A preliminary assessment for Pribilof Islands red king crab

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Contents

A. Executive summary

Pribilof Islands red king crab is assessed on a triennial cycle. The primary changes presented in this assessment draft are an update of GMACS, the inclusion of a pot survey by ADFG, and alteration of the weighting/prior specifications. Two of the considered models produced growth estimates inconsistent with the best available science on the dynamics of red king crab. The stock was more than double BMSY for all biologically plausible models. The author preferred model (25.3a) for September includes the ADFG pot survey and altered weighting schemes to reflect growth appropriately. Inclusion of the status quo model without the pot survey is also suggested to bring forward in September.

B. SSC comments

That the assessment author and other red king crab assessment authors (BBRKC) review the existing growth data and review potential additional sources of growth information.

Tagging data were provided from the Kodiak lab and used to inform the estimation of growth in this assessment (Figure 1). The data were not fit within the assessment, but used as priors as has been done historically for both PIRKC and BBRKC. The average growth increment across years time at liberty for the first molt (if present) was used as a prior on the molt increment within the assessment. Discussion from the plan team about the relative pros and cons of fitting these data within the assessment given they are primarily from Bristol Bay would be useful.

The CPT also recommended that the author examine whether the standard deviation around the growth increment matches the spread around the tagging data for BBRKC.

The input variability for the growth increment was similar to that observed in the tagging data (Figure 1). Sensitivities are included to the specified growth increment variability. Ultimately the status quo specifications seem appropriate for the assessment until a decision is made on whether or not to fit the tagging data inside the assessment model.

C. GMACS Assessment scenarios

Models

Six assessment variants were considered this year:

- 22.1: accepted model from 2022
- 25.1: Same data from 22.1, but updated GMACS model
- 25.2: 25.1 + ADFG pot survey
- 25.3: 25.2 + down-weighted size comps + prior on growth increment
- 25.3a: 25.3 + smaller variability in growth
- 25.3b: 25.3 + larger variability in growth

A large number of changes in both structure and formatting have occurred since 2022 when the GMACS version used for PIRKC was last updated. For example, functionality was extended to include allowing indices for immature crab, the .CTL file and variable naming schemes were rewritten, prior implementation was standardized across parameters, and jitter protocols were revised. For an exhaustive list of changes and bug fixes, see the very end of the .TPL file for the most recent GMACS version on the github repo. All of these appear to be improvements, but they did result in some changes to the model fits and derived management advice. The precise reasons for these changes are unclear given the volume of changes.

A pot survey around the Pribilof Islands was performed during 4 years from 2003-2011 (2003, 2005, 2008, 2011). Given the finer spatial resolution than the NMFS bottom trawl survey, it is possible that the inclusion of the pot survey in the assessment could provide more clarity on population trends during the 2000s. The number of survey stations and pots dropped varied across years with the most occurring in 2008 (220 stations and 1021 pots) and the fewest in 2011 (161 stations and 644 pots; **??**). The number of crab captured each year ranged from 98 to 6507 (2011 and 2008, respectively; Figure 3). The largest number of crab pot hours occurred in 2008 (Figure 4). The number of crab per 1,000,000 hours of soak time were used as an index of abundance from the pot survey. The unit 'Crab per 1,000,000 hours' was used in order to put the index on a similar scale as the NMFS bottom trawl survey and avoid convergence issues around estimating very small catchability coefficients that occurs because of the parameter space in which catchability is estimated.

Fitting the pot survey with the historical assessment specifications resulted in unrealistic estimates of population processes given other available information. First, the growth increment data available for red king crab in the Bering Sea suggest that the growth increment should be double what was estimated (Figure 1). Second, the estimated survey selectivity was shifted dramatically to the right, which is inconsistent with estimated survey selectivity estimated in the BBRKC assessment (though issues around catchability closer to the islands may be a consideration here). To respond to these issues, another model was ran in which a relatively tight prior (mean = 17, sd = 0.5) was placed on the mean growth increment based on available tagging data and the weightings on the size composition data were roughly halved.

Two sensitivities are presented on the input variance for growth increments used in calculating the size transition matrix. The distribution around the mean growth increment in the assessment is defined by a renormalized gamma distribution. The scale parameter for this distribution is currently specified as 0.25; sensitivities were performed where this value was input as 0.20 and 0.30. Models with larger or smaller specified values resulted in convergence problems.

Results

Model convergence and comparison

No models displayed signs of non-convergence based on the production of a Hessian and gradients near zero. Total likelihoods are not comparable across all models given the addition of an additional survey and alteration of the weighting schemes (Table 1). More extensive model diagnostics including jittering and retrospective anlayses will be provided in September.

Model fits

There was considerable variability in model fits to mature male biomass, particularly during the 1990s (Figure 5). Broader agreement among models existed from the mid-2000s to present. The fits to the ADFG pot survey were similar among models, but little of the variability in the pot survey CPUE was captured by the model (Figure 6). A large part of the difference among models was a result of different estimates for mean growth increment (Figure 7). Based on available tagging data, the model that was closest to observations for Bering Sea red king crab was the models without the ADFG pot survey data in them. Sensitivities to the value of the variability around growth suggest the currently used variability is close to the variability observed in the tagging data (Figure 8). Fits to the available catch data were all acceptable (Figure 9).

Size composition data are relatively sparse for many years in both the survey and observer data, particularly in early years of the assessment when red king crab were not as abundant around the Pribilof Islands (see .DAT files for sample sizes). Consequently, the fits among models to these early data are somewhat noisier than in later years (Figure 10). The models fit the data from the early 2000s until recently more similarly, until 2017, when more disagreement appears. This pattern is also apparent in the non-directed bycatch size composition data (Figure 11). There is a fair amount of difference in the fits to the ADFG size composition data among models as well (Figure 12). Only 2003 and 2011 were well fit by at least one model.

Estimated population processes

Much of the differences in fits to the survey data are related to the interplay of the differences in estimated recruitment, growth, and survey selectivity among models (Figure 13). Models that incorporate the ADFG pot survey data without placing priors on the estimated growth increment or down-weighting size composition data fit the survey data by estimating a very low molt increment, a survey selectivity curve shifted strongly to the right, and a large recruitment event at the beginning of the model that sustains the population throughout the modeled history of the population (Figure 15). Selectivity for the ADFG pot survey and observer data in the non-directed bycatch adjusts among those scenarios to fit their respective size composition data (Figure 14 & Figure 16). Changes in the estimated scale of the population directly impact the estimates of fishing mortality across models, with larger estimated populations having lower estimated fishing mortality (Figure 17). The probability of molting is specified in all models based on estimates from the BBRKC assessment (Figure 18).

MMB and management quantities

The impacts of differences in estimates of growth, recruitment, and selectivity across models are most easily seen through large differences in the estimates of mature male biomass (Figure 19). The MMB feeds directly into the control rule used to calculate the OFL. The harvest control rule for PIRKC is calculated based on a tier 4 rule that uses the specified natural mortality as a fishing mortality target and defines the proxy for $\mathrm{B}_{\mathrm{MSY}}$ as 35% of the average MMB over the years 2000-present minus 1 (provided the stock remains unfished). These management targets are then used in the harvest control rule below to calculate an OFL.

$$F_{OFL} = \begin{cases} Bycatchonly & if \frac{MMB}{MMB_{MSY}} \leq 0.25 \\ \frac{\lambda M(\frac{MMB}{MMB_{MSY}} - \alpha)}{1-\alpha} & if 0.25 < \frac{MMB}{MMB_{MSY}} < 1 \\ \lambda M & if MMB > MMB_{MSY} \end{cases} \tag{1}$$

Where MMB is the mature male biomass projected to the time of mating, MMB_{MSY} is 35% of the average mature male biomass over the years 2000-present, M is natural mortality, and α determines the slope of the descending limb of the HCR (here set to 0.1). The differences in estimated MMB resulted in large variability in the OFLs among models (Table 2). The current status of PIRKC from all models is more than twice the biomass targets, so the full FMSY proxy was applied to calculate the OFL, which ranged from 685-6328 tonnes.

Recommendations for GMACS in September

Bringing forward models 25.1 and 25.3a for consideration in September seems reasonable. Incorporating the ADFG data changed the model output substantially even when adjusting the weighting schemes and prior specifications, but including as many data sources as possible seems prudent when working with a small population with sparse data. More discussion on the treatment of the pot survey data and tagging data would be useful from the CPT. Given limited resources going forward and the lack of a fishery for PIRKC in the foreseeable future, discussion about the continuation of a model-based assessment for PIRKC may also be warranted.

Table 1: Likelihood components by category and model.

	22.1 Status quo	25.1 update_gmacs	25.2 ADFG pot survey	25.3 ADFG + weighting	25.3a ADFG + weight + growth _dn	25.3b ADFG + weight + growth _up
Catch	-76.85	-76.84	-76.86	-76.85	-76.86	-76.86
Index	31.42	40.69	29.38	37.48	34.94	35.23
Size	-8269.17	-8060.27	-8524.57	-8448.97	-8464.99	-8425.09
SRR	0.00	109.15	62.35	90.28	85.57	73.74
Tag	85.49	0.00	0.00	0.00	0.00	0.00
Penalties:	239.20	219.52	210.94	210.38	215.55	209.14
Priors:	104.58	157.05	165.25	162.99	185.34	166.42
Total:	-7885.33	-7610.70	-8133.51	-8024.69	-8020.46	-8017.41

Table 2: Management quantities derived from maximum likelihood estimates by model using Tier 4 reference points. Status and MMB were estimates for February 15 of the completed crab year.

	MMB	BMSY	Status	OFL	FMSY
22.1 Status quo	3616.74	1708.83	2.27	685.07	0.21
25.1 update_gmacs	4033.78	1506.56	2.87	764.06	0.21
25.2 ADFG pot survey	33410.19	12931.42	2.77	6328.42	0.21
25.3 ADFG + weighting	3632.48	1352.01	2.88	688.05	0.21
25.3a ADFG + weight + growth _dn	8564.54	4342.78	2.12	1622.26	0.21
25.3b ADFG + weight + growth _up	4270.39	1484.35	3.09	808.88	0.21

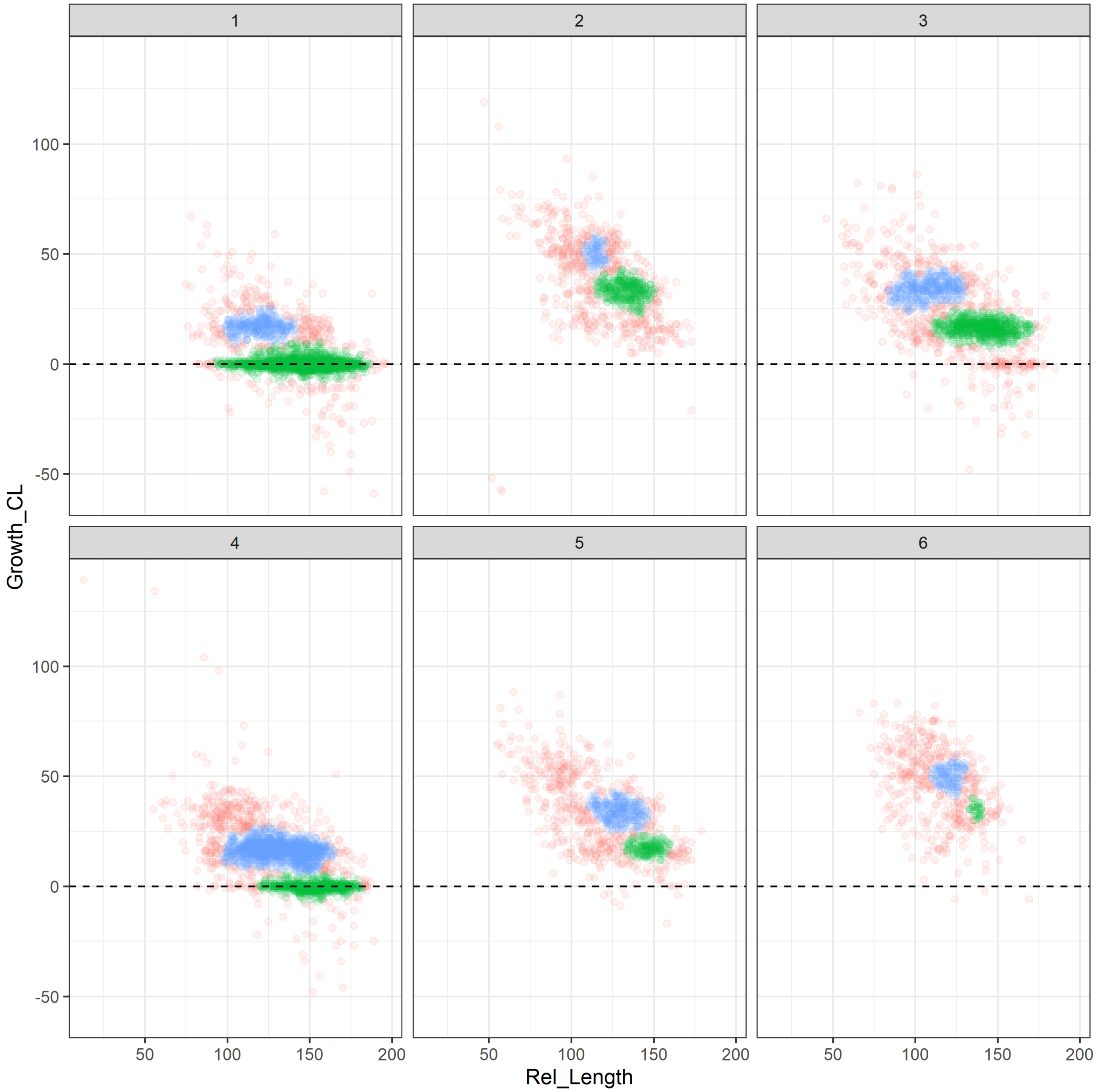


Figure 1: Tagging data for red king crab in the Bering Sea. Each dot represent a released and recaptured crab. Clusters identified with DBSCAN and represent different numbers of molts. The title of each panel represents the number of years elapsed since recovery of a tag. Y-axis is the growth from release to recapture; x-axis is the carapace length at release.

Figure 2: Locations of stations of ADFG pot surveys around the Pribilof Islands by year.

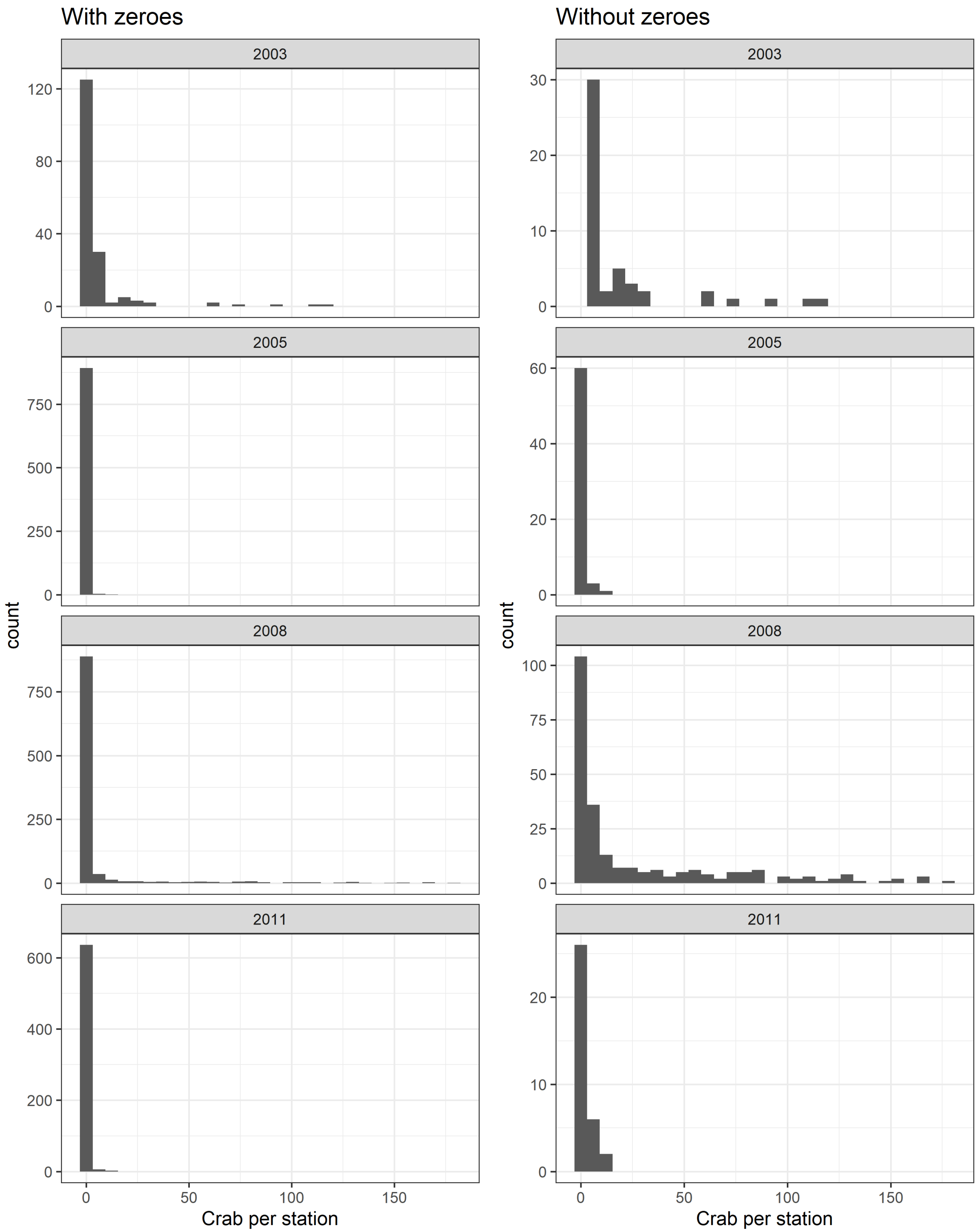


Figure 3: Histograms of the number of crab caught per station by year in ADFG pot survey.

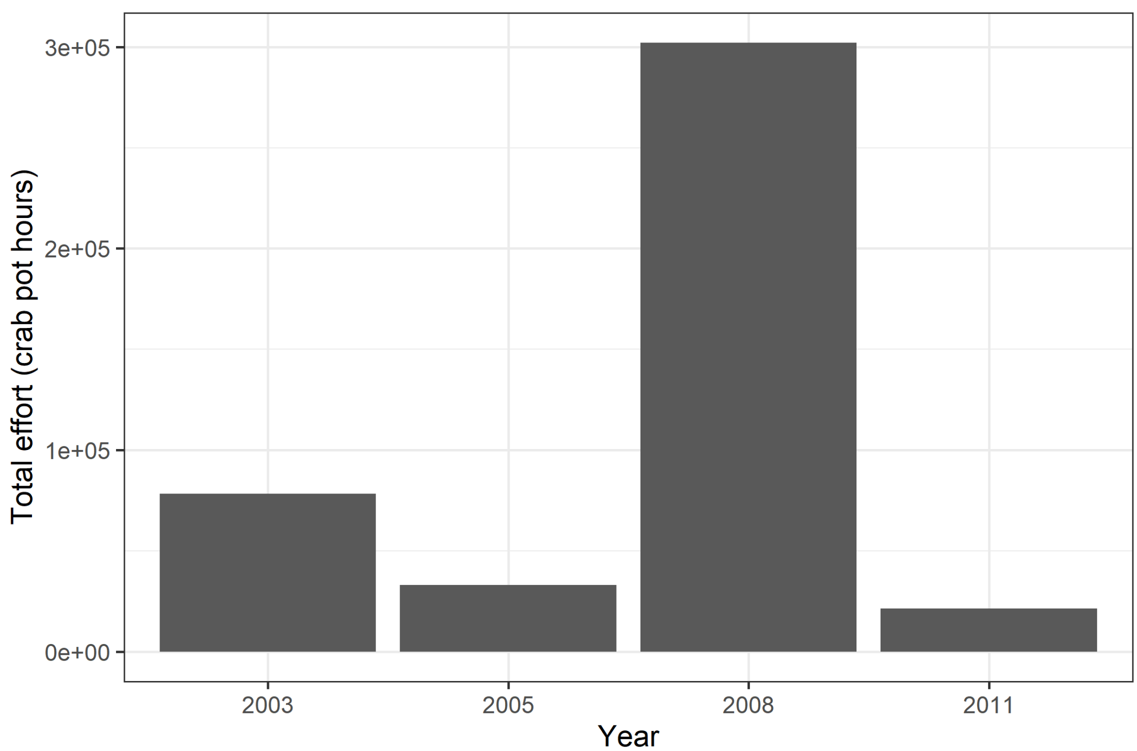


Figure 4: . Total hours of sampling effort by year in ADFG pot survey.

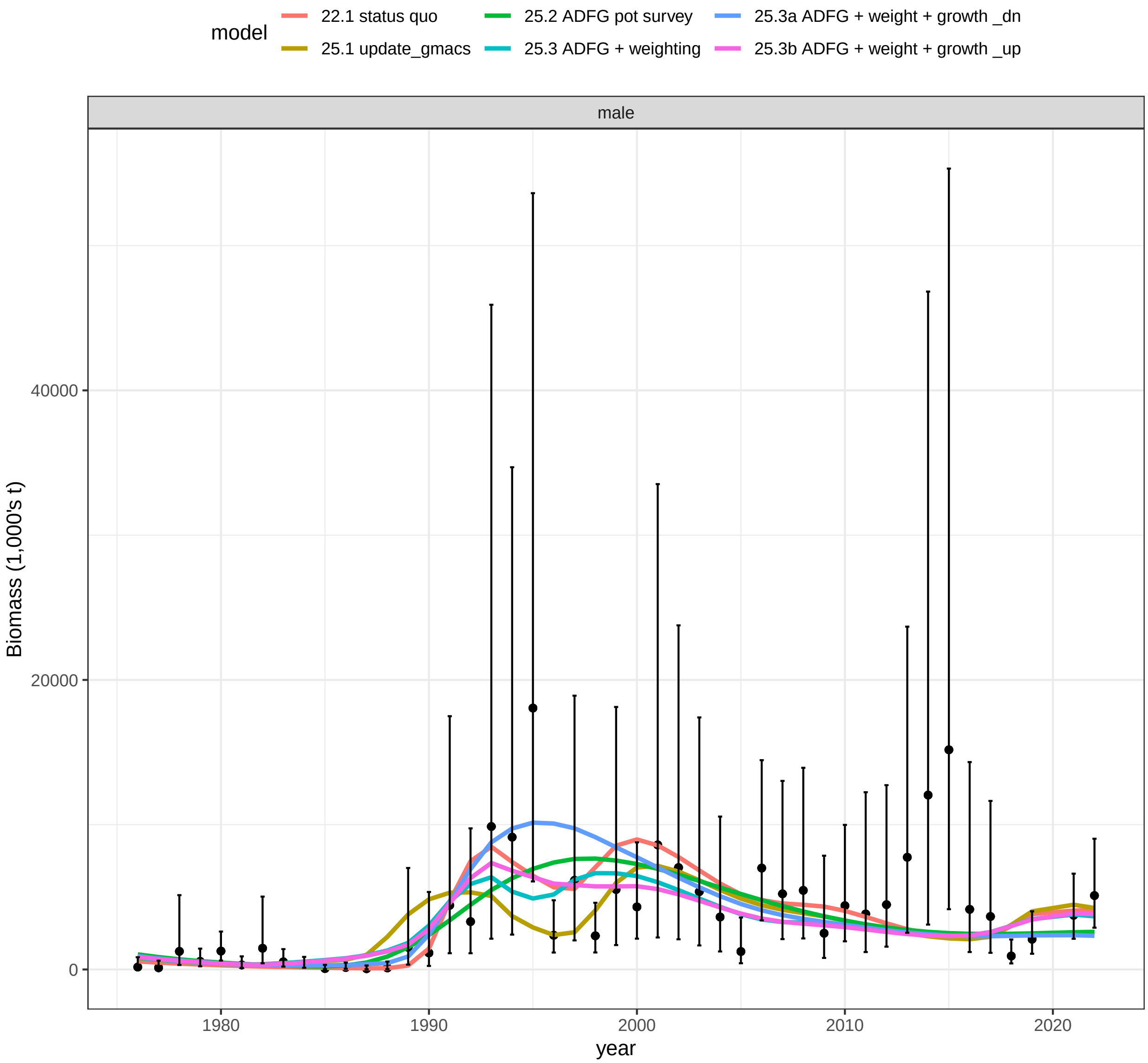


Figure 5: Model fits to the observed mature biomass at survey.

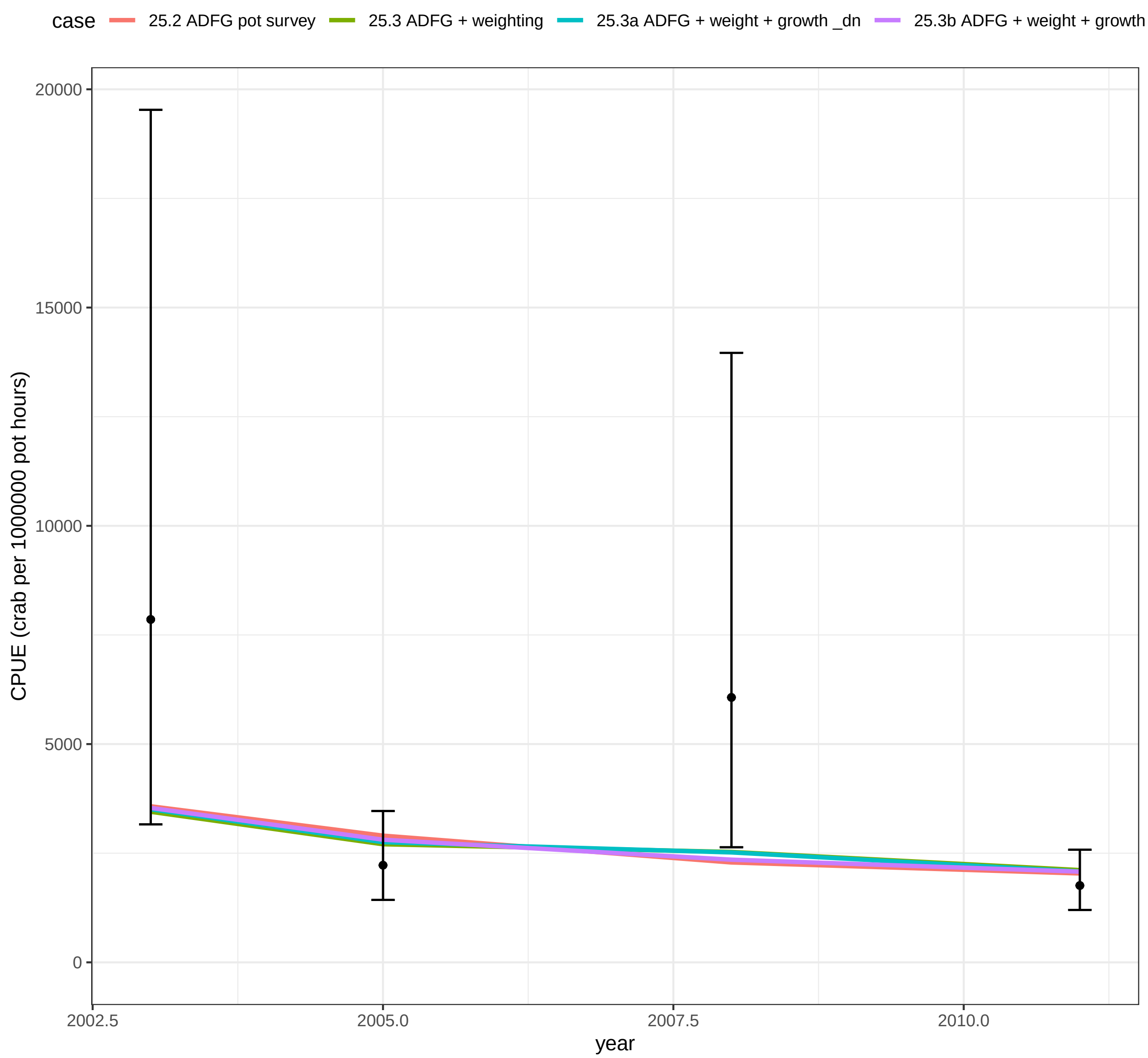


Figure 6: Model fits to the ADFG pot survey data.

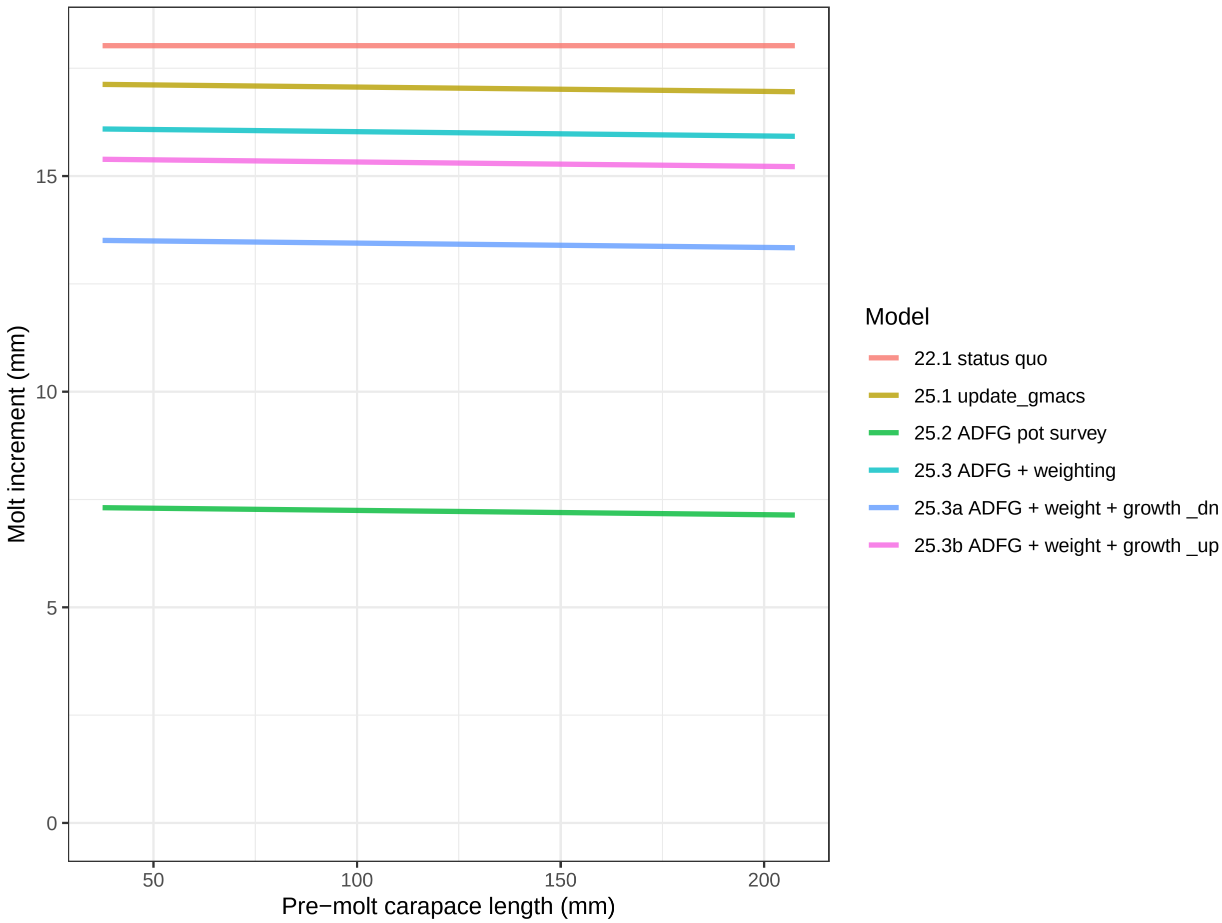


Figure 7: Model estimates of molt increment at size (colored lines).

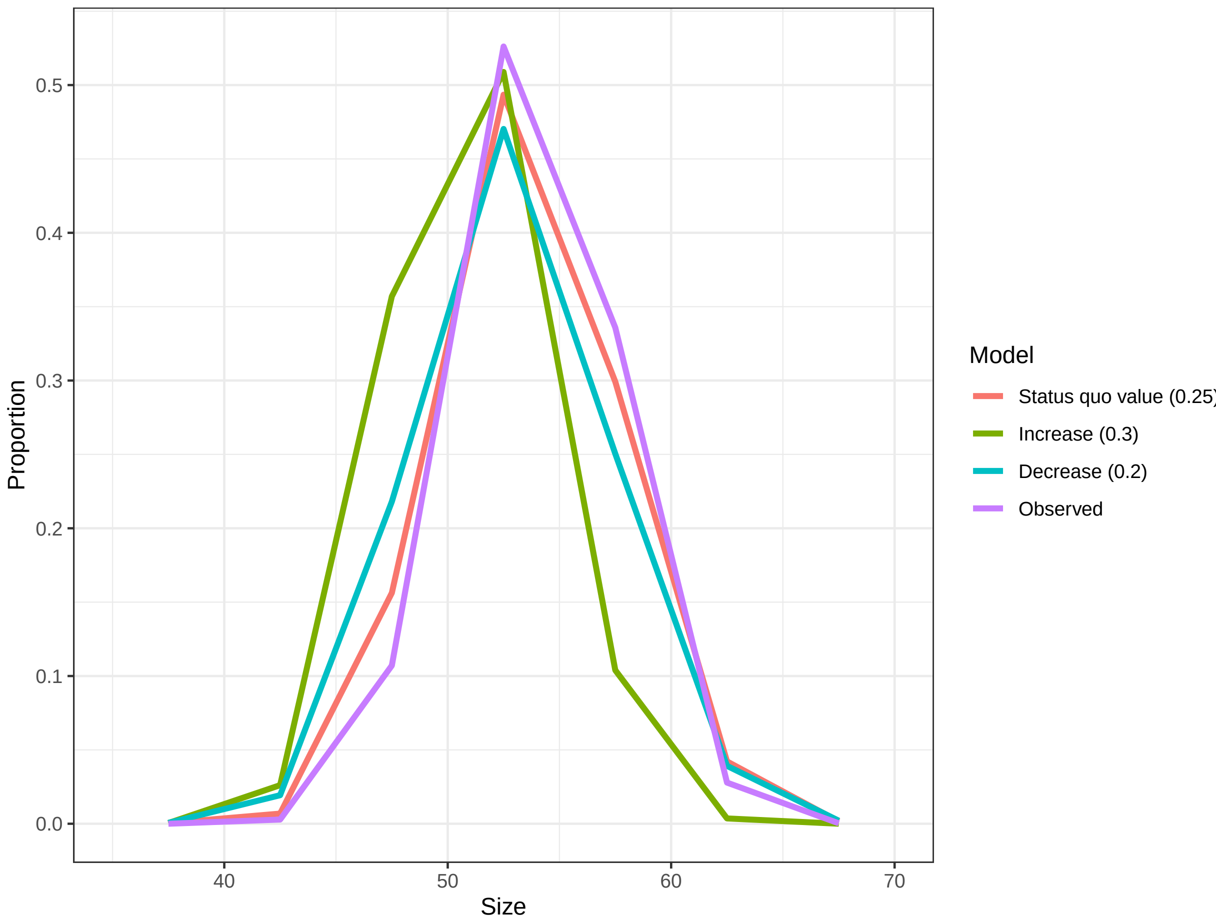


Figure 8: Comparison of variability around growth increments across model specifications. Lines represent the probability a crab of 37.5 mm carapace length molts into a given size on the x-axis.

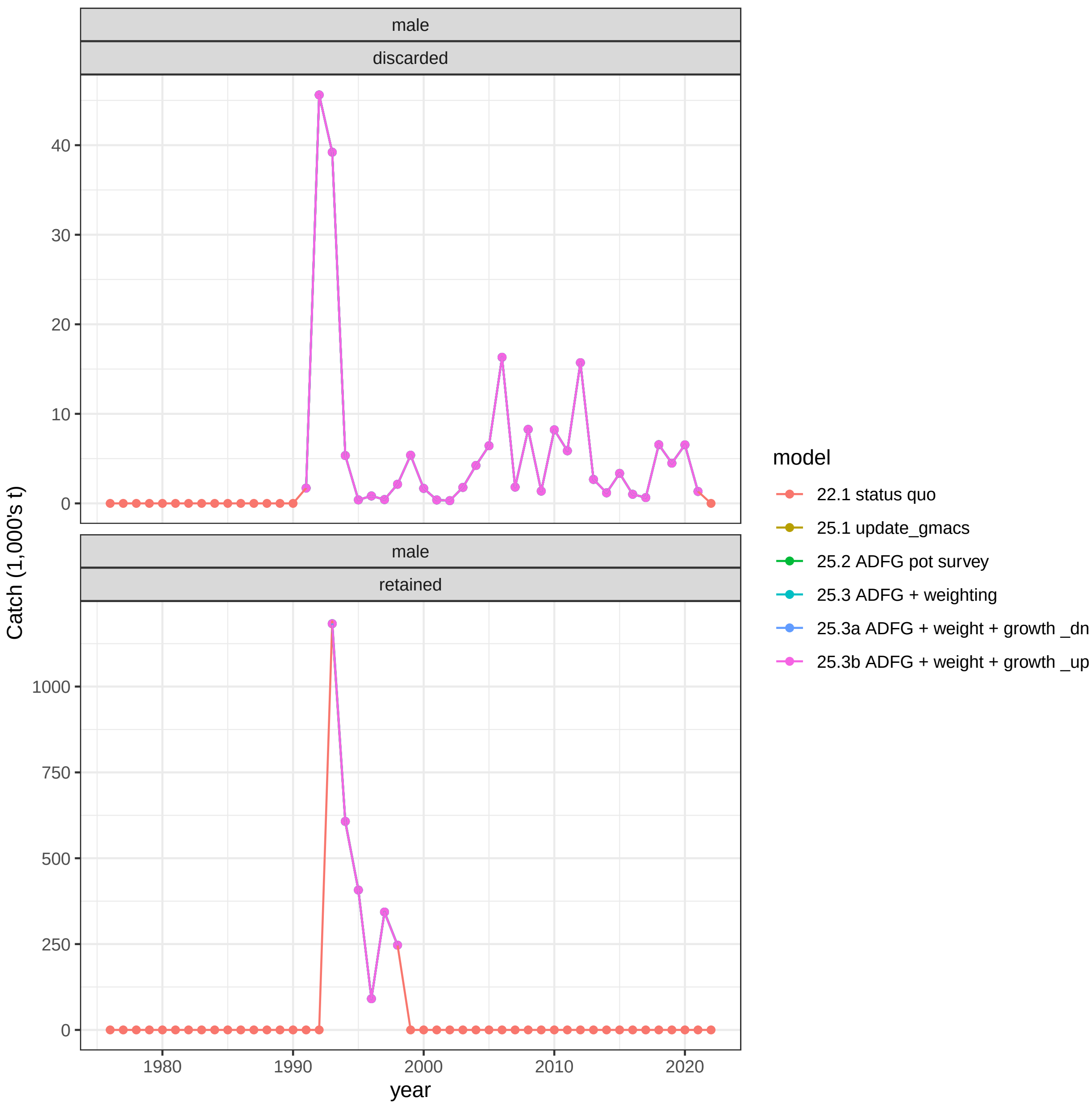


Figure 9: Model fits to non-directed bycatch data (top) and retained catch data (bottom).

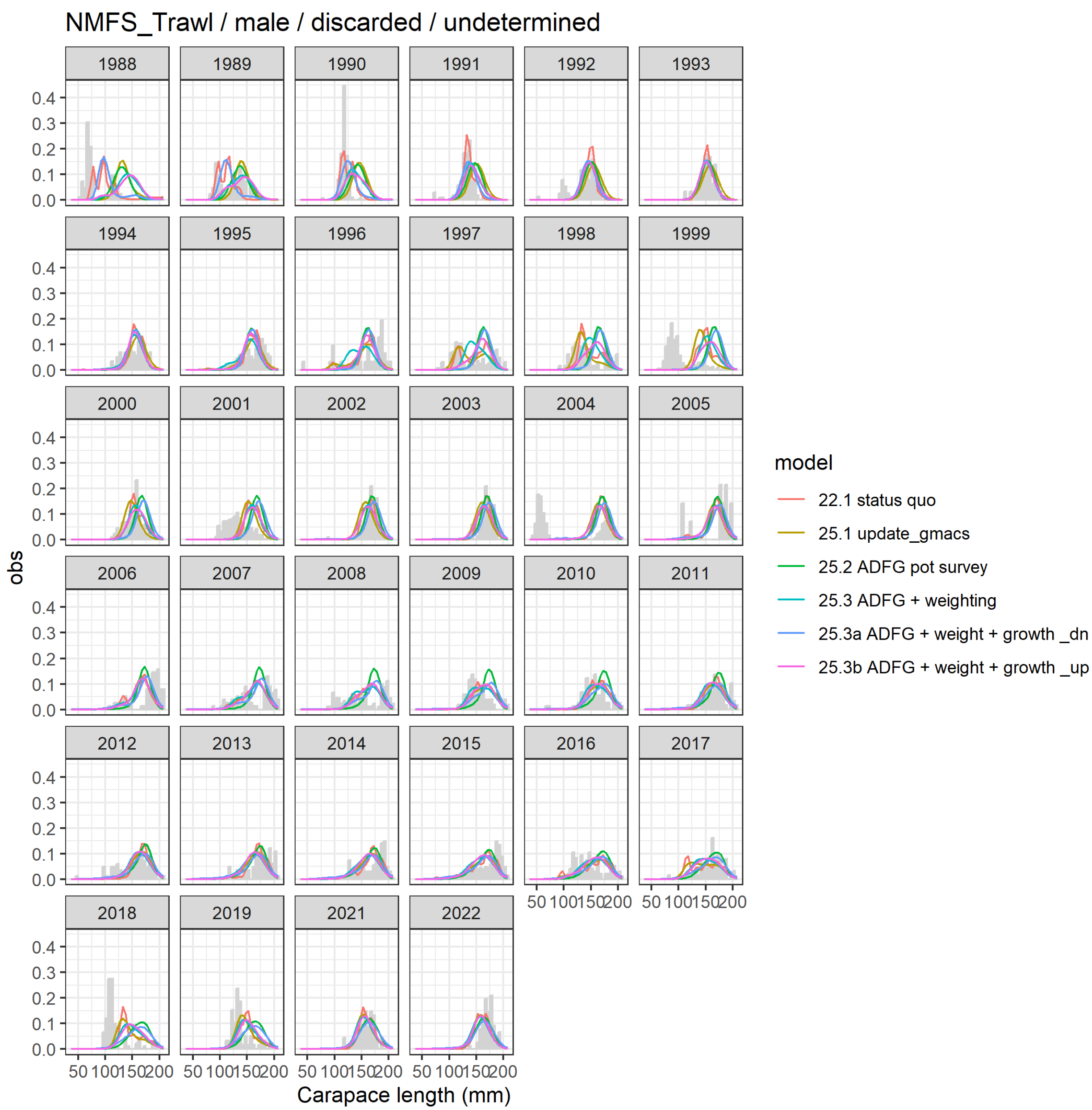


Figure 10: Model fits (lines) to the NMFS bottom trawl survey size composition data (grey bars).

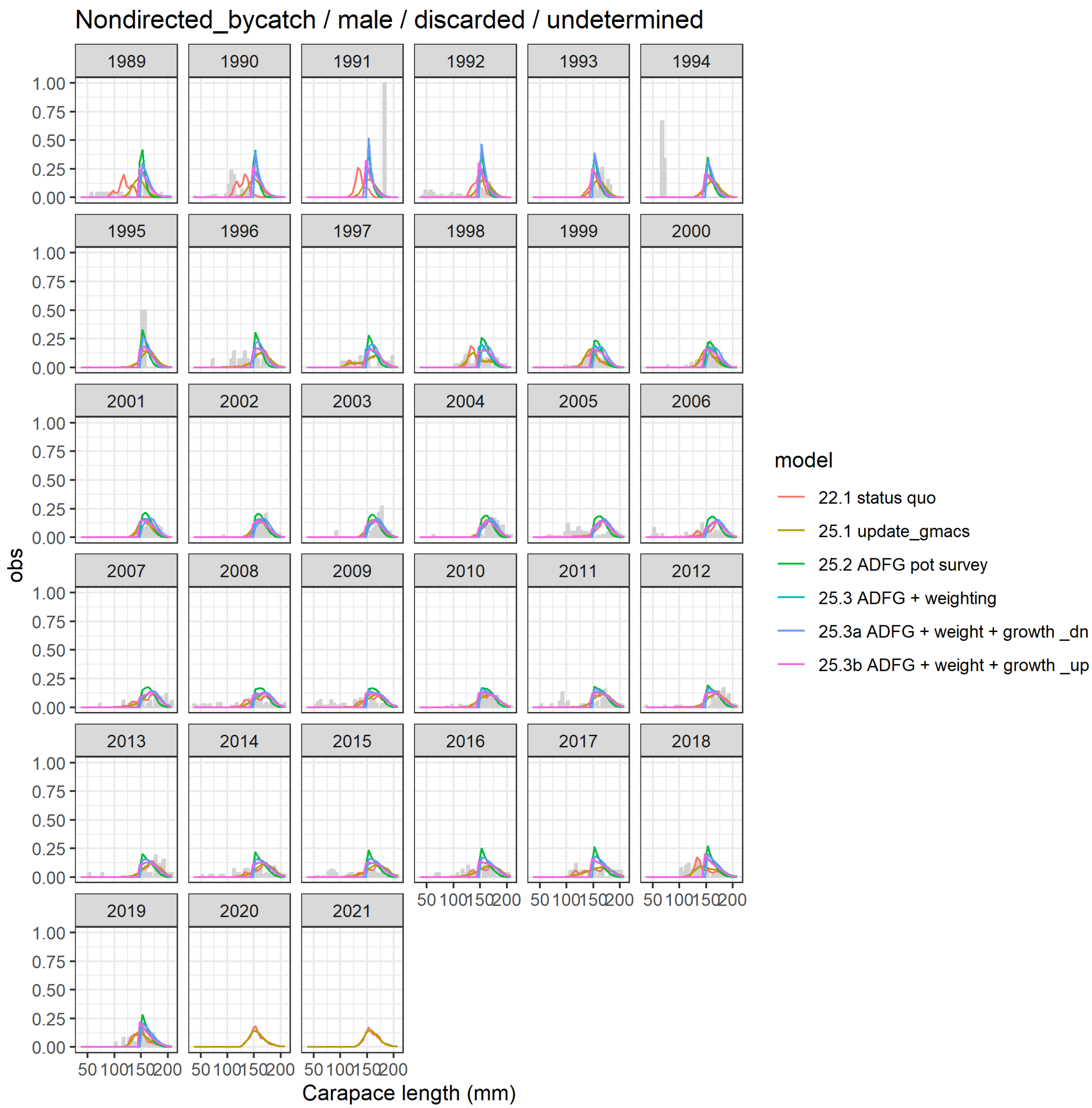


Figure 11: Model fits (lines) to the nondirected bycatch size composition data (grey bars).

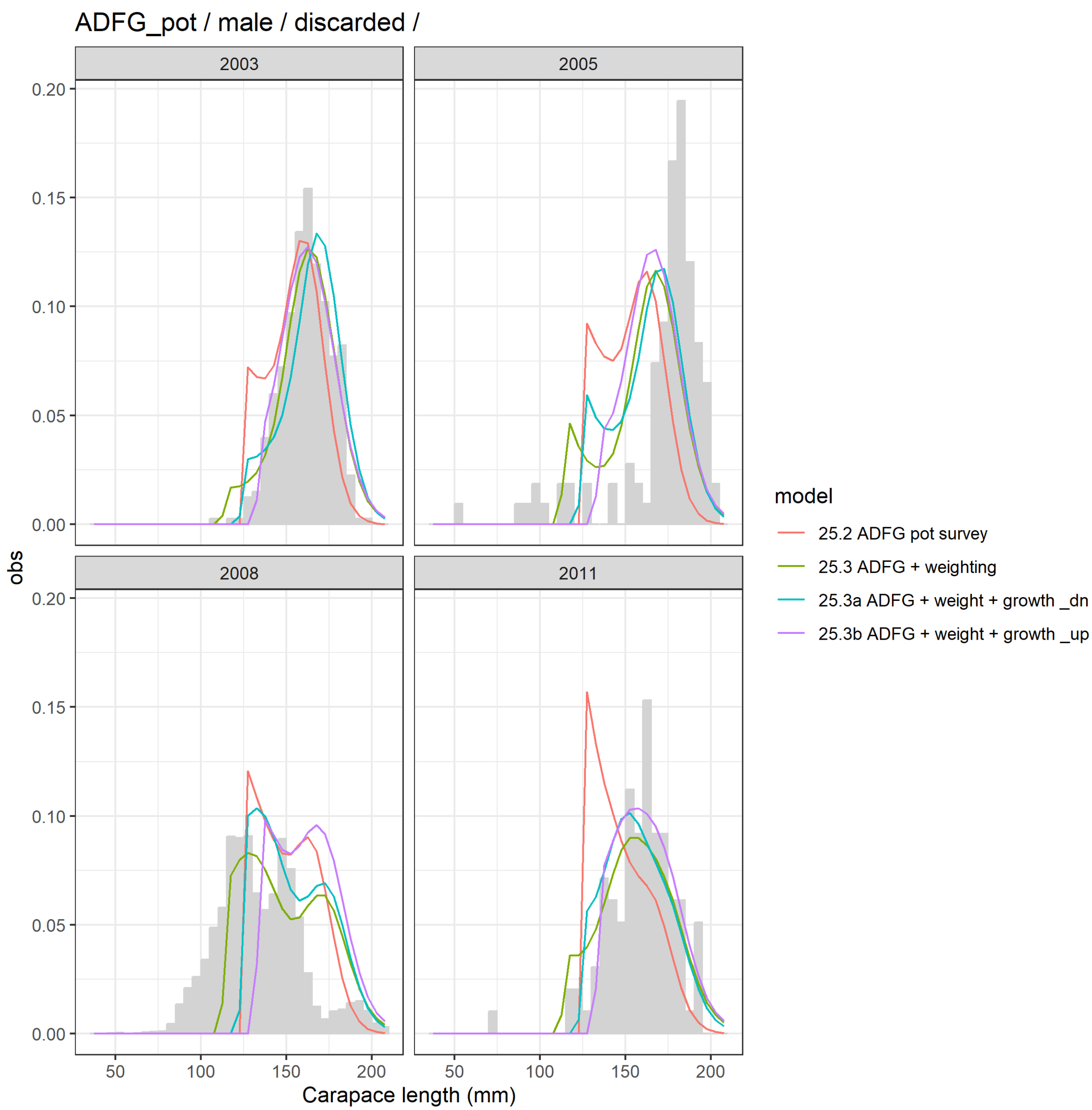


Figure 12: Model fits (lines) to the ADFG pot survey size composition data (grey bars).

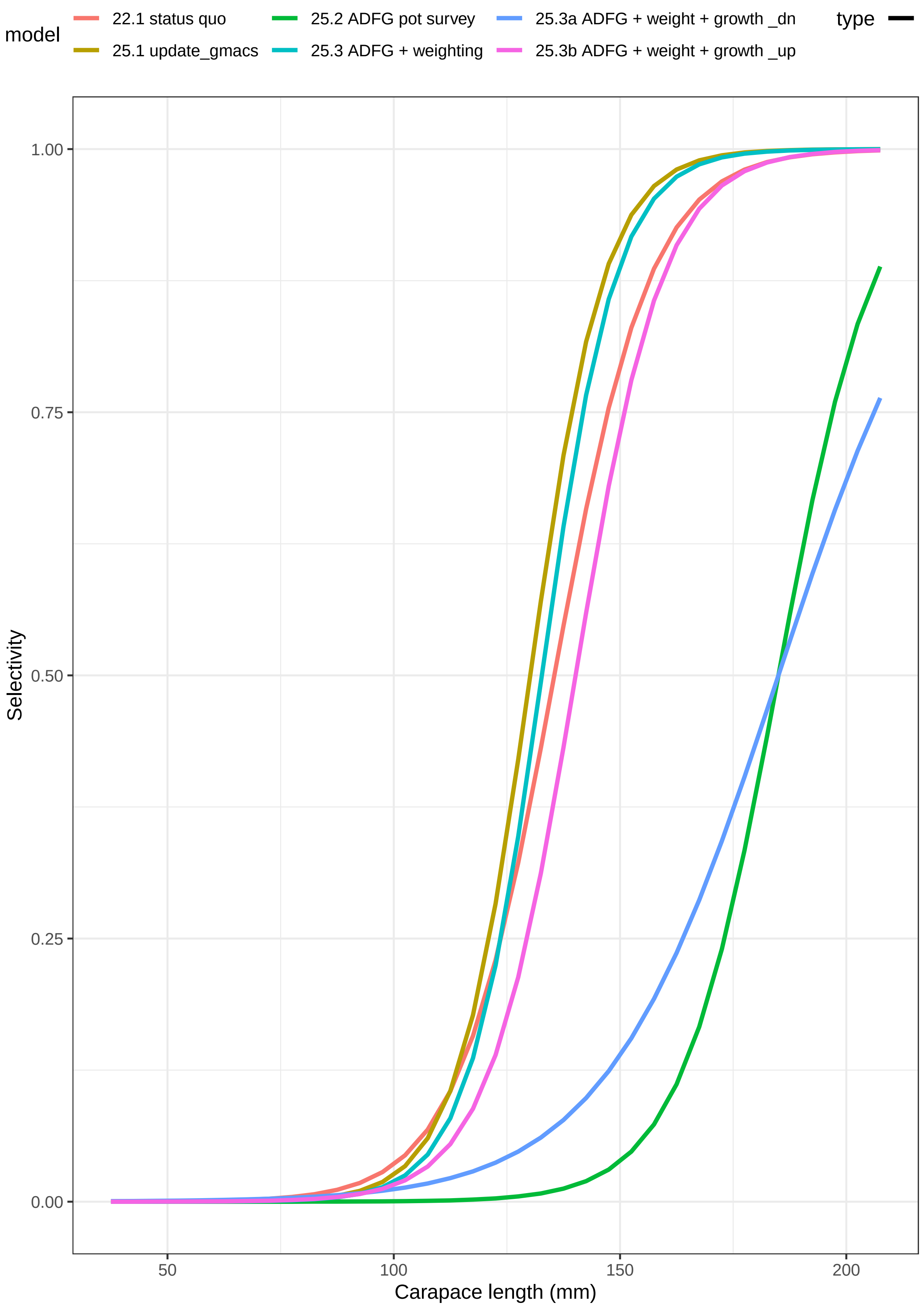


Figure 13: Estimated NMFS bottom trawl survey selectivity (lines) at size (x-axis)

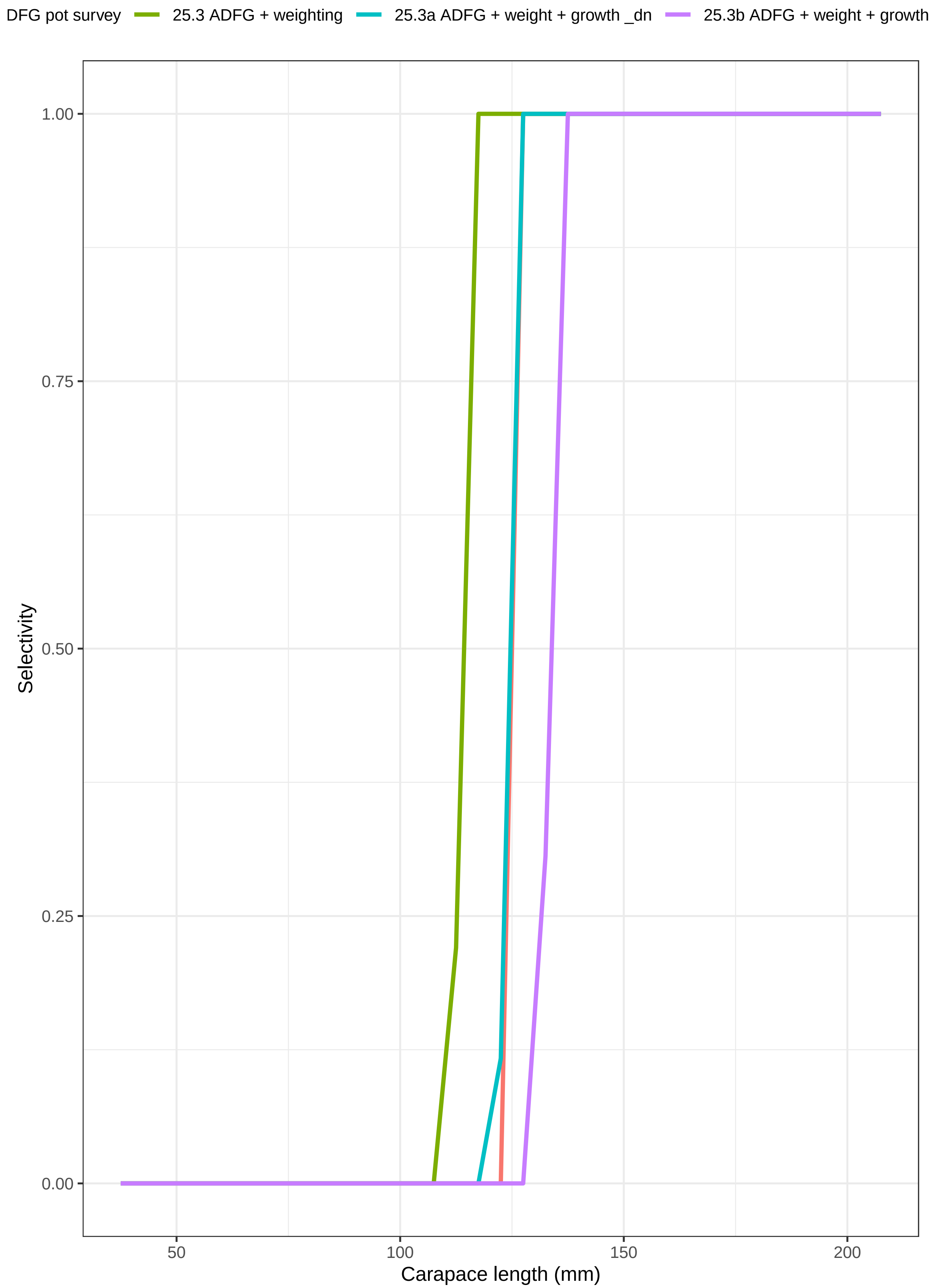
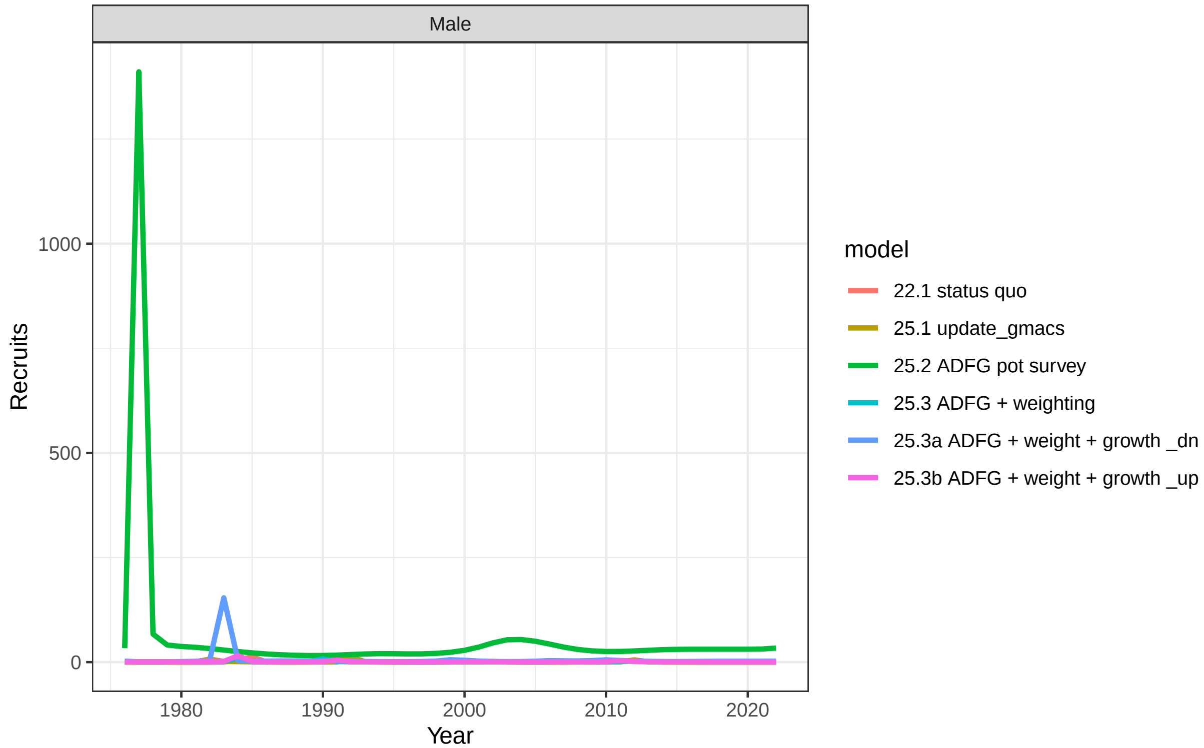


Figure 14: Estimated ADFG pot survey selectivity (lines)



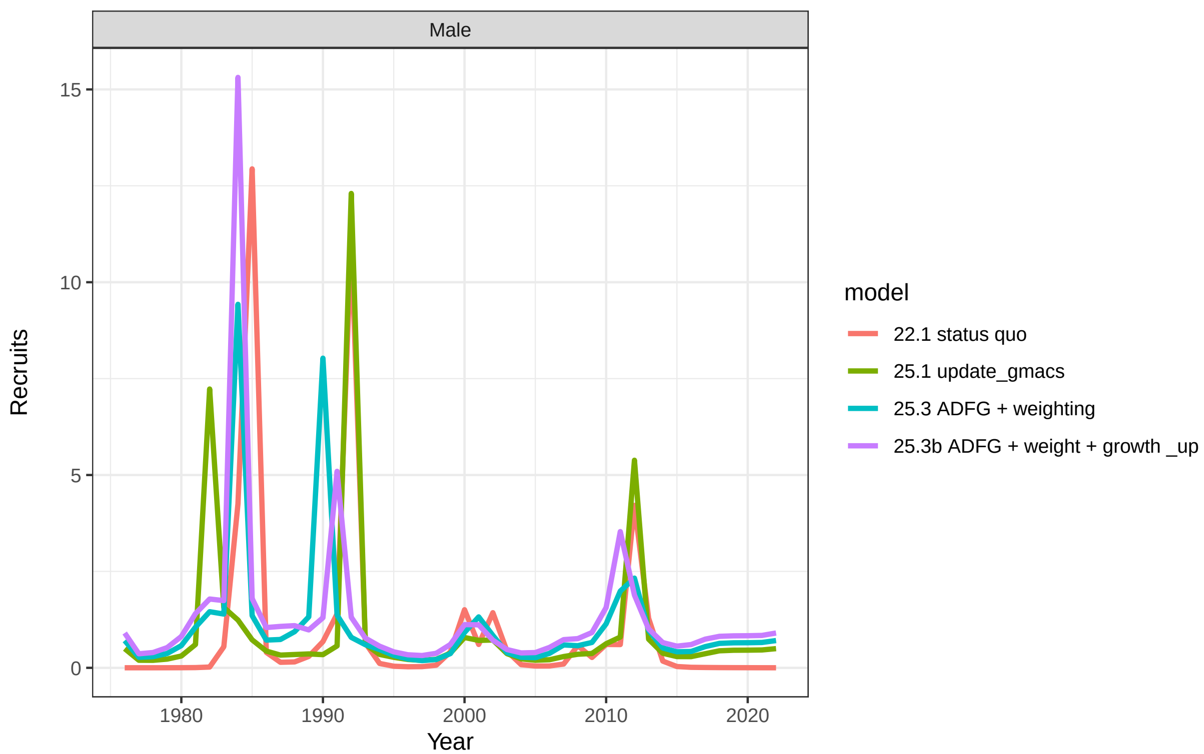


Figure 15: Estimated recruitment by model. Bottom figure excludes two models that had a different scale than the rest so the remaining models can be compared.

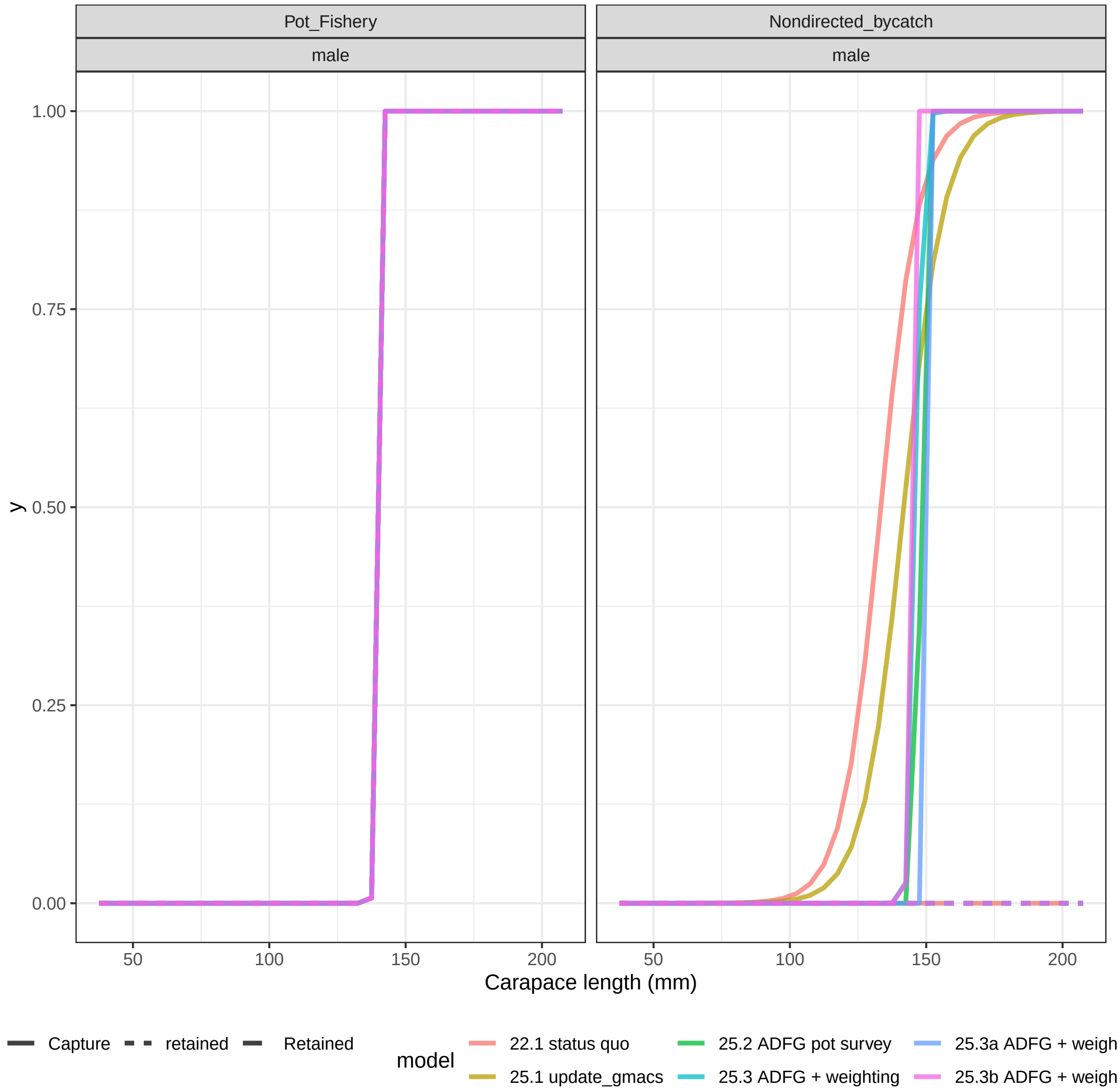


Figure 16: Estimated selectivities by fishing fleet and sex for capture and retained catches.

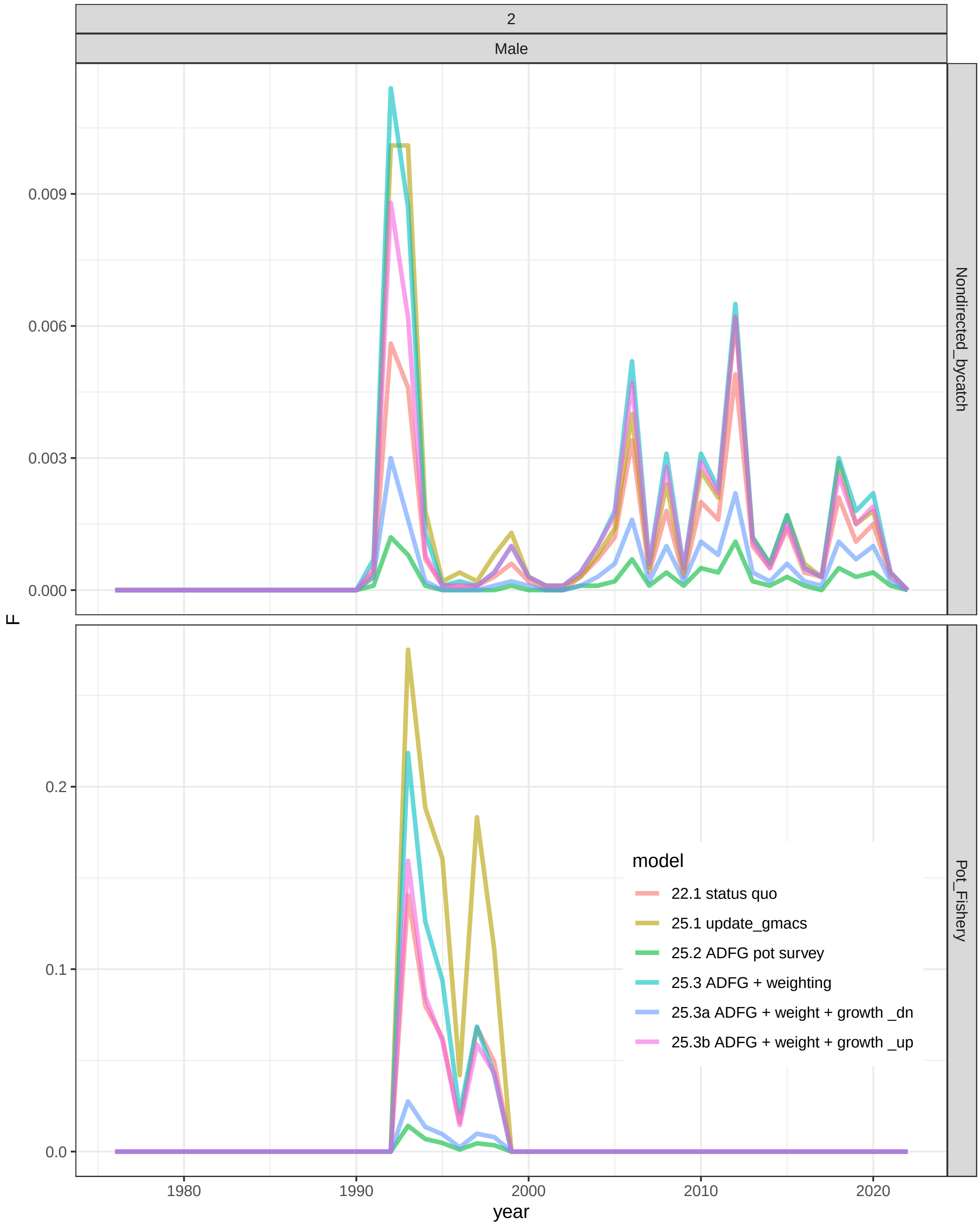


Figure 17: Estimated fishing mortalities for the directed and non-directed fisheries.

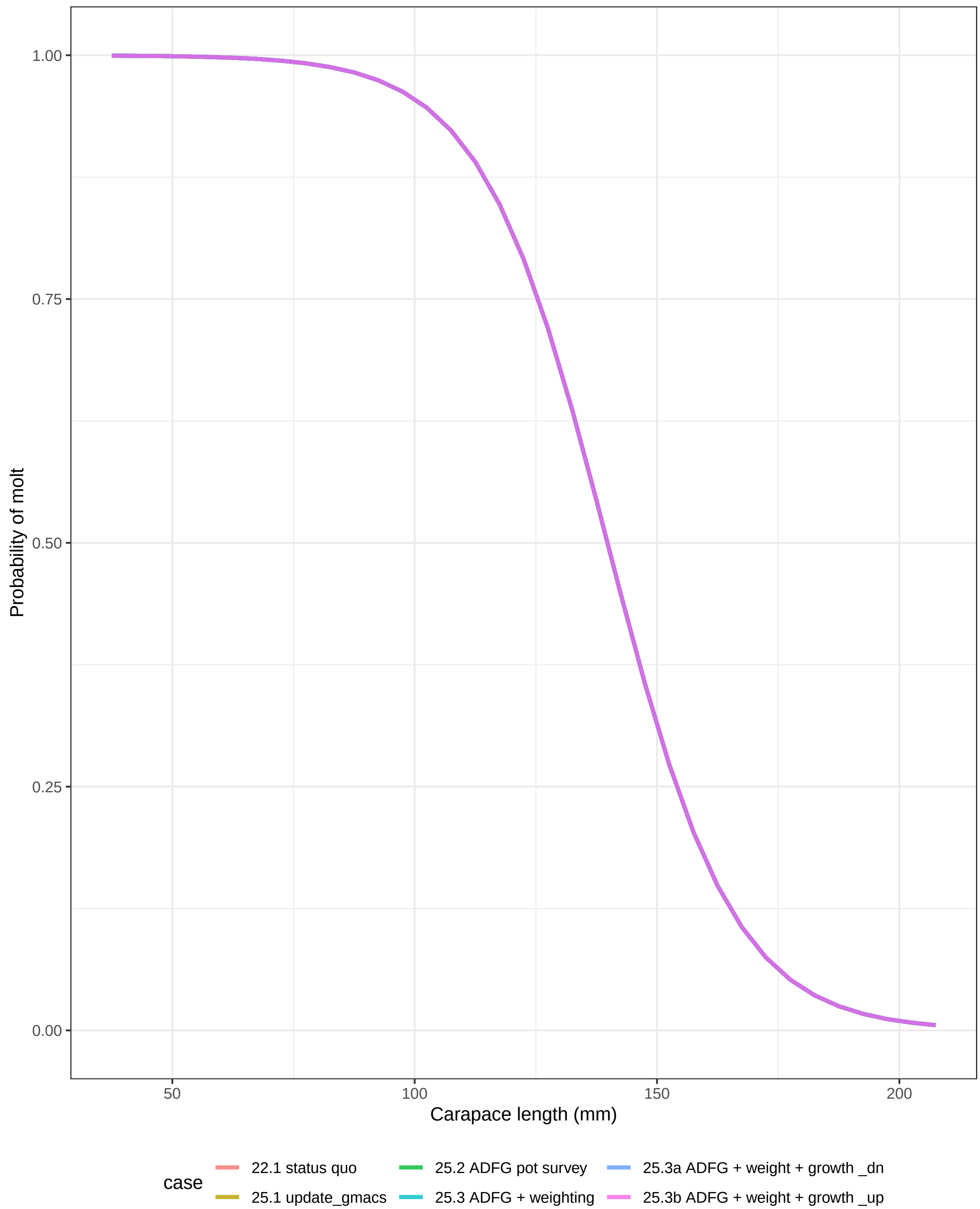


Figure 18: Probability of molting. Probability of molting at size was specified based on BBRKC for all models.

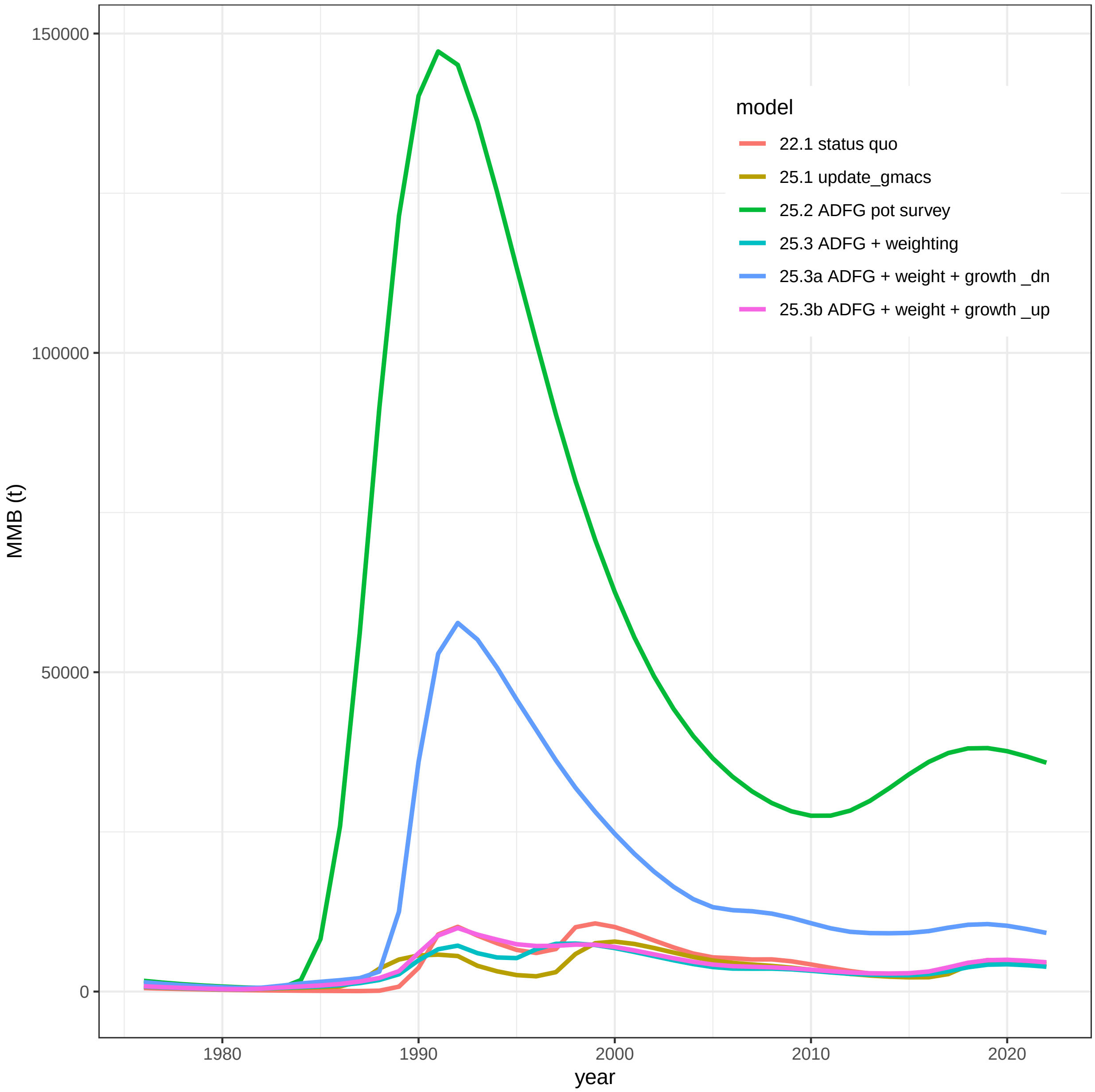


Figure 19: Model predicted mature male biomass at mating time in tonnes.