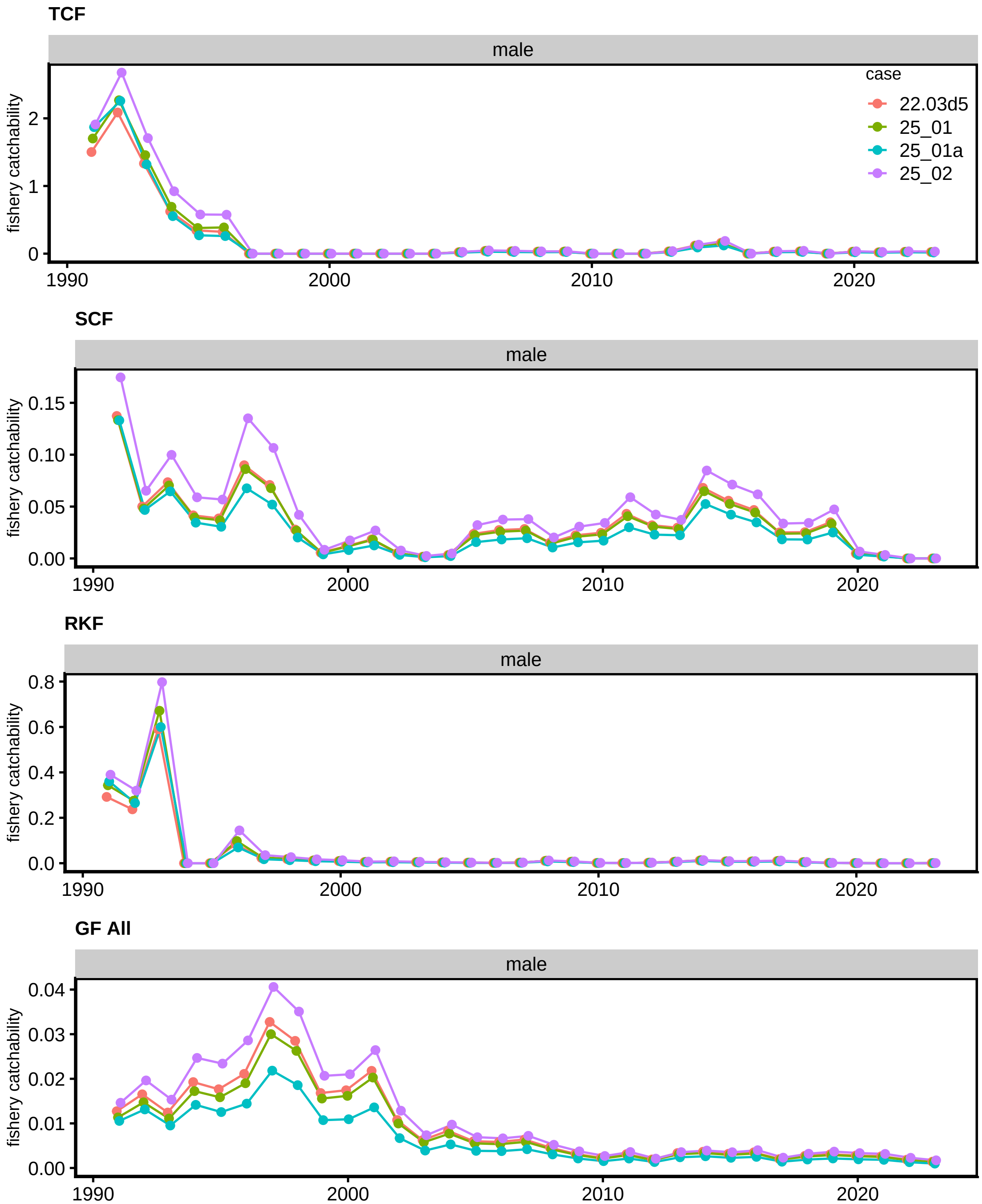


Figure 26. Estimated fully-selected capture rates (not mortality) for male Tanner crab in the directed and bycatch fisheries from the TCSAM02 models. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: all groundfish fisheries.

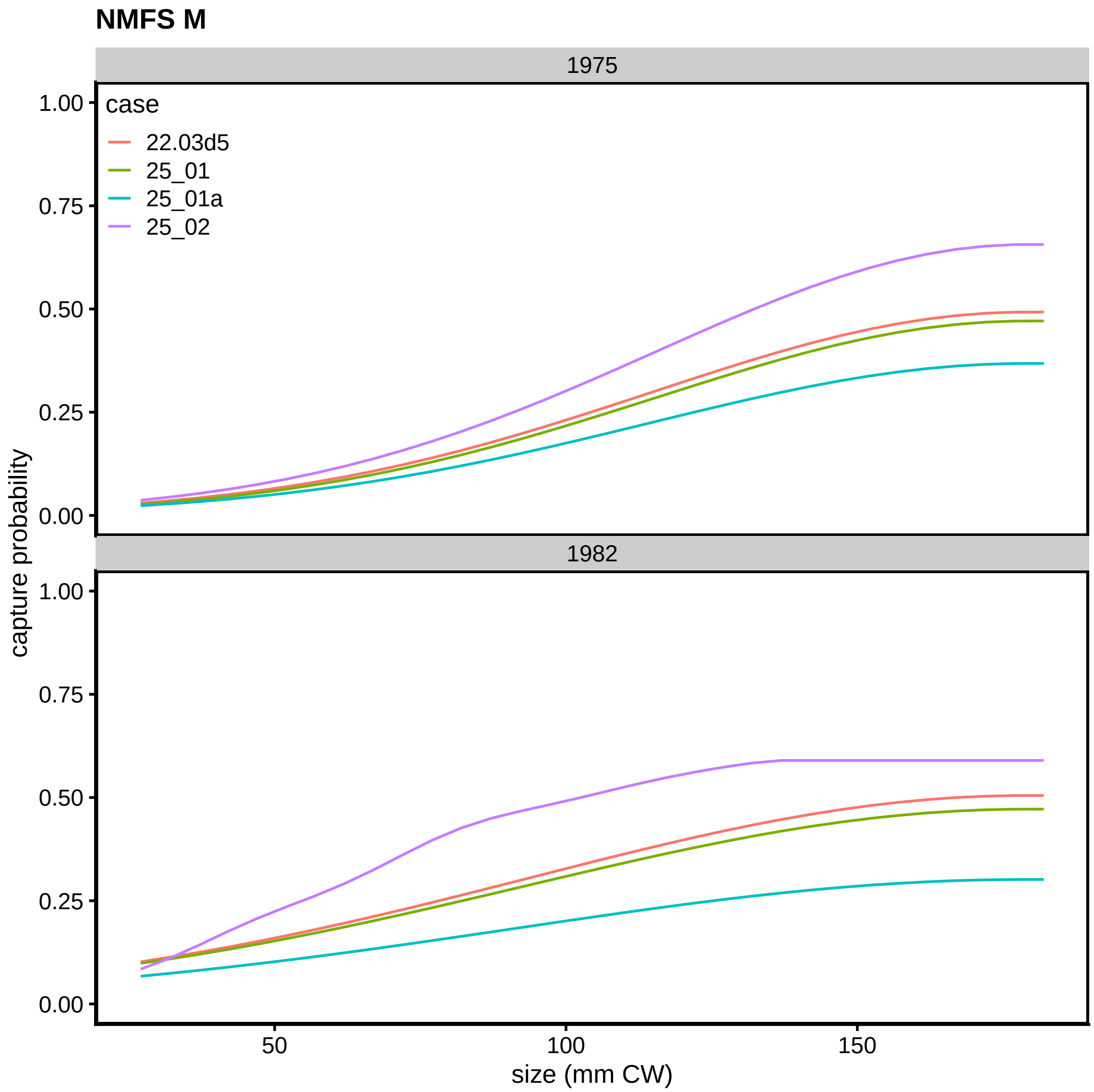


Figure 27. Estimated size-specific capture probability for male Tanner crab in the NMFS EBS bottom trawl survey from the TCSAM02 models. Estimated curves are applied in two time periods: 1975: 1975-1981; 1982; 1982+.

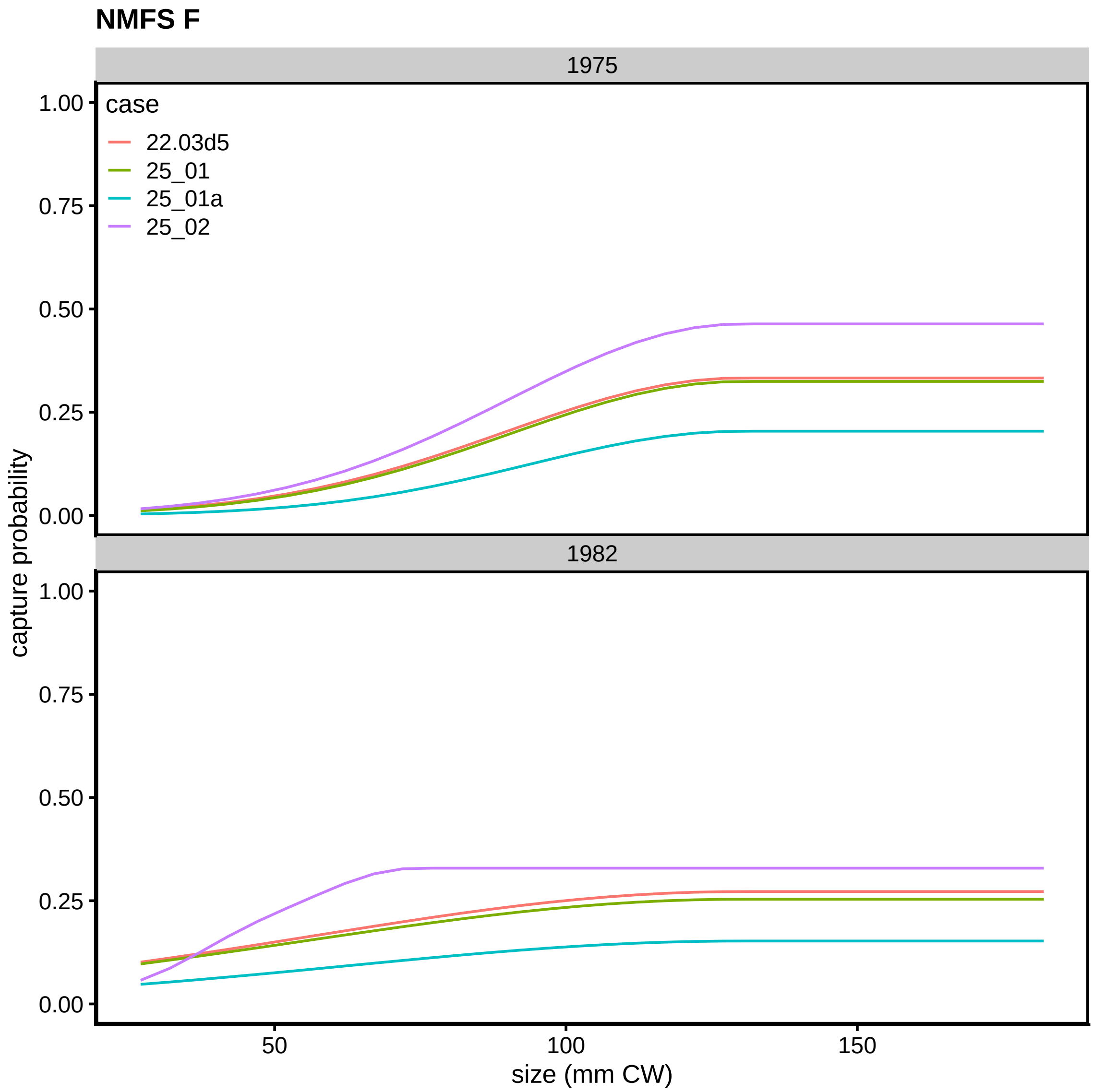


Figure 28. Estimated size-specific capture probability for female Tanner crab in the NMFS EBS bottom trawl survey from the TCSAM02 models. Estimated curves are applied in two time periods: 1975: 1975-1981; 1982; 1982+.

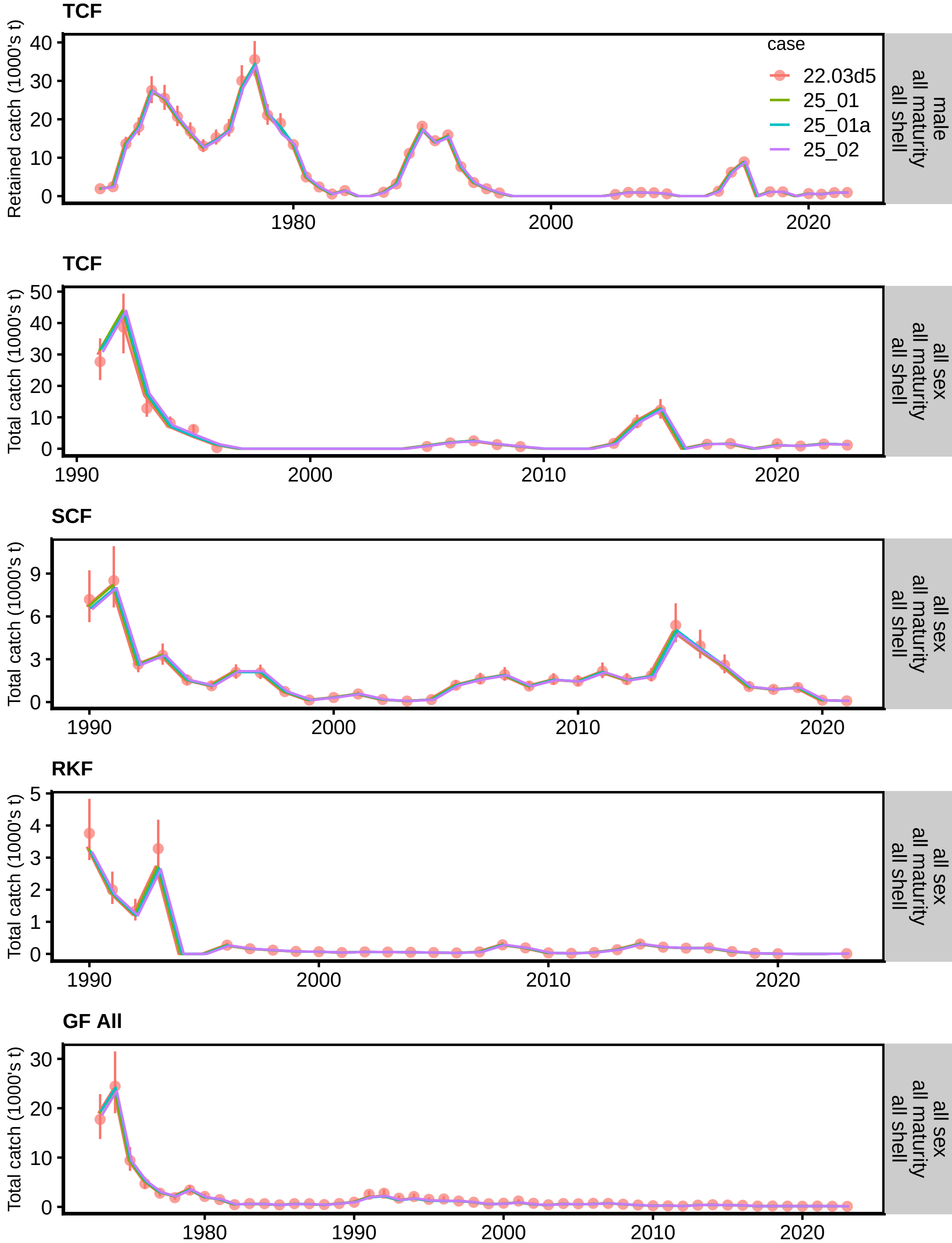


Figure 29. Fits to retained and total catch biomass in the directed fishery and bycatch fisheries.Vertical bars indicate assumed confidence intervals on the catch data. Points: data (labelled as 22.03d5, but same for all models); lines: model fits.

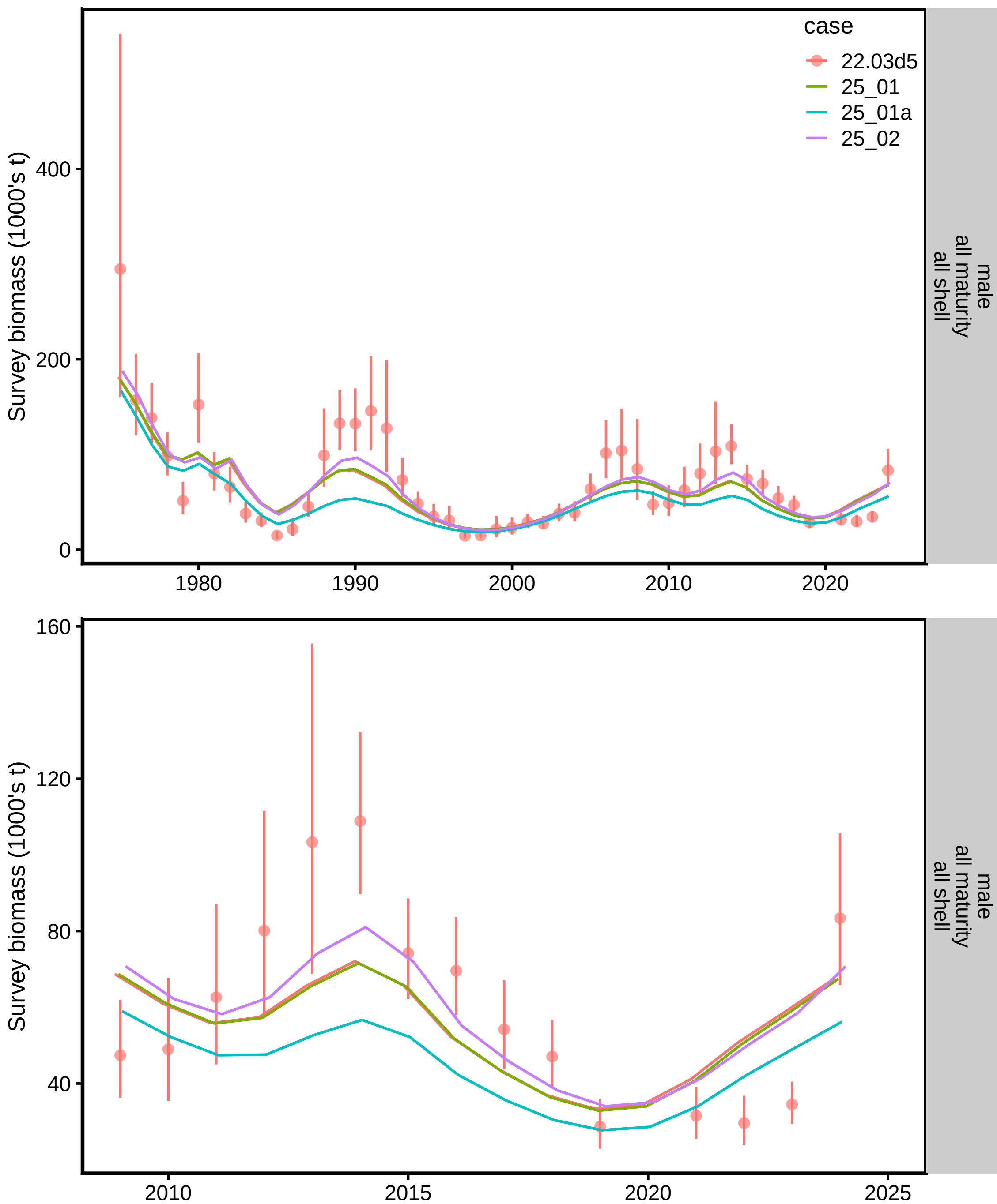


Figure 30. Comparison of TCSAM02 (22.03d5) and the alternative TCSAM02 models fits to NMFS survey biomass for males. Points and bars indicate the design-based estimates and confidence intervals. Points and vertical lines: data and confidence intervals (labelled as 22.03d5, but same for all models); lines: model fits.

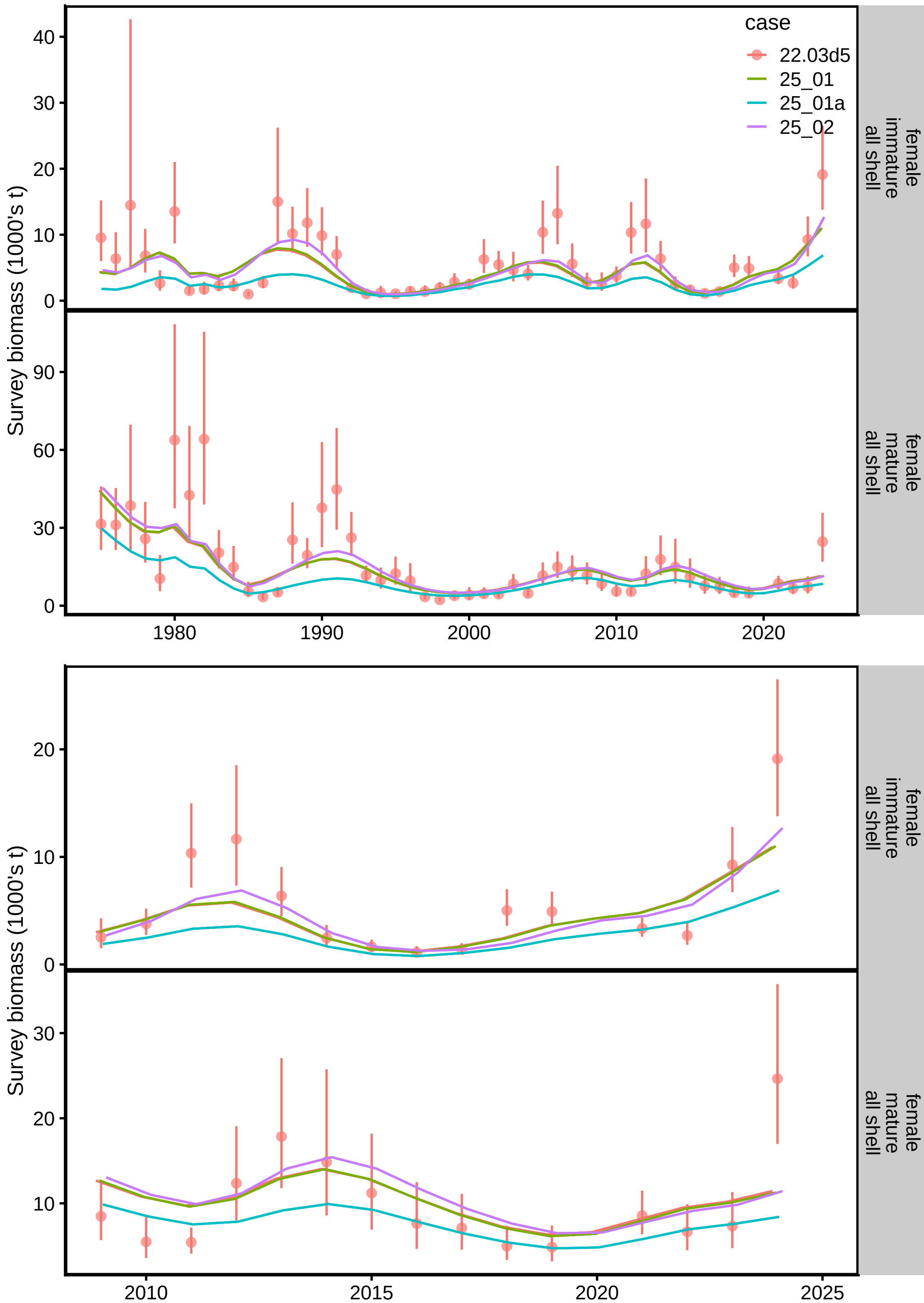


Figure 31. Comparison of TCSAM02 (22.03d5) and the alternative TCSAM02 models fits to NMFS survey biomass for females. Points and bars indicate the design-based estimates and confidence intervals. Points and vertical lines: data and confidence intervals (labelled as 22.03d5, but same for all models); lines: model fits.

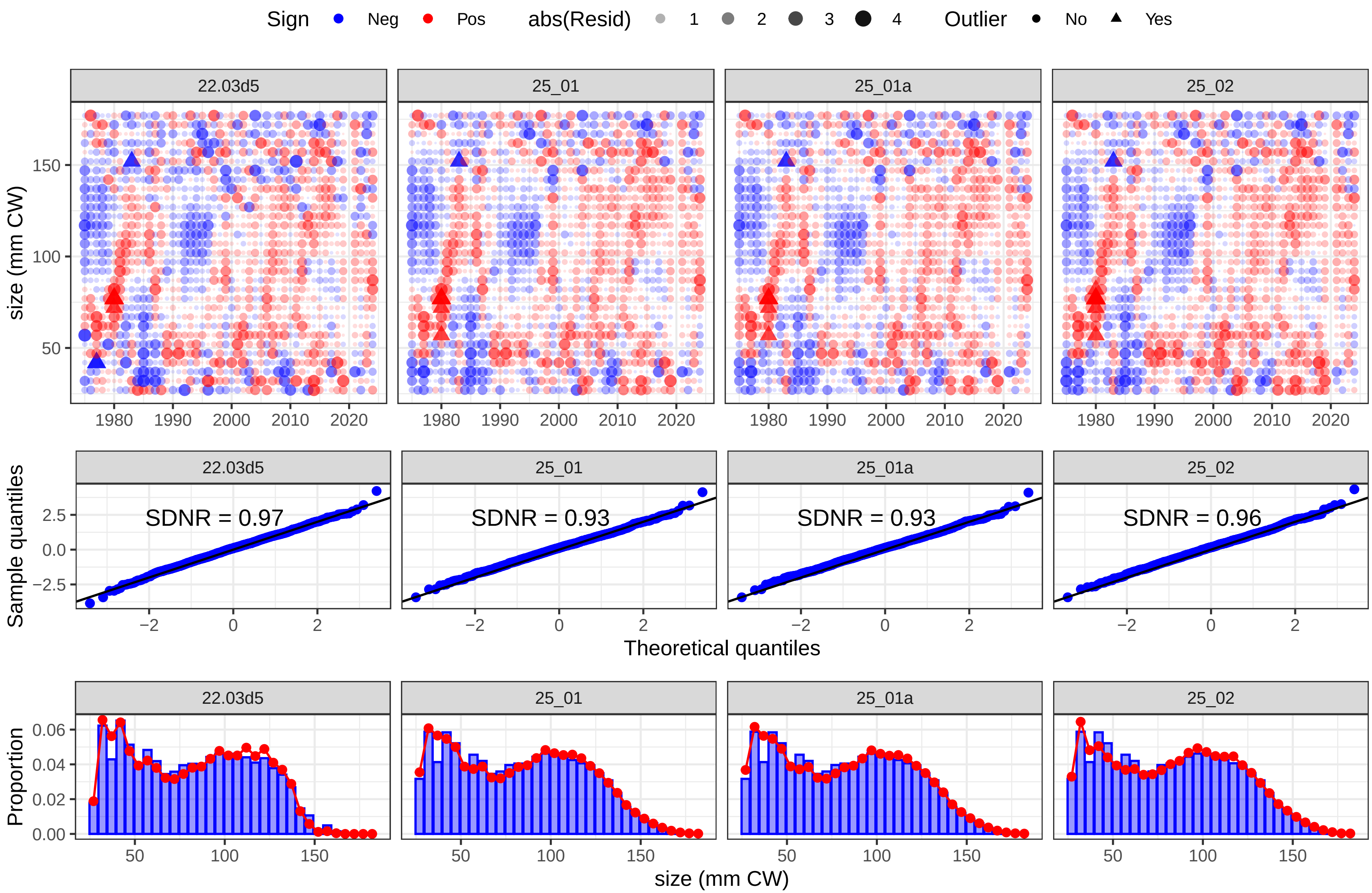


Figure 32. OSA residuals for TCSAM02 models'fits to male size compositions from the NMFS survey. The base model is 22.03d5.

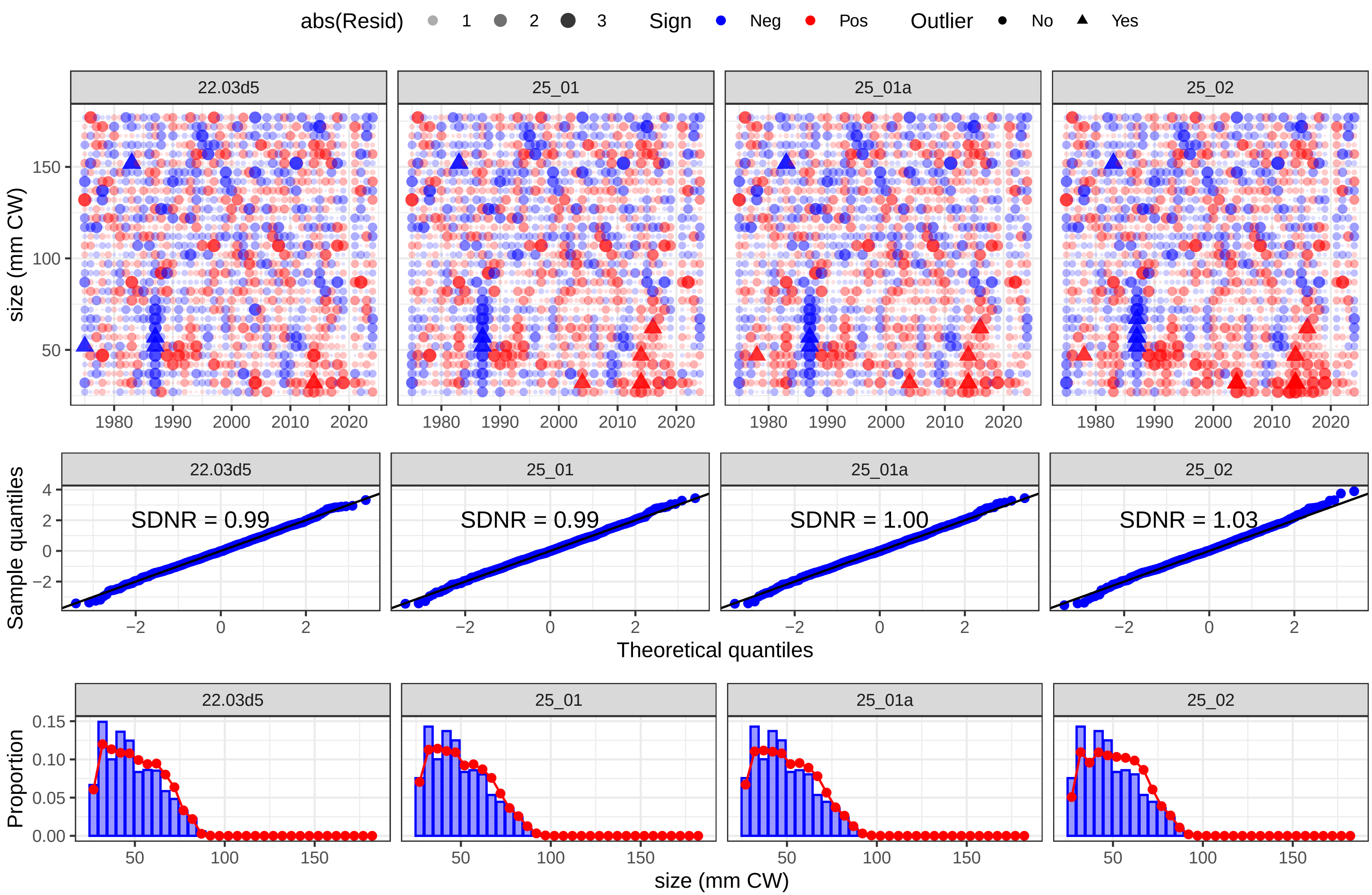


Figure 33. OSA residuals for TCSAM02 models'fits to immature female size compositions from the NMFS survey. The base model is 22.03d5.

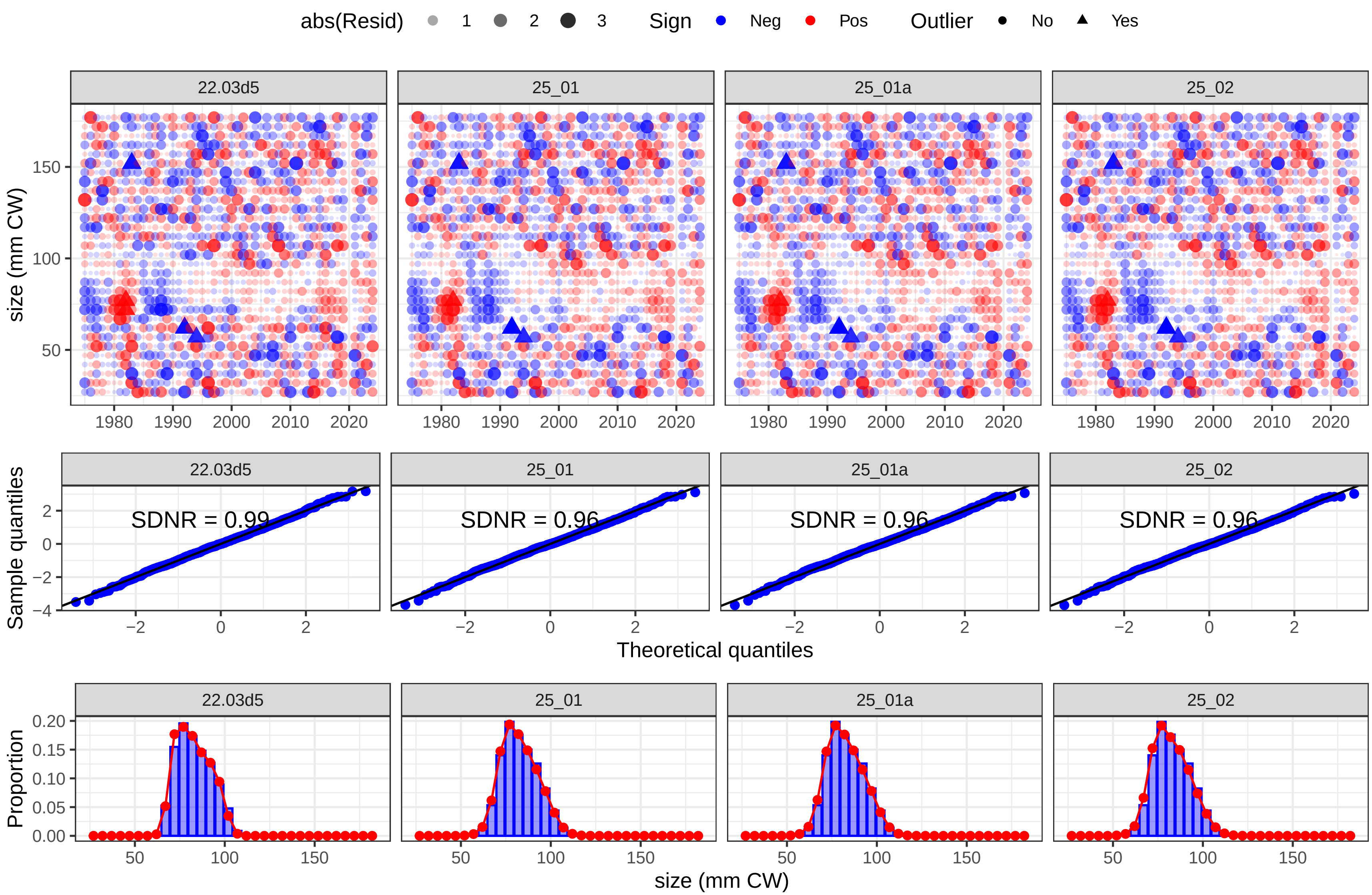


Figure 34. OSA residuals for TCSAM02 models'fits to mature female size compositions from the NMFS survey. The base model is 22.03d5.

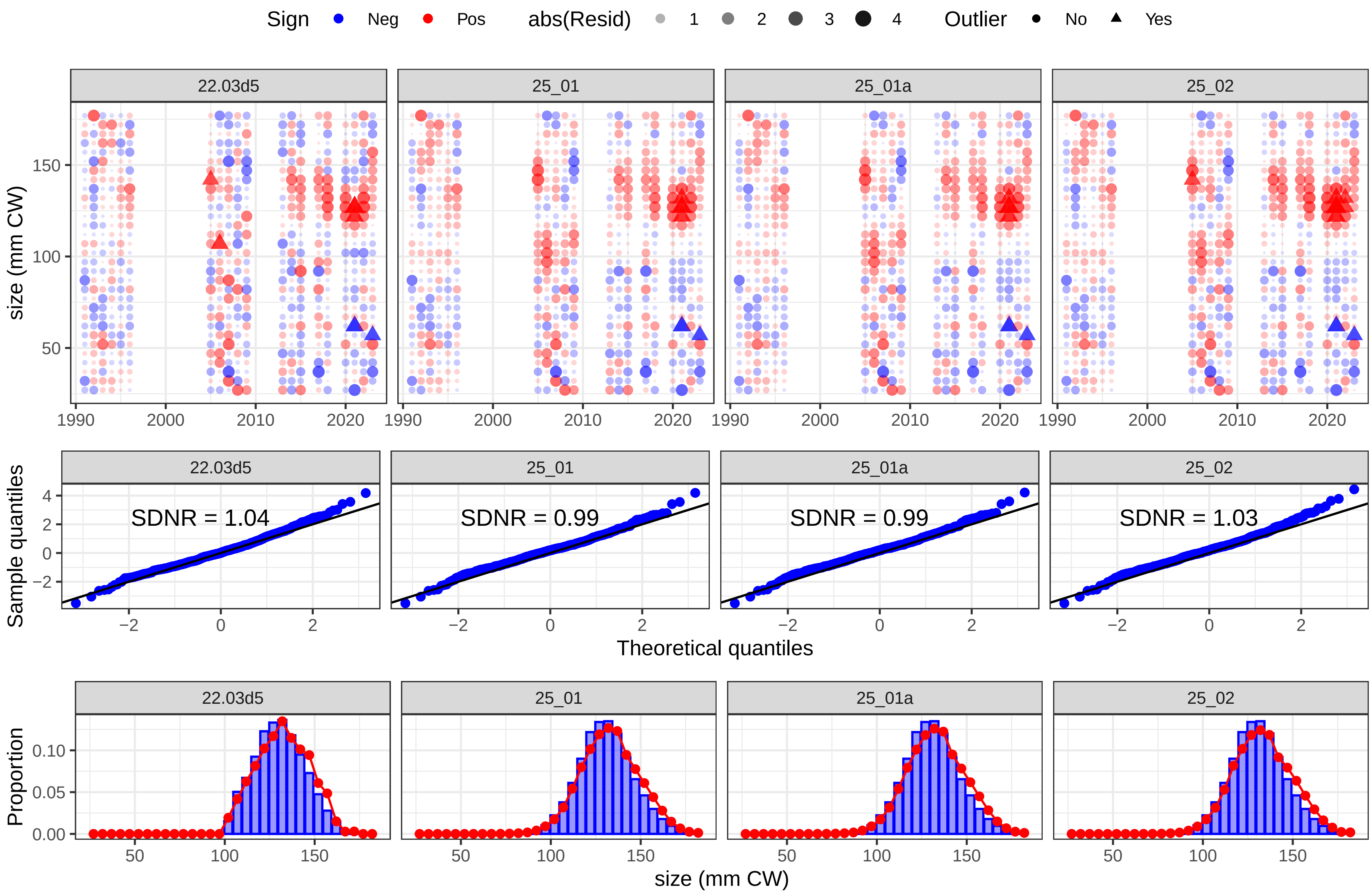


Figure 35. OSA residuals for TCSAM02 models fit to male size compositions from the TCF fishery. The base model is 22.03d5.

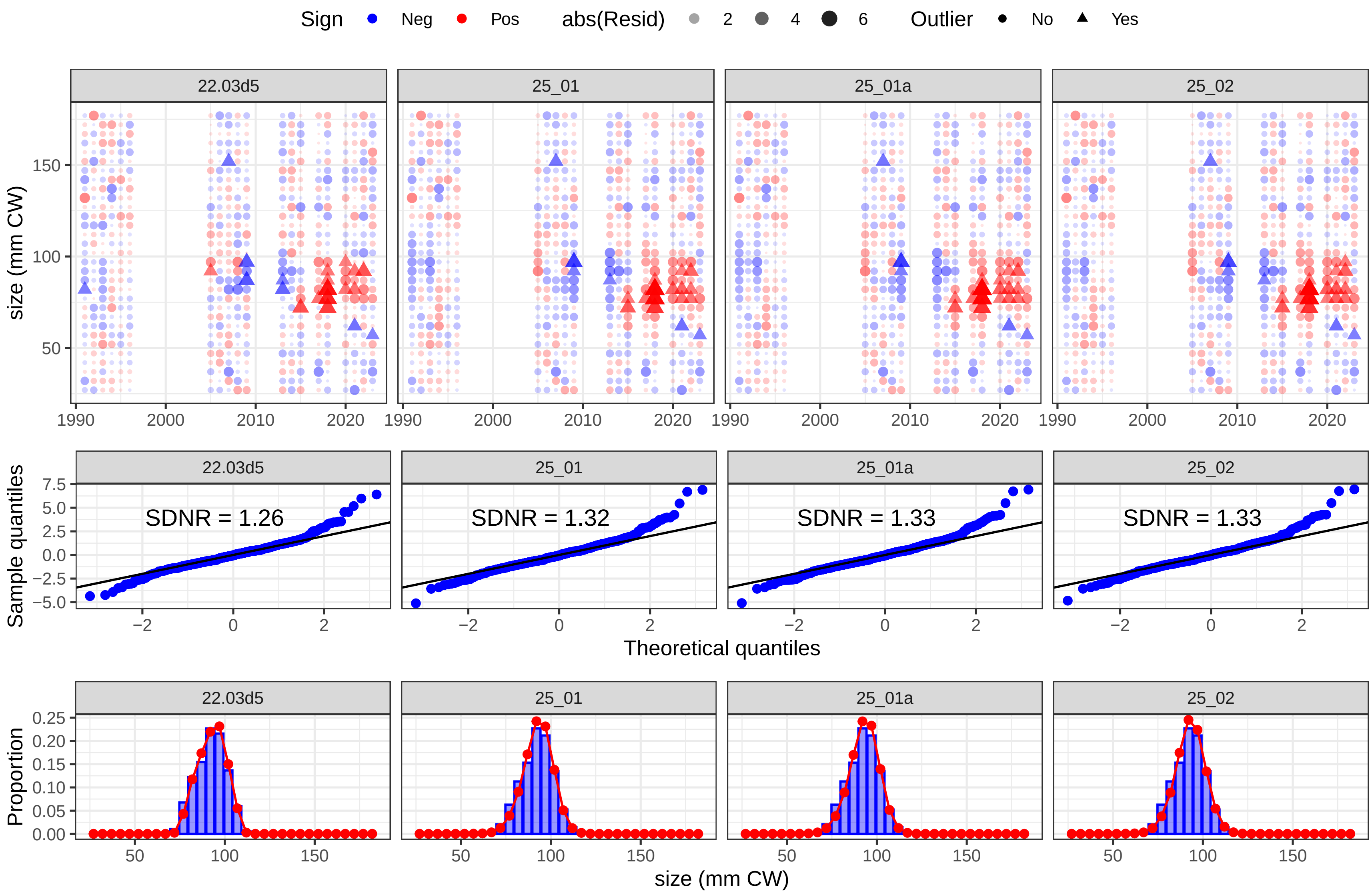


Figure 36. OSA residuals for TCSAM02 models fit to female size compositions from the TCF fishery. The base model is 22.03d5.

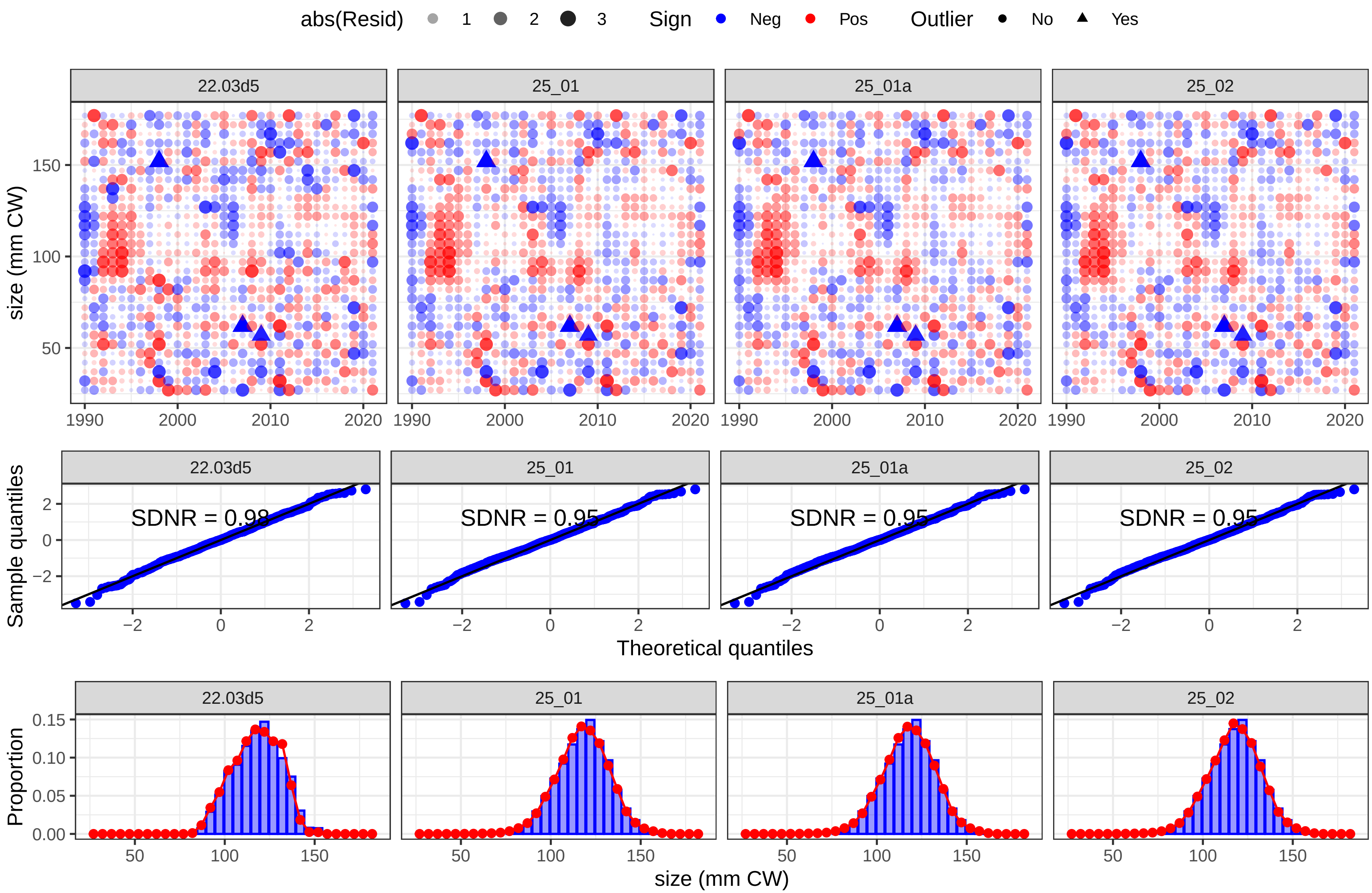


Figure 37. OSA residuals for TCSAM02 models fit to male size compositions from the SCF fishery. The base model is 22.03d5.

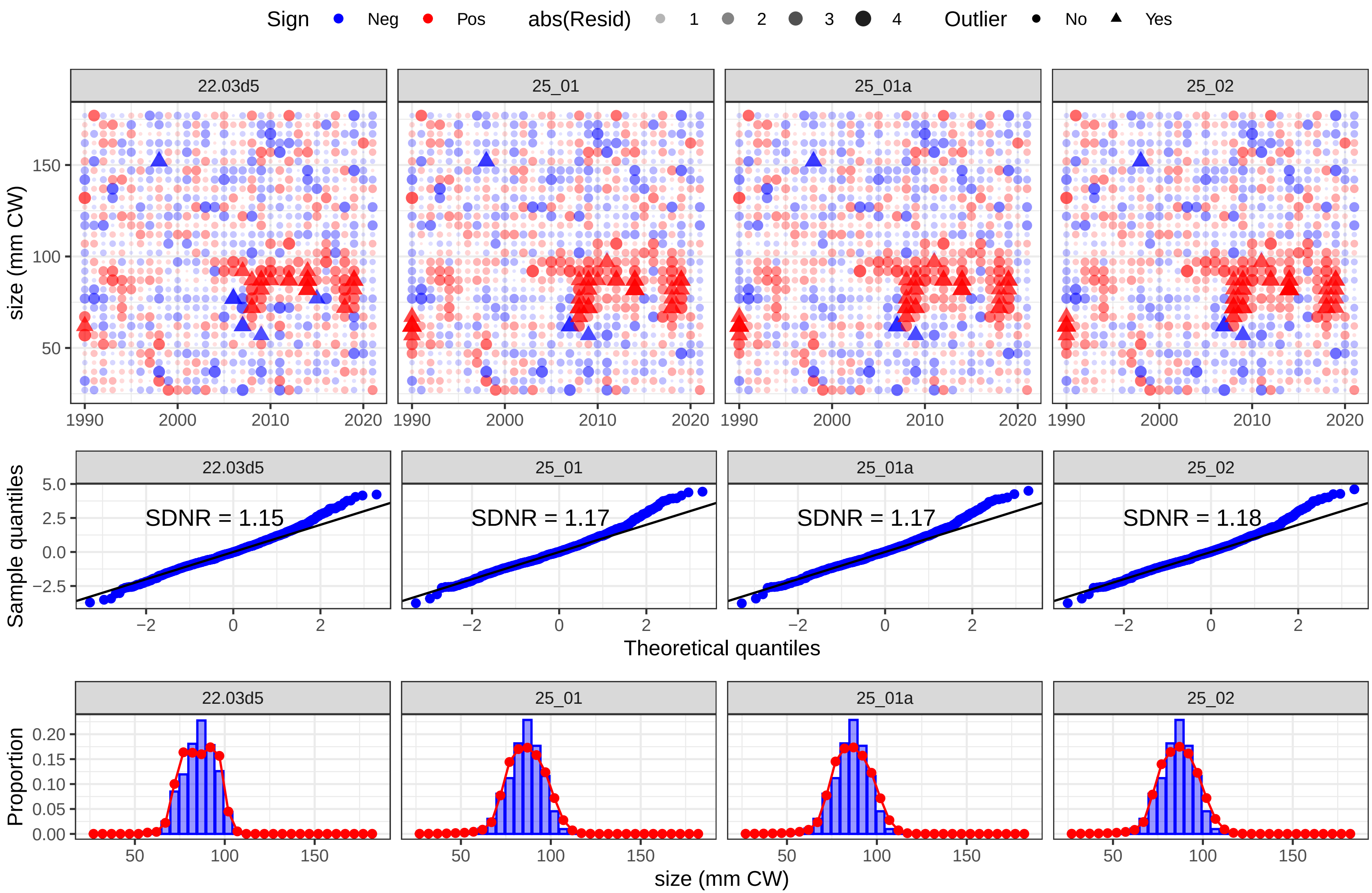


Figure 38. OSA residuals for TCSAM02 models fit to female size compositions from the SCF fishery. The base model is 22.03d5.

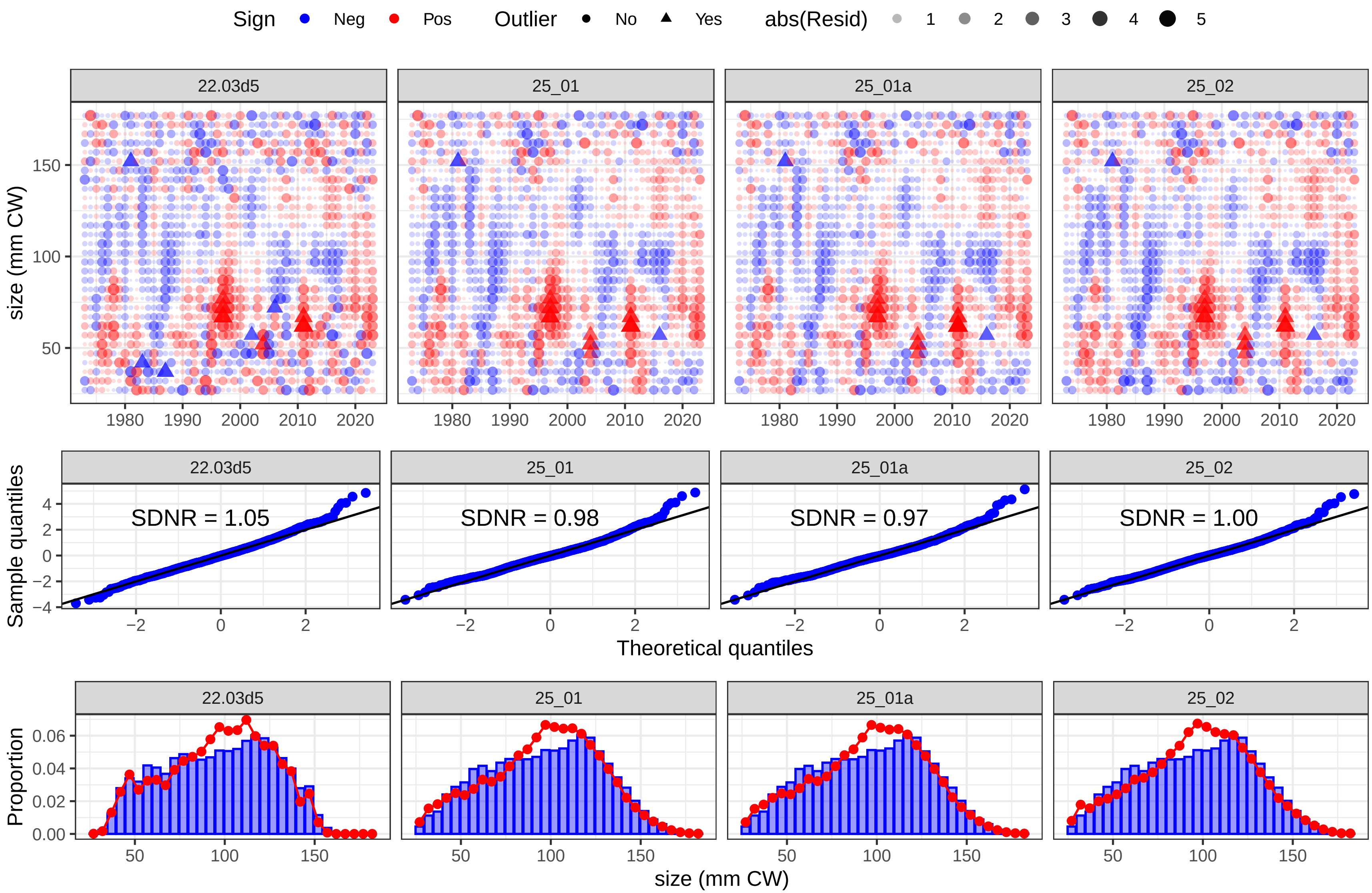


Figure 39. OSA residuals for TCSAM02 models fit to male size compositions from the GF All fishery. The base model is 22.03d5.

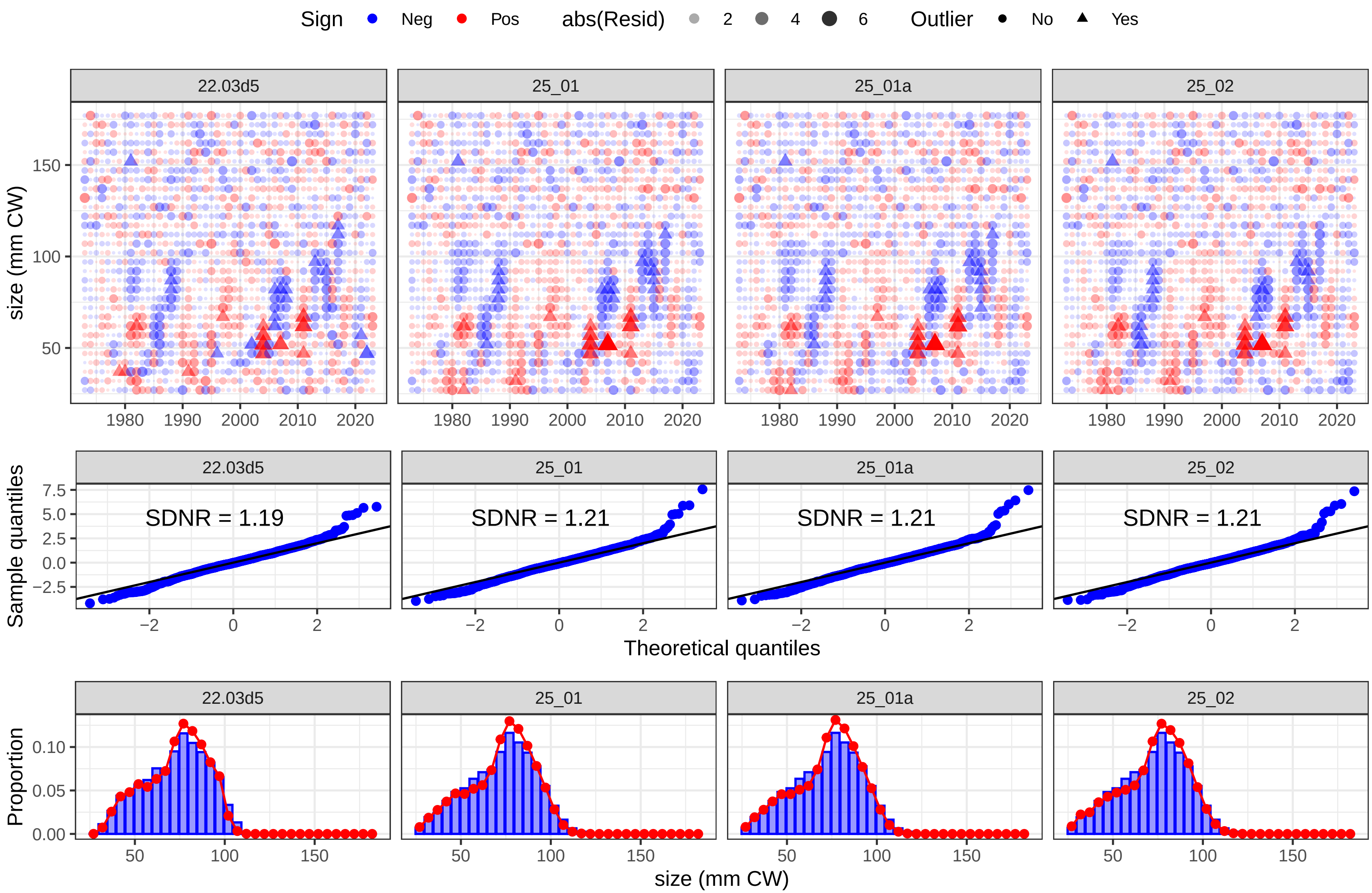


Figure 40. OSA residuals for TCSAM02 models fit to female size compositions from the GF All fishery. The base model is 22.03d5.

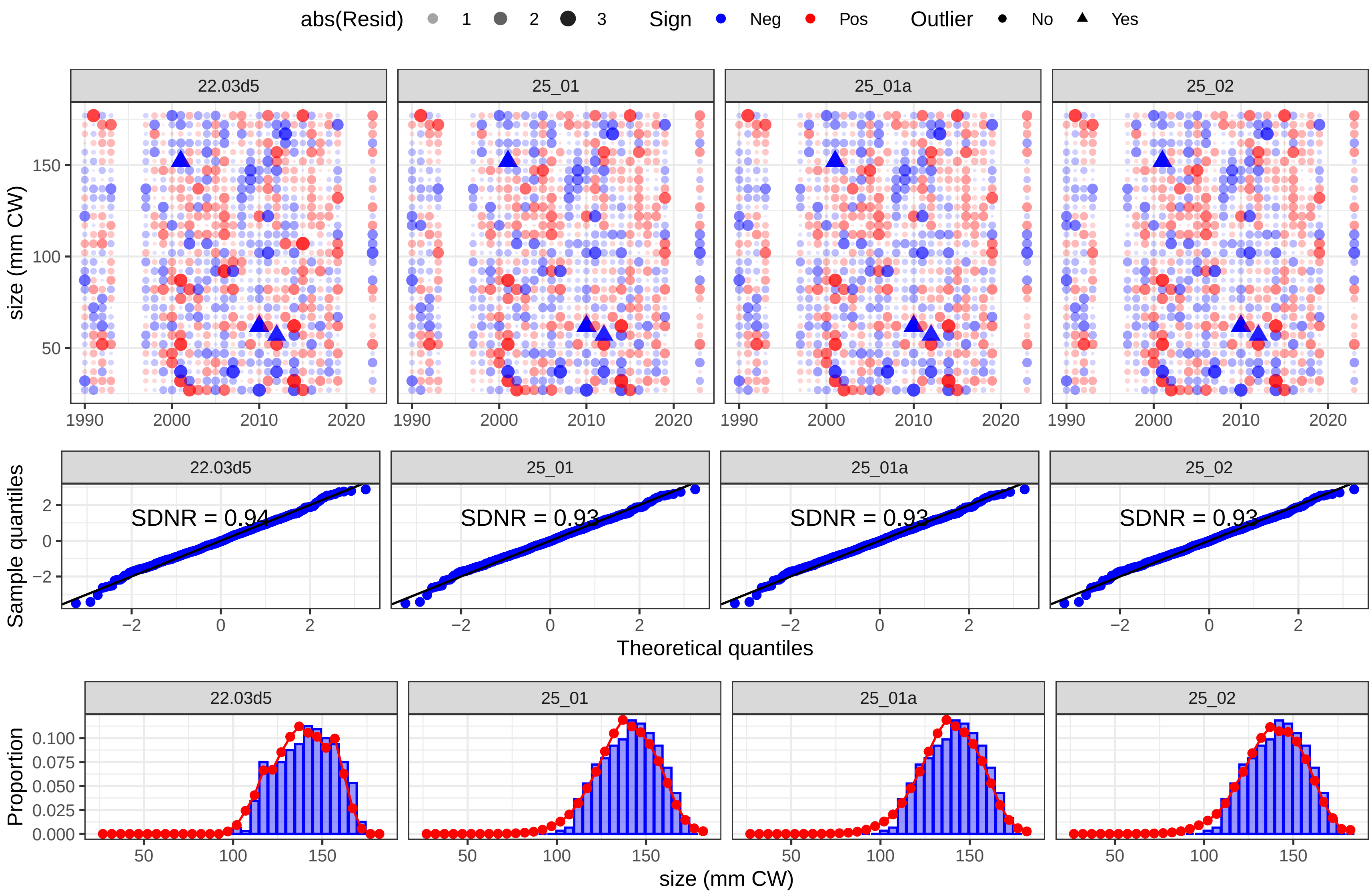


Figure 41. OSA residuals for TCSAM02 models fit to male size compositions from the RKF fishery. The base model is 22.03d5.

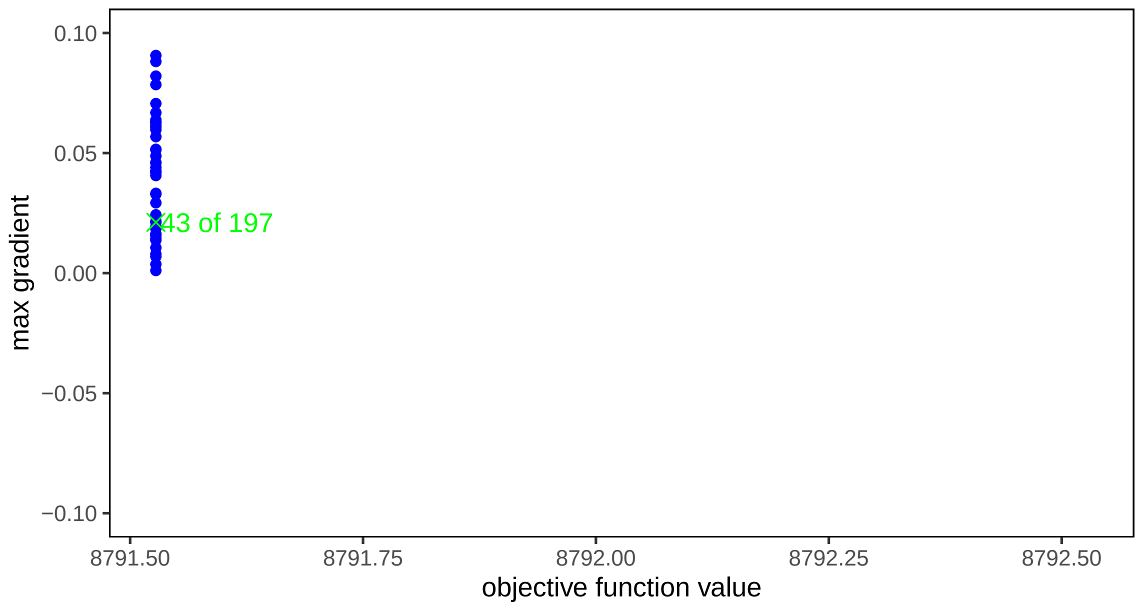


Figure 42. Results from a parameter jittering exercise with the GMACS model.

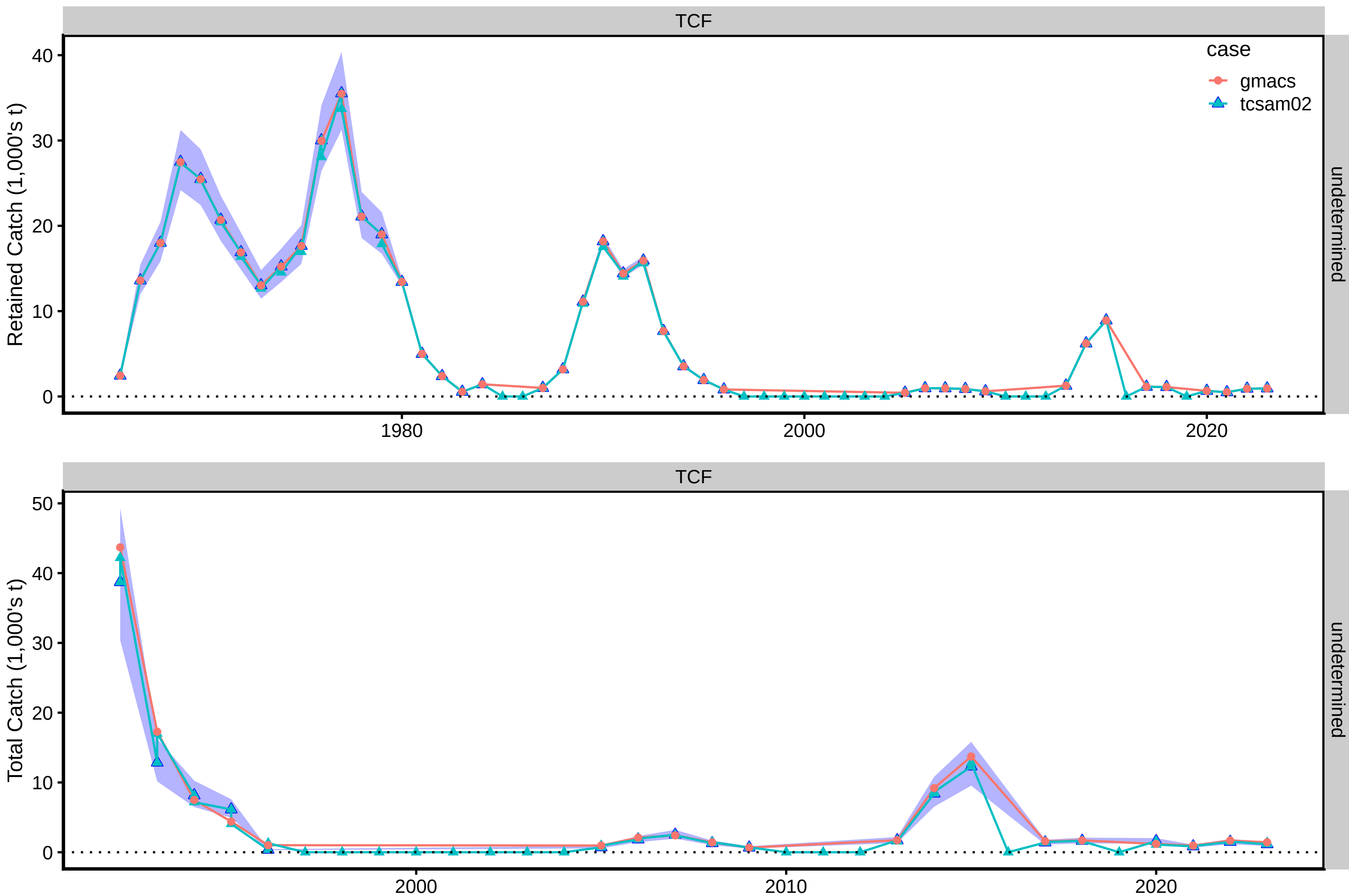


Figure 43. Model fits to retained (upper plot) and total catch (lower plot) data from the directed fishery. Shading indicates assumed observation error. Triangles are observed catch (the same for both models), circles are predicted catch.

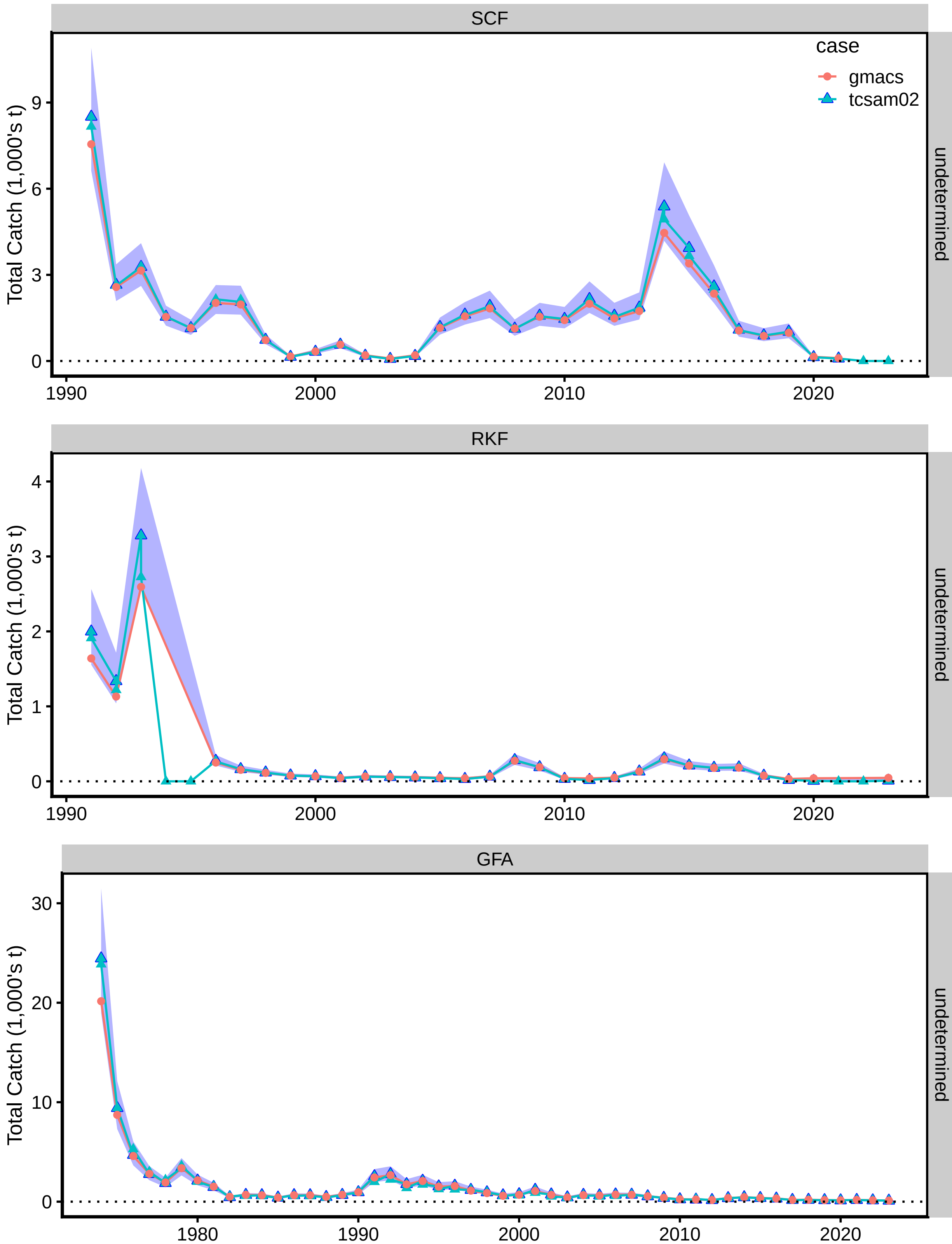


Figure 44. Model fits to total bycatch in the snow crab (upper plot), BBRKC (middle plot), and groundfish fisheries (lower plot). Shading indicates assumed observation error. Triangles are observed catch (the same for both models), circles are predicted catch.

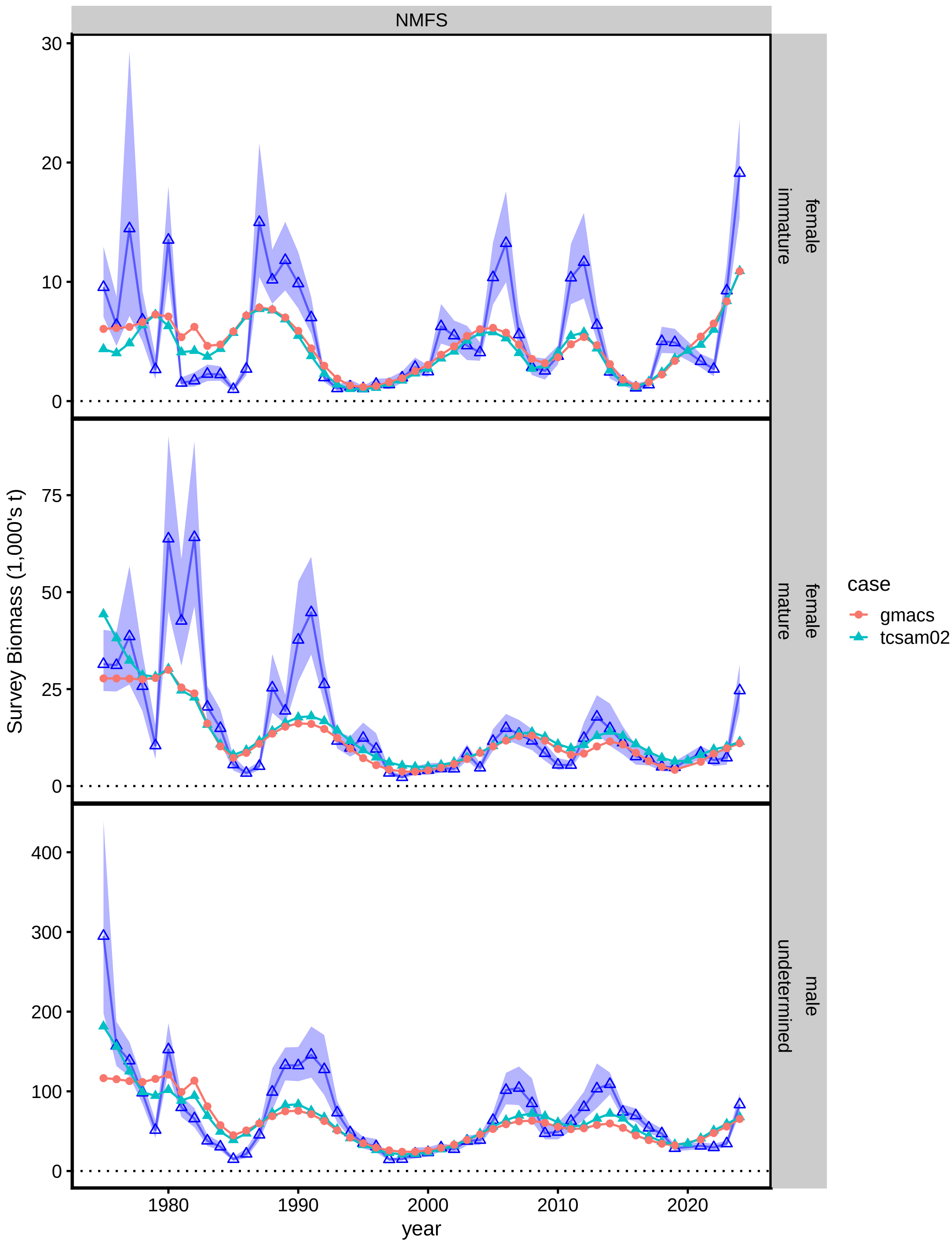


Figure 45. Model fits to NMFS survey biomass, by sex and female maturity. Shading indicates design-based observation error. Triangles are observed catch (the same for both models), circles are predicted catch.

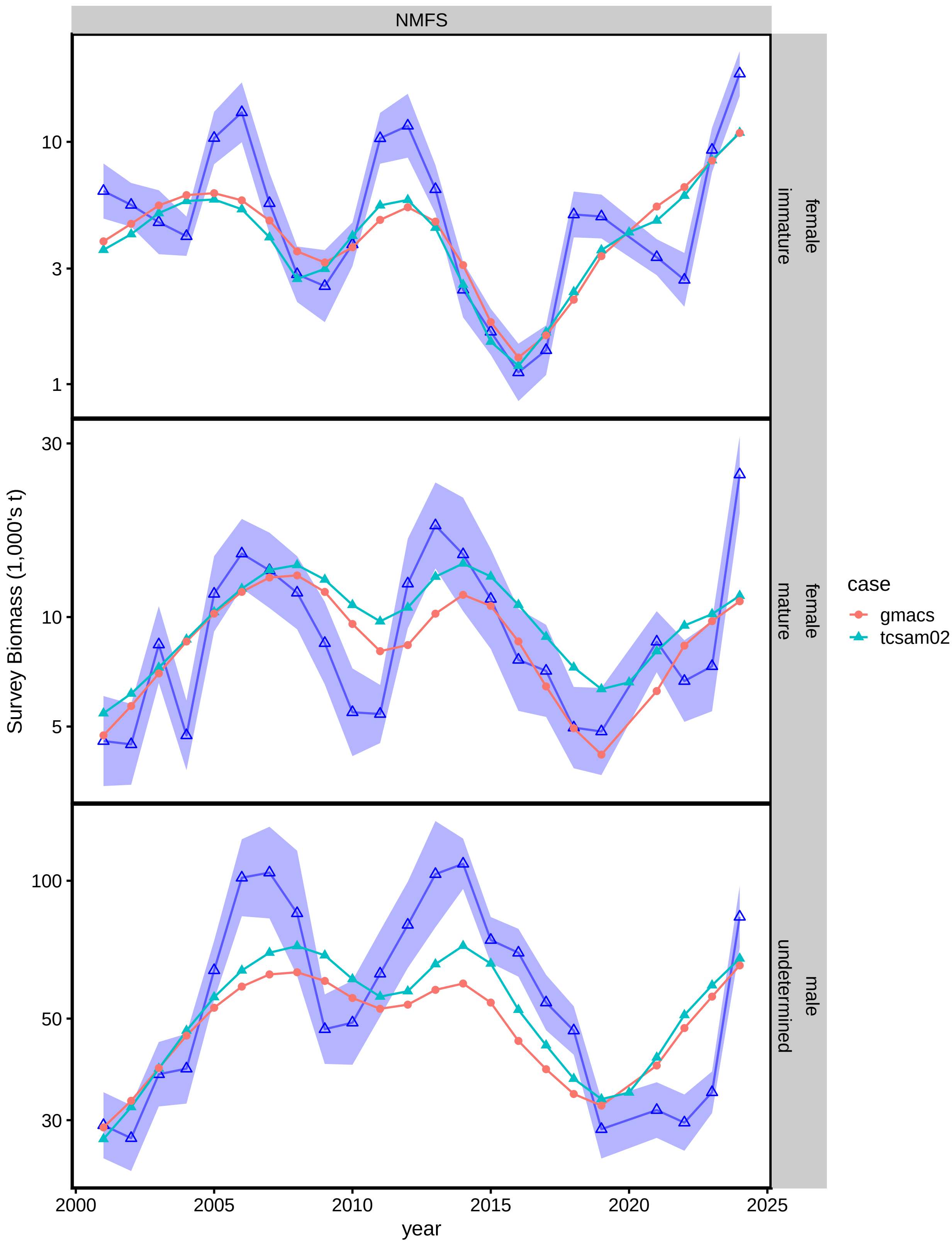


Figure 46. Model fits to NMFS survey biomass, by sex and female maturity, starting in 2001 on log10 scale. Shading indicates design-based observation error. Triangles are observed catch (the same for both models), circles are predicted catch.

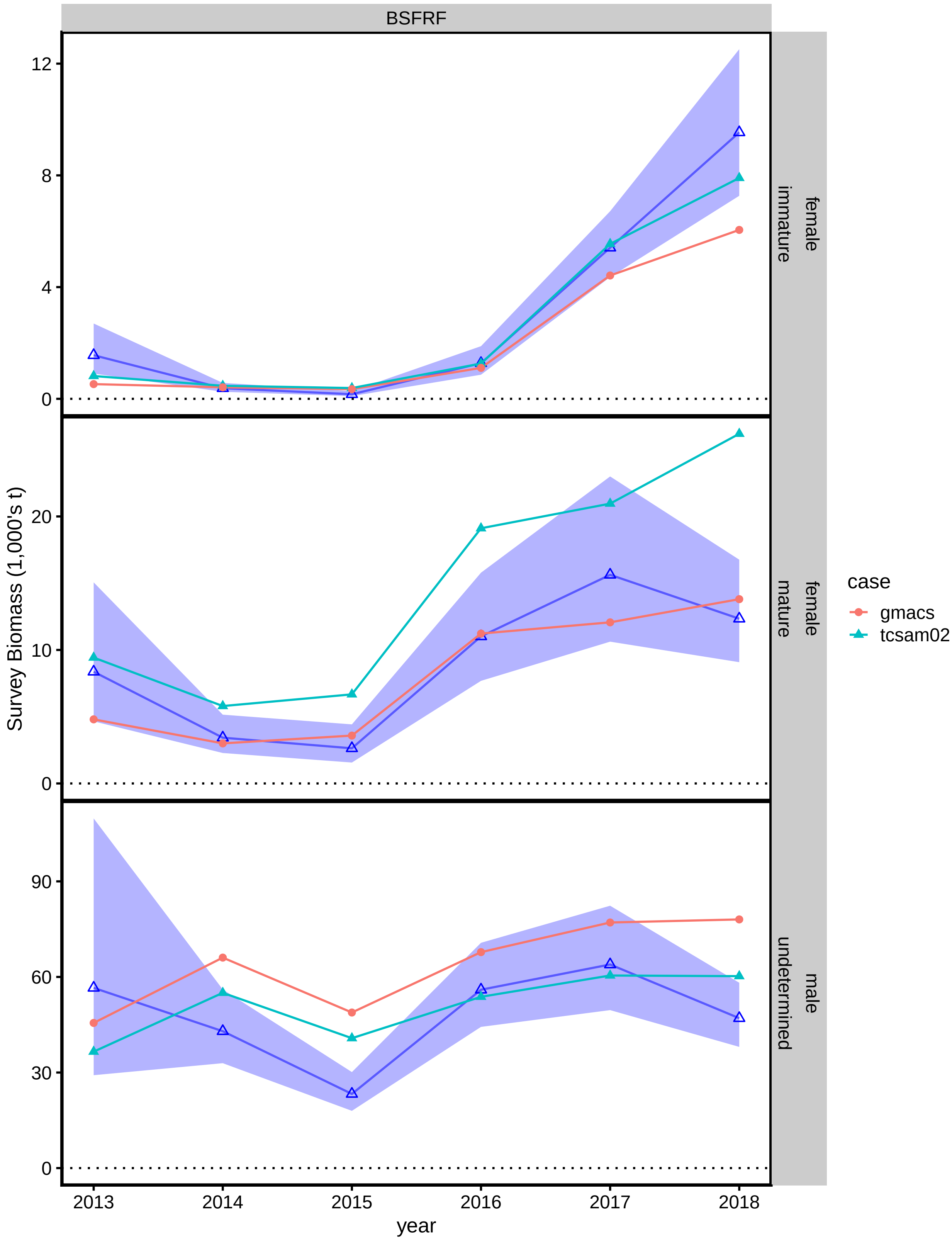


Figure 47. Model fits to BSFRF survey biomass, by sex and female maturity. Shading indicates design-based observation error. Triangles are observed catch (the same for both models), circles are predicted catch.

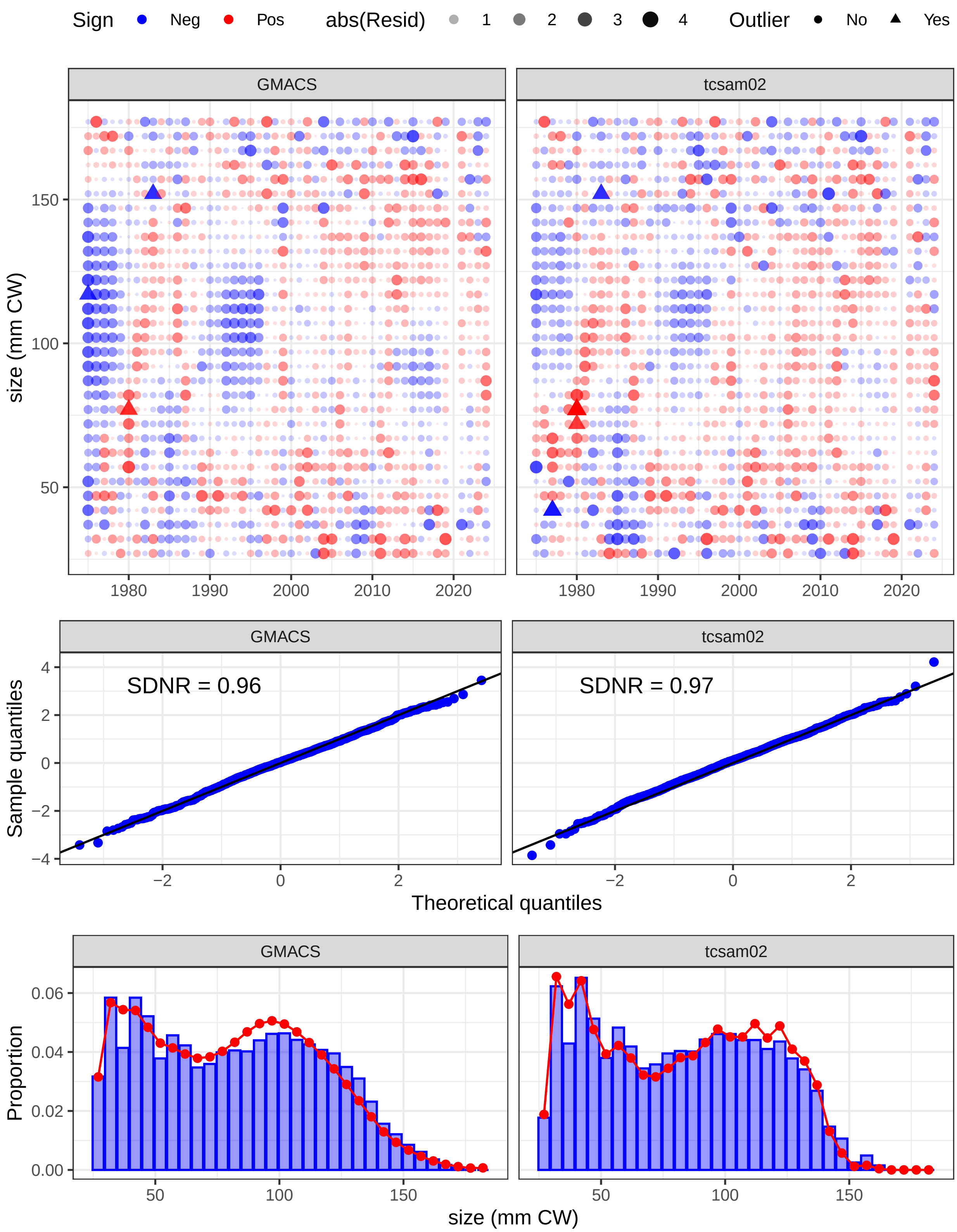


Figure 48. OSA (one step ahead) residuals for fits to NMFS survey size comps for male Tanner crab, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) and observed proprtions (bars).

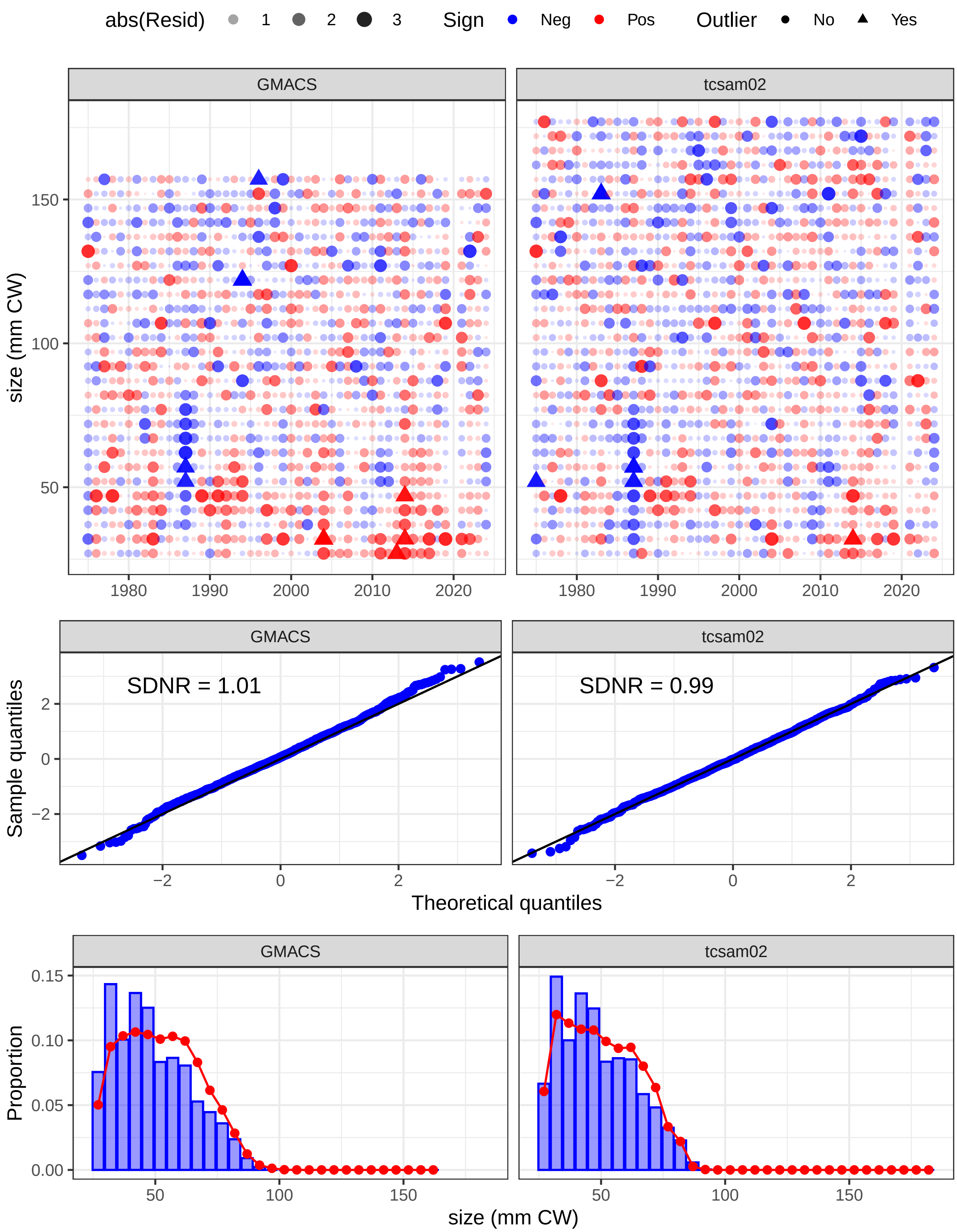


Figure 49. OSA (one step ahead) residuals for fits to NMFS survey size comps for immature female Tanner crab, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

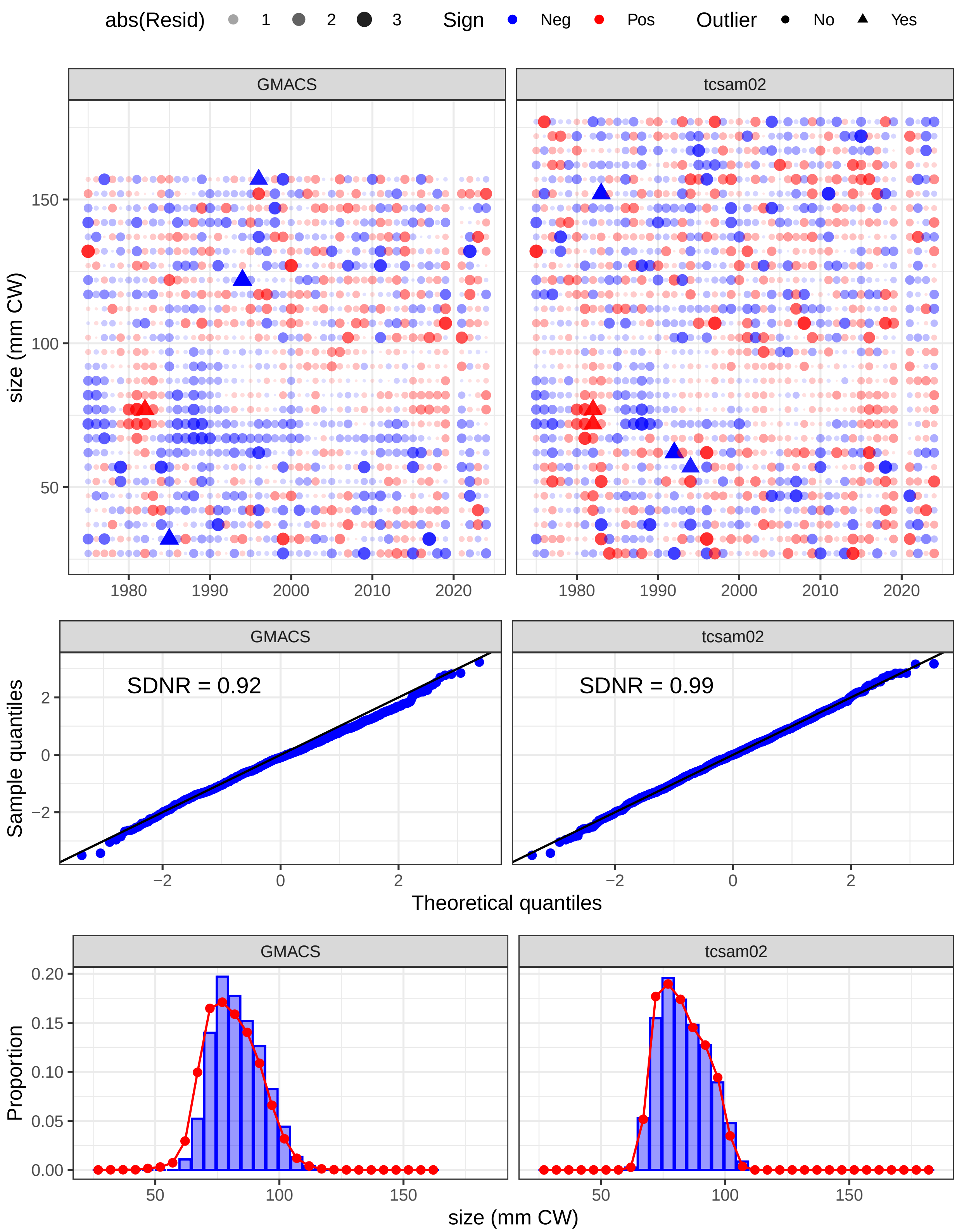


Figure 50. OSA (one step ahead) residuals for fits to NMFS survey size comps for mature female Tanner crab, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

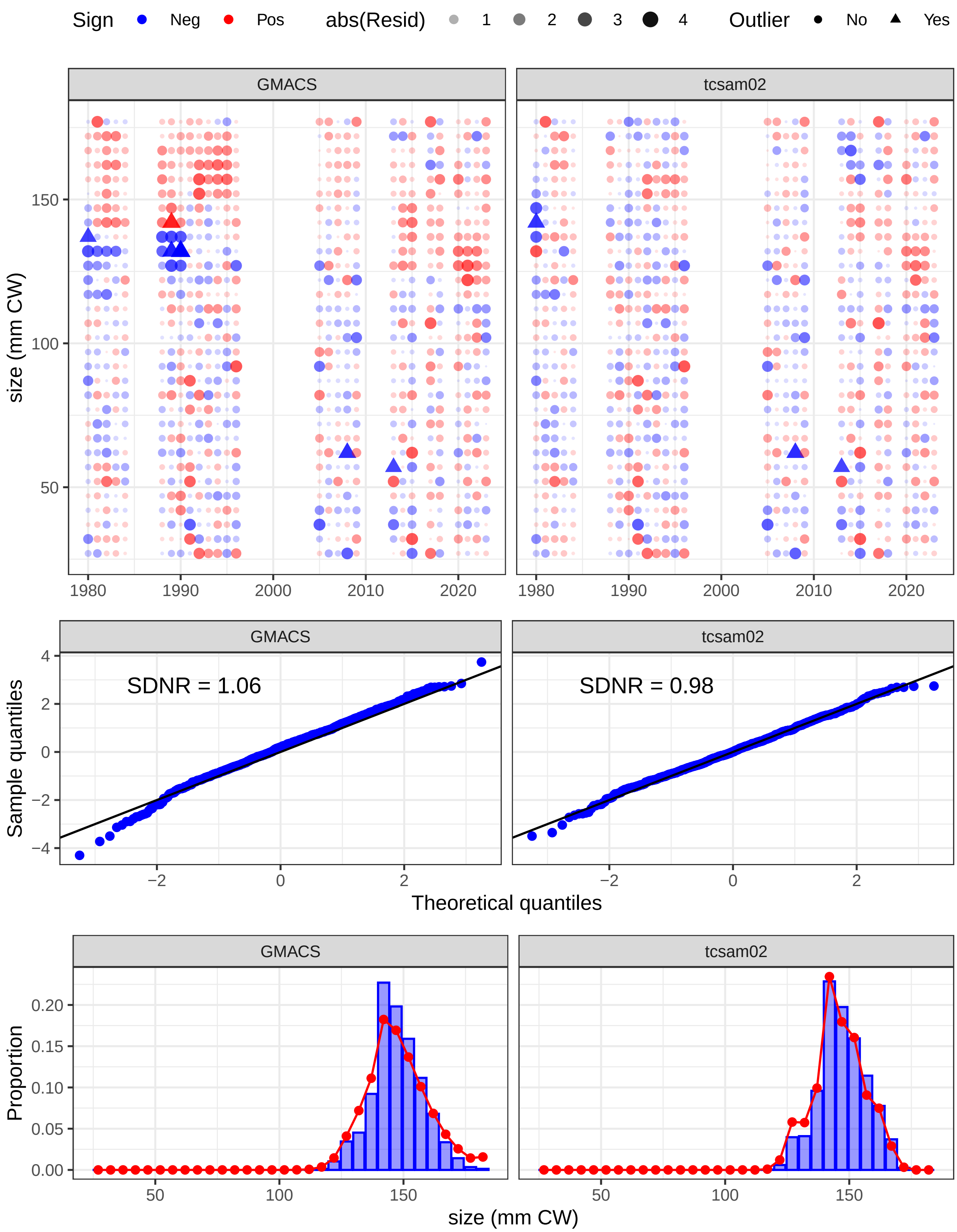


Figure 51. OSA (one step ahead) residuals for fits to retained catch size comps for male Tanner crab in the directed fishery, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

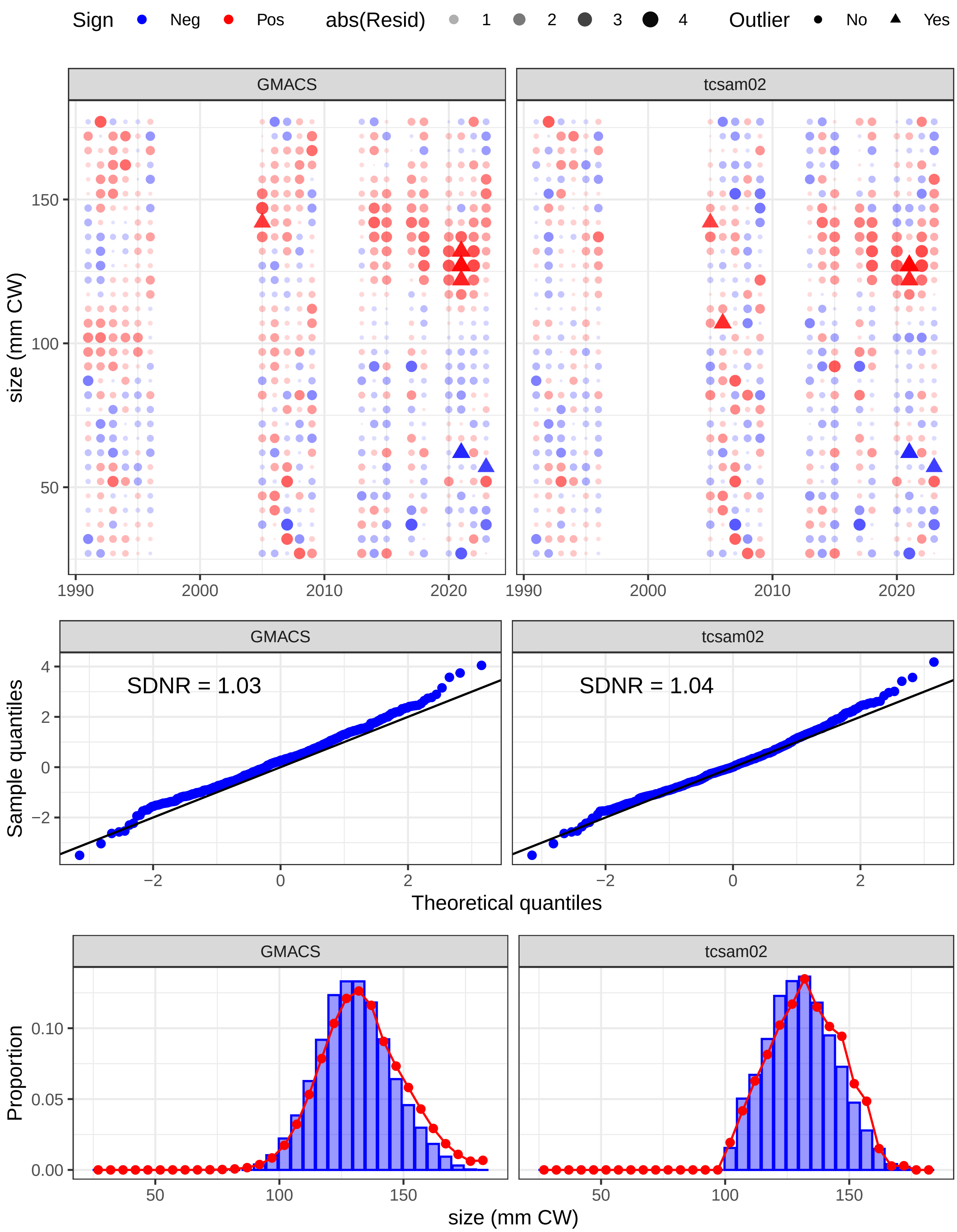


Figure 52. OSA (one step ahead) residuals for fits to total catch size comps for male Tanner crab in the directed fishery, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

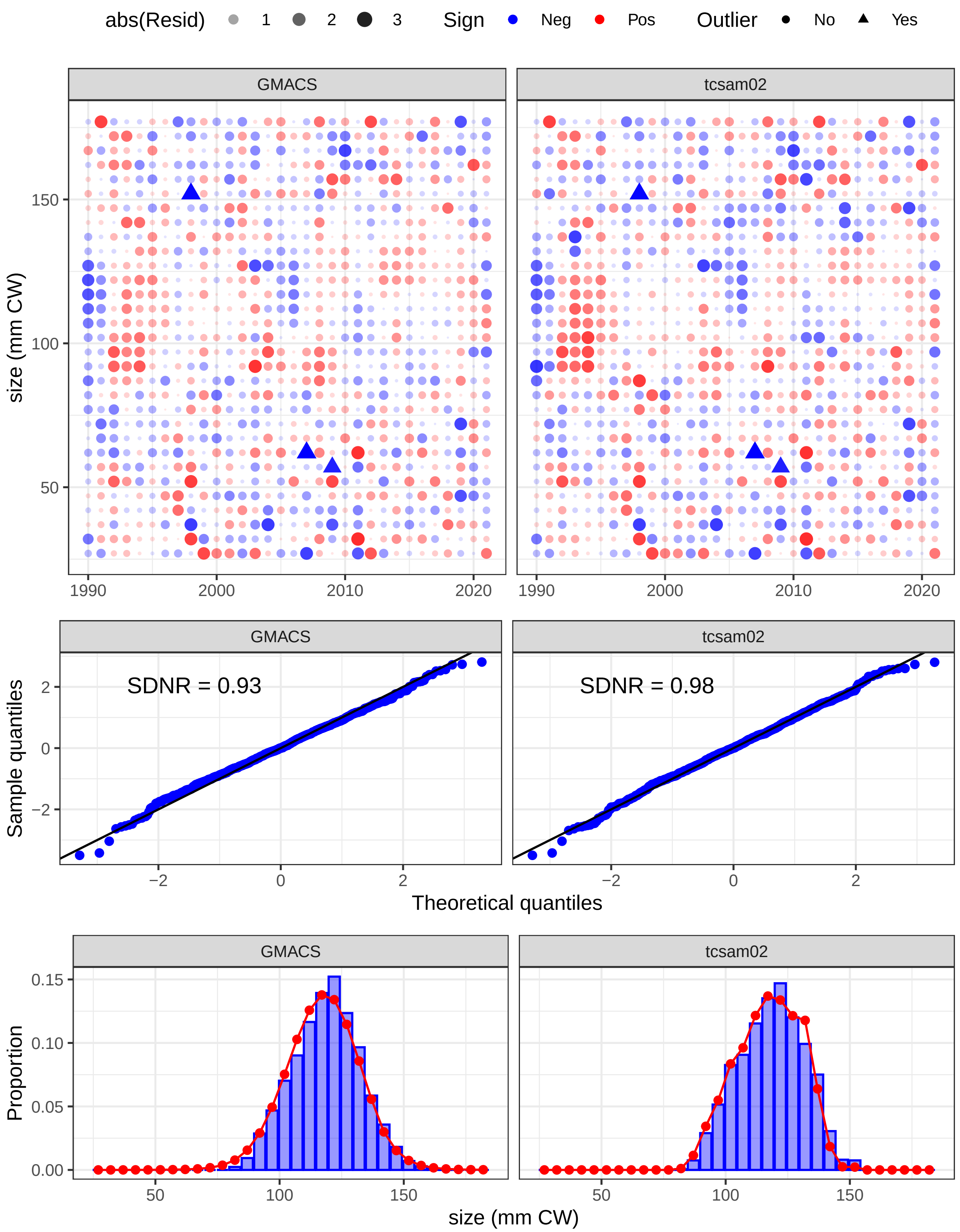


Figure 53. OSA (one step ahead) residuals for fits to total bycatch size comps for male Tanner crab in the snow crab fishery, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

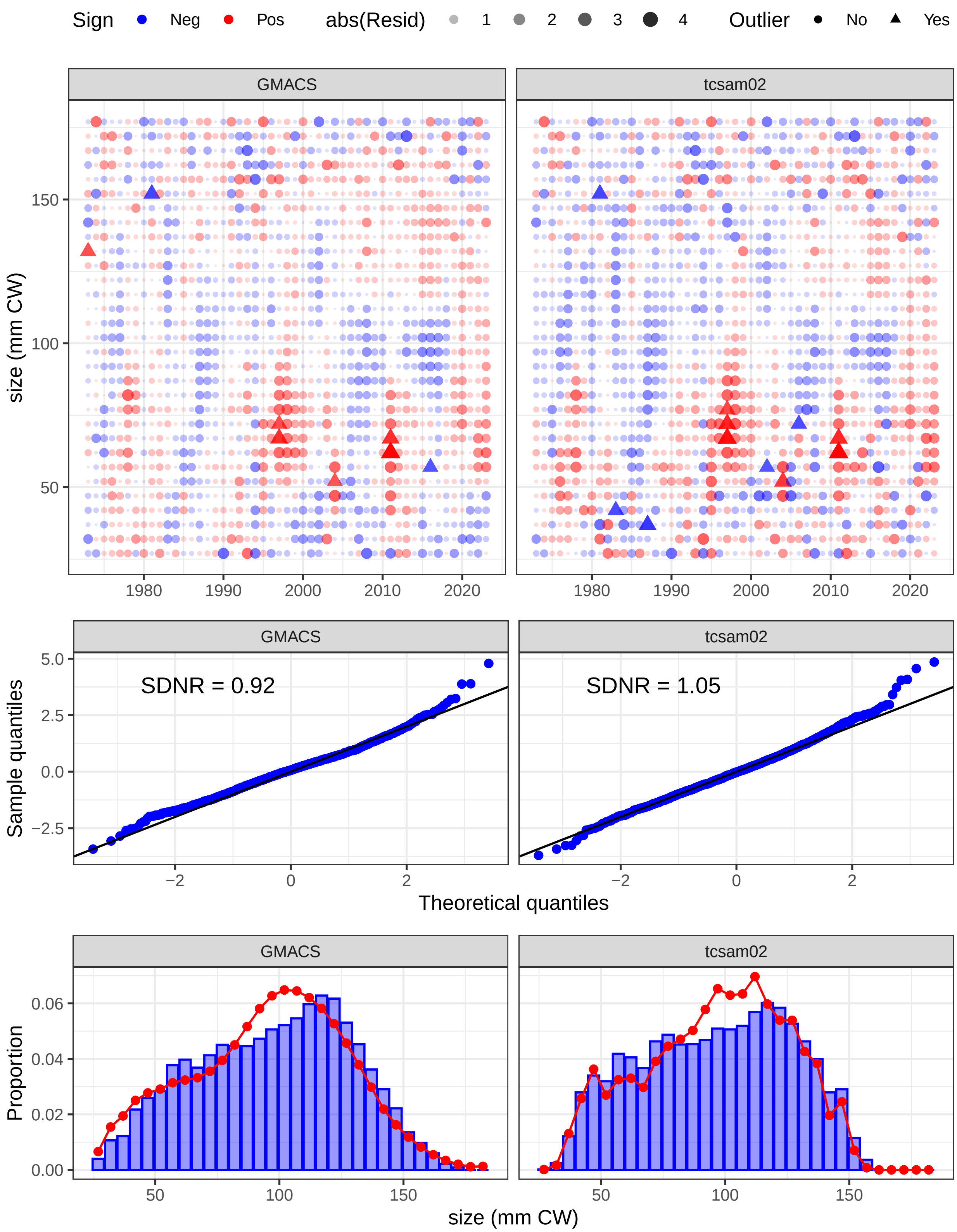


Figure 54. OSA (one step ahead) residuals for fits to total bycatch size comps for male Tanner crab in the groundfish fisheries, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

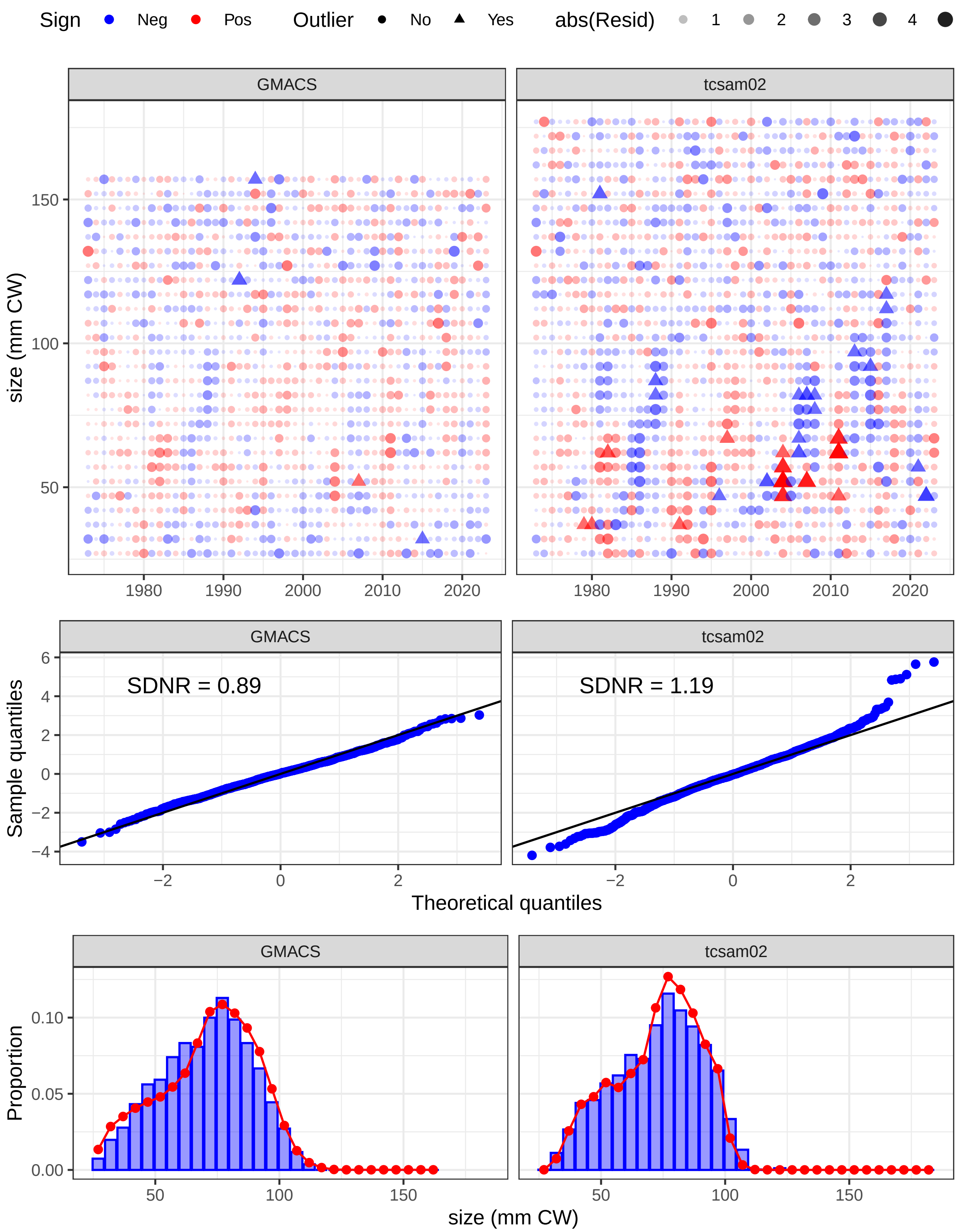


Figure 55. OSA (one step ahead) residuals for fits to total catch size comps for female Tanner crab in the groundfish fisheries, by case. Upper: bubble plot of residuals; middle: quantile-quantile plot; lower: mean fit (red) to mean proprtions (bars).

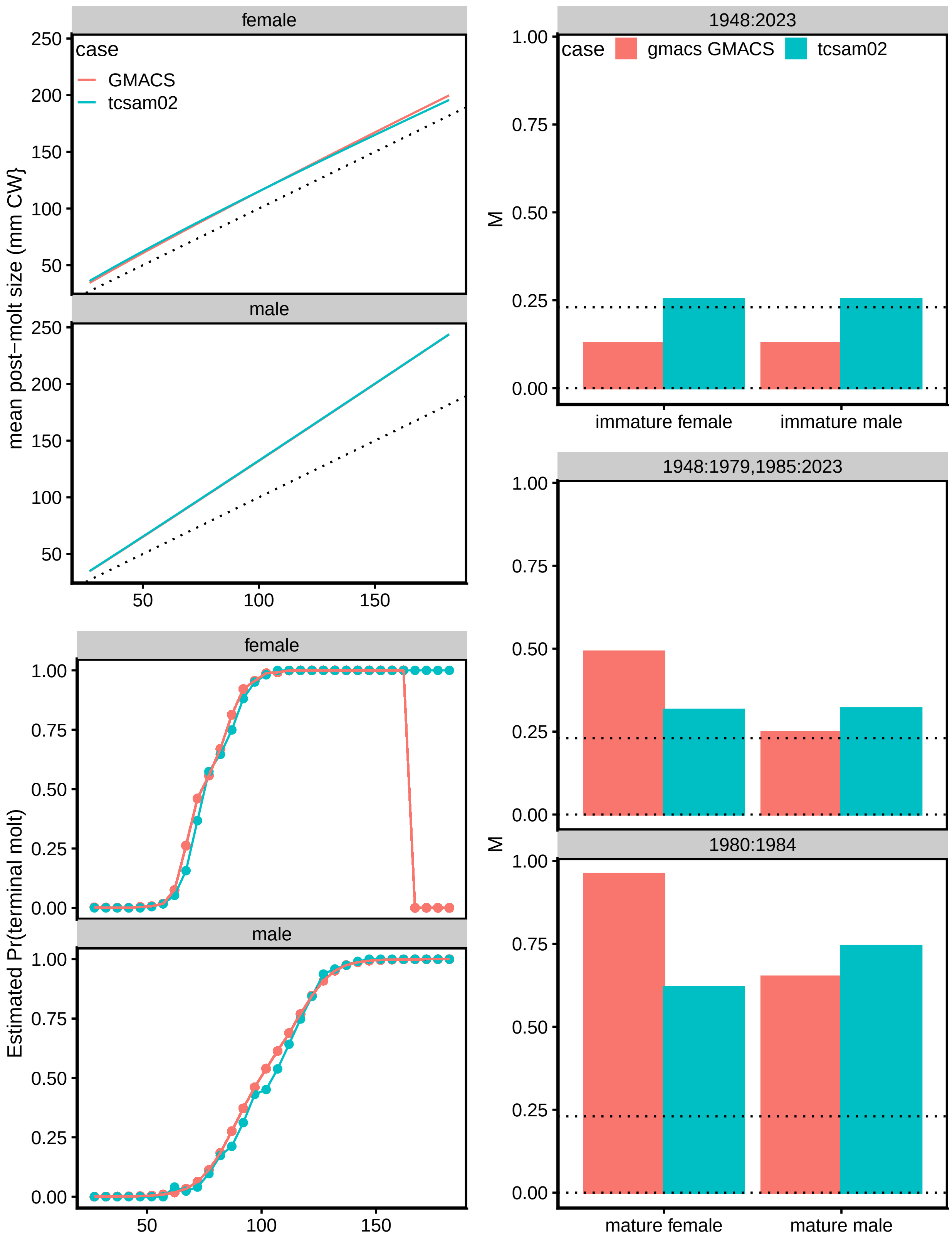


Figure 56. Estimated population quantities. Upper left: mean growth; lower left: probability of terminal molt; right: natural mortality by time block, sex and maturity state. X-axes for plots in lefthand column are carapace with (mm-CW). Note that Pr(M2M) for TCSAM02 is a function of pre-molt size, for GMACS it is a function of post-molt size and is determined outside the model.

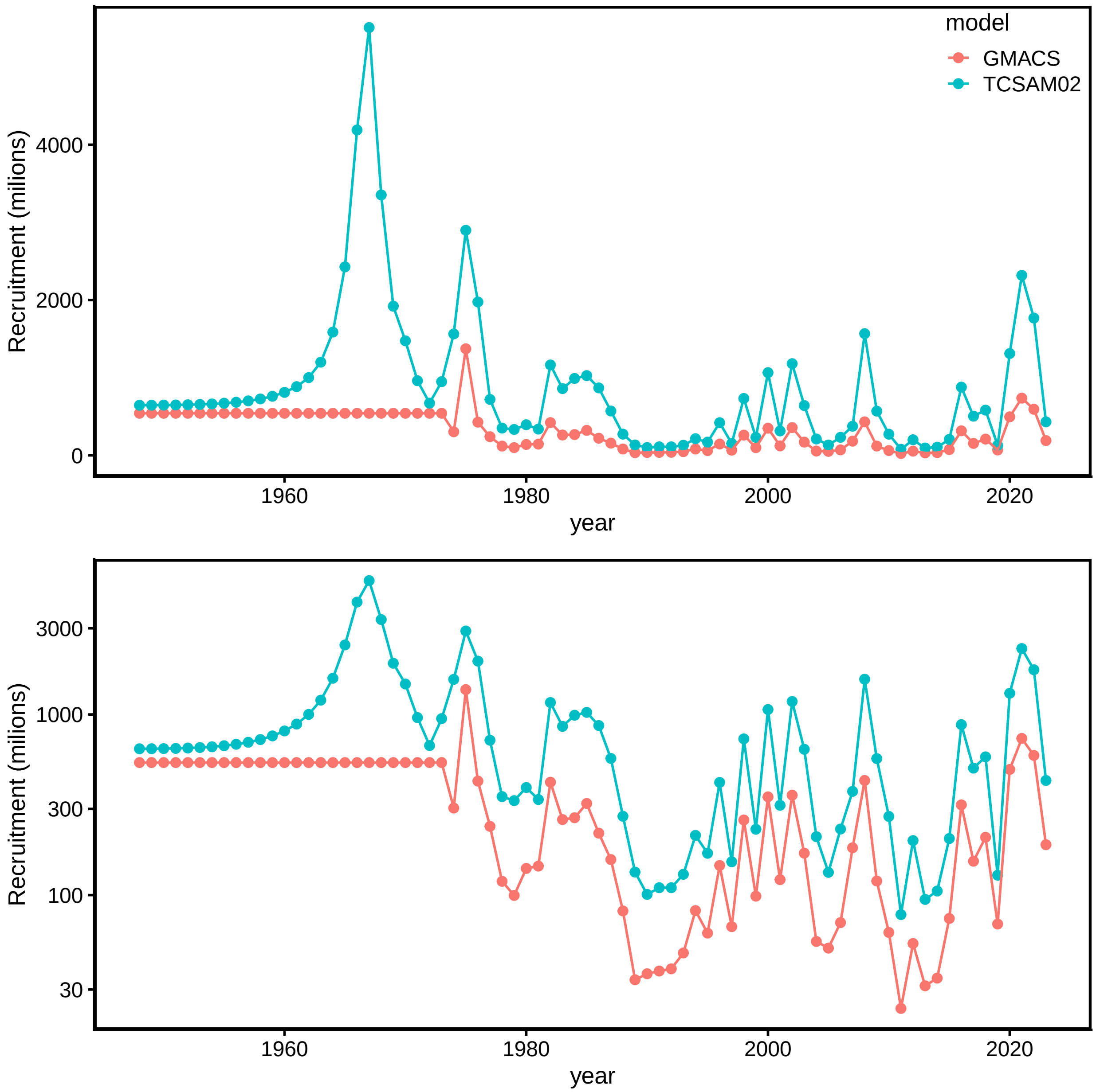


Figure 57. Estimated recruitment time series. Upper plot: arithmetic scale; lower plot: log10 scale.

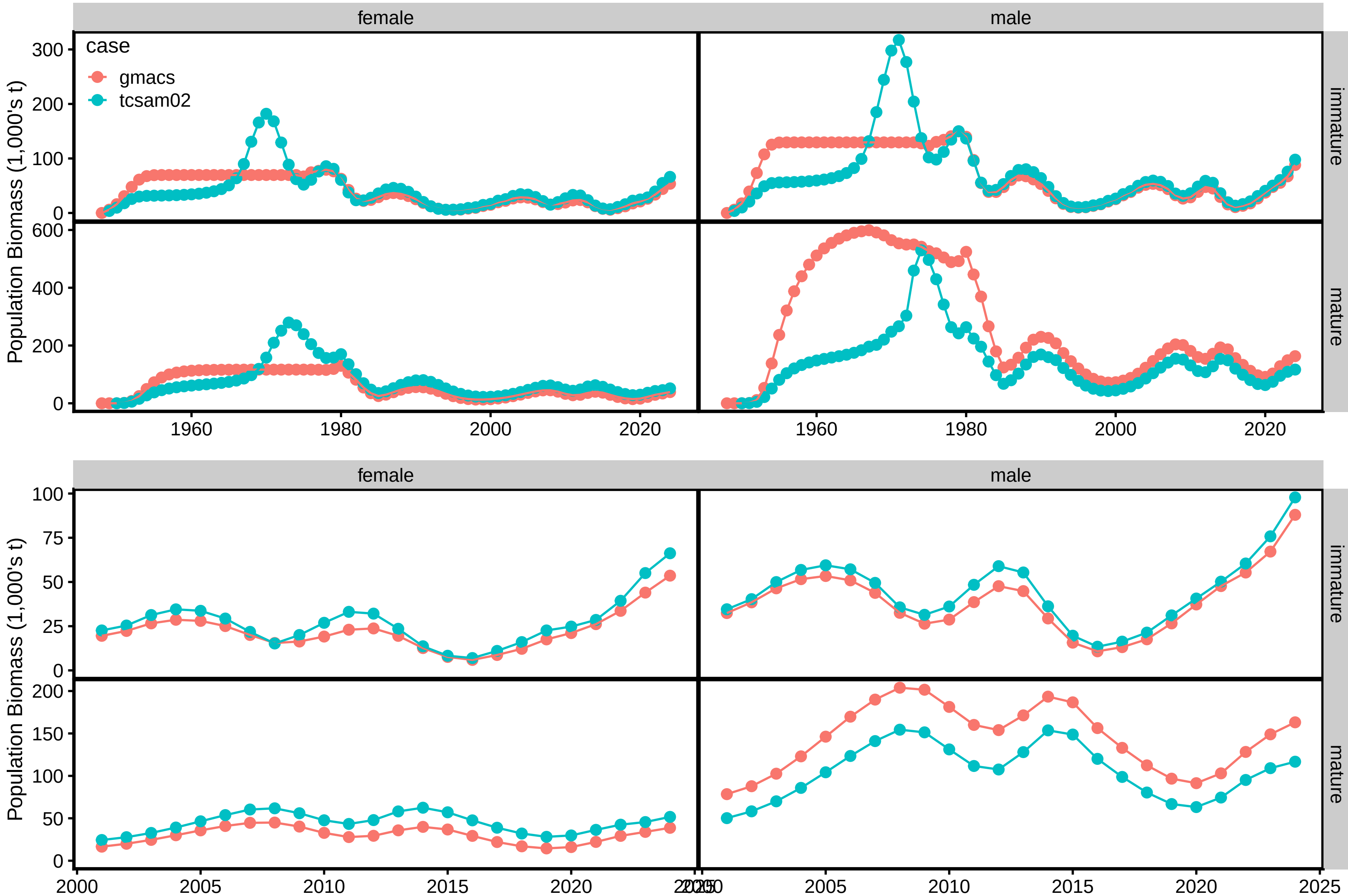


Figure 58. Estimated population biomass trajectories by sex and maturity state. Upper four plots: entire model time period. Lower four plots: detail since 2001.

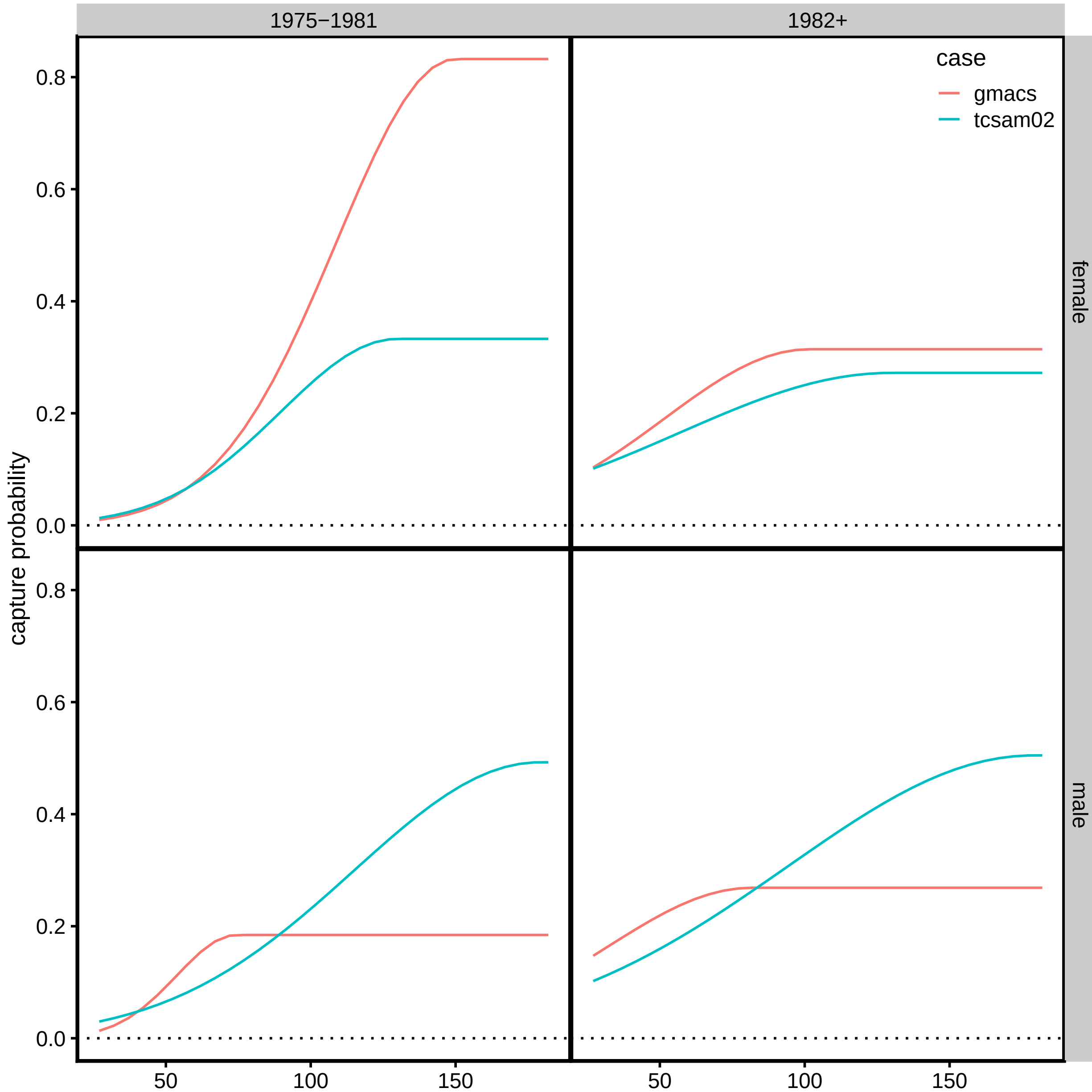


Figure 59. Estimated capture probability curves (q * selectivity) in the NMFS EBS bottom trawl survey, by sex and time period.

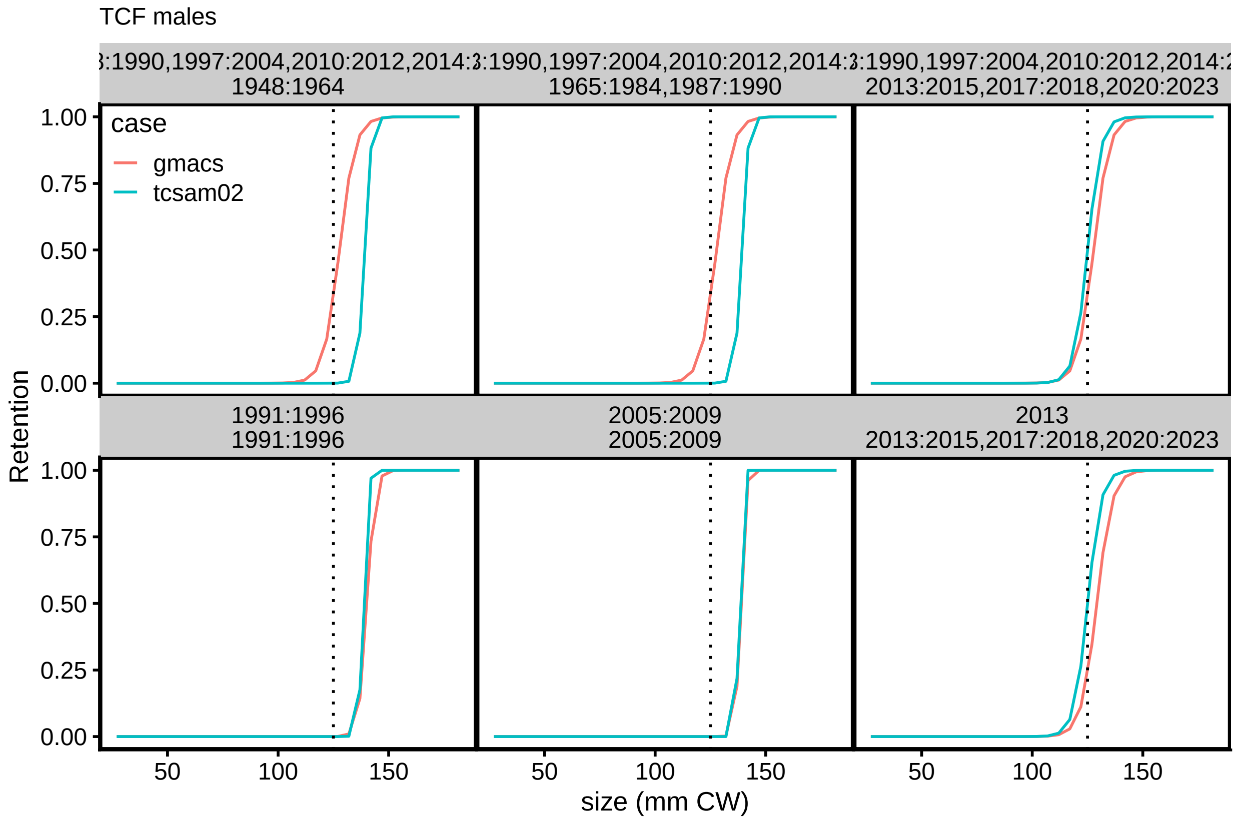


Figure 60. Estimated retention in the directed fishery. The upper time interval label in each panel refers to the GMACS model, the lower to the bespoke model.

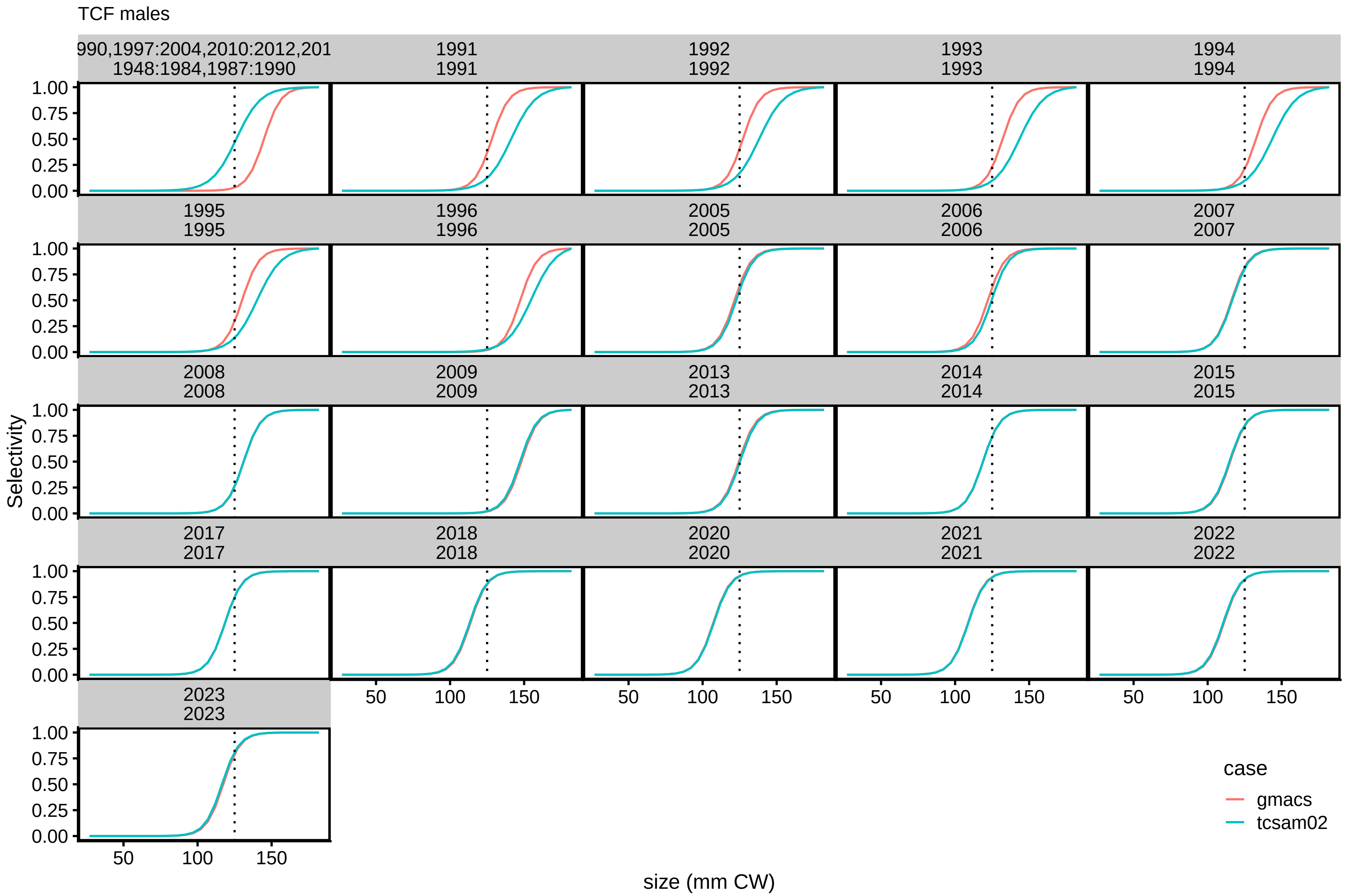


Figure 61. Estimated selectivity curves for males in the directed fishery. The upper time interval label in each panel refers to the GMACS model, the lower to the bespoke model.

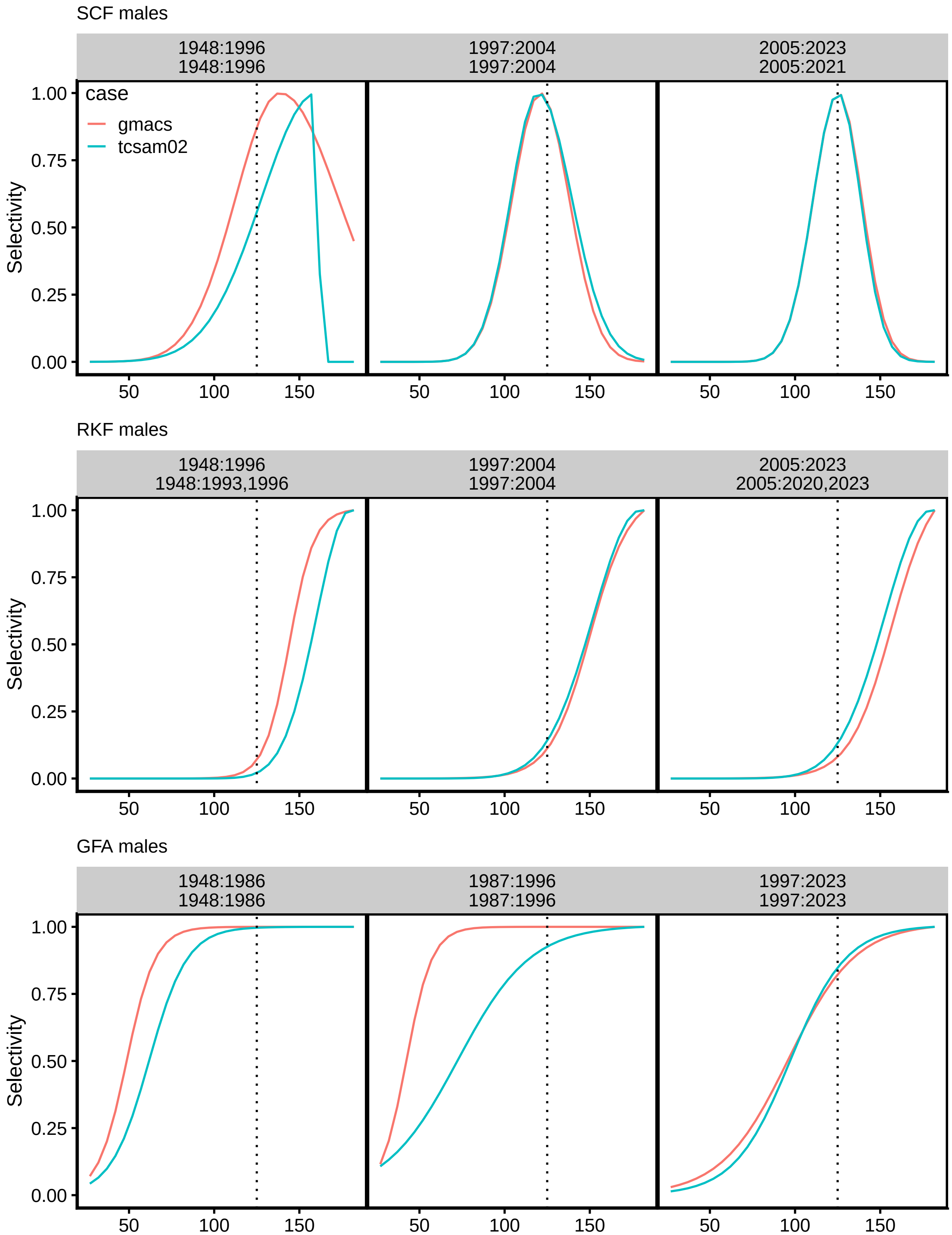


Figure 62. Estimated selectivity curves for males in the bycatch fisheries by time block. The upper time interval label in each panel refers to the GMACS model, the lower to the bespoke model.

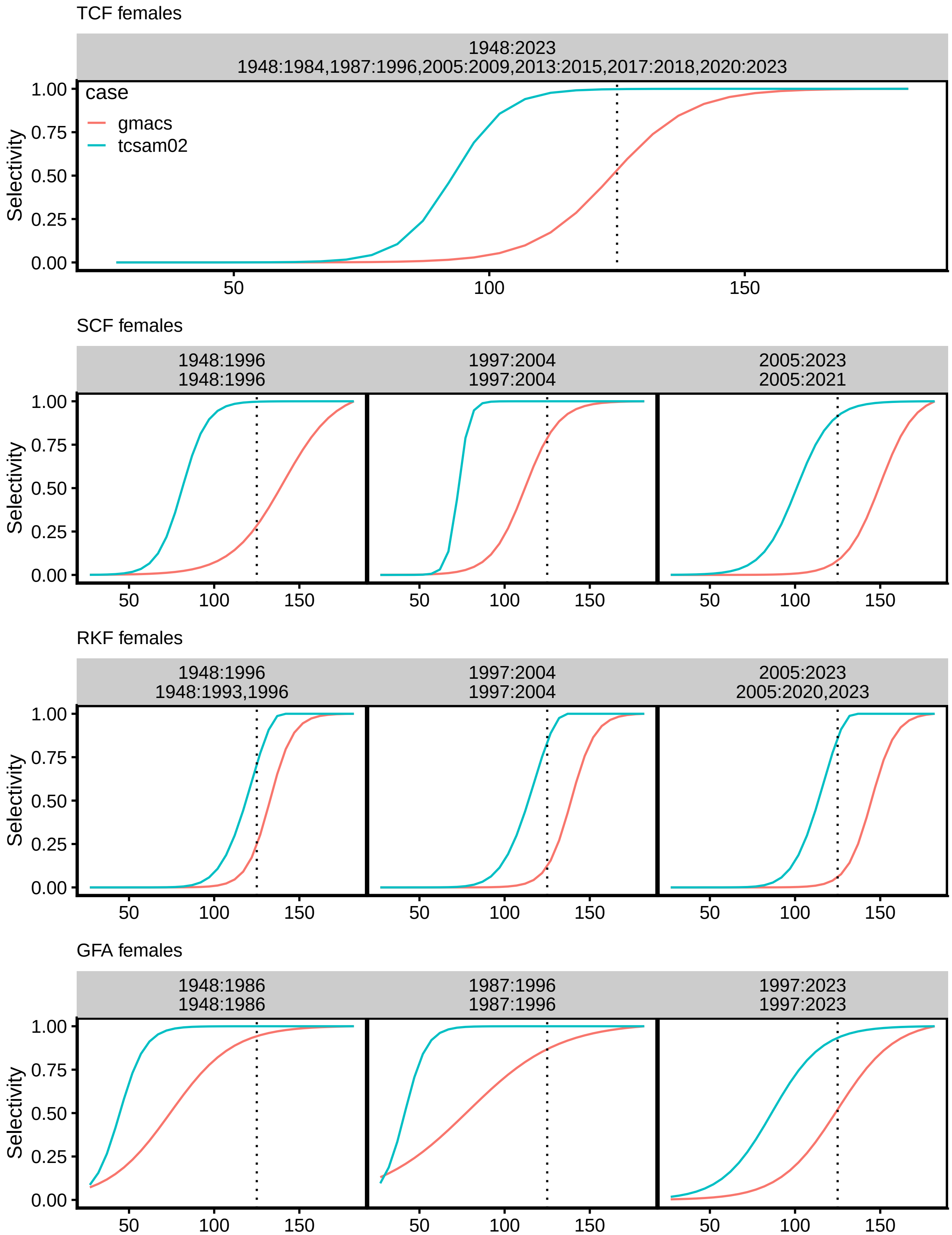


Figure 63. Estimated selectivity curves for females in the directed and bycatch fisheries by time block. The upper time interval label in each panel refers to the GMACS model, the lower to the bespoke model.

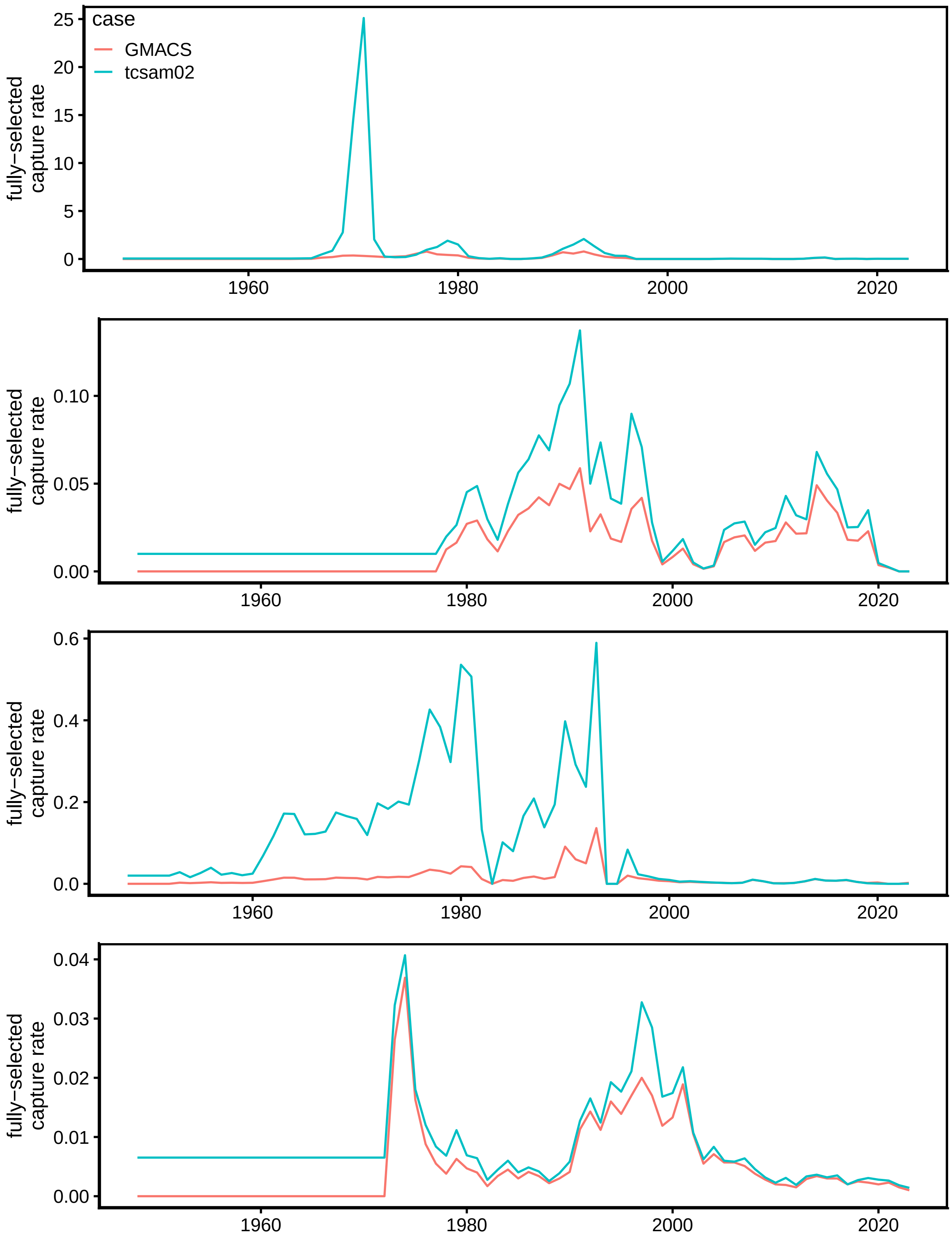


Figure 64. Estimated fully-selected fishery capture rates for males in the directed (uppermost plot), snow crab (upper middle), BBRKC (lower middle), and groundfish (lowermost plot) fisheries.

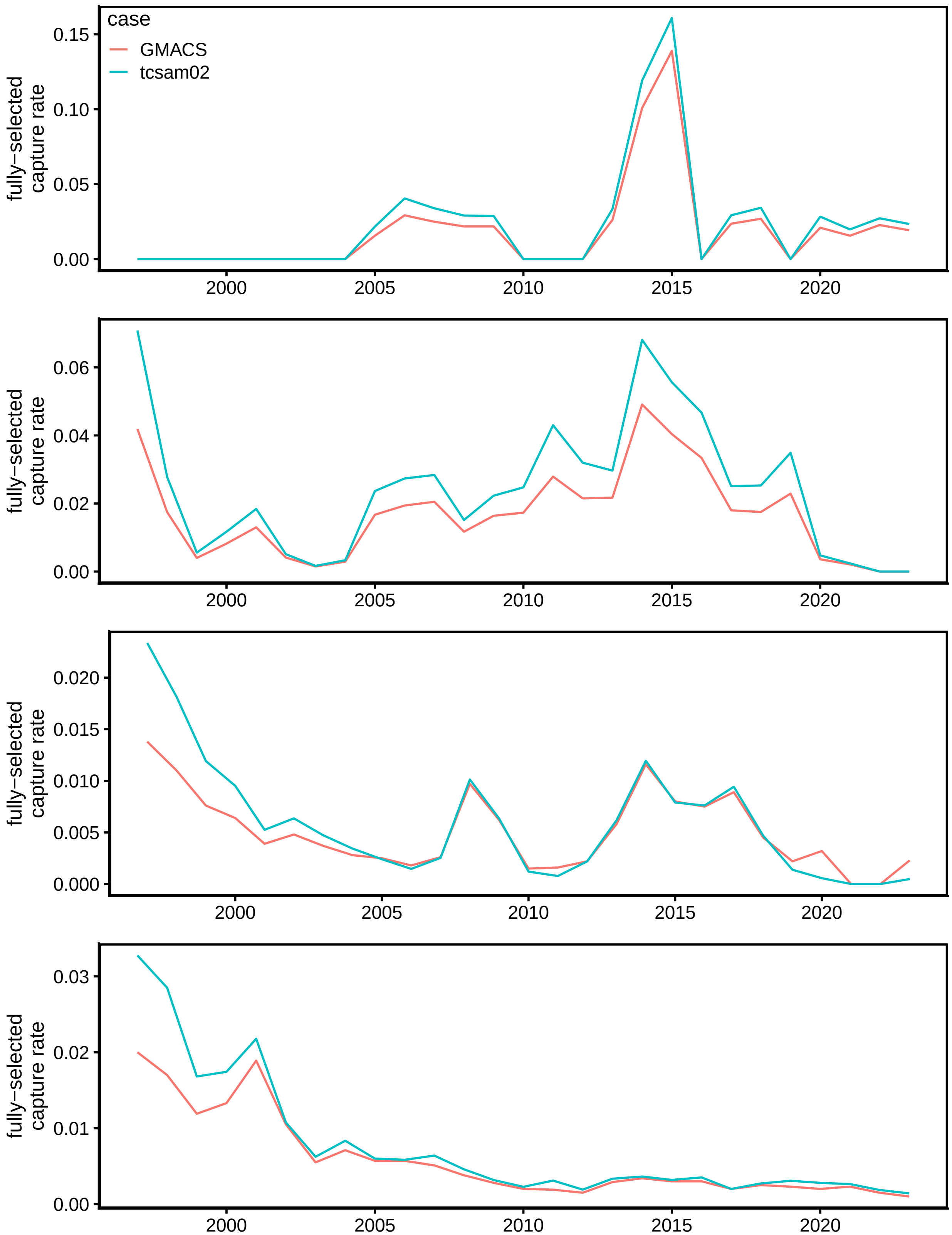


Figure 65. Estimated fully-selected fishery capture rates for males starting in 2001 in the directed (uppermost plot), snow crab (upper middle), BBRKC (lower middle), and groundfish (lowermost plot) fisheries.

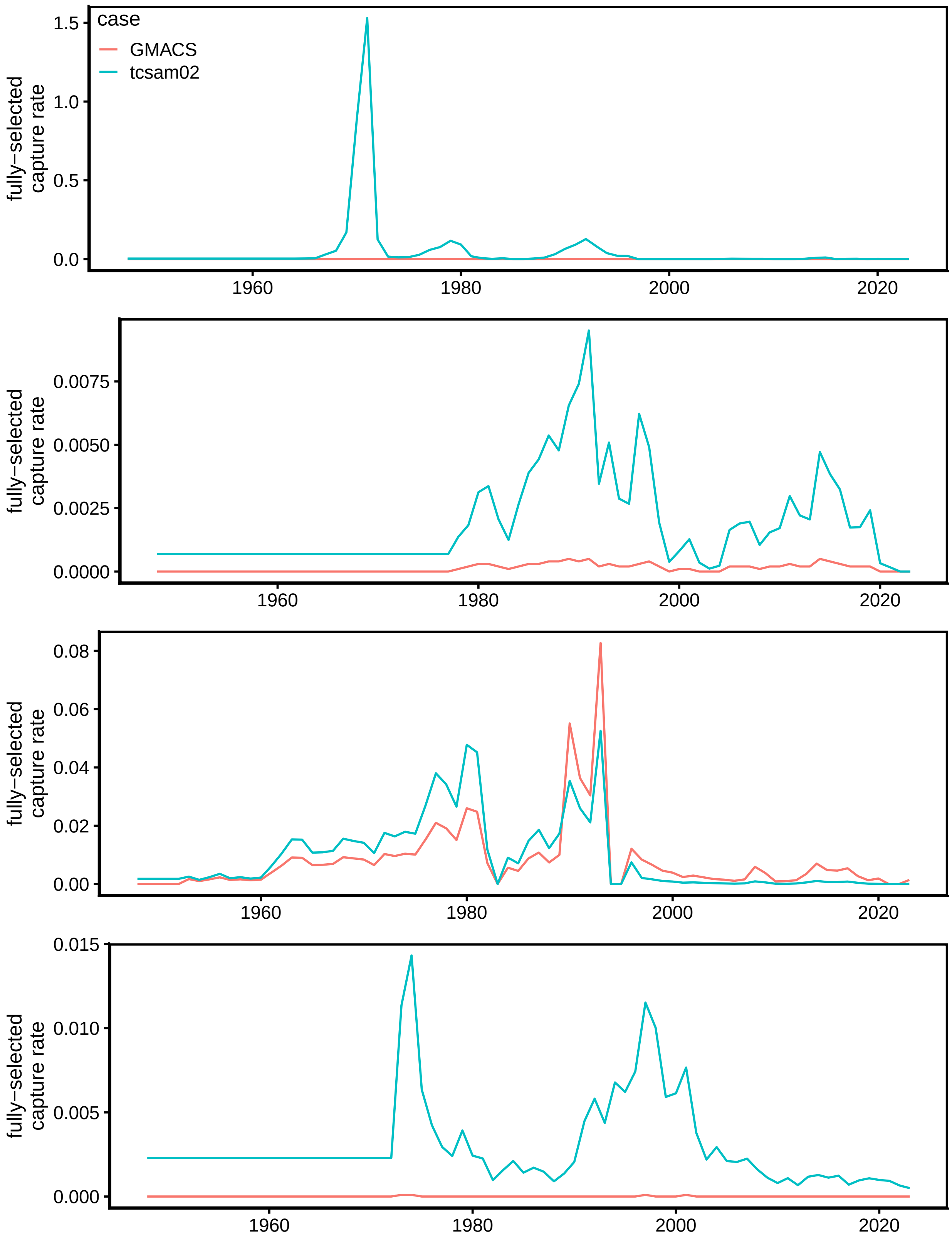


Figure 66. Estimated fully-selected fishery capture rates for females in the directed (uppermost plot), snow crab (upper middle), BBRKC (lower middle), and groundfish (lowermost plot) fisheries.

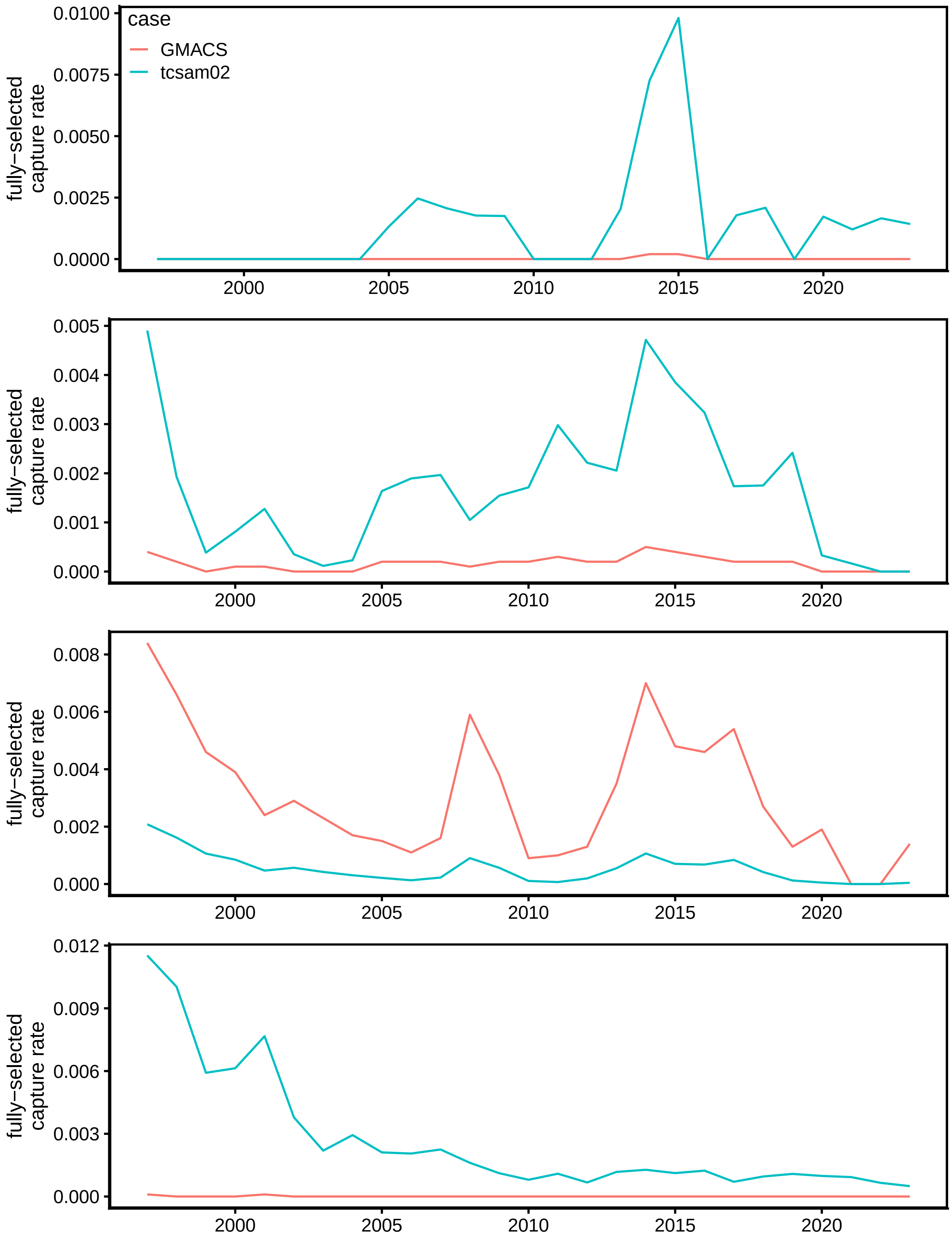


Figure 67. Estimated fully-selected fishery capture rates for females starting in 2001 in the directed (uppermost plot), snow crab (upper middle), BBRKC (lower middle), and groundfish (lowermost plot) fisheries.