2026 Tanner Crab Assessment Considerations

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1 Introduction

The next full assessment for the Tanner crab stock will be reviewed by the Crab Plan Team (CPT) in September 2026 and the NPFMC's (North Pacific Fishery Management Council) Science and Statistical Committee (SSC) in October 2026. The stock is on an annual cycle for assessment, with the last full assessment conducted in September 2025 (Stockhausen 2025a). This report addresses several topics, including new analyses with respect to the revised estimation of male maturity data, the potential impact of including hybrid Tanner/snow crab in the assessment, and continued work to develop a Generalized Model for Assessing Crab Stocks (GMACS) version of the Tanner crab assessment model.

Among the new analyses (Section 3), the AFSC's Shellfish Assessment Program (SAP) has developed a new workflow to estimate male maturity ogives for Tanner and snow crab based on a spatial approach similar to species distribution modeling (SDM). Staff have asked the author to compare assessment model results using maturity results from the new workflow with those using results from the previous workflow. Results of this comparison are presented in Section 3.1.

The abundance of *Chionoecetes* spp. (Tanner and snow crab) hybrids reached record levels in the 2025 NMFS eastern Bering Sea summer bottom trawl survey (Zacher et al. 2025), which raised concerns regarding their treatment, or lack thereof, in the Tanner crab and snow crab assessments. Most hybrid *Chionoecetes* crab are legally regarded as snow crab and are counted against snow crab overfishing limits (OFLs) and total allowable catch (TAC) limits (Ethan Nichols, ADFG, pers. comm.); only a small percentage are counted towards the Tanner crab OFL and TAC (they must have red eyes and an M-shaped epistome but otherwise exhibit snow crab characteristics to be classified as "Tanner crab"). To date, the Tanner crab assessment has not considered including hybrids in the assessment model, either in terms of population dynamics or fishery dynamics, for management reference point calculations. As a simple sensitivity experiment, the 2025 assessment model was re-run three times, each combining hybrid *Chionoecetes* with true (*C. bairdi*) Tanner crab abundance, biomass, and size composition data in different ways: 1) in the NMFS EBS survey data; 2) in the ADFG fishery catch data; and 3) the combination of 1) and 2); that tested the potential impact of including hybrids on management reference points for Tanner crab. Results from these model runs are compared with those from the 2025 assessment model in Section 3.2.

Finally, substantial progress has been made to create a Tanner crab model in the GMACS model framework that is "exactly equivalent" to the 2025 assessment model, which was created using the TCSAM02 model framework. A comparison of results from the GMACS model and a slightly modified version of the 2025 assessment model are presented in Section 4.

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

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

2.1 CPT Comments January 2026

2.1.1 CPT Comment (specific to assessment)

The CPT requested that Chionoecetes stock assessment authors present a comparison of results from models using the legacy versus new workflow data sets at the May 2026 CPT meeting.

Response

May 2026: Results from this modeling exercise for Tanner crab are presented in Section 3.1 of this document.

2.1.2 CPT Comment (specific to assessment)

Tanner and snow crab stock authors complete three model sensitivity runs (including size composition and abundance data):

- With hybrids included in survey data;
- With hybrids included in catch data;
- With hybrids included in both survey and catch data

Response

May 2026: Results from this modeling exercise for Tanner crab are presented in Section 3.2 of this document.

2.2 SSC Comments October 2025

2.2.1 SSC Comment (general)

The SSC notes that crab stock assessment authors currently use the OFL for catch projections. The SSC recommends that the authors and CPT provide a justification if catches are set to the OFL in projections, or use a more realistic estimate of future catches as is done in groundfish assessments.

Response

May 2026: It's a bit unclear what this comment is referring to. The Tanner crab assessment results provide projection results from a range of fishing mortality rates (fractions of F_{OFL}) for the directed fishery.

2.2.2 SSC Comment (specific to assessment)

The SSC thanks the assessment author for their extensive work documenting and addressing previous SSC and CPT requests. While the SSC appreciates the author's attention to detail, the SSC highlights that the SAFE and the included appendices are over 400 pages long, which makes review a daunting task. The SSC suggests additional streamlining of the material included in future assessment documents.

Response

May 2026: Noted. However, recent requests by the SSC to include results from a Tier 4 modeling approach, likelihood profiles on important parameters, retrospective assessment results, more information on jittering, and risk tables only increases the amount of material that needs to be included in the document. Specific suggestions as to what to remove, or how to reorganize the results into appendices, would be highly appreciated.

2.2.3 SSC Comment (specific to assessment)

The main recommendation from the SSC is to continue prioritizing the transition of the Tanner crab assessment into the GMACS framework. If a CIE review of this assessment is scheduled for 2026, the SSC strongly recommends that both the current and GMACS results are presented to the CIE, even if the GMACS conversion is still in progress

Response

May 2026: The transition of the Tanner crab assessment into the GMACS framework continues to be prioritized. A GMACS version of the Tanner crab model now achieves almost identical results to the bespoke model for population-level quantities, fishery quantities, survey quantities, and likelihood values when initialized at parameter values equivalent to those from the bespoke model and compared with the bespoke model results after a single iteration step (see Section 4). The only quantities substantially different are fits to "extended" size compositions and the OFL (~7.4% difference). The discrepancy in fitting "extended" size compositions (i.e., size compositions formed by appending the corresponding female size composition to a male composition) is caused by differences in how the two component compositions are weighted when forming the "extended" composition, but a path to resolving it has not yet been determined. The cause of the difference in the OFL has not yet been identified, but it is likely to be due to differences in the way the bycatch fisheries are treated in the two modeling frameworks. Current attention is also focused on reconciling the priors and likelihood penalties used in the two frameworks to achieve converged models yielding essentially the "same" values.

2.2.4 SSC Comment (specific to assessment)

An analysis of different inclusions/exclusions of hybrid data into the Tanner crab assessment (i.e., in survey and catch data) to evaluate sensitivity to these options and ensure an internally consistent approach. This is a lower priority for Tanner crab (see snow crab recommendations), but it may be helpful for the Tanner and snow crab assessment authors to work collaboratively on this topic.

Response

May 2026: Model runs similar to those for snow crab were made including/excluding hybrid survey and fishery data in the 2025 assessment model (see Section 3.2). Differences in management parameters under the different scenarios were relatively small (~10%) compared with the assessment results without hybrids.

2.2.5 SSC Comment (specific to assessment)

Continue reviewing pertinent literature for any new information on the maturity and reproductive biology of Tanner crab and other crab species with determinate growth (i.e., have a terminal molt) and re-examining the appropriateness of estimating maturity within the model or using an alternative (e.g., cut-line, size at 95% maturity) to better inform Tanner crab management decisions as new information becomes available. The SSC suggests that this could also be a high-priority topic for the upcoming CIE review.

Response

May 2026:

- "Continue reviewing pertinent literature": any suggestions? There are several fairly recent publications which focus on snow crab maturity and reproductive biology, but the only one I'm aware of that also considers Tanner crab is Slater et al. (2024).

- "the appropriateness of estimating maturity within the model": characterizing the size-specific transition of immature crab through terminal molt to "maturity" is necessary to accurately reflect the post-recruitment dynamics of individual cohorts within the model for both males and females. For females, of course, the transition from immature through terminal molt to maturity is morphologically unambiguous and maturity ogives do not need to be explicitly derived (maturity state-explicit survey size compositions provide this information) for the model to estimate the size-specific transition probabilities from immature to mature state. For males, the male maturity workflows (Section 3.1) developed by the SAP provide the estimates of size-specific post-growth fractions of newly-morphometrically mature males on an (almost) annual basis (since 2008) that the model uses as "data" to determine the size-specific probabilities of terminal molt for males. Unlike the snow crab model, which uses the ogives as "truth" to annually categorize post-growth new shell males into those that remain immature and those that underwent terminal molt and became mature, the current Tanner crab assessment model estimates time-invariant size-specific probabilities of terminal molt using the ogive data, although the modeling framework allows for estimating time variation across blocks of years.
- "estimating maturity within the model or using an alternative (e.g., cut-line, size at 95% maturity)": Whether it is better to use the estimated probabilities of terminal molt or alternatives such as a cut-line to determine proxies ($F_{35\%}$, $B_{35\%}$) for management reference points (F_{MSY}, B_{MSY}) is not strictly a biological issue and depends on the goals of management (e.g., using size-at-95% mature as the minimum size for "mature" males when calculating $B_{35\%}$ would protect a larger size range of males from exploitation than use of the maturity ogive, but might result in a greatly-reduced OFL).

2.3 SSC Comment (specific to assessment)

The SSC supports further exploration of an index of how changing environmental conditions might affect size at maturity of Tanner crab and considers this a research priority for both Tanner and snow crab.

Response

May 2026: Noted. Current snow crab research, which suggests this may be a complex problem involving both exogenous environmental conditions (e.g., temperature) and "endogenous" population conditions (e.g., size-specific density dependence) (C. Szuwalski, pers. comm.), may provide a template for future research.

2.4 CPT Comments September 2025

2.4.1 CPT Comment (general)

The CPT recommended that, when the CPT requests that only one model, essentially the last accepted model with updated data, be brought forward for a final SAFE, the final SAFE should be a complete document, but the associated presentation to the CPT need not provide a detailed description and evaluation of the model.

Response

May 2026: Noted.

2.4.2 CPT Comment (specific to assessment)

None.

2.5 SSC Comments June 2025

2.5.1 SSC Comment (general)

The SSC notes that a historical retrospective is different from a within model retrospective and requests that crab assessments include a plot comparing the model-estimated time series of mature male biomass from the current assessment with the time series from the ten previous assessments (i.e., historical retrospective).

Response

Sept. 2025: The requested plot is given in Figures 164 and 165 of the 2025 SAFE chapter (Stockhausen 2025a).

2.5.2 SSC Comment (general)

The SSC recommends that each crab SAFE chapter include a clear description of the buffers used in harvest specification over the most recent five years, as a basis for comparing the current year's buffer recommendations.

Response

Sept. 2025: The buffer on Tanner crab has consistently been set at 20% by the SSC in recent years, despite occasional recommendations by the author (if not the CPT) for a larger value. This is repeated several times in the text.

2.5.3 SSC Comment (specific to assessment)

The SSC concurs with the CPT and recommends bringing forward the base model (22.03d5) and the GMACS model (G25.05) in October.

Response

Sept. 2025: 22.03d5 has been brought forward. G25.05 was not brought forward due to unexpected (and currently unresolved) problems encountered with optimizing the model (the optimization failed after ~150 steps after generating an invalid gradient vector required to update the parameter values). Time constraints did not allow a solution to this to be found in time for model results to be included in the SAFE.

2.5.4 SSC Comment (specific to assessment)

The SSC also recommends bringing forward a Tier 4 calculation similar to 2024 and consistent with methods used for BBRKC and EBS snow crab.

Response

Sept. 2025: Done.

2.5.5 SSC Comment (specific to assessment)

The SSC agrees that focus should remain on transitioning this assessment into the GMACs framework and recommends developing a list of clear milestones for the transition for the October meeting.

Response

Sept. 2025: See GMACS-relevant responses below. A list of milestones would include: 1) agreement between GMACS and the bespoke model when the former is started in 1975 with a pin file derived from the bespoke model that includes the bespoke model's estimates of population structure in 1975; 2) successful optimization of the GMACS model (a current point of failure, as noted in responses above); 3) comparison of all likelihood components between the two models; 4) adjustment of priors and penalties to achieve model configurations that are as close as possible; 5) evaluation of the final comparison.

May 2026: 1) is almost completed, and will be complete pending resolution of discrepancies in how "extended" size compositions are formed. 2) the model now converges, but not to values equivalent to the assessment model due to the issues noted in 1). 3) all data-related likelihood components except "extended" size compositions are in agreement between the two models. 4) and 5) are TBD.

2.6 CPT Comments May 2025

2.6.1 CPT Comment (general)

With regard to Risk Tables:

- Given that baseline buffers or buffer ranges are not specified by tier level for crab stocks, buffers should consider uncertainty associated with tier level if warranted.

- The risk table should also be used to evaluate additional uncertainty, on a stock-by-stock basis, that is not already incorporated in the assessment model, tier level, or harvest control rules.
- No prescriptive formula will be used to adjust risk table scores or buffers across stocks.
- …assessment authors should coordinate with ESP authors (and ESR authors when an ESP is not available) to discuss ecosystem considerations prior to completion of a risk table.
- Risk tables should be conducted for all annual crab stock assessments (Snow crab, Tanner crab, BBRKC, NSRKC, and AIGKC). A full risk table will be contained as an appendix in each individual SAFE chapter with rationale given for risk table scoring. Brief risk table summaries will be included in the SAFE introduction (i.e., general description and risk table template, CPT-recommended risk table scores, and buffer for each stock).

Response

Sept. 2025: The risk table for the 2025 Tanner crab stock assessment is provided as an appendix (Stockhausen 2025b). It was created as a joint effort by the assessment author and the ESP and ESR authors. It does not use a prescriptive formula to adjust the risk table scores.

2.6.2 CPT Comment (specific to assessment)

The CPT agreed with using the high-precision carapace width data but recommended using the full set of 1979 stations provided in `crabpack`.

Response

Sept. 2025: Done.

2.6.3 CPT Comment (specific to assessment)

With regards to GMACS:

- The CPT suggested starting from inputting parameters via a .PIN file in the bridging analyses and then work towards estimating parameter values
- it might also be useful to consider how selectivity is being estimated. A closer look at how priors were placed on the NMFS survey selectivity seems warranted given large differences between estimates from each model.

Response

Sept. 2025: Since May, several Tanner-specific features have been added to GMACS (e.g., additional selectivity options, growth options, etc.) to better match the bespoke model configuration and to facilitate the comparison using a directly-comparable pin file. One major stumbling block to this approach is the difference in how recruitment is handled in each model. In the bespoke model, recruitment is modeled differently in the time periods before and after 1975, the first year that survey data is incorporated into the model: recruitment prior to 1975 (the first year that survey data is available) is modeled as a first-order autoregressive (AR1) process while after 1975 it is modeled as a random walk. This two-period strategy was found to be the best way of building up the population using recruitment during a "spin-up" period from zero in 1948 (an approach that ensures the population structure is consistent with modeled growth and mortality when the survey data become available in 1975). In GMACS, recruitment cannot be defined for different time periods: a single set of recruitment parameters is applied to the entire model time period. A work-around may be to start the GMACS model in 1975 but initialized with the population structure from the bespoke model for 1975, as well as other bespoke model-equivalent parameters and processes, but this has not been implemented yet. Another issue is that the GMACS model, when run from a pin file that is thought to provide the best match to the bespoke model, generates an invalid gradient structure (i.e., a vector of NaNs) after ~150 optimization steps and the reason for this has not yet been identified. As a consequence, no GMACS models are discussed in this document.

May 2026: A GMACS version of the 2025 Tanner crab assessment model run with one function call now yields values "exactly equivalent" to the assessment model when initialized with an equivalent pin file, except for the OFL and fits to extended size compositions (i.e., all fishery size compositions), see Section 4. The model also converges now, although not to values equivalent to the assessment because of issues with fitting the extended size compositions.

2.6.4 CPT Comment (specific to assessment)

The CPT recommended bringing forward only the base model (22.03d5) and the GMACS model (G25.05) so that more effort can be placed on bridging to GMACS.

Response

Sept. 2025: The base model, 22.03d5, has been updated with 2024/25 data and provides the basis for this assessment. It was not possible to bring a GMACS model forward at this point (see comment/response above).

2.6.5 CPT Comment (specific to assessment)

likelihood profiles over the OFL would be an interesting addition to the currently presented analyses.

Response

Sept. 2025: Time constraints did not allow this suggestion to be pursued, although the dependence of the OFL on several parameters which were themselves profiled is illustrated in an appendix to this document (Stockhausen 2025c). If time allows, the suggestion will be followed up on for the January Modeling workshop.

May 2026: No work has been done to address this. A likelihood component with a very large weight will need to be added to the overall likelihood to allow the model to be evaluated at a series of OFL values during the profiling.

2.7 SSC Comments October 2024

2.7.1 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 (Stockhausen 2024). Sept. 2025: “Raw” residuals have almost never been presented in the Tanner crab assessments; Pearson’s residuals have been presented. For this assessment, OSAs and DHARMa statistics are additionally presented for fits to size composition data.

2.7.2 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.

2.7.3 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.

2.7.4 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.

2.7.5 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.

2.7.6 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.

2.7.7 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.

2.7.8 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 (Stockhausen 2024) uses the mean molt to maturity curve based on the annual data.

2.7.9 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 (Stockhausen 2024) suggests differences in temperatures experienced by the "successful" and "unsuccessful" cohorts.

2.7.10 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 (see Stockhausen 2024). Further analysis will be presented in September.

Sept 2025: A limited set of likelihood profile results are presented in an appendix to this SAFE (Stockhausen 2025c).

2.8 CPT Comments September 2024

2.8.1 CPT Comment (general)

None.

2.8.2 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 of (Stockhausen 2024). Significant progress has been made towards an acceptable GMACS model (Section 5 of (Stockhausen 2024)).

Sept. 2025: Further work on the BSFRF selectivity remains a priority but other commitments did not allow time to complete this analysis. Further work will be presented at the January 2026 Modeling Workshop.

May 2026: Significant progress has been made towards an “exactly equivalent” GMACS model of the 2025 assessment model (see Section 4). Updates to the BSFRF selectivity analysis were presented at the January 2026 Modeling Workshop (link).

3 Analyses

3.1 New male maturity workflow

3.1.1 Introduction

In the Bering Sea, true crabs like Tanner and snow crab, as well as anomuran crabs like red king crab, grow through the discontinuous process of molting (Somerton 1981a). Whereas the latter (anomuran) continue to grow after becoming mature, *Chionoecetes* species (Tanner and snow crab) undergo a terminal molt to maturity and cease to grow (Somerton (1981b), Tamone et al. (2007)). Thus, it is critical to determine the proportion of mature crab at a given size for a *Chionoecetes* stock in order to assess its growth potential and resilience to exploitation. For female Tanner crab, maturity can be unambiguously determined from the shape of its abdomen. For male Tanner crab, the determination of maturity state is more nuanced and relies on statistically-determined classifications separating immature and morphologically-mature males based on the ratio of chela height (CH) to carapace width (CW) as a function of carapace width (Paul and Paul (1995), Richar and Foy (2022)).

The annual NMFS Eastern Bering Sea (EBS) shelf bottom trawl survey ("NMFS survey"; Zacher et al. (2025)) provides the primary source of fishery-independent data for indices of relative population size ("survey" biomass and abundance) size structure (size compositions), and maturity state for Tanner crab. Since 1975, the survey has been conducted during the summer on a standardized grid (Figure 1) with occasional changes to actual coverage: full coverage was implemented in 1987 and extended through 2023; since 2024 the higher density, so-called "corner", stations (represented circles in the figure) have been dropped to reduce costs, improve working conditions, and extend the survey into the northern Bering Sea (Zacher et al. 2025). While carapace width is measured for most Tanner crab caught in the survey, chela heights are measured only on a subsample of males for which carapace widths are measured. Starting in 1990, chela heights were measured to 1 mm more or less annually to 2007, as well as in 2009 (Richar and Foy 2022). Starting in 2008 (excluding 2009), chela heights (and carapace widths) have been measured to 0.1 mm. From 2008 to 2017, chela heights were collected for Tanner crab on even years until 2017; starting in 2018, chela heights for Tanner crab have been collected from a random subsample of up to 15 crab per survey haul annually except in 2020, when no survey was conducted (Zacher et al. 2020).

The "old" workflow for classifying the maturity state of male Tanner crab in the NMFS survey is described in (Richar and Foy (2022), Zacher et al. (2020)). Briefly, the paired CH and CW data are log-transformed, then binned by increments of the log-space carapace width. For each increment, the underlying bimodal (immature/mature) distribution of the data is then computed using kernel density estimation procedures from the R package stats (R Core Team 2022), and the minima between the peaks of the density distribution is calculated. Log-scale coordinates for the minima in each increment are extracted, and a linear relationship with log-scale CW is fit and applied as a cutline to classify morphometrically immature and mature males. The cutline is then applied to classify individual new shell crab as either immature or mature based on their paired CH, CW values and a maturity ogive (the proportion of the number of new shell mature males relative to all new shell males) is calculated using 10 mm CW size bins. Finally, the maturity ogive is applied to subsampling- and area-expanded estimates of the abundance of all new shell males on a haul-level basis to estimate the haul-level abundance of immature and mature new shell males.

The old workflow to some extent ignores the two-stage nature of CH data collection (stage 1: crab subsampled for CW measurements within a haul, stage 2: stage 1 crabs subsampled for CH measurements) as well as potential sub-regional scale spatial variability driven by environmental conditions such as substrate or temperature. The new workflow, developed by Emily Ryznar (AFSC-Kodiak), uses sdmTMB (Anderson et al. 2024) to build spatiotemporal models for the proportion of new shell, mature males (relative to all new shell males, both mature and immature) and resolve both these issues. The result is a spatiotemporal model for the maturity ogive that can provide haul-specific curves as well as a catch-weighted, survey-level ogive for use in the stock assessment model. Values of the latter are provided on 5 mm CW size bins to match the assessment model, as well as estimates of uncertainty that can be incorporated into the assessment model's likelihood component for the ogive "data". In addition, male maturity ogives can be estimated for years when CH data was not collected.

3.1.2 Male Maturity Ogive Data

On the whole, similar (but not identical) survey-level maturity ogives are estimated by the new and old workflows (Figures 2 and 3) in most years, although fairly large differences occur in 1992, 1993, and 2000 when CHs were measured to 1 mm precision (Figure 2) as well as in 2010, 2011, 2019, and 2025 when CHs were measured to 0.1 mm precision (Figure 3). In addition, the new workflow provides marginally smoother curves compared with the old workflow, although "kinks" still occur in some years (notably 1993 and 2000 in Figure 2 and 2019 in Figure 3)

3.1.3 Assessment considerations

To determine the potential impact of the new workflow on the Tanner crab assessment, the 2025 assessment model (Stockhausen 2025a) was re-run with the male maturity ogives from the new workflow and compared with results from the 2025 assessment (which used the maturity ogives from the old workflow). Results from the assessment model are voluminous, so only comparisons of key parameters and derived quantities are presented here.

Fits to data

Assessment model fits to the mature male ogive "data" provided by the two workflows are shown in the upper part of Figure 4; in the lower portion of the figure, the root mean square (rms) of the standardized deviations for each year that the ogives were provided is shown to provide a comparable measure of goodness of fit for the two datasets. By these latter measures, the assessment model fit the new workflow results more closely than those from the old workflow in all comparable years except 2023, when the difference was small. Growth data included in both models is also fit quite a bit better (15 likelihood units for males) in the model that includes the new workflow results (Figure 5), based on the differences in likelihood values. Fits to the aggregated fishery and survey catch data and size compositions can also be compared based on likelihood scores because the same data are in both models (fits to all of these components aggregate over maturity state and shell condition). The model fits to these data sources are somewhat worse with the new workflow for fishery ($<$ 4 likelihood units) and survey ($<$ 9 units) data after combining the likelihoods for aggregated catch and size compositions (Figure 6).

3.1.4 Estimated quantities

With the new workflow, the assessment model's estimated probability of undergoing terminal molt (Figure 7) is right-shifted to larger sizes. This means that proportionately fewer immature males undergo terminal molt to maturity at smaller sizes and instead have the potential to reach larger sizes. This is somewhat offset, however, by a concomitant reduction in estimated mean growth at larger sizes(Figures 5 and 8) and almost no change in the estimated rates of natural mortality for immature crab (Figure 9). The combined effects on a cohort of males recruiting at the same time to the models are illustrated in Figures 10 and 11. Figure 10 shows the time series of abundance for immature new shell, mature new shell, and mature old shell males over a 20-year time period. The effect of the right-shifted probability of terminal molt with the new maturity workflow can be seen in the slightly higher abundances of immature crab at ages 4 and 5 and the lower abundances of mature new shell males up to age 5 but higher abundances at ages 6 and 7 predicted by the model for that workflow. By age 8, effectively no immature or mature new shell crab exist under either model and abundances are almost identical. The evolution of the mature new shell and old shell size compositions over time tell a similar story. The similarity between models for the final size distributions in post-recruitment ages 8-10 reinforce the impression that population-level effects from the right-shifted terminal molt schedule estimated from the new workflow data are offset by the accompanying reduced mean growth.

Although differences exist between the model's estimated time series for population-level quantities during the "start-up" period prior to the inclusion of NMFS survey data in 1975, these are ultimately inconsequential. Thus the comparisons shown in Figures 12-16 start in 1975. The recruitment time series estimated using the two workflows generally agree to within 10%, with a larger difference (~25%) evident in 2019 (Figure 12) that is perhaps not surprising given that the NMFS survey was not conducted in 2020. The estimated time series for population abundance by sex and maturity state (Figures 13 and 14) exhibit closer agreement (differences < ~5%) with small, oppositely-drected biases evident in the differences in the estimates for immature and mature males, respectively, that reflect the differences in the estimated probability of undergoing terminal molt. The estimated time series for mature biomass-at-mating exhibit even smaller differences (< ~3%; Figure 15). And while fully-selected capture rates in the directed fishery (Figure 16) show some larger differences (over 20% in 1979) prior to fishery rationalization in 2005, differences are less than 5% in the post-rationalization period. Differences in capture rates in the bycatch fisheries (snow crab, Bristol Bay red king crab, groundfish fisheries) are even smaller (not shown).

The final comparison worth showing here between results from the 2025 assessment model and the model fitting the new maturity workflow data is that for fully-selected catchability ("q") in the NMFS survey (Figure 17). The estimated selectivity curves are almost identical between the two cases while the differences in "q" are very small for females (< 1%) but somewhat larger for males (< 7%).

Management quantities

Estimates for various management-related quantities (Figure 18) exhibit only very small differences between the 2025 assessment model and the model fitting the new maturity workflow. These are < 1% for abundance- and biomass-related quantities (mean recruitment, unfished mature male biomass, current mature male biomass, projected mature male biomass, MSY, and the OFL) and ~2% for quantities related to fishing moratlity rates (F_{MSY}, F_{OFL}).

3.1.5 Recommendations

It is perhaps somewhat reassuring that adoption of the new maturity workflow will probably not substantially alter management advice coming from the Tanner crab assessment model, although this should not really be a criterion for its adoption or rejection. Instead, the advantages provided by its use (better reflection of aspects of the data collection, incorporation of spatial heterogeneity, ability to provide finer size resolution, estimates of uncertainty) outweigh any disadvantages (increased analysis complexity) relative to the old workflow; the author fully supports adopting the new workflow.

3.2 Potential impacts of hybrids

3.2.1 Introduction

Abundance and biomass estimates for *Chionoecetes* spp. hybrids ("hybrids") in the 2025 NMFS EBS shelf bottom trawl survey were "unprecedented" across all sex/size/maturity categories (Zacher et al. 2025). Male crab ≥ 78 mm CW had a biomass estimate of 37,068 t, representing a 471% increase since 2024; it was also considerably higher than the previous 20-year average of 4,459 t. Twenty percent of all the *Chionoecetes* spp. males ≥ 101 mm CW in the eastern Bering Sea were hybrids. A peak of immature hybrid males was observed in the 50 – 90 mm range in the 2024 survey and many of these crab appeared to reach mature and legal size classes for snow crab in 2025. In addition, there were further large increases in juvenile size classes, portending future recruitment to those size classes. Hybrid males were found in highest abundance on the middle shelf to the east and northeast of the Pribilof Islands, with small male hybrids found further north than large male hybrids.

The astonishing abundance of hybrids led to concerns expressed by stakeholders and reiterated by the CPT and SSC at their respective Fall, 2025 meetings ((CPT 2025), (SSC 2025)). Comments from stakeholders included questions about the ways in which hybrids are included or excluded from the Tanner crab OFL calculation, as well as the need for rapid action on developing a plan for incorporating hybrids into assessments and regulations such that harvesters can take advantage of the increasing abundance of hybrid males at industry-preferred sizes.

As a preliminary step, Tanner and snow crab stock authors were asked to complete three model sensitivity runs (including size composition and abundance data):

- With hybrids included in survey data;
- With hybrids included in catch data;
- With hybrids included in both survey and catch data

Results from this request are addressed in this section of the report. Data on hybrids in the NMFS survey are discussed in Section 3.2.2 and in the fisheries in Section 3.2.3. Results from the three sensitivity runs requested by the CPT are reviewed in Section 3.2.4.

3.2.2 Survey Data

The annual NMFS EBS shelf bottom trawl survey ("NMFS survey"; Zacher et al. (2025)) provides the primary source of fishery-independent data for indices of relative population size ("survey" biomass and abundance) and size structure (size compositions) for EBS crab stocks, including Tanner crab. Since 1975, the survey has been conducted during the summer on a standardized grid (Figure 1) with occasional changes to actual coverage: full coverage was implemented in 1987 and extended through 2023; since 2024 the higher density, so-called "corner", stations (represented circles in the figure) have been dropped to reduce costs, improve working conditions, and extend the survey into the northern Bering Sea (Zacher et al. 2025).

Aggregated Time Series Data

Design-based estimates (and cv's) for trends in annual survey abundance and biomass for hybrids and Tanner crab from the NMFS survey are given in Tables 1-4 by sex and maturity state. Corresponding time series plots are given in Figures 19 and 20. For the most part, the addition of hybrids remains within the confidence intervals of the Tanner-only estimates of abundance and biomass. The *relative* annual abundance and biomass of hybrids in the survey are compared, by sex and maturity state, with the respective combined values in Figures 21 and 22. Prior to the 2025 survey, hybrid abundance (Figure 21) was typically less than 10% of Tanner crab in the same biological category, although this was exceeded in individual years (1982 and 1988 for mature females, 1984 for immature females, and 1988 for males) as well as several years during the period 2008-2019. However, total abundance peaked in 2025 across all three biological categories and exhibited the highest percentage (~ 30%) of hybrid abundance relative to Tanner crab abundance in the time series for immature females and males, as well as the second highest percentage for mature females (~60%; 2011 had a slightly higher percentage of mature females than 2025). Time series for hybrid biomass exhibit similar characteristics (Figure 22).

Size Data

Design-based, sex-specific abundance size compositions for hybrids and combined hybrids+Tanner crab from the NMFS survey shown in Figures 23-26. In most years, the hybrid size compositions are neglible compared to those for Tanner crab, with 2012 and 2025 the exceptions for males (Figure 24) and 2011 and 2025 the exceptions for females (Figure 26). However, the mean sizes for the hybrids are similar to those for Tanner crab and exhibit decadal-scale fluctuations similar to those for Tanner crab (Figure 27), suggesting the possibility that the timing of recruitment for hybrids and Tanner crab may be linked through shared environmental drivers.

3.2.3 Fishery data

For regulatory purposes in, and management of, the crab fisheries, ADFG defines "snow crab" as any *Chionoecetes* crab that does not have red eyes and an "M"-shaped epistome (Tyler Jackson, ADFG, pers. comm.). While most hybrid *Chionoecetes* do not meet these criteria and thus are classified as "snow crab", a small minority of hybrids do meet these regulatory criteria for being considered a Tanner crab but exhibit other features characteristic of *C. opilio* (i.e., true snow crab). Thus, at-sea total catch and dockside retained catch sampling may identify *Chionoecetes* hybrids as "Tanner-like" or "snow-like" hybrids. However, this distinction has not always been applied across the available time series and thus this refinement is not included here: all hybrid *Chionoecetes* crab are simply treated as "hybrids".

At-sea observer "total catch" data

At-sea observer coverage for total catch estimates nominally began in 1990 for the BSAI crab fisheries (Table 5), although the actual temporal coverage is complicated by fishery closures and changing seasons. To simplify things a bit for the assessment model sensitivity runs, the observer estimates of total hybrid catches from individual fisheries were first combined by a "stock group" designation (Table 5). After combining counts within stock group, the number of observed hybrids was generally largest, by far, in the snow crab fishery, followed by the Tanner crab fisheries while counts of male hybrids far exceeded those for females (Table 6).

After expanding the observer-quantified counts to estimates of total catch abundance and biomass of male hybrids in the various stock groups, the vast majority of the catch has occured in the snow crab fishery, with small amounts taken episodically in the Tanner crab fisheries and negligible amounts taken in the other fisheries (Figures 28 and 29). Relatively large catches ($>$ 10 million crab) occurred in the snow crab fishery in the early 1990s and the late 1990s but have since dropped almost two orders of magnitude following rationalization of the crab fisheries in 2005. The large catches in the 1990s in the snow crab fishery were similar in size to, or exceeded, the bycatch of male Tanner crab in that fishery. Since rationalizaton, the bycatch of male Tanner crab in the snow crab fishery has exceeded the catch of hybrid males in that fishery by an order of magnitude. The magnitude of male hybrids taken in the directed Tanner crab fisheries has always been very small compared with the catch of the target species: although the catch of hybrids in the directed fishery reached a maximum for the time series in 2024/25, it was ~50 times smaller than the total male catch estimated for that year in that fishery.

As with males, most female hybrids have been captured in the snow crab fishery, with generally smaller amounts captured in the directed Tanner fisheries and negligible amounts captured in the other crab fisheries (Figures 30 and 31). Estimated total catches for hybrid females have been on the order of $50x$ less than those for hybrid males and the relative decrease in catch between the pre- and post-rationalization periods appears similar to that for males.

Size compositions for male hybrids captured in the snow, Tanner crab, and combined other fisheries are shown in Figures 32-34. Total catch size compositions for females in these fisheries are not shown due to the small number of females captured in any year.

Retained catch data

Total numbers of hybrid males identified in sampling retained catch for size composition are presented for the Tanner and snow crab fisheries in Table 7. While not classified here explicitly as “Tanner-like” or “snow-like”, presumably the hybrids retained as “Tanner crab” or as “snow crab” would reflect which fishery they were retained in. The size compositions (counts only, not expanded to total numbers retained) for these retained hybrids are illustrated in Figures 35 and 36.

3.2.4 Assessment considerations

To determine the potential impact of accounting for hybrid *Chionoecetes* crab in survey and fishery data as Tanner crab (*C. bairdi*) in the Tanner crab assessment, the 2025 assessment model (Stockhausen 2025a) was re-run with: 1) only survey data with hybrids included; 2) only fishery data with hybrids included; and 3) both survey and fishery data included. Results from the model run with these data were compared with results from the 2025 assessment (which included only crab identified as *C. bairdi*, Tanner crab). Results from the models are voluminous, so only comparisons of key derived quantities are presented here.

Combined Tanner-hybrid data from the NMFS EBS survey (survey biomass time series and size compositions) were created by extracting haul-level, individual data for crab classified as *C. bairdi* and as *Chionoecetes* spp. hybrid from AKFIN using the `crabpack` R package (Hennessey 2025), reclassifying all individuals as *C. bairdi*, and subsequently calculating standard design-based, area-swept estimates for survey-level abundance and biomass time series and size compositions for immature female, mature female, and male “Tanner crab”. Assessment model input files for the resulting survey data were then created by treating these exactly as if they were *C. bairdi* data. The 2025 assessment model files for other “survey-related” input such as male maturity ogives and growth data were used in unaltered form because no information is available to construct “combined” Tanner-hybrid versions of them for this sensitivity study.

Combined Tanner-hybrid data for total catch in the crab fisheries (combined-sex catch biomass time series and sex-specific size compositions) were created using effort-expanded at-sea observer data for hybrid *Chionoecetes* to calculate time series for total catch biomass and sex-specific size compositions in the Tanner crab, snow crab, and BBRKC fisheries. These were then added to the Tanner-only data used in the 2025 stock assessment to create combined Tanner-hybrid total catch fishery data. Combined retained catch size compositions were created under the assumption that random sampling of the retained catch occurred and thus the count-level size compositions for retained crab identified as hybrids in the Tanner crab retained catch could simply be added to the count-level size compositions for *C. bairdi* to obtain the combined size compositions, which could then be expanded to total retained catch. Doing so, however, makes one realize that the retained catch biomass data going into the assessment somewhat overestimates the amount that is actually *C. bairdi*.

For the sensitivity runs, the 2025 assessment model was run with the scenario-specific input files using the parameter values from the 2025 MLE to initialize the model run. For each run, the model was run until the ADMB convergence criteria was met and the model hessian created. As an alternatie to parameter jittering, the model was then re-run using Cole Monahan’s “hess_step” procedure starting from the converged parameter values. This uses the model hessian to quadratically approximate the local likelihood surface to improve on ADMB’s convergence criteria and identify the set of parameter values that yield the actual local maximum in the likelihood surface (i.e., the point where all gradients with respect to parameters are zero).

Management quantities

Including hybrid *Chionoecetes* as Tanner crab in the Tanner crab assessment had relatively little effect on key management quantities (Figure 37). The largest percent difference from the 2025 assessment model occurred for stock biomass projected to 2026 (“prjB” in the figure; under the assumption that the OFL was taken with the directed fishery operating at F_{OFL} and the bycatch fisheries operating under recent bycatch mortality conditions) when hybrids were included in both the fishery and survey data. The effects of including hybrids appear to be additive for management quantities, with the impact of including hybrids in both fishery and survey data being approximately the sum of the effects of including hybrids in either data source.

Estimated quantities

population time series

Time series for estimated recruitment generally showed little effect of the inclusion or exclusion of hybrids in survey or fishery data except during the early 1990s with the inclusion of hybrids in the fishery catch data and since 2021 with the inclusion of hybrids in the NMFS survey data

(Figure 38). During 1992-1994, recruitment with the inclusion of hybrid fishery data was 10-15% higher than the assessment, while the scenario with survey-only hybrid data estimated recruitment ~5% smaller than the assessment during this period. The inclusion of hybrids in the NMFS survey data resulted in a dramatic swing in estimated recruitment from 2022 to 2024 of 15% higher to 25% lower than that estimated by the assessment model, preceding the dramatic rise in hybrid abundance/biomass in the NMFS survey data.

Estimated time series for mature biomass were impacted by the additions of survey and/or fishery data for hybrids(Figure 39), but the changes from the 2025 assessment results were fairly small with most years exhibiting differences less than 10%. The years 1995-2000 were the exception to this, when relatively large catches of hybrids in the snow crab fishery reduced mature male biomass by up to 20%. Interestingly, the addition of hybrids to the survey data tended to have a larger (and negative) impact, relative to the assessment results, on the estimates of mature biomass than their addition to the fishery data, except in the just-noted 1995-2000 time period when catch of hybrid males in the snow crab fishery was high (see Figure 29).

individual characteristics

The addition of hybrids to either the survey or fishery catch data had discernable impact on estimated natural mortality rates (“M”, Figure 40) only for mature males in the hypothesized “high mortality period” (1980-1984) when the addition of hybrids to the survey data increases the estimated M whereas the addition of hybrids to the fishery data decreased the estimates to such an effect that adding hybrids into both data streams canceled the effect. Outside this time period, the additions had no substantial effect on any natural mortality estimates. Estimates of other population characteristics (e.g., growth, maturation) were unaffected by the additions of hybrids (not shown).

survey characteristics

The estimated values for fully-selected catchability (“q”) in the NMFS survey exhibited almost no change when hybrids were included in the fishery data, but increased up to ~9% when they were included in the survey data (Figure 41), which is relatively consistent with the concomitant increase of ~10% in survey biomass starting in 2005 (Figure 22). Estimated survey selectivity curves were essentially unchanged by the inclusion of hybrids data (not shown).

fishery characteristics

Somewhat surprisingly, there was little difference when hybrids were added to the fishery data in estimated total capture rates in the directed Tanner crab fishery (Figure 42) across the time frame from 1975 (when the NMFS survey data begins) to the present, although some small differences were evident in 1979/80-1980/81 (the time at which retained catch size composition data starts) and for females in 1990/91-1993/94 (total catch estimates start in 1990/91 and 1991/92 for the crab fisheries). Similar results occurred for bycatch capture rates in the BBRKC fishery (Figure 43), although this was less surprising given there was very little difference in bycatch values in this fishery with the addition of hybrids. Not surprisingly, the largest differences occurred for estimated bycatch capture rates in the snow crab fishery (Figure 44) from 1978/79 to 2001/02, and particularly in the late 1990s, which coincides with the large catches of hybrids in that fishery. Although the figure suggests that relative differences continue into the post-rationalization period (after 2004) for females, the absolute difference is < 0.001, which is essentially negligible. The estimated bycatch capture rates in the groundfish fisheries (Figure 45) also exhibited differences across the late-1990s when hybrid catch data is combined into the crab fisheries data, even though the groundfish data was not changed. Fishery selectivity curves were only slightly changed with the additions of the hybrids data (not shown).

3.3 Discussion

The abundance and biomass of *Chionoecetes* spp. hybrids increased dramatically in the 2025 NMFS survey and ADFG set a separate "hybrid" quota for retained hybrid catches, raising concerns that these hybrids could skew assessment results and/or management advice. Simple sensitivity runs presented here treat hybrids as additional *C. bairdi* in either survey or fishery data (or both). These are intended to bracket the potential extremes of the effect of hybrids on the management of the Tanner crab stock. The results suggest that doing so would have little impact on current assessment-derived quantities important to management such as the OFL or F_{OFL} that consider only *C. bairdi* as "Tanner crab".

However, this conclusion needs to treated with some caution because the assumption that hybrids function biologically and ecologically the same as *C. bairdi* is substantially untested (Slater et al. 2024). Another consideration is that the majority of hybrids are retained and landed as "snow crab" rather than as "Tanner crab", because ADFG defines a "Tanner crab" as having red eyes and an "M"-shaped epistome while all other *Chionoecetes* are "snow crab". While a small percentage of hybrids exhibit red eyes and an M-shaped epistome but other *C. opilio*-like features and would thus be classified as "Tanner crab" and included in retained catch accounting as "Tanner crab", the overwhelming majority of hybrids are classified as "snow crab" and are included as such in retained catch accounting. For the simple scenarios considered here, time did not permit identifying the amount (numbers, biomass,size compositions) of hybrids retained as "snow crab" and including them as retained "Tanner crab". In addition, the difference in preferred size between snow crab and Tanner crab in their respective fisheries would further complicate any attempts to more realistically incorporate hybrids retained as "snow crab" into a retained "Tanner crab" catch.

The abundance and biomass of hybrid *Chionoecetes* seen in the 2025 NMFS survey and the 2024/25 crab fisheries has little precedent in the history of fisheries management for these stocks and may be an ephemeral concern. If the hybrid component of the joint *Chionoecetes* populations does not return to low levels again, more sophisticated models that more realistically take into account the interactions between and among hybrids, *C. opilio*, and *C. bairdi* on the population and fishery dynamics of all three components of *Chionoecetes* spp. in the eastern Bering Sea may need to be developed. If so, further basic biological and population dynamics research necessary to support the models will also need to be undertaken.

4 TCSAM02-GMACS Bridging Analysis

4.1 Introduction

The Tanner crab assessment has been based on the Tanner Crab Stock Assessment Model, version 2, (TCSAM02) modeling framework since the 2015 assessment (Stockhausen 2015). A detailed description of the framework is provided in Stockhausen (2023). The current TCSAM02 code is available as a repository on GitHub (the current development branch is "202603"). The framework consists of an AD Model Builder (ADMB; Fournier et al. (2012)) C++ template, native C++ code in several additional source and include files, and the C++ library wtsADMB. Although the framework has many options for defining an implemented "model", the characteristics of its current population dynamics are limited to *Chionoecetes* species (i.e., Tanner crab and snow crab) and cannot be applied to, e.g., king crab species. Thus, TCSAM02 does not provide a unified modeling framework for Alaskan crab stocks in a manner similar to that of the Generalized Model for Assessing Crustacean Stocks (GMACS). For several years, the SSC has requested that the Tanner crab assessment be moved to the GMACS framework so that all BSAI crab stocks are assessed using the framework, but it and the CPT have also indicated the necessity (CPT (2024), SSC (2024)) that a detailed bridging analysis from the bespoke model be conducted that demonstrates the resulting GMACS model is "exactly equivalent" to the bespoke model before the transition from TCSAM02 to GMACS should occur for the Tanner crab assessment. Up to now, three of the major barriers to development of an "exactly equivalent" GMACS Tanner crab model have been: 1) that several features utilized in the bespoke model have not been available in GMACS, 2) that results were not consistently reported between the two frameworks, and 3) that functions did not exist that allowed comparison of results between the two models. Since the 2025 assessment and the more recent Crab Modeling Workshop (January, 2026), these barriers have, on the whole, been surmounted. Three areas remain to be better reconciled: 1) fitting to "extended" size composition data, 2) calculation of the OFL and 3) priors and penalties applied to the model likelihood/objective function.

4.2 TCSAM02-GMACS compatability

4.2.1 Model comparison at initialization using exactly equivalent parameter values

"Exact equivalence" between a Tanner crab model in the two model frameworks is demonstrated here by 1) creating a TCSAM02 model that replicates the 2025 assessment model as closely as possible to allow direct comparison with a GMACS model, 2) creating the equivalent model in GMACS, and 3) running both models for a single iteration to determine that the models return identical results (allowing for a small margin of error due to the finite precision of the input files). The TCSAM02 model used for this comparison replicates the 2025 assessment model in all features except that fishing mortality rates prior to available catch and/or effort data were set to zero whereas the assessment model included small, fishery-specific rates that were thought to possibly improve "spin-up" of the modeled population from 1948 (the model start year) to the year(s) at which data became available to inform the model. GMACS does not allow for this extension of fishing mortality rates to the "spin-up" period and, because the effects of including these rates are minimal (at best) on data-informed model results, they were set to zero in the TCSAM02 model rather than trying to incorporate them into the GMACS model. The GMACS framework was, however, modified to incorporate several features of the bespoke model that have more impact. Most significantly, these were an alternative parameterization for a double normal selectivity curve used to describe male selectivity in the snow crab fishery and a likelihood component for fits to ogives describing the size-specific fraction of new shell mature male crab relative to all new shell males as determined on the basis of survey data. The new likelihood component applies specifically to the *Chionoecetes* stocks. In the GMACS snow crab model (Szuwalski and Adams 2025), annual survey-derived male maturity ogives have been used directly (i.e., assuming no uncertainty) to determine the annual fraction of immature males that underwent the terminal molt to maturity prior to the NMFS survey (and were thus observed as new shell mature males) whereas in the bespoke model the process of terminal molt is parameterized as a smoothly-varying function of crab size that has been informed statistically by including a likelihood component for the fit to the observed ogives. The addition of the selectivity function as an option in GMACS was relatively straightforward and quick while the addition of the maturity ogive likelihood was much more tedious that involved developing new ADMB code to read in the maturity ogives as a data source, predict annual male maturity ogives as seen by the NMFS survey, and compute a likelihood associated with the differences between the predicted and observed ogives. The version of GMACS used here is 2.20.36 (compiled 2026-04-13), which is available from the "devel_202603" branch of the GMACS_tpl-cpp_code GitHub repository.

Biological processes

Comparison of biological processes incorporated in the models include allometry (sex-specific weight-at-size, Figure 46), size at recruitment (Figure 47), sex/life stage-specific natural mortality rates (Figures 48 and 49), sex-specific mean growth (Figure 50) and growth transition matrices (Figures 51-54), and sex/size-specific probabilities of terminal molt (Figure 55). In general, differences between the two model frameworks were less than 10^{-5}%.

Fishery characteristics

Comparison of fishery characteristics between the model frameworks included sex- and size-specific retention and capture/selectivity functions (Figures 56-60) and fully-selected capture rates (Figure 61). The retention, capture/selectivity functions, and capture rates all differed by less than 10^{-6} between the the two model frameworks.

Survey characteristics

Comparison of survey characteristics between the model frameworks included sex- and size-specific selectivity functions for the NMFS survey and availability functions for the BSFRF survey (Figures 62 and 63) and fully-selected survey catchability (Figure 64). The selectivity and availability functions differed by less than 10^{-6} between the the two model frameworks, as did fully-selected catchabilty.

Predicted population quantities

Comparison of population quantities between the model frameworks included recruitment, cohort progression, aggregated sex- and stage-specific population abundance, sex- and stage-specific population size compositions, aggregated sex- and stage-specific population biomass, and size-specific male maturity ogives (Figures 65-82). All quantities differed by less than 10^{-4}% between the the two model frameworks.

Predicted fisheries quantities

Comparison of fishery-related quantities between the model frameworks included fishery-specific capture abundance and biomass, total fishing mortality, and retained catch mortality (Figures 83 and 88). All quantities differed by less than $3x10^{-4}$% between the the two model frameworks.

Predicted survey quantities

Comparison of survey-related quantities between the model frameworks included sex-specific survey biomass (Figures 89 and 90). All quantities differed by less than $1x10^{-4}\%$ between the the two model frameworks.

Likelihood components

growth and male maturity data

The likelihoods associated with growth (pre-molt, post-molt size data) and male terminal molt (male maturity ogives) data agreed between the two model frameworks to within 10^{-6} likelihood units (Figures 91 and 92).

fishery and survey time series data

Comparison of likelihood-related quantities for input data components between the model frameworks included summary likelihoods related to fishery catch biomass and abundance time series data (Figures 93-94) and to survey biomass time series data (Figure 95). Due to differences between the two frameworks in whether constant terms were included in the summary likelihoods, these were **not** directly comparable between the two models for fishery catch data and were not expected to agree (catch biomass: Figure 93; catch abundance: 94). In contrast, the constant terms were treated identically in the two frameworks when calculating summary likelihoods for the fits to survey biomass and thus these are directly comparable: these exhibited maximum differences on the order of 10^{-4} likelihood units (for male biomass from the NMFS survey).

To assess the fits to the fishery catch biomass and abundance time series data on a comparable basis, the individual likelihood values were recalculated from model output without the constant terms (Figures 96-98). The individual terms differed by less than $2x10^{-5}$ likelihood units between the the two model frameworks.

fishery and survey size composition data

Summary likelihoods related to fishery and survey size compositions (Figures 99 and 100) were also included in the comparisons, although these were **not** directly comparable because (again) different constant terms were included in the calculations in the two model frameworks. Graphical examination of the fits to the survey size composition data indicated that both the data and the predicted values agreed between the two frameworks (e.g., Figure 101; comparisons for other survey categories, as well as retained catch, exhibited similar agreement). In contrast, examination of the fits to the fishery total catch size composition data indicated that both the data and the predicted values were different between the two frameworks (Figures 102 and 103; comparisons for other fisheries exhibited similar disagreement). The source of these discrepancies appears to be due to differences between the two model frameworks in the way both the sex-specific observations and predictions are scaled when “extended” size compositions are formed (Figures 104 and 105). A path to resolving these discrepancies is currently being sought but has not yet been identified.

Management reference points

Comparison of management reference points included average recruitment, B_{100}, F_{MSY}, B_{MSY}, F_{OFL}, the OFL, and the biomass projected to the next year under the assumption that the OFL is taken (Figure 106). Of these quantities, the average recruitment, B_{MSY}, and the projected biomass differed less than 0.1%, while F_{MSY} and F_{OFL} differed less than 0.5%, but the OFLs differed by ~7.5%. The reason for this discrepancy in the OFLs is under investigation and likely involves differences in how fishing mortality rates and selectivity curves are applied for the non-directed fleets to calculate the OFL.

4.2.2 Model comparison at convergence

In contrast to GMACS model runs reported in the 2025 assessment which generated “not-a-number” errors and failed to converge when allowed to estimate parameters, the current model appears to successfully converge to a minimum likelihood solution–although that solution is known to be incorrect given the issues with fitting the fishery size composition data previously discussed. Consequently, converged model results are not discussed further.

4.3 Discussion

Substantial progress has been made since Sept. 2025 with regard to developing a GMACS alternative to the bespoke TCSAM02 model. The results presented here demonstrate the “exact equivalence” between the bespoke model and its GMACS counterpart for almost all model and management quantities when the GMACS version is initialized at equivalents to the final values of the bespoke model. Three issues remain: 1) the handling of “extended” size compositions needs to be aligned between the two frameworks; 2) although all other management quantities agree between the two frameworks to within fractions of a percentage point, the calculated OFLs differ by 7.4%; and 3) presumed differences in the priors and penalties used in the likelihoods of the two frameworks need to be resolved in order to achieve “exact equivalence” with a converged GMACS model. With regards to 1), the model framework codes are being examined to resolve the differences. With respect to 2), the two modeling frameworks take somewhat different approaches to determine Tier 3 management quantities and the differences need to be better elucidated. Finally, with regards to 3), the appropriate settings for priors and penalties in the GMACS framework to yield similar results to the bespoke model need to be identified and implemented.

5 Summary

In summary,

- the new male maturity workflow developed by Emily Ryznar (AFSC-SAP) is an improvement on the previous workflow and should be adopted for use in the 2026 and future assessments
- the experimental addition of hybrid survey and fishery data to the 2025 assessment model did not produce results or suggest management recommendations extremely different from the 2025 assessment itself, but this is *not* the same as providing a truly integrated Tanner-hybrid assessment. Such an assessment would necessarily include snow crab and would need to be able to accurately predict the reproductive dynamics of all three components (Tanner,

snow, and hybrids) at the stock/population level. Neither the model nor the information to construct such a model currently exists because hybrid abundance has typically been at such low levels with respect to the two species that addressing what are difficult research issues has not been a priority.

- substantial progress has been made with regard to developing a GMACS alternative to the bespoke TCSAM02 model. "Exact equivalence" has been adequately demonstrated between the bespoke model and its GMACS doppleganger for almost all model and management quantities when the GMACS version is initialized at its equivalents to the final values of the bespoke model. Three issues remain: 1) the handling of "extended" size compositions needs to be aligned between the two frameworks; 2) although all other management quantities agree between the two frameworks to within fractions of a percentage point, the calculated OFLs differ by 7.4%; and 3) presumed differences in the priors and penalties used in the likelihoods of the two frameworks need to be resolved in order to achieve "exact equivalence" with a converged GMACS model. With regards to 1), the codes are being examined to resolve the differences. With respect to 2), the two modeling frameworks take somewhat different approaches to determine Tier 3 management quantities and the differences need to be better understood by the author. Finally, with regards to 3), the appropriate settings for priors and penalties in the GMACS framework to yield similar results to the bespoke model need to be identified and implemented. I plan to continue to work on this over the summer and present a truly equivalent GMACS model as an "alternative" to the TCSAM02 model.
- the base 2026 assessment model will simply be an extension of the 2025 model updated with 2026 data, with an "exactly equivalent" GMACS model as an alternative.

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

6 Acknowledgments

The author would like to acknowledge Andre Punt (UW) for recent improvements to GMACS, as well as Emily Ryznar (AFSC-SAP) for developing the new male maturity workflow, Leah Zacher (AFSC-SAP) for providing hybrid Tanner/snow crab data from the NMFS EBS trawl survey, and Tyler Jackson (ADFG) for providing hybrid Tanner/snow crab data from the various crab fisheries. 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

List of Tables

Table 1. Design-based estimates for survey abundance trends (estimates, lower (5%) and upper (95%) arithmetic confidence intervals) for hybrids and Tanner crab ('bairdi') from the NMFS EBS shelf bottom trawl survey for males. Abundance units are millions of crab. Hybrids were not categorized before 1980; the survey was not conducted in 2020.

	hybrid			bairdi		
year	est	lower	upper	est	lower	upper
1975	–	–	–	535.4	359.6	711.1
1976	–	–	–	372.6	283.4	461.7
1977	–	–	–	380.3	248.0	512.5
1978	–	–	–	290.9	231.4	350.4
1979	–	–	–	196.8	128.6	264.9
1980	6.9	4.4	9.4	644.6	461.5	827.7
1981	2.0	1.3	2.8	266.1	201.1	331.2
1982	4.1	2.3	6.0	188.1	145.0	231.2
1983	0.8	0.5	1.2	177.3	126.2	228.4
1984	6.6	2.1	11.2	130.7	100.3	161.2
1985	0.3	0.1	0.5	55.4	45.3	65.6
1986	2.2	1.2	3.1	115.5	85.5	145.5
1987	14.0	9.1	18.9	255.0	190.9	319.1
1988	54.5	26.9	82.0	420.5	320.4	520.6
1989	10.2	5.0	15.5	532.9	410.9	654.8
1990	10.8	6.8	14.8	430.6	357.0	504.1
1991	32.3	21.4	43.2	434.5	341.5	527.5
1992	12.7	8.9	16.5	301.9	215.2	388.6

(continued)

			hybrid			bairdi
year	est	lower	upper	est	lower	upper
1993	2.5	1.6	3.4	173.7	141.1	206.2
1994	3.1	1.7	4.5	117.9	97.9	137.9
1995	0.9	0.4	1.4	86.4	68.9	103.9
1996	0.7	0.3	1.1	88.0	67.6	108.5
1997	0.7	0.4	1.0	71.4	51.9	90.9
1998	1.7	0.8	2.7	87.5	70.3	104.8
1999	1.6	1.0	2.1	141.0	96.1	185.9
2000	1.7	0.9	2.6	124.5	97.2	151.8
2001	7.6	5.2	10.0	265.8	191.6	340.0
2002	4.1	2.0	6.3	195.6	147.0	244.1
2003	3.2	1.8	4.7	235.6	177.5	293.6
2004	3.0	1.2	4.8	250.4	209.1	291.7
2005	1.5	0.4	2.6	345.7	274.4	417.1
2006	4.8	0.8	8.8	458.7	352.5	564.8
2007	15.4	3.8	27.0	422.5	314.5	530.6
2008	15.2	10.4	20.1	246.4	179.3	313.6
2009	14.1	9.0	19.1	177.6	141.3	213.8
2010	23.4	16.9	29.9	201.2	163.8	238.5
2011	43.2	28.6	57.9	365.4	281.7	449.2
2012	87.5	52.6	122.3	434.4	310.6	558.3
2013	52.2	38.3	66.2	385.9	287.3	484.5
2014	35.7	19.5	51.9	336.5	274.4	398.6
2015	16.4	11.7	21.0	198.9	172.1	225.8
2016	9.2	6.8	11.6	187.8	156.7	219.0
2017	11.8	8.8	14.9	172.7	143.1	202.3
2018	21.5	12.2	30.9	260.2	207.5	313.1
2019	8.5	6.2	10.7	201.3	158.2	244.4
2021	8.3	5.9	10.7	202.2	155.2	249.2
2022	7.0	4.8	9.2	195.3	143.0	247.5
2023	17.7	12.1	23.4	363.5	297.0	429.9
2024	62.4	33.0	91.7	630.8	507.3	754.2
2025	179.0	109.3	248.7	627.6	485.1	770.2

Table 2. Design-based estimates for survey abundance trends (estimates, lower (5%) and upper (95%) arithmetic confidence intervals) for hybrids and Tanner crab ('bairdi') from the NMFS EBS shelf bottom trawl survey for females. Abundance units are millions of crab. Hybrids were not categorized before 1980; the survey was not conducted in 2020.

	IMMATURE						MATURE					
	hybrid			bairdi			hybrid			bairdi		
year	est	lower	upper	est	lower	upper	est	lower	upper	est	lower	upper
1975	–	–	–	98.32	57.38	139.27	–	–	–	153.68	106.60	200.75
1976	–	–	–	136.68	61.85	211.51	–	–	–	152.71	103.28	202.14
1977	–	–	–	273.31	4.71	541.92	–	–	–	192.11	95.43	288.78
1978	–	–	–	152.02	83.76	220.29	–	–	–	136.81	85.51	188.11
1979	–	–	–	56.64	35.26	78.02	–	–	–	131.37	63.25	199.49
1980	2.66	0.65	4.67	170.30	106.69	233.91	15.33	−1.57	32.22	430.88	210.74	651.01
1981	0.26	0.00	0.52	25.03	15.06	34.99	6.76	−0.01	13.53	303.82	159.60	448.04
1982	1.10	−0.31	2.50	28.05	20.16	35.94	81.18	30.25	132.11	464.17	240.74	687.61
1983	0.27	0.08	0.45	107.36	59.25	155.46	4.44	0.96	7.91	128.21	86.82	169.60
1984	9.01	0.09	17.93	75.32	50.10	100.53	5.18	0.19	10.16	86.43	53.64	119.22
1985	0.06	−0.01	0.13	24.87	17.79	31.95	1.77	−0.30	3.85	29.34	17.02	41.67
1986	0.50	0.24	0.75	57.43	42.26	72.59	0.36	0.13	0.59	16.94	11.90	21.98
1987	10.31	5.40	15.21	194.37	120.73	268.00	1.06	0.50	1.61	26.35	19.98	32.72
1988	14.61	7.74	21.49	182.00	129.60	234.40	19.36	5.02	33.69	122.53	79.43	165.63
1989	1.03	0.40	1.66	279.08	175.64	382.53	2.31	0.77	3.84	101.06	75.95	126.17
1990	3.25	0.57	5.93	173.48	123.54	223.42	4.08	2.53	5.64	209.01	122.57	295.45
1991	3.53	1.54	5.52	121.63	77.06	166.20	8.26	5.37	11.15	255.09	159.12	351.05
1992	3.13	1.34	4.91	51.13	35.93	66.34	7.50	4.17	10.82	150.90	109.86	191.95
1993	0.92	0.22	1.62	27.77	19.12	36.41	0.74	0.18	1.29	67.47	51.00	83.95
1994	0.31	0.03	0.58	36.27	15.80	56.74	1.18	0.37	2.00	56.16	36.69	75.63
1995	0.17	0.00	0.34	24.55	17.12	31.97	2.08	−0.66	4.81	73.32	46.63	100.00
1996	0.28	−0.02	0.58	30.31	21.55	39.08	0.83	0.25	1.40	55.11	29.76	80.46
1997	0.06	−0.04	0.16	51.97	27.46	76.49	0.35	0.14	0.56	20.10	13.83	26.37
1998	1.59	−0.44	3.62	56.25	40.08	72.42	0.55	0.18	0.92	13.30	9.75	16.85
1999	1.03	0.44	1.63	91.65	65.33	117.97	0.21	0.08	0.35	22.68	15.35	30.01
2000	0.45	0.20	0.70	70.59	51.82	89.36	0.21	0.07	0.34	22.26	12.36	32.16
2001	2.12	1.21	3.02	214.83	143.92	285.73	2.11	0.84	3.38	28.17	18.16	38.17
2002	1.74	0.79	2.70	145.43	100.12	190.75	0.67	0.01	1.33	29.87	18.56	41.17
2003	1.74	0.93	2.56	127.09	79.78	174.39	0.51	0.21	0.82	60.49	37.96	83.03
2004	1.69	0.22	3.16	162.24	128.24	196.24	0.13	0.04	0.23	32.21	20.72	43.69
2005	2.63	−0.92	6.18	251.40	170.70	332.10	0.50	−0.05	1.06	76.75	51.27	102.24
2006	0.86	0.06	1.65	201.21	143.12	259.30	0.28	0.09	0.47	98.34	70.25	126.43
2007	1.56	0.48	2.64	108.17	74.53	141.81	1.16	0.54	1.78	82.00	59.59	104.40
2008	12.00	4.77	19.23	56.36	39.42	73.30	5.33	3.47	7.20	73.28	50.97	95.58
2009	2.90	1.47	4.32	84.53	54.82	114.25	4.07	2.05	6.09	51.32	34.87	67.78
2010	13.74	7.29	20.20	111.86	83.26	140.46	5.71	3.28	8.13	32.51	21.48	43.55
2011	23.75	12.04	35.47	232.62	167.86	297.38	21.26	11.95	30.57	32.48	25.27	39.69
2012	28.60	13.75	43.45	178.48	122.38	234.57	15.69	9.04	22.33	78.02	47.12	108.92
2013	5.63	3.69	7.57	115.84	86.69	144.99	12.35	8.44	16.25	108.77	70.34	147.21
2014	17.69	−6.30	41.67	88.14	52.71	123.57	14.69	6.95	22.43	88.36	47.88	128.84
2015	3.22	0.75	5.69	44.45	33.60	55.30	12.77	5.66	19.89	73.04	40.51	105.58
2016	0.86	0.40	1.31	38.87	24.11	53.63	12.41	5.61	19.21	50.29	27.03	73.56
2017	1.26	0.31	2.21	83.55	52.15	114.94	6.05	2.53	9.58	45.75	27.47	64.02
2018	22.20	9.43	34.97	191.17	138.03	244.32	5.77	1.04	10.50	33.79	22.64	44.95
2019	0.62	0.29	0.96	170.32	118.21	222.44	2.86	1.20	4.52	36.69	22.12	51.26
2021	2.94	2.19	3.69	103.10	62.64	143.57	1.08	0.45	1.71	54.26	39.22	69.31
2022	3.94	1.73	6.15	116.24	74.99	157.49	0.46	0.13	0.80	42.84	26.65	59.03
2023	17.71	9.36	26.06	318.03	247.02	389.05	0.80	0.20	1.41	48.50	30.19	66.81
2024	27.56	14.47	40.64	394.81	307.31	482.31	17.68	6.63	28.73	170.85	115.83	225.88
2025	95.43	44.12	146.74	314.01	189.56	438.46	113.09	64.61	161.57	189.83	139.30	240.36

Table 3. Design-based estimates for survey biomass trends (estimates, lower (5%) and upper (95%) arithmetic confidence intervals) for hybrids and Tanner crab ('bairdi') from the NMFS EBS shelf bottom trawl survey for males. Biomass units are thousands of t. Hybrids were not categorized before 1980; the survey was not conducted in 2020.

			hybrid			bairdi
year	est	lower	upper	est	lower	upper
1975	–	–	–	293.82	139.37	448.27
1976	–	–	–	157.02	121.36	192.68
1977	–	–	–	138.50	110.85	166.14
1978	–	–	–	98.30	79.22	117.39
1979	–	–	–	50.04	38.65	61.42
1980	3.43	2.05	4.80	152.48	113.56	191.40
1981	1.00	0.65	1.35	79.92	63.06	96.79
1982	1.15	0.71	1.58	65.85	50.39	81.31
1983	0.21	0.12	0.29	37.98	28.75	47.22
1984	0.92	0.54	1.29	30.50	24.10	36.91
1985	0.22	0.07	0.36	14.90	11.60	18.20
1986	0.41	0.23	0.59	21.59	13.76	29.43
1987	2.14	1.46	2.81	45.50	35.23	55.77
1988	11.52	6.57	16.47	99.21	65.25	133.16
1989	2.57	1.29	3.86	132.80	106.31	159.29
1990	3.96	2.73	5.18	132.42	104.90	159.93
1991	11.01	7.34	14.68	145.79	104.65	186.93
1992	4.90	3.34	6.46	127.58	79.30	175.86
1993	0.75	0.40	1.11	73.27	56.10	90.43
1994	1.69	0.91	2.48	48.33	38.88	57.79
1995	0.32	0.09	0.56	34.98	25.49	44.46
1996	0.28	0.11	0.45	30.76	20.08	41.44
1997	0.24	0.14	0.34	14.63	12.00	17.27
1998	0.24	0.13	0.36	15.00	12.57	17.44
1999	0.21	0.11	0.30	21.53	12.48	30.57
2000	0.21	0.11	0.31	23.33	15.77	30.88
2001	0.93	0.62	1.24	29.25	22.98	35.51
2002	0.54	0.35	0.73	27.41	21.57	33.24
2003	0.45	0.31	0.60	37.80	29.91	45.69
2004	0.40	0.19	0.61	38.87	30.06	47.68
2005	0.18	0.09	0.27	63.74	51.54	75.95
2006	0.94	0.23	1.65	101.53	76.16	126.90
2007	4.82	0.85	8.79	104.18	73.12	135.25
2008	4.14	2.69	5.59	84.90	50.08	119.72
2009	5.29	3.82	6.75	47.41	36.72	58.09
2010	5.48	4.30	6.65	49.00	35.59	62.40
2011	7.78	5.95	9.61	62.66	45.15	80.18
2012	17.57	11.27	23.86	80.11	57.67	102.55
2013	12.41	9.20	15.61	103.37	67.56	139.18
2014	13.36	8.48	18.25	108.91	91.16	126.65
2015	6.23	4.61	7.84	74.23	63.20	85.26
2016	4.11	2.81	5.41	69.62	58.85	80.40
2017	4.61	3.45	5.76	54.20	44.47	63.93
2018	2.64	1.74	3.54	47.08	39.70	54.47
2019	3.23	2.29	4.18	28.67	23.22	34.12
2021	1.16	0.71	1.60	31.56	25.88	37.25
2022	1.06	0.77	1.35	29.63	24.23	35.03
2023	2.07	1.45	2.69	34.52	29.87	39.16
2024	10.16	5.34	14.99	83.41	66.76	100.07
2025	45.80	25.55	66.04	110.91	84.82	137.01

Table 4. Design-based estimates for survey biomass trends (estimates, lower (5%) and upper (95%) arithmetic confidence intervals) for hybrids and Tanner crab ('bairdi') from the NMFS EBS shelf bottom trawl survey for females. Biomass units are thousands of t. Hybrids were not categorized before 1980; the survey was not conducted in 2020.

						IMMATURE						MATURE
			hybrid			bairdi			hybrid			bairdi
year	est	lower	upper	est	lower	upper	est	lower	upper	est	lower	upper
1975	–	–	–	9.55	5.77	13.33	–	–	–	31.42	21.30	41.54
1976	–	–	–	6.37	3.72	9.02	–	–	–	31.16	21.26	41.05
1977	–	–	–	14.47	0.28	28.66	–	–	–	38.57	18.97	58.18
1978	–	–	–	6.81	4.10	9.53	–	–	–	25.76	16.14	35.37
1979	–	–	–	3.83	2.42	5.23	–	–	–	19.32	9.84	28.80
1980	0.18	0.06	0.31	13.51	8.43	18.59	1.91	−0.23	4.05	63.78	34.86	92.71
1981	0.02	0.00	0.05	1.52	1.00	2.05	0.64	0.04	1.25	42.58	24.94	60.22
1982	0.04	0.00	0.09	1.71	0.95	2.48	8.92	3.25	14.58	64.14	36.91	91.38
1983	0.01	0.00	0.02	2.27	1.38	3.16	0.53	0.12	0.93	20.43	14.29	26.57
1984	0.32	−0.03	0.66	2.23	1.45	3.01	0.65	0.05	1.25	14.91	9.41	20.42
1985	0.00	0.00	0.00	0.99	0.70	1.29	0.22	−0.03	0.48	5.55	3.15	7.96
1986	0.03	0.02	0.05	2.69	1.94	3.45	0.04	0.02	0.07	3.37	2.27	4.46
1987	0.79	0.41	1.17	14.99	7.81	22.18	0.14	0.07	0.22	5.14	3.75	6.53
1988	0.87	0.48	1.26	10.17	7.27	13.07	3.07	0.69	5.46	25.37	15.64	35.09
1989	0.05	0.02	0.09	11.81	8.12	15.50	0.38	0.11	0.65	19.40	14.57	24.23
1990	0.30	0.01	0.59	9.86	6.83	12.88	0.66	0.41	0.91	37.69	21.15	54.24
1991	0.26	0.11	0.40	7.01	5.04	8.98	1.16	0.75	1.58	44.76	28.62	60.91
1992	0.17	0.07	0.26	1.98	1.43	2.53	1.09	0.60	1.58	26.23	19.16	33.29
1993	0.03	0.01	0.05	1.06	0.74	1.39	0.11	0.03	0.19	11.64	8.88	14.41
1994	0.01	0.00	0.01	1.20	0.56	1.84	0.18	0.05	0.30	9.85	6.51	13.18
1995	0.01	0.00	0.02	1.05	0.78	1.32	0.32	−0.10	0.74	12.40	7.94	16.86
1996	0.02	0.00	0.04	1.43	0.94	1.92	0.12	0.04	0.21	9.58	5.17	13.99
1997	0.01	0.00	0.02	1.39	0.78	2.00	0.05	0.02	0.08	3.40	2.36	4.43
1998	0.07	−0.02	0.15	1.96	1.34	2.57	0.07	0.02	0.12	2.28	1.69	2.87
1999	0.02	0.01	0.04	2.85	1.94	3.76	0.04	0.01	0.06	3.83	2.47	5.18
2000	0.02	0.01	0.03	2.47	1.85	3.09	0.03	0.01	0.05	4.13	2.21	6.05
2001	0.09	0.05	0.12	6.27	4.14	8.39	0.31	0.12	0.49	4.56	2.87	6.25
2002	0.07	0.03	0.11	5.49	4.02	6.97	0.09	0.01	0.16	4.47	2.99	5.95
2003	0.07	0.04	0.10	4.66	2.82	6.50	0.08	0.03	0.13	8.40	5.76	11.05
2004	0.05	0.01	0.09	4.08	3.09	5.06	0.02	0.01	0.04	4.73	3.38	6.08
2005	0.16	−0.07	0.40	10.37	7.02	13.72	0.05	0.00	0.11	11.58	8.01	15.15
2006	0.08	0.00	0.15	13.24	8.34	18.13	0.04	0.01	0.07	14.94	10.70	19.18
2007	0.09	0.01	0.17	5.58	3.48	7.68	0.16	0.08	0.24	13.44	9.29	17.59
2008	0.49	0.27	0.72	2.84	1.87	3.81	0.69	0.46	0.91	11.66	8.17	15.15
2009	0.09	0.05	0.13	2.54	1.40	3.67	0.55	0.30	0.80	8.48	5.60	11.35
2010	0.64	0.32	0.96	3.77	2.76	4.79	0.57	0.37	0.76	5.47	3.50	7.45
2011	1.19	0.61	1.76	10.34	7.10	13.58	1.54	0.90	2.18	5.41	4.13	6.70
2012	1.92	0.94	2.89	11.65	7.05	16.25	1.60	1.07	2.13	12.36	7.80	16.91
2013	0.29	0.20	0.39	6.37	4.48	8.27	1.56	1.06	2.07	17.85	11.54	24.15
2014	0.35	0.00	0.70	2.45	1.62	3.29	1.60	0.97	2.22	14.86	7.87	21.86
2015	0.10	0.03	0.16	1.65	1.18	2.11	1.30	0.63	1.96	11.21	6.60	15.83
2016	0.03	0.01	0.04	1.12	0.72	1.51	1.38	0.59	2.17	7.63	4.42	10.84
2017	0.06	0.01	0.11	1.38	0.96	1.80	0.60	0.33	0.86	7.11	4.42	9.81
2018	0.65	0.27	1.02	5.02	3.60	6.43	0.39	0.08	0.70	4.97	3.31	6.62
2019	0.02	0.01	0.03	4.92	3.59	6.24	0.29	0.12	0.47	4.85	3.11	6.58
2021	0.10	0.07	0.13	3.34	2.61	4.08	0.13	0.05	0.21	8.55	6.42	10.69
2022	0.10	0.05	0.15	2.69	1.80	3.59	0.07	0.02	0.11	6.67	4.44	8.90
2023	0.68	0.31	1.04	9.26	6.75	11.78	0.12	0.02	0.21	7.33	4.61	10.04
2024	1.90	0.93	2.87	19.12	13.83	24.40	2.35	0.81	3.90	24.64	16.88	32.40
2025	6.16	2.59	9.72	11.70	8.12	15.28	11.03	6.63	15.43	28.50	20.44	36.56

Table 5. Fishery stocks with hybrid *Chionoecetes* spp. catch data. “num. years”: number of years of observer data; extent: time extent of data collection.

stock id	stock group	num. years	extent	stock name
BBRKC	BBRKC	25	1990-2024	Bristol Bay red king crab
BSSC	snow crab	33	1990-2024	snow crab
EBT	Tanner crab	16	1991-2024	Eastern Tanner crab
WBT	Tanner crab	19	1991-2024	Western Tanner crab
PIGKC	GKC	5	2000-2018	Pribilof Islands golden king crab
PIRKC	Other RKC	2	1993-1995	Pribilof Islands red king crab
SMBKC_PIBKC	BKC	4	1996-2012	Combined St. Matthew Island/Pribilof Islands blue king crab

Table 6. At-sea observer counts of hybrid *Chionoecetes* spp. by year, target group, and sex for total catch.

		BBRKC		BKC		GKC		Other RKC		snow crab		Tanner crab
year	female	male	female	male	female	male	female	male	female	male	female	male
1990	–	1	–	–	–	–	–	–	259	19,191	–	–
1991	–	11	–	–	–	–	–	–	161	7,928	42	1,430
1992	–	3	–	–	–	–	–	–	57	11,396	55	1,677
1993	1	10	–	–	–	–	1	130	113	3,329	54	626
1994	–	–	–	–	–	–	–	–	115	1,767	13	93
1995	–	–	–	–	–	–	–	23	157	12,073	28	218
1996	–	1	2	1,197	–	–	–	–	218	22,622	2	209
1997	–	9	–	–	–	–	–	–	961	158,499	–	–
1998	–	12	–	53	–	–	–	–	220	72,185	–	–
1999	–	19	–	–	–	–	–	–	15	8,522	–	–
2000	1	221	–	–	1	2	–	–	27	10,960	–	–
2001	2	32	–	–	–	2	–	–	253	38,686	–	–
2002	–	34	–	–	1	2	–	–	9	5,277	–	–
2003	–	20	–	–	–	2	–	–	95	5,703	–	–
2004	–	27	–	–	–	–	–	–	5	3,568	–	–
2005	–	49	–	–	–	–	–	–	13	3,564	2	157
2006	2	35	–	–	–	–	–	–	10	1,274	5	184
2007	–	7	–	–	–	–	–	–	–	1,003	–	182
2008	1	2	–	–	–	–	–	–	–	3,427	–	26
2009	–	9	1	4	–	–	–	–	3	1,644	–	1
2010	–	–	–	–	–	–	–	–	6	2,421	–	–
2011	–	1	–	–	–	–	–	–	41	1,702	–	–
2012	–	2	–	1	–	–	–	–	6	2,903	–	–
2013	–	–	–	–	–	–	–	–	46	1,727	–	18
2014	–	–	–	–	–	–	–	–	151	3,773	22	185
2015	–	–	–	–	–	–	–	–	28	1,542	–	419
2016	–	–	–	–	–	–	–	–	39	2,839	–	–
2017	–	–	–	–	–	–	–	–	–	1,036	1	286
2018	–	–	–	–	–	–	–	–	9	–	105	–
2019	–	–	–	–	–	–	–	–	232	–	–	–
2020	–	–	–	–	–	–	–	–	–	–	10	–
2021	–	–	–	–	–	–	–	–	–	–	24	–
2022	–	–	–	–	–	–	–	–	–	–	3	–
2023	–	–	–	–	–	–	–	–	–	–	11	2
2024	–	1	–	–	–	–	–	–	3	71	76	1,848

Table 7. Numbers of crab sampled for retained catch size compositions of hybrid *Chionoecetes* spp. by year and target group.

year	snow crab	Tanner crab
1991	2,649	–
1992	–	826
1993	7,415	82
1994	934	25
1995	8,451	–
1996	4,322	–
1997	35,606	–
1998	37,605	–
1999	1,979	–
2000	4,546	–
2001	11,332	–
2002	996	–
2003	923	–
2004	309	–
2005	1,752	31
2006	409	1
2007	930	–
2008	406	–
2009	219	–
2010	321	–
2011	202	–
2012	602	–
2013	243	16
2014	1,103	118
2015	786	415
2016	782	–
2017	1,369	43
2018	471	105
2019	838	–
2020	198	184
2021	28	57
2022	–	26
2023	–	19
2024	61	59

Figures

List of Figures

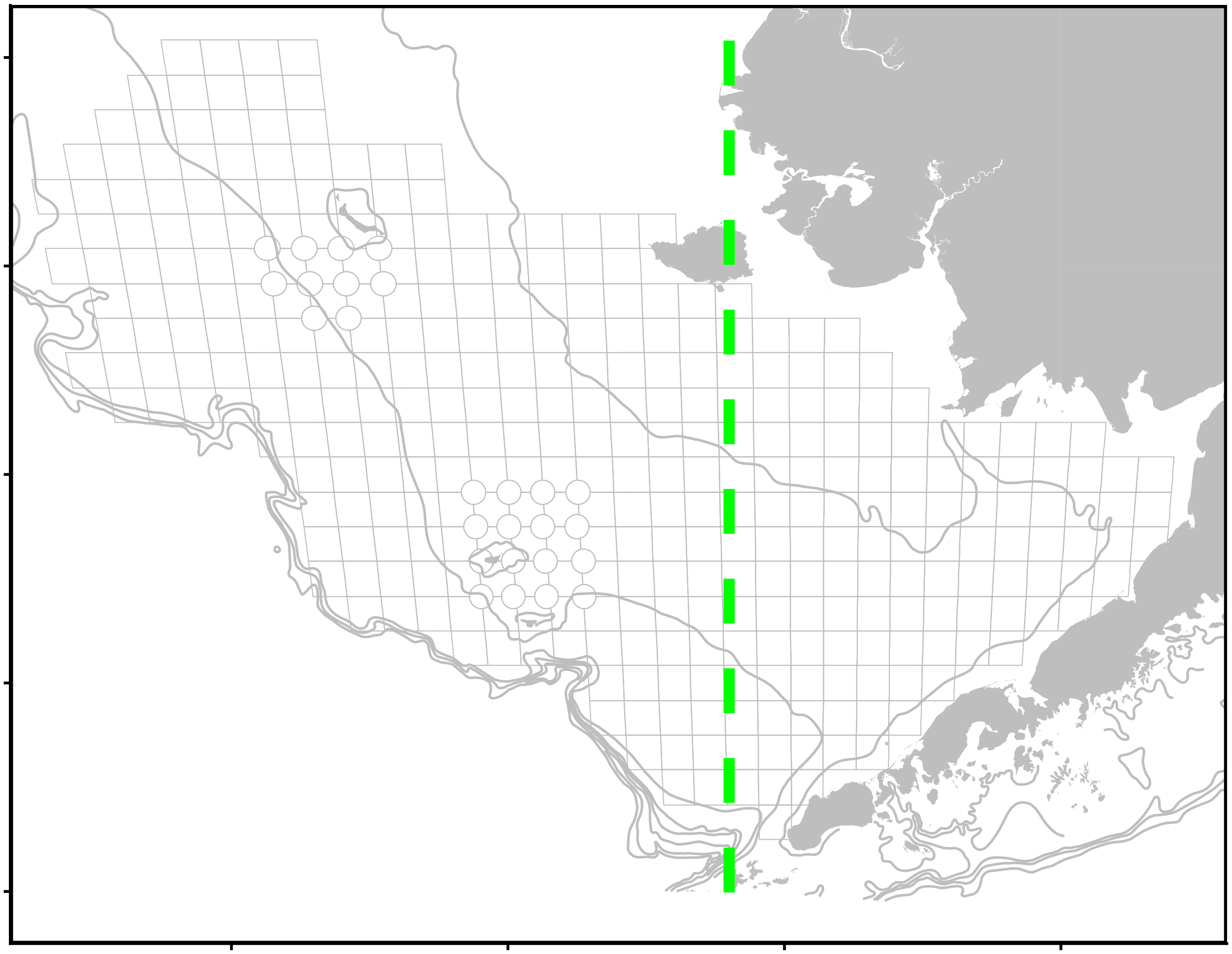


Figure 1. NMFS EBS shelf station grid (squares and circles). Hauls at the 26 so-called "corner" stations (circles) near the Pribilof Islands and St. Matthew Island were discontinued in 2024.

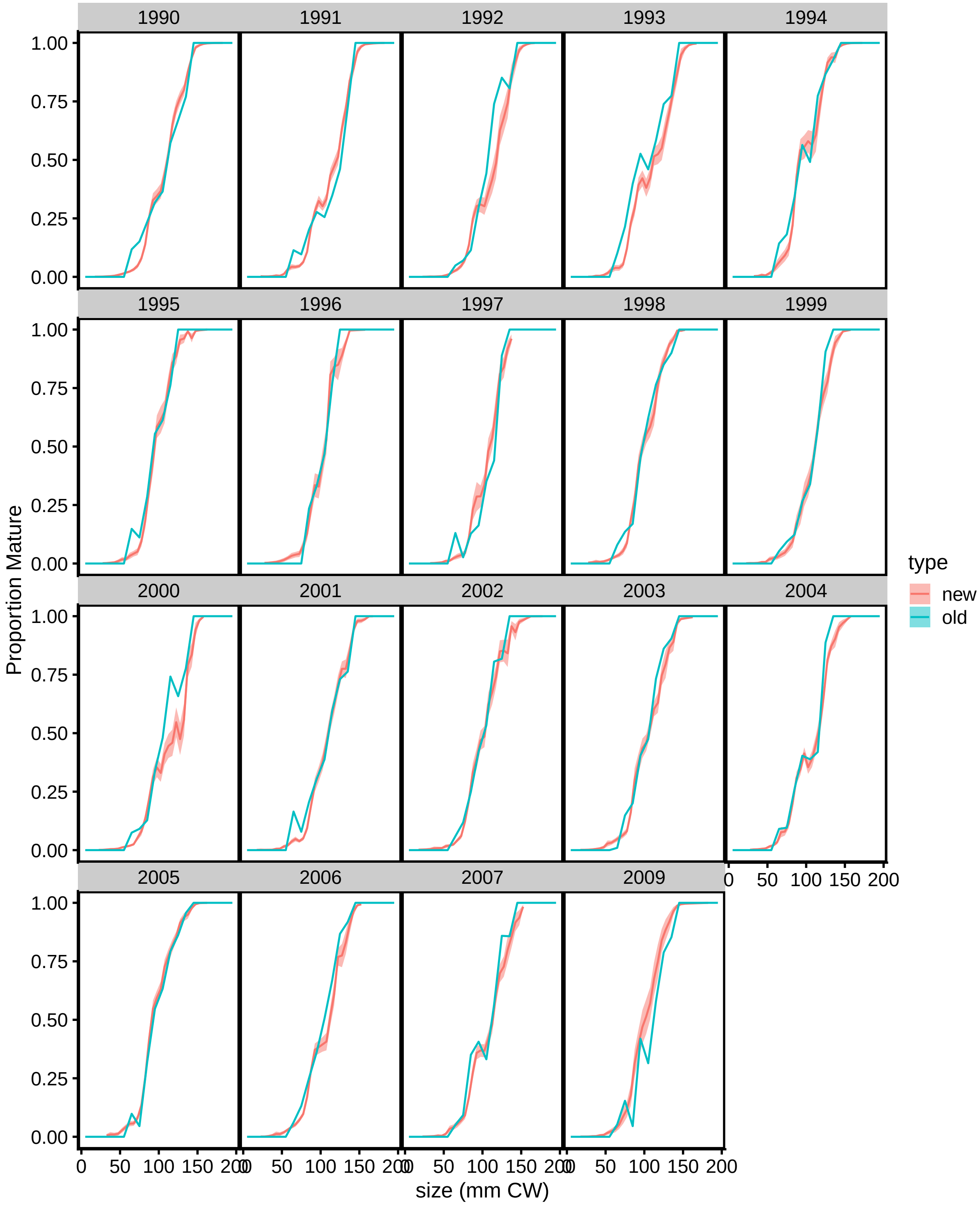


Figure 2. Comparison of mature male ogives from the new and old workflows from NMFS EBS survey data collections from 1990-2007 and 2009. Tanner crab chela heights and carapace widths were measured to 1 mm during this time period.

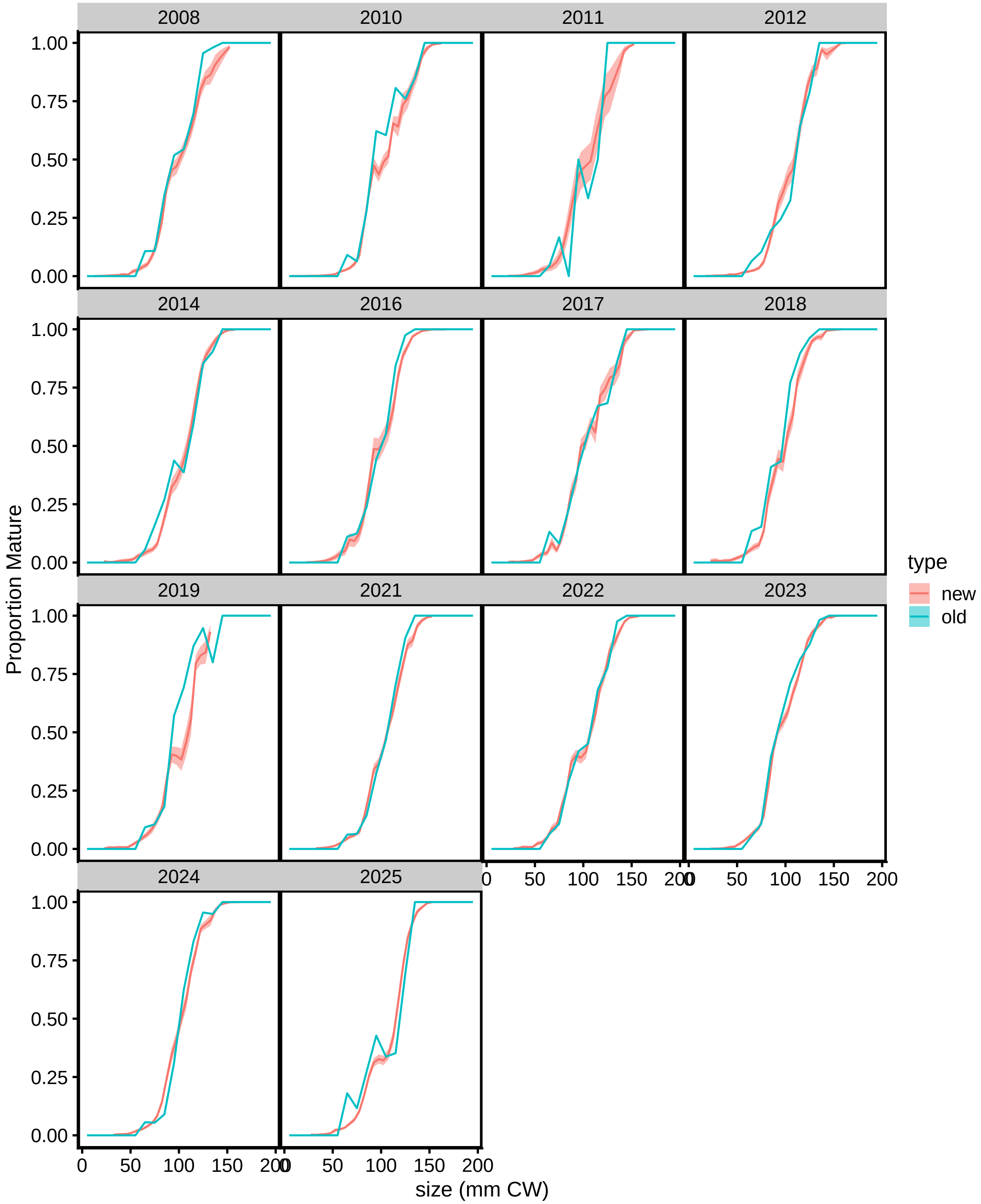


Figure 3. Comparison of mature male ogives from the new and old workflows from NMFS EBS survey data collections for 2008 and 2010-2025. Tanner crab chela heights were measured to 0.1 mm starting in 2008 (but not in 2009).

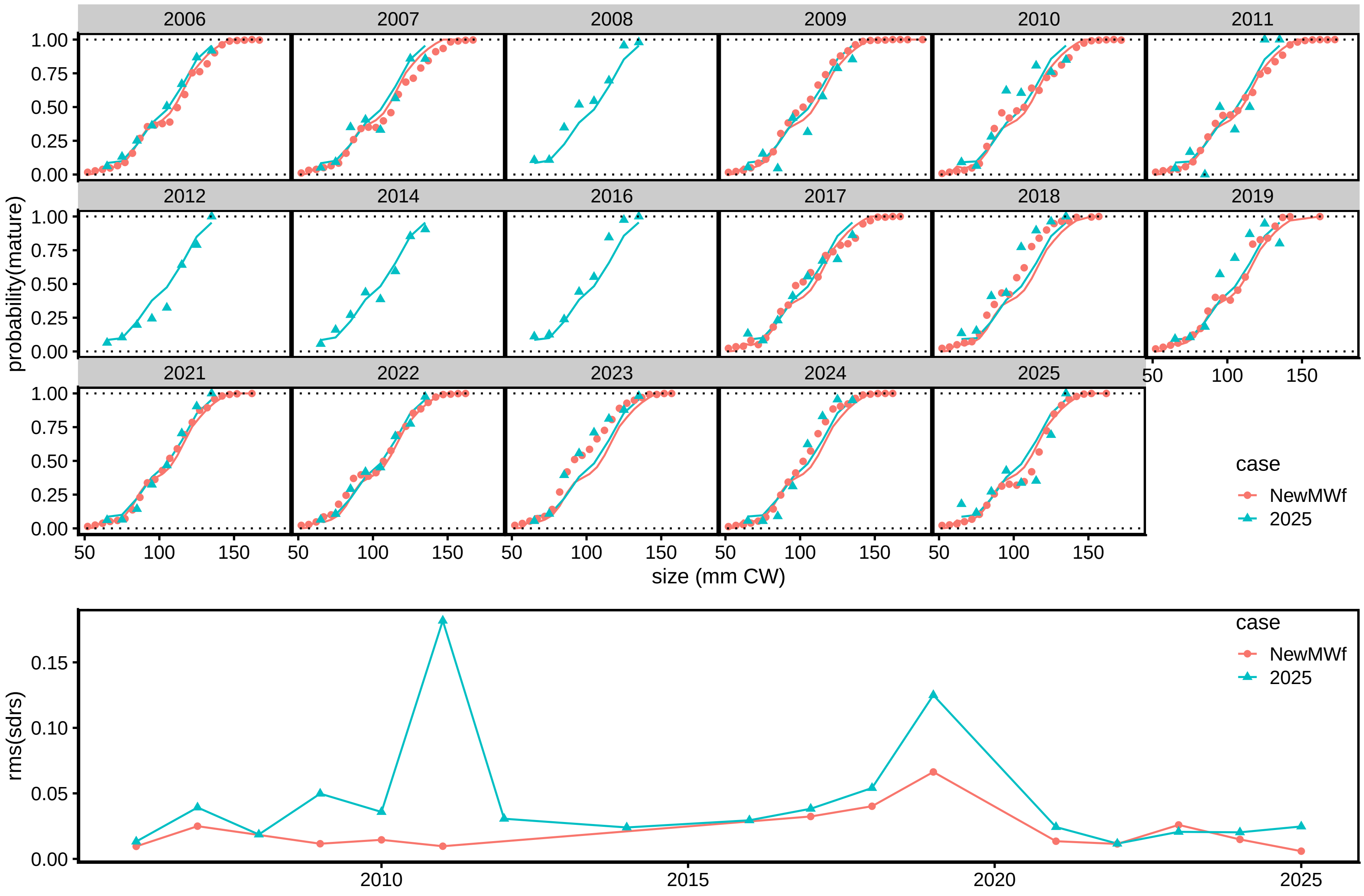


Figure 4. Comparison of fits to male maturity ogive "data" from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF") by year. Upper figure: "observed" data (shapes) from the workflows and assessment model-predicted values (lines).Lower figure: root mean square of standardized residuals by year.

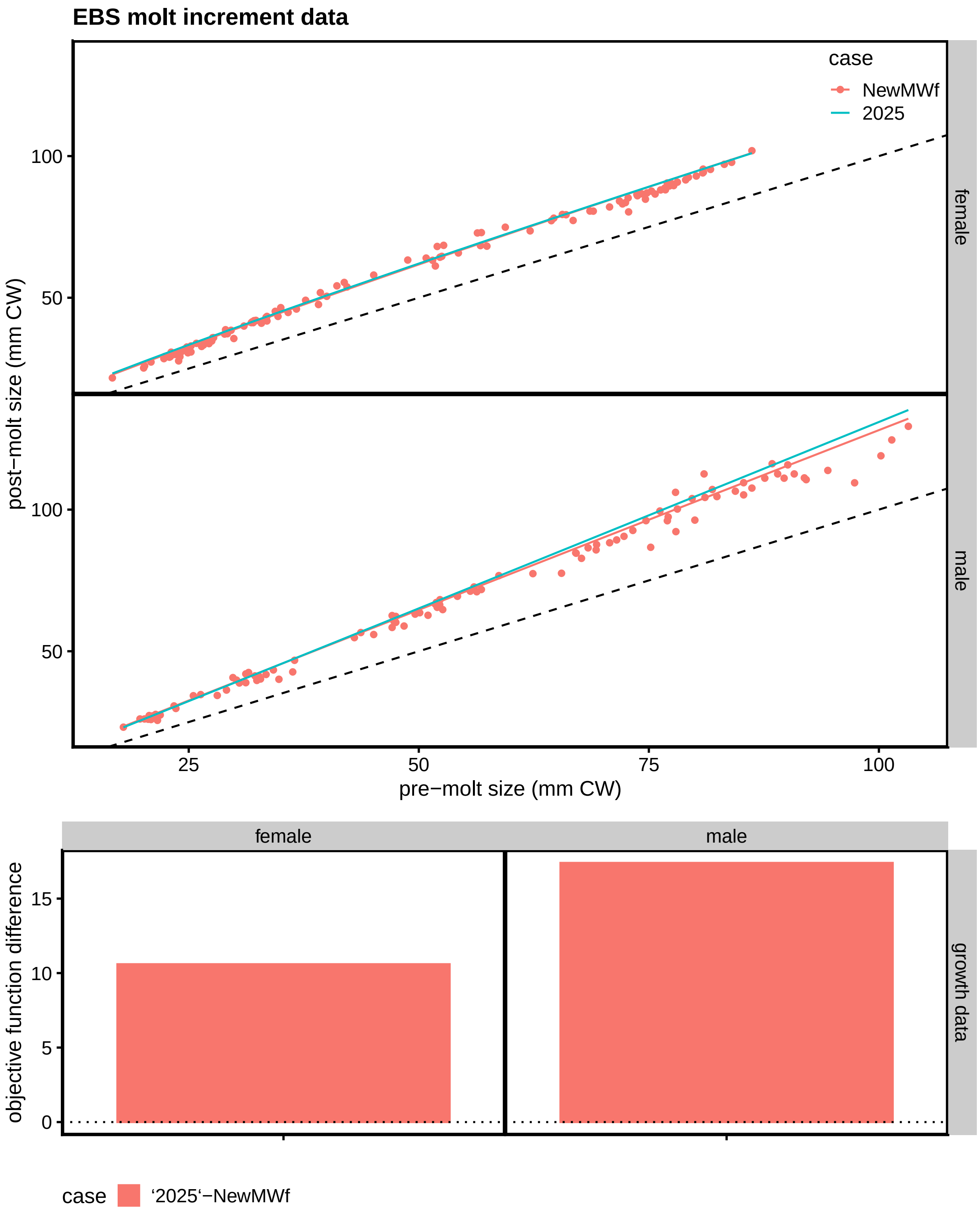


Figure 5. Comparison of fits to growth data from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper figure: post-molt size data (shapes) and mean predicted values (colours) given pre-molt sizeLower figure: difference (2025 - NewMWf) in aggregated objective function values (larger values indicate better fits in the model fitting the new workflow results.

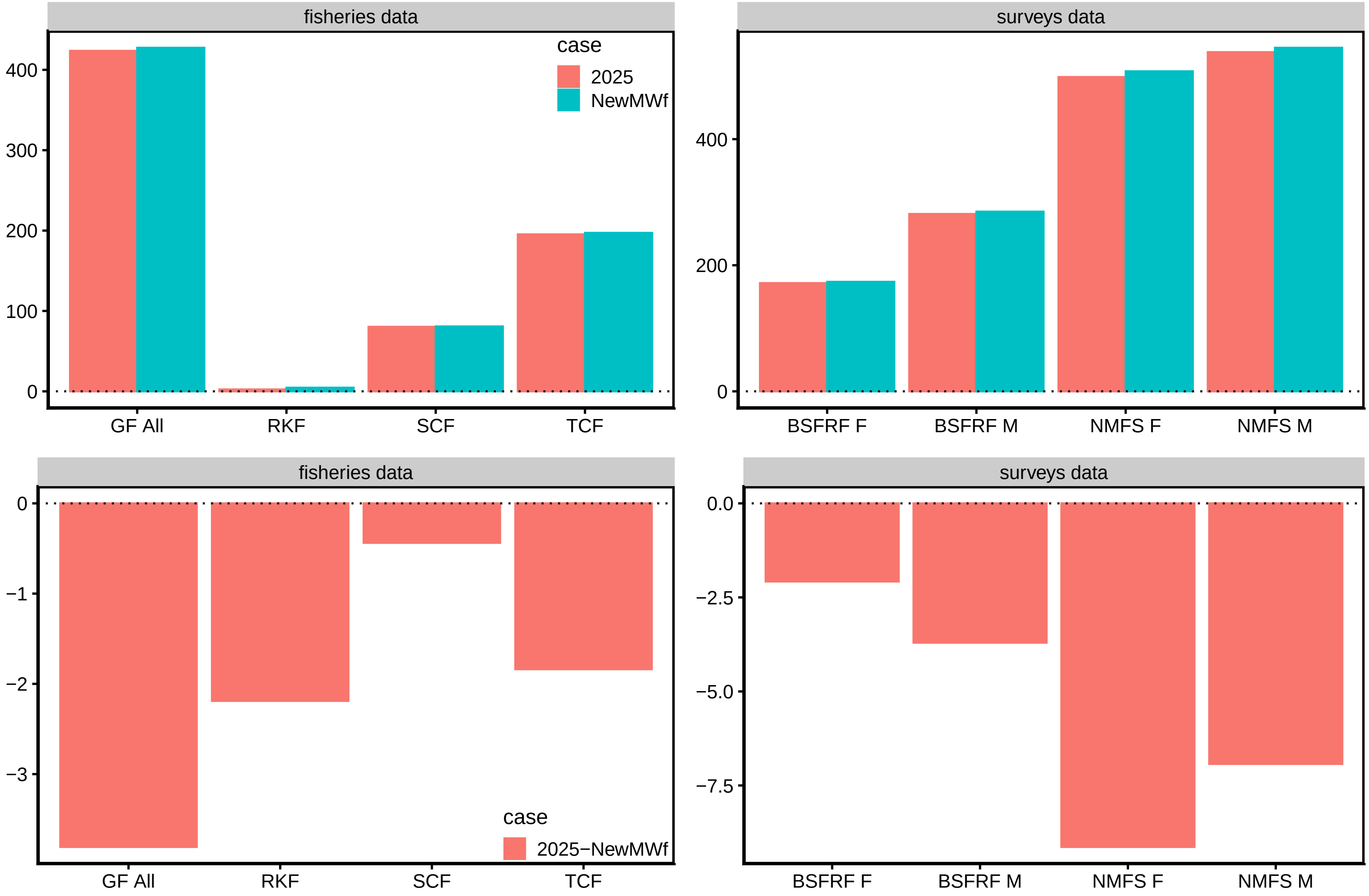


Figure 6. Comparison of summary objective function values by data category and fleet from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper plot: values (smaller values indicate a better fit); Lower plot: difference relative to 2025 (positive values indicate a better fit). Values for maturity ogive and male survey data are not shown because these are not directly comparable using NLLs between the two datasets.

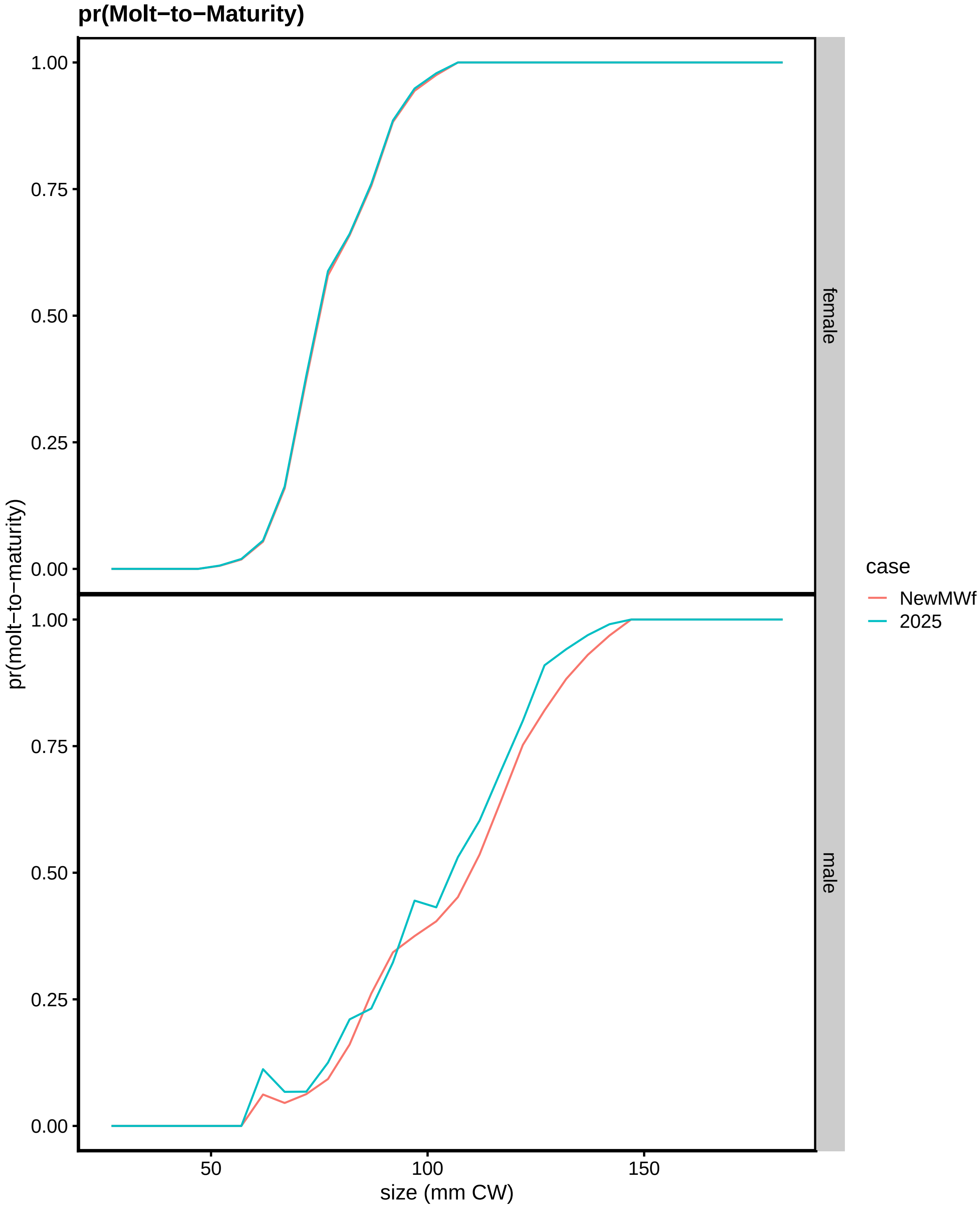


Figure 7. Comparison of the estimated probability of the molt to maturity (terminal molt) from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper plot: females. Lower plot: males.

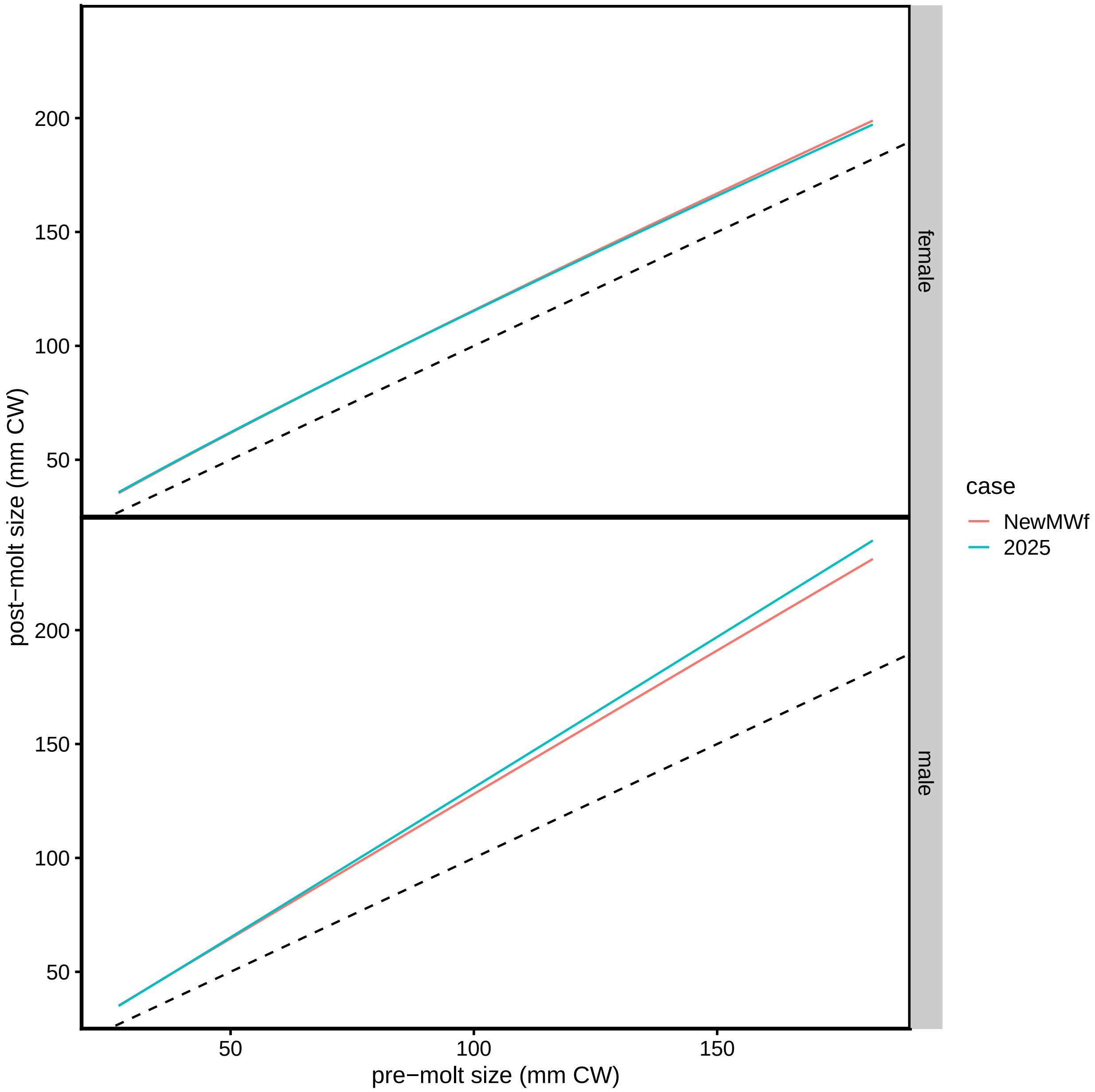


Figure 8. Comparison of mean growth (post-molt size) from the 2025 assessment model (“2025”) and the model with maturity ogives from the new maturity workflow (“NewMWF”). Upper plot: females. Lower plot: males.

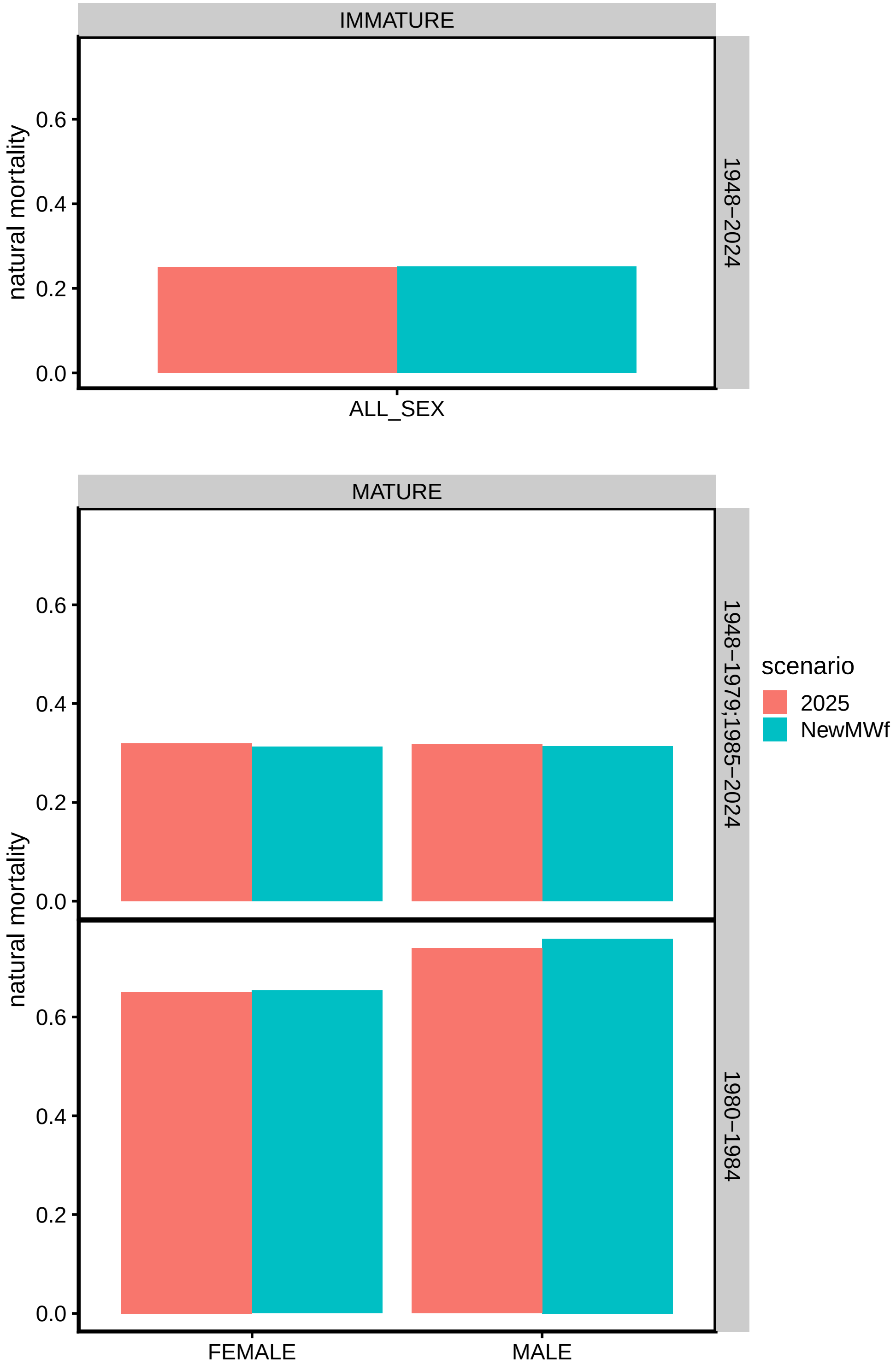


Figure 9. Comparison of natural mortality from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper plot: females. Lower plot: males.

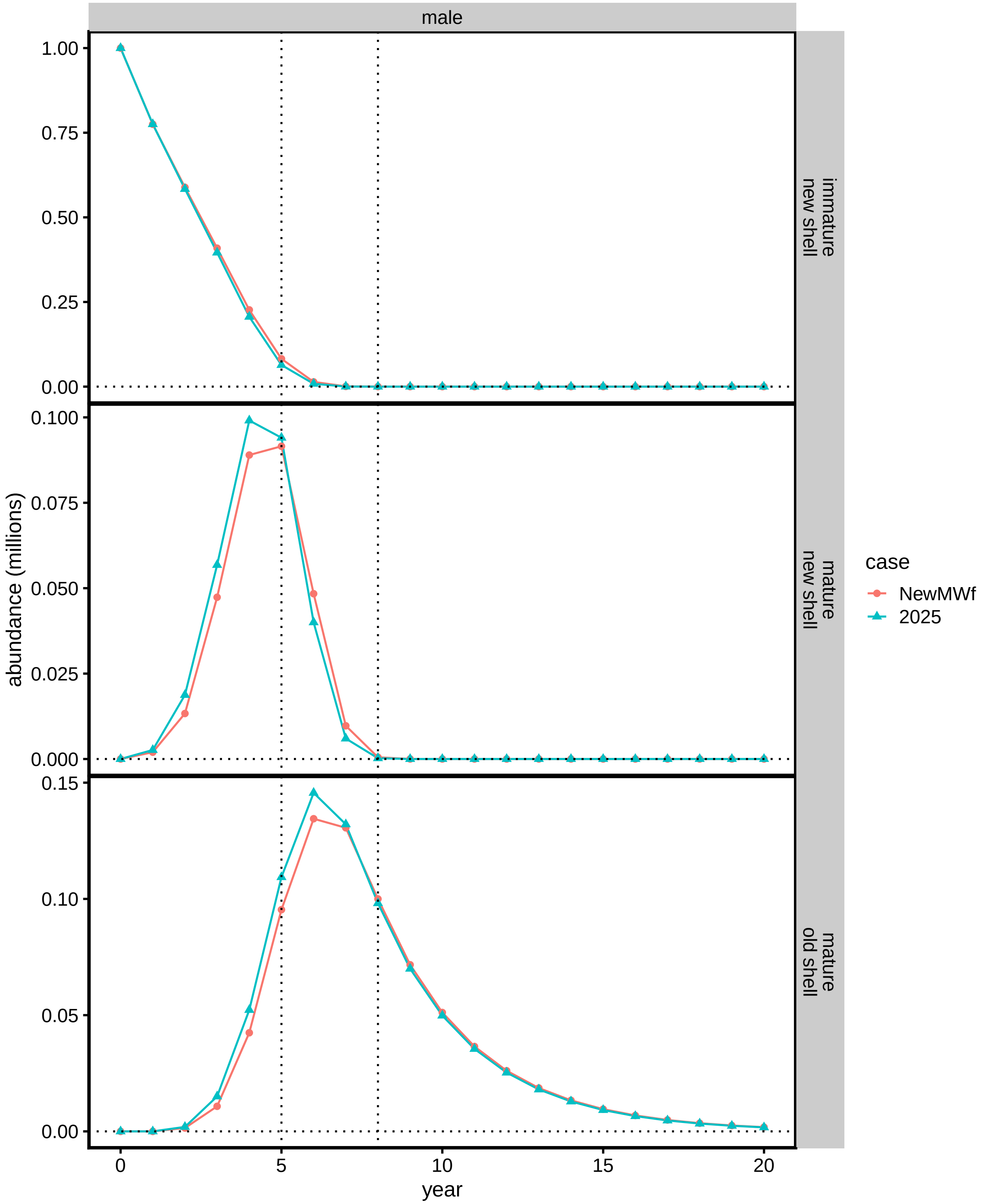


Figure 10. Comparison of the relative temporal progression in abundance of a cohort of male Tanner crab by biological category from the “2025 assessment model (”2025”) and the model with maturity ogives from the new maturity workflow (“NewMWF”).

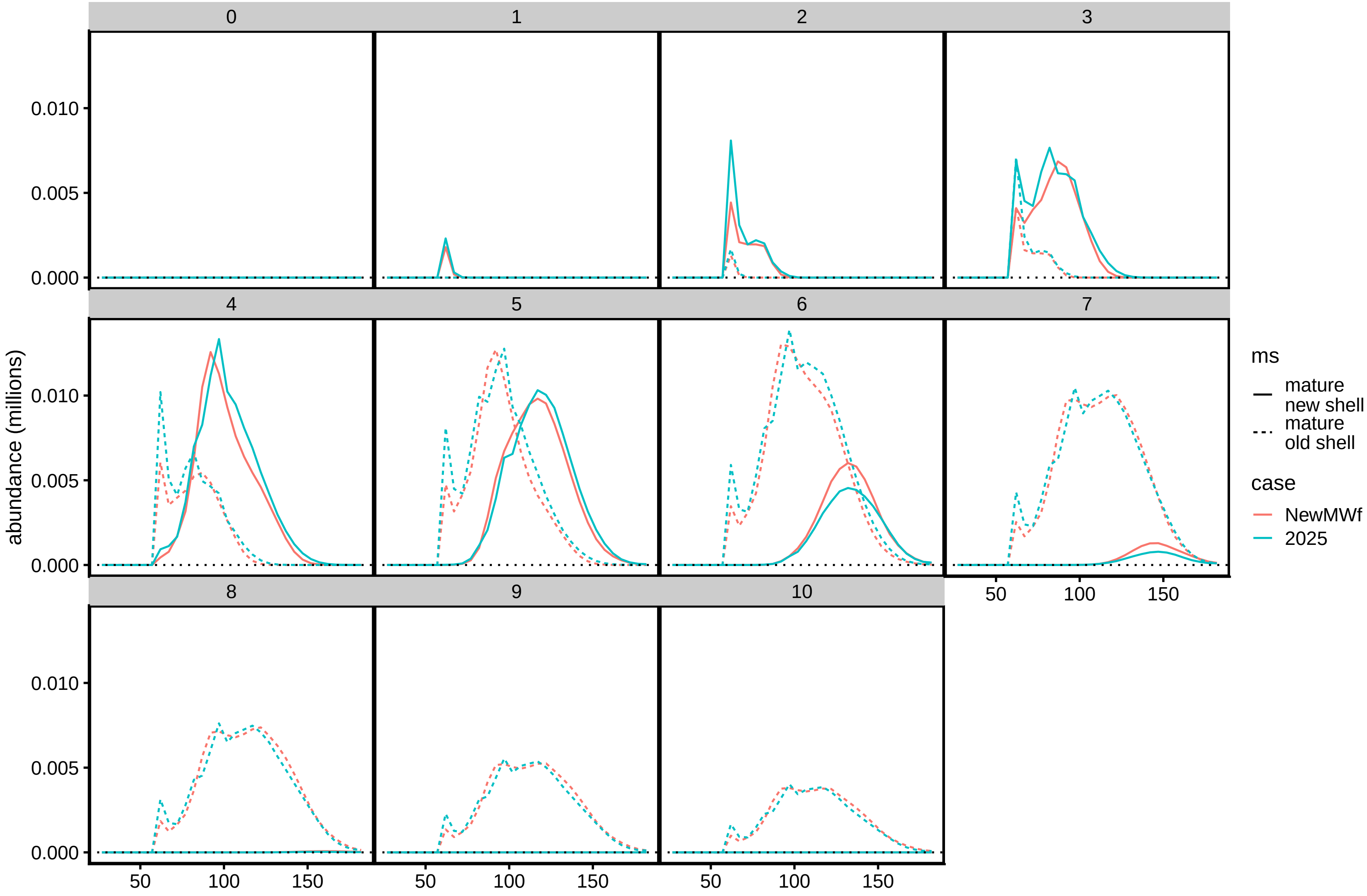


Figure 11. Comparison of the relative temporal progression in abundance-at-size of a cohort of male Tanner crab from the "2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Progression of abundance-at-size is shown for mature new shell and old shell males, not immature males.

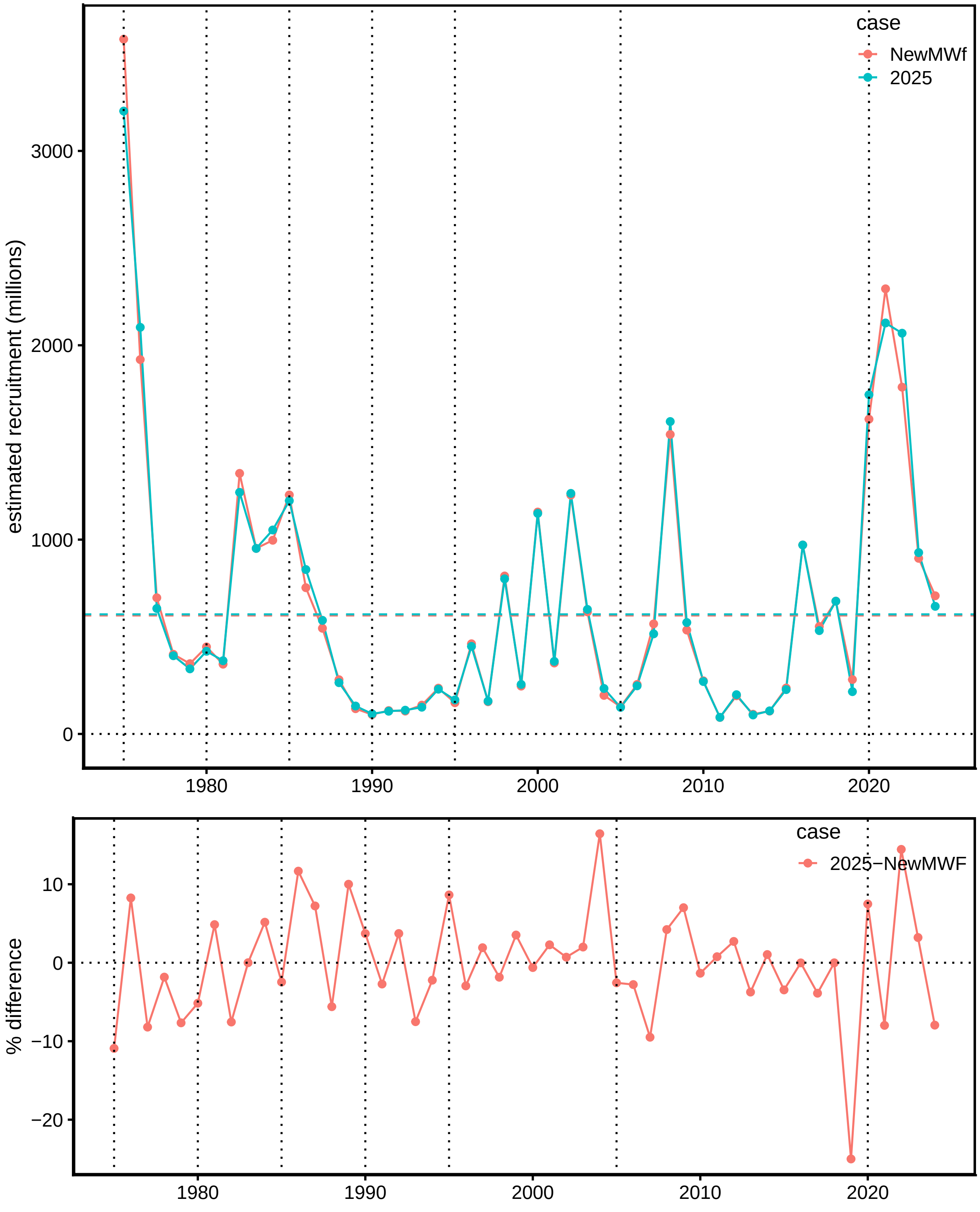


Figure 12. Starting in 1975, comparison of the estimated recruitment time series from the 2025 assessment model (“2025”) and the model with maturity ogives from the new maturity workflow (“NewMWF”). Upper: full time series; middle: time series since 1995.Vertical lines: 1975, 1995, 2005, 2020. Horizontal lines: 0 (dotted) and 1982-2024 avergage recruitment by case (dashed).

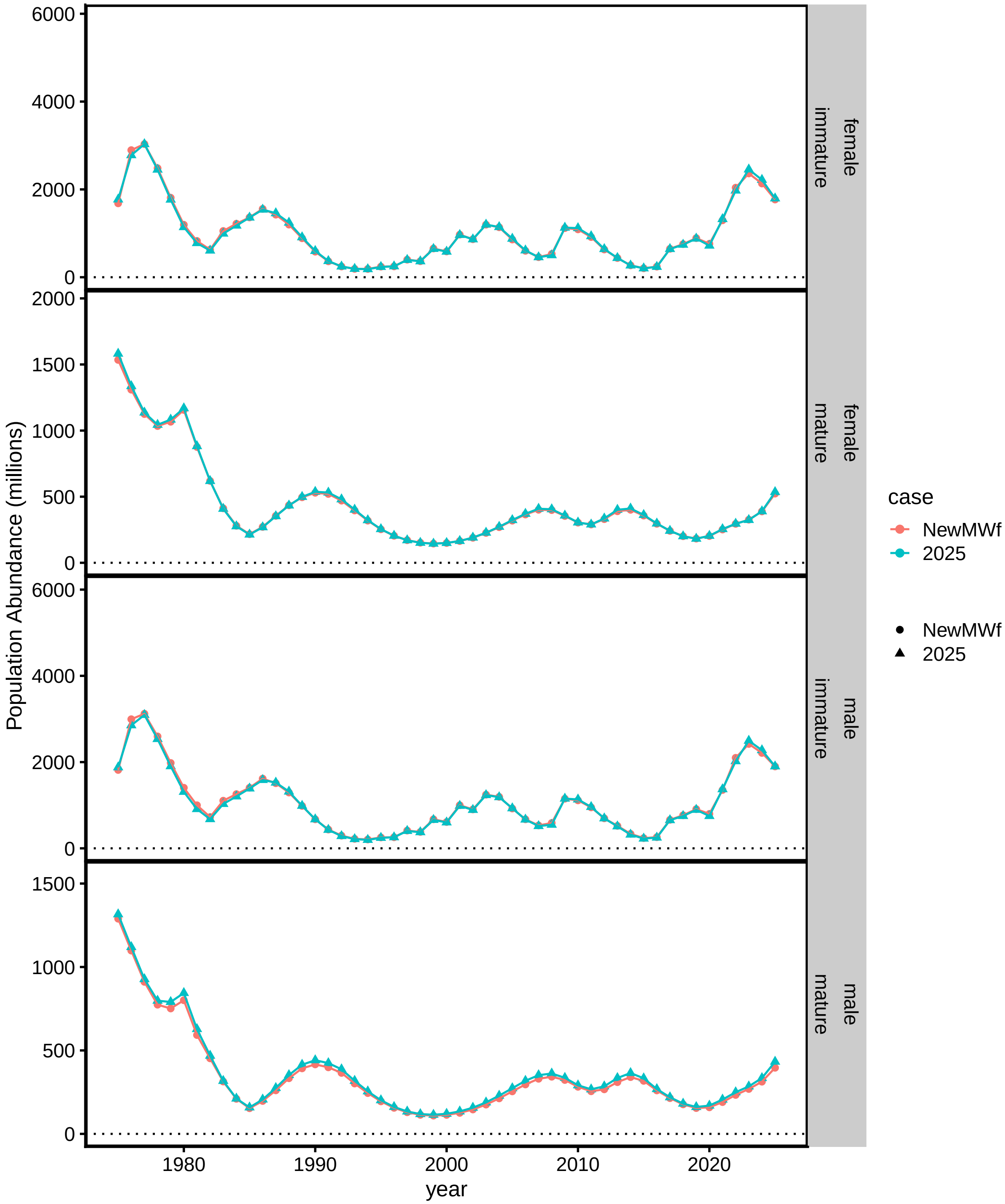


Figure 13. Starting in 1975, comparison of the estimated time series of population abundance by sex and maturity state from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF").

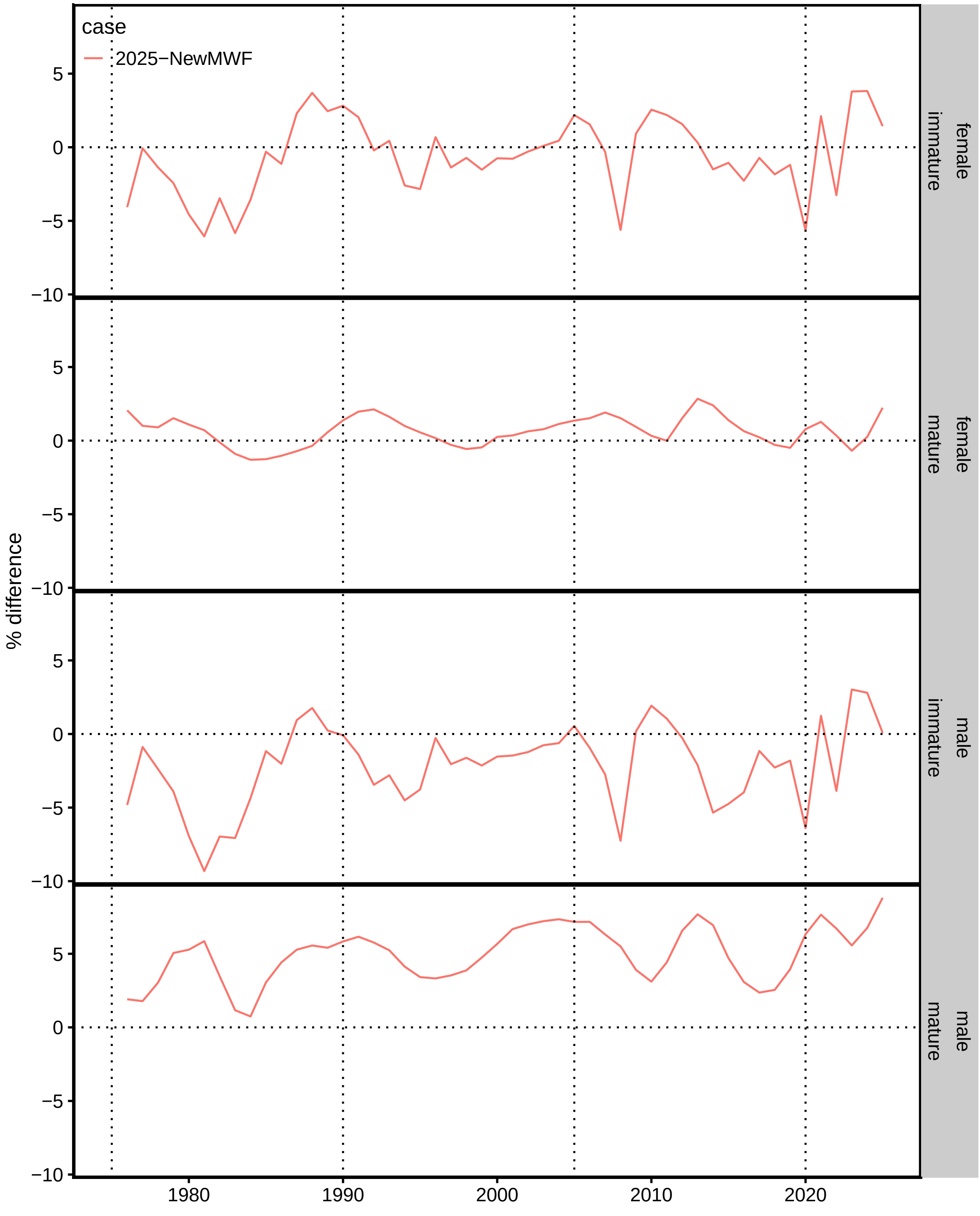


Figure 14. Startin in 1975, comparison of differences between the estimated time series of population abundance by sex and maturity state from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF").

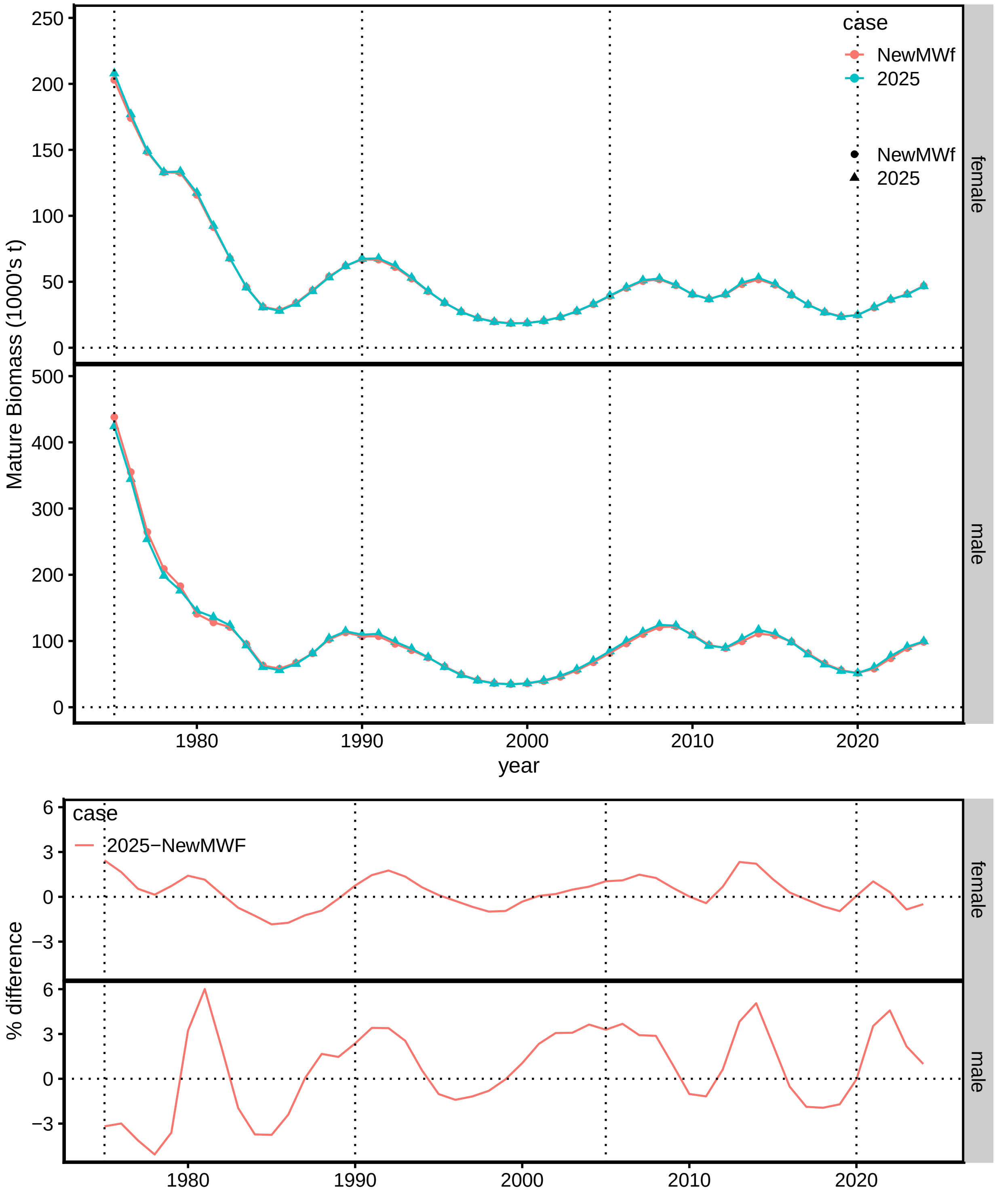


Figure 15. Starting in 1975, comparison of the estimated time series of mature biomass-at-mating by sex from the 2025 assessment model (“2025”) and the model with maturity ogives from the new maturity workflow (“NewMWF”).Upper two plots: estimated values by sex; lower tow plots: percent differences by sex.

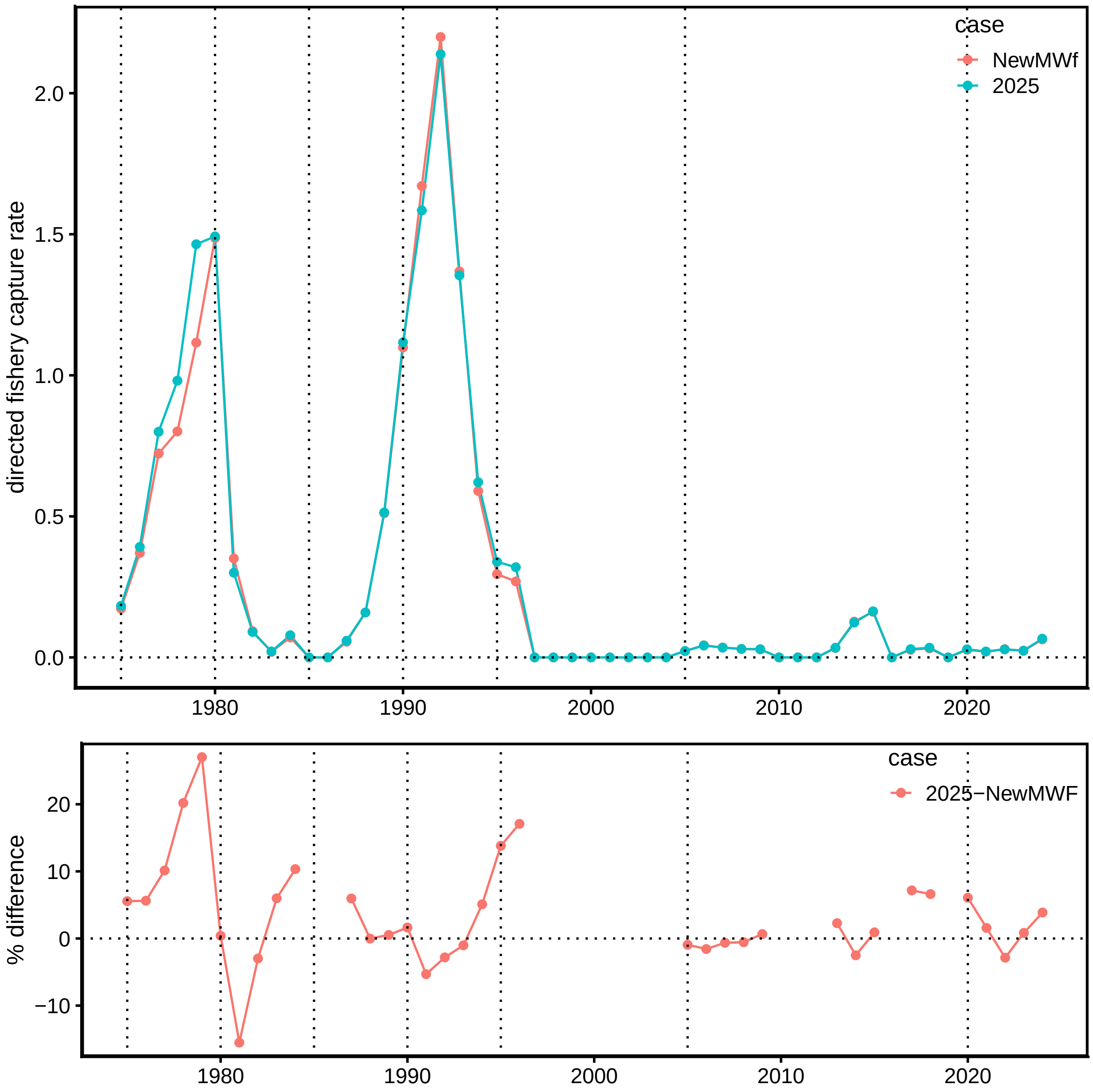


Figure 16. Starting in 1975, comparison of estimated fully-selected capture rates for males in the directed fishery from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper plot: estimated values; lower plot: differences.

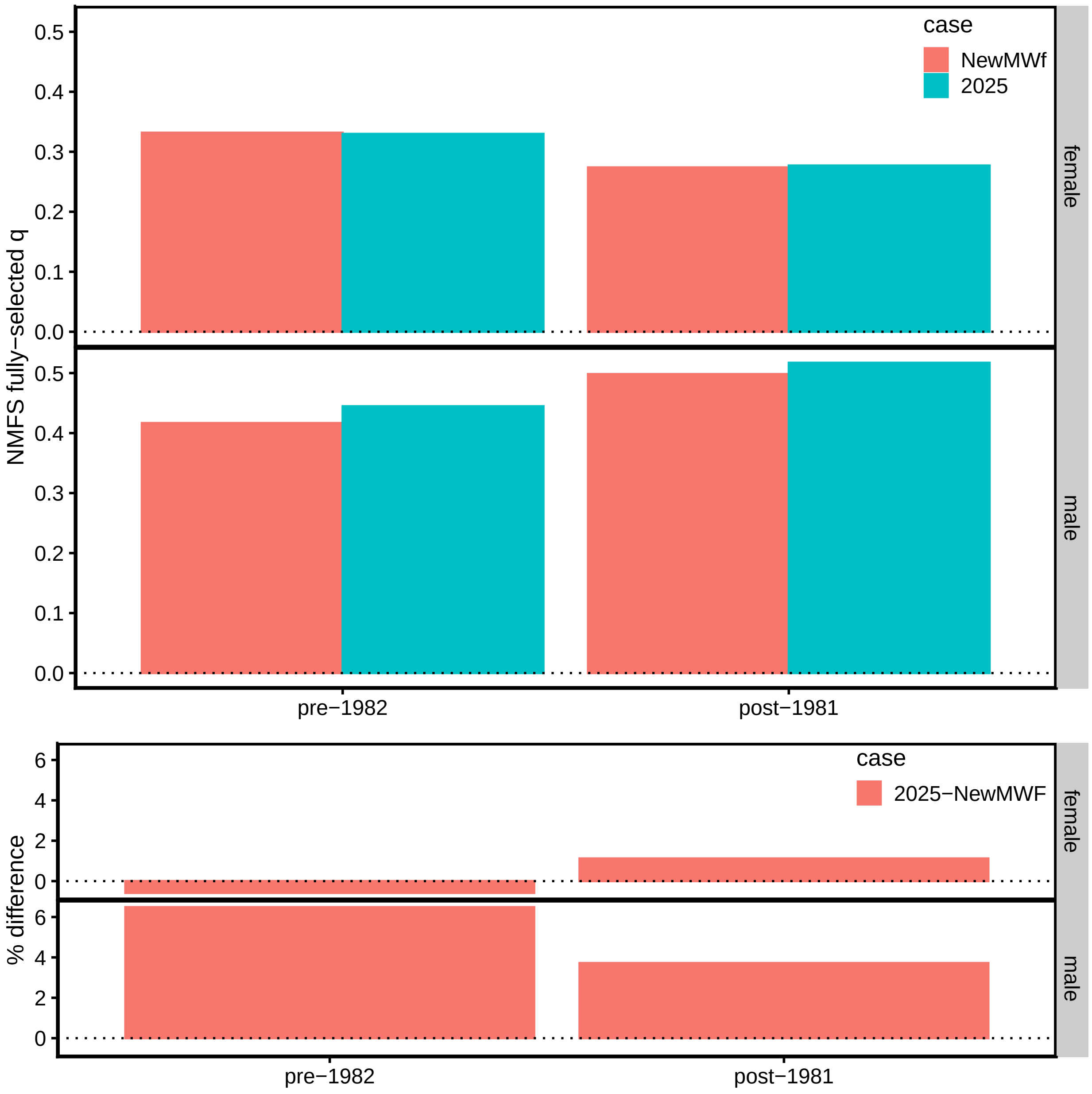


Figure 17. Comparison of estimated fully-selected catchability ("q") for the NMFS survey from the 2025 assessment model ("2025") and the model with maturity ogives from the new maturity workflow ("NewMWF"). Upper plot: estimated values for 1975-1981 and 1982-2025 by sex; lower plot: % differences.

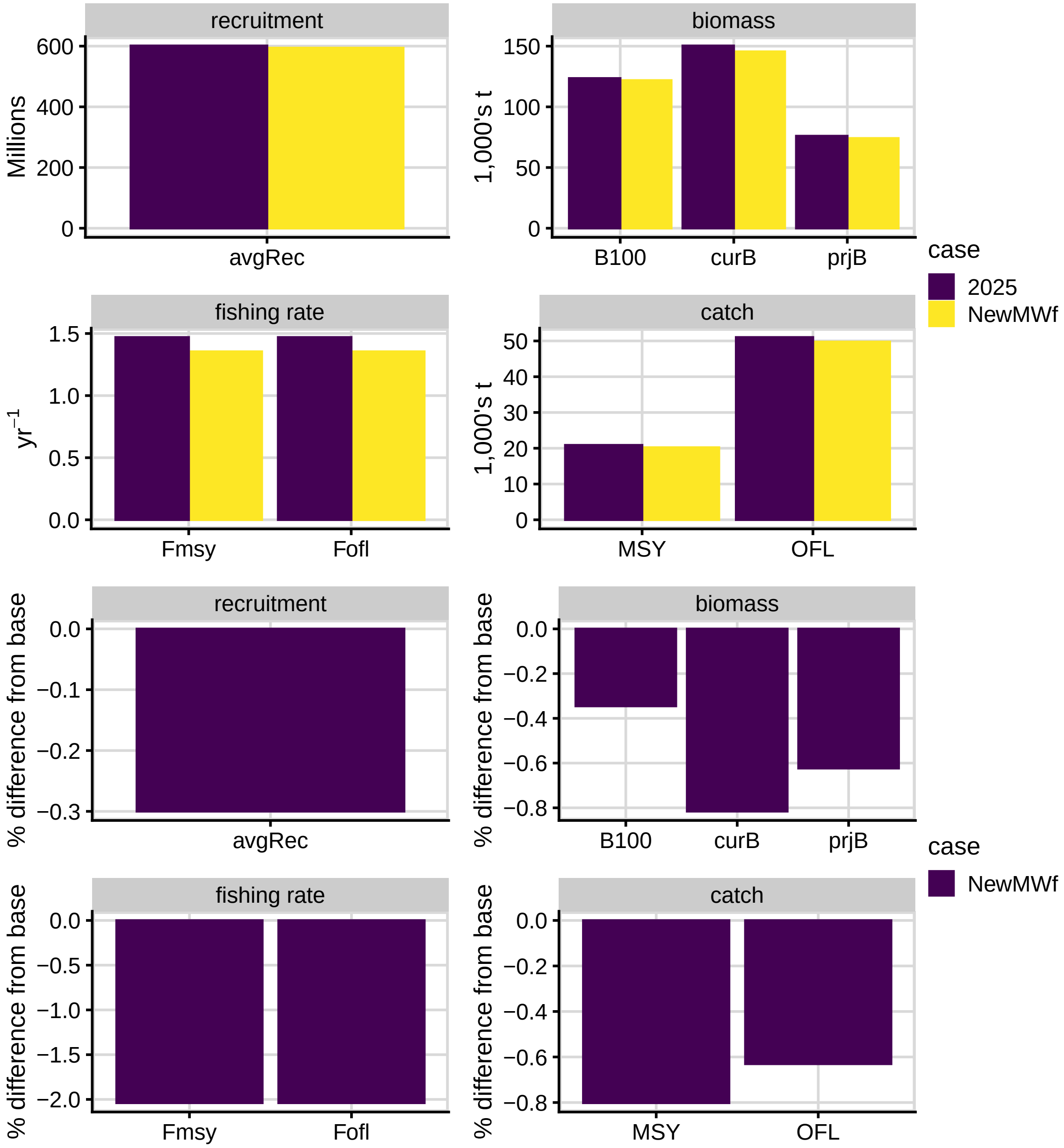


Figure 18. Comparison of values for various management reference quantities from the 2025 assessment model (“2025”) and the model with maturity ogives from the new maturity workflow (“NewMWF”). Upper four plots (clockwie from upper left): estimated values for avreage recruitment (“avgRec”); mature male biomass (MMB) under no fishing (“B100”), current MMB (“curB”), and projected MMB assuming the OFL is taken (“prjB”); maximum sustainable yield (“MSY”) and the overfishing limit (“OFL”); and the fishing mortalities yield MSY and the OFL (“Fmsy” and “Fofl” respectively). Lower four plots: percent differences between the 2025 assessment model (the “base” here) and the model with the new maturity workflow ogives.

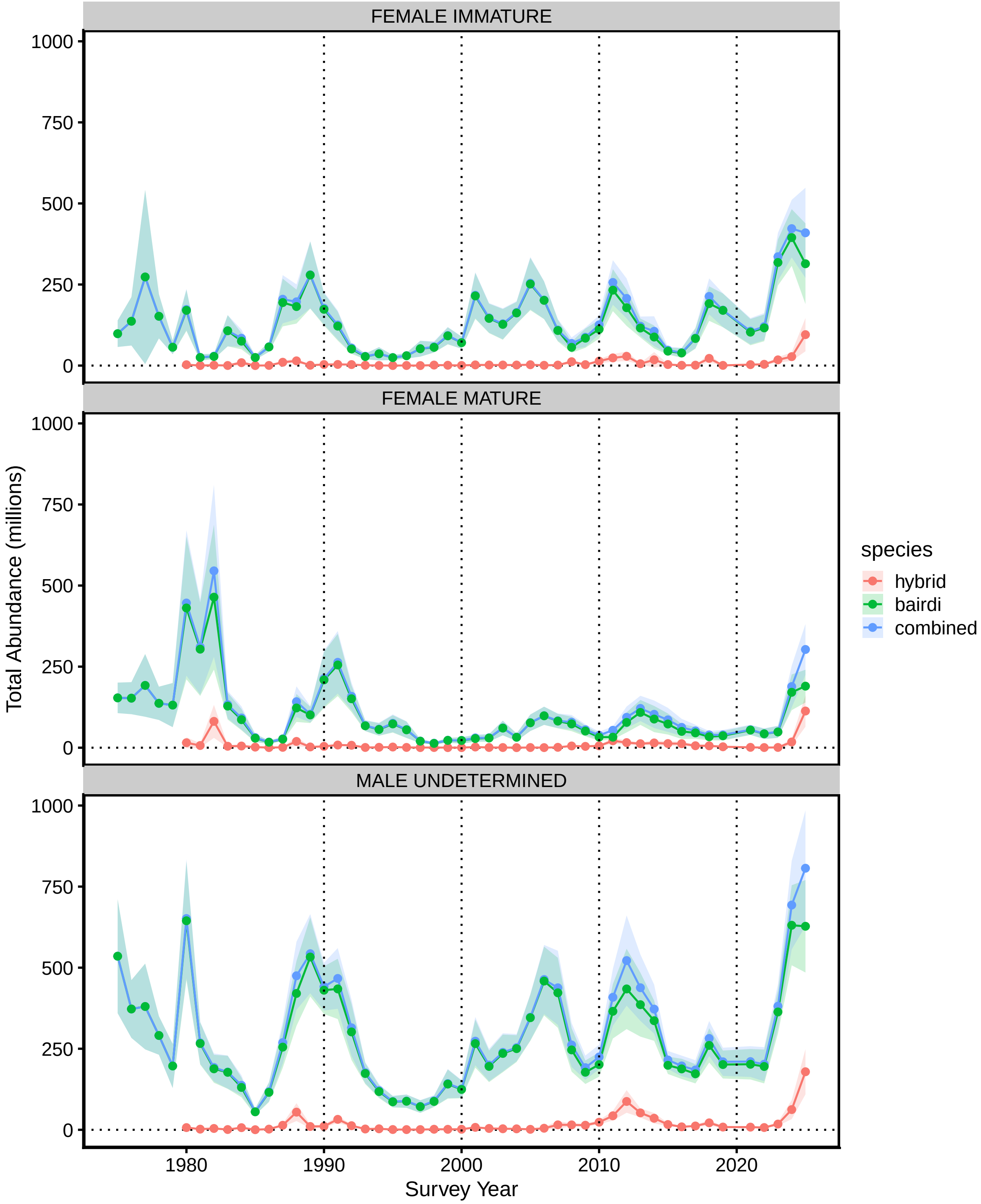


Figure 19. Comparison of hybrid, Tanner crab, and combined survey abundance time series for three population components.

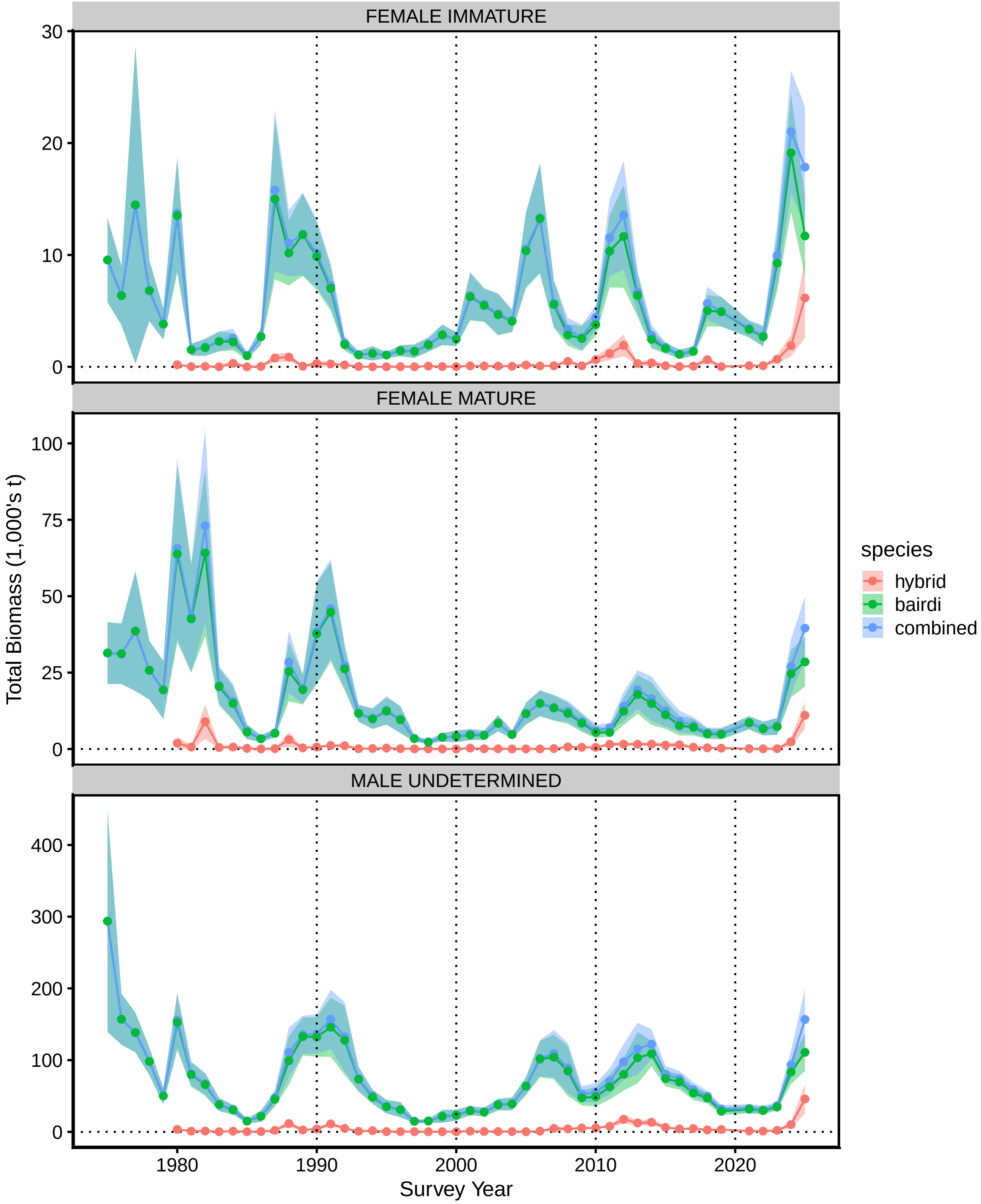


Figure 20. Comparison of hybrid, Tanner crab, and combined survey biomass time series for three population components.

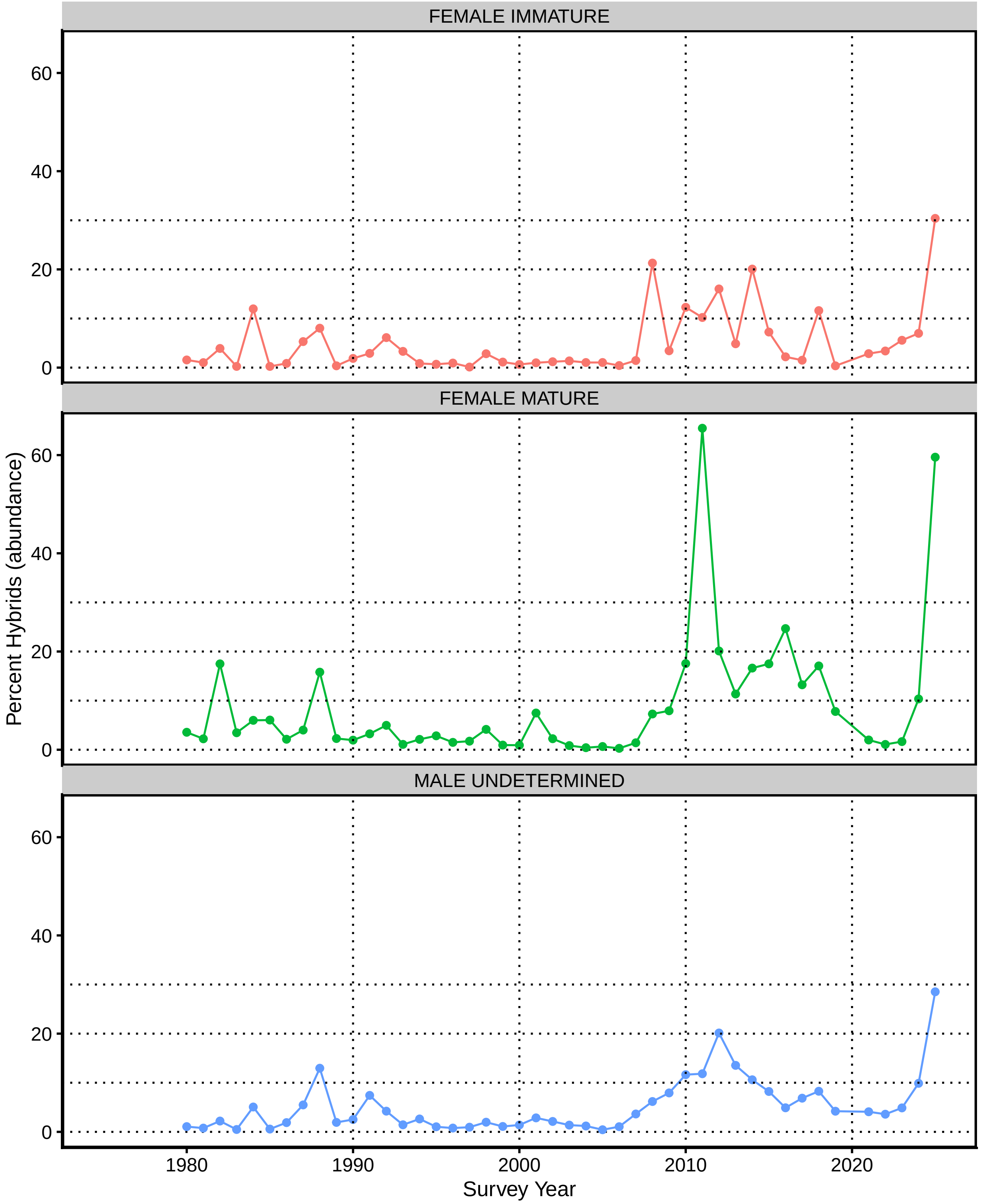


Figure 21. Percent hybrids, relative to Tanner crab survey abundance for three population components

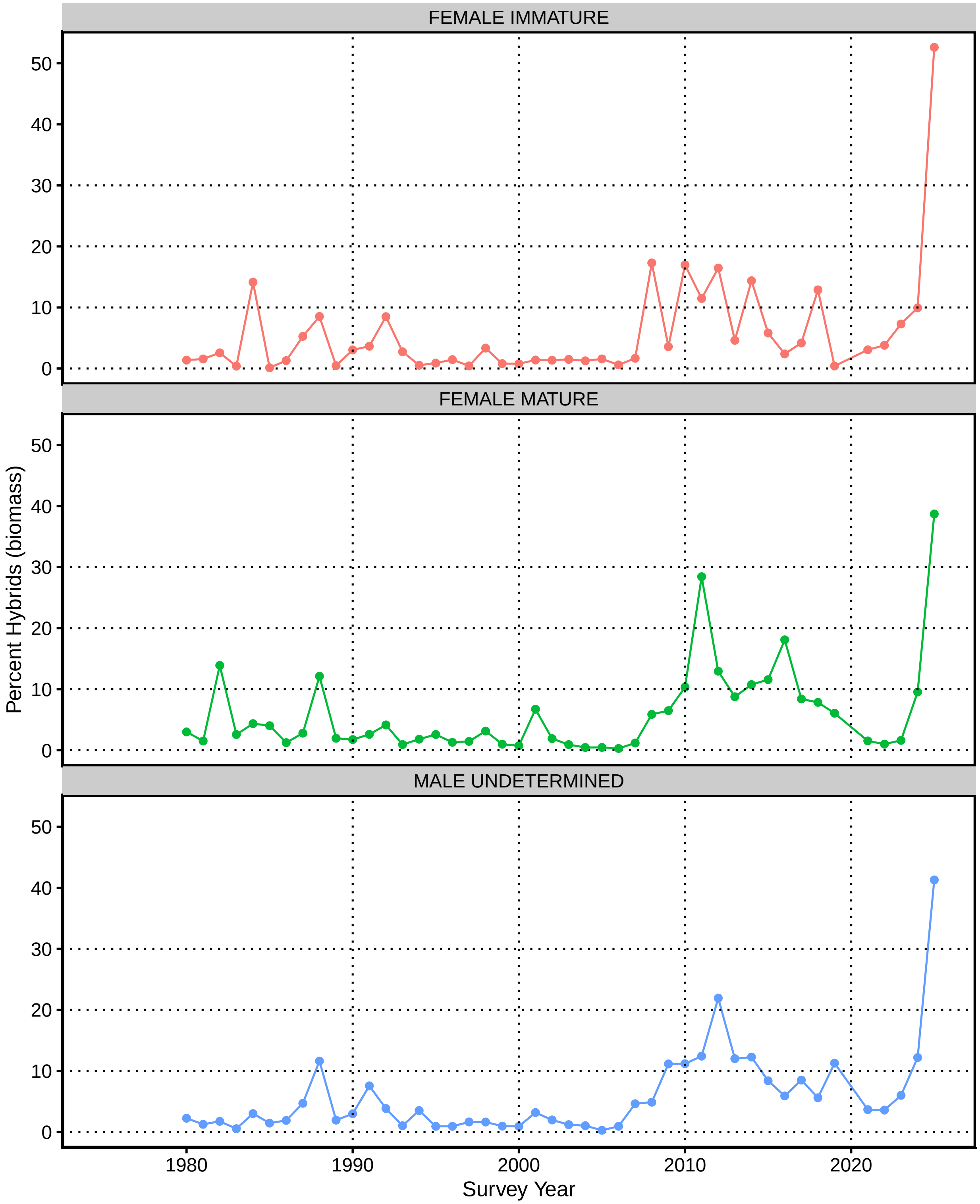


Figure 22. Percent hybrids, relative to Tanner crab survey biomass for three population components

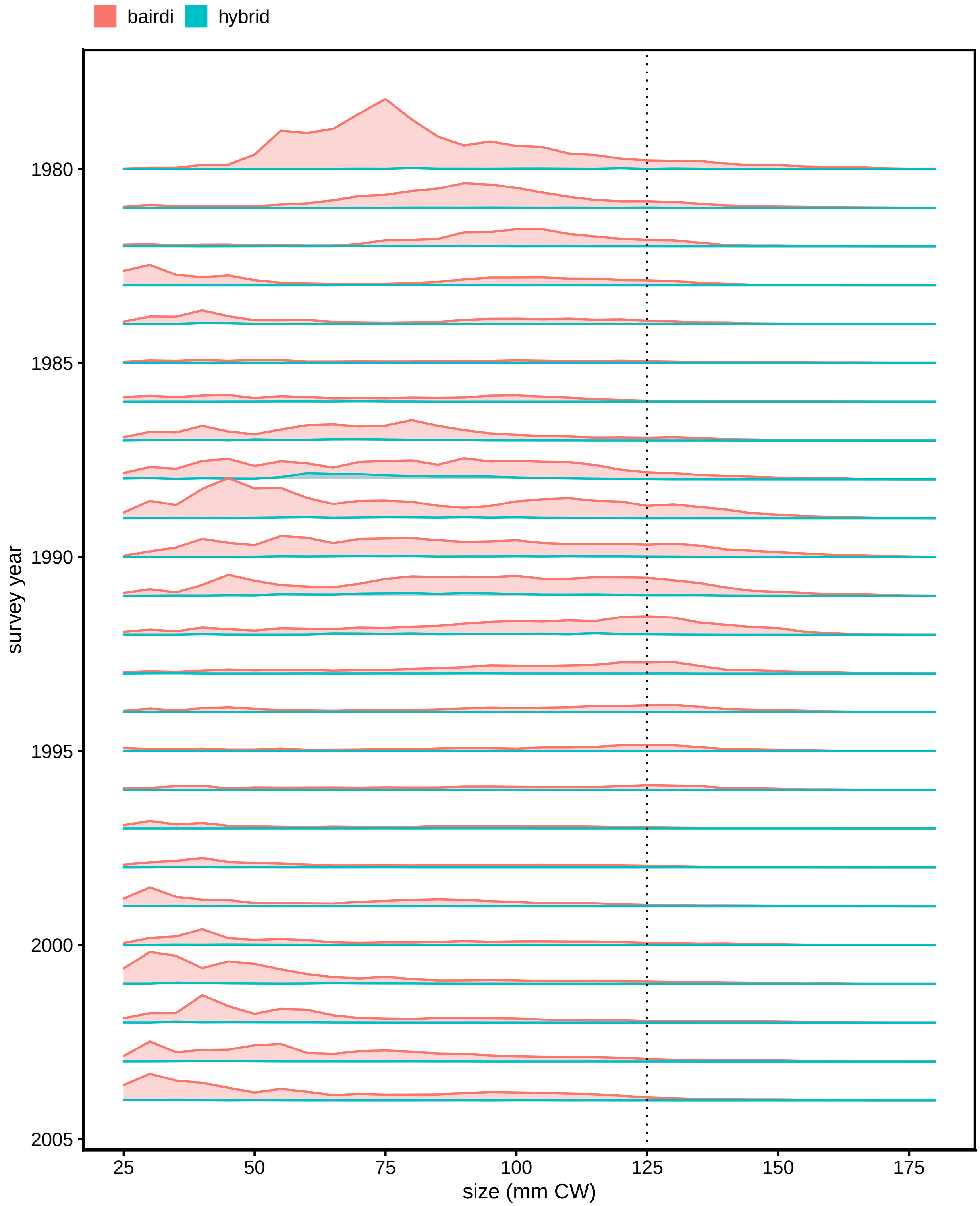


Figure 23. Comparison of expanded abundance size compositions for hybrid and Tanner males from the NMFS EBS trawl survey prior to 2005. Bin size is 5 mm.Dotted line indicates recent industry-preferred size.

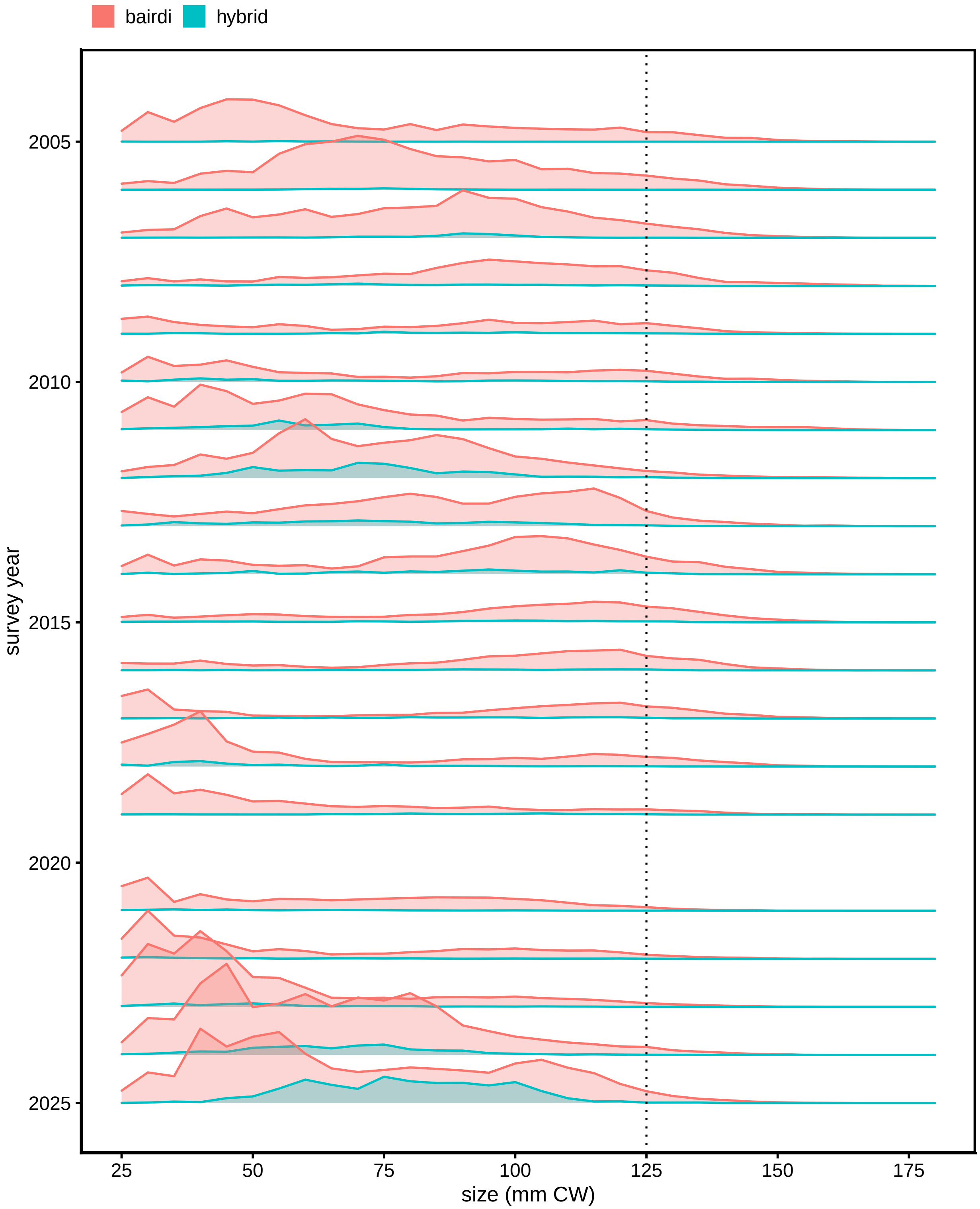


Figure 24. Comparison of expanded abundance size compositions for hybrid and Tanner males from the NMFS EBS trawl survey from 2005. Bin size is 5 mm.Dotted line indicates recent industry-preferred size.

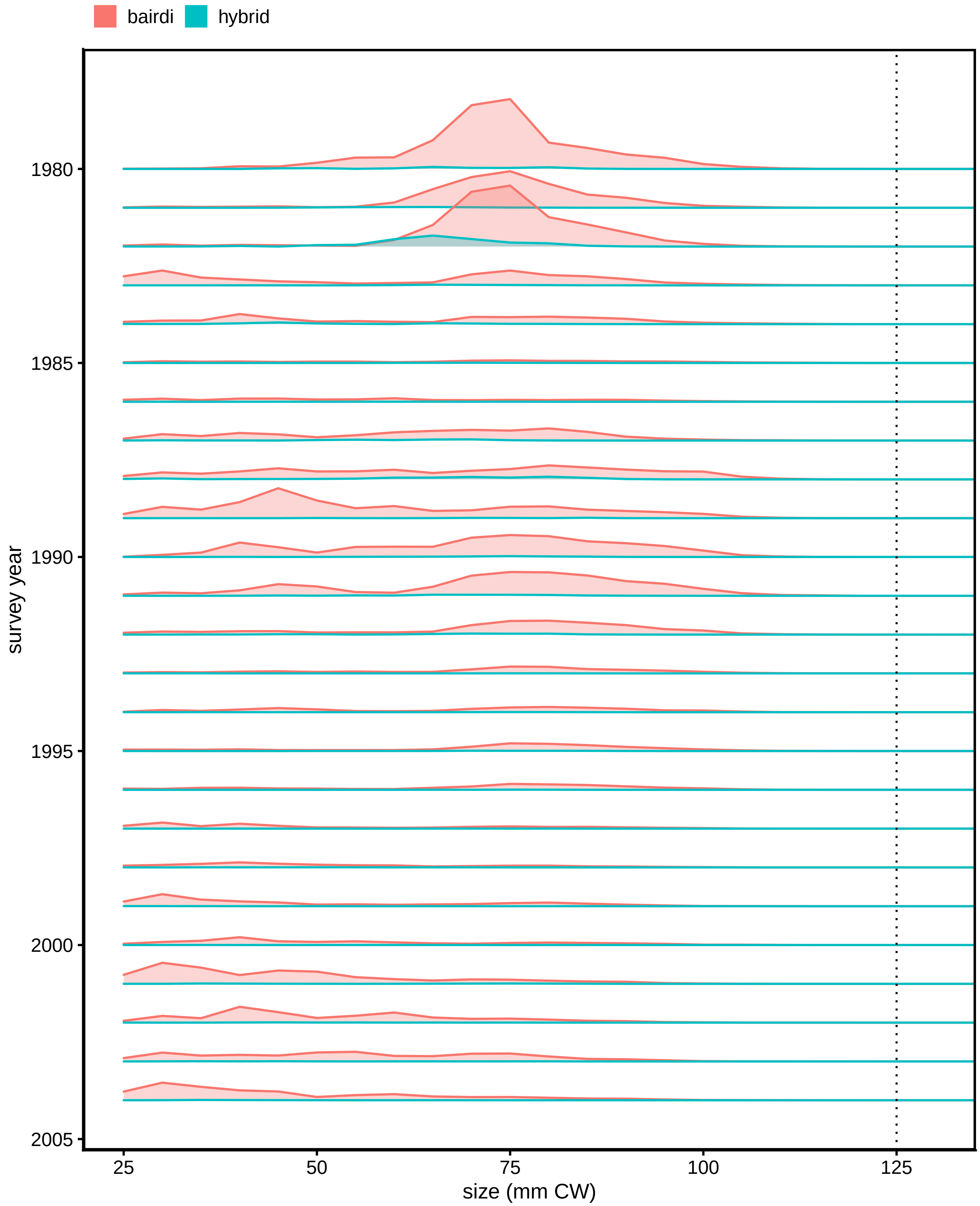


Figure 25. Comparison of expanded abundance size compositions for hybrid and Tanner females from the NMFS EBS trawl survey prior to 2005. Bin size is 5 mm.Dotted line indicates recent industry-preferred (male) size.

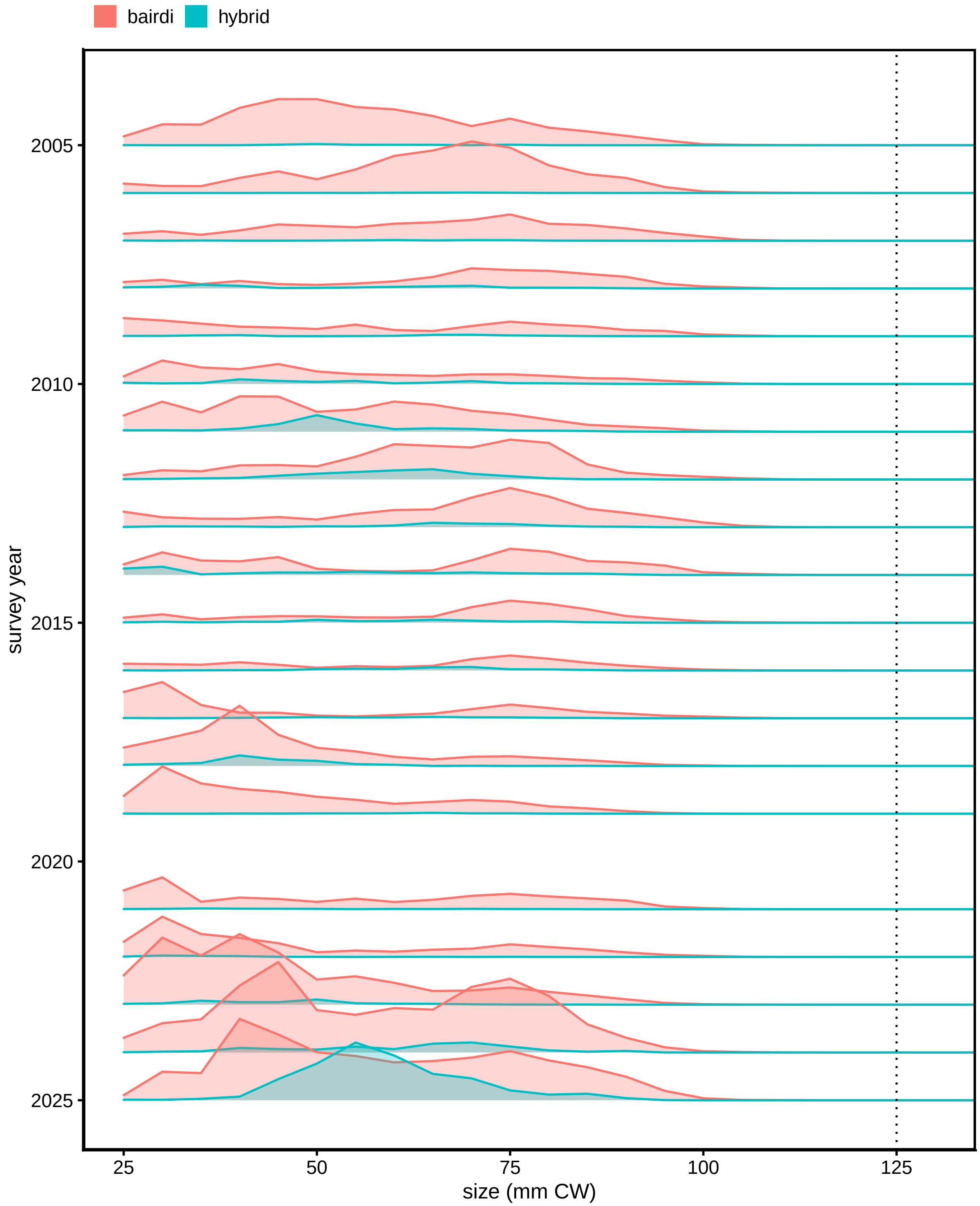


Figure 26. Comparison of expanded abundance size compositions for hybrid and Tanner females from the NMFS EBS trawl survey from 2005. Bin size is 5 mm.Dotted line indicates recent industry-preferred (male) size.

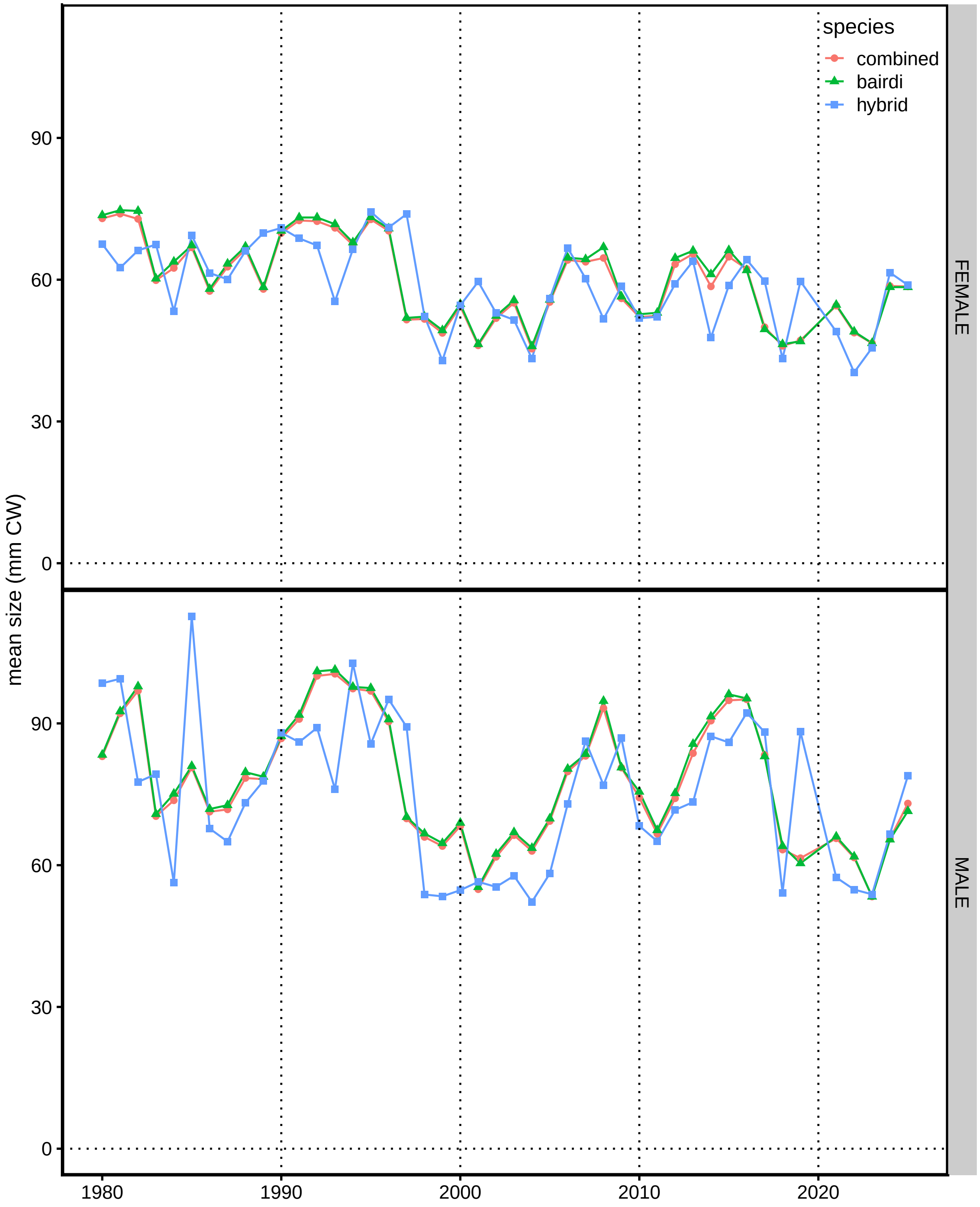


Figure 27. Comparison of mean sizes from size compositions for hybrid, Tanner, and combined data from the NMFS EBS trawl survey.

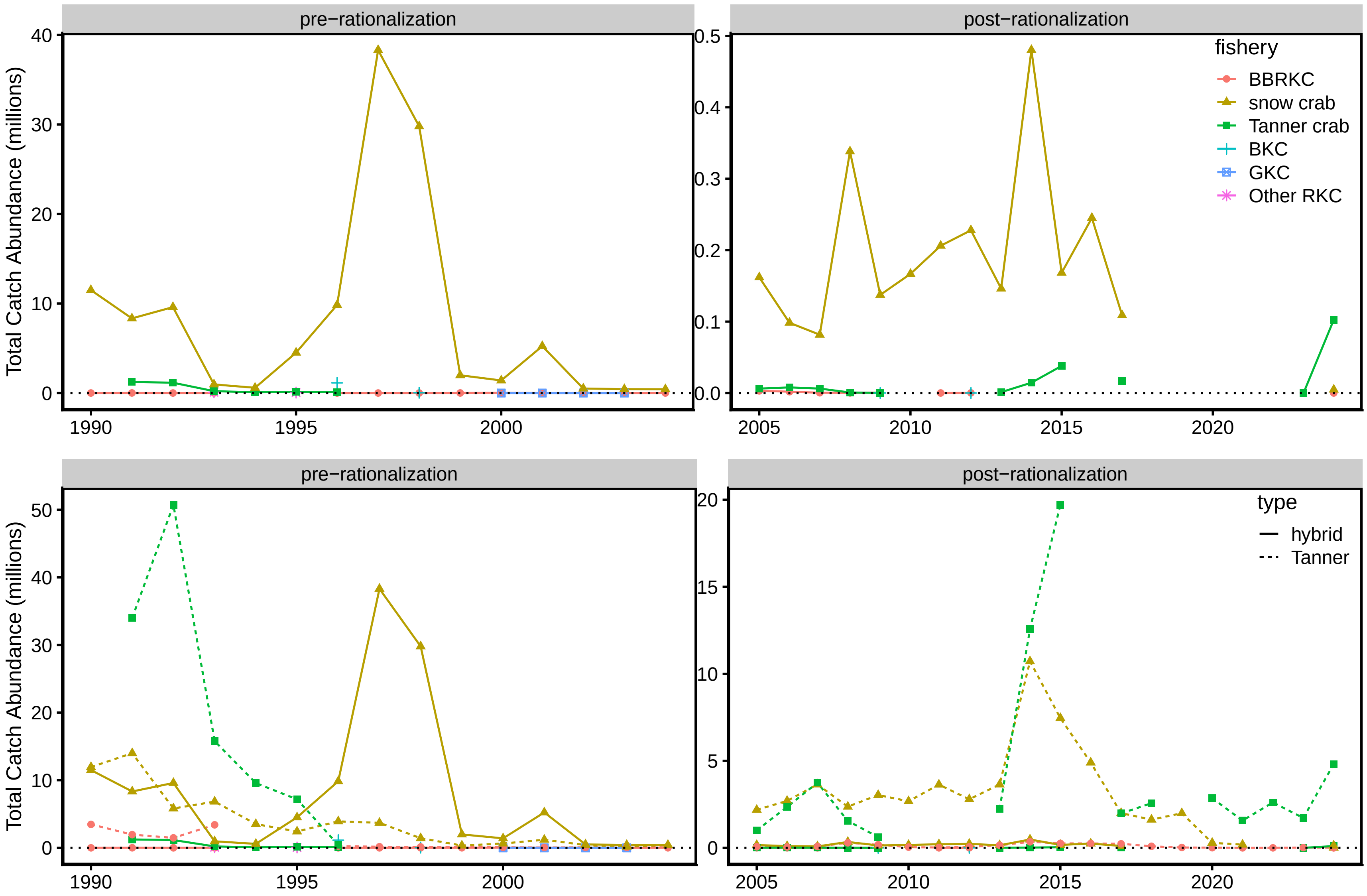


Figure 28. Comparison of male hybrid *Chionoecetes* spp. total catch abundance estimates in the crab fisheries. Upper row: hybrid data only; bottom row: with male Tanner crab total catch estimates (dashed lines). Left column: pre-rationalization (before 2005); right column: post-rationalization (after 2004).Only non-zero estimates are plotted.

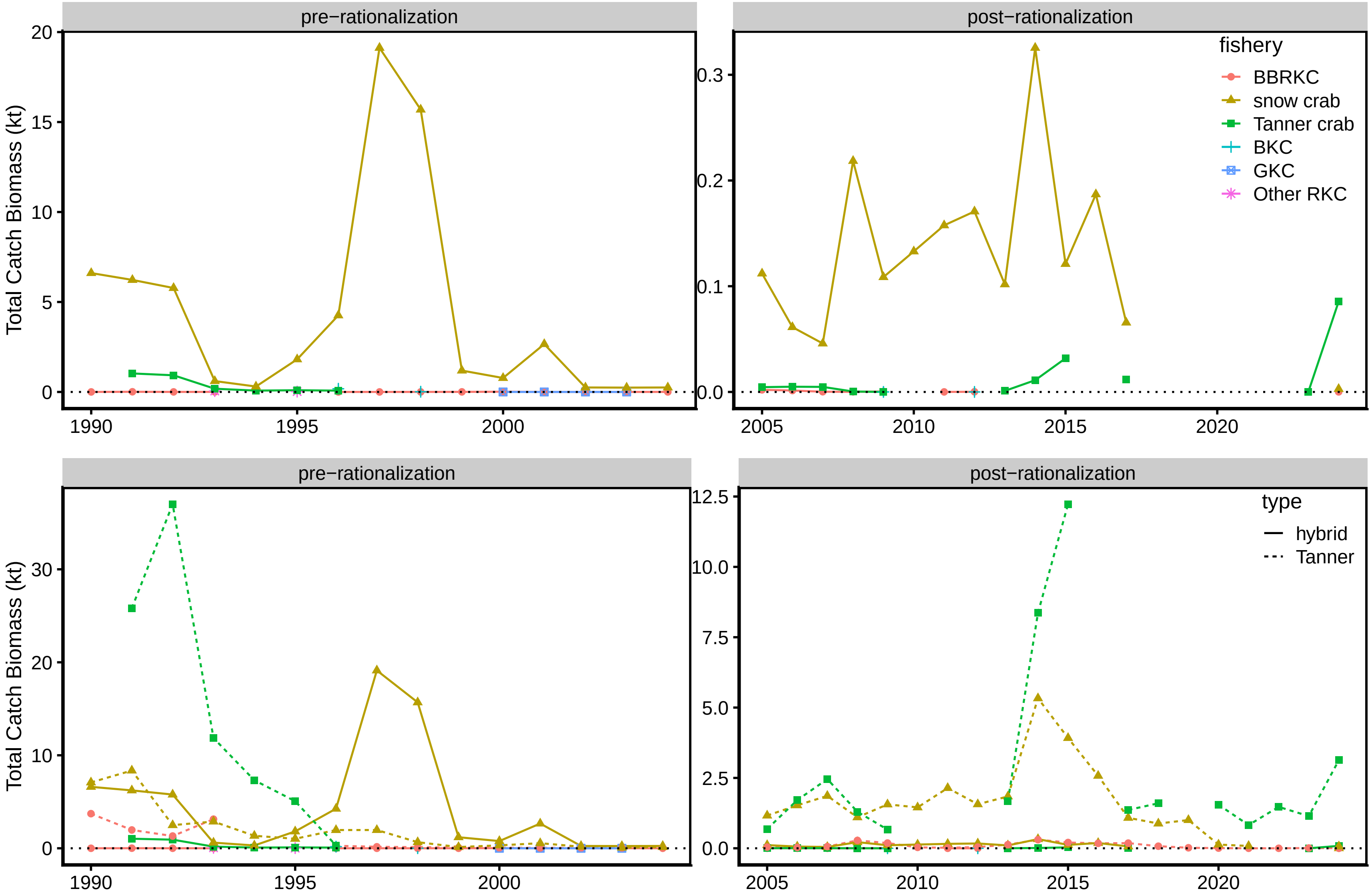


Figure 29. Comparison of male hybrid Chionoecetes spp. total catch biomass estimates in the crab fisheries. Upper row: hybrid data only; bottom row: with male Tanner crab total catch estimates (dashed lines). Left column: pre-rationalization (before 2005); right column: post-rationalization (after 2004).Only non-zero estimates are plotted.

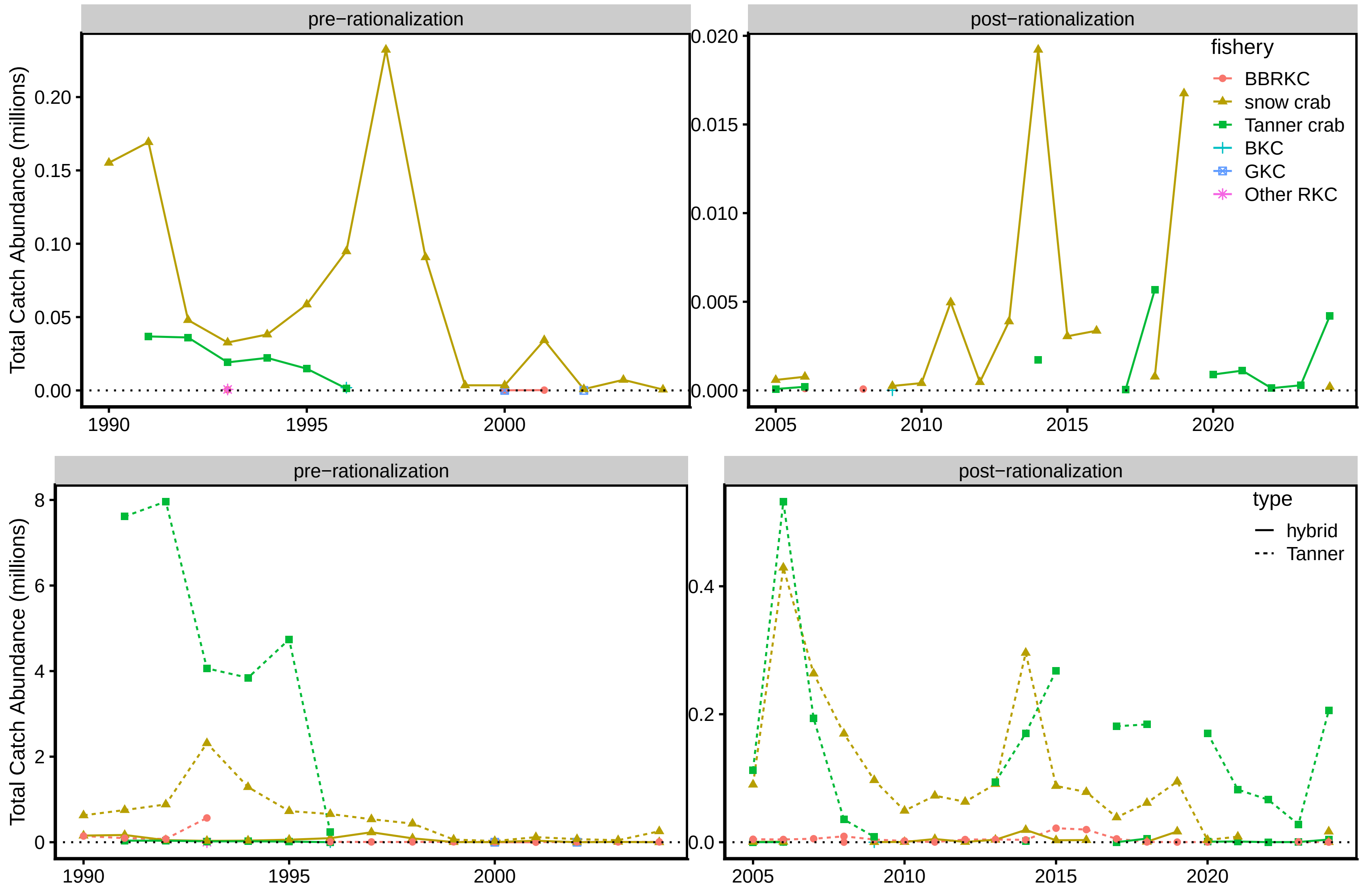


Figure 30. Comparison of female hybrid Chionoecetes spp. total catch abundance estimates in the crab fisheries. Upper row: hybrid data only; bottom row: with female Tanner crab total catch estimates (dashed lines). Left column: pre-rationalization (before 2005); right column: post-rationalization (after 2004).Only non-zero estimates are plotted.

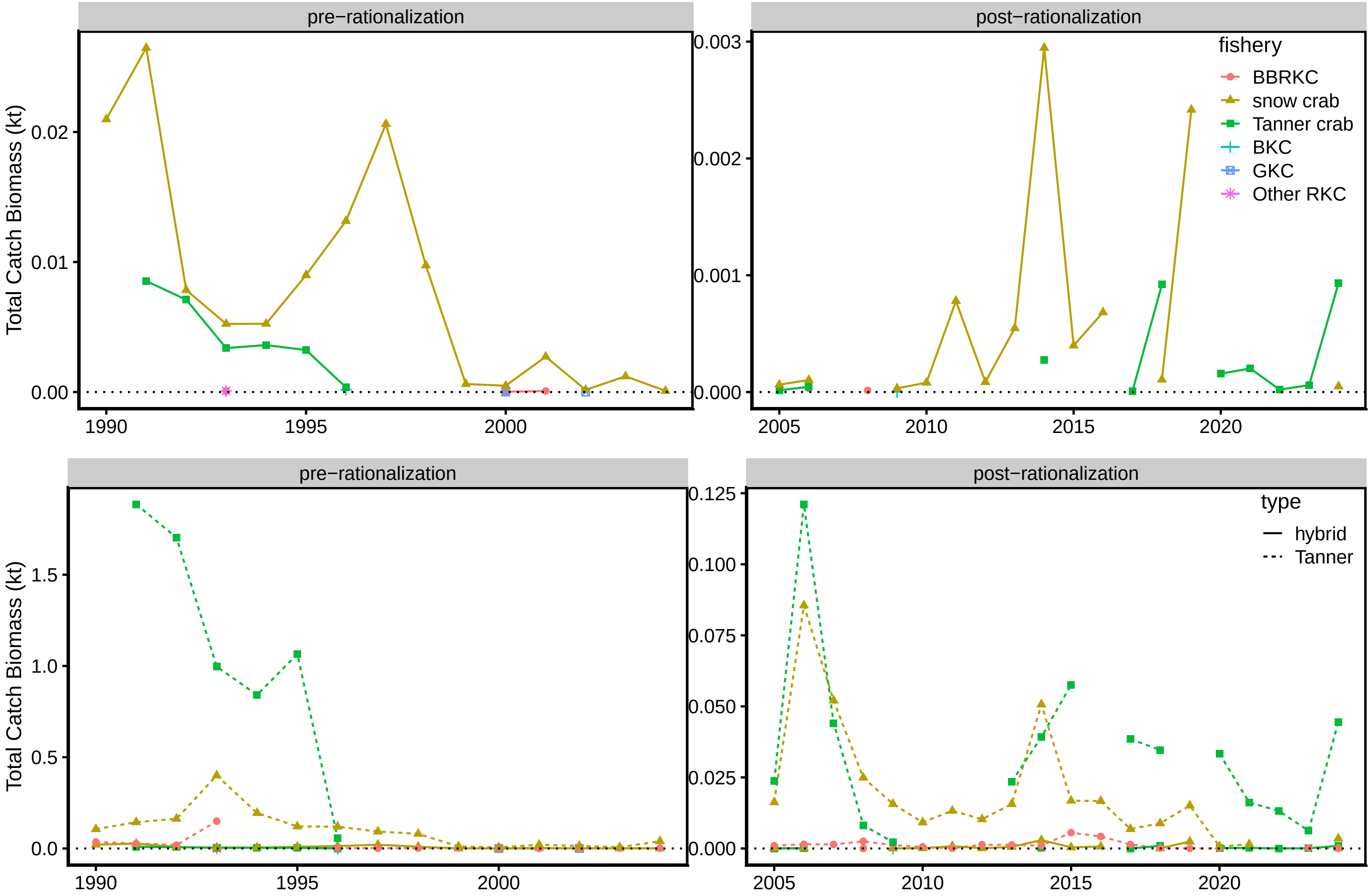


Figure 31. Comparison of female hybrid Chionoecetes spp. total catch biomass estimates in the crab fisheries. Upper row: hybrid data only; bottom row: with female Tanner crab total catch estimates (dashed lines). Left column: pre-rationalization (before 2005); right column: post-rationalization (after 2004).Only non-zero estimates are plotted.

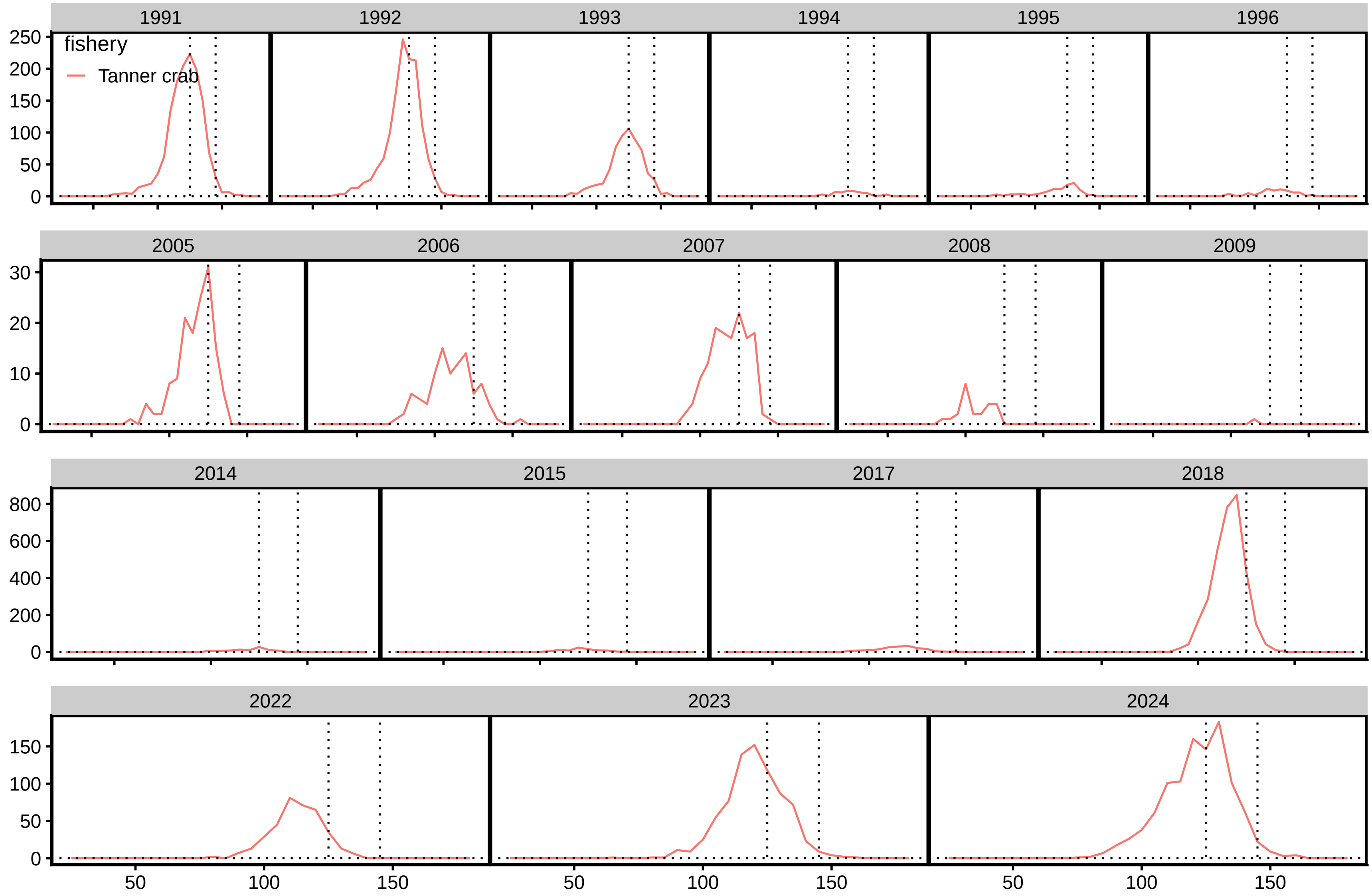


Figure 32. Male hybrid *Chionoecetes* spp. total catch size compositions in the Tanner crab fishery. The vertical dotted lines indicate the 125 and 145 mm CW sizes, respectively the current and historical Tanner crab industry-preferred sizes.

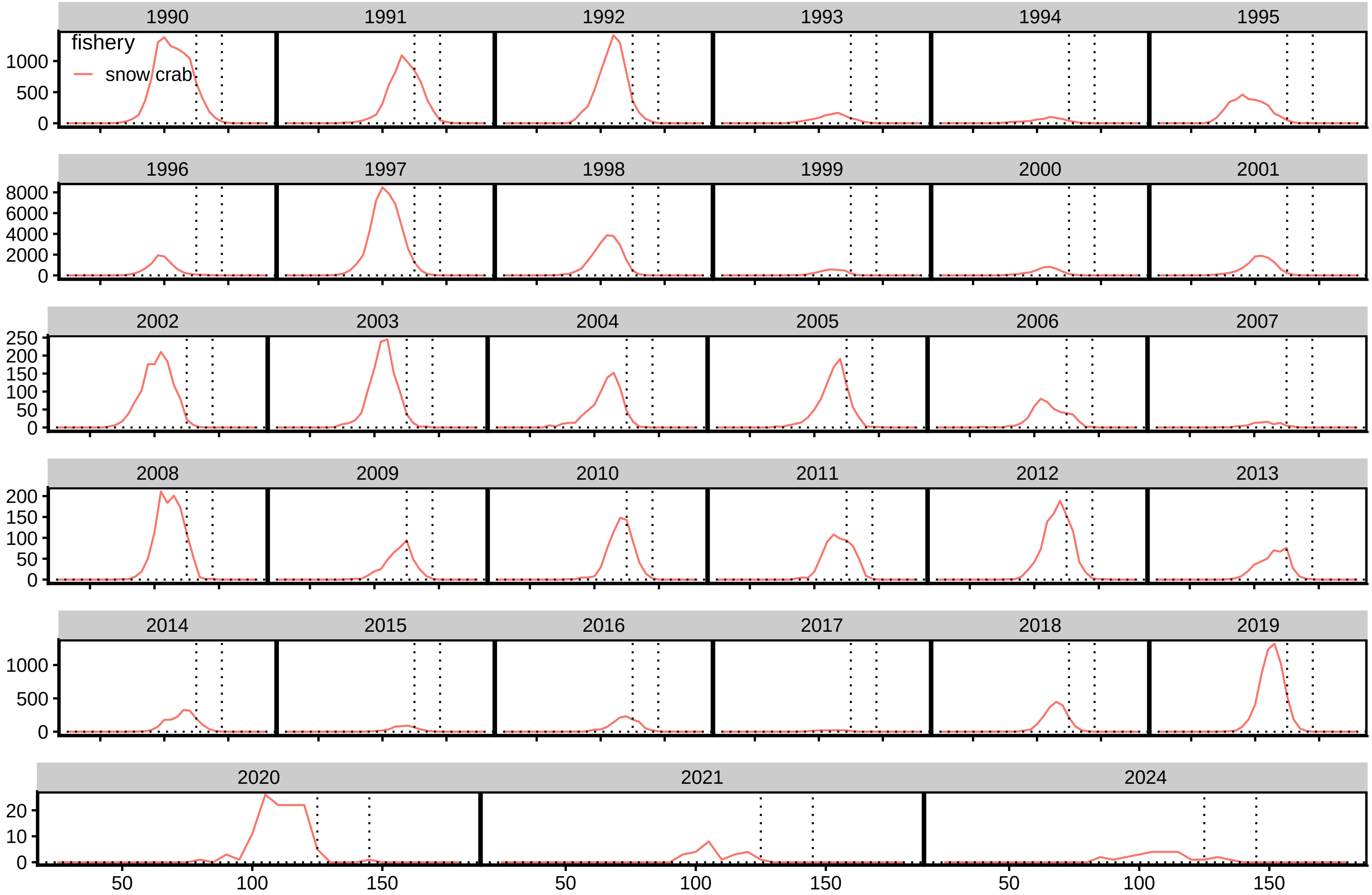


Figure 33. Male hybrid *Chionoecetes* spp. total catch size compositions in the snow crab fishery. The vertical dotted lines indicate the 125 and 145 mm CW sizes, respectively the current and historical Tanner crab industry-preferred sizes.

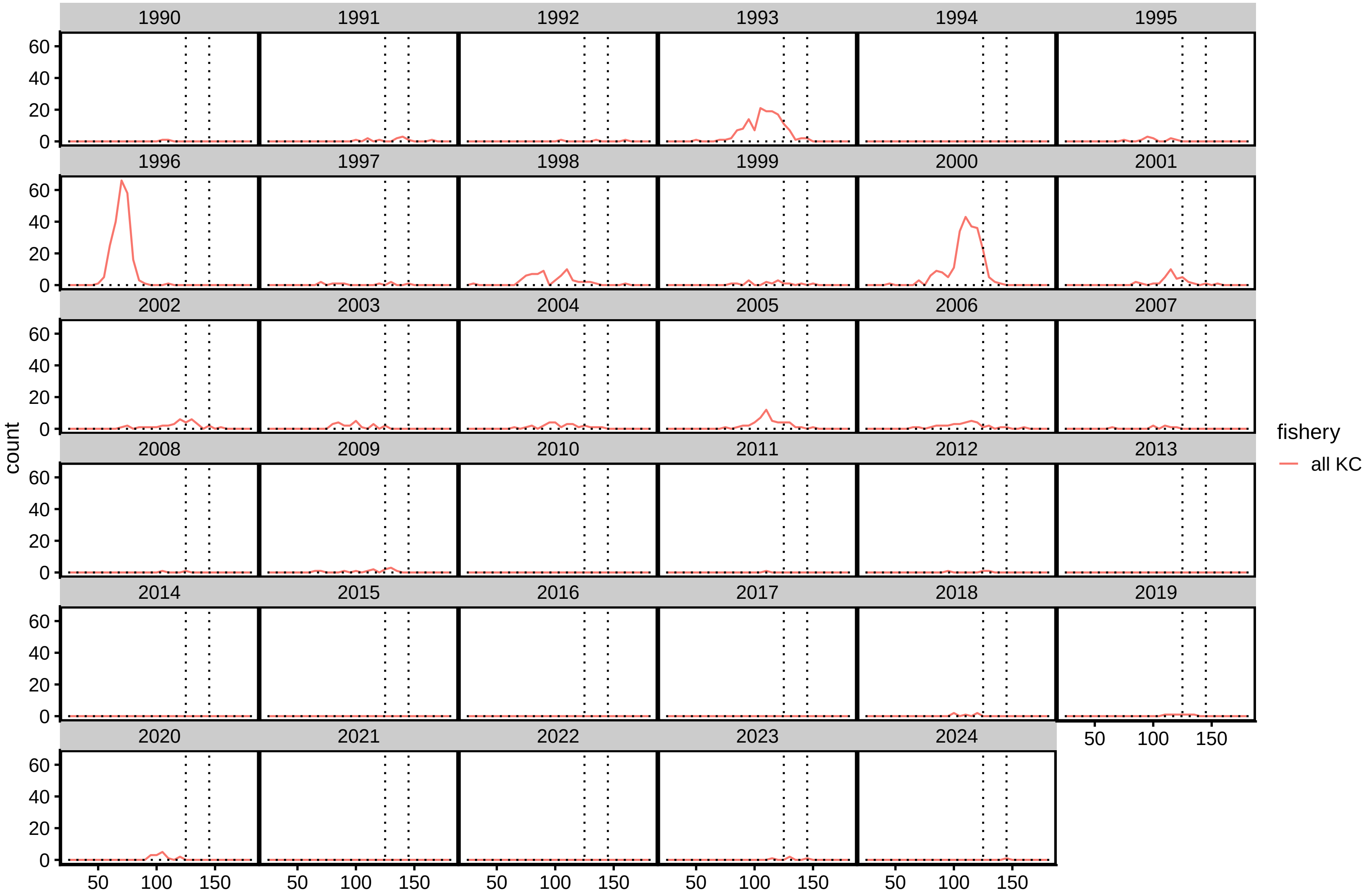


Figure 34. Male hybrid *Chionoecetes* spp. total catch size compositions aggregated across all king crab fisheries. The vertical dotted lines indicate the 125 and 145 mm CW sizes, respectively the current and historical Tanner crab industry-preferred sizes.

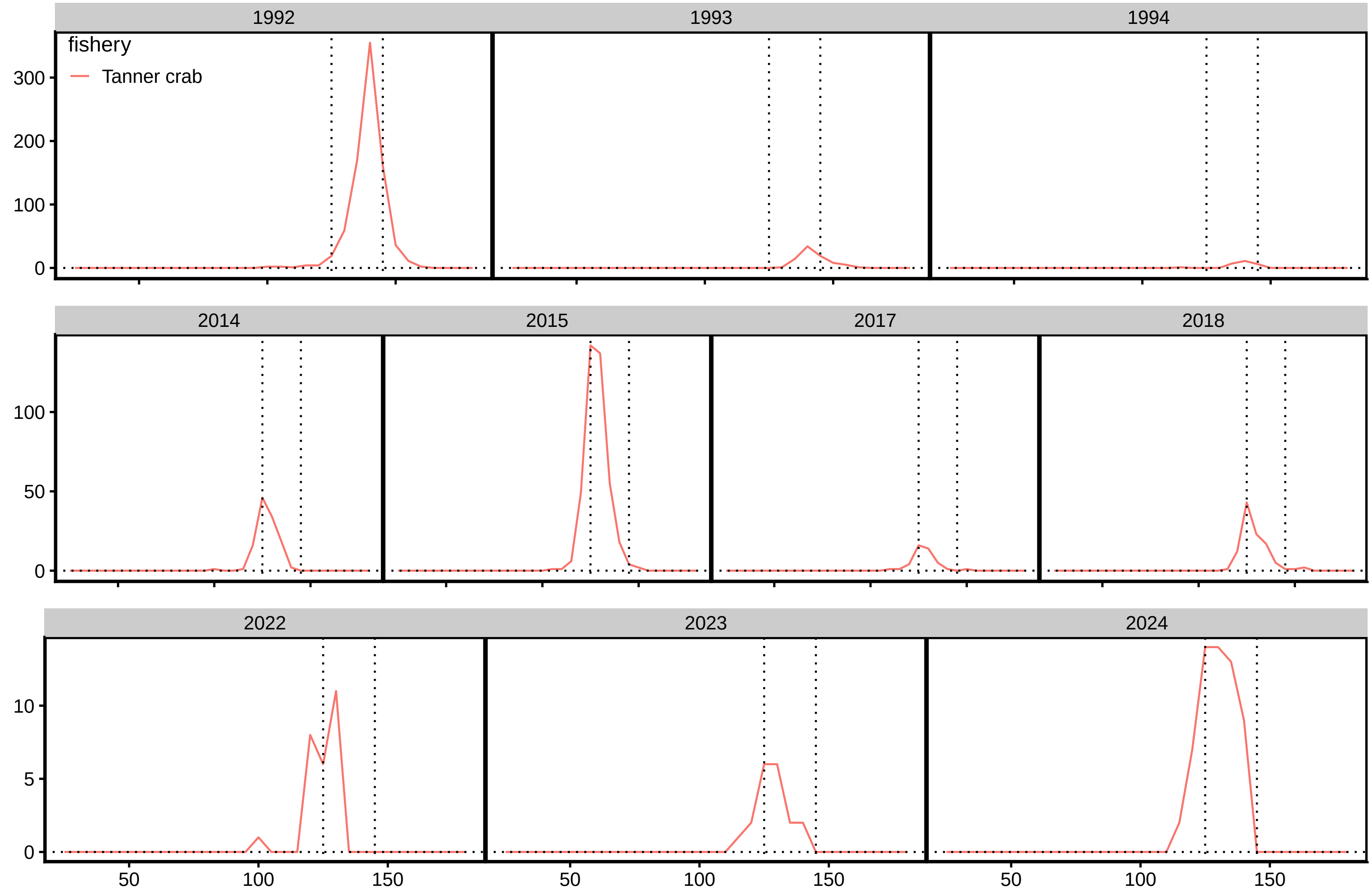


Figure 35. Male hybrid *Chionoecetes* spp. retained catch size compositions in the Tanner crab fishery. The vertical dotted lines indicate the 125 and 145 mm CW sizes.

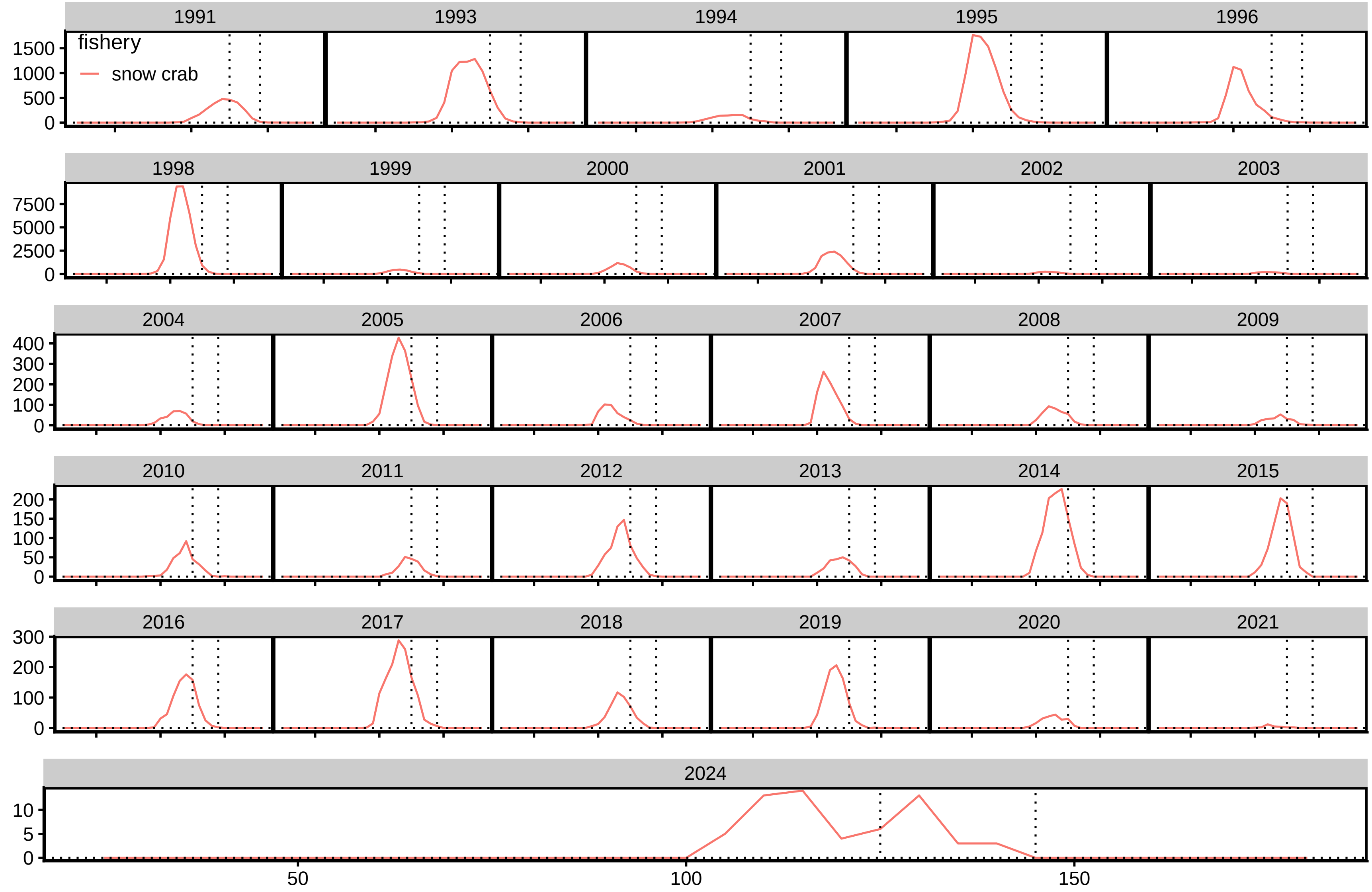


Figure 36. Male hybrid *Chionoecetes* spp. retained catch size compositions in the snow crab fishery. The vertical dotted lines indicate the 125 and 145 mm CW sizes.

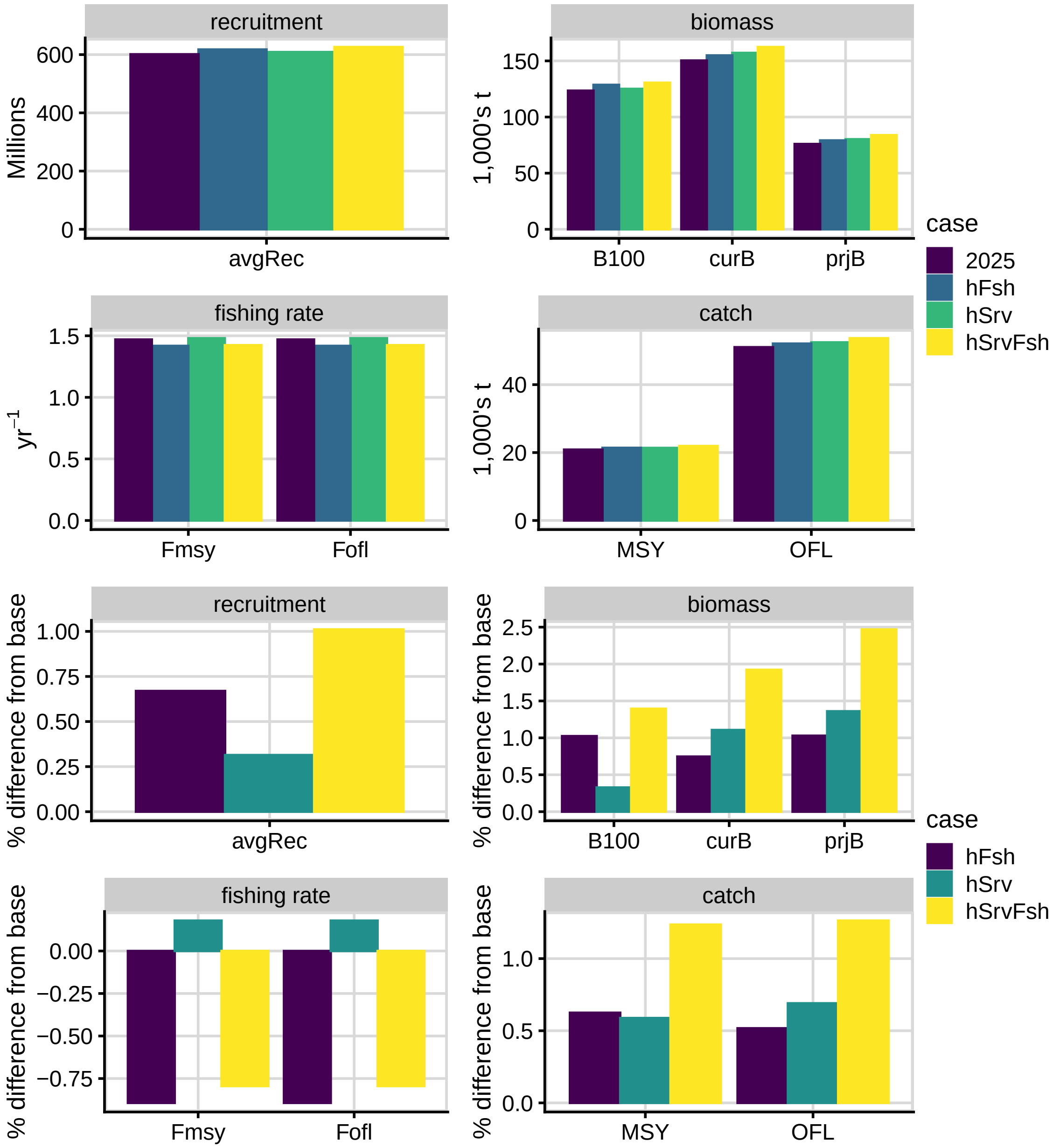


Figure 37. Comparison of values for various management reference quantities from the 2025 assessment model ("2025") and the models including hybrid survey ("hSrv"), hybrid fishery ("hFsh), and hybrid survey and fishery ("hSrvFsh") data. Upper four plots (clockwise from upper left): estimated values for average recruitment ("avgRec"); mature male biomass (MMB) under no fishing ("B100"), current MMB ("curB"), and projected MMB assuming the OFL is taken ("prjB"); maximum sustainable yield ("MSY") and the overfishing limit ("OFL"); and the fishing mortalities yield MSY and the OFL ("Fmsy" and "Fofl" respectively). Lower four plots: percent differences between the 2025 assessment model (the "base" here) and the models with hybrid data. Positive values indicate the base case value is less than the corresponding scenario value.

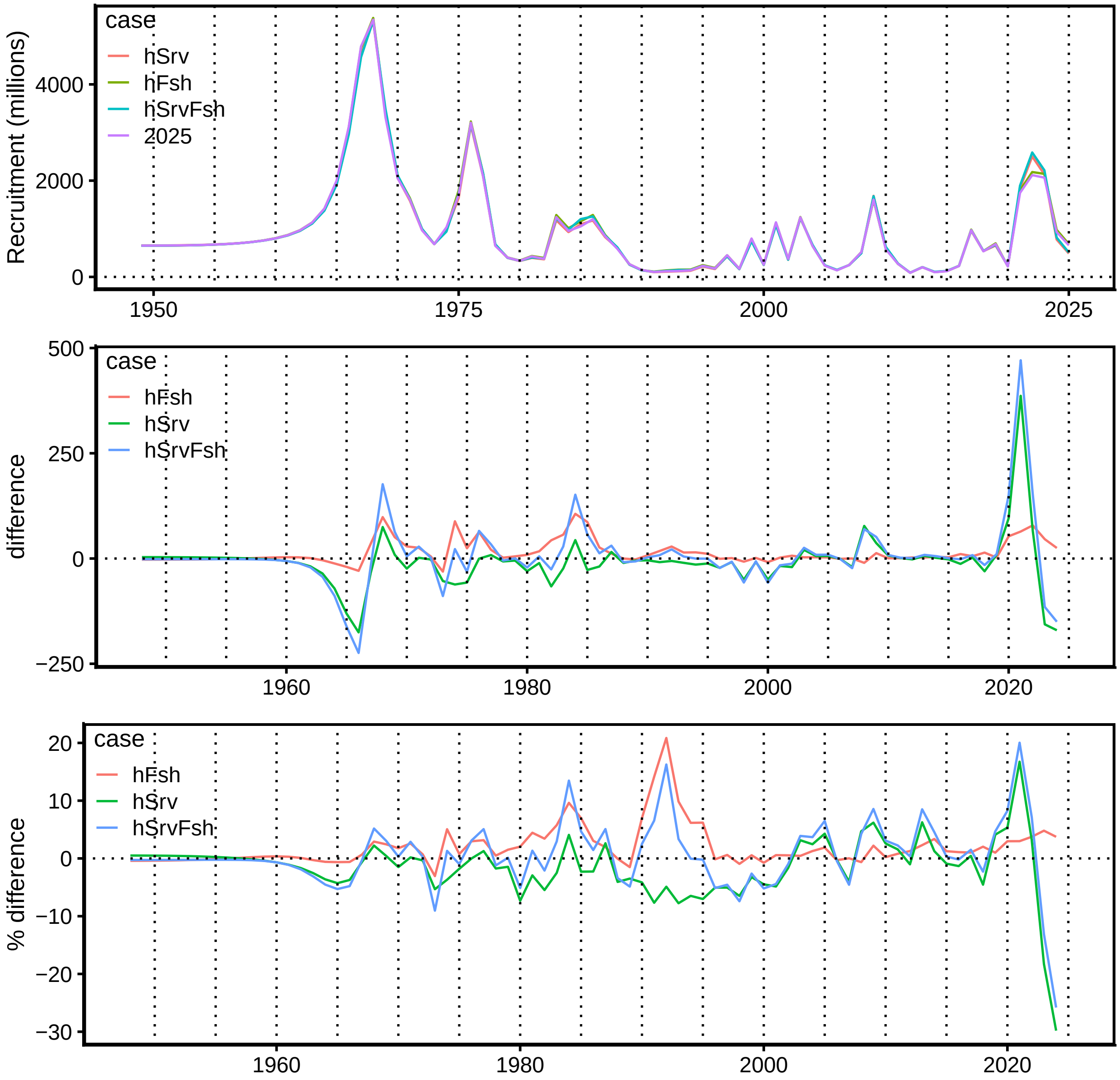


Figure 38. Comparison of estimated recruitment from the 2025 assessment model ("2025") and the models with hybrids data included ("hSrv": in survey data, "hFsh": in fishery data, "hSrvFsh": in both). Upper: values; middle: difference with assessment model; lower: % difference with assessment model. Positive values indicate the base case value is less than the corresponding scenario value.

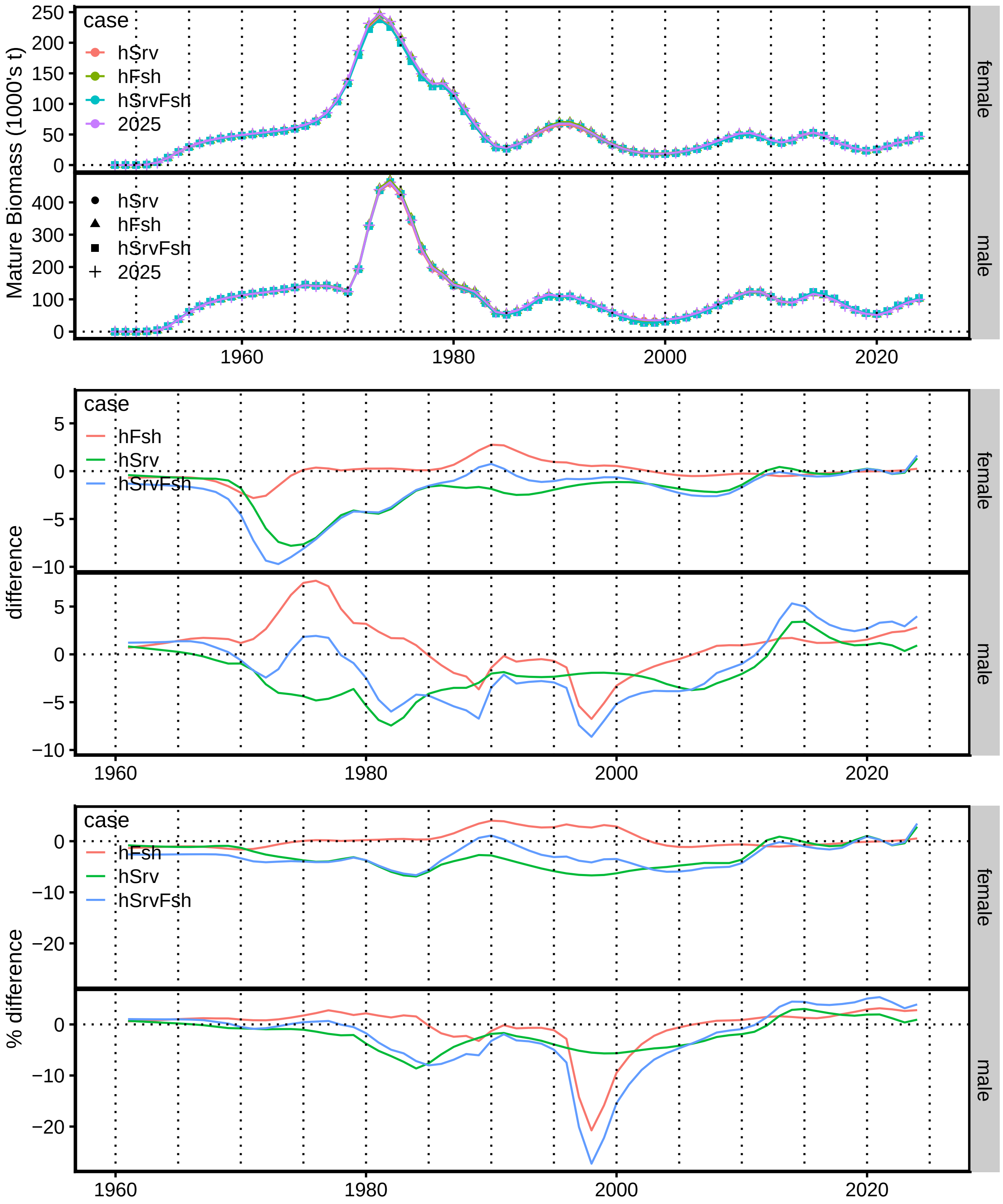


Figure 39. Comparison of time series of estimated mature biomass by biological category from the 2025 assessment model ("2025") and the models with hybrids data included ("hSrv": in survey data, "hFsh": in fishery data, "hSrvFsh": in both). Upper two plots: estimated values; middle two plots: difference from 2025 assessment results; lower two plots: precent difference from 2025 assessment results. Positive values indicate the base case value is less than the corresponding scenario value.

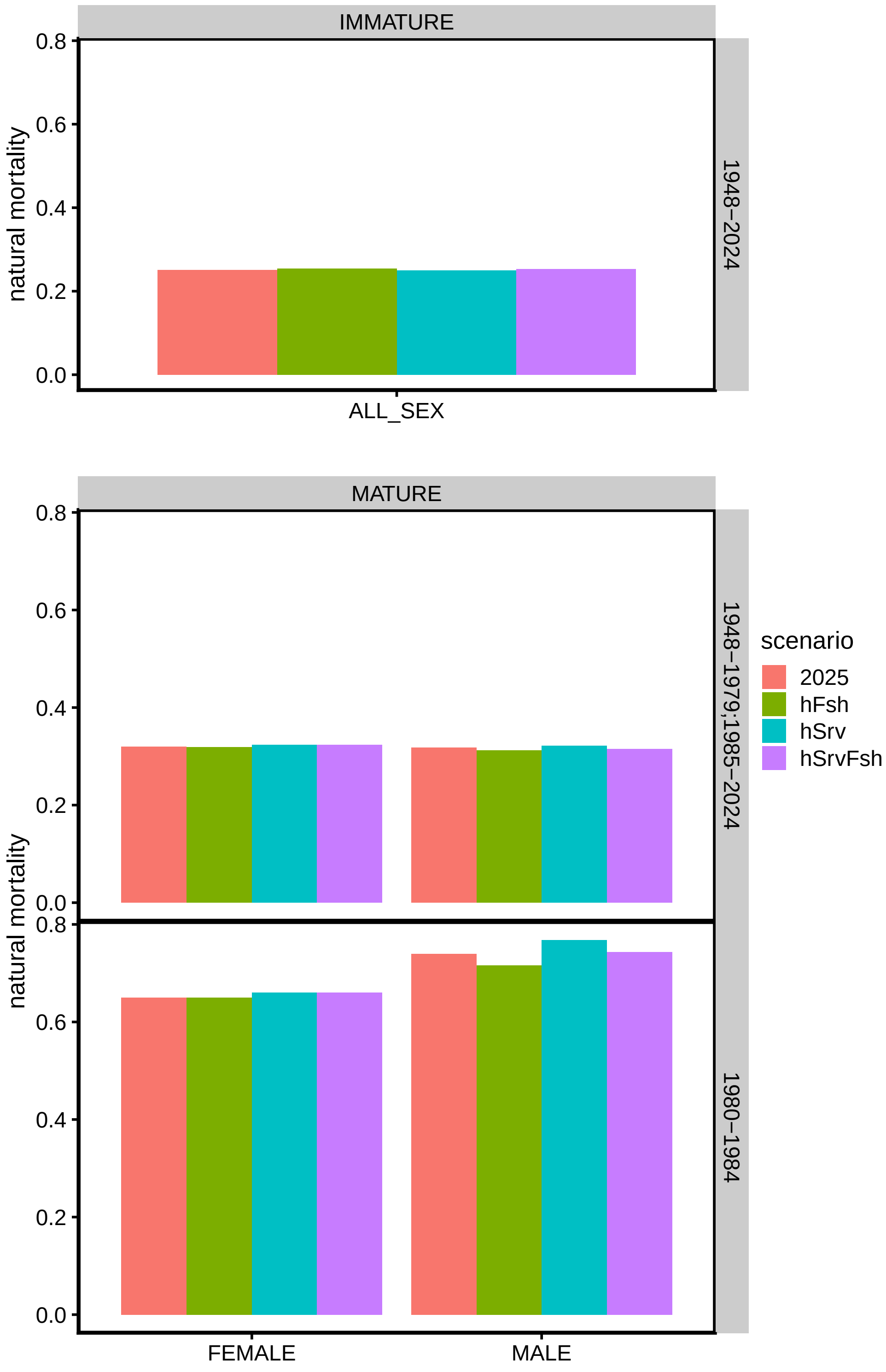


Figure 40. Comparison of natural mortality from the 2025 assessment model ("2025") and the models with hybrids data included ("hSrv": in survey data, "hFsh": in fishery data, "hSrvFsh": in both). Upper plot: immature crab. Lower plot: mature crab, by sex, in the "heighted mortality" period in early 1980s and in the remainder of the model time perdiod.

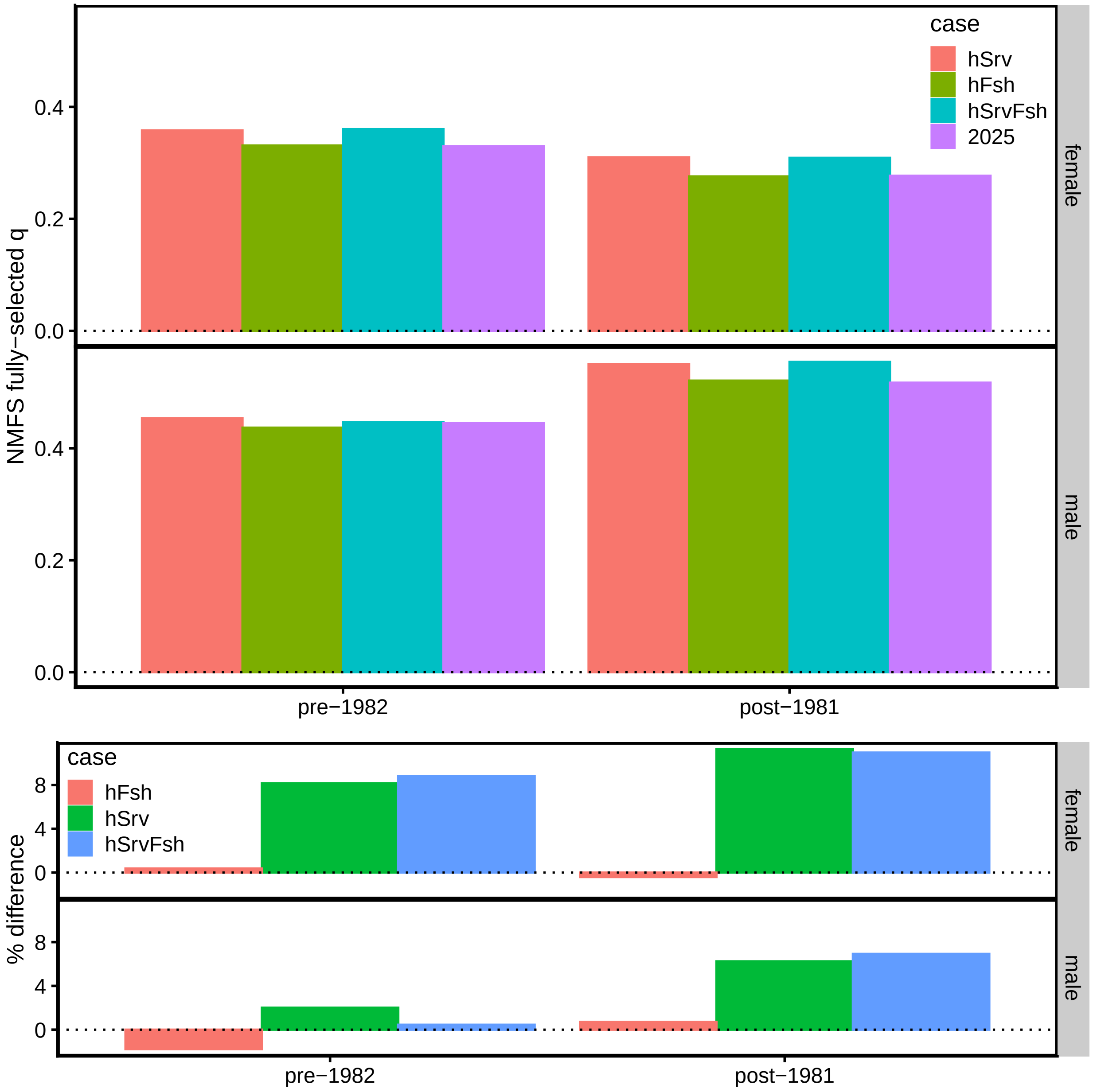


Figure 41. Comparison of fully-selected catchability in the NMFS surveyfrom the 2025 assessment model ("2025") and the models with hybrids data included ("hSrv": in survey data, "hFsh": in fishery data, "hSrvFsh": in both).Upper plot: estimated values for 1975-1981 and 1982-2025 by sex; lower plot: % differences. Positive values indicate the base case value is less than the corresponding scenario value.

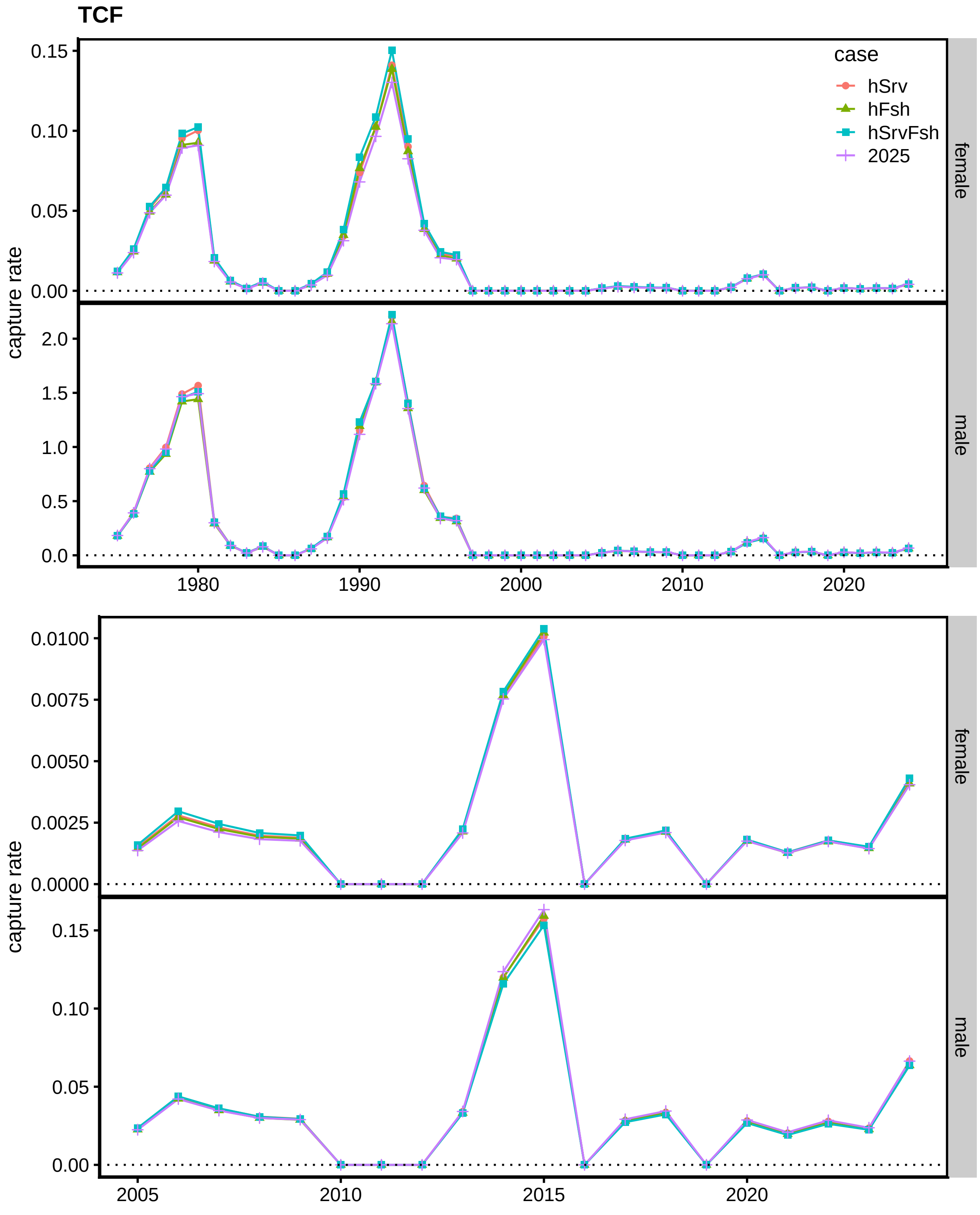


Figure 42. Comparison of fully-selected fishery capture rates in the directed fishery from the 2025 assessment model ("2025") and the models with hybrids data included ("hSrv": in survey data, "hFsh": in fishery data, "hSrvFsh": in both) Upper two plots: by sex starting in 1975; lower two plots: by sex starting in 2005.

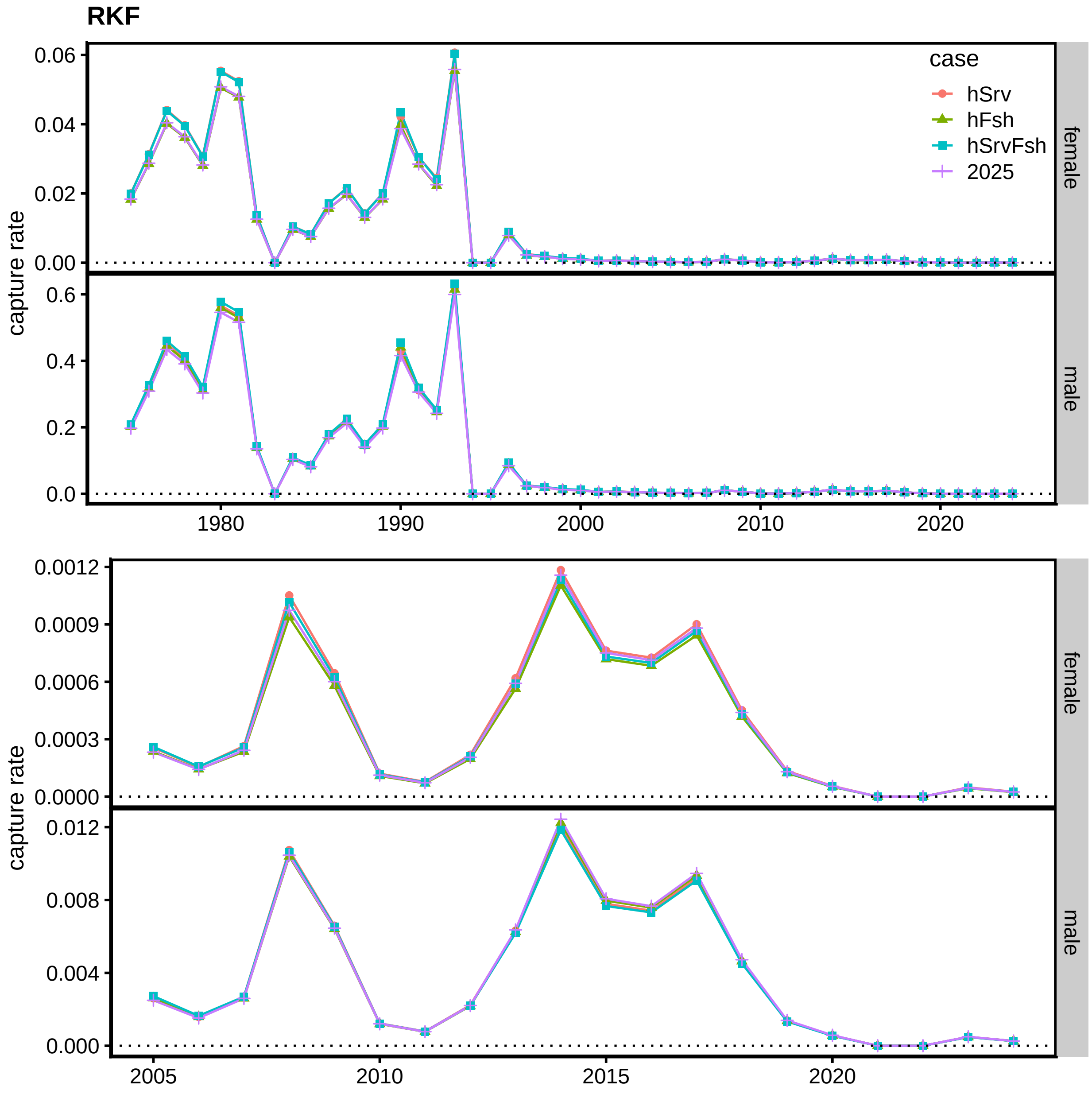


Figure 43. Comparison of fully-selected fishery capture rates in the BBRKC fishery from the 2025 assessment model (“2025”) and the models with hybrids data included (“hSrv”: in survey data, “hFsh”: in fishery data, “hSrvFsh”: in both) Upper two plots: by sex starting in 1975; lower two plots: by sex starting in 2005.

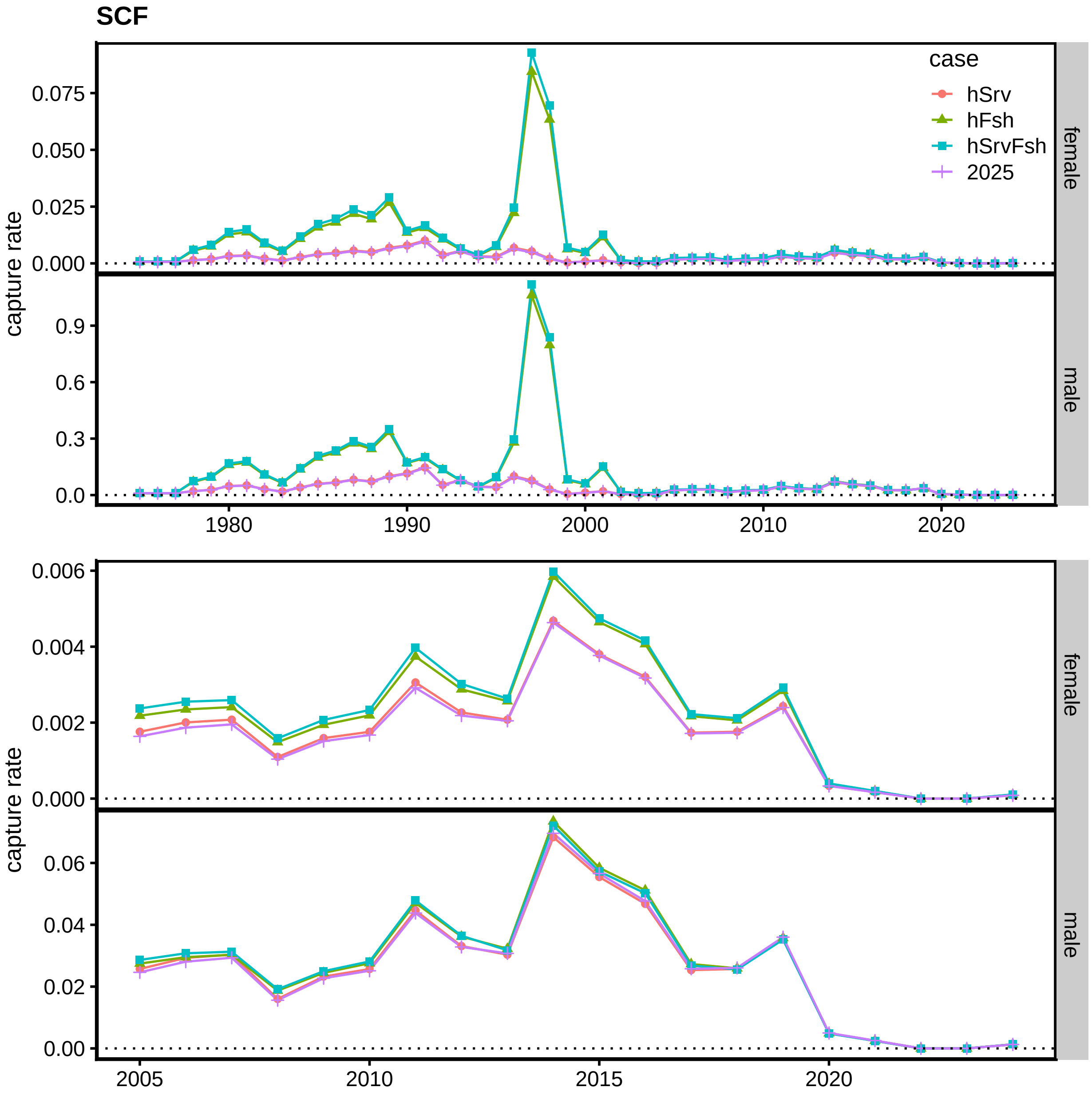


Figure 44. Comparison of fully-selected fishery capture rates in the snow crab fishery from the 2025 assessment model (“2025”) and the models with hybrids data included (“hSrv”: in survey data, “hFsh”: in fishery data, “hSrvFsh”: in both) Upper two plots: by sex starting in 1975; lower two plots: by sex starting in 2005.

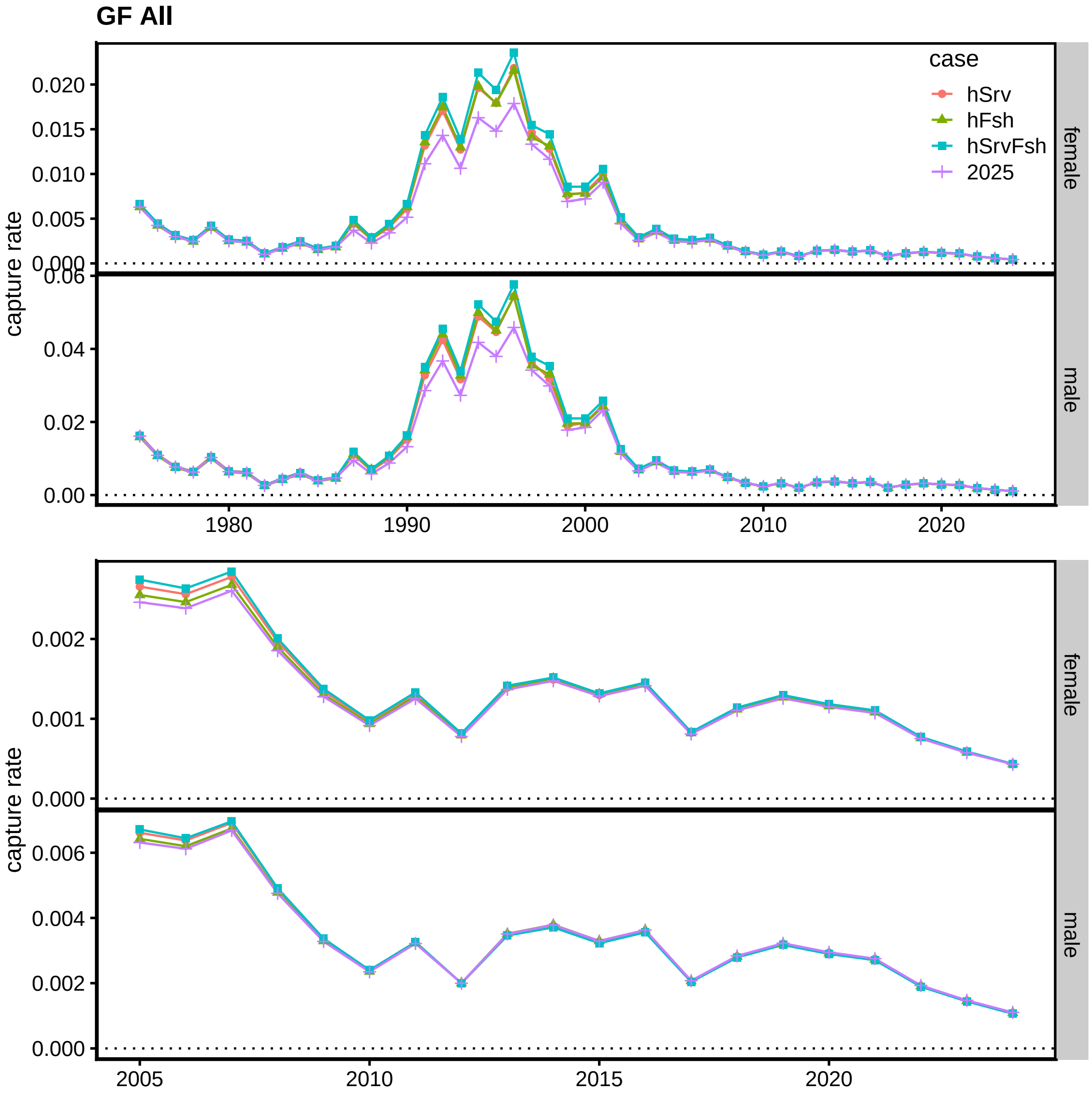


Figure 45. Comparison of fully-selected fishery capture rates in the groundfish fisheries from the 2025 assessment model (“2025”) and the models with hybrids data included (“hSrv”: in survey data, “hFsh”: in fishery data, “hSrvFsh”: in both) Upper two plots: by sex starting in 1975; lower two plots: by sex starting in 2005.

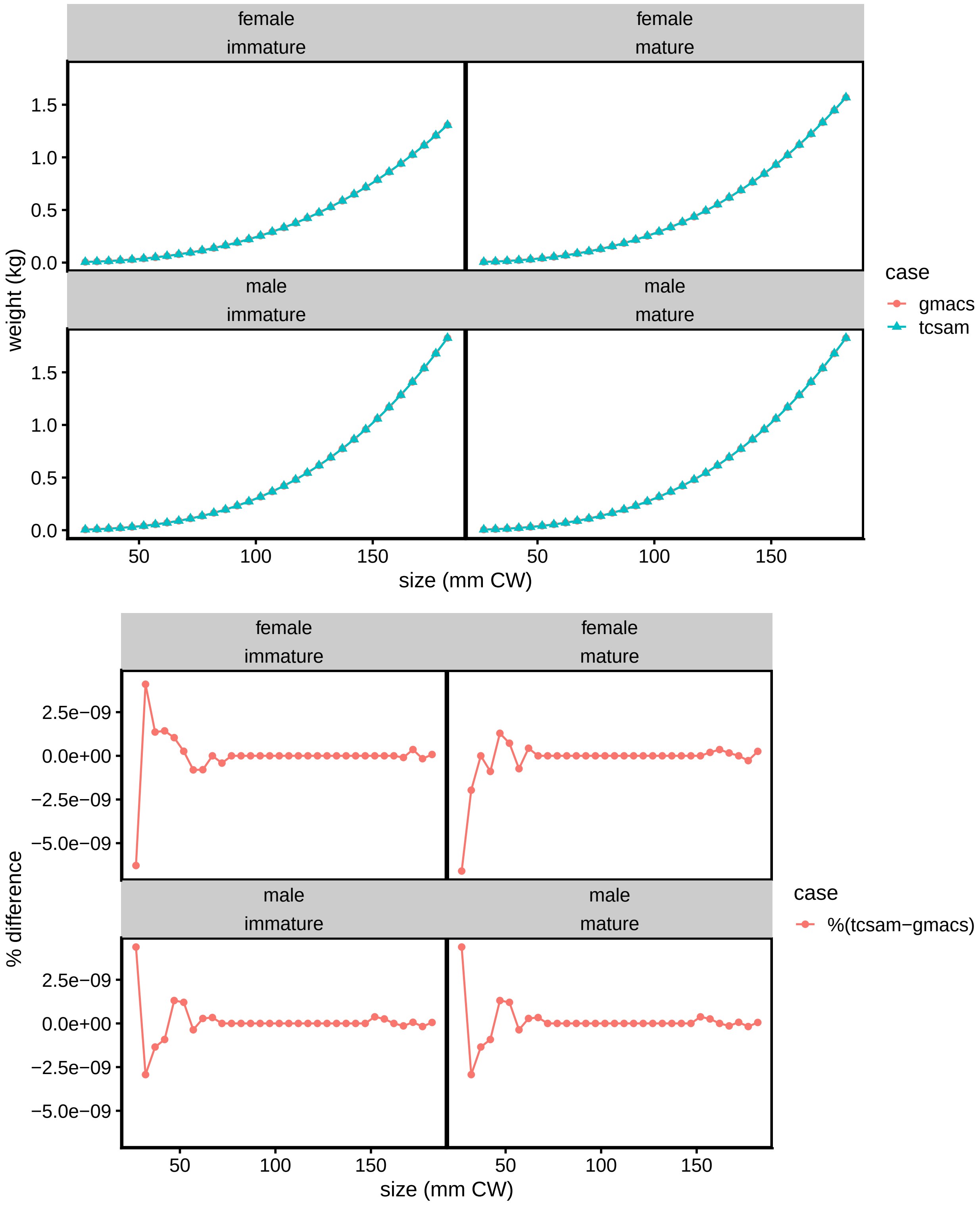


Figure 46. Comparison of weights-at-size used in the GMACS and TCSAM02 models by biological category. Upper: values overlaid; lower: percent differences.

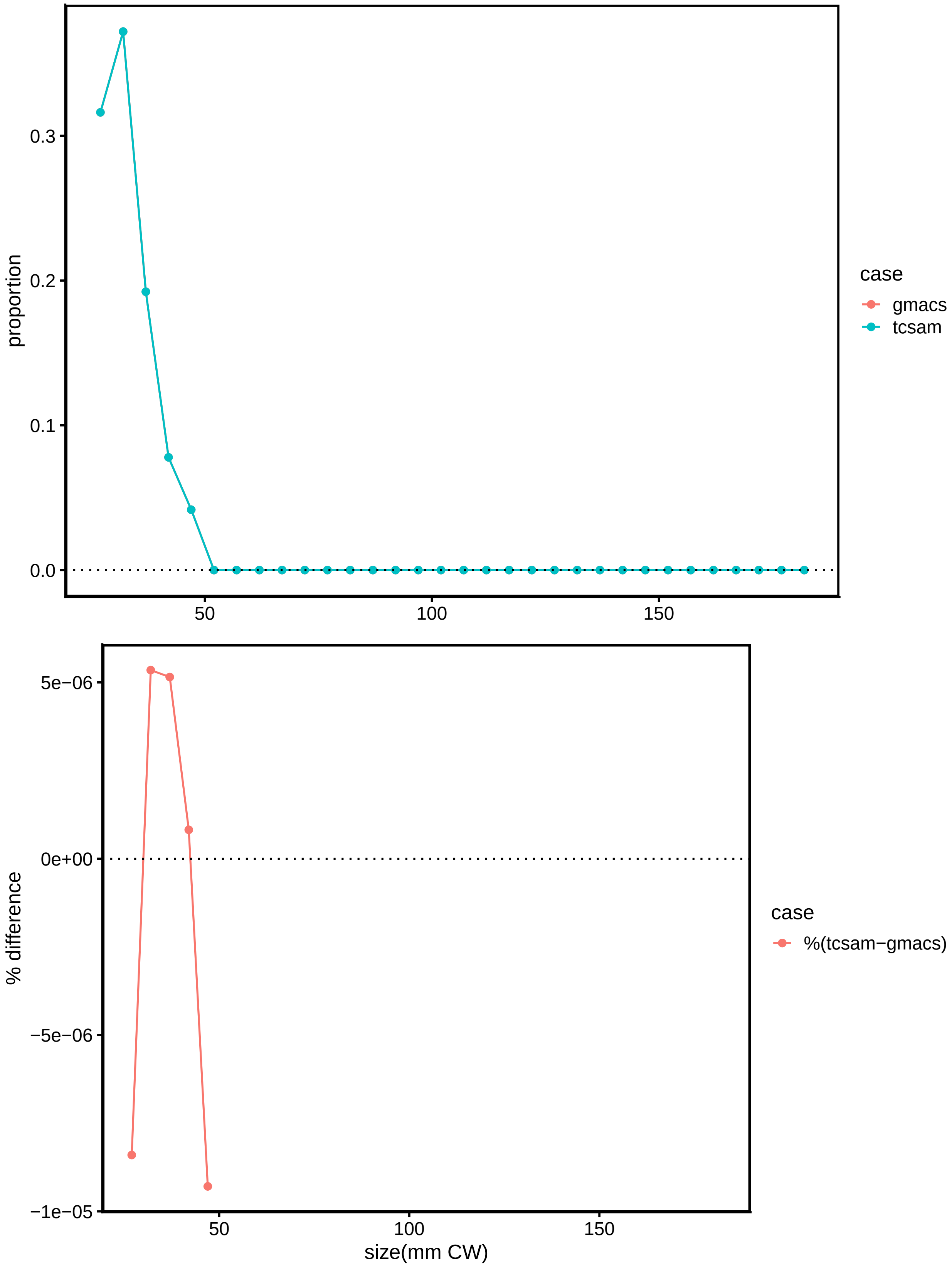


Figure 47. Comparison of size-at-recruitment from the GMACS and TCSAM02 models. Upper: values; lower: percent differences. The size distribution at recruitment is not sex-specific.

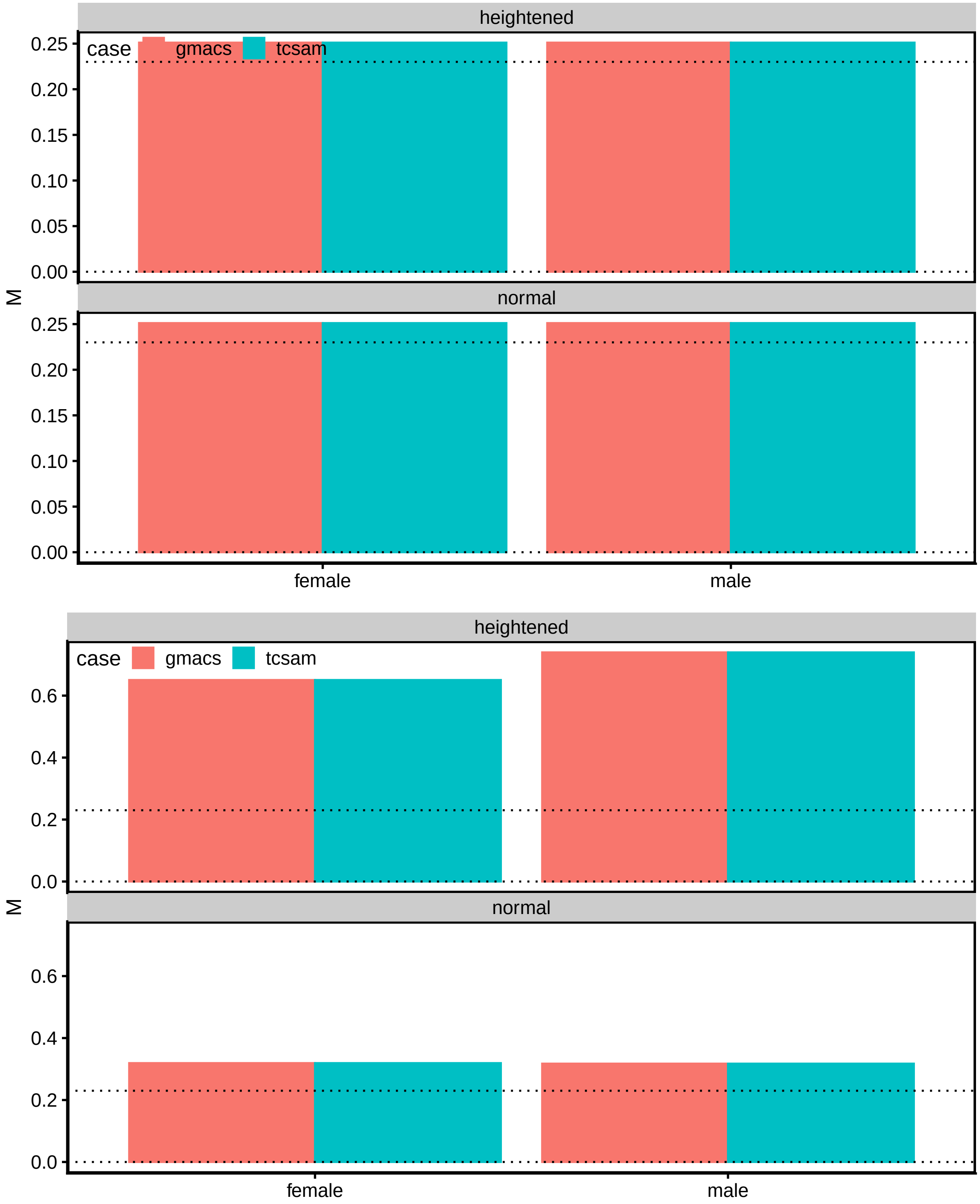


Figure 48. Natural mortality rates (M) used in the GMACS and TCSAM02 models, by biological category. Upper: immature crab; lower: mature crab. “heightened”: 1980-1984 time period; “normal”: remaining time period.

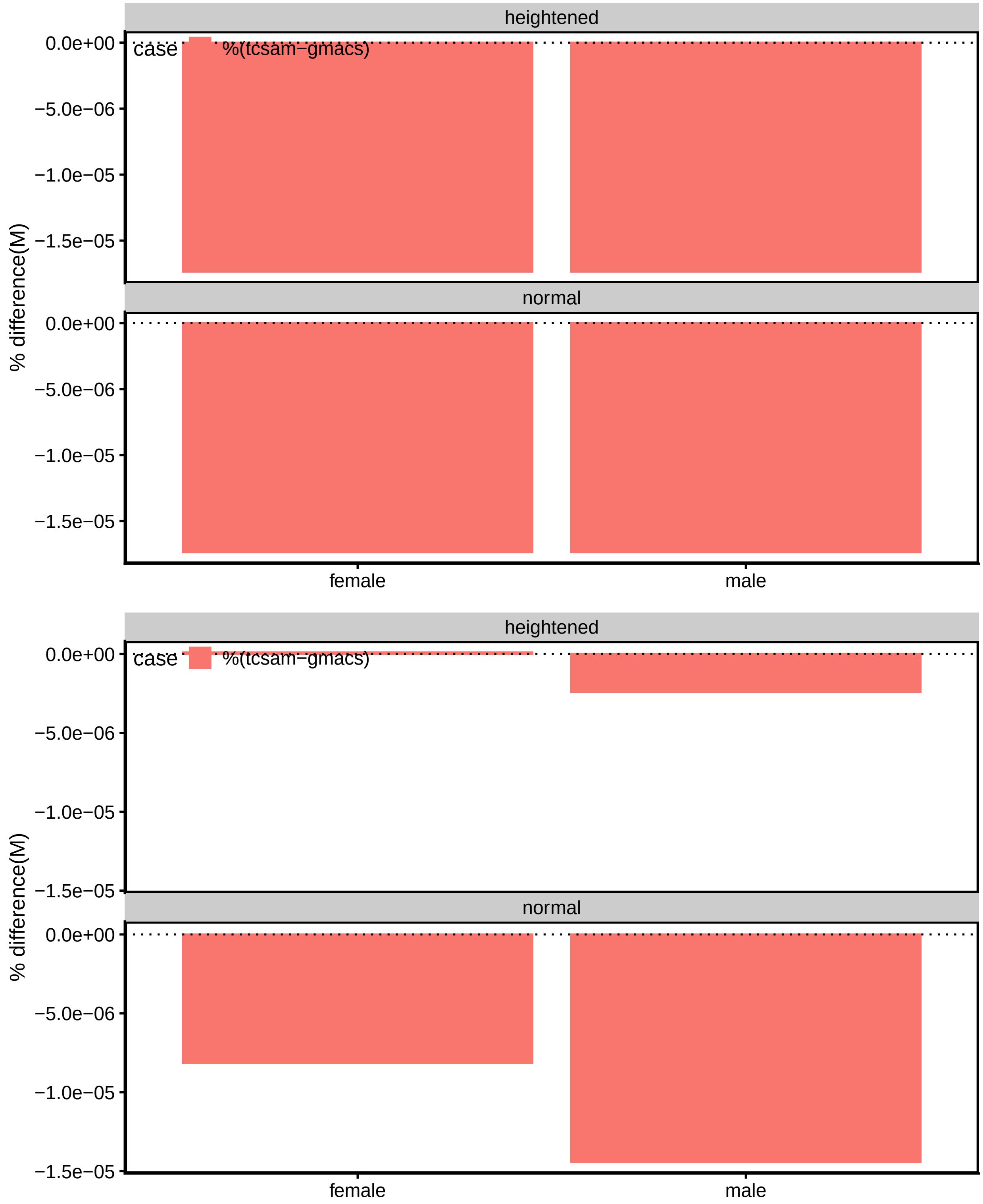


Figure 49. Percent difference in natural mortality rates (M) used in the GMACS and TCSAM02 models, by biological category. Upper: immature crab; lower: mature crab. “heightened”: 1980-1984 time period; “normal”: remaining time period.

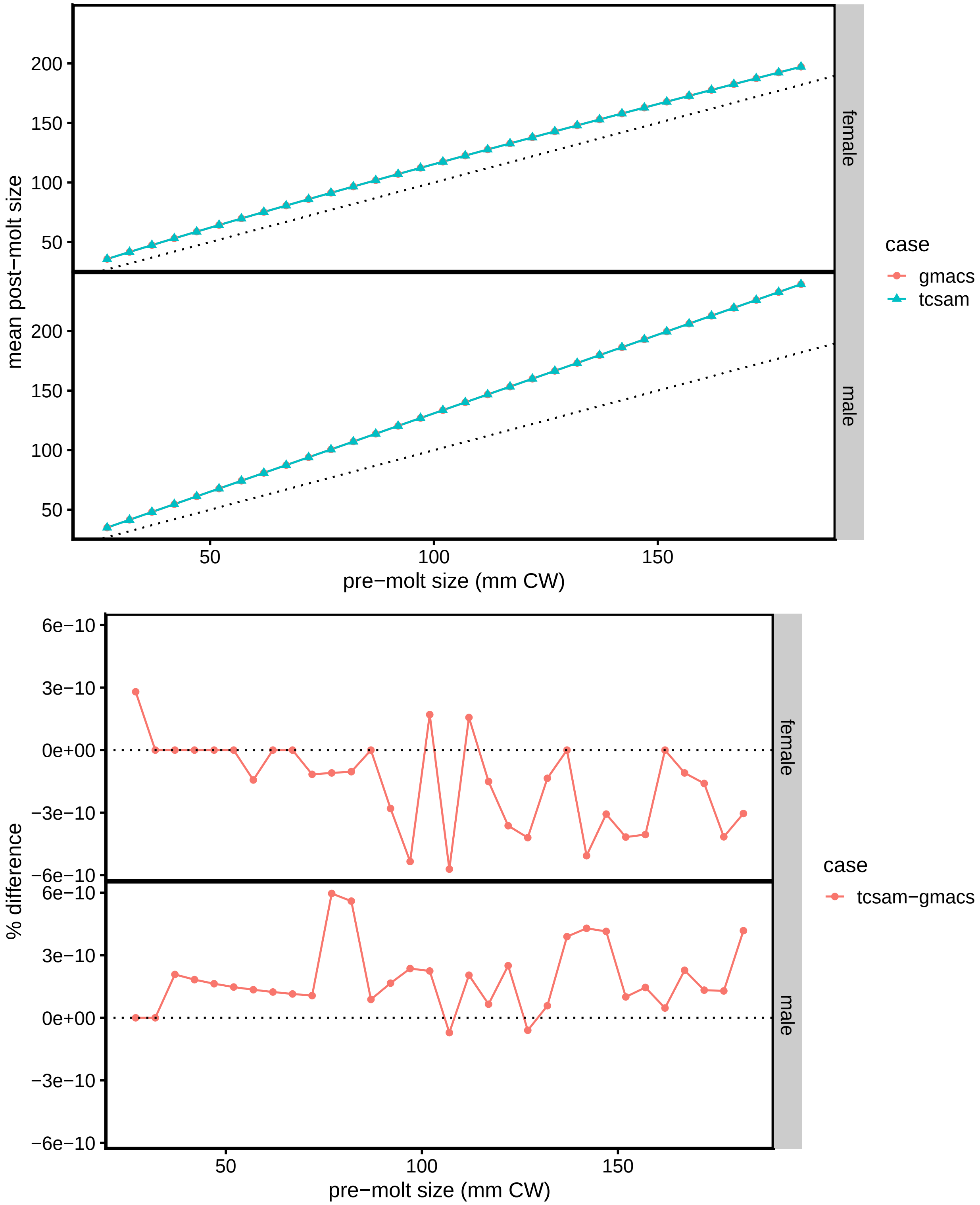


Figure 50. Mean postmolt size, as a function of premolt size, used in the GMACS and TCSAM02 models, by sex. Upper: values; lower: percent difference.

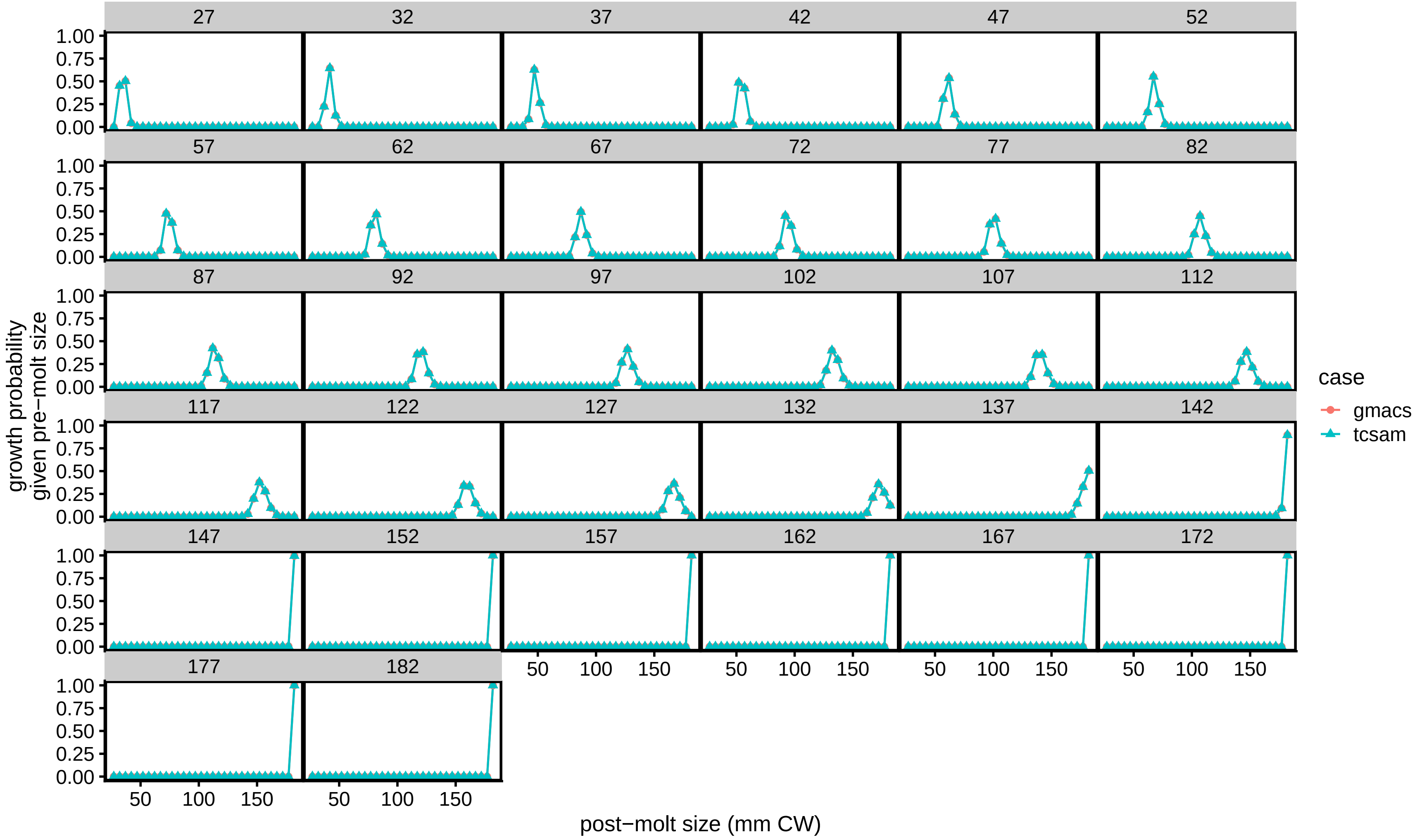


Figure 51. Distribution of postmolt sizes, as a function of premolt size, used in the GMACS and TCSAM02 models for males.

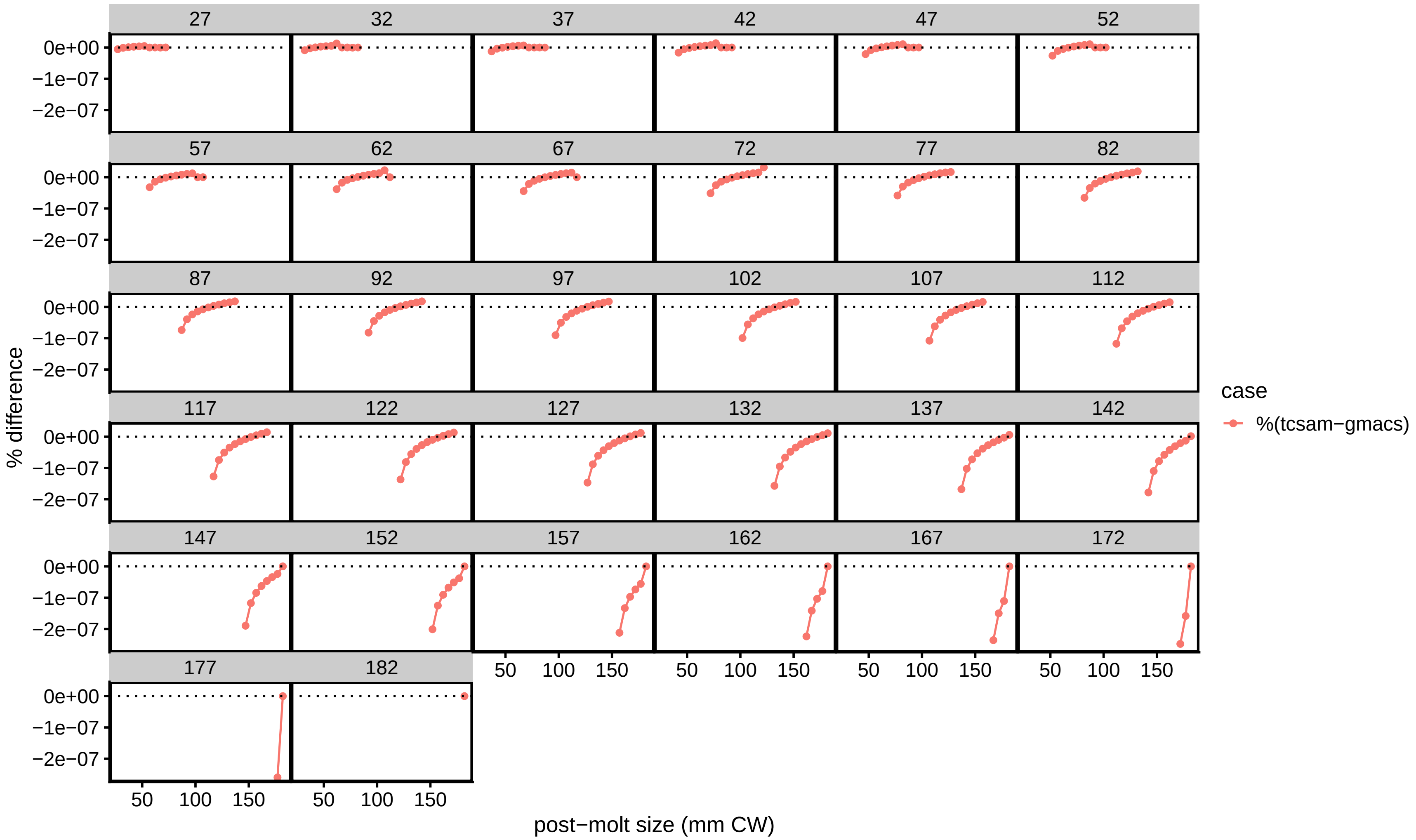


Figure 52. Percent difference in the distribution of postmolt sizes, as a function of premolt size, used in the GMACS and TCSAM02 models for males.

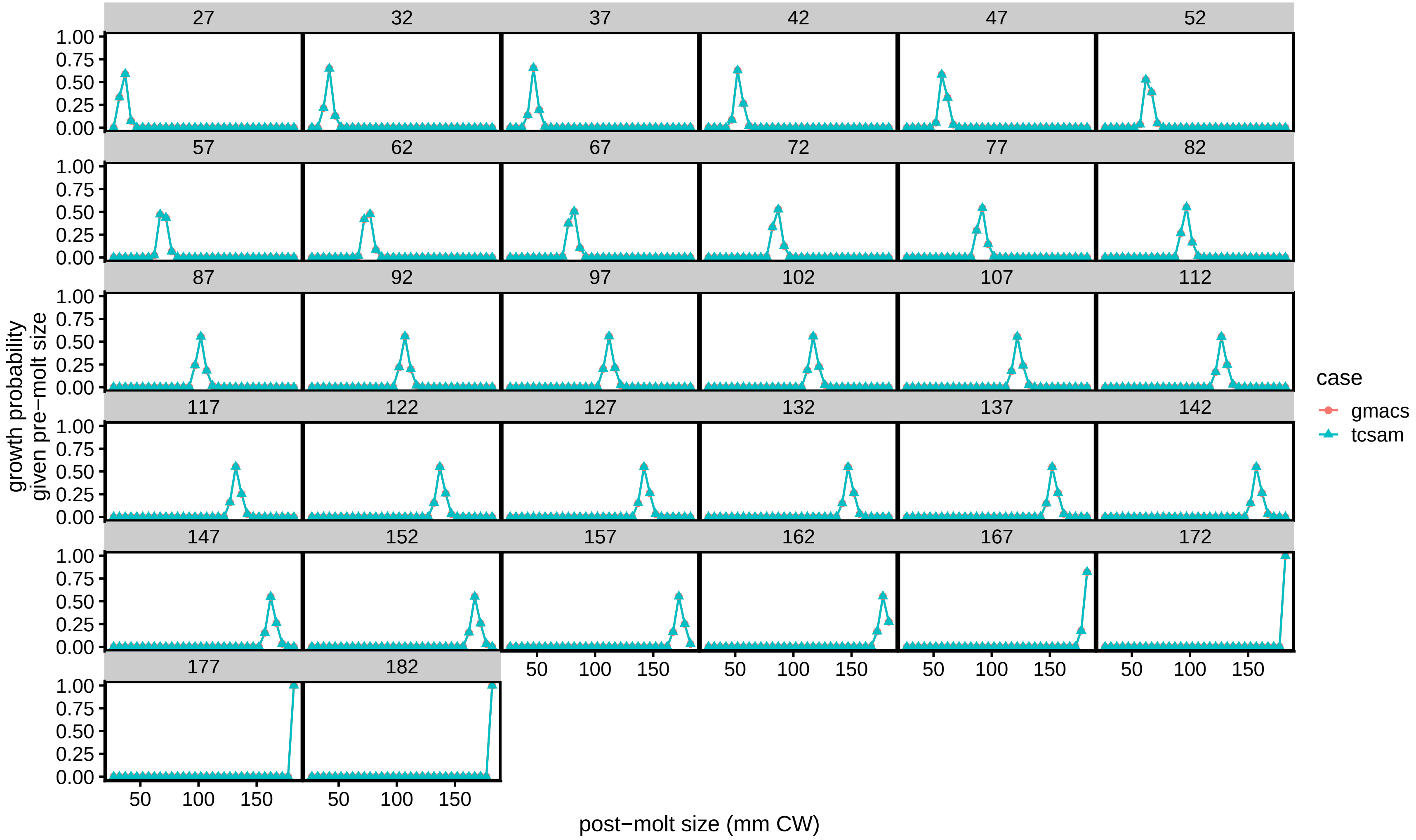


Figure 53. Distribution of postmolt sizes, as a function of premolt size, used in the GMACS and TCSAM02 models for females.

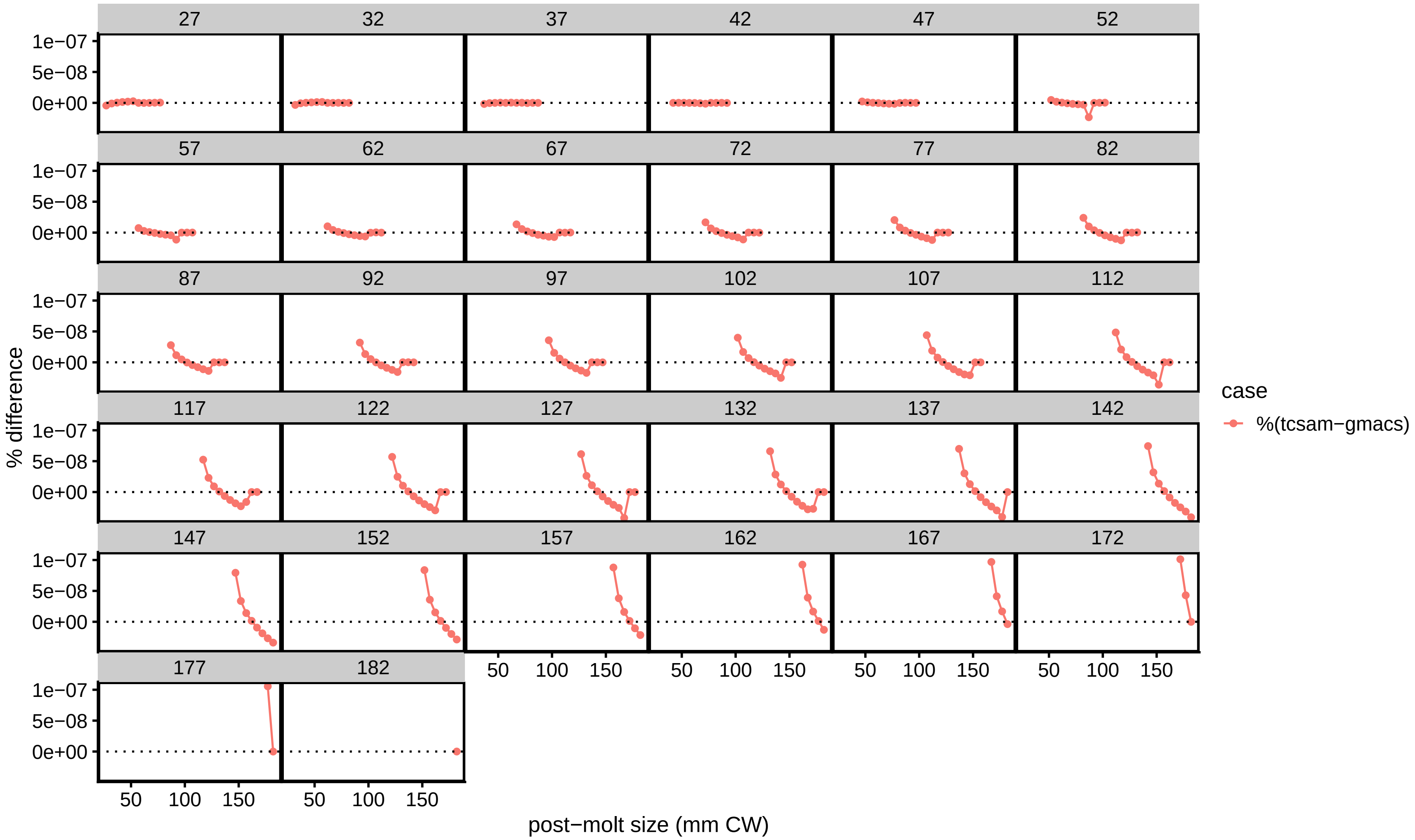


Figure 54. Percent difference in the distribution of postmolt sizes, as a function of premolt size, used in the GMACS and TCSAM02 models for females.

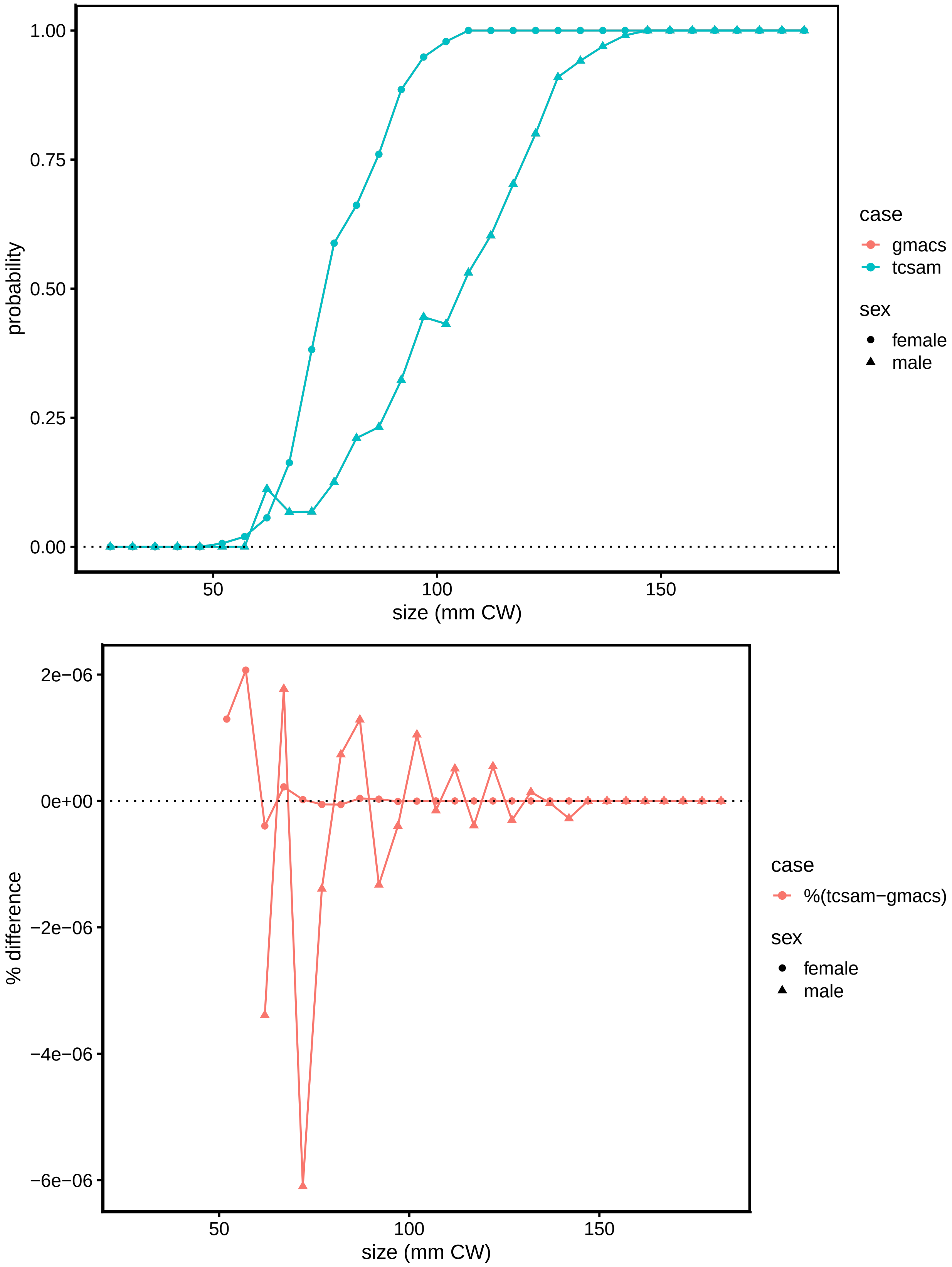
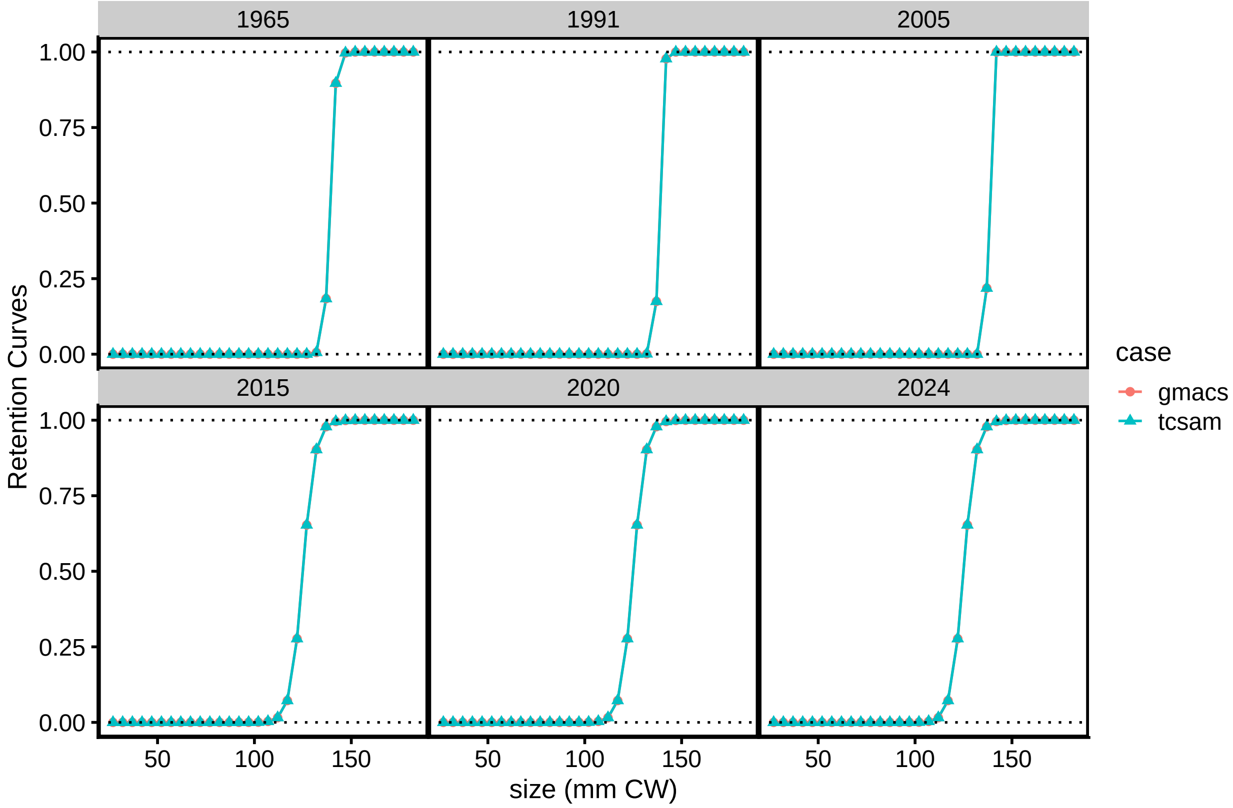


Figure 55. Comparison of the probability of terminal molt used in the GMACS and TCSAM02 models, by sex. Upper: values; lower: percent differences.



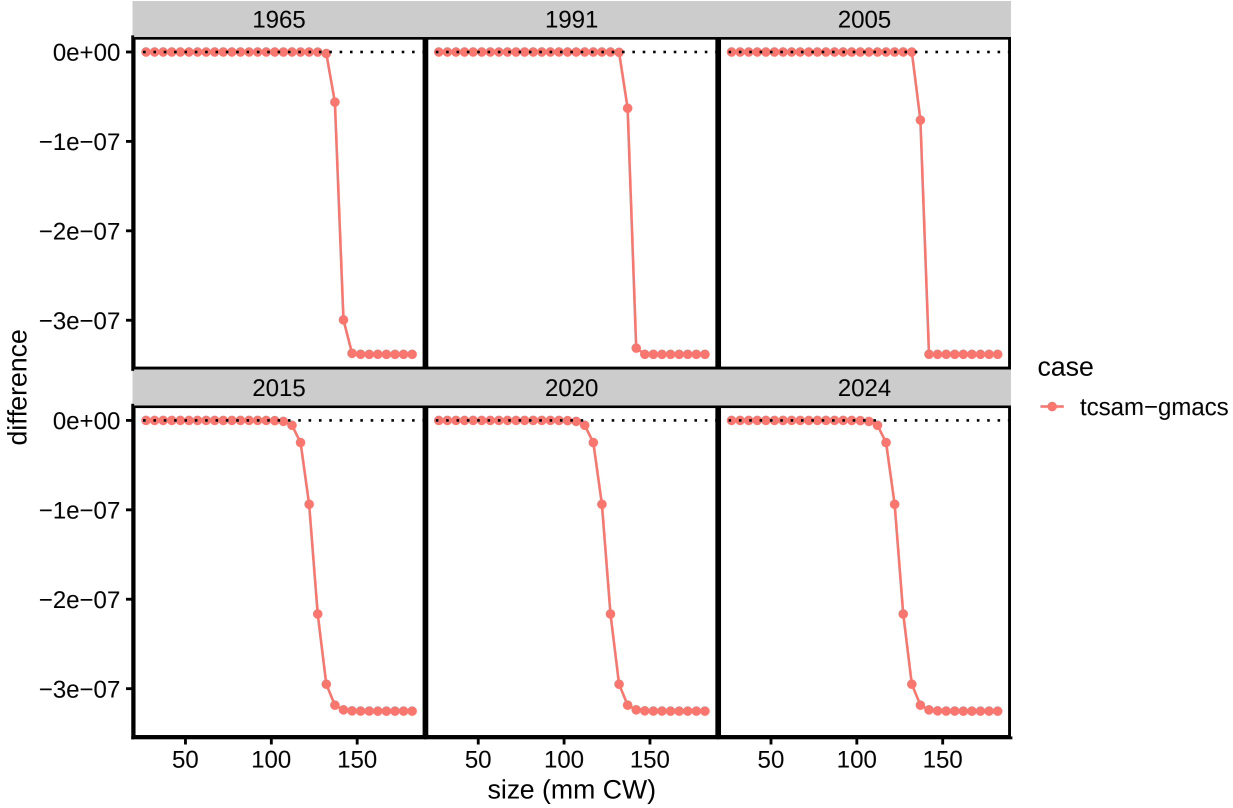


Figure 56. Comparison of the fishery retention curves used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences.

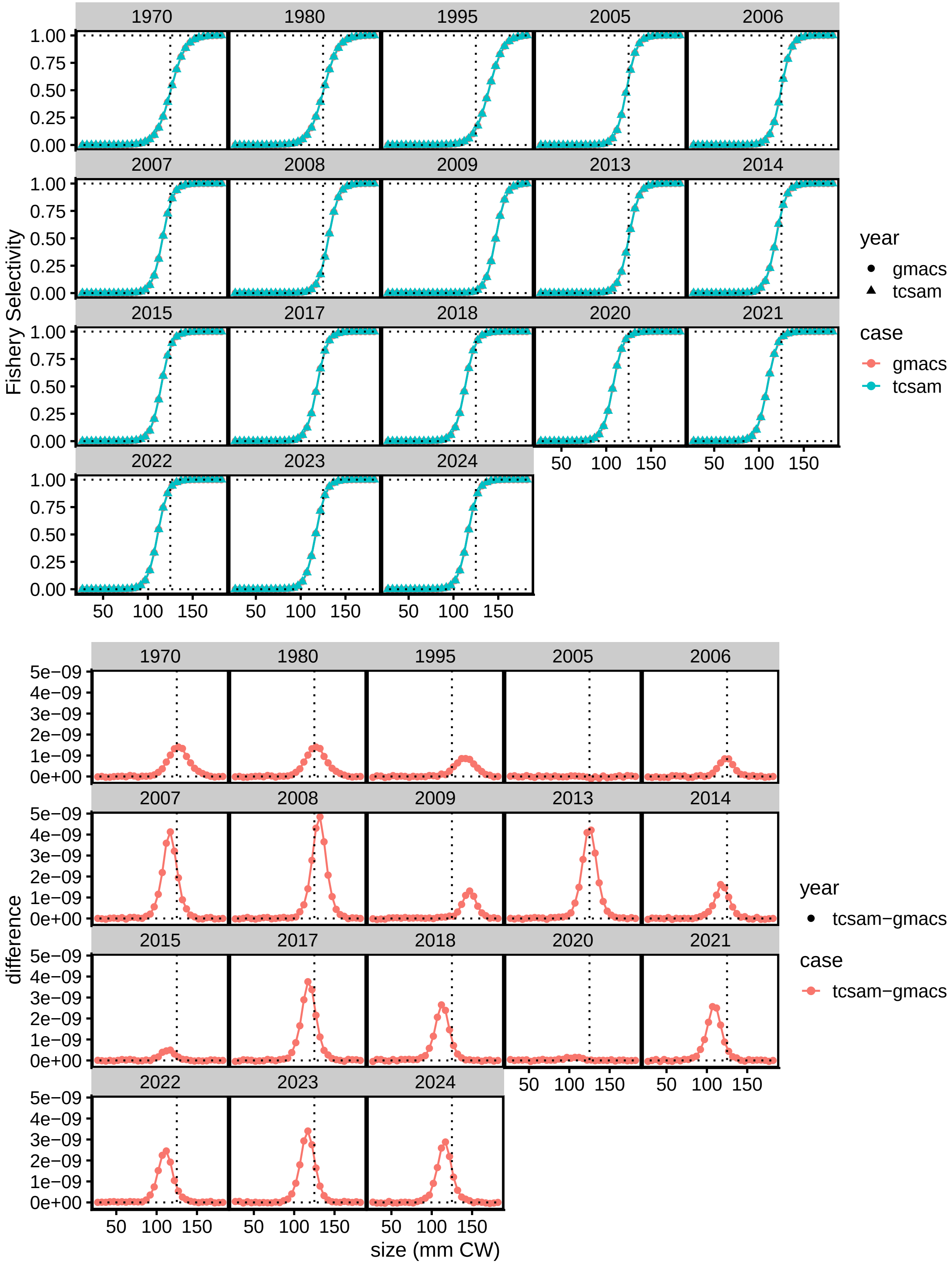


Figure 57. Comparison of the fishery selectivity curves for males in the directed fishery as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences. The dotted line at 125 mm CW provides a reference point to the current industry-preferred size.

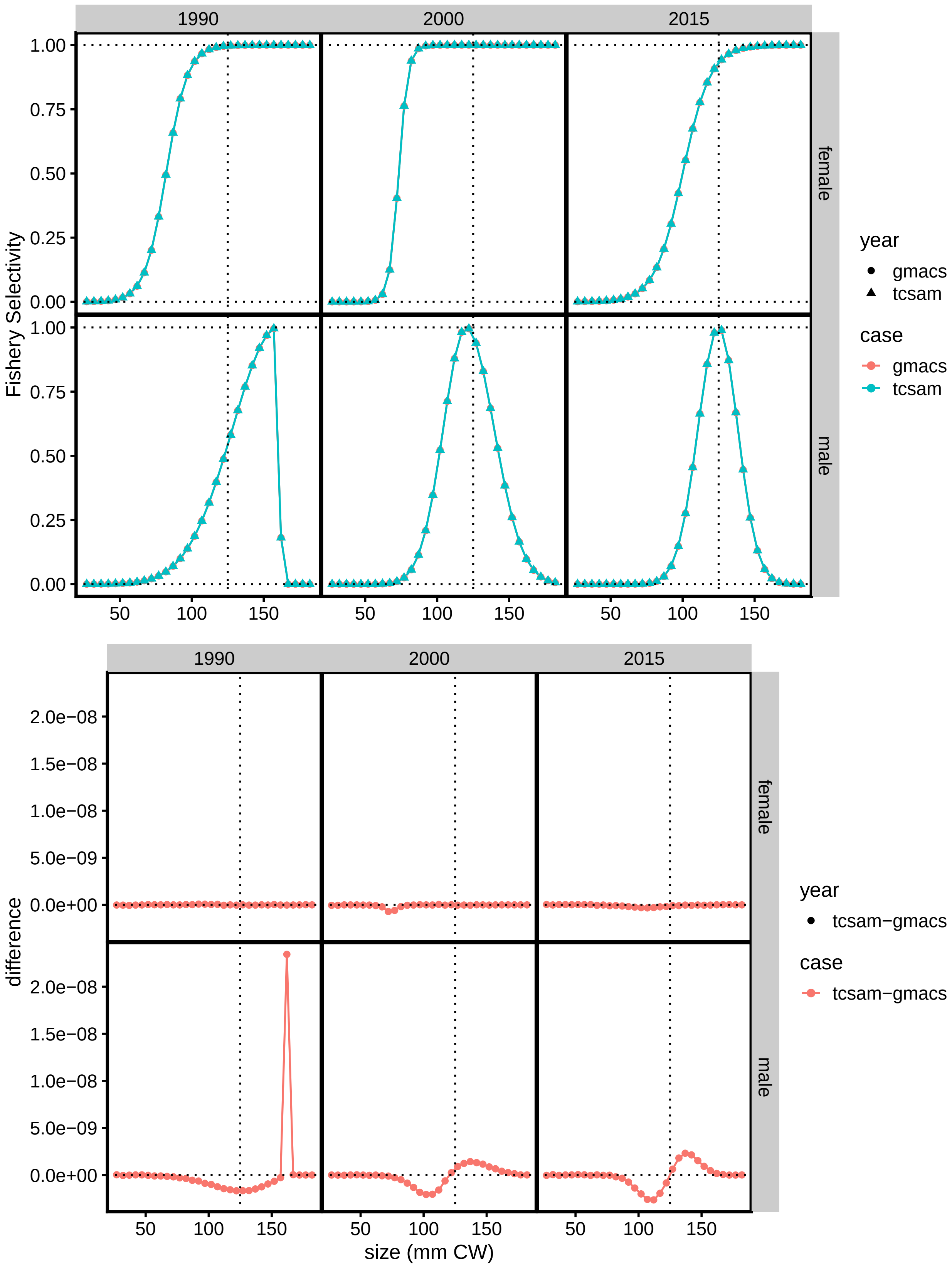


Figure 58. Comparison of the fishery bycatch selectivity curves by sex in the snow crab fishery as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences. The dotted line at 125 mm CW provides a reference point to the current industry-preferred size.

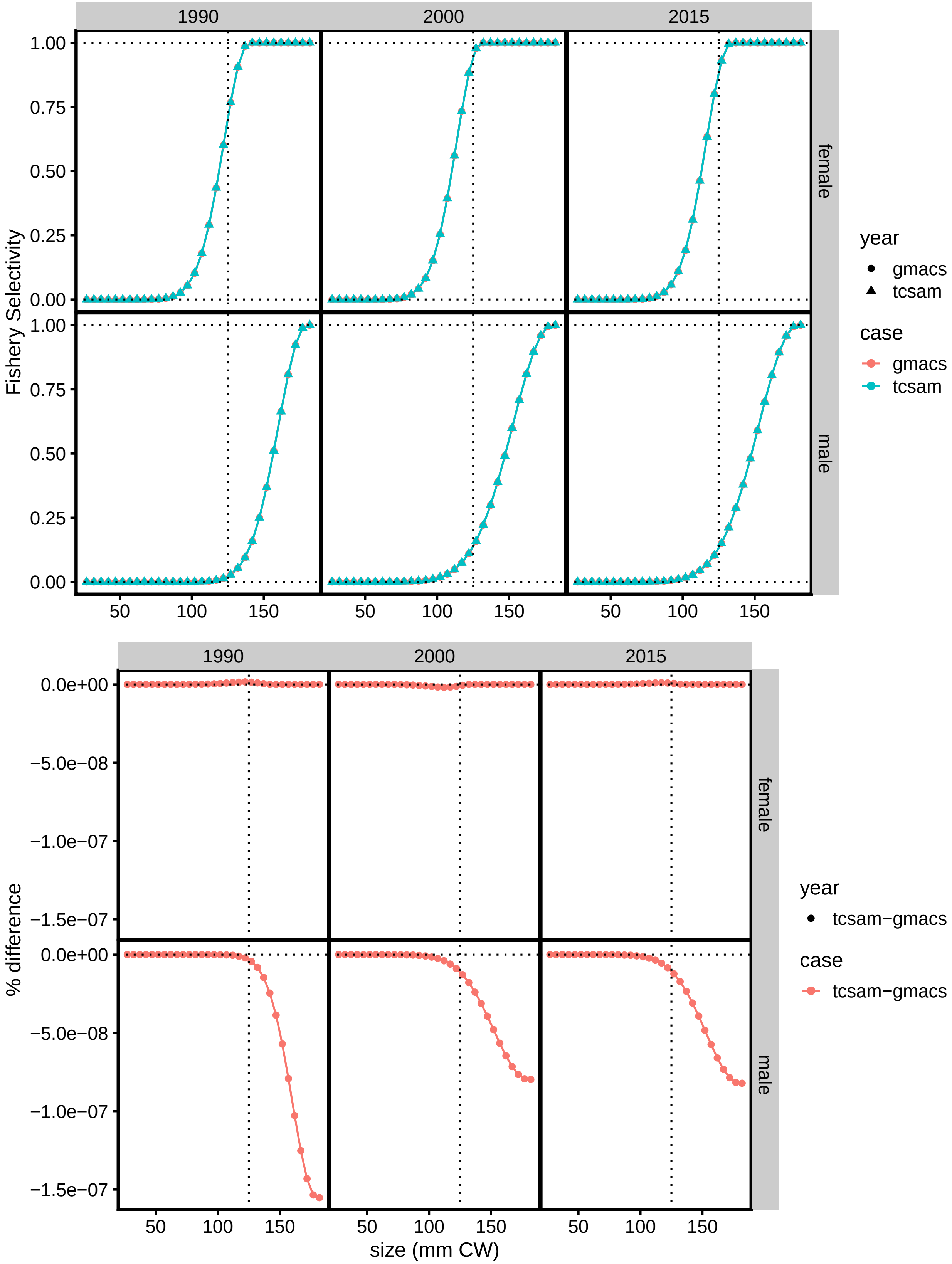


Figure 59. Comparison of the fishery bycatch selectivity curves by sex in the BBRKC fishery as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences. The dotted line at 125 mm CW provides a reference point to the current industry-preferred size.

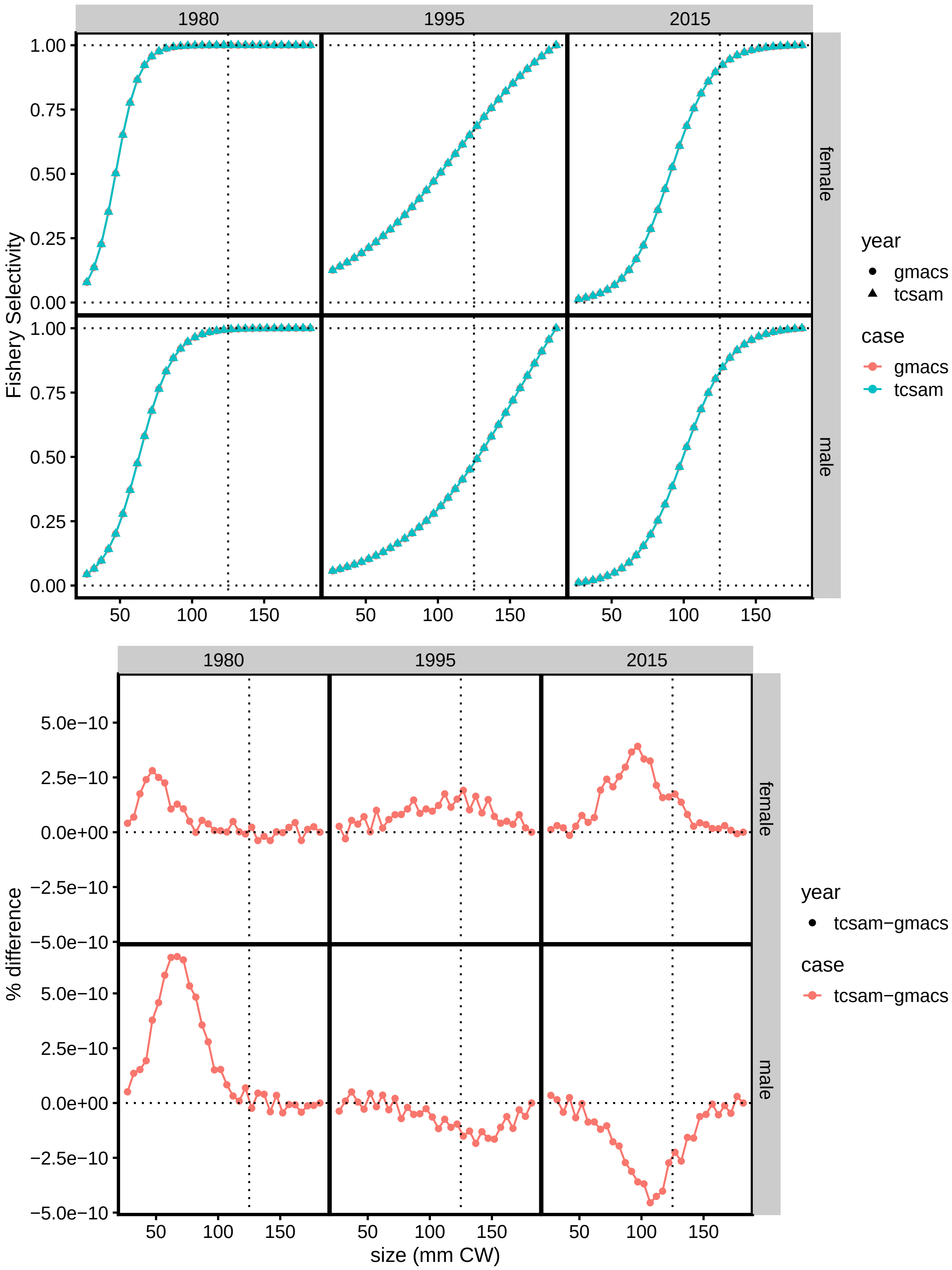


Figure 60. Comparison of the fishery bycatch selectivity curves by sex in the groundfish fisheries as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences. The dotted line at 125 mm CW provides a reference point to the current industry-preferred size.

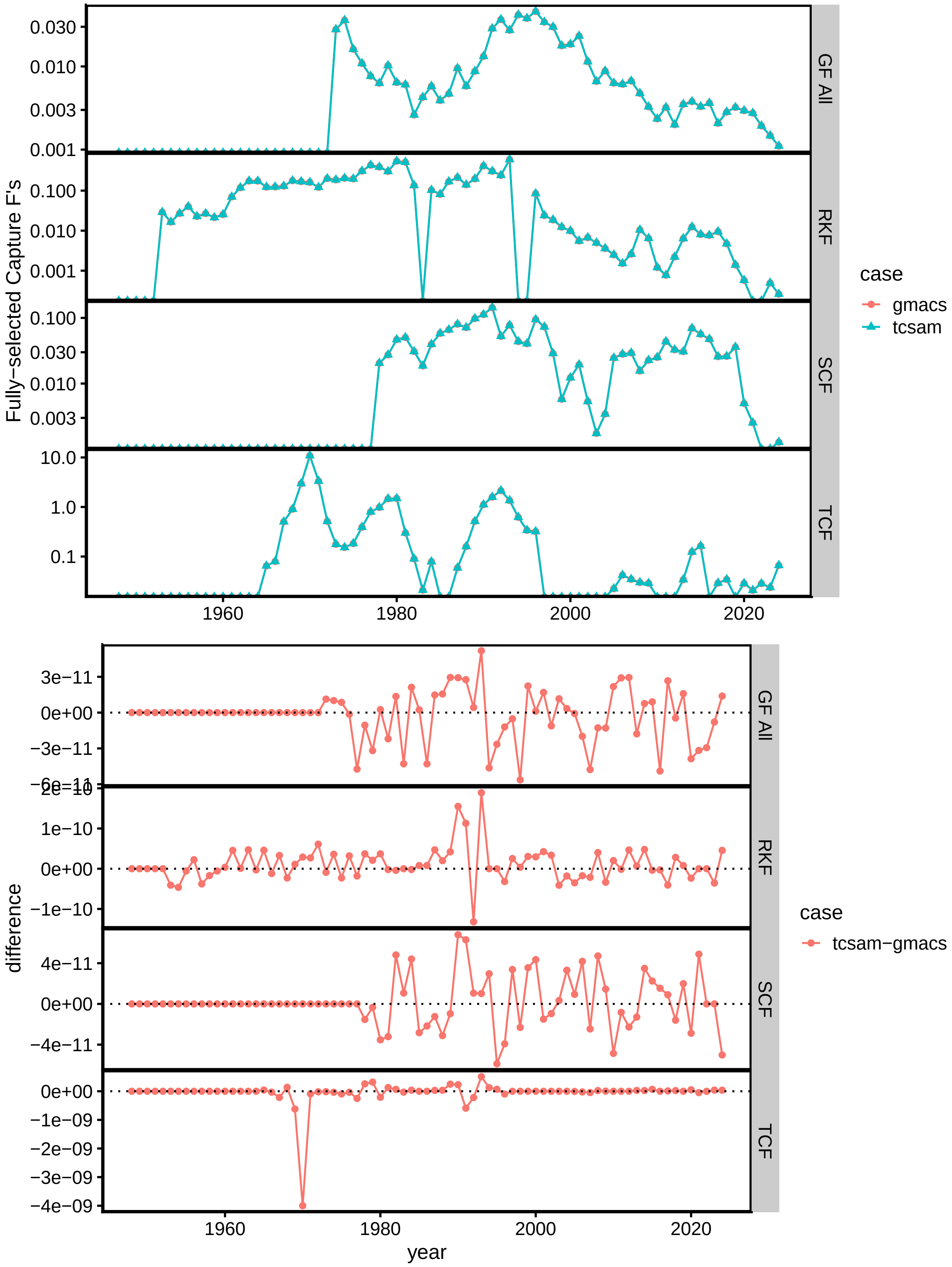


Figure 61. Comparison of the fully-selected fishery capture rates for males in the directed and bycatch fisheries as used in the GMACS and TCSAM02 models. Upper: values on log scale; lower: differences. TCF: directed Tanner crab fishery; SCF: snow crab fishery, RKF: BBRKC fishery; GF All: groundfish fisheries. Capture rates before 1990 in the snow crab and BBRKC fisheries are based on effort extrapolation. Capture rates for females (plots not shown) are propotional to those for males.

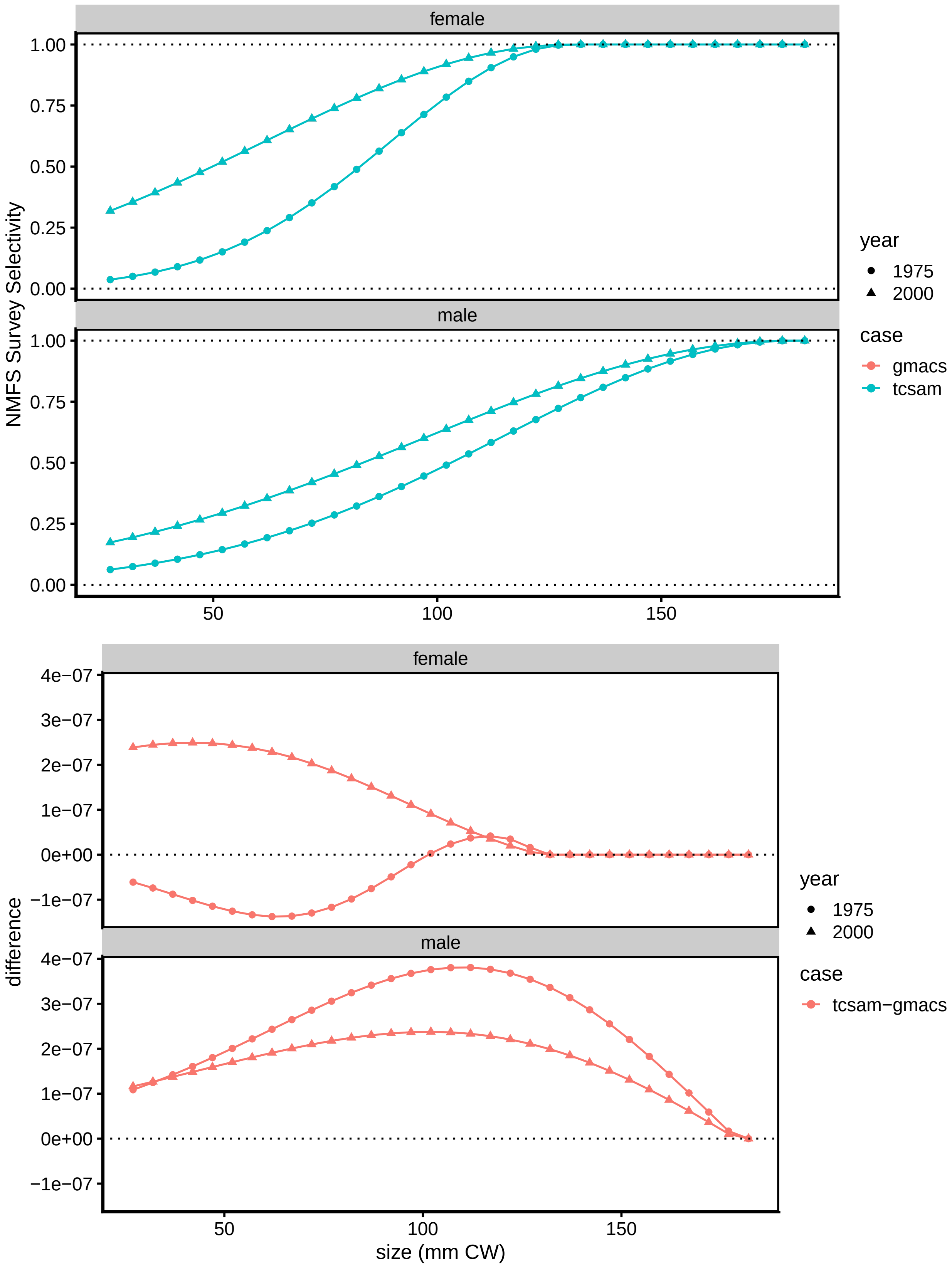


Figure 62. Comparison of the NMFS survey selectivity curves by sex as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences.

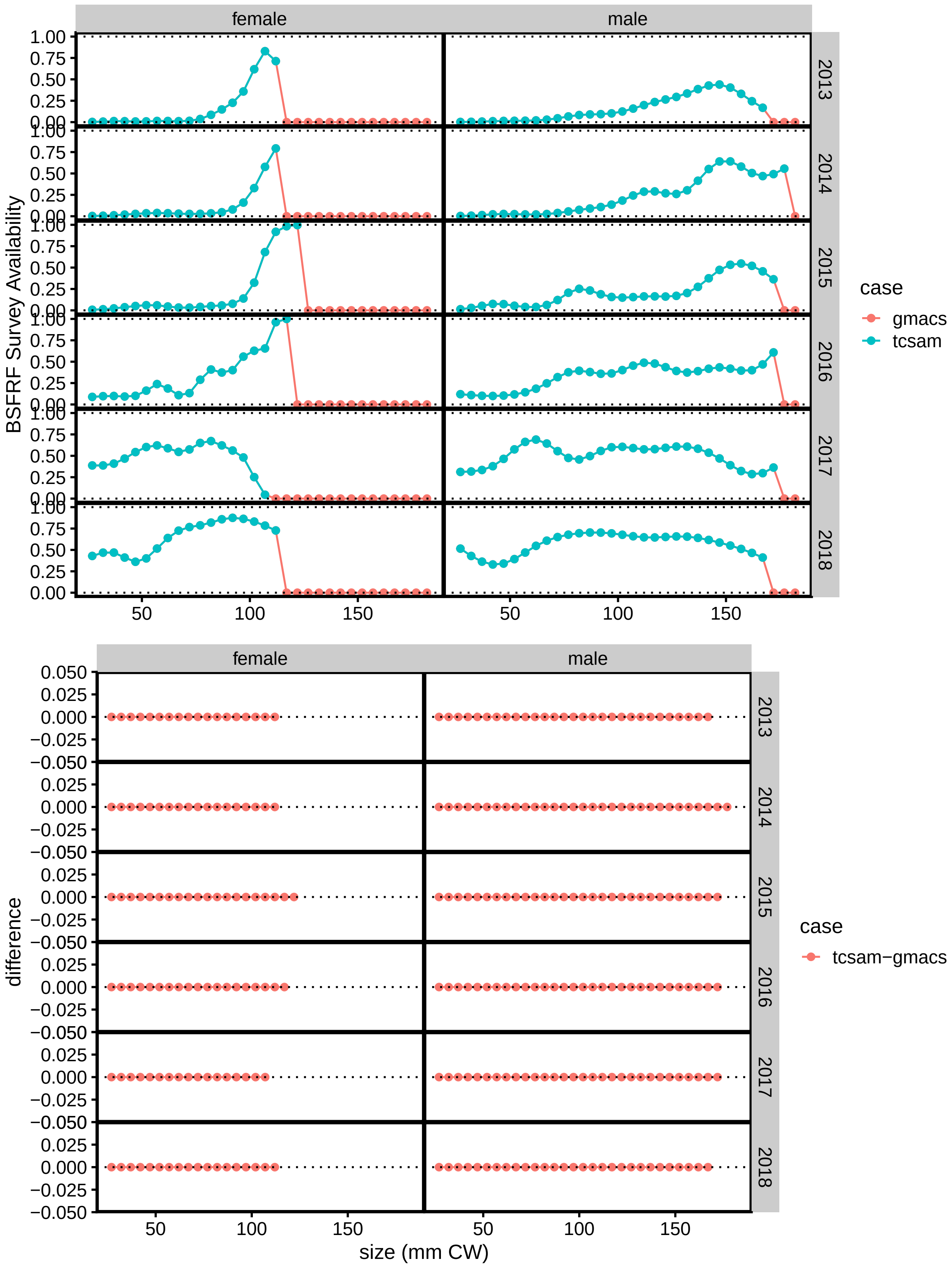


Figure 63. Comparison of the BSFRF survey availability curves by sex as used in the GMACS and TCSAM02 models. Upper: values for selected years; lower: differences.

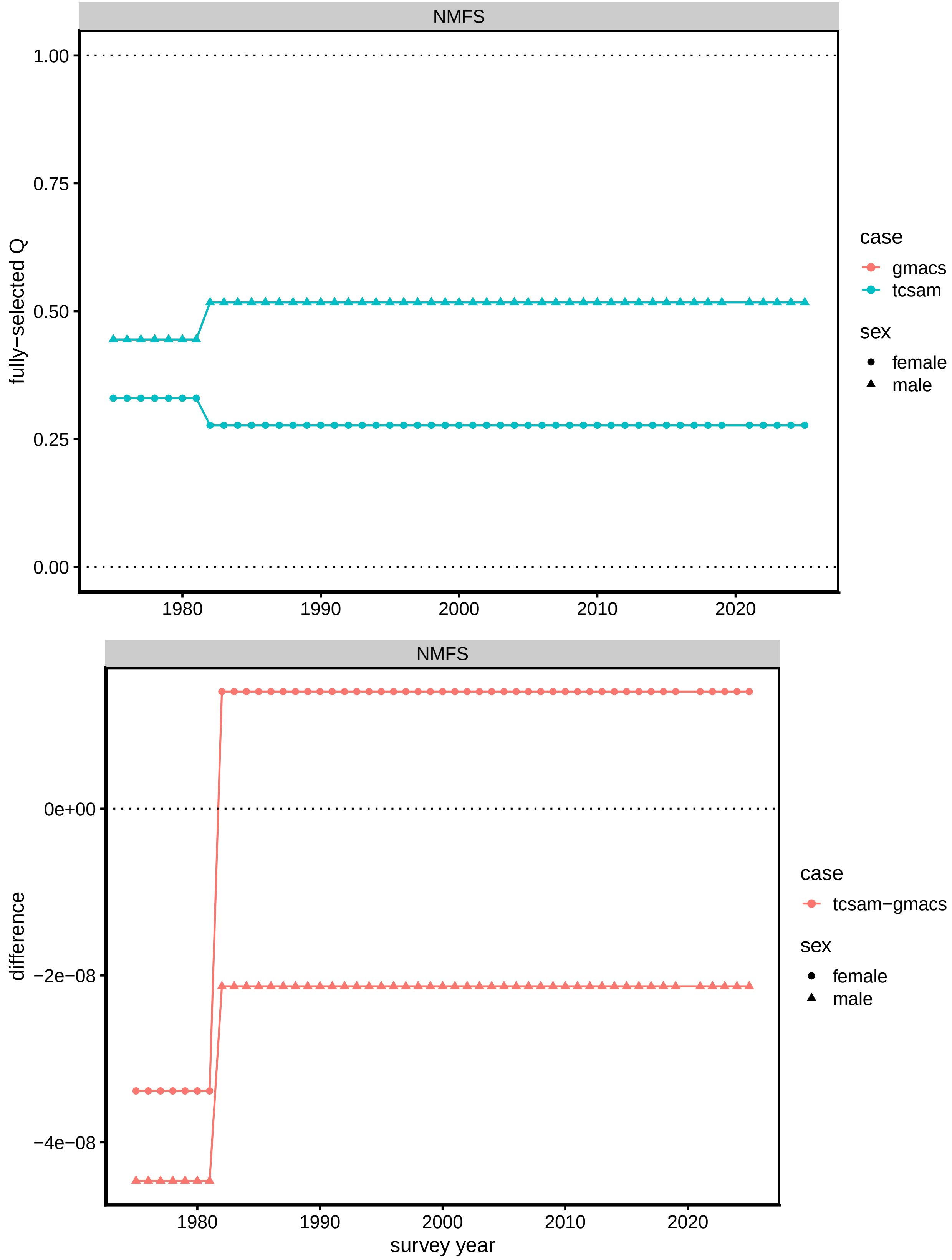


Figure 64. Comparison of fully-selected survey catchability ('q') for the NMFS survey by sex and year as used in the GMACS and TCSAM02 models. Upper: values; lower: differences. Fully-selected q's for the BSFRF surveys are 1 in both models and are not shown.

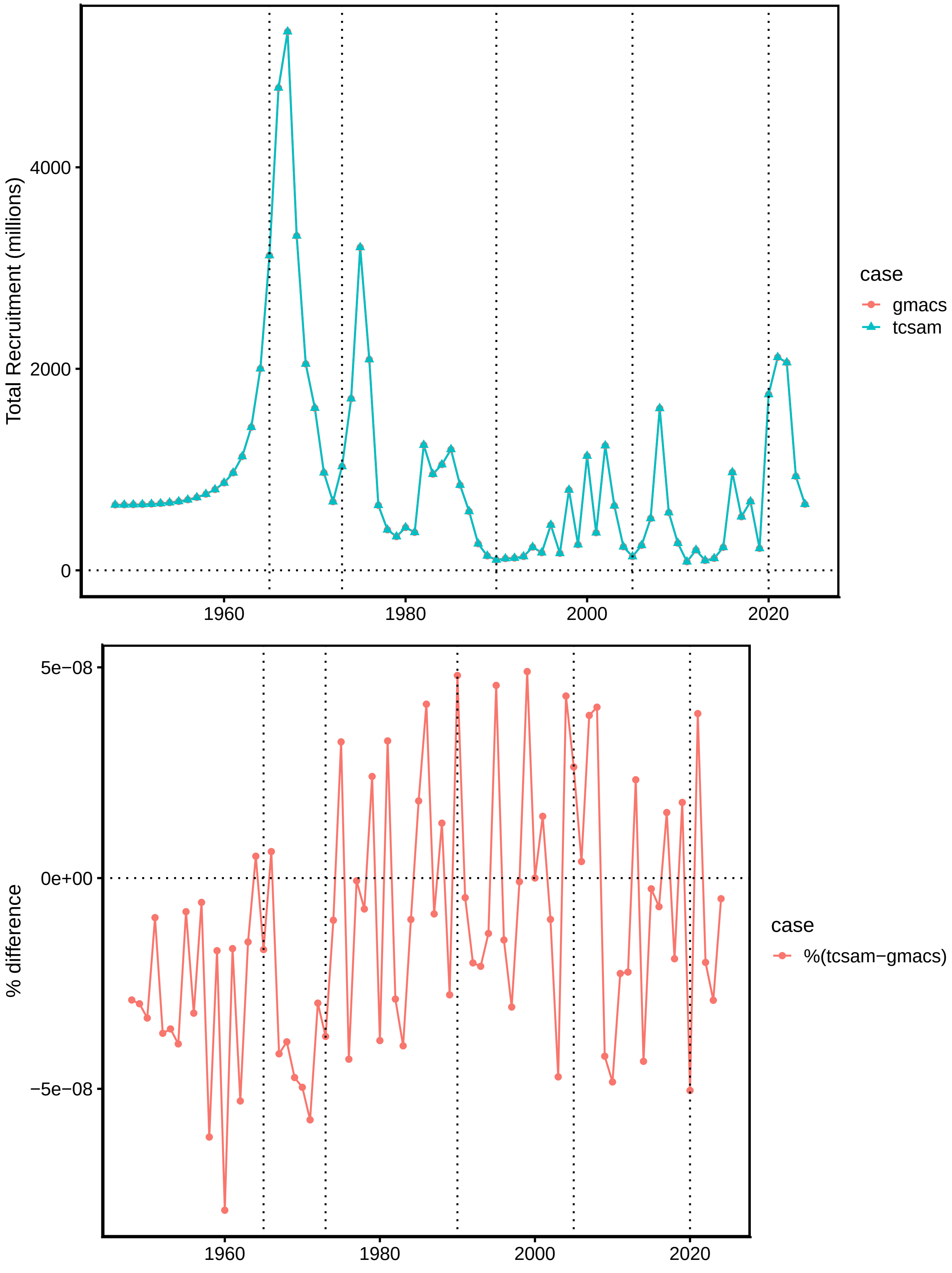


Figure 65. Comparison of recruitment by year from the GMACS and TCSAM02 models. Upper: values; lower: percent differences. The dotted vertical lines various temporal reference points: 1965-start of foreign fleet catch data; 1973-start of groundfish bycatch data; 1990-start of at sea observer estimates of total catch and size compositions in the crab fisheries; 2005-crab rationalization; 2020-no NMFS survey.

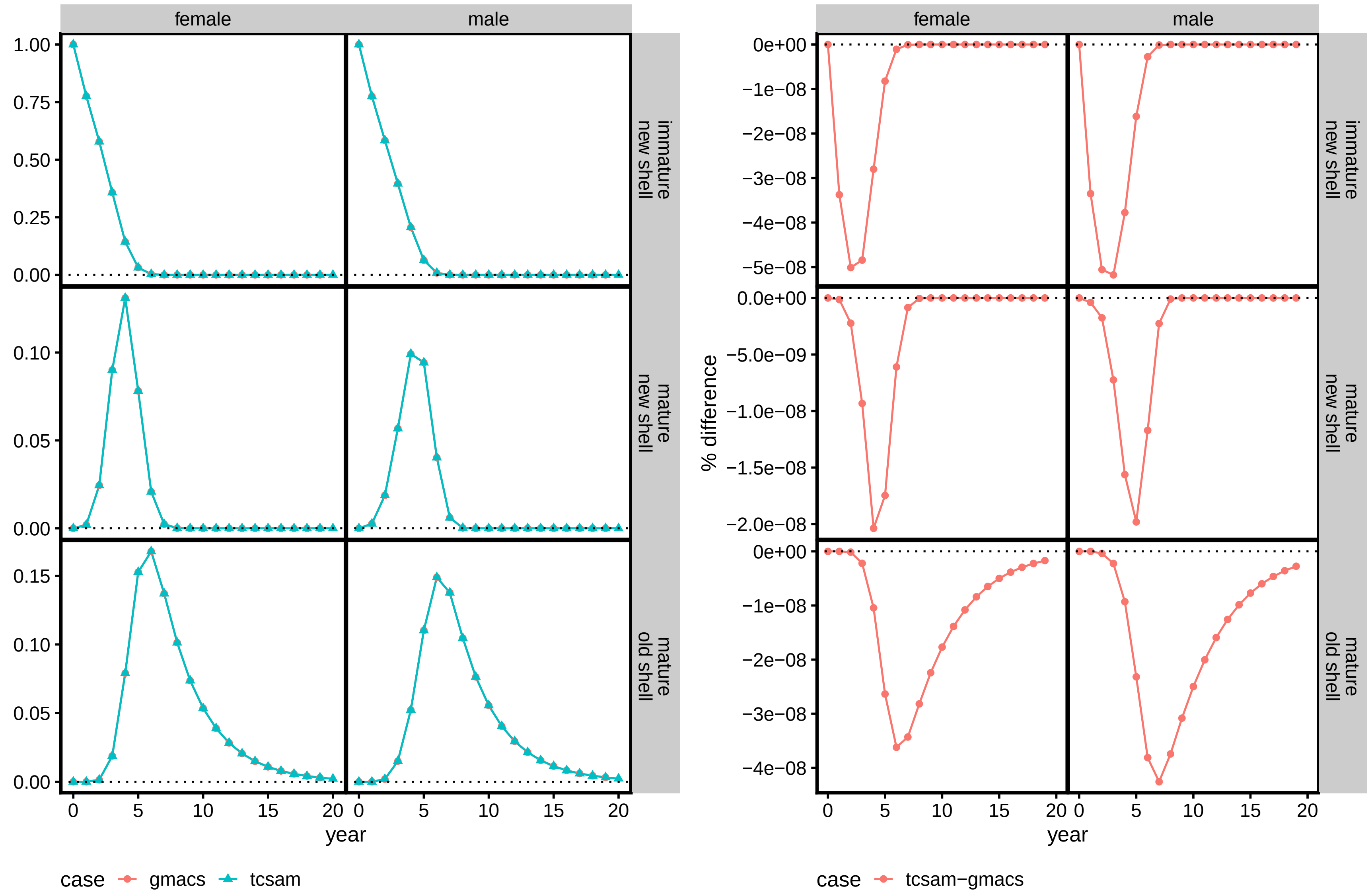


Figure 66. Comparison of the predicted abundance of a single recruitment cohort through time by sex and maturity/shell state using conditions from the final model year for the GMACS and TCSAM02 models. Left: values; right: percent differences.

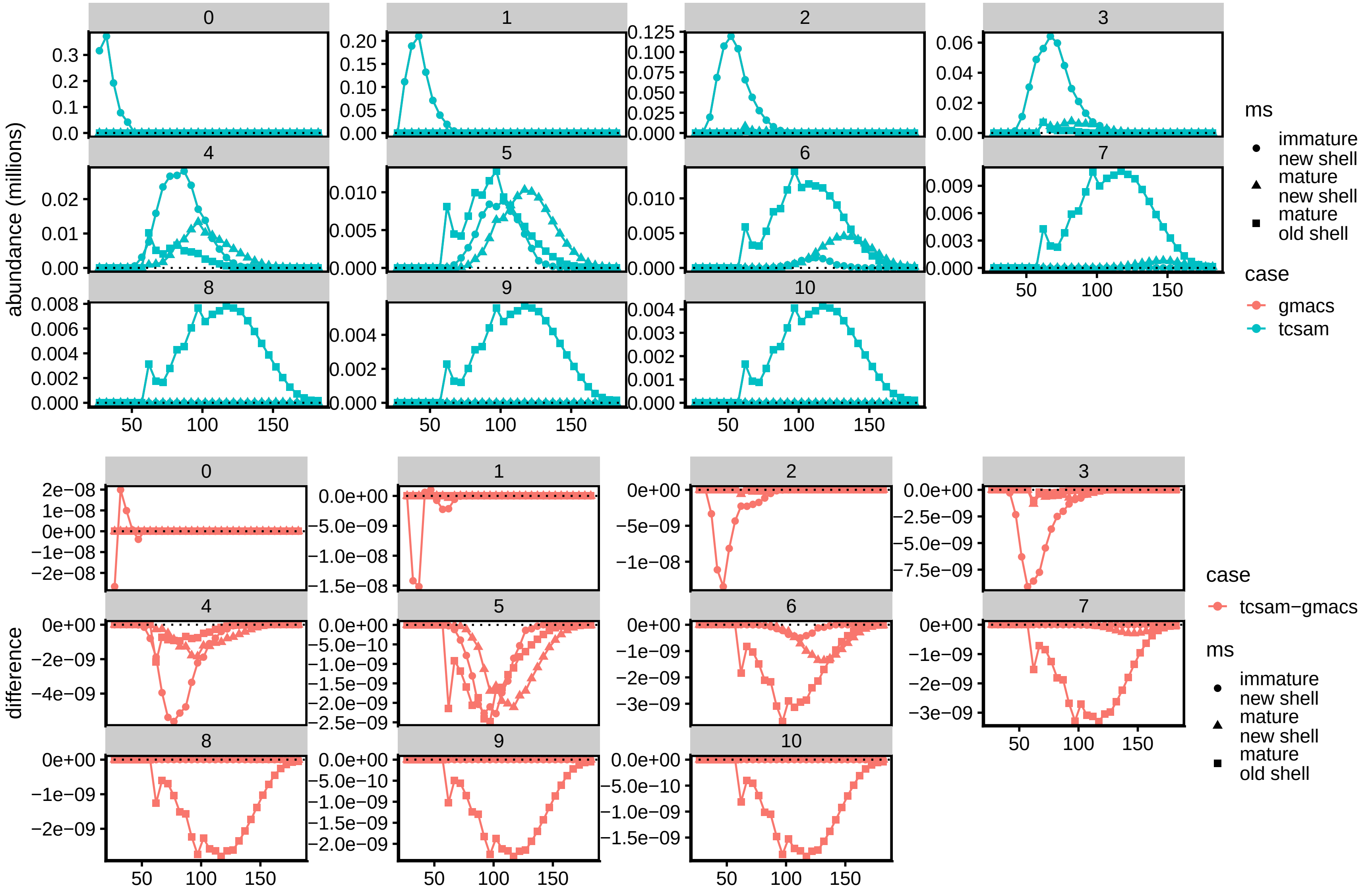


Figure 67. Comparison of the predicted abundance-at-size of a single recruitment cohort through time by sex and maturity/shell condition using conditions from the final model year for the GMACS and TCSAM02 models. Upper: values; lower: differences.

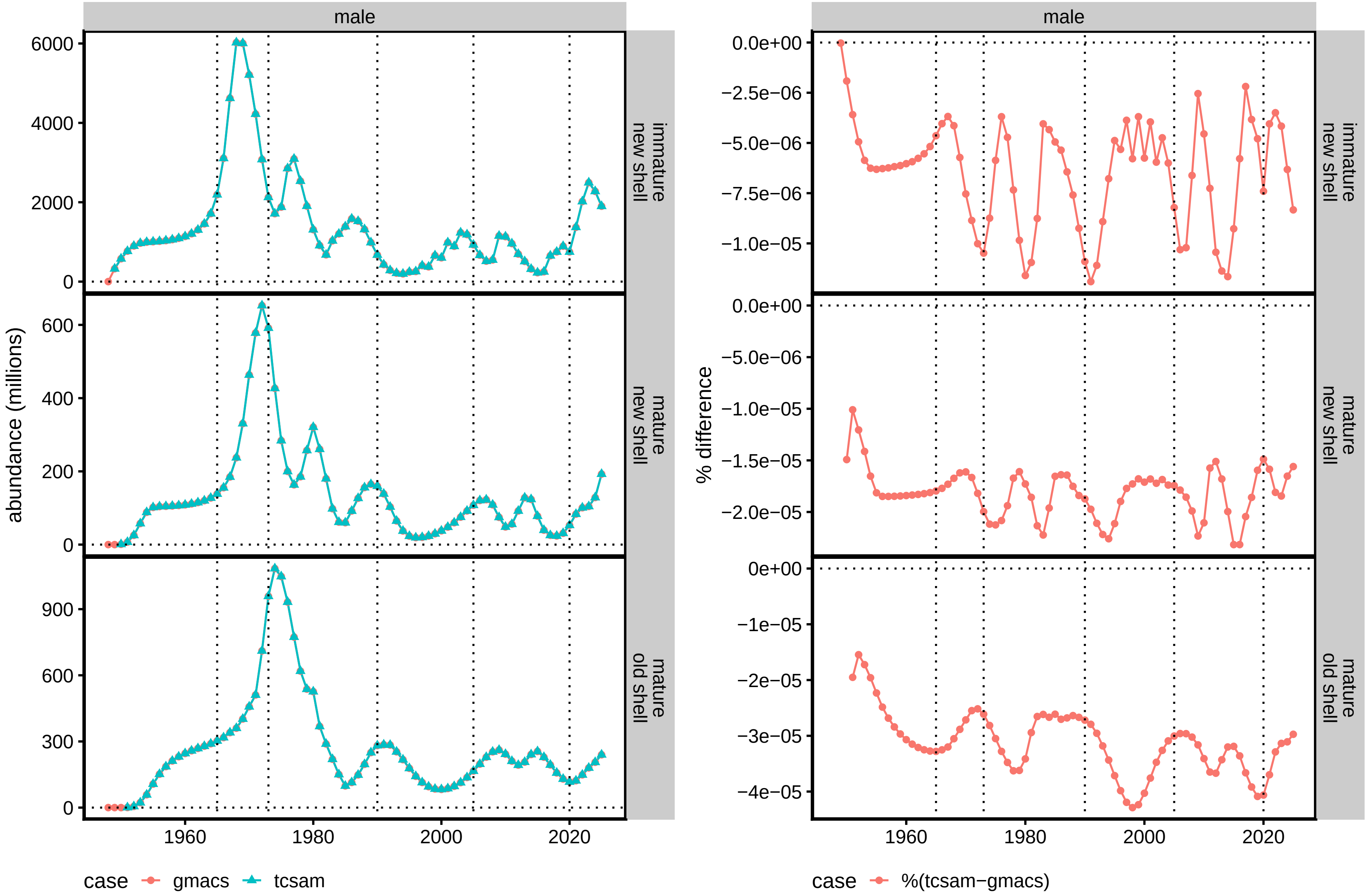


Figure 68. Comparison of the predicted population abundance through time by maturity/shell condition for males from the GMACS and TCSAM02 models. Left: values; right: percent differences. The dotted vertical lines indicate various temporal reference points: 1965-start of foreign fleet catch data; 1973-start of groundfish bycatch data; 1990-start of at sea observer estimates of total catch and size compositions in the crab fisheries; 2005-crab rationalization; 2020-no NMFS survey.

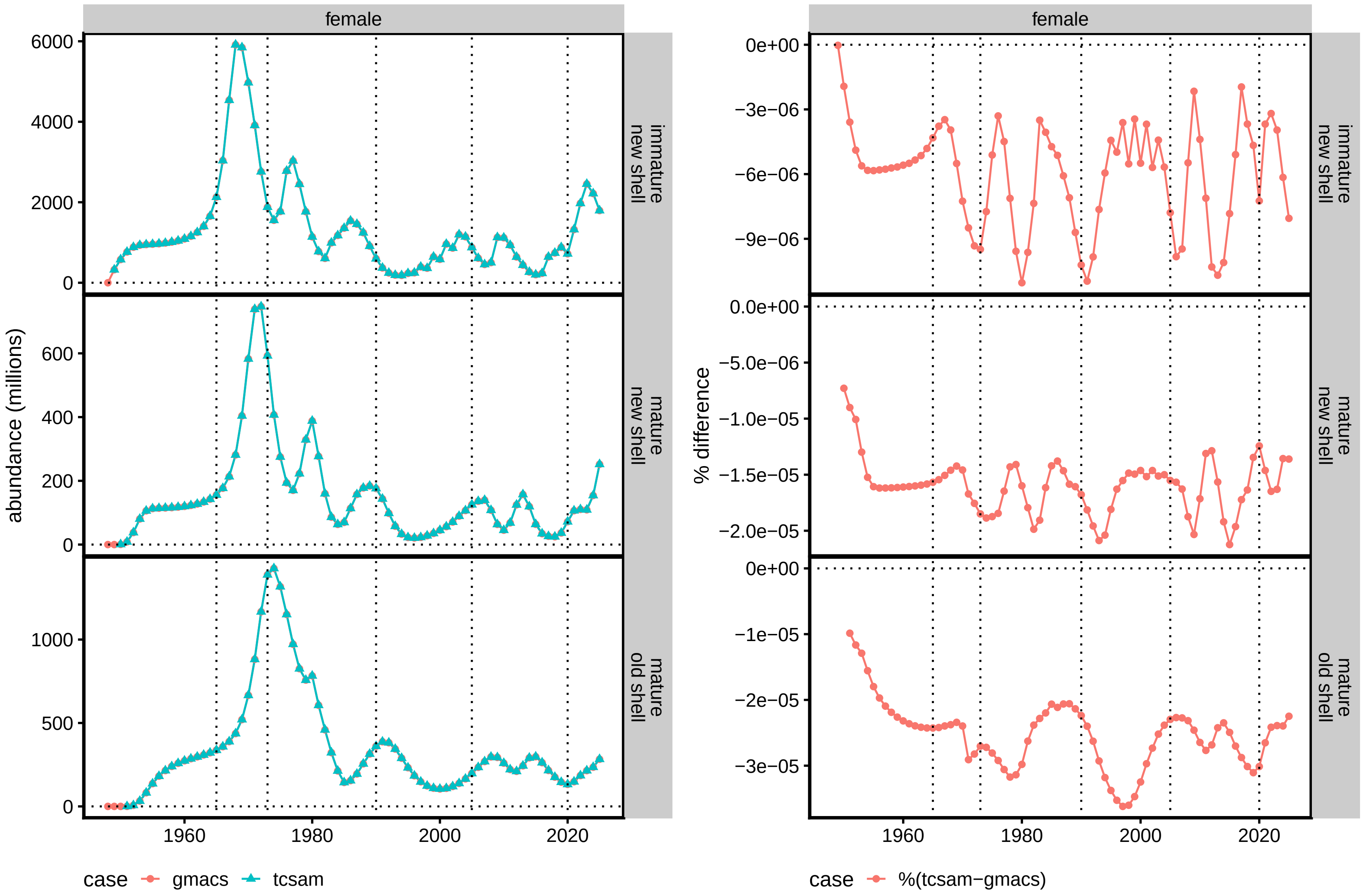


Figure 69. Comparison of the predicted population abundance through time by maturity/shell condition for females from the GMACS and TCSAM02 models. Left: values; right: percent differences. The dotted vertical lines indicate various temporal reference points: 1965-start of foreign fleet catch data; 1973-start of groundfish bycatch data; 1990-start of at sea observer estimates of total catch and size compositions in the crab fisheries; 2005-crab rationalization; 2020-no NMFS survey.

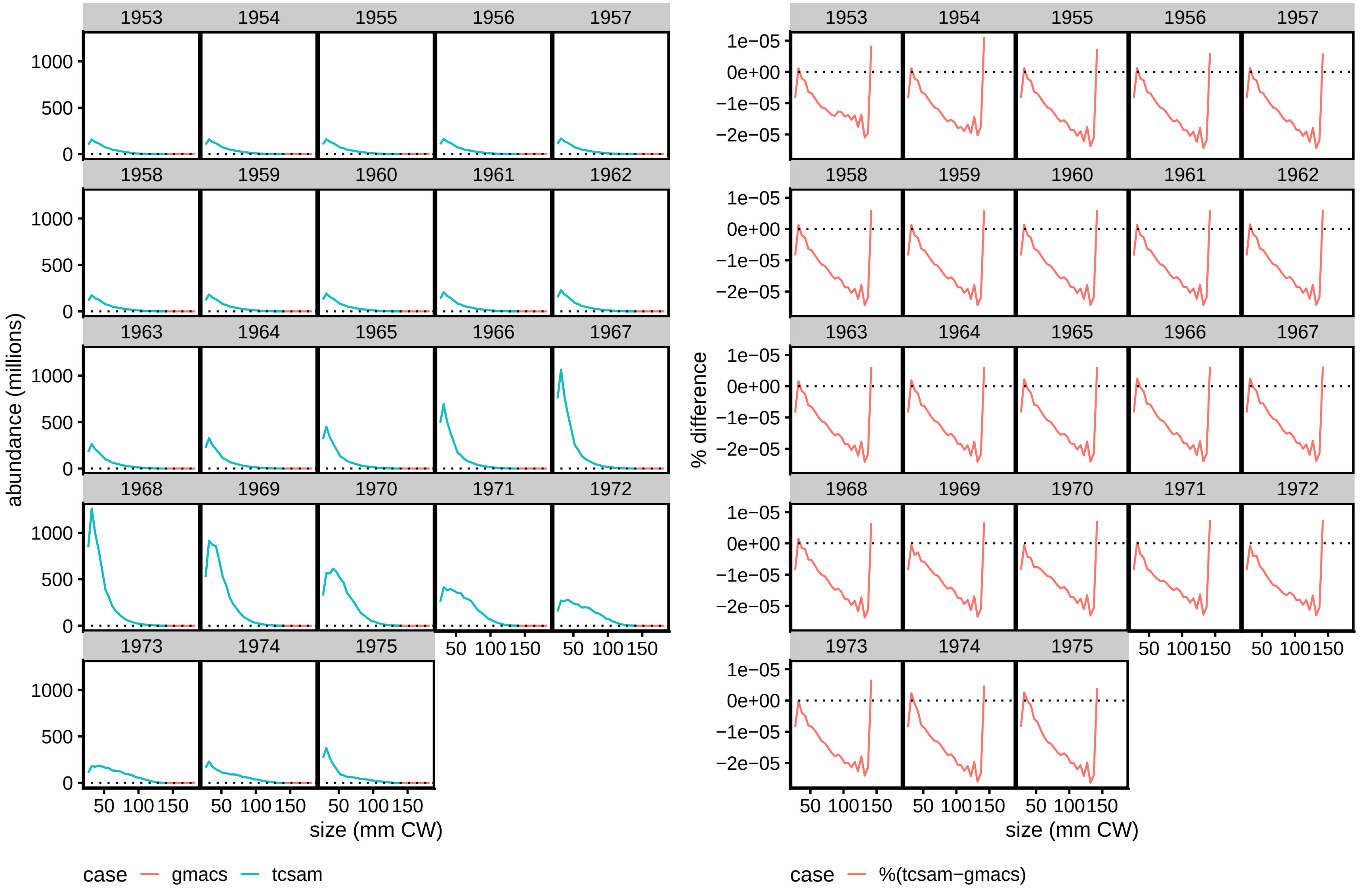


Figure 70. Comparison of the predicted population abundance-at-size through time (1953-1975) for immature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

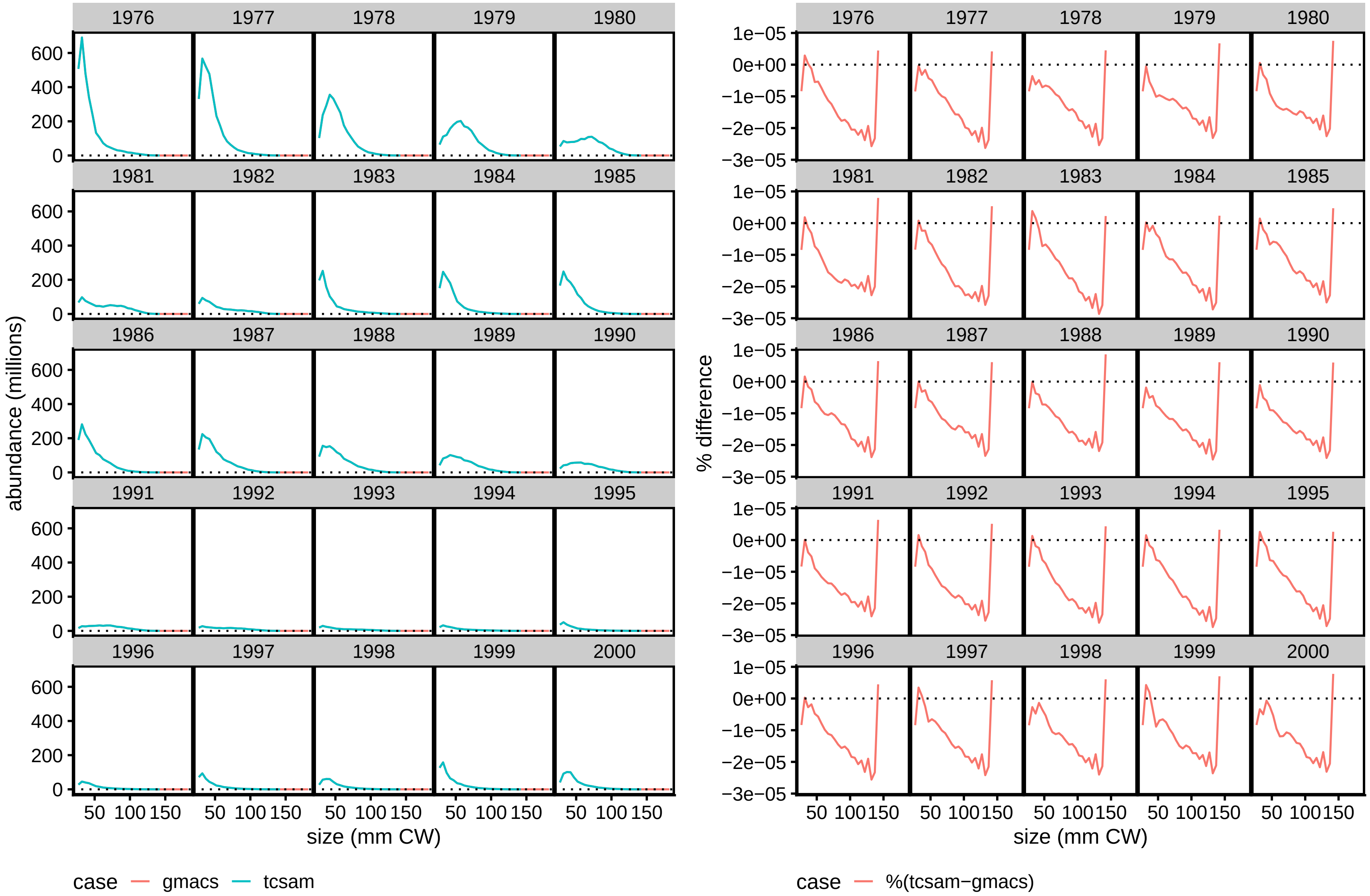


Figure 71. Comparison of the predicted population abundance-at-size through time (1976-2000) for immature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

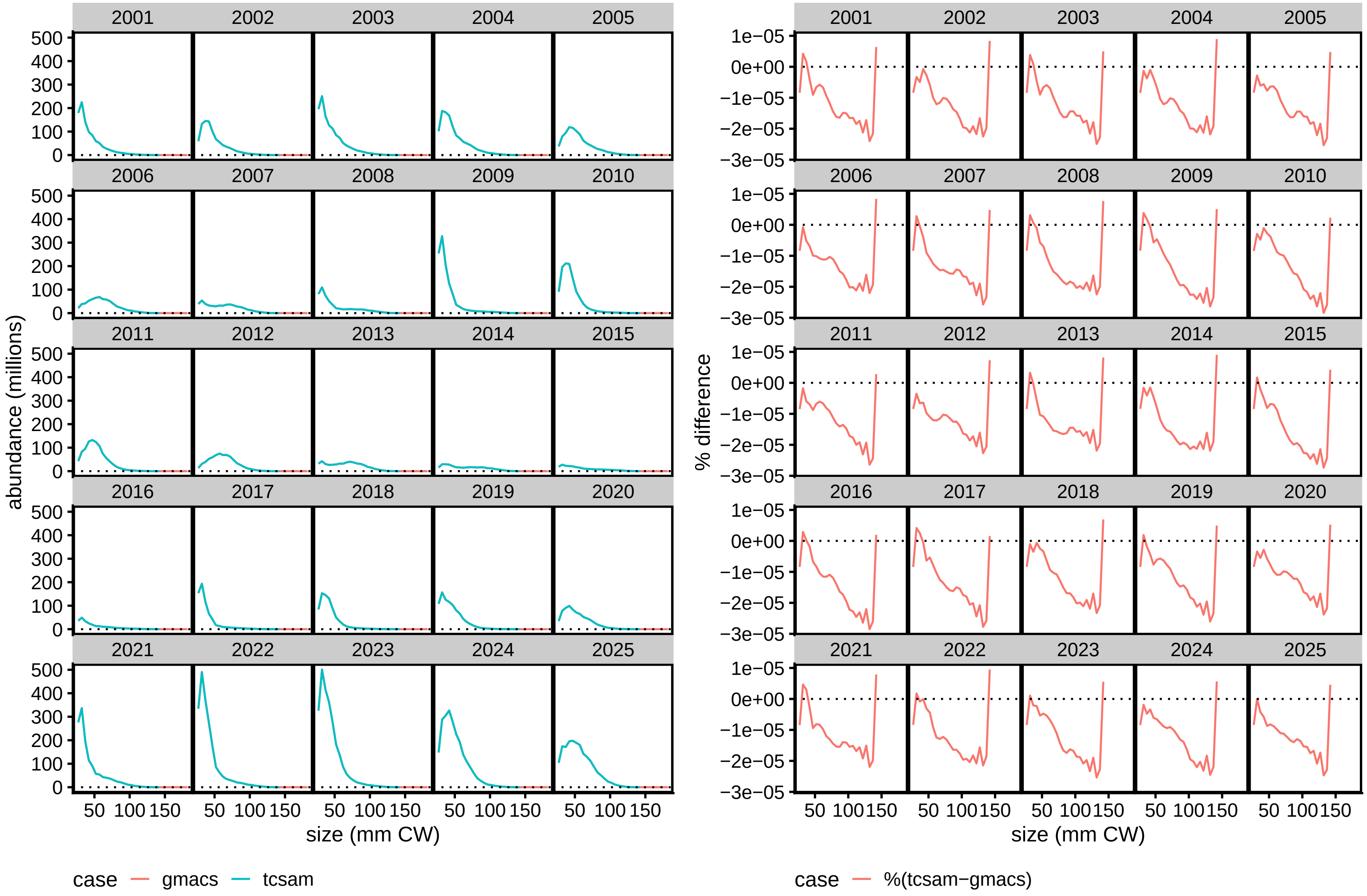


Figure 72. Comparison of the predicted population abundance-at-size through time (2001-2025) for immature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

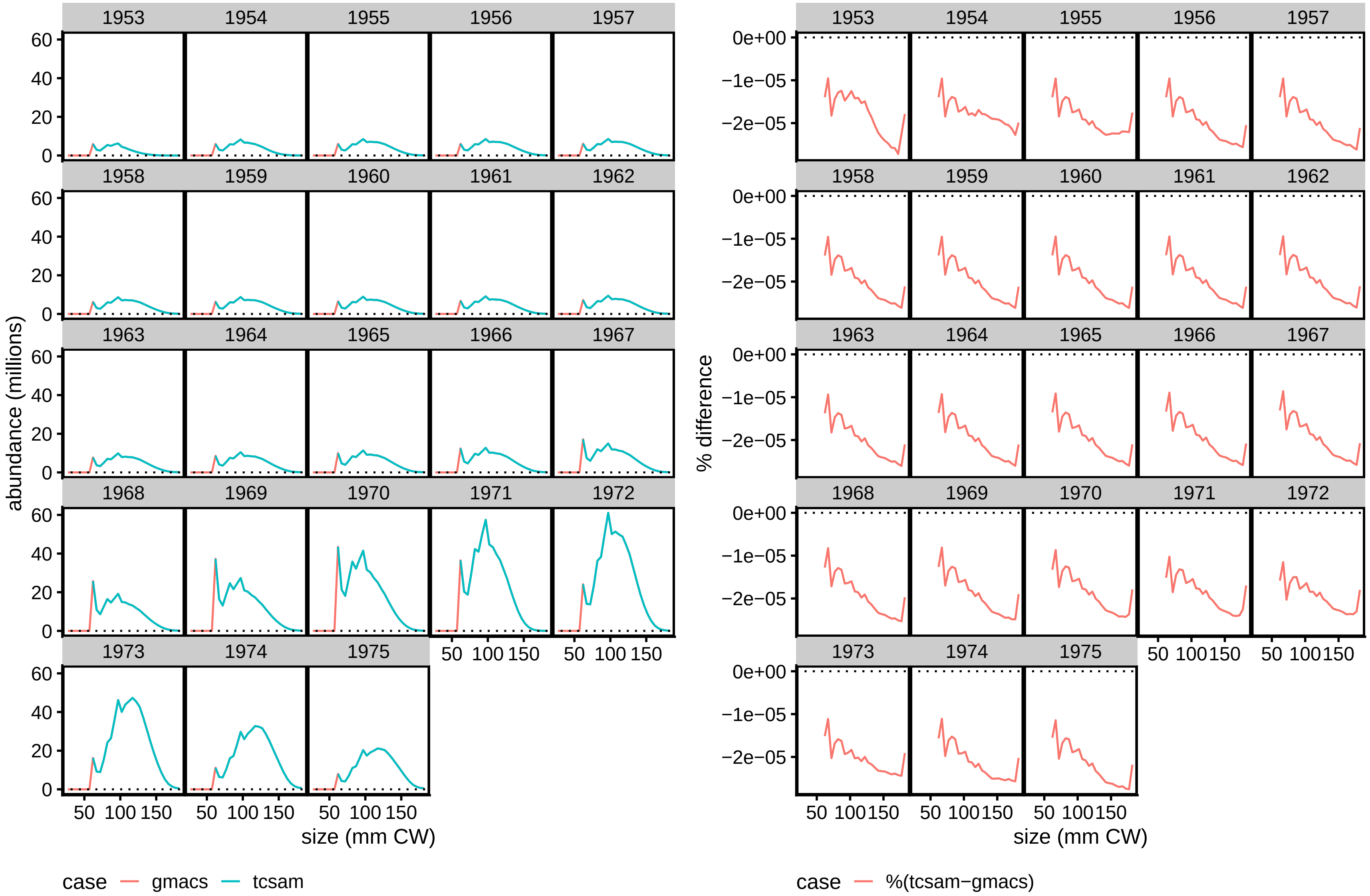


Figure 73. Comparison of the predicted population abundance-at-size through time (1953-1975) for mature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

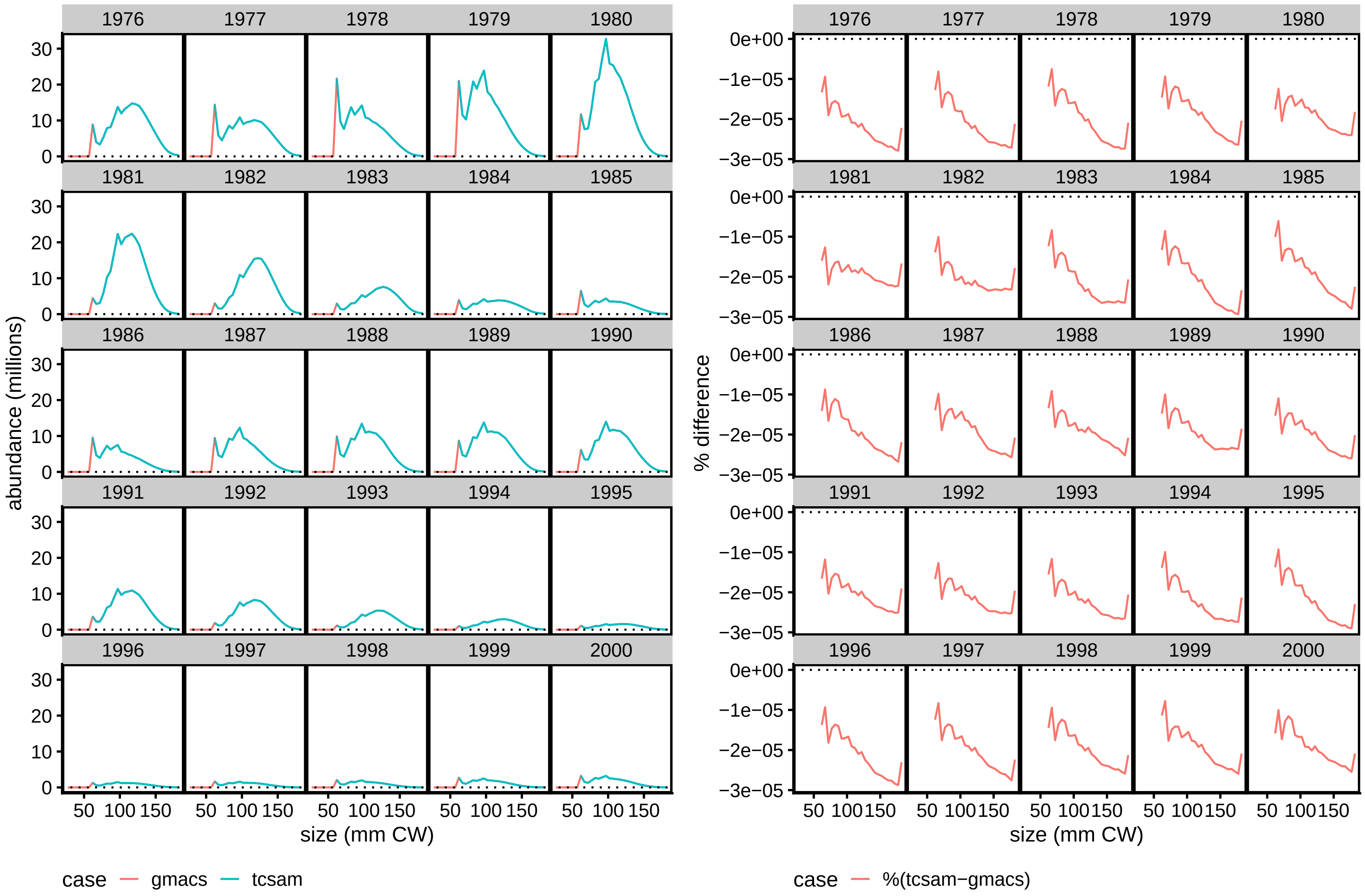


Figure 74. Comparison of the predicted population abundance-at-size through time (1976-2000) for mature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

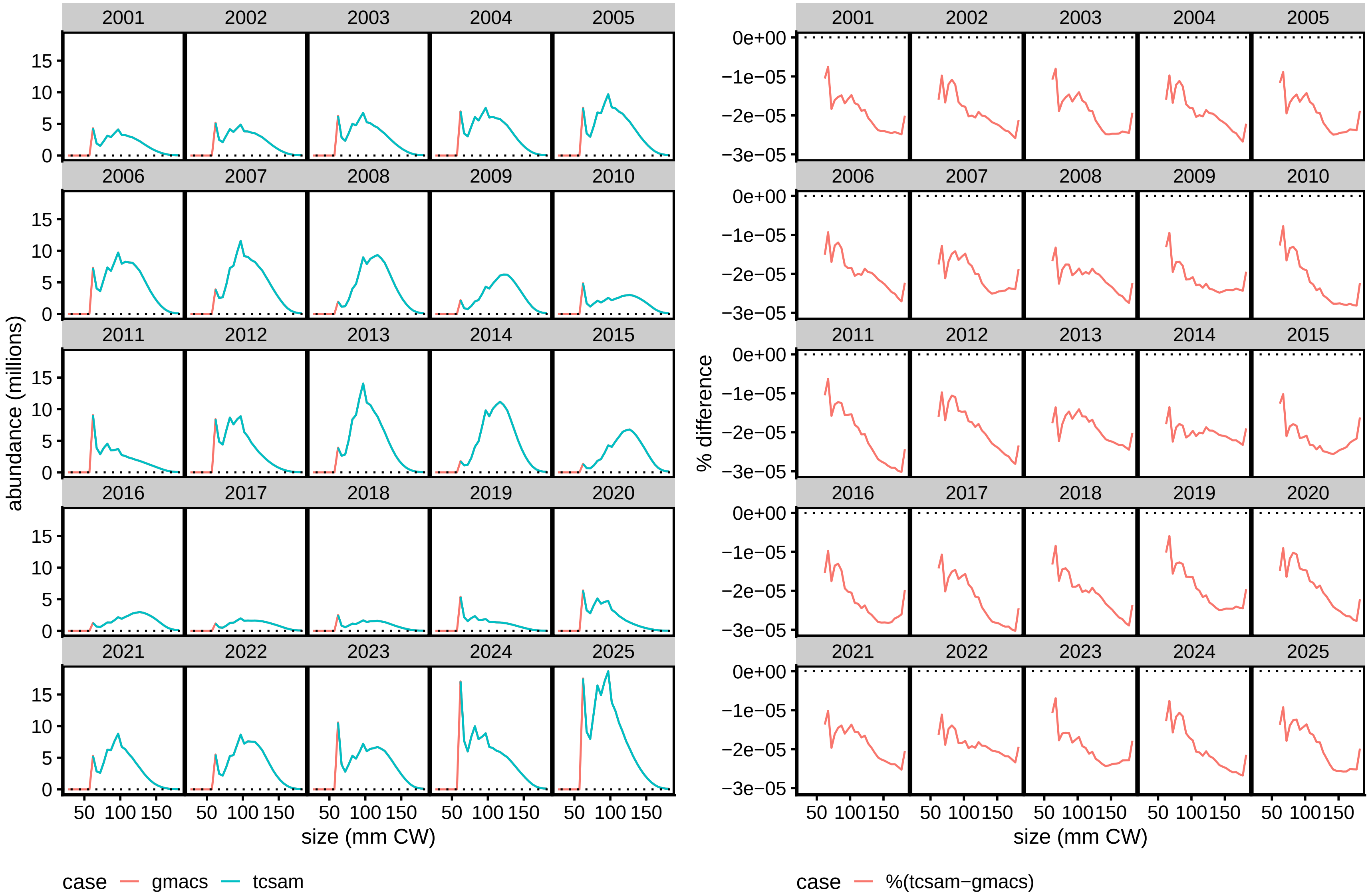


Figure 75. Comparison of the predicted population abundance-at-size through time (2001-2025) for mature, new shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

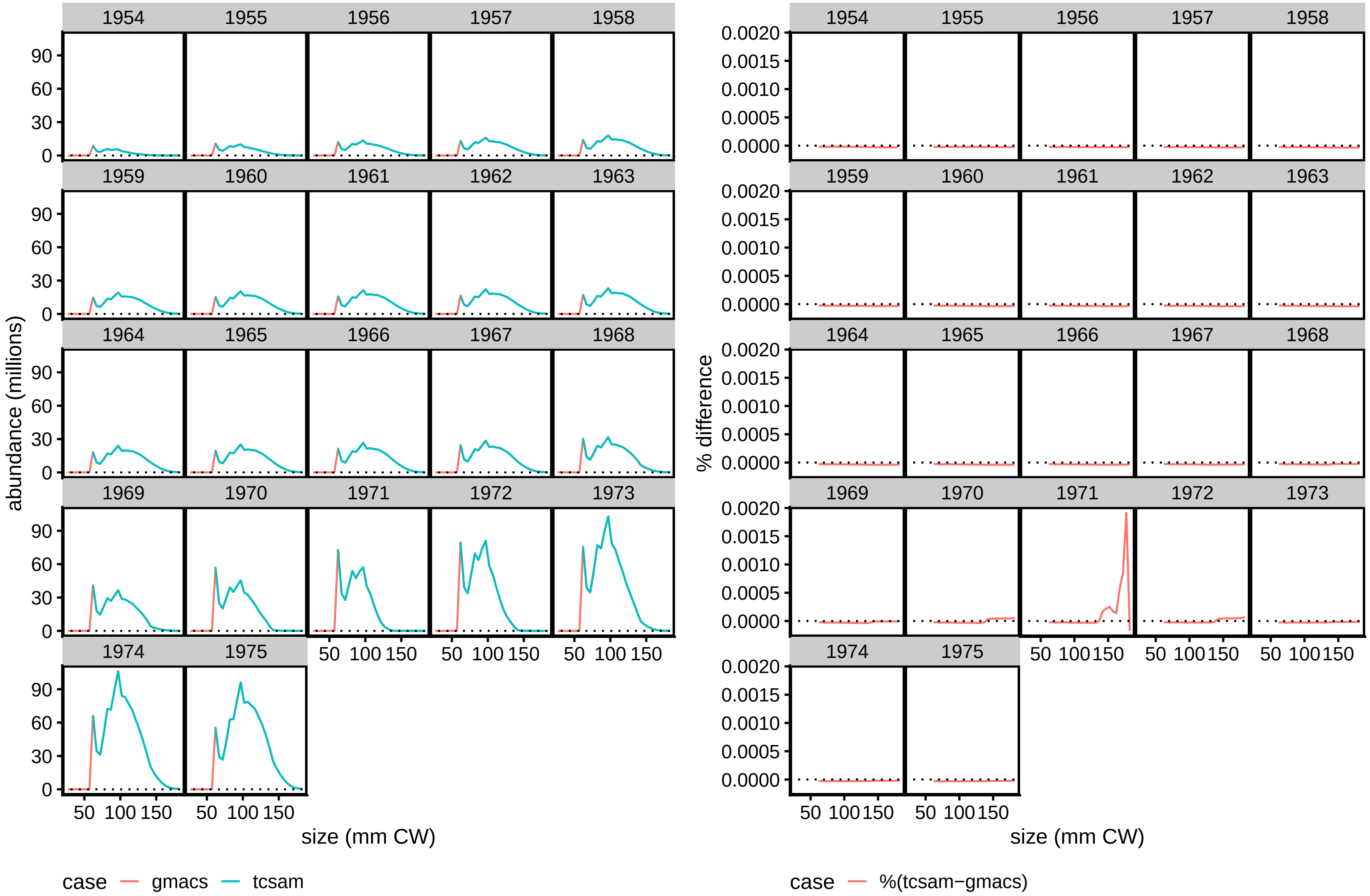


Figure 76. Comparison of the predicted population abundance-at-size through time (1953-1975) for mature, old shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

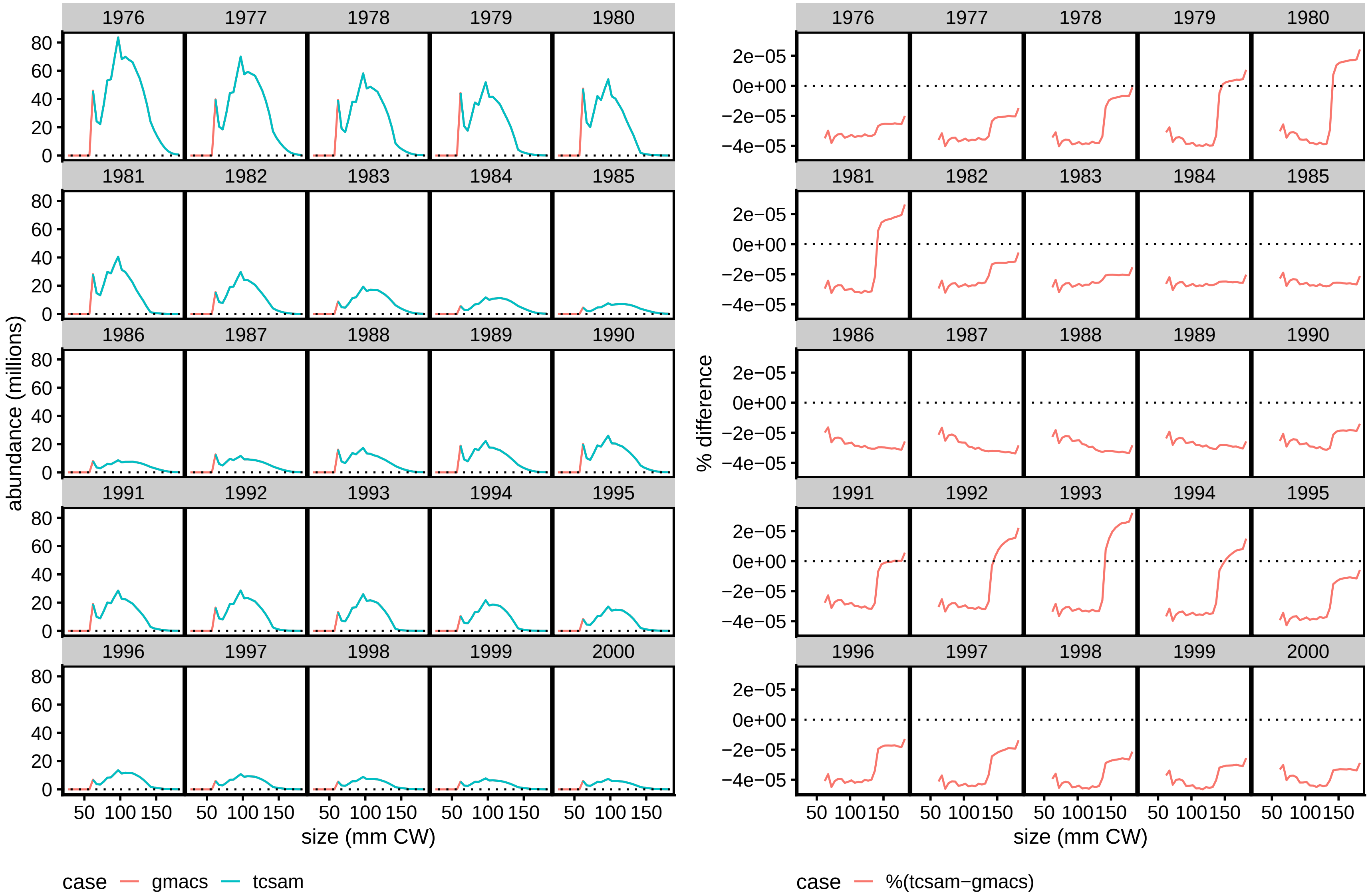


Figure 77. Comparison of the predicted population abundance-at-size through time (1976-2000) for mature, old shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

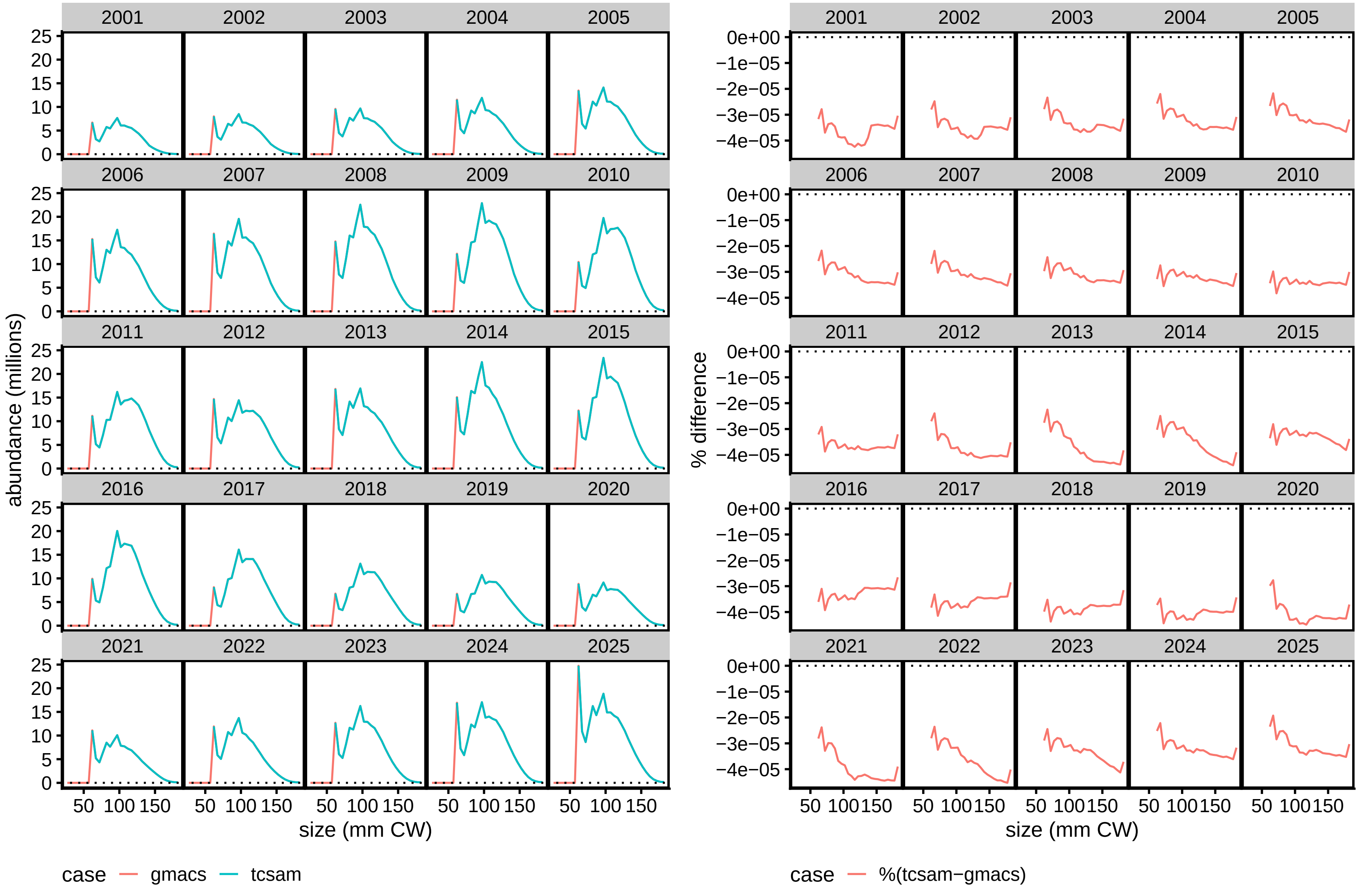


Figure 78. Comparison of the predicted population abundance-at-size through time (2001-2025) for mature, old shell males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

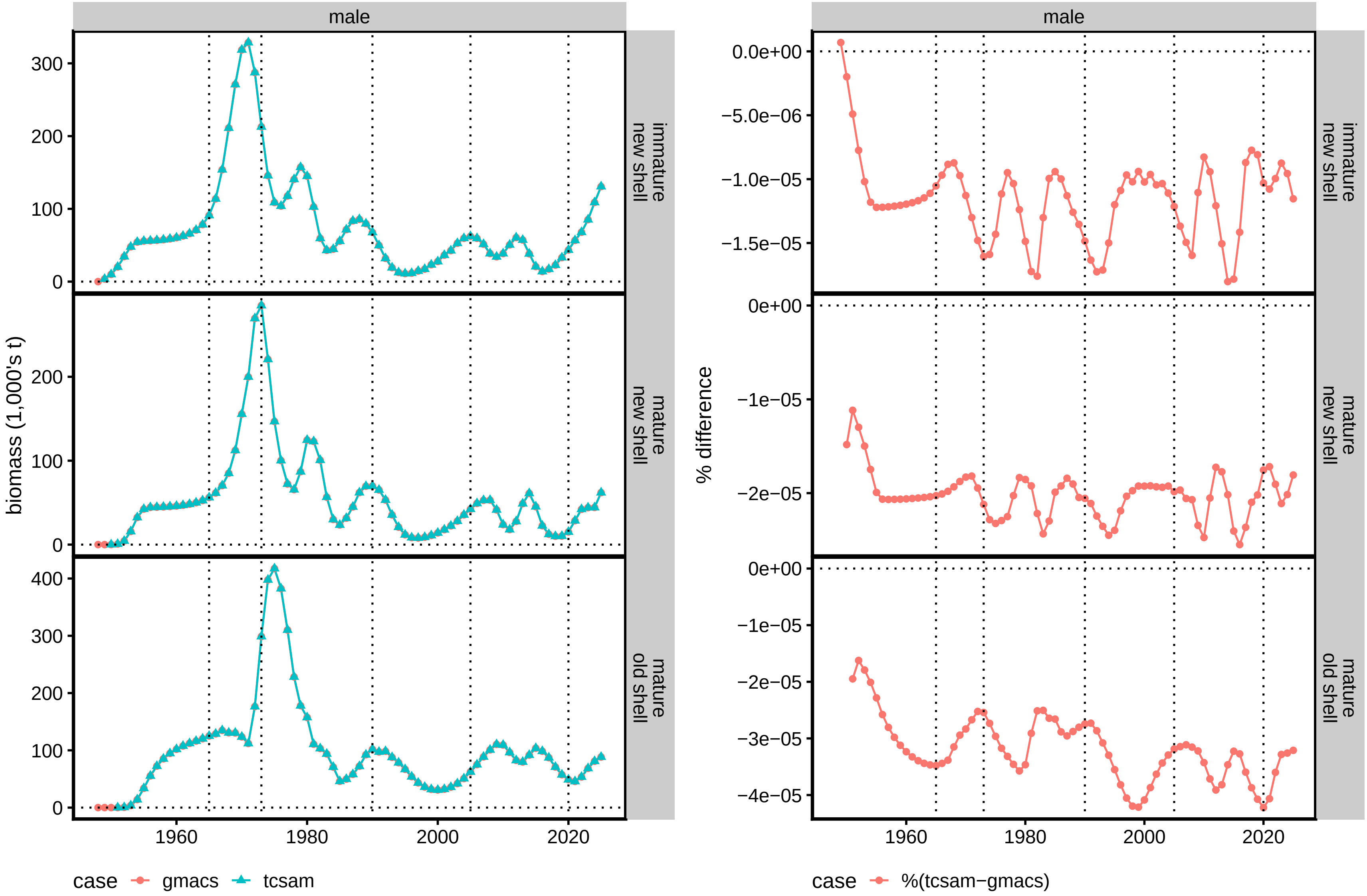


Figure 79. Comparison of the predicted population biomass through time by maturity/shell condition for males from the GMACS and TCSAM02 models. Left: values; right: percent differences. The dotted vertical lines indicate various temporal reference points: 1965-start of foreign fleet catch data; 1973-start of groundfish bycatch data; 1990-start of at sea observer estimates of total catch and size compositions in the crab fisheries; 2005-crab rationalization; 2020-no NMFS survey.

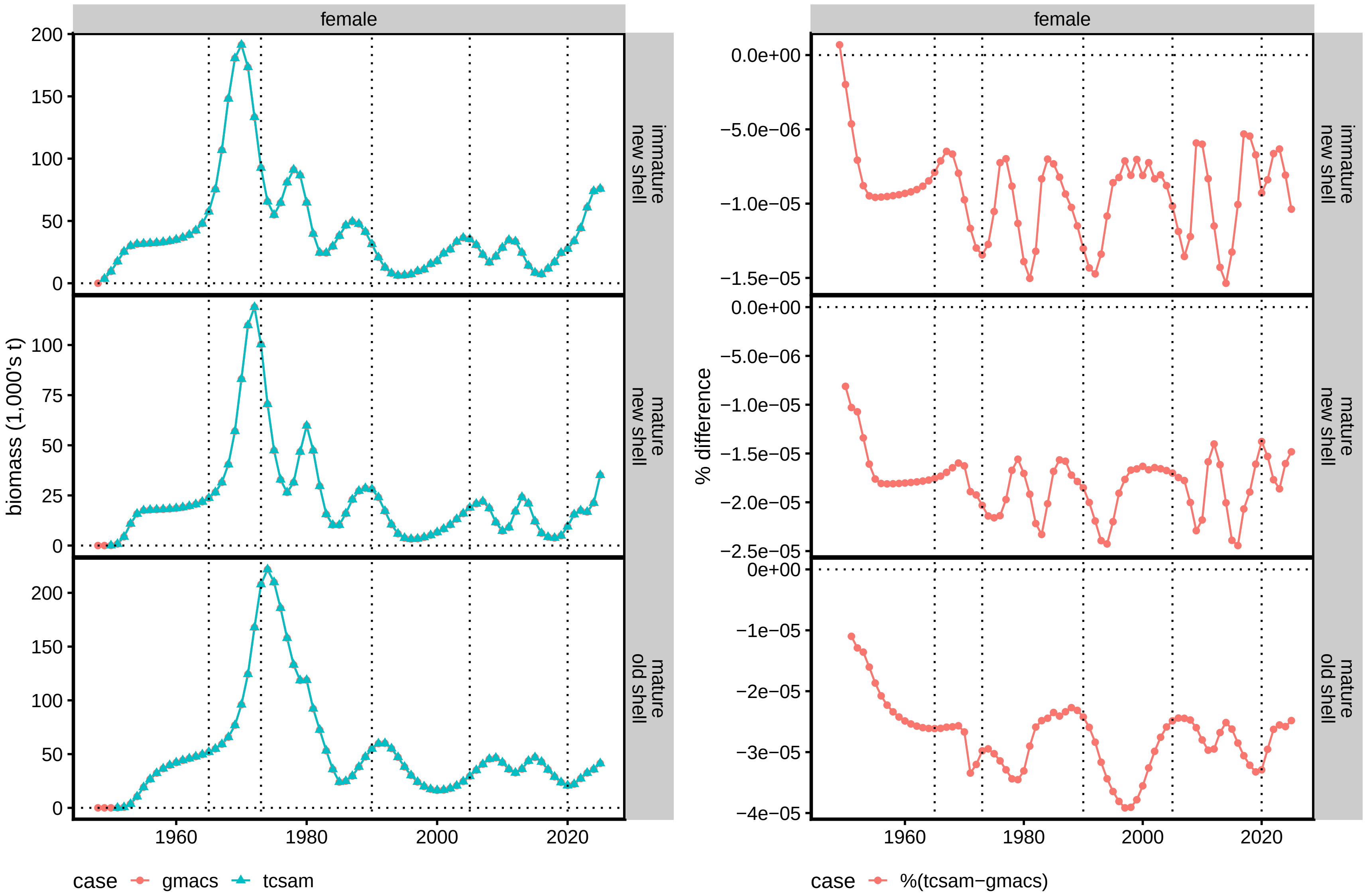


Figure 80. Comparison of the predicted population biomass through time by maturity/shell condition for females from the GMACS and TCSAM02 models. Left: values; right: percent differences. The dotted vertical lines indicate various temporal reference points: 1965-start of foreign fleet catch data; 1973-start of groundfish bycatch data; 1990-start of at sea observer estimates of total catch and size compositions in the crab fisheries; 2005-crab rationalization; 2020-no NMFS survey.

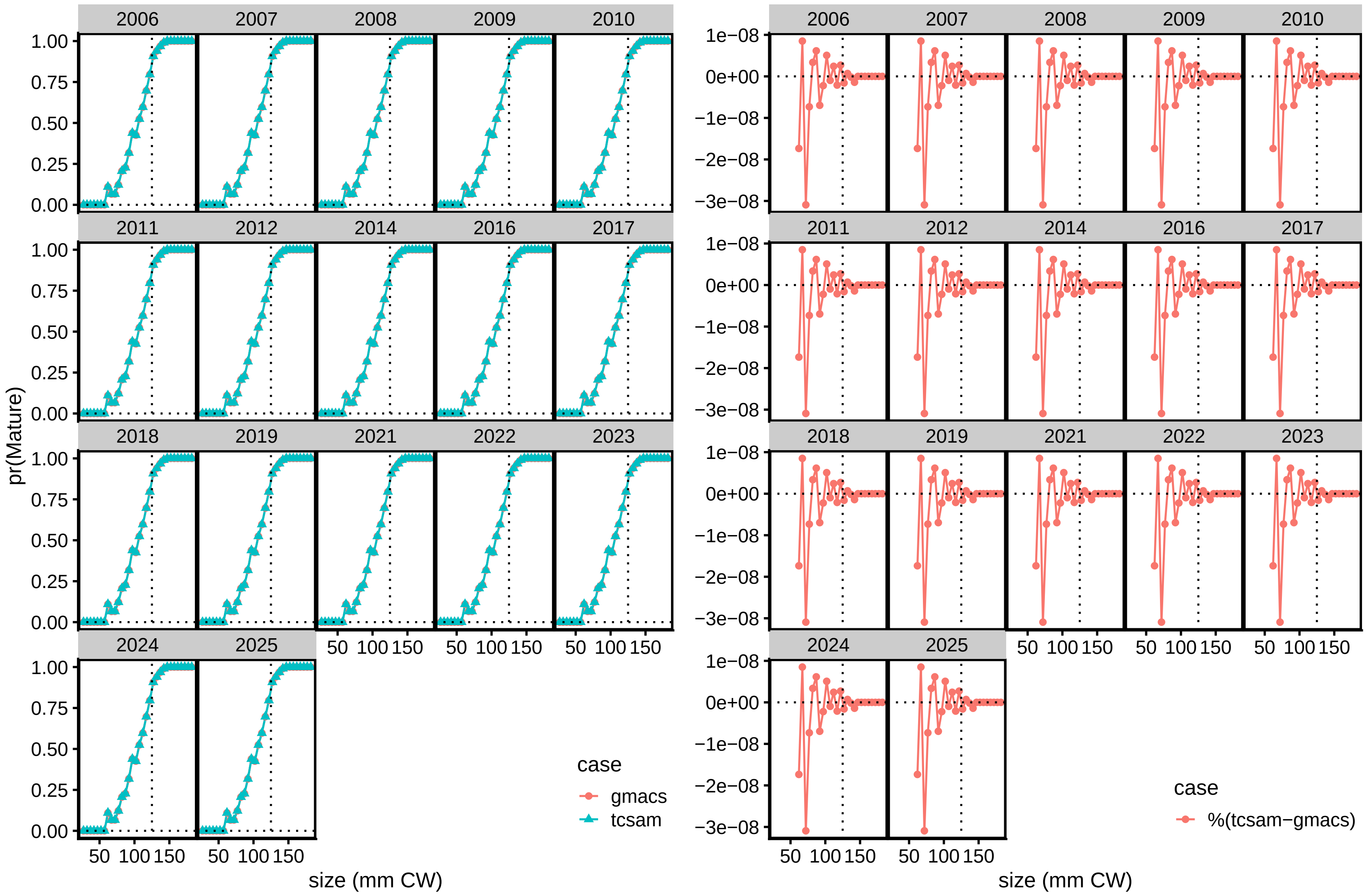


Figure 81. Comparison of the predicted male maturity ogives through time based on predicted NMFS survey abundance-at-size for immature and mature new shell crab from the GMACS and TCSAM02 models using model size bins. Left: values; right: percent differences.

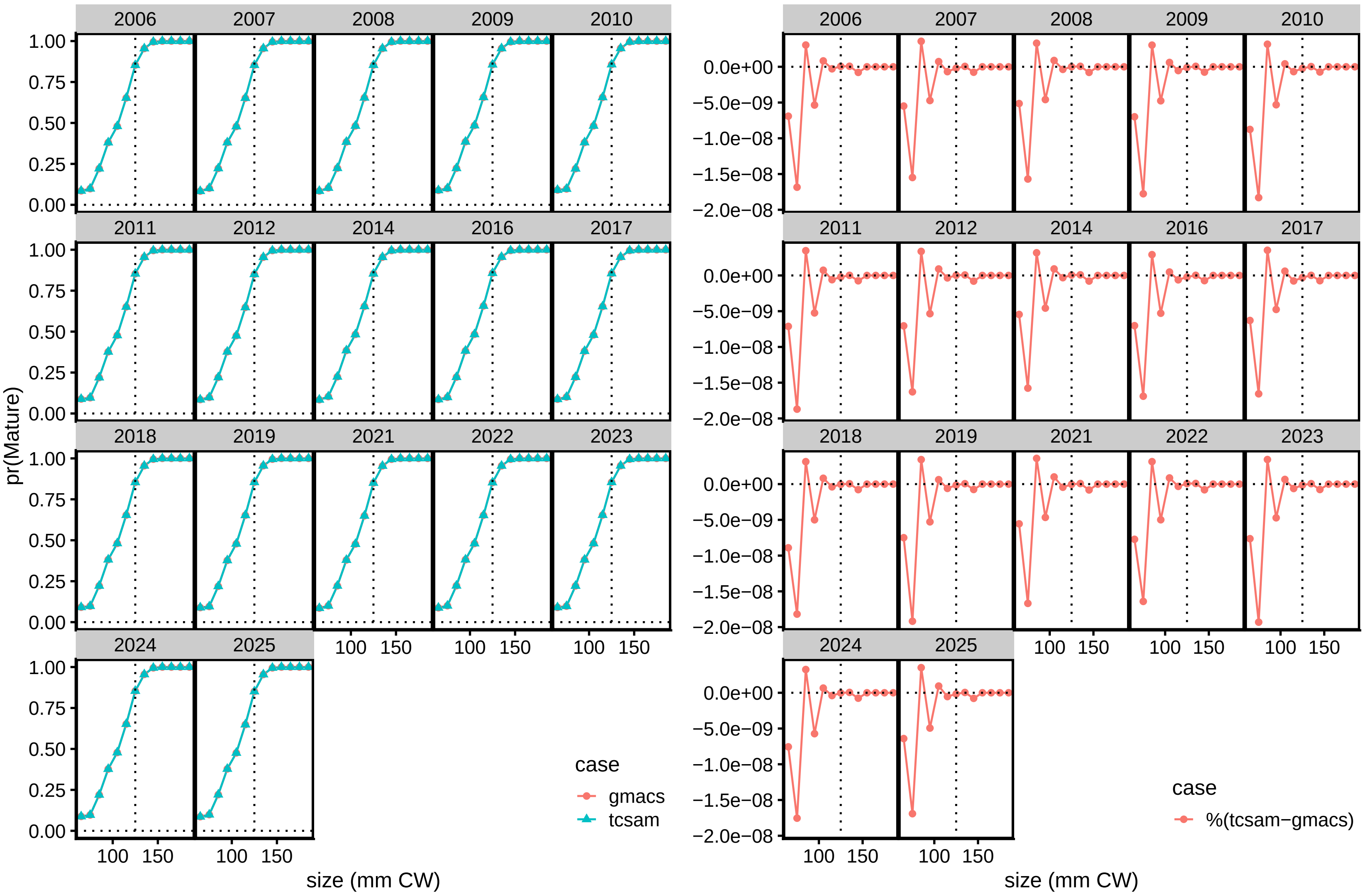


Figure 82. Comparison of the predicted male maturity ogives through time based on predicted NMFS survey abundance-at-size for immature and mature new shell crab from the GMACS and TCSAM02 models, using observed size bins. Left: values; right: percent differences.

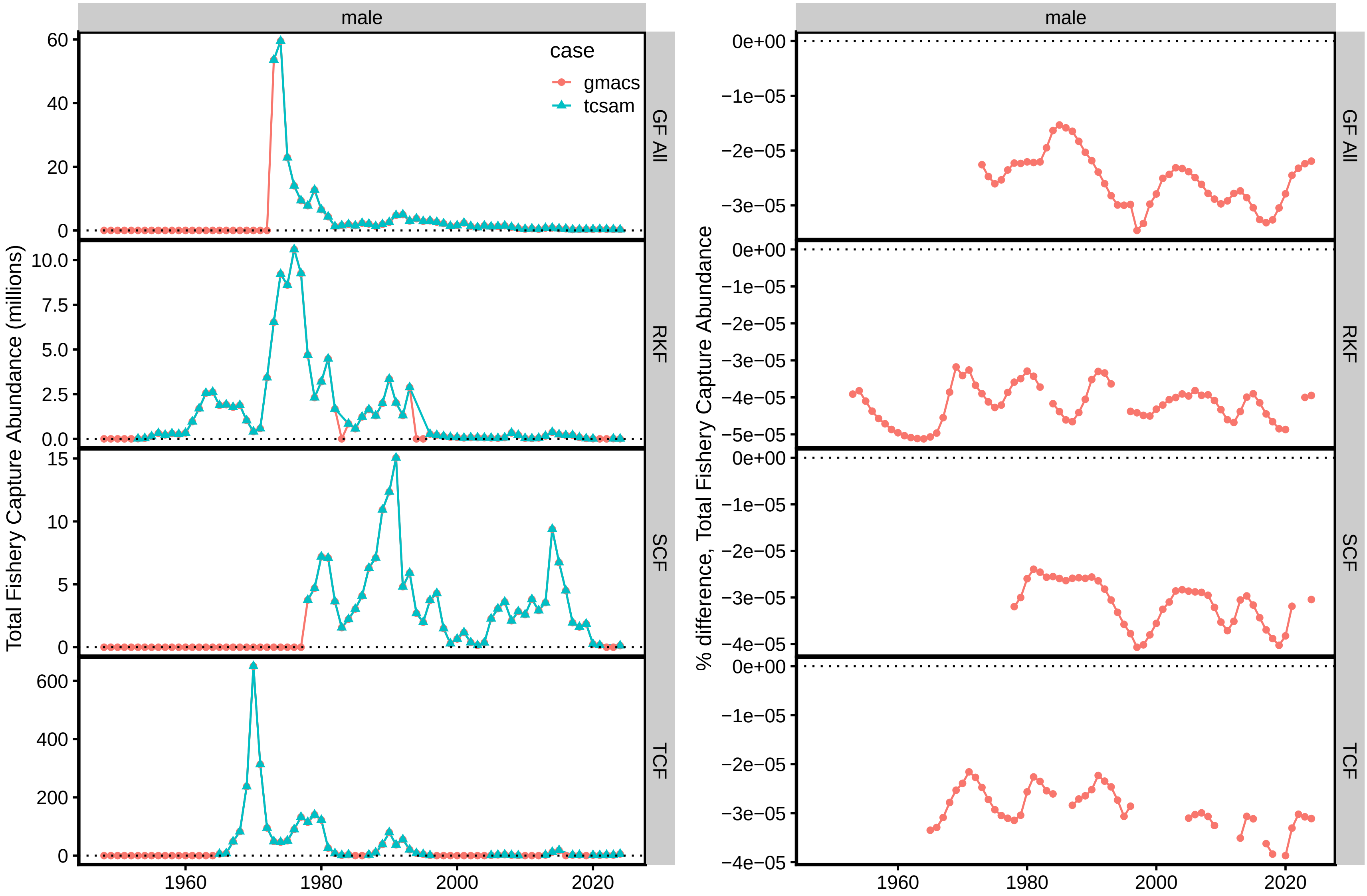


Figure 83. Comparison of the predicted capture abundance by fishery through time for males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

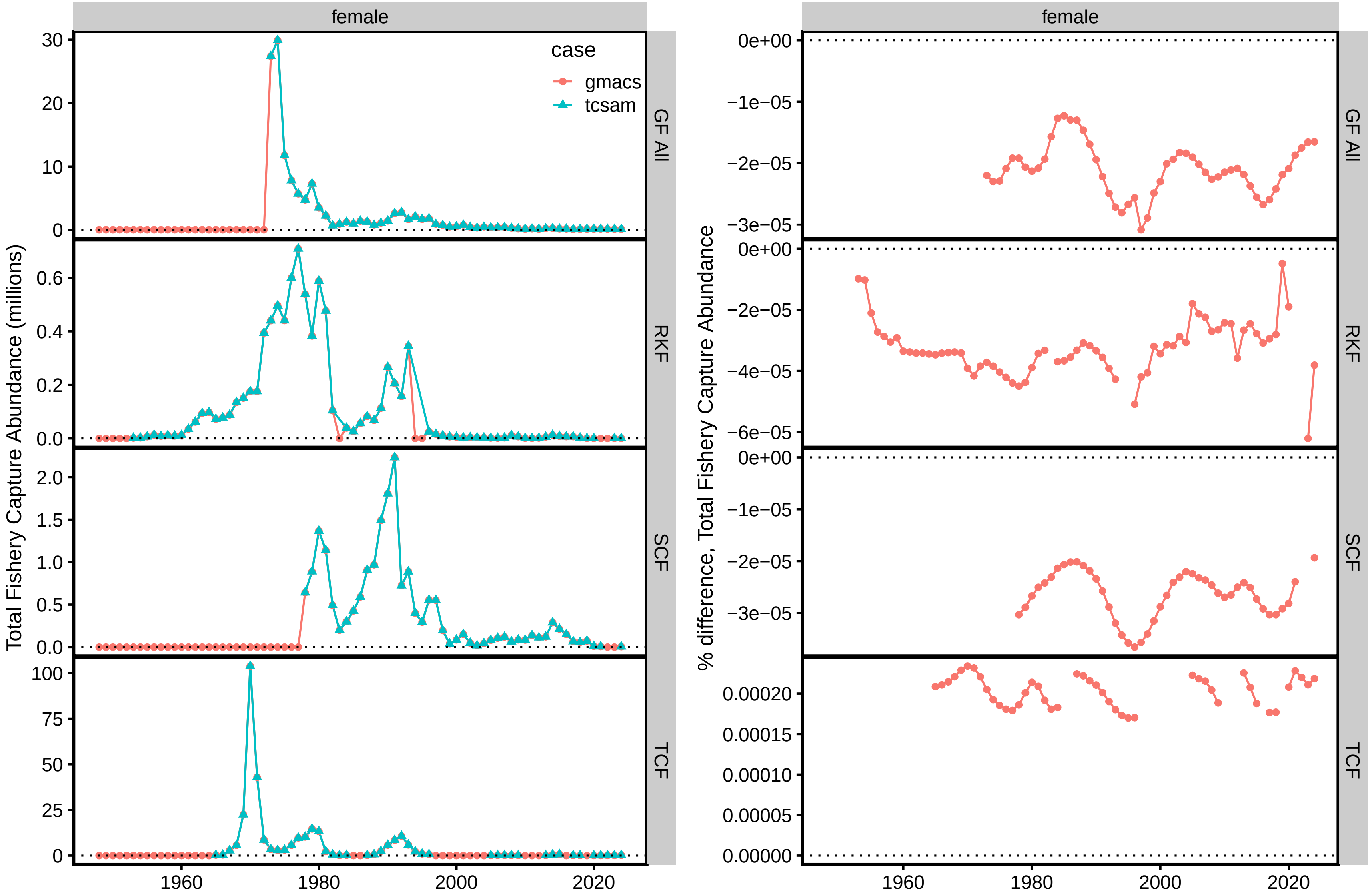


Figure 84. Comparison of the predicted capture abundance by fishery through time for females from the GMACS and TCSAM02 models. Left: values; right: percent differences.

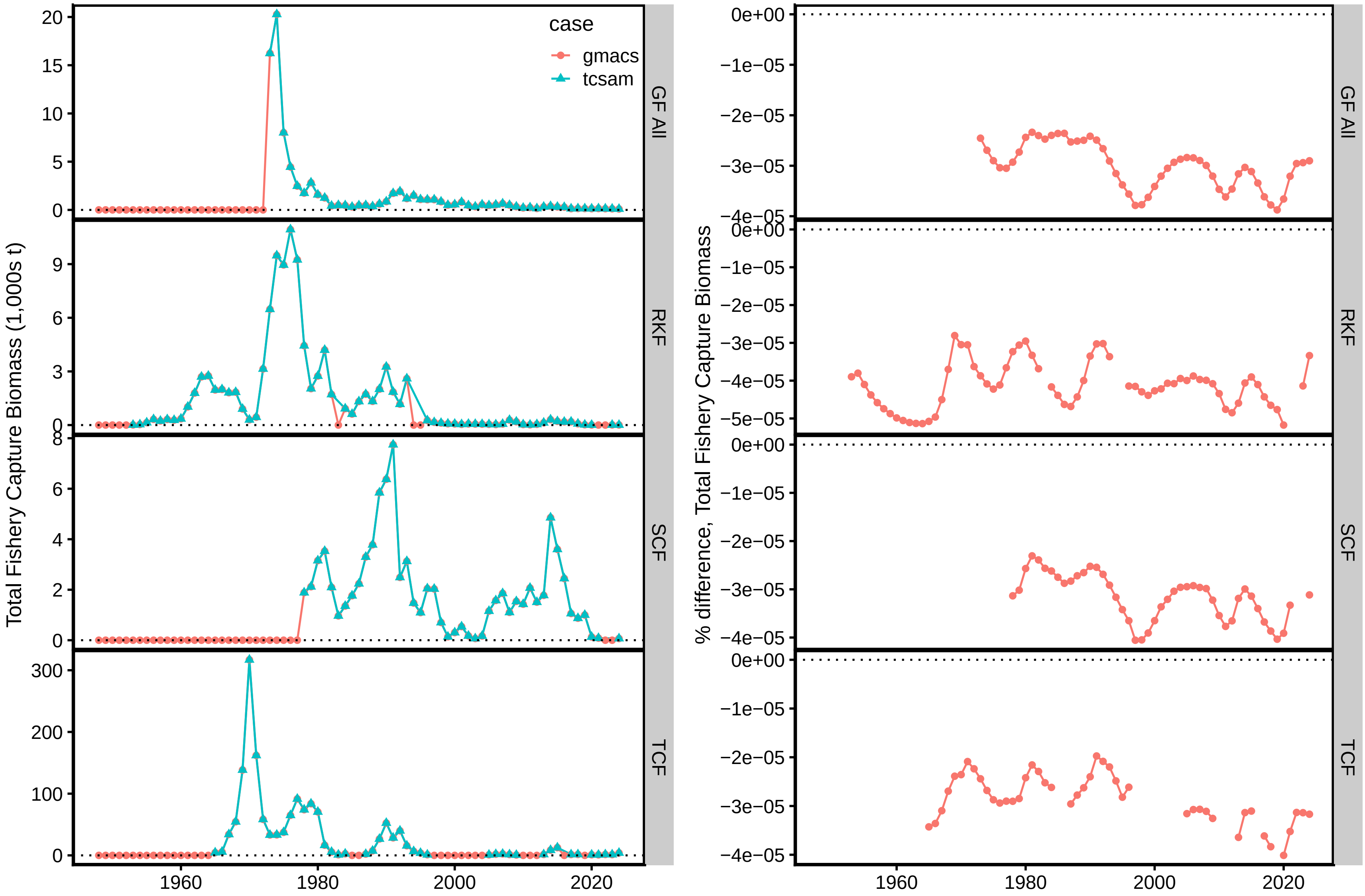


Figure 85. Comparison of the predicted capture biomass by fishery through time for males from the GMACS and TCSAM02 models. Left: values; right: percent differences.

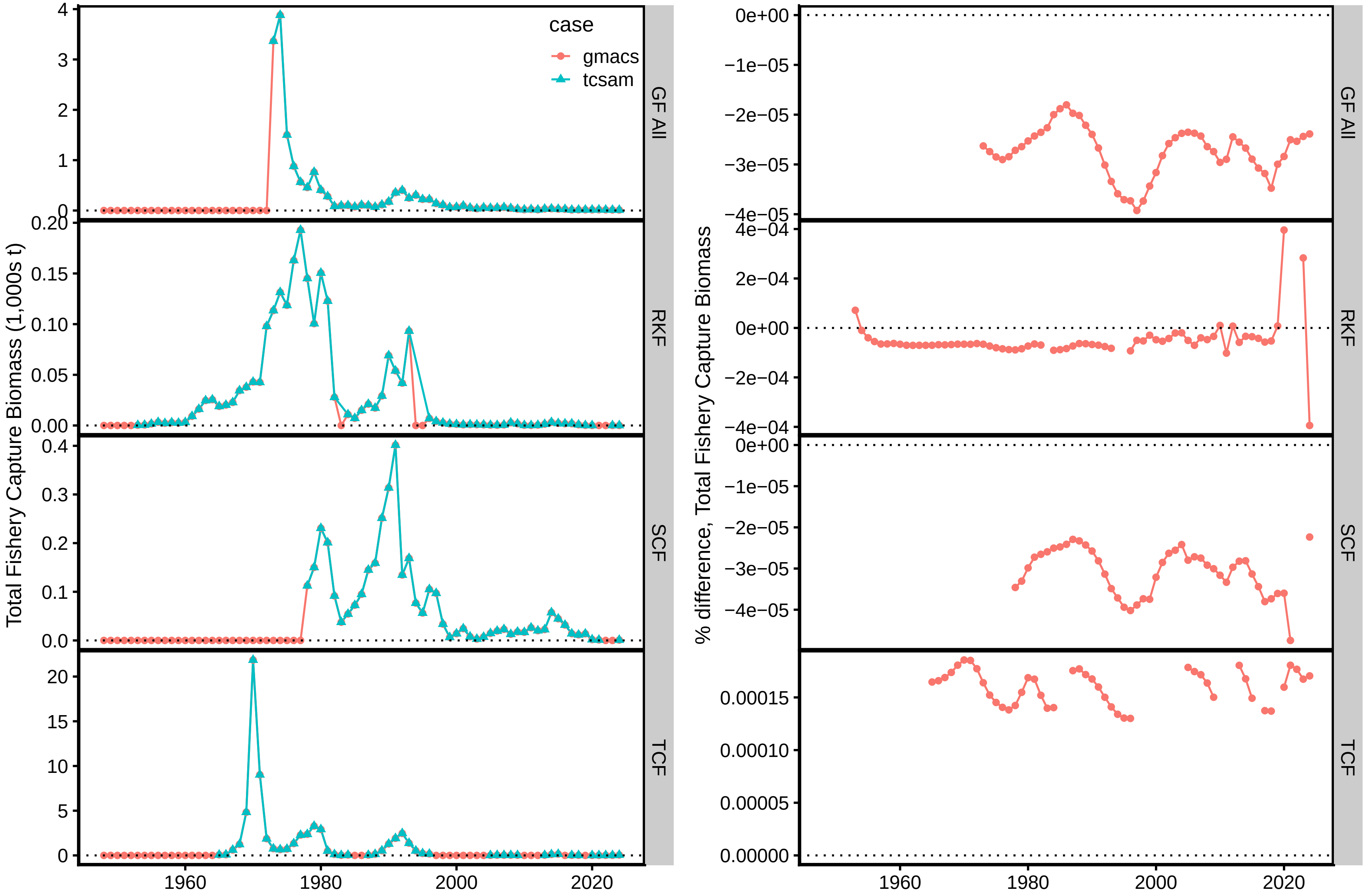


Figure 86. Comparison of the predicted capture biomass by fishery through time for females from the GMACS and TCSAM02 models. Left: values; right: percent differences.

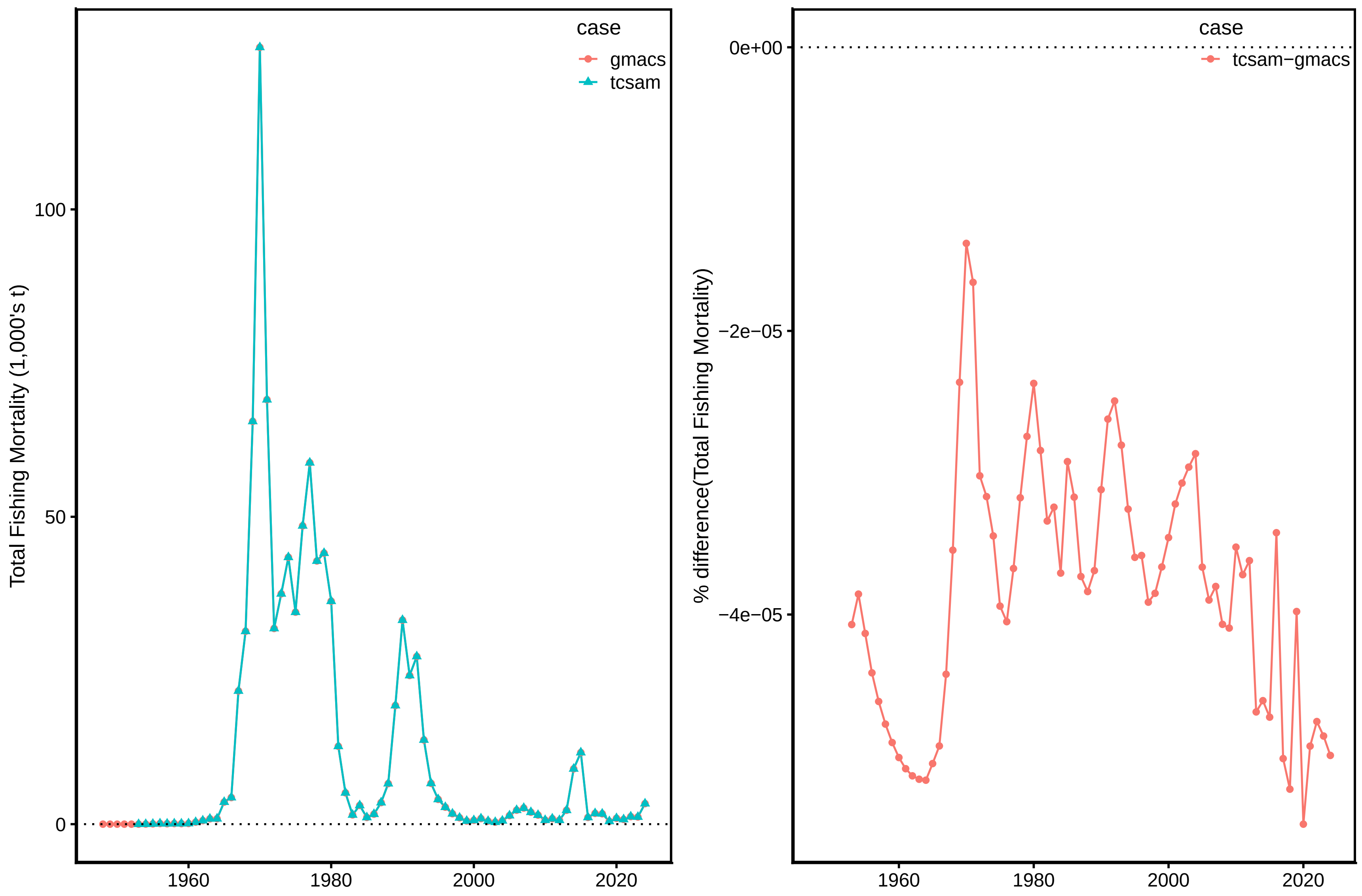


Figure 87. Comparison of the predicted toal fishing mortality (biomass) through time from the GMACS and TCSAM02 models. Left: values; right: percent differences.

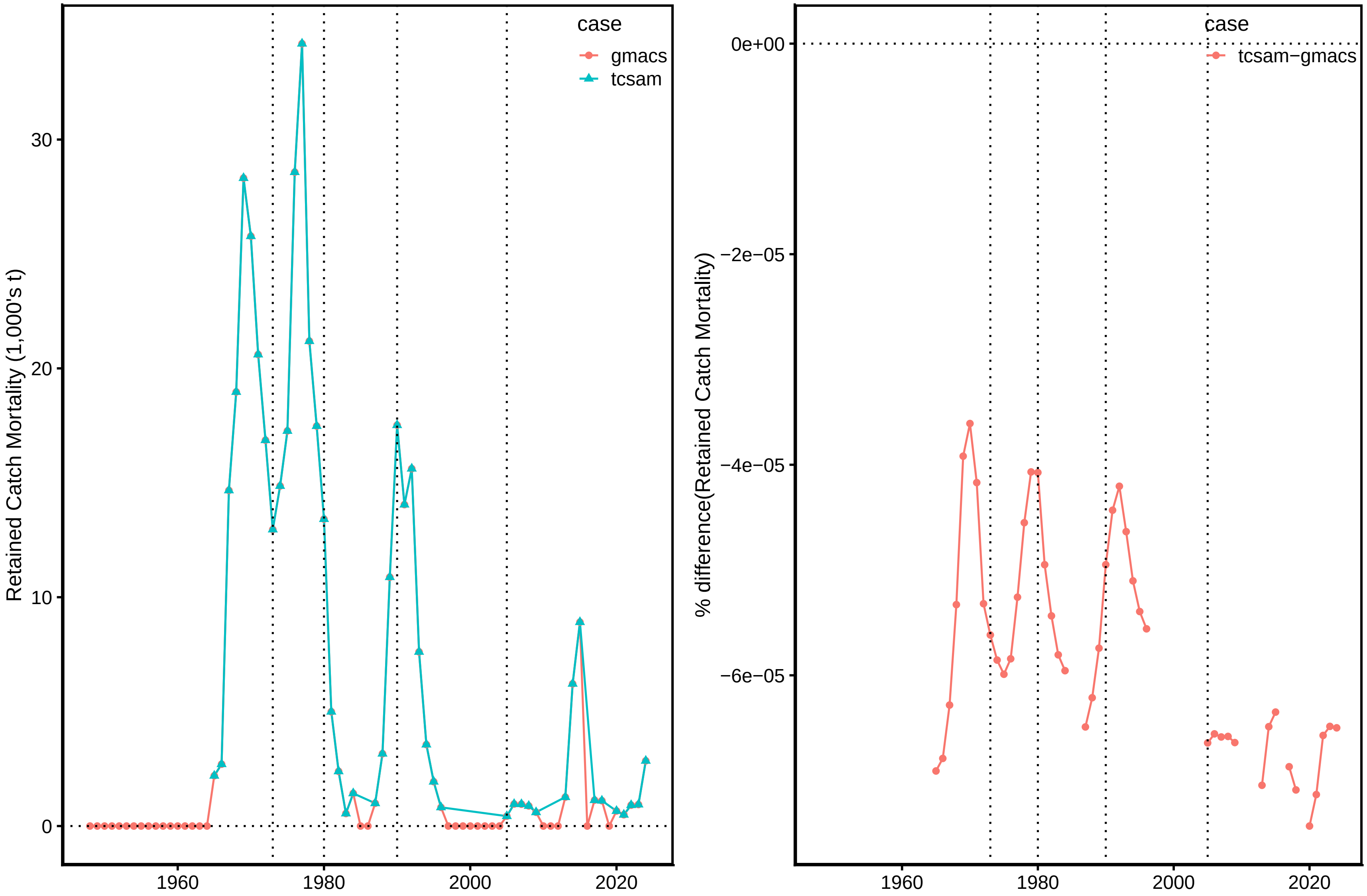


Figure 88. Comparison of the predicted retained catch mortality (biomass) through time from the GMACS and TCSAM02 models. Left: values; right: percent differences. Dotted vertical lines indicate 1973, 1980,1990, and 2005

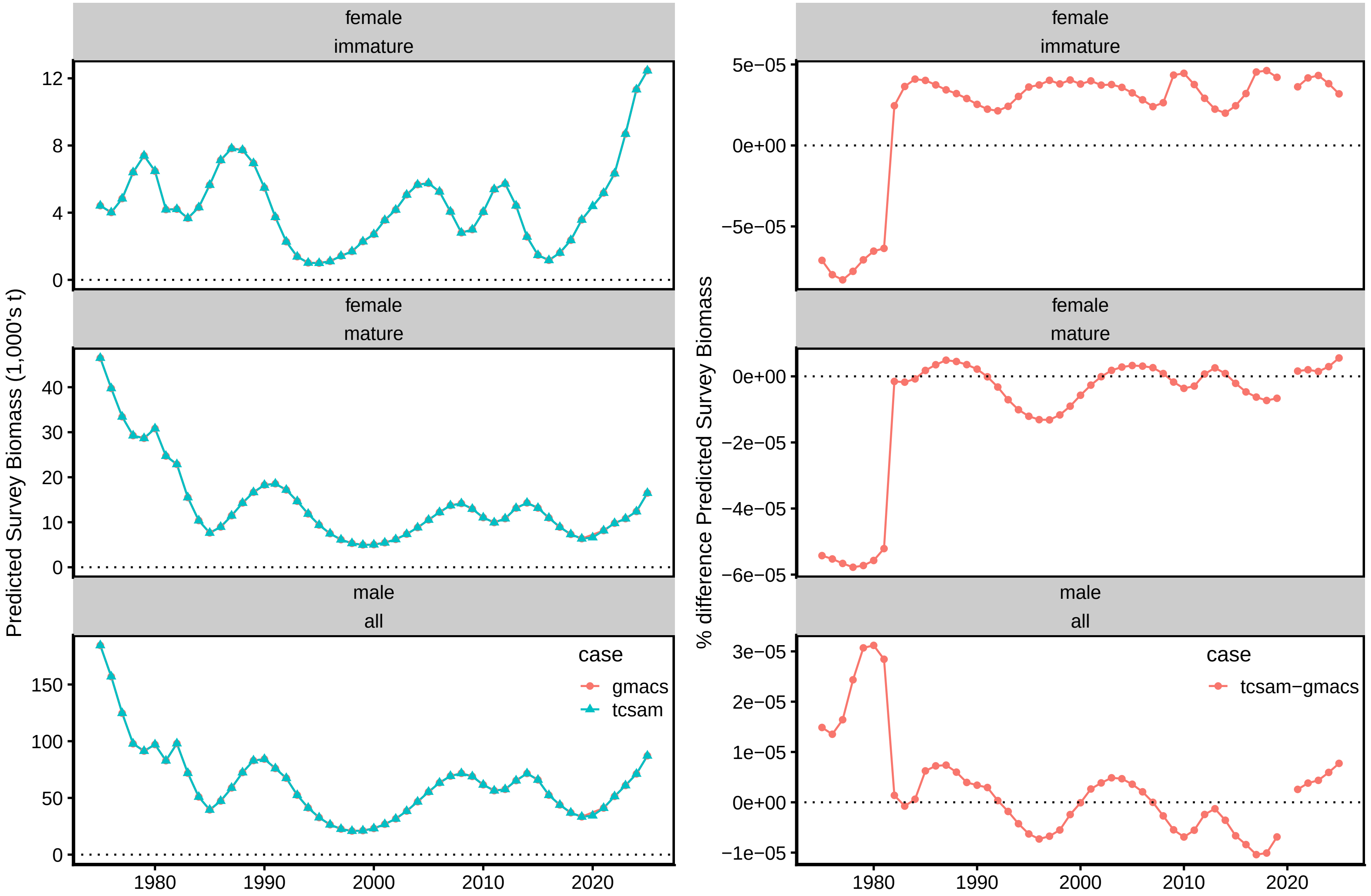


Figure 89. Comparison of the predicted NMFS survey biomass through time from the GMACS and TCSAM02 models. Left: values; right: percent differences.

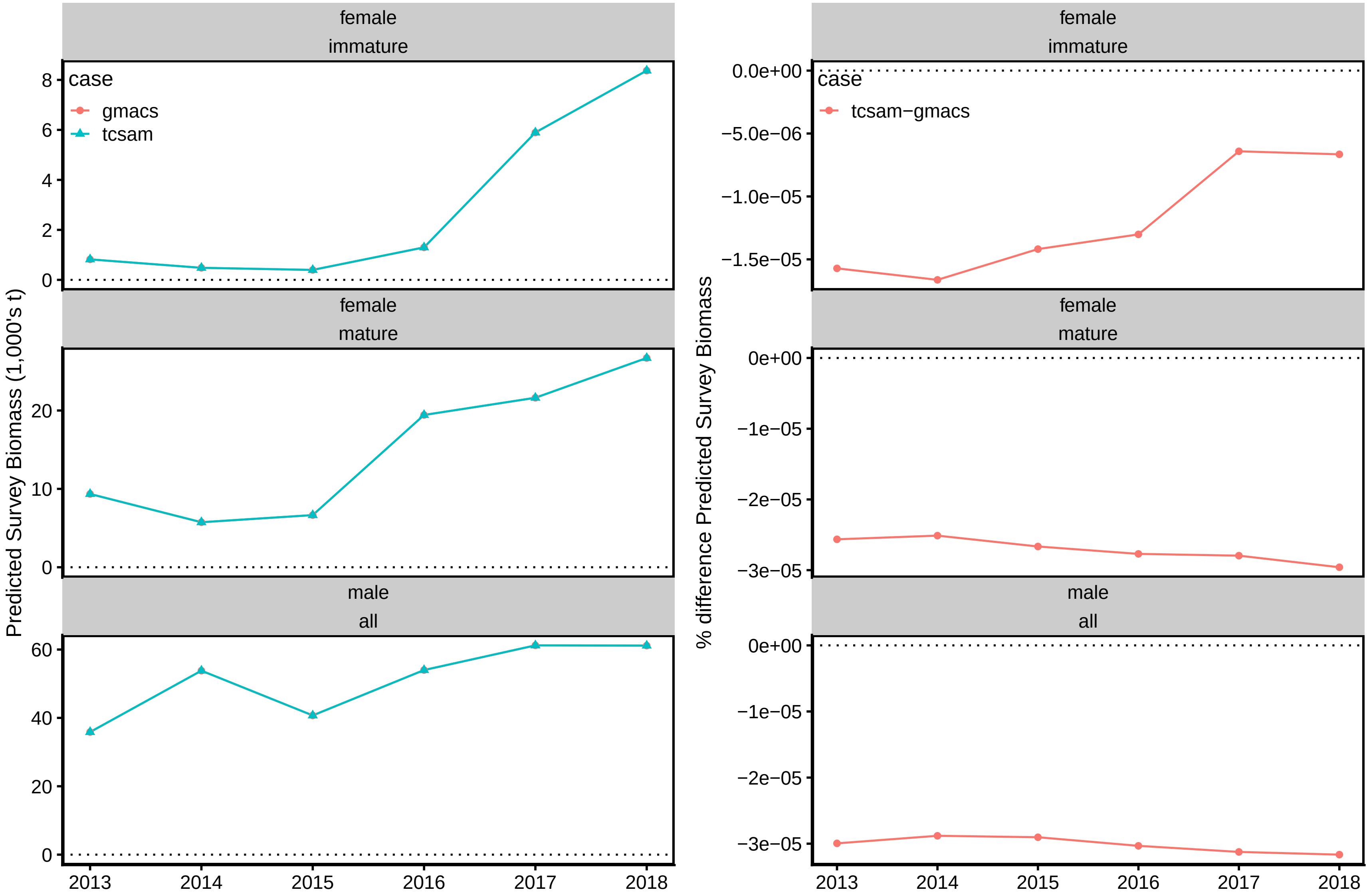


Figure 90. Comparison of the predicted BSFRF survey biomass through time from the GMACS and TCSAM02 models. Left: values; right: percent differences.

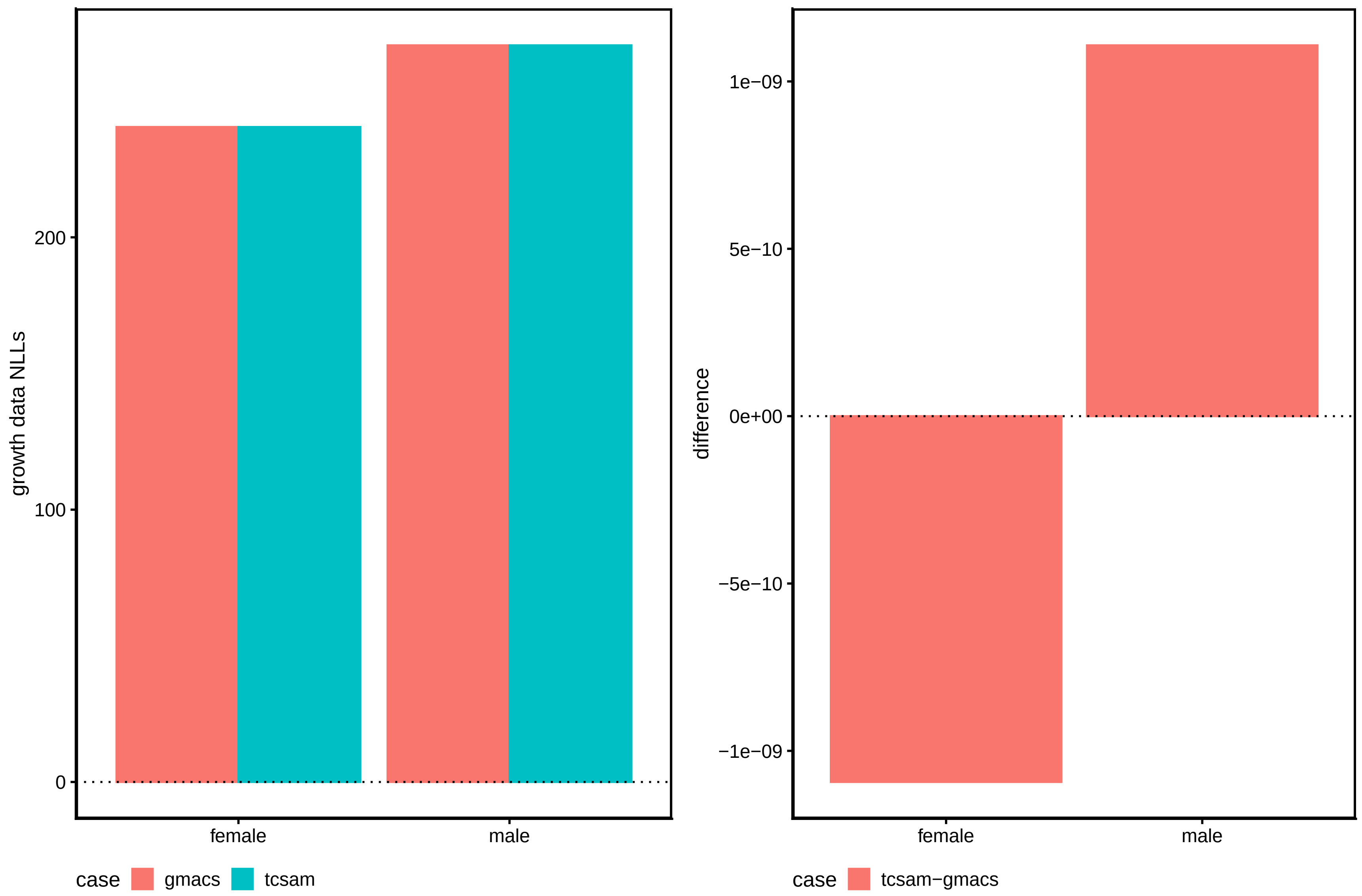


Figure 91. Comparison of summary negative log-likelihood (NLL) values for fits to sex-specific growth data from the GMACS and TCSAM02 models. Left: values; right: differences. These values are comparable between the model frameworks.

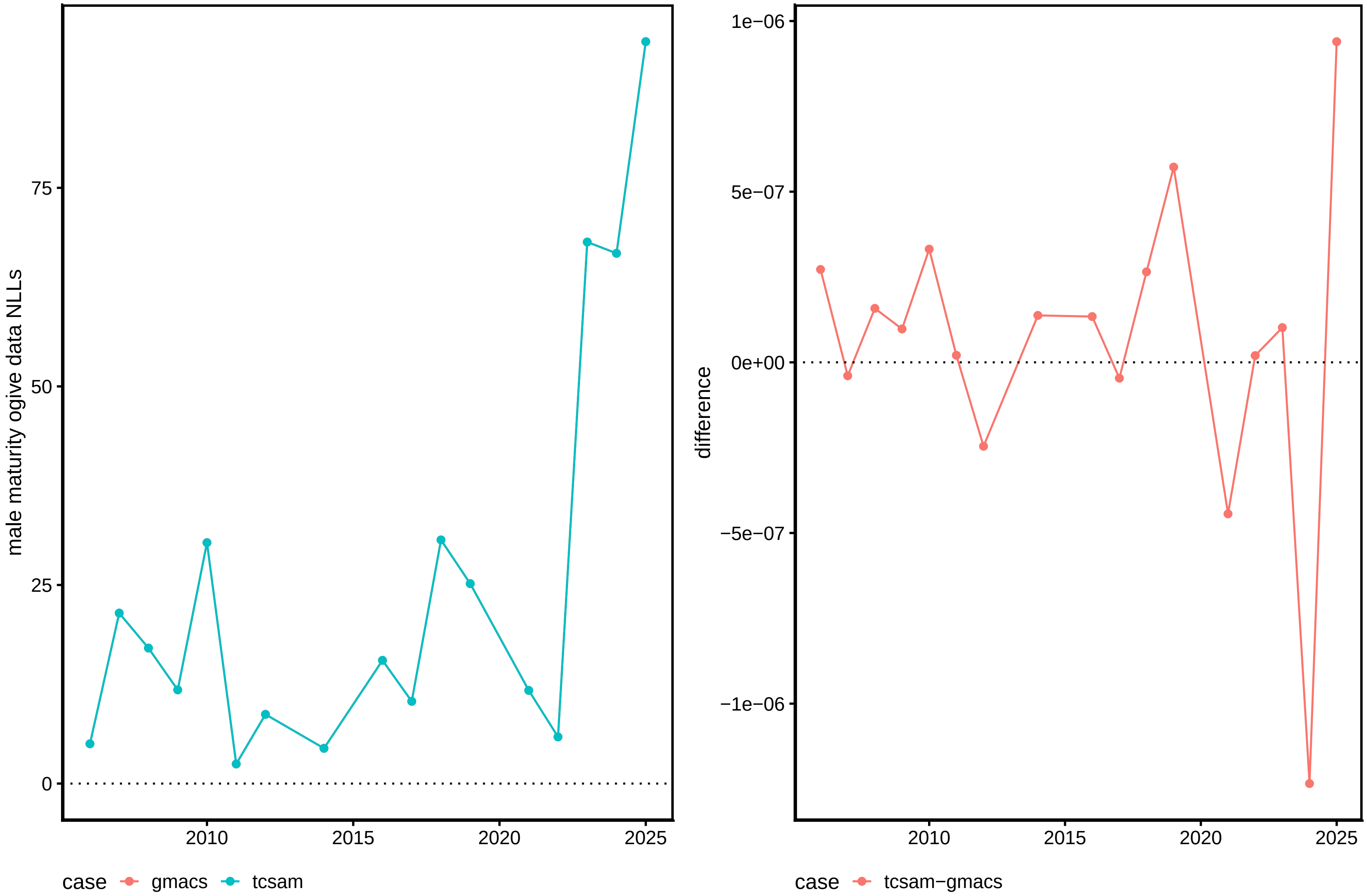


Figure 92. Comparison of summary negative log-likelihood (NLL) values for fits to male maturity ogive data from the GMACS and TCSAM02 models. Left: values; right: differences. These values are comparable between the model frameworks.

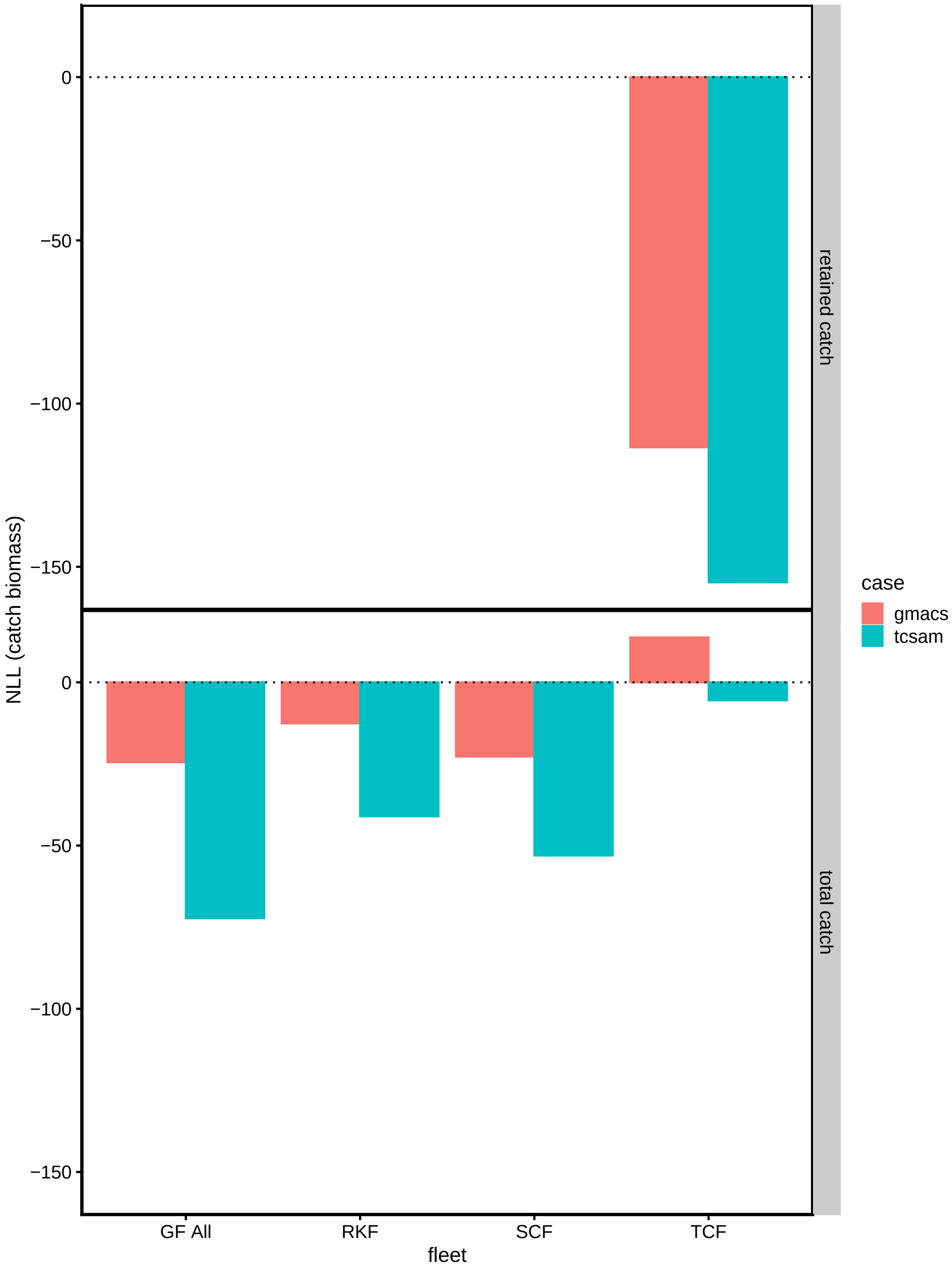


Figure 93. Comparison of summary negative log-likelihood (NLL) values for fishery catch biomass data from the GMACS and TCSAM02 models. Upper: retained catch; Lower: total catch. These values are **not** expected to agree between the models because constant terms in the NLL calculation are handled differently in the two model frameworks.

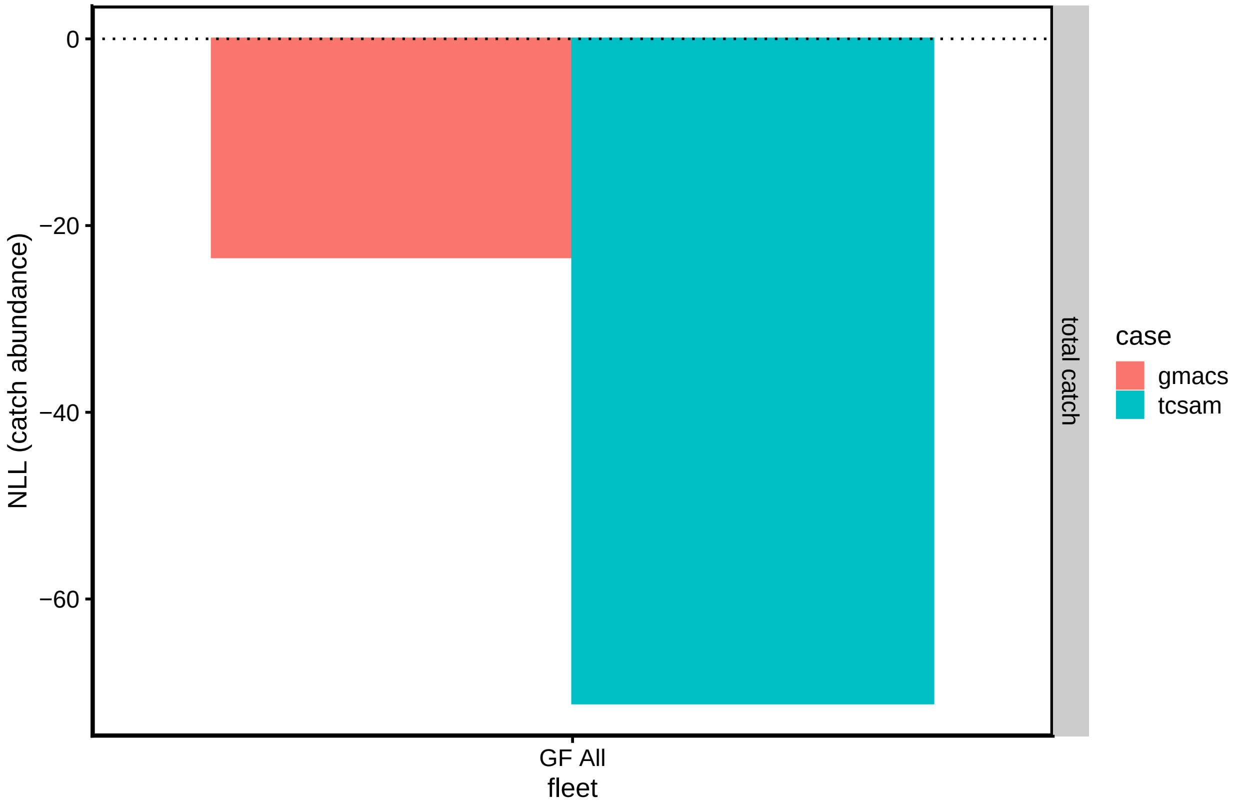


Figure 94. Comparison of summary negative log-likelihood (NLL) values for fishery catch abundance data from the GMACS and TCSAM02 models. Catch abundance is fit only from the groundfish fisheries. These values are **not** expected to agree between the models because constant terms in the NLL calculation are handled differently in the two model frameworks.

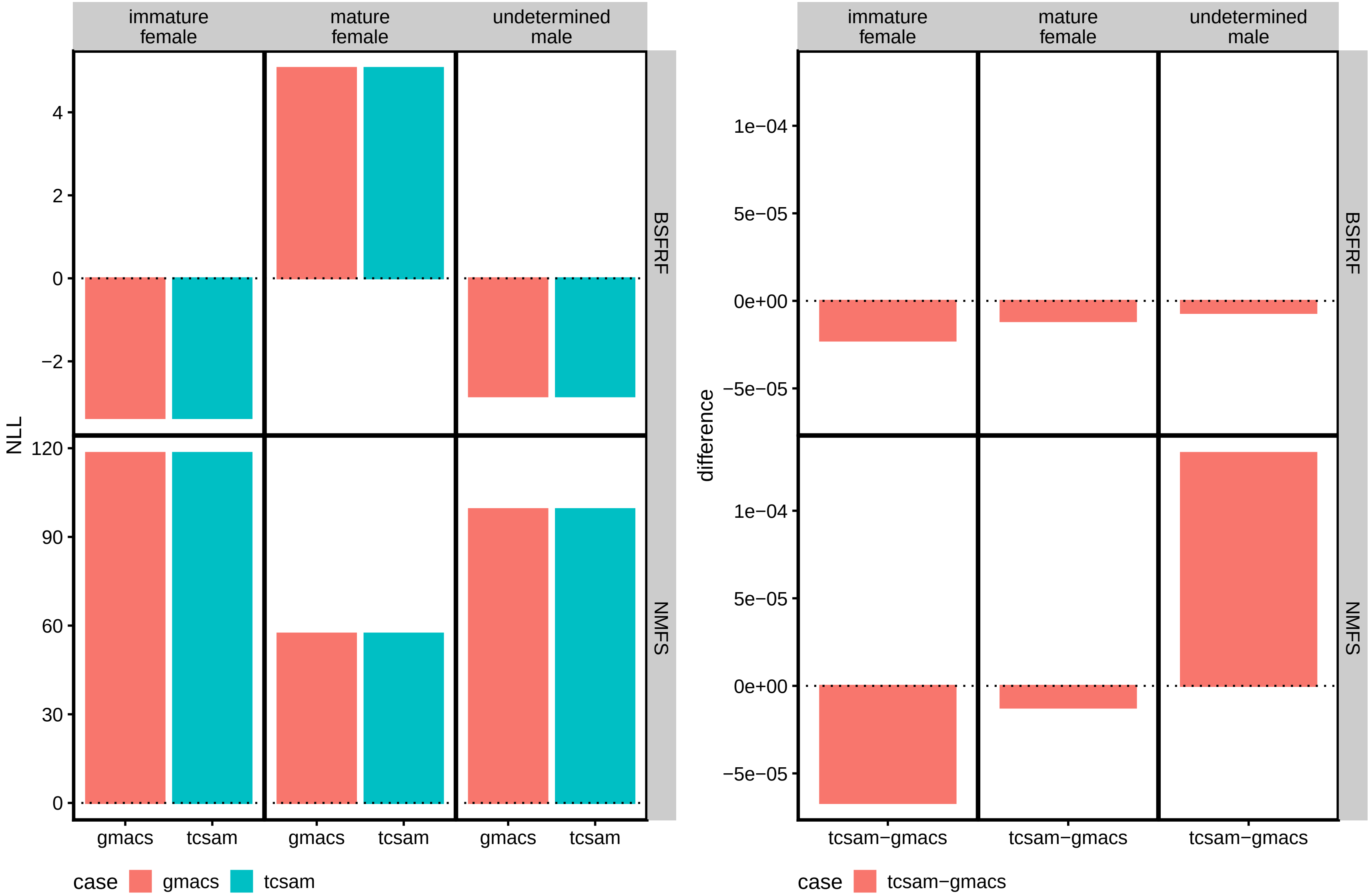


Figure 95. Comparison of summary negative log-likelihood (NLL) values for fits to survey biomass data from the GMACS and TCSAM02 models by fleet and biological category. Left: values; right: differences. These values are comparable.

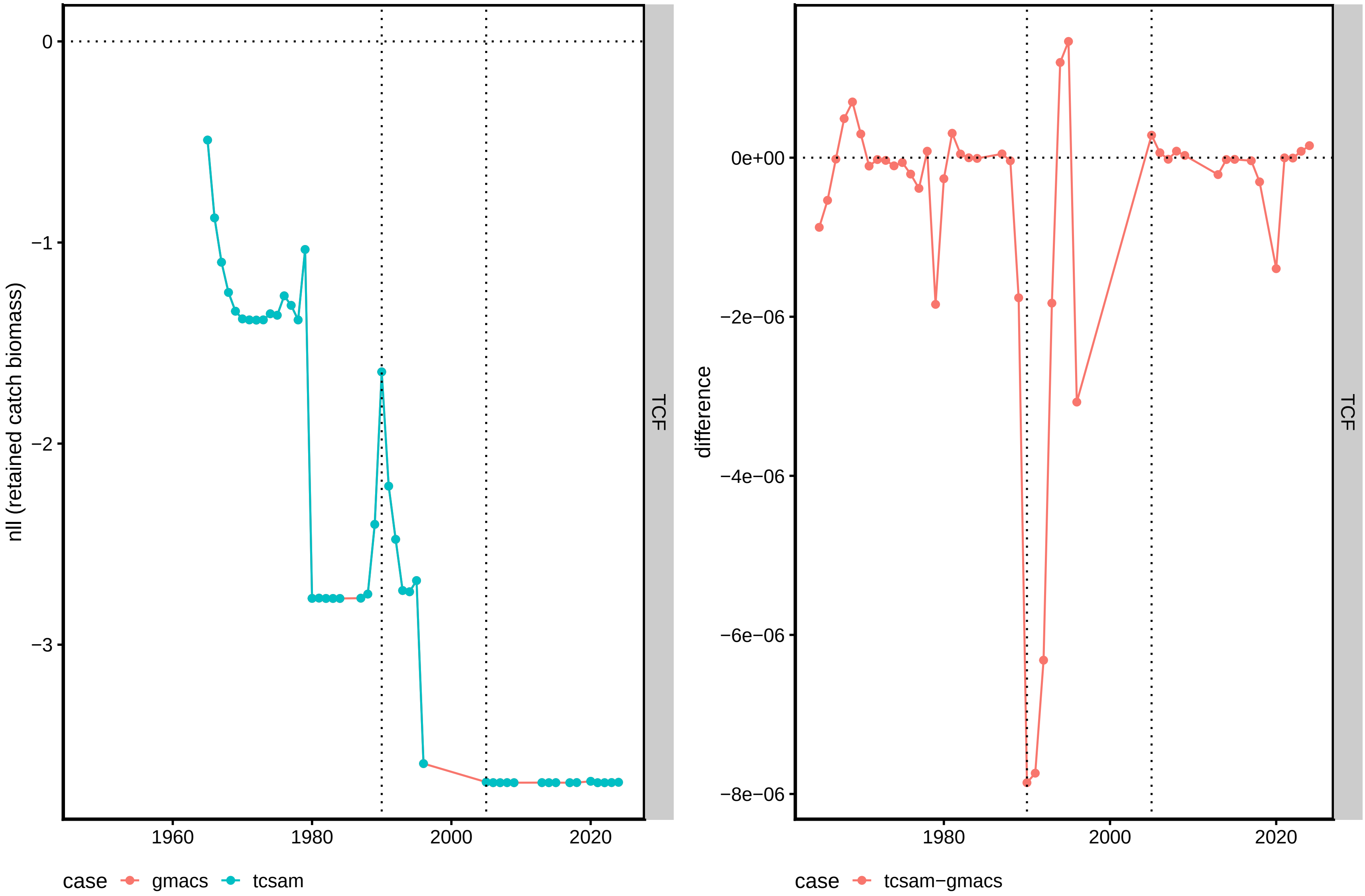


Figure 96. Comparison of summary negative log-likelihood (NLL) values for fits to fishery retained catch biomass data from the GMACS and TCSAM02 models. Left: values; right: differences. TCF: directed Tanner crab fishery. The vertical dotted lines indicate 1990 and 2005. These values are comparable.

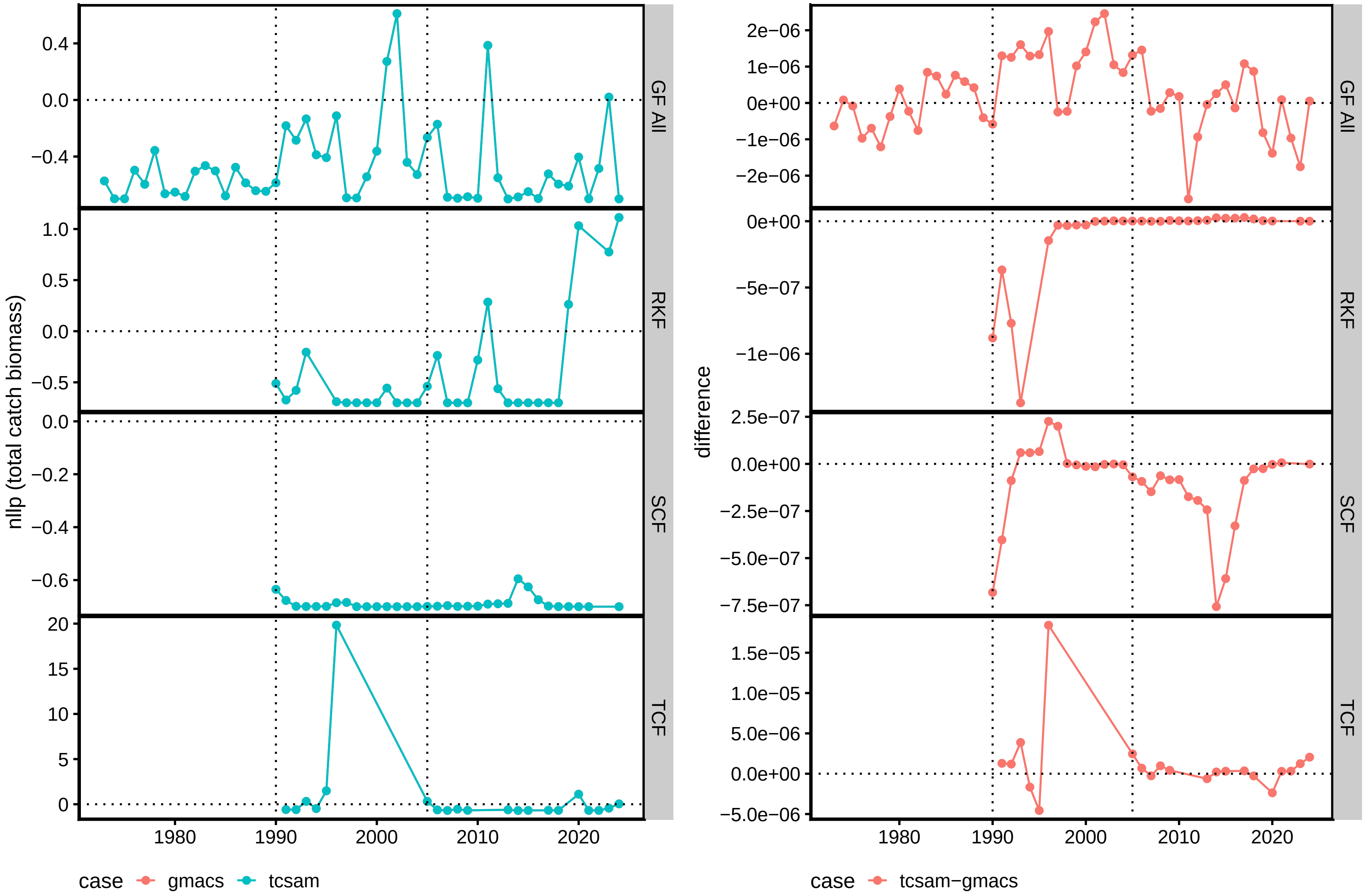


Figure 97. Comparison of summary negative log-likelihood (NLL) values for fits to fishery total catch biomass data from the GMACS and TCSAM02 models by fleet. Left: values; right: differences. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: groundfish fisheries. The vertical dotted lines indicate 1990 and 2005. These values are comparable.

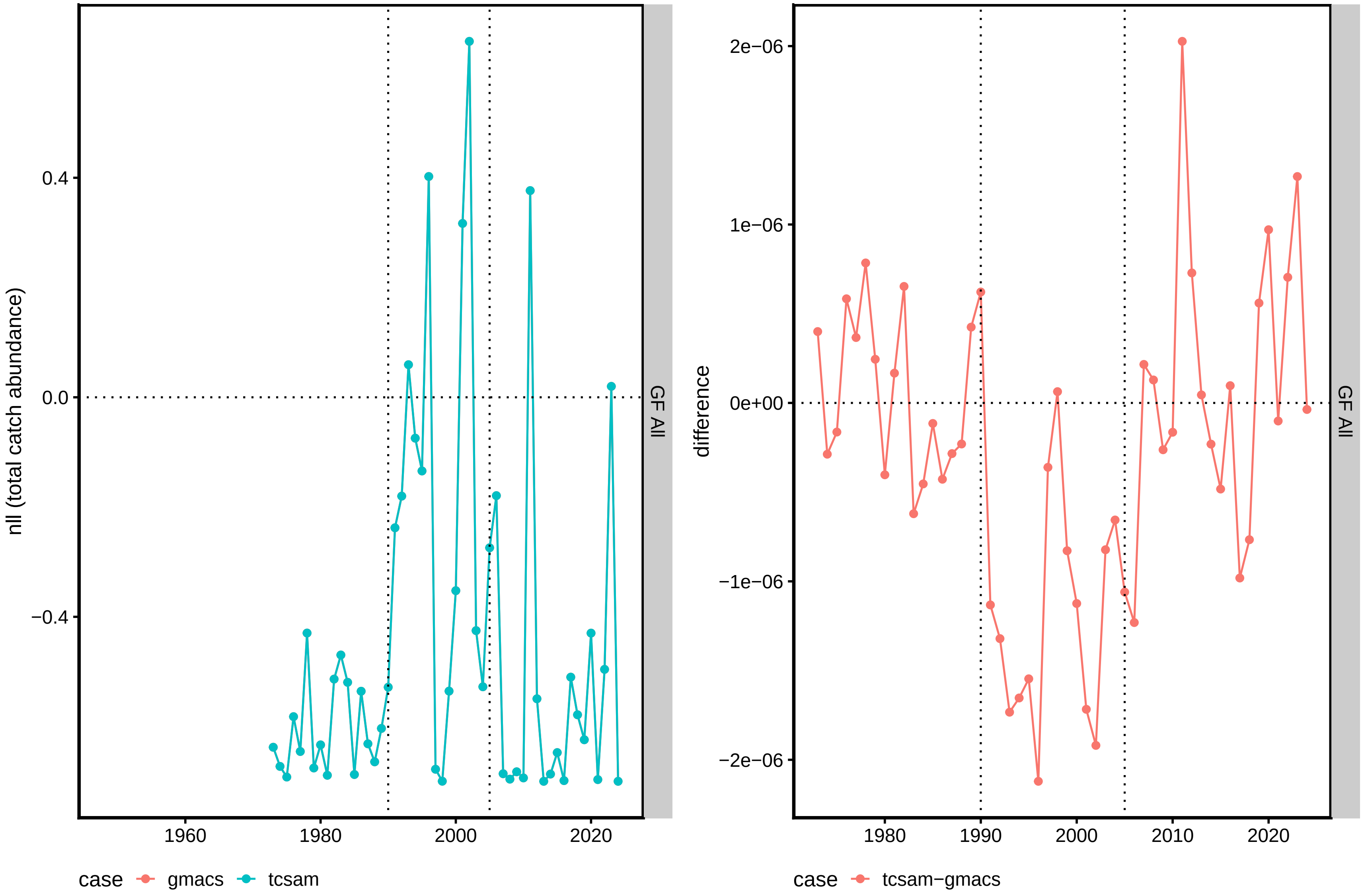


Figure 98. Comparison of summary negative log-likelihood (NLL) values for fits to fishery total catch abundance data from the GMACS and TCSAM02 models by fleet. Left: values; right: differences. Catch abundance data are fit only from the groundfish fisheries. The vertical dotted lines indicate 1990 and 2005. These values are comparable.

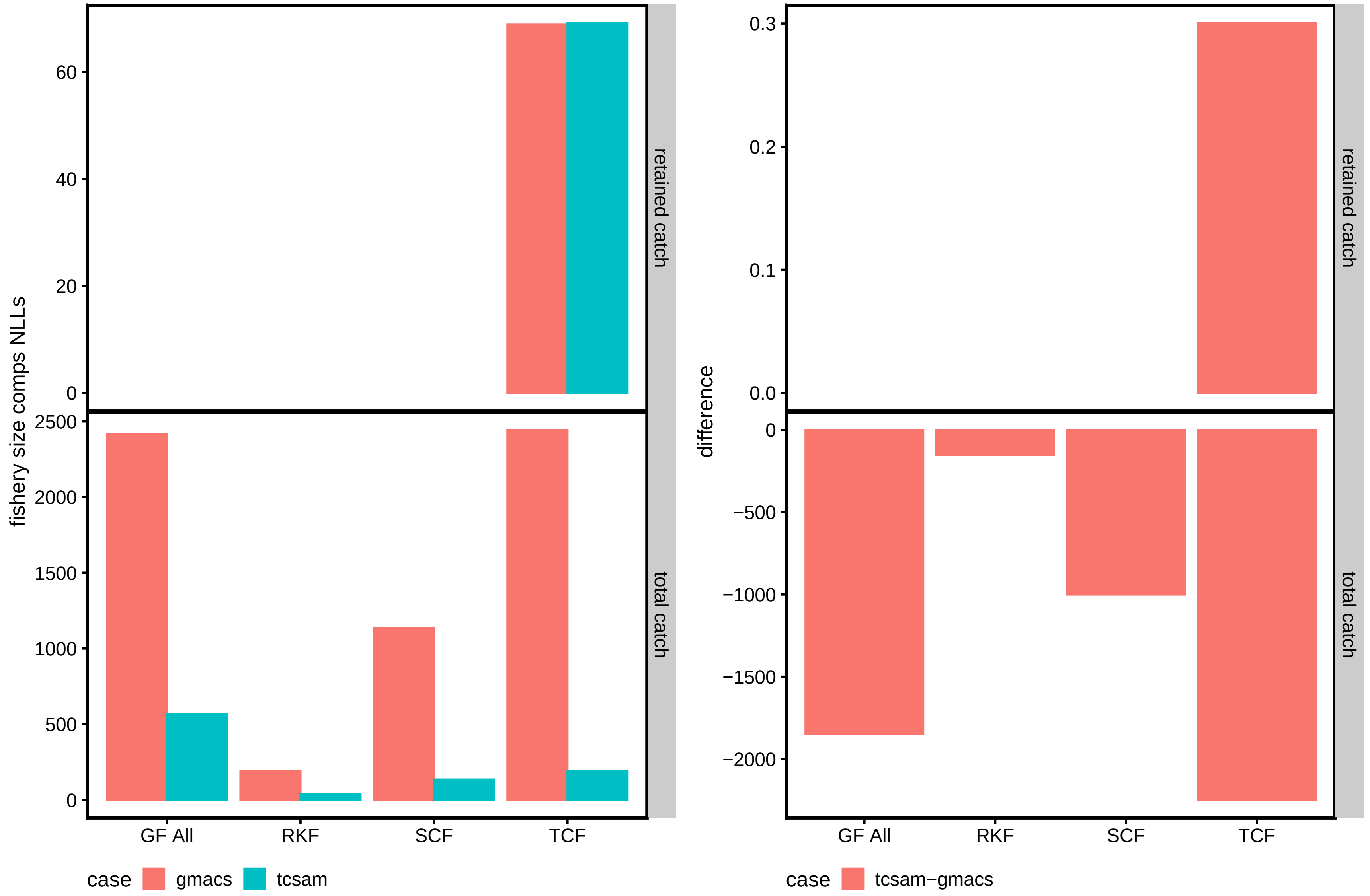


Figure 99. Comparison of negative log-likelihood (NLL) values for fits to fishery size composition data from the GMACS and TCSAM02 models by fleet. Left: values; right: differences. These values are **not** comparable between the model frameworks.

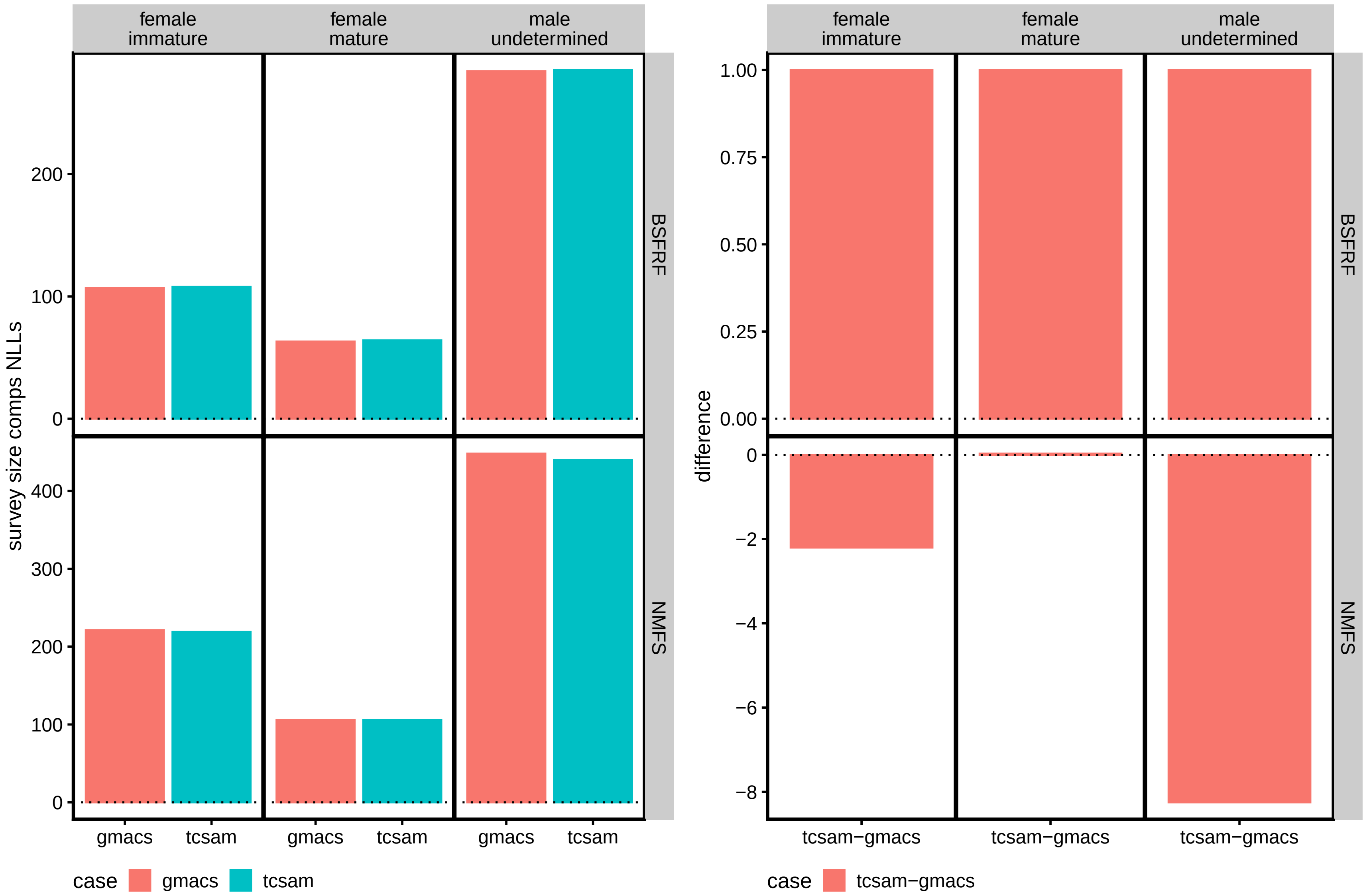


Figure 100. Comparison of negative log-likelihood (NLL) values for fits to survey size composition data from the GMACS and TCSAM02 models by biological category. Left: values; right: differences. These values are **not** comparable between the model frameworks.

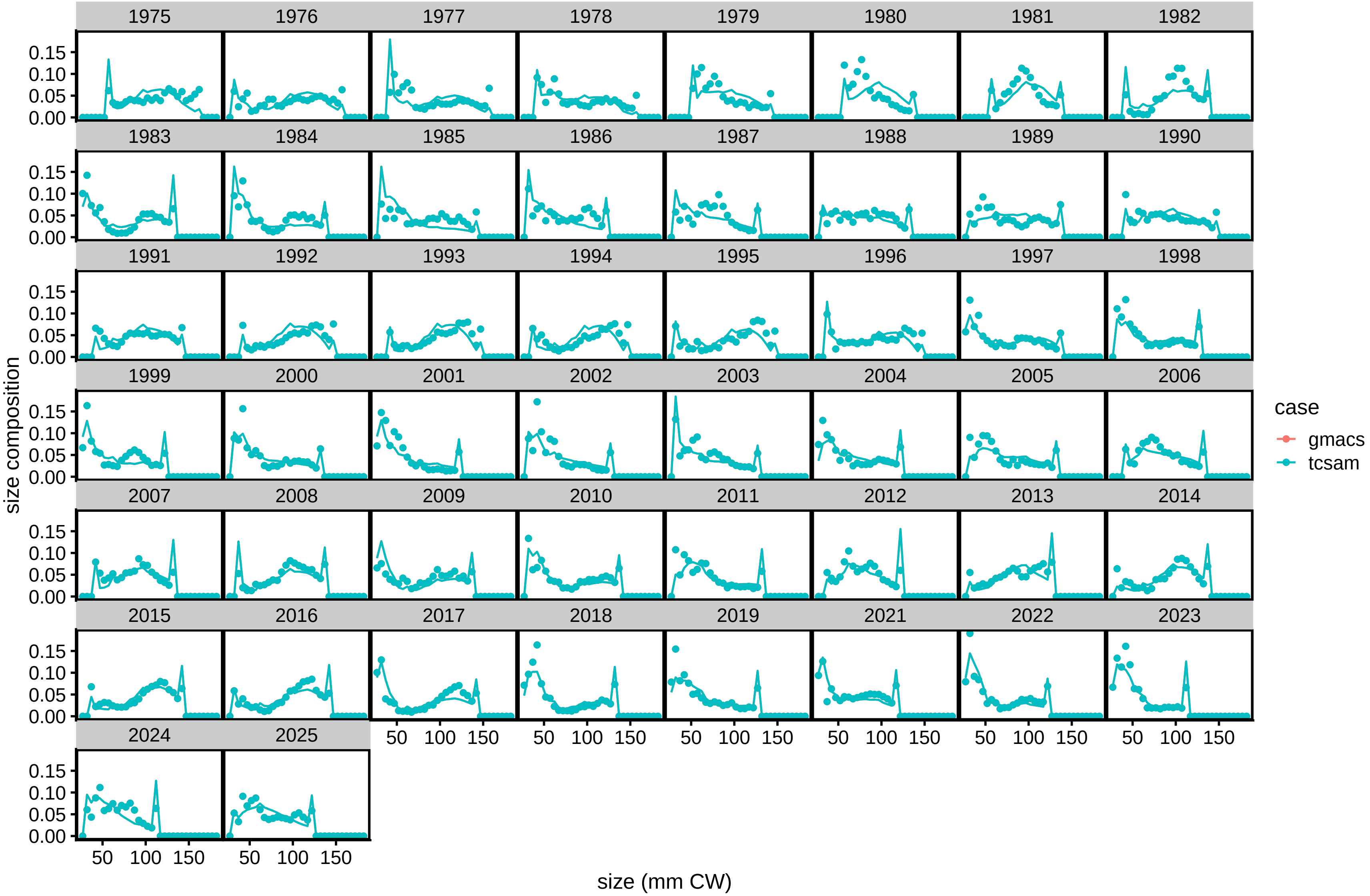


Figure 101. Comparison of fits to NMFS survey size comps for males. Points: data; lines: fit.

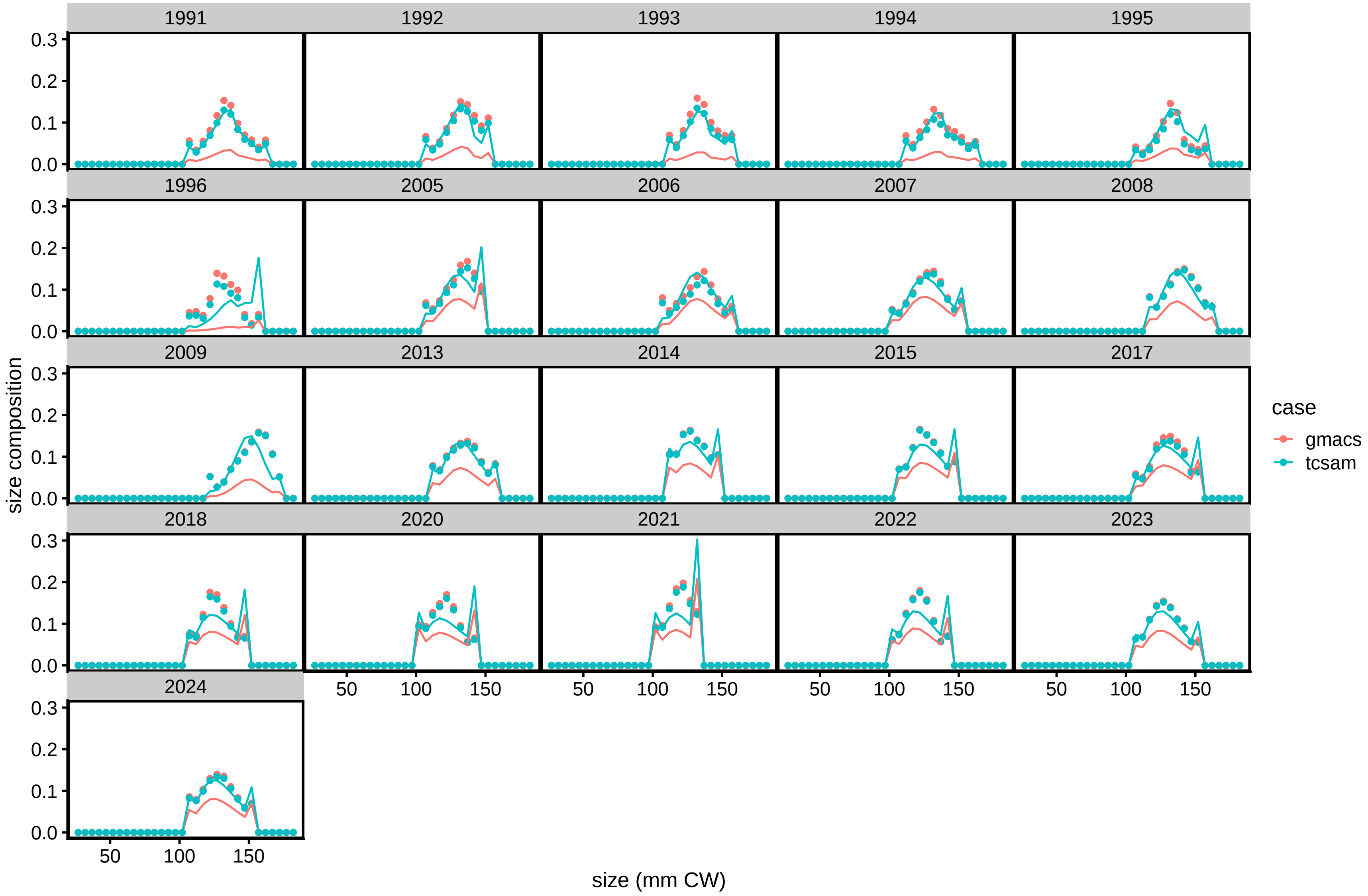


Figure 102. Comparison of fits to total catch size comps for males in the directed fishery. Points: data; lines: fit.

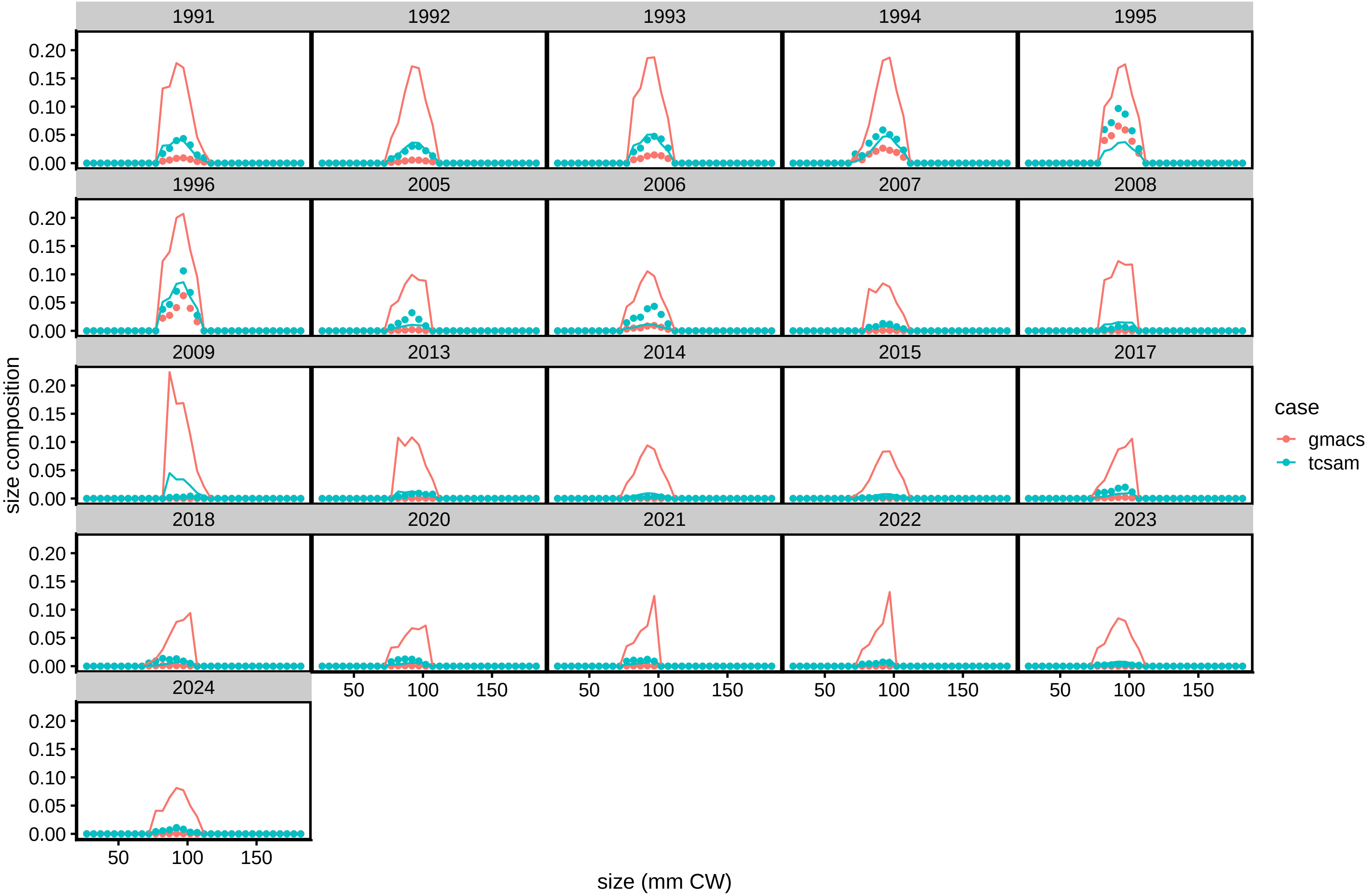


Figure 103. Comparison of fits to total catch size comps for females in the directed fishery. Points: data; lines: fit.

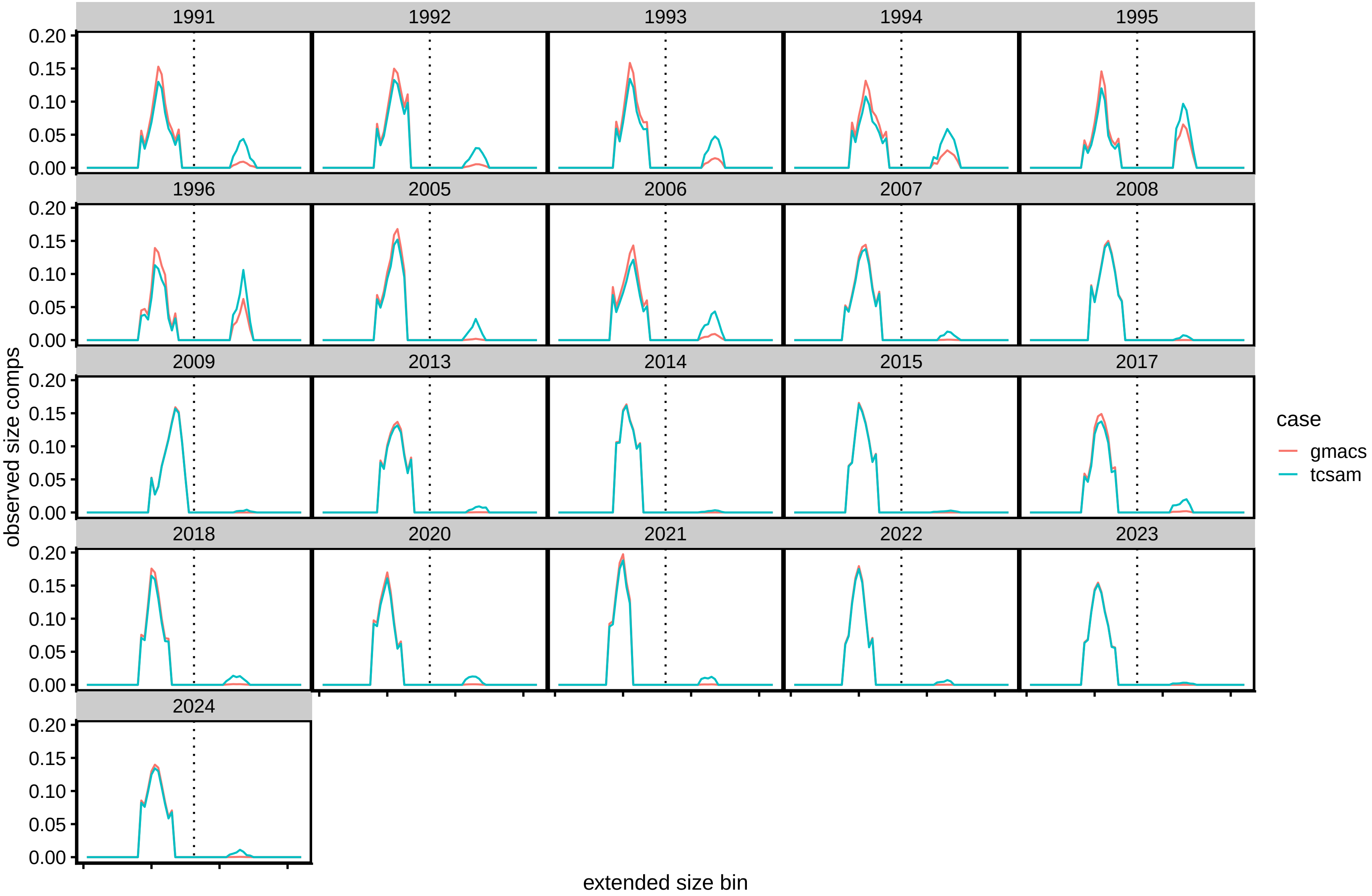


Figure 104. Comparison of "extended" observed total catch size comps for the directed fishery (TCF). In each panel, the vertical dashed line indicates the transition from males to females. A single likelihood valued is calculated for each "extended" size composition (rather than two likelihoods calculated by sex) based on the corresponding predicted size composition shown in the next figure.

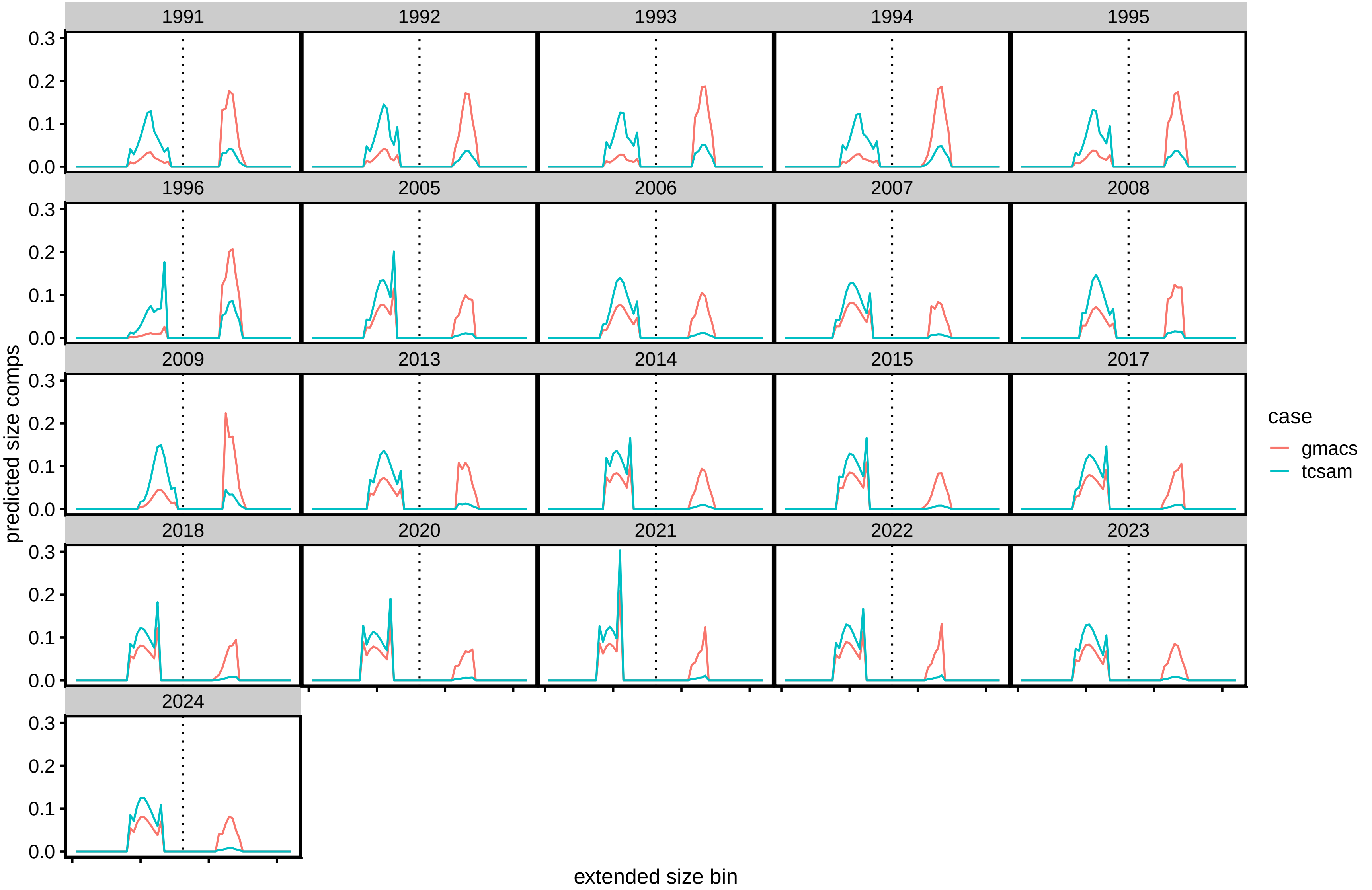


Figure 105. Comparison of “extended” predicted total catch size comps for the directed fishery (TCF). In each panel, the vertical dashed line indicates the transition from males to females. A single likelihood valued is calculated for each “extended” composition (rather than two likelihoods calculated by sex) based on the corresponding observed size composition shown in the previous figure.

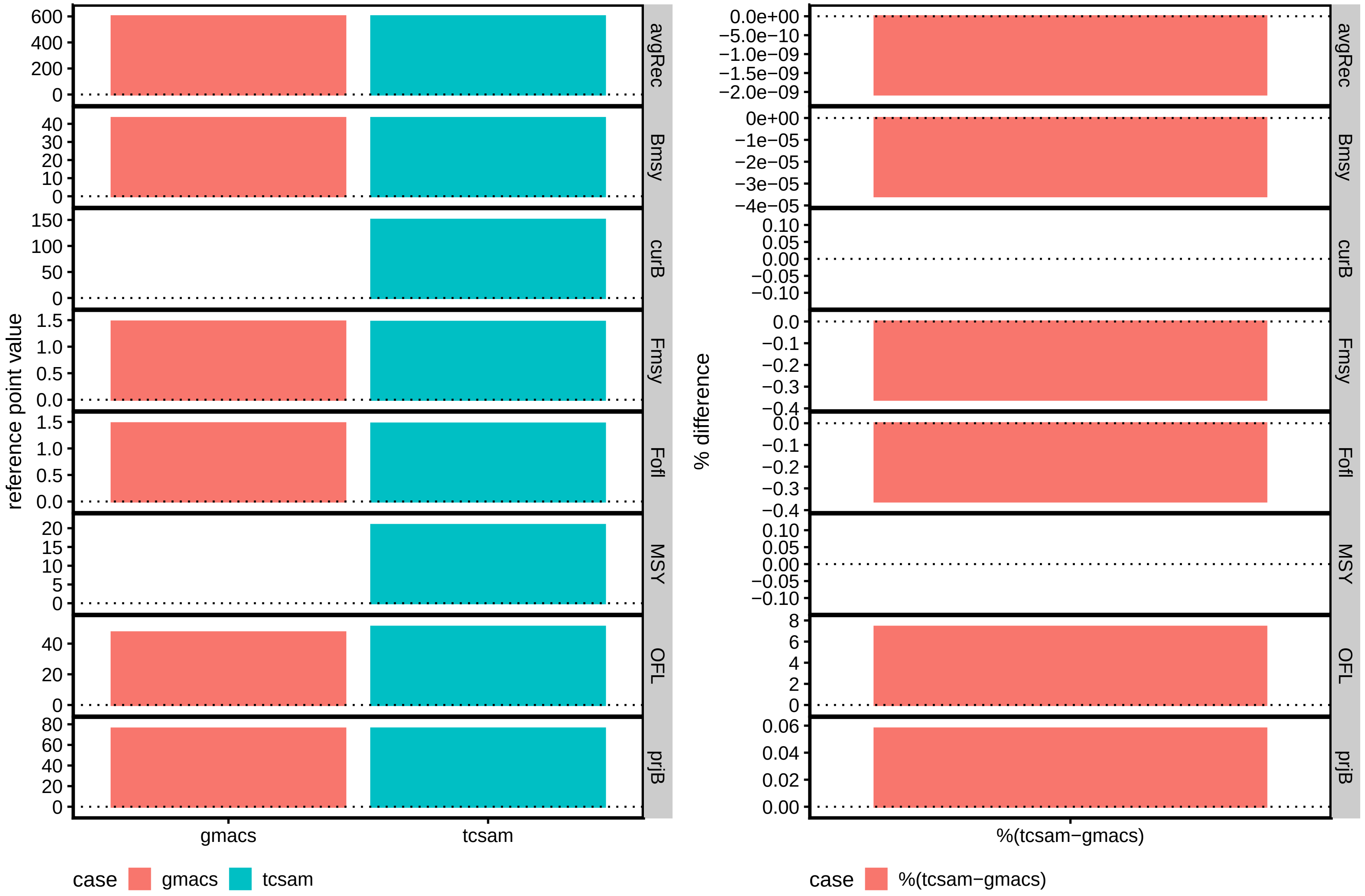


Figure 106. Comparison of management reference point values from the GMACS and TCSAM02 models. Left: values; right: % differences.