Aleutian Islands Golden King Crab Stock Assessment Draft Models

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January 2024

Response to Comments

CPT May 2023

Comment: "*Continue work to obtain an index using the cooperative pot survey data for use in the EAG assessment model.*"

Response: Model 23.2 explores the utility of the pot survey as an additional fleet.

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Comment: "*Identify and eliminate the conflict between the model and the data giving rise to the retrospective patterns for EAG models. Revisit the analysis considering a model with time-varying catchability, but impose a penalty on the devs to allow the index data to inform the model.*"

Response: We will revisit time varying catchability in a future assessment cycle.

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Comment: "*Plot observed vs. predicted values for fitted data to help diagnose misfits.*"

Response: It's unclear what model process this is referring to. When applicable, observations are always plotted with fitted data in this document.

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Comment: "*Add confidence intervals to plots of fits to catch data (i.e., retained catch, total catch) reflecting assumed data uncertainty.*"

Response: All plots of catch and index data now include confidence intervals.

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Comment: "*Perform retrospective analyses for all models that have the potential to serve as the basis for calculating reference points.*"

Response: Retrospective analyses were performed for all EAG and WAG models, and presented for 22.1e2, 23.0a, 23.1, 23.1b, 23.2, and AI 23.1b.

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Comment: "*Calculate reference points using both combined-area and area-specific size-at-maturity values.*"

Response: This can be evaluated in May 2024, or during the next cycle in January.

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Comment: "*Re-evaluate the time frame over which to calculate mean recruitment every year by, for example, using a plot of the variance in estimated recruitment deviations.*"

Response: See plots below. Standard error of recruitment deviations increases steadily after 2017 in the EAG and after 2019 in the WAG. Though the rate of increase in the EAG in 2019 is greater than pre-2017, the standard error value is not greater than in the beginning of the reference period (1987 - 1988). Retrospective analysis of recruitment uncertainty may provide insight to the most appropriate lag from the terminal year, but it was not conducted here, since retrospective analysis in GMACS did not produce parameter standard errors. This could be re-evaluated in May by constructing retrospective runs manually.

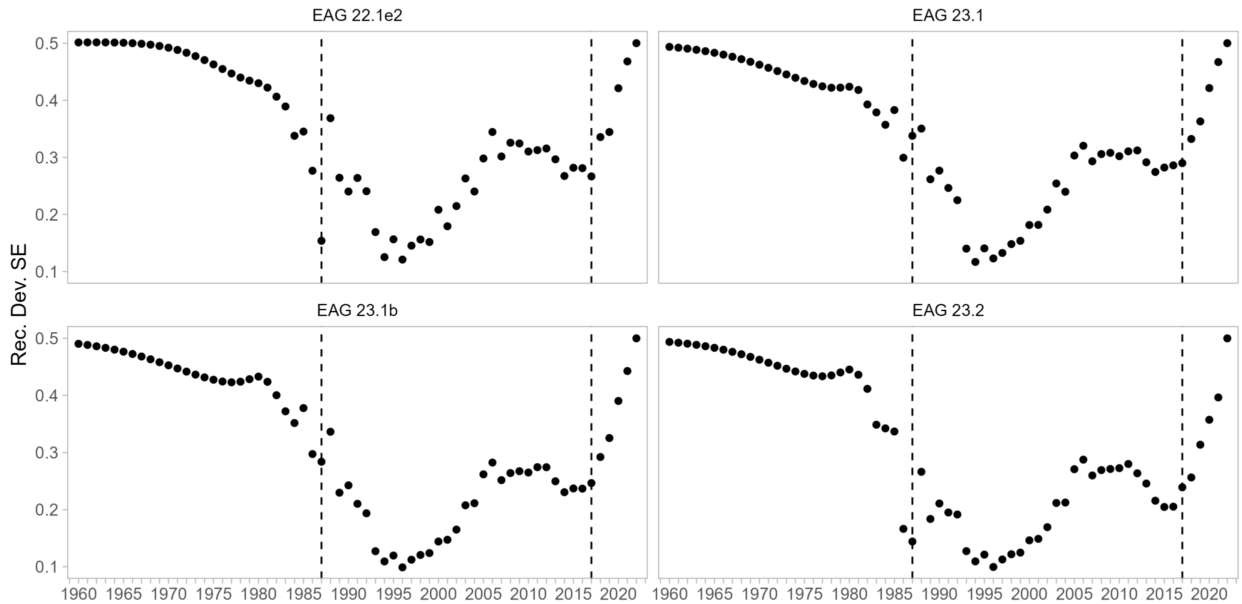

Figure 1: Standard errors of recruitment deviations of EAG models 22.1e2, 23.1, 23.1b, and 23.2. Dashed lines indicate bounds of time series used for calculation of mean recruitment.

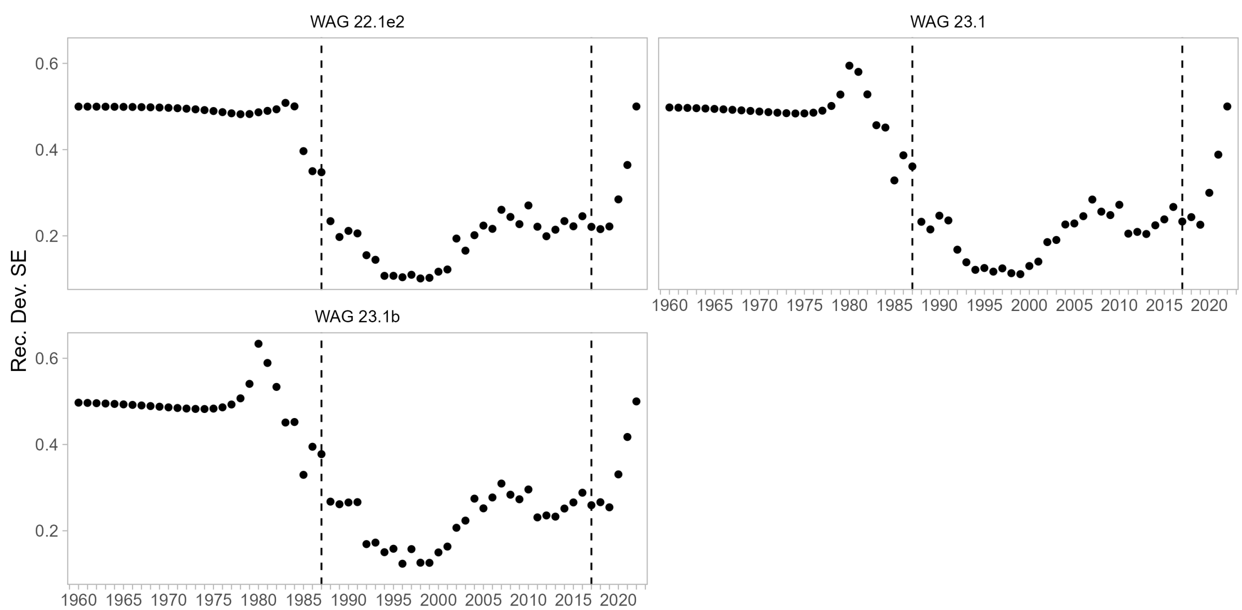

Figure 2: Standard errors of recruitment deviations of WAG models 22.1e2, 23.1, and 23.1b. Dashed lines indicate bounds of time series used for calculation of mean recruitment.

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Comment: "*Continue work to obtain an index using the cooperative pot survey data for use in the EAG* *assessment model.*"

Response: Analysis of the cooperative pot survey is detailed in Appendix C and model 23.2.

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Comment: "*The cooperative survey should be fit as an additional CPUE index, not substituted for existing indices as was done for models 22.1g and 22.1h.*"

Response: That is what has been explored here.

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Comment: "*Size-composition data should not include a "minus" group (i.e., crab smaller than the smallest size bin used in the model).*"

Response: This is rectified by model 23.1.

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Comment: "*The data used to determine the total catch size-compositions in the two areas should be re-examined to determine whether the abundances in the smallest size bin from 1990 to 2004 are correct.*"

Response: Appendix A recomputes size composition time series using data directly pulled from the observer database. Updated time series still appear to contain a disproportionate amount crab 101-105 mm CL, even without minus-sized crab (model 23.1). This is possibly do to escape mesh not being required until the 1997 season.

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Comment: "*Explore models that provide better fits to EAG CPUE data.*"

Response: More work in this area is needed during the next cycle.

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Comment: "*Use GAMs rather than GLMs to standardize the CPUE indices (e.g., use the R package "mgcv").*"

Response: All models derivative of 23.0a take this approach.

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Comment: "*Show both the original CV's and effective CV's (i.e., incorporating additional variance) when showing fits to the CPUE index time series.*"

Response: This has been done in all plots showing fits to CPUE index.

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Comment: "*In the SAFE document*

- *Add a note to explain that retained catch can exceed TAC in some years due to the cost recovery fishery associated with the cooperative survey.*
- *Drop Appendix D.*
- *Remove tier designation from area-specific management Table.*
- *Add explanation for extrapolation of total catch in final year"*

Response: All items will be addressed in the May 2024 SAFE document.

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SSC June 2023

Comment: "*The SSC agrees with the CPT recommendation for a 25% buffer for this assessment and supports the resulting ABC. For the future, the SSC specifically requests that jitter and retrospective analyses be conducted for all final models that have the potential to be used for setting harvest specifications*"

Response: Retrospective analyses were performed here, and jitter analysis will be performed on the author preferred model in the final assessment.

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Comment: "*The SSC places a high priority on incorporating information from the cooperative survey into the assessment and supports the CPT recommendation that this be incorporated as a separate fleet.*"

Response: Model 23.2 explores the utility of the pot survey as an additional fleet.

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Comment: "*Further examination of the retrospective pattern in terms of magnitude, direction and cause continues to be important.*"

Response: More work will be done to address the retrospective pattern in the EAG during the next cycle.

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Comment: "*Revisit the choice to maintain the recruitment years at 1987 – 2017 rather than successively adding recent years to the time series, as is done for other crab stocks.*"

Response: See response to similar comment above.

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Comment: "*The CPT recommended removing the data on the smallest size bin for the total catch prior to 2005/2006. The SSC requests first plotting these data and the model fit and providing further consideration of why these data may or may not be representative of the fishery at that time.*"

Response: For clarification, the CPT recommended to removed data on crab below the smallest size bin (i.e. $\leq$ 100 mm) that were being included in the 101-105 mm bin.

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Comment: "*The current method of projecting the remaining landings for the current incomplete season seems overly complicated and the SSC recommends that a more straightforward method for determining total catch be considered, such as basing it on the average fraction harvested to date.*"

Response: In May 2024, total catch will be determined using the effort required to achieve the TAC at current CPUE on the date when data were pulled. See Appendix A for details of total catch estimation.

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Comment: "*Further analysis and discussion of the retrospective pattern is needed to justify the size of the buffer used.*"

Response: This will be noted during the final assessment in May 2024.

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Modeling Approaches and Explorations, January 2024

This assessment adopted the GMACS modeling framework in 2023. GMACS version 2.01.I was used for the May 2023 assessment, and an updated version (2.01.M.02) is used here. Progress of GMACS development has been documented on the GitHub development site (GMACS-project).

Model explorations

Models explore in this document are:

- **22.1e2**: base model, accepted for specifications in May 2023;
- **22.1e2 (update)**: base model, implemented in GMACS version 2.01.M.02;
- **23.0**: 22.1e2 (update) with update catch and size composition time series (Appendix A);
- **23.0a**: 23.0 + GAM observer legal CPUE standardization;

- **23.1**: 23.0a + truncated size composition (i.e., first bin $\geq$ 101 - 105 mm);
- **23.1a**: 23.1 + number of sampling efforts as retained size composition effective sample size;
- **23.1b**: 23.1 + two selectivity periods in pre-rationalized directed fishery;
- **23.2 (EAG)**: 23.1b + cooperative survey as additional fleet (i.e., cpue + size composition).

Unless otherwise noted, all models were fit to data from both the EAG and WAG. A combined area model based on 23.1b was also explored (AI 23.1b). This model included three fleets: 1) the EAG directed fishery, 2) the WAG directed fishery, and 3) a combined groundfish bycatch fleet. GMACS data, control, and projection files for all models can be accessed here: Jan 2024 AIGKC Models.

Results

GMACS Update

Models 22.1e2 and 22.1e2 (update) evaluated sensitivities of the model to updates in GMACS. In both the EAG and WAG most likelihood components, terminal year MMB, $B_{35\%}$, and $F_{35\%}$ were identical between versions (to the 6th decimal place), though OFL was slightly different (Table 1 - 2).

Data Updates

Model 23.0 updated the time series of retained and total catch, groundfish fishery bycatch mortality, and directed fishery retained and total catch size compositions (Likelihood components are in Table 3 and 4). Time series updates were necessary to improve reproducibility of assessment inputs and align data summarization methods for other BSAI crab stocks. Details of time series updates are described in Appendix A. Models appeared to fit catches equally well for both subdistricts (Figure 3 - 4). Fits to fish ticket CPUE from 1985 - 1998 were better for model 23.0 in the EAG, though similar in the WAG. Neither model fit observer CPUE particularly well, except in the post-rationalized WAG since 2014 (Figure 5 - 6). There was very little difference among predicted size composition, and fit to total size composition in the WAG in 1993 was poor (Figure 7 - 10). Model 23.0 had marginally greater selectivity and was near linear in the pre-rationalized EAG (Figure 11 - 12). Greater selectivity in the pre-ration period of either subdistrict is likely due to the smallest size bin (101 - 105 mm) containing the minus group (CL $\leq$ 100 mm). Recruitment trends are similar, though model 23.0 did not predict an extreme spike in 1987 as model 22.1e2 did for the EAG (Figure 13 - 14). Estimated fishing mortality was slightly less that model 22.1e2 for much of the time series in the directed fishery, and tended to be larger in the groundfish bycatch fleet due to the use of expanded estimates (Figure 15 - 16). Model 23.0 estimated greater MMB since 1985 in the EAG, whereas the two models track more closely in the WAG (Figure 17 - 18). EAG management quantities suggested a similar stock status between models, though MMB at mating, and $B_{35\%}$, resulting in a slightly greater OFL (Table 6). MMB at mating in the WAG was similar among models, though $B_{35\%}$ was less for model 23.0. Resulting OFL in the WAG was similar among models (Table 7).

Model 23.0a replaced pre- and post-rationalized observer legal male CPUE index with an index standardized using general additive models (see Appendix B for details). Model 23.0a also updated 1985 - 1998 fish ticket CPUE using the data and standardization procedure described in Appendix B. Model 23.0 fit its 1985 - 1998 fish ticket CPUE index better than did model 23.0a in the EAG. Fits to fish ticket CPUE index in the WAG were adequate for both models 23.0 and 23.0a. Predicted observer CPUE indices were very similar between models in both the EAG and WAG (Figure 5 - 6). Difference in fits to catch and size composition data were negligible between models 23.0 and 23.0a in the EAG and WAG. Model 23.0a resulted in a marginally lower MMB throughout the time series in the EAG and since about 2000 in the WAG (Figure 17 - 18). Management quantities of model 23.0a were lower than model 23.0 in both subdistricts (Table 6 and 7).

Trunacted Size Composition

Model 23.1 truncated size composition data to remove the minus group (CL $\leq$ 100 mm) from the smallest size bin (CL = 101 - 105 mm). Fits to catch data are nearly identical among models 23.0a and 23.1 (Table 3 and 4; Figure 19 and 20). There were only minor differences among fits to CPUE indices in the EAG and the WAG and fits to EAG observer CPUE remained poor (Figure 21 and 22). Removing the minus improved fits to total size composition, especially pre-2000, and resulted in a more typical logistic selectivity (Figure 25 - 26, 30 - 31, 32 - 34). Model 23.1 also improved fits retained size composition in many years (Figure 23 - 24, 28 - 29). Recruitment highs and lows were slightly dampened in the EAG in model 23.1 compared with model 23.0a, while the trend remained largely the same. On the other hand, model 23.1 estimated larger recruitment pulses in the WAG in 1980 and 1985 than did model models 23.0a (Figure 35 - 36). Model 23.1 estimated greater fishing mortality throughout the time series in the EAG than model 23.0a, but not until 2004 in the WAG (Figure 37 - 38). As expected, model 23.1 estimated lower MMB than model 23.0a for the entire time series (Figure 39 - 40). Management quantities of models 23.1 were lower than model 23.0a in both subdistricts (Table 6 and 7).

Retained Size Composition $N_{\mathbf{eff}}$

Model 23.1a adjusted staged 1 sample sizes for retained catch size composition to reflect the amount of sampling effort. Fits to observer indices were marginally better than model 23.1, though the difference is negligible (Table 3 - 4; Figure 21 - 22). Fit to fish ticket CPUE was slightly worse from 1985-1990 (Table 3 - 4; Figure 21 - 22). Model 23.1a fit retained size composition data better than model 23.1 between 1988 - 1991 in both subdistricts, owing to considerably higher weight of those years in model 23.1a relative to 23.1 (Figure 23 - 24, 28 - 29). Recruitment closely aligned with model 23.1 except for an extreme decrease and subsequent spike in the EAG from 1983-1987, and much lower recruitment from 1980 - 1983 in the WAG (Figure 35 - 36). Estimated MMB was lower for model 23.1a from about 2000 to present in the EAG, and was slightly lower during the full time series in the WAG (Figure 39 - 40). Management quantities of model 23.1a were lower than model 23.1 in both subdistricts (Table 6 - 7). Revisiting size composition data weighting would likely be beneficial for resolving lack of fit to observer CPUE data in the EAG, though with more forethought than model 23.1a. Basing effective sampling size on observation error in size composition data (Stewart and Hamel 2014) would be a good avenue for further exploration.

Additional Selectivity Period

Model 23.1b split the pre-rationalized period into two selectivity periods (1960 - 1996 and 1997 - 2004) corresponding to the introduction of escape mesh by requirements beginning with the 1997 season under 5 AAC 34.625(b)(1). Model 23.1b fit total catch in the WAG better than model 23.1 (Table 3 - 4; Figure 20). There were marginal improvement to fits to post-rationalized CPUE and fish ticket CPUE from 1985 - 1998. As with the EAG, there was small improvement to fits to CPUE data in the WAG, but for the pre-rationalized period and fish ticket CPUE from 1985 - 1998 (Figure 21 - 22). Model 23.1b fit retained and total catch size composition better than model 23.1 in the EAG, but only improved fit to retained catch size composition in the WAG (Figure 23 - 31). Poorer fit to WAG total size composition appears to be due in large part to 1993, 1994, and 1997 (Figure 30 - 31). Directed fishery selectivity from 1997 - 2004 was more similar to the post-rationalized period than pre-1997 (Figure 32 - 34).

Recruitment variability during the pre-rationalized period is more attenuated in model 23.1 than model 23.1b (Figure 35 - 36). Differences in MMB between models 23.1 and 23.1b were minor throughout the time series, though sightly more apparent in the WAG (Figure 39 - 40). References points were similar between models 23.1 and 23.1b in the EAG (Table 6 - 7). Model 23.1b estimated a slightly larger $B_{35\%}$ and resulting OFL in the WAG (Table 7).

Cooperative Survey

Model 23.2 evaluated the EAG cooperative pot survey as additional survey fleet with an abundance index and size composition time series from 2015 - 2022 (Likelihood components are in Table 3). Fits to catch and observer CPUE time series were similar to model 23.1b (Figure 19 and 21). Fit to fish ticket CPUE from 1985 - 1998 was slightly worse. Model 23.2 fit approximately the average cooperative survey CPUE, and did not have quite the same increasing trend in predicted CPUE as observer data did in the same years (Figure 21). Model 23.2 fit retained catch size composition better than model 23.1b, but not total catch size composition (Figure 23 - 26). Fits to cooperative survey size composition were generally adequate in most years (the dominant cohort was under-predicted and skewed in 2018; Figure 27). Cooperative survey selectivity appeared similar to post-rationalized fishery selectivity (Figure 33). Model 23.2 estimated larger recruitment swings in 1985 and 1987, though followed recruitment of model 23.1b throughout much of the time series. Model 23.2 also estimated a decrease in recruitment from 2015 - 2016 (as opposed to an increase in model 23.1b) and a larger decrease from 2018 - 2020 (Figure 35). Estimated MMB was similar to model 23.1b until 2015, when model 23.2 estimated slightly less but followed the same trend (Figure 39). Projected MMB was lower in model 23.2 than model 23.1b and less than $B_{35\%}$, resulting in a lower OFL (Table 6).

Combined Area Model

Model AI 23.1b evaluated EAG and WAG version of model 23.1b combined as a single model with three fleets: 1) the EAG directed fishery, 2) the WAG directed fishery, and 3) a combined groundfish bycatch fleet (Likelihood components are in Table 5). Fits to catches were very similar among single and combine area models (Figure 41). Single area models fit CPUE data better than did AI 23.1b, with the exception of pre-rationalized observer CPUE (Figure 42). Model AI 23.1b estimated three selectivity periods for the EAG and WAG fisheries each. Selectivity was slightly lower than in EAG 23.1b among all periods, but higher than in WAG 23.1b (Figure 47). Fishing mortality was considerably lower throughout the time series in model AI 23.1b that in single area models (Figure 49). Recruitment generally followed the sum of single area recruitment estimates, but declined after a relative peak in 2013, similar to WAG 23.1b (Figure 48). Estimated MMB was very similar to the sum of single area model MMB estimates until 2017, and then decreased, perhaps following a better fit to observer CPUE in the EAG during that period (Figure 50). Model AI 23.1b estimated $B_{35\%}$ slightly larger than the sum of single area models. Mean recruitment during the reference period (1987 - 2017) was approximately the sum of estimated for single area models. Projected MMB was less than the sum of single area models, resulting in a lower stock status, F35%, and OFL (Table 8).

Retrospective Analysis

Retrospective analysis was performed by peeling up to ten years data for all models, but results are only discussed here for models 22.1e2, 23.0a, 23.1, 23.1b, and 23.2. Retrospective analysis of model 23.2 only peeled up to five years of data (to beginning of cooperative survey time series). EAG models 22.1e2 - 23.1b had similar retrospective patterns, tending to over estimate MMB in the terminal year relative to the full time series model. Retrospective bias increased with each model scenario (Mohn's ρ = 0.327 - 0.432; Figure 51). Model 23.2 had less of a retrospective pattern that other EAG models and did not tend to overestimate MMB until there were only two years of survey data remaining (Mohn's ρ = 0.157; Figure 52). WAG models also had similar retrospective patterns, though with smaller bias (Mohn's ρ = 0.152 - 0.183; Figure 53). Several peels for WAG models 22.1e2, 23.0a, and 23.1 had spikes in MMB around 1992 - 1996, which is likely owing to an issue of multiple local minima relating to the skewed total size composition data in 1993. The combined area model had a retrospective pattern in MMB more similar to WAG models, with comparable bias (Mohn's ρ = 0.156; Figure 54).

Conclusions

The author recommended models to be evaluated in the final assessment are models 23.1, 23.1b, and 23.2. These models use updated time series data, best capture the nuance of gear modifications, and evaluate use of the cooperative survey. The transition from the 2022 accepted model (22.1e2) to models 23.0 and 23.0a represent a necessary improvement to the transparency and reproducibility of this assessment, and model 22.1e2 should be evaluated solely for the purpose of comparison. Regardless of whether the CPT recommends the proposed methods for summarizing input data (Appendix A) or the use of GAMs for CPUE standardization (Appendix B), data inputs to model 22.1e2 cannot be reproduced as the raw data are not identical to fresh database pulls. Models 23.1 and 23.1b improve overall fit to size composition data with only minor change to fits to index data. None of the models evaluated here were able to resolve poor fits to observer CPUE data, particularly in the EAG. Poor fit to index data is likely due to the nature of relying on fishery dependent data, specifically the inability of CPUE standardization procedures to fully capture inter-annual differences in catchability and the conflict that causes with size composition data. Lack of fit to the post-rationalized observer CPUE also likely drives the greater retrospective bias of EAG models compared to WAG models.

Introducing the cooperative survey as an additional fleet (model 23.2) had relatively little impact on other model processes, though resulted in larger recruitment swings, higher recent fishing mortality, lower MMB, and lower management quantities. Treating the cooperative survey as a fishery independent survey is a step in the right direction, though more investigation is warranted, specifically with respect to data weighting.

The combined area model (AI 23.1b) estimated derived quantities that were similar to the sum of single are models (until 2017), but tended not to fit individual processes quite as well as subdistrict specific models. Interestingly, model AI 23.1b fit recent EAG observer CPUE considerably better than EAG 23.1b, which didn't respect the prevailing trend of observed data. This disparity may partly explain the departure in MMB of AI 23.1b from the sum of EAG and WAG models. Using a combined area model would have a large impact on management quantities, as the stock status was lower than either subdistrict specific model. Siddeek et al. (2023) evaluated a combined area model that merged EAG and WAG as a single fleet and estimated a similar $B_{35\%}$, but greater 2022 MMB, consistent with known retrospective bias. Given the poorer fits to various model processes compared with separate models, it may be best that a combined area model be set aside until a spatially explicit GMACS framework is developed.

Tables

Table 1: Comparison of likelihood components for EAG and WAG models 22.1e2 using GMACS version 2.01.I and 2.01.M2.

	EAG		WAG	
Component	v2.01.I	v2.02.M2	v2.01.I	v2.02.M2
Catch data	-436.540	-436.540	-375.988	-375.988
Index data	-42.975	-42.975	-58.234	-58.234
Size data	928.878	928.878	798.238	798.238
Stock recruitment	20.380	20.380	19.584	19.584
Tagging data	2,699.021	2,699.021	2,705.586	2,705.586
Penalties	0.037	0.037	0.069	0.069
Priors	25.724	25.724	25.031	25.724
Total	3,194.526	3,194.526	3,114.286	3,114.980

Table 2: Comparison of management quantities for EAG and WAG models 22.1e2 using GMACS version 2.01.I and 2.01.M2.

Subdistrict	Version	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
EAG	v2.01.I	7,584	6,651	1.14	2,611	0.57	0.57	2,882
	v2.01.M2	7,584	6,651	1.14	2,611	0.57	0.57	2,861
WAG	v2.01.I	4,572	4,979	0.92	1,977	0.55	0.50	1,242
	v2.01.M2	4,572	4,979	0.92	1,977	0.55	0.50	1,232

Subdistrict	Version	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
EAG	v2.01.I	16.72	14.66	1.14	2,611	0.57	0.57	6.35
	v2.01.M2	16.72	14.66	1.14	2,611	0.57	0.57	6.31
WAG	v2.01.I	10.08	10.98	0.92	1,977	0.55	0.50	2.74
	v2.01.M2	10.08	10.98	0.92	1,977	0.55	0.50	2.72

Table 3: Likelihood components for prospective EAG models.

Component	22.1e2	23.0	23.0a	23.1	23.1a	23.1b	23.2
Retained catch	-422.553	-424.817	-424.873	-424.707	-424.627	-424.526	-424.438
Total catch	-44.311	-66.540	-66.365	-66.097	-64.693	-65.835	-64.767
Groundfish Bycatch	30.325	29.423	29.425	29.421	29.422	29.418	29.423
Obs CPUE 1995 - 2004	-10.433	-9.548	-9.212	-8.124	-8.773	-8.204	-8.600
Obs CPUE 2004 - 2022	-17.471	-16.984	-16.898	-16.367	-17.532	-14.496	-14.374
FT CPUE 1985 - 1998	-15.071	-25.330	-16.613	-16.430	-13.849	-12.863	-11.169
Survey CPUE							-4.195
Retained size comp.	299.593	518.572	501.459	445.238	395.111	357.201	324.606
Total size comp.	629.285	530.996	542.878	428.854	440.385	228.191	250.629
Survey size comp.							104.115
Stock recruitment	20.380	19.453	19.394	19.048	19.575	20.304	21.349
Tagging data	2,699.021	2,698.581	2,698.296	2,694.676	2,696.111	2,694.830	2,696.471
Penalties	0.037	0.141	0.141	0.140	0.142	0.139	0.142
Priors	25.724	25.724	25.724	25.724	25.724	33.730	35.745
Total	3,194.526	3,279.672	3,283.356	3,111.378	3,076.997	2,837.889	2,934.938

*Not all models use the same data (see above for details).

Table 4: Likelihood components for prospective WAG models.

Component	22.1e2	23.0	23.0a	23.1	23.1a	23.1b
Retained catch	-420.433	-422.721	-422.516	-422.031	-421.843	-423.483
Total catch	14.119	-47.101	-47.070	-40.776	-36.965	-58.083
Groundfish Bycatch	30.326	28.488	28.488	28.489	28.489	28.488
Obs CPUE 1995 - 2004	-10.019	-9.148	-7.899	-8.120	-8.230	-10.689
Obs CPUE 2004 - 2022	-28.376	-31.074	-32.845	-32.803	-32.992	-32.415
FT CPUE 1985 - 1998	-19.839	-19.246	-18.198	-18.531	-17.684	-19.538
Retained size comp.	363.282	532.102	534.253	484.522	538.464	446.098
Total size comp.	434.956	412.726	409.554	274.943	250.332	356.137
Stock recruitment	19.584	19.716	20.619	20.780	20.256	22.173
Tagging data	2,705.586	2,699.875	2,700.526	2,698.487	2,700.309	2,694.503
Penalties	0.069	0.062	0.063	0.062	0.065	0.062
Priors	25.724	25.724	25.724	25.724	25.724	33.730
Total	3,114.980	3,189.404	3,190.699	3,010.747	3,045.926	3,036.982

*Not all models use the same data (see above for details).

Table 5: Likelihood components for models AI 23.1b, EAG 23.1b, and WAG 23.1b.

Component	AI 23.1b	EAG 23.1b	WAG 23.1b
EAG retained catch	-423.052	-424.526	
EAG total catch	-55.941	-65.835	
WAG retained catch	-423.248		-423.483
WAG total catch	-55.193		-58.083
Groundfish bycatch	30.366	29.418	28.488
EAG obs CPUE 1995-2004	-10.378	-8.204	
EAG obs CPUE 2005-2022	-11.813	-14.496	
EAG FT CPUE 1985 - 1998	-12.638	-12.863	
WAG obs CPUE 1995-2004	-8.178		-10.689
WAG obs CPUE 2005-2022	-31.209		-32.415
WAG FT CPUE 1985 - 1998	-14.384		-19.538
EAG retained size comp	450.031	357.201	
EAG total size comp	461.950	228.191	
WAG retained size comp	520.423		446.098
WAG total size comp	451.716		356.137
Stock recruitment	18.951	20.304	22.173
Tagging data	2,695.982	2,694.830	2,694.503
Penalties	0.141	0.139	0.062
Priors	48.474	33.730	33.730
Total	3,632.002	2,837.889	3,036.982

Table 6: Comparison of management quantities for EAG prospective models.

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
22.1e2	7,584	6,651	1.14	2,611	0.57	0.57	2,861
23.0	7,976	6,966	1.14	2,754	0.55	0.55	3,131
23.0a	7,767	6,877	1.13	2,716	0.56	0.56	3,012
23.1	7,524	6,713	1.12	2,701	0.55	0.55	2,841
23.1a	7,296	6,679	1.09	2,674	0.55	0.55	2,688
23.1b	7,251	6,788	1.07	2,748	0.59	0.59	2,837
23.2	6,192	6,786	0.91	2,735	0.59	0.54	2,182

Model	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
22.1e2	16.72	14.66	1.14	2,611	0.57	0.57	6.31
23.0	17.58	15.36	1.14	2,754	0.55	0.55	6.90
23.0a	17.12	15.16	1.13	2,716	0.56	0.56	6.64
23.1	16.59	14.80	1.12	2,701	0.55	0.55	6.26
23.1a	16.08	14.72	1.09	2,674	0.55	0.55	5.93
23.1b	15.99	14.97	1.07	2,748	0.59	0.59	6.25
23.2	13.65	14.96	0.91	2,735	0.59	0.54	4.81

Table 7: Comparison of management quantities for WAG prospective models.

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
22.1e2	4,572	4,979	0.92	1,977	0.55	0.50	1,232
23.0	4,556	4,780	0.95	1,905	0.54	0.51	1,268
23.0a	4,256	4,721	0.90	1,879	0.54	0.48	1,078
23.1	4,193	4,661	0.90	1,876	0.54	0.48	1,031
23.1a	4,171	4,661	0.89	1,869	0.55	0.48	1,000
23.1b	4,388	4,763	0.92	1,933	0.54	0.50	1,127

Model	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
22.1e2	10.08	10.98	0.92	1,977	0.55	0.50	2.72
23.0	10.04	10.54	0.95	1,905	0.54	0.51	2.80
23.0a	9.38	10.41	0.90	1,879	0.54	0.48	2.38
23.1	9.24	10.28	0.90	1,876	0.54	0.48	2.27
23.1a	9.20	10.28	0.89	1,869	0.55	0.48	2.20
23.1b	9.67	10.50	0.92	1,933	0.54	0.50	2.48

Table 8: Comparison of management quantities for EAG 23.1b, WAG 23.1b, and AI 23.1b.

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
AI 23.1b	9,917	11,516	0.86	4,676	0.37	0.31	2,562
EAG 23.1b	7,251	6,788	1.07	2,748	0.59	0.59	2,837
WAG 23.1b	4,388	4,763	0.92	1,933	0.54	0.50	1,127

Model	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
AI 23.1b	21.86	25.39	0.86	4,676	0.37	0.31	5.65
EAG 23.1b	15.99	14.97	1.07	2,748	0.59	0.59	6.25
WAG 23.1b	9.67	10.50	0.92	1,933	0.54	0.50	2.48

Figures

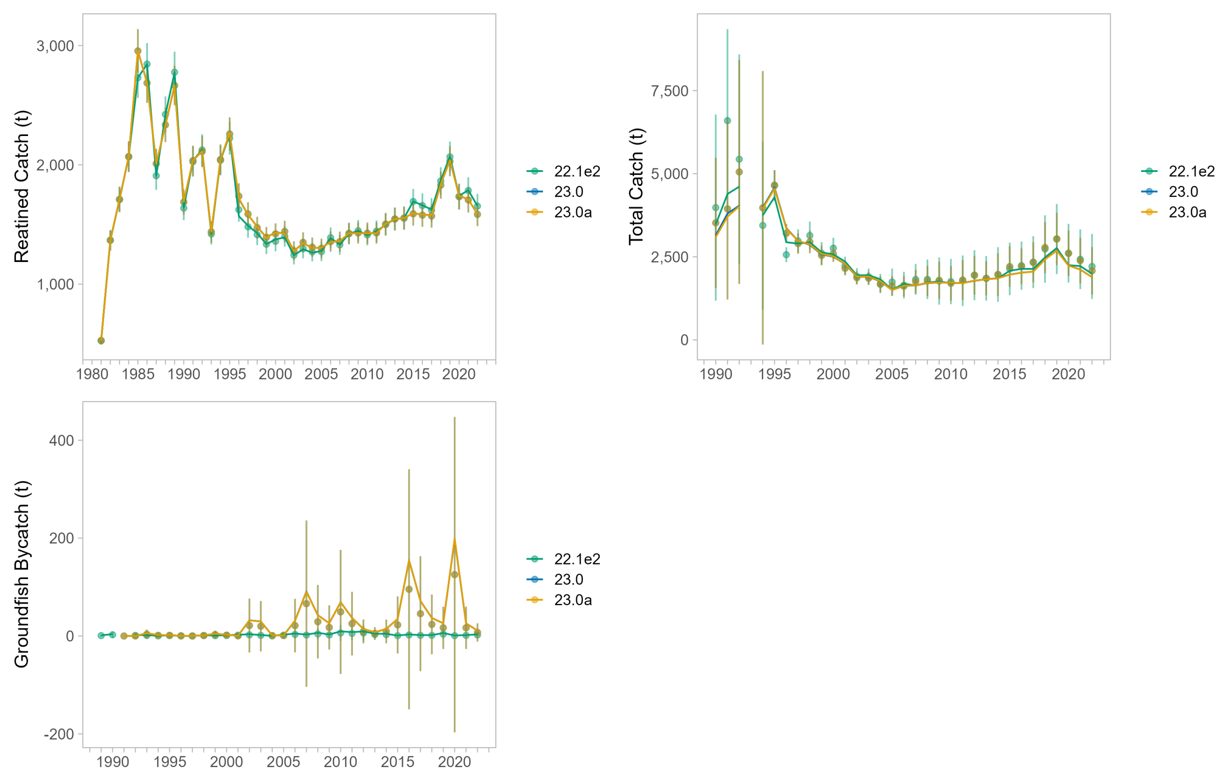

Figure 3: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the EAG. Error bars on observed values represent 95% confidence intervals. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

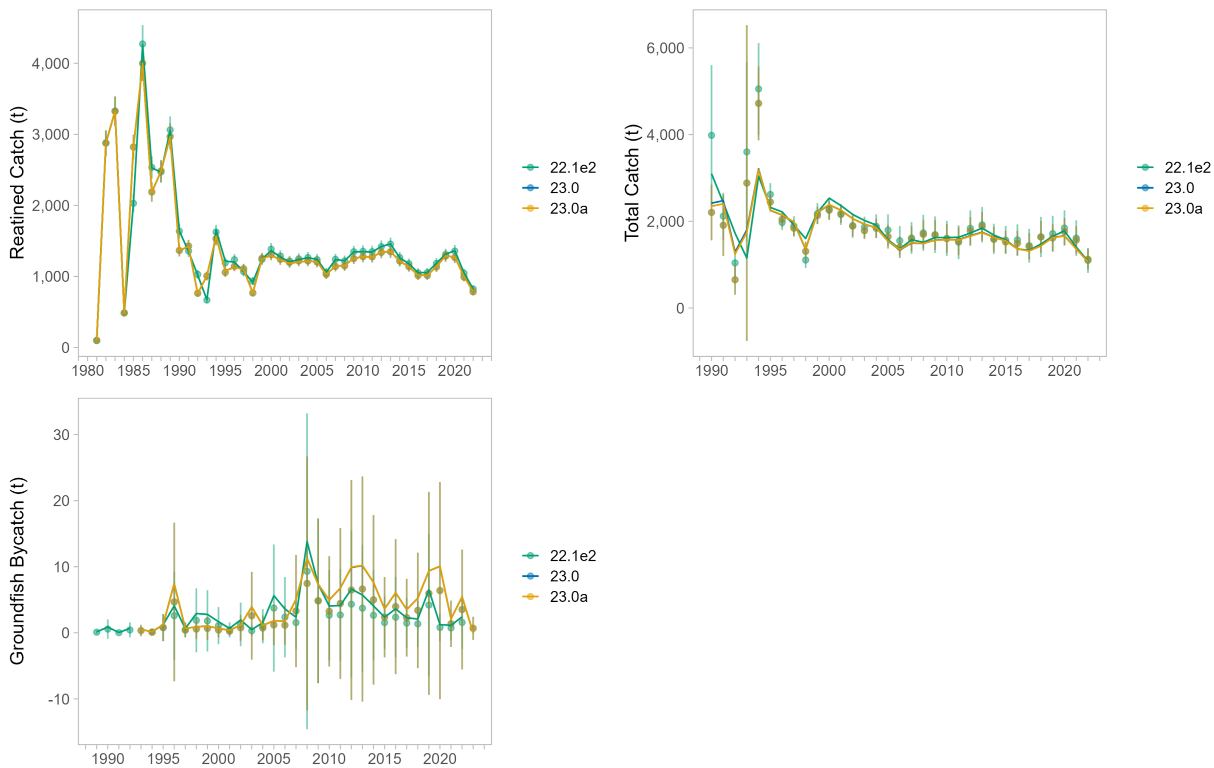

Figure 4: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the WAG. Error bars on observed values represent 95% confidence intervals. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

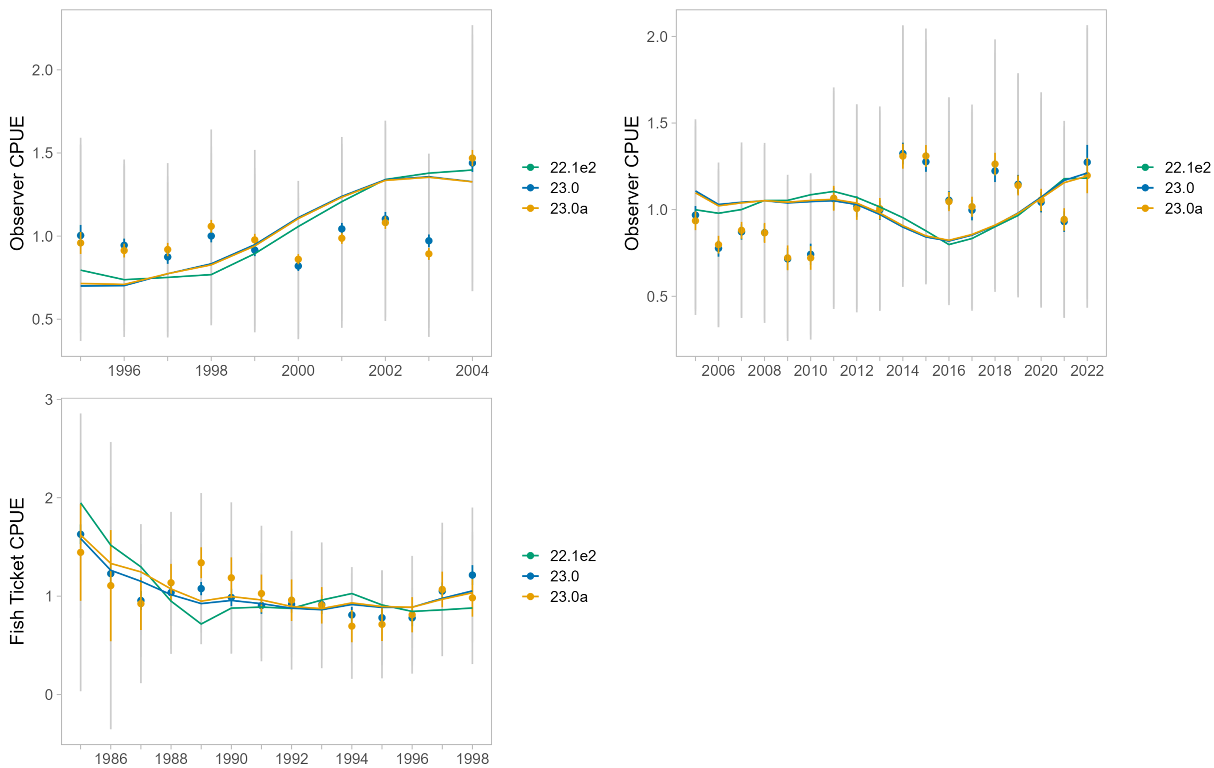

Figure 5: Comparison of model fit to EAG CPUE indices. Error bars on observed values respresent 95% confidence intervals (colored) and estimated additional error (grey). Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

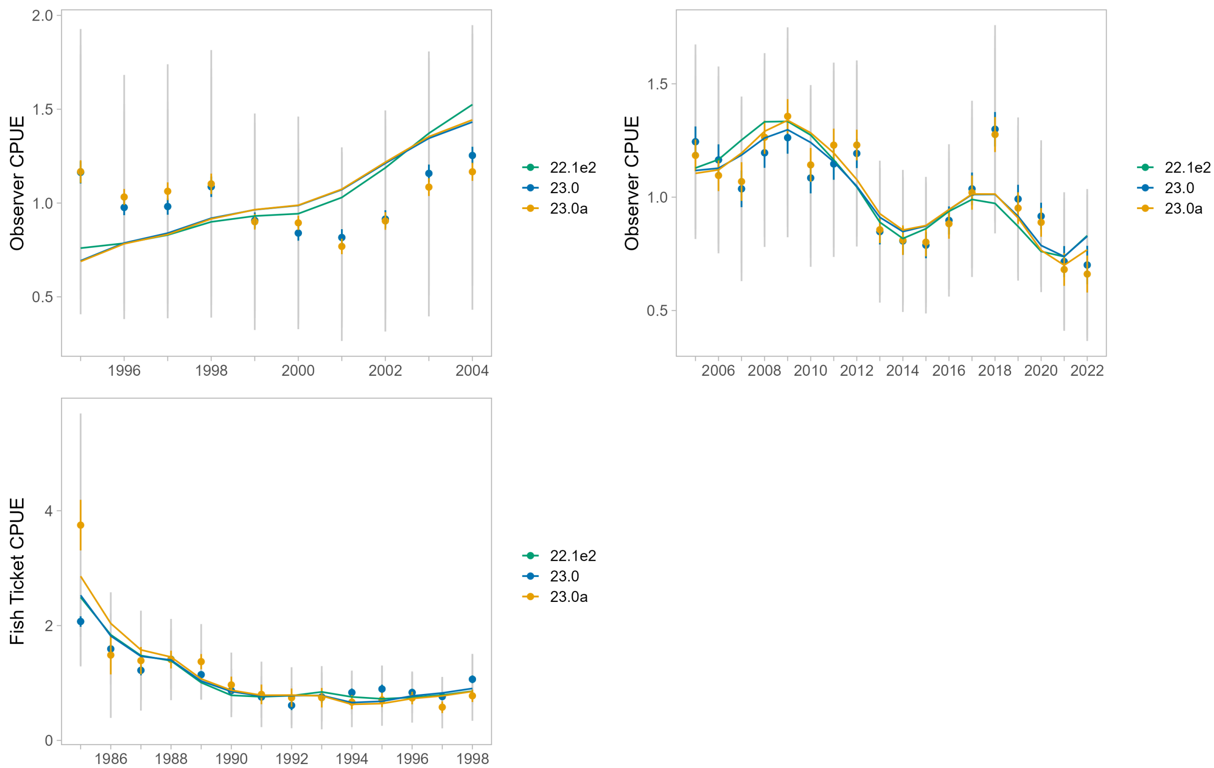

Figure 6: Comparison of model fit to WAG CPUE indices. Error bars on observed values respresent 95% confidence intervals (colored) and estimated additional error (grey). Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

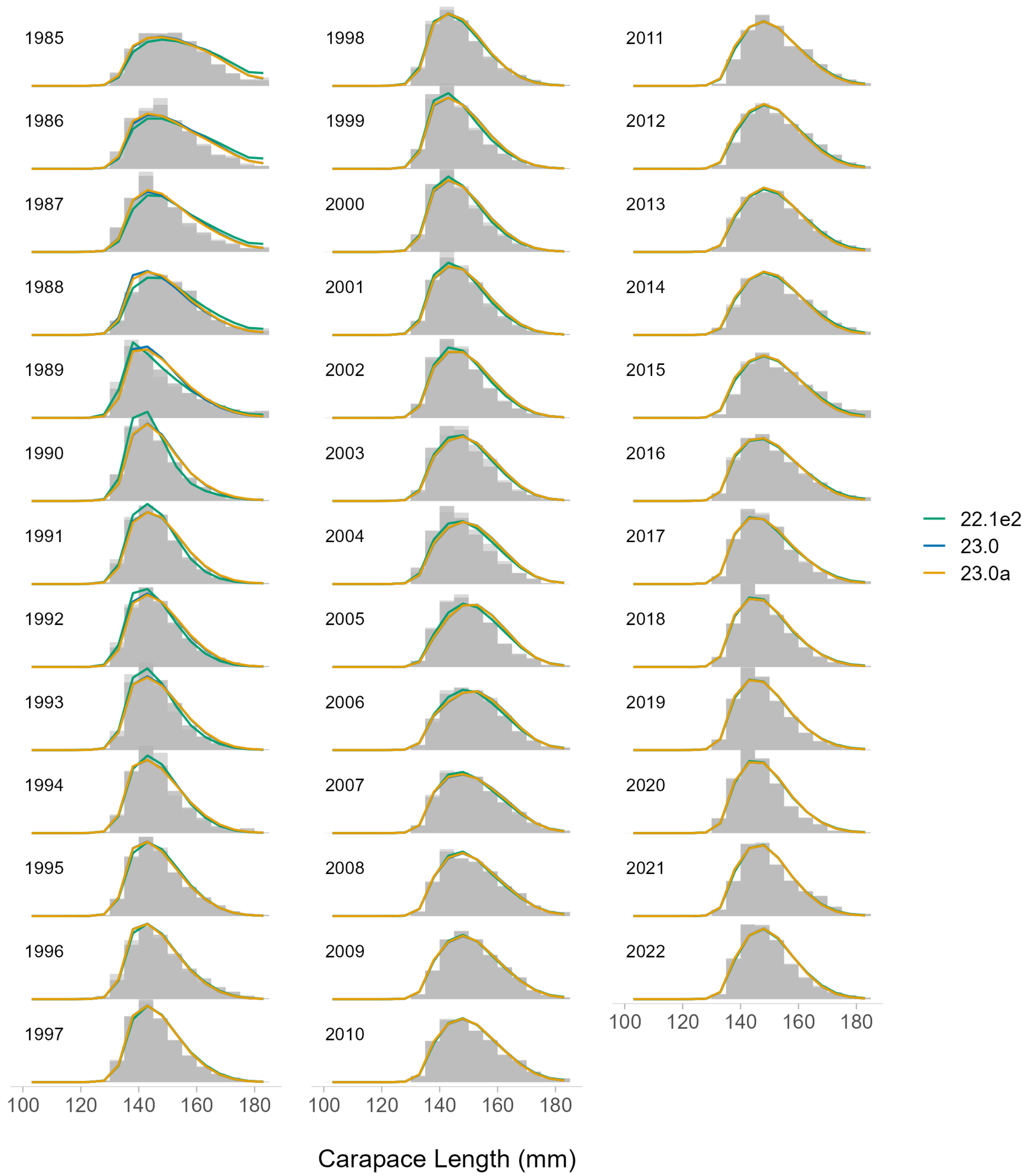

Figure 7: Comparison of model fit to reatined catch size composition in the EAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

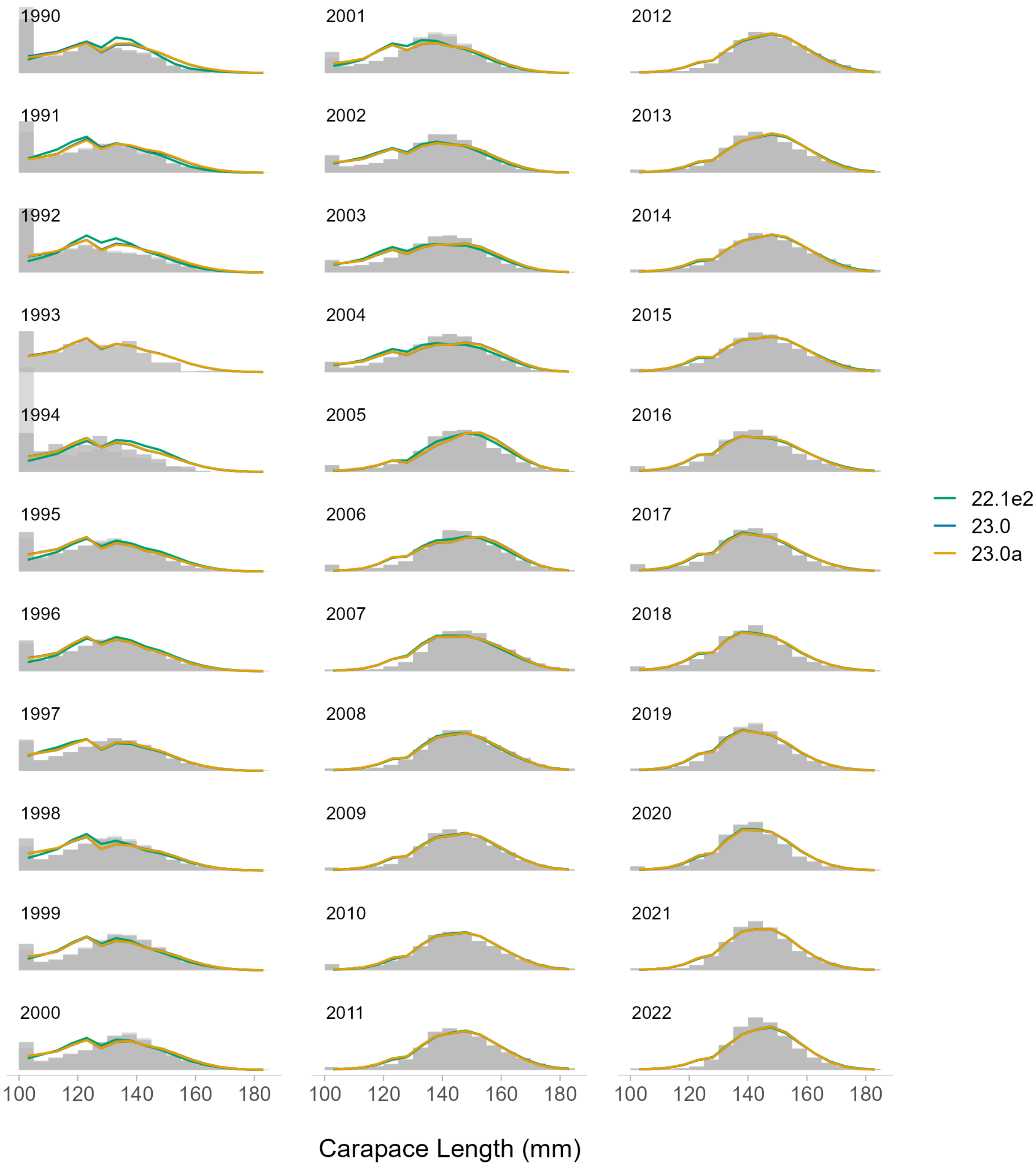

Figure 8: Comparison of model fit to total catch size composition in the EAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

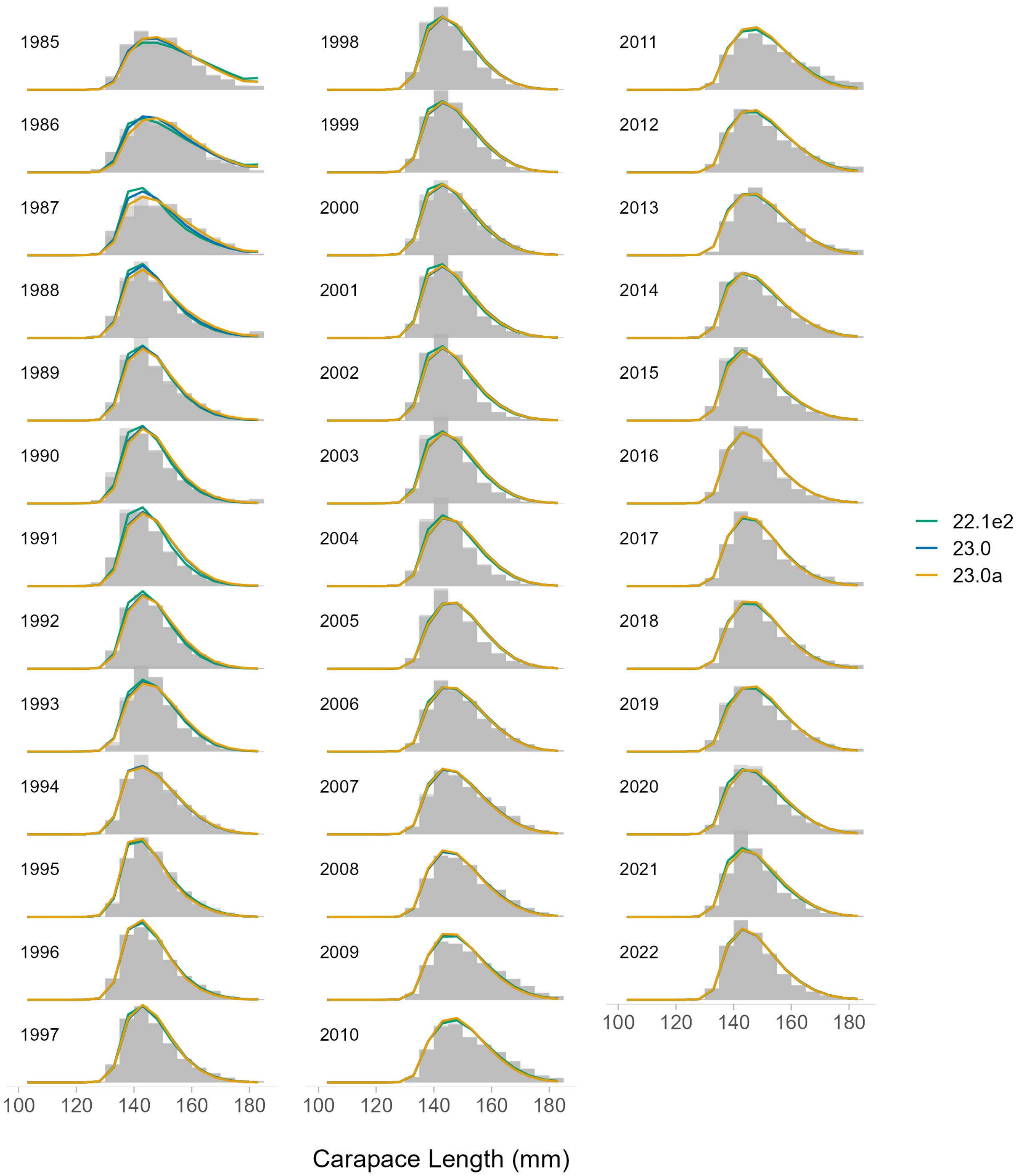

Figure 9: Comparison of model fit to reatined catch size composition in the WAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

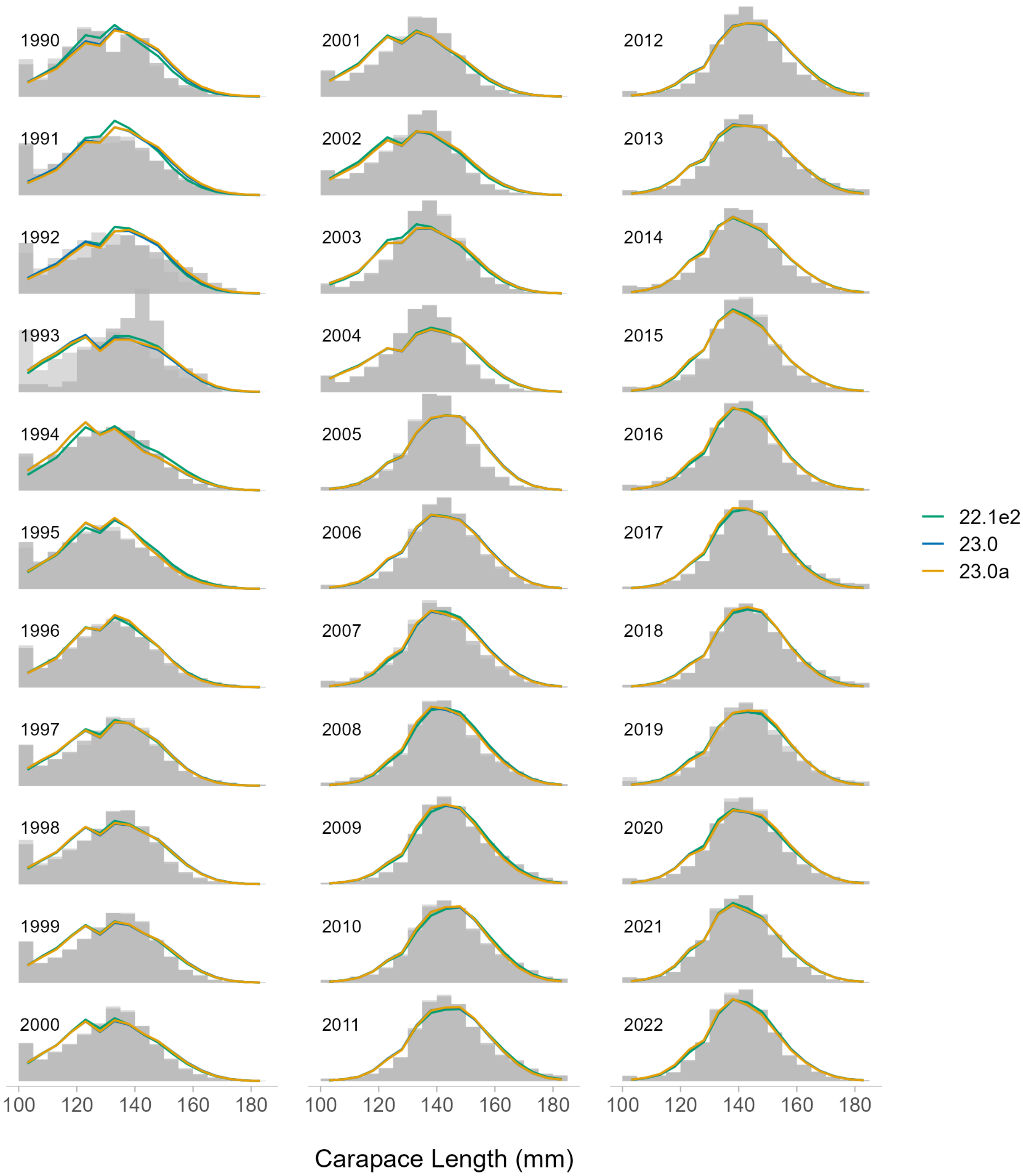

Figure 10: Comparison of model fit to total catch size composition in the WAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

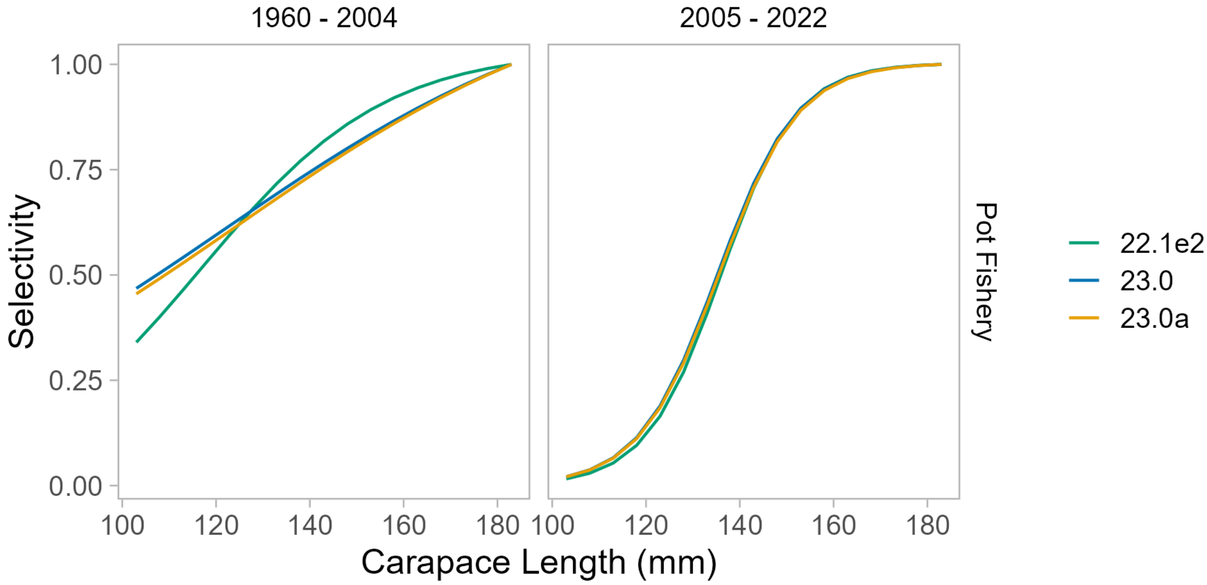

Figure 11: Comparison of estimated selectivity for the directed fishery in the EAG during the pre- and post-rationalized periods. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

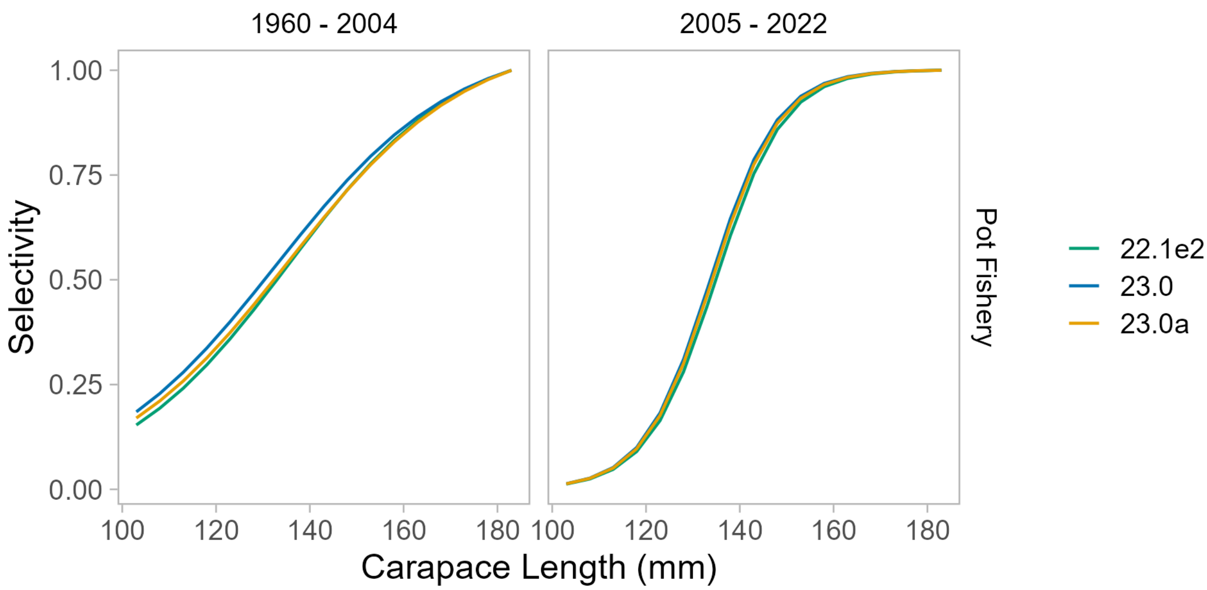

Figure 12: Comparison of estimated selectivity for the directed fishery in the WAG during the pre- and post-rationalized periods. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

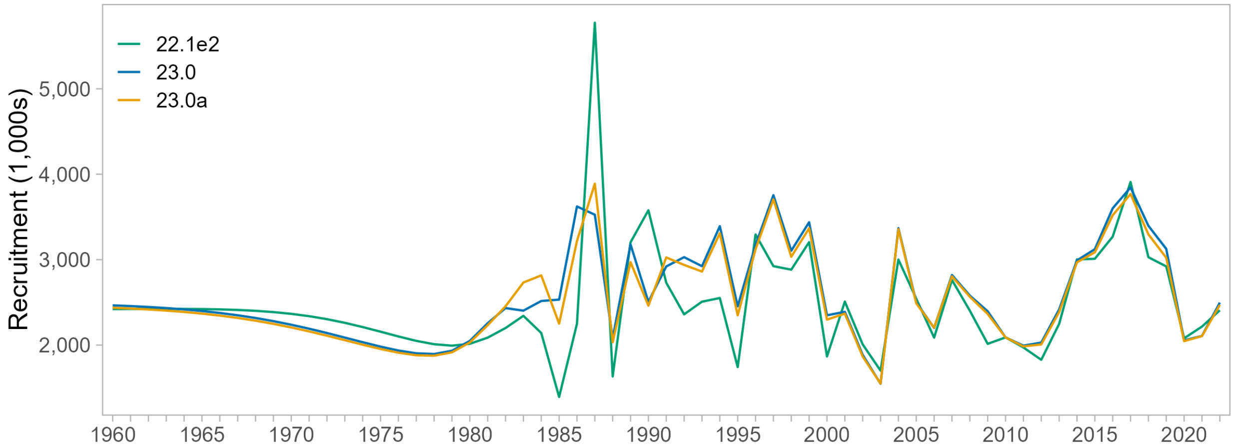

Figure 13: Comparison of model estimated recruitment in the EAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

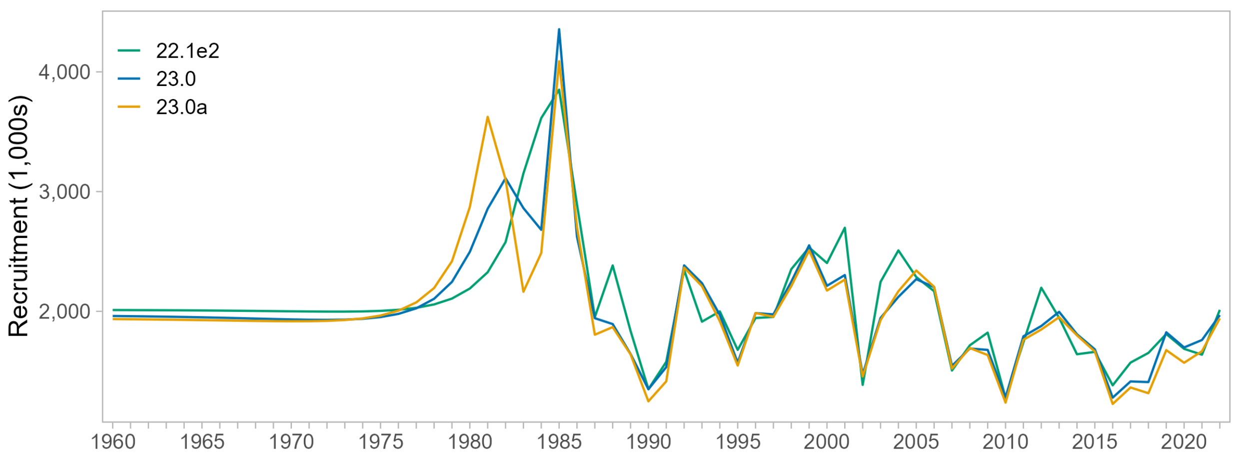

Figure 14: Comparison of model estimated recruitment in the WAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

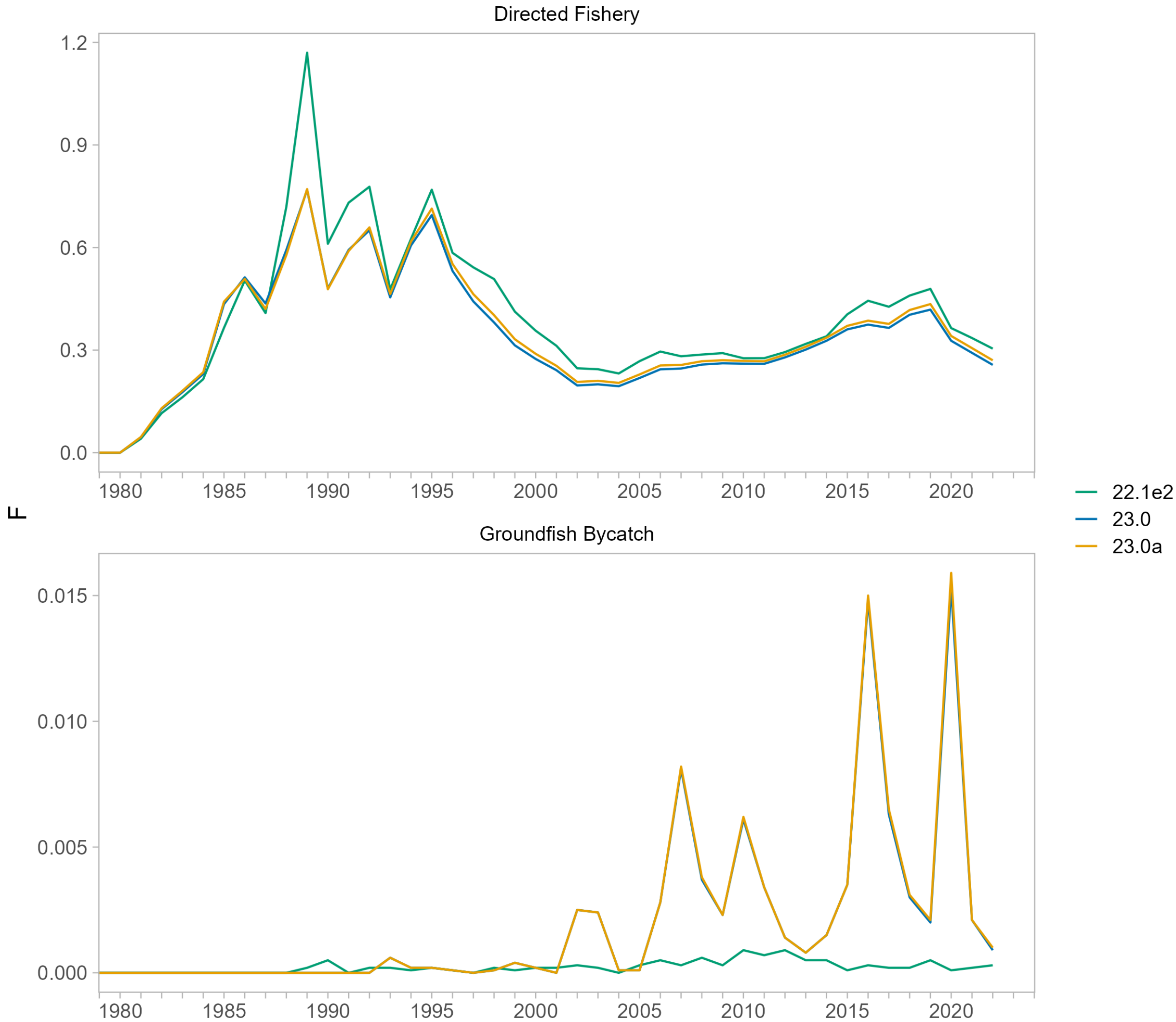

Figure 15: Comparison of model estimated fully selected fishing mortality in the EAG by fleet. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

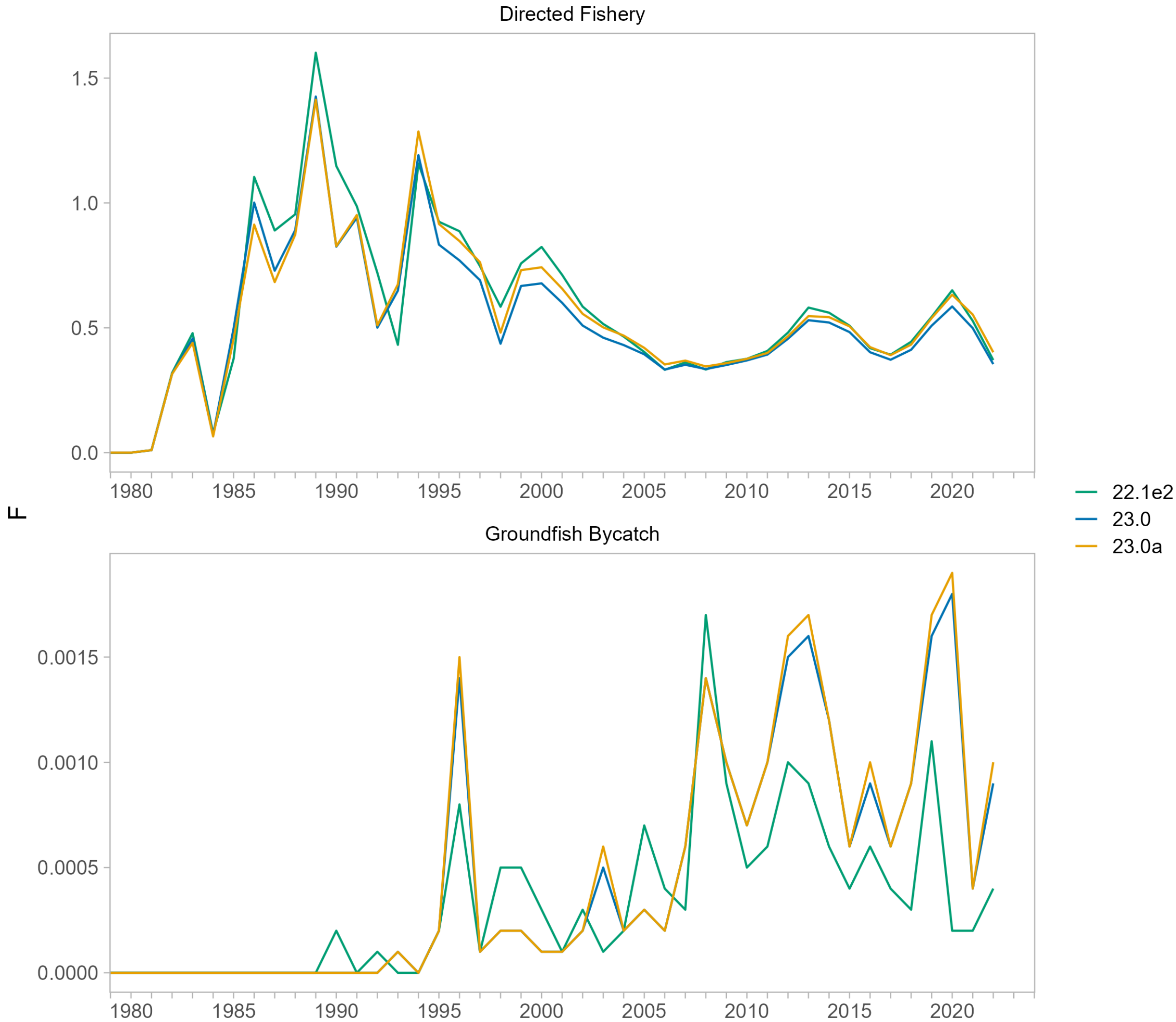

Figure 16: Comparison of model estimated fully selected fishing mortality in the WAG by fleet. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

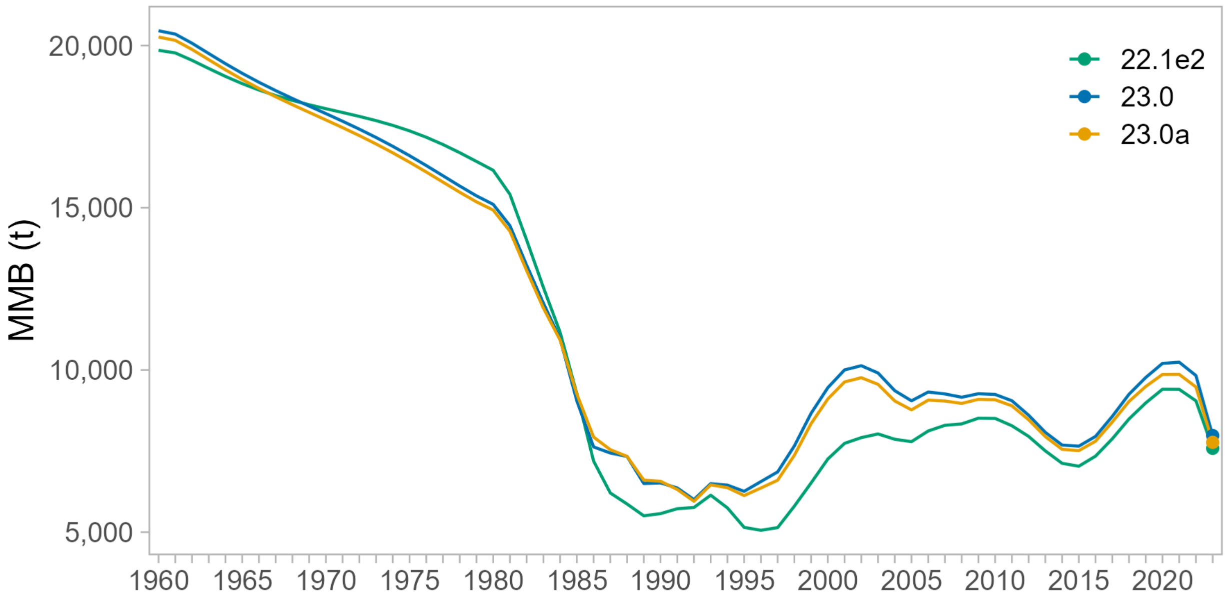

Figure 17: Comparison of model estimated MMB in the EAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

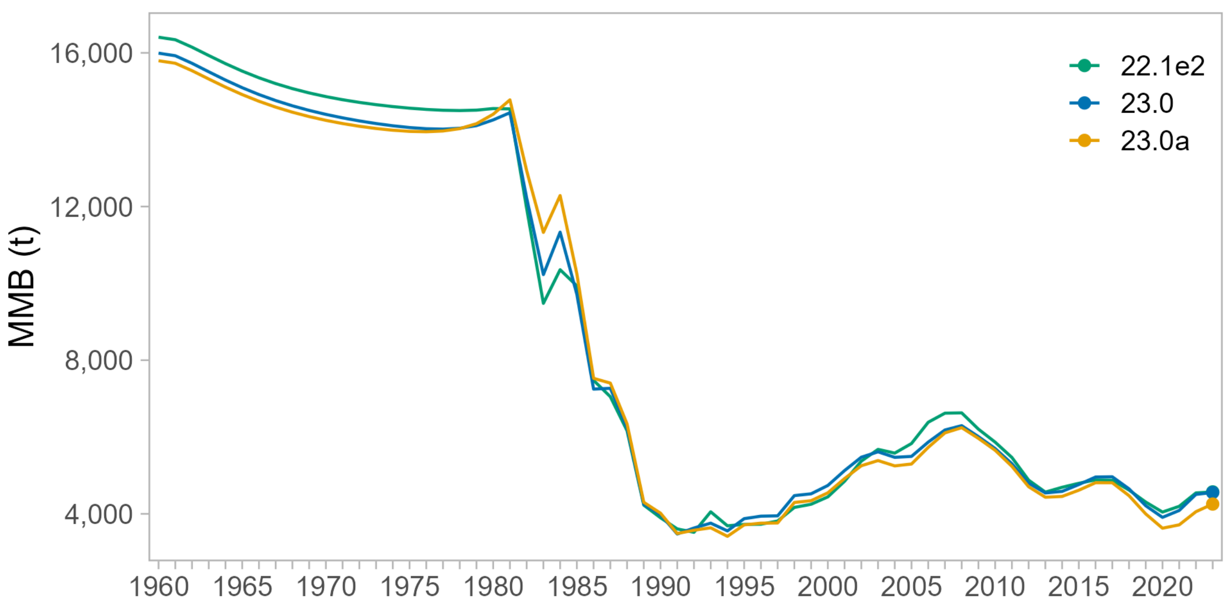

Figure 18: Comparison of model estimated MMB in the WAG. Model 22.1e2 is the base model, model 23.0 updates fishery data, and model 23.0a updates index data.

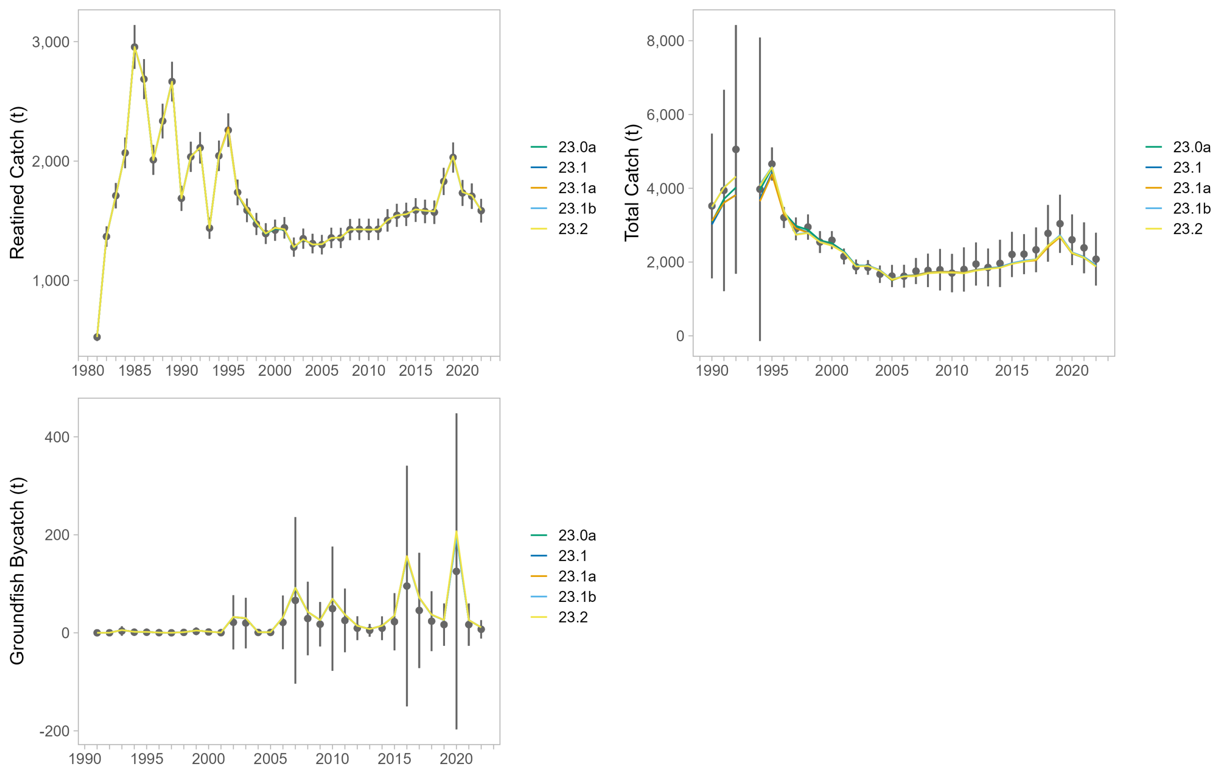

Figure 19: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the EAG. Error bars on observed values represent 95% confidence intervals. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

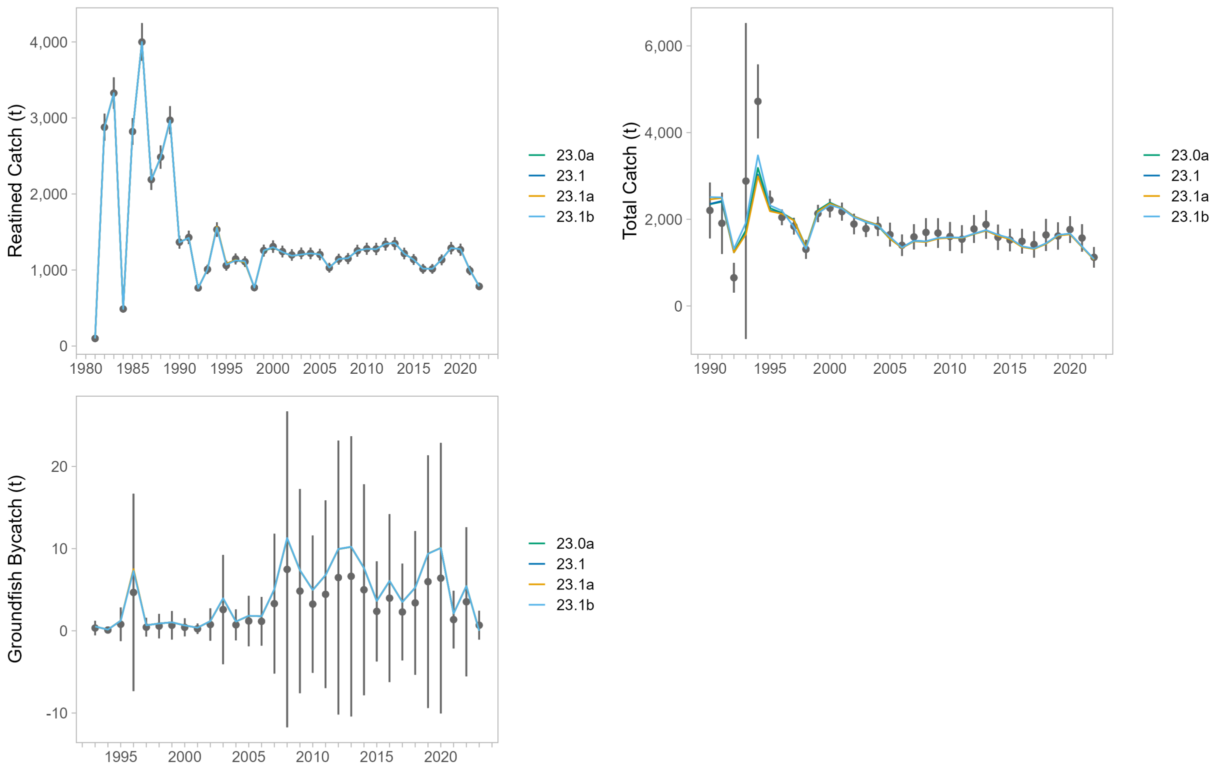

Figure 20: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the WAG. Error bars on observed values represent 95% confidence intervals. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

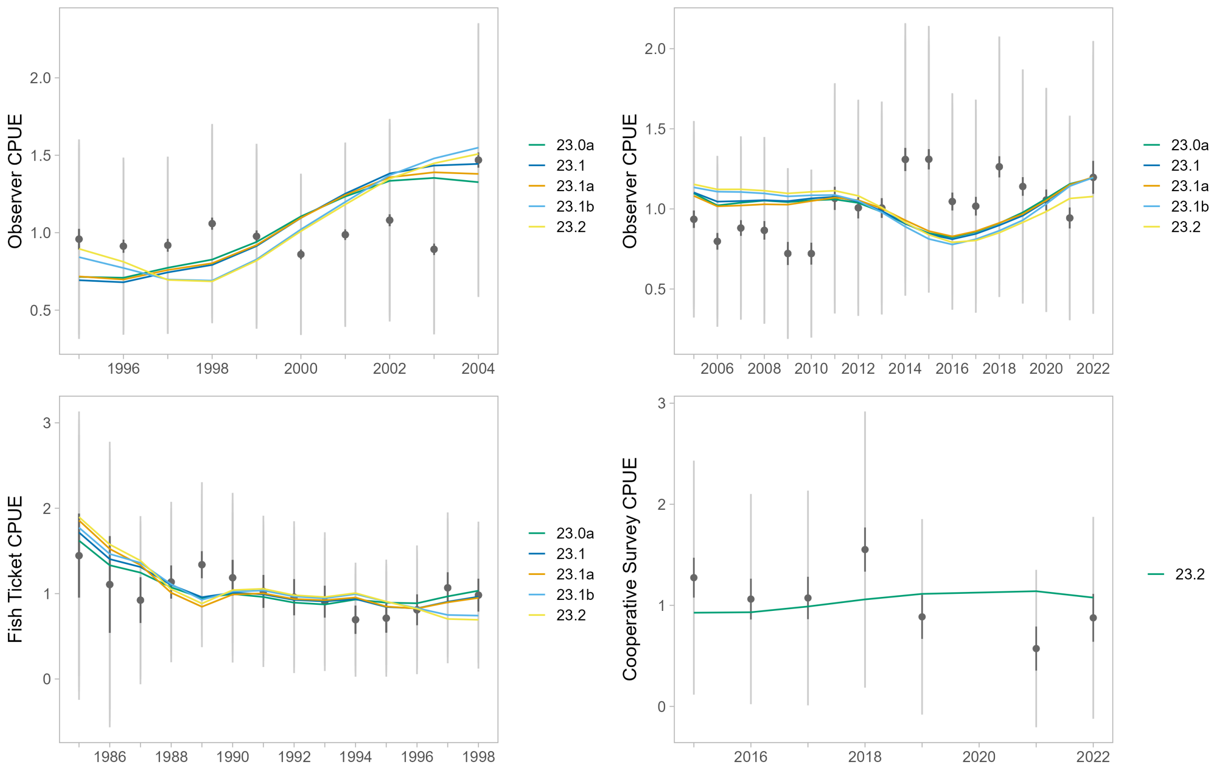

Figure 21: Comparison of model fit to EAG CPUE indices. Error bars on observed values respresent 95% confidence intervals (dark grey) and estimated additional error (light grey). Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

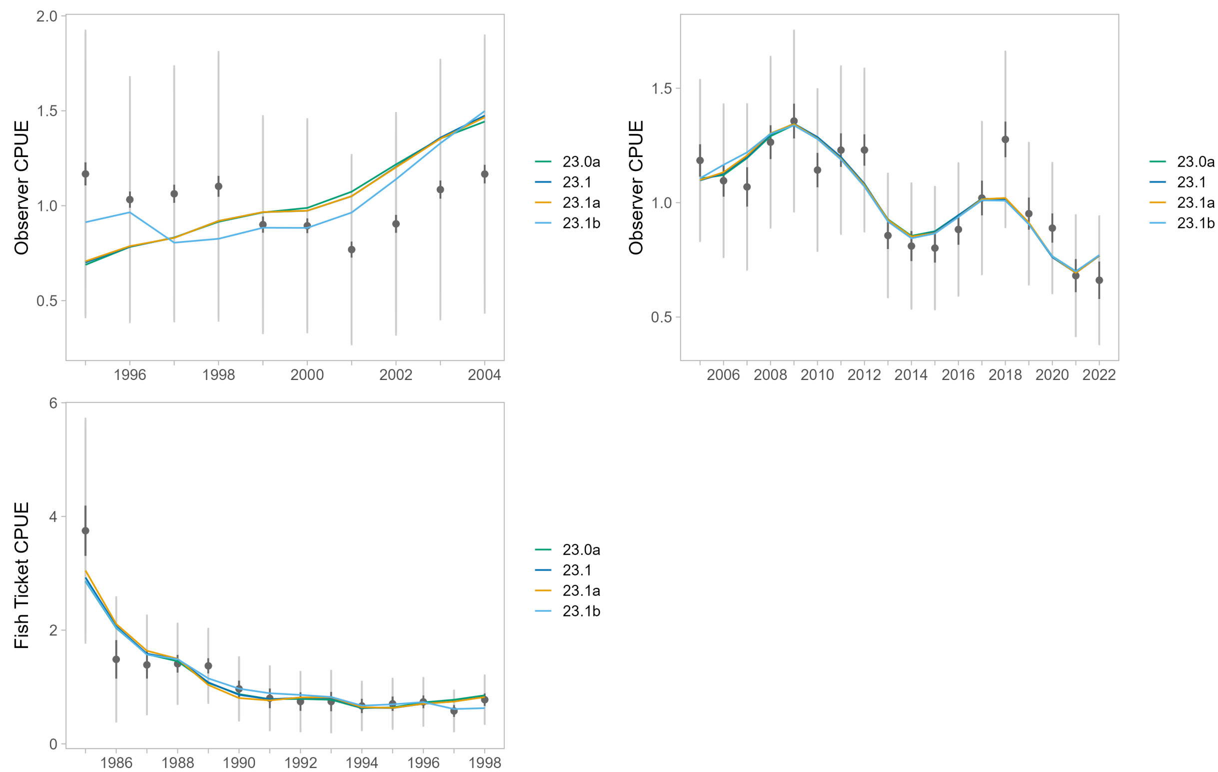

Figure 22: Comparison of model fit to WAG CPUE indices. Error bars on observed values respresent 95% confidence intervals (dark grey) and estimated additional error (light grey). Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

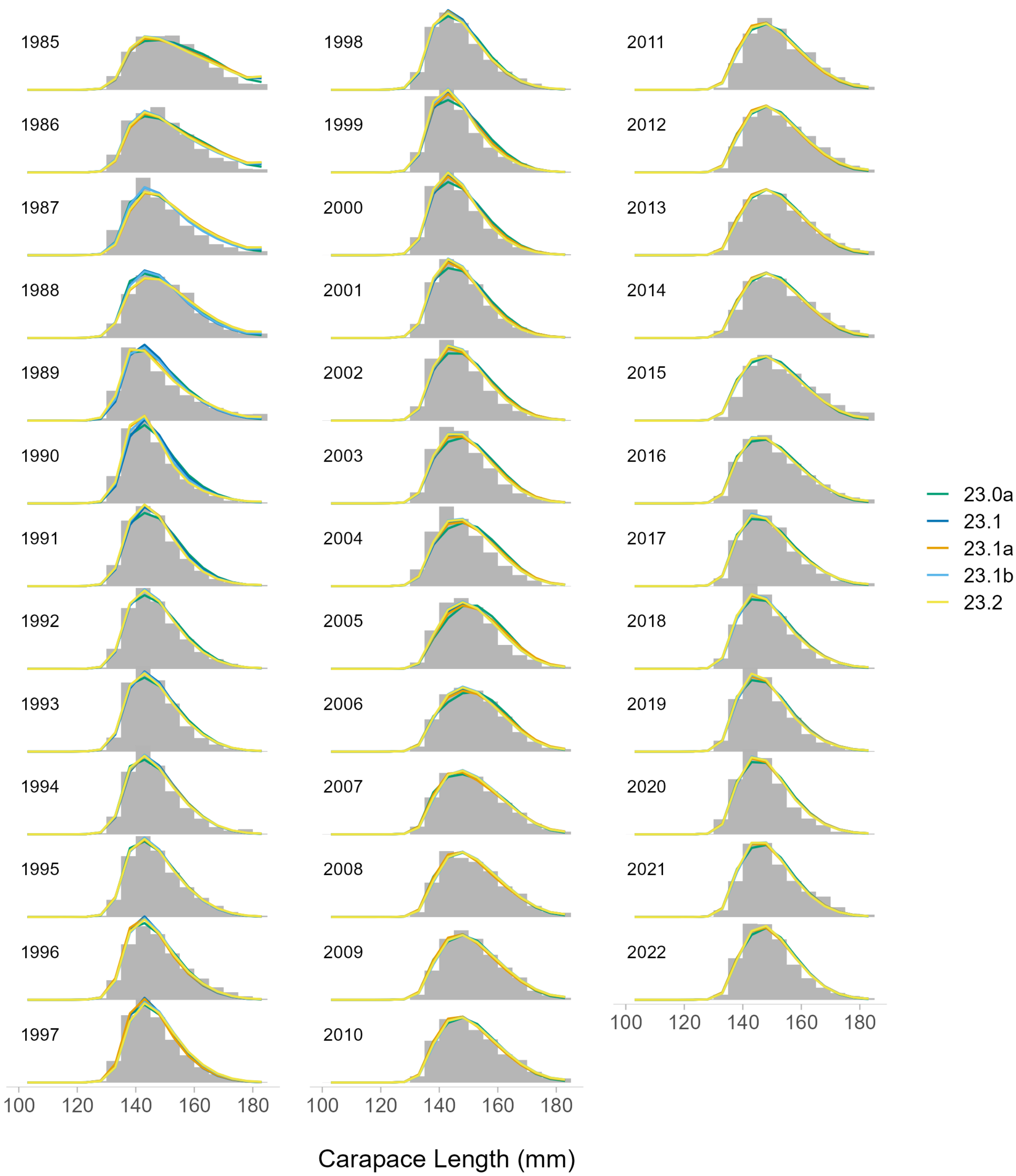

Figure 23: Comparison of model fit to reatined catch size composition in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

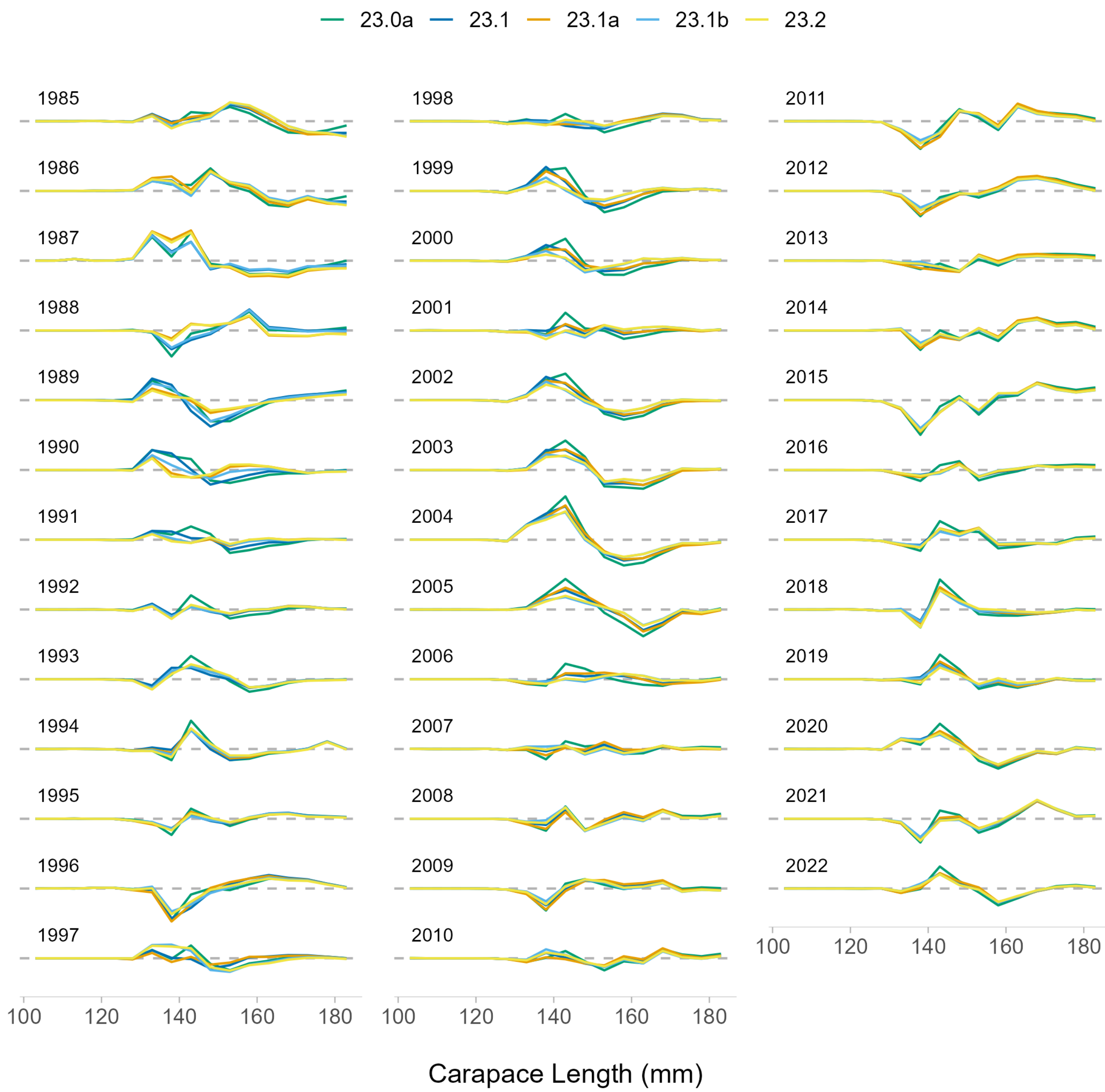

Figure 24: Comparison of reatined catch size composition residuals in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

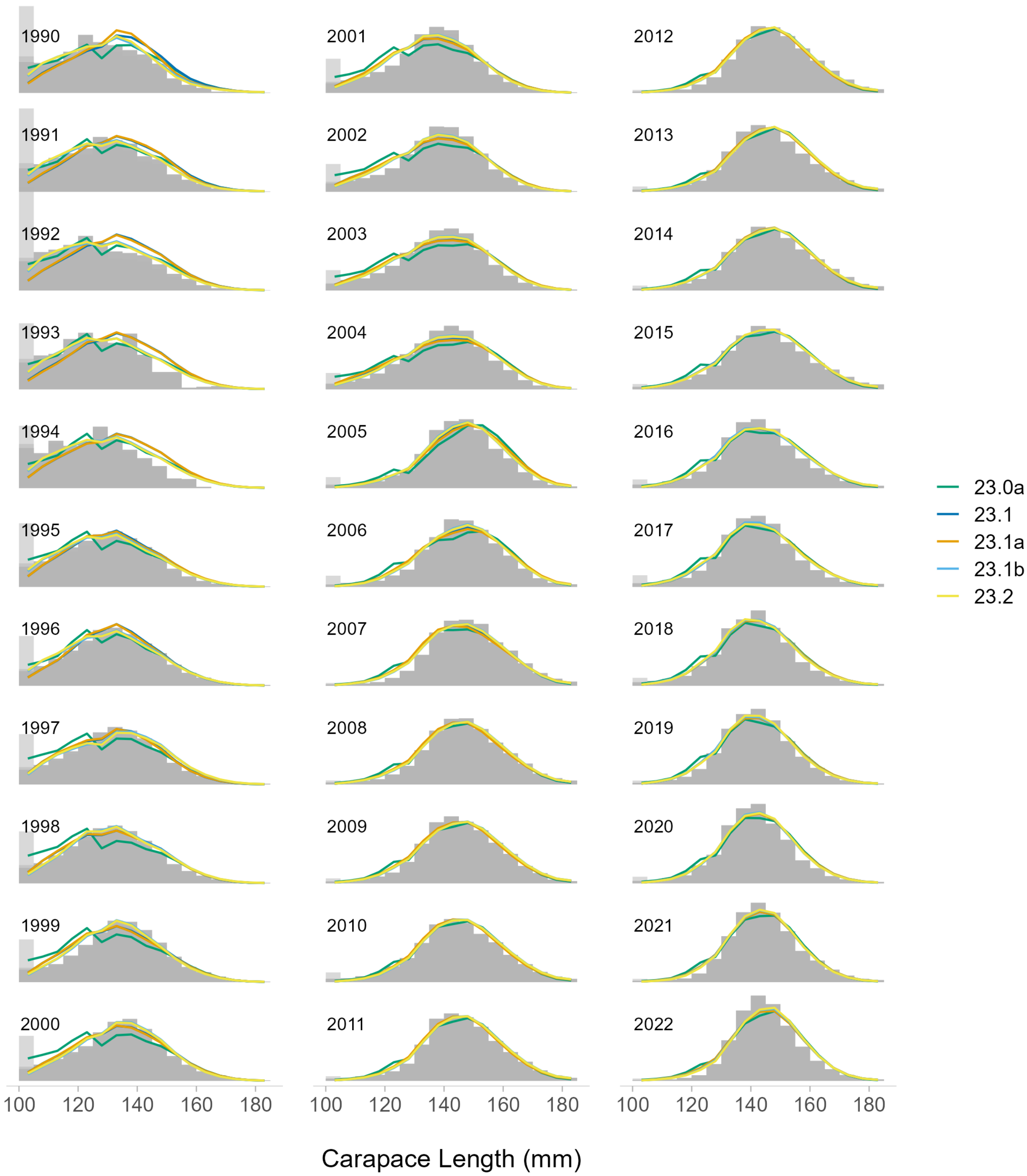

Figure 25: Comparison of model fit to total catch size composition in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

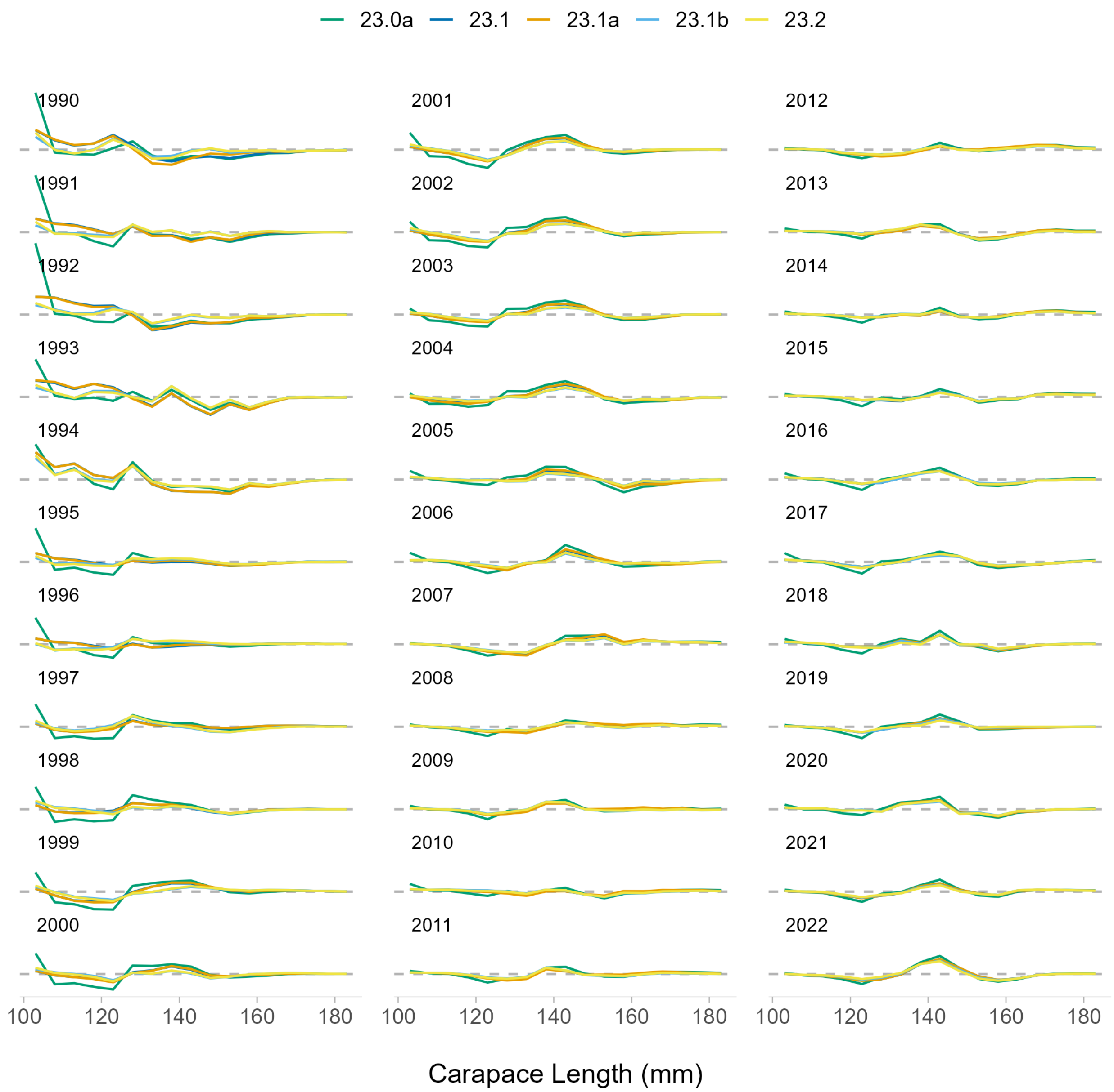

Figure 26: Comparison of total catch size composition residuals in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

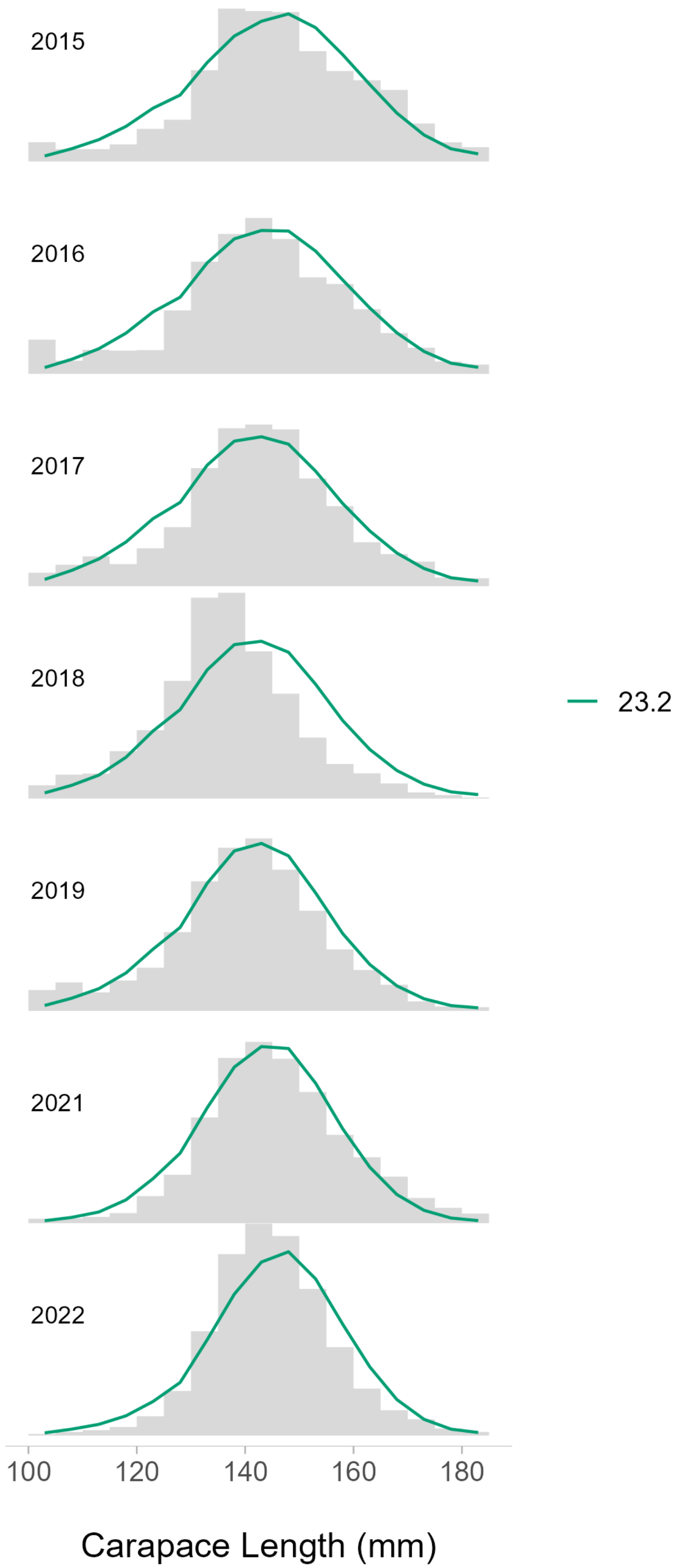

Figure 27: Comparison of model fit to cooperative survey catch size composition in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

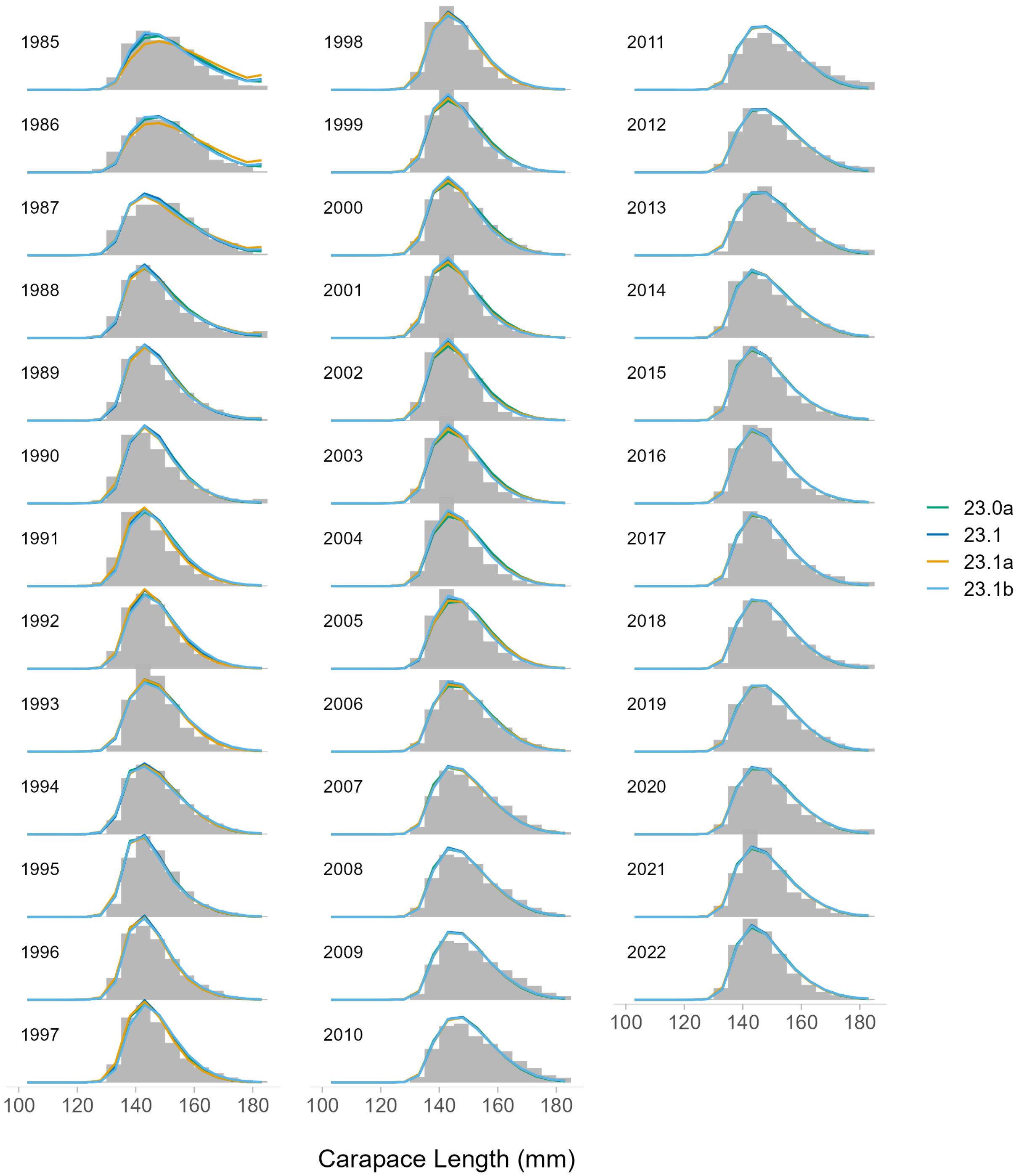

Figure 28: Comparison of model fit to reatined catch size composition in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

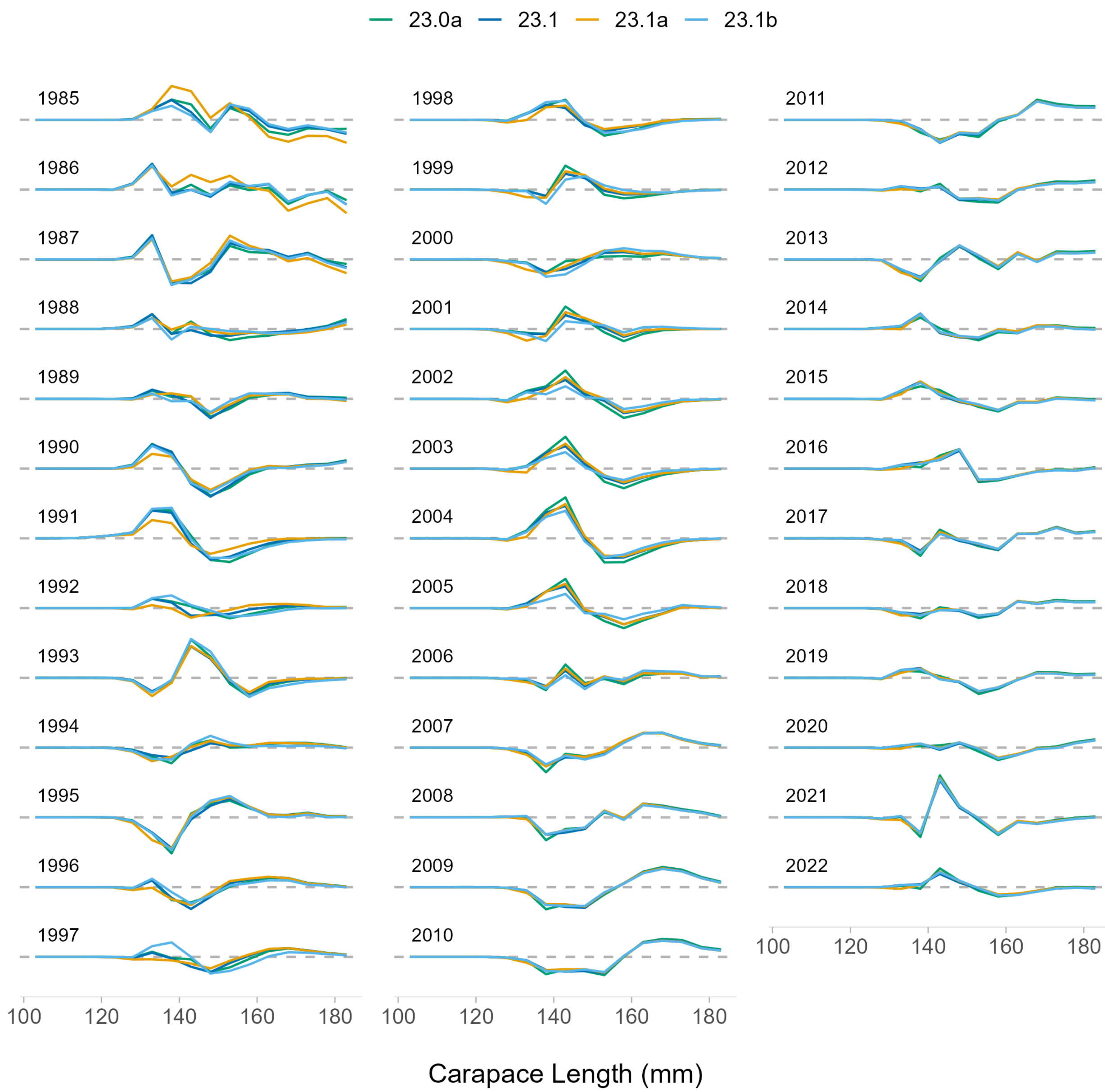

Figure 29: Comparison of reatined catch size composition residuals in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

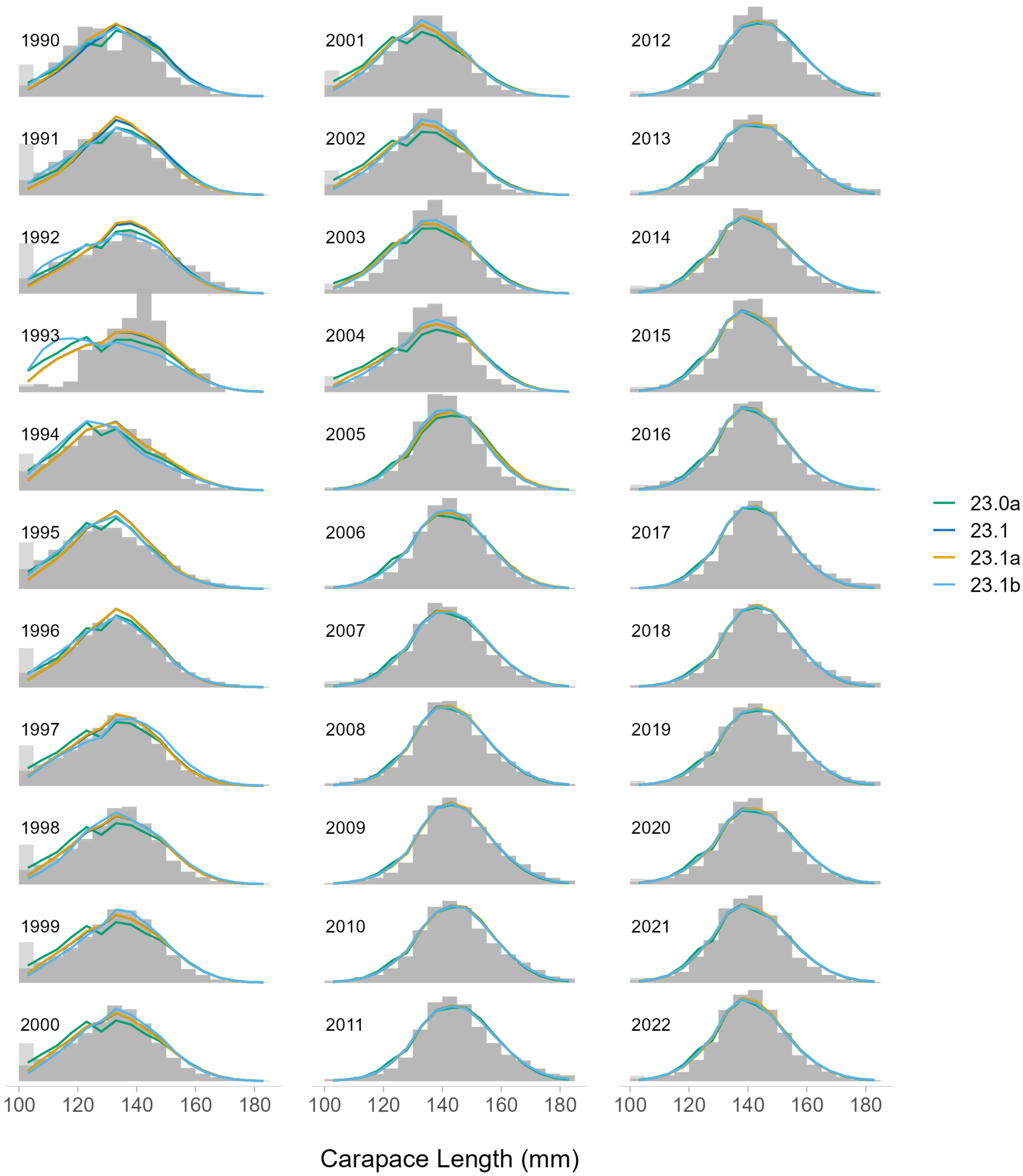

Figure 30: Comparison of model fit to total catch size composition in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

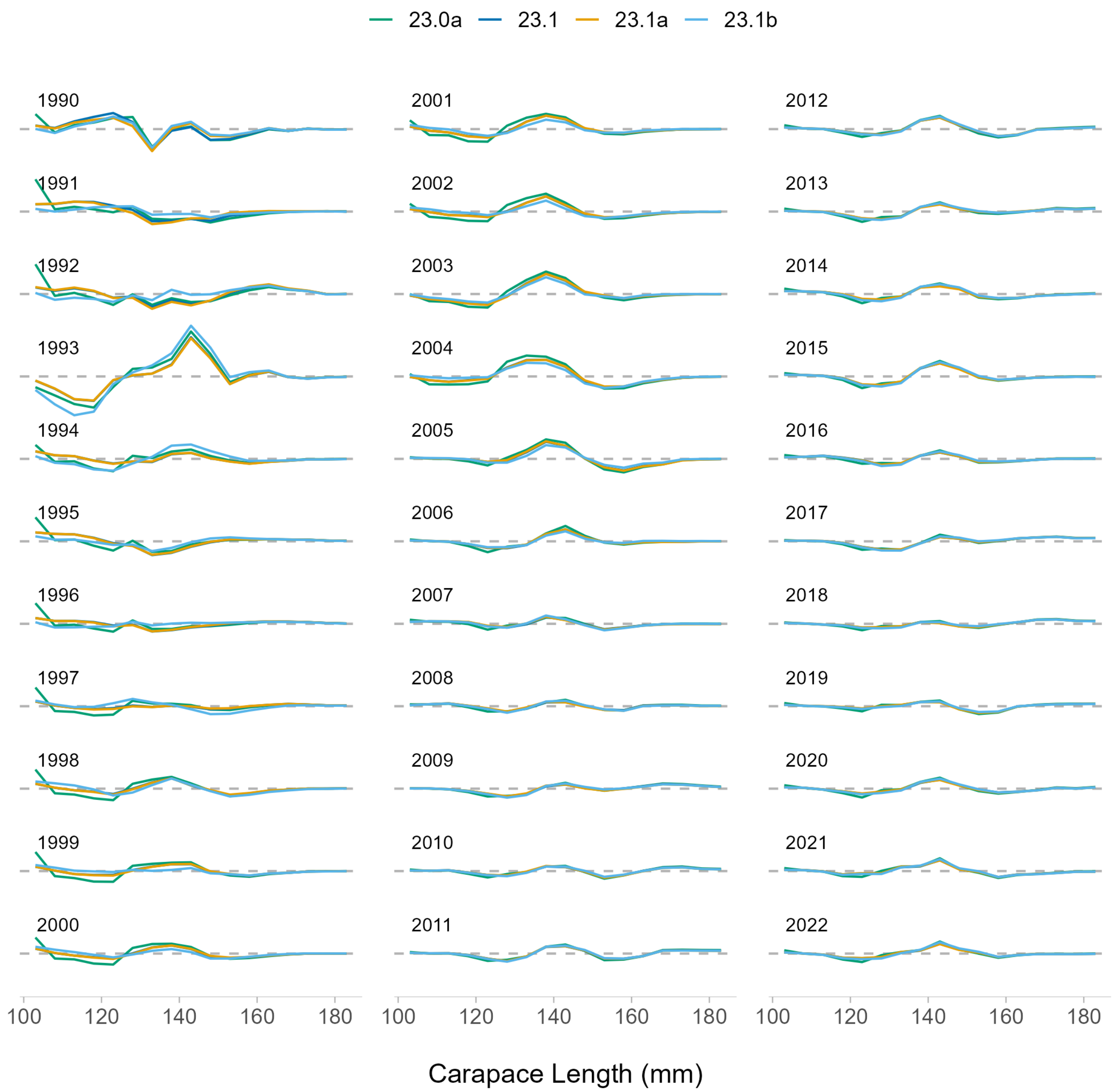

Figure 31: Comparison of total catch size composition residuals in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

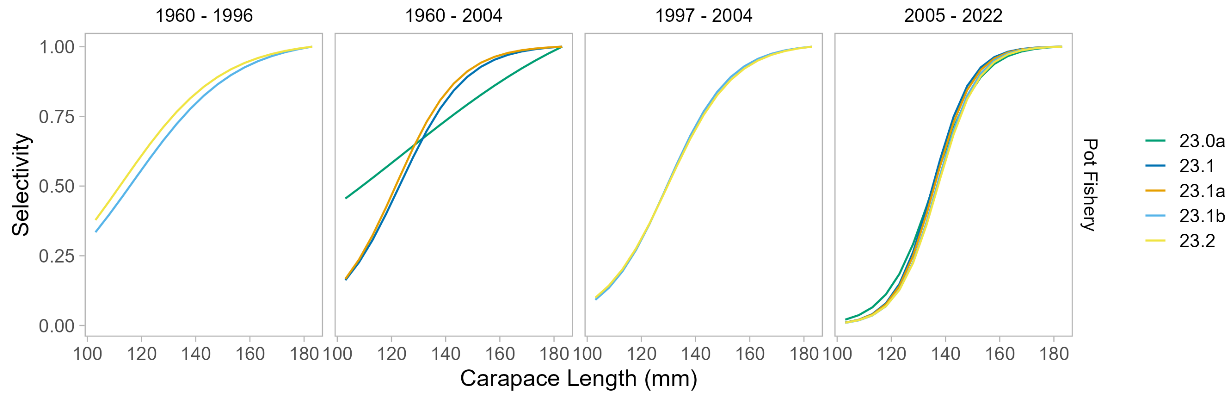

Figure 32: Comparison of estimated selectivity for the directed fishery in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

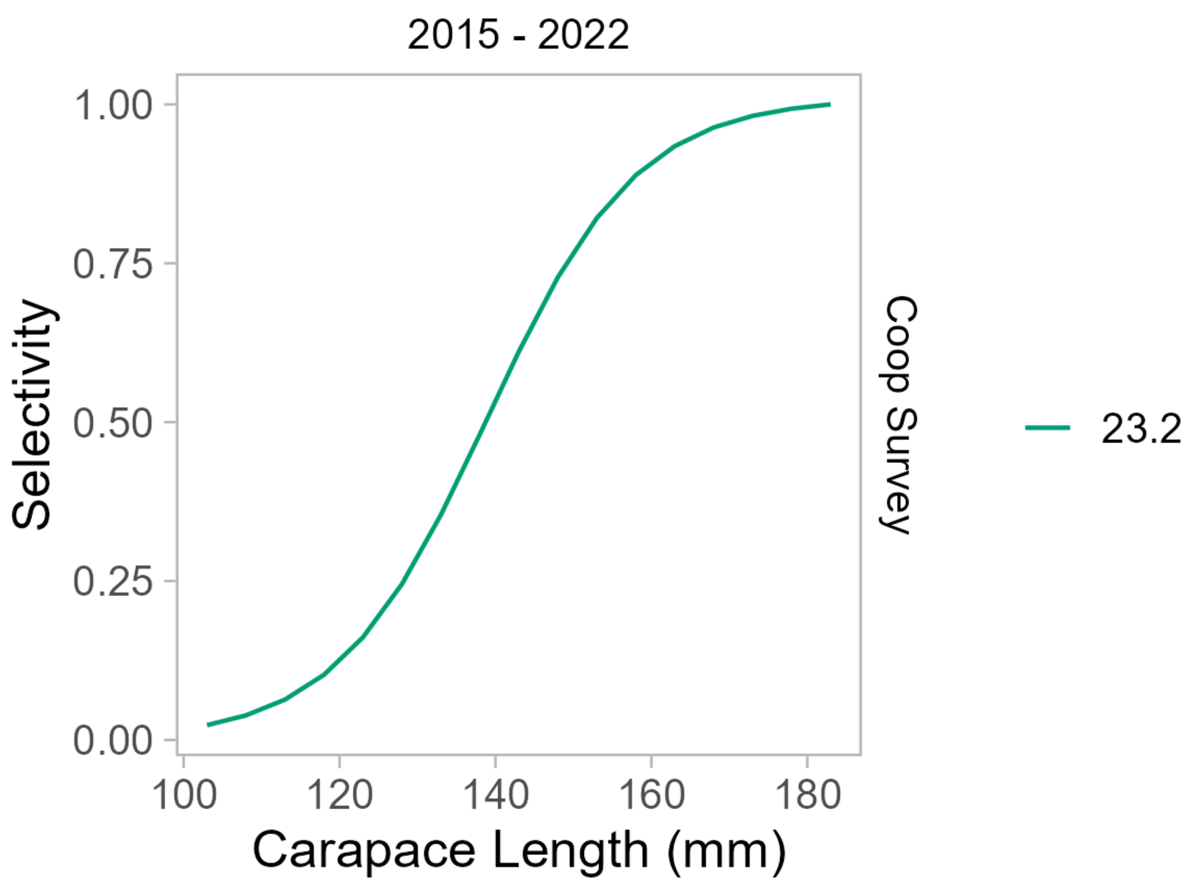

Figure 33: Estimated selectivity for the cooperative survey fisher in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

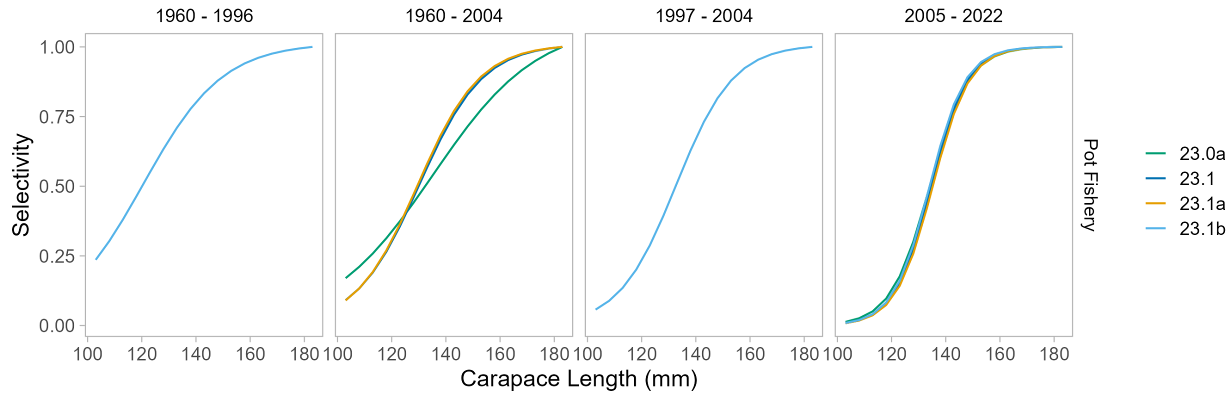

Figure 34: Comparison of estimated selectivity for the directed fishery in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

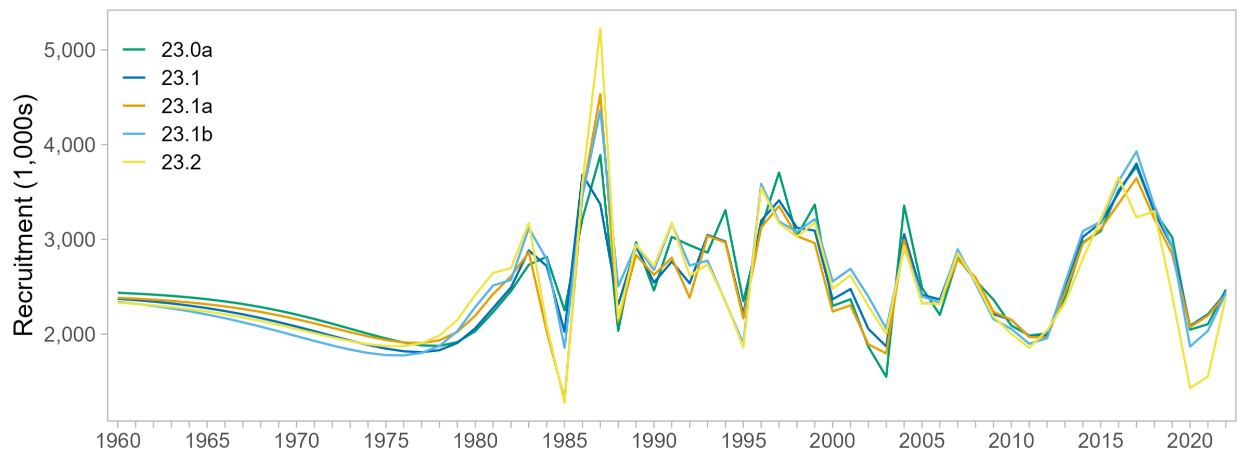

Figure 35: Comparison of model estimated recruitment in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

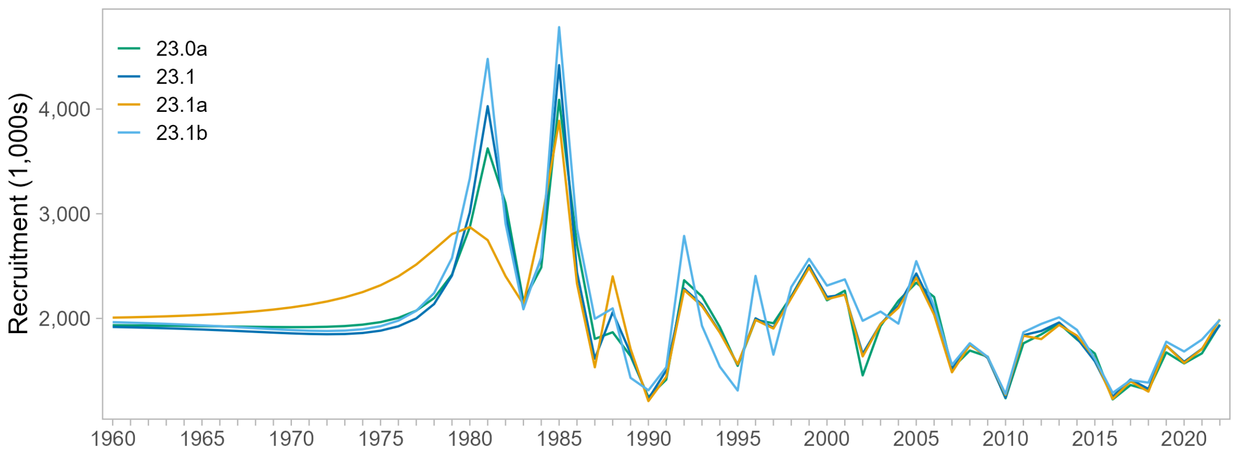

Figure 36: Comparison of model estimated recruitment in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

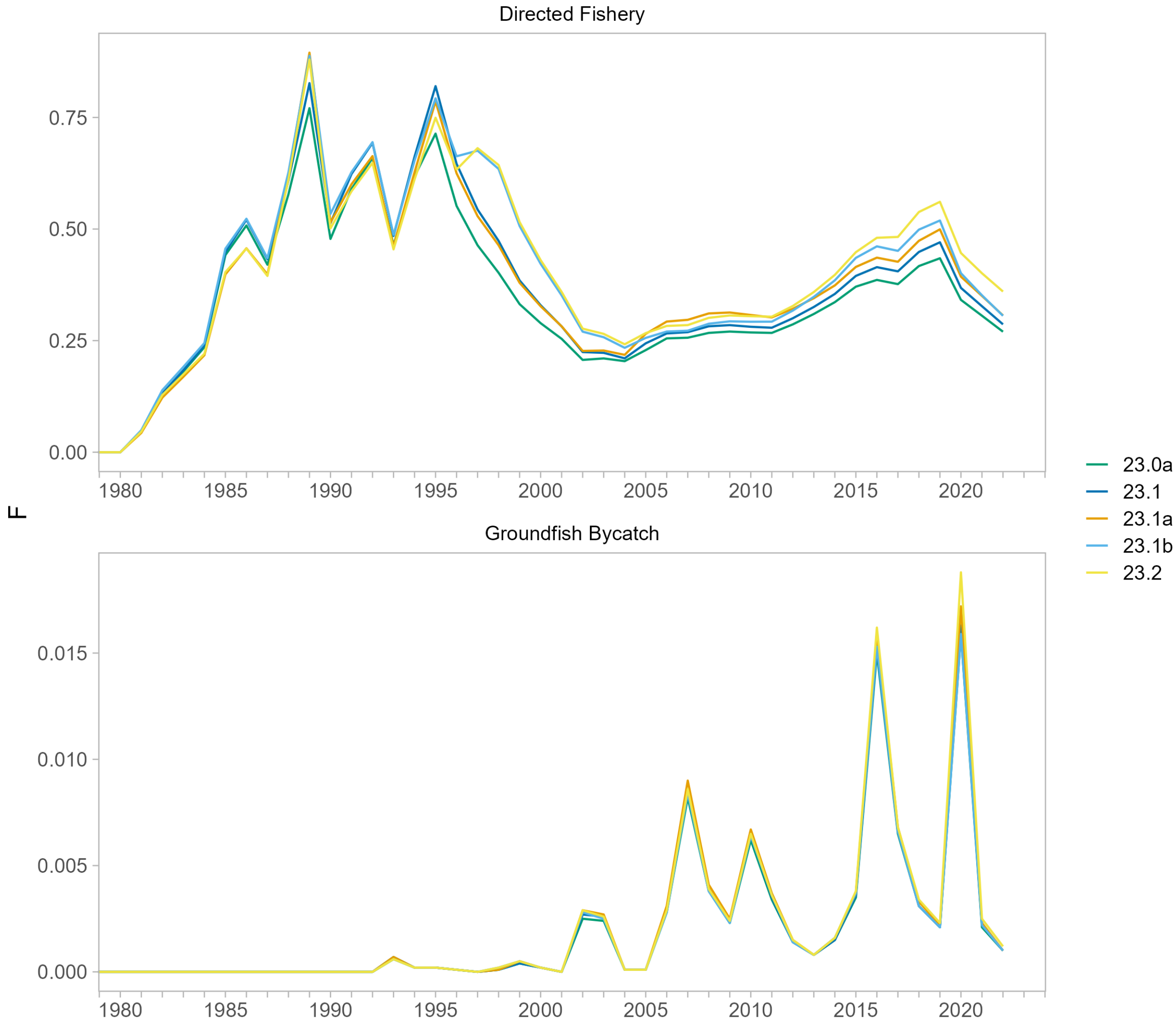

Figure 37: Comparison of model estimated fully selected fishing mortality in the EAG by fleet. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

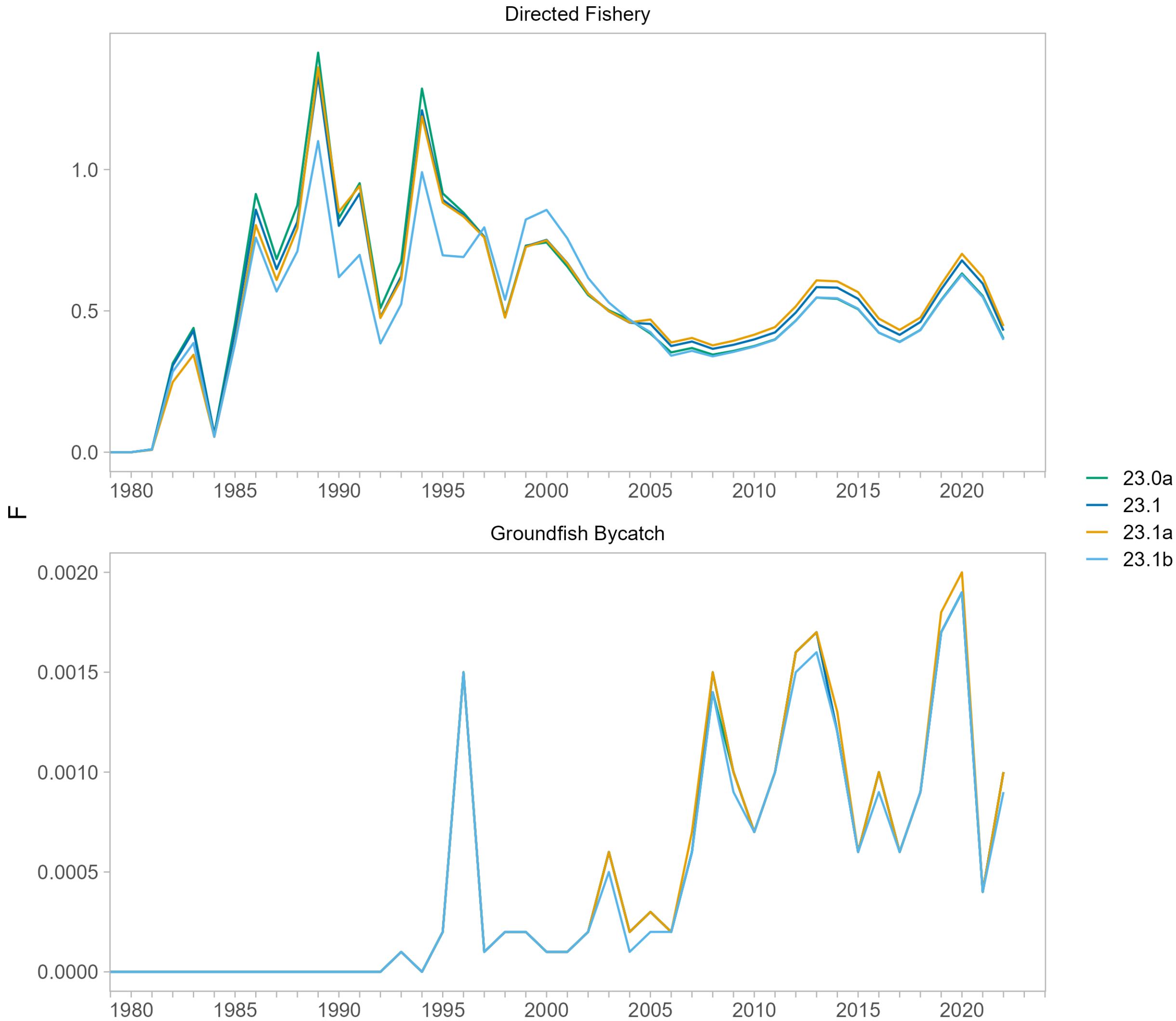

Figure 38: Comparison of model estimated fully selected fishing mortality in the WAG by fleet. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

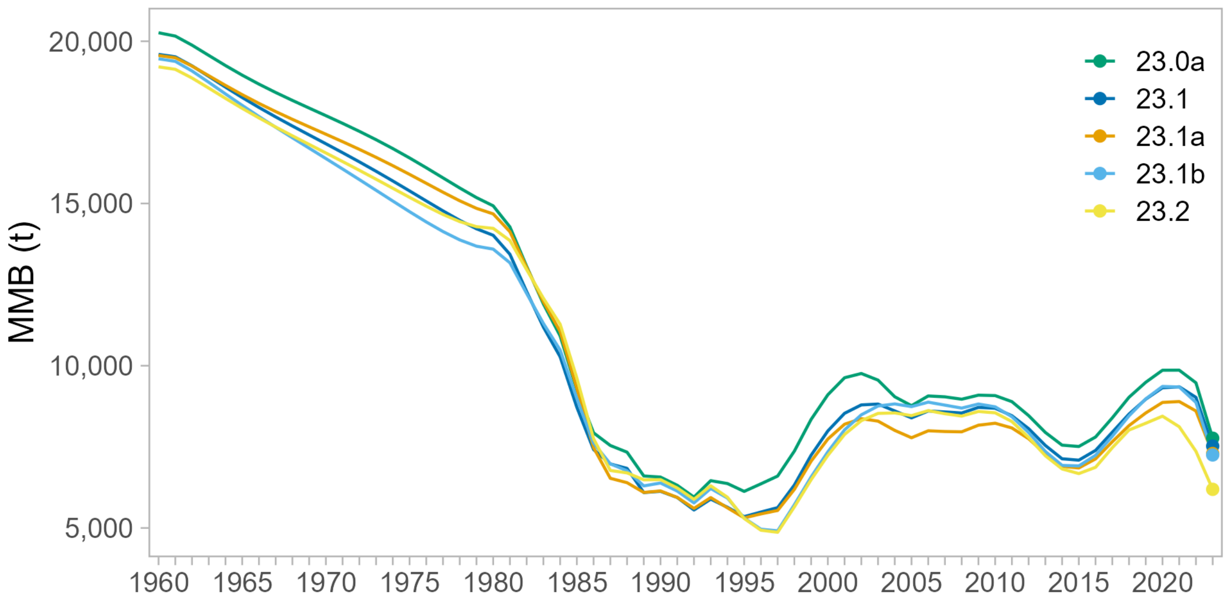

Figure 39: Comparison of model estimated MMB in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, 23.1b uses an additional selectivity period, and 23.2 uses survey data.

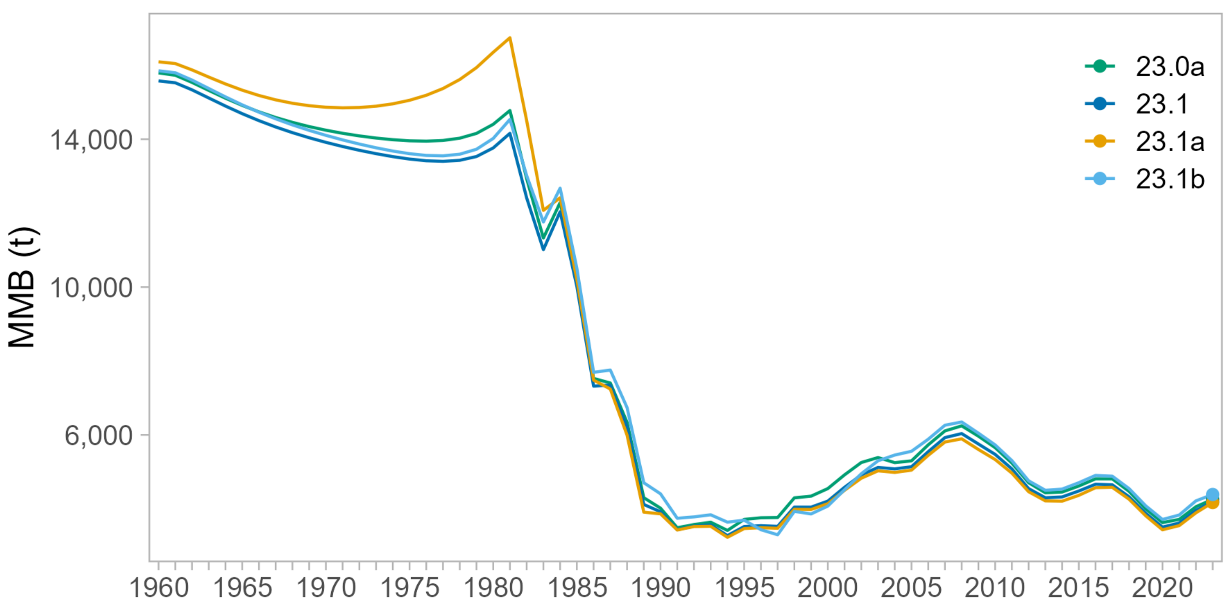

Figure 40: Comparison of model estimated MMB in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

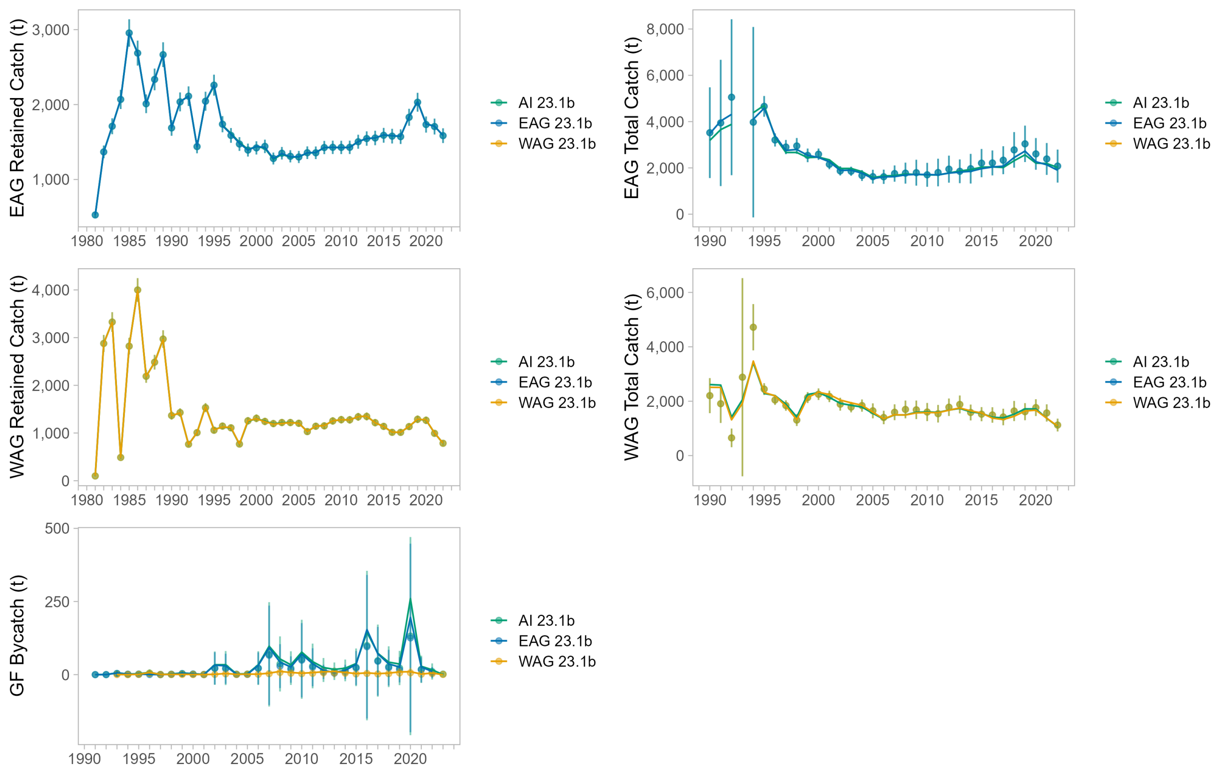

Figure 41: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for AI 23.1b, EAG 23.1b, and WAG 23.1b. Error bars on observed values represent 95% confidence intervals.

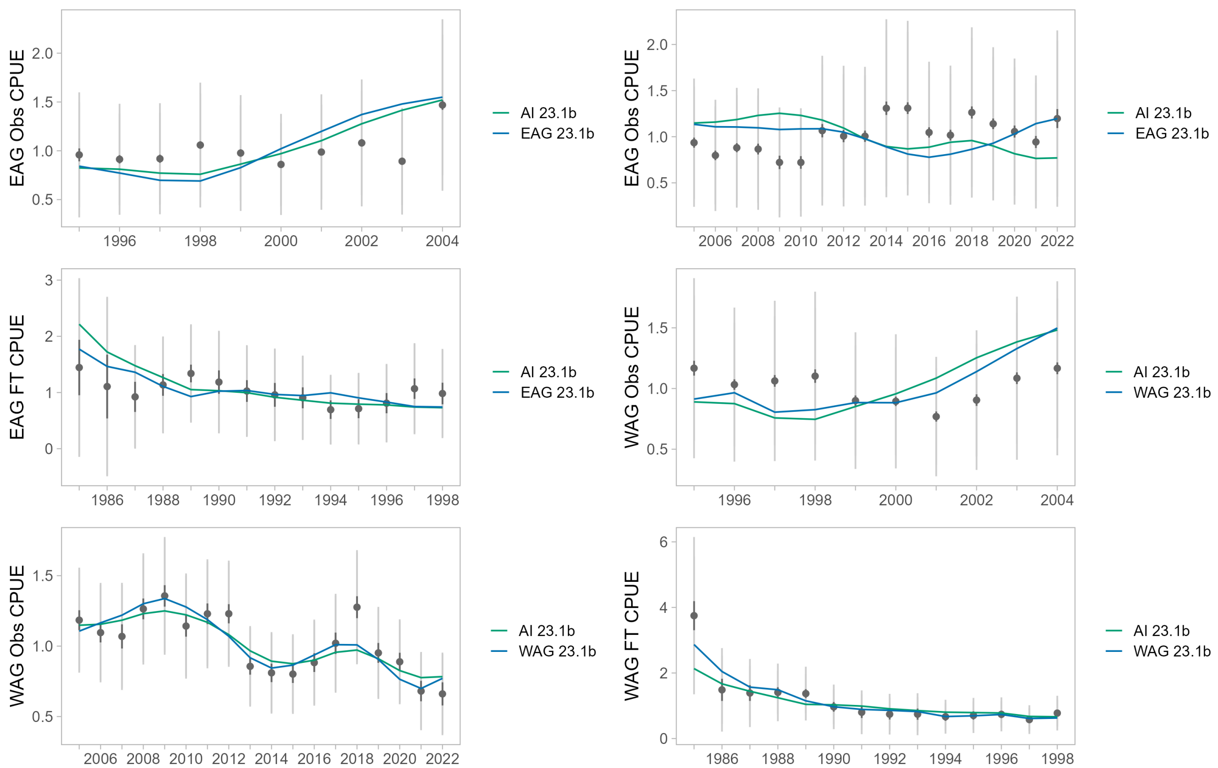

Figure 42: Comparison of model fit to CPUE indices for AI 23.1b, EAG 23.1b, and WAG 23.1b. Error bars on observed values respresent 95% confidence intervals (dark grey) and estimated additional error (light grey).

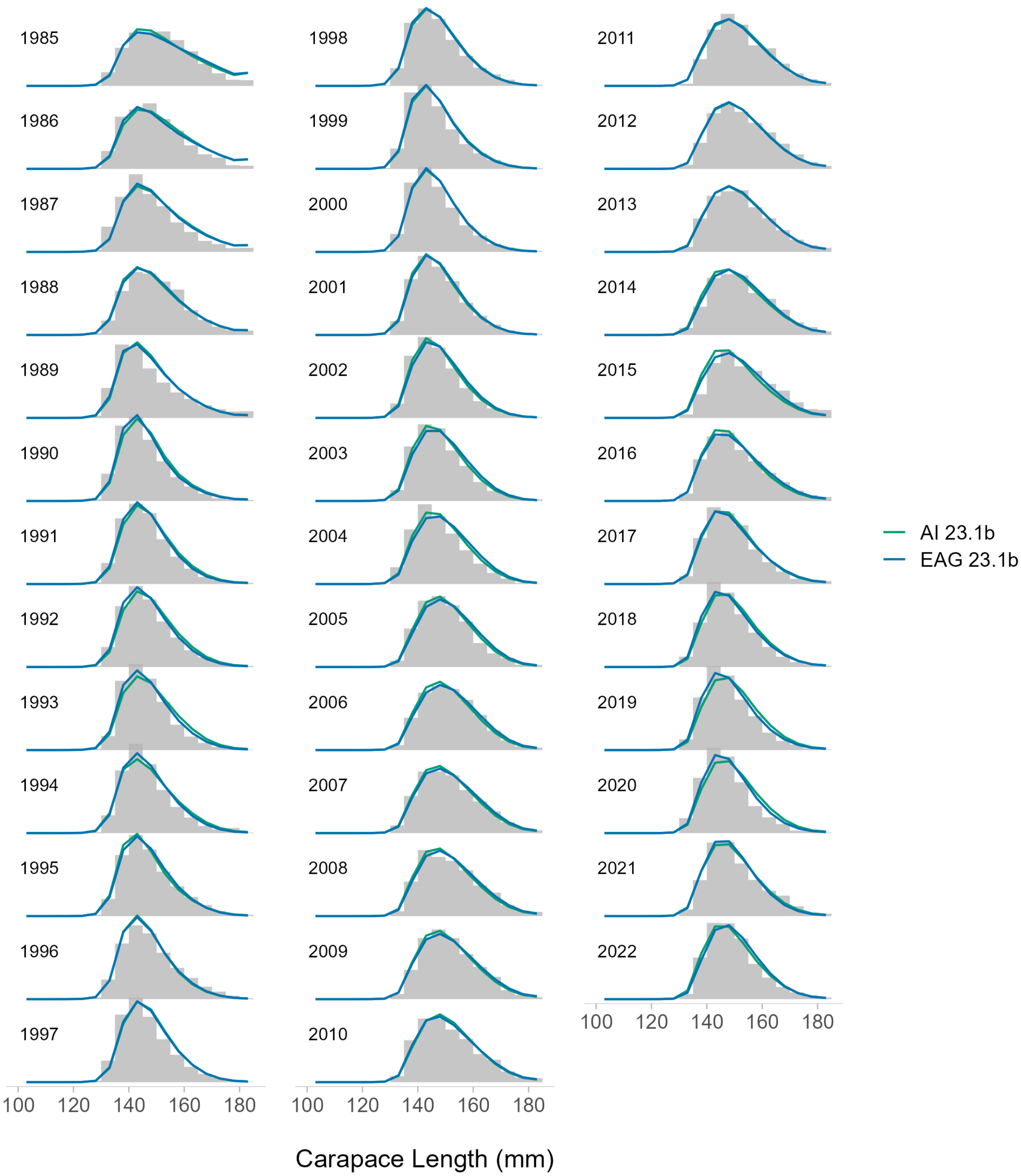

Figure 43: Comparison of model AI 23.1b and EAG 23.1b fit to reatined catch size composition in the EAG.

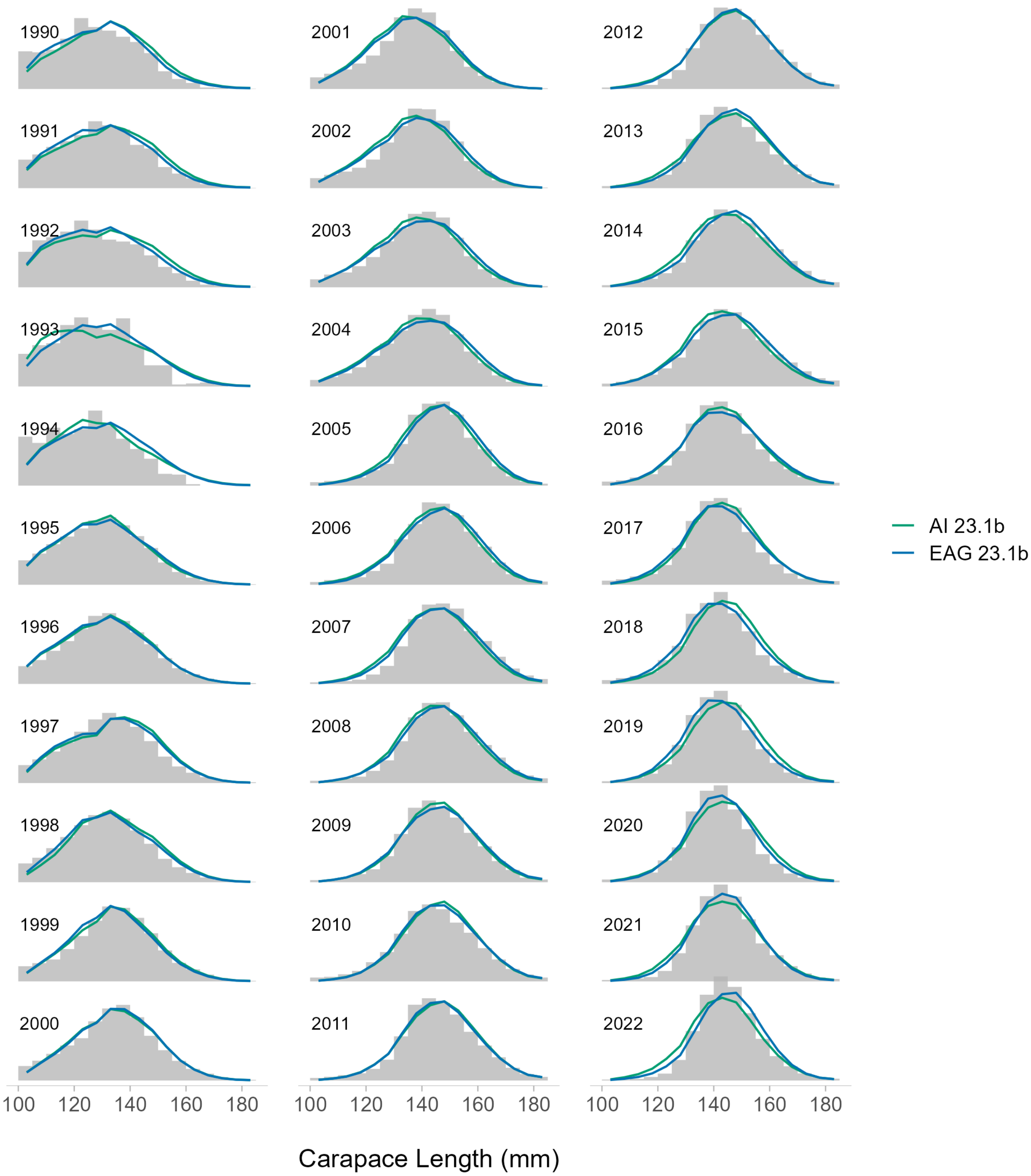

Figure 44: Comparison of model AI 23.1b and EAG 23.1b fit to total catch size composition in the EAG.

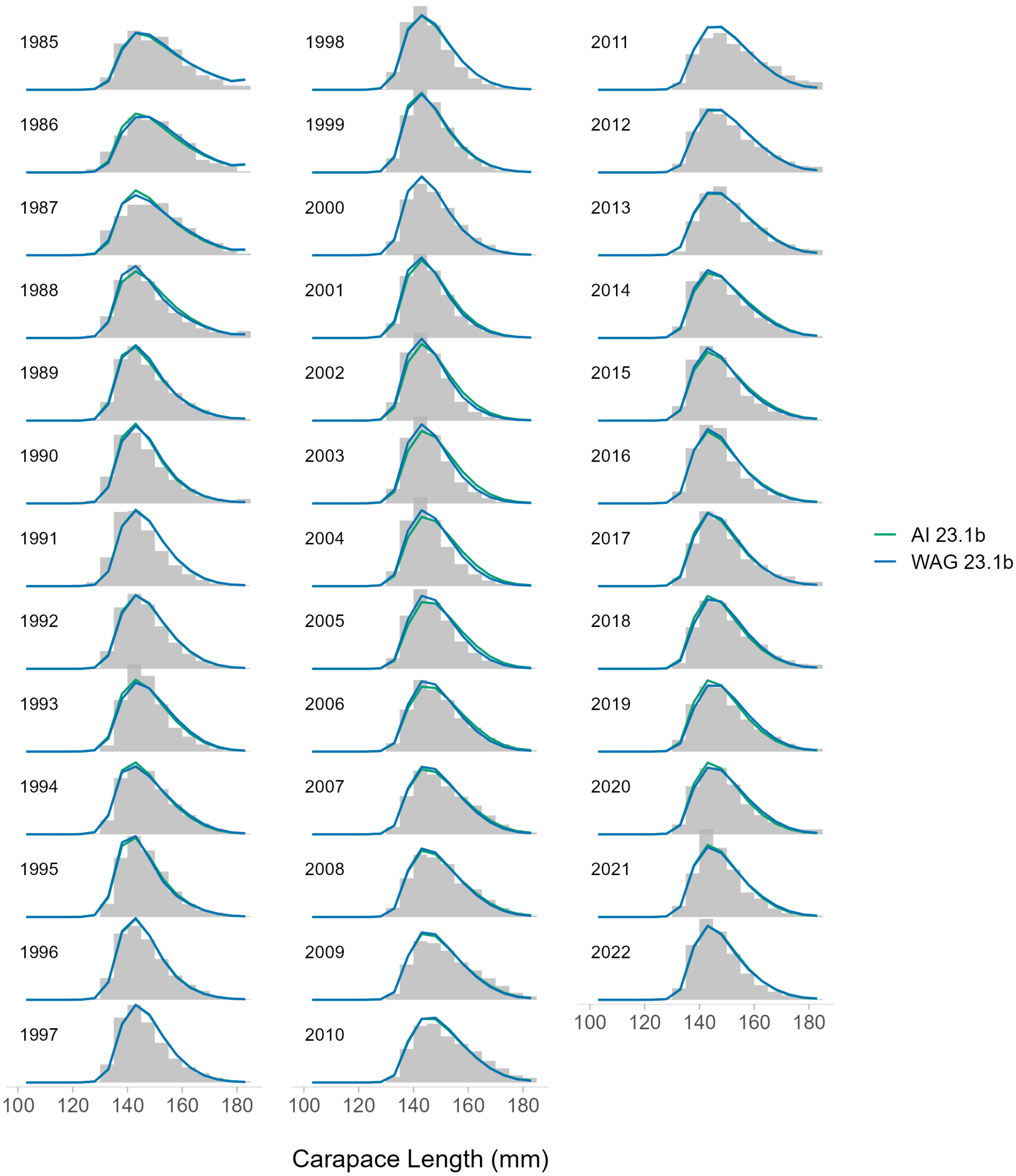

Figure 45: Comparison of model AI 23.1b and WAG 23.1b fit to reatined catch size composition in the WAG.

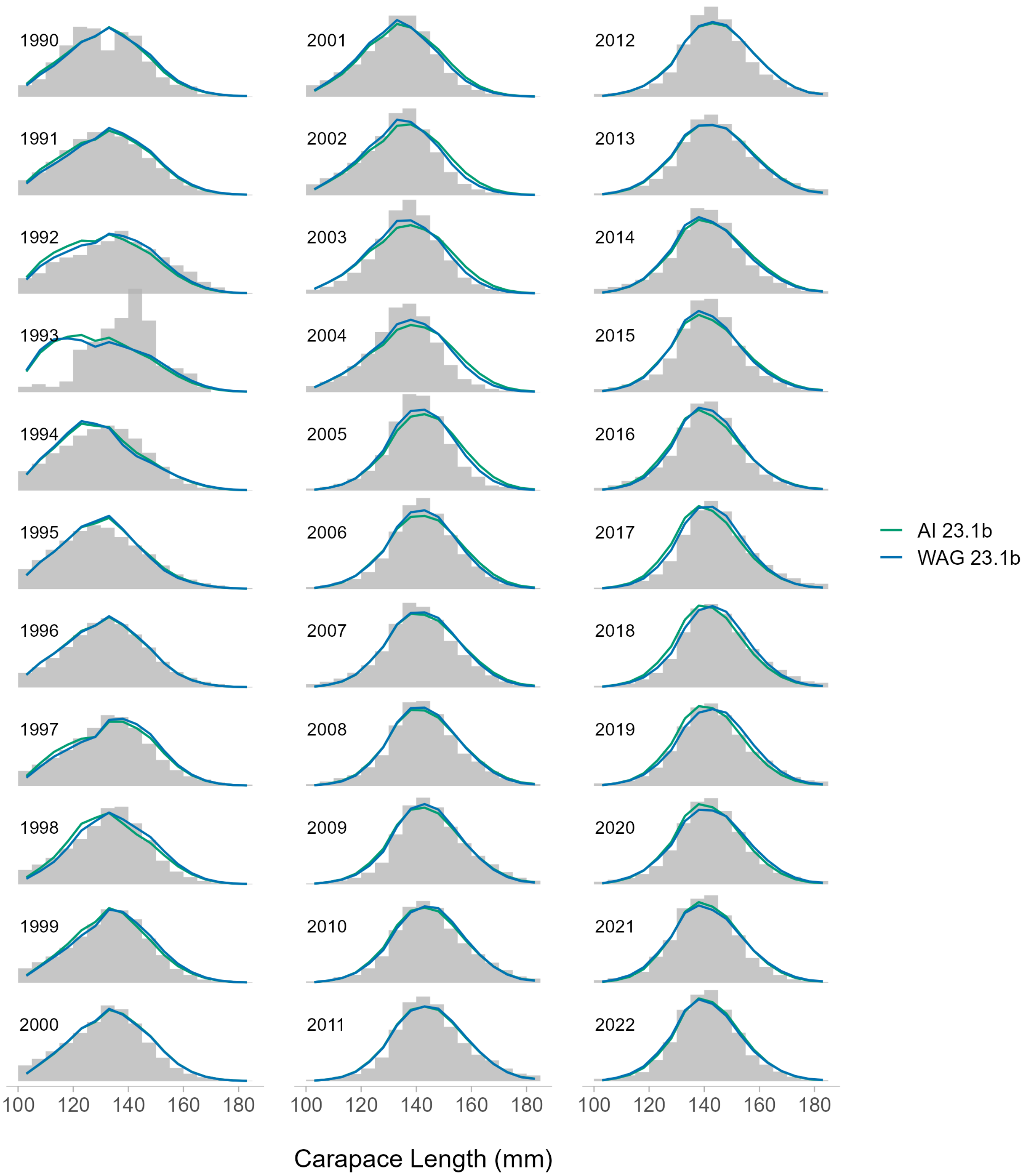

Figure 46: Comparison of model AI 23.1b and WAG 23.1b fit to total catch size composition in the WAG.

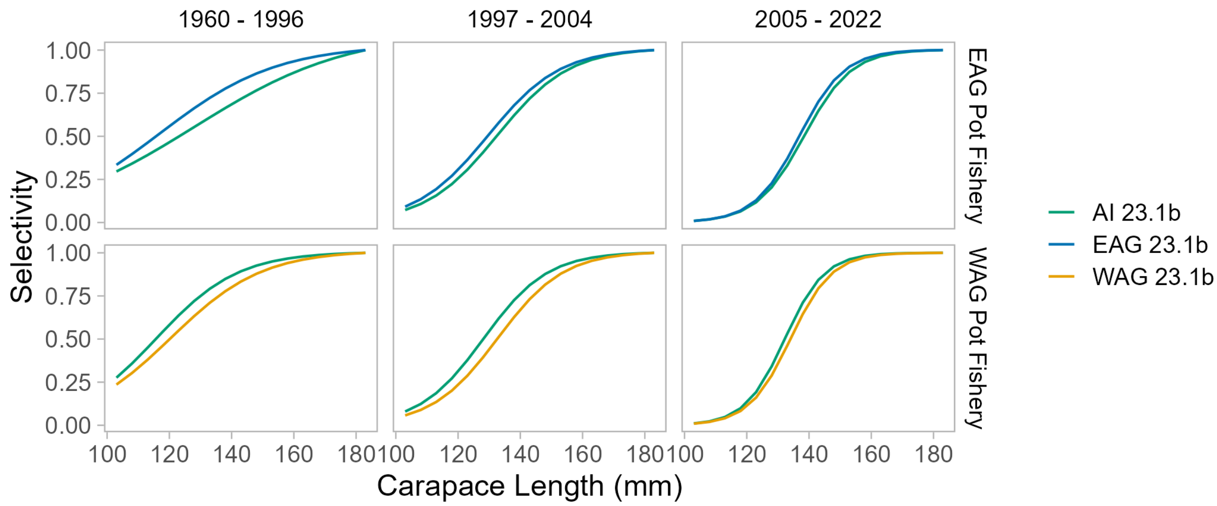

Figure 47: Comparison of estimated selectivity for the directed fishery in the EAG and WAG for models AI 23.1b, EAg 23.1b, and WAg 23.1b.

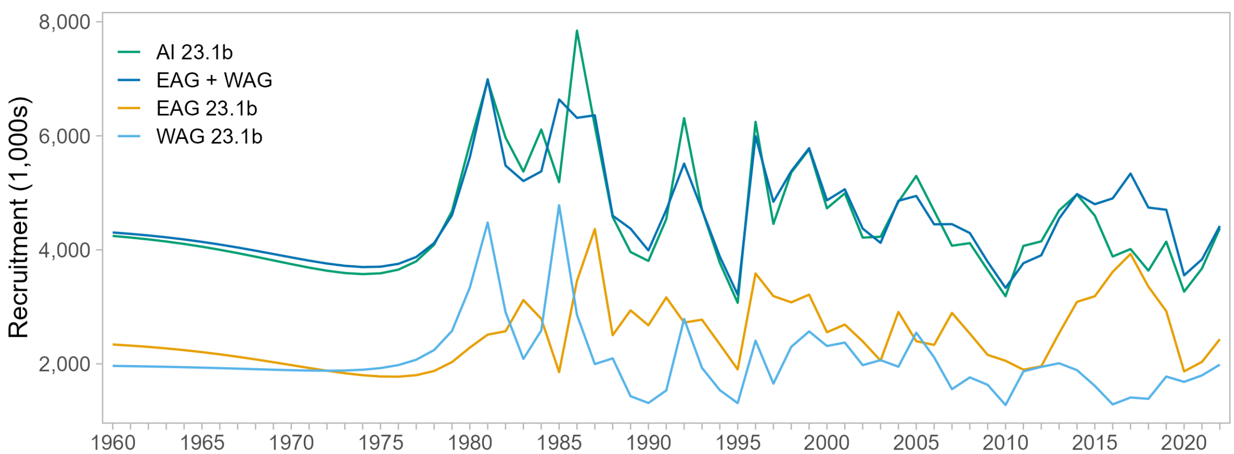

Figure 48: Comparison of model estimated recruitment for model AI 23.1b, EAG 23.1b, WAG 23.1b, and sum of EAG and WAG models.

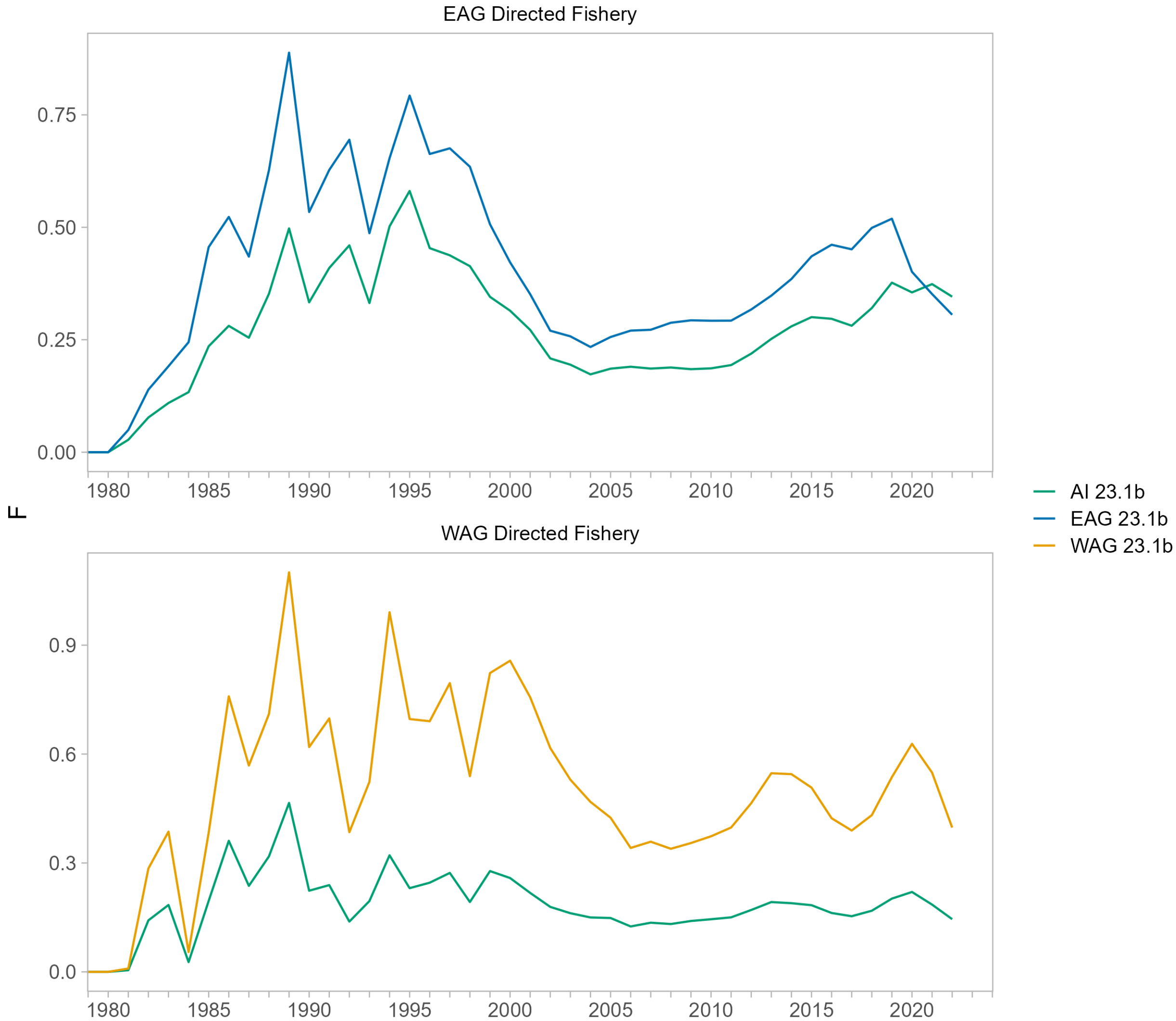

Figure 49: Comparison of model estimated fully selected fishing mortality for models AI 23.1b, EAG 23.1b, and WAG 23.1b by fleet.

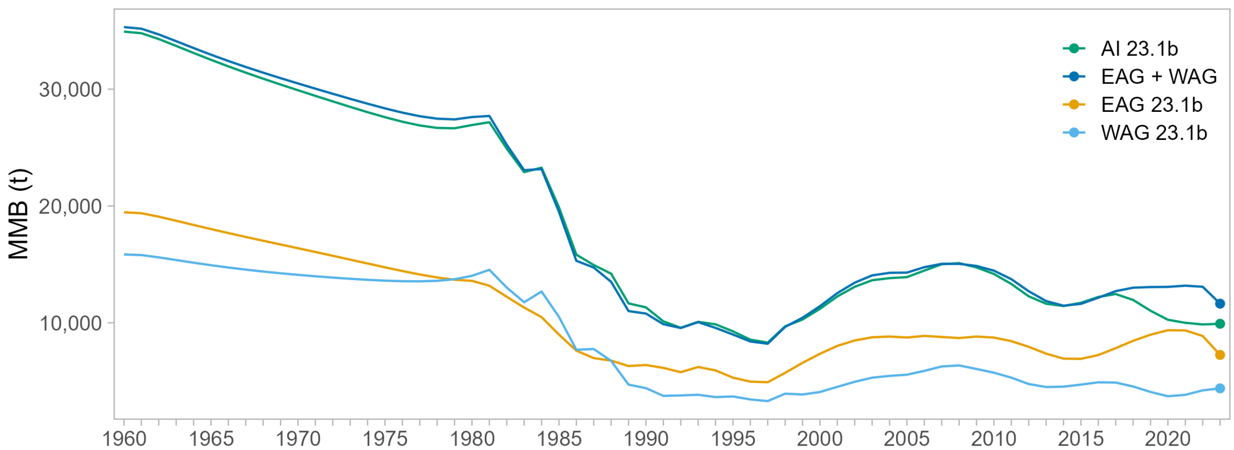

Figure 50: Comparison of estimated MMB for model AI 23.1b, EAG 23.1b, WAG 23.1b, and sum of EAG and WAG models.

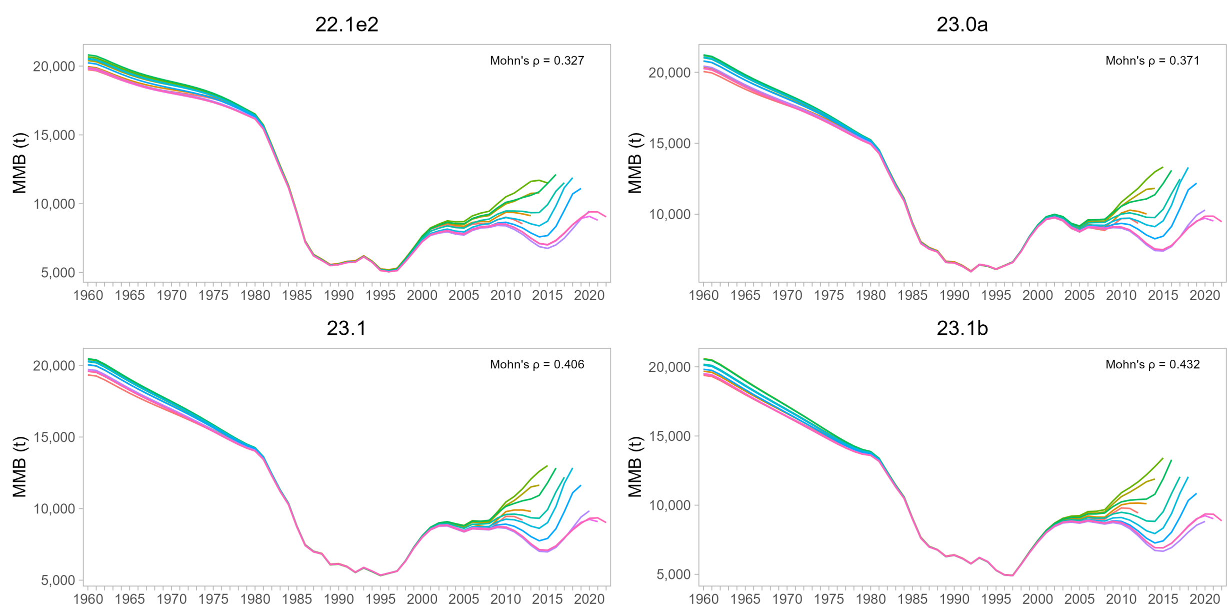

Figure 51: Estimated MMB and associtated Mohn's ρ from retrospective analysis of EAG models 22.1e2, 23.0a, 23.1, and 23.1b.

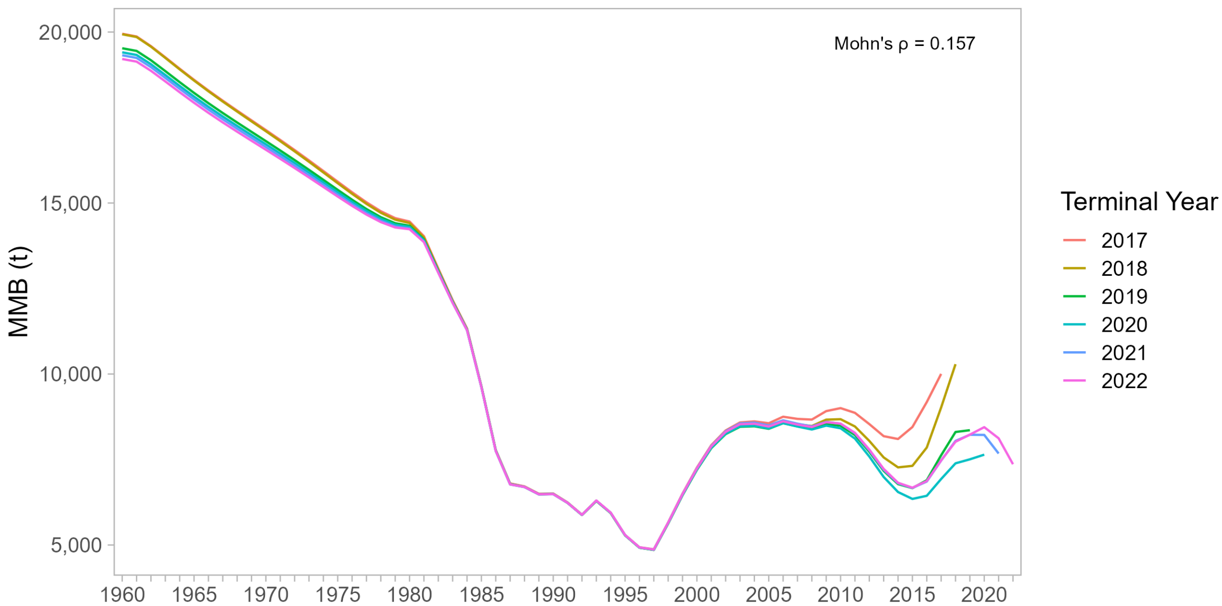

Figure 52: Estimated MMB and associtated Mohn's ρ from retrospective analysis of EAG model 23.2.

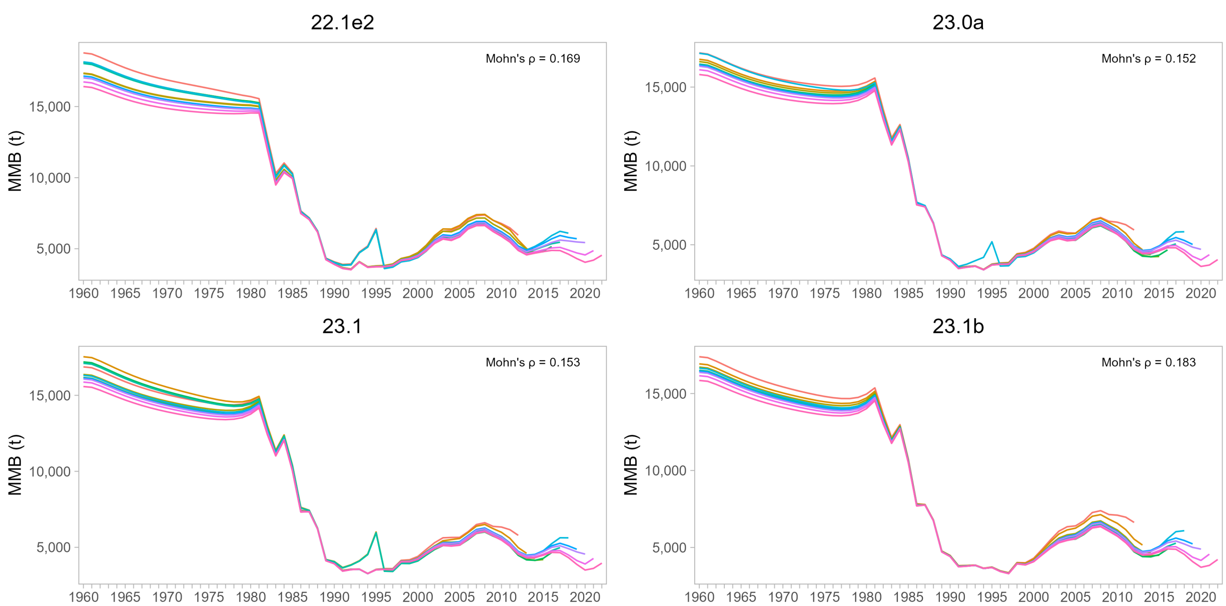

Figure 53: Estimated MMB and associtated Mohn's ρ from retrospective analysis of WAG models 22.1e2, 23.0a, 23.1, and 23.1b.

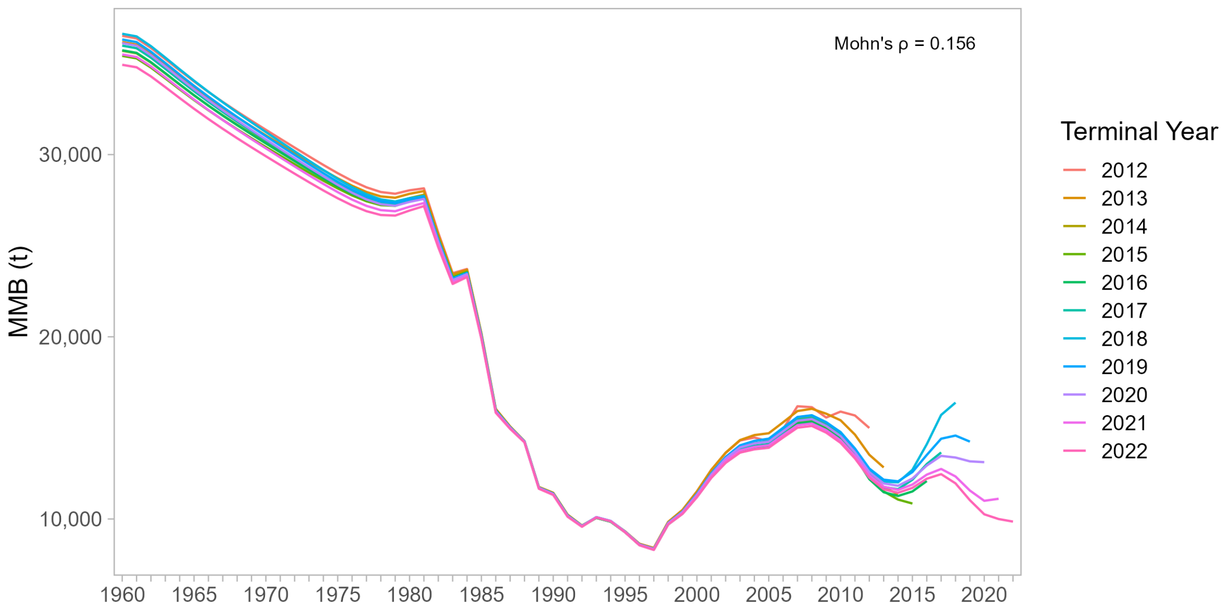

Figure 54: Estimated MMB and associtated Mohn's ρ from retrospective analysis of model AI 23.1b.

Literature Cited

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