Candidate Assessment Models for Tanner Crab

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1 Introduction

The next assessment for Tanner crab will be reviewed by the Crab Plan Team (CPT) in September 2023 and the NPFMC's Science and Statistical Committee (SSC) in October 2023. Here, several variations on the 2022/23 assessment model (22.03), along with supporting and additional analyses, are presented to allow the CPT and SSC to select alternative models to be considered for the assessment in the fall. The 2022/23 Tanner crab assessment model, referred to as "22.03" using the SSC's model numbering protocol, provides the base model for development and comparisons among the alternative Tier 3 models presented here. Of note, all Tier 3 models presented here are based on the "bespoke" TCSAM02 modeling framework. Work on implementing a candidate model in the GMACS modeling framework is progressing, but is not complete. Instead, a new Tier 4 model (Appendix D), developed at the request of the SSC, is presented. The latter is closely based on the Pribilof Islands blue king crab Tier 4 model formulation and is intended to provide a "fallback" for the SSC in the event that none of the alternative Tier 3 models presented in the fall are deemed acceptable to use for management advice.

2 The 2022/23 Assessment Model

The 2022/23 Tanner crab assessment model (Stockhausen, 2022), referred to as "22.03" using the SSC's model numbering protocol, is an integrated assessment model based on a stage/size-structured population dynamics model that incorporates sex (male, female), shell condition (new shell, old shell), and maturity (immature, mature) as different categories into which the overall stock is divided on a size-specific basis (Figure 1). The model is fit to indices of stock biomass from the NMFS EBS shelf survey and BSFRF selectivity studies, retained catch, total catch (retained catch + discarded bycatch), size compositions, molt increment data, and male maturity data. Parameters are estimated by minimizing a quasi-Bayesian/negative log-likelihood objective function, with priors and/or penalties placed on a number of parameters (see Appendix B: Moddel Parameter Values). The model uses the TCSAM02 modeling framework, which is similar to the more generic GMACS modeling framework, but was developed specifically for *Chionoecetes* crab (the reader is referred to Appendix C and the GitHub repository for specific details on TCSAM02).

Tables 1-5 summarize specific details of 22.03. In total, the model estimates 351 parameters describing population processes (recruitment, natural mortality, growth, and maturation), fishing mortality from four fisheries, and indices from two surveys. Fishing mortality in the directed Tanner crab fishery includes retained catch of legal-sized males and discard mortality on all other crab caught. Discard mortality is also accounted for on bycatch of Tanner crab caught in the snow crab fishery, the Bristol Bay red king crab (BBRKC) fishery, and the (combined) groundfish fisheries. An incidental amount of Tanner crab may be legally retained in the snow crab and BBRKC fisheries when the Tanner crab fishery is open, but this has always been a small fraction of the total retained catch; for the purposes of the assessment, any incidentally-retained catch is added to that from the directed fishery. The NMFS EBS shelf survey provides the primary fishery-independent relative biomass index and associated size composition data (annually, 1975-2022; with the exception of 2020). Data from BSFRF "side-by-side" (SBS) selectivity study surveys (2013-2017) are assumed to provide absolute indices of biomass (limited spatially and temporally by the study areas/years), as well as size composition data.

2.1 Model code development

Since the 2022 assessment, the TCSAM02 modeling framework has been updated to the latest version of the ADMB C++ libraries (version 13.1) and the abilities to

- specify length-weight relationships using regression coefficients
- estimate annually-varying natural mortality
- use different model and data size bins

have been added to the code.

3 Tier 3 Model Candidates

Thirteen Tier 3 model candidates were developed for possible consideration in the Fall 2023 Tanner crab assessment (Table 6). One other Tier 3 model, 22.03a, provided a check that changes since the 2022 assessment to the most recent versions of ADMB and the TCSAM02 modeling framework did not affect results from 22.03, the 2022 assessment model.

3.1 Model 22.03a

Model 22.03a uses the same model configuration, options, parameter settings, and data as 22.03, but was run using the most recent versions of ADMB (13.1, released in December, 2022) and the TCSAM02 modeling framework. TCSAM02 was modified after the 2022 assessment to optionally allow specification of length-weight relationships using regression coefficients, estimation of (stage-specific) annually-varying natural mortality rates, and the use of different size bins for model and data quantities.

3.2 Model 22.03b

Model 22.03 had one parameter, the slope of the logistic curve used to describe retention in the directed fishery from 2005 to 2009, estimated at its upper bound. Although the model hessian was invertible and standard errors for parameters could be obtained, parameters at bounds can be problematic in a maximum likelihood framework. Standard solutions to a parameter-at-a-bound problem include increasing the bounds, reparameterizing the modeled process, or fixing the parameter at its bound rather than estimating it. For the parameter in question, hitting it's upper bound implies that the fraction of crab retained during 2005-2009 changes abruptly as a "step" function from 0 (all crab discarded) to 1 (all crab retained) at some size. However, step functions are not differentiable and can't be used with ADMB. Thus, it is reasonable (and a standard fix) to assign a large, fixed value to the slope of a logistic function and estimate only the size at which the change occurs. Model 22.03b makes this "correction", fixing the slope parameter at 1.99, just below the assigned upper limit of 2. Consequently, 22.03b estimates one fewer parameters than 22.03 or 22.03a.

3.3 Models 23.01a and 23.01b

Recent assessment models, including 22.03, have estimated the dependence of molt increment on size for immature crab by fitting sex-specific curves to molt increment data simultaneous with fitting to fishery and survey catch data. In doing so, the models have always fit the female growth data well but consistently overestimated molt increments for large males, implying a disconnect somewhere between the growth data and size composition data for male crab included in the model optimization. One possible source of this discrepancy is a potential interaction between the size bin structure used in the model to describe population dynamics and the growth model, where overly-large size bins can lead to anomalously fast growth. Models 23.01a and 23.01b attempted to address this possible explanation by using 1-mm size bins to quantify the population dynamics, rather than the 5-mm bins that have been used in previous models. 22.03b was the starting point for both models. However, because the probability of immature crab undergoing terminal molt at size is estimated using sex-specific parameters for each size bin, the overall number of estimated parameters changed from 350 to 460. Additionally, because 2nd-derivative (with size) smoothing penalties were applied to the molt-to-maturity parameter vectors, the results depend on the degree of smoothing applied. Here, Model 23.01b applies a larger smoothing penalty (20**x**) than does 23.01a.

3.4 Model 23.02 (VAST)

Model 23.02 also builds on 22.03b, but fits VAST-derived time series (J. Richar, NOAA/NMFS/AFSC, pers. comm.; Thorson and Barnett, 2017; Thorson, 2019) for NMFS EBS shelf survey biomass rather than the design-based estimates fit in the assessment model. The VAST estimates generally follow the same trends as the design-based estimates, but with much smaller confidence intervals (Tables 7-9, Figures 2 and 3).

3.5 Models 23.03 (MSM)

Four models labeled "23.03", with variants "a", "a1", "b", and "b1", are based on attempts to develop a "maximally simplified model" (MSM) from the current assessment model by fixing model processes that can be estimated independently outside the assessment model rather than estimating them inside the model. The size-weight relationship for Tanner crab, characterized as a power-law regression of weight on size, is already fixed in the current assessment model. For the 23.03 models, two other processes were fixed based on previous analysis independent of the assessment model: 1) molt increment as a function of sex/size (Stockhausen, 2019) and 2) sex/size-specific catchability for the NMFS EBS shelf survey derived from the BSFRF side-by-side catchability studies for Tanner crab (Stockhausen, 2021).

3.5.0.1 Model growth

In the assessment model, the actual post-molt size z_{pst} for a crab, given that it was in size bin z_i prior to molting, is described using a γ distribution, with the probability that the post-molt crab falls into the jth size bin z_j given by:

$$p(z_j|z_i) = \int_{\alpha_i(z_j)-\frac{\delta\alpha}{2}}^{\alpha_i(z_j)+\frac{\delta\alpha}{2}} \gamma(\alpha - \overline{\alpha_i}) \cdot d\alpha$$

where $\alpha_i(z) = \frac{z-z_i}{\beta}$ represents the scaled molt increment, $\overline{\alpha_i} = \frac{\overline{z}_{pst}-z_i}{\beta}$ is the scaled mean molt increment for pre-molt size bin z_i, $\delta\alpha = \frac{\delta z}{\beta}$ is the scaled size bin width, and β is the scale factor. The largest model size bin, z_{max}, functions as an accumulator bin, so it is handled slightly differently: the probability of a post-molt crab ending up in the largest size bin is simply the probability of it ending up at any larger size than its lower cutpoint:

$$p(z_{max}|z_i) = \int_{\alpha_i(z_{max})-\frac{\delta\alpha}{2}}^{\inf} \gamma(\alpha - \overline{\alpha_i}) \cdot d\alpha = 1 - \int_0^{\alpha_i(z_{max})-\frac{\delta\alpha}{2}} \gamma(\alpha - \overline{\alpha_i}) \cdot d\alpha$$

The assessment model also allows one to limit potential growth to a maximum number of size bins, n_{max}, in which case $p(z_j|z_i)$ is set to 0 for $j-i > n_{max}$ and normalized to sum to 1 for $j-i \leq n_{max}$.

Sex-specific molt increment data was fit outside the assessment using a similar approach and likelihood component to those in the assessment model, but implemented as a stand-alone model using TMB and without constraining potential growth. The location parameters are similar for females, but the upper location value for males is larger in the assessment than in the external TMB analysis (Table 10). The scale parameters have not been estimated successfully in the assessment on a sex-specific basis, but can be estimated in the external analysis (Table 10). The end result is that the assessment model overestimates the male molt increment at large sizes while the TMB model fits the data well (Figure 4). Both models fit the female data well (Figure 5) .

3.5.0.2 NMFS EBS survey catchability

Annual estimates of sex/size-specific survey catchability for Tanner crab in the NMFS EBS shelf survey, and associated uncertainties, were obtained from analysis of BSFRF/NMFS "side-by-side" (SBS) selectivity studies data by Stockhausen (2021; Figures 8 and 9) and fit using the R package "mgcv" (Wood, 2011) with smooth functions of size using generalized additive models (gams) to reduce the variance in the annual estimates and obtain a single "mean" selectivity curve for each sex. Models specified as

$$S_{y,z} \sim s(z) \tag{1}$$

where $S_{y,z}$ indicates the SBS analysis-estimated selectivity value for year y and size z and $s(z)$ indicates a smooth function of size, were fit separately for each sex using a normal-identity, gamma-identity, or gamma-inverse family option. The $S_{y,z}$'s were weighted by the associated standard errors obtained in the original SBS analysis. AIC was used to identify the model that best balanced fit and parsimony. For both sexes, the model using the gamma-identity family was identified as the best model of the three (Table 12). Of note, also, the model that used the normal-identity family estimated a negative value for male selectivity in the smallest size bin.

The resulting curves for both sexes (Figures 8 and 9) seem to imply dome-shaped selectivity and that fully-selected catchability is substantially less than 1 (males: 0.620, females: 0.232). However, such conclusions are predicated on the assumption that the BSFRF survey gear is non-selective with catchability equal to 1.

3.5.1 Models 23.05 (VAST+annually-varying M)

In the current assessment model, natural mortality (M) is estimated separately for immature crab, mature males, and mature females. For mature crab, M is further estimated separately for two time "blocks":

- 1980-1984, a period of hypothesized enhanced mortality for mature crab
- the remaining model time period

Time did not permit the development and analysis of time-varying M models that fit both the design-based (22.03b) and VAST (23.02) biomass time series from the NMFS EBS shelf survey. Here, Model 23.05 was built on Model 23.02 and attempts to estimate life stage-specific annually-varying M in addition to fitting the VAST-derived biomass time series for the NMFS EBS shelf survey. For each life stage, annual variation in M was parameterized as

$$M_y = \bar{M} \cdot e^{\delta M_y} \tag{2}$$

where the δM_y's are estimated ln-scale deviations (subject to a sum-to-zero penalty) from an overall estimated median ($\bar{M}$).

To improve estimability, two types of penalties on the δM_y's can be added also to the likelihood. The first is simply a normal prior on their individual values:

$$\delta M_y \sim N(0, \sigma^2) \tag{3}$$

where σ_1 is the ln-scale variance about the median. The second is a smoothing penalty, P, on second differences in the δM time series:

$$P \ = \ \lambda \cdot \sum \left(\delta M_{y+1} - 2 \cdot \delta M_y + \delta M_{y-1}\right)^2 \tag{4}$$

where λ controls the relative degree of smoothing. Model 23.05 did not impose any penalties on the estimated δM's, but four additional variants, "a", "a1", "b", and "b1", did so. The "a" and "b" variants imposed smoothness penalties on the δM's with λ equal to 1 and 10, respectively. The "1" variants also imposed a prior, with $\sigma \ = \ 0.5$, in addition to the smoothness penalty.

4 Tier 3 model comparisons

Convergence information for all models is presented in Table 13. Model 22.03a was expected to match 22.03 exactly, but it converged to a slightly smaller (better) objective function value. The cause for the small difference is unknown. However, the differences in objective function and parameter values were negligible from a practical standpoint (see tables in Appendices A and B for comparisons of objective function component values and parameeter values, respectively, across all models), so it did not appear to be worthwhile to track down the source of the discrepancy. Model 22.03b converged to the same value as 22.03a, with identical parameter values.

Convergence criteria included the requirement that the maximum gradient in the model objective function at the achieved minimum be small (theoretically, the gradient at the minimum objective function should be 0, but the stopping criteria for ADMB's optimization routines typically result in small but non-zero gradients) and the ability to estimate standard errors by inverting the model hessian. Both of these criteria were satisfied by all the jittered solutions, with the largest maximum gradient being 0.00153 (23.03a).

Convergence for each model, with the exceptions of 22.03a and 22.03b, was also checked by a parameter jittering analysis to increase confidence that the solution achieved through the process of minimizing the objective function was the global, as opposed to a local, minimum (and thus coincident with the maximum on the likelihood surface). The jittering analysis consisted of running each model multiple times with randomly-selected starting values for the estimated parameters. The model run resulting in the lowest objective function was considered the coincident with the MLE and compared with the other runs to determine the degree to which the MLE solution was consistently achieved. Runs that came within 0.0001 likelihood units (LUs) of the MLE were considered identical to it for all practical purposes and were counted as consistent with the MLE. From this perspective, Models 23.02 and 23.05 performed particularly poorly, with only 14 out of 400 and 5 out of 200 runs (respectively) considered consistent with that model's MLE (Table 13).

A final check on convergence was the number of parameters estimated at a bound in the MLE. Ideally, bounds on estimable parameters should be wide enough that the optimal solution lies in the interior of the parameter space. Parameters estimated at bounds are indicative of two issues, either: 1) the parameter bounds are too constraining and the true optimal solution lies outside the allowed parameter space; or 2) the parameter value lies on the bound, but this invalidates the assumption made in ADMB's standard error calculations and MCMC algorithms that the likelihood surface at the MLE can be approximated by a multivariate normal function. Fixing the retention slope parameter at its upper bound in 22.03 to its bound in 22.03b resulted in a model with no parameters at a bound (Table 14). In contrast, Model 23.02, the 23.03s, and the 23.05s are all problematic to some degree. Time did not allow exploring ways to reduce the number of parameters hitting bounds for these models.

Model 23.02 has three parameters estimated at a bound (all upper): the value of fully-selected capture probability in the BBRKC fishery in 2020 for males, the size at 50%- selected in the groundfish fisheries during 1987-1996 for males, and the width of the ascending-normal NMFS EBS shelf survey selectivity function for males (Table 14). The first constitutes a very unreasonable "spike" in the fully-selected capture rate for crab in the BBRKC fishery for 2020/21 (see the row for pDevsLnC, index 37 in Table 37, Appendix B, and Figure 316). It would not make sense to increase the limit. The rationale for choosing the upper limit for the second parameter (120 mm CW) was rather weak, so it could certainly be increased without much justification. The value for the final parameter suggests the NMFS EBS shelf survey selectivity curve for males, when described as an ascending normal function, is less size selective than other the models using the same function. The rationale for choosing the upper limit for this parameter was also rather weak, although the BSFRF selectivity study suggests that NMFS survey selectivity is rather strongly size-dependent.

The 23.03 models all estimated the scale parameter for the size distribution at recruitment at its lower bound and the size at 50%-selected in the groundfish fisheries during 1987-1996 for males at its upper bound. The value of the recruitment size distribution parameter implies recruits primarily enter the first model size bin, rather than over several size bins as in other models (see Figures 296-298). Models 23.03a and 23.03b further estimated the slopes for the logistic curves describing retention in the directed fishery during two time periods as being at their upper limits (recall that the slope in the remaining period was already fixed at its upper bound).

Not too surprisingly, given the difficulty in estimating M in size-structured models (e.g., Cronin-Fine and Punt, 2022), the 23.05 models were the worst-behaved in terms of parameters-at-bounds. All had some number of ln-scale M deviation parameters (δM_y's from **?@sec-CandModsTVM**) estimated at their lower bounds in all three population categories (immature crab, mature males, mature females) for which they were estimated. The numbers of parameters-at-bounds decreased as smoothing penalties (a, b models) and priors (a1, b1 models) were applied, however, indicating it might be possible to obtain a model with time-varying mortality but no parameters-at-bounds by increasing the constraints imposed by either.

Summary tables comparing objective function components across models are included in Appendix A. Tables listing parameters estimates for all models are included in Appendix B.

4.1 Model fits to survey data

Models 22.03b, 23.01, and 23.01a fit the NMFS and BSFRF survey data almost identically (Tables 1 and 2, Appendix A; Figures 10, 11). However, the models typically underestimate values when the time series is near a peak and overestimate values when the time series is in a valley. Model 23.02 appears to fit the design-based NMFS survey biomass indices more closely than the former models and captures the peaks and valleys better, although it is actually fitting to the VAST-derived model-based indices (see Figures 14 and 15). The smaller VAST CV's "pull harder" on 23.02 to match peaks and valleys in the survey data than do the design-based CVs. When compared with the VAST-based estimates, though, 23.02 also tends to underestimate the peaks and overestimate the valleys.

Of the 23.03 models, a1 and b1 are practically identical to one another and fairly similar to 22.03b, while 23.03 and 23.03a and b are similarly identical to one another but are much less similar to 22.03b in overall scale for males, estimating consistently higher values (Figures 12, 13).

The 23.05 models all appear to fit the VAST-derived survey biomass time series better than 23.02 (Figures 14, 15, 24, 25), which is not too surprising given the extra degrees of freedom available to those models by estimating annually-varying natural mortality rates. Interestingly, Model 23.05 estimates a spike in immature female (and to a lesser extent, male) survey biomass in the year in which the NMFS EBS shelf survey was **not** conducted (2020) while the others do not.

Models 22.03b, 23.01, and 23.01a fit the NMFS survey size comps almost identically for males (Figures 28, 46-48). Model 23.02 had similar fits in most years, as well, but exhibited fairly substantial differences in 1986-1988 (Figures 28, 49). All four models fit the NMFS survey size comps almost identically for females (Figures 29 and 30, 59-62). In contrast, the 23.03 models all had similar fits to the NMFS survey size comps, but differed substantially from those for Model 22.03b for males and immature females (fits for mature females were remarkably similar to those for 22.03b; Figures 31-33 and 50-53). The estimated NMFS survey size comps for the 23.05 models were very similar to Model 23.02, but lacked the misfits at small sizes that the latter exhibited particularly for males in 1986-87.

4.2 Model fits to molt increment (growth) data

Models 22.03b, 23.01, and 23.01a all fit the male molt increment data equally well, while the latter fit the female molt increment data 6 LUs poorer than 22.03b (Table 3, Appendix A, Figure 98). Model 23.02 fits the molt increment data much worse from a likelihood standpoint (60 units for females, 40 for males), although there is little real difference between the mean growth curves.

The growth curves used in the 23.03 models were fit to the growth data outside the model, so they are expected to fit better than 22.03b. The fits are 45 (males) and 30 (females) LUs better than those for 22.03b, indicating the degree of tradeoff between the growth data and other likelihood components when growth is estimated inside the model.

While Model 23.05 fit the growth data slightly worse (~1 likelihood unit) than 22.03b, the remaining 23.05s fit the data better by ~8 LUs for either sex.

4.3 Model fits to male maturity data

Model 23.01 fits the male maturity ogive slightly better (2 LUs) than do 22.03b or 23.01a, possibly indicating the smoothing penalty on the male maturity parameters is somewhat overconstraining in the latter two models (Table 7 Appendix A; Figures 99 and 100). Interestingly, 23.02 also fits the maturity ogive data better (by 4 LUs), although it is not apparent why this should be the case. On the other hand, the 23.03 models fit the maturity data much worse than 22.03b: by over 200 LUs for the a, b models and over 120 LUs for the a1, b1 models. Estimating growth in the model allows a better fit to the male maturity, with the tradeoff being a worse fit to the male growth data–indicating these processes are confounded in the model and the available data is inadequate to resolve the issue. It may be noteworthy, as well, that estimating survey Q also seems to have an influence on the degree to which the maturity ogive data can be fit. Apparently also reflecting this confounding between growth and maturity, Model 23.05 fits the maturity ogive data 21-24 LUs better than the remaining 23.05 models (and 19 LUs better than 22.03b), whereas the latter had fit the growth data (both males and females) ~19 LUs better than 23.05.

4.4 Model fits to fishery data

Models 23.01 and 23.01a fit the retained catch time series data from the directed fishery and total catch time series from the directed fishery and bycatch fisheries as well as 22.03b, with absolute differences in likelihoods less than 1 LU (Tables 2, 3, 6, and 7, Appendix A; Figures 101 and 104-107). These models exhibited one extreme misfit, substantially overestimating total catch biomass in the directed fishery in 1996 (Figure 104).

Model 23.02 fit retained catch biomass more poorly than 22.03b by 10 LUs due to misfits in 1978-80, but it fit total catch biomass in the directed fishery more similarly to the latter, with a difference in likelihood of only 3 units (Tables 2 and 6 Appendix A; Figures 101 and 104). As with 23.01 and 23.01a, 23.02 substantially overfit total catch biomass in 1996. Fits to total catch biomass from the snow crab and BBRKC fisheries were less than 1 LU poorer than 22.03b, while the fit to the groundfish fisheries total catch data was actually slightly better than that from 22.03b (2.5 and 3.8 LUs for fits to abundance and biomass, respectively; Tables 2 and 6, Appendix A; Figures 105:107). One estimate that did stand out, though, was the substantial overestimate of catch in the BBRKC fishery in 2020, the year when the NMFS EBS shelf survey did not occur (Figure 106).

Models 23.03a1 and 23.03b1 fit retained just slightly poorer than 22.03b (~2 LUs) but 23.03a and 23.03b fit it worse ($>$ 25 LUs), significantly underestimating large retained catches in the late 1970s and early 1990s (Tables 10 and 14, Appendix A; Figure 102). All four models fit total catch biomass in the directed fishery better than 22.03b by 2-3 LUs, but 1996 again stood out as problematic. The fits to total catch biomass in the snow crab, BBRKC fisheries, and groundfish fisheries were extremely good and similar to 22.03b, although catch biomass in the BBRKC fishery prior to the fishery closure in 1994 was underestimated slightly more so than in 22.03b (Tables 10, 11, 14, and 15, Appendix A; Figures 109-111).

In contrast to 23.02, all of the 23.05s fit the retained catch biomass time series slightly better than 22.03b ($<$ 2 LUs difference; Tables 18 and 22, Appendix A; Figure 103): these models did not substantially underestimate retained catch biomass in the late 1970's and early 1990s as 23.02 did. However, as with all the other models, these substantially overestimated total catch biomass in 1996 in the directed fishery as well (Tables 18, 19, 22, and 23, Appendix A; Figures 112: 115). These models also fit total catch biomass in the other fisheries quite well.

Fits to retained catch size compositions in the directed fishery are shown as line plots for all models (divided into groups for easier comparison) in Figures 116-121 and as bubble plots of pearson's residuals in Figures 122-134. Somewhat remarkably, all of the models fit the data almost identically and, although they fit it reasonably well in most instances, examples where they fit the data poorly exist (e.g., 2021).

Fits to total catch size compositions are shown as line plots for all models (again divided into groups) in Figures 135-146 for the directed fishery, Figures 147-158 for the snow crab fishery, Figures 159-170 for the BBRKC fishery, and Figures 171-182 for the groundfish fisheries. Associated bubble plot figures for Pearson's residuals are given in Figures 183-208 for the directed fishery, Figures

209-234 for the snow crab fishery, Figures 235-260 for the BBRKC fishery, and Figures 261-286 for the groundfish fisheries. While the fits to the data were not always great (males in the directed fishery in 1996, Figure 135), they were, on the whole pretty, reasonable in most cases for all of the models and exhibit, as with the retained catch data, surprisingly little variability across models.

4.5 Estimated population processes

For those models that estimated M in time blocks, the estimates for immature crab were similar to those from the base model 22.03b for Models 23.01 and 23.01a but higher for models 23.02 and the 23.03s (Figures 287 and 288). In contrast, estimates for mature males and females outside the "enhanced mortality" period from 1980-1984 were similar for all these models, with 23.02 being the one exception. In the "enhanced mortality" period, the two models that fixed survey selectivity and catchability (23.03a and 23.03b) estimated lower values for M than the others while 23.02 estimated a higher value for mature males. Estimates for time-varying M ranged from almost 0 to larger than 1.5 (a survival rate of 22%), with large swings on a 3-5 year time scale (Figure 288). Interestingly, the results suggest that natural mortality has been elevated since 2010 for immature crab, depressed for mature males, and declining for mature females.

All of the models that estimated growth (all excluding the 23.03 models) did so for females consistent with the external analysis, with the exception of 23.02 which estimated comparatively smaller growth as well as a declining trend in growth at large sizes (Figures 290-292). For males, the models which estimated growth within the model estimated more rapid growth at large size compared with the external analysis.

All of the models estimated fairly similar size dependence for the probability of undergoing terminal molt by females (Figures 293-295) while those that estimated growth inside the model estimate a more rapid increase with size for males than the models which fix growth using the external analysis.

The 23.03 models, which fixed growth and NMFS survey selectivity based on external analyses, estimated recruitment size distributions that placed the entire pseudo-cohort in the first model size bin (25-20 mm CW) whereas the other models distributed recruitment over a 25-55 mm CW size range (Figures 296-298). This had the effect that the size composition structure in the 23.03 models lagged behind those of the other models by a year or so.

4.6 Estimated population time series

All of the models estimate recruitment time series with generally similar features in terms of temporal dependence (e.g., two peaks in recruitment prior to 1980, increasing variability in the late 1990s-early 2000s, an increasing trend since a low point 2019) but the exact timing of peaks can vary by a year or two and the overall scales can be very different (particularly in the "historical" part of the model time period prior to the start of the standardized NMFS survey data in 1982; Figures 299 and 300). Focusing on recent trends (Figure 300), substituting the VAST-derived survey biomass estimates for the design-based ones (Model 23.02) reduces the peaks in recruitment in Models 22.03b, 23.01, and 23.01a and shifts the largest peaks to a year later. The models in which growth is fixed (the 23.03s) provide substantially inflated estimates of recruitment relative to the base model, particularly since 2019. The scale of recruitment is also inflated, although less so, for the models which estimate time-varying mortality (and fit the VAST-derived survey biomass estimates: the 23.05s).

Given the differences in detail among the models in terms of recruitment, it may be a bit surprising that the trends in population-level mature biomass don't differ more among them (Figures 301 and 302), although this provides evidence for the large degree of smoothing imposed by the underlying model dynamics (even allowing for time-varying mortality). In general, the models all exhibit similar temporal variation but the overall scale differs. The difference in temporal pattern from the base model is most pronounced for the models estimating annually-varying M's, with the timing of peaks in female mature biomass shifted 1-2 years earlier. The differences in scale from the base model are most pronounced for Models 23.02 (which fits the VAST-derived NMFS survey biomass estimates) and 23.01a and b (which fix NMFS survey selectivity and catchability), with the scale smaller than the base for the former and larger for the latter two.

The differences in the temporal patterns of population-level mature abundance among the models (Figures 303-308) are generally the same as those for mature biomass, while the differences in the estimated time series for immature abundance are closer to those noted for the patterns in recruitment.

4.7 Estimated survey quantities

Estimates for fully-selected survey catchability ("Q") and selectivity for the NMFS EBS survey were very similar for the base model and Models 23.01 and 23.01a (Figure 309). Estimated Q for females was smaller than that for males in both survey time blocks, and smaller for the 1982+ time block than for the 1975-1981 block. Survey Q for males did not change substantively between the two time blocks. Estimated survey selectivity was also similar to the base model in Model 23.02, but fully-selected Q was larger. Survey selectivity was not estimated inside the model in the 23.03 models. The selectivity curves estimated outside the model increased more rapidly with size to full selection than did any of the corresponding curves estimated inside the model, with full selection in the former occurring at sizes 20-30 mm CW smaller than in the latter, although the sizes at which full selection occurred differed by sex. Survey Q estimated outside the model (Models 23.03a, 23.03b) was smaller than the estimate from the base model for females in either time block, but larger for males. When Q was estimated inside the model using the selectivity curves estimated outside the model, the resulting estimates were much smaller than either those for the base model or those estimated outside the model. When annual mortality rates were estimated (in conjunction with fitting the VAST-derived survey biomass estimates–the 23.05 models), the estimated selectivity curves for females in the two time block were all quite similar, as were those for males. However, the size at which selectivity reached 25% was shifted somewhat toward larger sizes ("right-shifted") relative to the base model (and more so for males than females) in the 1975-1981 time block but substantially right-shifted relative to the base model in the 1982+ time block because the size at which the base model curves reached 25% had shifted to smaller sizes. Relative to the base model, estimated Q's for females in the 23.05 models were smaller for the 1975-1981 time period but larger in the 1982+ time period. For males, estimated Q's were larger in both time periods than those from base model.

4.8 Estimated fisheries quantities

Estimates for the time series of fully-selected capture rates in the directed fishery are shown in Figure 310. Several of the models, including the base model and models 23.02 and 23.05, estimate a large, anomalous "spike" in capture rates in the early 1970s associated with building up recruitment and adding in historical fishing data. Model 23.02 estimates a second spike in 1978 as well. Following the addition of retained catch size composition data in 1980, the estimates across models are much more similar in temporal pattern, although the increase in capture rates that occurs at the end of the 1980s in most models is not as rapid in the time-varying models such that the local peak in capture rates occurs a year later than it does in the other models. All of the models estimate essentially the same directed fishery total catch selectivity curves for females (Figure 311) and males (Figures 312 and 313), in the latter case varying annually after 1990. The retention curves estimated by all the models appear to be identical (Figure 314).

Estimates for the time series of fully-selected capture rates and associated selectivity curves for Tanner crab bycatch in the snow crab fishery are shown in Figure 315. The selectivity curves are similar across all models for both sexes while the capture rate estimates exhibit similar temporal patterns but somewhat different scales because the associated population scales differ inversely. Similar comments apply to the capture rates and selectivity curves for Tanner crab bycatch in the BBRKC fishery (Figure 316), as well as to capture rates in the groundfish fisheries (Figure 317). One notable exception is the seemingly-anomalous "spike" in estimated capture rate for the BBRKC fishery in 2020 in Model 23.02. The selectivity curves for the groundfish fisheries also vary more substantially across models than is the case for the other fisheries, in particular those in the pre-1988 time period.

4.9 Management quantities

Differences in management quantities among the candidate models are presented here as diagnostics for model sensitivity and not with consideration to management implications. Management quantities in 23.01 and 23.01a differed little from the base model 22.03b (Figure 318), while those from 23.02 were smaller across all categories by up to 10% (projected MMB under the OFL). The latter differences are most likely driven mainly by the differences in estimated NMFS EBS survey catchability and scale of capture rates between the models.

In contrast, the management quantities from 23.03a1 and 23.03b1 were all larger than the corresponding quantities in 22.03b (Figure 319). Compared with 22.03b, values for average recruitment, F_{MSY} and F_{OFL} were larger in Models 23.03a and 23.03b by 6-20% while biomass measures (unfished biomass, current biomass, projected biomass, MSY, and OFL) were 5-10% smaller.

The management quantities for the 23.05 models, although presented here (Figure 320), raise the issue of how to handle time-varying processes in an equilibrium calculation. The management quantities in question were calculated using the rates of natural mortality estimated in the final model year, but whether or not these are representative of the dynamics of the stock sufficient for extrapolating to longterm behavior is an unanswered question.

5 Summary

Thirteen candidate Tier 3 models were considered from which to recommend a few for evaluation for the Fall 2023 assessment. The 2022 assessment model, Model 22.03, was adopted with a parameter for the estimated slope of the logistic retention curve in the directed fishery hitting its upper bound, implying retention in this case is basically a step function and increasing the bounds on this parameter would have no effect on model results. Thus, Model 22.03b fixed the value for this parameter to just inside the upper bound–it produced results almost identical to 22.03. I recommend this model be adopted as the "base" model for the Fall 2023 assessment (replacing 22.03 as the base).

Models 23.01 and 23.01a were posed to investigate the potential effects of decreasing the width of model size bins from 5mm to 1mm (and increasing the number of model size bins to maintain the same size range) on model dynamics (especially growth) and performance. Differences in results were small and the changes had very little overall effect on model results: estimates for model processes were similar and Tier 3 management quantities, as integrative measures for comparison, differed by less than 1% for these models compared with 22.03b. However,model performance in terms of processing time increased noticeably, so I do not recommend moving forward with either of these models.

Model 23.02 substituted model-based (VAST-derived) estimates of NMFS EBS shelf survey biomass for the (all) male, immature female, and mature female components of the stock in place of the standard design-based estimates when estimating model parameters, but the model was otherwise configured to be identical to 22.03b. Using the VAST estimates would seemingly be preferable to using the design-based alternatives because the former result in less uncertainty (smaller CV's) in the estimates than the latter. Previous attempts to use VAST-derived results have resulted in convergence issues, whereas the results from 23.02, while not completely satisfactory, seem to suggest the model could be considered a viable candidate for adoption. However, several concerns regarding the model's performance and results were identified, including:

- multiple (3) parameters-at-bounds
- relatively few jitter runs converged to the presumed MLE
- inability to fit the VAST data well from a likelihood perspective

The latter issue is no doubt the source of the first two issues: a number of standardized residuals reflecting the model's fit to the VAST data are larger than 4 (which is generally considered to indicate the data is highly unlikely given the model), so small changes in parameter values can result in very large changes on the overall likelihood and complicate the process of model convergence. In addition, the model dynamics do not allow the optimization process to achieve a set of parameters that fit the data better. One solution would be to "loosen up" the model dynamics, creating additional degrees of freedom to allow the model to achieve a better fit. To some extent, the 23.05 models that estimate annually-varying mortality represent one possible direction for such a solution. Another would be to estimate an "additional survey variance" term, and a third would be to estimate time-varying survey catchability. Estimating "additional survey variance" to better fit the VAST data has been tried unsuccessfully before for Tanner crab (the model inflated the additional variance to the extent that the survey data was essentially removed from the optimization), but it might be worthwhile trying it again given that the underlying model here (22.03b) is substantially different in configuration from the previous model used for the attempt. Estimating time-varying catchability is realistically a non-starter for the Fall 2023 assessment. Another rationale for considering this model in the fall is recognizing that, while the model may not fit the VAST estimates well from a likelihood perspective based on a lognormal error distribution, it does follow the trends in the survey biomass time series better than 22.03b in an arithmetic-scale root-mean-square error sense. That said, a similar effect might be achieved using 22.03b simply by upweighting the design-based survey biomass time series relative to the other data components in that model. As such, though, I tentatively recommend that Model 23.02 be brought forward as an alternative model for the Fall 2023 assessment.

I think that the 23.03 models that fixed growth and NMFS survey selectivity in the assessment model based on external analyses should not be considered as models for the Fall 2023 assessment at this point due to concerns regarding the selectivity analysis, but should be revisited after the 2018 selectivity study data has been provided by BSFRF and the selectivity analysis has been completed. One concern with the analysis is that it does not use all the available data–the 2018 study which was focused on Tanner crab whereas several of the years included thus far were focused on red king crab. Another concern is the assumption that the BSFRF nephrops gear is non-selective for Tanner crab across the size range used in the assessment (25-180 mm CW). It would be worthwhile exploring the impact of reasonable alternative assumptions, such as $Q < 1$, regarding the nephrops gear selectivity on the assessment model results.

The 23.05 models that estimate annually-varying M's must also be regarded as research tools at present. They cannot be used for management until a rationale is developed for determining how to project the stock forward under time-varying M to determine equilibrium-related management quantities such as B_{MSY} and F_{MSY}.

Consequently, I suggest one alternative Tier 3 model be brought forward in the fall for consideration: 23.02, with 22.03b as the base model.

Acknowledgments

I particularly want to acknowledge the help of Jim Thorson and Jon Richar (both AFSC) in exploring the feasibility of developing VAST-derived size composition estimates for Tanner crab. Although this effort ultimately proved unsuccessful as far as the assessment is concerned due to lack of computing resources, the effort was still worthwhile and very much appreciated.

I would also like to acknowledge the SSC/CPT workgroup on more focused models for the discussions we were able to have on developing "more focused" Tier 3 assessment models, simplifying the development of a Tier 3 GMACS Tanner crab model, and the basis for a fallback Tier 4 model.

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Tables

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Table 1. Biological processes included in 22.03, the 2022 assessment model.

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

Table 2. Description of modeled fishery processes and time blocks for the directed Tanner crab (TCF) and snow crab (SCF) fisheries included in 22.03, the 2022 assessment model.

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

Table 3. Description of modeled fishery processes and time blocks for the BBRKC (RKF) and groundfish (GTF) fisheries included in 22.03, the 2022 assessment model.

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

Table 4. Description of modeled survey processes and time blocks for the annual NMFS EBS shelf trawl survey and the BSFRF side-by-side catchability study surveys included in 22.03, the 2022 assessment model.

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

Table 5. Description of likelihood components in 22.03, the 2022 assessment model. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: groundfish fisheries.NMFS M and F surveys: NMFS EBS shelf trawl survey, distinguished by sex (M: males-only; F: females-only); BSFRF M and F surveys: BSFRF side-by-side (SBS) catchability study surveys, ditinguished by sex (M: males-only; F: females-only). Separate likelihood components are used for the male and female survey biomass indices: female survey biomass is fit separately by maturity state whereas total male biomass is fit. Consequently, the models treat them as separate data sets.

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

Table 6. Relationships of candidate models relative to the 2022 assessment model, 22.03.

model configuration	parent	number of estimated parameters	changes to parent model
22.03	--	351	--
22.03a	22.03	351	after model development, ADMB 13.1
22.03b	22.03a	350	fixed retention function slope parameter near upper bound
23.01	22.03b	460	1-mm size bins
23.01a	23.01	460	increased smoothing on estimated size-specific molt-to-maturity probability curves
23.02	23.03b	350	fitting to VAST estimates of NMFS EBS shelf survey abundance, biomass
23.03a	22.03b	337	fixed growth, NMFS EBS survey selectivities and Q's based on external analyses
23.03a1	23.03a	341	estimating NMFS EBS survey Q's
23.03b	22.03b	337	fixed growth, NMFS EBS survey selectivities and Q's based on external analyses; selectivities are non-descreasing after reaching max
23.03b1	23.03b	341	estimating NMFS EBS survey Q's
23.05	23.02	489	estimating time-varying M
23.05a	23.05	489	applied smoothing penalty w/ lambda = 1
23.05a1	23.05a	489	applied normal prior with sigma = 0.5
23.05b	23.05	489	applied smoothing penalty w/ lambda = 10
23.05b1	23.05a	489	applied normal prior with sigma = 0.5

Table 7. Comparison between VAST (model-based) and design-based estimates for male Tanner crab biomass in the NMFS EBS shelf survey. LCI: lower confidence interval; UCI: upper confidence interval.

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
1975	294.88	198.01	439.15	298.13	266.16	333.95
1976	157.02	131.66	187.25	195.45	175.69	217.44
1977	138.50	118.62	161.71	177.66	160.03	197.24
1978	98.30	84.55	114.29	115.41	104.53	127.42
1979	51.42	41.67	63.44	58.41	52.97	64.40
1980	152.48	125.13	185.81	154.46	139.92	170.51
1981	79.92	67.85	94.14	85.53	77.22	94.73
1982	65.85	54.89	79.00	71.47	65.42	78.07
1983	37.98	31.46	45.86	36.48	33.57	39.64
1984	30.50	25.91	35.90	30.63	28.13	33.35
1985	14.90	12.55	17.70	15.83	14.29	17.54
1986	21.59	16.33	28.55	16.92	15.61	18.34
1987	45.50	38.19	54.21	45.43	41.56	49.66
1988	99.21	76.20	129.16	83.22	76.16	90.92
1989	132.80	113.75	155.05	129.34	118.44	141.23
1990	132.42	112.70	155.59	143.84	132.26	156.43
1991	145.79	117.20	181.35	142.40	131.40	154.33
1992	127.58	95.36	170.68	107.08	97.80	117.25
1993	73.27	61.10	87.86	77.64	71.24	84.61
1994	48.33	41.52	56.26	52.61	48.34	57.26
1995	34.98	28.36	43.14	34.08	31.12	37.31
1996	30.76	23.54	40.20	28.84	26.10	31.88
1997	14.63	12.72	16.83	16.71	15.31	18.24
1998	15.00	13.22	17.02	16.67	15.39	18.05
1999	21.53	15.60	29.71	20.07	18.13	22.22
2000	23.33	18.17	29.95	24.37	21.85	27.19
2001	29.25	24.77	34.53	31.64	28.88	34.67
2002	27.41	23.23	32.33	30.60	27.77	33.72
2003	37.80	32.14	44.45	42.81	38.83	47.21
2004	38.87	32.60	46.34	41.30	38.04	44.85
2005	63.74	54.94	73.96	66.76	61.80	72.11
2006	101.53	83.66	123.21	100.66	92.75	109.25
2007	104.18	82.74	131.18	96.05	88.60	104.13
2008	84.90	61.97	116.30	75.32	69.36	81.80
2009	47.41	39.80	56.46	50.37	46.31	54.79
2010	49.00	39.65	60.55	49.09	45.07	53.47
2011	62.66	50.48	77.79	61.00	56.33	66.06
2012	80.11	64.50	99.50	74.19	68.08	80.83
2013	103.37	79.15	135.01	87.03	79.14	95.70
2014	108.91	95.95	123.61	115.97	107.14	125.52
2015	74.23	66.13	83.32	81.32	75.72	87.34
2016	69.62	61.73	78.52	75.95	70.56	81.76
2017	54.20	47.15	62.31	59.56	55.02	64.49

(continued)

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
2018	47.08	41.68	53.19	52.32	48.43	56.52
2019	28.67	24.74	33.24	31.06	28.83	33.46
2021	31.56	27.44	36.30	33.27	30.80	35.95
2022	29.63	25.72	34.14	31.36	29.08	33.81

Table 8. Comparison between VAST (model-based) and design-based estimates for immature female Tanner crab biomass in the NMFS EBS shelf survey.

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
1975	9.55	7.05	12.94	9.74	8.49	11.16
1976	6.37	4.63	8.76	5.82	5.17	6.55
1977	14.47	7.14	29.34	6.74	5.78	7.86
1978	6.81	5.02	9.26	8.14	6.94	9.56
1979	2.66	1.85	3.81	4.15	3.65	4.71
1980	13.51	10.12	18.04	15.18	13.02	17.70
1981	1.52	1.17	1.98	1.41	1.24	1.61
1982	1.71	1.22	2.41	1.51	1.30	1.75
1983	2.27	1.68	3.06	2.18	1.94	2.46
1984	2.23	1.71	2.92	1.98	1.78	2.21
1985	0.99	0.79	1.25	0.93	0.85	1.02
1986	2.69	2.17	3.34	2.53	2.30	2.78
1987	14.99	10.40	21.62	12.24	10.79	13.88
1988	10.17	8.16	12.68	9.40	8.56	10.32
1989	11.81	9.28	15.03	9.73	8.87	10.66
1990	9.86	7.78	12.50	8.93	8.17	9.75
1991	7.01	5.64	8.72	6.58	6.00	7.21
1992	1.98	1.60	2.46	2.00	1.81	2.21
1993	1.06	0.84	1.34	1.09	0.97	1.23
1994	1.20	0.80	1.80	1.02	0.89	1.17
1995	1.05	0.86	1.28	1.10	0.99	1.22
1996	1.43	1.10	1.86	1.42	1.28	1.58
1997	1.39	0.99	1.94	1.28	1.14	1.44
1998	1.96	1.54	2.49	1.81	1.65	1.99
1999	2.85	2.22	3.65	2.93	2.66	3.22
2000	2.47	2.03	3.00	2.52	2.30	2.76
2001	6.27	4.82	8.14	5.86	5.33	6.44
2002	5.49	4.46	6.76	5.71	5.16	6.31
2003	4.66	3.44	6.31	4.03	3.64	4.46
2004	4.08	3.38	4.92	4.10	3.77	4.47
2005	10.37	8.08	13.30	10.00	8.94	11.19
2006	13.24	9.96	17.60	11.52	10.45	12.71
2007	5.58	4.18	7.45	5.10	4.63	5.62
2008	2.84	2.18	3.70	2.54	2.29	2.82
2009	2.54	1.80	3.57	2.40	2.16	2.66
2010	3.77	3.07	4.65	3.47	3.19	3.77
2011	10.34	8.12	13.17	8.62	7.90	9.40
2012	11.65	8.60	15.78	10.16	9.07	11.39
2013	6.37	5.06	8.02	6.01	5.50	6.57
2014	2.45	1.89	3.19	2.30	2.11	2.51
2015	1.65	1.32	2.05	1.71	1.53	1.91
2016	1.12	0.85	1.47	1.00	0.88	1.15
2017	1.38	1.09	1.75	1.51	1.33	1.72
2018	5.02	4.03	6.24	4.75	4.33	5.21

(continued)

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
2019	4.92	3.99	6.06	4.69	4.30	5.11
2021	3.34	2.82	3.96	3.52	3.28	3.78
2022	2.69	2.09	3.48	2.42	2.20	2.66

Table 9. Comparison between VAST (model-based) and design-based estimates for mature female Tanner crab biomass in the NMFS EBS shelf survey.

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
1975	31.42	24.50	40.29	42.40	36.93	48.66
1976	31.16	24.38	39.81	33.77	30.68	37.17
1977	38.57	26.19	56.80	37.26	33.23	41.79
1978	25.75	19.32	34.32	24.09	21.68	26.77
1979	10.45	6.94	15.74	16.45	14.39	18.79
1980	63.78	45.09	90.23	54.16	47.34	61.95
1981	42.58	30.98	58.51	38.67	33.50	44.64
1982	64.14	46.32	88.82	57.62	50.70	65.48
1983	20.43	16.19	25.77	22.10	19.78	24.70
1984	14.91	11.23	19.81	14.36	12.79	16.11
1985	5.55	3.99	7.74	5.55	4.90	6.29
1986	3.37	2.62	4.32	3.36	3.05	3.70
1987	5.14	4.17	6.33	5.53	5.00	6.10
1988	25.37	18.89	34.06	22.45	20.29	24.84
1989	19.40	15.99	23.53	20.03	18.51	21.67
1990	37.69	26.94	52.75	31.23	28.74	33.94
1991	44.76	33.91	59.10	38.57	35.03	42.48
1992	26.23	21.29	32.31	25.56	23.50	27.80
1993	11.64	9.68	14.00	12.75	11.66	13.93
1994	9.85	7.58	12.78	9.95	9.02	10.97
1995	12.40	9.40	16.36	11.22	10.10	12.47
1996	9.58	6.74	13.62	8.24	7.38	9.19
1997	3.40	2.69	4.30	3.67	3.32	4.05
1998	2.28	1.86	2.79	2.57	2.31	2.87
1999	3.83	2.91	5.03	3.96	3.58	4.39
2000	4.13	2.90	5.89	3.78	3.36	4.26
2001	4.56	3.43	6.06	4.65	4.17	5.20
2002	4.47	3.46	5.77	4.84	4.31	5.43
2003	8.40	6.59	10.71	8.98	8.09	9.98
2004	4.73	3.79	5.89	4.93	4.48	5.44
2005	11.58	9.12	14.69	10.22	9.18	11.37
2006	14.94	12.00	18.60	15.40	13.94	17.00
2007	13.44	10.58	17.06	14.47	13.10	15.98
2008	11.66	9.26	14.70	12.28	10.99	13.71
2009	8.48	6.53	11.01	8.43	7.59	9.37
2010	5.47	4.15	7.22	5.51	4.92	6.17
2011	5.41	4.50	6.51	5.88	5.41	6.39
2012	12.36	9.30	16.41	10.69	9.82	11.64
2013	17.85	13.60	23.43	15.92	14.50	17.49
2014	14.86	10.38	21.29	11.97	10.94	13.09
2015	11.21	8.17	15.38	10.27	9.22	11.45
2016	7.63	5.52	10.53	6.69	6.04	7.41
2017	7.11	5.31	9.52	6.98	6.23	7.82
2018	4.97	3.84	6.43	5.18	4.65	5.77

(continued)

	design-based			VAST		
year	estimate	lci	uci	estimate	lci	uci
2019	4.85	3.68	6.38	4.95	4.44	5.51
2021	8.55	7.05	10.38	9.58	8.77	10.46
2022	6.67	5.15	8.63	6.95	6.33	7.62

Table 10. Estimated growth location parameters from the external analysis using TMB and the 2022 assessment model, 22.03. pGrA: post-molt size at 25 mm CW pre-molt size; pGrB: post-molt size at 100 (females) or 125 (males) mm CW pre-molt size.

	female		male	
parameter	22.03	TMB	22.03	TMB
pGrA	33.68	32.62	32.4	32.25
pGrB	94.34	93.33	105.5	100.06

Table 11. Estimated growth ln-scale scale parameters from the external analysis using TMB and the 2022 assessment model, 22.03. The assessment applies the parameter to both sexes.

	both 22.03	female TMB	male TMB
pLnGrBeta	0.8116	−1.315	−0.7088

Table 12. AIC values for the generalized additive models fit by sex to the annual estimates of sex/size-specific survey catchability for Tanner crab in the NMFS EBS shelf survey.

	Females		Males	
family	df	AIC	df	AIC
normal	10.68	Inf	10.70	Inf
gamma-identity	10.85	504.7	10.82	457.2
gamma-inverse	11.00	505.6	11.00	479.1

Table 13. Convergence information for the candidate Tier 3 models.

model configuration	number of parameters	no. of jitter runs	no. converged to MLE	no. of param.s at bounds	objective function value	max gradient	invertible for std. devs?
22.03	351	800	710	1	3044.61	2.92E-03	yes
22.03a	351	200	--	1	3044.51	3.93E-04	yes
22.03b	350	200	--	0	3044.51	3.08E-04	yes
23.01	460	200	184	0	3046.65	1.32E-04	yes
23.01a	460	200	187	0	3050.50	7.59E-05	yes
23.02	350	400	14	3	4156.53	2.41E-04	yes
23.03a	337	200	90	4	4033.78	1.53E-03	yes
23.03a1	341	200	134	2	3826.84	9.24E-04	yes
23.03b	337	200	79	4	4036.10	1.02E-03	yes
23.03b1	341	200	188	2	3810.22	9.30E-04	yes
23.05	489	200	5	43	2355.28	1.12E-04	yes
23.05a	489	200	147	14	2604.56	7.62E-04	yes
23.05a1	489	200	39	8	2891.94	4.42E-04	yes
23.05b	489	200	156	14	2604.56	4.65E-04	yes
23.05b1	489	200	32	8	2891.94	2.25E-04	yes

Table 14. Information on parameters estimated at a bound for the candidate Tier 3 models. Values are number of parameters of given type at a bound. Negative values: number at lower bound; positive values: number at upper bound

category	process	name	label	22.03	22.03a	22.03b	23.01	23.01a	23.02	23.03a	23.03a1	23.03b	23.03b1	23.05	23.05a	23.05a1	23.05b	23.05b1
fisheries	fisheries	pDevsLnC	RKF: 1992+	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
population processes	natural mortality	pDevsM	time varying M for immature crab	–	–	–	–	–	–	–	–	–	–	−16	−7	−4	−7	−4
			time varying M for mature females	–	–	–	–	–	–	–	–	–	–	−13	−4	−1	−4	−1
			time varying M for mature males	–	–	–	–	–	–	–	–	–	–	−14	−2	−2	−2	−2
	recruitment	pRb[1]	scale param for rec. size dist.	–	–	–	–	–	–	−1	−1	−1	−1	–	–	–	–	–
selectivity	selectivity	pS1[17]	z50 for GF.AllGear selectivity (males, 1987-1996)	–	–	–	–	–	1	1	1	1	1	–	–	–	–	–
		pS2[2]	width for NMFS survey selectivity (males, 1982+)	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
		pS2[28]	slope for TCF retention (2005-2009)	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–
		pS2[5]	slope for TCF retention (pre-1991)	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–
		pS2[6]	slope for TCF retention (1991-1996)	–	–	–	–	–	–	1	–	1	–	–	1	1	1	1

Figures

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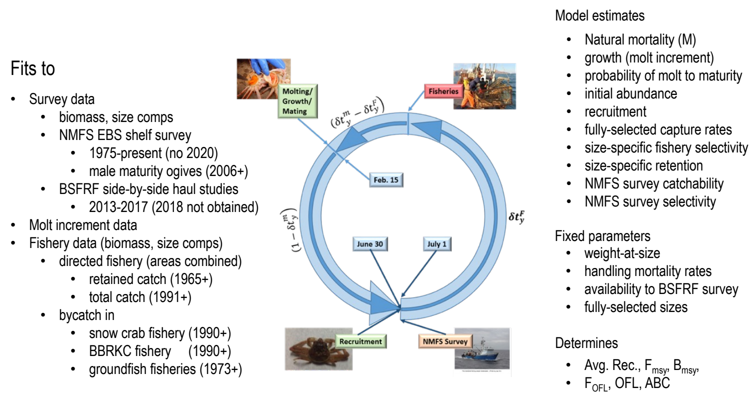

Figure 1. Description of likelihood components in 22.03, the 2022 assessment model. TCF: directed Tanner crab fishery; SCF: snow crab fishery; RKF: BBRKC fishery; GF All: groundfish fisheries.NMFS ‘M’ and ‘F’ surveys: NMFS EBS shelf trawl survey, distinguished by sex; BSFRF ‘M’ and ‘F’ surveys: BSFRF side-by-side catchability study surveys, ditinguished by sex

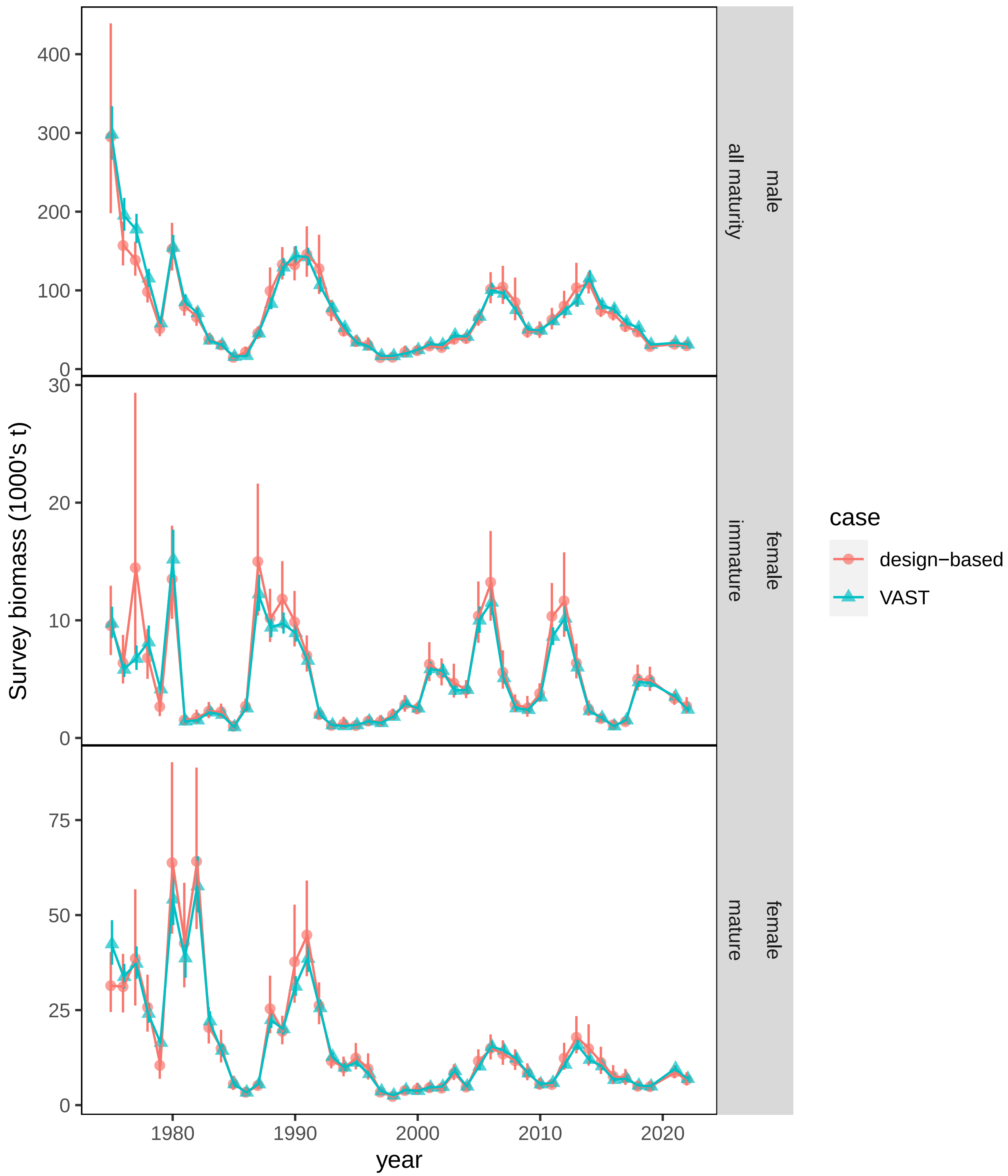

Figure 2. Comparison between VAST (model-based) and design-based estimates for Tanner crab biomass in the NMFS EBS shelf survey (full time period).

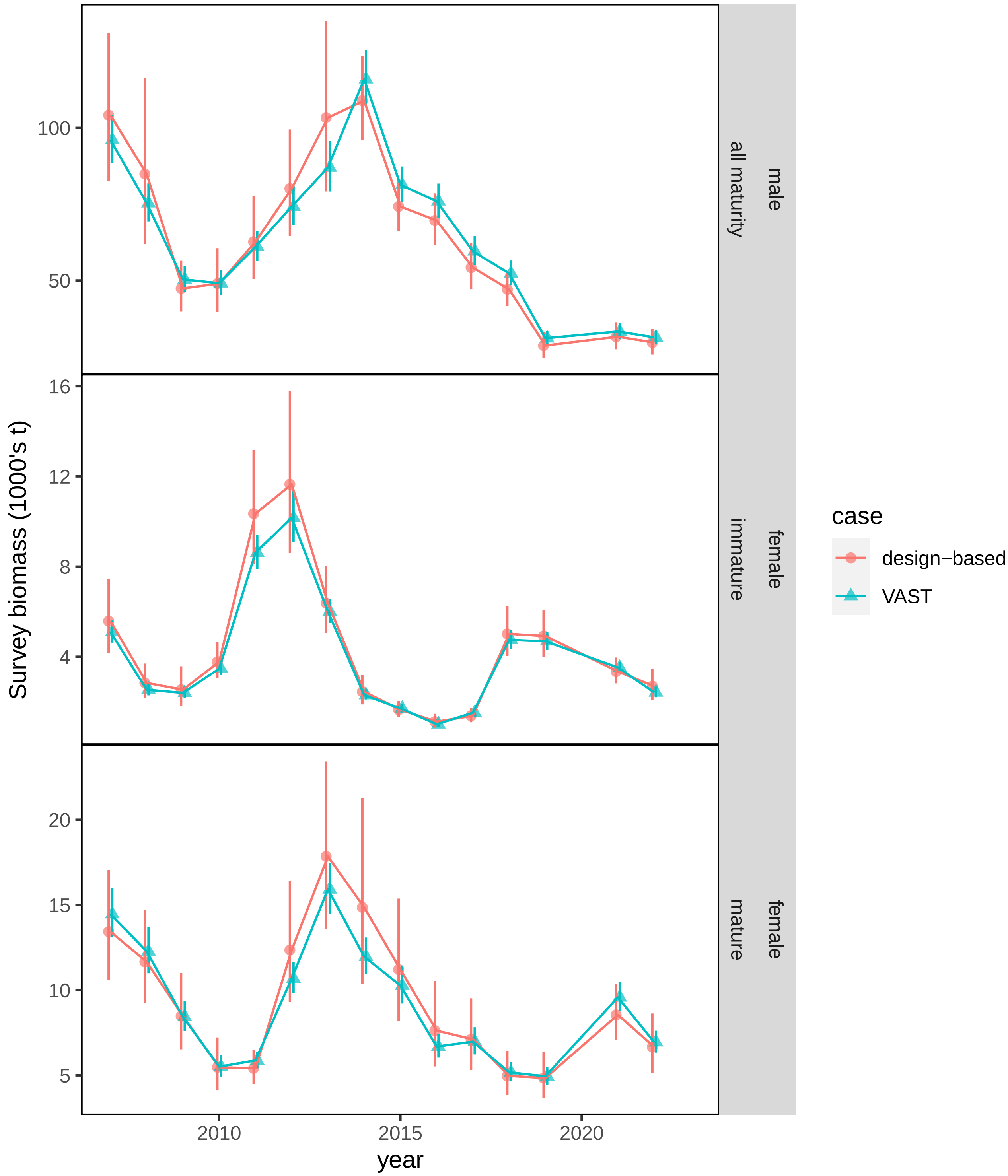

Figure 3. Comparison between VAST (model-based) and design-based estimates for Tanner crab biomass in the NMFS EBS shelf survey (recent time period).

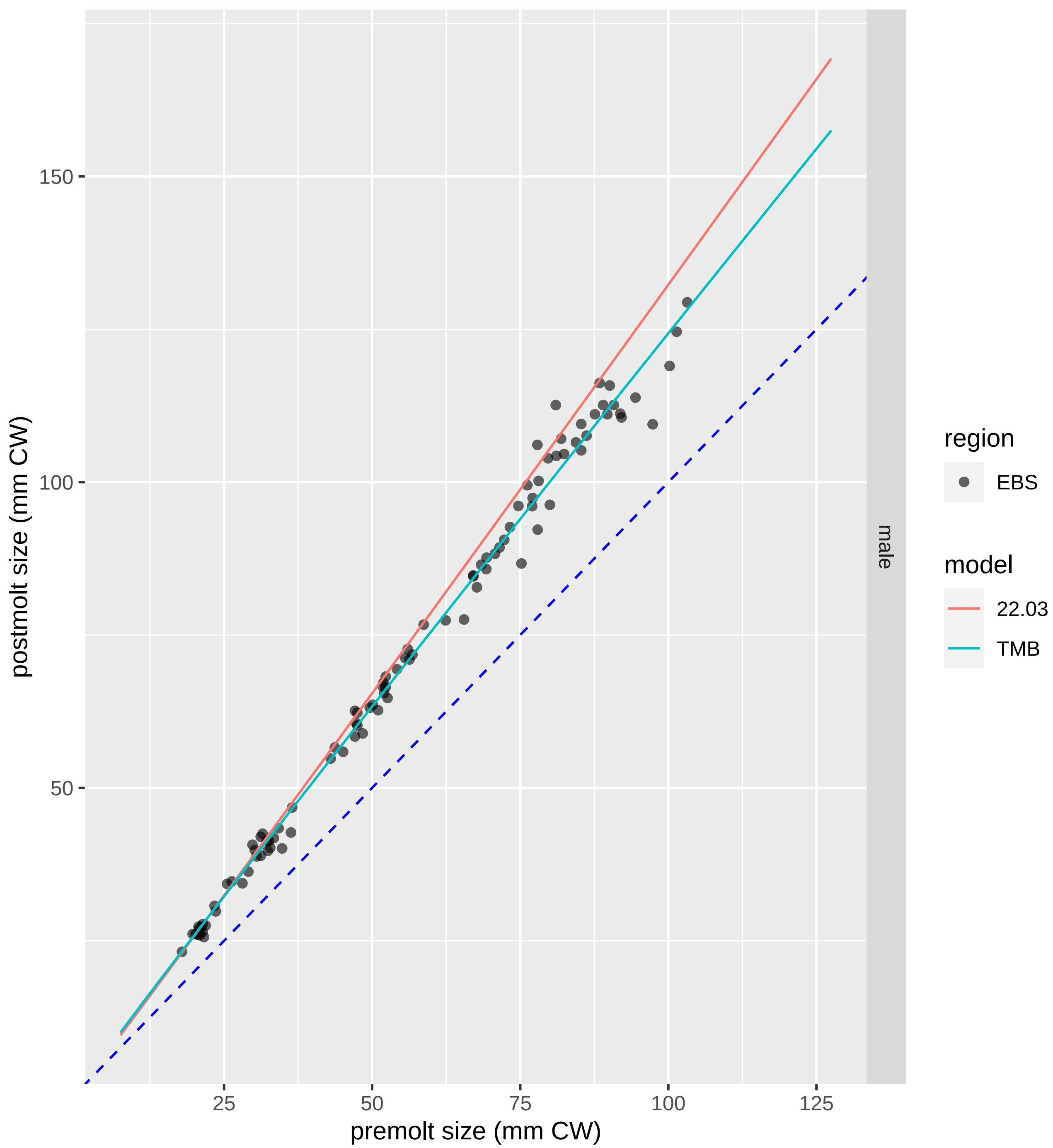

Figure 4. Tanner crab growth data for males. Colored lines indicate mean growth as determined by the indicated assessment model or the TMB model. The dashed line indicates no growth (post-molt size = pre-molt size).

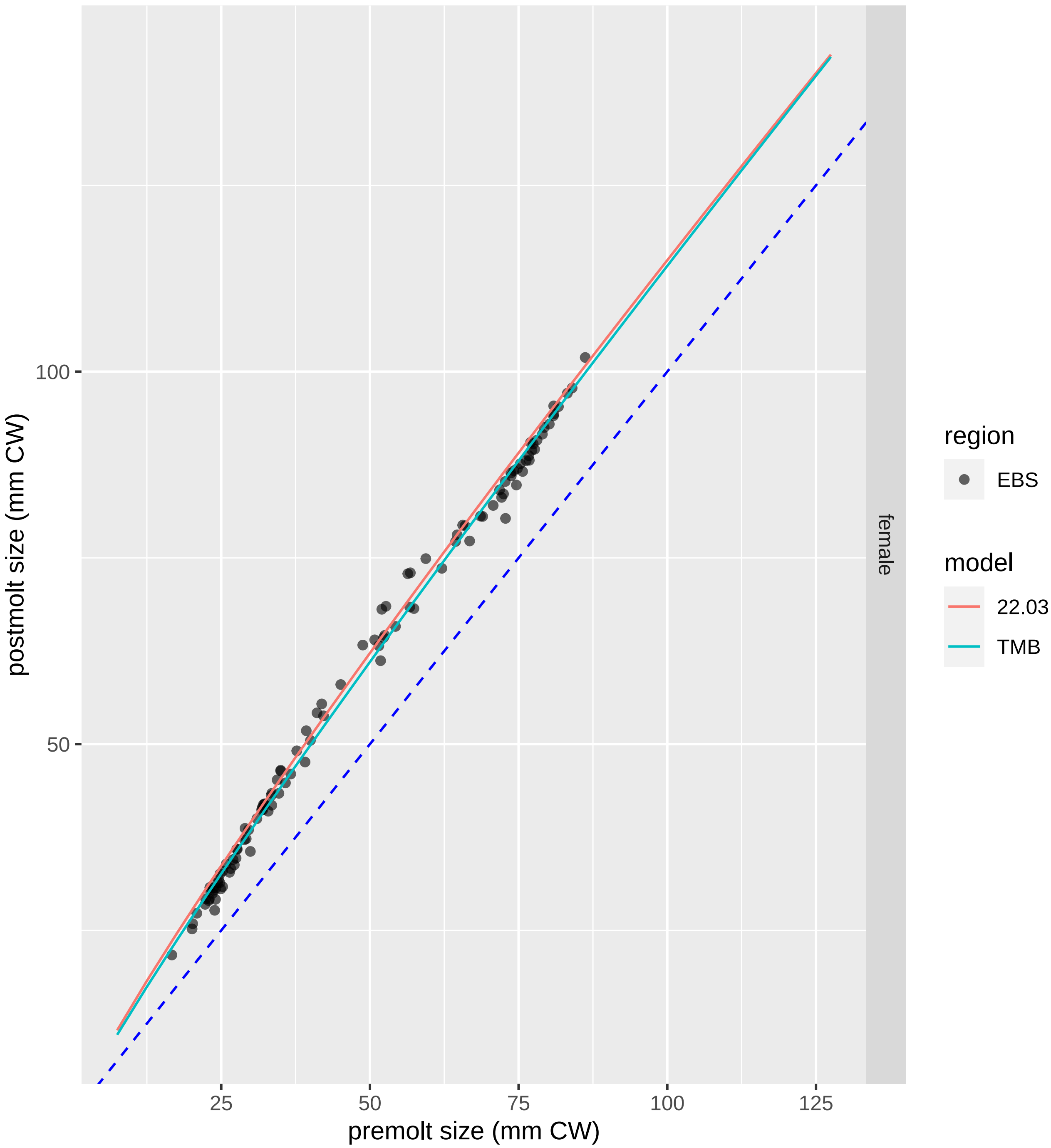

Figure 5. Tanner crab growth data for females. Colored lines indicate mean growth as determined by the indicated assessment model or the TMB model. The dashed line indicates no growth (post-molt size = pre-molt size).

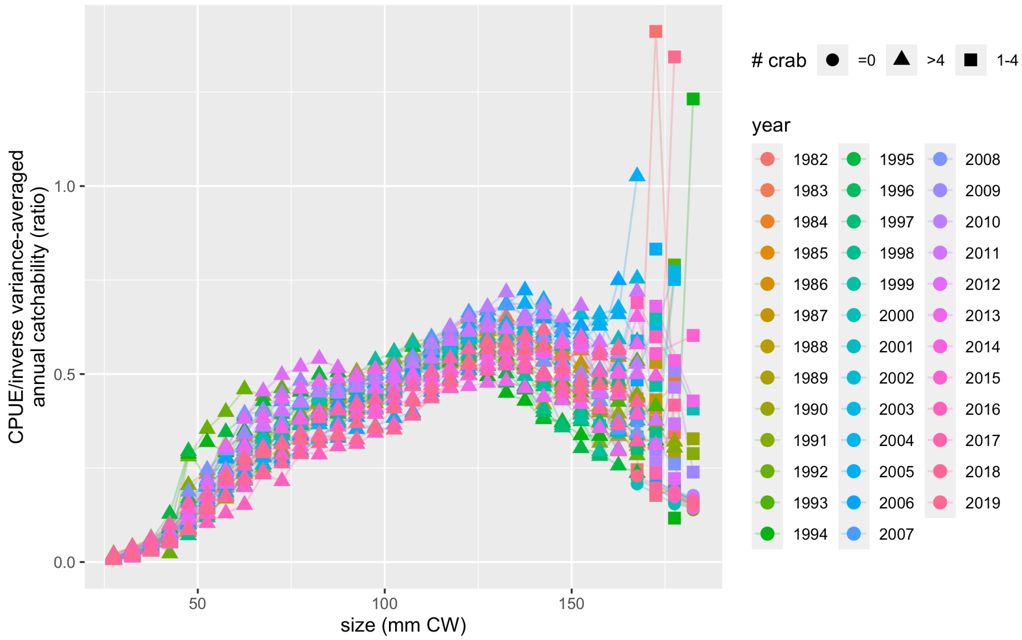

Figure 6. Annual NMFS EBS shelf catchability curves for male Tanner crab, based on haul-level analysis of BSFRF SBS studies data.

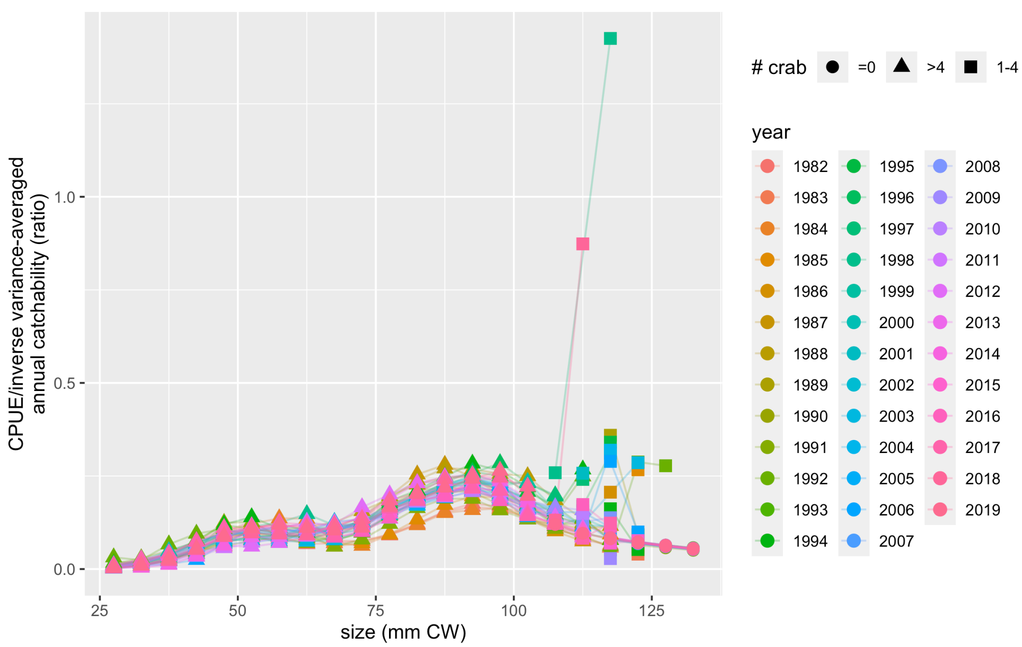

Figure 7. Annual NMFS EBS shelf catchability curves for female Tanner crab, based on haul-level analysis of BSFRF SBS studies data.

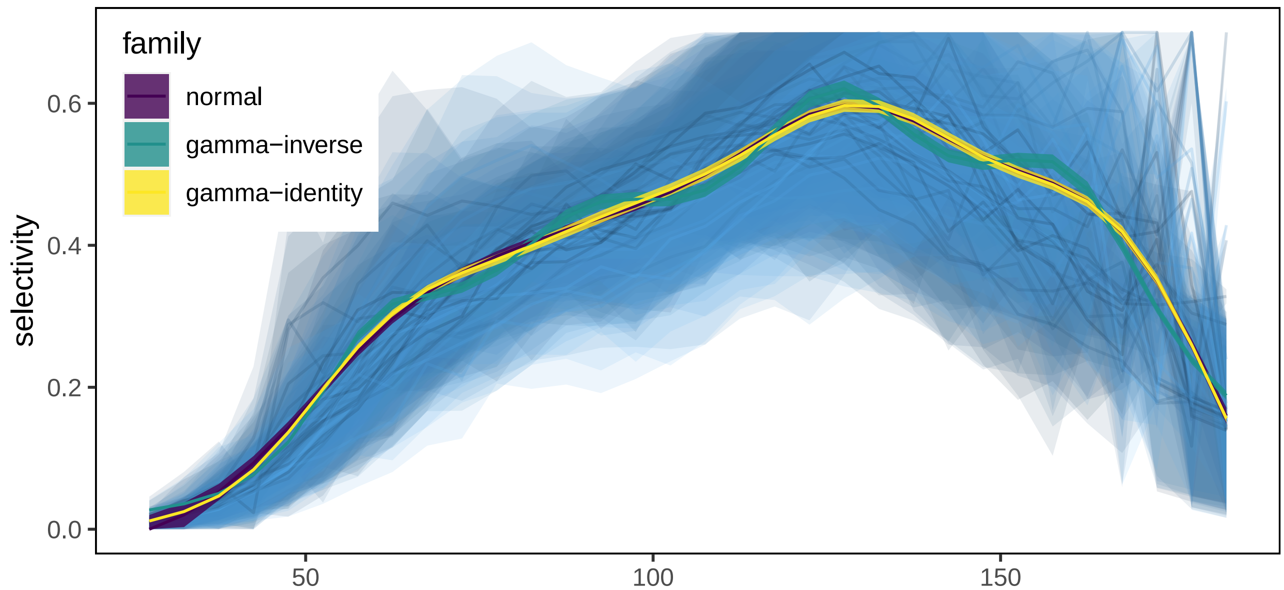

Figure 8. Generalized additive model (GAM) fits to estimated annual NMFS EBS shelf survey selectivity curves for males (starting in 1982) derived from the collaborative NMFS-BSFRF selectivity studies (2013-2017). Blue envelopes and lines indicate estimated annual curves and confidence interval for individual years. Fits to the annual curves are shown for models based on normal (purple), gamma-inverse (green), and gamma-identity (yellow) probability distribution/link families. The fit using the gamma-identity family is the preferred model.

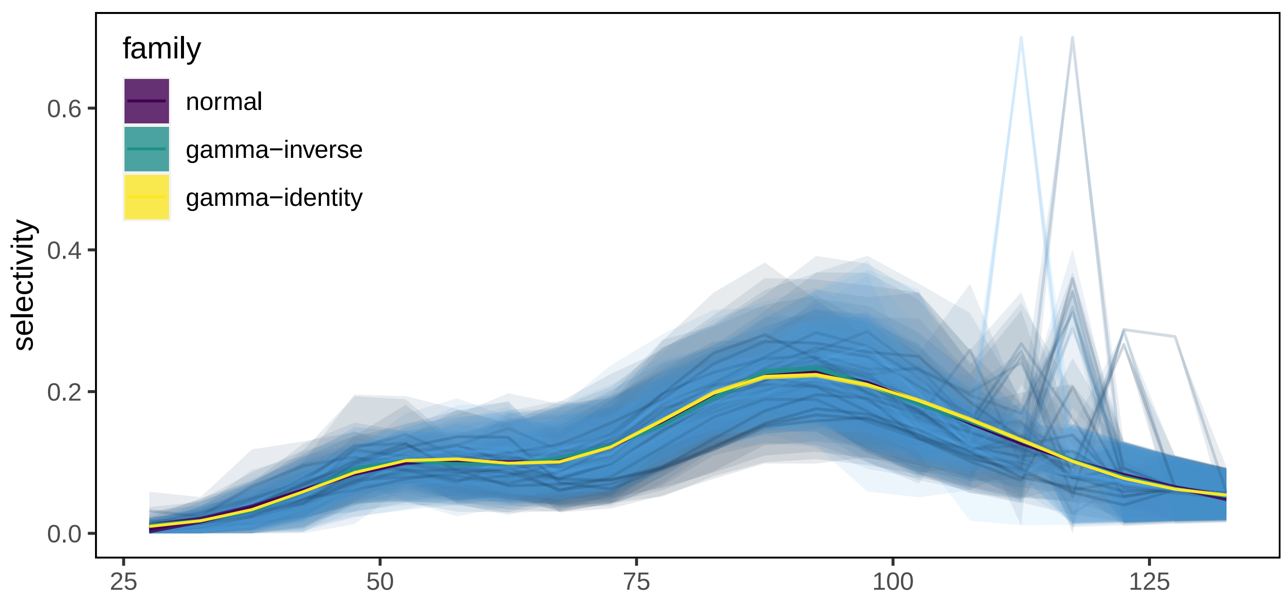

Figure 9. Generalized additive model (GAM) fits to estimated annual NMFS EBS shelf survey selectivity curves for females (starting in 1982) derived from the collaborative NMFS-BSFRF selectivity studies (2013-2017). Blue envelopes and lines indicate estimated annual curves and confidence interval for individual years. Fits to the annual curves are shown for models based on normal (purple), gamma-inverse (green), and gamma-identity (yellow) probability distribution/link families. The fit using the gamma-identity family is the preferred model.

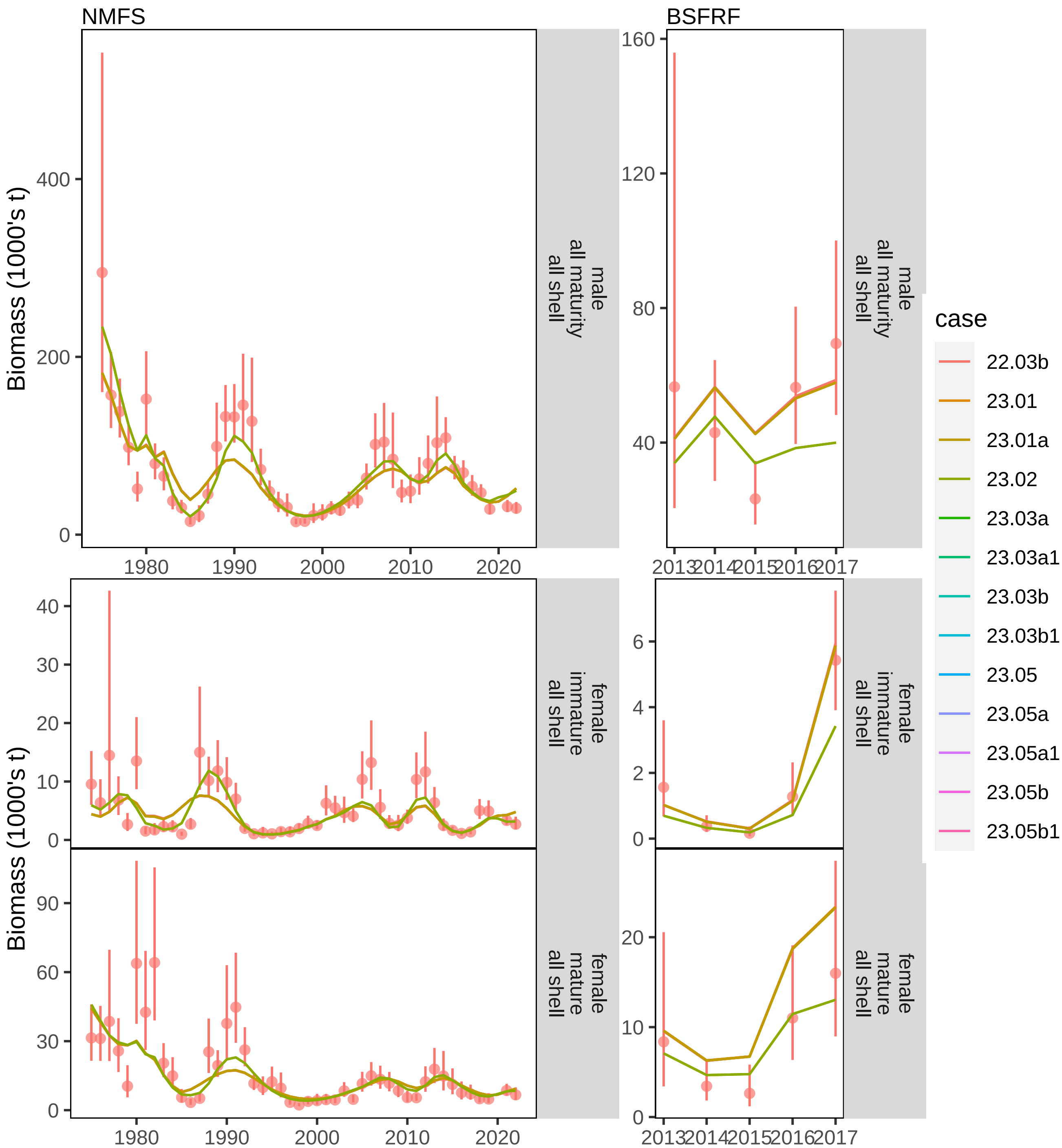

Figure 10. Fits to biomass time series from the NMFS EBS shelf survey and BSFRF SBS study. Models 22.03b, 23.01, 23.01a, 23.02.

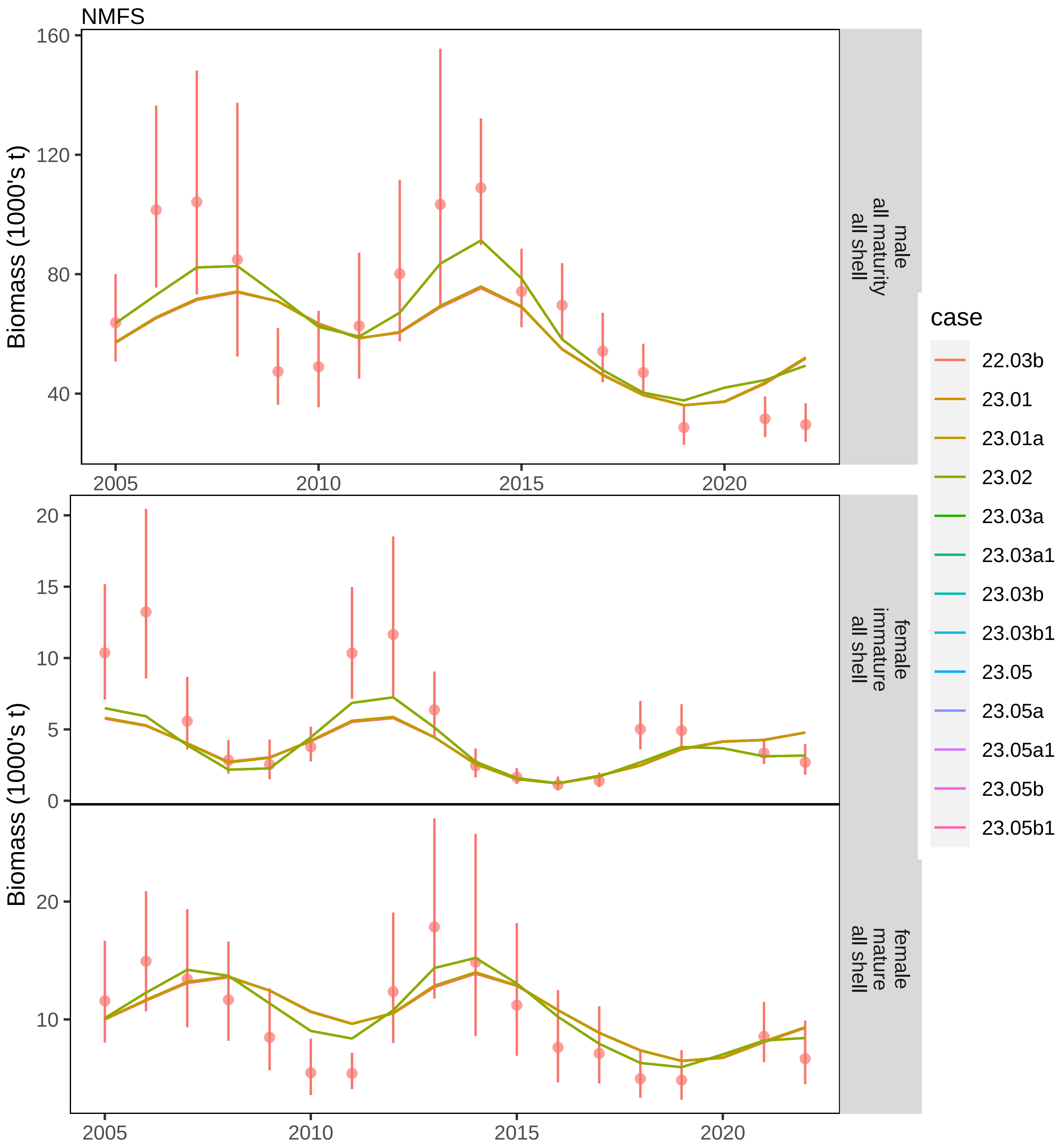

Figure 11. Fits to biomass time series from the NMFS EBS shelf survey, recent time period. Models 22.03b, 23.01, 23.01a, 23.02.

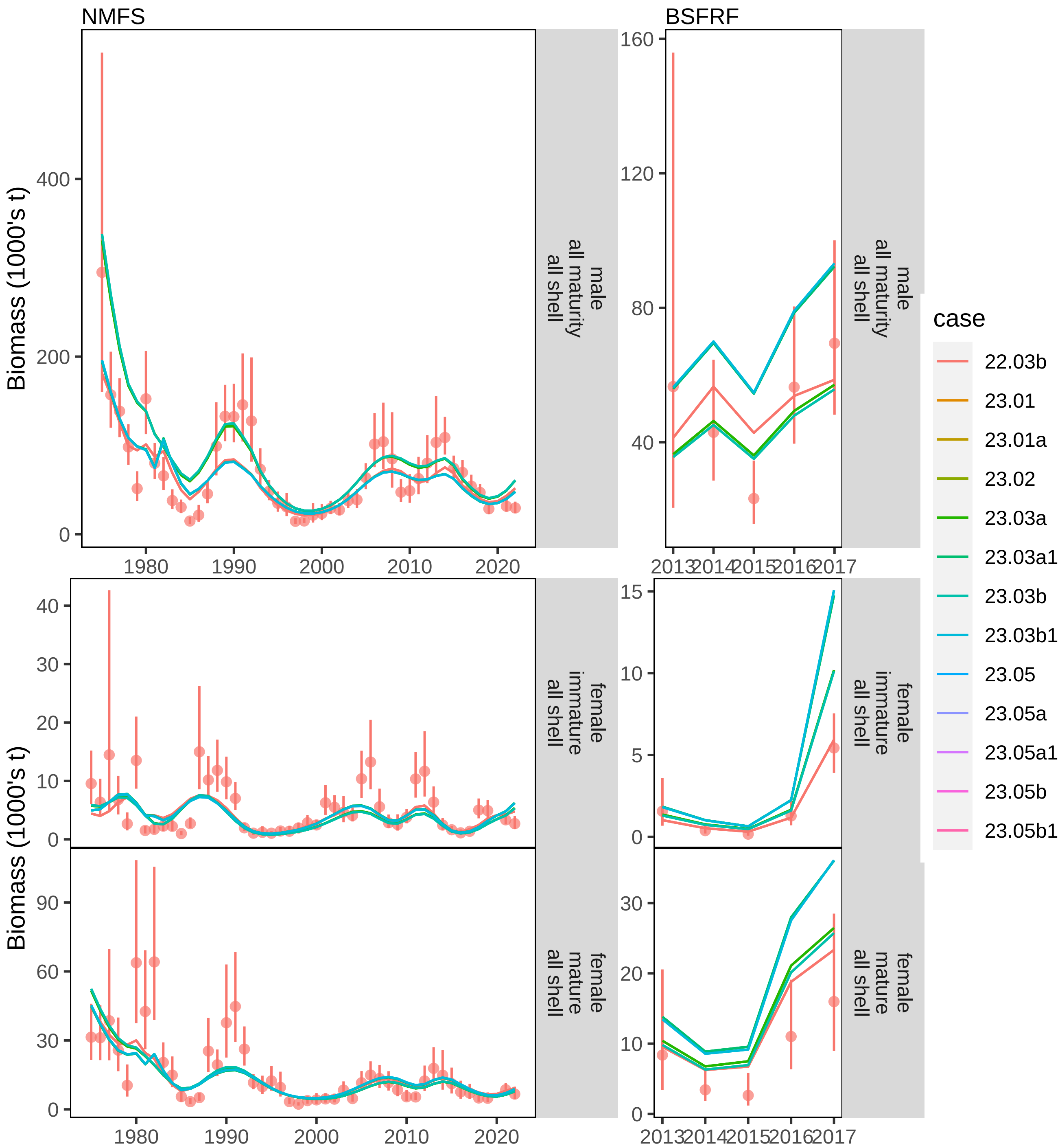

Figure 12. Fits to biomass time series from the NMFS EBS shelf survey and BSFRF SBS study. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

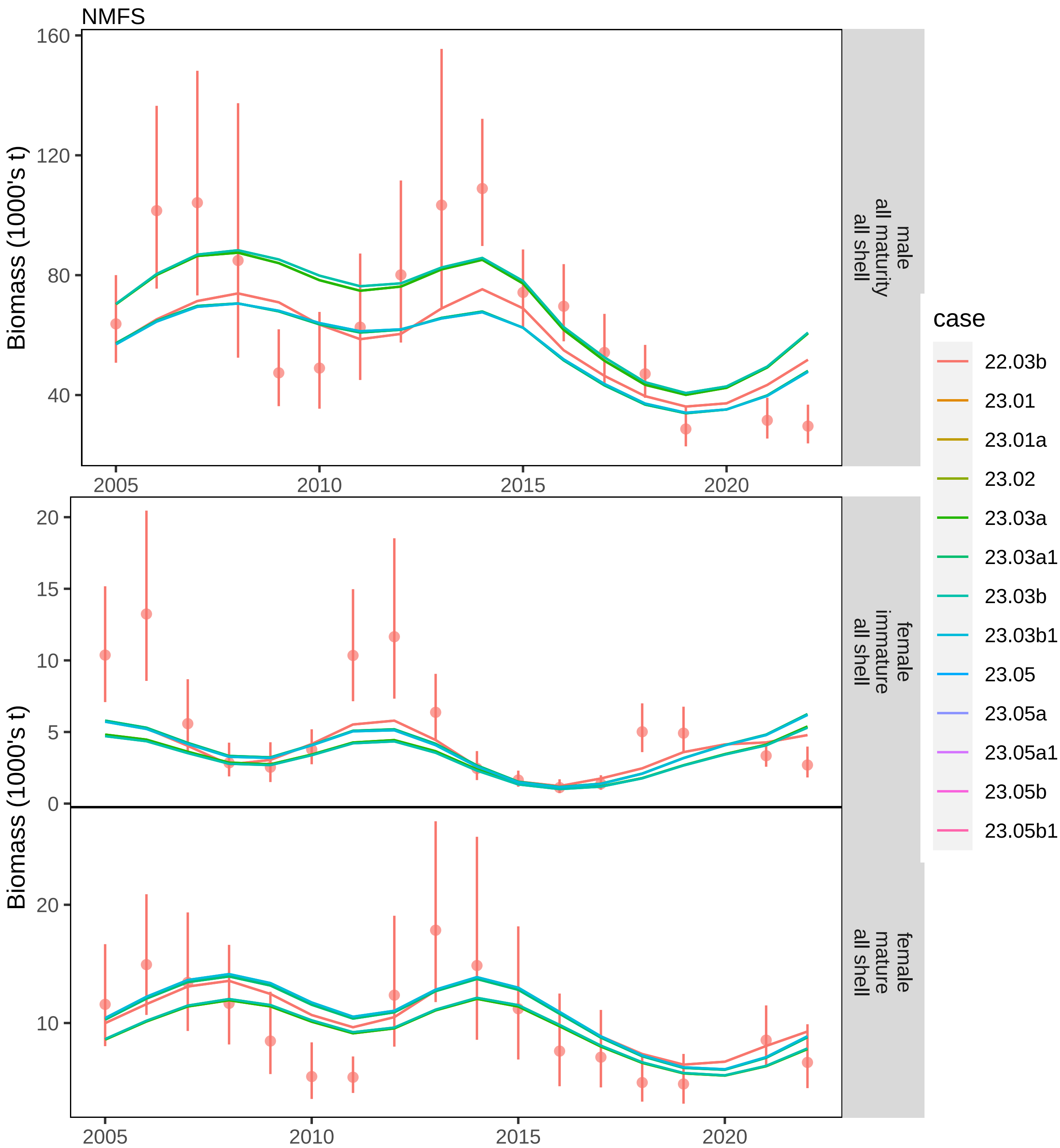

Figure 13. Fits to biomass time series from the NMFS EBS shelf survey, recent time period. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

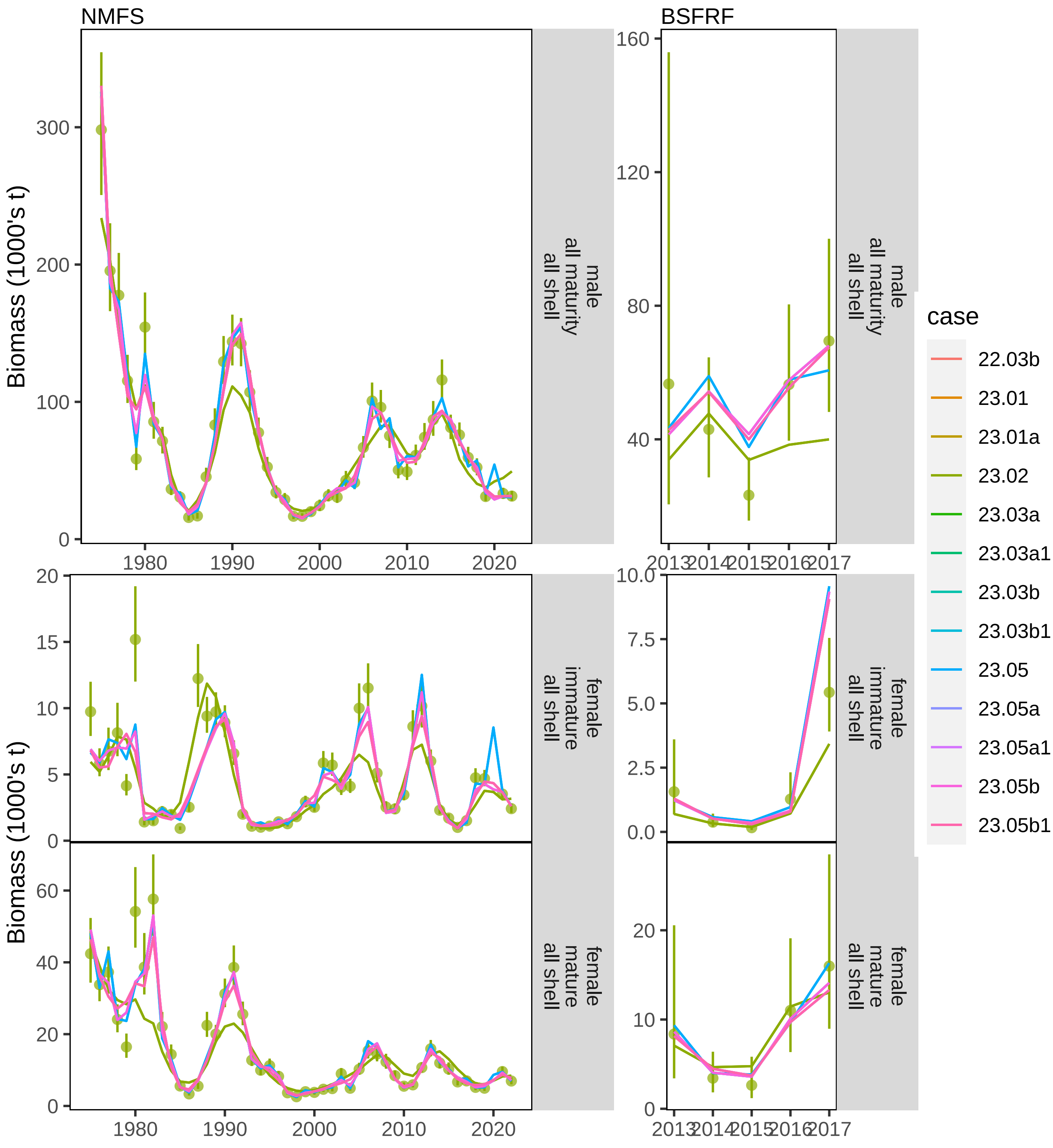

Figure 14. Fits to biomass time series from the NMFS EBS shelf survey and BSFRF SBS study. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

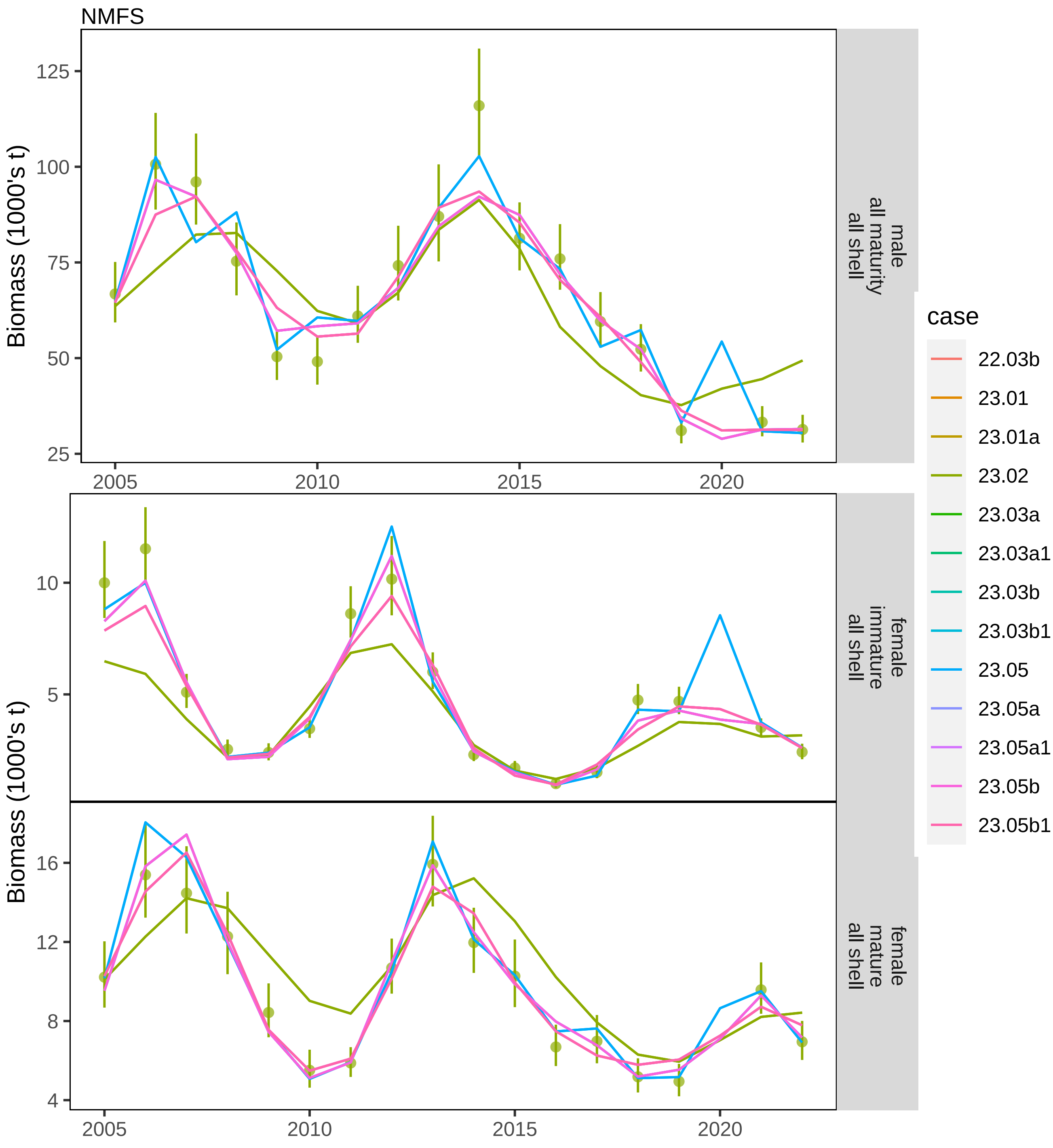

Figure 15. Fits to biomass time series from the NMFS EBS shelf survey, recent time period. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

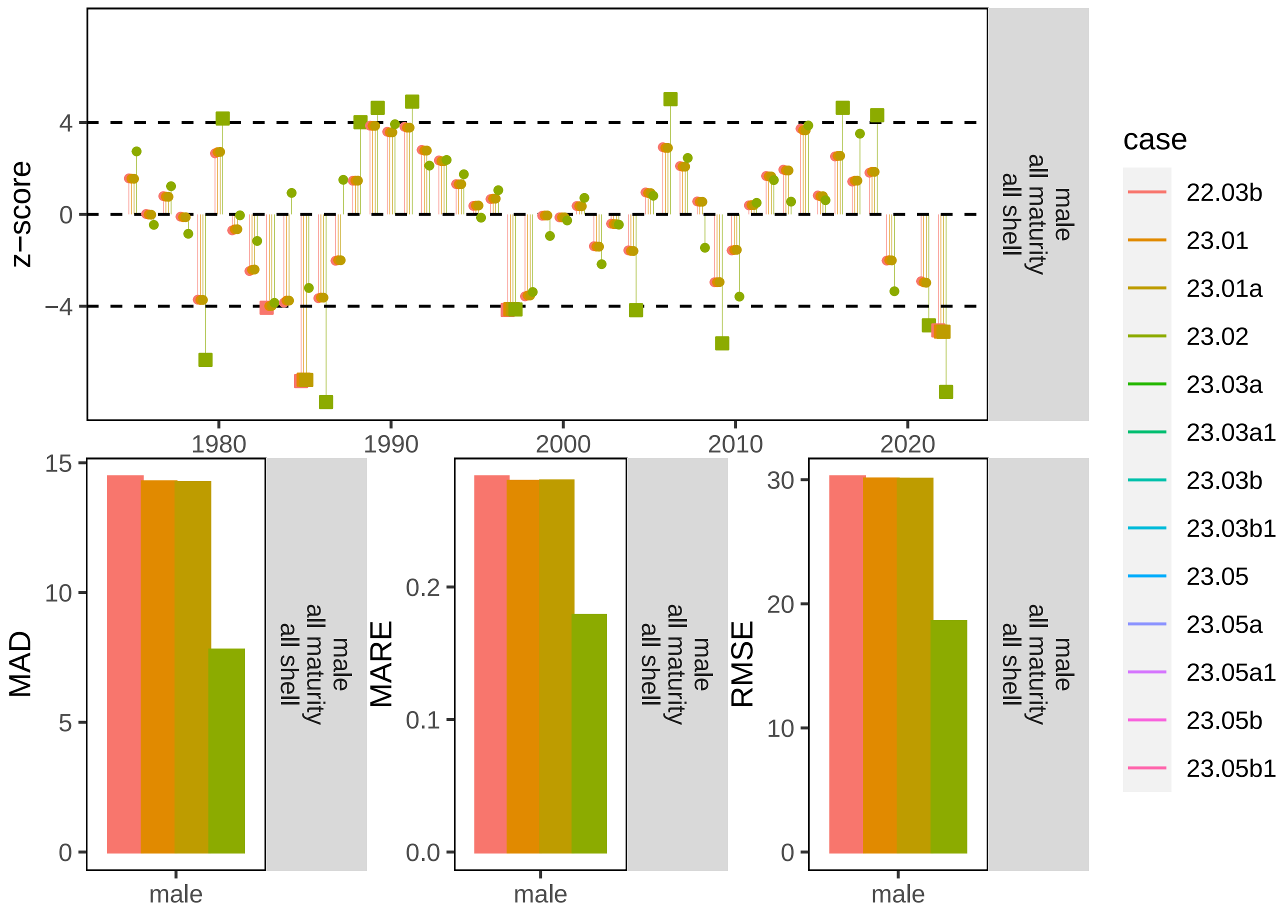

Figure 16. Residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

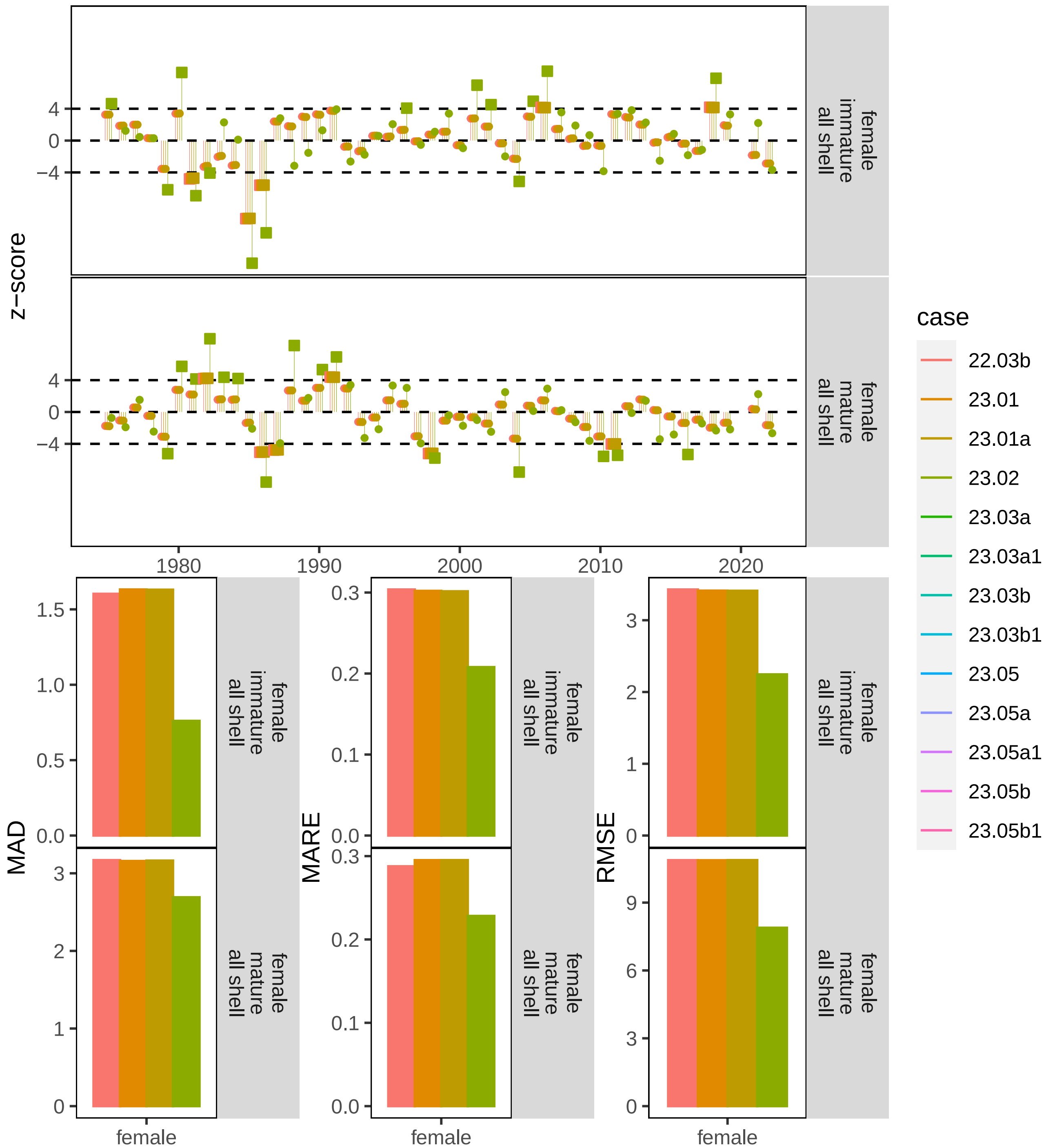

Figure 17. Residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

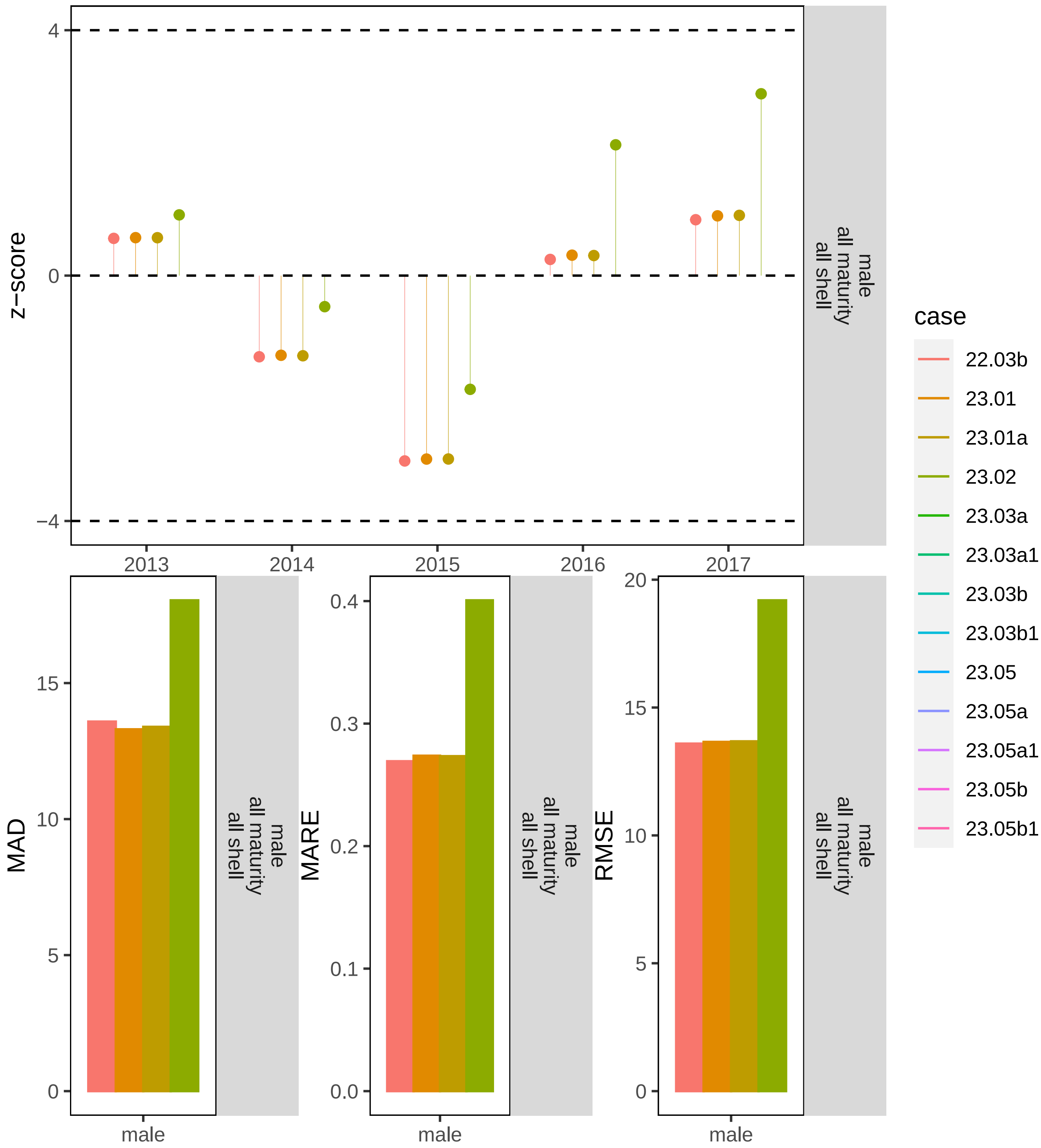

Figure 18. Residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

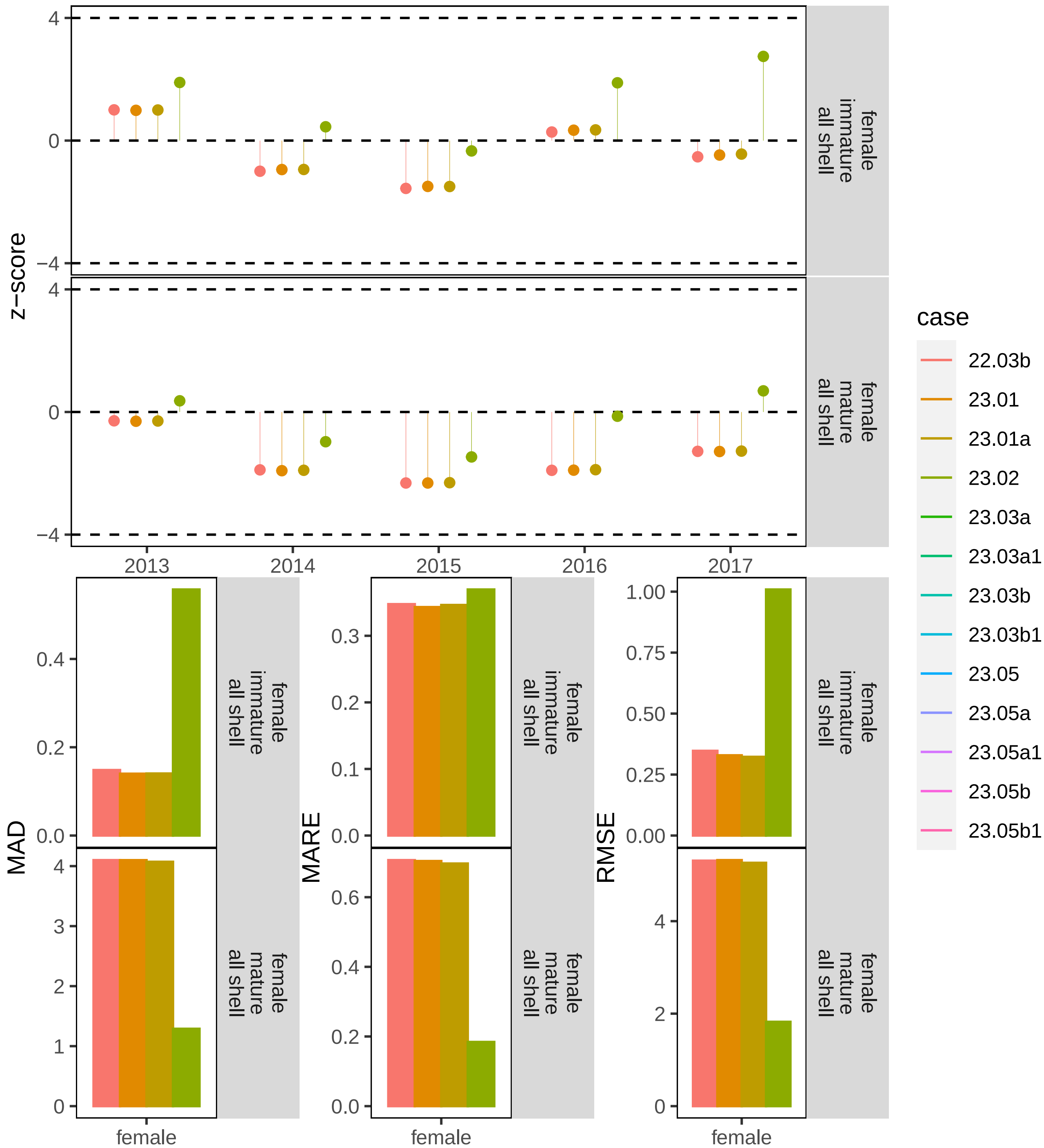

Figure 19. Residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

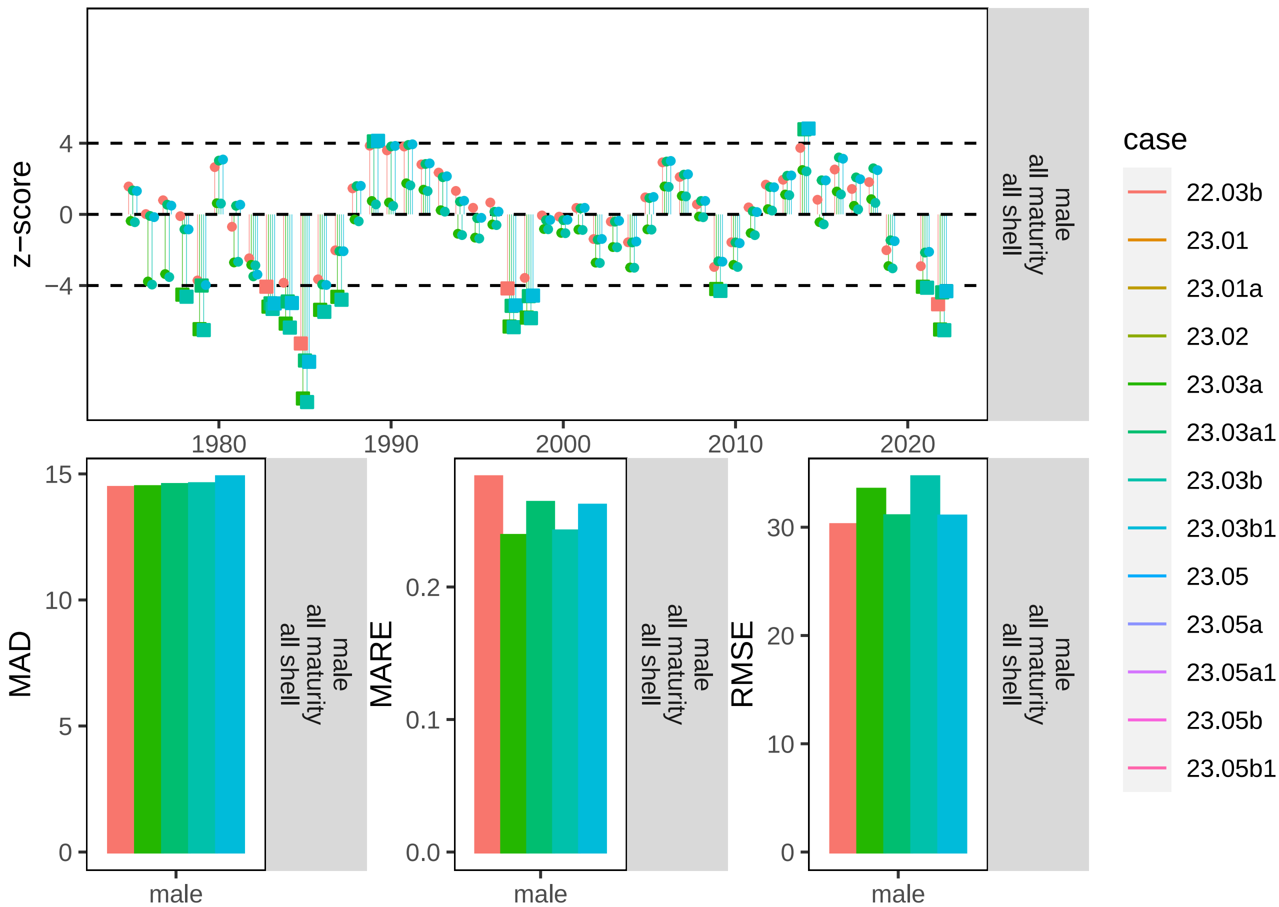

Figure 20. Residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

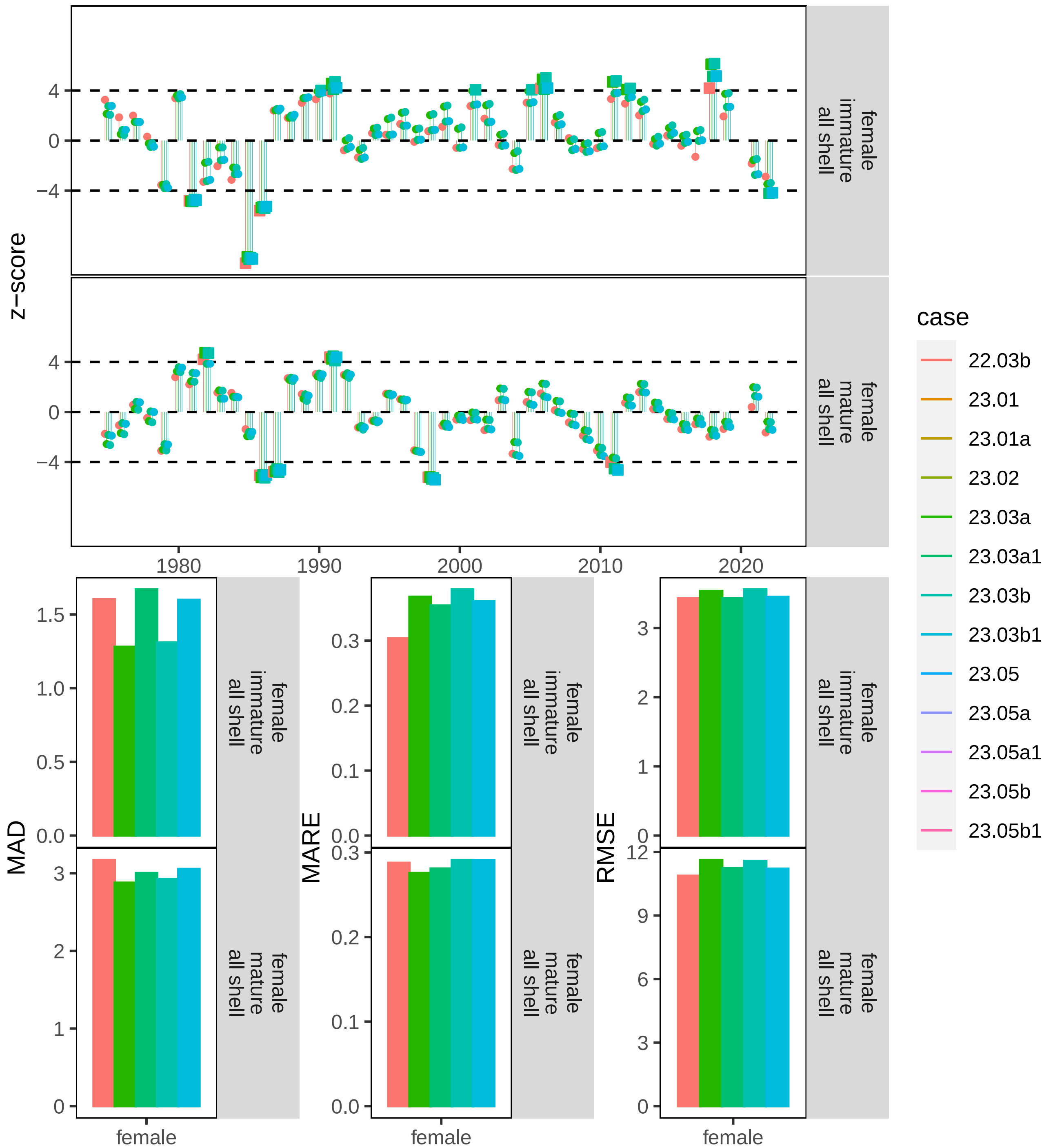

Figure 21. Residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

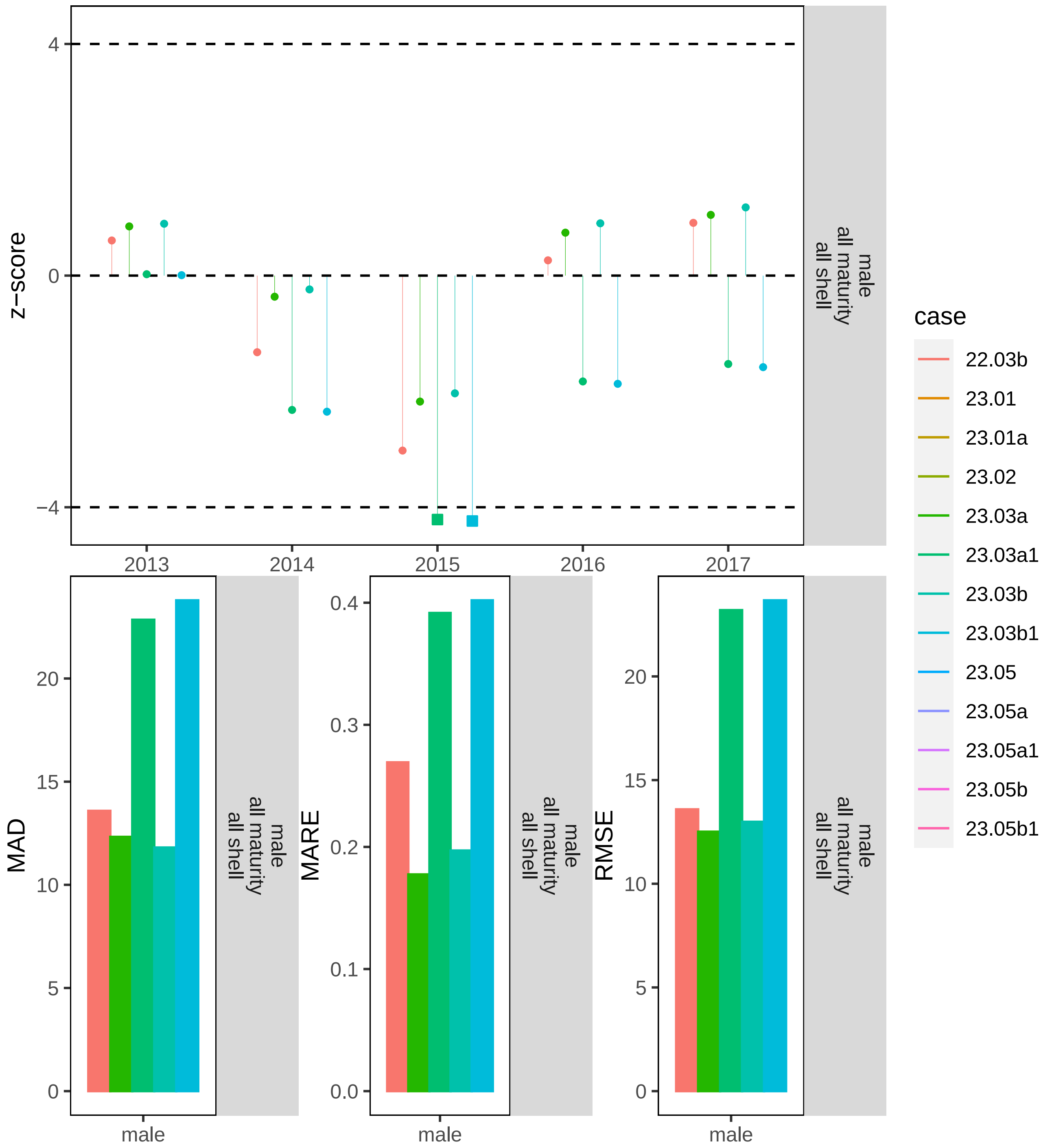

Figure 22. Residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

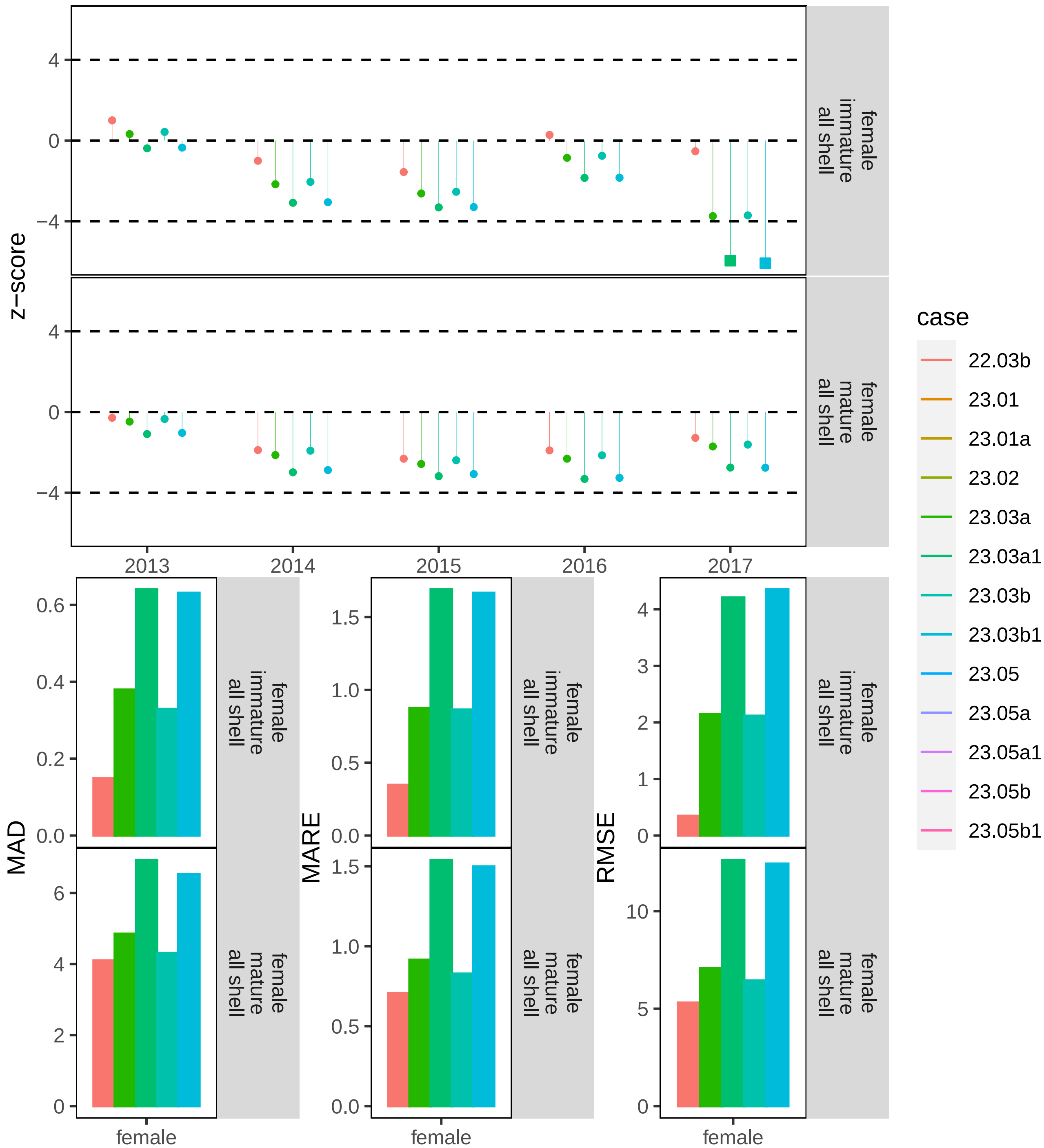

Figure 23. Residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

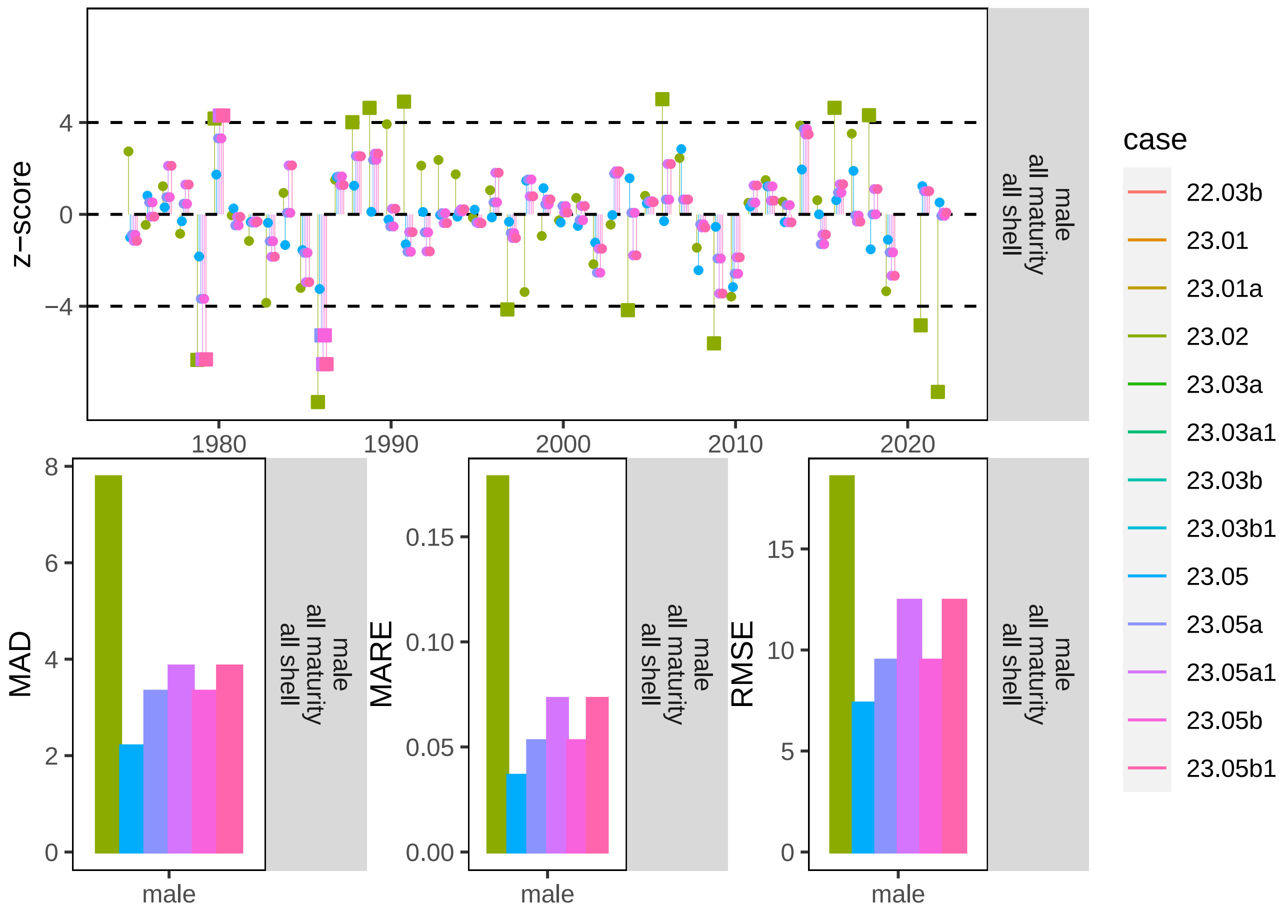

Figure 24. Residuals analysis by model scenario for fits to male biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

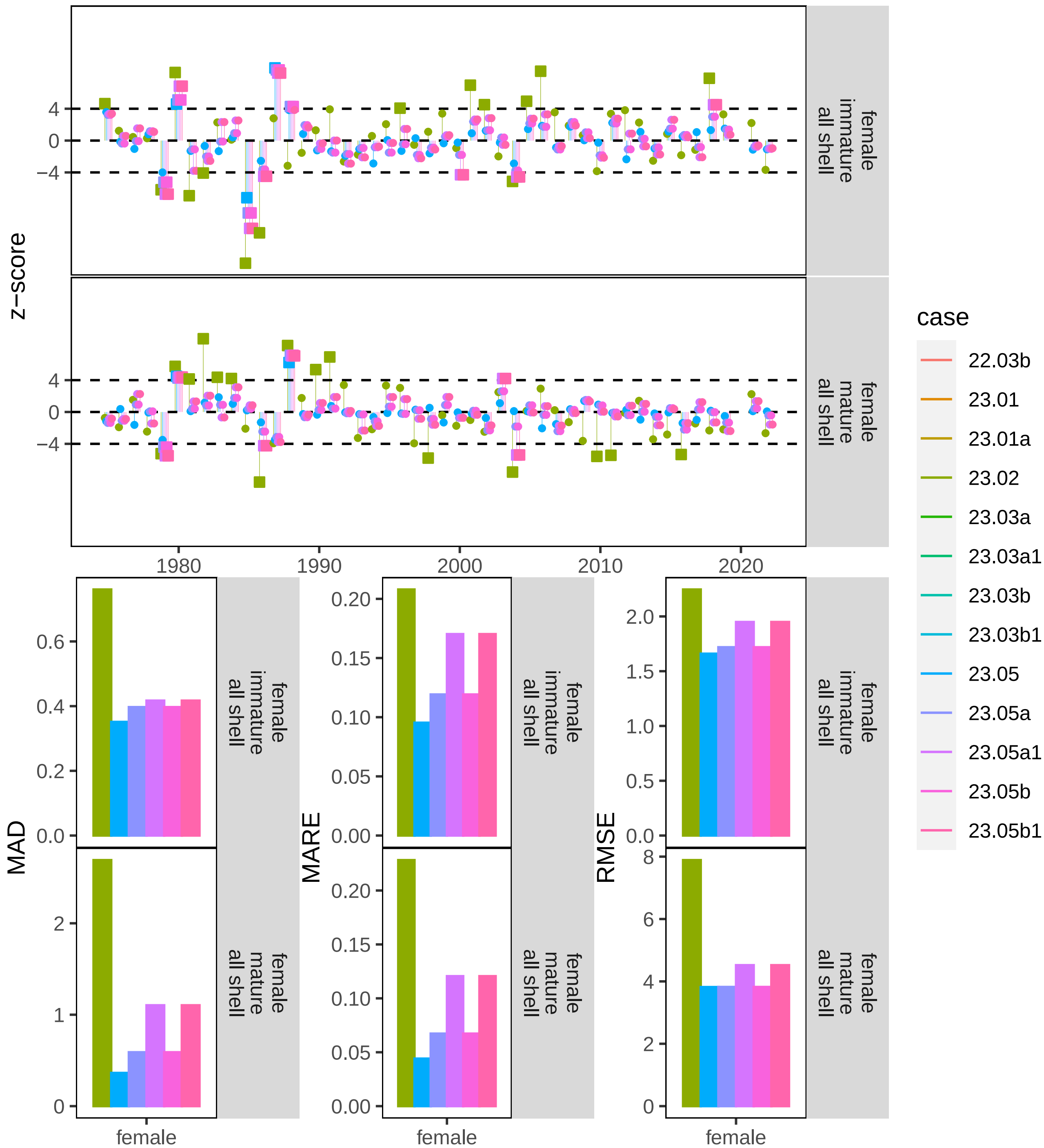

Figure 25. Residuals analysis by model scenario for fits to female biomass in the NMFS EBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

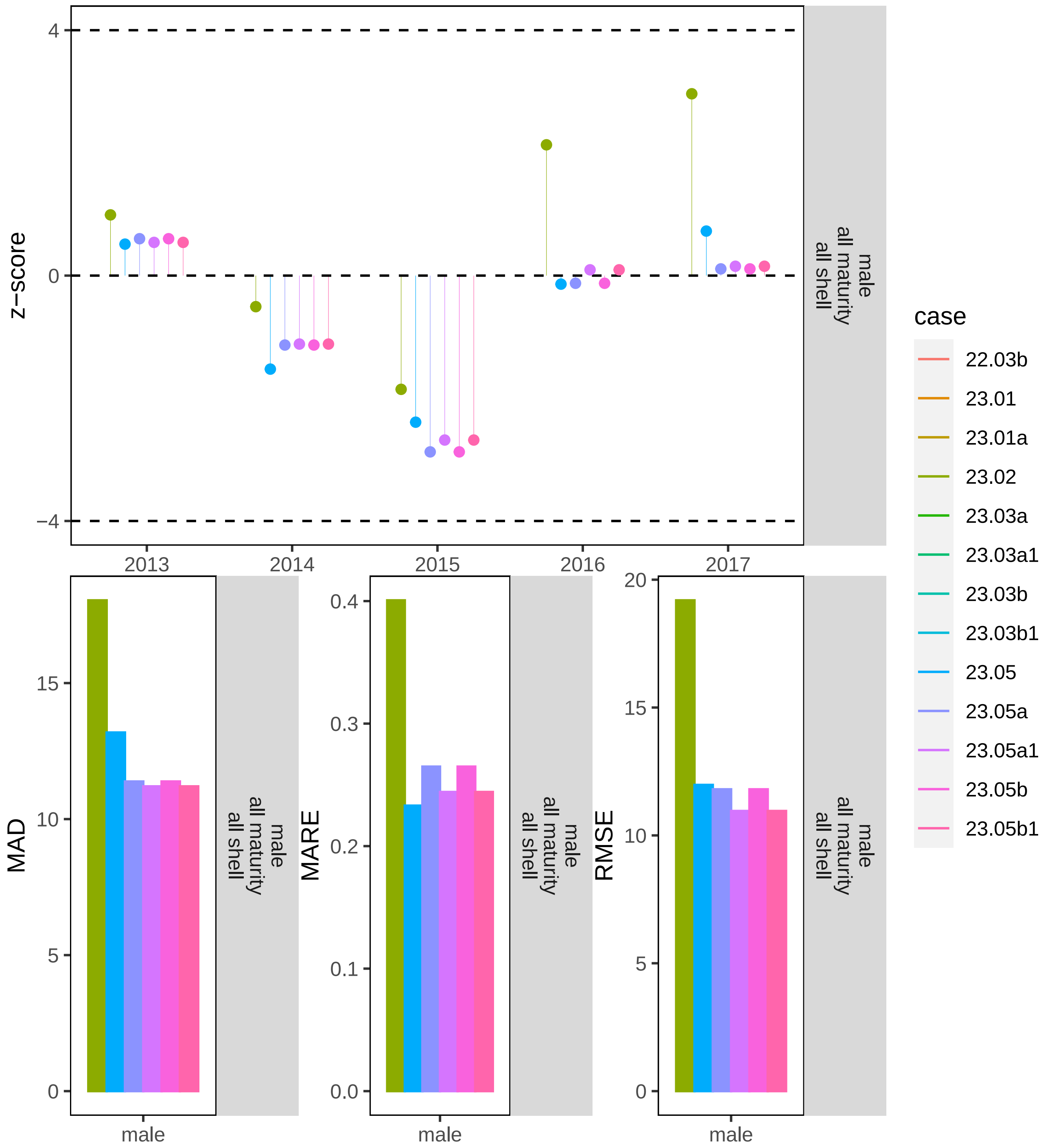

Figure 26. Residuals analysis by model scenario for fits to male biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

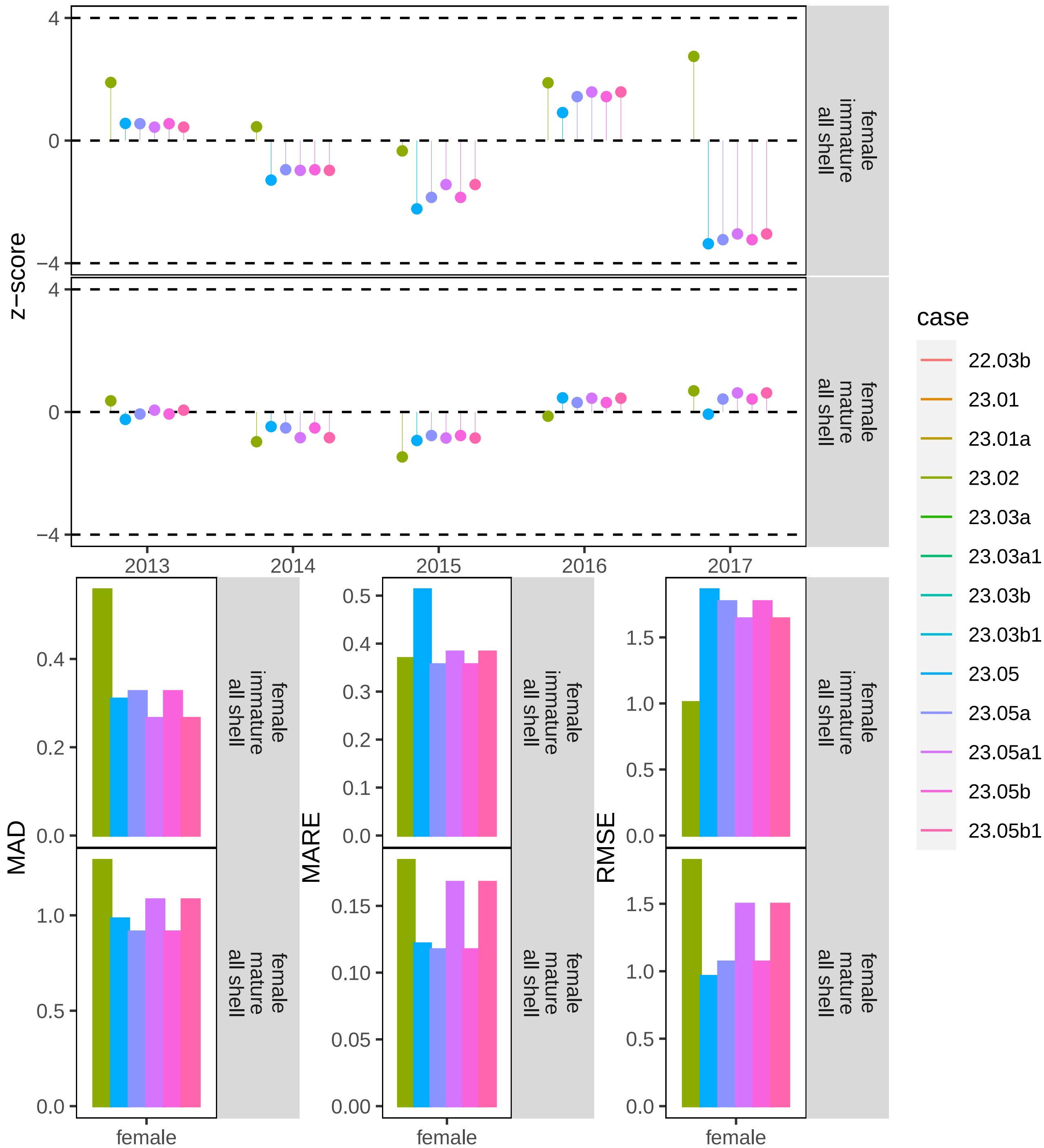

Figure 27. Residuals analysis by model scenario for fits to female biomass in the BSFRF SBS bottom trawl survey. Upper row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

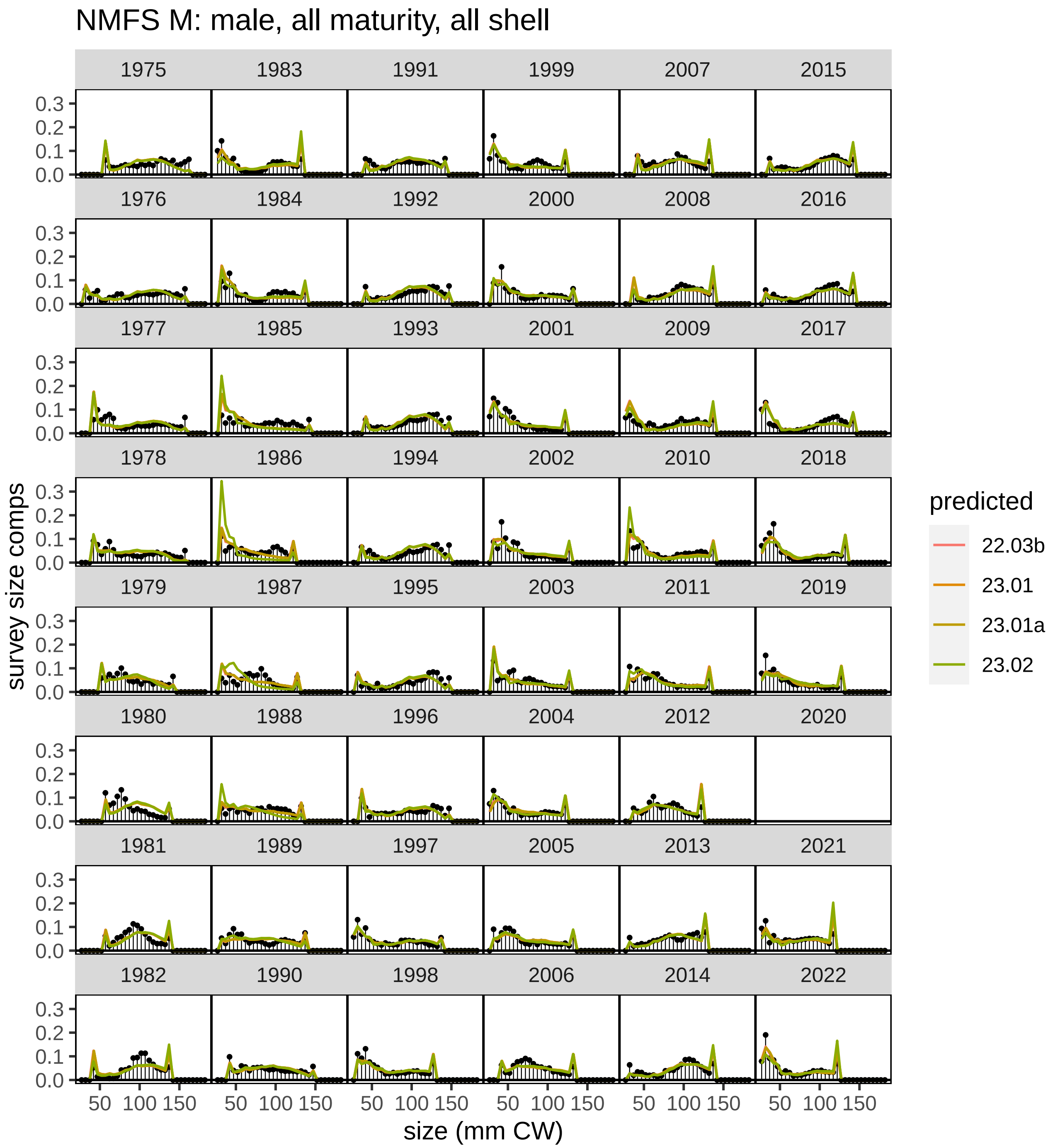

Figure 28. Fits to survey size compositions in the NMFS M survey for Models 22.03b, 23.01, 23.01a, 23.02.

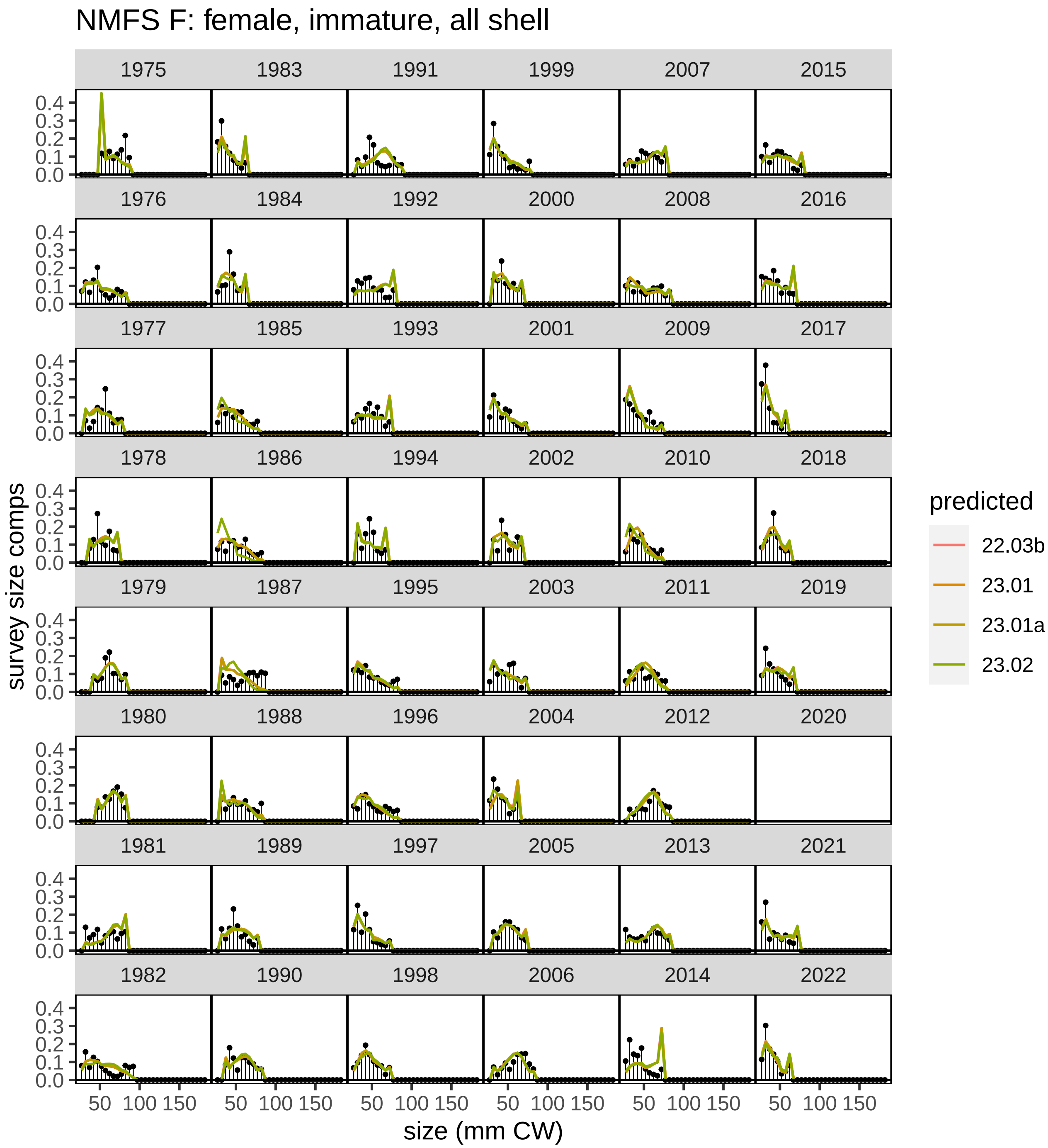

Figure 29. Fits to survey size compositions in the NMFS F survey for Models 22.03b, 23.01, 23.01a, 23.02.

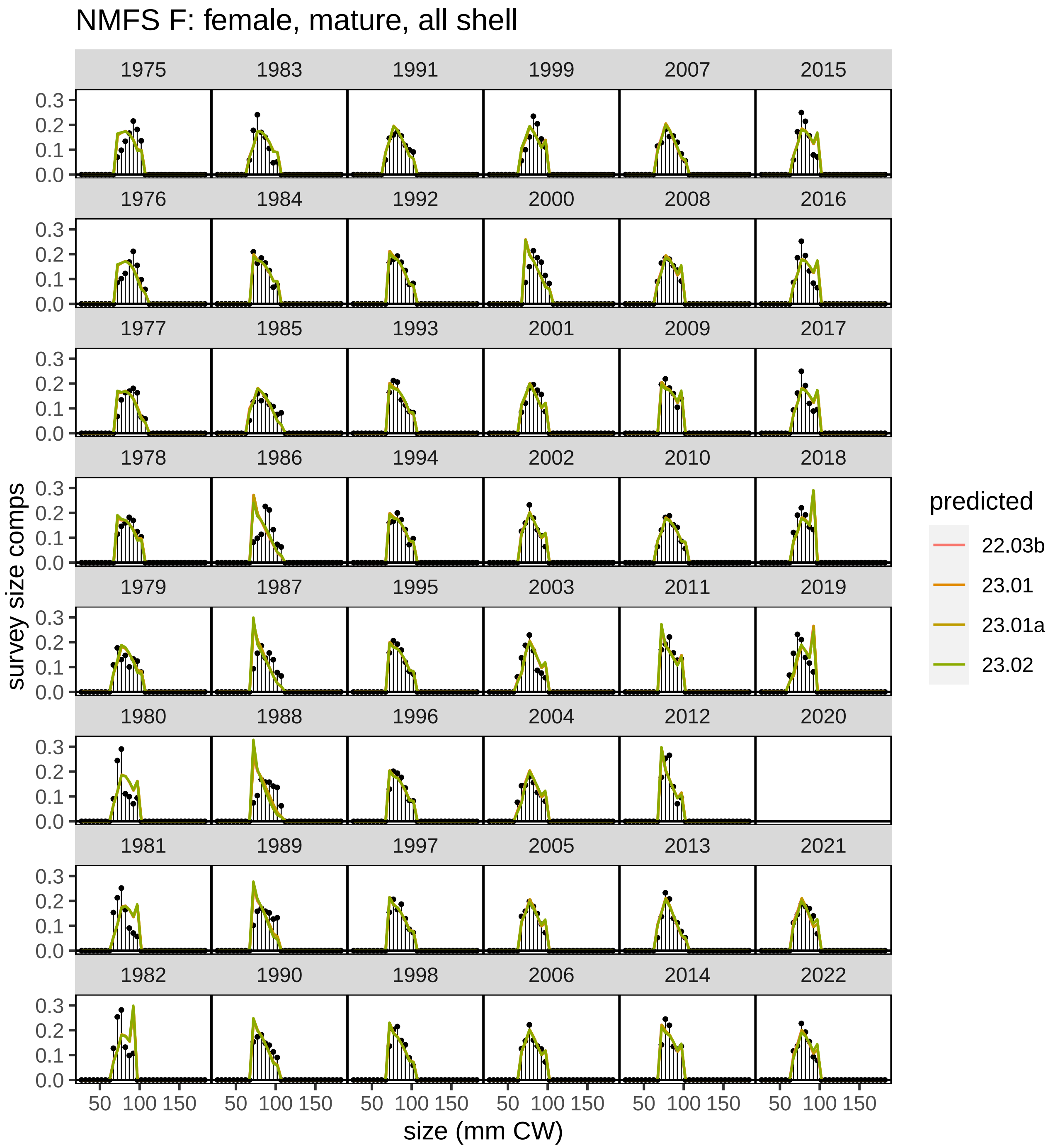

Figure 30. Fits to survey size compositions in the NMFS F survey for Models 22.03b, 23.01, 23.01a, 23.02.

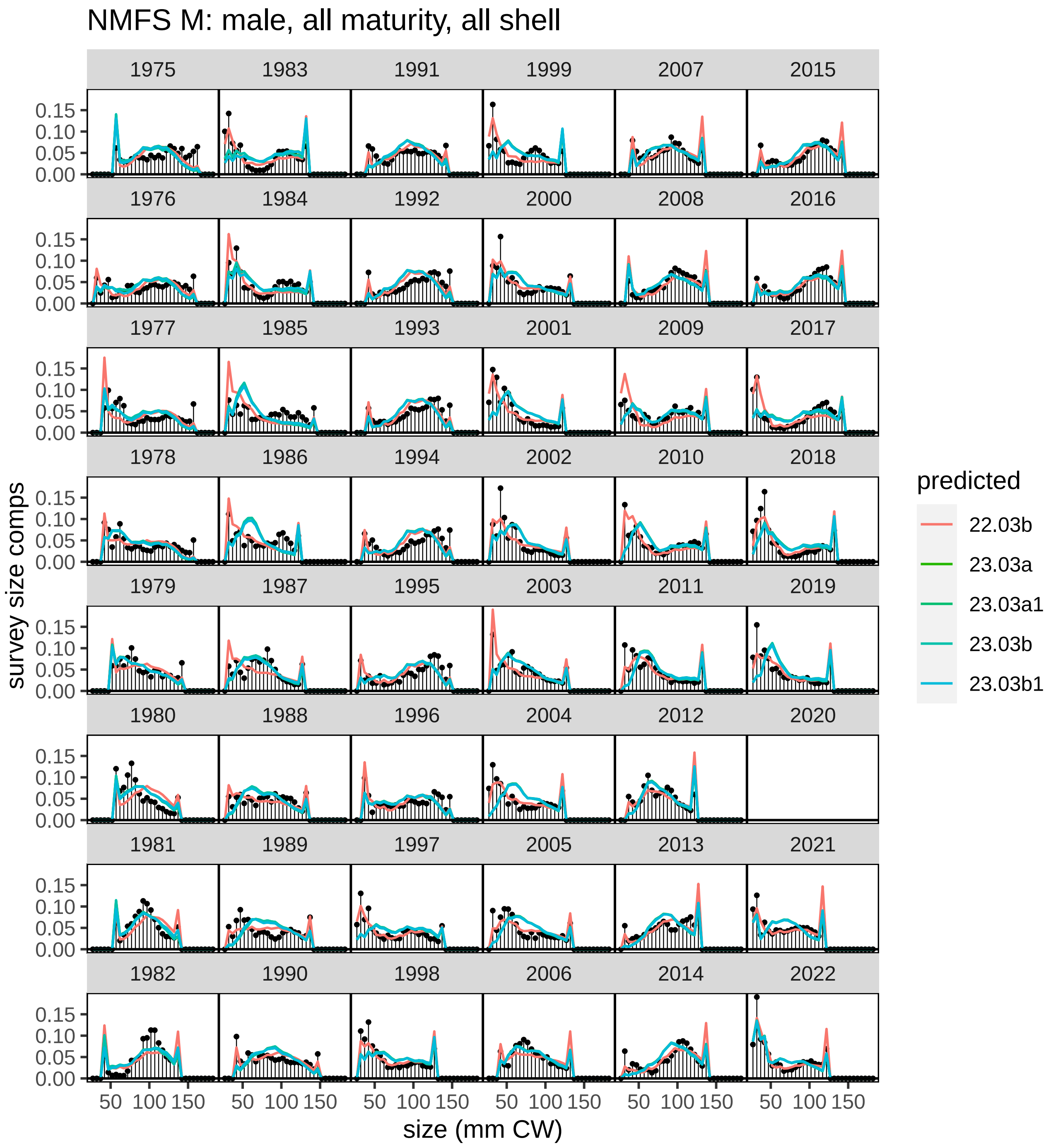

Figure 31. Fits to survey size compositions in the NMFS M survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

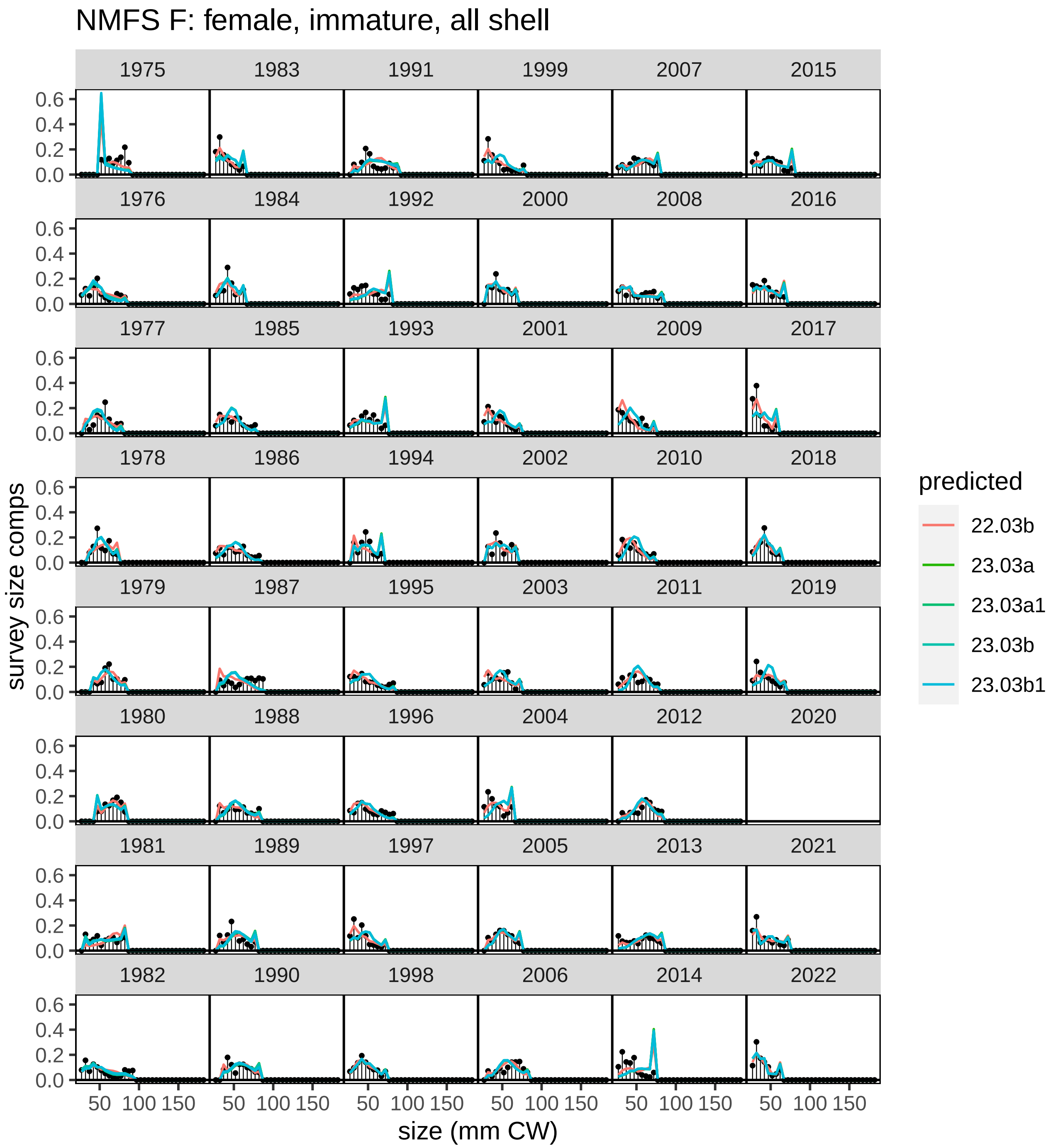

Figure 32. Fits to survey size compositions in the NMFS F survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

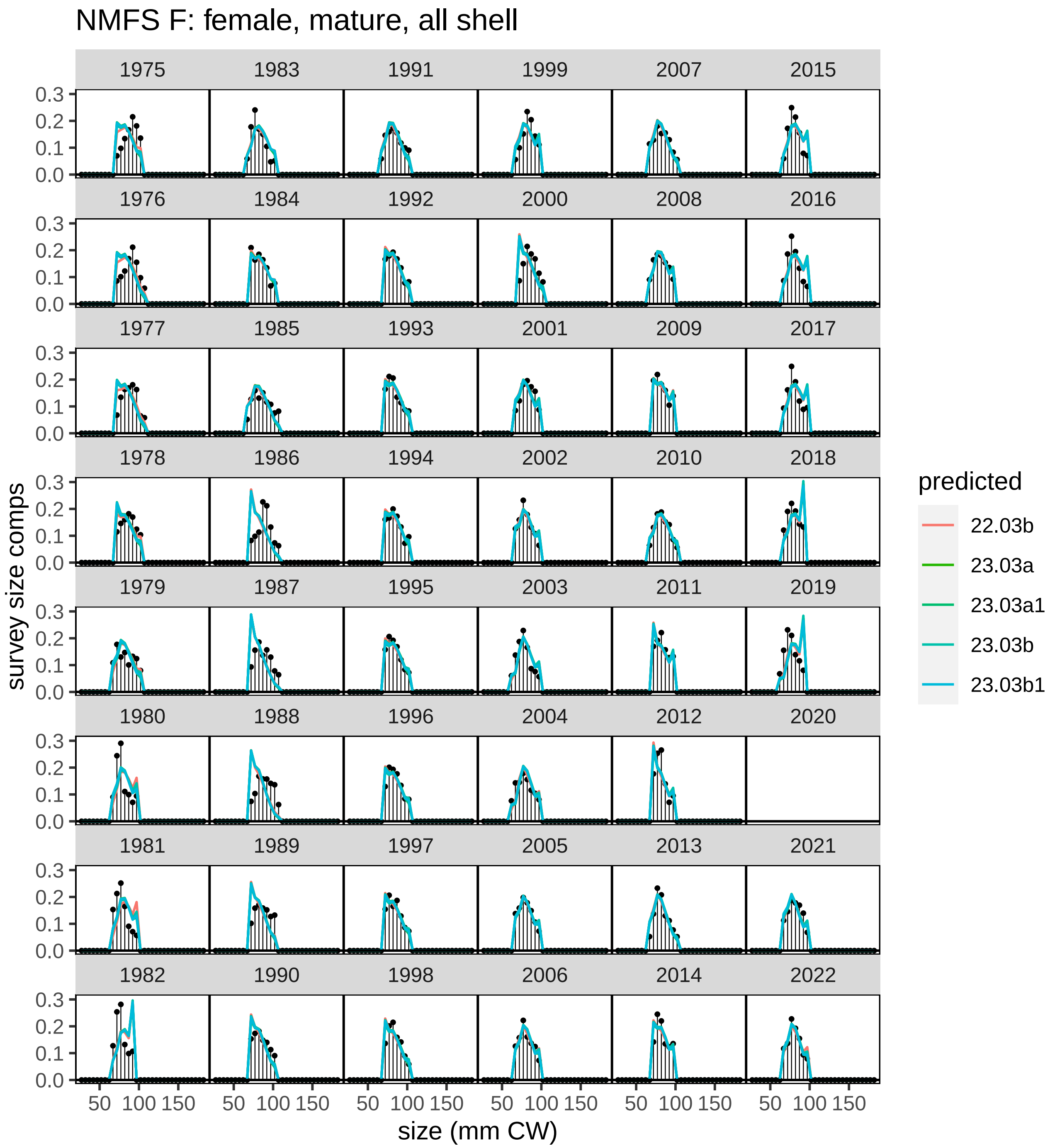

Figure 33. Fits to survey size compositions in the NMFS F survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

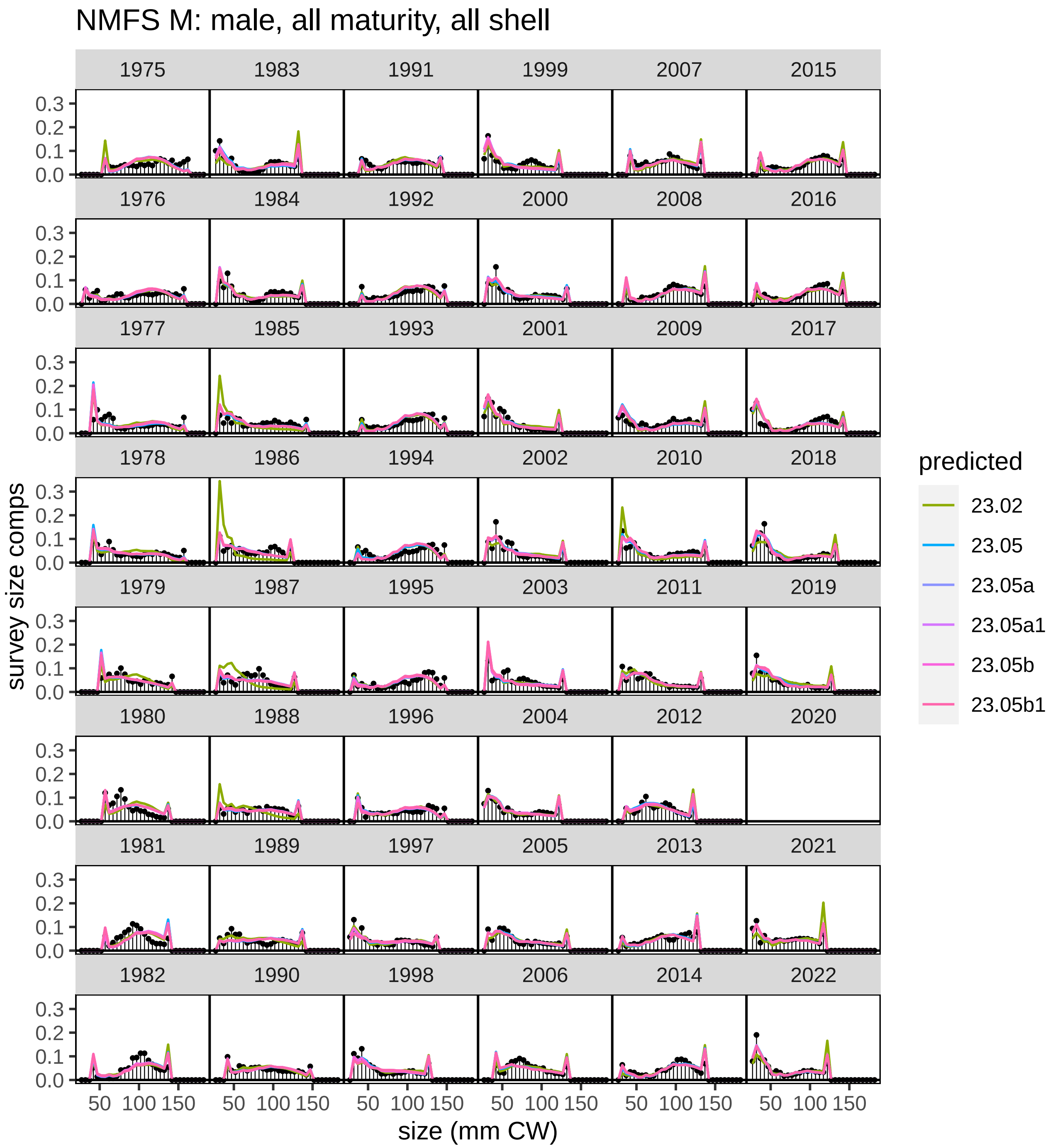

Figure 34. Fits to survey size compositions in the NMFS M survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

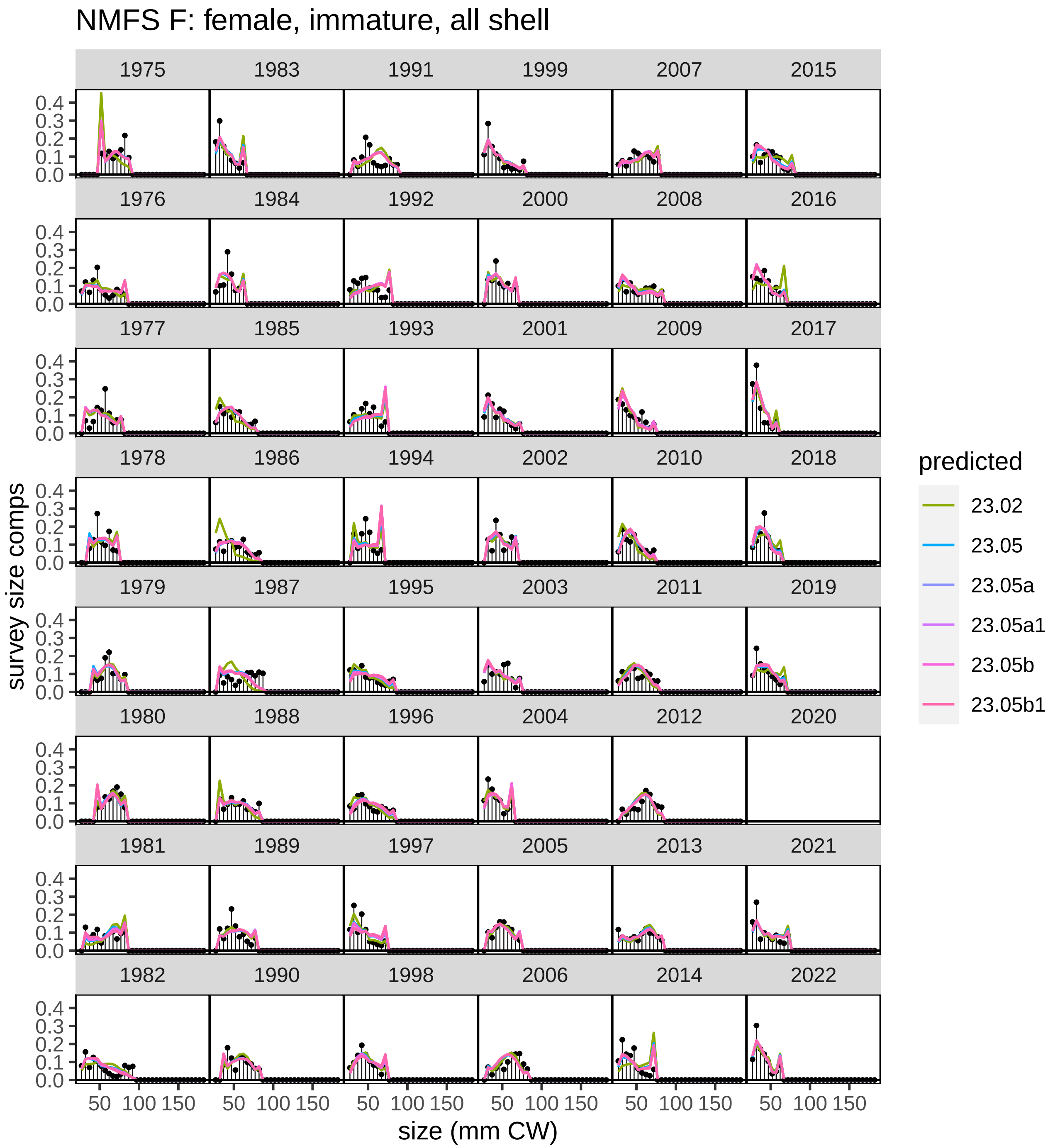

Figure 35. Fits to survey size compositions in the NMFS F survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

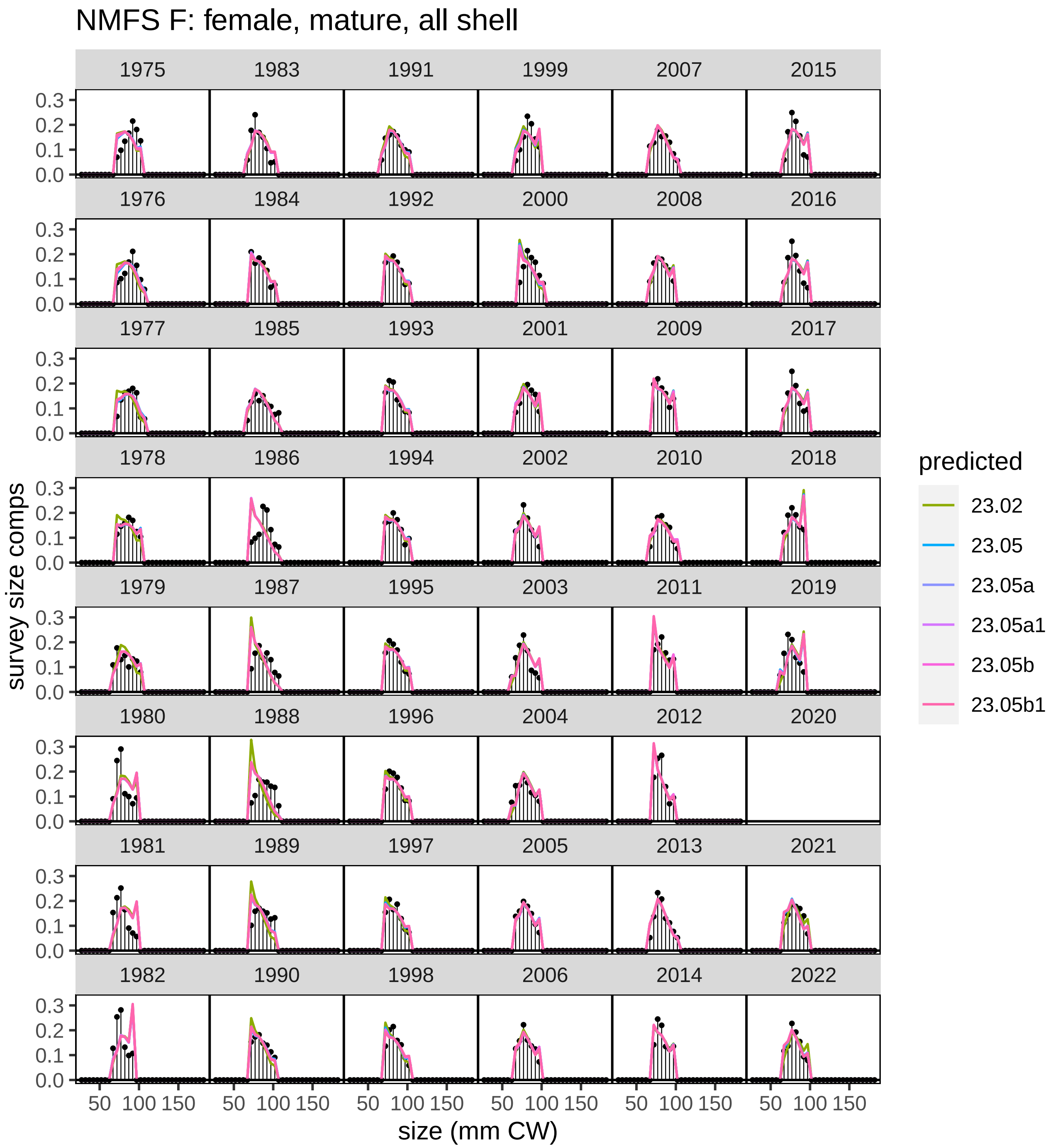

Figure 36. Fits to survey size compositions in the NMFS F survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

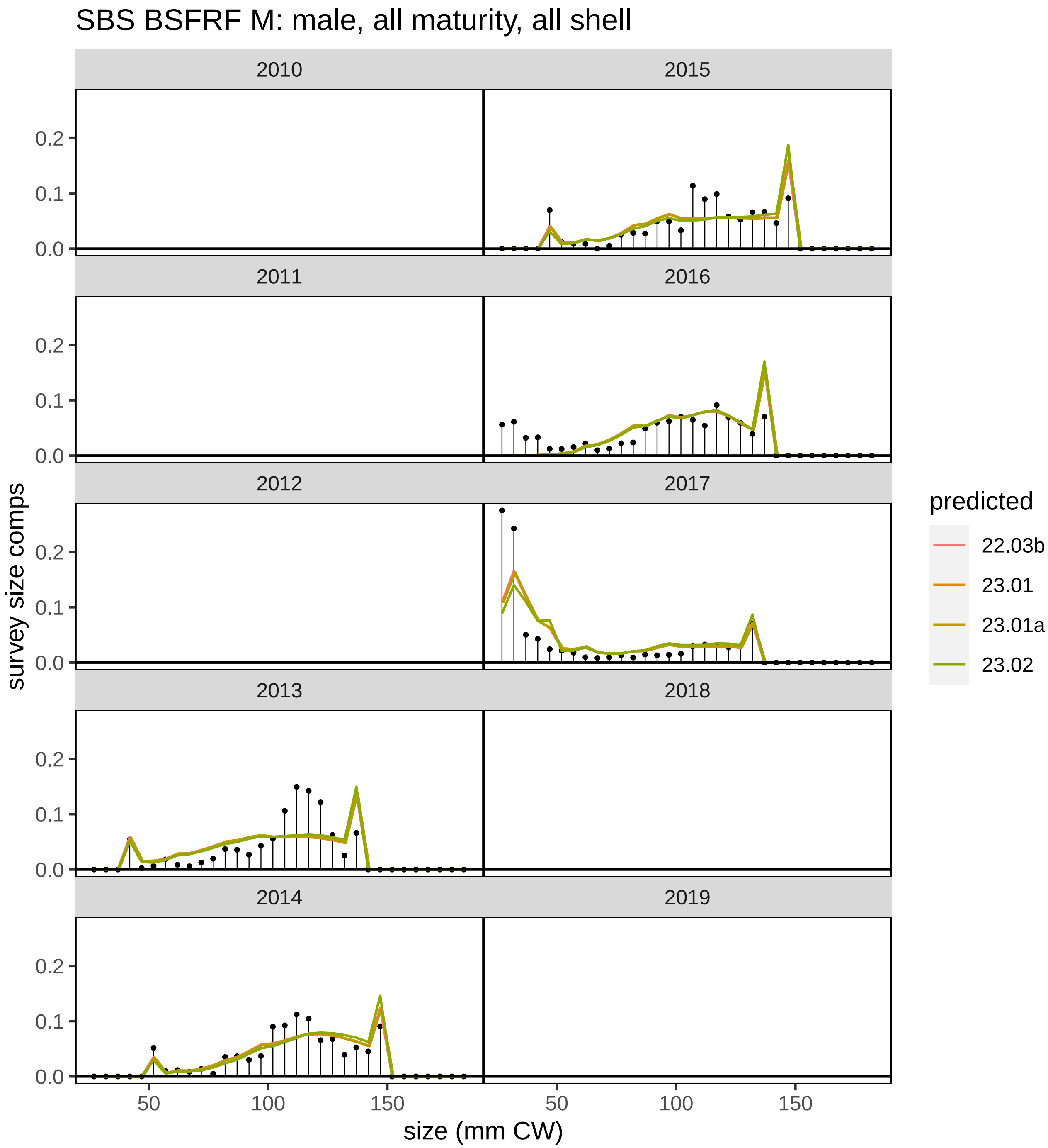

Figure 37. Fits to survey size compositions in the SBS BSFRF M survey for Models 22.03b, 23.01, 23.01a, 23.02.

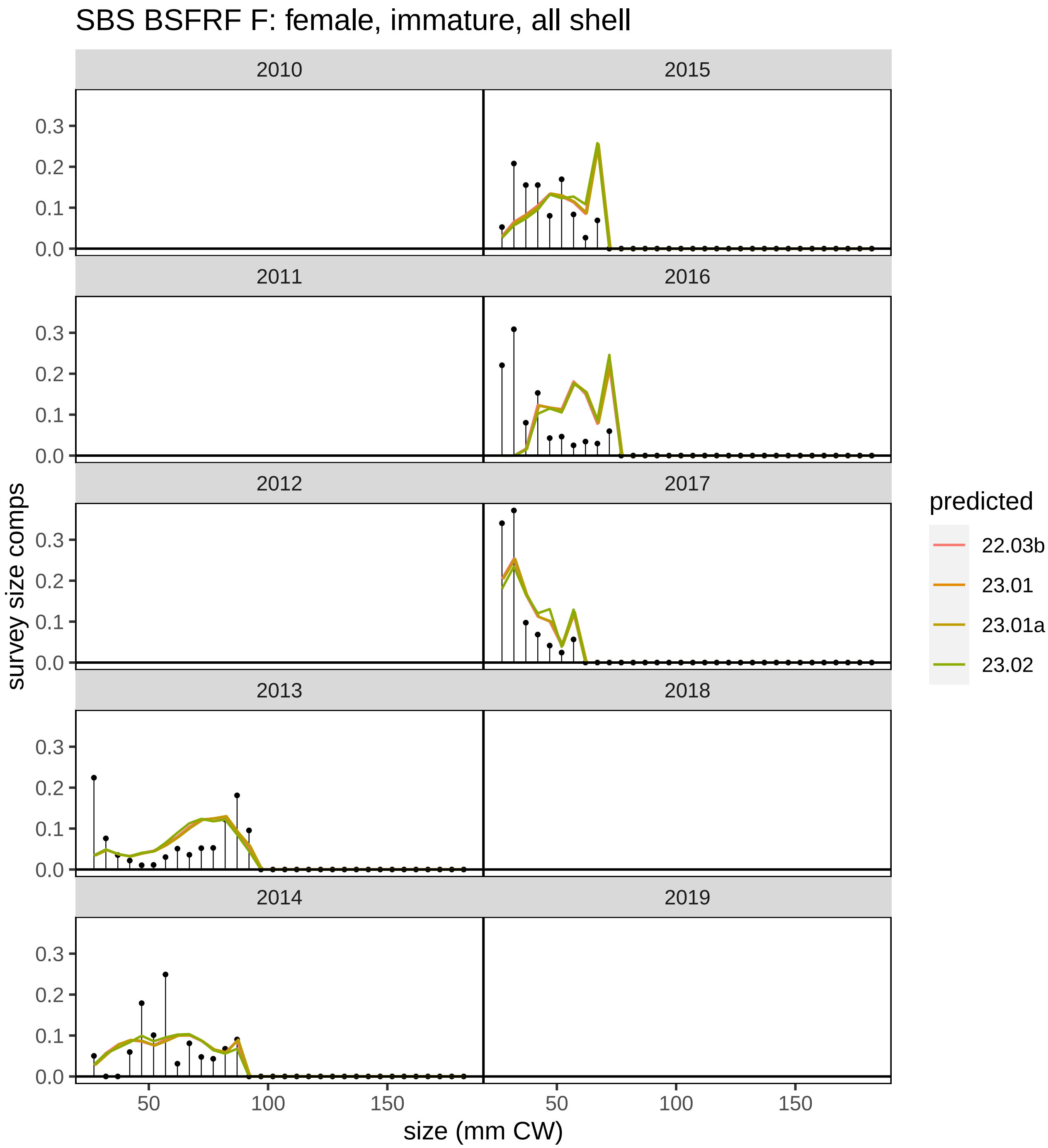

Figure 38. Fits to survey size compositions in the SBS BSFRF F survey for Models 22.03b, 23.01, 23.01a, 23.02.

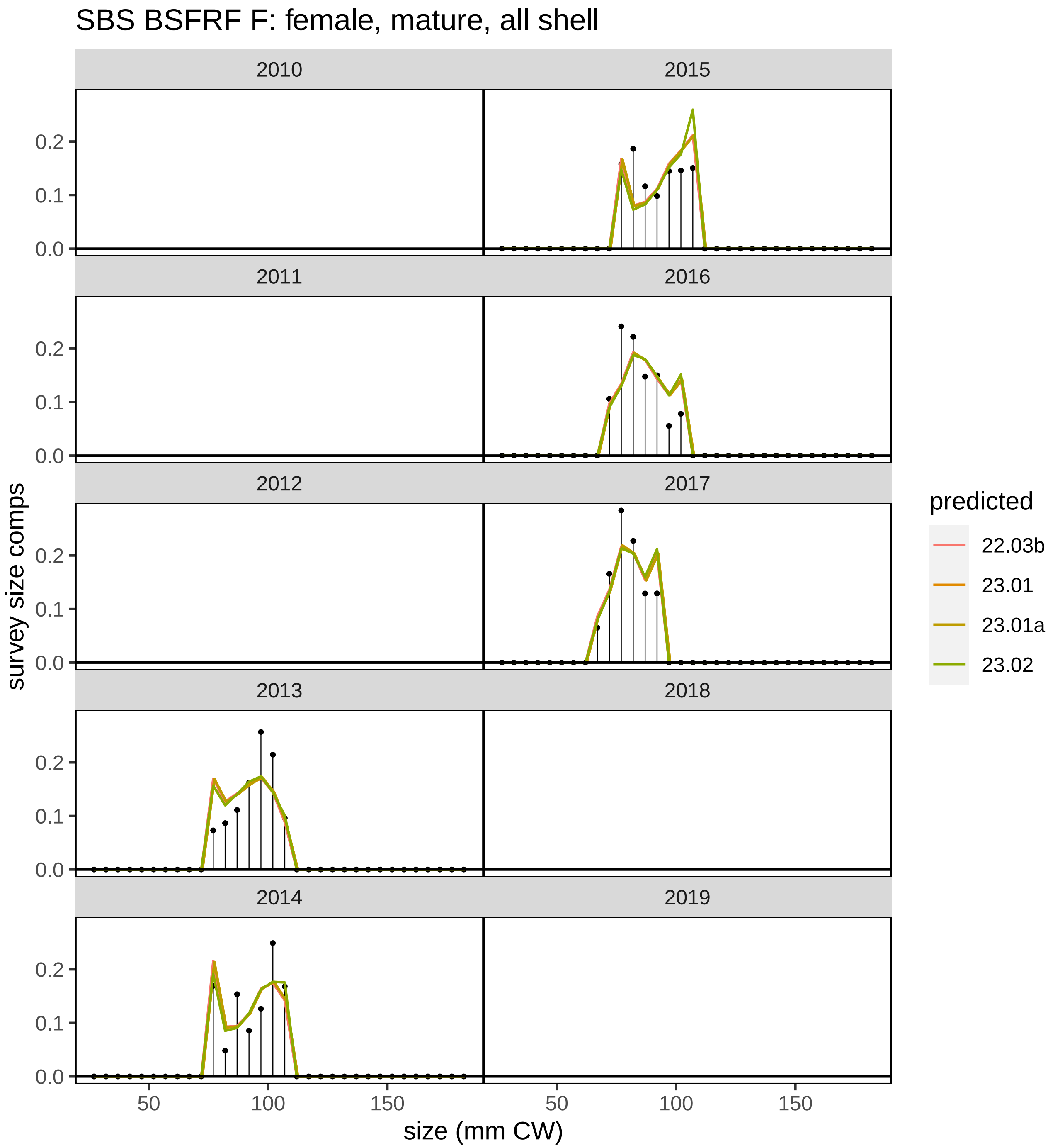

Figure 39. Fits to survey size compositions in the SBS BSFRF F survey for Models 22.03b, 23.01, 23.01a, 23.02.

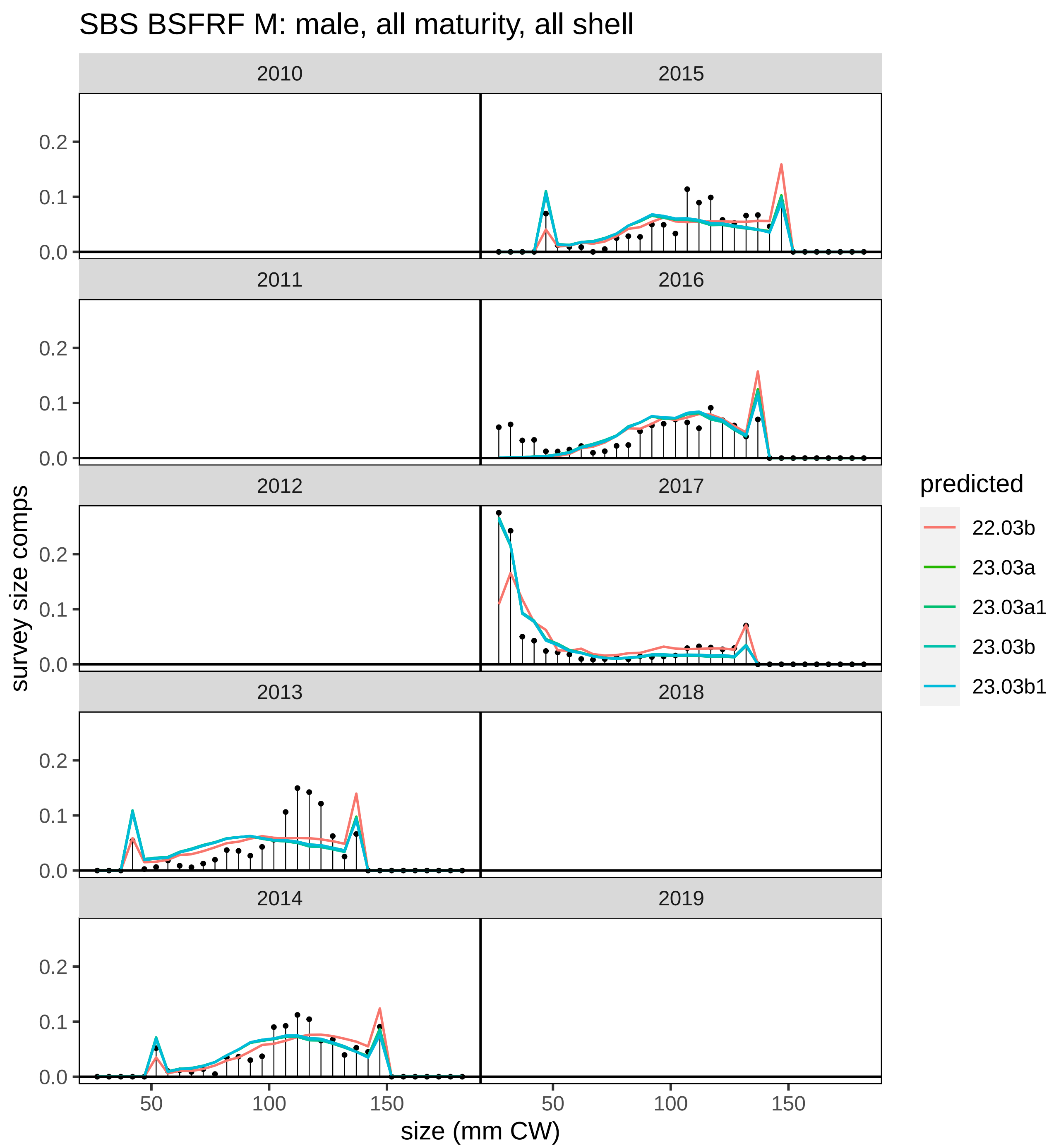

Figure 40. Fits to survey size compositions in the SBS BSFRF M survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

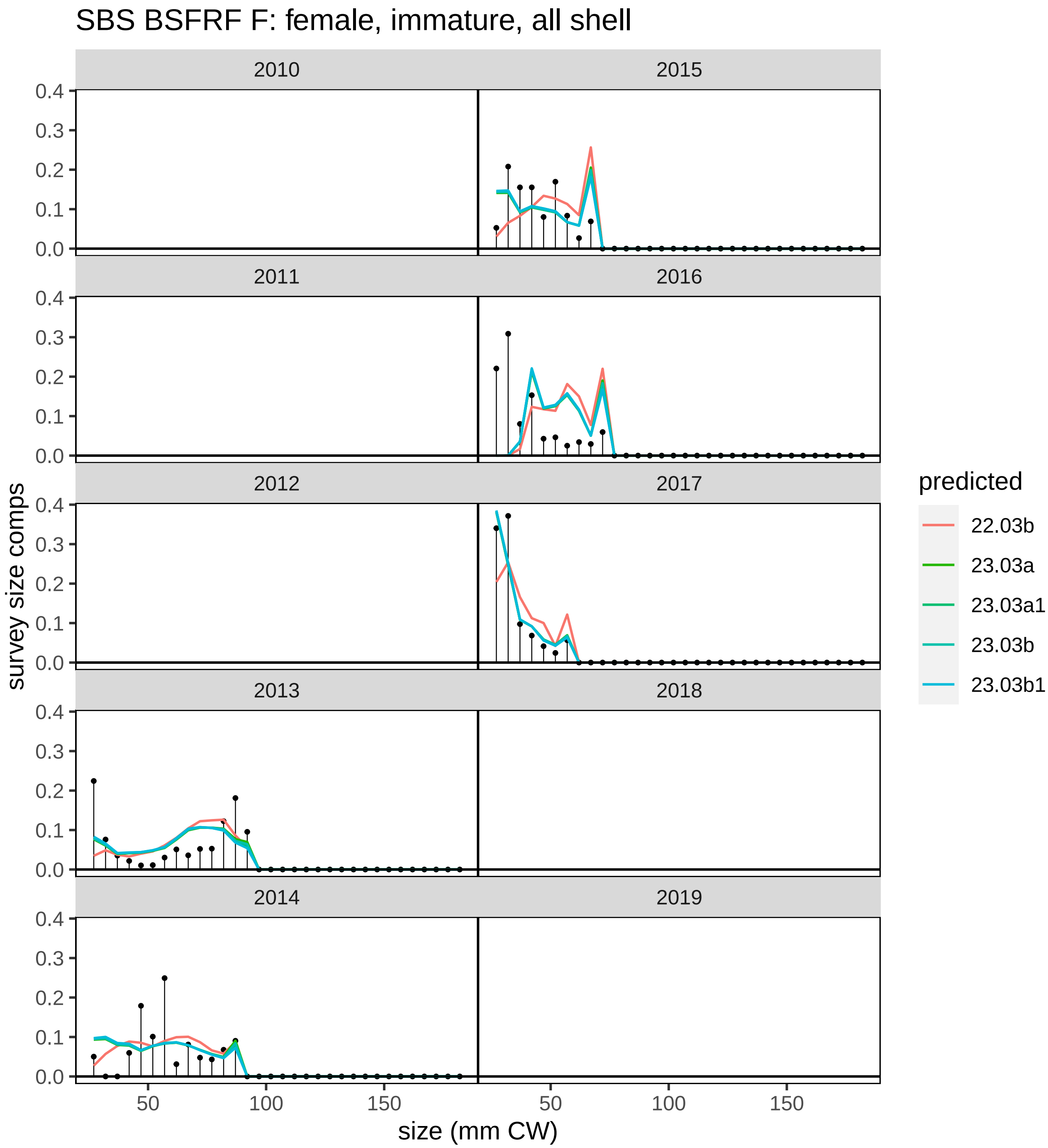

Figure 41. Fits to survey size compositions in the SBS BSFRF F survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

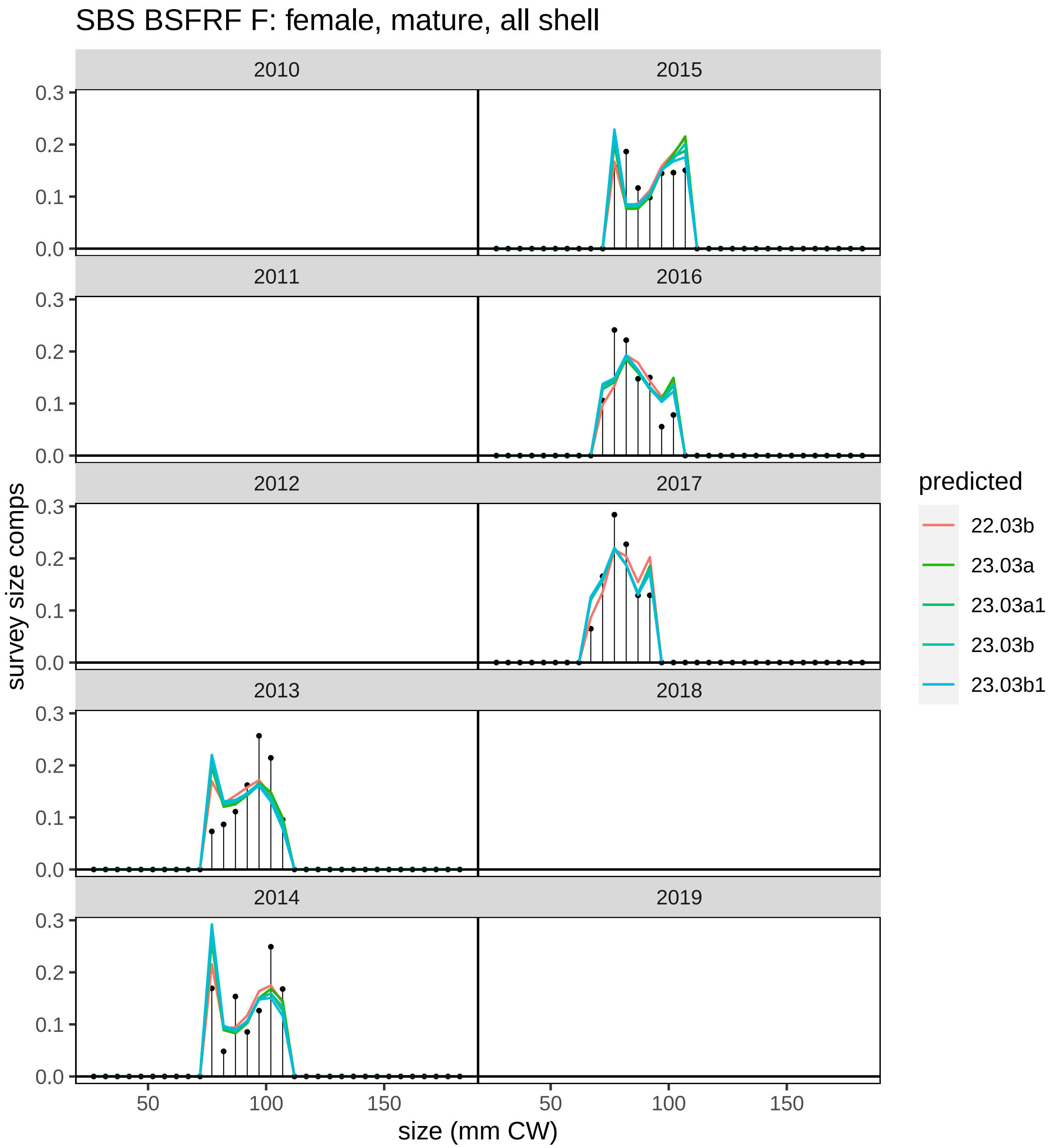

Figure 42. Fits to survey size compositions in the SBS BSFRF F survey for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

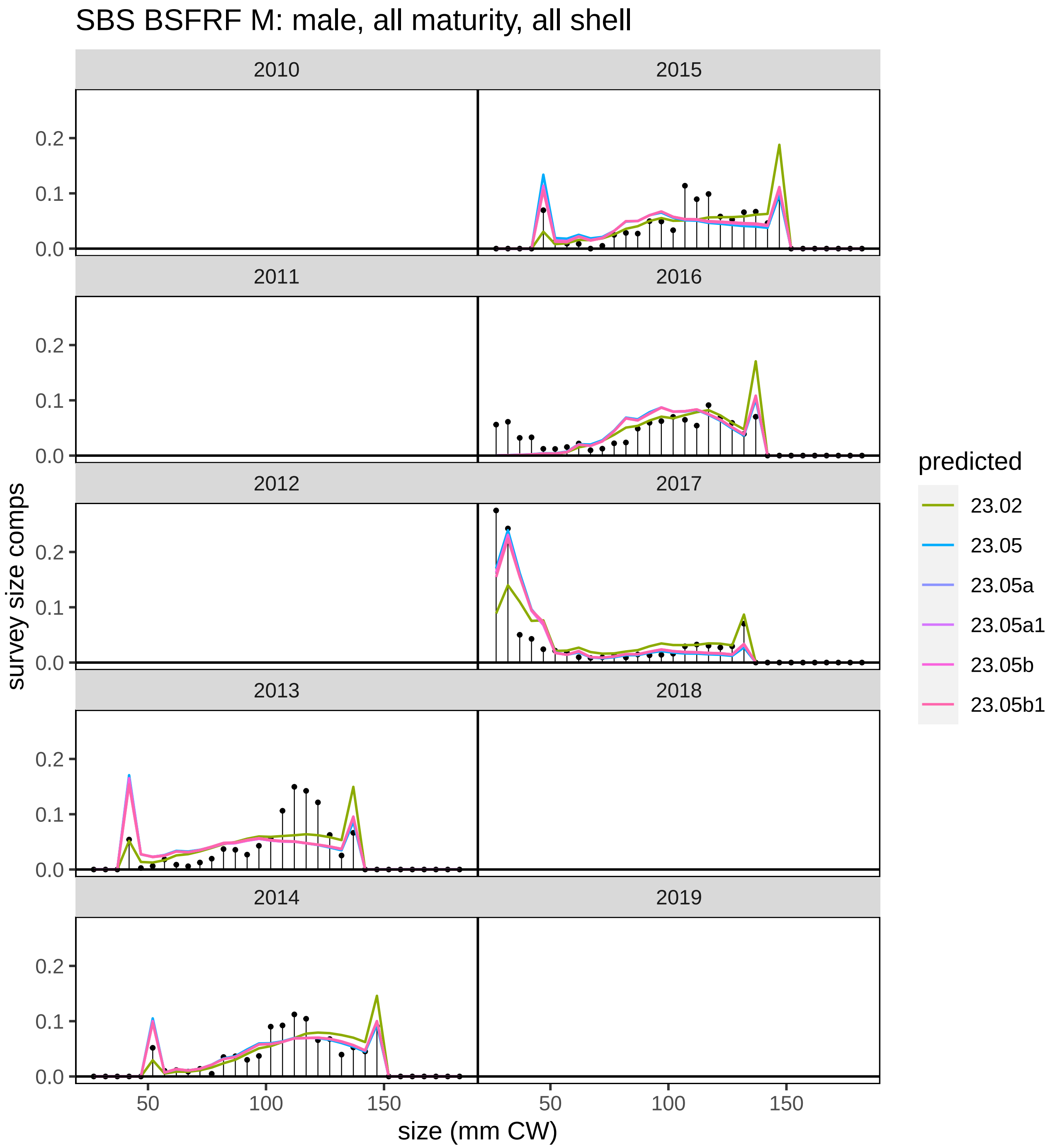

Figure 43. Fits to survey size compositions in the SBS BSFRF M survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

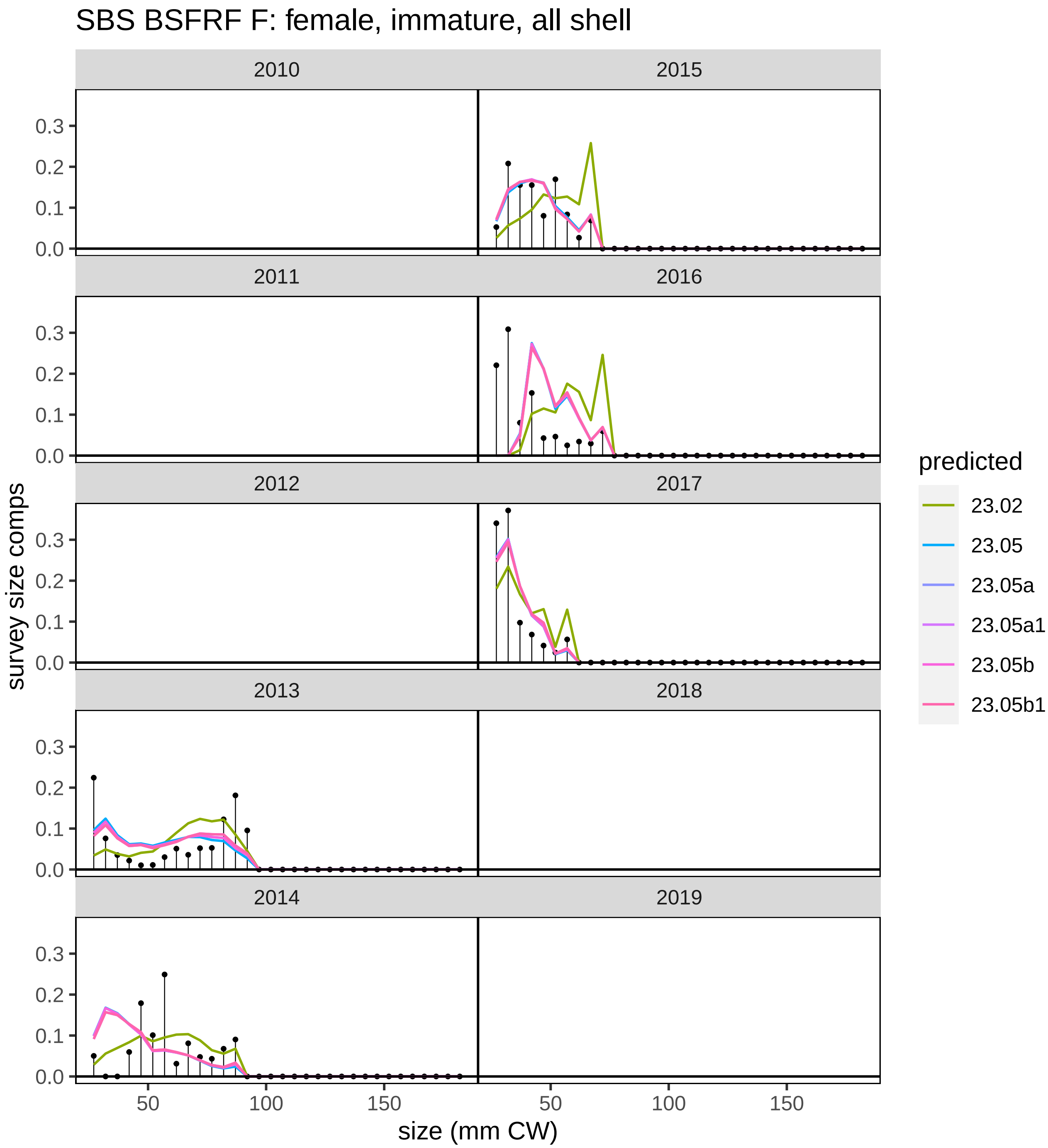

Figure 44. Fits to survey size compositions in the SBS BSFRF F survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

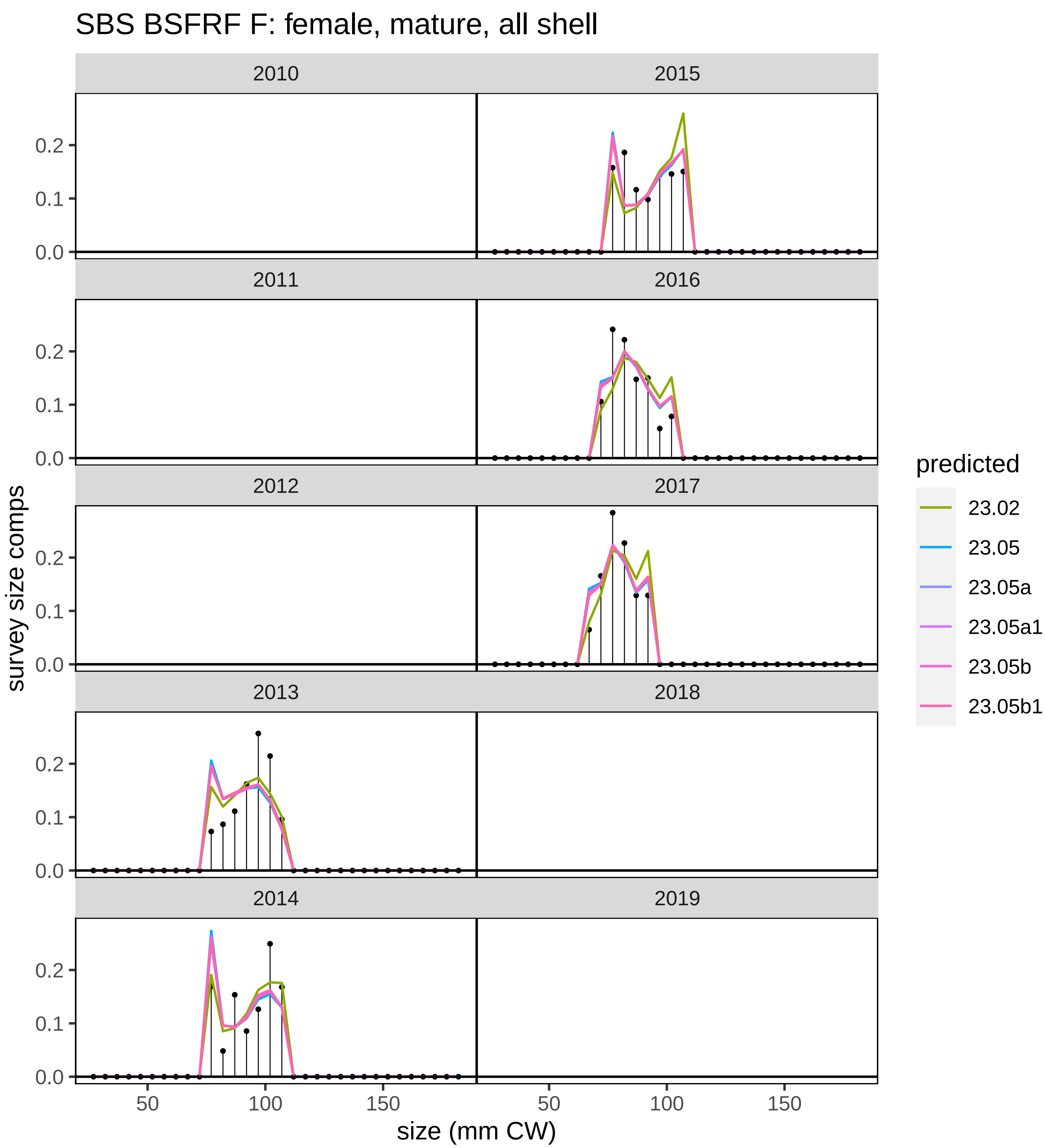

Figure 45. Fits to survey size compositions in the SBS BSFRF F survey for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

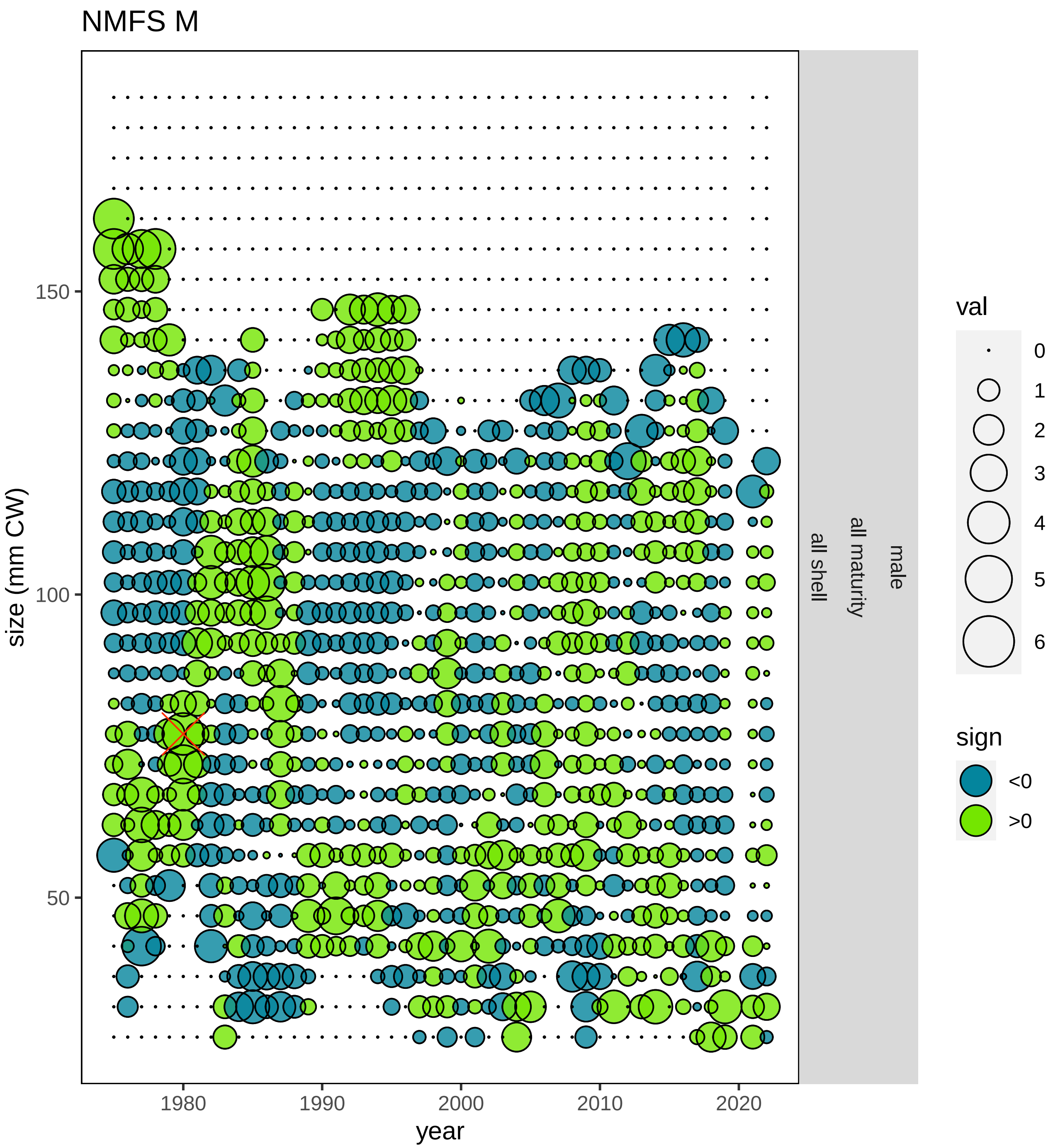

Figure 46. Pearson's residuals for fits to survey size composition data in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

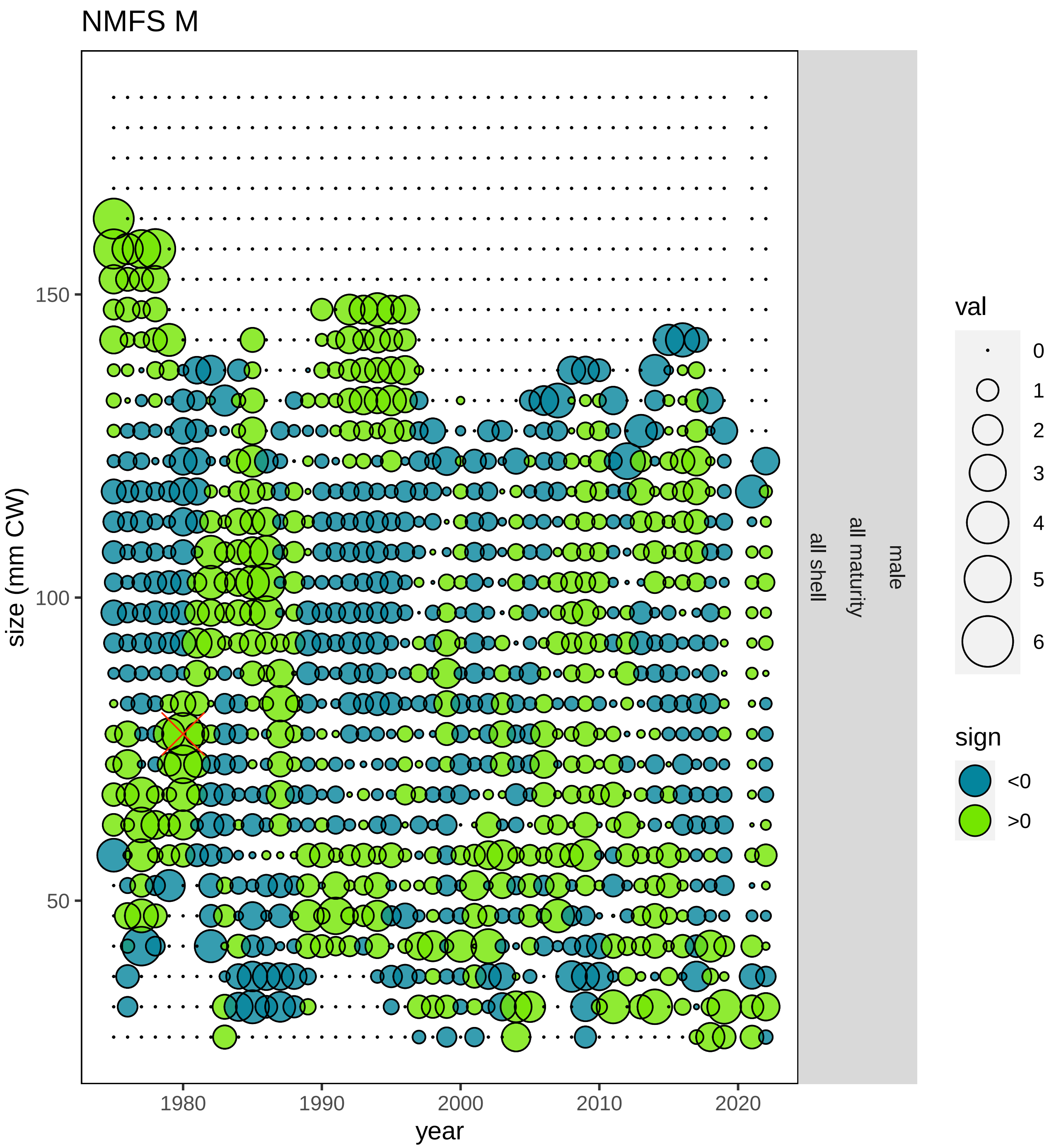

Figure 47. Pearson's residuals for fits to survey size composition data in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

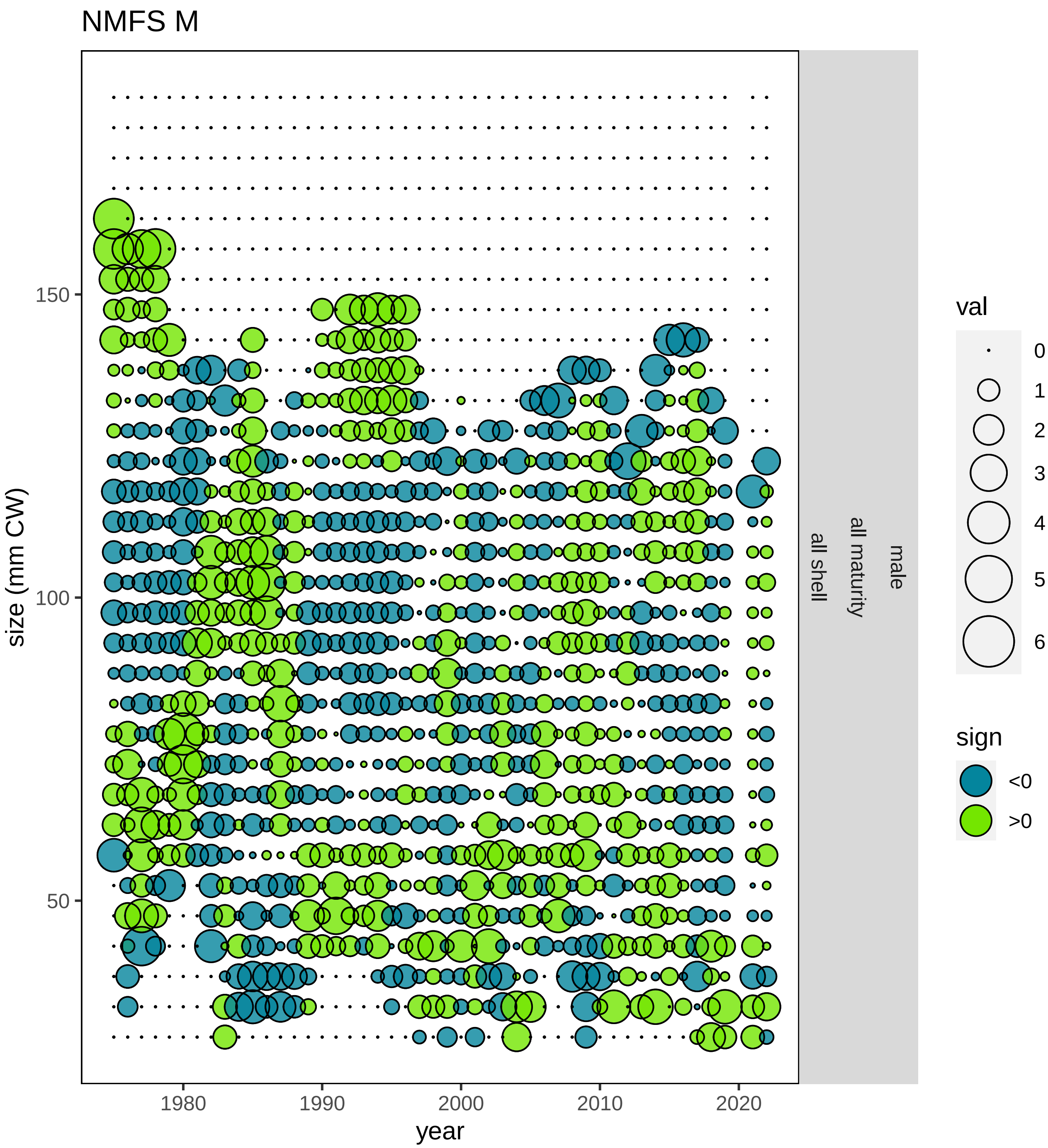

Figure 48. Pearson's residuals for fits to survey size composition data in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

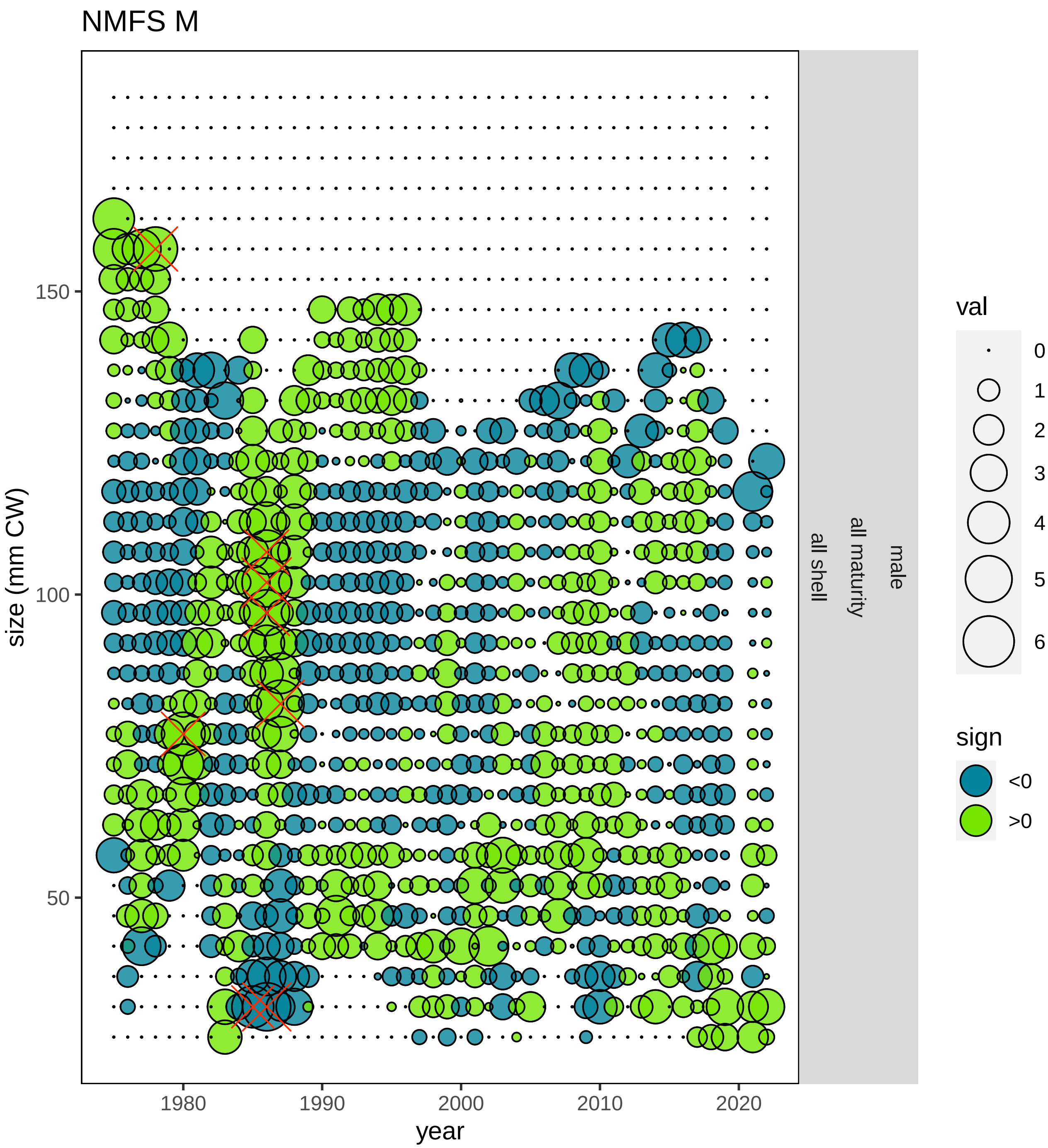

Figure 49. Pearson's residuals for fits to survey size composition data in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

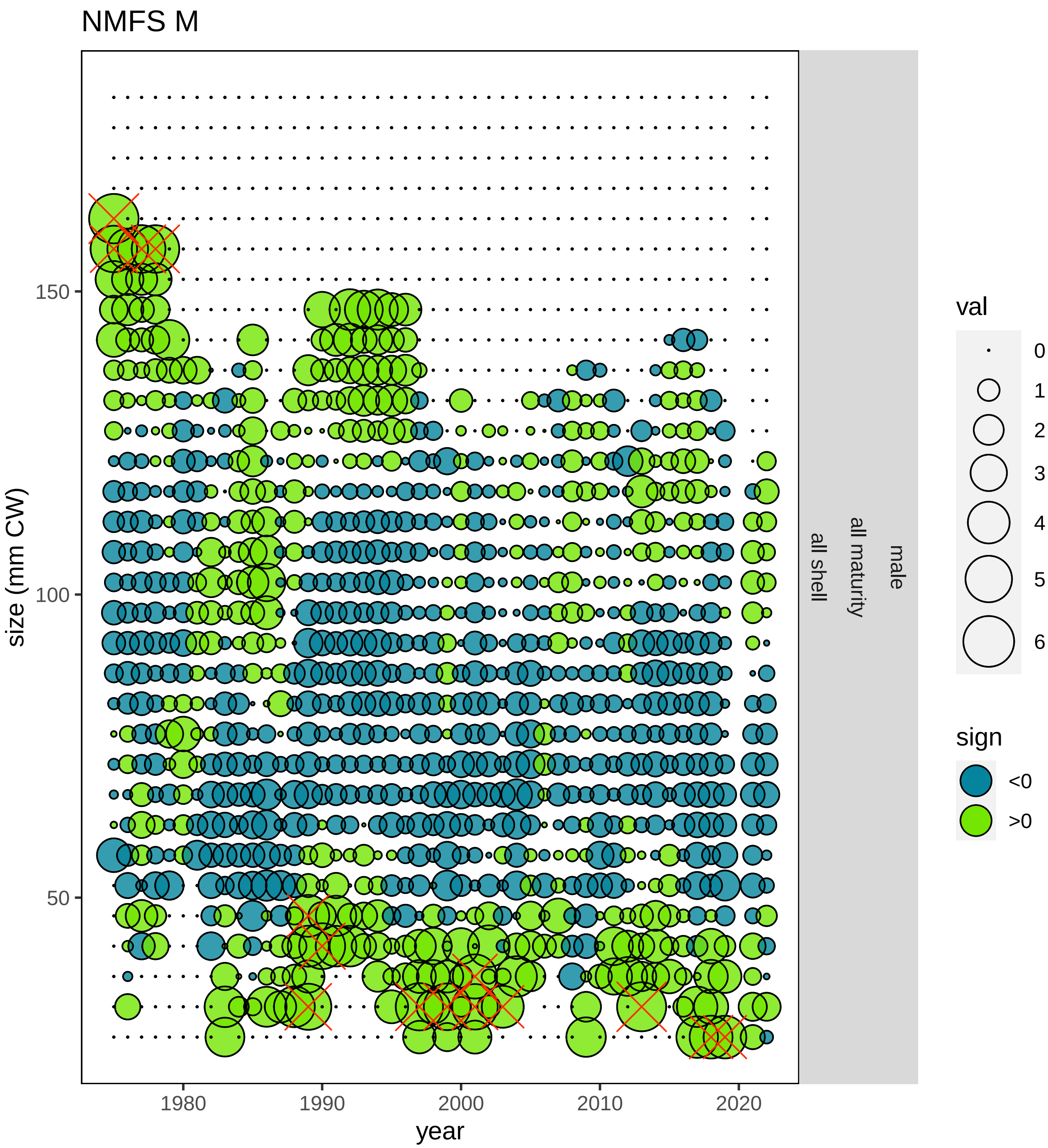

Figure 50. Pearson's residuals for fits to survey size composition data in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

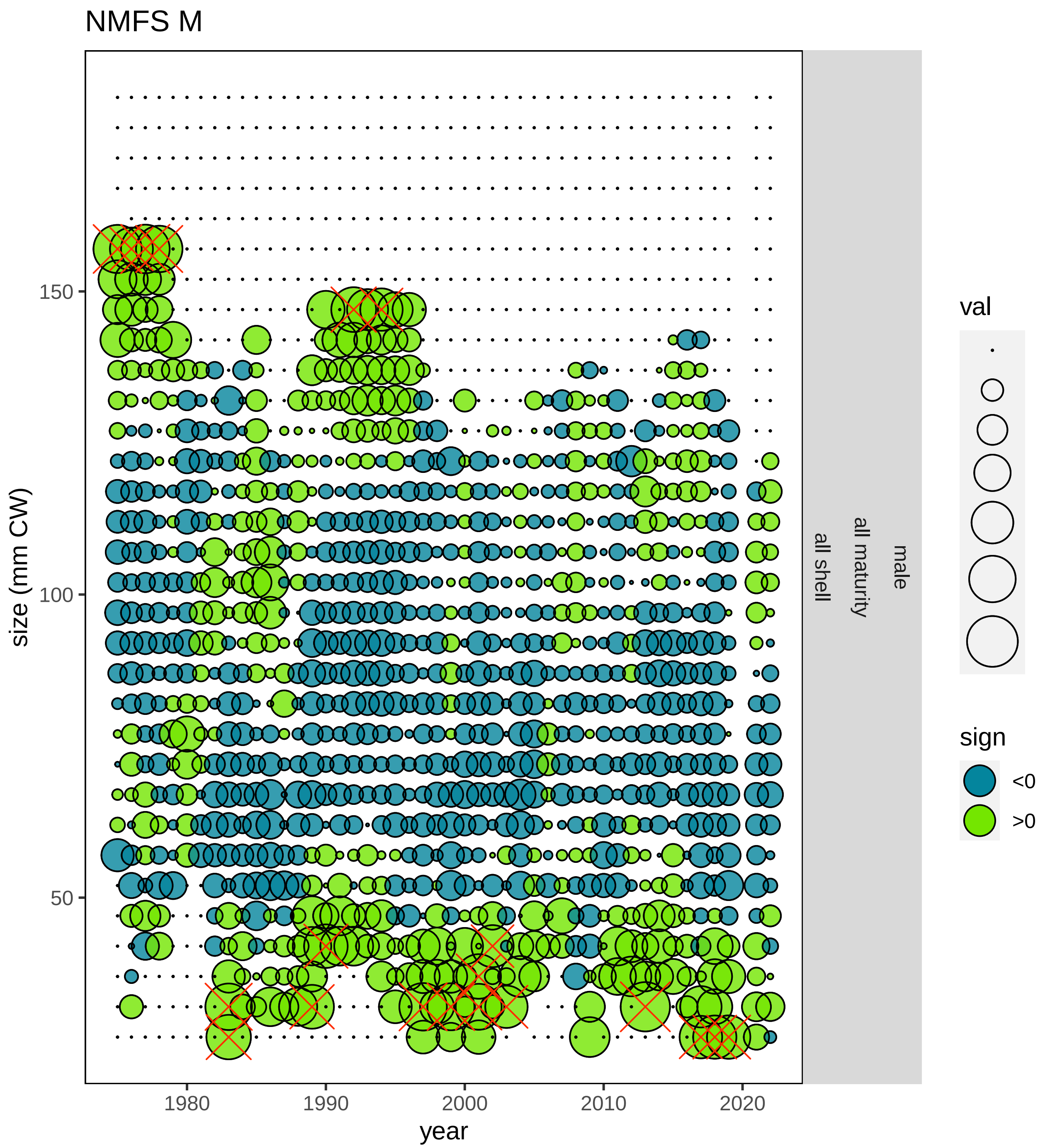

Figure 51. Pearson's residuals for fits to survey size composition data in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

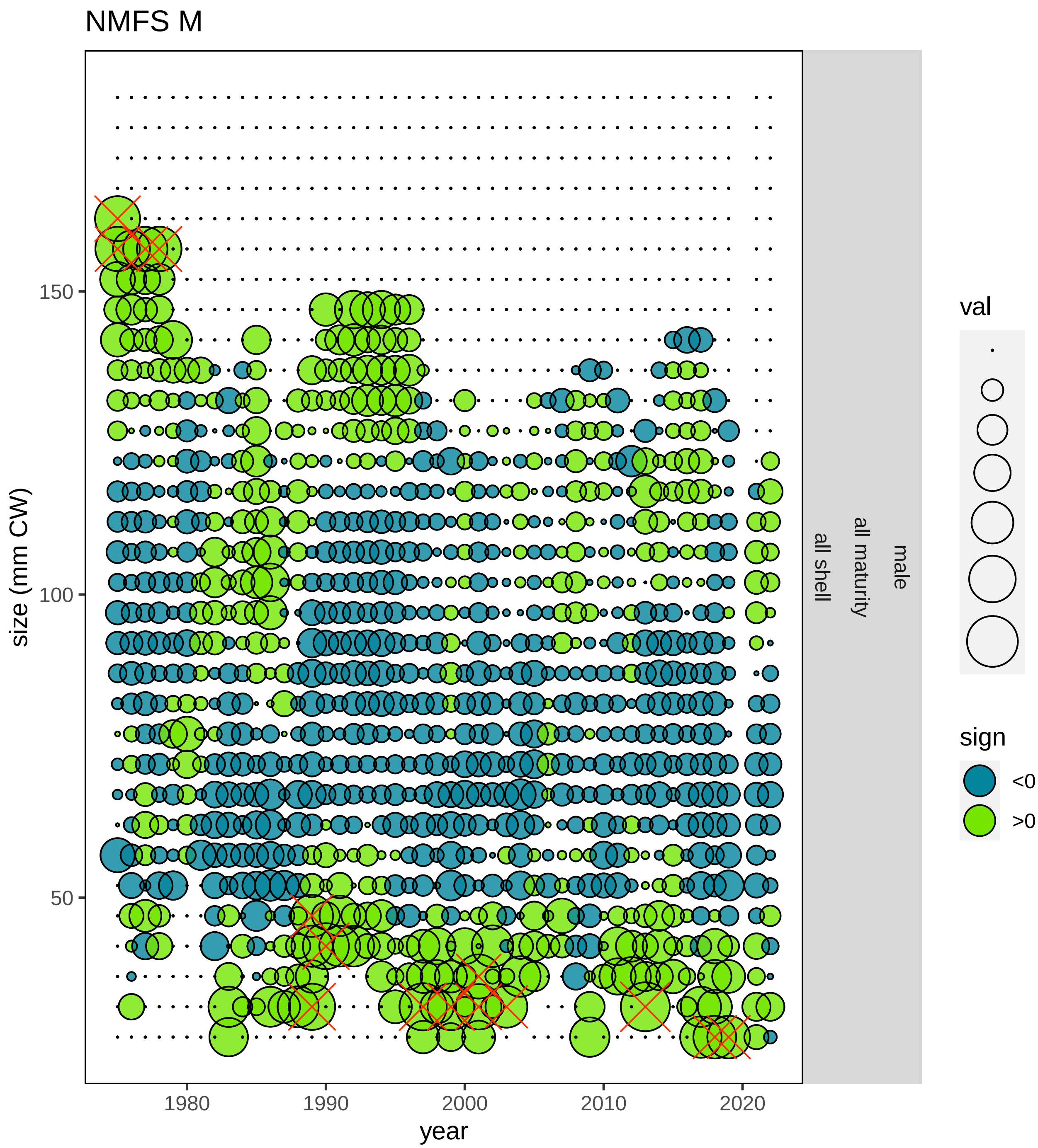

Figure 52. Pearson's residuals for fits to survey size composition data in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

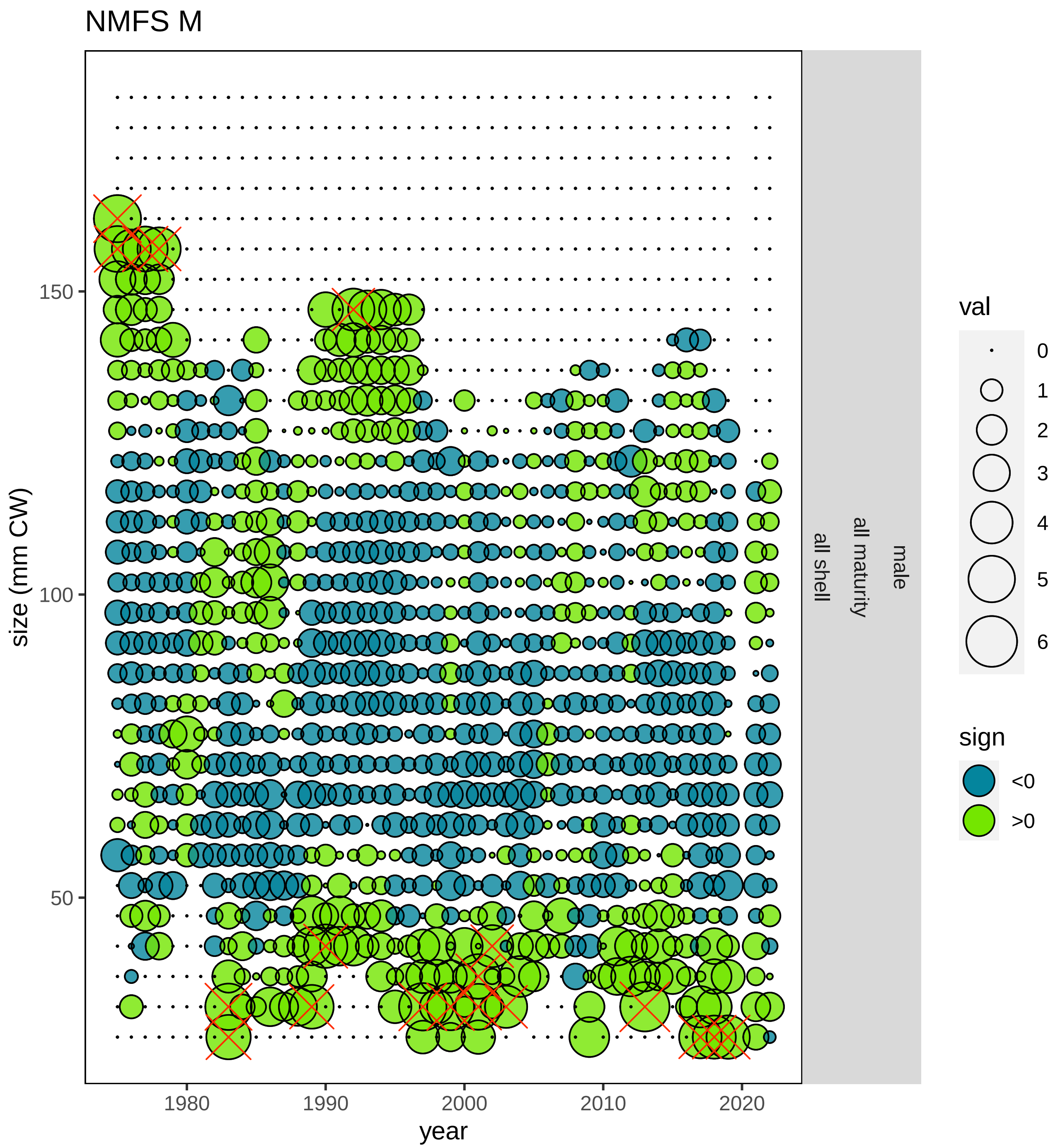

Figure 53. Pearson's residuals for fits to survey size composition data in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

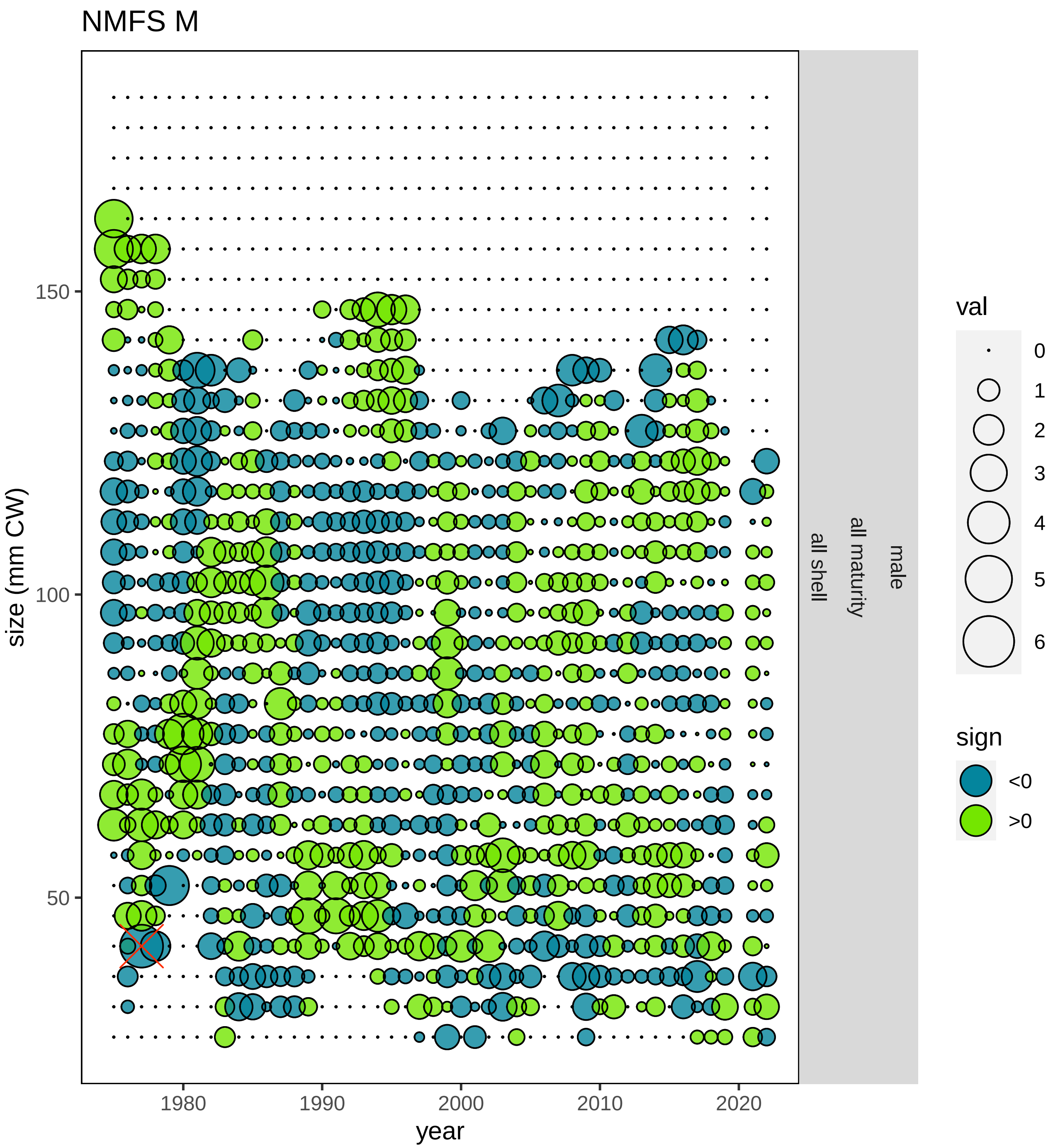

Figure 54. Pearson's residuals for fits to survey size composition data in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

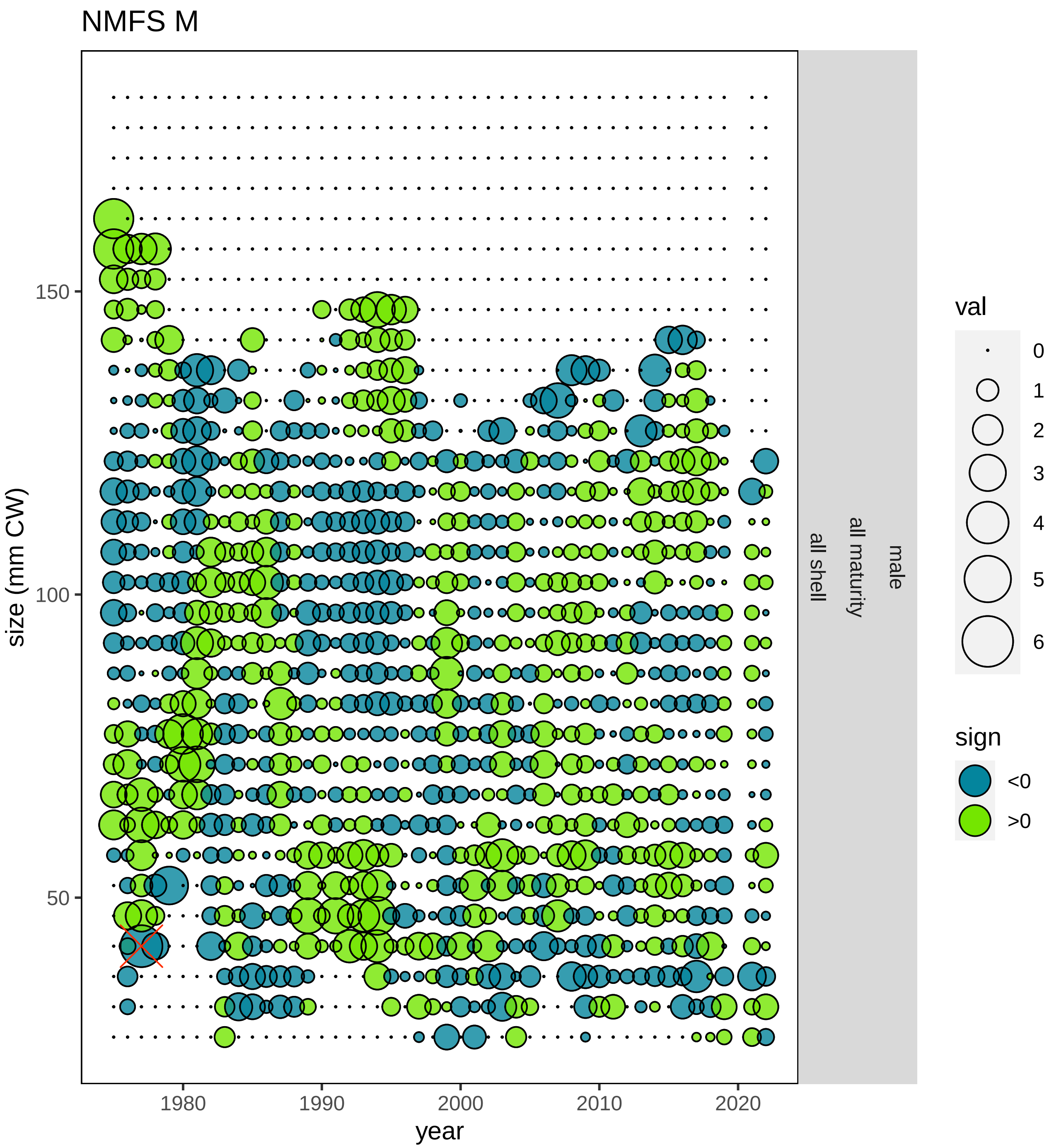

Figure 55. Pearson's residuals for fits to survey size composition data in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

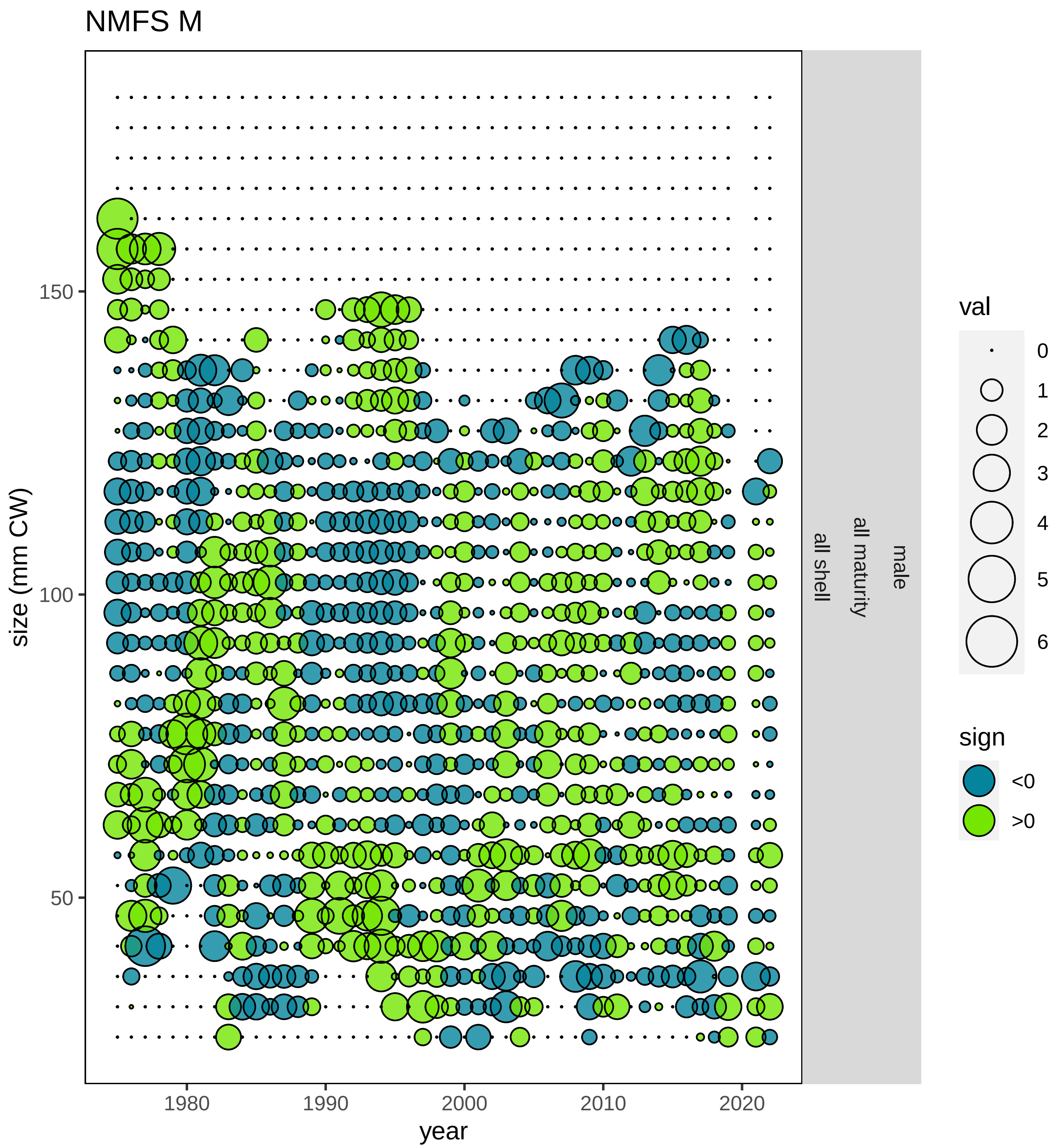

Figure 56. Pearson's residuals for fits to survey size composition data in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

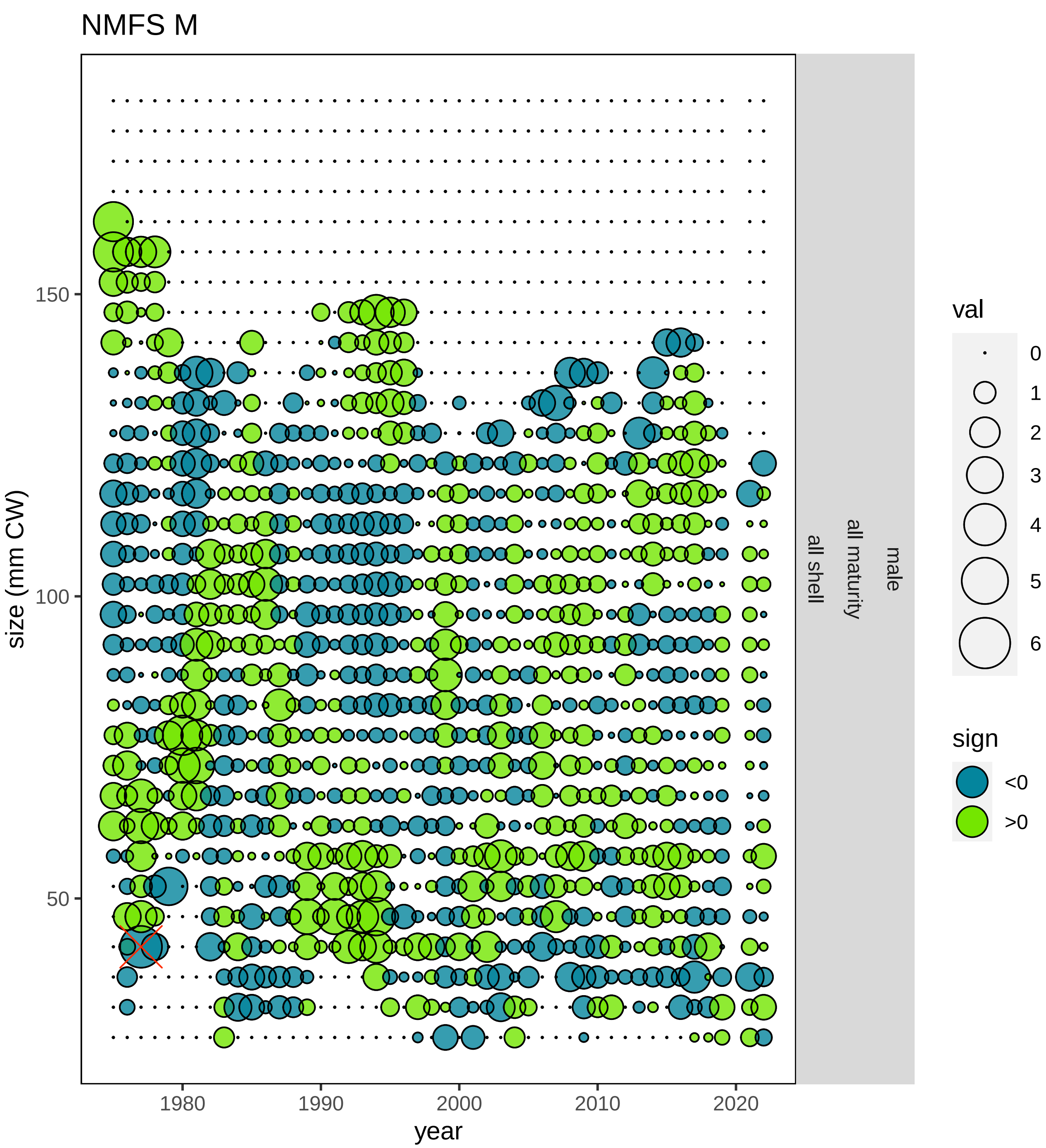

Figure 57. Pearson's residuals for fits to survey size composition data in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

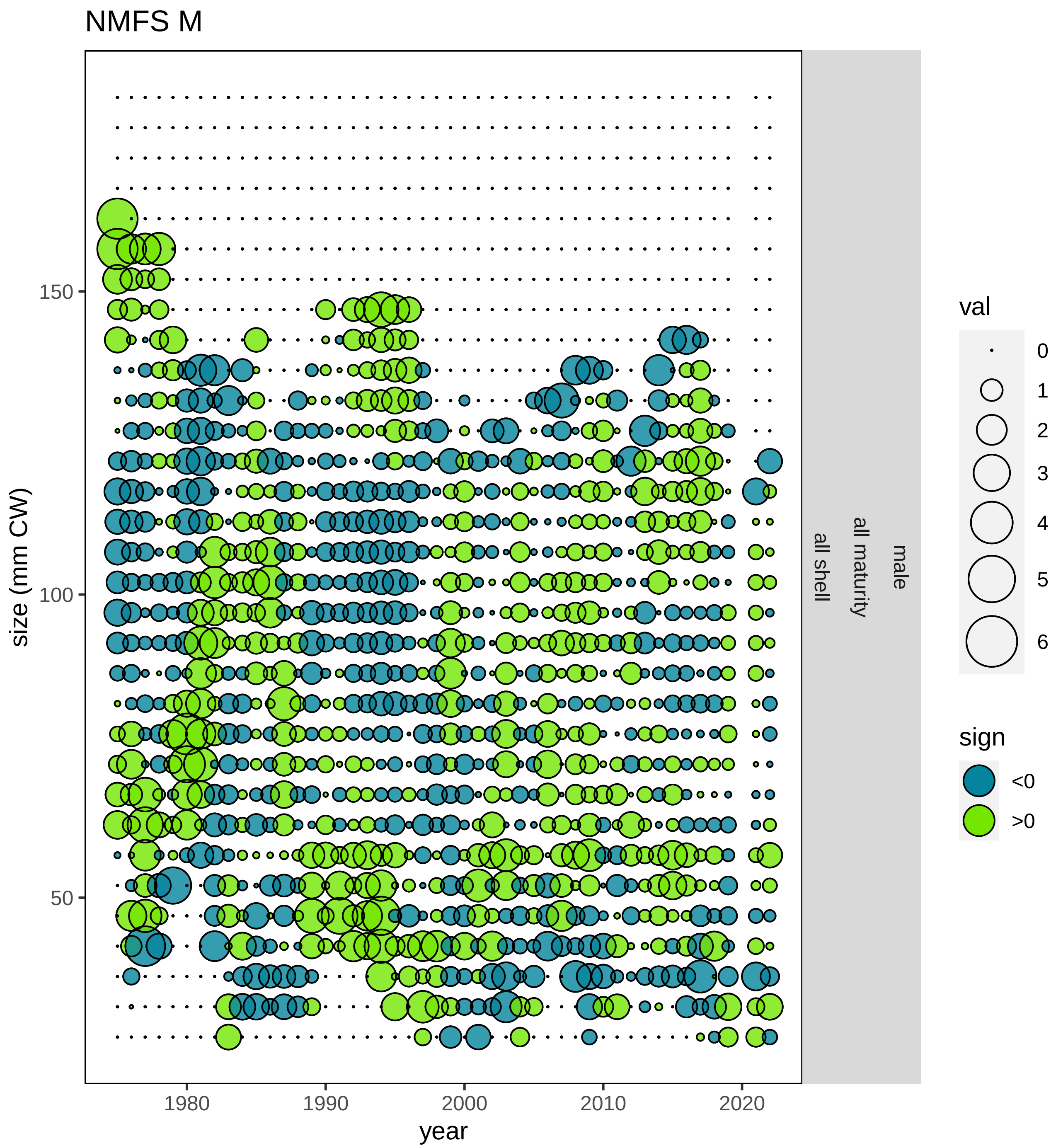

Figure 58. Pearson's residuals for fits to survey size composition data in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

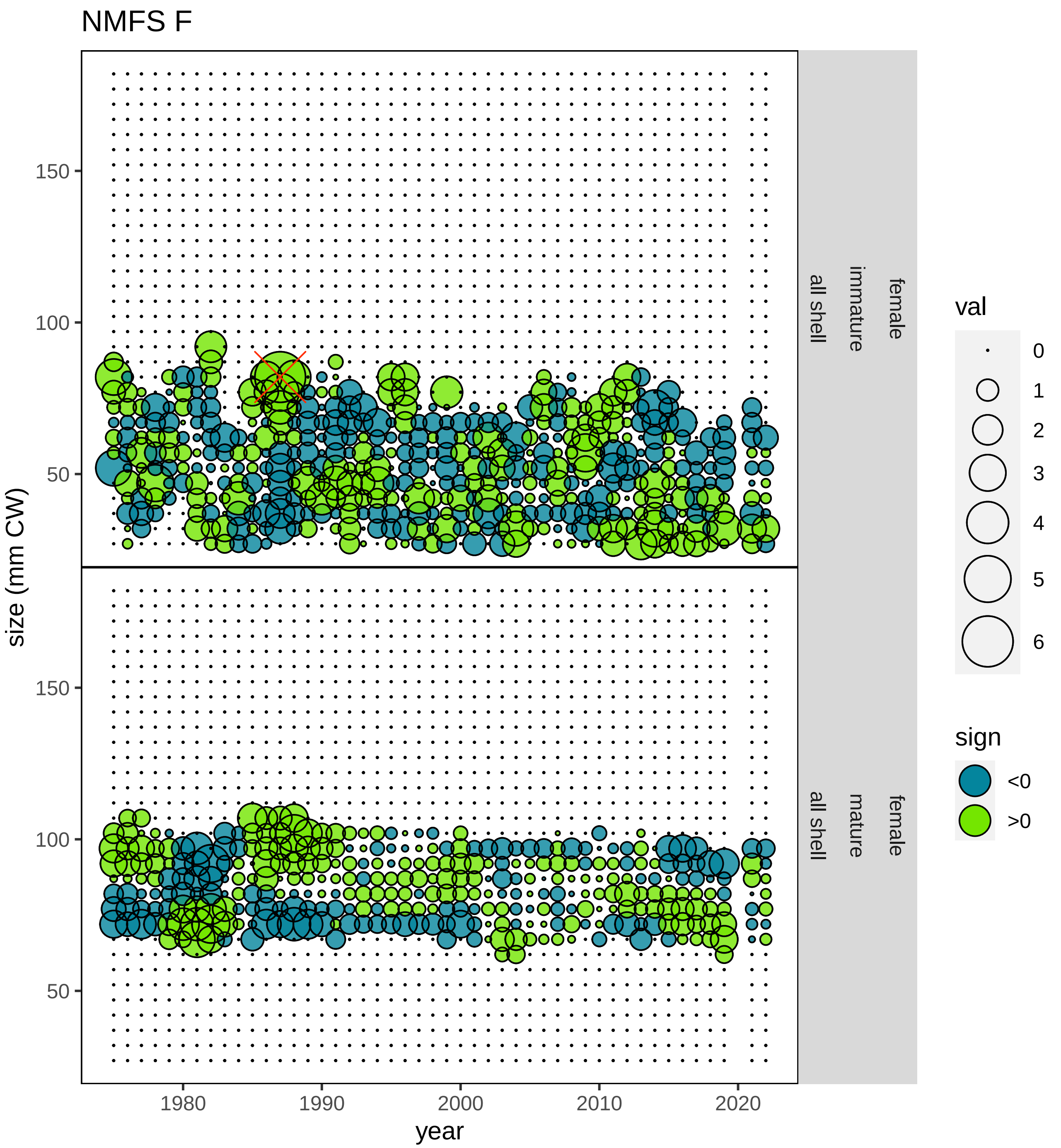

Figure 59. Pearson's residuals for fits to survey size composition data in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

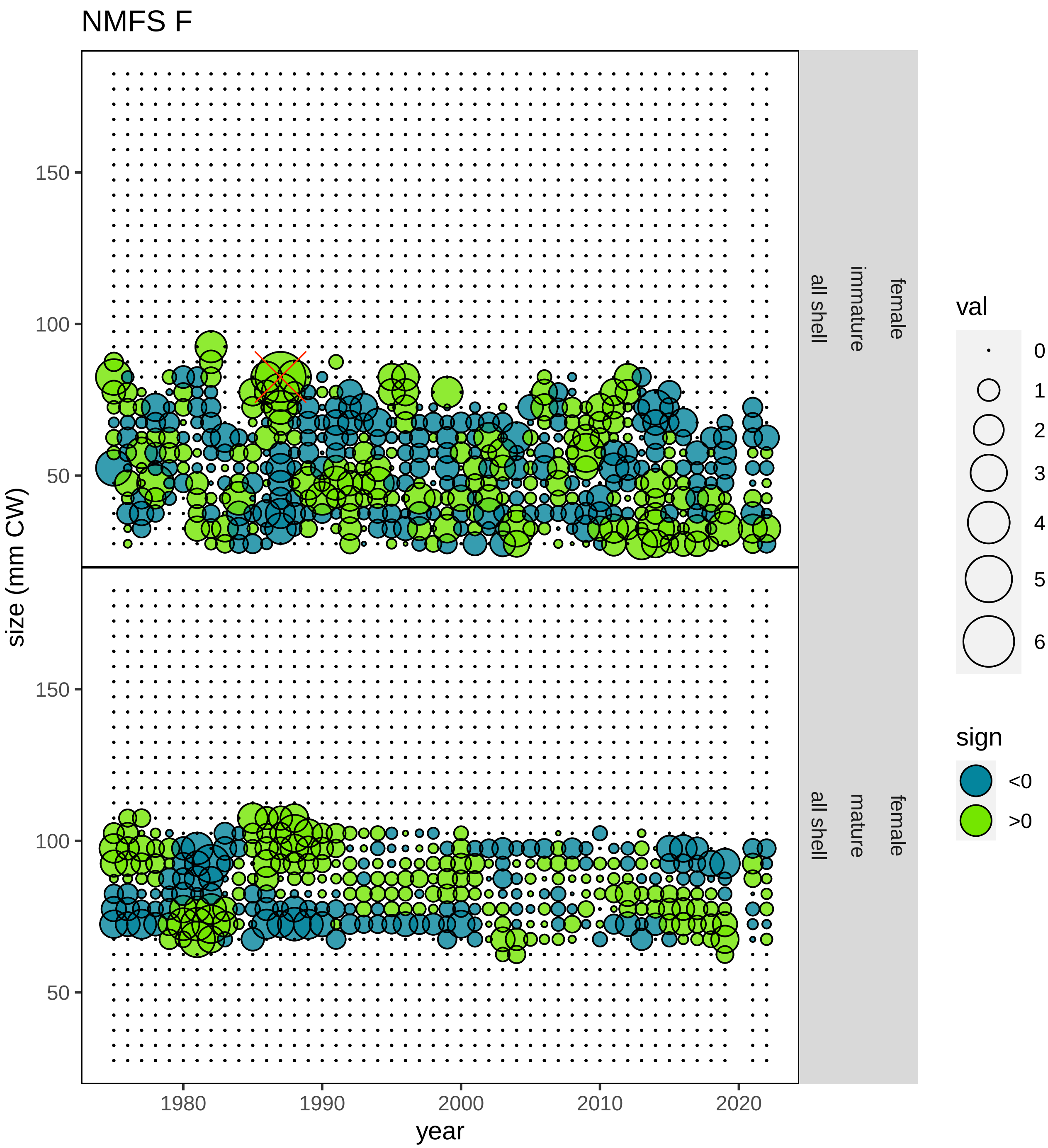

Figure 60. Pearson's residuals for fits to survey size composition data in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

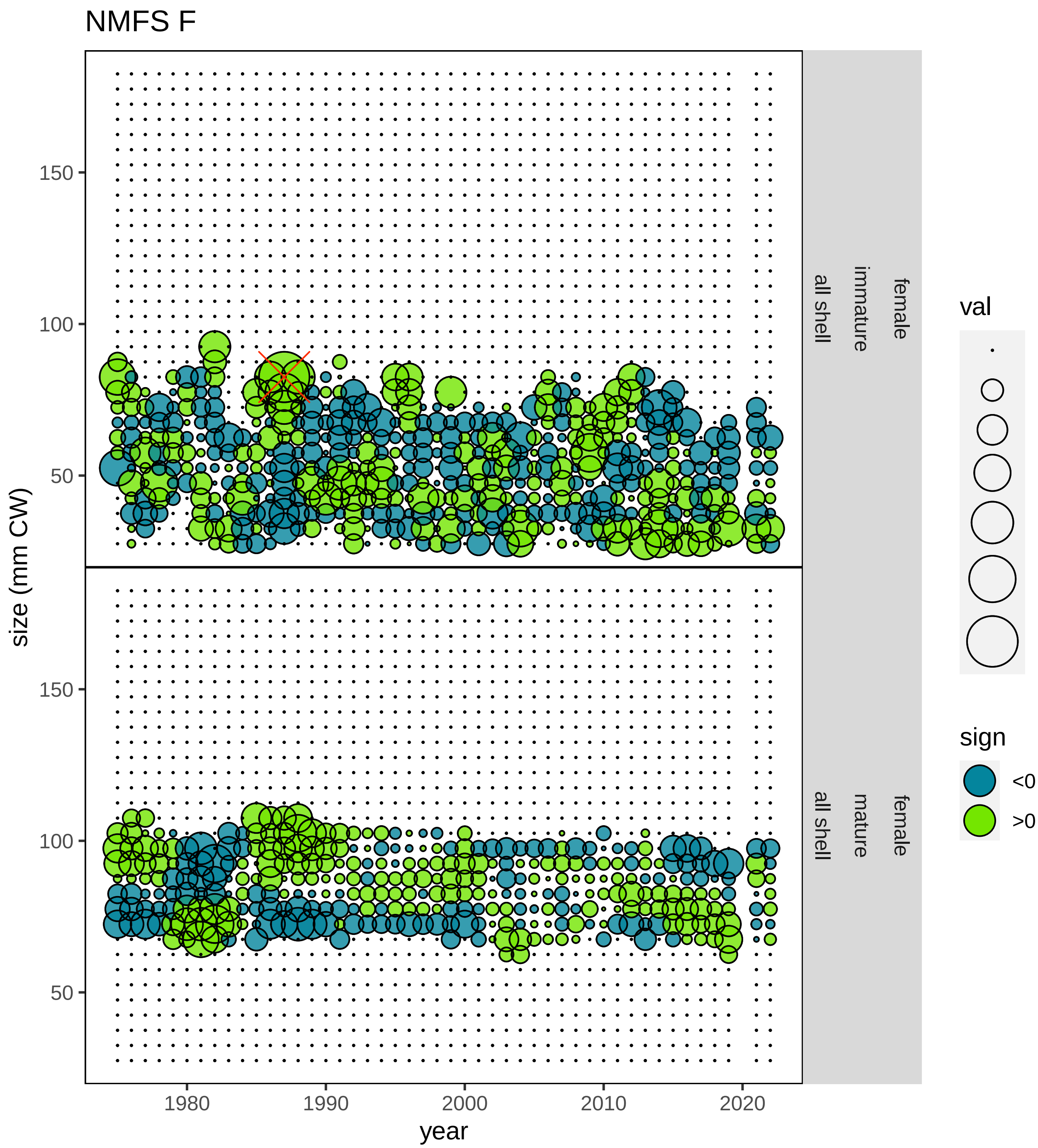

Figure 61. Pearson's residuals for fits to survey size composition data in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

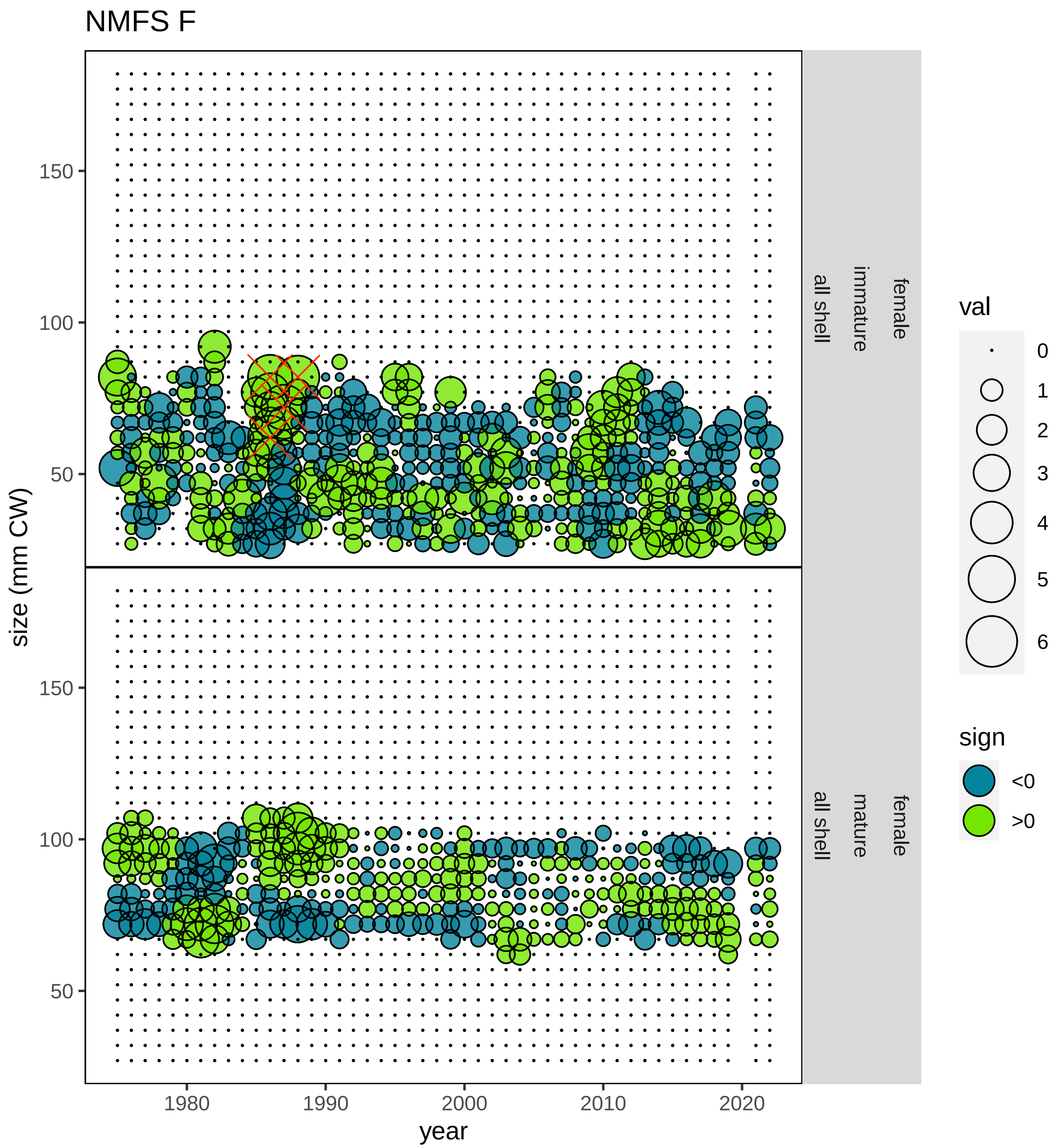

Figure 62. Pearson's residuals for fits to survey size composition data in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

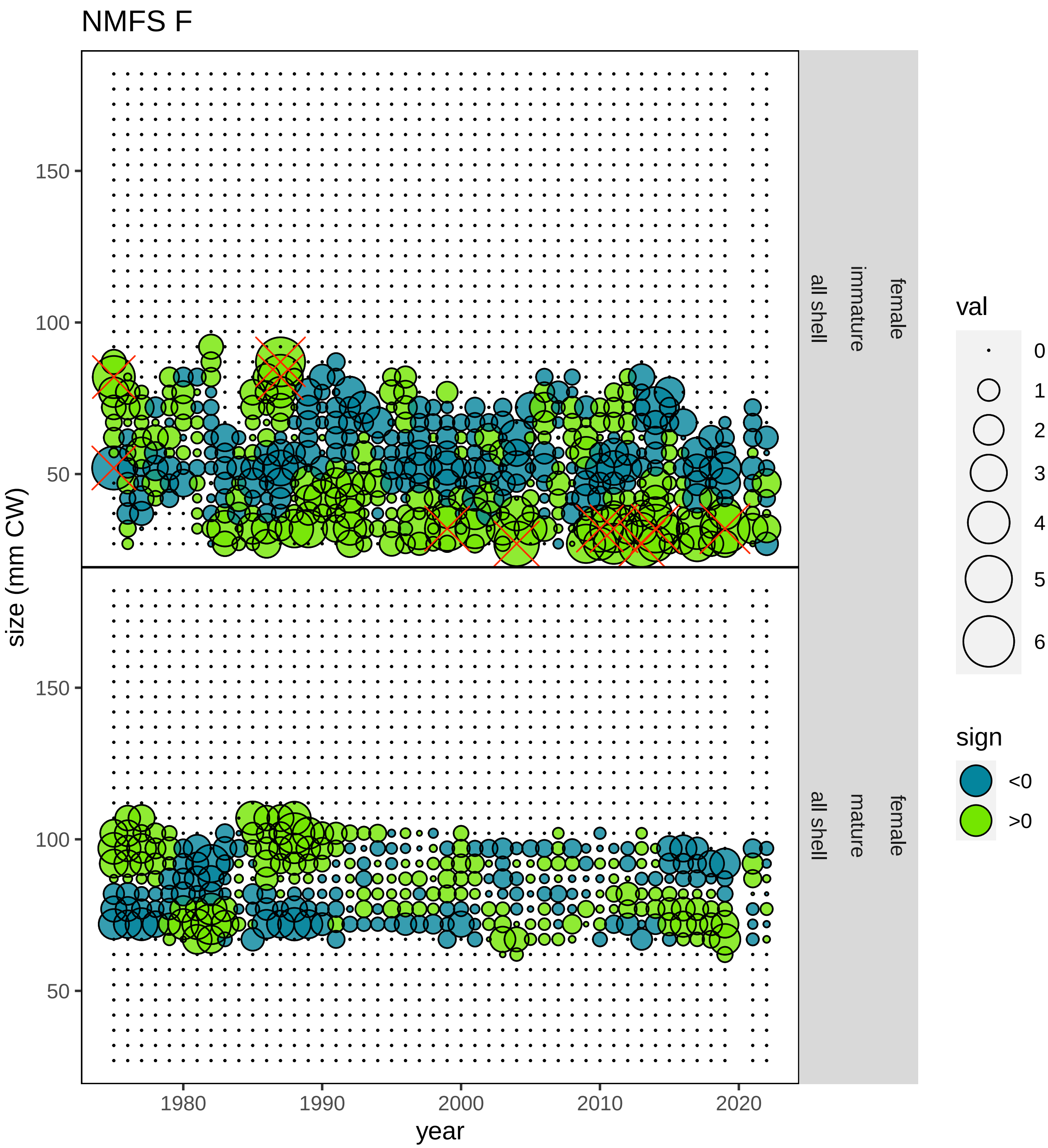

Figure 63. Pearson's residuals for fits to survey size composition data in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

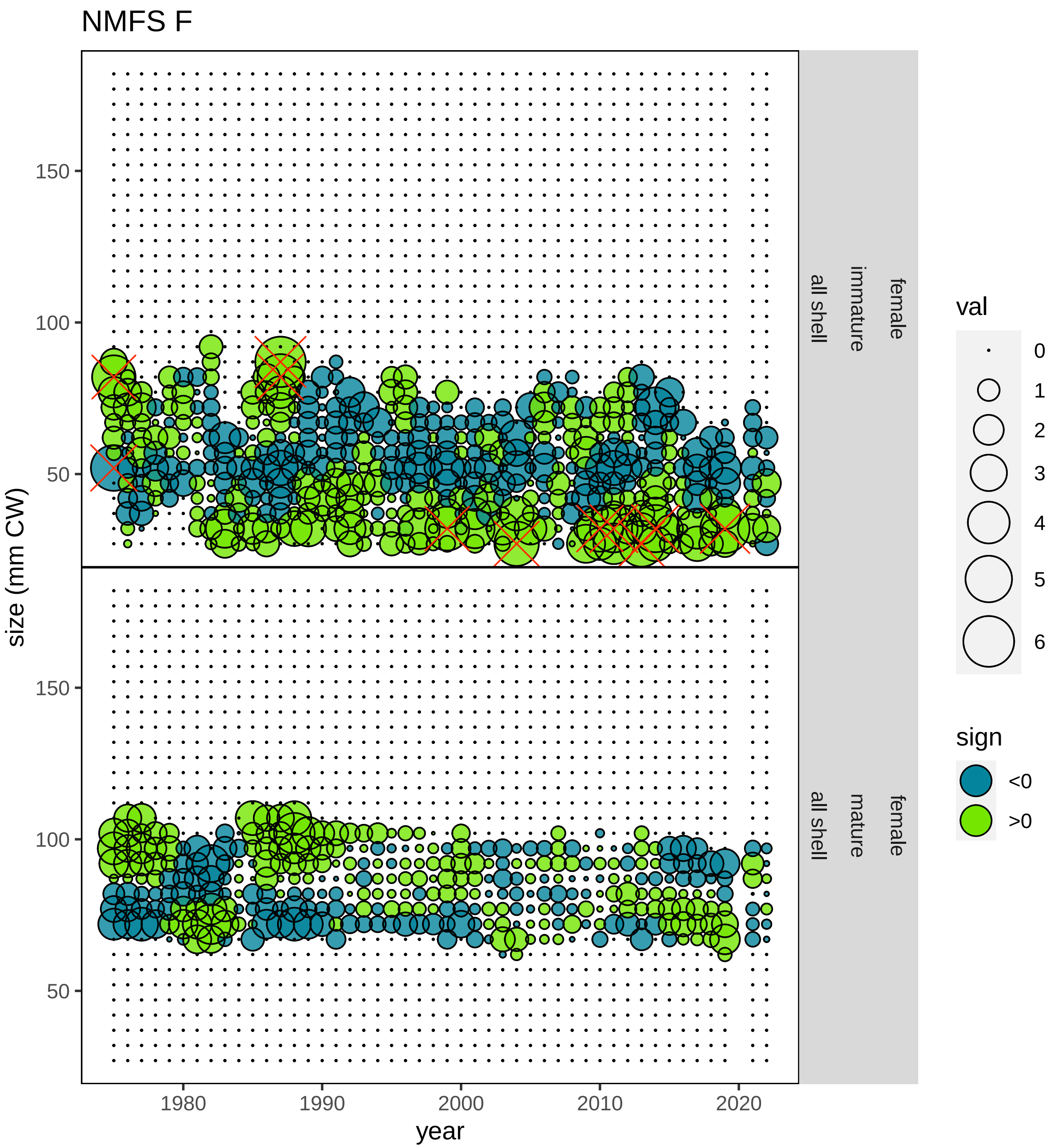

Figure 64. Pearson's residuals for fits to survey size composition data in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

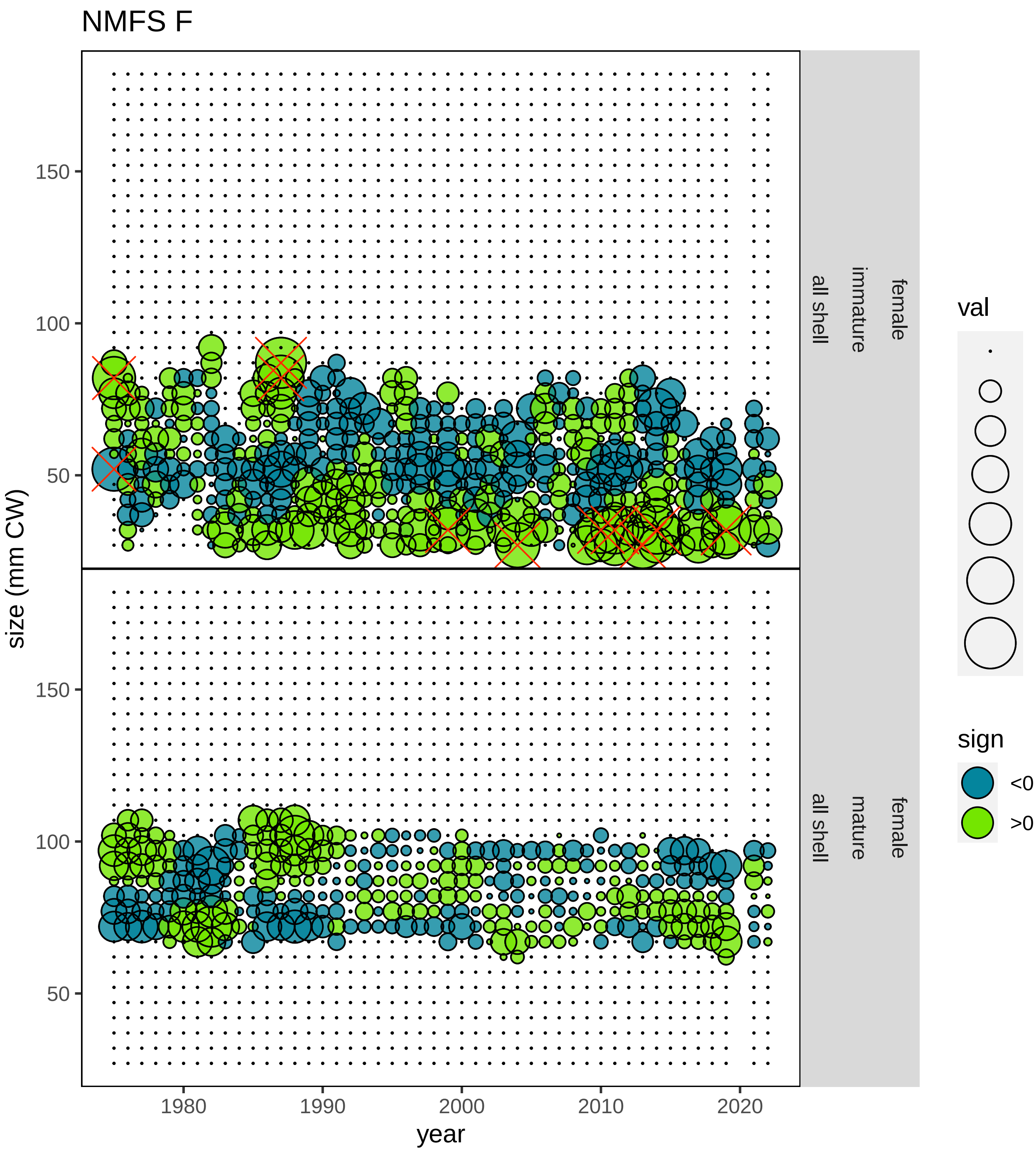

Figure 65. Pearson's residuals for fits to survey size composition data in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

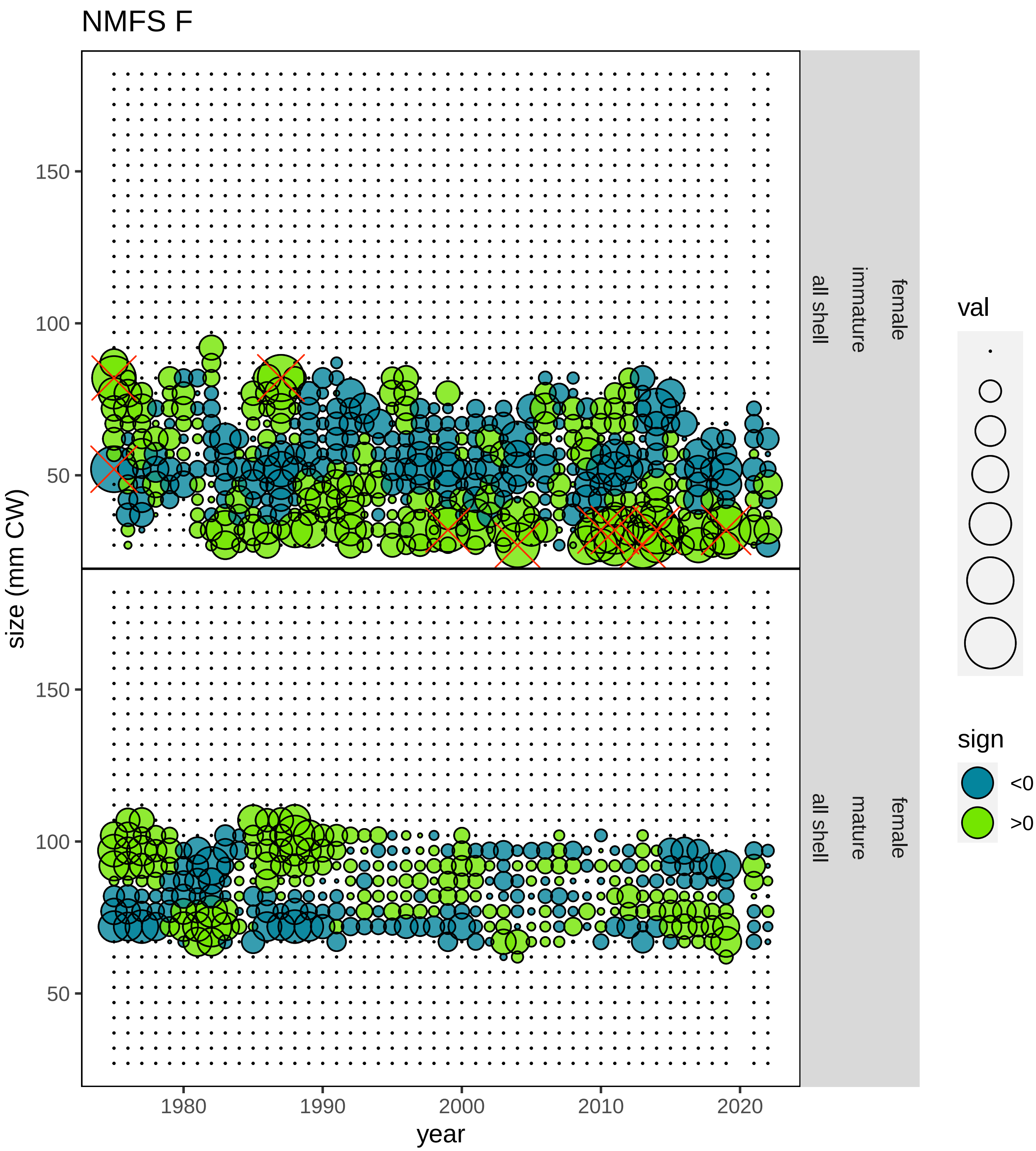

Figure 66. Pearson's residuals for fits to survey size composition data in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

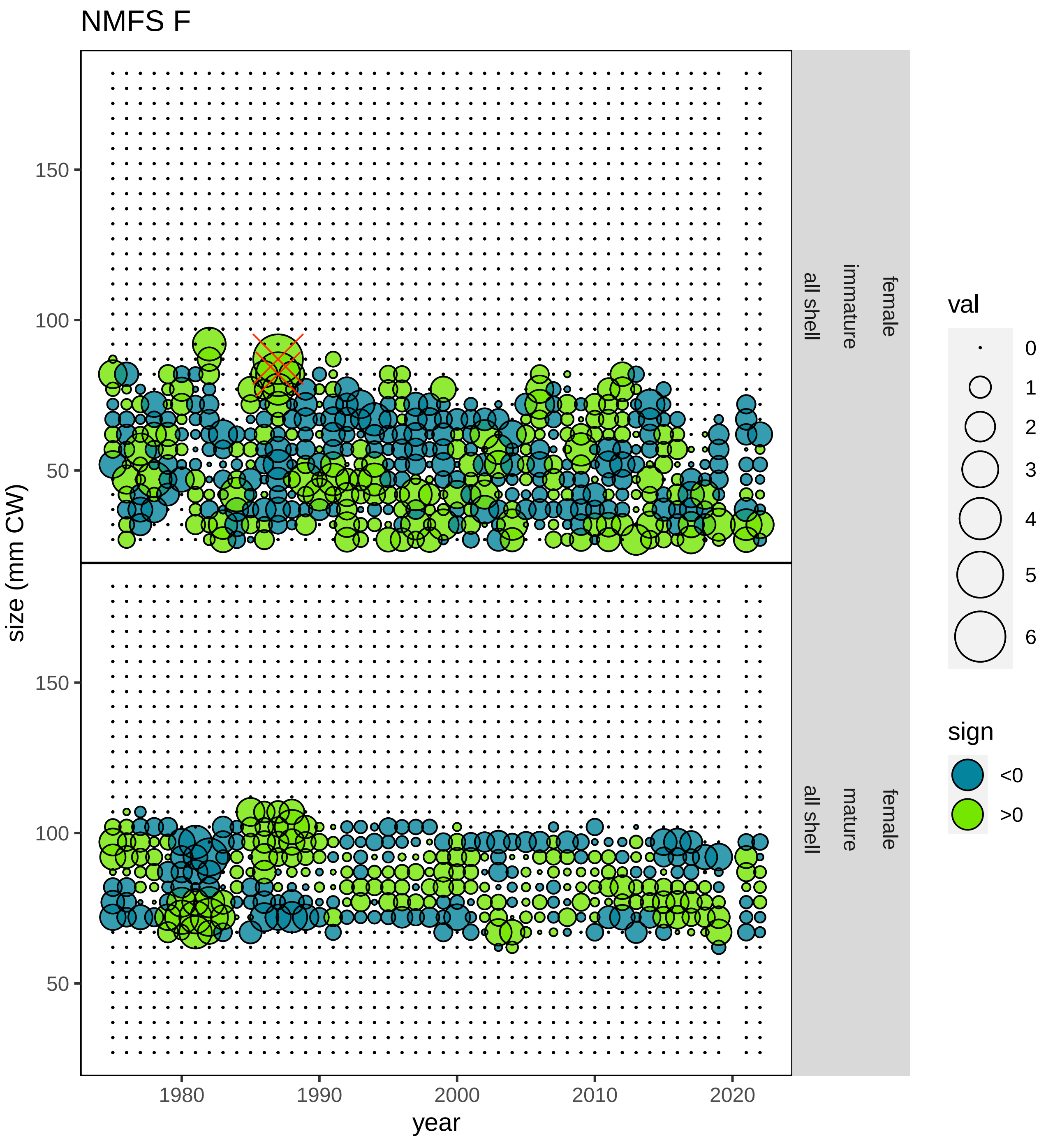

Figure 67. Pearson's residuals for fits to survey size composition data in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

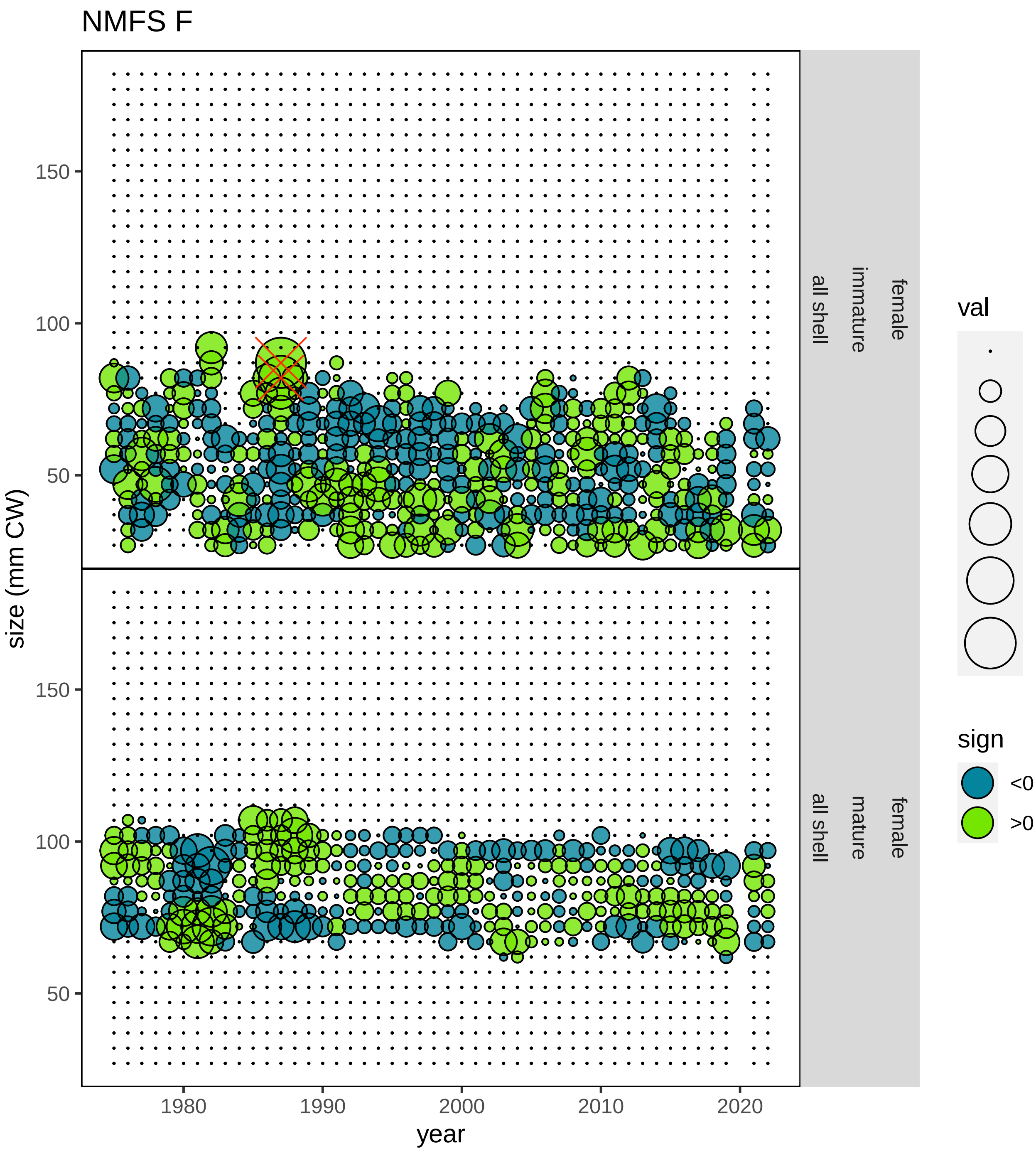

Figure 68. Pearson's residuals for fits to survey size composition data in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

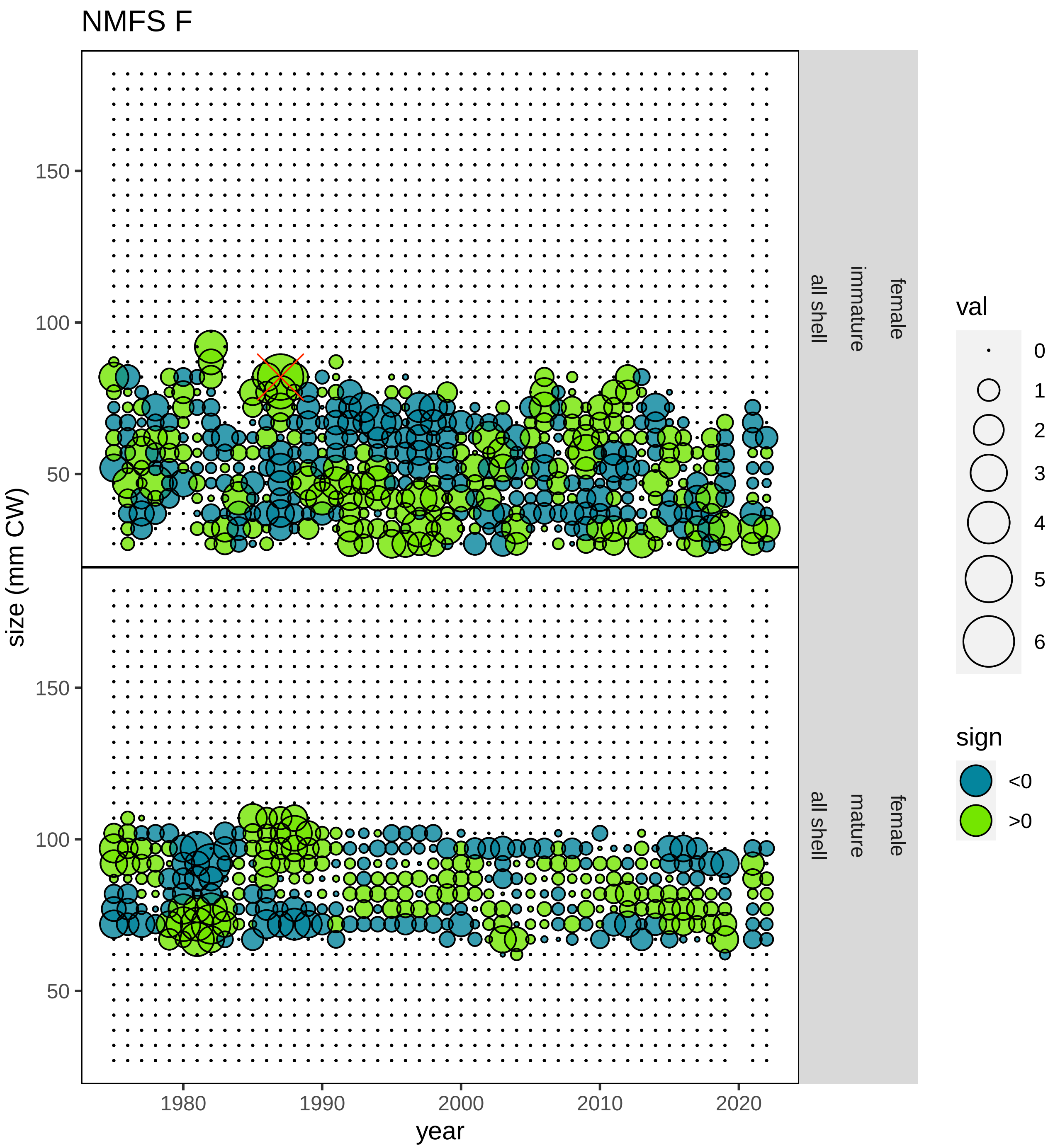

Figure 69. Pearson's residuals for fits to survey size composition data in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

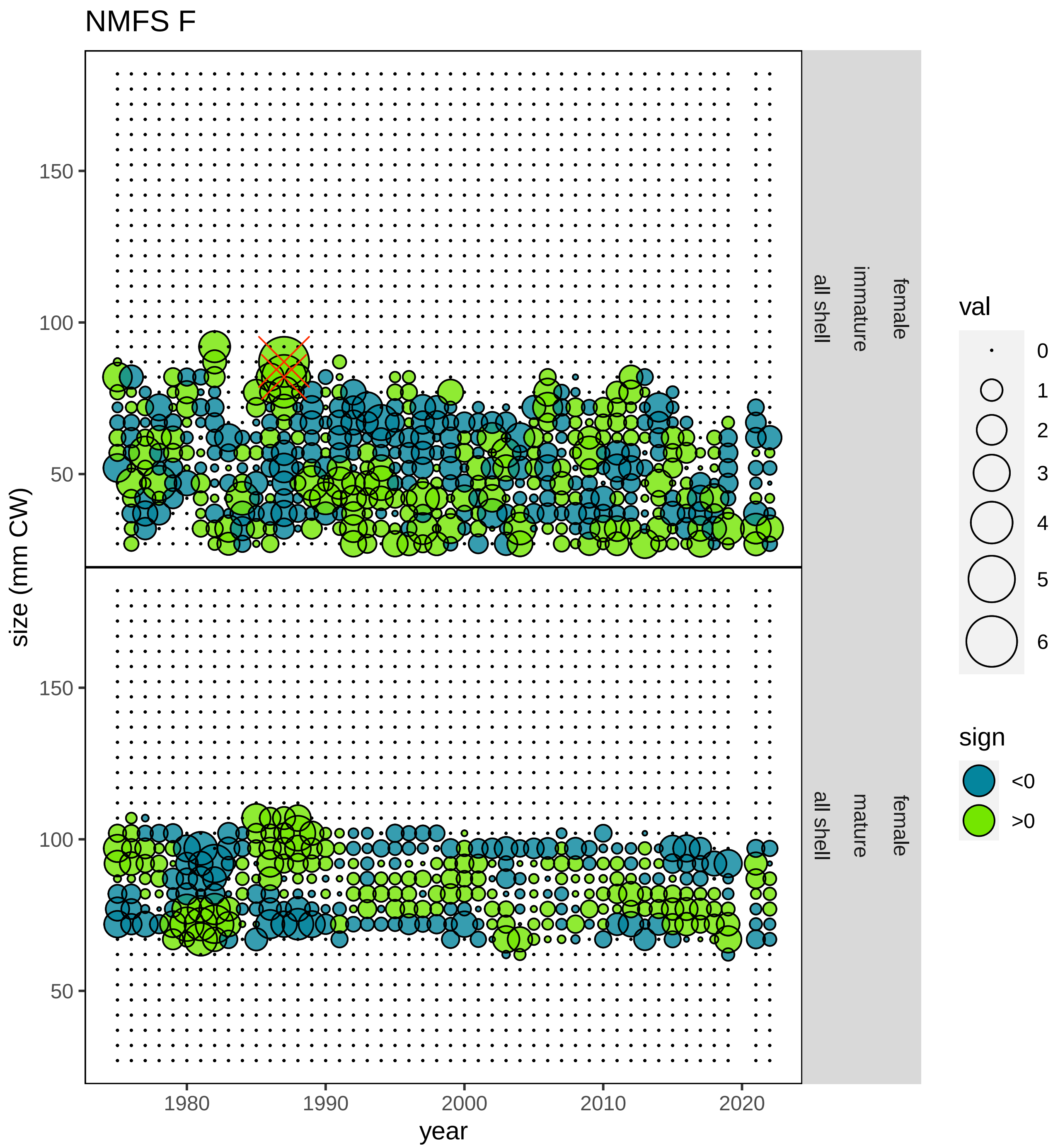

Figure 70. Pearson's residuals for fits to survey size composition data in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

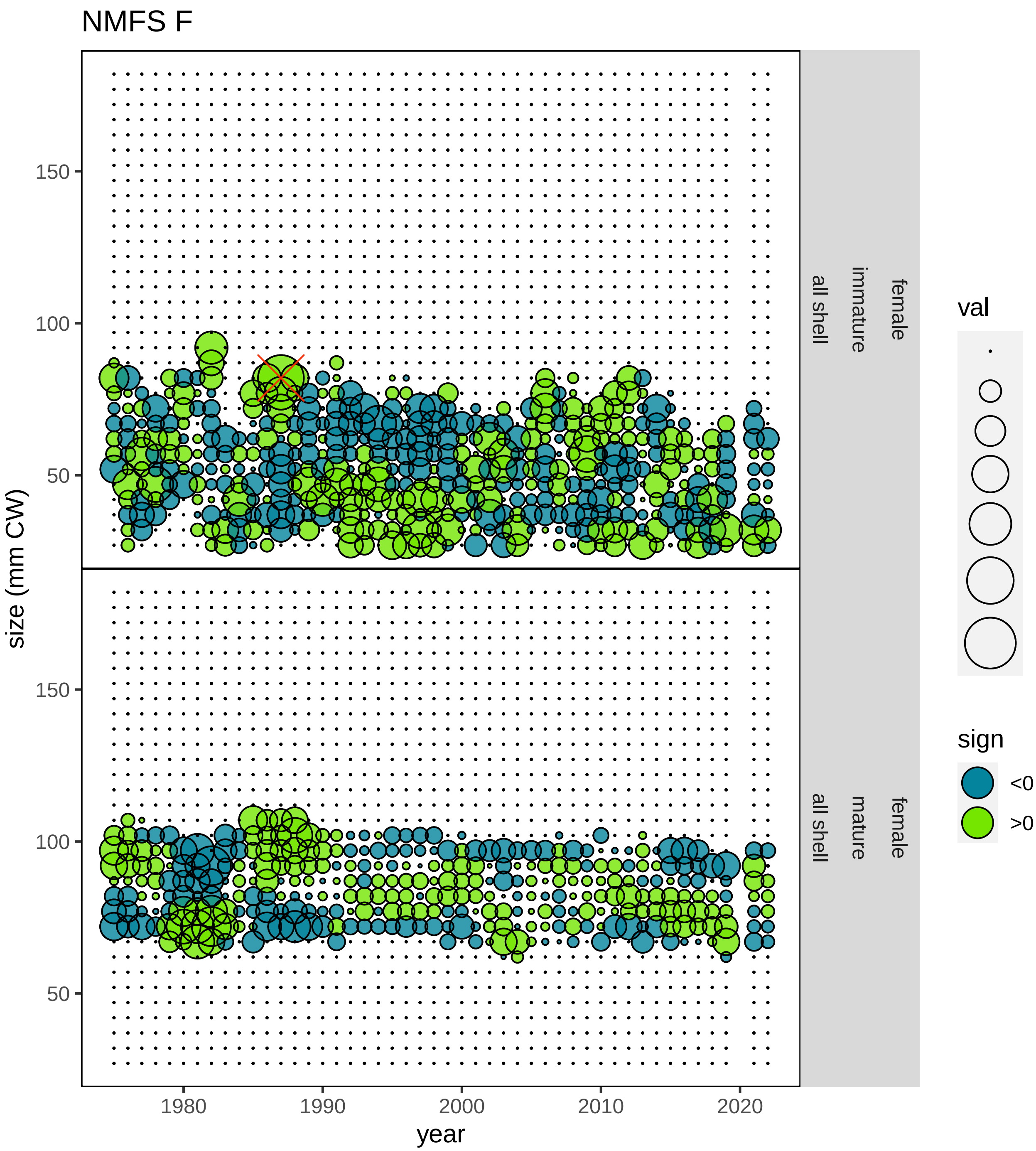

Figure 71. Pearson's residuals for fits to survey size composition data in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

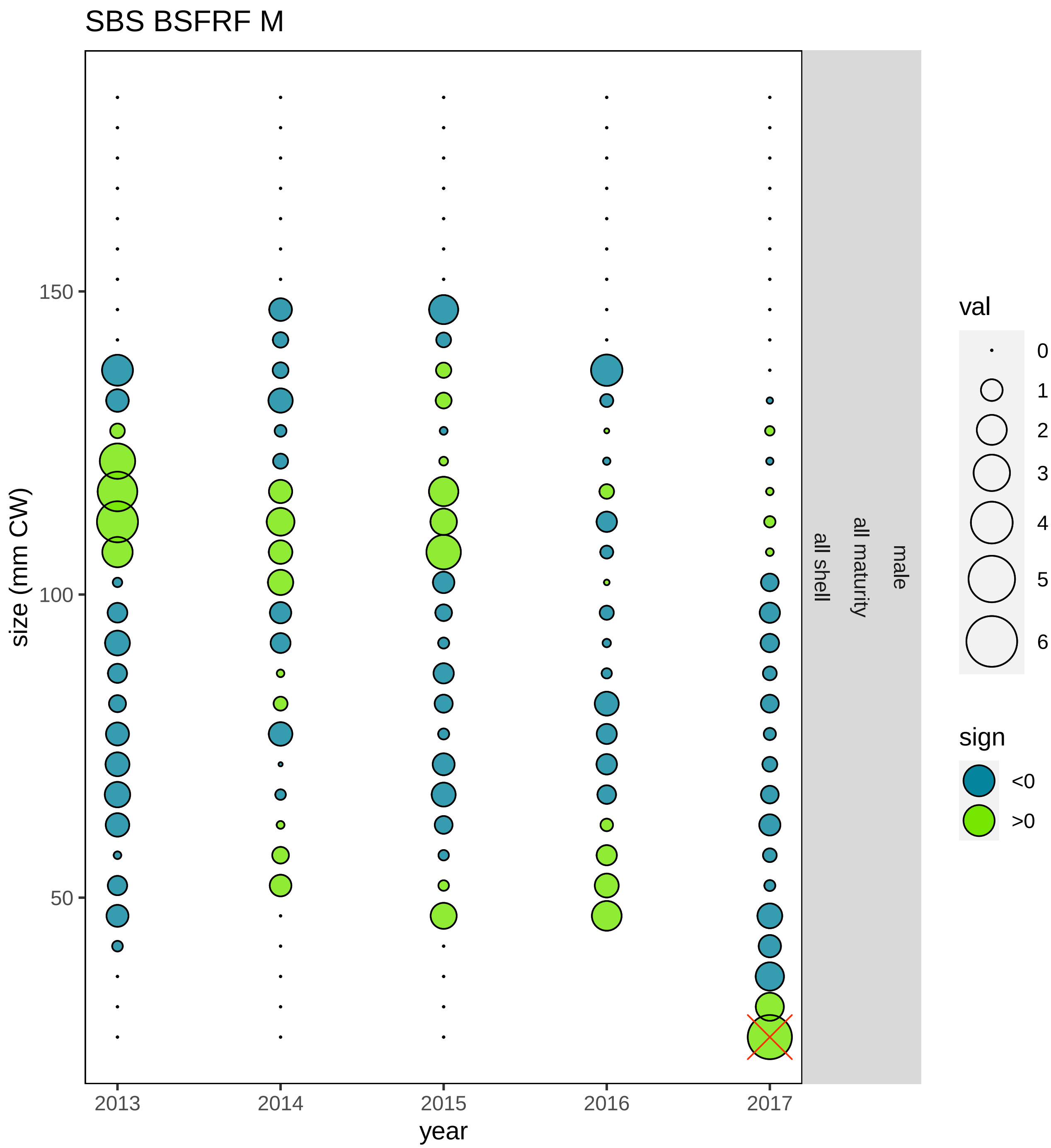

Figure 72. Pearson's residuals for fits to survey size composition data in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

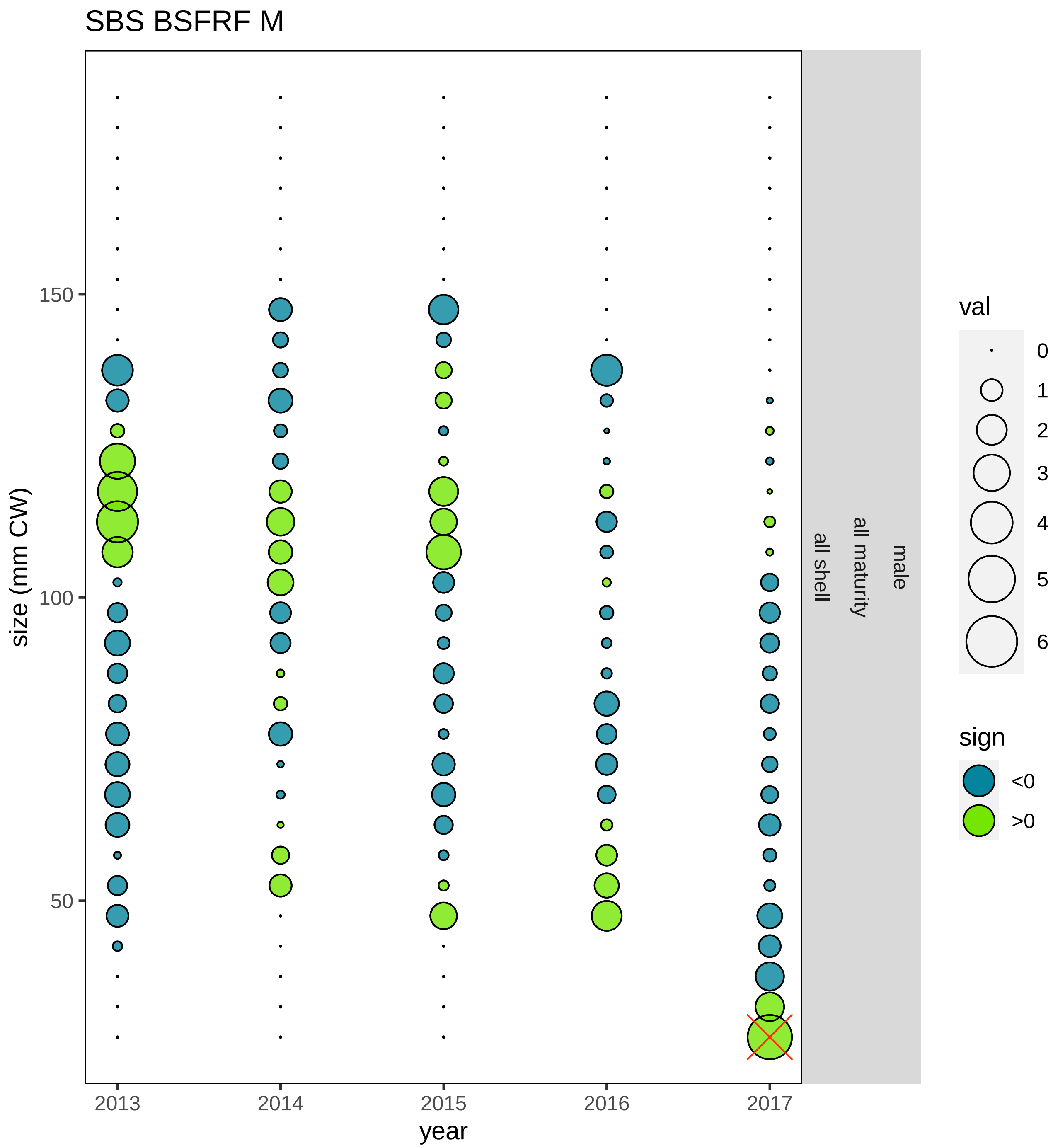

Figure 73. Pearson's residuals for fits to survey size composition data in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

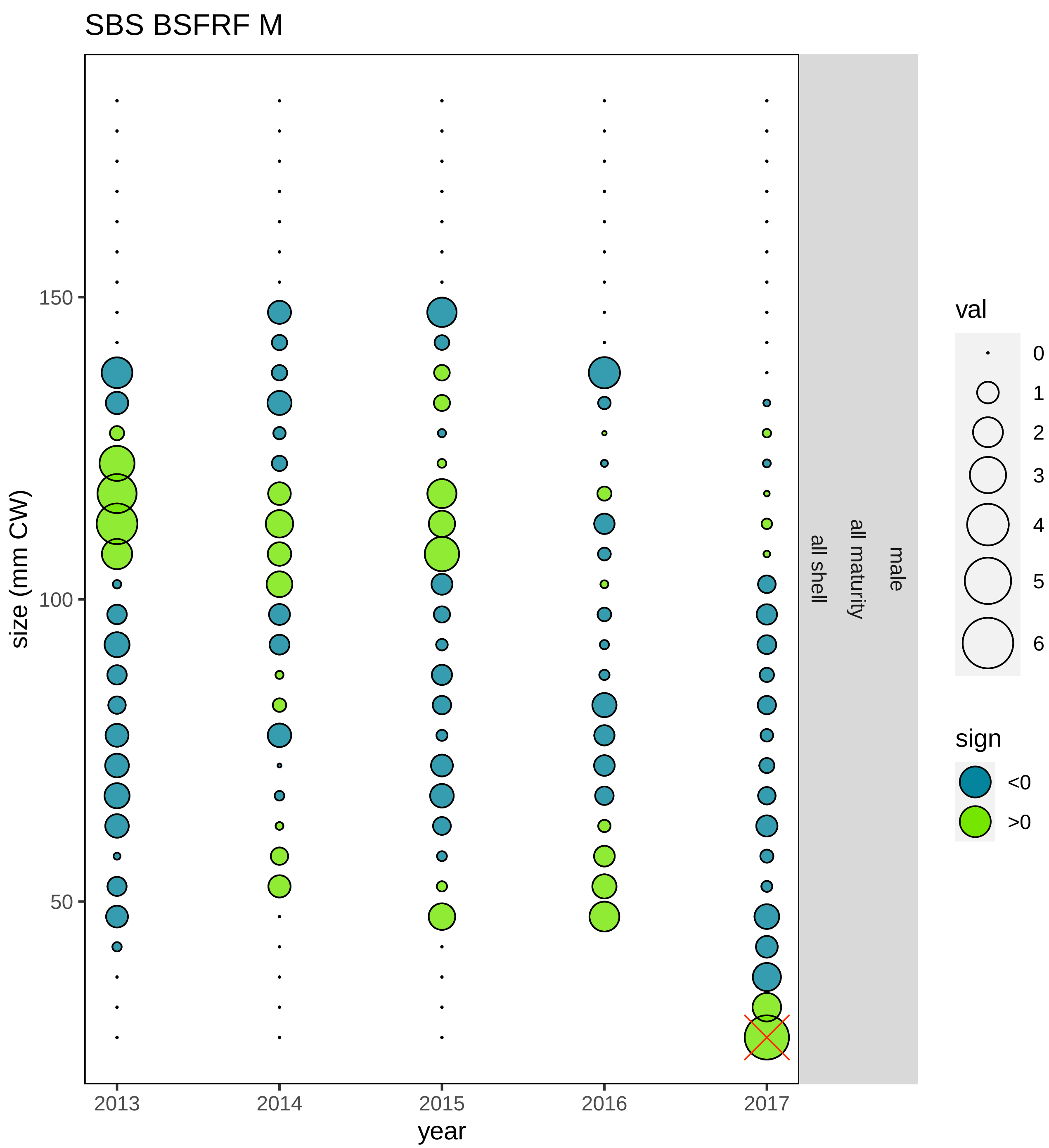

Figure 74. Pearson's residuals for fits to survey size composition data in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

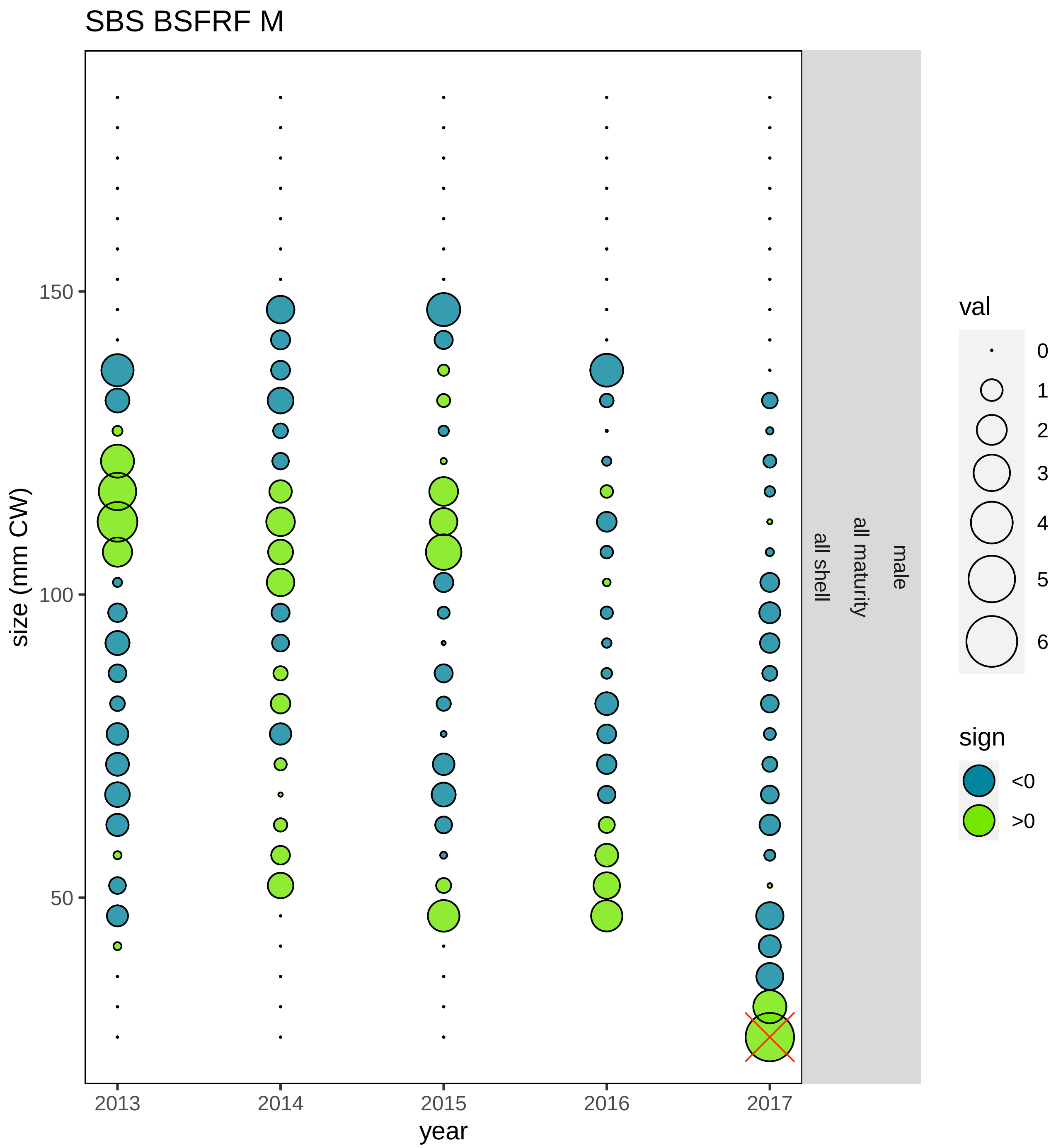

Figure 75. Pearson's residuals for fits to survey size composition data in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

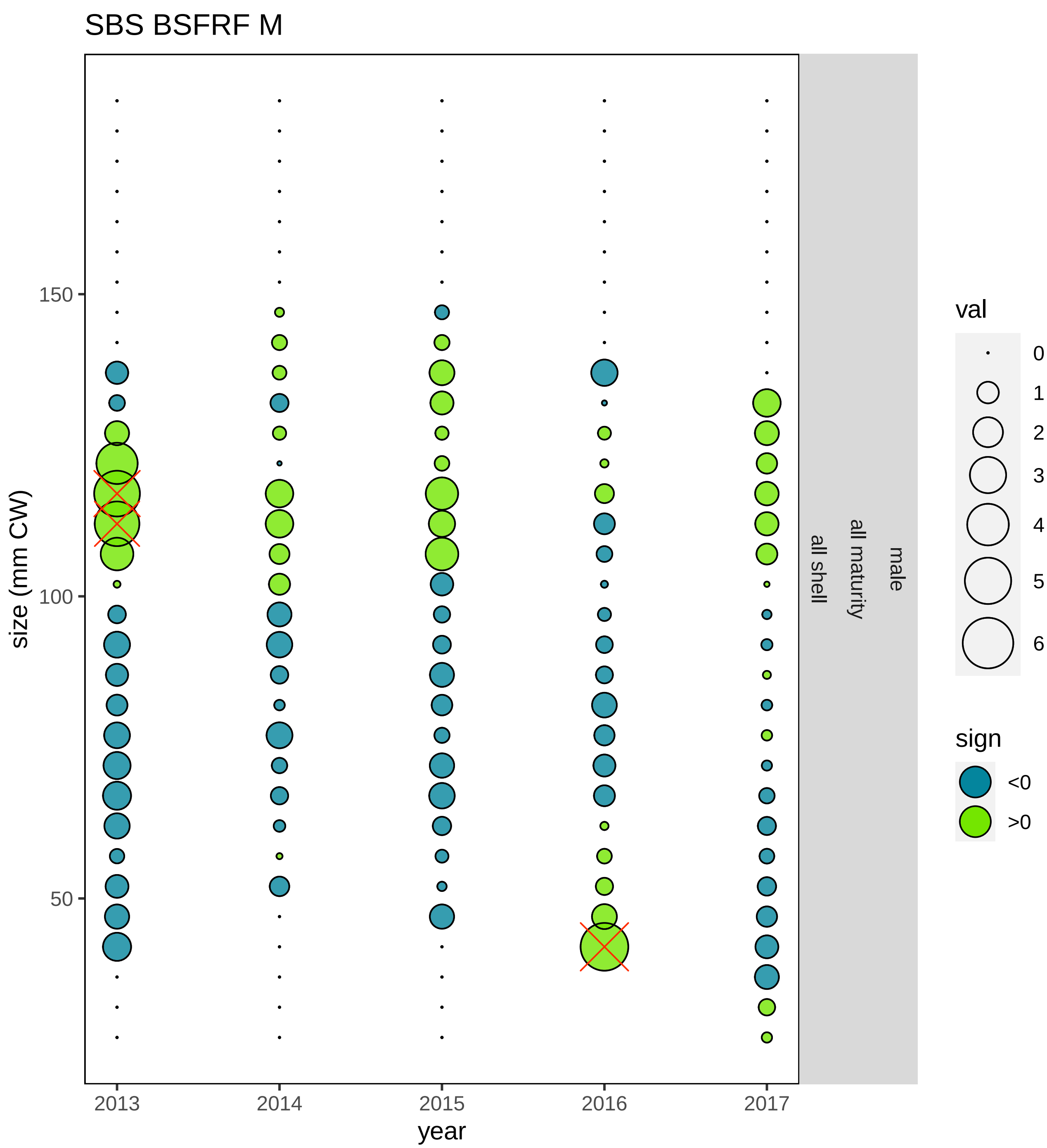

Figure 76. Pearson's residuals for fits to survey size composition data in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

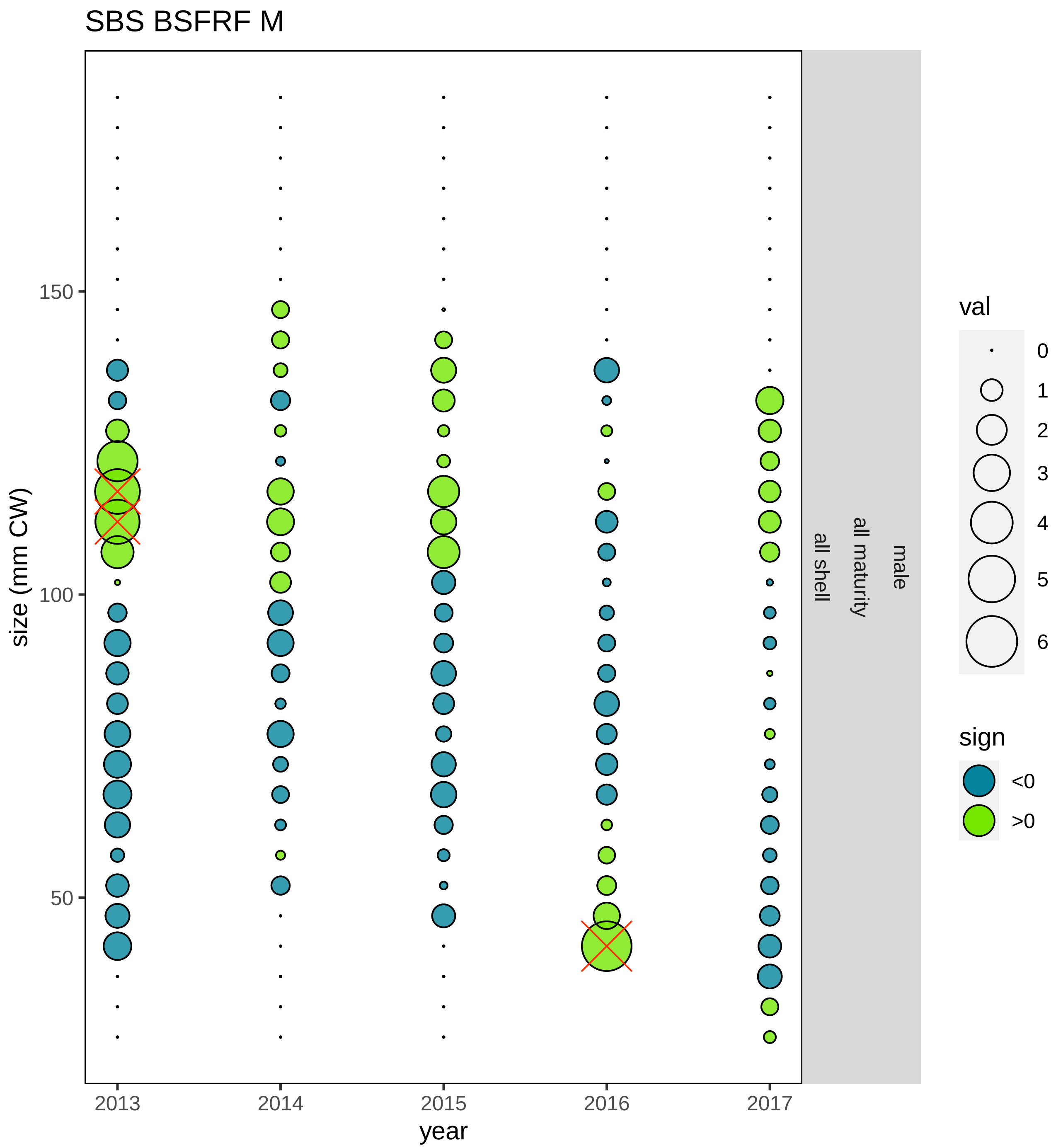

Figure 77. Pearson's residuals for fits to survey size composition data in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

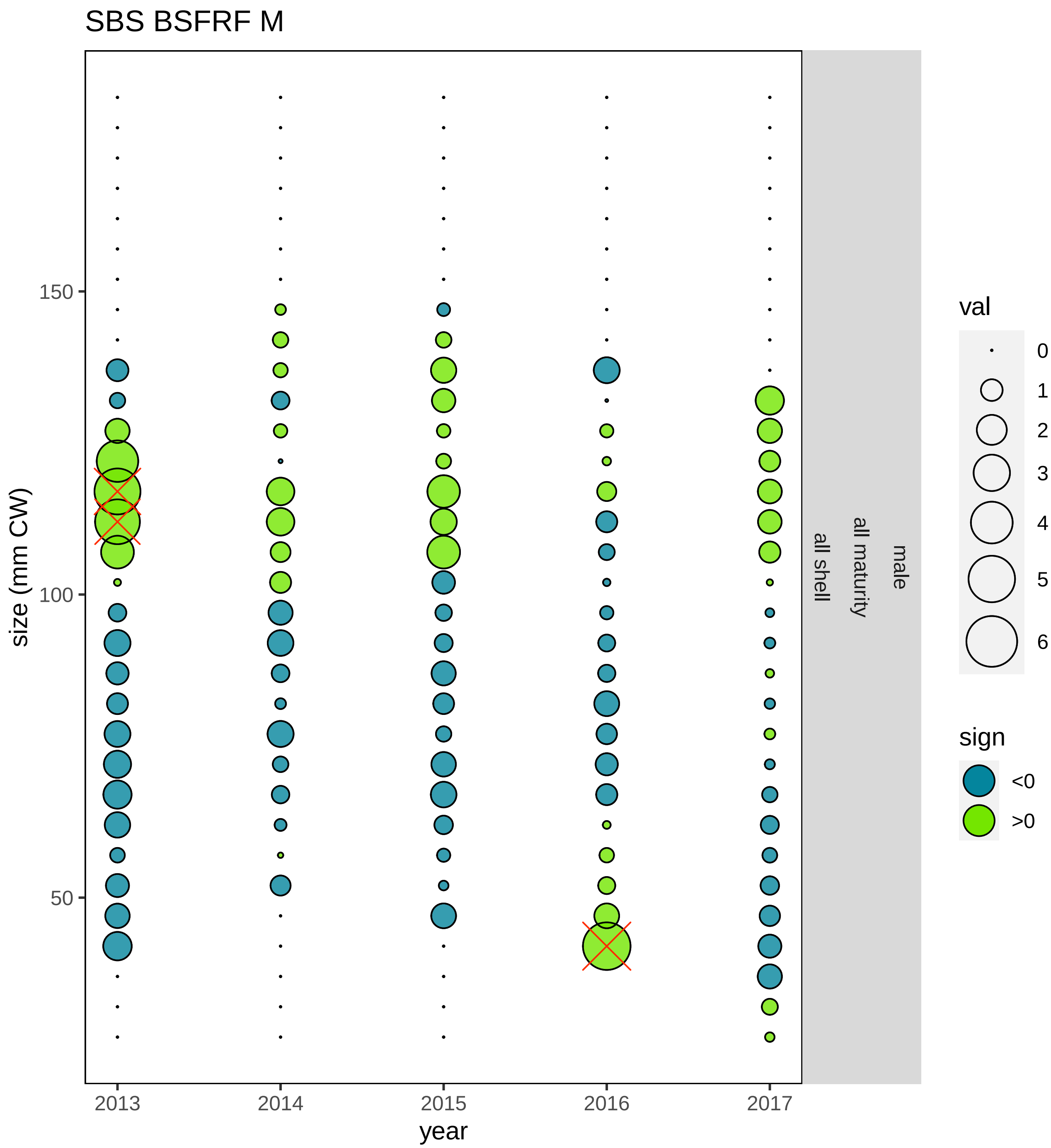

Figure 78. Pearson's residuals for fits to survey size composition data in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

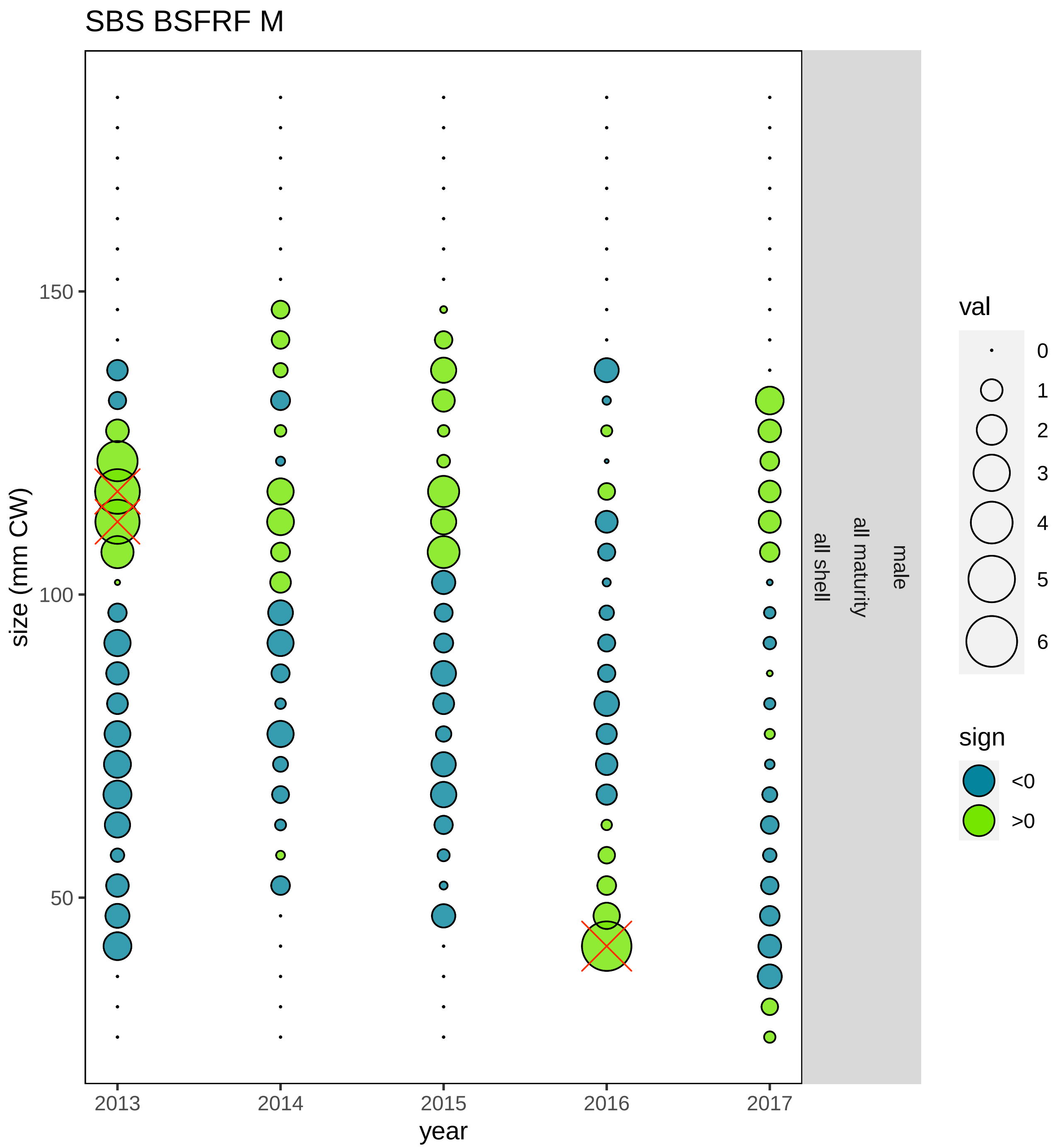

Figure 79. Pearson's residuals for fits to survey size composition data in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

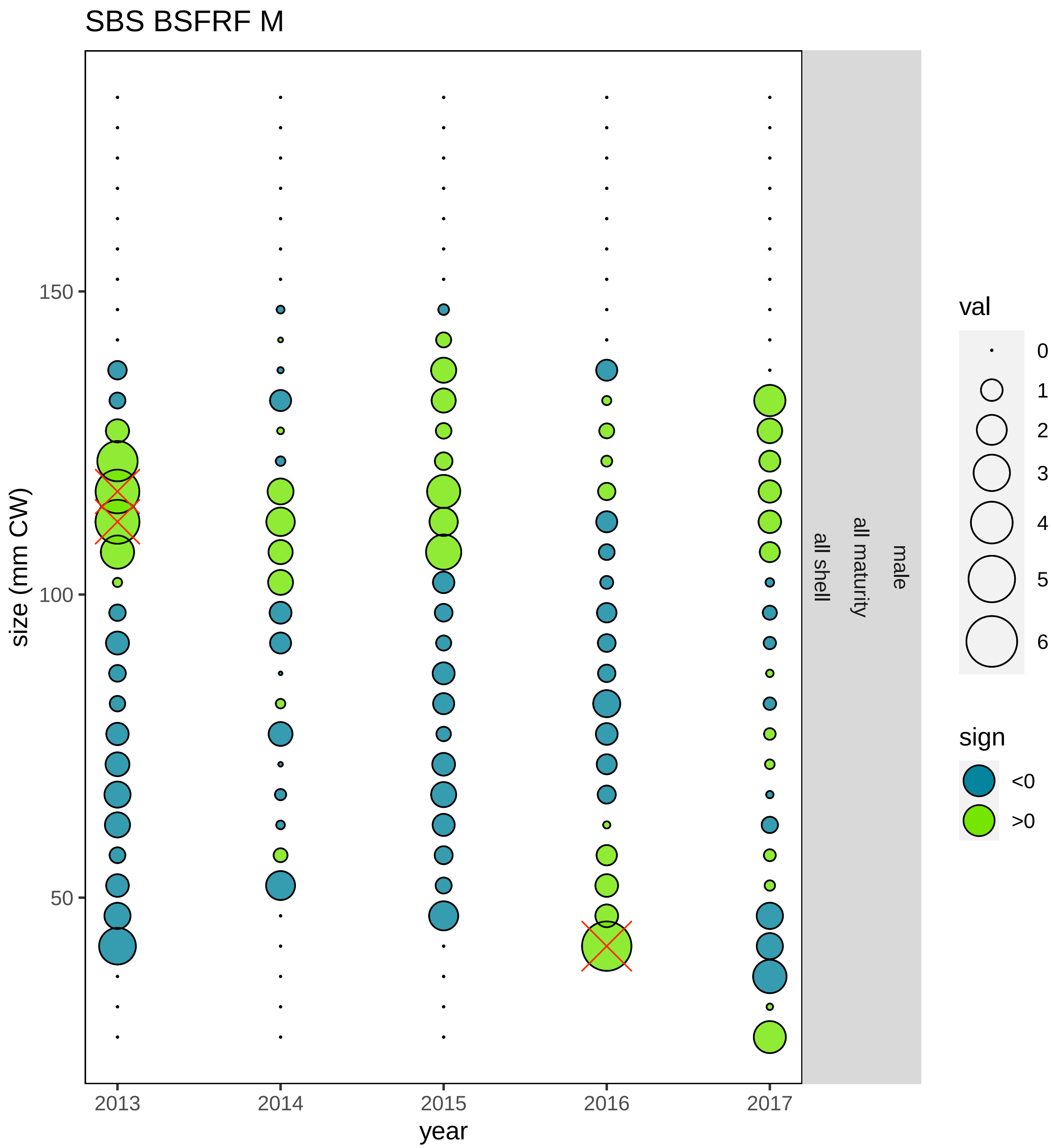

Figure 80. Pearson's residuals for fits to survey size composition data in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

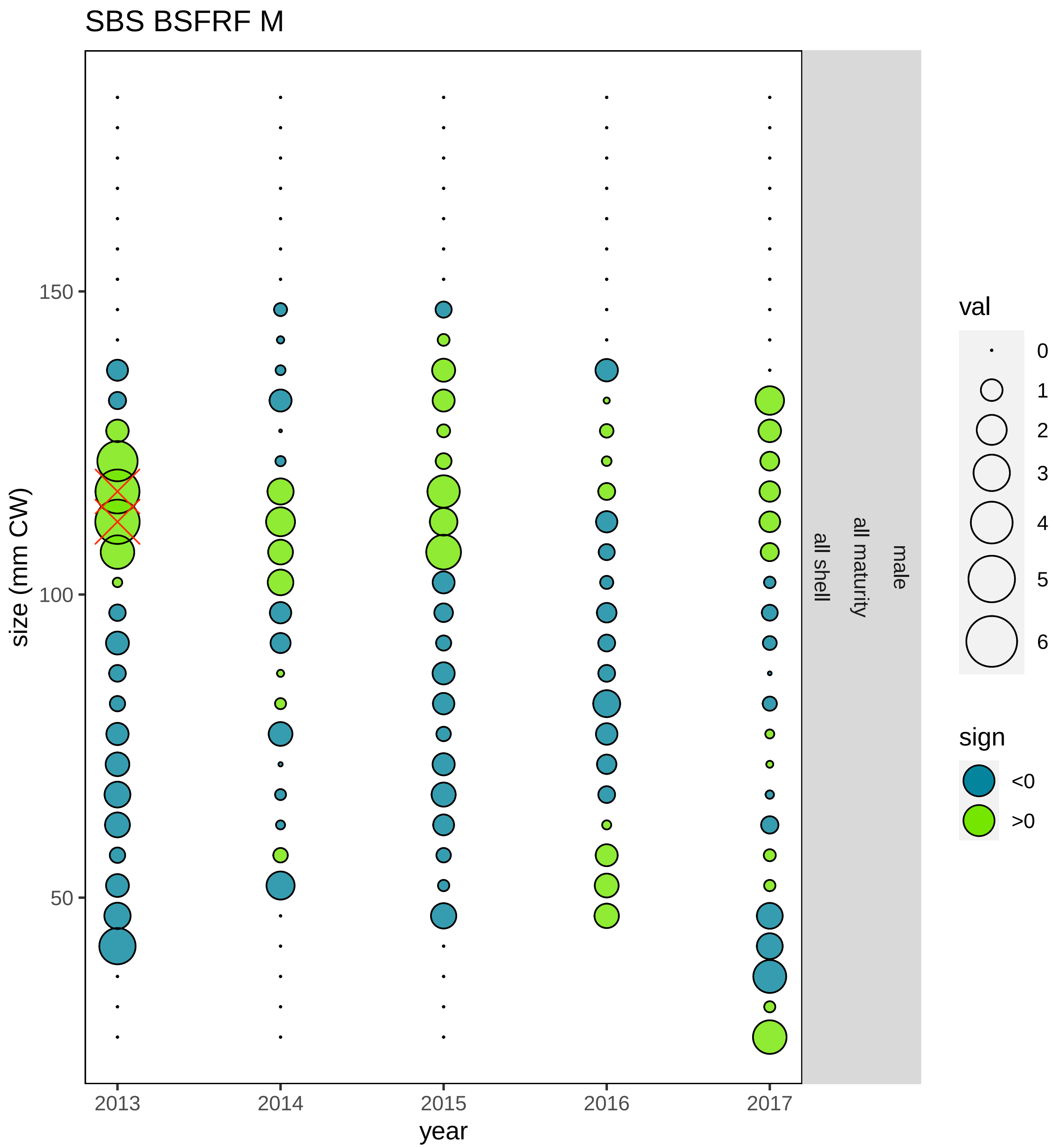

Figure 81. Pearson's residuals for fits to survey size composition data in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

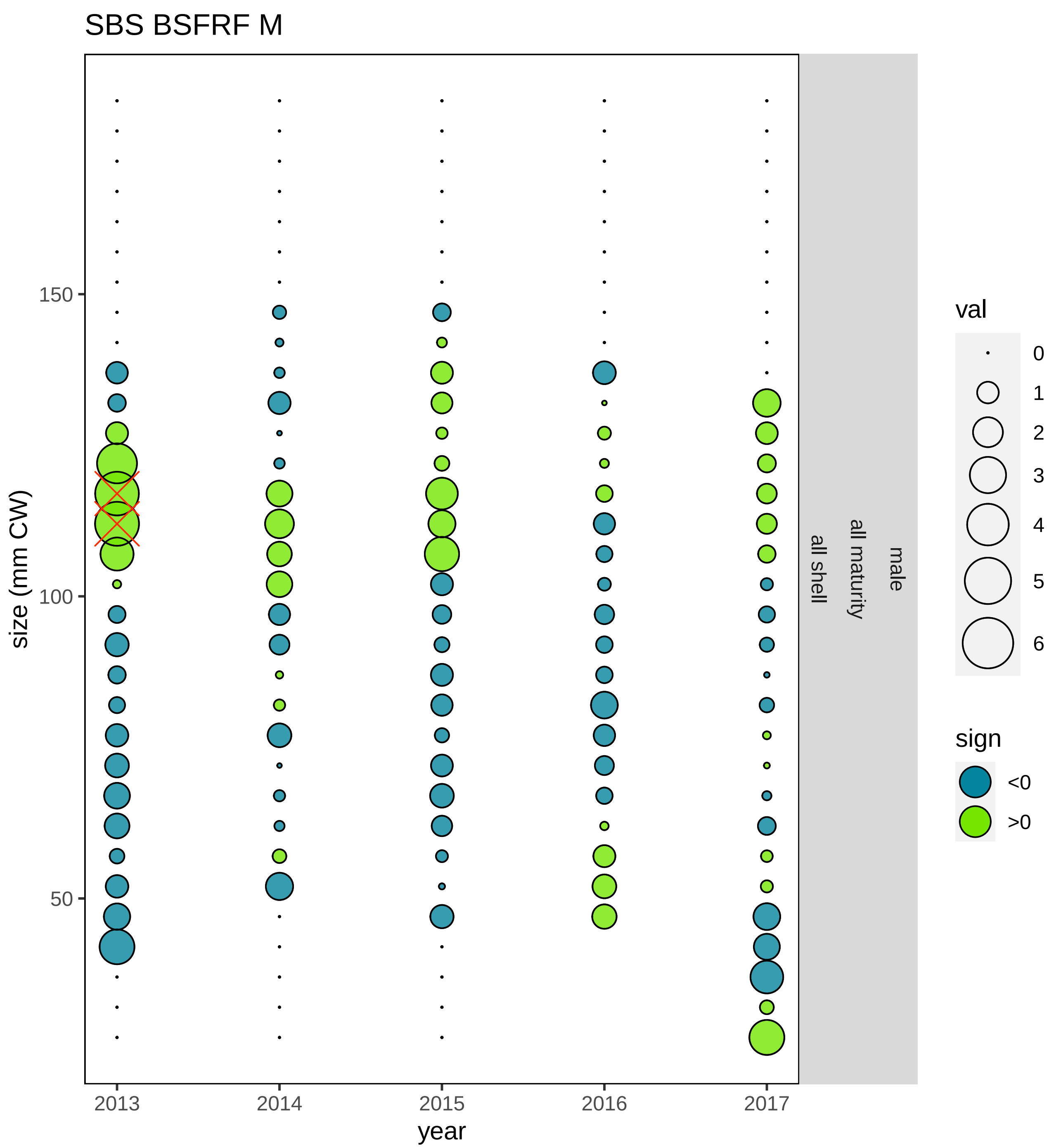

Figure 82. Pearson's residuals for fits to survey size composition data in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

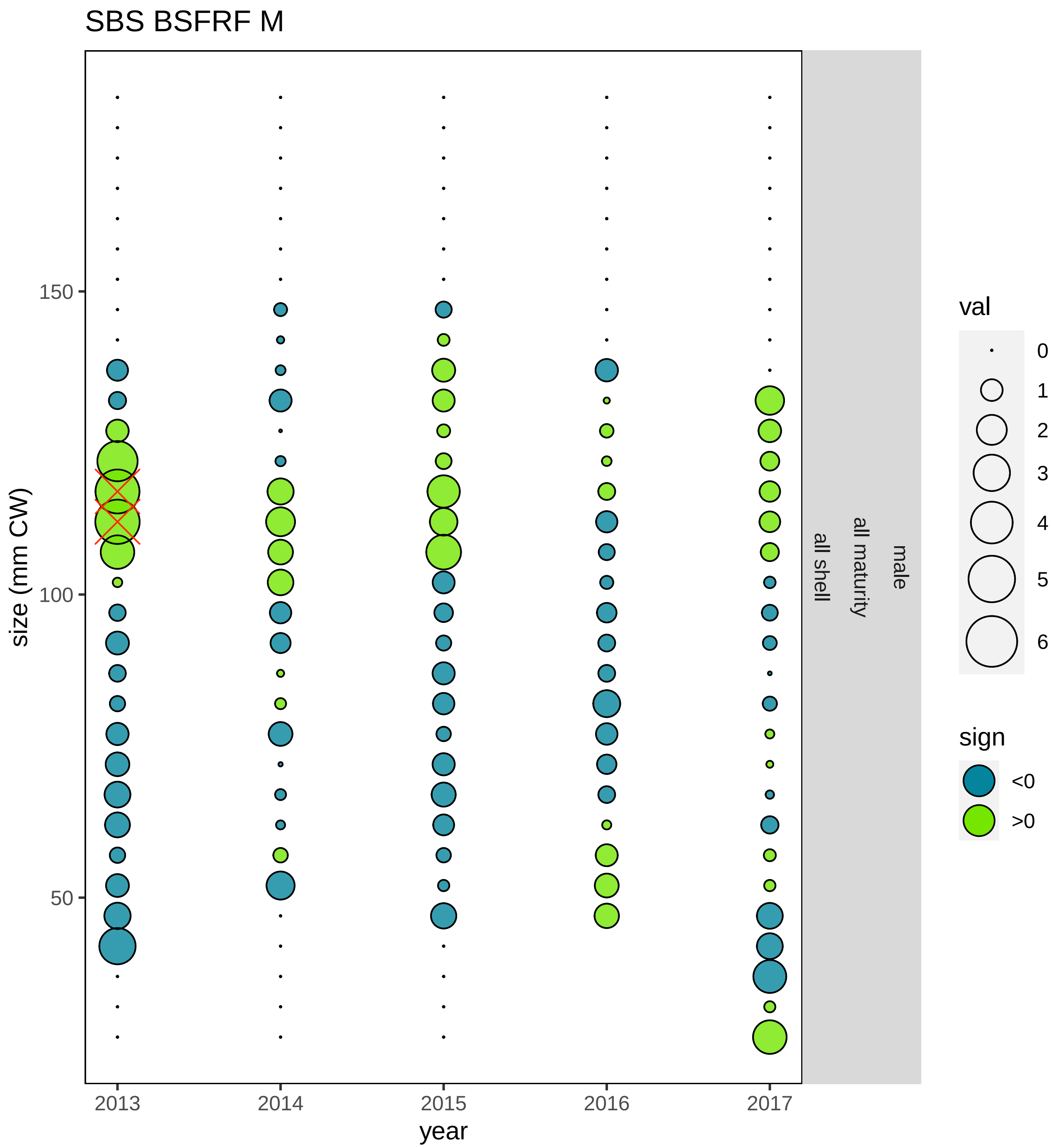

Figure 83. Pearson's residuals for fits to survey size composition data in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

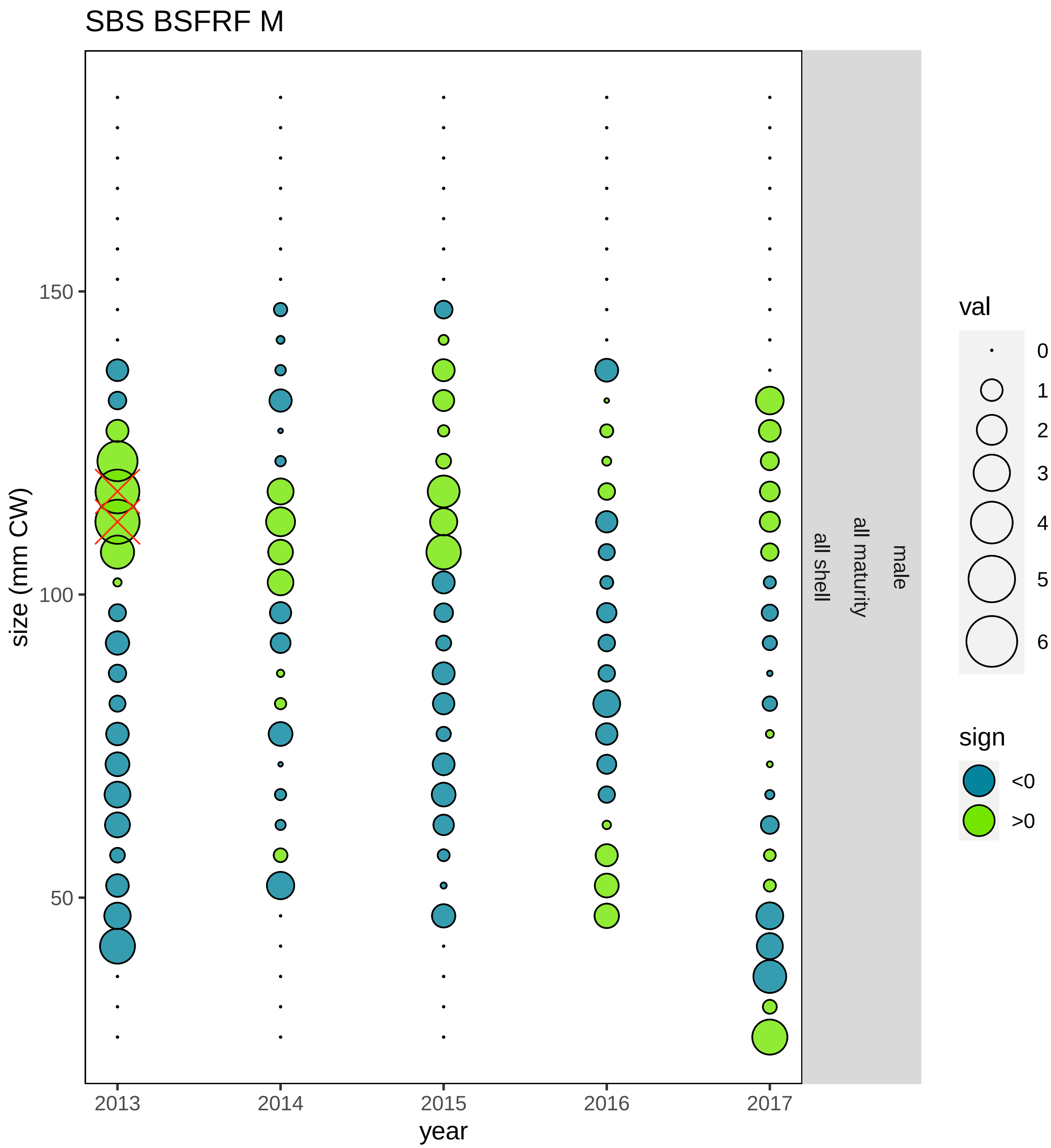

Figure 84. Pearson's residuals for fits to survey size composition data in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

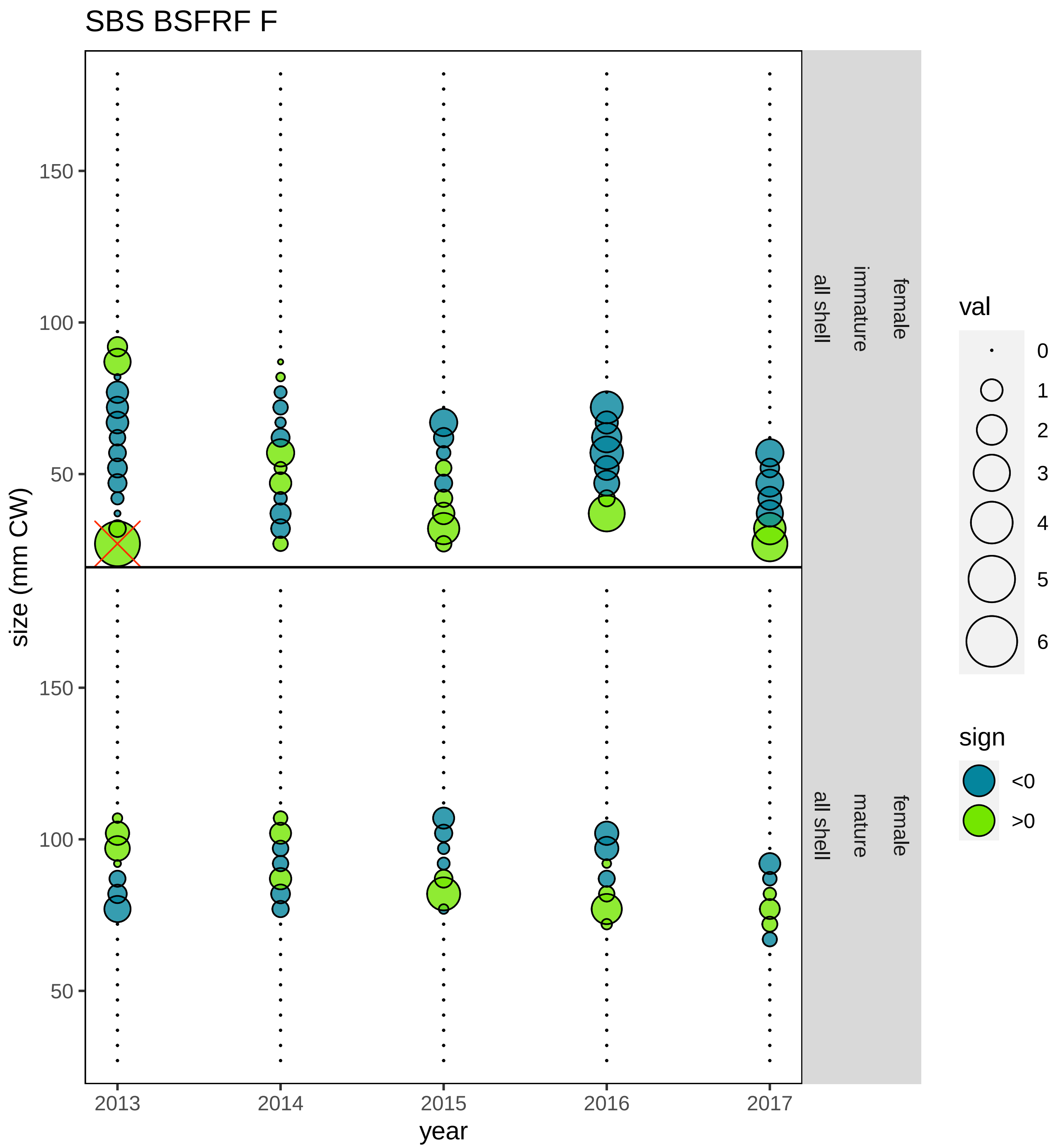

Figure 85. Pearson's residuals for fits to survey size composition data in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

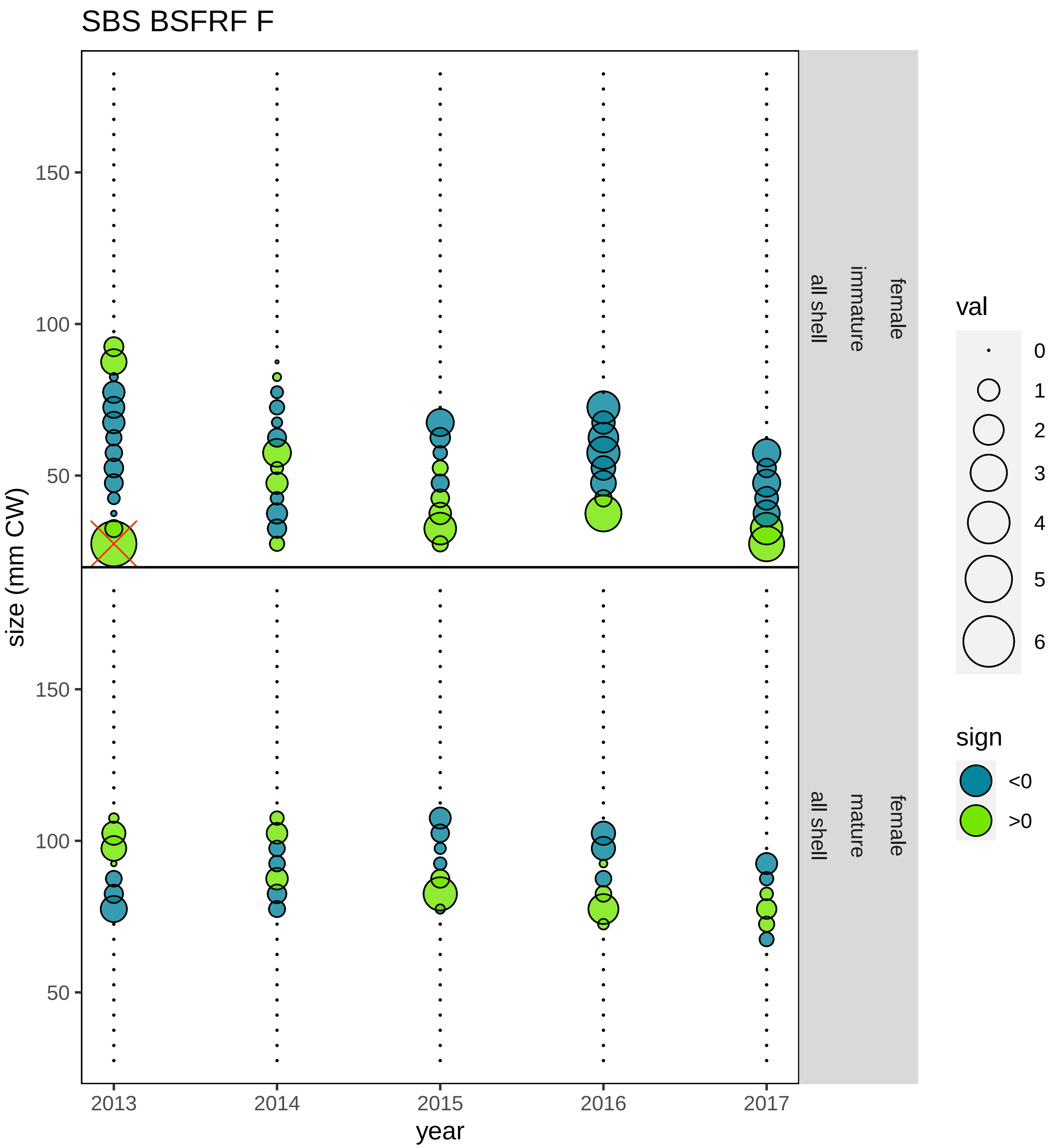

Figure 86. Pearson's residuals for fits to survey size composition data in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

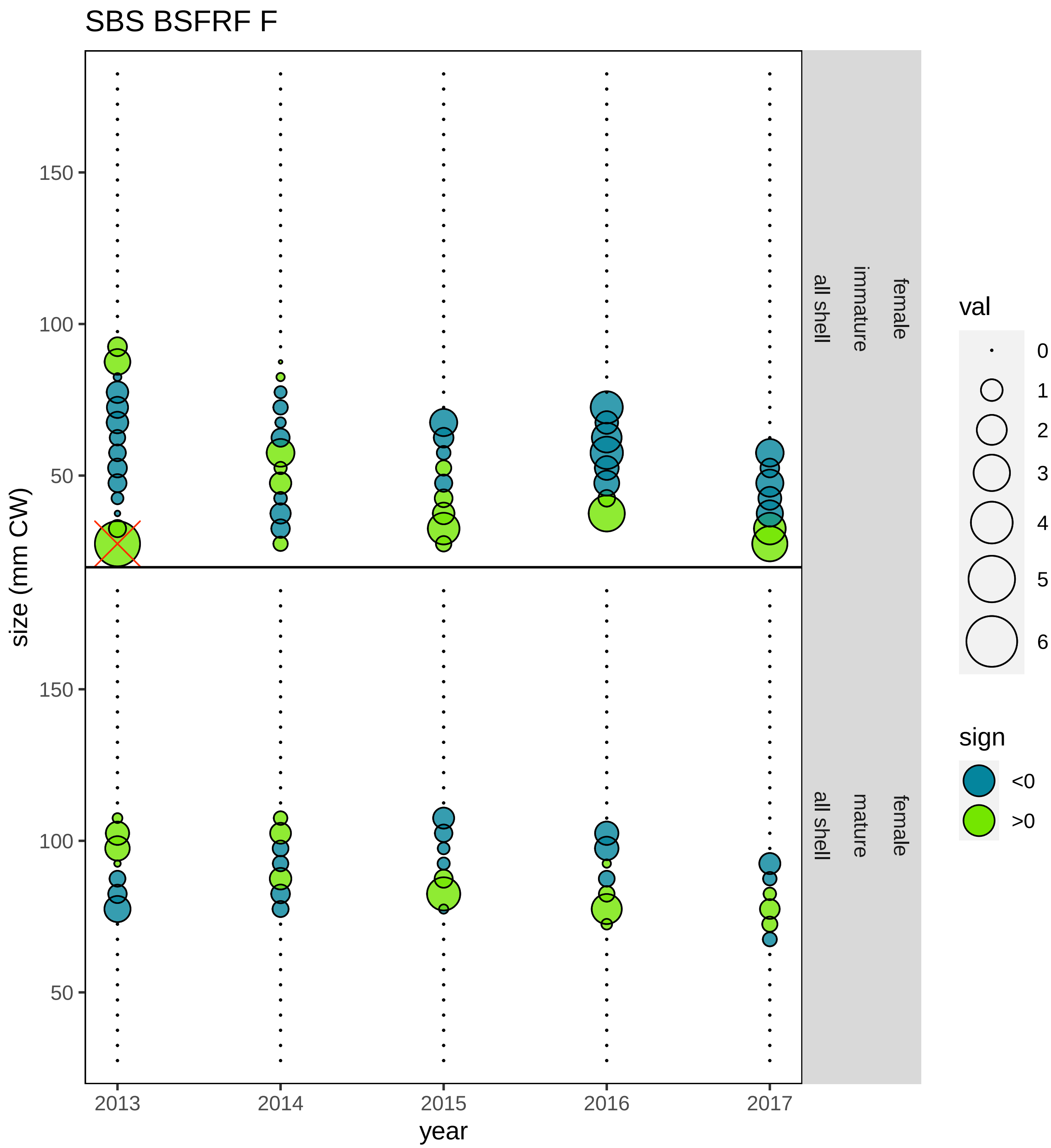

Figure 87. Pearson's residuals for fits to survey size composition data in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

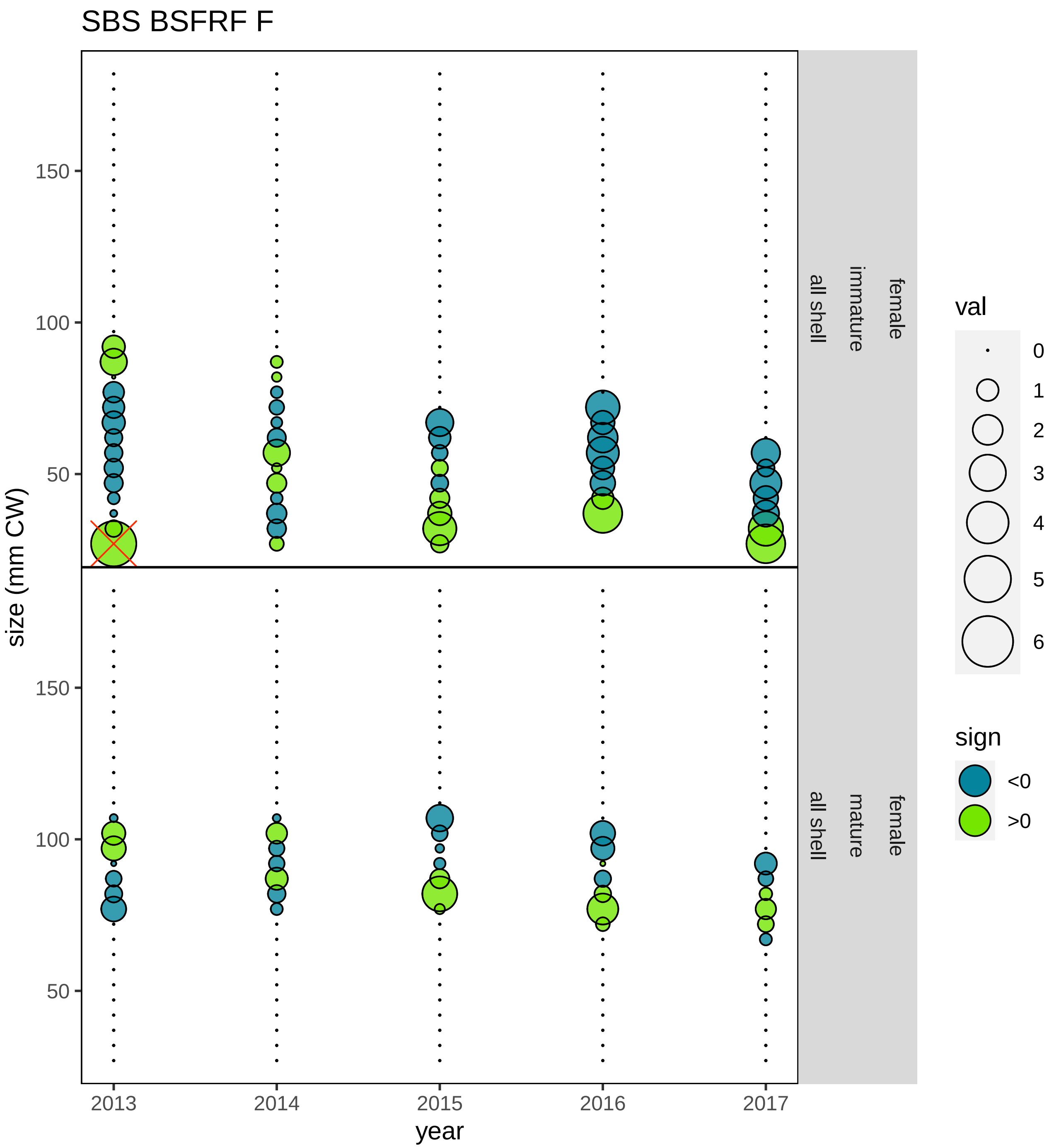

Figure 88. Pearson's residuals for fits to survey size composition data in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

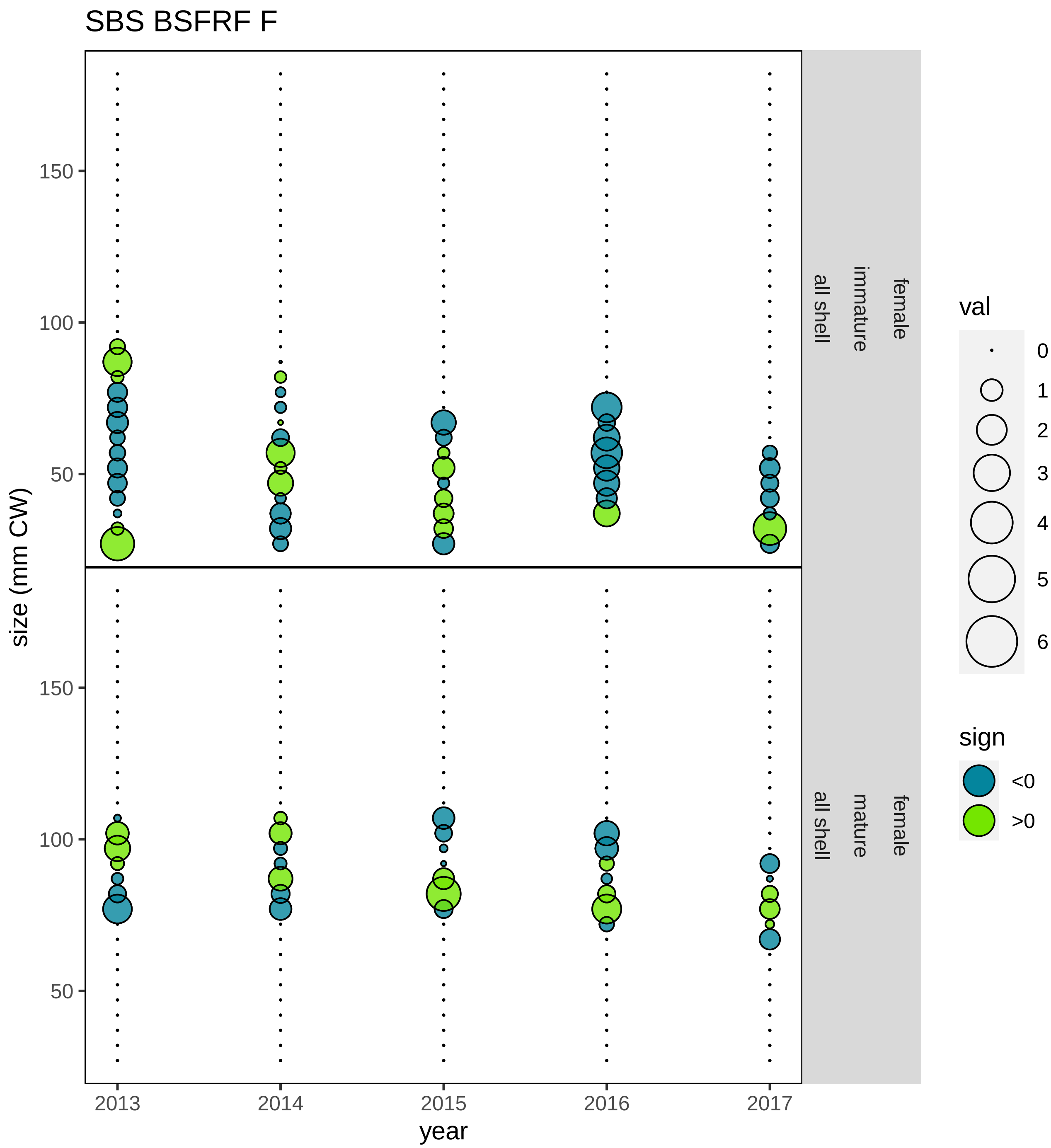

Figure 89. Pearson's residuals for fits to survey size composition data in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

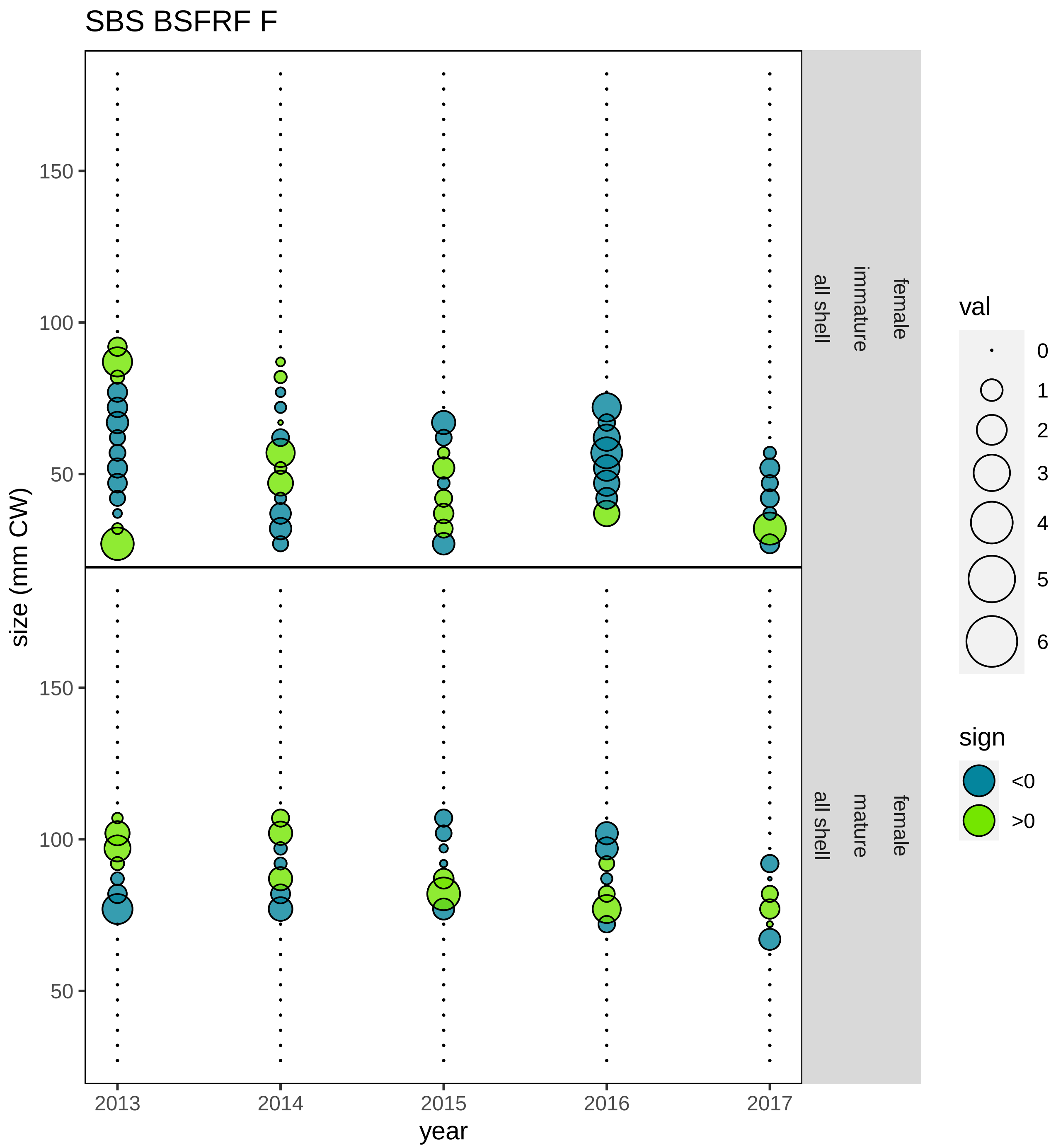

Figure 90. Pearson's residuals for fits to survey size composition data in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

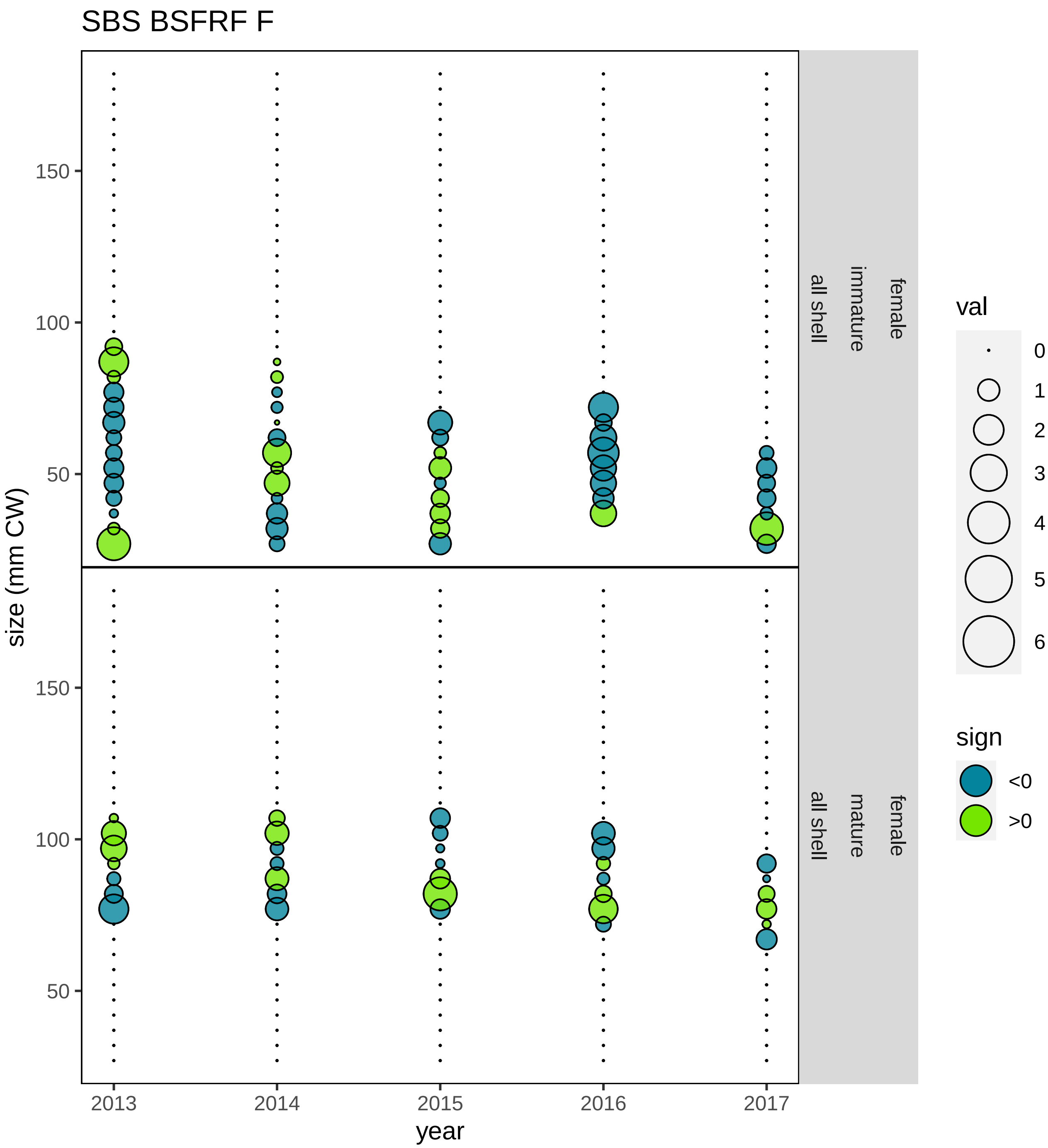

Figure 91. Pearson's residuals for fits to survey size composition data in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

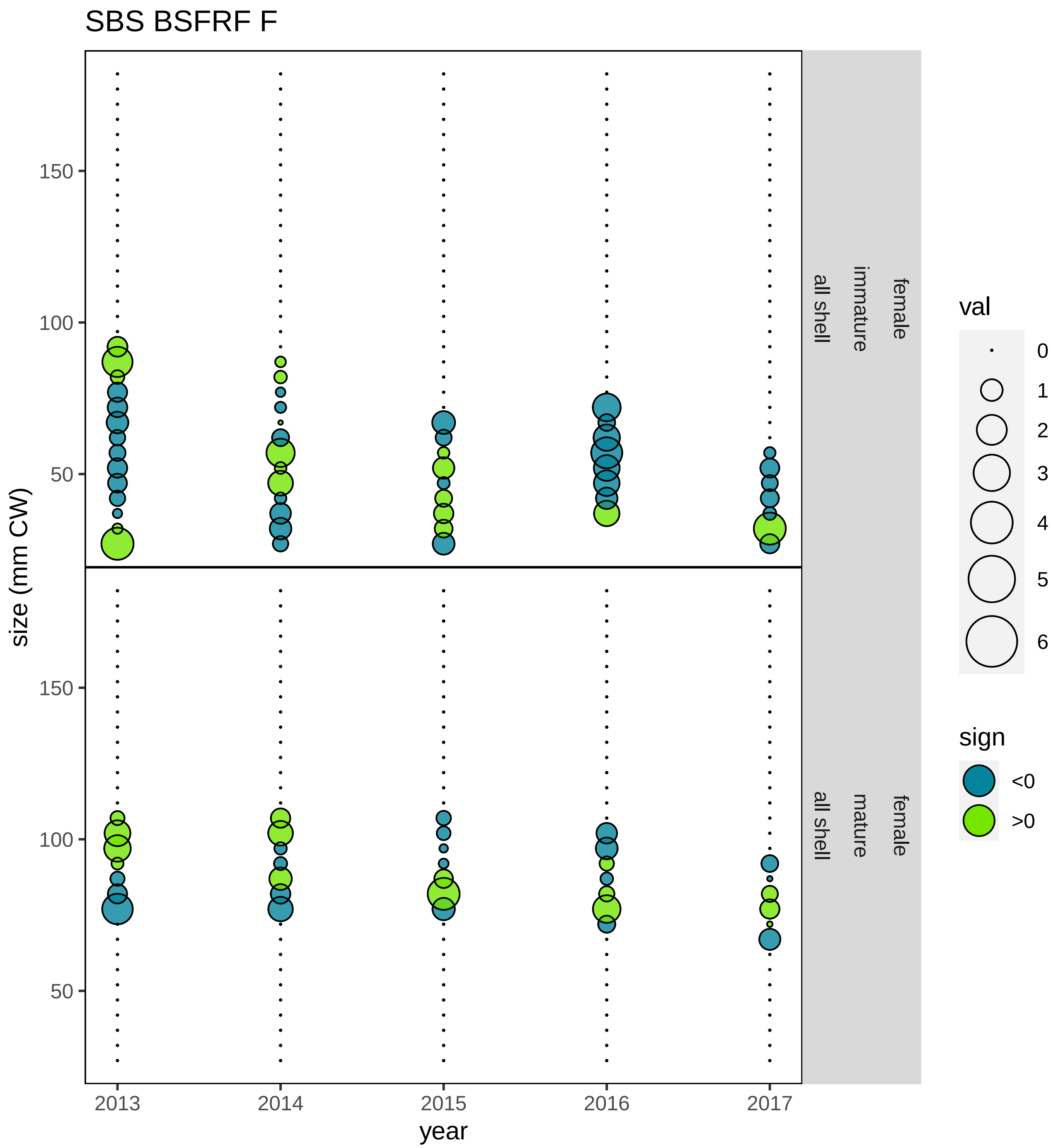

Figure 92. Pearson's residuals for fits to survey size composition data in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

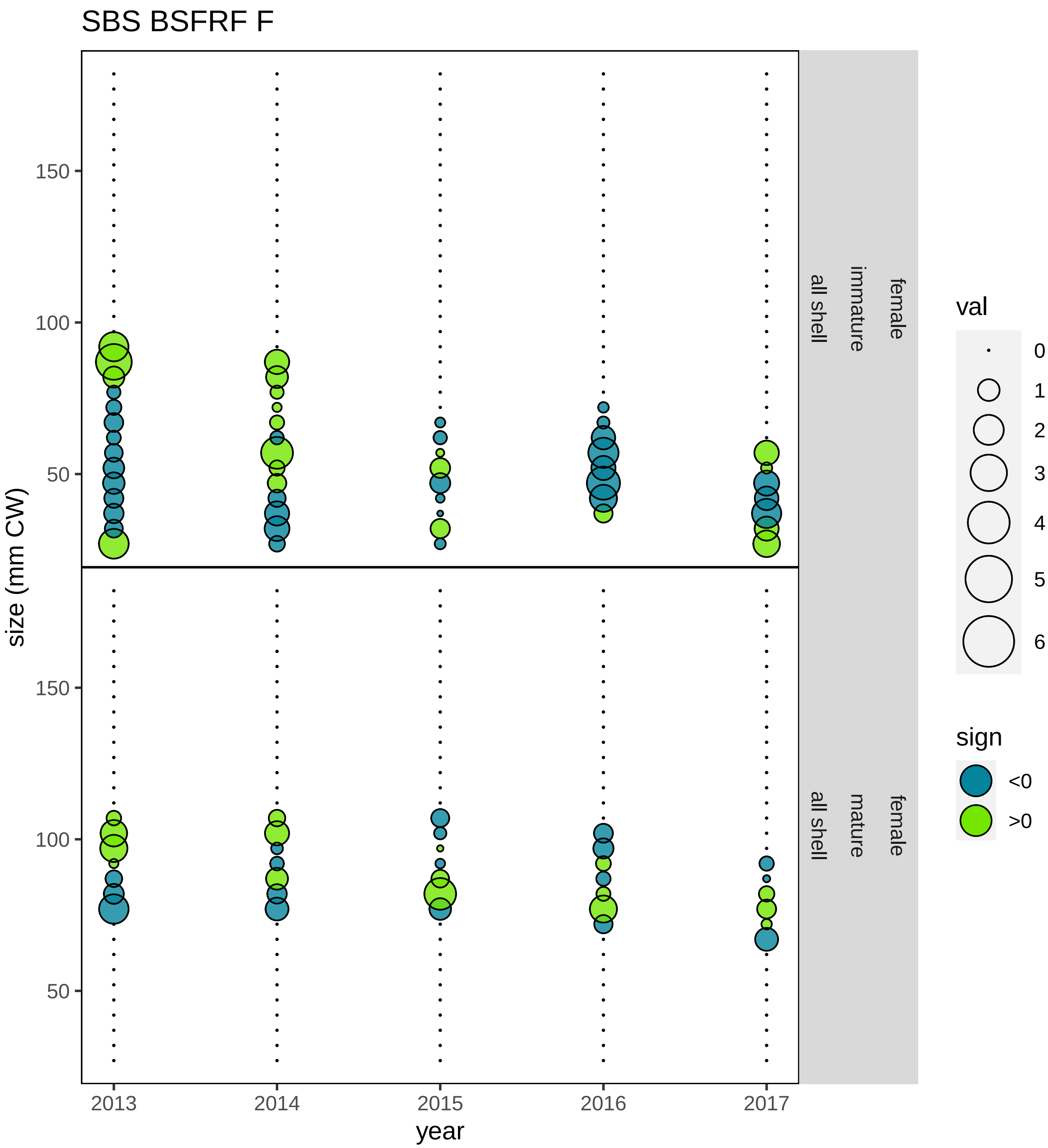

Figure 93. Pearson's residuals for fits to survey size composition data in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

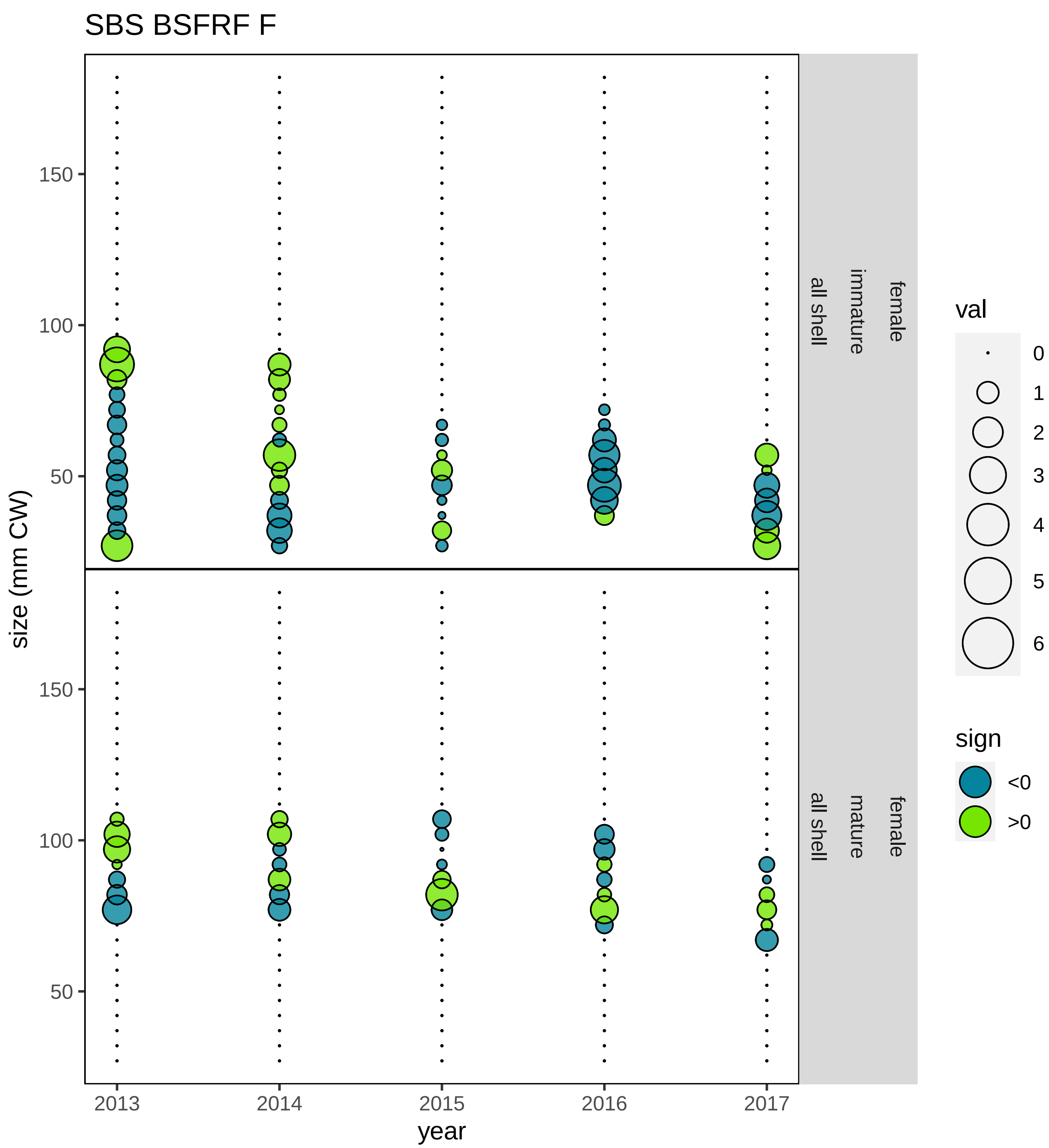

Figure 94. Pearson's residuals for fits to survey size composition data in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

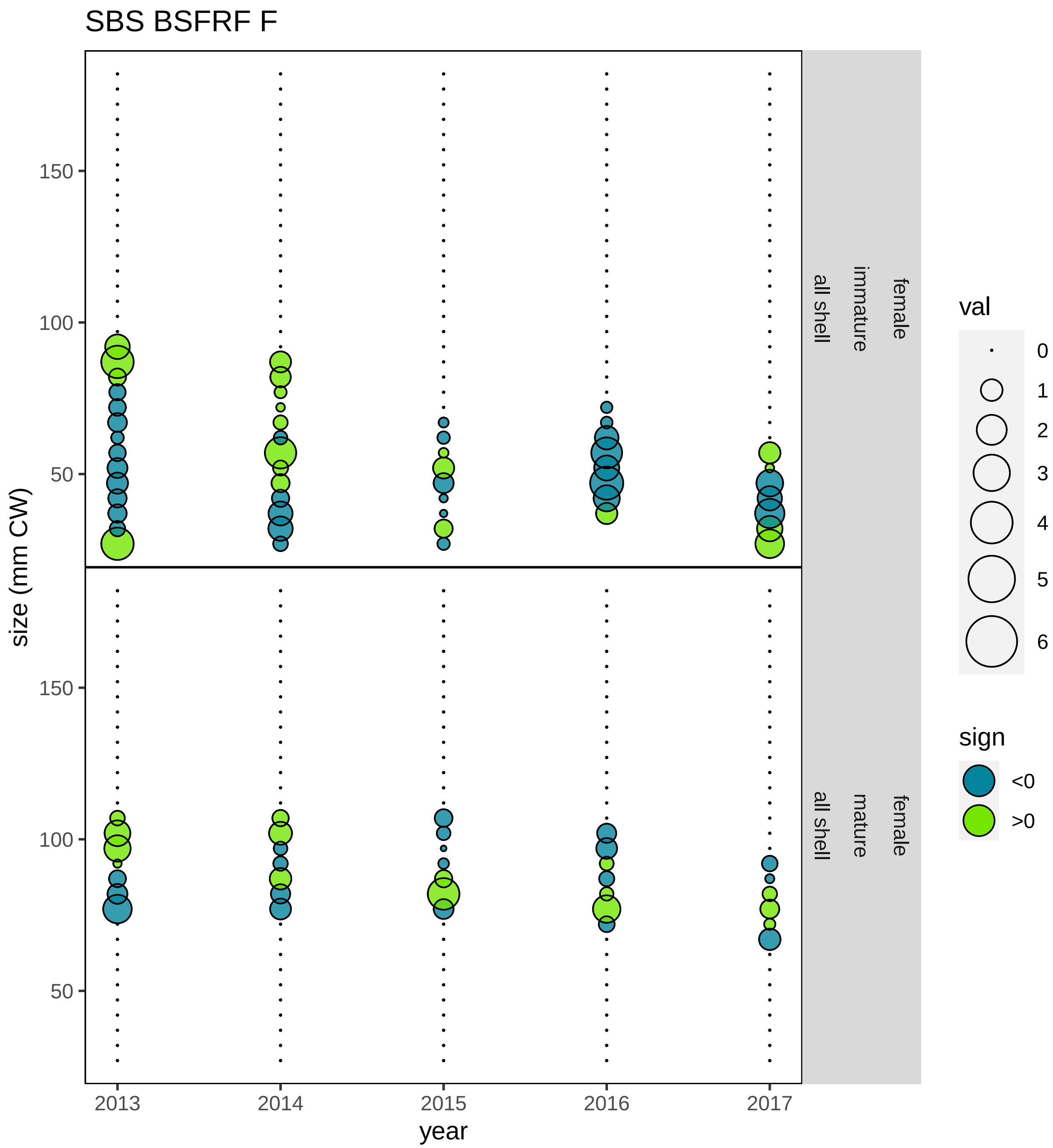

Figure 95. Pearson's residuals for fits to survey size composition data in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

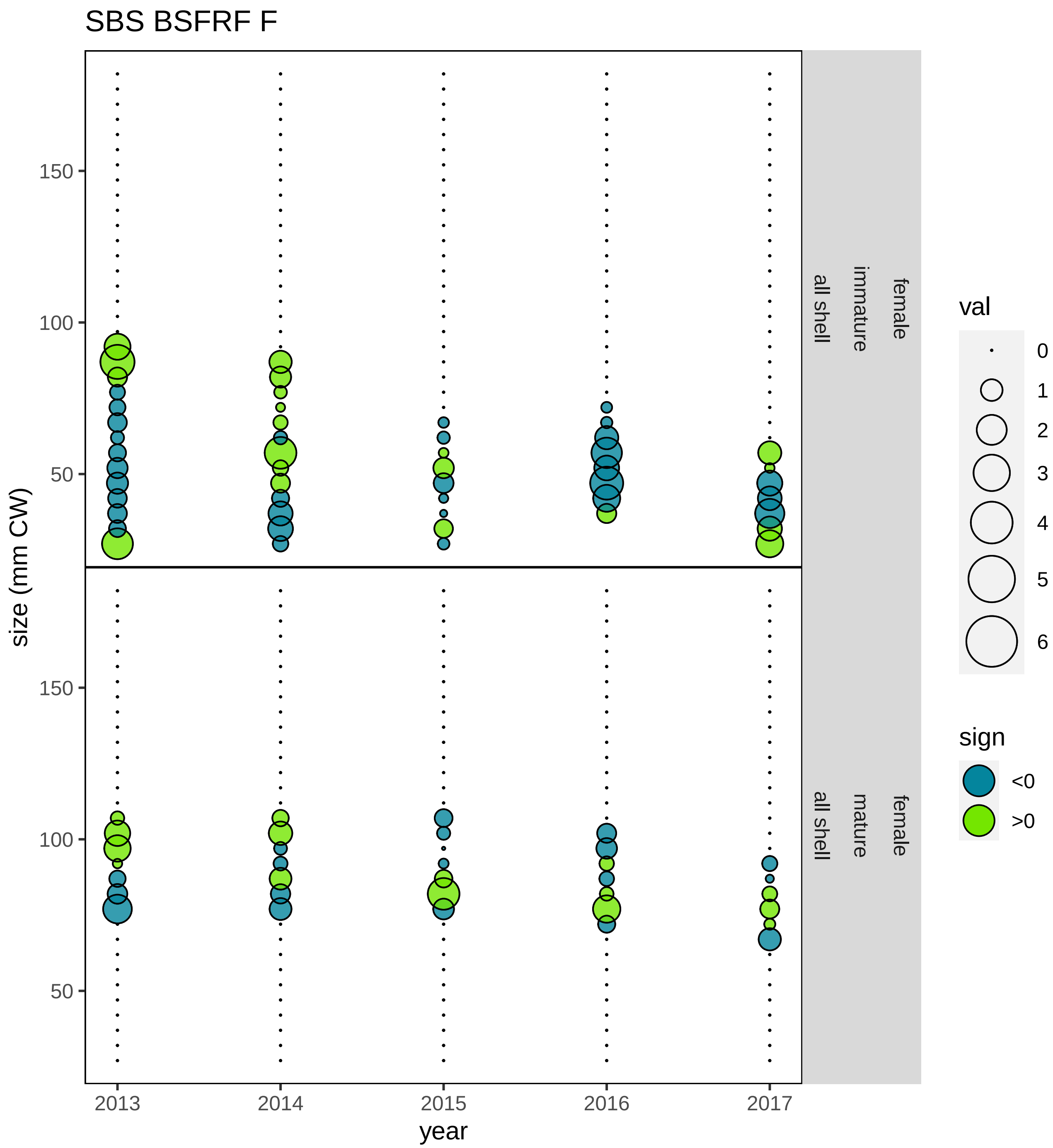

Figure 96. Pearson's residuals for fits to survey size composition data in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

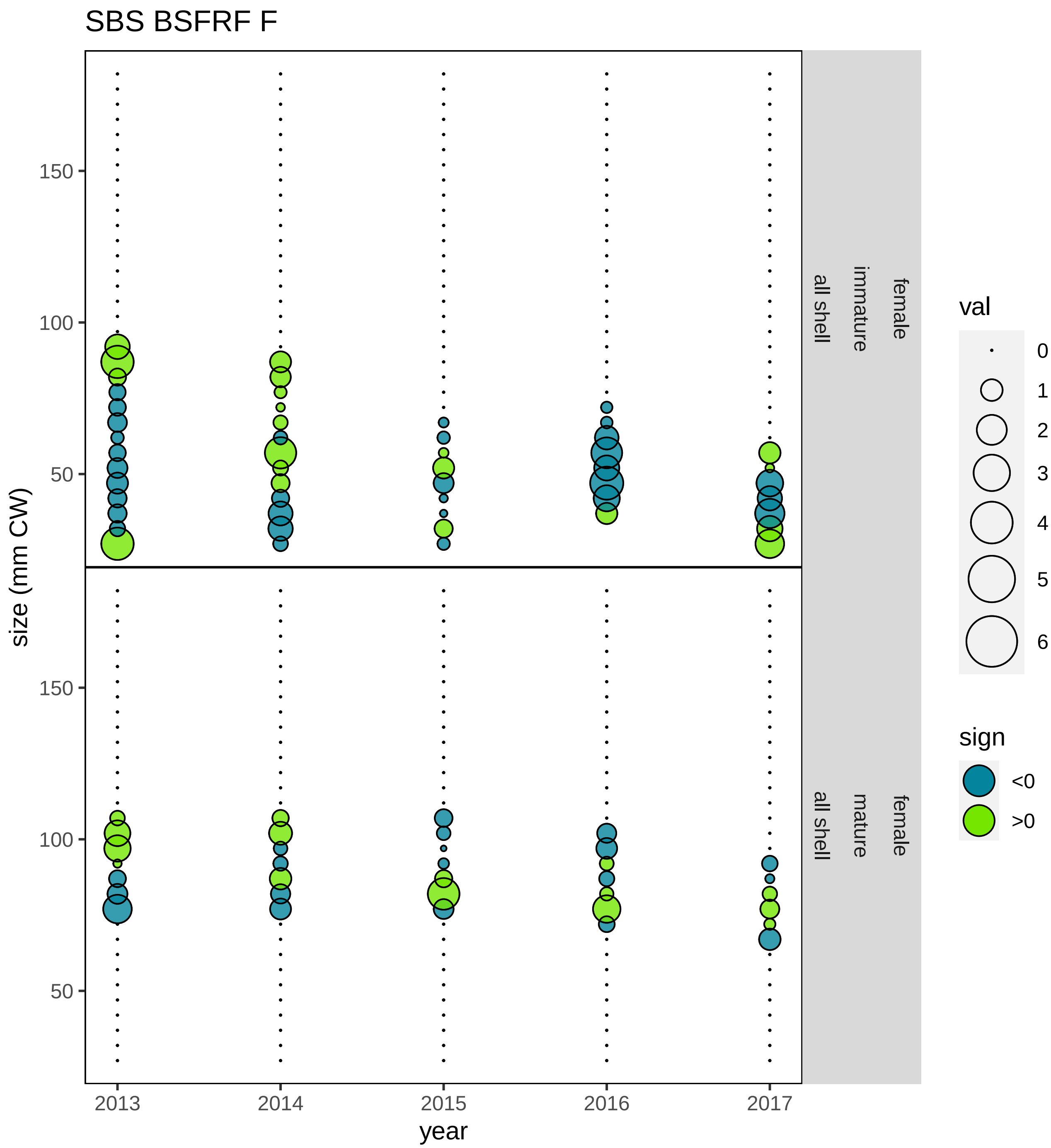

Figure 97. Pearson's residuals for fits to survey size composition data in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

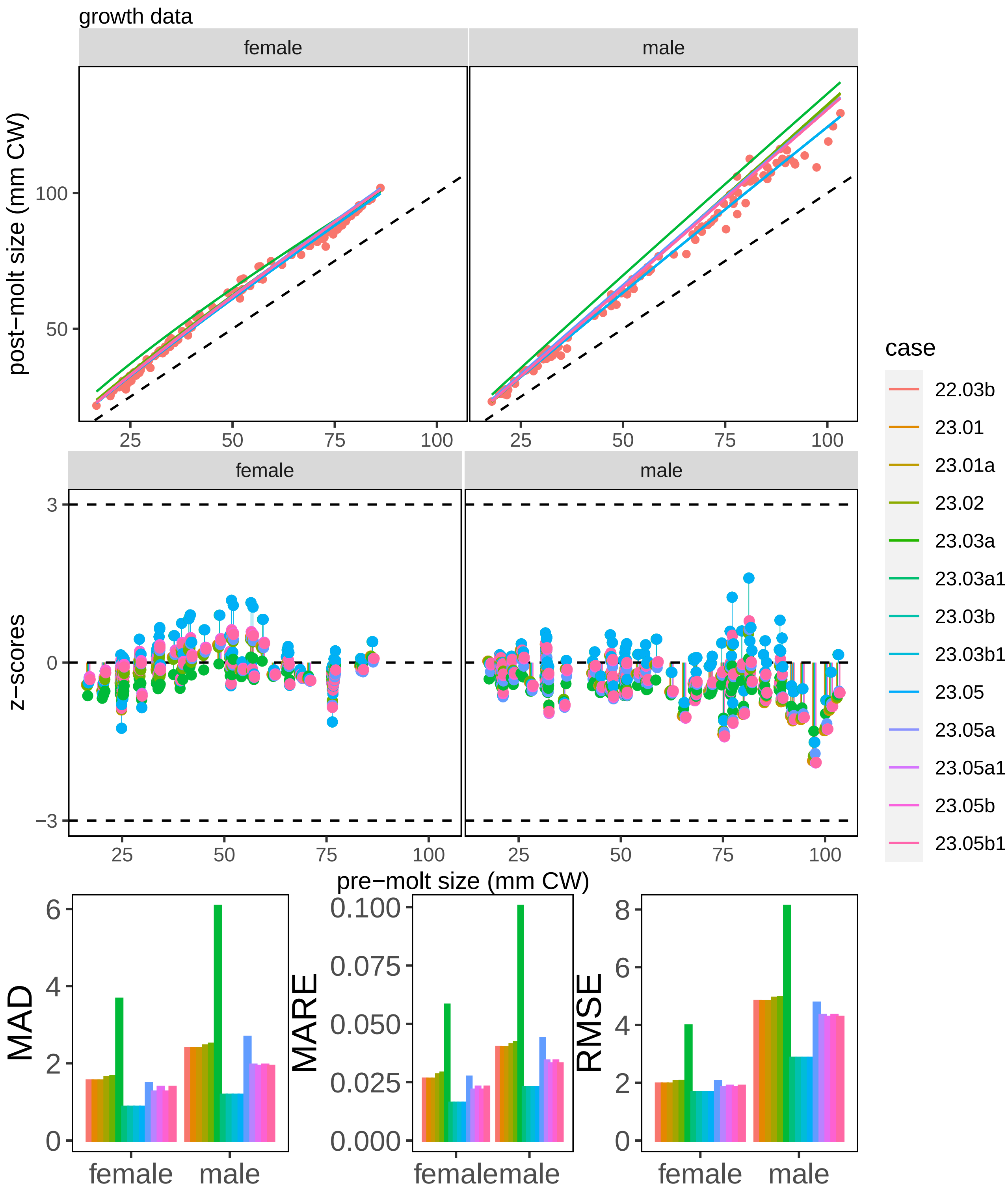

Figure 98. Fits and residuals analysis by model scenario for fits to molt increment data. Upper row: fits to data; center row: annual z-scores; bottom row: 1) MAD: median absolute deviations, 2) MARE: median absolute relative error; 3) RMSE: root mean square error.

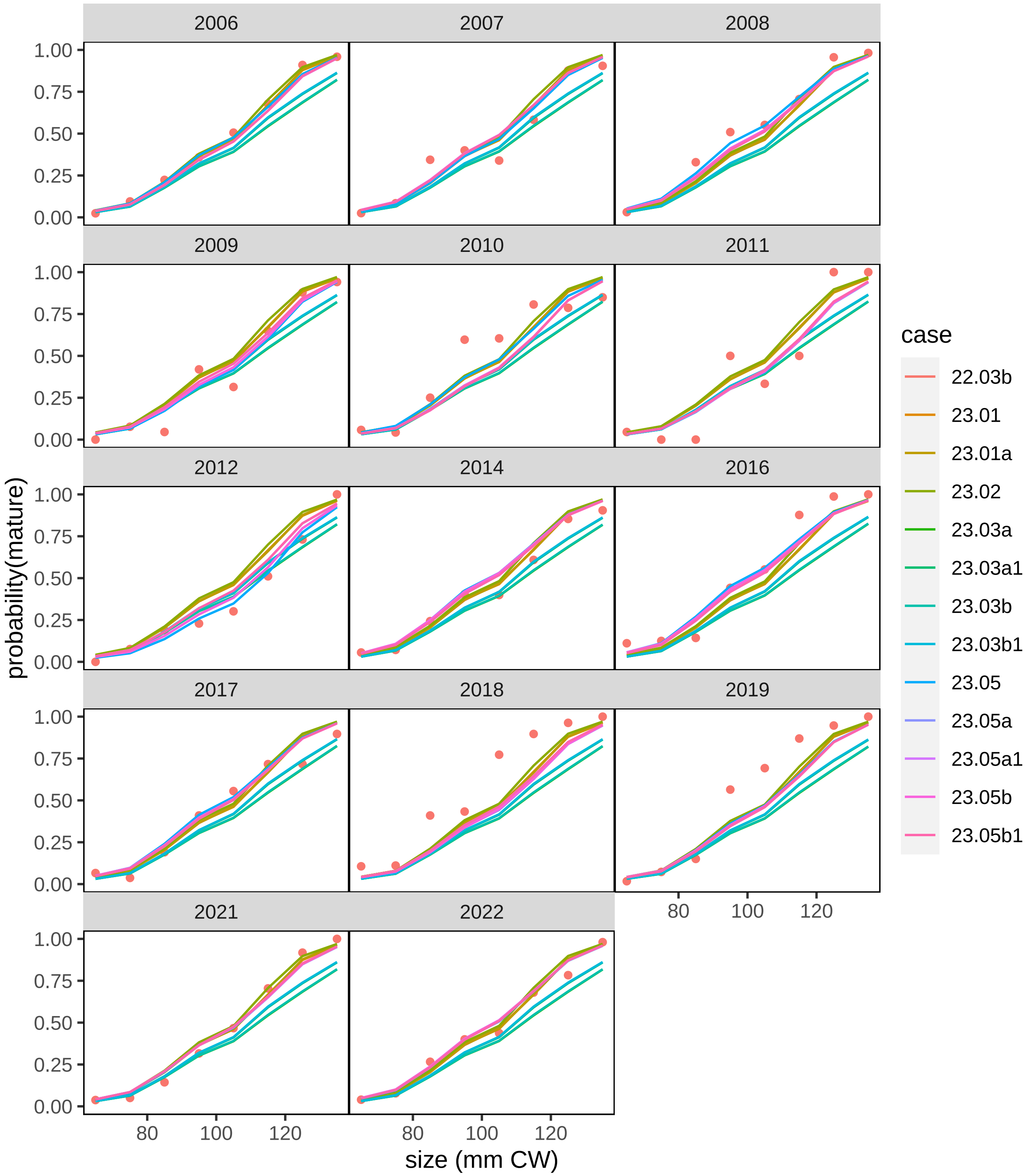

Figure 99. Fits to maturity ogive data by model scenario and year.

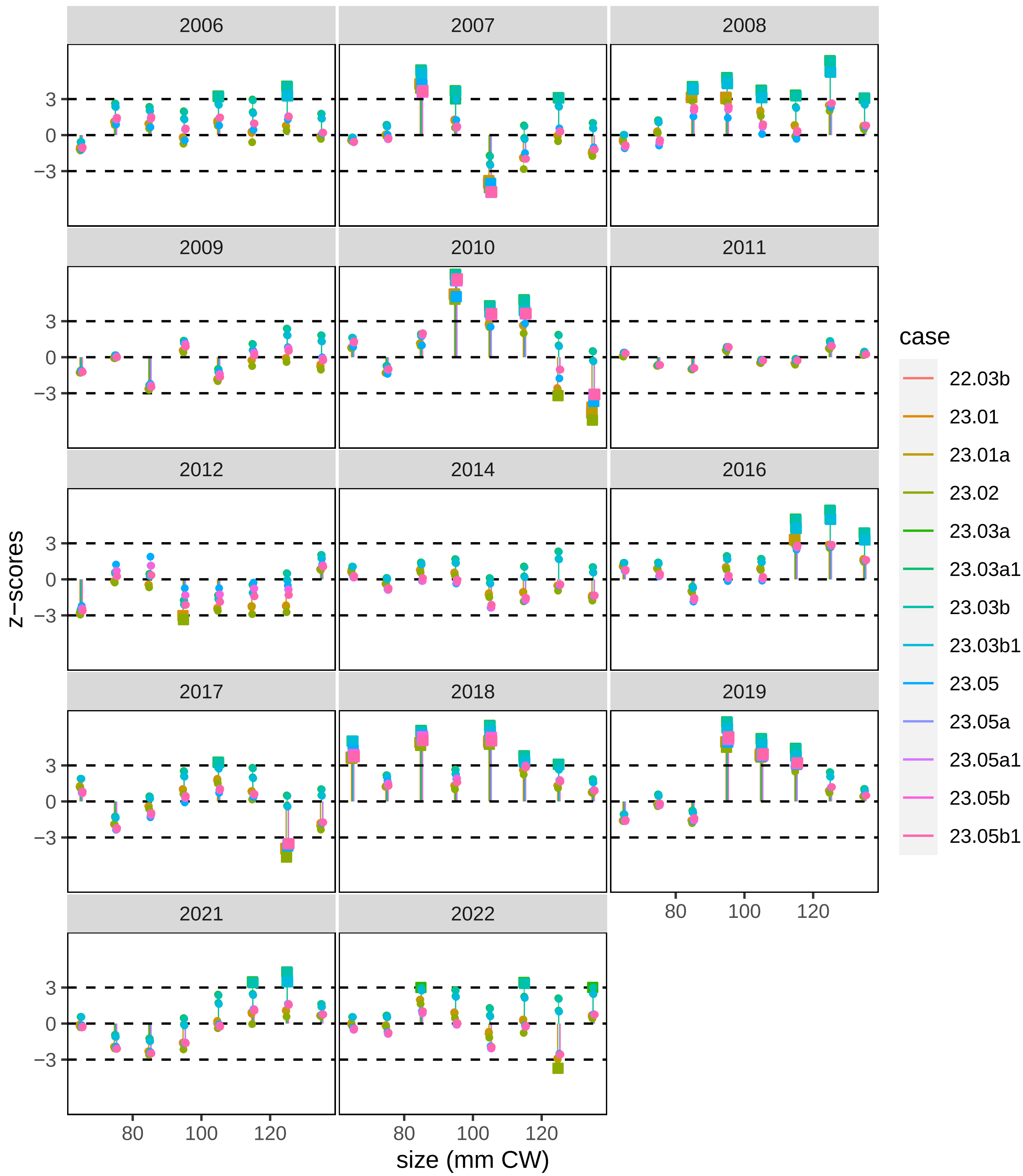

Figure 100. Z-scores for fits to maturity ogive data, by model scenario and year.

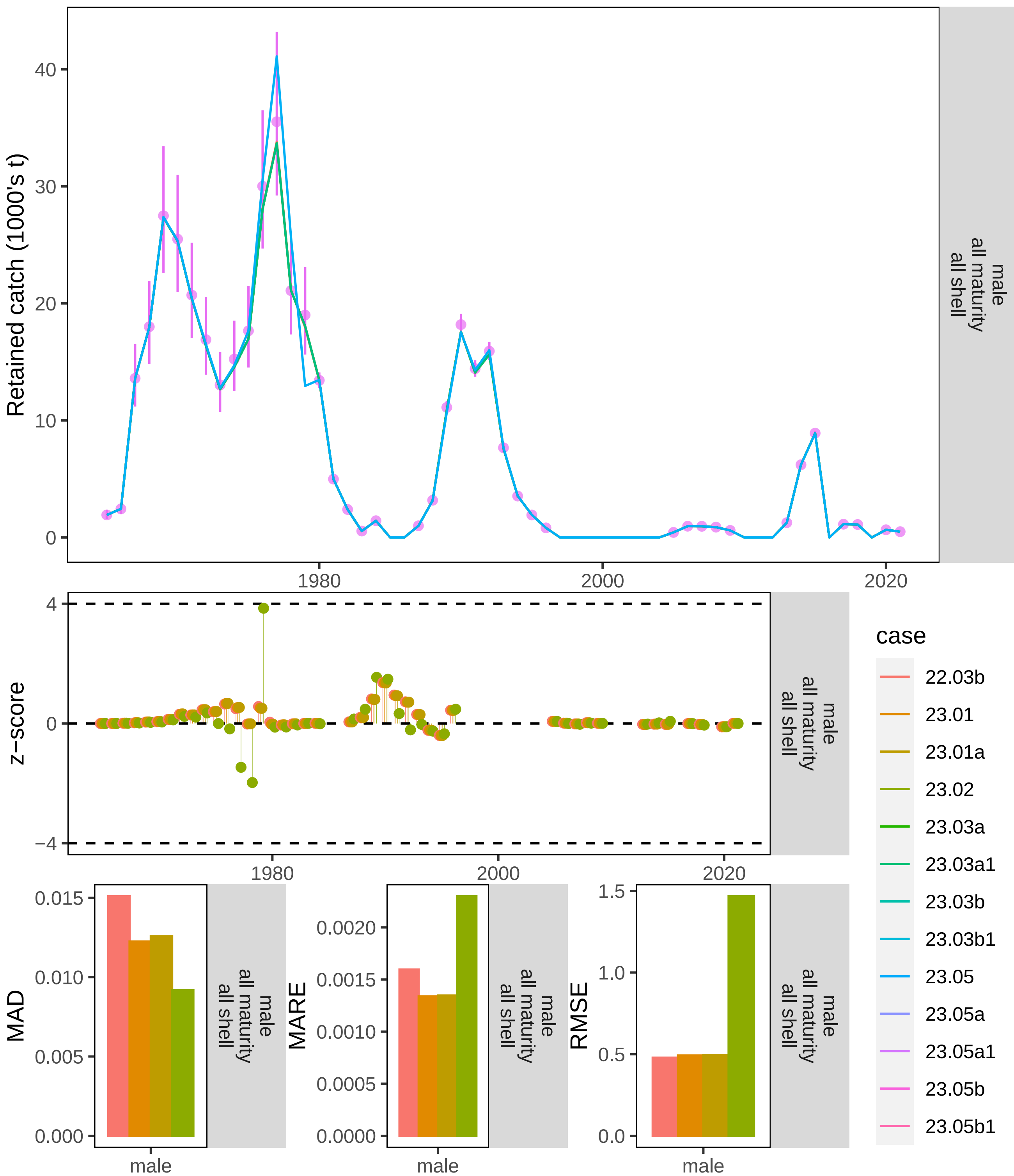

Figure 101. Fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.01, 23.01a, 23.02.

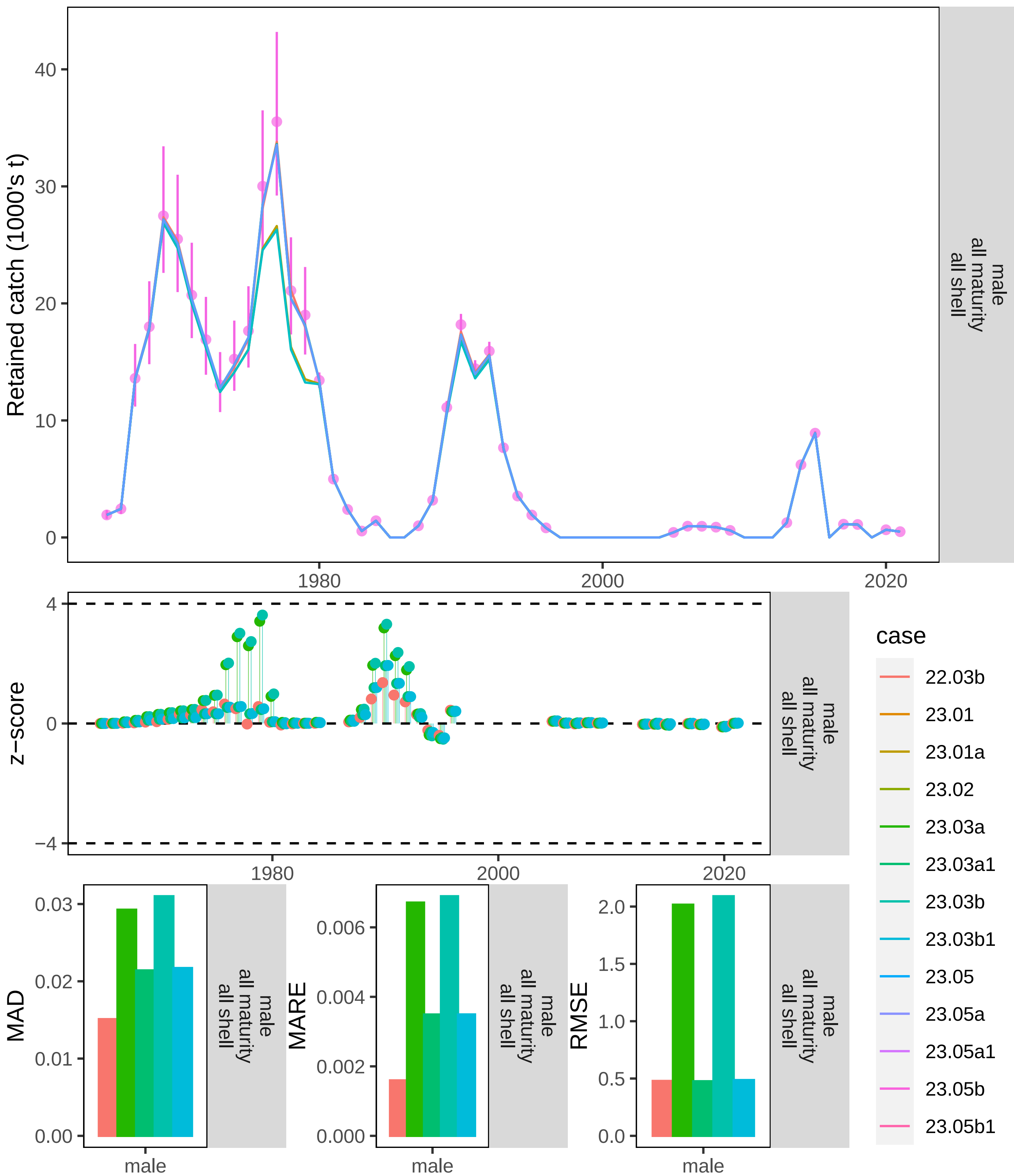

Figure 102. Fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

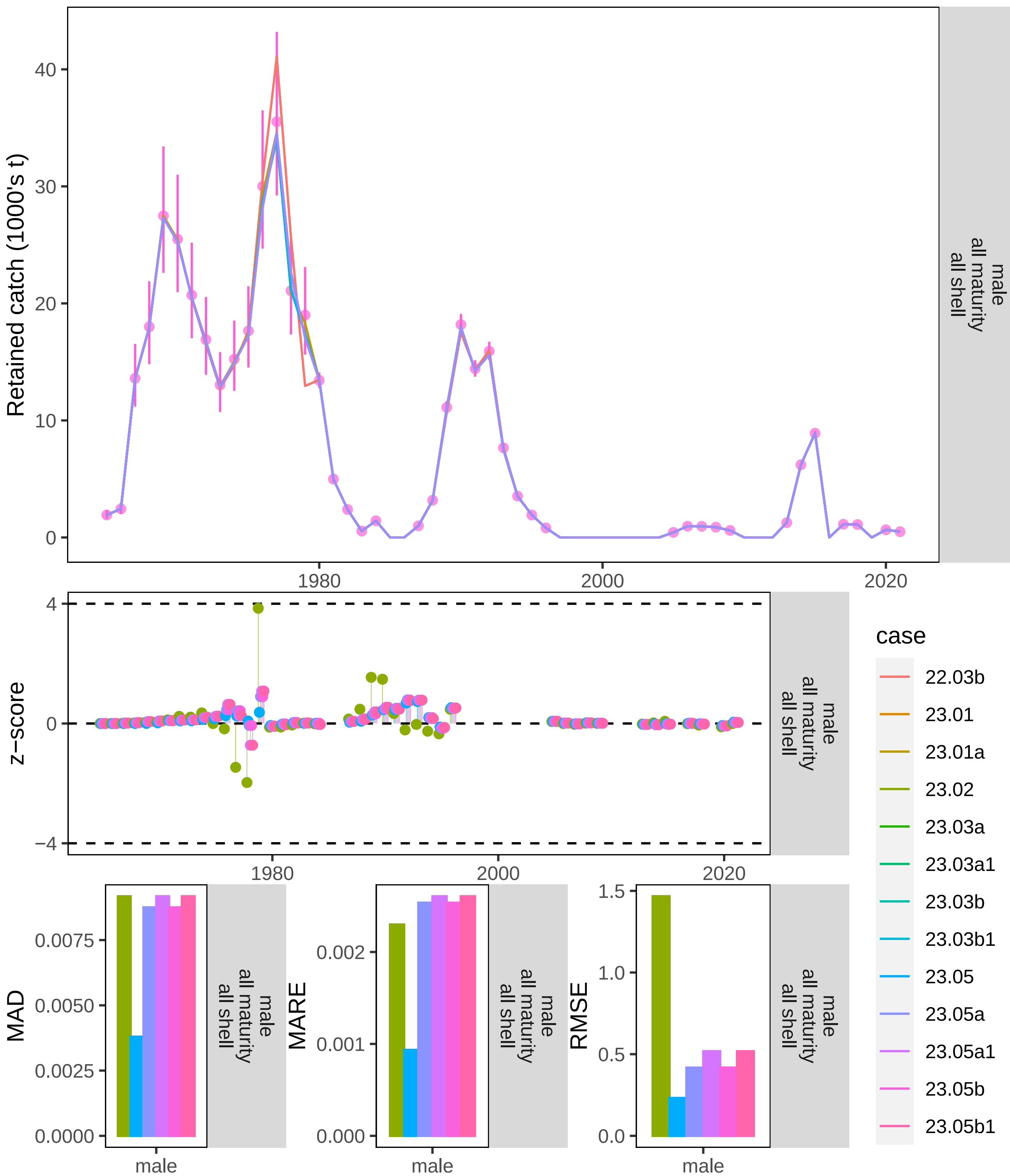

Figure 103. Fits to retained catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

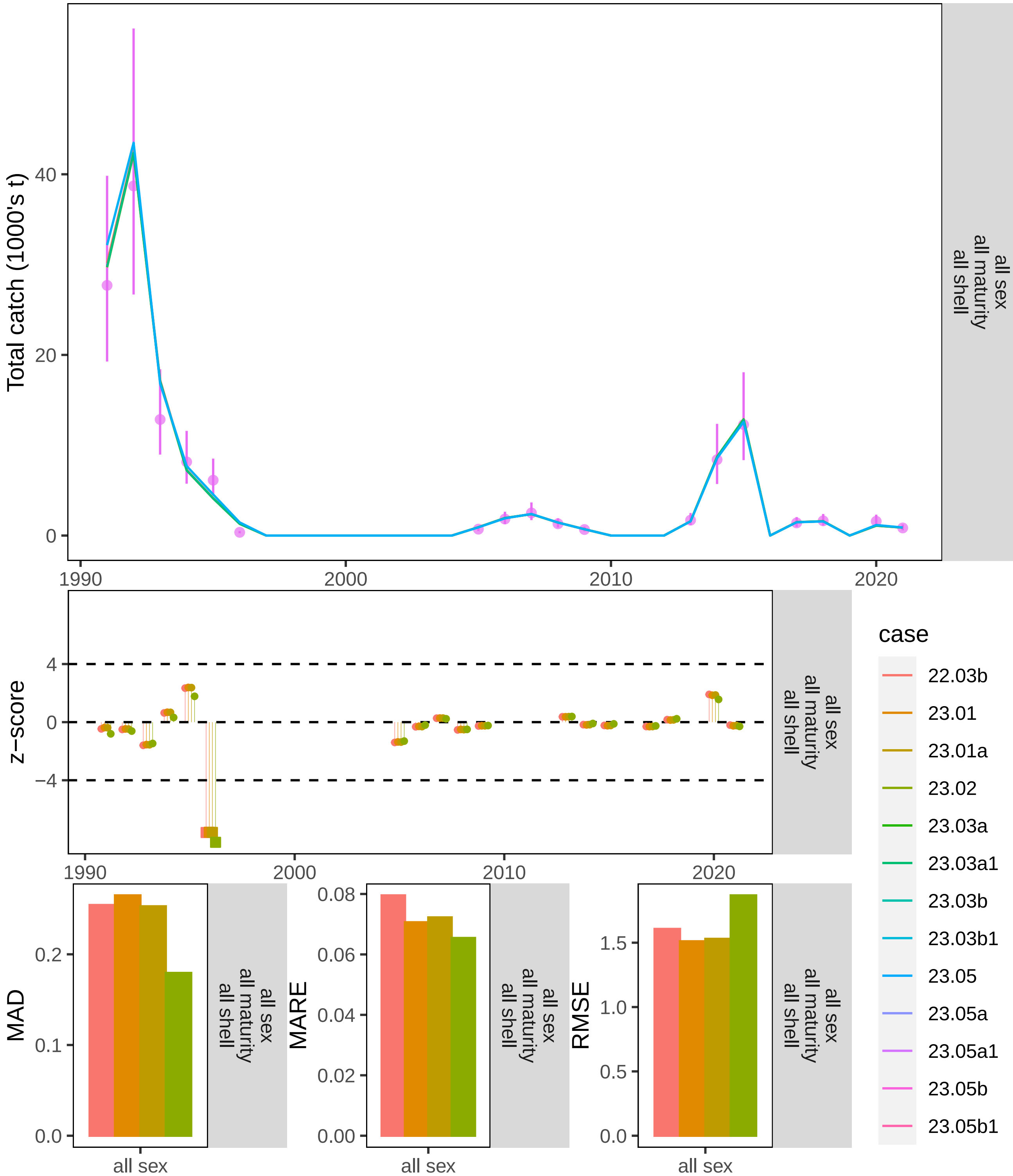

Figure 104. Fits to total catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.01, 23.01a, 23.02.

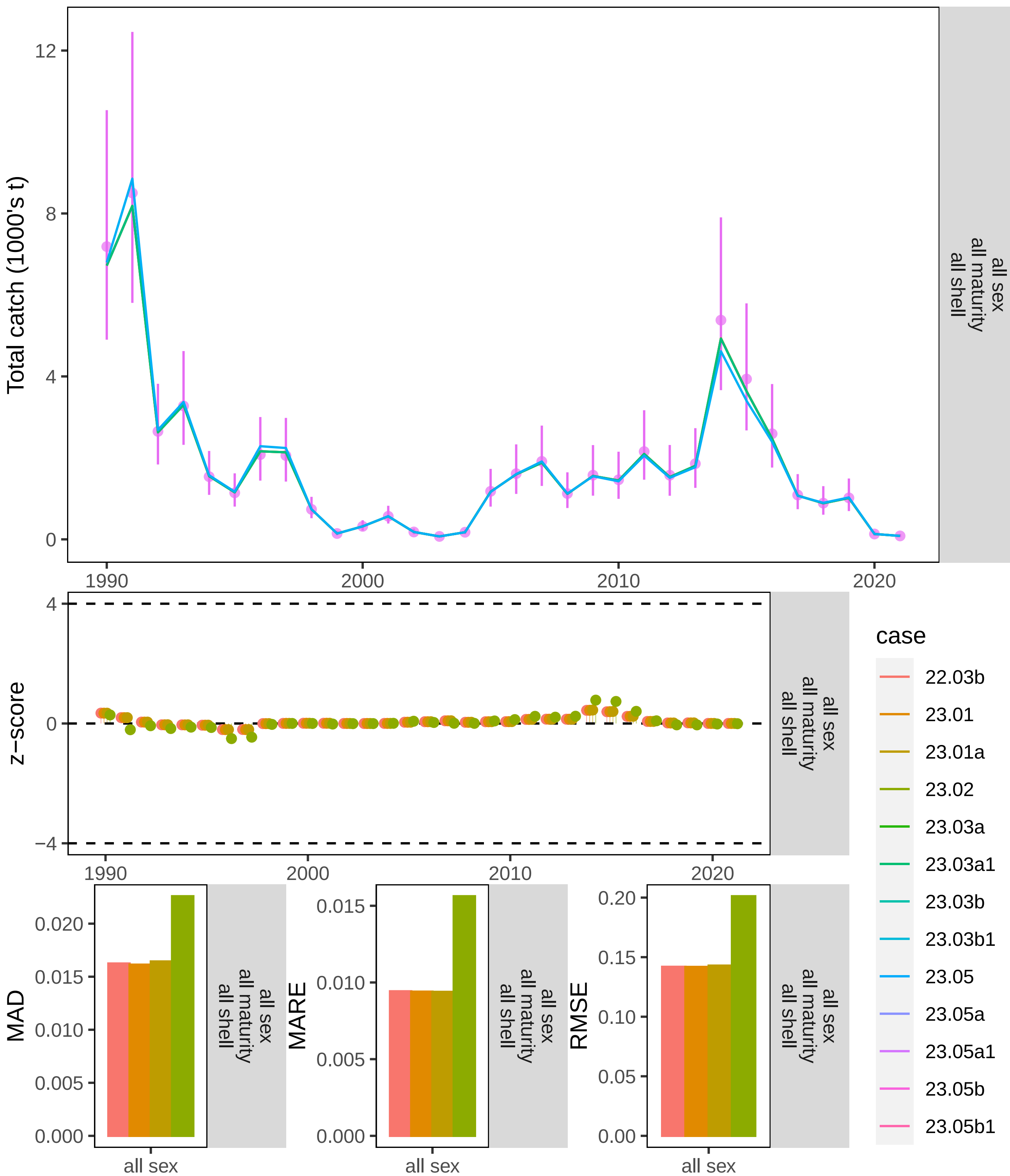

Figure 105. Fits to total catch biomass in the snow crab fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.01, 23.01a, 23.02.

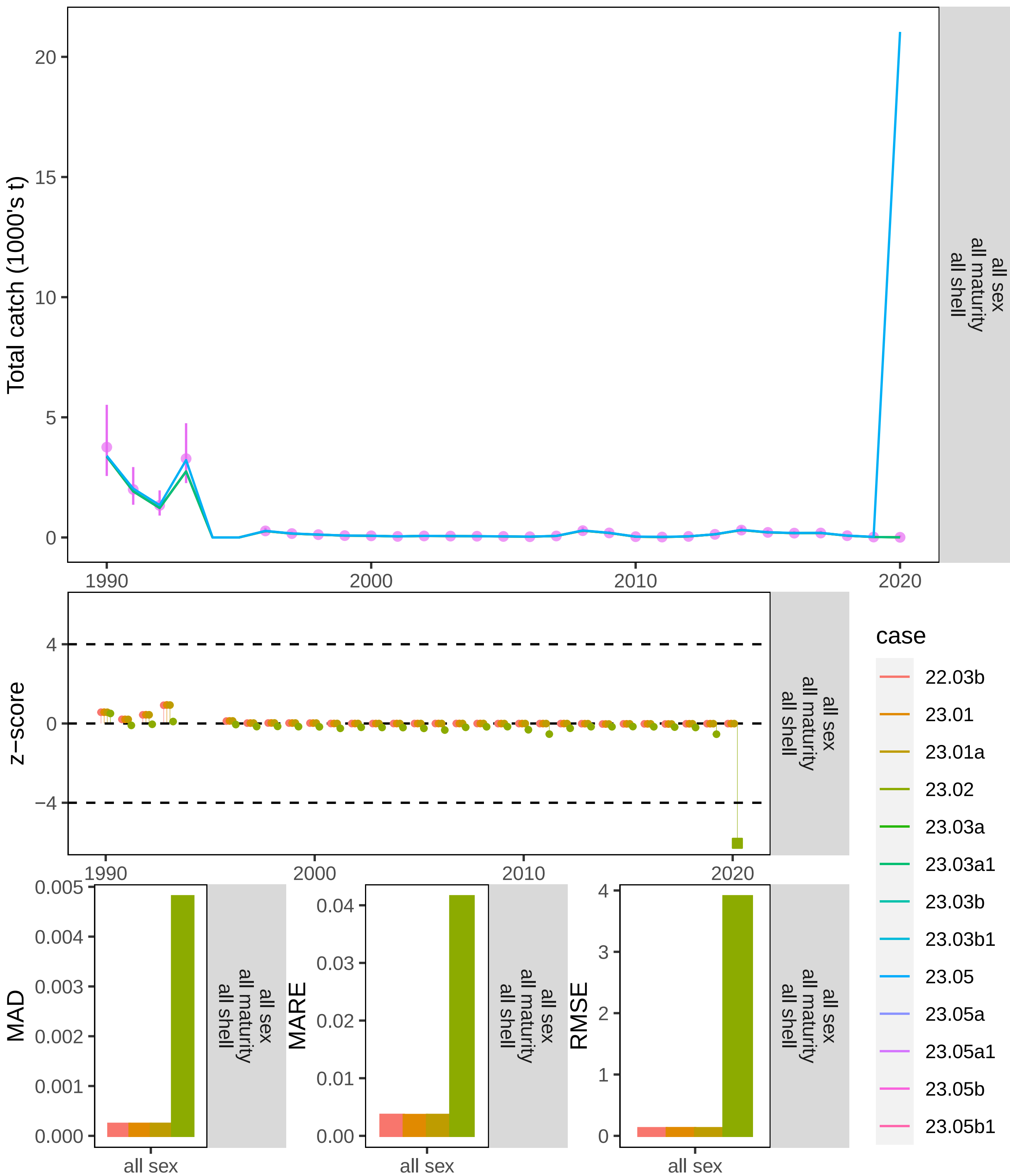

Figure 106. Fits to total catch biomass in the BBRKC fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.01, 23.01a, 23.02.

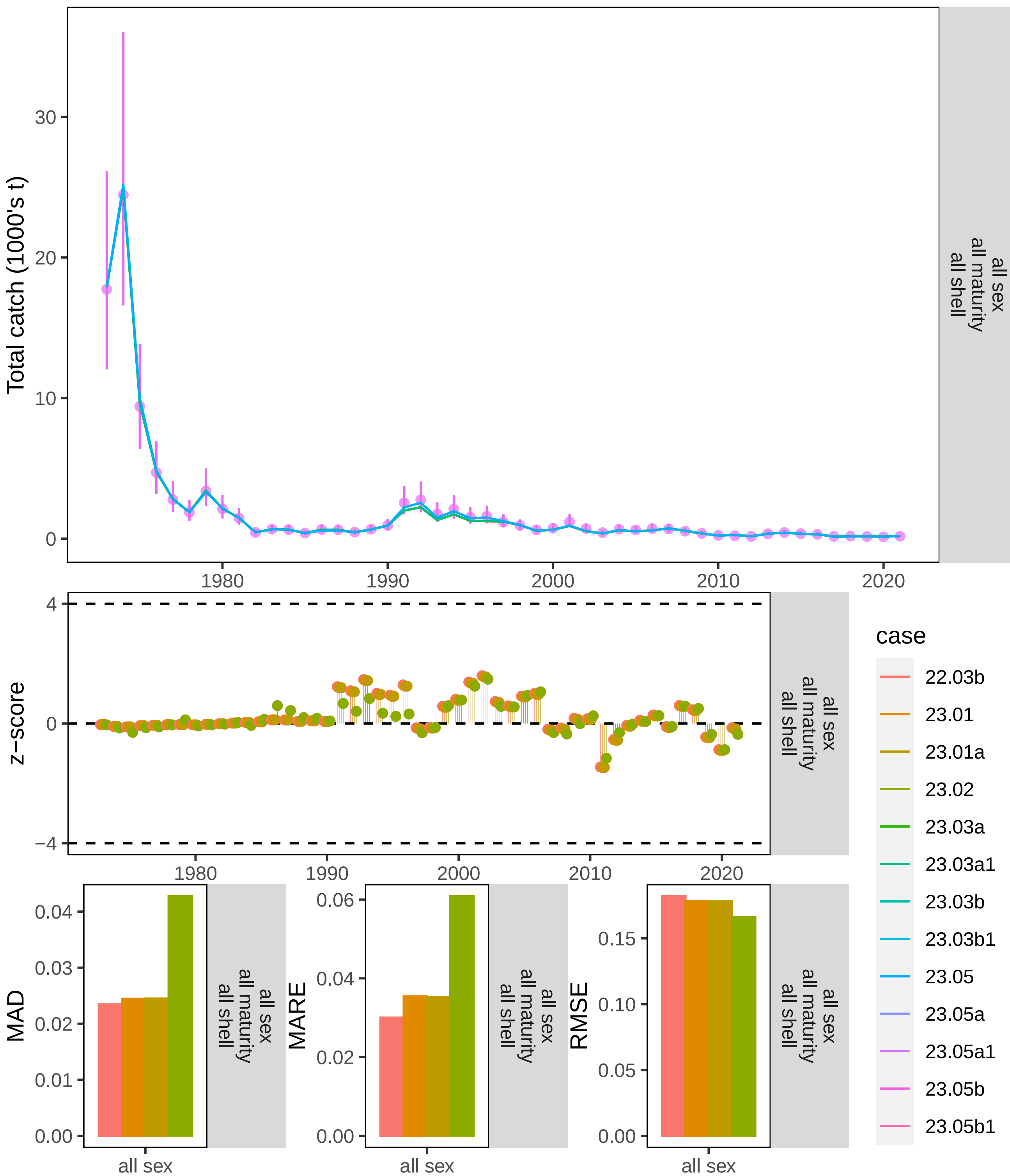

Figure 107. Fits to total catch biomass in the groundfish fisheries (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.01, 23.01a, 23.02.

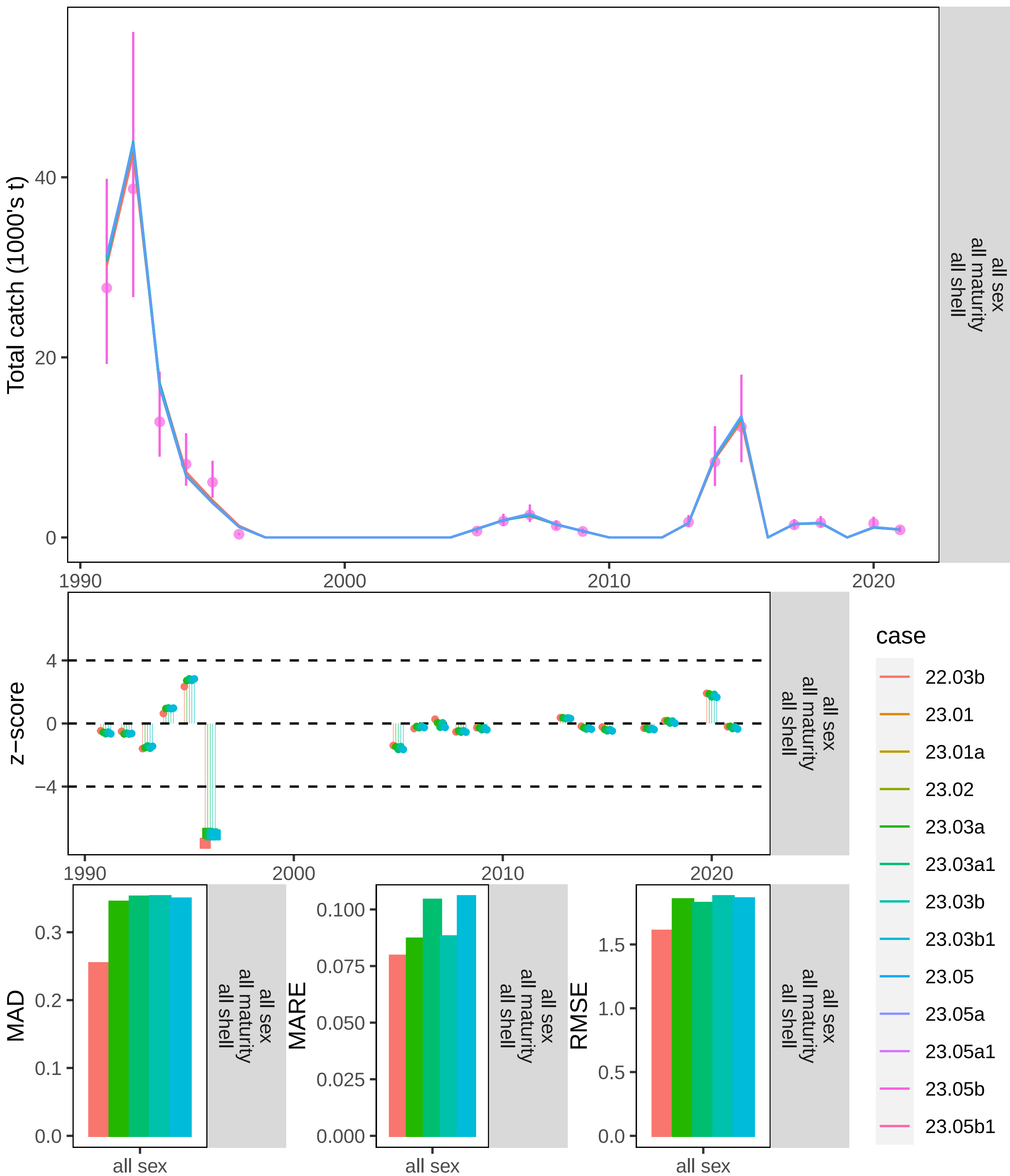

Figure 108. Fits to total catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

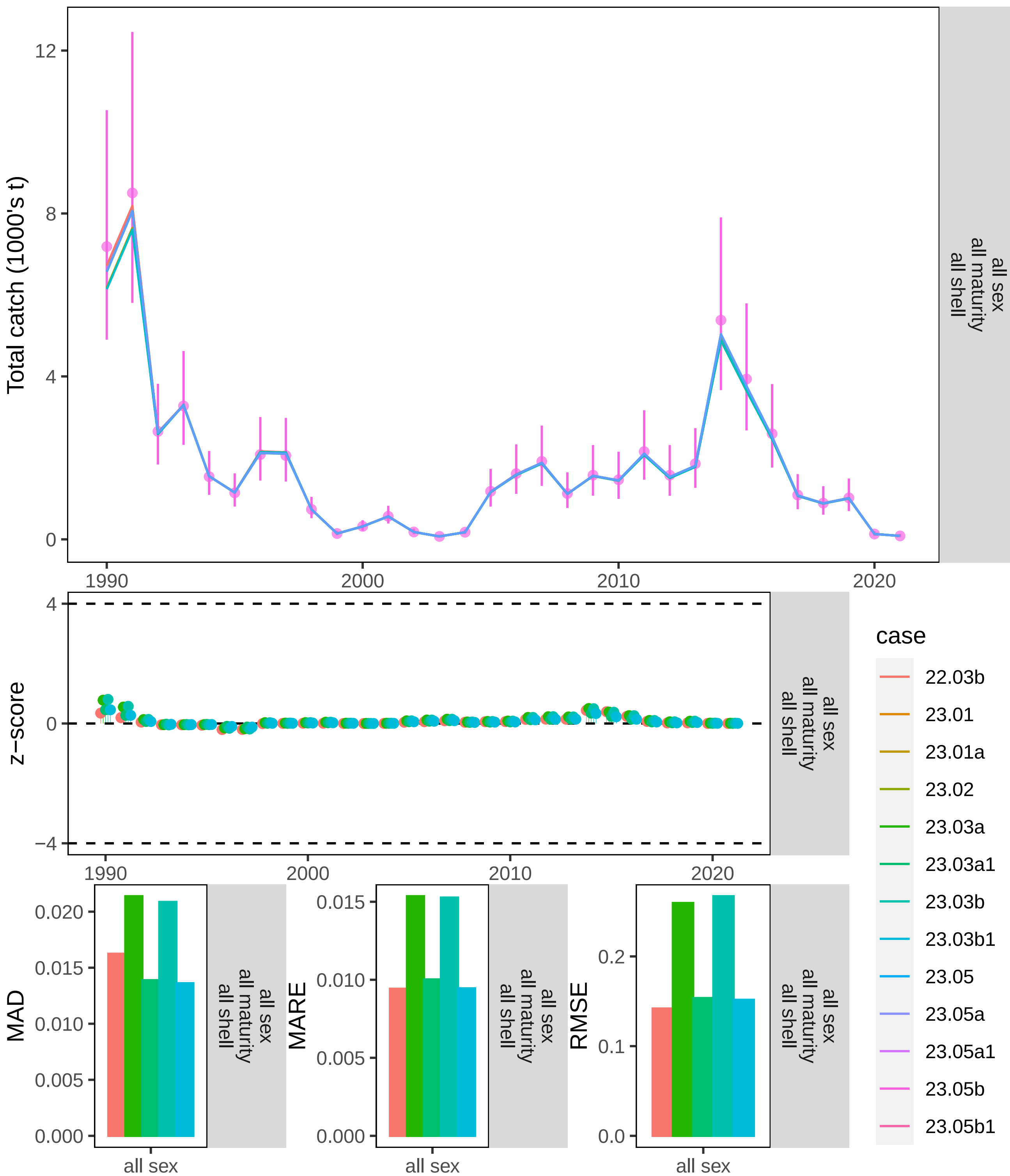

Figure 109. Fits to total catch biomass in the snow crab fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

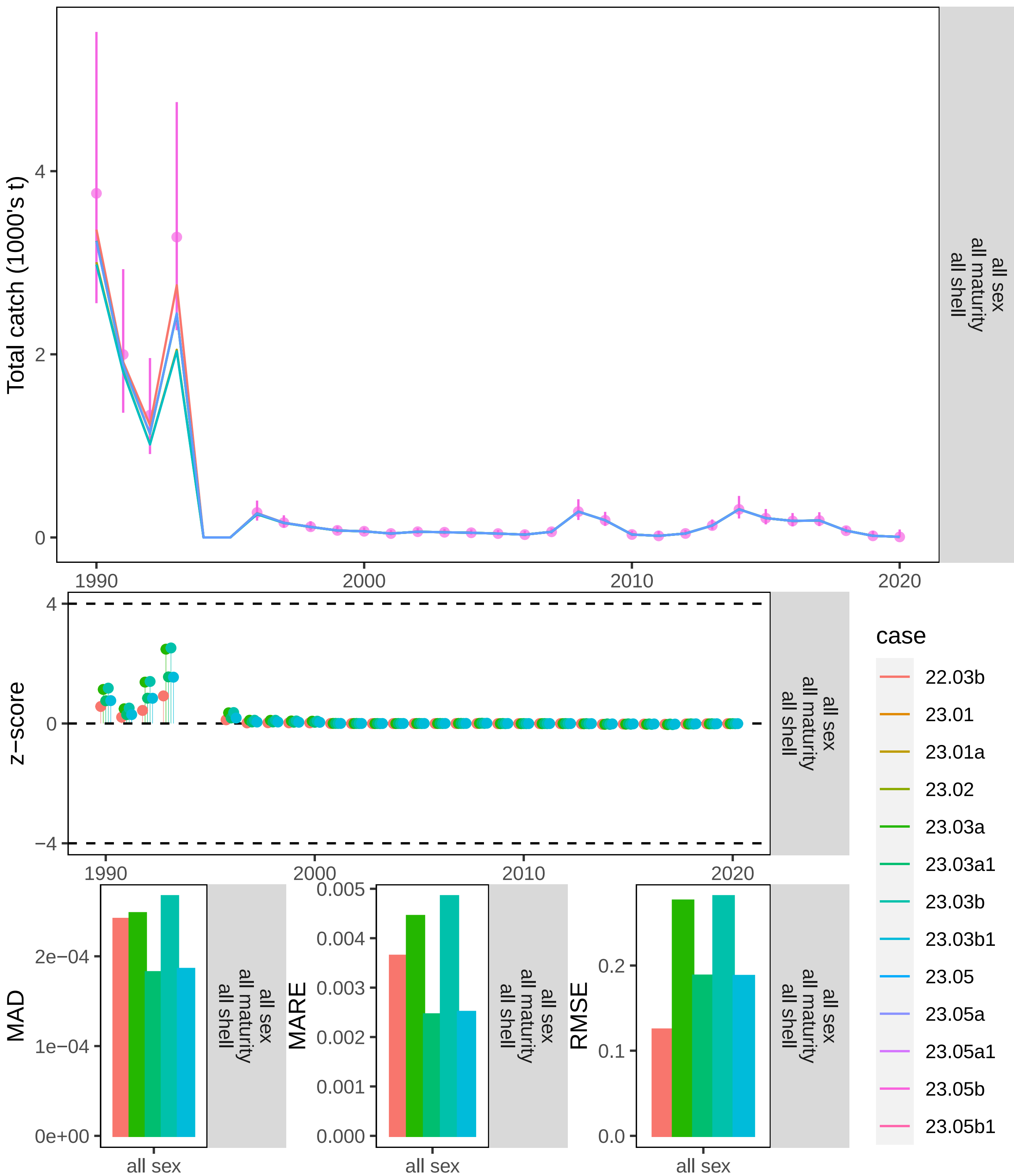

Figure 110. Fits to total catch biomass in the BBRKC fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

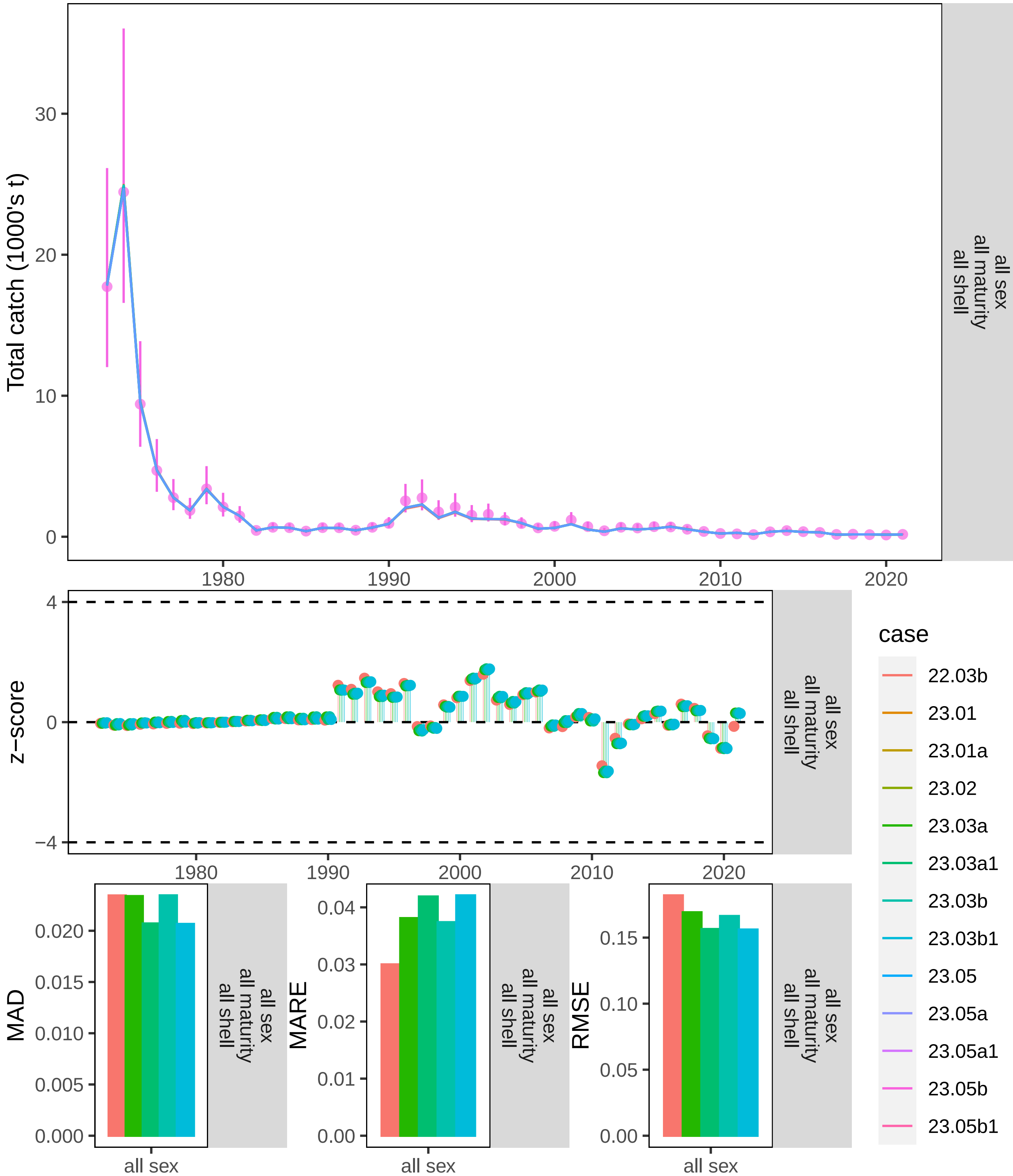

Figure 111. Fits to total catch biomass in the groundfish fisheries (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

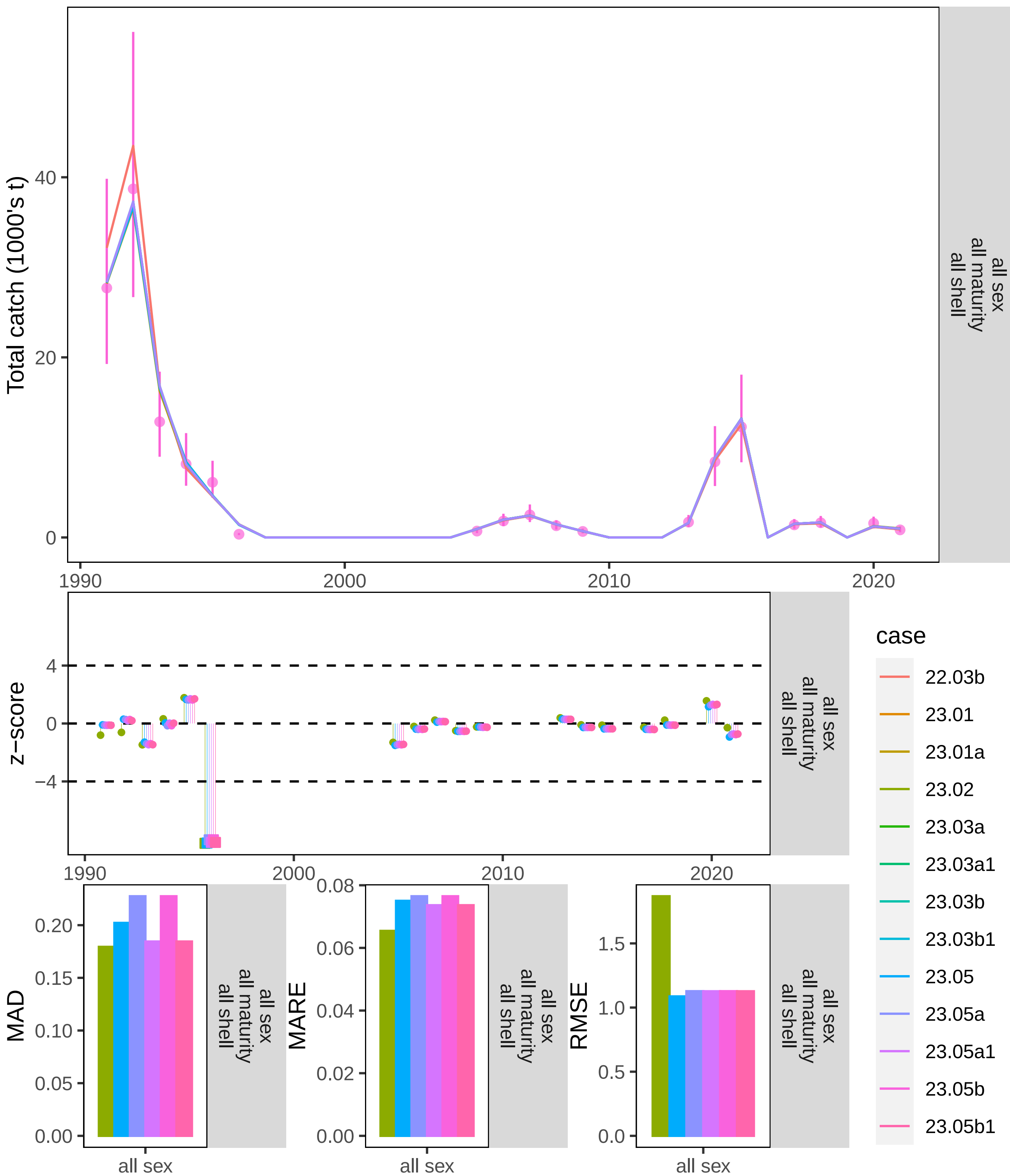

Figure 112. Fits to total catch biomass in the directed fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

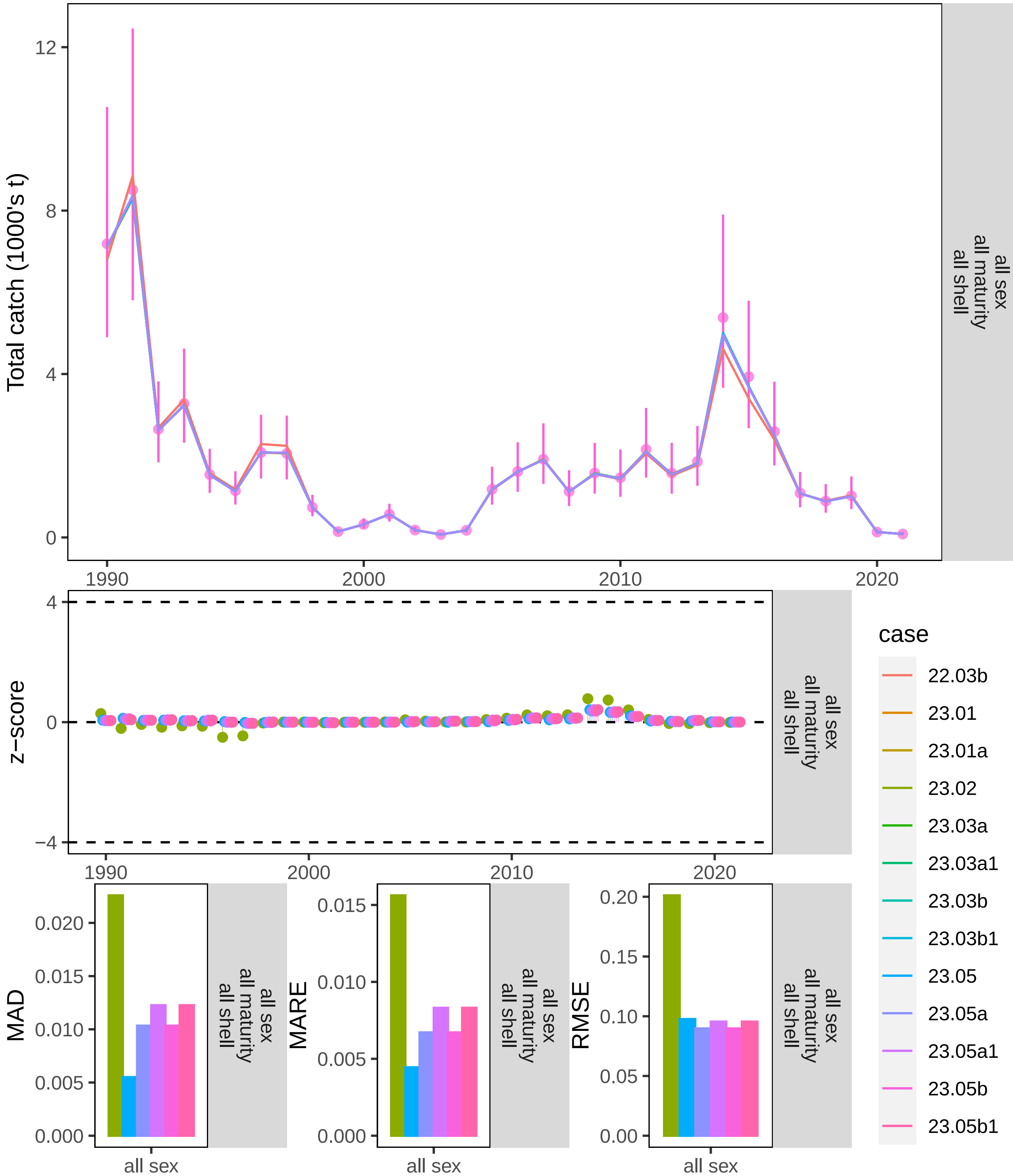

Figure 113. Fits to total catch biomass in the snow crab fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

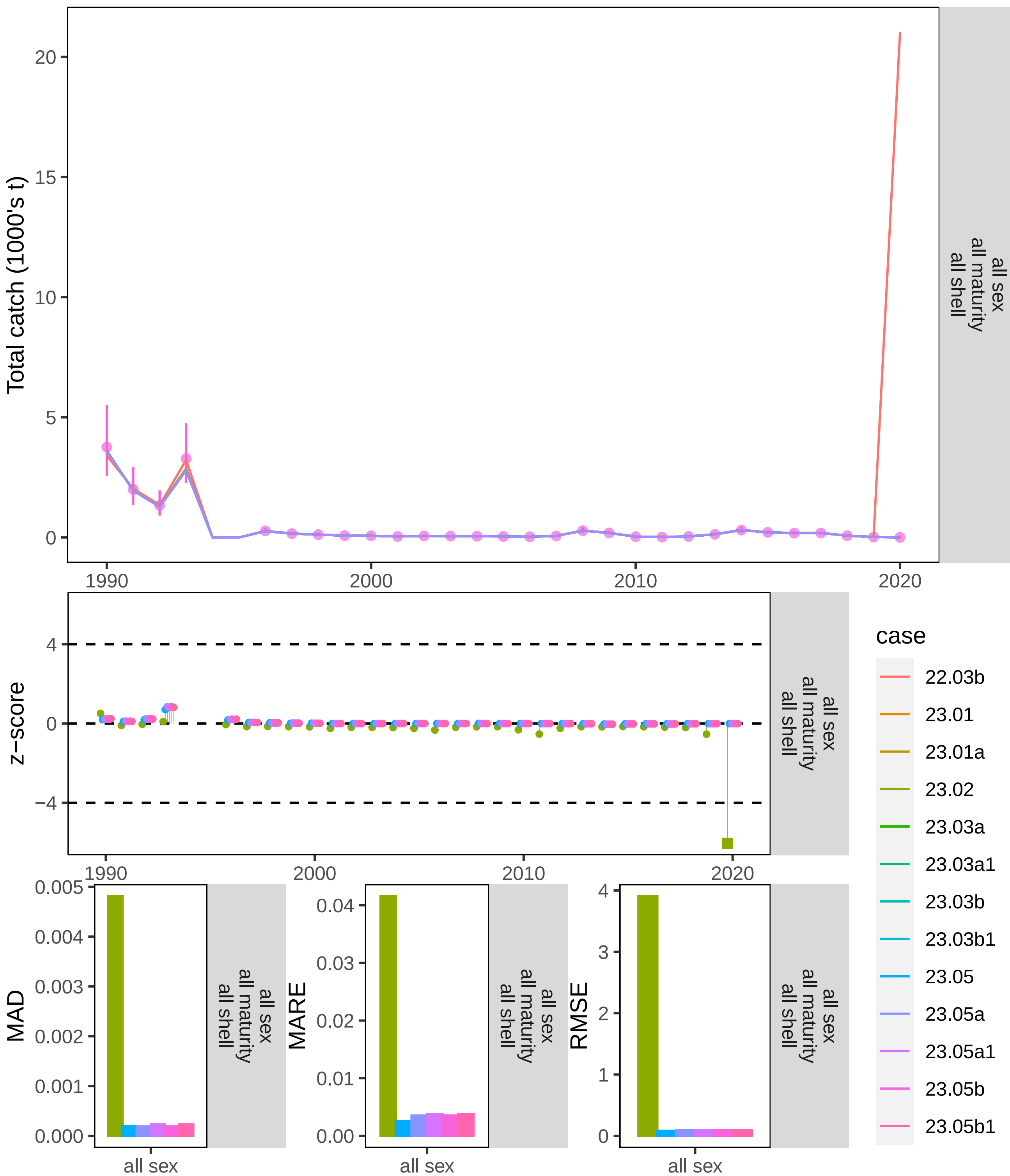

Figure 114. Fits to total catch biomass in the BBRKC fishery (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

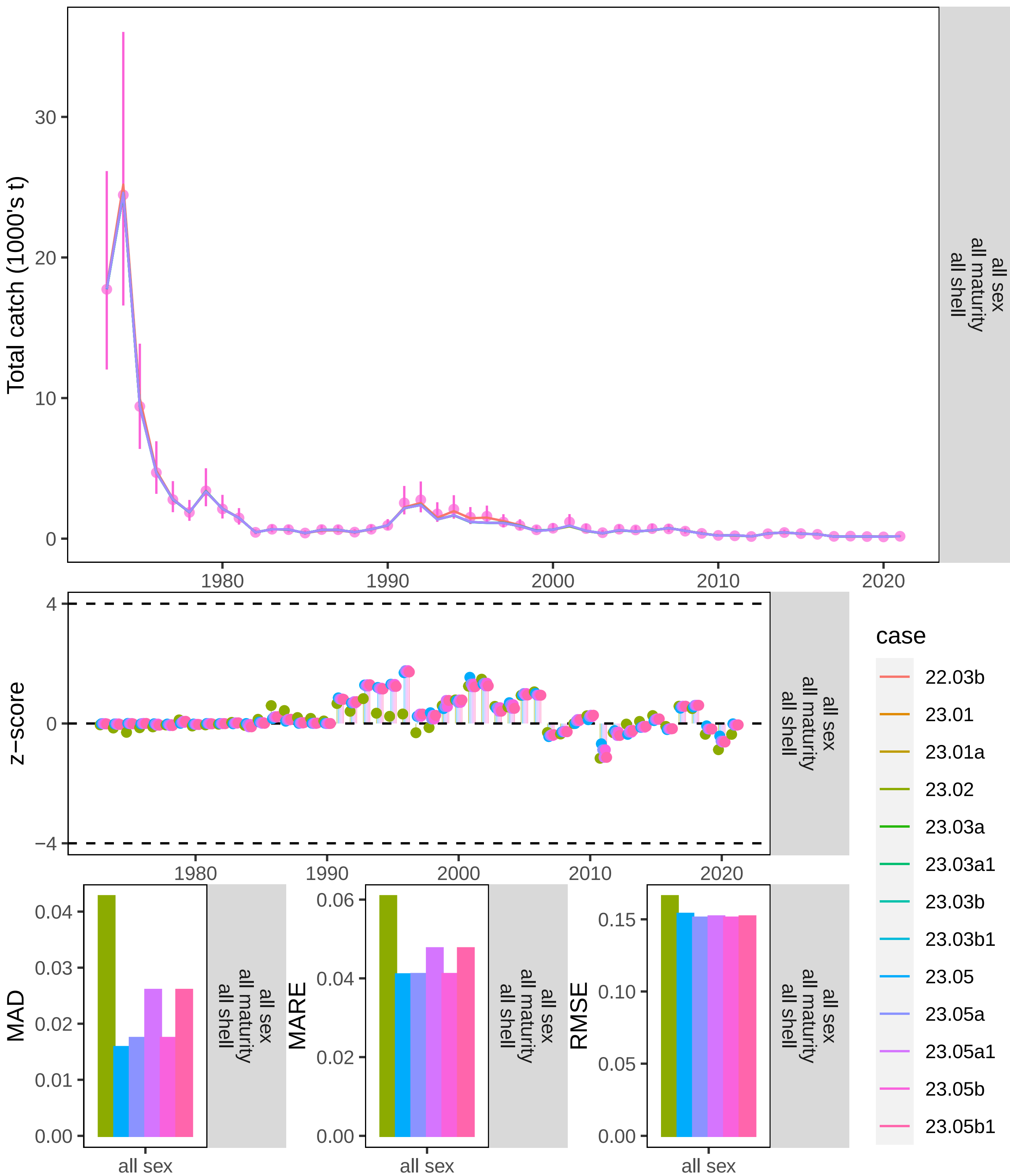

Figure 115. Fits to total catch biomass in the groundfish fisheries (upper two rows) and residuals analysis plots (lower two rows). Confidence intervals are 95%. Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

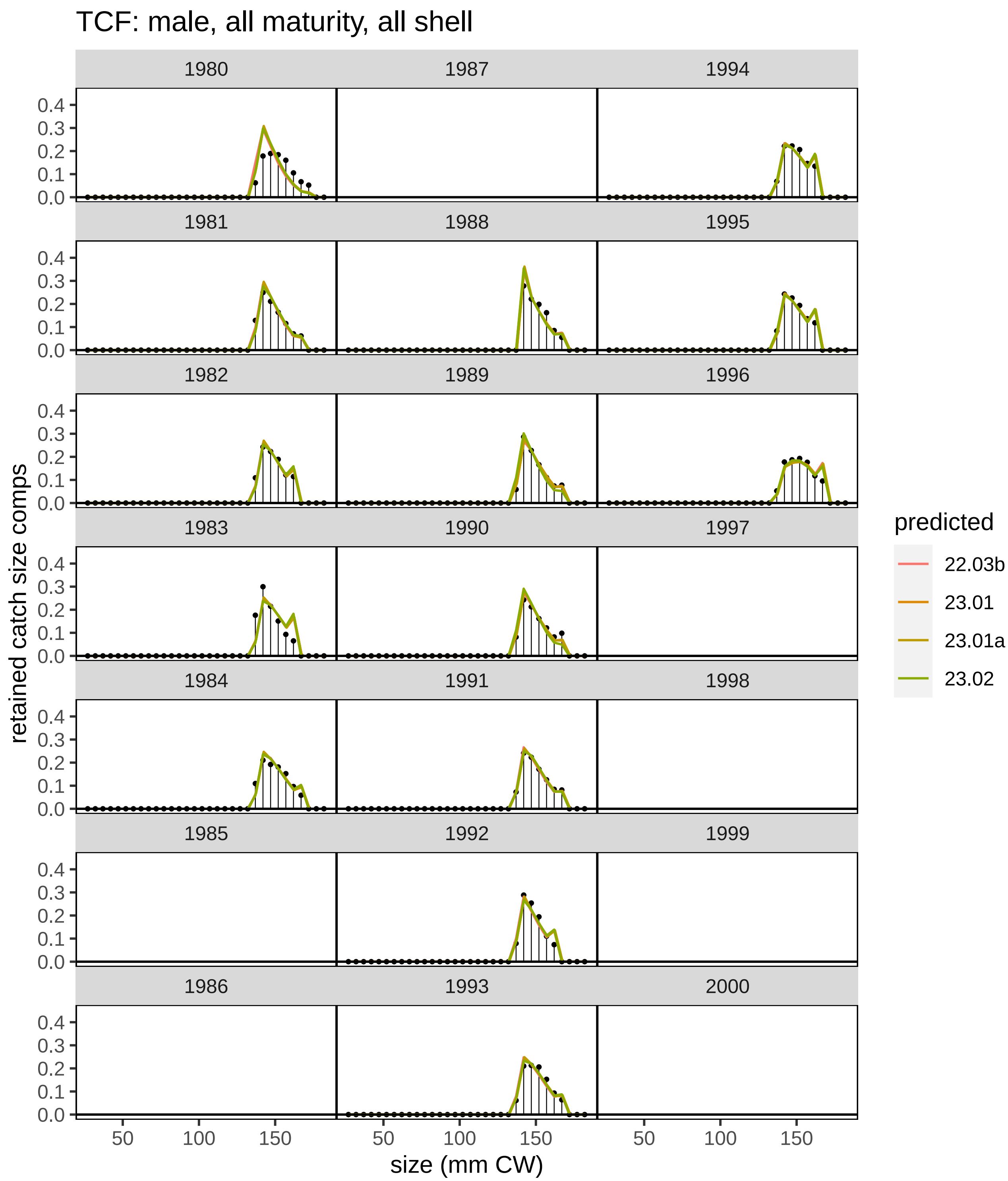

Figure 116. Fits to fishery retained catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

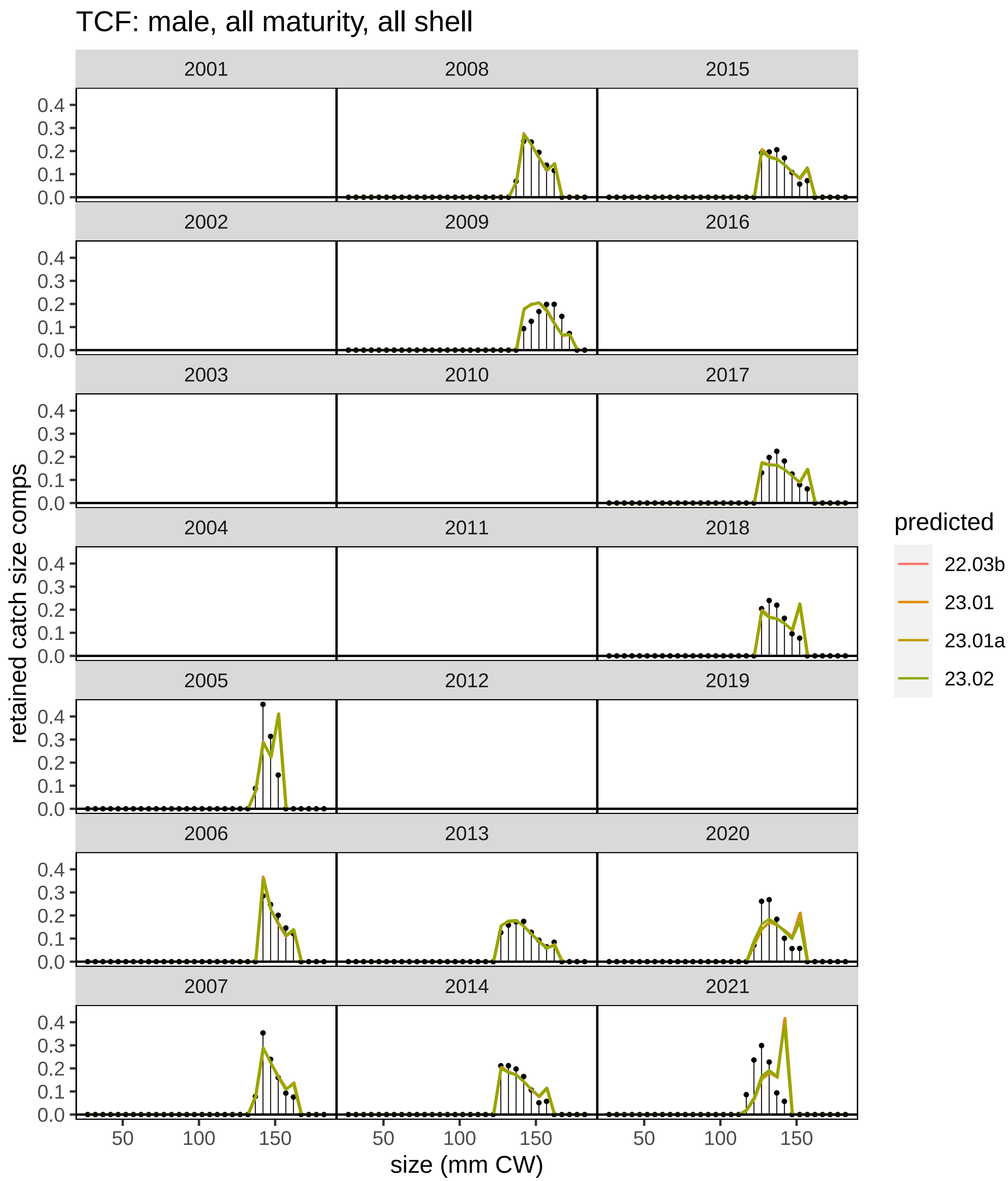

Figure 117. Fits to fishery retained catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

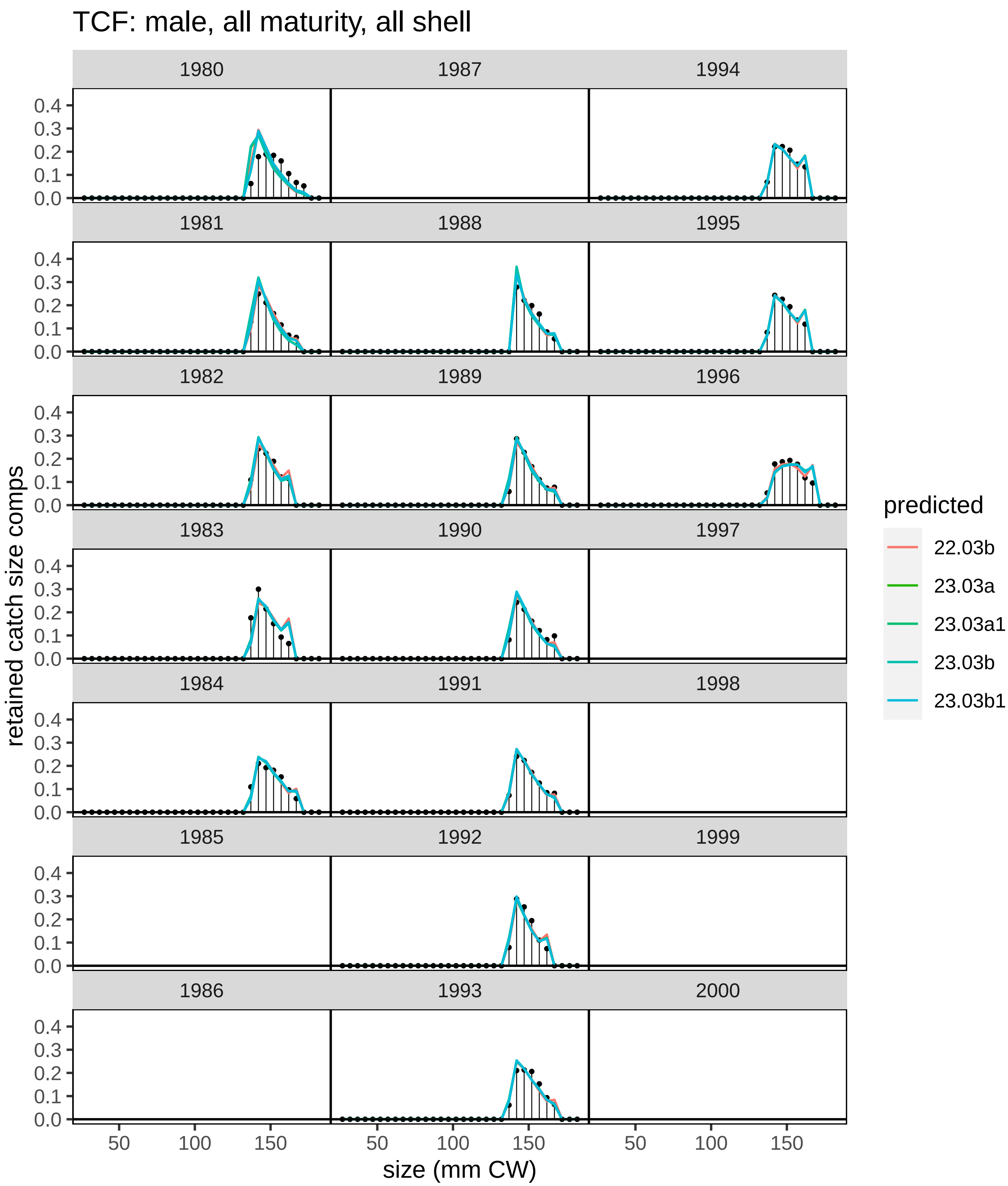

Figure 118. Fits to fishery retained catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

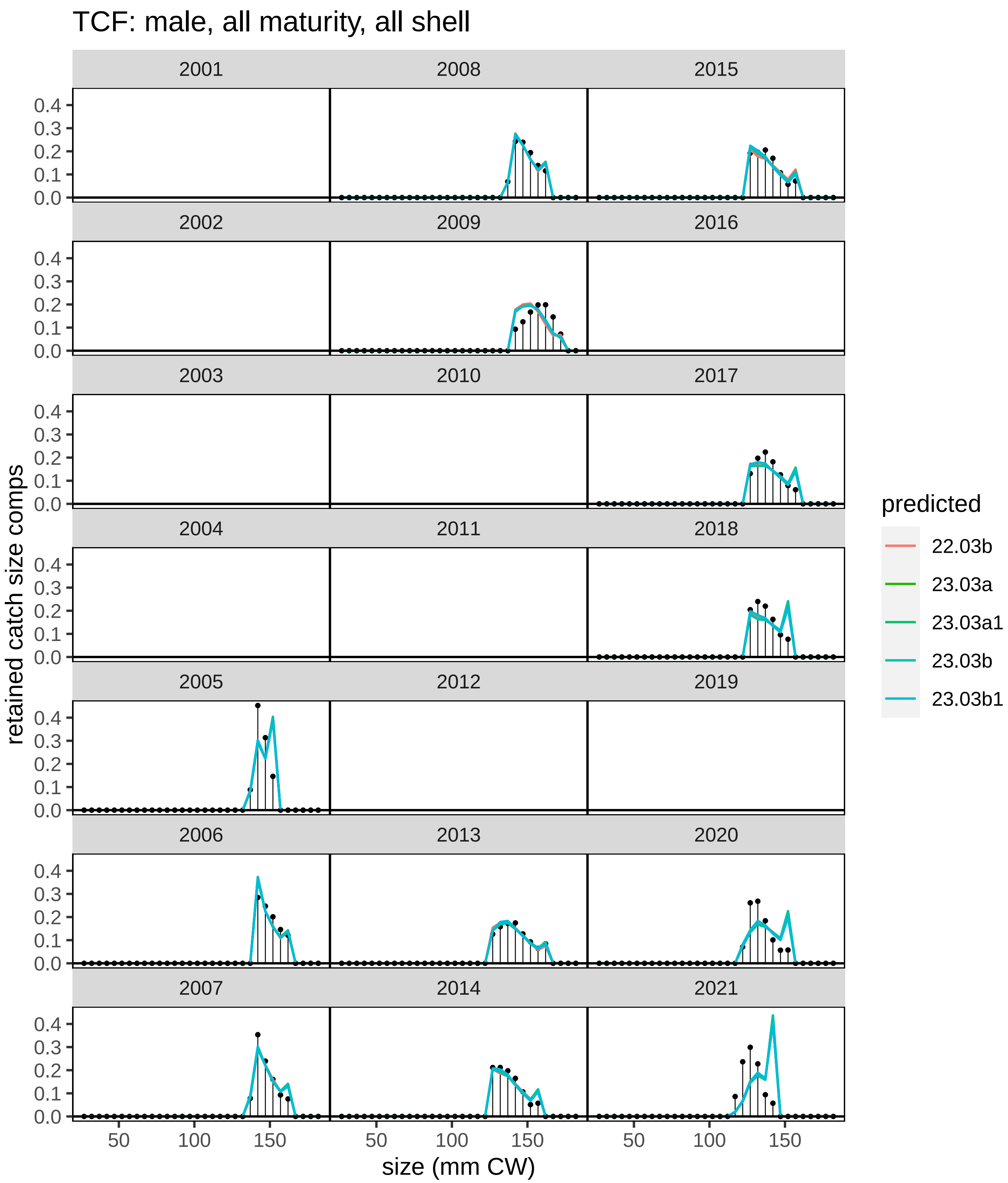

Figure 119. Fits to fishery retained catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

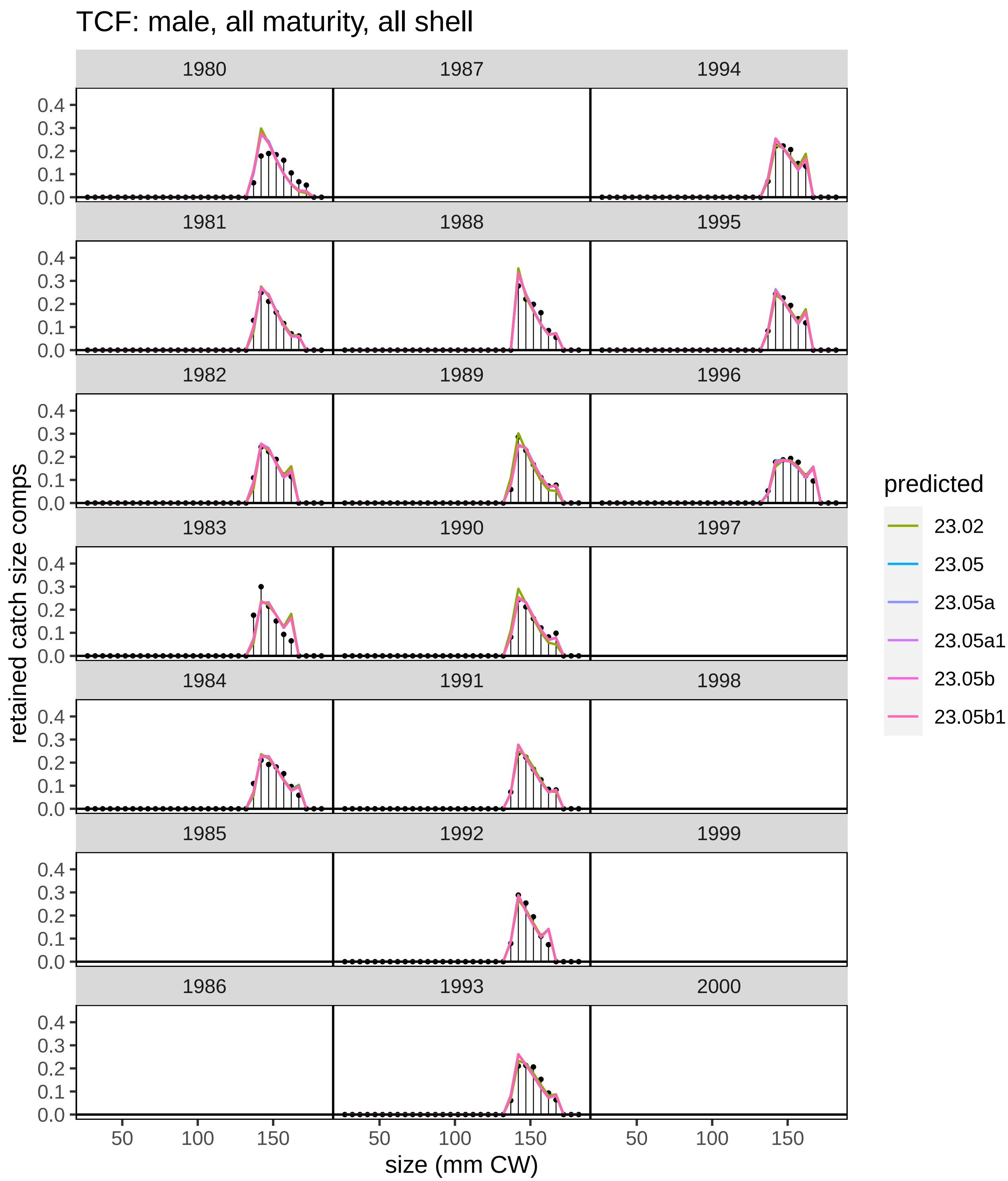

Figure 120. Fits to fishery retained catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

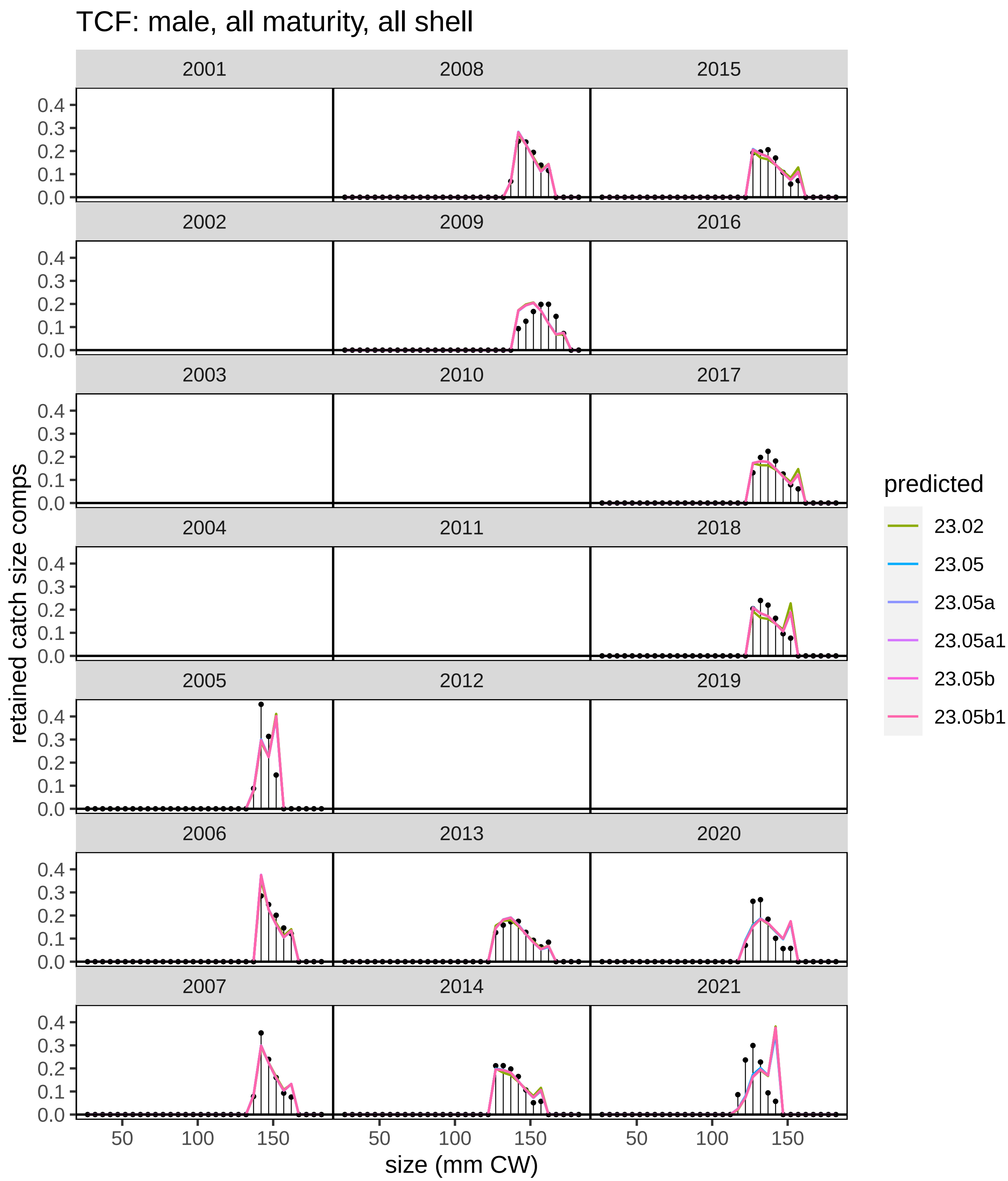

Figure 121. Fits to fishery retained catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

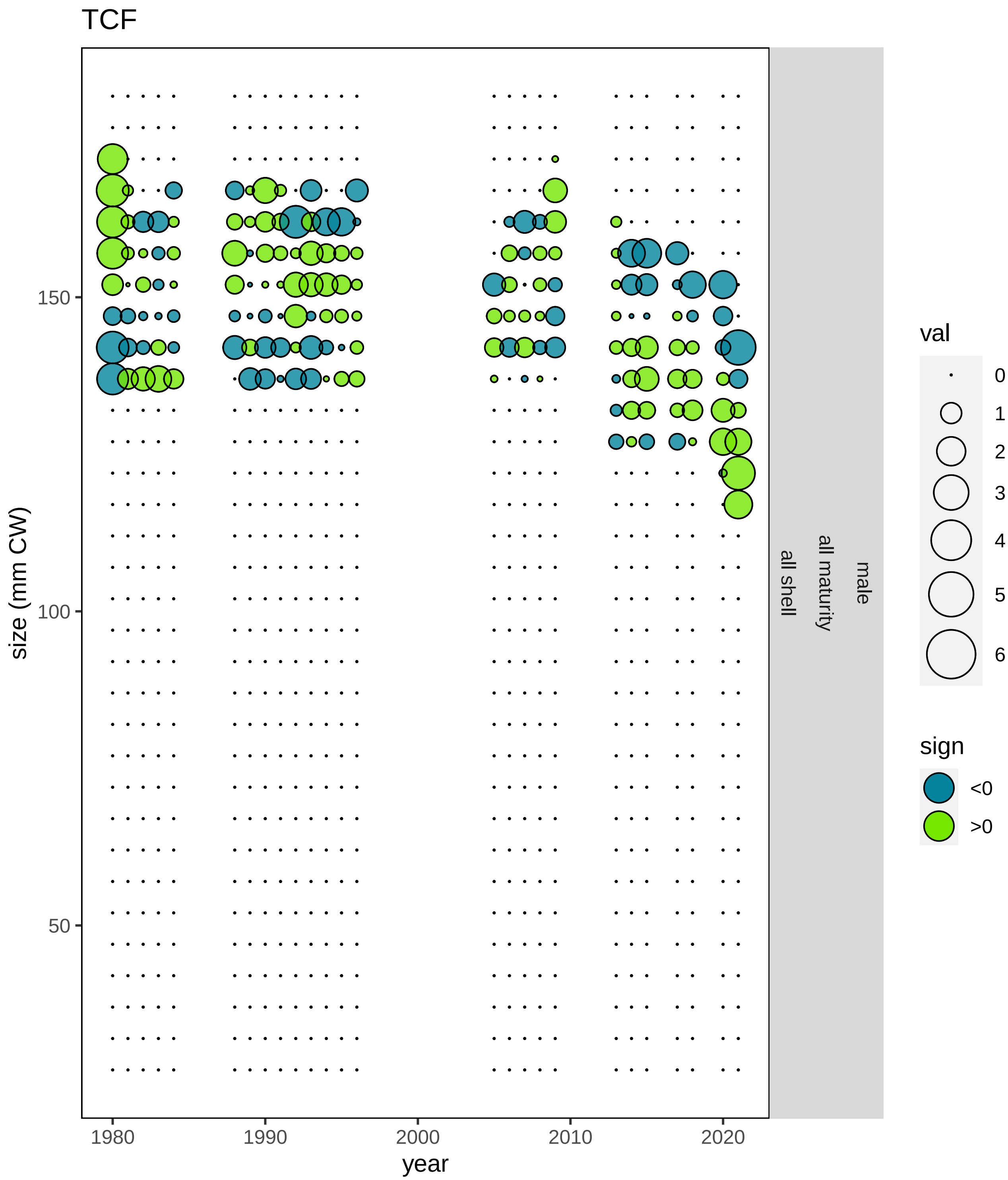

Figure 122. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

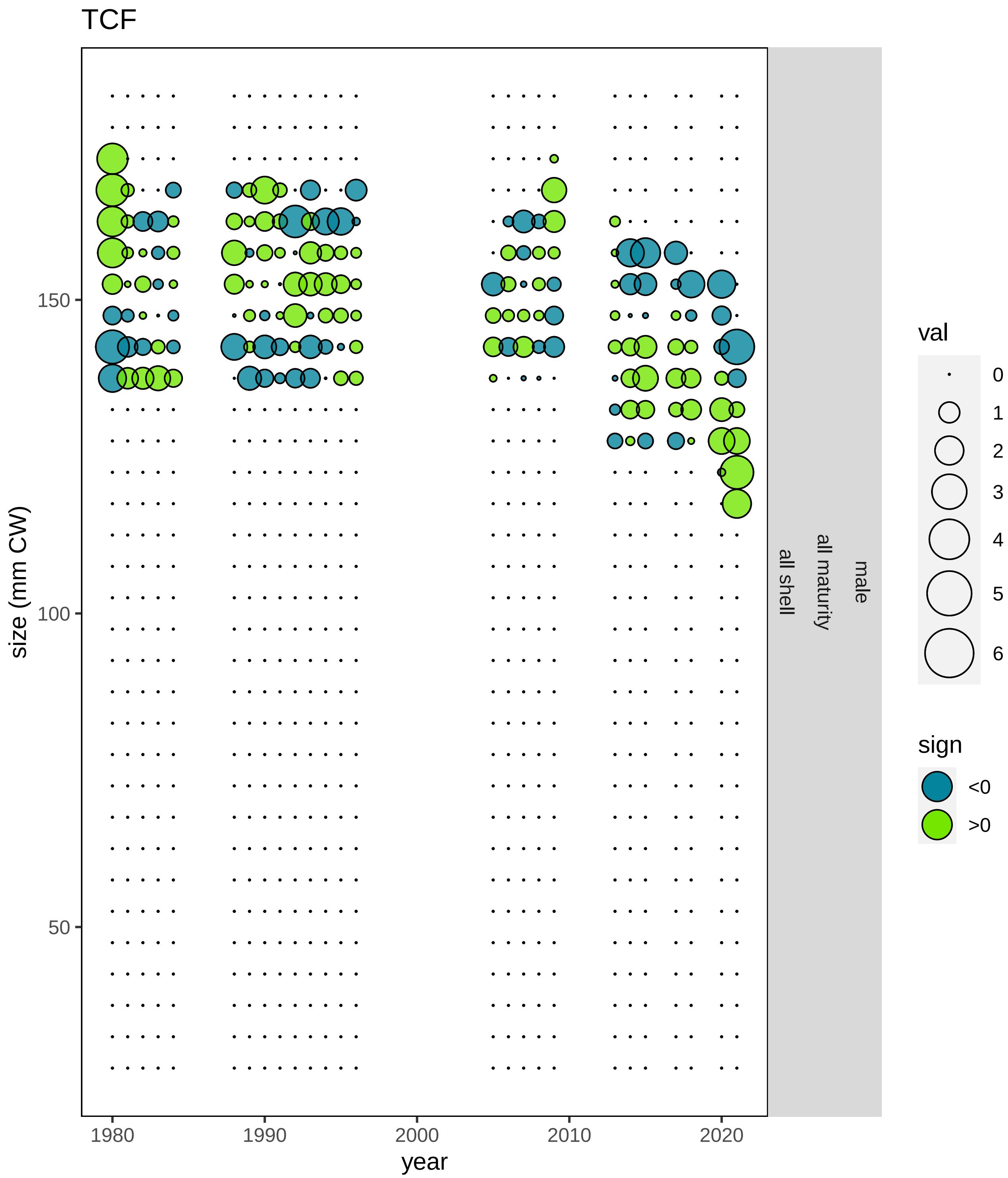

Figure 123. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

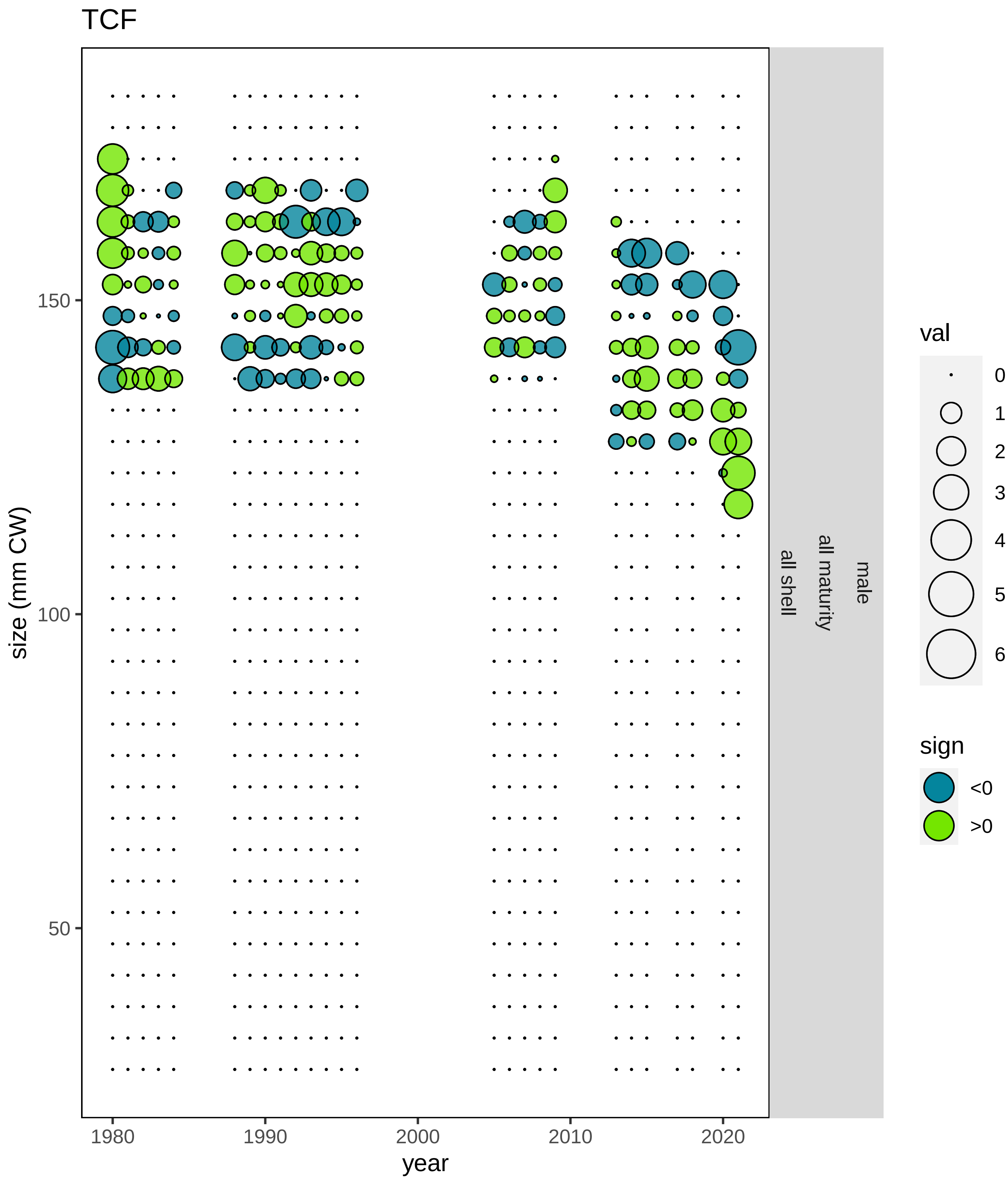

Figure 124. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

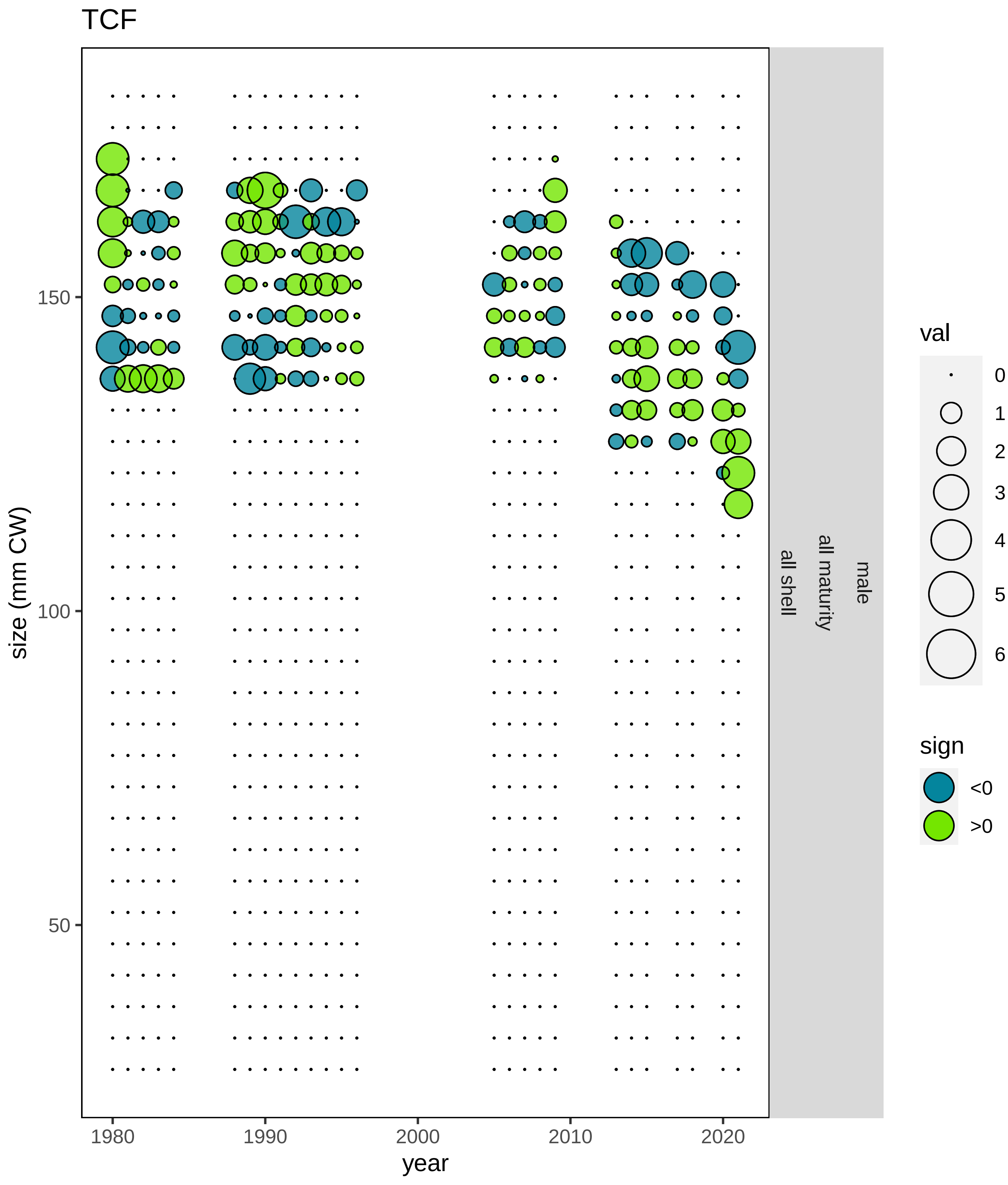

Figure 125. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

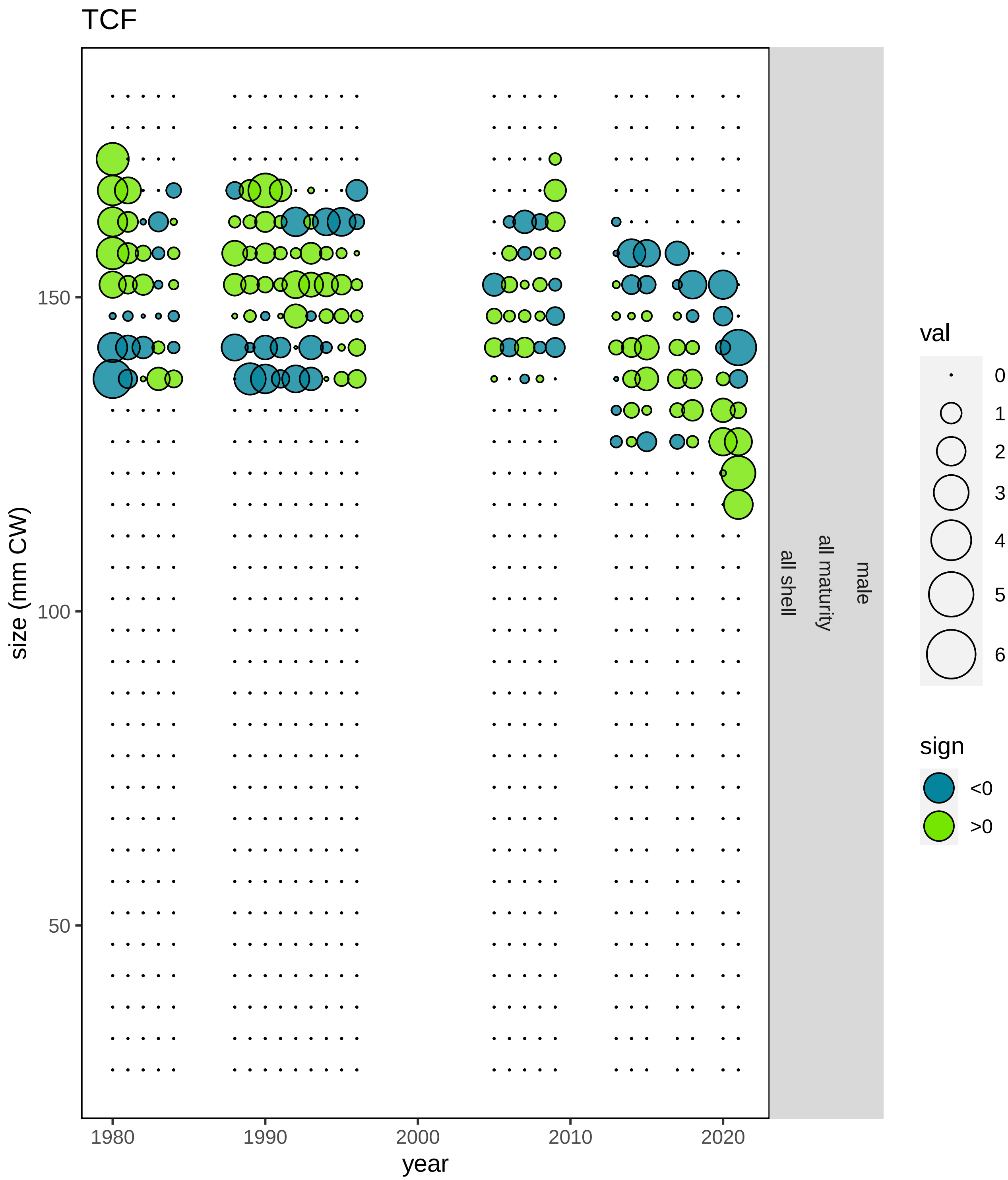

Figure 126. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

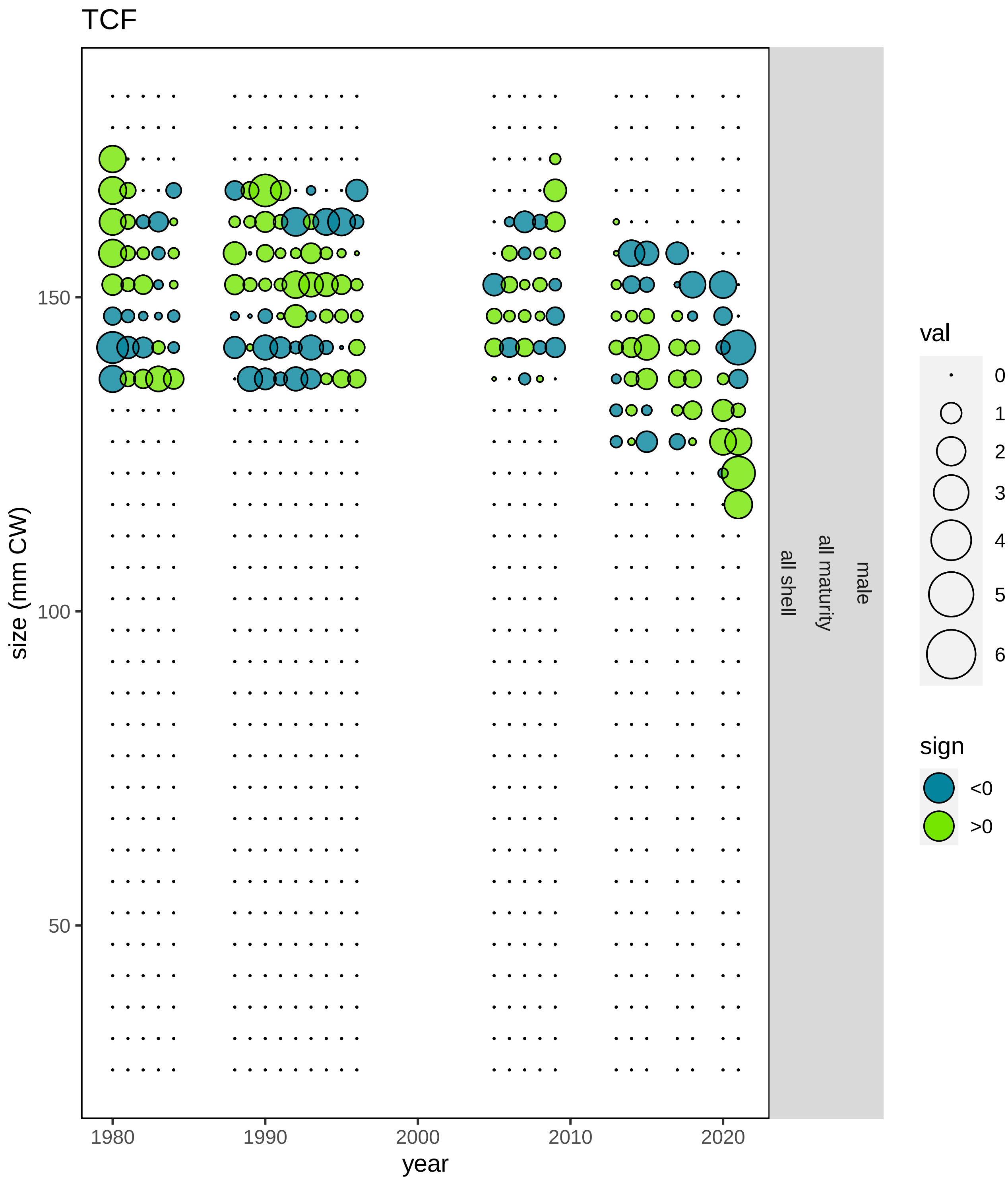

Figure 127. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

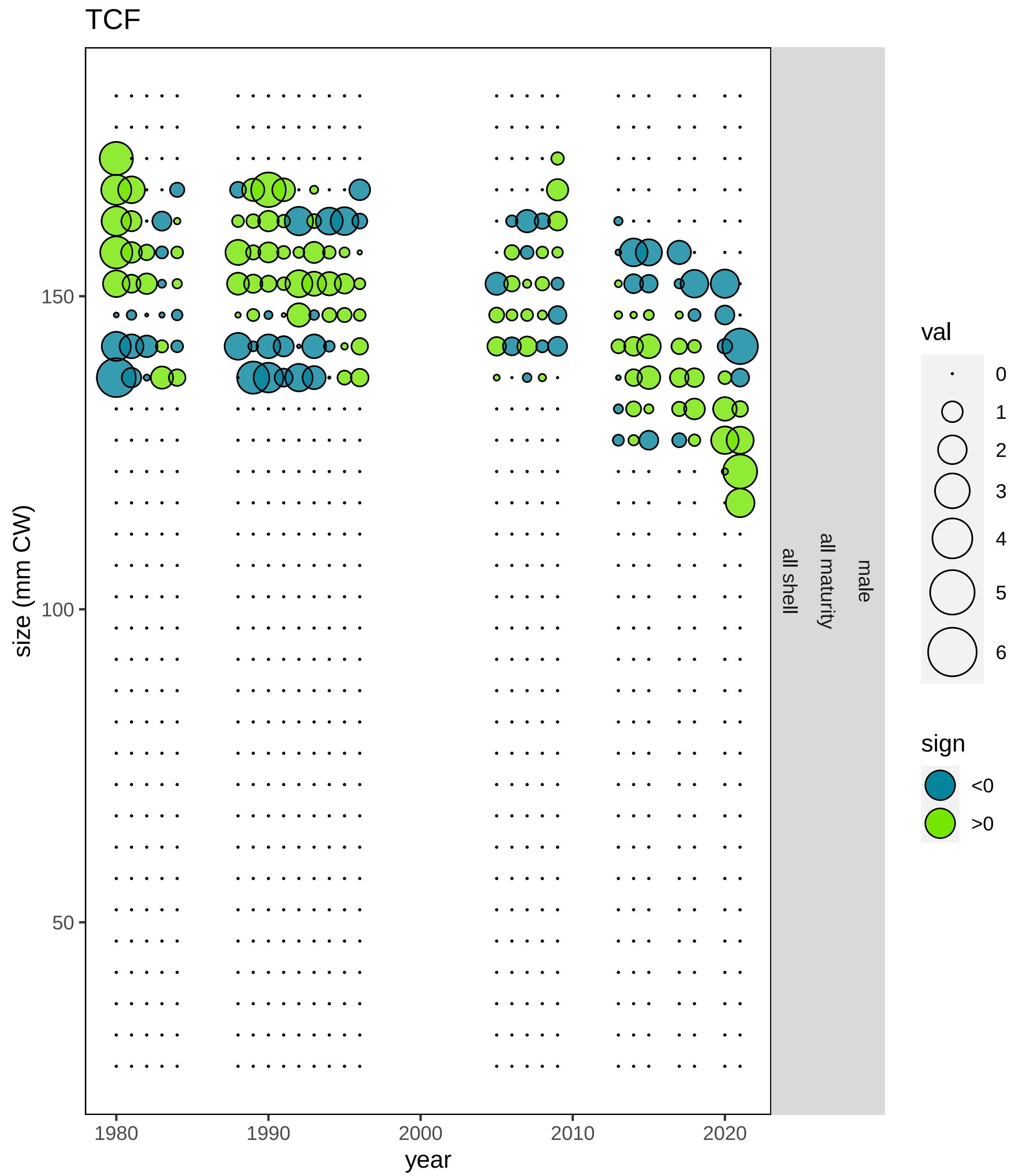

Figure 128. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

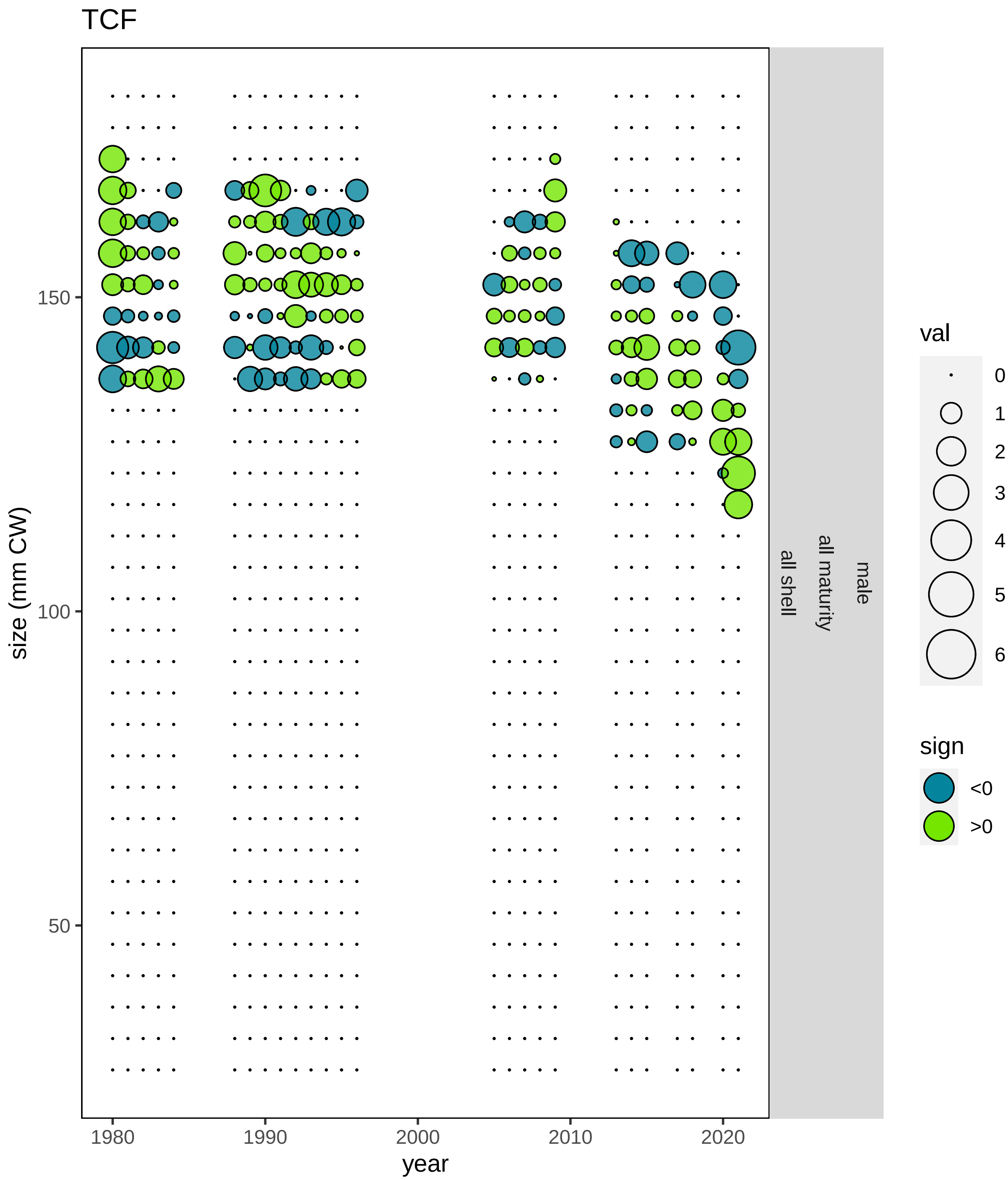

Figure 129. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

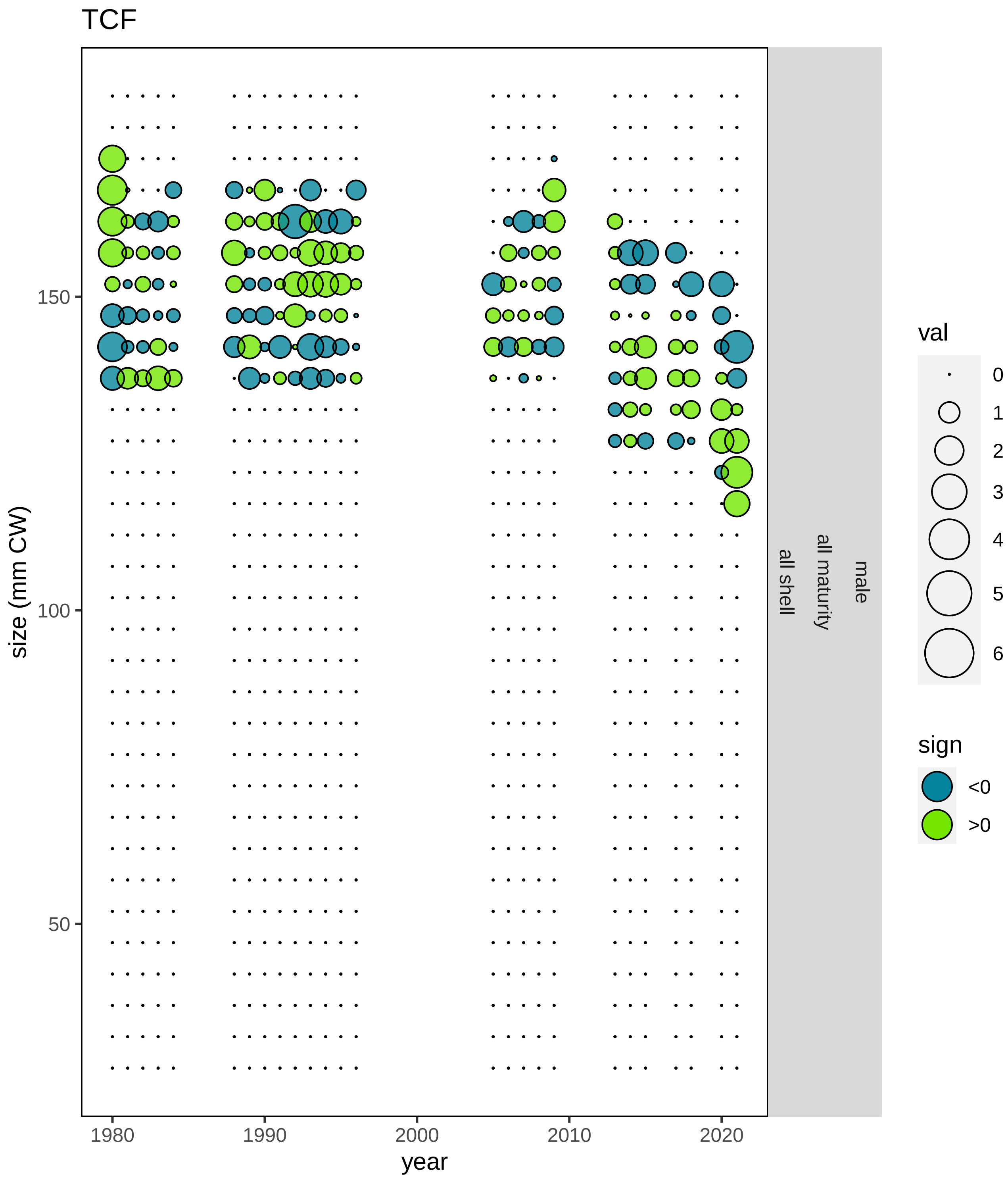

Figure 130. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

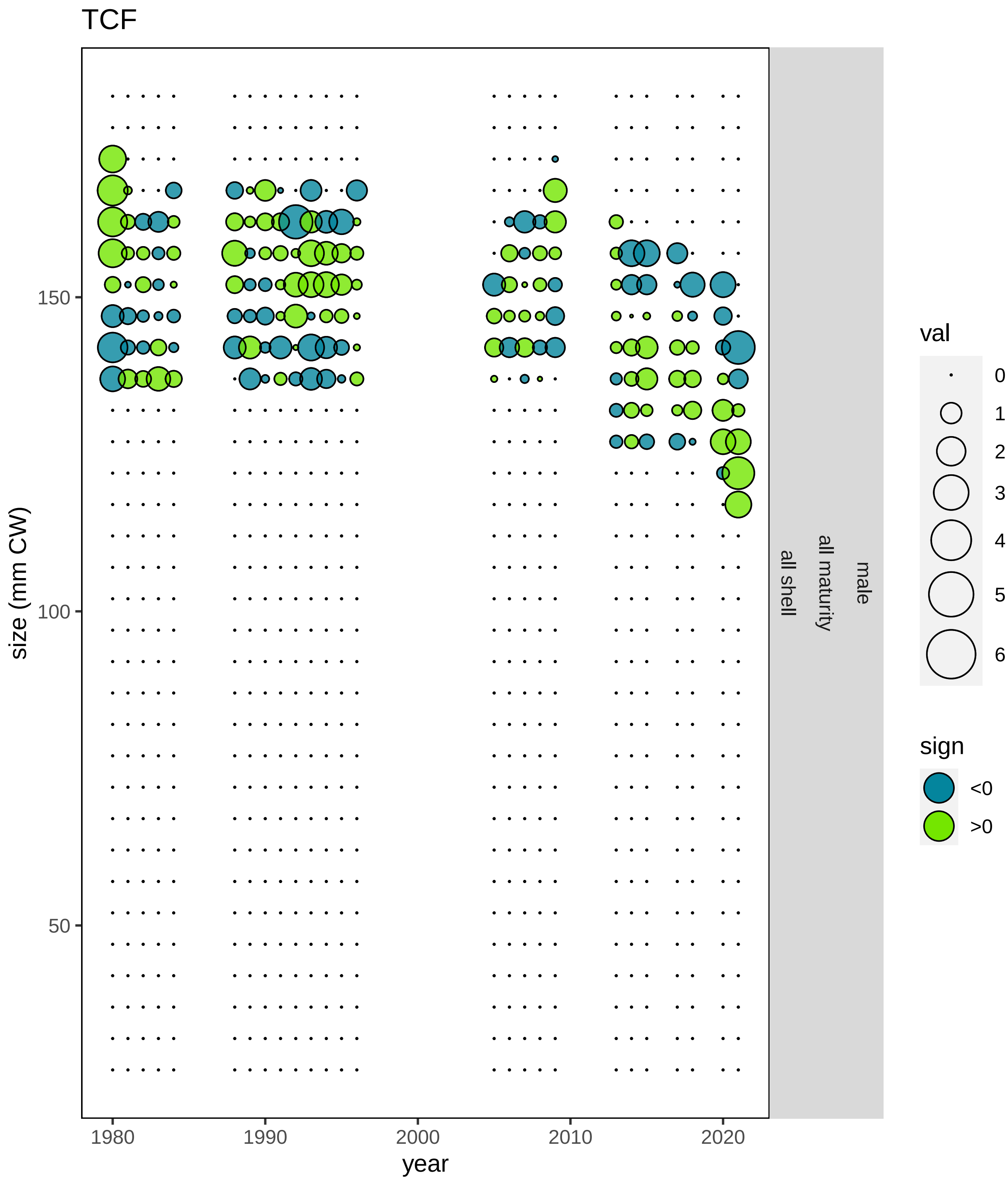

Figure 131. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

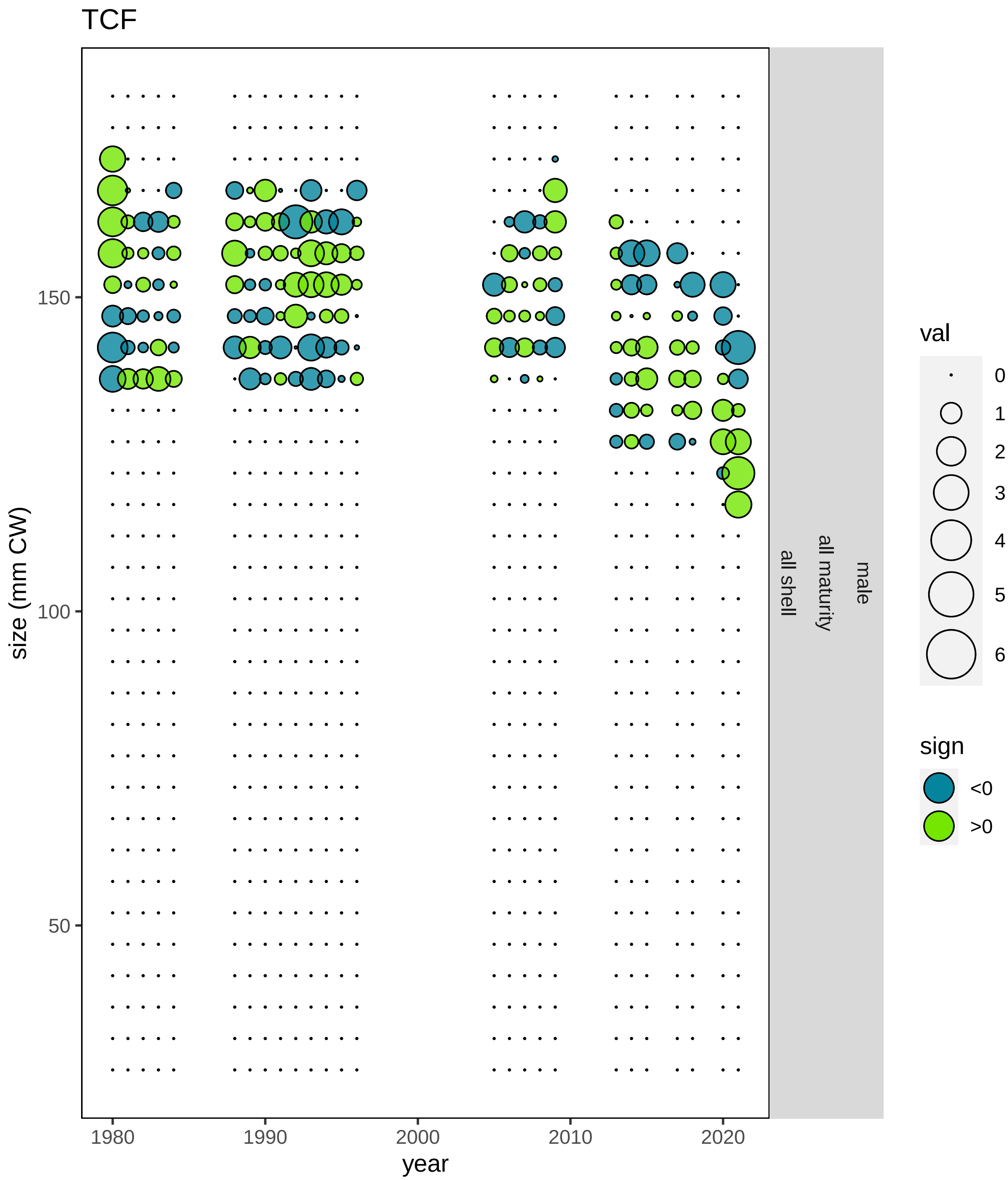

Figure 132. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

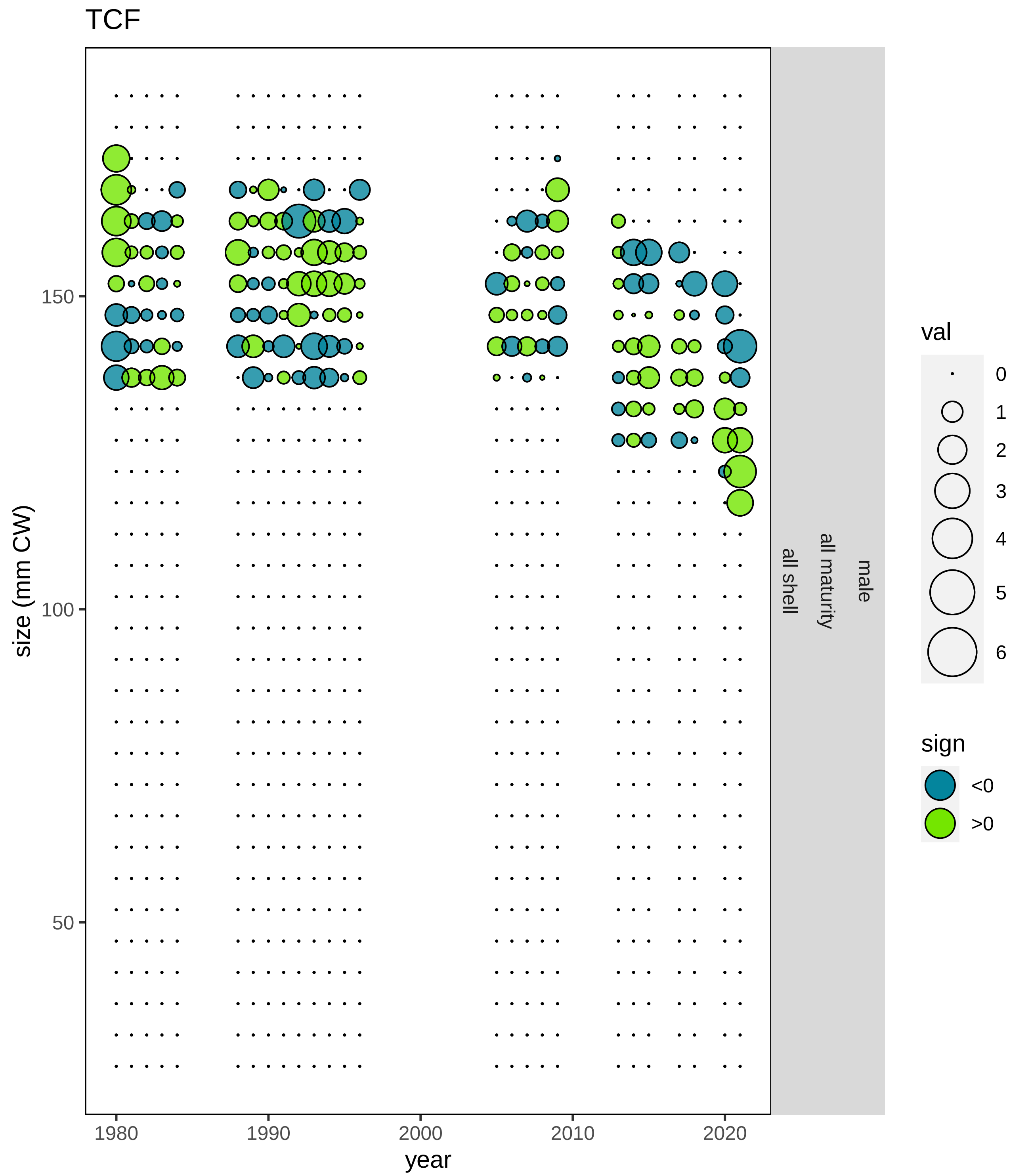

Figure 133. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

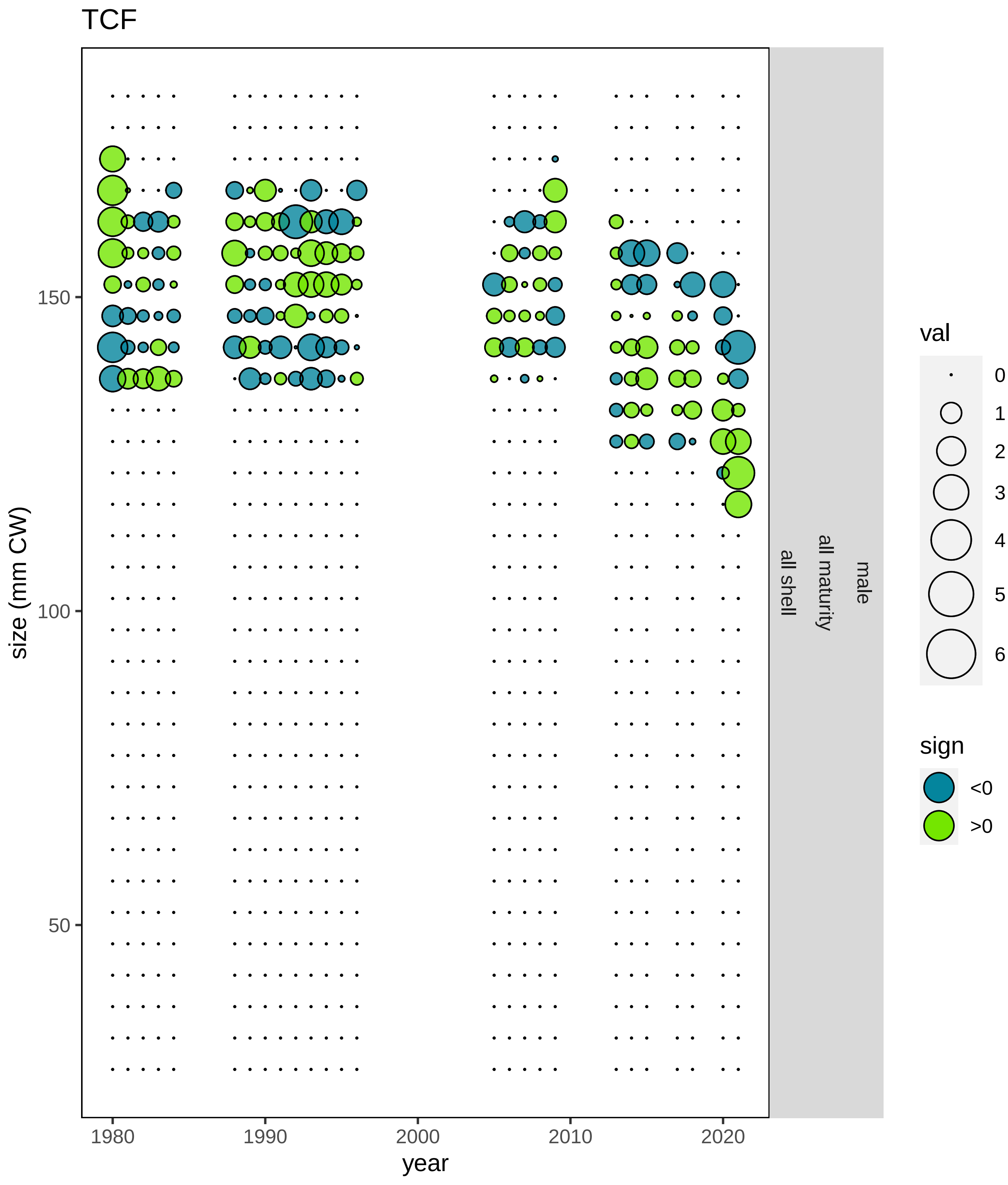

Figure 134. Pearson's residuals for fits to fishery retained catch size composition data from the TCF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

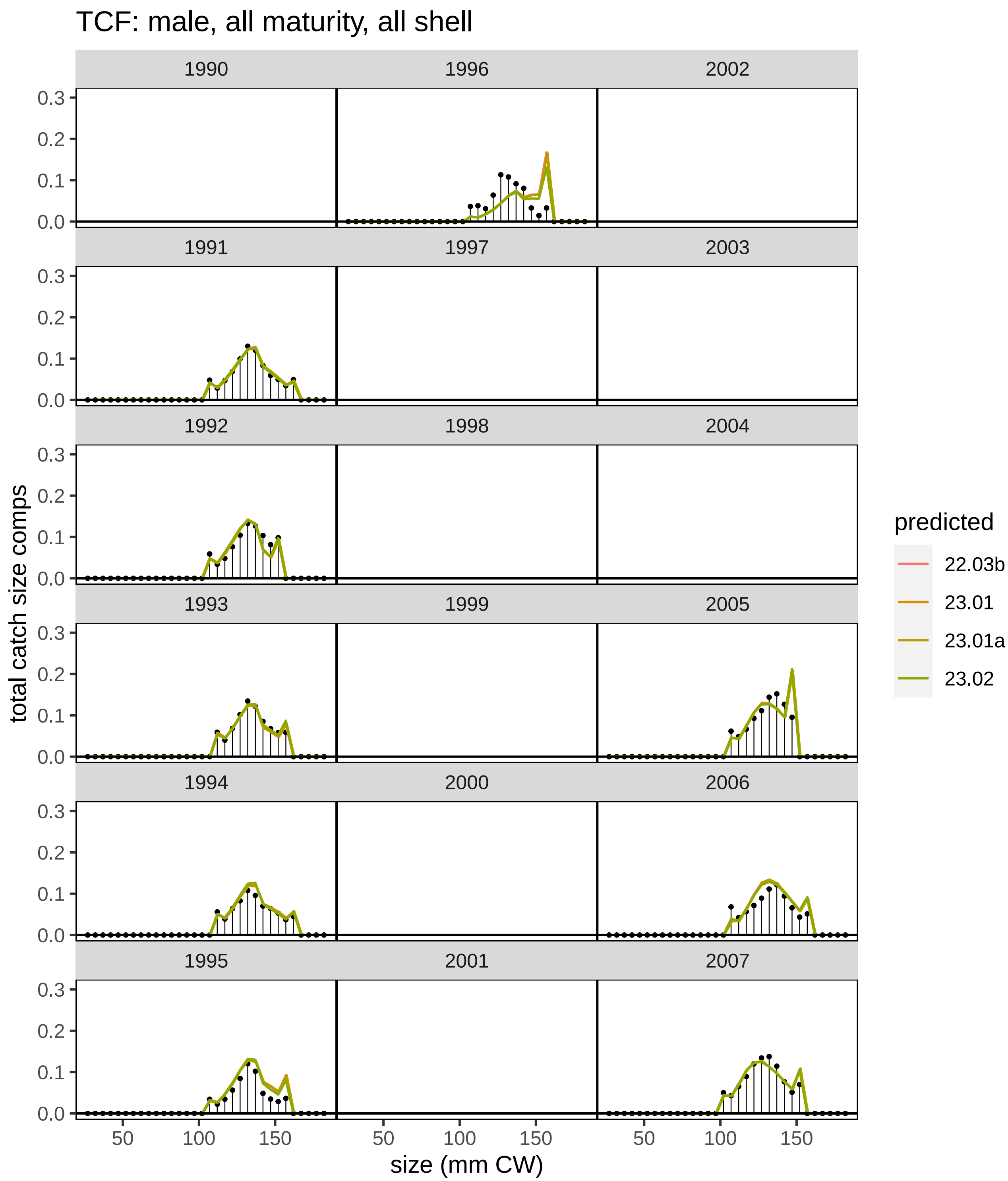

Figure 135. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

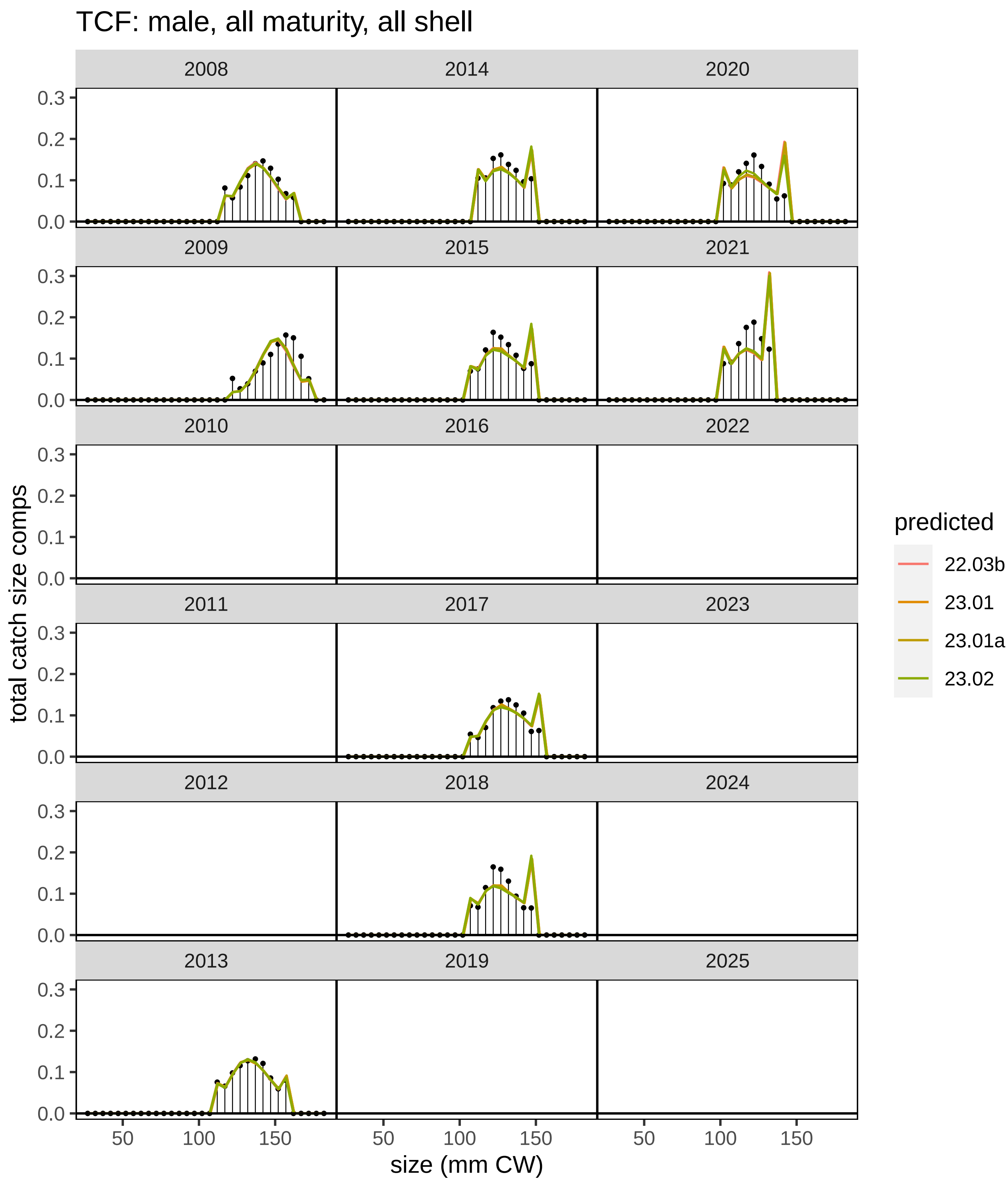

Figure 136. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

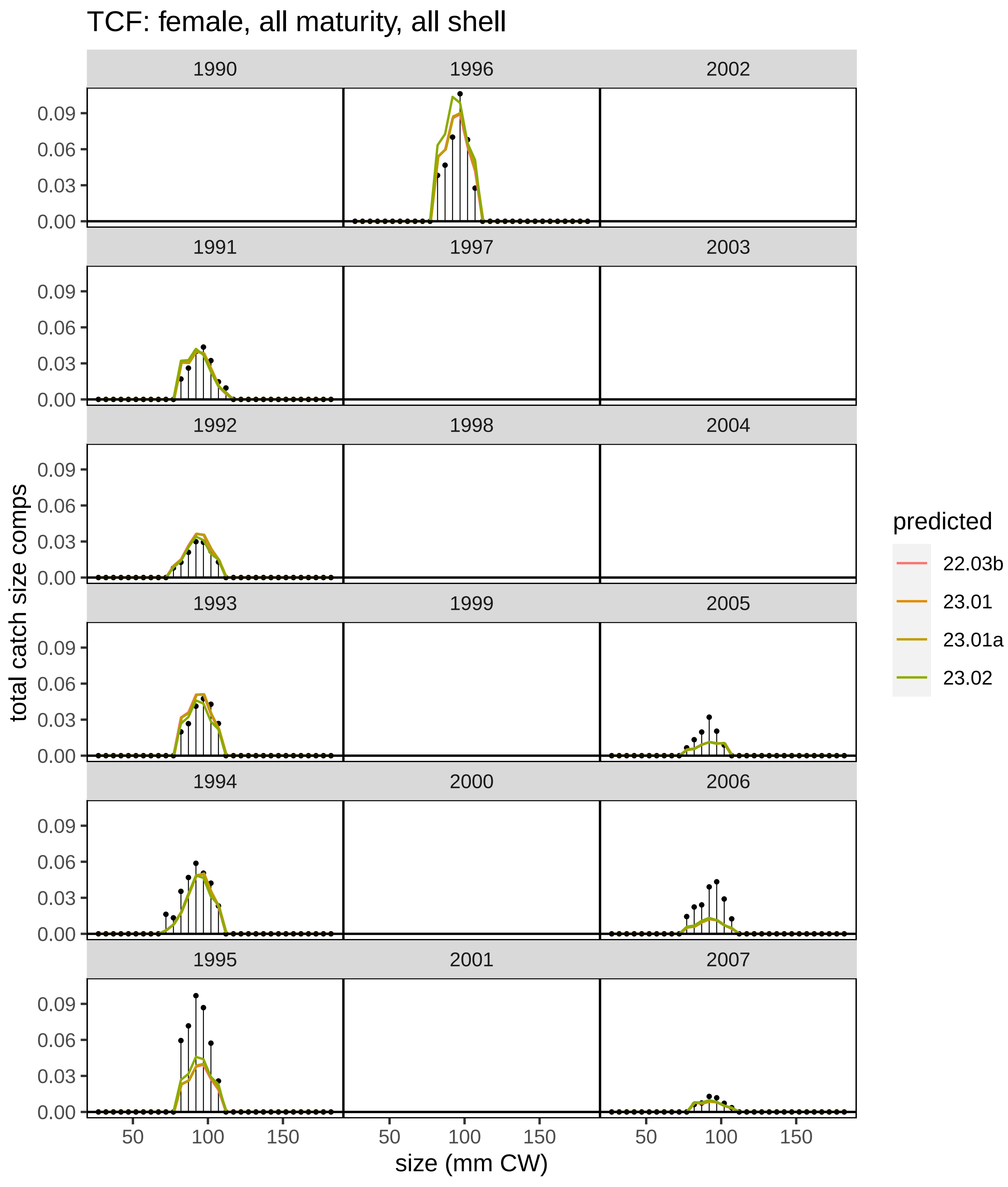

Figure 137. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

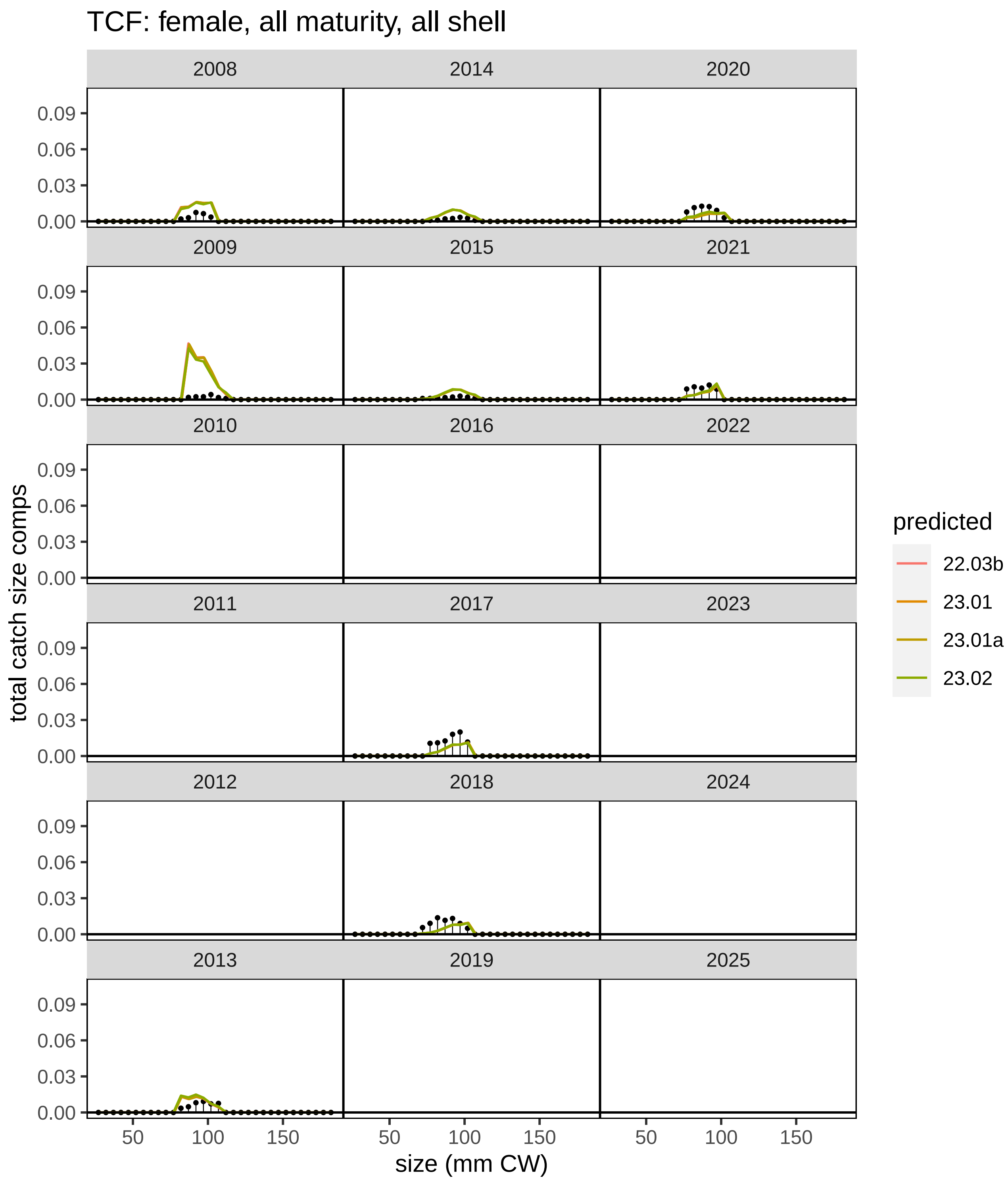

Figure 138. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

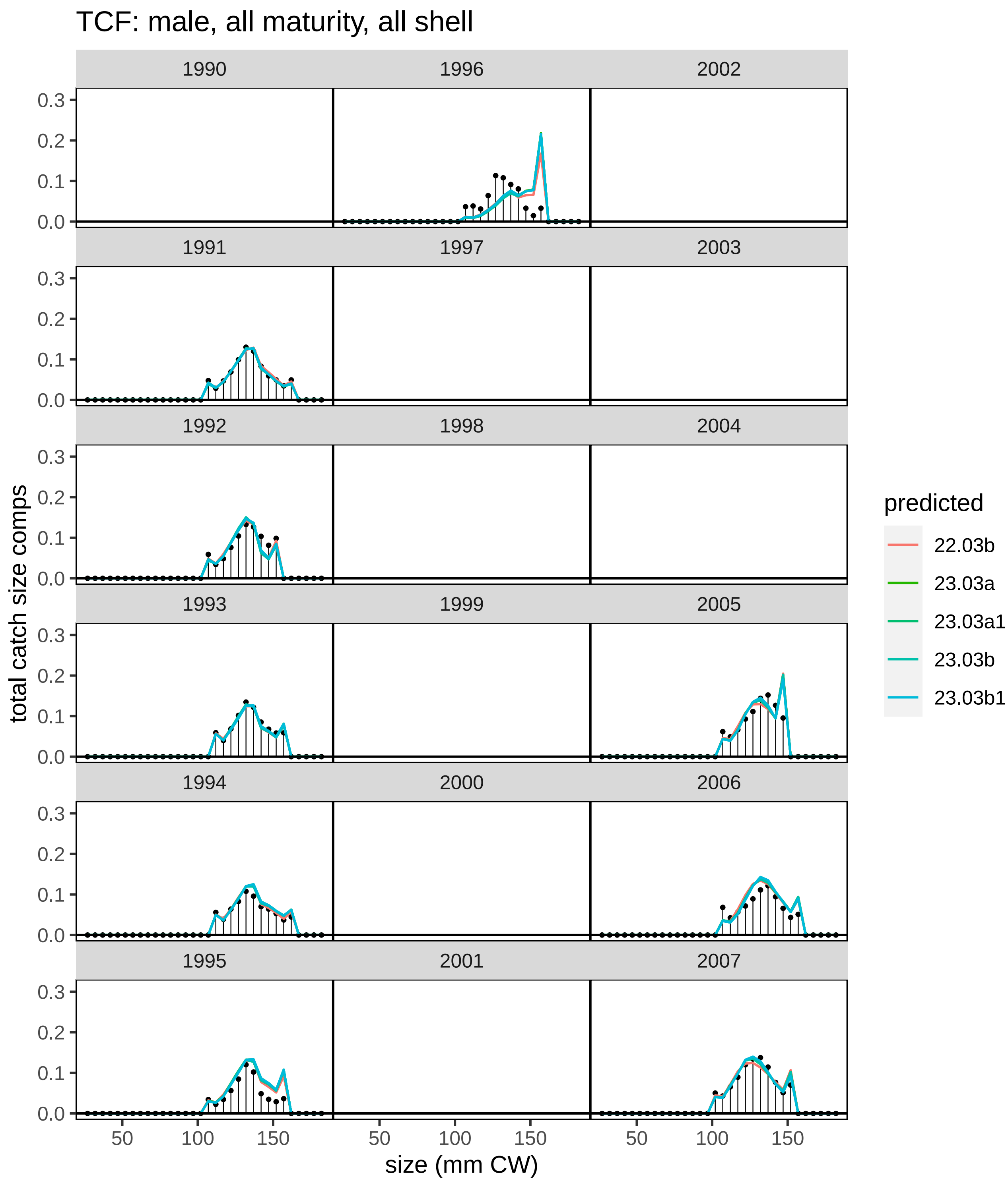

Figure 139. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

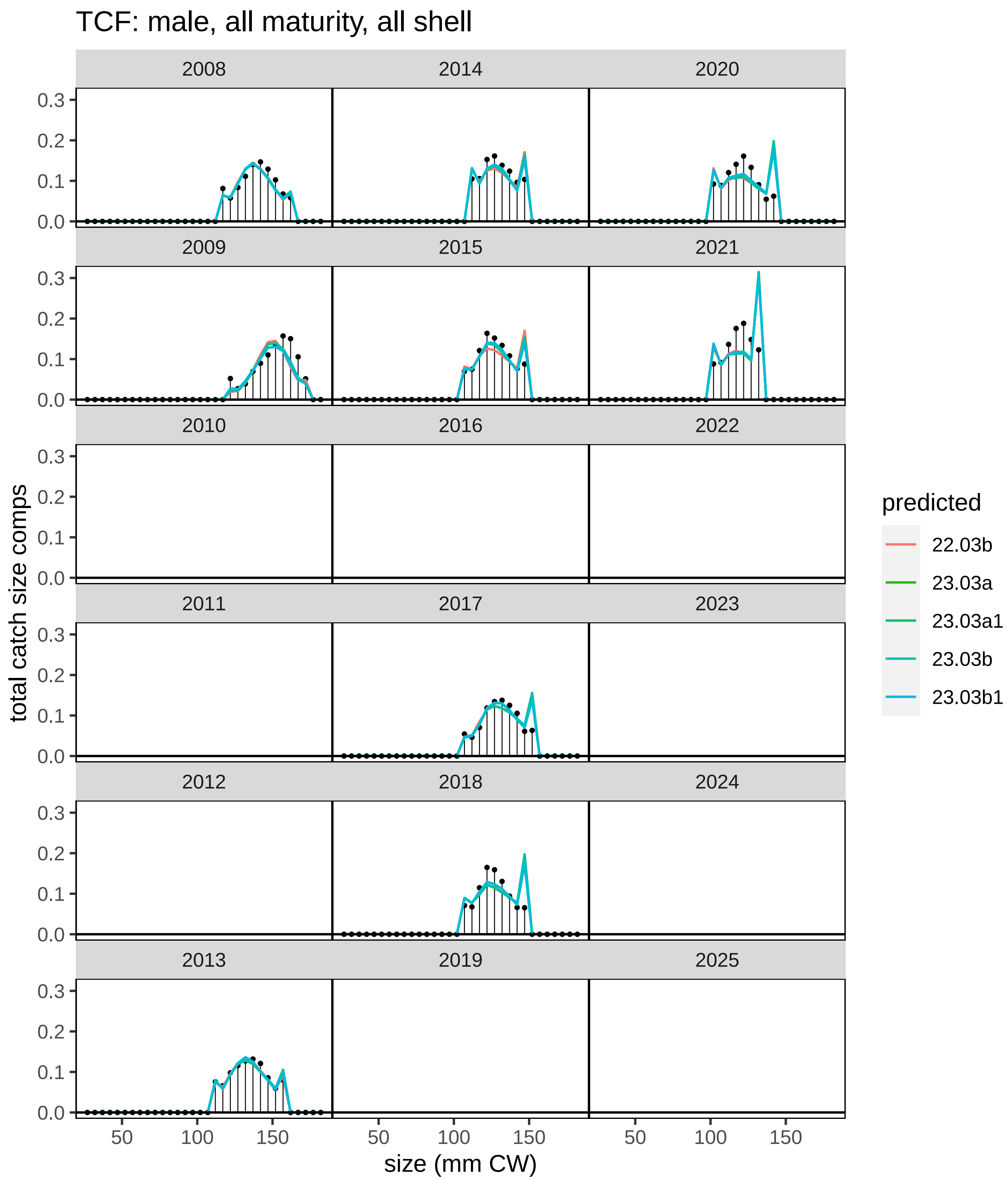

Figure 140. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

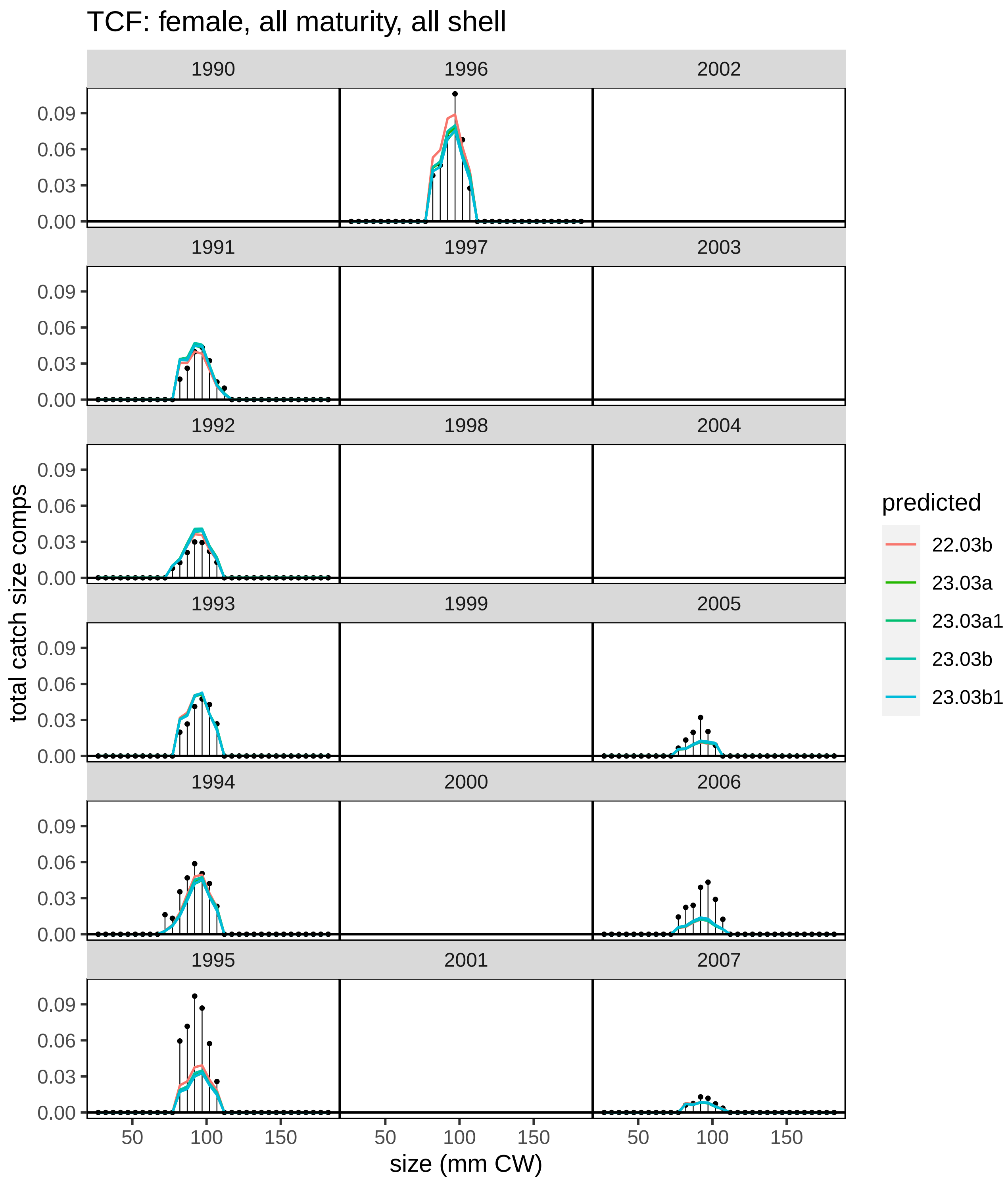

Figure 141. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

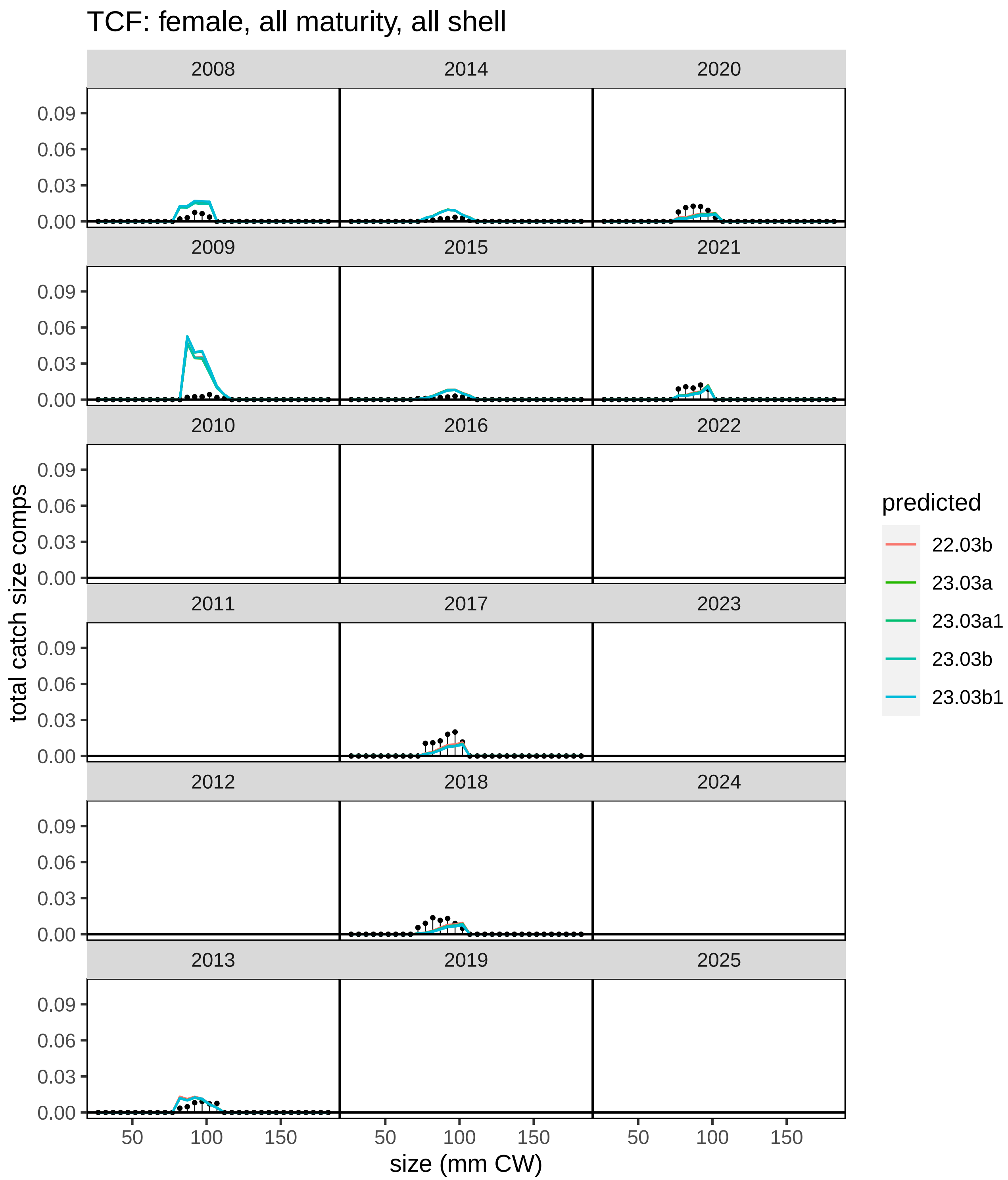

Figure 142. Fits to fishery total catch size compositions in the TCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

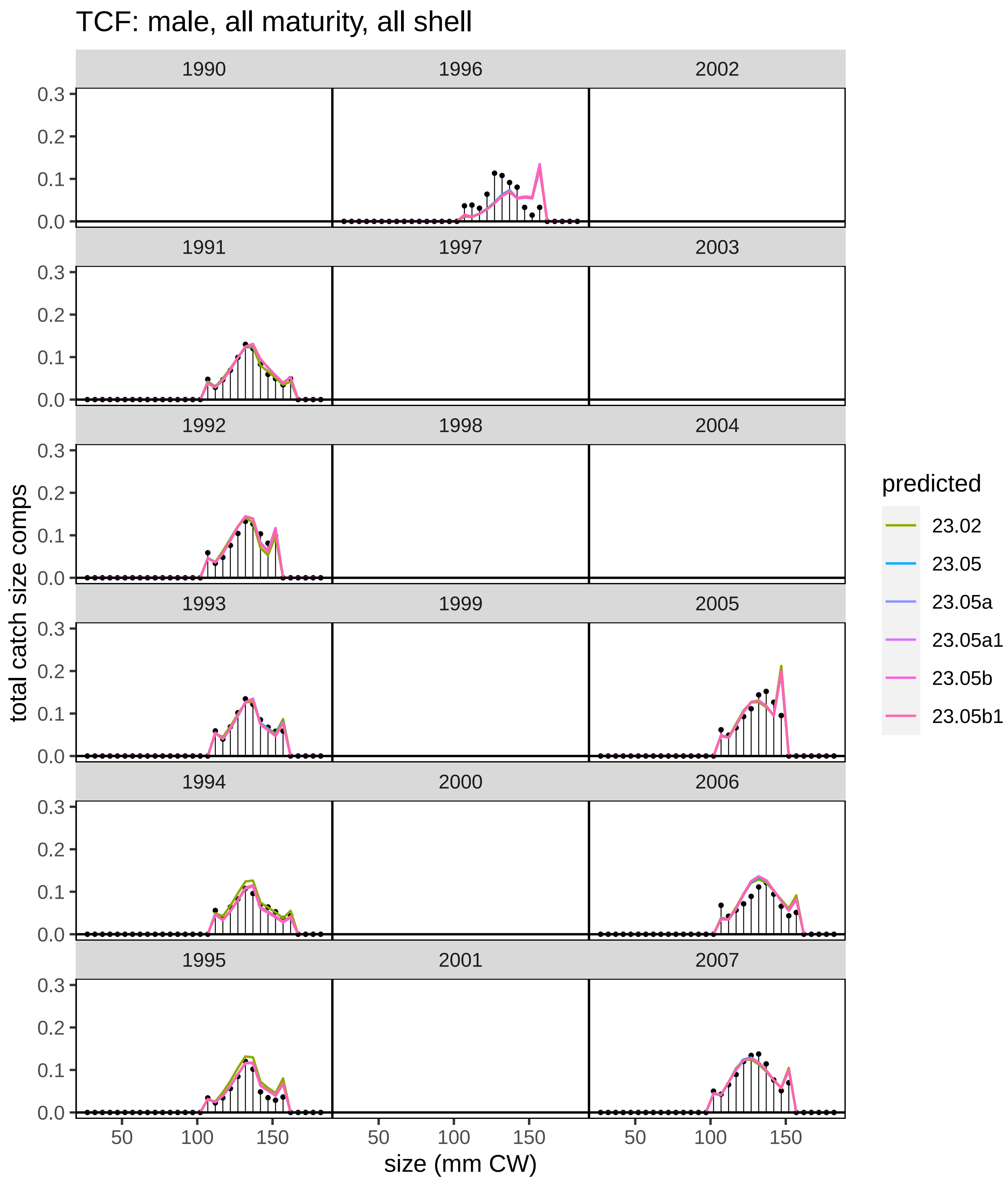

Figure 143. Fits to fishery total catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

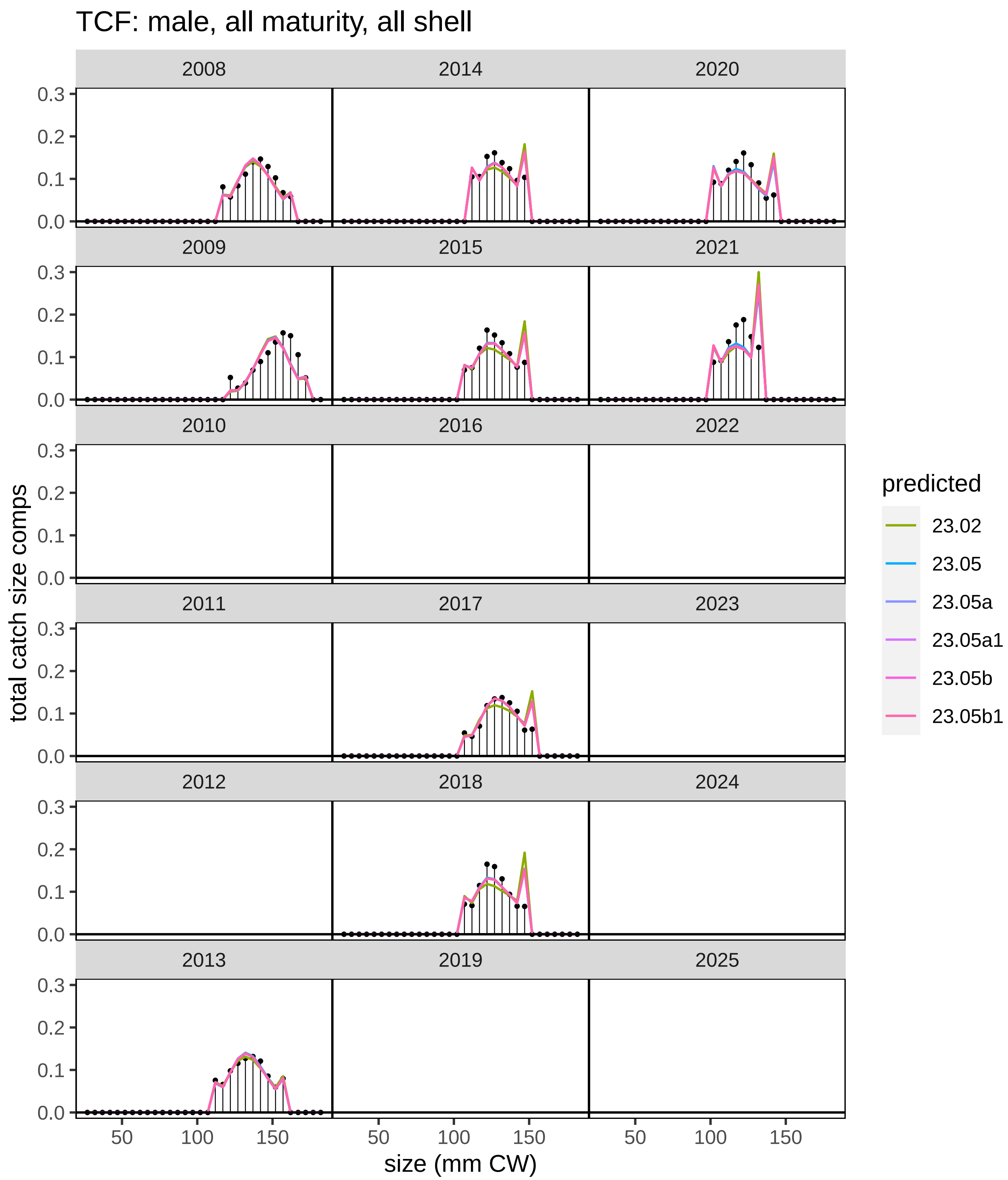

Figure 144. Fits to fishery total catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

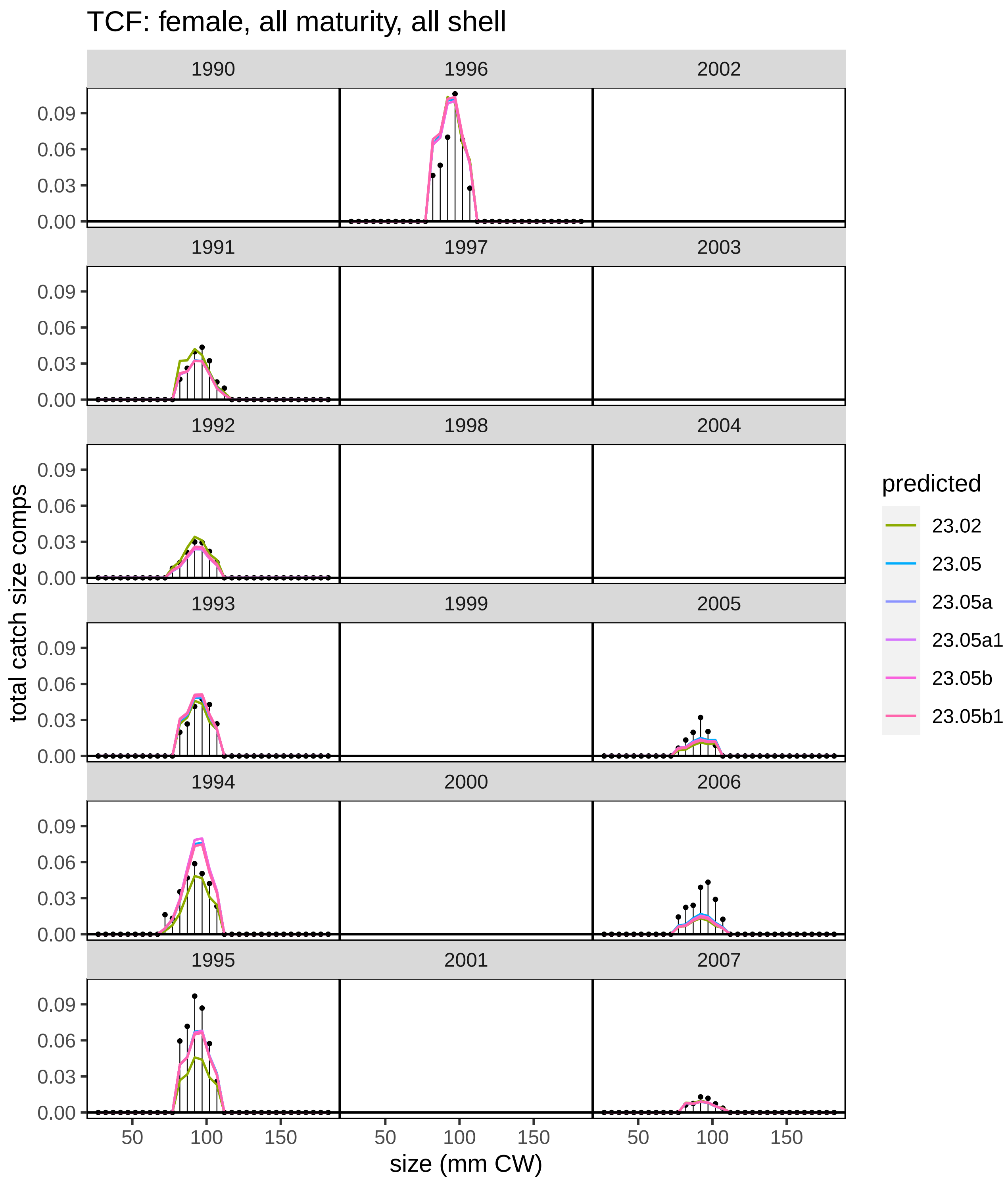

Figure 145. Fits to fishery total catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

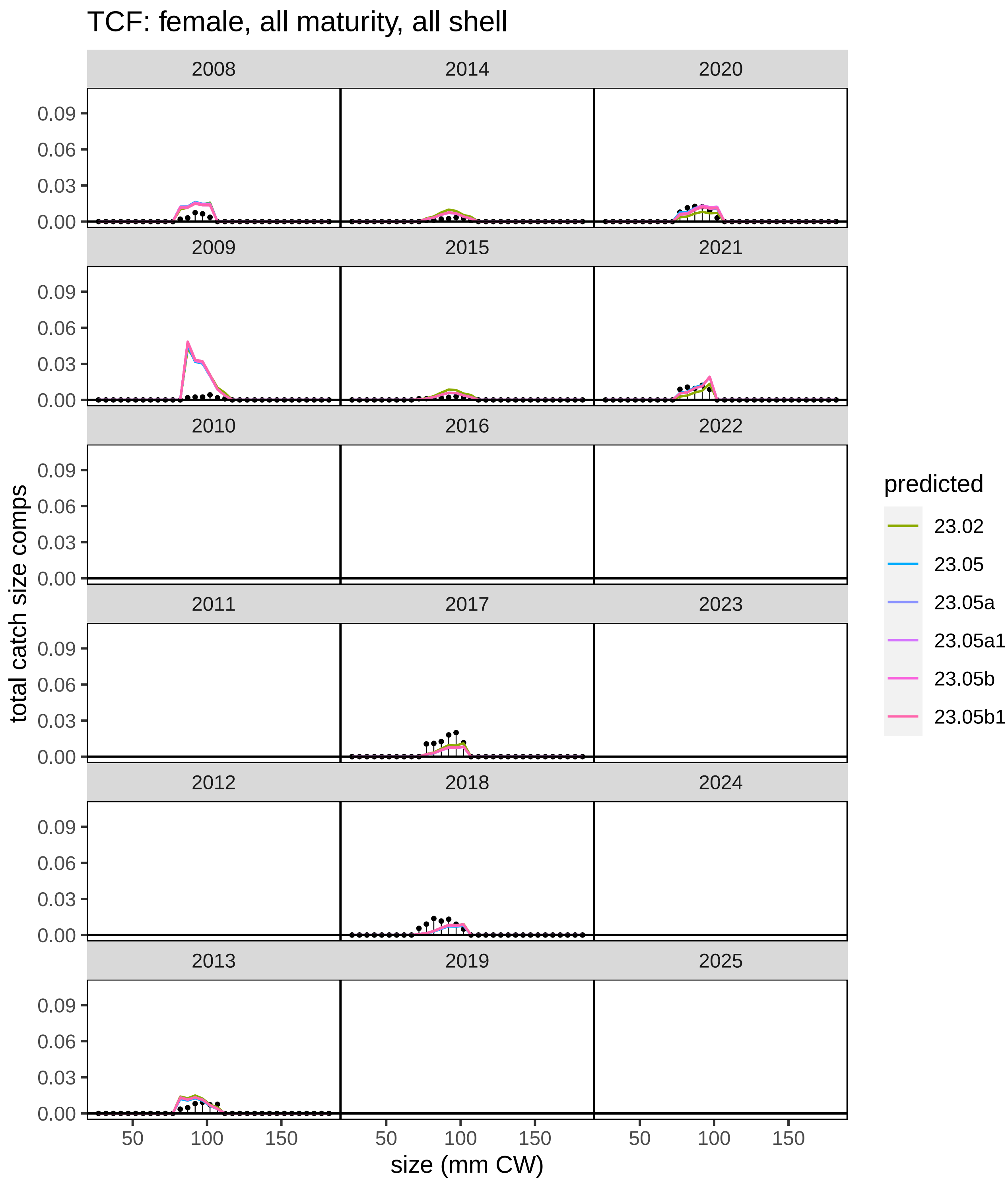

Figure 146. Fits to fishery total catch size compositions in the TCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

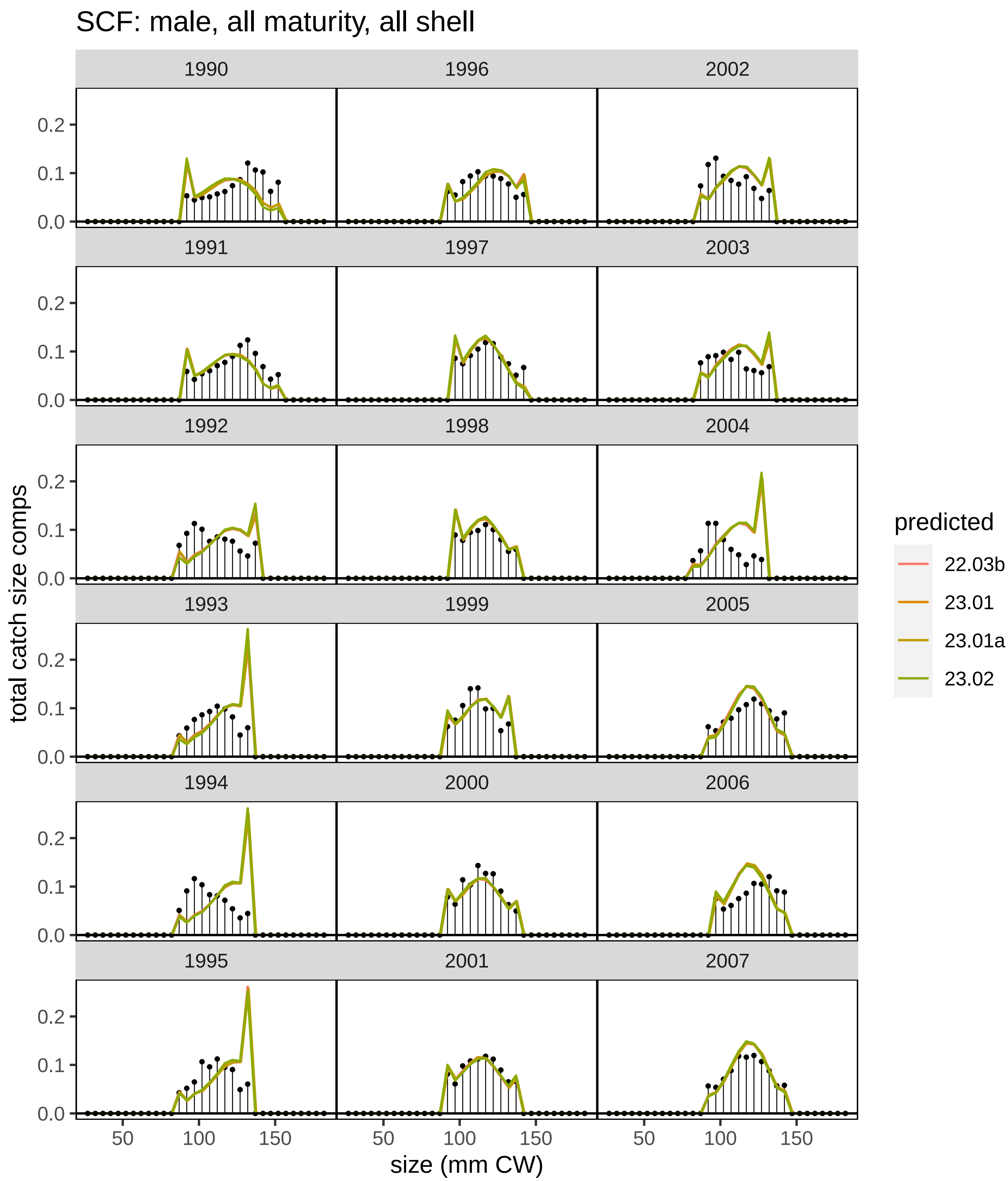

Figure 147. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

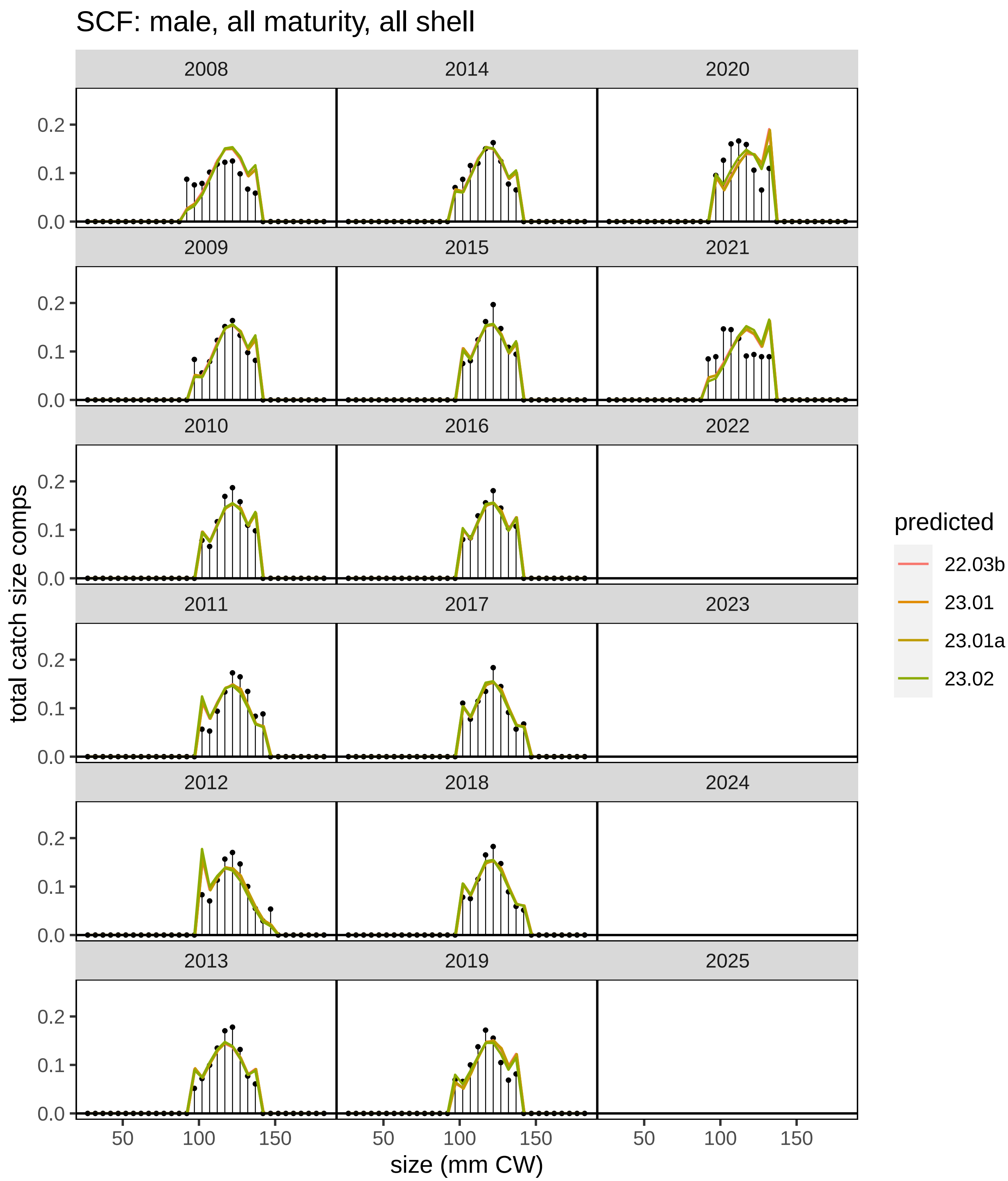

Figure 148. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

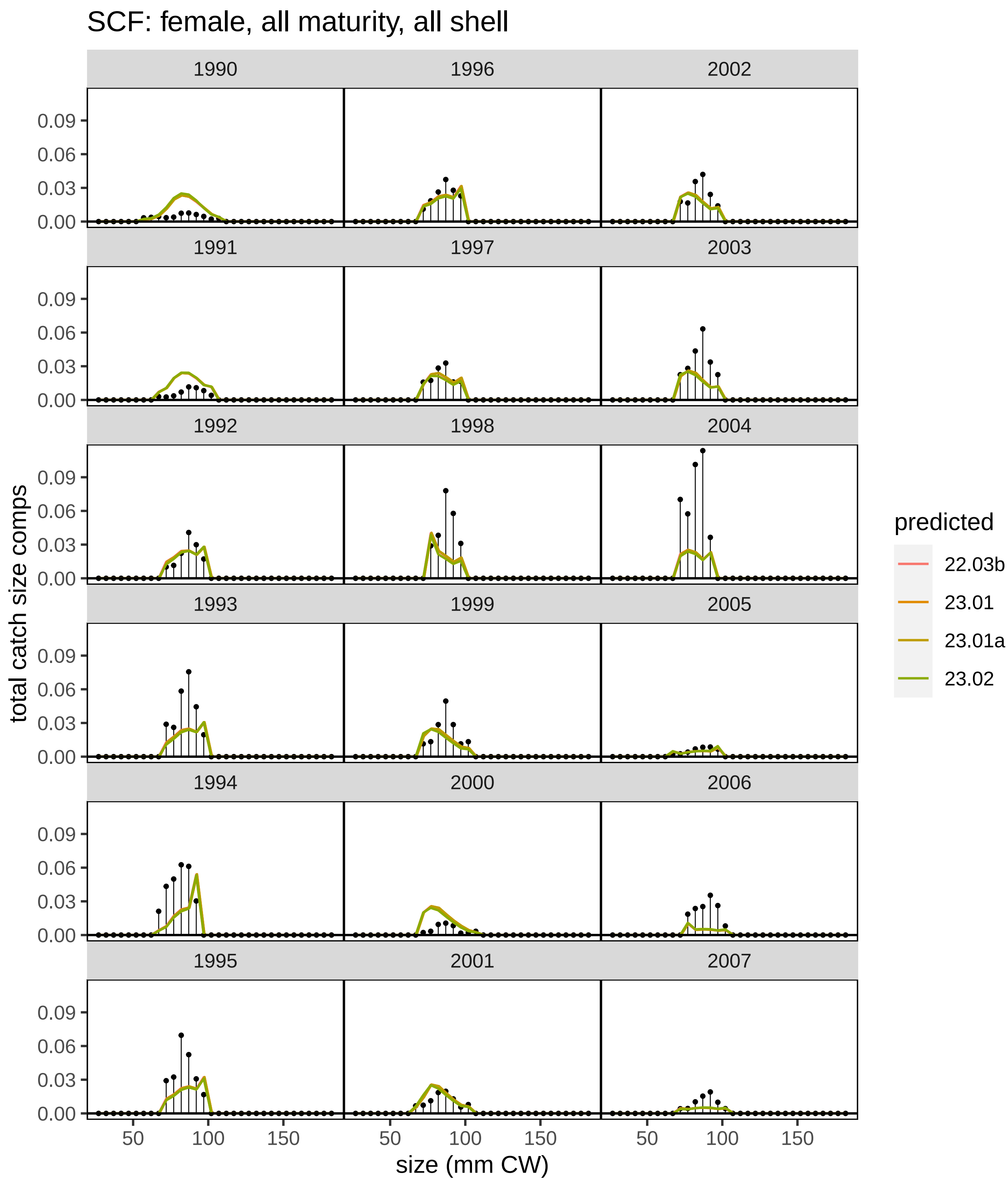

Figure 149. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

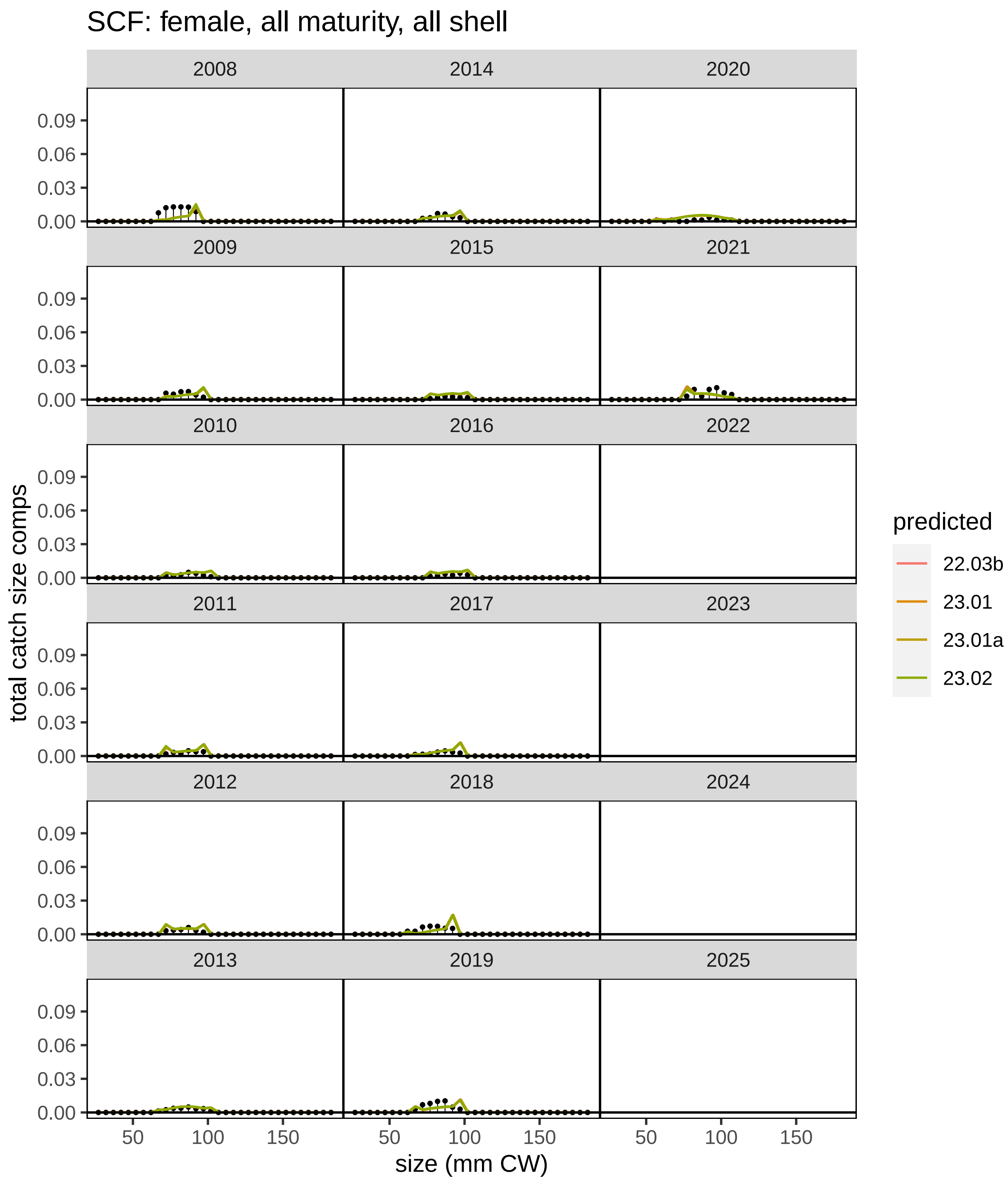

Figure 150. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

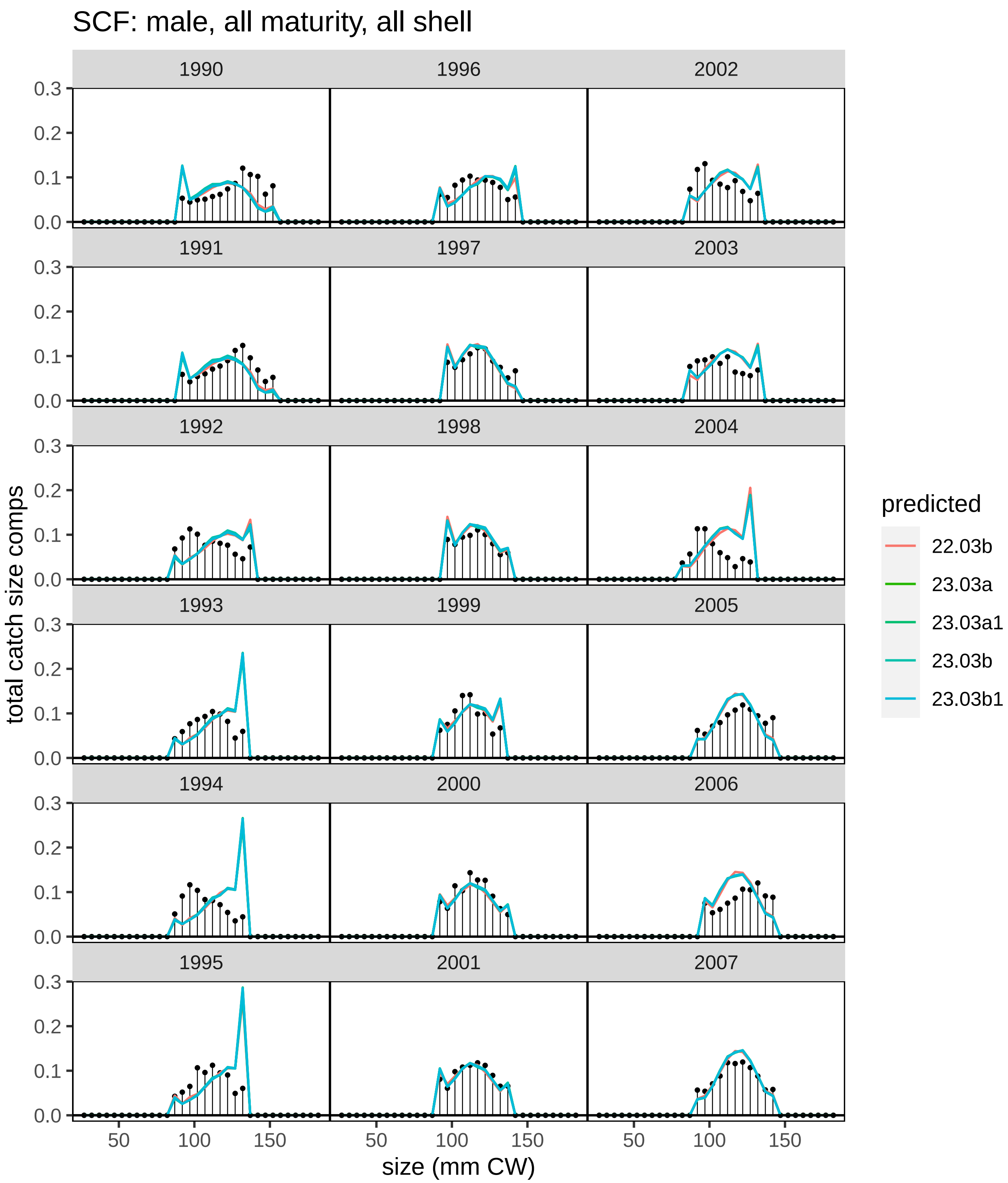

Figure 151. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

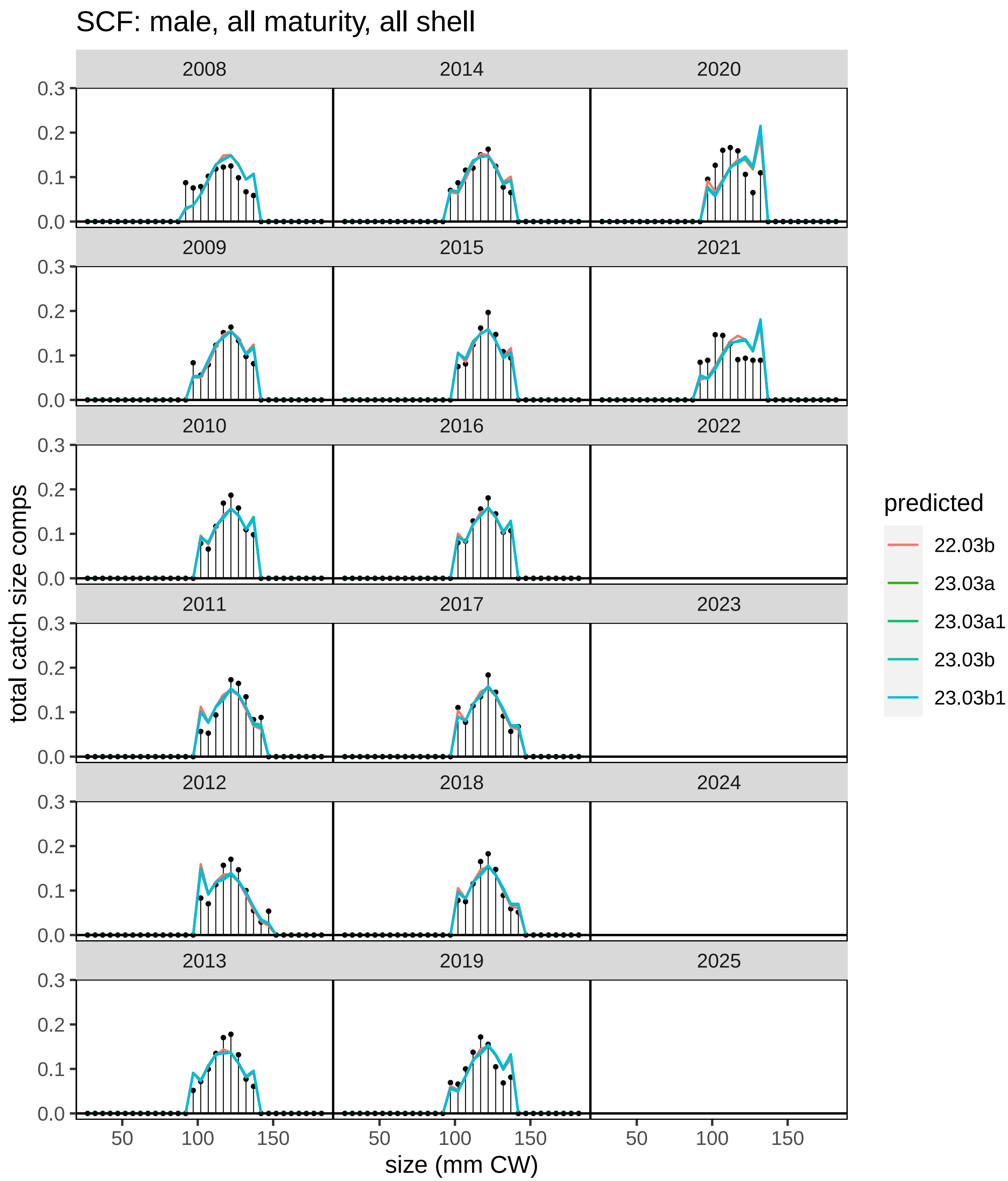

Figure 152. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

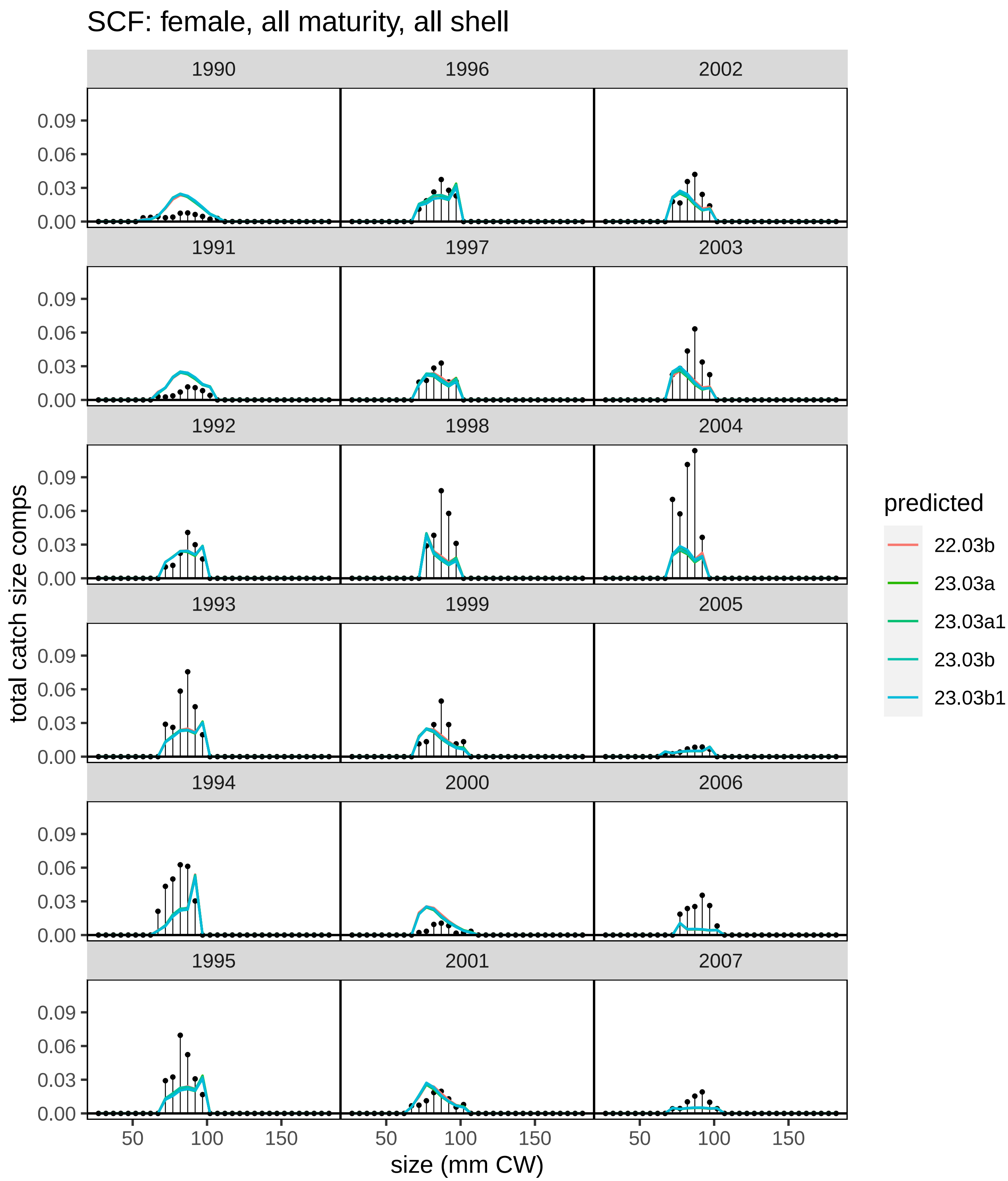

Figure 153. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

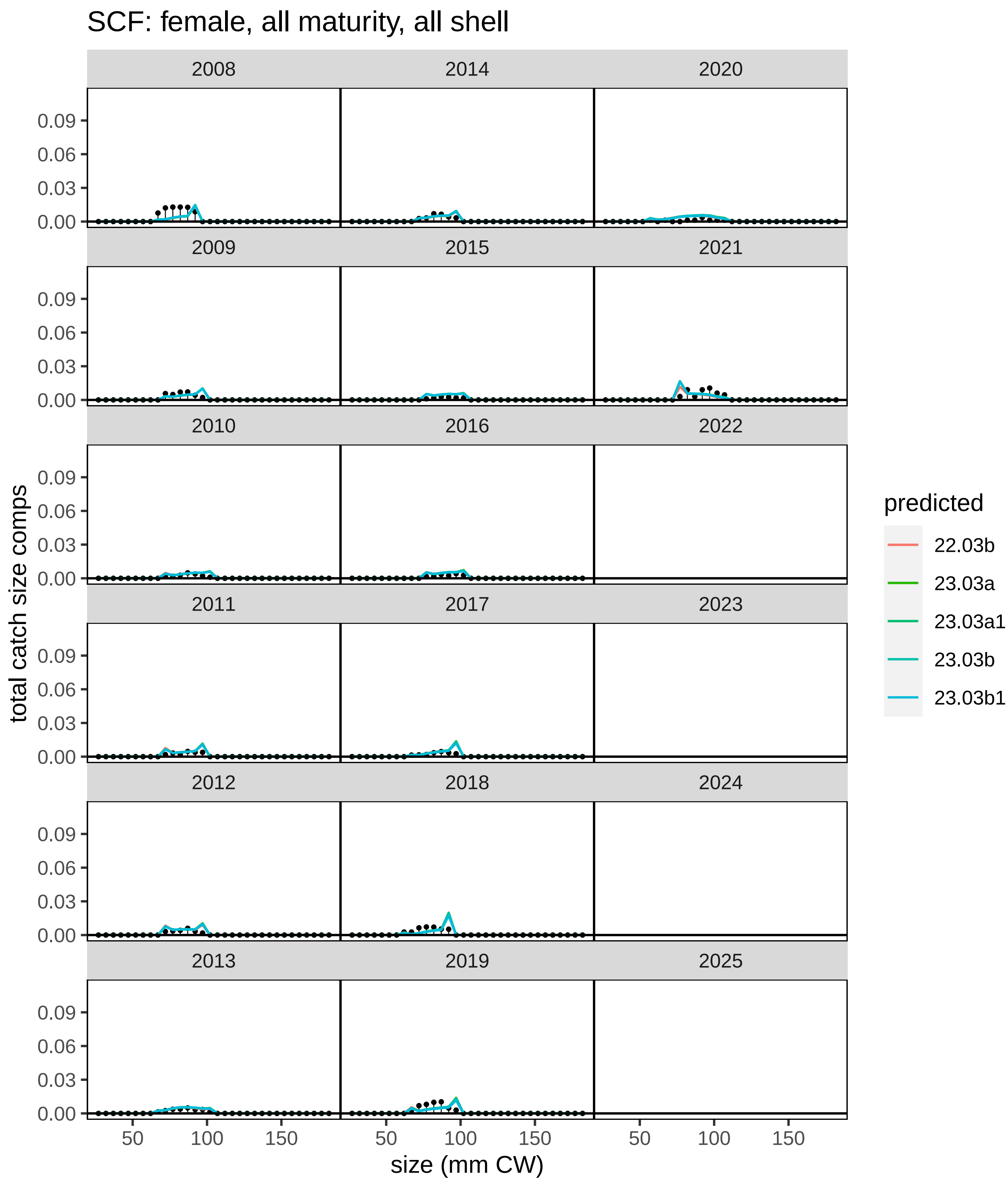

Figure 154. Fits to fishery total catch size compositions in the SCF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

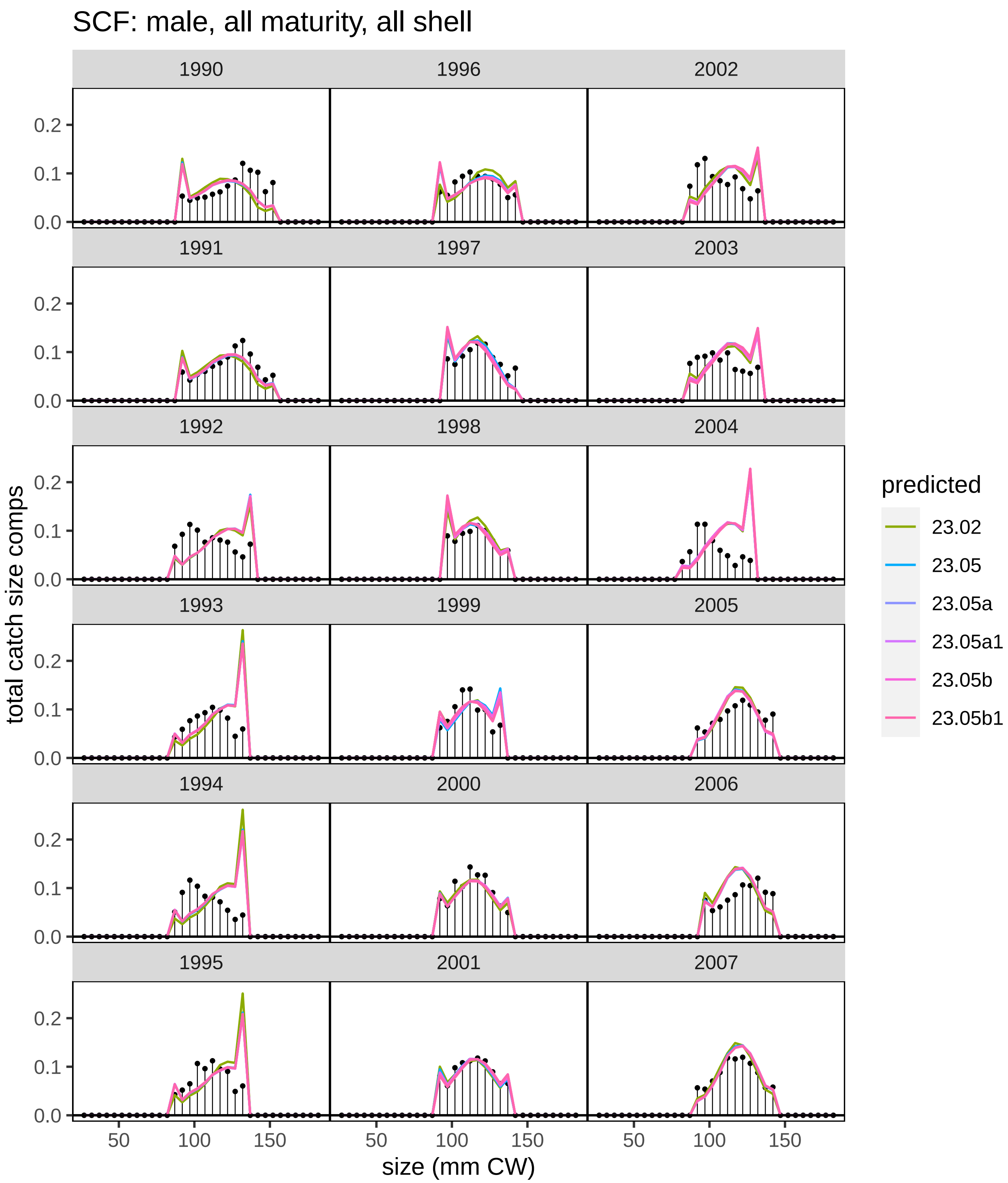

Figure 155. Fits to fishery total catch size compositions in the SCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

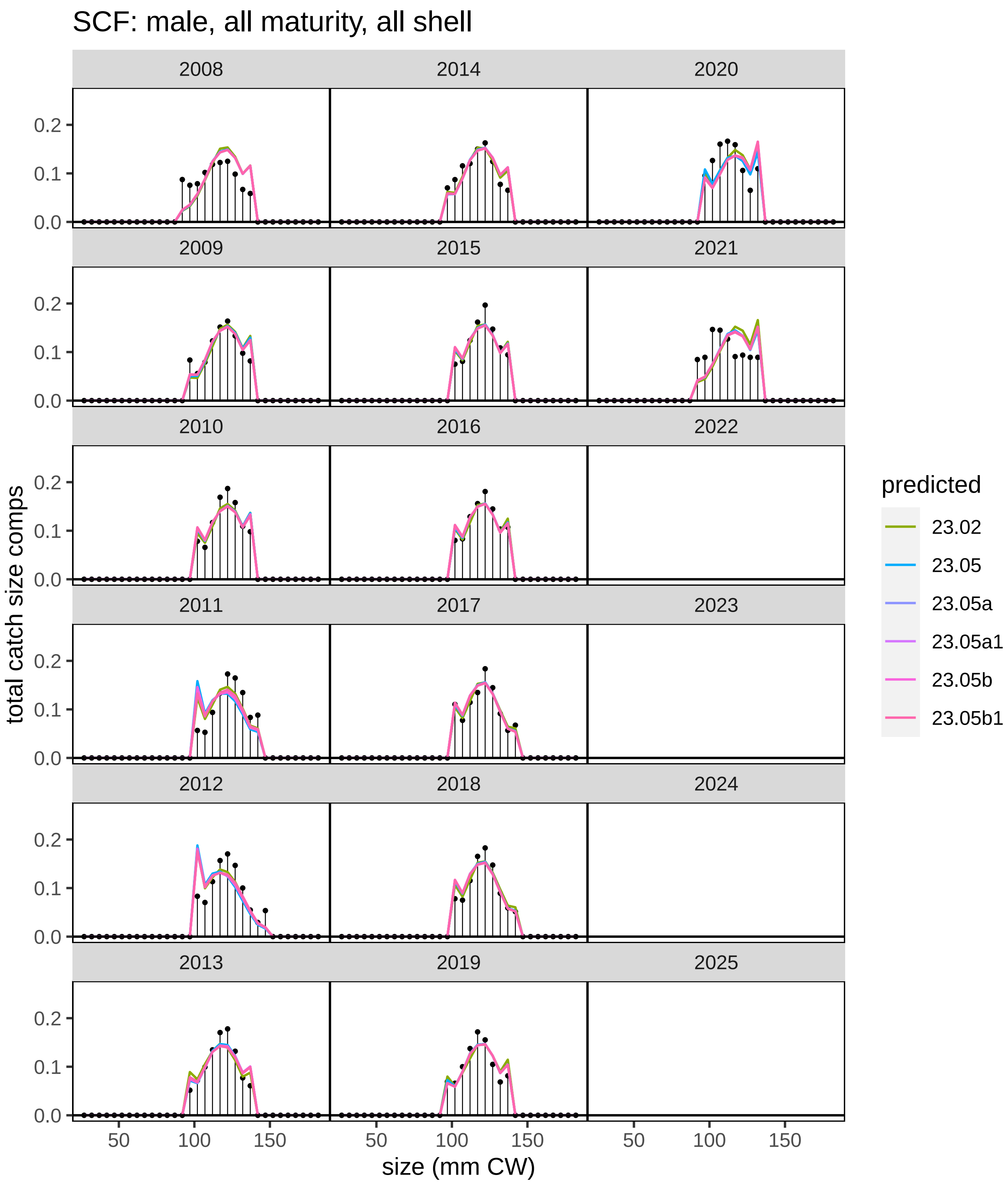

Figure 156. Fits to fishery total catch size compositions in the SCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

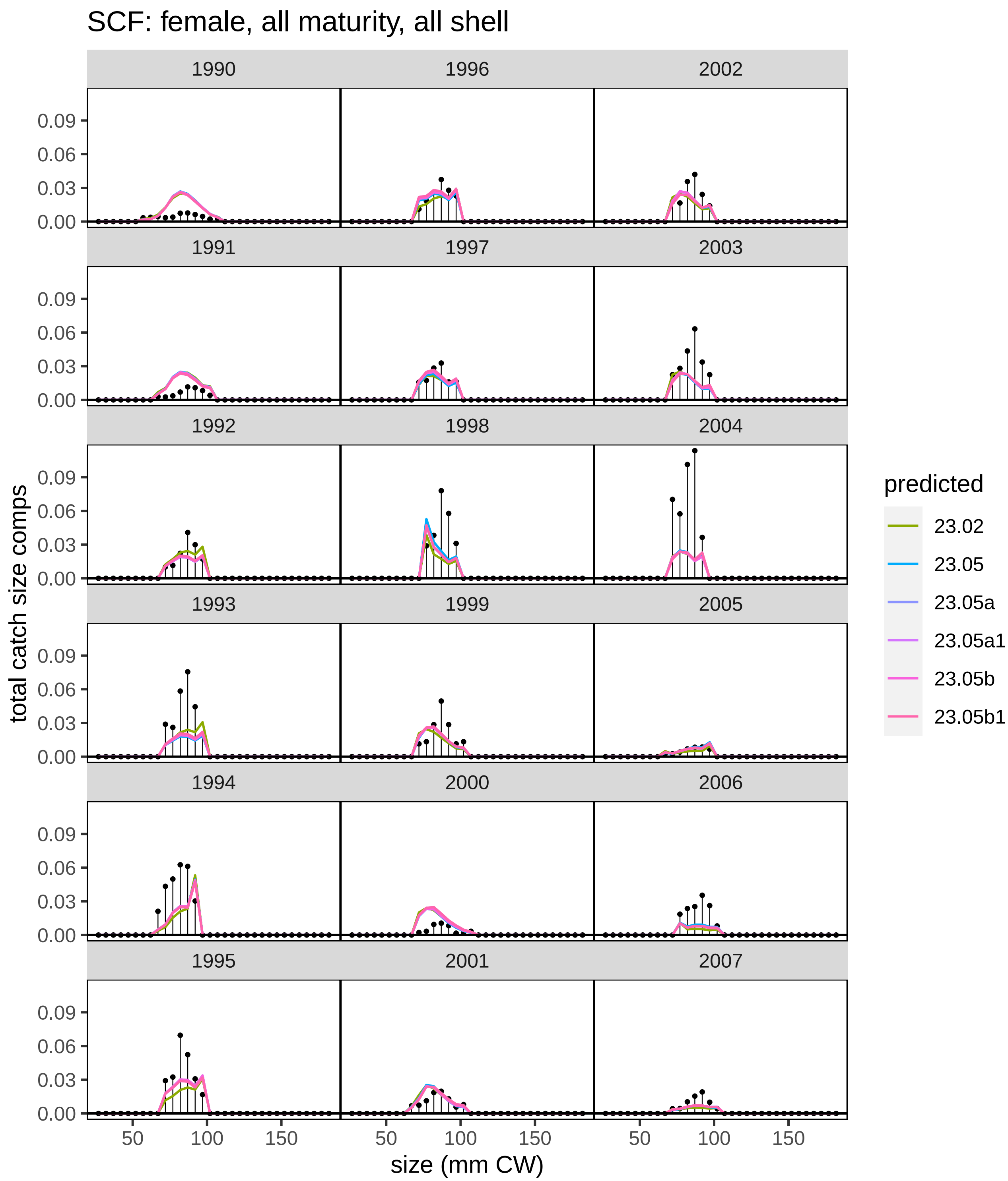

Figure 157. Fits to fishery total catch size compositions in the SCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

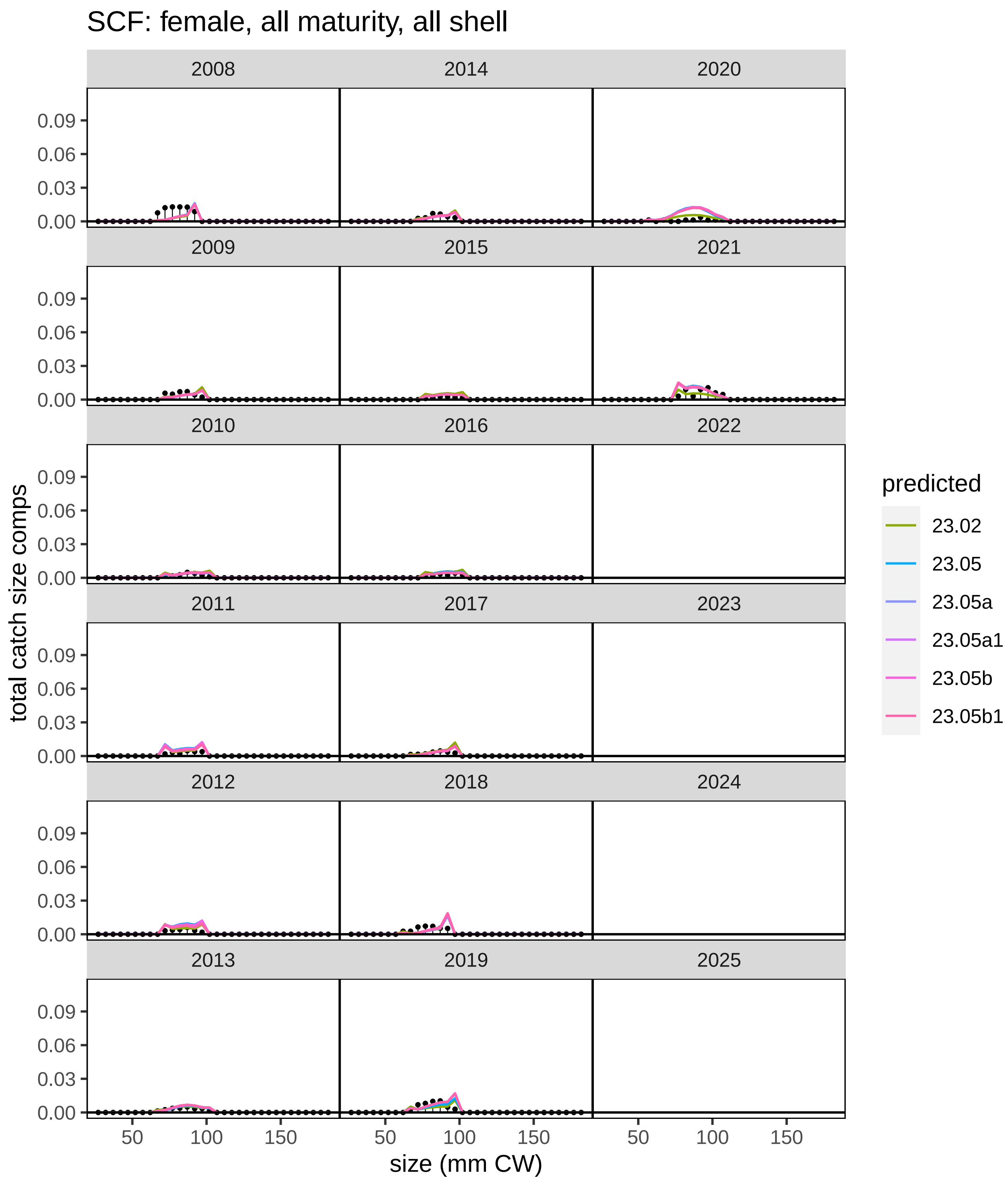

Figure 158. Fits to fishery total catch size compositions in the SCF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

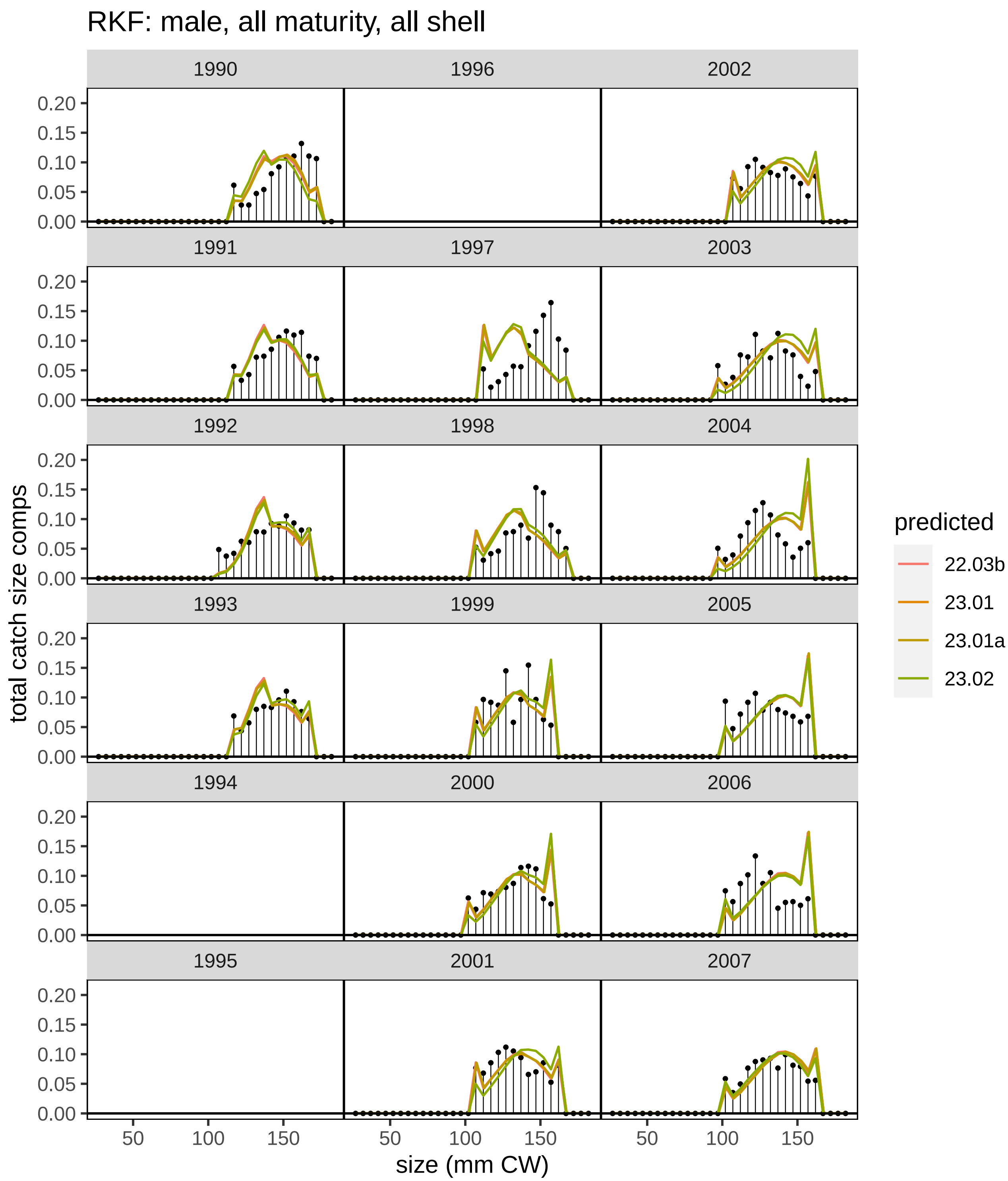

Figure 159. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

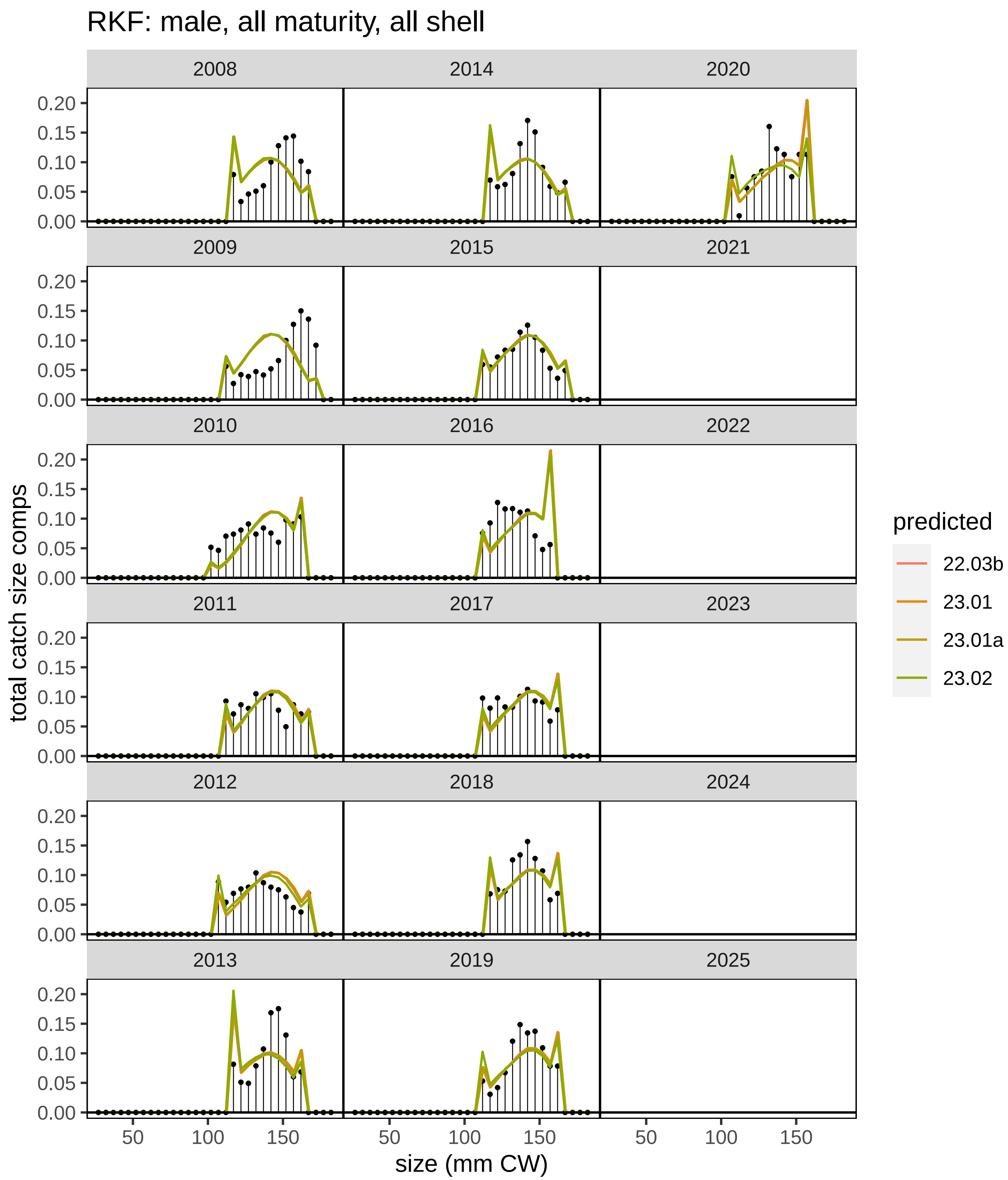

Figure 160. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

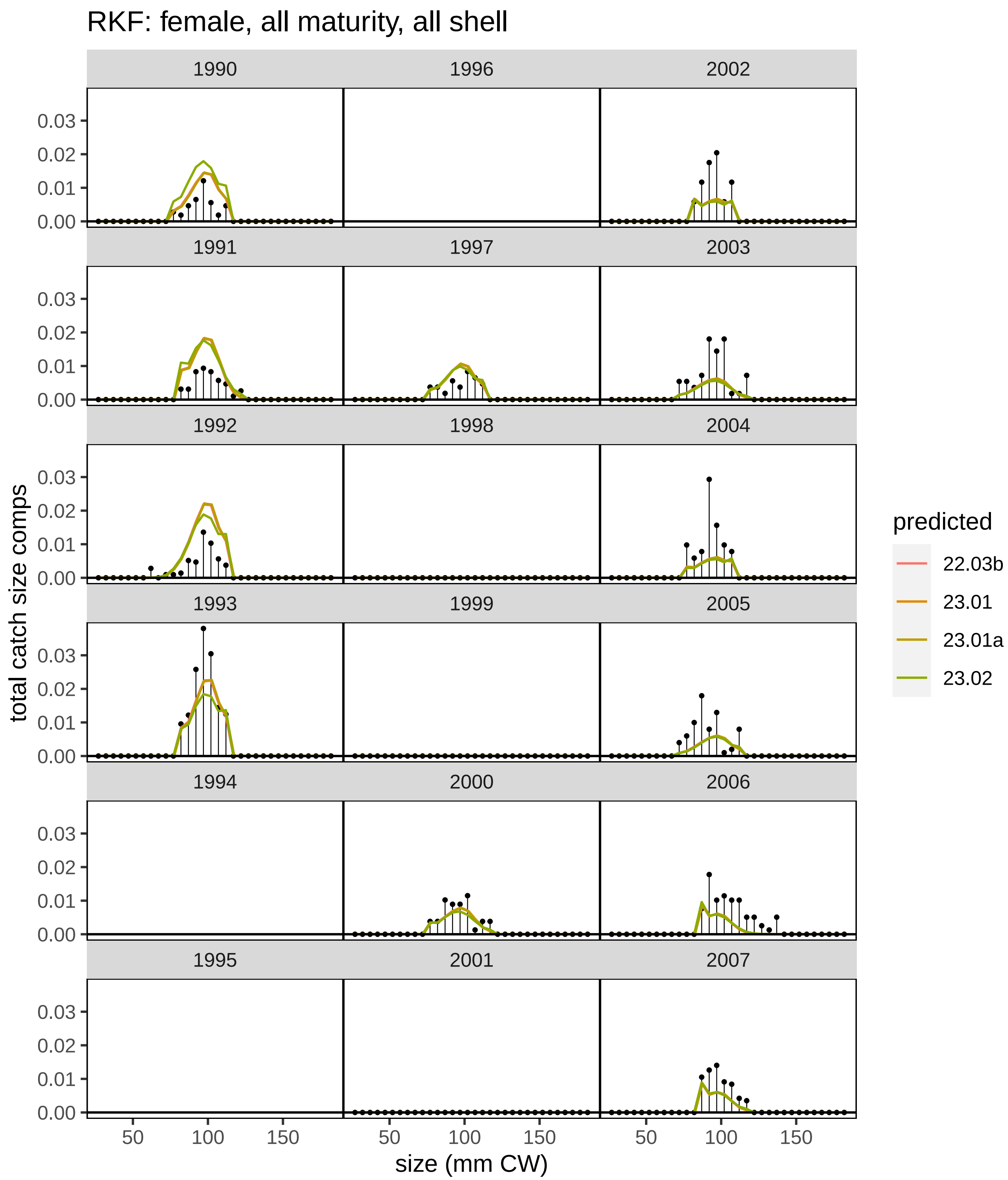

Figure 161. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

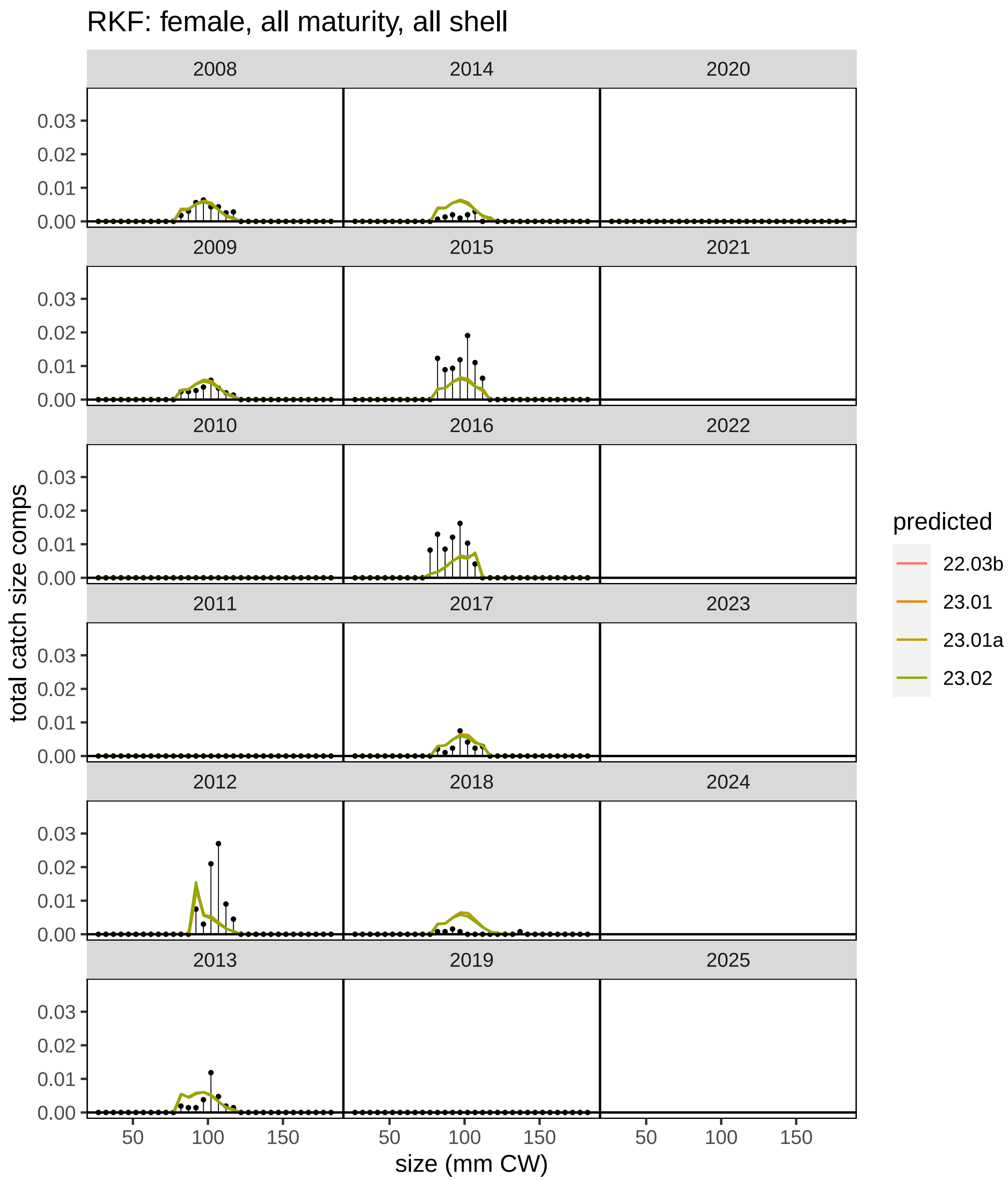

Figure 162. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.01, 23.01a, 23.02.

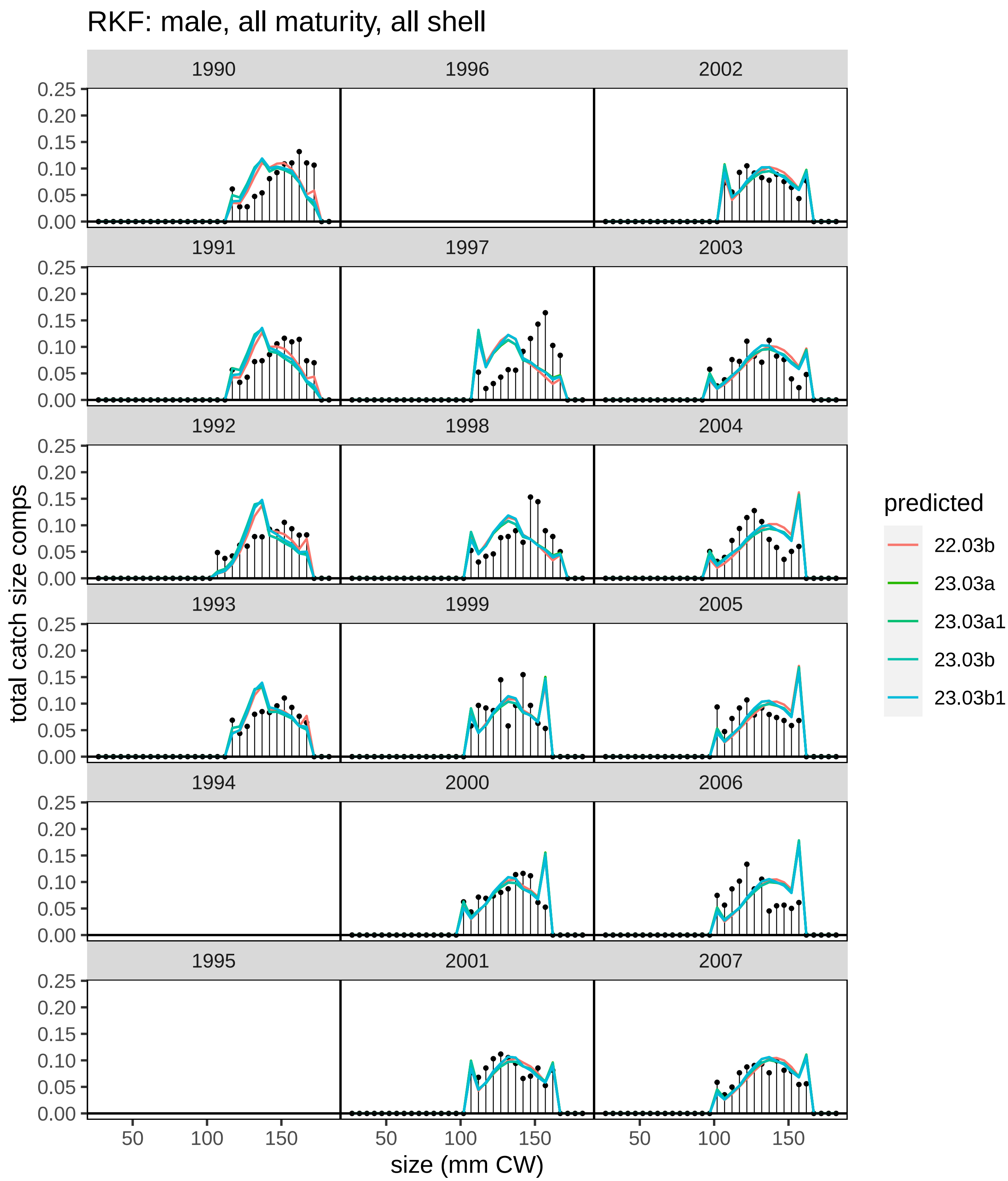

Figure 163. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

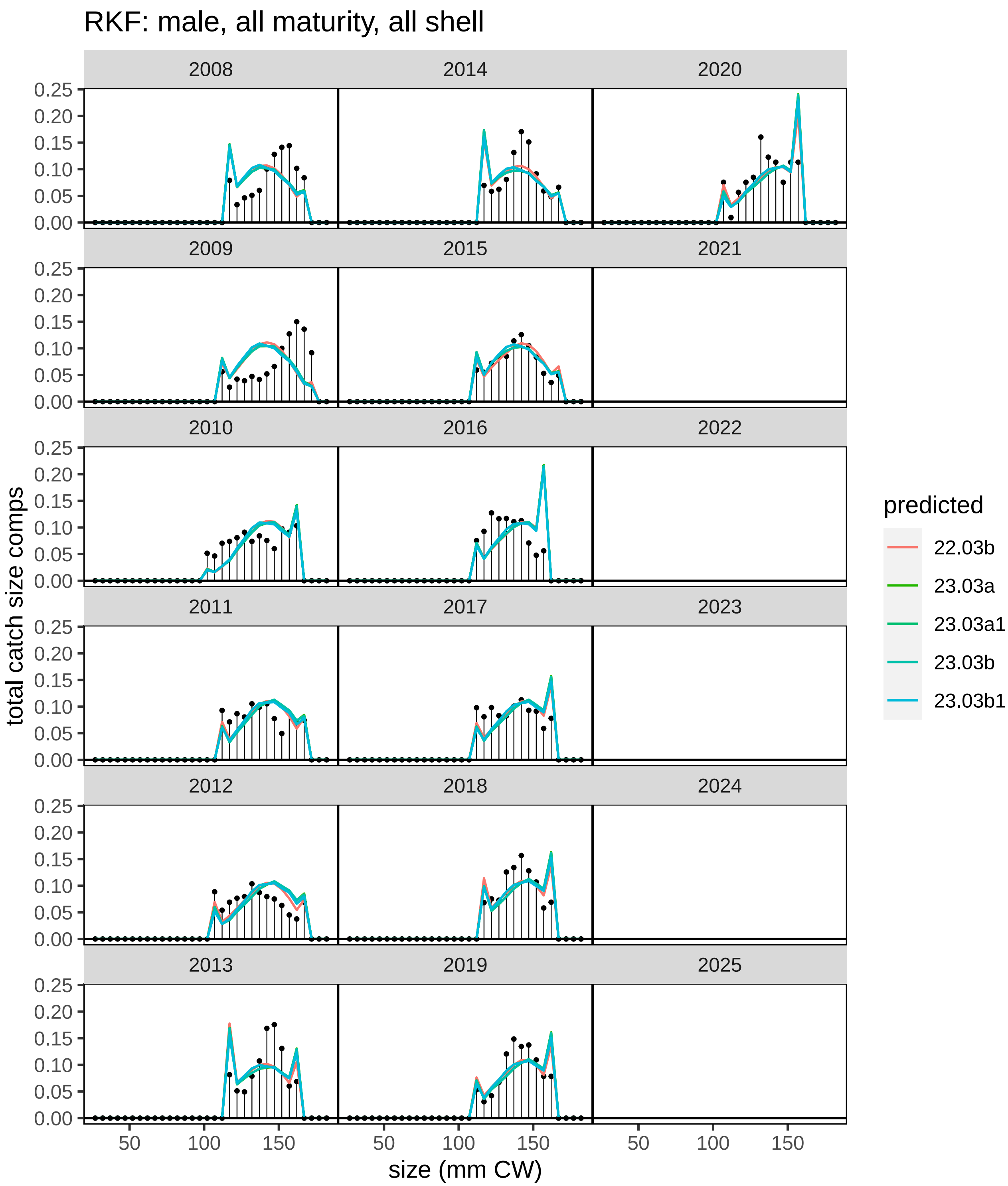

Figure 164. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

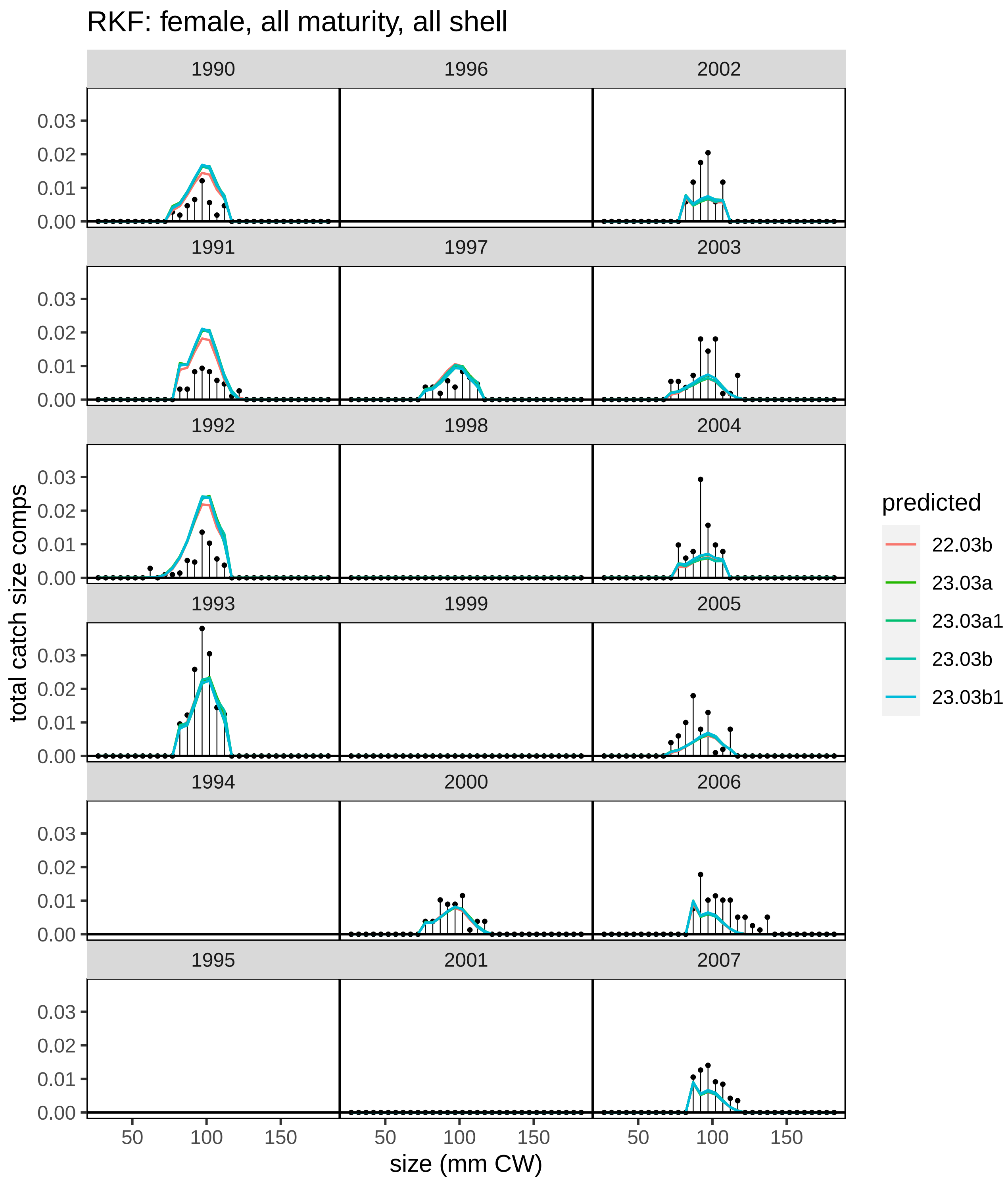

Figure 165. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

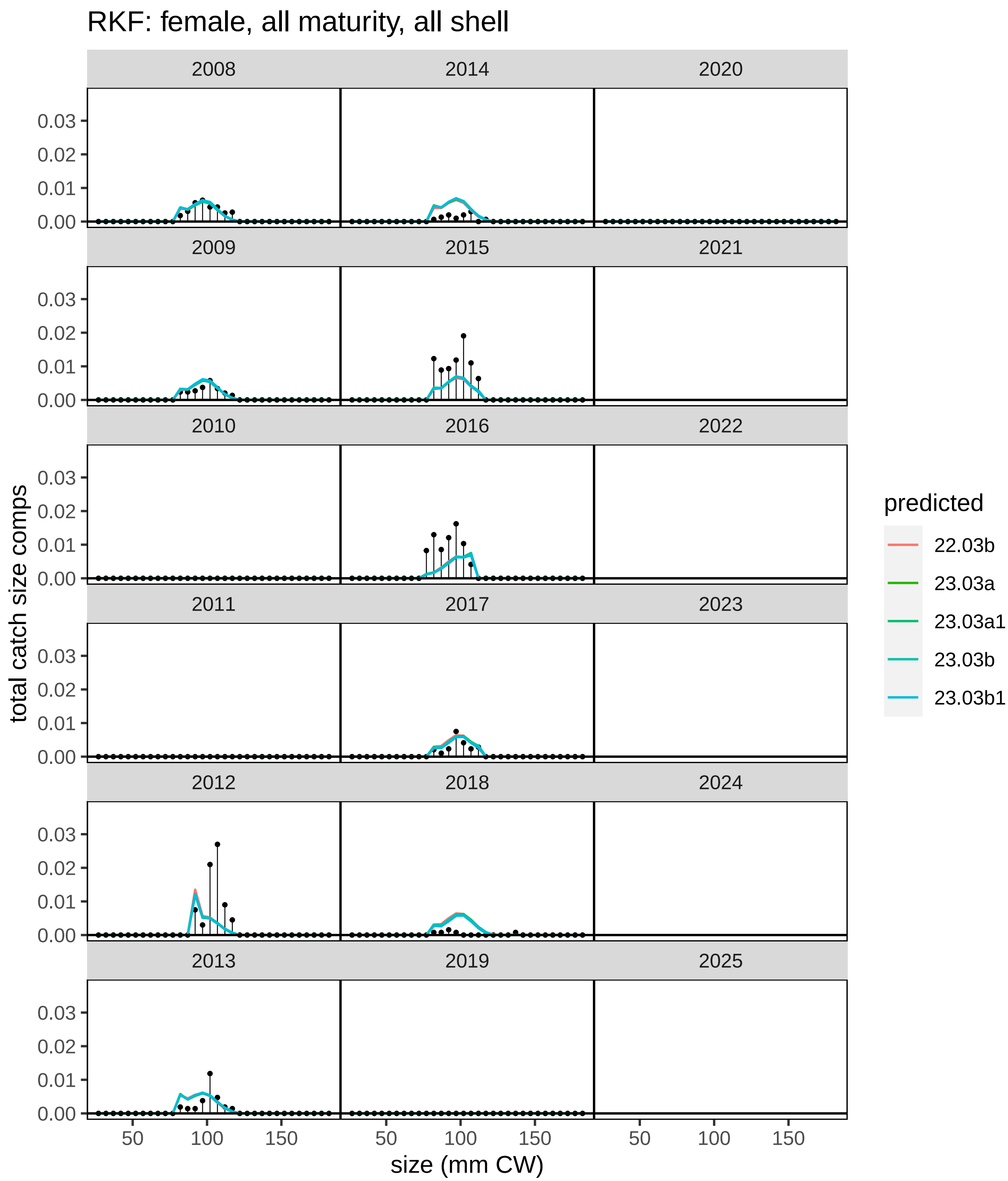

Figure 166. Fits to fishery total catch size compositions in the RKF fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

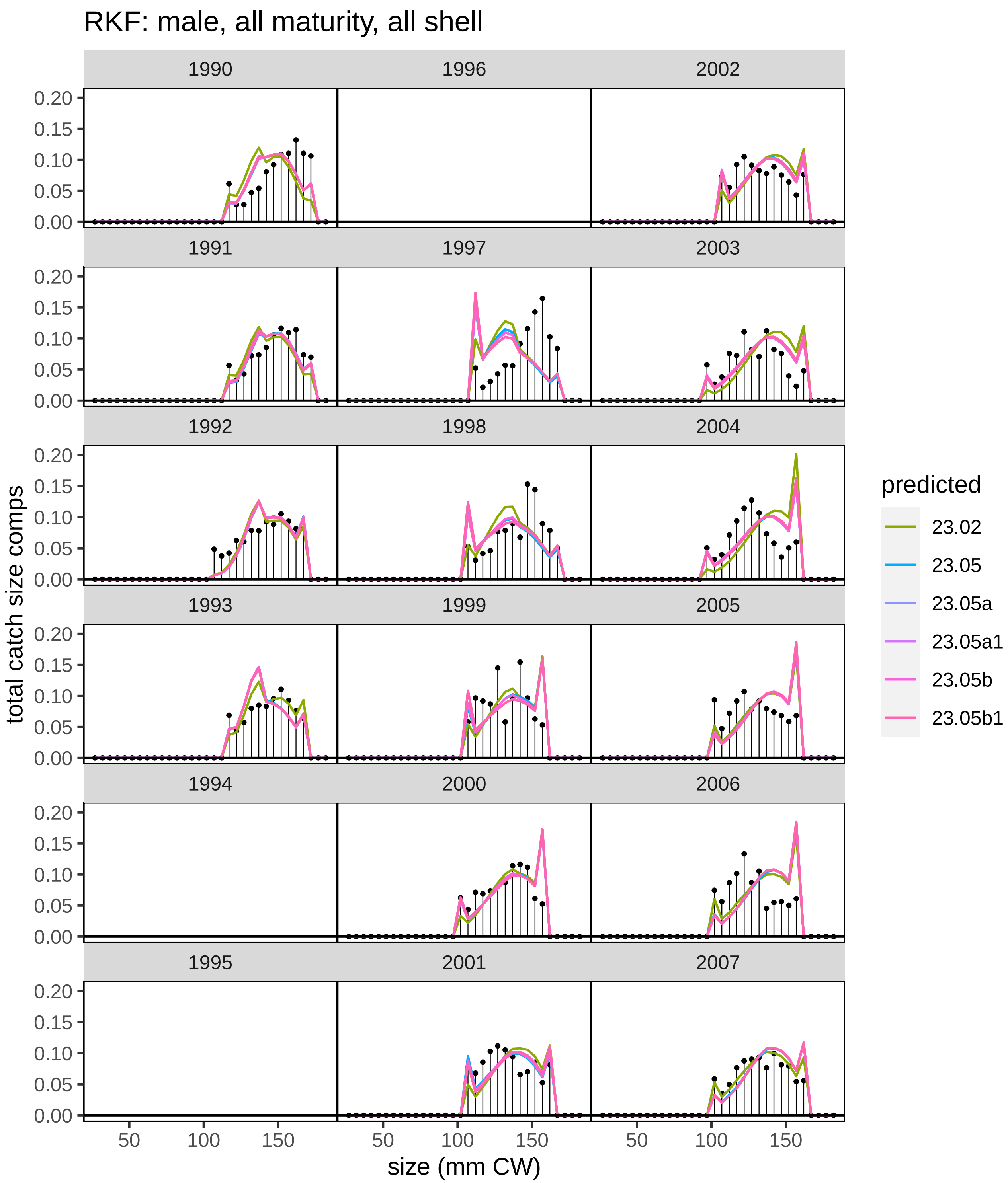

Figure 167. Fits to fishery total catch size compositions in the RKF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

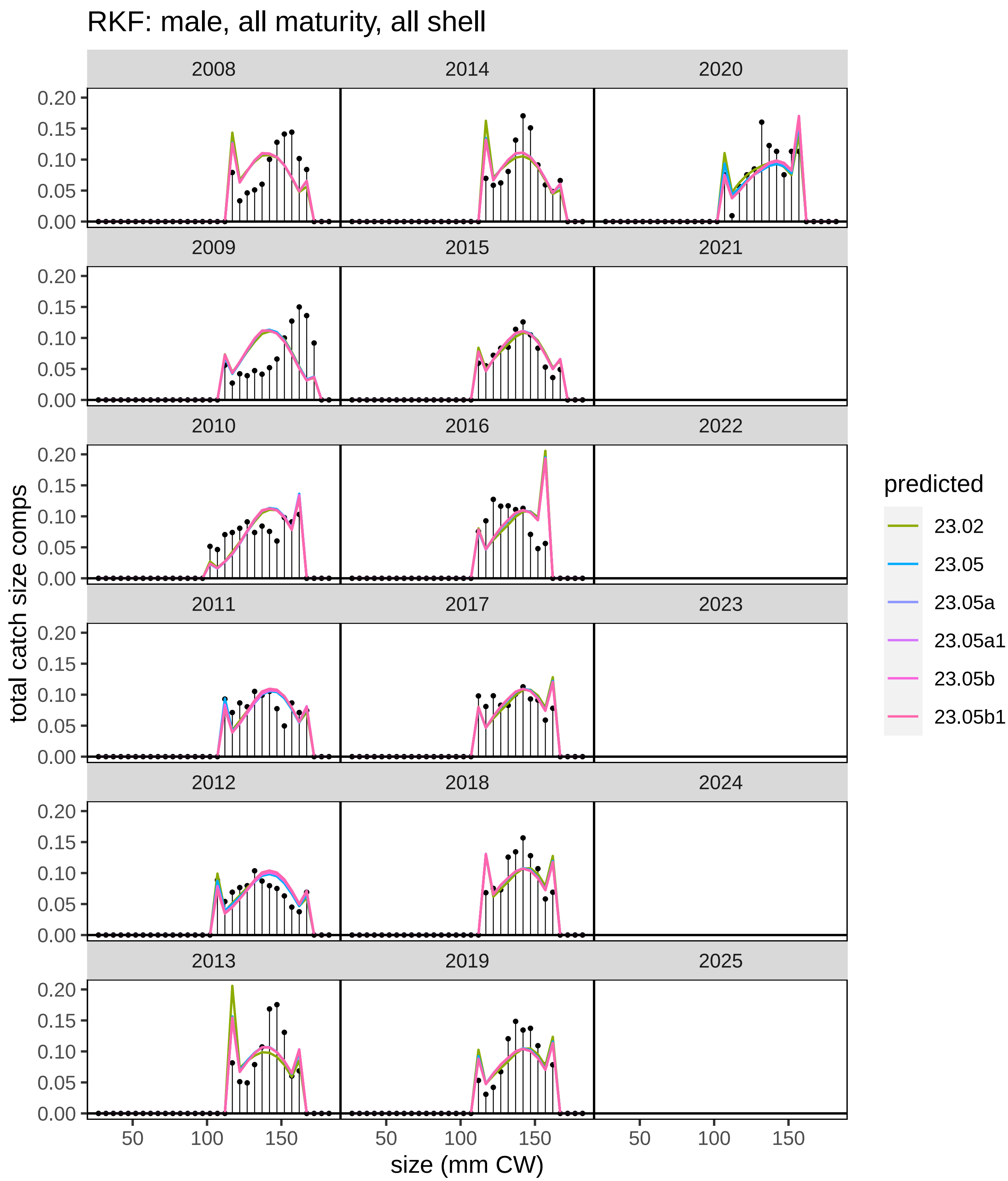

Figure 168. Fits to fishery total catch size compositions in the RKF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

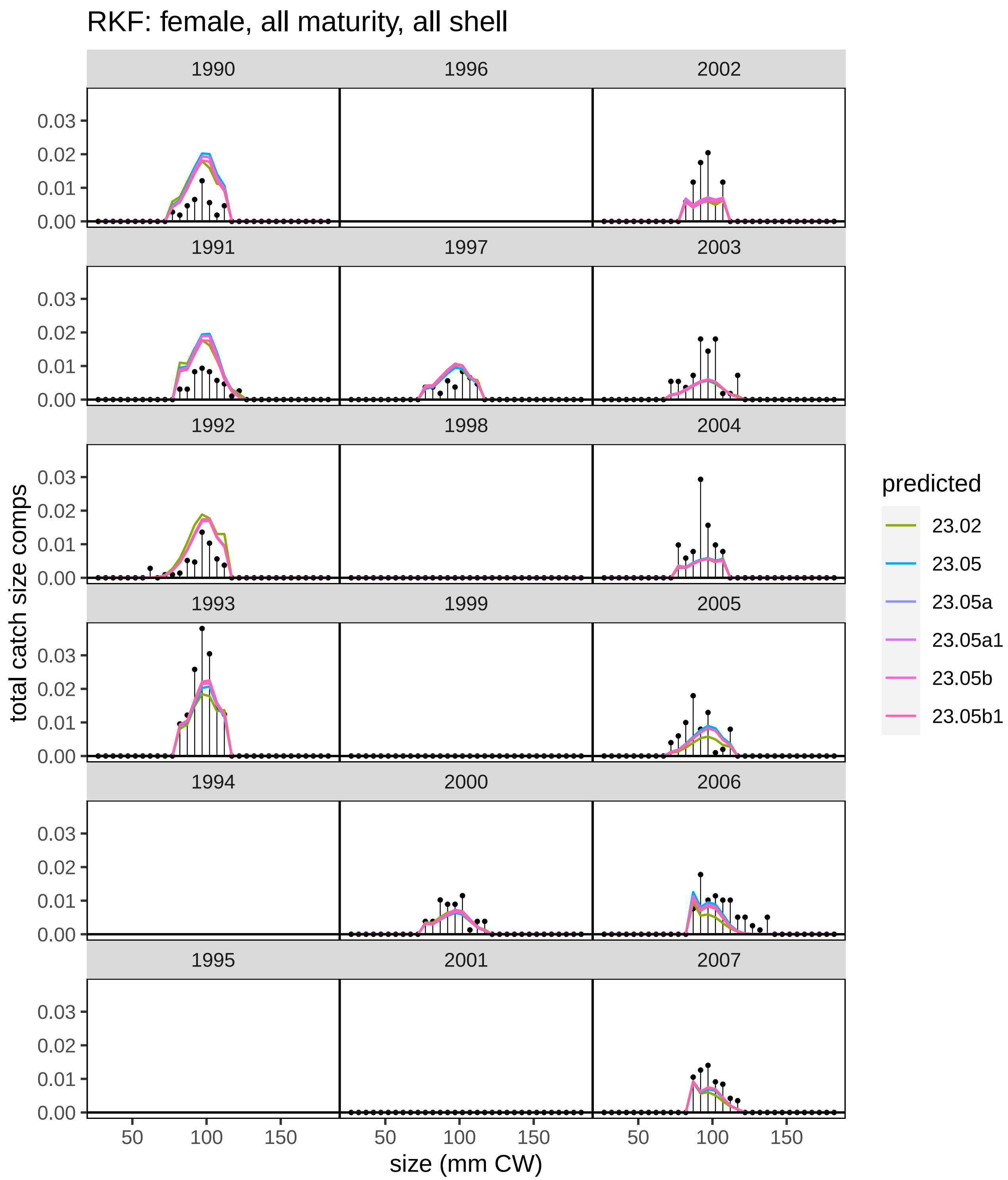

Figure 169. Fits to fishery total catch size compositions in the RKF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

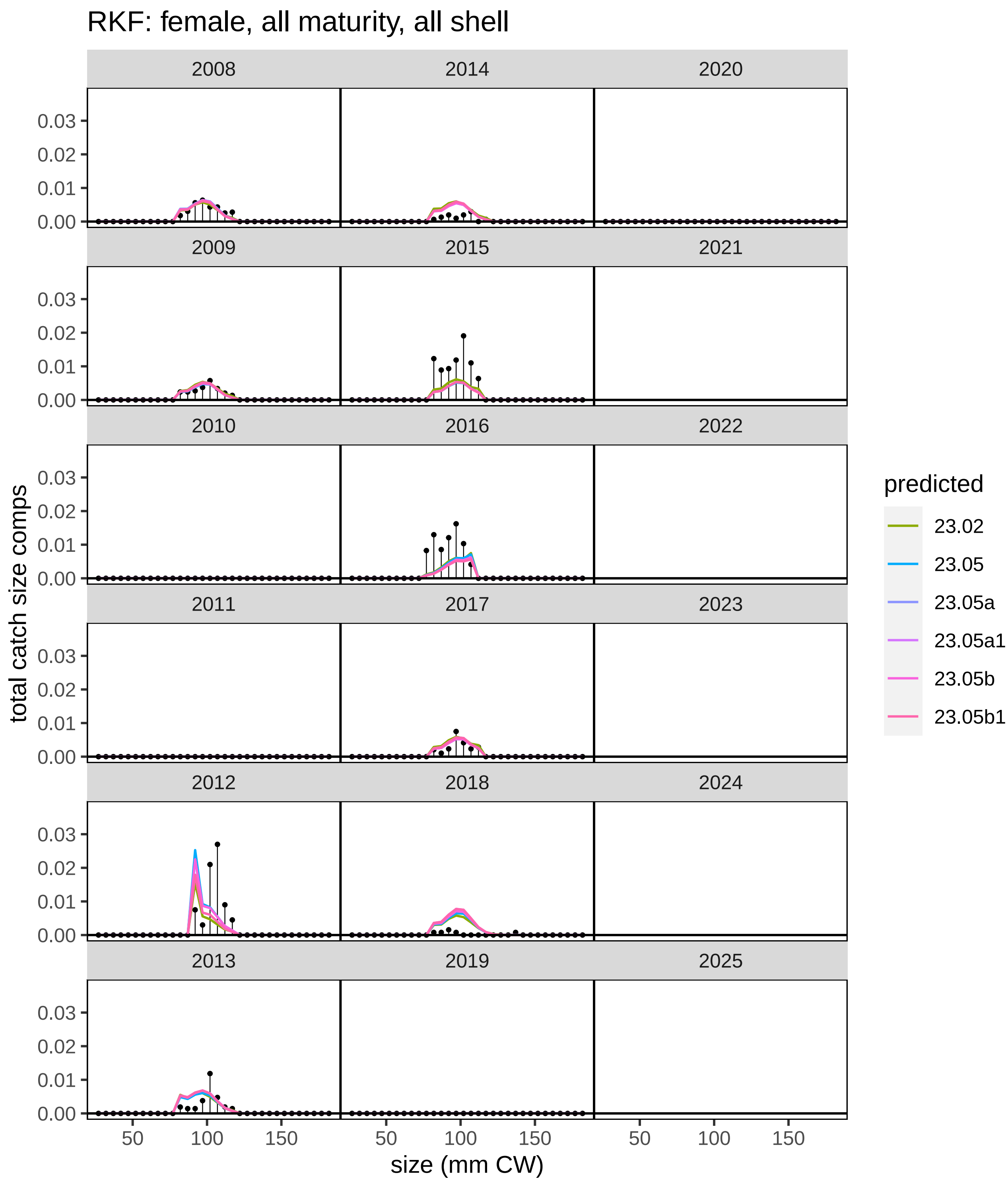

Figure 170. Fits to fishery total catch size compositions in the RKF fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

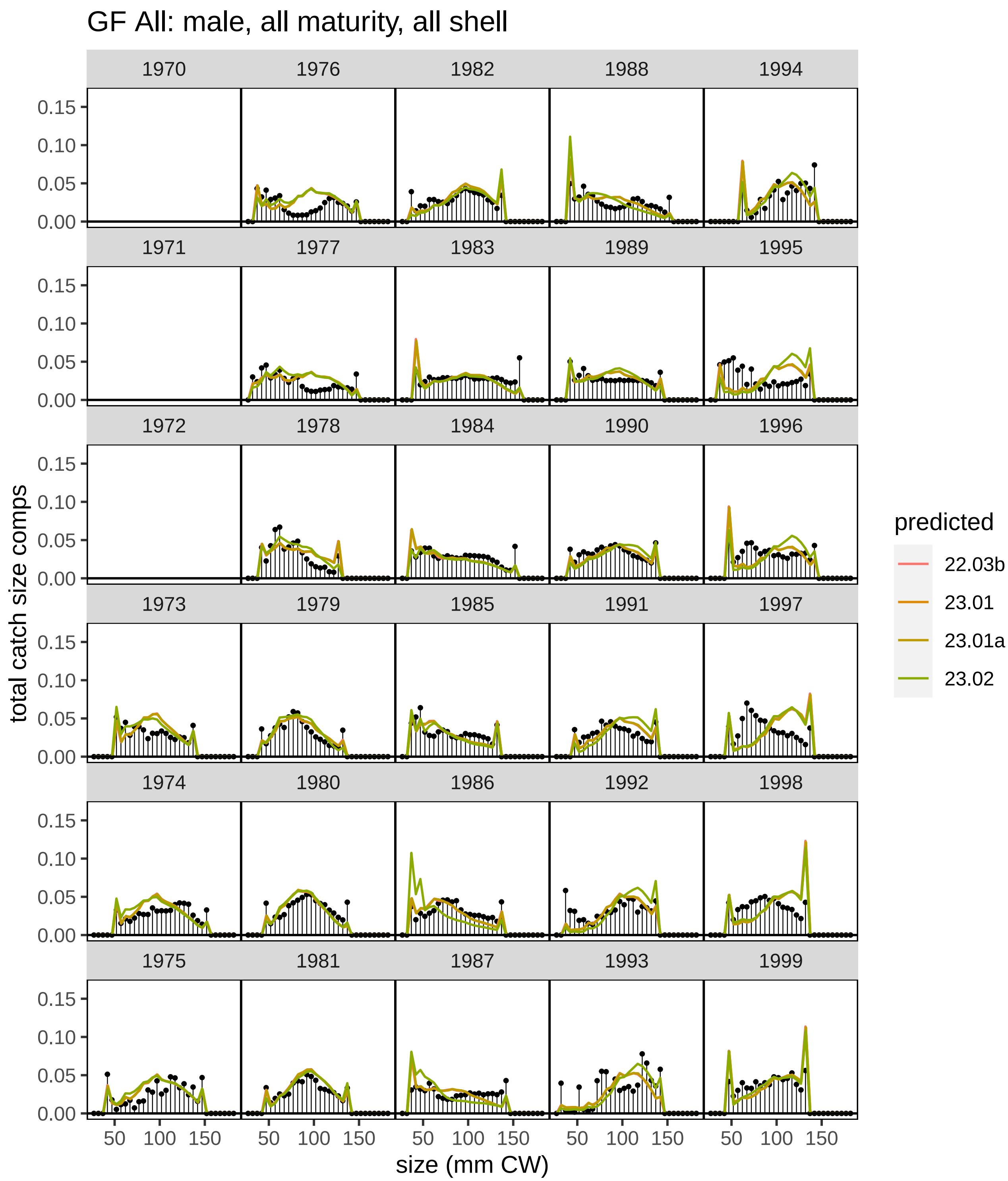

Figure 171. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.01, 23.01a, 23.02.

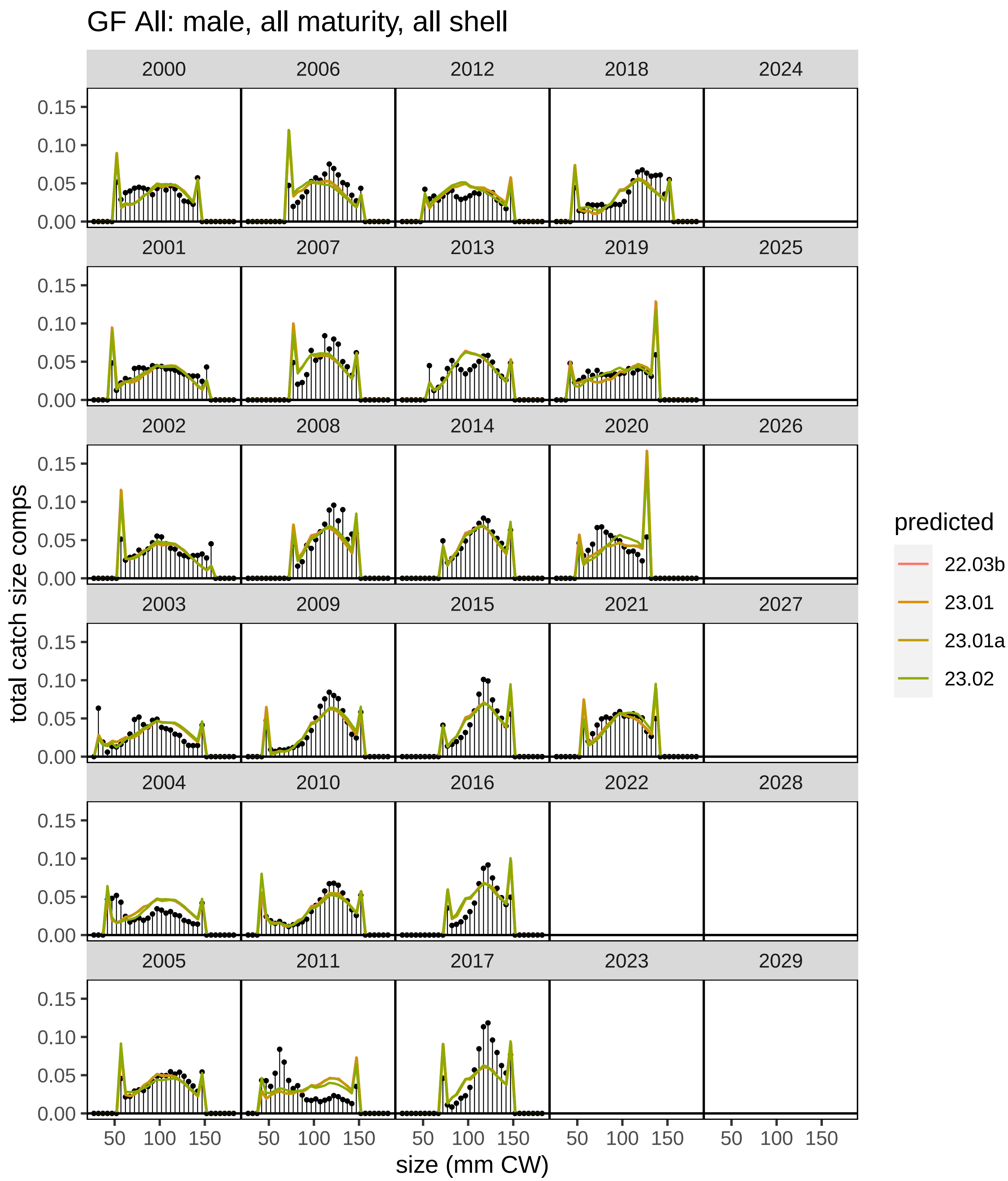

Figure 172. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.01, 23.01a, 23.02.

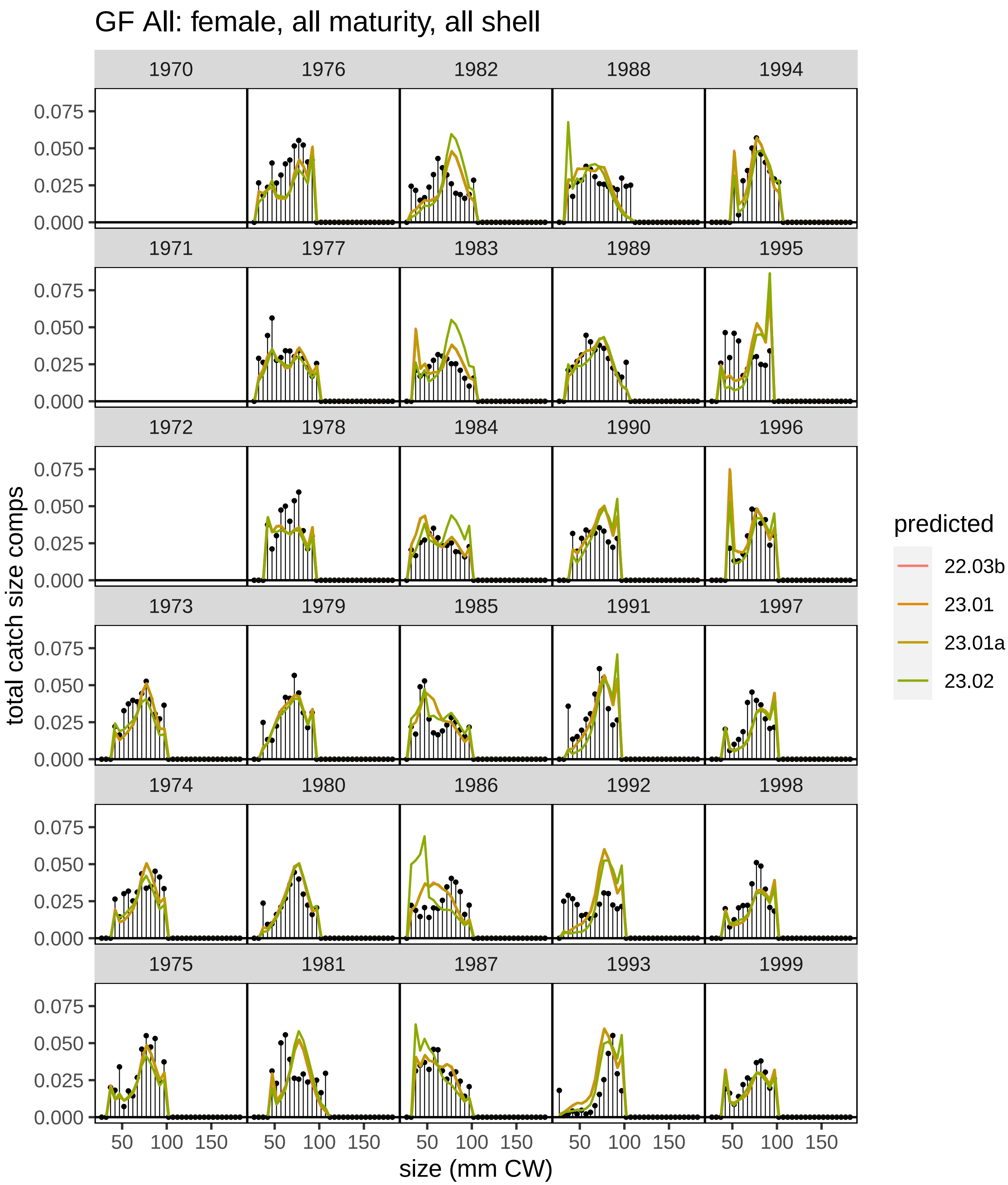

Figure 173. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.01, 23.01a, 23.02.

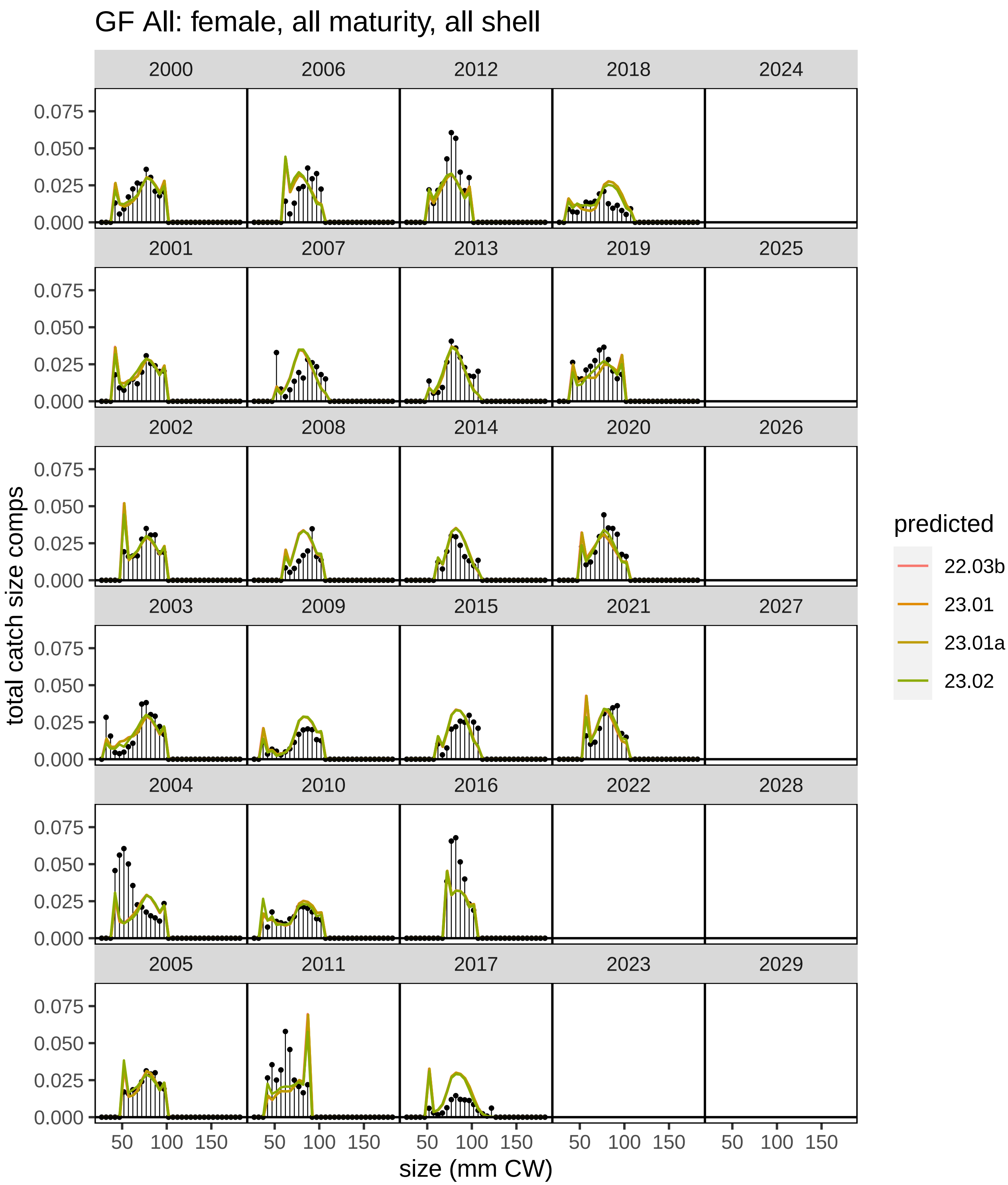

Figure 174. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.01, 23.01a, 23.02.

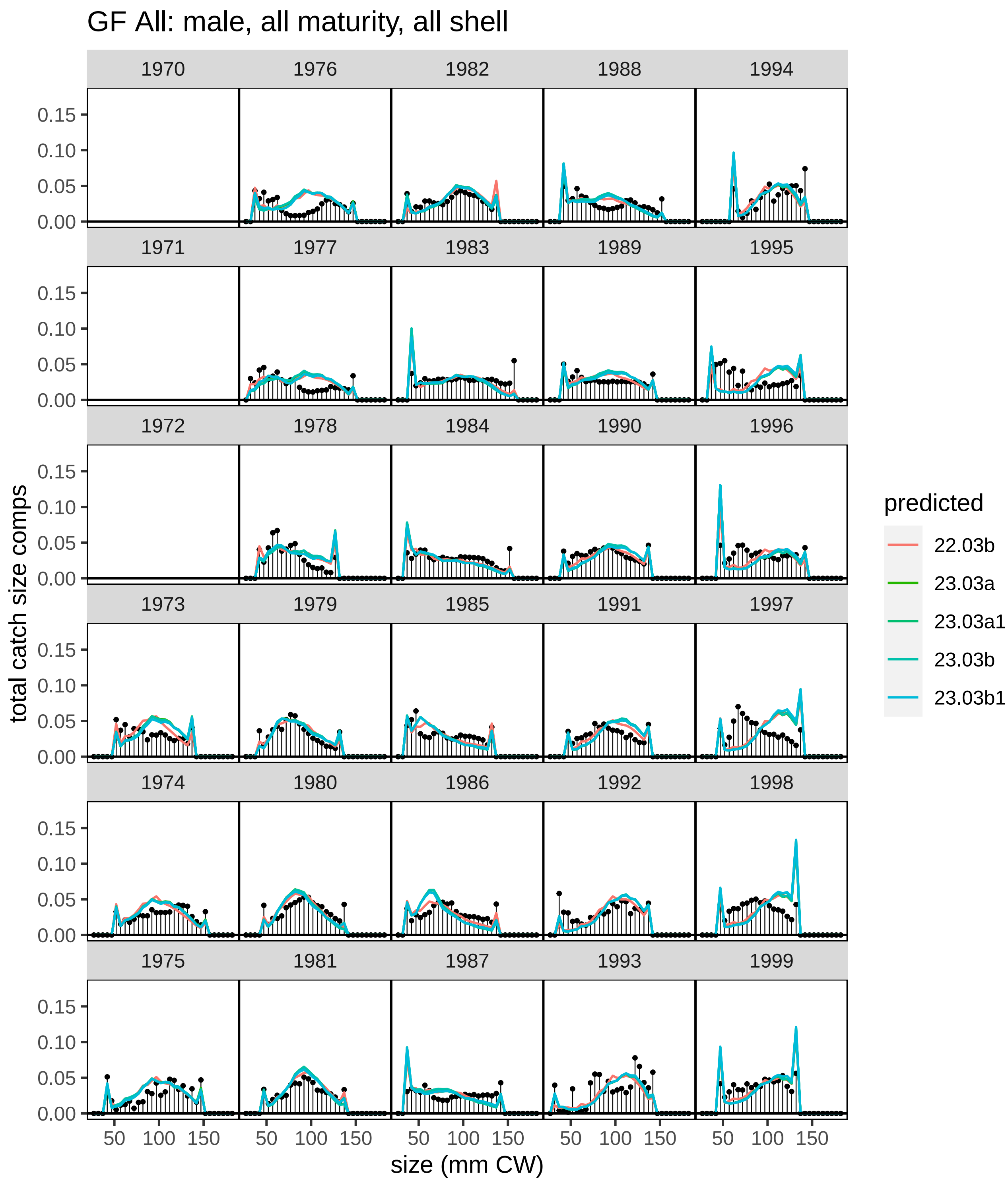

Figure 175. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

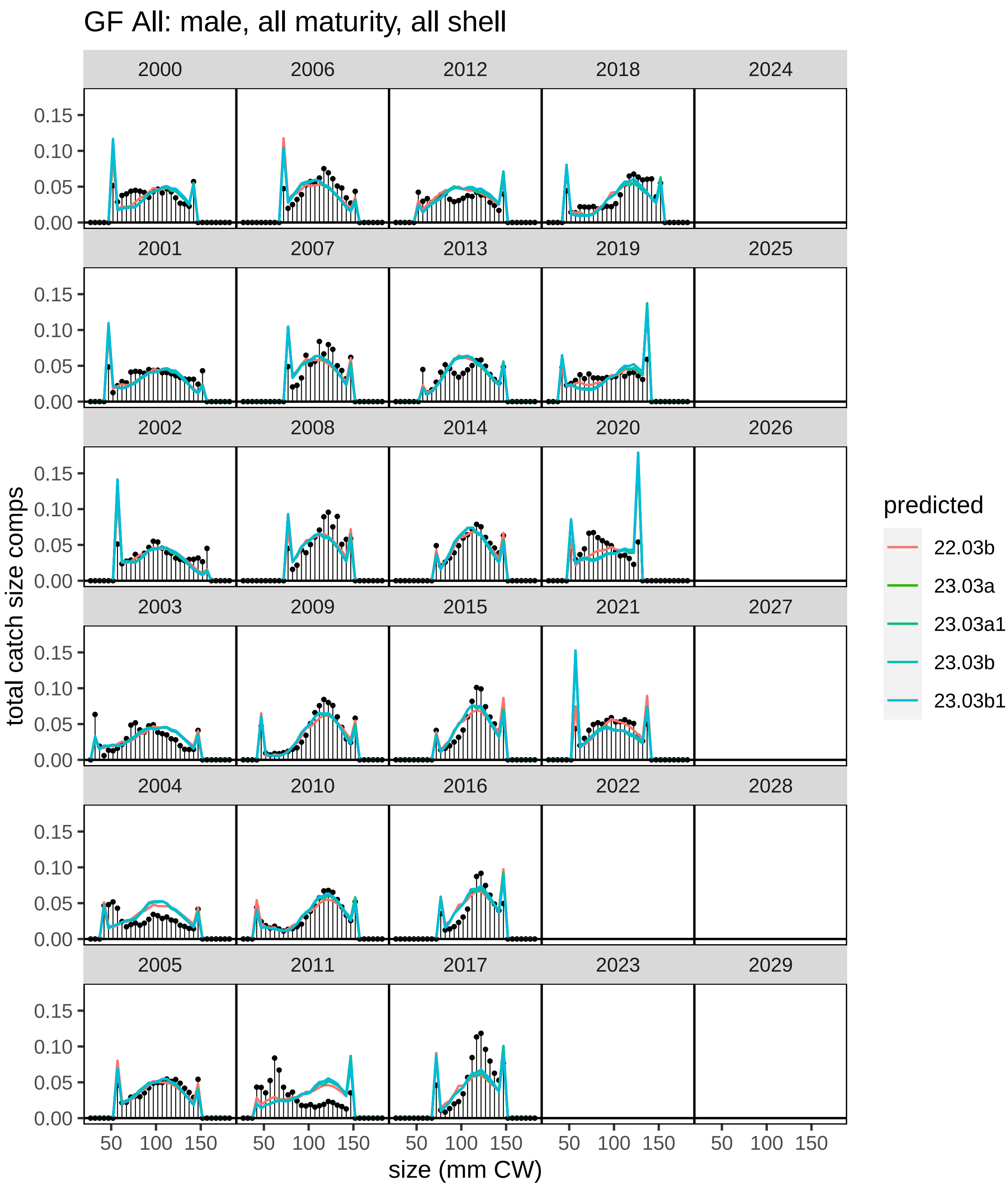

Figure 176. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

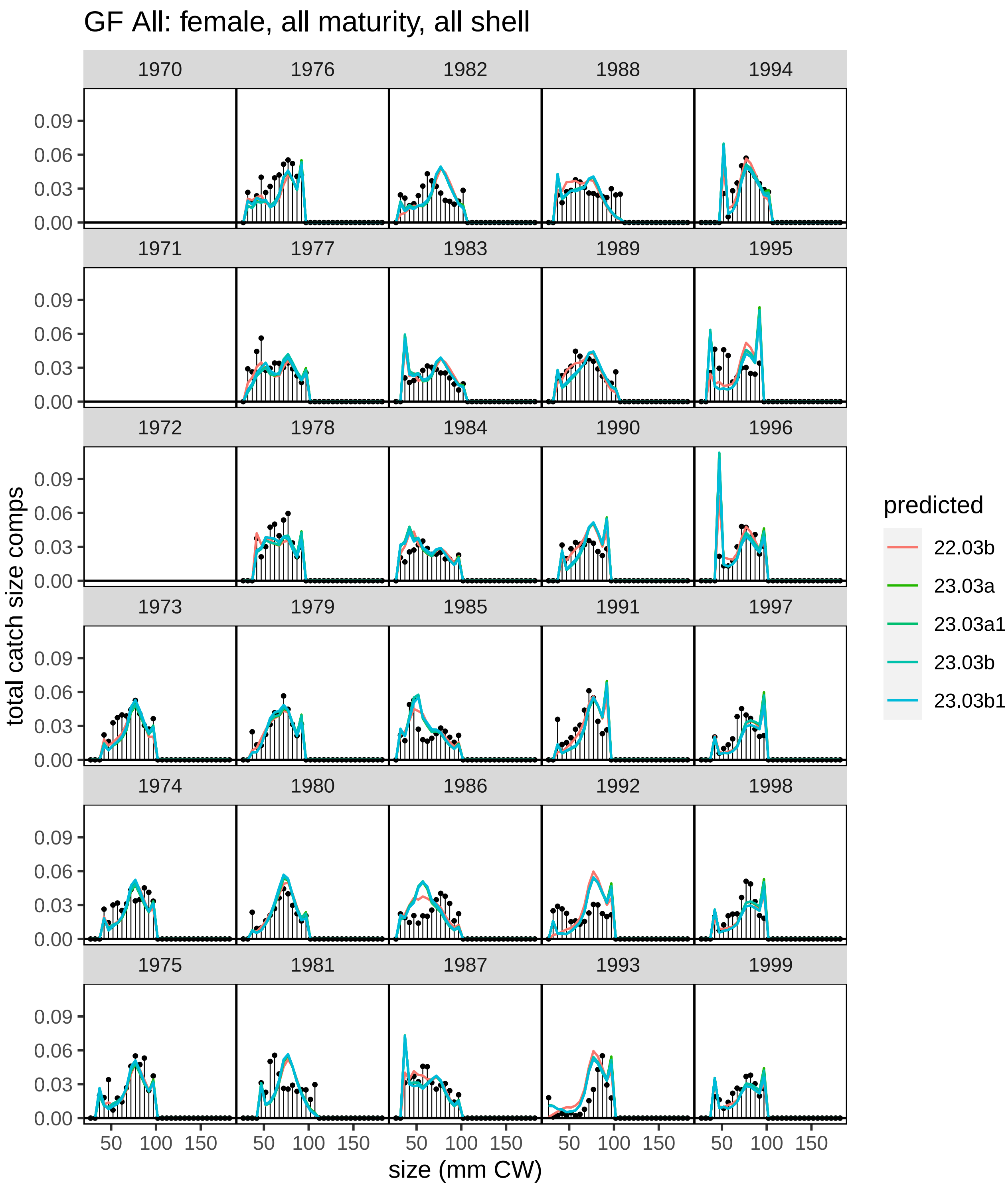

Figure 177. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

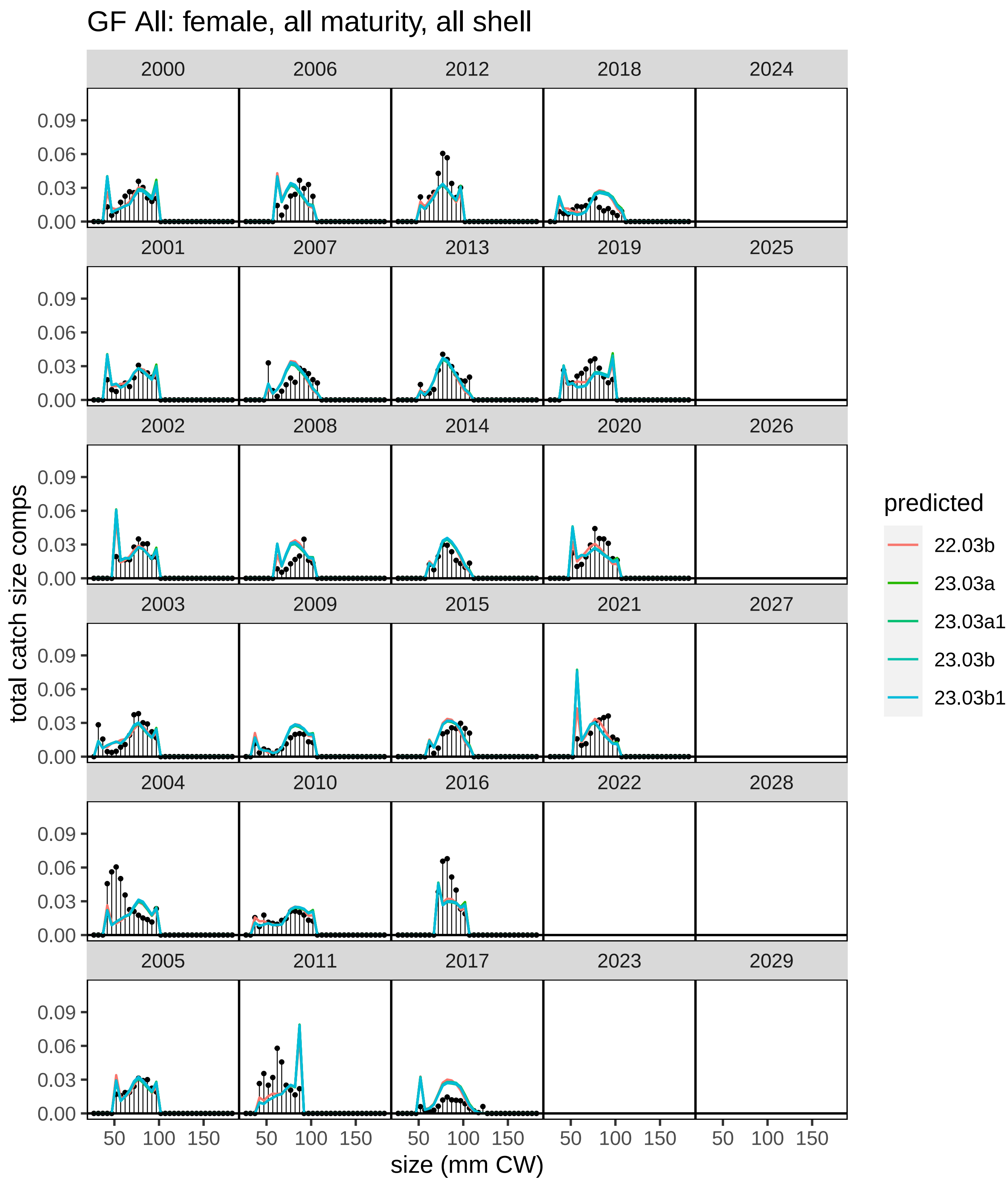

Figure 178. Fits to fishery total catch size compositions in the GF All fishery for Models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

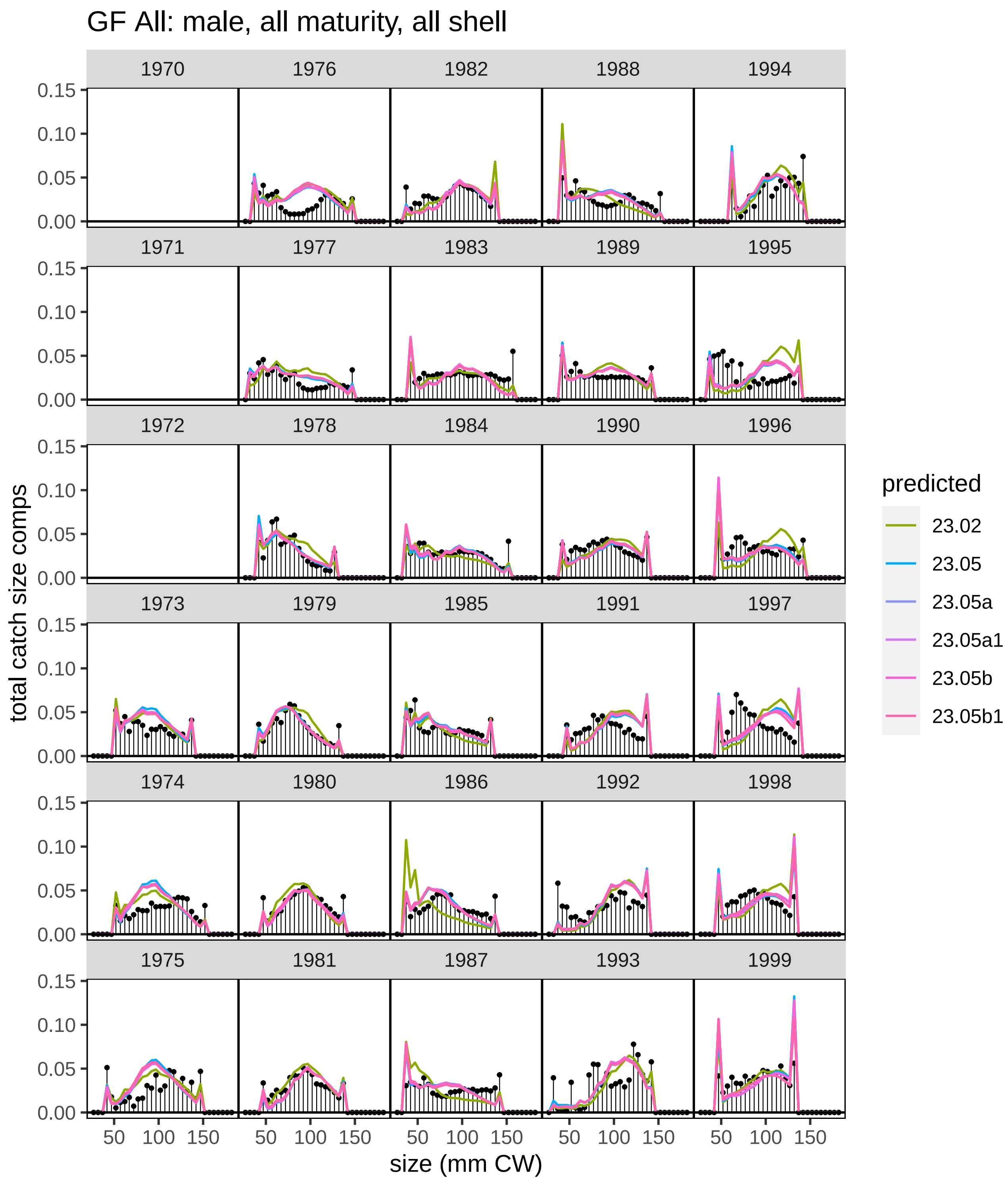

Figure 179. Fits to fishery total catch size compositions in the GF All fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

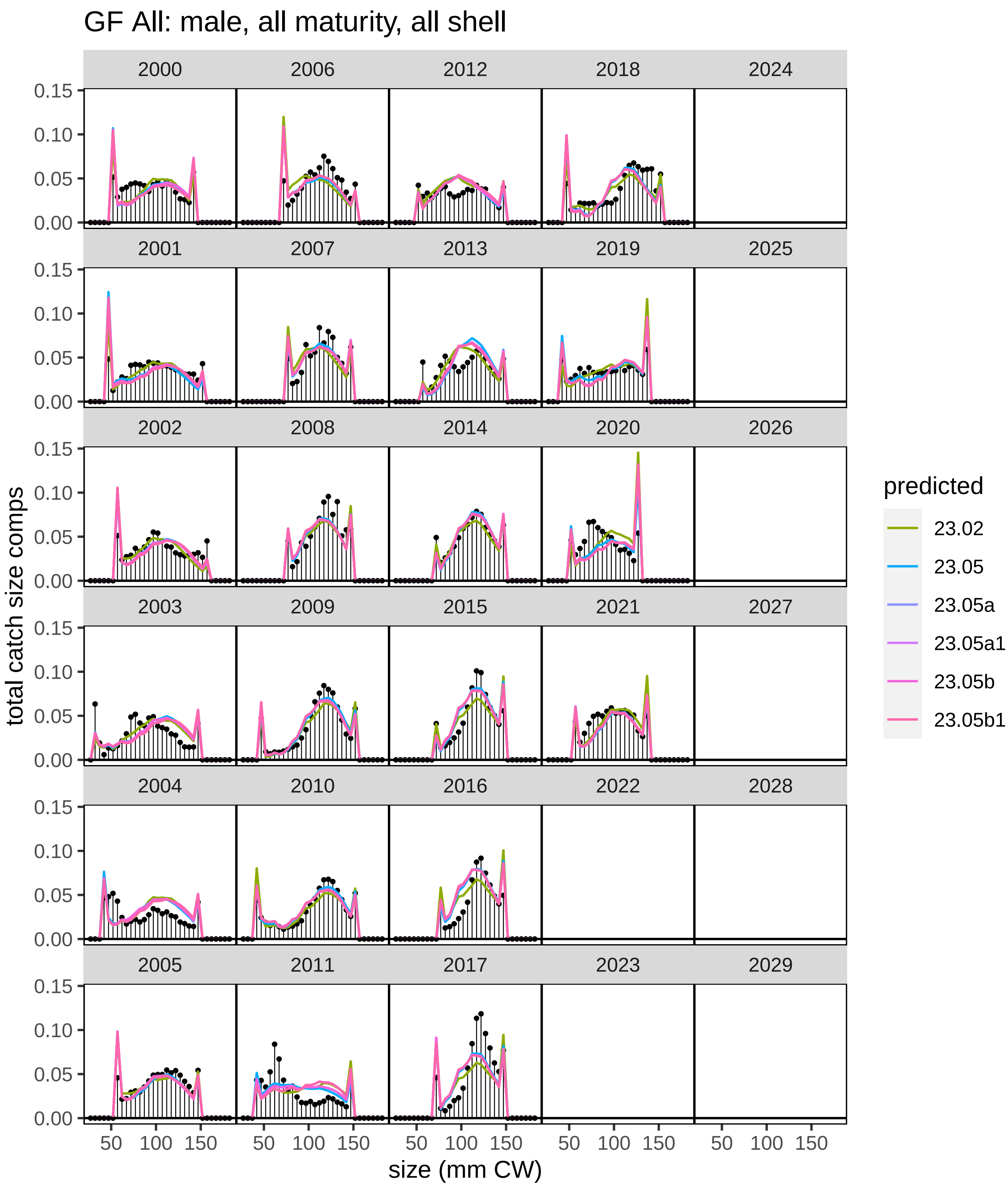

Figure 180. Fits to fishery total catch size compositions in the GF All fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

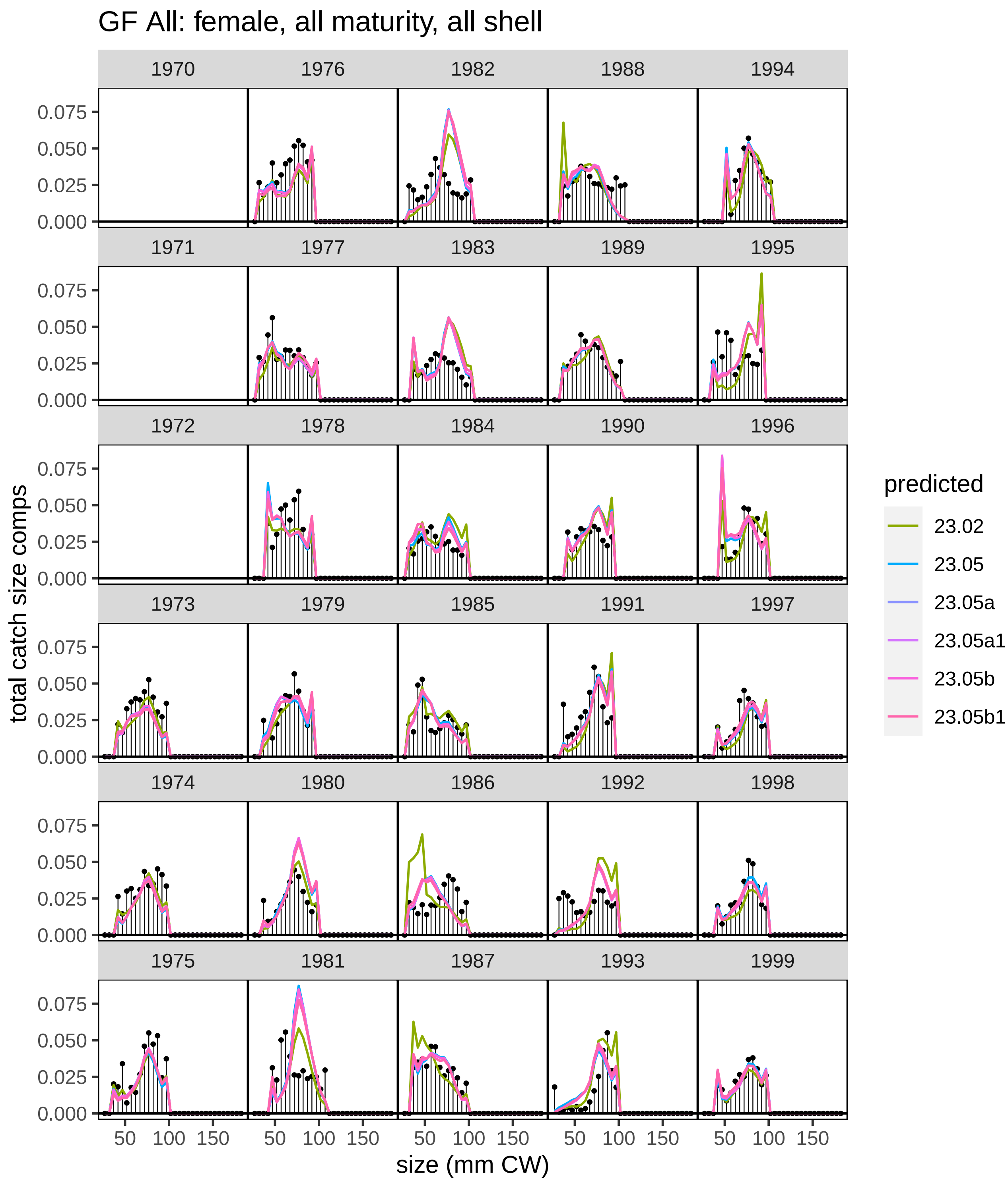

Figure 181. Fits to fishery total catch size compositions in the GF All fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

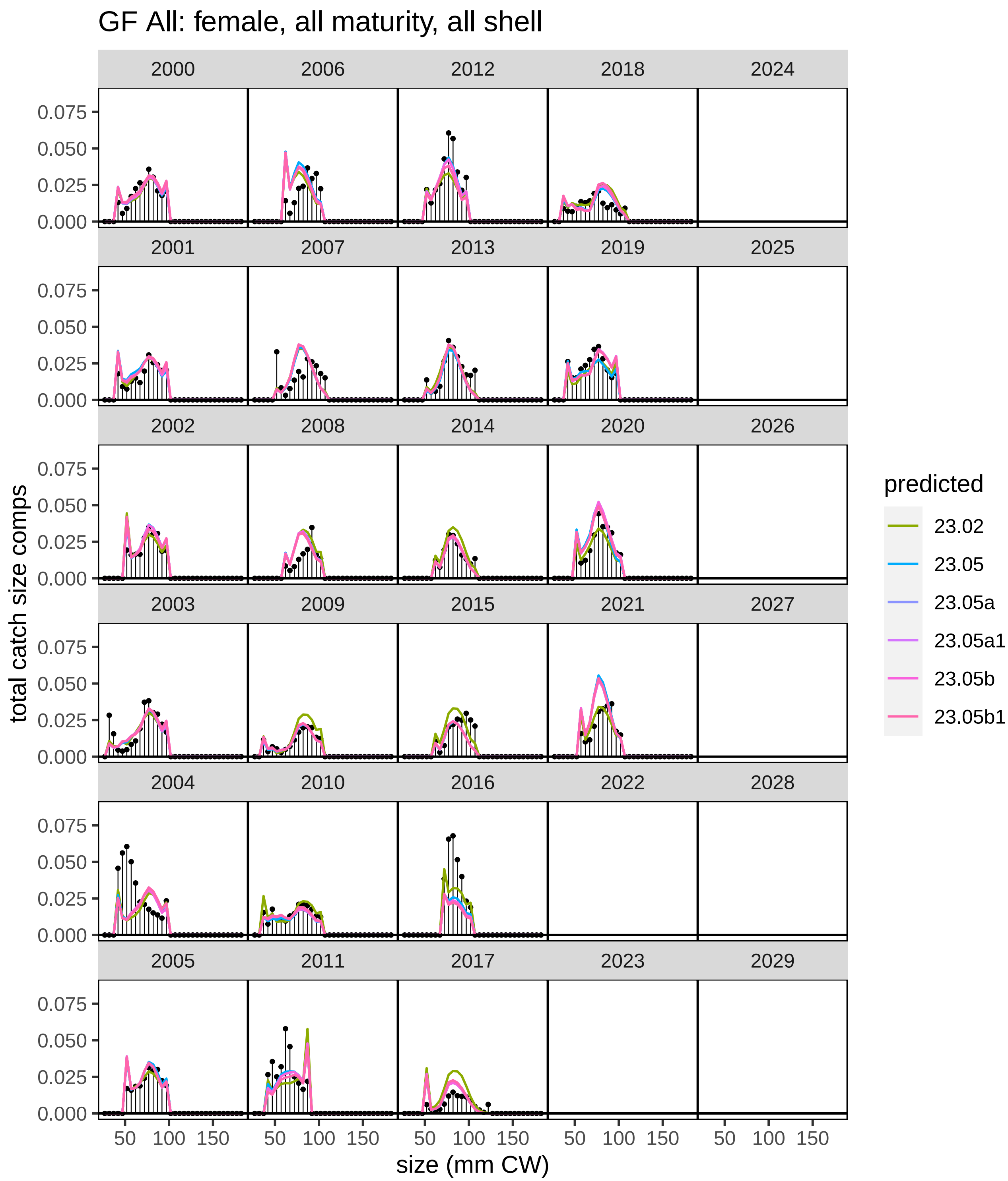

Figure 182. Fits to fishery total catch size compositions in the GF All fishery for Models 23.02, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

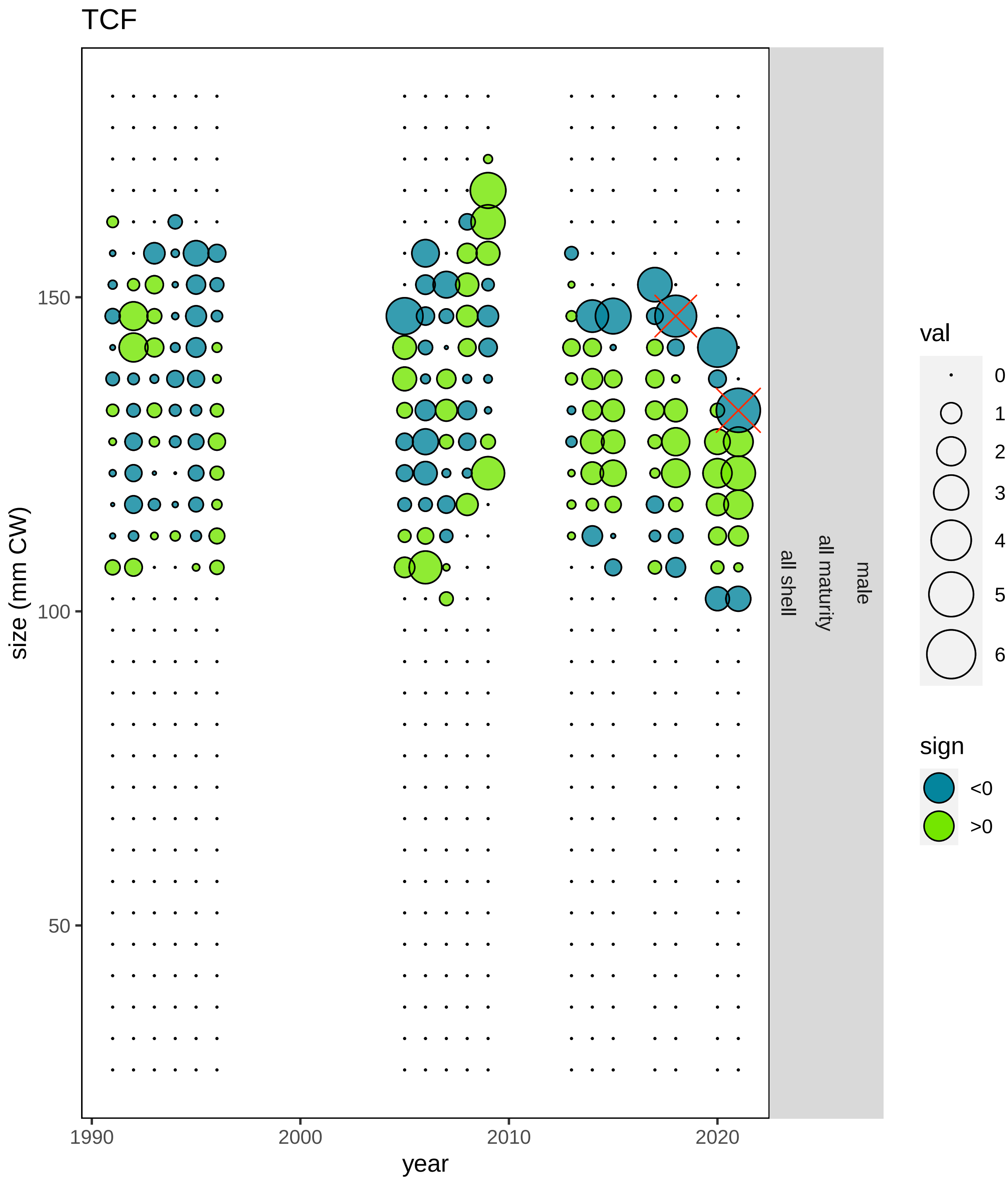

Figure 183. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

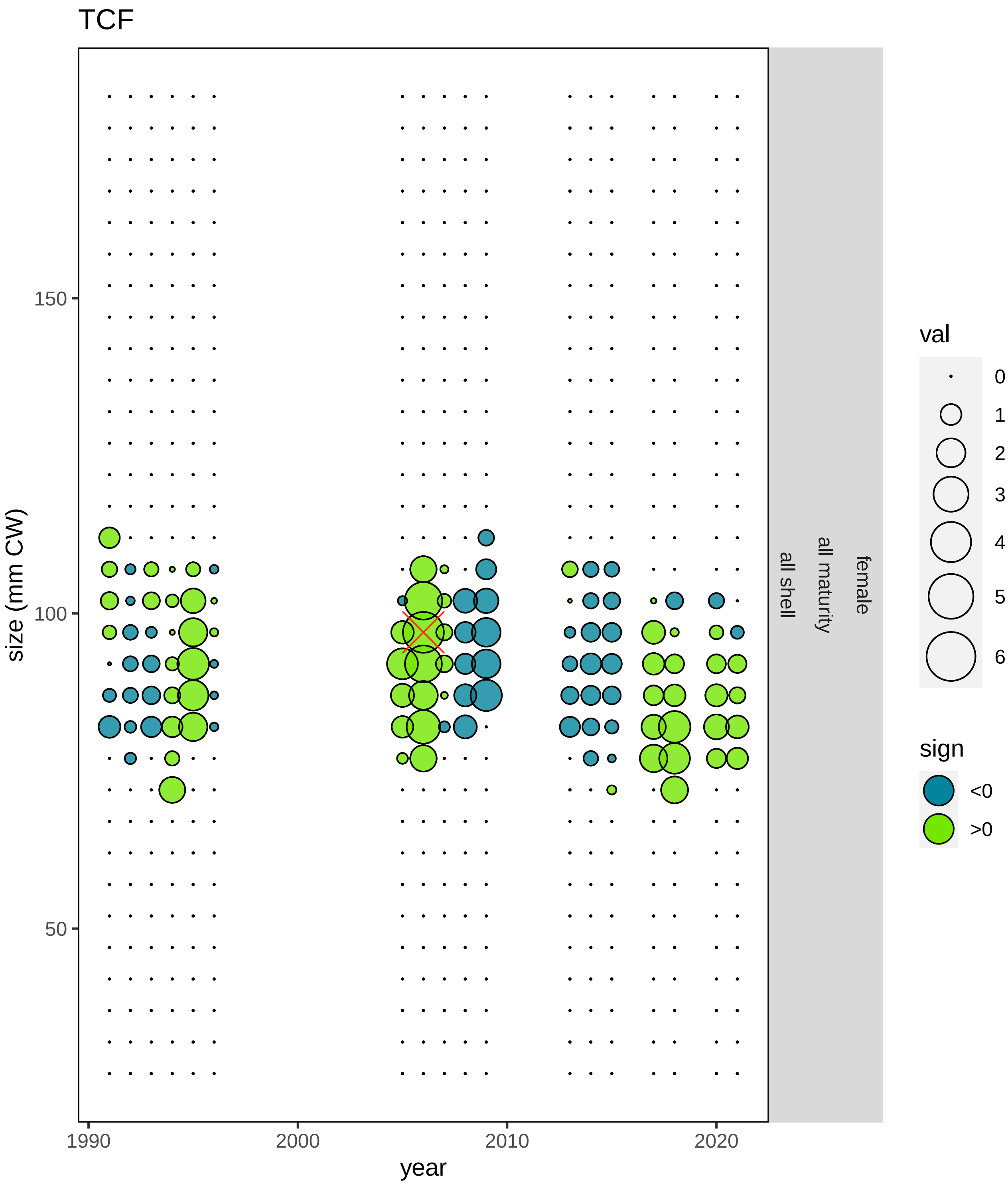

Figure 184. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

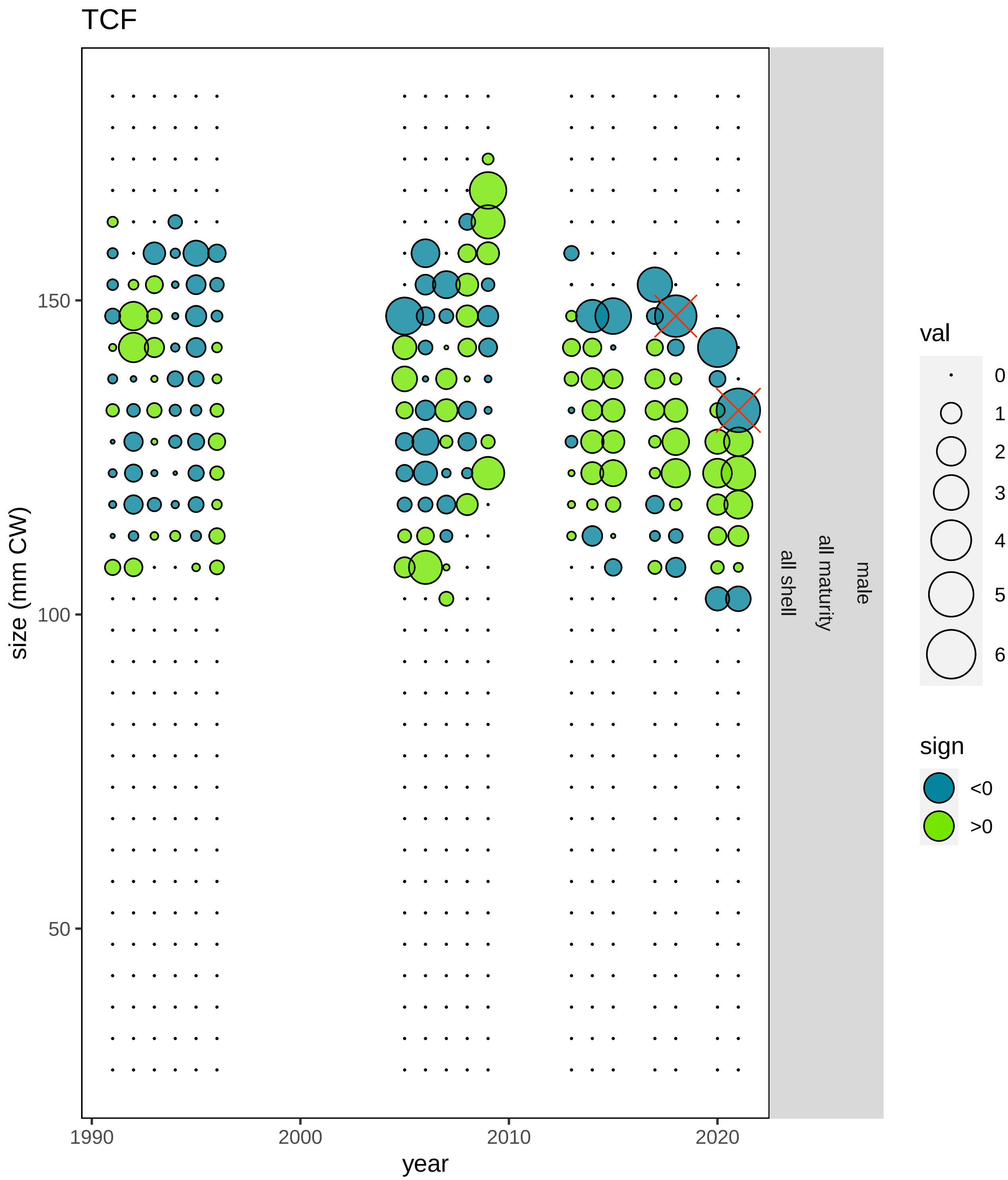

Figure 185. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

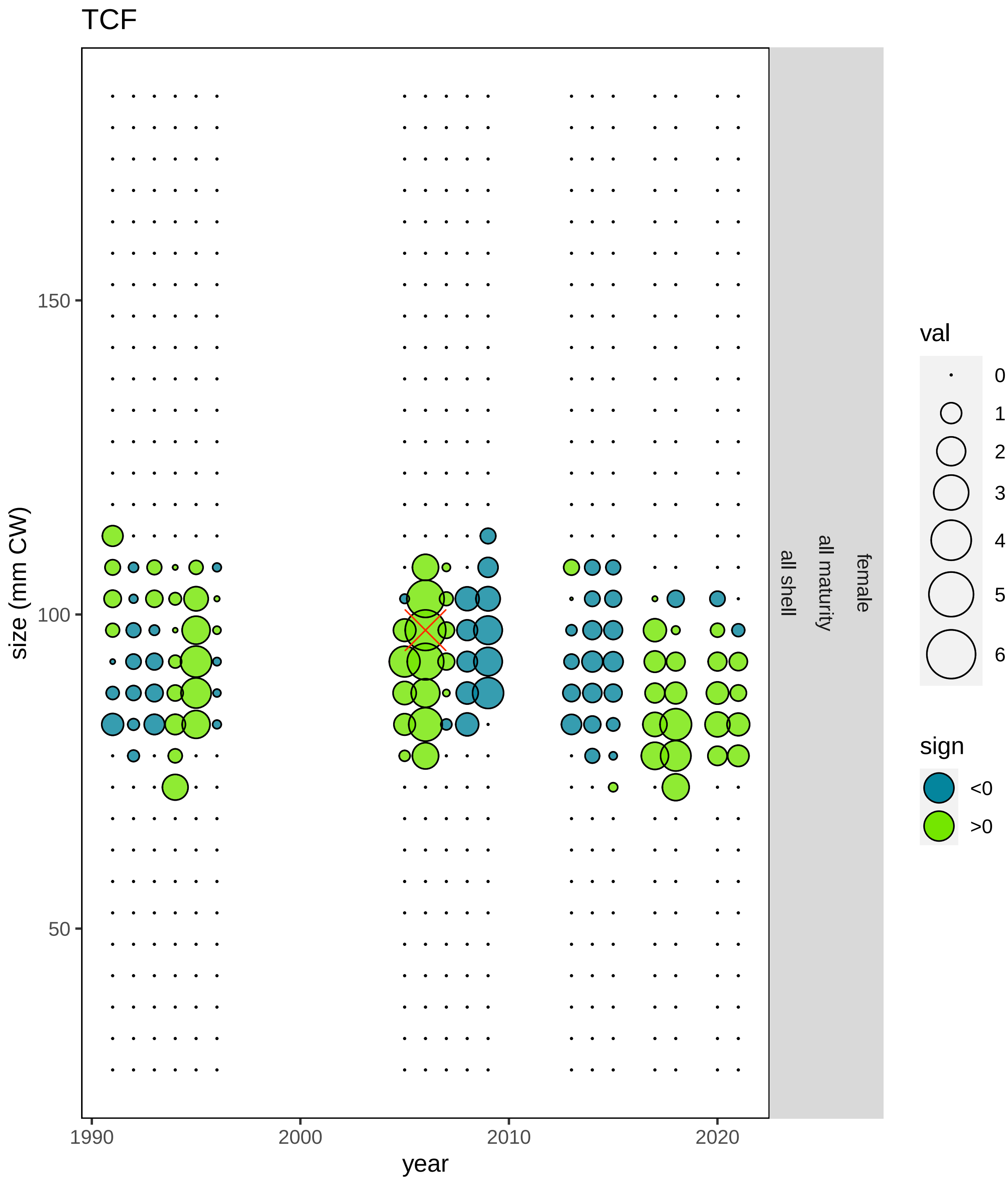

Figure 186. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

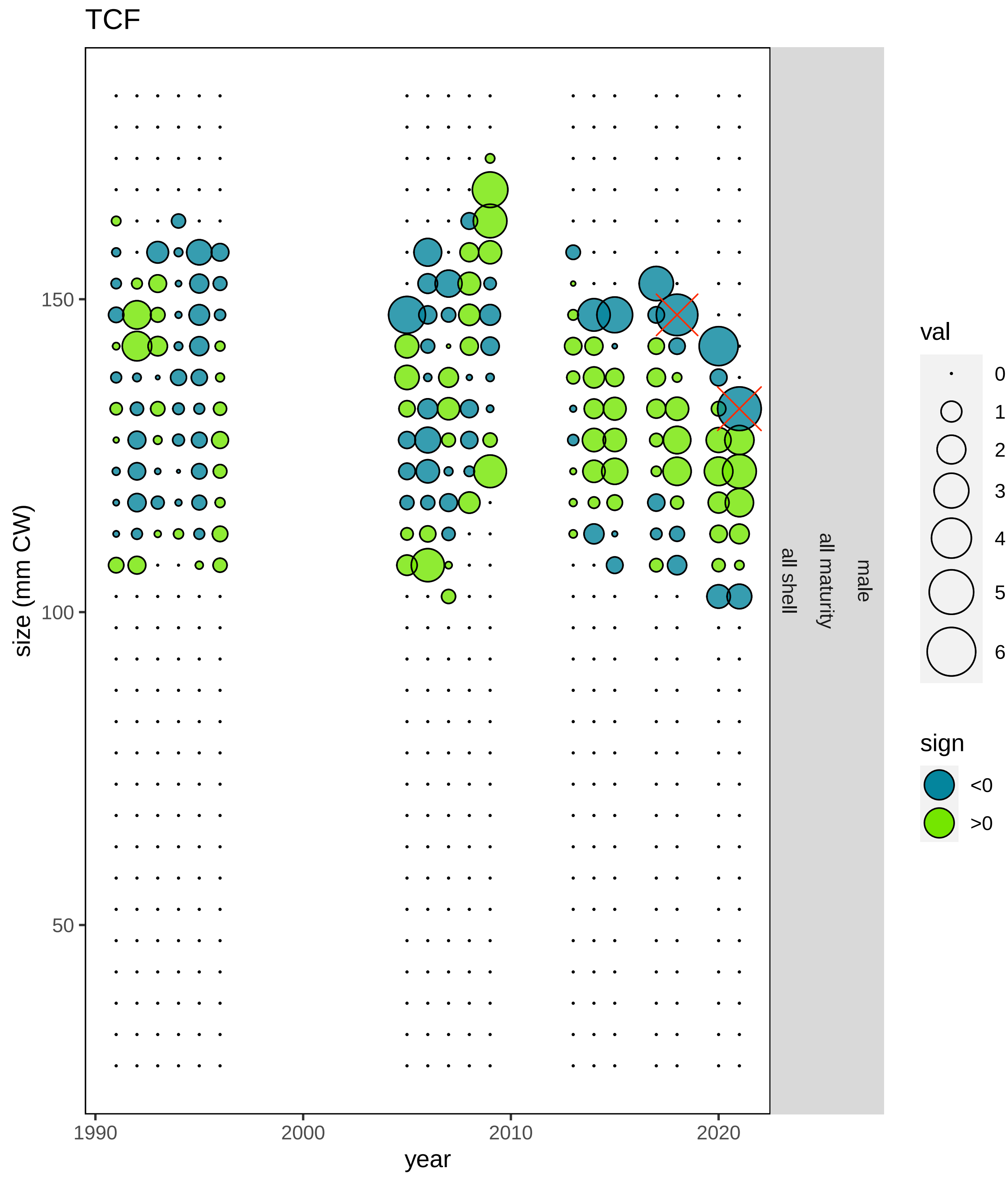

Figure 187. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

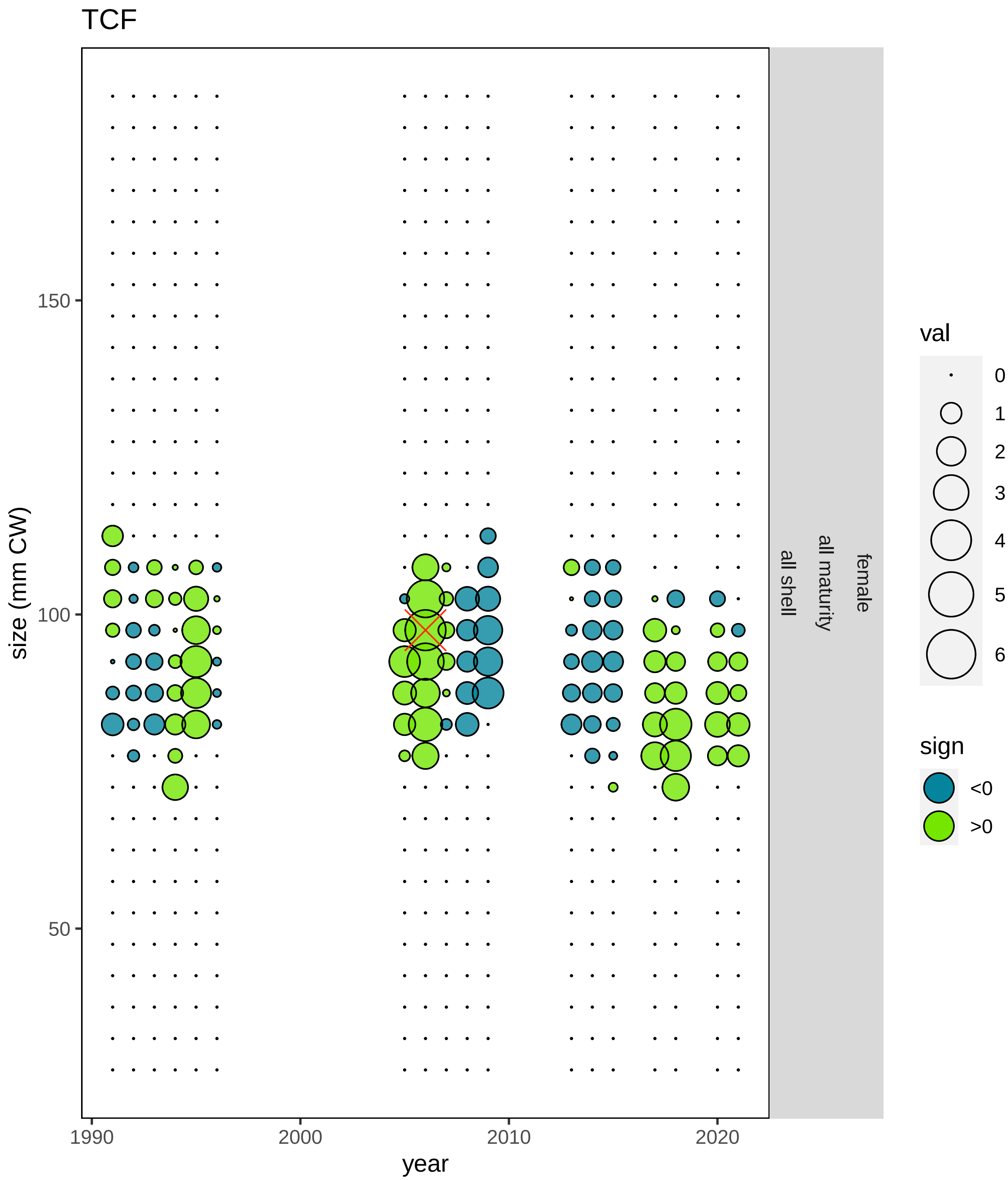

Figure 188. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

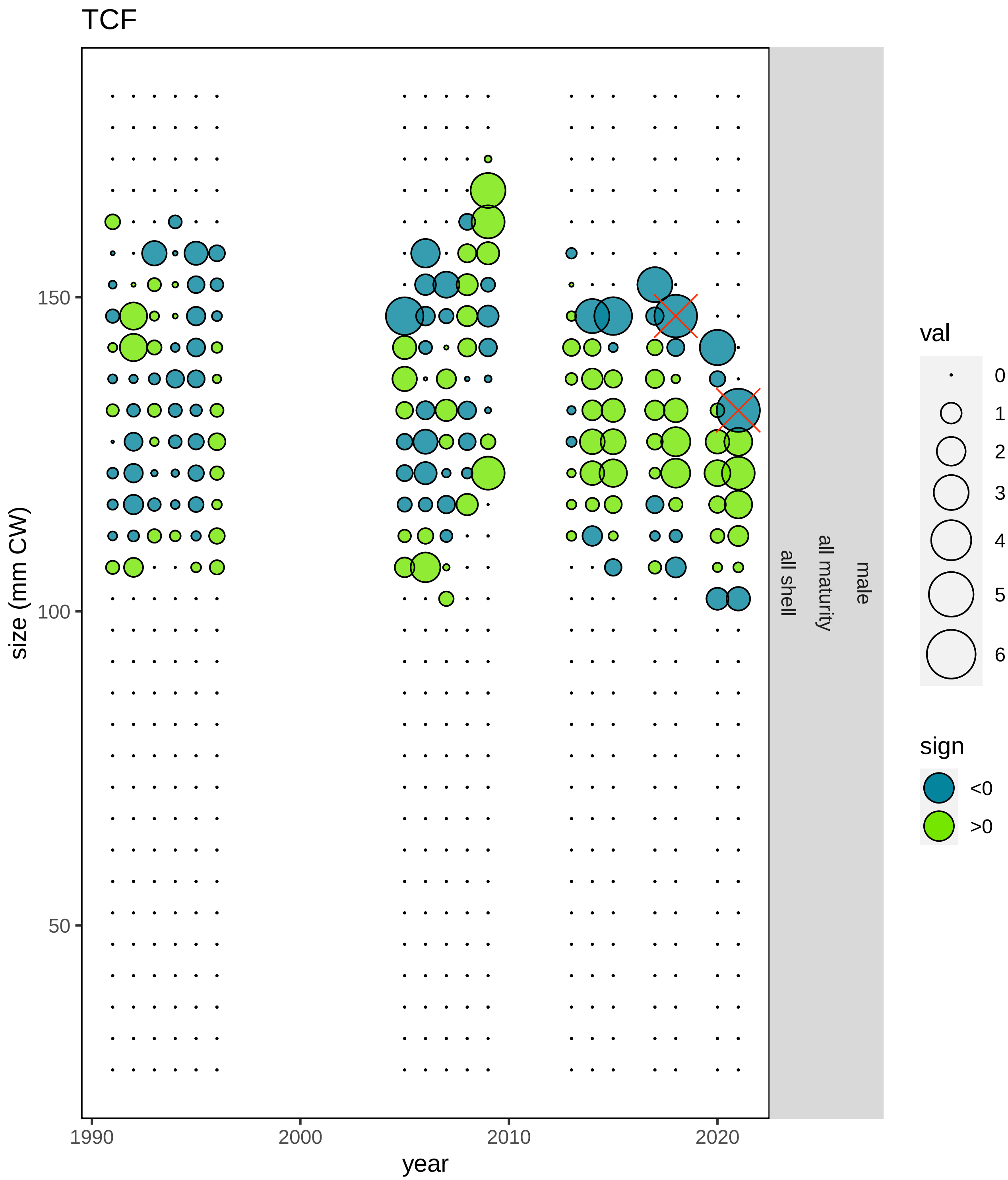

Figure 189. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

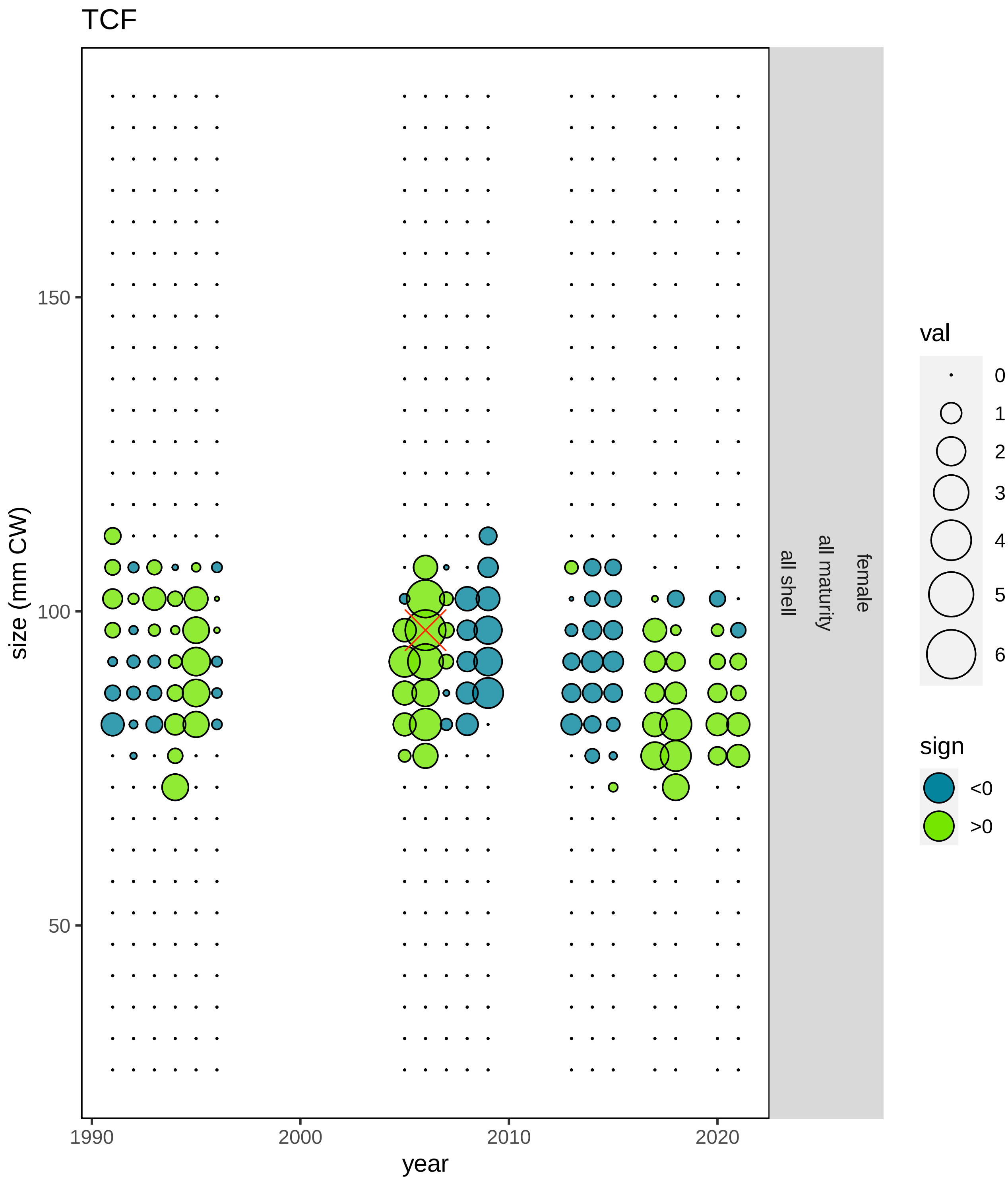

Figure 190. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

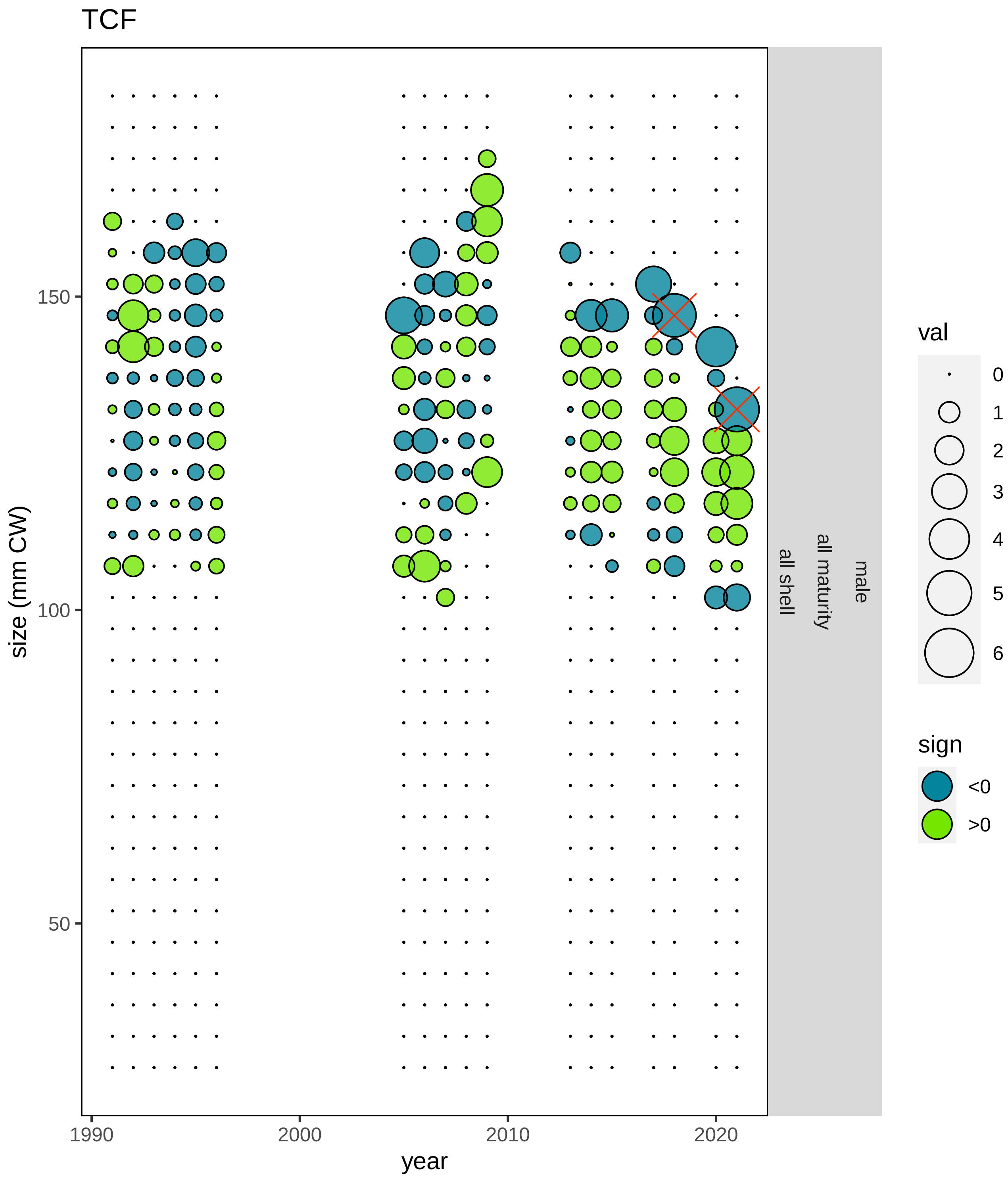

Figure 191. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

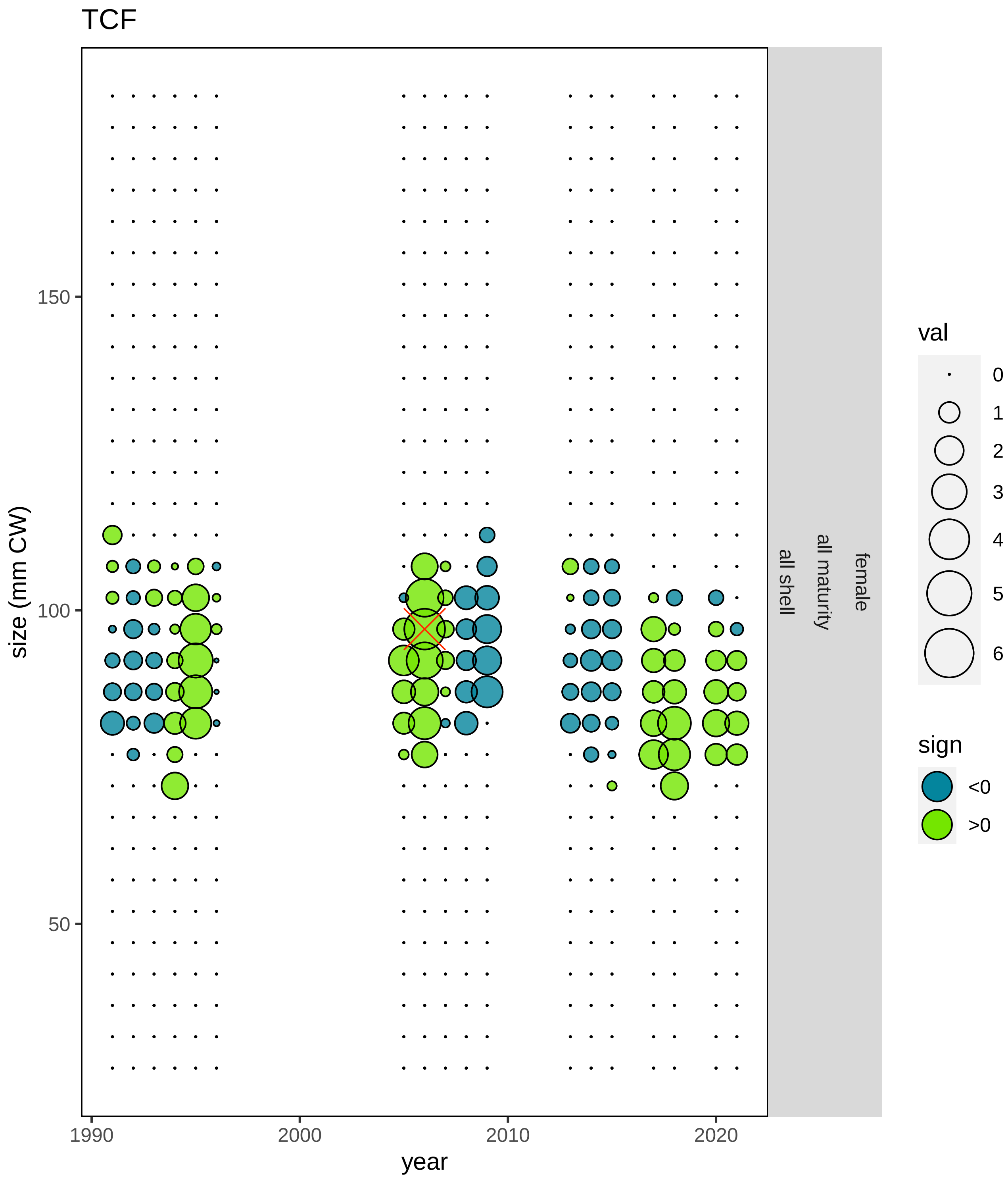

Figure 192. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

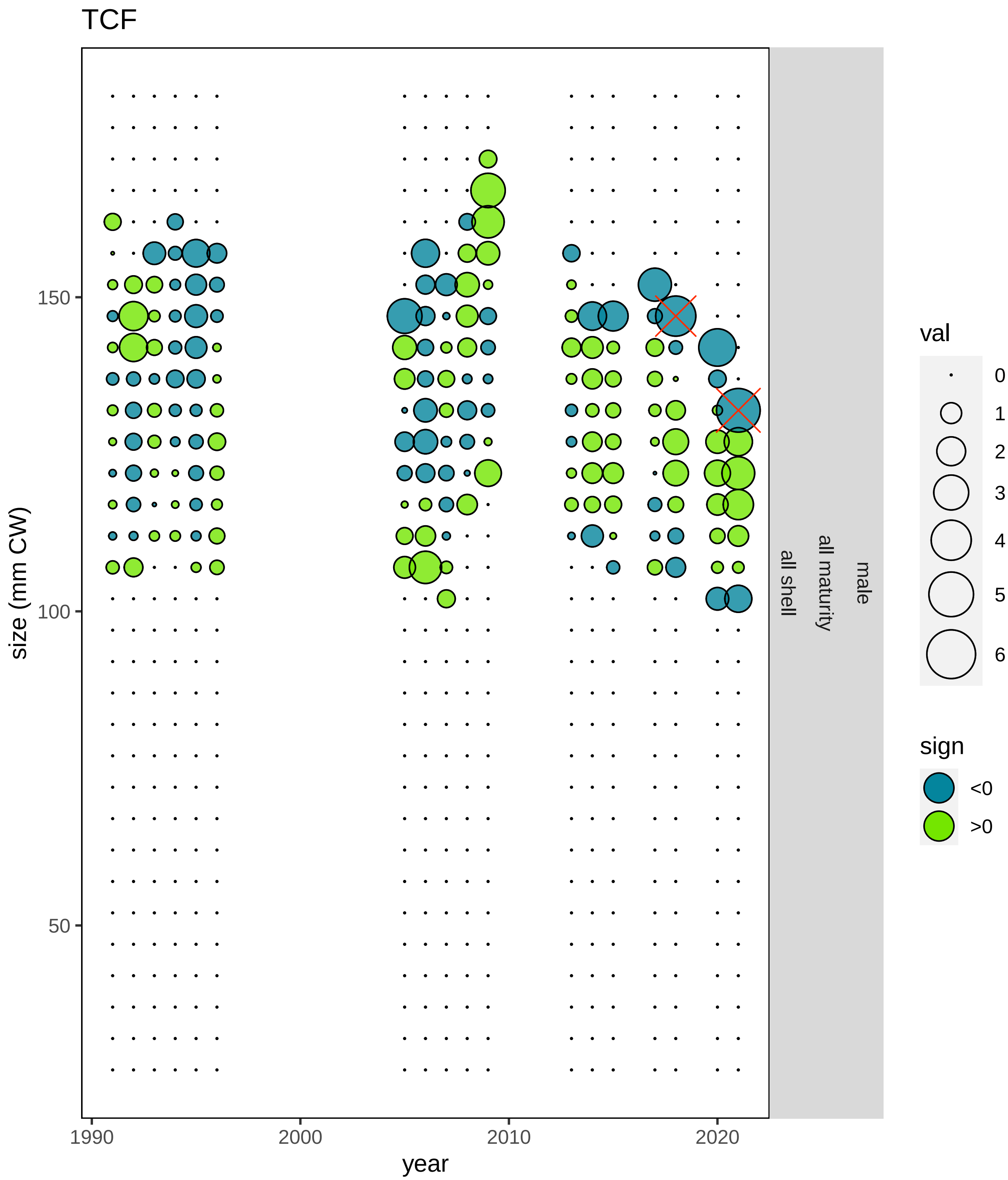

Figure 193. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

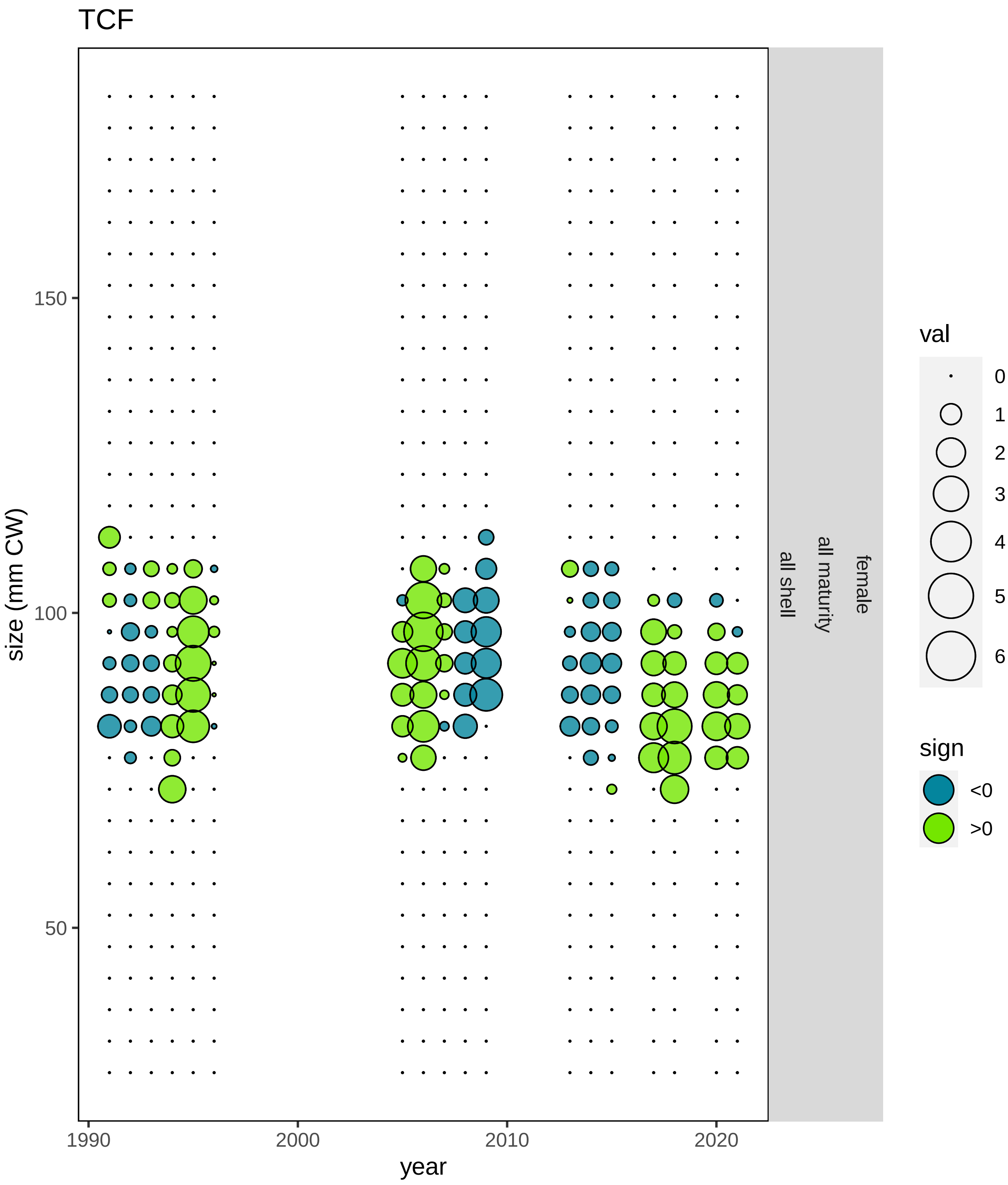

Figure 194. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

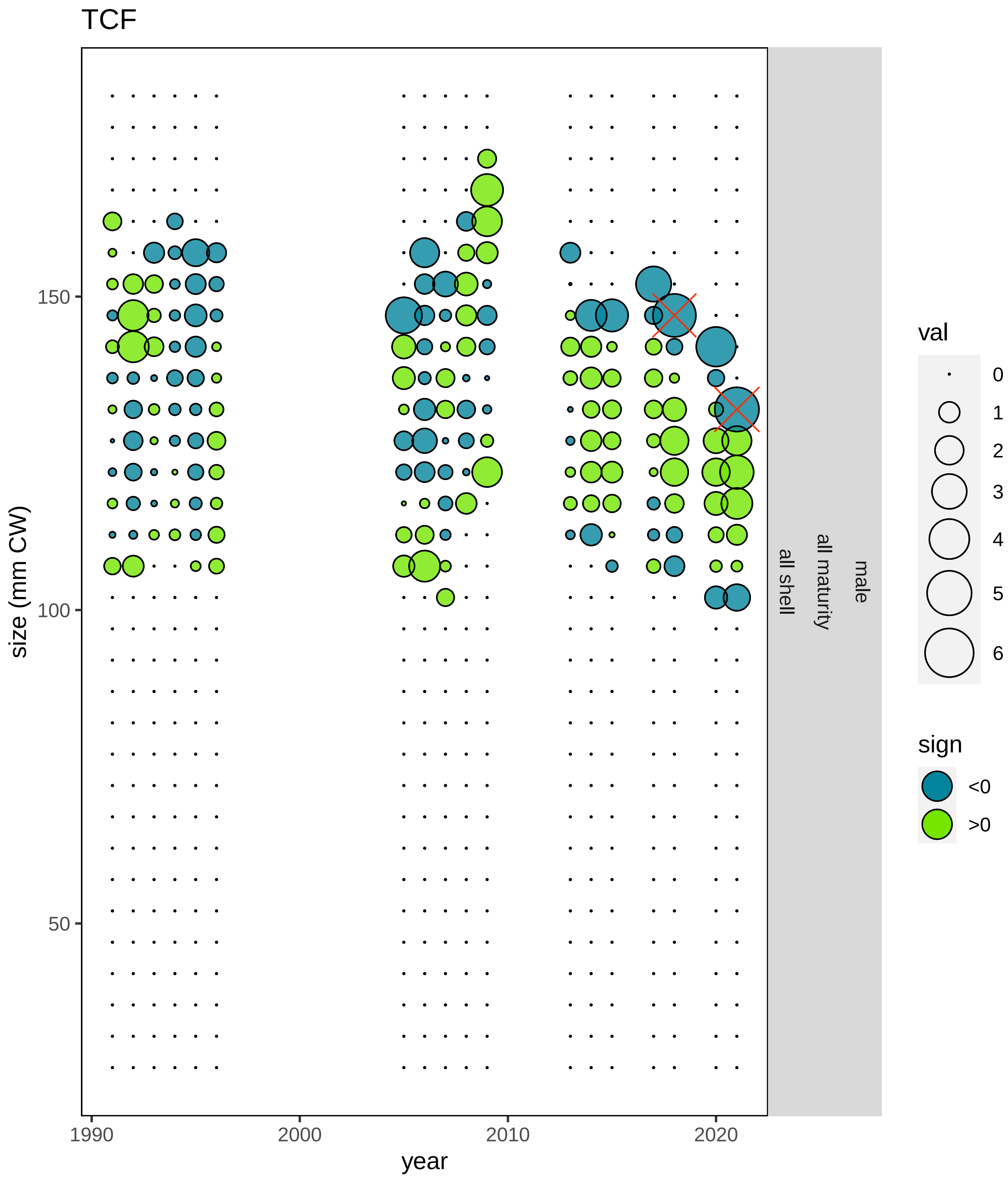

Figure 195. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

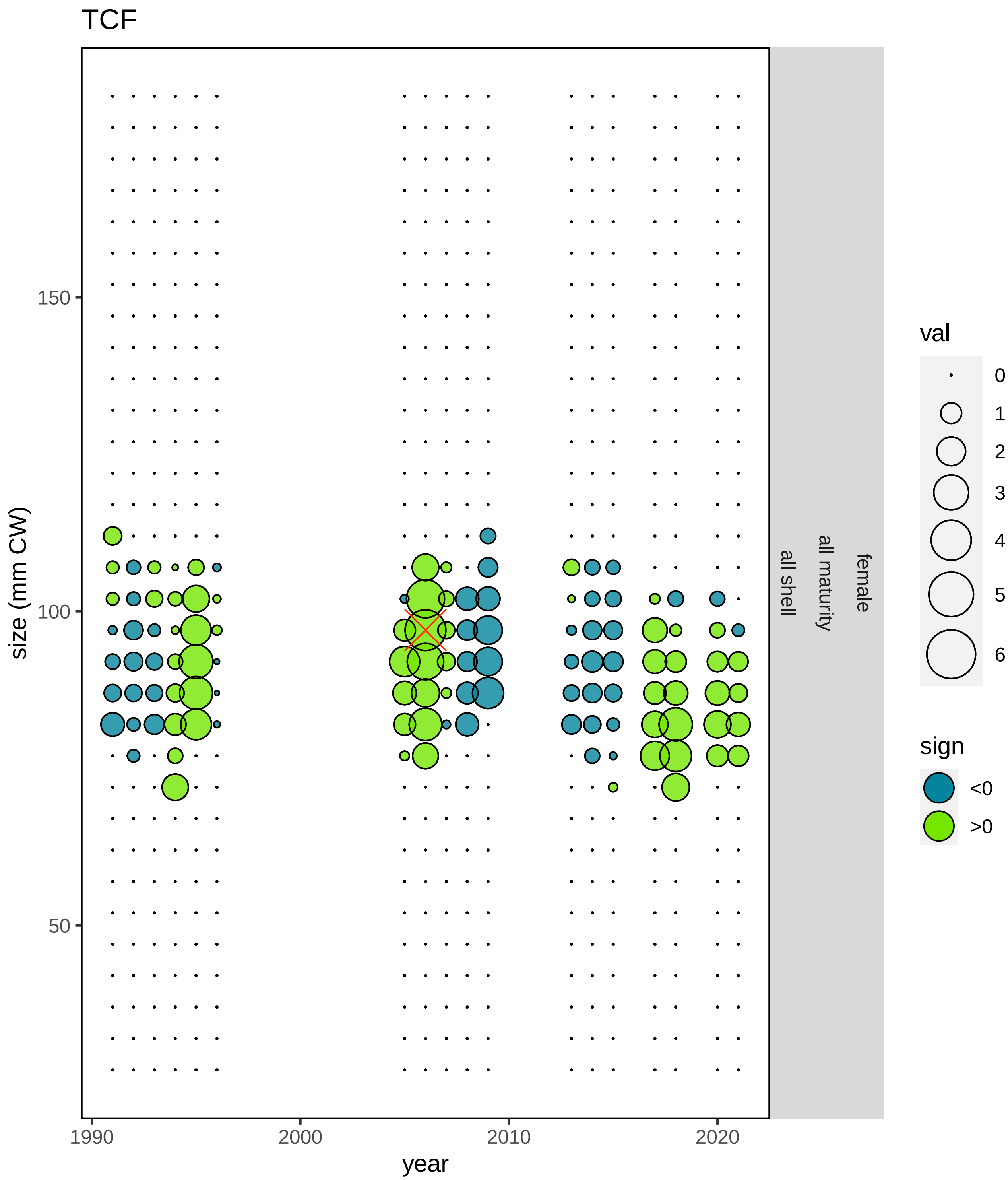

Figure 196. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

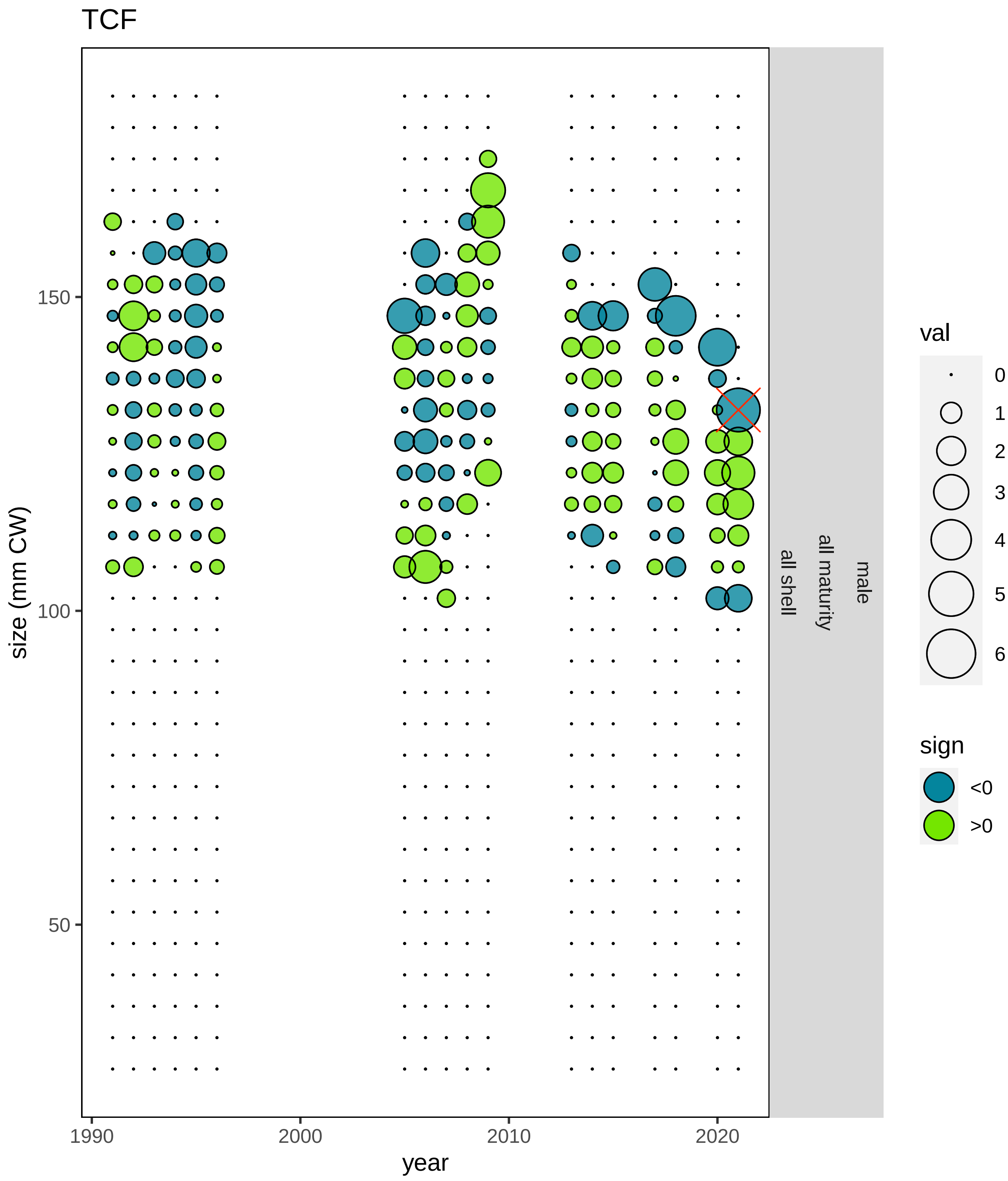

Figure 197. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

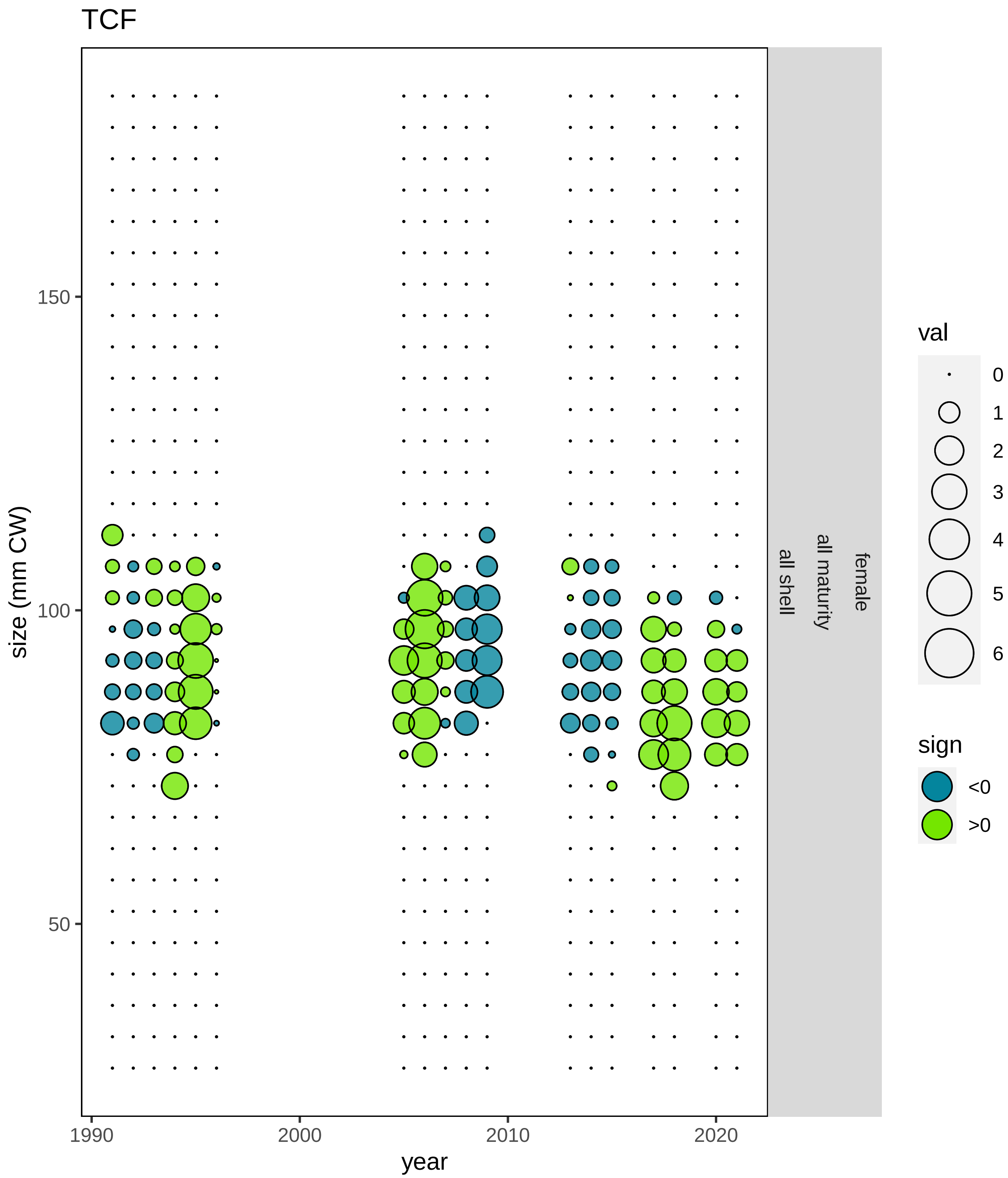

Figure 198. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

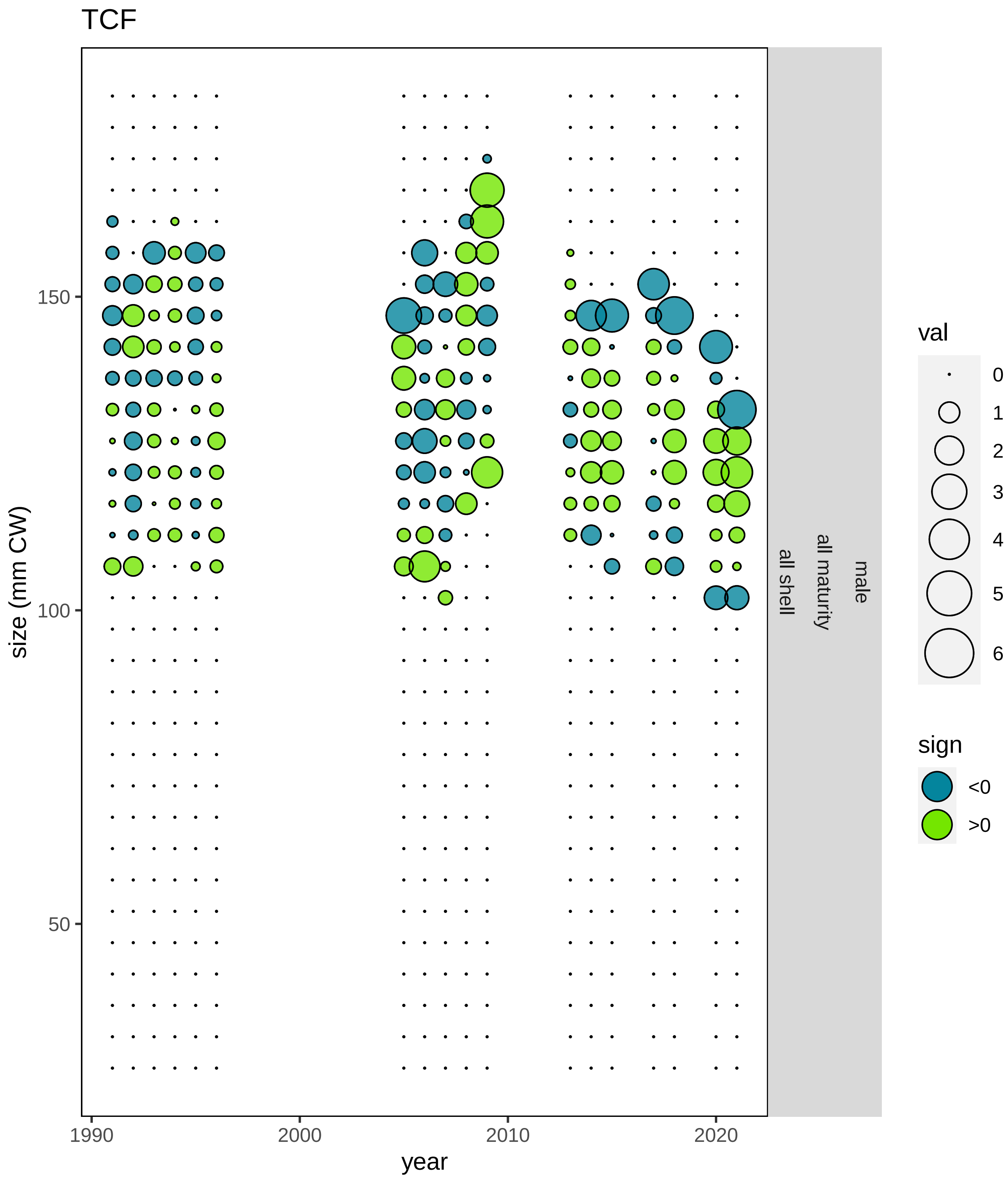

Figure 199. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

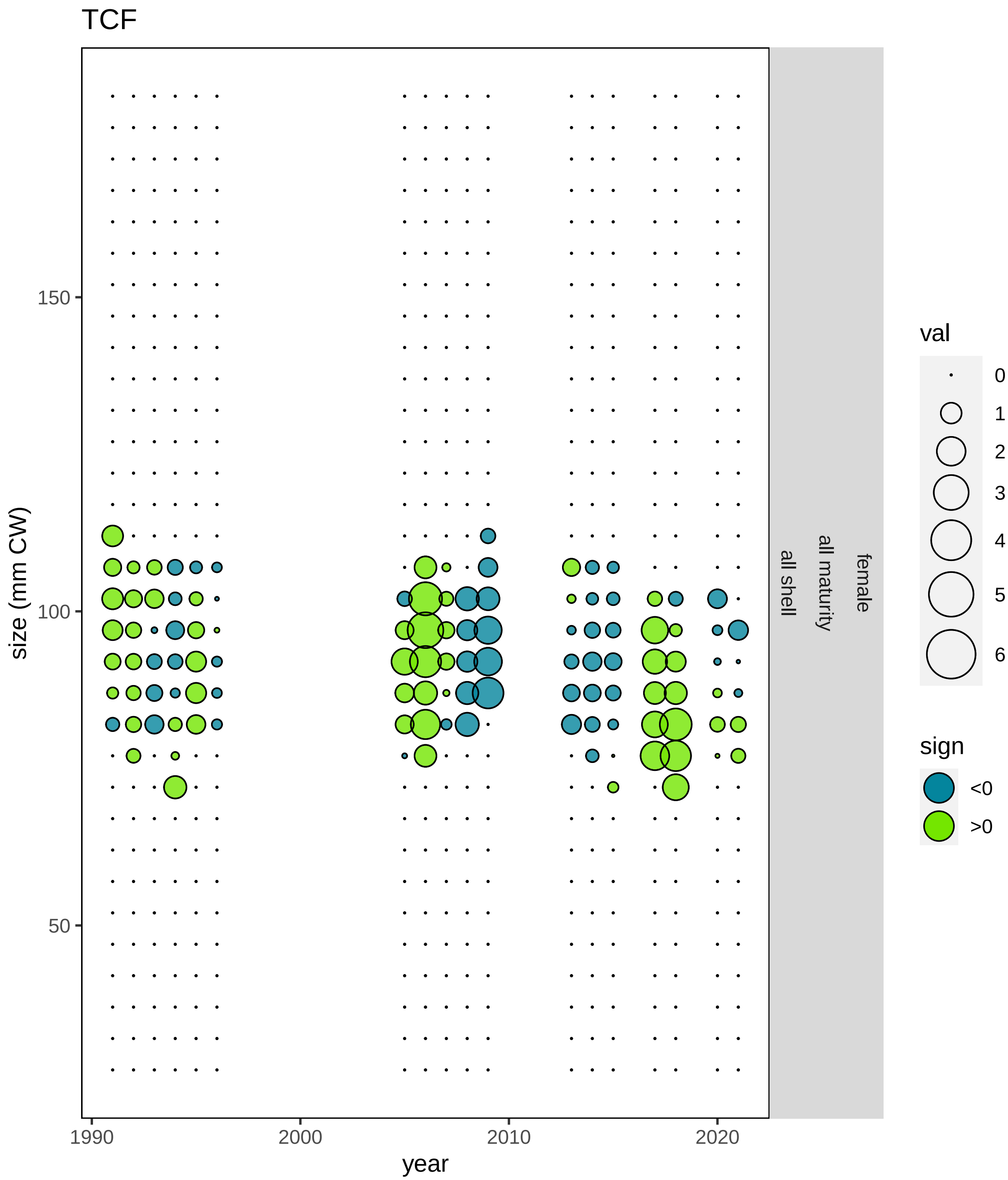

Figure 200. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

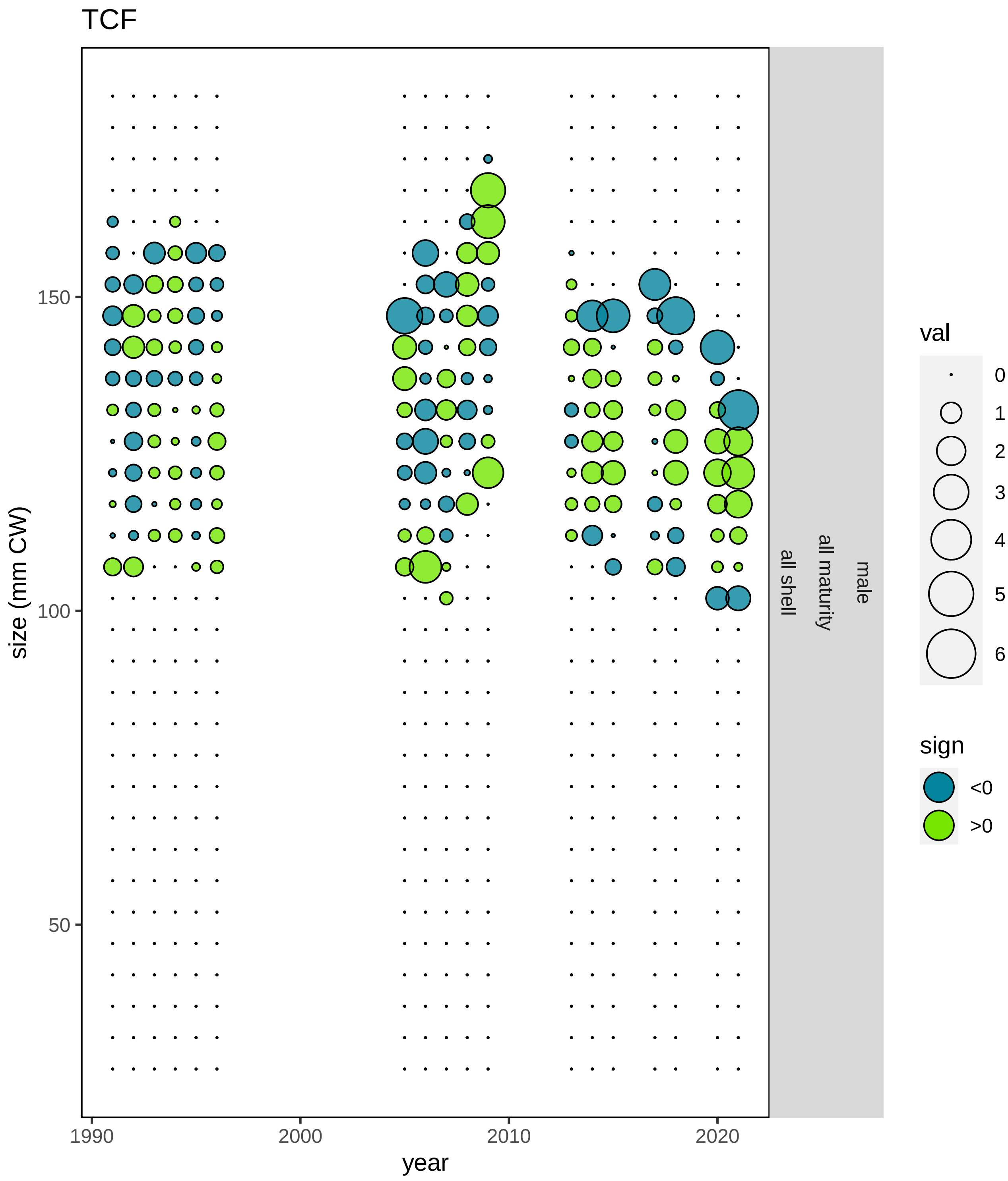

Figure 201. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

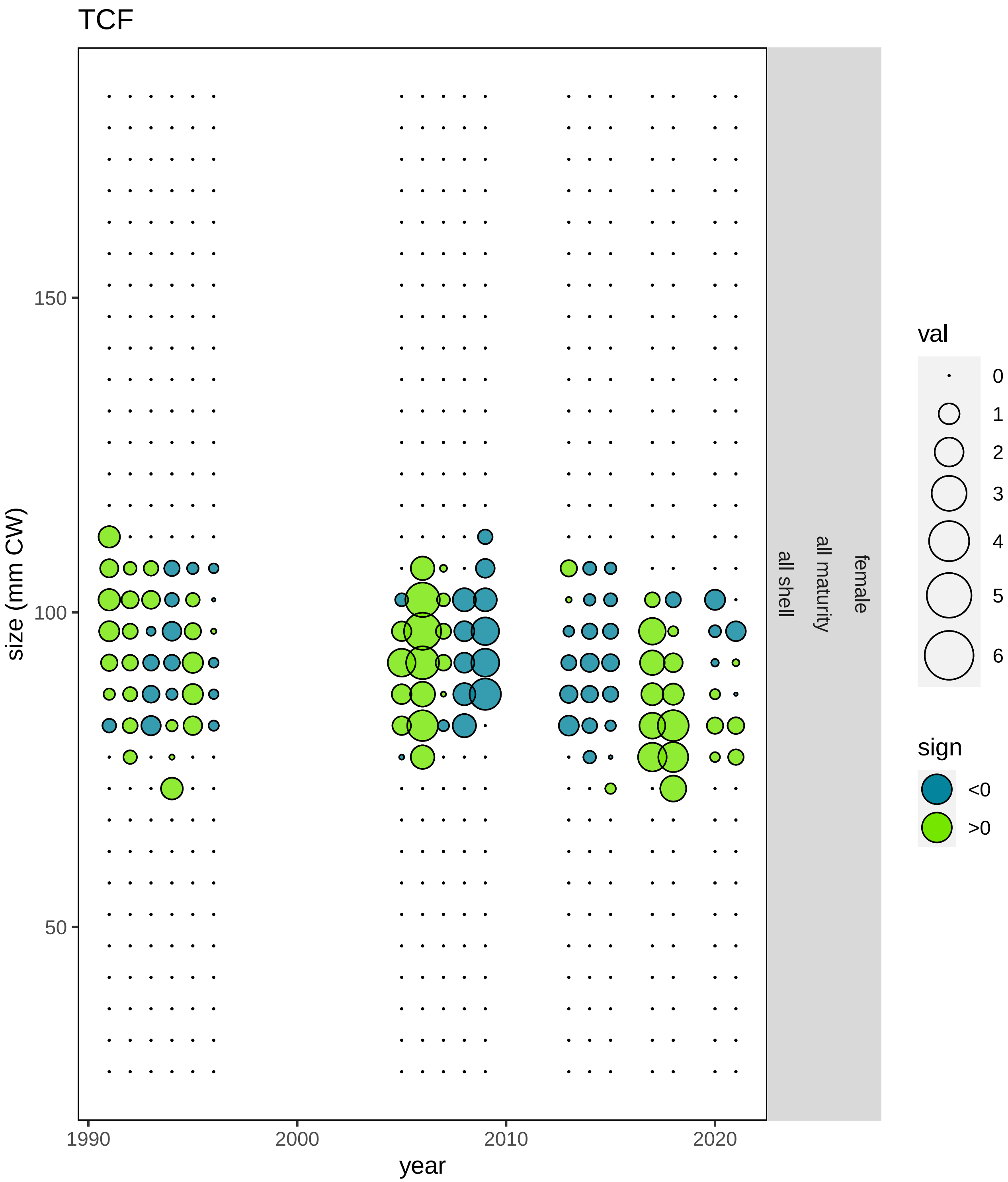

Figure 202. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

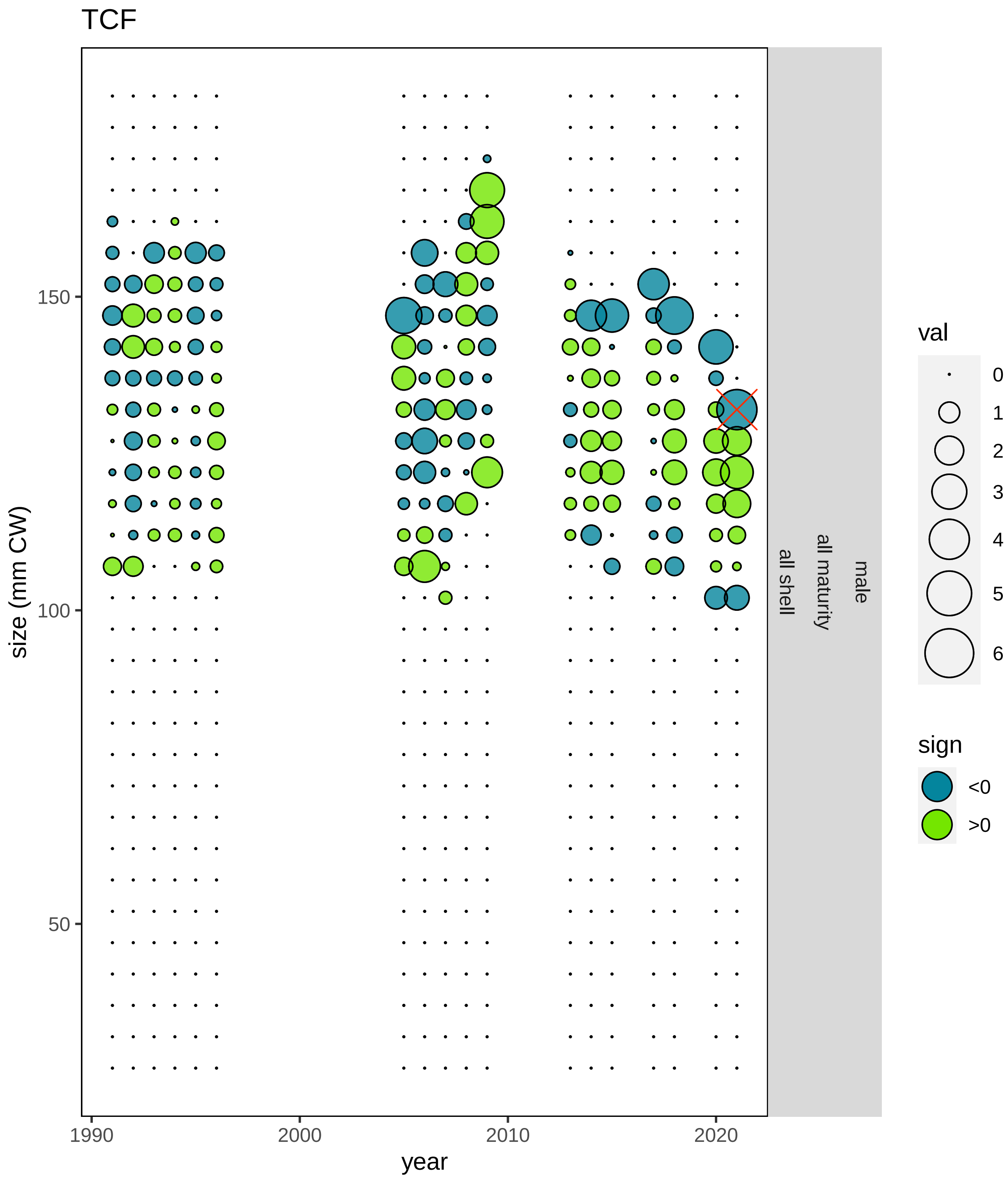

Figure 203. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

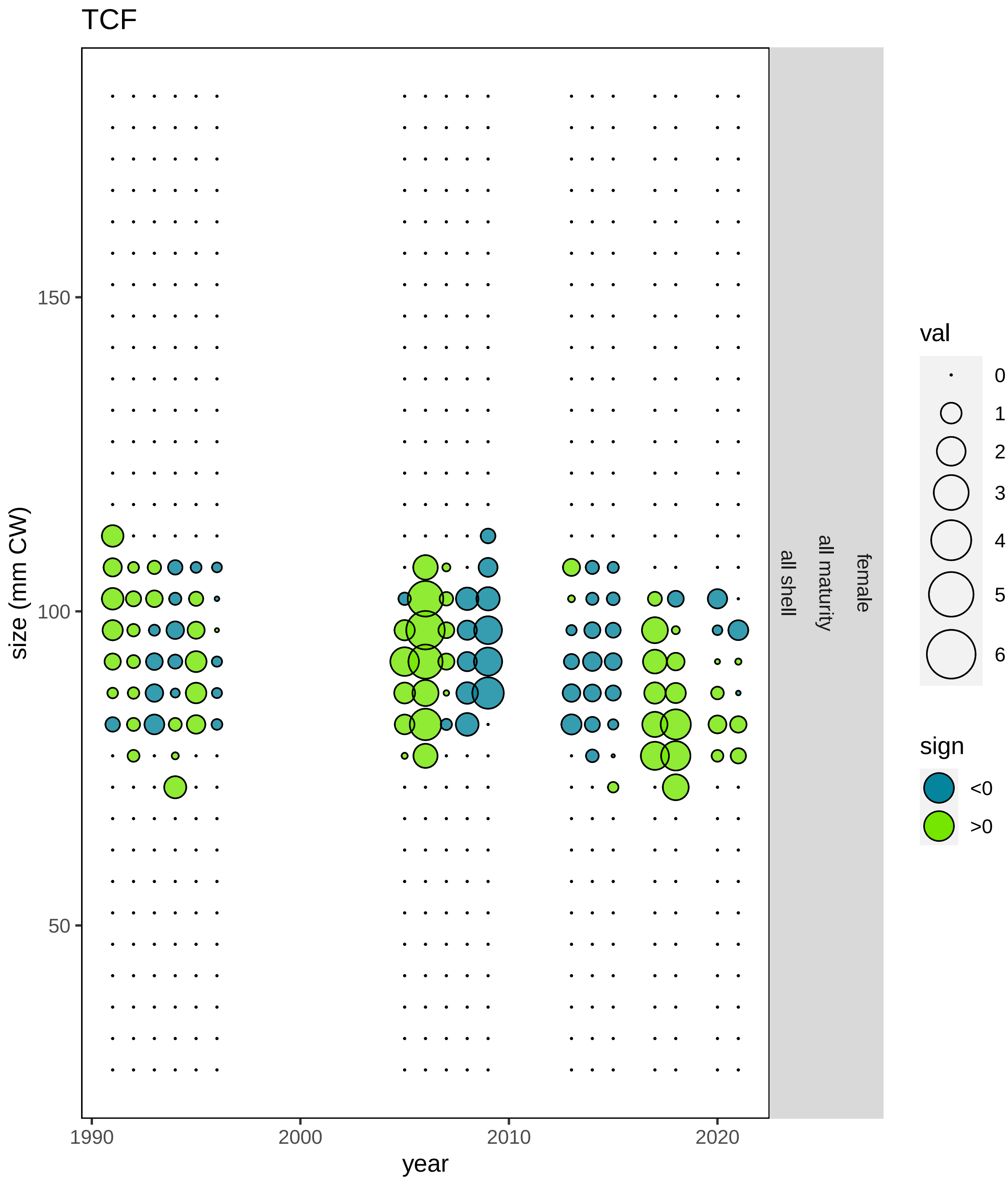

Figure 204. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

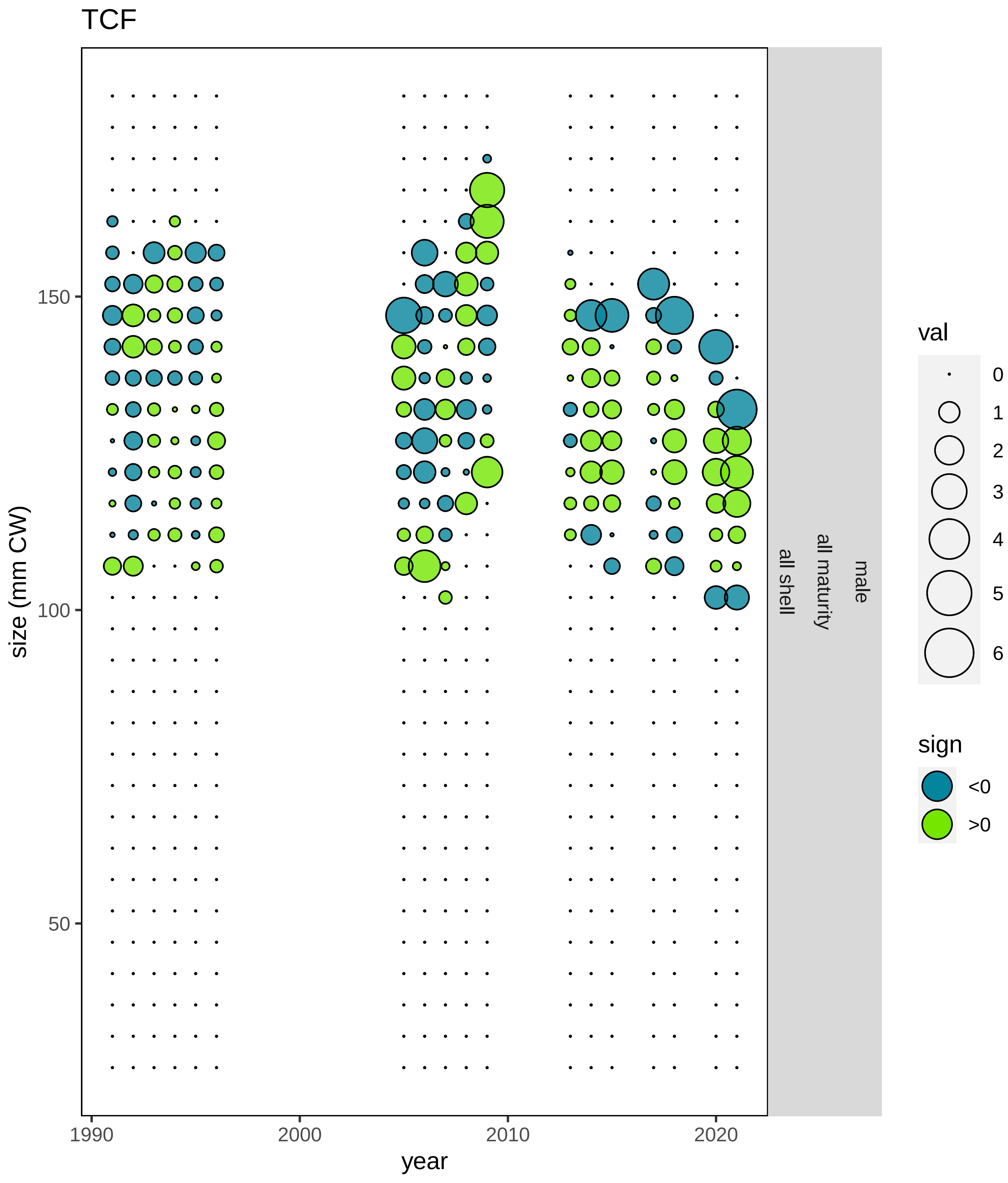

Figure 205. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

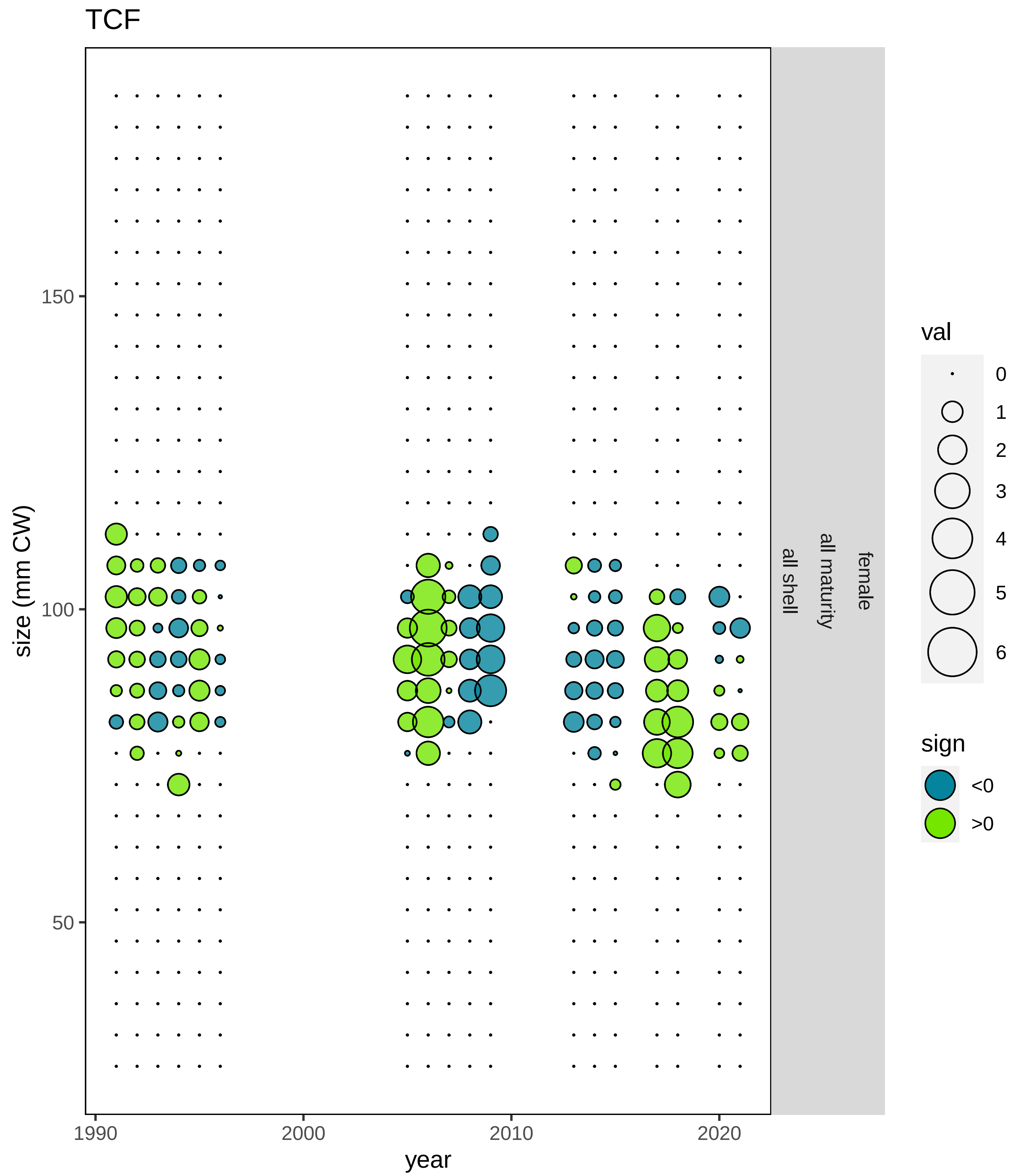

Figure 206. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

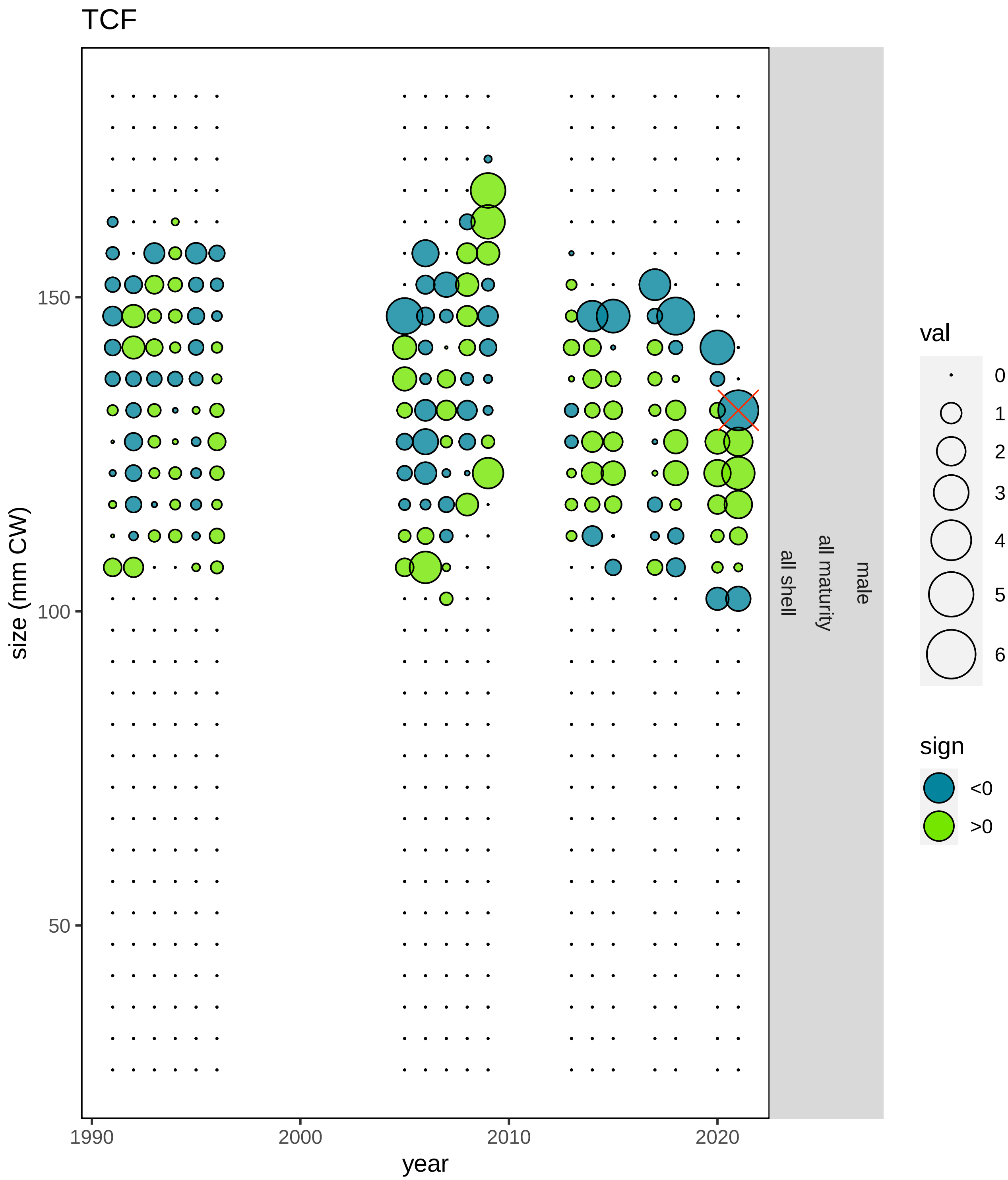

Figure 207. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

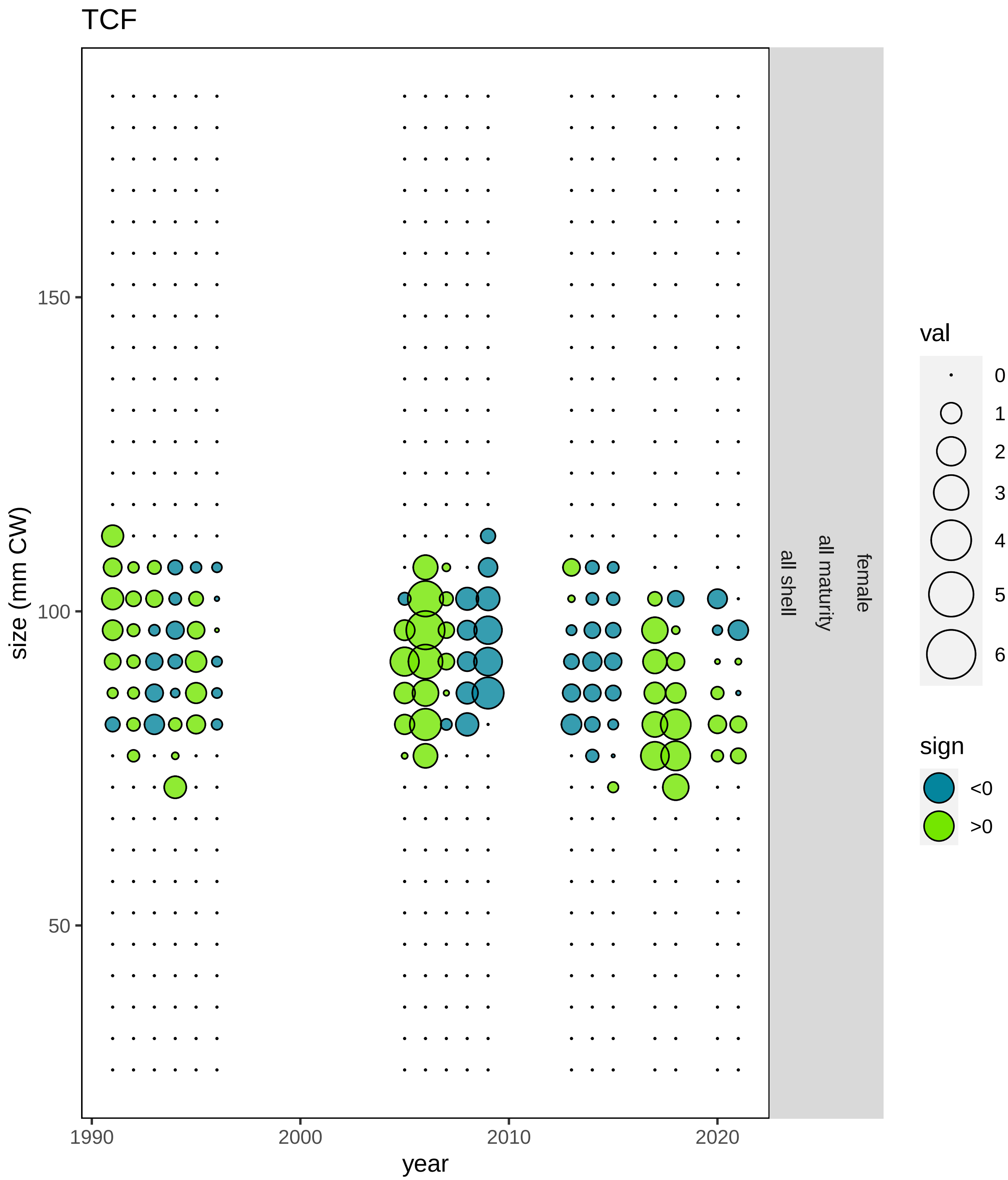

Figure 208. Pearson's residuals for fits to fishery total catch size composition data from the TCF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

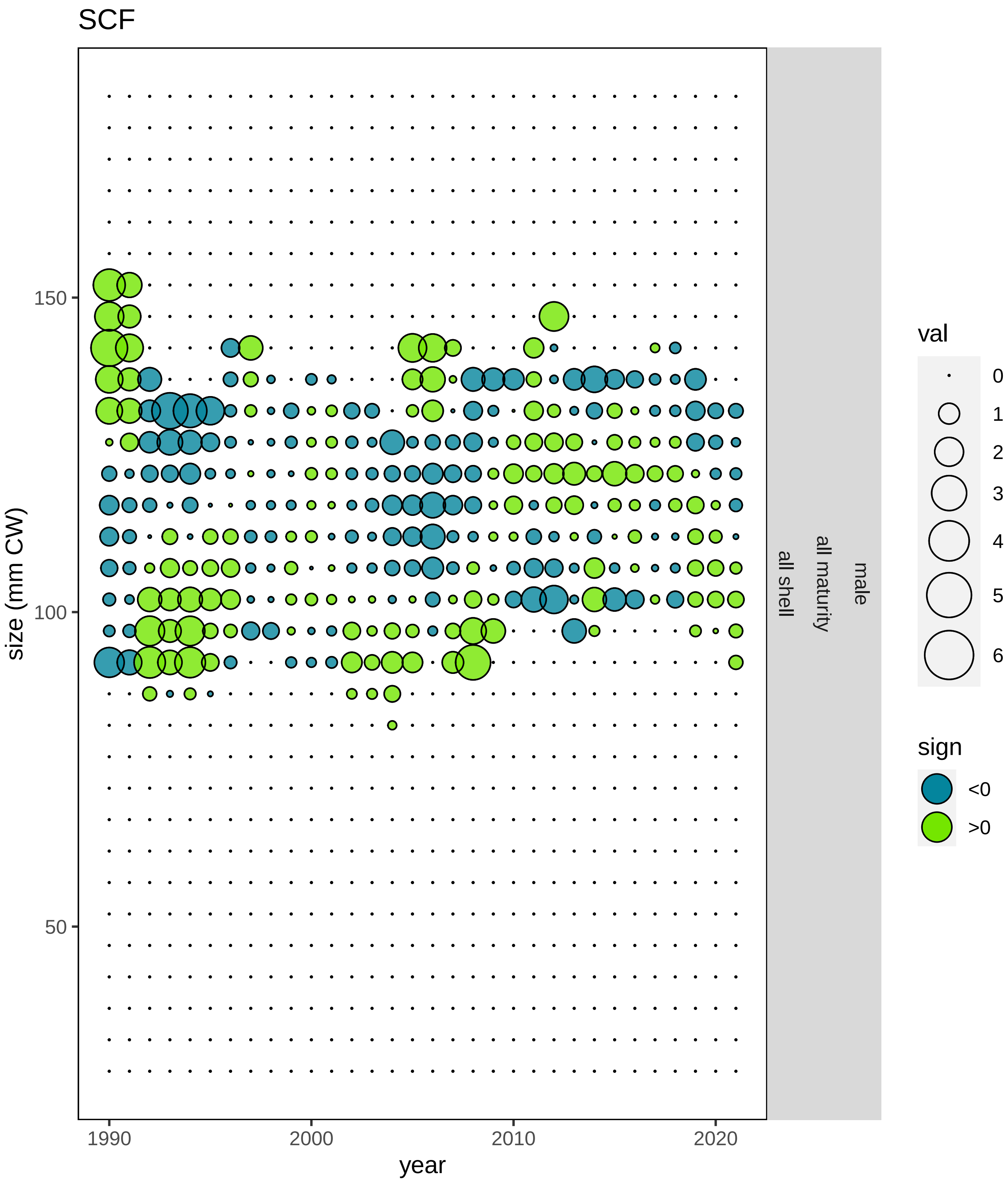

Figure 209. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

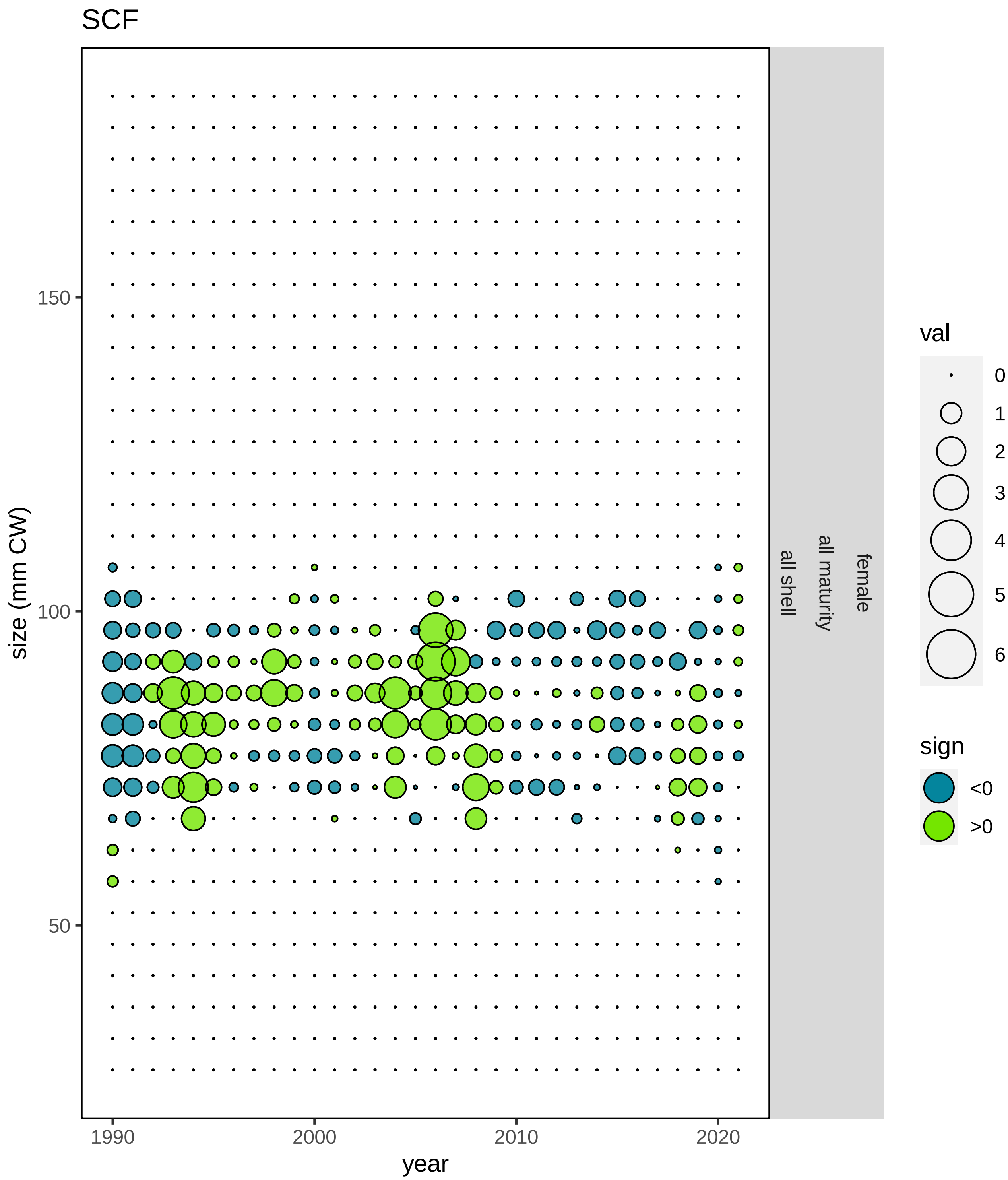

Figure 210. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

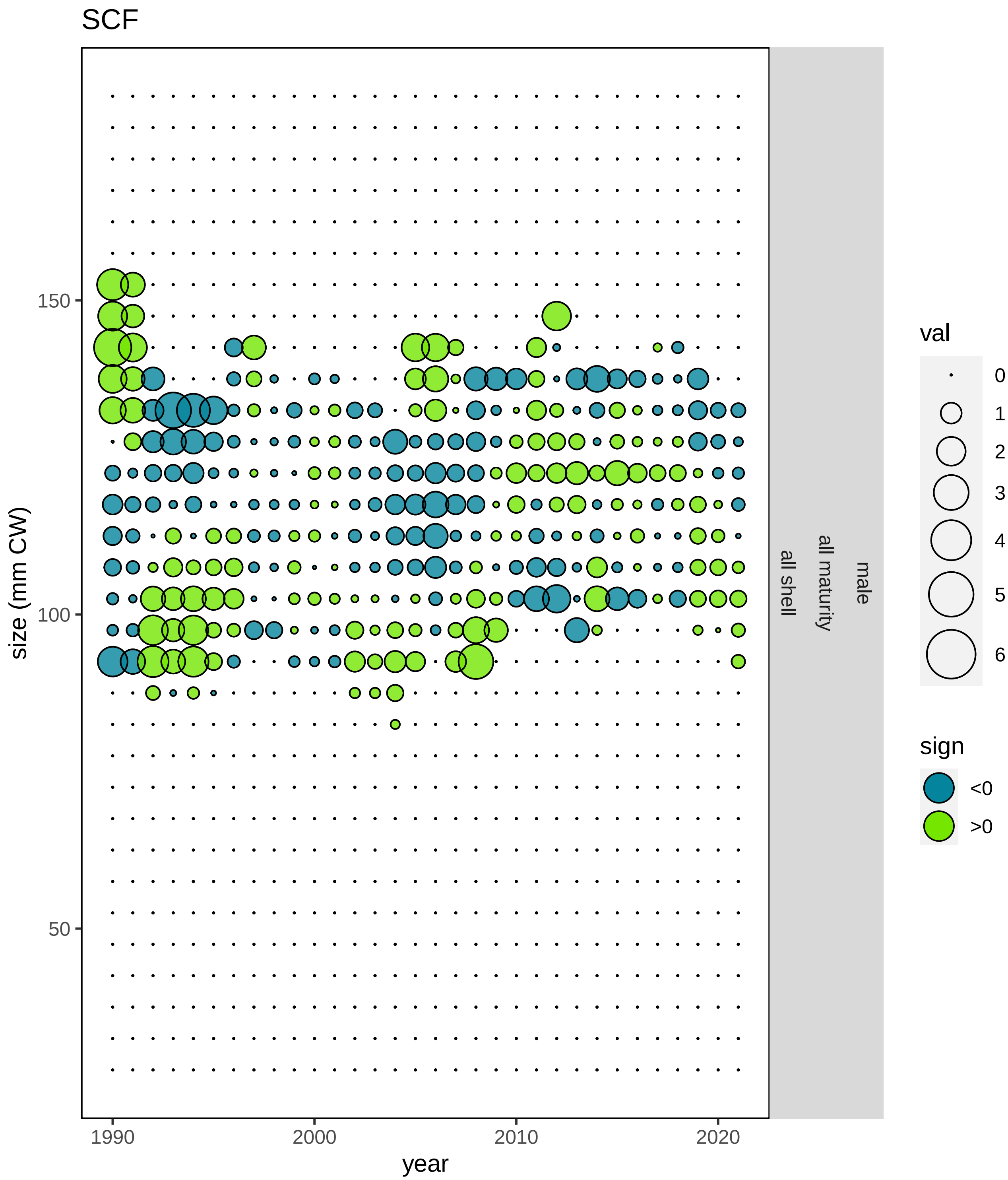

Figure 211. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

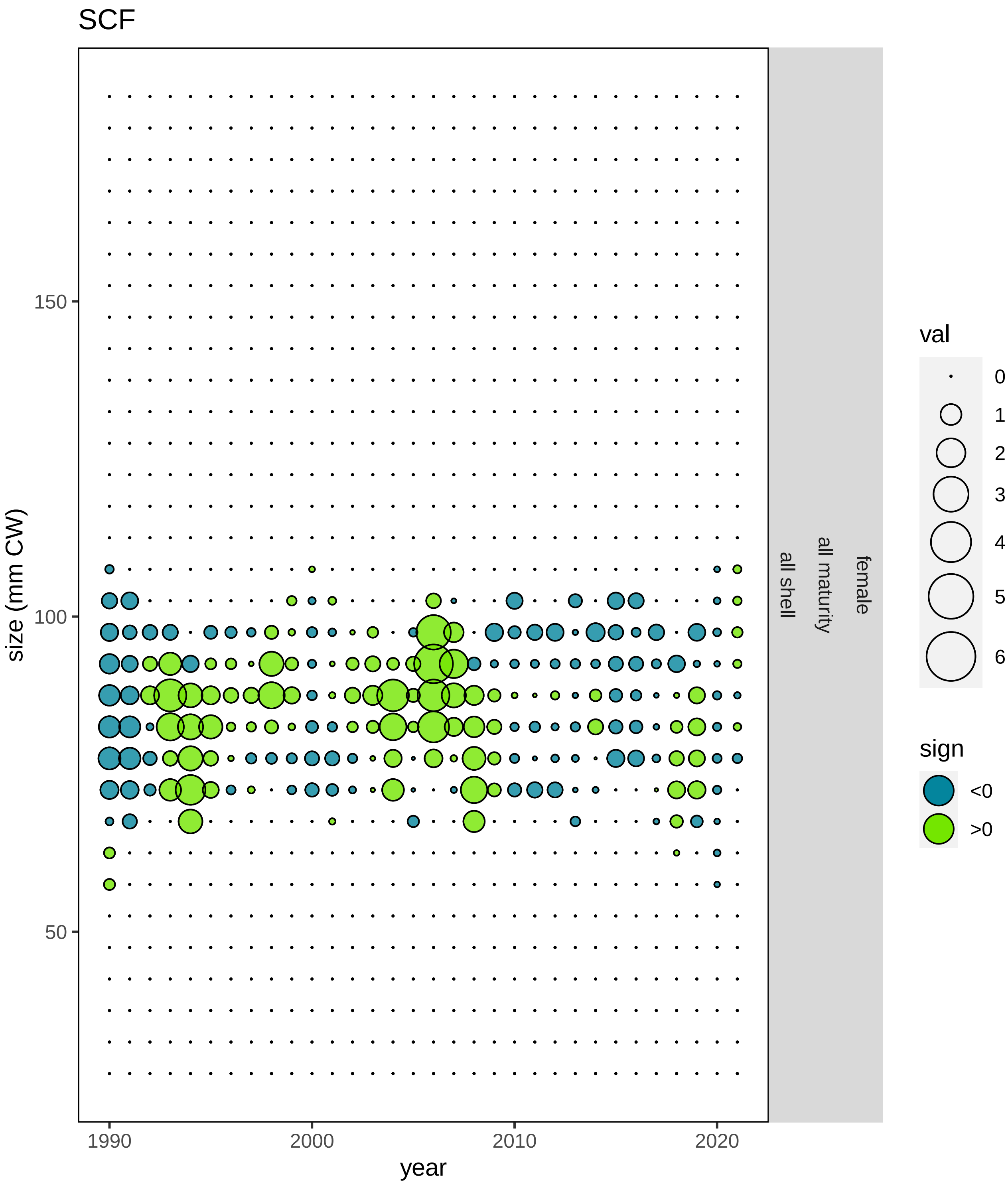

Figure 212. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

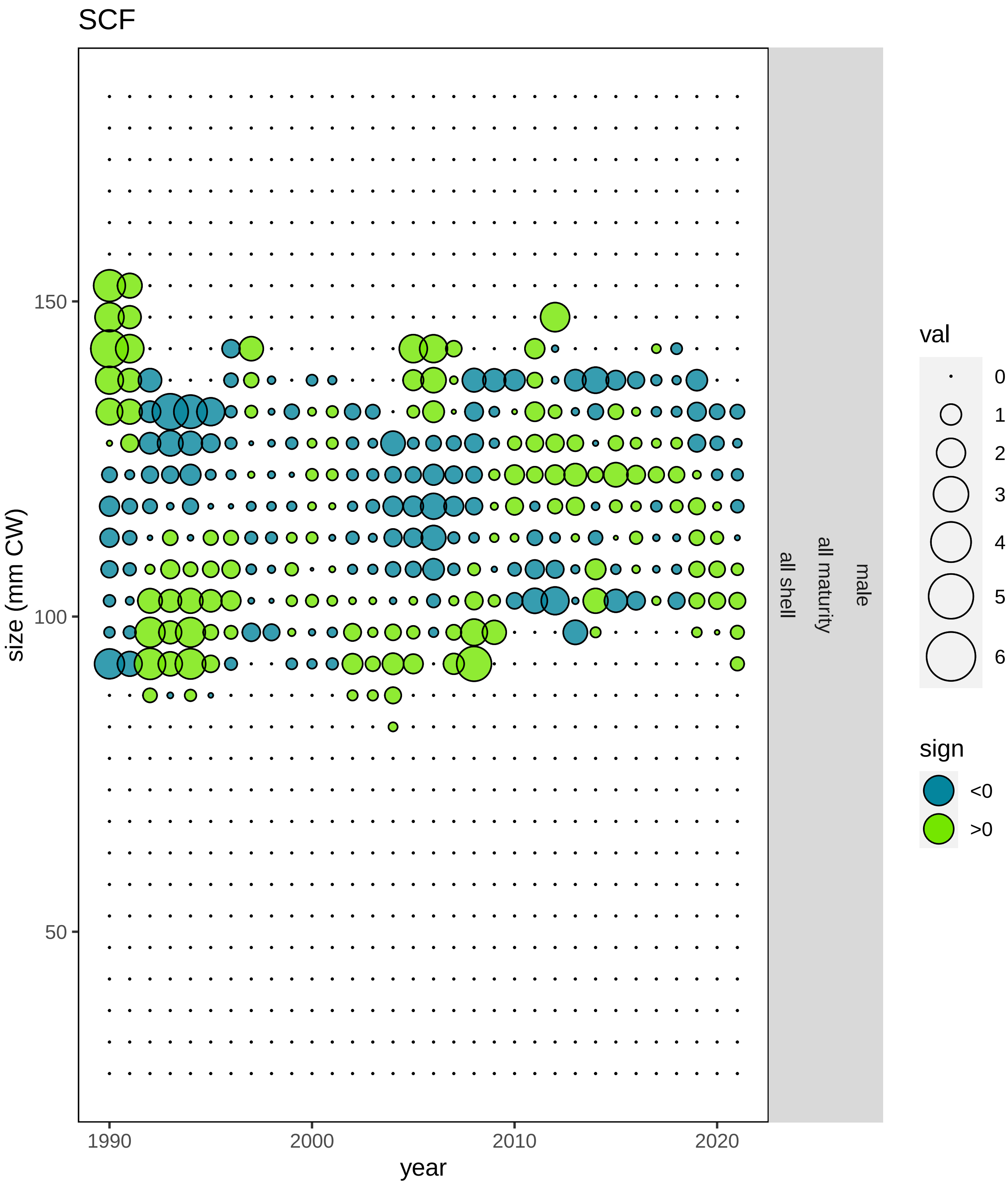

Figure 213. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

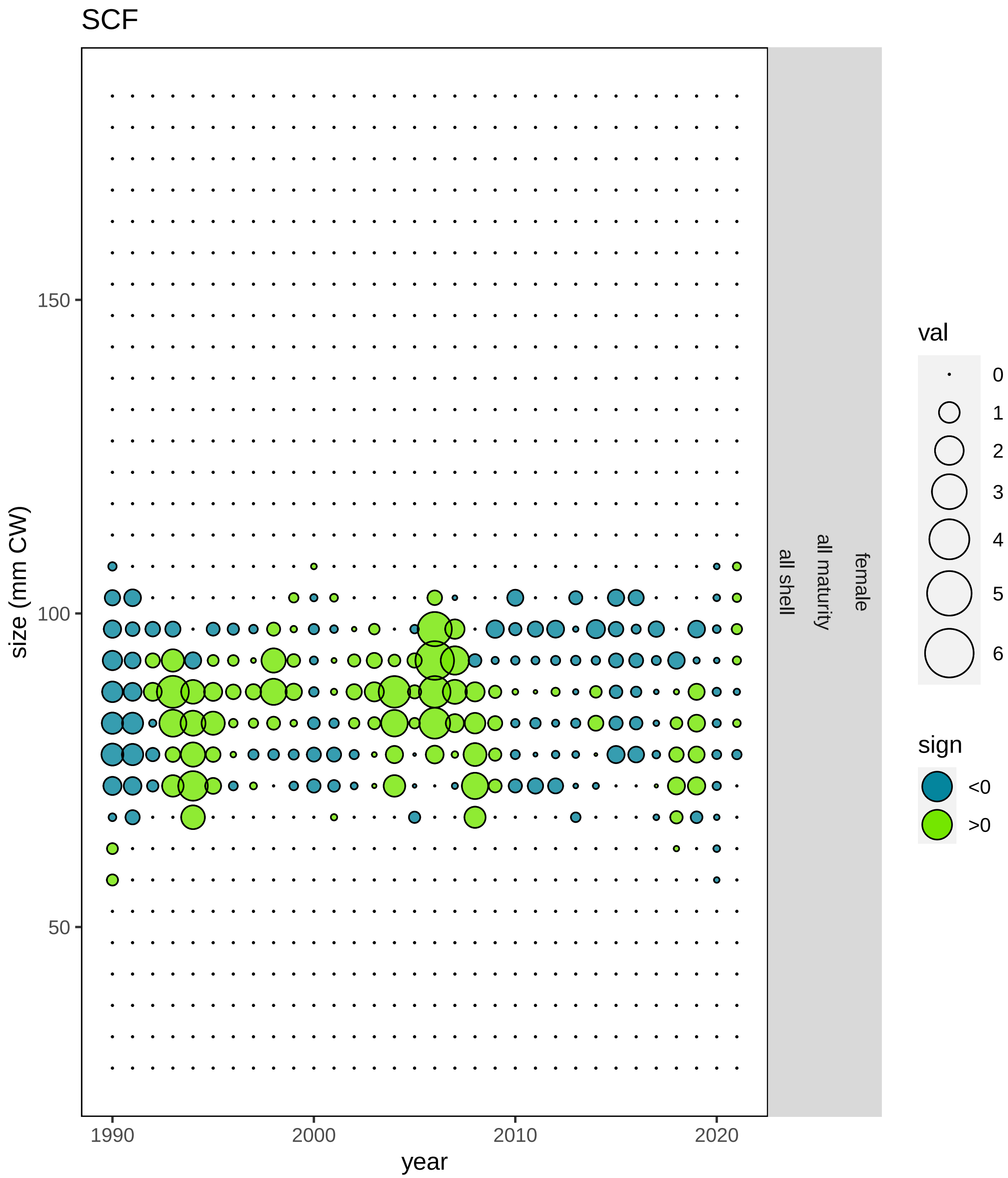

Figure 214. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

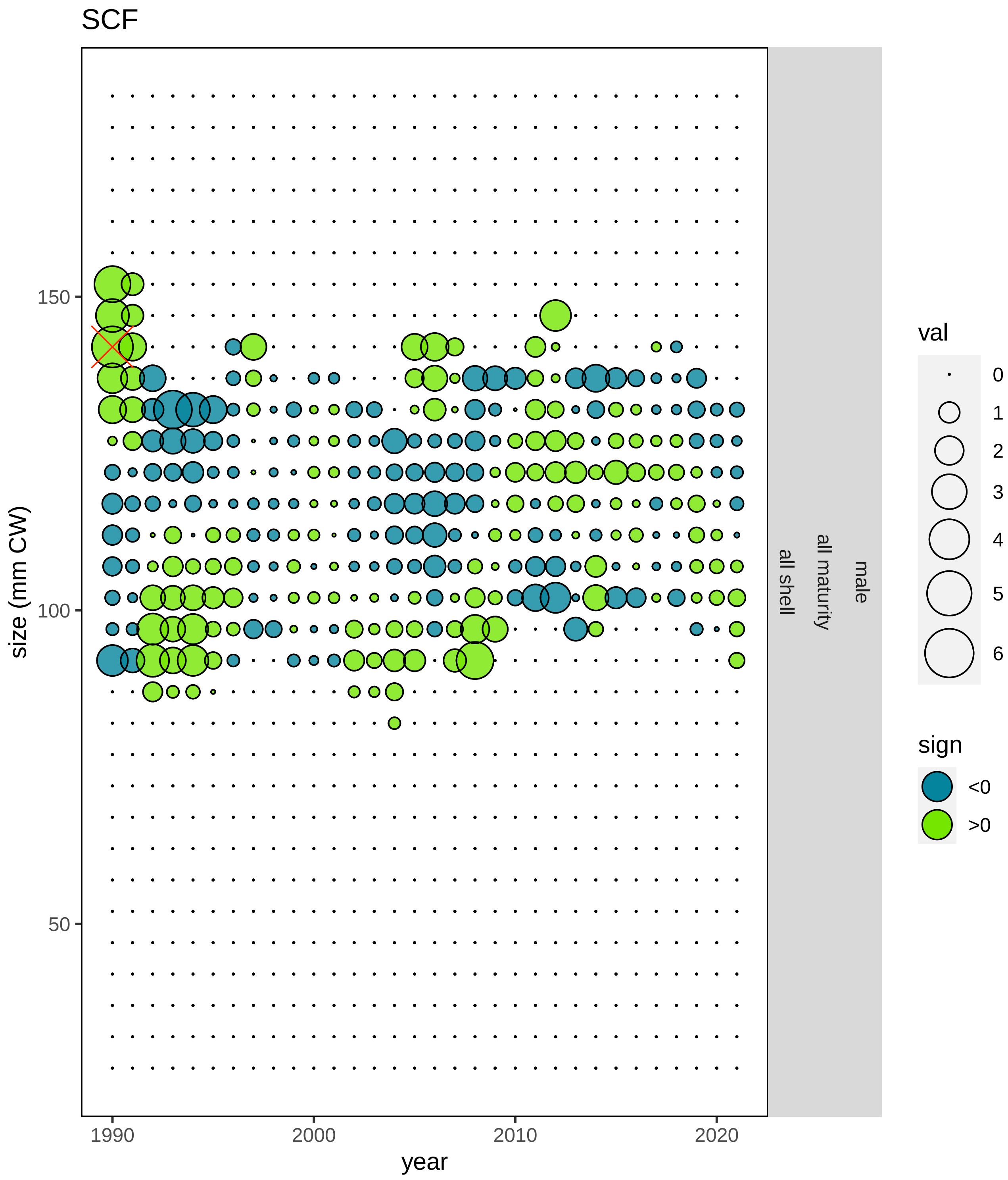

Figure 215. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

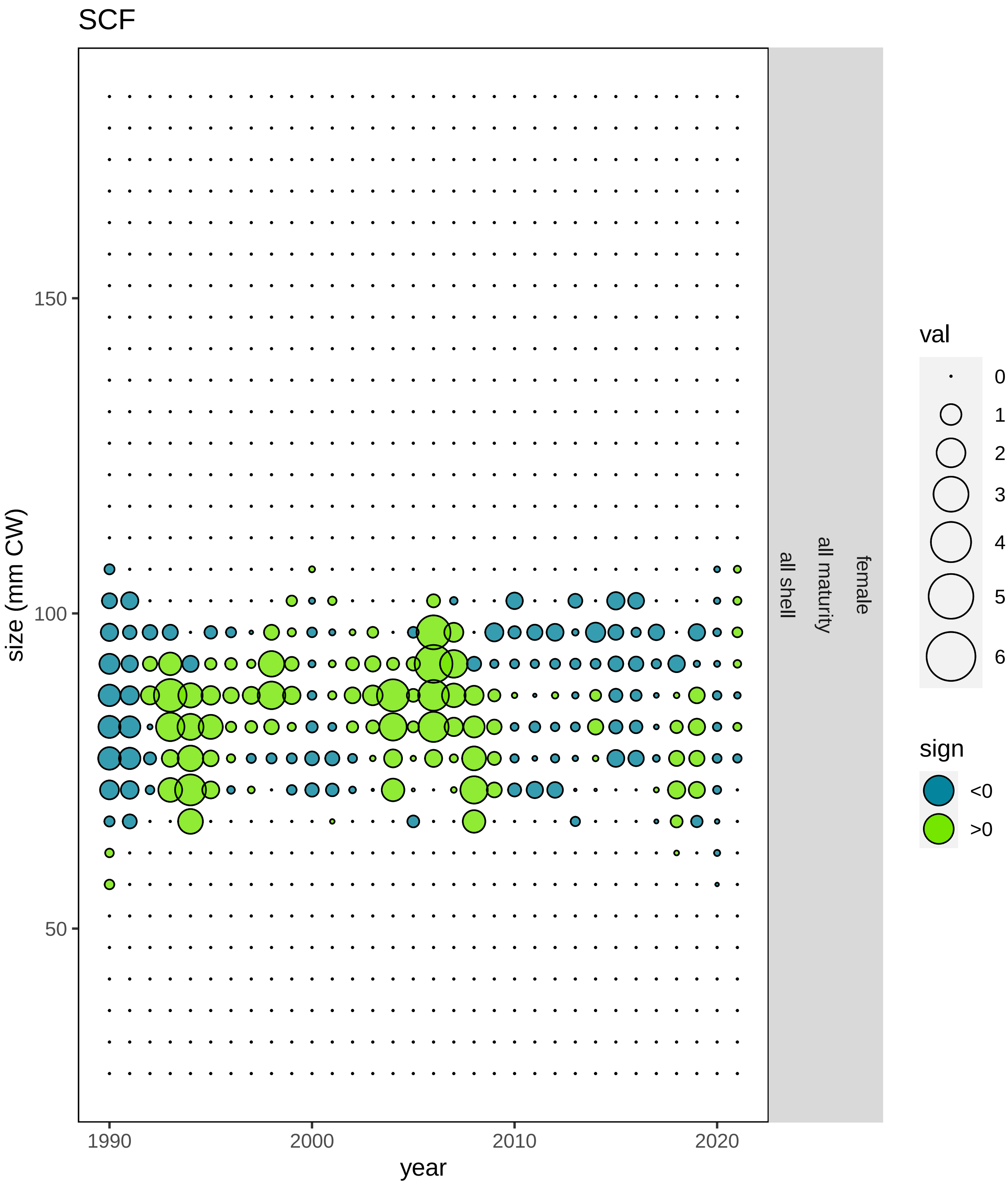

Figure 216. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

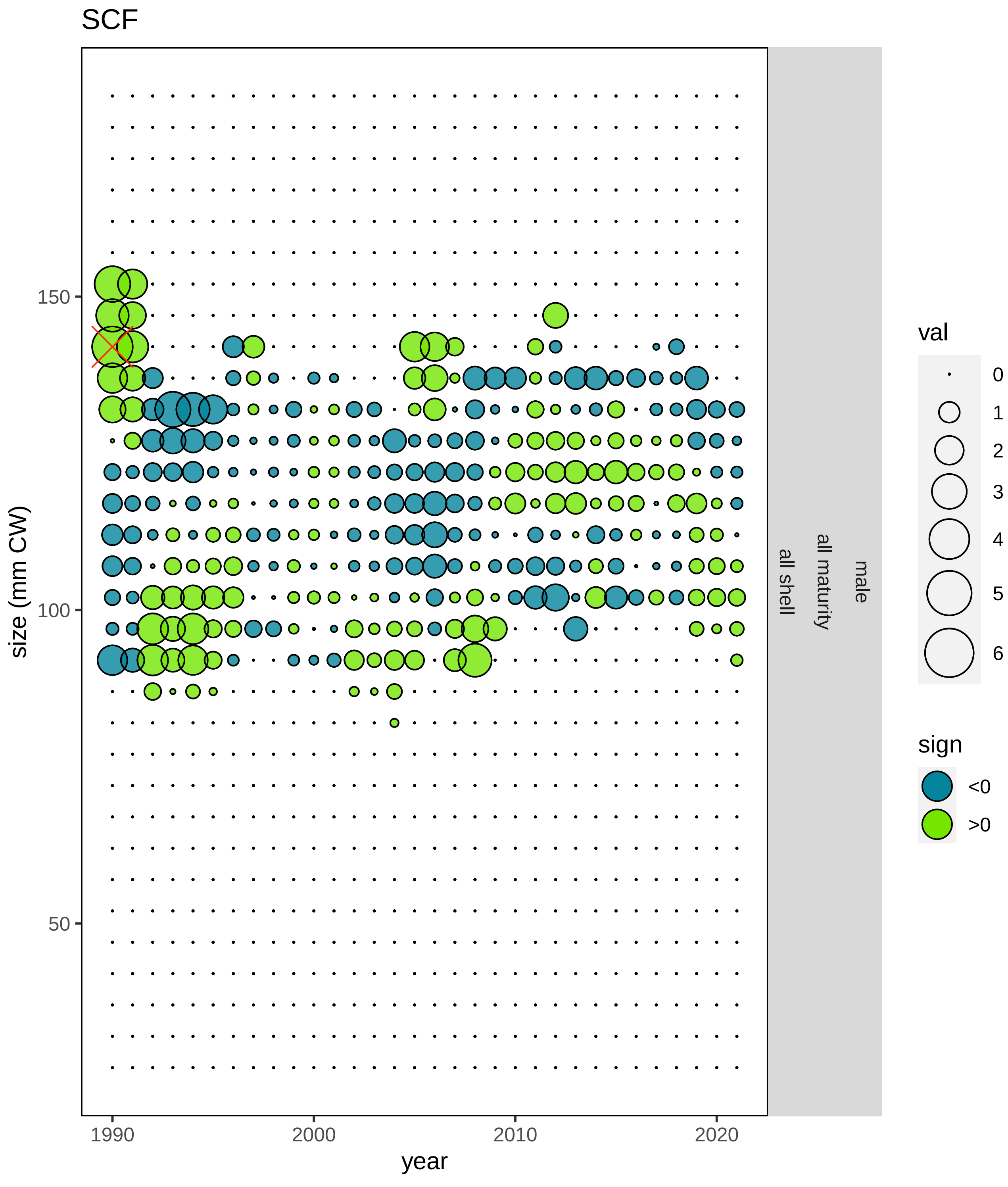

Figure 217. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

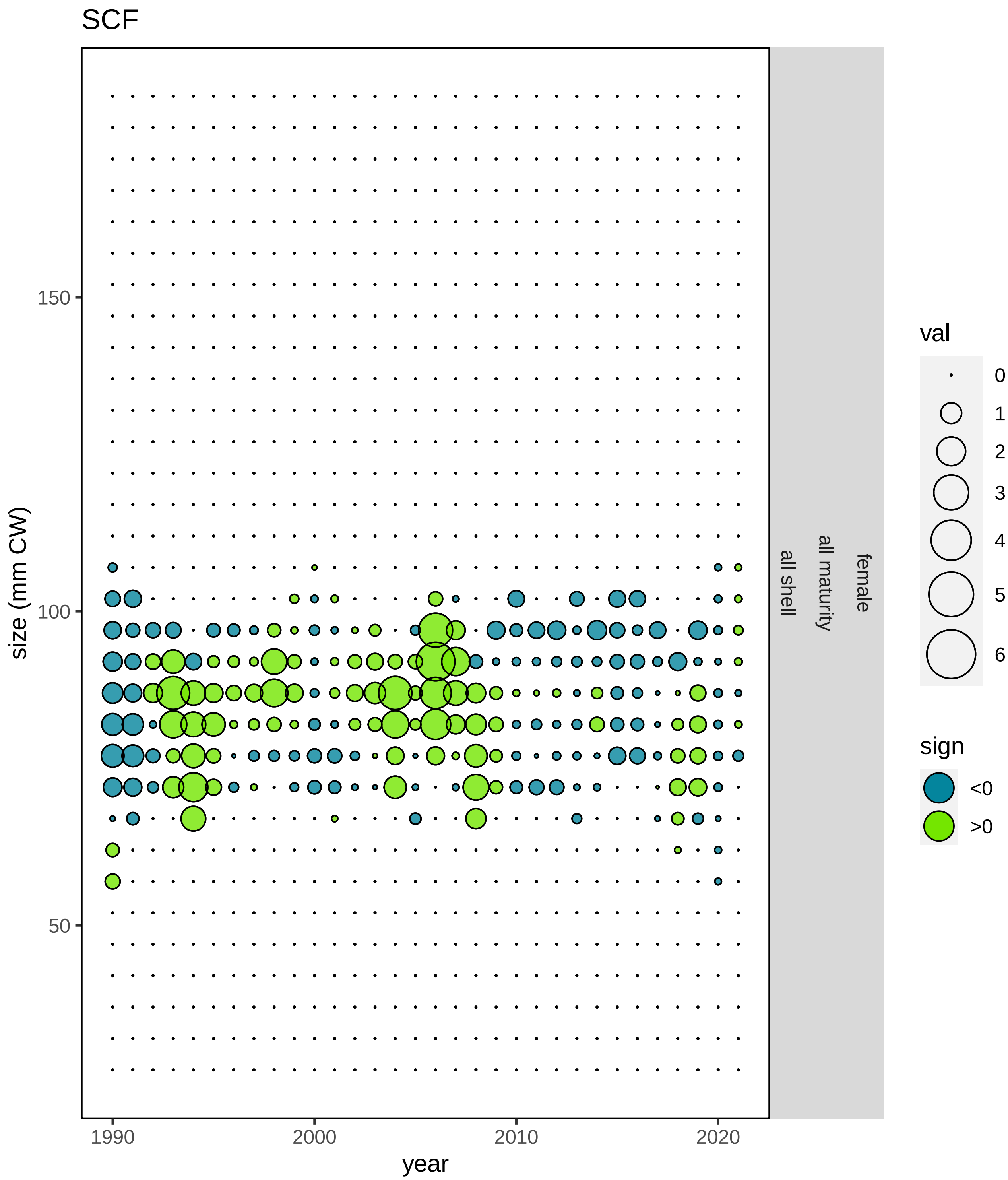

Figure 218. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

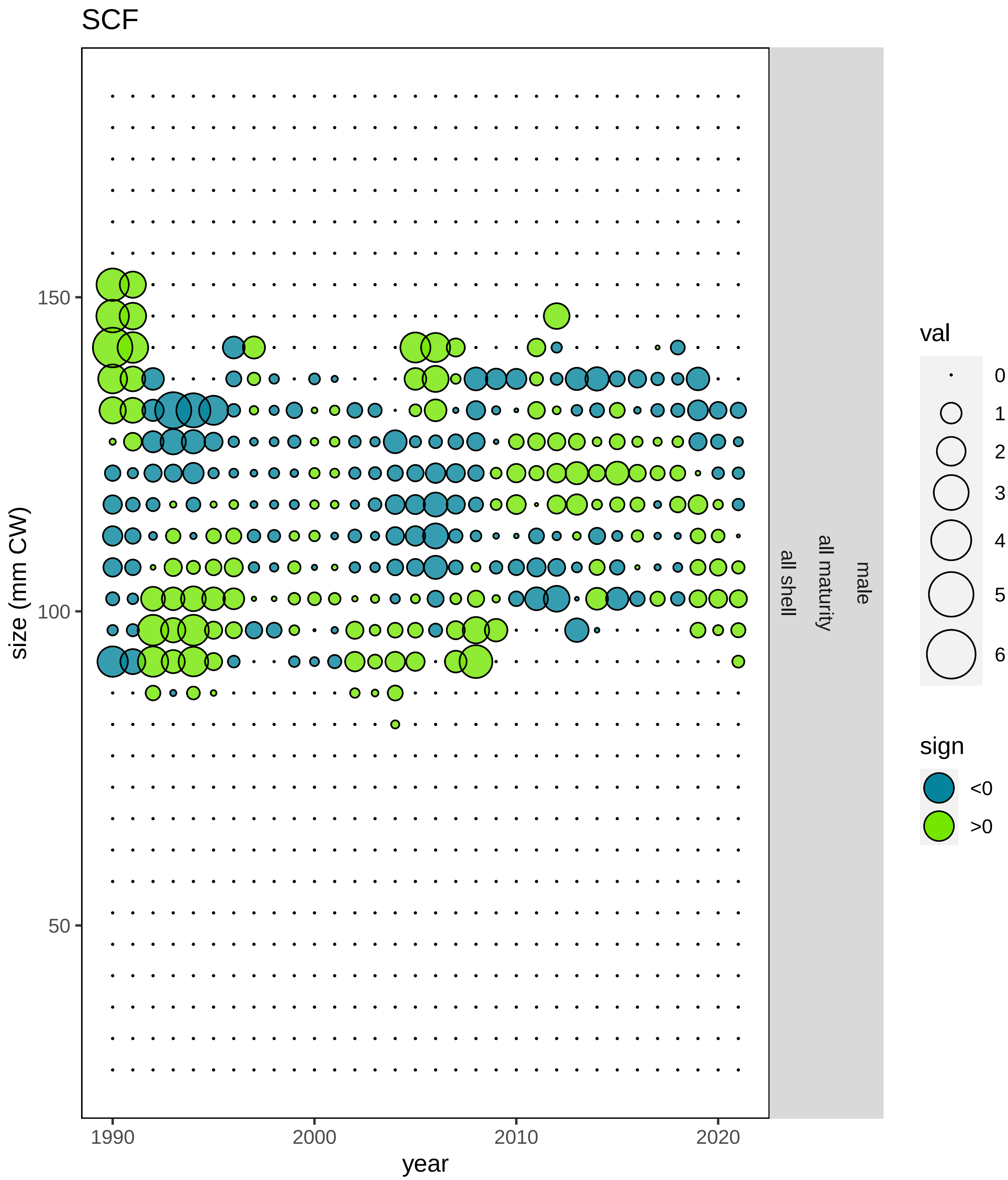

Figure 219. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

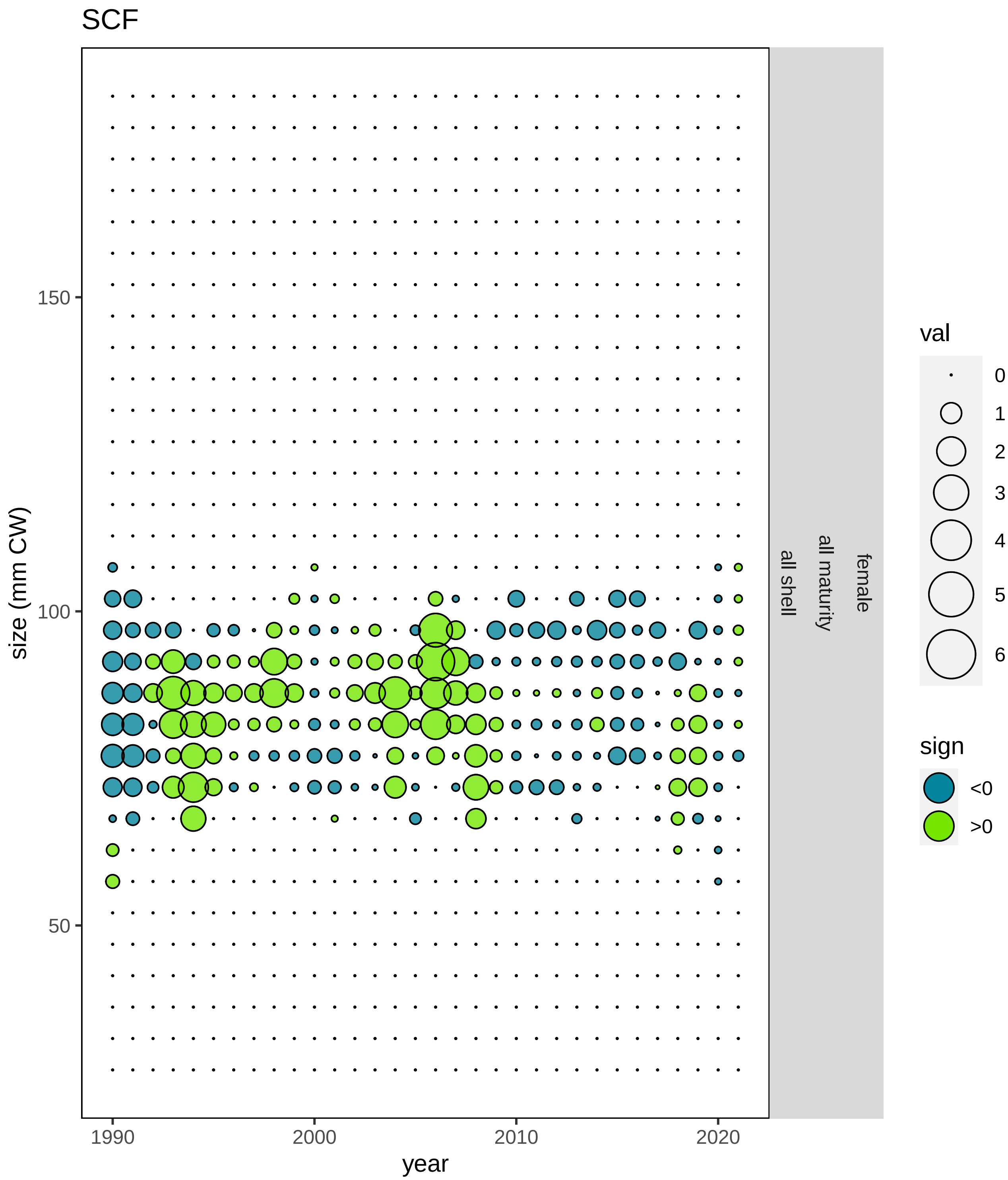

Figure 220. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

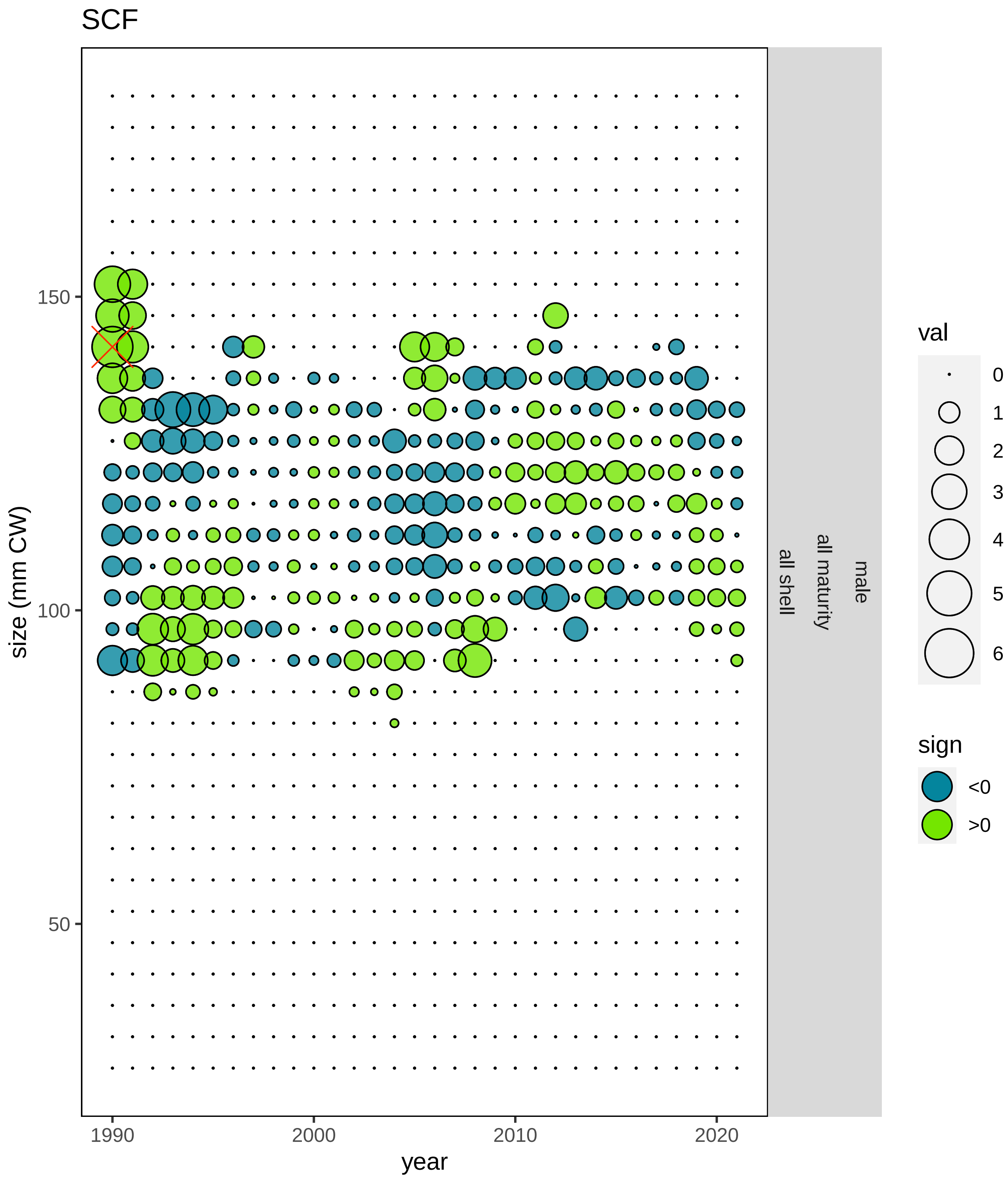

Figure 221. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

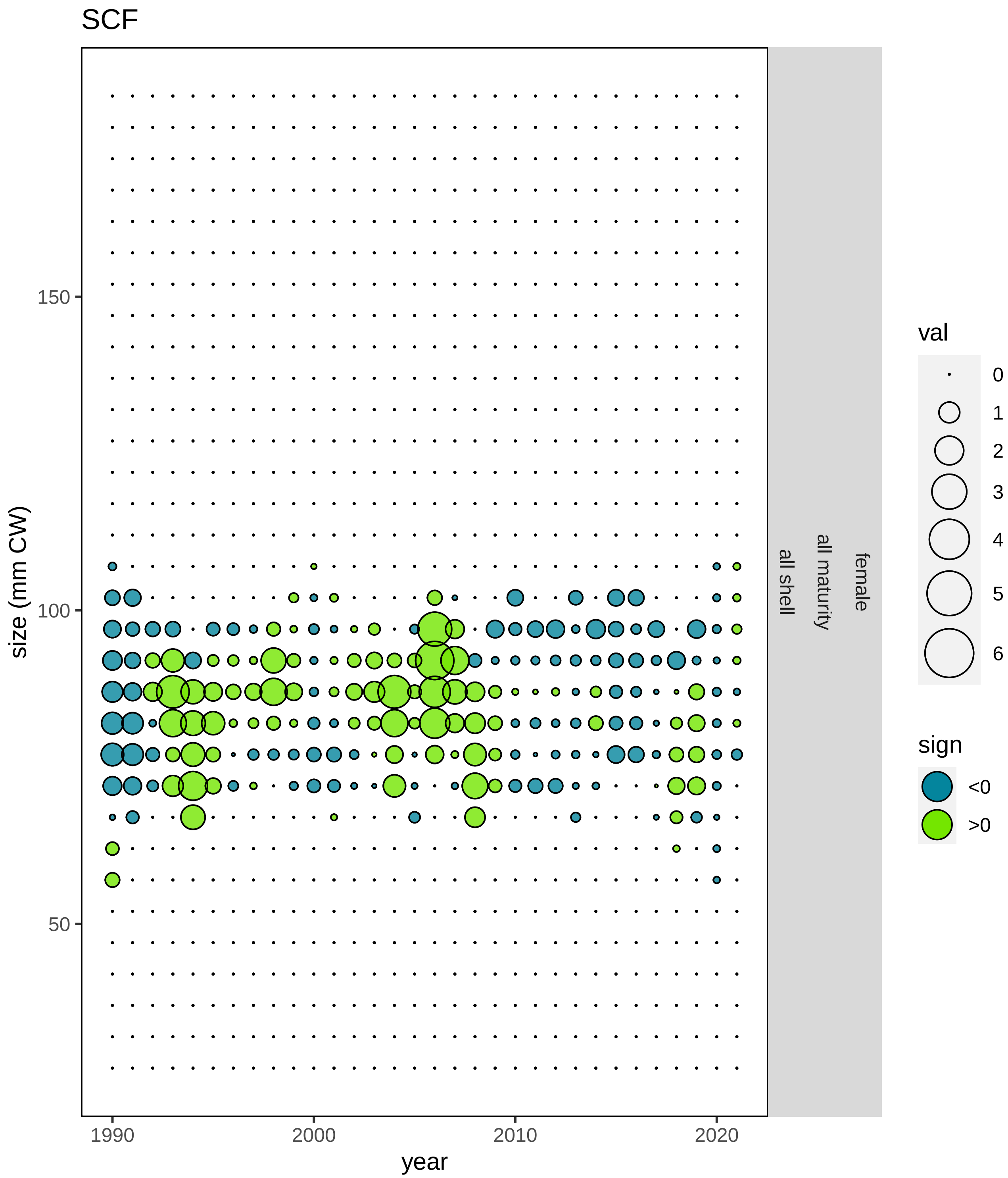

Figure 222. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

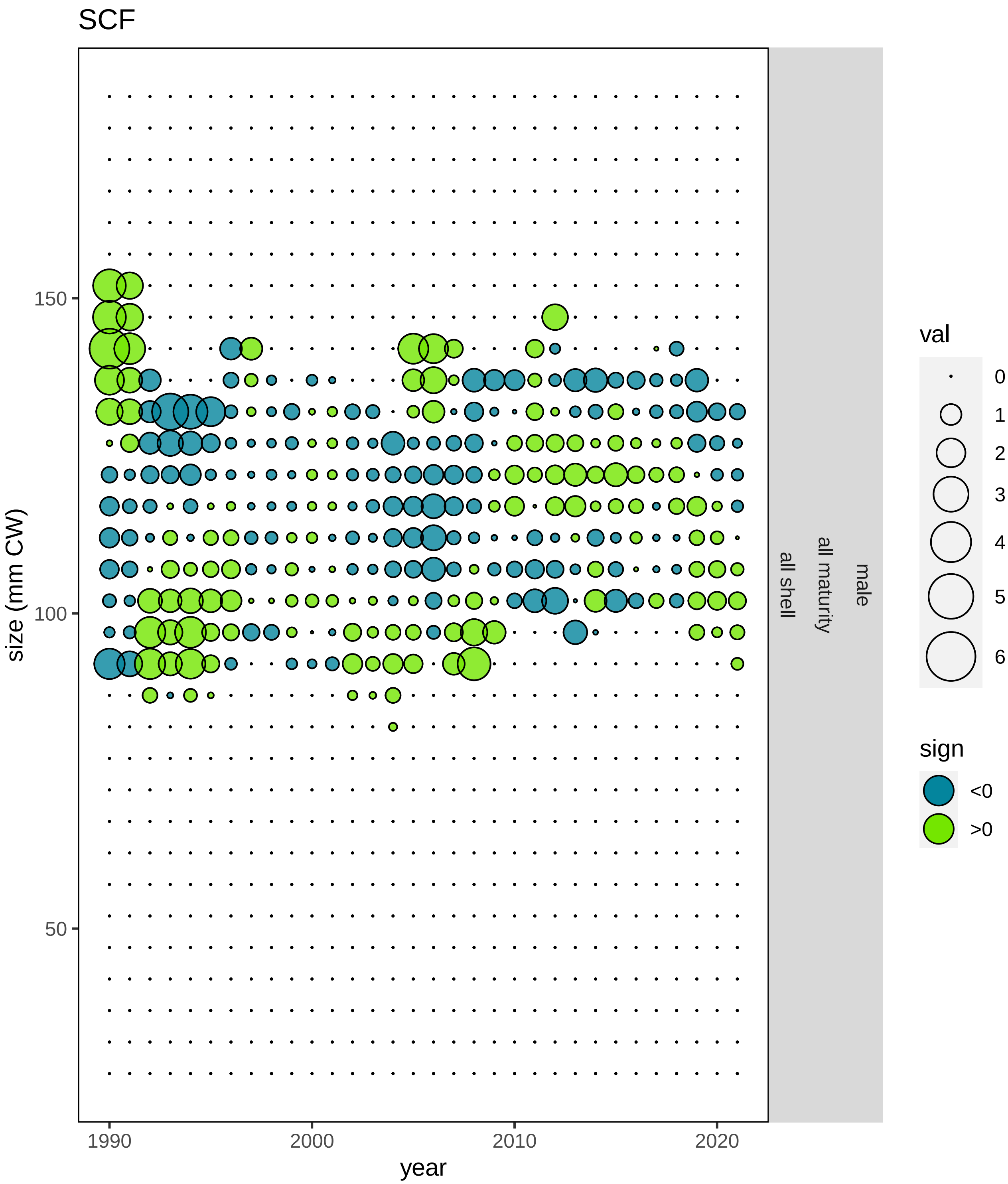

Figure 223. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

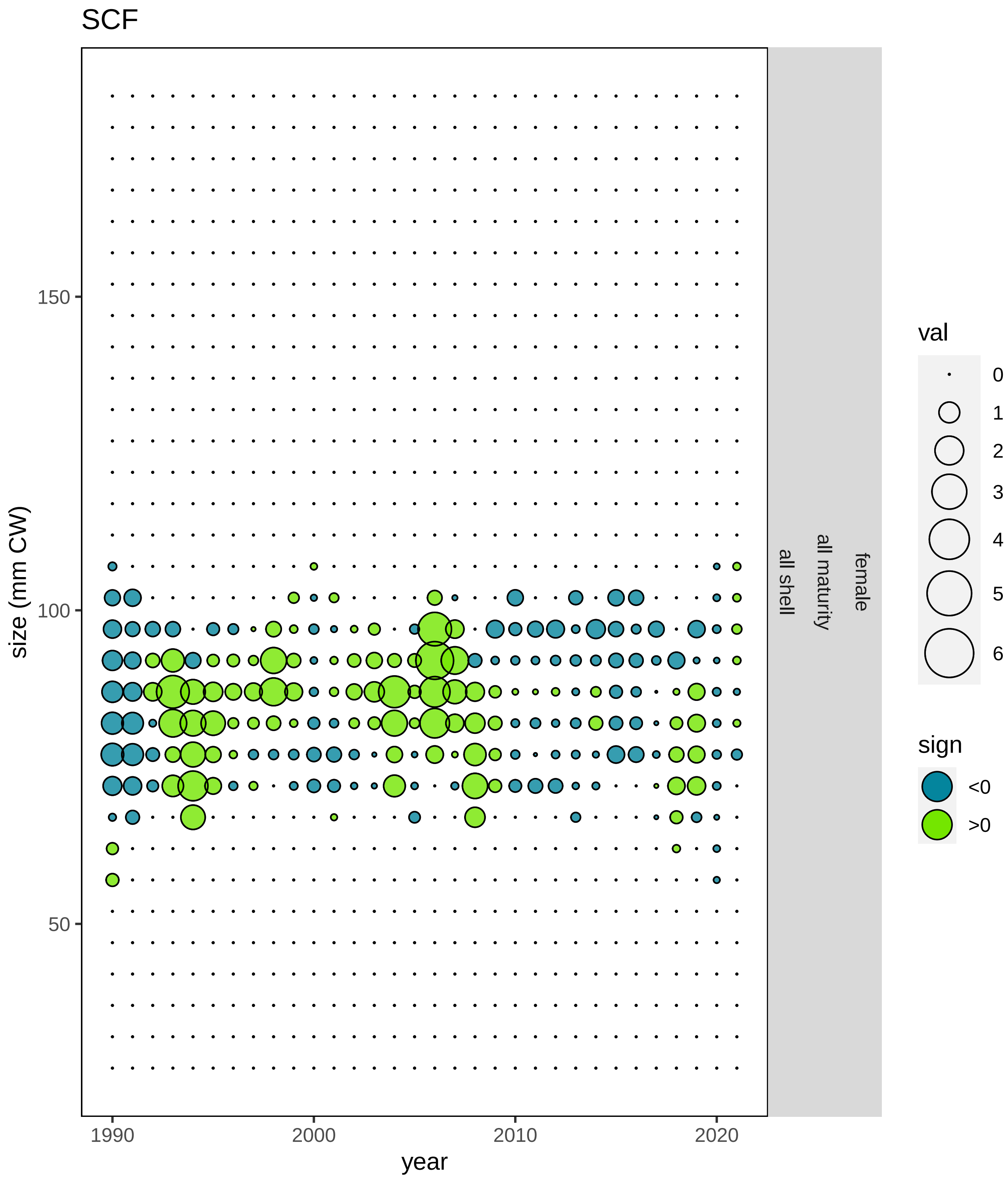

Figure 224. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

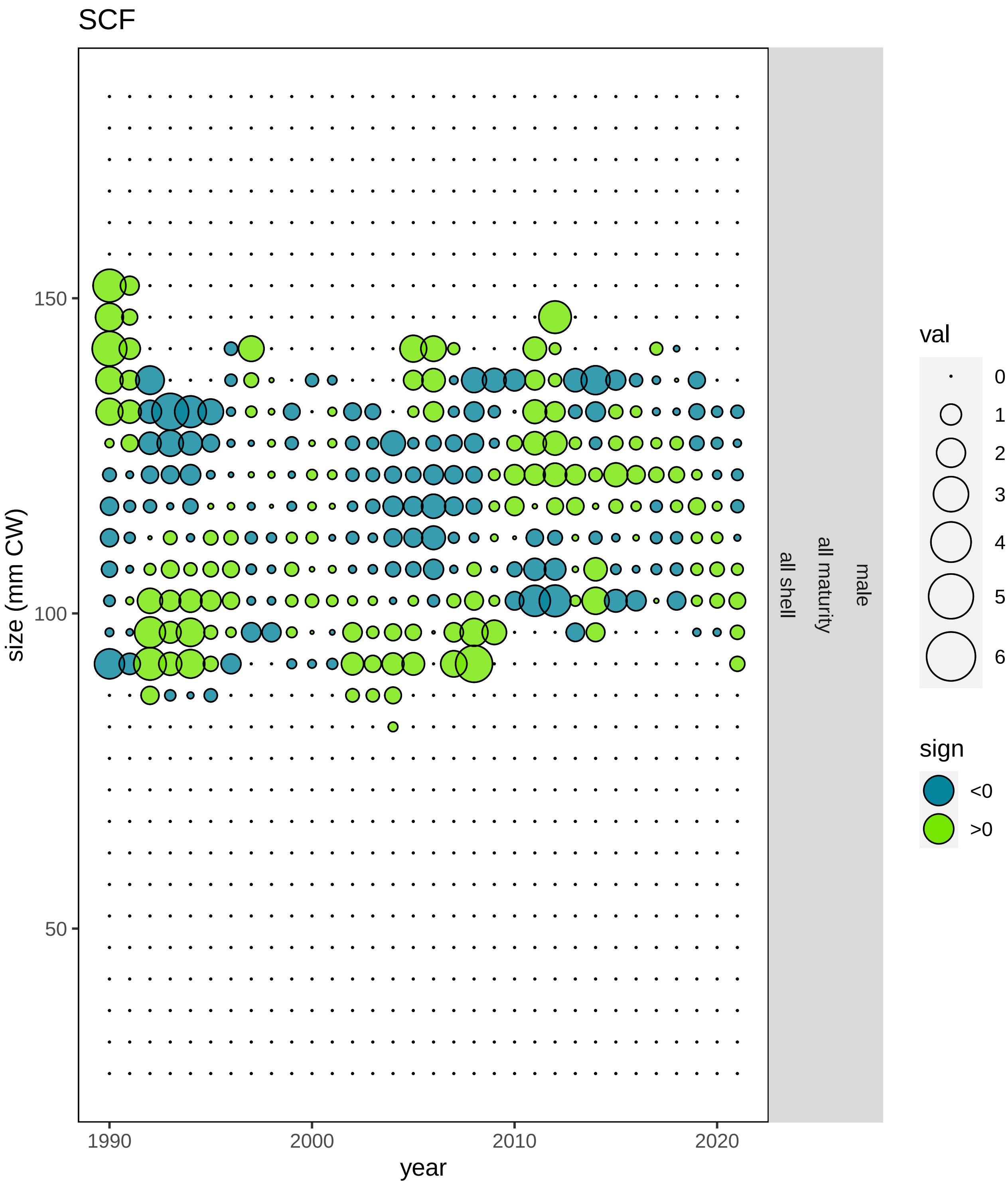

Figure 225. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

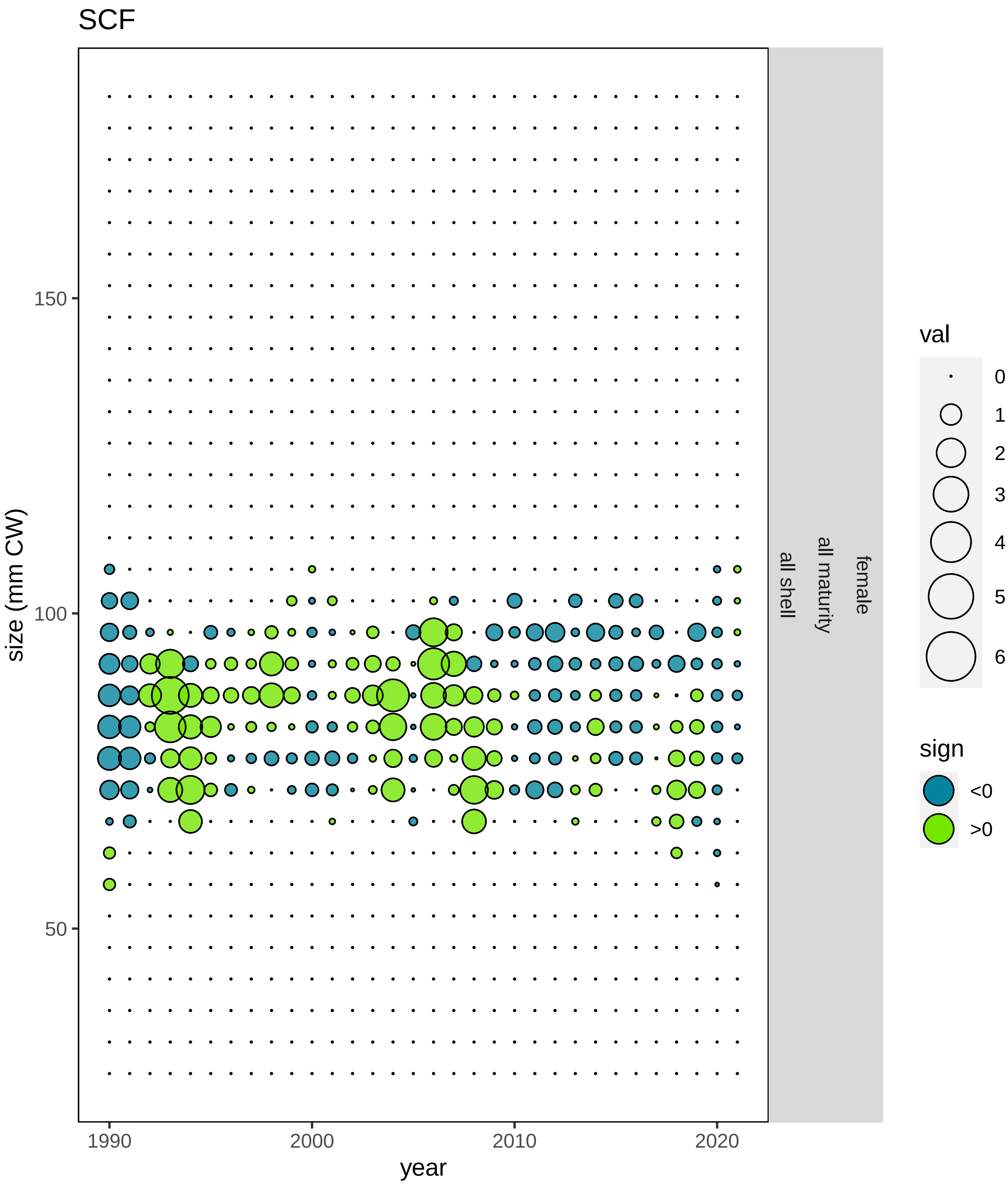

Figure 226. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

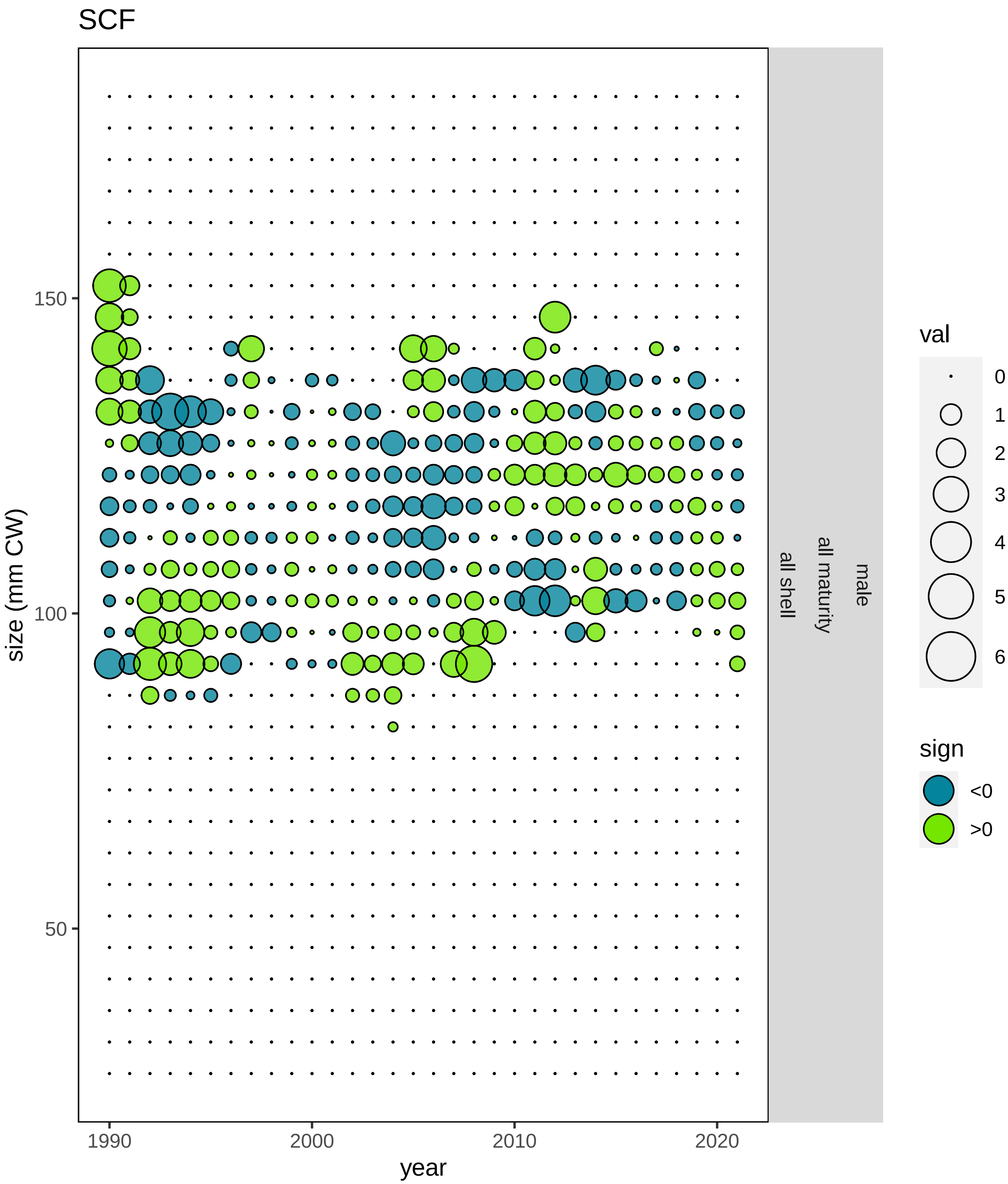

Figure 227. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

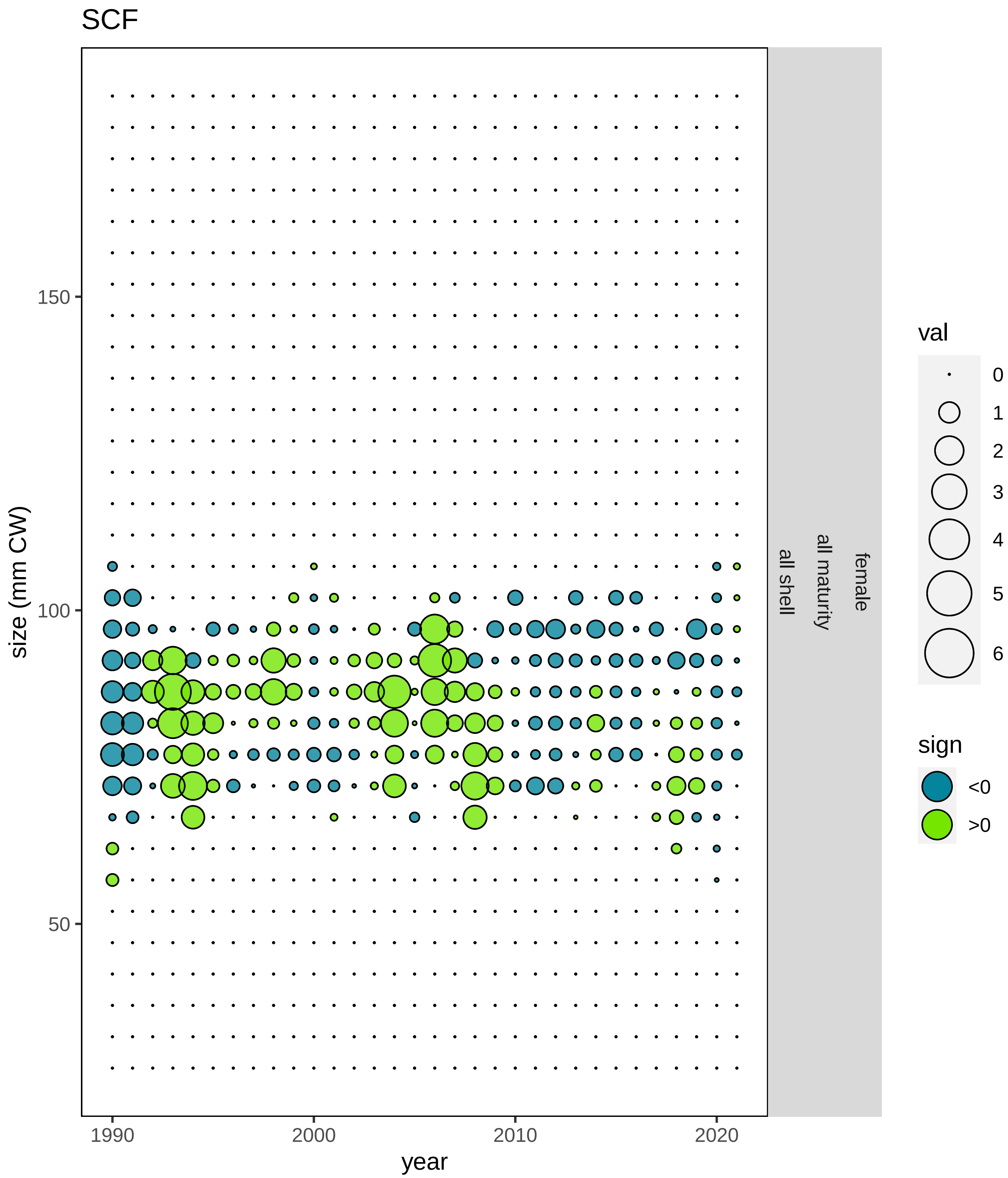

Figure 228. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

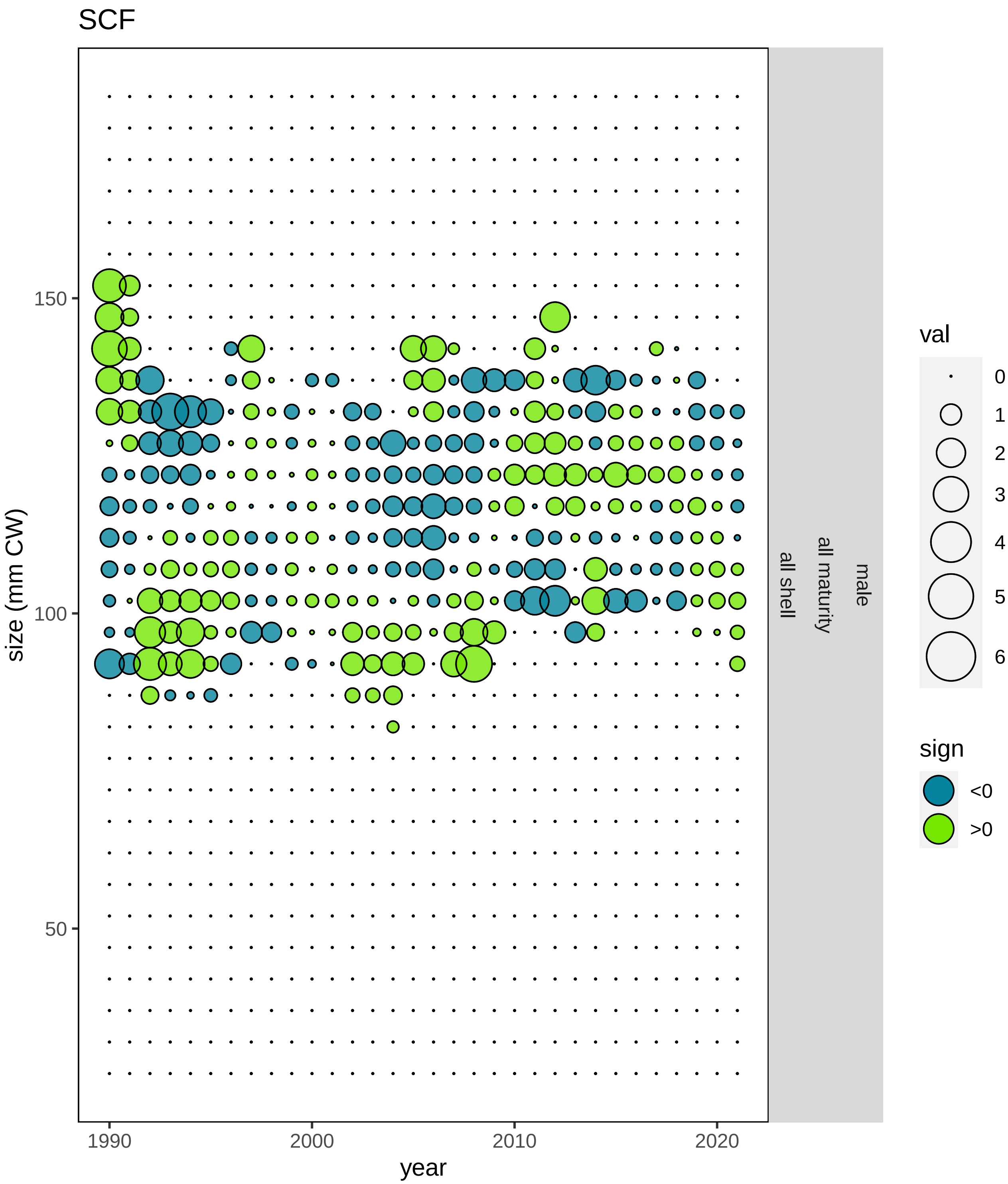

Figure 229. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

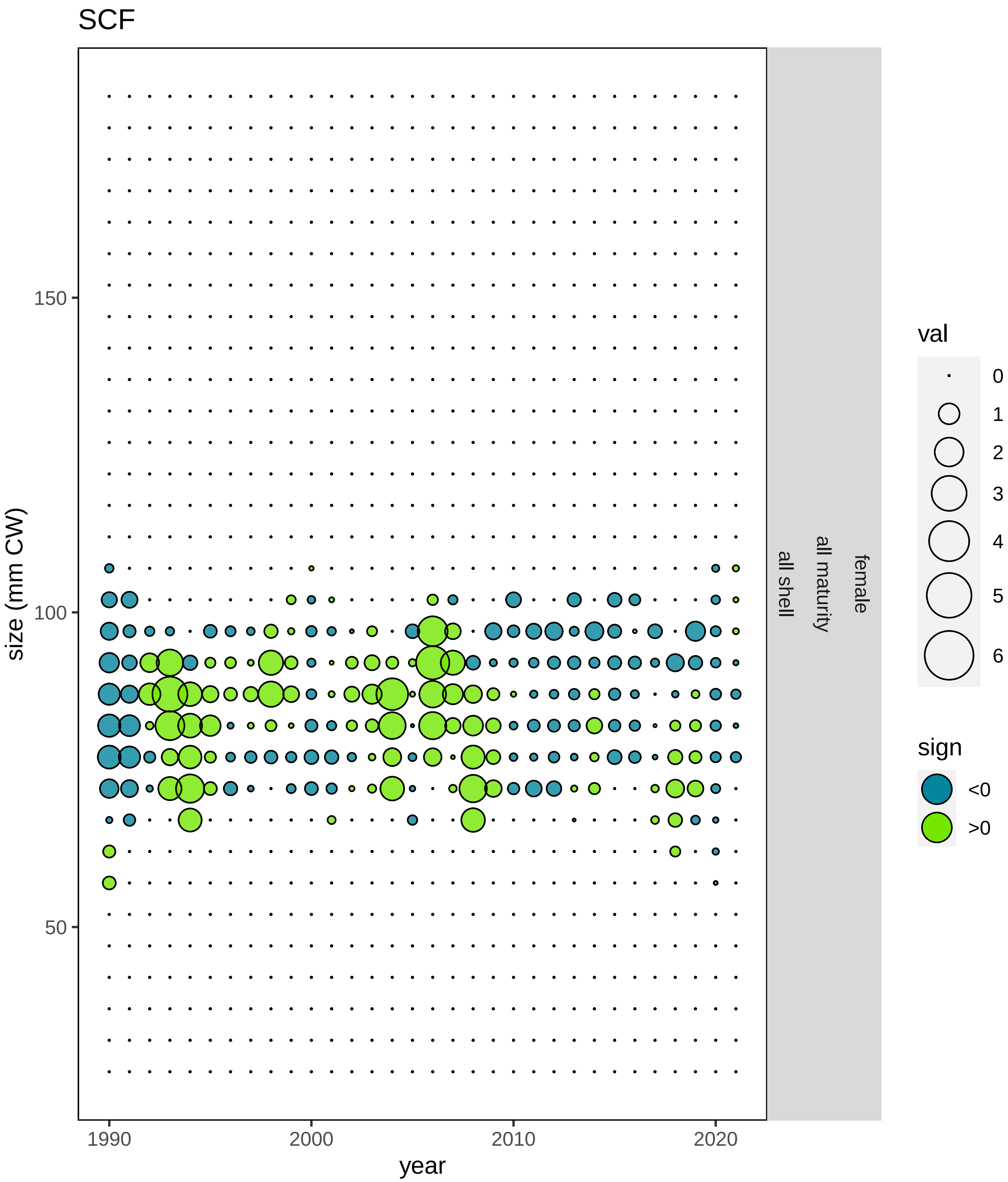

Figure 230. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

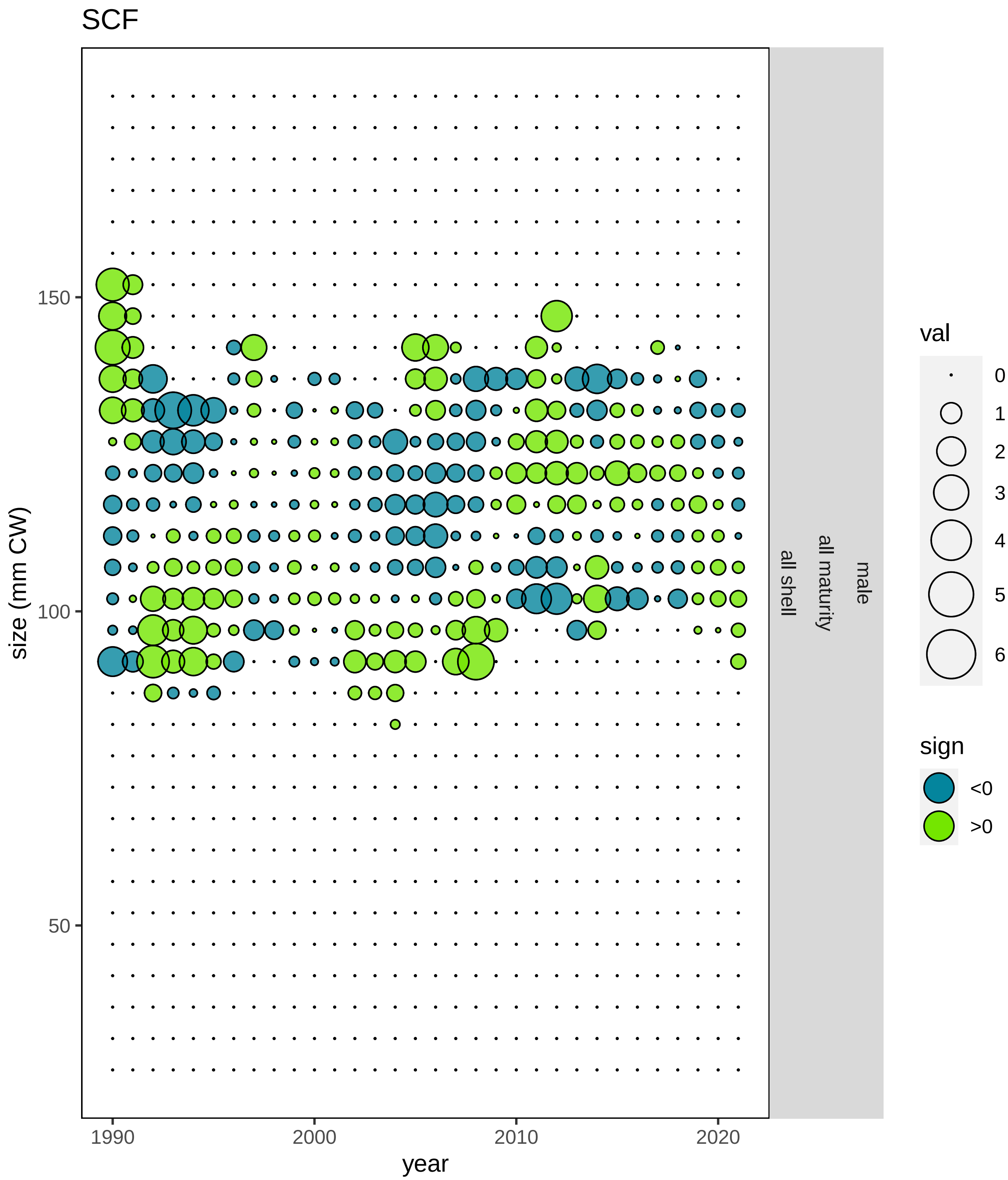

Figure 231. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

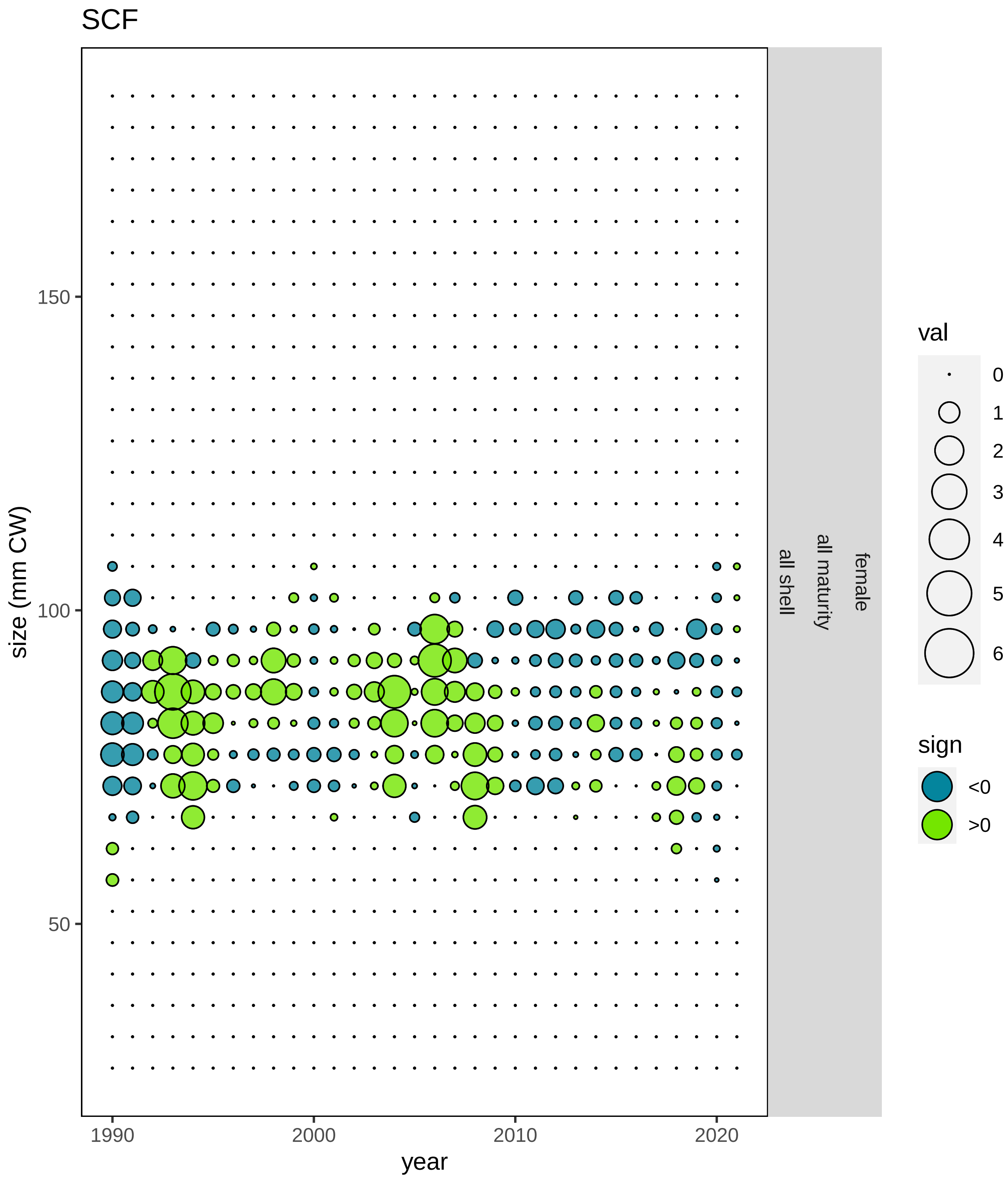

Figure 232. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

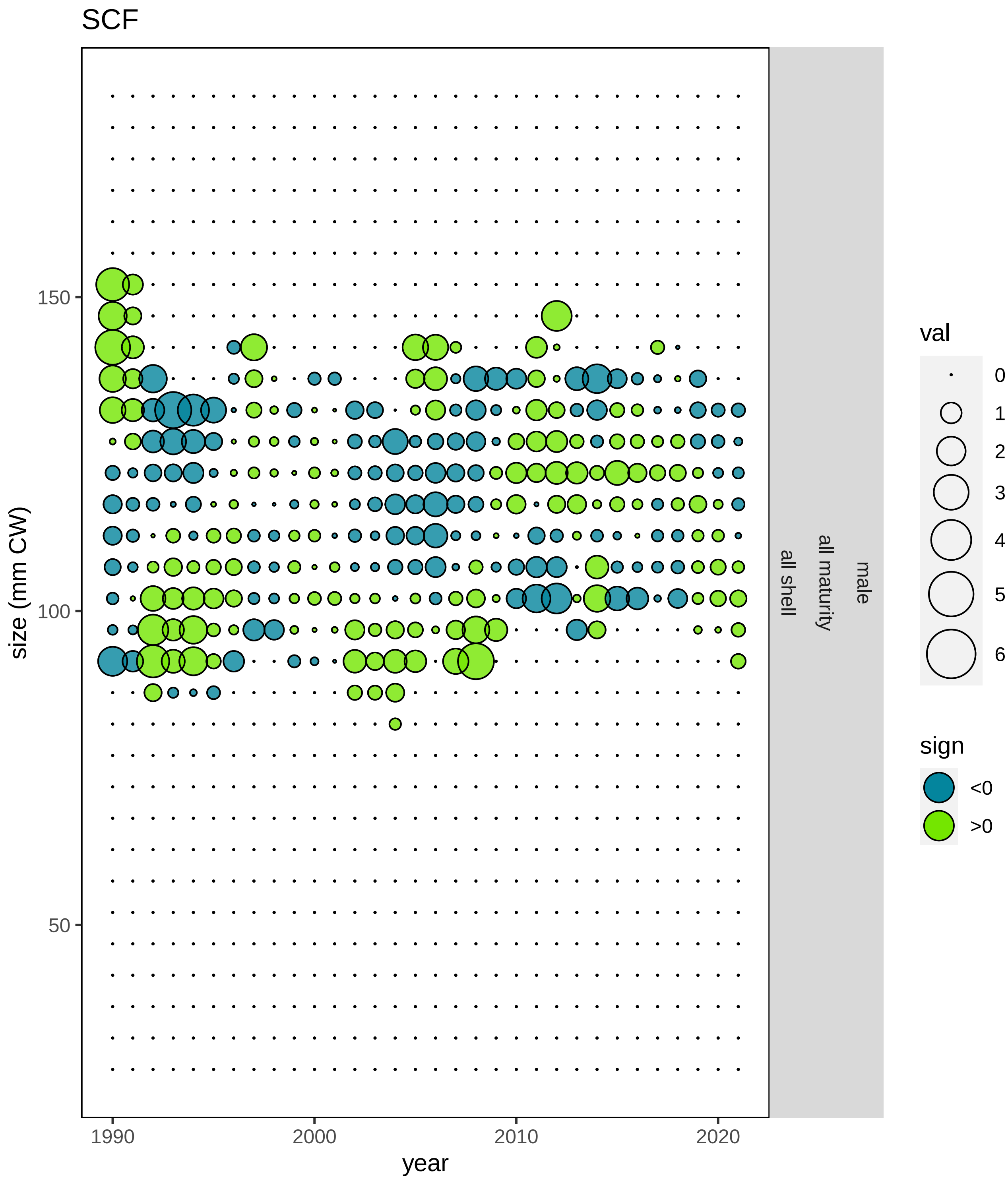

Figure 233. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

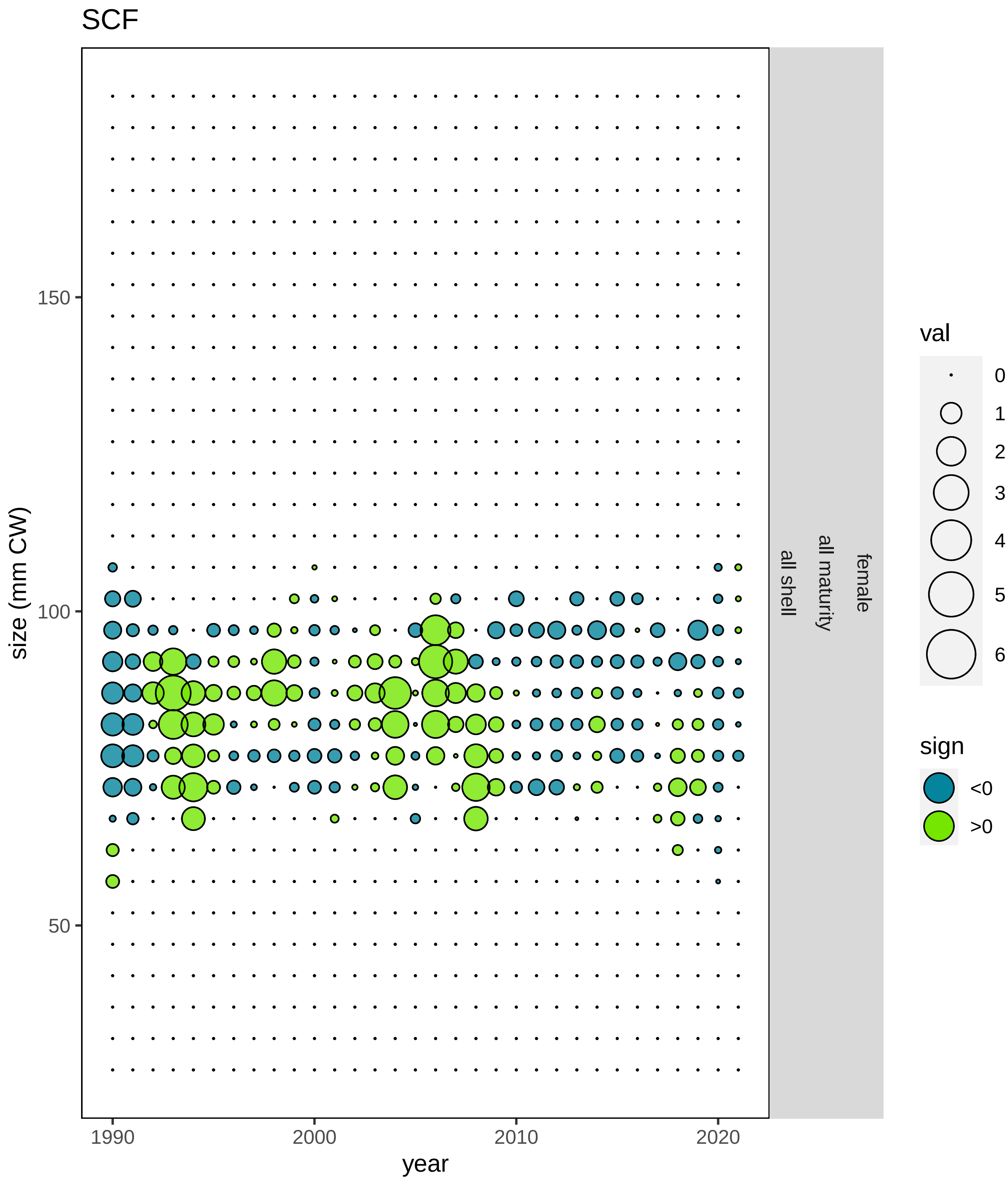

Figure 234. Pearson's residuals for fits to fishery total catch size composition data from the SCF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

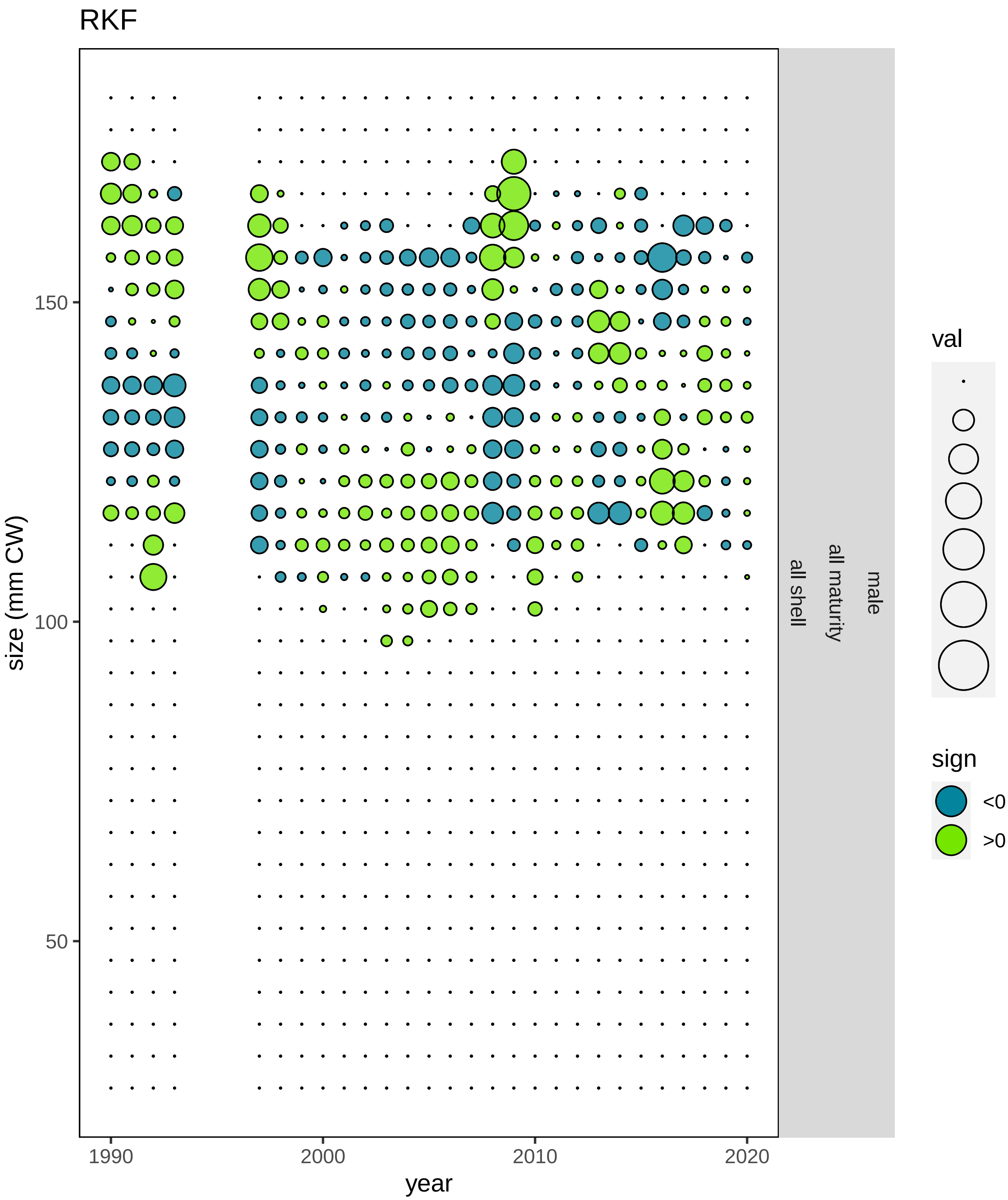

Figure 235. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

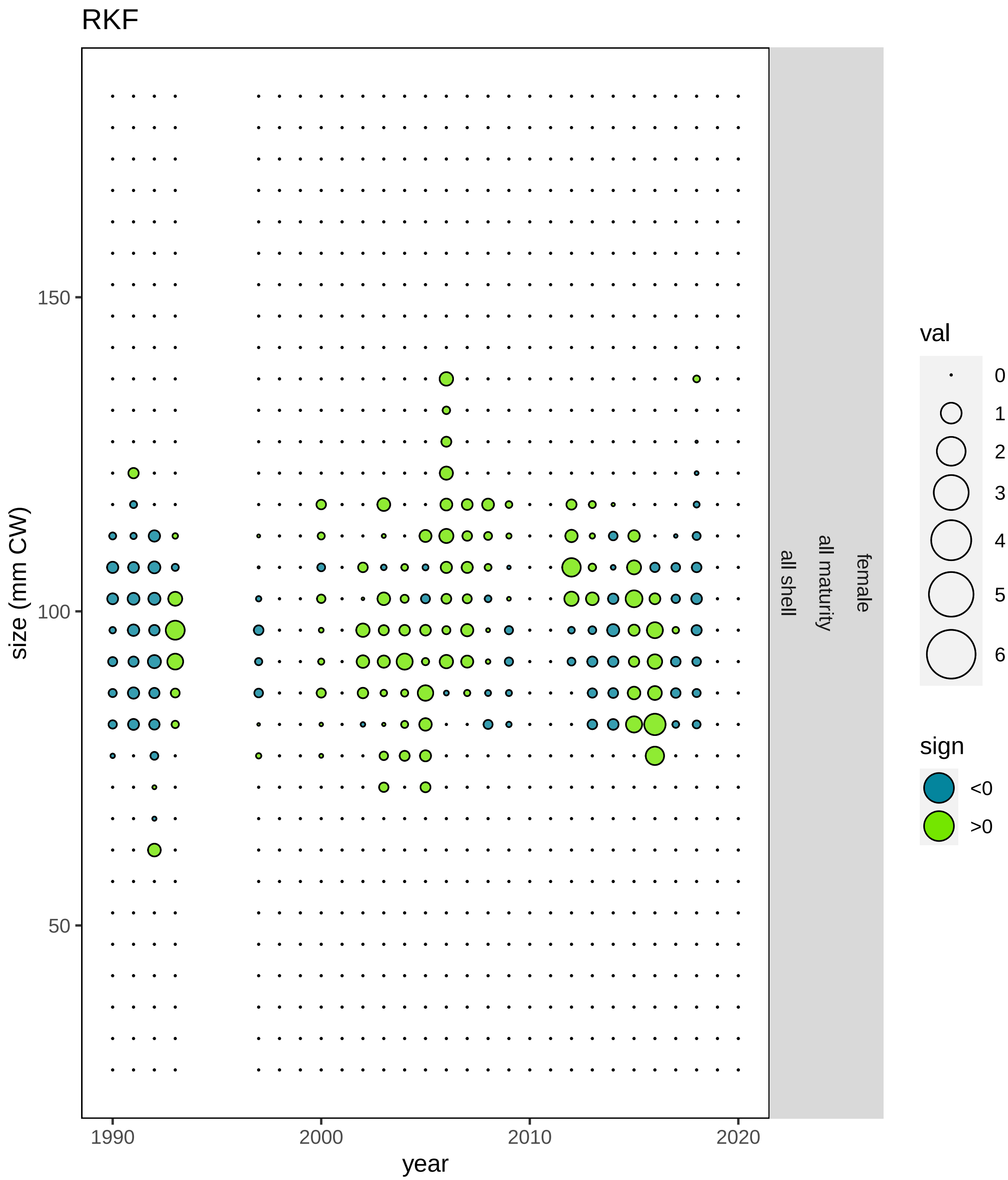

Figure 236. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

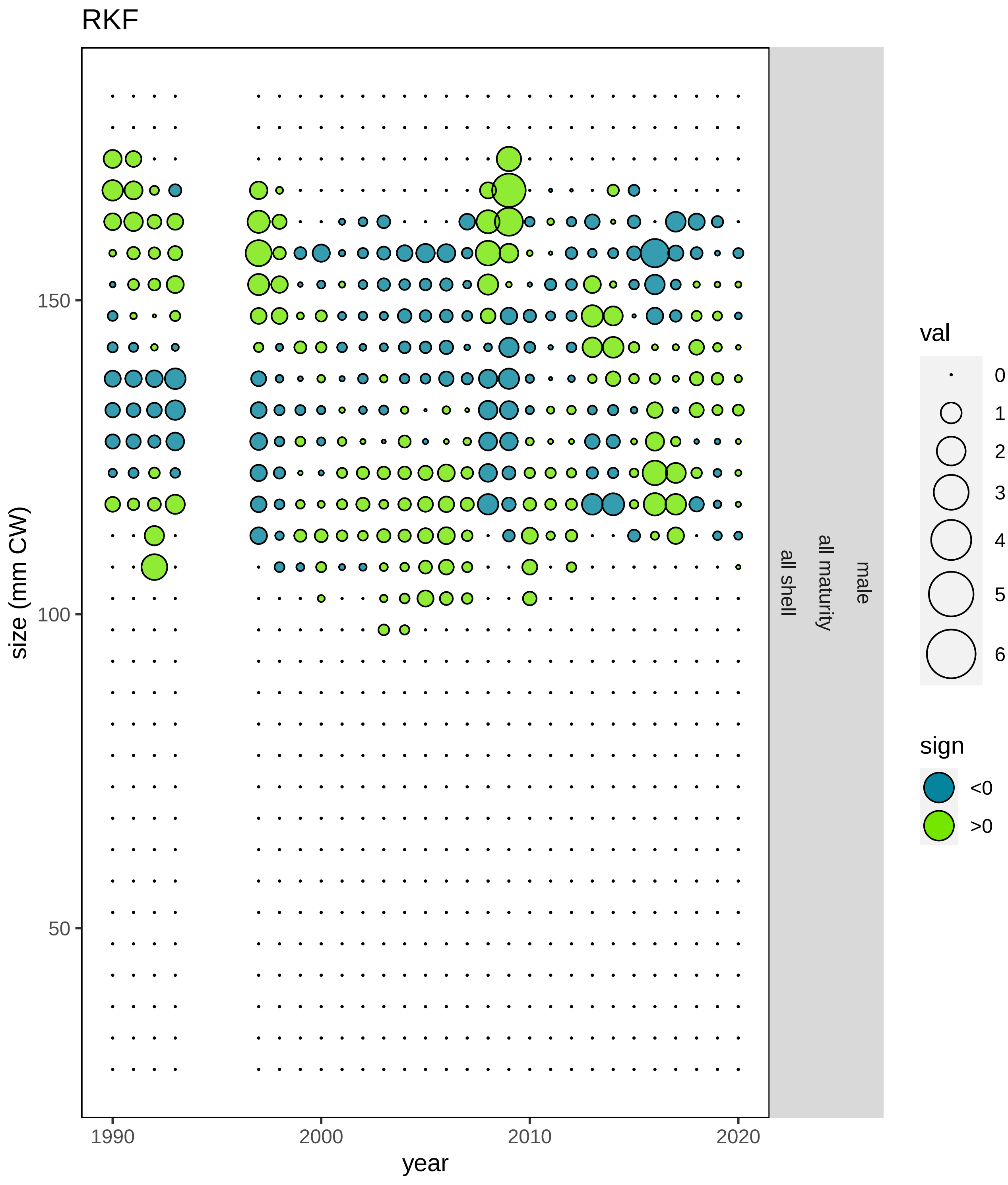

Figure 237. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

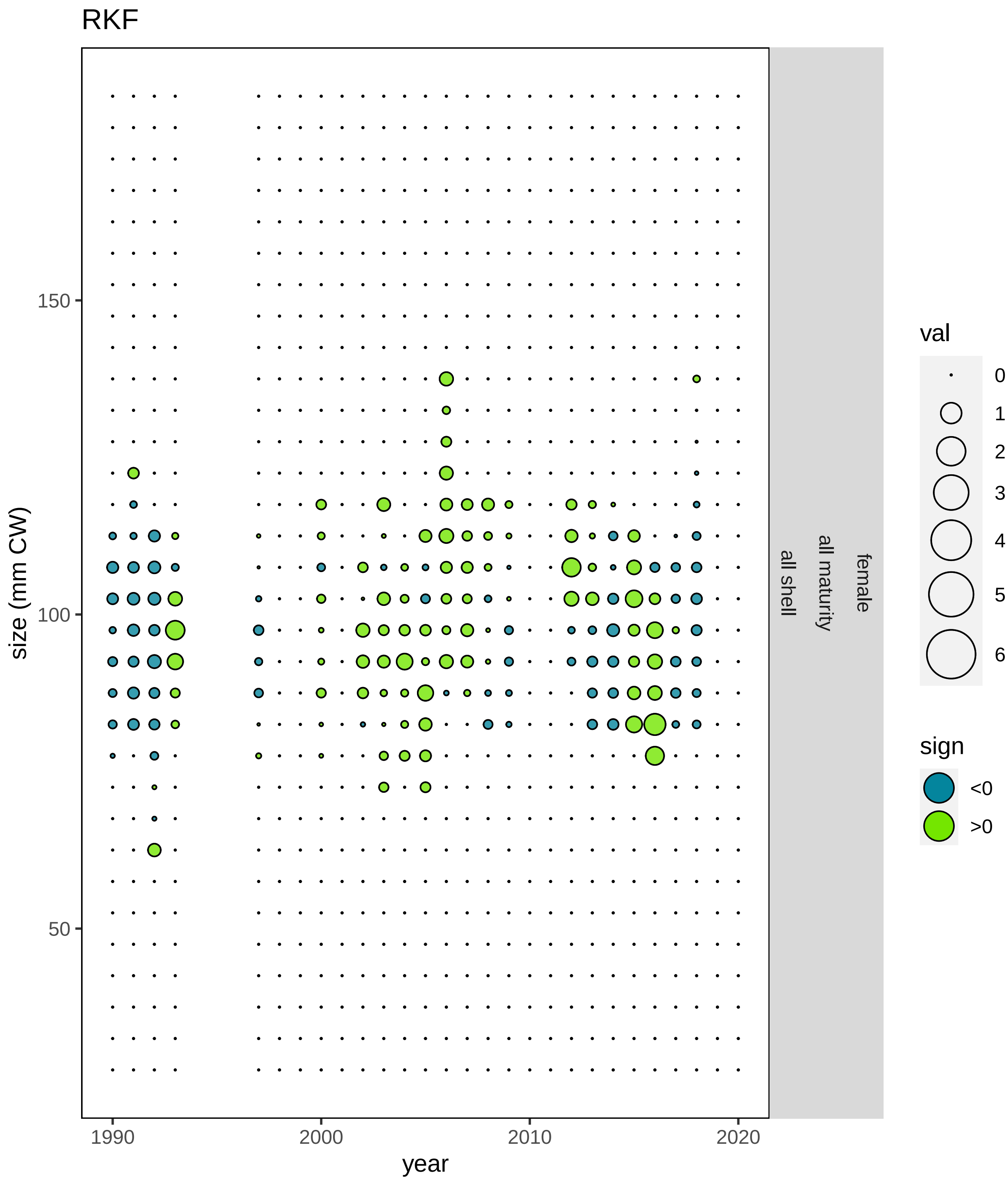

Figure 238. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

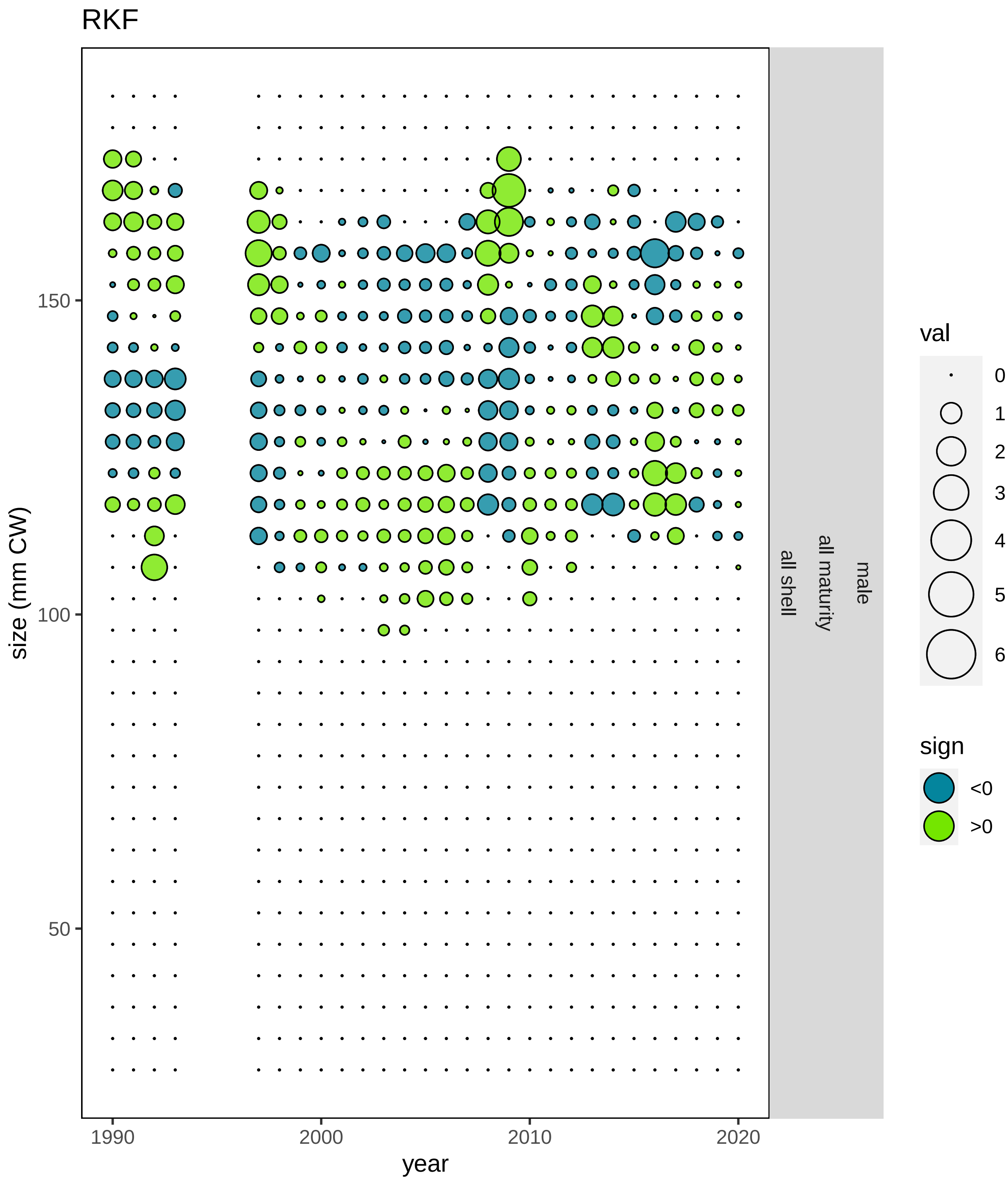

Figure 239. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

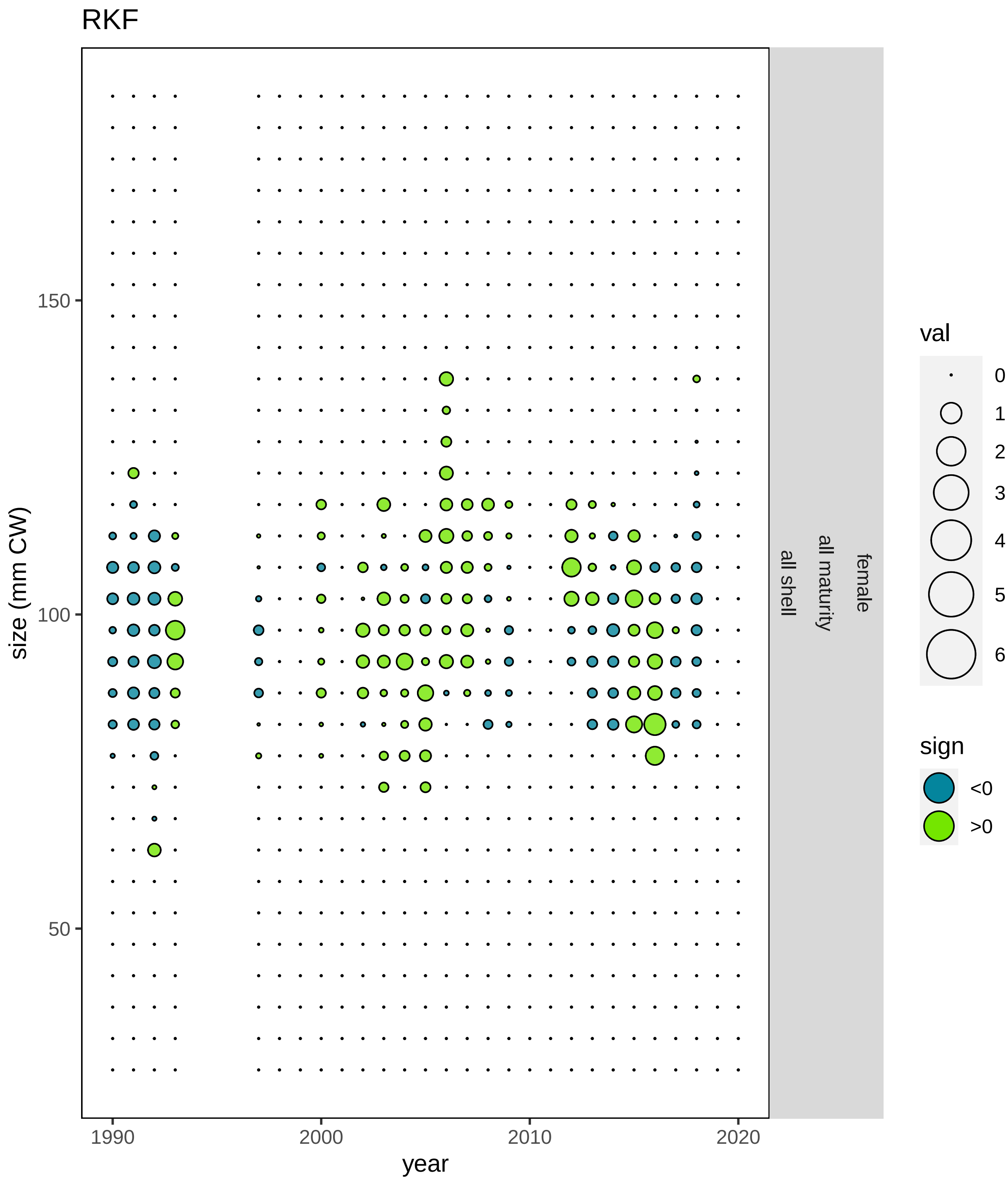

Figure 240. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

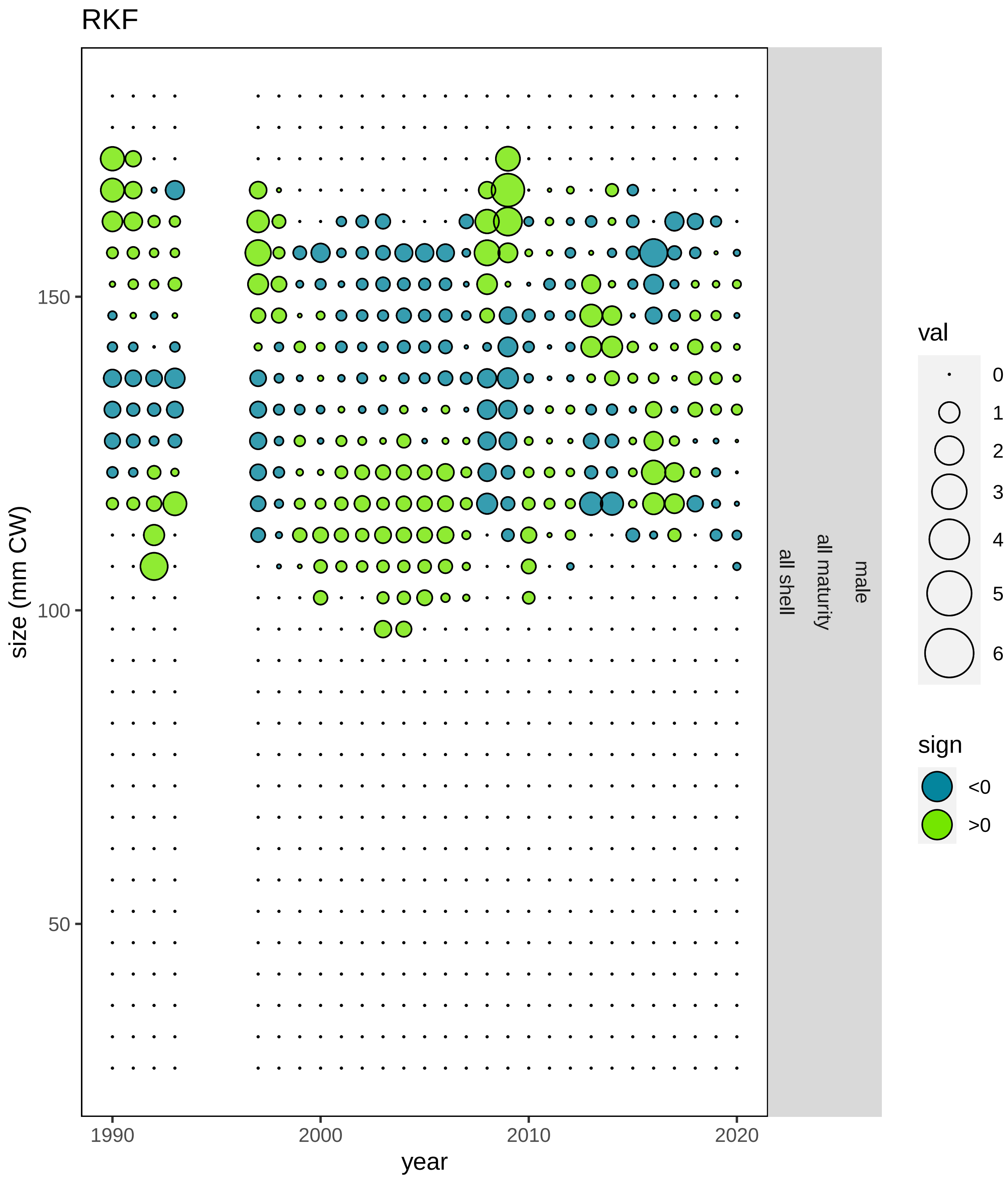

Figure 241. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

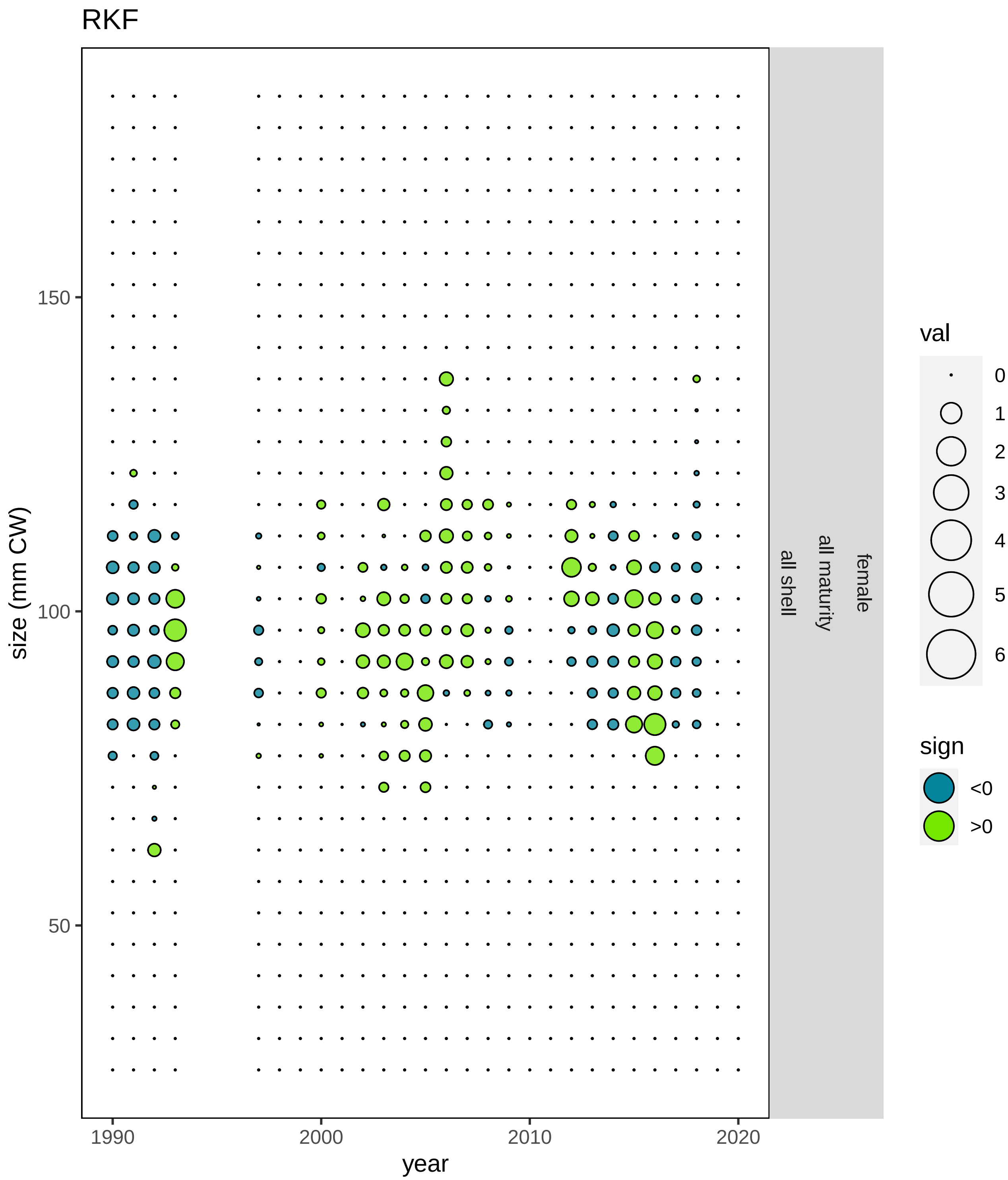

Figure 242. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

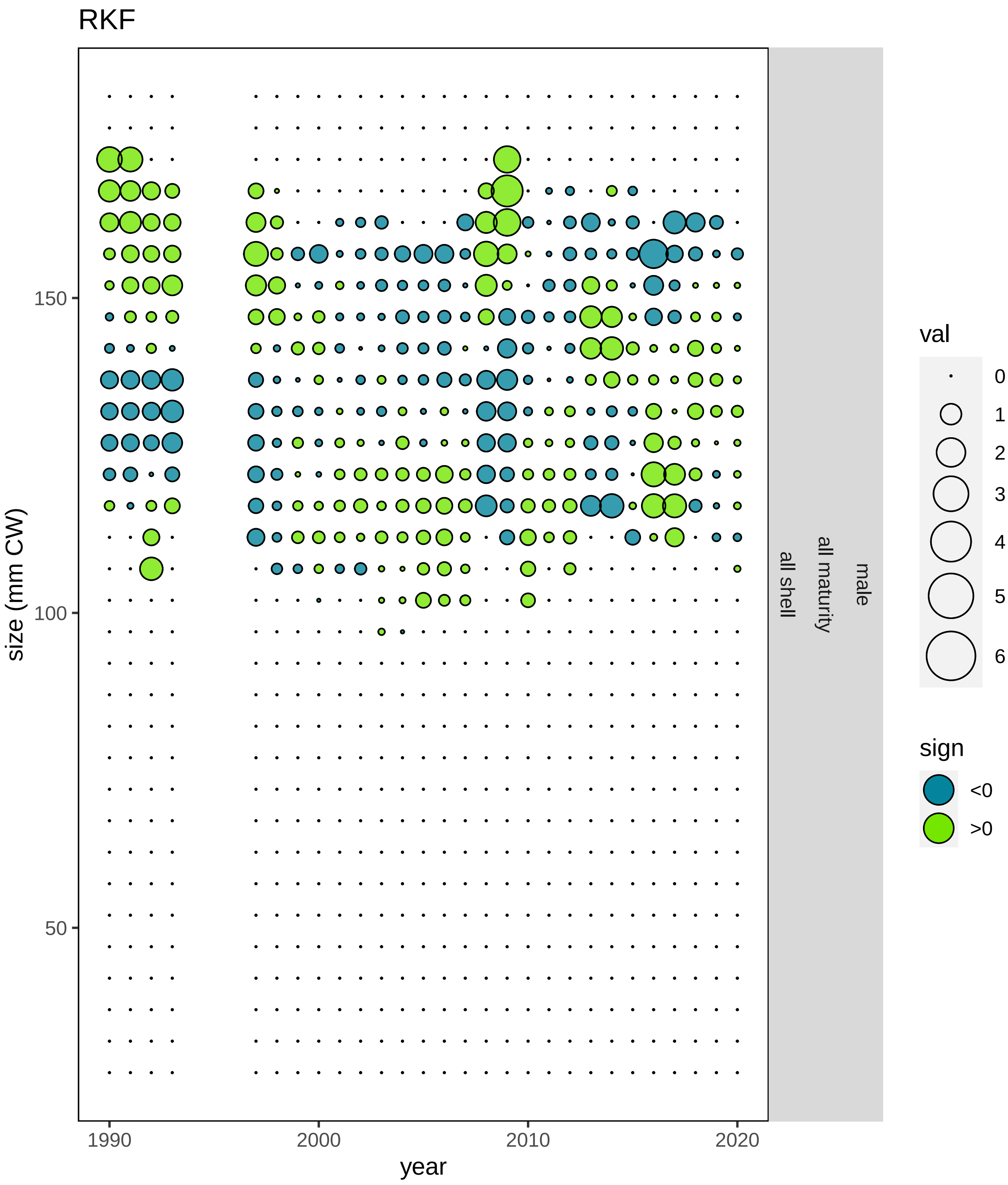

Figure 243. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

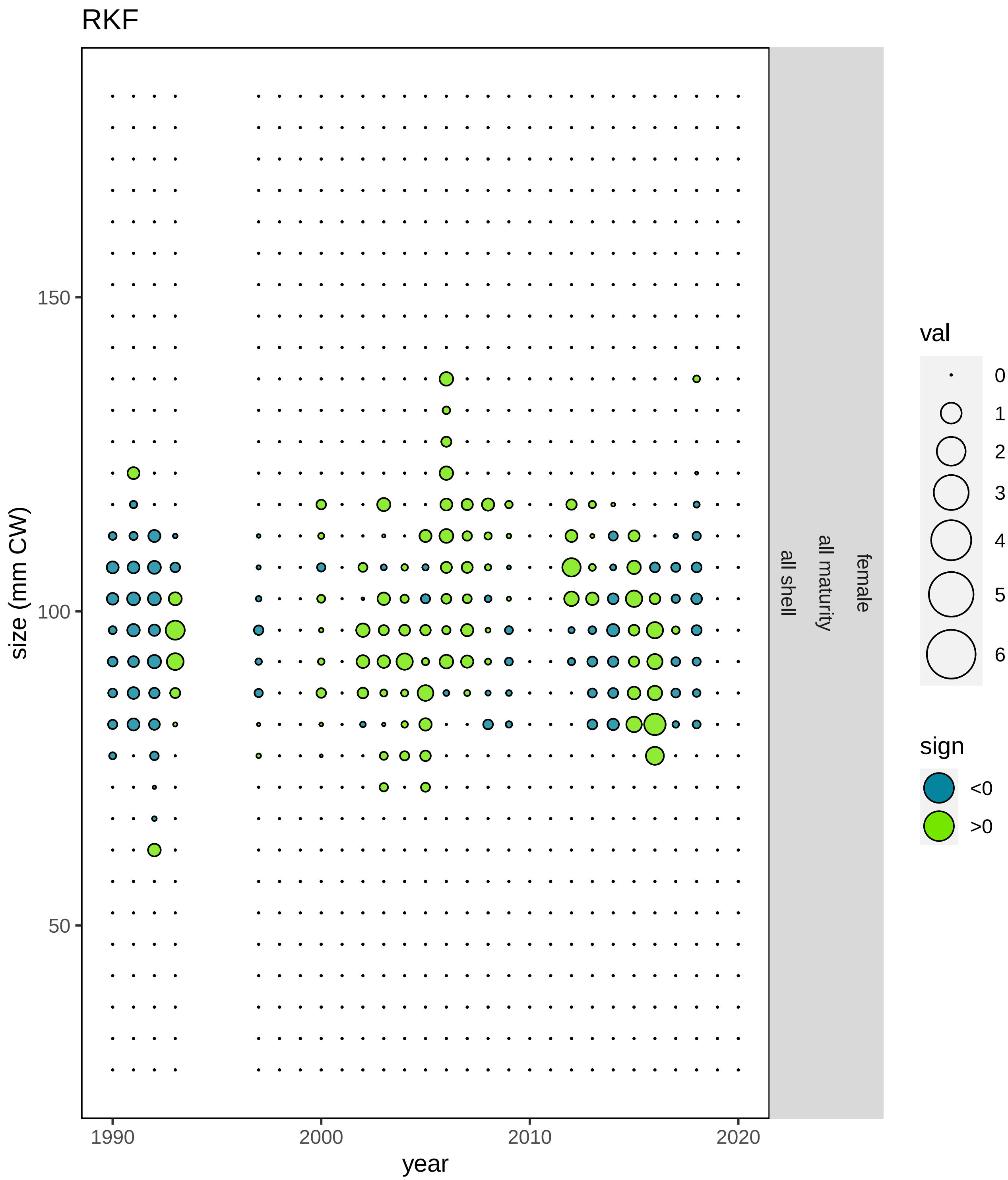

Figure 244. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

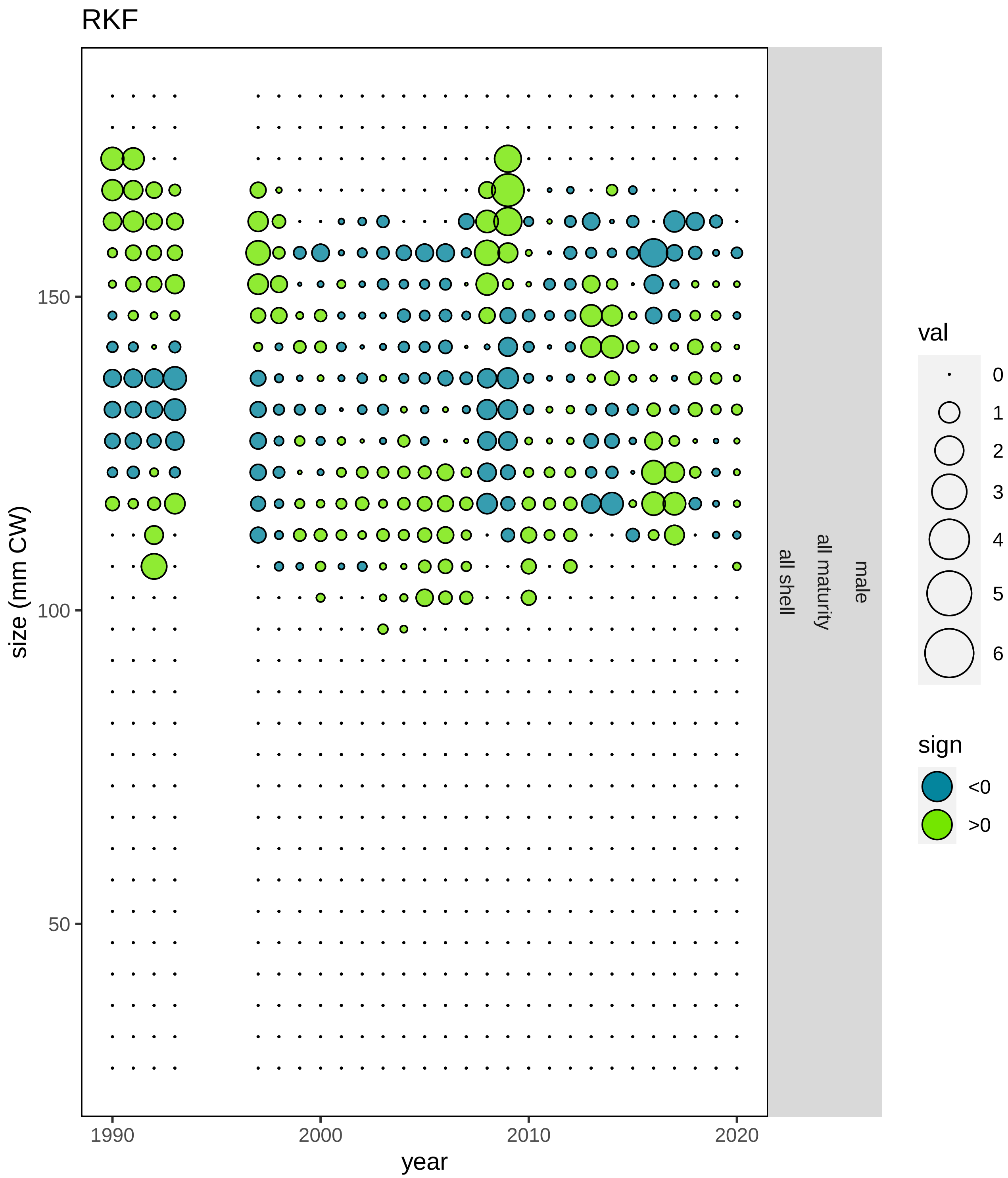

Figure 245. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

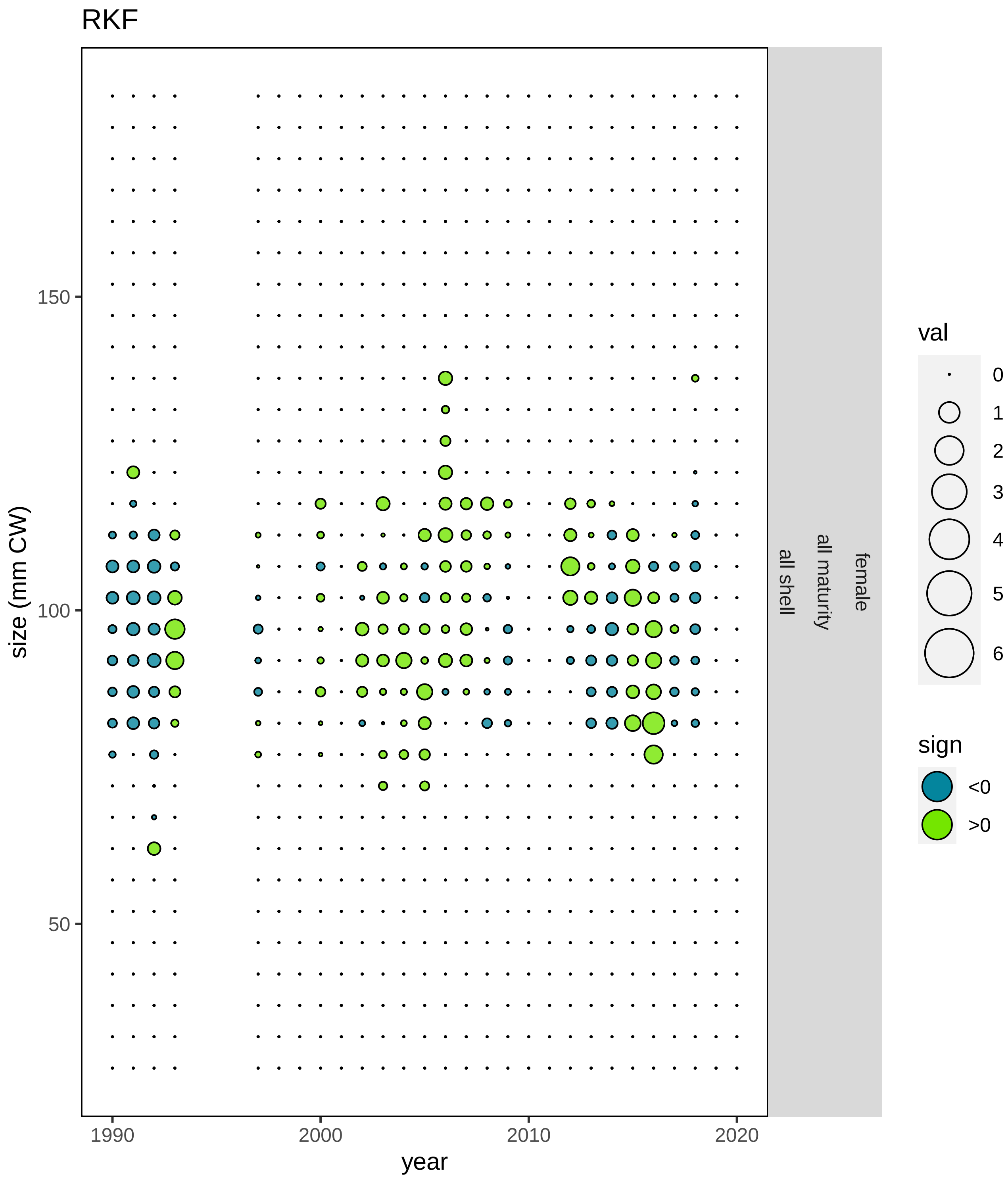

Figure 246. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

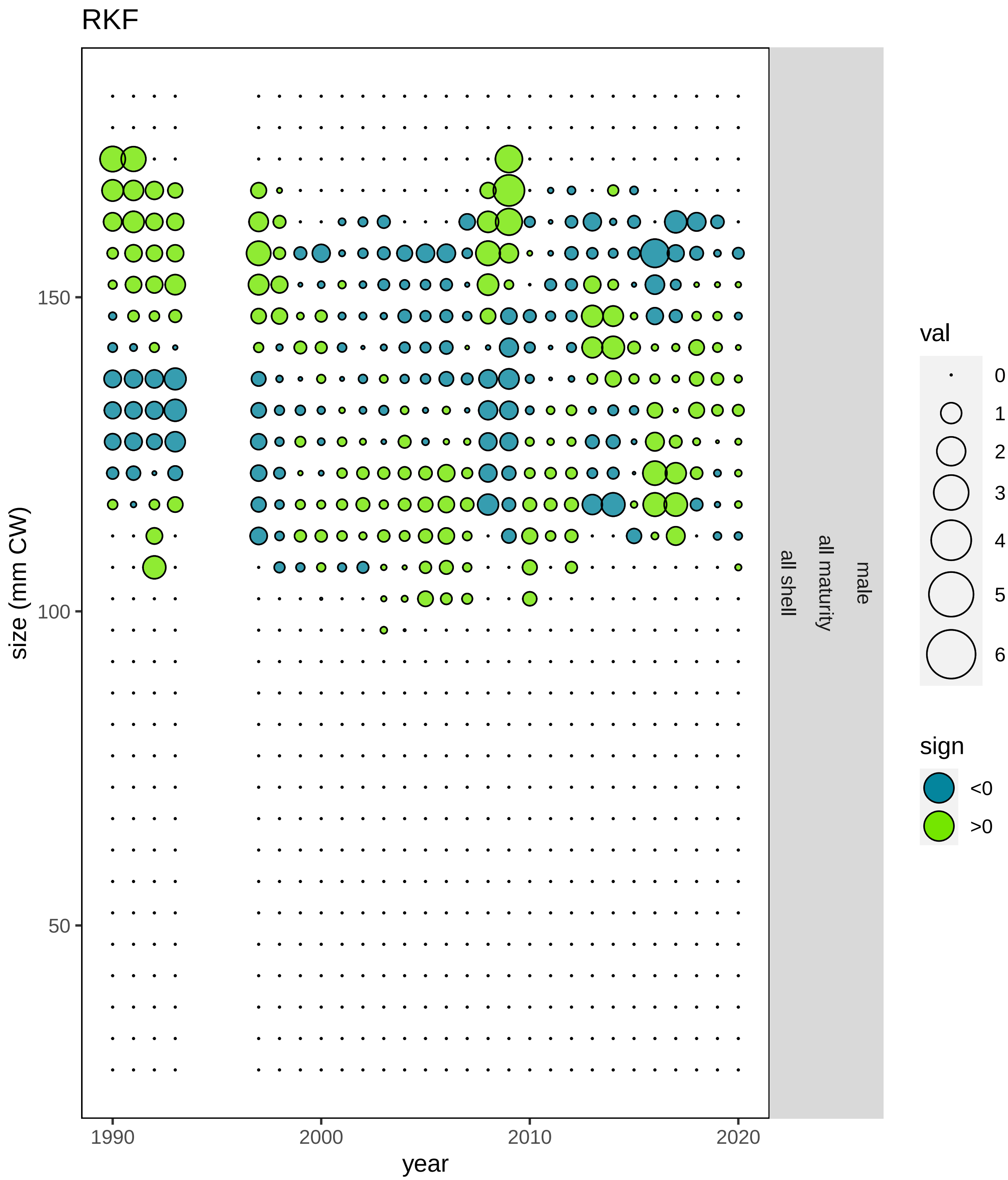

Figure 247. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

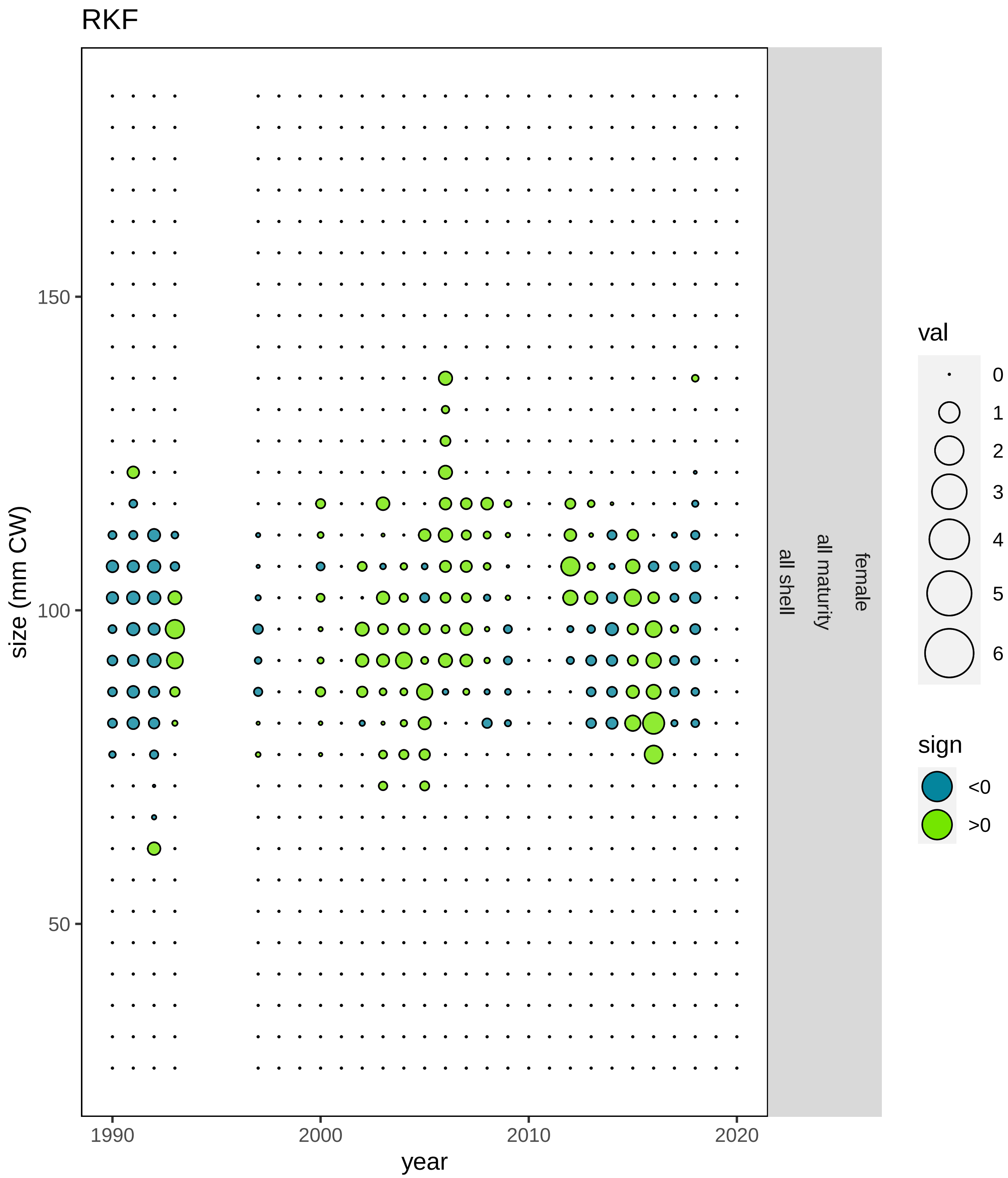

Figure 248. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

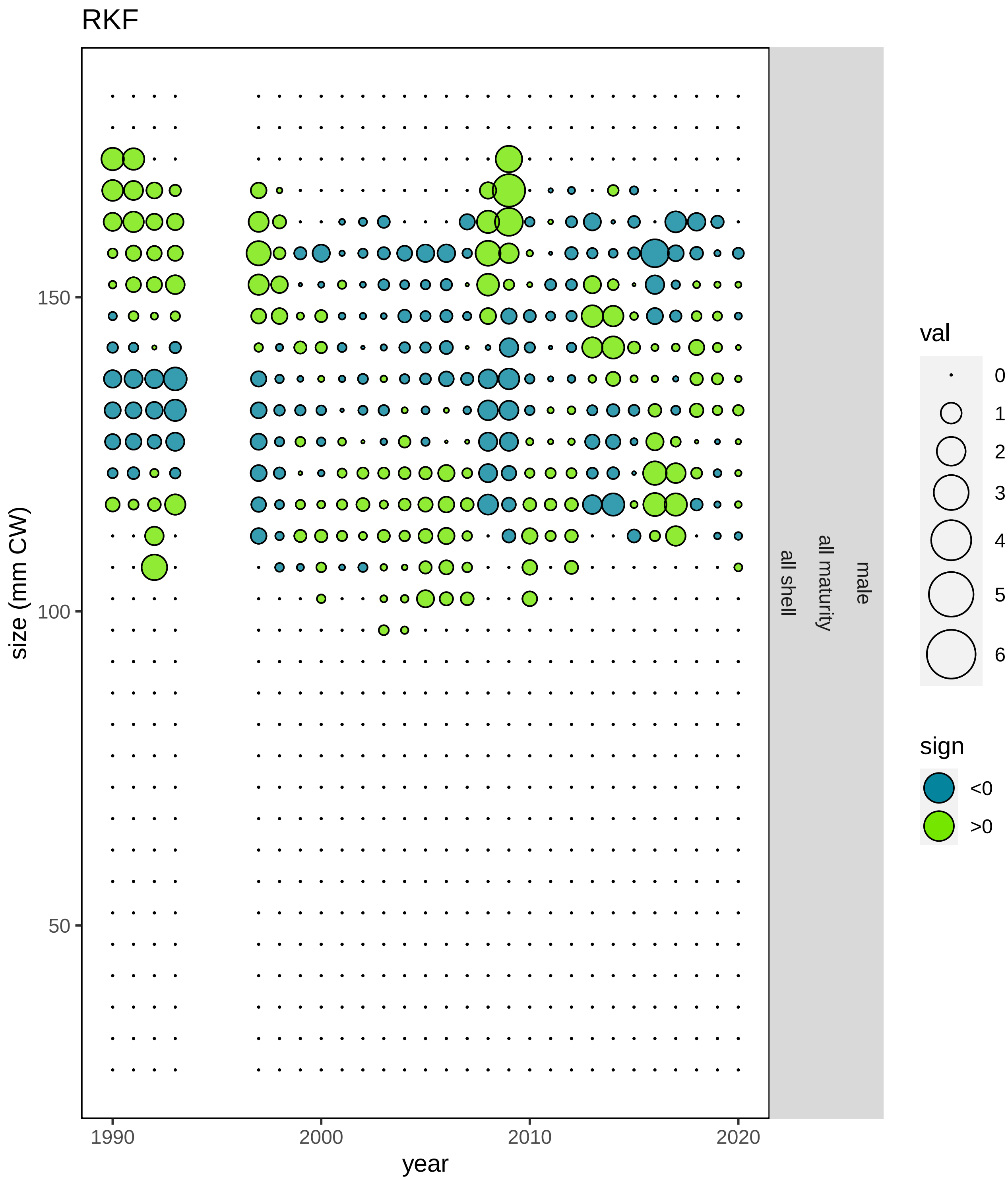

Figure 249. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

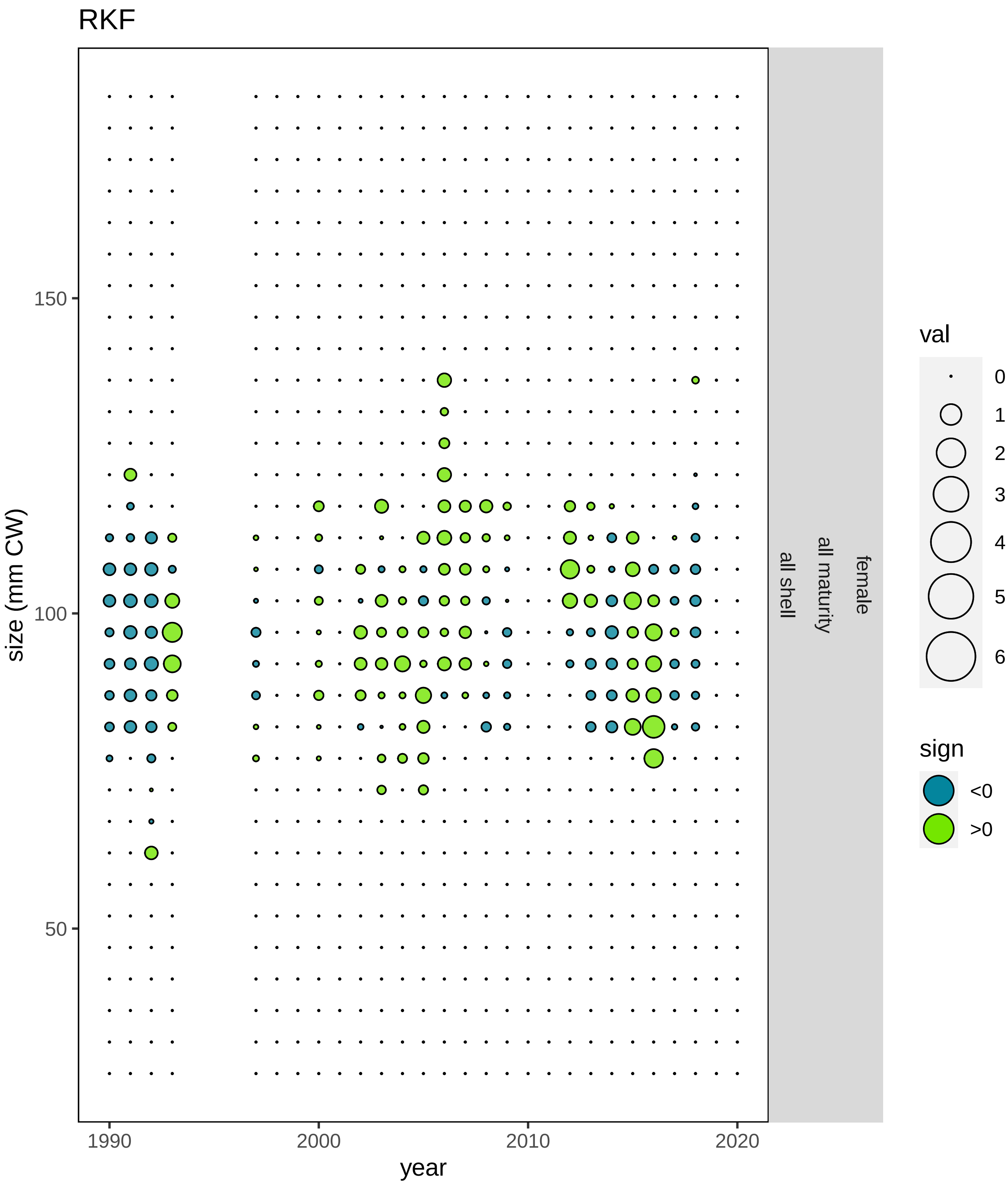

Figure 250. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

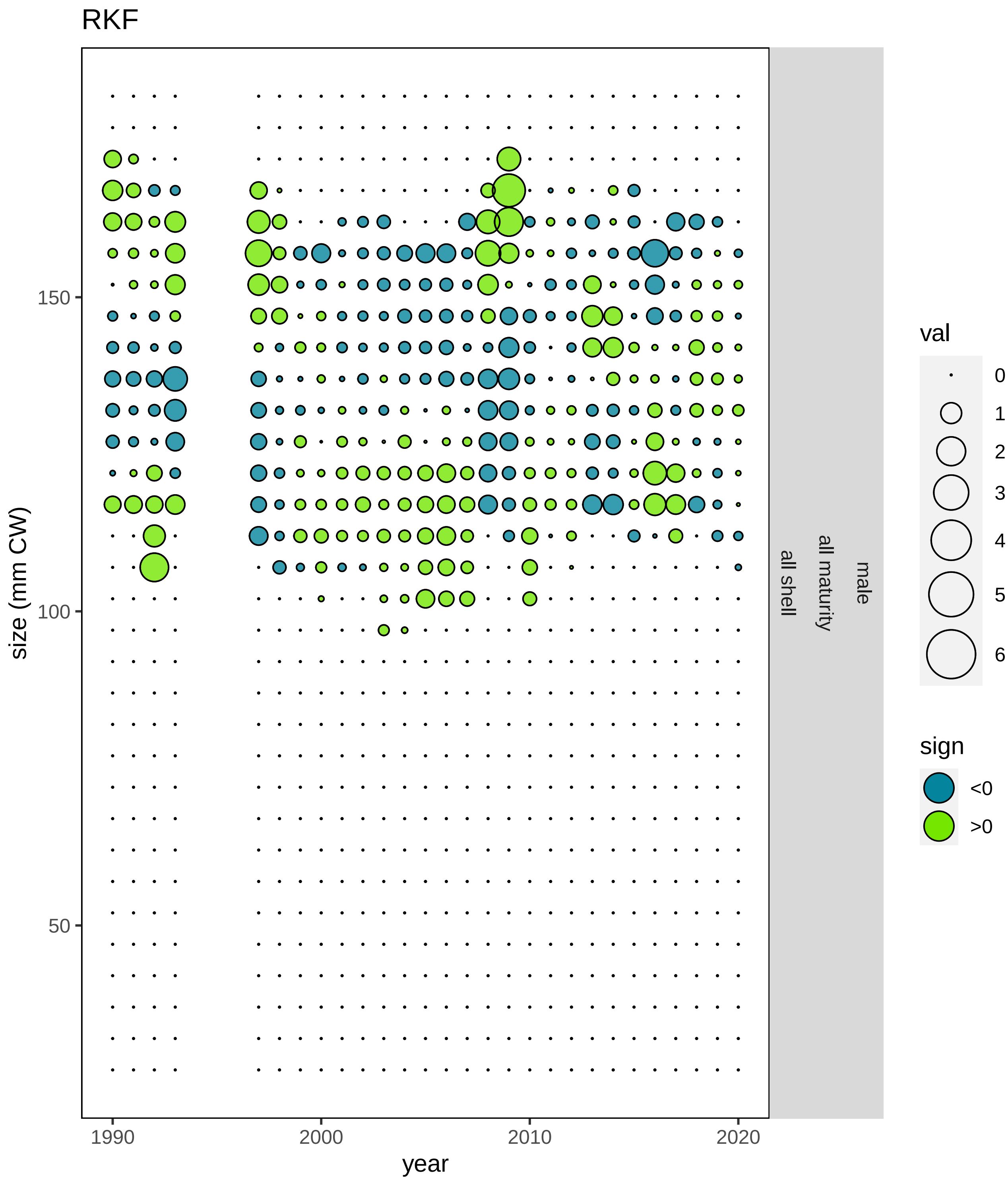

Figure 251. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

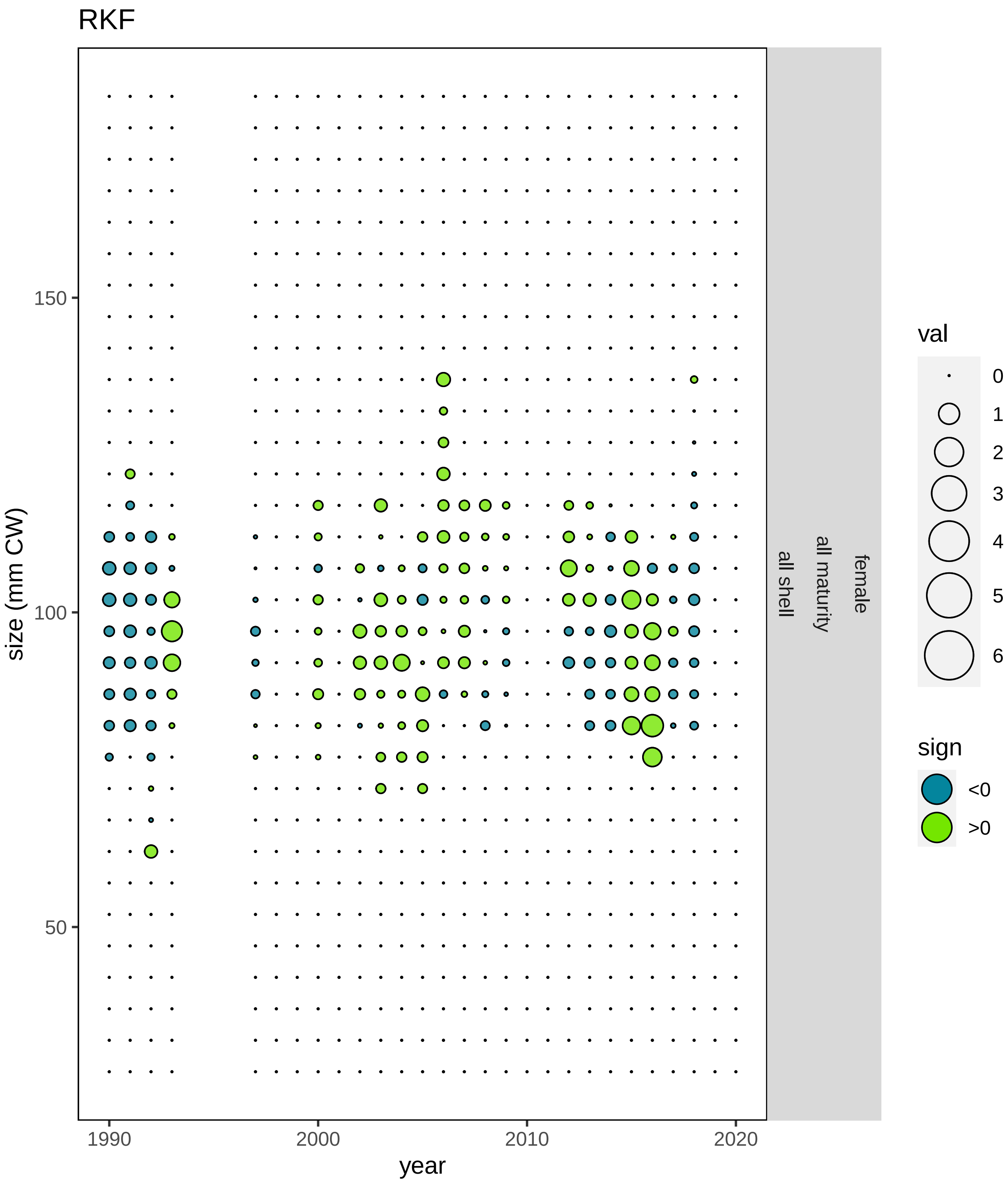

Figure 252. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

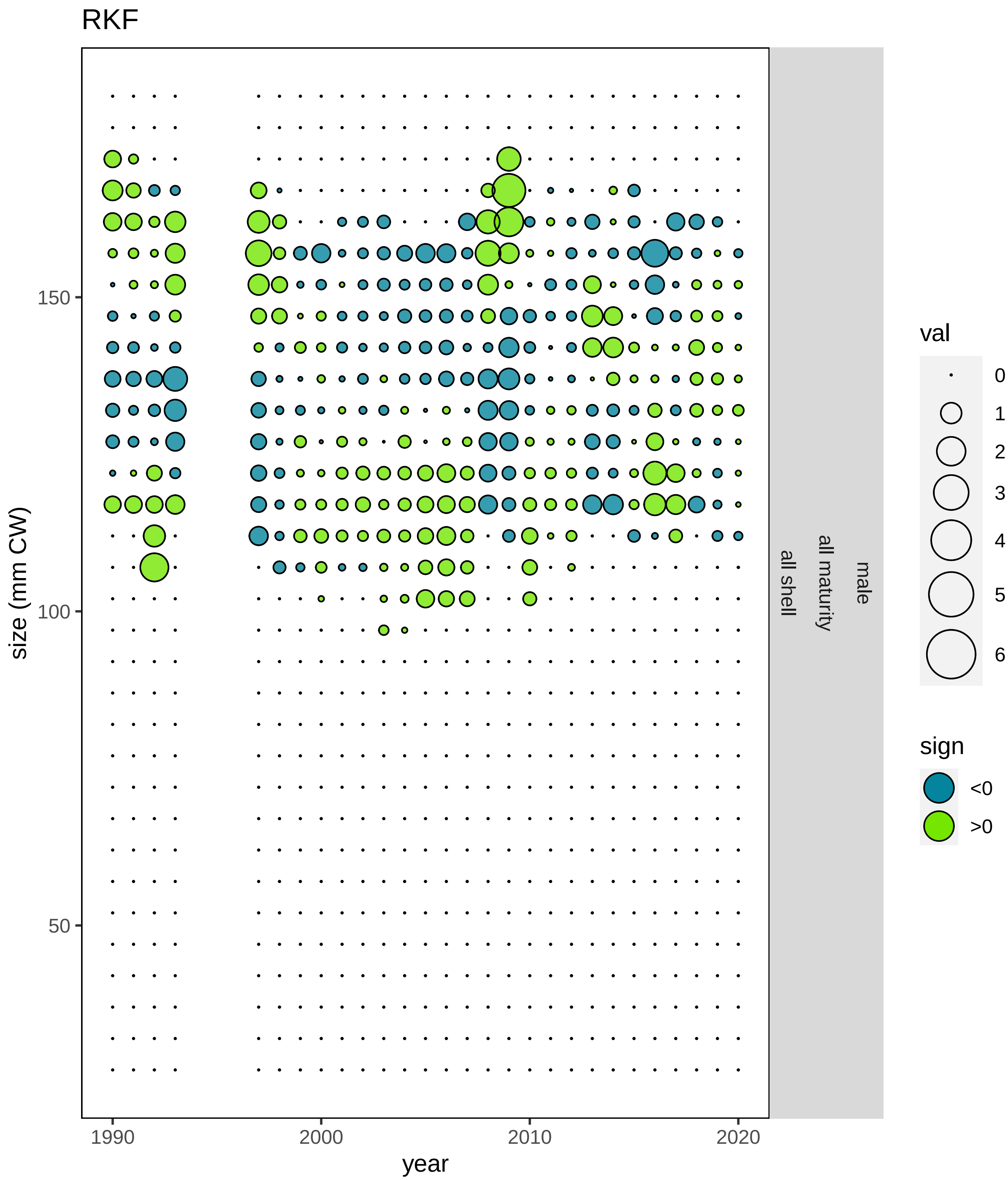

Figure 253. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

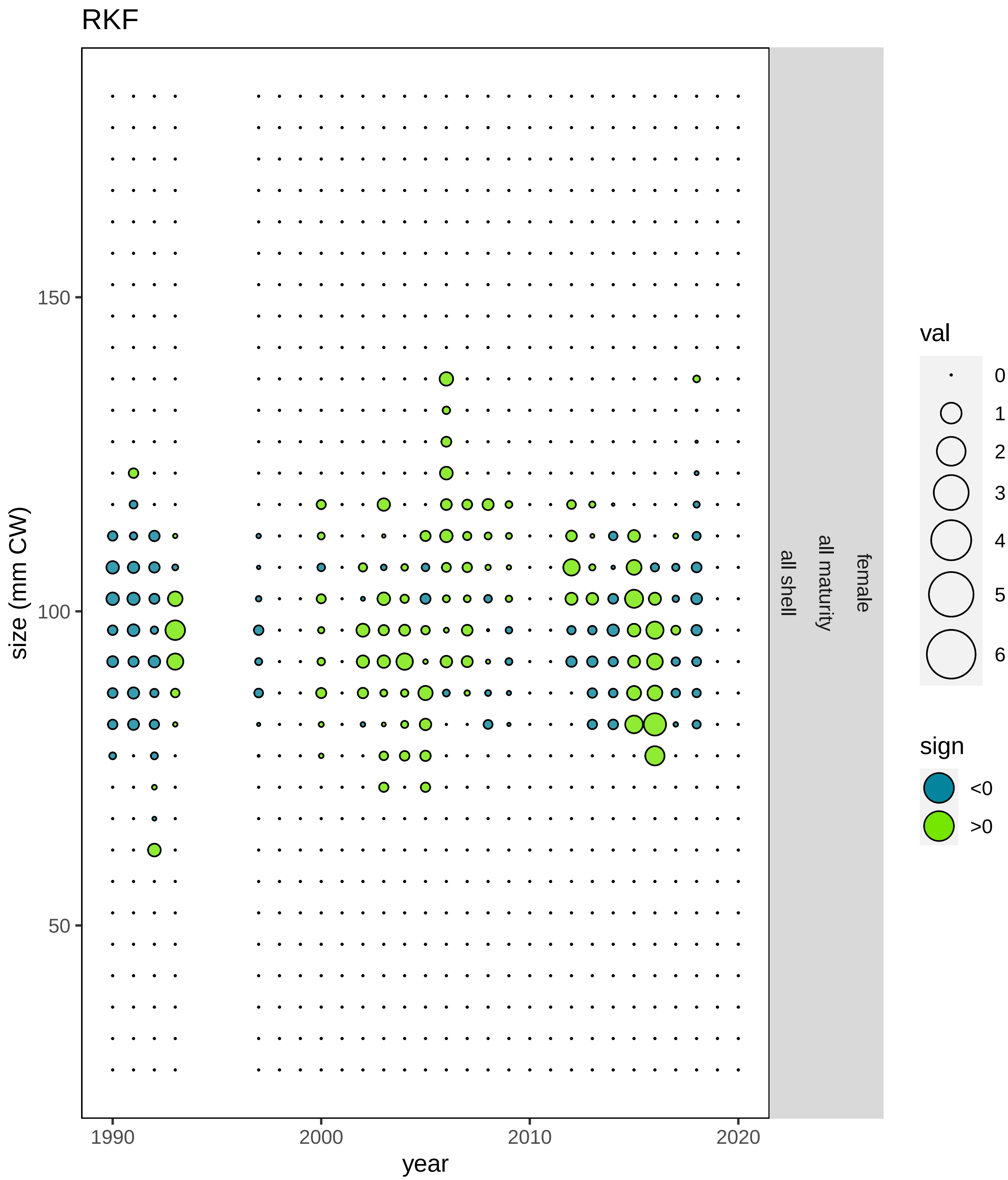

Figure 254. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

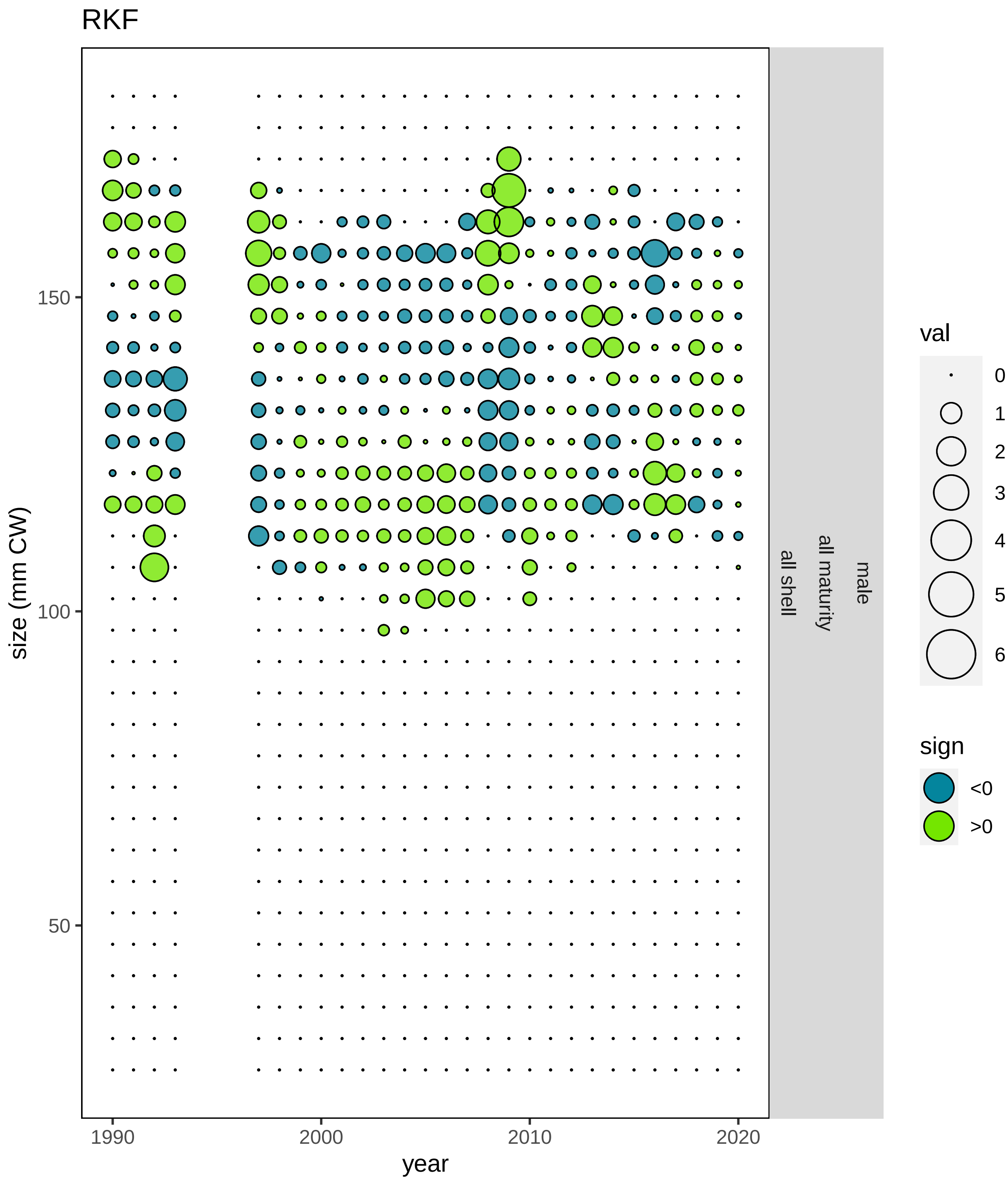

Figure 255. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

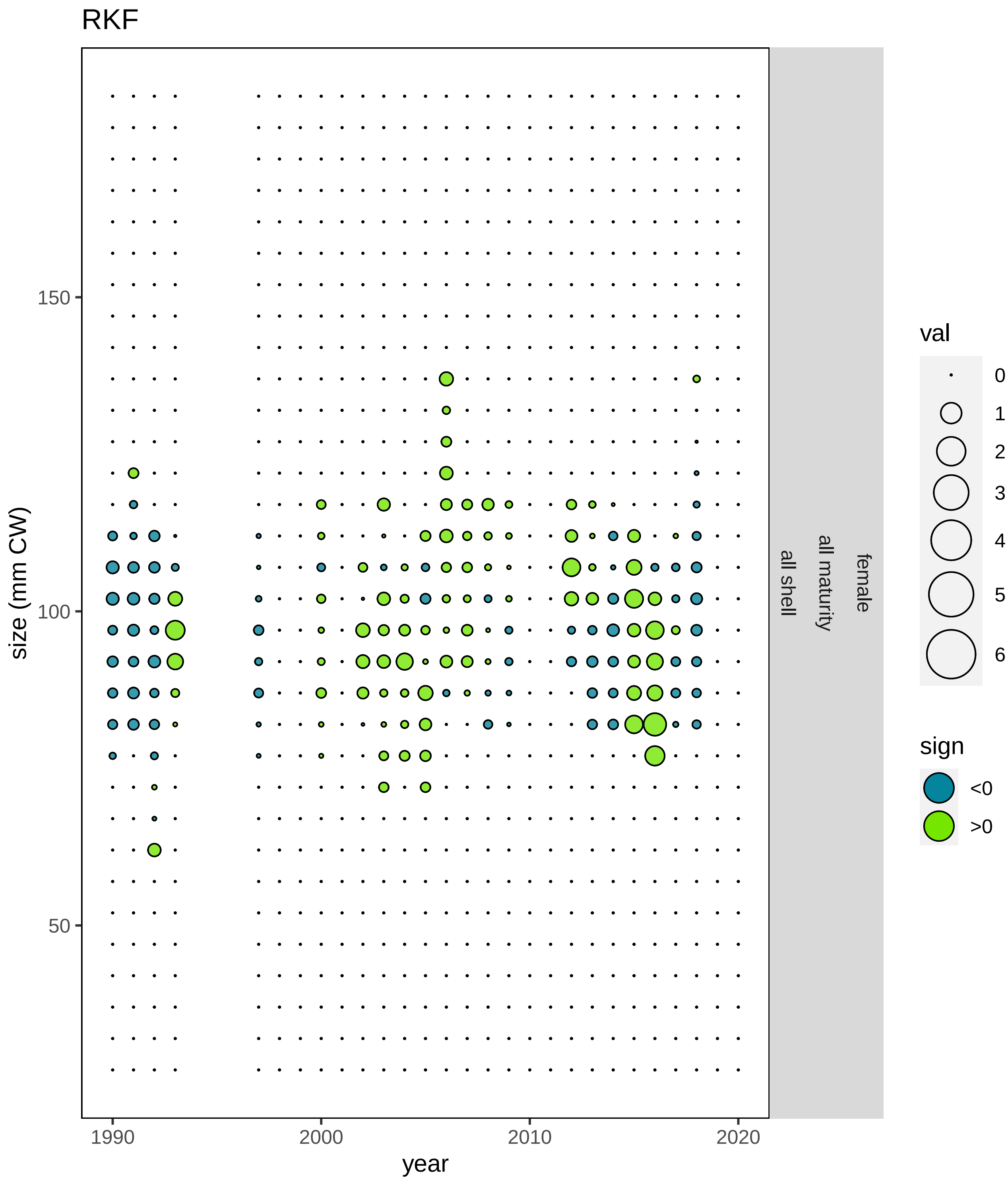

Figure 256. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

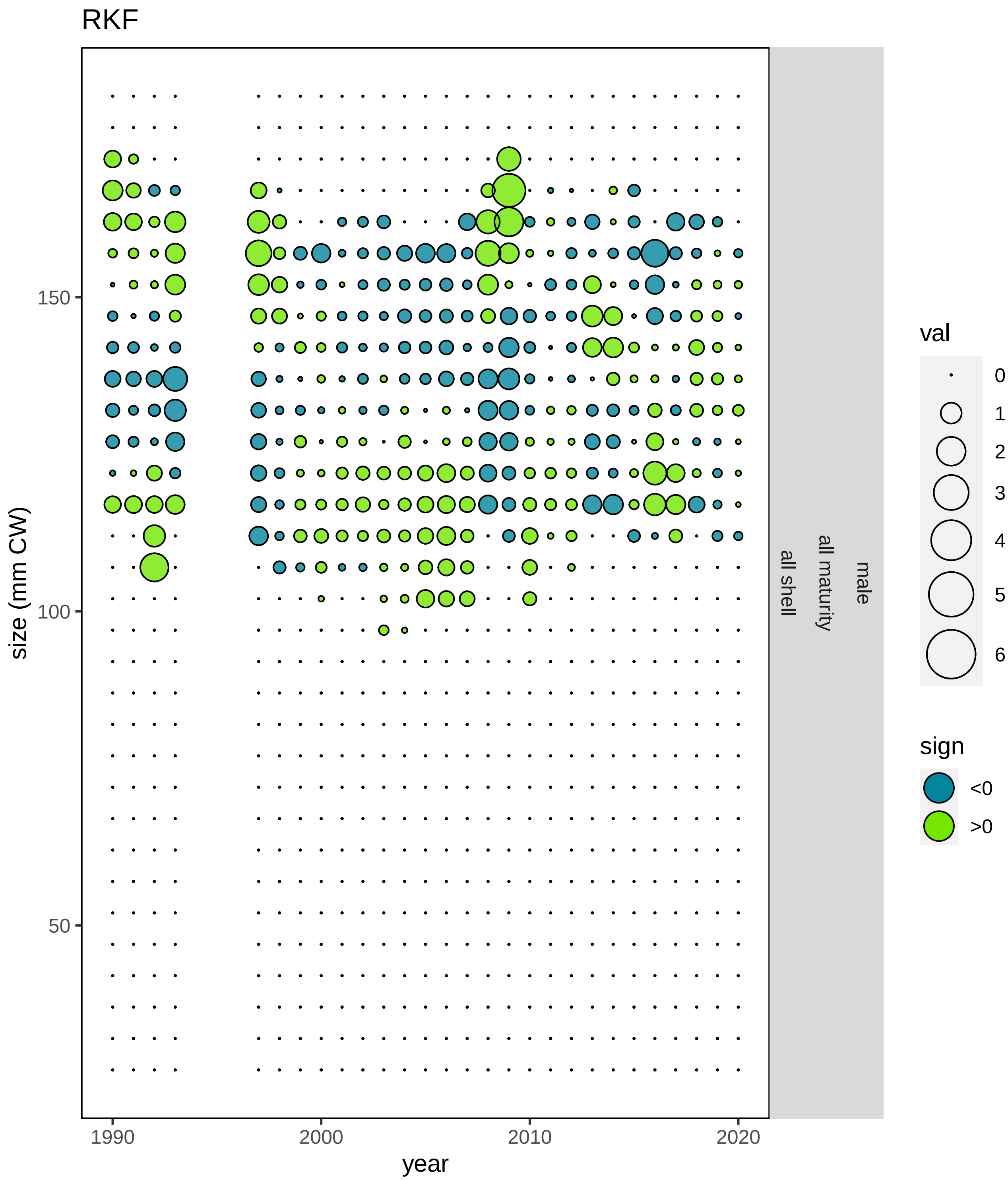

Figure 257. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

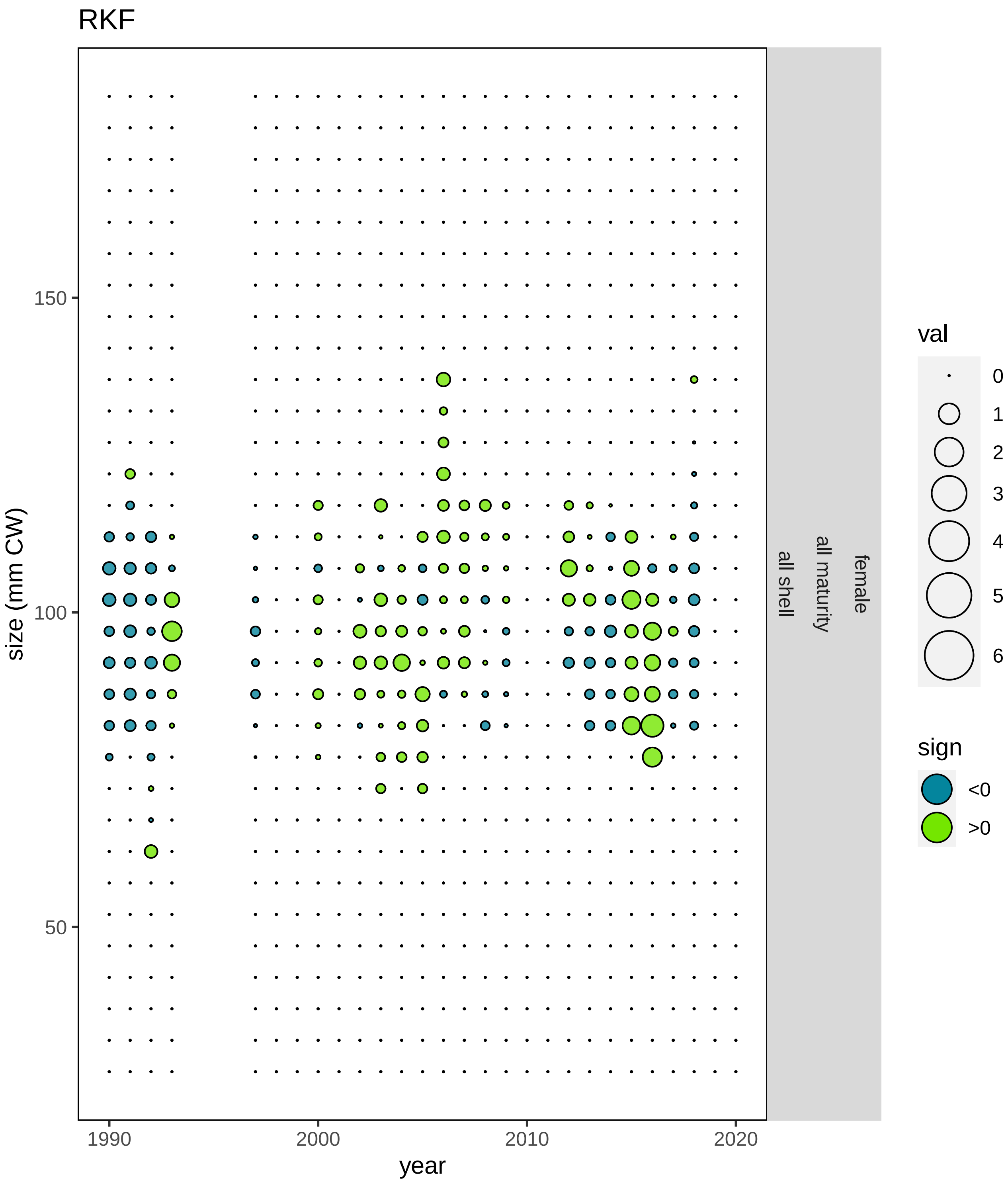

Figure 258. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

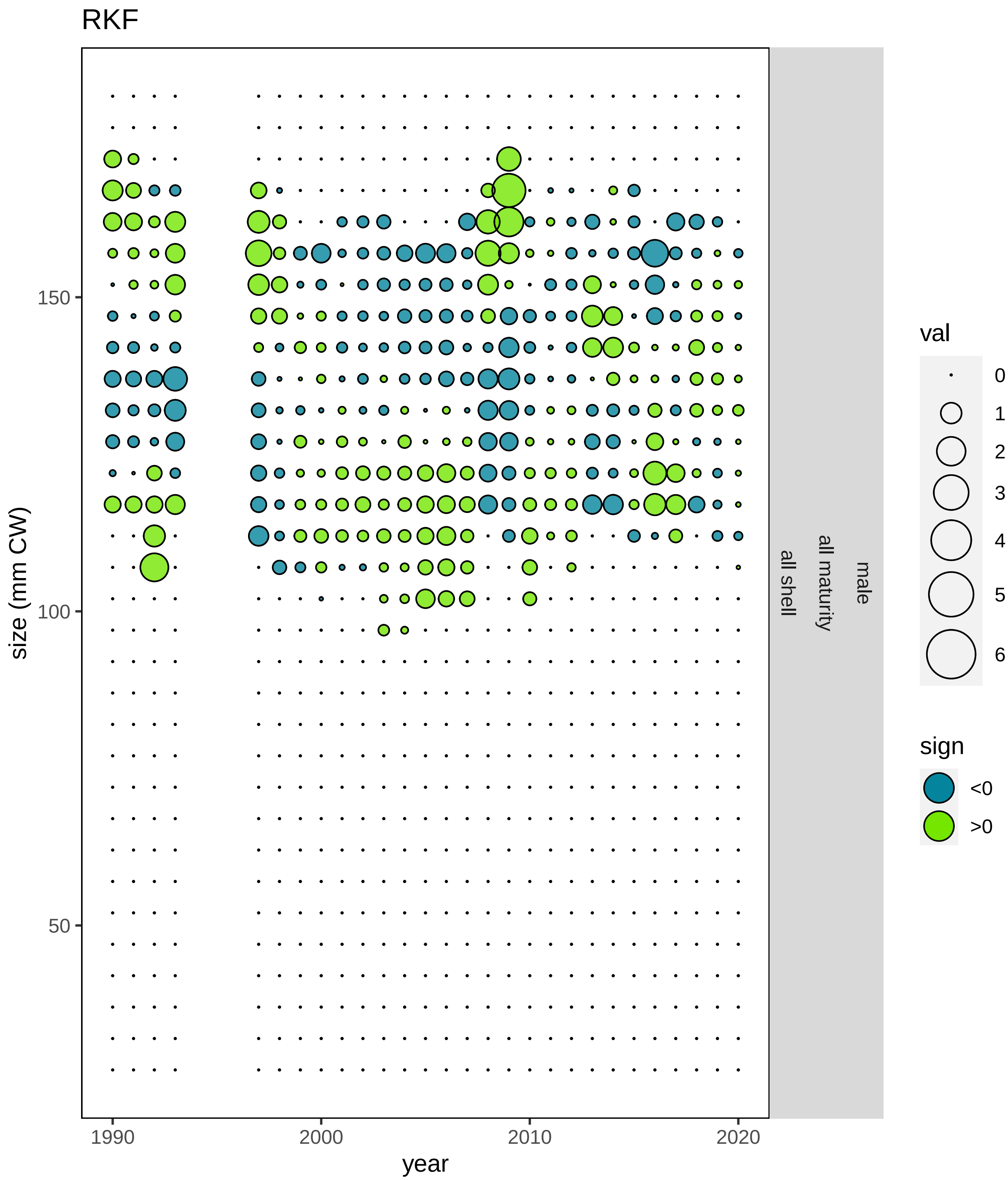

Figure 259. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

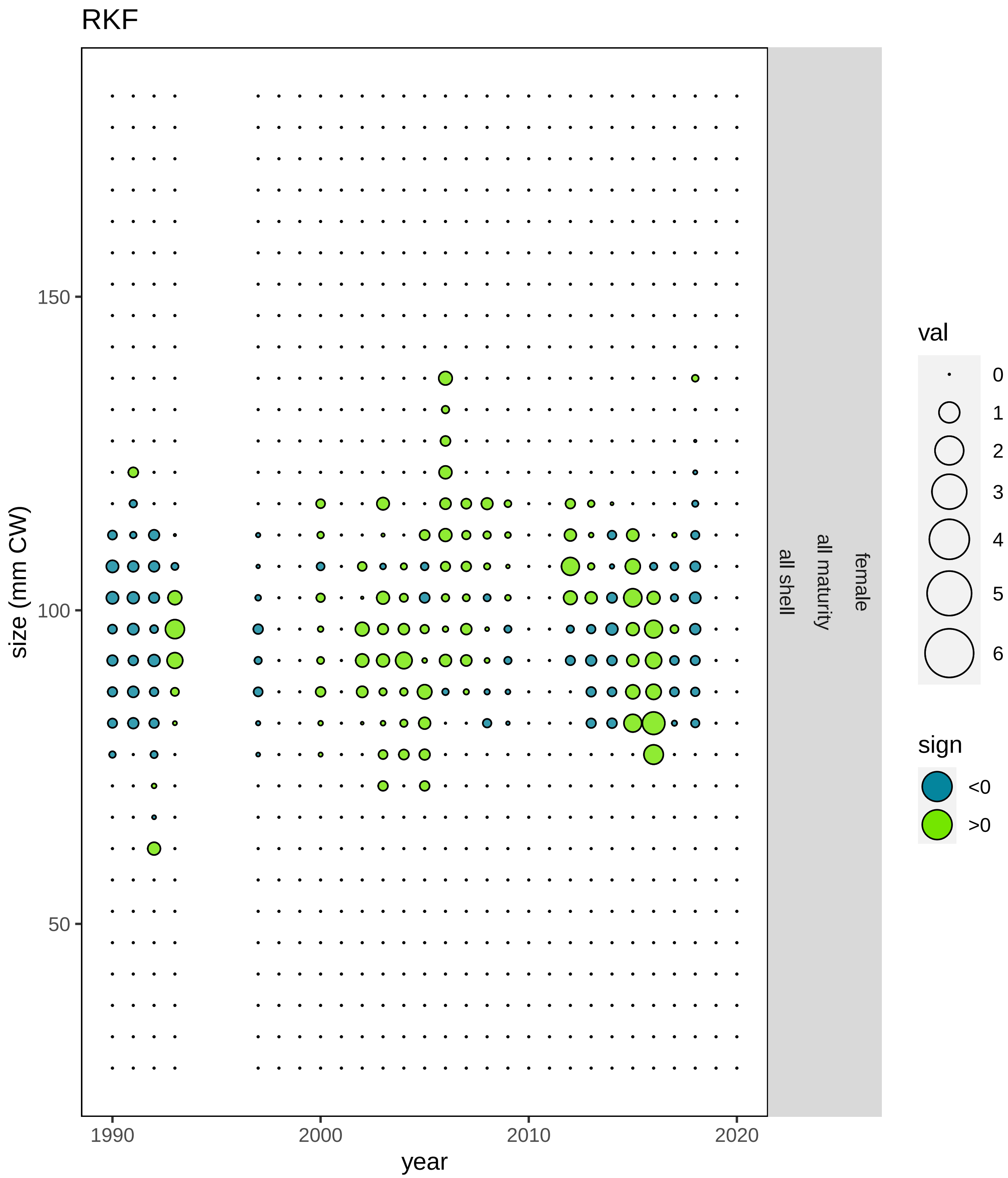

Figure 260. Pearson's residuals for fits to fishery total catch size composition data from the RKF in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

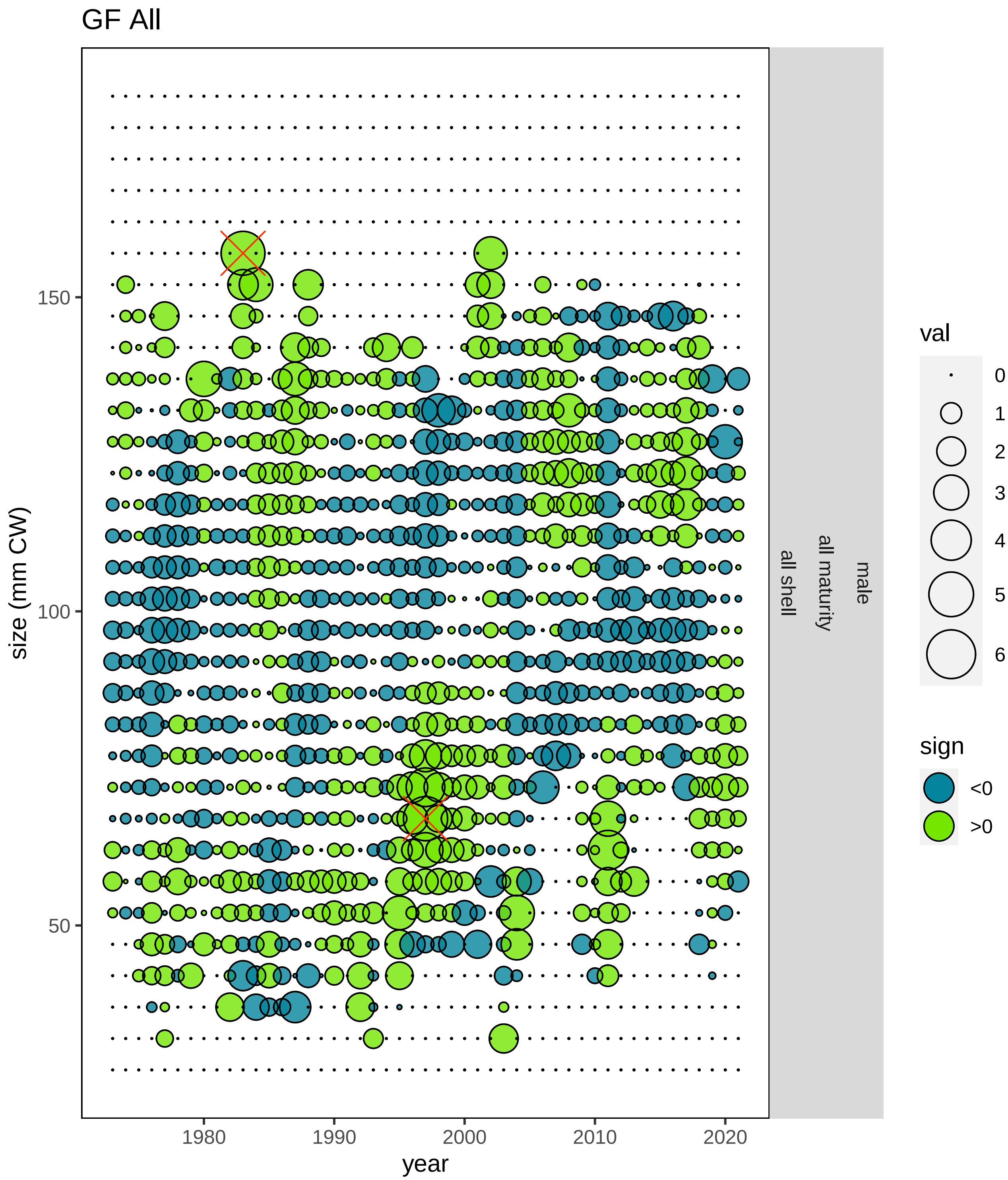

Figure 261. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

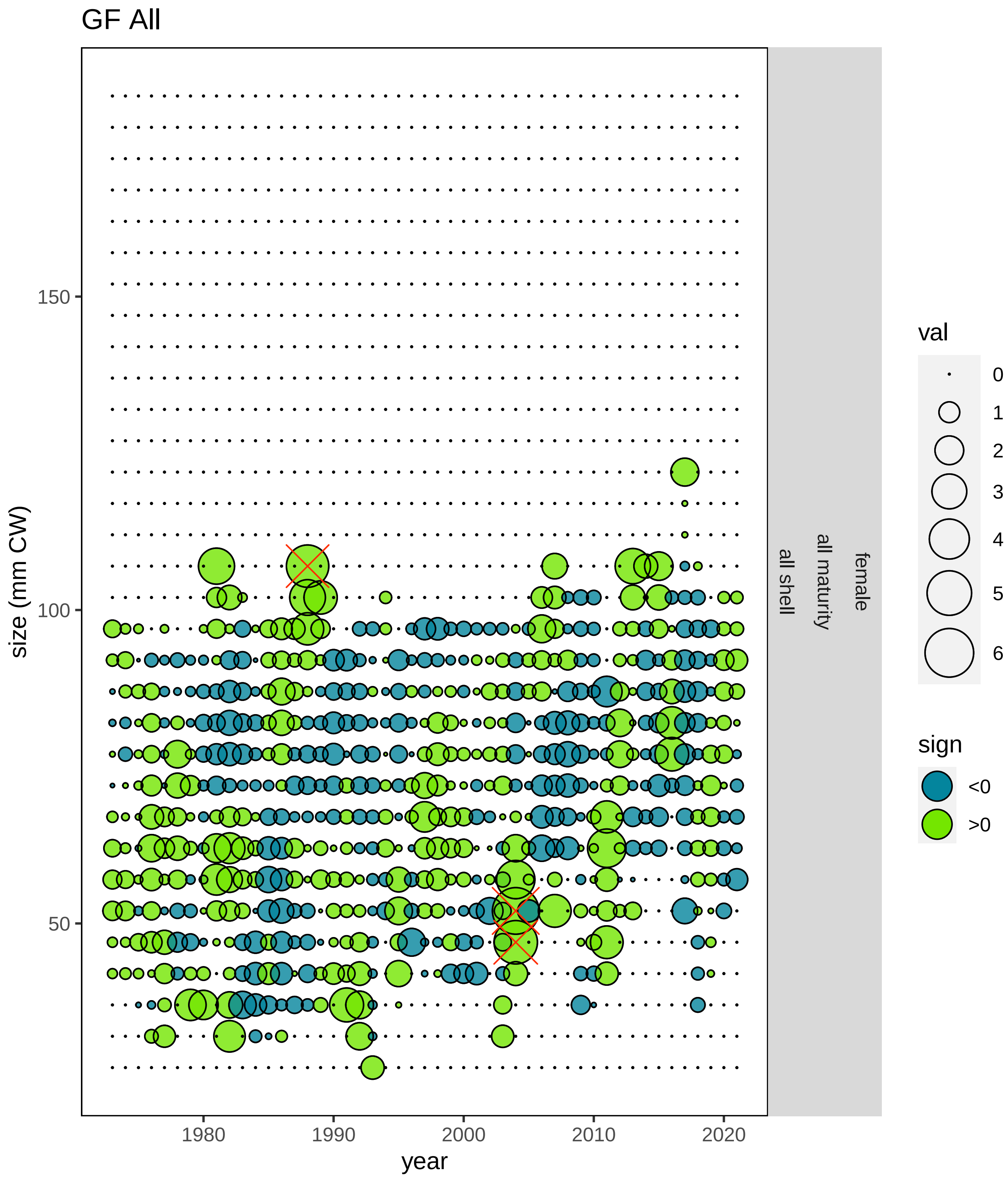

Figure 262. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 22.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

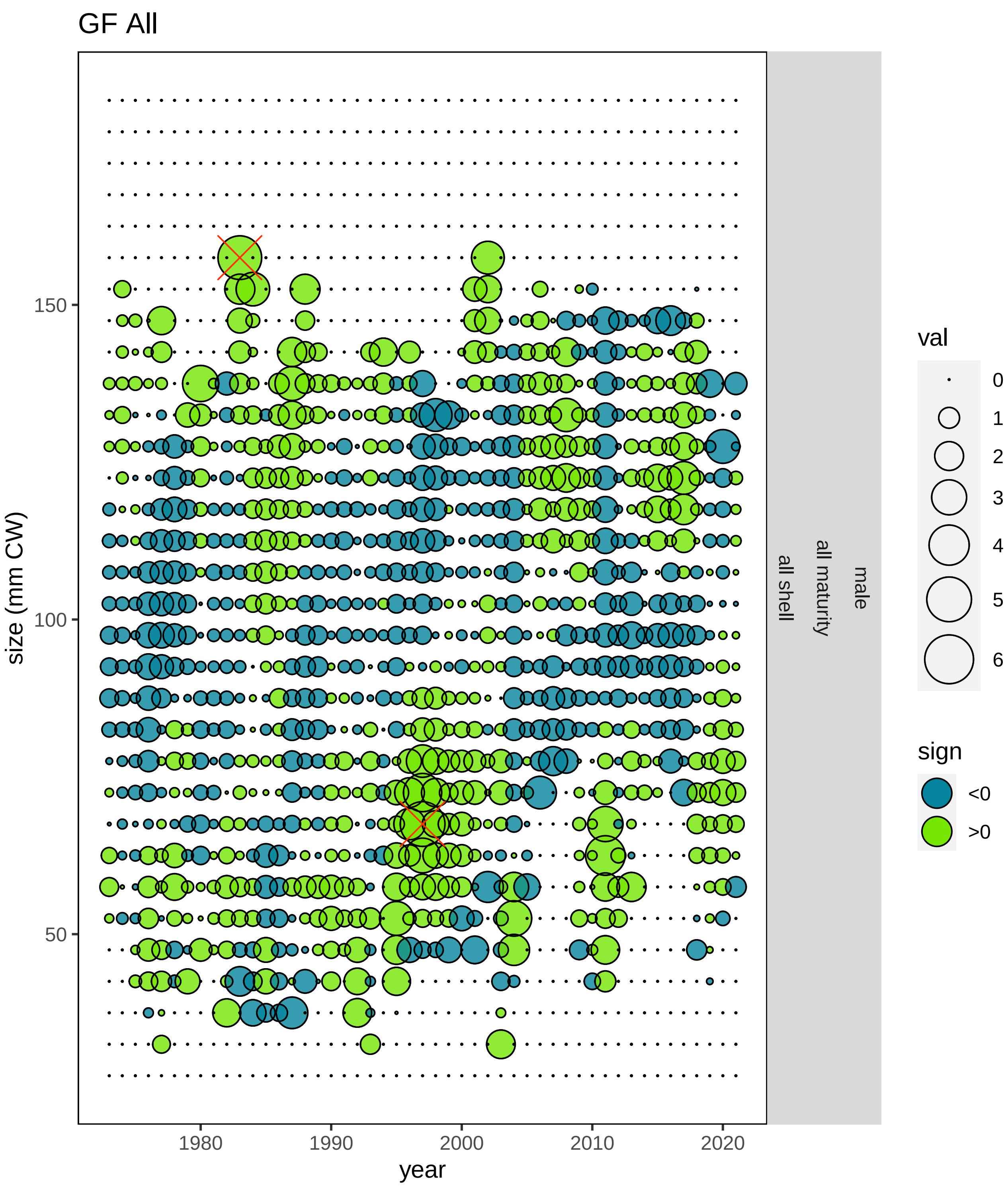

Figure 263. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

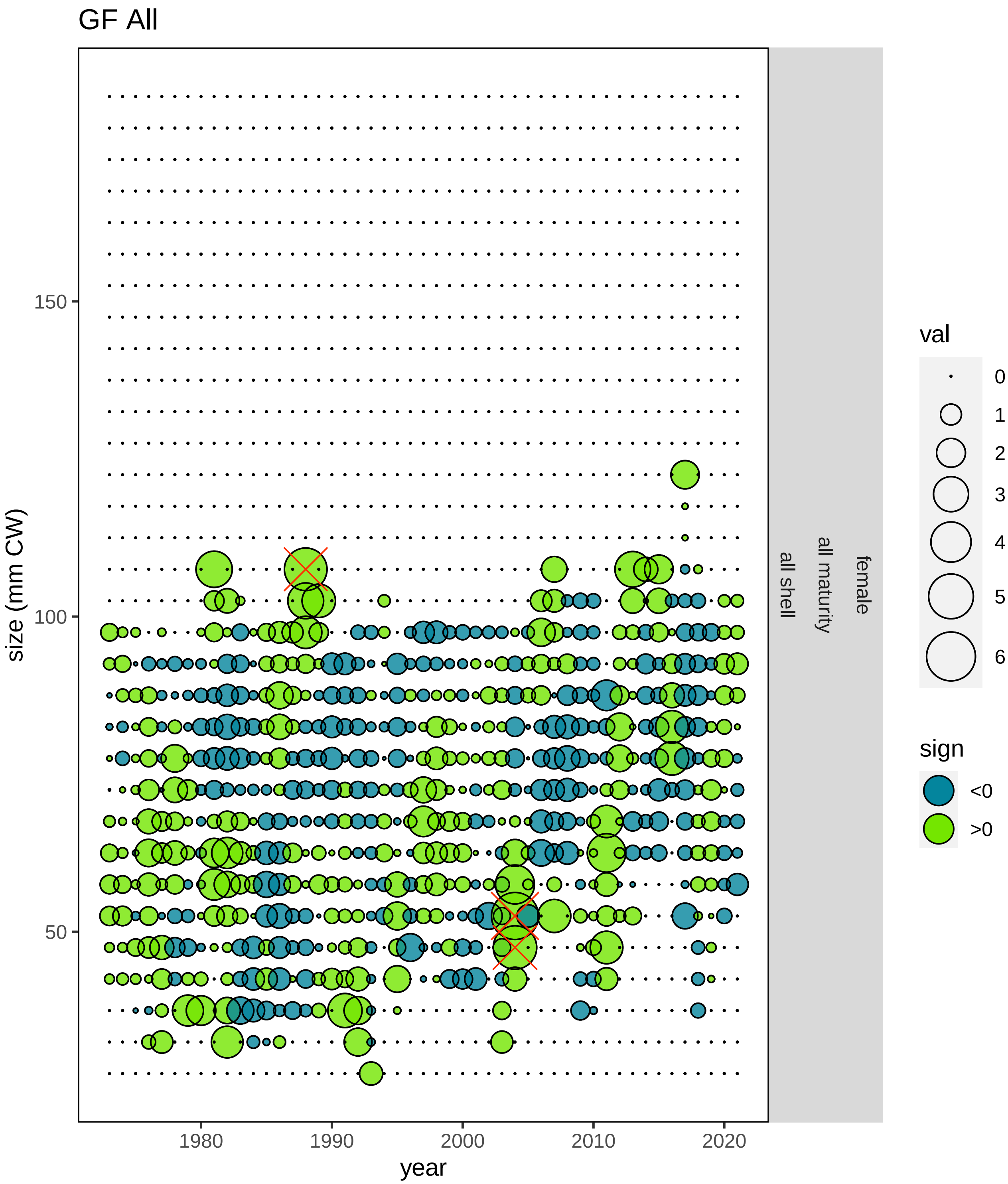

Figure 264. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.01. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

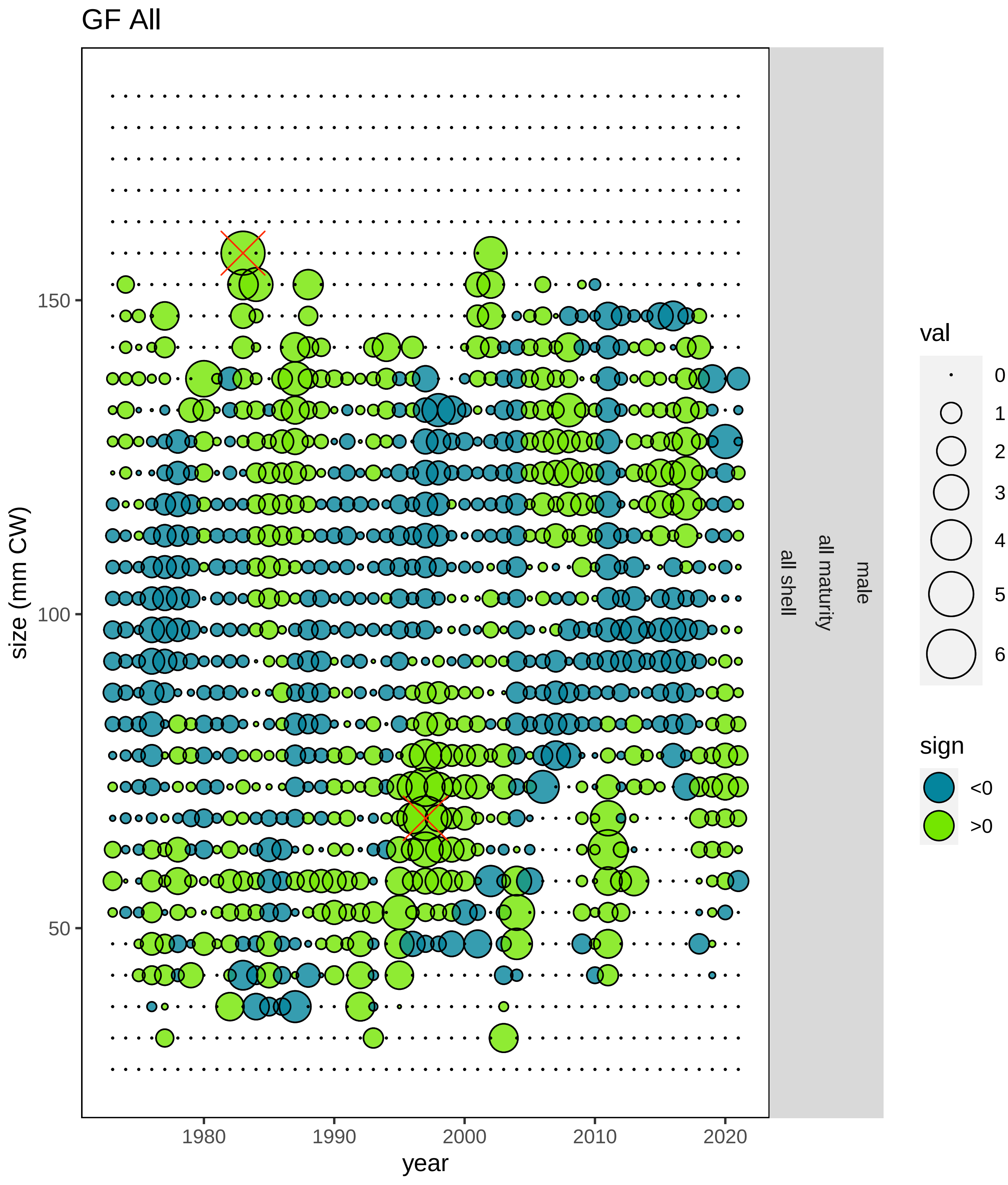

Figure 265. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

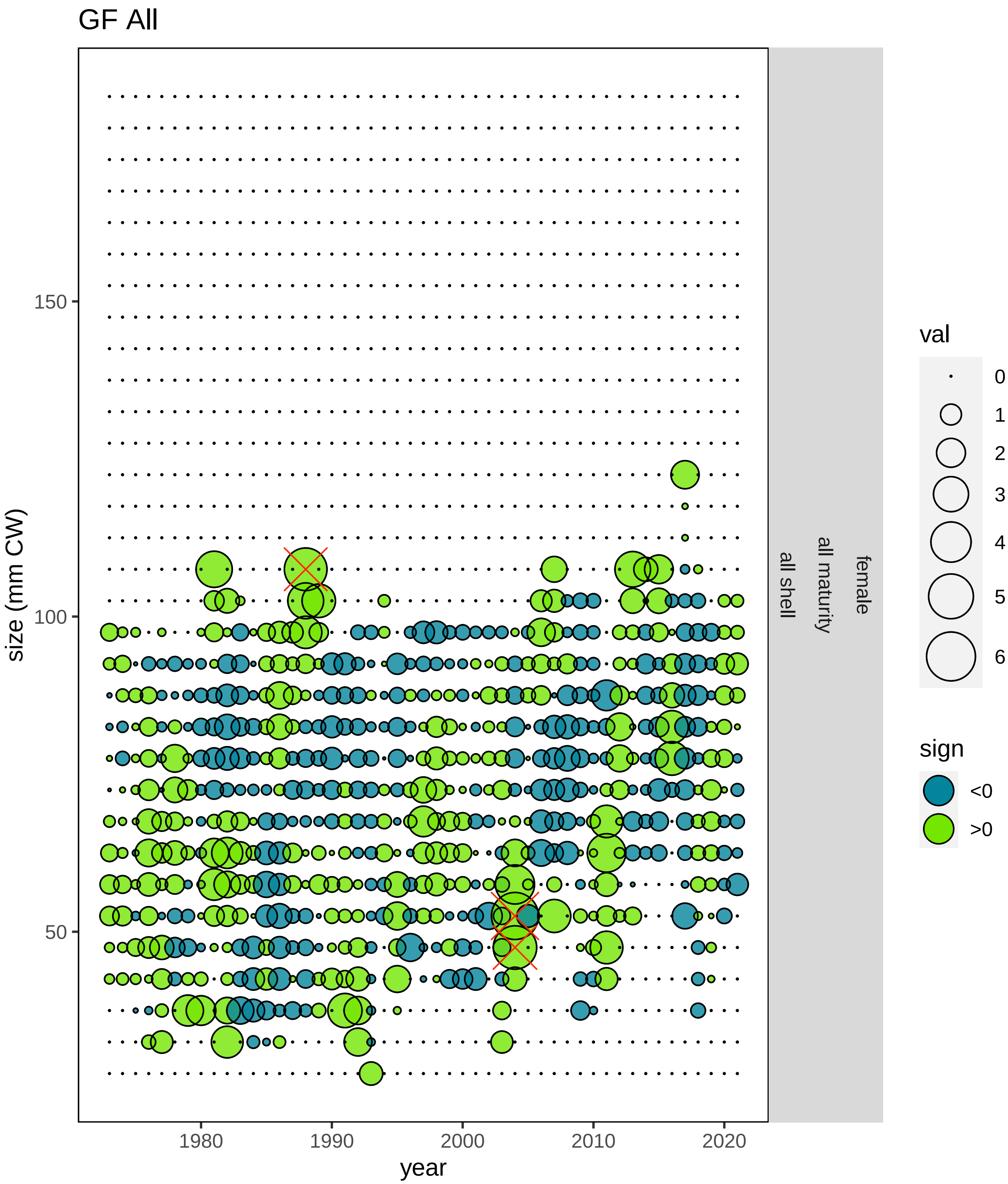

Figure 266. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.01a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

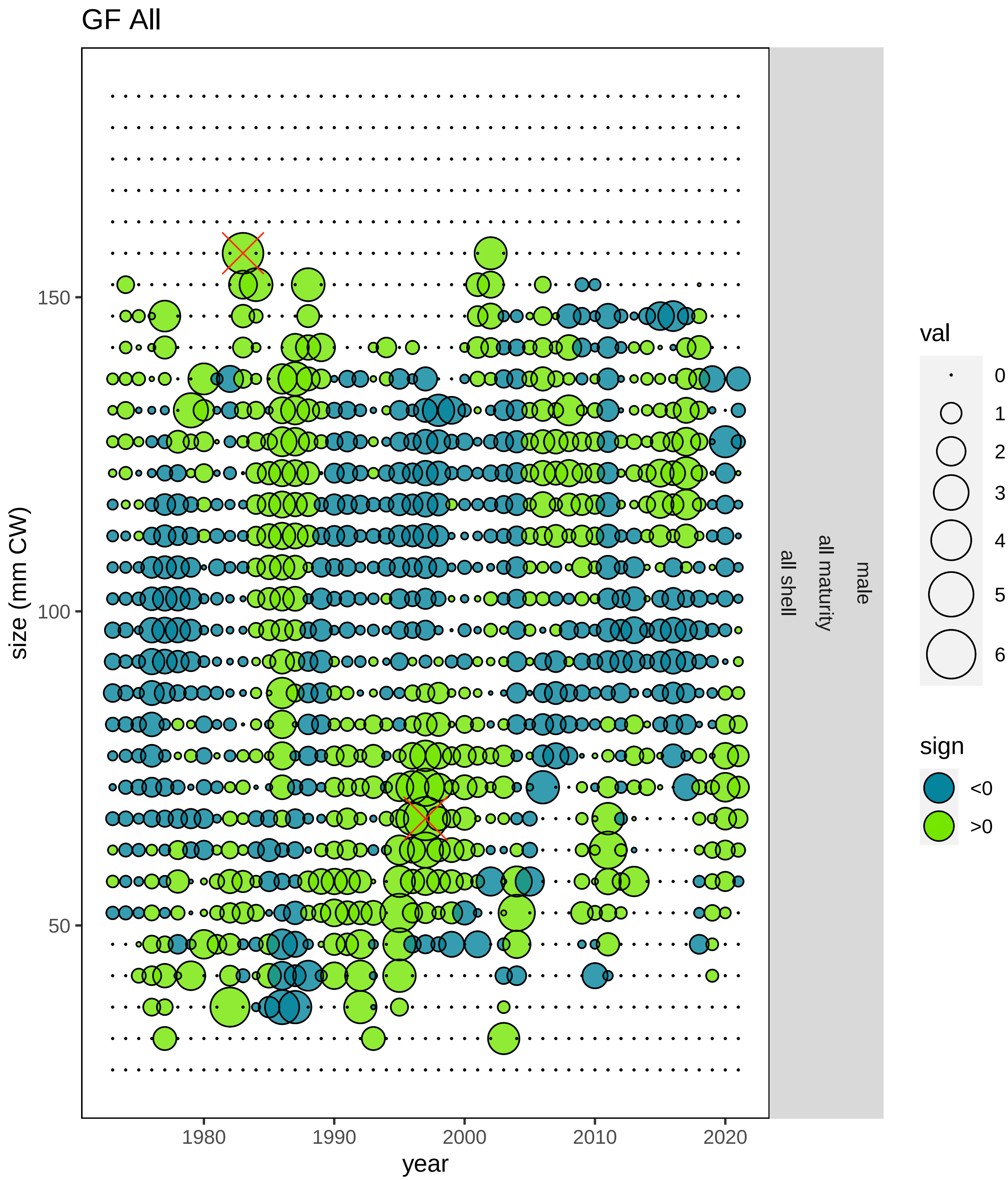

Figure 267. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

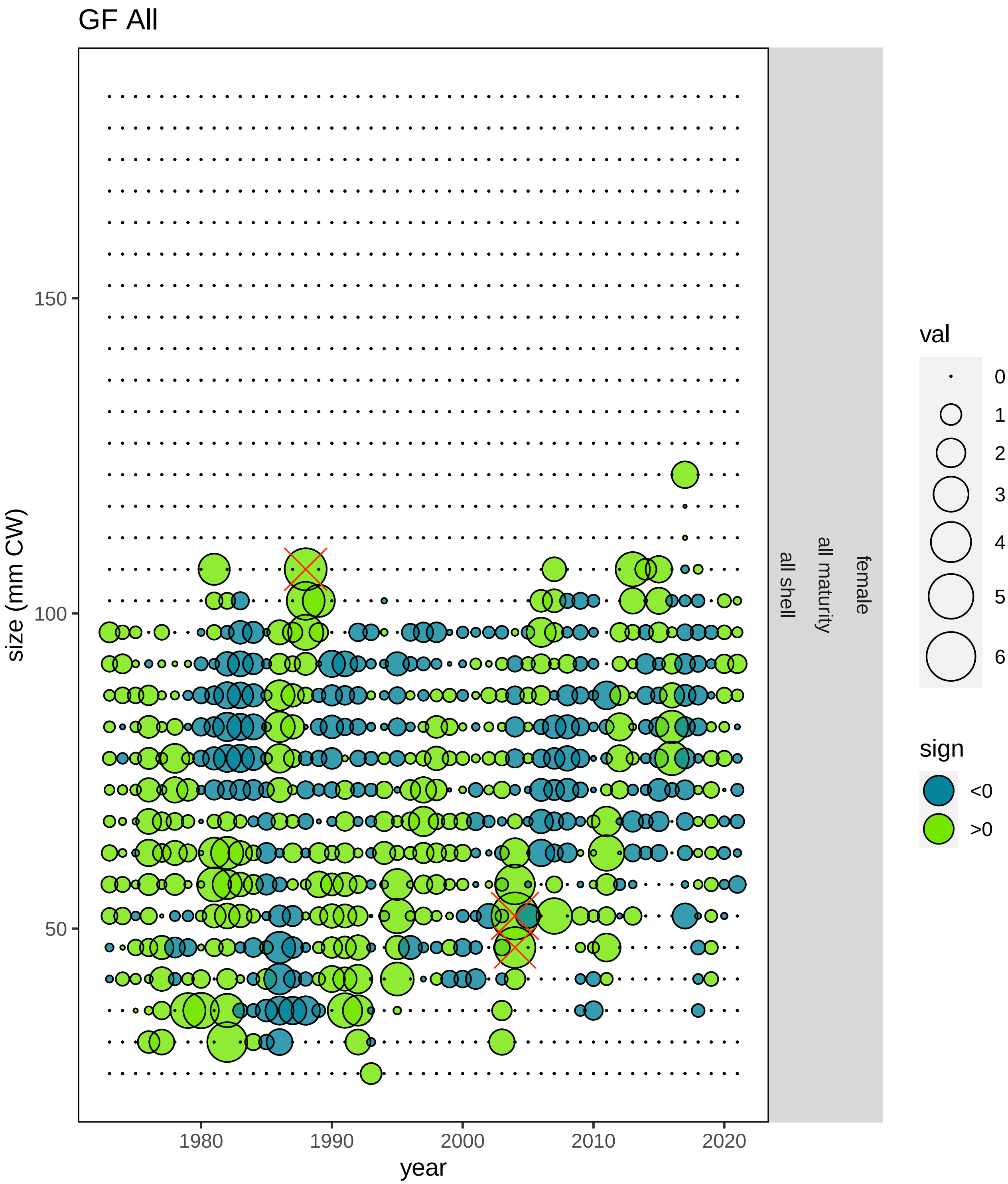

Figure 268. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.02. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

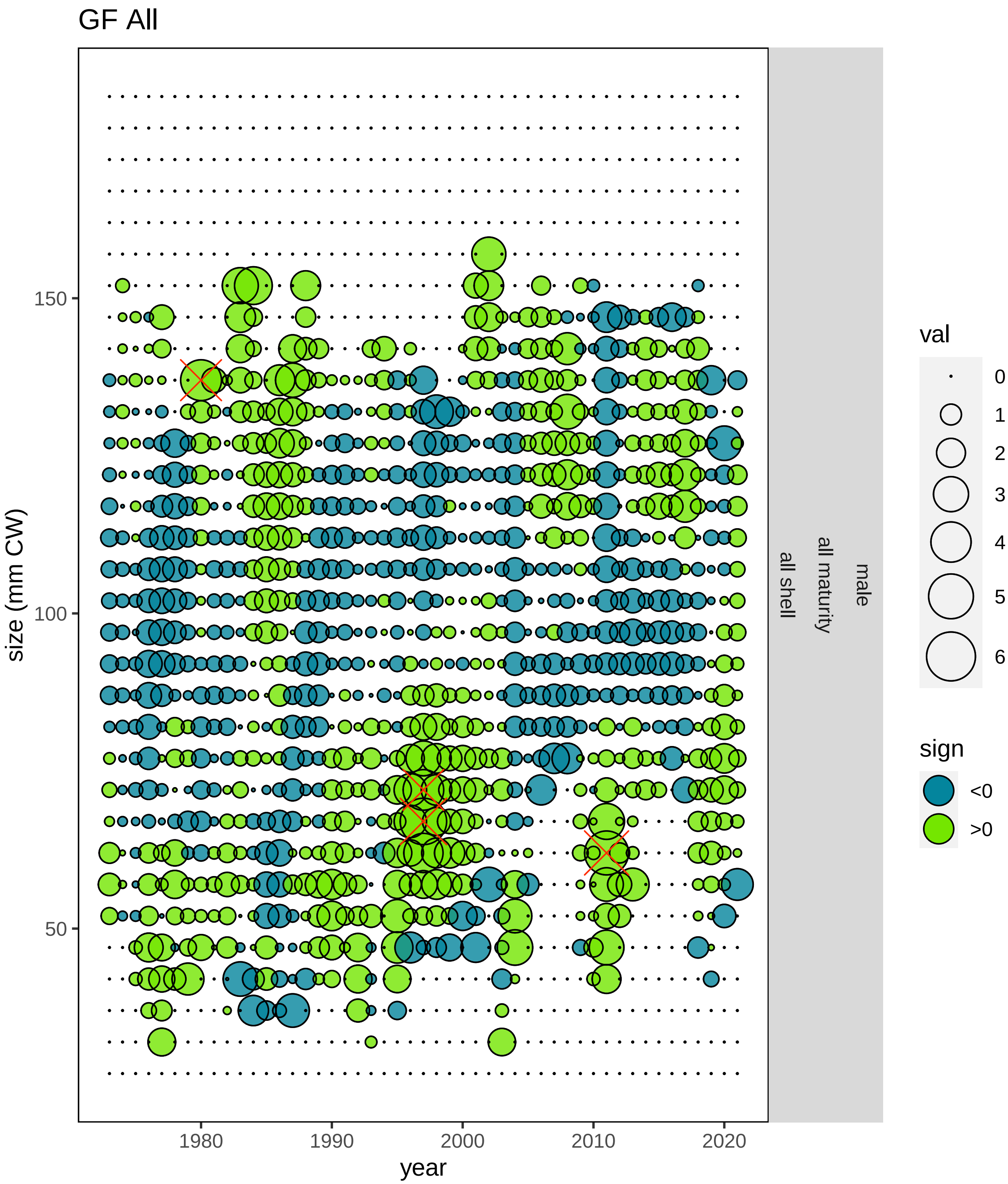

Figure 269. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

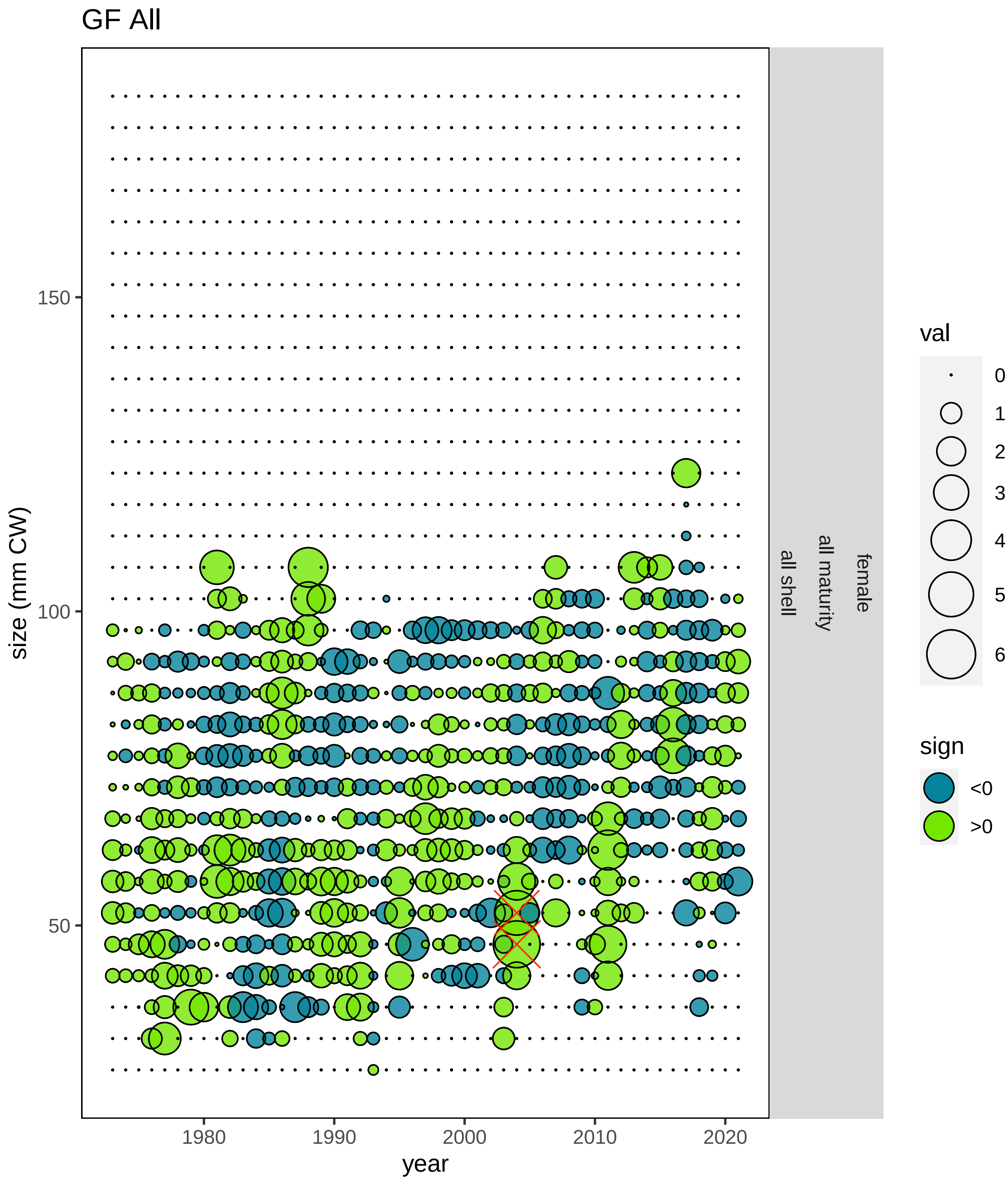

Figure 270. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

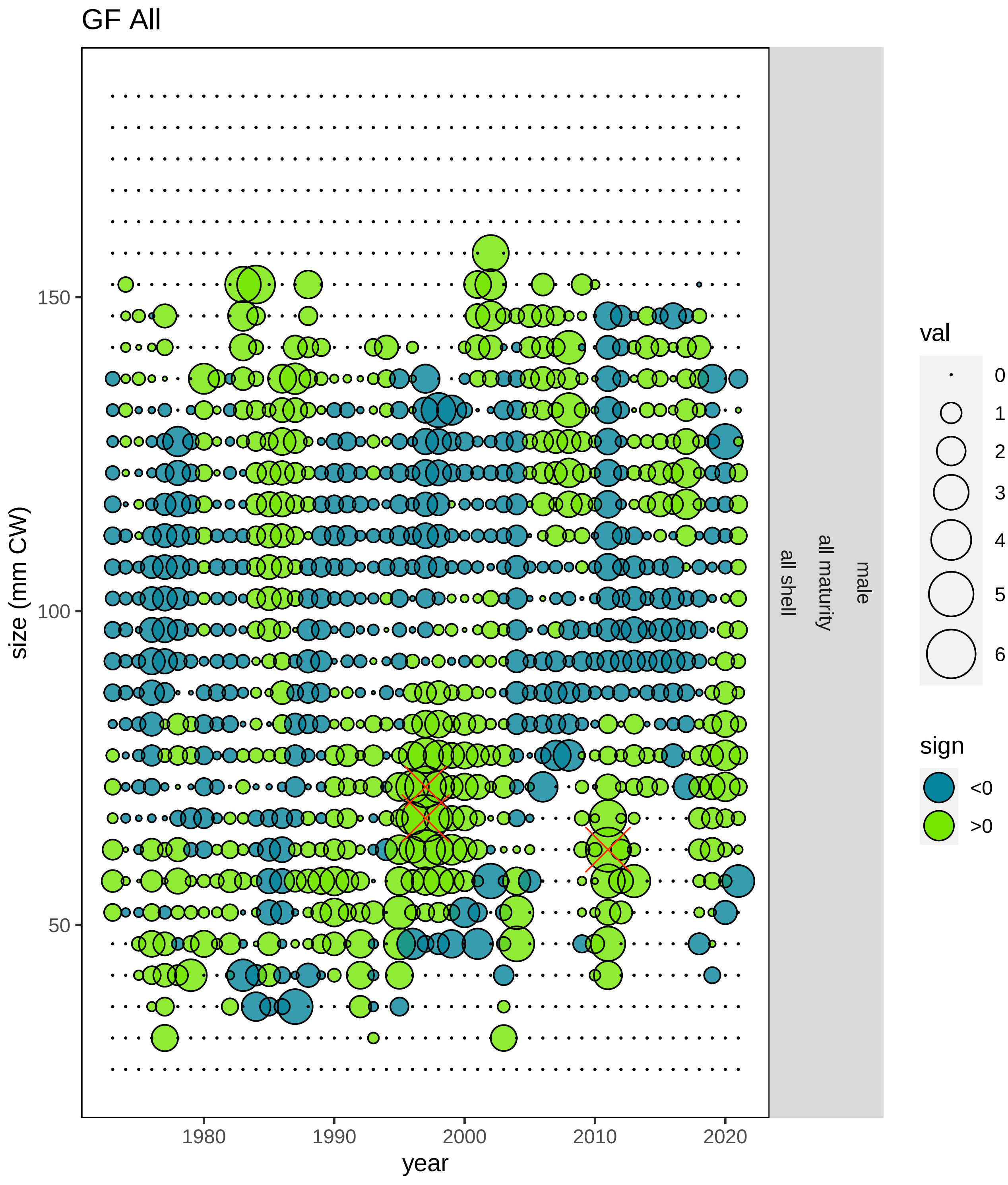

Figure 271. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

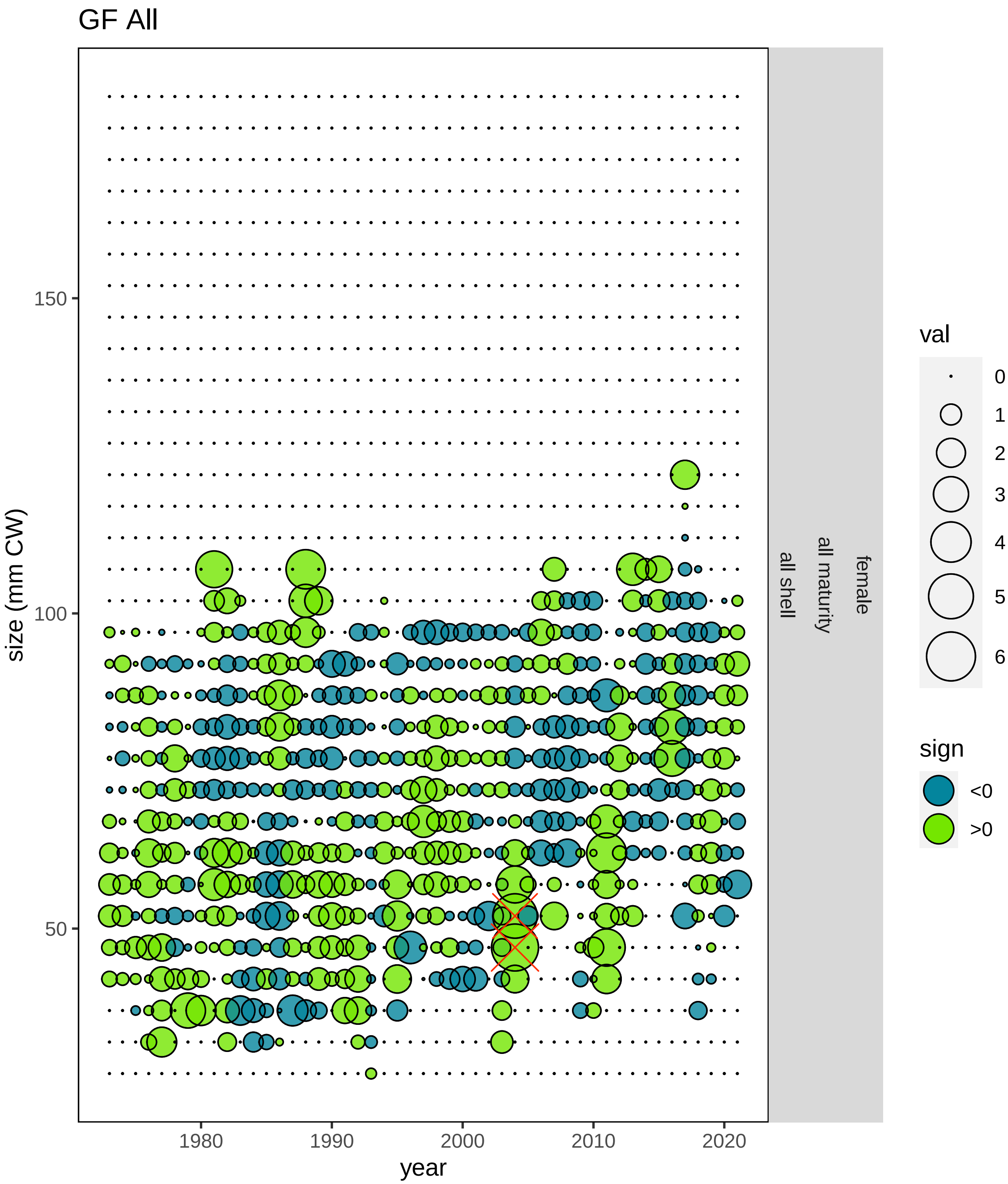

Figure 272. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

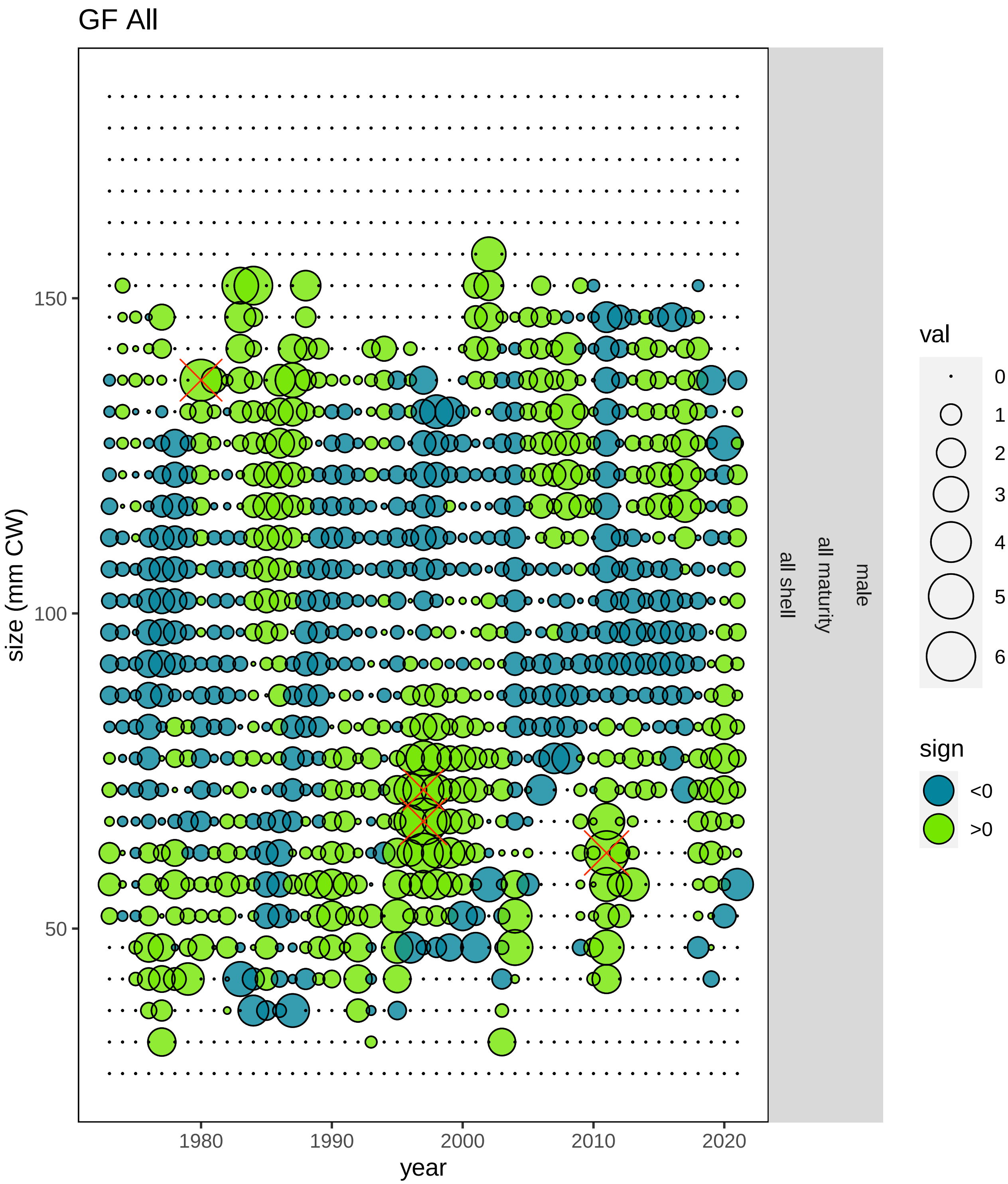

Figure 273. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

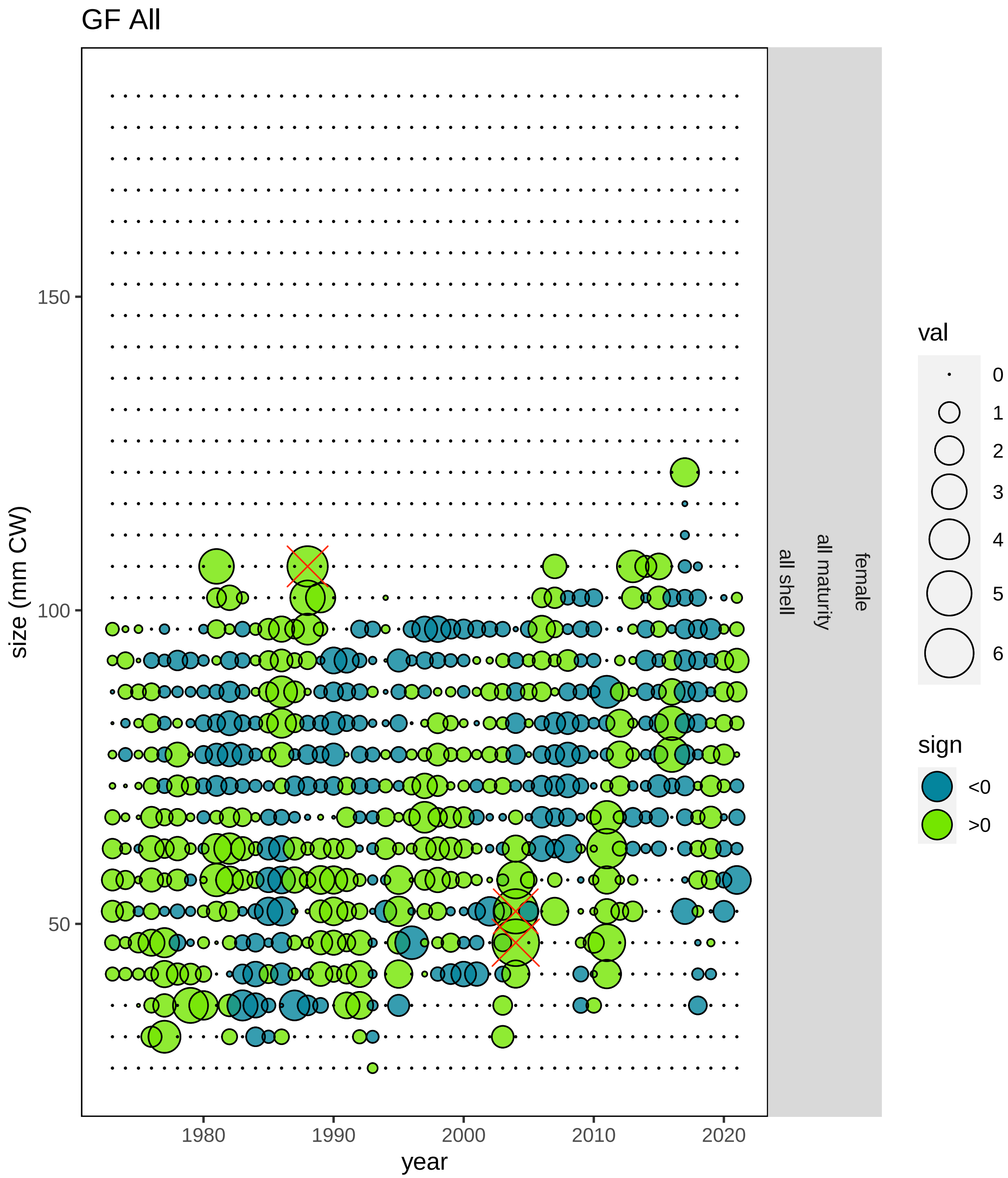

Figure 274. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

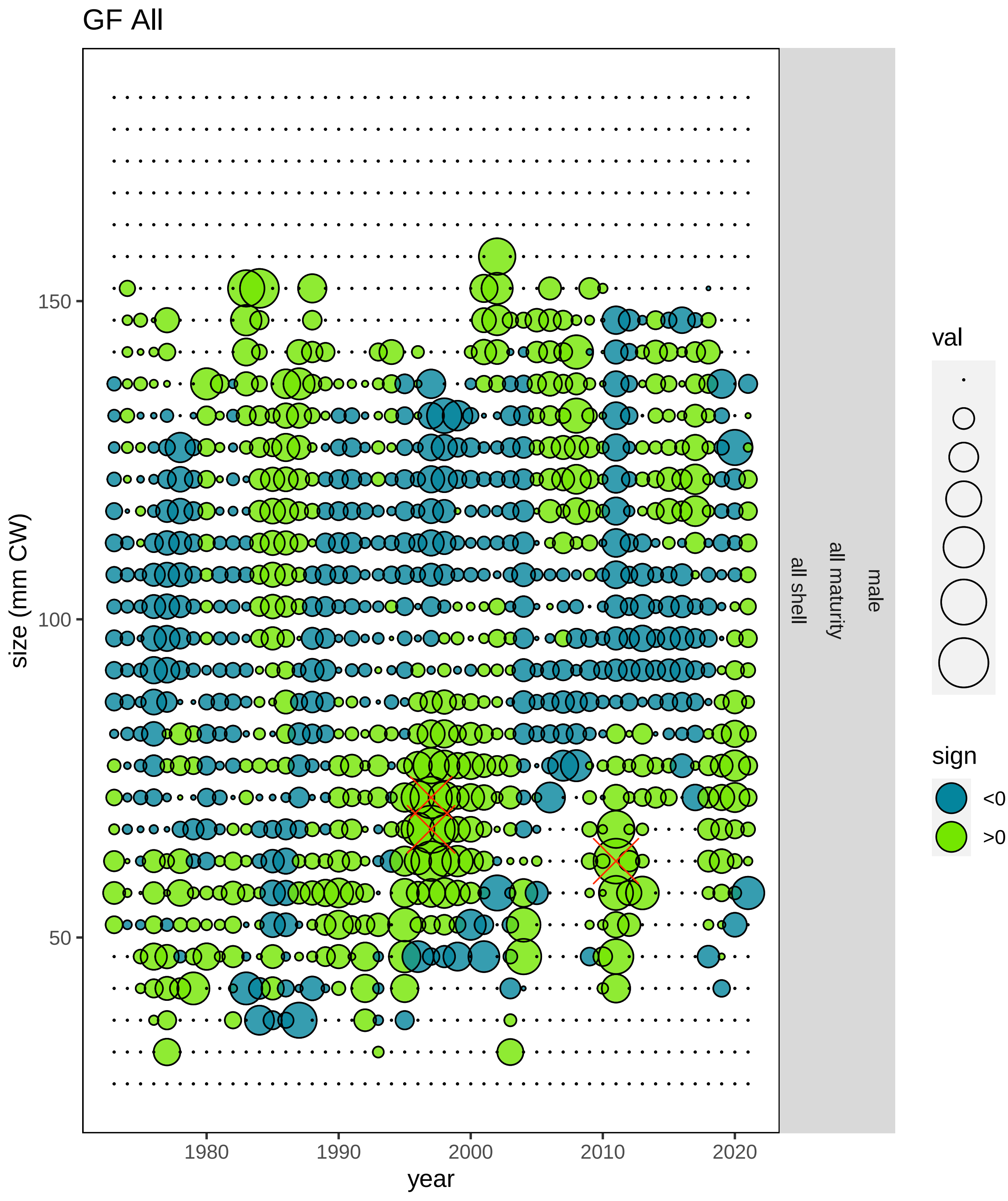

Figure 275. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

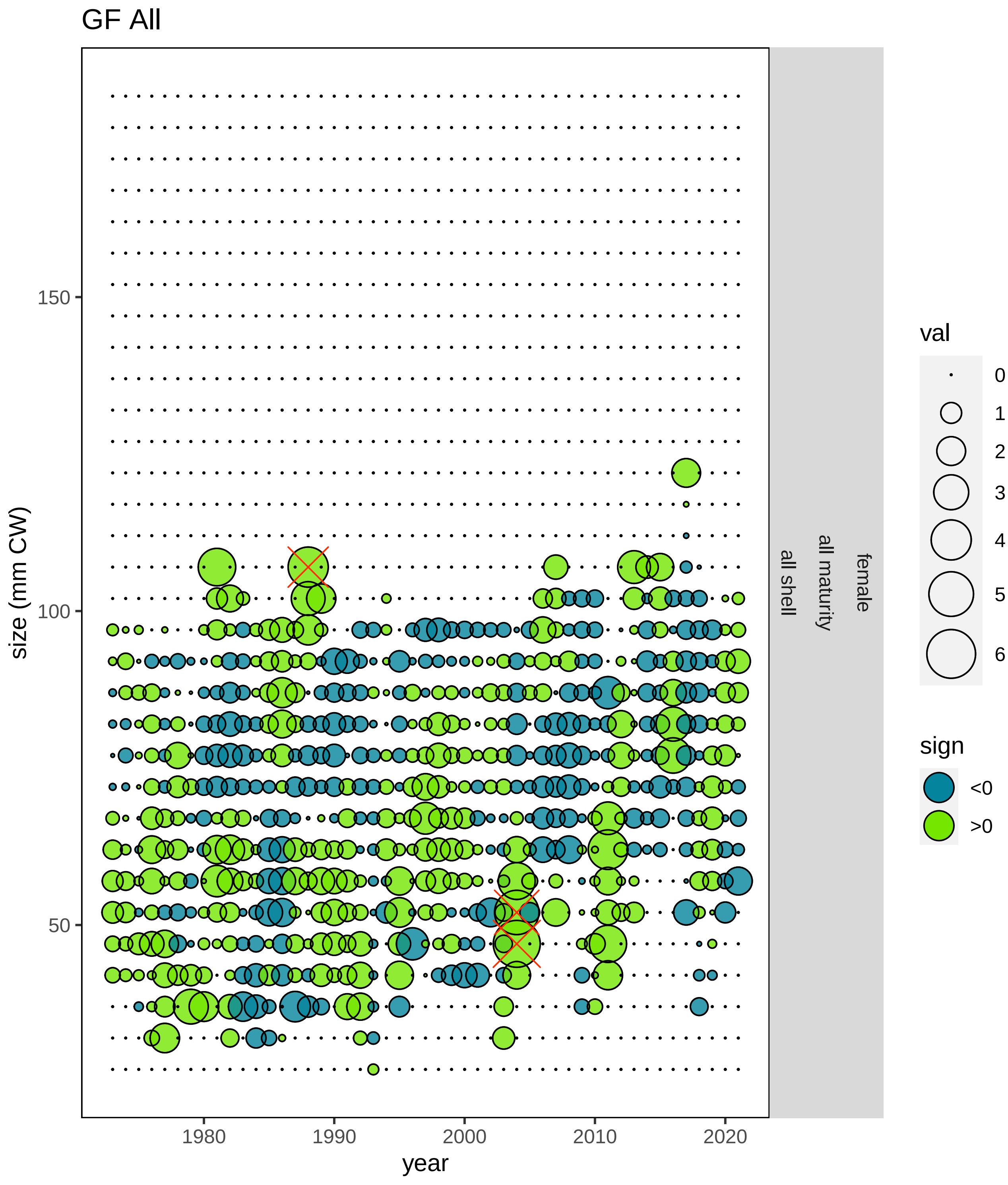

Figure 276. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.03b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

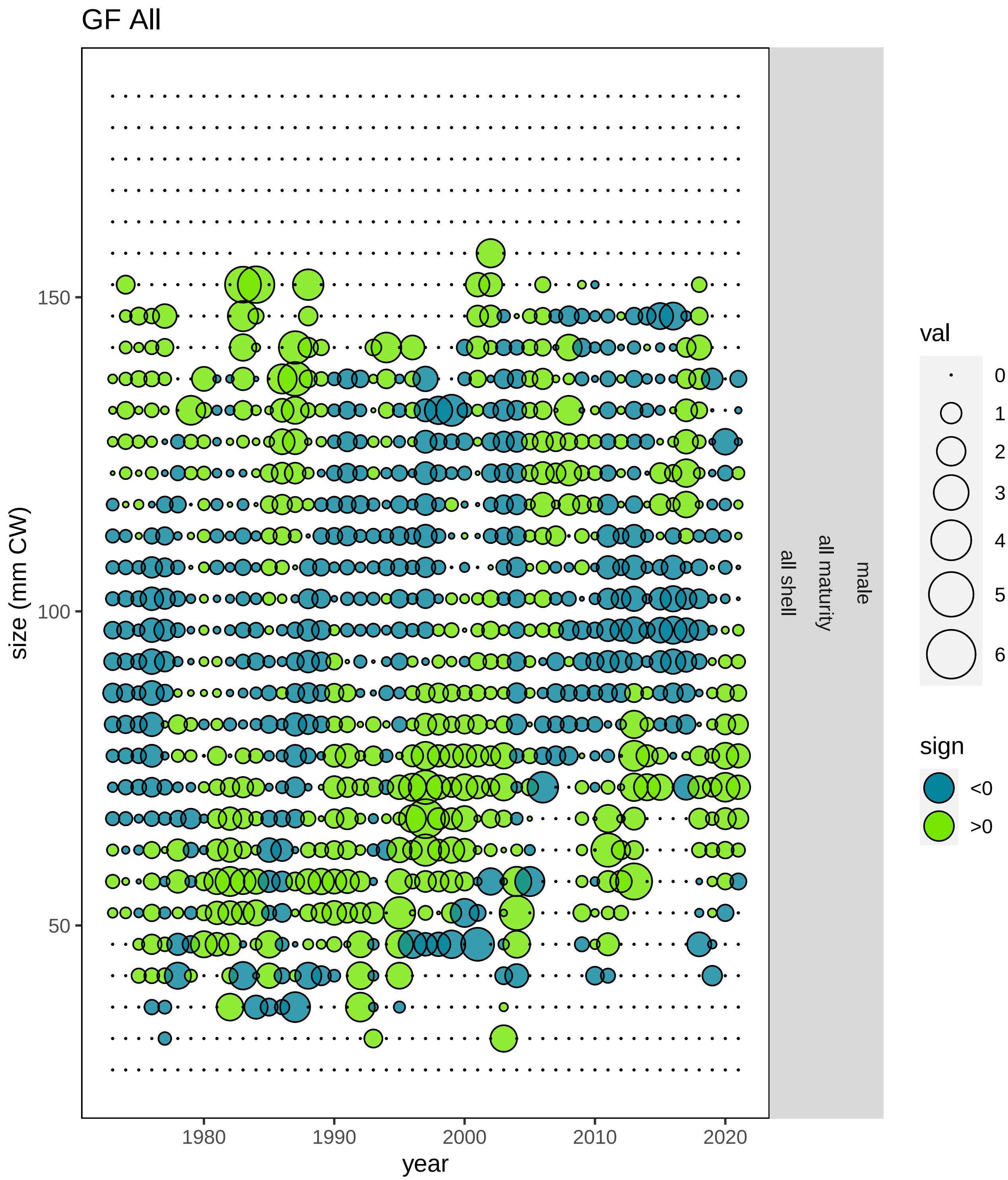

Figure 277. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

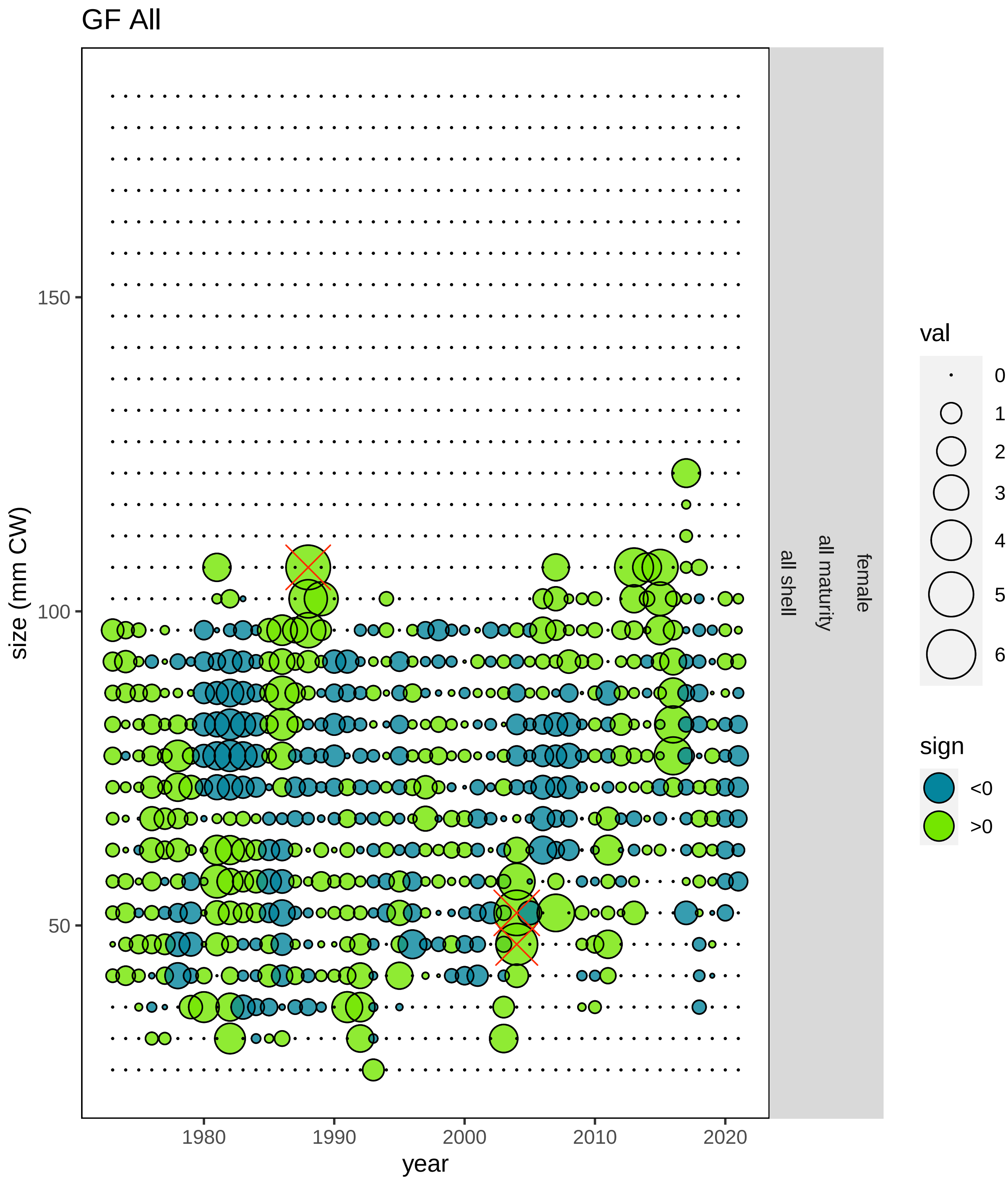

Figure 278. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

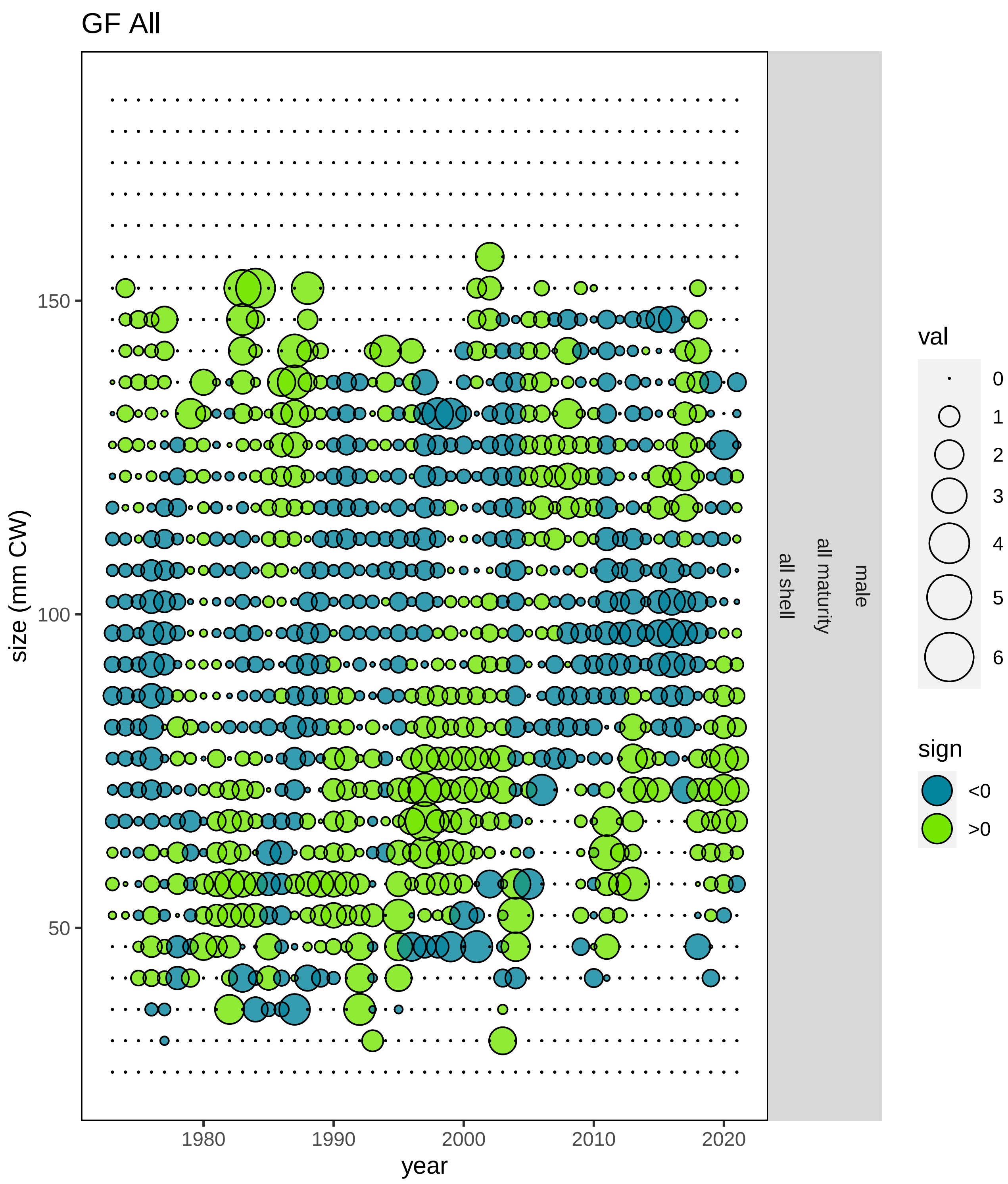

Figure 279. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

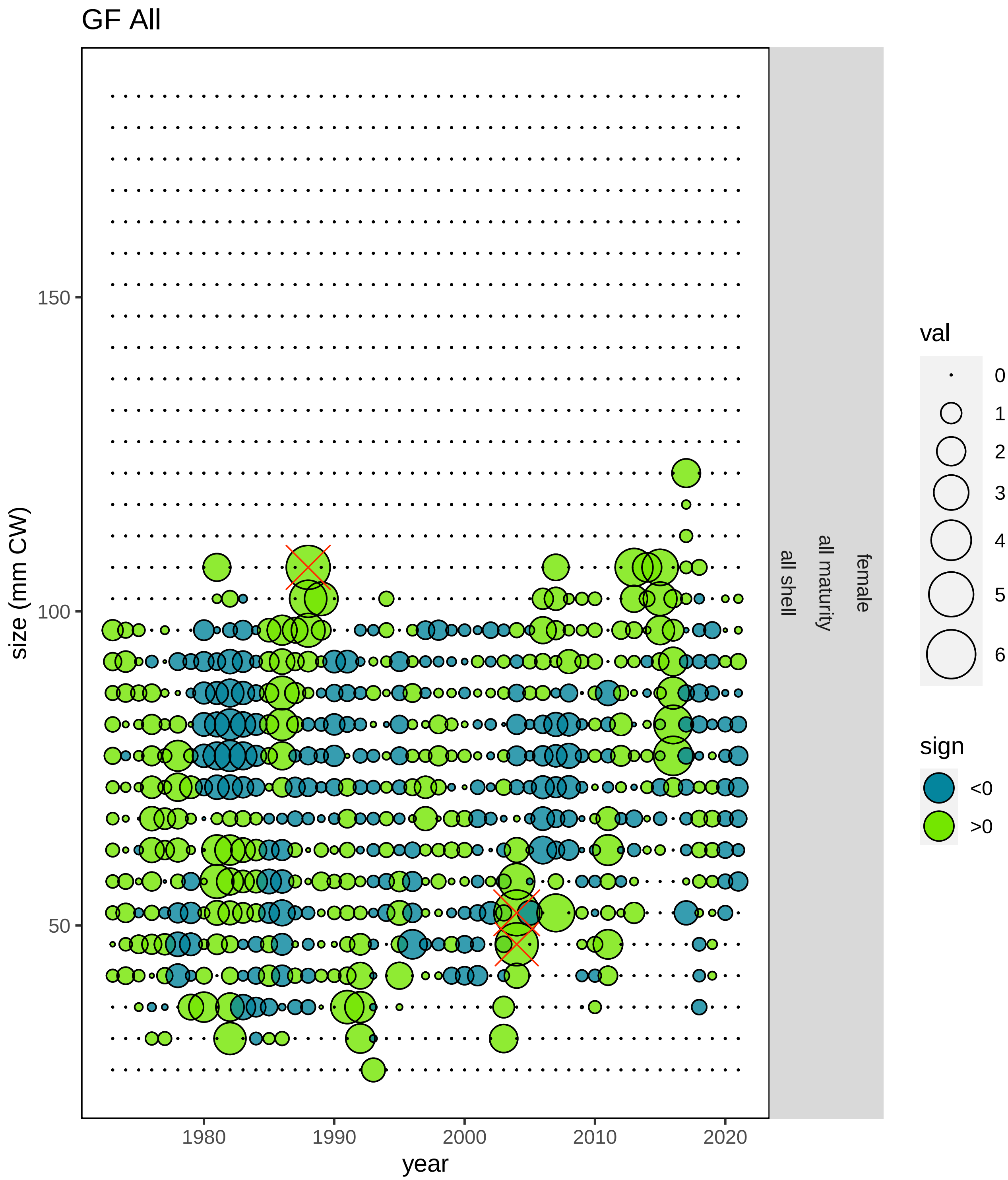

Figure 280. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05a. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

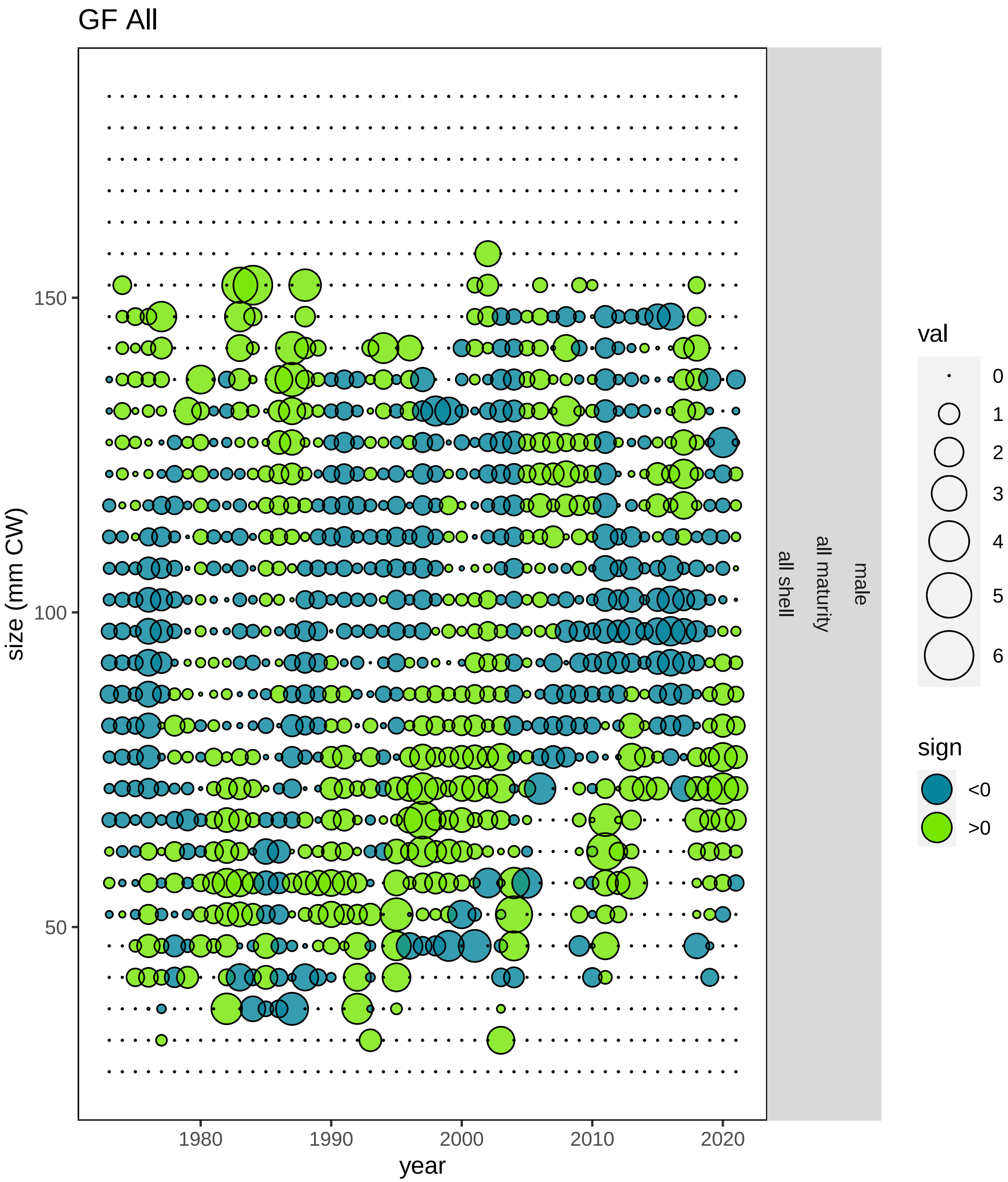

Figure 281. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

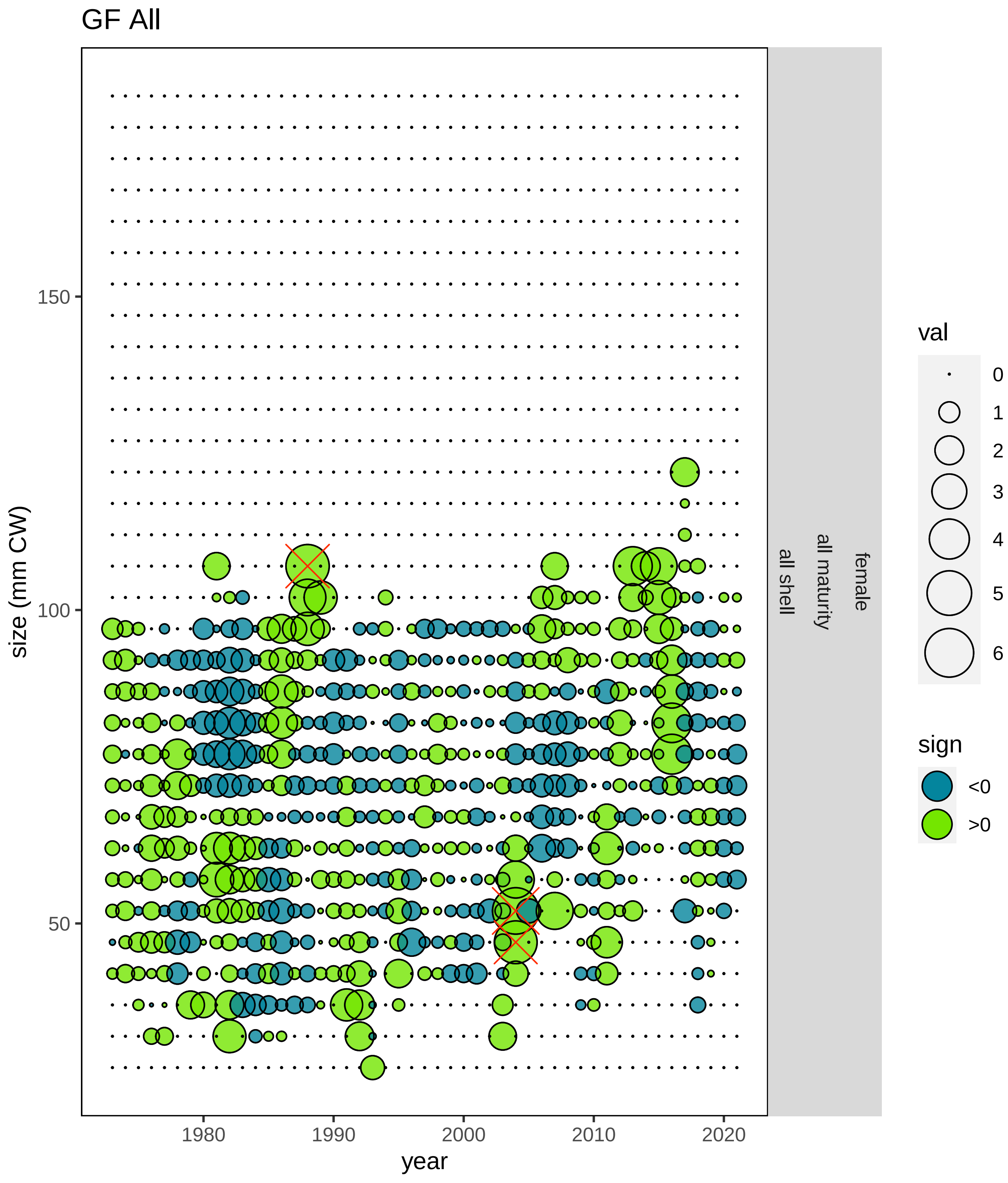

Figure 282. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05a1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

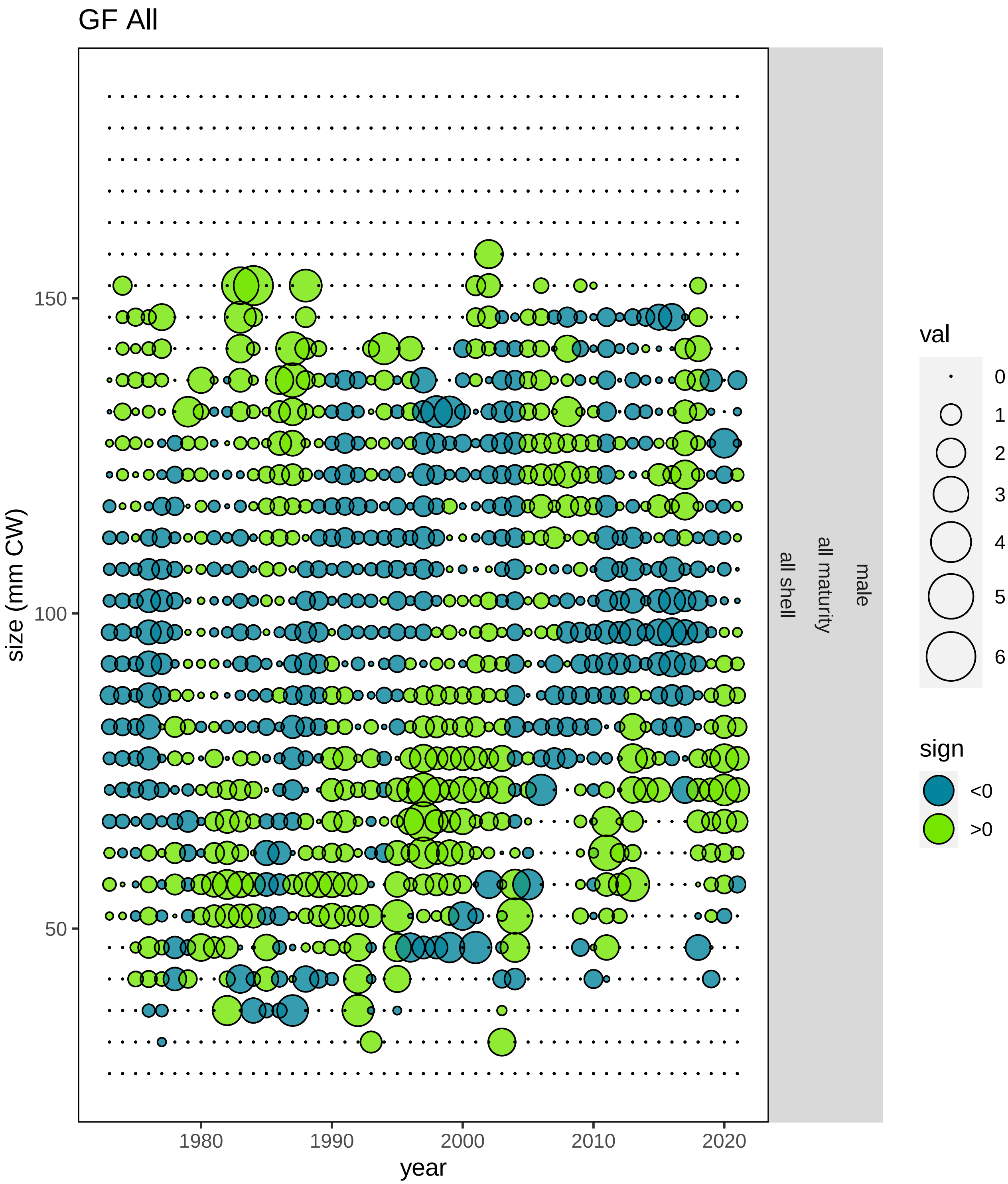

Figure 283. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

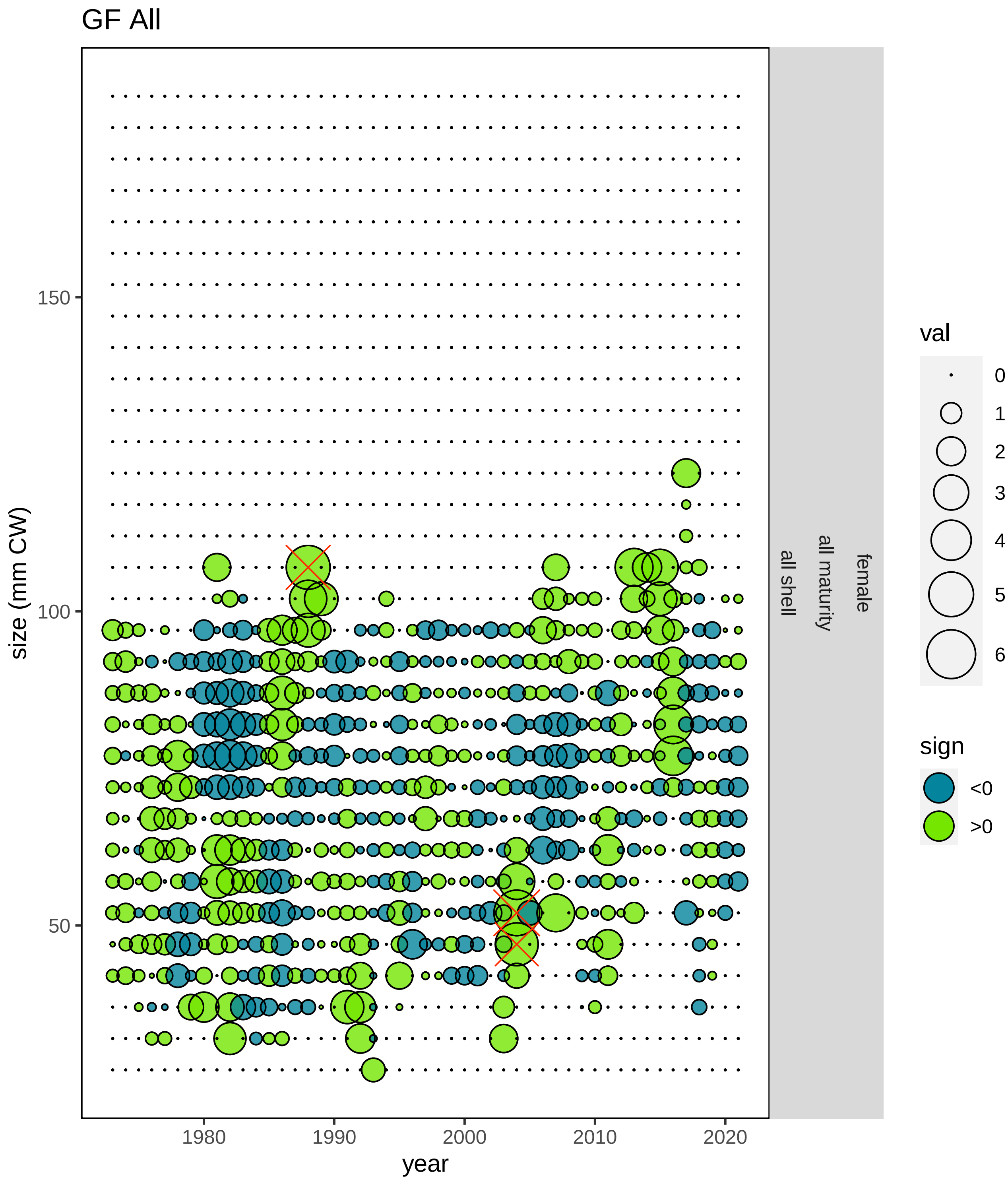

Figure 284. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05b. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

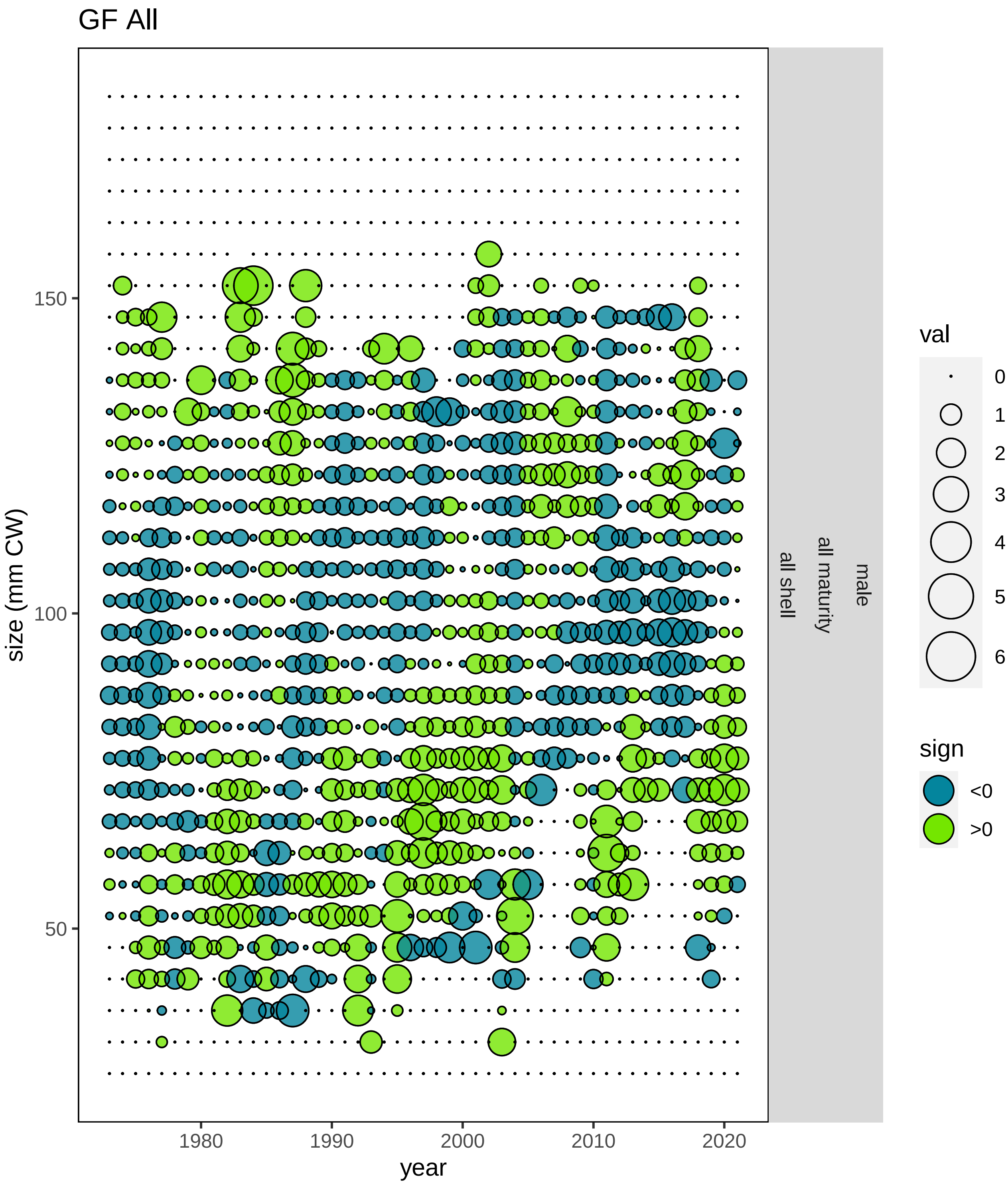

Figure 285. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

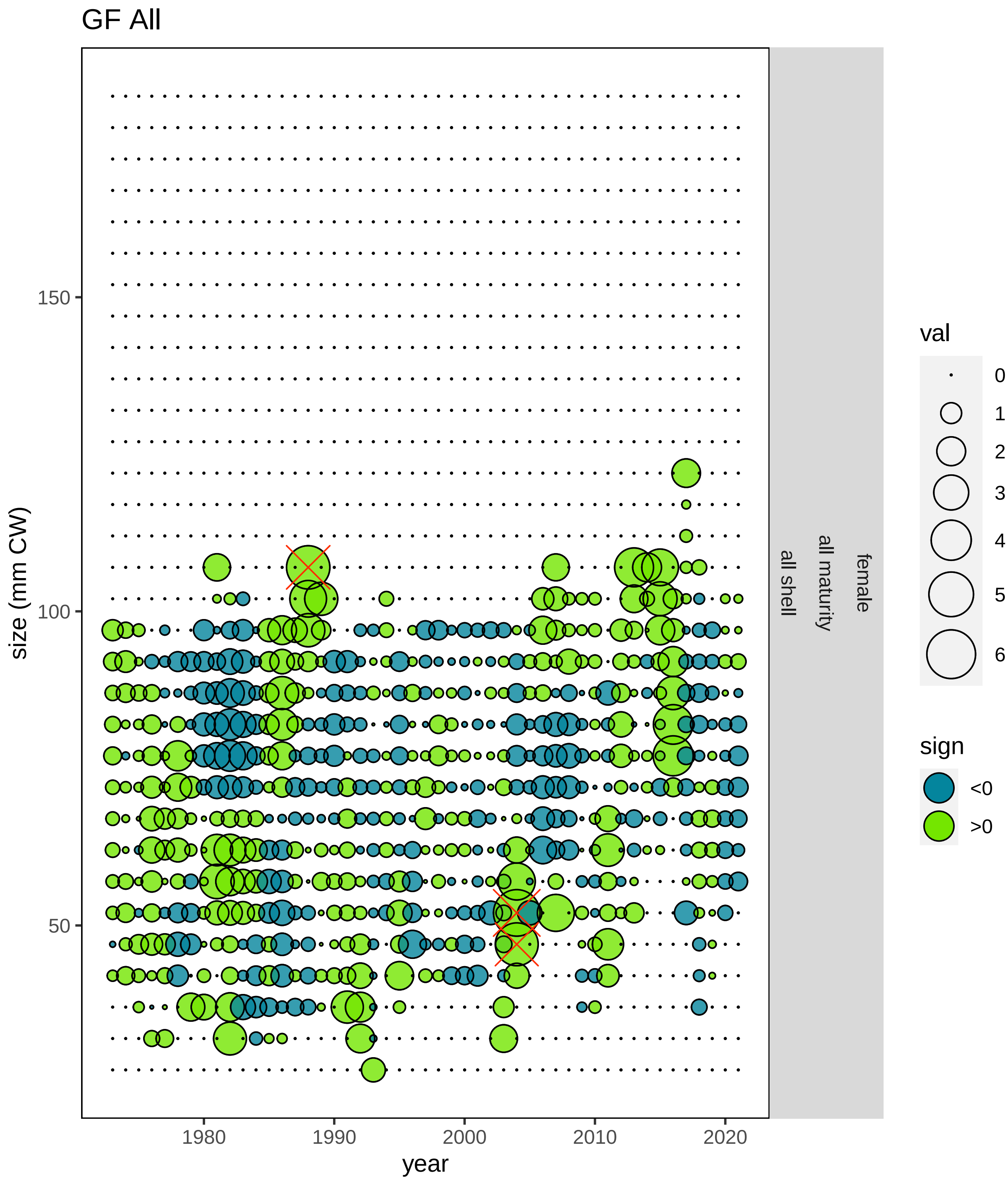

Figure 286. Pearson's residuals for fits to fishery total catch size composition data from the GF All in Model 23.05b1. Symbol areas reflect the size of each residual, extreme values (residuals larger than 4 in scale) are indicated with a red 'X' to facilitate identification.

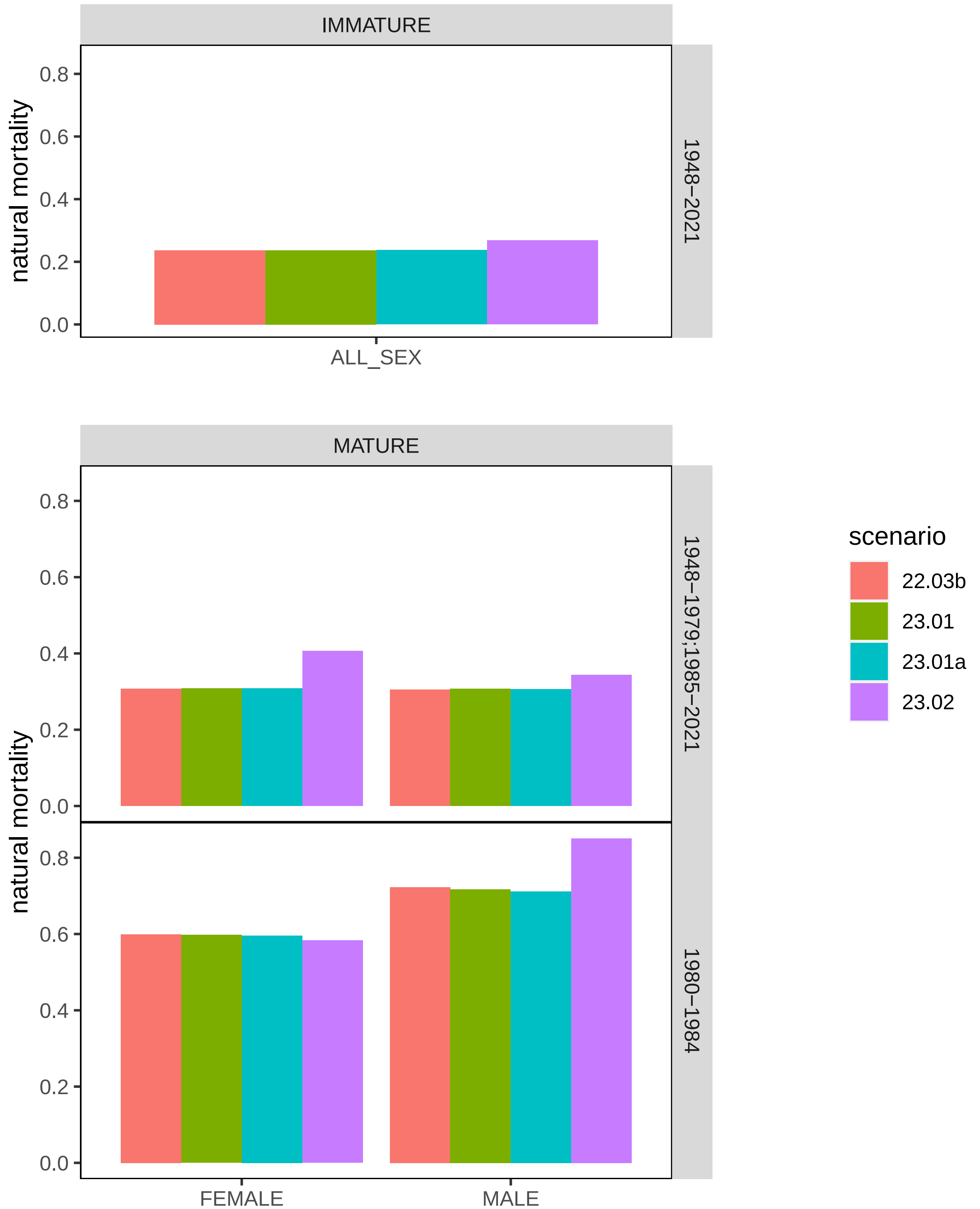

Figure 287. Estimated rates of natural mortality by life stage. Enhanced mortality period is 1980-1984.

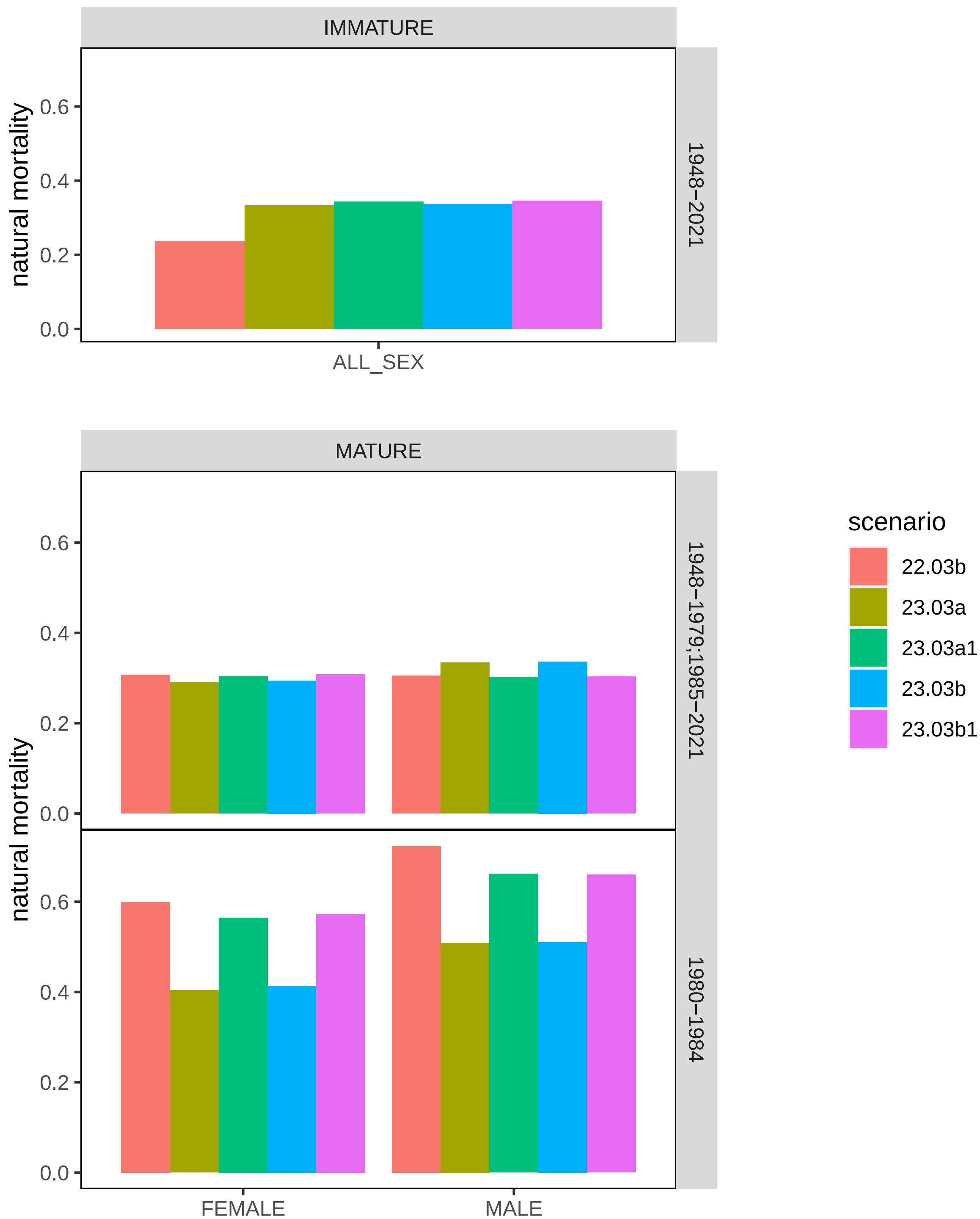

Figure 288. Estimated rates of natural mortality by life stage for models without time-varying M. Enhanced mortality time block is 1980-1984.

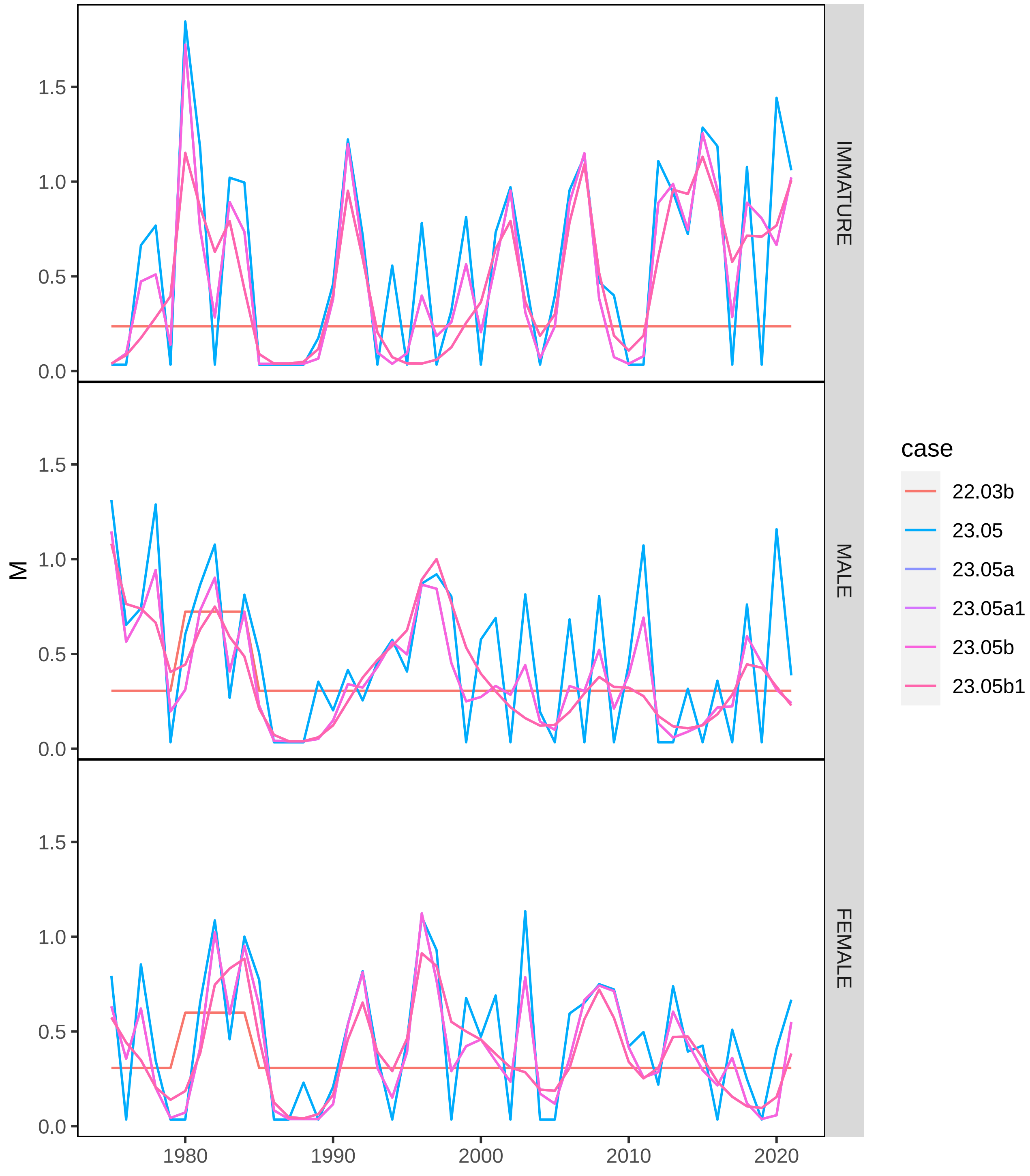

Figure 289. Estimated rates of natural mortality by life stage for 22.03b, 23.02, and the models with annually-varying mortality. Enhanced mortality block is 1980-1984.

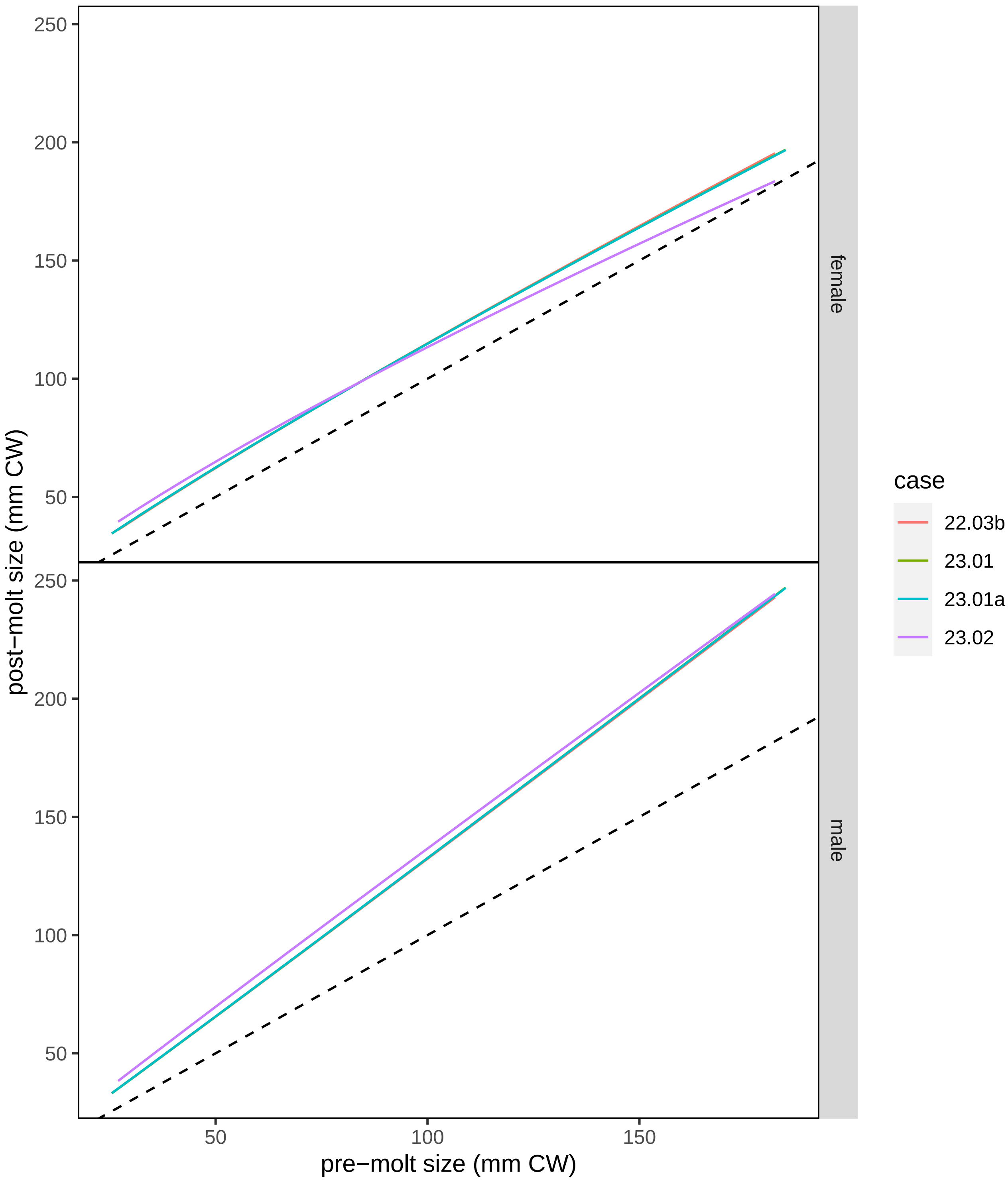

Figure 290. Estimated mean post-molt size, by pre-molt size.

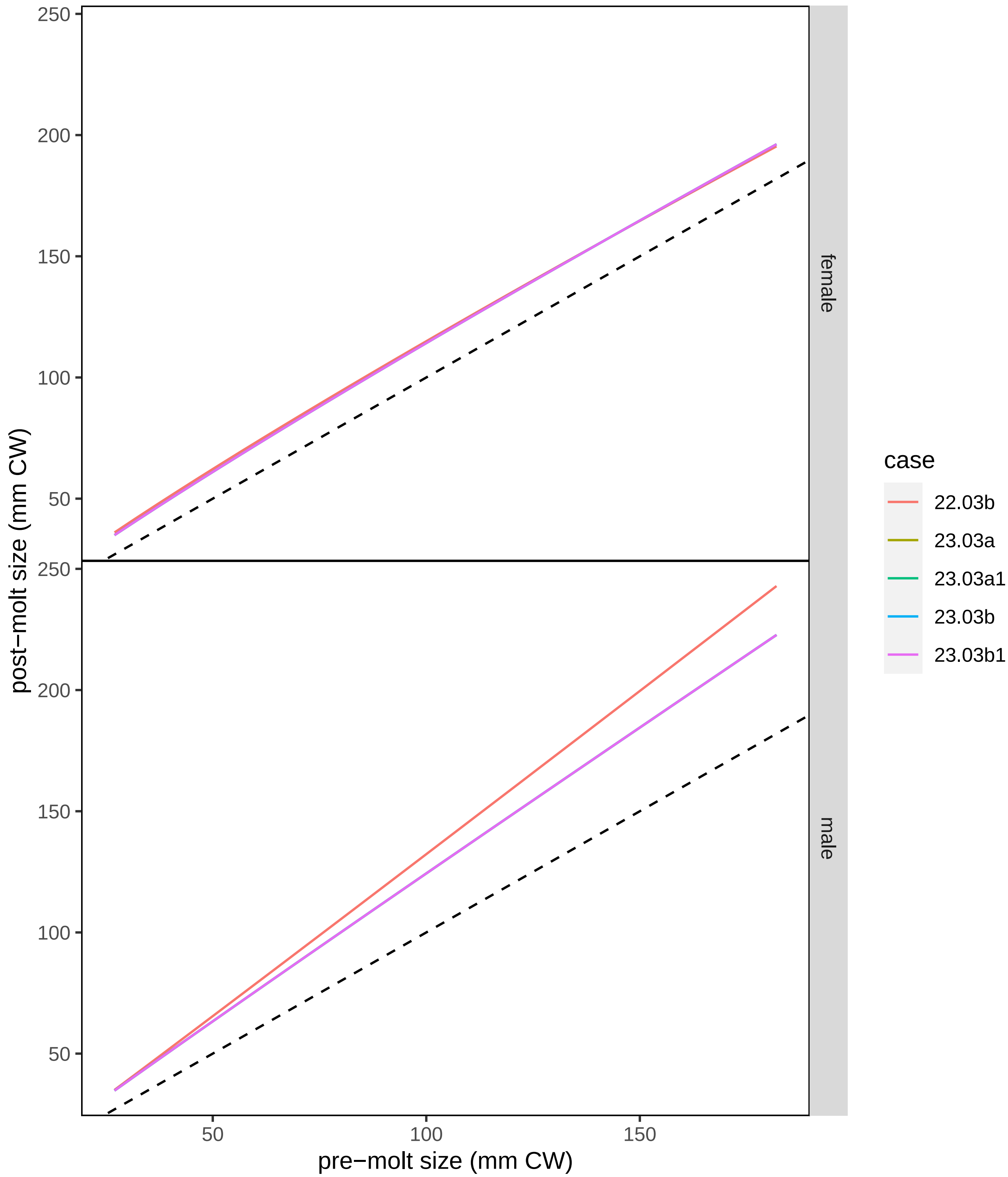

Figure 291. Estimated mean post-molt size, by pre-molt size.

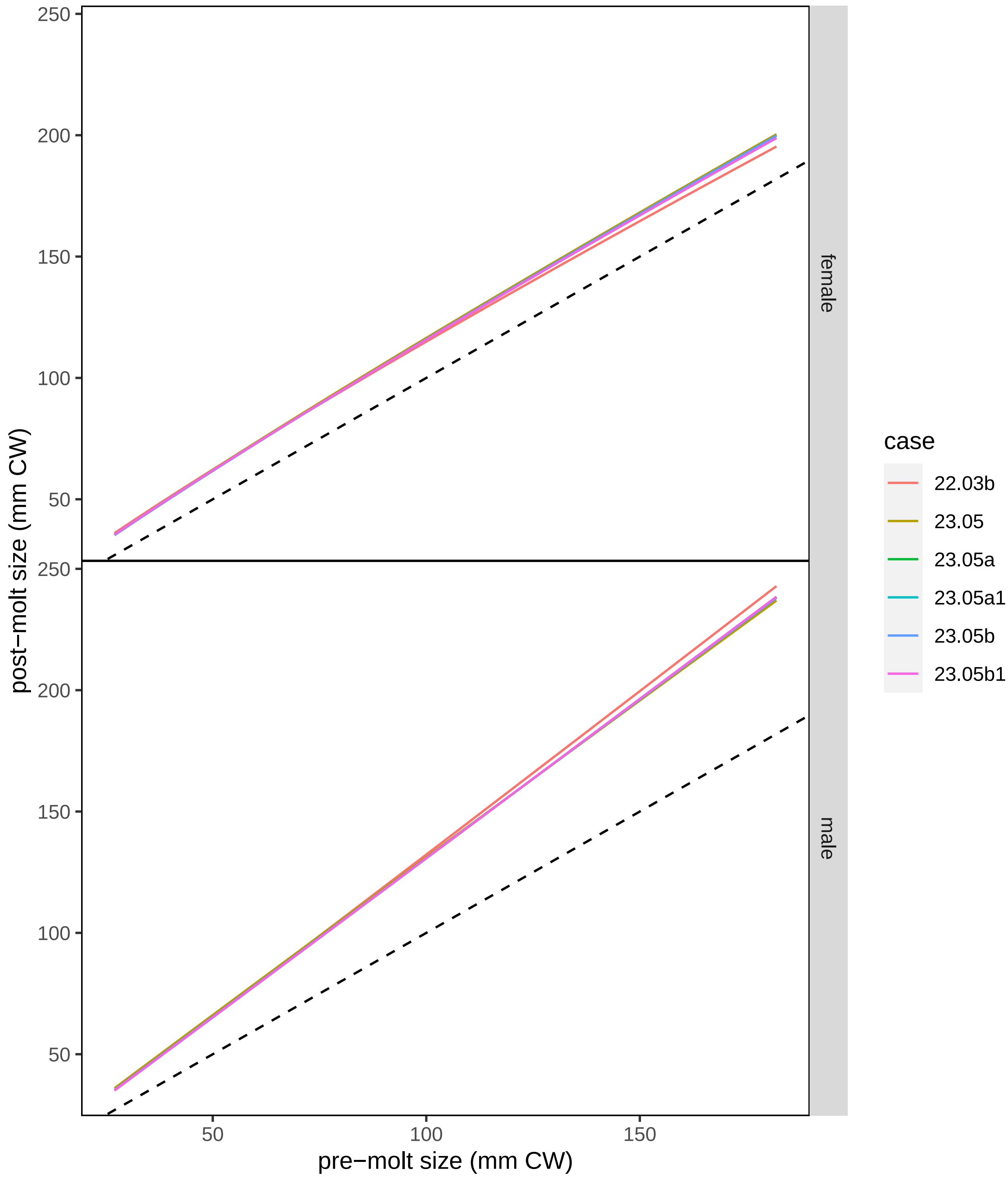

Figure 292. Estimated mean post-molt size, by pre-molt size.

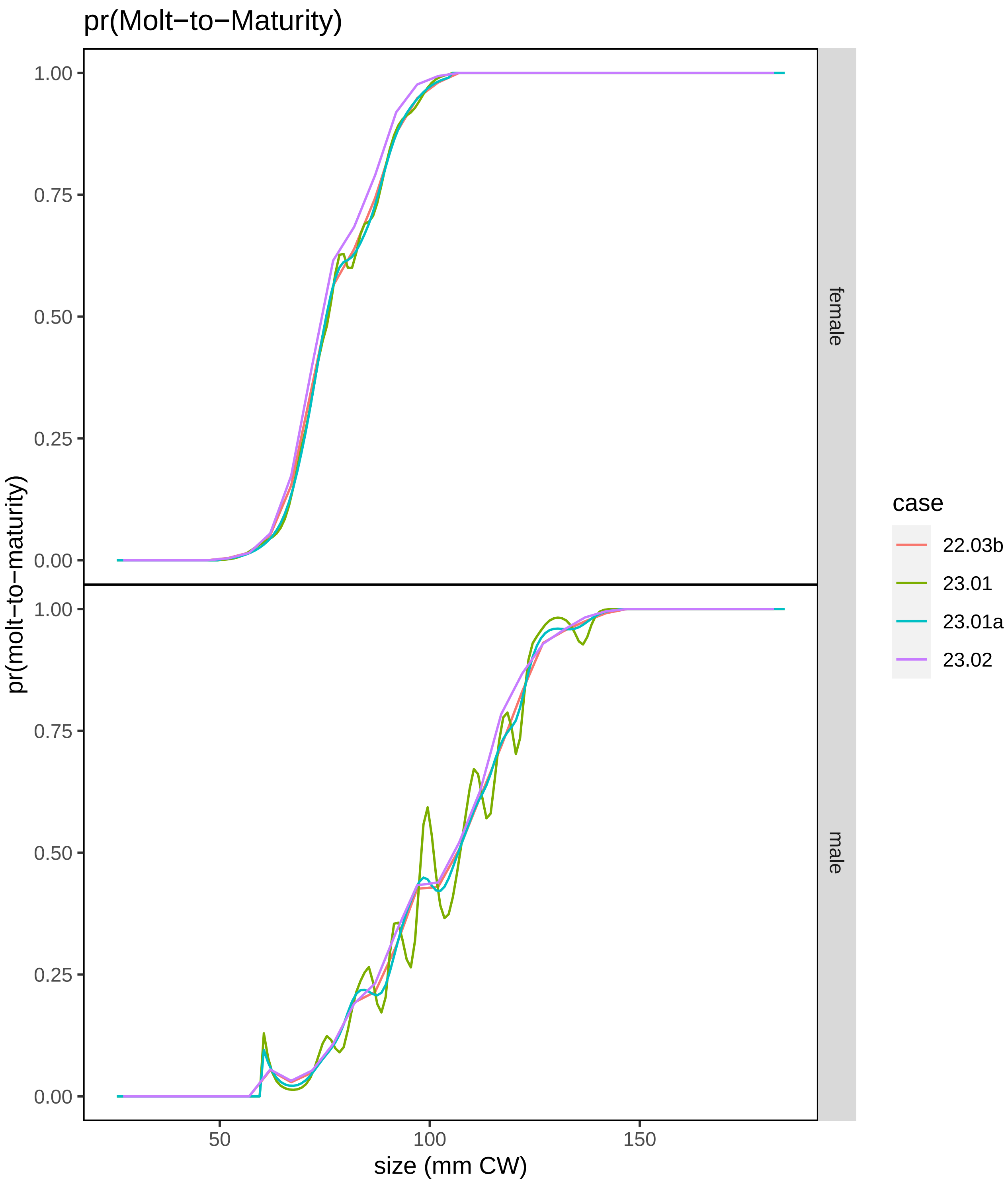

Figure 293. Estimated probability of undergoing terminal molt, as a function of pre-molt size.

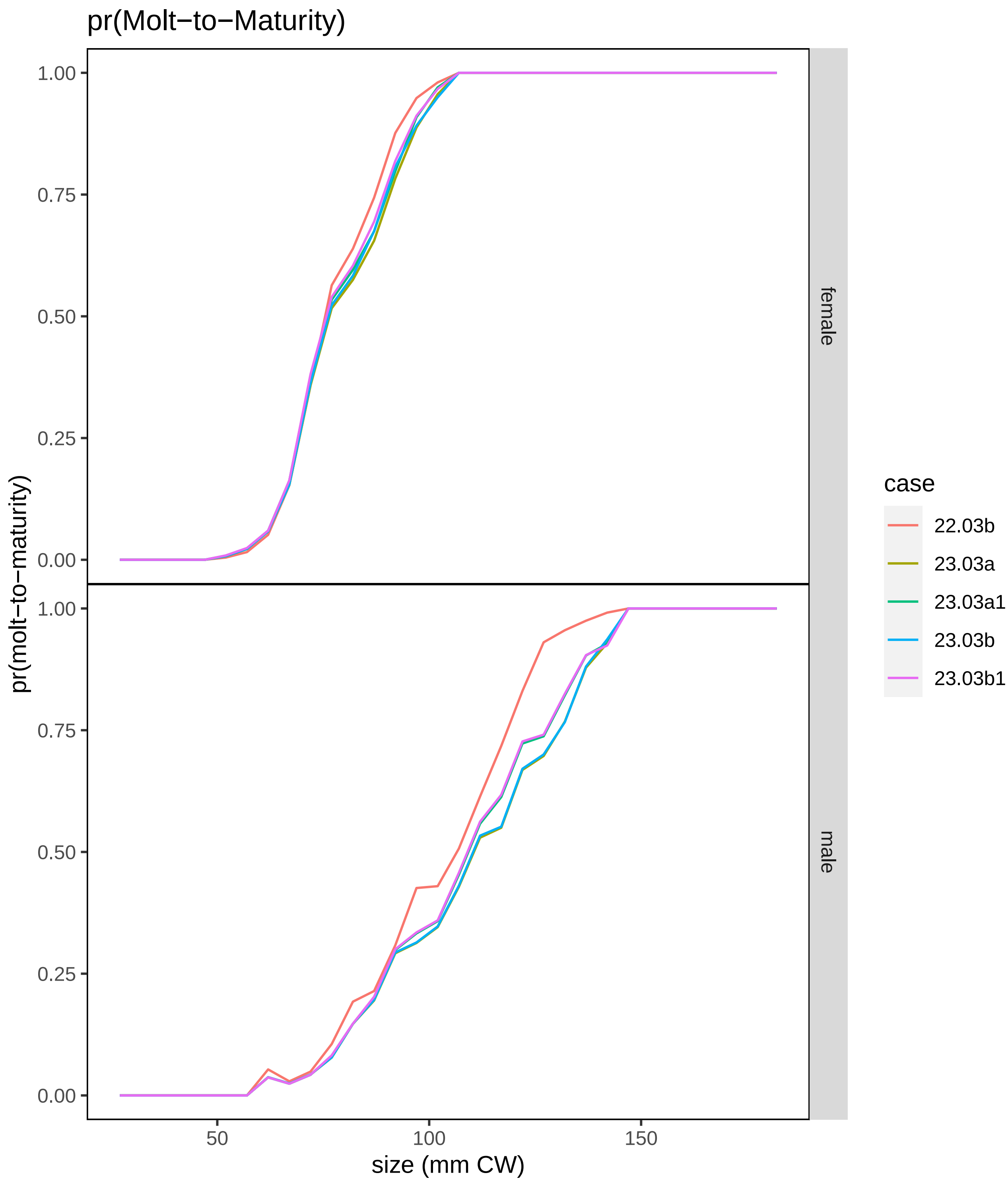

Figure 294. Estimated probability of undergoing terminal molt, as a function of pre-molt size.

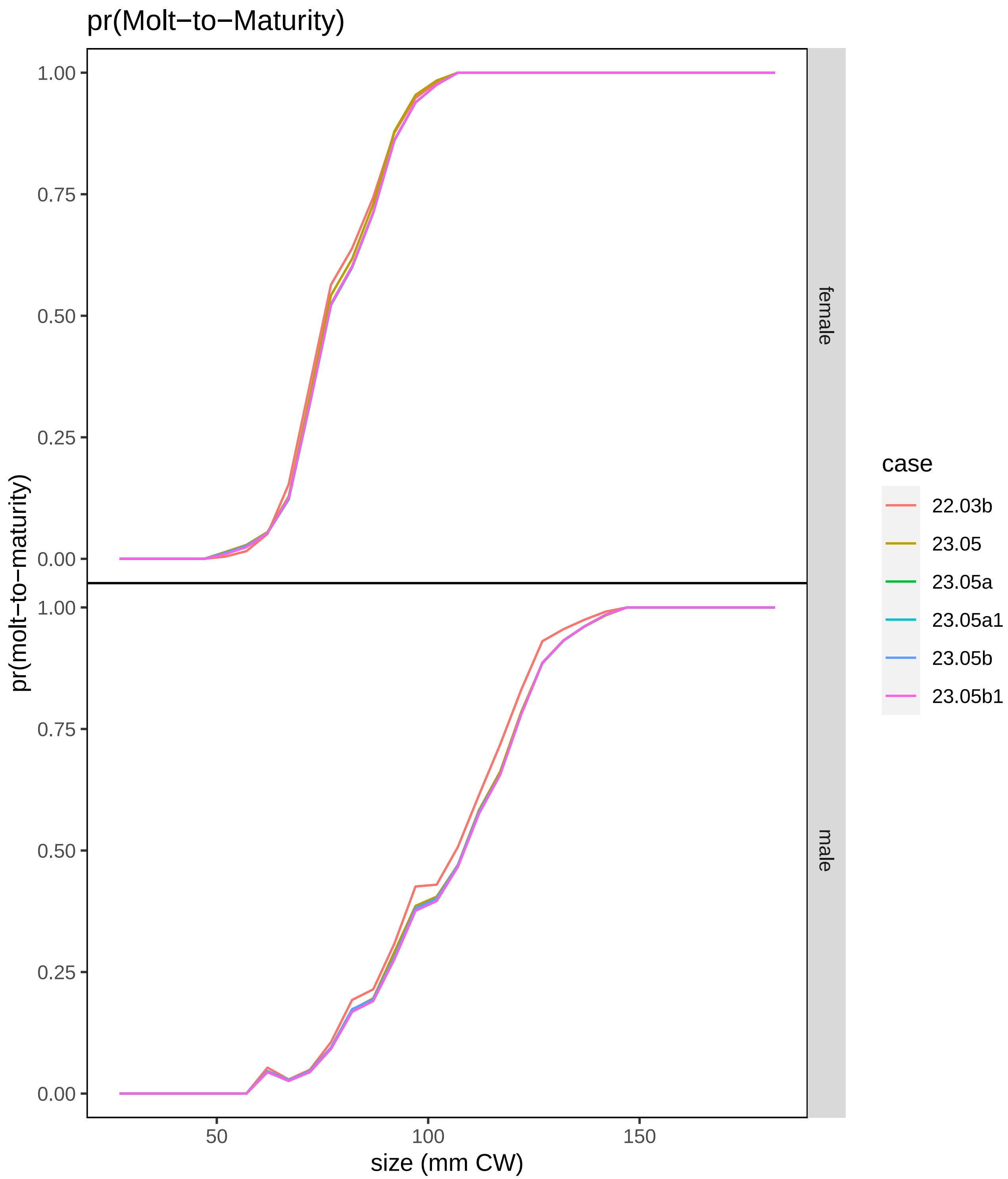

Figure 295. Estimated probability of undergoing terminal molt, as a function of pre-molt size.

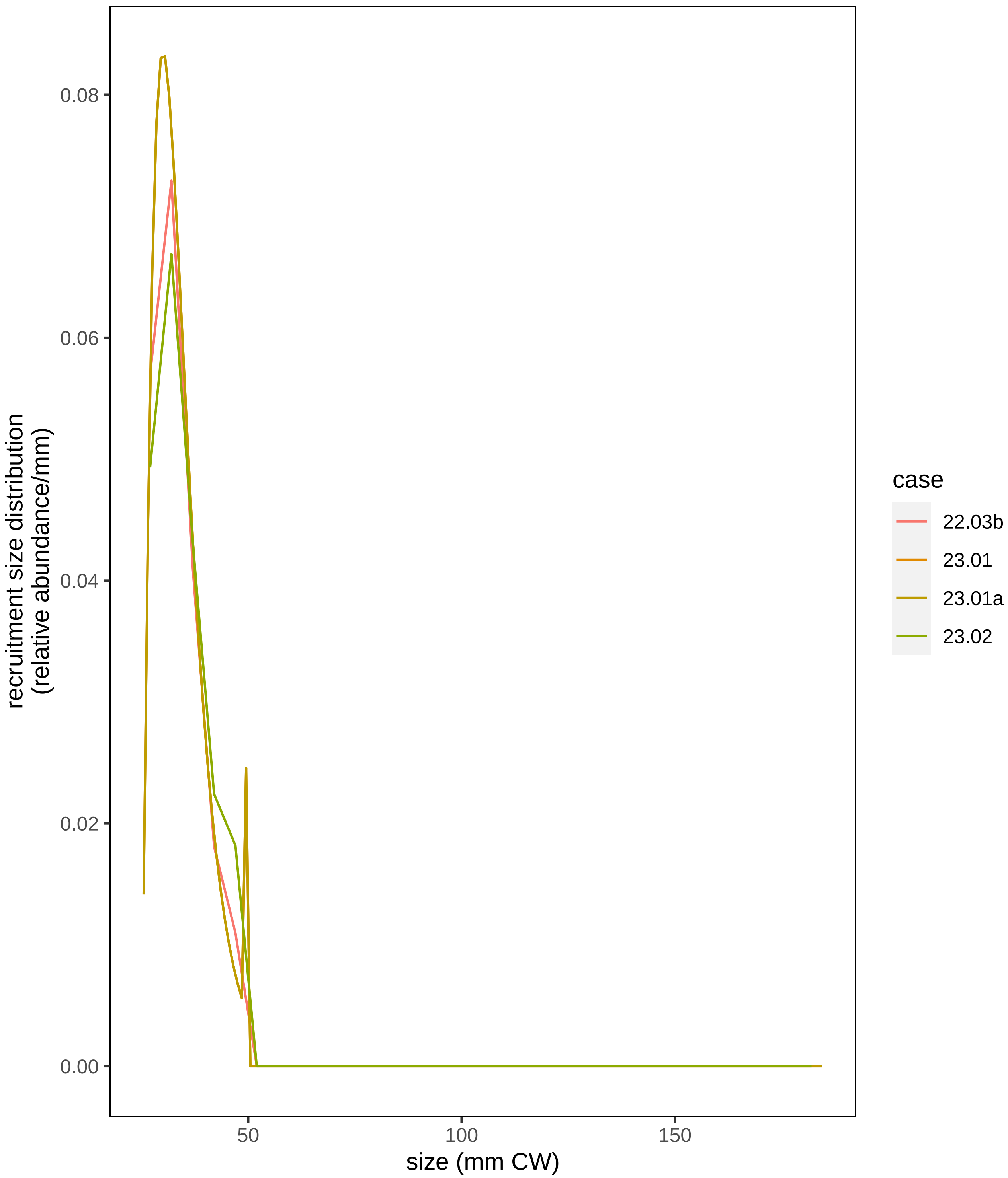

Figure 296. Estimated size distribution at recruitment from models 22.03b, 23.01, 23.01a, 23.02.

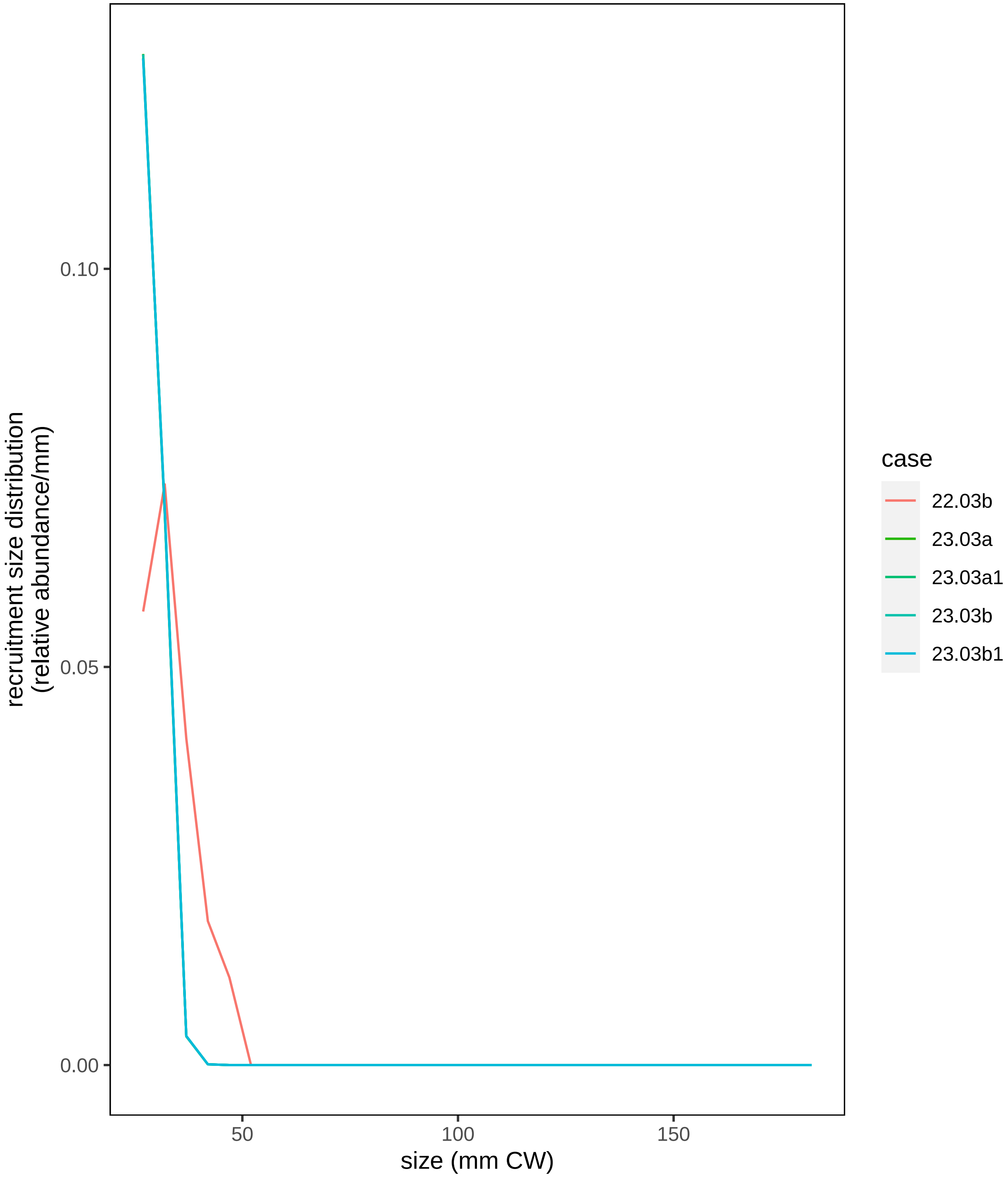

Figure 297. Estimated size distribution at recruitment from models 22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

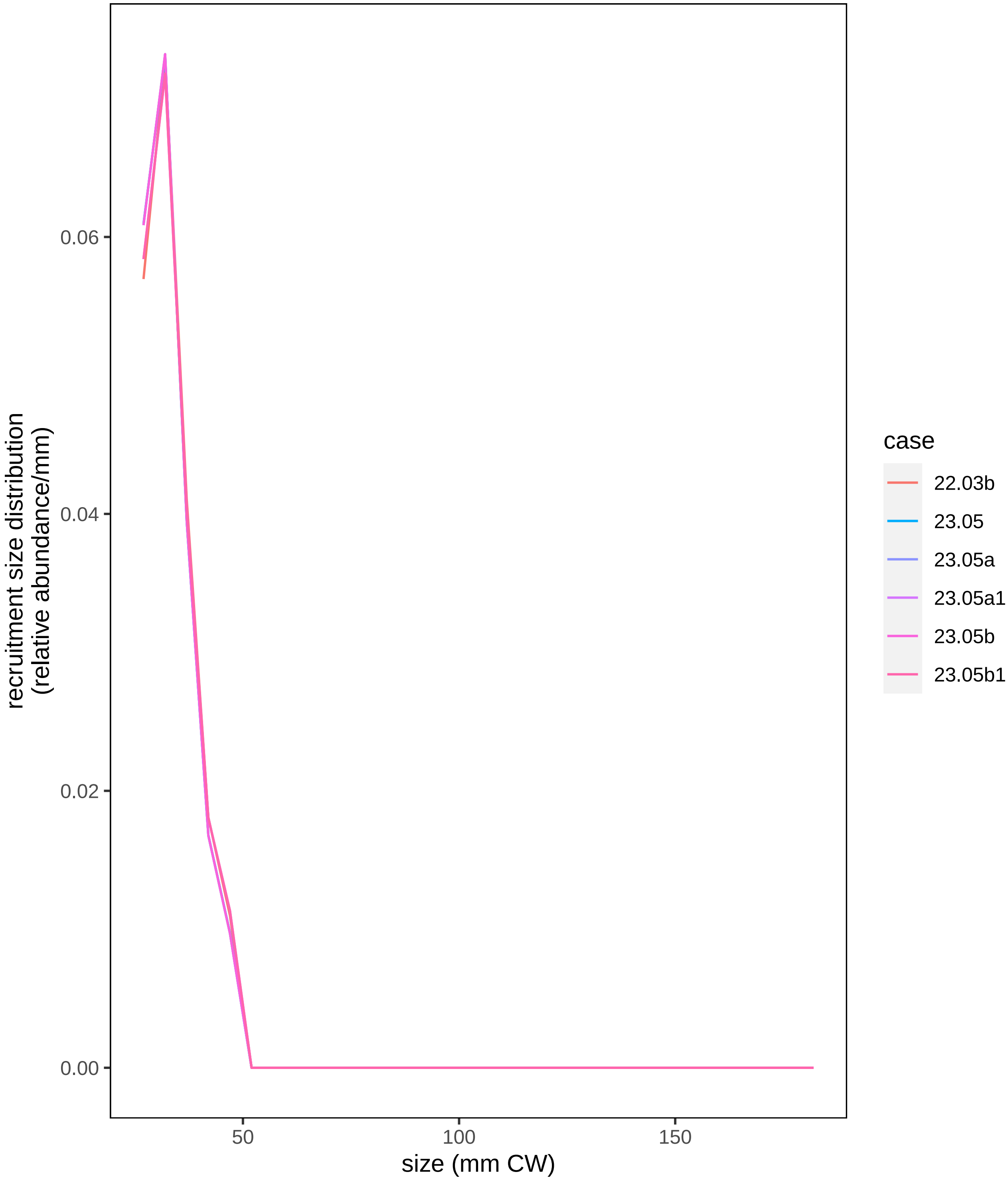

Figure 298. Estimated size distribution at recruitment from models 22.03b, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

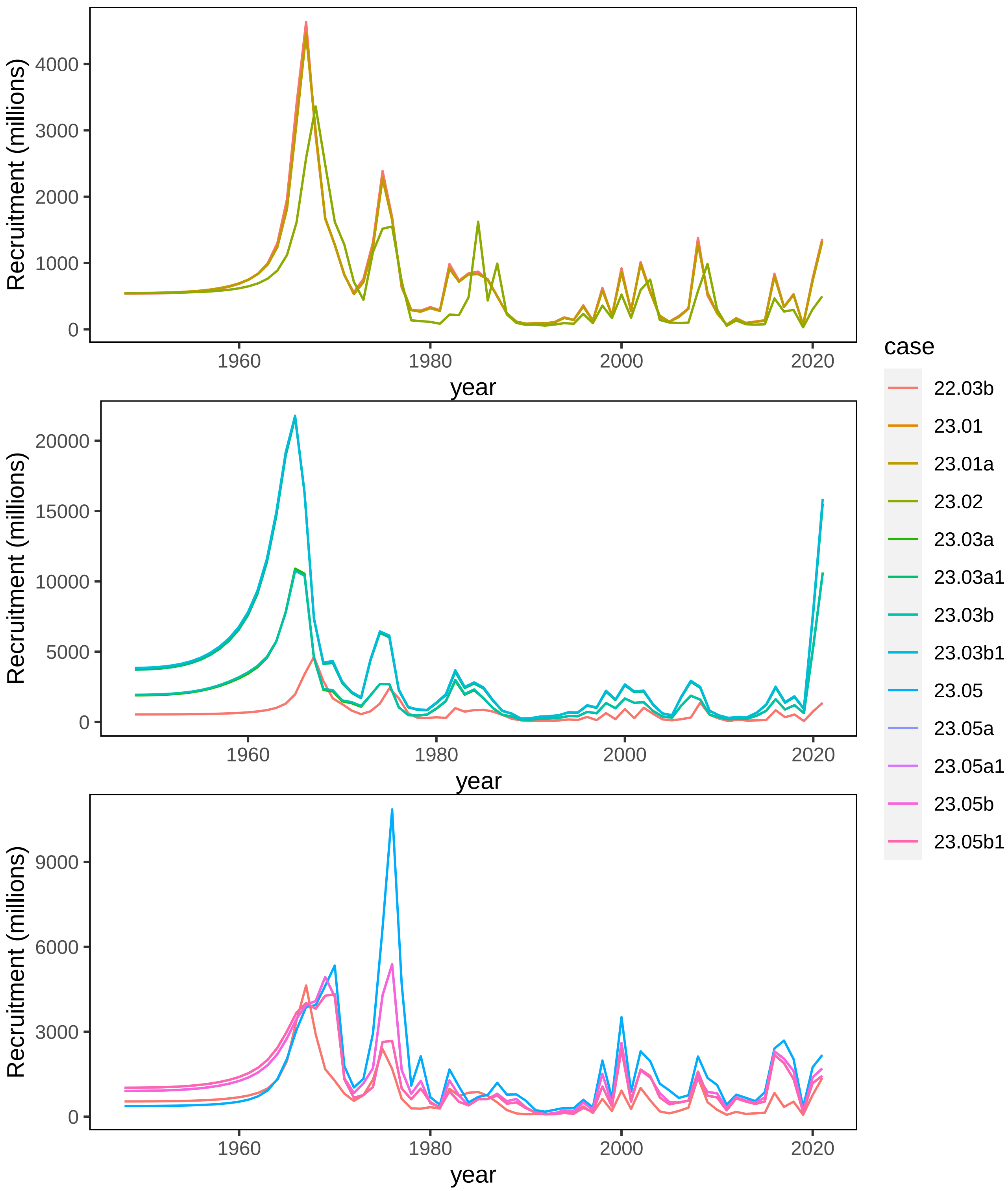

Figure 299. Estimated recruitment, full model time period. Note: y-axis scales differ between plots. Upper plot:22.03b, 23.01, 23.01a, 23.02center plot:22.03b, 23.01, 23.01a, 23.02lower plot:22.03b, 23.01, 23.01a, 23.02.

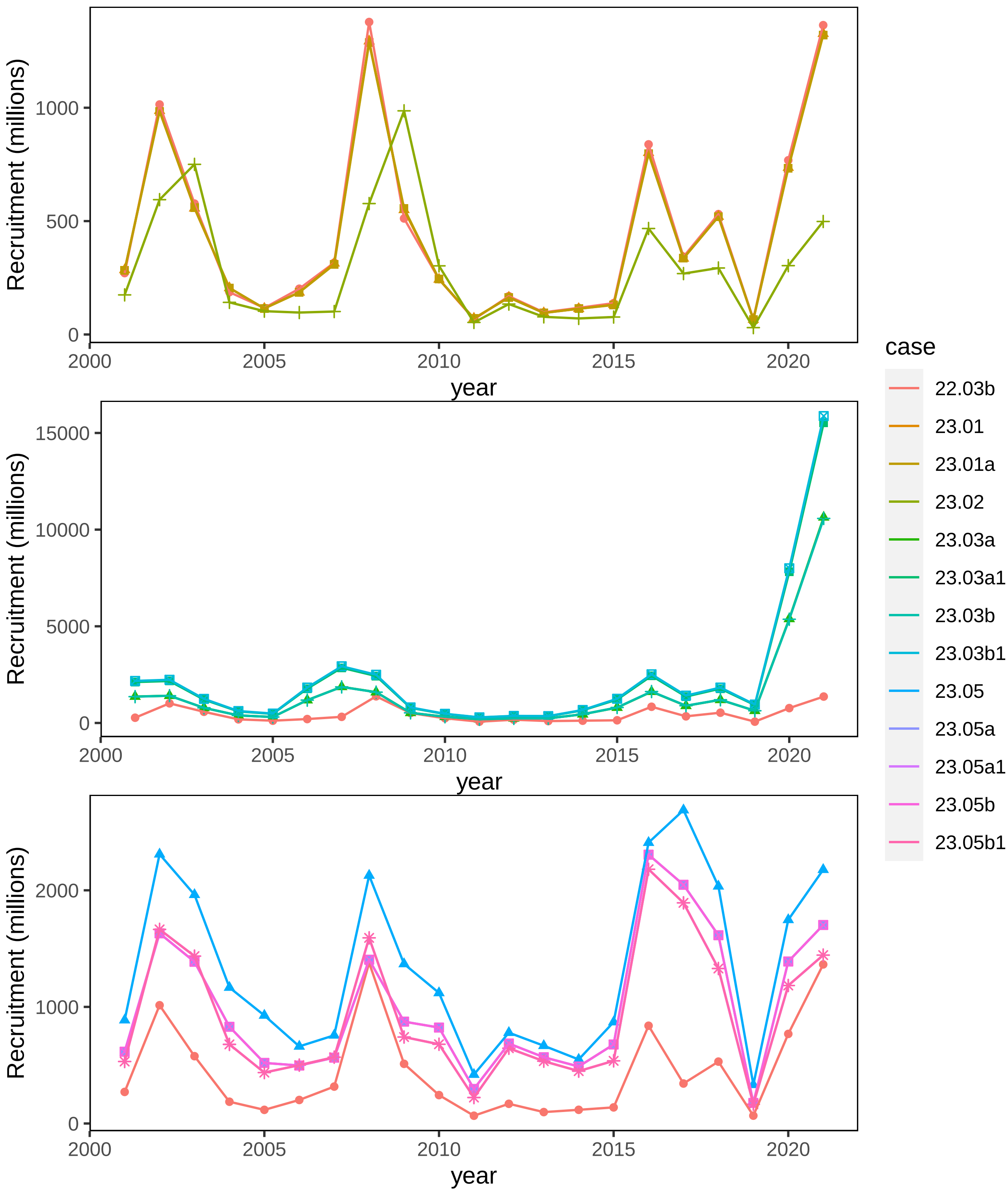

Figure 300. Estimated recruitment, last 20 years. Note: y-axis scales differ between plots. Upper plot:22.03b, 23.01, 23.01a, 23.02center plot:22.03b, 23.01, 23.01a, 23.02lower plot:22.03b, 23.01, 23.01a, 23.02.

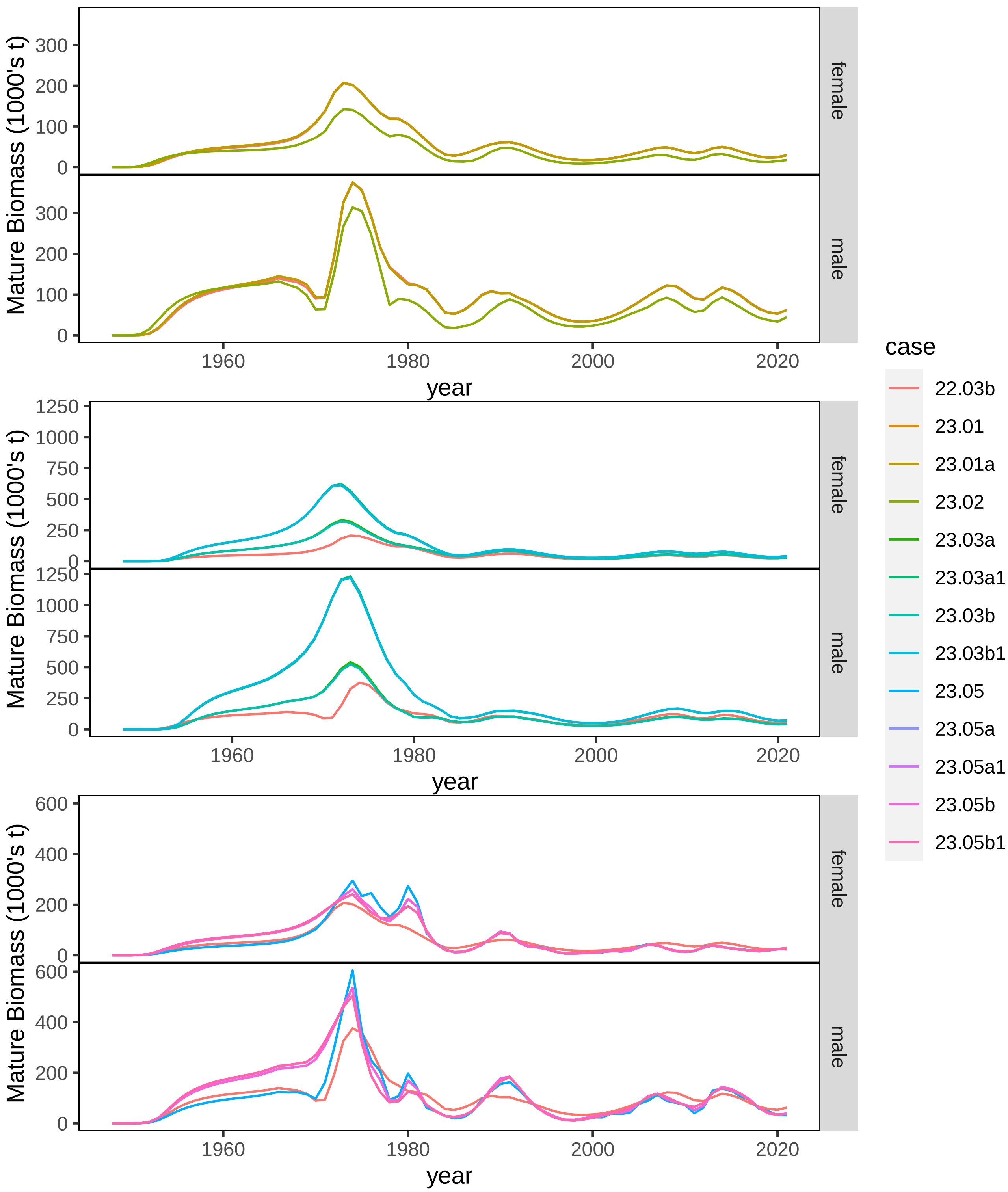

Figure 301. Estimated population-level mature biomass, full model time period. Note: y-axis scales differ between plots. Upper plot:22.03b, 23.01, 23.01a, 23.02center plot:22.03b, 23.01, 23.01a, 23.02lower plot:22.03b, 23.01, 23.01a, 23.02.

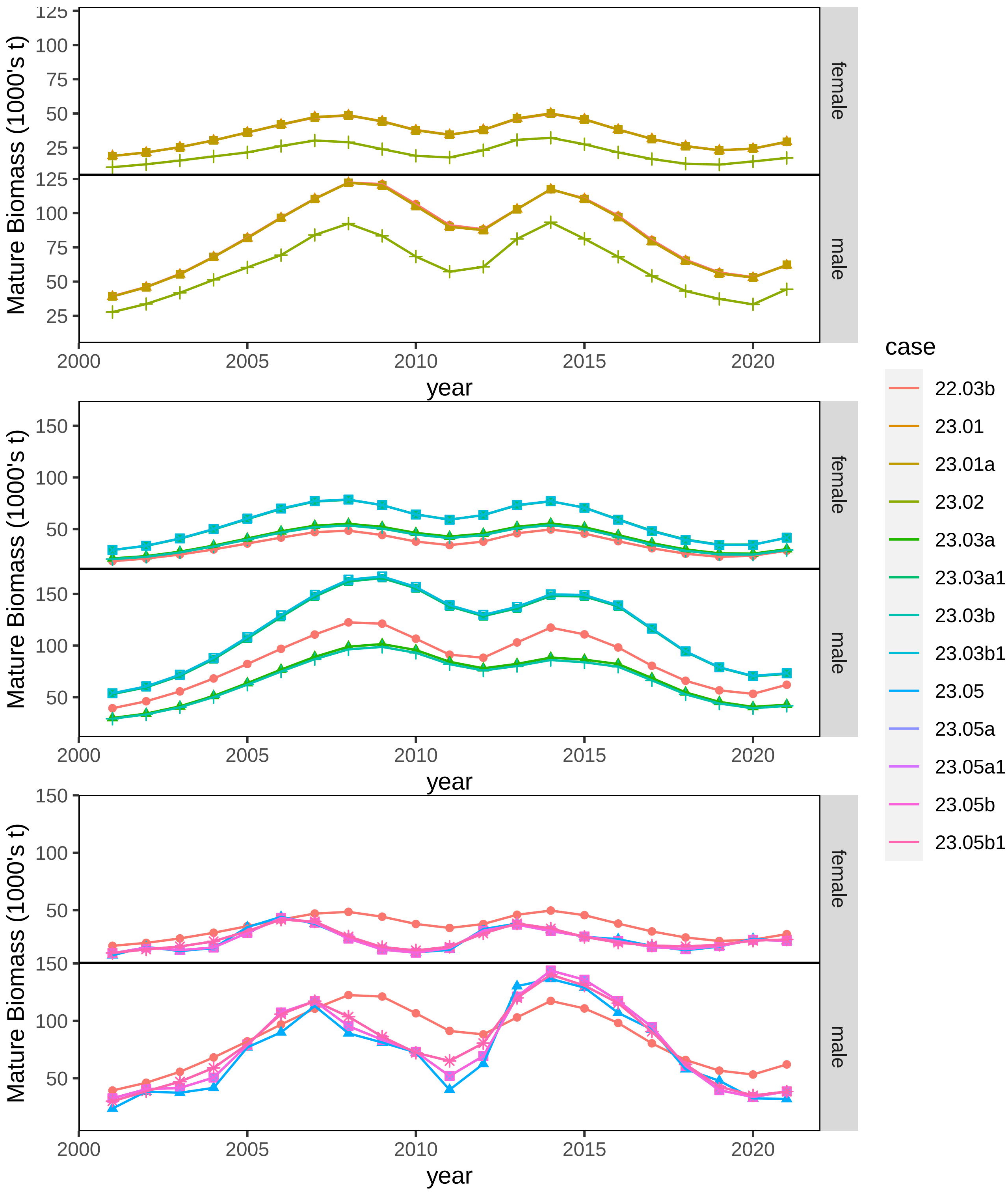

Figure 302. Estimated population-level mature biomass, last 20 years. Note: y-axis scales differ between plots. Upper plot:22.03b, 23.01, 23.01a, 23.02center plot:22.03b, 23.01, 23.01a, 23.02lower plot:22.03b, 23.01, 23.01a, 23.02.

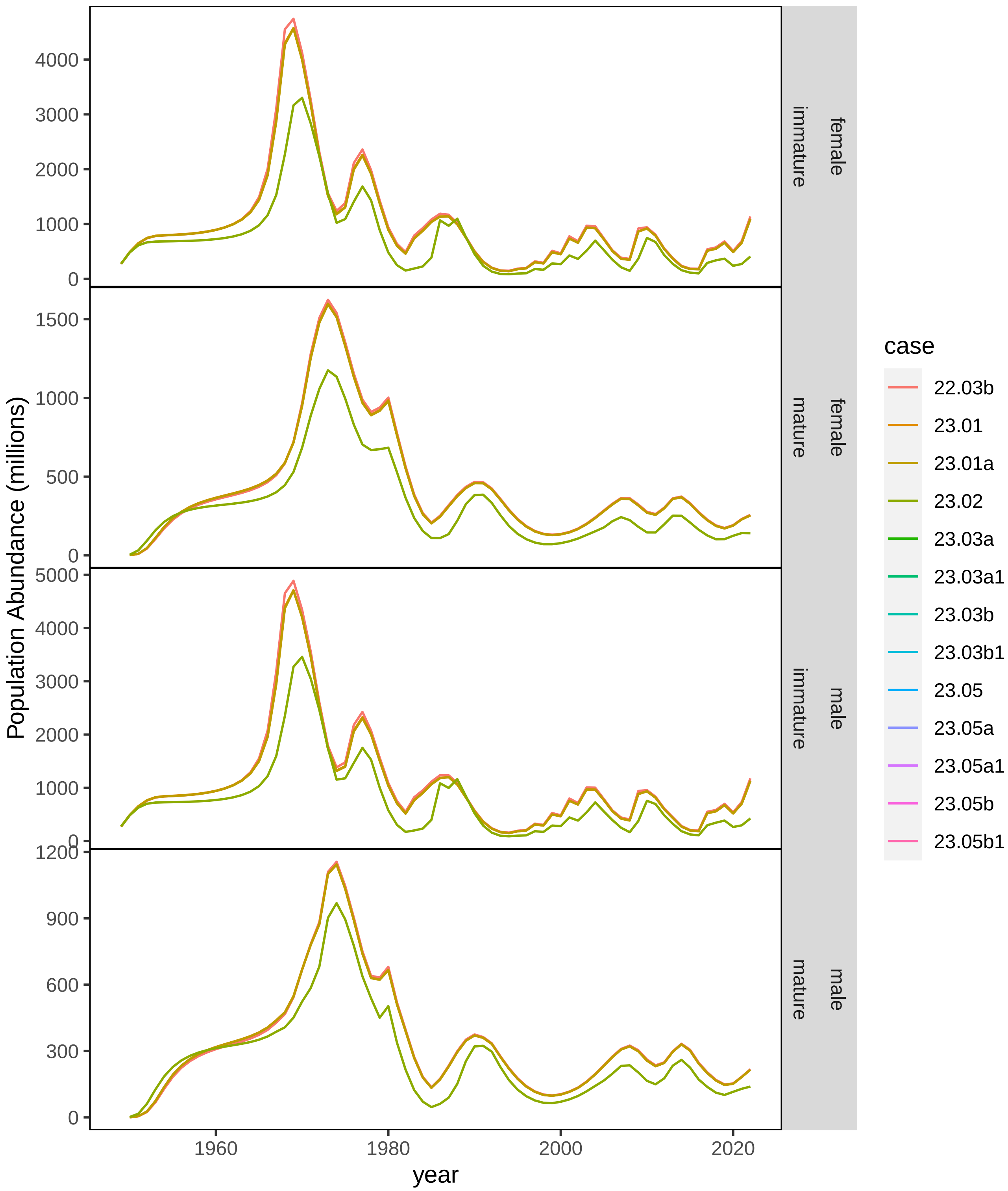

Figure 303. Estimated population abundance, full time period. Note: y-axis scales differ between plots. Models22.03b, 23.01, 23.01a, 23.02.

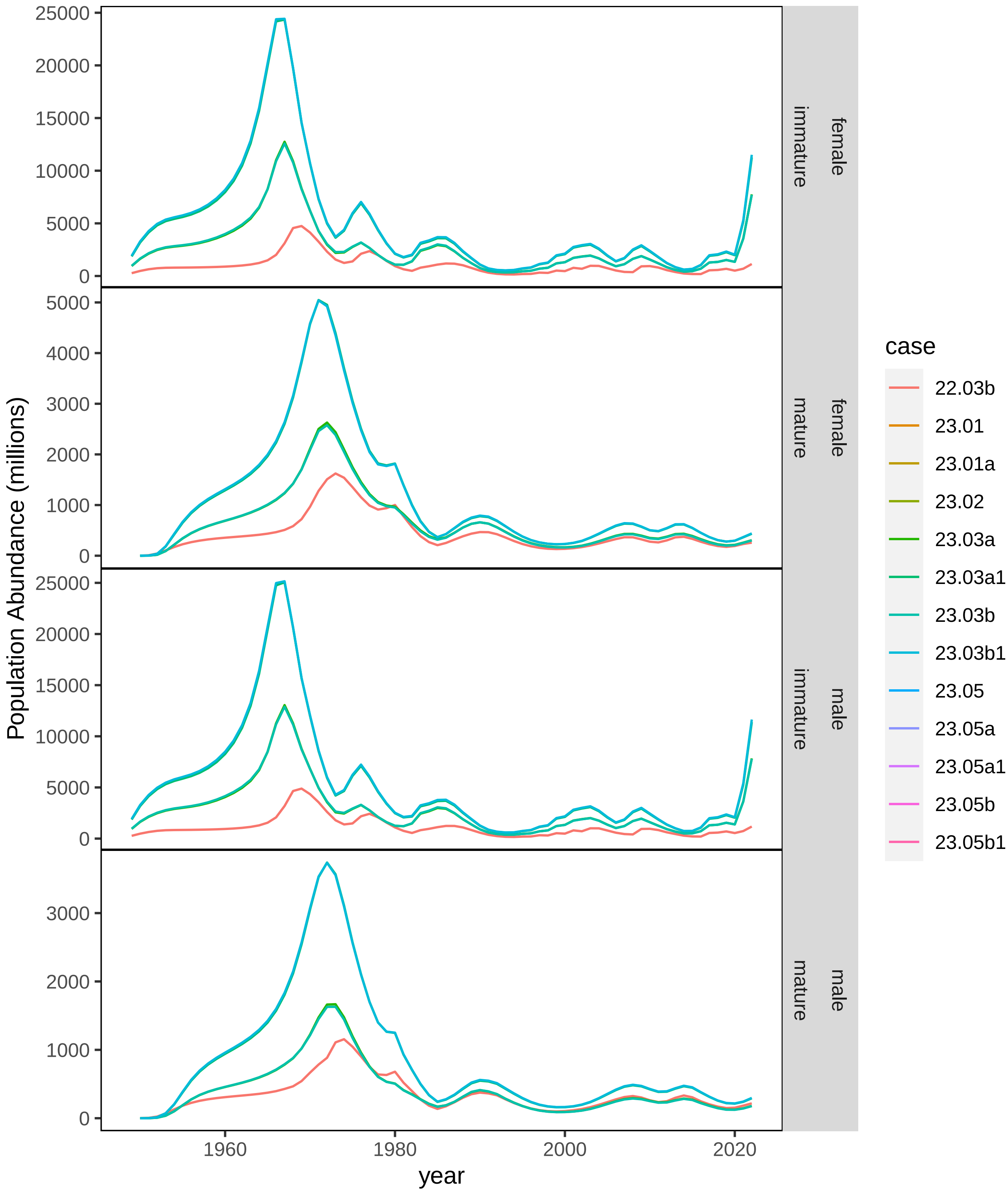

Figure 304. Estimated population abundance, full time period. Note: y-axis scales differ between plots. Models22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

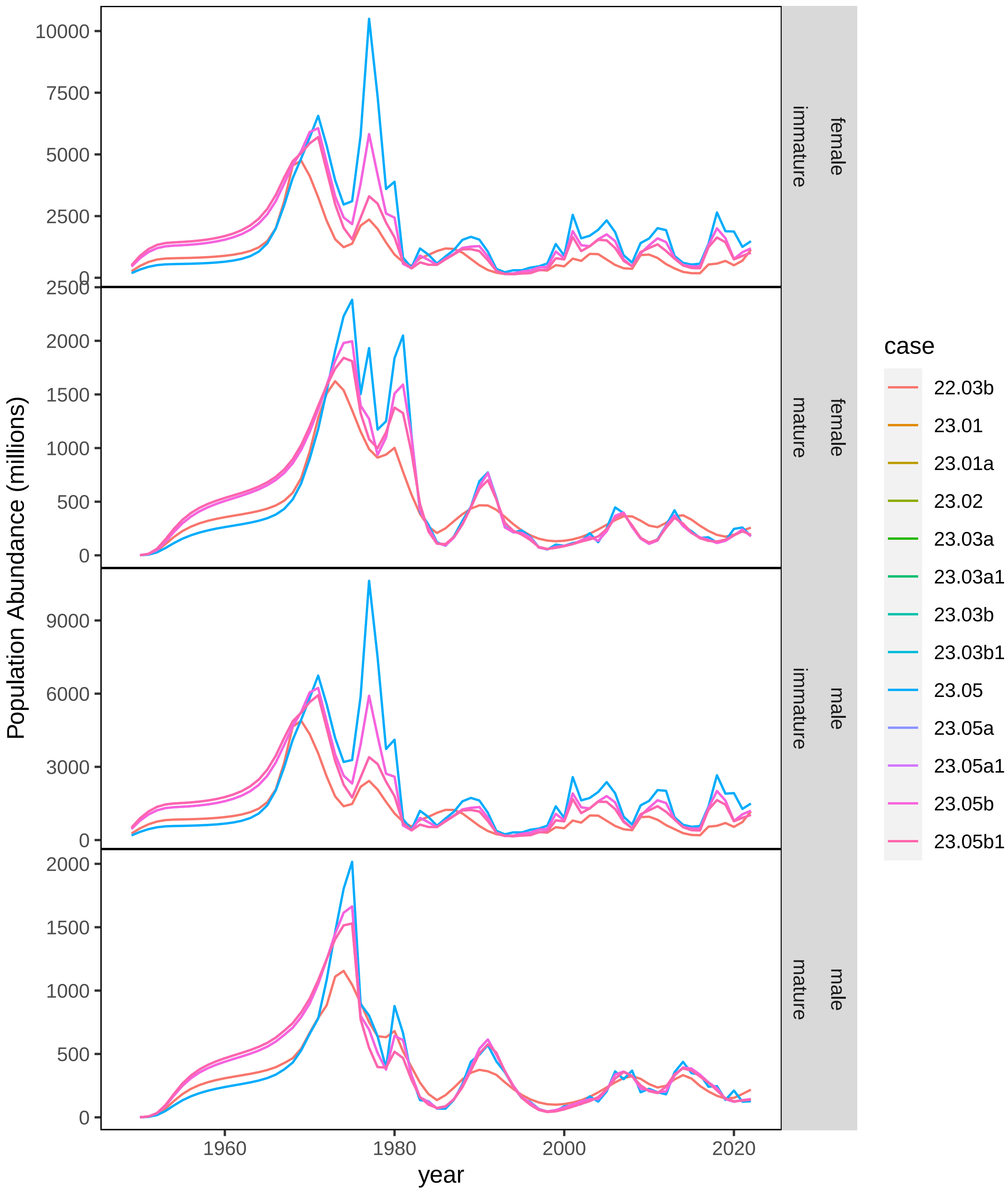

Figure 305. Estimated population abundance, full time period. Note: y-axis scales differ between plots. Models22.03b, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

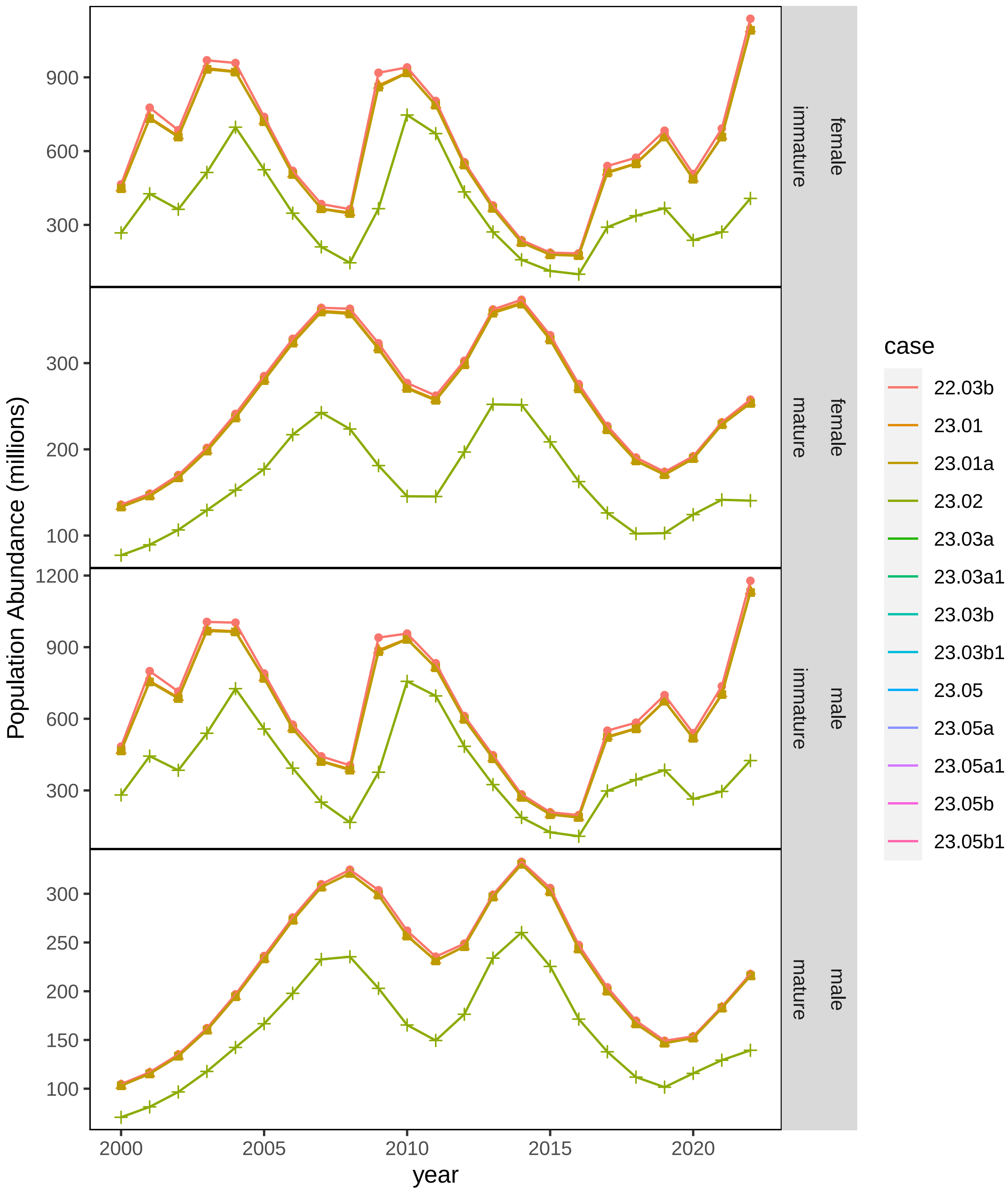

Figure 306. Estimated population abundance, recent time period. Note: y-axis scales differ between plots. Models22.03b, 23.01, 23.01a, 23.02.

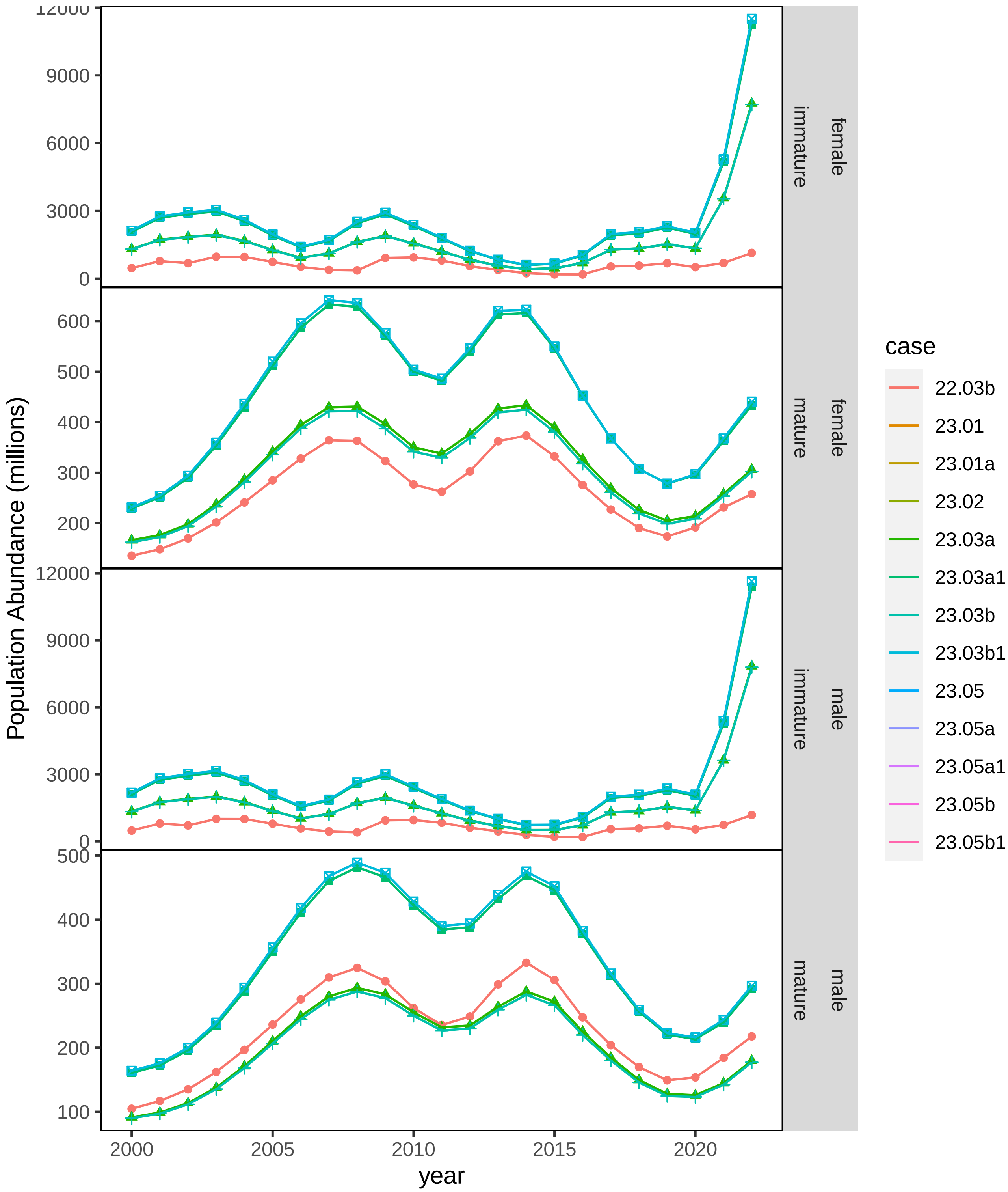

Figure 307. Estimated population abundance, recent time period. Note: y-axis scales differ between plots. Models22.03b, 23.03a, 23.03a1, 23.03b, 23.03b1.

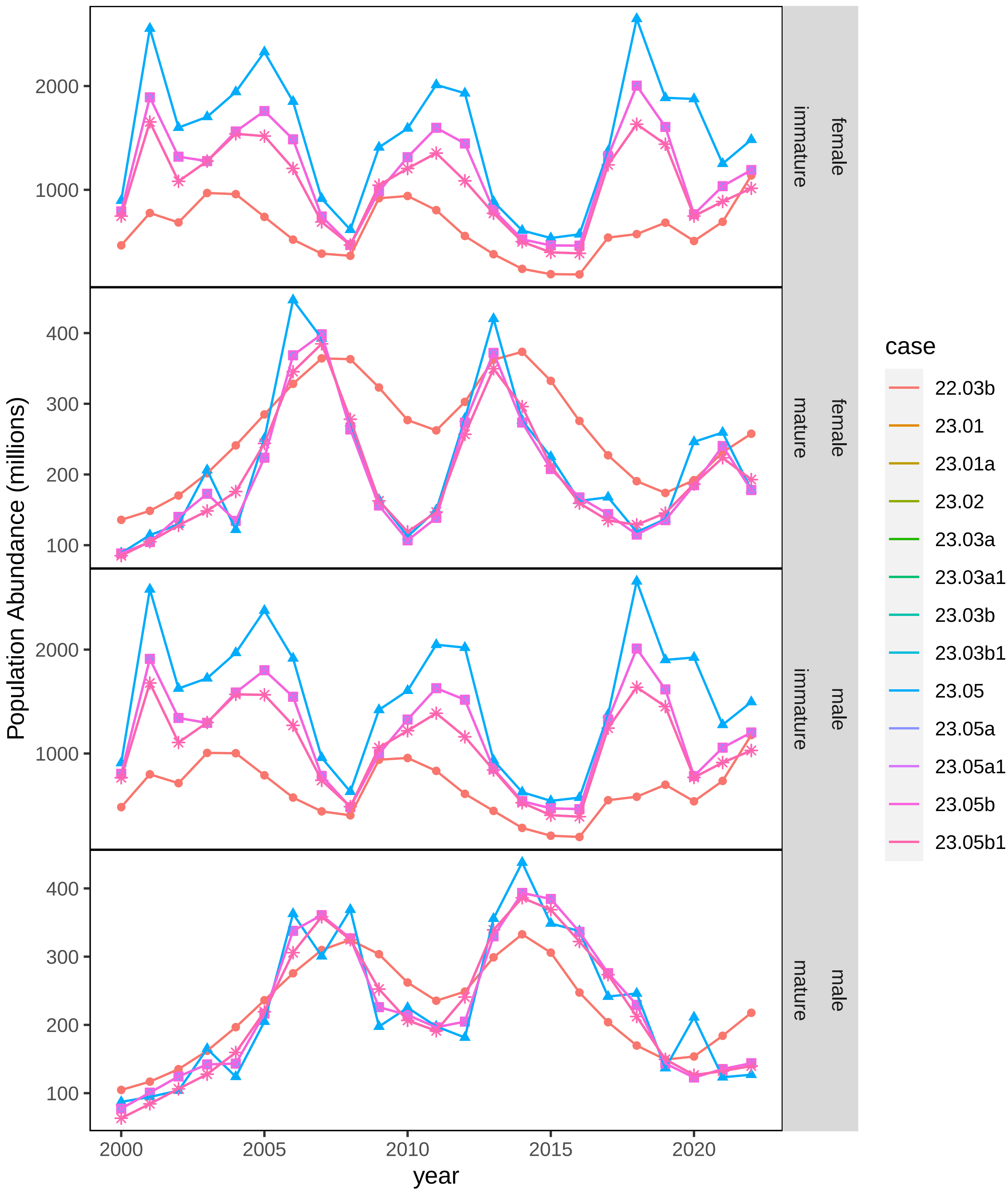

Figure 308. Estimated population abundance, recent time period. Note: y-axis scales differ between plots. Models22.03b, 23.05, 23.05a, 23.05a1, 23.05b, 23.05b1.

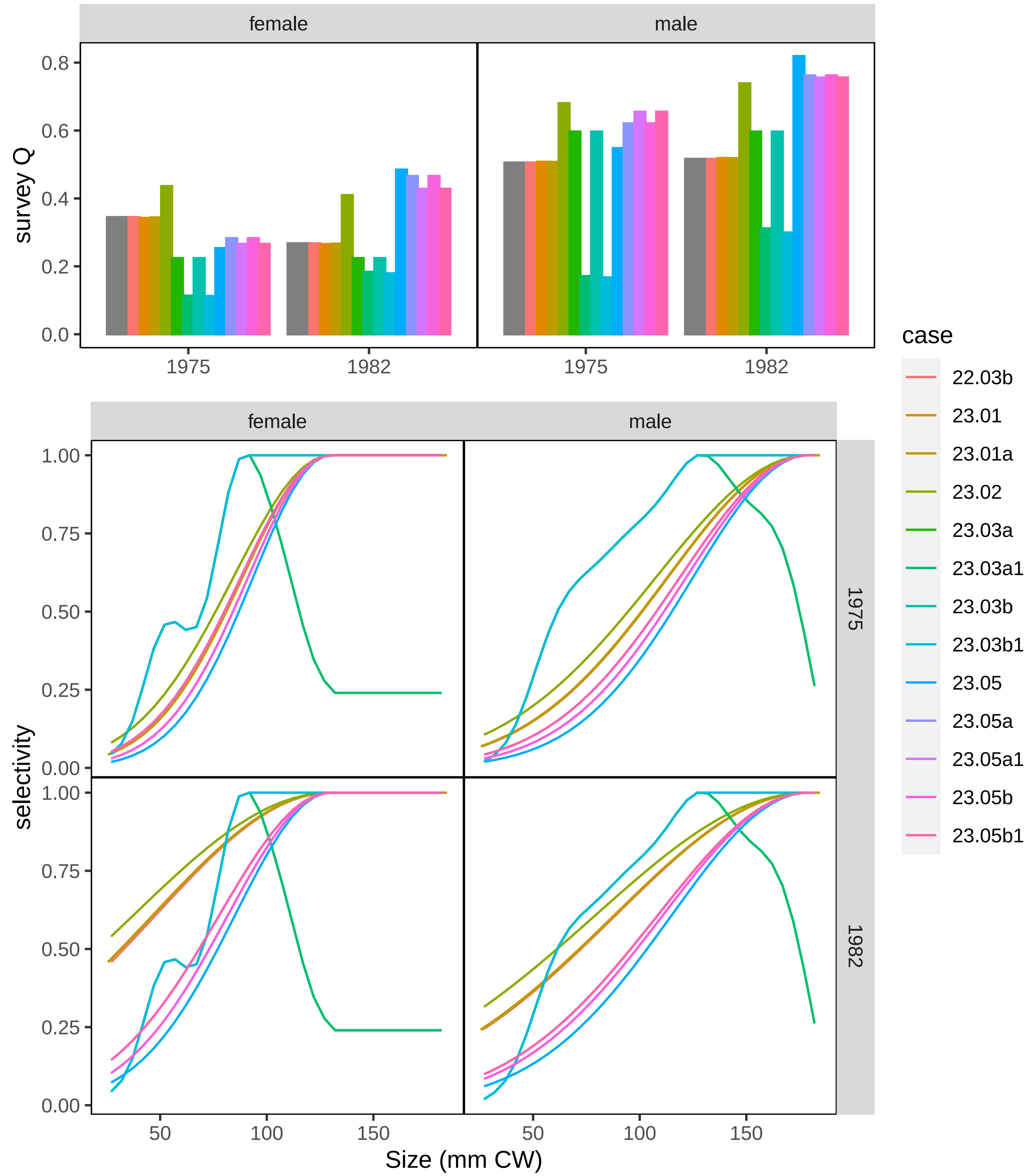

Figure 309. Estimated NMFS EBS Survey fully-selected catchability (survey Q's) and selectivity functions by sex for different time periods. 1975: 1975-1981; 1982: 1982-current.

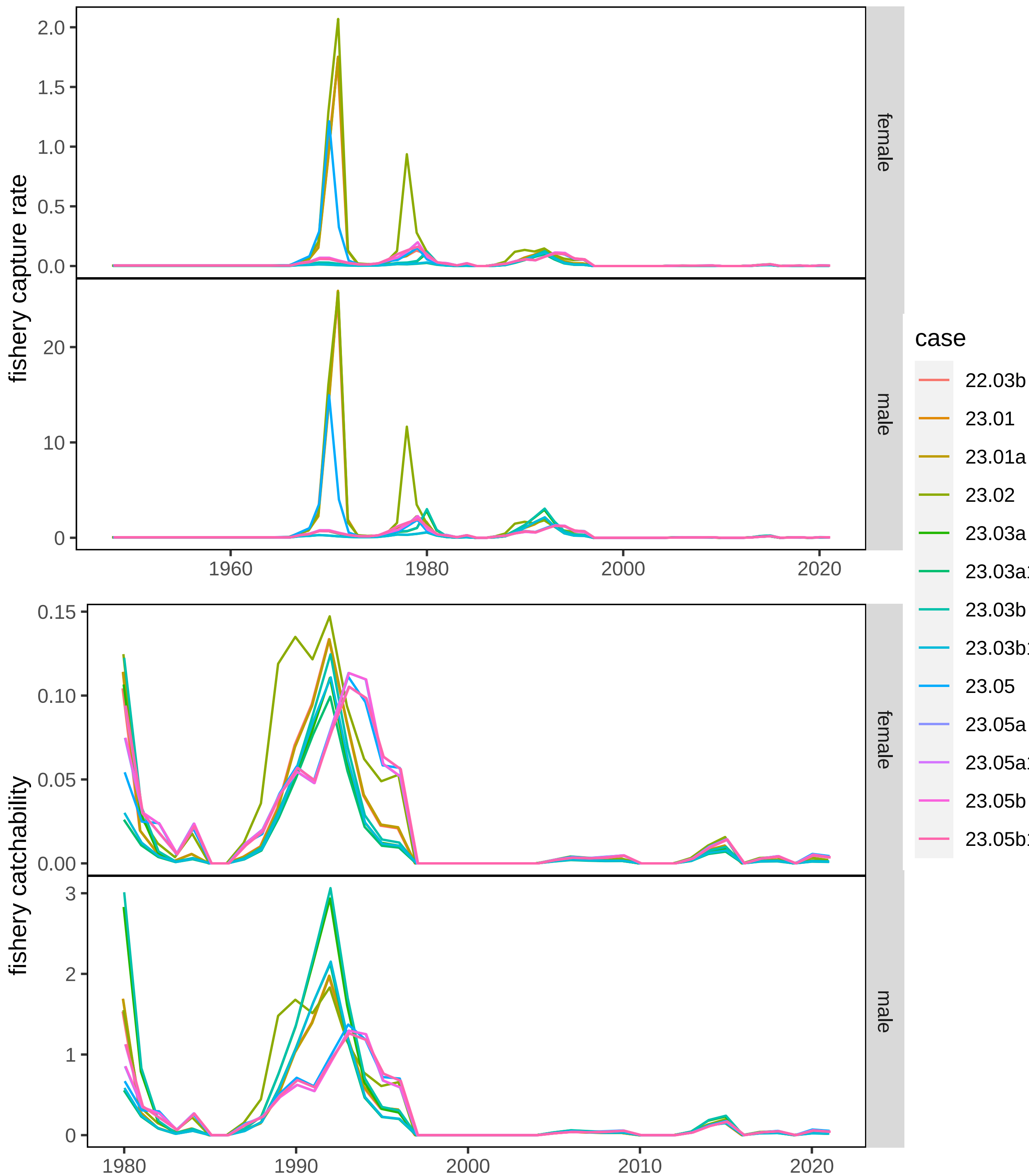

Figure 310. Estimated fully-selected capture rates (not mortality) in the directed fishery. The lower pair of plots show the estimated time series since 1980.

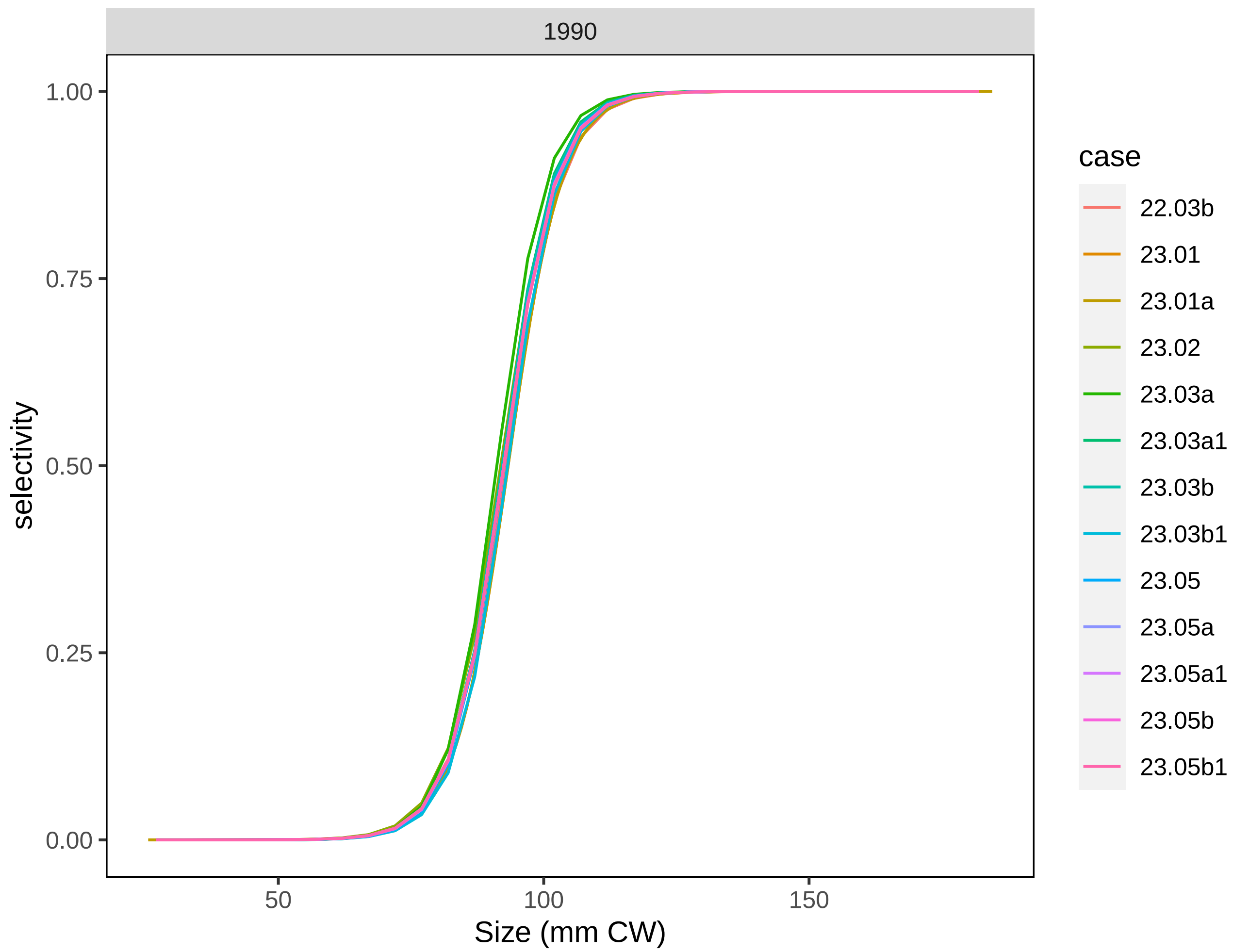

Figure 311. Estimated selectivity for females in the directed fishery for all years.

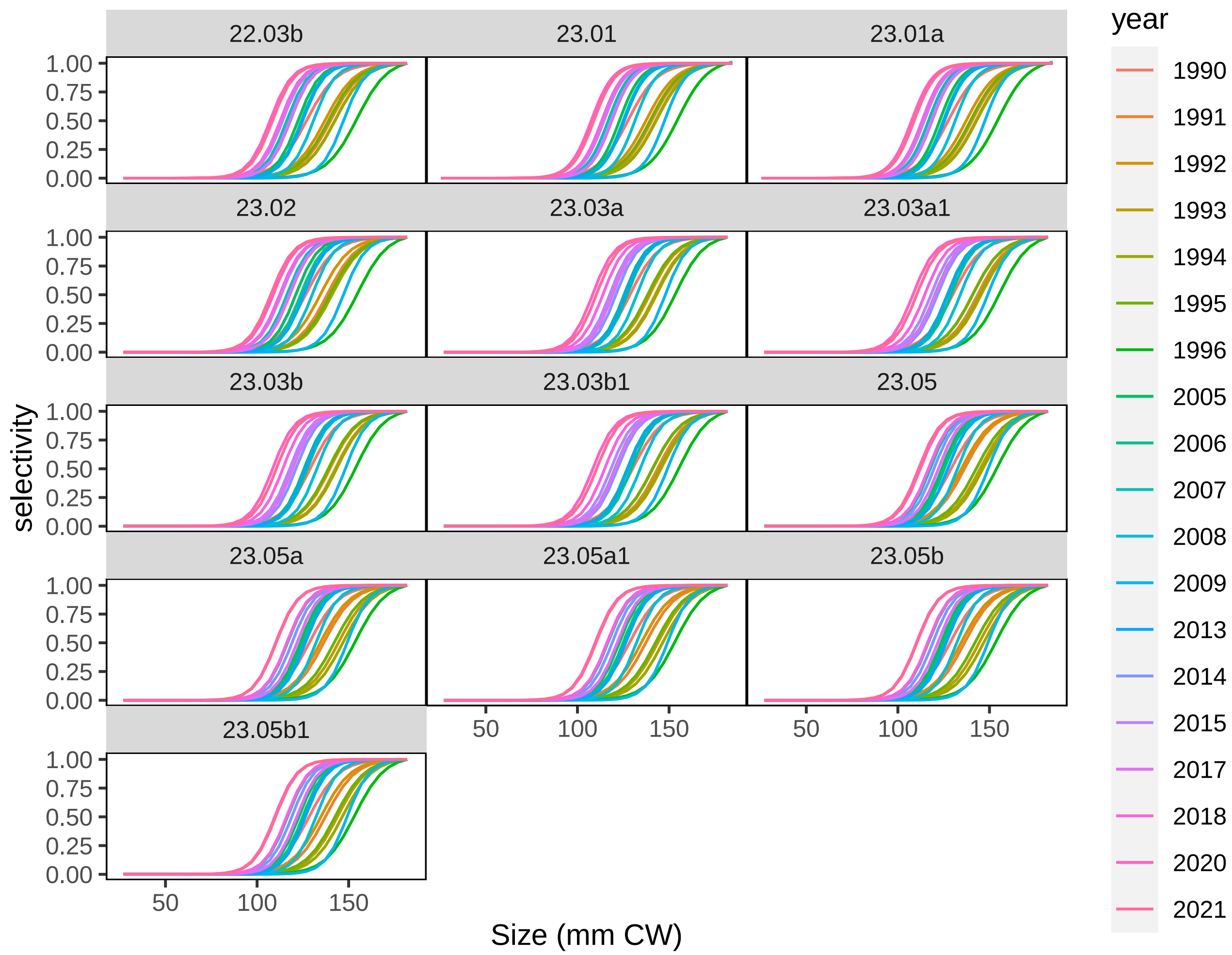

Figure 312. Estimated selectivity curves for males in the directed fishery, faceted by model scenario. Curves labeled 1990 applies to all years before 1991. Others apply in the year indicated in the legend.

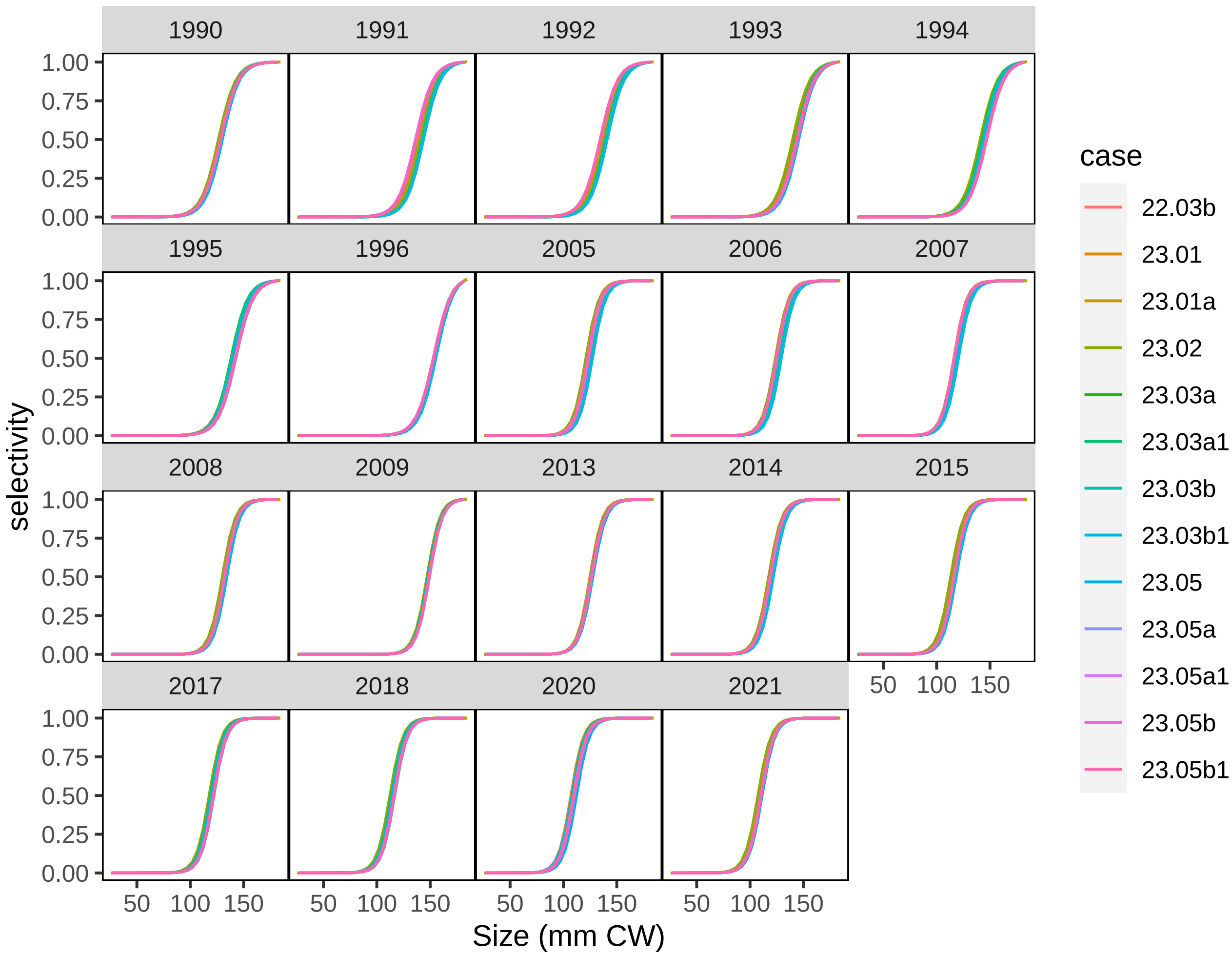

Figure 313. Estimated selectivity curves for males in the directed fishery by year. Curve labelled 1990 applies to all years before 1991. Others apply in the year indicated in the panel.

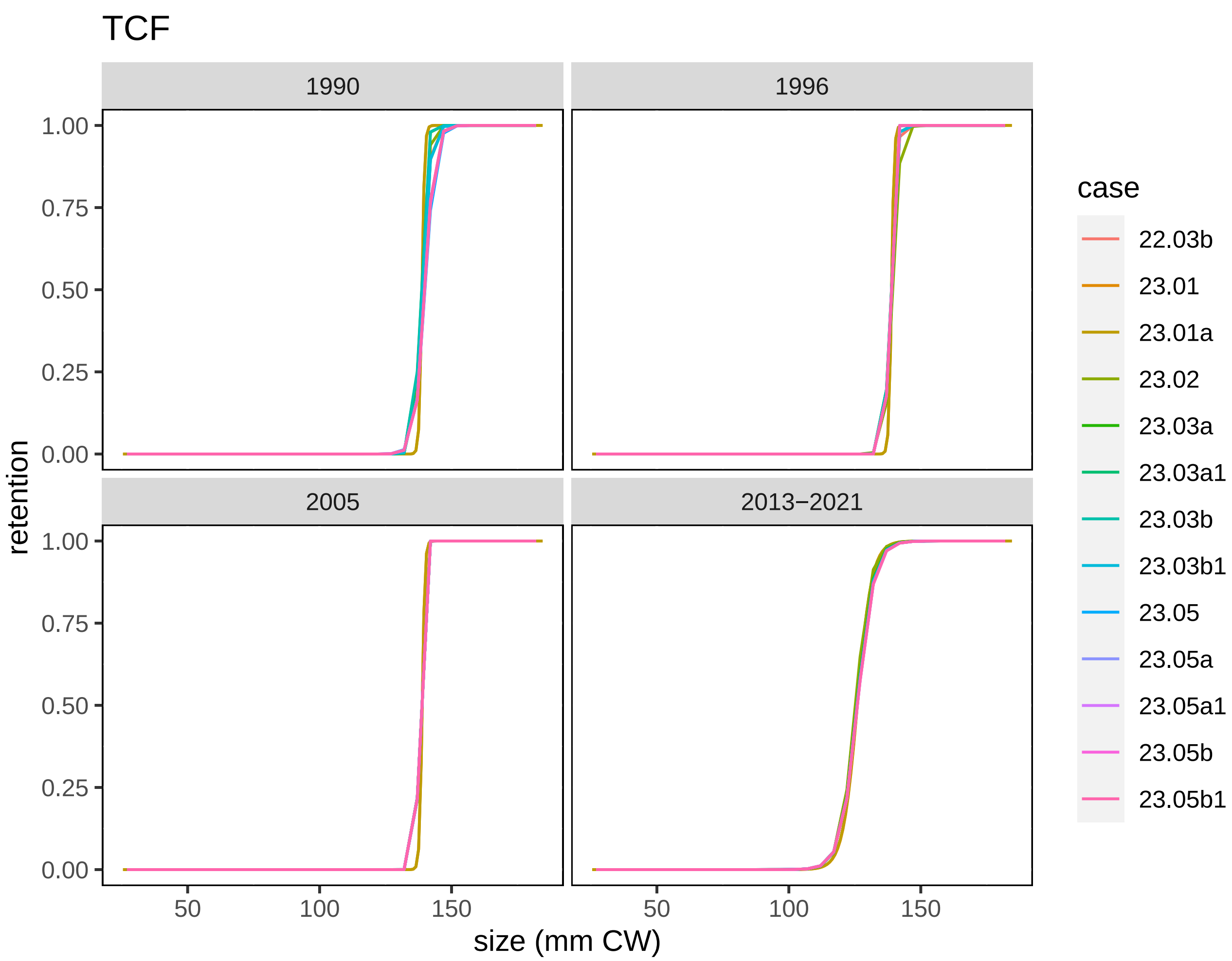

Figure 314. Estimated retention curves for males in the directed fishery by time block. Curve labelled: '1990' - applies to all years before 1991; '1996' - applies to 1991-2006; 2005 - applies to 2005-2009; '2013-2021' - applies to 2013-2021.

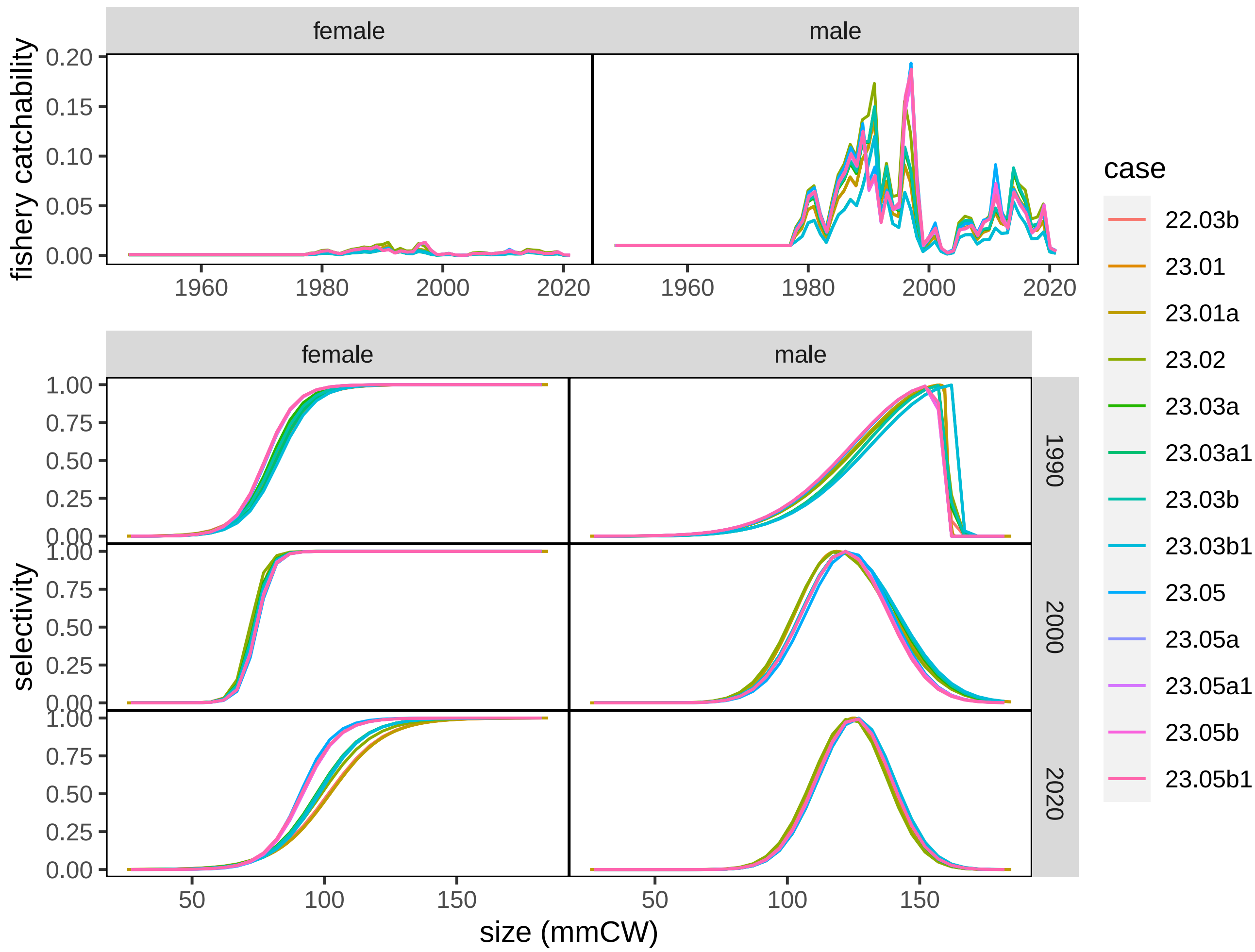

Figure 315. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the snow crab fishery (SCF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present.

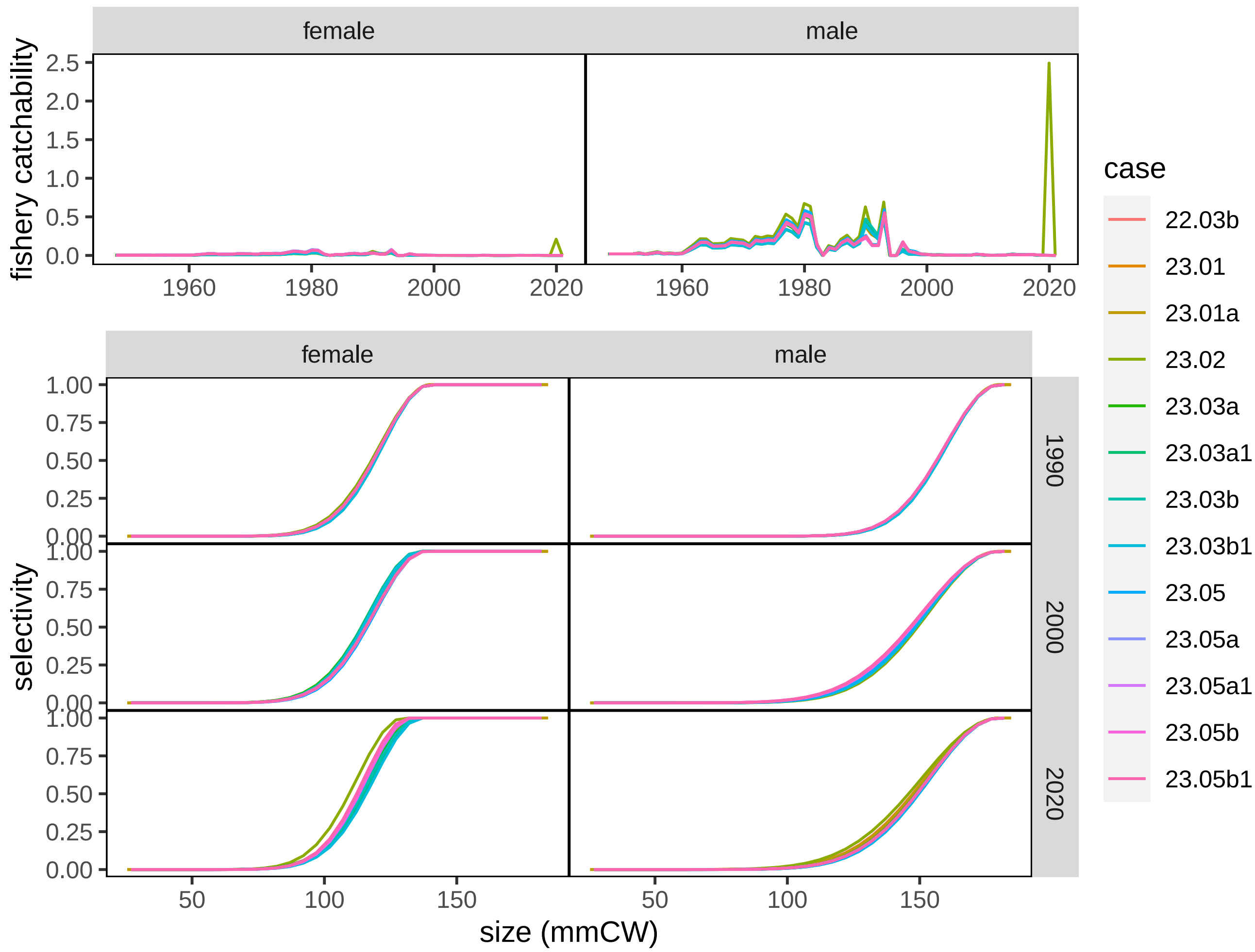

Figure 316. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the BBRKC fishery (RKF). Time blocks for selectivity functions are labelled: 1990) before 1997; 2000) 1997-2004; 2020) 2005-present.

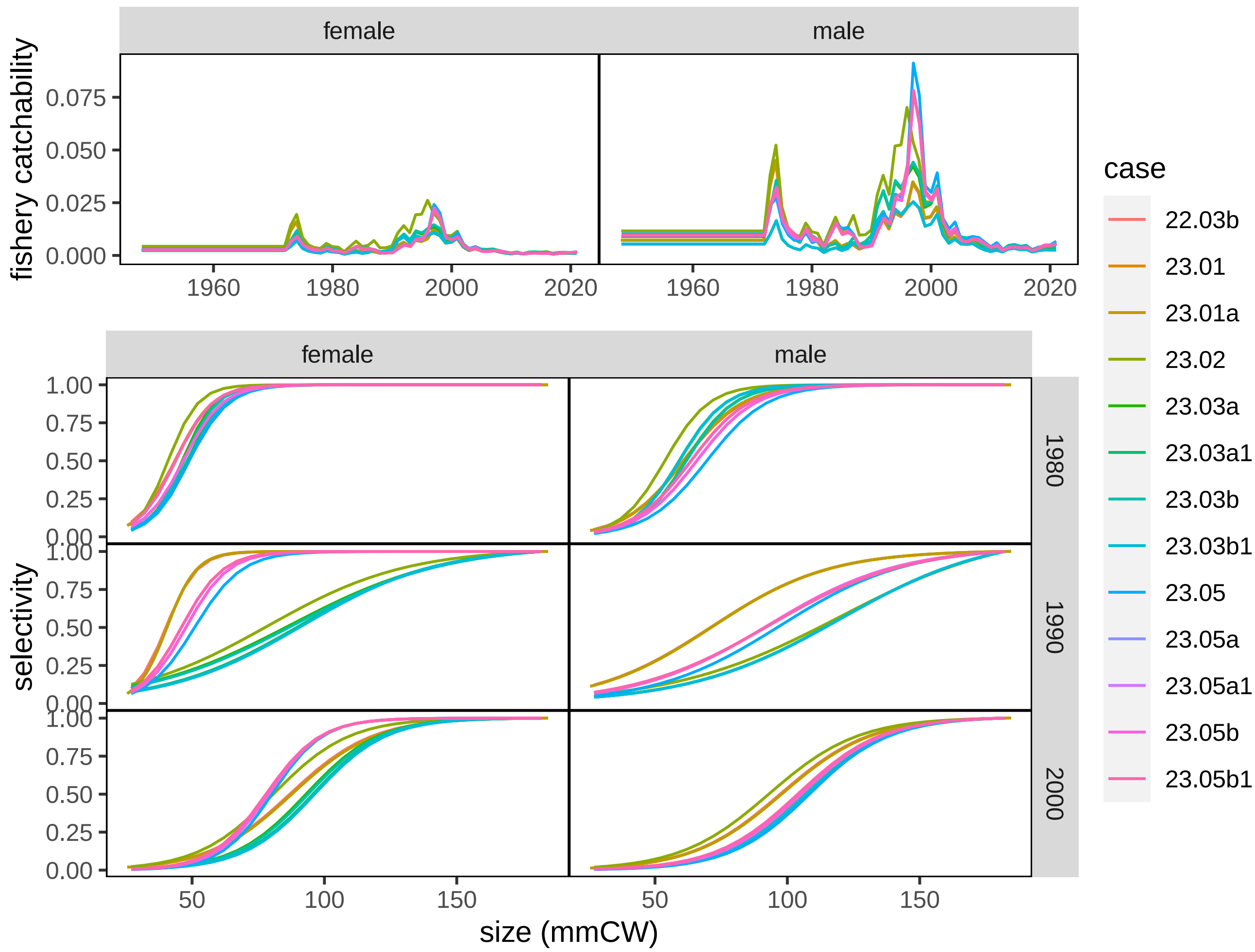

Figure 317. Estimated fully-selected bycatch capture rates (not mortality) and selectvity functions in the groundfish fisheries (GF All). Time blocks for selectivity functions are labelled: 1980) before 1988; 1990) 1987-1996; 2000) 1997-present.

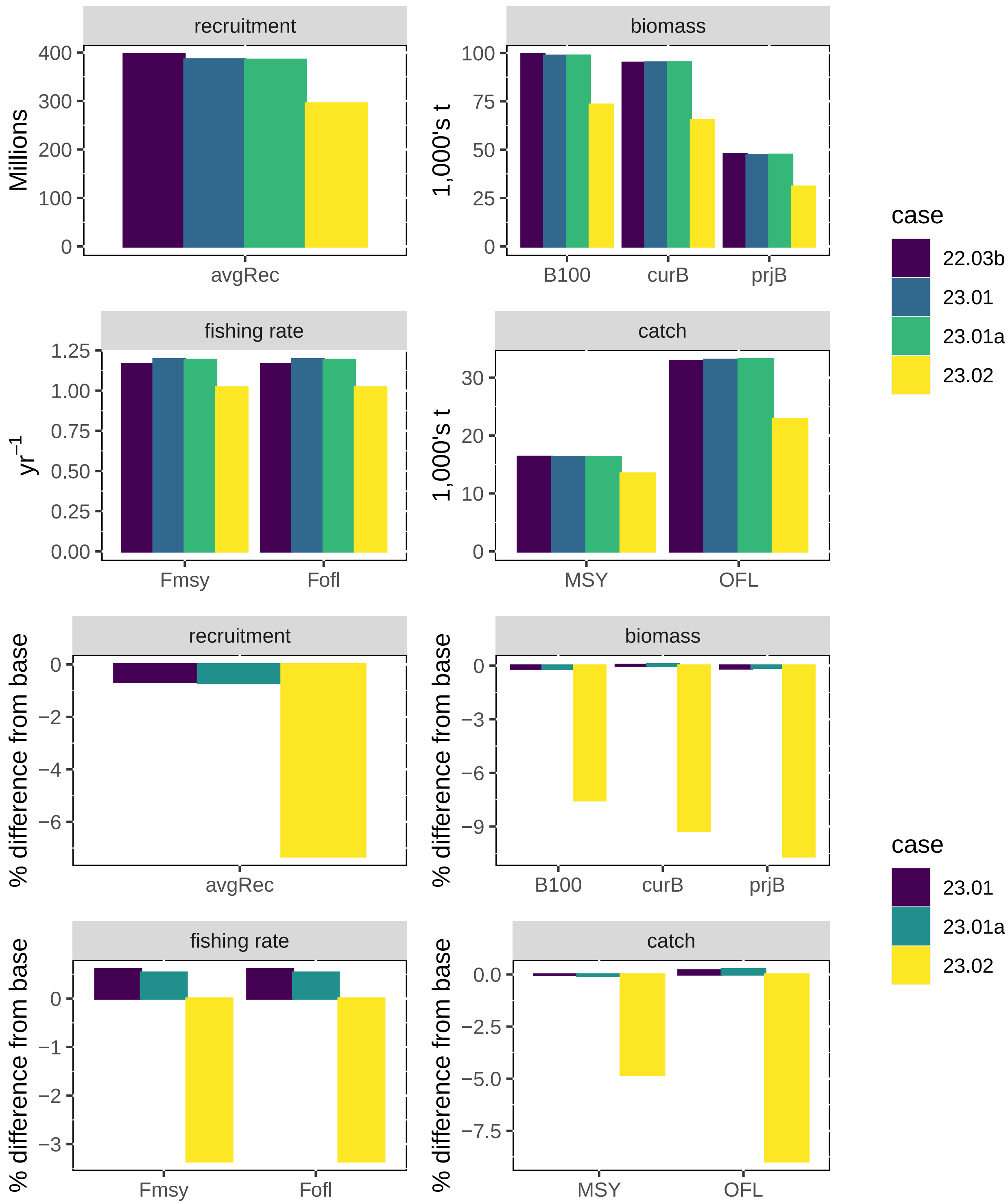

Figure 318. Upper: MLE-estimated management quantities. Lower: Differences from 22.03b.

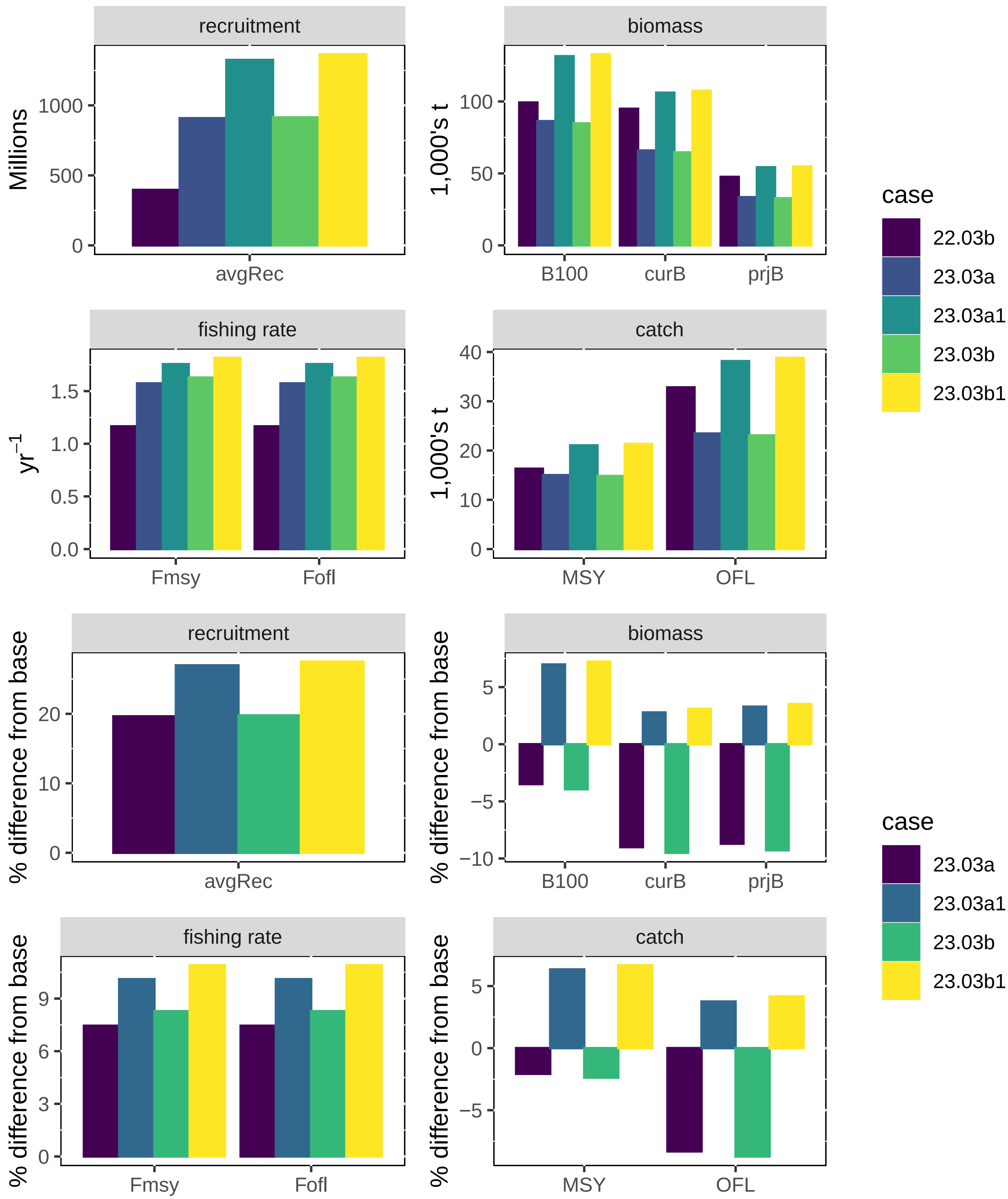

Figure 319. Upper: MLE-estimated management quantities. Lower: Differences from 22.03b.

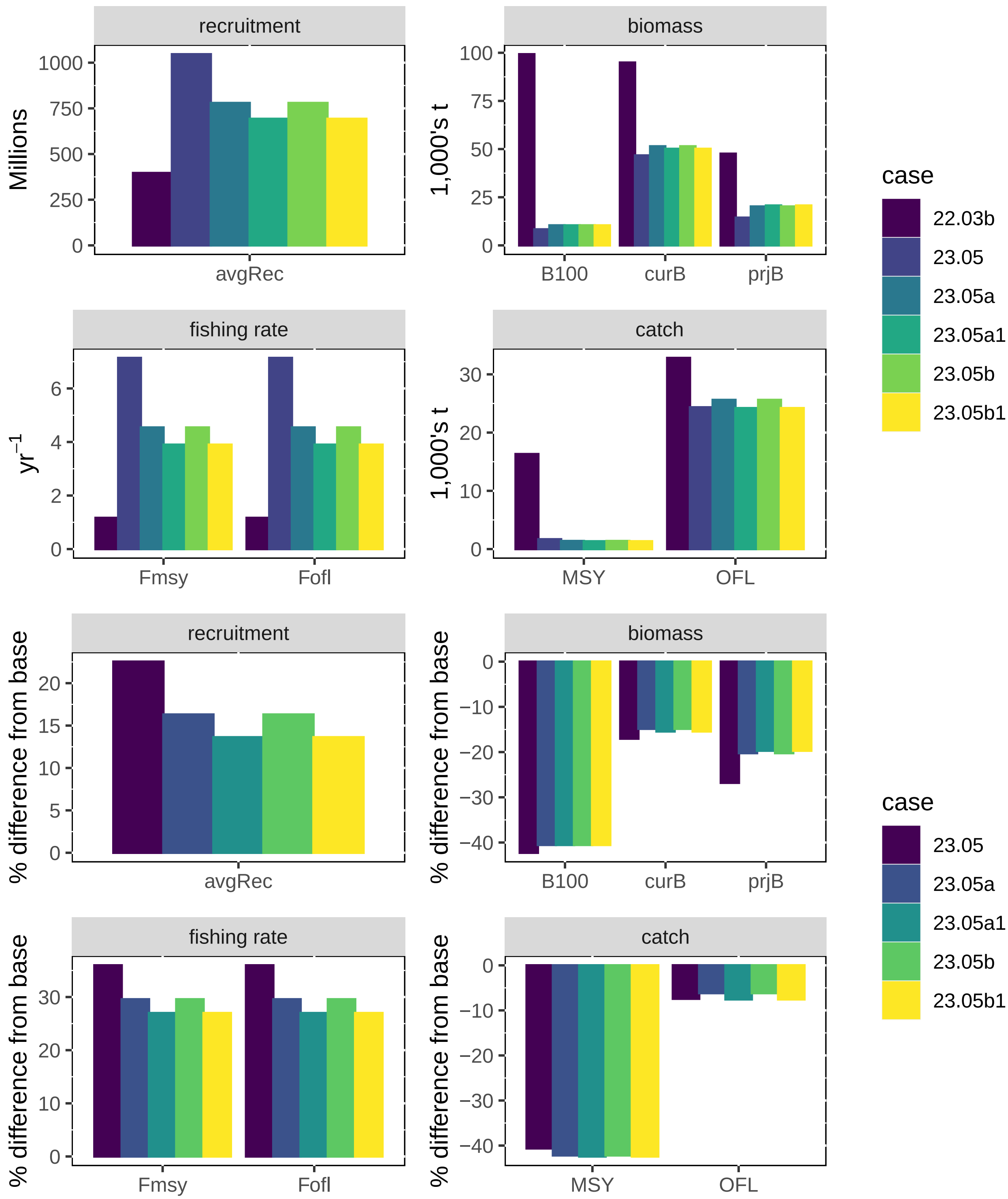

Figure 320. Upper: MLE-estimated management quantities. Lower: Differences from 22.03b.